

Transactions of the Missouri Academy of Science



Volume 41 (2007)

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. On August 14, 1934, the organization was incorporated.

The purpose of this Academy was presented in the fourth article of agreement as follows:

This corporation is organized, not for profit but for the purposes of promoting the 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 release and in other such 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 the 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 first organizational meeting on April 13-14, 1934 with 250 people attending. At the December 1934 meeting, more than 400 people registered. By May 1935, there were more than 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 an April 20, 1963 meeting 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 members. Activities of the Academy have expanded to include the awarding of modest grants for projects proposed by high school and college students, and to sponsor the establishment of a Junior Academy of Science. Since its reactivation in 1963, the Missouri Academy of Science has regularly held annual meetings at sixteen different sites around the state.

Presently, 36 colleges and universities around the State of Missouri hold an Institutional Membership status. Membership into the Academy is a year-round opportunity. Benefits include four *Bulletins*, one annual *Transactions*, and annual meeting lower pre-registration fees.

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

About the Transactions. The *Transactions of the Missouri Academy of Science* is a regional publication that has been printed consistently since 1967. Articles authored by regional, national, and international authors have been submitted and published in *Transactions*. Seven occasional papers have been released. In accordance with the *American Association for the Advancement of Science*, of which we are a member organization, the scope of the material published in the *Transactions* comes from disciplines such as Agriculture, Atmospheric Science, Chemistry, Computer Science, Ecology and Conservation, the Geological Sciences (including Geology and Geophysics), Physics, Soil Science, and Education. Other scientific disciplines have also contributed articles through the years. *Transactions* uses a blind peer-review process similar to the procedures used by the journals of professional societies in the disciplines cited above. Reviewers of *Transactions* manuscripts with the appropriate expertise have been drawn from regional as well as national and international institutions.

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Elemental Release Patterns of Low-level Pb-Zn Dolomitic Tailings in Missouri

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Abstract: Lead and zinc tailings are common in the Ozark region of Missouri and constitute an environmental hazard, particularly to soil and water resources. This study investigated the elemental release patterns of low-level Pb-Zn dolomitic waste-rock along Bee Fork Creek in Reynolds County, Missouri, to determine whether these tailings are releasing sufficient metal concentrations to adversely impact water and adjacent riparian resources. Aqua-regia digestion of control and impacted sites confirm the presence of substantial concentrations of As, Cd, Pb, Zn and other metals. Hot water and 0.01 M NaNO₃ extractions recovered small portions of the total elemental pool and that only a very small portion of the total metal pool is labile. The EDTA extraction recovered greater concentrations of Ca, Mg, Pb, Zn and Cd than the hot water extraction. The Ca and Mg concentrations recovered by the EDTA extraction suggest partial dissolution of the dolomitic waste rock, thus promoting metal release. The EDTA Pb, Zn and Cd concentrations reflect recovery of these metals from the organic, exchangeable and waste rock fractions. Long-term weathering of the dolomite waste rock may promote the continuous, but low level, release of metals to Ozark streams.

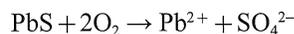
Key Words: lead, cadmium, mine tailings, EDTA extraction

Introduction

Tailings are milled or washed ores that have insufficiently low metal contents to be considered of commercial value and are commonly stored at the mine site. Lead tailings are common in Missouri, a state with a long history of Pb and Zn mining. These tailing piles, tailing ponds and other mining products are frequently adjacent to streams, predisposing the tailing water leachate to negatively impact the surface water quality, soil quality, and the surrounding ecosystem.

Missouri Pb deposits reside primarily in the Bonnetterre Formation; which is, a light-gray, medium to finely crystalline, medium bedded dolomite of the Cambrian system (Thompson, 1995). Lead occurs primarily as galena (PbS), with sphalerite

(ZnS) and other metal sulfides as important auxiliary minerals. Sulfur oxidizing bacteria (*Thiobacillus thiooxidans*, *Ferrobacillus ferrooxidans* and *Thiobacillus ferrooxidans*) appreciably advance the oxidation and hydrolysis of galena (Essington, 2004), which may be characterized as:



The direct oxidation of PbS by O₂, as a purely inorganic reaction, does not produce acid mine drainage; however, secondary reactions, especially when microbially mediated and involving FeS oxidation, may produce considerable quantities of acid mine drainage (Essington, 2004).

PbS oxidation produces Pb²⁺ and hydrolysis in a near-neutral pH environment commonly involves Pb(OH)⁺ adsorption on quartz, clay, and Fe-Mn oxyhydroxide substrates (Essington, 2004). Langmuir (1997), in a review, reported that oxyanion (SeO₄²⁻, SO₄²⁻, CrO₄²⁻, VO₄³⁻, AsO₄³⁻) and cation (Cr³⁺, Pb²⁺, Cu²⁺, Cd²⁺, Zn²⁺, Ni²⁺ and Ca²⁺) adsorption on many variable charge substrates is pH dependent. Oxyanion adsorption is favored in acidic environments on net-positively charged surfaces and cation adsorption is favored in neutral or alkaline environments on net-negatively charged surfaces. Sidle et al. (1992), Dorransoro et al. (2002), and Pueyo et al. (2003) demonstrated that metals have differing mobility, with Pb²⁺ considered to be a relatively immobile species.

Selective sequential extractions attempt to fractionate elements into discrete chemical environments, with each protocol allowing element mobility and biological availability estimates (Tessier et al., 1979; Shuman, 1985; Levy et al., 1992; Ostergren et al., 1999; Lim et al., 2002; Roussel et al., 2000; Pueyo et al., 2003; Mbila and Thompson, 2004). In broad context, selective extractions are semi-quantitative estimates of element partitioning into distinctive chemical environments, which may suffer because of incomplete metal extraction, metal precipitation, and the inadvertent extraction of metals from non-target fractions (Shuman, 1991). Single (non-sequential) selective extractions have less potential to describe metal partitioning in the soil environment; however, their simplicity is an attractive advantage.

The objectives of this research are: (1) to estimate element release potentials of waste-rock containing small concentrations of Pb, Zn, Cd and other elements, and (2) to assess the threat to the waters and sediments of a small Missouri Ozark stream. In essence, we wish to determine if waste-rock enters the stream from its upland confinement area and to elucidate whether or not waste-rock has the potential to release metals to stream waters.

Study Area and Sampling Protocols

Lead-zinc mine tailings are located adjacent and along the Bee Fork Creek in Reynolds County, MO and in the Clark National Forest. A rock dam, spanning the sides of a descending ephemeral stream channel restrains the tailings from entering Bee Fork Creek. Sampling occurred in the dry bed load of Bee Fork Creek, both above (control) and below (impacted) the Pb-Zn tailings (Fig. 1). One control sample site was located downstream, but was topographically elevated above the high water level of Bee Fork Creek and resided on a descending, ephemeral stream bottom. Eight control sites consisted of cherty sandy loam to cherty loamy sand material, composed primarily of quartz sand and silt with small quantities of clay. Ten impacted sites consisted of similar materials, coupled with secondary quantities of carbonate materials washed from the tailings areas. Thus, the labeling of "control sites" and "impacted sites" was based on the likelihood of rock-waste incorporation by a combination of mass wasting and stream processes.

Sampling consisted of 0.25 meter \times 0.25 meter wide and 0.05 meter deep excavations, each geo-referenced with a global positioning system. Samples were placed in plastic bags and oven-dried at 110°C for 48 hours. Samples were lightly crushed

and sieved through a 10 Mesh sieve to obtain the fine earth fraction; that is, material finer than 2mm equivalent spherical diameter. All procedures were performed using the fine earth fraction. Visual estimations of the gravel content were made.

Laboratory Protocols

Soil pH was measured using equal volumes of water and sediment with a pH meter equipped with a combination pH electrode (Carter, 1993). We measured the particle size distribution using the hydrometer method and sieves (Carter, 1993). Two *M* acetic acid extractable $\text{SO}_4\text{-S}$ was determined by the University Missouri-Columbia soil testing service.

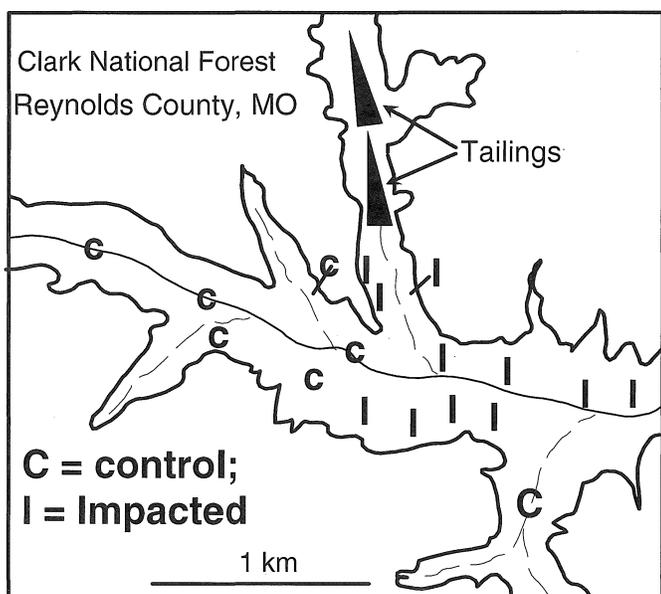
An aqua-regia (AR) digestion was performed to estimate the baseline concentrations of Pb, Cd, Zn and other elements. The AR digestion procedure completely recovers elements residing in soluble, exchangeable, carbonate, organic, Fe and Al oxide environments and partially recovers elements from phyllosilicate and calcic dominated feldspar environments. Quartz, orthoclase, albite, anatase barite, monazite, sphene, chromite, ilmenite, rutile and cassiterite are largely unaffected by the AR digestion (communication from chief analyst at SGS Laboratory). The AR procedure was performed by SGS Laboratories (Toronto, Canada). In this procedure, 0.25 g of finely ground fine earth fraction was digested in 0.01 liter of aqua regia (1 HCl:3HNO₃) for one hour, followed by 0.45 μm filtration. Digest solutions were analyzed using inductively coupled plasma — atomic emission spectroscopy (ICP-AES using ARL 3560 and Optima 4300 instruments). Selected duplicates and reference samples having known metal concentrations were performed.

A hot water extraction was performed to recover only the most labile or potentially labile fractions. The hot water extraction involved equilibrating 0.5 g samples in 0.02 L distilled-deionized water at 80°C for one hour followed by 0.45 μm filtration and aqueous elemental analysis using ICP-MS (Inductively coupled plasma — mass spectroscopy using an Optima 4300 instrument). The hot water extraction was performed by activation laboratories (Toronto, Canada).

A (i) NaNO₃ extraction and a (ii) NaNO₃ — EDTA extraction were performed by the authors to further characterize element availability. Samples were extracted using 10⁻² M NaNO₃ and a second sample set was extracted using 10⁻² M NaNO₃ buffered with 10⁻³ M EDTA (di-Na salt). Two grams of sediment were equilibrated with 0.02 liter of the extracting solutions (1:10 soil:solution) for two hours, with hand swirling every 20 minutes to re-suspend the equilibrating material. The suspensions were centrifuged (2000g for 10 minutes) and the decantate filtered (0.45 μm) before elemental analysis using ICP-MS.

We performed X-ray diffraction analysis using dry mount whole soil samples (<2 mm). X-ray diffractograms were obtained with a Scintag diffractometer using CuK α radiation. Samples were scanned from 20 to 90° 2 θ at 0.02° s⁻¹. Mineral identification was assisted using JCPDS International Centre for Diffraction Data, 1980).

Figure 1. An illustration showing the relative placement of the control and impacted sites and the locations of the tailings.



Statistics

Mean separation between the control and impacted sites was performed using the t-test statistic employing a two-tail format. Pearson correlations were performed to estimate element associations.

Results and Discussion

Routine Site Characterization

All sites have extremely gravelly loamy sand to extremely gravelly sandy loam textures. Clay contents varied from 1.6 to 9.9 percent with an average clay content of 3 percent. Sediment pH levels range from slightly acidic (pH 6.40) to moderately alkaline (pH 7.78), with the impacted sites being slightly more alkaline (mean ± standard deviation: 7.3 ± 0.3) than the control sites (6.8 ± 0.5), a result that is attributed to the presence of dolomitic rock. Extractable sulfate-S concentrations were not significantly different between the control (23.2 mg SO₄-S kg⁻¹) and the impacted (48.9 mg SO₄-S kg⁻¹) sites.

X-ray diffraction of dry powder mounts of the fine earth fraction revealed the near absolute dominance of quartz and phyllosilicates (primarily 2:1 layer clay) in the control sites and the near dominance of quartz and phyllosilicates, with trace to small quantities of dolomite, in the impacted sites. Quartz sand and chert nodules are commonly the dominant materials in Missouri Ozark streams. X-ray diffraction failed to reveal any diffraction peaks for galena (PbS), particularly for the stronger intensity lines at 0.3429 and 0.2969 nm (Moore and Reynolds, 1989), suggesting that galena is less than 0.5%. A few hand specimens from the impacted sites revealed tiny (hand-lens) galena crystals.

Aqua-Regia Digestion of the Control and Impacted Sites

Aqua-regia digestion was used to estimate the near-total element content of the control and impacted sites. Elements not discussed in the following narrative and showing no significant differences between the control and impacted sites are listed as a footnote in Table 1. Calcium and Mg concentrations were dramatically greater in the impacted sites. Interestingly, the Mg and Ca concentrations on a mole basis are present in nearly a one to one correspondence, suggesting the presence of small quantities of dolomitic waste-rock. Impacted sites had significantly greater Sr, As, Cd, Pb, Mn, Fe, Ni, Cu, Zn and Ag concentrations (Table 1).

Zinc concentrations in the control sites ranged from 11.3 to 85.8 mg Zn kg⁻¹, whereas Zn concentrations in the impacted sites ranged from 178 to 658 mg kg⁻¹. Similarly, lead concentrations in the control sites ranged from 8.9 to 214 mg Pb kg⁻¹, whereas the impacted sites ranged from 188 to 371 mg Pb kg⁻¹. Cadmium concentrations in the control sites ranged from 0 to 0.7 mg Cd kg⁻¹, whereas the Cd concentrations in the impacted sites ranged from 1.2 to 13.2 mg Cd kg⁻¹. The relatively modest coefficients of variance from the control sites reflect the small and somewhat variable geochemical background levels and the possibility that air-borne waste-rock dust may have slightly impacted the entire study area. The relatively large coefficients of variance from the impacted sites reflect the variable quantities of waste-rock incorporated into the stream's bed load.

As an example, Ag is an element commonly associated with Missouri's Pb deposits. The mean Ag concentrations of the impacted sites (0.22 mg Ag kg⁻¹) are substantially greater than those of the control sites (0.005 mg Ag kg⁻¹). The greatest Ag concentration from the control sites (0.04 mg Ag kg⁻¹) is smaller

Table 1. Aqua-regia digestion of soil samples selected from tailings impacted sites on Bee Fork Creek, Missouri.

	Mg	Ca	Sr	As	Cd	Pb	Mn	Fe	Co	Ni	Cu	Zn	Ag
	mg kg ⁻¹												
Control Sites (8 sites)													
Mean	4330.00	8080.00	6.0	4.00	0.4	74.00	675.00	10510.00	16.0	12.00	13.00	48.00	0.005
Standard Deviation	4940.00	9540.00	4.0	3.00	0.3	67.00	367.00	3340.00	16.0	5.00	7.00	28.00	0.014
CV	1.14	1.18	0.7	0.75	0.8	0.9	0.54	0.31	1.0	0.43	0.53	0.58	2.80
Impacted Sites (10 sites)													
Mean	71900.00	133000.00	32.0	30.00	6.2	274.00	2226.00	15320.00	26.0	49.00	52.00	390.00	0.22
Standard Deviation	48510.00	91070.00	19.0	23.00	3.3	84.00	951.00	4740.00	7.0	22.00	21.00	163.00	0.18
CV	0.67	0.67	0.6	0.8	0.5	0.3	0.4	0.31	0.3	0.45	0.41	0.42	0.83
Detection Limits	100.00	100.00	0.5	0.1	0.01	0.01	1.0	100.00	0.1	0.1	0.01	0.1	0.002
Mean T-test Probability	**	**	**	**	**	**	**	*	NS	*	**	**	**

* is significant (P < 0.05) and ** is highly significant (P < 0.01), NS is not significant. CV is the coefficient of variation (standard deviation/mean)
 The elements Li, Al, K, Sc, V, Ga, Se, Rb, Y,Zr, Mo, Sn, Sb, Te, Cs, Ba, Au, Tl, Bi, Th and the rare earth elements were not significantly different between the control and impacted sites.

than any Ag concentration from the impacted sites ($0.07 \text{ mg Ag kg}^{-1}$), suggesting that most of the impacted sites have accumulated Ag.

Arsenic concentrations from the control sites ranged from 0.5 to $8.2 \text{ mg As kg}^{-1}$, whereas the As concentrations from the impacted sites ranged from 4.1 to $76.5 \text{ mg As kg}^{-1}$. Mean As concentrations for the control and impacted sites were significantly different; however, the large impacted site As variance infers that a least one of the impacted sites has accumulated As and some of the sites may be considered pristine.

Zinc shows significant Pearson correlations with Pb and Cd. Pooling of the control and impacted sites shows that Pb is positively correlated with Zn ($r=0.89$) and Cd is positively correlated with Zn ($r=0.98$). The implication is that waste-rock incorporation acts as an "element provider" and that the elemental ratios are largely preserved.

Impacted sites were selected in the downstream portion of the creek, whereas the control sites were selected from the upstream portions of the creek. Elemental differences between the control and impacted sites imply greater metal accumulation in the downstream portion of the stream. No spatial distribution patterns were observed among the ten impacted sites; that is, the likelihood of a site adjacent to the confined rock-waste being impacted is identical to that of a site at some downstream distance. It is speculated that waste-rock entering the stream is segregated in the bed load.

Hot-Water Extraction

Elemental recovery by the hot-water extraction revealed that only a small portion of the total element pool is labile or potentially labile. Greater total element recoveries were observed from the impacted sites (Table 2). Mean As, Cd, Pb,

Co, Ni, Cu and Zn concentrations from the impacted sites are greater than the corresponding concentrations from the control sites. Control site Pb and Zn concentrations recovered by the hot water extraction averaged $64 \text{ } \mu\text{g Pb kg}^{-1}$ and $70 \text{ } \mu\text{g Zn kg}^{-1}$, whereas the impacted sites averaged $857 \text{ } \mu\text{g Pb kg}^{-1}$ and $2700 \text{ } \mu\text{g Zn kg}^{-1}$. Cadmium averaged $1.5 \text{ } \mu\text{g Cd kg}^{-1}$ in the control sites and averaged $32.6 \text{ } \mu\text{g Cd kg}^{-1}$ in the impacted sites. The large standard deviation in the impacted sites for Pb, Zn and Cd likely reflects different amounts of waste-rock incorporation. Considering only the impacted sites, two samples having decidedly smaller hot water Zn, Pb and Cd recoveries were the same sites having smaller Zn, Pb, and Cd aqua-regia recoveries, inferring that these two sites have smaller amounts of waste-rock. The substantial metal concentrations corresponding to the hot-water extractions from the impacted sites suggest that: (1) at least a portion of the total pool of these elements resides in potentially labile forms, and (2) continued weathering of the waste rock may slowly release elements.

NaNO₃ and NaNO₃-EDTA Extractions from Impacted Sites

Impacted sites were further characterized to estimate the metal release potential. The NaNO₃ extraction attempts to recover salt-displaceable (exchangeable) metals, whereas the NaNO₃-EDTA extraction attempts to recover exchangeable plus EDTA-chelatable metals. Iron showed similar recoveries between the NaNO₃ and NaNO₃-EDTA extractions (Table 3). Calcium, Mg and Mn show substantially greater EDTA recoveries, underscoring the capability of EDTA to partially recover Ca and Mg from dolomitic materials.

Cadmium was not detected in the NaNO₃ extraction, whereas Pb, Ni, Cu and Zn exhibited modest NaNO₃ concentrations (Table 3). The EDTA extraction recovered substantially

Table 2. Hot water extract of soil samples from control and impacted sites on Bee Fork Creek, Missouri.

	Mn	As	Cd	Pb	Co	Ni	Cu	Zn
	mg kg ⁻¹			μg kg ⁻¹				
Control Sites (8 sites)								
Mean	1.3	14.00	1.5	64.00	12.00	31.00	92.00	70.00
Standard Deviation	2.1	6.00	0.4	53.00	4.00	12.00	76.00	28.00
CV	1.6	0.46	0.28	0.81	0.33	0.39	0.82	0.40
Impacted Sites (10 sites)								
Mean	1.5	140.00	33.00	854.00	85.00	400.00	422.00	2550.00
Standard Deviation	1.0	120.00	20.00	387.00	70.00	352.00	200.00	1776.00
CV	0.7	0.87	0.60	0.45	0.82	0.88	0.47	0.69
Detection Limits	10.0	1.00	0.2	1.00	1.00	1.00	1.00	1.00
Mean T-test Probability	NS	**	**	**	**	*	**	**

* is significant ($P < 0.05$) and ** is highly significant ($P < 0.01$), NS is not significant.

CV is the coefficient of variation (standard deviation/mean)

The elements Li, Mn, Sr, Cs, Ba, Ti, Y, Zr, Nb, Hf, Ta, Br, I, V, Se, Mo, Sb, Th, U, Ga, Sn and the rare earth elements were not significantly different between the control and impacted sites.

Table 3. Sodium nitrate and sodium nitrate-EDTA extractions from impacted sites on Bee Fork Creek, Missouri.

	Ca	Mg	Fe	Mn	Cd	Pb	Ni	Cu	Zn
	mg kg ⁻¹								
0.01 M NaNO ₃ Extractions of Impacted Sites									
Mean	79.00	36.00	13.00	0.58	<0.1	0.33	0.24	0.14	2.1
Standard Deviation	39.00	16.00	8.5	0.55	0.38	0.22	0.05	1.2	
CV	0.49	0.44	0.65	0.94	1.15	0.92	0.34	0.58	
0.01 M NaNO ₃ buffered with 10 ⁻³ M EDTA Extractions of Impacted Sites									
Mean	280.00	117.00	18.00	9.1	1.6	33.00	4.0	3.1	71.00
Standard Deviation	128.00	60.00	7.1	1.6	1.2	20.00	4.3	1.8	73.00
CV	0.46	0.51	0.39	0.18	0.7	0.62	1.06	0.60	1.03

Arsenic was below detection limits (< 1 mg As/kg) for both the sodium nitrate and sodium nitrate-EDTA extractions. CV is the coefficient of variation (standard deviation/mean)

greater concentrations of Cd, Pb, Ni, Cu, and Zn than the NaNO₃ extraction. The effectiveness of EDTA rests with: (1) the affinity of EDTA to complex Ca and Mg, and (2) the ability of EDTA to form strong complexes with metals and prevent their subsequent re-adsorption or precipitation (Norvell, 1991). Both extractions infer that long term contact with surface waters will likely result in the low-level release of these elements, especially if the surface waters are buffered with natural chelating agents, e.g., fulvic acid and low molecular weight organic acids.

Conclusions

Dolomitic rock-waste was assessed to determine if metals leaching from these tailings were impacting a small Missouri Ozark stream. Aqua-regia extractions showed substantial reserves of Pb, Cd, Zn and other elements. Hot water and NaNO₃ extracts show that these materials have a small fraction of the total element pool that is labile or potentially labile. Lead, Cd and Zn recovered by EDTA suggests that dolomite weathering may allow a long-term, although at a low level, release of selected metals into the environment.

The severity of the elemental release would increase if soil or water conditions were to favor the congruent weathering of the dolomite, such as, microbial enhanced carbonation reactions:



Soil organic matter complexation may also augment the congruent weathering of the dolomitic waste-rock, as simulated by EDTA extraction. Thus, soil and geologic weathering processes may permit the continual release of metals; however, the kinetics of such releases is likely to be quite slow. The continual and slow release of Pb, Zn and Cd may not necessarily pose an appreciable threat to the environment because stream flow may effectively disperse these metals. However, further

research may elucidate chronic toxicity to aquatic organisms depending upon annual stream flow differences, the presence of particularly sensitive organisms, the presence of additional tailing spillage or other appropriate factors.

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A Comparison of Three Sampling Gears for Capturing Aquatic Turtles in Missouri: The Environmental Variables Related to Species Richness and Diversity

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Abstract: Donaldson Point Conservation Area (DPCA) is a lentic area within the Mississippi River floodplain that experiences seasonal flooding because of direct connectivity to the Mississippi River. Sampling for aquatic turtles was conducted during fall (October–November 2003) and spring (April–May 2004) using fyke nets, hoop nets and basking traps in both round and linear pools. Hoop nets were deployed with and without the use of leads, whereas paired fyke nets were positioned with their leads tied together or straight from the bank. The performance of each net and the turtle species captured were assessed. Catch-per-unit effort (CPUE) when using hoop nets and fyke nets was considerably greater in fall than in spring. Fyke nets set perpendicular to the bank produced a CPUE greater than did the other gears deployed in the spring and fall. We captured eight turtle species: *Trachemys scripta elegans*, *Graptemys pseudogeographica pseudogeographica*, *Alapone muticus muticus*, *Alapone spinifer spinifer*, *Sternotherus odoratus*, *Graptemys ouachitensis*, *Chrysemys picta dorsalis* and *Chelydra serpentina serpentina*. Species richness was greater in areas with deeper water with low transparency, and lower in water with high dissolved oxygen and with greater depth of hoop net deployment. Species abundance was the lowest when hoop nets were deployed in linear water bodies with high turbidity, lower pH and low dissolved oxygen. Because turtle species are important biotic components of large river communities, protecting floodplain aquatic habitats such as those found within DPCA may help sustain large river turtle assemblages.

Key Words: fyke net, hoop net, floodplain, Mississippi River, bootheel, *Trachemys*, *Graptemys*, *Alapone*, *Sternotherus*, *Graptemys*, *Chrysemys*, *Chelydra*

Introduction

Lentic areas within the Mississippi River floodplain have been understudied because of sampling difficulties (Bodie et al. 2000). Floodplain habitats have high productivity (Meganigal et al. 1997) and provide habitat for freshwater turtle feeding, immigration, and reproduction (Wigley and Lancia 1998, Bodie et al. 2000). Unfortunately, much of the lentic floodplain habitat in the southeast and south-central U.S. has been lost or degraded (Dahl 2000). In southeast Missouri, for example, less than 10% of the historic bottomland hardwood forests remain today (MDC, unpubl. data). Further, in the middle Mississippi River (MMR – reach of river from Cairo to St. Louis), the main river channel is disjunct from approximately 82% of its floodplain by an extensive levee system (Barko et al. 2006). Hence, little ecologically functional floodplain remains in this region.

Previous sampling projects in the MMR and southeast Missouri primarily emphasized fishes (Barko et al. 2004a, 2004b; Open Rivers and Wetlands Field Station, unpubl. data). As a result, turtle data from large river floodplains along the MMR are lacking. Baseline data are needed to better understand how floodplains influence large river turtle assemblages and to provide baseline data to evaluate of the faunal impacts of such projects as the proposed St. Johns Basin-New Madrid Floodway Project (USACE 2002).

The sampling methods available for capturing aquatic turtles include a variety of hoop net configurations, basking traps, hand picking, and visual observations (Ream 1966, Dreslik and Kuhns 2000, Ream and Thomas 2002). However, no single sampling method is effective for all species in all habitats. Sampling methods need to be evaluated and standardized so that comprehensive and comparable assemblage surveys can

be conducted throughout floodplains in Missouri and the southeast U.S. Furthermore, knowledge which methods are effective for sampling aquatic turtles in floodplains is needed to reliably document existing assemblages. Floodplain habitats in southeast Missouri provide habitat that could support rare species such as the Alligator Snapping Turtle (*Macrolemys temminickii*) and Western Chicken Turtle (*Deirochelys reticulariaria*) (Johnson 2000). Previous studies in this region yielded little information about the presence and quantity of these species, because these studies were species specific (Santhuff 1993, Shipman and Riedle 1994).

The objectives of this study were 1) to compare the number of aquatic turtles captured using three gear types and, 2) model the habitat variables that are correlated with species richness and species abundance.

Methods

Sampling Site

Our study was conducted at Donaldson Point Conservation Area (DPCA), New Madrid County, Missouri. This conservation area consists of a large river floodplain that is unobstructed by levees (Fig. 1). Hydrology is influenced by seasonal flooding by the Mississippi River (Fig. 2). Donaldson Point Conservation Area is dominated by a bottomland hardwood forest composed of eastern cottonwood *Populus deltoides*,

hackberry *Celtis occidentalis*, box elder *Acer negundo*, green ash *Fraxinus pennsylvanica*, pecan *Carya illinoensis*, silver maple *Acer saccharinum*, sweet gum *Liquidambar styraciflua*, and sycamore *Platanus occidentalis* (MDC 2000). Natural depressions and floodplain pools within DPCA support bald cypress *Taxodium distichum* and tupelo *Nyssa aquatica* (MDC unpublished data 2000). Blew holes, borrow pits, and chutes comprise 25.5 ha of the aquatic habitat. Aquatic habitat sampled and designated round or linear. Land use in areas surrounding DPCA is primarily agricultural, with the crops including cotton (*Gossypium hirsutum*), rice (*Oryza sativa*), soybeans (*Glycine max*), and corn (*Zea mays*) (MDC unpublished data 2000).

Sampling Techniques

Data were collected during October–November 2003 and April–May 2004. We sampled these months because water temperatures generally exceeded 15°C, which presumably ensured turtle activity (Finkler 2004).

Aquatic habitats were selected and designated round (R) or linear (L). We divided all aquatic habitats into 50 × 50 m grids using a Geographic Information System (GIS) and aerial photography. We then assigned each grid a number, and selected sampling sites using a random number generator. Three types of gear were deployed: hoop nets, fyke nets, and basking traps.

Hoop nets were 1.2 m long and consisted of seven fiberglass hoops, with the first being 1.2 m in diameter. Successive hoops decreased in 2.5 cm increments towards the cod end. The

Figure 1. Location of Donaldson Point Conservation Area, New Madrid County, MO. in relation to the Mississippi River. Site types, Round (R) and Linear (L) are also indicated.

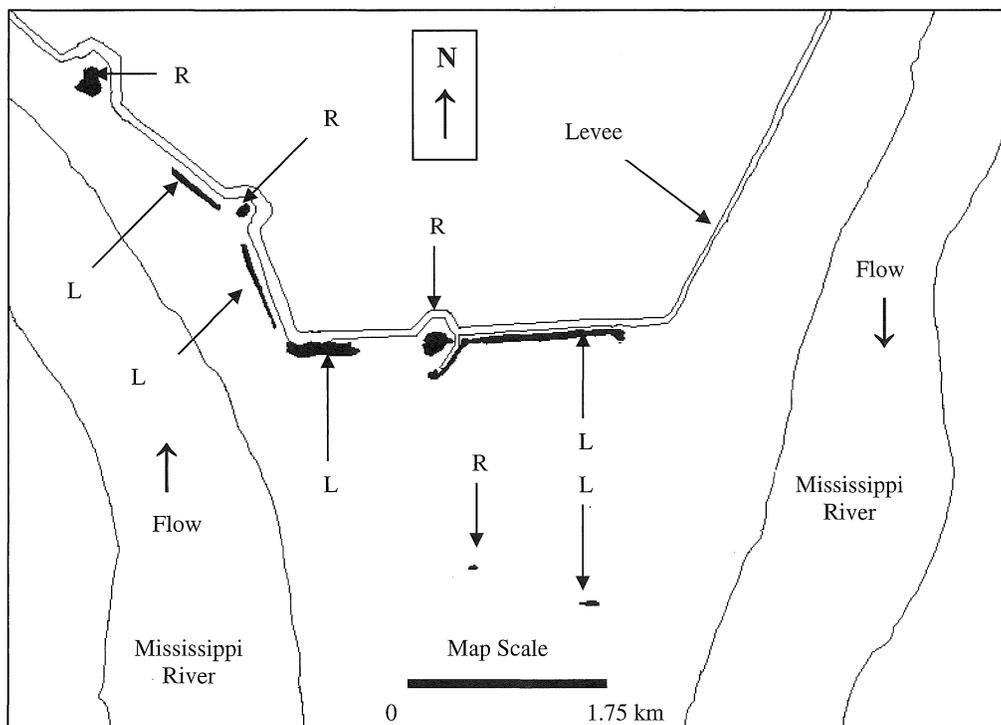
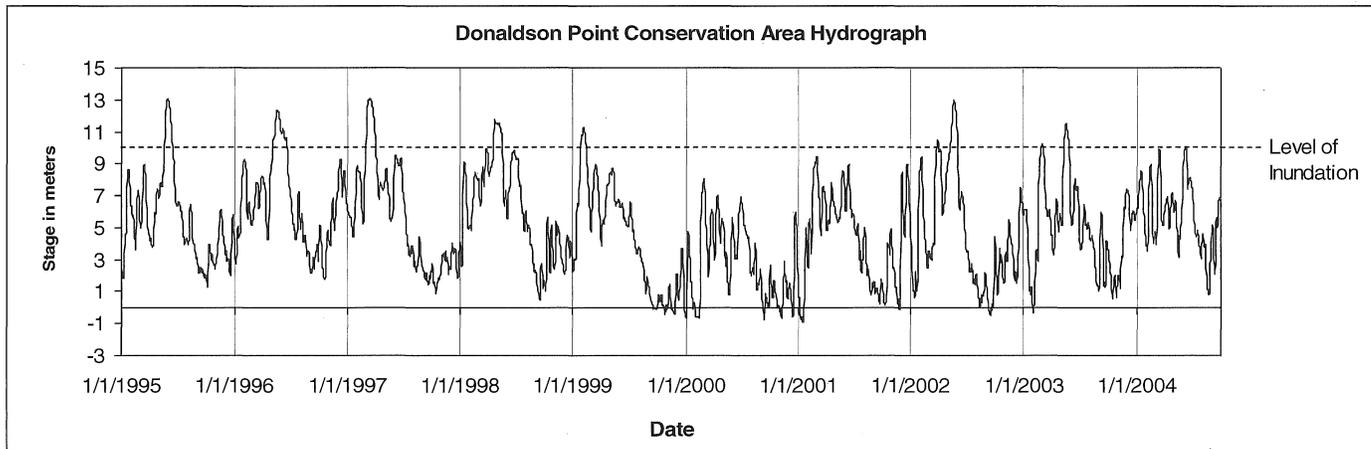


Figure 2. Seasonal flooding cycles where Donaldson Point Conservation Area is inundated at a river stage of 10 m. Location of river gauge (latitude. 36-34-59, longitude 89-31-56 at Lower Mississippi River KM 1430.7).



mesh was 1.8 cm bar (consistent with that of our fyke nets). Finger-style throats were attached at the second and fourth hoops of each net. The throat apertures (size of the throat opening) were 50.4 cm and 39.6 cm diameter, respectively. Hoop nets were set in two configurations to determine the effectiveness of a lead extending from the opening. Hoop net pairs with a lead were set with their open ends facing each other. Leads were 1.2 m \times 10 m with a mesh size of 0.32 cm bar. Hoop nets with no leads were run in the same configuration but bridles of 10 m \times 0.3 cm rope were used to hold the nets in place. Rock bags were attached to the cod ends of all net sets to prevent the nets from collapsing.

Fyke nets consisted of a lead, frame, and cab. The lead was 15 m long and 1.3 m high. The frame and cab together were 6.0 m long when fully extended. Two rectangular spring-steel rods that were 0.9 m high and 1.8 m wide formed the frame. Two mesh wings extended from the sides of the first frame to the middle of the second frame forming a 5.1 cm vertical gap, and the cab was constructed of six 0.9 m diameter steel hoops. There were two throats, one on the first hoop (40 mesh aperture) and on the third hoop (32 mesh aperture). Fyke nets were set in two different configurations to determine the efficacy of having one large lead between two fyke nets compared to two separate leads. One configuration consisted of two fyke nets tied lead to lead so that the combined lead length was 30 m. The second configuration was a single fyke net set with the lead tied to the bank with the remainder of the net running perpendicular into the water. For every fyke net pair set with leads tied together, two LTRMP fyke nets were run off the bank.

Basking traps consisted of 15.24 cm PVC cut into 0.9 m sections fitted together using 90° elbows to form a square float. From this float, 1.8 cm bar mesh netting was hung to form a basket underneath. From the top of the float, a 90 cm \times 5 cm \times 20 cm board was placed bisecting the float. At each end of the board, 50 cm \times 5 cm \times 20 cm boards were attached using hinges. These end boards angled down and into the water forming ramps that enabled turtles to climb onto the board to bask.

Each gear was set a minimum of 10 times each season. The sample site was recorded using Global Positioning System (GPS) coordinates, and all gear were baited with cut fish and set for 24 h. Bait consisted of a mixture of shortnose gar *Lepisosteus platostomus*, common carp *Cyprinus carpio*, bluegill *Lepomis macrochirus*, and gizzard shad *Dorosoma cepedianum* (Santhuff 1993). For each net set, the date, time, UTM, gear, site type, effort in time (h/min.), water temp (°C), dissolved oxygen (mg/l), Secchi disk visibility (cm), specific conductance (μ S/cm), and water depth at gear deployment (m) were recorded. All captured turtles were identified to species, abundance, and measured for carapace length (mm).

Statistical Analyses

Before analysis, we separated turtles into adult and juvenile categories following reported carapace lengths (Johnson 2000). We used a Principal Components Analysis (PCA) on each data set to reduce the dimensionality of the environmental variables (SAS v.6, 1989). We then used stepwise multiple regression with indicator variables in an effort to describe the relationship between the predictor and response variables (Neter and Wasserman 1974; Kullberg and Scheibe 1989; Barko et al. 2004a). For example, if sampling occurred in the spring, $X_1 = 1$ and 0 otherwise (i.e., fall sample). The default conditions were used for entrance into the model ($P \leq 0.15$), and only sampling episodes that captured turtles were used in these analyses.

The regression model for species richness had the form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

where X_1 represents Secchi transparency, X_2 represents dissolved oxygen, X_3 represents hoop netting, and X_4 represents depth of gear deployment.

The regression model for species abundance had the form:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

where X_1 represents Secchi transparency, X_2 represents dissolved oxygen, pH, and turbidity, X_3 represents hoop nets, and X_4 represents hole shape and season.

To evaluate the efficacy of each gear type, we compared overall CPUE for each gear type and CPUE for each species captured.

Results

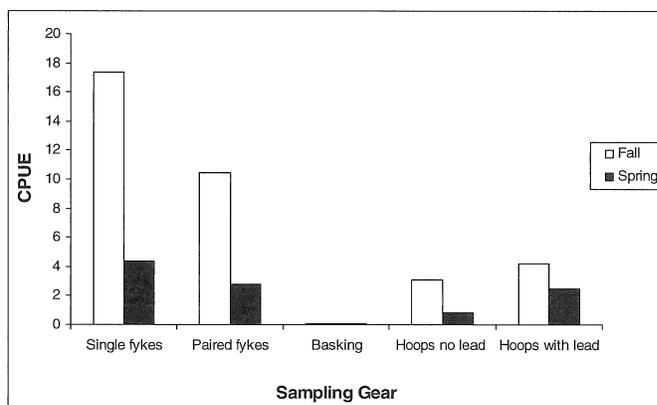
We captured a total of 724 turtles representing eight species (Table 1); 92% were adults and 8% were juveniles. Eighty-three percent of all turtles captured were trapped in fall. The most abundant turtle was red-eared slider *Trachemys scripta elegans* (64%), followed by false map turtle *Graptemys pseudogeographica pseudogeographica* (28%).

Single fyke nets captured the most turtles in both seasons, followed by fyke net pairs with attached leads, hoop nets with leads, hoop nets without leads, and basking traps (Fig. 2). The same trend held when CPUE was examined for species representing $\geq 1\%$ of the relative abundance (Fig. 3). Environmental variables measured at the sampling sites varied among seasons (Table 2). In summary, Secchi transparency, conductivity, temperature, net depth, pH and DO were generally higher in the fall, whereas turbidity was generally higher in the spring.

Table 1. Turtle species and abundance collected at sampling sites within Donaldson Point Conservation Area, Missouri, during fall 2003 and spring 2004.

Turtle Species	Fall 2003	Spring 2004	Total
Red-eared slider (<i>Trachemys scripta elegans</i>)	402	62	464
False map turtle (<i>Graptemys pseudogeographica p.</i>)	161	40	201
Common snapping turtle (<i>Chelydra serpentina s.</i>)	11	12	23
Stinkpot (<i>Sternotherus odoratus</i>)	16	1	17
Southern painted turtle (<i>Chrysemys picta dorsalis</i>)	8	2	10
Eastern spiny softshell (<i>Alapone spinifera s.</i>)	0	7	7
Midland smooth softshell (<i>Alapone muticus m.</i>)	0	1	1
Ouachita map turtle (<i>Graptemys ouachitensis o.</i>)	0	1	1
Total	598	126	724

Figure 3. Seasonal comparison of catch-per-unit effort (CPUE) by gear types deployed at Donaldson Point Conservation Area in fall 2003 and spring 2004.



For species richness, the first 7 PCA axes produced eigenvalues greater than 1.0 (3.1, 2.1, 1.7, 1.5, 1.3, 1.1, and 1.0, respectively), yet only axes 1, 2, 3, and 7 explained a significant amount of variation (41%) and remained in the stepwise regression model ($F = 18.84$, d.f. = 4, 107, $P < 0.0001$; Table 3). The eigenvectors that defined these axes were: PCA1 = Secchi transparency (-0.51), PCA2 = dissolved oxygen (-0.50), PCA3 = hoop nets (-0.75), and PCA7 = depth of gear deployment (0.70). Species richness was greatest when gears were deployed in deeper waters, whereas richness declined as transparency (Secchi depth) increased, dissolved oxygen increased, and hoop nets were deployed (Table 3). This model did not reveal any

Table 2. Mean (\pm SD) and range (in parentheses) of values for environmental variables collected at turtle sampling sites within Donaldson Point Conservation Area, Missouri, during fall 2003 and spring 2004.

Environmental Variables	Fall 2003	Spring 2004
Secchi transparency (cm)	57.2 \pm 17.9 (100–33)	36.8 \pm 12.4 (54–18)
Conductivity (μ S/cm)	404.7 \pm 65.7 (607–331)	384.8 \pm 15.4 (402–353)
Temperature (C°)	20.2 \pm 3.3 (25.7–14.0)	18.3 \pm 2.3 (22.5–14.5)
Depth at net deployment (m)	2.1 \pm 1.0 (4.5–0.5)	1.9 \pm 1.9 (9.8–0.6)
pH	8.0 \pm 0.7 (9.3–6.9)	7.9 \pm 0.4 (8.4–7.2)
Turbidity (NTU)	13.7 \pm 6.0 (27.0–6.4)	30.0 \pm 18.5 (74.0–11.5)
Dissolved oxygen (mg/L)	9.3 \pm 4.5 (17.3–3.6)	7.2 \pm 2.4 (11.3–3.2)
Mean fish length (mm)	160.8 \pm 28.5 (240.0–101.33)	174.1 \pm 61.2 (435.5–92.5)

Table 3. Results of the stepwise multiple regression analysis comparing species richness of turtles sampled at Donaldson Point Conservation Area, Missouri, to environmental variables measured at each sampling site and three gear types.

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	P	Model R ²
Intercept	1.2590	0.0850	177.5089	219.49	<0.0001	
PCA Axis 2	0.3686	0.0669	31.8992	39.44	<0.0001	0.2163
PCA Axis 3	0.3488	0.0662	22.4111	27.71	<0.0001	0.3682
PCA Axis 1	0.1099	0.0484	4.4628	5.15	0.0253	0.3965
PCA Axis 7	-0.1470	0.0839	2.4825	3.07	0.0826	0.4133

Table 4. Results of the stepwise multiple regression analysis comparing turtle species abundance environmental variables measured at each sampling site and three gear types deployed at Donaldson point Conservation Area, Missouri.

Variable	Parameter Estimate	Standard Error	Type II Sum of Squares	F	P	Model R ²
Intercept	5.0625	0.8024	2870.4375	39.81	<0.0001	
PCA Axis 2	2.0464	0.5542	983.1294	13.63	0.0004	0.0948
PCA Axis 3	2.1145	0.6256	823.7565	11.42	0.0010	0.1742
CA Axis 1	1.3731	0.4572	650.3244	9.02	0.0033	0.2368
PCA Axis 4	-1.0970	0.6552	202.0310	2.80	0.0971	0.2563

significant effects of conductivity, fyke nets, basking traps, turbidity, pH, hole shape, mean fish length, or season.

For species abundance, the first 7 PCA axes produced eigenvalues greater than 1.0 (3.1, 2.1, 1.7, 1.5, 1.3, 1.1, and 1.0, respectively), yet only axes 1, 2, 3, and 4 explained a significant amount of variation (26%) and remained in the stepwise regression model (F=9.22, d.f.=4, 107, P<0.0001; Table 4). The eigenvectors that defined the axes were: PCA1=Secchi transparency (-0.50), PCA2=turbidity (0.42), pH (-0.40), and dissolved oxygen (-0.50), PCA3=hoop nets (-0.75), and PCA4=hole type (0.52) and season (-0.48). Species abundance declined when Secchi transparency increased, hoop nets were deployed, gears were deployed in linear holes in the spring, and sample sites had higher turbidity combined with lower pH and dissolved oxygen. This model did not reveal any significant effects of conductivity, fyke nets, basking traps, depth at gear deployment, or temperature.

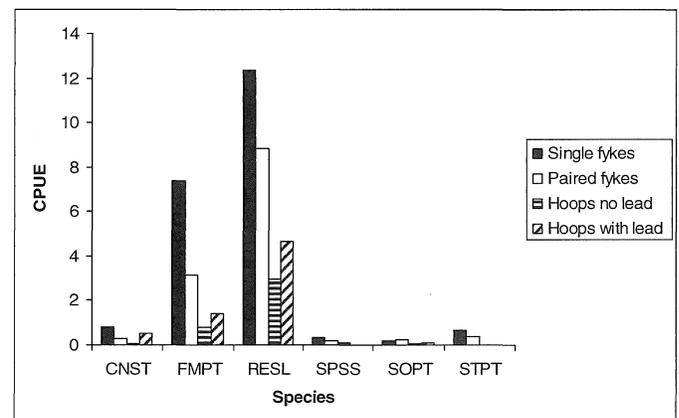
Discussion

Given the location of DPCA in relation to the Mississippi River, river water flows over and through the area at approximately 2–3 m/s at flood stage, which likely affected the spring assemblage. Studies have suggested that spring and fall mating peaks increases turtle activity (Cagle 1950). However, we captured more turtles in the fall, suggesting that activity was greater during this season. We speculate that the difference in relative abundance of turtles captured among our sampling seasons may be due to spring flooding of DPCA, contributing to higher turbidity levels. This may hinder the ability of turtles to carry out courtship rituals, which in turn may lead to lower turtle activity during spring mating peak. For example, courtship in

red-eared sliders as explained by Cagle (1950), consists of a delicate “dance” by the male who, positioned in front of the female, swims backwards while the female swims forward. While the dance takes place the male titilates the females head. This dance is highly unlikely to occur where water velocity is of 2 m/s (Cagle 1950, Ernst and Barbour 1972). Because of spring flooding at DPCA, turtles may concentrate their courtship and mating habits during the fall; hence, the reason catch was greatest during this season.

Seasonal flooding may have other implications regarding habitat use by turtles. Bodie et al. (2000) showed that *T. scripta*

Figure 4. Comparison of catch-per-unit effort (CPUE) by gear types for each species (CNST=common snapping turtle, FMPT=false map turtle, RESL=red-eared slider, SPSS=eastern spiny softshell, SOPT=southern painted turtle, STPT=stinkpot) captured at Donaldson point Conservation Area in fall 2003 and spring 2004. Basking gear and the mid-land smooth softshell was omitted due to low catch rate.



used scoured wetland habitats in the fall for overwintering, which may also help explain the greater number captured in the fall. Bodie and Semlitsch (2004) found that turtle species moved to seasonal wetlands from March–August because of the increased productivity in these habitats during this time. Lower water levels often occur in the fall, concentrating turtle populations (Cagle, 1950), which could also contribute to greater trapping success.

Red-eared sliders were caught in the greatest abundance in the fall and spring, which may be due to their preference for calm shallow water with the soft substrate, and presence of aquatic vegetation during much of the year (Cagle 1950, Ernst and Barbour 1972) which occurs at DPCA during much of the year. This species has not been shown to exhibit intraspecific competition through aggression for food or available habitat, which may contribute to the abundance commonly seen in red-eared sliders (Cagle 1950). Map turtles were less abundant at DPCA, likely because their preferred habitat includes large rivers and their adjacent backwaters (Ernst 1994), not floodplain pools. We speculate that these species were washed into the area because of seasonal flooding from the MMR, along with other big river turtle species such as spiny and smooth soft shells (Ernst 1999).

Observed species richness was greatest when fyke nets were deployed in deeper water. This may reflect the fact that our fyke net leads were set perpendicular to the bank, with depth being recorded at the cod end of the net. When deployed in deeper water, the lead extended across a greater range of depths, which could have captured different species that inhabit these different depths. Species differences in feeding may explain the differences in depth preference. For example, southern painted turtles forage along the bottom (Ernst 1994), whereas common snapping turtles may actively peruse or ambush their prey (Ernst 1994). Red-eared sliders forage along shallow edges (Ernst 1994), whereas false map turtles specialize in mollusks using a search and grab method (Ernst 1994). The lesser species richness in our hoop net captures is likely has a similar explanation. Hoop nets deployed, with or without leads, covered an area with a relatively consistent depth, and thus would probably not capture turtles foraging along the bank, reducing the likelihood of capturing species with this feeding strategy.

The fact that high transparency and low turbidity were associated with lower richness and abundance is likely a reflection of leads being used on most of our gears. In relatively clear water, leads and nets become more visible and may be more easily avoided by turtles. The lower catch of turtles during the spring in linear holes may be a consequence of linear holes having been more subject to flowing and deeper flood water, which would decrease turtle population density and, the lower catch (Cagle, 1950).

In general, our findings support those of Barko et al. (2004c) who also captured more turtles in fyke nets. Barko et al. (2004c) speculated that this was because of the 15-m lead attached to these nets, which likely created a greater opportunity for

turtles to come into contact with the gear. In our study, we used the same length lead, which was longer than the 10-m lead used on our hoop nets. Although hoop nets have been used in many turtle studies (e.g., Frazer et al. 1991, Busby and Parmelee 1996, Harrel et al. 1996) and have been reported to capture approximately 3 to 5 turtles/net night in southeast Missouri as bycatch (Barko et al. 2004c), our findings indicate that fyke nets have the greatest efficacy for capturing turtles in large river floodplain systems, especially in the fall.

Our study suggests that large river floodplain turtle assemblages may respond to seasonal cues differently than lentic assemblages that are not subjected to unpredictable flood spates. The presence of large river species in our floodplain habitats suggests that lentic floodplain pools, with seasonal connections to large rivers, may be important for these species. Because information on the effect of flood pulse on the behavior of turtles is unknown, studies in large river floodplains are warranted.

Acknowledgments

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Antimicrobial Activity of Mono- and Di-Methyl Substituted Benzhydrols and Benzophenones *In Vitro*

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Abstract: Twelve compounds of mono methyl and symmetrical dimethyl substituted benzhydrol and benzophenone were synthesized using standard synthetic procedures and screened for possible antimicrobial activity against thirteen known Gram-positive and Gram-negative bacteria, as well as two yeasts. Most benzhydrol and benzophenone derivatives under investigation demonstrated some antimicrobial activity, with ortho-methylbenzophenone, dapsone, meta-dimethylbenzophenone, and para-dimethylbenzhydrol showing the greatest inhibition. Only four compounds, ortho-methylbenzhydrol, para-methylbenzhydrol, para-methylbenzophenone, and para-diaminobenzophenone, completely lacked antimicrobial activity. An Analysis of Variance (ANOVA) showed a significant difference between both the microorganisms and the chemical compounds used, which may provide insight into novel compounds to combat infections in humans and animals.

Key Words: Antimicrobial, Bacteria, Benzhydrol, Benzophenone, Yeast

Introduction

Bacteria and fungi continually evolve mechanisms to evade antimicrobial agents, causing drug resistance problems when treating human and animal infections. As natural or synthetic pharmaceutical drugs become less effective on microbes due to resistance mechanisms, new agents must be discovered or developed to combat this problem (Waugh and Long 2002). This process can encompass screening known natural and synthetic agents, or chemically synthesizing derivatives of known compounds (Ma *et al.* 1999, Setti and Micetich 2000).

Computational studies (Dais 1990, Gore *et al.* 1980, Trovato *et al.* 1973) and crystallographic studies (Kutzke *et al.* 1996) have been performed for benzophenone and benzhydrol

derivatives to determine conformational preferences and minimum energy structures, but investigation of the use of these small molecules with unique conformations in medicine is minimal. Studies of benzophenone reduction by microorganisms (fungi and bacteria) conducted by Spassov *et al.* (1993) showed that benzophenone could be taken up by microbes and be used in their metabolic pathways. Therefore, the antimicrobial activity of benzophenone and benzhydrol (the reduced product of benzophenone, a metabolite in the process), which has not been previously investigated, warrants scientific investigation. This study compares potential antimicrobial activities of mono- and dimethyl-substituted benzhydrols and benzophenones on various microorganisms.

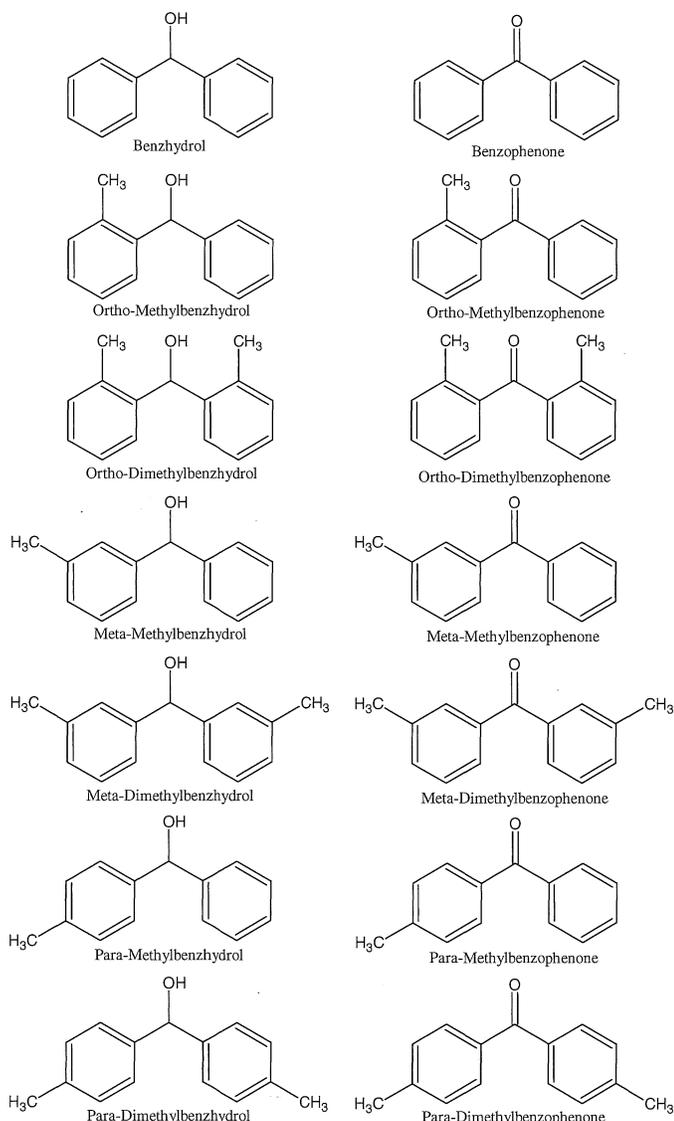
A series of methyl derivatives of benzophenone and benzhydrol were synthesized. Gram-positive and Gram-negative bacteria and yeast were subjected to the compounds to determine initial susceptibility since very little has been published thus far on the compounds. The substitution of methyl groups introduces lipophilicity to the compound without adding bulky side chains (Coleman *et al.* 1997).

Materials and Methods

Compounds

ortho, *meta*, and *para* mono-methyl substituted benzhydrols (Fig. 1) were prepared using benzaldehyde and a corresponding bromotoluene isomer utilizing a standard Grignard Reaction (Zanger and McKee 1995). Symmetrical di-methyl substituted benzhydrols (Fig. 1) were prepared using substituted bromotoluenes and respective tolaldehydes. All starting materials to prepare the compounds were purchased from Sigma-Aldrich (St. Louis, MO). All benzhydrol derivatives and benzophenone derivatives are known in the literature, but only

Figure 1. Benzhydrol and benzophenone compounds used in this study.



a few were commercially available during our studies. All starting materials and subsequent products were characterized by proton Nuclear Magnetic Resonance (NMR) spectroscopy, C-13 NMR with a 270 MHz Jeol spectrometer, and melting point determination for solids. Spectral data for all compounds were matched with the literature values.

Synthesis of Benzophenones

Mono- and di-methyl substituted benzophenones (Fig. 1) were synthesized from mono- and di-methyl substituted benzhydrols via a silica gel-supported Jones Oxidation. Ten grams of silica gel was added to a 250 mL Erlenmeyer flask. Jones Reagent (Ali and Wiggin 2001) (2.7 M, 8.8 mL) was added drop-wise to the silica gel with stirring until an orange "slurry" was formed. An additional 30 mL of dichloromethane

was added to the reaction mixture after the slurry was formed with the substituted benzhydrols (250 mg, mono = 1.267 mmol, dimethyl = 1.183 mmol). The reaction mixtures were allowed to stir vigorously at room temperature overnight. Upon completion, the mixture was filtered, washed with three 10 mL portions of dichloromethane, the solvent was removed on a rotary evaporator, and then dried on a vacuum pump. Depending upon the states, products were recrystallized using hexane, and dried under vacuum before the antimicrobial study was conducted. Tables 1 and 2 show the states of benzhydrol and benzophenone, and the percent yields. The commercially available *para*-diaminobenzophenone and *para*-dihydroxybenzophenone structures are depicted in Figure 2.

Bacteria and growth

Fifteen different microorganisms including Gram-positive, Gram-negative, and yeasts were used in this study. Cultures were purchased from Hardy Diagnostics (Santa Maria, CA) or Wards Scientific (Rochester, NY) and subjected to biochemical testing before experimentation to ensure bacterial purity and identity. Cultures included *Bacillus cereus* ATCC 14579, *Candida albicans*, *Citrobacter freundii* ATCC 8090, *Enterobacter*

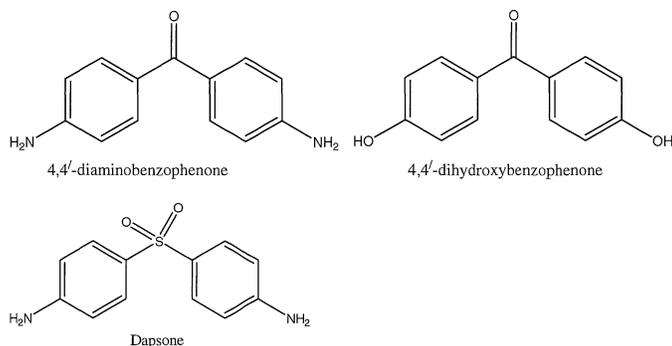
Table 1. Compound characteristics of the benzhydrol derivatives.

Compound	State	Percent Yield
Benzhydrol		
Ortho-Dimethylbenzhydrol	Liquid	82
Ortho-Methylbenzhydrol	Liquid	81
Meta-Dimethylbenzhydrol	Solid (mp 118°C)	82
Meta-Methylbenzhydrol	Solid (mp 95°C)	69
Para-Dimethylbenzhydrol	Liquid	81
Para-Methylbenzhydrol	Liquid	59

Table 2. Compound characteristics of the benzophenone derivatives.

Compound	State	Percent Yield
Benzophenone	Solid	Commercially available
Ortho-Dimethylbenzophenone	Liquid	Quantitative
Ortho-Methylbenzophenone	Liquid	yield
Meta-Dimethylbenzophenone	Solid (mp 72.5°C)	ranging form
Meta-Methylbenzophenone	Liquid	95–98%
Para-Dimethylbenzophenone	Solid (mp 95°C)	
Para-Methylbenzophenone	Solid (59°C)	

Figure 2. Diamino- and dihydroxy-benzophenones and dapsone used in this study.



cloacae ATCC 13047, *Escherichia coli* ATCC 14948, *Micrococcus luteus* ATCC 9341, *Micrococcus roseus*, *Mycobacterium phlei*, *Providencia stuartii* ATCC 33672 49809, *Pseudomonas aeruginosa* ATCC 27853, *Saccharomyces cerevisiae* ATCC 2601, *Serratia marcescens* ATCC 14756, *Shigella flexneri* ATCC 9199, and *Staphylococcus aureus* ATCC 6538. *Bacillus cereus* produces toxins, endospores, causes food poisoning, and was chosen for its similarity to *Bacillus anthracis*, the gram positive causative agent of anthrax. Since we wanted to compare two yeasts, *Candida albicans*, a dimorphic yeast known to cause reproductive tract infections, thrush, and nosocomial deaths, and *Saccharomyces cerevisiae*, used in fermentation and usually considered non-pathogenic, were chosen for this study. *Enterobacter cloacae*, *E. coli*, *Providencia stuartii*, *Serratia marcescens*, and *Shigella flexneri* belong to the Gram-negative Enterobacteriaceae family known to inhabit the intestines of humans and animals. They all cause urinary tract infections, food-borne infections, are opportunistic pathogens, and can be drug resistant, leading to death. *Micrococcus luteus* and *M. roseus* are Gram-positive bacteria commonly found in the environment that do not produce endospores or toxins, and are rarely pathogenic. *Pseudomonas aeruginosa* is a gram negative, multi-drug resistant bacterium that is pathogenic causing skin, ear, lung, and urinary tract infections, with only a few drugs available for treatment. *Mycobacterium phlei* contains mycolic acid as part of its cell wall, which allows it to be drug resistant, and is considered to be an acid-fast bacterium. We chose this microbe because we could not work with the more pathogenic *Mycobacterium tuberculosis* or *M. leprae*, which cause tuberculosis and leprosy respectively, but we could determine if a drug could potentially penetrate the mycolic acid layer. Finally, *Staphylococcus aureus* is a Gram-positive skin bacterium that produces many toxins, is a leading cause of nosocomial and food-borne infections, and can be drug resistant.

Bacteria were initially grown on Tryptic Soy Agar (TSA) or Nutrient Agar (NA), yeasts were incubated on Sabouraud (Sab) Agar, and all cultures were subsequently transferred to broth. *Mycobacterium phlei* was grown on TSA supplemented with sterile glycerol. All cultures were incubated for 24–48 h at

their optimal temperature (25°C, 30°C, or 37°C) to achieve log phase growth.

In vitro antimicrobial assessment

Mueller Hinton plates (pH 7.3) were inoculated with a microbial lawn of growth from standardized broth cultures, which were measured by spectrophotometry at 625 nm. Powdered solids were aseptically weighed and 10 mg was added to the surface of the agar. Liquids (7 μ l) were added directly to blank disks measuring six mm in diameter, and plates were incubated at the optimal temperature for 24–48 h. Final concentrations of the liquids were 0.007567 g for monobenzhydrol, and 0.007469 g for dimethylbenzophenone. Zones of inhibition were measured and recorded. The Clinical and Laboratory Standards Institute guidelines (2007) mix insoluble compounds with dimethyl sulfoxide (DMSO) to determine the minimum inhibitory concentration, but no consideration is given to compound structure or functionality when it is mixed with the DMSO in a research setting. Thus, for solids, zones were measured in two perpendicular locations since no work has been performed on insoluble solids to achieve standardization (Gould 2000). Inhibition ratios were determined by dividing the zone of inhibition area by the compound area, thus allowing for comparisons between liquids and solids. A ratio of one represents no compound activity.

Results

Antimicrobial Effectiveness

The null hypothesis was that no difference existed for the inhibition ratios between compounds and between organisms. An analysis of variance (ANOVA) for the fourteen compounds revealed a *P* value of 0.026, thus demonstrating significance ($P \leq 0.05$) between the compounds, and testing of each organism revealed a value $P < 0.0001$, demonstrating that there was also a difference in the ratios seen between the microbes.

Six compounds, *ortho*-methylbenzhydrol, *ortho*-dimethylbenzhydrol *para*-methylbenzhydrol, benzophenone, *para*-methylbenzophenone, and *para*-diaminobenzophenone completely lacked antimicrobial activity by demonstrating no zones of inhibition. Of the six, only *para*-methylbenzophenone is a solid, with the rest in a liquid state. Minimal inhibitory activity (a ratio < 3.5) was seen by *ortho*-dimethylbenzophenone and *meta*-methylbenzophenone against all microbes tested.

A ratio of five was used to qualify a microbe as inhibited, since the inhibition zone was considered large enough to avoid any technical error. A ratio of five meant that for discs, the zone of inhibition was at least 30 mm, and for solids, the zone was at least 30 mm and could potentially be even larger, depending on the surface area of the solid. According to the Clinical and

Laboratory Standards Institute guidelines (2007) for reference microbes, zones from 18–21 mm and greater were classified as sensitive. Thus, we can be confident that those microbes were indeed inhibited by the compound with a ratio of five. The other nine compounds demonstrated antimicrobial activity with at least one microbe having a zone ratio greater than five. Based upon the sizes of the inhibition zones, dapsone, benzhydrol, monomethylbenzhydrol, *ortho*-methylbenzophenone and *meta*-dimethylbenzhydrol showed the greatest inhibition, exhibiting ratios above 25, which is shown in Table 3. Two compounds, *para*-dimethylbenzhydrol and *ortho*-dimethylbenzophenone, each inhibited eight microbes, thus demonstrating broad spectrum activity. *meta*-dimethylbenzhydrol, *meta*-dimethylbenzophenone, and *para*-dihydroxybenzophenone each inhibited five microbes. Dapsone and *meta*-methylbenzhydrol each inhibited two bacteria, whereas benzhydrol and *para*-diaminobenzophenone each inhibited one bacterium.

Bacterial responses to the compounds are also shown in Table 3. *Citrobacter freundii* was resistant to all the compounds tested, whereas *M. phlei* and *M. roseus* was susceptible to six of the compounds. *Micrococcus luteus* showed susceptibility to five compounds. *Pseudomonas aeruginosa* was the only microbe susceptible to *para*-dimethylbenzophenone, but it was also inhibited by *ortho*-methylbenzophenone and *meta*-dimethylbenzhydrol. The two yeasts were both susceptible to *ortho*-methylbenzophenone and *meta*-dimethylbenzophenone. All other bacteria were inhibited by at least one compound.

Discussion

The most broad spectrum compounds were *ortho*-methylbenzophenone and *para*-dimethylbenzhydrol. The yeasts *Candida albicans* and *Saccharomyces cerevisiae* both showed similar inhibition zones to *ortho*-methylbenzophenone and *meta*-dimethylbenzophenone, although *C. albicans* was also susceptible to *para*-dimethylbenzhydrol. Benzhydrol and *para*-dimethylbenzophenone appeared to have narrow spectrum activity to one bacterium, *M. phlei* and *P. aeruginosa*, respectively. Besides *M. phlei*, *M. luteus* and *M. roseus* were the most susceptible to the compounds, which is expected of environmental microbes due to lack of antibiotic selective pressures.

Although the cut-off for the significant values were based upon the zone of inhibition ratios so that solid and liquid compounds could be compared, one must keep in mind that organisms demonstrate variability in sensitivities of up to 2 mm (Gould 2000). Media pH can affect the zone sizes seen on the media. Zones can be too small if the pH of the media is too low, or vice versa. Our media pH was 7.3, and inoculation and incubation conditions were all within guidelines (Clinical Laboratory Standards Institute 2007). Since the compounds have a high pK_a , the pH of the media was not changed and did not affect zone sizes.

The numbers bold-faced in Table 3 indicate the microbes and compounds who exhibited five mm zones and greater.

Although some microbes were not highly inhibited, we are still able to report that these compounds do inhibit microbes to some extent, and can possibly be developed as alternative antimicrobial agents to existing, sometimes ineffective, drugs. Each compound's solubility was tested in deionized water and found to be poorly soluble. Benzhydrol is slightly soluble in water, but benzophenone is reported as insoluble (www.chemcialland21.com), which correlates with the lack of antimicrobial activity seen by the benzophenone. However, the addition of methyl groups appears to allow some of the derivatives to become slightly soluble and exhibit antimicrobial activity. Since the disk diffusion method is based upon agents diffusing into the agar media in order to control microbial growth, this makes the results of the inhibition zones even more profound. The compounds which demonstrated an inhibition zone below five may even be more effective *in vivo* than our results suggest. Further, the results of the small zones must be carefully evaluated since increasing the agents' bioavailability may also increase their effectiveness. Industrial applications such as antimicrobial agents in cosmetics and fuel lines of naval ships may exist.

Mycobacterium phlei was greatly inhibited by six compounds. Dapsone was used as a control for *Mycobacterium* (Levy 1976) as it is commercially available and standardized inhibition zones are known with this compound. Other antibacterial studies performed in the laboratory on the same strain of *Mycobacterium* (data not shown) showed standard resistance patterns to most antibiotics, so the strain was not considered unusually susceptible to compounds. Drug resistance is often due to the impervious mycolic acid layer on the outside of the cells of *Mycobacterium leprae* and *M. tuberculosis*, so these results show potential new drugs to treat these disfiguring and deadly diseases.

Another major finding was that *para*-dimethylbenzophenone only inhibited the highly resistant bacterium, *P. aeruginosa*. *Pseudomonas* is well documented to use alternative metabolic pathways like the Entner Duoderoff pathway, so this could explain why no other microbes were inhibited. *ortho*-methylbenzophenone and *meta*-dimethylbenzhydrol also showed activity against this pathogen. *Pseudomonas* frequently grows in disinfectants and causes swimmer's ear, wound infections, and is often a cause of death in burn patients.

Staphylococcus aureus, a major cause of nosocomial and wound infections, was inhibited by *para*-dimethylbenzhydrol. Due to increasing drug resistance, overall cost to society in billions of dollars per year (Rubin *et al.* 1999), and human deaths attributed to this bacterium, any new potential drug should be evaluated.

Candida albicans, a major cause of reproductive tract yeast infections in women and thrush in immunocompromised individuals, was inhibited by *ortho*-methylbenzophenone and *para*-dimethylbenzhydrol. Since yeasts are eukaryotic, further studies would need to be performed to determine potentially harmful effects on human cells.

The promising results we obtained against *Mycobacterium*, *Pseudomonas*, *Staphylococcus*, and *Candida* are even more

Table 3. Ratios of antimicrobial activities as determined by dividing the compound area by the inhibition zone. Highlighted squares indicate zones of inhibition of ≥ 25 mm and bolded numbers represent zones ≥ 5 mm. Abbreviations: Daps = dapsone, BH = benzhydrol, OMB = *ortho*-methylbenzhydrol, ODMB = *ortho*-dimethylbenzhydrol, MMB = *meta*-methylbenzhydrol, MDMB = *meta*-dimethylbenzhydrol, PMB = *para*-methylbenzhydrol, PDMB = *para*-dimethylbenzhydrol, BP = benzophenone, OMBP = *ortho*-methylbenzophenone, ODMBP = *ortho*-dimethylbenzophenone, MMBP = *meta*-methylbenzophenone, MDMBP = *meta*-dimethylbenzophenone, PMBP = *para*-methylbenzophenone, PDMBP = *para*-dimethylbenzophenone, PDHBP = *para*-dihydroxybenzophenone, PDABP = *para*-diaminobenzophenone.

	Daps	BH	OMB	ODMB	MMB	MDMB	PMB	PDMB	BP	OMBP	ODMBP	MMBP	MDMBP	PMBP	PDMBP	PDHBP	PDABP
<i>B. cereus</i>	3.75	3.667	1	1	2.04	3.714	1	8.571	1	2.286	1	1	3.184	1	1.6	3.75	1
<i>C. albicans</i>	1	2.27	1	1	3.673	2.918	1	13.796	1	21.778	1	1	6.245	1	3.3	1	1
<i>C. freundii</i>	3.517	1	1	1	2.245	1	1	1.102	1	1.8	1	1	2.02	1	1	1.5	1
<i>E. cloacae</i>	1.067	1.92	1	1	1.796	5.816	1	7.714	1	4.767	1.203	2.02	3.429	1	1	6.38	1
<i>E. coli</i>	1	2.763	1	1	1	1	1	1.306	1	1	1	1	1	1	1	8	1
<i>K. pneumoniae</i>	1	1.65	1	1	2.245	1	1	1	1	12.5	1	1	1	1	1	1.944	1
<i>M. luteus</i>	1	2.222	1	1	4.571	5.143	1	18.367	1	7.875	1.481	1	8.449	1	1.867	10.357	1
<i>M. roseus</i>	1	2.743	1	1	10	5.551	1	18.163	1	11.333	1.3	1	18.367	1	2.24	7.14	1
<i>M. phlei</i>	100	27.188	1	1	25.306	3.429	1	6.429	1	36.417	1	1.469	48.98	1	1	2.75	1
<i>P. stuartii</i>	1	1.778	1	1	1.653	1	1	4.163	1	3.575	1.143	1	3.061	1	1	5.25	1
<i>P. aeruginosa</i>	1.429	1.2	1	1	3.449	15.429	1	1	1	28.125	1.212	3.184	1	1	14.667	1	1
<i>S. cerevisiae</i>	1	1.909	1	1	3.98	1	1	1	1	19.5	1.731	1.837	6.612	1	4.667	1	1
<i>S. marcescens</i>	8	1.328	1	1	1	11.102	1	4.571	1	1	1.821	1	1	1	1	2.4	1
<i>S. flexneri</i>	1	1	1	1	1	4.408	1	8.143	1	7.4	1.658	1.561	1	1	1	3.6	1
<i>S. aureus</i>	1	1.95	1	1	2.245	4.286	1	7.367	1	4.375	1	1	2.245	1	2.4	3.091	1

significant since these microbes often exhibit antimicrobial resistance problems in clinical settings, and can cause death in humans and animals (Poikonen *et al.* 2003, Rubin *et al.* 1999, Van Delden and Iglewski 1998). Any new drugs to combat these microorganisms could help alleviate some chronic infections, to which there currently is no treatment.

The location of the methyl groups does appear to have an effect on the compounds ability to serve as an antimicrobial. Benzophenone lacked activity, but the *ortho*-methylbenzophenone exhibited broad spectrum activity against a large number of microbes, and *para*-dimethylbenzophenone only inhibited *Pseudomonas*, thus demonstrating narrow spectrum activity. Although we do not know the mechanisms of antimicrobial activity at this time, placement of the methyl groups, as well as dimethyl composition, appears to show differences in activity among the various microbes.

Due to the lack of activity by racemic monomethylbenzhydrols, we did not pursue synthesis of enantiomerically pure monosubstituted benzhydrols (Ohkuma *et al.* 2000), although this could be a potential new avenue to pursue in antimicrobial agent development.

Acknowledgments

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Determining the Relative Canopy Coverage with a Digital Image and Adobe Photoshop®: A Pilot Project to Introduce a Low Cost Technique

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Abstract: *Determining canopy coverage in rice (*Oryza sativa* L) between the 4th tillering stage to internode elongation to harvest allows the assessment of the degree of tillering and indicates the adequacy of the nitrogen fertilization program. This investigation is a technique project to determine if images obtained from moderately priced digital cameras (\$200–\$300 range) and commercially available imaging processing software (Adobe Photoshop®) may effectively estimate the percent canopy coverage. The image analysis is performed using the “magic wand” feature in the software package to isolate and then recolor the soil using the “paint bucket” feature to enhance the color contrast. The second procedure involves overlaying the image with a grid so the percent canopy cover area can be estimated for the area of the photograph. Preliminary work in the field shows that this technique can discriminate canopy coverage in high and low nitrogen plots in rice.*

Key Words: *rice, remote sensing, canopy coverage, plant density*

Introduction

Nitrogen is a key component in the production of rice, promoting yield primarily by increasing the degree of tillering and greater panicle development. Nitrogen also promotes photosynthesis on a unit leaf area basis, translating into a greater overall field photosynthesis rate (Cassanova, et.al., 1998; Ackerly, et. al., 1999; Jiang, et. al., 2005; Omar, et. al., 2006). Previously plant area boards have been employed to gauge mid-season N application; however, these field measurements are labor and time-consuming (Ntamatugiro, et. al., 1999)

A need exists for a method to evaluate or measure the efficiency of the pre-flood N fertilizer applications during the 3rd to 4th tiller period or at panicle differentiation. Plant tissue measurements of total N is misleading because N concentrations

may not appreciably vary from N-deficient plants to N-sufficient plants because tillering in properly nitrogen fertilized fields will produce greater biomass and effectively dilute the nitrogen concentration. Rice fields that have low rates of N may tiller poorly and maintain relatively high N concentrations because of the lack to vegetative development to “dilute” the nitrogen (Takebe, et. al., 1990; Jiang, et. al., 2005).

A method should be able to measure the degree of tillering, especially when coupled with N tissue concentrations. The use of remote sensing techniques offers the promise of rapid field estimation of tillering, especially if the techniques are rapid and relatively easy to perform; so that, fertilizer application can be adjusted. Remote sensing techniques are currently not available to moderately-sized rice farms, thus a farmer-available method is desired.

Recent developments in digital photography and the availability of image manipulating software (Adobe Photoshop®) permit growers to estimate rice tillering. These digital photographs are sufficiently small scale that geo-rectification is unnecessary.

We define canopy coverage to be the percent of soil covered by foliage. Canopy coverage is a response of plant tillering, given that additional culms per plant will permit a greater vegetation mass to occupy a given land area. Canopy coverage is frequently correlated with field biomass and, in turn, the harvestable yield (Freeman et. al., 2006). Any technique that allows rice farmers to evaluate canopy coverage gives a tool for determining if additional fertilizer is necessary or if interventions should be performed to maximize field yields.

Materials and Methods

The proposed technique is non-invasive and is best performed just before panicle differentiation, but may be performed at any time during the growing season. The requirements

for this technique are: (1) a digital camera, (2) a camera tripod, (3) a computer capable of processing the necessary software packages and (4) the Adobe Photoshop® package (Adobe Photoshop Elements® will also perform adequately).

Field work entails setting up the camera on the tripod. The photographer must maintain a uniform height and angle of the camera when comparing one area to another. The choice of angle for the camera is vertical or as near vertical as possible, allowing the image to reveal the most soil in relation to plant material and minimizing diept of field distortion.

Taking photos of different areas of the field using a randomized sampling technique is the next process. Good technique involves choosing camera directions that minimizes shadowing. In this pilot project, we oriented the camera both parallel and perpendicular to the row direction and subsequently determined that parallel to the row orientation resulted in substantially better images for subsequent processing.

Computer processing entails opening the images in Adobe Photoshop®. The magic wand tool is a software feature that

permits isolation by pixel similarity. Using the “magic wand tool” soil areas are isolated because of their spectral patterns. To accomplish this procedure necessitates “fine tuning” the magic wand tool. The magic wand tool has a “tolerance” setting that allows for increasing or decreasing selectivity for discriminating between soil and vegetation. It is necessary to choose a tolerance setting that minimizes plant material in shadows from being grouped with the soil. In this study several tolerances were attempted and a tolerance of 10 was found to minimize plant material inclusion. The “similar” feature of the magic wand allowed the grouping of other portions of the image that had similar light reflectance, saturation and hue. Thus the magic wand tool is used to isolate one soil area in the image and the “similar” feature selects all of the remaining soil portions or areas.

Once the soil has been discriminated throughout the image the next procedure involves marking the grouped areas. This task is accomplished with the “bucket” tool. A color is selected that has a substantial contrast (white or red) and the bucket tool

Figure 1. Digital photograph of rice stand being considered.



Figure 2. Rice stand cropped to limit area for determining percent coverage and stained for ease in differentiating soil from plant.



Figure 3. Grid in place on Fig. 2 for percent area coverage.



stains the areas that the magic wand tool and similar feature has selected.

A grid is created by accessing the file portion of the tool bar and opening “new” with a transparent background, creating a blank image with no background (Adobe, 2006). This blank-background is set to the desired pixel size and we employed both 50 and 20. The reason for two grid sizes is that one desires a grid that excludes as much of the vegetation from the soil as possible; so that, when you calculate the percent vegetation partially filled grid cells do not appreciably bias the results. The grid was created using the line tool to boarder this image. The image is saved as a pattern (using define pattern) under the programs Edit feature. The grid is superimposed on the image using the Edit-Fill feature (Adobe, 2006). Having the soil stained with a distinctive color permitted easy calculation of the amount of soil (or plant material) as an estimation of canopy coverage.

The same effect can be accomplished with the less expensive Adobe Photoshop Elements 5.0. With this program you can use the “magic brush” tool. To “draw” with this tool on areas that you wish to select by holding down the left mouse button as you draw. When you release the mouse, Adobe Photoshop Elements 5.0 will select areas that are similar to those you have selected. This will act like the magic wand and similar utilities discussed earlier. As with the magic wand you can modify the pixel size selection. For the magic brush this is accomplished with the size selection. The larger the size the more will be selected, giving you things that you may not want. The grid is formed again by file, new (select transparent for the background). Lines of 1 pixel size are placed and the image flattened (layers, merge layers). Go to edit and select define pattern. You can name your pattern. Bring up the selected image of your stand with the selected areas colored and use the edit, fill, custom, pattern to superimpose the grid on the photo. Adobe Photoshop Elements 5.0 is significantly less expensive than Adobe Photoshop but still seems capable of classifying areas so that stand density can be calculated.

The technique for both Adobe Photoshop Elements® 5.0 and Adobe Photoshop® are similar to the analysis done in remote sensing. Here the technician selects training sites to train the computer to group like area with regards to light reflectance over several band widths (Cassanova et. al., 1998). This is mimicked by the magic wand and the magic brush tools, where the user selects an area and the magic wand “similar” function and the magic brush group areas according to similarities of hue, saturation and brightness.

With the Adobe Photoshop® technique, a low cost commercial software is used on digital images from a camera. This system is cost effective relative to high cost of acquiring software and satellite or hyperspectral images and it is less labor intensive relative to plant area board (rice gauge). While it may not be as exact, it is fast, readily available and easy to use with little training necessary. This technique could be easily adapted for use with any crop, or for plant management for

lumber, forage etc. This procedure may be used with aerial photographs be used with aerial photographs.

Example to Illustrate the Technique

Figure 1 shows a digital photograph of the rice. The angle of the camera (~15% with respect to the soil surface normal) had the height (approximately 1.7 meters) for all images of the rice field. The image is then transferred to Photoshop where the supervised classification is performed using the magic wand tool. The similar areas were stained to increase contrast (Fig. 2 — the contrast is extreme in color). The photo can be cropped at this point to limit the area to count. A grid is fabricated and placed using the file new, line and overlay tool as seen in Figure 3. The percent coverage can then be manually estimated.

The technique discussed has a broad range of applications. Stand density is used in forestry as well as in biology. General plant counts for an area in the field are time consuming and there is no way to duplicate them at a later date. This technique overcomes these drawbacks by creating a permanent record of the area and giving a method to also monitor changes in plant size without having to measure individual plant diameters.

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Multispectral and Biogeochemical Evaluation for Possible Smelter and Power Plant Emission Effects on Trees in a Missouri Conservation Area and Illinois Nature Preserve

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Abstract: Stack emission and deposition of heavy metals from industrial sites continues to be an environmental concern, and the effects of it on particular ecosystems need to be further investigated. This has become more practicable with recent advancements in information gathering systems and analysis techniques, like those afforded by remote sensors and GIS. The intent of this research was to determine the utility of Landsat multispectral imagery, biogeochemical sampling of black oak trees, and hyperspectral scanning of leaf reflectance for the purpose of assessing forests at the Magnolia Hollow Conservation Area in Missouri and the Fults Hill Nature Preserve in Illinois, both located downwind from a lead smelter facility and a coal fired power plant. Vegetation index models using multiband images were derived to characterize tree health status at the time of leaf sample collection, and change detection analysis was conducted to quantify temporal variations over a 13 year period. Multivariate statistics were used to identify relationships between spectral reflectance, biogeochemistry, and forest attributes. Preliminary results have found relatively high concentrations of several metals (e.g., Hg and Cd) accumulated in leaf tissue. These may be sufficient enough to induce discernible contamination effects in specific reflectance wavelength regions, and change detection has revealed that there is a notable

difference in forest coverage that has occurred at these areas during the timeframe assessed.

Key Words: Biogeochemistry, Change Detection, Emission Effects, Heavy Metals, Multispectral Data, Vegetation Index

Introduction

Smelters and coal-fired power plants have been in operation for decades and have resulted in substantial atmospheric deposition of heavy metals in the surrounding countryside. For example, Bornstein and Bolter (1989) found that significant amounts of heavy metals were accumulated in the soil and oak leaf litter around a lead smelter in southeast Missouri. Sarappo (1998) also noted similar deposition in vegetation and soils from a power generating facility in east-central Minnesota. Such accumulation can cause vegetative stresses that lead to morphological effects (e.g., stunting and reduced biomass) and species distribution changes, which in turn, can be denoted via biogeochemical sampling and multispectral evaluation methods.

Regarding the latter, Ufimtseva and Zaickina (1996) stated that phytochemical indication constitutes one of the

promising methods for urban environmental monitoring. Vassileva et al. (2000) put this to the test when they used black oak tree leaves as bioindicators for the assessment of heavy metal air pollution in Sofia, Bulgaria. Rock (1998) noted that the use of multispectral data acquired from the Landsat Thematic Mapper (TM) satellite was a highly effective way to detect, map, and monitor changes in forest health related to exposure to poor air quality. More recently, Schroter and Obermeier (2003) found that hyperspectral remote sensing of air pollutant emissions is more effective than other emission measurement methods, particularly for the detection of diffuse emissions, which are hard to quantify with ordinary ground-based point measurements.

Research studies, however, must continue to further demonstrate the efficacy of using these methods to monitor possible results of such contamination in particular forest ecosystems. Consequently, a study was undertaken to determine the presence of heavy metals, such as Hg and Cd found in leaves and soil underlying black oak trees at the Magnolia Hollow State Conservation Area in Missouri and Fults Hill Nature Preserve in Illinois, that might induce discernible abnormal effects which could be detected on Landsat multitemporal imagery and from hyperspectral scanning of oak leaves.

Study Areas

The project's first study area is located within the 1,740-acre Magnolia Hollow State Conservation Area that is found about 10 miles north of Ste. Genevieve, Missouri (Fig. 1). It is a heavily forested area that overlooks the Mississippi River,

and is bordered by Establishment Creek and Schmidt's Island. The forest consists mainly of mixed hardwood trees, with black oak (*Quercus velutina*) being one of the dominant species. The underlying soil is comprised of the Gasconade-Menfro complex, where the Gasconade soils have a surface layer of very dark grayish brown stony silty clay loam about 9 inches thick. The typical Menfro soils have a surface layer of dark brown silt loam of similar thickness. Both types overlie limestone bedrock.

Another area with similar biophysical attributes was also selected for comparative purposes. It is located at the Fults Hill Nature Preserve that is found across the Mississippi River about 25 miles south of Belleville, Illinois (Fig. 1). The Preserve consists of 532 acres of woodlands in which the same species of black oak trees and underlying soil types as those in the Magnolia Hollow Area are found.

Both areas are downwind and in proximity of two heavy metal sources of potential air pollution contamination that have been in operation for at least the past 2 decades (Fig. 1). They are the lead smelter in Herculaneum, Missouri and a coal-fired power plant on Rush Island, Missouri. Prevailing wind data collected during the past several decades at Lambert International Airport in St. Louis indicate that between December and March

Figure 1. Locations of the Magnolia Hollow and Fults Hill Areas.

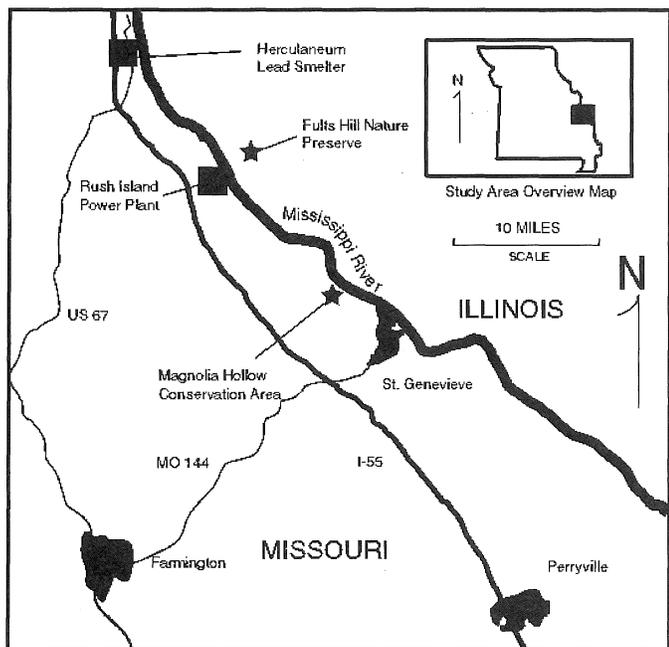
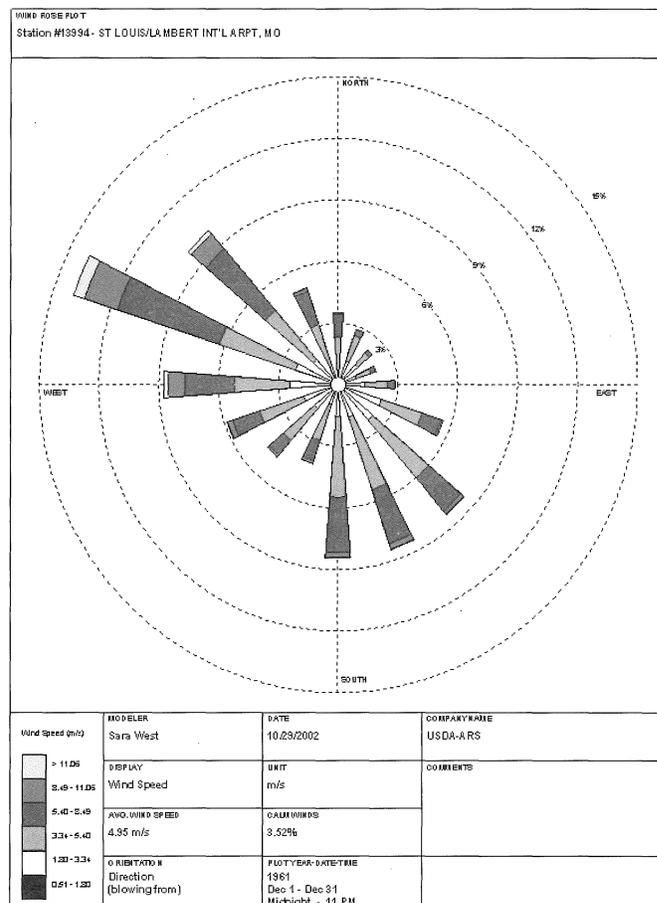


Figure 2. Wind Rose Diagram Showing Prevailing Wind Direction for Study Areas.



the most predominant direction of airflow (and generally its greater strength) is from the northwest toward the Magnolia and Fults areas (see Fig. 2 for an example). Also, while the winds tend to have a more southerly flow during the warmer months, the second most common direction is out of the west-northwest (Missouri Climate Center).

Experimental Methods and Materials

Collection of Leaf and Soil Samples

Leaf and soil samples were collected in late August and early September 2002. A total of 44 samples (i.e., 22 soil and 22 leaf) were gathered at the Magnolia area, and 36 of each type at Fults. All leaf samples taken from black oak trees were clipped from the highest reachable branches using a telescoping tree trimmer and then placed in an ice chest to maintain freshness during transport back to the lab for subsequent spectral analysis. Each soil sample was obtained from a depth of 2–3 inches very near the base of the sampled trees. Due to limited access constraints at Magnolia, the samples were taken randomly alongside an unimproved gravel roadway; from Fults, samples were acquired every 200 feet where oak trees were present adjacent to a circular nature trail. All sample locations were recorded using a Garmin GPS 12 Personal Navigator receiver.

Laboratory Protocols

The leaf and soil samples were first prepared following the Environmental Protection Agency's Method 3050B (EPA, 1996a) which entails acid digestion of a representative 1-gram (dry weight) sample using repeated additions of nitric acid and hydrogen peroxide. Hydrochloric acid is then added to the initial digestate and it is filtered with hot HCl and reagent water to increase the solubility of some metals. After the digestate was finally diluted to a volume of 100 mL, an inductively coupled plasma-optical emission spectroscopy (ICP-OES) instrument (housed in S.E. Missouri State University's Chemistry department) was used to determine each sample's heavy metal content following EPA Method 6010B (EPA, 1996b).

Remote Sensing Techniques

Two subscenes from late August 1988 and early September 2001 Landsat Thematic Mapper (TM) and Enhanced TM+ images covering the Magnolia and Fults areas were subjected to various geoprocessing methods, such as band ratioing, principal component analysis, and change detection procedures. With regard to the first of these, various forms of ratio combinations using the red and infrared wavelength bands of the TM sensors have been developed for vegetation monitoring, such as assessing biomass or leaf area index and discriminating between stressed and non-stressed trees. These ratio combinations are

Table 1. Comparison of Elemental Range (In Parts Per Million): Bargagli/Shacklette (Background Standards) vs. Fults & Magnolia Areas.

Element	Bargagli Leaf Samples	Shacklette Soil Samples	Fults Leaf Samples	Fults Soil Samples	Magnolia Leaf Samples	Magnolia Soil Samples
Al	27.5–77.7	3.0–7.0	0.224–3.857	10.03–151.2	8.933–18.45	10.03–127.6
As	0.17–0.43	4.1–6.5	0.007–0.077	0.001–0.182	0.069–0.195	0.001–0.227
Cd	0.02–0.10	No Samples	0.007–0.03	0.033–0.993	0.726–1.04	0.063–2.208
Cr	1.27–1.44	30–70	0.031–0.046	0.038–2.552	0.118–0.274	0.096–1.986
Cu	5.3–9.8	1.0–15	0.01–0.106	0.016–0.689	0.156–0.358	0.095–2.072
Mg	0.12–0.31	0.005–0.3	14.77–65.05	9.376–49.14	36.46–50.92	6.833–67.64
Pb	0.5–5.6	10.0–15	0.028–0.965	0.221–3.325	1.333–2.354	0.892–4.772
Zn	14–37	28–45	0.106–13.69	0.259–13.69	1.39–3.895	0.109–13.8
Se	No Samples	0.3–0.5	0.002–0.067	0.001–0.054	0.107–0.344	0.056–0.299
Ba	15.4–156	10–700	0.35–7.216	0.965–14.82	5.605–14.39	0.686–16.39
Co	No Samples	7.0–70	0.017–0.028	0.049–1.835	0.00	0.21–1.848
Cs	No Samples	No Samples	11.13–28.48	0.00	0.00	0.00
Fe	52–157	0.01–1.5	0.419–5.953	4.028–143.3	6.004–15.88	10.89–117
Ni	4.81–8.21	7.0–15	0.035–0.133	0.05–0.918	0.007–0.1	0.033–7.918
Sr	No Samples	5.0–150	0.00	0.00	0.00	0.00
U	No Samples	No Samples	0.144–0.303	5.979–5.979	0.00	0.00
V	0.6–0.9	30–50	0.01–0.033	0.005–1.037	0.109–0.129	0.126–0.976
Tl	No Samples	No Samples	0.00	0.00	0.00	0.00
Ga	No Samples	7.0–10	0.028–0.039	0.00	0.00	0.00
Hg	0.04–0.06	0.051–0.13	0.00	0–0.043	0.287–0.299	0–0.293

Table 2. Statistical Comparison¹ of Fults Hill Nature Preserve Soil Elements vs. Magnolia Hollow Conservation Area Soil Elements.

Element	T-Value	Significant
Aluminum	-6.21	Yes
Arsenic	-6.57	Yes
Cadmium	-11.46	Yes
Chromium	-5.95	Yes
Copper	-4.57	Yes
Magnesium	-5.57	Yes
Lead	-6.26	Yes
Zinc	-1.08	No
Selenium	-8.61	Yes
Barium	-2.45	Yes
Cobalt	-5.66	Yes
Iron	-6.77	Yes
Nickel	-1.31	No
Vanadium	-6.66	Yes
Mercury	-1.40	No

¹Significance assessed for all at the p < .01 level

known as vegetation indices (VI's). Employed in this study were the slope-based VI's, which include the NDVI (Normalized Difference Vegetation Index), the TVI (Transformed Vegetation Index), and the TTVI (Thiam's Transformed Vegetation Index) [see Curran, 1980 for computational details]. Principal Component Analysis (PCA) effectively computes a new set of variables or components from several multispectral images that are largely independent of the others and convey different information found within them. One technique, called

Table 3. Statistical Comparison¹ of Fults Hill Nature Preserve Leaf Elements vs. Magnolia Hollow Conservation Area Leaf Elements.

Element	T-Value	Significant
Aluminum	-23.5	Yes
Arsenic	-1.94	No
Cadmium	-45.64	Yes
Chromium	-12.98	Yes
Copper	-14.62	Yes
Magnesium	1.28	No
Lead	-21.45	Yes
Zinc	-1.89	No
Selenium	-14.12	Yes
Barium	-13.25	Yes
Cobalt	29.59	Yes
Cesium	8.53	Yes
Iron	-13.65	Yes
Nickel	6.52	No
Uranium	20.67	Yes
Vanadium	-53.59	Yes
Gallium	27.27	Yes
Mercury	-362.12	Yes

¹Significance assessed for all at the p < .01 level

TASSCAP (Crist and Cicone, 1984), creates 4 distinct categorical images, the second of which (called greenness) acts as a vegetation index of sorts that isolates on the extent and condition of biomass found in a TM scene. Finally, change detection analysis was conducted to quantify temporal variations in the forest cover at the 2 areas over the 13-year period between 1988 and 2001.

Table 4. Comparison of Mean & Standard Deviation Values of the Elements in the Coal Burned at the Rush Island Power Plant and Values of the Elements in Samples from the Fults and Magnolia Areas.

Element	Cordero Rojo Coal Mean & Standard Deviation (ppm)	Fults Leaf Samples Mean & Standard Deviation (ppm)	Fults Soil Samples Mean & Standard Deviation (ppm)	Magnolia Leaf Samples Mean & Standard Deviation (ppm)	Magnolia Soil Samples Mean & Standard Deviation (ppm)
Arsenic (As)	1.39 ± 0.62	0.04 ± 0.02	0.05 ± 0.05	0.11 ± 0.03	0.16 ± 0.05
Barium (Ba)	373 ± 82.6	1.22 ± 1.47	7.39 ± 3.82	8.28 ± 1.95	10.2 ± 3.64
Cadmium (Cd)	0.2 ± 0.04	0.03 ± 0.005	0.18 ± 0.27	0.83 ± 0.08	1.4 ± 0.41
Chromium (Cr)	6.14 ± 1.38	0.04 ± 0.004	0.41 ± 0.56	0.18 ± 0.05	1.45 ± 0.57
Cobalt (Co)	2.89 ± 1.74	0.02 ± 0.004	0.26 ± 0.37	0.00	1.0 ± 0.50
Copper (Cu)	14.5 ± 2.24	0.04 ± 0.03	0.15 ± 0.16	0.24 ± 0.05	0.57 ± 0.39
Mercury (Hg)	0.09 ± 0.03	0.00	0.03 ± 0.01	0.29 ± 0.004	0.15 ± 0.14
Nickel (Ni)	2.54 ± 2.08	0.09 ± 0.02	0.19 ± 0.21	0.03 ± 0.03	0.83 ± 2.23
Lead (Pb)	3.14 ± 1.27	0.13 ± 0.20	0.90 ± 0.74	1.51 ± 0.21	2.39 ± 0.80
Selenium (Se)	1.15 ± 0.5	0.04 ± 0.02	0.02 ± 0.02	0.23 ± 0.06	0.15 ± 0.07
Vanadium (V)	21.7 ± 4.98	0.22 ± 0.05	0.25 ± 0.23	0.12 ± 0.005	0.72 ± 0.23
Zinc (Zn)	10.2 ± 4.92	0.89 ± 2.94	3.31 ± 3.73	2.12 ± 0.61	4.44 ± 3.0

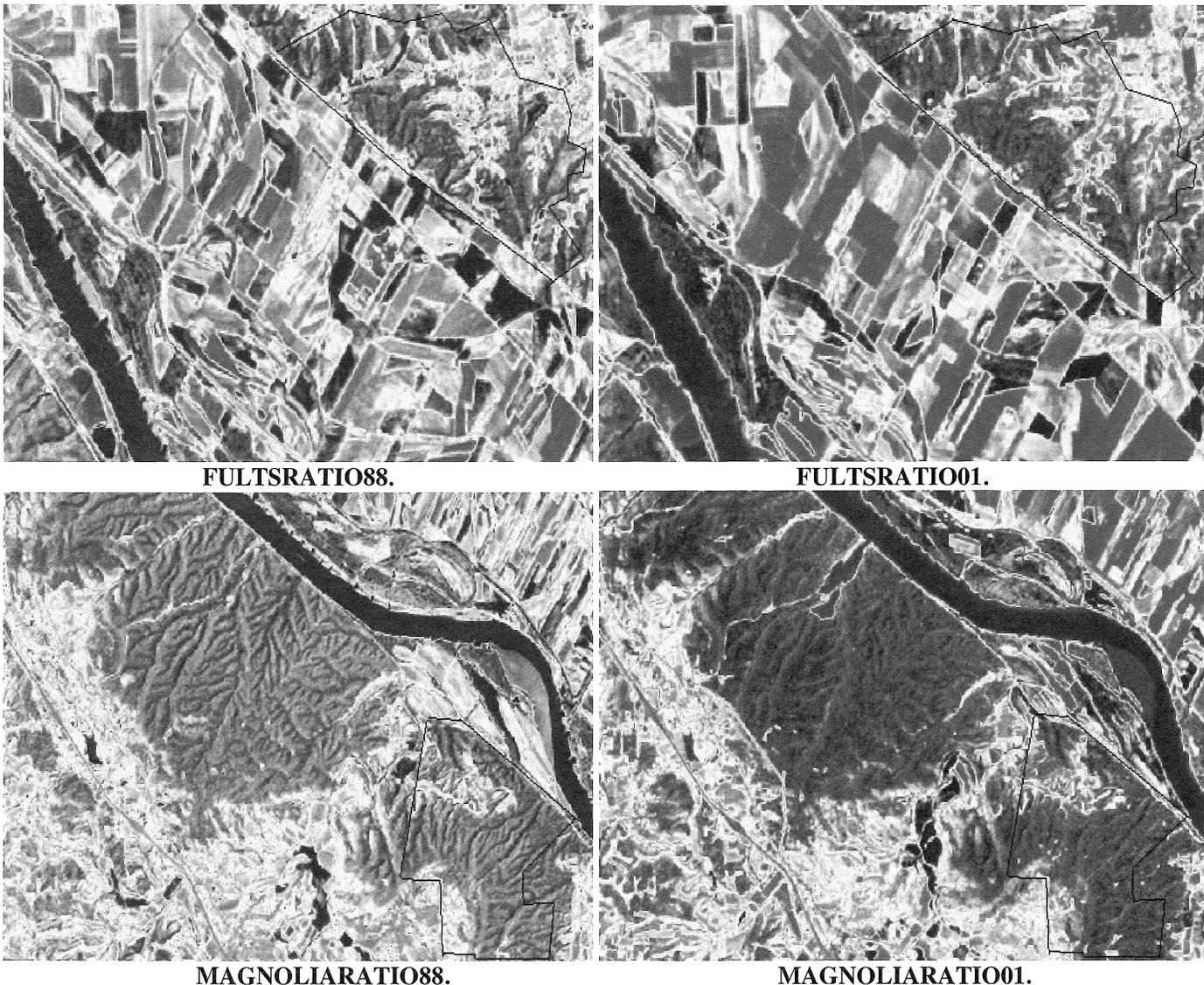
A Spectron Engineering SE-590 spectroradiometer, operated indoors in a darkened room having the following described setup configuration, was used to obtain spectral reflectance measurements of the black oak leaf samples. The instrument's scanner head was placed in a stand mounted a measured distance above a photolab layout table to give a sensor field of view of 6 degrees. The leaves were consistently arranged below it in a circular mound (about 0.5 in. thick), flattened to totally fill the viewfield, and illuminated from opposite sides with 4 quartz halogen lamps. A standard procedure was implemented, whereby the spectrometer was first calibrated using a Spectralon reflectance panel, two measurements per sample were averaged to generate a spectral reflectance curve, and the result was ratioed with the calibration. Consequently, the curves produced are

normalized, with plotted relative amplitude values corresponding to percent reflectance.

Evaluative Assessments

Descriptive statistics were generated for soil and tree leaf elemental concentrations. Sample geochemical amounts were compared with available counterpart data (Shacklette and Boerngen, 1984; Bargagli, et al., 2003) which served as background standards. Derived spectral reflectance curves of analyzed tree leaves were both qualitatively and quantitatively evaluated to ascertain differences between the project's study areas.

Figure 3. Comparison of Fults and Magnolia Simple Ratio Vegetation Indexes Using 1988 and 2001 LANDSAT TM Images.



Results and Discussion

Leaf and Soil Metal Concentrations

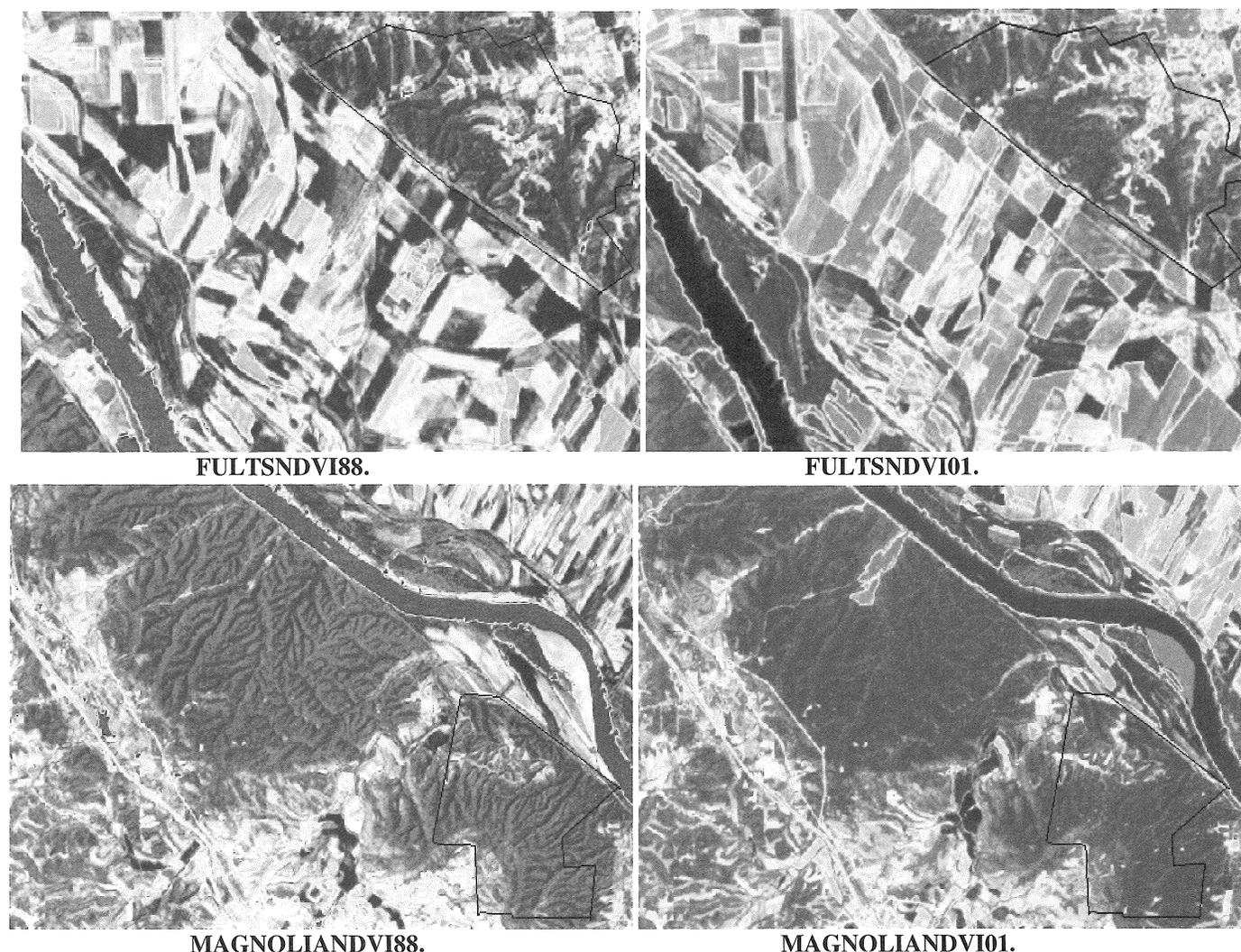
Differences in elemental concentrations between background sources and each area's leaf and soil samples are presented in Table 1. With regard to the oak leaves, it is apparent that all metal elemental amounts (except Co and Ni) are higher at the Magnolia area than at Fults, especially Al, Cd, Cr, Pb, Fe and Hg. Except for Al, Cr and Fe, this is generally the case also in the soil. The results of one-tailed, parametric t-tests used to assess the mean data derived from the leaf and soil samples found at the project's study areas are presented in Tables 2 and 3. A comparison of the soil samples yielded no significant difference for Zn, Ni and Hg. As for the leaf samples, there was no significant difference found for As, Mg, Zn and Ni. All other elements were found to be significantly different in concentration between the two areas. A further comparison was made between the mean concentration of these elements found

in the leaves and soil at each area and those found in the coal burned at the nearby power plant operating on Rush Island. These results are shown in Table 4. Despite considerable variability in some cases between coal concentrations and those in the leaves or soil, relatively high mean values of elements like Hg and Cd (and possibly Pb) found in the samples at Magnolia may suggest some relationship between the coal plant emissions and deposition at this area.

Evaluation of Remotely Sensed Data

Figures 3 and 4 depict vegetation index (VI) images derived from Landsat TM data collected over the Magnolia and Fults areas. These are designed to detect, among other characteristics, evidence of stress in trees that might result from the uptake of heavy metals (such as those noted above). Such stress, if present, can induce unique or anomalous variations in spectral responses across the visible and near-infrared (IR) wavelength regions that would be manifested as tonal contrasts in the

Figure 4. Comparison of Fults and Magnolia NDVI Vegetation Indexes Using 1988 and 2001 LANDSAT TM Images.



images. Qualitative examination of ratio and NDVI scenes, which contrast red and IR spectral bands, revealed a reduction in reflective tonal intensity and definition at both areas over the 13 year period assessed, particularly at Magnolia. The 2001 images show less distinct and extensive vegetation coverage than was present in their 1988 counterparts. Quantitative evaluation of pixel values calculated from a 3 × 3 “kernel” of pixels surrounding each sample location at Magnolia found that in 1988 they had an average reflectance response of 105 for the infrared band, whereas in 2001 the average pixel value was 84, indicative of less vigorous growth since healthy vegetation generally has higher response values in the IR region.

Comparison was also made between the mean spectral reflectance curves of sampled oak leaves from both areas (Fig. 5). It is apparent that there are notable differences in the trace of the two, particularly in the infrared region (between ~ 750nm and 1045nm) where a decrease in Magnolia’s reflectance was seen. This difference was found to be statistically significant at the 0.1 level. Previous studies (like the aforementioned above) have found that relatively high concentrations of certain heavy metals (such as Hg, Cd and Pb) found in the leaves of oak trees can adversely affect their cell wall structure, causing them to reflect less IR energy.

Conclusions

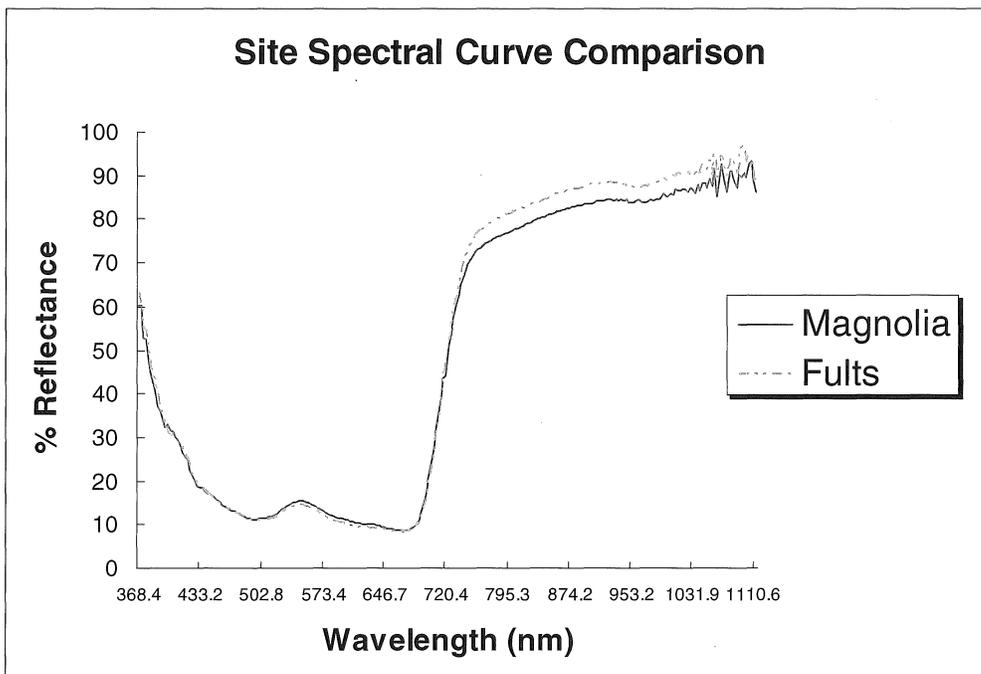
Preliminary geochemical data findings indicate that accumulation of certain heavy metals has occurred in varying

amounts in the soil and leaves of oak trees found at the Magnolia Hollow Conservation Area in southeastern Missouri and the Fults Hill Nature Preserve in Illinois. These concentrations may be of sufficient quantity to produce discernible effects on remotely sensed imagery and in leaf spectral reflectance response. Furthermore, these data suggest there is a possible link to the emissions of such metals emanating from a source located upwind of the area, namely a coal-fired power plant on Rush Island, Missouri.

Comparative assessments made between soil and leaf samples collected from Magnolia, Fults, and a previous regional geochemical survey show that there are relatively higher concentrations of Hg (among others) at the Magnolia area. These were found to be statistically significant in some cases. Comparison of the contents of the coal used at the power plant with those found deposited at Magnolia, along with its location and the prevailing wind direction, imply that the plant may likely be a cause of contamination there. Lower than expected amounts of lead found in the samples collected as part of this study makes the Herculaneum smelter a less likely contributor of this element.

The remote sensing data also corroborate the geochemical findings in that there are noticeable changes in vegetation reflectance responses from corresponding sample areas. Evaluation of mean pixel reflectance values showed that a relative decrease in magnitude had occurred between 1988 and 2001 (particularly in the infrared region), and this could be seen as a tonal change on vegetation index images of those years. This was further

Figure 5. Plots of Mean Spectral Reflectance of Oak Leaves from the 2 Study Sites.



substantiated via the derivation of spectral reflectance curves generated from sampled oak leaves which showed a significant difference in the infrared “plateau” between the project’s study areas.

Finally, it is interesting to note that the remote sensing image differences detected also possibly show a qualitative measure of the impact of the heavy metals on tree growth during the 13 year timeframe assessed. Our vegetation index image findings indicate that there was relatively more vigorous growth in 1988 during a time of drought and less growth in 2001 when this region experienced above normal amounts of rainfall during the spring and summer months.

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School Science Safety Education and Laboratory Safety Report

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Introduction and Overview

Safety is essential in all facets of our lives. It is especially important when working in the sociologically complex and demanding educational settings in the post-911 era. Ethics demand that we provide appropriate protective measures for children and adolescents in the school environment in order to assure the best education possible for the next generation. Legislative mandates and legal precedent further pressure and guide science educators in the pursuit of safety excellence. Professional organizations are helping encourage science teachers to add safety and provide safe learning environments.

The *National Science Education Standards* — NSES (National Research Council, 1996) state that students at the K–4, 5–8, and 9–12 levels should know and be able to “utilize safety procedures during scientific investigations.” A study initiated by Gerlovich, McElroy, Parsa, and Wazlaw reflects the escalating interest and demand for safety in all facets of science teaching in academic environments. This study, “A National Science Safety Indexing Project: A Beginning,” is detailed in the September 2005 issue of *The Science Teacher*. In a 1997 study by Gerlovich, involving 1,230 experienced science educators from 11 states, it was shown that these professionals had very poor understandings of applicable laws, codes, and professional standards relating to safety in their classroom.

A study by Gerlovich and colleagues (1998) found some very disturbing insurance and accident trends in Iowa school science programs. It was observed that accident rates have increased significantly as science teachers have attempted to follow the “inquiry based” NSES. In 400 Iowa school districts the number of bodily injury cases in science grew from 674 in 1990–93 to over 1,000 in 1993–96. For the same time frame the dollar value for these injuries grew from \$1.7 million to \$2.3 million. Concomitantly, lawsuits grew from 96 to 245 for the same period, while legal costs escalated from \$600,000 to \$1.3 million. Approximately one in six bodily injury cases developed into a lawsuit.

It was revealed in a 1999 study of North Carolina secondary schools (Stallings, Gerlovich and Parsa) that very few science labs were properly equipped for conducting contemporary hands-on, inquiry-based science programs. The most dangerous part of this revelation was the fact that a high percentage of the teachers had no knowledge of this lack of proper equipment. In the fall of 1999 and spring of 2000, a yearlong science safety project was completed in Wisconsin (Gerlovich, et al; 2001). As part of that effort, teachers completed a pre-training survey of their facilities, equipment, and understanding of their legal and professional obligations towards safety. It was discovered that most of the facilities and equipment were below state minimal standards for these institutions. Also, nearly 50 % of the public school facilities were in excess of 21 years old and not up to current safety codes and standards. Even more disturbing was the fact that few of the teachers knew what the standards

were. In addition, over 50% of the science teachers had never received training regarding safety in school science settings.

In “A National School Science Safety Preliminary Report” (Gerlovich and Parsa 2002), conducted in the fall of 2000, 302 science teachers representing 47 states and three US territories participated in a voluntary survey of their facilities, equipment and safety procedures. The survey was conducted via the National Science Teachers Association website and it revealed some serious concerns involving facilities limitations, safety equipment and teacher understanding of their obligations. These deficiencies raised questions about these teachers’ abilities to effectively and safely teach the inquiry-based NSES.

Gerlovich et al; (2004) evaluated the status of safety in Tennessee school science programs as part of a 2003–2004 year-long science safety project involving Tennessee secondary science teachers. Based on this study an instructional CD was developed to help address safety needs. This study found significant safety concerns including classroom/lab size that were inadequate to meet the professional standards for student enrollment and the lack of regular testing of equipment. Teachers from the participating schools did not consistently observe most standard safety procedures. In addition, most participating science teachers were not aware of applicable science safety laws, codes, and standards. However, it did appear the accompanying training and the CD prepared participants to address applicable federal and Tennessee science safety laws, codes, and professional standards. In many instances, science teachers are being held accountable for information and skills they do not have. Proven tools and training are needed to cope with these mandates and responsibilities.

Missouri Project

During the fall of 2003, the Missouri Center for Safe Schools, located at the University of Missouri-Kansas City, assembled a state School Science Safety Project Committee consisting of safety professionals, researchers, educators, emergency response personnel, and waste disposal experts. Over an 18-month period the committee worked with Jack Gerlovich (Drake University) and Dennis McElroy (Graceland University) of JaKel, Inc. to develop a science safety program for Missouri secondary schools. On committee recommendation, the Missouri Center for Safe Schools prepared and sent a letter to every Missouri school superintendent inviting them to submit data on excess, expired, or unidentified chemicals and biological materials in their laboratory storage areas. The letter explained that the Missouri Center for Safe Schools would use the schools’ input to seek grant funding for disposal of the hazardous materials and clearly stated that there was no certainty funding could be obtained. The letter was distributed to the districts in the October 2003 Missouri Department of Education Commissioner’s Mail Bag.

Applications for formal chemical clean-up programs were received from 92 school districts (105 public schools), one charter school, and one parochial school by the December 2003

deadline. Applications were reviewed and then consolidated onto one spreadsheet. Calls were made to schools to clarify data returns and on March 3, 2004, the list was consolidated into 2,424 different item descriptions. The spreadsheet was turned over to the HAZMAT professionals from Kansas City Missouri (KCMO) Household Hazardous Waste and the Department of Natural Resources for combining similar items and adding relevant coding. The work was completed in early July 2004 and resulted in a list of 1318 unique chemicals.

In March 2004, representatives from the Missouri Department of Natural Resources (DNR), a partner organization in this project, visited three rural schools (Kirksville, Knob Noster, and Macks Creek) that applied for assistance and KCMO Household Hazardous Waste visited three urban schools (Blue Springs, Independence, and Hickman Mills). The purpose of the visit was to confirm the inventory. It was quickly learned that the inventories submitted should be considered “approximations” of what would be actually on hand when the clean-up was to be conducted.

Clean-up began in August 2004 when the Missouri Environmental Improvement and Energy Resources Authority (EIERA) funded the disposal of hazardous waste materials for the three rural school districts visited by the Missouri Department of Natural Resources.

Due to the work on this project, it became apparent that in order to improve the school science safety situation in Missouri a training program on science lab safety was needed.

Based on 25 years of safety work throughout the nation, science education safety researchers and college professors Jack Gerlovich and Dennis McElroy had developed a total science safety management system in use in 20 states across the nation. *The Total Science Safety System — National Edition* formed the basis for the custom version due to its proven track record. Applicable information concerning Missouri laws, codes, and standards was secured from the following agencies and included in the CD:

- Department of Natural Resources
- Department of Education (Facilities Consultant, Science Consultant)
- State Fire Marshal’s Office
- Occupational Safety and Health Administration (OSHA)
- Department of Health
- Department of Transportation
- Homeland Security
- Others as designated by the Committee members.

Over a one-year period, Gerlovich and McElroy met with the School Science Safety Project Committee to develop *The Missouri Edition — Total Science Safety System CD* to reflect Missouri laws and codes, and professional science education standards. Development of this CD was completed in the fall of 2004. In January 2005, EIERA expanded their grant to purchase 107 copies of the CD.

The interactive CD was designed to help Missouri teachers develop a safe science learning environment. It includes tools for conducting safety audits of facilities, equipment, and

procedures, 6 safety videos, 2 chemical management systems (large storeroom, small storeroom), over 250 Internet links to science safety websites, hundreds of photos of science safety issues, training tools and assessment instruments, along with customizable inventory management tools (for producing labels, separating non-compatibles, conducting inventories, generating material safety data sheets, etc.).

Beginning in the spring of 2005 and extending through the spring of 2006, training programs in the effective use of *The Missouri Edition — Total Science Safety System CD* were offered at Regional Professional Development Centers to science teachers participating in the chemical clean-up project. Schools/districts not included in the grant application had the opportunity to purchase the CD.

Teachers were required to complete a pre-training survey and bring it to the training program as a condition for receiving a free copy of *The Missouri Edition — Total Science System CD*. The information collected included 41 questions concerning Facilities, Equipment, and Procedures as well as participants' understanding of laws, codes, and professional standards. That information formed the basis for this report and provides a basis for gauging safety improvement in Missouri secondary school science settings.

The workshops were provided to enable the Missouri science educators to effectively use *The Missouri Edition — Total Science Safety System CD* so that they could:

- Comply with applicable law and regulations,
- Reduce liability and the risk of negligence judgments,
- Decrease the likelihood of accidents, injuries, and diseases due to hazards in schools,
- Make peers, administrators, and students more aware of science safety issues,
- Comply with the safety components of the NSES,
- Recognize and comply with the guidelines of professional science education organizations,
- Locate and comply with specific Missouri laws, codes, standards, and
- Establish district policies, identify and correct safety hazards, comply with Missouri mandates, and properly manage chemicals.

During the 2004, 2005, and 2006 academic years, workshops were conducted throughout the state of Missouri. A total of 123 Missouri secondary school science teachers participated in the six workshops.

Missouri Science Safety Pre-Training Survey Results and Summary

The survey results revealed that the facilities across the state fall into two broad categories with nearly 30 percent of laboratories being less than ten years of age, while nearly 34% are over 30 years of age (see Table 1). The age of facilities can certainly have an impact on what can and cannot be attempted

in such facilities. In many instances older facilities do not comply with the latest safety demands. In these cases, teachers must be attentive to the limitations imposed.

The survey also revealed that most science labs are quite small by today's standards. Approximately 43% of laboratories had less than 750 square feet of floor space. The NSTA guidelines (Biehl et al, 1999) of 45 square feet of floor space per student would allow only 17 students in the lab at one time. In Lab/classroom combination rooms, it was discovered that nearly 49% of the facilities had less than 1000 square feet of space. Using the NSTA guidelines of 60 square feet per student in these rooms, this would allow only 16 students in the room simultaneously. These figures are especially disconcerting when considering that 90% of teachers reported that their they typically allowed between 17 and 25 students in their classes. Forty percent reported allowing more than 25 students regularly.

Forty percent of the responding teachers reported that they either did not have or did not know if their outlets were equipped with Ground Fault Interrupter (GFI) protected electrical outlets in their laboratories. Fire extinguishers (typically ABC — tri-class) are essential for almost all laboratories. Ninety-four percent reported having one or more of these items available. A follow-up question to be asked later would be if they had ever received training in the effective use of the equipment. Along with this equipment, it was noted that 86% of the teachers reported having at least one fire blanket available in their labs. Again, the question remained as to whether they had they received training in the proper use.

Approximately 80% of participating teachers indicated they had at least one eyewash station capable of delivering aerated running water. Nearly 20% reported not having at least one of these essential safety items. Just under 74% of the responding teachers reported that they had ANSI Z87 approved eye protective equipment. Twenty Six percent did not have this equipment or did not know if it was approved. Nearly 46% reported that they did not have, or did not know if they had, sterilizing equipment for cleaning eye protective devices. Equally disconcerting were reports from 42% of the participating teachers stating they had unidentified chemicals or did not know if they had such in their inventories. This is especially worrisome when noting that studies by Gerlovich and others in the late 1990's reported time and shock sensitive chemicals such as picric acid common in their inventories. Nearly 80% of teachers reported that they either had Environmental Protection Agency's (EPA) P-Listed chemicals or did not know what they were. Many teachers inherit chemical repositories that have been accrued over many years by their predecessors without the knowledge concerning how to manage the dangerous substances. Over 50% of respondents reported that they had chemicals they would like to purge.

Finally, the survey responses indicated that only 53% of the classrooms had more than one exit with outward opening doors. This is contrary to the professional standards (National Fire Protection Association, NFPA 45-2004) recommending a minimum of a least two outward opening exits in a science classroom.

Table 1. Missouri Science Safety Pre-Training Survey Results – Facilities and Equipment.

How old is your lab facility?			How many total square feet of floor space do you have in your science lab?		
Age	Count	Percent	Sq. Ft.	Count	Percent
0–10 yrs.	36	29.75%	500–749	50	43.48%
11–20 yrs.	21	17.36%	750–999	27	23.48%
21–30 yrs.	20	16.53%	1000–1499	14	12.17%
30+ yrs.	41	33.88%	More than 1500	4	3.48%
NA	3	2.48%	NA	14	12.17%
Total	121	100.00%	NR	6	5.22%
			Total	115	100.00%

If you have a lab/classroom combined area, how many total square feet of floor space does it have?			What is the maximum number of students in your lab during a class?		
Sq. Ft.	Count	Totals	Max Students	Count	Percent
500–749	29	24.37%	1–8	2	1.67%
750–999	29	24.37%	9–16	10	8.33%
1000–1499	24	20.17%	17–24	60	50.00%
More than 1500	10	8.40%	More than 25	48	40.00%
NA	21	17.65%			
NR	6	5.04%			
Total	119	100.00%			

Are lab electrical outlets GFI/GFCI protected?			How many ABC Tri-class fire extinguishers do you have in your lab?		
Response	Count	Percent	# Fire Extinguishers	Count	Percent
Yes	70	58.82%	0	7	6.42%
No	21	17.65%	1	67	61.47%
I don't Know	26	21.85%	2	28	25.69%
2-some	2	1.68%	More than 2	7	6.42%
Total	119	100.00%	Total	109	100.00%

Do you have at least one fire blanket in your lab?			How many functioning eyewash stations do you have in your lab capable of delivering aerated, running water?		
Response	Count	Percent	Eyewash Stations	Count	Percent
Yes	101	86.32%	0	23	18.70%
No	16	13.68%	1	81	65.85%
Total	117	100.00%	2	13	10.57%
			More than 2	5	4.07%
			NR	1	0.81%
			Total	123	100.00%

Do you have appropriate “ANSI” approved chemical splash eye protection for all students in your labs?			Do you have eye protective equipment sterilizing equipment?		
Response	Count	Percent	Response	Count	Percent
Yes	88	73.95%	Yes	68	57.14%
No	17	14.29%	No	44	36.97%
I don't Know	14	11.76%	I don't Know	7	5.88%
Total	119	100.00%	Total	119	100.00%

Table 1. Continued.

Do you have any unidentified chemicals			Do you have any P-List chemicals		
Response	Count	Percent	Response	Count	Percent
Yes	39	33.05%	Yes	7	5.93%
No	69	58.47%	No	22	18.64%
I don't Know	10	8.47%	I don't Know	87	73.73%
Total	118	100.00%	NR	2	1.69%
			Total	118	100.00%

Do you have any hazardous chemicals you would like to purge?			How many exits does your lab have with outward opening doors?		
Response	Count	Percent	# of Exits	Count	Percent
Yes	59	50.00%	1	57	47.11%
No	39	33.05%	2	52	42.98%
I don't Know	19	16.10%	3	12	9.92%
NR	1	0.85%	4	0	0.00%
Total	118	100.00%	Total	121	100.00%

NA=Not applicable; NR=No response.

Having relevant, current training, and experience, with safety issues is essential in the science teaching field to provide a safe environment for middle and high school students who are relying on the teacher to protect them. Results from participating teachers reported that just over 56% had either never received training or had received such more than 10 years ago (see Table 2). When asked when they allowed students to wear contact lenses when working with chemicals in their science laboratories, 14% responded never, while 64% allowed them with safety glasses or a face shield, and 21% allowed them only with non-vented cover goggles that seal to the face. Several medical and professional organizations have approved the wearing of contact lenses as long as they are worn with proper eye protective equipment. It must be remembered that aerosols and splashes can enter the eye, and contact lens, through all of the above eye protective equipment except the non-vented cover goggle that seals to the face.

Three practices that contribute to the development of a safety first environment include safety contracts, safety testing, and the inclusion of safety reporting in student laboratory journals. Approximately 82% of responding teachers reported requiring safety contracts with students. This is an essential strategy when attempting to confirm that students have received appropriate safety training before being involved in science activities that could have some danger associated with them. Equally positive were responses from teachers stating that approximately 72% of them administered safety tests to their students. This can be a very powerful preventative tool for teachers in identifying, and addressing safety issues, before students are exposed to them. Twenty-four percent of the teachers required students to address safety in their laboratory reports. This is a critical practice that encourages students to maintain a safety mind-set. This requirement also provides the teacher

with information that could be essential in keeping students safe. It also can be used as a very effective verification of teacher efforts to protect students should an injury and accompanying negligence allegations occur.

Seventy-four percent of the participating teachers reported that they stored their chemicals in compatibility groupings. The remainder reported using alphabetical storage or some other system. This raises serious questions about potential unwanted synergistic chemical reactions.

One serious safety concern related to chemical management and use was the fact that only 57% of teachers reported having Material Safety Data Sheets (MSDS's) for all categories of chemicals, including those purchased over-the-counter. This lack of MSDS's is a very dangerous practice considering the poignant data the sheets provide and their ease of obtainment. One of the best sites for such information is the free access site maintained by the University of Vermont at: www.hazard.com

Another issue of serious concern is allowing students to have access to chemical storage areas. This can present a multitude of potential safety issues ranging from theft of essential instructional materials to doing harm to others with chemicals they might acquire. Twenty-six percent of the responding teachers allowed this questionable practice.

When asked about what the three duties of a teacher are relevant to science teaching, only 39% could answer — Instruction, Supervision, Maintenance (see Table 3). If all of these are addressed it is very unlikely, in the case of an accident, that allegations of negligence could be made successfully. When asked if teachers were aware of the Missouri Good Samaritan legislation (Sections 537.037, RSMo, 1988) protecting professionals in the event of accidents, 71% responded they were unaware of the legislation. However, upon review, it appears questionable as to whether this would apply to educators as

Table 2. Safety Procedures.

How recently have you received science safety training?			Under what conditions do you allow students to wear contact lenses when working with chemicals?		
Safety Training	Count	Percent	Contact Lenses	Count	Percent
Never	57	47.90%	Never	17	14.41%
0–5 yrs.	31	26.05%	With safety glasses	75	63.56%
5–10 yrs.	21	17.65%	With nonvented goggles	25	21.19%
10+ yrs.	10	8.40%	With a faceshield	1	0.85%
Total	119	100.00%	Total	118	100.00%

Do you require student safety contracts?			Do you administer student safety tests?		
Response	Count	Percent	Response	Count	Percent
Yes	97	81.51%	Yes	85	72.03%
No	22	18.49%	No	33	27.97%
Total	119	100.00%	Total	118	100.00%

Are students required to address safety in their lab reports?			How do you store chemicals?		
Response	Count	Percent	Storage Order	Count	Percent
Usually	28	23.93%	Alphabetical	11	9.17%
Occasionally	54	46.15%	Compatibility groups	88	73.33%
Never	23	19.66%	Other	13	10.83%
NA	12	10.26%	NA	7	5.83%
Total	117	100.00%	NR	1	0.83%
			Total	120	100.00%

Do you have readily accessible MSDS in your laboratories/stockrooms?			Do students have access to chemical storage areas?		
Response	Count	Percent	Response	Count	Percent
Yes	63	56.76%	Usually	2	1.71%
No	42	37.84%	Occasionally	29	24.79%
NR	6	5.41%	Never	86	73.50%
Total	111	100.00%	Total	117	100.00%

Table 3. Laws, Codes and Professional Standards.

What are the three legal duties a Missouri science teacher must follow to help prevent a negligence suit against them?			In Missouri is there “Good Samaritan” legislation to protect educators rendering good faith emergency aid?		
Response	Count	Percent	Response	Count	Percent
Teach, Practice, Verify	14	11.76%	Yes	35	29.41%
Instruct, Test, Verify	7	5.88%	No	20	16.81%
Instruct, Supervise, Maintain	47	39.50%	I Don’t know	64	53.78%
I Don’t Know	51	42.86%	Total	119	100.00%

In Missouri, is there specific Eye Protective Equipment legislation for science?			What organization(s) recommend(s) minimal floor-space/student in science labs?		
Response	Count	Percent	Response	Count	Percent
Yes	51	42.86%	NSTA	20	16.39%
No	4	3.36%	ANSI	31	25.41%
I Don’t know	63	52.94%	NSELA	4	3.28%
NR	1	0.84%	I Don’t Know	66	54.10%
Total	119	100.00%	NR	1	0.82%
			Total	122	100.00%

NA=Not applicable; NR=No response.

the legislation specifically mentions only professional medical personnel.

The potential for student injury increases while participating in any hands-on activity such as inquiry-based science. Missouri does have specific eye protection legislation to address this issue. The document entitled “Missouri Eye Protection Legislation” (Section 170.005, RSMo, 2006) was put into place in August 2003. However, only 43% of the responding teachers were aware of this. This legislation, which defines the audience targeted and the appropriate equipment, can be of great value to science teachers who attempt to secure the equipment for themselves and their students, and enforce the wearing of appropriate eye protection in their science settings.

When asked what professional organization recommends minimal floor-space/student in science labs, only 16% could identify the National Science Teachers Association (NSTA). Teachers should also be aware that many courts look at the professional guidelines of such organizations as almost equivalent to laws or codes in safety settings. As professionals, teachers should know the standards of their profession.

The results of this study demonstrate definite strengths and weaknesses with regard to school science safety in the State of Missouri. A high proportion of responders reported the presence of major safety equipment (fire extinguishers, blankets, and eyewashes) and a high level of ANSI approved personal protective equipment (goggles). Also, many responders reported using contracts to demonstrate student safety training and compliance. Major issues of concern are related to older and potentially unsafe facilities, lack of current science safety training, safety standard awareness, student/teacher ratios in laboratories, MSDS access, chemical inventory and storage (including student access to stockrooms and unlabeled/unknown chemicals), and regulatory responsibilities involved in science teaching. Responding educators also demonstrated concern about a large number of unwanted, unlabeled, and P-listed chemicals.

Future Improvements

The implementation of the safety CD and the associated training program are positive first steps in resolving the issues raised by this study. Further implementation of this project to include all middle and high school teachers in Missouri is a logical “next step.” A further extension of this program would reach into higher education, particularly teacher preparation institutions. A long-term solution would be for the state to require ongoing safety training as a part of the teacher licensure process. School administrators need to become more involved in the establishment of a safe environment throughout the school science program and provide the needed support to make requested corrections and modifications.

For additional information concerning The Missouri Science Safety Project and related educational materials, please contact:

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Senior Division

Abstracts by Section

Agriculture

*Aide, C. Department of Physics and Engineering Physics, Southeast Missouri State University. DETERMINING CANOPY COVERAGE WITH A DIGITAL IMAGE AND ADOBE PHOTOSHOP®. Determining canopy coverage in rice (*Oryza sativa* L) between the 4th tillering stage to the internode elongation stage allows the assessment of the degree of tillering and indicates the adequacy of the nitrogen fertilization program. This investigation is a technique project to determine if images obtained from moderately priced digital cameras and commercially available imaging processing software (Adobe Photoshop®) may effectively estimate the percent canopy coverage. The image analysis is performed using the “magic wand” feature to isolate the soil and then recolor the soil using the “paint bucket” feature to enhance the color contrast. The last procedure involves overlaying the image with a grid so the percent canopy cover area can be estimated. Preliminary work in the field shows that this technique can discriminate canopy coverage in high and low nitrogen plots in rice.

*Aide, M. Department of Agriculture, Southeast Missouri State University. THE GEOCHEMISTRY OF MERCURY IN SOILS HAVING A SEASONAL WATER TABLE. Mercury (Hg) is a toxic element, particularly when chemical conditions promote the formation of methyl mercury in water bodies. Much of the soil Hg in low-impacted regions is inherited from the soil parent materials and derived from the atmosphere. Three pedons were sampled at Mingo Wildlife Refuge in Southeastern Missouri. The soils are poorly drained soils having redoximorphic features resulting from glaziation and near-surface acidification. Of the three pedons, one pedon had approximately 0.09 mg Hg/kg, whereas the other two pedons had less than 0.05 mg Hg/kg. A pyrophosphate extraction, which reveals the concentration of Hg held primarily by organic matter complexation, was less than 0.1 mg Hg/kg throughout the three pedons. A hot water extraction demonstrated that all soil horizons had less than 0.001 mg Hg/kg, suggesting that any Hg release by water was extremely small. The elements Al, Fe, Cu, Mn, Ni, Cd, Pb, V, Se and Zn had concentrations that are considered normal for the soil environment and pose no environmental threat. We propose that Hg is complexed with soil organic matter and transported as a Hg-organic complex from the soil resource to water bodies, promoting Hg accumulation in the water bodies. The amount of Hg from any one soil body is vanishing small; however, the aggregate of many soil bodies may act to supply sufficient Hg that aquatic organisms may experience Hg accumulation.

*Johnson, S. and N.V. Nkongolo. Center of Excellence for Geospatial Information Sciences, Lincoln University. FLUCTUATIONS OF CO₂, CH₄ AND N₂O EMISSIONS AND SOIL THERMAL PROPERTIES FROM A GRASSLAND IN MISSOURI. Knowledge of the spatial distribution of CO₂, N₂O, and CH₄ is important in establishing practical methods of reducing greenhouse gases emissions. The objective of this study was to map the distribution of CO₂, CH₄ and N₂O fluxes from soil in a grassland. The experiment was conducted from May to December 2006 at Lincoln University’s Carver farm. Twenty static chambers were installed in a 1.42 ha plot. The locations of chambers were recorded using Geo-Explorer pathfinder 3-GPS. The gas sampling process consisted in closing the chamber’s top and the two ventilation holes with rubber stoppers and collecting soil air samples at 30-minute intervals. Analysis of CO₂, CH₄ and N₂O from soil air samples were done within two hours of sampling with a Shimadzu Greenhouse Gas GC-14. Maps of CO₂, N₂O, and CH₄ fluxes were produced with ARCGIS 9.2 Spatial Analyst Extension. Inverse distance weighing (IDW) was used as the interpolation method. In June, CO₂ emissions were low in the north and high in the southwest. This trend continued throughout the month of August. Overall, CO₂, N₂O and CH₄ fluxes distribution showed shifts from high emissions in the north, at the beginning of the month, to low emissions in the north at the end of the month.

*Kaps, M.L., P.L. Byers and M.B. Odneal. Department of Agriculture, Missouri State University. ANNUAL SYSTEMS FOR STRAWBERRY PRODUCTION IN MISSOURI. The objective of the research was to produce high yields of large fruit with lower inputs of pesticide and labor. Day-neutral cultivars were planted in 1996 and June-bearing cultivars in 1996, 1997 and 2000. Day-neutrals bear within the same year and June-bearers in the following year. Experimental plantings were randomized complete blocks with four replications of thirty plants (4.6 m of row). In 1996 ‘Tribute’ had moderate and ‘Tristar’ had high yields. Marketable yields and berry weights were low for both of these cultivars. In 1997 ‘Chandler’ had higher yields from early compared to late September plantings. In 1998 ‘Chandler’ yield, did not differ among early, mid, and late September plantings. Yield of ‘Chandler’ was moderate in 1997 and high in 1998. Berry weight varied inversely, larger in 1997 and smaller in 1998. Branch crown number and harvest season length were not as high or long, respectively as obtained in other regions of the U.S. Yields of 15 June-bearing strawberry cultivars ‘Allstar’, ‘Delmarvel’, ‘Earliglow’, ‘Honeoye’, ‘Jewel’, ‘Lateglow’, ‘Latestar’, ‘Mira’, ‘Northeast’, ‘Primitime’, ‘Redchief’, Seneca’, ‘Surecrop’, ‘Sweet Charlie’, ‘Winona’ were low to moderate in 2001. Berry weights were

larger than 'Tribute' and 'Tristar' but usually smaller than 'Chandler'. Branch crown numbers varied among cultivars. Harvest season length averaged 4.5 weeks as occurred for 'Chandler' in 1997. There was no benefit to carrying-over the 15 June-bearing cultivars for a second fruiting season in 2002. An annual system using day-neutrals 'Tribute' and 'Tristar' is not recommended. June-bearers 'Allstar', 'Chandler', 'Late-glow', 'Latestar', 'Northeast', 'Primetime', and 'Sweet Charlie' are reasonably productive in an annual system under southern Missouri environmental conditions.

*Paro, R. and N.V. Nkongolo. Center of Excellence for Geospatial Information Sciences, Lincoln University. FLUCTUATIONS OF CO₂, CH₄, AND N₂O FROM SOIL IN A SECONDARY FOREST OF CENTRAL MISSOURI. Greenhouse gas fluxes vary considerably across the landscape, thus understanding their distribution is essential for designing reduction strategies for the future. We studied the fluctuations of greenhouse gases fluxes from soil of a secondary forest at Lincoln University's Busby Farm. Twenty static chambers were installed on a 0.49 ha plot and their locations recorded with a GPS. Chambers were sealed for 30 minutes and air samples collected and analyzed within two hours for determinations of CO₂, CH₄ and N₂O. Fluxes ranged from 11.86 to 172.90 mg CO₂-C m⁻² h⁻¹ for CO₂ emissions, -5.72 to 18.80 ug N₂O-N m⁻² h⁻¹ for N₂O emissions and -203.48 to -91.94 ug C-CH₄ m⁻² h⁻¹ for CH₄ uptake (negative flux). Data was fitted to variogram models using GS + software. Interpolated maps were created in ARGIS 9.2 and Inverse distance weighing (IDW) was used as the interpolation method. As expected, CO₂ and N₂O emissions and CH₄ uptake displayed a wide variation and responded to various variogram models. The choice of a particular variogram model was based on a combination of visual observation and respective R² values. Both CO₂ and N₂O fitted a Gaussian model with an R² values of 0.92 and 0.82, respectively. CH₄ fitted a spherical model with an R² value of 0.65. This study will provide a better understanding of gas fluctuations in this forest and aid in designing of future control strategies.

Atmospheric Science

*Buonanno, C.C. National Weather Service, Little Rock AR. ANALYSIS OF THE ARKANSAS TORNADO OUTBREAK WITH STORMS ASSOCIATED WITH HURRICANE RITA. Hurricane Rita made landfall early in the morning of 24 September, 2005. The hurricane accelerated northward through western Louisiana and eastern Texas, then turned northeast, moving across southern Arkansas and northern Mississippi. Eighteen tornadoes were produced in Arkansas with storms associated with the hurricane. Of these eighteen tornadoes, three were responsible for F2 damage, eleven were responsible for damage meeting the F1 criteria, and four met F0 criteria. The tornadoes occurred during an eight-hour period. The rapid

evolution of this tropical system, along with the swift movement of individual storms provided challenges to warning forecasters. An analysis of the storm event will be provided, along with detailed investigation of individual tornadic storms. Lessons learned by forecasters will be offered as best practices for future warning events concerning land-falling tropical systems.

*Athar, H.¹, A.R. Lupo¹ and S. Dostoglou², ¹Department of Soil, Environmental and Atmospheric Sciences and ²Department of Mathematics, University of Missouri-Columbia. A CALCULATION OF LYAPUNOV EXPONENTS FOR ATMOSPHERIC BLOCKING. Lyapunov exponents quantify the average leading order stability properties of a dynamical system. Atmospheric blocking may be considered as a quasi-stable state in zonal atmospheric flow. We report a calculation of Lyapunov exponents for atmospheric blocking using Dymnikov et. al. conjecture. This conjecture correlates the sum of regional positive Lyapunov exponents with the area integrated enstrophy of the large scale atmospheric flow. Selected case studies are performed to examine this correlation for blocking events occurring during the three-year period (2002–2004), both for Northern as well as Southern Hemispheres, using the NCEP gridded re-analysis data. In particular, it is noted that the time variability of Lyapunov exponents is suggestive of the role played by instability in large-scale flow during onset, maintenance and decay of blocking. Our diagnostic study thus indicates that Lyapunov exponents along with the geopotential height of atmospheric flow may be used as a stability index for atmospheric blocking.

*Roets, J.N. Lead Forecaster, Aviation Weather Center, Kansas City, Missouri. THE ROLE OF MICROSOFT FLIGHT SIMULATOR FOR WEATHER AND AIRCRAFT FAMILIARIZATION. Flight simulators are used daily by aircrew for training on new procedures or to introduce them to the flight characteristics of new aircraft. Simulators are also used for refresher or recurrent training on how to handle hazardous weather events. Up until 9/11, National Weather Service (NWS) meteorologists have been allowed to fly with aircrew on airliners in order to better understand what the aircrew goes through during a flight. The Familiarization Flight Program (FAM) was a valuable training opportunity. Because of security concerns the FAM program is no longer available to the NWS. Using Microsoft Flight Simulator, I will show how it's possible to recreate weather events in the course of a virtual FAM flight. I will also recreate two real-world aircraft accidents to show how weather played a key part in them. Using the simulator I will show how to train both current and newly-hired NWS meteorologists in the recognition of hazardous weather from the aircrew perspective.

*Schnetzler, A.E.¹, G. Amenta², H. Athar¹, J. Glisan¹, P. Market¹, B. Pettegrew¹, R. Redburn¹ M. Reagan¹ and M. Wood². ¹Department of Soil, Environmental, and Atmospheric Sciences and ²Department of Physics, University of Missouri — Columbia.

A COMPARATIVE STUDY TO QUANTIFY THE CHAOTIC BEHAVIOR IN NUMERICAL MODELS. Studies have shown that numerical models are representative of chaotic systems, and as such, the solutions are sensitive to initial conditions. Through an examination of the Kain-Fritsch, the Grell and the Kuo-Mesoscale convective parameters in the MASS and the WRF model, results show that 48-hour forecast were not exact. Lyapunov exponents were calculated by plotting forecast trajectories in a phase diagram and estimating the rate of divergence. These demonstrated that forecast trajectories did show divergence at a rate, which yielded realistic differences in model height in 48-h forecasts. Also, a qualitative analysis comparing various model runs (pseudo-ensemble) was performed in order to determine if there were regions or areas where there were consistent differences between runs. Initial results demonstrated that areas associated with developing cyclones had the most significant differences.

*Schnetzler, A.E.¹, C.F. Dierking² and A.R. Lupo¹. ¹Department of Soils, Environmental, and Atmospheric Sciences, University of Missouri-Columbia and ²National Weather Service Forecast Office-Juneau. SEASONAL TEMPERATURE AND PRECIPITATION DEPENDENCIES IN SOUTHEAST ALASKA. The climate of southeast Alaska is primarily influenced by moist maritime air from the adjacent Pacific Ocean that is occasionally modified by drier continental air from Canada. This battle between maritime and continental air masses can also have implications in terms of the relationships between temperature and precipitation in this region. In order to gain a better understanding of this relationship, linear regression was used to determine the correlation between seasonal temperature and precipitation values at four locations in southeast Alaska. In addition, a mean 700-mb and 500-mb height composites were calculated for seasons with anomalous mean temperature and precipitation values at the same four locations. A comparison of these composites helped to identify flow characteristics that were conducive to the anomalous conditions. These identified flow characteristics in the upper-level height patterns will help the forecasters at the National Weather Service Office in Juneau, Alaska detect seasons the Climate Prediction Center forecast that will have temperatures that are warmer or colder than normal and have precipitation amounts that are higher or lower than average.

Biology

*Aldridge, R.D., S.S. Wisniewski and M.J. Betley. Department of Biology, Saint Louis University. THE STRUCTURE AND FUNCTION OF COPULATORY PLUG IN THE AFRICAN BROWN HOUSE SNAKE (*LAMPROPHIS FULIGINOSUS*). The copulatory plug in snakes has been described as a gelatinous material that the male deposits into the female's cloaca during copulation. This material may have an effect on the

attractivity of females after copulation by discouraging courtship, or it may physically prevent re-mating. Only seven snake species have been examined for the existence of a copulatory plug. The most thorough study of the plug (Shine et al., 2000) in a snake (*Thamnophis sirtalis parietalis*), concluded that males deposit a "thick gelatinous plug that occludes the female cloaca after copulation", thus preventing subsequent copulation. This study describes and examines the role of the copulatory plug in brown house snake (*Lamprophis fuliginosus*). In laboratory trials, most mating events occurred within one-hour, however, snakes will mate after two or more hours of courtship activity. Most copulations lasted over 4 ½ hours. A copulatory plug structure was found in the cloaca of all mated females. Following copulation, the mated female was unattractive for 2–4 days. The plug consisted of a 1–2 ml clear, syrup-like viscosity liquid. This material filled the cloaca and would drip out of the vent with palpation. These copulatory secretions, when placed on attractive females, did not alter their attractiveness.

*Aldridge, R.D.¹, D.A. Kangas², J.M. Jones³, L. McGuire⁴, and K.M. Graves⁵. ¹Department of Biology, Saint Louis University, ²Science Division, Truman State University, ³Biology Department, Culver-Stockton College, ⁴Clopton High School and ⁵Bowling Green High School. AMPHIBIAN POND SELECTION: AN INQUIRY BASED STUDY. The goal of this research is to determine if amphibians choose to lay eggs in ponds that have fewer competitors and predators than in adjacent ponds that have neither. Nine ponds, 4 × 4 m, 0.7 m deep, lined with a rubber pond liner, were constructed in a field along a tree line in Pike County, Missouri. The ponds received one of three treatments in a randomized order. Three of the ponds were stocked with 125 bullfrog tadpoles (*Rana catesbeiana*), three were stocked with 25 goldfish (*Carassius auratus*) and (later) bluegill sunfish (*Lepomis macrochirus*), and three served as controls. The first amphibians to use the ponds for breeding were American toads (*Bufo americanus*). The number of toad tadpoles in the three pond treatments was not statistically different. In mid-June American toad and gray treefrog (*Hyla versicolor* complex) tadpoles were present. In mid-July, the vast majority of the tadpoles were tree frogs of the *Hyla versicolor* complex and cricket frogs (*Acris crepitans*). The distribution of these tadpoles was statistically different by treatment. In most of the samples *Hyla* and *Acris* tadpoles were absent from the fish treatment ponds.

*Amspoker, M.C. Department of Biology, Westminster College. *HYALONEIS*, A NEW DIATOM GENUS FROM THE SUNNY SANDS OF SOUTHERN CALIFORNIA. *Dimeregramma* (*Dimeregramma*) *hyalinum* Hustedt, a relatively common diatom of marine littoral benthic assemblages, was described from mud samples collected from Beaufort, North Carolina, U.S.A. in 1955. Hustedt and later workers noted that the frustule of this species was completely hyaline. Studies of *D. hyalinum* from the type sample and from material collected

from Scripps Beach, California, U.S.A. in 1972 and Beaufort, North Carolina in 2006 with the light and scanning electron microscopes confirmed the hyaline nature of the valve face and cingulum, but revealed the presence of apical slit fields located on the mantle at the apices of each valve. The valves of *D. hyalinum* lack the uniseriate striae composed of round areolae, sternum, transapical ribs, and spines arising near the mantle of the valve characteristic of *Dimeregramma*. Furthermore, the apical pore fields composed of loosely packed porelli found in *Dimeregramma* differ markedly from the apical slit fields observed in *D. hyalinum*. Results of these studies suggest that *D. hyalinum* is sufficiently unique from *Dimeregramma* and araphid genera with apical slit fields to warrant its transfer to a new araphid genus, *Hyaloneis*, in the Fragilariaceae.

Mitchell, A.K. and A.R. Oller*. Department of Biology and Earth Science, University of Central Missouri. RECOVERY OF VIABLE *STAPHYLOCOCCUS AUREUS* CELLS FROM WASHED TOWELS. *Staphylococcus aureus* is known for causing nosocomial infections within hospitals and has recently become a problem in community-acquired infections. Studies have linked infections to sharing personal items such as soaps and clothes. Bacterial transfer rates for cotton to cotton surfaces have been shown to be the highest when wet, but different types of cotton have not been tested to determine if absorbency or thread count plays a role in cell viability. Towels were autoclaved and pre-wash samples collected before the procedure confirmed no contamination from the environment. Template areas were inoculated with known *Staphylococcus aureus* concentrations onto Terry, Egyptian, and Upland cotton. Towels were subjected to simulated washing in control, detergent, or bleach water conditions for 15 minutes. Replica plating of the template region revealed surface bacteria to be highest on towels laundered in control cycles, slightly decreased on detergent, and no bacteria on those in bleach. Replica plating outside of the template revealed displacement of the bacterium to be predominantly in the wash water. Significance was determined by a three-way ANOVA and a post-hoc Tukey test, both with alpha levels set at 0.05. Bacterial viability differences were determined to be between the detergents and bleach washing conditions. Transfer rate in relation to time was determined to be highest on dry towels tested immediately after inoculation, moderately high after 24 hours, and lowest after 48 hours. Our study demonstrated that fabric type is not a significant contributor to survival of the bacterium, but that washing condition does affect *Staphylococcus* viability.

*Quick, L. and J.S. Ely. Department of Biology, University of Central Missouri. GRAZING PREFERENCES AND CHARACTERISTIC AMONG ANGUS AND MAINE-ANJOU CATTLE. Cattle producers are looking for new methods to improve grazing and forage crops for their livestock without increasing production costs. Previous grazing studies have focused on the harmful effects of forage to cattle. The purpose of this study was to understand grazing preferences and weight

gain between two breeds of cattle (*Bos taurus* L.). Thirty-four Angus and Maine-Anjou breed-influenced individuals grazed in a planned grazing system. The percent cover of forage crops or plants species were surveyed from grazed (treatment) and ungrazed (control) plots over an eight-week period. Height and weight of each breed was determined before and after grazing. Grazing preferences, treatments and height and weight data were analyzed through Multi-Response Permutation Procedure (MRPP), mean and standard error figures, and 2×2 ANOVA's. There was a significant difference in height and weight of each breed (e.g. Angus and Maine-Anjou) before and after the experiment ($p < 0.05$; Tukey, $p < 0.05$). Although there was no statistical difference in height and weight gain between the two breeds ($p > 0.05$), a biological trend may be evident. Maine-Anjou cattle prefer the nitrogen rich plant species while the Angus prefer other species. There were significant differences in the pre- and post-grazing on plant species composition (MRPP, $p < 0.05$). The post-grazing dung yielded no significant difference in total nitrogen output between the two breeds. The latter may suggest that the Maine-Anjou are better at nitrogen assimilation than the Angus because one would expect more nitrogen output from the Maine-Anjou because of a larger intake of nitrogen rich forage.

Computer Science

*Fosdick, B. and Y. Wang. Department of Computer Science, Missouri State University. ON COLLISION DETECTION ALGORITHMS. Computer generated games have been booming in today's entertainment world. In order to deliver a real-world visual experience to a user, often, one has to solve a common problem: object collisions, while programming for computer games. For example, normally, a ball would bounce off a wall, instead of penetrating the wall. Various collision detection algorithms have been developed. These algorithms vary from very simple ones to very complex ones. Each of the algorithms has its own advantages and disadvantages over the other methods. Thus, one algorithm that is good to use under one scenario might not be good to use under another scenario. This paper will describe some commonly used collision detection algorithms for simple shapes as well as for complex polyhedra. Comparisons, which include discussion of problematic behaviors in regards to numerical robustness and special geometrical cases, will be made among these algorithms. Also, optimizations on the process of collision detection will be discussed.

*Naugler, D.R. Department of Computer Science, Southeast Missouri State University. IS COMPUTER SCIENCE DYING? A serious decline in enrollments in undergraduate Computer Science has persisted for several years. Numerous explanations have been suggested. Is the decline merely part of a normal "boom or bust" cycle? Is the problem that there is too much

mathematics or that it is not made sufficiently appealing? Should we change the curriculum to be more attractive to women and other under represented groups? To be more people oriented? Are students unwilling to tolerate the rigors of the subject? Are “off-shoring” and H1-B visas reducing the career potential for graduates and scaring them away from the subject? Efforts to recruit and retain more students are guided by the perceived reasons for the decline and these efforts have not been very successful. Perhaps the perceived reasons are wrong. Computer Science now competes for students with SE, CIS, IS, CE, MIS and IT, all of which were once part of it or which significantly overlapped it. In establishing its disciplinary identity it has deepened but narrowed its focus. Its relevance to students has likewise narrowed.

Conservation

*Cooper, C.L., M. Torrey, C.B. Holloway, I.C. Onyewadume, A.C. Schroeder and S.N. Schoening. Division of Science (Biology), Truman State University. ANALYSIS OF BACTERIAL AND CHEMICAL INDICATORS OF WATER QUALITY IN THE LOCUST AND EAST LOCUST CREEKS. Three prairie streams were analyzed for several indicators of water quality. Locust Creek is one of the few remaining meandering streams in north-central Missouri with no known point source pollution. The Elmwood Creek collects discharge from a packing plant and feeds into the East Locust Creek, also a discharge site for municipal wastewater treatment and pasture run-off from a livestock sale barn, and which merges with the Locust Creek near Browning, MO. Analytical methods were from *Standard Methods for the Examination of Water and Wastewater* (1998) and *Environmental Protection Agency Method 1604*. Seven sites were sampled on 4 or 5 dates from June 4 to September 2 in 2006. *Escherichia coli* in the Elmwood and E. Locust Creeks exceeded the limit for Whole Body Contact category B (548 colonies/100ml) in 6 of 15 samples. The Locust Creek exceeded this limit in 2 of 9 samples from the region downstream of the merge with E. Locust Creek. In addition, two sites (Elmwood Creek and E. Locust Creek at state highway 6) showed frequent evidence of impact from point source pollution based on nitrogen, conductivity, ammonia, pH and phosphate. The results suggest a negative impact of chemical and bacteriological pollution in this watershed caused by human activities along these streams. Funding was provided by Truman State University and the Missouri Stream Team Volunteer Program (Department of Natural Resources).

*Haskins, M.F.¹ and G.L. Cox². Biology Department, Rockhurst University¹ and Abitibi-Consolidated Recycling Division, Kansas City, MO². INDIVIDUAL RECYCLING EFFORTS YIELD LARGE-SCALE CUMULATIVE BENEFITS. The recycling of paper and paper products has increased from a mere 16.9% in 1960 to 50% in 2005 (EPA, 2006). Since these products typically represent the largest single component in

U.S. landfills, the recycling of these materials is extremely important. This increase in recycling, although impressive, has failed to keep up with the even more dramatic increase in paper and paperboard production. Although Americans currently recycle higher volumes of paper and paperboard than in the past, there is still much room for improvement as evidenced by the fact the United States landfilled more paper products in 2005 than were produced in 1960, 42 million tons and 30 million tons respectively (EPA 2006). In an effort to promote recycling, many websites have developed “recycling calculators” to help people mathematically quantify the impact of recycling. However, in our opinion, these calculators don’t allow individuals to quantify their personal impact on resource conservation. In an effort to bridge this gap we gathered weight and volume measurements for three types of paper, i.e., newspaper, office paper, and mixed paper that were in three sizes of “personal recycling containers” i.e., grocery sacks, plastic bags, and curbside recycling bins (n=20 for each paper type and container type). After adjusting for volume differences we found no significant differences ($p \leq 0.05$) between our measurements and that of large-scale recycling operations (EPA 1994). We then quantified, for each size of container and type of paper, the resources that could be conserved through recycling. We believe that by quantifying recycling efforts on a small scale, individuals can better understand their small, but extremely valuable, contribution to society.

*Heth, R.K. Department of Biology, Missouri Southern State University. DIVERSITY, LIFE HISTORIES, AND PRODUCTION OF MAYFLIES IN FOUR OUACHITA MOUNTAIN HEADWATER STREAMS. Mayfly patterns are poorly known in the Interior Highlands. Diversity, life-histories, and annual production of mayflies were estimated in four intermittent Ouachita Mountain headwater streams 1997–1998. I collected five replicate benthos samples on each of 18 dates June 1997–May 1999 along with light traps during warmer months. Size-frequency production was estimated from size by date distributions and published length-weight regressions. Twenty-seven species were collected, ranging from 21 in the most permanent stream to 9 in the most intermittent. Multivoltine and warm-season species were excluded from the most intermittent streams where growth was primarily restricted to a winter-spring window. Rarely collected endemics included *Paraleptophlebia calcarica* and *Habrophlebiodes annulata* that were widely distributed in these four streams. Egg diapause appeared the most common survival strategy during dry season. Density (506/m²), average biomass (0.061gdw/m²), and production (0.636gdw/m²-yr) were greatest in the most permanent stream but did not differ significantly among the three more intermittent streams. Mayflies contributed 1.3 to 1.4% of total invertebrate production (range 0.636/6.18 in most permanent stream to 0.044/3.18gdw/m²-yr in driest stream). Diversity per site was similar to many other permanent Ozark streams. Minimal mayfly production is perhaps the result of the loss of warm-season growth opportunities, shading, and the removal of allochthonous carbon during winter spates.

*Kiehl, K. and C. Chevalier. Department of Biology, Missouri Western State University. INTERN NATURALIST WITH CLAY COUNTY PARKS SYSTEM: AN EXAMPLE OF SERVICE LEARNING THROUGH AGENCY AND UNIVERSITY COOPERATION. Education about conservation and management issues to the public is important to the future of natural resources. It is especially important to educate youths. During June-September of 2006, I interned with Clay County Parks Department at Smithville Lake. I was hired as a intern naturalist and conducted nature programs for disadvantaged youths including fishing, archery, and live animal programs. Other duties included were giving presentations to the public in the campgrounds once a week. I also performed non-law enforcement duties, and participated in Missouri Department of Conservation's Annual Goose Roundup at Smithville Lake.

Styczynski, A.R, L.L. Hause, J.W. Akers, M.A. Claeys-Jacobson, L. Bruce and *M. Lockhart Division of Science (Biology), Truman State University. AN ANALYSIS OF MICRO BIOTA IN FOREST LAKE AND HAZEL CREEK LAKE. Recently, land surrounding one of the Kirksville water supplies (Hazel Creek Lake) was sold to cattle farmers. This led to controversy concerning the risk of fecal contamination from field run-off. Water samples were collected monthly from five different locations from each of the two Kirksville water sources, Forest Lake and Hazel Creek Lake, for six months. Forest Lake permits whole body contact, class A, such as swimming, whereas Hazel Creek Lake has been approved for whole body contact, class B, such as wading, canoeing. Total heterotrophic bacteria were enumerated using the plate count technique after incubation at 25°C. Membrane filtration of water samples has demonstrated the presence of coli forms, including *Escherichia coli*. All samples were below acceptable limits set by standards set by the Missouri Department of Natural Resources. Acceptable limits for *E. coli* are 126 CFU/100 mL for class A and 584 CFU/100 mL for class B. Some of the samples have been tested for the pathogenic *E. coli* strain O157:H7 and have been found to be negative. This data provide a valuable baseline for monitoring potential contamination in the future. Further research may reveal whether the source of *E. coli* present in the water samples originated from human or cattle wastes and whether any of the *E. coli* collected represent pathogenic strains.

*Rushin, J. and R. Evans. Department of Biology, Missouri Western State University. SUCCESSIONAL CHANGES IN THE PLANT COMMUNITY IN A MISSOURI RIVER BOTTOM AREA BEFORE AND AFTER THE CONSTRUCTION OF A CHUTE. As part of a joint project of the Missouri Department of Conservation (MDC) and the U. S. Army Corps of Engineers (COE), a chute of the Missouri River was opened through the Lower Hamburg Bend Conservation Area (LHBCA) in the northwest corner of Missouri in an attempt to create an island, sloughs and backwater areas. Within a 300-acre area primarily affected by the new chute, 232 evenly spaced permanent sampling plots and 18 randomly located plots selected on a yearly basis were used to sample herbaceous plants, woody

seedlings, saplings and over-story trees according to the Vegetative Monitoring System (VMS) of the MDC. All sampling was done during late May, June and early July of 2002, 2003, 2004, 2005 and 2006. This study describes over 85 plant species sampled from all plots and it also compares VMS importance values of the top species in the study area. Although the river chute was open in the study area during the final two years of the study (2005 and 2006), there was no major flooding and the anticipated sloughs and backwater areas were not yet formed in the LHBCA at the conclusion of this project. Most of the plants recorded during the surveys were introduced and/or generalist species according to the VMS Coefficient of Conservatism. *Populus deltoides* was the primary woody species that survived to maturity. *Salix nigra* showed a fairly steady and high importance for seedlings, saplings and Overstory trees. *Salix interior* demonstrated its role as a pioneer species by having high importance values for seedlings and high but decreasing importance values for saplings throughout the study. Overstory trees of *Salix nigra* were only significant during the first year (2002) of the study. It is expected that native wetland species will increase in importance in the LHBCA with future flooding and the establishment of backwater areas and sloughs. Support from the Missouri Department of Conservation.

*Rushin, J. and S. Murril. Department of Biology, Missouri Western State University. A COMPARISON OF BIRD DIVERSITY IN SEVERAL SUCCESSIONAL HABITAT TYPES IN N.W. MISSOURI. Seventy-seven bird species were observed in several different successional habitat categories at the Pony Express Conservation Area near Osborn, Missouri, during five consecutive ten-day sampling intervals from May 21 to June 20, 2006. A standard point count method with sampling points evenly spaced at one hundred meters was used for this study. The sampling time was ten minutes per plot per sampling interval. The highest bird diversity indices based on Simpson and Shannon-Weaver determinations were found in the plots dominated by old field/tall grass/shrubby field/forest edge and old-field shrubby field/forest edge habitat category combinations. These were followed by old field/tall grass/forest edge and then agricultural field/old field/ tall grass habitat category combinations. The lowest two bird diversity indices were found in the tall grass/old field/agricultural field followed by the old field/tall grass/agricultural field habitat category combinations. Water features (ponds and lakes) were also shown to have a positive effect on overall bird diversity. The diversity index differences among the different habitat category combinations were fairly consistent throughout the study with highest bird diversities occurring in May before the nesting safe dates for most species. Support from the Missouri Department of Conservation.

Engineering

*Sauer, H.J., Jr., and P. Hande. Department of Mechanical and Aerospace Engineering, University of Missouri-Rolla.

MODULATING AND MIXING CHARACTERISTICS OF AIR FLOW DAMPERS. The operating characteristics of air flow control dampers are critical to indoor air quality (IAQ), energy efficiency, and the overall performance of a building's heating, ventilating, and air-conditioning (HVAC) system. Recent research sponsored by ASHRAE and Ruskin Manufacturing Co. has evaluated both modulating and mixing performance of parallel- and opposed-blade operation of standard mixing plenum airflow dampers. Analysis and synthesis of the resulting data are reported in this presentation. Correlations for the modulating performance of various combinations of damper type and damper mounting have been established in terms of a pressure loss coefficient (C_L) as an exponential function of damper opening (x), in degrees. Results show significant difference in performance between damper types and for the same damper mounted differently. Results from the mixing tests and simulations indicate that the old rule of thumb of "parallel blade dampers aligned to directed the two air streams at each other, will provide good mixing" is inaccurate. Improved mixing effectiveness can be obtained by either properly extending the mixing chamber and/or with the addition of baffles, unfortunately at the expense of additional pressure drop. However, properly configuring the mixing chamber can result in significant mixing improvement with minimum pressure drop increase, e.g., some 10% increase in effectiveness for a pressure drop increase of less than 0.1 in. wg.

Nelson, H.F., Jr., *H.J. Sauer, Jr., and C. Schillebeeckx. Department of Mechanical and Aerospace Engineering, University of Missouri-Rolla. **PREVENTING OVERHEATING OF ELECTRICAL POWER TRANSFORMERS.** The life of oil-filled electrical power transformers is strongly dependent on the maximum temperature in the transformer coils (i.e., the hot spot). During overload conditions, the hot spot temperature may rise significantly and quickly. In oil-immersed transformers the IEEE recommended maximum value for the hottest spot temperature is 140°C. Emergency external cooling can be produced by blowing air, or water, or both on the external walls of the transformer. This project evaluated the time response of the internal parts of the transformer with these types of external cooling. A one-dimensional, unsteady state finite difference heat transfer model was developed along the radial direction of the transformer consisting of, in order from the center, copper low voltage windings, paper insulation, copper high voltage windings, oil coolant, and steel external tank. Central-difference approximations were used for the spatial derivatives and forward difference approximations were used for the time derivatives. Input data of dimensions, thermal properties, and operating conditions were obtained from a transformer manufacturer. Overloads of 25% and 50% were examined with results indicating forced air cooling (fans) could prevent overheating at 25% overload; however, a water spray would be needed at 50%. Evaporative fine-mist fogging, as has been used for gas turbine inlet cooling, should be examined in more detail. Supported by AMEREN-UE and Pauwels Transformers.

Geology/Geophysics

*Gaunt, D.A., C. Rovey, G. Balco and M. Forir. ¹Department of Geology, Geography, and Planning, Missouri State University, ²Department of Earth and Planetary Science, University of Washington and ³Springfield Greene County Parks Department. **CHRONOLOGY OF SEDIMENT DEPOSITION IN RIVER BLUFF CAVE USING COSMOGENIC ISOTOPES AND PALEOMAGNETIC DATING TECHNIQUES.** The sediment within River bluff cave generally consists of well-stratified continuous layers. This sediment was deposited into the cave during episodic events of the adjacent James River and its Ward Branch tributary. We have focused dating attempts on the Cave's main room at two separate sites where the sediment is divided into ten layers (L-1 through L-10, youngest to oldest). We have dated these layers with paleomagnetic and cosmogenic-isotope techniques. L-10 (oldest layer currently exposed) gave a depositional age of 0.97 Ma \pm 0.5 Ma. L-9 gave a depositional age of 0.87 Ma \pm 0.5 Ma. Portions of L-8 are reversely magnetized, indicating deposition prior to 0.78 Ma. Consistent with the magnetization, quartz grains within this layer gave a depositional age of 0.80 Ma \pm 0.05 Ma. L-7 and L-6 (Mammoth Horizon) are the lower and upper subdivision, respectively, of a coarse-grained (gravel), channel facies, which contain disarticulated bones, of large Pleistocene-age mammals. This gravel facies gave a burial age of 0.66 Ma \pm 0.05 Ma. Younger slackwater deposits (L-5 through L-1) are normally magnetized with L-5 giving a depositional age of 0.57 Ma \pm 0.06 Ma. The L-5 thru L-2 levels is a micro-laminated homogeneous deposit and is virtually undistinguishable between divisions. The subdivision given is based on composite samples and paleomagnetic sampling locations, but is believed to be one depositional unit. L-1 is a distinctly different unit with high percentages of small bone.

*Nold, J.L., and M.A. Dudley. Department of Earth Science, University of Central Missouri. **TEXTURAL AND MINERALOGICAL INDICATIONS OF AN IGNEOUS ORIGIN FOR THE PILOT KNOB MAGNETITE DEPOSIT.** Study of thin sections and polished sections from ten newly acquired core holes are providing textural and mineralogical details in this poorly understood deposit. Various workers have suggested that the deposit may have originated by either igneous intrusion, igneous extrusion, or hydrothermal replacement. Our work suggests that the deposit is dominantly of igneous intrusive origin with a minor, late hydrothermal overprint. Textural and mineralogical indications of the deposit having resulted from an ore magma intrusion are as follows: The dominant matrix mineral is albite plagioclase with a composition of about An₂-An₅. Albite plagioclase being the dominant matrix mineral, plus the fine-grained nature of the ores, makes magnetite microsyenite the most common petrologic name for the ore. Magnetite shows porphyritic textures where the phenocrysts are zoned. Most of the magnetite and matrix minerals have a hypidiographic

granular igneous texture. Some of the magnetite ores are layered which is considered to be of rhythmic gravitational origin. Some of the plagioclase has an intercumulus polyclinic texture and contains included magnetite. Calcite is a common matrix mineral and where it is dominant in small segregations within the magnetite microsyenites, the rock is considered to be a magnetite carbonatite. Brecciation is also an important ore feature. Fragments are composed both of host rock volcanic, and pieces of the magnetite ore itself. It is suggested that fragments of magnetite ore within the magnetite ore intrusion originated by autobrecciation during intrusion. Contacts between magnetite ore and host rock volcanic are very sharp.

*Stinchcomb, B.L. and C. Braught. St. Louis Community at Florissant Valley. ARCHEAN? STROMATOLITES IN GLACIAL ERRATIC FROM THE WYACONDA RIVER, LEWIS CO., MISSOURI. A localized concentration of glacial boulders three miles upstream from the Wyaconda's confluence with the Mississippi contains many greenstone and other lithologies suggestive of providence from Archean terrains of the Canadian Shield. One of these large boulders consists of part of a stromatolite reef containing the stromatolite form genus *Kussiella* sp. in a black, iron-rich limestone. The lithology and morphology of the stromatolite is similar to that of the Archean Steep Rock Lake Limestone associated with a greenstone belt of western Ontario. It is suggested that this boulder might be from the same or a similar greenstone belt, possibly derived from Archean strata in the area now occupied by Lake Superior.

Geography

*Hoffman, B.L. Department of Natural and Physical Sciences, Park University. A GEOGRAPHY OF DISEASE ALONG THE SAINT JOE ROAD IN 1860. Although Independence and Westport, Missouri are roundly recognized as trailheads for the Oregon-California-Santa Fe Trails, Saint Joseph became an important alternate starting point during the cholera epidemics c. 1850. By 1860, Saint Joseph's economy was highly dependent on the outfitting of emigrants to the West. The western terminus of the Saint Joe Road, Marshall County, Kansas was the site of two important fords across the Blue River and was the union point with the Westport branch of the Oregon-California Trail. According to 1860 United States Census Mortality Schedules, infectious disease was the leading cause of death along this trail spur, with Buchanan County, Missouri and Doniphan, Brown, Nemaha and Marshall Counties in Kansas reporting a mean of 69% of all deaths due to infectious disease. The incidence of specific diseases along the trail varied greatly, however. In Buchanan County, Missouri, and Doniphan County, Kansas, with a more stable and dense population centered around Saint Joseph, the disease causing the most deaths was tuberculosis (22% and 17%, respectively). Marshall County, Kansas had a more transient population and experienced typhoid

fever as the leading cause of death at 36%. The patterns of diseases with lower fatality, such as malaria, meningitis, and streptococcal diseases will also be examined.

Physics

*Manivannan, K.¹ and A. Manivannan.² Department of Physics, Astronomy and Materials Science, Missouri State University¹ and Department of Physics, University of Virginia.² GEOMETRICAL OPTICS ON SPREADSHEET: 2-D PARAXIAL RAY TRACING. Geometrical methods such as ray tracing communicate the physical interpretation of optical image formation more effectively than formulas. However, introductory college and high school physics courses teach geometrical optics using mostly the lens equations. Ray diagrams to scale are used to a lesser extent, partly owing to the drudgery of repetitive drawing ray diagrams with multiple values of focal lengths and object distances. On the other hand, visualizing ray diagrams is an effective way to gain deeper insight into optical image formation, and in this presentation we will show how this can be done easily with the use of spreadsheet programs such as Microsoft Excel.³ Spreadsheets such as Excel are very user-friendly, have powerful graphics capabilities, and have been recognized as a powerful tool in teaching physics for some time. One significant advantage of the spreadsheet is that it enables us to change focal lengths and object locations and *instantly* redraw rays to display new images. Using Excel spreadsheet we will show the instant image formations of one- and two- dimensional objects such as a vertical line, rectangle, triangle, and a figurine. In particular, we will demonstrate that, in the simplest case of paraxial optics, transverse magnifications behave as expected but longitudinal magnifications are affected differently, producing distorted images.

³A. Manivannan and K. Manivannan, "Geometrical Optics on Spreadsheet," 124th National AAPT Meeting, AAPT Announcer, 31(4), 120, 2001.

*Ottinger, M.B.¹ and M.A. Johnson.² ¹Department of Computer Science, Mathematics and Physics, Missouri Western State University and ²Department of Industrial Management, Missouri State University. COMPUTER MODEL OF LONGITUDINAL AND TRANVERSE WAVE PROPAGATION IN METALS WITH FREE SURFACE REFLECTION. A common technique to find imperfections in metals is to measure the travel time for a transverse wave pulse to reflect off the imperfection (such as a crack) and return to the transducer that created the initial pulse. When the longitudinal wave speed in the metal is known, the location of the imperfection can easily be determined. In such experiments, where the pulse travels through a one-inch thick piece of iron, a second, much attenuated, reflected wave pulse is observed at times that could correspond to the travel time of a reflected transverse wave. To test the hypothesis that this second reflection is from a transverse wave, we designed a simple computer model of the metal. This model divides the

metal into an array of cells that interact with each other through compression and shear forces. Poisson's relation is used to link the longitudinal and transverse compressions of each cell. Longitudinal waves are created at one end of the metal, as in the experiment, and propagated through the array using Euler's method for finite differentiation. Using the code, we observe the reflected waves at the initial surface, as in the experiment. We also are able to graph the wave propagation (longitudinal and transverse) throughout the metal.

*Redd, E. Department of Physics, Astronomy, and Materials Science, Missouri State University. RECONCILING "FROZEN STAR" AND "POINT SINGULARITY" MODELS OF BLACK HOLES. Kevin S. Brown¹ gives a good discussion of the formation and growth of black holes (BH). However, he does not reconcile the "frozen star" (corresponding to the "field interpretation" of Weinberg) and the "point singularity" ("geometric interpretation" of Misner/Thorne/Wheeler) models. His main concern is "there is no known mechanism for" "pushing [a frozen star's mass] outward". However, no push is required because all event horizons (little ones, big ones, or growing ones) are at the same potential energy level. He correctly claims that the BH's mass is "in two places (both inside and outside the event horizon) at the same coordinate time," and that the event horizons are surfaces of future null infinity. These three facts reconcile the models and leads to more satisfactory answer to how gravity gets out of a BH, i.e., it does not have to get out; it exists outside the event horizon until future null infinity. And, at the same coordinate time, it is at the point singularity, creating the event horizon.

*Shaw, J. E. Department of Chemistry and Physics, Northwest Missouri State University. A COMPARISON OF HEAT ENGINES USING TEMPERATURE RATIO AND COMPRESSION RATIO. All introductory physics texts mention that no engine operating between two temperature extremes is more efficient than a Carnot cycle operating between the same two temperature extremes. Some texts give a formula for the efficiency of an Otto cycle, which depends only on the compression ratio. How do we compare a Carnot cycle with an Otto cycle? Writing the efficiency in terms of temperature and entropy gives a good means of comparison as was shown in a previous presentation to the Missouri Academy of Science in 2006. In this presentation the efficiency of the Otto cycle, Diesel cycle and Stirling cycle as a function of temperature ratio and compression ratio will be given. For a given temperature ratio, there can be both upper and lower limits on the compression ratio. As an example, if the compression ratio of an Otto cycle is increased then the amount of heat input per cycle must decrease in order to maintain the same temperature ratio. Eventually, an upper limit is reached in which the heat input to the cycle is zero. It turns out that this upper limit is the same as the lower limit on the compression ratio of the Carnot cycle operating between the same two temperature extremes. Similar limits exist for

the Diesel and Stirling cycles. For the Otto, Diesel and Stirling cycles, graphs of the efficiency as a function of compression ratio for different temperature ratios exhibit a law of diminishing return—efficiency increases with compression ratio but the amount by which the efficiency increases becomes smaller with increasing compression ratio.

*Sim, Y., P. Gibbons and J. Wieggers. Department of Physics, Washington University. K-8 ELEMENTARY TEACHERS' RESPONSES ON WHAT AND WHY QUESTIONS ABOUT CIRCUITS AND ELECTRIC CURRENT. In a professional development course in 2007 Spring at Science Outreach at Washington University in St. Louis, K-8 elementary teachers are asked about electricity and magnetism in pre and post test. The teachers' answers reveal their prior knowledge and post knowledge before and after class activities. In this paper, I focus on teachers' answers to what and why questions on circuits and electric current. In the first question, teachers are given a set of pictures showing a battery, wire, and bulb. The teachers are asked which pictures represent a complete circuit. This paper reports on teachers' answers to these questions: 1) What are the teachers' alternative conceptions in their reasoning about circuit? 2) What are their meanings of a complete circuit? In the next question, teachers are given four different models showing a battery, bulb, and electric current through wires. The teachers are asked which model represents the scientific idea about electric current and why the other models are not good representations. This paper reports on teachers' answers to these questions; 1) What are the teachers' alternative conceptions in their reasoning about electric current? 2) Is the scientific term represented or used correctly?

*Thomas, A., P. Gibbons and J. Wieggers. Department of Physics, Washington University. K-8 ELEMENTARY TEACHERS' ANSWERING WHAT QUESTIONS WITH WHY ANSWERS. During a physics professional development for practicing teachers, the teachers were asked to make observations and create operational definitions based on what they could actually see, feel, hear, or touch. Many have difficulty with this task, often using non-observational terms. At the beginning of one class, teachers, using observational terms, were asked to define an electrical circuit. Teachers were then provided with activities and instruction. They wrote on these activities in their reflective journals. A comparison was then made of their pre and post instruction responses. Results will be discussed later.

Science Education

*Aide, C. Department of Physics and Engineering Physics, Southeast Missouri State University. EARTHQUAKE SCENARIO AN EFFECTIVE TEACHING TOOL FOR NON-MAJORS. Today's students have been educated in a learning environment emphasizing simulation and action learning; wherein, the student "experiences" a situation and is expected

to draw conclusions. Experiential Learning differs from structured or traditional learning that emphasizes learning facts and then being tested on said facts. The Earthquake Scenario combines both with the bulk of the semester being a traditional education in the causes and effects of earthquakes, how to measure earthquakes and the effect of different substrates and building materials on earthquake damage. With a sound foundation the students then “experience” two earthquakes. I have created a computer-based simulation of a fictional town with images of buildings and maps of water depth and substrates. The students do emergency planning for this town then, with the use of forum, interact with each other for an earthquake scenario. Out of 50 students that responded to the evaluation 36 strongly felt that the scenario was effective, 14 felt it was effective and 1 felt it was not. Comments indicated that the scenario tied the first part of the class together.

*Daggett, M.A.F. Department of Biology, Missouri Western State University. THE USE OF ADULT AND EMBRYONIC ZEBRA FISH IN EXTENDING BIOASSAYS IN UNDERGRADUATE RESEARCH PROJECTS. Zebra fish have been incorporated into independent undergraduate research projects at Missouri Western State University. This poster outlines and presents protocols and practical information for using zebra fish as a model organism at a predominately undergraduate institution. Currently zebra fish are being used for independent research projects in BIO 215 Molecular Cell Biology and BIO 311 Animal Physiology at MWSU. Zebra fish have become an accepted model organism for the study of embryonic development and genetic based diseases. Zebra fish are also becoming an established organism for use in undergraduate teaching laboratories. The advantages of using zebra fish include ease of culturing and maintaining the fish in the lab and the availability of information on the Internet for performing various scientific investigations using zebra fish. Independent research projects offer an opportunity for students to design, perform and report on their own research question. This poster will present examples of past student projects in which simple bioassays have been extended to include experimental techniques required to detect and quantify the expression of specific genes during exposure to pharmaceuticals, personal care products and environmental toxins.

*Daggett, M.A.F. and B.D. Caldwell. Departments of Biology and Chemistry, Missouri Western State University. DEVELOPMENT AND IMPLEMENTATION OF SKILL-SPECIFIC ASSESSMENTS IN INTRODUCTORY CELL BIOLOGY AND BIOCHEMISTRY TEACHING LABORATORIES. Curriculum requirements in the sciences often reflect the importance of a laboratory experience as an opportunity to enhance the learning of science-related skills, content and processes. Most science faculty would agree that laboratories play an important role in enhancing the learning and retention of new information. In today’s high tech laboratories and professions,

students will be required to work with increasingly sophisticated equipment that many teaching institutions do not have available. However, the lack of experience on sophisticated equipment may not be the most important factor that prevents our students from excelling after graduation, but rather a lack of basic laboratory skills that many laboratory veterans, including faculty, take for granted. In order to ensure that students graduate with the basic skills required for succeeding in the day-to-day operation of a laboratory or as a professional, a series of skill-related assessments are being developed and tested for use in the introductory cell biology and biochemistry courses at Missouri Western State University. These standardized skills can then be assessed later in advanced courses in order to monitor retention. The advantage of developing and using standardized assessment tools will permit changes in future laboratory assignments in order to improve the retention of these skills.

*Hegger-Ferguson, P. and S.H. Mills. Sedalia Middle School and Department of Biology, University of Central Missouri. MIDDLE SCHOOL INVESTIGATIVE STUDY: TEMPERATURE EFFECTS ON INSECT DIVERSITY. Middle school students were encouraged to develop a comparative study of regions of the school yard resembling a prairie, woodland, and wetland. Students began their investigation with several visits to each of these areas during which they took notes on their observations followed by compiling a web of ideas. After discussing their observations, the question was narrowed to the effects of ambient temperature on insect diversity. Students in each of 4 classes recorded the different insect species found in each ecosystem and recorded ambient temperatures at three sites over a series of days during Fall, 2006. Students summarized their data by plotting the number of different insects in each ecosystem over time. The average ambient temperature was also plotted over time. By overlaying the numbers of insects and ambient temperatures, it appears that the number of insects decreased in all ecosystems as the ambient temperature tended to decrease. It appears that the number of species observed was reduced as ambient temperature decreased. Students observed fewer insects on days with lower temperatures, and fewer insects in early morning classes.

*Saha, G. Department of Education, Lincoln University of Missouri. GAINING THE POWER OF REASONING WITH EVIDENCE FROM INQUIRY SCIENCE. Scientific literacy has become a critical global need for humans to take informed decision and necessary actions for the overall sustainability of our planet. Attributes of scientific literacy such as evidential basis of active reasoning skills are teachable via inquiry and so science teachers can take a leading role to reverse the current predominance of unscientific minds in our society that are being used as pawns to promote activities ominous to this planet. This paper describes one component of a full scale professional development (PD) study and answered two questions: 1)

Do in-service teachers necessarily develop better scientific reasoning skills from their PD on inquiry science pedagogy? And (2) To what extent does teachers' participation in the PD impact students' scientific reasoning in an inquiry science environment? A pre-and-posttests, nonrandomized, comparative-group quasi-experiment research design was used to answer those questions. Results from the exploration indicate that there

was a 21% ($<.000$) gain of science reasoning skills for the participating teachers. This gain was in turn translated into their students' significantly ($<.004$) higher (26% increase) scientific reasoning skills. The framework developed in this research can serve as a menu of teaching techniques that educators and researchers can pilot and evaluate in their local settings. Further research possibilities and limitations are discussed.

Collegiate Division

Abstracts by section

Agriculture

*Banks, M.L. and N.V. Nkongolo. Center of Excellence for Geospatial Information Sciences, Lincoln University. SPATIAL ANALYSIS OF CARBON DIOXIDE (CO₂) AND SOIL THERMAL PROPERTIES IN A PASTURE. Mapping the distributions of CO₂ is vital in establishing practical methods of reducing the emissions of greenhouse gases. The objective of this study was to map the distribution of CO₂ fluxes, soil temperature (T), thermal conductivity (K) and resistivity (R) from soil in a pasture. This research was carried out at Carver Farm, Lincoln University, from May to December 2006. The soil of the experimental site is silt loam. The methods consisted of installing 20 static chambers on a 1.42 ha plot of land and positions recorded by using the Geo-Explorer Pathfinder 3-Global Positioning System. For collection of the gas samples the chamber top was closed with rubber stoppers and the air samples were collected every thirty minutes. Within two hours soil air samples were analyzed with a Shimadzu Greenhouse Gas GC-14. Using ARCGIS 9.2 Spatial Analyst Extension, maps of the CO₂ fluxes were created using Global Polynomial Interpolation (GPI) interpolation method. CO₂ ranged from 24.21 to 38.76 mg CO₂-C m²h⁻¹ and soil thermal properties from 24.39 to 24.97°C, 0.62 to 0.95 Wm⁻¹c⁻¹, and 1.07 to 2.14 m²cw⁻¹ for T, K, and R, respectively. Significant linear correlations were also found between CO₂ and T ($r = -0.39$, $p = 0.00001$) and K ($r = 0.46$, $p = 0.00001$). In June, CO₂ emissions were low in the north and high in the southwest and continued through August. These preliminary results have shown that gas emissions need to be monitored and reduced using applicable methods.

*Banks, M.L., H.Y. Johnson, and F. Eivazi. Department of Agriculture, Biology, Chemistry, and Physics and Cooperative Research Programs, Lincoln University. QUALITY ASSESSMENT OF COMPOST AND VERMICASTING PRODUCED IN CENTRAL MISSOURI. This project was designed to evaluate physical and chemical properties of ten composted samples of various sources and one a soil sample. Ten composted samples included a nursery potting medium, Jefferson City Compost, LU food waste compost at various maturity stages, turkey manure compost, and worm castings collected from three worm farms were examined. Fresh samples were used to determine moisture, pH, conductivity, and concentrations of NH₄⁺ & NO₃⁻. Dried samples were used to determine the contents of total carbon, total nitrogen, and the essential elements. Worm casting contained the highest moisture levels of 50% to 70% and turkey manure compost had the lowest of 13%. Jefferson City compost had the highest pH of 8.56 and potting mix had the lowest of 5.3. Turkey manure compost has the highest

conductivity levels of 25 mS/cm, a low C:N ratio of 8, and a high ammonium:nitrate ratio of 10 indicating its immaturity and high phytotoxic potential. Turkey manure compost contained high macro nutrients and can be used as fertilizer if applied sparingly. Results showed composted samples varied in chemical and physical characteristics. It is recommended that both compost and soil or potting medium are tested before compost application to achieve safe use of compost and quality improvement of potting medium and soil.

*Gannaway, M. and N.V. Nkongolo. Center of Excellence for Geospatial Information Sciences, Lincoln University. SPATIAL ANALYSIS OF NITROUS OXIDE (N₂O) AND SOIL THERMAL PROPERTIES IN A PASTURE. Being able to visualize spatial relationships and patterns makes a difference in understanding problems with the environment and in obtaining a solution. The objective of this study was to map the distribution of N₂O fluxes from soil in a pasture and correlate its relationship between soil temperature (T), resistivity (R), and thermal conductivity (K) from the soil of Lincoln University's Carver Farm. The research was conducted from June to December 2006. Mapping the distribution of N₂O consisted of installing 20 static chambers on a 1.42 ha plot of land. A KD2 probe was used to measure the thermal properties inside each chamber. The site positions were recorded using the Geo-Explorer Pathfinder 3-Global Positioning System. The gas samples were collected every thirty minutes and analyzed within two hours of being collected. The results of the measured fluxes for 2006 yielded that the mean of the N₂O ranged from 8.41 to 52.01 and from 24.39 to 24.97°C, 0.62 to 0.95 Wm⁻¹c⁻¹ and 1.07 to 2.14 m²cw⁻¹ for T, K, and R, respectively. Soil temperature ($r = -0.44$, $p = 0.0001$) and thermal conductivity ($r = 0.35$, $p = 0.0001$) correlated with N₂O emissions. Maps of the distribution of N₂O were created using Global Polynomial Interpolation of ARCGIS 9.2 Geostatistical Analyst Extension. The results suggest that N₂O emissions from a pasture can be controlled by acting on soil thermal properties through proper soil management practices.

*Heard, D. and N.V. Nkongolo. Center of Excellence for Geospatial Information Sciences, Lincoln University. MAPPING METHANE (CH₄) EMISSIONS AND SOIL THERMAL PROPERTIES FROM A SOYBEAN. Mapping the distribution of CH₄ is important in establishing practical methods of reducing greenhouse gases emissions. The objective of this study was to map the distribution of CH₄ fluxes and assess the relationship between CH₄ fluxes and soil temperature (T), thermal conductivity (K), resistivity (R) and diffusivity (D). The study was conducted from June to December 2005 at Lincoln University's Freeman Farm. Twenty static chambers were installed in a

1.42 ha field cropped to soybean. The locations of chambers were recorded using a GPS. Soil air samples were collected and analyzed for determination of CH₄. Soil thermal properties were measured with a KD2 probe. Maps of CH₄ fluxes were produced with ARCGIS 9.2 Spatial Analyst Extension. Global Polynomial Interpolation was used as the interpolation method. CH₄ emissions ranged from -44.18 to 27.52ug CH₄-C m⁻²h⁻¹. Means for soil thermal properties were 10.37°C, 0.88 wm⁻¹c⁻¹, 1.21 and 0.19 for T, K, R, and D, respectively. CH₄ fluxes were correlated with T (r=0.54, p=0.0001), K (r=0.63, p=0.0001) and D (r=0.79, p=0.0001). CH₄ fluxes and soil thermal properties exhibited tremendous spatial variability throughout the sampling period. These preliminary results stress the need to monitor the fluctuations of gas fluxes in space and time. The results also suggest that soil thermal properties may be important factors in controlling greenhouse gas fluxes from soil.

*Herring, J.A. and H.Y. Johnson. Department of Agriculture, Biology, Chemistry, and Physics and Cooperative Research Programs, Lincoln University. OPERATIONS AND THE MONITORING OF COMPOSTING CAFETERIA FOOD WASTE. The purposes of this project are to convert cafeteria food waste into value added product and to monitor the process to ensure its success. Lincoln University (LU) composts an average of one ton of plate scrapings and kitchen food residues weekly using an in-vessel compost drum. LU cafeteria food waste is mixed with horse manure as a carbon source at a 1 to 2 (v/v) ratio. A hand squeeze method is applied to ensure 50–60% moisture content before loading it into the compost drum. Feedstock is continuously loaded into the compost drum for a two month period with temperature and oxygen being monitored weekly. A gradual increase of temperature reflects the increased activity of aerobic composting. The highest level of temperature coincided with the lowest level of oxygen at a total of ten tons of feedstock composting in the vessel. Samples were collected before, during, and after composting to monitor changes of physical and chemical properties. The pH of feedstock changed from 6 at the mixing stage, increased to 8 one week after composting, and then declined to 7.5 after a five month curing process. Electrical conductivity of the composted material increased during composting and decreased when cured. The end product of LU composting contained 2% N, 0.7% P, and 2% K which has been successfully used to support LU landscaping. This project demonstrated that through careful monitoring, cafeteria food waste can be successfully converted to a high quality soil amendment; rather than being disposed to a landfill polluting the environment.

*Mire, M.L. and J.R. Benne. Department of Agriculture, Biology, Chemistry and Physics, Lincoln University. SURVEY OF MOSQUITO GENERA PRESENT IN AN AGRICULTURAL SETTING IN MID-MISSOURI. Mosquitoes are the number one disease vector in the world. Recent outbreaks of West Nile virus have stimulated interest in species specific

transmission models. Although *Culex* species are the traditional vectors of West Nile and other encephalitic viruses, multiple other genera are vectors as well. A survey involving the collection of adult female mosquitoes was conducted during the months of September and October of 2006 at Lincoln University's Carver Farm located in Jefferson City, Missouri. The study involved the use of UV light traps baited with granular CO₂ to capture the specimens. The traps were maintained near a water source as well as near livestock grazing and holding areas. At this one small location six genera of mosquitoes were found. Of these six, four of the genera have been implicated as vectors of a variety of encephalitic viruses. The results of this survey will prove useful in further testing of the species collected for the presence of a number of encephalitic viruses including West Nile. Future testing of livestock at the survey site will aid in determining the transmission rate from vector to host.

*Mitchell, L. and N.V. Nkongolo. Center of Excellence for Geospatial Information Sciences, Lincoln University. CARBON DIOXIDE (CO₂) EMISSIONS AND SOIL THERMAL PROPERTIES IN A SOYBEAN FIELD. This study was conducted (1) to map CO₂ emissions and (2) assess their relationship with soil temperature (T), thermal conductivity (K), resistivity (R) and diffusivity (D) in a soybean field. The study was conducted from May to December 2005 at Lincoln University Freeman Farm. Twenty four static chambers of 0.30 m long and 0.20 m diameter were randomly installed in a 1.2 ha field and their locations recorded with a GPS. Soil air samples for determinations of CO₂ were collected and analyzed within two hours after sampling with a Shimadzu Greenhouse Gas GC-14. Soil thermal properties were directly measured in the field at 0.06 m depth with a KD2 probe. CO₂ emissions ranged from 83.83 to 219.59 mg C-CO₂m⁻²h⁻¹ and soil thermal properties from 9.35 to 11.78°C, 0.73 to 1.08 wm⁻¹c⁻¹, 0.97 to 1.49 and 0.16 to 0.24 for T, K, R, and D, respectively. CO₂ emissions were linearly correlated with T (r=0.76, p=0.0001), K (r=-0.55, p=0.0001) and D (r=-0.63, p=0.0001). Maps portraying the distribution of CO₂ emissions and T, K, R, and D were produced using ARCGIS 9.2 Geostatistical Analyst Extension. The results suggest that soil thermal properties are important controlling factors for greenhouse gas fluxes from soils.

*Nelson, T and N.V. Nkongolo. Center of Excellence for Geospatial Information Sciences, Lincoln University. SPATIAL ANALYSIS OF NITROUS OXIDE (N₂O) AND SOIL THERMAL PROPERTIES IN A SOYBEAN FIELD. This study aimed to (1) quantify N₂O fluxes from soil in a field cropped to soybean and (2) to assess the relationship between N₂O fluxes and soil temperature (T), thermal conductivity (K), resistivity (R) and diffusivity (D). The study was conducted in 2005 at a Lincoln University Freeman Farm. Twenty four static chambers of 0.30 m long and 0.20 m diameter were installed in a 1.2 ha field and their locations recorded with a GPS. Soil air samples for determinations of N₂O were collected from May to December 2005. The sampling process consisted of closing two

ventilation holes of the chamber with rubber stoppers, collecting at least 3 air samples every 30 minutes with a 50 ml syringe and storing each sample in 400ml Tedlar bag. Analysis of N_2O in air samples was done within two hours after sampling with a Shimadzu Greenhouse Gas GC-14. N_2O emissions ranged from 64.84 to 215.22 $\mu g N_2O-N m^{-2}h^{-1}$. Means for soil thermal properties were 10.37°C, 0.88 $Wm^{-1}c^{-1}$, 1.21 and 0.19 for T, K, R, and D, respectively. Significant linear correlations were also found N_2O emissions and T ($r=0.61$, $p=0.00001$) and K ($r=0.56$, $p=0.00001$) and D ($r=0.64$, $p=0.00001$). ARCGIS 9.2 Spatial Analyst Extension was used to map N_2O fluxes and soil thermal properties. The Global Polynomial Interpolation (GPI) interpolation method was used. N_2O emissions varied considerably across the field as did soil thermal properties.

*Patlan, M. and H. Y. Johnson. Department of Agriculture, Biology, Chemistry, and Physics and Cooperative Research Programs, Lincoln University. EFFECTS OF COMPOST ENRICHED POTTING MEDIA ON SEED GERMINATION AND SEEDLING GROWTH. Greenhouse experiments were conducted to evaluate the effects of Promix incorporated with compost at various rates on seed germination and subsequent seedling growth of selected plants. Seeds selected for this study were lettuce 'Black Seeded Simpson', radish 'Cherry Belle', eggplant 'Black Beauty', and fescue 'Kentucky 31' and 'Rembrandt'. Three types of compost tested in this study including Lincoln University (LU) food waste compost, turkey manure compost, and a vermicasting. Promix mixed with compost at rates of 5, 10, 20, and 40% and 100 % compost were prepared for the tests. Vermicasting at all rates did not affect seed germination of all plants, while 100% of LU food waste compost significantly reduced seed germination and 100% turkey manure compost completely inhibited seed germination. Dose responsive increases of plant heights were observed for lettuce and radishes grown in Promix incorporated with LU food waste compost at all rates, vermicasting up to 40%, and turkey manure compost up to 20%. Vermicasting at a rate of 40% incorporation in Promix best promoted the radish growth and root development. Turkey manure compost at 5% incorporation level promoted the highest growth of stem cuttings of scented geranium. Fescue seeds could tolerate higher rates of compost as compared to other plants based on seed germination tests and the subsequent seedling monitoring. Data indicated that plants responded variably to compost of different sources and rates of application and higher amount of compost could be applied for grass establishment.

*Rugelio, J. and N.V. Nkongolo. Center of Excellence for Geospatial Information Sciences, Lincoln University. MAPPING CARBON DIOXIDE (CO_2) EMISSIONS AND SOIL THERMAL PROPERTIES IN A CORNFIELD. Greenhouse gas emissions are the main cause of global warming, therefore understanding their distribution and that of soil properties is important for control purpose. The objective for this study was to map and analyze the trends of CO_2 emissions and soil temperature (T),

thermal conductivity (K), resistivity (R) and diffusivity (D) soil in a cornfield. The study was conducted from May to December 2006 at Lincoln University's Freeman Farm. Thirty two static chambers were installed in a 2 ha field and the locations of each chamber recorded with a GPS. Soil air samples were collected at thirty minutes intervals and analyzed within two hours of sampling with a Greenhouse Gas GC-14 for determinations of CO_2 . In June 2006, CO_2 ranged from 19.21 to 71.32 $mg CO_2-C m^{-2}h^{-1}$ and from 15.91 to 16.32°C, 0.33 to 0.64 $Wm^{-1}c^{-1}$, and 1.74 to 4.11 $m^{\circ}Cw^{-1}$ and 0.26 to 0.40 $mm s^{-1}$ for T, K, R and D respectively. No significant linear correlation was found between CO_2 emissions and soil thermal properties. Spatial trends in data was studied using ARCGIS 9.2-Geostatistical Analyst Extension. The global polynomial interpolation (GPI) and simple kriging methods were used. CO_2 emissions and soil T, K, R and D fitted to spherical variogram models in the simple kriging. The results obtained stress the need to further monitor the fluctuation of greenhouse gas fluxes.

*Schulte, K. B., H.Y. Johnson and K. Lee. Department of Agriculture, Biology, Chemistry, and Physics and Cooperative Research Programs, Lincoln University. MICROBIAL MONITORING AND ASSESSMENT OF COMPOST PRODUCED IN MID MISSOURI. The objectives of this experiment are to monitor the microbial population during the Lincoln University (LU) composting process, as well as the amount of microbes present in various compost. Samples taken from the LU composting facility included: carbon source, food waste mixed with carbon source, compost processed for a month, and the cured end product. Compost samples were also collected from a turkey manure composting facility and a vermicomposting farm. Individual samples were extracted with distilled water at a 1:10 ratio. Extracts were further diluted to a serial 10^3 to 10^9 solutions. A solution of 0.5mL was plated on Trypticase Soy agar and MacConkey agar media to examine the presence of broad spectrum bacteria and gram negative bacteria respectively. In examining the samples collected from the LU composting process, a range of 18 millions to 5 billions of total bacterial counts (TMC) per gram dry weight was detected. The food waste mixed with the carbon source before composting contained the highest TBC, and the cured end product contained the lowest TMC. In comparing microbial counts in compost collected from various sources, the turkey manure compost, vermicasting, and LU compost contained 0.3, 3, and 23 millions TMC per dry weight basis respectively. Data supported aerobic composting and vermicomposting could drastically reduce the microbial population contained in the original feedstock while retaining appreciable microbes in the end product for soil enrichment.

*Williams, L and N.V. Nkongolo. Center of Excellence for Geospatial Information Sciences, Lincoln University. MAPPING METHANE (CH_4) FLUXES AND SOIL THERMAL PROPERTIES IN A CORNFIELD. Methane is among the greenhouse gases involved in global warming and understanding its

behavior is important. The objective for this investigation was to map CH₄ fluxes and soil temperature (T), thermal conductivity (K), resistivity (R), diffusivity (D) and volumetric heat capacity (C) in a cornfield. The study was conducted from May to December 2006 at Lincoln University's Freeman Farm. Thirty two static chambers were installed in a 2 ha field and the locations of each chamber recorded with a GPS. Soil air samples were collected at thirty minutes intervals and analyzed within two hours of sampling with a Greenhouse Gas GC-14 for determinations of CO₂. Soil T, K, R, D and C were measured using a KD2 probe. In June 2006, CH₄ ranged from -32.59 to 12.78 mg CH₄-C m²h⁻¹ and from 15.91 to 16.32°C, 0.33 to 0.64 W m⁻¹c⁻¹, 1.74 to 4.11 m²kw⁻¹, 0.26 to 0.40 mm s⁻¹ and 1.17 to 1.67 or T, K, R, D and C, respectively. A significant linear correlation was found between CO₂ emissions and C (r=0.15, p=0.05). ARCGIS 9.2-Geostatistical Analyst Extension was used to map the distribution of CH₄ and soil properties. As suggested by a coefficient of variation (CV) of 96.36%, interpolated maps confirmed that CH₄ was highly distributed across the cornfield. The same trend existed for soil thermal properties.

Biology

*Atherton, J.D., and R. L. Kervin. Department of Biology, College of the Ozarks. STRESS INDUCED IN VIVO APOPTOSIS IN MURINE LYMPHOCYTE POPULATIONS. This study was done to determine the association between psychological stress and immune suppression. Over prolonged periods of psychological stress the adrenal cortex will over-secrete the glucocorticoid hormone. Excess amounts of glucocorticoids can initiate apoptosis (programmed cell death) in lymphocytes. Lymphocytes are vital to the immune system, and significantly depleting the number of these cells will cause immune suppression. The focus of this study was to determine the amount of apoptosis of lymphocytes in the spleens and thymuses of mice chronically stressed. All mice were kept in a controlled environment. The experimental mice were stressed two times a day, over a 21 day period. After the period of induced stress, control and test mice were sacrificed via cervical dislocation. Following sacrifice, spleens and thymuses were removed. The organs were washed with PBS, weighed, fixed with 4% paraformaldehyde, chemically processed, and embedded in paraffin wax. Embedded tissues were cut into 4µm sections and adhered to positively charged glass slides. Apoptosis was then determined in the tissues via Upstate's TUNEL staining technique. The TUNEL protocol attaches a FITC (green) fluorescent marker to cleaved DNA, a characteristic of apoptosis. Nonapoptotic nuclei were counterstained with the blue DAPI fluorescent stain. Percent apoptosis was determined by randomly observing approximately 200 cells per slide. Preliminary results indicate that the thymuses of the experimental group weighed slightly less than the control group, suggesting apoptosis. However, the preliminary results of the TUNEL protocol have been inconclusive for increased lymphocyte apoptosis in the tissue sections. These results are still being investigated.

*Brown, C. and A.R. Oller. Department of Biology and Earth Science, University of Central Missouri. ROLE OF ANTIBIOTIC TREATMENT ON GROWTH OF *CANDIDA ALBICANS*. Antibiotics are traditionally thought of as an aid in medicine can also do harm under specific conditions. When taken incorrectly or by immunocompromised patients, antibiotics can yield secondary infections from opportunistic pathogens. The use of broad-spectrum antibiotics can lead to yeast infections. Candidiasis is an infection most commonly caused by the normal-flora yeast *Candida albicans* and can cause life-threatening infections. This study explores the growth of *Candida albicans* under different antibiotic environments. Inoculating a range of concentrations of *Candida albicans*, and the bacteria *Lactobacillus acidophilus* and *Klebsiella pneumoniae* into specialized media LB8664 was performed in the study. The series of inoculations contained varying volumes of yeast and bacteria, not unlike what would occur in the body's microflora. Antibiotics were used in the media to test their effect on *Candida* growth. The LB 8664 media used contained erythromycin, bacitracin, or no antibiotics. The antibiotic erythromycin was used in concentrations of 5 µg/mL and 2.5 µg/mL, while bacitracin was used in concentrations of 30 µg/mL and 15 µg/mL. Plate counts and an alcohol assay confirmed that concentrations of antibiotics and co-inhabiting microorganisms do play a role in *Candida* growth, with larger concentrations allowing yeast growth. The information gained in this study, as well the results of similar studies, can be used to further the understanding of opportunistic fungal infections prevention and treatment.

*Comer, J.R. and J.H. Rettig. Biology Department, College of the Ozarks. PHYLOGENETIC ANALYSIS OF *CAREX* SECTION *ACROCYSTIS* DUMORTIER (CYPERACEAE) USING RDNA INTERNAL TRANSCRIBED SPACERS. The purpose of this study is to determine the phylogenetic relationships within section *Acrocystis* using the ITS region of rDNA. The internal transcribed spacer (ITS) region is located between the 18S and 26S' ribosomal genes. This region's usefulness comes from the fact that it is small in size, has a high mutation rate, and can easily be amplified. This study investigated whether *Carex* section *Acrocystis* is a monophyletic taxon. Subgroups within section *Acrocystis* also were addressed. Procedures for amplification, sequencing, and alignment followed previously published protocols. The Qiagen DNeasy® Plant Mini Kit was used for the DNA extraction with a few modifications. Sample material consisted of dried specimens. Initial primers used were 17SE, ITS 4, 18SR and ITS-L. Due to degradation of the herbarium specimens the internal primer ITS 3 and the external primer ITS 4i were used to amplify only the ITS 2 region. Amplified products were purified using the Qiagen MinElute™ Gel Extraction Kit. Sequencing was performed with a Beckman Coulter CEQ™ 8000 Genetic Analysis System and sequence analysis was carried out with PAUP* 4.0b10. Preliminary results indicate *Carex* section *Acrocystis* is monophyletic, but subgroups within the section are not.

*Cox, A. and M.A. Idachaba. Cooperative Research Programs, Lincoln University. OPTIMIZATION OF FOOD WASTE AT LOW COST FOR THE PRODUCTION OF MOSQUITO-PATHOGENIC *BACILLUS SPHAERICUS* AND *BACILLUS THURINGIENSIS*. Substrate cost is a critical component in the production of both *Bacillus sphaericus* (*Bs*) and *Bacillus thuringiensis* (*Bt*) for the control of mosquito and other pests. This study presents the development of substrate for the production of *Bs* and *Bt* using food waste, and its evaluation and optimization as alternative substrate for the growth of these bacteria. The growth of *Bs* and *Bt* was evaluated at food waste concentrations of 10g/L, 20g/L, and 50g/L. Growth of *Bs* and *Bt* obtained on the food substrates were also compared with that obtained on yeast extract, an industrial substrate. The growth of the two organisms on the food waste substrate and yeast extract substrate were similar at weight-to-weight comparison. The maximum biomass of *Bt* was substantially higher than that of *Bs* at similar levels of food waste substrate. For *Bt*, increasing the food waste substrate concentration from 10g/L to 20g/L resulted in a doubling of the biomass. No further increase in the maximum biomass was observed with increase in the food waste substrate concentration from 20g/L to 50g/L. For *Bs*, increase in the food waste substrate concentration from 10g/L to 20g/L did not increase the biomass. Further increases in biomass were obtained for both organisms when the food waste substrate was supplemented with minerals (magnesium, manganese, calcium), and 0.5g/L of yeast extract as a source of vitamins.

*Doyle, A.L. and S. Miller. Biology Department, College of the Ozarks. EFFECTS OF THE PLEISTOCENE GLACIATION ON THE GENETIC VARIATION OF *GAMMARUS PSEUDOLIMNAEUS*. Genetic variation within two populations of the amphipod *Gammarus pseudolimnaeus* north of the southern Pleistocene glacial boundary was compared to variation within three populations south of the glacial boundary. The current range of *G. pseudolimnaeus* is approximately cut in half by this glacial boundary. It is likely that populations in the Northern part of the current range were extirpated during glaciations. Southern, non-glaciated, populations would have served as founding populations for colonizing or recolonization of northern parts of the range following glacial retreat. It was hypothesized that southern populations would be more genetically diverse than the northern populations because of founder effects. Samples were collected from six populations with one population, *Crangonyx forbesi*, being used as an out-group. Sample sites for *Gammarus pseudolimnaeus* included Mammoth Spring, Arkansas; College of the Ozarks, Missouri; Bennett Springs, Missouri; Parfrey's Glen, Wisconsin; and Sugar Loaf Creek, Minnesota. *Crangonyx forbesi* was from Rollins Spring, Missouri. Sequence variation in the mitochondrial gene, cytochrome oxidase I, was investigated using a Beckman-Coulter CEQ™ 8000 Genetic Analysis System and data was analyzed using PAUP* 4.0b10 software.

*Mack, M.R., K.E. Riggs and L.J. Swatzell. VOLUME CHANGE DURING GERMINATION OF *CHEILANTHES*

LANOSA SPORES. Department of Biology, Southeast Missouri State University. Fern spores typically uptake water during germination, which is accompanied by an increase in spore volume. However, *Cheilanthes lanosa* spores germinate without any visible source of water present. This would suggest that there is no significant water imbibition in germinating *Cheilanthes* spores. In addition, these spores do not express PIP₁ aquaporins, which are typically found in germinating seeds and young leaves in higher plants, and which are found in the early protonematal stages of the fern. Therefore, it is unclear whether imbibition actually occurs, or whether germination involves cytoplasmic osmotic changes. We proposed that, if imbibition occurs, then there would be an increase in spore volume. To test this hypothesis, spores were observed throughout the germination period, 13 days. Spore images were captured every three days until germination occurred and volume was calculated using the cross-sectional area. Results show that there is a significant increase in volume over the total germination period. These results suggest that a significant amount of water imbibition does occur during germination of *Cheilanthes lanosa* spores, and thus, there must be some mechanism for rapid water uptake.

*Ndessokia, R. and M. Scott. Department of Agriculture, Biology, Chemistry and Physics, Lincoln University. DEPRE- DATION AT AN OUTDOOR AQUACULTURE RESEARCH FACILITY. Potential fish predators were observed by reviewing continuous time-lapse video recordings with natural and near infrared illumination from June 15 to September 17, 2004. The vast majority were Little Green Herons. On a daily basis, Little Green Heron activity peaked during early morning, mid day and late afternoon time periods. No mammalian predators were observed. In 2005, exclusion methods were tested for effectiveness for preventing Little Green Herons from accessing the ponds. Initially, half the ponds were randomly assigned to be surrounded with plastic netting or a two-strand electric fence located at the water edge with 30 cm separation. Bird activity was observed at each pond by reviewing continuous time-lapse video recordings with natural and near infrared illumination for 30 days. No birds were observed in the three ponds surrounded by netting. It became apparent that the two-strand electric fence was not effective at excluding Little Green Herons as 64% of them crossed the fence. A third strand was added to the electric fences (15 cm spacing) and observations continued for an additional 30 days. The netting continued to be very effective at excluding Little Green Herons while the three-strand electric fence prevented 80% of them from accessing the ponds.

*Pearcy, S.M., C. M. Cortelyou, K.J. Beulke, C.M. Scholes and J.M. Chapman. Departments of Biology and Chemistry, Rockhurst University. PRELIMINARY ANALYSIS OF FRE- QUENCY AND COMPOSITION OF TANNINS IN ACORNS, WEEVILS, AND FRASS. *Curculio* sp. weevils develop through several instars living in and consuming acorns, depositing frass within the acorn as they feed and grow. These weevils live on

this diet despite the presence of tannins, reportedly higher in red oaks than white oaks. We examined the amount and composition of tannins in acorns (*Quercus macrocarpa* — a white oak and *Q. rubra* — a red oak), weevils and frass by subjecting them to liquid chromatography electrospray ionization mass spectroscopy (LC/ESI/MS). By comparing the mass spectroscopy data consisting of molecular weights and fragmentation data, we can determine if the tannins in acorns provide any nutritional value to the weevil. Tannins that weevils ingest are affected differently; some pass through without being utilized, appearing in the frass. Others are metabolized and the weevil gut absorbs some of the breakdown products. The tannins we have found in the acorns, weevils, and frass are from two classes of tannins: ellagic acid and gallic acid. The ellagic acid type tannins are seen at a higher frequency than gallic acid tannins. Most of the tannins found in acorns were also found in frass, but very few tannins were found in larvae tissue.

Peoples, B. and M. Scott. Department of Agriculture, Biology, Chemistry and Physics, Lincoln University. MAMMALS OF THE LINCOLN UNIVERSITY LIVING LABORATORY. The Lincoln University Living Laboratory is an approximately 2 hectare wooded area on the Lincoln University campus. The site history includes previous use as an industrial area and a rock quarry that is currently flooded. The site is adjacent to a city park, residential areas and a secondary city street that serves as one of two main entrances to the campus. The primary objective for the Living Laboratory area is to be an outdoor educational environment for the local community and Lincoln University. Initial work at the site has included efforts to conduct physical and biological surveys of the site. We are reporting on the work that has been conducted to identify the mammalian species on the area using direct visual observations and several trapping techniques. The results from two years of observations demonstrate a clear pattern. The area has a large number of meso-predators including free-ranging and / or feral pets but has very low numbers of small mammal species. We hypothesize that the abundant meso-predators are negatively impacting the small mammals. We propose to test this hypothesis by manipulating the environment to provide potential refugia for small mammal species. It is expected that this study may have significant implications for managing small mammals on “natural” urban areas.

*Rangel, D.¹, M. Scott¹ and H. Shen². ¹Department of Agriculture, Biology, Chemistry, and Physics, Lincoln University and ²Department of Microbiology, University of Pennsylvania, School of Medicine. TOWARD DETERMINING THE ADJUVANT EFFECTS OF rOv-ASP-1 (Recombinant *O. volvulus* Activation-Associated Secreted Protein-1). Alum is currently the only adjuvant licensed in the United States for the purpose of increasing the human immune response to protein-based vaccines. The use of Alum is limited in that it does not stimulate a cytotoxic (Th1) response to intracellular pathogens (Lustigman 2002). The NIH has expressed a clear need for the development

of a protein adjuvant that elicits a stronger immune response while producing fewer side effects. The protein adjuvant rOv-ASP-1 is a helminthes secretion that stimulates a Th1 immune response without producing adverse side effects (McDonald 2005). The ultimate aim of this study is to determine if rOv-ASP-1 can serve as an adjuvant to enhance CD8 + T cell responses. This phase is for the purpose of eliciting a CD8 + T cell response to the model antigen OVA for comparison with response to OVA + rOv-ASP-1 adjuvant. OVA specific CD8 + T cell response will be quantified using MHC 1 tetramer staining, and the functionality of these cells will be assessed by, measuring production of cytokines, via intracellular staining.

*Rivas-Herrera, A and L. Brandt. Mathematic, Science and Agriculture Department, State Fair Community College. CONDITIONING PLANARIA IN A TRAIN-A-MAZE. The process of the brain, such as the learning ability and the retention of memory continue to remain a mystery. Dating back to the mid 1950s, the planaria organism has been used to study basic learning ability and memory retention. In previous studies, planaria have been used because they seem to be the first organisms to develop a true centralized central nervous system, as well as encephalization. The planaria in this study were placed in a Train-A-Maze and a naïve base test was performed to determine if there was a direction (right or left) that they preferred. The planaria were trained to go in the opposite direction that they preferred. If the subject made the wrong choice, shock was applied through electrodes, which forced them to turn around. During testing, all subjects were kept separately, and fed once a week. Previous experiments have demonstrated that as the number of trials increase, the number of correct responses in the planaria also increased. Further experiments will continue to determine if memory is passed on through regeneration. Planaria will be cut into two equal parts along the horizontal plane, and both new organisms will be retested to determine if the learning was retained along the superior and inferior planes.

*Sappington, D. R. and J. H. Rettig. Biology Department, College of the Ozarks. REPRODUCTIVE TOXICITY DETECTED WITH *CERIODAPHNIA DUBIA* FROM GOLF COURSE EFFLUENT SAMPLING. Golf courses are often targeted for polluting the environment with pesticides, herbicides, and fertilizers. Yet, golf course effluent has very little bioindicator-linked toxicity data. Bioindicators, like *Ceriodaphnia dubia*, can be used to test for toxins found in runoff. The purpose of this study was to use Whole Effluent Toxicity (WET) testing to add to these data. WET testing followed the Environment Protection Agency guidelines for static renewal chronic (7 day) toxicity with *Ceriodaphnia dubia* (cladoceran). Sampling took place subsequent to precipitation, downstream of a local Branson, Missouri, golf course that is in the Lake Taneycomo watershed. A dilution series % ≥ 0.5 of the effluent was used. Preliminary results showed that the lowest observable effected concentration (LOEC) was 50% ($p = 2.61 \times 10^{-2}$) and the 100% effluent showed reproductive toxicity as well ($p = 1.88 \times 10^{-3}$).

Lethality was not observed at any dilution. Toxicity could be from the golf course but could also be due to runoff from urban areas upstream.

*Senne, S. and D. Williams. Department of Natural and Physical Sciences. Park University. THE CHEMICAL BARRIER TO CHEMICAL EVOLUTION. Evolution is the most popular explanation among scientist for how life arose, however there are some important questions that are often overlooked. Biochemical evolution is credited for the self assembly of biochemical molecular compounds like proteins, from non-living, raw chemicals given the right environmental conditions. However, scientists rarely follow up with a plausible chemical mechanism that could scientifically support biochemical evolution. For biochemical evolution to be considered a plausible explanation to abiogenesis, there are some barriers that must first be overcome. These barriers include a lack of molecular separation, lack of chiral differentiation, lack of a sequencing mechanism, and unique process requirements to name a few. Molecular separation of the essential amino acids and the over 500 nonessential amino acids must take place before life can occur. There is only about 20 essential amino acids, out of those essential amino acids, chiral differentiation between left and right handed amino acids must take place before abiogenesis can take place. Proteins range from 50 to over 1500 amino acids, yet there is no chemical mechanism to explain the sequencing order of proteins. Until scientists recognize these barriers, and find scientific answer, biochemical evolution can be nothing more than a theory by name only.

*Steele, A.G. Department of Biology, Maple Woods Community College. CORRESPONDING EFFECTS BETWEEN PLANTS AND CARBON DIOXIDE LEVELS. Previous observations have shown that C3 plants thrive in Carbon Dioxide (CO₂) rich environments. This study was conducted to test if adding C3 plants to a confined CO₂ rich environment would cause CO₂ levels to drop. The Carbon Dioxide levels were measured within a 10 gallon aquarium using 4 lbs. of dry ice as the CO₂ source with recordable readings of 12,000ppm and a reading of atmospheric CO₂ levels were 328ppm. *Festuca Pratensis* seeds were planted in two clay pots using Miracle Grow potting soil and sealed within the aquarium. The third pot was set beside the aquarium and used as the control. After nine days numerous sprouts were noticed and CO₂ levels had dropped to 1400ppm within the aquarium while atmospheric levels of CO₂ remained 328ppm. Upon penetration of the soil the *Festuca Pratensis* decreased the CO₂ levels by 10,500 to 10,600ppm within 3 to 5 days. Throughout the experiment the atmospheric levels of CO₂ remained 328ppm. Correspondingly there was a substantial increase in plant growth in the presence of increased CO₂. Based on these results one is able to accept the hypothesis that adding C3 plants in a confined CO₂ rich environment will cause CO₂ levels to drop.

*Theobald, S.D. and R. L. Kervin, Department of Biology, College of the Ozarks. NOREPINEPHRINE EFFECT ON

GLUCOCORTICOID INDUCED APOPTOSIS OF MATURE LYMPHOCYTES. Previous studies have shown that glucocorticoids (GC) and their synthetic form, dexamethasone (DEX), induce considerable apoptosis in immature thymic lymphocytes and, to a lesser extent, apoptosis in mature lymphocytes. Further, norepinephrine (NE) can induce apoptosis in certain cells such as cardiac myocytes. These hormones are both released in physiological stress. This study was developed to determine the combined effect of NE and GC induced apoptosis on the primary immune cells, the mature lymphocyte. Laboratory mice were sacrificed, spleens were removed, and cells were released from the organs. Lymphocytes were isolated by removing adherent cells and lysing red blood cells. Cell suspensions were adjusted to a 2×10^6 cells per ml in RPMI enriched with 10% fetal bovine serum. One ml aliquots were then distributed to tubes containing combinations of NE and DEX in concentrations associated with physiologic stress. Propanolol (PN), a beta blocker, was also added to additional control tubes to inhibit NE's effect. All tubes were incubated for three hours at 37°C with 5% CO₂. Cells were then washed and lysed by freeze-thawing. Amount of apoptosis was determined by using Invitrogen's Caspace-3 Assay Kit and a standard fluorometer. Preliminary results showed that both stress hormones induced apoptosis with significantly greater apoptosis in tubes containing DEX alone. Tubes containing both DEX and NE, had lower apoptosis than tubes containing only DEX. Since both DEX and NE are released by the sympathetic nervous system in stress, results imply that NE may be protective against glucocorticoid induced apoptosis of mature lymphocytes.

*Wilson, M.¹, T. Gabor¹, C. Sanders¹ and K. Foster². ¹Department of Biology, Park University and ²Platte Land Trust. BRUSH CREEK MID-SHED PROJECT: FIRST YEAR OF STREAMFLOW DATA. Platte County, Missouri, like many other suburban areas, is experiencing a major boom in commercial and residential development. Many watersheds are affected by increasing development activities, but the true impacts of development on most watersheds are unknown. The purpose of this study is to obtain baseline data on the streamflow of Brush Creek in Platte county, Missouri prior to major development within the watershed. Gauging stations were set at each station near 3 bridges: Highway 152, 76th Street, and Highway 45. Each station consists of 1) an in-stream staff gauge, 2) an adjacent reference staff gauge in case the in-stream gauge is destroyed, and 3) a computerized logger that takes depth readings every 15 minutes. Data from the loggers are dumped onto a laptop once each month. Visual readings of stream depth are taken each time we are on site to verify logger accuracy. Discharge (cubic feet of flow) of Brush Creek is also measured 3 times per month at various gauge heights. As of 1 January 2007, about 30,000 automatic logger readings have been taken at each of the 3 stations. About 20 discharge ratings have been calculated for each of the 3 stations. Discharge curves have been approximated using this preliminary data.

Chemistry

*Alt, M. L. and P. A. Chernovitz. Department of Natural and Physical Sciences, Park University. SYNTHESIS OF DIAPOCYNIN. Apocynin is a compound that has generated much interest in treating or preventing diseases of inflammation, heart disease, cancer, stroke, and Alzheimer's disease. It has also been suggested that apocynin is metabolized to diapocynin, which may be more active than apocynin. The synthesis of diapocynin described in a dissertation was based on a synthesis of a similar compound in 1916. Our goal was to develop an improved method. Diapocynin was synthesized by oxidative coupling of apocynin, through in situ generation of the strongly oxidizing sulfate radical. Washing three times with boiling water purified Diapocynin. The purity of the diapocynin was determined by negative liquid chromatograph-mass spectrometry (LC-MS), with atmospheric pressure chemical ionization (APCI) and selected ion monitoring (SIM). The structure was validated by Fourier transform infrared (FT-IR) and nuclear magnetic resonance (NMR) spectroscopy techniques. The student tried to optimize the synthesis by changing reaction time, concentration of reagents, and solvents used for purification by recrystallization. The undergraduate course provided the student drug development experience and the student will follow the process through the developmental process.

*Hemmila, A., J. McGill and D. Ritter. Department of Chemistry, Southeast Missouri State University. AGE DETERMINATION USING LATENT FINGERPRINTS. Studies were conducted to determine whether the age of a human subject can be estimated by Fourier transform infrared spectroscopic (FTIR) analysis of their latent fingerprint residue. Latent fingerprints were collected from 155 individuals ranging in age from 4 to 68 years following a protocol approved by the Southeast Missouri State University Committee for Research Involving Human Subjects. Fingerprints were deposited on tin plates, and their attenuated total reflectance (ATR) FTIR spectra were collected in duplicate. Spectral data were analyzed using partial least squares (PLS1) regression analysis and by principal component analysis (PCA). PLS1 revealed a 92% correlation between the actual and predicted age of an individual. Examination of smaller age segments within the sample population reveal interesting differences between age groups and better predictive ability for certain age subsets. PCA permitted grouping of individual fingerprint samples by subject age as well. Comparison with the known literature on changes in sebum composition with age and postulation of chemical compound classes likely responsible for this phenomenon will be presented.

*Hicklin, R. W. and S. Sarkar. Department of Chemistry and Physics, University of Central Missouri. COMPUTATIONAL ANALYSIS OF α,α' -BIS(2-NAPHTHYLOXY)-PARA-XYLENE AND PARA-BIS(2-NAPHTHYMETHOXY)BENZENE. Molecular clips are acyclic compounds, which may be used as synthetic receptors to bind a neutral or ionic "guest" molecule. Our efforts to synthesize two such units, namely α,α' -bis

(2-naphthylxy)-*para*-xylene (1) and *para*-bis(2-naphthylmethoxy)benzene (2), for complexation studies revealed that whereas compound 1 is soluble in commonly used organic solvents, compound 2 is insoluble in most solvents. The difference between these two constitutional isomers involves switching the positions of the methylene group and the oxygen in the structure. Computational studies using Gaussian 2003 have been done for these two compounds in order to determine whether the origin of this solubility difference could be tracked from the conformations and the dipole moments of these two molecules. Computations were done at the semi-empirical level using the AM1 method on twenty potential conformations and then the three lowest energy structures for both compounds were refined using the ab initio method with diffused function (6-31G* + pd). In both conformations the naphthyl groups are on the same side of the phenyl ring diverging away from each other, which is completely different, compared to the crystal structure of 1,4-bis(benzyloxy)benzene. From the computational findings, the solubility differences and potential conformations of each of the two compounds have been assessed.

*Porter, M.M. and J.L. Hayes. Mathematics, Science and Agriculture Department, State Fair Community College. ATTEMPTS AT GENERATING PERCHLORATES WITH CONSUMER BASED GOODS. With the increasing concerns about the potential for domestic terrorism, the Office of Homeland Security is continuously enforcing new safety measures. Their main focus, especially in airports, usually deals with detecting improvised explosive devices (IED), commonly referred to as "dirty bombs." The objective of this experiment was to evaluate the ease of synthesizing a powerful oxidizing agent that has many applications in the fields of pyrotechnics and explosives. If large quantities of such materials could be produced in a simple and relatively efficient manner, terrorists could have access to a readily available source of explosives to wreak havoc and destruction. In our experiments, we attempted to produce potassium perchlorate by means of electrolysis through the use of readily available consumer goods and supplies (*i.e.*, a used, standard car battery, a battery charger, sodium chloride, and potassium chloride). It is our contention that we were unable to produce usable perchlorates in this manner. However, at the end of our experiments, the electrodes used in the process did have a reddish brown corrosion that was identified through literature information as lead tetraoxide. Additionally, based on Ag-iodometric titrations, we determined that no perchlorates were produced — all chlorides used were reasonably accounted for. Any chlorides not specifically quantified are assumed to have escaped as chlorine gas indicated by the distinct irritating aroma detected during the experiment.

Rivas-Herrera, A., M. Daniel, J. Schuknecht*, A. Green*, A. Friese*, J. Hayes and L. Brandt. Mathematics, Science, and Agriculture Department, State Fair Community College. SYNTHESIS OF AMINO ACIDS: RECREATING MILLER-UREY EXPERIMENT. The Miller-Urey experiment is based on the

Haldane-Oparin hypothesis of prebiotic environmental conditions. Haldane and Oparin both independently proposed “chemical evolution” in which amino acids and other biomolecules could have formed in a reducing environment. The purpose of our experiment was to replicate the system created in the Miller-Urey experiment, as well as the results. The bottom flask of the system represents the oceans; the top flask denotes the terrestrial environment and open air, tungsten electrodes that produced the amount of energy hypothesized to have been present at the time, and the condenser, which allowed the biomolecules that were formed to be collected as a liquid. After a vacuum was pulled from the environment to create a reducing atmosphere, equivalent parts of hydrogen and methane were added to the top flask. Water and ammonia were added to the bottom, and the ammonia was allowed to boil off so that it could react with the other gases in the top reaction flask. The experiment was allowed to run for a total of three days after which a liquid specimen was collected for chemical testing; spectrophotometry was an option, however, due to time constraints, we were not able to finish this test. Although we had a positive test for amino acids, we feel that these were false-positive results because no prior testing was done on the system or the water prior to the experiment, and it is very possible that either could have been contaminated. We are continuing to redesign our experiment for further experimentation.

Geosciences

*Dowdy, K.N. and S.A. Hageman. Department of Geology-Geography, Park University. DINOSAURS FROM STERNBERG’S 1917 FIELDWORK IN THE RED DEER RIVER, ALBERTA, CANADA. Charles H. Sternberg collected dinosaurs during 1912–1917 from the Red Deer River, Alberta, Canada. In March of 1919, Sternberg shipped a collection of Cretaceous specimens to Park University. Sternberg’s original letter and packing list aided in recently curating the Sternberg dinosaurs. Red Deer River dinosaurs comprise 103 out of the 157 specimens shipped. These 103 divide into three distinct groups: 72% hadrosaur, 20% theropod, and 8% ceratopsid. The 74 hadrosaurid bones belong to a common species (*Corythosaurus casuarius*, *Lambeosaurus* sp., or *Prosaurolophus* sp.). The hadrosaur material is split into 35 vertebrae, 31 phalanges, six unguals, a dental battery, and an occipital bone. The theropod specimens are composed of 21 bones (four claws, 16 phalanges, and one vertebra). Claw identification suggests the theropod material represents the species *Gorgosaurus libratus* and *Dromaeosaurus* sp. Sternberg appears to refer to *Dromaeosaurus* bones as “carniverous dinosaurs” since *Dromaeosaurus* was not described until 1922. The ceratopsid material consists of one ankylosed-cervical vertebrae, two caudal vertebrae, two phalanges, one claw, and two nasal horn-cores. The horn-cores represent *Centrosaurus apertus* and *Styracosaurus albertensis*. Most, or all, of these dinosaur bones are from the 1917 field

season when Charles Sternberg and son Levi acted as independent collectors. Unfortunately, there is a lack of evidence about their 1917 collections due to no known field notes. The San Diego Museum of Natural History, the United States National Museum, and the American Museum of Natural History are known destinations of the 1917 material. This Park University collection will aid in understanding of all the collections from this historic dinosaur expedition.

*Kohl, M., and N.V. Nkongolo. Center of Excellence for Geospatial Information Sciences, Lincoln University. SPATIAL DISTRIBUTION OF NITROUS OXIDE (N₂O) EMISSIONS AND SOIL THERMAL PROPERTIES IN A CORNFIELD. Investigating the spatial distribution of greenhouse gas emissions and their relationship to soil thermal properties may provide insight on ways to increase the ability of the soil to sequester greenhouse gases. The emergence of Geospatial Information Science provides a unique opportunity to process and analyze the data. Our objective was to determine if GIS technology is an effective tool to emphasize spatial correlation of data and display it in ways that aid understanding of these relationships. We used ArcMap 9.2 and various extensions to generate interpolated maps of data collected in a cornfield located at Lincoln University’s Freeman Farm. Field data from thirty-two gas collection chambers were gathered over an eight months period in 2006. Soil thermal properties were measured using a KD2 probe. A GPS was used to record UTM coordinates of the field and chamber locations. Data on Nitrous Oxide (N₂O) and soil temperature (T), thermal conductivity (K), resistivity (R), diffusivity (D) and volumetric heat capacity (C) were processed using Spatial and Geostatistical Analyst Extensions. Interpolation methods used included IDW, global polynomial, and cokriging. These tools allowed us to generate layers of spatial information about the data. Range of values for N₂O were 0.024 to 15.582 $\mu\text{g N}_2\text{O-N m}^{-2}\text{h}^{-1}$. Significant linear correlations existed between N₂O and C ($r=0.24$, $p=0.0032$), R ($r=-0.18$, $p=0.0296$) and T ($r=-0.27$, $p=0.0006$). These correlations are difficult to visualize using conventional statistical analysis. Spatial analysis with GIS provided a useful tool in visualizing the distribution of N₂O emissions and soil thermal properties.

*Steadman, J.A. and J. Nold. Department of Earth Science, University of Central Missouri. A PETROGRAPHIC STUDY OF THE WEAUBLEAU-OSCEOLA AND CROOKED CREEK IMPACT STRUCTURES, MISSOURI. Impact structures are unique phenomena caused by high-velocity collisions of extraterrestrial rock/ice bodies with the surface of the earth. Almost 30 are currently recognized in the United States alone (Koeberl and Anderson 1996). The State of Missouri contains three such structures. One of the three, the Weaubleau-Osceola impact structure, has only recently been recognized as an impact structure (Evans et al. 2003). A petrographic study of breccia samples from Weaubleau-Osceola and from the Crooked Creek structure in Missouri was performed in order to contribute to a

better understanding of the formational history of both of these structures. The breccia samples from the Weaubleau-Osceola structure examined in this study are of two types: the first is a heterogeneous breccia containing mostly brachiopod and echinoderm hash. The other type is similar, but secondary weathering processes have dissolved some of the fossil hash, making the rock highly porous. In addition to fossil hash, other types of fragments include angular to rounded quartz grains, chert, limestone, broken oolites, and iron oxides (limonite/hematite). The Crooked Creek samples are much different. They consist of chert breccias, dolomite breccias, and dolomite shatter cones. Opaque minerals, angular to well-rounded quartz grains (several with shock features), chert, and pulverized dolomite are characteristic of these samples. (240ish)

Physics/Engineering/Computer Science

*Alaboson, J., C. Vera, R. Gupta, J. Harkins, A. Manivannan, P. Kahol, K. Ghosh and K. Manivannan. Department of Physics, Astronomy and Materials Science, Missouri State University. UV-VISIBLE SPECTROSCOPIC STUDIES OF GOLD NANOPARTICLES USED FOR DESIGN AND FABRICATION OF A BIOSENSOR. In recent years, biosensors have been given a great deal of attention as our nation strives for improved security against potential biological, chemical and radiological threats. In our laboratory, using Pulsed Laser Deposition (PLD) technique, we have fabricated a biosensor by embedding gold (Au) nanoparticles on a biocompatible material.^{a,b,c} UV-Visible (UV-VIS) spectroscopy is a useful tool in producing valuable information about nanoparticles. We have used UV-VIS spectroscopy to perform size characterization of Au nanoparticles by probing its Surface Plasmons. Surface Plasmons are free electrons at the surface of a material, which collectively oscillate at optical frequencies. As generally accepted Mie theory predicted, the intensity and shape of the Surface Plasmon absorption Band (SPB) strongly depends on the size and shape of the nanoparticles. From the UV-VIS spectra obtained of Au nanoparticles, we seek to further understand this size dependence of the SPB and take advantage of it in fabricating Au nanoparticles of specific size and uniform features. (Work supported by NSF Award #DMR-0321187 to K. Ghosh and a Missouri State University Sabbatical Leave Award to K. Manivannan.)

^aA. Manivannan, "Growth and Characterization of Nanomaterials," *PROC 15th NASA MO Consortium*, 2005. ^bK. Manivannan et al., "Design and Fabrication of a Biosensor Utilizing Gold Nanoparticles," *MAS Conference*, Kirksville, Missouri, April 22, 2006. ^cVera et al., "Biosensor Design and Fabrication Using Gold Nanoparticles," *Third Annual Missouri Nanotechnology Alliance Conference*, Columbia, Missouri, October 6–7, 2006.

*McPheeters, M. R. and R. A. Mayanovic. Department of Physics, Astronomy and Materials Science, Missouri State

University. X-RAY ABSORPTION SPECTROSCOPY OF A NEODYMIUM CHLORIDE AQUEOUS SOLUTION AT HIGH TEMPERATURES AND PRESSURES. A greater understanding of the structure of aqueous rare earth element (REE) complexes at high temperatures (T) and pressures (P) is required in order to more completely understand the stability of such complexes under hydrothermal conditions. Neodymium was used in the experiments described here as part of a broader study of the structure and structural properties of series-spanning REE aqueous ion complexes under hydrothermal conditions. X-ray absorption spectroscopic (XAS) measurements were made in fluorescence mode on a 0.05 *m* neodymium chloride (NdCl₃) aqueous solution in a hydrothermal diamond anvil cell at up to 500°C and 400 MPa pressure. The measurements were made on PNC-ID 20 beam line at the Advanced Photon Source in the Argonne National Laboratory, Argonne, IL. Analysis of XAS spectra indicates the existence of inner sphere chloro aqua complexes of the type Nd(H₂O)_{*m*}Cl_{*n*}^{+3-*n*}, for which the spectral average number of coordinated H₂O molecules (*m*) is reduced from 4.6 to 3.5 whereas the number of Cl⁻ ligands (*n*) is increased from 0.5 to 1.15 upon increasing the temperature of the aqueous solution from 300 to 500°C. Preliminary evidence shows that some chloride (Cl⁻) ligands may be coordinated to the Nd³⁺ ion at 150°C but further analysis is required to verify this result.

Social/Behavioral Science

Berhorst, S., V. Orscheln and R. Ghinescu. Department of Social and Behavioral Sciences, Lincoln University. ALL CREATED EQUAL? A PERSPECTIVE ON GENDER BIAS. Terror management theory posits that reminders of death increase both positive evaluations of people that support one's views and negative evaluations of people that threaten one's views. In the present study we will investigate whether reminders of death (mortality salience) would increase males'/ females' prejudice of persons of the opposite sex. Participants will complete a questionnaire packet which will include basic demographic information and two filler questionnaires (The Social Desirability Scale, Crowne & Marlowe, 1960 and the L, F, and K scales of the Minnesota Multiphasic Personality Inventory, Hathaway & McKinley, 1967). Participants will be divided into two groups on the basis of their gender. Participants will then be randomly assigned to one of two conditions. In one condition, participants will be asked to write an essay about their own death (mortality salience condition). In the second condition, participants will be asked to write an essay about a neutral topic, such as watching television (control condition). Participants will read essays describing the behavior of a male/female. Gender bias will be measured by asking participants to evaluate these behaviors. Data will be analyzed in a 2 (mortality salience: death vs. television) × 2 (gender: male vs. female) ANOVA on gender bias.

*Powell, L.R., K.A. DeBord and M. S. Aruguete. Department of Behavioral Sciences, Lincoln University. THE NATURE VERSUS NURTURE DEBATE REGARDING SEXUAL ORIENTATION: DO YOUR BELIEFS MAKE A DIFFERENCE? Although some research has shown that homophobia is related to the degree to which a person believes that sexual orientation is a matter choice, few studies have closely analyzed college students' beliefs about the genetic and/or biological determinants of sexual orientation. We intend to expand upon a research project that was presented at Missouri Academy of Sciences in the spring of 2006 (Powell & DeBord, 2006). That study was based upon research previously conducted by Wilkinson (2004)

which showed that college students' attitudes toward gay men and lesbian women were influenced significantly by the students' overall level of religiosity and authoritarianism. Also, Negy and Eisneman (2005) found homophobia to be heavily influenced by the racial background of college students. In the current study, we will create a new measure designed to assess the beliefs students have about the determinants of sexual orientation. We will determine and report the psychometric properties of the new scale. Additionally, we will test our hypothesis that this new measure will account for significant variance in homophobia, above and beyond that accounted for by authoritarianism, religiosity, and demographic factors.



