

# Transactions of the Missouri Academy of Science



Volume 38 (2004)

# 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.

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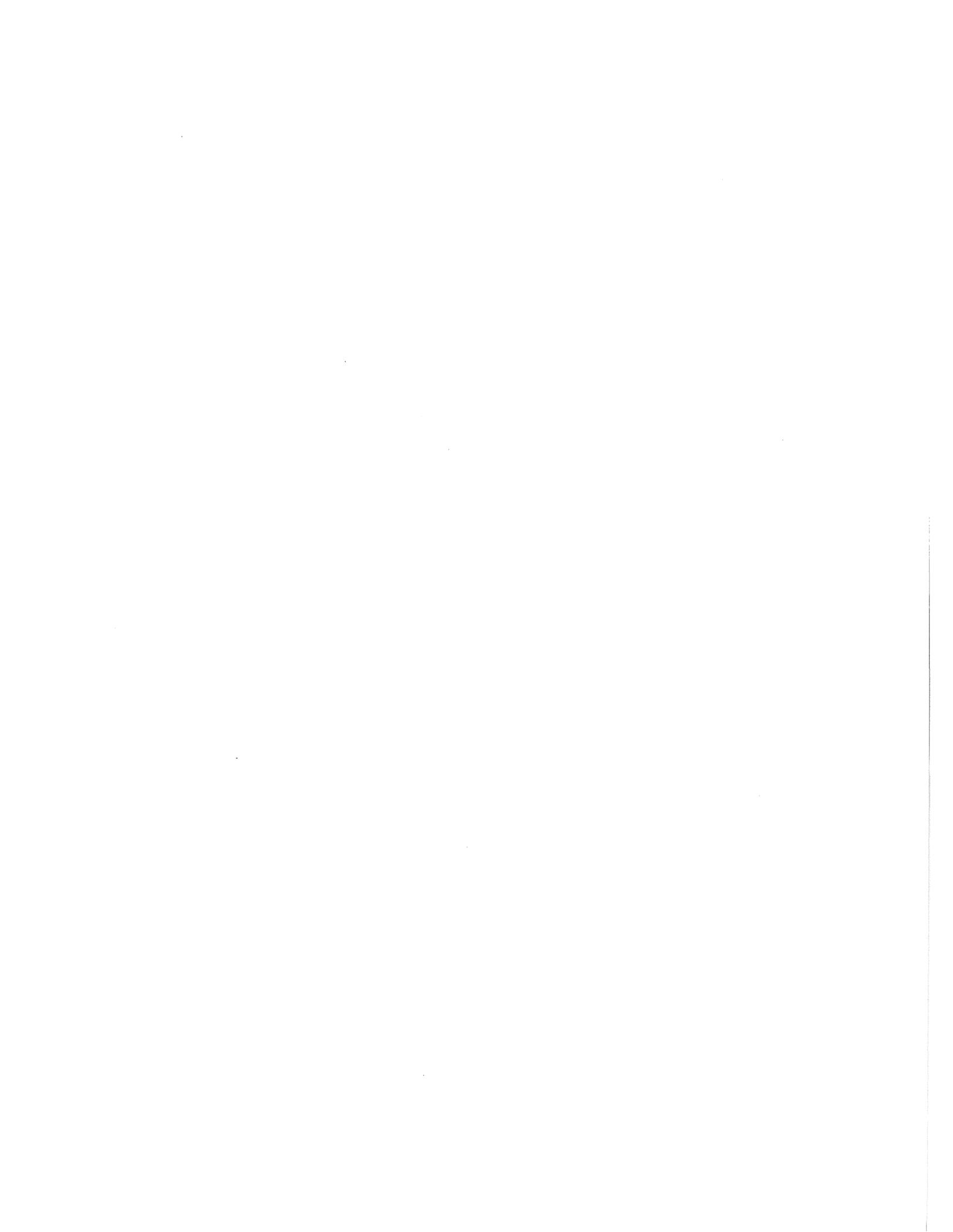
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# Growth Effects of Corn in Rotation with Rice

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## Abstract

*The growth and development of upland crops after rice (*Oryza sativa* L.) in the Lower Mississippi River Valley is frequently disappointing. We hypothesized that ponded rice water on weakly structured silty-textured soils further weakens the soil structure, fostering the slaking of the fine silt and clay separates into the remaining pore space. The degrading of the soil structure augments soil compaction, leading to a higher bulk density, reduced pore space, decreased aeration and limited root proliferation. A two year experimental design involving corn (*Zea mays* L.) after rice consisted of tillage as the main treatment and nitrogen and phosphorus as sub and sub-sub treatments. Soil fertility treatments were not significantly different. The tillage treatments consisted of raised beds (hipped beds) and flat beds (direct planting on zero grade land). The hipping treatments increased the root and top biomass; as well as, the yield in both years. Measurements of selected soil properties inferred that oxygen diffusion into the root zone was a limiting factor and future research into tillage practices that augment oxygen diffusion into the rooting zone is likely to be beneficial.*

**Key Words:** Corn (*Zea mays* L.), rice (*Oryza sativa* L.), tillage, oxygen diffusion, soil

## 1. Introduction

Corn (*Zea mays* L.) grown after rice (*Oryza sativa* L.) in the Lower Mississippi River Valley frequently experiences yield reductions, greater lodging problems, and overall reduced vigor. There is no clear consensus that exists to explain corn's poor performance following rice; however, the alteration of the soil's physical properties because of rice flooding is likely an important aspect. Recently, numerous research efforts have been directed towards understanding the interplay between soil organic matter (SOM) content and soil structure's resiliency in promoting a favorable

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root zone (Baldock and Nelson, 2000; Kay and Angers, 2000; Burke et al., 1998; Cambardella and Elliot, 1993; Franzluebbers and Arshad, 1997).

Soil structure is defined as the arrangement and organization of the primary soil particles (Hillel, 1980). The primary soil particles may be present in various quantities, sizes, shapes, and orientations. Their incorporation into aggregations may be complex, producing natural aggregates that differ in size, shape, strength (Hillel, 1980). These aggregates may be strengthened by SOM and other cementing agents (Beare et al., 1994ab; Bowman et al., 1999).

The value of soil structure revolves around the creation of soil porosity, thereby augmenting aeration, water holding capacity and root expansion. Soil structure is profoundly affected by climate, biological activity of the soil, crop rotations, and management practices (Al-Darby and Lowery, 1987; Bruce et al., 1990; Hill, 1990; Merrill et al., 1996). Agricultural practices that may reduce benefits afforded by the soil structure include: (1) tillage operations and (2) crop rotation and (3) irrigation.

Gas exchange in soils is important in supplying oxygen for root respiration and reducing potentially toxic soil CO<sub>2</sub> concentrations. Soil structure provides pore space for this gas exchange; however, the total porosity is only one factor in the overall efficiency of the gas exchange process. Oxygen diffusion in air is 10<sup>4</sup> times more effective than oxygen diffusion in water (Kramer and Boyer, 1995), thus water-filled pores hinder effective gaseous exchange. Secondly, soil aeration is advanced in soils having a continuous network of interconnected soil pores. The gas composition of a soil commonly includes N<sub>2</sub>, O<sub>2</sub>, CO<sub>2</sub>, trace gases and water vapor. Oxygen and CO<sub>2</sub> levels are largely determined by the intensity of root and microbial respiration and the degree of interaction with the atmosphere.

The partial pressure of atmospheric CO<sub>2</sub> is approximately 3.4 × 10<sup>-4</sup> atm, whereas the partial pressure of CO<sub>2</sub> in the soil atmosphere may reach concentrations approaching 3 × 10<sup>-3</sup> atm. At this level CO<sub>2</sub> could become

phytotoxic (Hillel, 1980). Oxygen consumption in the soil environment may exceed the supply of  $O_2$  from the atmosphere, resulting in  $O_2$  depletion and the onset of anaerobic conditions. Root surfaces generally require  $O_2$  flux rates of  $0.4 \text{ mg } O_2 \cdot \text{cm}^{-2} \cdot \text{min}^{-1}$  for normal physiological functioning, whereas  $O_2$  flux rates below  $0.2 \text{ mg } O_2 \cdot \text{cm}^{-2} \cdot \text{min}^{-1}$  are considered limiting (Hillel, 1980).

The root system of a plant provides many important physiologic functions essential to the proper growth, development, and functioning of a plant. These functions include: anchorage, hormonal synthesis, nutrient and water uptake, and carbon storage (Kramer and Boyer, 1995). Reduced aeration affects hormonal synthesis in the root system, resulting in reduced production of exportable cytokinins and gibberellins and enhanced production of abscissic acid (Kramer and Boyer, 1996). The nutrient uptake of P, K, and other elements is restricted because of a reduced respiratory rate (Tisdale et al., 1985).

Many soil and climatic factors limit root function, with soil water extremes, soil acidity and reduced aeration being the most important. Typically, plants that experience reduced oxygenation of their root systems are associated with poorly drained and fine-textured soils; in which, a large percentage of the pore space contains water and the air-filled pores present a torturous pathway for oxygen diffusion. Typical symptoms include a reduced and shallow root system, anoxic conditions in the stele, stunting, reduced nutrient uptake, a proliferation of adventitious roots near the soil surface, thin culms, and reduced crop yields (Kramer and Boyer, 1996).

The purpose of this research is: (1) to determine the effect of flooding associated with rice production on the physical and fertility properties of the soil, and (2) to estimate if these soil changes are detrimental to the subsequent growth of corn.

## 2. Materials And Methods

Experiments were conducted to assess corn growth and development because of tillage treatments and the nature of the previous crop. In particular, for corn following rice, tillage treatments involving soil hipping (raised beds) are a better tillage option than no-till planting. Secondly, we wished to assess corn growth on land that had been previously planted to: (i) soybeans (*Glycine max.* L), (ii) drill-seeded rice, and (iii) water-seeded rice. The goals of these experiments are designed

to determine: (1) whether the nutrient status of the soil is different because of the treatments, and (2) whether the culture of rice predisposes the soil to lower yielding upland crops in succeeding years after rice. Lastly, we wish to infer the exact mechanism responsible for crop yield reductions following rice.

### a. Experiment One: Raised Beds (Hipping) versus No-till Planting (Flat)

An experiment evaluating corn growth on hipped and flat seedbeds was conducted at the Missouri Rice Research and Demonstration Farm near Glennonville, MO on a somewhat poorly drained Crowley silt loam (fine, montmorillonitic, thermic Typic Albaqualfs) during 2000 and 2001. Soil testing demonstrated that the soil had a satisfactory soil fertility level during 2000 and was somewhat P and K deficient during 2001 (Table 1). The experimental design consisted of replicated blocks for the hipped and flat beds with individual plots established after stand development. Raised and flat beds had a row spacing of 36 inches (0.914 m) and were planted with hybrid corn to establish 20,300 plants acre<sup>-1</sup> in 2000 and 26,000 plants acre<sup>-1</sup> in 2001. Urea was applied according to soil test (120 lbs N • acre<sup>-1</sup>) at planting in 2000 and at emergence in 2001. The crop was furrow irrigated.

After planting, the bulk density and the saturated hydraulic conductivity were estimated in triplicate for the raised bed, the flat bed, and the underlying subsoil (Carter, 1993). The soil aggregate size distribution was estimated using dry sieving. In this procedure, bulk soil samples were dried at 110 C and gently sieved (4, 0.8 and 0.25 mm openings) to roughly assess if the tillage program altered the distribution of the aggregates (DeFreitas et al., 1996).

Tissue testing in 2000 was performed five times [22 May (fully emerged leaves from 20 plants), 6 June (fully emerged leaves from 20 plants), 27 June (uppermost fully-developed leaf from 10 plants), 17 July (leaf one node above first-developing ear from 10 plants)]. Tissue testing in 2001 consisted of a mid-July sampling involving leaf sampling, one node above the developing ear, from 10 plants. Nitrogen was determined using semi-micro Kjeldahl, whereas S, P, K, Ca, Mg, Na, Al, Fe, B, Mn, Cu and Zn were determined by inductive-coupled plasma-emission spectroscopy (ICP-AES) after ignition at 500 C in a controlled temperature furnace, followed by uptake in 5%  $HNO_3$ . Roots were similarly collected (6 June and

Table 1. Soil Chemical and physical property characterization of hipped and non-hipped corn planted after rice.

Treatment	pH	SOM %	Phosphorus lbs P/ac	Ca	Exchangeable Cations			CEC
					Mg	K	Na	
					cmol <sub>p(+) </sub> • kg:soil <sup>-1</sup>			
2000								
Hipped	5.00	1.70	23.00	4.45	2.08	0.20	0.15	10.00
Flat	5.00	1.70	16.00	4.32	1.94	0.20	0.15	10.00
2001	7.10	1.50	27.00	5.61	1.38	0.17	0.32	7.48
Treatment	Aggregate Distribution							
	Bulk Density g • cm <sup>-3</sup>	Pore Space %	Hydraulic Conductivity cm • s <sup>-1</sup>	5 to 1 mm %	1 to 0.25 mm %	Finer than 0.25 mm %		
Hipped	1.1 (1.0)	62	1.05 x 10 <sup>-4</sup>	26		53		21
Flat	1.1 (1.1)	58	2.65 x 10 <sup>-5</sup>	28		55		17
Subsoil	1.4 (1.4)	46	2.39 x 10 <sup>-6</sup>	—		—		—

17 July) and washed repeatedly in distilled water before tissue testing.

Total plant biomass was assessed twice during the 2000 growing season and once during the 2001 growing season. Four (2000) and eight (2001) visually representative plants were selected for analysis from each plot. The plant and its allotted soil volume were excavated and transported to the laboratory. The soil was carefully washed from the root system after soaking of the soil-root mass in large tubs of water for several days. Roots, stems (culms), leaves, tassels, and ears were separated and dried at 70 °C for several days. Plant dry weight (mass) was obtained by weighing.

#### b. Experiment Two: Corn after Soybeans, Drill Seeded Rice, and Water Seeded Rice

Experiment two was conducted in a commercial field in 2000 where corn was planted after previous crops of soybeans, drill-seeded rice, and water-seeded rice. The soil type was a somewhat poorly drained Crowley silt loam (fine, montmorillonitic, thermic Typic Albaqualfs). Soil testing demonstrated that the soil had a satisfactory soil fertility level (Table 3). Fertilization consisted of 90 lbs of urea, 90 lbs of a (0-23-30) mixed fertilizer at planting and 200 lbs of liquid N after emergence. Planting dates for corn were 7 April (soybeans and drilled seeded rice plots) with a 29 inch row spacing for the soybean plot and an emergence count of 1.4 plant row-foot<sup>-1</sup> and a 31 inch row spacing and an emergence rates of 1.3 plants row-foot<sup>-1</sup> for the drill seeded rice plot. Corn was planted on 13 April for the water seeded rice plots, consisting of 31 inch row spacing and an emergence rate of 1.3 plant row-foot<sup>-1</sup>.

Irrigation was furrow irrigation. All methods are similar to those described for the above experiment.

### 3. Results Involving Corn Planted on Hipped versus Flat Beds

#### a. Soil Fertility and Physical Measurements

Soil test results in 2000 suggest that the plots have reasonable soil fertility and soil fertility differences between the plots are minor (Table 1). Phosphorus is somewhat P deficient (P value of 30 lbs P ac<sup>-1</sup> is considered adequate for rice, whereas a value of 45 lbs P ac<sup>-1</sup> is adequate for corn). Soil-test results for 2001 indicate that P and K are somewhat deficient. The level of soil fertility was roughly equivalent throughout the study area and differences in soil fertility are not sufficient to influence or bias tillage treatments.

The soil bulk density is low, indicating a pore space of approximately 58% for the hipped and flat surface soil layers (Table 1). The bulk density of the subsoil is appreciably higher, indicating a more compact soil layer and a reduced total pore space. The pore space of the subsoil, if air-filled and consisting of connected pores, should be sufficient to support root development. However, the moisture content and the fine soil texture suggest that the soil pores are small and frequently water saturated. The soil structure of the subsoil immediately below the seedbed is composed entirely of moderate, very fine to medium platy structures, suggesting a torturous pathway for water and air transmission. Additionally, the compact subsoil has the likelihood of restricting the developing root system of corn because of reduced soil temperatures, wetness, and physical

Table 2. Nutrient concentration in the developing corn crop (2000).

Treatment	Plant Part	N	S	P	K	Mg	Ca	Fe	Mn	B	Cu	Zn	
		-----%-----						-----mg · kg <sup>-1</sup> -----					
Normal levels													
High Range		5.00	0.40	0.40	4.00	0.40	1.00	250	500	18	20	150	
Low Range		1.00	0.10	0.10	1.00	0.10	0.20	50	20	6	5	25	
6 June													
Hipped	leaf	3.46	0.26	0.16	2.93	0.49	0.80	2.7	150	10	8	45	
Flat	leaf	3.53	0.23	0.18	2.59	0.51	0.67	2.6	132	9	9	48	
Hipped	root	2.21	0.16	0.11	0.90	0.32	0.60	2237	208	6	12	40	
Flat	root	1.97	0.18	0.08	0.65	0.28	0.47	2367	231	5	9	69	
17 July													
Hipped	leaf	3.39	0.27	0.34	0.85	0.67	0.59	122	221	7	14	58	
Flat	leaf	3.05	0.26	0.27	1.16	0.35	0.45	109	85	8	12	44	
Hipped	root	1.82	0.10	0.12	0.37	0.24	0.58	2337	493	5	21	21	
Flat	root	1.32	0.26	0.14	0.73	0.20	0.26	1955	175	1	40	21	

hindrance of the elongating roots.

The aggregate size analysis indicates that the majority of the A horizon in the seed-bed is composed of very fine spherical aggregate and non-aggregated material, suggesting that the water culture of the earlier rice crop has "slaked" the natural aggregates and promoted the potential for compaction, filling of pores with silt, and reducing the diffusion of oxygen to the developing root system.

The saturated hydraulic conductivity for the hipped plots averages  $1.05 \times 10^{-4} \text{ cm} \cdot \text{s}^{-1}$ , whereas the flat plots averaged  $2.65 \times 10^{-5} \text{ cm} \cdot \text{s}^{-1}$ . The flat plots have a significantly reduced infiltration capacity, indicating that water flow and presumably air flow have been compromised by the lack of large connected pores (Table 1). The saturated hydraulic conductivity of the subsoil is ( $2.39 \times 10^{-6} \text{ cm} \cdot \text{s}^{-1}$ ) is very low, suggesting

appreciable water and air resistances.

#### b. Tissue Testing of Corn Planted in Hipped and Flat Beds following Rice

Tissue testing demonstrates that the nutrient levels for corn are appropriate and that soil fertility has not limited plant growth (Table 2). Nutrient levels decline with later sampling dates, a trend that is consistent with a normal corn growth pattern (Tisdale et al., 1985). Root tissues have smaller macronutrient concentrations than leaf tissues; however, Fe and Mn are appreciably more concentrated in root tissues, indicating root accumulation that is consistent for a soil with an acidic pH. Nutrient levels between the hipped and the flat tillage designs are equivalent, indicating that any yield differences between these two treatments

Table 3. Tissue test results for corn having hipped and flat bedding systems.

Treatment	S	P	K	Mg	Ca	Fe	Mn	B	Cu	Zn	
		-----%-----					-----mg · kg <sup>-1</sup> -----				
Normal Levels											
High Range		0.40	0.40	4.00	0.40	1.00	250	500	18	20	150
Low Range		0.10	0.10	1.00	0.10	0.20	50	20	6	5	25
Mean											
Hipped		0.23	0.26	1.31	0.43	0.69	168	162	4.7	10.1	33.5
Flat		0.21	0.25	1.42	0.34	0.69	165	159	5.7	9.7	32.7
Standard Deviation (n=8 samples)											
Hipped		0.03	0.08	0.25	0.19	0.17	33.4	29.3	1.4	2.2	12.5
Flat		0.05	0.08	0.08	0.05	0.14	27.4	31.1	0.9	1.7	13.2

Table 4. Soil chemical and physical property characterization for corn grown after soybeans, drill seeded rice and water-seeded rice.

Previous Crop	pH	SOM	Phosphorus	Exchangeable Cations			
				Ca	Mg	K	CEC
		%	lbs P/ac	----cmol <sub>p(+)</sub> • kg <sup>-1</sup> soil <sup>-1</sup> ----			
Soybeans	6.4	2.7	59	9.86	3.31	0.36	14.11
Drilled rice	6.8	2.3	46	7.66	2.99	0.36	11.65
Water-seeded	7.0	1.9	27	9.53	3.11	0.33	13.87

SOM = soil organic matter by loss on ignition

Table 5. Tissue test results for corn following soybeans, drill-seeded and water-seeded rice (2000).

Treatment	Plant Part	N	S	P	K	Mg	Ca	Fe	Mn	B	Cu	Zn	
		-----%-----						-----mg • kg <sup>-1</sup> -----					
Normal levels													
High Range		5.00	0.40	0.40	4.00	0.40	1.00	250	500	18	20	150	
Low Range		1.00	0.10	0.10	1.00	0.10	0.20	50	20	6	5	25	
17 July													
Soybean	leaf	3.17	0.22	0.31	1.71	0.29	0.60	190	122	31	17	24	
Drill	leaf	2.95	0.20	0.26	1.90	0.19	0.49	149	158	26	14	42	
Water	leaf	3.24	0.22	0.31	1.72	0.26	0.49	153	130	37	14	28	
Soybean	root	1.14	0.13	0.09	1.54	0.13	0.26	1908	317	4	41	14	
Drill	root	0.93	0.19	0.08	1.77	0.14	0.25	1221	218	4	19	12	
Water	root	1.28	0.28	0.13	1.48	0.24	0.46	2247	244	4	26	11	

Tissue concentrations for 3 June and 27 July are similar and are not shown.

are not likely attributable to soil fertility. Tissue testing in 2001 suggests that K is slightly low and B was low; however, differences in these nutrients between treatments were not significant (Table 3).

### c. Biomass and Yields for Corn Following Rice

The total plant biomass and the distribution of the biomass among the root system, stem, leaf, and ear in 2000 indicate differences because of the tillage

treatments (Fig. 1). Total biomass, stem and root growth are appreciably greater in the hipped system. In 2001, the total biomass was greater for the hipped system (Fig. 1); however, the distribution of the biomass was roughly equivalent between the tillage systems. The leaf to root ratio for the hipped system (mean = 1.24, standard deviation = 0.08) was significantly smaller than the flat system (mean = 2.0, standard deviation = 0.8). Average plant height (not measuring tassel length) was significantly greater for the hipped system (mean = 67 inches, standard deviation = 7.5 inches) than the flat system (mean = 58 inches, standard deviation = 4.7 inches). Yield estimates indicate that the hipped system in 2000 returned 5,900 lbs acre<sup>-1</sup>, whereas the flat system returned 4,700 lbs acre<sup>-1</sup>. Yield estimates in 2001 for the hipped treatment averaged 5,670 lbs acre<sup>-1</sup>, whereas the flat treatment averaged only 3,920 lbs acre<sup>-1</sup>. Thus the yield potential of hipped system was consistently and substantially greater.

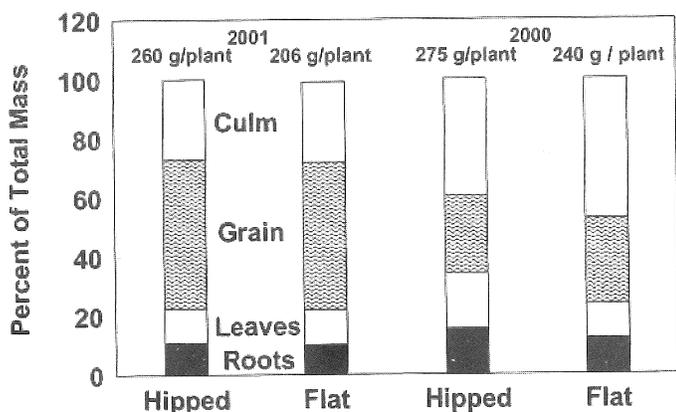


Fig. 1. The partitioning of plant mass of corn.

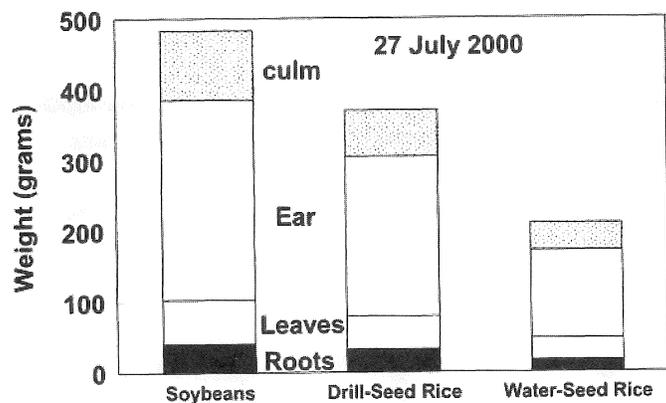


Fig. 2. Corn in rotation with either rice or soybeans

#### 4. Results Involving Corn after Soybeans, Drill-Seeded, and Water-seeded Rice

##### a. Nutrient Concentrations of Corn Following Soybeans, Drill-seeded Rice, Water-seeded Rice

Soil-test results suggest that the plots have reasonable soil fertility for rice culture and soil fertility differences between the plots are minor. Tissue testing demonstrates that the nutrient levels for the corn plant are appropriate, suggesting that the soil fertility has not hindered plant growth (Table 5). Nutrient levels decline with later sampling dates (data not shown), a trend that is consistent with a normal growth pattern of an annual crop (Tisdale et al., 1985). Root tissues are generally lower in the macronutrients than the leaf tissues; however, selected micronutrients such as Fe and Mn are appreciably greater in root tissues, indicating root accumulation. Nutrient levels in the root systems and the leaves among the soybean, drill seed and water seeded designs are largely equivalent, indicating that any yield differences between these three treatments are not likely attributable to soil fertility.

##### b. Biomass and Yields for Corn Following Soybeans, Drill-Seeded Rice, Water-Seeded Rice

The total plant biomass and the distribution of the biomass among the root system, stem, leaves, and ears indicate differences because of the previous crop (Fig. 2). Total biomass, ear, stem, leaves, and root growth are appreciably greater in corn-after-soybean systems than either of the corn-after-rice systems. The corn after drill-seeded rice produced a greater total biomass and greater biomass among the root system, stem, leaves, and ear than the corn after water-seeded rice (Fig. 2). The leaf to root ratio for the corn after soybean system

(mean = 1.76, standard deviation = 0.52) was similar to the leaf to root ratio for the corn after rice systems (mean = 1.8, standard deviation = 0.48). Average plant height (not measuring tassel length) for the corn after soybean system (mean = 68.5 inches, standard deviation = 6.1 inches) was roughly equivalent to the corn-after-drill-seeded rice (mean = 71.3 inches, standard deviation = 8.7 inches) and significantly greater than the corn-after-water seeded-rice (mean = 52.5 inches, standard deviation = 3.0 inches).

Yield estimates indicate that the corn-soybean system returned 8,571 lbs acre<sup>-1</sup> and the corn-drill-seeded rice system returned 8,686 lbs acre<sup>-1</sup>, yields that are roughly equivalent. The yield of the corn-water-seeded rice system was significantly and negatively impacted by the previous water-seeded rice system, returning only 5,828 lbs acre<sup>-1</sup>.

#### 5. Summary

The following conclusions appear valid:

(1) Soil fertility did not appear to be a deciding factor in the development of corn between rotations involving corn-soybeans and corn-rice.

(2) Physical properties of the soil suggest that the total pore space is normal for a silt loam soil; however, the distribution of the pores, the average moisture content and the platy soil structure is such that the majority of pores are small and the movement of water and air is difficult. Slaking of the soil structure during flooding of the previous rice crop weakened the expression of the granular or blocky soil structures and fostered a large percentage of smaller pores.

(3) Hipping promoted corn growth and yield, suggesting that the tillage system provided a more suitable rooting environment and gas exchange. Perhaps subsoiling may promote a deeper soil aeration capacity.

(4) It is the consensus of the research team that oxygen diffusion from the atmosphere to the developing root system of corn is a limiting factor. Future research should address the augmentation of oxygen diffusion in soil.

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# Effect of Two Different Burn Treatments on the Vegetation of a Successional Tallgrass Prairie Site

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## Abstract:

Based on pre-treatment comparisons of species overlap and Index of Commonness values, the vegetation in the three survey areas used in this study at the Pony Express Conservation Area near Osborn, Missouri, were considered similar in initial plant composition. Two of the three survey areas were treated as follows: 1.) a spring burn followed by another spring burn after three years and 2.) a fall burn followed by a spring burn after three and one half years. The third survey area remained unburned throughout the study and served as the control. Although Index of Commonness values showed little bluestem (*Andropogon scoparius*) to be

the major species in all three survey areas before and after treatments, commonness results also showed that the study area was undergoing ecological succession during the six years of this study with Jerusalem artichoke (*Helianthus tuberosus*) and grass-leaved goldenrod (*Solidago graminifolia*) increasing in all survey areas. In addition, Indian grass (*Sorghastrum nutans*), a native tallgrass, and the exotic weedy species sericea lespedeza (*Lespedeza cuneata*) both showed dramatic increases in the treatment survey areas over the control area. Support was provided by the Missouri Department of Conservation.

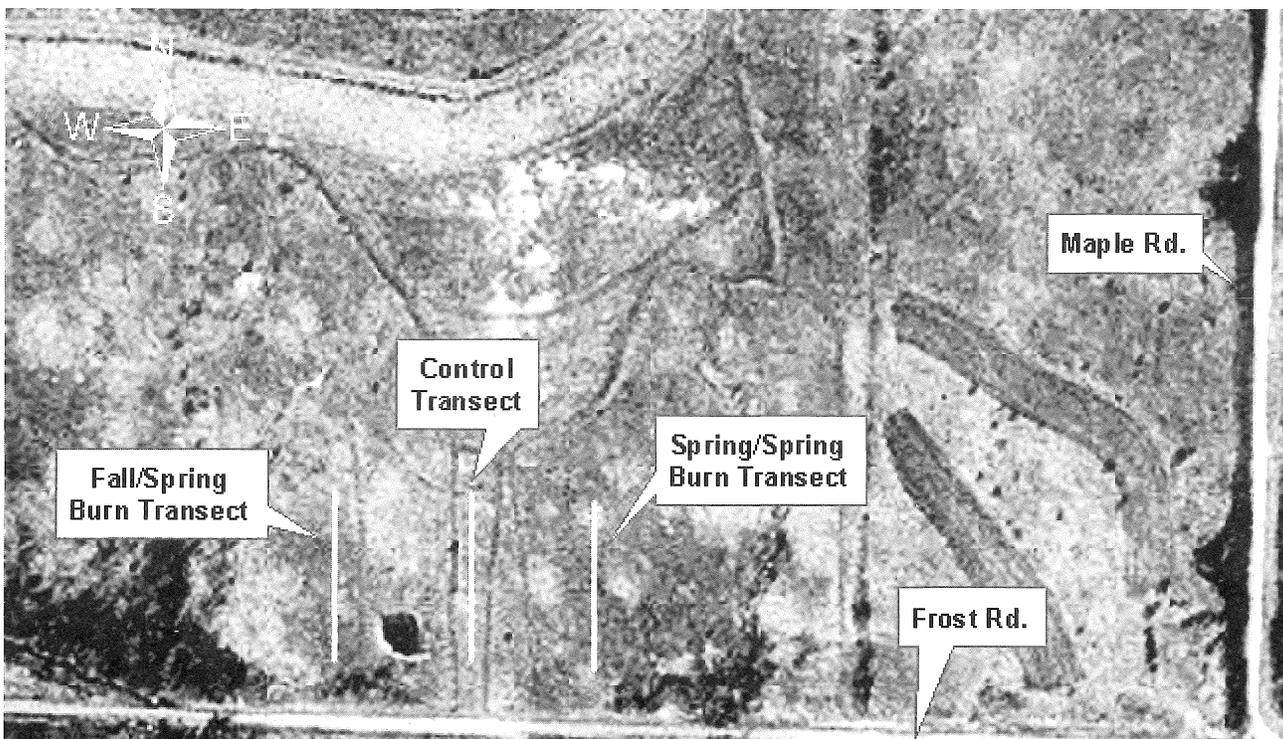


Figure 1. Pony Express Conservation Area Study Site Including The Three Plant Survey Transects.

## 1. Introduction

Fire on the prairie stimulates the growth of many native prairie plant species, including many native grasses (Towne and Owensby 1984; Svejcar and Browning 1988; Howe 1995; Towne and Knapp 1996; Briggs and Knapp 2001) and eradicates invasive shrub species (Gibson and Hulbert 1987). Fire also removes the accumulated dead plant material releasing nutrients back to the soil and allowing more sunlight to reach new growth. Fire suppression is degrading to the tallgrass prairie habitat and may eventually allow a forest to dominate (Collins 1990).

The purpose of this study was to determine the effect of prescribed burns on the flora of a successional tallgrass prairie site. Plants of special concern during this study included all of the native prairie species plus sericea lespedeza, a recent non-native invader in the study area.

This study involved a survey and comparison of plants in the following three survey areas: 1.) an area treated with a spring burn followed by another spring burn three years later, 2.) an area treated with a fall burn followed by a spring burn three and one half years later and 3.) an area left untreated to serve as the control. Floristic surveys before and after treatments

were compared in an attempt to quantify the response of plant species to the treatments without the use of statistical analysis.

## 2. Methods

The area used for this study was a successional tallgrass prairie within the Pony Express Conservation Area near Osborn, Missouri. The climate of this geographical area is subhumid with an average yearly precipitation of 38 inches. The soil is a Clarinda silty-clay loam (USDA Conservation Service 1997). Few land use records for the specific study site were found but it is known that the land was used for agriculture in the past. Missouri Department of Conservation records show that there were no prescribed burns in this area between 1990 and the time that this study began.

The three specific survey areas used in this study were each 20 meters by 100 meters. These three survey areas were adjacent to one another but were separated by plowed firebreaks at least 10 meters wide. A sampling transect was established along the midline of each survey area and 18 one meter by one meter quadrats were positioned 5 meters apart along the transect line (figure 1). All plants within each quadrat were identified and a percent cover value was

**Table 1. Commonness Values for Top Species on Each of the Three Transects in the Pretreatment (1993) and Post-treatment (1999) Surveys.**

	Transects and Survey Year					
	spring-spring burn transect		control transect		fall-spring burn transect	
	(1993)	(1999)	(1993)	(1999)	(1993)	(1999)
<i>Andropogon scoparius</i>	3180	3278	4260	3944	2940	3389
<i>Sorghastrum nutans</i>	56	1644	987	267	56	1756
<i>Solidago nemoralis</i>	584	33	684	22	292	22
<i>Ambrosia artimisiifolia</i>	524	44	540	56	220	11
<i>Solidago altissima</i>	764	494	520	711	444	1167
<i>Lespedeza cuneata</i>	772	1533	484	406	1396	1994
<i>Panicum oligosanthos</i>	612	167	424	300	260	144
<i>Rubus flagellaris</i>	324	761	416	1461	92	211
<i>Helianthus tuberosus</i>	476	839	160	992	392	700
<i>Pycnanthemum tenuifolium</i>	172	411	108	417	182	1044
<i>Solidago graminifolia</i>	264	600	100	2289	156	1078
<i>Fragaria virginiana</i>	88	661	24	244	320	978
<i>Antennaria neglecta</i>	460	661	12	12	400	44

determined for each species in August of 1993 before any burn treatments. Spring burns were done in April of 1994 and 1997 in one of the treatment areas. In the other treatment area a fall burn was done in November of 1993 and a spring burn was done in April of 1997. All plants within each quadrat were sampled again in August of 1999, two and one half years after the final treatment.

The ambient environmental conditions required for each burn during this study included a humidity range of 20 to 70 percent, a mid-flame wind speed range of 1 to 12 miles per hour and a temperature range of 20

to 95 degrees Fahrenheit. The ring-head fire method was used for each prescribed burn. Two fire ignition crews would simultaneously start backing fire lines into the prevailing wind from approximately the same point. These two crews would then proceed in opposite directions lighting the edge of the treatment area until both crews met on the upwind side of the treatment area to complete the fire ring. This procedure initiates a backing fire which burns approximately one fourth of the way into the treatment area before a heading fire completes the burn of the entire treatment area.

Flora of Missouri (Steyermark 1963) was

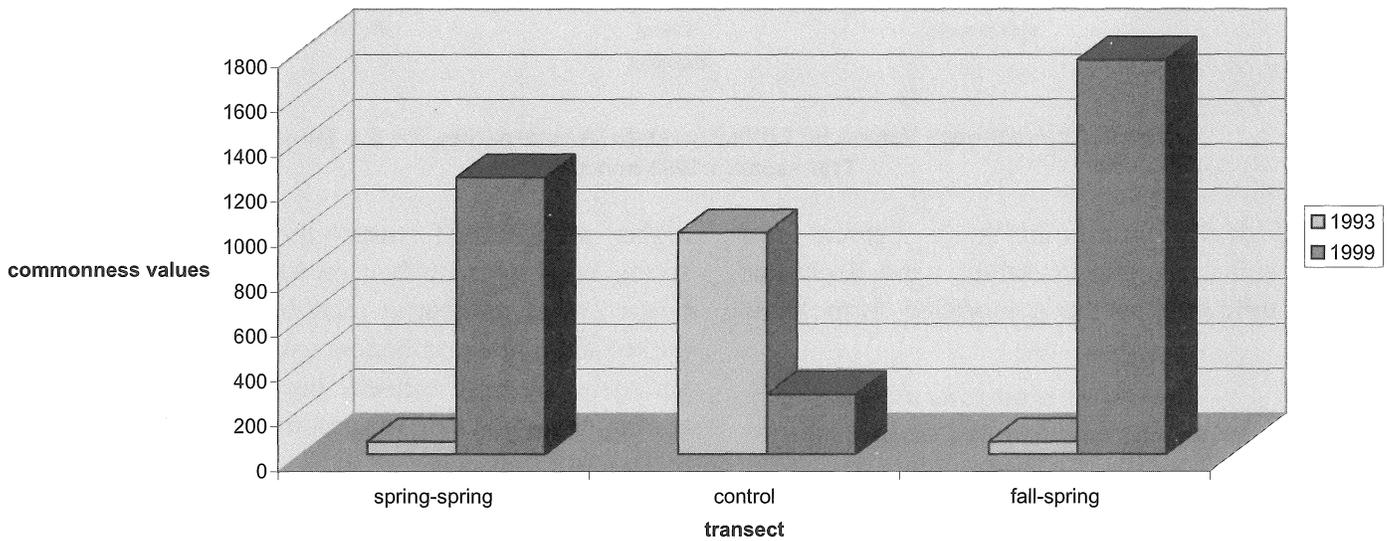


Figure 2. Commonness Values for Indian Grass (*S. nutans*) in the Three Survey Transects in 1993 and 1999.

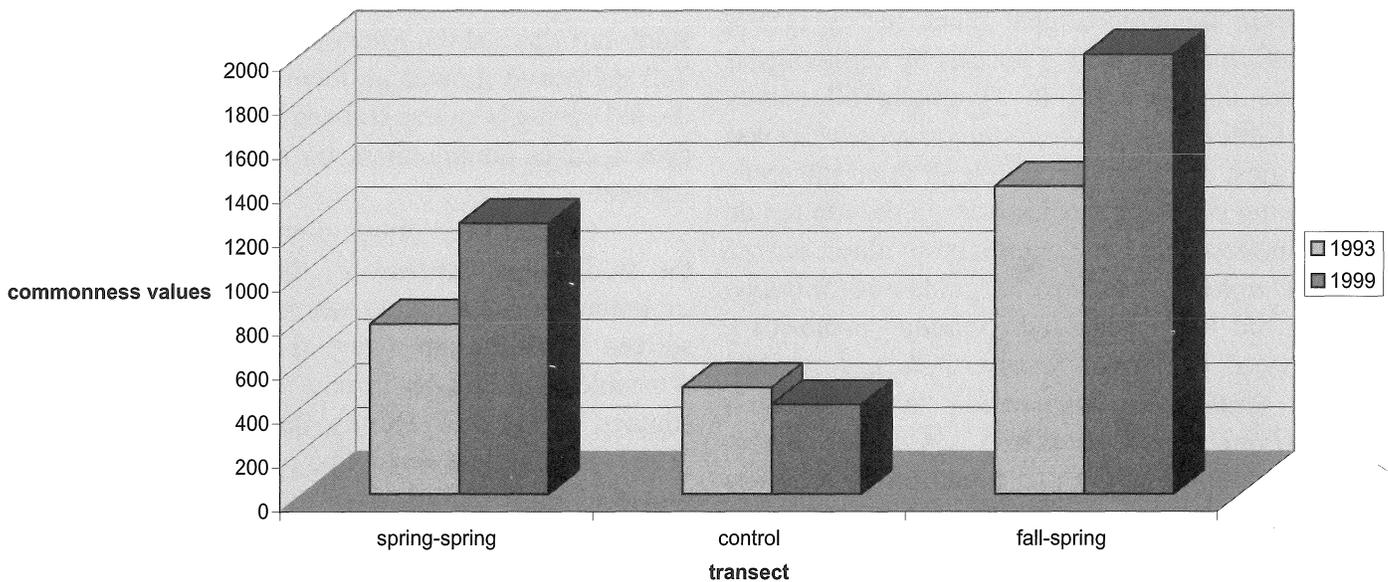


Figure 3. Commonness Values for Sericea Lespedeza (*L. cuneata*) for the Three Survey Transects in 1993 and 1999.

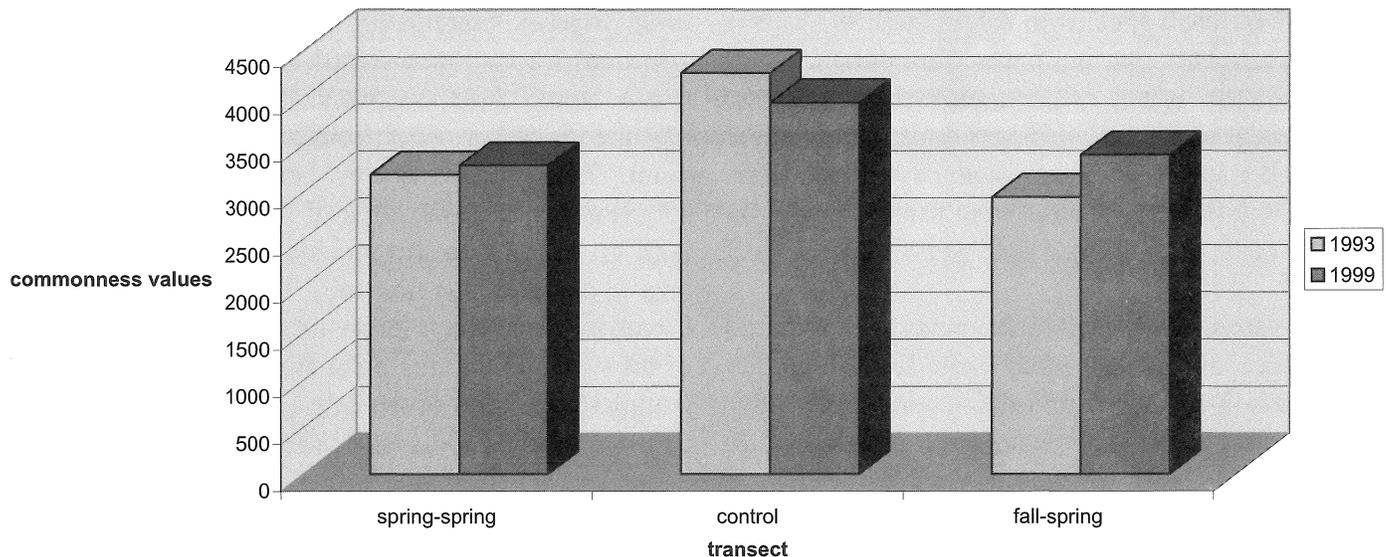


Figure 4. Commonness Values for Little Bluestem (*A. scoparius*) for the Three Survey Transects in 1993 and 1999.

used for all identification in this study. Percent cover, frequency and commonness values were determined using the following methods modified from Knoop (1984).

$$\text{Average Cover} = \frac{\text{sum of cover values for a species}}{\text{\# of quadrats where the species occurred}}$$

$$\text{Frequency} = \frac{\text{\# of quadrats where the species occurred} \times 10}{\text{total \# of quadrats}}$$

$$\text{Index of Commonness} = \text{Frequency} \times \text{Average Cover}$$

### 3. Results and Discussion

During the pretreatment plant survey (1993) general similarities for the top species by commonness values were observed (Table 1) among all survey transects. Little bluestem (*Andropogon scoparius*) was by far the most common species on all three transects. The following six other species were in the top ten on all three transects based on commonness values: sericea lespedeza (*Lespedeza cuneata*), tall goldenrod (*Solidago altissima*), old field goldenrod (*Solidago nemoralis*), small ragweed (*Ambrosia artemisiifolia*), Jerusalem artichoke (*Helianthus tuberosus*) and Scriber's panicum (*Panicum oligosanthes*). Although Indian grass (*Sorghastum nutans*) was found on all transects during the pretreatment survey, its commonness value was much higher on the control transect compared to the treatment transects. Sericea lespedeza (*Lespedeza cuneata*), another plant found in all three transects during the pretreatment survey, had a dramatically

higher pretreatment commonness value on the fall-spring burn transect than on the other two transects. Grass-leaved goldenrod (*Solidago graminifolia*) was ranked tenth in commonness value on the pretreatment spring-spring burn transect but it ranked eleventh in commonness value on the pretreatment fall-spring burn and control transects.

A comparison of commonness values between pretreatment (1993) and post-treatment (1999) surveys shows little bluestem to be the most common species on all transects before and after treatments (Table 1). Jerusalem artichoke increased on all of the transects during the entire study. Grass-leaved goldenrod also increased in commonness on all transects during the study but showed the greatest increase on the control. Tall goldenrod showed an increase in commonness on the fall-spring burn transect and the control transect but decreased in commonness on the spring-spring burn transect.

Overall, the most dramatic changes during the study were increases in the commonness values of Indian grass, a native warm season tallgrass, and sericea lespedeza, an exotic species that has become a troublesome invader in prairies across the Midwest (figures 2 and 3). During the pretreatment survey (1993) Indian grass was found primarily on the control transect (figure 2); however, over the entire period of the study Indian grass increased in commonness on both burn treatment transects but showed a decrease in commonness on the control transect. An increase in native tallgrasses such as Indian grass is expected in burn treated areas based on some other studies (Town

and Owensby 1984; Svejcar and Browning 1988; Howe 1995). *Sericea lespedeza* showed dramatic increases in commonness on both burn treatment transects but showed a slight decrease in commonness on the control transect (figure 3).

Little bluestem, the other common native warm season grass surveyed in this study, showed the expected increases in commonness on both burn treatment transects but showed a decrease in commonness on the control transect (figure 4).

The results for *sericea lespedeza* in this study confirms what other studies have suggested, that is, *sericea lespedeza* tends to increase with prescribed burns (Whitehead, et al. 1998; Fick 1990). *Sericea lespedeza* is a nitrogen-fixing perennial legume that was brought to the United States from East Asia in 1896 for erosion control and wildlife food. The first record of the presence of *sericea lespedeza* in Missouri (the site of this study) dates back to 1936 and its occurrence has been increasing in recent years. *Sericea lespedeza* is a hardy, disease resistant plant that flowers from early July through October in Missouri and produces large quantities of seeds (1500 seeds/stem) that remain viable for up to twenty years with approximately 15% of the one-year old seeds germinating. The fact that the germination of *sericea lespedeza* seeds can reach up to 88% (Young and Eddy. 1998) following a fire at least partly explains why *sericea lespedeza* increases so rapidly following prescribed prairie burns.

Although there is no known effective biological control for *sericea lespedeza* at the present time, other control methods such as grazing (Escobar 1998) and chemical control (Wehtje et al. 1999) have been suggested. Mowing is especially effective in late July or early August when flowering is well underway and food reserves within the plant are at a critically low point. Whitehead et al. (1998) suggested that a fall burn followed by a burn the next spring is effective in controlling established stands of *sericea lespedeza*. In our study at the Pony Express Conservation, the transect that was treated with a fall burn followed by a spring burn actually showed a dramatic increase in commonness for *sericea lespedeza* (figure 3). However, the spring burn came more than three years after the fall burn in our study compared to burns during consecutive seasons in the Whitehead et al. (1998) study. Spring burning to enhance seed germination in *sericea lespedeza* followed by mowing or hand-applied chemical treatment with a herbicide such as Remedy or Round-up is recommended for future testing as a

possible method for reducing *sericea lespedeza* at the Pony Express Conservation Area.

## 4. Acknowledgements

Support for this study was provided by the Missouri Department of Conservation.

Special thanks to Marcia Pfeleiderer, Craig Crisler, Roland Spilker and Dennis Browning of the Missouri Department of Conservation for conducting the prescribed burns and providing expert advise during this study.

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# Potential Effects of Mowing Prior to Summer Burning on the Eastern Massasauga (*Sistrurus c. catenatus*) at Squaw Creek National Wildlife Refuge, Holt County, Missouri, USA

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## Abstract:

We conducted a pilot study to begin evaluating the use of pre-burn mowing to reduce or eliminate Eastern Massasauga (*Sistrurus c. catenatus*) mortality during summer prescribed fires. Drift fencing was used to determine the presence of Eastern Massasaugas on a 8.1 ha portion of native wet prairie at Squaw Creek National Wildlife Refuge during the summer 2001. Twenty-two days of trapping with 10 randomly located drift fence traps (n=220 trap nights) resulted in the capture of 96 snakes representing 8 species, including 9 Eastern Massasaugas. After trapping was completed the site was mowed to a height of 20 cm and then burned 13 days after mowing was completed. Post-burn transect searches of the site revealed one yellow-bellied racer (*Coluber constrictor*) mortality due to the fire. The low mortality rate suggests that pre-burn mowing may potentially reduce fire related mortality of Eastern Massasaugas and other snake species by negatively modifying occupied habitat which in turn forces snakes to leave the area or seek refuge below ground.

Key Words: Eastern massasauga, rattlesnake, *Sistrurus catenatus catenatus*, prescribed fire, Missouri

## 1. Introduction

The Eastern Massasauga is a state endangered species in Missouri (Missouri Natural Heritage Program, 2003) as well as a candidate species for listing under the United States Endangered Species Act (Szymanski, 1998 and Federal Register, 1999). The general ecology of this species is well summarized in Johnson et al. (2000). In Missouri massasaugas mainly utilize wet prairie and to a lesser extent drier upland prairie habitat with minimal

shrub and tree cover (Seigel, 1986 and Johnson et al., 2000). Preservation of this early successional habitat is imperative for the continued survival of this species in Missouri.

A common problem for land managers trying to maintain prairie habitat is encroachment of woody vegetation. An effective tool for controlling this problem is the utilization of prescribed fire during the summer months which may either kill or temporarily set back woody vegetation (Anderson, 1997 and Adams et al., 1982). Other means of controlling woody growth include herbicides and mechanical manipulation, although controlled burning appears to be the most efficient and cost effective method.

Unfortunately, prescribed fire during the summer months coincides with the middle of the seasonally active period for massasaugas, as well as other reptile species, and can result in direct mortality. Durbian (2001) reported a 21% mortality rate for massasaugas after a spring burn conducted on 18 April at Squaw Creek National Wildlife Refuge and Frese (2003) reported an 85% mortality rate for all snakes found after a fall burn on tallgrass prairie in northern Missouri. Mortality and injury to reptiles from seasonal fires has also been described by Babbitt and Babbitt (1951), Erwin and Stasiak (1979) and Heinrich and Kaufman (1985). The potential risk for direct mortality of massasaugas from summer burns creates a tenuous management situation when dealing with prescribed fire as a management tool. For this reason it is vitally important to explore management techniques that can be used to reduce or eliminate mortality due to summer burning. A potential solution may be mowing prior to conducting prescribed fire. The reduction of cover through mowing, during the warm summer months, may result in habitat conditions that are intolerable to massasaugas, due to higher surface temperatures, which

Figure 1. Location of the study site on Squaw Creek National Wildlife Refuge.

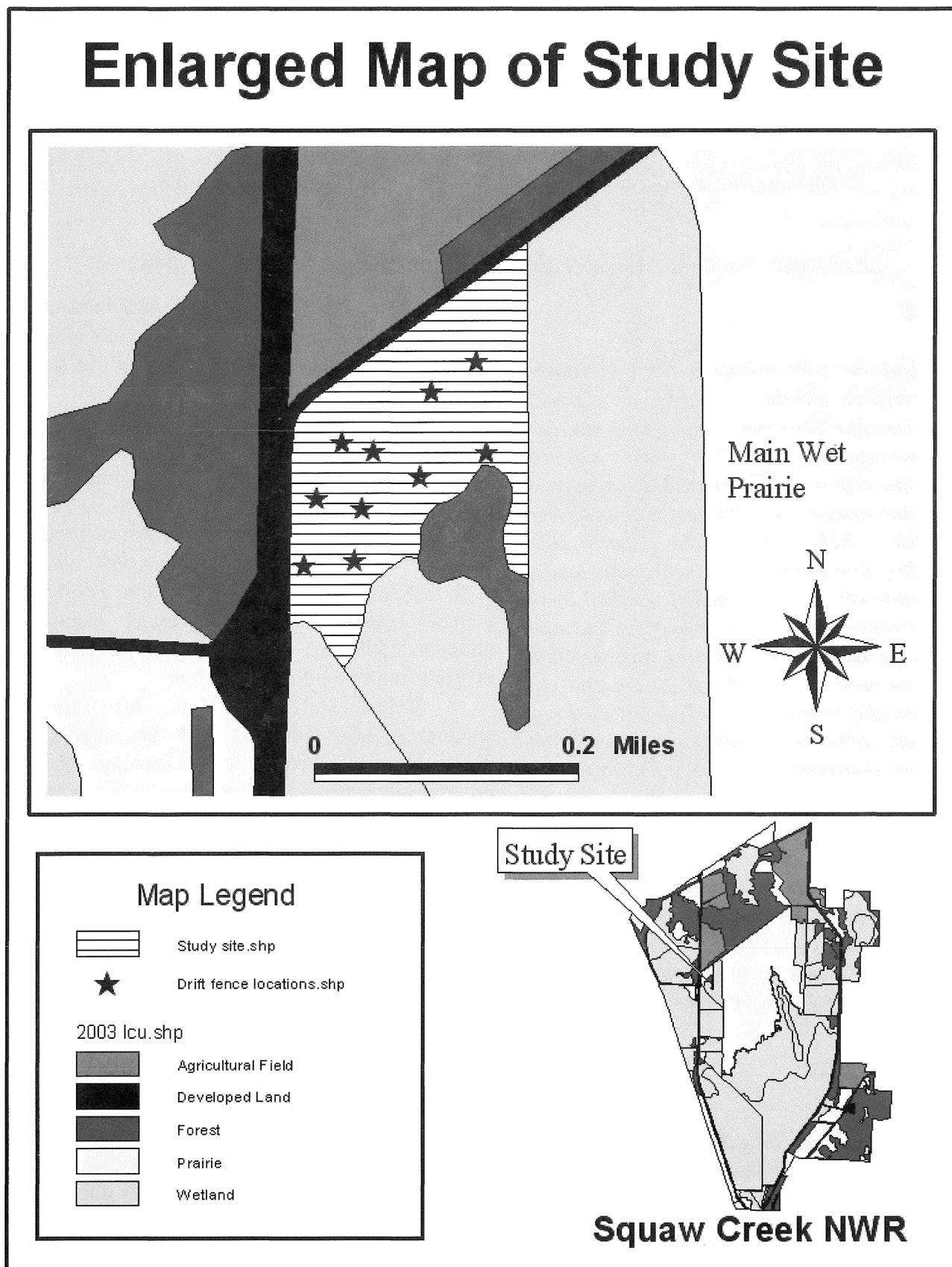


Table 1. Fire behavior parameters based on maximum environmental variables. Parameters and variables are reported in English units of measure to maintain consistency with standard fire behavior reporting.

Input Variables	Value
Fuel Model	3.0
1 Hour Fuel Moisture (%)	5.0
20 Foot Wind Speed	12.0
Wind Adjustment Factor	0.3
Slope (%)	0.0
Aspect (deg)	180.0
Output Variables (Maximum Values)	Value
Rate of Spread (chains/hour)	85.0
Heat/Unit Area (Btu/ft <sup>2</sup> )	783.0
Fireline Intensity (Btu/ft/sec)	1227.0
Flame Length (ft)	12.0

may force them to temporarily leave the area or go under ground until the habitat conditions are once again suitable. Burning habitat that snakes have temporarily abandoned or during a period when snakes are under ground should prevent direct mortality from fire. We initiated a pilot study during the summer 2001 to begin evaluating the potential effects of pre-burn mowing on summer burn mortality of Eastern Massasaugas.

## 2. Materials and Methods

This study was conducted on the 3,012 ha Squaw Creek National Wildlife Refuge located on the Missouri River floodplain in Holt County, Missouri. Squaw Creek National Wildlife Refuge consists of 6 main habitat types including old field (24 ha), developed

land (102 ha), agricultural cropland (234 ha), forest (558 ha), prairie (643 ha), and wetland (1,451 ha)(Figure1). The refuge currently harbors one of three known populations of Eastern Massasauga Rattlesnakes in Missouri (Johnson, 2000). The main wet prairie (380 ha), located in the center of the refuge, supports the largest portion of the population.

The study site encompassed an 8.1 hectare portion of native grass located in the northwestern corner of the main wet prairie (Figure 1) which consists of saturated soil that has been managed for native warm season grasses including Eastern gamma grass (*T. dactyloides*), Indian grass (*S. nutans*), switch grass (*P. virgatum*) and big bluestem (*A. gerardi*) since 1996. This area is immediately adjacent to a seasonally flooded wetland, on the east and south sides, that is principally managed for waterfowl and shorebirds (Figure 1). The wetland

Table 2. Total number of each species captured prior to the burn treatment and associated capture rate.

Species	Number Captured	Capture Rate (%)
Red-sided Garter Snake ( <i>Thamnophis sirtalis</i> )	41.0	18.6
Western Plains Garter Snake ( <i>Thamnophis radix</i> )	23.0	10.5
Western Ribbon Snake ( <i>Thamnophis proximus</i> )	10.0	4.5
Eastern Massasauga ( <i>Sistrurus catenatus</i> )	9.0	4.1
Western Fox Snake ( <i>Elaphe vulpina</i> )	7.0	3.2
Yellow-bellied Racer ( <i>Coluber constrictor</i> )	4.0	1.8
Prairie Kingsnake ( <i>Lampropeltis calligaster</i> )	1.0	0.5
Diamond-backed Water Snake ( <i>Nerodia rhombifer</i> )	1.0	0.5
Total	96.0	43.6

Figure 2. Photograph of a drift fence and associated funnel trap.



is dry during the summer months and does not provide a barrier to snake movement to and from the main wet prairie. During 1999 and 2000 the site was encroached by cottonwood (*populus* sp.) and willow (*salix* sp.). A vegetation survey conducted in 2001 indicated that the percent frequency of woody vegetation on this site was 14.8% for cottonwood and willow combined (F.E. Durbian, Unpublished Data).

Snakes were captured using 10 drift fences (Fitch, 1960) randomly located on the site (Figure 2). Each 0.6 m x 7.3 m fence was constructed from 1.3 cm plywood. A single 0.6 cm hardware cloth funnel trap was placed at either end of each fence for a total of 20 traps. Trapping took place 4-5 days per week during the period of 11 June - 13 July. Traps were checked daily, typically late morning, and twice daily when temperatures exceeded 32° C. Grass was placed over the traps to provide shade and reduce heat stress/mortality. The number of each species captured and released was recorded daily.

All drift fences were removed on 16 July and the entire site, excluding approximately 1.2 ha of mature trees located on the east side, was mowed to a height of approximately 20 cm on 17 July. This height was chosen based on recommendations by Johnson et al. (2000) who suggested that mowing at heights greater than 10-15 cm can “reduce or eliminate mortality from mowing.” The controlled burn took place on 30 July (13 days post-mowing) and followed protocol within the refuge fire management plan (Speer, 2001). A combination of backing (25%), flanking (25%) and head (50%) fire was utilized to achieve a safe and effective burn. The BehavePlus Fire Modeling System (Systems for Environmental Management, PO Box 8868, Missoula,

Montana, 59807) was used to calculate the maximum burn parameters for the fire (Table 1) using variables collected on the day of the fire. Maximum values were used to provide the most extreme conditions that could have occurred on the fire. On the morning of 31 July, a transect search for burned snakes was conducted by 3 refuge staff members who walked 10 meter wide grids on the entire burn site. All three staff members were experienced in looking for both live and burned snakes.

### 3. Results

A total of 8 species, including 9 massasaugas, were captured during 220 drift fence nights (1 fence with 2 traps/24 hrs) (Table 2). Other species captured and released unharmed included two prairie voles (*M. ochrogaster*), one least shrew (*C. parva*), one yellow warbler (*D. petechia*) and one indigo bunting (*P. cyanea*).

The controlled burn took approximately 3 hours to complete and burned 100% of the site down to mineral soil. A post-fire inspection revealed that a majority of the standing woody vegetation was affected (scorched) by the fire.

The transect search effort took approximately 2 hours to complete. One dead yellow-bellied racer and one dead western painted turtle were located. The snake appeared to have been burned while the turtle was likely dead prior to the fire, based on body decomposition.

### 4. Conclusion

The mortality rates, based on total captures, of 0% for massasaugas and 1.04% for all snakes were much lower than expected relative to the figures reported by Durbian (2001) and Frese (2003) who found post-burn mortality rates of 21% for massasaugas and 85% for all snakes, respectively, after active season prescribed fires. This information suggests that mowing prior to summer burning has the potential to reduce the mortality of massasaugas, and other snake species, that occurs during active season burns. These low mortality rates may possibly be attributed to the creation of an environment inhospitable to snakes. Mowing vegetation to 20 cm greatly reduced the amount of shade present and reduced humidity at the surface level. These factors combined with high daytime ambient temperatures

(~32°C) likely created a very hot micro-climate near the ground, forcing snakes to leave the area and/or seek shelter below ground during the hotter portion of the day. Alternatives to this hypothesis include: 1) Many snakes were burned but not located. This is highly unlikely as the staff members involved in the search effort all had experience finding both live and dead snakes in burned areas. 2) General weather conditions, regardless of mowing, prompted snakes to emigrate to cooler areas. This is also unlikely because snakes were captured in the area prior to burning under the same weather conditions. 3) Direct mortality of snakes was incurred by the mowing that took place prior to burning. No post-mowing mortality search was conducted based on the recommendation that mowing to heights greater than 10-15 cm during the hotter portions of the day will have minimal impact on massasaugas (Johnson et al., 2000). Although a survey conducted immediately after mowing would have provided an opportunity to identify the potential impact to massasaugas and other reptiles, it is doubtful that mortality due to mowing would be 100% and there were likely snakes still on the site immediately after mowing.

The results of this pilot study are encouraging and warrant additional research efforts on a larger and more intensive scale. Utilization of radio instrumented snakes and post-mowing searches will provide more conclusive data on the direct effects of both mowing and burning.

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# The Short and Long-term Variability of F2 or Stronger (Significant) Tornadoes in the Central Plains

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## Abstract

*An analysis of the interannual and interdecadal variability of significant tornado events that occurred over a four state region in the central plains was performed over a 53 year period (1950 – 2002) using the Storm Prediction Center (SPC) archives and simple statistical techniques. A synoptic composite analysis using the National Centers for Environmental Prediction (NCEP) – National Center for Atmospheric Research (NCAR) re-analyses was performed in order to determine whether there was support for the statistical relationships through the large-scale composite dynamics. The results showed that when the 53 year raw annual tornado occurrences are used, there was no statistically significant El Nino-related variability, and El Nino years produced slightly more tornado occurrences. However, when annual tornado occurrences were examined across different phases of the Pacific Decadal Oscillation, there was a likely tendency for more tornado occurrences in El Nino years during PDO2 and no significant interannual variability during PDO1 years. During the 1950 – 1976 period, other studies have found that significant tornado occurrences were overestimated. When a simple correction factor was applied here and the interannual variability re-examined, the strength of the statistical relationships changed such that there was now a likely tendency for fewer tornado occurrences in El Nino years during the PDO1 period, and no statistically significant relationship for PDO2 years. Finally an examination of the composite dynamics during the bulk of tornado season revealed that, out of five years examined, the large-scale flows were of similar dynamic character for four of them. The season which produced the most*

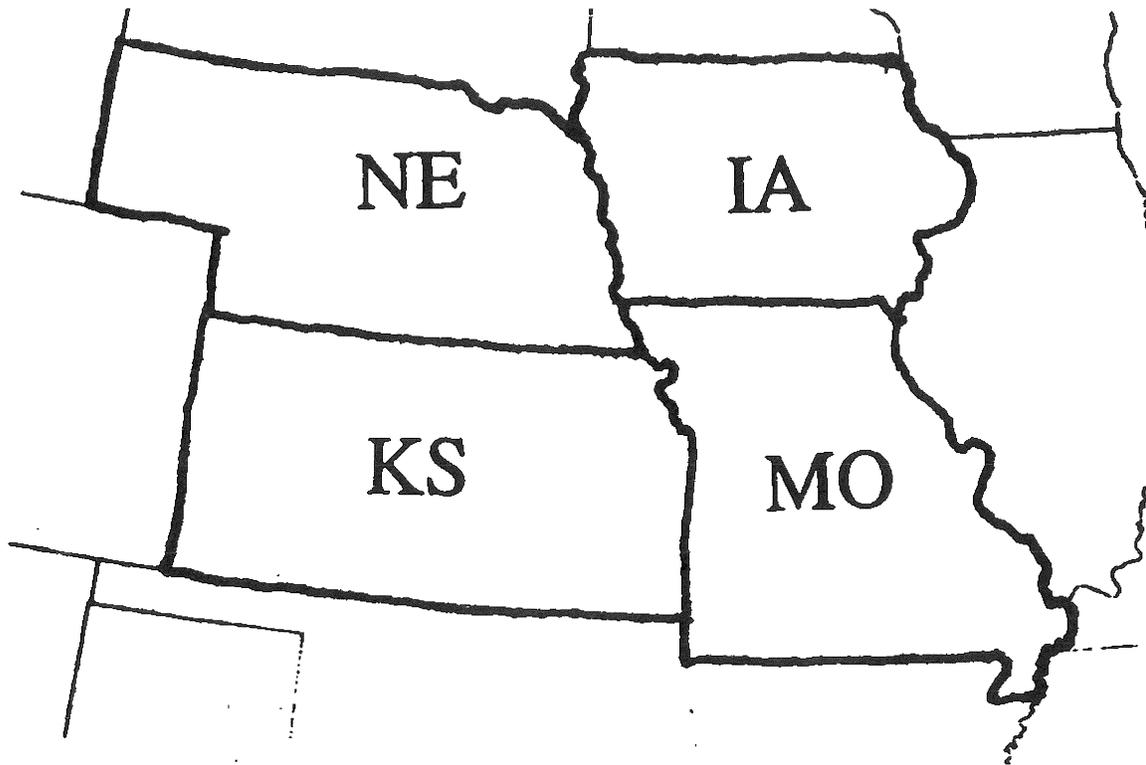
*tornadoes qualitatively was shown to be slightly more conducive to severe weather production when using simple empirical severe weather indexes.*

## 1. Introduction

In spite of the number of papers published addressing the long-term variability in tornado occurrences (e.g., Bove, 1998; Agee and Zurn-Birkhimer, 1998; Marzban and Schaefer, 2001) there is still uncertainty regarding this problem, and these problems include, but are not limited to, the observation of tornado events and the procedures for damage survey ratings (e.g., Marzban and Schaefer, 2001). Even with these challenges faced by researchers, recent studies have shown that mesoscale events do exhibit interannual variability that can be related, at least in part, to the El Nino and Southern Oscillation (ENSO) phenomenon. In the central plains region, for example, Browning (1998) and Berger et al. (2003) found significant interannual variations in the number of tornadoes and heavy snowfall events. This interannual variability in small-scale phenomena, especially in the Berger et al. (2003) study, was then associated with regional interannual variability in the large-scale weather regimes that occurs in conjunction with ENSO.

Recent attempts to quantify the interannual variability in tornado occurrences used a variety of statistical methodologies, examined different geographical regions, included either all or some tornadoes (e.g., F2 or greater), and using slightly differing definitions for ENSO, have yielded mixed results. For example, Schaefer and Tatom (1998) found very weak and statistically insignificant relationships between ENSO and tornado occurrences across various regions of North America. Agee and Zurn-Birkhimer

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*Figure 1.* The four state region considered for this study – Iowa (upper right), Kansas (lower left), Missouri (lower right), and Nebraska (upper left).

(1998) found that there were no significant ENSO-related interannual variations in tornado occurrences nationwide, but that there were geographical shifts in the areas of maximum occurrence. They found that the central and southern plains states (tornado alley) experienced more events during strong El Niño (EN) years. However, Bove (1998) found that this region experiences significantly more tornado events during La Niña (LN) years using bootstrap techniques to enlarge the data set. Marzban and Schaefer (2001) found that there was a weak, but significant, tendency for more tornado occurrences in tornado alley (the plains states) during LN months, and thus, by extension, LN seasons. Wikle and Anderson (2003) reported similar results to Marzban and Schaefer (2001) over the western plains states using a Bayesian Spatio-Temporal model.

A study of interannual variability only, however, can be misleading as shown by the Berger et al. (2003) study of northwest and central Missouri snowfall events. Their work revealed that there were

only slightly more snowfall events that occurred in LN winters when comparing to EN years using a 50 year data set. When this ENSO variability was analyzed in conjunction with long-term variations (e.g., the Pacific Decadal Oscillation or PDO), however, it was shown that the character of the ENSO-related variability itself changed when examined separately within each phase of the PDO. In particular, there was little ENSO variability snowfall occurrences during the middle portion of the 20<sup>th</sup> century, but very strong ENSO related variability in the latter half of the century after a change in phase of the PDO. Berger et al. (2003) also linked these changes in snowfall variability to variability in the larger-scale patterns that brought snowfalls to their study region. Thus, the changes in the behavior of ENSO variability found by their study could possibly be linked to PDO variability. Some model (Knutson et al., 1997; Collins, 2000) and observational (e.g., Gu and Philander, 1995; Mokhov et al., 2000, 2004) studies have shown that the period and amplitude of ENSO does vary on the time-

scales of decades or more, and Weitlich et al. (2003) suggest that this may be related to changes in phase of the PDO.

Then, in an attempt to gain a better understanding of the interannual variability of tornado occurrences in the central plains region of the United States, this climatological study considered all tornadoes of F2 or greater that occurred across a four-state region (Iowa, Kansas, Missouri, and Nebraska) from 1950 to 2002. Once all applicable observed tornado events were collected, a statistical analysis was performed in order to examine interannual and interdecadal variations in tornado frequencies. Finally, representative composites of synoptic-scale features were examined and these demonstrate that the statistical relationships found here may result from variability in the character of these synoptic and larger-scale environments.

## 2. Data and Methodology

### *a. Data*

Figure 1 shows the region of concern for this study. A climatology of all tornadoes of F2 intensity or greater from Iowa, Kansas, Nebraska, and Missouri from 1950 through 2002 was compiled using data acquired from the Storm Prediction Center (SPC)<sup>1</sup> in order to establish a large data set of central plains tornadoes. The multi-state region was chosen not only to enlarge the data set overall, but also since some studies (e.g., Agee and Zurn-Birhimer, 1998; Palecki and Leathers, 2000) suggested that the ENSO variability in general may be different across the western portion of this region versus that in the eastern and southeastern portion of this region. This gradient in the interannual variability was also suggested examining the results of Martins and Smith (2003), who found that the cyclone tracks (with fewer but stronger cyclones) were located further south during EN years across the eastern portion of the region and the eastern two-thirds of the U.S. overall.

This study selected the data and the time-period of 1950 – 2002 for several reasons. Climatological studies of tornadoes are sensitive to many external factors influencing their count such as; population densities, technical innovations, and individual subjectivity in damage surveys and how these damage surveys are performed (e.g., Marzban and Schaefer, 2001). As advances in technology have led to better tornado detection, it is likely that the number of F0

and F1 tornadoes have been responsible for a dramatic increase in raw tornado frequencies (e.g., Marzban and Schaefer, 2001)<sup>2</sup>. Thus, our study excluded these events. Other problems with tornado counts such as; the bias in tornado counts to populated areas, and differences in observation techniques (e.g., damage surveys by the National Weather Service, rather than inference from newspaper accounts – for example see Marzban and Schaefer, 2001; Ray et al., 2003) are difficult to account for in a purely objective manner. Thus, only raw counts have been examined, as done by other studies cited above.

A synoptic analysis was performed in order to relate tornado occurrences with the larger-scale environment. Relating the planetary-scale to the synoptic and mesoscale, however, can also 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 these interactions may be highly non-linear (e.g., Yarnal, 1993; Lupo, 1997). Even with these difficulties, however, and in order to be valid, any credible statistical result regarding the interannual variability of tornado occurrence, whether they are strong or weak, should be at least physically consistent with the composite synoptic variability and the interannual variability found in large-scale patterns as found by previous studies. Finally, the choice of the 1950 - 2002 time-period is a long enough period of time to include several El Nino (12) and La Nina (14) events and to examine the interdecadal variability.

### *b. definitions*

After compiling all applicable tornado occurrences, the maximum intensity of each tornado was recorded as measured using the Fujita Scale (e.g., Ahrens, 2000, Table 15.1). Then, all tornado occurrences were stratified by EN, neutral (NEU) and La Nina years (LN) in order to determine whether large-scale flow regime variations associated with sea surface temperature (SST) variations in the Pacific Ocean basin were reflected in the tornado climatology. The dataset was stratified also by phase of the Pacific Decadal Oscillation (PDO). Berger et al. (2003) outlined the definitions of ENSO and PDO and the methodologies for performing the analysis and we describe these briefly below.

For identifying years with respect to El Nino and Southern Oscillation, this study used the Japan Meteorological Agency (JMA) ENSO Index. This

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

La Nina (LN)	Neutral (NEU)	El Nino (EN)
1949	1945-1948	1951
1954-1956	1950	1957
1964	1952-1953	1963
1967	1958-1962	1965
1970-1971	1966	1969
1973-1975	1968	1972
1988	1974	1976
1998-1999	1977-1981	1982
	1983-1985	1986-1987
	1989-1990	1991
	1992-1996	1997
	2000-2001	2002

definition has been used in several published studies in order to examine the interannual variability in a variety of phenomenon (e.g., Bove, 1998, Lupo and Johnston, 2000; Berger et al., 2003), and is similar to another commonly used definition (e.g., Trenberth, 1997). Additionally, there is no consensus in the scientific community as to which ENSO index best captures ENSO as of this time (Hanley et al. 2003). The reader will find a list of EN, LN, and NEU years (Table 1), as well as a more detailed description of the JMA ENSO Index, by accessing the Center for Ocean and Atmospheric Prediction Studies (COAPS) website<sup>3</sup>. 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 both the Nino 3 and 3.4 regions in the central and eastern tropical Pacific. The SST anomaly thresholds used to define EN and years are those greater and less than +0.5° C, less than -0.5° C, respectively, and NEU otherwise. For classification as an EN or LN year, these values must persist for six consecutive months including October, November, and December.

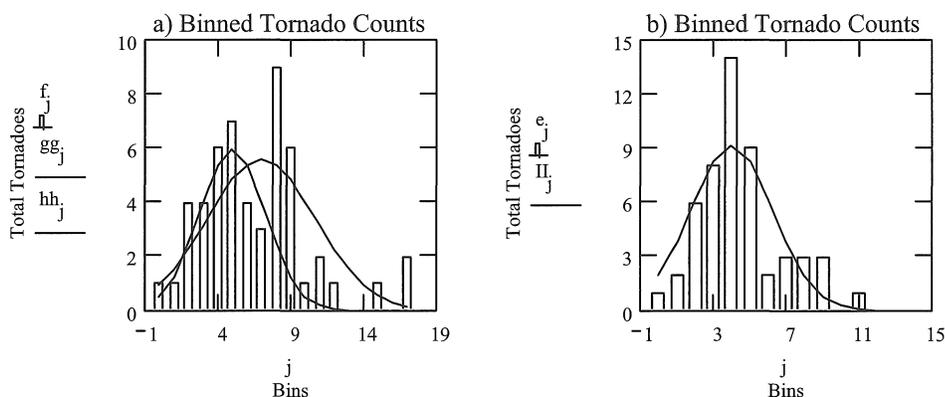
The JMA ENSO criterion defined the El Nino year as beginning on 1 October of the previous year. Thus, for example, the ENSO year 1970 begins in October of 1970 (Table 1) and ends in September 1971. Since most tornado occurrences during the spring and summer (April to June throughout the region studied is the peak time for tornado occurrences<sup>2</sup>), all calendar year 1971 tornadoes were considered ENSO year “1970” in order to remain consistent with the JMA criterion in our analysis. This study noted very few tornado occurrences across the region during October through December period in general, and a separate analysis of this period did not reveal any statistically significant variations and constitute a small sample. Since also the peak of tornado occurrences across this region was April to June or July<sup>2</sup>, while ENSO typically sets in during the late fall

Table 2. The phase of the Pacific Decadal Oscillation (PDO).

PDO PHASE	PERIOD OF RECORD
Phase 1	1933-1946
Phase 2	1947-1976
Phase 1	1977-1998
Phase 2	1999-Present

and early winter of the previous year, the use of these annual statistics implicitly included a 4 to 6 month lag between ENSO onset and the bulk of tornado season. This was appropriate since there are many published papers which demonstrate that there is approximately a 3 to 6 month lag between the SST distributions in the Pacific region and the general circulation over North America (e.g., Namias, 1982, 1983; Hoskins et al., 1983; Park and Kung, 1988; Lee and Kung, 2000). Other climatological studies correlated monthly SST's against monthly tornado occurrences and this assumed an “instantaneous” response by the general circulation to changes in SST's. Marzban and Schaefer (2001) acknowledge, however, that an instantaneous response by the general circulation may not strictly be a valid assumption.

The PDO is a longer-term SST oscillation occurring over a 50 to 70 year period (e.g., Minobe, 1997) within the eastern Pacific Ocean basin. Gershonov and Barnett (1998) defined the positive phase of the PDO as characterized by an anomalously deep Aleutian Low. Cold western and central north Pacific waters, warm eastern Pacific coastal waters. Warm tropical Pacific waters also characterize this phase of the PDO, which we refer to as PDO1. The reverse conditions characterized the negative phase of PDO and we refer to these conditions as PDO2. Table 2 shows the period for each phase of the PDO (also see Gershonov and Barnett, 1998; Weitlich et al., 2003; Lupo et al., 2004). Gershonov and Barnett (1998) found a correlation between PDO phase and the intensity of ENSO as they both affect the atmospheric climatological flow regimes over the United States simultaneously. In particular, they found that the PDO serves to either enhance or weaken the ENSO phenomenon, and thus the strength of the influence of the ENSO phenomenon (depending on the PDO phase). During PDO1 (PDO2), the intensity of EN and its impacts on North American atmospheric



*Figure 2.* The total annual frequency of a) raw, and b) modified central plains tornado occurrences are binned into 18 classes (bin width = 5), beginning with bin 1 (1-5 events). The dashed line in a) and b) is a normal distribution fitted (see Neter et al., 1988, p. 212, eq. 7.5) to the histogram plotted, while the solid line in a) is the normal distribution fitted by simply throwing out all occurrences greater than 41 events.

climatological flow regimes and circulation features tends to be greater (weaker), with a less (more) intense LN impact.

### *c. Statistical Testing*

This study performed a simple statistical analysis by assuming that the distribution of annual frequencies of tornado occurrences across this region was (near) normal, in the absence of significant changes in the climate. A simple two sided “standardized test statistic” ( $z^*$ ) was used for the comparison of sample means for tornado frequencies and the details for this analysis can be found in any standard statistics textbook (e.g., Neter et al., 1988) In Fig. 2a, the raw annual frequencies are binned into 18 classes, each class being 5 events wide. The standard normal distribution was fitted then to the data (dotted curve). Carrying out a chi square goodness-of-fit test demonstrated that the raw annual tornado occurrences were not normally distributed. This result appeared to have occurred because of several years in which 41 – 90 tornadoes occurred, many of these seasons occurring before 1977.

Schaefer and Edwards (1999) and Marzban and Schaefer (2001) state that the occurrence of F2 tornadoes prior to the mid-1970’s may be overestimated since damage surveys were carried out based on second-

hand information (newspaper reports). They also state that the National Weather Service began carrying out immediate damage surveys in the late 1970’s. Brooks and Craven (2002), however, put this change in damage survey procedure which lead to overestimation of intensity around 1973. In a simple exercise to test the impact this problem may have on the annual distribution of tornado occurrences, while retaining a large enough sample for statistical testing, seasons with 41 or more tornadoes prior to 1977 only were discarded (17 of them). We chose the year 1977 since it was close to the time when the National Weather Service began carrying out damage surveys and this coincided with a change in phase of the PDO. Fitting a normal distribution to this dataset (Fig. 2a - solid curve) demonstrates that the annual occurrences were much closer to being normally distributed. While we concede that this simple analysis does not take into account overestimation prior to 1977 for years with fewer than 41 occurrences (in order to retain a large enough sample), it is likely that, if this overestimation could be properly accounted for and assuming no significant climate change, the dataset would be normally distributed (or close to normally distributed). Also, while this test is arbitrary, this was the simplest way that we decided to treat these data without imposing any further artificial assumptions on a dataset already fraught with potential observational

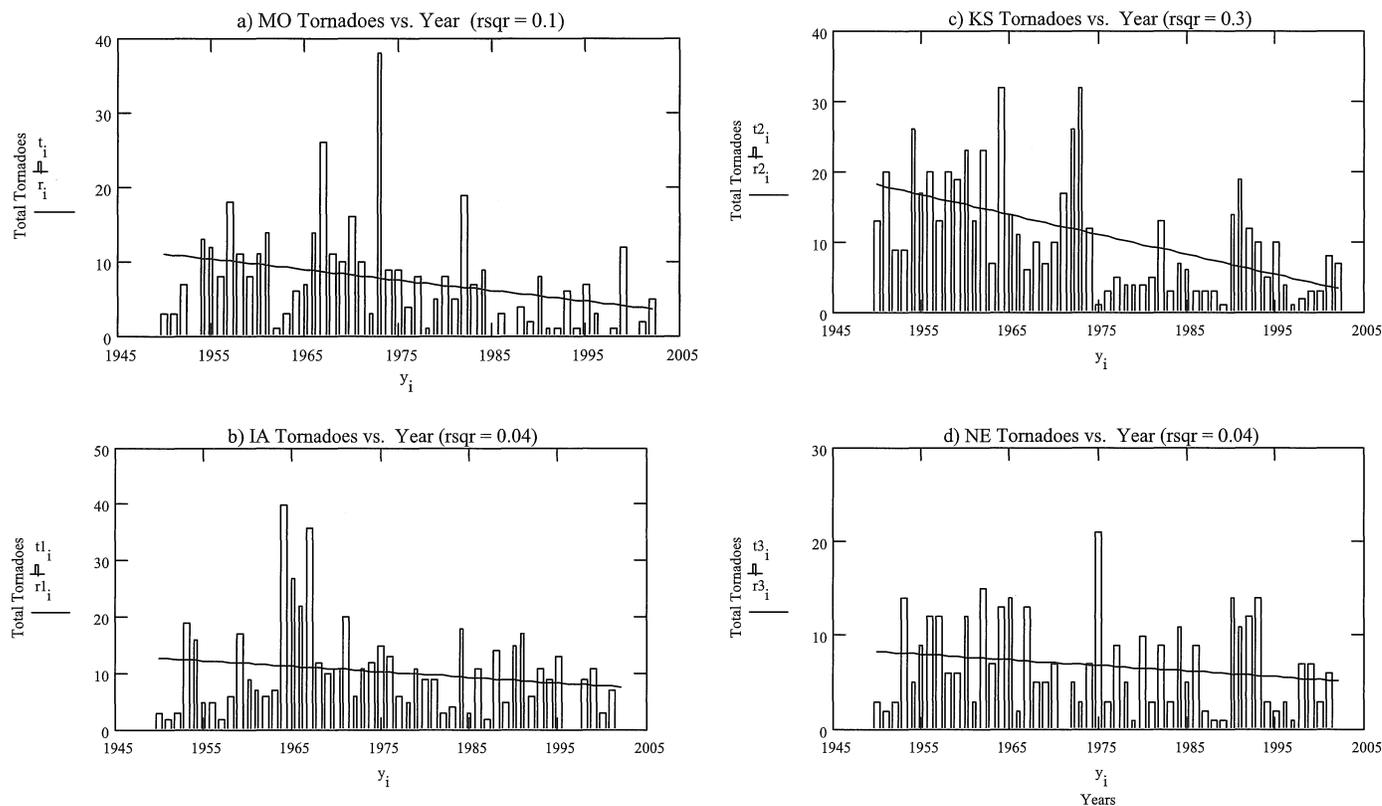


Figure 3. Long term trends in tornado occurrence per year for a) Missouri, b) Kansas, c) Iowa, and d) Nebraska.

problems.

### 3. Climatological Analysis

#### a. Trends

Our study carried out an analysis of the long-term trends by examining the annual frequency of occurrence in each state (Fig.3). Each state was treated separately in order to account for the possibility of spatial inhomogenities in long-term trend, which may be the result of real changes in climate or observing practices as discussed by some studies reference above. Observing practices could differ between National Weather Service county warning areas, which in many cases approximate state boundaries. These trends were derived using simple linear regression and tested for significance using an F-test (e.g., Neter et al., 1988). Each state exhibited a downward trend in the number of significant tornadoes, which again is likely to be the result of overestimation of the number of F2 events commented on Schaefer and Edwards (1999), Marzban and Schaefer (2001), or Brooks and Craven (2002). Thus, trend analysis here may not be reasonable. Even in the face of these problems, however, the downward

trend was statistically significant (at the 95% confidence level), but only for Kansas and Missouri tornadoes (Fig. 3). Thus, the possible overestimation in the early part of this dataset additionally precluded an attempt to detect PDO-related variability (since the method of determining F-scale intensity changed at approximately the same time as the shift in phase of the PDO, or 1977) and changes in tornado counts due to climate change. Nonetheless, if tornado frequencies were overestimated prior to 1977, the degree to which this bias impacted the dataset may not have been spatially uniform. At the same time however, we must state that it would not be possible to assess what part of each state's trend may be due to bias or inherent natural variability given the information that was available to the study.

#### b. Interannual and Interdecadal Variations

Table 3 displays the raw number of tornadoes that occurred across the entire region and the average number of events per year. These numbers demonstrate that more tornadoes occurred during NEU years across the region of study than for LN and EN years. However, an examination of the mean annual frequency of tornado occurrences revealed that more tornadoes occurred

Table 3. All Iowa, Kansas, Missouri, and Nebraska significant tornadoes from 1950 – 2002 stratified by ENSO phase.

	La Nina	Neutral	El Nino	All
Tornadoes	502	908	456	1866
Annual Average occurrence	35.8	33.6	38.0	35.2

Table 4. Average annual significant tornado occurrence in each ENSO phase for all states considered.

	La Nina	Neutral	El Nino	All
Iowa	9.9	10.0	11.2	10.2
Kansas	10.9	10.3	11.8	10.8
Missouri	7.7	6.4	9.4	7.4
Nebraska	7.3	7.0	5.6	6.8

Table 5. All Iowa, Kansas, Missouri, and Nebraska significant tornadoes from 1950 – 2002 divided by PDO phase.

	PDO1	PDO2	All
Tornadoes	553	1313	1866
Annual Average occurrence	25.1	42.4	35.2

Table 6. Average annual significant tornado occurrence in each PDO phase for all states considered in this study.

	PDO1	PDO2	All
Iowa	8.2	11.7	10.2
Kansas	6.3	14.0	10.8
Missouri	4.5	9.5	7.4
Nebraska	6.2	7.2	6.8

during EN years, and there was less difference in the mean number of occurrences in LN and NEU years. None of these differences rose to the level of statistical significance, and none of these differences even indicated a “likely relationship” (66-90% significance).

A state-by-state breakdown (Table 4) revealed that the interannual variability was similar across three of the four states as EN years lead LN years, however, again, none of these results are statistically significant, which is a result consistent with Agee and Zurn-Birkhimer (1998). Several of the studies referenced above found weak statistical relationships to ENSO phase using sophisticated statistical techniques, with LN years leading EN years in tornado occurrence across this region. Only in Nebraska did LN years lead EN years and this interannual variability is consistent with that found many of the studies cited above, and consistent with that found by Browning (1998) who found LN years produced more tornadoes, but in northwestern Missouri.

Our results and those of Agee and Zurn-Birkhimer (1998) would also agree with the study of Martins and Smith (2003), who showed that during EN years, there was a strong storm track across the eastern southern tier of states. More and stronger synoptic-scale cyclones in the southeastern portion of our study region during EN years would plausibly result in more opportunities for tornado occurrences in the Southern Plains. Martins and Smith (2003) indicate that LN years were associated with a storm track across the northern tier of states, and that there were more cyclone events across the eastern two-thirds of the United States as a whole during these years. Our results here also agree qualitatively with those discussed by COAPS<sup>3</sup> regarding the typical ENSO impacts on temperature and precipitation over this region, as they imply the storm track resides further south during the spring months across this region during EN years.

As described above, the impact of the change in the way F-scale intensities were determined which

*Table 7.* The total number / average annual occurrence of all significant tornadoes considered in this study stratified by PDO and ENSO phases (\* represents a likely relationship).

	PDO1	PDO2
La Nina	9 / 9	493 / 37.9
Neutral	420 / 28.0	488 / 40.7
El Nino	124 / 20.7	332 / 55.3*

*Table 8.* Average Annual tornado occurrence from 1950 – 1976 versus 1977 – 2002, and the correction factor used to modify the earlier period.

	1950 - 1976	1977 – 2002	Correction Factor
Iowa	12.7	7.7	0.61
Kansas	15.3	6.1	0.4
Missouri	10.2	4.5	0.44
Nebraska	7.6	5.8	0.76

had occurred roughly during the same time as a change in phase of the PDO precluded using the raw data to determine directly a possible signal in the interdecadal variability in annual tornado occurrences. However, if it is assumed that the change in observation practice occurred approximately in a systematic way and almost concurrently with the change in phase of the PDO, then it is still possible to detect interactions between PDO and ENSO signatures. Studies cited in the introduction have shown that within this region, changes in phase of the PDO were associated with a change in the nature of ENSO-related variability in this region. It was to this end that an attempt was made to detect PDO related variations in tornado occurrence, by examining the change in ENSO variations within each phase of the PDO (Table 5 - 7).

Table 7 stratified the data by ENSO year within each phase of the PDO. During the PDO1 period, there was no significant interannual variability in the number of tornado occurrences. During these years, there were more events in NEU years as opposed to EN years. LA years were not included here since there was only one LN year during PDO1. However, during PDO2 years, the mean number of tornado occurrences was greater during EN years, and this was significant at only the 85% confidence level (indicating a likely relationship). A similar number of events occurred in both LN and NEU years. The finding that EN years generally lead in tornado occurrence during the PDO2 period is consistent

with the results of Agee and Zurn-Birkhimer (1998) for the study region and the time periods of observation for PDO2 and their study have considerable overlap. This analysis demonstrates, however, that the nature of ENSO variability possibly changed within each PDO period. As suggested by Berger et al. (2003), it would be difficult to determine reliably the statistical character of the ENSO related variability within the entire 53-year period since studies have shown the character of ENSO to change significantly over the latter portion of the 20<sup>th</sup> century (Gu and Philander, 1995; Mokhov et al., 2000, 2004).

### *c. Modified annual tornado occurrences from 1950 – 1976: an experiment*

When examining the annual frequency of tornadoes (Table 5 and 6) for the whole region and state-by-state, there were far more tornadoes in the earlier period (1950 – 1976) versus that of the later period (1977 – 2002). In an attempt to apply a simple correction to the possible overestimate in significant tornado occurrences prior to 1977, the ratio of the mean tornado occurrences from 1977 - 2002 was divided by the mean of those occurring from 1950 – 1976 (Table 8) for each state, and then multiplying this number by the raw annual frequencies during the earlier period. This had the effect of normalizing the earlier period with

*Table 9.* As in Table 3, except using the modified tornado occurrences from 1950 – 1976.

	La Nina	Neutral	El Nino	All
Tornadoes	295	695	293	1283
Annual Average occurrence	21.1	25.7	24.4	24.2

*Table 10.* As in Table 4, except using the modified tornado occurrences from 1950 - 1976.

	La Nina	Neutral	El Nino	All
Iowa	6.6	8.1	8.1	7.7
Kansas	4.7	6.9	6.1	6.1
Missouri	4.1	4.5	5.1	4.5
Nebraska	5.7	6.3	5.0	5.8

*Table 11.* All IA, KS, MO, and NE tornadoes from 1950 – 2002 divided by PDO phase after application of the Table 8 correction factors to the 1950 – 1976 occurrences state-by-state.

	PDO1	PDO2	All
Tornadoes	553	730	1283
Annual Average occurrence	25.1	23.5	24.2

respect to that of the later period or imposing no long-term trend on the dataset (Fig. 2b). This can be justified by assuming that if observed trends were slight and/or statistically insignificant and if no bias in the earlier period were present, then a similar result (no-trend) could be obtained by random chance and no long-term trend at all is an equally likely outcome. If a true climate change did occur, however, then this experiment would not present credible results. Nonetheless, this simple experiment also had the effect of “detrending” the time series, a technique often applied to such data when the goal of the work is to find periodicity on time-scales smaller than that of the entire time series by using sophisticated techniques, such as Fourier or wavelet techniques (e.g., Mokhov et al., 2000, 2004).

Performing this analysis modified the interannual variability overall and/or state-by-state (Tables 9 and 10). Table 9 showed that, overall, ENSO neutral years produce more tornadoes across the region, but EN years slightly lead still LN years. Table 10 shows that in each state, EN and/or NEU years lead LA years. Then, as a result of applying the correction

factor in Table 8, the average annual occurrence of tornadoes was similar across each phase of the PDO (Table 11). After application of this correction factor to the annual tornado occurrences before 1977, however, a different statistical interpretation emerges region-wide as concerns the ENSO-related variability (Table 12). During the PDO2 period, now there was no statistically significant interannual variability, but EN years still produced more events per year than NEU and LN years, regionally. During the PDO1 period, however, EN years experienced fewer significant tornado events per year across the region than ENSO NEU years, a relationship indicated to be statistically “likely” (significant at the 70% confidence level). These results were still consistent with the Martins and Smith (2003), and fewer tornado occurrences during PDO1 ENSO years region-wide. Thus, the modification did not change qualitatively the results found using the raw tornado occurrences.

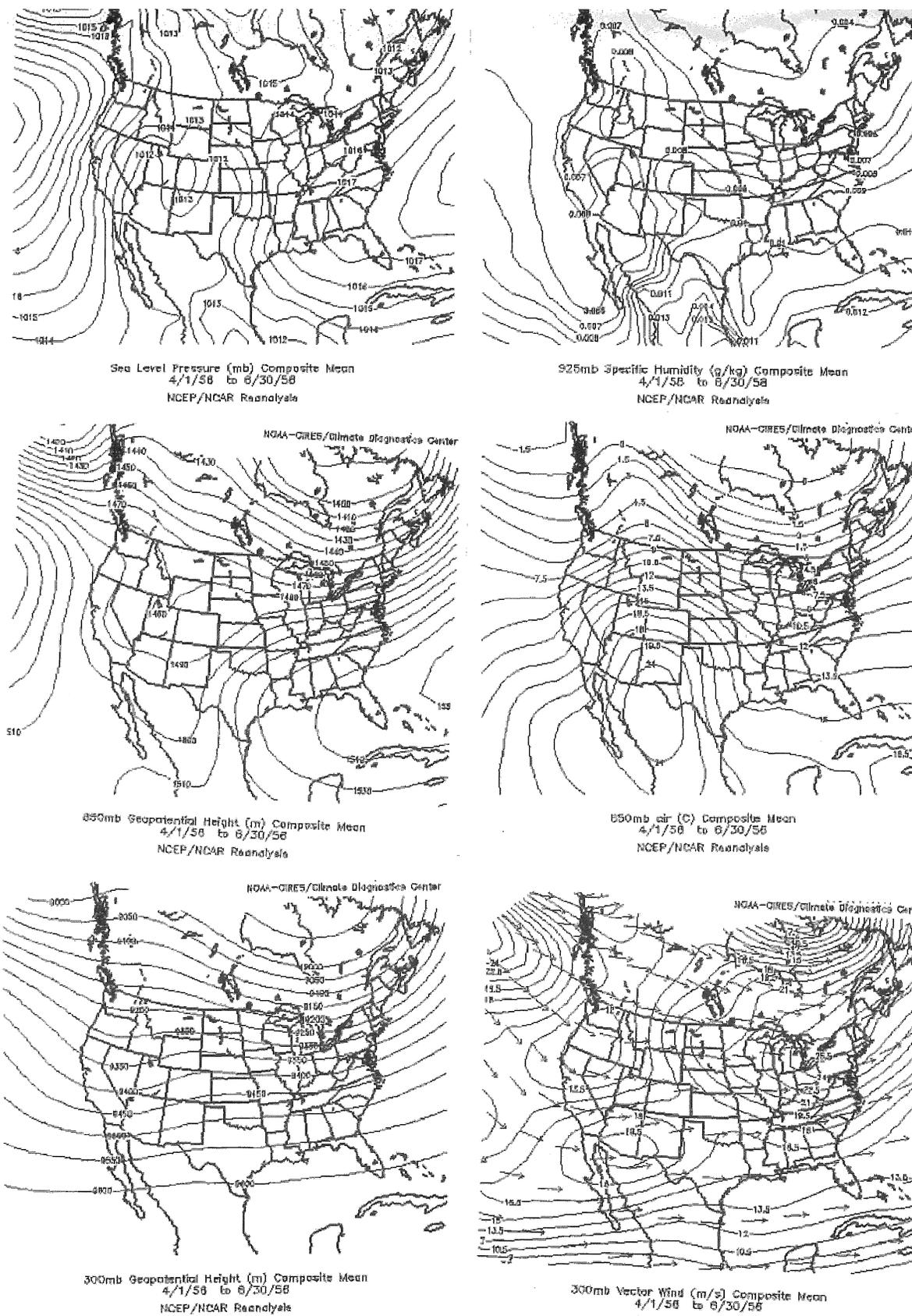


Figure 4. The synoptic composites using the NCEP re-analyses for 1 April to 30 June 1956 of a) sea level pressure (hPa, contour interval every 4 hPa), b) 925 hPa specific humidity ( $\text{g kg}^{-1}$ ,  $0.00025 \text{ g kg}^{-1}$ ), c) 850 hPa heights (m, 30 m), d) 850 hPa temperatures ( $^{\circ}\text{C}$ ,  $1.5 \text{ }^{\circ}\text{C}$ ), e) 300 hPa heights (m, 120m), and f) winds ( $\text{m s}^{-1}$ ,  $1.5 \text{ m s}^{-1}$ ).

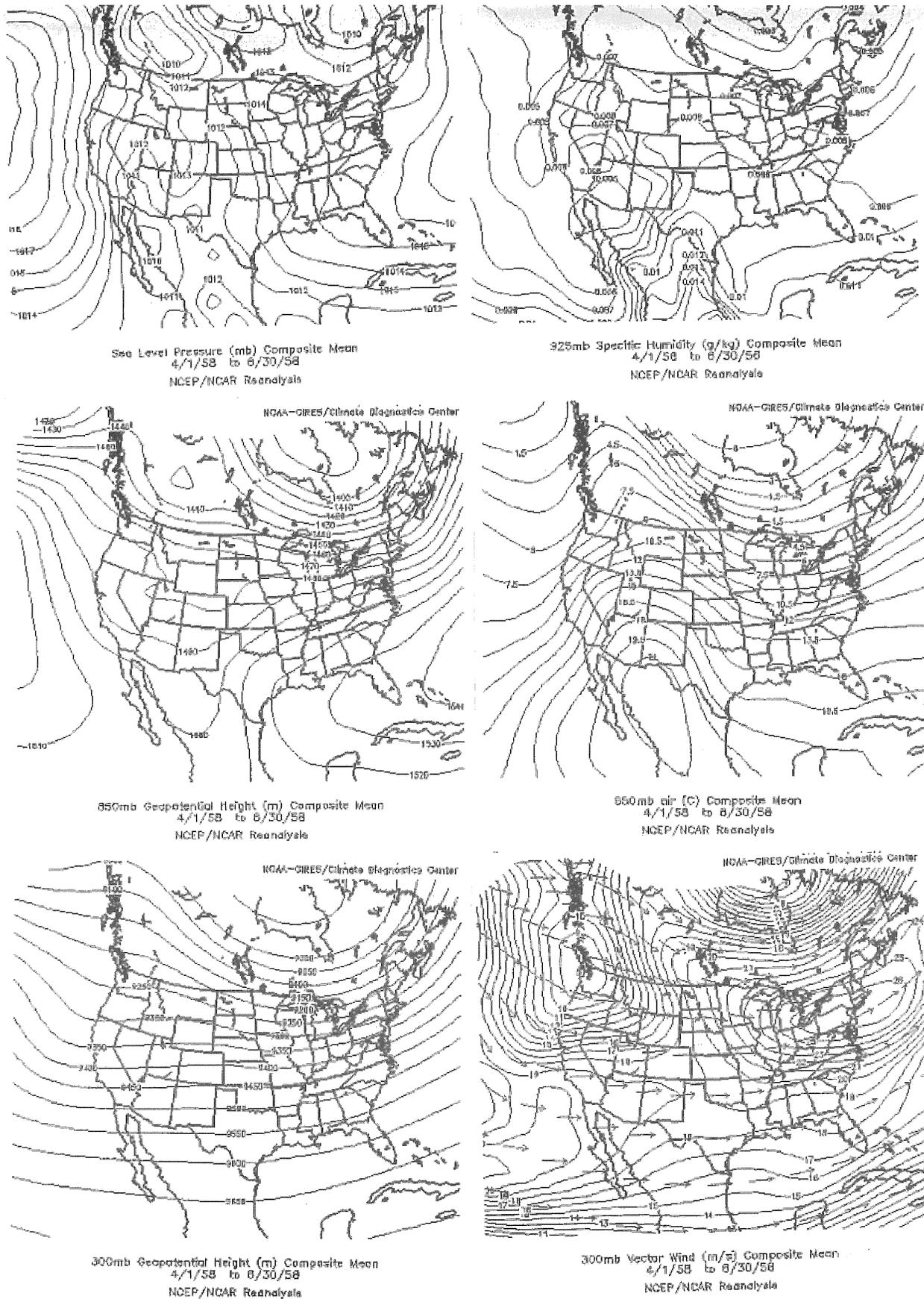


Figure 5. As in Fig. 4, except for the year 1958.

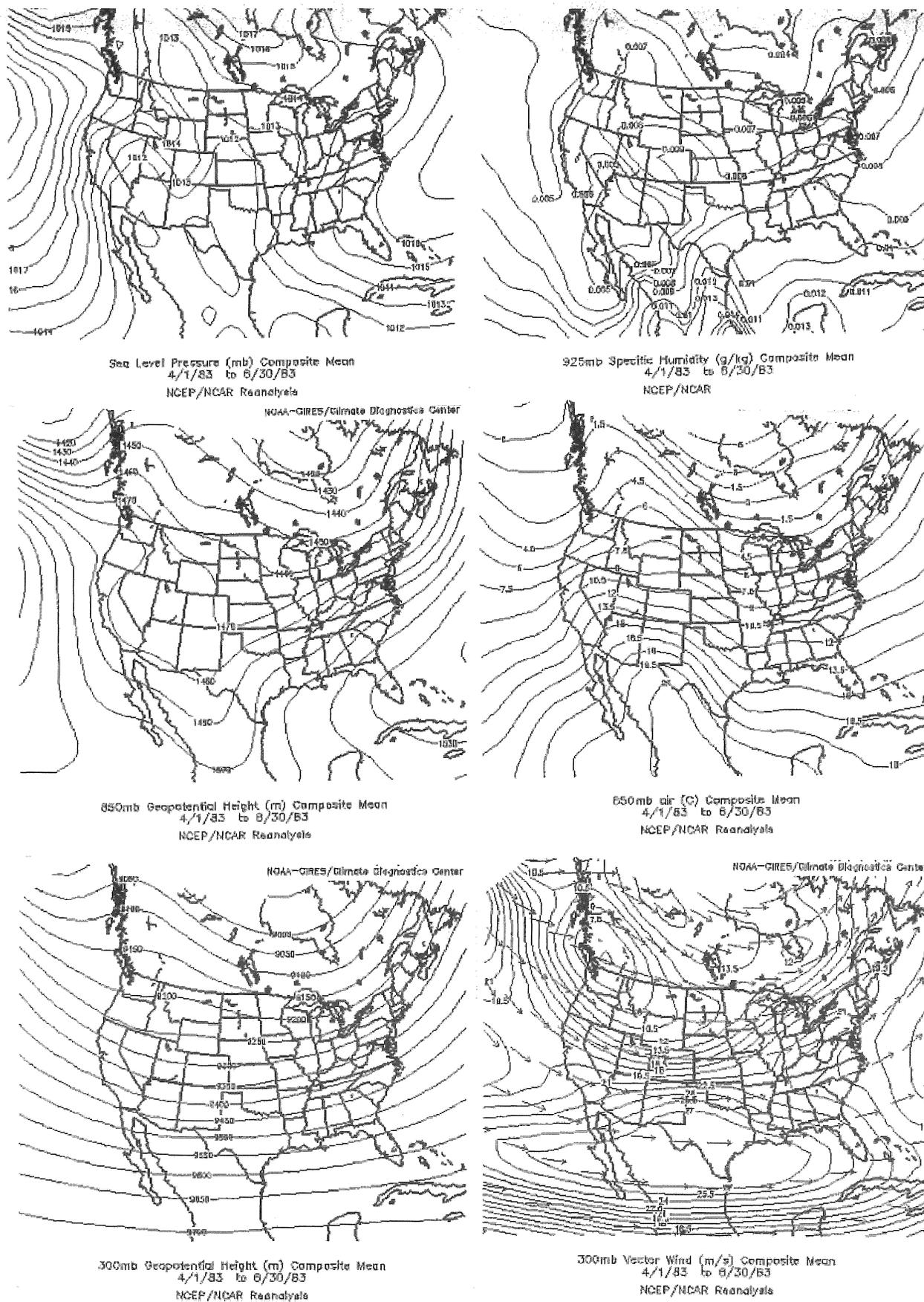


Figure 6. As in Fig. 4, except for the year 1983.

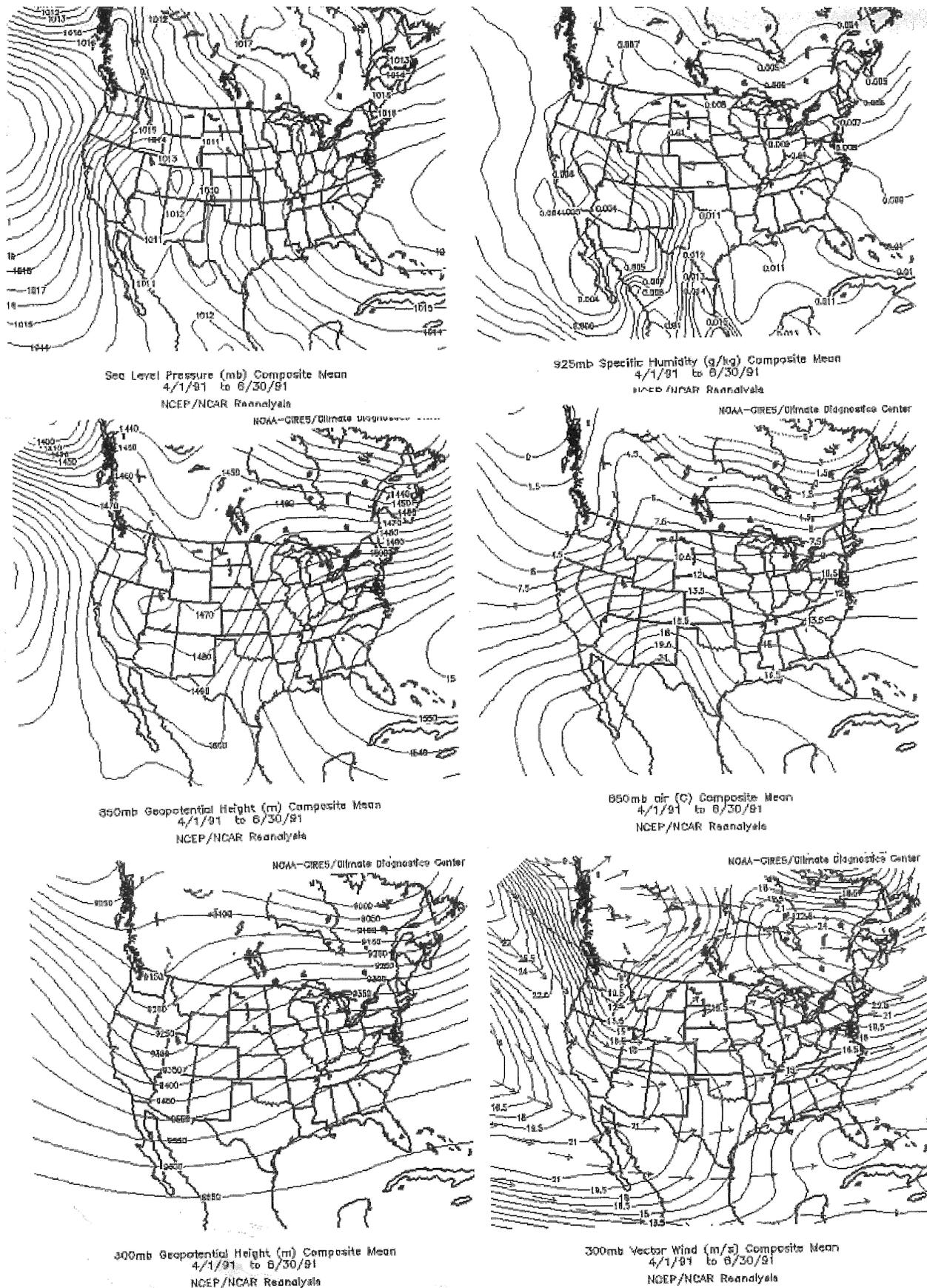


Figure 7. As in Fig. 4, except for the year 1991.

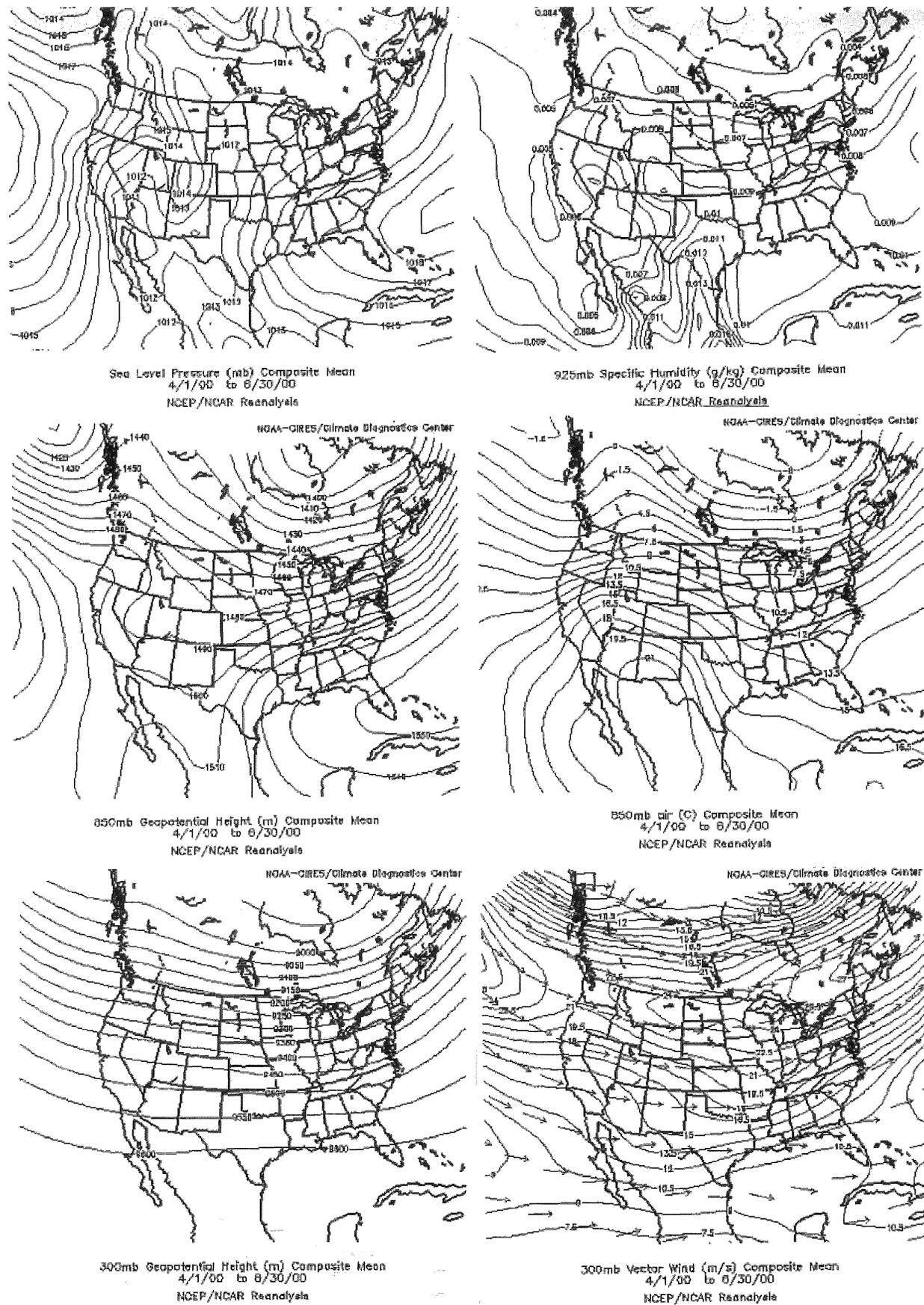


Figure 8. As in Fig. 4, except for the year 2000.

#### d. Synoptic Composites and Discussion

The previous results demonstrate that it is difficult to determine if there is statistically significant interannual variability in tornado occurrences. Bias and subjectivity in determining whether or not a tornado event occurred, how intense the event was, and the rapid improvements in tornado detection perhaps make deriving useful climatologies of these small-scale events not possible yet. The results found here using raw tornado counts and modified counts using elementary statistical methods, however, were consistent with each other and in general with the synoptic analyses of other studies. These same techniques also demonstrated that the character of the interannual variability in tornado counts supposedly related to ENSO appears to have changed on longer time-scales, just as the frequency and character of the ENSO itself has been shown to change as well (e.g., Gu and Philander, 1995; Mokhov et al., 2000, 2004). That the character of the interannual variability of tornado occurrences seems to be different across each phase of PDO also agreed with the results of Lupo and Johnston (2000) and Berger et al. (2003), who showed similar results in their study of north Atlantic hurricanes and northwest Missouri snowfalls, respectively.

In order to determine if any of the relationships were supported by examining synoptic and/or dynamic relationships, our study performed a qualitative dynamic analysis using composites for various primary atmospheric quantities during the peak of severe weather and tornado season across the region. A lack of strong statistical relationships may not preclude relationships, which may have a synoptic or dynamic basis (e.g., Nicholls, 2001). The synoptic composites used here were for the April to June period and chosen to represent seasons in which strong EN, strong LN, or NEU conditions persisted during the late fall and into the compositing timeframe. We used observed tornado frequencies, which were representative of the

climatology, to choose these years. Observed tornado frequencies were not examined, however, within the April to June period before compositing. Finally, we constructed these composites using the National Centers for Environmental Prediction (NCEP) re-analyses available through the Climate Diagnostic Center (CDC) Daily Mean Composites Page<sup>4</sup>. It should be noted here, however, that compositing procedures smooth out day-to-day variations and individual events. Nonetheless, compositing can demonstrate that the overall environment may have been more or less conducive to the formation or presence of strong synoptic-scale features that produce severe weather.

The NCEP - NCAR gridded re-analyses (Kalnay et al., 1996) are archived at NCAR and were obtained from the mass-store facility in Boulder, CO. The re-analyses used here were the 2.5 degrees by 2.5 degrees latitude-longitude gridded analyses available on 17 mandatory levels from 1000 to 10 hPa at 6-h intervals. These analyses include standard atmospheric variables such as geopotential height, temperature, relative humidity, vertical motion,  $u$  and  $v$  wind components and surface information.

The composite variables used here (e.g., Fig. 4) were sea level pressure (hPa), 925 hPa specific humidity ( $\text{kg kg}^{-1}$ ), 850 hPa and 300 hPa geopotential heights (m), 850 hPa temperature ( $^{\circ}\text{C}$ ), and 300 hPa vector winds ( $\text{m s}^{-1}$ ). We used these variables to infer relevant larger-scale dynamic quantities such as upper level divergence, tropospheric directional and/or speed shear, or the importance of various quantities such as available moisture. These quantities are some examples of variables used by forecasters in assessing the threat or risk of severe weather in short range forecasting and nowcasting from the large and synoptic-scale pattern.

The first two composites examined were from the years 1956 (Fig. 4) and 1958 (Fig. 5). These two seasons occurred within the early period (PDO2) and produced a similar number of significant tornadoes (45 versus 43,

*Table 12.* The total number / average annual occurrence of all tornadoes considered in this study stratified by PDO and ENSO phases (\* represents a “likely” relationship) after application of the simple correction factor in Table 8 to the 1950 – 1976 occurrences.

	PDO1		PDO2	
	Total	Average	Total	Average
La Nina	9	9	286	22.0
Neutral	420	28.0	275	22.9
El Nino	124	20.7*	169	28.2

Table 13. The Total Totals (TT) / Severe Weather Threat (SWeaT) index values for three locations within the four state region studied here for five composite tornado seasons.

Location	1956		1958		1983		1991		2000	
	TT	SWeaT								
Omaha, NE (KOAX)	43	197	45	215	46	202	48	236	44	218
Topeka, KS (KTOP)	45	207	46	224	46	209	48	246	44	236
Springfield, MO (KSGF)	44	240	44	208	44	199	46	240	43	245

Table 14. The five most productive significant tornado producing years for the PDO2 and PDO1 period. The modified tornado occurrences are used for the earlier period.

Rank	PDO 2 (1950 – 1976, 1999-2002)			PDO 1 (1977 – 1998)		
	Number	Year	ENSO phase	Number	Year	ENSO phase
1	50	1964	El Nino	51	1990	Neutral
2	46	1967	Neutral	48	1991	Neutral
3	39	1973	El Nino	45	1984	Neutral
4	36	1965	La Nina	44	1982	Neutral
5	33	1999	La Nina	41	1993	Neutral

respectively) region-wide. More tornadoes occurred during the April - June period than for any other period during those years (42% and 47%, respectively), and 1956 (1958) was a LN (EN) year. There was no clearly identifiable surface low in either composite (Fig. 4a, 5a) east of the Rockies, but there was southerly flow across the four state region examined. At 925 hPa (Figs. 4b and 5b), the specific humidity field indicated that the low-level moisture field was similar in each case as well, as the 0.008 kg kg<sup>-1</sup> contour can be seen across the middle of the region and the 0.009 kg kg<sup>-1</sup> contour nosed into the southern part of the region. Each composite period exhibited similar upper air distributions of 850 hPa height and temperature (Figs. 4c,d and 5 c,d) and 300 hPa height and vector winds (Figs 4 e,f and Figs. 5 e,f). Specifically, there was low-level baroclinicity evident over the four state region, and a low-level trough over the Rockies. There was favorable tropospheric directional shear for severe weather (assuming the 850 hPa winds are nearly geostrophic) as winds veered from southwesterly at 850 hPa to westerly at 300 hPa. The four state region was also located coincident with the equatorward entrance region of the large-scale 300 hPa jet, implying upper-level divergence over the region.

Thus, in a statistical sense and in a synoptic and dynamic sense, there did not seem to be a significant difference between these two tornado seasons, which were representative of El Nino and La Nina years during the PDO2 period. Each season produced a similar number

of tornadoes and the differences in the number of events produced were likely to be attributable to individual synoptic transients and their mesoscale environments. These results regarding weaker differences between the large-scale environments during PDO2 EN and LN years for the tornado season composites would agree with those of Gershonov and Barnett (1998) and the regional study of Berger et al. (2003).

During the PDO1 period, two years were chosen using the same strategy outlined before, except that the tornado season with the second greatest number of events was included here (1991, 48 tornado events, 67% of which occurred during the April to June period). The other season chosen was 1983, which was an EN year and produced a similar number of tornadoes to the long-term EN year average (17 events) the majority of which (14 events) occurred during the compositing period. Fig. 6 demonstrates that the 1983 season was very similar to the composites in Figs 4 and 5, with the exception that there was even less low-level moisture in the northeast part of the four state region. The region was under the poleward exit region of the large-scale upper level jet, which was located across the southern part of North America. This upper level jet configuration was quite common for El Nino spring seasons, especially during the latter part (PDO1 period) of the 20<sup>th</sup> century (see COAPS website<sup>3</sup>).

For the 1991 composite (Fig. 7), all the favorable ingredients for severe weather formation were in place

including a composite surface low along the Texas-New Mexico border (Fig. 7a), more low-level moisture (Fig. 7b), and stronger tropospheric shear than any of the other years shown here (Fig. 7). The upper level divergence was likely enhanced over the four state region as the region was located within the equatorward (poleward) entrance (exit) region of a downstream (upstream) and relatively poleward (equatorward) large-scale jet maximum (Fig. 7f). Rogers and Bosart (1991) also described this scenario for enhanced upper level divergence for flow regimes off the east coast of North America. Additionally, the 850-hPa temperatures were warmer in this composite than in any other composite year shown (Fig. 7d). Thus, the composite, which represents the sum total of individual days within April to June 1991 period, demonstrates this season would have a reasonably better chance at producing more severe weather events than the other three composites.

In order to demonstrate in a quantitative sense which of these composites represented a more favorable environment for the production of severe weather events, two simple and commonly used empirical severe weather indices (Total Totals and SWeaT indices) were manually estimated for three current locations that launch twice-daily radiosondes within the four state region (Table 13). These indices are empirical estimates of the stability and/or baroclinicity in the lower troposphere. We concede here that the values produced by this composite analysis will not meet the threshold values for severe weather, and that the thresholds may be attained during a particular synoptic time. These index values produced for each composite did provide, however, in a relative sense, an estimate of which environment would be more favorable for producing severe weather including tornadoes. The index values for composite period of 1991 (Table 13) produced the highest values, and thus as inferred from the synoptic maps, severe weather and tornado occurrences would be most favored for producing severe weather of the composites shown.

In order to examine a composite season that stood in contrast with 1991 in terms of tornado occurrences, the April to June period for 2000 was chosen (Fig. 8). Only nine significant tornadoes occurred during that year, six of which occurred during the April to June period, and the year was considered to be an LN year. The flow regime for the compositing period, however, does not look significantly different from Figs. 4, 5, and 6. Table 13 also revealed that the composite Total Totals and SWeaT indices were also similar to the

other periods displayed. Then, as may be expected, the difference in the number of significant tornado events between the 1956, 1958, 1983, and 2000 was controlled by smaller scale processes than could be examined here. The year 1991, nonetheless, stood out as a year where the synoptic and large-scale composite flows would reveal a more favorable background setting for severe weather production.

Finally, an examination of the five most productive significant tornado years from the PDO2 period (Table 14) revealed that there was no preference for these years to be associated with one phase of ENSO over another, as the statistics earlier revealed. During the PDO1 period, however, all of the five most productive seasons were ENSO neutral years, and a qualitative examination of the flow regime for two of these seasons (1984, 1990), revealed characteristics similar to those of 1991 (not shown). Thus, it would appear that during PDO1 years a more favorable large-scale background for severe weather occurrence could be associated with ENSO NEU years in general. Recall, the statistical analysis revealed a "likely" relationship for fewer annual tornado occurrences and ENSO years for this period. This contrasted with the other four years analyzed here in which there were no other seasonally composited detectable synoptic or dynamic explanation in the large-scale for any of the weak statistical results. The results of other long-term synoptic climatologies were also consistent with our statistical results found here.

## 4. Summary and Conclusions

An analysis of tornado activity in four central plains region states has revealed the importance of considering not only interannual but also longer-term variability in severe weather occurrences and their relationship to variability in the synoptic flow regimes. The tornado climatology across a four state region, which did not result in a homogeneous climatology, was generated using archived tornado data from SPC for the time period 1950 through 2002. Only F2 tornadoes were considered since F0 and F1 tornado occurrence numbers have dramatically increased due to external factors (e.g., technology, increased populations, etc). There was little ENSO-related variability found in the 53 years of raw tornado occurrences with LN years producing slightly more events. This agreed with the interannual variability found in related studies

(e.g., Agee and Zurn-Birkhimer, 1998). These studies examined tornado occurrences across different regions and used different statistical techniques.

Other studies have shown, however, that the number of significant tornado occurrences before 1977 may have been overestimated due to the techniques used in assessing their F-scale rating. When applying a simple correction procedure to these years by assuming no long term climatic trend, the number of tornado occurrences was reduced drastically, but the interannual variability was similar to that using the raw annual tornado occurrences. Additionally, a study of the interannual variability in tornado occurrences, and how this may vary on an interdecadal scale, revealed the following results. The raw number of tornado occurrences showed a likely tendency for more tornadoes in EN years during the PDO2 period, and no significant ENSO-related variability during the PDO1 period. When the modified annual tornado occurrences were used, however, there was no significant variability related to ENSO during the PDO2 period, but a likely tendency for fewer occurrences of significant tornadoes in EN years.

A synoptic and dynamic analysis using composites maps of the mass and thermal distributions over the United States, and estimates of empirical severe weather indices, reveals that there was little difference in the large-scale character of the 1956, 1958, 1983, and 2000 tornado seasons. Each of these years produced most or a majority of the year's significant tornadoes during the composited period, and only the year 2000 produced noticeably fewer events than the other years. The year 1991 produced the second most tornadoes during the 1977 – 1999 period, and an examination of the synoptic maps showed that the lower troposphere was warmer and moister than for that of the other years. This season was an ENSO neutral year, and during the PDO1 period, the five most productive tornado seasons were ENSO neutral years. Additionally, the character of the composite flow regime for two more of these five years (1990 and 1984) appeared to be qualitatively similar to that of 1991. This implies that for PDO1 years, the large-scale flow may be predisposed to producing more severe weather events than LN or EN years. For most years within the PDO2 period, the character of the large-scale flow regime did not result in comparably favorable conditions for tornado occurrence, and smaller-scale processes controlled likely the number of tornado events that occurred during those individual years.

## 5. Acknowledgements

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# Nitrogen Assessment in Rice Using Hyperspectral Reflectance

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## Abstract

*A completely randomized greenhouse project was performed to determine if hyperspectral reflectance curves could differentiate rice tissue grown on three soil types and with three different commonly used nitrogen fertilizers. Hyperspectral reflectance is a remote sensing technology that, in this case, measures the light distribution reflected from rice leaves and allows estimates of the distribution of various pigments. The concentrations of these pigments (chlorophylls, carotenoids, phycobilins, etc) in rice are partially based on soil fertility, especially nitrogen. Thus, hyperspectral reflectance could become a major diagnostic tool to monitor rice production in the field. The results of the greenhouse project demonstrated that (1) soil type differences were important to the overall plant biomass, (2) nitrogen sources promoted biomass production compared to the zero-N control, (3) the three N-sources were equally effective in promoting plant biomass. The hyperspectral reflectance curves were able to discriminate between the zero-N control and the N-sources; however, the hyperspectral reflectance curves were not able to discriminate among the three N-sources. Elemental analysis of the rice tissue demonstrated that the nitrogen concentrations were relatively uniform and possibly deficient. Field trials with rice tissue having higher nitrogen levels may reveal the ability to hyperspectral reflectance curves to discriminate between nitrogen sources.*

*Key Words: Nitrogen, Rice, Hyperspectral Reflectance*

## 1. Introduction.

Remote sensing is a collection of technologies to detect an attribute of a system without interacting with that system. Hyperspectral reflectance (HR) is

a remote sensing technology that measures the light distribution reflected from an object and analyzes the light distribution to infer the composition of the object or some quality parameter derivative from the composition. In plant agriculture, HR has been extensively investigated to infer plant health or nutrient status (Table 1).

HR technologies generally operate within the realm of the visible (380 to 720 nm) and infrared (720 to 106 nm) bandwidths. Most commonly, plant agriculture studies use the blue (380 to 500 nm), green (500 to 600 nm), red (600 to 720 nm) and NIR (720 to 1300 nm) bandwidths; whereas soil studies may use the entire visible and infrared regions. Because the total reflectance is partially dependent on climatic and plant canopy parameters, wavelength ratios provide useful information related to plant pigment contents and nutrient concentrations. Numerous studies have focused on ratios involving the NIR and either the green or red bandwidths. The green and red bandwidths are substantially influenced by chlorophyll and carotenoid pigment concentrations, which are primarily influenced by the leaf nitrogen content (Bronson et al., 2003; Shanahan et al., 2001; Stone et al., 1996). Phosphorus concentrations may also be important towards chlorophyll and carotenoid content expression (Osbourne et al., 2002; Milton et al., 1991). The NIR region is more responsive to the presence of cellular structures created by air - cell wall - protoplasm - chloroplast interfaces (Ma et al., 2001; Bronson et al., 2003).

In plant agriculture, leaf hyperspectral reflectance curves are influenced by crop selection, variety, growth stage, soil water availability, nutrient status, plant pathogens, insect damage, crop protection chemicals, and other environmental constraints (Table 1). Thus, proper experimental protocol requires standardizing conditions to minimize the variance of genetic, cultural

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Table 1. Significant investigations using hyperspectral technologies to monitor field crop production.

Authors (date)	Crop	Remote Sensing Technology	Important Applications
Bausch et al. 1996	Corn	Spectral Reflectance	GVI for N in predicting growth/yield
Blackmer, Schepers, 1994	Corn	Chlorophyll meter	Monitor N status
Blackmer, Schepers, 1996	Corn	Spectral Reflectance	Wavelengths at 550 and 710nm for N deficiencies
Cassanova et al. 1998	Rice	Spectral Reflectance	Effective for biomass and leaf area index
Huete et al. 1885	Cotton	Spectral Reflectance	Separate soil/plant reflectance
Huete 1987	Cotton	Spectral Reflectance	Separate soil/plant reflectance
Hussain et al. 2000	Rice	Chlorophyll meter	Monitor N status
Wood et al., 1992	Cotton	Chlorophyll meter	Monitor N status
Li et al. 2001	Cotton	Spectral Reflectance	Plant growth-soil influences assessed by RNDVI
Ma et al. 2001	Soybean	Spectral Reflectance	NDVI-yield relations, screening genotypes
Saranga et al. 1998	Cotton	Near-infrared Analysis	NIRA analysis for leaf nitrogen content
Varvel et al. 1997	Corn	Chlorophyll meter	Determine N sufficiency levels
Thomas and Gausman, 1977	Corn, etc	Spectral Reflectance	Leaf chlorophyll / carotenoid content estimation
Shanahan et al. 2001	Corn	Spectral Reflectance	GNDVI at mid-grain fill correlated yield
Bronson et al. 2003	Cotton	Spectral Reflectance	GNDVI predicted leaf N, RNDVI predicted biomass
Osborne et al. 2002	Corn	Spectral Reflectance	NIR and blue wavebands estimated phosphorus stress
Masoni et al. 1996	Corn, wheat	Spectral Reflectance	Fe, S, Mg, Mn deficiencies decreased adsorption
Milton et al. 1991	Soybean	Spectral Reflectance	P-deficiency related to higher reflectance in green-yellow
Stone et al. 1996	Winter Wheat	Spectral Reflectance	log (1/NIR reflectance) indicated N, Green - chlorophyll c
Maas. 1998	Cotton	Spectral Reflectance	Estimate cotton canopy ground cover
Raun et al. 2002.	Wheat	Spectral Reflectance	Variable rate fertilization practices
Takebe et al. 1990	Rice	Spectral Reflectance	Reflectance ratios to estimate rice canopy N
Tarpley et al. 2000	Cotton	Spectral Reflectance	NDVI correlated with leaf N
Wu et al. 1998	Cotton	Spectral Reflectance	correlated band ratios with N and chlorophyll

and environmental conditions not associated with the main treatment to be investigated.

A typical normalized reflectance curve demonstrates two minima, located near 490 nm and 670 nm, and one maximum, located near 550 nm. The NIR region typically shows a broad, relatively flat, plateau between 750 and 950 nm. Two vegetative indices (GNDVI and GVI) have been proposed using the NIR and green portions of the visible spectrum and two vegetative indices have been proposed using the NIR and red portions (RNDVI and RVI) of the visible spectrum (Blackmer et al., 1996; Bronson et al., 2003). These vegetative indices are calculated as:

$$(1) \text{GNDVI} = \frac{R_{820} - R_{550}}{R_{820} + R_{550}}$$

$$(2) \text{GVI} = \frac{R_{820}}{R_{550}}$$

$$(3) \text{RNDVI} = \frac{R_{820} - R_{670}}{R_{820} + R_{670}}$$

$$(4) \text{RVI} = \frac{R_{820}}{R_{670}},$$

where R is the relative reflectance.

Normalizing the spectral reflectance curves is a common practice. Normalizing spectral reflectance curves in laboratory situations is usually performed using commercially prepared ceramic plates, whereas field normalization typically involves optimally

fertilized plots prepared similarly to the canopy to be surveyed (Blackmer et al., 1996; Bronson et al., 2003; Huete, 1987; Stone et al., 1996; Ruan et al., 2002).

In the United States, rice acreage is less extensive than that of many other crops and the amount of research is correspondingly smaller. HR presents an attractive option to monitor early season nitrogen sufficiency and to predict the timing of mid-season nitrogen applications. Nitrogen sources for rice production commonly include urea and ammonium sulfate; however, Japanese rice production relies almost exclusively on ammonium chloride (Tisdale et al., 1985). Thus, HR may become a useful nitrogen monitoring tool provided the influences of soil type, variety type, N-source, N-application options, and other soil fertility parameters are understood.

The purpose of this investigation is to determine if HR may differentiate among a popular rice variety cultured to three different soil types and fertilized with three different nitrogen sources.

## 2. Materials and Methods

A greenhouse experiment involving rice (*Oryza sativa*, var. cocodrie) was performed to determine if early-season nitrogen levels in the plant tissue could be correlated with hyperspectral reflectance. A completely randomized block design was developed having three soil types as the main treatment and having sub-treatments consisting of three nitrogen sources. All combinations of the factorial design contained three

replications.

Three soils were collected from production fields by excavating the A horizon and were considered soils representative of the (1) Commerce series (Fine-silty, mixed, nonacid, active, thermic Aeric Fluvaquents), (2) Sharkey series (Very-fine, montmorillonitic, nonacid, thermic Vertic Haplaquepts), and the (3) Crowley series (Fine, montmorillonitic, thermic Typic Albaqualfs). Soil samples were air-dried and gently crushed to pass a 2mm screen. Routine soil tests were performed by the University Missouri Soil Testing Laboratory.

Three nitrogen sources were selected: (1) ammonium sulfate (21 - 0 - 0), (2) ammonium chloride (25 - 0 - 0) and (3) urea (45 - 0 - 0). In addition, a zero nitrogen rate served as a control. Air-dried soil was added to plastic lined greenhouse pots to provide 5.3 lbs (2.4 kg) and planted with the variety 'Cocodrie'. For each pot, a nitrogen source was added at a rate equivalent to 120 lbs N Acre-1 (134 kg ha-1). Fertilizer additions were accomplished by dissolving sufficient fertilizer in distilled water; such that, a 0.025 L aliquot added to standing rice (4 inches, 10 cm) provided the indicated nitrogen. Immediately, a standing pond of water (simulated paddy) was imposed and continuously maintained for the duration of the experiment at a depth of approximately 1 inch (2.5 cm). Harvest of plant material, 0.5 cm above the soil surface, occurred approximately 8 weeks after plant emergence. For each pot, the number of plants was counted. Plant tissue analysis was performed by a laboratory specializing in plant tissue analysis.

A Spectron Engineering SE-590 spectroradiometer was operated indoors in a darkened

room to obtain spectral measurements. The instrument was placed in a stand and mounted a measured distance above a photolab layout table to give a sensor field of six degrees. Samples were consistently placed in a circular mound (about 0.5 cm thick and 15 cm diameter), flattened to totally fill the viewfield and illuminated from opposite sides with four quartz halogen lamps. The spectrometer was first calibrated using a Spectralon reflectance panel, then two measurements per sample were averaged to generate a hyperspectral reflectance curve. The hyperspectral response curves were ratioed with the white-plate reflectance curve to generate a normalized hyperspectral reflectance curve (NHRC).

NHRCs were prepared by plotting relative amplitude on the ordinate and wavelength on the abscissa. In-addition, the mean vegetative index values (GNDVI, GVI, RNDVI, and RVI) were calculated from the three replications of each experimental unit. Statistical evaluation of plant biomass, elemental concentration and the various hyperspectral features involved analysis of variance, Duncan's multiple range test, linear regression and Pearson correlation (Hoshmand, 1994) using a Microsoft-Excel format.

### 3. Results And Discussion

#### a. Plant Biomass and Nutrient Concentrations

Analysis of variance and multiple range testing demonstrated that biomass production (top growth normalized to 100 plants) was significantly different (P

Table 2. Plant productivity and nitrogen, phosphorus, sulfur composition in a factorial nitrogen design in involving rice.

Treatment	weight • 100 plants <sup>-1</sup> gram	Height cm	Plant Tissue			N / 100 plants gram
			N %	P %	S %	
<b>Commerce</b>						
No-Nitrogen	12.5a	—	1.82a	0.45a	0.18a	0.23a
Ammonium Sulfate	55.0b	—	1.76a	0.37b	0.50b	0.97b
Ammonium Chloride	55.0b	—	1.94a	0.37b	0.19a	1.07b
Urea	25.8c	—	1.79a	0.37b	0.18a	0.46c
Mean Across N treatments	37.1 -I	—	1.83 I	0.39 I	0.26 I	0.68 -I
<b>Sharkey</b>						
No-Nitrogen	11.4a	21.6a	1.89a	0.39a	0.26a	0.22a
Ammonium Sulfate	33.0b	35.1b	1.66a	0.31b	0.32b	0.55b
Ammonium Chloride	39.7b	34.7b	1.82a	0.33b	0.19b	0.72c
Urea	27.6b	28.7b	1.69a	0.33b	0.22b	0.46b
Mean Across N treatments	27.9 I, -	30.1	1.77 I	0.34 I	0.26 I	0.49 I, -
<b>Crowley</b>						
No-Nitrogen	18.4a	25.4a	1.99a	0.38a	0.17a	0.37a
Ammonium Sulfate	68.0b	42.0b	1.82a	0.29b	0.42b	1.23b
Ammonium Chloride	63.4b	42.3b	2.15a	0.31b	0.17a	1.36b
Urea	37.4c	35.1b	1.81a	0.36a	0.19a	0.68c
Mean Across N treatments	46.8 II,I	36.2	1.94 I	0.34 I	0.24 I	0.91 II,I

Identical arabic letters within columns for individual soils indicate N-sources are not significantly different at P = 0.05% probability. Identical Roman letters within columns indicate that soil differences are not significantly different at P = 0.05% probability

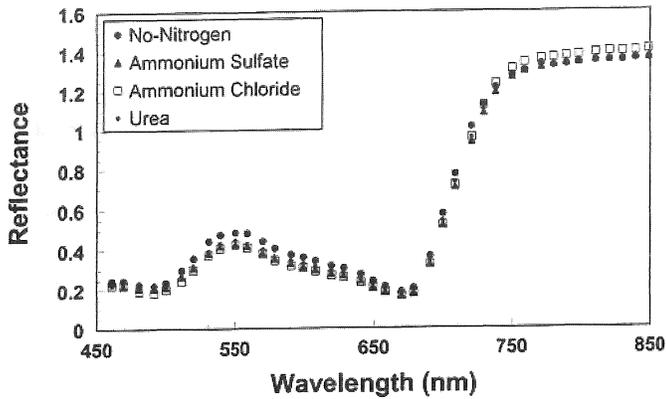


Fig. 1. Normalized hyperspectral reflectance curves for the Commerce series.

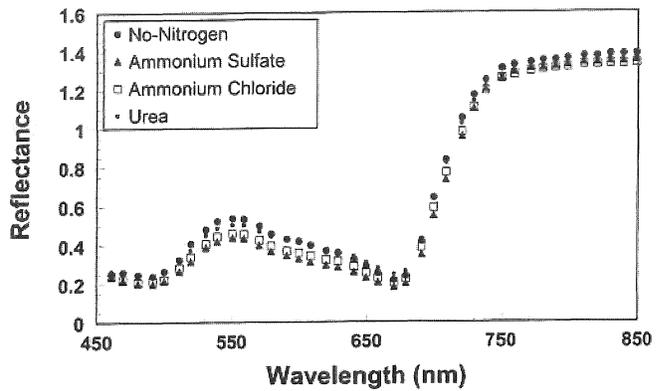


Fig. 2. Normalized hyperspectral reflectance curves for the Sharkey series.

= 0.02) between the Sharkey and Crowley soils, with the Crowley soil having the greatest biomass (Table 2). All other soil-biomass comparisons were not significant.

Analysis of variance demonstrated that within soil type differences were apparent ( $P = 0.0001$ ) and that N-sources were a dominant factor in the production of biomass. The ammonium sulfate and ammonium chloride sources were consistently superior in the production of biomass (Table 2). Urea was less effective in encouraging plant growth in the Commerce and Crowley soil systems and as effective as the other N-sources in the Sharkey soil. The No-Nitrogen (control) treatment produced dramatically less biomass than the fertilizer N-sources. Plant height generally correlated ( $r^2 = 0.93$ ) with biomass production (Table 2).

Soil type had no significant influence on the nitrogen content of the rice tissue. Within soil type comparisons of the various N-sources also produced insignificant N concentration differences. Nitrogen concentrations for all treatments are appreciably smaller than the 3.9 to 4.2 sufficiently range established by the California Plant Health Association (CPHA, 2002). We

suspect that the 2.5 cm level of standing water (typically rice fields maintain 10 to 15 cm standing water) promoted nitrification and subsequent denitrification because of low-level O<sub>2</sub> diffusion into the soil surface. We also suggest that the additional growth resulting from the nitrogen fertilizer sources promoted biomass production and effectively “diluted” the nitrogen. The well-known “dilution effect” is discussed in CPHA (2002) and Tisdale et al. (1985).

Phosphorus concentrations are adequate (0.1 to 0.5 % P are commonly accepted phosphorus sufficiency levels; CPHA, 2002) and soil differences are not evident; however, within individual soil types the P tissue concentrations are generally greater in the control units when compared to the N-source units. We also partially attribute the slightly diminished P concentrations associated with the nitrogen source treatments to the “dilution effect”. The ammonium sulfate treatment appreciably enhanced the sulfur tissue content, a reasonably expected result.

Table 3. Hyperspectral reflectance ratios for rice cultured under different N treatments.

Treatment	GNDVI	GVI	RNDVI	RVI
Commerce				
No Nitrogen	0.47a	2.77a	0.76a	7.27a
Ammonium Sulfate	0.52b	3.14b	0.78a	8.16b
Ammonium Chloride	0.53b	3.26b	0.79a	8.45b
Urea	0.50b	3.00b	0.77a	7.54a
Sharkey				
No Nitrogen	0.44a	2.55a	0.72a	6.26a
Ammonium Sulfate	0.51a	3.05b	0.76a	7.35b
Ammonium Chloride	0.48a	2.88b	0.73a	6.49a
Urea	0.46a	2.67a	0.69a	5.40c
Crowley				
No Nitrogen	0.45a	2.56a	0.73a	6.49a
Ammonium Sulfate	0.52b	3.20b	0.79b	8.40b
Ammonium Chloride	0.55b	3.48b	0.82b	10.10c
Urea	0.48a	2.84a	0.73a	6.61a

Identical letters within columns indicate not significantly different at  $P = 0.05\%$  probability.

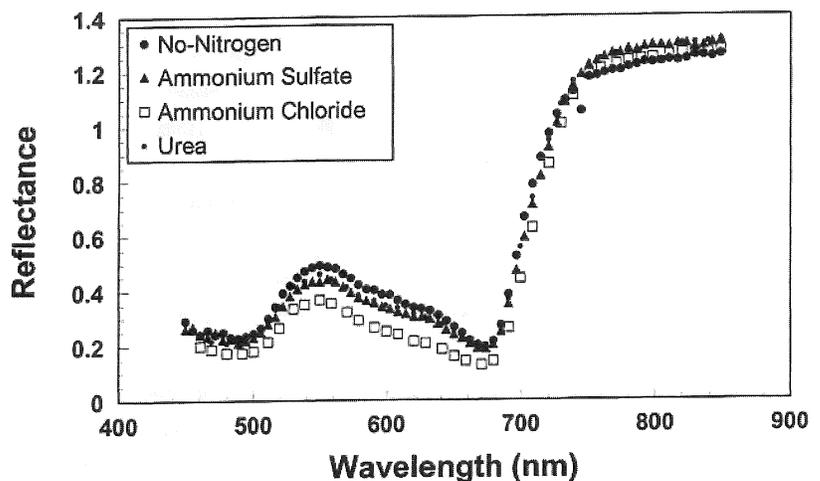


Fig. 3. Normalized hyperspectral reflectance curves for the Crowley series.

### *b. Normalized Hyperspectral Reflectance Curves*

The NHRC's typically span from 350 to 1150 nm; however, the various green and red vegetative indices only require spectral values ranging from 500 to 850 nm. The curves are similar in showing a minimum near 490 nm and 670 nm, with a broad plateau from 770 nm to 850 nm. A reflectance maximum generally occurs between the two reflectance minima, near 550 nm (Fig. 1 to 3).

The NHRC's from each experimental unit were used to calculate individual vegetative indices, which were averaged to obtain vegetative indices for each N-source treatment. Analysis of variance demonstrated no soil influence on the vegetative indices (Table 3). Analysis of variance and multiple range testing showed that the GNDVI had smaller reflectance values for the control, with no significant differences consistently demonstrated among the N-sources. Plant biomass and the GNDVI did reveal a reasonable correlation, a feature mostly attributed to the small GNDVI and biomass values for the no-nitrogen control ( $GNDVI = 0.0015 * \text{plant biomass} + 0.435$   $r^2 = 0.75$ ). Nitrogen contents were not significant in influencing the vegetative indices. The total uptake of nitrogen ( $\text{biomass} * \%N$ ) also correlated to the GNDVI; however, this relationship may be viewed as a re-expression of the GNDVI-Biomass relationship, given the lack of significance in the nitrogen concentrations. Other vegetative indices were less significant in predicting plant performance.

## 4. Conclusions

This greenhouse study attempted to determine if NHRC of rice tissue could differentiate the effects of soil type and nitrogen source. NHRC were not able to discriminate any influence of soil type or N-source. The GNDVI was able to discern spectral differences between the N-source and the zero-nitrogen control.

We speculate that the greenhouse environment did not permit the establishment of sufficient water ponding to effectively reduce the nitrification-denitrification processes, leading to marginal nitrogen contents in the tissues. We further speculate that a field trial having a range of nitrogen rates, resulting in a range of N tissue concentrations from 1 to 4% may allow NHRC to discern these N concentration differences.

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# Nutrient Limitation Promotes Pigment Production in *Aureobasidium pullulans*

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## Abstract

*Aureobasidium pullulans* ATCC 42023 is an environmental fungus found in soil and on plant leaves that produces both melanin-like pigments and exopolysaccharides such as pullulan. Industrial processes remove the melanin before pullulan can be used in consumer products such as breath freshener strips. The melanin-like pigments are also known to enhance fungal virulence. Thus, control of pigmentation and pullulan production is important in industrial and medical applications. The goals of this project were to determine if nutrient limitation or ultraviolet (UV) light exposure impacted pigmentation production. Results indicate that nutrient deficiencies of salt and potassium phosphate may contribute to pigment production. Exposure to UV-light for up to eight minutes does not appear to play a significant role in reducing pigmentation or polysaccharide production.

**Keywords:** *Aureobasidium*, melanin, pigment, ultraviolet

## 1. Introduction

The polymorphic fungus *Aureobasidium pullulans* produces pullulan and the black pigment melanin (Cooke 1961). The fungus is commonly found in the environment on apple tree leaves, in the soil, and in ventilation ducts. Pigment and polysaccharide synthesis occurs in fungal cell walls (Campbell et al. 2004; Shingel 2004). Pigmentation is seen in organisms frequently exposed to the sun and is thought to protect the cells from UV-rays (Jacobson 2000). Melanin normally is bleached or removed from pullulan for commercial applications (Gibson and Coughlin 2002) which is expensive (Tarabasz-Szymanska and

Galas 1993). Effects of UV-rays on *Aureobasidium* have been investigated by Vasilevskaia et al. (2003) and experiments by Tarabasz-Szymanska and Galas (1993) utilized a 15 minute UV-exposure to reduce the population count to 10% of the original inoculum. Studies to determine polysaccharide and pigment synthesis regulation have been performed, and attempts to mutate colonies to reduce melanin-like pigment production and increase pullulan yields have met with moderate success (Pollock et al. 1992).

The fungus is also implicated in human diseases such as peritonitis and nosocomial infections (Caporale et al. 1996; Bolignano and Criseo 2003). Invasive fungi often produce pigmentation, such as melanin, and are referred to as dematiaceous (Jacobson 2000). *Aureobasidium pullulans* var. *melanigenum* is considered among this group of dematiaceous fungi (Bolignano and Criseo 2003). The polymorphism of *A. pullulans* complicates studies because observations of pigmentation or polysaccharide production may not be consistent due to variations in ingredients or manufacturers of media. Morphological stages responsible for pigmentation and pullulan elaboration have been widely studied with conflicting results (Badr-Eldin et al. 1994; Buliga and Brant 1987; Campbell et al. 2004; Catley 1971; Seviour et al. 1992).

The purpose of this study was to determine if nutrient limitation promotes pigmentation by *A. pullulans*, as well as to determine the response of fungal pigmentation to varying times of UV-light exposure.

## 2. Materials and Methods

*Aureobasidium pullulans* ATCC 42023 was purchased from the American Type Culture Collection and grown on modified Ueda medium. Traditional Ueda medium contains 0.5%  $K_2HPO_4$ , 0.1% NaCl, 0.02%  $MgSO_4 \cdot 7H_2O$ , 0.06%  $(NH_4)_2SO_4$  and 10%

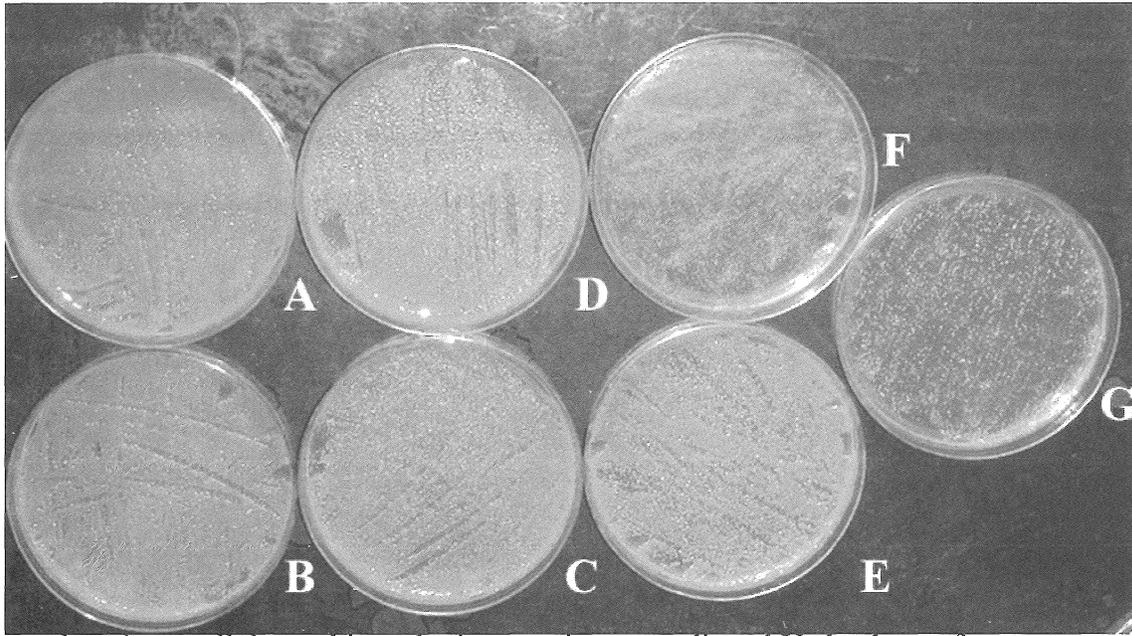


Figure 1. *Aureobasidium pullulans* white colonies growing on traditional Ueda plates after exposure to UV Light. (A) 0 s. (B) 30 s. (C) 60 s. (D) 90 s. (E) 120 s. (F) 240 s. (G) 8 min.

(weight/volume) sucrose per liter (Ueda et al. 1963). The modified recipe halves each ingredient except for sucrose, which remains the same. To determine specific nutrient deficiencies which affect melanin synthesis, four 150 ml broth cultures, each lacking one ingredient of the modified Ueda media, were prepared in duplicate. Traditional Ueda broth served as a control for melanin synthesis, and modified Ueda broth served as a control containing all nutrients. Cultures were grown in a shaker incubator for 9 days at 28°C at 175 rpm. Samples (1 mL) were aseptically removed each day and placed in sterile 1.5 mL microcentrifuge tubes and centrifuged to pellet the cells. The supernatant was removed and ethanol was added to the pellet. Slides were prepared to determine microscopic melanin-like pigment production.

Traditional Ueda and modified Ueda plates were inoculated with a lawn of growth (200  $\mu$ l of a log-phase broth culture) and immediately subjected to ultraviolet radiation (LabConco, 30W) approximately 45 cm above the agar surface ranging from 0 seconds up to eight minutes. Cultures were allowed to grow at 28°C for up to seven days. Photographs were taken on day four with a Nikon 990E digital camera, and no changes were seen after day four.

### 3. Results

Traditional Ueda broth cultures remained white in color throughout the experiment, whereas modified Ueda and the ingredient-deficient broth cultures (except

the magnesium sulfate deficient cultures) eventually produced melanin. Cultures grown on modified Ueda began producing melanin at day two, whereas the salt and  $K_2HPO_4$  deficient broth cultures turned color on days three to four. The ammonium sulfate deficient culture was the slowest, beginning pigment synthesis on day five, and the magnesium sulfate deficient broth did not show any culture growth.

Results of the UV-exposure showed that traditional Ueda colonies will remain white, even when subjected to long periods of UV-light (Figure 1). Modified Ueda colonies, subjected to the same UV-light exposure times, produced pigmentation from the time growth was observed at forty-eight hours (Figure 2). Colonies on traditional Ueda only began to show slight pigmentation at day seven. Both figures also show a decrease of colonies by plate G in comparison with the time zero control plate. Based upon UV experiments by Tarabasz-Szymanska and Galas (1993), approximately half of the original inoculum count should be present by plate G. A polysaccharide sheen was also seen on the traditional Ueda plates, although it was not as prominent as the sheen observed on the pigmented colonies on modified Ueda (Figure 2). As UV-light exposure increased, it appeared that the polysaccharide sheen was more prominent than the time zero control plates. Since the organisms were grown on agar plates, and pullulan precipitation requires an ethanol precipitation step, the polysaccharide was not quantified.

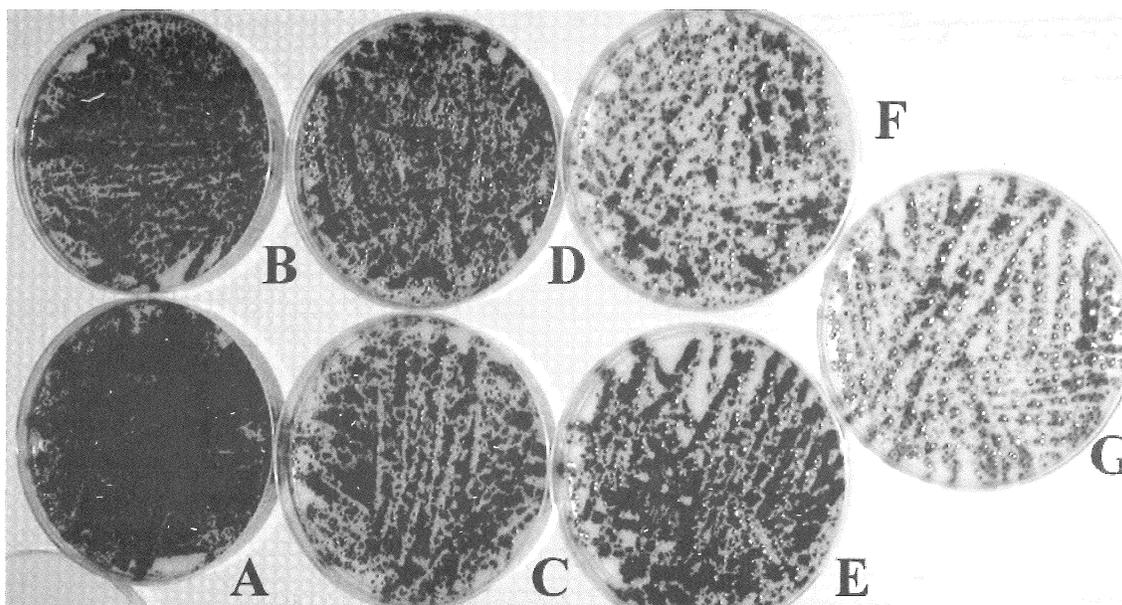


Figure 2. *Aureobasidium pullulans* pigmented colonies exhibiting polysaccharide glistening growing on modified Ueda plates after exposure to UV-light. (A) 0 s. (B) 30 s. (C) 60 s. (D) 90 s. (E) 120 s. (F) 240 s. (G) 8 min.

## 4. Discussion and Conclusions

*Aureobasidium pullulans* exhibits pigmentation on varying (two to five) days after inoculation, depending upon the ingredients in the media. Since modified Ueda almost always induces pigmentation and traditional Ueda only does so with an aged culture, it appears that nutrient limitation promotes the protective response of a melanin-like pigment. Pigmentation production also appears to be linked to nutrient limitations of  $K_2HPO_4$  and salt, with ammonium sulfate a secondary limitation. This supports similar observations by Calvo et al. (2002) that *Aspergillus flavus* inhibits sclerotia development when grown on nitrate or ammonium medium. Since chlamydo spores are often observed with a pigmented cell wall in *A. pullulans*, perhaps ammonium is required for chlamydo spore formation, particularly after other ingredients are depleted.

The results indicate that salt and  $K_2HPO_4$  are required in the production of melanin-like pigments and reduction in these compounds slows pigmentation production. Further, no growth observed on magnesium sulfate deficient medium precludes that magnesium sulfate is required for metabolic pathways and sustainability of the fungus. Molecularly, a G protein subunit has been shown to be responsible for melanin regulation in *Cryptococcus neoformans* and a mitogen activated protein (MAP) kinase stimulates filamentous growth in *Saccharomyces cerevisiae* when nutrients are depleted (Calvo et al. 2002). Molecular experiments would enhance the understanding of regulatory

mechanisms in *A. pullulans*.

Exposure to UV-radiation does not appear to reduce visual pigmentation levels microscopically. Colonies on both media types showed polysaccharide production, which may be pullulan or a  $\beta$ -glycan. Further analysis of the polysaccharide is needed. Traditional Ueda white colonies did not show decreased polysaccharide production from the controls on this media, nor were any pigmented mutants seen. Further, no mutated white colonies were seen after UV treatment on the modified Ueda medium. Without melanin protection, it is possible that the polysaccharide may prevent UV-light penetration and be protecting the cells. Future experiments are needed to determine if the polysaccharide is protecting the cells and to ensure that pullulan yields are not compromised if melanogenesis is inhibited.

## 5. Acknowledgements

Thanks to William Kirby for laboratory support of this project.

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# The Columbia, Missouri, Heat Island Experiment (COHIX) and the Influence of a Small City on the Local Climatology

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## Abstract

*The heat island effect is a well known feature in the microclimate of urban areas but only a few studies have addressed the effect for smaller urban areas. We examine here the impact of Columbia, Missouri and the University of Missouri campus on the microclimate (temperature and precipitation) of central Missouri. We purchased twenty Radio Shack® digital Max/Min thermometers and ten standard raised-edge rain gauges and these were given to students, staff, and faculty participants who were chosen for their reliability to provide daily data over the course of a year, site the instrument, and their location (in order to provide reasonable coverage locally). We also included information provided by automated and cooperative weather stations, and the weather station at the regional airport located 11 km (7 miles) southeast of Columbia. Our results indicate that the city has no discernable impact on the distribution of monthly precipitation totals. We found a distinct urban influence on the local surface temperatures, and the inner city region and the urbanized area of south Columbia were approximately 2 – 3 °F (1.0 – 1.5 °C) warmer in the mean than the surrounding environment. This difference grows to 3 – 6 °F (1.5 - 3.5 °C) when comparing the mean of the warmest station in the city to that of coolest station outside Columbia. We also observed a seasonal influence, as the heat island effect was more evident in*

*the mean monthly maximum (minimum) temperatures during the warmest (coldest) months.*

*Keywords: Heat island effect, climatology, microclimate, urban influences*

## 1. Introduction

The effect of urban environments on local temperature and precipitation distributions have been examined often in the past (e.g., Changnon, 1981; Segal and Arritt, 1992; Karl and Knight, 1997; Melhuish and Pedder, 1998; Pinho and Manso-Orgaz, 2000; Baik et al., 2001; Rozoff and Cotton, 2001; Shepherd et al., 2002) and usually for cities that have very large populations. Melhuish and Pedder (1998) and Pinho and Manso-Orgaz (2000), however, examine the heat island effect in smaller urban areas. The “heat-island effect” produced by such cities can have a profound impact, sometimes adverse, on the well-being of its residents (e.g., Karl and Knight, 1997).

The heat island effect is produced by many factors which result in a change in the underlying energy budgets in the boundary layer due to urbanization. These include such effects as (e.g., Oke, 1982); an increase in sensible heating (e.g., due to changes in surface albedoes), an increase in thermal storage capacity of the underlying surface, decreased evapo-transpiration, and heat given off (generated) by urban structures. These processes then can have a large impact on the temperature field

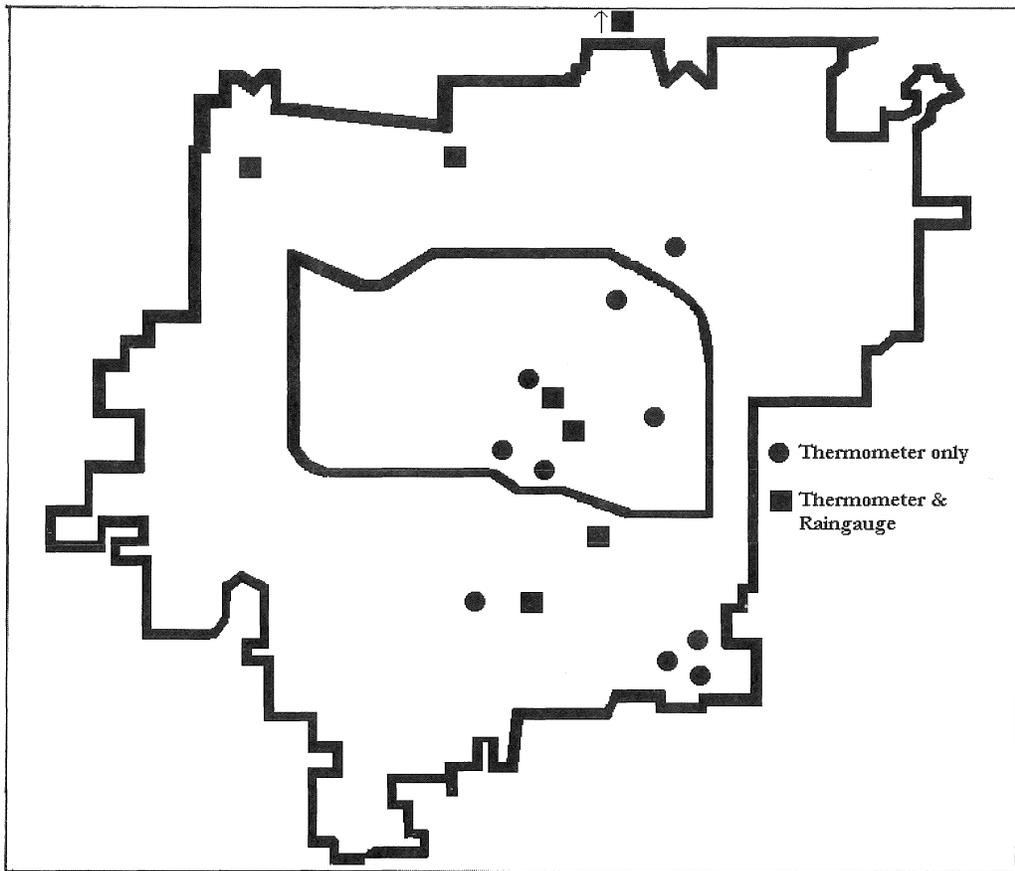


Figure 1. The station location and distribution of the temperature and rain gauge network. Closed squares represent the deployment of both thermometers and rain gauges, while closed circles represent the deployment of only one instrument (see legend).

(see references above) and the precipitation field (e.g., Shephard et al., 2002). A few studies examined also the climatological (long-term) impact of heat islands including their variance by season (e.g., DeMarrais, 1975; Ackerman, 1985).

Some authors examined the impact of agricultural practices on local environments and they demonstrated that a regional (covering parts of several states) heat island can be produced (e.g., Raymond et al. 1994). The study of local and regional heat islands is a topic that has enjoyed renewed interest lately, especially within the context of global climate change and the impact on human health (e.g., Gaffen and Ross, 1998; NAS 2000; Houghton et al. IPCC, 2001). Additionally, there are many examples of studies in the published literature that explore the impact on local atmospheric phenomena by the unique distribution of regional geography (e.g., Colle and Mass, 1996; Doesken and Weaver, 2000). These also include phenomena such as lake effect snows and the influence of the Great Lakes on larger-scale disturbances (e.g., Sousounis and Fritsch, 1994).

Published work (e.g., Melhuish and Pedder, 1998; Pinho and Manso-Organz, 2000) recently

demonstrated that medium-sized and small urban areas may also be responsible for heat-island effects. Heat islands associated with medium-sized and smaller urban areas would not be expected to be as pronounced as those of larger cities in general, however, the heat island effect in the latter study was shown to be quite substantial (up to 7.5° C). Thus, Pinho and Manso-Organz (2000) concluded that steps should be taken to mitigate the problem, including the implementation of more green-space. Available anecdotal evidence available suggests that Columbia, Missouri, may be responsible for a detectable heat-island effect, in spite of recent attempts to increase the amount of green-space and vegetation in the city limits over the past 15 years. Columbia would be at the smaller end of the spectrum of what is considered to be an urban area in the United States and is composed of a downtown area and the University of Missouri campus. Intensive residential and retail development flanks these two core regions.

Our objective in the COlumbia Heat Island eXperiment (COHIX) was to determine the extent to which Columbia, Missouri, and the University of Missouri campus produce a heat-island effect. We

deployed several thermometers and rain gauges in and around the city limits to measure the urban impact on the microclimate and the variation in the strength of the heat-island effect with respect to season. Additionally, we measured precipitation in order to determine if the urban area had a discernable impact on precipitation microclimatology in spite of the very short period of record. In order to examine the urban impact on precipitation patterns, at least a few years of data collection would be necessary (e.g., Changnon, 1981). In section two, we discuss the data and methodologies used, and we describe and discuss the heat island study results in section three. In section four, we discuss the effect of cloudiness, wind directions, and wind speeds on the strength of the heat island, and we summarize our work and present the main conclusions in section 5.

## 2. Data and Methodology

### *a. Data*

Participants in our study provided the temperature and precipitation data. We measured temperature data using a Radio Shack® Indoor/Outdoor Maximum-Minimum thermometer (Item #63 - 1014). Our instruments resided indoors and included a 3 m (10-ft) probe, which was then deployed outdoors. The Missouri Climate Center, the Columbia Regional Airport, two cooperative weather stations, and two automated weather stations in the Columbia area provided additional temperature data. The Columbia Regional Airport (COU) is located approximately 11 km south-southeast of the city. We also provided participants in this study with a standard clear plastic raised-edge bucket rain gauge (Item RG #6608 – <http://www.windandweather.com>) to report rainfall information, and which can be purchased from any weather instrumentation vendor. Not every “station” reported every single month or every single day, thus we evaluated the data for suitability and discarded incomplete data in calculating the heat island using monthly means accordingly. Monthly station data was discarded if more than two days temperature readings were missing. Stations with two or less days missing were evaluated subjectively in order to ensure that the missing information would not have skewed the monthly mean substantially. We reported temperatures here in degrees Fahrenheit and precipitation values in

inches, since these units are still the standard for surface data in the United States, but these are supplemented with metric units in the text.

### *b. Methodology*

For the purposes of our study, Columbia Missouri (Fig. 1) was considered to be a small urban area. Here, we define a small city as one that has a population of more than 75,000 (but less than 200,000) residents and covers an area of roughly 40 km<sup>2</sup> (25 mi.<sup>2</sup>) or more. Excluding the transient student population, Columbia, Missouri has roughly 80,000 residents. This number is greater than 120,000 if the residential areas near the city limits are included; 140,000 when the student population is in residence. This is smaller than the urban area studied by Meluish and Pedder (1998), but considerably larger than that in the Pinho and Manso-Orgaz (2000) study.

We invited faculty, staff, and students in the Atmospheric Sciences Program (and some outside the program) to participate in our study. A total of 22 participants (17 were observers and 7 analyzed or archived the data) volunteered to take part in the experiment. Enlisting volunteer participants to measure local variations in climatic parameters has produced successful results in other locations (e.g., Doesken and Weaver, 2000). We selected those who deployed instruments ultimately on the basis of location with respect to their location in the Columbia region, and their ability to accommodate the proper deployment techniques of the instrument(s). We provided students with explicit instructions on how to deploy the instruments. All temperature instruments were deployed in shaded and/or sheltered (but shielded from the sky and precipitation and well ventilated) environments and were deployed close to two meters above the surface. Also we attempted in our site selection to concentrate some instruments in the south-central part of Columbia, which has less green-space in comparison to other regions of the city due to recent development.

In order to determine if the heat island effect was detectable given the fact that each Radio Shack® instrument did not read the same value in spite of being subject to the same conditions, we compared the instruments to a standard instrument. During this test, we also calculated the standard deviation among the set thermometers. The temperature range for our instrument set was 1.0 °F/0.6 °C (1.3 °F/0.7 °C) at room temperature (in an ice bath – occasionally stirred to

Tab 1e 1. The mean maximum and minimum temperatures (°F) for various regions in the Columbia, MO region for July 2000 - June 2001, where the mean temperature of the instruments is represented by (Tic) for the inner city domain (see Fig. 1), (Tos) for the domain outside the city limits, (Tb) represents the mean temperature of instruments between Tic and Tos, and Ts is the temperatures of instruments inside the city, but south of the University of Missouri campus (located inside the Tic domain).

Month	Tic		Tos		Tb		Ts		HI		HI <sub>max</sub>	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
July 2000	88.1	68.8	85.4	66.0	85.7	68.6	88.0	68.4	2.7	2.8	3.3	4.7
August 2000	92.2	70.9	88.8	69.0	88.8	70.8	91.6	70.3	3.4	1.9	4.8	3.3
September 2000	81.8	58.0	80.5	54.9	81.0	56.0	81.4	55.9	0.7	3.1	3.6	6.0
October 2000	72.0	51.5	71.1	49.1	71.2	50.3	71.5	50.1	0.9	2.4	3.1	3.5
November 2000	50.3	33.4	48.5	29.9	49.6	32.3	50.3	32.2	1.8	3.5	2.3	5.5
December 2000	31.5	14.9	29.4	10.5	30.4	13.2	30.7	12.9	2.1	4.4	5.6	6.4
January 2001	39.5	24.0	38.4	21.3	38.7	22.0	39.8	23.2	1.1	2.7	3.4	3.3
February 2001	46.2	26.2	44.1	23.2	45.4	24.7	47.3	25.1	2.1	3.0	3.4	3.1
March 2001	52.6	32.0	51.4	29.2	53.1	30.9	54.4	31.2	1.2	2.8	3.0	3.6
April 2001	74.2	52.9	72.8	50.1	74.6	50.0	75.1	48.7	1.4	2.8	4.0	2.4
May 2001	77.8	58.2	75.8	55.5	76.9	57.0	77.1	56.7	2.0	2.7	3.8	4.1
June 2001	85.4	64.3	81.6	61.5	83.6	63.0	85.3	62.9	3.8	2.8	6.8	5.0

increase homogeneity), and the standard deviation was 0.35 °F (0.2 °C) in our set for both the room temperature and ice bath trials during the test day. Thus, any heat island effect would have to be significantly larger than the standard deviation after correcting our data to the standard. Also, we tested a Radio-Shack® instrument in real time against an electronic thermometer, the HMP35C, which is used by the automated weather stations, and there was remarkable agreement between the two instruments (this automated instrument would fall somewhere in the middle of our max/min. instrument sample). We did not perform rigorous statistical testing other than the informal test described above since the small sample precludes producing statistically robust results. In spite of this problem, meaningful results can be obtained (e.g., Nicholls, 2001) here and we can compare to similar studies which found similar results.

The participants collected the maximum and minimum temperature once daily at 10:00 pm local time (0300 UTC – or - 0400 UTC during standard time). These data were recorded (instrument displays temperature to the nearest tenth of a degree) and we then averaged these, with the goal of first determining if the heat island existed in the mean data field. We define the strength of the heat island effect (HI) as:

$$HI = T_{ic} - T_{os} \quad (1)$$

where  $T_{ic}$  is the mean temperature recorded by the “inner city” units (9 of these - see enclosed rectangular region which encloses the most intensive development inside Fig. 1 and includes the University of Missouri Campus) and  $T_{os}$  is the mean temperature recorded by the instruments more than 1.6 km (1 mile) outside the city limits (four of these). We decided to consider stations (Tos) more than 1.6 km outside the city limits in order to ensure that these regions were much less densely developed than city regions. The remaining instruments (9) were inside the city limits, but outside the inner city domain, and this region can best be described as mixed residential and commercial areas, and is the rectangular shaped area bounded by interstate and main highways. We then compared the mean temperatures and monthly precipitation amounts produced by this instrumentation network in these regions in order to examine the distribution of the heat island effect and measure the effect of the urban area on the precipitation field. Finally, we defined the difference in the mean temperatures between the warmest individual Tic station and the coolest Tos station as the variable HI<sub>max</sub>.

If we could detect the heat island effect in the mean, then we would stratify individual days first with respect to cloud cover, wind direction, and wind speed. Then we combined the cloud cover and wind speed categories in order to determine under which synoptic conditions the heat island effect was greatest. We also

*Table 2.* The observed monthly mean temperatures (°F) and precipitation (inches) and their departures from the mean (1961 - 1990) for the 1 July 2000 to 30 June 2001 period for the Columbia Regional Airport (COU).

Month	Temperature	Departure from Mean Temperature	Precipitation	Departure from Mean Precipitation
July 2000	75.8	-1.6	4.09	+0.42
August 2000	78.5	+3.3	9.11	+5.83
September 2000	67.8	-0.1	1.75	-2.11
October 2000	59.9	+3.4	3.60	+0.38
November 2000	38.7	-5.4	1.74	-1.19
December 2000	19.8	-12.0	0.87	-1.60
January 2001	29.3	+1.8	2.69	+1.24
February 2001	33.2	+1.1	4.41	+2.57
March 2001	39.9	-3.2	1.09	-2.08
April 2001	61.3	+6.6	3.39	-0.44
May 2001	65.1	+1.5	6.37	+1.36
June 2001	71.2	-0.8	5.24	+0.92

stratified the data in time by month and season in order to determine which time(s) of the year the effect was most influential.

### 3. Season-by-season results using monthly means

Our analysis of the COHIX project data started with July 2000. Table 1 and Fig. 2 show the results after we examined the data collected from 1 July 2000 to 30 June 2001. Table 2 shows the observed mean monthly temperatures and precipitation values and their departures from the 1961 - 1990 means (since part of the experiment took place in 2000).

#### *a. July and August 2000 results*

The monthly mean temperature for July (August) was below (above) normal when comparing the mean at the COU airport with the 30-year normals (Table 2). The precipitation amounts for July were close to normal for the month (Table 2), while August experienced several heavy rainfalls that resulted in a total rainfall amount of 9.11 inches (231 mm). This was a new all-time August record for COU. While this might imply cloudier-than-normal conditions prevailing for August, many of these rainfalls were associated with overnight thunderstorms in the first 21 days. Then, the latter half of the month experienced sunny (mostly clear), hot, and

dry days generally.

As shown in Table 1, we found a difference of 2.7 and 2.8 °F (1.5 °C) between the mean of the inner city and outside city stations (HI) for the maximum and minimum temperatures for July, respectively. All the inner city stations, in general, recorded monthly mean temperatures that were higher than the highest means recorded outside the city for maximum or minimum temperatures. The difference between the warmest individual inner city station and the coolest outer city station was 3.3 °F (1.9 °C) and 4.7 °F (2.7 °C) for the maximum and minimum temperatures, respectively (Table 1, HI<sub>max</sub>). During August, the heat island effect was stronger for the maximum temperatures than that found for July (3.4 °F/1.9 °C), while the minimum temperatures produced a weaker signal (1.9 °F/1.1 °C). The largest differences between individual stations were 4.8 °F (2.7 °C) for maximum temperatures and 3.3 °F (1.9 °C) for the minimum temperatures. We found that the warmest individual stations were inner city stations, while the coolest stations were outside the city.

Our examination of the precipitation distributions for July across the Columbia, Missouri region (not shown) reveals that there was a general west-to-east increase in the precipitation amounts. The heaviest monthly precipitation amounts were found southeast and northeast of the city and exceeded 4 inches. Our measurements on the western side of the city revealed less than 2.4 inches (61 mm) of rain fell during July (including one measurement of 1.92 inches/49mm). In our study, the variance was defined as the ratio of the

highest monthly precipitation reading divided by the lowest in the region of study. For July, that value was 2.13 in / 54 mm, or the highest value was more than twice the value of the lowest amount (the maximum exceeded the minimum by 113%). The pattern for precipitation measurements taken during July and described above reflected the statewide (Missouri) distribution of precipitation, in which the heaviest amounts were found across north-central Missouri and decreased to the south and west.

For the month of August, our precipitation amounts across the Columbia, Missouri, region were more uniformly distributed than July precipitation amounts. Precipitation amounts ranged from a minimum of 8.62 inches (219 mm) to a maximum of 10.01 inches (254 mm). This represents a variation of 16% across the region, which was remarkably low considering the high precipitation amounts. This reflects the fact that for the first part of the month we observed that a stationary front lay across north central Missouri. Thus,

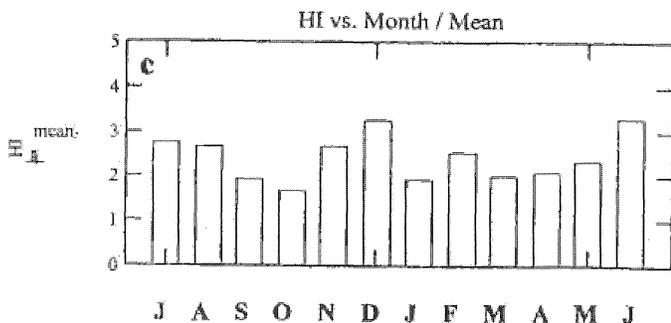
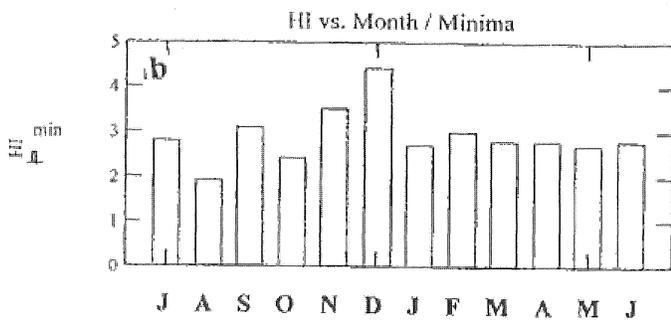
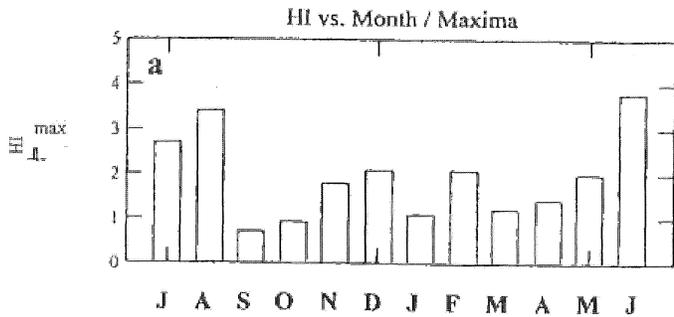


Figure 2. The monthly mean strength of HI (°F) as defined by Eq. (1) for the a) maximum, b) minimum, and c) monthly average temperatures.

even in the summertime (July and August), we found that the precipitation distributions across the Columbia, Missouri region tended to be strongly influenced by larger-scale and storm-scale features and there is little evidence of a distinct urban-scale influence on the precipitation field. This does not preclude the possibility that other regional features (e.g., the Ozark Mountains, or other topographical features) may be influential in

regional precipitation distributions.

### *b. September - November 2000 results*

In general, the fall season of 2000 was cooler and drier than normal, with the exception of October, a month that was warmer than normal for temperature and fairly close to the climatological average for

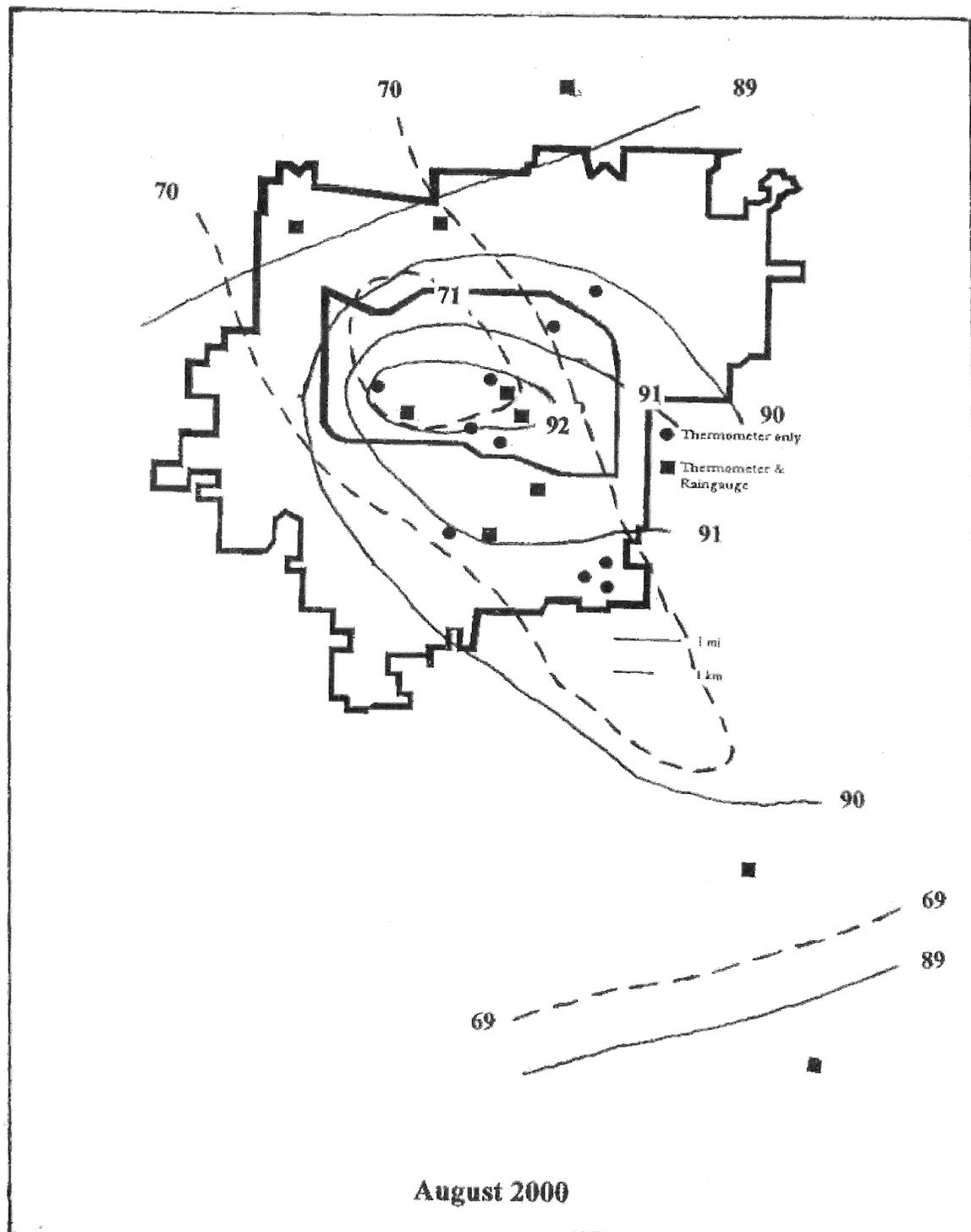


Figure 3. A contour map of monthly mean maximum (solid) and minimum (dashed) temperatures ( $^{\circ}\text{F}$ ) for August 2000.

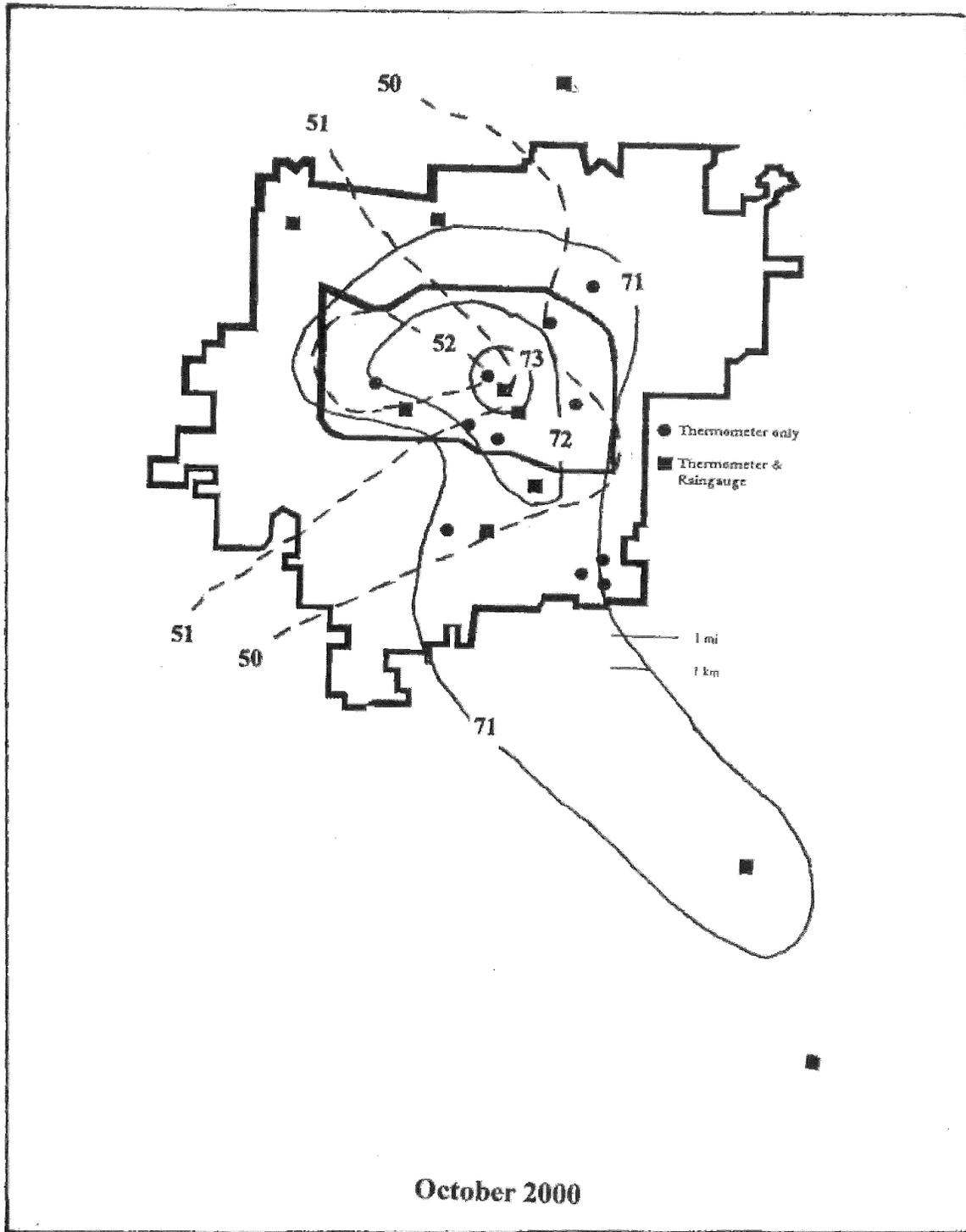


Figure 4. As in Fig. 3, except for October 2000.

precipitation. A large-scale ridge dominated the midwestern United States during the first part of September resulting in warm conditions during the first half of the month for Columbia. This flow regime broke down during the second part of the month and the net result was a month with close to average temperatures (Table 2). Precipitation was fairly evenly distributed across the state with 2 - 3 inches (51 mm - 76 mm) falling in most locations and isolated pockets

of 4 inches or more ( $> 102$  mm) in the northern and southern parts of the state. During October, temperatures remained consistently above normal and there were fewer cloudy days than are typically experienced. The synoptic flow regime favored more rain falling across central and southwestern Missouri, while the rest of the state received less than normal precipitation. Finally, November was quite cold across the state as large-scale troughing prevailed over the mid-western US

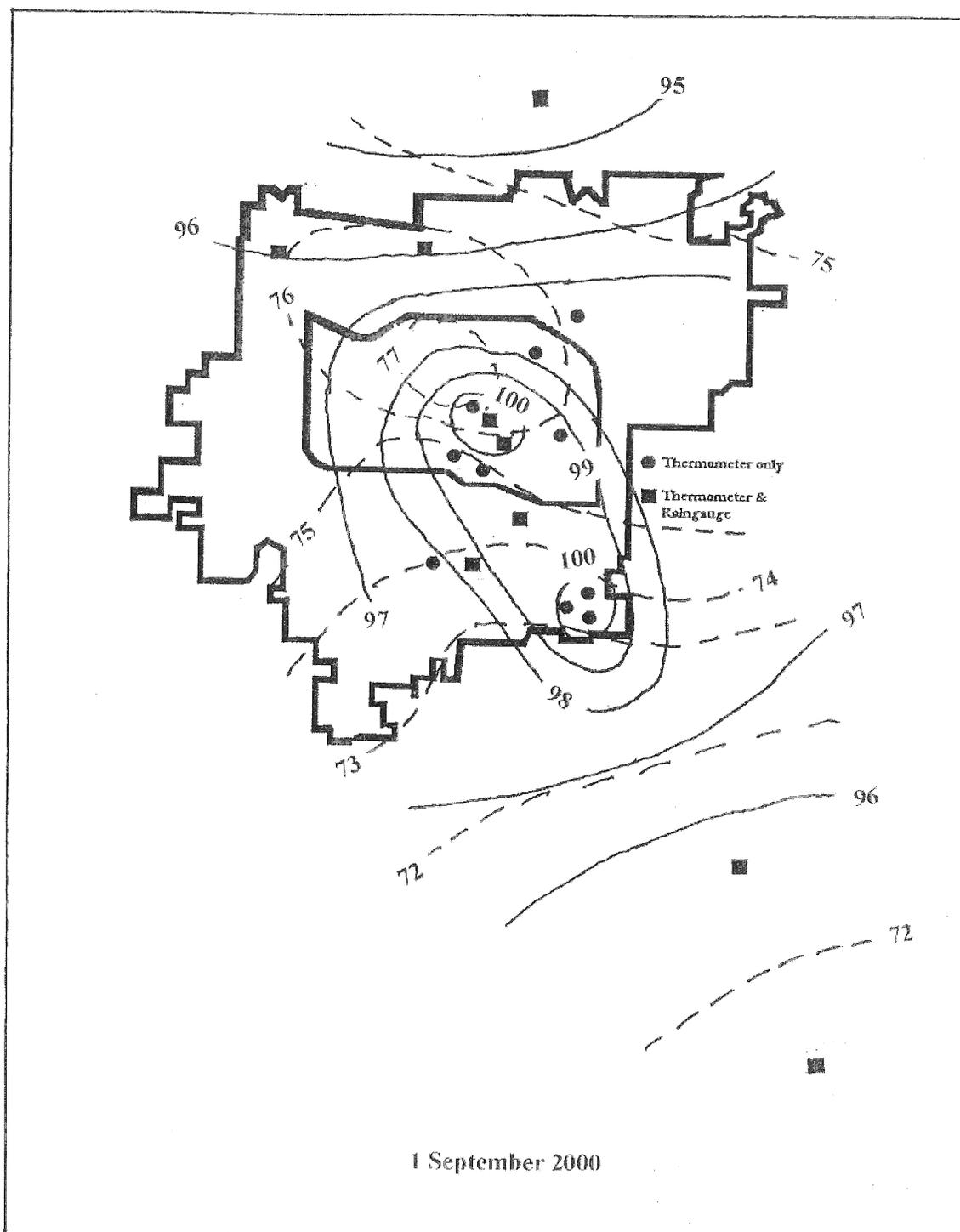


Figure 5. As in Fig. 3, except for 1 September 2000.

(Table 2). This resulted in Columbia experiencing the 8th coldest November on record dating back to 1871. Rainfall generally increased from north to south across Missouri, with lower amounts in the northeast part of the state and the heaviest amounts in the southernmost corner of the state.

Our HI values for the fall months were smaller for the maximum temperatures than for the minimum temperatures across all months (Table 1). For September and October, we found that the maximum

temperatures were slightly less than 1 °F (0.5 °C) in the city of Columbia as compared to the outside, while the minimum temperatures were nearly 2.5 °F (1.4 °C) warmer in the city. These values are smaller than the comparable values for the July and August period. During November, however, we found that the heat island effect was comparable to that of August in spite of the cloudier conditions, with the minimum temperatures showing the stronger signal. Our examination of the differences between the warmest and coldest individual stations

(Table 1) revealed that these values are comparable to those of the warmer months. This suggests that the coverage of the heat island effect may have shrunk in area in addition to weakening during the cooler months, and examining contour plots of August (Fig. 3) versus October (Fig. 4) supports this hypothesis.

Our precipitation distributions for September and October (Fig. 4) both show a maximum over the southeastern part of the urban area, while the November precipitation in Columbia, Missouri does not show a maximum that is discernable above the synoptic distribution for precipitation described above. During both September and October, we found that the precipitation amounts and distribution were similar to that of the synoptic-scale distribution, except for the distinct maximum that prevails centered over southeastern Columbia. The September maximum was smaller in scale but greater than the background values measured by the volunteer network than was the October maximum, and this is made clearer when examining the variability in precipitation amounts. Our precipitation amounts were more variable across the Columbia region during September (93%) versus those of October (27%) or November (23%). However, it is not speculated here that the September and October maxima are necessarily evidence of an urban influence.

### *c. December 2000 - February 2001 results*

December 2000 was the second coldest December (12 °F/6.7 °C less than the 30 year mean - see Tables 1 and 2) on record for the Columbia, Missouri, region (Table 1) as a large-scale trough was responsible for very cold weather throughout the entire midwest. We found that December precipitation was also below normal throughout the state as amounts generally increased from north to south. However, the

most pertinent feature for the discussion below was the persistent snow cover that became established in the Columbia region around 12 December and persisted through the rest of the month. January and February were characterized by a more zonal flow regime over the midwest and the result was slightly warmer than normal temperatures throughout Missouri, including Columbia (Table 1). The temperatures were more variable across the state during February with below (above) normal temperatures across the northern (southern) part of the state. The gradient of monthly precipitation values was oriented such that during January, there was above (below) normal precipitation in the northwest (southeastern) part of the state. The gradient reversed itself for February and statewide maximum and minimum values were located in the opposite corners of Missouri. Central Missouri received about 2.5 to 3.5 in/64 – 89 mm (3.5 - 4.5 inches/89 – 115 mm) of precipitation in January (February).

We found that the heat island effect for December was as strong as the heat island effect in the summer months (Table 2), but like the fall season, the region of Columbia affected was smaller in area and effect was greater for the minimum temperature. However, December showed the greatest difference of any month between the warmest inner city station and the coolest station outside the city. This may be related to the persistent snow cover that remained in place for much of the month fundamentally altering characteristics of the underlying surface and, thus, the radiation balance at the earth's surface. During January and February, the strength (Table 2) and distribution (not shown) of the heat island effect was more typical of the values for the fall season.

In spite of the low precipitation totals for December, we found that the precipitation amounts varied from a maximum of 1.23 inches (31 mm) in Columbia to a minimum of 0.51 inches (13 mm)

*Table 3.* Variables used in heat island correlations to prevailing synoptic conditions and their characterization.

Cloudiness Classification	Percent coverage	Wind Speed Characterization	Speed (Kts)
Clear	< 20%	Light Winds	< 5 kts
Partly Cloudy	20% - 50%	Light Breeze	5 – 10 kts
Mostly Cloudy	50% - 80%	Moderate Winds	10 – 20 kts
Overcast	> 80%	Strong Winds	> 20 kts

outside the city, which represents a variance of 141%. Amounts across the city were fairly uniform throughout the winter season and the amounts were consistent with the statewide distribution described above. The precipitation amounts for January and February were less variable across the city, 38% and 22% for January and February, respectively. We then found a small scale, but discernable, maximum in the precipitation field over the southeast part of Columbia, Missouri. The February maximum is more prominent and larger in area than the January maximum (not shown).

#### *d. March - June 2001 results*

A northwesterly upper-air flow pattern persisted over Missouri for much of the month of March resulting in below normal temperatures for most of the state, including Columbia (Table 2). This flow regime deprived storms of moisture from the Gulf of Mexico as they crossed the state, and precipitation values were below normal for most of Missouri. Nonetheless, precipitation amounts increased from northwest to southeast across Missouri. For April and the first part of May, ridging persisted over the midwestern states in the large-scale flow pattern. This resulted in warmer than normal conditions for the state and Columbia (Table 2) in spite of the fact that a strong trough and cold conditions persisted over the midwest during the latter part of May and into June. This cool period was associated with an unusual blocking event that persisted over the eastern part of the North American continent and adjacent Atlantic region (e.g., Lupo and Smith, 1995; Lupo and Bosart 1999). April precipitation amounts were close to normal around the state, but during May, the northern (southern) part of the state was wetter (drier) than normal, and the precipitation amounts decreased significantly going southward. During much of June,

however, daytime conditions were mostly sunny with intermittent bouts of rain associated with the passage of synoptic systems.

Here we found that the strength of the heat island for the spring months was similar to that of the other months when examining HI or taking the difference between the warmest inner city station and the coldest station outside the city (Table 1). There was a difference in our area coverage of the heat island, however, as the effect expanded during these months and by May and June the area coverage was similar to that of July and August of 2000 (not shown). Also, the strength of our heat island effect was quite large during June, and the effect was larger for the maximum temperatures than for the minimum temperatures. Table 1 supports our assertion of an expanded heat island when comparing the values of  $T_b$  (temperatures at stations inside the city limits but not in the inner domain) to those of the inner ( $T_{ic}$ ) and outer ( $T_{os}$ ) city stations. During the latter part of the fall and throughout the winter months, the values of  $T_b$  were closer to those of  $T_{os}$ . Then during the spring season, these two values were closer to  $T_{ic}$  as they were during July and August of 2000.

Examining the precipitation distributions across the Columbia region reveals that during the spring months and June, our precipitation amounts were not as variable as they were during other months. The precipitation variability in the region as defined by our study was 54%, 32%, 40%, and 42% for March, April, May, and June, respectively. Our precipitation distributions were also similar to that of the synoptic variations described above, and the precipitation maximum found during other seasons was found only for the month of April.

*Table 4.* The number of samples and correlation coefficients for cloud cover and windspeeds versus the heat island strength (\* indicates statistical significance at the 95% confidence level or greater).

Cloud Cover	Wind Speeds	Number of Days	Correlation Coefficient
Overcast	Moderate and Strong	13	0.179
Overcast	Light Winds and Light Breeze	13	-0.30
Clear	Moderate and Strong	16	-0.273
Clear	Light Winds and Light Breeze	38	-0.391*

### e. Discussion

Our examination of the data reveals that when the monthly average of inner city stations is compared to those outside the city (Fig. 2), we found a discernable urban influence in the local temperature fields on the order of 2 - 3 °F (1.0 - 1.5 °C). The difference grows to 3 - 6 °F (1.5 - 3.5 °C) when comparing the monthly means of the warmest inner city station versus the coldest station outside the city. Our values are consistent with those found by Pinho and Manso - Orgaz (2000) for a city half the size of Columbia, and are a little less than those which might be expected for a city of Columbia's size (about 7° C or 12 - 13° F, e.g., Aguado and Burt, 2001). However, the values shown for Columbia reflect monthly averages rather than daily values of maximum or minimum temperatures as were reported in the two references above. We found individual days in which the difference in temperature between the warmest inner city station and the coolest station outside the city was on the order of 10° F (> 5.5 °C) or more. Thus, we are confident that our result is robust even though no rigorous statistical testing was performed due to the small sample size. We also note that the heat island effect found here is larger than the spread in the instrument sample, the standard deviation of the sample, and even the precision of the instruments used (+/- 1° C or 1.8 °F for the Radio-Shack® instrument).

That our heat island effect is not of the magnitude expected for a city of Columbia's size may be partially due to the fact that Columbia has made an effort to increase the amount of green-space within city limits over the last 15 years. The assertion that green-space can reduce the heat island effect is supported by Table 1 when comparing the values of  $T_s$  (stations in the southern part of the city where there has been more intensive development and decreasing green-space) to those of  $T_{ic}$ ,  $T_{os}$ , and  $T_b$ . Our values of  $T_s$  are generally more similar to  $T_{ic}$  than those of  $T_b$  or  $T_{os}$ . Another possible reason for our results found here, however, may be that we did not deploy instruments in the center of town where there are more buildings and more concrete and asphalt covered surfaces. We did not deploy instruments in this area since we could not guarantee proper instrumentation techniques, data collection, and instrument integrity.

The heat island itself did vary with the seasons as we show in Table 1, Figs. 3 and 4, and the discussion above. The heat island effect did expand in area extent during the warmer months and contracts

during the colder months. While our result contradicts the commonly held belief that the heat island expands during the cooler months (e.g, Aguado and Burt, 2001), the contraction of our heat island found here may be due to several factors, including increased cloudiness during the cold season or the low sun angle during the winter months. Also, the Columbia region does not have the construction density of larger cities, thus we propose that it is equally likely that the regional surface may be of more uniform character in terms of the surface albedoes after the vegetation dies off in the fall and before it grows again in the spring. The heat island seemed to be stronger again after April, when regional vegetation grew out.

Our HI values are similar for all months whether the means of all the inner city and stations outside the city are used, or the warmest (coldest) station from the former (latter) group is compared. The heat island effect found here is stronger also in the maximum (minimum) temperatures during the summer (winter) months. This is likely due to the stronger absorption of solar radiation during the warmer months, and more excessive long wave cooling during the cooler months outside the city. For example, December 2000 stands out as a month in which our heat island effect was strongest. We propose that this may be due to this month being the second coldest December in the history of Columbia, and being associated with an unusually persistent snow cover. The persistent snow cover would fundamentally alter the regional surface radiation balance as snow cover is well known to be a strong reflector (emitter) of shortwave (longwave radiation). Also, snow cover in the regions outside the city could be expected to stay fresher for a longer period of time, while snow is removed from large portions of Columbia's surface area. What snow remains in the city becomes dirtier more quickly in Columbia since the city maintenance department liberally spreads black cinders on the roads to improve vehicle traction on snow covered roads in order to absorb more sunlight. Also, the dirty snow would not be as effective of a longwave emitter at night, which possibly accounts for the large difference in the December minima

Our examination the precipitation fields demonstrated that there was not a persistent feature present that can be attributed to the urban area specifically and which stood apart from the synoptic-scale precipitation distribution. A precipitation maximum is present in our monthly precipitation field totals during six of the 12 months in this study, and for

only one month (Sept 2000) was this maximum nearly double the value found at the Columbia Regional Airport. Additionally, the precipitation during that month was associated primarily with thunderstorms. Larger cities have been shown clearly to have a more persistent impact on convective-type or convectively driven precipitation events (e.g., Biak et al., 2001; Shepherd et al. 2002). Changnon et al. (1991) showed this impact to primarily be a warm season effect for a city like St. Louis, MO.

#### 4. Stratification by synoptic variables

The purpose of this part of our study was to examine which variable; cloud cover, wind direction, or wind speed, made the greatest impact on the strength and distribution of the heat island effect. We divided the city into four quadrants and the one station which recorded both temperature and precipitation information the most consistently in each quadrant was chosen to represent each quadrant (not shown). In order to keep the impact of larger scales to a minimum, we only included days where there was no precipitation or wind shifts. Our classification of cloud cover and wind speeds are shown in Table 3. We classified cloud cover as in Lupo and Market (2002), where clear (cloudy) skies represent less than 20% (more than 80%) coverage. We partitioned wind speeds to represent light winds, light breeze, moderate winds, and strong winds. We then correlated wind directions versus the quadrant of maximum temperature in order to determine if the wind direction had any impact on the distribution of the heat island effect.

Table 4 shows the correlations between the quadrant of maximum temperature and wind direction under all combinations of cloud cover and wind speeds and the number of time periods (days) which satisfied the combined criterion. While only the clear skies and light wind and light breeze category contained a large enough sample and showed statistically significant negative correlations (greater than the 95% confidence level), the outcome of this exercise are consistent with what should be expected based on the results of studies using larger cities (e.g., Oke, 1982 and later studies referenced above). The negative correlation between the quadrant of maximum temperature and wind direction under most combinations of cloud cover and wind speed indicates that the heat island effect for

this city was advected down wind. Finally, as expected, the heat island was least noticeable under conditions of cloudy skies and strong winds, since cloudy skies would block out incoming solar radiation and strong winds promote increased mixing of air close to the ground. This accounts for the weak correlations as well. We also found the strongest heat island effect under the conditions of clear skies and light winds. These days provided for the maximum insolation and least amount of mixing. A sample of this type of day is shown in Fig. 5.

#### 5. Summary and conclusions

Many publications have shown the impact on small-scale regional surface temperatures as caused by urbanization or agricultural activities. The heat island effect has been studied extensively for larger cities, but there are comparatively few studies examining this effect for smaller urban areas. For our study, we bought 20 thermometers and 10 rain gauges and distributed 17 of the thermometers throughout the Columbia, MO, region to examine the impact of the city and the University of Missouri campus on the surface temperature fields. Participants gathered daily data points from 1 July 2000 to 30 June 2001. Our experiment provided University of Missouri undergraduate students with an opportunity to participate in meteorological research. Students helped to gather the data, check the data for quality, and process it. Some students also participated in lecture sessions, as this experiment served as the template for the recent development of an instrumentation and experimentation course in the atmospheric science program at the University of Missouri.

The first step in our experiment was to examine mean monthly data in order to determine if the heat island effect is detectable in the region's microclimate. All 12 months exhibited a clear "heat island effect" as the mean temperature of the inner city sites exceeded those of the sites outside the city. This was true for every individual site as well. The heat island effect was much larger than both the standard deviation of the 20 individually purchased (and deployed) instruments or their range when they were tested under "uniform" conditions. Our results suggest that the Columbia, MO, heat island effect is a significant feature in the local microclimate. We also found that the heat island effect was larger in area during the warm season with a stronger effect shown in the maximum temperatures during the summer months and in minimum temperatures during

the winter months. We also suggest that fundamentally altering the surface type, such as the persistence of winter snow cover, could have influenced the strength of the heat island. This possibly lead to a stronger heat-island signal being reflected in the minimum temperature for December 2000 as opposed to the stronger signal in the summer season maxima. Additionally, we detected no discernable or persistent urban effect during this period on the precipitation distributions. Finally, our examination the strength of the heat island as calculated as the difference between the means of the warmest individual station inside the city and the coolest station outside the city revealed temperature differences of 3 - 6 °F (1.5 - 3.5 °C).

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# *Collegiate & Senior Divisions*

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\*Arrey, Frida T., B. McDaniel, M.F. Haskins, T. Holliger, B. White, and G. Lona. Biology Department. Rockhurst University. **LICHEN Abundance And Distribution On Oak Trees In Kansas City, Mo.** The purpose of this study was to measure lichen abundance and distribution on oak trees near heavily trafficked streets in comparison to lichen coverage in more distant areas that receive less pollution from car exhausts. Four measurements were taken from each tree using a 100-circle grid. The study area was located in Swope Park located within Kansas City, MO. Historically, the area was primarily an oak-hickory forest and was established as a park in 1896. Through the years the 1,805 acre park has been partially developed with public attractions, and city streets within the park are currently used as thoroughfares. Much of the park is still characterized by a rugged oak-hickory landscape and is, hopefully, protected from further development. GPS technology and GIS software were used to map the study area and city streets.

\*Bell, I., A. Townsend and M. Scott. Department of Agriculture and Natural Sciences, Lincoln University. **A Comparison Of Time-**

**Lapse Video Recordings And Passive Infrared Still Cameras For Surveying Small Mammalian Predators.** A comparison of time-lapse video recordings and passive infrared still cameras for surveying small predators at baited stations was made in conjunction with a study on the abundance and behavior of small predators in an urban environment. The time-lapse video system (Security Labs SL811) continuously recorded images using natural sunlight and/or infrared illumination at a speed equivalent to 8 frames per second. The passive infrared still camera (Highlander Sports Photo Spy) was initiated using a passive infrared trigger. The primary advantages of the battery powered still camera were portability and weather resistance. The primary advantages of the time-lapse video were continuous recording and the ability to monitor animal behaviors. The disadvantages of the battery powered still camera were the time lag between the triggering event and the image capture and the lack of behavioral data. The disadvantages of the video recording system were the reliance on 110 V AC power and weather resistant storage. Overall, in an urban environment, time-lapse video recording offers more advantages than disadvantages. In a less urban environment, the portability of a battery powered recording system is a great advantage but limits the type of data that may be collected.

\*Callaghan, T. N., Biology Department, Park University; Slitt, A., University of Kansas Medical Center; Maher, J., University of Kansas Medical Center; Gonzalez, F., National Institute of Health; Klaassen, C. D., University of Kansas Medical Center. **Changes In Gene Expression After The Loss Of Hepatocyte Nuclear Factor 1 Alpha.** We studied hepatocyte nuclear factor 1 alpha (HNF-1 $\alpha$ ), a transcription factor enriched mainly in the liver, but it is also found in the kidneys, stomach, intestine, and pancreas. Mice deficient in HNF-1 $\alpha$  were produced, livers were collected, and total RNA was extracted. Using bDNA assays, we observed changes in gene expression in the family members of phase 1 enzymes, Oatps, Mrps, sterol transporters, bile salt transporters, and nuclear hormone receptors. Results confirm

that HNF-1 $\alpha$  plays a critical role in altering gene expression for metabolic and transport activity in the liver, demonstrating that HNF-1 $\alpha$  can stimulate or suppress gene expression when present. Phenotypic and physiological changes, based on the presence of HNF-1 $\alpha$ , vary within each of the families studied.

\*Farmer, D., \*Taylor, H. and K. L. Schaffer. Department of Biological Sciences, Northwest Missouri State University. **Response of *Robinia pseudoacacia* to cambial treatments of two herbicides. *Robinia pseudoacacia* I.** is highly invasive and effectively outcompetes native prairie species. During the past decade, *Robinia* has become established in a prairie conservation area on our campus and, in an attempt to eradicate this population, we subdivided a densely populated 82 x 34 meter area into smaller plots and cut the trees 10-20 cm above the soil surface. We then applied the following treatments to the stumps: Plot 1-Garlon 3A before bud break, Plot 2-control/water before bud break, Plot 3-Garlon 3A after bud break, Plot 4-control/water after bud break, Plot 5-Tordon after bud break. Plots were observed periodically during summer and fall of 2002. Plot 1, which had fewer stump resprouts and more individual saplings, was subdivided, recut, and treated with Garlon 3A. Subsequent investigations revealed that 99% of these *Robinia* saplings consisted of root sprouts. Therefore, initial cambial herbicide application of Garlon 3A before bud break was not successful in eradicating the *Robinia* population because it did not penetrate the length of the root and inhibit further resprouting. Supported by Applied Research Grant 122218.

\*Hays, J.M. and L.M. Bowe. Department of Biology, Southwest Missouri State University. **Missouri's Yellow Wood Sorrel (*Oxalis*): Preliminary Genetic Analysis Of Amplified Fragment Length Polymorphisms (Aflps).** This study aims to find genetic markers that can be used to establish relationships among closely related Missouri *Oxalis* species and determine if clearer morphological characteristics can be used to distinguish species. In Steyermark's *Flora of Missouri*, three species of yellow-flowered *Oxalis* are described, but only two are common: *O. stricta* L., which has been called *O. europaea* Jord., and *O. dillenii* Jacq., which had been called *O. stricta* by some, indicating debate about the nomenclature of these highly morphologically variable

species. AFLPs are short fragments of DNA that are polymorphic enough to distinguish closely related species (and even individuals). In this preliminary study of populations from five counties, approximately 55 informative AFLP loci were found using three primer combinations. AFLPs from 40 individuals were coded as presence-absence data and analyzed in PAUP. Preliminary analysis identified two genetic groups that would key to *O. dillenii* and possibly just one that would key to *O. stricta*. While some overlap in morphological characteristics remains in these genetic groups, most "*O. dillenii*" could be identified by their deflexed pedicels. This study demonstrates the use of AFLPs for this type of research and indicates that abundant data can be acquired with fairly few primer combinations.

\*Montoya, B. and J. Benne. 2004. **West Nile Virus and Its Arthropod Host.** West Nile Virus (WNV) is currently one of the most widespread mosquito based viruses in the world. WNV occurs in a complex life cycle involving a non-human primary vertebrate host (usually bird) and a primary mosquito vector. WNV is amplified during periods of adult mosquito blood-feeding by continuous transmission between mosquito vectors and bird hosts. Infectious mosquitoes carry virus particles in their salivary glands and infect susceptible bird species during blood meal feeding. The principal route of human infection with WNV is through the bite of an infected mosquito. For this reason U.S. mosquito populations are under constant surveillance for the presence of virus in adult mosquitoes. Although the relationships described here indicate the most common interactions between virus, vector and host, they are not the only possible reservoirs or modes of transmission. Just as horses may serve as an alternative vertebrate target, it is possible that blood-feeding arthropods other than mosquitoes may serve as vectors. This study examines the use of reverse transcriptase polymerase chain reaction (RT-PCR) to determine the presence of WNV and then utilizes this technology to examine alternate vector possibilities including black flies, horse flies and ticks.

\*Nedich, B.L., and S.S. Daggett. Department of Biology, Avila University. **Extraction Of Isoenzymes From *Chlamydomonas Reinhardtii*.** *Chlamydomonas reinhardtii* is a unicellular alga commonly found in freshwater and soil systems. The

alga has a haplobiontic life cycle and has long used as a genetic model organism. Very little is known about the population genetics of *Chlamydomonas* species because its small size, simple cell structure, and life cycle idiosyncrasies has restricted the number of discrete phenotypes that can be studied. Isoenzymes would seem to be ideal phenotypic markers for such studies. However, very few studies have been carried out using isoenzyme analysis with *Chlamydomonas* species. This project involved the development of a method to extract and assay isoenzymes from laboratory cultures of *C. reinhardtii*. Lysates collected from 100 Bold's agar cultures of mt<sup>+</sup> cells yielded 4 mg/ml of total protein. Starch gel electrophoresis was used to run samples of extracted protein and stained for the isoenzyme malate dehydrogenase (MDH). Results suggest a heterozygotic banding pattern that fits with expectations based on previous work. Additional isoenzyme markers are currently being sought, including leucine aminopeptidase (LAP), which has been resolved with the same buffers as MDH.

\*Parker, E. E. and H.W. Keller. Department of Biology, Central Missouri State University. **Correlation of pH with assemblages of corticolous myxomycetes in big oak tree state park, missouri. Big oak tree state park**, located in the "Bootheel" region of Missouri, is a unique park within the Missouri Division of State Parks. The 1029 acres represent all that remains of an ancient virgin bottomland hardwood deciduous forest now recognized as a National Natural Landmark. The canopy of towering champion-sized trees provides the perfect environment for cryptogams such as mosses, liverworts, ferns, fungi, and especially the myxomycetes. Twenty trees were climbed over a two-week period in July of 2002. Bark samples from eight trees, representing five tree species, were cultured using the moist-chamber culture technique. Hydrogen ion concentration (pH) values were measured for the five tree species, and later compared to the recorded myxomycete species assemblages. Myxomycete species were associated with narrow or broad pH ranges. Some species were found exclusively on tree species with a near neutral pH of 7.0, while others preferred the trees with an acidic pH as low as 4.6, still others were found on all five tree species, showing a wide pH tolerance. One new species was found on a bald cypress tree with an acidic pH. This is the first

tree canopy study in the state of Missouri and the Midwestern United States. A total of 40 myxomycete species were recorded for Big Oak Tree State Park, which were new records for the park and the state of Missouri. Funded in part by the United States Department of Education, Ronald E. McNair Post-baccalaureate Achievement Program and the Missouri Department of Natural Resources, Division of State Parks.

\*Roberts, M.W., J. J. Millsbaugh, and D. C. Dey. Department of Fisheries and Wildlife Sciences, University of Missouri (MWR, JJM). US Forest Service (DCD). **Movement Dynamics Of Eastern Cottontail In The Missouri River Floodplain**. Our study was initiated to help understand movement dynamics of eastern cottontails (*Sylvilagus floridanus*) to mitigate herbivory damage to oak tree seedlings planted in the Lower Missouri River floodplains. At Plowboy Bend Conservation Area we collected radio telemetry locations from 23 rabbits (10 males and 13 females) during winter and spring for two years. We analyzed 50% and 95% adaptive kernel (AK) and minimum convex polygon (MCP) home ranges using 'CALHOME'. Home range size (95% contour) averaged 5.9 ha (Range = 0.84 to 45.3ha, SD = 7.49). Rabbit core areas (50% contour) averaged 0.57 ha (Range = 0.8 to 1.8 ha, SD = 0.57). Males core areas (50% contour) averaged 0.83 ha (Range = 0.08 to 1.8 ha, SD = 0.74); home range (95% contour) averaged 9.1 ha (Range = 1.8 to 45.3 ha, SD = 9.72). Females core area averaged 0.33 ha (Range = 0.09 to 0.79 ha, SD = 0.17); female home range averaged 2.97 ha (Range = 0.84 to 8.94 ha, SD = 2.28). The largest distance traveled between successive locations was 600m, by a male. Also, we observed that rabbits moved almost exclusively at night, being near or in the same form daily. Managers will use these movement dynamics data to mitigate herbivory damage.

\*Smith, K.M., and T.R. Bragg. Agricultural Science, Truman State University. **Allometric scaling in three sizes of equids (*equus caballus*)**. As an extension of an ongoing study, this research project concerns relative growth patterns of body parts in equids (*Equus caballus*) of three body types. In a previous study, eight body dimensions, including body mass, were determined for 32 Quarter Horse and Paint mares (light body type) and 29 Percheron mares (heavy body type). With the current study, 11

miniature horses of mixed gender were integrated into the dataset to test if the smaller body type would follow previously determined allometric and isometric patterns observed with the two larger body types. Male miniature horses were included in the data set as they fit well with data for the females, with no outliers. Compared to previous trials,  $R^2$  values improved greatly with the addition of the miniature horse data, indicating that previously noted allometric and isometric growth patterns are consistent across a variety of body sizes within this species. Results indicate the most closely correlated dimensions are withers height and leg length with an  $R^2$  of 0.9774. A preliminary formula for computing body mass was also developed, utilizing body dimensions of withers height, leg length, and body length ( $R^2=0.9668$ ). Future studies will incorporate Arabian horse mares, and males (geldings and/or stallions) of the light and heavy body types.

\*Swearingin, R. M., J. J. Millspaugh, and D. C. Dey. Department of Fisheries and Wildlife Sciences, University of Missouri (RMS, JJM). USDA Forest Service (DCD). **Resource Selection Habits Of Eastern Cottontail Rabbits In Missouri Bottomlands.** Recent management at Plowboy Bend Conservation Area has created bottomland forest by reestablishing mast producing trees that were lost to flooding in 1993. The trees were planted in two 40-acre fields of different cover types, natural vegetation vs. redtop grass. Other grasses and crops exist around these fields. Since their planting, the 3,700 mixed oak trees have received considerable browsing damage from eastern cottontail rabbits (*Sylvilagus floridanus*). We collected locations from 23 rabbits (10 males and 13 females) five days a week using radio telemetry during winter and spring 2003 and 2004. Using these data, we assessed micro-site resource selection. We found that rabbits selected for resources offering concealment during daylight hours such as Johnson grass (*Sorghum halepense*) and eastern cottonwoods (*Populus deltoides*). At night they selected open areas in corn (*Zea mays*) and wheat stubble (*Triticum aestivum*), as well in willows (*Salix alba*) and smartweed (*Polygonum spp.*). Rabbits avoided redtop grass (*Agrostis alba*), soybean stubble (*Glycine max*), and sunflower fields (*Helianthus annuus*), possibly due to the lack of protective cover and food availability. Although different trends in habitat selection existed among day and night, selection between seasons was very similar. The findings from this research will offer

ways to manipulate the structure and composition of the habitat to reduce the herbivory impact on the planted trees, and focus it on alternate habitat types.

\*Townsend, A., I. Bell and M. Scott. Department of Agriculture and Natural Sciences, Lincoln University. **The Abundance And Behavior Of Small Mammalian Predators In An Urban Environment.** The primary objectives of this project were to survey the small mammalian predators attracted to baited stations in an urban environment and to monitor their behavioral responses to an experimental exclusion device. Stations at several locations in or near Jefferson City, MO were baited with sardines. Animal visits to the baited stations were simultaneously recorded using time-lapse video recordings and passive infrared still cameras. A total of four mammalian predator species were recorded visiting the stations (domestic cats, domestic dogs, opossums and raccoons). The frequency and duration of visits of were also recorded and used in before and after comparisons to monitor the effectiveness of an experimental exclusion device (a two strand electric fence). The number of visits by domestic pets was relatively small at most locations. The response of raccoons to the placement of the exclusion device was to avoid the electric fence following the initial encounter. Opossums were more likely to return to the bait stations for short duration visits and often defeated the exclusion device.

## *Chemistry Collegiate Section*

### **James S. Gordon**

#### *Central Methodist College*

\*Dorn, S.M. and E.V. Patterson. Division of Science, Truman State University. **Ab Initio Molecular Dynamics On The Phenylcarbene Rearrangement.** The photochemical rearrangement of phenylcarbene to cycloheptatriene has been studied using ab initio density functional theory coupled with atom-centered density matrix propagation (ADMP) molecular dynamics. Previous computational work indicates that bicyclo[4.1.0]heptatriene should form as an intermediate during the course of this rearrangement. However, no experimental evidence for the existence of bicyclo[4.1.0]heptatriene has been found, despite several attempts by various

research groups to isolate this molecule. The previous computational work employed the Born-Oppenheimer approximation, and nuclear kinetic energy was taken to be zero. The current calculations allow for the inclusion of nuclear kinetic energy according to Newton's classical laws of motion and thus provide a more accurate representation of the potential energy surface under experimental conditions. The dynamics calculations were started at the transition state structure previously determined to connect phenylcarbene and bicyclo [4.1.0] heptatriene. The reaction was allowed 212,482 microHartrees of kinetic energy, corresponding to experimental photolysis conditions. Two hundred random trajectories were each integrated over 400 femtoseconds. Analysis of the results will provide an accurate picture of the minimum energy pathway connecting phenylcarbene and cycloheptatriene. The results will also provide lifetime data for all involved species and will lead to a better understanding of the role bicyclo[4.1.0]heptatriene plays in this rearrangement.

\*Kennett, K.J., Nagan, M.C. Science Division, Truman State University. **Molecular Dynamics Simulations Of The Rev-Rre Complex.** Translation of viral messenger RNA (mRNA) encoded by the genome of human immunodeficiency virus type-1 (HIV-1) originally produces viral regulatory proteins, such as rev. Rev protein recognition of a sequence of mRNA called the rev response element (RRE) serves as a switch for shuttling unspliced and singly spliced viral mRNA out of the nucleus and into the cytosol of the host cell. Without this protein-RNA interaction, most viral mRNA cannot be translated on host cell ribosomes. Nuclear magnetic resonance (NMR) spectroscopy structures have already characterized the structure of the rev-RRE complex. Molecular dynamics (MD) simulations of the rev-RRE complex have been acquired starting from three different NMR structures (Battiste, J.L., et al. (1996) *Science*, 273, 1547). The root mean square displacement (RMSD) from starting and average structures have shown that the MD simulations have reached equilibrium, thus allowing for accurate analysis of the occurrence and duration of interactions between arginine side chains of rev and the RRE. The results of this study could eventually be used to develop antiviral pharmaceuticals that would inhibit binding between rev and RRE, thus slowing or possibly arresting the HIV life cycle.

\*Mengwasser, J., Lincoln University and Dr. Wimalasea, Wichita State University. **"Synthesis of Phenylcyclopropylamines for Structure-Activity Studies of Monoamine Transporters."** Dibenzylformamide was treated with cyclohexylmagnesium chloride in the presence of titanium tetraisopropoxide and styrene, as well as two of its derivatives, 4-fluorostyrene and 3-fluorostyrene. This reaction produced N, N-dibenzylcyclopropylamines. The cis and trans isomers of these compounds were isolated. Then the compounds were debenzylated by catalytic hydrogenation, giving the primary cyclopropylamines. Following debenzylation, they were converted to HCl salts. Later, the compounds will be used for structure-activity studies of monoamine transporters.

\*Menke, J.L. and E.V. Patterson. Division of Science, Truman State University. **Ab Initio Density Functional Studies Of Twisted Intramolecular Charge Transfer (Tict) Characteristics Of Substituted Pyrrolypyridines.** Pyrrolypyridines such as 2-(1-pyrrolyl)-pyridine and three of its methylated derivatives, 3-methyl-2-(1-pyrrolyl)-pyridine, 2,4-dimethyl-6-(1-pyrrolyl)-pyridine, and 5-methyl-2-(1-pyrrolyl)-pyridine are known to show fluorescence behavior consistent with a low-lying twisted intramolecular charge transfer excited state. Such behavior is often revealed through dual fluorescence and a significant solvatochromic shift of the long-wavelength emission. All four pyrrolypyridines mentioned above display these characteristics, although the various methyl substitutions affect both the intensity of emission and the magnitude of the solvatochromic shift. To better understand these differences, these molecules have been studied using quantum mechanical density functional calculations. The ground state energy surface for the rotation about the central axis between the two ring systems was obtained at the B3LYP/6-31G\* level of theory. The corresponding excited state surface was obtained through time-dependent density functional theory (TD-DFT), also at the B3LYP/6-31G\* level. The effect of polar (acetonitrile) and non-polar (cyclohexane) solvent is accounted for through the integral equation formalism polarizable continuum model (IEF-PCM). Trends show that the excited states of each of these molecules are more stable in a twisted conformation whereas the ground states prefer planar

or near-planar geometries, confirming that these are TICT molecules.

\*K. Schembri, M.C. Nagan, M. Varner, and A. Combs. Science Division, Truman State University. **Molecular Dynamics Simulations Of The Trna<sup>Lys,3</sup><sub>UUU</sub> Anticodon Stem Loop.** Transfer ribonucleic acid (tRNA) anticodon recognition of messenger RNA (mRNA) codons in the context of the ribosome is critical to accurate translation of the genetic code. Nuclear magnetic resonance (NMR) structures of the third human tRNA that codes for lysine indicates that the inclusion of the posttranscriptionally modified base threonylcarbamoyladenine at position 37 (t<sup>6</sup>A37) changes the anticodon stem loop structure such that uracil 34 flips around, leaving only two remaining uracil bases to interact with the messenger RNA codon. It has been proposed that the unusual C32•A<sup>+</sup>38 base pair stabilizes t<sup>6</sup>A37. The NMR structure was obtained in acidic conditions but at physiological pH, this base pair should not form. The purpose of this study is to analyze the dynamics of t<sup>6</sup>A37 in the tRNA<sup>Lys,3</sup><sub>UUU</sub> structure at pH 7. Four tRNA<sup>Lys,3</sup> variants are being analyzed using molecular dynamics simulations. They include an unmodified tRNA molecule, one containing t<sup>6</sup>A37, one containing the A<sup>+</sup>38 modification, and one with both modifications. Trajectories for all four systems have been collected. Root mean square displacements from starting and average structures as well as helical parameters, all indicate that the systems are equilibrated.

\*Soemo, A. R., M. C. Nagan. Science Division, Truman State University. **Molecular Dynamics Studies Of Arginine Side-Chain Dynamics In The Hiv Rev-Rre Complex Under High And Low Salt Conditions.** The human immunodeficiency virus Type 1 (HIV-1) leads to the onset of the acquired immunodeficiency syndrome (AIDS) which has resulted in the deaths of 3 million people in 2003 alone (UNAIDS). The interaction between the Rev protein and the rev response element (RRE), a sequence in messenger RNA (mRNA), is a critical step in the HIV-1 lifecycle. Rev-RRE binding allows mRNA to be transported out of the nucleus and into the cytoplasm of the cell where viral proteins can be translated. The purpose of our study is to examine Rev-RRE interactions to better understand the recognition mechanism. The Rev peptide is

arginine rich with 11 arginines of 23 total amino acids. Arginine has a long chain of carbons ending with two amine groups, one of which is positively charged. We are using molecular dynamics simulations to determine how these positively charged arginine side-chains bind to RRE. Specifically, the effects of high and low salt concentrations (150 mM and 50 mM, respectively) are examined to assess the strength of arginine binding to the RRE RNA. All simulations began from a high-resolution nuclear magnetic resonance structure (Battiste et al.). It is believed that an increase in salt concentration reduces non-specific Rev-RRE recognition. Arginine side-chain dynamics and affinity for RRE will be compared to experimentally determined side-chain mobility.

\*Tiemann, S.M., Nagan, M.C. Science Division, Truman State University. **The Role Of Pseudouridine At The Spliceosomal Branch Site: A Molecular Dynamics Analysis.** The spliceosome, a complex which contains small nuclear RNA (snRNA) and small nuclear ribonucleoproteins (snRNPs), is where the splicing of pre-messenger RNA (pre-mRNA) molecules occurs. The spliceosome excises or cuts the non-coding regions (introns) and splices together the coding regions (exons). In absence of snRNPs, the splicing reaction still can occur, albeit at a slower reaction rate, and is therefore known as a ribozyme. Two of the five snRNA molecules, U2 and U6, comprise the catalytic active site. In the splicing reaction, which occurs via two transesterification reactions, the branch site adenosine (A24) 2'-OH acts as a nucleophile and attacks at the 5'-phosphate on the intron site to form a lariat structure. Biochemical studies have shown that a nonstandard highly conserved base in U2, pseudouridine, is required for splicing activity and in general, increases thermal stability. Nuclear magnetic resonance (NMR) structures show that this pseudouridine induces a structural change in the intron:U2 snRNA helix and places the A24 in an extrahelical position. Molecular dynamics (MD) simulations of the helix containing the pseudouridine have been acquired in the presence of water and sodium counterions. All simulations utilize the Cornell *et al.* forcefield and particle mesh Ewald treatment of electrostatics. Equilibration of the MD simulations is assessed with root mean square displacement plots and analysis of helical parameters.

## *Geology Collegiate Section*

**David J. Wronkiewicz**

*University of Missouri — Rolla*

\*Crews, J. and J. Hogan. Department of Geology and Geophysics, University of Missouri-Rolla. **Origin of Elevated Sub-horizontal Surfaces in the Wichita Mountains, Oklahoma.** Digital Elevation Models (DEMs) were used to identify and characterize sub-horizontal topographic surfaces that are readily observed in the Wichita Mountains of Oklahoma. The origin of these surfaces is problematic: 1) Are they remnants of an ancient peneplain? 2) Are they the topographic expression of the roofs of sub-horizontal igneous sills? To address this question, the Tertiary erosional surface of the Southern High Plains was modeled from coordinates and elevations extracted from DEMs. Extracted data was used to generate both a linear and a logarithmic mathematical model. These models were used to predict the elevations of the paleo-erosional surface present throughout the Wichita Mountains during Tertiary time. Coordinates from Flat Mountain generated elevations of 1590' from the linear model and 2188' from the logarithmic model. The actual elevation of Flat Mountain is 2168'. Coordinates from Elk Mountain generated elevations of 1679' from the linear model and 2226' from the logarithmic model. The actual elevation of Elk Mountain is 2262'. The agreement between the actual elevations and those generated by the logarithmic model are consistent with the surfaces in the Wichita Mountains representing remnants of the ancient Tertiary erosional surface.

\*Euler, G.E., G. Abdel Aal, and E.A. Atekwana. Department of Geology and Geophysics, University of Missouri – Rolla. **Influence Of Microbial-Mineral Interactions On The Electrical Properties Of Unconsolidated Sands.** Meso-scale column experiments were conducted to investigate the influence of microbial activity on electrical properties of rocks. The experimental setup consisted of sand-filled columns amended with bacteria and nutrients and/or diesel as well as sand-filled control columns. Results show that the highest relative percent changes in electrical conductivity and alkane-degrading microbial populations occur within the hydrocarbon impacted zones with maximum changes occurring in the free phase diesel layer just above the water

saturated zone. The control column showed minimal changes in both the electrical conductivity and microbial populations. Measurements of the microbial population are found to be concomitant with the geophysical data. Induced polarization measurements on cores retrieved from the columns show that the real component of the complex conductivity, a measure of mainly the electrolytic conductivity, is greater in magnitude for both the saturated and unsaturated zones of the diesel-contaminated column in comparison to the uncontaminated column. We conclude that this increase is caused by mineralization of the diesel and subsequent weathering of minerals. Furthermore, measurements of the imaginary component of complex conductivity, a measure of the grain-fluid interface conductivity, shows variations in magnitude between saturated and unsaturated zones in the contaminated and uncontaminated columns. We conclude that microbial-mineral interactions cause a change in both the electrolytic and interfacial conduction properties of unconsolidated sediments.

\*Hemmann, R.J. and D.J. Wronkiewicz. Department Geology and Geophysics, University of Missouri – Rolla. **Alteration Phase Development During The Oxidative Weathering Of Remnant Sulfide Ores.** Metal contamination in the Big River system of southeastern Missouri has been associated with the oxidative weathering and breakdown of remnant sulfide ores from tailings piles and tailings particles that were transported into the river by fluvial processes. The tailings materials contain remnant ore grains of galena, pyrite, sphalerite, and other minerals. Samples of pyrite, galena, and sphalerite were cut and polished to a 600-grit finish and then reacted in stainless steel bombs at 200°C for time periods of 7 and 35 days. These tests were conducted to gain an understanding of the corrosion processes affecting the sulfides and potential release mechanisms affecting  $Pb^{2+}$ ,  $Zn^{2+}$ ,  $Cd^{2+}$ ,  $As^{5+}$ , and  $SO_4^{2-}$ . Reacted samples were examined with an optical microscope and scanning electron microscope equipped with energy dispersive spectroscopy. Dissolution pits on sulfides and secondary alteration phases were visible on all samples. Alteration phases included various Pb-, Fe-, Zn-oxide and/or sulfate minerals, with phases on sphalerite also containing small amounts of arsenic.

\*Johnson, R., and Wronkiewicz, D.J.  
Department of Geology and Geophysics, University

of Missouri – Rolla. **Concentration And Transportation Analysis Of Heavy Metals In Sediment Core: Ber Juan, Park, Rolla, Mo.** The concentration of lead and other metals in urban lake sediments were determined to elucidate fate and transport mechanisms affecting metal distribution patterns. X-Ray diffraction analysis of clay samples showed a mixed assemblage of kaolinite, smectite, and illite clays, as well as a large quantity of quartz. Inductively Coupled Plasma - Mass Spectroscopy (ICP-MS) performed on sediment samples ranging in depths from 0 to 20 centimeters show lead concentrations that correlate with anthropogenic lead usage. Lead concentrations ranged from a minimum of 39.26 ppm to a maximum of 57.48 ppm. Distributions correlate with automotive usage of lead, transport to the lakes may however include lead particles released by air, and/or those deposited in the soil, and subsequently washed into the basin by meteoric water. When compared to other studies of nearby lakes, lower concentrations of lead in these Ber Juan's sediments are evident. These differences may exist due to travel distance of lead particles; more to traffic congestion in other areas, as well as local point sources (i.e. spills at gasoline stations).

\*Lasco, D. and J. Hogan, Department of Geology and Geophysics, University of Missouri-Rolla. **Crystallization History of the Mount Sheridan Gabbro, Oklahoma.** The Mt. Sheridan Gabbro displays evidence for multiple impulses of magma into the chamber resulting in mineralogical layering within the gabbro. Twenty-eight samples were collected up "little" Mt. Sheridan, encompassing 714 vertical feet. The chamber can be subdivided into a large, layered, lower zone, and a homogenous upper zone. The lower zone coarsens upward, displays repetitions in the modal abundance of plagioclase, and the disappearance and reappearance of olivine. Plagioclase in the lower chamber grades from unaltered to heavily altered and displays zonation that changes from poorly developed, patchy zones to sharp, oscillatory zones. Reversely zoned plagioclase phenocrysts and modal variations in key minerals (i.e. olivine) are indicative of influx of fresh magma into the chamber during crystallization. These changes are repeated at least three times in the lower chamber. The upper chamber is a homogenous gabbro that increases in the modal abundance of plagioclase towards the top of the chamber. Field, petrographic,

and chemical evidence suggest rock types present in the Mount Sheridan Gabbro formed from fractional crystallization of multiple batches of magma rather than crystallization of a single batch of magma.

Powers, Elizabeth A., Holbrook, John M. Department of Geosciences and Physics, Southeast Missouri State University. **Investigation Into Lewis And Clark The Braided/Anastomosing Missouri River From Miami Station To Carrllton.** The first mapping of the Missouri River was in 1804 by Lewis and Clark. Since then the river has changed to a single-channel meandering system, assumedly because of human modification. The first alluvial map is underway –by students and faculty at Southeast Missouri State University. They have found that island braided pattern is no older than 3,000 years, making it late Holocene in age. Furthermore, the island braded system was preceded by generations of single-channel meandering rivers within the late Holocene. The question addressed here is why the river had changed its pattern to an island braided system in the late Pleistocene. Braided patterns are usually seen in high slope areas, due to the necessity to have as much surface area of the flow on the bed as possible. However, the slope has not substantially changed over the period in question. One possible alternative is that the river altered to island braided during the Little Ice Age, which lasted from 1400's to 1850. Glacial outbursts may produce similar island-braided patterns. Through literature searches of all modern braided, anastomosing rivers we have come to a potential explanation as to why the river could have shown this island braided morphology. We propose that ice damming the flow of the river during Little Ice Age spring thaw periodically blocked the channel simulating outburst conditions. This created many single channels in and an overall anastomosing river system, with bars.

## *Physics, Engineering, & Computer Science*

**Daniel B. Marsh**

*Missouri Southern State University*

\*Burchfield, S. J., R. D. Chelf, and D. B. Marsh. Department of Physical Science, Missouri Southern State University-Joplin. **Some**

### **Thermodynamic Properties Of Candle Wax In**

**Large, Flat Candles.** When large candles are burned, the wax is observed to melt in a pattern around the wick. The size and shape of this pattern depends on the size of the candle and the composition of the candle wax (most candles are a mix of paraffin and stearin, to prolong the burn time of the candle). In this study, we examine the burning of large candles, with no scent or dye added, by looking at the energy of combustion, the specific heat capacity, and latent heat of fusion. This allows us to determine how much energy is getting from the flame to the wax in the burning process. A bomb calorimeter is used to determine the total amount of energy present in a given sample of wax. Standard calorimeters are used to find the specific heat and the heat of fusion. Then by burning the candle for a known time, we determine how much of the sample burns away completely, how much is simply melted, and the geometry of the melted and burned wax. The geometry of the melt pattern created by the melting wax is determined by pouring out the amount melted and observing the resulting cavity.

\*Clymer, N. R. E., R. D. Chelf, and D. B. Marsh. Department of Physical Science, Missouri Southern State University-Joplin. **Thermodynamics And Fluid Flow Of The Ranque – Hilsh Vortex Tube.** The Ranque – Hilsch vortex tube, also known as “Maxwell’s Demon”, is a device, which separates a pressurized air stream into two streams of different temperature. It receives tangential input from a pressurized air source. This air is sent in a spiral down the vortex tube where a portion escapes through a valve and forms the hot air stream. The volume that does not escape creates a secondary spiral within the first. This secondary vortex has the same rotational velocity but its longitudinal direction is opposite to the first. When air escapes from the secondary vortex it forms the cold air stream. Experiments are conducted where we vary the lengths and diameters of the vortex tube, exhaust valve types, input orifices, and input pressures. Temperature differentials of over 70 degrees Fahrenheit have been obtained from an input of 65 degrees Fahrenheit at 135 PSI. Although filtered factory compressed air is the ideal input, we used air from a standard compressor. Ramifications of this will be discussed as our data is compared to similar experiments. Data gathered in these experiments will be discussed. Theories of energy transfer within the device will also be discussed.

\*Hunt, C., \*Hoffman, M., Department of Physics and Chemistry, Northwest Missouri State University. **Musical Acoustics Of Guitar Strings** This research focused on the differences between different manufacturer’s guitar strings. The frequency spectrum was measured as well as the time for the amplitude of the string to decay. The Pasco sonometer was used in place of a guitar so that the observed spectrum was due to the string and not vibrations in the guitar body. A guitar pick was attached to the pendulum of a ballistic pendulum and swung across the guitar string to pick it. Picking the string in this way gave a fairly reproducible frequency spectrum. In previous experiments an apparatus was constructed upon which the guitar strings could be mounted between the poles of a powerful magnet. By pulsing a current through the string it could be excited so as to generate reproducible frequency spectra. However, this did not produce much amplitude. A computer interfaced microphone was used to measure the decay of sound from the vibrating string. Comparisons were made between different manufacturer’s guitar strings. They were also compared with the sound they produced on a guitar to examine the effects of the guitar body on the frequency spectrum. It was found that the guitar body produces the majority of the higher order harmonics. Substantial differences were seen between the different strings in both their frequency spectrum and decay times.

\* Mallory, M. J., R. D. Chelf, and D. B. Marsh. Department of Physical Science, Missouri Southern State University-Joplin. **The Lift Of A Joukowski Airfoil.** We look at the lift produced by a special kind of airfoil generated by a conformal transformation developed by Russian mathematician Joukowski. This was done in the regime of low Reynolds numbers appropriate to small-scale aircraft. The low Mach numbers involved allows us to safely assume an incompressible airflow and we also assume the flow is inviscid and irrotational. Our approach is two fold. Theoretically, using Joukowski’s transformation, which generates an airfoil in one complex plane from a circle in another complex plane, we converted the flow field around a cylinder with rotation into the flow field around our desired airfoil. From this flow field, we derive the velocities and pressures around the airfoil, which in turn allow us to compute the lift it generates. Then we look at the lift coefficients

determined from measurements of model Joukowsky airfoils in a wind tunnel and compared them to theoretical values. Our results will be presented.

\*Roelfsema, J. A., R. D. Chelf, and D. B. Marsh. Department of Physical Science, Missouri Southern State University-Joplin. **The Effect Of Guitar Bodies On The Acoustics Of Guitar Strings.** In this study, we look at the acoustical change of the guitar body on guitar strings in amplitude (volume), harmonics, and overall sound quality. The study was conducted to see the overall improvement that the guitar gives to the sound of a vibrating string. Experiments are carried out on the same type of string under different settings with data recorded with an oscilloscope. An electric guitar is used for the unamplified string to see the quality of sound without the (acoustic) guitar body. Readings are taken on both the unamplified string and amplified string of the guitar. The data is recorded and interpreted utilizing functions available on a digital storage oscilloscope. With analysis, data shows an increase in amplitude for nearly all tones and overtones. This increase in amplitude of the harmonics gave the sounds an increased quality over all ranges. By increasing the sound quality, the guitar body does more than simply making the vibrating string audible; it greatly increases the listener's pleasure.

## *Agriculture*

### *Senior Section*

#### **Michael T. Aide & Mack Wilson**

*Southeast Missouri State University*

\*Bowling, D. and F. Kidwaro. Department of Agriculture, Central Missouri State University. **Nitrogen Management For Eastern Gamagrass Production In Mid-Missouri.** Eastern gamagrass (*Tripsacum dactyloides*) is a warm season grass that is very palatable to livestock. Gamagrass performs well under dry conditions in the southeastern USA where precipitation exceeds 35 inches. This characteristic makes gamagrass a potential forage for Missouri farmers. The purpose of this study was to investigate the performance of Eastern gamagrass in Mid-Missouri and to ascertain the optimum nitrogen (N) rate for maximum yields. Sixteen 50 ft by 100 ft plots were established on a Macksburg silt loam in Warrensburg. Treatments of 0, 50, 100, and 150 lbs

of N per acre were applied in the spring of 2003. The plots and treatments were replicated four times in a randomized complete block design. Our results show a 15 inch difference in height with N treatment. The highest yields were 9.5 tons/acre in plots receiving 150 lbs of N. The lowest yields were 3.9 tons/acre in plots without N. Yields from plots that received 100 and 150 lbs of N/acre were not significantly different. However, yields from the 50 lbs plots and 100 lbs/acre plots were significantly different. Similar yields were recorded in plots that received 0 and 50 lbs of N/acre. Since Eastern gamagrass is a heavy N feeder, application of N above 100 lbs/acre will result in optimum yields.

\*Burkhalter, A.R., F. Worman. Department of Agriculture, Central Missouri State University. **The Difference In Birth Weight Of The Hereford Breed In Different Climatic Regions.** Research was conducted to determine whether the climate where a calf is carried and then born has an effect on how much the calf will weigh at birth and how well the expected progeny differences (EPD) match that weight. There is a need to understand the effect that climate will have on birth weight. The assumption is that the colder the climate, the heavier the calf will be at birth, and that the warmer the climate, the lighter the calf will be at birth. Bulls were selected: one from Canada, one from Nebraska, and one from Texas. Data were collected for the progeny of these bulls. The data included actual birth weight, location where the calf was born, and the sire of the calf. The American Hereford Association was contacted, and information on birth weight, location of birth, and the bull that sired the calf was obtained. Results showed that calves that were born in the colder climate of Canada weighed significantly more than those born in the United States. The results showed that the progeny of the Canadian bull that were born in the United States weighed more than the progeny of the Nebraska bull that were also born in the United States. The results did show that there was a significant difference in birth weight of the calves that were selected. The study also indicated that weather does play

\*Geyer, W.A., G.G. Naughton, and D.L. Chambers. Forestry Division, Kansas State University. **Sugar From Black Walnut Trees.** Native Americans enriched their diet with the sugary products from the native maples in eastern United States. Today, syrup

is made from the sap of sugar maple (*Acer saccharum* Marsh.); however, most other maples can also be used. Our objective was to determine if sap collected from pole-sized black walnut trees could be boiled down to make syrup.

Twenty black walnut (*Juglans nigra* L.) trees were tapped beginning in middle February 2003 and the sap was collected for five weeks. Trees were about 23 years old and 25 to 30 cm in DBH. Trees were tapped about 1 m above the ground on the east side. Holes were drilled deep enough to fully penetrate the sapwood. Plastic 3.8-liter milk jugs were used as the primary collectors. We coordinated the collection with cold nights and warm days. A standard brewer's hydrometer (Balling scale) was used to estimate the sugar content in percentage by weight. The sap was mixed together for refrigerated storage until processing. A small electric hotplate and a 2-liter cast-iron saucepan were used to concentrate the sap.

The sap quantity varied by individual trees and days. All trees produced sap, but with great variation. Although most trees produced less than 2.0 L, the highest producer had 13.21 L and 0.43 L for the lowest tree. The sugar content was 1.8 percent with a 1:60 sugar:sap ratio. Sap production was highly correlated with the thickness of the sapwood.

The Sensory Center at Kansas State University evaluated the syrup using over 100 consumers tasted- tested our product on pancakes. Comparisons were made to Log Cabin syrup, pure maple syrup, and our black walnut product. The Log Cabin product was preferred over the walnut syrup because it was sweeter and had a greater aftertaste. The walnut syrup was diluted to 85 and 50 percent with little change in appearance. Additional tests with five highly trained tasters indicated that the 50 percent dilution was more desirable having lower color intensity and no woody, nutty or musty/earthy flavor.

\*Gichunge, C. and F. Kidwaro. Department of Agriculture, Central Missouri State University. **Effect Of Defoliation On Yield And Nutrient Content Of Amaranth Grain And Leaf.** Developing nations that face population explosion must explore alternative crops such as amaranth (*Amaranthus hypochondriacus*) to feed their increasing population. The objective of this study was to investigate the effect of defoliation on amaranth grain yield and leaf nutrient content and ascertain its potential as a dual purpose crop. A greenhouse study was established at CMSU in the

spring of 2003. Amaranth was planted in pots and thinned down to ten plants per pot. Four treatments (the number of leaves defoliated every week 0, 10, 15, and 20) were randomly assigned to pots and replicated four times in a randomized complete block design. Results show that there was no significant difference in grain yield with defoliation. Even though the grain yields were low from pots where 20 leaves were defoliated every week when compared with the ones that were not defoliated, this difference was not significant. This means that Amaranth is a crop that can be used for dual purpose (grain and vegetable) in developing nations to feed the increasing population.

\*Kidwaro, F.M. and K. Kephart. Department of Agriculture, Central Missouri State University. **Winter Wheat Response To Fall Application Of Stabilized Nitrogen Fertilizer In Missouri.** A three year study was conducted at Columbia, Novelty, and Portageville to evaluate fall application of stabilized nitrogen for soft red winter wheat production in Missouri. Anhydrous ammonia with and without nitrapyrin (2-chloro-6-(trichloromethyl) pyridine) added was injected into the soil in the fall at rates varying from 0 to 112 kg N/ha in 28 kg N/ha increments. Urea was applied in the spring to augment fall application for a total of 112 kg N/ha per plot. Yields ranged from 752.7 kg/ha to 5,852.2 kg/ha. The lowest yields were observed in unfertilized plots at all three locations. Addition of N fertilizer almost doubled yields at all locations when compared with the unfertilized wheat. There was no significant difference in wheat yield due to the addition of nitrapyrin at any location. Application of N improved the number of heads m<sup>-2</sup>, but did not influence thousand kernel weights (TKW). Nitrogen use efficiency (NUE) increased as the level of N applied in the spring increased. The highest NUE was observed by applying 50% of the total N preplant in the fall and 50% at Feekes growth stage 3 in the spring. High NUE also resulted from application of 25% of the N in the fall and 75% spring, and from application of all N in the spring. Use of nitrapyrin did not influence grain yield for soft red winter wheat production in Missouri.

\*Lamai, A. and F. Kidwaro. Department of Agriculture, Central Missouri State University. **Performance Of Legend Lespedeza In Mid-Missouri.** Lespedeza (*Kummrowia striata*) is a unique annual legume grown for pasture, hay and

soil improvement due to its qualities as a drought resistant, acid tolerant, non-bloating when fed to livestock, tolerance to low fertility and as a warm season plant. Several varieties of lespedeza have been introduced to mid-Missouri over the years. Legend is the latest variety to be introduced. A study was initiated at Central Missouri State University farm on a Macksburg silt loam. The objective was to evaluate performance of Legend over other common varieties in mid-Missouri and to identify phenotypic characteristics of existing legend variety for potential development of a new variety- Legend II. Five varieties (Legend, Marion, Korean, Kobe, and Summit) were randomly selected and assigned to five plots. The plots were replicated four times in a randomized complete block design. Legend yields were significantly (0.05 level) higher during the 2002-2003 growing season when compared with other varieties. Both seeding and re-seeding studies show that Legend lespedeza was the top yielder, out-yielding other varieties such as Marion by over 30%.

\*Schafer, T.C. and, J.H. Heinrichs, Department of Geosciences, Fort Hays State University. **Impact Of Teleconnections On Kansas Regional Winter Wheat Yields, 1900 – 2000.** Winter Wheat is one of the most important grain crops in the state of Kansas, both in terms of dollar value and in acres planted. Very little of this wheat is irrigated, which makes this crop very sensitive to climate variations, especially with regard to temperature and precipitation. Previous research has indicated that climate variability in Kansas is significantly influenced by oscillations elsewhere. In this study, winter wheat yield data for nine agricultural reporting districts were aggregated, detrended, and compared to time-series characterizing major teleconnections, including El Nino – Southern Oscillation (ENSO), North Atlantic Oscillation (NAO) and the Pacific- North American Oscillation (PNAO). Comparisons were done using linear regression techniques with leads and lags, as well as periodicity and autocorrelation analysis.

## *Atmospheric Sciences*

### *Senior Section*

**Patrick S. Market**

*University of Missouri — Columbia*

\*Adegoke, J. and K.P. Gallo. Department of Geosciences, University of Missouri-Kansas City. **A Multi-Sensor Approach To Estimating Global Urban Heat Island Signature.** Major urban centers and their metropolitan areas affect the local and regional climate by altering the surface heat, moisture, momentum and gas exchanges between the land surface and the lowest 1-2 km of the atmosphere. With the changes in the character of natural landscape that result from the city-building process, a greater proportion of incoming solar energy is absorbed into paved surfaces and rooftops. Here we present a method for estimating UHI effects on a global temperature data set and provide guidance on urban heat-island influence temperature adjustments for stations included in global climatological data networks. The method is based on satellite-derived normalized difference vegetation index (NDVI) sampled during the warm season months over urban and rural regions composed of a variety of land surface environments.

We use the following globally available, satellite derived, data sets: a global 1-km AVHRR-derived NDVI 10-day composite data, a global DMSP-OLS city lights data, and the IGBP global 1-km land cover data set.

The mean estimated temperature difference between Northern Hemisphere stations identified as urban based on local and regional differences in observed NDVI, and their surrounding rural environment, ranged from 0.69 °C for September of 1992 to 0.98 °C for August of 1993. Over the warm-season months examined the mean estimated temperature differences were 0.90 °C (stations identified as urban) and 0.19 °C (stations classified as rural). The maximum estimated temperature difference between an urban station and its surrounding environment ranged from 2.03 °C (October 1992) to 3.2 °C (August 1993). These differences were statistically significant ( $p = .01$ ) for those stations identified as urban, for each month examined. Significant differences were also observed for those stations identified as rural, based on the NDVI

thresholds, for each of the months examined. The local samples associated with the rural stations were found to have significantly greater temperature values than the regional samples. Exceptions were observed, most notably in desert environments where the local samples occasionally displayed greater NDVI values than the surrounding environments. Differences in local and regional NDVI were also significant for all months for both the urban and rural sets of stations. The observed differences in NDVI and estimated temperature between local and regional samples of stations classified as urban were anticipated. The uniqueness of this study is the demonstrated value of satellite-derived datasets for estimating the UHI influence on a global basis. On going work includes an assessment of the impact of these results on the current data sets used to estimate regional and global temperatures.

Akyüz, F. A.<sup>1</sup>, \*Lack, S. A.<sup>1</sup>, Mike Palecki<sup>2</sup>. Atmospheric Science Program, University of Missouri-Columbia<sup>1</sup>, Midwestern Regional Climate Center<sup>2</sup>. **Variation Of Peak Wind Speed With Averaging Time.** The U.S. Weather Bureau and the successor National Weather Service have reported peak wind speeds with a variety of averaging periods. Prior to 1964, the Local Climatological Data (LCD) publication reported the peak wind speeds averaged over 1 hour. From 1965 to August 1989 the publication adopted the fastest-mile wind definition, which is the time it takes for 1 mile of wind to pass through the anemometer. This can be thought of as effectively a peak wind averaged over a variable range of period lengths, depending on how long it took for the mile of wind to pass the instrument. Starting in September 1989 and continuing through 1994, LCDs reported the fastest-minute wind, which is averaged over a 1-minute period. Finally, from the advent of ASOS in 1995 to the present, the peak wind speed has been reported in terms of both 5-second and 2-minute winds. If one is interested in comparing peak winds or processing a peak-wind-climatology for a period spanning current to pre-1964 data, a standard averaging period must be developed to facilitate these activities. This paper addresses a joint project between Midwestern Regional Climate Center, National Climatic Data Center and Missouri Climate Center to make operational a simple algorithm that converts peak wind speeds observed using one averaging period to an averaging period chosen by the user. A Web

interface will receive the input peak wind speed and known averaging period and request the desired output wind-speed averaging period. The algorithm will make the conversion based on a study by Durst (1960), who developed a statistical relationship between 1-hour peak wind and the wind speed of various averaging periods. The algorithm will also convert the fastest mile wind to other averaging periods.

\*Alabi, O. Department of Geosciences, University of Missouri-Kansas City. **Validation Of Trmm Satellite Data Over Nigeria.** This study investigated rain bearing convective systems over Nigeria, a region in the tropics bounded by latitudes 4°N – 14°N and Longitudes 3°E – 14°E, using conventional and satellite derived precipitation data. The period of study was 1998, with special emphasis on the month of July when Nigeria normally falls within the most convectively active zones in the West African region. Tropical Rainfall Measuring Mission (TRMM) satellite derived rainfall over Nigeria was compared with rain gauge measurements obtained at 31 meteorological stations located within the country. The agreement between the two sets of data varied between 31% and 97%. The disparity in rainfall amounts, which was greatest for the months of June to September, especially at the inland stations, was attributed to the inability of the TRMM satellite to capture the super cells in the numerous cloud clusters that were prevalent over the region during these months of the year. These super cells, clearly identifiable on METEOSAT visible imagery, were found to be almost stationary and randomly distributed within the cluster. They were not uniformly arranged as in the case of fast moving squall lines. Such systems, which were short lived, produced very heavy precipitation. The TRMM satellite, due to its low frequency of observation did not detect these.

\*Guinan, P.E., W.L. Decker, and A.R. Lupo. Department of Soil, Environmental, and Atmospheric Science, University of Missouri-Columbia. **Using Seasonal And Weekly Precipitation Patterns To Predict The Probability Of Summer Drought And The Effects On Crop Yields Over Northwestern Missouri.** This study is an examination of weekly precipitation records and annual crop yield data for USDA crop reporting district one (CRD 1) in northwestern Missouri. Weekly precipitation data were collected for the period 1919-2002, and crop yield

data for corn and soybeans were gathered between 1920-2002 and 1944-2002, respectively. Regression analyses using 1990's crop technology were applied to the corn and soybean yield data in order to eliminate yield bias due to the introduction of fertilizer and improved hybrids. Antecedent precipitation periods for autumn, spring, and summer were analyzed each year and compared to the corn and soybean yields of that year. Contingency tables were constructed comparing precipitation periods to yields and divided into 5 categories. Probability statements predicting the likelihood of summer agricultural drought and yield potential were developed.

\*Kunz, A. R., and A. R. Lupo. Department of Soil, Environmental, and Atmospheric Sciences, University of Missouri – Columbia. **The Role Of The Planetary-Scale Flow Regime In The May 2003 Tornado Outbreaks: How Unusual Was The Situation?** During the last few years, two studies have explored the role of the planetary-scale in contributing to devastating synoptic and mesoscale events. These studies have shown that the planetary-scale can play a critical role in providing a favorable background for the occurrence of the smaller-scale events. This study examined the role of the planetary-scale in providing a favorable background for the May 2003 tornado outbreaks. We demonstrate that simultaneous blocking events in the Eastern Pacific and Western Atlantic regions maintained an active jet stream and stationary front across the southern portion of the North American continent. This front was the boundary between a large-scale region of cold air to the north and warm humid air to the south. This scenario was maintained by the two blocking events, and provided a favorable background for the occurrence of at least three rapidly successive severe weather outbreaks during the first ten days of May 2003. These blocking events then decayed as the planetary-scale background flow regime transitioned from one balanced state to another. After the breakdown of the planetary-scale flow pattern, the background was no longer favorable for the continued occurrence of severe weather. Additionally, it was found that simultaneously occurring blocking events such as these are not uncommon occurrences in the Northern Hemisphere flow pattern. Thus, it is reasonable to assume that severe weather outbreaks such as the May 2003 event are not unprecedented even if such an event has not been documented during the last 50 years.

Podzimek, J. Cloud and Aerosol Sciences Laboratory, University of Missouri-Rolls. **Contribution To The Microphysical And Meteorological Explanation Of Measured Dimensional Parameters Of Columnar Snow Crystals.** The concentrations and shapes of snow crystals in the ground air layer are important for the description of the precipitation and for the investigation of radiative transfer processes and visibility. In this paper are summarized the main results of columnar crystal concentration measurements during several years at Groveland, IL, and determined the prevailing crystal size distributions. Microscopical evaluation of 738 columnar crystals included their main dimensions (lengths and widths) and the detailed description of their shapes. The main conclusion of this investigation was that the simple exponential relationship between the two main axes holds approximately for most of the evaluated crystals. However, e.g. for short columns, collected at ground air temperatures below  $-16^{\circ}\text{C}$ , the observed axes ratios ( $c/a$ ) were in mean 37% larger than those calculated according to the parameters published by other investigators. The remarkable temperature dependence of snow crystal habits (primary crystal growth) and the modification of the crystal shapes by the water vapor distribution in the immediate vicinity of the surfaces of falling columnar crystals (secondary crystal growth) is discussed in more detail.

Podzimek, J. Cloud and Aerosol Sciences Laboratory, University of Missouri-Rolls. **Composition And Dimensional Parameters Of The Main Snowflake Types.** The main types and size distributions of snowflakes collected at the ground in the Midwestern USA during the years 1998-2002 were described by Podzimek and Market (2004). This contribution brings into focus more detailed analysis of the composition of snowflakes in the first five groups of the suggested seven classes of snow element aggregates. Included are needles, sheaths, small columnar and planar crystals, medium size stellar and planar crystals and large dendritic crystals. Mean percentages of different snow crystals in each group are mentioned, because usually each snowflake represents a mixture of different snow crystals with one dominant crystal type. During several snowfalls in December 2003 were evaluated the maximal size

and approximate width of each snowflake replica for determining its asymmetry. The snowflake asymmetries are changing considerably during a snowfall and are strongly affected by the interaction of snow crystals from different levels in a cloud system and by meteorological conditions in the ground air layer. It is shown how the presence of large dendritic and stellar crystals, of needles and of deposited minigraupels modifies strongly the snowflake asymmetry.

\*Silberberg, S.R. NOAA/NWS/NCEP/Aviation Weather Center. **Accuracy Of Global Model Thunderstorm Forecasts.** Global model thunderstorm forecasts are used as guidance by aviation forecasters to prepare worldwide 24 h forecasts of thunderstorm height and location. The accuracy of global model thunderstorm forecasts affects the forecast process and the accuracy of issued aviation thunderstorm forecasts. These forecasts are used by world airlines for route planning and fuel load management on all international routes. Global model thunderstorm 24 h forecasts are verified four times a day by global composite satellite imagery, which has been processed to show active thunderstorms. Model forecasts are 70% accurate over the tropical Atlantic, Pacific, and Indian Oceans and 30% accurate over the continents such as Australia, South America, and Africa. Based on these results, the Aviation Weather Center is revising procedures for forecasting convection over Australia, South America, and Africa and the global oceans. In addition, poor model thunderstorm forecasts reduce the accuracy of model forecasts of jet streams and storm systems, which in turn, reduce the accuracy of short-range and long-range public forecasts.

\*Tilly, D.E., A.R. Lupo, and C.J. Melick. Department of Soil, Environmental, and Atmospheric Science, University of Missouri-Columbia. **Calculated Vertical Motions In A Southern Hemisphere Blocking And Cyclone Event.** In this study, several methods were used to calculate vertical motions in a Southern Hemisphere blocking and cyclone event, which occurred during a 48 hour period beginning with 1200 UTC 28 July 1986. The results were then compared to the vertical motions provided with the National Centers for Environmental Prediction (NCEP) re-analyses. The vertical motions were calculated using the kinematic

method and the Omega Equation. In order to use the kinematic method, several numerical methods for the integration were tested, including the trapezoidal method and Simpson's Rule. Second and fourth-order finite differencing were used to calculate horizontal divergence. These results demonstrated that the vertical motions were similar for the two finite differencing methods, and that the Simpson's Rule integrations produced the most robust vertical motions. Several forms of the Omega Equation were used including the use of Q-vectors, and the Q-G, Extended (diabatic processes included), and Full versions of the Omega Equations. Each of these forms used fourth order finite differencing to calculate derivative quantities, and to invert the laplacian quantity on the left-hand-side of the equation. The Q-vector form produced the smoothest pattern which was similar to the NCEP and Kinematic Omegas. The Full Omega equation produced the most robust vertical motions, however, the results using the Full and Extended Omega Equations were similar. These results demonstrate that most methodologies were adequate for estimating vertical motions for use as a diagnostic in SH synoptic events.

\*Zuki, Z.M., and A.R. Lupo. Department of Soil, Environmental, and Atmospheric Science, University of Missouri-Columbia. **Interannual Variability Of Tropical Cyclone In The Southern South China Sea.** A study of the variability of tropical cyclones (TC) activity in the southern South China Sea (south of 10 degrees North), which is part of the West North Pacific basin, was carried out during a 44 year period (1960 – 2003). Fewer studies have done in this region compared to the West North Pacific and South China Sea itself. The initial results of this study shows that only 3.3 percent of the total of TC (tropical depression, tropical storm and typhoon) activity in the West North Pacific basin occurred in this area during the period of study. The trend of the TC activities in this region over the past years and correlation with the large scale phenomena like El-Nino-Southern Oscillation (ENSO) and Pacific Decadal Oscillation (PDO) will be studied. Further results showed that there were fewer TC activities in this region during El-Nino year compare to the La-Nina and neutral year. These results also show that roughly half of the TC activities in this area were of local origin. Analysis of a time series for monthly mean Sea Level Pressure (SLP), Sea Surface Temperature (SST) and steering

wind over this area also will be examined in order to find any correlation with the variability of TC activity in this region.

## **Biology**

### **Senior Section**

**Rex M. Strange**

*Southeast Missouri State University*

\*Bernard, S.M. Department of Biology, Pittsburg State University. **Induced Spawning Of Black Crappie (*Pomoxis nigromaculatus*) In A Recirculation System.** Production of black crappie (*Pomoxis nigromaculatus*) as a marketable food source requires the development of a methodology to stimulate and control reproduction. Crappie have been successfully reared in ponds and natural environments; however, the least success has been with artificial environments. Work conducted with crappie in recirculation systems is very limited, and almost nonexistent in determining if these fish can spawn in artificial settings. This project will evaluate the techniques used on other fish species to stimulate artificial and aseasonal reproduction in black crappie. The objectives of this project are to: 1) determine if crappie can be stimulated into their reproduction cycle in an artificial environment, and 2) determine if crappie can reproduce aseasonally. Ten specimens were randomly selected from a brood stock accustomed to a recirculation system. After gender was determined, mating pairs were placed in separate tanks in a recirculation system where temperature and photoperiods were adjusted to mimic those occurring naturally. Four mating pairs were injected with 1000 international units of human chorionic gonadotropin. Three days after injection the crappie began to release eggs and milt. The eggs were fertilized, but did not develop offspring due to a fungal infection, which is the current area of work.

\*Claxton, J.L., and A.R. Oller, Ph.D. Department of Biology and Earth Science, Central Missouri State University. **Isolation Of Oral Microbes By Selective And Differential Media.** The oral cavity is home to thousands of different microbial species. Pathogenic bacteria can lead to oral or systemic diseases such as atherosclerosis. Oral flora populations are known to change with age of human

subject, due to hormonal changes and antibiotic usage. This study surveyed teeth extracted from people of known age and sex, with the intent of determining antibiotic resistance over age categories (18-39, 40-59, and 60+). The methodology utilized was to identify gram negative (Enterobacteriaceae) and gram positive (*Streptococci*) bacteria by culturing microbes on brain heart infusion broth (BHI) and BHI containing blood components as initial media. Sabaroud-dextrose (SAB) broth and BHI supplemented with penicillin and streptomycin were used as initial culturing media for yeasts. Initial classification used gram stains, wet mounts, and flagella stains, with further analysis performed on MacConkey, Mannitol Salt, BHI with blood, Peptone Yeast Agar with sorbitol, SAB with penicillin and streptomycin, and Ueda plates. Two plates were made for each tooth (three in each age group at this time), with one plate incubated aerobically and one incubated anaerobically. All isolated organisms were grown in broth culture and cryopreserved for future use, including antibiotic susceptibility testing. Biooxidation tests were used to further identify microbes. This project will lead to the identification of bacteria via molecular techniques for determination of new species. The research was funded by a grant from Central Missouri State University.

\*Dyger, J.R., T.W. Valliant, D.J. Dibben and H.M. Krempa. Department of Biology, Benedictine College. **Annual Biodiversity Patterns Of Aerial Invertebrates On The Benedictine Bottoms Mitigation Site.** Benedictine College Biology Department is monitoring the biodiversity of the Benedictine Bottoms Mitigation Site, including invertebrates inhabiting the area. Aerial invertebrate sampling was conducted from May 1995 to October 2003 along permanently established transects. Sampling included aerial, aquatic, and terrestrial invertebrates. Sticky traps were used for aerial collection, set up 1-1.3 meters above the ground with 96 cm<sup>2</sup> covered with the adhesive Tanglefoot, and left for two days. Since 1995, over 62 thousand aerial invertebrates have been collected, enumerated, and identified to order. In 2000, biomass was incorporated into the aerial collection, of which the size was determined for a sub-sample of the invertebrates trapped. The five most commonly occurring orders are: Diptera, Coleoptera, Thysanoptera, Hymenoptera, and Homoptera. The data analyzed up to this point,

using ANOVA have shown that the year, month, and habitat are significant factors in determining the abundance of invertebrates. The aerial invertebrate abundance from 1995 to 1998 has shown an overall downward trend, with a small increase in 1999. The highest abundance occurs in May and June with a decline in abundance leading up to the first frost in late October.

\*Jones, D.M., and L. Sievert, Department of Biological Science, Emporia State University. **Temperature And Digestive Rate Of Cornsnakes, *Elapheguttata*.** Temperature is a factor in controlling the digestive rate of reptiles. We compared the transit rates of juvenile cornsnakes, *Elaphe guttata*, at 22 C and 32 C. Snakes were acclimated to the test temperature for at least three days prior to the experiments. Before the experiment they were fed every other day. Thirteen snakes were fed three uniquely marked meals and the time from ingestion to defecation was recorded. The average mass for the snakes was 53.37 g ( $\pm 0.8889$  SD), and the meal was approximately 5% of the snake's mass. Transit rates were significantly faster at 32 C than at 22 C ( $P = 0.005319$ ). We used randomized unpaired testing between these two temperatures, at 22 C (5.65 d) 32 C (3.28 d), only using values from snakes which consumed 2 or 3 meals. During our study some of the snakes underwent ecdysis. Transit rate was significantly slower in snakes undergoing ecdysis ( $P = 0.01701$ ). We again used randomized unpaired testing finding the average of non-shed snakes (5.13 d) and shed (8.82 d), ignoring temperature. We observed that snakes retained feces until they shed.

\*Keane, K.J. and A.R. Oller, Ph.D. Department of Biology and Earth Science, Central Missouri State University. **Visualizing Human Phenotypic Characteristics Via Molecular Techniques For Forensic Science Applications.** Identification of a perpetrator or victim can be difficult to determine when only residual evidence is present. The DNA sample quantity is often too small to run analytical tests, resulting in a large database of DNA profiles without a direction to pursue. While there are currently published PCR protocols for each trait under investigation, this study developed a single PCR reaction to limit the amount of DNA required for thorough genomic analysis. The University Human Subjects Committee approved teeth collection from a

local dentist. Age, sex, and other characteristics of the person were provided. Dental pulp DNA was isolated and purified using standard protocols. Blood residue on the teeth was also collected and saved for DNA isolation and comparison to the tooth DNA results. Primers were synthesized for the AMEL gene for sex determination and ABO blood typing genes. Results were visualized and analyzed by electrophoresis on 2% agarose gels. Gels were photographed using a documentation camera. Selected DNA sequences will be excised from the gel and sent for sequencing to confirm correct primer binding. Other sequences such as telomere length for age determination will be included in this study. This PCR technique will allow law enforcement officials to use key identifying characteristics to narrow their search for a perpetrator or victim. This project was funded by a Willard North Award and CMSU.

\*Stokes, K.M., L.A. Hilger, D.E. Bowen, M.P. Simon, and J.W. Davis, Department of Biology, Benedictine College. **Plant Species On The Benedictine Bottoms Fish And Wildlife Mitigation Site.** In 1993, the U.S. Army Corps of Engineers purchased 855 hectares of land located 1.5 kilometers northeast of Atchison, KANSAS in the southern section of the Rushville Bend. The area is now known as the Benedictine Bottoms Fish and Wildlife Mitigation Site (Bottoms). Since 1994, the U.S. Army Corps of Engineers has planted 176,100 tree and shrub seedlings on 550 acres. They have also planted 750 acres with native grass species and legumes. In 1994, the Biology Department of Benedictine College initiated the Benedictine Bottoms Missouri River Biodiversity Assessment Program on the Bottoms. The transition of the Benedictine Bottoms from agricultural land back to its native floodplain habitat provides an opportunity for a long-term biodiversity survey of the Bottoms in order to monitor the success of the Corps' program. The plant biodiversity assessment project began in 1995. All vascular plant species were collected and voucher specimens were made. They are preserved in the Benedictine College Herbarium. These specimens were identified using the Flora of the Great Plains, and updated using the plants.usda.gov website. As new species are collected, they are added to the computer database. This total plant list is continually growing, and currently 263 species, 162 genera, and 61 families have been found on the Bottoms. The process of collecting all plant species is

repeated every five years. The first five-year collection was taken from 1995 to 2000. Currently, we are in the second five-year collection from 2001 to 2005. These five-year groups are compared to determine plant succession and changes in plant biodiversity on the Bottoms.

\*Valliant, T.W., J.R. Dygert, D.J. Dibben, and H.M. Krempa. Biology Department, Benedictine College. **Annual Biodiversity Patterns Of Terrestrial Invertebrates On The Benedictine Mitigation Site.** In 1993 the U.S. Army Corps of Engineers initiated a mitigation project to restore 855 hectares of farmland back to its original Lower Missouri River floodplain habitat. Benedictine College Biology Department is monitoring the biodiversity of the Benedictine Bottoms Mitigation Site. Invertebrate sampling on the Bottoms was initiated in May 1995, along randomly chosen 200-400 m transects. Sticky traps were used to monitor the aerial invertebrate population. Pitfall traps were introduced in 1998 to monitor the terrestrial invertebrate population. These 179 cm<sup>2</sup> pitfall traps were set in the ground and filled with 2.5 cm of preservative to collect terrestrial invertebrates. Specimens were preserved in 75% ethyl alcohol until identification. Since 1998, nearly 10,000 invertebrates have been collected, measured and identified to 21 different orders using this method. The two most common orders are Coleoptera and Orthoptera. These data have been used to determine which factors such as site, year, month, rainfall, temperature, technique, and habitat are important determinants of patterns biodiversity of biomass trends. For example, the amount of monthly rainfall has shown a significant impact on the abundance of these orders.

## *Biomedicine & Biotechnology*

### *Senior Section*

**Colette M. Witkowski**

*Southwest Missouri State University*

\*Corrigan, G. E. MS MD PhD. The Corrigan Laboratory. **The Cytogenetics Of The Benign Lipoma.** Previous studies demonstrated the clinical appearance and pathology of the benign lipoma. A complete literature review of lipoma cytogenetics covering the past half-century is fulfilled. Three eras

are identified as 1. the Classic Cytogenetic era of Giemsa stained whole cell karyotyping, 2. the era of Molecular Cytogenetics with the use of fluorescent probes as FISH, SKY, and CGH techniques, which overlaps with 3. a concurrent period of Molecular Genetics identified with PCR, RT-PCR, DNA fingerprinting, micro array analysis, flow cytometry, and Northern and Southern Blotting. Works on the lipoma in each era are presented and identify the major cytogenetic qualities of the benign lipoma : cytogenetic heterogeneity with over twenty identified karyotypes; nonconcordance with gross morphology in size, shape, depth, location or sex; broad patterns of congruence with histopathological classifications, and limited utility in behavioral predictability. Frequencies of karyotypic change include an overall incidence of 78% alteration with 25% of all known bands recorded as involved. Gene probes have demonstrated that a major change is the deletion of genetic material in the 12q13-15 region and that breakpoints cluster about the band 13q14. Mitochondrial DNA mutations are recorded in some typical but multiple lipomas.

\*Glauser, H.M. and R.C. Garrad. Biomedical Sciences Department, Southwest Missouri State University. **The Effect Of C-Terminal Tail Mutations On Desensitization Of The P2Y<sub>2</sub> Nucleotide Receptor.** Cystic Fibrosis (CF) is the most prevalent genetic disorder in Caucasians. CF is caused by mutations in the Cystic Fibrosis Transmembrane Conductance Regulator gene encoding the protein that regulates the secretion of chloride ions across the pulmonary epithelium. Present in pulmonary epithelium are P2Y<sub>2</sub> nucleotide receptors of the G protein-coupled receptor (GPCR) family. Activation of the receptor by the agonist (ATP or UTP) leads to an increase in the concentration of intracellular calcium, thereby mediating the opening of calcium-dependent chloride channels and serving as an alternate pathway for chloride secretion. On repeated exposure to the P2Y<sub>2</sub> agonist, the receptor becomes desensitized and is unable to continue to elicit its original response within the cell. The focus of this study is to investigate the effects of mutations of potential phosphorylation sites in the C-terminal tail of the P2Y<sub>2</sub> receptor on desensitization. A better understanding of the process of desensitization could contribute to improved treatments for CF patients. Mutant P2Y<sub>2</sub> receptors have been constructed and expressed in a cell line

normally devoid of the receptor, 1321N1 astrocytoma cells. Effects of these mutations on P2Y<sub>2</sub> receptor signaling and desensitization are currently being studied using calcium assays, SDS-PAGE, and Western blotting techniques.

\*Njau, J., S. Schul, D. Potter, B. Areheart, and L.C. Sudlow. Department of Biological Sciences, Emporia State University. **Igf-1 But Not Estrogen Reduces  $\beta$ -Amyloid Toxicity In Cell Cultures.** AB<sub>1-42</sub> is responsible for the toxicity of the  $\beta$ -amyloid neurofibril extracellular plaques of Alzheimer's Disease (Felician and Thomas, 1998, *Neuropsych* 11:19). 17- $\beta$ -Estradiol (Manly et al., 2000, *Neurology* 4:833) and IGF-1 (Dore et al., 1997, *PNAS* 94:4772) were chosen as ameliorative treatments for AB<sub>1-42</sub> because levels of both hormones are reduced in the geriatric population and both have been individually demonstrated to improve cell survival during exposure to AB<sub>1-42</sub>. We sought to determine if treating cells with combinations of more than one hormone would further improve cell survival in the face of AB<sub>1-42</sub> challenge. Survival of HT-22 hippocampal hybridoma culture cells was measured via the MTT colorimetric assay. Low levels of IGF-1 (<0.1  $\mu$ M) were sufficient to improve cell survival during AB<sub>1-42</sub> challenge compared to DMSO or AB<sub>40-1</sub> reversed-sequence exposure. In contrast, 17- $\beta$ -estradiol at higher doses (10  $\mu$ M) contributed to an overall reduction of cell survival during the AB<sub>1-42</sub> challenge. When both IGF-1 and 17- $\beta$ -estradiol were applied in combinatorial mixtures, only IGF-1 appeared to contribute to a hormone-dependent elevation of cell survival during AB<sub>1-42</sub> challenge while 17- $\beta$ -estradiol provided no protective effect at lower doses. In the HT-22 cultures, only IGF-1 improved HT-22 cell survival in the face of the AB<sub>1-42</sub> toxicity. It would appear that reduction of IGF-1 levels could serve as a pre-disposing factor towards susceptibility of the cells to the toxic effects of AB<sub>1-42</sub>.

\*Stone, D.K., C.M. Witkowski. Department of Biomedical Sciences, Southwest Missouri State University. **Production Of A Functional Collagen Type Iv::Gfp Fusion Protein In *Ceanorh̄abditis Elegans*.** Collagen type IV is one of the most abundant structural molecules in the basement membrane. We have previously studied collagen type IV in *C. elegans* using immunofluorescent staining techniques that involve fixation, which kills the animals, or indirectly

in live animals using reporter constructs of proteins that are in close proximity to the basement membrane. It is of interest to study the localization, structure, and dynamics of this macromolecule in living worms by directly tagging the collagen type IV molecule with a green fluorescent protein (GFP) reporter that allows the protein to be visualized *in vivo*. A reporter is being created by using a specialized PCR technique to fuse GFP to collagen type IV. The technique involves sequential PCR reactions, two of which use heterologous primers to create an overhang on the amplified portions of the *emb-9* gene, homologous to the *gfp* gene. During the final two PCR amplifications the overlapping sites produced in the previous reactions are fused producing a product containing the necessary sequence information for translation of a protein containing the functional properties of both collagen type IV and GFP. Sites selected for *gfp* insertion into *emb-9* include an asparagine linked glycosylation site near the 7S domain, a thirteen amino acid interruption in the Gly-X-Y region, and the Gly-X-Y/7S domain junction. The final PCR product will be microinjected along with *rol-6*, a dominant selectable marker, into the syncytial gonad of *C. elegans* heterozygous for a collagen type IV null mutation which causes embryonic lethality. Production of a functional fusion protein will be indicated by rescue of the homozygous recessive class with roller and GFP phenotypes.

\*Tucker, D.K and R.C Garrad. Department of Biomedical Sciences, Southwest Missouri State University. **The Effect Of Protein Kinase C Inhibition On P2Y<sub>2</sub> Receptor Desensitization.** Upon agonist (UTP) activation the G protein-coupled P2Y<sub>2</sub> receptor facilitates an increase in intracellular calcium that stimulates calcium-dependent chloride secretion in airway epithelia. The release of chloride anions via the P2Y<sub>2</sub> receptor is an alternate pathway that can bypass the defect present in Cystic Fibrosis. This alternative pathway is short lived due to receptor desensitization and internalization. It is known that the P2Y<sub>2</sub> signaling cascade activates protein kinase C (PKC), however whether PKC plays a specific role in agonist-induced P2Y<sub>2</sub> desensitization has yet to be determined. Direct activation of PKC by phorbol esters (PMA) or a PMA analog, phorbol 12, 13 dibutyrate, desensitizes the receptor. To investigate the role of PKC we monitored intracellular calcium levels in 1321N1 astrocytoma cells stably transfected with

murine P2Y<sub>2</sub> receptor cDNA using a dual excitation, single emission fluorometric measurement. The PKC inhibitor, GF109203X caused a concentration-dependent decrease in UTP-mediated desensitization, an effect not produced by the inhibitor RO 31-8220 or by rottlerin. Incubation with GF109203X may increase the number of receptors on the cell surface, allowing a greater response to the second challenge of UTP. Currently, we are investigating the effects of GF109203X and rottlerin on PMA- and phorbol 12, 13 dibutyrate-mediated desensitization.

\*Wijesinghe, R. W., Department of Physics, Pittsburg State University. **Comparison Of Electric And Magnetic Techniques For The Determination Of Conduction Velocity Distribution Of Nerve Bundles.** There are three main objectives for the research described in this paper. The first is to improve the existing method of predicting Conduction Velocity Distributions of nerve bundles from electrically measured Compound Action Potentials. We accomplished this by using a volume conduction model that includes the effect of an off-center in an isotropic nerve bundle surrounded by an epineurial sheath lying in a saline bath. Furthermore, we allow the transmembrane potential to vary with the temperature and the conduction velocity. The latencies at the stimulating electrodes of the fiber classes are included into our model. Frequency dependent conductivities are used in the volume conduction model to include the dependence of the frequency on the bundle conductivities. Thus far in the literature the calculation the Conduction Velocity Distribution from nerve bundles is based on the electrically measured Compound Action Potentials from the nerve bundles. Therefore, the second objective is to introduce a new method of predicting the Conduction Velocity Distributions of nerve bundles from the Compound Action Currents that are measured magnetically using toroids. The third objective is to compare the variation in the Compound Action Current and Compound Action Potential as the parameters of the model are varied and to compare the Conduction Velocity Distributions predicted from these two signals recorded from nerve bundles with that predicted from histological examination. Based on this detailed analysis of the Compound Action Current, the Compound Action Potential, and the Conduction Velocity Distributions we can conclude that the magnetic technique has certain advantages of the

electrical technique.

## *Computer Science Senior Section*

**David R. Naugler**

*Southeast Missouri State University*

\*Jones, R., Departments of Physical Science, Emporia State University. **Chaining Case-Based Reasoners.** Case-based reasoners (CBRs) contain a set of stored records or "cases" which are compared with new inputs ("inquiries"). If the inquiry closely resembles one of the stored records the output (prediction) associated (stored) with that case is assumed to apply to the new situation as well (Case-Based Reasoning, J. Kolodner, Morgan Kaufmann, 1993). Traditional CBRs follow a radical behaviorist-like model in that only inputs and outputs are employed; there are no intermediate ("internal" or "hidden") variables. All reasoning goes straight from inputs to conclusions. In our new system, however, input variables first generate intermediate results and these, in turn, are then combined (chained, like logic-based production systems) in order to calculate further intermediate variables and, ultimately, make output predictions. Any number of CBRs may then be combined (chained) to produce a complete fuzzy knowledge based expert system. In effect, each rule in a production system has been replaced by a case-based reasoner.

\*Kumaran, J. K. Mitchell, and A. van de Liefvoort. School of Computing and Engineering, University of Missouri-Kansas City. **An Analytic Model Of Correlations Induced In A Packet Stream By Background Traffic In {Ip} Access Networks.** In this paper we show that background traffic at a server in an IP access network can have a significant effect on the performance for a tagged class. In particular, we present an analytic model for two traffic classes with general arrival patterns and general service requirements that are multiplexed at an IP server. The model is general in that it incorporates first- and second-order statistics for the processes involved and is not limited to a heavy traffic analysis. We study the effects of multiplexing on the departure process for the tagged class, and quantify the impact of the background traffic on the mean and variance. More

importantly, it shows that the background traffic can introduce slowly decaying correlations in the tagged stream, which, if ignored, will cause performance predictions to be underestimated by several orders of magnitude. We show that significant correlations are introduced by the background traffic when the arrival time distribution for the background class deviates from those of the tagged class, thereby severely limiting the operational range of the server. Supported in part by NSF under grant No. ANI 0106640

\*Naugler, R. Department of Computer Science, Southeast Missouri State University. **Functional Programming In Java And C#**. In Scheme, ML and other functional languages functions are “first-class” objects and can be passed as parameters, constructed in other functions and returned as values. This allows a distinct programming style quite different from the style in imperative and most object oriented languages. Superficially neither Java nor C# has functions, although methods and static methods serve well. In both Java and C# it is fairly easy to mimic some of the important features of functional programming. Java and C# make an interesting contrast since different constructs in each must be used to do this. In Java interfaces and inner classes can be used. C# does not have inner classes. In C# delegates are used to implement these features instead of interfaces and inner classes. It is shown how to program in a functional way in both Java and C#. The contrasting way this is done shed light on the similarities and the differences between the interface and inner class combination in Java and delegates in C#. Functional languages are much superior for teaching functional programming. However, these approaches allow modes of thinking learned in the study of functional languages to be used directly in programmes written in Java and C#, and they provide a comparison/contrast of useful and often poorly understood constructs in Java and C#.

\*Saquer, J. M. Computer Science Department, Southwest Missouri State University. **Formal Concept Analysis And Data Mining**. Formal concept analysis (FCA) is a branch of mathematics that emerged when a group of researchers were trying to develop applications for lattice theory. It formalizes the notion of a concept in a given context. For example, consider the context of transactions at a grocery store where each transaction consists of

the items bought together. A concept here is a pair of two sets  $(X, Y)$ .  $X$  is the set of all transactions that contain all the items in  $Y$  and  $Y$  is the set of items common to all the transactions in  $X$ . A successful area of application for FCA has been data mining (DM), which deals with the automatic extraction of useful patterns and knowledge from large volumes of data. Data mining is a new interdisciplinary topic in computer science that ties ideas from other well established fields such as databases, machine learning, algorithms, information retrieval, pattern recognition, and computer vision. DM has been used successfully in fraud detection, bioinformatics, sequence analysis, and predicting users' behaviors on the World Wide Web. In this presentation, I will give a brief overview of the basic notions of FCA. I will also show how the idea of a formal concept in FCA can be successfully used in many areas of data mining including clustering and generating association rules. The ideas I will show can be easily adopted in an upper-level undergraduate and low level graduate course on data mining.

\*Shade, E. Computer Science Department, Southwest Missouri State University. **A Parametric Automata-Theoretic Programming Language For The Chomsky Hierarchy**. The Chomsky hierarchy includes the regular, context-free, context-sensitive, and unrestricted formal languages, which have both grammatical and automata-theoretic definitions. While this makes a theoretical comparison of the descriptive power of these languages possible, many people (particularly students) find it difficult to understand the distinctions in intuitive and practical terms. I have defined a programming language with one conditional statement, one iterative statement, nonrecursive subroutines, and a nondeterministic *guess* operator that can be parameterized to correspond precisely to each of the formal languages in the Chomsky hierarchy. For example, a language is context-free if and only if it can be recognized by a program that is permitted to use the *push*, *pop*, *top*, and *empty* stack operations. Programs are usually quite short and easier to understand than either grammars or automata.

\*Wang, Y. Department of Computer Science, Southwest Missouri State University. **Pedagogy For Introducing The Concept Of Object-Oriented Programming With Java In Cs I**. Object-oriented programming techniques are essential to contemporary software development and the computer industry. In

order to expose the students to the concept of object-oriented programming as early as possible, many schools have chosen using Java in the course CS I. However, the numerous Java textbooks have shown that there is a broad range of opinions on how and in what sequence the basic programming schemes and object-oriented programming techniques should be taught to those first-time programmers. In this paper the author compares those different teaching pedagogies, and intends to stir up a discussion on this issue among the peer educators.

## *Conservation*

### *Senior Section*

**Cary D. Chevalier**

*Missouri Western State College*

LaCombe, L., and S. Carins. Department of Biological Sciences, Central Missouri State University. **Recreational Effects On Aquatic Insect Communities, Buffalo National River, Arkansas.** The Buffalo National River became part of our national park system in 1972. Demands on parks like this one increase each year. Even though this river is protected by national park status, its fragile ecosystems are impacted by recreational activities of nearly one million annual visitors to the park. The purpose of this study was to evaluate impact of recreational use on aquatic insect communities. Three river accesses were selected as sampling sites from the upper, middle, and lower sections of the river. Aquatic insects were collected using a stratified random sampling strategy from riffle habitat. At each of these sites, four samples were collected upstream and four samples were collected at the terminus of the recreation access. The insects were identified to lowest taxonomic level possible. Samples were quantitatively rated using a multi-metric community analysis. Preliminary results will be presented.

\*Maccarone, A.D., Biology Department, Friends University, and C. H. Cope, Kansas Department of Wildlife & Parks. **Recent Trends In The Winter Population Of Canada Geese In Wichita, Kansas.** We have taken a half-day census of Canada geese (*Branta canadensis*) inside the Wichita city limits every January since 1983, when we counted 1600 birds. Recent estimates suggest

that the size of the winter population of Canada Geese continues to increase, with an estimated 18000 birds counted last winter. Annual population growth follows a strong linear pattern ( $R^2 = 0.78$ ), and closely follows population growth patterns for both the City of Wichita and the State of Kansas ( $r = 0.70$  in both cases). The growth of the winter population does not appear to be closely related to the size of the local breeding population. Aggregations of < 30 birds accounted for 37% of all flocks, and those of <100 birds accounted for 68% of all flocks. Canada geese were associated with three primary habitats: grass, bodies of water, and agricultural fields. We consider the possible implications for continued population growth.

Metcalf, D., S. Cairns, T. Yasger, K. and K. Sullivan. Department of Biology, Central Missouri State University and Fisheries Division, Missouri Department of Conservation. **Evaluation Of Paddlefish Spawning Locations And Success Of Spawning Eforst On The Marais Des Cygnes River: Year Two.** Since the construction of Truman Dam, all known paddlefish (*Polydon spathula*) spawning sites have been eliminated. The Marais Des Cygnes River, which offers the greatest potential for natural reproduction, has not been thoroughly investigated for location of suitable spawning habitat. The Missouri Department of Conservation and Central Missouri State University have initiated this study to assess habitat suitability for paddlefish spawning. Four potential spawning location, between Highway 71 and the US Fish & Wildlife Service Marais Des Cygnes Refuge in Kansas, were sampled. Adult paddlefish were sampled using gill nets as they migrated upstream to spawn. Paddlefish lethyoplankton were sampled below and above the sample sites using boat-mounted drift nets. Spawning habitat was assessed for each sample site using modified Missouri Department of Natural Resources Stream Habitat Assessment Procedures. Natural reproduction was observed with the collection of larval paddlefish at some river sites. Preliminary analysis of larval and adult abundance for years one and two will be presented.

\*Nations, M.W. and S. Cairns. Department of Biology, Central Missouri State University. **Larval Amphibian Communities Of Pertle Springs.** Amphibian population numbers have been declining over the past several decades. The amphibian

community present in an ecosystem may be a key indicator of that system's health. Larval amphibians were sampled in May and June in four golf course ponds and three ponds in Pertle Springs. Dissolved oxygen, pH, turbidity, conductivity, and temperatures were specific water parameters sampled during May and June of all seven ponds. Dominant plant species were sampled along randomly selected transects in one meter square quadrats around the seven ponds in late August. Larval amphibian communities, water parameters, and dominant plant vegetation were analyzed for correlation among the selected parameters.

\*Neerhof, L. and S. Cairns. Department of Biology, Central Missouri State University. **Eutrophication Monitoring And Management Strategies Of Four Ponds Located In Pertle Springs Recreational Area.** Four ponds located in the Pertle Springs recreational area are a part of Central Missouri State University (CMSU) in Warrensburg, Missouri. Eutrophic conditions ranged from phytoplankton dominated communities to predominately macrophyte communities. Seven sites on the four ponds were sampled monthly from June 2002 to September 2003. Depth profiles of dissolved oxygen, temperature, turbidity, conductivity and pH were taken at each site. Laboratory analysis of orthophosphate, nitrate, alkalinity, hardness, ammonia, and suspended solids were performed at CMSU's Water Quality Laboratory. Results determined the management strategies for each pond.

Sass, C. and \*J. Rushin. Biology Department, Missouri Western State College. **A Preliminary Study Of Plants At The Lower Hamburg Bend Conservation Area Prior To Flooding With A Reopened Chute Of The Missouri River.** The Lower Hamburg Bend Conservation Area (LHBCA) contains approximately 3,000 acres of wetland habitat located on the east side of the Missouri River just south of the Iowa border. As part of a joint project of the Missouri Department of Conservation (MDC) and the U. S. Army Corps of Engineers (COE), a chute is scheduled to be reopened through the LHBCA to form island, sloughs, and backwater areas. Within a 300-acre study area that will be primarily affected by the new chute, 232 evenly-spaced permanent sampling plots and 18 randomly located permanent sampling plots were used to collect herbaceous plants,

woody seedlings, saplings, and trees according to the Vegetation Monitoring System (VMS) of the MDC. (All sampling was done in June and July of 2002 and 2003.) This study describes 97 species of herbaceous and woody plants collected from all of the study plots. It compares VMS Importance Values of the top herbaceous species including (*Solidago altissima*, *Setaria Faberii*, *Abutilon Theophrasti*, *Polygonum pennsylvanicum*, *Erigeron canadensis*, *Helianthus annuus*, *Setaria glauca* and *Bromus inermis*) in the entire study area. In addition, it was found that most of the plants sampled during this preliminary survey are introduced and/or generalist species. Slight changes in bare ground, litter and water were due to a 2002 late winter burn and beaver dam construction in 2003. It is expected that native wetland species will increase as the marsh habitat expands after the river chute is reopened. Support from the Missouri Department of Conservation.

\*Wisker, D. Department of Biology, Central Missouri State University. **Genetic And Morphometric Variation In Fragmented Missouri Populations Of The Texas Mouse *Peromyscus Atwateri*.** Fragmented, isolated populations are subject to loss of genetic diversity through inbreeding and genetic drift. Loss of diversity renders these populations susceptible to increased disease and local extinction. Glades are isolated, open patches of habitat surrounded by hardwood forest areas, and are found throughout Missouri. In the Missouri portion of its range, the Texas mouse (*Peromyscus atwateri*) is restricted to glade habitat fragments in the southwest corner of the state. This study will use Amplified Fragment Length Polymorphism (AFLP) and morphometric data to assess genetic diversity of selected glade populations and evaluate the effects of habitat fragmentation on genetic structure. Information gathered from this project will be of interest to conservation biologists concerned with the viability of fragmented populations, and evolutionary biologists interested in population divergence

## *Engineering Senior Section*

**Virendra K. Varma**

*Missouri Western State College*

Card, Nathan\*, V. Varma. **“Self Consolidating Concrete – A Comparison With Conventional Concrete.”** Self Consolidating Concrete (SCC), also known as Self Compacting Concrete, was first proposed in 1986 by Professor Hajime Okamura of Kochi University of Technology, Japan. SCC is still an emerging technology, only in its infancy. SCC consolidates under its own weight. Unlike conventional concrete that needs vibration to fill all the voids and surround the rebar in the forms, SCC uses little or no vibration. This paper examines many of the aspects of SCC including comparisons of strength and durability with conventional concrete. Also are compared, shrinkage, resistance to cycles of freezing and thawing, and cost. The ability of concrete plants to use locally available material to make SCC is also evaluated in the paper, in addition to discussion on some of the admixtures used in making self consolidating concrete.

Rai, M. and T. Guess. Department of Mechanical Engineering, University of Missouri - Kansas City. **Development Of A Three Dimensional Computational Dynamic Model Of The Knee Joint For A Detailed Understanding Of Its Function.** The knee is one of the most complex joints in the human body and experiences a significant amount of stress and loading during motion. Two joints exist in the Knee. One is the patellofemoral joint between the patella and femur and the other is the tibiofemoral joint between the tibia and femur. We are developing a rigid body model with deformable contacts that will incorporate the inertial properties of the tibia, femur and patella. The model is being developed in MSC. ADAMS and includes geometries from MRI images of the tibia, femur and patella. Appropriate insertion sites for muscles have been determined and will be used to define the line of action of muscle forces. In addition, major ligaments crossing the knee will be modeled as non-linear springs. The material properties of cartilage covering the articulating surfaces of the knee will be formulated into contact parameters for the deformable contacts at the patello-femoral and tibio-

femoral joints. The three dimensional model will help in the analysis of muscle activation patterns and the motion of the patella in a step up task. It will also aid in the understanding of the magnitude and direction of forces that will act on the femur, tibia, and patella. This analysis will be used for the study of dynamic stress development on the patella and to find ways of reducing it.

Rayaprolu, J. and T. Guess. Department of Mechanical Engineering, University of Missouri - Kansas City. **Control Of Muscle Activation And Force To Minimize Stresses In The Patello-Femoral Joint.** The Patello-femoral joint is a complex joint that experiences high forces during everyday activities. This joint is comprised primarily of the patella, femur, tibia, quadriceps muscles, and the patellar tendon. Bone geometries provide static constraints to patellar motion and muscle forces provide dynamic constraints. It is generally believed that poor tracking of the patella is a prevailing cause in the onset of patello-femoral pain. In this project we are trying to minimize the patellar stress while performing a step up task using a 3-Dimensional dynamic knee model focusing on the dynamic constraints. The model is being constructed as a rigid body model that includes muscle forces, ligament constraints, and anatomical bone geometries with deformable contacts. Clinical studies have shown that the muscle activation pattern of the quadriceps has a relation to patello-femoral joint pain. This pattern will affect muscle forces which could in turn control patellar tracking; our study will prove or disprove this hypothesis by controlling the muscle activation to minimize stress and analyze the results. To this end we will be developing a control algorithm with a defined “Joint Stress” as an error signal. The difference between maximum stress and the average stress over a finite area would give the stress which is a variable. This variable stress is fed as an error signal to minimize the joint stress. Our study will help give better insight into the dynamics of the knee joint and could contribute to the prevention and treatment of patello-femoral pain.

## *Geology & Geophysics*

### *Senior Section*

**John Nold**

*Central Missouri State University*

Dudley, M.A., and J. Nold. Department of Earth Sciences, Central Missouri State University. **Mineralogy, Textures And Origin Of Iron Deposits, Se Missouri.** The Cedar Hill and Russell Mountain deposits exhibit thinly laminated banded iron formation (BIF) hematite with oolitic hematite laminae and red jasperoid. The oolites at Cedar Hill and Russell Mountain lead us to the conclusion that these bedded ores are of undoubted sedimentary origin. The Pilot Knob Hematite deposit (PKH) represents a laminated BIF, and though the ores at PKH lack oolites, the close similarity of the laminated BIF ores at PKH to the Cedar Hill and Russell Mountain ores leads us to the conclusion that PKH is also sedimentary. The College Hill deposit is a laminated BIF with considerable disturbed bedding having associated siltstones and flat-pebble sedimentary breccia cemented by specular hematite. The Hogan Mountain deposit consists of crustiform open space fillings within a rhyolitic breccia, suggesting deposition in a hot spring vent. The Shepherd Mountain and Shut-Ins deposits are composed of magnetite and hematite deposited in steep veins. They represent a somewhat deeper look into the plumbing system than the surface deposits described above. The Cedar Hill, Russell Mountain, and Pilot Knob Hematite BIF's apparently were deposited in shallow, restricted basinal settings (caldera lakes?) that were fed by iron-rich hot spring waters. The Hogan Mountain deposit appears to represent one of the hot spring vents, while the Shepherd Mountain and Shut-Ins deposits apparently represent conduits from the developing magmatic/hydrothermal system below, feeding iron-rich solutions to the sedimentary basins.

\*Mataragio, J.P. and J.P. Hogan. Geology and Geophysics Department, University of Missouri-Rolla. **Terrane Accretion In Coastal Maine: Insights From The Isotopic Characterization Of Granite Sources.** The initial Nd and Sr isotopic composition of Paleozoic granitic rocks from Medial New England Terrane (MNET) and Composite Avalon Terrane (CAT) in Maine were investigated in order to

characterize the source regions of the granitoids and constrain the subsurface distribution and timing of juxtaposition of these terranes. Two major episodes of granitic magmatism associated with terrane collision are well documented in this area. The "older" Silurian event is characterized by the formation of epizonal bimodal igneous complexes, layered gabbros, and granitic plutons. The "younger" Devonian event is characterized by intrusion of peralkaline, metaluminous, and peraluminous granitoid stocks and batholiths. The initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios and  $\epsilon_{\text{Nd}}$  values for Devonian granites range from 0.701 - 0.710, and 0.8 to -2 respectively. The Silurian granites are more diverse;  $\epsilon_{\text{Nd}}$  values range from 2.5 to -8 and initial  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios vary from 0.703 to 0.713. Devonian and Silurian granites define fields with distinctly different slopes on the Nd-Sr isotopic correlation diagram. This indicates their derivation from partial melting of crustal basement source regions that had unique geologic histories. The lower field is defined only by Silurian granites and yields a  $T_{\text{DM}}$  age of 1.6 Ma. The upper field is defined only by the Devonian granites and yields a  $T_{\text{DM}}$  age of 1.3 Ma. Silurian granites and Devonian granites intrude both MNET and CAT. This suggests 1) "terrane-bounding" faults may juxtapose distinct surface terranes but not distinct basement terranes. 2) The Silurian granites and their host terranes are allochthonous and were thrust over the MNET basement after the Silurian melting event and prior to the Devonian melting event. 3) Paleozoic terrane accretion in coastal Maine is dominated by "Thin-skinned" crustal tectonics.

## *Paleontology*

### *Senior Section*

**Mark Dudley**

*Central Missouri State University*

\*Beatty, B. L. Division of Vertebrate Paleontology, University of Kansas Natural History Museum. **Testing The Use Of The Extant Phylogenetic Bracket For Making Paleobiological Inferences.** The inference of various paleobiological characteristics of fossil animals has long been the realm of discussion sections following descriptive texts of osteology. While living animals allow us to observe soft anatomy and behavior, the interpretation

of the same in fossil taxa has been left to qualitative arguments of justification. The most parsimonious inference of such unknowable characteristics has been suggested to be those that are shared by the Extant Phylogenetic Bracket (EPB). This holds that given a crown group including the fossil taxon in question, we should assume that it shares characteristics that are shared between its fellows in the crown group and that of the sister taxon to the crown group. To test the reliability of this method of inference I propose to use the EPB method to make a prediction of a character state for an extant, known taxon. After making this prediction we can compare it with the known character state of the same extant taxon and, compiling such data for the entire clade, assign a character predictability index (CPI) for the character being inferred. With this CPI we can compare the relative security with which we can make inferences about certain behaviors and anatomical features. To avoid circular reasoning, these comparisons could be performed using a molecular phylogenetic tree. Once a CPI is well established for modern knowable taxa we can then move on to making paleobiological inferences based upon the EPB with a measure of our confidence in the results concerning each type of character.

\*Burnham, D.A. Department of Geology, The University of Kansas. **Comparison Of The Tarsus And Pes In The Dromaeosaurs *Bambiraptor* And *Microraptor***. Controversies surrounding evolution of flight are usually framed around the hands and arms (wings) rather than the structure of the foot. The anatomy and functional morphology of deinonychosaur tarsus and pes has been overlooked and is herein examined in light of recent discoveries. The study included a cursorial form, *Bambiraptor* (North America), and a newly reported arboreal form, *Microraptor* (Asia). Lifestyles of these animals should be reflected in the morphology of their feet since locomotion is fundamentally different between ground and tree-dwelling forms. It was found that the arboreal and cursorial morphotypes do have contrasting foot morphology, although both possess the retractable sickle claw, a synapomorphy of the Dromaeosauridae. The arctometatarsalian foot of *Microraptor* was proportionally smaller with deeply recurved claws on each digit, the hallux was reversed, and long, vaned feathers attached to the tarsus. These feathers alone would seem to encumber a cursorial lifestyle. It is

more likely that it was arboreal, using the sickle claw for climbing with the reversed hallux and recurved unguals for perching. The foot of *Bambiraptor* had a normal tarsus that functioned well as a killing claw to disembowel prey. The hallux was not reversed and was positioned more proximally than *Microraptor*. The flattened pes unguals, combined with other features, implies it was cursorial. The resulting insight on foot morphology and function indicates the tree-dwelling forms acquired the specialized claw apparatus for climbing much earlier than the cursorial members of this group who subsequently modified the claw as a weapon. This would seem to support that an arboreal phase took place during the evolution of flight in birdlike dinosaurs.

\*Gobetz, K.E., and J.L. Green, Natural History Museum and Biodiversity Research Center, University of Kansas, and Florida Museum of Natural History, University of Florida. **Comparison Of Kansas And Florida Mastodon Diets Using Phytoliths In Calculus**. Pilot studies to extract opal phytoliths from calculus on the molars of mammoth *Mammuthus columbi* and mastodon *Mammuthus americanum* from Kansas suggest that phytoliths may reveal major dietary constituents. Calculus of late Pleistocene Kansas *M. americanum* contained a mixture of pooid (cool, moist) grasses and deciduous tree leaves, suggesting that mastodons in Kansas may have been mixed-feeders rather than exclusive browsers. These results vary from the traditional view of mastodons as forest-dwelling browsers. They may reflect a preservation bias due to high amounts of silica in grasses compared to dicotyledonous plants. Alternatively, Kansas mastodons may have been mixed-feeders as a result of habitat. *M. americanum* phytoliths from Aucilla River (Pleistocene: late Rancholabrean) in Florida are compared with Kansas mastodon phytoliths to determine possible regional differences in diet. Previous mastodon dietary studies from Aucilla River using isotopes, microwear, and gastrointestinal contents have shown mastodons to be primarily browsers. Comparative studies of Kansas and Florida mastodons may help to resolve these questions and refine the use of phytoliths as dietary indicators.

\*Gobetz, K.E., and L.D. Martin. Natural History Museum and Biodiversity Research Center and Department of Ecology and Evolutionary Biology,

University of Kansas. **Social Behavior In Extinct Beavers.** Recently the discovery of an Oligocene beaver den in France documented the antiquity of social behavior characteristic of the modern semi-aquatic beaver, *Castor*. At about the same time (Oligocene), a group of North American beavers with short tails and flattened incisors (*Palaeocastorinae*) radiated into upland terrestrial fossorial niches. These beavers developed social structures more similar to those of fossorial squirrels than to other beavers. The species *Palaeocastor fossor* constructed deep (up to 3 m) burrows that were organized into large colonies of several hundred. These were probably similar to modern prairie dog colonies. A second, larger species, *P. magnus*, inhabited smaller aggregations of burrows that were spatially separated from the colonies of *P. fossor*. The smallest-sized beaver, *Pseudopalaeocastor barbouri*, excavated burrows of about 1 m depth. These are found in small groups of less than 10, and may occur within the *P. fossor* colonies. The difference in depth between burrows of the separate genera indicate a niche difference between these two beavers that enabled them to live in close proximity to one another.

## *Physics*

### *Senior Section*

**James M. Borgwald**

*Lincoln University*

\*Donaldson, N.L. Department of Math, Physics and Computer Science, Rockhurst University. **Investigating Student Learning In An Application – Based Physics Course.** The research for this course resulted from a desire to serve student learning and satisfy the Physics needs of Occupational Therapy and Communication Science Disorder students at Rockhurst University. Students in Rockhurst's Occupational Therapy and Communication Science Disorder programs are required to take only one semester of physics for their major. With previously offered physics courses, students were getting a heavy emphasis on mechanics and the associated mathematical problems and missing all of the second semester physics concepts that are very applicable to their majors (states of matter, thermodynamics, waves and sound, electricity, optics). A one-semester physics course was therefore developed for the Occupational Therapy and Communication

Science Disorder students to cover topics that illustrate the applicability of physics to students' major area of study. A course project was incorporated for physics students to relate physics topics learned to career interests. A pre/post attitude survey was developed and administered by graduate Occupational Therapy students who chose the relevance of physics to Occupational Therapy as their graduate Capstone Project. Results from pre/post attitude and content tests administered by the instructor showed a strong improvement in attitude and content knowledge regarding physics concepts. Additionally, students submitted quality end-of-semester presentations relating physics to their major area of study (Occupational Therapy or Communication Sciences Disorders).

Fricke, B.A., D. Bandyopadhyay\*, A.K. Ranjan, M.F. McClernon and B.R. Becker. Civil and Mechanical Engineering Division, School of Computing and Engineering, University of Missouri – Kansas City. **Determination Of Heat Transfer Coefficients Of Foods.** The freezing of food is one of the most significant applications of refrigeration. In order for freezing operations to be cost-effective, it is necessary to optimally design the refrigeration equipment. This requires estimation of the freezing times of foods and the corresponding refrigeration loads. These estimates, in turn, depend upon the surface heat transfer coefficient for the freezing operation. This paper describes the thermodynamics of food freezing and reviews basic freezing time estimation methods. It also describes a study which was initiated to resolve deficiencies in heat transfer coefficient data for food freezing processes. Members of the food refrigeration industry were contacted to collect freezing curves and surface heat transfer data. A unique iterative algorithm was developed to estimate the surface heat transfer coefficients of foods based upon their freezing curves. Making use of this algorithm, heat transfer coefficients for various food items were calculated from the freezing curves collected during the industrial survey. The accuracy of the calculated heat transfer coefficients was found to be within  $\pm 30\%$ . These heat transfer coefficients were used to calculate the Nusselt number, Prandtl number and Reynolds number for the various food items and a logarithmic correlation was obtained in the form of  $Nu = CPr^m Re^n$ . Such information is important in the design and operation of cooling and freezing facilities and will be of immediate usefulness to engineers

involved in the design and operation of such systems.

\*Shen, J., P.C. Gibbons, and J. F. Wieggers. Department of Physics, Washington University. **Using Research Based Assessment Tools In Professional Development – Electricity & Magnetism** We adapted and used for different purposes, in an electricity and magnetism course for K-8 school teachers in fall 2003, three research-based tests (Mainly from Cohen, R., Eylon, B., Ganiel, M. 1983; Fredette, N.H., Lochhead, J. 1980; Osborne, R. 1983; Shipstone, D. M. 1984 & 1988). The course is designed to accomplish conceptual change toward accepted scientific conceptions (Gibbons, P.C., McMahon, A.P., & Wieggers, J.F. 2003). Our results support that using the research-based tests to identify alternative conceptions is a promising way to use the knowledge of alternative conceptions in professional development. Comparing the teachers' conceptions to accepted scientific conceptions in discussions of test results with teachers, encourages them to try to understand the scientific conceptions and to make them their own.

## *Science Education*

### *Senior Section*

**Richard Frazier**

*Central Missouri State University*

\*Gordon, A.R. Department of Biomedical Sciences, Southwest Missouri State University. **Early Self Analysis Of Negative Science Attitudes And Emphasis On Thinking Skills Improve Student Attitudes Toward Science.** The challenge for the college science educator in general education science courses is not only to improve science literacy, but also to correct the misconceptions that these students have about science and scientists. Informal surveys in one, non-majors introductory, human biology course indicate that less than 5% of the students have had contact with a practicing scientist. An earlier report showed that these students hold many erroneous views of science and scientists. Previously, this author reported success in improving attitudes by including topics that address student misinformation of science in ten attitude categories. Since negative attitudes toward science often originated from the student's high school science experiences, an important element

to improve attitudes was to provide a closer interaction of students with a practicing scientist who served as coordinator of a discussion period. In the previous study, discussion topics to improve student attitudes toward science and scientists were determined by the instructor and students were not assessed for attitude changes until the end of the semester. The process was student-passive. More recently, near the beginning of the class, students are given an assignment to evaluate the bases for their personal attitudes. Discussion exercises and a greater emphasis on the rules of critical thinking and logic have been implemented. These changes have resulted in improved student attitudes toward science and scientists. Promoting realistic and more positive attitudes toward science and scientists should be as important a task for the science educator as is increasing scientific literacy in college science courses for non-majors.

\*Johnson, J. Departments of Physical Sciences, Emporia State University. **Adapting The Modeling Methods Of High School Physics Instruction To A First Year College Course.** The Modeling Methods of high school physics instruction were developed by David Hestenes and others at Arizona State University to improve student conceptual understanding. High school teachers who take a "Modeling Physics Workshop" learn a packaged pedagogy and curriculum that enables those with minimal physics background to achieve significant student conceptual understanding of mechanics. While the curriculum in a college level course must cover a greater topical range, the pedagogies can be used to improve student understanding. Significant features include: introduction of material in the laboratory, student designed investigations, Socratic questioning by the teacher, and student presentations of their work to the entire class. This talk documents the strategies used at Emporia State.

Kemp, B., A. Gordon and B. Wing. Departments of Mathematic, Chemistry, and Biology, Southwest Missouri State University. **Opening The Horizons Of Science For Rural Middle School Girls In Southwest Missouri.** Opening the Horizon: Strengthening Science Education for Middle School Girls in Rural Southwest Missouri is a three year project funded by the National Science Foundation. The purpose of the program is to help keep middle school aged girls interested in science and math and to

help their teachers. Many science and math teachers in rural Southwest Missouri have \$100 or less to buy supplies for all of their classes in an academic year. In its third and final year, the grant has begun to have some positive impacts. The hands-on workshops in which the students have participated have been very successful in helping them to see that science and math can be fun. Teacher participants have benefited from networking with other science and math educators, additional curricular materials and classroom equipment.

\*Mills, S.H. and T. Bisby. Department of Biology, Central Missouri State University. **Jamaica Medical Experience: Environmental Factors.** Environmental conditions contribute to medical conditions of low income residents in Falmouth, JA. Volunteer teams from the United States come together to provide medical care, improved housing, and fellowship since 1987. As members of these teams, pre-med students along side physicians and nurses help with delivery of medical care, educate locals on a more healthy lifestyle, and improve living conditions for those in need. With four to eleven teams providing staffing each year, the Falmouth Clinic sees over 500 patients during a week only when a team is available. Falmouth has regressed to a quiet coastal town as the port's economy has failed to keep up with the changes in the Jamaican economy and change in the environment. With emancipation, many freed slaves established over 20 free villages in Trelawny. Like the US, hypertension, heart disease, and diabetes are common health problems seen in the Falmouth clinic. Americanization of the Jamaican lifestyle, high economic dependence on tourism, migration of youth to coastal tourist centers, high unemployment, and young age of first pregnancy contribute to medical conditions experienced by patients.. As one travels from plush resort areas and beach parties to the "bend down" market and street protests, the contrasts between the developed and undeveloped worlds is striking. Increasing demands on inadequate and overloaded wastewater treatment facilities appears to contribute to water borne diseases. The tourist areas support large populations of tourists with high-income lifestyles and these effects harm both the environment and the people of Jamaica.

Moffatt, D.S., M. Hansen\*, T. Owen and B. Rakes. Missouri Virtual School of Southwest Missouri

State University. **The Use Of Microsoft Frontpage Web-Forms In Online Homework Assignments.** Web-forms have been used to administer homework assignments to classes in several schools across Missouri. The homework results are then written on a web page as well as collected by email. In this talk we will describe the entire process of designing an assignment in a web page form all the way to returning the students graded work. Many assignment formats work well as web forms including true/false, multiple choice, short answer, and also essay questions. A benefit of using true/false and multiple choice questions is that students can have instant feedback of their graded work. This method requires access to a web server and some work to put in place, but after experience the grading takes only a little more time than regular paper and pencil homework. The process of using web forms for homework begins with the creation of a web form containing the assignment. Along with this, another web page is created to collect the results. Students work can be graded on this second page and the corrected work returned to the students by email. This method seems very reliable and flexible enough to recommend it highly. It can be used in teaching different areas of Science, especially as a tool for distance learning, but also as an enhancement to regular classroom work.

\*Moffatt, D.S., and L.E. Banks. Southwest Missouri State University. **A Systems Analysis Approach To Teaching About Interrelationships In The Circulatory System.** The variables that control the circulatory system of the body are so interrelated that it is difficult to explain the operation of this system in detail with beginning students. The educational process might then proceed by summarizing some effects of the major variables and ignoring more subtle interactions. We have used the program STELLA in our teaching at the Missouri Virtual School with beginning science students for several years now, and we believe it represents an understandable solution to problems such as the one above. Using simple drag and drop graphics, STELLA can represent complicated systems by means of Flows, Reservoirs, Constants, and Variables. Connectors are then used to make a map of relationships between these constructs. As this graphical representation is created, STELLA automatically constructs the equations that are required to mathematically describe the interrelationships. (These equations are totally

hidden unless you just want to see them.) Given the sizes of the necessary parameters, which can easily be varied by students, STELLA provides graphical outputs of different variable combinations of the system being studied. As students' knowledge is increasing, their capacity to "think through" interrelated effects increases more slowly. They can think about two equations at the same time, and maybe three. But, somewhere around three or four equations an understanding how things work becomes a rather hopeless matter – until they see STELLA's graphical portrayal of the situation. Starting from very basic flow concepts, we plan to show how STELLA can be used to describe the potential role of the kidneys in the control of blood pressure.

\*Saha, G. C., Division of Education, Lincoln University, Missouri. **A Psychometrically Consistent Performance-Based Laboratory Assessment Of 'Diffusion' At The High School Level.** A 'do-able' psychometrically consistent laboratory-based performance assessment task on diffusion using water and  $\text{KMnO}_4$  was developed through a step-wise repetitious process of trial testing. The developed task was administered to 224 high school biology students from six greater Buffalo, NY area schools to measure students' performance expectations geared to science procedural knowledge and diffusion specific declarative knowledge. There were six end-of-the-task items to measure these skills. Procedural skills were grouped into planning, performing and reasoning categories. High inter-rater reliability [ $r = .95 (> 0.01)$ ], Chronbach Alpha (.77) and correlation estimates between the task, the items and three skill categories and also across the items demonstrated a high internal consistency possessed by the task. The task captured both the science procedural and declarative skills of the students. However, statistical analysis demonstrated that students performed better than reasoning and planning. General Linear Model Repeated Measure analyses found no effect of tasks and skills on students' performances. Mean difference, ANOVA ( $F = .05 (223, 1) p=0.82$ ), and differential analyses support no gender variation in performances in this study. Limitations, implications of the study and directions for further research are discussed.

## *Speleology* *Senior Section*

**David C. Ashley**

*Missouri Western State College*

\*Lerch, R.N. USDA-Agricultural Research Service, Columbia, Missouri. **Water Quality Monitoring In Two Karst Watersheds Of Boone County, Missouri.** Karst watersheds with significant losing stream reaches represent a particularly vulnerable setting for ground water contamination because of the direct connection to surface water. Due to existing agricultural land-use and future urban development pressures, two losing stream karst watersheds were chosen for intensive monitoring in Boone County, MISSOURI: Hunters Cave and Devils Icebox Cave. Year-round monitoring was conducted from April, 1999 to April, 2002 with the objective of characterizing the water quality status of the main cave streams relative to herbicide, nutrient, and bacterial contamination. Herbicides were frequently detected in both cave streams at very low levels (e.g.  $<0.1$  ppb), but higher levels ( $>1$  ppb) were observed in runoff events each spring. Nitrogen and phosphorus concentrations in both caves were generally much higher than EPA guidelines for nutrient contamination of streams, and the Icebox had consistently higher levels of both nutrients than Hunters Cave. Fecal coliform bacteria levels were generally above the whole body contact standard (200 cfu/100 mL) in the Icebox, regardless of flow conditions. Under runoff conditions, fecal coliform levels in both caves can exceed 10,000 cfu/100 mL. Fecal coliform levels were significantly correlated to turbidity, indicating transport primarily occurs via sorption to suspended sediment. Current management efforts should focus on implementing BMPs to reduce contaminant transport from row cropped fields and rangelands. Future management considerations for these watersheds are focusing on impending urbanization, and the development of a comprehensive watershed land-use plan. Education efforts will continue to stress that cave systems are directly affected by surface land-use activities.

\*Samoray, S.T. Resource Science Division, Missouri Department of Conservation. **Bat "Graveyards"**. Great Spirit Cave in Pulaski County,

Missouri, has an assortment of cave life and interesting features. The cave is home to numerous biological and cultural resources including, a bat “graveyard”, containing hundreds if not thousands of bat remains as well as newly dead and dying bats. The vast majority of these are Red bats (*Lasiurus borealis*) with a lesser number of Hoary bats (*Lasiurus cinereus*). I conducted literature reviews and personal interviews to determine first, the rarity of such an occurrence and second, the possible reasons for it. I will present findings from my research and my personal hypotheses on the subject. It appears that Lasiurine bats may enter caves more often than reported and may frequently remain there until their death. Although this situation may not be as isolated as originally thought, it is still very interesting and several questions remain to be answered by further, more intensive studies.

**Corregidum**

In the 2003 edition of the Transactions of the Missouri Academy of Science, there was an error in the article, *Structural State of K-feldspar in the Younger Granites of the Western St. Francois Mountains, Southeastern Missouri: Further Evidence for Pervasive Alteration of the Mesoproterozoic St. Francois Mountains Complex* by Mathenia and Plymate. In it, the references had an error in it that was missed. For clarity, here is the entire reference section reprinted with corrections. The Transactions regrets the error.

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