

**TRANSACTIONS OF
THE MISSOURI ACADEMY
OF SCIENCE**



Vol. 24, 1990



About the Academy

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

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

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

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

The Academy held its organizational meeting on April 13-14, 1934 with 250 people attending. At the December, 1934, meeting, more than 400 people registered and by May, 1935, there were approximately 750 members of the Academy. Statewide interest at a high level continued until activities made necessary by World War II caused disruption of Academy affairs except for some activity in the College Section.

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

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

Presently, 49 colleges and universities around the State of Missouri hold an Institutional Membership status. Many industries and other private businesses are supporting the Academy with Corporate Memberships.

Membership into the Academy is a year-round opportunity for everyone and runs from January 1 to December 31. Benefits include four quarterly newsletters, one annual *Transactions*, and annual meeting lower pre-registration fee.

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

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1. *Editorial Policy.* Authors must pay \$25 per printed page for publication costs. Transactions publishes several types of original contributions from the disciplines within the Academy: research papers, research notes, reviews, and annotated bibliographies. Manuscripts must be authored or co-authored by a member of the Academy. Each manuscript is subject to peer review. The Editor has final authority for acceptance or rejection. Manuscripts should be submitted to the Editor:

Dean Harry J. Sauer, Jr.
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2. *Manuscript Preparation.* Type all material double spaced, on one side of standard sized bond paper. Submit 4 copies of the manuscript with illustrations for review purposes. Retain the original typescript and illustrations in your files. If accepted for publication, the final copy of the text and original art work will be requested.

Each paper must include an informative abstract which records succinctly the essential findings, followed by a short list of key words for abstracting purposes.

Each table must be typed on a separate page and be suitable for direct reproduction. Number tables consecutively and provide a short title at the top of each page.

All illustrations must be high contrast black and white and reproducible. Handwritten or typewritten lettering or symbols are normally not acceptable.

The manuscript is to be assembled in the following order: title, authors names and affiliations, abstract, key words, text, acknowledgments, literature cited, tables, figure legends, figures. Number all pages.

Authors should refer to current Transactions and a style manual appropriate to the discipline for details on style, format, and citation of references. Use the common and binomial Latin name of an organism when first mentioned. Subsequently the genus or common name may be used. Names of taxa should be underlined.

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Much thanks to the following persons who have served without tangible reward as reviewers for the full-length papers in this volume of the Transactions. They make this publication a "refereed" journal.

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Fellows of the Missouri Academy of Science are among the most highly regarded members of the Academy for their distinguished scientific reputation and their major contributions to the Academy. Nominations for Fellows of the Missouri Academy of Science are solicited by the Committee on Fellows. Nominations should address each of the criteria specified below and should be submitted to Chairman, Committee on Fellows; Missouri Academy of Science; Box 828; Kirksville, MO 63501, by December each year.

Criteria for Designation of Fellow:

1. The nominee has been, and is an active member of the Academy.
2. The nominee has served in a responsible position that has advanced the goals and stability of the Academy.
3. The nomination should cite a specific contribution to the Academy that has enhanced the Academy in its service to its membership.

The Committee on Fellows will review the credentials of the candidates and screen the candidates to no more than three primary nominees. Fellows will be elected by the Council upon recommendation by the Committee on Fellows. Each individual so honored will be recognized for his/her election at an Annual Meeting and receive a plaque designating him/her a Fellow of the Missouri Academy of Science.

1990 Fellows

Dr. Wallace B. Howe, Missouri Geological Survey, was president of the academy in 1977-78. He has been very active and currently serves as chairman of the Nominations and Elections Committee.

Dr. Alfred Robertson, Professor of Geography, Southeast Missouri State University, has served the academy as both treasurer and secretary holding these offices for a total of six years. He is a recognized teacher and this year is President of the Faculty Senate at Southeast Missouri State University.

Dr. Al Gordon, Professor of Biomedical Sciences, Southwest Missouri State University, was president of the academy during 1983-1984. He has been an active and very supportive member at every level over the years but most recently has been a successful chairman of the Individual Membership Committee.

Transactions of The Missouri Academy of Science

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Nesting Ecology of Red-Tailed Hawks in Central Missouri

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Abstract: Characteristics of 110 red-tailed hawk (*Buteo jamaicensis borealis*) nest sites in central Missouri are described. Ninety-nine percent of the nests were in deciduous hardwoods. Nests averaged 16.7m in height (74% of nest tree height). Fifty-eight percent of the nest trees were on a slope, all were located in small, medium, or large tracts of woodlands or in solitary trees, and none were positioned towards the southwest directional exposure. Breeding density averaged 1 nesting pair per 7.4 km².

Mean clutch size ($n = 140$) was 2.47 (range 1-3), hatching success was 89.4%, fledging success was 92.7% of the eggs that hatched, and an average of 2.05 young fledged per successful nest. Red-tails occupied nests that were never used by great horned owls (*Bubo virginianus*) significantly more often than nests that at some time harbored owls.

Mammals comprised 71.4% of the diet by occurrence and 89.4% in estimated biomass. During nesting, red-tails maximized hunting efficiency by taking much larger prey items ($\bar{x} = 351\text{g}$) than during the non-nesting seasons ($\bar{x} = 165\text{g}$). Adults captured larger prey species and exhibited higher hunting success rates than did juveniles and immatures.

Key Words: Red-tailed hawk, *Buteo jamaicensis*, habitat, central Missouri.

Introduction

The red-tailed hawk (*Buteo jamaicensis*) is an ubiquitous, familiar raptor and its nesting ecology has been thoroughly studied (e.g., Bent 1937, Craighead and Craighead 1956, Hagar 1957, Austing 1964, Luttich *et al.* 1971, Gates 1972, Johnson 1975, Belyea 1976, Mader 1978, Peterson 1979, Gilmer *et al.* 1983). The fourteen subspecies of red-tailed hawks nest throughout North America, south to Panama, the Virgin Islands, and Puerto Rico (Brown and Amadon 1968, Newton 1979, Santana C. *et al.* 1986). Although the red-tailed hawk is one of the most common raptors of the Midwest, few exhaustive investigations detailing large samples of nests over an extended time period have been published. I could find no published studies on nesting ecology of red-tails in Missouri.

Changing land use patterns, especially urbanization and monotypic row-crop agricultural practices, could precipitate long-term population declines in many species of raptors (Wakeley 1978, Bechard 1982, Gilmer and Stewart 1984, Toland 1987). To assess the effects of such environmental changes on raptor populations, information on reproductive success, habitat use, population density, survival, and food habits must be accumulated from different segments of a species' range.

The objectives of this study were to describe red-tailed hawk nest site characteristics in central Missouri, monitor productivity and nesting success, analyze affects of competition by great horned owls (*Bubo virginianus*) on

nesting red-tails, determine food habits, and investigate other aspects of nesting ecology.

Study Area and Methods

My study was conducted from January 1980 through June 1986 in Boone, Callaway, and Cole Counties in central Missouri. This tri-county area is part of the Ozark Border region, a physiographically heterogeneous area interphasing the Glaciated Plains natural division to the north and the Ozark Plateau natural division to the south (Thom and Wilson 1980). This gradation of featureless plains into precipitous bluffs and rolling hills yields a high diversity of habitat types. The study area was composed of old fields, meadows and pastures, croplands and farmsteads, oak-hickory forests, and bottomland forests, frequently interlaced with meandering creeks and rivers, rugged limestone bluffs and cliffs, pockmarked with springs, sink-holes, and other "karst" topography. Two cities and their associated suburbs, Columbia and Jefferson City, are located within the tri-county area.

Typical upland woodlands consisted of an overstory dominated by oaks (*Quercus spp.*) and hickories (*Carya spp.*), a mid-story of eastern redcedar (*Juniperus virginiana*), flowering dogwood (*Cornus florida*), sugar maple (*Acer saccharum*), persimmon (*Diospyros virginiana*), American plum (*Prunus americana*), eastern redbud (*Cercis canadensis*), and sassafras (*Sassafras albidum*). Typical bottomland forest and riparian woodlands consisted of American sycamores (*Platanus occidentalis*), green ash (*Fraxinus pennsylvanica*), American elm (*Ulmus americana*), black walnut (*Juglans nigra*), sugar maple, silver maple (*Acer saccharinum*), eastern hophornbeam (*Ostrya virginiana*), and willows (*Salix spp.*).

I identified paired red-tailed hawks within a breeding season by unique plumage characteristics (Janes 1984a) and molt patterns of primaries and rectrices. I ascertained the sexes of the hawks by relative position during copulation or by physical and behavioral characteristics including, relative size (female larger), incubation duties (female does most; Janes 1984b), nest attentiveness after hatching (female greater; Stinson 1980), response to congeneric territorial intruders (male more aggressive; Janes 1984b), and response to humans near the nest (female more aggressive; Fitch et. al 1946, Janes 1984b).

Red-tail nests were found: 1) by systematically searching for nests along roads by vehicle and in woodlots and forest by foot, during winter and early spring prior to tree canopy leaf-out, when these bulky structures are quite conspicuous (Craighead and Craighead 1956), 2) by visiting nest sites reported to me by farmers, falconers, birders, and other local residents, 3) by noting the locations of red-tail aerial courtship displays during late winter-early spring which invariably culminated in the vicinity of the nest tree, and 4) by visually tracking adult red-tails that were carrying sticks, greenery, or prey to their nests.

To reduce the probability of sampling error bias resulting in an overestimation of reproductive success, all nest monitoring was initiated prior to or during the incubation stage (Steenhof and Kochert 1982). I tried to locate all territorial pairs each year in order to document nest failures as well as successful nest attempts (Steenhof 1987).

Nest locations were plotted on aerial photos, topographical maps, and county highway maps, facilitating calculations of nest distances from closest stream, nearest road, nearest human dwelling, closest woodlot edge or forest opening, and size of woodland tract. I recorded whether the nest tree was on a slope or on flat terrain, directional exposure of the slope or woodlot opening/edge (N,NE,E,SE,S,SW,W,NW), and species of each nest tree. Nest height was measured by climbing to the nest with a tape measure, and nest tree height was obtained with a 400mm telephoto lens.

Within an intensively monitored 70 km² study area in Boone County, I found all territorial pairs each year to determine red-tail population densities.

Each nest was visited or observed from a neighboring tree three or more times to facilitate data collection for clutch size, hatching success, and fledging success. Nestlings three weeks of age or older were banded with U.S. Fish and Wildlife Service aluminum bands. Adult red-tails were captured using a bal-chatri (Berger and Mueller 1959) or noose-harnessed (Beebe and Webster 1964) rock dove (*Columba livia*), and subsequently measured, weighed, and banded.

An occupied nest was one in which two adults were present near or on a nest with fresh greenery on top; an active nest or nesting attempt was one in which at least one egg was laid (Postupalsky 1974). A successful nest or nesting attempt was one which fledged at least one young (Postupalsky 1974, Newton 1979). Hatching success was the number of eggs that successfully hatched divided by the total number of eggs laid. Fledging success was the number of nestlings that successfully fledged divided by the total number of young that hatched (Toland 1986c, Toland and Elder 1987). Total nesting success was the percentage of all eggs laid that resulted in fledged young (Toland 1985a, 1986c) and productivity was the mean number of fledglings produced per pair (Toland 1986c).

Fresh prey remains at most nest sites and associated perches were identified to at least the genus ranking if possible. For each prey type, frequency of occurrence, percent composition, and estimated percent biomass were calculated (Toland 1985b, 1986c). I used average weights presented in Schwartz and Schwartz (1959), Terres (1980), Steenhof (1983), and Dunning (1984) to compute estimated percent biomass. Hunting success (the percentage of all capture attempts that result in prey capture) was determined by recording the number of capture attempts, successful captures, and the prey species taken (Toland 1986a). All capture attempts with undetermined outcomes were excluded from analysis (Toland 1986a).

I identified nest predators by direct observation, signs (i.e., hair, feathers, or scats at the depredated nest site), or interpretation of species specific patterns of depredation (Rearden 1951).

Results and Discussion

Courtship began in January and February each year, evidenced by mutual soaring, aerial leg-dangling, aerial talon presentation or grappling, sky-dancing, mutual high-perching, courtship feeding, and copulation, as described by Palmer (1988). Both males and females carried nest material to nests, but females did most of the actual nest construction.

Nest Sites

A total of 110 different nests was found during the seven-year study. Nests were discovered in 11 species of trees, of which 99.0% were deciduous hardwoods. Although 55.4% of the nests were in four species of oak (*Quercus*) inclusively, American sycamores were the most frequently used nest tree. I found 44 (40.0%) nests in sycamores, 35 (32.0%) in white oaks (*Quercus alba*), 21 (19.1%) in black oaks (*Q. velutina*), 2 (1.9%) in shingle oaks (*Q. imbricaria*), 2 (1.9%) in eastern redcedars, 1 (0.9%) in a red oak (*Q. rubra*), 1 (0.9%) in an American elm, 1 (0.9%) in a green ash, 1 (0.9%) in a shagbark hickory (*Carya ovata*), 1 (0.9%) in a mockernut hickory (*C. tomentosa*), and 1 (0.9%) in an eastern cottonwood (*Populus deltoides*).

Red-tailed hawk nests averaged 16.7 m in height (s.d. \pm 4.5, range 11.7-26.7 m), were placed in or near the canopy (nest height = 74.0% of nest tree height), on primary or major secondary crotches of trees that were significantly taller than the average height of randomly selected trees in the nest site plot ($\chi^2 = 12.23$, $df = 1$, $P < 0.01$). Several other studies in the eastern United States have reported nearly exclusive use of deciduous trees by nesting red-tails (Hagar 1957, Orians and Kuhlman 1956, Gates 1972, Titus and Mosher 1981, Speiser and Bosakowski 1988). The use of a wide variety of tree species for nesting by red-tails throughout their range suggests selection of structural characteristics as nest site criteria (Bednarz and Dinsmore 1982, Mosher *et al.* 1986, Santana C. *et al.* 1986, Speiser and Bosakowski 1988). Common features of red-tail nest sites in widely different geographical areas and habitats include; (1) large trees, (2) nest height-nest tree height ratios of from 67-81%, (3) relatively open canopies that facilitate a wide view of the breeding territory, render the nest conspicuous to conspecifics, and permit unobstructed access to the nest by the resident pair (Gates 1972, Bohm 1978, Peterson 1979, Titus and Mosher 1981, Bednarz and Dinsmore 1982, Santana C. *et al.* 1986, Speiser and Bosakowski 1988).

In this study, more nest trees (58.0%) were on a slope than on flat terrain (42.0%), but the difference was not significant ($\chi^2 = 2.56$, $df = 1$, $P > 0.05$). Slope aspects and nest site exposures were significantly different ($\chi^2 = 22.75$, $df = 7$, $P < 0.01$) with 56.5% of the nests oriented towards the north, northwest, and northeast. The southwest exposure was completely avoided while 10.3, 8.0, 6.9, and 5.7% of the nests faced west, east, southeast, and south respectively. Bechard *et al.* (1990) documented similar nest site exposures for nesting red-tails in Washington. Avoidance of the southwest direction by nesting red-tails has also been reported in Iowa and New York (Bednarz and Dinsmore 1982, Speiser and Bosakowski 1988). It may be that southwest exposures tend to increase excessive heat stress during the afternoon and decrease nest insolation during late winter and early spring storms which blow into Missouri from that direction.

Red-tail nests in central Missouri averaged 36.9 m (range 1-500 m) from the nearest opening, 543 m (range 30-3200 m) from the nearest road, 627 m (range 100-2000 m) from the nearest human dwelling, and 58.3 m (range 1-800 m) from the nearest stream. Thirty-three percent of the nest trees were in woodlots 0.4 ha or less in size, 33.0% were in woodlots 0.81 to 4.0 ha in size, and 26.0% were in mostly continuous woodlands greater than 4.0 ha in size. Only 8.0% of the nests were located in solitary trees, usually in open pastures. Nesting success

of pairs in solitary trees and the various sized woodlots was similar ($\chi^2=1.24$, $df=3$, $P>0.05$). Relative distance of nests from roads or human dwellings had no detectable influence on productivity. For example, the nest located closest (100 m) to an occupied rural home was successful for 3 successive years—a rate exceeded by only a few other nest sites. In Iowa, Wisconsin, and New York, red-tail nests were typically in solitary trees, small woodlots, or forest edge, usually on a steep slope. These nests were often associated with roads and farm buildings with no adverse affects (Gates 1972, Bednarz and Dinsmore 1982, Speiser and Bosakowski 1988). Red-tail nest sites in Maryland were all located in relatively continuous forest (Titus and Mosher 1981). Many regional red-tail studies have failed to show a positive association of red-tail nest sites with water (Gates 1972, Mader 1978, Titus and Mosher 1981, Bednarz and Dinsmore 1982, Santana C. *et al.* 1986, Speiser and Bosakowski 1988). However, Bechard *et al.* (1990) reported that red-tailed hawks in Washington nested significantly closer to streams than did sympatric Swainson's hawks (*Buteo swainsoni*) or ferruginous hawks (*B. regalis*). The apparent preference of red-tails in central Missouri for nest sites close to streams may indicate they select the largest, tallest trees with the most commanding view and most accessible canopy—in this case American sycamores which are the largest trees which have not been cleared due to the difficulty of access and construction along the precipitous stream floodplains and watersheds in the study area.

Breeding Density

Red-tailed hawk breeding population density during the 7 years averaged 1 nesting pair per 7.4 km² (range 5.6-9.5 km²). Nesting population densities of red-tailed hawks in other parts of temperate North America ranged from 1 pair per 46.6 km² in marginal habitat in Alaska, to 1 pair per 5.2-8.0 km² in more typical habitats in New York, Alberta, Wisconsin, and Montana, up to 1 pair per 1.3 km² in optimal habitat in California (Fitch *et al.* 1946, Orians and Kuhlman 1956, Hagar 1957, Luttich *et al.* 1971, Johnson 1975, Lowe 1978). Red-tailed hawk nesting densities are limited by prey availability, nest tree distribution, hunting perch numbers and distribution, and competition from other raptors (Newton 1979).

Nesting Phenology

Nesting phenology was similar from year to year. I obtained nesting dates from 81 breeding pairs during the seven-year study. Based on a 34-day incubation period (Kirkley and Springer 1980, Palmer 1988) and a 48-hour average egg laying interval (Newton 1979, Palmer 1988), I backdated from known hatch dates at nests where I was unable to visually confirm clutch initiation. Egg laying ranged from 5 March through 29 March (mean: 13 March), hatching occurred from 9 April through 2 May (mean: 17 April), and fledging, which normally required 44-46 days, ranged from 26 May through 17 June (mean: 2 June). Kirkley and Springer (1980) reported similar nesting chronology of red-tails in Ohio. Mean nesting dates in Arizona were surprisingly similar (9 March, 12 April, 27 May) although nesting ranged nearly 2 weeks longer (Mader 1978), and nesting in western regions was approximately 1, 2, 4, and 5 weeks later in California, Alberta, Wyoming, and Montana, respectively (Luttich *et al.* 1971, Seidensticker and Reynolds 1971, Johnson 1975, Wiley 1975).

Productivity

Within my intensively monitored 70 km² study area I estimated the component of non-breeding resident pairs was less than 10 percent. The mean percentage of non-breeders documented for North America is 12% (Palmer 1988) with reported rates of from 4.5% in California (Wiley 1975) to 35% in New York (Hagar 1957).

I collected nesting data for 140 nest attempts (Table 1). Central Missouri red-tail mean clutch size was 2.47 (range 1-3). Two nests contained single egg clutches, 65 nests had 2 eggs, and 63 nests supported clutches of 3. Hatching success pooled for the 7 years was 89.4% (Table 1). Fledging success was 92.7%—mortality of nestlings was extremely low with only 1 confirmed instance of nestling death after 2 weeks of age. In that case a raccoon (*Procyon lotor*) depredated 2 nestlings at 3-4 weeks of age. Nest desertion occurred at 14 nests, of which 7 (50%) resulted from wind damage. However, 4 of the documented desertions happened prior to egg-laying and as such, were not considered failed nesting attempts. A total of 10 (7.1%) nesting attempts failed due to: high winds (5), raccoon predation of eggs (2), American crow (*Corvus brachyrhynchos*) predation of eggs (1), addled eggs (1), and nestling predation by the great horned owl (1).

Of 140 total nesting attempts, 130 (93%) resulted in successful fledgings of at least 1 young. Total nesting success (number of eggs that fledged successfully) was 83.0% (Table 1); an average of 2.05 young fledged per successful nest. For all nesting pairs the mean productivity was 1.85 young per nest. Using North American productivity and mortality data, Henny and Wight (1972) estimated that temperate latitude red-tail populations must produce between 1.3 and 1.4 young per breeding attempt, to maintain population stability. Red-tails in central Missouri surpassed this critical productivity threshold 6 of 7 years (Table 1), evidence that the population is apparently expanding. Productivity of red-tails in other studies has generally been lower than in central Missouri. Reported nest desertion rates range from 10.0-46.0%, average clutch sizes range from 2.0 to 2.9 (generally increasing in size from east to west and south to north in North America), and mean productivity rates range from 0.9 to 1.6 young per nest (Fitch *et al.* 1946, Hagar 1957, Luttich *et al.* 1971, Henny and Wight 1972, Cornman 1973, Smith and Murphy 1973, Wiley 1975, Lowe 1978, Kirkley and Springer 1980).

Nest Reoccupation and Competition

Longevity of 78 nest structures of red-tailed hawks in central Missouri for which complete chronological history was known, averaged 3.8 years (range 1-10 years). These 78 nests were occupied by red-tails for periods of 1 to at least 6 years and averaged 1.82 years. Thus, nests built by red-tails were occupied by the hawks 48% of the years they were available. Red-tailed hawks used the same nest successively for at least 2 years 45% (35 of 78) of the time. The longest a nest was continuously occupied was for 5 consecutive years, but successive use of a nest averaged only 1.6 years for all nests. Successive nest reuse rates reported from other regions of North America ranged from 17 to 50% (Orians and Kuhlman 1956, Hagar 1957, Seidensticker and Reynolds 1971, Belyea 1976, Bohm 1978). Most red-tails in central Missouri maintained 2 nests within

Table 1. Red-tailed hawk productivity and nesting success in central Missouri, 1980-86.

Year	No. nests	Failed nests	Success. nests	Total No. eggs laid	Mean Clutch size	Total No. hatched	Mean brood size	% hatch success ¹	Total No. fledged	% fledge success ²	Young* fledged per nest	% Total nesting success ³
1980	23	1	22	48	2.2	42	1.9	87.5	36	85.7	1.6	75.0
1981	18	2	16	38	2.4	27	1.7	71.0	24	89.0	1.3	63.2
1982	21	2	19	47	2.5	38	2.0	81.0	34	89.5	1.6	72.3
1983	29	1	28	78	2.8	75	2.7	96.2	71	94.7	2.4	91.0
1984	19	2	17	38	2.2	38	2.2	100.0	36	94.7	1.9	94.7
1985	16	1	15	40	2.7	38	2.5	95.0	36	94.7	2.3	90.0
1986	14	1	13	32	2.5	29	2.2	90.6	29	100.0	2.1	90.6
Total -	140	10	130	321	2.47	287	2.2	89.4	266	92.7	1.85	83.0

(range 1-3)

*Includes both successful and failed nests.

¹Number of eggs that successfully hatched divided by total number of eggs laid.

²Number of young that fledged divided by total number of young that hatched.

³Number of young that fledged divided by total number of eggs laid.

their territories. Nearly all (96%) territories that I monitored were occupied and resident pairs nested in both nests over several years resulting in all nests being occupied approximately half (48%) the available nest years.

Special attention was focused on the great horned owl in order to document possible nesting interference or other affects of interspecific competition on nesting red-tails. During the 7 years of this study I monitored 30 great horned owl nests of which 84% were in red-tailed hawk nests (Toland, unpubl. data). Great horned owls utilized red-tail nests for breeding at some time during the nesting histories of 27 of 78 (34.6%) intensively monitored red-tail nests. Twenty-six out of the 27 (96%) owl nestings subsequently resulted in the nest remaining unoccupied and deteriorating. The average occupancy time for red-tails at 27 nests used by horned owls averaged 1.56 years, while red-tail nests which never harbored owls were occupied by hawks an average of 1.92 years ($\chi^2 = 1.37$, $df = 1$, $P > 0.05$). Nests that were never impacted by great horned owls were occupied by red-tails significantly more often (58.7% of available nest years) than nests that at some time supported owls (36.5% of available nest years) ($\chi^2 = 7.93$, $df = 1$, $P < 0.01$). Although great horned owls did not use any of the few red-tail nests constructed in solitary trees in open pastures, they occupied red-tail nests in the three size classes of woodlots in proportion to availability; small (0.1-0.4 ha), medium (0.81-4.0 ha), and large (>4.0 ha) tracts of woodlands supported 33.0, 33.0, and 26.0% of the red-tailed hawk nests, respectively, and 33.0, 33.0, and 33.0% of all great horned owl nests, respectively ($\chi^2 = 3.02$, $df = 2$, $P > 0.05$). Similar habitat requirements and overlapping home ranges of these two species have previously been reported (Craighead and Craighead 1956, Hagar 1957, Luttich *et al.* 1971, Seidensticker and Reynolds 1971, Houston 1975, Peterson 1979, Kirkley and Springer 1980, Palmer 1988).

Great horned owls have been reported to utilize their generally greater size and earlier nesting phenology to usurp hawk nests or to cause nest failures through interference or predation (Craighead and Craighead 1956, Hagar 1957, Smith 1970, Luttich *et al.* 1971, Houston 1975, Wiley 1975, Kirkley and Springer 1980). I banded and measured 117 red-tailed hawks (Toland 1986b) which weighed an average of 1190g (range 720-1750g). Great horned owls ($N = 52$) in the study area weighed an average of 1400g (range 1150-1750g) (Toland, unpubl. data). In addition to this general advantage in size (about 15%), horned owls in central Missouri initiated egg laying around 5 weeks earlier than red-tails (mean clutch initiation date: 3 February) (Toland, unpubl. data).

Red-tails responded to a nest usurped by owls by moving to their alternate nest or building a new one. Because the owls do not add nest material and the young, relatively heavier and clumsier owlets degrade the nest platform, owl-used nests deteriorated or disappeared over the winter. Nesting success and productivity of red-tails that shared their nesting territories with great horned owls were the same as hawks that were not exposed to neighboring owls ($\chi^2 = 0.35$, $df = 1$, $P > 0.05$). Great horned owl predation on red-tailed hawks (adults or young) during nesting was insignificant, occurring at only 1 of 140 nests. Overt aggressive interactions between the two species during nesting were rare, while mutual tolerance was frequently observed. At two different red-tail nest sites, respective pairs of hawks and great horned owls successfully nested

less than 100 m apart in full view of each other. At one of these sites both species successfully fledged 3 young, while at the other site the hawks and owls fledged 3 and 2 young, respectively. Proximal nesting by these two raptors has been reported in other areas but the result is typically desertion by one or both species (Smith 1970, Houston 1975). Success of close-nesting red-tailed hawks and great horned owls in my study may be a reflection of high rodent prey availability in the study area (Toland 1985a, 1987), as well as temporal partitioning of foraging activities (Craighead and Craighead 1956, Houston 1975, Peterson 1979). The small mammal component of the great horned owl nesting season diet was similar to that of red-tailed hawks (75.0% and 71.4%, respectively). However, 25% of the rats and mice captured by horned owls were primarily nocturnal species including white-footed mouse (*Peromyscus leucopus*), eastern woodrat (*Neotoma floridana*), Norway rat (*Rattus norvegicus*), and meadow jumping mouse (*Zapus hudsonius*) (Schwartz and Schwartz 1959). These species composed just 3% of the rats and mice taken by nesting red-tails (Toland, unpubl. data).

These observations suggest a commensalistic relationship between red-tailed hawks and great horned owls in central Missouri. While horned owls are dependent on red-tails for nest sites and reduce nest structure longevity, they apparently do not affect nesting success, productivity, or nest site selection of this hawk when prey availability is adequate. In Montana, Canada, and Ohio most of the great horned owl nests were built by red-tails (Seidensticker and Reynolds 1971, Houston 1975, Kirkley and Springer 1980).

Food Habits

Nesting season food habits of red-tails consisted of at least 40 species of prey animals. Mammals comprised 71.4% of the 601 total prey items by occurrence and 89.4% in biomass (Table 2). Birds comprised 18.0% of the diet by occurrence and 7.7% in biomass. Among prey items, cotton rats (*Sigmodon hispidus*) were most frequent (19.0%), but eastern cottontails (*Sylvilagus floridanus*) contributed the most biomass (44.0%). In order of their occurrence as prey, the 5 species delivered most often were: cotton rat, prairie vole (*Microtus ochrogaster*), eastern cottontail, eastern fox squirrel (*Sciurus niger*), and southern bog lemming (*Synaptomys cooperi*) (Table 2).

Overall, the average size of red-tailed hawk nesting season prey was 351g. (range 0.5-1800g.) or approximately 29% of the average red-tail's body weight. The average weights of captured birds, reptiles, and fish were similar (152, 153, and 160g. respectively). Mammalian prey weighed an average of 443.7g. Red-tail nesting season average prey weights in other regions ranged from 216g to more than 1300g (Meslow and Keith 1966, Gates 1972, Smith and Murphy 1973, Knight and Erickson 1976, Mader 1978). Foraging red-tails are capable of exploiting both open and wooded habitats and their opportunistic food habits reflect the relative availability of prey animals in a given area. Diets dominated by mammalian prey (62-90%) are most frequently reported, with lagomorphs and ground squirrels the most important contributors of biomass (Errington 1933, Fitch *et al.* 1946, Craighead and Craighead 1956, Meslow and Keith 1966, Luttich *et al.* 1971, Smith and Murphy 1973, Mader 1978). Bird-dominated diets (58-65%), with ring-necked pheasants (*Phasianus colchicus*) being most

Table 2. Nesting season food habits of red-tailed hawks in central Missouri, 1980-86.

Prey species	N	% Occurrence	Ave. weight (g)	% Estimated biomass
Birds				
Northern bobwhite (<i>Colinus virginianus</i>)	15	2.5	172	1.2
Domestic duck (<i>Anas platyrhynchos</i>)	2	0.3	1200	1.1
Yellow-billed Cuckoo (<i>Coccyzus americana</i>)	4	0.7	50	tr ^a
Northern flicker (<i>Colaptes auratus</i>)	2	0.3	132	tr
Red-headed woodpecker (<i>Melanerpes erythrocephalus</i>)	2	0.3	80	tr
American kestrel (<i>Falco sparverius</i>)	1	0.2	125	tr
Eastern meadowlark (<i>Sturnella magna</i>)	26	4.3	95	1.2
Common grackle (<i>Quiscalus quiscula</i>)	6	1.0	112	tr
Red-winged blackbird (<i>Agelaius phoeniceus</i>)	13	2.2	50	tr
Northern robin (<i>Turdus migratorius</i>)	2	0.3	79	tr
Brown thrasher (<i>Toxostoma rufum</i>)	5	0.8	70	tr
Gray catbird (<i>Dumetella carolinensis</i>)	1	0.2	40	tr
American crow (<i>Corvus brachyrhynchos</i>)	10	1.7	525	2.5
Bluejay (<i>Cyanocitta cristata</i>)	6	1.0	89	tr
American goldfinch (<i>Carduelis tristis</i>)	1	0.2	15	tr
Unidentified small birds	12	2.0	45	tr
Subtotal	108	18.0	152 ^b	7.7
Mammals				
Opossum (<i>Didelphis marsupialis</i>)	2	0.3	1800	1.7
Eastern mole (<i>Scalopus aquaticus</i>)	6	1.0	100	tr
House mouse (<i>Mus musculus</i>)	2	0.3	19	tr
Norway rat (<i>Rattus norvegicus</i>)	3	0.5	250	tr
Eastern woodrat (<i>Neotoma floridana</i>)	4	0.7	300	0.5

Table 2 (continued)

Cotton rat (<i>Sigmodon hispidus</i>)	114	19.0	150	8.0
Prairie vole (<i>Microtus ochrogaster</i>)	84	14.0	38	1.5
Southern bog lemming (<i>Synaptomys cooperi</i>)	32	5.3	35	0.5
Western harvest mouse (<i>Reithrodontomys megalotis</i>)	8	1.3	21	tr
Unidentified mice	9	1.5	30	tr
Eastern fox squirrel (<i>Sciurus niger</i>)	63	10.5	900	26.6
Eastern gray squirrel (<i>Sciurus carolinensis</i>)	24	4.0	500	5.6
Eastern cottontail (<i>Sylvilagus floridanus</i>)	<u>78</u>	<u>13.0</u>	<u>1200</u>	<u>44.0</u>
Subtotal	429	71.4	443	89.4
Reptiles				
Ratsnake (<i>Elaphe obsoleta</i>)	6	1.0	200	0.6
Racer (<i>Coluber constrictor</i>)	4	0.7	125	tr
Bullsnake (<i>Pituophis melanoleucus</i>)	2	0.3	225	tr
Eastern garter snake (<i>Thamnophis sirtalis</i>)	2	0.3	109	tr
Northern water snake (<i>Nerodia sipedon</i>)	3	0.5	125	tr
Rough green snake (<i>Ophedrys aestivus</i>)	1	0.2	75	tr
Unidentified snakes	<u>19</u>	<u>3.1</u>	<u>150</u>	<u>1.4</u>
Subtotal	37	6.1	153	2.7
Fishes				
Unidentified fish	2	0.3	160	tr
Invertebrates				
Unidentified crayfish	3	0.5	10	tr
Orthopterans	14	2.3	1	tr
Coleopterans	<u>8</u>	<u>1.3</u>	<u>0.5</u>	<u>tr</u>
Subtotal	25	4.1	1.9	tr
Totals	601	100.0	351	100.0

^apercent estimated biomass less than 0.5

^bmeans

important, were reported from Wisconsin (Orians and Kuhlman 1956, Gates 1972). Knight and Erickson (1976) reported food habits of Washington red-tails to be dominated by snakes.

Red-tailed hawk nesting season food habits were characterized by larger average prey size ($\chi^2 = 80.17$, $df = 1$, $P < 0.01$), a significantly higher percentage of birds, a lower percentage of invertebrates ($\chi^2 = 16.22$, $df = 3$, $P < 0.01$), and

wider diversity of prey species captured than during the non-nesting seasons (Table 3). Shifts toward larger prey items or energy packages during the nesting season enable a raptor to maximize foraging efficiency in terms of energy used

Table 3. Seasonal characteristics of red-tailed hawk food habits in central Missouri, 1980-86.

	N	Average Prey weight (g)	% Mammals	% Birds	% Reptiles	% Inverts	No. Species
Nesting	601	351	71.4	18.0	6.1	4.1	40
Non-nesting	1370	188	81.2	3.7	4.1	11.5	30

per unit of energy gained (Cade 1982). This is of particular importance during the nestling stage when the adults are provisioning several rapidly growing young having energy requirements similar to their own (Brown and Amadon 1968). This phenomenon has been documented in several other species of raptors in Missouri; the American kestrel (*Falco sparverius*), northern harrier (*Circus cyaneus*), Cooper's hawk (*Accipiter cooperii*), and great horned owl (Toland 1983, 1986c, 1987, unpubl. data). Smaller average prey size during the nonnesting period (\bar{x} = 188g, range 0.5-1200g), including higher percentages of small rodents and invertebrates, may reflect both lower prey abundance and diversity (insects and migratory birds are unavailable) as well as the limited hunting ability of juvenile hawks during the two month average post-fledging dependency period (Newton 1979, Johnson 1986). The importance of experience in the gradual development of hunting in young red-tails and other raptors is influential in their selection of invertebrates and relatively low capture rate of vertebrate prey (Sherrod 1983, Johnson 1986, Toland 1986a). Once immature red-tails became completely independent of adults, they spent the remainder of their first year subsisting almost entirely on voles and mice weighing less than 50g (Toland, unpubl. data).

Hunting Success

The overall hunting success (the percentage of all capture attempts that result in prey capture) of red-tailed hawks in central Missouri was 60.6% (N = 465). Adults were significantly more successful hunters than immatures ($\chi^2 = 7.10$, $df = 1$, $P < 0.01$); the success rates were 66.4 and 54.0% respectively (Toland 1986a). Orde and Harrell (1977) calculated a hunting success rate of 78.8% (N = 169) for red-tails in South Dakota.

Red-tailed hawk hunting success varied according to agility and size of prey. Birds (the most agile prey group) comprised only 2.0% (6 of 282) of the total observed successful captures and were caught by red-tails on 6 of 38 (15.8%) attempts. Immature red-tails were never successful in capturing avian prey and were only observed to chase birds six times. Their highest rate of hunting success (69.4%, 34 of 49) was with invertebrate prey. Adult red-tails were most successful in catching herpetofauna (85.0%) and invertebrates (83.3%), least successful (20%, 6 of 30) when pursuing birds, but most frequently captured small mammals (131 of 166 successful strikes) with a success rate of 70.8% (Toland 1986a).

Summary

Red-tailed hawks were studied in central Missouri during the seven-year period from 1980 through 1986. A total of 110 nests was found, of which 99.0% were in deciduous hardwoods including, *Quercus spp.* (55.4%) and American sycamores (40.0%). Nests were constructed at an average height of 16.7 m (74.0% of nest tree height), avoided the southwest exposure, were more frequently on a slope than flat terrain, and were rarely in solitary trees in open pastures.

Breeding population density averaged 1 nesting pair per 7.4 km² and the percentage of pairs that did not attempt to nest was less than 10%. Mean egg-laying, hatching, and fledging dates were 13 March, 17 April, and 2 June, respectively. Mean clutch size for 140 nest attempts was 2.47. The most common cause of nest failure was high winds. Of 140 nest attempts, 130 (93%) resulted in at least one successfully fledged young. Mean annual productivity was 1.85 young fledged per nest.

Longevity of 78 red-tail nest structures averaged 3.8 years (range 1-10) and occupation by red-tails averaged 1.82 years (range 1-6). Red-tailed hawks used nests successively 45.0% of the time up to 5 consecutive years. Nests utilized by great horned owls during some interval of their history suffered quicker deterioration and were occupied by red-tails significantly less often than were nests that never supported owls. There was no difference in nesting success between red-tails that were not exposed to nesting great horned owls and those experiencing owl encroachment. However, horned owls were apparently dependent upon red-tailed hawks for nest sites in central Missouri.

Mammals comprised 71.4% of the diet of nesting red-tailed hawks by occurrence (89.4% in estimated biomass). During nesting, red-tails maximized hunting efficiency by taking significantly larger prey items (\bar{x} = 351g) than during the non-nesting seasons (\bar{x} = 165g). Adult red-tailed hawks captured larger prey species and exhibited higher hunting success rates than did immatures.

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Association of Bacteria with Velvetleaf Roots

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Abstract: The association between velvetleaf (*Abutilon theophrasti* Medik.) seedling roots and selected rhizobacteria in nutrient solution culture was studied by standard bacteriological procedures and scanning electron microscopy (SEM). Velvetleaf seedlings inoculated with selected rhizobacteria became chlorotic and developed abnormal root systems compared with noninoculated sterile controls. Root systems adsorbed significantly higher numbers of selected rhizobacteria, *Pseudomonas* spp. and *Erwinia herbicola*, than of the soil isolate, *Alcaligenes faecalis*. High numbers of rhizobacteria were present in crevices between epidermal cells and along root hairs. Certain isolates of rhizobacteria appeared to be embedded in variable amounts of mucigel associated with root hairs. Rhizoplane populations of rhizobacteria were maintained between 10^4 and 10^8 cells per cm of root during seedling growth, indicating continuous colonization of roots. Deleterious rhizobacteria, a component of the diverse rhizosphere community in nature, may be potential biocontrol agents if weed rhizospheres can be manipulated to favor their attachment to the rhizoplane.

Key Words: Biocontrol, rhizobacteria, rhizoplane, scanning electron microscopy, velvetleaf, weed control.

Introduction

Velvetleaf is one of the most troublesome and economically important weeds throughout the northcentral and southern United States (Spencer, 1984). Current herbicides and cultural practices often do not satisfactorily control this weed (Jordan *et al.*, 1987). Biocontrol of velvetleaf offers an attractive and economic alternative to conventional methods. Some fungi have been found to be specifically pathogenic on the foliage of velvetleaf, however, they require specific conditions of high humidity and moderate temperature to be effective (Wymore *et al.*, 1987). Additionally, these mycoherbicides are applied to plants established in the field that are actively competing with the crop.

An alternative biocontrol approach would be to select certain microorganisms that inhibit weed seedling development. The resultant reduction in seedling vigor would retard the establishment of a competing weed population. Schroth and Hancock (1982) described bacteria that aggressively colonized and readily established on plant root surfaces and termed them rhizobacteria. Rhizobacteria can either be plant growth promoting, deleterious or neutral in their effects. Plant growth promoting rhizobacteria have the ability to improve plant growth through the production of plant growth regulating substances and/or suppression of deleterious root colonizing microorganisms (Suslow and Schroth, 1982). Deleterious rhizobacteria reduce seed germination and seedling vigor in several crop and horticultural plants by producing phytotoxins or other substances that are absorbed by the plant (Suslow and Schroth, 1982). These organisms are likely ubiquitous and common to all plant roots, and thus, may well exist on roots of economically important weeds.

Manipulation of the weed rhizosphere by introducing selected deleterious rhizobacteria that readily colonize root surfaces could lead to an effective weed biocontrol system. Preliminary studies have shown that bacteria isolated from roots of velvetleaf and other weed seedlings significantly reduced seedling growth when inoculated onto seedlings under controlled conditions (Kremer *et al.*, 1990). Also, the occurrence of detrimental rhizobacteria on downy brome (*Bromus tectorum* L.) has been reported (Cherrington and Elliott, 1987). Descriptions of bacterial attachment to the rhizoplane of weed seedlings and the association of the bacteria with host tissue is unknown. An understanding of the mode of attachment of bacteria to root surfaces of weed seedlings may greatly aid in developing methods for biological control of weeds based on specific deleterious rhizobacteria. Scanning electron microscopy (SEM), successfully applied in other studies of bacteria-rhizoplane relationships (Dart, 1971; Foster, 1981; Foster and Bowen, 1982), was used in this investigation because of its high resolution of surface structures and great depth of field.

Previous work with rhizobacteria deleteriously affecting economically important crops (Campbell *et al.*, 1987; Schroth and Hancock, 1982; Suslow and Schroth, 1982) serves as the premise for studying the potential of detrimental rhizobacteria on weed seedling roots as biocontrol agents. Therefore, the objectives of this study were to understand the association of rhizobacteria with root surfaces of velvetleaf seedlings and to relate these associations to effects of rhizobacteria on root growth and morphology.

Materials and Methods

Bacterial cultures and plant host

Pseudomonas fluorescens 007 and 239, *P. putida* 001, *Pseudomonas* sp. 254, and *Erwinia herbicola* 423 were isolated from the rhizoplane of velvetleaf seedlings growing in Boone County, MO in 1985. These cultures were previously shown to decrease velvetleaf seedling growth and were nondetrimental to several crop plants (Kremer *et al.*, 1990). *Alcaligenes faecalis* 285 was isolated from root-free soil from Knox County, MO. For inoculation experiments, all bacterial isolates were cultured on agar medium (Sands and Rovira, 1970) incubated at 27 C for 48 h.

An accession of velvetleaf grown at the University of Missouri Agronomy Research Center, Columbia, MO, was used as the host plant. Seeds were surface sterilized by immersion in 1.25% (w/v) sodium hypochlorite for 8 min, followed by immersion in 70% ethanol (v/v) for 4 min. Seeds were washed thoroughly (at least 10 times) with sterile distilled water, then allowed to imbibe water for 24 h at 27 C on germination paper. Imbibed, contaminant-free seeds with emerging radicles were used in inoculation experiments.

Inoculation experiments

Surface-sterilized, imbibed seeds of velvetleaf were planted in enclosed culture tube assemblies using the method of Araujo *et al.* (1986) with slight modifications. Our assemblies consisted of a large outer test tube (195 mm long, 25 mm diam) containing an inverted smaller test tube (100 mm long, 15 mm diam) and a folded filter paper positioned on one side of the large tube. Each assembly received 40 ml of plant nutrient solution supplemented with 1.5 mM

potassium nitrate (Hoagland and Arnon, 1938). All assemblies used in this experiment were sterilized by autoclaving at 121 C and 104 kPa for 15 min. One imbibed seed was planted per assembly which was kept enclosed during the two week growth period in order to maintain sterile growth conditions. Inocula were prepared by suspending agar cultures of each isolate in sterile distilled water. Seeds in each treatment were inoculated with 0.5 ml of a bacterial suspension containing 10^8 cells. Each bacterial culture was inoculated on 10 seeds and the experiment was repeated three times. Noninoculated seeds served as controls. Seedlings were grown in the growth chamber maintained at 28 C during a 16 h light period and at 21 C during an 8 h dark period. Light in the growth chamber was supplied by fluorescent and incandescent lamps at a photon flux density of $250 \mu\text{Em}^{-2}\text{s}^{-1}$. At harvest, root systems of each plant were thoroughly rinsed in sterile distilled water after which they were suspended in sterile phosphate-buffered saline (PBS; 0.01 M K_2HPO_4 , 0.14 M NaCl, pH 7.2) containing 0.01% (v/v) Tween 20 and agitated vigorously on a vortex shaker for 5 min. Bacterial populations were determined by serially diluting (10-fold steps) the root suspension in PBS and spread plating onto duplicate plates of agar medium (Sands and Rovira, 1970). Colonies were enumerated after incubation at 27 C for 72 h. In all experiments the development of any abnormality in the seedlings was recorded and root length was measured for each plant at harvest.

A parallel time course study was conducted to assess the colonization pattern of selected bacteria on velvetleaf seedling roots over time. Seeds were planted in 24 tube assemblies each for *Pseudomonas* sp. 254, *E. herbicola* 423, and *A. faecalis* 285 and inoculated as described above. Noninoculated seeds were treated similarly except for exclusion of bacteria. Three tubes from each treatment were removed from the growth chamber at each of eight sampling dates. Root populations of rhizobacteria were determined on the seedlings as described above and are reported as the means \pm standard errors for duplicate trials.

Scanning electron microscopy

Roots of inoculated and noninoculated seedlings grown in the enclosed culture tube assemblies were sectioned into 2-3 mm lengths and fixed in glutaraldehyde (2.5% in 0.1 M PO_4 buffer, pH 7.0) for 24 h at 4 C. The fixed root specimens were rinsed in distilled water, dehydrated in a graded series up to absolute ethanol and dried by the critical point method in liquid carbon dioxide. Dried specimens were mounted on aluminum specimen stubs with foil-backed tape and sputter-coated with gold-palladium alloy. The specimens were examined and photographed with a JEOL JSM 35 scanning electron microscope operating at 20 kv.

Results and Discussion

Noninoculated velvetleaf seedlings and those inoculated with *A. faecalis* 285 grown in enclosed culture tube assemblies exhibited vigorous growth as indicated by dark green foliage and well developed roots. In contrast, the inoculated seedlings exhibited chlorotic foliage developing at 7-10 days post inoculation. Seedlings (grown for SEM) inoculated with *E. herbicola* 423, *Pseudomonas* sp. 254, and *P. putida* 001 had significantly ($P = 0.05$) shortened

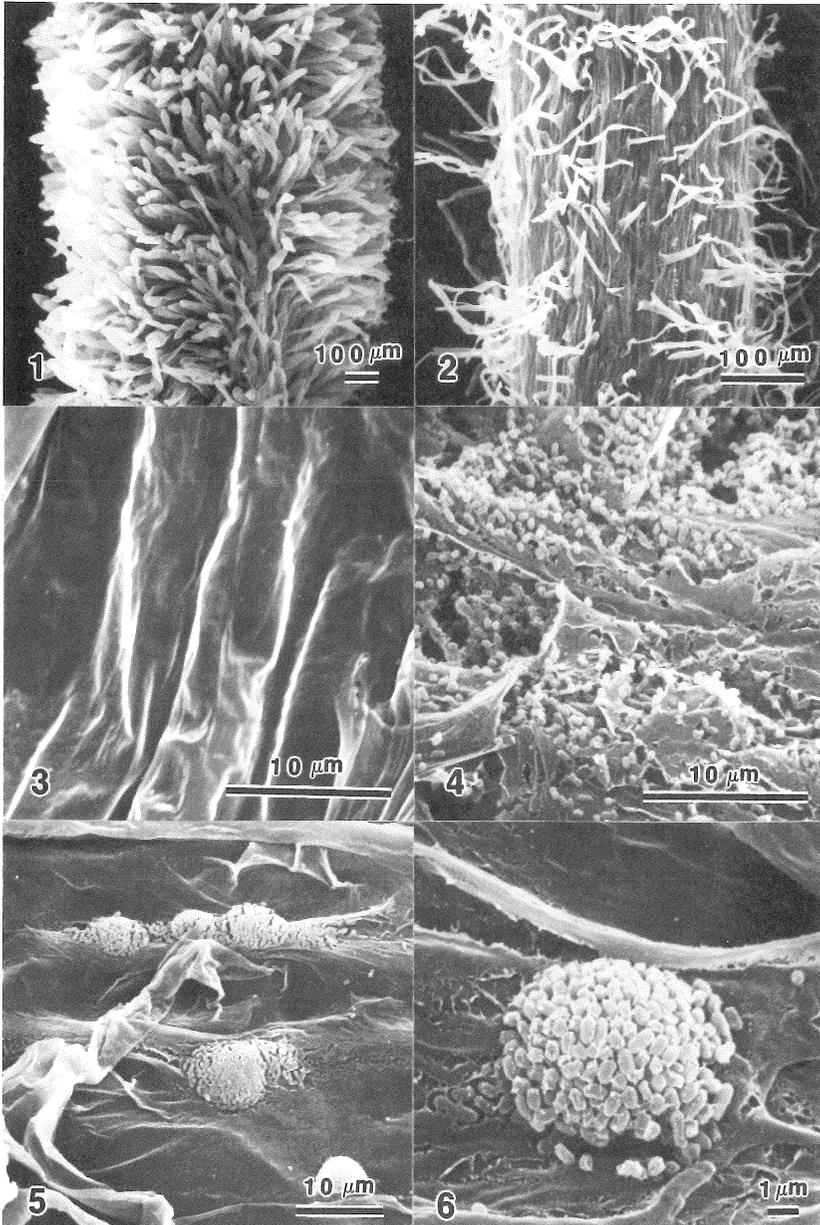


Plate 1

Fig. 1. A segment of a 2-week old noninoculated velvetleaf seedling root with abundant and turgid root hairs. Magnification, X 60.

Fig. 2. A segment of a 2-week old velvetleaf seedling root inoculated with *Pseudomonas* sp. 254 exhibiting few and collapsed root hairs. Magnification, X 150.

tap roots compared to the noninoculated seedlings (Table 1). The observed effects on plant foliage and root morphogenesis may result from production of

Table 1. Effects of bacterial inoculation on root growth and rhizoplane colonization of velvetleaf seedlings after 14 days growth in nutrient solution.

Isolate	Tap root length (cm)	Rhizoplane population (log ₁₀ cells/cm root)
<i>P. putida</i> 001	6.8	5.01
<i>P. fluorescens</i> 007	7.5	4.35
<i>P. fluorescens</i> 239	8.6	4.83
<i>Pseudomonas</i> sp. 254	4.3	8.22
<i>E. herbicola</i> 423	3.9	7.75
<i>A. faecalis</i> 285	10.2	2.33
Control	11.0	ND ^a
LSD (0.05)	3.9	1.11

^aND, not detectable (< 2.0 log₁₀ cells)

plant hormones and/or phytotoxins by the rhizobacteria (Schroth and Hancock, 1982; Suslow and Schroth, 1982). For example, *Pseudomonas* sp. 254 used in this study is a Gram-negative, oxidase-negative, fluorescent rod closely related to the phytopathogen, *Pseudomonas syringae*, and may produce toxins during root colonization, reducing plant growth (Campbell *et al.*, 1987; Suslow and Schroth, 1982). We previously demonstrated that the rhizobacterial isolates used in this study are potentially phytopathogenic based on phytotoxin indicator and host plant screening assays (Kremer *et al.*, 1990). Several of the isolates had siderophore activity, which might affect iron uptake by seedlings resulting in the observed foliar chlorosis.

- Fig. 3.** Root surface of a 2-week old noninoculated velvetleaf seedling grown in nutrient solution. Note absence of bacteria and no associated mucigel. Magnification, X 3,000.
- Fig. 4.** Root surface of a 2-week old velvetleaf seedling inoculated with *P. putida* 001 showing adherent bacteria and associated mucilaginous material. Magnification, X 3,000.
- Fig. 5.** Microcolonies of rhizobacteria, *P. putida* 001, distributed on the surface of velvetleaf tap root. Magnification, X 1,600.
- Fig. 6.** Close-up of a microcolony of bacteria, *P. putida* 001, on the surface of velvetleaf tap root. Magnification, X 5,400.

Examination by SEM revealed that roots of control seedlings had abundant and turgid root hairs (Plate 1, Fig. 1) compared to the collapsed and sparse root hairs of inoculated seedling roots (Plate 1, Fig. 2). Bacteria were not observed on root surfaces of control seedlings (Plate 1, Fig. 3). Both tap root epidermal and root hair surfaces of seedlings inoculated with *P. putida* 001 were densely covered with bacterial cells (Plate 1, Fig. 4). This particular isolate established on the root surface as definite aggregates of cells (Plate 1, Fig. 5). Plate 1, Fig. 6 shows an individual microcolony in the same area in which Plate 1, Fig. 5 was photographed at a greater magnification. The attachment of bacteria on both tap root epidermal and root hair surfaces as small aggregates may be due to the attraction of rhizobacteria to specific nutrients in root exudates at sites along the root, thereby stimulating bacterial growth (Bowen and Rovira, 1976; Rovira, 1969). Occurrence of microcolonies has been reported to be relatively common on infected roots and may represent points for subsequent penetration by rhizobacteria (Campbell *et al.*, 1987).

Pseudomonas sp. 254 colonized root surfaces covered with mucigel (Plate 2, Fig. 7). Mucigel on plant roots is derived partially from root surface cells and from root-associated microorganisms (Greaves and Darbyshire, 1972). In the present study, accumulation of mucigel on the root surface was apparently favored by the presence of selected rhizobacteria. In contrast, root surfaces of noninoculated seedlings (Plate 1, Fig. 3) or those inoculated with *A. faecalis* 285 exhibited very sparse mucigel accumulation. Rhizobacterial isolates *P. fluorescens* 007 and 239 did not appear to induce excessive mucigel accumulation on the rhizoplane (Plate 2, Figs. 8 and 9). However, isolate 239 exhibited a characteristic colonization pattern of cell alignment along crevices of the root surface (Fig. 9). Similar colonization patterns by selected rhizobacteria have been observed on root surfaces of seven-day-old wheat and barley seedlings (Bennet and Lynch, 1981) and canola seedlings (Campbell *et al.*, 1987). It has been suggested that intercellular spaces between root cells may provide a unique environment for eliciting bacterial synthesis of phytotoxins and/or tissue-degrading enzymes, thereby contributing to the observed pathogenic effects (Campbell *et al.*, 1987).

Particularly abundant colonization was observed on root hair surfaces (Plate 2, Fig. 10). Bacteria were distributed over the length of root hairs and, in several areas, appeared embedded in mucigel. Mucigel accumulation on root hairs is likely involved in bacterial adherence (Campbell *et al.*, 1987) but also may serve as a protected microenvironment for rapid bacterial multiplication, a barrier against colonization by other microorganisms, and as a site for accumulation of root-exuded nutrients (Greaves and Darbyshire, 1972; Umali-Garcia *et al.*, 1980). Recognition sites on root hairs may also promote adherence of specific bacteria, as demonstrated for diazotroph-grass root associations (Haahtela *et al.*, 1986; Umali-Garcia *et al.*, 1980). However, actual mechanisms of adherence of non-diazotrophic bacteria to plant root surfaces remain to be determined.

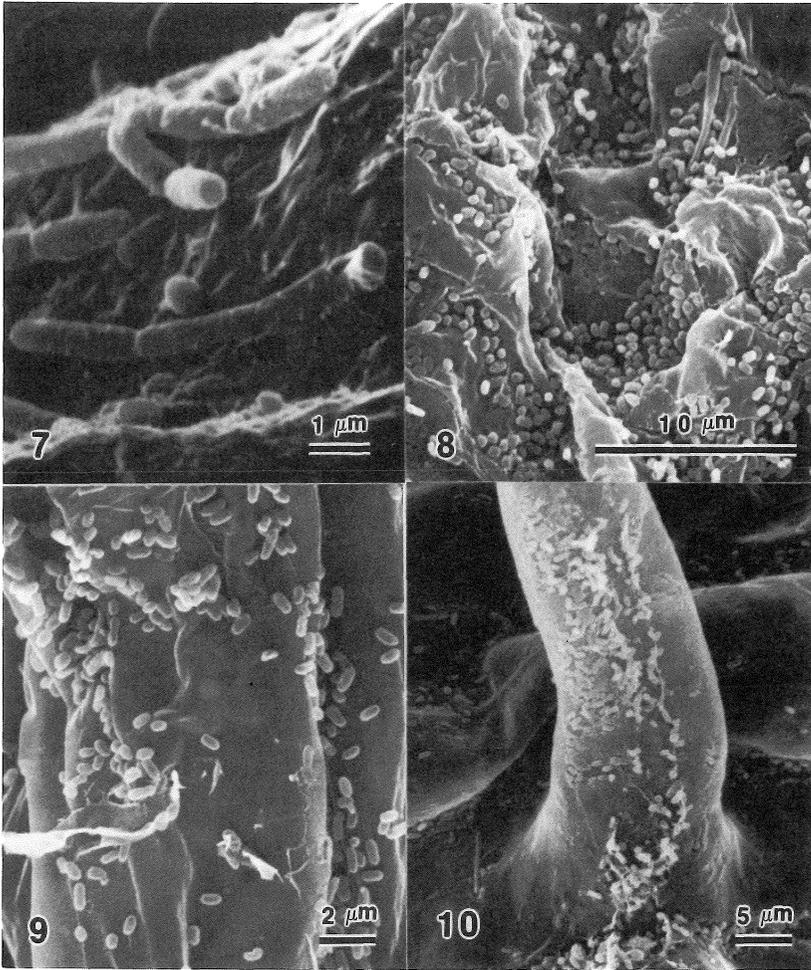


Plate 2

- Fig. 7.** *Pseudomonas* sp. 254 attached to root surface of a 2-week old velvetleaf. Note the associated mucilaginous material. Magnification, X 10,000.
- Fig. 8.** Root surface of a 2-week old velvetleaf seedling inoculated with *P. fluorescens* 007. Note the very high population of bacteria. Magnification, X 3,600.
- Fig. 9.** Root surface of a 2-week old velvetleaf root inoculated with *P. fluorescens* 239, showing several bacterial cells aligned in the crevices between root epidermal cells. Magnification, X 4,800.
- Fig. 10.** Root hair of a 2-week old velvetleaf seedling inoculated with *Pseudomonas* sp. 254 showing adherent bacteria and associated mucigel. Note embedment of the bacteria into the root surface mucigel. Magnification, X 2,000.

In the parallel time course study, rhizoplane populations of rhizobacteria isolates *Pseudomonas* sp. 254 and *E. herbicola* 423 increased to about 10^7 cells per cm root after two days and fluctuated between 10^7 and 10^8 cells per cm throughout the remaining incubation period (Fig. 1). These population counts confirmed SEM observations, which indicated that the selected rhizobacteria continuously colonized growing roots. In contrast, populations of the soil isolate, *A. faecalis* 285, continually declined during incubation, indicating an inability to establish on the rhizoplane in high numbers (Fig. 1). These data illustrate the importance of rapid and consistent colonization of the rhizoplane by rhizobacteria for producing their phytopathogenic effects. Other studies have also noted the relationship between rhizosphere/rhizoplane colonization and effectiveness of growth inhibition (Campbell *et al.*, 1987) or promotion (Kloepper *et al.*, 1980) of host plants.

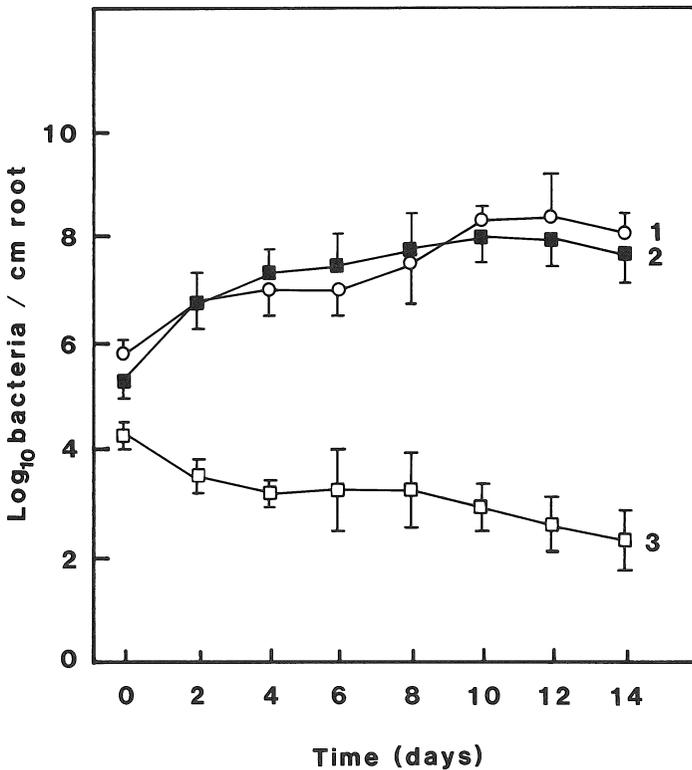


Fig. 1. Populations of *Pseudomonas* sp. 254 (1), *E. herbicola* 423 (2), and *A. faecalis* 285 (3) on roots of velvetleaf seedlings grown in enclosed culture tube assemblies. Vertical bars represent the standard error of the mean of log cell numbers per cm of root (fresh tissue).

This study demonstrated that a dense population of selected rhizobacteria became established on the rhizoplane of velvetleaf plants. Although it is difficult to assess the impact of this type of establishment on the rhizoplane, Dart (1971) suggests simply that high numbers of bacteria concentrated at root surfaces may indeed affect the physiology of roots. Additionally, the rhizoplane-associated mucigel, in which a high proportion of rhizobacteria were embedded, may also enhance absorption by roots of any phytotoxins produced by the bacteria without causing the noticeable symptoms (root lesions, necroses, etc.) usually associated with many recognized plant pathogens. Association of bacteria within root epidermal cells was not observed, indicating no invasiveness by the rhizobacteria. These observations agree with the general characteristics of deleterious rhizobacteria (Schroth and Hancock, 1982; Suslow and Schroth, 1982) which include a noninvasive mode of action resulting in subtle effects on plant roots through production of toxins. Indeed, preliminary results have shown that several rhizobacterial isolates from weed seedlings produce phytotoxic metabolites in culture (Kremer, 1989).

In laboratory-growth chamber studies, together with SEM, we have demonstrated the effects of rhizobacteria on seedling growth and the details of colonization of the root surface of velvetleaf. In the complex soil environment, indigenous organisms will undoubtedly influence this association (Lynch, 1982). Our results suggest, however, that manipulation of bacterial components of weed rhizospheres to favor attachment of specific phytotoxin-producing rhizobacteria to root surfaces may be a desirable method for weed control.

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Scattering of Polarized Light from Surfaces

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Abstract: This is a review of radiation scattered by surfaces and defines the scattering surfaces as fundamental and statistical. Three types of statistical surfaces are observed—Lambertian, incoherent, and rough. The Mueller scattering matrix and methods to measure it are reviewed. The experiments can be performed in an advanced physics laboratory or as a special research project for the undergraduate student.

I. Review of the Literature

A. Fundamental and Statistical Surfaces

This paper reviews scattering in terms of reflection from surfaces, but all comments will hold for scattering from particles suspended in a transparent fluid. There are two types of scattering surfaces—fundamental and statistical. Fundamental surfaces are ideal entities in which the scattering, except for minor perturbations, can be theoretically predicted. Bickel, *et al.*¹ have given examples of fundamental surfaces: mirror, thin film on a perfect surface, slit, single fiber, fiber array, diffraction grating, interference filter, etc. Statistical surfaces are rough irregular surfaces that give rise to diffuse scattering. The Lambertian and incoherent surfaces are ideal statistical surfaces. The general rough surface scatters a coherent (polarized) beam as a partially coherent and depolarized diffuse beam. Some of these surfaces are shown in Figure 1.

II. Review of Effects of Impurities on a Near Perfect Surface

This section of the paper reviews the results of Bickel, *et al.*¹ They observed the effects of a small amount of impurity (perturbation) on a nearly perfect surface. An aluminum surface was prepared and tested immediately to avoid dust contamination. By superpolish techniques, surfaces flat to a few Angstroms were produced and showed a deviation in flatness of $\sigma = 16 \pm 3 \text{ \AA}$. Figures 2 (a) and (b) from Bickel, *et al.*¹ showed the usual bistatic reflectometer arrangement for the study of the reflectance of a surface. θ_R was the specular reflection angle, measured from the direction of the incident beam to the specularly reflected beam and θ_S was an angle of diffuse scattered light measured with respect to the direction of the incident beam. Bickel's experiment using a perfect mirror surface is shown in Figure 3. The surface was gradually covered with $10 \text{ }\mu\text{m}$ latex spheres and the scatter signal was measured vs. the scattering angle θ_S .

For the superpolished surface there was a strong specular reflected line at the angle of specular reflection but even for the near perfect mirror there was a small scattered signal. The surface was now gradually covered by latex spheres and the signal was measured. In the region in which $D \gg \lambda$ there was a

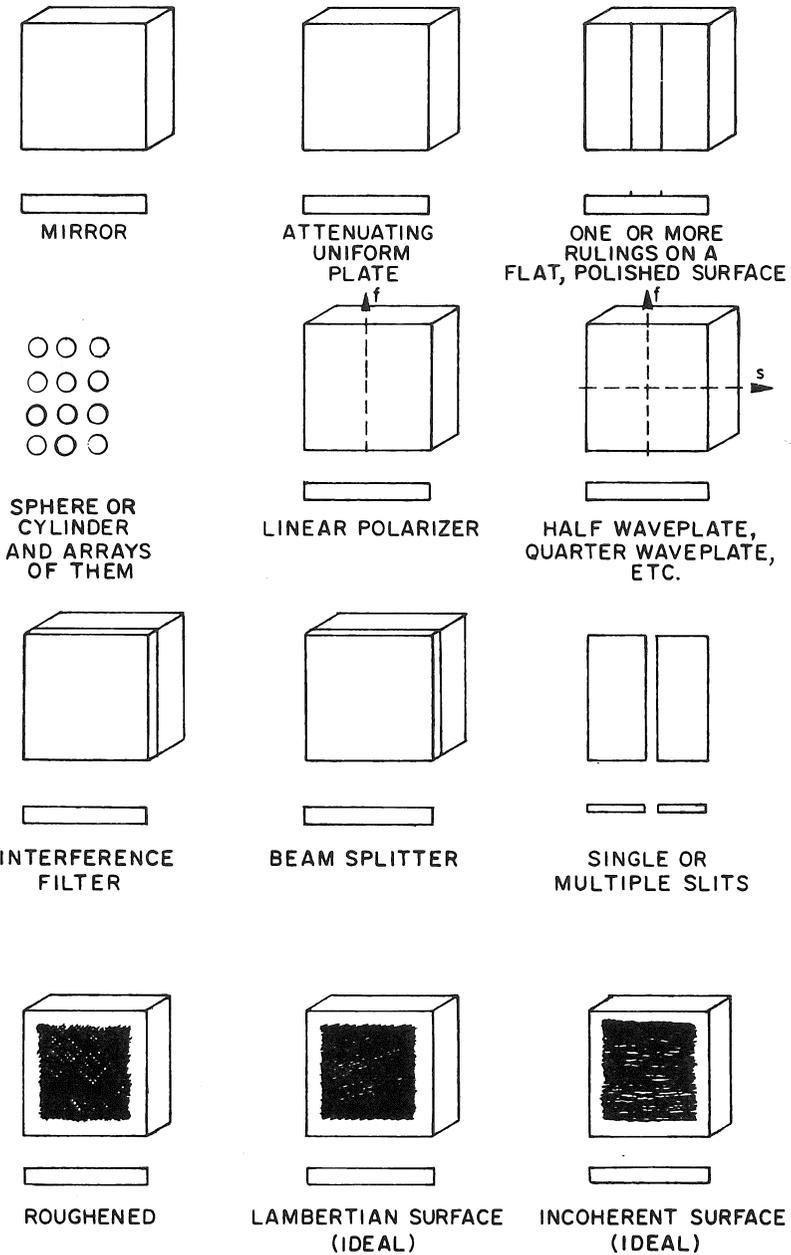


Fig. 1. Scattering surfaces.

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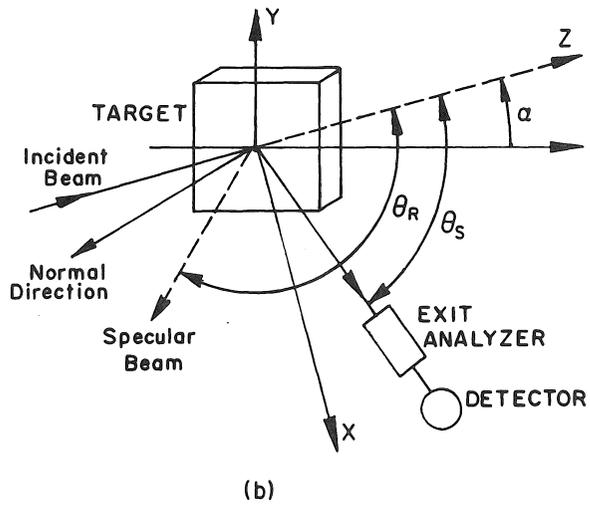
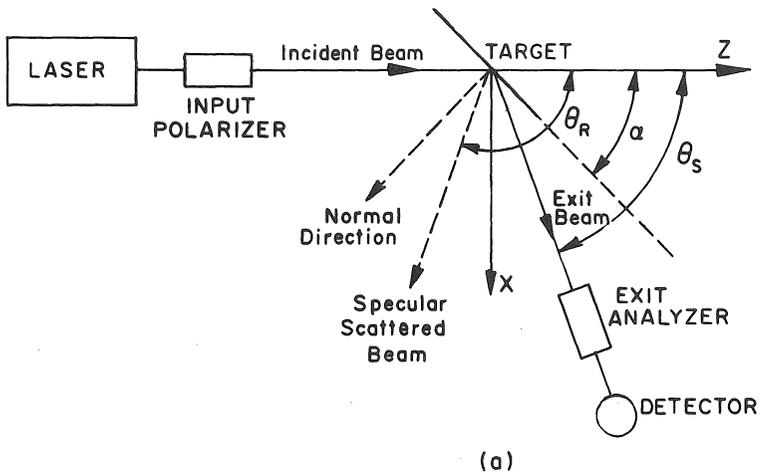


Fig. 2. Bistatic reflectometer.

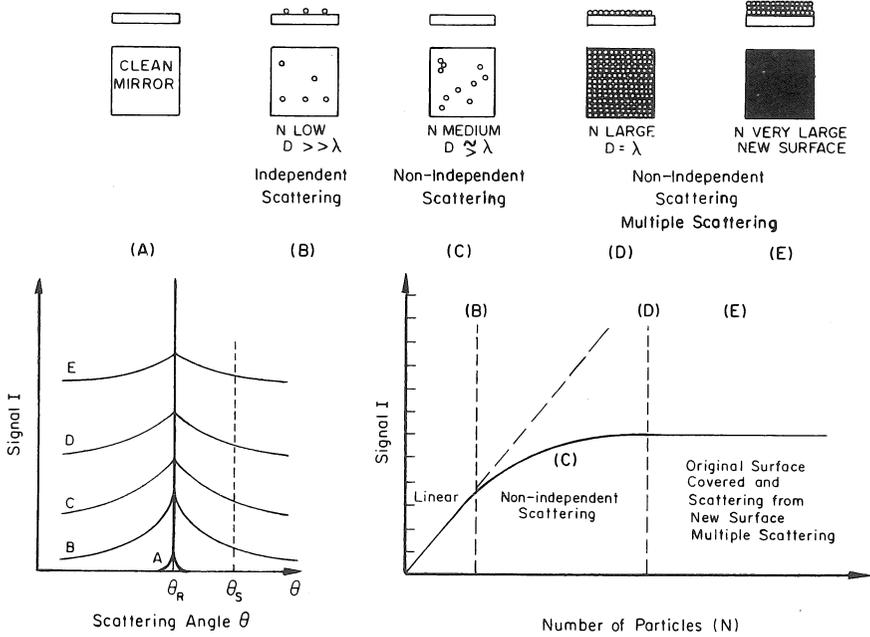


Fig. 3. Latex covered surfaces, the diffuse nature of the scattering as the surface is covered, and the signal versus number of particles.

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pronounced diffuse scattering from the surface. D was the mean separation distance of the particles on the surface and λ was the incident light's wavelength. In this region, at some angle $\theta_S \neq \theta_R$, the scattered signal depended linearly upon the number of impurity particles. When $D \approx \lambda$, the signal increased at a smaller rate as the number particles N increased. When the surface was covered with a single layer of particles, the scattered signal saturated. When it was covered by more than a single layer, it took on the characteristics of the new surface. In Figure 3 the effects of the number of impurity particles were plotted vs. the signal and as N increased the signal had an increasing diffuse component. They called the initial region the independent region (linear), the next region the non-independent region, and the final region the saturation region. At saturation, the scattering became similar to the new latex surface. Bickel, *et al.*¹ showed that these various regions could be predicted. They assumed that an area A_o of the surface was illuminated and there were N particles on the surface and each was of area a , so the fractional area covered by molecules was Na/A_o . The surface was assumed to undergo a "raindrop effect" in which the

probability of the surface remaining uncovered was $A_c = A_o e^{-Na/A_o}$. The area covered was

$$A_t = A_o \{1 - \exp[-(Na/A_o)]\} \tag{1}$$

The scattered intensity was

$$I_s = I_o A_o \epsilon \{1 - \exp[-(Na/A_o)]\} \tag{2}$$

where ϵ was the scattering efficiency in the saturated region and had the units of M^{-2} . When N was large, $N \rightarrow \infty$, the equation became

$$I_s = I_o A_o \epsilon \tag{3}$$

which was the saturated region. When N was small, $N \rightarrow 0$, the equation became

$$I_s = I_o N \epsilon A_o a/A_o = I_o \epsilon Na \tag{4}$$

which was the predicted linear variation.

III. A Review of the Measurement of the Scattering Matrix

A. Bickel and Bailey's Technique

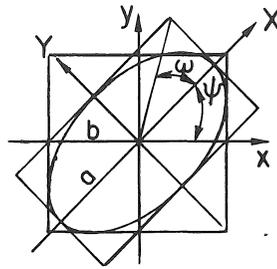
Bickel and Bailey² have written an excellent paper on Stokes vectors, Mueller matrices, and the experimental technique used to measure the Mueller scattering matrix of a scattering medium. Shurcliff³ has written an excellent elementary book on polarized light, to which students should refer if their background is weak on the subject of polarized light.

Polarized light is described by three parameters. The first is the ellipticity $\tan\omega = b/a$ where a and b are the semi-major and semi-minor axes of the ellipse. The inclination angle or azimuthal angle Ψ of the semi-major axis to the x axis must be known. Finally, since arbitrarily polarized light is generally elliptical polarized, the direction, or handedness, that the tip of the field vector traces to form the ellipse must be designated. A general elliptically polarized beam of light is shown in Figure 4 (a) where the angles ω and Ψ and the semi-major and -minor axes are shown.

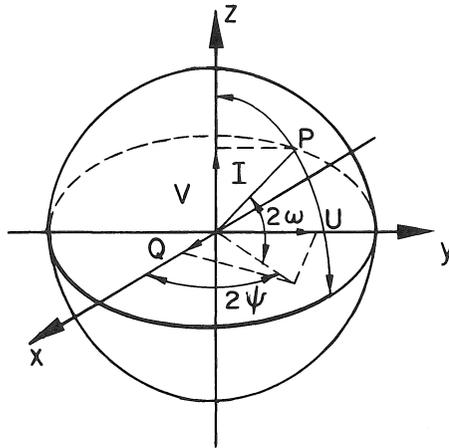
The state of polarization of a beam of light is represented by a (4x1) vector called the Stokes vector. The components of the vector have been designated differently by different authors, as an example Bickel and Bailey² and Shurcliff,³ respectively, designate the vector as shown below:

$$\bar{S} = \begin{bmatrix} I \\ Q \\ U \\ V \end{bmatrix} = \begin{bmatrix} I \\ M \\ C \\ S \end{bmatrix} = \begin{bmatrix} A_x^2 + A_y^2 \\ A_x^2 - A_y^2 \\ 2A_x A_y \cos\delta \\ 2A_x A_y \sin\delta \end{bmatrix} \tag{5}$$

where the field components in the x and y directions are A_x and A_y and δ is the phase difference between these field components. The Stokes vector can also be represented on a Poincare sphere, as shown in Figure 4(b). On the Poincare sphere any arbitrary elliptically polarized light beam is designated by the point P on the sphere's surface. Any point on the positive x -axis corresponds to



(a)



(b)

POINCARÉ SPHERE

**Fig. 4. (a) Elliptically polarized light.
 (b) Poincare sphere.**

horizontally polarized light, any point on the negative x-axis represents vertically polarized light, any point on the positive y-axis represents light polarized at 45° to the horizontal, any point on the negative y-axis corresponds to light polarized at -45° to the horizontal, and any point lying in the x-y plane corresponds to linearly polarized light at an angle Ψ to the horizontal. Any point lying on the positive z-axis corresponds to right hand circular polarized light and any point on the negative z-axis corresponds to left hand circular polarized light. The radius of the sphere is $I_o = A_x^2 + A_y^2$, which is the intensity of the light beam. The azimuth and declination angles of the sphere are two times the azimuth and ellipticity angles of the general elliptical polarized beam of light in Figure 4(a). In terms of the Poincare sphere, the Stokes components are

$$\bar{S} = \begin{bmatrix} I_o \\ I_o \cos 2\omega \cos 2\Psi \\ I_o \cos 2\omega \sin 2\Psi \\ I_o \sin 2\omega \end{bmatrix} \tag{6}$$

This means the first Stokes component is the intensity, the second component indicates the preference for horizontal over vertical polarized light, the third component indicates the preference for light polarized at 45° to the horizontal over light polarized at -45° to the horizontal, and the last component indicates the preference for right hand circularly polarized light over left hand circularly polarized light. The Stokes vector based on the Poincare sphere is normalized to unit intensity so that the sphere's radius is unity. The normalized Stokes vector is

$$\bar{S} = \begin{bmatrix} 1 \\ \cos 2\omega \cos 2\Psi \\ \cos 2\omega \sin 2\Psi \\ \sin 2\omega \end{bmatrix} \tag{7}$$

In this discussion the Stokes vector is designated \bar{S} so the Mueller scattering matrix must be designated as \bar{M} . In the discussion a bar over a symbol indicates a vector and an asterisk over the symbol indicates a matrix. The Poincare sphere may be used to determine the Stokes vectors for common polarization states and these matrices are given below:

$$\bar{S}_h = \begin{bmatrix} 1 \\ 1 \\ 0 \\ 0 \end{bmatrix} \qquad \bar{S}_v = \begin{bmatrix} 1 \\ -1 \\ 0 \\ 0 \end{bmatrix}$$

Horizontal $\Psi = \omega = 0$ Vertical $\Psi = \pi/2, \omega = 0$

$$\bar{S}_{45^\circ} = \begin{bmatrix} 1 \\ 0 \\ 1 \\ 0 \end{bmatrix} \quad (8)$$

Polarized at 45° to Horizontal $\Psi = \pi/4, \omega = 0$

$$\bar{S}_{-45^\circ} = \begin{bmatrix} 1 \\ 0 \\ -1 \\ 0 \end{bmatrix}$$

Polarized at -45° to Horizontal $\Psi = -45^\circ, \omega = 0$

$$\bar{S}_r = \begin{bmatrix} 1 \\ 0 \\ 0 \\ 1 \end{bmatrix} \quad \bar{S}_l = \begin{bmatrix} 1 \\ 0 \\ 0 \\ -1 \end{bmatrix}$$

Right Hand circular Polarized

Left Hand Circular Polarized

$$\Psi = 0, \omega = \pi/4$$

$$\Psi = 0, \omega = -\pi/4.$$

An incident polarized beam of light is represented by a definite Stokes vector \bar{S} and when it interacts with a surface or is transmitted through a scattering medium its intensity and state of polarization are changed. This interaction is represented by a (4x4) Mueller scattering matrix \hat{M} . If the devices are fundamental scatterers, then this Mueller scattering matrix can be calculated theoretically. If the surface is a statistical scatterer, the Mueller scattering matrix must be evaluated experimentally. The (4x4) Mueller matrix is

$$\hat{M} = \begin{bmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{bmatrix} \quad (9)$$

The Mueller scattering matrices³ for three common fundamental devices are given below:

$$\hat{P}(\theta) = 1/2 \begin{bmatrix} 1 & \cos 2\theta & \sin 2\theta & 0 \\ \cos 2\theta & \cos^2 2\theta & \sin 2\theta \cos 2\theta & 0 \\ \sin 2\theta & \sin 2\theta \cos 2\theta & \sin^2 2\theta & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad (10)$$

Linear Polarizer Transmission Axis at an Angle θ to Horizontal

$$\hat{Q}(\theta) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos^2 2\theta & \sin 2\theta \cos 2\theta & -\sin 2\theta \\ 0 & \sin 2\theta \cos 2\theta & \sin^2 2\theta & \cos 2\theta \\ 0 & \sin 2\theta & -\cos 2\theta & 0 \end{bmatrix} \quad (11)$$

Quarter Waveplate with Fast Axis at an Angle θ to Horizontal

$$\hat{H}(\theta) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos^2 2\theta - \sin^2 2\theta & 2\sin 2\theta \cos 2\theta & 0 \\ 0 & 2\sin 2\theta \cos 2\theta & \sin^2 2\theta - \cos^2 2\theta & 0 \\ 0 & 0 & 0 & -1 \end{bmatrix}$$

Half Waveplate with Fast Axis at an Angle θ to Horizontal

The linear polarizer is assumed to transmit only one of the orthogonal components of the incident field and the transmitted intensity is reduced by 1/2.

A schematic of the scattering apparatus is seen in Figure 5. In order to determine the scattering matrix components the source was unpolarized and in each step of the experiment light passed through a hole, horizontal linear polarizer, vertical linear polarizer, linear polarizer at 45° to the horizontal, linear polarizer at -45° to the horizontal, right hand circular polarizer and left hand

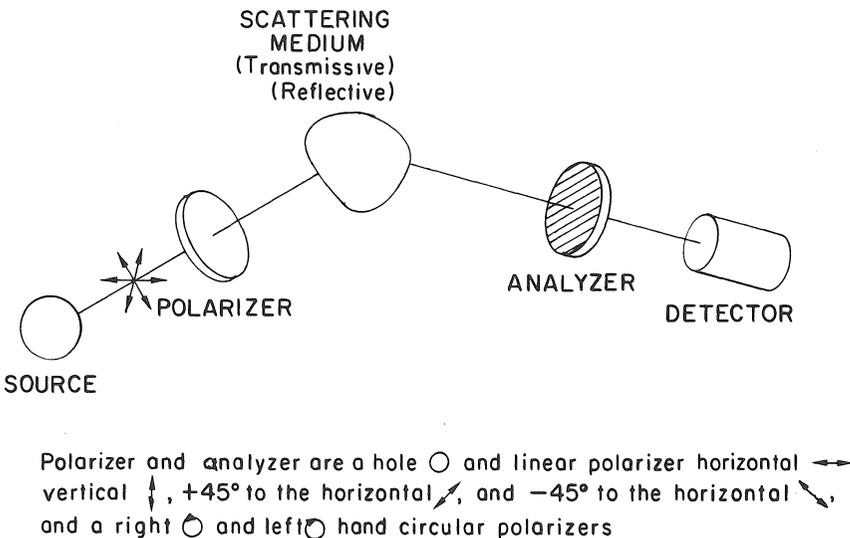


Fig. 5. Schematic of scattering apparatus.

circular polarizer. For each state of incident polarization the light scattered from the medium was analyzed for all of the same states of polarization. The system equation can be written in the form

$$\bar{S}' = \hat{A} \hat{M} \hat{P} \bar{S} \quad (13)$$

where \bar{S} and \bar{S}' were the incident and emergent Stokes vector, respectively, \hat{A} was the Mueller matrix of the analyzer, \hat{M} was the Mueller scattering matrix of the medium, \hat{P} was the Mueller matrix of the polarizer.

In this discussion two Mueller scattering matrix components will be examined so the reader can follow the results shown in Bickel and Bailey's² paper. The two matrix components evaluated are M_{31} and M_{33} , which are designated S_{31} and S_{33} in their paper. In the evaluation of M_{31} the incident light passes through a hole and remains unpolarized and the emergent light is analyzed with a linear polarizer at an angle of 45° to the horizontal and at -45° to the horizontal and the detector measures the intensity in each case. The result for the measurement of M_{13} is shown below where the Stokes vector emerging from the analyzer is

$$\bar{S}'_{*,45^\circ} = \begin{bmatrix} I' \\ Q' \\ U' \\ V' \end{bmatrix} = 1/2 \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

so

$$\bar{S}'_{*,45^\circ} = 1/2 \begin{bmatrix} M_{11} + M_{31} \\ 0 \\ M_{11} + M_{31} \\ 0 \end{bmatrix} \quad (14)$$

and in the second orientation

$$\bar{S}'_{*,45^\circ} = \begin{bmatrix} I' \\ Q' \\ U' \\ V' \end{bmatrix} = 1/2 \begin{bmatrix} 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

so

$$\bar{S}'_{*,-45^\circ} = 1/2 \begin{bmatrix} M_{11} - M_{31} \\ 0 \\ -M_{11} + M_{31} \\ 0 \end{bmatrix} \quad (15)$$

The measured intensities are

$$I_{*,45^\circ} = 1/2(M_{11} + M_{31})$$

and

$$I_{*,-45^\circ} = 1/2(M_{11} - M_{31}).$$

The matrix component M_{31} can be evaluated by subtracting the two intensities

$$M_{31} = (I_{*,45^\circ} - I_{*,-45^\circ}). \quad (16)$$

The matrix component M_{33} can be determined by using the four combinations of the polarizer and analyzer at 45° and -45° to the horizontal and these combinations are given below:

$$\bar{S}'_{45^\circ,45^\circ} = \begin{bmatrix} I' \\ Q' \\ U' \\ V' \end{bmatrix} = 1/4 \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{bmatrix} \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

so

$$\bar{S}'_{45^\circ,45^\circ} = 1/4 \begin{bmatrix} M_{11} + M_{13} + M_{31} + M_{33} \\ 0 \\ M_{11} + M_{13} + M_{31} + M_{33} \\ 0 \end{bmatrix} \quad (18)$$

$$\bar{S}'_{45^\circ,-45^\circ} = \begin{bmatrix} I' \\ Q' \\ U' \\ V' \end{bmatrix} = 1/4 \begin{bmatrix} 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{bmatrix} \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

so

$$\bar{S}'_{45^\circ,-45^\circ} = 1/4 \begin{bmatrix} M_{11} + M_{13} - M_{31} - M_{33} \\ 0 \\ -M_{11} - M_{13} + M_{31} + M_{33} \\ 0 \end{bmatrix} \quad (19)$$

$$\bar{S}'_{-45^\circ,45^\circ} = \begin{bmatrix} I' \\ Q' \\ U' \\ V' \end{bmatrix} = 1/4 \begin{bmatrix} 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{bmatrix} \begin{bmatrix} 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

so

$$\bar{S}'_{-45^\circ, 45^\circ} = 1/4 \begin{bmatrix} M_{11} - M_{13} + M_{31} - M_{33} \\ 0 \\ M_{11} - M_{31} + M_{31} - M_{33} \\ 0 \end{bmatrix} \quad (20)$$

$$\bar{S}'_{-45^\circ, -45^\circ} = \begin{bmatrix} I' \\ Q' \\ U' \\ V' \end{bmatrix} = 1/4 \begin{bmatrix} 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{bmatrix} \begin{bmatrix} 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

so

$$\bar{S}'_{-45^\circ, -45^\circ} = 1/4 \begin{bmatrix} M_{11} - M_{13} + M_{31} - M_{33} \\ 0 \\ -M_{11} + M_{13} - M_{31} + M_{33} \\ 0 \end{bmatrix} \quad (21)$$

The first components of these Stokes vectors (intensity measured by the detector) are

$$I_{45^\circ, 45^\circ} = 1/4 (M_{11} + M_{13} + M_{31} + M_{33})$$

$$I_{45^\circ, -45^\circ} = 1/4 (M_{11} + M_{13} - M_{31} - M_{33})$$

$$I_{-45^\circ, 45^\circ} = 1/4 (M_{11} - M_{13} + M_{31} - M_{33})$$

and

$$I_{-45^\circ, -45^\circ} = 1/4 (M_{11} - M_{13} - M_{31} + M_{33}).$$

From these intensities the matrix component M_{33} may be evaluated so

$$M_{33} = (I_{45^\circ, 45^\circ} + I_{-45^\circ, -45^\circ}) - (I_{45^\circ, -45^\circ} + I_{-45^\circ, 45^\circ}). \quad (23)$$

Similar results for all the matrix components were presented by Bickel and Bailey² in Figures 5 and 6 in their article. In their article, a hole was represented by a 0, horizontal polarized light by \leftrightarrow , vertical polarized light by \updownarrow , 45° to the horizontal polarized light by \swarrow , -45° to the horizontal polarized light by \searrow , right hand circular polarized light by \odot , and left hand circular polarized light by \ominus .

In the paper by Bickel and Bailey² only fundamental surfaces were analyzed and the Mueller matrices were known. The transmitting surfaces were the linear polarizer with its transmission axis at an angle θ to the horizontal, a quarter waveplate with its fast axis at an angle θ to the horizontal, and the circular polarizer. Most experimental surfaces are statistical surfaces on which most Mueller scattering components exist, a some of which are extremely small compared to others. In the first row and column in Figure 6 in Bickel and Bailey's² paper the matrix component can be measured by subtractions of intensities while for all other matrix components their measurement requires eight additions or subtractions of the intensity measurements. If the desired matrix component is small relative to others in the intensity measurements to be added or subtracted, this can lead to a large error in the value of the small

component. This problem is partially overcome in the measurement technique described in the next section.

B. The Technique of Aspnes, Hauge, and Azzam

Aspnes,⁴⁻⁶ Hauge,⁸⁻⁹ and Azzam^{7,10-11} and others have used a rotating compensator (quarter waveplate) technique to measure both the emergent Stokes vector from an experiment. The Mueller matrix of a rotating quarter waveplate compensator,⁷ is

$$C(\theta) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos^2 2\theta & 1/2 \sin 4\theta & -\sin 2\theta \\ 0 & 1/2 \sin 4\theta & \sin^2 2\theta & \cos 2\theta \\ 0 & \sin 2\theta & -\cos 2\theta & 0 \end{bmatrix} \quad (24)$$

Consider the experimental apparatus shown in Figure 6 in which the light beam is incident upon a horizontal polarizer followed by a rotating compensator rotating at an angular frequency ω . The emergent beam is scattered from the target medium and both its intensity and polarization are changed. The Mueller scattering matrix, \hat{M} , represents this interaction. The emergent light enters an analyzer consisting of a rotating compensator, rotating at an angular frequency ω' , and a horizontal polarizer. The signal detected by the detector is the first component of the Stokes vector emerging from the analyzer which is

$$\bar{S}' = \hat{A} \hat{C}_2 \hat{M} \hat{C}_1 \hat{P} \bar{S}_i \quad (25)$$

where \hat{A} is the Mueller matrix of the last horizontal linear polarizer, \hat{C}_1 and \hat{C}_2 are the Mueller matrices of the rotating compensators rotating at angular frequencies ω and ω' , respectively, \hat{P} is the Mueller matrix of the horizontal linear polarizer in the incident beam, and \bar{S} and \bar{S}' are the Stokes vectors of the incident and emergent light. The incident light is unpolarized and of intensity I_i .

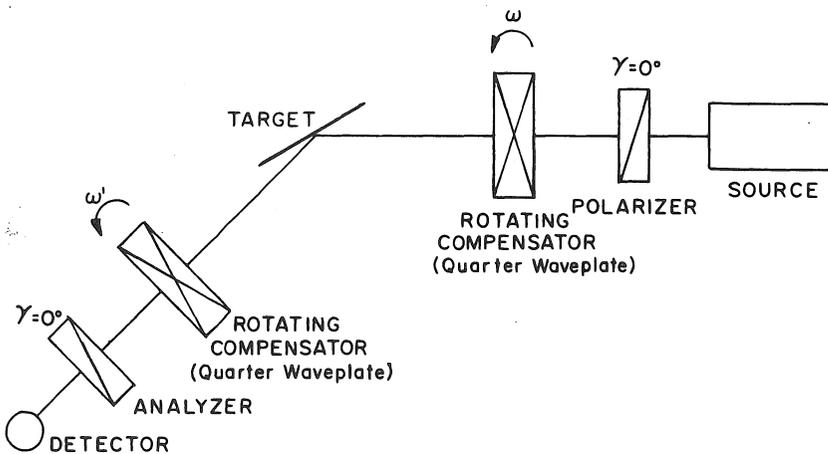


Fig. 6. Schematic of the rotating compensator reflectometer.

The matrix product in Equation (25) is

$$\bar{S}' = 1/4 \begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos^2 2\theta' & 1/2 \sin 4\theta' & -\sin 2\theta' \\ 0 & 1/2 \sin 4\theta' & \sin^2 2\theta' & \cos 2\theta' \\ 0 & \sin 2\theta' & -\cos 2\theta' & 0 \end{bmatrix}$$

$$X \begin{bmatrix} M_{11} & M_{12} & M_{13} & M_{14} \\ M_{21} & M_{22} & M_{23} & M_{24} \\ M_{31} & M_{32} & M_{33} & M_{34} \\ M_{41} & M_{42} & M_{43} & M_{44} \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos^2 2\theta & 1/2 \sin 4\theta & -\sin 2\theta \\ 0 & 1/2 \sin 4\theta & \sin^2 2\theta & \cos 2\theta \\ 0 & \sin 2\theta & -\cos 2\theta & 0 \end{bmatrix}$$

$$X \begin{bmatrix} 1 & 1 & 0 & 0 \\ 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} I_1 \\ 0 \\ 0 \\ 0 \end{bmatrix} \quad (26)$$

where $\theta = \omega t$ and $\theta' = \omega' t$. The first component of the above Stokes vector from the matrix product is

$$I' = I_1/4 \{ (M_{11} + M_{12}/2 + M_{21}/2 + M_{22}/4) + (M_{14} + M_{24}/2) \sin 2\theta \\ + (M_{13}/2 + M_{23}/4) \sin 4\theta - (M_{41} + M_{42}/2) \sin 2\theta' + (M_{31}/2 + M_{32}/4) \sin 4\theta' \\ - M_{42}/4 \sin(2\theta' - 4\theta) - M_{42}/4 \sin(2\theta' + 4\theta) + M_{24}/4 \sin(4\theta' + 2\theta) \\ - M_{24}/4 \sin(4\theta' - 2\theta) + (M_{32}/8 + M_{23}/8) \sin 4(\theta' + \theta) \\ + (M_{32}/8 - M_{23}/8) \sin 4(\theta' - \theta) + (M_{12}/2 + M_{22}/4) \cos 4\theta \\ + (M_{21}/2 + M_{22}/4) \cos 4\theta' - (M_{33}/8 - M_{22}/8) \cos 4(\theta' - \theta) \\ - (M_{33}/8 + M_{22}/8) \cos 4(\theta' + \theta) - M_{34}/4 \cos(4\theta' - 2\theta) \\ + M_{34}/4 \cos(4\theta' + 2\theta) + M_{43}/4 \cos(2\theta' - 4\theta) - M_{43}/4 \cos(2\theta' + 4\theta) \\ + M_{44}/2 \cos 2(\theta' - \theta) - M_{44}/2 \cos 2(\theta' + \theta) \}. \quad (27)$$

In order that no sinusoidal terms be the same it is required that $\theta = \omega t$ and $\theta' = 5\omega t$ in Equation (27) and the detector sensitivity is assumed to be K_d , the intensity measured by the detector becomes

$$I' = K_d I_1/4 \{ (M_{11} + M_{12}/2 + m_{21}/2 + M_{22}/4) + (M_{12}/2 + M_{22}/4) \cos 4\omega t \\ + M_{43}/4 \cos 6\omega t + M_{44}/2 \cos 8\omega t - M_{44}/2 \cos 12\omega t - M_{43}/4 \cos 14\omega t \\ - (M_{33}/8 - M_{22}/8) \cos 16\omega t - M_{34}/4 \cos 18\omega t + (M_{21}/2 + M_{22}/4) \cos 20\omega t \\ - M_{34}/4 \cos 22\omega t + (M_{33}/8 + M_{22}/8) \cos 24\omega t + (M_{14} + M_{24}/2) \sin 2\omega t \\ + (M_{13}/2 + M_{23}/4) \sin 4\omega t - M_{42}/4 \sin 6\omega t - (M_{41} + M_{42}/2) \sin 10\omega t \\ - M_{42}/4 \sin 14\omega t + (M_{32}/8 - M_{23}/8) \sin 16\omega t - M_{24}/4 \sin 18\omega t \\ + (M_{31}/2 + M_{32}/4) \sin 20\omega t + M_{24}/4 \sin 22\omega t + (M_{32}/8 + M_{23}/8) \sin 24\omega t \}. \quad (28)$$

Equation (28) can be represented by the Fourier series

$$I' = a_0 + \sum a_n \cos 2n\omega t + \sum b_n \sin 2n\omega t. \quad (29)$$

The detected signal is recorded and Fourier-analyzed, the Fourier coefficients are evaluated. The relative scattering matrix coefficients can be evaluated from sums and differences of the Fourier coefficient and these results are given in Table 1. In

Table 1. Fourier Coefficients

n	0		1	2	
a _n	[M ₁₁ + M ₁₂ /2 + M ₂₁ /2 + M ₂₂ /4]		0	[M ₁₂ /2 + M ₂₂ /4]	
b _n	0		[M ₁₄ + M ₂₄ /2]	[M ₁₃ /2 + M ₂₃ /4]	
n	3	4	5	6	7
a _n	M ₄₃ /4	M ₄₄ /2	0	-M ₄₄ /2	-M ₄₃ /4
b _n	-M ₄₂ /4	0	-[M ₄₁ + M ₄₂ /2]	0	-M ₄₂ /4
n	8		9	10	
a _n	-[M ₃₃ /8 - M ₂₂ /8]		-M ₃₄ /4	[M ₂₁ /2 + M ₂₂ /4]	
b _n	[M ₃₂ /8 - M ₂₃ /8]		-M ₂₄ /4	[M ₃₁ /2 + M ₃₂ /4]	
n	11	12			
a _n	M ₃₄ /4	[M ₃₃ /8 + M ₂₂ /8]			
b _n	M ₂₄ /4	[M ₃₂ /8 + M ₂₃ /8]			

Mueller Matrix Components in Terms of Fourier Coefficients

$$\begin{aligned}
 M_{11} &= (a_0 - a_2 + a_8 - a_{10} + a_{12}) & M_{12} &= 2(a_2 - a_8 - a_{12}) & M_{13} &= 2(b_2 + b_8 - b_{12}) \\
 M_{14} &= (b_1 - b_{11} + b_9) & M_{21} &= 2(a_{10} - a_8 - a_{12}) & M_{22} &= 4(a_8 + a_{12}) & M_{23} &= 4(b_{12} - b_8) \\
 M_{24} &= 2(b_{11} - b_9) & M_{31} &= 2(b_{10} - b_8 - b_{12}) & M_{32} &= 4(b_8 + b_{12}) & M_{33} &= 4(a_{12} - a_8) \\
 M_{34} &= 2(a_{11} - a_9) & M_{41} &= (b_3 + b_7 - b_5) & M_{42} &= -2(b_3 + b_7) & M_{43} &= 2(a_3 - a_7) \\
 M_{44} &= (a_4 - a_6)
 \end{aligned}$$

most cases, the Mueller scattering matrix component can be evaluated by the addition or subtraction of only two Fourier components and only the M₁₁ component is as complicated as in the previous discussed technique. It should be noted that these results differ from those of Azzam¹⁰ for the linear polarizers are rotated by 90° from the orientation used by Azzam.

IV. Conclusions

This paper has reviewed two techniques that may be used to obtain the Mueller scattering matrix from a reflective surface or from a transparent medium containing a suspension. Either of these experiments can be performed in an undergraduate or special projects laboratory. These experiments acquaint the student with polarization, a topic not stressed in an undergraduate optics course.

V. References

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***Peromyscus leucopus* Response to Clearcutting in a Missouri Oak-Hickory Forest¹**

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Abstract: We studied the response of a *Peromyscus leucopus* population to clearcutting in an oak-hickory forest in central Missouri from 1982-88. We captured and released 291 *P. leucopus* at two study sites - 79 before clearcutting began, 143 up to six years following clearcutting, and 69 in uncut control areas. Population trends were similar between clearcut and control areas, but clearcuts generally had greater numbers of *P. leucopus*. Clearcutting appeared to have little effect on overall population fluctuations.

Key Words: Clearcutting, minimum number alive, Missouri, oak-hickory, *Peromyscus leucopus*

Introduction

Even-aged forest management, with regeneration by clearcutting, is the principle forest management system used in the central hardwood forest of North America (Zeedyk and Evans, 1975). However, clearcutting may alter the abundance and species composition of small mammals because of the drastic habitat change caused by the near total removal of the forest overstory. In coniferous forests, some studies (Tevis, 1956; Gashwiler, 1959; Ahlgren, 1966; Sims and Buckner, 1973) have concluded that clearcutting resulted in increases in at least some small mammal populations, while more recent studies (Petticrew and Sadleir, 1974; Sullivan, 1979) have reported little difference in small mammal densities between clearcuts and uncut areas. Studies that have measured effects of timber harvest in hardwood forests other than the oak-hickory (*Quercus-Carya* spp.) type have reported no increases in small mammal populations following clearcutting (Krull, 1970; Kirkland, 1977; Healy and Brooks, 1988).

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The effects of clearcutting on small mammal populations in oak-hickory forests in the Midwest have not been addressed. The objective of this research was to measure population changes of an abundant small mammal, *Peromyscus leucopus*, on 2 similar sites before and after clearcutting.

Site Description

We conducted this study on the 900 ha Thomas S. Baskett Wildlife Research and Education Center (TSBWREC), located in Boone County in central Missouri. The TSBWREC is composed of 45% upland oak-hickory sawtimber, 18% upland oak-hickory poletimber, 16% mixed cedar-hardwoods, 9% open non-woody vegetation, 6% bottomland hardwood sawtimber, 4% pine plantations, and 2% upland oak-hickory regeneration (Thompson and Fritzell 1989). Two study sites, each having a clearcut and a control (uncut, mature forest) area, were sampled. The overstory at Site 1 was dominated by white oak (*Quercus alba*), chinquapin oak (*Q. prinoides*), American elm (*Ulmus americana*), and eastern redcedar (*Juniperus virginiana*), with an understory containing sugar maple (*Acer saccharum*), ironwood (*Ostrya virginiana*), and flowering dogwood (*Cornus florida*). Site 2 was dominated by white oak, shagbark hickory (*Carya ovata*), and pignut hickory (*C. glabra*), with an understory containing sugar maple, downy serviceberry (*Amalanchier arborea*), flowering dogwood, and blackhaw (*Viburnum prunifolium*). In January 1983, a 1.5 ha area, encompassing one of the trapping grids at Site 1, was clearcut. The clearcut grid bordered the eastern edge of the clearcut area and the control grid began 50 m east. In September 1983, a 3.5 ha area was clearcut encompassing one of the trapping grids at Site 2. The clearcut grid bordered the northern edge of the clearcut area and the control grid began 50 m north. Approximately 85-95% of the standing trees were felled. All merchantable timber was removed, and the remainder was left on the site. After one growing season following the removal of the overstory, herbaceous vegetation, slash, and some residual trees dominated both clearcut sites. Following the second growing season, both clearcut sites had large numbers of small trees (Table 1) resulting from stump sprouts and advanced

Table 1. Woody stem densities at two study sites in central Missouri, August 1985.^a

	# Woody Stems / ha			
	<3cm ^b	3-10cm	11-23cm	>23cm
Site 1				
Clearcut ^c	14,306	442	67	37
Control	1,466	1,295	460	376
Site 2				
Clearcut ^d	8,060	435	49	49
Control	3,761	1,317	264	230

^aUnpubl. 1985 forest inventory data, on file at TSBWREC.

^bTree diameter at breast height (1.4 m).

^cAfter 3 growing seasons.

^dAfter 2 growing seasons.

regeneration as well as abundant slash, blackberry (*Rubus* spp.), and herbaceous vegetation.

Methods

We captured small mammals with Sherman live traps baited with rolled oats and peanut butter. At each study site, two permanent 135×135 m trapping grids were established with 100 traps at 15 m intervals. The two trapping grids were 50 m apart at their closest point. The overstory vegetation on one grid at each site remained undisturbed throughout the study (control), while the other was clearcut after the first year. We trapped at Sites 1 and 2 yearly during spring (mid-May—early June) from 1982-88 and 1983-88, respectively. The control and clearcut grids at each site were simultaneously trapped for five consecutive nights each year (= 500 trap-nights). Captured animals were individually marked by toe-clipping or ear tags, and were released at the point of capture.

Each year we estimated the *P. leucopus* population for each grid by the minimum number alive (total number of individuals released alive). Trends in population numbers were compared between sites and between habitats with correlation coefficients (Snedecor and Cochran, 1980:175). Differences in *Peromyscus* numbers between sites and between habitats were analyzed with paired *t*-tests (PROC MEANS, SAS Institute, 1985). We normalized the distribution of minimum number alive estimates with a square-root transformation (Snedecor and Cochran, 1980:288). To test the accuracy of the minimum number alive estimates, we estimated *P. leucopus* numbers with the Jolly-Seber capture-recapture model (Jolly, 1965; Seber, 1965) using program JOLLY (J. E. Hines, U.S. Fish and Wildlife Service, Patuxent Wildlife Research Center). The model we selected accounted for death but not immigration, because we assumed immigration was negligible during the 5-night trapping periods. The JOLLY estimates reported are means of the four daily trapping interval estimates.

Results

We captured and released 291 *Peromyscus leucopus* (79 before clearcutting began, 143 up to six years following clearcutting, and 69 in control grids) a total of 665 times from 1982-88. Other species captured included 1 eastern wood rat (*Neotoma floridana*), 2 woodland voles (*Microtus pinetorum*), 5 short-tailed shrews (*Blarina brevicauda*), 2 eastern cottontails (*Sylvilagus floridanus*), and 2 southern flying squirrels (*Glaucomys volans*).

We were unable to calculate JOLLY estimates from 10 of 13 trapping periods (20 of 26 individual grids) because of the low numbers of *P. leucopus* captured. Available JOLLY estimates (Table 2) were similar to minimum number alive estimates. The 95% confidence intervals of the JOLLY estimates included all corresponding minimum number alive values. We did not calculate home range estimates because of limited recaptures, but these were apparently small, because only one individual moved between control and clearcut grids.

Site 1

Numbers of *P. leucopus* before clearcutting (1982) were similar between control and "clearcut" grids (Table 3). In 1983, we observed peak numbers on

Table 2. Program JOLLY estimates of the number of *Peromyscus leucopus* on six 135m x 135m trapping sites in central Missouri, 1982-88.

	Season	Year	Habitat	Number	95% CI
Site 1	Spring	1982	Clearcut	17.37	8.71-26.03
			Control	14.99	9.62-20.36
	Spring	1983	Clearcut	51.12	45.64-56.60
			Control	29.28	25.51-33.05
	Spring	1986	Clearcut	25.69	23.50-27.87
			Control	15.42	13.75-17.09

Table 3. Minimum number alive estimates for *Peromyscus leucopus* at all 135m x 135m trapping sites in central Missouri from 1982-88. Numbers in parentheses are from pre-clearcut sampling. NA = data not available.

Year	Site 1		Site 2	
	Clearcut	Control	Clearcut	Control
1982	(16)	(14)	NA	NA
1983	48	28	(19)	(30)
1984	3	3	6	2
1985	8	1	6	2
1986	25	15	17	12
1987	5	1	12	3
1988	7	1	6	1

both trapping grids, but numbers on the newly clearcut grid were higher. The population remained low during 1984-85, then increased in 1986, but again was higher in the clearcut. Numbers were low in 1987-88. Population trends were very similar between clearcut and control grids ($r=0.96$, $P<0.01$). However, from 1983-88, minimum number alive estimates were greater ($t=4.58$, $P=0.006$) for clearcut grids than for control grids.

Site 2

P. leucopus numbers were at a peak in 1983, before clearcutting began (Table 3). By 1984, numbers were substantially reduced, even on the newly clearcut grid. From 1984-88, population fluctuations were similar to those at Site 1 ($r=0.81$, $P<0.05$ and $r=0.98$, $P<0.01$ for clearcut and control grids, respectively). Trends between clearcut and control grids were similar ($r=0.86$, $P<0.02$), but from 1984-88, minimum number alive estimates for clearcut grids were greater ($t=6.36$, $P=0.003$) than those for control grids.

Discussion

Clearcutting oak-hickory stands apparently had little influence on overall population trends of *Peromyscus leucopus*. A similar result was reported by

Sullivan (1979) for *P. maniculatus* in coniferous forests in British Columbia. The timing of our clearcuts also had little influence on *P. leucopus* numbers. At Site 1, numbers peaked immediately after the clearcut was made, while at Site 2 numbers peaked before clearcutting, dropping substantially afterwards. Krull (1970) found irregular yearly fluctuations in *P. leucopus* densities that occurred irrespective of the effects of earlier habitat manipulation of northern hardwood stands in New York. *P. maniculatus* densities in coniferous stands in British Columbia (Petticrew and Sadleir, 1974) varied more between years than between the three habitats studied (clearcut, clearcut/burned, and uncut areas).

Although clearcutting may not have affected population trends of *P. leucopus*, clearcut grids had greater or equal numbers of *P. leucopus* than control grids in all trapping periods after clearcuts were made. Clearcut areas produce large quantities of seeds, fruits, and insects (Tevis, 1956; Ahlgren, 1966; Hooven, 1973), foods that make up a large proportion of the diet of *Peromyscus* (Hamilton, 1941; Williams, 1959). This may explain why clearcuts in our study generally had higher numbers of *P. leucopus* than uncut areas. In New York, however, Krull (1970) reported that densities of *P. leucopus* were lower in northern hardwood clearcuts 3-19 years old than in uncut hardwood stands in 9 of 10 years, although the 10-year means were not significantly different. Similarly, Healy and Brooks (1988) found no significant differences in the numbers of *P. maniculatus* caught among seedling, sapling, sawtimber, and mature hardwood stands in West Virginia, although numbers were lowest in the seedling stands.

Our results suggest that *Peromyscus leucopus* numbers will fluctuate regardless of whether an oak-hickory site has been clearcut or not. However, the carrying capacity for *P. leucopus* apparently is greater on clearcut sites, at least up to six years of age, probably because of the increased cover and food supply created by regeneration of the oak-hickory stands.

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Morphological Attributes of Gliding Rodents: A Preliminary Analysis

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Abstract: In this paper we use multivariate statistical techniques to explore some morphological attributes associated with ground dwelling, arboreal, and gliding sciurids and anomalurids. The data were obtained from the literature and included three external and three internal measurements. A principal components analysis revealed a general size axis and an axis associated with tail length. A canonical discriminant function analysis showed significant morphological differences between the three groups of mammals. Ground dwelling forms had short tails and narrow interorbital breadths while the arboreal and gliding forms did not. The gliding forms had shorter hind feet and longer maxillary tooth rows than the other mammals. The data are interpreted in light of the evolution of ground dwelling, arboreal and gliding life histories.

Key words: Gliding, Sciuridae, Anomaluridae.

Introduction

The evolution of vertebrate flight has received considerable attention (Cagle *et al.*, 1983; Nopsca, 1907; Norberg, 1985; Ostrom, 1974). However, most of this research has been focused on flight in birds or on the transition from gliding to powered flight. The evolution of gliding in amphibians, reptiles, and mammals has not been extensively studied (Savile, 1962). The fact that fish, frogs, lizards, snakes, phalangers, anomalurids, sciurids, dermopterans, and chiropterans are all capable of some form of flight indicates that the invasion of the aerial habitat is not a rare event. At the same time, the transition from an arboreal life style to a glissant one has been largely overlooked. It is not clear precisely how the morphologies of gliding mammals are related to habitat use, diet, or ecology.

Thorington and Heaney (1981) studied the flight characteristics and external morphology of flying squirrels and identified some morphological differences with tree squirrels. Others, (McKenna, 1962; Black, 1963; Mein, 1970) have studied the phylogenetic evolution of gliding sciurids, but few attempts have been made to study the selective forces that have led to the evolution of volant locomotion in non-chiropteran mammals.

One hypothesis that has been suggested for the evolution of gliding is foraging optimization (Norberg, 1985). This hypothesis states that gliding from one tree to another and then climbing upwards can maximize energy gain (Norberg, 1981; 1983). However, the presence of patagia reduces maneuverability and speed of locomotion on the ground (Sollberger, 1940). While glissant rodents may be optimizing foraging efficiency within the canopy, they are probably minimizing their ability to forage on the ground.

Predator avoidance is an alternative or concomitant hypothesis for the evolution of glissant locomotion. The importance of predation to sciurids is

obvious. Arboreal squirrels respond to noises in the forest by moving to the opposite sides of trees. Flying squirrels respond to disturbances in the forest by evacuating their tree holes, climbing upwards and gliding to the next tree. While gliding may provide an escape from mammalian and reptilian predators, it is not clear that it provides an escape from their most likely predators, owls. Thus, the flying squirrels may actually suffer increased levels of predation rather than decreased predation.

Finally, patagia may simply allow the squirrels to reduce or control landing speeds. *Tamiasciurus* and *Sciurus* will "parachute" when jumping from tree to tree, and will assume the position of a landing *Glaucomys*. Patagia would add some degree of control to a landing (Thorington and Heaney, 1981).

This study is an attempt to characterize a few morphological attributes associated with gliding mammals. When the morphologies of ground dwelling, arboreal, and glissant mammals are well understood, it may be possible to develop and carefully evaluate hypotheses for the selective regimes that have led to gliding.

Methods

In order to gain some insight into the morphologies associated with different modes of squirrel locomotion, we used principal components analysis and canonical discriminant analysis to study the morphological attributes of ground dwelling, arboreal, and volant sciurids and anomalurids. Morphological measurements were obtained for 85 species representing 315 subspecies and races of ground-dwelling, arboreal, and flying sciurids and anomalurids. The measurements for the animals were obtained from taxonomic treatises on European (Miller 1912), African (Rosevear 1969), Eurasian (Ognev 1940, 1947), and North American mammals (Hall and Kelson 1959), and included head and body length, tail length, hind foot length, total skull length, interorbital breadth, and length of the upper tooth row.

For the principal components analysis, the data were averaged across subspecies, localities, and gender to produce mean values for each species. The factor scores for each species were then derived, and plotted with respect to the first two principal axes. The factor scores for the three groups of squirrels were compared using nonparametric schematic plots (Tukey, 1977). For the canonical discriminant analysis, the data were not averaged in an effort to maximize the degrees of freedom associated with the test. The centroids of the three groups (ground dwelling, arboreal, and gliding) were then plotted with respect to the first two canonical discriminant axes.

Results

The results of the principal components analysis are presented in Table 1. The first two principal components explained almost 92 percent of the variation in the data set. Principal component 1 explained 77.5 percent of the variation in the data set, and was loaded relatively evenly by all variables except the tail length variable. Since all of the loadings were positive, the first principal component is considered a general size axis. The second principal component explained 14.2 percent of the variation in the data set, and was loaded most heavily by the tail length variable. The second principal component is interpreted as a tail length axis.

Table 1. Eigenvectors for the principal components analysis. PC 1 represents the first principal component while PC 2 represents the second principal component.

Variable	PC 1	PC 2
Head & Body Length	.408	-.222
Tail Length	.251	.896
Hind Foot Length	.456	.008
Skull Length	.453	-.119
Interorbital Breadth	.421	.139
Maxillary Tooth Row Length	.423	-.338
Variance	.775	.142
Cumulative Variance	.775	.917

The distribution of the 85 species of mammals with respect to the first two principal components is presented in Figure 1. Overall, ground dwelling forms tend to have negative values for principal component two while arboreal and

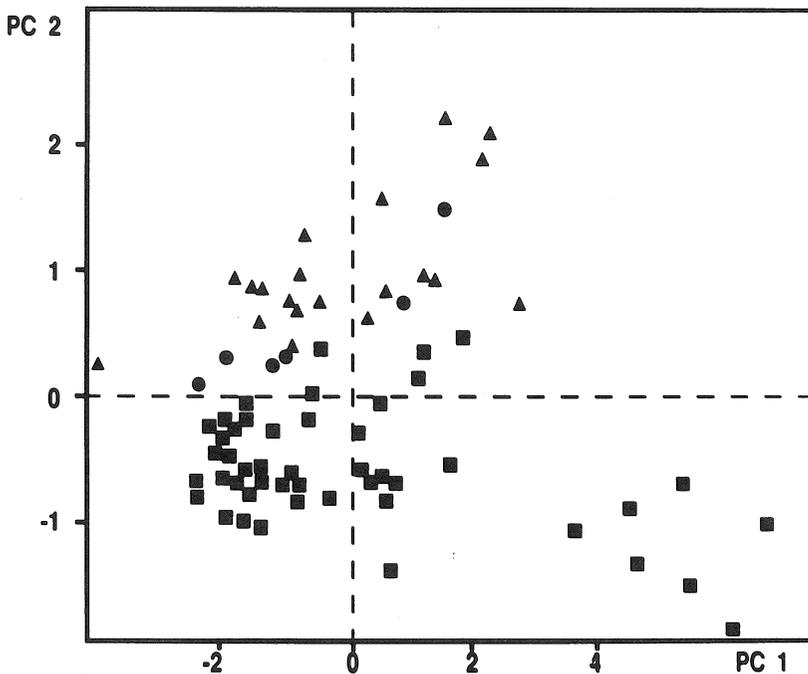


Fig. 1. The distribution of the 85 species of ground-dwelling (plus signs), arboreal (open squares) and flying (closed squares) sciurids and anomalurids with respect to the first two principal axes. Some observations are hidden.

gliding forms tend to have positive values. Thus, ground squirrels have shorter tails than do the other animals. However, it is interesting to note that gliding forms tend to be intermediate in terms of tail length. The arboreal forms tend to have the longest tails. These results are also indicated by the nonparametric schematic plots (Tukey 1977) presented in Figure 2. These plots present the medians, quartiles, and pseudo-standard deviations of each group (arboreal, flying and ground dwelling) with respect to the first and second principal components. From this figure it is clear that there are no significant differences with respect to the first size axis. The distributions are completely overlapping. However, with respect to the second "tail length" axis, ground forms have much shorter tails than do the arboreal and flying forms, and arboreal forms tend to have longer tails than the flying forms.

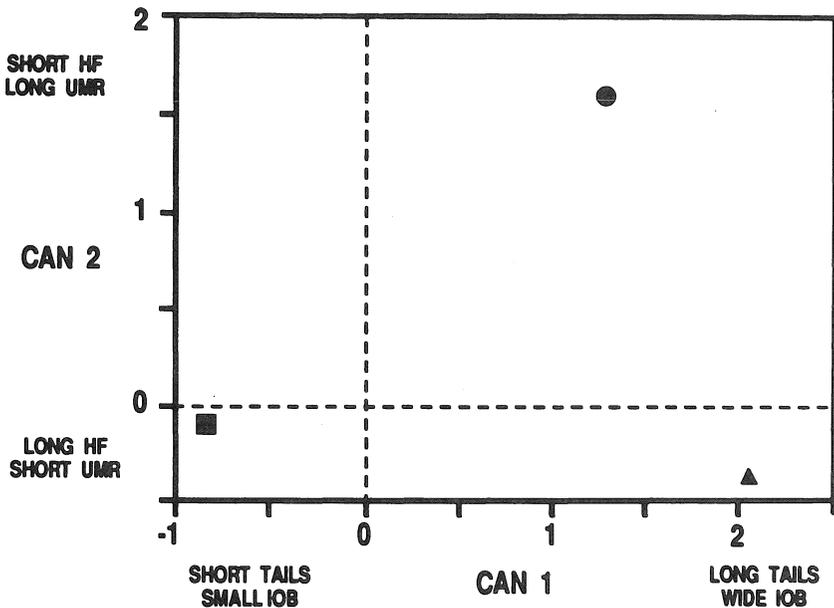


Fig. 2. The distribution of the principal component scores along the first two principal axes (PC 1 = a general size axis, PC 2 = a tail length axis) for ground-dwelling (G), arboreal (A) and flying (F) sciurids and anomalurids. The vertical line associated with each box represents a pseudo-standard deviation. The upper, middle, and lower horizontal lines represent the upper quartile, median, and lower quartiles respectively.

The results of the canonical discriminant analysis are presented in Table 2. Here, the first canonical discriminant function is loaded most heavily by tail length and interorbital breadth, while the second canonical discriminant function is loaded most heavily by hind foot length and upper tooth row length. Thus, the variables that provide the best discrimination between the gliding, arboreal, and

Table 2. Canonical coefficients for discrimination of squirrel habitats based on squirrel morphology. Can 1 = the first canonical discriminant axis, Can 2 = the second canonical discriminant axis.

Variable	Can 1	Can 2
Head & Body Length	-.790	.970
Tail Length	1.249	1.419
Hind Foot Length	-.073	-2.693
Skull Length	-.598	-1.436
Interorbital Breadth	1.129	-.241
Maxillary Tooth Row Length	-.460	2.906

ground dwelling forms are tail length and interorbital breadth, followed by hind foot length and upper tooth row length.

The distribution of the group means with respect to the canonical discriminant space is presented in Figure 3. From this figure it is clear that ground

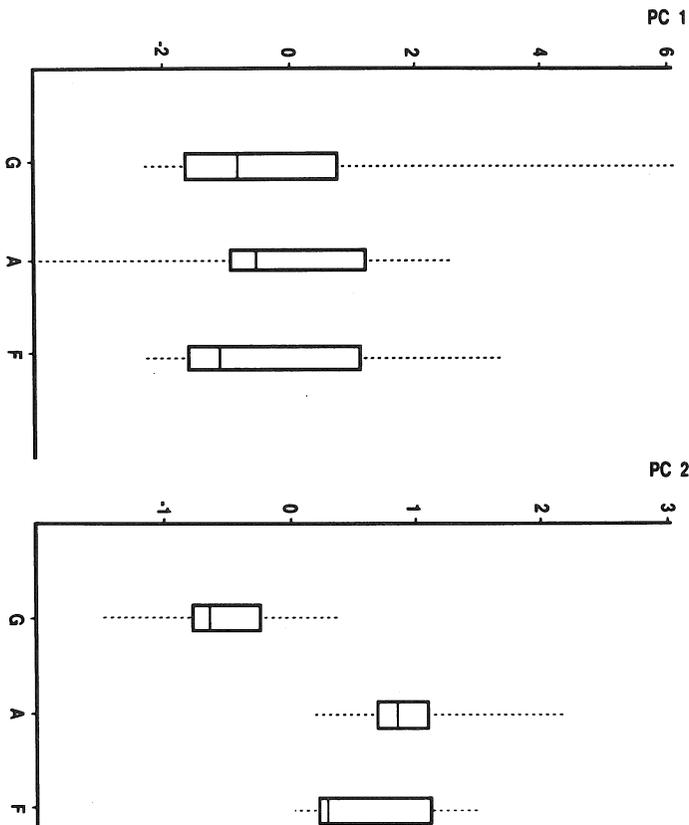


Fig. 3. The distribution of the group centroids for ground-dwelling (plus), arboreal (open square) and flying (closed square) sciurids and anomalurids in the canonical discriminant space.

dwelling forms have short tails, small interorbital breadths, long hind feet, and short maxillary tooth rows. The arboreal forms have long tails, wide interorbital breadths, long hind feet, and short maxillary tooth rows. The gliding forms are similar to the arboreal forms with respect to tail length and interorbital breadth, but differ from them in that they have short hind feet and long maxillary tooth rows.

Discussion

Relative to powered flight, the evolution of gliding has received little attention. This is curious since the selective pressures involved in the transition are unclear. Even though the development of patagia may be relatively simple, they impose both foraging and predation costs that may be significant.

The canonical discriminant analysis revealed the importance of the tail in discriminating between ground-dwelling and volant/arboreal animals, but also identified interorbital breadth as an important discriminatory variable. Interorbital breadth may in some way be a measure of binocularity. The plot of arboreal, volant, and ground-dwelling animals relative to the canonical space shows that both arboreal and volant forms tend to have wide interorbital breadths, while ground-dwelling forms tend to have narrow interorbital breadths. Binocular vision would have a selective advantage for volant or arboreal animals that jump or glide from one tree to the next.

Along the second canonical discriminant axis, the volant animals were separated from the arboreal and ground-dwelling animals. This axis shows that the gliding animals have shorter hind feet and longer maxillary tooth rows than do the other two groups. Running speed depends on stride length, and increased stride length can be achieved in part by increasing the length of the foot. The advantages of short feet to a gliding animal are not clear.

Perhaps of greater importance, gliding animals possess longer maxillary tooth rows than do nonvolant animals. Longer tooth rows provide greater surface area for food mastication and may increase the efficiency with which an animal uses a particular food item. It appears that the volant animals may possess greater foraging efficiency than do nonvolant animals, not only by being able to move from one foraging patch to another at a lower cost, but also by being able to extract more energy from each food item taken. This supports the foraging efficiency hypothesis. However, the foraging behavior of most volant forms limits their ability to utilize food items on the ground to the same extent as nonvolant animals. Thus, these animals may be effectively restricted to foraging in the tree canopies, whereas arboreal sciurids and anomalurids can forage both in the tree canopies and on the ground. Because of their restricted foraging niches, the volant sciurids and anomalurids may be forced to utilize their limited foraging opportunities more effectively. The longer tooth rows may represent a consequence of their mode of locomotion.

Head and body length did not provide good discrimination between the three groups. This suggests that there is no real difference in the overall sizes of gliding, arboreal, and ground dwelling forms. As noted by Thorington and Heaney (1981), large flying squirrels compensate for large size through increased glide speeds rather than through an allometry that allows reduced wing loadings.

It is clear that much work needs to be done to provide a better understanding of the transition from arboreal squirrel to gliding squirrel. A more complete data set containing additional form-function variables may provide some new insights into the problem. Perhaps more important are data on the comparative life histories, foraging characteristics, and predator regimes of ground dwelling, arboreal, and flying squirrels. Obviously, the phalangers provide a unique opportunity to test any new hypotheses. Perhaps only when the comparative biology of gliders and nongliders is well understood will it be possible to truly understand the selective regimes that have led to the evolution of glissant locomotion.

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Survival Estimation When Fates of Some Animals are Unknown

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Abstract: MICROMORT, a computer program based on a modified Mayfield method, is being used to estimate survival rates from radio-telemetry studies (Heisey and Fuller 1985). Estimates of survival are based on the number of deaths and the number of radio-days during a period of interest. In many studies, the radio-transmitter signals from a number of animals are lost before the end of the period, and the fate (alive or dead) of the animals is unknown. Monte Carlo simulations were used to examine four ways of treating the data from animals whose fates were unknown (censored animals). The four ways were to: 1) assume all censored animals died on the day radio contact was lost; 2) assume all censored animals lived through the period of interest after radio contact was lost; 3) exclude all radio-days for censored animals from the analysis; and 4) include radio-days for censored animals to the time of signal loss. We evaluated the performance of each of the four ways of handling censored animals by three criteria: 1) bias; 2) mean square error; and 3) the number of 95% confidence intervals that encompassed the true survival value. The results indicated that including radio-days for censored animals (method 4) provided the best estimates of survival.

Key Words: Censored animals, MICROMORT, Monte Carlo simulation, radio-telemetry, survival estimation.

Radio-telemetry offers an excellent, and often the only, opportunity for wildlife biologists to estimate seasonal and annual survival rates and cause-specific mortality rates. Radio-transmitters are available that will indicate whether an animal is alive or dead. In Missouri, radio-telemetry has been used to estimate survival for a variety of species such as white-tailed deer (*Odocoileus virginianus*) (Bryan 1980, Dalton 1985, Root 1986), wild turkeys (*Meleagris gallopavo*) (Kurzejeski *et al.* 1987), bobwhite quail (*Colinus virginianus*) (Janvrin, unpubl. data), prairie-chickens (*Tympanuchus cupido*) (Burger 1988, Jones 1988), ruffed grouse (*Bonasa umbellus*) (Kurzejeski and Root 1989), and coyotes (*Canis latrans*) (Hallett 1977).

To determine survival rates, wildlife biologists usually locate each radio-marked animal on a regular (usually daily) basis to determine its fate. There are three possibilities: 1) the animal is found to be alive; 2) the animal is found to be dead; or 3) radio contact is permanently lost and the fate of the animal is unknown. When the fate of an animal is unknown, the observation is defined as censored. Radio contact may be lost because of transmitter failure, the animal permanently leaves the study area, or the transmitter falls off the animal.

One of the most popular methods for estimating survival is a modification of the Mayfield method (Mayfield 1961, 1975, Trent and Rongstad 1974, Johnson 1979, Hensler and Nichols 1981, Bart and Robson 1982). Heisey and Fuller (1985) further modified this method and developed a computer program, MICROMORT. MICROMORT calculates survival estimates and their corre-

sponding variances for daily rates, intervals of interest, and spans of intervals (Heisey and Fuller 1985:670) using their modified (HF) method. The inclusion of censored observations during the period of interest was not originally considered in the conceptualization of the HF method. However, Heisey and Fuller (1985:673) suggested that the true survival rate could be bracketed by handling censored animals in two ways. First, all censored animals can be assumed to have died on the day radio contact was lost, providing a minimum survival rate estimate. Second, all censored animals can be assumed to have lived through the period of interest after radio contact was lost, providing a maximum survival rate estimate. Other researchers have excluded all information from censored animals (Lindzey *et al.* 1988).

Because censored observations were not originally considered in the development of the HF method, we used computer simulation techniques to evaluate the effects of censoring on HF estimates of survival by handling animals whose fate were unknown in four ways:

- 1) By assuming all animals whose fates were unknown died on the day radio contact was lost;
- 2) By assuming all animals whose fates were unknown lived through the period of interest (e.g., 30 days) after radio contact was lost;
- 3) By excluding from the analysis all information for animals whose fates were unknown from the analysis; and
- 4) By including the information for animals whose fates were unknown until the time of signal loss.

The purpose of this paper is to determine which of the four methods of handling censored observations provides the best estimates of survival when using the HF method.

Survival Estimator and Assumptions

The HF method provides estimates of daily survival rates. The daily survival rate, \hat{s} , is calculated as:

$$\hat{s} = (x-y) / x,$$

where x is the total number of radio-days and y is the total number of deaths in the period of interest. To calculate the survival estimates, \hat{S} , for the period of interest which is L days in length,

$$\hat{S} = \hat{s}^L.$$

We used the following equation to estimate variance for the daily survival rate ($\text{var}(\hat{s})$):

$$\text{var}(\hat{s}) = \hat{s} * (1 - \hat{s}) / x.$$

The 95% confidence interval for the daily survival estimate is calculated as:

$$\hat{s} \pm 1.96 * \text{sqrt}(\text{var}(\hat{s})).$$

The 95% confidence interval for the survival estimate for periods, \hat{S} , of length L is calculated as:

$$(\hat{s} \pm 1.96 * \text{sqrt}(\text{var}(\hat{s})))^L.$$

The above formulas are the same ones used by the program MICROMORT (Heisey and Fuller 1985) to calculate daily and interval survival rates and their 95% confidence intervals.

The use of the HF method requires that certain assumptions must be met:

- 1) Survival times of individual animals should be independent;
- 2) Survival rates for the period of interest must remain constant; and
- 3) The sample should be representative of the population being studied.

Computer Simulation

We ran 100 Monte Carlo simulations at each combination of 11 survival rates and 12 rates of censoring (Table 1) to determine which of the four ways of handling censored observations was best. A sample of 100 animals was used. Period lengths of 30, 90, 180, and 365 days were used for each combination of survival and censoring rates. Because period length did not affect our conclusions, only data from the 30-day simulations will be shown.

On each of the 30 days of a simulation, an animal could have three possible fates. It could die, be censored, or live. The survival and censoring probabilities for each simulation determined the likelihood of the occurrence of a particular fate. We assumed that the censoring mechanism was random by giving each animal a 50% chance of either being considered for censoring first or being considered for death first. If the animal was considered for censoring first and was not censored, then the animal was considered for death. If the animal was considered for death first and did not die, then the animal was considered for censoring. When an animal was either censored or died, it was not considered for any alternate fate thereafter.

Data recorded for each simulation included the total number of radio-days (TOTDAYS), number of animals that died (TOTDEAD), number of animals censored (TOTCENS), and number of radio-days associated with animals that were censored (CENDAYS). These data were then used to calculate survival estimates for each of the four ways of handling censored observations. To calculate x , total number of radio-days, and y , total number of deaths, for each of the four ways, we used the following formulas:

1. When we assumed that the censored animals died,

$$x = \text{TOTDAYS},$$

$$y = \text{TOTDEAD} + \text{TOTCENS}.$$
2. When we assumed that the censored animals live to the end of the period,

$$x = (\text{TOTDAYS} - \text{CENDAYS}) + \text{TOTCENS} * L,$$
 where L is 30 days for the results reported in this paper,

$$y = \text{TOTDEAD}.$$
3. When we excluded censored animals from the analysis,

$$x = \text{TOTDAYS} - \text{CENDAYS},$$

$$y = \text{TOTDEAD}.$$
4. When we included censored animals in the analysis,

$$x = \text{TOTDAYS,}$$

$$y = \text{TOTDEAD.}$$

Evaluation Criteria

We evaluated the performance of each of the four methods of handling censored observations by three criteria; bias, mean square error, and the number of 95% confidence intervals that contained the true value.

Bias (B) was calculated as

$$B = \frac{\sum (\hat{S} - S)}{N}$$

where \hat{S} is the estimated period survival rate, S is the true survival rate, and N is the number of simulations where a value for S was obtained.

The mean square error (MSE) was calculated as

$$\text{MSE} = \frac{\sum (\hat{S} - S)^2}{N}$$

where \hat{S} , S , and N were the same as for B . A small MSE shows that the estimator not only has bias near zero but a small variance as well (DeGroot 1975:349).

The number of 95% confidence intervals that contained the true value was calculated by enumerating the number of simulations in which the confidence interval encompassed the true survival value. The 95% confidence interval was expected to encompass the true value in 95 of 100 simulations.

For the four methods of handling censored observations, the best estimator should have bias near 0, a mean square error near 0, and a count of near 95 for the number of 95% confidence intervals that were correct throughout all combinations of survival and censoring probabilities.

Results

The four methods of handling censored observations using the HF survival estimator were evaluated using each of the three criteria. The numerical results of each of the evaluation criteria are shown in the appendices (A, B, C). Because patterns within the data were easier to visualize in graphical form, the information shown in the appendices was used to create Figures 1 (Appendix A), 2 (Appendix B), and 3 (Appendix C).

Bias

When censored animals were assumed to have died, bias became increasingly negative as the rate of censoring and survival increased (Figure 1a). When censored animals were assumed to have lived, bias became more positive as censoring increased and survival decreased (Figure 1b). Bias became more negative as censoring increased and the mid-range of survival values was approached when censored animals were excluded from the analysis (Figure 1c). When censored animals were included in the analysis, bias was nearly zero throughout the entire range of censoring and survival probabilities (Figure 1d).

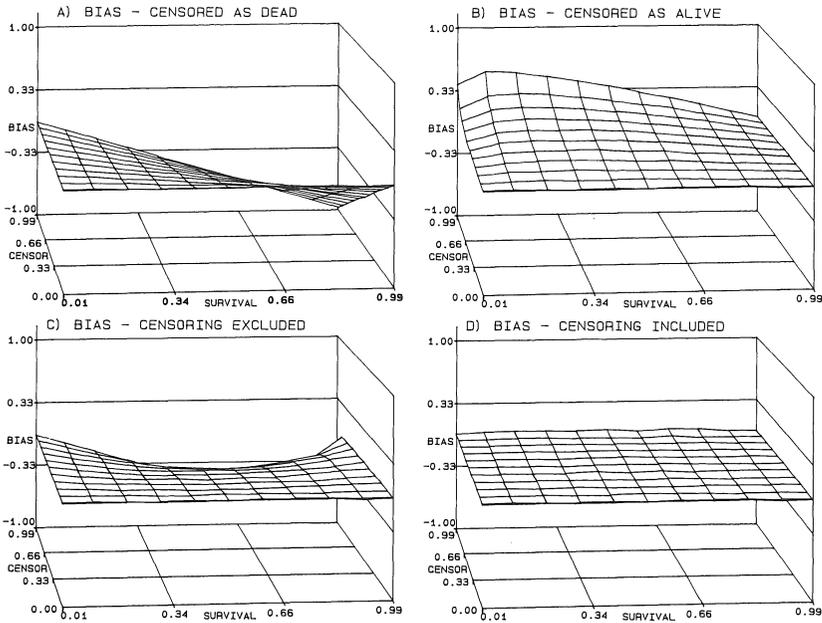


Fig. 1. Bias at each of 11 rates of true survival and 12 rates of censoring for each of the four methods of handling censored observations. For each combination of survival and censoring rates 100 simulations were performed. Period length for each simulation was 30 days. Each simulation began with a sample size of 100 animals. A) Assumes all censored animals died on the day radio contact was lost, B) Assumes all censored animals lived through the period of interest, C) Excludes all radio-days for censored animals from the analysis, D) Includes radio-days for censored animals to the time of signal loss.

Mean Square Error

Mean square error increased as survival and censoring increased when censored animals were assumed to have died (Figure 2a). When censored animals were assumed to have lived, mean square error increased as survival decreased and censoring increased (Figure 2b). Mean square error increased as the rate of survival and censoring increased when censored animals were excluded from the analysis (Figure 2c). When censored animals were included in the analysis, mean square error was low throughout the entire range of censoring and survival rates (Figure 2d).

95% Confidence Interval Counts

When censored animals were assumed to have died, to have lived, or were excluded from the analysis, the 95% confidence interval encompassed the true

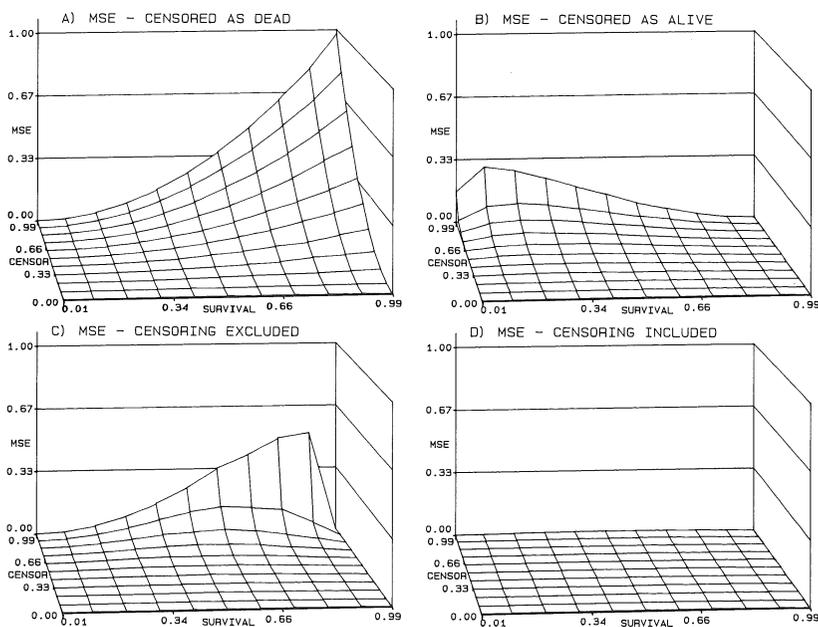


Fig. 2. The mean square error at each of 11 rates of true survival and 12 rates of censoring for each of the four methods of handling censored observations. For each combination of survival and censoring rates 100 simulations were performed. Period length for each simulation was 30 days. Each simulation began with a sample size of 100 animals. A) assumes all censored animals died on the day radio contact was lost, B) Assumes all censored animals lived through the period of interest, C) Excludes all radio-days for censored animals from the analyses, D) Includes radio-days for censored animals to the time of signal loss.

value of survival fewer and fewer times as the rate of censoring increased (Figures 3a, 3b, 3c). However, when censored animals were included in the analysis, the 95% confidence interval of the survival estimate included the true survival value nearly 95 of 100 times at all combinations of censoring and survival probabilities, except at a true survival value of 0.99. Counts ranged from 18 to 70 at this survival level (Appendix C).

Discussion

The simulations also provided an evaluation of the survival estimator, \hat{s} , used by the HF method, because we included a rate of censoring of 0 in the

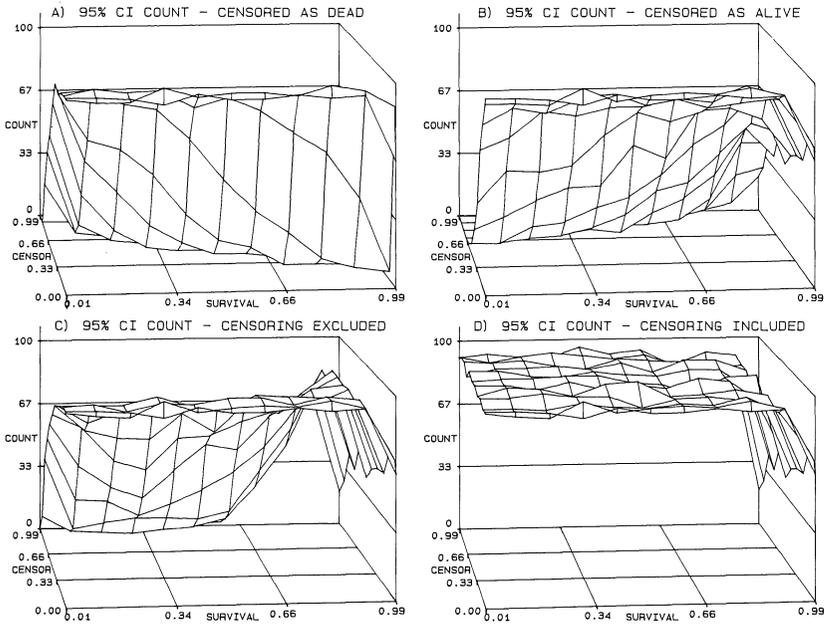


Fig. 3. The number of simulations where the true survival rate was within the 95% confidence limits of the estimated survival rate at each of 11 rates of true survival and 12 rates of censoring for each of the 4 methods of handling censored observations. For each combination of survival and censoring rates 100 simulations were performed. Period length for each simulation was 30 days. Each simulation began with a sample size of 100 animals. A) assumes all censored animals died on the day radio contact was lost, B) Assumes all censored animals lived through the period of interest, C) Excludes all radio-days for censored animals from the analyses, D) Includes radio-days for censored animals to the time of signal loss.

simulations. Over the range of true survival values (Table 1), bias ranged from -0.00890 to 0.00847 , the mean square error ranged from 0.000027 to 0.002633 , and the 95% confidence interval counts ranged from 62 to 96 (excluding the 0.99 survival value, the counts ranged from 91 to 96). Thus, we conclude that the survival estimator, \hat{s} , will provide good estimates of survival when the fates of all animals are known.

Radio-telemetry studies in which the fates of some animals are unknown require the assumption that death and censoring are independent events. If a radio-marked animal dies and the cause of death also results in the loss of its radio signal (i.e., the transmitter is destroyed or the transmitter continues to

Table 1. Levels of true survival and censoring used in combinations of each other in Monte Carlo simulations of the Heisey-Fuller survival estimators. The rates are for a period length of 30 days.

Rates of Survival	Rates of Censoring
0.01	0.00
0.1	0.01
0.2	0.1
0.3	0.2
0.4	0.3
0.5	0.4
0.6	0.5
0.7	0.6
0.8	0.7
0.9	0.8
0.99	0.9
	0.99

operate but the investigator cannot receive the signal) then this assumption is violated. If this assumption is violated and radio-days associated with censored animals are included in the analysis, the resulting survival estimate will be too high. The results of the simulation demonstrate that censored animals cannot be excluded from HF survival analysis, because if they are the estimate will be biased. Therefore, when death and censoring are not independent events, a conservative approach would be to assume that all censored animals died on the day radio contact was lost. This approach would provide a minimum estimate of survival unless the loss of radio contact was always caused by death, in which case the estimate would be correct. If loss of radio contact is only sometimes caused by death, the survival estimate will have an unknown negative bias and the 95% confidence interval may or may not encompass the true value.

By all three evaluation criteria, the best estimates of survival were obtained when censored animals were included in the HF analysis. When censored animals were included in the analysis, the survival estimate had bias near 0, a low mean square error, and a 95% confidence interval that encompassed the true value of survival nearly 95 of 100 times throughout the entire range of survival and censoring probabilities. The only exception to this occurred at the highest survival value (0.99). At a true survival value of 0.99, a sample size of 100 "animals" was too small to provide adequate estimates of survival.

When the daily survival rate is constant during the period of interest, our simulation results indicate that reasonable estimates of survival can be obtained with the HF method when censored animals are included in the analyses. We recommend that radio-days associated with animals whose fates are unknown should be included in HF analyses of survival and when using MICROMORT.

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Appendix A

Average bias at each of 11 rates of true survival and 12 rates of censoring for each of the four methods of handling censored observations. For each combination of survival and censoring rates 100 simulations were performed. Period length for each simulation was 30 days. Each simulation began with a sample size of 100 animals.

(cd - Assumes all censored animals died on the day radio contact was lost. cl - Assumes all censored animals lived through the period of interest after radio contact was lost. woc - Excludes all radio-days for censored animals from the analysis. wc - Includes radio-days for censored animals to the time of signal loss.)

Survival Rates	Censor Rates												
	0.0	0.01	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.99	
0.01	cd	0.00044	0.00007	-0.00045	-0.00223	-0.00230	-0.00303	-0.00423	-0.00588	-0.00638	-0.00772	-0.00892	-0.00968
	cl	0.00044	0.00064	0.00552	0.00531	0.02005	0.03263	0.04451	0.06525	0.10101	0.13607	0.20166	0.39553
	woc	0.00044	0.00008	-0.00034	-0.00208	-0.00199	-0.00275	-0.00394	-0.00562	-0.00608	-0.00741	-0.00879	-0.00995
	wc	0.00044	0.00020	0.00077	-0.00023	0.00114	0.00193	0.00180	0.00106	0.00343	0.00279	0.00260	0.00577
0.1	cd	0.00074	0.00458	-0.00715	-0.01694	-0.03443	-0.04149	-0.04870	-0.05849	-0.06855	-0.07956	-0.08927	-0.09896
	cl	0.00074	0.00637	0.01914	0.03764	0.05335	0.06223	0.11409	0.14683	0.19190	0.25130	0.33311	0.53873
	woc	0.00074	0.00464	-0.00480	-0.01314	-0.02943	-0.03511	-0.03997	-0.05074	-0.06169	-0.07489	-0.08564	-0.09844
	wc	0.00074	0.00536	0.00326	0.00385	-0.00395	0.00015	0.00365	0.00386	0.00519	0.00604	0.00820	0.02728
0.2	cd	0.00272	-0.00335	-0.01235	-0.04425	-0.06019	-0.08157	-0.10035	-0.11917	-0.13662	-0.15835	-0.17875	-0.19773
	cl	0.00272	0.00121	0.02702	0.03879	0.07218	0.09764	0.13561	0.17374	0.22242	0.27924	0.35427	0.51827
	woc	0.00272	-0.00248	-0.00965	-0.03111	-0.03995	-0.05948	-0.07319	-0.09418	-0.10926	-0.13787	-0.16603	-0.19563
	wc	0.00272	-0.00104	0.00755	-0.00419	0.02098	0.00044	0.00384	0.00699	0.01219	0.01261	0.01487	0.03191
0.3	cd	-0.00229	-0.00542	-0.03111	-0.05538	-0.08963	-0.12360	-0.15329	-0.18051	-0.20854	-0.23608	-0.26828	-0.29655
	cl	-0.00229	-0.00124	0.01880	0.05150	0.07536	0.10168	0.12682	0.16392	0.21413	0.26775	0.33844	0.47374
	woc	-0.00229	-0.00435	-0.01725	-0.02661	-0.04906	-0.07549	-0.10365	-0.12723	-0.15574	-0.18928	-0.24126	-0.29239
	wc	-0.00229	-0.00284	-0.00214	0.00649	0.00315	-0.00040	-0.00313	-0.00033	0.00708	0.01571	0.01634	0.03040
0.4	cd	-0.00150	-0.00135	-0.04294	-0.08522	-0.11849	-0.15329	-0.19775	-0.24130	-0.27756	-0.31865	-0.36019	-0.39577
	cl	-0.00150	0.00559	0.02112	0.03957	0.06964	0.10668	0.12747	0.16809	0.19886	0.24658	0.30350	0.42094
	woc	-0.00150	0.00155	-0.01897	-0.04138	-0.05536	-0.07142	-0.10677	-0.14003	-0.18161	-0.23627	-0.31239	-0.38658
	wc	-0.00150	0.00326	-0.00085	-0.00412	0.00223	0.01431	0.00571	0.00975	0.00889	0.01102	0.00674	0.02304
0.5	cd	0.00419	-0.01268	-0.04156	-0.10477	-0.14787	-0.20353	-0.24865	-0.29383	-0.35093	-0.39663	-0.45126	-0.49449
	cl	0.00419	-0.00460	0.02775	0.03926	0.05376	0.06142	0.11913	0.15101	0.18177	0.21387	0.26558	0.36614
	woc	0.00419	-0.00865	-0.00816	-0.03807	-0.06089	-0.08895	-0.10934	-0.13702	-0.19926	-0.25622	-0.38655	-0.48189
	wc	0.00419	-0.00701	0.00956	-0.00292	-0.00483	-0.00343	0.00701	0.01607	0.01181	0.00839	0.00685	0.03529
0.6	cd	0.00350	0.00037	-0.05773	-0.12846	-0.17394	-0.23727	-0.29771	-0.35715	-0.04154	-0.48333	-0.54217	-0.59385
	cl	0.00350	0.00737	0.02227	0.03217	0.05666	0.08247	0.10295	0.12323	0.14883	0.18295	0.21835	0.29363
	woc	0.00350	0.00460	-0.01096	-0.03868	-0.04741	-0.07005	-0.10189	-0.14099	-0.19295	-0.27522	-0.39589	-0.57687
	wc	0.00350	0.00610	0.00554	-0.00375	0.00589	0.01103	0.01035	0.00937	0.01067	0.00828	0.00032	0.01157
0.7	cd	0.00281	-0.00267	-0.06936	-0.14267	-0.20244	-0.28106	-0.34865	-0.42160	-0.48845	-0.55783	-0.62836	-0.69164
	cl	0.00281	0.00609	0.01296	0.03097	0.03993	0.05222	0.07906	0.09457	0.11401	0.14215	0.02042	0.22937
	woc	0.00281	0.00352	-0.01281	-0.02567	-0.04412	-0.07341	-0.08735	-0.12997	-0.18150	-0.24712	-0.37309	-0.62805
	wc	0.00281	0.00474	0.00013	0.00370	0.00101	-0.00492	0.00661	0.00356	0.00402	0.01018	0.02042	0.03385
0.8	cd	0.00847	-0.00179	-0.08285	-0.15434	-0.24750	-0.31100	-0.40391	-0.47530	-0.55804	-0.63735	-0.71998	-0.79133
	cl	0.00847	0.00596	0.00571	0.02096	0.02290	0.04149	0.05350	0.06257	0.08070	0.09871	0.11309	0.15747
	woc	0.00847	0.00526	-0.01307	-0.01727	-0.04316	-0.04599	-0.07305	-0.10084	-0.13475	-0.19114	-0.35566	-0.68555
	wc	0.00847	0.00643	0.00371	0.00323	-0.00685	0.00361	0.00308	0.00006	0.00554	0.01193	-0.00260	0.02982
0.9	cd	-0.00890	-0.01306	-0.08989	-0.17727	-0.26799	-0.36076	-0.45180	-0.53348	-0.63329	-0.71875	-0.80912	-0.89046
	cl	-0.00890	-0.00322	0.00548	0.01343	0.01379	0.02722	0.02309	0.03729	0.41853	0.04865	0.05893	0.07675
	woc	-0.00890	-0.00422	-0.00347	-0.00686	-0.02023	-0.01680	-0.04695	-0.04636	-0.08198	-0.13157	-0.22870	-0.06625
	wc	-0.00890	-0.00368	0.00176	0.00408	-0.00094	0.00819	-0.00406	0.00721	0.00301	0.00177	0.00155	0.00496
0.99	cd	0.00040	-0.01251	-0.10049	-0.19867	-0.29125	-0.39811	-0.49927	-0.58727	-0.68699	-0.79094	-0.89308	-0.97984
	cl	0.00040	-0.00180	-0.00121	0.00189	0.00229	0.00349	0.00419	0.00249	0.00479	0.00509	0.00659	0.00799
	woc	0.00040	0.00182	-0.00243	0.00012	-0.00940	-0.00958	-0.00511	-0.00058	-0.00730	-0.01427	-0.02054	-0.14889
	wc	0.00040	-0.00166	-0.00178	0.00098	0.00091	0.00174	0.00208	-0.00128	0.00126	0.00037	0.00173	0.00142

Appendix B

The mean square error at each of 11 rates of survival and 12 rates of censoring for each of the four methods of handling censored observations. For each combination of survival and censoring rates 100 simulations were performed. Period length for each simulation was 30 days. Each simulation began with a sample size of 100 animals. (cd - Assumes all censored animals died on the day radio contact was lost. cl - Assumes all censored animals lived through the period of interest after radio contact was lost. woc - Excludes all radio-days for censored animals from the analysis. wc - Includes radio-days for censored animals to the time of signal loss.)

Survival Rates		Censor Rates											
		0.0	0.01	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.99
0.01	cd	0.00027	0.000026	0.000023	0.000019	0.000022	0.000020	0.000029	0.000040	0.000045	0.000061	0.000080	0.000098
	cl	0.00027	0.000031	0.000089	0.000189	0.000595	0.001533	0.002552	0.005096	0.011691	0.020801	0.043997	0.160197
	woc	0.00027	0.000026	0.000025	0.000020	0.000022	0.000023	0.000029	0.000038	0.000044	0.000057	0.000078	0.000097
	wc	0.00027	0.000027	0.000029	0.000021	0.000031	0.000035	0.000042	0.000051	0.000060	0.000068	0.000043	0.000129
0.1	cd	0.000627	0.000700	0.000549	0.000688	0.001524	0.001992	0.002566	0.003583	0.004824	0.006392	0.007995	0.009793
	cl	0.000627	0.000729	0.001176	0.002331	0.003811	0.008302	0.015046	0.023452	0.039507	0.065726	0.114530	0.293127
	woc	0.000627	0.000703	0.000578	0.000684	0.001333	0.001604	0.001927	0.002855	0.004056	0.005778	0.007420	0.009694
	wc	0.000627	0.000711	0.000616	0.000558	0.000569	0.000693	0.000712	0.000747	0.000849	0.000893	0.001211	0.002438
0.2	cd	0.001312	0.001339	0.001484	0.002640	0.004509	0.007461	0.010628	0.014652	0.019019	0.025288	0.032009	0.039100
	cl	0.001312	0.001347	0.002521	0.002762	0.007093	0.011817	0.020819	0.033074	0.052430	0.080727	0.128637	0.270662
	woc	0.001312	0.001347	0.001498	0.001840	0.002875	0.004914	0.006534	0.009903	0.012932	0.019712	0.027963	0.038634
	wc	0.001312	0.001338	0.001649	0.000966	0.001445	0.001718	0.001649	0.001710	0.002158	0.002272	0.002951	0.004741
0.3	cd	0.002510	0.001474	0.002521	0.004228	0.009412	0.016568	0.024328	0.033218	0.044035	0.056053	0.072090	0.087947
	cl	0.002510	0.001436	0.002027	0.004607	0.008264	0.012799	0.018744	0.029727	0.044841	0.075360	0.117098	0.227207
	woc	0.002510	0.001457	0.001985	0.002260	0.004458	0.008196	0.012529	0.017939	0.025923	0.037844	0.059031	0.085612
	wc	0.002510	0.001452	0.001615	0.001686	0.002405	0.002418	0.002205	0.002442	0.002392	0.004117	0.004359	0.007740
0.4	cd	0.001887	0.002211	0.004132	0.008948	0.015628	0.024857	0.040252	0.059295	0.077887	0.101985	0.128891	0.156642
	cl	0.001887	0.002403	0.002784	0.004035	0.006839	0.014129	0.019077	0.031282	0.042724	0.063329	0.094506	0.178781
	woc	0.001887	0.002295	0.002890	0.003959	0.005118	0.008011	0.014113	0.022929	0.036075	0.059391	0.097079	0.151179
	wc	0.001887	0.002311	0.002369	0.002343	0.001903	0.002894	0.003018	0.003667	0.004311	0.004298	0.004683	0.008251
0.5	cd	0.002633	0.002778	0.004133	0.019967	0.023521	0.043298	0.063300	0.087467	0.123929	0.157966	0.203855	0.244532
	cl	0.002633	0.002521	0.003037	0.004353	0.004766	0.009494	0.016846	0.025535	0.035154	0.048228	0.072914	0.135261
	woc	0.002633	0.002645	0.002630	0.005003	0.006051	0.011536	0.015529	0.023141	0.044015	0.074003	0.138269	0.232742
	wc	0.002633	0.002607	0.002542	0.003174	0.002082	0.003170	0.003214	0.003865	0.003175	0.004627	0.005571	0.009541
0.6	cd	0.002521	0.002019	0.005687	0.018996	0.033069	0.058483	0.090934	0.128783	0.173383	0.234369	0.294236	0.352666
	cl	0.002521	0.002188	0.002509	0.003273	0.005919	0.008874	0.012718	0.017561	0.024228	0.035328	0.049188	0.087074
	woc	0.002521	0.002112	0.002381	0.004262	0.006403	0.008542	0.011572	0.024871	0.042893	0.062812	0.103032	0.333573
	wc	0.002521	0.002165	0.002107	0.002535	0.003328	0.002902	0.003249	0.003643	0.003902	0.004732	0.005382	0.007822
0.7	cd	0.002040	0.002055	0.007110	0.022585	0.043325	0.081180	0.123584	0.179098	0.239719	0.312200	0.395215	0.478391
	cl	0.002040	0.002087	0.002331	0.003087	0.003831	0.004479	0.008729	0.010060	0.014217	0.021438	0.032508	0.053280
	woc	0.002040	0.002080	0.002589	0.003382	0.005253	0.008828	0.013521	0.021247	0.038278	0.070534	0.154880	0.404164
	wc	0.002040	0.002080	0.002248	0.002452	0.002656	0.002452	0.003943	0.002833	0.002408	0.003608	0.005551	0.008398
0.8	cd	0.001653	0.001322	0.008533	0.026166	0.063359	0.099118	0.165102	0.227817	0.312731	0.406975	0.518867	0.626219
	cl	0.001653	0.001296	0.001281	0.002076	0.002108	0.002923	0.004064	0.005048	0.007459	0.010973	0.013509	0.025192
	woc	0.001653	0.001300	0.001609	0.002513	0.004622	0.004829	0.009216	0.014758	0.023237	0.049686	0.143292	0.489997
	wc	0.001653	0.001299	0.001354	0.001889	0.002095	0.001725	0.002042	0.002207	0.002228	0.003660	0.003537	0.006572
0.9	cd	0.000967	0.001111	0.009463	0.033173	0.073833	0.134800	0.020637	0.286774	0.402678	0.517857	0.655113	0.792931
	cl	0.000967	0.000930	0.001010	0.000995	0.009740	0.001580	0.001160	0.002094	0.002263	0.002810	0.003878	0.006157
	woc	0.000967	0.000948	0.001191	0.001264	0.001916	0.002458	0.004273	0.005611	0.011735	0.025888	0.072580	0.519484
	wc	0.000967	0.000936	0.001057	0.001004	0.001076	0.001376	0.001083	0.001529	0.001423	0.001594	0.002197	0.004220
0.99	cd	0.000090	0.000358	0.010897	0.041234	0.087024	0.160775	0.251477	0.346769	0.474071	0.626864	0.798275	0.960108
	cl	0.000090	0.000112	0.000098	0.000097	0.000077	0.000069	0.000082	0.000073	0.000078	0.000065	0.000082	0.000084
	woc	0.000090	0.000115	0.000124	0.000146	0.000144	0.000172	0.000259	0.000489	0.000668	0.001177	0.003979	0.109270
	wc	0.000090	0.000113	0.000110	0.000117	0.000101	0.000097	0.000122	0.000156	0.000152	0.000151	0.000231	0.000365

Appendix C

The number of simulations in which the true survival rate was within the 95% confidence interval of the estimated survival rate at each of 11 rates of true survival and 12 rates of censoring for each of the four methods of handling censored observations. For each combination of survival and censoring rate 100 simulations were performed. Period length was 30 days for each simulation. Each simulation began with a sample size of 100 animals.

(cd - Assumes all censored animals died on the day radio contact was lost. cl - Assumes all censored animals lived through the period of interest after radio contact was lost. woc - Excludes all radio-days for censored animals from the analysis. wc - Includes radio-days for censored animals to the time of signal loss.)

Survival Rates		Censor Rates											
		0.0	0.01	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	0.99
0.01	cd	95	94	93	91	87	83	76	56	44	24	0	0
	cl	95	92	79	63	33	16	5	1	0	0	0	0
	woc	95	94	94	91	88	85	77	69	58	44	10	0
	wc	95	94	93	95	93	95	94	96	90	95	94	91
0.1	cd	95	92	96	92	64	50	29	10	2	0	0	0
	cl	95	92	87	69	49	22	5	1	0	0	0	0
	woc	95	92	95	91	79	72	70	47	26	7	2	0
	wc	95	92	93	95	97	95	95	96	94	94	91	93
0.2	cd	94	92	94	85	59	34	11	2	0	0	0	0
	cl	94	91	84	82	48	30	13	3	0	0	0	0
	woc	94	91	91	91	85	68	53	36	25	10	1	0
	wc	94	91	92	97	96	92	95	93	94	95	94	91
0.3	cd	91	99	95	82	46	17	2	0	0	0	0	0
	cl	91	99	91	79	51	36	15	4	0	0	0	0
	woc	91	99	95	95	87	67	48	30	17	12	0	0
	wc	91	99	95	95	92	96	96	92	95	92	96	90
0.4	cd	96	94	86	67	26	8	0	0	0	0	0	0
	cl	96	92	93	83	66	37	22	8	3	0	0	0
	woc	96	93	94	90	85	80	64	44	23	12	2	0
	wc	96	93	93	95	98	92	96	95	93	90	94	96
0.5	cd	93	96	91	47	13	2	0	0	0	0	0	0
	cl	93	95	87	83	77	57	27	14	1	1	0	0
	woc	93	95	97	87	87	70	65	57	30	11	3	1
	wc	93	95	92	89	99	94	92	93	96	95	92	92
0.6	cd	93	96	84	31	9	2	0	0	0	0	0	0
	cl	93	96	90	87	72	50	38	26	11	1	0	0
	woc	93	96	97	95	90	86	72	54	39	15	7	2
	wc	93	96	94	93	91	92	91	92	91	94	94	94
0.7	cd	95	94	73	20	0	0	0	0	0	0	0	0
	cl	95	95	84	82	77	74	53	30	18	3	0	0
	woc	95	95	93	94	91	79	77	71	52	36	24	23
	wc	95	95	93	94	92	97	85	95	97	93	88	86
0.8	cd	93	99	63	7	0	0	0	0	0	0	0	0
	cl	93	98	96	84	87	75	63	45	30	14	4	0
	woc	93	98	97	93	87	91	85	82	71	58	45	49
	wc	93	98	97	92	94	95	94	95	97	87	95	83
0.9	cd	94	96	40	2	0	0	0	0	0	0	0	0
	cl	94	94	89	86	85	69	60	54	43	22	4	0
	woc	94	94	95	92	94	93	94	94	87	88	80	68
	wc	94	94	89	89	91	84	95	83	91	91	93	88
0.99	cd	62	88	4	0	0	0	0	0	0	0	0	0
	cl	62	88	70	55	54	50	42	55	39	43	26	18
	woc	62	88	70	55	54	50	42	55	39	43	26	17
	wc	62	88	70	55	54	50	42	55	39	43	26	18

Polymeric N-Oxides Past Present and Future

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An extensive literature has grown up on the chemistry of heterocyclic N-oxides, since the discovery of the naturally occurring substances "iodinine¹ and "aspergillitic acid"² as potent antibiotics. A large number of N-oxides have been tested for their biological effect, and the findings have created new research enthusiasm. The biological activity of N-oxides varies from very carcinogenic, such as 4-nitroquinoline N-oxide,^{3,4} to a very potent antibiotic such as iodinine. One interesting example of a pharmaceutical application is chlorodiazepoxide, as a tranquilizer.⁵ Surprisingly, no well-defined mechanism for the biological activity of such compounds has emerged yet.

However, there is relatively very little in the literature about polymeric N-oxides. Poly2-vinylpyridine N-oxide was amongst the first of this kind to attract the attention of both chemists and biologists. We became interested in this polymer in 1968 when we studied its interaction with mono- and polysilicic acid, and its adsorption onto quartz dust.⁶ A greater interest in this water soluble compound evolved since it was found that it inhibits silicosis and asbestosis in animal experiments.^{7,8} Indeed, that was the first breakthrough in silicosis treatment. It was shown that minute amounts of this polymer in aqueous solution protects the macrophages and reduces the fibrolytic effect of silica dust in animal lungs. Two nice reviews^{9,10} were written on the effect of poly2-vinylpyridine N-oxide on silicosis and asbestosis. It was interesting to find that the monomer analogue, 2-ethylpyridine N-oxide, has no effect against silicosis. That justified the search for other polymeric N-oxides which have biological activity.

Another characteristic of poly2-vinylpyridine N-oxide is that it is a strong chelating agent.¹¹ It forms a much more stable complex with metal ions than does 2-ethylpyridine N-oxide. This property was explored in removing minute amounts of toxic heavy metal ions in aqueous systems. Indeed, this polymer was found to have several advantages¹¹ over the well-known dimercaprol (BAL) which is currently used in metal ion detoxication. Now, we incorporate N-oxide groups in cross-linked polymers in the preparation of ion-exchange resins¹² for the same purpose. These findings stimulated an interest in further studies of N-oxide polymers. The chemistry and future prospects of such polymers were discussed in a recent presentation.¹³

N-oxidation of pyridine units on a polymer chain has several advantages:

- 1) $\overset{+}{\text{N}}-\bar{\text{O}}$ creates a charged water soluble molecule.
- 2) it is less basic than the parent amine polymer.

- 3) it forms a strong hydrogen bonding $\overset{+}{\text{N}}-\bar{\text{O}}\dots\text{H}-\text{O}-$.
- 4) N-oxide polymers attract heavy metal ions by chelation. Such characteristics give polymeric N-oxide compounds greater merits in industrial applications, especially in aqueous systems.
- 5) the $\overset{+}{\text{N}}-\bar{\text{O}}$ group is strongly hydrophilic.

This marked hydrophilic character of the N-oxide polymers stimulated an interest in the preparation and application of water-swellaible materials or hydrogels.

Hydrogels have become of increasing interest in several applications, especially in the manufacture of hygiene aids, wound dressings, denture cleaners, skin creams, and membranes. At present, there is a need for low-cost materials of this kind.

We have made an attempt lately to prepare hydrogels by N-oxidation of poly4-vinylpyridine/cross-linked with divinylbenzene. A variation of the amount of divinylbenzene as a cross-linking agent (also a hydrophobic agent) can lead to different polymer properties. A polymer with a lower degree of cross-linking is one in which the amount of divinylbenzene is sufficiently low that the N-oxide polymer is highly swellaible, but not so low that there is enough cross-linking to keep the N-oxide polymer water-insoluble. This means that the required material (the required degree of swellaibility, density, toughness), can be achieved by controlling both the degree of cross-linking and the degree of N-oxidation. At present, we are investigating the advantage of using ethylene glycol dimethacrylate as a cross-linking agent compared to divinylbenzene.

There are only few examples from the literature on the study of polyvinylpyridines (or copolymers) for biological purposes

1) Both poly2- and poly4-vinylpyridines have been tested in the preparation of oxygen and moisture resistant tablets.¹⁴

2) Poly4-vinylpyridine itself has been tried as a carrier¹⁵ for the antitumor drug "Alkeran" or "Leukeran."

3) Many attempts have been made to develop oxygen-separating membranes of high efficiency by using a metal chelate which binds molecular oxygen selectively and reversibly. Lately,¹⁶ a membrane of this kind was prepared by impregnating the chelate N,N'-Bis(2-hydroxybenzal)ethylenediimine cobalt(III) onto a copolymer of 4-vinylpyridine/hexylmethacrylate.

These examples provide enough background for exploring further the possibility of incorporating a vinylpyridine in a copolymer, as a biomaterial. The advantage of a copolymer carrying a pyridine base is that the material can be made more flexible with regard to pH sensitivity and solubility. The hydrophilic property or water-solubility of a pyridine base copolymer can be achieved by N-oxidation or by quaternary salt formation.

In a fluid-bed coating technique for coating a pharmaceutical product, the polymer fluid must have controllable pH, solubility, and the desired durability. The advantage of incorporating a pyridine base into the copolymer is that it provides a slightly basic material which is required to protect the drug from an acidic stomach, but at the same time the coating must be stable enough not to disintegrate too soon, i.e., to delay the release of the drug.

There have been many attempts to prepare a drug coating material to meet certain requirements, especially those regarding drug release timing, pH-sensitivity, and ability to reduce toxicity of drugs which otherwise are too toxic. One example is a neutral coating consisting of the copolymer vinylpyrrolidone/acrylamide.¹⁷ Recently, some acidic coatings were reported using acidic such groups as methacrylic acid/styrene¹⁸ copolymer.

We are currently studying a basic copolymer, 4-vinylpyridine/acrylamide as a drug coating material and for other applications. We believe that a basic coating, if durable enough, may serve as a better material in acidic gastric juice, compared to a neutral or an acidic coating. Acrylamide-based materials are of increasing interest in a wide variety of industrial applications, such as film coatings and membranes.

Vinylpyridine-N-oxide/Acrylamide copolymers open the door for a new class of water-soluble non-ionic polymers. The chelating properties of such copolymers, which we are studying at present, may provide another approach to the problem of toxic metal ions in industrial waste and other aqueous systems.

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Effect of Testis Width and Performance Traits on Behavior of Test Station Boars

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Abstract: The objective of this study was to determine the correlation between boar testis size and mating behavior. Data were obtained from 75 purebred boars tested and sold over an 18 month period. The study data were restricted to six breeds selling in the normal commercial price range (\$275 to \$1800). Boars were started on performance test at 32 kg. and removed at 104 kg. Boars were ultrasonically measured for loin muscle area and backfat, while calipers were used to determine testicle pair width. Boar buyers trained in a detailed procedure evaluated initial mating behavior. Buyers scored the mating behavior using a prearranged scale of 1 to 6, with 1 being no interest in a gilt in estrus to 6 being mount and mate on first attempt. Least squares means and correlation analysis of variance indicate a significant correlation between testis width and average daily gain, days to 104 kg., feed per gain, index, and sale price. No significant correlation between testis width and mating behavior was found. Mating behavior was significantly correlated to sale price. Significant breed differences were found for mating behavior, index, average daily gain, feed per gain, and testis width. Testis size was significantly correlated to performance traits but not to mating behavior.

Key words: Mating behavior, Testis size, Swine

Introduction

Frequently, swine producers experience problems of mating behavior in young boars. Nelson (1976) analyzed data from purebred swine sales and showed that 18 percent of sold boars were replaced due to mating failures. Additionally, 21% of the replaced boars displayed sickness or soundness problems soon after purchase.

Dewsbury (1975) showed heterosis for several mating behavior traits, e.g., number of mounts, number of intromissions, number of ejaculations, and time interval between various traits in mice. Dufour *et al.* (1984) reported that in sheep, testosterone concentration was highly associated with testis size and libido. They also reported that testis size was influenced by breed and season of the year. In swine, Hauser *et al.* (1952), Wilson *et al.* (1977), Neely *et al.* (1980), and Fent *et al.* (1983) have published significant heterosis effects for testis width and sperm production. Schinckel *et al.* (1984) reported that at 140 days of age, *in situ* testis width and length measurements were taken and boars were probed for backfat thickness, castrated and testis and epididymis weights were determined. Subsequently, testis width and length were highly correlated to testis weight, percent of seminiferous tubules with active spermatogenesis and seminiferous tubule diameter. Mean concentration of luteinizing hormone and follicle-stimulating hormone were not significantly correlated to testis length or width. Toelle (1984) has demonstrated that larger testes produce more total sperm.

Boars reared at most swine test stations are penned in groups. Tonn *et al.* (1985) conducted trials to determine the effects of group and individual penning on mating behavior and soundness. Penning treatment had little effect on mating behavior, but individual penning markedly reduced leg soundness after the 27 weeks of test.

Ellis (1985) used purebred boars to demonstrate that breed had a significant influence on testis length, testis width, day to 104 kg of weight, backfat thickness, National Swine Improvement Federation (NSIF) index, and feed efficiency. Testis width was correlated with gain and NSIF index.

The major objective of this study was to determine if testis size is an indicator of mating behavior in swine. Minor objectives were to identify correlation between testis size and various swine traits, mating behavior and various swine traits, and additionally breed means and standardization for testis size and mating behavior.

Materials and Methods

Data were obtained from 75 boars tested and sold at the Southeast Missouri State University Swine Test Station in Cape Girardeau, Missouri. Boars were evaluated over an 18 month period for body weight and testis length and width (right and left) were measured *in situ* at approximately 104 Kg and 160 days of age. Testes measures were not adjusted for body weight at the time of measurement since they have been reported to be moderately to highly correlated (Hauser *et al.* 1952). Adjustments may incorrectly consider genetics. Correlations were from analyses not including age in the model.

Backfat depth and loin eye area were measured ultrasonically. Backfat thickness was reported as an average of 3 measurements from the first rib, last rib, and last lumbar vertebra. The loin eye area measurement was obtained from the longissimus dorsi muscle between the tenth and eleventh ribs.

Boars were indexed for sale purposes upon completion of their official test. This index was used in the correlation model. The National Swine Improvement Federation Index was:

$$\text{Index} = 100 + 60(G - G) - 75(F - F) - 70(B - B)$$

where

G = average daily gain of individual

G = average daily gain of contemporaries

F = feed efficiency of individual

F = feed efficiency of contemporaries

B = backfat thickness of individual

B = backfat thickness of contemporaries

Feed efficiency was calculated for each animal. On-test weight was 31.75 kg and off-test weight was 104 kg. Boars were evaluated in a 3-boar sire group. Feed efficiency is an average of the group.

Testis width was used as the means of assessing testis size. Previous studies showed the correlation between testis width and length to be .75 ($P < .01$), (Ellis, 1985).

The project involved the support of the boar buyer. The buyer agreed to participate in the scoring of the young boars' initial mating behavior. Buyers isolated the boar for 10 days. They then placed two barrows with the boar for 20 days. The boar was next exposed to a gilt in estrus for mating. The buyer scored the mating behavior according to the following scale developed by the author.

<i>Behavior</i>	<i>Score</i>
No interest	1
Interest but failure to mount	2
Interest, mount, no mating	3
Mount and mate — third attempt	4
Mount and mate — second attempt	5
Mount and mate — first attempt	6

Eighty-four percent of the buyers completed the project correctly as determined by the author. Those that could not were eliminated from the study.

Analysis of variance, least square means, and correlation coefficients were calculated using a SAS package implemented by Helwig and Council (1979).

Results and Discussion

Testis size was significantly correlated with average daily gain, days to 104 Kg, feed efficiency, NSIF index, and sale price (Table 1). The results agree with those reported by Ellis (1985). Mating behavior was not significantly correlated with testis size. Sale price was significantly correlated with mating behavior (Table 2). The sale prices and mating behavior interaction can be explained by two separate correlations that interact. Producers pay a higher price for boars with higher average daily gains (Ellis 1987), and Table 1 shows that sale price is significantly correlated with testis size. These data indicate mating behavior is not related to performance traits or testis size. Producers were selecting for gain, not testis size or mating behavior.

Table 1. Correlation coefficients and their levels of significance between testis size and various traits.

Traits	"r"	Level of significance
Average daily gain	0.55	0.01
Days to 104 kg.	-0.39	0.01
Feed per gain	-0.33	0.01
Index	.60	0.01
Sale price	.41	0.01
Mating behavior	.15	0.19
Loin muscle area	.13	0.26
Backfat	-0.01	0.97

Table 2. Correlation coefficients and their level of significance between mating behavior and various traits.

Traits	'r'	Level of significance
Sale price	0.27	0.01
Index	0.22	0.06
Average daily gain	0.21	0.07
Loin muscle area	0.17	0.15
Days to 104 kg.	-0.17	0.15
Feed per gain	-0.16	0.16
Testis size	0.15	0.19
Backfat	-0.07	0.56

Table 3 reveals the interaction and significant differences for testis width by breed. Breed has a significant influence on width ($P < .001$) as determined by the analysis of variance. Greater average width was displayed by the Spot, Duroc, and Landrace breeds. Hampshire showed the smallest testis width and Spots the largest. Testis width means were separated by the least significant difference test ($P < .05$). Breed of boar was a significant influence on mating behavior ($P < .04$). A least significant difference test conducted on mean mating behavior ($P < .05$) showed that Landrace, Chester White, Hampshire, and Yorkshire had greater average mating behavior scores, with Landrace having the highest mean average and Spots displaying the smallest.

Conclusions

Purebred boars evaluated at Southeast Missouri State University were used to study the correlation between mating behavior, testis size, and various swine performance traits. Area swine producers purchasing the boars at auction were trained to score the boars mating behavior. Boars were managed and scored according to a standardized consistent procedure by buyers. Testis size mea-

Table 3. Least squares means and standard deviations for testis width by breed.

Breed	N	Mean testicle* width (cm)	SD
Spot	8	11.89 ^a	1.55
Duroc	18	11.68 ^a	0.87
Landrace	8	11.35 ^a	0.55
Yorkshire	22	10.98 ^b	0.96
Chester White	9	10.49 ^b	0.76
Hampshire	10	10.32 ^b	0.85

*Significance level for effect of breed from analysis of variance where designated. ($P < 0.01$)

^{a,b}Means in the column not sharing common superscript differ ($P < 0.05$).

ured *in situ* was significantly correlated with average daily gain, days to 104 kg, feed efficiency, NSIF index, and sale price at auction. Producers did not purchase the boars with larger than average testicle size because breeders purchase decision is influenced most by gain (Ellis 1987) and gain is correlated with testicle size. Unfortunately, larger than average testicle size boars did not display more desirable mating behavior. Mating behavior was only significantly correlated with sale price because the boars with large testes had above average growth rates. Breed is a significant source of variation for mean testicle width and mating behavior. In this study, Spots had the largest mean testis width, and Landrace displayed the highest mean mating behavior score.

These data reveal that testis size was significantly correlated to swine performance traits but not to mating behavior.

Acknowledgments

Special thanks to Drs. Michael T. Aide and William E. Meyer for manuscript review. Gratitude is extended to the breeders and buyers who support the swine test station.

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The Occurrence of *Eubosmina Tubicen* (Brehm) (Crustacea: Cladocera) in Missouri: A New Record

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Abstract: Preliminary analysis of zooplankton samples gathered on April 12, 1986 from Monopoly Marsh in Mingo National Wildlife Refuge of Stoddard County, Missouri yielded several specimens of *Eubosmina tubicen* (Brehm). This report represents the first record for this species in Missouri and provides one of the most western locality records for this taxon in the United States.

Key words: Missouri, *Eubosmina tubicen*, crustacean biogeography

On April 12, 1986 series of zooplankton samples were gathered from pools of Monopoly Marsh in Mingo National Wildlife Refuge of Stoddard County, Missouri. To ensure collection of uncommon or rare taxa and obtain a representative collection of the zooplankton community in Monopoly Marsh, the samples were collected by drawing a 15-cm wide conical student plankton net of 150 μ m Nitex webbing through all obvious and accessible aquatic microhabitats in the marsh. The samples were preserved in the field with 5% formalin solutions. Preliminary inventory of the samples to determine species present yielded several specimens of *Eubosmina tubicen* (Brehm 1953). Samples positive for *E. tubicen* were collected near inundated stands of buttonbush (*Cephalanthus occidentalis*). Deevey and Deevey (1971a) indicate *E. tubicen* is a neotropical cladoceran which has extended its range of distribution into eastern North America. However, until now, there is no official record on the occurrence of this species in Missouri. Therefore, the purpose of this report is to officially document the occurrence of *E. tubicen* in Missouri and to provide one of the most western locality records for this taxon in the United States. The occurrence of *E. tubicen* in Missouri is also significant in that it indicates investigators examining Cladocera in limnological investigations or dietary studies of aquatic organisms in this state should use caution before assigning specimens with *Bosmina*-like characteristics to the genus *Bosmina*. *Eubosmina tubicen* and *Bosmina longirostris* can co-occur in the same body of water (e.g., Roff and Kwiatkowski 1977, Yan and Strus 1980, Roff *et al.* 1981) and there is some indication species in the genus *Eubosmina* are more vulnerable to

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predation than *Bosmina longirostris* (Deevey and Deevey 1971b). Although further collecting efforts are needed to determine the exact distribution and habitat preference of *Eubosmina tubicen* in Missouri, the author speculates the distributional range of this species in Missouri is limited to the lowlands of the bootheel. Surface waters in the Southeastern Lowlands of Missouri are characteristically softer than those in other geographic subdivisions of the state (Jones 1977) and the geographic distribution of *E. tubicen* in northeastern North America is associated with soft waters (Carter *et al.* 1980).

Acknowledgments

The author thanks Dr. R. Wilkinson and the Department of Biology at Southwest Missouri State University for the opportunity to sample Monopoly Marsh. Gratitude is extended to Dr. E. S. Deevey, Florida State Museum, University of Florida, for his time and confirmation of *E. tubicen* identifications. The production of this report is in memory of Dr. Milton S. Topping for his inspiration and guidance.

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Missouri Academy of Science 1990 Annual Meeting

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MACELWANE HALL

Senior Division

Agriculture, Entomology and Herpetology

Kellogg, M. A., Moore, T. and Tabor, R., Department of Agriculture, Central Missouri State University, GERMINATION OF PEPPER SEED PRIMED IN SOLUTIONS OF POLYETHYLENE GLYCOL 8000 AND GIBBERELLIC ACID. Polyethylene Glycol (PEG) priming has been shown to produce rapid and uniform radicle emergence in certain seeds. Each species and cultivar reacts differently to priming. Gibberellic Acid (GA3) + PEG are synergistic. Ten seeds/treatment were germinated in petri dishes with filter paper. Five ml of solution was added/treatment and primed for 24 hours using 250, 500 and 1000 ppm GA3 + PEG to reach water potentials of -0.5 , -1.06 , and -1.5 Megapascals (MPa) using a 4×4 Randomized Complete Block (RCB) factorial. Germination was determined by radicle emergence. Five replications were made using a (RCB) and Duncan's Multiple Range for mean separations. At 50% germination, there was no significant differences at the 0.05 level. At 90% germ., there was a significant decrease in germ. time at the 0.05 level between control and GA3 1000 ppm, GA3 250 ppm, GA3 1000 ppm with -5 MPa water potential, and GA3 500 ppm. There was a 0.01 level of difference between control and GA3 1000 ppm and GA3 250 ppm. GA3 1000 ppm had the fastest and most uniform germ. rate. There was a possible synergistic effect between GA3 1000 ppm with PEG at -5 MPa.

Walk, T. C. and Niblack, T. L., Department of Plant Pathology, University of Missouri, Columbia, MO. THE EFFECT OF ZINC SALTS ON THE HATCHING OF HETERODERA GLYCINES. Zinc chloride ($ZnCl_2$) and zinc sulfate ($ZnSO_4$) are known stimuli of *H. glycines* hatching. We studied the relationship between zinc concentration and rate of hatching. Three replicates of 1200 eggs from a greenhouse isolate of *H. glycines* were exposed to 0.5, 2, 4, 8, 16, 32, 64, or 128 mM $ZnCl_2$ or $ZnSO_4$ for two weeks, with exposure to sterile distilled water as a control. Hatching was determined by counting emerged juveniles. Hatching was positively correlated with time for up to 12 days. Relative to water, both forms of zinc significantly ($p < .05$) stimulated hatching; $ZnCl_2$ at 4-64 mM and $ZnSO_4$ at 8-128 mM. Hatching peaked at 15 times that in water for both forms of zinc; $ZnCl_2$ at 8-32 mM and $ZnSO_4$ at 8-64 mM. This study verified that zinc salts stimulate hatching of *H. glycines*. In contrast to earlier work by others we found that this stimulation peaks within a specific range of concentration, and $ZnCl_2$ was required in higher concentrations to stimulate hatching than was previously reported. This work will be used to help identify possible hatching stimulants from various plants and microorganisms. Supported by State and Hatch funds, and USDA Special Grant No. 89-34113-4271.

VanCleave, H. B. and Beeghly, C. W., Department of Agriculture, Central Missouri State University, FESTUCA ARUNDINACEA FIELD TRIALS FOR 1989. To eliminate the animal health problems caused by the fungal endophyte (*Acremonium coenophialum*) in tall fescue (*Festuca arundinacea*), many endophyte free species/varieties are being promoted. This study was conducted to compare eleven grasses for yield, nutritional value, and fungal endophyte infection. Plots of Kentucky 31 (control), Tall Safe, Festerina, Johnstone, Mozark, Martin, Forager, Kenhy and Fawn tall fescue, along with smooth brome and orchardgrass were established. Tissue samples were collected and analyzed. Martin tall fescue yielded the highest percent crude protein (9.54), Fawn tall fescue provided the highest percent TDN (58.72), and orchardgrass produced the highest percent crude fiber (38.03). Fawn yielded the lowest percent crude fiber (31.00). Results of endophyte infection ranged from 33.3% (Fawn) to 83.3% (Kenhy). Yield comparisons resulted in a mean of 5,250 lbs/acre, with Martin leading all other species/varieties by producing 8,250 lbs/acre. Martin tall fescue produced the most favorable overall results.

Suntra, C. and Aldridge, R. D., Dept. of Biology, Saint Louis University, THE FEEDING BIOLOGY AND FAT STORAGE IN THE DIAMONDBACK WATER SNAKE (*NERODIA RHOMBIFERA*) FROM VERACRUZ, MEXICO. Snakes were collected on the Papaloapan River and nearby lagoons, near Tlacotalpan, Veracruz, Mexico ($18^{\circ}40'N, 95^{\circ}45'E$). Feeding frequency and mean coelomic fat mass was compared by gender for mature and immature snakes. Food consisted entirely of fish and feeding occurred with equal frequency throughout the year. Feeding frequency (food in stomach) was low ($X = 23.2$) and was not significantly different for groups examined. Coelomic fat mass was highly correlated with snout-vent length for all groups. Mean coelomic fat mass was not significantly different by gender for the groups examined. This study was conducted under Permit No. 303300, La Secretaria de Relaciones Exteriores, to RDA.

Butcher, L. E. and Terry, D. E., Department of Agriculture, Central Missouri State University, CONSUMER ATTITUDES REGARDING IRRADIATED STRAWBERRIES: A UNIVERSITY COMMUNITY'S APPRAISAL. Using survey techniques, this study was implemented to examine the effects of socioeconomic variables on consumer willingness to purchase irradiated produce. The project's sample was taken from the Central Missouri State University population. Of 174 valid responses, 41.9% reported a willingness to purchase irradiated strawberries at a price equal to that of nonirradiated strawberries, and 33.9% reportedly would pay a premium for the irradiated produce. Of those stating familiarity with the process, 46% thought irradiation was safe and a good idea. Over 82% of all respondents said they would like their favorite supermarket to feature irradiated strawberries. Results of logistic regressions indicated that predicting group membership with traditional socioeconomic characteristics resulted in substantial inadequacies. The age of the respondent (dummy variable format) was the only significant factor that categorized consumer willingness to purchase irradiated produce. Predictive ability above random placement was 29.2%. Support: CMSU Faculty Research Grant.

Tabor, R. L. and Terry, D. E., Department of Agriculture, Central Missouri State University. SPOILAGE IN REPRESENTATIVE SAMPLES OF IRRADIATED AND NONIRRADIATED STRAWBERRIES. This study was conducted to ascertain possible differences in spoilage rates of irradiated and nonirradiated strawberries. Strawberries were purchased from a wholesaler in West Memphis, Arkansas and irradiated at a nearby irradiation facility. The control sample (48 berries) received no irradiation while the other sample received between 57 and 99 kilorads of irradiation. Eight sets of spoilage measurements were taken at approximately 48 hour intervals beginning April 1, 1989. Spoilage was defined as any area which showed change in color or texture. A transparent grid containing 64 dots to the square inch was used to measure the extent of spoilage on each strawberry. Measurements on the first day indicated no spoilage in either sample. The second measurement, April 3, resulted in no significant difference (as evaluated using a unpaired t-test) in spoilage rates. However, significant differences of .0110, .0030, .0001, .0001, .0030 and .0003 were observed on April 5, 8, 10, 12, 14, and 16, respectively. On the final day of observation 8.3% of the irradiated and 79.2% of the nonirradiated strawberries were completely spoiled.

Wilson, M. A. and Aide, M., Department of Agriculture, Southeast Missouri State University. YIELD OF FALL PLANTED BROCCOLI AND CABBAGE AS INFLUENCED BY SEVERAL ROW COVERS. Studies on four row covers (spunbonded polyester, clear slitted, insolar slitted and VisPore®) were evaluated at Southeast Missouri State University farm, Cape Girardeau, Missouri, with 'Gourmet' cabbage and 'Packman' broccoli. However, row covers had significantly higher yield with broccoli for size and weight of heads ($P > .05$). Yields were higher with cabbage except for the clear slitted row cover, but the data was not significant. It may be suggested that three of the four row covers (except clear slitted) may be used for fall production of broccoli and cabbage in Southeast Missouri providing the growing season is long enough.

Atmospheric Sciences

Elkins, H. A., Zacher, C. A. and Moore, J. T., AERO Research, St. Louis, Missouri. SNOWFALL DOCUMENTATION RELATED TO THE STUDY OF MID-LATITUDE CYCLONES AND THUNDERSTORMS WITH SNOW. Snowfall documentation is proposed as a means to better understand mid-latitude cyclones and thunderstorms with snow (TS). When combined with other observational data snowfall types (crystal, aggregate or graupel) and their characteristics (size and degree of riming) can provide insight concerning both cyclone structure and cloud electrification. Describing synoptic and cloud physical environments has led to a new conceptual model of the cyclone. Snowfall types plotted with respect to the cyclone reveal an ordered structure. Similarly, study of TS has shown consistent tendencies with respect to its synoptic climatology environment. Profiles of equivalent potential temperature (θ_e) reveal characteristic regions of convective instability when TS is reported with height. The corresponding snowfall data has shown a preference for graupel production. The graupels' greater fall velocities help to increase charge separation necessary for lightning production. The preliminary investigation (1986-1988) has been followed by a field study from 1988-1990. The objective was to test the capability to collect a synoptic snowfall data in the St. Louis metro area. Kits developed for this study contained a snow board, 16 × magnifying glass and a reference guide with observation forms. Over 300 observations from 12 storms were collected.

Zacher, C. A., AERO Research. OCCURRENCE OF POSSIBLE SYSTEMATIC FILTERING ERROR DISTORTION OF ISOCERAUNIC LEVELS WITH LATITUDE. Technological means have greatly increased the ability to detect thunderstorms, e.g. self-actuated lightning counter coverage such as the LDIS System, which is fine for cloud-ground (cg) flashes however does miss inter-cloud (ic) and cloud-cloud (cc) flashes generally. Yet isoceraunic levels reflect integrated counts of all these forms - one thunder-day (td) being the accepted measure of ts frequency since 1893 in U.S. records and defined as any day one or more peals of thunder are heard in a 24 hr period by ground observer(s). So while cc and especially ic flashes represent a major component for studies in atmospheric electrical variation worldwide, this investigation shows that for several reasons, notably their acoustic signature and attenuation of some audible frequencies, confusion of single flashes with other sounds or masking by others, and the slow-fronted waveshapes (i.e. non-impulsive character vs. cg impulsive type discharges which contain return-strokes) leading to the sometimes soundless condition popularly called "heat lightning", all may contribute to systematic underrepresentation in td counts. This should hold for flash registration in the Tropics (indeed anywhere mT influence is felt) more strongly as cloud flashes increase with decreasing latitude.

Gultepe, I. and Rao, G. V., Department of Atmospheric Sciences, Colorado State University and Department of Earth and Atmospheric Sciences, St. Louis University. DISSIPATION RATE CALCULATION FROM AIRCRAFT MEASUREMENTS DURING FIRE - OCTOBER 19 CASE STUDY. Data for this study were collected from the NCAR King Air on 19 October 1986 during the FIRE (First International Satellite Cloud Climatology Regional Experiment) which took place over Wisconsin. One Hz measurements of the wind (u, v, and w) components from the constant altitude flight legs are used in the calculation of spectral turbulent kinetic energy (TKE). Dissipation rate ϵ of TKE plays an important role in the turbulent structure and maintenance of cirrus clouds. In this study, two different techniques are applied to obtain ϵ : (1) the spectral technique and (2) the isotropic technique. The first technique uses the fast Fourier transformation of measured parameters and the second technique, assuming isotropy, uses the shear characteristics of the wind components perpendicular to the aircraft path. Results show that ϵ is approximately $10^{-4} \text{ m}^2 \text{ s}^{-3}$ at about 8 km altitude in the cirrus and approximately $10^{-6} \text{ m}^2 \text{ s}^{-3}$ at about 7.6 km altitude in the clear air. Dissipation values from both techniques showed approximately similar values. These results are found to be comparable to those found in the earlier studies.

Moore, J. T. and Whistler, J. P., Department of Earth and Atmospheric Sciences, St. Louis University. RESEARCH ON ISENTROPIC POTENTIAL VORTICITY, TROPOPAUSE FOLDING AND CYCLOGENESIS. Recently, renewed attention has been given to the relationship of isentropic potential vorticity (IPV) and the process of tropopause folding to cyclogenesis. IPV is quasi-conserved on isentropic surfaces in the absence of diabatic and frictional effects. High values of IPV are often diagnosed as subsiding from the lower stratosphere into the troposphere during tropopause folding. An alternate way of viewing this process is through iso-potential vorticity surfaces which depict the variation of potential temperature (or pressure) on a surface of constant potential vorticity. Typically, a value of IPV equal to $2 \times 10^{-6} \text{ m}^2 \text{ K s}^{-1} \text{ kg}$ is used to depict the tropopause. Isentropic trajectory analysis and cross sections depicting ageostrophic vertical circulations help to document the IPV advection/tropopause folding process noted during cyclogenesis. These processes will be illustrated for cases of strong cyclogenesis associated with heavy snow events and severe thunderstorm activity.

Zacher, C. A., AERO Research. SIMULATION OF THE BEHAVIOR OF RARELY OBSERVED LIGHTNING PHENOMENA IN A PLASMA GENERATOR. Experimentation with each of two plasma generators has enabled replication, and confirmed visually, some very rare and/or obscure ionization processes insofar as similar full-scale phenomena are known, or have been hypothesized. Lightning-like channels stand out in regularly produced paths several cm. in length, arc between a ball electrode and a surrounding borosilicate glass sphere. Within, residence times, continuity and variation are all completely controllable by rheostat adjustment. Some analogs of lightning phenomena produced in the chambers include brush discharge, the pilot leader, forked channels with multiple terminals, and flashover. 'Steering' of the arc channels to other attach-points on the sphere is easily demonstrated, as is the influence of convection on more vigorous highly-ionized channels, and electrical repulsion, while on one of the generators the high-impulse electrode (ball) itself exhibits some of the characteristics attributed occasionally to ball-lightning. Caution must be applied in generalizing and drawing conclusions about the full-scale phenomena under different environmental conditions from these laboratory models however.

Trueblood, M. B., Cloud Physics Research Center, University of Missouri-Rolla. PRINCIPLES OF OPERATION OF CLOUD PHYSICS INSTRUMENTS, II: PARALLEL PLATE THERMAL DIFFUSION CHAMBERS. Over the past 30 years the continuous flow thermal diffusion chamber (CFD) has evolved from a somewhat crude, static device to a rather well developed one that serves as the central measurement instrument in many cloud physics laboratories. The historical development of the thermal diffusion chamber will be outlined bringing us up to the present model in the UMR laboratory. The strengths and weaknesses of the chamber at each of its levels of development will be discussed.

Recent experiments with the UMR CFD will be discussed. These include coagulation rate measurements (carbon aerosol and polystyrene latex spheres), the properties of laser dye aerosols used as tracers, and the generation and characterization of carbon aerosols.

Lin, Y. J. and Shen, H., St. Louis University. STRUCTURAL FEATURES OF A SQUALL LINE OVER THE TAIWAN STRAITS REVEALED BY DUAL-DOPPLER RADAR. In this study, structural features of a subtropical squall line, which occurred on 17 May 1987 over the Taiwan straits, were investigated using the dual-Doppler data collected during the Taiwan Area Mesoscale Experiment (TAMEX). Our emphasis is placed on the pre-squall and post-squall environmental conditions and the kinematic structure of a squall line in the convective region. Results show that many structural features of a subtropical squall line are similar to those for a fast-moving tropical squall line. A low-level jet (LLJ) associated with the frontal system provides the necessary strong shear at lower levels. On the front side of a squall line, the front-to-rear environmental flow prevails at all levels and is accompanied by the shallow rear-to-front flow on the back of the line. There are many individual cells embedded within the squall line. Relatively weak convective downdrafts occur between the cells and behind the main cells. The interaction between the convective updraft and downdraft plays an important role in maintaining the three-dimensional circulation within a squall line.

Karmini, M. and Coy, L., Department of Earth and Atmospheric Sciences, Saint Louis University. RADAR OBSERVATION OF WIND IN THE TROPICAL STRATOSPHERE. The purpose of this study is to investigate tropical stratosphere winds using recent radar wind data. The data were taken hourly, during the day, using the MST radar at Jicamarca, Peru ($12^{\circ}\text{S}, 77^{\circ}\text{W}$), from 20-26 June and 4-13 August, 1987. Data are presented as time-height sections, showing the wind variations. Clearly seen are the easterly and westerly winds of the quasi-biennial oscillation (QBO), and several wave motions on time scales of hours to days. These waves are believed to be important in producing the QBO.

Combined Biology, Oncology, Gerontology and Biomedical Sections

Radford, D. M., Department of Surgery, St. Louis University, **Ashley, S. A.**, Department of Surgery, Washington University, **Wells, S. A.**, Department of Surgery, Washington University and **Gerhard, D. S.**, Department of Genetics, Washington University. MOLECULAR ANALYSIS OF MEN-TUMORS. Using DNA-based polymorphisms, we have examined DNA from 12 separate tumors that arose in patients from 4 different families segregating Multiple Endocrine Neoplasia Type I (MEN-I). In kindred M all 5 tumors (parathyroid) examined showed a loss of chromosome 11 when compared to somatic DNA. By using probes for 9 loci distributed along the length of the chromosome, we determined that the whole chromosome was lost. In addition, we have typed the

rest of the kindreds for some of the RFLPs and have determined that the lost chromosome is the one transmitted from the unaffected parent. This result suggests that tumor progression depends on the loss of the normal allele. The examination of the other tumors (5 parathyroid and 2 pancreatic islet), also revealed a loss of the whole or a part of chromosome 11. Two tumors exhibited different deletions of the long arm. The common region of loss is between loci D11S288 and INT2, suggesting that the MEN-I gene resides there. These data confirm linkage analyses which identify the closest marker to the disease as being PYGM.

Corrigan, G., St. Louis University School of Medicine and the St. Louis Veterans Administration Medical Center. AN EDUCATIONAL EXERCISE IN GERIATRIC PATHOLOGY. A program is presented which organizes the pathology of ageing and senescence into a standardized set of objective test items with verification which is then followed by selective testing of pathologists from a randomly selected pool of items. A quadrennial certification program is demonstrated. Application to other disciplines is examined.

Vaccaro, S. A., Foster, L. S., and Lilly, W. W., Dept. of Biology, Southeast Missouri State University. COMPARISON OF ENZYME ACTIVITIES OF *SCHIZOPHYLLUM COMMUNE* UNDER CONTROL AND CADMIUM STRESS CONDITIONS. The wood-decaying basidiomycete *Schizophyllum commune* exhibits altered colony and hyphal morphology in response to Cd⁺² added to the growth medium. We have examined the effects of exogenous cadmium (13.7 ppm) on the activities and isozyme patterns of several hydrolytic enzyme systems in this fungus. Exposure to cadmium resulted in only a slight depression of the specific activities of phosphodiesterase, beta-N-acetylglucosaminidase and protease. Each of these activities showed an activity profile over a 2 to 6 day growth period which was similar to controls. In contrast, beta-glucosidase and acid phosphatase exhibited activity profiles which differed markedly from controls. Native polyacrylamide gel electrophoresis of extracts showed no differences in isozymes of acid phosphatase, beta-glucosidase or esterase between control and cadmium stressed colonies.

Foster, L. S. and Lilly, W. W., Department of Biology, Southeast Missouri State University. ELECTROPHORETIC CHARACTERIZATION OF ESTERASE ISOZYMES PRODUCED BY *SCHIZOPHYLLUM COMMUNE*. Wood-decaying fungi, such as *Schizophyllum commune*, produce a variety of hydrolytic enzymes which are active at acid pH. These enzymes, which are suspected to be located in lysosomes, likely play a role in metabolism of exogenously located nutrients and in normal autolytic processes. Among the most diverse and least understood of these hydrolases are non-specific esterases. A minimum of ten esterase isozymes, having relative mobilities ranging from 0.16 to 0.99 in native (7.5% T) polyacrylamide gels, is produced by exponentially growing colonies of *Schizophyllum*. Mobilities of these isozymes in gels of various concentrations suggest that they exist in four sets of molecules having similar molecular weights. Within each of these sets the isozymes vary on the basis of charge. In addition, it is apparent from relative staining intensity that either the isozymes exist in different concentrations in the colony or that they differ in affinity for the substrate alpha-naphthyl acetate.

Higgins, S. M. and Lilly, W. W., Department of Biology, Southeast Missouri State University. ISOLATION AND CHARACTERIZATION OF mRNA'S FROM CONTROL AND NITROGEN-STARVED COLONIES OF *SCHIZOPHYLLUM COMMUNE*. The physiology of exponentially growing colonies of *Schizophyllum commune* is markedly altered upon transfer to nitrogen-deficient media. Among the changes which occur are enhanced translocation of amino acid pools, derepression of general proteolysis, derepression of specific proteolytic systems and increased autolytic activity. Analysis of differential gene activity as a part of this response requires isolation of mRNAs and characterization of their products. mRNA (as poly-(A)+RNA) has been isolated from control and nitrogen-stressed colonies by hot phenol extraction of total RNA followed by affinity separation on oligo-(dT) cellulose. *In vitro* translation of mRNA isolated from control colonies shows a wide diversity of products. In contrast, *in vitro* translation products of nitrogen-stressed colonies are considerably reduced in number and concentration.

Katti, P., Manalu, W., Johnson, H. D., and Bell, B., Dept. Animal Sci., University of Missouri-Columbia. PROLACTIN AND GROWTH HORMONE RESPONSES OF AFRICAN PYGMY GOATS TO SHORT TERM COLD AND HEAT EXPOSURE. The objective of this investigation was to measure the effects of 2 cold environments (C₁, 5°C, 95%rh, and C₂, 10°C, 70%rh) and 3 Hot environments (H₁, 30°C, 90%rh, H₂, 30°C, 20%rh, H₃, 35°C, 68%rh) vs Thermoneutral (TN, 20°C, 38%rh) on nonlactating goats. A switch-back sequence was as follows: Tn, H₁, TN, C₁, Tn, C₂, TN, H₂, TN and H₃ with 7 days exposure at all treatments. Blood samples were taken on day 2, 4, 6 and 7 of each treatment. Prolactin (PRL) decreased from 14.3 ng/ml at TN to 3.4 and 2.4 respectively at C₁ and C₂, and increased to 80, 39, 90 ng/ml at H₁, H₂ and H₃ respectively. Growth Hormone (1.3 ng/ml) only changed when exposed to H₃. Cortisol (1.5 ng/ml) increased moderately at all cold and hot exposures. Triiodothyronine (T₃) at TN (1.5 ng/ml) increased at C₁ to 1.8 ng/ml and decreased during H₁, H₂ and H₃ to 0.9, 0.9, and 0.7 ng/ml. Rectal temperatures and Respiratory rates increased at H₁, H₂ and H₃. Plasma Prl, Cortisol and T₃ are good indicators of short term Cold and Heat Stress in the Pygmy Goat with Prolactin being the most sensitive indicator.

Froemdsorf, D. E. and Gathman, A. C., Biology Department, Southeast Missouri State University. COLCHICINE TREATMENT OF *CUPHEA LANCEOLATA* AITON. Tetraploid *Cuphea* plants would be desirable for studies of chromosome affinities within the genus. In an effort to induce chromosome doubling, we treated seed and seedlings of *Cuphea lanceolata* with 0%, 0.05%, 0.1%, 0.2%, 0.4%, and 1.0% aqueous colchicine solutions for 8 hours. Survival rates for seeds one week after treatment were 75.6%, 83.6%, 81.2%, 81.2%, 83.2%, and 0% respectively. Fibrous root development occurred only in the 0%, 0.05%, and 0.1% treatments. Meiotic chromosome analysis of buds from the resulting plants showed only diploids. Treated seedlings did not survive any colchicine treatment. We suggest that shoot treatment of rooted cuttings may be more effective.

Chemistry

Nasrallah, E. T., Department of Chemistry, University of Missouri-Kansas City. POLYMERIC N-OXIDES. A review of the past research on polyvinylpyridine N-oxides is presented. Polymeric N-oxides seem to have some important applications both in industrial and biological areas. The incorporation of an N-oxide group into a polymer chain increases the water-solubility, hydrogen bonding, and metal chelation properties. A cross-linked polymer carrying both N-oxidized pyridines and N-alkylated pyridines form a new class of ion-exchange resins. By varying the degree of cross-linking (varying the hydrophobic property) and by varying the degree of N-oxidation (varying the hydrophilic property) a material of the desirable degree of swellability, density, pore size and toughness can be obtained. Recently, copolymers of vinylpyridines are being investigated for film preparations in pharmaceutical applications.

Wilbur, J. M., Jr., Department of Chemistry, Southwest Missouri State University. ZWITTERIONIC POLYMERIZATION. New 1:1 alternating copolymers of 2-ethyl-2-oxazoline (EtOXZ) with ethynyl phenyl ketone (EPK) and ethynyl phenyl sulfone (EPS) were synthesized and characterized by IR, ^1H NMR, and ^{13}C NMR spectroscopy. The copolymerizations were conducted by reaction of equimolar quantities of EtOXZ and EPK or EPS in polar solvents such as acetonitrile, N,N-dimethylformamide, and N,N-dimethylacetamide at temperatures ranging from 0° to 130°C in a N_2 atmosphere. This alternating polymerization occurs, without added initiator, between a nucleophilic monomer (M_N) and an electrophilic one (M_E) by a zwitterionic mechanism.

Mohite, S. S., Center for Scientific Research, Southwest Missouri State University, **Gibbons, J. J.**, Dayco Technical Center. THERMAL PROPERTIES OF NEW DISILOXANE-CONTAINING ARAMIDS. Due to the continued promise and use of high-modulus fibers, researchers have studied the aramids extensively. Twelve new disiloxane-containing aramids were synthesized by low temperature interfacial polycondensation technique. In order to evaluate the effect of diamine and diacid chloride structure on the thermal properties of aramids, the thermo-oxidative degradation was studied by dynamic thermogravimetry. Thermogravimetric analysis, differential thermal analysis and derivative thermogravimetry were made simultaneously in air over the range of $25\text{-}900^\circ\text{C}$ at a heating rate of $10^\circ\text{C}/\text{min}$. The heat resistance temperature of these polymers was in the range of 360 to 410°C . The decomposition kinetic parameters such as an activation energy (E^*) and frequency factor (A) were determined from original thermograms. The E^* values varied between $129.8 - 166.6$ KJ/mole and those of A between $5.884 \times 10^8 - 1.978 \times 10^{10}$. The thermal properties will be discussed in relation to the polymer structure.

Thompson, C. C. and Thompson, S. E., Department of Chemistry, Southwest Missouri State University. A SIMPLE QUANTITATIVE APPROACH TO LOCALIZED CHEMICAL BONDS. Most introductory treatments of chemical bonding, especially molecular orbital theory, are highly qualitative in nature. For example, bonding and antibonding orbitals are typically presented without proof and are then used to rationalize bond energies, bond orders and related properties. This paper describes a simple multi-level quantitative approach to localized two-electron interactions for both homonuclear and heteronuclear bonds. At the general chemistry level, meaningful bond energies (within 5 - 10 percent of experimental values) and electron distributions can be computed using three empirical parameters and simple algebraic manipulations. Building on this introductory framework, and without having to "unlearn" previous material, students can proceed to more advanced topics such as the LCAO formalism, the choice of basis functions, and computational strategies for evaluating overlap, coulomb and resonance integrals.

Guimon, R. K., Lofgren, G. E. and Sears, D. W. G., Department of Natural Science, Missouri Baptist College, THERMOLUMINESCENCE PROPERTIES OF SYNTHETIC FELDSPARS: IMPLICATIONS FOR CHONDRITE THERMAL HISTORIES. Several classes of meteorites show systematic variations in their thermoluminescence (TL) properties which are related to metamorphic or shock histories (1-3). These variations are usually associated with differences in the amount and nature of feldspar. Annealing experiments have proved of considerable value in interpreting these variations (2-5). Changes in TL sensitivity are known to be caused by the formation or destruction of feldspar and changes in the TL peak temperature and width are related to the relative proportions of feldspar in the high (disordered) and low (ordered) forms. A complete quantitative interpretation of such meteorite data is limited by uncertainties over the composition and history of their feldspar. We have studied the TL properties of feldspars synthesized from a gel using the methods of ref. 6. Our data suggest a strong temperature dependence on the form in which the feldspar exists, thus has palaeothermometry implications. 1. Sears et al. (1982) SCA 46, 2471; 2. Hasan et al. (1986) GCA 50, 1031; 4. Guimon et al. (1985) GCA 49, 1515-5. Guimon et al. (1986) GCA, submitted; 6. Luth & Ingamells (1965) Amer. Min. 50, 255.

Williams, S., Vollmer, D. and Zweerink, G., Department of Chemistry, Missouri Western State College. ANALYSIS OF FUNGICIDES IN LEATHER. The analysis of fungicides such as busan and amical has involved long, cumbersome and incomplete extraction processes. To overcome these shortcomings a thermal pyrolysis gas chromatographic analysis has been developed. The new analysis has the advantages of the use of smaller samples and quickness. A study of the distribution of the fungicides in leather as a function of thickness has been made possible by the use of smaller samples. This presentation gives the development of the analysis and the distribution of the fungicide in the leather.

Fujiwara, H., Kotyik, J. J. and Sharp, C. R., Life Sciences Research Center, Monsanto Co. NMR STUDIES ON THE IMMUNOCHEMISTRY OF COMMERCIAL HERBICIDES. We have been working on development of useful detection methods for hapten-protein binding using known conjugates. To characterize binding of hapten-protein

conjugates for immunochemistry of alachlor and glyphosate, ^{13}C NMR and ^1H NMR methods are of interest. The ^{13}C indirect-detection NMR techniques such as two dimensional (2D) proton-detected heteronuclear multiple-quantum coherence (HMQC) and proton detected heteronuclear multiple-bond connectivity (HMBC) are particularly useful to determine one-bond and multiple-bond correlations between protons and ^{13}C elements in specifically ^{13}C enriched hapten-protein conjugates. These methods allow us to characterize chemical binding of a properly ^{13}C labeled hapten attached to protein by observing coupling between the ^{13}C isotope and protons in the conjugate. We have discovered that HMQC and HMBC techniques are extremely useful to determine unambiguously hapten-protein covalent bonds for extremely large molecules using specific ^{13}C labeling in alachlor portion. These techniques offer a great applicability to the other class of haptens such as glyphosate and its analogs bound to proteins if each of haptens is properly labeled with ^{13}C isotope.

Sheets, R. W. and Thompson, C. C., Department of Chemistry, Southwest Missouri State University. ALPHA-RADIOACTIVITY OF TOTAL SUSPENDED PARTICULATE SAMPLES. When large volumes of air are drawn through a Hi-Vol sampler to collect total suspended particulates (TSP), atmospheric radioactivity is also collected on the filter and can be monitored by alpha scintillation counting. Exponential alpha decay of the sample during the first two hours after end of sampling is mostly due to short-lived progeny of radon (polonium-218 and polonium-214). Exponential alpha decay from about 5 to 100 hours is due to thoron progeny (bismuth-212 and polonium-212). After about 150 hours, alpha activity of the sample begins to increase at a rate of about 0.03 pCi/day due to growing in of the alpha-emitting radon daughter polonium 210. Measurement of alpha activity during the period 5 to 100 hours after end of sampling can be used to determine atmospheric lead-212 concentration.

Anderson, H. D., Stephens College and University of Missouri Research Reactor (MURR) and **Morris, J. S.**, MURR and UMC-Chemistry Department. CUTTER CONTAMINATION OF TOENAILS IN DIETARY STUDIES. Contamination of toenails used in dietary studies, such as the Nurses' Health Study, have been a concern of the authors for some time. Concern for the possible metallic contamination by the cutting instrument used by the cohorts resulted in the following neutron activation analysis experiments. First an off-the-shelf clipper was irradiated and used to cut cleaned polyethylene sheeting of a hardness similar to toenails. Any radioactivity measured on the polyethylene had to come from the clippers. A variation of this was then successfully tried in which the clippings were made first and then analyzed via NAA. The latter experiment was then repeated, but with the clippings undergoing an ultrasonic cleaning prior to irradiation. Contamination found to be present can be effectively removed in the cleaning procedure. Results will be discussed. This research was supported by NIH Grant No. R15 CA41999-01A2.

Computer Science

Osborne, L. J., Computer Science Department, Southwest Missouri State University. A COMPARISON OF TWO SIMULATED ANNEALING ALGORITHMS. The well-known Steiner Problem on Graphs is an NP-complete problem for which there are many heuristic and exact algorithms that are deterministic. In this study, a new approach to the directed version of this problem is made by applying the ideas of statistical mechanics through the use of the method of simulated annealing. A version of annealing is developed for the Directed Steiner Problem and compared by means of regression analysis with one of the best known general dynamic annealing schemes. Both methods gave near-optimum answers and the level of accuracy was independent of the problem size. There seems to be a tradeoff in using one or the other technique. The general dynamic cooling schedule appears to be faster, but the tailored schedule gives slightly more accurate answers. Moreover, the distribution of first occurrences of near-optimum answers approximated the exponential for both methods.

Black, J. D. and R. Boehning, Department of Computer Science, Southwest Missouri State University. ARTIFICIAL NEURAL NETWORKS (ANN): AN INTRODUCTION. The purpose of this study was to develop a set of ANSI-C source code toolboxes which would serve as a starting point in the development of a set of combined undergraduate Computer Science and Psychology courses. The project begins with the introduction of single-layer static networks, and proceeds with the development of learning algorithms to be used in ADALINES, MADALINES, and multiple-layer backpropagation networks. A three layer (64 input nodes, 70 middle nodes, 8 output nodes) backpropagation network has proven capable of "learning" to recognize 94 8*8 OCR-style character matrices in 8075 training iterations.

Naugler, David R., Department of Computer Science, Southeast Missouri State University. A GRAPHICS CONJECTURE ON SPHERES SOLVED. Dr. Alan Schoen, a graphics expert at SIUC, conjectured the following: if $n + 1$ points ($n \geq 1$) are selected randomly on the unit sphere in Euclidean n space, then the probability that the tetrahedron with these points as vertices contains the origin is $1/2^n$. This is trivial if $n = 1$, can be proved directly if $n = 2$ and is empirically true if $n = 3$. The conjecture is shown to be misleadingly posed and to not really make sense in general. The conjecture is recast, and the recast result is proved. This result shows that the conjecture is "true". A set of $n + 1$ pairs of antipodal points on the unit sphere in n space is said to be independent if each of the sets of $n + 1$ points obtained by selecting one point from each pair forms an independent set of points. Theorem: Select any independent set of $n + 1$ pairs of antipodal points on the unit sphere in euclidean n space. Select one of each of the pairs randomly forming a set P of n distinct points on the sphere. Then the probability that the convex hull of P contains the origin is $1 / 2^n$.

Ford, C. E., Department of Mathematics and Computer Science, Saint Louis University. THE RELIGIOUS ROOTS OF MODERN SOVIET MATHEMATICS. Many modern Soviet achievements in science, usually attributed

to the 1917 revolution, are currently being shown to have roots in the Christian culture of pre-revolutionary Russia. Nothing better illustrates this than the career of the Russian Orthodox priest Fr. Pavel Florensky (1882 - 1937), philosopher and theologian, art theorist and mathematician, engineer and inventor. Florensky enrolled as a student in mathematics and physics at Moscow University at the beginning of this century. He played a key role in the early history of the Moscow school of mathematics, shaping the direction of its research. He gave up a promising career in mathematics to pursue a career in theology and became a major figure in the Russian religious-philosophical renaissance of the early twentieth century. Forced to abandon his career in theology after the revolution of 1917, he made many contributions to science and technology in the Soviet Union. He continued his scientific work even after his arrest in 1933, right up to his execution in 1937. Among those destroyed after the revolution who are being rediscovered in the Soviet Union today, none is more prominent than Pavel Florensky.

Salehnia, A. R., Department of Computer Science, South Dakota State University, and Pournaghshband, Hassan. Department of Mathematics and Computer Science, University of Missouri-St. Louis. A SYSTEMATIC APPROACH TO MATCHING QUERY LANGUAGES WITH THE USER TYPES. A major activity in database research and development has been the formulation of query languages. Considering the wide variety of query languages developed, and different classes of users using them, much work remains to be done to appropriately match query languages with classes of users. It is the purpose of this work to establish a framework for choosing and recommending a database query language category for particular user classes, and to give an extensive analysis of "optimal" query language characteristics. Preliminary work towards establishing this framework has been done by other researchers. Due to the fact that many crucial issues have been left open, these preliminary results can be used for preselecting a query language for a given class of users.

Conservation and Environmental Science

Ashley, David C., Biology Department, Missouri Western State College and **Figg, Dennis E.**, Natural History Section, Missouri Department of Conservation. PRELIMINARY STUDIES ON THE OCCURRENCE OF THE PRAIRIE WHITE FRINGED ORCHID AND IT'S POSSIBLE HAWKMOTH POLLINATORS AT TARKIO PRAIRIE. A study was initiated in the spring of 1989 to determine the status of a prairie orchid (*Platanthera praeclara*) which is listed as an endangered species in Missouri. MDC records allowed us to locate the specific sites where 14 individual stems of *P. praeclara* had been seen as recently as 1987. No orchids were observed (presumably due to drought) during nine visits to the prairie from May 18 to August 26. Hawkmoths (Sphingidae) attracted to lights were collected and identified to determine the occurrence of potential pollinators at Tarkio Prairie. Eleven species of hawkmoths were collected during four visits: *Ceratomia amyntor*, *C. hageni*, *C. undulosa*, *Darapsa myron*, *Loathoe juglandis*, *Manduca quinquemaculata*, *M. sexta*, *Paonias excaecatus*, *P. myops*, *Pachysphinx modesta*, and *Smerinthus jamaicensis*. This study was supported by the MDC Natural History Small Grant Program and the Missouri Western State College Foundation, Inc.

Vangilder, L. D. and Sheriff, S. L., Missouri Department of Conservation. SURVIVAL ESTIMATION WHEN FATES OF SOME ANIMALS ARE UNKNOWN. MICROMORT, a computer program based on a modified Mayfield method, is being used to estimate survival rates from radio-telemetry studies (Heisey and Fuller 1985). Estimates of survival are based on the number of deaths and the number of radio-days during a period of interest. In many studies, the radio-transmitter signals from a number of animals are lost before the end of the period, and the fate (alive or dead) of the animals is unknown. Monte Carlo simulations were used to examine 4 ways of treating the data from animals whose fates were unknown (censored animals). The 4 ways were to: (1) assume all censored animals died on the day radio contact was lost, (2) assume all censored animals lived through the period of interest after radio contact was lost, (3) exclude all radio-days for censored animals from the analysis, and (4) include radio-days for censored animals to the time of signal loss. We evaluated the performance of each of the 4 ways of handling censored animals by 3 criteria: (1) bias, (2) mean square error, and (3) the number of 95% confidence intervals that encompassed the true survival value. The results indicated that including radio-days for censored animals (method 4) provided the best estimates of survival.

Blue, J. K. and Mills, S. H., Department of Biology, Central Missouri State University. SEASONAL VARIATION IN TEMPERATURE REGULATORY RESPONSES IN A HIBERNATOR (*SPERMOPHILUS TRI-DECEMLINEATUS*). Ten ground squirrels were stimulated by a series of temperature changes before, during, and after hibernation. Temperature regulatory responses such as core temperature, body movement, behavior, posture, and piloerection were evaluated as the animals were exposed to 20 minute intervals of 10C, 15C, 20C, and 25C ambient temperatures during heating and cooling sequence. Core temperature monitored via implanted FM transmitters differed significantly from pre-hibernation to post-hibernation tests ($p < .05$). Excluding two ground squirrels which did not hibernate, no differences between individuals were observed ($p < .05$). Core temperature responded differently over time following ambient temperature changes from pre-hibernation to post-hibernation studies ($p < .05$). These responses also differed for the different temperature changes ($p < .05$). Behavior, posture, and piloerection were evaluated with a videotape monitoring system. Body movement responses to ambient temperatures differed significantly from pre-hibernation to post-hibernation ($p < .05$).

Fox, H. A., Department of Geology, University of South Carolina. **Tibbs, N. H.**, Department of Earth Sciences, Southeast Missouri State University. REGULATORY REQUIREMENTS FOR CLOSING THE CAPE GIRARDEAU MUNICIPAL LANDFILL. The Cape Girardeau Municipal Landfill has reached capacity and must be closed in the

near future. New EPA regulations (40 CFR, Part 258) promulgated in February, 1990 will regulate that closure. Our field investigations in Spring, 1989 showed that this site has ineffectual leachate collection and runoff control. Leachate analyses with a LaMotte Pollution Detection Kit showed hardness, chlorides, calcium, magnesium, total dissolved solids, alkalinity, ammonia, and possibly cyanide exceeded background levels. Field investigations also revealed that there is no valid methane monitoring or venting program at this site. Published reports cite groundwater contamination and an incomplete knowledge of groundwater movement. EPA regulations clearly delineate the actions necessary to remediate these deficiencies and bring this site into compliance.

Mantei, Erwin J., Geosciences Department. **Foster, Melvin V.**, Computer Science Department, Southwest Missouri State University. HEAVY METAL CONTENT IN THE STREAM SEDIMENTS ADJACENT TO AN INDUSTRIALIZED REGION AND TWO LARGE CLOSED SANITARY LANDFILL AREAS. The content of 11 heavy metals (Cu, Pb, Zn, Cd, Ag, Co, Ni, Mn, Fe, Cr, Ba) in six geochemical phases (exchangeable cations, carbonate, Mn oxide and hydroxides, Fe oxides and hydroxides, organics, and residual fraction) was determined in the stream sediments from the Sac River located north of Springfield, Mo. The 170-200 mesh portion of each of the 46 samples collected at a 0.4 kilometer interval along the path of the stream was used for this study. All metal quantities were determined by atomic absorption techniques and statistical methods were applied to analyze the data.

The results indicate that various metals would concentrate in different phases. The quantities of some metals were higher in the more populated portions of the study area. Higher quantities of some of the metals were observed in the vicinity of each landfill site. A single nitric extraction method of a second portion of each sample showed similar results.

The authors feel this type of study can be used to help monitor the heavy metal emissions from industrialized and landfill areas.

Rhodes, R. G. and Thompson, C. C., Center for Scientific Research and Services, Southwest Missouri State University. THE OCCURRENCE OF ALGAE AND CHEMICAL CHARACTERISTICS IN WATER SAMPLES TAKEN FROM WELLS IN GREENE CO. AND ADJACENT COUNTIES IN MISSOURI. Wells in Greene Co., Missouri occasionally yield water that is turbid, in some cases discolored, and in other cases bad tasting. While some of these characteristics are due to the chemical properties of the groundwater, the biological parameters have generally been ignored, especially the presence of algae. In the present study water samples drawn from area wells were inoculated into media designed to stimulate algae growth. Of 23 wells algae were found in 8 wells. The majority of the algae were members of the Division Chlorophyta. The predominate taxa were *Chlorella* and *Ankistrodesmus*. Other taxa included *Scenedesmus*, *Chlorococcum*, and *Anabaena*. There appeared to be no correlation of the chemical characteristics of the well water that yielded algae. Supported by USDI GS 14-08-0001-G1572.

Spratt, Henry G., Jr., Southeast Missouri State University. **Howes, Brian L.**, Woods Hole Oceanographic Institute. SALT MARSH SULFUR CYCLING IN HIGH-MARSH SEDIMENTS EXPERIMENTALLY ALTERED TO REGULATE INTERSTITIAL WATER MOVEMENT. Sulfur cycling was investigated in sediments from salt marshes in Tuckerton, NJ and Great Sippewissett marsh, Cape Cod, MA. Interstitial water movement in high-marsh experimental plots was accelerated by either enhanced drainage or by stimulation of plant evapotranspiration, and inhibited by surface flooding. Sulfate reduction rates at 2 to 4 cm depth were elevated by nearly 2 fold in plots with enhanced drainage compared with control plots (1.0 to $2.25 \text{ umol}\cdot\text{cm}^{-3}\cdot\text{da}^{-1}$). Sulfur pools, including H_2S , FeS_2 , S^0 , and SO_4^{2-} , were greatest in sediments of the flooded plots and lowest in the drained plots. Acid volatile sulfur pools (H_2S and FeS) in sediments from drained plots were similar to or slightly higher than in control plots, although soluble sulfides were virtually absent in the drained plots. If we assume that H_2S , FeS , and S^0 turnover more rapidly than FeS_2 , then as much as 95% of these pools can be recycled per day in plots with enhanced interstitial water movement.

Engineering

Kim, Sung-Soo, Intelligent Systems Center, University of Missouri-Rolla. PATTERN RECOGNITION WITH THE CROSS-CORRELATION OF DIGITAL SIGNALS EXTRACTED FROM OBJECTS. In previous studies, many different methods have been developed in order to create a proper form of information for pattern recognition. In the two dimensional pattern, the main concern is how the recognition process can be invariant on the shifted, scaled, and rotated patterns. In order to solve this problem, an algorithm has been developed in the way of extracting critical information from patterns. The algorithm possesses a particular characteristic of being invariant on the scale, shift, and rotation of the patterns. The digitized images have been changed to binary patterns by choosing a proper threshold for individual patterns and the boundaries of patterns have been transformed into a digital signal for each of them. This paradigm extracts information concerning the corner, line, and curves of patterns. Each pattern shows a unique digital signal which is independent of the size, position, and rotation. Also, a cross-correlation between a learned pattern and a problem pattern has been extracted in order to find the degree of rotation. The advantage of this algorithm is that the information from cross-correlation can provide much critical information in many application.

Kotob, M. and Bourquin, J. J., Intelligent Systems Center, University of Missouri-Rolla. CHARACTER RECOGNITION USING NEURAL NETWORKS, A REVIEW. Image recognition on computers is a time consuming

process. It requires a tremendous amount of calculation to be able to recognize a simple shape. Character recognition is a subset of the pattern recognition problem. Neural Networks (NNs) is an important field that may make this job easier. This study is a review of many efforts in the area of character recognition using NNs. Some papers are to recognize printed characters or numerals others recognize handwritten numerals. It will be seen that the NN replaces one or more phase(s) of the traditional image recognition approaches. As a result, you can see that the key factor of the solution to the character recognition problem involves data representation issues (e.g. pixel vs. feature presentations.) This is as important as data manipulation (e.g. NN vs. symbolic algorithm.)

Exercise Physiology

LaFontaine, Tom and Thacker, Greg. Boone Hospital Center Cardiovascular Rehabilitation Program and the Missouri Heart Institute at Boone Hospital. THE PREVALENCE OF LOW HDL'S IN THE PRESENCE OF DESIRABLE CHOLESTEROL LEVELS (below 200 mgs/dl) IN THE BLOOD OF PATIENTS WITH CORONARY ARTERY DISEASE. Blood lipids were reviewed in 90 consecutive patients with CAD. Sixty-one had had CABGS, 21 had had PTCA, and 8 had angiographically documented CAD and were being treated with aggressive risk factor reduction only. There were 8 (9%) females and 82 (91%) males. Means, standard deviations, & ranges for age, ejection fraction, total cholesterol, HDL's, & TC/HDL are below:

Variable	Mean	Std	Range
Age (yrs)	61	10.1	32-81
Ejection Fraction	55.8	14.8	24-81
Total Cholesterol	211	45.4	125-336
HDL-Cholesterol	30.3	7.4	16-53
TC/HDL ratio	7.2	2.1	4.4-15.3

Thirty-five (39%) patients had a desirable total cholesterol but an HDL of below 35 mgs/dl. This report emphasizes the importance of HDL-cholesterol in the risk of the development and progression of atherosclerosis (CAD).

Geography

Salter, C. L., Department of Geography, University of Missouri-Columbia. THE CYCLES OF TRUTH IN CHINESE AGRICULTURAL REPORTAGE: THE CASE OF DAZHAI. For a decade and a half, beginning in 1964, the North Chinese village of Dazhai was heralded as China's greatest agricultural phenomenon. This village of fewer than 500 people shone as a beacon to hundreds of millions of Chinese who were seeking guidance in self-reliance and development. In the last decade, considerable new information on Dazhai has emerged and these data help to make this village serve as a model for the study of the cycles of truth in China's presentation of itself to the West.

Meserve, Peter H., Department of Geology and Geography, Northwest Missouri State University. THE MISSOURI/NEBRASKA BOUNDARY DISPUTE: PRIVATE AND PUBLIC DIMENSIONS. Disputed state boundaries strongly impact bordering land-owners and governments since local taxation, ownership records and administration are in dispute. Along the Missouri/Nebraska border, meandering (avulsion) of the Missouri River at the turn of this century resulted in several thousand acres being jointly claimed by Otoe County, Nebraska, and Atchinson County, Missouri. Thirty years of court cases over property rights are tied to issues of state sovereignty and duration of ownership. Legislative efforts are now underway to resolve these disputes by relocating the boundary to the thalweg of the stabilized Missouri River channel. The proposed 'Missouri-Nebraska Boundary Compact' will not affect pending litigation but will henceforth define government ownership and authority.

Maxwell, D. T., Department of Geology and Geography, Northwest Missouri State University. WEATHERING EFFECTS OF YELLOWSTONE NATIONAL PARK FIRE OF 1988. The Yellowstone fire of 1988 provides an opportunity to observe what are normally slow and imperceptible weathering processes in an "accelerated" environment. A field study was conducted in August 1989 to examine the possible changes in rate or type of weathering resulting from extremely high temperature for a short period of time. At that time extensive rainfall had not yet occurred since the fire and much of the burned area showed little or no biological regrowth. Runoff and rill erosion were observable but poorly developed, probably because of lack of rain. Wind erosion was also occurring. Extensive weathering of rock boulders during the fire was indicated by the frequently occurring circle of flakes immediately surrounding many boulders. These flakes were usually 5-10 times longer in two dimensions than in the third and were invariably covered with soot on one side. In one boulder, 19 in. by 10 in., there were 79 flakes of this type. Mud flows occurred after early August when the rains finally came. Information collected during this study indicates surface weathering is accelerated by fires and extensive flaking of rock boulders results.

Schroeder, Walter A., Department of Geography, University of Missouri-Columbia. THE LEGACY OF COLONIAL GEOGRAPHY IN THE PRESENT LANDSCAPE OF ST. LOUIS. The organization of space by the Spanish government and landowners, mostly French, in the St. Louis area before 1803 has left a strong imprint on the urban landscape nearly two centuries later. The pattern of French-Spanish utilization of streams, lakes, prairies,

and marshes is still discernible. Large tracts, including commons and commonfields, kept geographically intact, translate into major parks and city subdivisions today. Radial roads from St. Louis continue as major routes. Above all, pre-American property lines are preserved indelibly in the irregular street pattern of St. Louis city and county.

Corcoran, W. T. and Johnson, E., Department of Geosciences, Southwest Missouri State University. A FEASIBILITY STUDY IN THE USE OF METEOROLOGICAL SATELLITE DATA FOR LAND COVER MAPPING OF MISSOURI. Building on recent research that illustrated the use of Advanced Very High Resolution Radiometer (AVHRR) data from meteorological satellites for the detection of broad-scale vegetation land cover types, this study assesses the feasibility of discerning general vegetation land cover types for Missouri. An AVHRR scene from 25 April, 1987 was acquired and used for this mapping. Selection of spectral bands and a transformed vegetation index was dictated by previous research. Filtering techniques were used on the data prior to classification in order to reduce the spatial complexity of land cover, and an unsupervised statistical classification was performed to develop homogeneous categories of land cover. These categories were compared to known broad-scale distribution of vegetation and a high degree of visual association was noted, especially in the Bootheel, Ozarks, and general floodplain areas. From this high degree of association for the April scene, an integrated data set which includes several calendar dates should produce a good vegetation map for the State of Missouri.

Astroth, Joseph H., Jr., Department of Geography, University of Missouri-Columbia, **Burson, Ryan**, Missouri Office of Administration, and **Pepmiller, Craig E.**, Campus Computing Services, University of Missouri-Columbia. THE USEFULNESS OF A GEOGRAPHIC INFORMATION SYSTEM APPROACH TO LEGISLATIVE REDISTRICTING. The goal of this research effort is to demonstrate the usefulness of a geographic information system (GIS) to achieve a more efficient, cost effective, and accurate legislative redistricting process. Two significant changes since the last decennial census in 1980 have rendered a manual approach to redistricting impractical, if not impossible. The first change is related to the massive increase in data and geographic information that will be reported in the 1990 census. The entire state of Missouri will be subdivided into census blocks for the first time in 1990. This translates into detailed census information being reported for nearly a quarter of a million census blocks. The second change is the expanded emphasis on voting information. Missouri's participation in the Census Bureau's 1990 Census Redistricting Data Program will ensure that census counts and geography will be reported for the state's 4,500 voting precincts. As a result of these changes, voluminous election and census databases will have to be merged with the new and expanded census geography to provide the necessary support for a legally sound and efficient redistricting process. We believe that this can be effectively accomplished within a GIS environment.

Spooner, J. D., Department of Geography, University of Missouri-Columbia. AUTOMATED URBAN CHANGE DETECTION USING DIGITAL CARTOGRAPHIC AND SATELLITE IMAGE DATA. The objective of this study is to develop a digital procedure to detect and measure the amount of urban change that has occurred in an area since the publication of its corresponding 1:24,000-scale topographic map. Historically, change detection techniques have been dependent upon the visual comparison of high altitude aerial photographs to a corresponding topographic map. However, an experimental procedure recently investigated indicated that it may be possible to spectrally isolate and digitally quantify areas of urbanization in a merged file of satellite image and digitized topographic map data. While this procedure is not intended to specifically identify the nature of any change, it will provide a means of differentiating between areas which have or have not experienced change in order to determine appropriate revision strategies.

Fair, S. F. and Haithcoat, T. L., Department of Geography, University of Missouri-Columbia. DEVELOPING A GEOGRAPHIC INFORMATION SYSTEM FOR COUNTY-LEVEL EXTENSION AGRICULTURE. Livingston County in north Missouri has been chosen as the site for a pilot GIS. There are three problems associated with this project: 1. The selection of base maps which would provide the best resultant compilation maps. 2. How to best integrate this GIS with an existing computer-based Farm Decision Support System (FDSS) for Low Input Sustainable Agriculture (LISA). and 3. Evaluation criteria for deciding whether this is a valuable project for wider use. Results so far indicate that the GIS / LISA-FDSS will be a useful combination for locating specific fields and their owners (with the GIS) for consideration of alternative cropping systems (through the FDSS). The first cropping season available for implementation will be 1991.

Geology/Geophysics

Noweir, M. Atef and Grant, S. K., Department of Geology and Geophysics, University of Missouri-Rolla. BALANCED CROSS-SECTIONS IN LEADING-EDGE FOLDS IN OVERTHRUST BELTS. The Utah hingeline-thrust belt region occupies an elongate northeast-trending belt approximately 360 miles long by 75 miles wide. The area under study roughly corresponds to the eastern edge of the overthrust belt. It is a geologic transition zone between the Colorado Plateau province to the east and the Basin and Range province to the west. Balanced cross-sections are an important aid to understand overthrust-belt structures. Cross-sections are drawn at intervals over a distance of 30 miles, using balanced principles and kink style folding. Balancing techniques used to reconstruct cross-sections in the deformed, partially deformed and the undeformed states include maintaining consistent bed length, thickness and/or area. Of the three fundamental fault-fold types, evidence supports a modified fault-propagation fold as the principal mechanism in leading edge structures. Minor thrusts on limbs and in the axial zone can be added at the end of the balance exercise, without disturbing the major balancing effort.

Keller, D. J. and Bolter, E. A., Department of Geology and Geophysics, University of Missouri-Rolla. MINERALOGY AND CHEMISTRY OF A MISSOURI FLINT CLAY DEPOSIT. This research will examine the chemistry and mineralogy of a carbonaceous flint clay deposit in the Cheltenham Formation (Pennsylvanian) found in a typical "sink hole" type deposit in Gasconade County, Missouri. The samples were collected from a vertical profile at one to five feet intervals to a total depth of 53 feet. The purpose of the study is to correlate mineralogical and chemical properties of the samples with their refractory properties. The results will include the concentrations of minor elements (e.g. iron, manganese, potassium, sodium, calcium, lithium, fluorine) and organic carbon. In addition data from X-Ray Diffraction (XRD), Differential Thermal Analysis (DTA) and Scanning Electron Microscope (SEM) studies will be used to explain the changes in the refractory properties of the clay.

Bolter, Ernst and Vincent, Alex H., Department of Geology and Geophysics, University of Missouri-Rolla. HEAVY METAL-HUMIC ACID COMPLEX FORMATION IN A FOREST IN SE MISSOURI. The tendency of metals to form complexes with organic acids is well known. While a great deal of theoretical and experimental work has been done on this subject, few instances have been observed in nature. This study investigates a situation where very intensive heavy metal pollution from a smelter in southeast Missouri in a forested area with decaying leaf litter results in an ideal situation for heavy metal-humic acid complex formation. Previous unpublished results from our laboratory have shown that a high percentage of heavy metals are removed from the drainage basin in a complexed state. We are presently confirming this complexation, and are trying to correlate the degree of complexation in the stream waters with parameters such as precipitation and distance from the smelter.

Howard, John T., Department of Earth Sciences, Southeast Missouri State University and Southern Clay Division of Edward Lowe Industries, Inc. GEOCHEMICAL FILTRATION AND TREATMENT OF ACID MINE DRAINAGE. The technology developed by the coal industry for treatment of acid mine drainage can now be applied to acidic drainage created by clay producers in West Tennessee. Development of a high CaCO₃ limestone (L.S.) filter in an oxygen-deficient environment allows for buffering of acidic water. Upon release from the filter, iron is oxidized and deposited into a wetland structure. Preliminary water sampling and analyses indicate a tenfold drop in the iron concentration after buffering and settlement into the wetland system. pH determinations have resulted in a 1.0 to 1.5 unit increase in alkalinity over a two month period.

Hagni, R. D., Department of Geology and Geophysics, University of Missouri-Rolla. THE USE OF DARK FIELD IN ORE MICROSCOPY AND PETROGRAPHY. The use of dark field has been neglected in ore microscopy and petrography. Dark field reflected light microscopy has been found to constitute a valuable ancillary technique in the ore microscopy laboratory at the University of Missouri-Rolla to detect and accentuate several properties of ore minerals in polished sections. It is especially useful to enhance the internal reflections in many ore minerals, such as sphalerite, hematite, anatase, cinnabar, and orpiment, even in cases where those reflections are weak or absent under conventional bright field reflected light microscopy. Internal textures, such as fine-grained bands within massive sphalerite, are readily distinguished under dark field. The colors of internal reflections under dark field are darker and more distinctive than those shown under bright field for many ore minerals and those colors may form an additional property for the identification of those minerals. Many of the common ore minerals, such as pyrite, galena, and sphalerite, can be easily recognized in covered thin sections by dark field microscopy.

Nold, John L. and Dudley, Mark, Dept. of Earth Science, Central Missouri State University. MINERALOGICAL AND TEXTURAL STUDIES OF THE PILOT KNOB MAGNETITE DEPOSIT, IRON CO., MISSOURI. Textural and mineralogical studies of thin sections from the Pilot Knob Magnetite deposit indicate that late-stage minerals were deposited in interstices of breccias composed mainly of fragments of two different types of iron ores: 1) magnetite-rich ores with igneous textures, apparently originating as a magnetite rhyolite "ore magma" intrusion, and 2) hematite-magnetite-rich rhyolite lapilli tuff, apparently having originated by partial replacement of the tuff by iron minerals. The iron oxide-rich breccia fragments are angular and unaltered, apparently having been little-affected by the hydrothermal activity during open-space filling. Descriptions in the literature of inclusions of the disseminated tuffaceous ores within the more massive igneous-appearing ores indicate that the latter ores are younger. The hydrothermal replacement of the tuffs by magnetite and hematite apparently occurred very early in the deposit, and was followed by the intrusion of the magnetite rhyolite "ore magma". Brecciation then provided open space for deposition of late-stage minerals.

Fraunfelder, G. H., Department of Geology, Southern Illinois University at Carbondale. ICHNOFOSSILS FROM THE AUX VASES SANDSTONE (MISSISSIPPIAN) IN EASTERN MISSOURI AND SOUTHERN ILLINOIS. This investigation is part of an ongoing study of the ichnofauna of the Aux Vases Sandstone. Ichnofossils were collected from the type section of the Aux Vases near the mouth of River Aux Vases in Ste. Genevieve County, Missouri, and from a quarry one-half mile south of Shetlerville in Hardin County, Illinois. This ichnofauna is dominated by horizontal traces preserved in convex hyporelief. These traces exhibit behavioral evidence for grazing, *Torowangea*; crawling, *Palaephycus*; feeding, "stuffed" burrows; resting, *Lockeia*; dwelling construction, *Skolithos*; and of coprolitic material, castings and fecal pellets. The most common ichnofossils present are *Palaephycus* and *Torowangea*. No invertebrate fossils were found in association with the ichnofossils. The beds in which the ichnofossils occur at Aux Vases type section consist of white, tan-weathering, fine-grained quartzose sandstones that are interbedded with light green mudstones. Near Shetlerville, the ichnofossil-bearing beds are medium green-colored, fine-grained, quartzose sandstones. At both localities the beds are extensively rippled and mud-cracked. These beds have been interpreted to be mixed flat and sand flat deposits, respectively. The ichnofossils, in general, confirm this interpretation.

Stinchcomb, B. L., Department of Geology, St. Louis Community College at Florissant Valley. UPPER CRETACEOUS ANGIOSPERM COMPRESSIONS FROM MARBLE HILL, BOLLINGER CO., MO. Excavations for a highway 34 bypass around Marble Hill, Missouri in 1975 exposed a complex of grey and pink plastic clays, lignites and gravels between large boulders of mid Paleozoic limestone. Laminated grey clays at the northwest part of the cut yielded well preserved leaves of angiosperms of several genera. Represented in the small collection obtained are compressions of fig, similar to *Ficus tennesseensis* Berry, *Banksia* sp. and *Apocynophyllum* cf. *A. giganteum*. Leaf compressions similar to these are known from the Upper Cretaceous Ripley Group and from the lower Eocene Wilcox Group. Identical forms of *Banksia* sp. occur in clay lenses of the McNairy Sand of the Upper Cretaceous Ripley Group in Scott County and these leaf bearing clays are considered as being Upper Cretaceous in age. These clays, possibly preserved in a graben are similar to vertebrate bearing clays of late Cretaceous age at the Chronister site, six miles to the northwest of Marble Hill.

Laudon, Robert C., Department of Geology & Geophysics, University of Missouri-Rolla. HISTORICAL PERSPECTIVE ON GAS PRODUCTION, SOUTH KANSAS CITY AREA. During the years 1928 to 1941, approximately 1.7 BCF gas was produced from a total of 183 gas wells in seven fields in the south Kansas City area. Another 82 dry holes were drilled in exploring for this gas giving an average success ratio of 69 percent. Gas was produced from 12 different, very shallow, mainly Pennsylvanian aged horizons including some coal horizons. Initial flowing tubing pressures range from 60 to 120 psi. Nominal decline rates for the fields ranged from 40 to 76 percent and averaged 48 percent, with increasingly poor performance towards the tail-end of production. Such poor reservoir performance occurs only in fields where the reservoir rock quality is poor, or in fields that are badly overproduced. Both occurred in the south Kansas City area fields.

Linguistics

Barry, Bert, Coordinator of International Students and Chairperson: Department of Foreign Language, Fontbonne College. COMPUTERS AND LANGUAGE UNDERSTANDING A NEW TECHNOLOGY OF THE WORD. The computer, like the technologies of writing and print before it, has changed the way people regard and use language. It offers us all sorts of new possibilities, but with these potentials come certain dangers. This paper analyzes and evaluates those dangers, coming to the conclusion that the computer is best viewed as the latest evolution of language technology.

Bergen, R. D., Department of Foreign Languages, Hannibal-LaGrange College. LEXICAL DISTRIBUTION AND THEME PRODUCTION IN HEBREW NARRATIVE: A STUDY OF GENESIS 1:1–2:3. This study was carried out as an investigation of the role that vocabulary distribution plays in the production of theme in a "successful" piece of classical Hebrew narrative, the Story of the Seven Days of Creation. The computer-assisted research made use of a lexically tagged ASCII version of the BHS Hebrew text. The distribution of each lexical item among the story's episodes was noted and plotted. The vocabulary was then classified according to more general semantic categories—e.g., expressions of domination, extremity, fertility/creativity/sexuality, and deity—and the lexical distribution by semantic categories noted. The study revealed that compared to the other episodes, the peak episode, 1:24–31, utilized the highest percentage of the total story lexicon (56.4%), in addition to containing the highest number of unique lexical items (20). This text zone also contained the highest count of words expressing domination (8 of 23), extremity (13 of 18), fertility/creativity/sexuality words (21 of 49), and deity references (10 of 35). Results suggest an intimate link exists between lexical distribution and theme production within classical Hebrew narrative.

Pearson, L., Foreign Languages, University of Missouri-Rolla. POSSIBLE INFLUENCE OF ARABIC "USTAAD" ON SPANISH "USTED." Although "usted" (you, formal form) in Spanish has been documented as having evolved as a contraction of "vuestra merced" (your mercy), there was a similar word used by speakers of Arabic in Spain, "ustaad," which may have guided the contraction of "vuestra merced" into "usted." "Ustaad" is the Arabic title used when talking to someone in the role of teacher (in both formal and popular discourse); in popular speech, it is the equivalent of the English "mister," "sir"; and it has a very similar phonology to "usted" (inter-dental *d*). The Portuguese equivalent of "vuestra merced" became "você."

Physics

Kapoor, Y. M., Department of Natural Sciences and Mathematics, Lincoln University. HIGH PRESSURE AND ITS EFFECTS. High pressure technique deals with measurements at pressures greater than 10 Kbar. The applications of high pressure technique have expanded to various problems in different fields such as Physics, engineering, etc. Many apparatuses have been designed to generate pressure ranging up to 300 Kbar and temperatures ranging from low of 0.05 K to very high of 5000°C. Regular methods for pressure measurements can not be used for pressure measurement. Using these apparatuses, effects of high pressure on the electrical resistance, compressibility, Mossbauer effect, x-ray diffraction and optical properties were studied. The purpose of this presentation is to review different high pressure high temperature apparatuses including tetrahedral anvil and diamond anvil cell. Different methods used for pressure measured in these apparatuses will be discussed. One of the major applications of high pressure in industry to produce synthetic diamonds from graphite will also be discussed.

Anderson, Richard, Department of Physics, University of Missouri-Rolla. COMMENTS ON FRESNEL DIFFRACTION. In this paper, Kirchhoff's diffraction equations shall be applied to Fresnel diffraction by a circular aperture. The incident wavefront is plane and is incident upon a circular aperture in the Fresnel regime. The theory in most texts state that for an axial observation point the field is that from the first zone if an odd number of Fresnel zones are exposed or nearly zero for an even number of zones. The actual differences from these results can be calculated.

Northrip, J. W., Department of Physics and Astronomy, Southwest Missouri State University. ALTERNATIVE APPROACHES TO THE TEACHING OF INTRODUCTORY OPTICS. Current developments in optics provide concepts and techniques which may improve student understanding in the sequence of topics normally taught in introductory optics. Understanding of the eye-brain cybernetic system aids in the presentation of topics such as ray optics, color perception, and contrast. It also allows the introduction of concepts from modern image analysis. Matrix techniques can be used to present lens/mirror systems and to introduce the concepts of polarization more clearly. Computer graphics aid in ray tracing, interference/diffraction, and description of aberrations. Modification of our current sequence of topics may lead to a clearer understanding of traditional material and a more exciting application of the topics.

Benofy, L. P., Department of Physics, St. Louis University. PADÉ APPROXIMANTS AND THE CONVERGENCE OF SERIES. Often greatly improved estimates can be obtained from the so-called Padé approximants [ratios of polynomial expressions] associated with the series. This fact will be illustrated through some examples. Finally, a brief description of some work on quantum many-particle systems will be presented in which Padé approximants are useful.

Science Education

Scism, A. J., Department of Chemistry and Physics, Central Missouri State University. THE ENHANCED LEARNING OPPORTUNITIES PROGRAM IN CHEMISTRY. The Enhanced Learning Opportunities Program (ELO) provides supplemental instruction to students in certain "high risk" courses. First used with General Chemistry I spring semester 1988, the success of that trial and of those in other courses led to the current ELO program. ELO has been used in three offerings of Elementary Organic and Biochemistry, a course primarily for nursing and dietetics majors. Four supplementary sessions per week are provided by the ELO instructor, a senior chemistry major who attends all classes with the students, takes notes and works with those who attend the ELO sessions. The success of the program depends heavily on the ability of the ELO instructor to establish credibility and to communicate well with the students. While significant amounts of data have yet to be gathered, it appears that the number of W, D, and F marks is lower with ELO than without. Additionally, students who attend 3 or more ELO sessions earn more grade points than those who do not.

Huckins, S. D., Chemistry and Biology Teacher, Glasgow Senior High School. THE SCHOOL BURNED DOWN, NOW WHAT DO I DO? September 1, 1989 the High School burned to the ground. Upon resuming classes in make-shift classrooms, the problem of providing hands-on, challenging science was addressed. Colleges and Universities were contacted for help with equipment. Periodicals, textbooks, and interviews were conducted for ideas. Stock was taken of what could and could not be handled in the present facilities. A plan of attack, involving kitchen chemistry, trips to College and University facilities, etc. was developed. Due to lack of support material based on previous experience, a creative curriculum was devised.

Gathman, A. C. and Janzow, F. T., Biology Department, Southeast Missouri State University. A HYPOTHESIS-TESTING METHOD FOR TEACHING EVOLUTION. As evolution is a central organizing concept in biology, we want to give all our students an understanding of it. Non-biology majors are frequently very resistant to evolutionary theory because it contradicts their prior beliefs. In our course, Biology for Living, we use students' strong opinions on this topic as the basis for a cyclical hypothesis-testing approach in a lecture-discussion format. First we ask students to present their hypotheses about the history of living things. Students then make predictions based on their hypotheses and compare the predictions with various types of evidence. The students then reevaluate their hypotheses based on the evidence, and modify them if necessary. The revised hypotheses are then tested using the next category of evidence. Evidence covered varies, but may include skeletal anatomy, fossil record, the genetic code, and DNA and protein sequences. Based on comments and evaluations, students seem to respond positively to this approach. A sample class exercise based on evidence from skeletal anatomy will be presented.

Meuser, J. A. and Hoggard, F. E., Chemistry Department, Southwest Missouri State University. DEVELOPMENT OF INTELLIGENT COMPUTER-AIDED INSTRUCTIONAL PROGRAMS. Several prototype programs were developed to assist students in the reading and solution of Inorganic Chemistry word problems. These prototypes were designed as training aids to reinforce the student's search into the deep structure of the English language. Three basic concepts were considered: intension, conversion, and correspondence. Frames were prepared to present and to reinforce these elements. A frame is a remembered structure to be adapted to fit reality by changing details. Intensional attributes of reality are imagination, interdependence, and essence. Each program could recycle the student's response to a question. This procedure was an effort to focus the student's attention to the essence of the question. The programs seek to break through the false opinions held by the student due to either forgetfulness or to personal prejudice. A series of questions relate the interdependence of the concept under

review to the wider world of problem considerations. The programs were written and compiled using the C programming language.

Westling, B. D., Science Department, John Burroughs School. TOWARD A UNIVERSAL COMPUTER-BASED DATA STATION FOR THE BIOLOGY LABORATORY. Teachers at John Burroughs have developed an inexpensive data collection interface for the Apple II computer. The system consists of an A/D converter, power supply card, instrumentation amplifier, current to voltage amplifier, and a number of transducers. All components have been assembled, over the past 8 years, by teachers and students from commercial IC chips, transducers and related parts. Control of sampling rates, calibration, data storage and plotting is accomplished through a single program. With the data station students are able to measure fermentation, aerobic respiration, breathing, chemical reactions, photosynthesis, pulse rate, muscle contraction, lung volume, reaction time, pH, and D.O. levels. The development of the data station is significant because of lowered costs and the improved calibre of the student laboratory experience.

Powers, M. H., Department of Chemistry and Physics, Central Missouri State University. TEACHERS, INDUSTRY AND ENVIRONMENT: A UNIQUE IN-SERVICE WORKSHOP FOR SECONDARY SCIENCE TEACHERS. Teachers, Industry and Environment (TIE) is a unique in-service opportunity for secondary science teachers sponsored by the Missouri Chemical Council and its potential member companies, the Missouri Department of Natural Resources and Central Missouri State University. After the sixth annual TIE Workshop, nearly 400 secondary science teachers have participated in the workshop and many have completed follow-up studies. Many aspects of the TIE project, such as its origin, funding, programs, format, evaluation and subsequent spin-offs, combine to produce its unique character. Unanticipated outcomes have also resulted yielding many dividends, such as sources of funding, identification of exemplary teachers and a cooperative spirit between teachers, industrial chemists and others with a concern for the environment. Supported by NSF: TEI 8650101; TE 18470538.

Rodgers, M. L., Department of Chemistry, Southeast Missouri State University. PRODUCTION OF INDIVIDUALIZED CHEMISTRY HOMEWORK ASSIGNMENTS USING APPLEWORKS®. The assignment of graded homework often creates a dilemma for the instructor: does the instructor prohibit student-student consultation, thereby eliminating the opportunity for students to learn from the interaction, or does the instructor allow consultation which could lead to the assignment of passing grades for plagiarized work? The dilemma can be reconciled by assigning problems that contain a unique set of data for each student. The Appleworks® integrated software package, running on an Apple II GS computer, was used to produce serial-numbered copies of homework assignments for 82 students in our University Studies chemistry course. The numerical data were generated in an ASCII file, and a calculated answer key was produced for each serial number to facilitate grading. Data suggest the dilemma was indeed resolved: six otherwise undetectable cases of plagiarism were identified, while weekly attendance at group tutoring sessions increased from 0.2 hours/student to 0.9 hours/student, indicating increased problem-solving activity within student study groups.

Jones, J. Michael, Department of Biology, Culver-Stockton College. A DISCUSSION-ORIENTED CRITICAL THINKING TECHNIQUE. Critical thinking is used as an integral part of a large, introductory biology course to illustrate an important methodology used in science. A structured activity is used to introduce critical thinking and discussion; the technique is reinforced throughout the course. The important components of the method include: 1) a written seven step preparation of an assigned article, 2) group organization to facilitate assignment of roles and adequate coverage of the important material, 3) the actual discussion follows the seven step sequence used in preparation, and 4) evaluation of the group discussion to improve learning through the discussion process. This approach recognizes the tradeoffs among presentation of factual material, developing skills in critical thinking, and development of discussion skills. Students develop skills in analysis, evaluation and application.

Northrip, J. W., Department of Physics and Astronomy, Southwest Missouri State University. TEACHING MATHEMATICS AS THE LANGUAGE OF SCIENCE. Science is the attempt to give a precise description of the real universe. Such a description requires a language with less ambiguity than common languages which depend on human background. For this reason, the language of mathematics has developed with precise definitions for both its elements and its operations. Describing various systems requires many different types of mathematics, ranging from algebras to geometries to statistical and probabilistic systems. The concept of mathematics as a language often helps to explain its techniques as well as its close interrelationship with science. Examples of various aspects of mathematics as applied to different scientific systems will be given.

Ashley, David C., Crumley, Richard E., Andresen, William F., Boutwell, Richard A., Rachow, Thomas E., Robbins, Donald J. and Rushin, John W., Biology Department, Missouri Western State College and **Lambing, Devera L. and Braxdale, Barb A.**, Midland Empire Girl Scout Council. MISSOURI WESTERN STATE COLLEGE GIRL SCOUT SCIENCE BADGE WORKSHOPS. Students and faculty in the Biology Department at MWSC collaborated with the staff of the Midland Empire Girl Scout Council in 1986 to initiate a series of all-day workshops for local Girl Scouts. Over 2000 participants have enrolled in these workshops which continue to be held once each semester. Each workshop gives the scouts the opportunity to earn three proficiency badges in science-related areas. To date, six different badges have been offered: Ecology, Science Sleuths, Water Wonders, Wildlife, Computer Fun, & Science Around Town. The response from the Girl Scout community concerning this program has been enthusiastically positive.

Science, Technology and Society Section

Salehnia, A. R., Department of Computer Science, South Dakota State University, and **Pournaghshband, H.**, Department of Math/Computer Science, University of Missouri-St. Louis. **STUDENTS' COMPUTER BACKGROUND IN A COMPUTER INFORMATION SYSTEM COURSE.** The results of a pretest of previous computer experience and knowledge of students enrolled in an introductory Computer Information Systems class is reported. The relation between students' gender, their prior computer experience, their ACT scores and the pretest and post-test scores are discussed. The relation between students' gender and their level of success in the course is analyzed. The analysis of data indicates that: 67% of students had computer experience; 75% of those who had computer experience had worked with BASIC language; AppleWorks was used by majority of students in secondary schools; Female students were more successful in the course than male students; Previous exposure to computers does not necessarily mean that students can succeed in a computer course; Students learn more by doing and they did better in lab related questions.

Salehnia, A. R., Department of Computer Science, South Dakota State University, and **Echternacht, L. J.**, Department of Practical Arts and Vocational Technical Education, University of Missouri-Columbia. **COMPUTER PERCEPTIONS OF MISSOURI SECONDARY AND VOCATIONAL AREA BUSINESS TEACHERS.** The purpose of the study was to determine whether there is a difference between the perceptions of secondary school and area vocational school business teachers who teach computer/data processing courses in Missouri regarding the trends and advancement of computer hardware and software technologies and the use of these technologies in education and business education programs in 1995. It also focused on assessing the types of computer hardware and software being used and the computer/data processing course offerings in business education programs. Data for the study were collected by a questionnaire. A random sample of 215 secondary schools and 80 area vocational schools in Missouri with business education programs in 1988-89 were contacted. The null hypothesis was tested at the .05 level of significance. A significant difference among the perceptions of teachers was found. The Null Hypothesis was rejected.

Social & Behavioral Sciences

Giffen, J. E., Department of History/Political Science, University of Missouri-Rolla and **Leuthold, D. A.**, Department of Political Science, University of Missouri-Columbia. **THE ROLE OF THE MEDIA IN POLITICAL PARTICIPATION.** Residents of free-standing communities located outside metropolitan areas are more likely than residents of similar sized suburbs to participate in local political activities, but not more likely to vote in national elections. The increased participation in local politics is closely related to readership of newspapers, with newspapers in free standing communities much more likely to present information about local political activity. These conclusions are based upon an intensive study of four cities similar in size and socio-economic characteristics—two free-standing cities (Jefferson City and Cape Girardeau) and two suburbs (Lee's Summit and Raytown). A random survey was conducted in each community. All measures of participation were adjusted for socio-economic status. Local newspapers played a major role in stimulating participation, but broadcast media had little impact. In each community, we found a strong statistical association between use of newspapers for local news and participation in community activities, even after controlling for income and education. Residents of the free standing cities read local newspapers more frequently than did residents of suburbs, in part because local newspapers in free standing communities were published more frequently.

Montgomery, R. L., Department of Psychology, University of Missouri-Rolla. **SOCIAL ANXIETY, SOCIAL SUPPORT, AND SCORES ON THE REVISED CALIFORNIA PSYCHOLOGICAL INVENTORY.** To see how socially anxious people function in a number of domains, Jones' (1987) Social Reticence Scale (SRS) and Watson and Friends' (1969) Social Avoidance and Distress (SAD) scales were administered to 165 undergraduates along with the 1987 revised version of the California Psychological Inventory (CPI) and the Social Provisions Scale (Russell and Cutrona, 1984), a measure that examines the number and frequency of contacts with kin and nonkin and the specific interpersonal support provisions that are conveyed in these contacts. Additionally, a perceived attractiveness measure and various measures related to being over-weight were taken. Overall, the results suggested that the socially anxious person has deficits ($p < .0001$) in a variety of personal (CPI) and interpersonal domains (e.g., fewer social provisions from nonkin).

Muse, K. R., Department of Sociology/Anthropology, Westminster College. **IS SOCIOLOGY A CUMULATIVE SCIENCE? A REPLY TO RANDALL COLLINS.** In a recent article in the *American Sociological Review*, "Sociology: Proscience or Antiscience," Randall Collins presents a tour de force summarization of the latest thinking within sociology concerning the question of its scientific status. Collins argues that criticisms by those who claim that sociology is intrinsically incapable of achieving a science of social life have performed a helpful role in moving the discipline beyond narrowly positivist interpretations of sociological method, but that their claims do not undermine the feasibility of a scientific project of formulating generalized explanatory models. If we understand "science" in a sufficiently broad and mature sense, sociology not only can become but is in fact already a cumulative science. After summarizing Collins' position, I will reply to it by agreeing that sociology is in reality a cumulative science, but that that fact does not mitigate against an interpretive, hermeneutic, or humanistic understanding of sociology. A hermeneutic self-understanding for sociology can be articulated which is fully consistent with its scientific status, but which goes beyond the scientific self-presentation Collins advances for the

discipline's public image and emphasizes instead the more important humanistic goals and social contributions of the discipline: self-understanding, value-clarification, and liberating social change.

Sheets, D. F., Topping, E. E. and Carroll, J. M., Department of Economics and Office of Planning and Policy, Southwest Missouri State University. RELATIONSHIP OF COURSE LOAD AND CLASS SIZE TO EVALUATION OF TEACHING PERFORMANCE OF UNIVERSITY FACULTY. In recent years at many universities part or all of the changes in pay of individual faculty have been based on an annual evaluation of performance. The methods of appraising performance in teaching typically rely on student questionnaires and rarely involve directly the size of the faculty member's teaching load. The purpose of this paper is to determine whether there are significant differences in teaching loads among faculty and to determine the nature of the relationship between teaching load and evaluation of teaching performance. The authors have compiled statistics on a variety of measures of workload for faculty at Southwest Missouri State University, including number of preparations, class size, total load equivalents, and division of assignments between upper and lower division courses. These data are analyzed by the use of multiple regression and other statistical techniques. The relationships between teaching evaluations and the various measures of faculty workload are reported.

Poster Section

Lambing, Devera L. and Braxdale, Barb A., Midland Empire Girl Scout Council and **Ashley, David C., Crumley, Richard E., Andresen, William F., Boutwell, Richard A., Rachow, Thomas E., Robbins, Donald J. and Rushin, John W.,** Biology Department, Missouri Western State College. SCIENCE BADGE WORKSHOPS. A ten minute video program will be shown which concerns the Girl Scout Science Badge Workshops conducted at Missouri Western State College in collaboration with the Midland Empire Girl Scout Council. Each semester since Fall, 1986, the Biology Department at MWSC has scheduled an all-day workshop for 250 area Girl Scouts. During this workshop each Girl Scout earns three science-related proficiency badges. The video contains excerpts from an actual workshop and discusses the importance of the workshop program.

Collegiate Division

Biology

Fulton, B. K. and Robbins, D. J., Biology Department, Missouri Western State College. A SUMMARY OF WHITE-TAILED DEER REPRODUCTIVE DATA FROM 1988, 1989 AND 1990 PRIMITIVE WEAPONS HUNTS AT SQUAW CREEK NATIONAL WILDLIFE REFUGE. Sixty-two pregnant uteri were collected in January hunts held at Squaw Creek National Wildlife Refuge. Twenty-six fetuses from 1988, forty-three fetuses from 1989 and thirty fetuses from 1990 were aged according to crown-rump or forehead-rump length, weight, and physical characteristics. These measurements were used to calculate approximate conception dates and birth dates. Sex ratios and productivity rates were also calculated. The range of fetal ages was from 45-52 days to 66-75 days for 1988, from 45-52 days to 96-105 days for 1989, and 42-48 days to 84-90 days for 1990. It appeared that peak conception occurred in early to mid-November. The mode of birth dates was from the middle of May to the first of June. The fetal sex ratio for 1988 was 18 males to 8 females, 20 males to 23 females for 1989 and for 1990 was 17 males to 13 females. The productivity rate for 1988 was 1.23 embryos per doe, 1.80 embryos per doe for 1989, and 1.36 embryos per doe for 1990.

Chemistry/Geology

Ingle, Amy, Long, Chris and Roy, R. N., Chemistry Dept., Drury College. THERMODYNAMIC STUDIES OF AQUEOUS MIXTURES OF BORATES AND SULFUROUS ACID WITH METAL CHLORIDES AT 25°C. Potentials for the cell: Pt; H₂(g, 1 atm)|B(OH)₃(m₁), NaB(OH)₄(m₂), MCl (m₃)|AgCl; Ag where M is Na⁺, Mg⁺² were reported over a range of ionic strengths. Cell potentials were treated with the Pitzer ion interaction treatment and Millero's ion pairing model for mixed electrolytes with linear ionic strength dependence assumed for the activity of the un-dissociated acid. Parameters for both the treatments were determined for the metal borates and MgSO₃ by fitting to the cell results. Apparent association of alkaline earth borates to form monovalent species requires the use of the extended form of the treatment. Association constants for ion pair formation are compared with ion pair formation constants available in the literature. Trace activity coefficients for the metal borates and MgSO₃ were also calculated at 25°C. and various ionic strengths. The results will be discussed in terms of applications to chemical oceanography, industrial chemistry and brines. The paper will be submitted to *J. Solution Chemistry*.

Farwell, Greg, Department of Chemistry, Drury College. CHANGES IN PLASMA MEMBRANE SIALIC ACID LEVELS IN ERYTHROCYTIC GHOST CELLS OF DIABETIC HUMAN PATIENTS. A modified Dodge method was devised for the collection of erythrocyte ghost cells. By using a modified Lowry method (Sigma's Diagnostic Protein Assay Kit—Peterson, G. L.: *Anal Biochem*) and a sialic acid determination method (Boehringer Mannheim Biochemica Farb-Test Colorimetric Method (Zopp: *Fetal* 1985, *Biochem Clin.* 9, 1978), total protein and total sialic acid concentrations were determined for both diabetic and nondiabetic human patients. A ratio of micrograms sialic acid to milligrams protein was set up. It was found that the mean ratio of sialic acid to protein in erythrocyte ghost cells in human diabetic patients was 10.71 ug/mg. The mean ratio of sialic acid to protein in erythrocyte ghost cells of human nondiabetic patients was 13.19 ug/mg. This led to a 1.23 times higher ratio than that of diabetic patients. Our findings are in agreement with rat data obtained by Chandramouli and Carter et al 1974.

Rose, Leigh Ann, Folsted, Angie and Roy, R. N., Chemistry Department, Drury College. THE DETERMINATION OF THE DISSOCIATION CONSTANT OF URIC AND CHOLIC ACID IN WATER USING SPECTROPHOTOMETRIC METHODS. The first acid dissociation constant of uric acid in water was determined at 25° and 37°C, using spectrophotometric methods. Spectrophotometric titration of uric acid was carried out with a solution 0.1M in NaCl, 0.005M in NaC₂H₃O₂ and 5 × 10⁻⁵M in uric acid at λ-195 nm. The pH of the solution was first adjusted to 11 with 1M NaOH and then titrated with HCl. A titration curve of absorbance versus pH was constructed and the pK determined from the curve. The results will be discussed in terms of complications of metal ions present in body fluids.

Willard, Demara, Long, Chris, Rogers, Jenissa and Roy, R. N., Chemistry Dept., Drury College. DETERMINATION OF THE APPARENT MOLAL VOLUMES OF SODIUM CHLORIDE AND THE SURFACTANTS SODIUM DODECYL SULFATE (SDDS), AND DECYL TRIMETHYL-AMMONIUM BROMIDE, AT 5°, 25° AND 45°C. The apparent molal volumes of aqueous solutions of sodium chloride and SDDS were determined from precise density measurements at 5°, 25°, and 45°C. Molalities of sodium chloride solutions ranged from 0.01m to 6m and from 0.002m to 0.021m for SDDS and DTAB solutions. The values of the infinite dilution molal volumes were determined by least squares fit to the equation $\phi_v = \phi_v^\circ + S_m$ where m is the molality, and s is the experimental slope. Values of ϕ_v will be discussed in terms of the various ion interaction models including Millero, Pitzer, and Burchfield-Woolley.

Physics/Engineering

Jennens, M. L., Department of Natural Sciences, Stephens College. Sponsors: H. Anderson, Stephens College and S. K. Loyalka, UMC-Nuclear Engineering. MEASUREMENT OF BIOAEROSOLS IN A CLINICAL ENVIRON-

MENT. Building design and construction dictated by considerations of energy conservation can lead to indoor environments where bioaerosols are a health concern. Measurement and classification of these bioaerosols will allow us to create filtration systems to minimize the possible effects on human inhabitants. In this study, an attempt was made to measure types and concentrations of bioaerosols in a clinical environment. Air samples were taken in three areas of a clinic at times of maximum and minimum usage. Upon collection, concentrations were determined and the different types of bacteria were isolated and identified through different biochemical tests. We discuss the methods of collection, identification, and measurement of bioaerosol concentration and the health consequences of these bioaerosols. Supported by NSF/REU #ENG-89-00881.

Roberts, J. A., Loyalka, S. K., Hickey, K., Hamoodi, S. and Chan, P., Particulate Systems Research Center, College of Engineering, University of Missouri-Columbia. MODELLING OF INDOOR RADON CONCENTRATION IN A FORMER RADIUM EXPERIMENTATION LABORATORY. The Environmental Protection Agency model for Indoor Air Quality is a computer program which is adopted to help scientists estimate pollutant concentrations in buildings/rooms. With the input of such data as room air flows, room volume, initial pollutant concentrations, air flows between rooms, a pollutant concentration (radon, CO₂, etc.) can be calculated. To test the validity of the model, Pickard Hall — Museum of Art and Archaeology, UMC — was modelled for radon using this system. Rooms with known radon concentrations were used in the assimilation. Data needed, but not measured, was approximated. Radon was monitored in each room. The model output showed a constant concentration after a certain amount of time. This disagreed with the actual experimental data obtained by Dr. K. Hickey (Health Physicists, UMC.) In this experiment, Data Loggers were used to measure radon levels. Validation of the EPA model will be discussed in this paper. Supported by NSF/REU #ENG-89-00881.

Karlberg, K. K., Anderson, H. and Loyalka, S. K., Department of Natural Sciences, Stephens College, and Department of Nuclear Engineering, University of Missouri-Columbia. NEUTRON RADIOGRAPHY OF FILTERS. This experiment was conducted at the University of Missouri, Columbia, and at the University of Missouri Research Reactor. The study of the deposition distribution of an aerosol on a filter is of current interest. This study of an aerosol of boron-10, a neutron sensitive element, on standard cellulose acetate filters can be nondestructively monitored by thermal neutron radiography. The aerosol is distributed by a fluidized bed aerosol generator. Filters, which have been subjected to the fluidized bed system, are compared to a set of standards developed by a procedure of alternate freeze-drying and deposition of a saturated boric acid solution. The amount of boron-10 deposited on the filter, and the pattern of the deposition can be studied by direct thermal neutron radiography. Supported by NSF/REU ENG-89-00881.

Social/Behavioral Sciences

Beneke, W. M., Schulte, S. E. and Vander Tuig, J. G., Human Nutrition Research Program, Lincoln University. EXERCISE-INDUCED ANOREXIA IN RATS: CHUNK VS POWDERED FOOD. Recent research has shown that adjunctive behaviors obtained in rats using food pellets as reinforcers did not occur when the food was powdered. To explore this effect in an animal model of exercise-induced anorexia, rats were fed Purina Lab Chow either in CHUNK form or ground into POWDER through baseline, treatment and reversal phases. Baseline and reversal phases consisted of ad lib food and no access to running wheels. Treatments consisted of factorial combinations of (ad lib food, 23 hr deprivation) and (22 hr wheel access, no access). Treatment for each animal continued until the animal self-starved (25% weight loss) or survived (weight gain over four consecutive days). All ad lib animals survived in 4 days. Deprivation alone produced survival in all 5 CHUNK animals and 3 of 5 POWDERED animals (mean days = 10.6). Deprivation + wheel access produced self-starvation in 4 of 5 CHUNK animals (mean days = 10.2) and all 5 POWDERED animals (mean days = 5.0). Self-starvation was accompanied by excessive running (mean individual maximums = 7.24 km/day \pm 1.63 SE). Unlike adjunctive behavior, exercise-induced anorexia is a robust effect that is enhanced by the use of powdered feed. Supported by USDA/SEA Grant MO-X-OH85-514.

Schulte, S. E. and Hancock, R. A., Department of Social and Behavioral Sciences, Lincoln University. THE EFFECTS OF SIGNAL LOCATION ON RESPONSE OVERSHADOWING IN RATS. On variable interval (VI) schedules of reinforcement, when a signal occurs during a half-second, response-reinforcer delay (Correlated condition) response rates are lower than when a signal occurs randomly (Uncorrelated condition). The sign-tracking explanation of this phenomenon was tested by manipulating the signal's location as well as its correlation with delayed reinforcers. The signal was the illumination of an LED either imbedded in the plexiglas lever to which the subject responded (On Bar condition) or located approximately 6 cm from the response lever (Off Bar condition). Signal correlation (Correlated or Uncorrelated) and signal location (On Bar or Off Bar) conditions were manipulated in a 2 \times 2 factorial design. An analysis of variance revealed a statistically significant effect of signal correlation ($p < .05$) but no significant effects of either signal location ($p > .05$) or the interaction between signal correlation and signal location ($p > .05$). These results contradict the sign-tracking explanation which predicts a significant interaction. The results do, however, lend support to an overshadowing explanation. Supported by Missouri Academy of Science and NIH/DRR RR08202.

