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Distribution of Forestland in Missouri

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Abstract: Conversion of forestland to agricultural uses continues in Missouri, but at a much slower rate than around the turn of the century. Yet, impacts of these changes on resource management and outdoor recreation are important. This study was initiated to determine the current amount and distribution of forestland by county and statewide. Forest/non-forest determinations were made from photographic images generated by a LANDSAT satellite Thematic Mapper (TM). Tabular estimates of forestland and detailed maps were provided on a county and statewide basis. An estimated 13,811,718 acres of forestland were identified. This represents 31.0% of the land area of Missouri. Forestland by county ranged from 2.0 to 87.4%. Fifty percent of forestland tracts were 10.0-49.9 acres in size.

Key Words: distribution, forestland, Missouri, range, status

Introduction

The timber resource is important to the people of Missouri. In 1983, approximately 2000 firms not only produced forest products and related services worth almost $3 billion, but also employed 33,000 people who earned $483 million in wages (Phelps and Smith 1985). In addition, forestlands provide recreational opportunities, wildlife habitat, watershed protection and aesthetic values more difficult to estimate.

Forestland inventories have been conducted periodically in Missouri (King et al. 1949, Gansner 1965, Spencer and Essex 1976). Yet, due to continued loss of forests primarily to agricultural uses (USDA 1978, Othic et al. 1982), updated inventory data were needed to evaluate trends in forestland conversion and potential impacts on forest wildlife species. In 1984, the Missouri Department of Conservation, in cooperation with the Geographic Resources Center at the University of Missouri-Columbia, initiated a study to determine the current status of forestland in Missouri. The purpose of this paper is to present detailed data on forestland by county and statewide.

Methods

Visual interpretation and manual digitizing schemes were used to compile a forest/non-forest cover map for each county in Missouri (all scales were ½″ =

1 mile). Fig. 1 shows the flow of data from selection to final map products and acreage statistics. Sixteen TM scenes from the 1984 growing season provided complete cloud-free coverage of the state. Earliest coverage date utilized was 18 April, and the latest was 18 September. A 3-band (wavelengths 0.45-0.52, 0.63-0.69 and 0.76-0.90 nanometer), false-color, composite film positive was used for each scene. Scenes were split into quadrants and enlarged to scale.

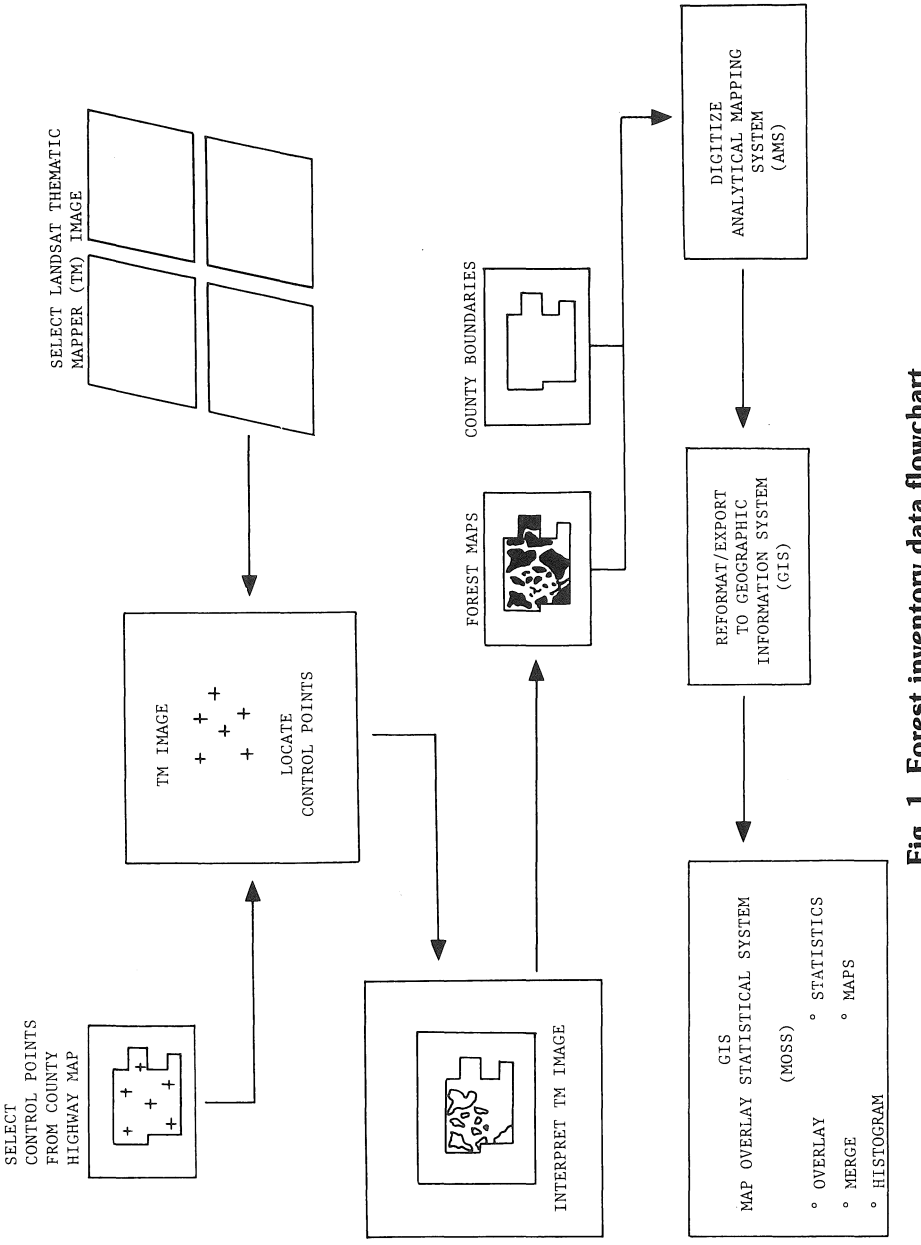

Fig. 1. Forest inventory data flowchart.

A set of control points (Fig. 1) was established to maintain mapping accuracy for each county. A minimum of 8 control points, described in latitude and longitude coordinates, was located and marked on county highway maps. These control points also were marked on the TM imagery. A drafting paper overlay then was placed over the TM imagery and registered to control points marked on the imagery. TM imagery was visually interpreted and forestland drawn on drafting paper overlays for each county. To qualify for mapping, a forested area had to exceed 5 acres with at least 10% canopy closure.

A manual digitizing software package called the Analytical Mapping System (AMS) was used to create computer compatible digital files for each county's forestland. Positional (geographic) accuracy was guaranteed on county highway maps by using control points previously plotted. All AMS files were converted for incorporation into a geographic information system (GIS). Map Overlay Statistical System (MOSS), a polygon based GIS, was used to manage digitized data for production of area estimates and maps.

Results

Cartographic products included maps of forest cover by county (Fig. 2) and a statewide map (Fig. 3) showing forested areas at least 5 and 160 acres in size, respectively. A total of 13,811,718 acres of forestland was identifed (Table 1). This represented 31.0% of the land area of Missouri. Forestland by county ranged from 6291 acres in Pemiscot County to 535,090 acres in Shannon County. Mean percent forestland by county was 29.3%, and ranged from 2.0% in Pemiscot County to 87.4% in Carter County. Statewide, 50% of forestland tracts were 10.0-49.9 acres in size, 28% were <10.0 acres and 22% were >50.0 acres. One-half (57) of Missouri's counties contained less than 20.0% forestland (Table 2.)

Discussion

Estimates of presettlement forestland (Mayes 1937, USDA 1978) suggest that about 70% of Missouri was originally forested. European immigrants to the state established a commercial wood industry which peaked between 1890 and 1920. Soon after, wildfires and land clearing contributed to the rapid loss of forestland (Phelps and Smith 1985). Mayes (1937) estimated that only one-half of the original forestland existed by 1937. More recent surveys (King et al. 1949, Gansner 1965, Spencer and Essex 1976) indicated that total forestland area has decreased at a slower rate, and that about one-third of the state has remained forested.

The 1972 Forest Survey of Missouri (Spencer and Essex 1976) presented detailed tabular data and forest area estimates for each county. However, the survey was not designed to provide a basis for mapping forested tracts. In 1977, the School of Forestry, Fisheries and Wildlife, University of Missouri-Columbia, and the Missouri Department of Conservation cooperated on a forest cover survey. The 1977 survey, based on LANDSAT imagery, provided county and statewide maps of forestland tracts, but did not supply numerical estimates of area. Our survey provides tabular estimates of forestland as well as detailed maps for each county and statewide.

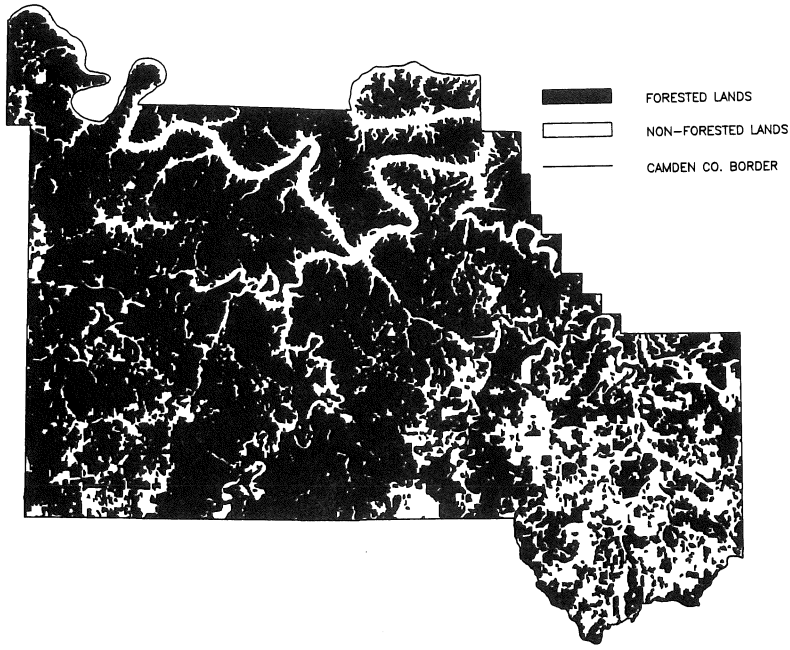

Fig. 2. Forest cover map of Camden County, MO (forested tracts ≥5 a).

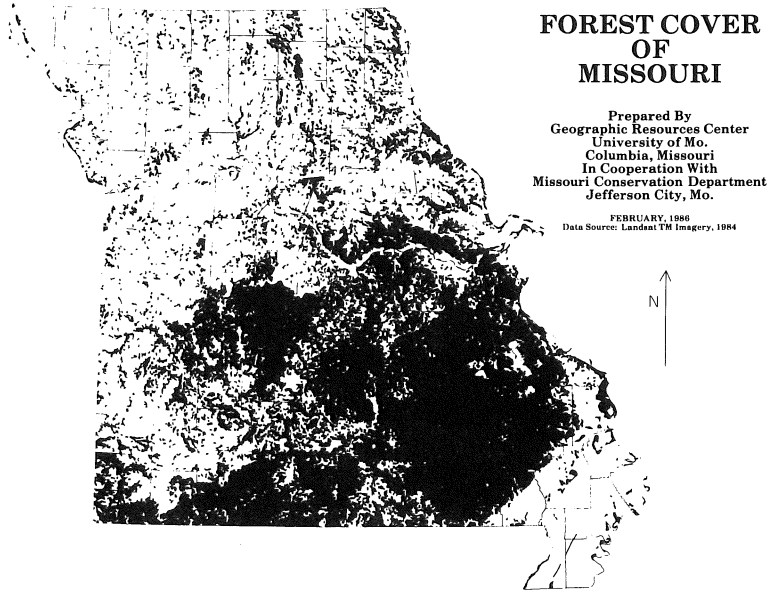

Fig. 3. Forest cover map of Missouri (forested tracts ≥160 a).

Table 1. Total area, percent and size distribution of forestland in Missouri counties, 1984.

County	Total area (a)	Forestland area-a (%)		Number of forestland tracts (a)						
				<10.0	10.0-49.9	50.0-99.9	100.0-499.9	500.0-999.9	>1000.0	Total
Adair	364,226	65,047	(17.8)	376	379	90	90	7	7	949
Andrew	279,952	25,880	(9.2)	280	427	70	47	2	1	827
Atchison	356,631	14,121	(4.0)	152	196	19	13	3	2	385
Audrain	445,633	28,251	(6.4)	82	230	63	73	6	0	454
Barry	505,820	200,992	(39.8)	534	679	98	79	13	21	1,424
Barton	381,433	29,803	(7.8)	280	164	42	52	9	2	549
Bates	545,347	57,192	(10.4)	475	635	126	102	7	4	1,349
Benton	481,666	214,581	(44.6)	191	271	60	84	11	30	647
Bollinger	397,986	208,397	(52.4)	24	136	44	62	13	9	288
Boone	442,042	108,105	(24.4)	76	370	101	110	17	20	694
Buchanan	266,429	32,597	(12.2)	210	436	59	56	1	3	765
Butler	448,534	145,103	(32.4)	51	213	34	29	3	7	337
Caldwell	274,876	13,182	(4.8)	154	202	45	25	0	1	427
Callaway	541,529	188,656	(34.8)	54	294	75	68	13	17	521
Camden	452,203	282,578	(62.4)	179	198	40	63	11	19	510
Cape Girardeau	375,953	79,485	(21.2)	48	308	61	58	7	9	491
Carroll	449,800	22,658	(5.0)	179	264	43	33	8	1	528
Carter	325,512	284,643	(87.4)	14	23	1	0	0	1	39
Cass	450,045	41,273	(9.2)	269	609	93	75	6	2	1,054
Cedar	319,385	87,901	(27.6)	176	409	101	113	21	10	830
Chariton	490,922	46,282	(9.4)	116	396	86	80	8	3	689
Christian	360,420	165,125	(45.8)	200	367	51	54	5	6	683
Clark	327,550	63,342	(19.4)	209	380	80	80	16	12	777
Clay	261,448	15,247	(5.8)	203	268	51	31	0	0	553
Clinton	270,278	10,236	(3.8)	128	213	31	12	1	0	385
Cole	257,172	77,448	(30.2)	276	605	152	167	13	3	1,216
Cooper	364,895	60,115	(16.4)	293	607	124	114	10	4	1,152

Table 1 (continued).

County	Total area (a)	Forestland area-a (%)		Number of forestland tracts (a)						
				<10.0	10.0-49.9	50.0-99.9	100.0-499.9	500.0-999.9	>1000.0	Total
Crawford	475,783	317,865	(66.8)	140	224	54	51	8	11	488
Dade	322,999	55,032	(17.0)	105	303	97	92	10	5	612
Dallas	346,141	157,427	(45.4)	148	318	66	62	16	15	625
Daviess	363,800	35,369	(9.8)	248	607	107	64	0	1	1,027
DeKalb	272,613	19,339	(7.0)	234	433	60	24	0	0	751
Dent	482,477	329,157	(68.2)	13	71	31	38	12	9	174
Douglas	521,839	286,139	(54.8)	222	417	77	111	17	24	868
Dunklin	353,987	13,908	(4.0)	18	35	17	13	1	3	87
Franklin	595,738	247,303	(41.6)	683	1,166	235	258	29	27	2,398
Gasconade	335,188	156,457	(46.6)	266	439	89	120	28	21	963
Gentry	315,319	29,451	(9.4)	271	508	81	49	4	0	913
Greene	432,351	93,268	(21.6)	190	582	120	113	17	15	1,037
Grundy	280,470	14,851	(5.2)	89	132	30	20	4	1	276
Harrison	465,124	36,974	(8.0)	201	587	77	70	3	1	939
Henry	467,536	48,278	(10.4)	184	340	55	57	7	7	650
Hickory	263,182	125,136	(47.6)	126	185	38	50	8	15	422
Holt	300,618	21,000	(7.0)	217	300	39	25	4	2	587
Howard	302,313	54,257	(18.0)	114	329	88	66	14	6	617
Howell	593,632	269,243	(45.4)	322	702	144	186	29	22	1,405
Iron	353,644	286,379	(81.0)	66	67	11	10	1	3	158
Jackson	391,542	47,493	(12.2)	355	576	99	77	8	5	1,120
Jasper	410,804	60,631	(14.8)	74	372	92	80	13	8	639
Jefferson	425,595	238,459	(56.0)	263	402	107	121	29	33	955
Johnson	533,186	65,628	(12.4)	494	855	138	103	6	3	1,599
Knox	323,953	39,965	(12.4)	198	397	69	89	5	2	760
Laclede	491,472	213,367	(43.4)	344	512	133	129	30	21	1,169
Lafayette	408,250	19,376	(4.8)	245	377	65	26	2	0	715

Table 1 (continued).

County	Total area (a)	Forestland area-a (%)		Number of forestland tracts (a)						
				<10.0	10.0-49.9	50.0-99.9	100.0-499.9	500.0-999.9	>1000.0	Total
Lawrence	391,575	52,237	(13.4)	188	565	110	94	6	4	967
Lewis	328,289	52,594	(16.0)	214	414	109	101	11	3	852
Lincoln	410,121	97,276	(23.8)	606	559	86	115	11	15	1,392
Linn	396,665	30,209	(7.6)	315	373	60	58	4	1	811
Livingston	346,218	23,410	(6.8)	133	213	43	29	5	3	426
McDonald	346,663	170,463	(49.2)	241	330	50	88	13	27	749
Macon	520,731	84,355	(16.2)	552	564	138	134	27	7	1,422
Madison	317,555	245,330	(77.2)	3	17	7	4	2	3	36
Maries	338,321	147,997	(43.8)	235	373	83	126	13	23	853
Marion	283,280	45,164	(16.0)	145	321	67	83	11	4	631
Mercer	290,877	29,626	(10.2)	179	434	59	54	3	1	730
Miller	383,958	181,208	(47.2)	246	455	120	137	21	29	1,008
Mississippi	278,487	13,112	(4.8)	14	50	26	22	1	3	116
Moniteau	268,069	52,089	(19.4)	270	549	116	87	7	6	1,035
Monroe	429,249	68,937	(16.0)	169	414	113	121	16	7	840
Montgomery	346,016	100,527	(29.0)	314	263	54	56	13	18	718
Morgan	393,858	200,675	(51.0)	137	283	71	62	12	11	576
New Madrid	451,811	13,184	(3.0)	15	44	9	7	1	4	80
Newton	399,291	128,630	(32.2)	145	396	98	98	18	23	778
Nodaway	562,198	15,022	(2.6)	279	352	43	16	0	0	690
Oregon	507,233	300,296	(59.2)	167	381	83	85	13	11	740
Osage	390,638	184,351	(47.2)	215	472	104	141	34	26	992
Ozark	482,496	285,512	(59.2)	108	254	47	49	10	17	485
Pemiscot	329,268	6,291	(2.0)	10	41	9	7	1	2	70
Perry	307,872	104,572	(34.0)	179	538	94	76	6	8	901
Pettis	439,293	50,515	(11.4)	339	671	103	99	7	2	1,221
Phelps	431,577	258,867	(60.0)	155	322	76	101	12	23	689

Table 1 (continued).

County	Total area (a)	Forestland area-a (%)		Number of forestland tracts (a)						
				<10.0	10.0-49.9	50.0-99.9	100.0-499.9	500.0-999.9	>1000.0	Total
Pike	437,625	101,020	(23.0)	402	485	89	98	17	19	1,110
Platte	273,506	40,258	(14.8)	242	448	93	85	4	4	876
Polk	411,924	116,457	(28.2)	331	533	114	126	16	21	1,141
Pulaski	351,975	232,558	(66.0)	57	201	48	44	4	11	365
Putnam	333,168	44,215	(13.2)	384	345	70	86	10	4	899
Ralls	309,341	62,743	(20.2)	140	268	65	63	17	16	569
Randolph	311,894	59,828	(19.2)	197	327	74	85	12	11	706
Ray	368,293	36,655	(10.0)	164	241	61	71	10	2	549
Reynolds	520,101	447,529	(86.0)	21	22	4	0	1	2	50
Ripley	404,003	270,467	(67.0)	52	206	48	39	2	9	356
St. Charles	380,335	84,592	(22.2)	526	446	82	80	15	5	1,154
St. Clair	448,591	155,142	(34.6)	248	359	87	82	28	19	823
St. Francois	325,706	182,585	(56.0)	140	303	35	31	2	14	525
Ste. Genevieve	291,104	163,473	(56.2)	147	263	57	49	5	14	535
St. Louis	376,656	78,795	(21.0)	407	438	80	55	16	6	1,002
Saline	488,308	43,961	(9.0)	614	600	89	71	4	3	1,381
Schuyler	196,753	22,215	(11.2)	214	307	43	15	4	4	587
Scotland	281,206	30,911	(11.0)	218	461	60	66	5	0	810
Scott	273,789	17,786	(6.4)	3	51	14	7	2	4	81
Shannon	641,910	535,090	(83.4)	68	121	31	33	6	4	263
Shelby	320,275	38,835	(12.2)	134	300	69	65	9	6	583
Stoddard	531,134	41,958	(7.8)	23	149	45	32	3	7	259
Stone	326,857	159,513	(48.8)	158	267	58	63	2	16	564
Sullivan	416,090	47,951	(11.6)	201	503	91	59	7	6	867
Taney	416,264	278,208	(66.8)	71	128	29	28	11	12	279
Texas	752,970	431,010	(57.2)	95	464	105	110	14	17	805
Vernon	536,013	69,567	(13.0)	408	649	107	99	15	10	1,288

Table 1 (continued).

County	Total area (a)	Forestland area-a (%)		Number of forestland tracts (a)						
				<10.0	10.0-49.9	50.0-99.9	100.0-499.9	500.0-999.9	>1000.0	Total
Warren	279,557	130,677	(46.8)	226	189	42	40	6	7	510
Washington	486,727	384,431	(79.0)	67	131	24	16	3	6	247
Wayne	495,777	402,713	(81.2)	2	17	4	9	1	4	37
Webster	380,220	122,943	(32.4)	172	581	140	160	30	22	1,105
Worth	170,453	13,790	(8.0)	122	282	30	26	0	0	460
Wright	436,748	171,401	(39.2)	265	620	141	186	31	32	1,275
Total	44,614,125	13,811,718	(31.0)	23,151	40,868	8,166	8,003	1,106	1,052	82,346

Table 2. Number and percent of counties by forestland percentage.

% forestland	Number of counties	(%)	Cumulative %
0.0- 9.9	28	(24.6)	24.6
10.0- 19.9	29	(25.4)	50.0
20.0- 29.9	11	(9.6)	59.6
30.0- 39.9	9	(7.9)	67.5
40.0- 49.9	14	(12.3)	79.8
50.0- 59.9	9	(7.9)	87.7
60.0- 69.9	7	(6.1)	93.8
70.0- 79.9	2	(1.8)	95.6
80.0- 89.9	5	(4.4)	100.0
90.0-100.0	0	(0.0)	100.0
TOTAL	114	(100.0)	

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New and Noteworthy Macrolichens From Missouri

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Abstract: Twenty species of macrolichens are reported for Missouri. Many of these represent considerable extensions of known ranges for the species. Four have affinities to the Atlantic and Gulf coastal plain flora, 7 are southeastern, 5 are boreal and 2 are southwestern.

Key Words: Missouri, lichens, macrolichens

Introduction

Recent research and field work have added to our understanding of Missouri's macrolichen flora. Several taxa, previously unrecorded for the state, have been discovered; many of these represent significant range extensions. Twenty such taxa are discussed in this work, along with information regarding each species' range and comments on their distribution and habitats in Missouri. Chemical substances were determined through the use of thin layer chromatography with 3 solvent systems. The methods outlined by Culberson (1972) were followed. Unless otherwise noted, all specimens are deposited in the herbarium of the Morton Arboretum (MOR), Lisle, IL. In the following text, voucher specimens are cited by county following the species name. Synonyms are provided at the end of each species discussion where the names differ from those used by Hale (1979). Nomenclature for vascular plants follows Steyermark (1963).

Cladonia atlantica A. Evans

Franklin: Parker 2634
Gasconade: Parker 2702
Iron: Parker 2725
Jefferson: Hubricht B71 (US); Ladd 10378
Lincoln: Ladd et al. 9633; Ladd & Schuette 8091
Montgomery: Ladd 10651
Ste. Genevieve: Ladd 10571, 10583, 11412; Ladd & Ladd 6360; Parker 2337, 2387, 2600; Wilhelm & Parker 13666, 13668, 13673

Hale (1979) describes the range of this lichen as the "southeastern states," and Thomson (1967) attributes it to the Atlantic and Gulf coastal plains and up the Mississippi valley northward to Illinois and Kentucky. Wilhelm and Ladd (1985) cite a specimen from a sandstone canyon in southwestern Illinois. This species occurs locally at several stations in east central Missouri. All our records are from shaded canyon walls of St. Peter and LaMotte sandstone. Although Hale (1979) considers this lichen to be a chemical variant of *C. crispata* (Ach.) Flot., Missouri and Illinois populations usually display poor cup development and strongly resemble depauperate specimens of *C. squamosa* (Scop.) Hoffm.

The presence of baeomycic and squamatic acids in *C. atlantica* readily distinguishes it from the latter species, both of which contain squamatic acid only. Curiously, the Iron County specimen contains barbatic acid instead of baeomycic acid.

Cladonia cariosa (Ach.) Spreng.

Camden: Hubricht B600 (US)
St. Louis: Wilhelm 10709
Reynolds: Apfelbaum 278
Shannon: Bush s.n., 1894 (US)

This is a circumpolar species with a North American range extending south to Connecticut, Wisconsin, Arizona and New Mexico (Thomson 1967). According to the map in Thomson (1984), the closest station to Missouri is in extreme northern Wisconsin. Culberson (1969), however, cities the specimens from Camden and Shannon counties, and Wilhelm and Ladd (1985) cite a specimen from southern Illinois. Schutte (1983) cites this lichen from 4 counties in eastern Iowa. The St. Louis County specimen was collected from xeric cherty soil.

Cladonia leporina Fr.

Carter: Redfearn 10925 (SMS)

Both Hale (1979) and Thomson (1967) restrict the United States range of this species to the southeast coastal plain, extending inland as far as Arkansas; Evans (1947) cites a specimen from Conway County, AR. A specimen collected on a rhyolite glade in the eastern Ozarks is the only known record of this plant in Missouri. This species is similar to *C. caroliniana* Schwein. ex Tuck., but the leathery, dull cortex, red pycnidia and chemistry distinguish it readily.

Cladonia polycarpia G. K. Merr.

Greene: Ladd & Ladd 8468

Hale (1979) characterizes the North American distribution of this lichen as "southeastern United States." Culberson (1969) maps it from no nearer than northwestern Alabama. It is known from a sandstone glade in southwestern Missouri. Here it occurs as large sterile squamules resembling dingy squamules of *C. apodocarpa* Robb. The combination of atranorin, stictic acid and norstictic acid is unique in the genus.

Cladonia rei Schaer.

Adair: Ladd 11317
Lewis: Schuette 854

Hale (1979) restricts the United States range of this species to the northern states. Though Thomson (1967) characterizes the range of the species as "circumboreal," he later (1984) evidently excludes it from the arctic region. It is relatively frequent in sandy or worn-out soils in the Chicago, IL, area (Wilhelm and Lampa 1987) and Schutte (1983) cites it from east central Iowa. One of the Missouri populations occurs in an abandoned sand pit, the other is on an eroded, leached spoil pile at an old mine site. Our specimens are cupless and resemble *C. decorticata* (Flk.) Spreng.; the podetia are long, attenuate and occasionally branched. Both specimens contain homosekikaic acid only.

Dirinaria picta (Sw.) Clem. & Schear

Pemiscot: Wilhelm 11144

Hale (1979) restricts the United States range of this pantropical species to the southeast coastal plain, extending northward into the Mississippi embayment only as far as central Louisiana. It is known from a single collection in the bootheel region of extreme southeastern Missouri. There it was collected at a rest stop along Interstate 55 on the trunk of a planted *Acer saccharinum*. It is interesting to speculate whether this species was imported with landscape material or is native in Missouri. The vegetation of the bootheel region has strong affinities to the vegetation of the Gulf coastal plain (Steyermark 1963). According to our records, *Heterodermia albicans* (Pers.) Swinsc. & Krog, another coastal plain species, is similarly restricted to the bootheel region.

Flavopunctelia soredica (Nyl.) Hale

Lincoln: Ladd & Skinner 9667, 9679

Hale (1979) maps the United States range of this lichen as the western mountain region and the extreme northern portions of the central states. Culberson (1960) cites specimens from no nearer than Dunn and Chippewa counties, WI; and McKnight et al. (1987) report this species from Illinois. The Missouri population may well be a recent introduction from farther north. It occurs on lightly shaded deciduous tree trunks in a small zone of an abandoned field in east central Missouri. = *Parmelia ulophyllodes* (Vain.) Sav.

Hypotrachyna pustulifera (Hale) Skorepa

Carter: Wilhelm 11517
Oregon: Ladd & Wilhelm 7580
Ripley: Ladd 10234
Shannon: Ladd et al. 8675; Ladd 10201
Ste. Genevieve: Ladd 10523, 10563
Washington: Ladd 9791

According to Hale (1972), this species is restricted to the Ozark and Piedmont regions of the southeastern United States. He maps records from as near as northwestern Arkansas and northeastern Oklahoma. It is infrequent on old-growth *Pinus echinata* and *Juniperus virginiana* in the eastern Missouri Ozarks; it rarely occurs on *Quercus marilandica* and on granite bluffs. For a discussion of the nomenclature of this species see Skorepa (1983).

Parmotrema hypoleucinum (B. Stein) Hale

Osage: Ladd 6828

Culberson (1986) gives the United States range of this chemical variant of *P. hypotropum* (Ach.) Hale as on the coastal plain from Massachusetts to Mississippi and in southern California, and states that its principal habitat is conifers. In Missouri, it occurs on *Acer saccharum* in an overgrown upland woods. For a discussion of this species and its relationship to *P. hypotropum* in southern Illinois, see Wilhelm and Ladd (1985).

Parmotrema madagascariaceum (Hue) Hale

Ste. Genevieve: Parker 2336

Hale (1979) implies that the range of this species corresponds to that of *P. xanthinum* (Muell.Arg.) Hale, which he maps from the extreme southeastern

portion of Missouri. Almeda and Dey (1973) indicate that the ranges are not identical; both Skorepa (1973) and Wilhelm and Ladd (1985) report only *P. madagascariaceum*, the gyrophoric acid strain, from southern Illinois. In Missouri it is represented by a single collection from a shaded, dry, sandstone wall. This appears to be a characteristic habitat for this species locally.

Parmotrema sp.

Barry: Ladd & Rogers 9476
Butler: Ladd 10418
Lincoln: Ladd & Skinner 9668
Shannon: Wilhelm 10505, 10510
Wayne: Ladd 11778

Specimens of this material resemble chemically and morphologically *P. michauxianum* (Zahlbr.) Hale, and differ only in that they are notably sorediate; the soredia generally are in round, capitate soralia. It keys, therefore, to *P. robustum*, a tropical species, but differs in general aspect and in the color tone of the upper cortex. Mason Hale, of the Smithsonian Institution, is studying our material and specimens from elsewhere in the southeastern United States. His initial reaction is that it is an undescribed species. It is known from 5 widely scattered Missouri locations, ranging from east central to southwestern and southeastern parts of the state. All of our collections are from deciduous trees associated with high quality natural areas.

Parmotrema subisidiosum (Muell.Arg.) Hale

Dunklin: Trelease 8720 (US)
Shannon: Ladd 10191

According to Hale (1979), this is a species of the southeastern United States, although Skorepa (1973) reports it as rare in southern Illinois. The only known extant Missouri population occurs on a chert escarpment at the mouth of a large cave. The Trelease collection was made in 1897.

Peltula euploca (Ach.) Ozenda & Clauz.

Osage: Ladd 6795

Wetmore (1970) characterizes the range of this lichen as "Arid Southwestern with a few outliers," and according to his mapped distribution, the closest station to Missouri is in southwestern Minnesota. The only known occurrence of this species in Missouri is in the crevices of an exposed Jefferson City/Cotter Dolomite escarpment in the central part of the state. This carbonate substrate apparently is unusual; Wetmore (1970) characterizes the ecology of this species as "more or less restricted to non-calcareous rock."

Psora icterica (Mont.) Muell.Arg.

Cedar: Ladd 11572
Lawrence: Ladd & Ladd 6028; Ladd 6323
"Missouri": Wolf s.n., 1876 (US)

This lichen is widely distributed on exposed soils in the southwestern United States. It is known from 2 locations in southwestern Missouri. At both localities it occurs with *Geocarpon minimum* in exposed thin soil pockets on glades of an

unnamed Pennsylvanian channel sandstone. Channel sandstone glades in this area support a unique community of plants, many of which evidently are relicts from the recent post-glacial geothermal period. In addition to *P. icterica* and *Geocarpon minimum*, a number of relictual vascular species are present, including *Portulaca mundula, Sedum nuttallianum, Selenia aurea,* and *Valerianella stenocarpa* var. *parviflora.*

Psorula rufonigra (Tuck.) G. Schneid.

Christian: Ladd & Ladd 9155
Dade: Ladd 7894
Greene: Ladd & Ladd 8462, 8466
Hickory: Ladd & Ladd 7741
Laclede: Ladd 5951
Madison: Ladd 10306
Montgomery: Ladd 10635
Ozark: Ladd & Wilhelm 7453
Taney: Ladd & Ladd 9383
Warren: Ladd 10691
"Missouri": Hall s.n., (US)

According to Fink (1935), this species is widespread in the United States. These are the first reports, however, for Missouri. It grows in exposed, thin, organic or silty soil pockets and adjacent rocks over a variety of siliceous and carbonate substrates.

Ramalina intermedia (Del. ex Nyl.) Nyl.

Douglas: Wilhelm & Ladd 10850
Ste. Genevieve: Ladd 10556

According to Bowler and Rundel (1974), this species displays essentially an Appalachian/Great Lakes distribution in the United States and Canada, with several stations in Iowa and the western United States. Wilhelm and Ladd (1985) and Skorepa (1973) report several specimens from southern Illinois. In Missouri it is known from 2 collections made on the shaded lower faces of sheltered sandstone escarpments in dry sites under overhangs.

Tuckermannopsis americana (Spreng.) Hale *in ed.*

Shannon: Ladd et al. 8653a

Brodo (1984) describes this lichen as a boreal species; he shows the closest station to Missouri to be in southern Wisconsin, although both Culberson and Culberson (1969) and Thomson (1984) mention it from northeastern Iowa. Kärnefelt (1979) also excludes it from Missouri. The Missouri specimen was associated with *T. ciliaris* on the trunk of an old-growth *Pinus echinata* in a timber plantation. This specimen contains atranorin and alectoronic acid, but lacks collatolic acid. = *Cetraria halei* W. Culb. & C. Culb.

Tuckermannopsis ciliaris (Ach.) Gyel.

Dent: Ladd 9644
Douglas: Ladd & Ladd 6072
Shannon: Ladd 10197; Ladd et al. 8653

According to Brodo (1984), this is a temperate species with a well-defined Appalachian/northern Great Lakes distribution; he mapped the nearest popula-

tions to Missouri in eastern Kentucky and Tennessee. In Missouri, this species occurs on old-growth *Pinus echinata* in the eastern Ozarks. = *Cetraria ciliaris* Ach.

Usnea angulata Ach.

Shannon: Summers 1301 (US)

According to Hale (1979), this is a rare lichen of northern North America, extending south to the Great Lakes region, Appalachians and New England. In 1984 a large colony was discovered in extreme southern Missouri, growing on an old-growth, blufftop juniper along the North Fork River.

Xanthoparmelia mexicana (Gyel.) Hale

Dade: Ladd 10749
Jefferson: Parker 2498
Polk: Ladd 10792
Taney: Ladd & Ladd 9370

According to Hale (1964), this species is known from points just west and south of Missouri, as well as from the northern Great Plains and Rocky Mountains to Mexico and Argentina. In Missouri it is known from several collections, all on exposed siliceous rocks in glades. Gier and Kendrick (1972) suggested that this species might grow in Missouri. A previous report of this species (Ladd and Wilhelm 1983) is referable to *X. subramigera* (Gyel.) Hale, which in southern Missouri is the common isidiate *Xanthoparmelia*. Curiously, both *X. conspersa* (Ehrh. ex Ach.) Hale and *X. plittii* (Gyel.) Hale are rare in Missouri, despite their greater abundance in other areas of the Midwest.

Discussion

It is interesting to note that these new lichens for Missouri display various patterns of phytogeographic affinities. It is now obvious that Missouri's lichen flora exhibits a much stronger affinity to the lichen flora of the southeastern coastal plain than was previously thought. Seven of the lichens discussed in this paper have southeastern distributions in the United States. Three of these were restricted heretofore to the southern Atlantic and Gulf coastal plains: *Cladonia leporina, Dirinaria picta* and *Parmotrema hypoleucinum*. The presence of these coastal plain species so far inland suggests that additional stations for these lichens should be sought along the Mississippi embayment.

Five lichens discussed in this paper display northern or circumpolar phytogeographic affinities: *Cladonia cariosa, C. rei, Flavopunctelia soredica, Tuckermannopsis americana* and *Usnea angulata*.

Perhaps most interesting of all has been the discovery in the state of 2 species of lichens with phytogeographic affinities to the arid southwest: *Peltula euploca* and *Psora icterica*. These represent a phytogeographic element previously unrepresented in Missouri's macrolichen flora.

Circumstances associated with the discovery of 3 species discussed in this report raise an interesting question: to what degree is the present-day lichen flora of Missouri representative of the presettlement lichen flora of the region? *Cladonia rei, Dirinaria picta* and *Flavopunctelia soredica* are each known from sites that are either altogether artificial or have undergone traumatic perturbations

of the natural vegetation. None of these lichens could have occupied its present site a decade ago. The presence of these lichens in newly available habitats suggests at least the possibility of recent introduction. It is well known that large numbers of vascular plant species are not native to the midwestern United States, but have become established in anthropogenically disrupted areas. Many of these species are native to the Old World, but some represent introductions from North American areas which are remote from the Midwest. For example, only 77% of Missouri's vascular flora is thought to be native to the state (Steyermark 1963). The profound and wide-ranging alteration of the native landscape that has occurred in Missouri since European settlement may have provided similar opportunities for disturbance-tolerant lichens to become established locally.

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Cytological Differentiation of Gray Treefrogs from Missouri

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Abstract: Cytological techniques based on distinctions in cell size and numbers of nucleoli were used to differentiate preserved specimens of the diploid-tetraploid gray treefrog complex (*Hyla chrysoscelis/versicolor*) from Missouri. Verification of the technique involved application to specimens whose specific identity had been determined prior to preservation.

Key Words: gray treefrog, *Hyla chrysoscelis, Hyla versicolor,* Missouri

Introduction

Hyla chrysoscelis and *Hyla versicolor* represent a diploid-tetraploid species pair. No morphological or ecological factors capable of consistent discrimination have been described. Mating cell analyses, determinations of chromosome numbers and distinctions in sizes of red blood cells have all been used to outline the geographic ranges of these species (Johnson 1977). These methods all require living or freshly killed animals. In order to effectively utilize preserved specimens, Cash and Bogart (1978) developed a method of identification based on differences in cell sizes and nucleolar numbers. We applied this method to treefrogs collected in Missouri.

Methods

Twenty-one gray treefrogs were collected or acquired from several localities in Missouri. All were subjected to analyses of cell size and nucleolar number as described by Cash and Bogart (1978), who also provided illustrations of specific differences. Twelve of the animals had been previously identifed by call analyses or, in the case of those from Boone County, were taken from a locality which has been extensively studied over a number of years during which no *Hyla chrysoscelis* have been taken, nor have any been taken within 50 km in any direction (Carl Gerhardt, Univ. of Missouri, pers. comm.). These were used to verify the validity of the other data generated.

Results

Of the 21 animals studied, 14 were *Hyla chrysoscelis* and 7 were *Hyla versicolor.* Identification of only 2 animals (1 of which had been previously identified) was in any way questionable. In both cases, treatment of a sample from the other eyelid resolved the question. Since analysis of 23 of 24 samples from previously identified animals supported the previous identification (the exception was inconclusive rather than contradictory), accuracy of the method exceeded 95%. Results are summarized in Table 1.

Table 1. Results of cytological differentiation of gray treefrogs from various localities in Missouri.

County	No.	Species	County	No.	Species
Barry	1	*H. chrysoscelis*	Hickory	1*	*H. chrysoscelis*
Boone	5*	*H. versicolor*	Jackson	1	*H. chrysoscelis*
Carroll	1	*H. chrysoscelis*	Livingston	1	*H. chrysoscelis*
Christian	1	*H. chrysoscelis*	Ray	1	*H. chrysoscelis*
Clay	2*	*H. chrysoscelis*	Wayne	1	*H. versicolor*
Daviess	1	*H. chrysoscelis*	Worth	4*	*H. chrysoscelis*
Grundy	1	*H. versicolor*			

**Previously identified (see text).*

Discussion

Considering the difficulties in distinguishing the 2 gray treefrog species, any method capable of using specimens already in museum collections would be of great value in elucidating distributional patterns. This would be of special significance in areas, such as much of Missouri, where the 2 species are sympatric. The technique applied here clearly has the potential to facilitate such biogeographic studies. Localities confirmed by these data have been included in Johnson (1987).

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A Qualitative Study of Fish-Amphibian Interactions in 3 Missouri Ponds

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Abstract: This study reports on the effect of the invasion of fish upon the composition of the amphibian community in 3 man-made ponds in east central Missouri. Fourteen species of anuran and caudate amphibians utilized 1 or more of the ponds before the invasion by fish of 2 of them. The amphibian community of the pond colonized by 6 species of fish was reduced to adults of 2 species of ranids. That of the pond invaded by 2 species of fish changed very little as did that of the pond which remained fish-free. The green sunfish, *Lepomis cyanellus*, was the species most responsible for the demise of the amphibian community.

Key Words: island biogeography, fish invasion, predation on aquatic amphibians, man-made ponds, Missouri

Introduction

Predatory fishes are capable of regulating the distribution of aquatic stages of many species of amphibians (Burger 1950, Blair 1951, Levi and Levi 1955, Brandon and Bremer 1967, Efford and Mathias 1969, Pennak 1969, Tanner et al. 1971, McCan 1977, Sexton and Bizer 1978). This study contrasts effects of the invasion by fishes upon species composition of the amphibian fauna of 3 man-made ponds subject to differential rates of invasion by fishes.

Study Area and Methods

The 3 ponds (Fig. 1) are located at the Washington University Tyson Research Center in western St. Louis County, MO. The 3 ponds differ in the likelihood of their being invaded by fish from a source area, the Meramec River.

The most readily invaded pond is Railroad Pond. It was excavated in July 1970. It is roughly circular and has a maximum width of 36 m and length of 42 m. A central depression is 1.7 m deep, but most of the pond is less than 1 m in depth. Runoff water enters the pond through a ditch. Water exits through a culvert in time of high water and flows 200 m through a ditch to Tyson Creek, an intermittent stream. Flow between the pond and river is episodic, but the pond can be in direct contact with the Meramec River at times of high flood. Water within the pond is turbid, and there are no rooted aquatic plants. This pond has never dried completely. A satellite pond (15 X 3 X 0.4 m) is located 20 m east of Railroad Pond. All species of amphibians using both Railroad Pond and the satellite invaded naturally.

New Pond is the next most readily invaded pond. It was constructed in February 1968 at a location 2.2 km south of Railroad Pond. It is circular with a

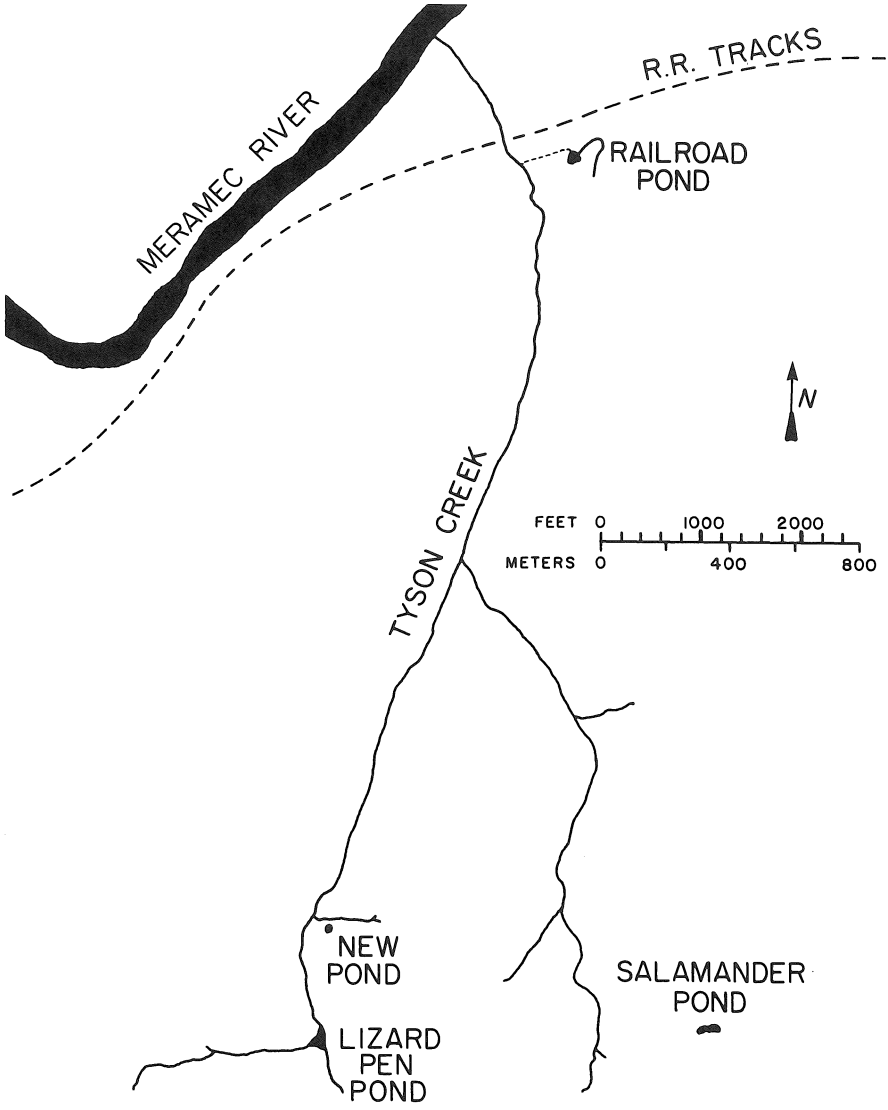

Fig. 1. Location of the 3 man-made study ponds at the Washington University Tyson Research Center, St. Louis County, MO (Coles 1981).

diameter of 15 m and a maximum depth of 1 m. It is filled with runoff water; excess water exits through a ditch before it empties into Tyson Creek. There is no rooted aquatic vegetation, and this pond sometimes dries completely. Eggs of *Ambystoma annulatum* were introduced in the fall of 1977 as were eggs of *Rana sylvatica* in the spring of 1980. All other species invaded naturally.

Salamander Pond has remained fish-free and is used as a control. The pond basin was excavated in a moist depression in August 1965 about 2.4 km south of Railroad Pond. The crescentic pond is 45 m long, 5 m wide and 1 m deep, maximally. The pond bottom is filled with dead leaves from the surrounding oak-hickory forest. Water, dark in color, is supplied by runoff; there is no outflow. A few rooted aquatic plants grow in the southwestern corner. This pond has never dried. Ambystomatid larvae (presumably *A. maculatum* but perhaps *A. tigrinum* also) were introduced in the fall of 1965 and eggs of *A. maculatum* were introduced in March 1968. Egg masses of *R. sylvatica* were transferred here in the spring of 1980. All other species invaded naturally.

Prior to this study, there were 2 major sources of information about the presence of fish and amphibians in the 3 ponds. The first source was from PhD theses and subsequent publications which dealt with various aspects of amphibian biology. The second source was information obtained initially through seining exercises by field courses and by general observations. Subsequent to the appearance of fish in 2 ponds, we initiated systematic sampling procedures. All ponds were sampled during the breeding and larval seasons by using 1 cm mesh seines dragged over specific distances. Relative abundance of each species of fish on any sampling date was estimated as the frequency of the total number of individuals of 1 species relative to the total number of individuals of all species seined on that date. These estimates of relative abundance were standardized by dividing them by the total length of the seine hauls to provide an estimate of among date abundance. Standard lengths of fish were measured upon several occasions. Drift fences with adjoining pit traps were placed around Railroad Pond in 1975, New Pond in 1984 and Salamander Pond from 1975 to 1986 to capture animals moving in and out of the ponds. Dip nets were used for making selective captures. Visual and aural identifications of breeding amphibians were also made.

The taxonomy of the amphibians follows Johnson (1977) except that members of the *Hyla versicolor - H. chrysoscelis* were classified as belonging to the *H. versicolor* complex and *R. utricularia* (=*spenocephala*) and *R. blairi* are treated as the *R. pipiens* complex. The taxonomy of the species of fish follows Pflieger (1975).

Results

Fish Ponds

Eleven species of amphibians are known to have utilized Railroad Pond for part of their life cycle during the pre-invasion period (Table 1). Members of the *R. pipiens* complex invaded Railroad Pond within 11 days after the pond filled with water. This population also bred during that summer of 1970 (Axtell 1974). *H. crucifer* bred in the spring of 1971, and some adult *Notophthalmus viridescens* were present then. Seale (1973, 1980) undertook an investigation of

the role of amphibian larvae in the cycling of nitrogeneous compounds in Railroad Pond in 1971 and 1972. She observed breeding adults of 9 species of amphibians: *Bufo americanus, H. crucifer, H. versicolor* complex, *Acris crepitans, R. catesbeiana, R. pipiens* complex, *Ambystoma maculatum, A. tigrinum and A. texanum.* She also estimated that there were 1100 larval *R. catesbeiana* present in 1971 and about that same number of larval *A. tigrinum* in 1972. Hatchlings of *B. americanus* numbered approximately 200,000 in both 1971 and 1972. Our observations added *Pseudacris triseriata* to the faunal list prior to 1979.

The first fish known to inhabit the pond were seined on 12 March 1979 when 11 fathead minnows, *Pimephales promelas*, were collected. Additional specimens were obtained on 22 March. Seining on 11 September 1979 produced 2 additional species: the green sunfish and golden shiner, *Notemigonus crysoleucas.* Young-of-the-year individuals of the latter 2 species were present.

The fourth species of fish, the black bullhead (*Ictalurus melas*) was first collected on 18 February 1984. The fifth and sixth species, bluegill, *Lepomis macrochirus*, and largemouth bass, *Micropterus salmoides*, were first obtained in the late spring and summer of 1986.

Fish were abundant in Railroad Pond following initial invasion. The number of individuals of the 4 species most commonly collected per meter of the seine haul ranged from 0.3 to 6.5 (Table 2). *Lepomis (cyanellus* only prior to 1986) was the most abundant taxon overall. It had a frequency of 0.9 or above in 5 of the 7 sampling events. *Ictalurus* had the highest frequency on 1 occasion. Most of the individuals of all species were small. Maximal standard lengths were: *L. cyanellus*, 15 cm; *I. melas*, 11 cm; *N. crysoleucas*, 8 cm; *P. promelas*, 7 cm; *M. salmoides*, 46 cm.

R. catesbeiana and *R. pipiens* complex were the only 2 species found in Railroad Pond after the fish invasion (Table 1). The last 2 larval *R. catesbeiana* seined from the pond in 1982 were 14.7 and 15.5 cm in total length. The other records for this species were of adults.

A variety of amphibians utilized the outlet ditch of Railroad Pond and the satellite pond near Railroad after the fish invasion. On 20 March 1982 the satellite pond had calling *Pseudacris triseriata*, larval *A. opacum* and egg masses of *A. maculatum* and of *R. pipiens* complex. A subadult *R. catesbeiana* was on the outlet ditch. On 7 April 1984 *Pseudacris* was calling from the satellite pond and ranid egg masses were present in it.

New Pond has an amphibian fauna of 12 species (Table 3). Ochs (1970) recorded a total of 6 species of anurans as being present prior to 1979. Subsequently, we noted the presence of 4 species of caudates and 1 other anuran. We also introduced egg masses of the ringed salamander, *A. annulatum*, in 1977 and of the wood frog, *R. sylvatica* in 1980.

Two species of fish, *N. crysoleucus* and *Pimephales promelas*, invaded the pond sometime between 7 April and 26 July 1984 (Table 3). *P. promelas* remained until the late summer of 1986 when the pond dried. No individual of either species had a standard length greater than 7 cm.

The above fish had little effect on the amphibians in New Pond. On 26 July 1984, we seined 9 ambystomatids and 32 ranid larvae as well as 68 fish (Table 2). The seine haul of 29 April 1985 yielded 1 adult *N. viridescens*, 2 *A. maculatum* egg masses with hatching larvae, 1847 ranid larvae and numerous

Table 1. Presence data for the known occurrence of amphibians in Railroad Pond, Washington University Research Center, St. Louis Co., MO. A = adult; E = egg mass; L = larva; P = *Pimephales promelas*; N = *Notemigonus crysoleucas*; I = *Ictalurus melas*; L_1 = *Lepomis cyanellus*; L_2 = *Lepomis macrochirus*; M = *Micropterus salmoides*.

Species	Year								
	Pre-1979	79	80	81	82	83	84	85	86
Ambystoma maculatum	A E L		E						
A. texanum	A								
A. tigrinum	A E L	A							
Notophthalmus viridescens	A								
Bufo americanus	A E L								L
Hyla crucifer	E	A							
H. versicolor complex	A								
Acris crepitans	A	A							
Pseudacris triseriata	A	A							
Rana catesbeiana	A E L	A L	A L	A	L			A	
R. pipiens complex	A E L	A L	A	A				A	
Fish species present		P L_1 N	P L_1 N	P L_1 N	P L_1		P L_1 I	L_1 N I	P L_1 L_2 N I M

Table 2. Summary of the abundance of fish in Railroad Pond based upon the numbers of individuals collected by hauling a 6.5 x 1.0 m seine over known distances. L = *Lepomis*; N = *Notemigonus*; P = *Pimephales*; I = *Ictalurus*; – = not yet invaded.

Date	Length of haul (m)	No. of hauls	No. and (Frequency) of individuals				Total no. fish	No. fish/m of haul
			L	N	P	I		
Railroad Pond								
8 May 81	10	3	99 (0.75)	13 (0.10)	20 (0.15)	–	132	4.4
20 March 82	10	5	17 (1.0)	0	0	–	17	0.3
12 July 82	20	3	110 (0.99)	0	1 (0.01)	–	111	1.85
7 April 84	13	2	61 (0.36)	0	0	108 (0.64)	169	6.5
26 July 84	16	3	46 (0.98)	0	0	1 (0.02)	47	0.99
29 April 85	20	1	111 (0.90)	7 (0.06)	0	5 (0.04)	123	6.15
2 July 86	13	2	131 (9.94)	1 (0.01)	0	7 (0.05)	139	5.35
New Pond								
26 July 84	16	1	–	67 (0.99)	1 (0.01)	–	68	4.25
29 April 85	10	1	–	0	25 (1.0)	–	25	2.50
2 July 86	12	1	–	0	38 (1.0)	–	38	3.17

Table 3. Presence data for the known occurrence of amphibians in New Pond. See Table 1 for key to abbreviations.

Species	Year								
	Pre-1979	79	80	81	82	83	84	85	86
Ambystoma annulatum							A		E
A. maculatum			L		E		A E L	A E L	A E
A. texanum						A	A	A	
A. tigrinum							A	A	
Notophthalmus viridescens						A	A	A	
Bufo americanus	A			A			A E L	A E L	
Hyla crucifer	A		E				A	A	
H. versicolor complex	A			A	A L				
Acris crepitans	A			A	A		A		A
Pseudacris triseriata	A		A E						A
Rana catesbeiana							A	A L	
R. pipiens complex	A		A	A L	E L	A	A E L	A E L	A E L
R. sylvatica			E						
Fish species present							N P	P	P

B. americanus larvae too small to be seined, along with the 25 *Pimephales*. During the collection of 2 July 1986, we seined 22 ranid larvae.

Fishless Pond

Amphibians rapidly invaded Salamander Pond after its construction (Table 4). Individuals of the *R. pipiens* complex were present within 2 weeks after completion of the pond. Ten species were established by 1979. This same species composition changed very little after 1979 with only *Acris crepitans* disappearing after 1982. The introduced *R. sylvatica* had established a large breeding colony by 1985.

Table 4. Presence data for the known occurrence of amphibians in Salamander Pond. See Table 1 for key to abbreviations.

Species	Year								
	Pre-1979	79	80	81	82	83	84	85	86
Ambystoma maculatum	A E	A E	A E L	A E L	A E L	A E	A E L	A E L	A E L
A. tigrinum	A E	A L	A E	A			A L	A L	A E L
Notophthalmus viridescens	A	A	A	A	A	A	A	A L	A L
Bufo americanus	A	A	A					A	A
Hyla crucifer	A L		A			A	A	A	A
H. versicolor complex	A	A L			L			L	L
Acris crepitans	A	A	A	A	A				
Pseudacris triseriata	A		A					A	A
Rana catesbeiana	A	L	A L		L	A			A
R. pipiens complex	A	A L	A E L	A L		A E L	A	A E L	A E L
R. sylvatica			E			A		A E L	A E L
Fish species present	None								

The population of breeding adults of *A. maculatum* was monitored from 1975 to 1986. The pond was completely surrounded by a drift fence in 1975, 1976, 1977 and 1986. The total numbers of immigrating adults were 1001, 1208, 629 and 1351, respectively. The breeding population of this species has not declined since 1979.

Discussion

Newly formed ponds are aquatic islands isolated within a terrestrial matrix. Colonizing individuals can invade them by dispersing from aquatic or terrestrial source areas. The likelihood of successful invasion is determined by such factors as spatial and temporal contiguity of the ponds to the source areas, mode of dispersal and physiological constraints of the potential colonists and the physical and biological properties of the pond (MacArthur and Wilson 1967).

The Meramec River fish fauna just above the confluence of Tyson Creek is composed of 89 species and is the richest fish fauna of any stream in the state (Pflieger, pers. comm.). Fish from this source can invade ponds under 2 contingencies. The more frequent case is that in which heavy, localized rains fill ponds with excess water so that there is a short-term outflow of water from the ponds to Tyson Creek and then to the river. For example, on 11 April 1979, 12.5 cm (4.91 inches) of rain fell within 1 hour. This rainfall was the heaviest hourly record for April up to its occurrence. The second case occurs during heavy flooding on the Meramec. On 8 December 1982, the river rose high enough to flood the outlet of Railroad Pond. New Pond was not so affected. Salamander Pond has never been in contact with the Meramec or its tributaries. Thus, the 3 ponds form a continuum relative to the ease of invasibility by fish from the Meramec from Railroad to New to Salamander ponds.

The earliest species to invade the 2 ponds share certain traits (Pflieger 1975). *Pimephales, L. cyanellus* and *I. melas* are pioneer species which invade aquatic habitats characterized by silt, turbidity and variable temperature and oxygen regimes, etc. *Notemigonus* is also tolerant of such conditions. It is a generalized feeder; approximately half of its diet consists of plant material and half of small crustaceans, snails and terrestrial insects. *Pimephales* eats mostly plant material but will take insects. *Ictalurus* feeds upon immature aquatic insects. *L. cyanellus* will take animal prey as large as adult insects, small fish and crustaceans. Thus, 2 of the 4 early invaders are, in part, primary consumers and all 4 are members of lower order consumer trophic levels. A later invader, *L. macrochirus*, can switch to algae and other plants if its normal diet of adult insects, crayfish and small fish is unavailable. Adult *M. salmoides* are carnivores which feed on large prey. Overall, this early-invading fish fauna appears to conform to the expectations of Heatwole and Levins (1972) about the trophic position of the early invaders of islands.

Nineteen species of amphibians inhabit the terrestrial source area surrounding the ponds, and 14 species use the ponds during some phase of their life cycle. Access to the aquatic islands from the terrestrial matrix is not dependent upon spatially and temporally variable connections as it is for the connection of aquatic sources to the ponds. Ten of these species utilized all 3 ponds. One (*A. opacum*) was found only in the satellite pond of Railroad Pond; *A. texanum* occurred in 2 ponds. The recently introduced species *A. annulatum* and *R.*

sylvatica have each successfully colonized only 1 pond to date. The utilization of newly formed ponds by amphibians is initially dependent upon the distribution of amphibians throughout the terrestrial domain. The fact that all 3 ponds were readily exploited by amphibians (excluding the few instances of introductions) indicates that there are "floating" populations of all species, which are not restricted to using specific aquatic areas but which will invade suitable situations. The fact that amphibians used the satellite pond subsequent to the invasion of Railroad Pond by fish, demonstrate that there is a residual population available for reinvasion under favorable conditions.

The result of these 2 types of invasions is that amphibians are more likely to invade newly available ponds before fish can, but that fish can later modify the species composition of amphibian communities. However, ponds, such as upland ones (e.g., Salamander Pond) which are not readily susceptible to invasion by fish, are more likely to have a more diverse amphibian fauna than are ponds open to invasion. Thus, predation, per se, may not always contribute to an increase in species diversity of certain faunal groups (Paine 1966).

Not all species of fish can effect changes. Data from New Pond suggest that *P. promelas* and *N. crysoleucas* have little or no effect upon the amphibians, and the food habits of the 2 species (Pflieger 1975) indicate why. *L. cyanellus* is the predator which decimated the Railroad Pond amphibians. The later presence of *I. melas, L. macrochirus* and *M. salmoides* would have exacerbated the situation. Although many species of amphibians have anti-predator adaptations (Kruse and Francis 1977, Ward and Sexton 1981), the presence of a large number of predators could overwhelm the effectiveness of these defenses, particularly those of vulnerable, newly hatched young. The continuation of *R. catesbeiana* and *R. pipiens* complex in Railroad Pond may be an indicator that only large adults of some species are able to escape predation by fish such as *L. cyanellus*.

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The Golden Wedding: 50 Years of Cooperative Endeavor at the Missouri Cooperative Fish and Wildlife Research Unit

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Abstract: The Missouri Cooperative Fish and Wildlife Research Unit and its antecedents have a 50-year history of cooperative support by the host University of Missouri-Columbia, and state, federal and private natural resource organizations. Three hundred and six students have received Master's and PhD degrees. About 62% of those providing adequate records were employed by natural resource agencies and 20% by universities or other teaching or research organizations. Participation by staff, students and graduates in professional organizations has been strong. Unit participants have authored nearly 700 publications, 66% of them in refereed journals.

Key Words: Cooperative Fish and Wildlife Unit, Missouri, history, fisheries research, wildlife research, conservation education

Introduction

The Missouri Cooperative Wildlife Research Unit, an antecedent of the present Cooperative Fish and Wildlife Research Unit, was authorized in July 1937. For 50 years, the Missouri Unit has been a prominent source of research findings useful in preserving and managing fish and wildlife resources in the state and elsewhere. The Unit has also been a source of fish and wildlife biologists, trained at the graduate level, for research and management positions in resource agencies, and of wildlife scientists at universities.

The Missouri Unit is a member of the national Cooperative Fish and Wildlife Research Unit program, a successful arrangement fostering cooperation among universities, the U.S. Fish and Wildlife Service and state and private conservation organizations. In this paper, we describe the history and accomplishments of the Missouri Unit, and provide perspective with information about the national Unit program.

The National Cooperative Unit Program

The Unit system started in Iowa, and the key person was Jay Norwood Darling. "Ding" Darling was a nationally famous editorial cartoonist, identified with the Des Moines *Register*. He was also an ardent and well-informed conservationist who became Chairman of the Iowa Fish and Game Commission in the early 1930's. In consultations with wildlife experts of the time, notably

Aldo Leopold, Darling was astonished at the shortage of factual knowledge needed to manage wildlife resources and at the scarcity of biologists trained to perform wildlife research, apply the results and administer programs in a professional manner.

In 1932, he responded in "typical, direct Darling fashion" (Lendt 1979:79) by proposing an arrangement in which Iowa State College would join with public resource agencies in a cooperative program of wildlife research and graduate training. Funds would be contributed by the College, the Iowa Fish and Game Commission and personally by Darling himself, who pledged $3000 per year for 3 years. The proposal was accepted and Dr. Paul Errington, a young PhD graduate of the University of Wisconsin with ties to Aldo Leopold, joined the Iowa State College faculty in July 1932 to organize and guide the unique cooperative venture (Haugen 1966).

In 1934, Darling was called to Washington to serve as Chief of the Bureau of Biological Survey under fellow Iowan Henry A. Wallace, then Secretary of Agriculture. Darling entered the Washington scene at full speed. By 1935-36, he had secured funding sufficient to place a federal biologist at Iowa and each of 8 other Cooperative Wildlife Research Units at state land-grant institutions throughout the nation. These funds, added to those from state sources, came partly from appropriated federal monies and partly from the American Wildlife Institute, the latter supported by sporting arms and ammunitions manufacturers (Lendt 1984). The federal "Unit Leaders" received regular academic appointments, had their own research and graduate student programs and coordinated affairs of the Units. The 9 Units, 8 of them staffed in 1935 (Jackson 1937), marked the beginning of the Cooperative Research Unit program as we know it now. Colleges have been renamed universities, the Bureau of Biological Survey has become the U.S. Fish and Wildlife Service (now within the Department of Interior), many state agencies have been renamed and positioned differently in state governmental schemes and the American Wildlife Institute is now the Wildlife Management Institute. But the basic arrangements and means of support have survived. Fishery units, structured similarly, were added to the family beginning in the 1960's; many fishery units and wildlife units were later combined.

In general, the program has been very effective, partly because internal mechanisms permit input from conservation agencies that focus research efforts on problems important to resource managers. Nationally it has been a popular program, perhaps too popular, because federal funding has not kept pace with the expansions authorized. For federal fiscal year 1987, 36 cooperative research units are authorized: 5 wildlife, 9 fishery and 22 combined fish and wildlife units. The last-named arrangement seems the wisest in today's fiscal climate, and the Missouri Unit is a combined one.

Each Unit is guided by a Coordinating Committee with 1 representative from each of the 3 major supporting agencies: the university, the state conservation agency and the U.S. Fish and Wildlife Service. The arrangement is like a marriage; if the participants want it to work, it affords an excellent home for fish and wildlife research and training at the graduate level. If, however, participating agencies or their local representatives consistently put narrow interests first, the arrangement can be unproductive and miserable; a few have failed.

Events at the Missouri Unit, 1937-87

The Missouri Cooperative Wildlife Research Unit was established in July 1937, 2 years after the first "surge" of units. Formation of the Missouri Unit had awaited creation of the new bipartisan Missouri Conservation Commission. The first official action of the commissioners, after electing their own officers, was to sign the agreement that brought life to the Unit. Unit staff members were Rudolf Bennitt, Professor of Zoology at the University, Werner O. Nagel, Research Associate at the University and Paul D. Dalke, representing the U.S. Bureau of Biological Survey (Table 1).

Table 1. Principal events and personnel changes related to the Missouri Cooperative Fish and Wildlife Research Unit program, School of Forestry, Fisheries and Wildlife, University of Missouri-Columbia, 1937-1987.

1937 Cooperative Wildlife Research Unit authorized; was attached to the Department of Zoology (later changed to Division of Biological Sciences), College of Arts and Science, UMC.

1938 Wildlife Research Unit operating, staffed by Rudolf Bennitt and Werner O. Nagel (UMC) and Paul D. Dalke (U.S. Bureau of Biological Survey).

1939 Edward K. Love Conservation Foundation money first made available for Unit wildlife fellowships.

1940 Nagel accepted position with Missouri Department of Conservation; Douglas E. Wade appointed Instructor in Field Zoology.

1943 Wade resigned to accept a position at Dartmouth College, Hanover, NH.

1944 Robert S. Campbell appointed Assistant Professor of Zoology; fishery program implemented.
William H. Rucker endowed chair at UMC established; Rudolf Bennitt was first William Rucker Professor.

1945 William H. Elder appointed Assistant Professor of Zoology, developed graduate course in wildlife management.

1947 Unit Leader Dalke transferred to the Idaho Cooperative Wildlife Research Unit as Leader.

1948 Thomas S. Baskett reported as Wildlife Unit Leader.

1950 Rudolf Bennitt died. Daniel Q. Thompson appointed Instructor in Zoology.

1952 Arthur Witt, Jr., appointed as Assistant Professor of Zoology to enlarge fishery program.

1953 Thompson resigned to complete PhD requirements.
Robert L. Dunkeson appointed Instructor in Zoology, a post held until June 1954.

1960 Ashland Wildlife Research Area transferred from federal government to UMC.
Gaylord Laboratory agreement signed; under its terms, UMC operates the Laboratory with funds provided jointly by MDC.

1961 John P. Rogers appointed Director of Gaylord Laboratory and Instructor in Zoology, UMC.

1962 Cooperative Fishery Unit established.

1963 David I. Foster was named Fishery Unit Assistant Leader; Richard O. Anderson reported as Leader.

1965 Sandy Clark became Wildlife Unit Secretary, now Unit Administrative Assistant.

1966 Foster transferred to the Albuquerque Regional Office of the U.S. Bureau of Sport Fisheries and Wildlife (BSFW) and was replaced in 1967 by Daniel W. Coble.
Rogers resigned as Director, Gaylord Laboratory, to join the Washington, DC, staff of the Wildlife Research Division (WRD), BSFW. He was replaced temporarily by Nicholas R. Holler, and permanently in 1967 by Leigh H. Fredrickson.

1968 Baskett appointed Chief, WRD, BSFW, in Washington, DC; W. Reid Goforth reported as Assistant Wildlife Unit Leader (Acting Leader).

Table 1 (continued).

1969 Goforth named Leader.
Rollin D. Sparrowe assigned as Assistant Wildlife Unit Leader.
1971 Paul K. Wehmiller Fund established; income used for graduate fellowships in fisheries.
Coble went to the Wisconsin Fishery Unit as Leader; replaced in 1972 by James B. Reynolds.
1973 Units moved, with UMC fisheries and wildlife program, to the College of Agriculture to join the School of Forestry, as the School of Forestry, Fisheries and Wildlife.
Goforth became Assistant Director of the Northern Prairie Wildlife Research Center, U.S. Fish and Wildlife Service (FWS).
Baskett returned as Wildlife Unit Leader and Professor in wildlife.
1975 John R. Jones appointed Assistant Professor in limnology.
1976 Sparrowe was promoted to Head, Cooperative Wildlife Research Units in Washington, DC; Fred B. Samson became Assistant Wildlife Unit Leader.
1978 Robert S. Campbell retired; William W. Taylor appointed Assistant Professor in fisheries.
Erik K. Fritzell became Assistant Professor in wildlife.
Reynolds was promoted to Leader of the Alaska Fishery Unit.
1979 Charles F. Rabeni became Assistant Leader of the Fishery Unit.
1980 Taylor left to become Assistant Professor at Michigan State University; replaced by Terry R. Finger as Assistant Professor in fisheries.
1983 Arthur Witt, Jr., retired; replaced by Thomas G. Coon as Assistant Professor in fisheries.
Ernie P. Wiggers hired as Ashland Wildlife Research Area Manager, and became Assistant Professor in wildlife in 1985.
1984 William H. Elder retired; replaced by Mark R. Ryan as Assistant Professor in wildlife.
1985 Units combined as Cooperative Fish and Wildlife Research Unit; Rabeni named Unit Leader.
Baskett retired from FWS; continues as UMC Professor, part time.
Anderson became Director of the FWS National Fishery Center in San Marcos, TX.
1986 Ronald D. Drobney reported as Assistant Unit Leader-Wildlife.

Dr. Bennitt, who was chairman of the Unit's first Administrative Committee, was already an important force in Missouri's conservation movement. E. Sydney Stephens, the prime mover in the successful drive to create a Missouri Conservation Commission via constitutional amendment, and the first Chairman of the Commission, frequently relied on Bennitt for technical advice. Bennitt also helped select the first Director of the Conservation Department, and was repeatedly consulted by Department personnel as their program developed. He had a strong hand in obtaining funds for the Wildlife Conservation Building (Stephens Hall) on campus, and in arrangements for the University's Ashland Wildlife Research Area, at first leased by the University from the federal government.

Werner Nagel, with Bennitt, conducted Missouri's game survey of the 1930's and coauthored the results in *University of Missouri Studies* (Bennitt and Nagel 1937). He later joined the Conservation Department as a writer and editor. His book, *Conservation Contrasts* (Nagel 1970), contains many evidences of interaction between the Conservation Department and the Cooperative Wildlife Research Unit, particularly in their early histories.

Dr. Dalke received his PhD in one of the early advanced-degree wildlife programs, at the University of Michigan under guidance of Professor H. M. Wight. Dalke emphasized forest-wildlife research during his stay in Missouri, and was coauthor of a landmark publication on the wild turkey in Missouri (Dalke et

al. 1946). This bulletin was the first published by the Missouri Conservation Department in its technical wildlife series, now termed "Terrestrial Series."

Additions to the University's faculty during the first decade had profound and progressive consequences on the Missouri Unit program in the years to come. The appointment of Dr. Robert S. Campbell in 1944 added a fisheries dimension which was strengthened in 1952 by the addition of Dr. Arthur Witt, Jr. Existence of the University's fisheries program was a crucial factor in Missouri's securing a Cooperative Fishery Research Unit in 1962 (Table 1). Dr. William H. Elder's arrival in 1946 brought a strong emphasis on waterfowl biology that has persisted and has been greatly augmented by the program at the Gaylord Memorial Laboratory in Puxico, MO, beginning in 1960.

By mid-1985, when the Wildlife and Fishery Units combined, all the faculty and staff of the first 2 decades of Unit existence had departed through transfer, retirement or death. Following combination, the Unit has been served capably by Drs. C. F. Rabeni, Leader, and R. D. Drobney, Assistant Leader-Wildlife (the Assistant Leader-Fisheries position is unfilled). University faculty members involved with Unit research are Dr. L. H. Fredrickson at the Gaylord Laboratory and on the Columbia campus, Drs. E. K. Fritzell, M. R. Ryan and E. P. Wiggers in wildlife. In fisheries-aquatic biology, they are Drs. J. R. Jones, T. G. Coon and T. R. Finger (Table 1).

The Missouri Cooperative Research Unit program has benefitted greatly from special gifts and bequests. The earliest example is money for graduate fellowships in wildlife, available annually since 1939 from the Edward K. Love Conservation Foundation. Mr. Love, who established the Foundation, was a member of the first Conservation Commission, and was prominent in forming the Conservation Federation of Missouri. The Foundation provides money, also, for an educational program through the Federation. In 1944, the estate of William H. Rucker of St. James, MO, provided funds to endow a chair in wildlife conservation at the University. Drs. Bennitt and Elder have held the Rucker appointment. Since 1971, the Paul K. Wehmiller Fund has provided income for use as graduate fellowships in fisheries.

Accomplishments of the Missouri Cooperative Research Unit Program

In summarizing Unit accomplishments over 50 years, we have drawn on records for the entire fisheries and wildlife program at the University of Missouri-Columbia. It is impossible to define a tighter circle, because virtually all research projects, whether carried out by faculty or graduate students, have benefitted from the Unit presence. These benefits include stipends and travel reimbursement in many cases, and equipment, facilities and supplies for nearly everyone. Unit staff have often led the way in securing outside grant funding for research projects; those funds in turn allowed Unit resources to be widely shared within the fisheries and wildlife program. Based on this cooperative arrangement, Unit staff are treated as faculty, University professors are Unit Cooperators and all fisheries and wildlife graduate students are Unit students.

In 50 years, 306 students have received 320 advanced degrees: 286 Master's, 20 PhD's and 14 both degrees. One hundred and seventy-four were in the wildlife program and 132 in fisheries, the latter program having started later.

Through faculty and student research, the Missouri Unit has made important and sometimes outstanding contributions to fishery and wildlife science. Pioneering work on such diverse wildlife subjects as bobwhite quail populations, wild turkeys, biology of furbearers and waterfowl and wetland management all come to mind. In the aquatic field, early contributions were made through the study of acid pollution characteristics in stripmine lakes and in the broad subject of freshwater fishery management.

Many of these research thrusts have been continued or strengthened. In the Unit's midlife, research on pollution in both terrestrial and aquatic systems was a prominent addition, as were studies of structural indices of fish populations and biology and management of mourning doves and means of habitat evaluation.

In still more recent years, forest wildlife, furbearers and predators and birds of grasslands and agricultural ecosystems have received new or renewed attention. On the aquatic side, both reservoirs and streams have been intensively studied in subjects ranging from nutrients to fish communities.

Changing research emphases over the years are reflected quantitatively in tallies of publications and theses according to subject matter (Table 2). As an example, the emergence of concern about endangered species is mirrored in the numbers of publications and theses on this subject in the last 2 decades.

Table 2. Missouri Cooperative Fish and Wildlife Research Unit publications and theses during the 50 years of the program, arranged by subject area in descending order by numbers of *publications*. No thesis was required of 3 MA students.

Subject area	1937-46		1947-56		1957-66		1967-76		1977-87		% of total	
	Pub	Th*	Pub	Th	Pub	Th	Pub	Th	Pub	Th	Pub	Th
Mammals	13	8	22	8	26	12	21	12	34	12	17	16
Fishes	1	0	11	18	11	21	25	25	49	28	14	29
Waterfowl/wetlands	2	0	16	5	28	9	8	7	43	15	14	11
Gamebirds/raptors	24	2	9	9	23	12	12	10	24	9	13	13
Limnology/benthology	1	1	4	3	8	4	12	14	43	16	10	12
Nongame birds	1	0	4	0	5	1	2	2	47	7	8	3
Education and information	18	0	12	1	4	2	5	0	7	0	7	1
Habitat/habitat evaluation	10	1	7	0	1	1	1	4	9	3	4	3
Contaminants	0	1	2	2	4	1	8	10	12	7	4	7
Wildlife management	11	0	2	0	6	1	2	0	4	1	4	1
Endangered species	0	0	0	0	0	0	3	1	17	7	3	3
Reptiles and amphibians	1	0	4	2	5	1	3	0	5	1	2	1
Total	82	13	93	48	121	65	102	85	294	106	100	100

*Pub = publications; Th = theses.

Productivity of any organization dedicated to research and graduate training is judged in part by its publication record. In 50 years, the Missouri Unit program has produced nearly 700 publications, 66% of them in refereed, technical journals. Many of the remaining one-third are in non-refereed but highly useful and often technical sources, including the *Transactions of the North American Wildlife and Natural Resources Conference.* Still others are popular or semipopular articles, and they too have very useful functions.

Professional performance can also be judged by participation of faculty, students and graduates in professional societies. Three persons with close ties to the Missouri Unit have served as presidents of The Wildlife Society, including the first President, Rudolf Bennitt. The other 2 were T. S. Baskett and Bill T. Crawford (MA 1942). Oliver Torgerson, a Missouri Unit Master's degree recipient, is now Vice-President of that Society and the other nominee, Bettina Sparrowe, is also a Missouri Unit Master's graduate. Erik Fritzell, a University of Missouri faculty member, is presently the North-Central Section Representative to the national Wildlife Society Council. Joseph Dillard, a Missouri Unit MA graduate, is the current Second Vice-President and future President of the American Fisheries Society. During their service on the University of Missouri faculty, Campbell and Witt had important roles in organizing the North American Benthological Society, a professional group very important to aquatic biologists.

Both The Wildlife Society and the American Fisheries Society have state chapters and regional divisions or sections. Almost annually, Missouri Unit graduates hold important offices in these subgroups of the parent societies.

Placement of Missouri graduates testifies to fulfillment of an important objective of the Unit program. Complete placement records are available on all but 30 of the 306 graduates. Fifty of the Missouri Unit's advanced degree recipients were permanently placed with the Missouri Department of Conservation (MDC), 45 with the U.S. Fish and Wildlife Service (FWS) and 3 with the University of Missouri. Thus, 35% of the graduates for whom records are adequate, were employed by the 3 principal organizations funding the Missouri Unit. One Director and 3 Assistant Directors of MDC, an Assistant Director and 2 Regional Directors of FWS are among these.

Another 45 graduates were employed by state resource agencies other than MDC, and 31 by federal resource agencies besides FWS. In total, 62% of the graduates with known placement records were hired by federal or state resource agencies.

Fifty-six Missouri Unit advanced degree recipients were placed in teaching or research positions in universities (other than UMC) or other institutions, including high schools. Many of these persons have fine records in fisheries and wildlife and closely related fields as authors, editors, teachers and university administrators. Still other graduates serve in private organizations—Ducks Unlimited, for example—dedicated to natural resource conservation and management.

The very close ties and indistinct boundaries between Unit and University of Missouri have greatly strengthened the total program in fisheries and wildlife. Outstanding cooperation among agencies, as well as quality and breadth of interests of these agencies are also very important factors in program strength.

The Missouri Unit has thus been able to produce valuable research results and strong professional graduates.

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Fall Foods and Nutrition of Ruffed Grouse in Missouri

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Abstract: The crop contents of 53 ruffed grouse killed between 1 October and 18 December were analyzed. Principal food groups ranked by aggregate percent volume were: soft mast, hard mast, green leafy material, buds and catkins and animal matter. The 6 most prevalent fall food items in crops were: wild grapes, acorns, multiflora rose fruits, white avens leaves, poison ivy fruits and sweet William leaves. Proximate chemical composition of crop contents was 11.4% crude protein, 34.6% crude fiber, 9.5% crude fat, 10.4% ash, 33.5% nitrogen free extract, 0.5% calcium and 0.2% phosphorus. Our findings are compared to those of Korschgen (1966), which were based on analysis of fecal droppings.

Key Words: Missouri, ruffed grouse, fall foods, nutrition

Introduction

Throughout the southern portion of the ruffed grouse's range its principal foods are green leafy plants, soft and hard fruits, buds and catkins (Korschgen 1966, Stafford and Dimmick 1979, Norman and Kirkpatrick 1984). Korschgen (1966) reported foods and nutrition of ruffed grouse in central Missouri based on analysis of fecal droppings. Although large samples of crops are more difficult to obtain than droppings, analysis of crop contents is more accurate because undigested foods from crops are more easily identified; and differential digestibility does not bias results. We investigated fall food habits and nutrition of ruffed grouse in Missouri based on crop contents of hunter killed birds.

Study Area and Methods

Ruffed grouse crops were requested from hunters as part of the Missouri Department of Conservation's 1984 and 1985 Ruffed Grouse Hunter Survey. Each Missouri grouse hunter was mailed a questionnaire and postage paid envelope in which to return grouse crops. The grouse season extended from 1 October to 15 November 1984 and from 15 October to 18 December 1985. Only the southern portions of Boone, Callaway, Warren and Montgomery counties in central Missouri were open to hunting. This region is characterized by oak-hickory forest interspersed with pasture and cropland. Abandoned agricultural land supports characteristic oldfield vegetation including eastern red cedar (*Juniperus americana*), oak (*Quercus* spp.), hickory (*Carya* spp.), sassafrass (*Sassafrass albidum*), persimmon (*Diospyros virginiana*), sumac (*Rhus* spp.), multiflora rose (*Rosa multiflora*) and bittersweet (*Celastrus scandens*). Oak-hickory forest is primarily large pole and sawtimber with understories of

hophornbeam (*Ostrya virginiana*), flowering dogwood (*Cornus florida*), serviceberry (*Amelanchier arborea*) and sugar maple (*Acer saccharum*).

Crop contents were air dried in paper envelopes. The contents of each crop were then separated, identified and the volumetric displacement of each food type determined. Measurement to 0.1 cc was possible; any volume less than that was recorded as a trace. Percent occurrence and aggregate percent volume (Martin et al. 1946) were determined for each food type. The aggregate percent volume method was used because sample size was small and crop contents differed widely in volume (Korschgen 1980). Crop contents were reassembled and total contents from both years were sent to Livestock Nutritional Laboratory Services, Columbia, MO, for proximate analysis.

Results and Discussion

Thirty-four crops containing food items were received in 1984 and 19 in 1985. Eighty-three questionnaires were returned with the crops and indicated the distribution of the grouse harvest was: 19% from 1-15 October, 28% from 16-31 October, 14% from 1-15 November, 22% from 16-30 November and 17% from 1-18 December. Twenty-five food types were identified and classified into 5 major groups. Both food types and food groups were ranked by aggregate percent volume (Table 1).

Soft mast, especially fruits of wild grape, multiflora rose and poison ivy, made up the majority of the fall diet (Table 1). In Virginia soft fruits comprised 28.9% of ruffed grouse crop contents in October and increased to 69.9% during winter (Norman and Kirkpatrick 1984). Soft mast was the largest component (47%) in crops collected in Ohio during November (Gilfillan and Bezdek 1944). In Tennessee and North Carolina fruits represented 28.5% of crop contents and were the second most abundant food group during fall and winter (Stafford and Dimmick 1979).

Hard mast, the second most prevalent food group, consisted primarily of white oak (*Quercus alba*), red oak (*Q. rubra*), chinkapin oak (*Q. muehlenbergii*) and black oak (*Q. velutina*) acorns. Acorns were the most important food source used by grouse during early fall in Virginia (Norman and Kirkpatrick 1984), but were of minor importance in Ohio (Gilfillan and Bezdek 1944). Soft and hard mast are significant foods throughout the southern portion of the ruffed grouse range during fall, and their use has been associated with fat deposition (Norman and Kirkpatrick 1984).

Green leafy material, on average, comprised only 11.4% of crop contents but was present in nearly 40% of all crops (Table 1). Green leafy material was the most important component of fall and winter grouse diets in Tennessee and North Carolina, but in Virginia it was used relatively little (Norman and Kirkpatrick 1984). Buds and catkins comprised a small percentage of ruffed grouse diets in this study (Table 1), in Virginia (Norman and Kirkpatrick 1984) and in South Carolina and Tennessee (Stafford and Dimmick 1979). However, they are an important ruffed grouse food in the northern U.S. and Canada (Svoboda and Gullion 1972).

The diet of ruffed grouse was dominated by 6 food items: wild grape fruits, acorns, multiflora rose fruits, white avens leaves, poison ivy fruits and sweet William leaves. These species were ranked highly in both occurrence and

Table 1. Fall foods of ruffed grouse in Missouri.

Food	Part utilized	Aggregate % volume	% occurrence
Soft mast		44.8	66.5
Hard mast		27.2	41.5
Leafy plant material		11.4	39.6
Buds and catkins		1.6	5.6
Animal		Trace	1.9
Wild grape (*Vitis* spp.)	Fruit	29.7	39.6
Oak (*Quercus* spp.)	Acorns	15.3	30.2
Multiflora rose (*Rosa multiflora*)	Fruit	10.3	20.8
White avens (*Geum canadense*)	Leaves	7.1	20.1
Poison ivy (*Rhus radicans*)	Fruit	5.3	9.4
Sweet William (*Phlox acrostichoides*)	Leaves	4.6	11.3
Christmas fern (*Polystichum acrostichoides*)	Leaves	1.9	5.6
Violets (*Viola* spp.)	Leaves	1.9	9.4
Hazel (*Corylus americana*)	Catkins	1.8	1.9
Tick trefoils (*Desmodium* spp.)	Seeds	1.5	17.0
Ladies' tobacco (*Antennaria* spp.)	Leaves	1.6	3.7
Smooth sumac (*Rhus glabra*)	Fruit	1.4	1.9
Unidentified plant material	Leaves	1.2	22.6
Fleabane (*Erigeron* spp.)	Leaves	1.2	13.2
Plant galls	Gall	1.2	3.7
Fragrant sumac (*Rhus aromatica*)	Fruit	1.2	1.9
Eastern hophornbeam (*Ostrya virginiana*)	Catkins	0.7	5.6
Spleenwort (*Asplenium* spp.)	Leaves	0.5	1.9
Unidentified seeds	Seeds	0.5	3.7
Fungus		0.4	1.9
Rocks		0.4	3.7
Flowering dogwood (*Cornus florida*)	Fruit	0.3	3.7
Bush clovers (*Lespedeza* spp.)	Leaves	0.2	3.7
Grasshoppers (*Acrididae*)		Trace	1.9

volume. Tick trefoil seeds and fleabane leaves occurred in low volume but were present in >10% of the crops. The 6 most prevalent foods reported here were also reported by Korschgen (1966), though only wild grape, acorns and multiflora rose were abundant in fall diets. Korschgen (1966) found hophornbeam to be a heavily used grouse food from December to March, but we detected only small amounts of it in our samples predominantly from October and November.

Korschgen (1966) approximated the nutritional composition of average grouse diets based on proximate composition of foods and their relative volume in droppings. Proximate analyses of crop contents in this study indicated a diet lower in protein and nitrogen-free extract and higher in fat, fiber and ash than that estimated by Korschgen (1966) (Table 2). In the southern part of the ruffed grouse's range fall diets high in fat and carbohydrates may be important for fat storage, allowing ruffed grouse to undergo periods of negative energy balance during the winter (Norman and Kirkpatrick 1984). Gullion (1966) questioned

Table 2. Proximate chemical composition of fall ruffed grouse diets in Missouri.

Source	% crude protein	% crude fat	% nitrogen free extract	% crude fiber	% ash	% calcium	% phosphorus
This study	11.38	9.48	33.48	34.64	10.44	0.40	0.18
Korschgen (1966)[a]	16.44	8.02	51.74	19.17	4.59	—	—

[a]Mean calculated from October, November and December values.

the importance of fall food habits to grouse survival because they may indicate a high preference for foods that may not sustain grouse through the season of greatest environmental stress. In northern habitats aspen is available all winter and is an important and nutritious winter food (Svoboda and Gullion 1972). Grouse there apparently do not demonstrate a fall lipolytic response (Thomas et al. 1975), and fall diets may be less important to winter survival.

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Nesting Ecology of Northern Harriers in Southwest Missouri

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Abstract: Characteristics of northern harrier (*Circus cyaneus hudsonius*) nesting habitat at Prairie State Park in southwest Missouri are described. Fourteen of 15 (93%) harrier nests were built in patches of dense vegetation composed entirely or mostly of blackberry (*Rubus* sp.). These patches averaged 98 m^2 in area and 79.2 cm in height. Nests were placed an average of 3.5 m from the outer edge of each patch. Nesting success was higher in pairs nesting in idled sections of the park than in managed sections. Mean clutch size was 5.3 (range 4-8), hatching success was 69.6%, fledging success was 60% of the eggs that hatched and an average of 3.3 young fledged per successful nest. Mammals comprised 44.9% of the diet by occurrence and 65.5% in estimated biomass. Avian prey species included greater prairie-chickens (*Tympanuchus cupido*).

Key Words: northern harrier, habitat, Prairie State Park, prairie

Introduction

Northern harriers nest throughout North America with the exceptions of northern Canada, Alaska, southern California, Texas and the deep southeastern states (Brown and Amadon 1968). This species is also represented by a race in Europe and much of Asia, the hen harrier (*C. c. cyaneus*). The northern harrier is the only North American representative of the harrier subfamily Circinae, which is comprised of 10 species mainly in the eastern hemisphere (Brown and Amadon 1968). Although northern harriers are highly adaptable ground nesters, utilizing most habitats except forest (Hamerstrom and Kopeny 1981), their ground nesting habits make them more vulnerable to a wide range of predators and other disturbances. Known causes of nestling mortality include a plethora of carnivores, snakes and raptors, as well as deer, cattle, carrion beetles and human activities (Brown and Amadon 1968, Hamerstrom 1969).

Declining numbers of breeding harriers, especially in the eastern United States (Arbib 1975), have elicited nationwide concern. Population declines have been reported throughout the Midwest and East (Hamerstrom 1969, Henny 1972, Hamerstrom 1979, Newton 1979). Population declines are apparently related to pesticide contamination at a local level (Hamerstrom 1969, 1979) and habitat alteration at a more widespread and general level (Lokemoen and Duebbert 1976). Extensive draining of wetlands, plowing of prairies and monotypic farming have probably had the most severe impact on northern harrier breeding populations (Lokemoen and Duebbert 1976).

In Missouri, northern harriers are relatively common during the non-breeding seasons (Toland 1984) but have experienced a significant decline in nesting populations (pers. observ. and John Wylie, pers. comm.). Only 6 harrier nests were reported in Missouri during the 15 years (1970-83) prior to this study

(Anderson 1974, Robbins 1976, Wilson 1982). Presently, the harrier is listed as a Missouri state endangered species (Missouri Department of Conservation 1984) and is on the National Audubon Society Blue List. No studies of the nesting biology and ecology of the northern harrier have been published for Missouri, and few from the Midwest. The objectives of this study were to describe harrier nesting habitat in southwestern Missouri, to monitor productivity and nesting success, to determine food habits and to investigate other aspects of nesting ecology.

Study Area and Methods

My investigation was conducted from March through August in 1984 and 1985 in Barton, County, MO, 1.6 km southwest of Liberal. The study area of 850 ha consisted of Prairie State Park and some surrounding private lands.

Approximately 672 ha in the park is virgin tallgrass prairie. Dominant warm season grasses in the study area were big bluestem (*Andropogon Gerardi*), little bluestem (*A. scoparius*), broomsedge (*A. virginicus*), switch grass (*Panicum virgatum*), Indian grass (*Sorghastrum nutans*), prairie dropseed (*Sporobolus heterolepis*) and cordgrass (*Spartina pectinata*). More than half of the prairie area has been invaded by cool season grasses, notably fescue (*Festuca* sp.), but nearly 250 ha remain as native grasses and forbs. Deciduous woody growth, mainly along stream courses, composes 40 ha of the park while neighboring border lands are largely fescue pasture, crops and old fields (Larson 1982).

Harrier nests were found: 1) by watching for aerial food transfers, whereby females catch prey in mid-air dropped by the male and subsequently return to the nest, 2) by following males carrying prey, 3) by closely observing females on perches near the nest site and 4) by using the increased intensity of nest defense behavior by adults as an indicator of distance to the nest.

I recorded the species, height and percent ground cover of dominant plants within 90 cm of each nest. Each nest was visited 3 times to facilitate data collection for clutch size, hatching success and fledging success. I identified nest predators by direct observations (coincidental to other investigations), signs (i.e., hair, feathers or scats at the depredated nest-site) or interpretation of species specific patterns of depredation (Rearden 1951). Nests and young were photographed and young 3 weeks of age and older were banded with U.S. Fish and Wildlife Service bands. All prey remains and pellets found at the 15 nest sites were collected and identified at least to order. For each prey type, frequency of occurrence, percent composition and estimated percent biomass were calculated. I used average weights given in Schwartz and Schwartz (1959), Terres (1980) and Steenhof (1983) to compute percent biomass. Nestling and immature harriers were sexed by differential iris color and tarsus diameter (Hamerstrom 1969). 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 prey species taken. All capture attempts with undetermined outcomes were excluded from analysis (Toland 1986).

Results and Discussion

Courtship began in early April, evidenced by mutual soaring, tail-chasing, sky-dancing, courtship feeding and copulation, as previously described by

Hamerstrom (1969) and Newton (1979). In what I interpreted as possible nest site selection, paired males and females took turns landing in and taking off in close succession from patches of thick vegetation ("leap frog" style). This previously undescribed behavior occurred only during courtship prior to nest building.

During the last half of April, harriers of both sexes carried nest material; males transferred material by dropping it to females in mid-air or on the ground at nest sites. Females did most of the actual nest building, as also was reported by Brown and Amadon (1968).

A total of 15 nests was found, 7 in 1984 and 8 in 1985. All nests were found in 1984, but the nest location of a ninth nesting female could not be found during 1985. Twelve of 15 (80%) nests were located in bramble patches composed entirely of blackberry. Blackberry was the most prominent plant at 2 other nest sites. One of these sites was also composed of bastard toad-flax (*Comandra umbellata*), blackeyed Susan (*Rudbeckia hirta*), milk-vetch (*Astragalus canadensis*), gray-headed coneflower (*Ratibida pinnata*), lead plant (*Amorpha canescens*) and purple coneflower (*Echinacea purpurea*). The second nest site was composed of rough-leaved dogwood (*Cornus drummondi*), bluestem grasses, smooth sumac (*Rhus glabra*) and wild rose (*Rosa carolina*), in addition to blackberry. The fifteenth nest site was in a patch consisting entirely of rough-leaved dogwood. In Wisconsin, Hamerstrom and Kopeny (1981) reported the 6 most frequent dominant plants around harrier nests were willow (*Salix* spp.), grasses (*Graminae*), meadow-sweet (*Spiraea alba*), goldenrod (*Solidago* spp.), sedge (*Carex* and *Scirpus* spp.) and stinging nettle (*Urtica dioica*). In North Dakota, smooth bromegrass (*Bromus inermis*), intermediate wheatgrass (*Agropyron intermedium*), alfalfa (*Medicago sativa*) and sweet clover (*Melilotus* spp.) were the dominant vegetative components of northern harrier nest sites (Duebbert and Lokemoen 1977).

In this study, harriers selected blackberry as nesting cover even where there was an abundance of other usable vegetation such as bluestem grasses, aster (*Aster* spp.), goldenrod, sassafras (*Sassafras albidum*), sumac (*Rhus* spp.), bromegrass and fescue (*Festuca pratensis*). The use of blackberry as nest sites by northern harriers has rarely been reported previously. Hamerstrom and Kopeny (1981) reported that only 1 nest of 184 studied was in brambles. Of a total of 307 harrier nests reported from the Midwest, only 5 (1.6%) were placed in rose bushes or brambles (Apfelbaum and Seelbach 1983).

Ground cover at all harrier nest sites was 100%. The average height of vegetation around harrier nests in this study was 79.2 cm (Table 1). Nest site patch size averaged 98 m^2, and nests averaged 3.5 m from the perimeter of the patch (Table 1). These factors may have been advantageous in providing protection from nest predators for several reasons: 1) the height of the brambles rendered the nest difficult to see, 2) density of the brambles might have made eggs or young difficult to smell and 3) the thorns on these briars might have deterred predators from reaching the nest. Characteristics of tall, dense patches of vegetation probably decrease the incidental discovery of nests by foraging mammalian predators because they are not normally used for travel lanes by mammals (Hamerstrom and Kopeny 1981).

Table 1. Characteristics of northern harrier nest sites in southwestern Missouri, 1984-1985.

Nest number	Nest diameter (cm)	Nest height (cm)	Nest distance from patch perimeter (m)	Height of surrounding vegetation (cm)	Patch size (m^2)	Patch diameter (m)
1	35.6	6.4	6.0	89.0	66	12.0
2	40.6	10.2	4.6	61.0	250	16.5
3	40.6	10.2	0.0	76.0	250	17.0
4	39.4	10.2	3.1	94.0	67	8.1
5	40.6	8.9	4.0	66.0	47	7.2
6	38.1	7.6	3.7	73.7	141	12.5
7	55.9	7.6	5.5	61.0	65	10.6
8	60.0	8.0	1.0	80.0	90	10.0
9	62.5	7.6	4.0	70.0	72	8.5
10	35.0	6.5	3.0	105.0	45	6.7
11	35.0	7.0	4.5	90.1	81	9.0
12	75.0	9.5	5.0	81.0	100	10.0
13	65.0	8.4	2.0	75.0	80	9.0
14	42.0	9.0	4.0	91.0	95	9.5
15	50.3	6.4	2.5	75.0	25	5.0
Means	47.7	8.2	3.5	79.2	98	10.1

Predation seemed to occur at nests located on the periphery of bramble patches, but the sample of such events was too small to statistically evaluate. The 2 nests placed close to the edge (<1 m) of patches were destroyed by a great horned owl (*Bubo virginianus*) and an unidentified mammalian predator. Brush clearing activity by park personnel left 1 other nest, which had been placed in the center of its patch, more vulnerable to a mammalian predator which destroyed the entire clutch. The fourth nest, also placed in the center of its bramble patch, was destroyed during the egg stage by a striped skunk (*Mephitis mephitis*).

Only undisturbed, idled sections of the prairie were utilized as nest sites by northern harriers at Prairie State Park, a tendency reported by other researchers (Hamerstrom 1969, Duebbert and Lokemoen 1977, Hamerstrom and Kopeny 1981, Apfelbaum and Seelbach 1983). Harriers at Prairie State Park apparently responded to a controlled park burn regimen by shifting their nesting activities to the closest idled vegetation in sections where fire occurred in alternate years. In park sections which were never burned, harriers nested in the same fields during both years. Approximately one-third of the park was burned during each year of this study. The preference of northern harriers for undisturbed tracts of nesting cover was such that nests were clumped in several loose aggregations with inter-nest distances ranging from 300 to 600 m. This tendency to nest in loose colonies has been reported elsewhere (Hall 1947, Hecht 1951, Brown and Amadon 1968, Hamerstrom 1969).

Harriers selected the undisturbed half of the park (never burned) for nesting 8 times and were successful 7 times (87.5%), while harriers nesting in the

managed half of the park were successful only 4 of 7 times (57%) (Fisher Exact Test, $P = 0.2803$). Within this managed half, ⅓ was burned in 1984, ⅓ in 1985 and ⅓ in both years. Harriers shifted their nesting activities back and forth between the 2 alternately-burned sections, avoiding the regularly-burned third.

Higher harrier nesting success in the unmanaged, permanently idled, half of the park may be due to accumulation of residual vegetation from previous growing seasons. Dead vegetation has been shown to be an important component of preferred cover for ground nesters (Duebbert and Lokemoen 1977, Skinner et al. 1984).

Nesting phenology was approximately 11 days later in 1984 than in 1985. Based on a 28-30 day incubation period (Hammond and Henry 1949, Craighead and Craighead 1956, Brown and Amadon 1968, Hamerstrom 1969), mean dates of clutch initiation were 1 May and 21 April during 1984 and 1985, respectively. Incubation, which starts with the third or fourth egg of the clutch (Brown and Amadon 1968), began around 8 May 1984 and 28 April 1985. By early May it was obvious that females were laying and/or incubating their clutches, for only males were seen hunting over the prairie. Mean hatching date in 1984 was 8 June (range 24 May-28 June) and in 1985 it was 28 May (range 16 May-4 July). During 1984 young harriers fledged from 28 June to 6 August ($\bar{x}$ = 12 July), while in 1985 fledging occurred from 19 June to 6 August ($\bar{x}$ = 1 July). Yearly variation in nesting phenology has been reported from North Dakota with clutch initiation ranges of 5 May-28 June, 13-22 May, 26 April-30 May and 7 May-1 June (Hammond and Henry 1949, Duebbert and Lokemoen 1977).

The average clutch size of harrier nests in southwest Missouri was 5.3 (range 4-8) and hatching success for the 2 years was 69.6% (Table 2). Fledging success was 60%; in addition to the aforementioned 4 depredated nests, a fifth brood starved to death at 3 weeks of age when both adults disappeared. Total nesting success (number of eggs that fledged successfully) was 41.8%, and an average of 3.3 young fledged per successful nest. Only 2.2 young fledged per nesting pair (including nesting failures). Clutch and brood sizes and nesting success were similar to those reported from Wisconsin, North Dakota and Saskatchewan (Hammond and Henry 1949, Bent 1961, Sealy 1967, Brown and Amadon 1968, Hamerstrom 1969, Duebbert and Lokemoen 1977, Apfelbaum and Seelbach 1983). A hatching rate of 42.0%, clutch size of 4.0 and total nesting success of 28.0% indicate that the European race (hen harrier) may have much lower productivity and breeding success in England than do populations of *C. c. hudsonius* in North America (Balfour 1962).

Nestling sex ratios were significantly biased, with 67.5% (27 of 40) of all nestlings being female (binomial test $z = 1.986$, $P = 0.024$, 2-tailed). Female fledglings comprised 68.5% (24 of 35) of the total young fledged.

Mammals comprised 44.9% of the 201 total prey items by occurrence and 65.5% in biomass (Table 3). Birds comprised 27.5% of the diet by occurrence and 25.0% in biomass. Average weight of harrier prey was 177g (range 0.5-1200). Among prey items, prairie voles were most frequent (24.4%), but eastern cottontails contributed the most biomass (52.8%). Female harriers apparently captured all adult prairie chickens (Toland 1985). Males provided all of the food until nestlings were nearly 2 weeks old. The hunting success rate of

Table 2. Nesting productivity and success of northern harriers in southwest Missouri, 1984-85.

	Number of nests	Total number eggs	$\bar{X}$	Total number nestlings	Percent[1] Hatching success	Number fledged	Percent[2] fledging success	$\bar{X}$ productivity (fledglings/ successful nest)	Percent[3] total nesting success
1984	7	39	5.6	27	69.0	13	48.0	3.25	33.3
1985	*8*	*40*	*5.0*	*28*	*70.0*	*20*	*71.4*	*3.33*	*50.0*
Both years	15	79	5.3	55	69.6	33	60.0	3.30	41.8

[1]Number of eggs that successfully hatched divided by total number of eggs laid.
[2]Number of young that fledged divided by total number of young that hatched.
[3]Number of young that fledged divided by total number of eggs laid.

male harriers (41.2%) was higher than the rate for females (31.3%), but the difference was not statistically significant ($x^2 = 3.17$, $df = 1$, $P > 0.05$; Toland 1986). Unsexed juvenile harriers were less successful per capture attempt than were adults, but the difference was not significant (Toland 1986). The relatively high success rates of immature harriers (28%) may result from their concentrating on smaller, more numerous and more easily caught prey types (Toland 1986).

Management Recommendations

Nesting northern harriers in southwestern Missouri utilized large tracts of undisturbed tallgrass prairie interspersed with patches of invading woody plants that averaged 98 m^2 in area. Because large tracts of prairie with suitable nesting cover in the form of blackberry brambles are apparently preferred by Missouri harriers, management for expansive tracts of pure native grasses is not compatible with northern harrier conservation. Annual burns, haying, mowing and brush removal decrease woody plant species which harriers used as nesting cover during this study. Light grazing by a small herd of bison (*Bison bison*) now present at Prairie State Park appears compatible with harrier nesting ecology.

Moderate disturbances to grasslands, including rotated grazing, haying, mowing and plowing, created habitat heterogeneity and increased rodent vulnerability to raptors, which improved raptor hunting success in England (Shrubb 1980), Canada (Baker and Brooks 1981), Michigan and Wyoming (Craighead and Craighead 1956), Washington (Bechard 1982) and Missouri (Toland, in press). However, prairie management tools such as burning, haying or brush-hogging should be timed to avoid the harrier nesting period of April through July.

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Table 3. Food habits of nesting northern harriers in southwest Missouri, 1984-85.

Prey species	N	Percent occurrence	Average weight (g)	Percent estimated biomass
BIRDS				
Greater prairie-chicken (*Tympanuchus cupido*)	8	4.0	677[a]	16.0
Mourning dove (*Zenaida macroura*)	4	2.0	134	1.6
Eastern meadowlark (*Sturnella magna*)	8	4.0	95	2.2
Common grackle (*Quiscalus quiscula*)	3	1.5	112	1.0
Red-winged blackbird (*Agelaius phoeniceus*)	12	6.0	50	1.8
Brown-headed cowbird (*Molothrus ater*)	4	2.0	41	0.5
Unidentified passerines	16	8.0	40	1.9
Subtotal	55	27.5	–	25.0
MAMMALS				
Prairie vole (*Microtus ochrogaster*)	49	24.4	38	9.8
Fulvous harvest mouse (*Reithrodontomys fulvescens*)	8	4.0	21	0.5
Deer mouse (*Peromyscus maniculatus*)	2	1.0	20	tr.
Cotton rat (*Sigmodon hispidus*)	1	0.5	120	tr.
Eastern wood rat (*Neotoma floridana*)	1	0.5	255	0.7
Unidentified rodents	14	7.0	30	1.2
Eastern cottontail (*Sylvilagus floridanus*)	15	7.5	1200	52.8
Subtotal	91	44.9	–	65.5
REPTILES				
Plains garter snake (*Thammophis radix*)	3	1.5	109	1.0
Bull snake (*Pituophis melanoleucus*)	2	1.0	225	1.3
Unidentified snakes	13	6.5	190	7.2
Subtotal	18	9.0	–	9.5
INVERTEBRATES				
Coleopterans	17	8.5	0.5	tr.
Orthopterans	20	10.0	1.0	tr.
Subtotal	37	18.5	–	tr.
Total	201	100.0		100.0

[a]Average weight of 3 adult and 5 immature birds.

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Effectiveness of Lithium Chloride Induced Taste Aversions in Reducing Waterfowl Nest Predation

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Abstract: Field experiments to evaluate the efficacy of lithium chloride (LiCl) as an aversive conditioning agent on waterfowl nest predators were conducted at Sand Lake National Wildlife Refuge (NWR) during 1980 and 1981. Three experimental plots were treated by placing artificial nests containing chicken eggs injected with 1 g LiCl along transects throughout the plots. A significant decline in LiCl egg consumption ($P<0.01$) 4-6 weeks after initiation of treatment indicated that predators were avoiding treated eggs. Comparisons of waterfowl nest success on treated with that on untreated plots showed no significant difference in 1980 ($P>0.10$), but a significant reduction in nest success on treated plots in 1981 ($P<0.01$). We conclude that LiCl is not an effective deterrent to waterfowl nest predators under the conditions in which it was tested during this study.

Introduction

Predation is often a major factor limiting success of waterfowl nests (Byers 1974, Duebbert and Kantrude 1974, Sargeant and Johnson 1977). Predator control techniques, such as trapping and poisoning, can reduce predator numbers, but are time consuming, expensive and often undesirable because of lethal effects on nontarget species. LiCl is a non-toxic chemical that has been used extensively as an aversive conditioning agent to reduce coyote (*Canis latrans*) predation on domestic livestock (Gustavson et al. 1975, Conover et al. 1977, Olsen and Lehner 1978). The application of LiCl as a deterrent to waterfowl nest predation could potentially provide a more effective and acceptable method of predator control.

The objective of this study was to test the efficacy of LiCl as an aversive conditioning agent in upland nesting habitat used by waterfowl.

Methods

Three pairs of plots (ranging in size from 37 to 64 ha) were studied for 12 weeks (4/13-7/19), 1980 and 1981 at Sand Lake NWR in Columbia, SD. Plots were paired based on similarity in size and topography. Each plot contained a dense mixture of brome (*Bromus* spp.) and legumes planted to encourage nesting by waterfowl. Major waterfowl predators included the red fox (*Vulpes*

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vulpes), raccoon (*Procyon lotor*), striped skunk (*Mephitis mephitis*), mink (*Mustela vison*) and Franklin's ground squirrel (*Spermophilus franklinii*).

Plots #1, #2 and #3 were treated with LiCl eggs and paired with control (untreated) plots #4, #5 and #6, respectively. Artificial nests, consisting of scrapes lined with grass, were constructed at 61 m intervals around the perimeter of each treated plot and along transects spaced at 61 m intervals throughout the plots. Plots #1-3 contained 84, 94 and 98 artificial nests, respectively. Three white chicken eggs injected with 1 g LiCl per egg were placed in each nest. Nests were marked with willow sticks placed 2 m from their location. Beginning in mid-April, each artificial nest was monitored at weekly intervals, and eaten or missing LiCl eggs were replaced with freshly treated eggs. Weekly percentages of eggs eaten on each plot were determined. In 1981, artificial nests were placed only along the plot perimeters during the first 3 weeks. A z-test was used to detect significant differences between weekly egg consumption percentages.

During 1980, we modified the method of treatment for plot #2. Counts of shell remains at treated nests indicated that within a 5-week interval 90% of the LiCl eggs were removed from the nest. These eggs were presumably carried away by predators. Apparently the predator removing the eggs was not only failing to consume the LiCl but was greatly reducing the number of LiCl eggs available to other predators in the area. To ensure that LiCl would be ingested, wires were placed through treated eggs and secured to the ground during weeks 6, 7 and 8 of 1980. Wired eggs would split open when removed from the nest, increasing the likelihood of consumption.

Waterfowl nests were located on each plot by use of a cable-chain drag (Higgins et al. 1977). The stage of incubation for each nest was determined using a field candler (Weller 1956). Waterfowl nests were marked with the same procedures used for LiCl nests and were monitored at weekly intervals until hatched or terminated. To determine if predator aversion to LiCl eggs was transferred to waterfowl eggs, nest success on treated and control plots was calculated using methods developed by Mayfield (1961, 1975) and modified by Johnson (1979).

Results

We hypothesized that predator response to treated eggs would be characterized by an increase in egg consumption during the period of initial exposure, followed by an avoidance phase during which consumption would decline. Weekly percentages of LiCl eggs eaten on all plots followed the expected pattern (Fig. 1). With the exception of plot #2 in 1980, LiCl egg consumption remained significantly below peak consumption during the remaining weeks ($P<0.01$). The wiring of LiCl eggs on plot #2 during weeks 6-8 in 1980 resulted in a significant reduction in egg consumption ($P<0.01$). However, egg consumption on this plot increased significantly ($P<0.01$) after the wires had been removed.

Species found nesting on the area included blue-winged teal (*Anas discors*), mallard (*Anas platyrhynchos*), common pintail (*Anas acuta*), gadwall (*Anas strepera*) and northern shoveler (*Anas clypeata*). Sample sizes were inadequate to reliably calculate nest success for individual plots and, therefore, nest data were pooled for analysis. Estimated nest success on treated plots was 6.7% ($SE = 1.2\%$, $n = 54$) in 1980, and 9.5% ($SE = 1.3\%$, $n = 34$) in 1981. On control

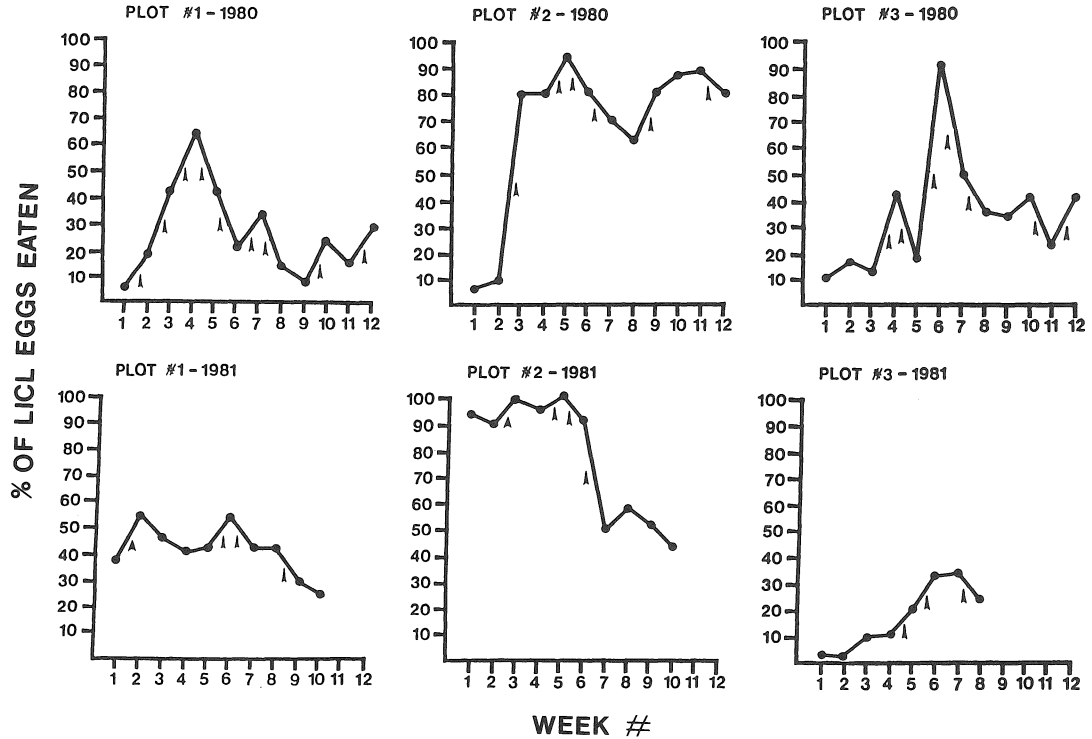

Fig. 1. Weekly percentage of lithium chloride (LiCl) treated eggs eaten on study plots (n = 252, 282 and 294 for plots #1, #2 and #3, respectively). In 1981, LiCl eggs were placed only along plot perimeters for weeks 1-3 (n = 150, 126 and 135 for plots #1, #2 and #3, respectively). Significant differences (z, $P<0.01$) between the percentage of eggs eaten during 2 consecutive weeks are designated by arrows.

areas, nest success was estimated to be 8.2% (SE = 1.5%, n = 27) in 1980, and 20.8% (SE = 1.4%, n = 18) in 1981. Nest success did not differ significantly between treated and control plots during 1980 ($P>0.10$), but was significantly lower on treated plots during 1981 ($P<0.01$).

Discussion

The pattern of LiCl egg consumption indicates that predators can be conditioned to avoid treated eggs. However, LiCl did not completely eliminate predation of treated eggs on any of the plots (Fig. 1). The magnitude of the reduction in predation varied between plots and within plots from week to week. These findings are probably due to differences in the species composition of predators on the 3 plots (Sheaffer 1982) and to temporal changes in their numbers and distribution. It is also possible that conditioning to LiCl eggs was not complete for some species of predators or individuals.

The deviation of treated egg consumption from the expected pattern on plot #2 in 1980 was most likely attributable to the removal and caching of eggs by predators. This behavior is commonly found in red fox (MacDonald 1976), and there was an active fox den in close proximity to the plot. The escalation in LiCl egg consumption following removal of the wires indicates that some predators require frequent exposure to treated eggs to achieve continuous conditioning.

The lag time between placement of treated nests in the field and the peak in consumption that preceded the decline ranged from 4 to 6 weeks. This lag is most likely a function of the time needed to expose predators in a given area to treated eggs rather than a delayed response by predators that have consumed LiCl. Differences in the size and species composition of predator populations probably account for variations in response time between plots. An important implication is that if the LiCl technique is to effectively reduce waterfowl nest predation, treatment of an area should be initiated at least 1 month before nesting begins.

A 2-phase process for mammalian taste-aversion conditioning was first proposed by Gustavson et al. (1974). During phase I, the taste of the LiCl treated prey becomes aversive to a predator after induced illness. Auditory, visual and olfactory clues may still elicit attacks on prey, but the taste inhibits ingestion by the predator. Phase II occurs when the predator associates the distal clues (auditory, visual and olfactory) with the aversive taste and subsequent attacks are avoided. Our results indicate that conditioning of predators to LiCl eggs could have been complete for some predator species or individuals; however, there was no evidence of transference of taste-aversion to waterfowl eggs.

We propose that the lower nest success on treated plots could be due to one or more of the following factors: (a) predator densities were higher on treated than on control plots, (b) LiCl eggs may not have been placed in the field far enough in advance of waterfowl nest initiation to allow for sufficient exposure, (c) conditioning could have been adequate for some predator species or individuals, but ineffective for others, (d) the presence of LiCl eggs could have attracted predators to treated plots thereby increasing waterfowl nest predation and (e) predators could have detected differences between LiCl eggs and waterfowl eggs, and subsequently waterfowl eggs were not avoided. Additionally,

investigator activity was greater on treated plots because of weekly visits to LiCl nests and could have negatively affected waterfowl nest success. We conclude that the LiCl taste-aversion technique is ineffective for increasing nest success under the conditions in which it was tested during this study.

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Ostracode Paleoecology of Some Middle Devonian Beds in the Wittenberg Trough of Southeastern Missouri and Southwestern Illinois

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Abstract: The Wittenberg Trough extends from eastern Ste. Genevieve County, MO, into western Jackson County, IL. Ostracode faunas were collected from 3 localities within the Trough and from 1 locality just outside it on the western shelf of the Illinois Basin. Significant parameters displayed by these ostracodes indicate that compaction and sedimentation rates were moderate at all localities except the Backbone near the mouth of the Trough, where rates were high. Winnowing action was strong at all localities, but decreased slightly toward the deeper shelf area. Most "shells" are highly-ornamented, indicating marine conditions. None of these data suggest the presence of a trough; but rather, along with the associated megafaunas, are indicative of shallow marine shelf conditions.

Key Words: paleoecology, Middle Devonian, ostracodes, Missouri, Illinois

Introduction

The Wittenberg Trough, which was named by Meents and Swann (1965), is located in southeastern Missouri and southwestern Illinois (Fig. 1). It extends from Ste. Genevieve County, MO, southeastward through Perry County, MO, into western Jackson County, IL. The ostracodes for this study were collected from the lower part of the St. Laurent and Lingle Limestones (Middle Devonian) (Figs. 2 and 3) within the Trough. Samples were collected within the Trough at Union and Ridge schools in eastern Perry County, MO, and from the Backbone near Grand Tower in southwestern Jackson County, IL; a section outside the Trough was sampled along Clear Creek in northeastern Union County, IL (Fig. 1). These samples were collected parallel to the length of the Trough, as well as within it. Unfortunately, lack of outcrops made it impossible to collect samples perpendicular to axis of the Trough. Samples collected from other St. Laurent and Lingle outcrops in the Trough area did not contain ostracodes.

The purpose in looking at ostracode paleoecology of the lower Middle Devonian beds in this area was to determine whether or not the Wittenberg Trough existed during early Middle Devonian time. The megafaunas—mostly brachiopods, mollusks, trilobites and corals (Table 1)—associated with the ostracodes studied indicate shallow, marine shelf environments. It seemed likely that more definitive evidence could be obtained by utilizing more mobile and environmentally sensitive organisms like ostracodes, which are present in much larger numbers.

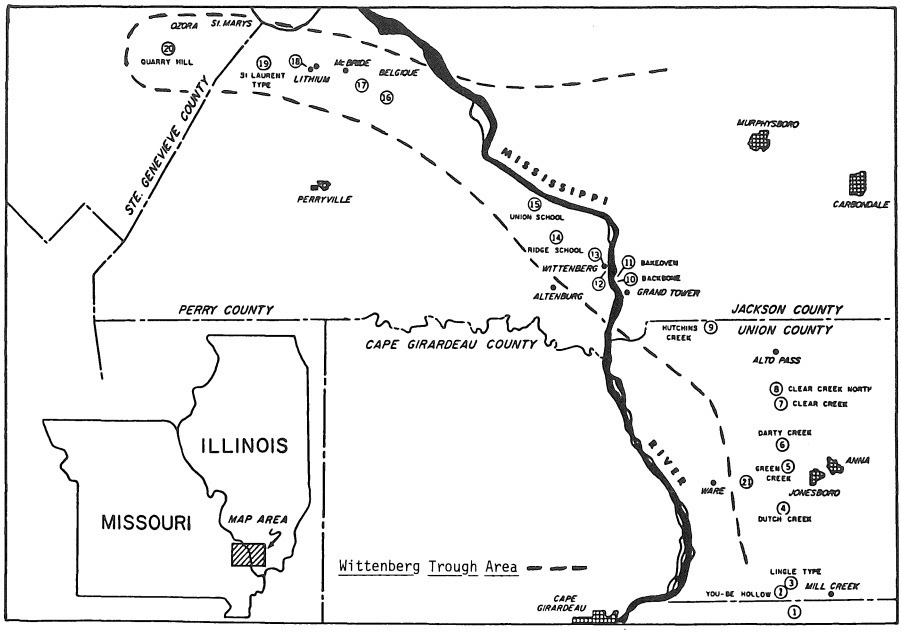


Fig. 1. Locality Map showing St. Laurent and Lingle Limestone outcrops. Ostracodes were collected from localities 7, 10, 14 and 15.

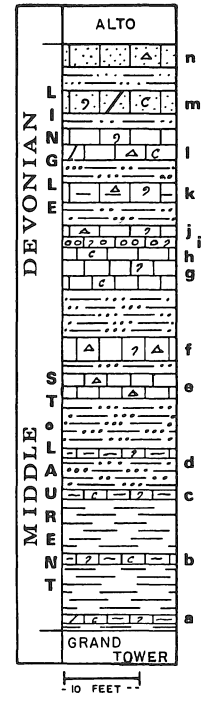


Fig. 2. Composite columnar section of the St. Laurent and Lingle Limestones. Ostracodes were collected above and below the a and b limestones.

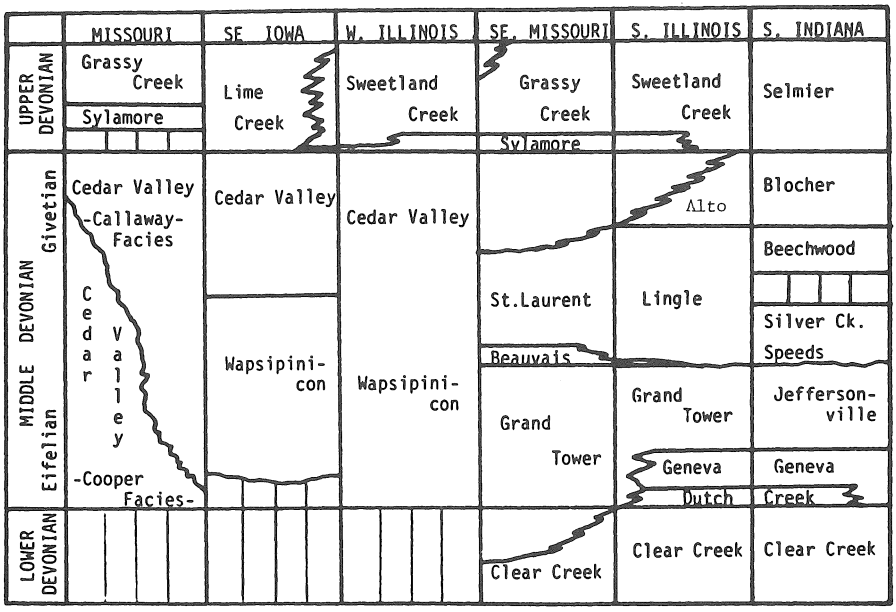


Fig. 3. Correlation chart of Midwest Middle Devonian.

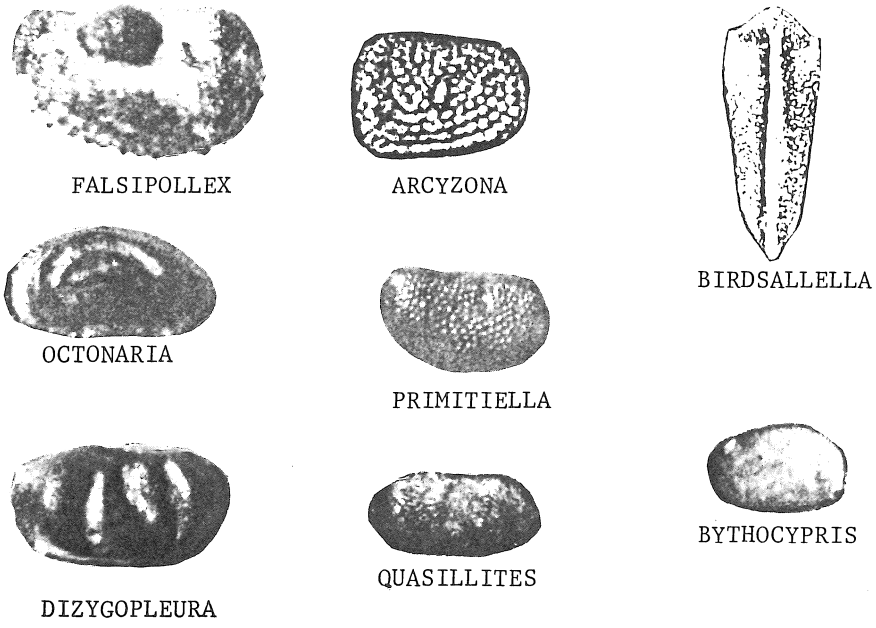


Fig. 4. Ostracode genera found in samples collected from some Middle Devonian beds in the Wittenberg Trough of southeastern Missouri and southwestern Illinois.

Table 1. Megafaunas associated with ostracodes studied in some Middle Devonian beds in the Wittenberg Trough of southeastern Missouri and southwestern Illinois.

	LOCALITIES			
	Clear Creek	Backbone	Ridge School	Union School
PORIFERA ?				
Clionides cf. *hackberryensis* (Thomas)		X		X
Clionides sp.		X		
Clionides thomasi Fenton and Fenton		X	X	X
Clionolithes irregularis Fenton and Fenton				X
CNIDARIA				
Aulacophyllum multiseptum Fraunfelter			X	X
Cystiphylloides americanum (E. & H.)				X
Heliophyllum halli Edwards and Haime	X			
Heterophrentis delicalycula Fraunfelter	X			X
Microcyclus discus Meek and Worthen	X	X	X	X
BIVALVIA				
Leptodesma rogersi Hall		X	X	
Nucula cf. *corbuliformis* Hall	X			
Nuculites? sp.			X	
Paracyclas rowleyi (Branson)		X		
GASTROPODA				
Devonema typicum Fraunfelter			X	
Gastropod borings		X		X
Ianthinopsis sp.			X	
Platyceras (Euthyrachis) indianensis Miller & Gurley		X		X
Platyceras (Platyceras) echinatum Hall		X		
Platyceras (Platyceras) erectum (Hall)		X		
Platyceras (Platyceras) cf. *thetis* Hall		X		
Tentaculites bellulus Hall	X			
Tentaculites scalariformis Hall				X
BRACHIOPODA				
Athyris spiriferoides (Eaton)	X	X	X	X
Atrypa imbricaria Fraunfelter	X	X	X	X
Callipleura nobilis (Hall)			X	
Centronella impressa Hall	X			X
"Chonetes" lepidus (Hall)	X			
Cranaena lincklaeni (Hall)	X			
Cryptonella cf. *attenuata* (Whiteaves)			X	
Cyrtina dariensis Ehlers				X
Cyrtina hamiltonensis (Hall)	X		X	X
Cyrtina hamiltonensis recta (Hall)				X
Douvillina (Douvillina) inequistriata	X		X	
Elita fimbriata (Conrad) Conrad	X			
Emanuella subumbona (Hall)	X		X	
Leptaena trilobamuscula Fraunfelter		X	X	X
Longispina mucronata (Hall)	X	X	X	X

Table 1 (continued).

	LOCALITIES			
	Clear Creek	Backbone	Ridge School	Union School
Mediospirifer audaculus (Conrad)	X			X
Mediospirifer audaculus subpyramidatus Fraunfelter			X	X
Megastrophia (Megastrophia) concava (Hall)		X	X	X
Mucrospirifer mucronatus (Conrad)	X	X		X
Nucleospira concinna (Hall)	X	X	X	X
Orthopleura sp.			X	
Pholidostrophia (Pholidostrophia) iowensis (Owen)	X			
Pholidostrophis (Pholidostrophia) pennsylvanica Kindle			X	X
Protoleptostrophia perplana (Conrad)	X			
Pustulatia pustulosa (Hall)	X		?	
Retichonetes scitulites (Cooper)	X	X	X	X
Retichonetes tumidellus (Cooper)	X	X	X	X
Rhipidomella vanuxemia (Hall)	X			
Schizophoria minalata Fraunfelter		X	X	X
Schuchertella perversa (Hall)	X			
Sinotectirostrum minutum Fraunfelter	X		?	
Strophodonta (Strophodonta) demissa (Conrad)	X	X	X	X
Strophodonta (Strophodonta) subdemissa Hall		X		X
Truncalosia truncata (Hall)	X		X	X
Tylothyris? bella Cooper	X	X	X	X
Tylothyris? mucronata Fraunfelter	X			
ARTHROPODA				
Dechenella sp.		X		
Phacops rana crassituberculata Stumm	X	X	X	X
ANNELIDA				
Conchotrema sp.		X		
Vermiforichnus clarkei Cameron		X	X	

Methods

The first 100 complete carapaces or single valves from 1 sample from each locality were used for counting purposes. The ostracode genera found in the samples are illustrated in Fig. 4. Most of the genera represented here have highly ornamented shells, but 3 genera, *Birdsalella, Primitiella* and *Bythocypris* are essentially "smooth-shelled."

Results and Discussion

Several aspects of ostracode faunas are useful environmental indicators. Oertli (1970) considered some "bulk" aspects of ostracode faunas, rather than just looking at their shell morphology. Among those aspects studied by Oertli

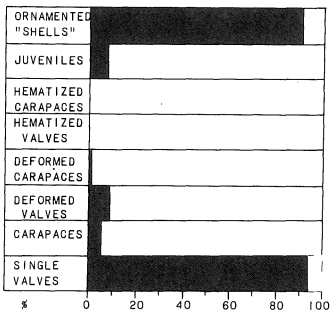
were: 1) the ratio of light-colored to dark-colored shells, 2) the ratio of juvenile to adult shells, 3) the ratio of non-deformed to deformed shells and 4) the ratio of single valves to carapaces. The larger the number of pyritized shells in a fauna, the more reducing the environment. The higher the percentage of adults in the fauna, the more winnowing has taken place and the higher the current index. The higher the percentage of deformed shells in the fauna, the higher rate of compaction. And, the higher the percentage of carapaces in the fauna, the higher the rate of sedimentation. However, carapaces of burrowers would tend to remain intact.

On Clear Creek, just outside the mouth of the Wittenberg Trough, an ostracode fauna from the lower Lingle Limestone contains only light-colored shells, indicating well-oxygenated conditions; only 8% of the shells are juveniles, indicating a high level of winnowing and high current index; 11% of the shells are deformed, indicating a low rate of compaction; and only 6% of the shells are carapaces, indicating a low rate of sedimentation (Fig. 5A). At the Backbone, within but near the mouth of the Trough, the lower Lingle ostracode fauna contains 100% light-colored shells, indicating well-oxygenated conditions; only 2% juveniles, indicating a high level of winnowing activity and current index; 75% deformed shells, indicating a high rate of compaction; and 74% carapaces, indicating rapid sedimentation (Fig. 5B). Near Ridge School, in the Trough, the lower St. Laurent Limestone ostracode fauna contains only 1% dark-colored shells; these were hematized, indicating well-oxygenated conditions. No juvenile shells were found, indicating much winnowing and a high current index; 46% deformed shells, indicating a moderate compaction rate; and 47% carapaces, indicating a moderate sedimentation rate (Fig. 5C). At Union School, still within the Trough but farther to the northwest, the lower St. Laurent Limestone ostracode fauna contains 38% dark-colored shells, all hematized, and 62% light-colored shells, which indicates well-oxygenated conditions; no juveniles, indicating a high current index and much winnowing; 22% deformed shells, indicating a relatively low compaction rate; and 40% carapaces, indicating a moderate rate of sedimentation (Fig. 5D). Hematization was probably diagenetic.

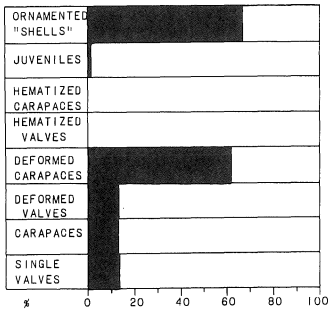
At Clear Creek 87% of the ostracode shells are highly-ornamented and 13% are smooth, while at the Backbone 67% of the shells are highly-ornamented and 33% are smooth. At Ridge School 85% of the ostracode shells are highly-ornamented and 15% are smooth, while at Union School 80% of the shells are highly-ornamented and 20% are smooth. These figures are indicative of shallow, marine conditions. Among the carapaces present, on Clear Creek 5 of 6 carapaces were smooth, at the Backbone 2 of 11 carapaces were smooth, at Ridge School 1 of 18 carapaces was smooth, while at Union School 7 of 25 carapaces were smooth. Thus, even if these smooth-shelled forms represented burrowers, their small numbers would not significantly affect the rate of sedimentation.

A list of the associated invertebrate faunas from each locality is shown in Table 1. These faunas are indicative of the Strophomenid-Trilobite Community, a shallow, marine shelf community (Bretsky 1968), as evidenced by the abundance in these faunas of strophomenid, orthid and productid brachiopods and trilobites (Fraunfelter 1970, 1972, 1974, Fraunfelter and Baesemann 1972).

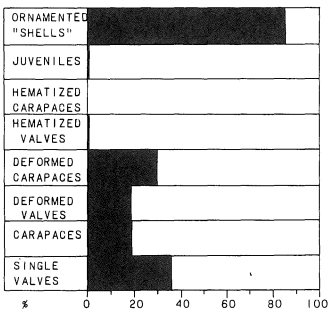
The above data indicate: 1) well-oxygenated conditions at all localities sampled, 2) a high level of winnowing and current activity at all localities, 3) a low to moderate rate of compaction except near the mouth of the Trough area, 4) a moderately high to high rate of sedimentation except in the shelf area outside of the Trough and 5) normal marine shelf conditions are indicated at all localities, as evidenced by the large percentage of highly-ornamented shells in the ostracode faunas, and by the composition of the associated invertebrate megafaunas.



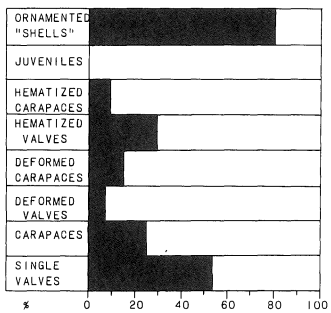
A. Clear Creek



B. Backbone



C. Ridge School



D. Union School

Fig. 5. Data from ostracodes collected within the Wittenberg Trough of southeastern Missouri and southwestern Illinois.

Conclusions

The available faunal evidence points to a shallow, marine shelf environment for the area supposedly occupied by the Wittenberg Trough. The relatively small percentage of smooth-shelled ostracodes in the faunas studied would not affect this conclusion, even if they were burrowing forms.

The increased rate of sedimentation and compaction near the mouth of the Trough could well be explained by the steepening of the slope of the shelf, as well as by the opening of the Trough into the Illinois Basin.

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Photoreflectance Study of GaAs/Al GaAs Multiple Quantum Wells

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Abstract: Multiple quantum well structures are artificially created materials in which very thin layers of 2 dissimilar semiconductors are alternately grown. The 2 semiconductors we have studied are Gallium Arsenide (GaAs) and Aluminum Gallium Arsenide ($Al_xGa_{1-x}As$). The latter is an alloy with a larger electronic band gap than that of GaAs. This leads to potential wells in the GaAs layers in which the electrons can be trapped. Since these wells are very narrow (a few atomic layers), quantum effects can be observed. This paper describes the observation of such quantized energy states by the technique of photoreflectance. A quantum mechanical calculation of these energy levels, including band structure effects, yields a satisfactory explanation of the data.

Key Words: photoreflectance, modulation, multiple quantum wells

Introduction

The nature of subband states in both the conduction and valence bands of multiple quantum well structures has been studied by a number of optical techniques.[1-4] One such technique is photoreflectance, which has the advantage of being a contactless method of electromodulation. The most extensively studied quantum well structure is made from alternate layers of GaAs and $Al_xGa_{1-x}As$ ($x<0.4$). Alloying with Al makes the band gap of $Al_xGa_{1-x}As$ greater than that of GaAs, which leads to discontinuities of conduction and valence band edges at the interfaces.

In this paper we report the observations and analysis of the higher order transitions in GaAs/$Al_xGa_{1-x}As$ ($x=0.3$) multiple quantum wells at 300 K using photoreflectance spectroscopy. Transitions up to states corresponding to $n=9$ in the conduction and valence bands are observed.

Modulation Spectroscopy

One of the branches of optical spectroscopy is modulation spectroscopy.[5,6] Its objective is to modulate an internal parameter of the sample (e.g., band gap) or of the measuring system (e.g., wavelength) to produce a corresponding change in optical reflectance of the sample. The result is a sharp, well resolved and highly structured spectrum. The changes are small, so that differences in the spectra are closely related to the derivative of the absolute spectrum with respect

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to the modified parameters. There are a number of advantages in measuring changes in the spectrum: 1) The change in spectrum is much easier to measure accurately than measuring the absolute spectra and taking their differences. 2) The derivative nature of the modulation spectrum suppresses uninteresting background effects and emphasizes the structure localized in energy.

Multiple Quantum Wells

Quantum wells in semiconductors have structures with 1-dimensional periodic potentials where the characteristic dimension is less than the mean free path of the electrons. This causes the electrons confined within such periodic wells to demonstrate quantum effects. Molecular beam epitaxy which is an ultra high vacuum thin film technique, has made possible the growth of atomically smooth layers resulting in sharp changes in potential energy at the interface required to observe quantum size effects. Important features of the quantum wells are the quantized energy levels inside the wells, which depend on the wells' thicknesses. Such systems exhibit novel electronic and optical properties such as exceptionally high mobility and optical bistability for electrons.

A schematic view of a typical quantum well is shown in Fig. 1. Well layers of thickness L_z and energy gap E_g^I are periodically placed in between barrier layers of thickness L_b and energy gap E_g^{II}. For GaAs and $Al_xGa_{1-x}As$ ($x<0.4$) there is almost perfect lattice match with direct band extrema at $k=0$. The band gap of the $Al_xGa_{1-x}As$ barrier can be made considerably larger than that of the

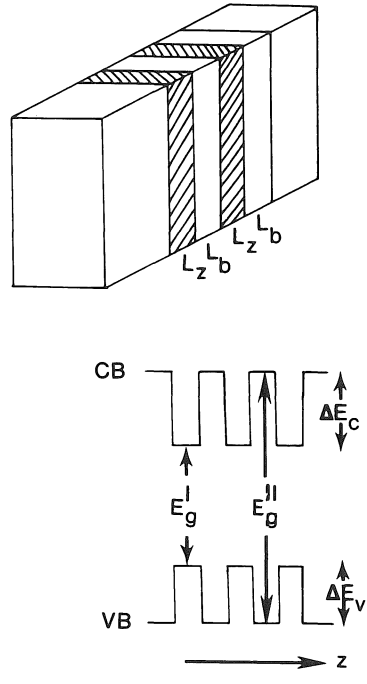

Fig. 1. A multiple quantum well shown with its periodic potential. E_g^I is the energy gap of the well material (GaAs) and E_g^{II} is the energy gap of the barrier material (AlGaAs).

GaAs well by controlling the Al content in $Al_xGa_{1-x}As$. This leads to discontinuities in the conduction and valence band edges at the interfaces. These discontinuities are important parameters which determine the potential for electrons and holes in the quantum well. There have been several determinations of the compositional dependence of the energy gap in $Al_xGa_{1-x}As$. The expression used for calculations in this paper is taken from Adachi[7] and is given by

$$E_g \text{ (in eV)} = 1.424 + 1.247x \text{ for } 0<x<0.45 \quad (1)$$

so that the total band gap discontinuity is given by

$$\Delta E_g \text{ (in eV)} = 1.247x \text{ for } 0<x<0.45 \quad (2)$$

65% of the total band gap discontinuity[8,9] is in the conduction band (ΔE_c), which is equal to the value of the potential well height (V_e) for the electron. Thirty-five percent of total band gap discontinuity is in the valence band (ΔE_v), which is equal to the value of the potential well height (V_h) for the hole.

In a GaAs/AlGaAs superlattice the energies of different energy states can be approximately calculated using a 1-dimensional infinite square well with the energies given by $E_n = \frac{n^2h^2}{8m^*L_z^2}$, where $n = 1, 2, 3, \ldots$, m^* is the effective mass in the band and L_z is the width of the square well, which is equal to the width of GaAs layer. These quantized levels are present in the conduction band as well as in the heavy and light hole valence bands. In a real situation the potential well has finite depth. To make the exact calculations of the energies of these energy states, a standard method of solving a 1-dimensional Schrodinger equation for a particle in a finite well is used.[10] The Shrodinger equation for a particle (electron in conduction band or hole in valence band) in the well of width L_z is given by

$$\frac{d^2\psi_1}{dz^2} + k_1^2\psi_1 = 0 \quad (3)$$

where $k_1^2 = (8\pi^2 m_w E)/h^2$, m_w is the effective mass of the particle in the well and E is the energy of the particle measured with respect to the bottom of the well; ψ_1 is the envelope wave function for the particle in the well.

The Schrodinger equation for a particle in the barrier of width L_b is given by

$$\frac{d^2\psi_2}{dz^2} + k_2^2\psi_2 = 0 \quad (4)$$

where $k_2^2 = [8\pi^2 m_b (V-E)]/h^2$, m_b is the effective mass of the particle in the barrier and V is the barrier height energy measured with respect to the bottom of the well; ψ_2 is the envelope wave function for the particle in the barrier.

The energies (E) for different states can be found by solving equations (3) and (4) with boundary conditions for continuity of the particle current and probability density at the boundary $z = L_z/2$. The equation for energy of the particle in the even parity state is given by[10]:

$$\left[\frac{E}{m_w}\right]^{1/2} \cdot \tan\left[\left(\frac{8\pi^2 m_w E}{h^2}\right)^{1/2} \cdot \frac{L_z}{2}\right] = \left[\frac{(V-E)}{m_b}\right]^{1/2} \cdot \tanh\left[\left[\frac{8\pi^2 m_b (V-E)}{h^2}\right]^{1/2} \frac{L_b}{2}\right] \quad (5)$$

A similar equation for energy of the particle in the odd parity state is given by[10]:

$$\left[\frac{E}{m_w}\right]^{1/2} \cdot \cot\left[\left(\frac{8\pi^2 m_w E}{h^2}\right)^{1/2} \cdot \frac{L_z}{2}\right] = -\left[\frac{(V-E)}{m_b}\right]^{1/2} \cdot \coth\left[\left[\frac{8\pi^2 m_b (V-E)}{h^2}\right]^{1/2} \frac{L_b}{2}\right] \quad (6)$$

Equations. (5) and (6) are solved numerically for E using an IBM-PC computer to find energies of different energy states of electrons in the conduction band and of holes in the valence band. Effective mass of the electron used is $0.067m_o$ in GaAs well and $(0.067 + 0.083x)m_o$ in $Al_xGa_{1-x}As$ barrier,[11] where m_o is the mass of free electron. Effective mass for the heavy hole is given by $m_{HH} = m_e/(\gamma_1 - 2\gamma_2)$ and for the light hole by $m_{LH} = m_e/(\gamma_1 + 2\gamma_2)$. The value of γ_1 and γ_2 used are taken from Lawaetz.[12] Barrier height energy (V) is equal to the potential well height. The value of barrier width used in these calculations is 130 Å.

The energy of transition from mth state in conduction band to nth state in valence band is given by the equation:

$$E_{Cm,\,Hn}(L_z) = E_g + E_{m,e}(L_z) + E_{n,h}(L_z) \quad (7)$$

where E_g is the band gap of GaAs, $E_{m,e}(L_z)$ is the energy of the electron in mth state of the conduction band and $E_{n,h}(L_z)$ is the energy of the heavy hole. For transition energies in which the light hole is involved, equation (7) will have CmLn on the LHS and $E_{n,1}(L_z)$ on the RHS instead of $E_{n,h}(L_z)$. Fig. 2 shows results of the calculation.

Photoreflectance

Photoreflectance measures modulated reflectivity. This modulation is produced by photoinjection of electron-hole pairs by a secondary light source such as a laser. It has the advantage of being a contactless method of electromodulation. The band gap is modulated by using the electric field from the laser beam. By chopping this laser beam, bands are alternately populated and depopulated with electrons or holes, which decreases and increases the band gap alternately. The net effect is modulation of the band gap. A second beam from a monochromator is used to measure change, ΔR, in reflectance as band gap is modulated by the laser beam. Phase sensitive detection is used to detect these extremely small changes in reflectance. When the ratio of change in reflectance (ΔR) to reflectance (R) is taken, a spectrum related to the derivative of absolute reflectance is obtained. The derivative nature of photoreflectance spectrum emphasizes structure that is localized in energy band. Lineshapes have been

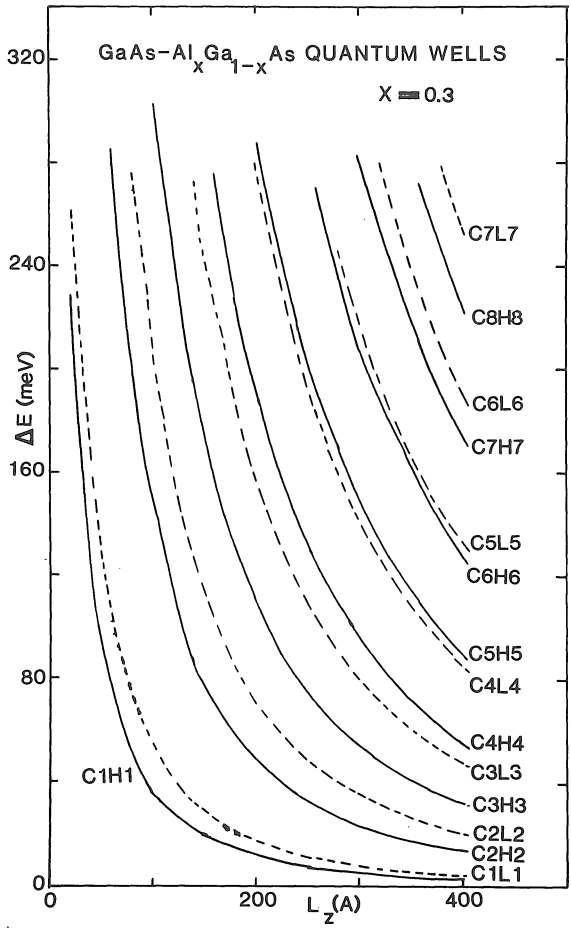

Fig. 2. The change in energies, calculated for different transitions, as function of well width for GaAs/$Al_{0.30}Ga_{0.70}As$ multiple quantum well.

closely related to third derivative of the reflectivity with respect to energy. Since photoreflectance results from a modulation of the internal electric field, it behaves like low electricfield electroreflectance and produces third derivativelike features[13] in the optical dielectric function in the vicinity of the critical points. This result is particularly significant, from a spectroscopic point of view, because third derivative lineshapes are characterized by the presence of strongly enhanced critical point structures and strongly suppressed background effects.

Fig. 3 shows a schematic of the experimental setup. A white light source and monochromator are used as the probe source and a He-Ne laser as the

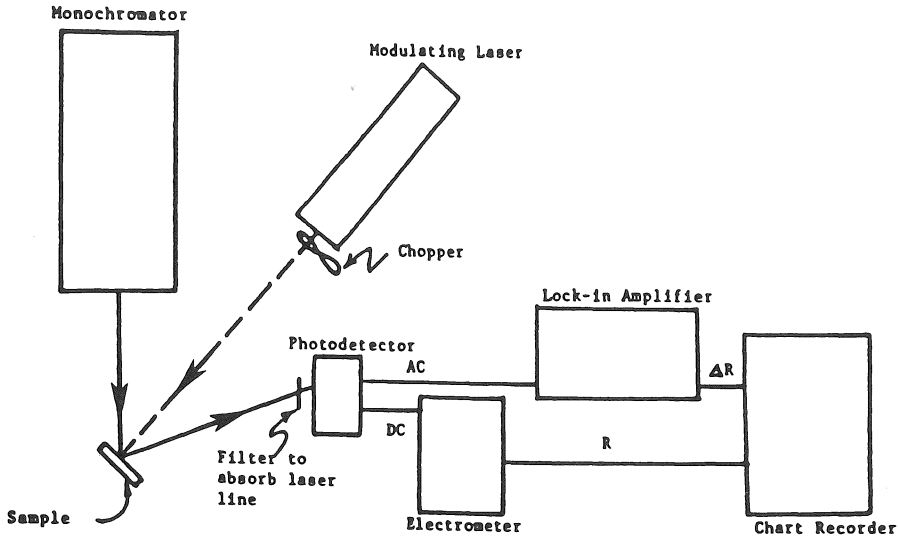

Fig. 3. Schematic diagram of experimental setup for photoreflectance spectroscopy.

modulating source. Light from the modulating laser and from the monochromator are focused at the same spot on the sample. By using a filter in front of the detector, elastically scattered laser light from the modulating laser is rejected. Chopping of the laser light provides modulation and its chopping frequency is used as reference for the lock-in amplifier to detect modulated reflectance, ΔR, of the monochromator light by the sample. A sensitive electrometer is used to measure DC signal from photomultiplier tube, which gives the measurement of reflectivity, R. The photoreflectance spectrum is a graph of the ratio $\Delta R/R$ against the energy of the monochromator light.

Results and Discussion

With the above experimental setup, preliminary measurements show a large number of energy levels in quantum wells in GaAs/$Al_xGa_{1-x}As$ with $x = 0.3$. Measurements shown in this paper were carried out at 300 K using a He-Ne or an Argon laser radiation as the pump beam. Samples of different well widths were used. Measurements of their photoreflectance spectra show that the number of transitions depend on well width. A sample with a smaller well width shows only a couple of transitions, while the sample with a larger well width gives a larger number of transitions. Fig. 4 shows the photoreflectance spectrum for a sample with a well width of 400 Å. The solid line shows the curve from experimental data. The Aspnes third derivative functional form (TDFF) lineshape expression[14,15] is used to fit these data:

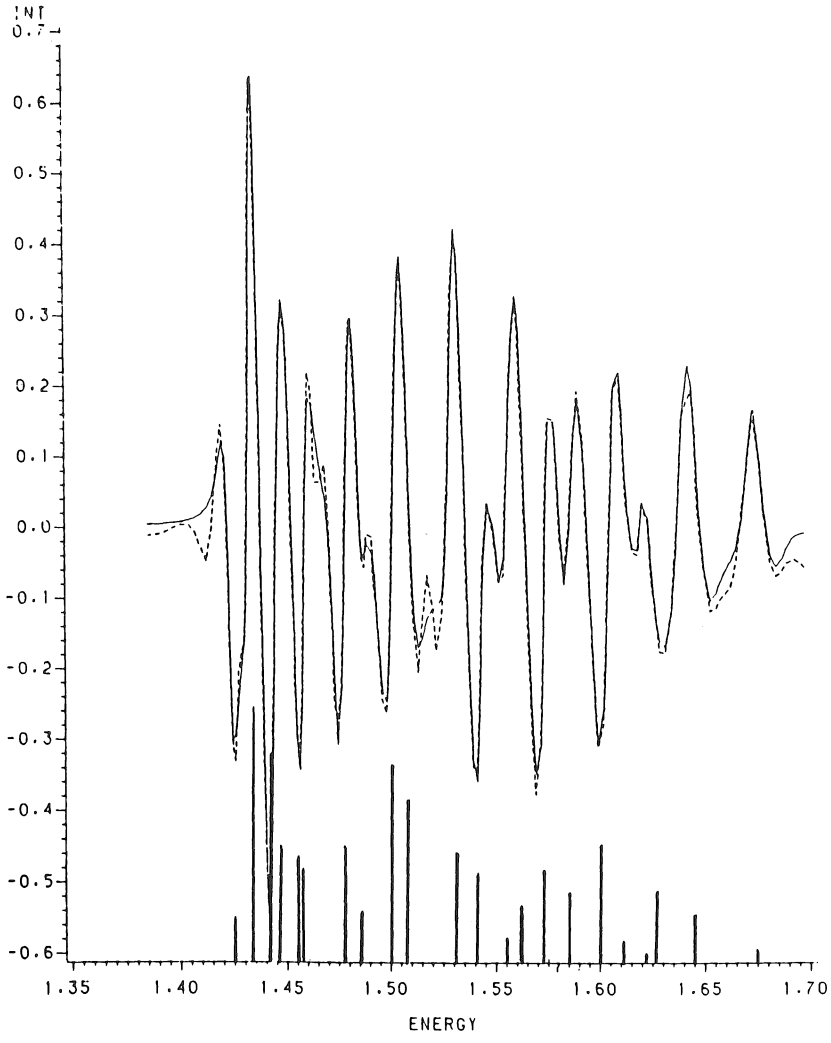

Fig. 4. Measured and calculated photoreflectance spectrum of a GaAs/$Al_{0.30}Ga_{0.70}As$ multiple quantum well sample.

$$\frac{\Delta R}{R} = Re\left[\sum_{j=1}^{p} \left[c_j e^{i\Theta_j} (E - E_{g,j} + i\,\Gamma_j)^{-m_j} \right] \right] \qquad (8)$$

where p is the number of spectral features in the region to be fitted, C_j, Θ_j, $E_{g,j}$ and Γ_j are the amplitude, phase, energy and broadening parameter, respectively, of the jth structure, while m_j denotes the type of critical point. Since we are dealing with 3-dimensional critical point, $m_j = 2.5$ is used.[5] This expression

enables us to find accurate values of transition energies, amplitudes, broadening parameters and phases. The 2 curves in the figure, the solid from experimental data and the dotted from Aspnes expression for third derivative functional form lineshape, show excellent agreement. A histogram, drawn at the bottom of this figure, shows intensities of various transitions.

The finite square well model described previously is used to calculate energies of different states of electrons in the conduction bands and of heavy holes and light holes in the valence bands. Early work by Glembocki et al.[16] did not take the nonparabolicity effect into account, which leads to a discrepancy between calculated and experimental peak positions, especially for large n. Due to the nonparabolicity of the conduction band, effective mass of the electron cannot be considered a constant. The variation of mass with energy is given by the equation[17]:

$$m^*(E) = m^*[\,1 - \frac{16\pi^2 pEm^*}{h^2}\,] \qquad (9)$$

$$\text{where} \quad p = \frac{h^2}{8\pi^2 m^*} \cdot [\,\frac{3+4y+2y^2}{3+5y+2y^2}\,] \cdot (1 - \frac{m^*}{m_0})^2 \cdot \frac{1}{E_g}\,, \qquad (10)$$

$y = \Delta/E_g$, m^* is the effective mass of the electron at the bottom of the conduction band; Δ is the spin orbit splitting and E_g is the band gap energy. The values used in our calculations are $\Delta = 0.340$ eV, and $E_g = 1.424$ eV, their values for GaAs.

Energies of various transitions are calculated using equation (7) and with respect to the level ClHl. Fig. 5 is a plot of these energies against well width L_z. Positions of all bands are calculated with respect to the ClHl level. Positions of these bands for different samples are shown in Fig. 5. A large number of forbidden transitions, which violate $\Delta n = 0$ selection rule, have to be considered to fit and identify all the peak positions.

Conclusion

In conclusion, we measured the photoreflectance spectra at 300 K in $GaAs/Al_xGa_{1-x}As$ ($x=0.3$) multiple quantum wells. A large number of higher order transitions were observed. We use a finite square well model (with band structure effects included) which gives good agreement with the energies. Observation of forbidden transitions indicates that a theory which includes mixing between different states is needed to explain the intensity data.

Acknowledgments

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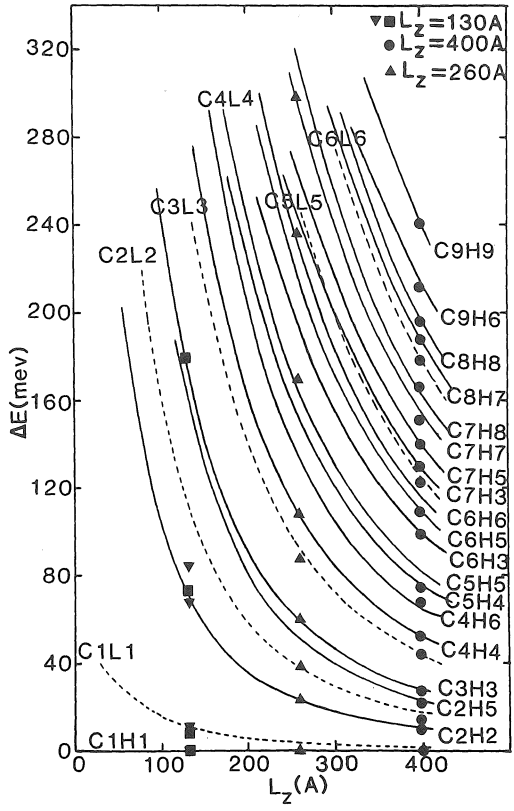

Fig. 5. Measured and calculated change in energies as a function of well width for GaAs/$Al_{0.30}Ga_{0.70}As$ multiple quantum well sample. The different symbols represent experimental data for samples with various well widths.

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The 1986 Annual Meeting of the Missouri Academy of Science April 25-26, 1986 Central Missouri State University Warrensburg, MO

Senior Division

Agriculture - Entomology

Wilson, S. W. and A. G. Wheeler, Jr., Department of Biology, Central Missouri State University, Warrensburg, MO 64093 and Bureau of Plant Industry, Pennsylvania Department of Agriculture, Harrisburg, PA 17110. LIFE HISTORY OF *THIONIA ELLIPTICA* (HOMOPTERA: FULGOROIDEA) WITH DESCRIPTION OF A NEW ISSID PLANTHOPPER FROM TEXAS. The immatures of *Thionia elliptica* (Germar) are described and illustrated and the life history outlined. This issid is univoltine, apparently overwinters as eggs, has 5 nymphal instars and feeds on scrub oak (*Quercus ilicifolia* Wang.). Specimens are recorded from Pennsylvania, North Carolina, Missouri and Arkansas. Specimens from Texas described by Doering as *T. elliptica* are different in the morphology of the aedeagus and, thus, are described as new.

Schreiber, A. and M. Linit, Department of Entomology, University of Missouri, Columbia, MO 65211. THE IMPACT OF INSECTS ON NUT PRODUCTION IN A BLACK WALNUT PLANTATION. A study was initiated to determine what insects caused nut mortality, how much damage insects inflicted and on what stage of the nut the damage occurred. An earlier study by Blair in 1978 reported that 50% of the black walnut nut crop was destroyed by the black walnut curculio (*Conotrachaleus retentus*). Ninety-six clusters of nuts on 12 trees were examined every week from May 2 through October 6, and then every 2 weeks till nut maturation. A life table for the nuts was contructed, and particular attention was given to the insect component of nut mortality. Two hundred twenty-five nuts were selected initially to start the study, 76% of the nuts fell prematurely and 23% of the nuts were infested with the curculio. Only 2 insects were found to be attacking the nuts: the walnut husk maggot (*Rhagoletis sauvis*) and the black walnut curculio. Only the latter insect caused significant damage to the nut crop.

Robertson, R. E. and R. L. Tabor, Department of Agriculture, Central Missouri State University, Warrensburg, MO 64093. A STUDY OF THE MODE OF ACTION OF SEVERAL ACARICIDES FOR CONTROL OF THE SPIDER MITE, *TETRANYCHUS URTICAE*. Infestations of the 2-spotted spider mite are having an increasing effect on crop production. This study was undertaken to evaluate effectiveness of the acaricides: Kelthane, Omite, Plictran, Monitor and Di-Syston. Treatments, replicated 4 times, were used to evaluate contact, ovicidal and systemic properties of the acaricides. In order to evaluate contact and ovicidal effectiveness, leaf disks infected with 30 spider mites or 340 eggs were dipped into acaricides of appropriate concentrations for 3 seconds and then placed in petri dishes. Treatment evaluations were done at 2, 4 and 6 days. Systemic test utilized live plants. Acaricide concentrations of 0.0005% were used. In the contact mode, Kelthane controlled 99% of the *T. urticae*, while both Omite and Plictran controlled 92%. In the systemic mode, Kelthane controlled 97%, while Omite and Plictran controlled 92% and 94%, respectively. Ovidical testing resulted in 100% control by Kelthane, Omite and Plictran. Separation of replication mean values was done to determine significant differences.

Aide, M. T. and P. Wells, Department of Agriculture, Southeast Missouri State University, Cape Girardeau, MO 63701. THE INTERACTION OF CHROMIUM (VI), PHOSPHORUS AND POTASSIUM ON GROWTH AND LEAF TISSUE CONCENTRATION OF ORCHARDGRASS (*DACTYLIS GLOMERATE* L.). A factorial experiment involving orchardgrass seedling growth was attempted. The experimental design involved 2 rates of phosphorus, 3 of potassium and 4 of potassium dichromate. Eaeh unit was replicated 4 times. Chromium (VI) did not affect dry weight; however, chromium (VI) did significantly reduce potassium and phosphorus leaf tissue concentrations. An equilibrium relationship between soil adsorbed chromium (VI) and solution chromium (VI) was linear.

Aide, M. T., B. Brown and K. Gregg, Department of Agriculture, Southeast Missouri State University and Soil Conservation Service, Cape Girardeau, MO 63701. GENESIS OF FRAGIPAN SOILS IN ST. FRANCOIS AND STE. GENEVIEVE COUNTIES, MO. A series of soils were selected to determine whether there exists a correlation between fragipans and the loess distribution. Three soil series were selected and 2 site profiles for each soil were described and sampled. The major conclusion is that deep loessial soils did not form fragipans, while thin loess cappings tended to form fragipans. Complete physical and chemical analysis of each profile demonstrated that iron, aluminum or clay bridging are not plausible mechanisms for the physical properties of the fragipans. Evidence from silica adsorption implies that the hardness and brittleness of fragipans may be due to silicon. A model of fragipan genesis is proposed.

Aide, M. T. and B. Baiken, Department of Agriculture, Southeast Missouri State University, Cape Girardeau, MO 63701. THE ANALYSIS OF 5 SOIL SERIES IN IRON COUNTY, MO. Five soils were selected, described and sampled. The 5 soils are the Goss, Killarney, Knobtop, Irondale and Taumsauk, Phosphorus adsorption isotherms were obtained and phosphorus adsorption was determined to be a function of clay and iron oxide contents. The Taumsauk, Irondale and Knobtop soils will be contrasted and differences in profile characteristics related to relief and parent materials. The clay mineralogy of all soils consists essentially of interlayered vermiculite.

Allen, D. Jr., Department of Agriculture, Central Missouri State University, Warrensburg, MO 64093. ANTHELMINTIC COMPARISONS IN SWINE. The purpose of this study was to compare various anthelmintic products in swine and their ability to control *Ascaris suum* larvae migration. Four separate pens with 3 pigs in each pen were used for the study. The animals in each pen were dosed orally with infective *Ascaris suum* larvae. One pen was used as a control and no anthelmintic products were used, the pigs in 1 pen were wormed with Fenbendazole (FEN), those in 1 were injected with Ivermectin (IVER) and in another pen were fed continuous Banminth Mecadox (BAN-MEC). Following initial treatment, the pigs were reinfected with a second dose of infective *Ascaris suum* larvae. Pigs from each pen were slaughtered and autopsied to determine the effectiveness of each product in preventing ascarid larval migration. The Controls, FEN and IVER pens had extensive liver scarring and a high degree of inflammation in the lungs due to larvae migration. The BAN-MEC pigs were virtually free of liver damage and showed no signs of lung inflammation. The BAN-MEC pigs also had the highest average daily weight gain and the best feed efficiency.

Atmospheric Sciences

Podzimek, J., Department of Mechanical and Aerospace Engineering and Graduate Center for Cloud Physics Research, University of Missouri, Rolla, MO 65401. IMPACT OF FOREST DERIVED AEROSOLS ON METEOROLOGICAL PROCESSES IN THE TROPOSPHERE. Forest derived aerosols—especially in tropical and subtropical regions—represent a significant part in the aerosol budget in global scale. Besides the ecology, these aerosols play an important role in cloud formation and radiative transfer. Our cooperation with the Department of Physics of the Ivory Coast University at Abidjan focused on the physico-chemical properties of tropical-forest and savannah derived aerosols in the dry and rainy season as well. The most important results are: Savannah is a prolific source of cloud condensation nuclei (CCN). Their concentration (around 1500 N/cm^3) at a supersaturation of 0.25% in the dry season is comparable with the most polluted regions of the USA (e.g. Buffalo, NY). On the other hand the concentration of Aitken nuclei (AN) in the savannah is very low—and in the dry season comparable with the CCN counts. In the rainy season tropical forests are an intense source of AN indicating the existence of an effective gas-to-particle conversion mechanism.

Stowell, G. and J. Podzimek, Department of Mechanical and Aerospace Engineering and the Graduate Center for Cloud Physics Research, University of Missouri, Rolla, MO 65401. ON THE METHODOLOGY OF AITKEN NUCLEI COUNTING IN A HIGHLY POLLUTED ATMOSPHERE. A polluted atmosphere is featured by a very polydisperse aerosol of different particulate compositions. Reliable ultrafine and giant nuclei counting presents several problems because of fast small particle depostion by diffusion, or intense settling of particulates and droplets in the gravitational field. Many of the particles produced by different gas-to-particle conversion mechanisms might not be counted at all. Peculiarities of particulate counting in a Nolan-Pollak counter—which is used by many counter producers as a secondary standard—are discussed in detail with regard to the counter's thermodynamics and polydisperse aerosol sampling. Special attention is given to the mixing of well defined ultrafine, and large particulates in the size range of 0.005 micrometers to several micrometers.

McCaskill, J. I. and C. A. Zacher, AERO Research, St. Louis, MO 63141. EVENTS, POLARITY AND PROCESSES OF LIGHTNING DEVELOPMENT. From onset the lightning discharge is a progressive development, the flash representing a complex sequence of events influenced by both meteorological factors and the marked effect of earth's potential and/or the field from any grounded elevated terminals. We have employed instruments measuring the corona currents as well as electronic camera configurations to: 1) isolate and identify events within individual flashes, 2) ascertain the polarity of net charge transfer in a flash and 3) arrive at tentative conclusions about larger scale occurrences or processes with regard to the domains producing lightning—and including illustrations of some measures of "intensity" both within and between storms; phase change results; and, by correlation with other data, geographical differences in lightning modes or types.

Zacher, C. A., AERO Research, St. Louis, MO 63141. ANTICIPATORY TRIGGERING FOR A LIGHTNING CAMERA: IDENTIFICATION OF A POSITIVE POLARITY FLASH. Negative cloud-to-ground flashes constitute the bulk of lightning observations, and there is reasonably complete knowledge of their characteristics. Estimates of positive-flash frequency is typically 10% (ranging from 2-3% to over 30% in some seasons/locations) that of negative flashes. Positive cloud-to-ground lightning discharges have received considerable attention recently. But their identification is difficult, and confusion with intracloud flashes can result in the absence of sufficient corroborating data. Because of a substantial inbuilt filtering mechanism, the very first photography sequence made with a new, sensitive optical triggering system did yield results leading to the conclusion that this was a relatively effective means sufficient to distinguish the positive lightning flash. Telltale identifying parameters include the time for charge separation (fallout), channel length in the field-of-view employed, "unstepped" smoothness of channel and occurrence at end (rearward) part of the dissipating storm.

Biology

Sells, G. D. and T. R. Weigand, Science Division, Northeast Missouri State University, Kirksville, MO 63501. FLUCTUATION OF PROLINE IN THE SECOND TRIFOLIATE LEAF OF SOYBEANS UNDER FIELD CONDITIONS. Proline was extracted from the second trifoliate leaf of soybeans (*Glycine max*, var. Dekalb-Pfizer CX380) over the summer of 1984 and measured by spectrophotometric methods. Proline levels were found to fluctuate more during July than in August or September, and the change was observed to correspond only slightly to periods of high and low water stress. The summer of 1984 was considered a dry year. Concentrations of proline ranged from 5.5 ± 0.5 to 68.4 ± 0.8 ng proline per gram of fresh weight of leaf tissue. Because the accumulation of proline in the upper leaves of soybean fluctuated erratically it would seem appropriate to study effects of water stress on a total plant basis rather than from selected leaves at the top.

Weber, M. D. and G. D. Sells, Science Division, Northeast Missouri State University, Kirksville, MO 63501. SHIFTS IN PROLINE METABOLISM IN RESPONSE TO INCREASING TEMPERATURE (30-40C) IN MITOCHONDRIA ISOLATED FROM MAIZE SHOOTS. Mitochondria were isolated from Dekalb-Pfizer XL73 maize shoots after germination for 3 days at 30C and then at either 32, 34, 36, 38 or 40C for 1 day. Shoots germinated at 30C for 4 days served as the control. Respiratory rate, respiratory control and ADP/O ratios were determined upon addition of succinate, malate + pyruvate (M+P), proline and exogenous NADH. Oxidation of all substrates remained nearly the same over the 30-34C range. When the temperature was raised to 38-40C, a change in the oxidation pattern for proline was observed. Rates dropped by approximately 80% and a loss of coupling was observed. Use of selected inhibitors (KCN and propyl gallate) indicate that this loss of coupling is associated with a shift in the electron pathway.

Thomas, L. M., Northeast Missouri State University, Kirksville, MO 63501. EFFECTS OF WILD, VESTIGIAL, APTEROUS GENOTYPE *DROSOPHILA MELANOGASTER* ON REPRODUCTIVE CAPACITY, GENERATION TIME AND SURVIVORSHIP. This study was conducted to investigate the effects of genotype on generation time and fecundity of *Drosophila melanogaster*. For both experiments, 5 cultures of each of the following 9 crosses of known genotype were established: 1) wild*wild, 2) wild*ves, 3) wild*apt, 4) apt*apt, 5) ves*ves, 6) ves*apt, 7) apt*ves, 8) apt*wild and 9) ves*wild. To determine fecundity, parent flies were removed and the number of flies produced in the F_2 generation were determined. Cultures were counted and cleared 3 times to account for all offspring. Developmental time was established by noting the time of emergence of the flies into each of the different life cycles for each cross. Generation time for each cross was then computed by adding the hours together. Both homozygous mutant genotypes (vestigial and apterous) proved to have a longer generation time and a lower fecundity than the homozygous wild genotype. The wild allele appeared to add approximately 46% to the fitness of individuals from the wild*apt cross and 73% to the fitness of individuals in the wild*ves cross.

Easton, C. M. and D. J. Feir, Biology Department, St. Louis University, St. Louis, MO 63103. OVIPOSITION PREFERENCES IN A BLOWFLY. The majority of work on blowfly oviposition has been with those species that cause myiasis on sheep and therefore lead to economic loss to the rancher. Other blowfly species have been studied for feeding responses to various chemicals but rarely for oviposition responses. Since certain blowfly maggots are used in the forensic sciences to estimate time of death of a homicide victim, it is important to understand factors affecting oviposition of blowflies which are found on carrion. Two methods were used to provide flies with choices of oviposition substrates. One was a Y-tube chamber which tested the attracting and stimulating powers of meats and chemicals. The other was a jar (3.5x5 cm) with 2 tubes (2.5x1 cm) inserted on opposite sides of the jar, and this tested the same factors over a shorter distance. The parameters measured were: time between exposure to the meat and landing on the meat, number of flies attracted to the meat and number of eggs laid. The results indicated that the type of meat significantly affected the number of eggs laid in a specified time period.

Ashley, D. C., D. J. Robbins and S. Monks, Biology Department, Missouri Western State College, St. Joseph, MO 64507. DISTRIBUTION AND PREVALENCE OF *SETARIA YEHI* (FILAROIDEA:ONCHOCERCIDAE) IN WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS*) IN NORTHERN MISSOURI. Thirty-six white-tailed deer from 8 counties in northern Missouri have been examined for infections with the abdominal worm, *Setaria yehi* Desset, 1966. Most deer were obtained from counties in northwest Missouri. However, we also necropsied deer

harvested during the Primitive Weapons hunts at Swan Lake Wildlife Area (6 deer) in Chariton County and Rebel's Cove Wildlife Area (7 deer) in Putnam County. Twenty (55.6%) deer have been infected. The mean number of worms recovered per infected deer is 10.7 (standard deviation = 13.75). We have examined 6 or more deer from each of 4 counties (Andrews, Chariton, Holt, Putnam). The prevalence of infection by county ranged from 33% to 100%. Mean numbers of worms recovered per infected deer in each county ranged from 3.0 to 22.5. This project was supported in part by professional development grants from The MWSC Foundation, Inc.

Ashley, D. C., J. E. Jochim and R. C. Garrison, Biology Department, Missouri Western State College, St. Joseph, MO 64507. HEARTWORMS FROM WILD FURBEARERS OF NORTHWEST MISSOURI. Two hundred and thirty-one samples of hearts and lungs from wild furbearers obtained from furbuyers in northwest Missouri were examined for heartworms (*Dirofilaria immitis*). One badger (*Taxidea taxus*), 1 gray fox (*Urocyon cinereoargenteus*), 4 red foxes (*Vulpes vulpes*), 17 opposums (*Didelphis marsupialis*) and 80 raccoons (*Procyon lotor*) were not infected with heartworms. Seven (5.5%) of 127 coyotes (*Canis latrans*) contained from 2 to 26 adult worms in chambers of the heart or pulmonary arteries. The mean number of worms collected from infected coyotes was 12.0 (standard deviation = 9.56). There seemed to be no major difference in prevalence of infection between male or female coyotes. Coyotes from a Rock Port furbuyer had a higher prevalence (7.0%) and a higher mean number (15.8) of worms per infected coyote than did coyotes from 2 Savannah furbuyers (3.6% prevalence, mean = 2.5 worms per infected coyote).

Monks, S., Science Department, Central High School, St. Joseph, MO 64507, and **D. C. Ashley**, Biology Department, Missouri Western State College, St. Joseph, MO 64507. ANALYSIS OF ROAD-SIDE SIGHTINGS OF WHITE-TAILED DEER FROM SQUAW CREEK NATIONAL WILDLIFE REFUGE. During 29 visits to SCNWR between June 26 and October 4, 1985, sightings of white-tailed deer (*Odocoileus virginianus*) were recorded as we traveled a standardized route on refuge roads. A total of 612 deer sightings were recorded. These data include location on the refuge, number of deer seen, time and date of sightings and apparent presence of single or multiple births. These data have allowed us to calculate ratios of offspring/adult sightings and twin/single fawn sightings. Almost 39% of the deer sighted were young of the year, giving an offspring/adult ratio of 0.64. Of 238 sightings of fawns, 129 (54.2%) seemed to be members of a set of twins or triplets. This project was supported in part by a professional development grant from the MWSC Foundation, Inc.

Zimmerman, S. and T. D. Wyllie, Department of Plant Pathology, University of Missouri, Columbia, MO 65211. THE EFFECT OF PHOSPHORUS AND POTASSIUM CONCENTRATION IN AXENIC CULTURE AND IN AMENDED NATURAL SOIL ON SAPROPHYTIC GROWTH OF *MACROPHOMINA PHASEOLINA*. This work was designed to determine the effect of phosphorus (P) and potassium (K) on the growth and behavior of the charcoal rot fungus. Growth of *M. phaseolina* was determined in complete and in P and K adjusted Czapek broth solution; and in naturally infested soil amended with 100 and 200 pounds a.i. P and 100, 400 and 800 pounds a.i. K. Using a Czapek broth solution from which all but trace amounts of P and K were removed, *M. phaseolina* maintained substantial growth, whereas competing fungi could not. Varying levels of P and K in naturally infested soil did not influence saprophytic growth of *M. phaseolina* as measured by numbers of microsclerotia. These data suggest that *M. phaseolina* may be able to outcompete other microflora in nutrient deficient soils. Host plant effects may be more important than soil fertility per se.

Johnson, G., R. Kneib, J. Alter, C. Steenstry, S. Whiteside and S. Moser, Department of Agriculture, Missouri Western State College, St. Joseph, MO 64507. NITRIFICATION INHIBITOR. The compound known as N-SERVE was used to inhibit the nitrification bacteria Nitrosomonas and Nitrobacter, while growing corn on a Knox silt loam soil type. Anhydrous ammonia was applied to each of 6 plots at the rate of 150 units of nitrogen per acre. N-SERVE was also applied with the anhydrous on every other plot. Soils were chemically analyzed for ammonia and nitrate nitrogen 6 times during the growing season. Yield data were collected and a "1 way analysis of variance, with multiple entries" type of statistical analysis was performed. There was a significant difference in favor of the plots treated with N-SERVE. The 3 plots with N-SERVE had an average yield of 148.7 bushels per acre while the 3 plots that had not been treated with N-SERVE had an average yield of 123.9 bushels per acre.

Millikan, D. F., M. R. Warmund and M. L. George, Department of Plant Pathology, University of Missouri, Columbia, MO 65211. RESISTANCE TO LOW TEMPERATURES IN THE FRUIT BUDS AND WOOD OF SOME EXOTIC AND AMERICAN CULTIVARS OF PEACH, *PRUNUS PERSICA* SIEB. & ZUCC. Xylem tissue of 3 seedlings of Chinese peach possess enhanced levels of resistance to low temperatures (Trans. MO Acad. Sci. 18:102). In 1985 these seedlings (W-1, W-2 and N-10) and 3 American cultivars (Loring, July Elberta and Redhaven) were subjected again to artificial freezing tests. All 3 of the American cultivars exhibited extensive xylem injury when the twigs were exposed to -18C. Exposure to -18C also was lethal to the fruit buds of the Loring, and caused extensive damage to July Elberta and Redhaven. Xylem tissue of all 3 of the seedlings survived exposure to -26.5C, but was severely injured when exposed to -33C. The flower buds of W-2 and N-10 were no hardier than those of the American cultivars, while those of W-1 survived exposure to -25C but not -28.5C. These preliminary tests suggest that W-1 may represent valuable germ plasm for incorporating increased fruit-bud cold hardiness into American cultivars of peach.

Millikan, D. F., S. J. Stefan and W. H. Shaffer, Department of Plant Pathology, University of Missouri, Columbia, MO 65211. INVESTIGATIONS ON GRAFT TRANSMISSIBLE DISORDERS OF GRAPES. The introduction of French hybrid grapes enables the Midwest to produce wines competitive with those of California and Europe. However, latent infections such as corky bark, fan leaf, stem pitting and leafroll (all graft transmissible

disorders) reduce quality of the juice and quantity of the berries. Consequently, a nursery certification program has been initiated in Missouri. During the 1983-84 season, 30 random samples of table and wine grapes from a nursery were tested serologically for fan leaf. All results were negative. Other tests for corky bark, leafroll and stem pitting also were negative. Severe temperature damage in January 1985 to the grape vines precluded any tests in 1985. However, these tests indicate that the grape material presently used for increase are relatively healthy.

Stefan, S. J. and D. F. Millikan, Department of Plant Pathology, University of Missouri, Columbia, MO 65211. STUDIES ON THE ROOTING (STAGE III) OF CLONALLY PROPAGATED *JUGLANS NIGRA* L. PLANTLETS. Media and cultural requirements for the establishment (Stage I), proliferation and multiplication (Stage II) of black walnut explants have been reported previously. Cultures initiated from 5-year-old trees began producing adventitious buds after approximately 4 months in culture. These buds have been used to generate 8 generations of subcultures which have been used in rooting studies. Several hormonal variations, substrate types and environmental changes have been applied, but proper conditions for root development have not yet been determined. An alternative method—the grafting of plantlets onto first-year seedlings—has produced healthy plants. Successful rooting of plantlets will permit the micropropagation of pathogen-free black walnut trees.

Biomedical

Fayed, A. H., R. R. Anderson and D. A. Nixon, Department of Dairy Science, University of Missouri, Columbia, MO 65211. SALIVARY AND BLOOD PROGESTERONE LEVELS IN HOLSTEIN COWS. Pregnancy diagnosis depends on progesterone(P) levels in blood plasma which are lower in cycling females at estrous than in pregnant animals. Body fluids such as milk and saliva might be used for P measurement. The objective of this study was to measure salivary P and to correlate it to blood. Samples were collected from 12 pregnant Holstein cows and analyzed for progesterone concentration by RIA. Tritiated P was used as the radioactive tag and dextran-coated charcoal was used for separation of bound and free fractions. The results showed a significant correlation (0.789; $P<0.01$) between salivary and blood P. Sixty-two percent of the variation of salivary P was explained by changes in blood P. However, the level of salivary P ranged between 0.27 and 0.82 ng/ml, and this amount represented 6-15% of blood P levels. It was concluded that salivary P concentration could be used as a tool to diagnose pregnancy in cattle, especially in heifers, because of the high cost of taking blood samples from these animals under field conditions.

Akasha, M. A., R. R. Anderson and D. A. Nixon, Department of Dairy Science, University of Missouri-Columbia, MO 65211. RELATIONSHIP BETWEEN THYROID HORMONE CONCENTRATION AND GROWTH IN MALE GUINEA PIGS. Thyroid hormones have been demonstrated to be important during growth and development of animals, particularly in maturation of the skeletal and nervous systems. Twelve groups of growing male guinea pigs starting from 10 days old and up to 180 days were used. Blood serum was measured by radioimmunoassay for thyroxine (T_4), triiodothyronine (T_3) and reverse-triiodothyronine (rT_3). Serum T_4 concentration was significantly different ($P<0.01$) due to age of animals; 10-day-old guinea pigs had T_4 significantly lower ($P<0.01$), while T_4 concentration on day 35 was significantly higher ($P<0.01$) than all other age groups. Serum T_3 concentration was highest at 10 days and decreased significantly in a rectilinear fashion with increasing body weight. Serum rT_3 was highest on day 15 and then decreased until day 180. Day 35 marks the time of peak thyroxine secretion coincidentally with the onset of puberty. We conclude that the enhanced thyroid function is a stimulant to FSH, LH and testicular development in the guinea pig.

Nixon, D. A., M. A. Akasha, T. E. Palomo and R. R. Anderson, Department of Dairy Science, University of Missouri, Columbia, MO 65211. SERUM CONCENTRATIONS OF FREE AND BOUND THYROID HORMONES IN RATS. An experiment was undertaken to explore the effects of hormone replacement in ovariectomized rats on total and free serum thyroxine (T_4) and triiodothyronine (T_3). Blood samples were obtained from rats after 20 daily injections of relaxin(R), estradiol benzoate(EB), progesterone (P) or 1 of each combination. Serum samples were analyzed by RIA. Control values were as follows: total T_4, 89.1 ng/ml; free T_4, 4.58 ng/dl; percent free T_4, 0.052%; total T_3, 0.965 ng/ml; free T_3, 5.97 pg/ml; and percent free T_3, 0.62%. All significant ($P<0.05$) effects on serum T_4 decreased it from controls. Effective treatments were EB, P + R and EB + R^4. Free T_4 did not differ from controls ($P>0.05$), although percent free T_4 increased in the EB, EB + P and P + R groups. All significant effects on total T_3 were increases. These groups were EB, EB + P, P + R and EB + P + R. For free T_3, all groups showed an increase over controls ($P<0.05$). Percent free T_3 did not change for any group. While most parameters changed, free T_4 and percent free T_3 remained constant. An undefined physiological mechanism maintains statis of the free hormones.

Palomo, T. E. and R. R. Anderson, Department of Dairy Science, University of Missouri, Columbia, MO 65211. RESPONSES OF RAT UTERI TO ESTROGEN, PROGESTERONE AND RELAXIN. Ovariectomized rats were injected subcutaneously each day for 20 days with oil carrier (0.2 ml), 1 ug estradiol benzoate (EB) and/or 3 mg progesterone(P). Relaxin(R) at 100 GPU was injected each day for the last 20 days. Uteri were analyzed chemically for DNA, RNA and collagen(C). Total uterine DNA increased from 5.25 mg in controls to 17.63 mg in the group receiving EB + P + R ($P<0.05$). The lowest uterine DNA was in rats treated with R at 2.10 mg, but not significantly less than control rats. Uterine DNA after EB treatment was 10.69 mg (not greater than control). Total RNA of the uterus was 1.45 mg in controls and significantly greater in EB rats at 7.28 mg and in triply injected rats

at 7.41 mg ($P<0.05$). Total C in the uterus was increased nonsignificantly from 37.8 mg in controls to 63.9 in triply injected rats and significantly in EB injected rats at 97.9 mg ($P<0.05$). R alone reduced uterine C nonsignificantly to 17.8 mg. It was concluded that EB stimulates uterine fibroblasts to synthesize C while R suppresses these specialized cells. All three hormones (EB+P+R) are required for optimal hyperplasia of uterine cells.

Katti, P., D. Gudev and H. D. Johnson, Department of Dairy Science, University of Missouri, Columbia, MO 65211. EFFECTS OF TRANSPORTATION STRESS ON BOVINE PLASMA AND MILK CATECHOLAMINES. The objective of this report is to measure catecholamines in plasma and milk to determine the level of stress. Epinephrine and norepinephrine are regarded as indicators of acute stress. In 2 experiments, plasma and milk samples were collected prior to and following transportation (10 miles) initially at 30 min, and every 2 hr for the remainder of the 7-hr test period. Deproteinized plasma and milk samples were extracted and analyzed by high performance liquid chromatography and electrochemical detection (HPLC/EC) system. Plasma epinephrine and norepinephrine were increased from 70 and 114 pg/ml under farm conditions to 180 and 223 pg/ml at the 1-hr post-transportation measures. Values then declined toward prestress (farm) conditions. In the second experiment, milk epinephrine and norepinephrine were elevated at 30 min posttransportation to 299 and 225 pg/ml, respectively; 2 hr later values were near prestress (farm) conditions of 23 and 22 pg/ml, respectively. In summary, both plasma and milk catecholamines indicate levels of acute stress in the bovine.

Luche, R. M. and A. R. Gordon, Departments of Biology and Biomedical Sciences, Southwest Missouri State University, Springfield, MO 65804. PATTERNS OF CHANGE IN CATALASE ACTIVITY AS A PARAMETER TO ASSESS PHYSIOLOGICAL AGE IN ADULT *DROSOPHILA MELANOGASTER*. The maximum lifespan (approx. 120 days) of adult *Drosophila melanogaster* reared at 17°C is about 3 times longer than those reared at 29°C. Catalase activity was measured in extracts of individual males over their lifespan. The pattern of changes plotted at both temperatures corresponds to physiological age, not to age in days. These results suggest that the pattern of catalase changes parallel the progression of aging or senescence. When adults are reared in elevated oxygen, longevity is decreased but the patterns of catalase changes are not significantly different. Therefore, elevated oxygen does not increase the rate of aging in *Drosophila*, but reduces longevity by some other mechanism. As a conclusion, a model is presented summarizing the different ways in which environmental agents may interact to decrease longevity. Supported in part by the Southwest Missouri State University Foundation Award #627.

Nunez, W. J., Department of Biology, Missouri Western State College, St. Joseph, MO 64507. USE OF THE VIRIDANS STREPTOCOCCI AND THE MEMBRANE FILTER FLUORESCENT ANTIBODY (MFFA) TECHNIQUE FOR MONITORING HUMAN FECAL POLLUTION IN WATER. The Viridans streptococci (*Streptococcus mitis* and *salivarius*) in conjunction with the MFFA technique were utilized in an attempt to develop a rapid (i.e., within 12 hours) and specific means for detecting human fecal pollution levels in water. The MFFA technique with specific fluorescein labelled antisera for *S. mitis* and *S. salivarius* was shown to be effective for the rapid and specific enumeration of the Viridans streptococci in laboratory-prepared sham samples, and gave quantitative data comparable to that obtained by standard viable counting methods for environmental samples known to contain human fecal contamination. These findings suggest that the Viridans streptococci in conjunction with the MFFA technique may be useful for rapid and definitive identification of human fecal pollution levels in water, and hence serve as indication of potential enteric pathogen presence.

McKenzie, W. N., Jr., J. L. Kavanaugh, D. S. Geiger, E. V. Sunderrajan, and **S. R. Braun,** University of Missouri School of Medicine and Veterans Administration Hospital, Columbia, MO 65212. AGE AND SEX RELATED INCREASES IN RIGHT VENTRICULAR PRESSURE IN A MURINE MODEL OF LUPUS. Vascular invasion of the lungs can be demonstrated in MRL/Mp=1pr mice, a murine model of systemic lupus erythematosus. To further understand the vascular invasion, we measured right ventricular pressure in 2 and 4 month old lupus-prone mice and compared them with same age CD-1 controls. They were ventilated with a rodent respirator while pH and PO_2 were kept constant. A catheter was placed in the right ventricular cavity and connected to a pressure transducer. Mean fight ventricular pressure (mmHg) in 2-month-old MRL/Mp-1pr females was significantly less ($P<0.05$) when compared to same age MRL/Mp-1pr males and control CD-1 males and females. In contrast, at 4 months of age, ventricular pressure (mmHg) in MRL/Mp-1pr females was significantly greater ($P<0.05$) when compared to same age MRL/Mp-1pr males and CD-1 males and females. The mean right ventricular pressure observed in MRL/Mp-1pr females appears to be associated with the vascular invasion previously demonstrated in 4-month-old females.

Mitra, R., D. Peckham and J. B. Durham, Department of Pathology, University of Missouri, Columbia, MO 65211. STABILITY OF ESTROGEN RECEPTOR PROTEIN IN LYOPHILIZED BREAST CANCER CYTOSOL. We monitored the estrogen-binding activity in breast cancer cytosols that were lyophilized and stored at various ambient temperatures. Samples stored at -20°C for 40 months and at 4°C for 6 months showed remarkable stability both in binding affinity and receptor content, whereas those stored at 25°C showed a rapid loss of receptors consistent with time. This indicates that a stable source of estrogen receptor protein can be generated for extended use in receptor research. The lyophilized aliquots tested at various time intervals were prepared from receptor positive cytosol pools, and the estrogen binding activity in rehydrated samples was monitored by the dextran-coated charcoal method. The affinity of receptor binding was obtained by Scatchard analysis of multi-point saturation assay.

Mitra, R., P. M. Erhart, D. Peckham, N. Basco, R. Johnson and K. Hayden, Department of Pathology, University of Missouri, Columbia, MO 65211. FETAL LUNG MATURITY TESTING IN THE CLINICAL LABORATORY. Measurement of lecithin/sphingomyelin ratio in the amniotic fluid is a standard test for fetal lung maturity. This test has shown false positive results in diabetics necessitating additional testing for phosphatidylglycerol (PG). We evaluated 2 methods of PG assay: a 2-dimensional TLC (Gluck) test that takes 3 hours and a new immunoassay (Amniostat) method which requires 20 minutes to complete. Of the 47 cases compared, the Gluck method showed 30 positive and 17 negative, whereas the Amniostat gave 18 positive, 22 negative and 7 equivocal (±) results. This indicates that the Amniostat method, although fast and simple to perform, is not as sensitive as the Gluck method. We conclude that the Amniostat method can be clinically used for rapid screening, but negative results by this test must be validated by the Gluck procedure.

Corrigan, G. E., St. Louis University and the St. Louis VAMC, St. Louis, MO 63125. BIO-MEDICAL INFORMATICS—A NEW SCIENCE OR ADVANCED LIBRARIANSHIP? The definition and composition of Informatics is presented using the medical laboratory as a model. The combination of computer systems applications, together with the recently developed methods in information systems, presents a formidible amount of teaching material whose place and role in the sciences at all levels must be evaluated. A positive recommendation is given in the recently published study by the American Association of Medical Colleges: the GPEP report. The development of the "information center" is detailed.

Cave Symposium

Weaver, H. D., Missouri Department of Natural Resources, Public Affairs, PO Box 176, Jefferson City, MO 65102. SPELEOLOGY IN MISSOURI—SCHOLARS AND STUDIES OF THE DARK ZONE. Modern speleology in Missouri was born in 1956 with the advent of the book *Caves of Missouri* by Dr. J. Harlen Bretz. His theory of a phreatic origin for limestone caves challenged the accepted vadose theories of geologic textbooks in his day. But Bretz was not the first scholar to test scientific theories in the caves of Missouri. He was preceded by Luella Owen in the 1890's who postulated a geyser theory for cave origin, and Gerard Fowke in the early 1900's who searched for evidence to support the theory that aboriginal races migrated to the United States from Asia. Today, laymen and professional scholars alike, as members of the Missouri Speleological Survey, Inc., combine their talents to probe the secrets of Missouri caves. Supported by DNR and the MSS.

Tibbs, N. H., Department of Earth Sciences, Southeast Missouri State University, Cape Girardeau, MO 63701. CALCITE ICE IN LOST MAN CAVE, CARTER COUNTY, MO. Calcite ice is a rare cave formation in which a thin film of $CaCO_3$ crystallizes and floats on the surface of still pools. The lower main passage of Lost Man Cave contains a long gentle cascade of rimstone pools, some of which contain large quantities of sunken calcite ice thickened by continued deposition. Under ideal conditions, i.e. a pool has not been disturbed for some time, thin crystalline rafts of calcite ice up to several inches across have been observed on the surface of pools. Observations of a very rare calcite coated bubble and small isopods(?) walking on the surface of 1 pool indicate an abnormally high surface tension for pool water with active calcite ice formation. Other data regarding pool geochemistry and the cave environment are lacking. A more thorough study of this rare occurrence of calcite ice is recommended to assess its importance within the context of the purposes of the Ozark National Scenic Riverways in which Lost Man Cave occurs.

Knox, B. R., Department of Earth Sciences, Southeast Missouri State University, Cape Girardeau, MO 63701. THE GEOLOGY OF CREVICE CAVE, PERRY COUNTY, MO. The Crevice Cave System is Missouri's longest, with some 28 miles of mapped passages. The system is dissolved mostly in the Joachim carbonate of Ordovician age in the Perry County Sinkhole Plain. Evidence suggests that the cave system evolved in response to the water table control of Cinque Hommes Creek, which in turn responded to the changing regimen of the nearby Mississippi River. Factors that control the locations of individual passages include local folds, water table gradient, regional structure and the joint system. The map of the major cave systems in Perry County relative to Cinque Hommes Creek strongly suggests that this surface stream was once a major cave passage. The Rimstone River, Mystery and Crevice Systems were probably tributary passages of this ancient supersystem.

Taylor, R. L., Missouri Speleological Survey, 2244 South Roanoke, Springfield, MO 65807. A MODEL OF CAVERN EMERGENCE AND EVOLUTION. A common supposition in studies of speleogenesis is that the extensive breakdown which results from the loss of buoyant support to the cave ceiling during emergence from saturated conditions is dissolved away and has no significant effects upon further evolution of the cave. In contrast to supposition, this model considers that breakdown is often too rapid, too extensive and often too protected by sediment to be dissolved away—with the result that both the cave floor and ceiling experience a rapid and extensive upward migration that, in effect, lifts the affected areas of the cave completely out of near-saturated conditions. Further, since this condition of rapid emergence represents a major change in the cave's morphology, it in turn radically disrupts the energy conditions within the cave by changing conditions of stream flow. Depending upon the location(s) and extent of the breakdown, this change in stream flow can lead to such secondary forms as meanders and distributary passages, and even to the upstream formation of mazes when blockage is total or nearly so.

Vineyard, D., Missouri Department of Natural Resources, Geological Survey, Rolla, MO 65401. DISTRIBUTION AND CHARACTERISTICS OF CAVES IN MISSOURI. Missouri has a resource base of 4,759 caves (January

1986) non-uniformly distributed through 78 counties. The resource base may reach 5,500-6,000 caves by the year 2000. There are 283 caves north of the Missouri River; 4,476 south of the river. Cave distribution is relatively uniform on either side of a NE-SW line from St. Louis through Joplin, except for an anomalous concentration of 614 caves in Perry County. Most caves occur in the Cambro-Ordovician dolomites of the Ozark region; significant numbers occur in Mississippian strata and fewer in Pennsylvania limestone. A few very small caves occur in Precambrian igneous rocks of the St. Francois Mountains, and there are numerous shelter caves in sandstone. Crevice Cave in Perry County is Missouri's longest at 45.4 km; there are 44 mapped caves over 1.6 km in length. Patterns range from simple, linear passages through geometric mazes to complicated, multi-level systems. Many caves contain extensive and scenic speleothems. Cave-making continues in the Ozark region through large spring systems that represent caves in developmental stages.

Chemistry

Thompson, C. C. and S. E. Thompson, Department of Chemistry, Southwest Missouri State University, Springfield, MO 65804. CHEMICAL CALCULATIONS USING AN ELECTRONIC SPREADSHEET PROGRAM. To date, the immense popularity of integrated software packages in business-oriented practices has not extended into the area of scientific applications. In this work the utility of Lotus 1-2-3 is demonstrated in a variety of chemical calculations with particular emphasis on kinetics, thermodynamics and statistical analysis of laboratory data. Among the advantages of this approach are: first, a simplification of programming, since only the computational steps need to be entered directly; second, the ease with which graphic displays can be generated. Principal limitations center around a lack of flexibility inherent in any preprogrammed general purpose software.

Gibbons, J. J., DAYCO Technical Center, Box 3258, Springfield, MO 65808. APPLICATIONS OF THERMAL ANALYSIS METHODS TO POLYMERS AND RUBBER ADDITIVES. Thermal analysis techniques have been applied to studies involving polymeric materials and rubber compounds. Methods discussed include applications of 3 major techniques of thermal analysis: 1) differential scanning calorimetry (DSC), 2) thermogravimetric analysis (TGA) and 3) thermomechanical analysis (TMA). DSC measures heat flowing into or out of the sample as a function of its temperature, whereas TGA monitors decreases in a sample's mass as a function of its temperature. On the other hand, TMA determines linear dimensional changes or any alterations in the modulus of a sample, again as a function of its temperature. All applications discussed will be based on capabilities unique to Perkin-Elmer thermal analysis instrumentation.

Sheets, R. W., Department of Chemistry, Southwest Missouri State University, Springfield, MO 65804. INDOOR RADON POLLUTION. Exposure to airborne radon-222 and its radioactive decay daughters is known to cause lung cancer in uranium miners. In recent years it has been found that radon levels inside many houses and other buildings are well above recommended exposure levels, and high enough to increase the risk of lung cancer. The main source of indoor radon pollution is diffusion from uranium-containing rocks and soil. Other contributions to indoor radon pollution are from building materials, water and natural gas. Methods of detecting and determining radon and radon daughter concentrations are discussed. Results of some analyses are presented.

Computer Science

Burlakoff, M., Department of Computer Science, Southwest Missouri State University, Springfield, MO 65804. ADA COMPILER EVALUATION AND VALIDATION (E&V) TAXONOMY. The Department of Defense Ada® computer programming language is supported in an Ada Programming Support Environment (APSE). In order to provide a means of assessing and evaluating APSE's, the Ada Joint Program Office (AJPO) formed an E&V Task in June 1983. The goal of this task is to develop and provide to the Ada community, technology for E&V of APSE's. Since an Ada compiler is the major component of an APSE, technology for the E&V of Ada compilers is needed. This research defines, develops and provides a taxonomy upon which the E&V of Ada compilers may be accomplished. Using the taxonomy approach, specific requirements and issues that should be evaluated or validated are specified. Recommendations for improvement, refinement and expansion of the work are given. Supported by the Air Force Office of Scientific Research. Ada is a registered trademark of the U.S. Government-AJPO

Marchal, J., Department of Computer Science, University of Missouri, Rolla, MO 65401. INTELLIGENT SYSTEM OR IDIOT SAVANT: CONCEPTUAL PROBLEMS IN DEVELOPING EXPERT SYSTEMS. Part of the current hard sell of knowledge engineering packages features their capacity to facilitate the development of expert systems that can explain the behaviors that they recommend to end users. There are several reasons why this turns out to be an important selling point, not the least of which is that providing an explanation is an example of intelligent human behavior. Thus, if an expert system can provide explanations, we would seem to have both good reasons to believe and legitimate grounds to sell such a system as intelligent. But do we? Artificial intelligence enthusiasts and their critics do not agree on the answer to this question. In this example, we have a paradigm case of the controversial attribution of a human capacity to a non-human entity. And the legitimacy of such attributions of intelligence to expert systems seems to be an open question. I will discuss these issues, focusing on the questions: in what sense do expert systems provide "explanations," and does this provide a good reason for both calling and

selling them as "intelligent"? The discussion will be informed by the difficulties experienced in prototyping an expert system with kindred concerns in mind. That is, part of the prototyping project was to look at available knowledge engineering packages, with an eye to their capacity to develop expert systems that could explain their recommendations.

Popov, O. B., Computer Science Department, University of Missouri, Rolla, MO 65401. TOWARD A UNIFIED MODEL OF REASONING. Proliferation of knowledge-based expert systems, and the excessive but understandable attention they have received in the scientific and industrial community, have enormously raised the expectations concerning their applicability, usefulness, validity and credibility. Whether these artifacts work in a structured or semi-structured domain, diagnostic, causal or situation-oriented problem spaces, the fundamental issue is that they have to deal with uncertainty which is present at all levels of knowledge engineering: acquisition, representation, inference and explanation. The models of reasoning over uncertainty have primarily been based on numerical schemes, with some employing the theory of subjective probability through generalization or isomorphic systems, with others developing their own "heuristic" calculi that usually incorporates the specific demands of the domain. The intention of a researcher is to make the inferences transparent and psychologically appropriate, causing some authors to avoid numerical representations and to use symbols from the domain-colored part of the natural language. This paper explores some objectives and principles that epistemologically adequate and sound reasoning calculus with evidence should have in order to provide the intended significance of generality. The importance is even more apparent, in the light of emergence of the second generation expert systems, those trying to use models of deep reasoning, in domains where the intuitive and the inductive are the very primitives of the possible ampliative inferences that might produce learning features. The Unified Model of Reasoning prototype that is currently being developed is an attempt in that direction.

Mayfield, B. E., Department of Computer Science, University of Missouri, Rolla, MO 65401. LOOPS: A MULTI-FACETED ENVIRONMENT FOR THE DEVELOPMENT OF ARTIFICIAL INTELLIGENCE APPLICATIONS. There are many times when a programmer would like to utilize the best features of several programming languages or methodologies in one application. The LOOPS system running on a Xerox 1108 workstation provides just such an environment. Four paradigms are currently available in LOOPS: procedure oriented, object oriented, data oriented and rule based programming. These 4 methodologies are integrated in such a way that a function may be written to use any or all of them. I will be describing each of the paradigms and how they work together. Examples will be demonstrated on a Xerox 1108 AI workstation.

Mattson, E. J., Center for the Study of Data Processing, School of Technology and Information Management, Washington University, St. Louis, MO, 63130. A SOFTWARE ENGINEERING APPROACH TO EXPERT SYSTEMS. Currently, artificial intelligence has not used system development techniques that have been created in data processing. Use of a structured methodology would improve expert system design. The creation of a system development life cycle and structured tools for analysis of all aspects of design and building of expert systems will improve the product and ensure consistency. This paper examines the framework of problem selection, system architecture, artificial intelligence tools and techniques. A development life cycle consisting of analysis, design, prototype testing and implementation applies consistent procedures to expert system development.

Vila, J. and A. Dekock, Department of Computer Science, University of Missouri, Rolla, MO 65401. EXPERT SYSTEM FOR AUTOMATIC TRANSLATION OF SEVERAL NATURAL LANGUAGES TEXT TO PHONETICS. The work here described shows an expert system able to animate (graphically) and reproduce (sonorously) a text in any language which uses the Latin alphabet. A rule editor has been developed to create and modify the set of letter-to-sound rules of the source languages (SL). These translate SL into the International Phonetic Alphabet (IPA). And a small set of rules translates IPA into the phonetic coding of the Votalker IB (commercial speech synthesizer of Votrax). Each phoneme has a unique sound and so a particular position of the vocal organs. (These are displayed in 2 different projections: a front view and a profile cross view of a human face). Finally, this report describes the hardware used and the software developed.

DeKock, A. R., Department of Computer Science, University of Missouri, Rolla, MO 65401. TEACHING AN UNDERGRADUATE COURSE IN ARTIFICIAL INTELLIGENCE (AI). The last few years a number of textbooks and a variety of software have become available for use in an undergraduate AI course. Textbooks range from pure theory to those that are little more than reference manuals for a particular language. Several good compilers/interpreters have become available for microcomputers, including LISP, PROLOG, OPS-5 and M.1 among others. This paper reviews a number of the available texts and evaluates the software available for PC's. A discussion follows concerning the various alternatives for structuring a 1-semester course.

Martin, R. A., Department of Computer Science, Southwest Missouri State University, Springfield, MO 65804. AN INTERDISCIPLINARY APPROACH TO TEACHING SOFTWARE ENGINEERING. The traditional approach to teaching software engineering relies on term projects taken from data processing and/or computer science. For example, most texts suggest projects as: interactive text editors, database systems, language debuggers, games, language compilers and interpreters. This paper discusses an interdisciplinary approach to software engineering, whereby term projects are taken from areas such as physics, engineering, computer science and data processing.

Lowsley, I. H., Jr., Department of Computer Science, Southwest Missouri State University, Springfield, MO 65804. A COMPARISON OF SORTING ROUTINES. Sorting routines are necessary in a wide variety of programs, with time required for sorting depending on various factors. Several sorting routines (including bubble, insertion,

selection, shell, shell/Metzner, quicksort and heapsort) are compared with respect to length of list to be sorted and degree of sort that has already been accomplished. Results obtained when using Applesoft BASIC on an Apple IIe microcomputer are reported.

Frazier, M., Department of Computer Science, University of Missouri, Rolla, MO 65401. GAME DEPICTION AND STRATEGY HEURISTICS FOR SPROUTS. The game of SPROUTS can be graphically represented as a planar multigraph. The game itself has until recently eluded successful computer representation, and current literature does not provide a reliable strategy. Non-graphical representation heuristics and a static board evaluator are discussed.

Foster, M. V., Department of Computer Science, Southwest Missouri State University, Springfield, MO 65804. CAUCHY SIMULATION: FACT OR FICTION. Computer generated Cauchy random observations and their relationship to the central limit theorem are discussed.

Hanna, R. L., Department of Computer Science, University of Missouri, Rolla, MO 65401. AN O(n) PARALLEL MAXIMAL SUBARRAY ALGORITHM. This paper appears in response to a problem presented by Ulf Grenander of Brown University. The problem was to take an nxn array of numbers and find the subarray contaned in this nxn whose numbers would sum to a maximum positive value. Study of the problem resulted in an $O(n^3)$ algorithm. But more interestingly, application of parallel techniques to this algorithm can result in O(n) running time.

Nichols, J. and G. W. Zobrist, Department of Computer Science, University of Missouri, Rolla, MO 65401. SOFTWARE PACKAGE FOR A CONSTRAINED OPTIMIZATION ALGORITHM. A software package has been developed to model and solve constrained optimization problems. The algorithm is based upon the penalty function procedure. This package uses various menus to enter the function to be optimized, constraints and other algorithm requirements, such as step size, error, number of variables and constraints, etc. These equations and constants are then attached to the optimization algorithm and compiled. The algorithm is a FORTRAN package and the menu driver and interface is written in PL/M. The software package runs on an INTEL 310 with an iRMX operating system.

Conservation

Elick, G. E., Biology Department, Missouri Southern State College, Joplin, MO 64801, **R. F. McMahon and J. Cleland**, University of Texas, Arlington, TX 76019. COMPARISON OF TWO MORPHS OF THE EXOTIC CLAM, *CORBICULA FLUMINEA* IN TEXAS. Survivorship was used to compare the purple morph and white morph collected from Texas streams in 1985. The purpose morph showed better survivorship in starvation tests than did the white form. Preliminary heat tolerance tests also suggest better survivorship in the purple morph. Research was backed by a sabbatical leave and a Faculty Development Committee research grant from MSSC for spring semester 1985 to G. E. Elick.

Fishback, J. E. and C. A. Taber, Southwest Missouri State University, Springfield, MO 65804. RATES OF MATURATION OF OVA IN 3 SPECIES OF DARTERS (*ETHEOSTOMA*). Rates of maturation of ova in *Etheostoma punctulatum, E. cragini* and *E. flabellare* were investigated to provide an alternative and more efficient means of estimating fecundity in darters. By making weekly collections of these fish prior to and through the spawning period it was possible to determine what proportion of the egg complement a species actually spawned and if new oocytes were continually recruited throughout the season. The effects of temperature on maturation rate and recruitment were also studied. Maturation rates were determined by measuring progressive mean diameter changes in clutches of developing ova.

Jackson, J. R., Biology Department, Missouri Southern State College, Joplin, MO 64801. PRAIRIE RESTORATION AT GEORGE WASHINGTON CARVER NATIONAL MONUMENT. A historical, flora and soil analysis was initiated in 1981, on the prairie at George Washington Carver National Monument. This analysis revealed 6 prairie units whose flora ranged from an approximation of a native prairie to a depauperate array of vegetation. Soil classification showed that the prairie management units were on soil types that support native prairie. Historical analysis suggested that prairie units were native prairies during the 1880's. Separate management plans were developed for each unit that included burning, discing, mowing, plowing, woody plant removal, seeding and planting with native prairie species. Follow-up studies were conducted on these management units. It was found that in all units, except one, native prairie species increased and noxious plants were controlled. Soil analysis showed that the soil conditions either improved or stayed the same under this regime of management techniques.

Topping, M. S., W. R. Mabee, G. F. Stauffer and J. E. Fishback, Biology Department, Southwest Missouri State University, Springfield, MO 65804. A PRELIMINARY REPORT ON CRUSTACEAN ZOOPLANKTON IN SOUTHERN MISSOURI WATERS. As part of a study of the distribution and composition of zooplankton in southern Missouri waters, samples from 26 lakes, ponds, sloughs and ditches characteristic of the Springfield Plateau and Southeastern Lowlands regions have been analyzed. To date, 42 species have been identified.

Engineering

Eastman, R. M., Department of Industrial Engineering, University of Missouri, Columbia, MO 65211. MATERIAL HANDLING SYSTEM DESIGN IN THE COMPUTER ERA. The purpose of this paper is to discuss changes in material handling system engineering in the last 5 years due to the computer revolution. The increased speed, capacity and capability and decreased size and cost of computers have made material handling applications feasible. These include automated guided vehicles, automated storage and retrieval systems, robots and carousels. Computers can plan, schedule, direct and control material handling systems and collect real time information on system status and inventories.

Guoxiang, G. and Miller, W. H., Department of Nuclear Engineering, University of Missouri, Columbia, MO 65211. POWER FLATTENING DESIGN AND DEPLETION CALCULATIONS FOR UPGRADING MURR. The study to upgrade the University of Missouri Resarch Reactor (MURR) from 10 to approximately 30 MW will require obtaining the maximum feasible power output from each of its 24 fuel plates. The depletion code LEOPARD and the diffusion codes 2DBUM (R-Ø, R-Z) and 3DBUM (R-Ø-Z) were employed for this study. The 2DBUM calculated value in k_{eff} is within 0.5% of experiment, and 10% for the lifetime of the core for the currently used design. The flux and power distribution and burnup results are satisfactory compared with experiment. Calculations show that the flux distribution is almost constant in the core, power is directly dependent on the fuel loading per plate and adjusting this loading is the easiest and most effective method to flattening power. Using this method, the radial power peaking factor decreases from 3.22 to 1.15; the total power peaking factor is 1.629. The average burnup is 10E + 5 MWD/T. The lifetime of the core is 110 MWD. These results with safety analysis show the new upgrade is feasible without changing the fuel geometry.

Sandgren, E., B. M. E. de Silva, R. Duffield, V. Bhatt, D. Marjadi and K. M. Ragsdell, Design Productivity Center, University of Missouri, Columbia, MO 65211. THE DESIGN OF ULTRA-LIGHT VEHICLES IN A PARALLEL COMPUTING ENVIRONMENT. Modern and future automobiles, high performance aircraft and spacecraft require new design methodologies to achieve performance goals. The use of new materials with exceptional strength amplifies the need to balance competing objectives such as weight and safety. Our recent efforts have concentrated on developing very powerful nonlinear optimization strategies using decomposition and advanced re-analysis techniques. The efficient use of a parallel (super-computer) computing environment is a pivotal ingredient of this effort.

Prelas, M. A., G. Guoxiang and J. F. Kunze, Department of Nuclear Engineering, University of Missouri, Columbia, MO 65211. AN AEROSOL CORE REACTOR CONCEPT FOR NUCLEAR-PUMPED LASER. High power lasers for space applications will require an energy source with a high ratio of energy output per mass of the device. Nuclear reactors can be used to drive such lasers, either with direct or indirect coupling. Direct coupling is usually referred to as a nuclear-pumped-laser (NPL). The interface between the nuclear fuel and the laser is the critical problem. An aerosol core reactor concept which utilizes a transmissive fuel-to-laser interface was studied to determine from calculations what power output might be expected from such a NPL. The process is one of first creating visible or ultraviolet fluorescence in the aerosol fuel region, and then using that fluorescence to drive a centrally located laser. We have examined the nuclear reactor design of such a system, using both diffusion and transport codes. Based on the results, it is feasible to build such a reactor employing low fuel particle densities of about 1 mg/cc, in a cell surrounded by heavy water or graphite moderator. A typical reactor would have several hundred such cells.

Environmental Science

Mills, S. H. and D. M. Anglen, Departments of Biology and Industrial Hygiene, Central Missouri State University, Warrensburg, MO 64093. DETECTION AND SOME EFFECTS OF 2,5 HEXANEDIONE ON RATS. Rats have been effectively intoxicated with a metabolite (2,5 hexanedione) of hexacarbons by treatment of their drinking water. A gas chromatographic technique for detecting this metabolite was developed using a Perkin-Elmer gas chromatograph interfaced to an Apple IIe microcomputer. This microcomputer interfacing technique has also been used to monitor skin temperature responses of normal and intoxicated rats to transient heating. Reduced insulation associated with this intoxication has been evaluated by monitoring the patterns of skin temperature change during transient heating.

Yourtee, D., University of Missouri, Kansas City, MO 64108; **Akande, B.,** University of Lagos, Lagos, Nigeria. THE FATE OF AFLATOXIN B_1 METABOLITES: PRODUCTS FROM AFLATOXIN Q_1 METABOLISM BY MOUSE, RABBIT AND HUMAN LIVER PREPARATIONS. Aflatoxin Q_1 is a detoxified liver metabolite of aflatoxin B_1. The latter is a potent environmental hepatocarcinogen in experimental animals. In this study, the investigation of *in vitro* metabolism of aflatoxin Q_1 by the post-mitochondrial fraction of mouse, rabbit and human liver is reported. A human liver specimen donated at biopsy yielded upon metabolism aqueous, chloroform soluble and bound metabolites of Q_1. Both experimental animals metabolized this substance at a turnover similar to aflatoxin B_1. There was a higher bound fraction and lower aqueous fraction from the metabolism of B_1 than from aflatoxin Q_1. The aqueous fraction of the metabolisms evidenced the β-D-glucuronide of aflatoxin Q_1. The rabbit metabolism of Q_1 was characterized by high levels of chloroform soluble metabolites. In contrast, the mouse

metabolism resulted in high glucuronide and bound Q_1 metabolite levels. Understanding the metabolic fate of aflatoxin Q_1 for each species of interest is, therefore, important in the risk analysis of B_1.

Ward, D. W., Department of Biology, Central Missouri State University, Warrensburg, MO 64093. TERRITORIAL FUNCTION OF FOOTDRUMMING AND VISUAL DISPLAYS IN THE BANNERTAIL KANGAROO-RAT (*DIPODOMYS SPECTABILIS*). I tested the hypothesis that adult bannertail kangaroo-rats have different footdrumming responses when exposed to stimuli of varying degrees of threat. Adult bannertail kangaroo-rats were studied in the field near Portol, AZ. They were exposed to 3 treatments: audio (airborne footdrumming playback), visual (stuffed and mounted kangaroo-rat) and audio-visual (a combination of the 2). In addition, cricket strigulation was used as a control. Significant differences existed between the control and each treatment. Also, a significant difference existed between audio and both the audio-visual and visual treatments. This difference is perhaps due to the greater potential threat expressed in the visual component of the 2 treatments. Results are consistent with behavioral theory which predicts that greater stimuli should elicit a greater response.

Tillman, D. L. and J. Swift, Department of Biology, Missouri Southern State College, Joplin, MO 64801. SHELFLIFE OF FRESH SEAFOOD S DETERMINED BY BACTERIOLOGICAL ANALYSIS. During the summer of 1985 (July 18-22) daily bacterial counts were conducted on 2 frozen-thawed and 2 fresh-chilled fish flesh types. Fish samples were primarily examined for total aerobic plate counts (TAPC) with some subsequent examination for coliform and *Staphylococcus aureus* bacteria. TAPC's of 10^5 or higher per gram of flesh were considered unacceptable. The presence of any coliform or *Staphylococcus aureus* in the sample was also considered unacceptable. One frozen-thawed flesh type exceeded the TAPC criteria the first day of shelflife, the other exceeded the criteria limit the second day of shelflife. One fresh-chilled fish flesh type exceeded the criteria after 1 day shelflife, the other exceeded the limit after the fourth day. Inadequate shipping and handling procedures appeared to be the cause of premature bacterial contamination and loss of shelflife expectancy.

Emrie, G. E., and D. Castillon, Department of Geosciences, Southwest Missouri State University, Springfield, MO 65804. FECAL COLIFORM AS AN INDICATOR OF RECREATIONAL CARRYING CAPACITY IN THE OZARK NATIONAL RIVERWAYS (ONSR). Visitor impacts on the Riverways has been a continuing concern of the park management at ONSR. Preliminary studies done in 1980 indicated a positive relationship between levels of canoe use and fecal coliform densities. This study collected water quality data at 7 locations on the Current and Jacks Fork rivers during the summer of 1985. Water quality tests performed were dissolved oxygen, conductivity, nitrates, pH, temperature, fecal strep and fecal coliform. Fecal coliform data were correlated to 4 variables, canoe and innertube use, back country and gravel bar campers, horseback riders and precipitation. The strongest correlation was between precipitation and fecal coliform, second was horses and fecal coliform levels. No significant relationship was found between canoe use or campers and fecal coliform densities. Mean coliform levels for each sampling location were compared. The highest levels were found on the lower Jacks Fork. Sources of contamination from runoff are difficult to determine without more study.

Mantei, E. J., Department of Geosciences, Southwest Missouri State University, and **D. Coonrod,** Director, Watershed Coordinating Committee, Springfield, MO 65804. DISPERSION OF METALS IN THE STREAM SEDIMENTS ADJACENT TO THE WEBSTER COUNTY, MO, SANITARY LANDFILL. Forty-seven samples representing the background, and 66 samples from the contaminated area were collected. Reconnaissance analyses indicated high quantities of Cu, Zn, and Ag, and the presence of Cd and Pb in the samples from the contaminated area. The quantity of each element was determined for each sample using atomic absorption techniques. An overall relative precision of 9.65% was obtained for the analysis method. Statistical results indicate a relationship between Cu, Zn and Ag, and between Cd and Pb. The mean content for each element (Cu, Zn, Ag) in the contaminated area is about twice the value of the mean content of the same element in the background area. The same comparison for Cd and Pb shows little or no variation. The authors conclude that Cu, Zn and Ag are being added to the area adjacent to the landfill.

McGinnes, E. A., Jr., School of Forestry, Fisheries and Wildlife, University of Missouri, Columbia, MO 65211. DISTRIBUTION OF LEAD WITHIN THE FOLIAGE, TWIGS, BRANCHES, BARK AND WOOD OF EASTERN REDCEDAR (*Juniperus Virginiana*, L.). In order to use old, slow-growth redcedar specimens to establish pollution histories in the lead belt regions of Missouri, it is necessary to determine distribution characteristics of lead in the various tissues of the tree. Two mature redcedar trees growing about 100 yards from the roadway in a wildlife area near Ashland, MO, were felled for analyses. Lead determinations were done according to previously reported techniques (Wiley-milled samples, wet ashing and atomic absorption). Distribution trends were similar for the 2 trees. External foliage had lower lead concentrations than internal foliage (5.35 vs. 9.75 ug/g). External twigs (bark plus wood) also had lower lead concentrations than internal twigs (9.35 vs. 25/50 ug/g). External branches contained more lead than those internal close to the main trunk (6.35 vs. 1/85 ug/g). Bark contained more lead than wood. Both bark and wood in the crown contained more lead than those same tissues near the ground.

McGinnes, E. A., Jr., School of Forestry, Fisheries and Wildlife, University of Missouri, Columbia, MO 65211. SAPWOOD CHARACTERISTICS OF OLD, SLOW-GROWTH EASTERN REDCEDAR (*Juniperus Virginiana*, L.) TREES OF MISSOURI. This study was done to determine the area, age and rate of growth for the sapwood regions of representative specimens of old (154-578 ring count) redcedars. Data were obtained from cross-sectional disks which were sanded and then rubbed with steel wool to facilitate ring count. Eighteen old samples and 2 controls from younger (48 and 61 ring count) trees were analyzed. Sapwood area ranged from a low of 3.56% of the tree cross-section for the 578 ring count specimen to 100% for the 2 controls. Sapwood age for the older trees ranged

from 11 to 30 years, while rate of growth ranged from 12.43 to 37.98 rings per centimeter. After an initial period of growth during which sapwood width will decrease, there is a period where sapwood area will be more or less constant in trees after a dieback mishap. The stressed (slowest growth) trees with the smallest percentage of sapwood will have the widest sapwood rings among older trees.

Forensic Science

Dahl, D. B. and P. F. Lott, Department of Chemistry, University of Missouri, and **G. R. Howell**, Regional Criminalistics Laboratory, Kansas City, MO 64110. GUNSHOT RESIDUE DETERMINATION BY ATOMIC ABSORPTION SPECTROPHOTOMETRY AND HIGH-PERFORMANCE LIQUID CHROMATOGRAPHY. Information will be presented on the use of graphite furnace atomic absorption spectrophotometry for the determination of metallic residues (Sb, Ba and Pb) that are left from a firearm discharge. Two procedures will be discussed: a manual method and an automated injection procedure. Also presented will be information on the detection of diphenylamine and centralite (substituted diphenylureas) which remain on the hand from a discharge where smokeless powder was employed. Determination of the latter constituents is done by high-performance liquid chromatography. Combination of the techniques can provide irrefutable evidence for the presence of gunshot residues. This work was supported in part by a research grant from the University of Missouri-Kansas City.

Geography

Johnson, E., Department of Geosciences, Southwest Missouri State University, Springfield, MO 65804. LAND COVER MAPPING OF GREENE COUNTY, MO: A FURTHER ASSESSMENT BY USE OF MULTIDATE LANDSAT 5 DATA. A land cover map of Greene County, MO, was completed for April 27, 1984, by use of LANDSAT 5 data. Ten primary land cover classes were delineated and subsequently mapped. But, the diverse land cover types of winter wheat, alfalfa and certain fields of fescue clustered together from similar spectral responses. Data from LANDSAT 5 for August 1, 1984, revealed different spectral values for these 3 cover types in several sampled areas, but considerable variation in spectral responses remain because of farming practices during this time of the year.

Fitzwater-Dewey, D. A., Department of Geosciences, University of Missouri, Kansas City, MO 64110. GEOGRAPHICAL ELEMENTS AFFECTING TOURIST TOWN DEVELOPMENTS—TOPOGRAPHY AND TRANSPORTATION. The effects of topography and transportation on a tourist town's ability to retain the distinct character of the region is the focus of this study. My hypothesis is that the greater the accessibility to a region and the greater the relief in the topography of that region, the more tourist development will occur. Eureka Springs, AR, and Branson, MO, were used as case studies. Both have similar topography, climate and natural resources, and are located in the same geographical region. Distance from major urban population centers are similar. Accessibility and topography were found to play a role in the development of these tourist towns. Further research will need to be implemented before the other determining variables can be found for these 2 towns.

Fair, S. F., Department of Geography, University of Missouri, Columbia, MO 65211. U.S. FARMS. The ideal of the independent family farm is explored in research on the broad charateristics of farming in the United States, and concludes with an overview of the 4-state area of Missouri, Kansas, Arkansas and Oklahoma. Historical trends and current status are taken into account using data on farm population, sales and size. A 3-tiered layer of farming emerges with most sales coming from the less numerous large farms, most farms being small in size and the medium farm declining in number from an already small proportion of the total. The overall description of U.S. farms includes data on cropland usage: increase/decrease, exports and major crops. Mapped data from the 1978 Census of Agriculture is used to focus on the 4-state area. Farming characteristics of this area are related to the nationwide profile. It is concluded that the independent family farm of our ideals is difficult to locate and define because the structure of farming has changed.

Rafferty, R. P., U.S. Army Corps of Engineers, 601 East 12th Street, Kansas City, MO 64106. THE RELATIONSHIP BETWEEN DIFFERENCES AMONG THE SEXES AND THE POVERTY LEVEL IN THE OZARK REGION. This study is a synthesis of geographic, planning and economic concepts that portray the relationship between sex differences in the labor market and the economic health of the Ozark Region of Missouri. This relationship is demonstrated with a long-run and short-run perspective. These perspectives are developed with the new analytical tools of the Long-Run and Short-Run Difference Curves. A basic conclusion of the study is that the differences between the sexes was less in poorer regions than in richer regions of the Ozarks.

Driever, S. L., and D. M. Vaughn, Department of Geosciences, University of Missouri, Kansas City, MO 64110. AN ASSESSMENT OF FLOODPRONE AREAS IN KANSAS CITY. This paper examines the topography, land uses and management controls of 4 floodplains (Missouri, Blue, Little Blue and Brush Creek) of varying size in Kansas City. Floodstage elevations were used to delineate the boundaries of floodways. Then we assessed the effectiveness with which public policy has guided and protected land uses in the floodprone areas. Although the rate of urban development in Kansas City floodplains has slowed in recent years due to the National Floodplain Insurance Program, management controls of such growth are not always satisfactory.

Stettes, S. S., Department of Geosciences, Southwest Missouri State University, Springfield, MO 65804.CHANGES IN THE POTENTIOMETRIC SURFACE IN FRANKLIN COUNTY, MO, 1931-1980. Groundwater is present in abundant quantities in Franklin County, MO. A study based on the observed water level in new wells during 5 consecutive 10-year periods shows moderate fluctuation in the potentiometric surface through time. Groundwater flow throughout the county is in a north-northeast direction and no pronounced groundwater divides are present. The results indicate that the groundwater level along the Missouri River, the northern boundary of the county, has decreased during the period particularly in the New Haven-Washington area. A similar decrease was observed along the eastern boundary near Pacific. Increased population growth and industrial activity during the 50-year study period are factors responsible for the decline in the potentiometric surface in these areas.

Geology-Geophysics

Mantei, E. J., Department of Geosciences, Southwest Missouri State University, Springfield, MO 65804. USING THE VARIATION OF TRACE ELEMENT QUANTITIES AS A GUIDE TO THE MOVEMENT OF ORE FLUIDS RELATED TO IGNEOUS BODIES AND TO SULFIDE ORES. As a magma differentiates in certain directions, successively higher quantities of gold and silver may be entrapped in the "open" silicate structures of the biotites and hornblendes. An increasing gold and silver content in the biotites and hornblendes of the Marysville, Montana Quartz Diorite Stock from the finer grained interior to the periphery, suggests a possible outward movement of the solutions carrying the gold and silver. Previous research has indicated that the quantities of certain trace elements in primary ores may decrease in the direction of ore fluid movement. Galena cubes were collected from various stratigraphic levels in the mines of the "Viburnum Trend," MO, and were analyzed for Sb quantities using neutron activation analysis. A decreasing Sb content in the galena northward and southward from the center of the "Viburnum Trend," MO, may indicate a 2-directional ore fluid movement.

Cocke, J. M., Department of Earth Science, Central Missouri State University, Warrensburg, MO 64093. TAXONOMIC STATUS OF PENNSYLVANIAN CORALS ASSIGNED TO *DIBUNOPHYLLUM* THOMSON AND NICHOLSON 1876. Traditionally, Pennsylvanian corals bearing spider-web columellae have been placed in *Dibunophyllum*, a Lower Carboniferous genus from Scotland. These corals are large with degenerate minor septa, numerous major septa and a distinct cardinal fossula. It is recommended here that American forms be placed in *Amandophyllum* and *Sestrophyllum*. Both contain small to moderate sized corals with well-developed minor septa, numerous radiating lamellae and no cardinal fossula. The latter differs from *Amandophyllum* in having long lanceolate minor, subhorizontal dissepiments peripherally and septa that rise above the epitheca.

Jaquess, J. C. and R. D. Hagni, Department of Geology and Geophysics, University of Missouri, Rolla, MO 65401. PRELIMINARY STUDY OF MINERALOGY OF MINERAL DEPOSITION IN PIPES AT HOT SPRINGS, AR. The thermal springs at Hot Springs, AR, are internationally renowned. One of the most important functions of the Hot Springs National Park Service is to collect, partially cool and distribute the hot water for consumption and especially for bathing purposes. Both collection and distribution pipes have significant and progressive mineral deposits that partially constrict the flow of hot water. A mineralogical study of these mineral deposits, in cooperation with the Arkansas Geological Commission and the Hot Springs National Park Service, has been initiated by collection of samples of mineral linings from the pipes and tufa deposited at pipe exits and in surface outcrops. Preliminary mineralogical studies indicate the presence of calcite, silica, manganese and iron minerals. Ore microscopic, petrographic, X-ray and microbeam studies are in progress.

Priesendorf, C., Department of Geology, University of Missouri, Columbia, MO 65211. TRILOBITES, BIOSTRATIGRAPHY, LITHOSTRATIGRAPHY AND ENVIRONMENTS OF DEPOSITION OF THE FORT SILL LIMESTONE, WICHITA MOUNTAINS, OK. Over 1400 trilobite cranidia and pygidia were recovered from the Upper Cambrian Fort Sill Limestone. Thirty-one species, including 2 new genera and 3 new species, were discovered. A prograding carbonate ramp environment is proposed for the Fort Sill. The lower 80 feet consist of uncleanly washed glauconitic biosparites, indicative of depths slightly above effective wave base. This interval is followed by 200 feet of lagoonal sediments, indicated by thinly laminated biomicrites and oncolites. Overlying this lagoonal environment are 50 feet of oolites, stromatolites and edgewise conglomerates, representing an intertidal environment. Above these intertidal carbonates are 155 feet of Royer Dolomite. Remnant oncolites and stromatolites indicate a lagoonal to intertidal environment. The Royer Dolomite is overlain by 45 feet of fenestral limestone, indicative of a supratidal environment. A 1-foot interval of glauconitic trilobite biosparite overlies this supratidal environment, suggestive of a return to the deeper, normal marine environment.

Burney, D. W., Amax Lead Company of Missouri, Boss, MO 65440. FAULTING AT BUICK. East-west and northeast trending strike slip faults have been mapped at the Buick Mine. The amount of horizontal displacement has not been determined, and only minor vertical displacement has been observed. The faults are open, and cross-cut the mineralized trends. Incipient horizontal slickensides are often present. The faults often contain cubic galena, and frequently the galena shows minor stress suggesting post mineral movement. Fault breccia is occasionally associated with the faults. Accompanying a primary fault, there are several secondary discontinuous faults. The most significant observation is the cross-cutting characteristic of the faults with no apparent horizontal displacement of the mineralization. Underground observations have shown that many of the faults extend through the upper one-half of the Bonneterre Formation, and underground drilling has suggested the faults extend through

the underlyiong Lamotte sandstone. Surface drilling has identified faults in the Precambrian, however, no correlation with the overlying faulted strata can be made with any certainty. No data are available for the overlying strata, and no surface expression of the faults has been observed.

Medary, T. and T. Freeman. Department of Geology, University of Missouri, Columbia, MO 65211. STRATIGRAPHIC PETROGRAPHY OF DOLOMITES IN THE BONNETERRE FORMATION (CAMBRIAN, MISSOURI). A series of drill cores from across the Viburnum Trend was studied in an effort to delineate multiple species of dolomite in the Bonneterre Formation and interpret their histories. Partial dolomitization resulted in generally idiotopic dolomites that exhibit a correlation between sediment grain size and dolomite crystal size: the finer grained the sediment, the more finely crystalline the dolomite. More thorough dolomitization resulted in more uniformly coarsely crystalline xenotopic dolomites believed to record a thermal, epigenetic event. Furthermore, they exhibit vuggy porosity, some of which is occluded with dolomite cement, which further attests to rigorous burial epigenesis. The spacial correlation between epigenetic dolostones and ore within the Bonneterre suggests that either: a) the 2 record the passage of a common mineralizing fluid or b) vuggy porosity and paleoporosity in the epigenetic dolostone guided the flow of later mineralizing fluid.

Nethington, D. R. and R. C. Laudon, Department of Geology and Geophysics, University of MIssouri, Rolla, MO 65401. REMOTE SENSING ANALYSES OF SALT DIAPIRS IN THE SVERDRUP BASIN, CANADA. A remote sensing study of 3 well-exposed evaporite diapirs on Ellef Ringnes Island, Northwest Territories, Canada, demonstrates that Cretaceous formations surrounding the diapirs have essentially equal lineament densities. This suggests that salt dome emplacement probably occurred at the same time that the formations were being deposited. It implies that the domes are not true piercement structures, but rather syndepositional features.

Starbuck, E. A. and A. C. Spreng, Department of Geology and Geophysics, University of Missouri, Rolla, MO 65401. PRELIMINARY RESULTS OF AN INVESTIGATION OF THE DIAGENETIC HISTORY OF THE RHYTHMIC LIMESTONE-SHALE SEQUENCE OF THE UPPER FAYETTEVILLE FORMATION (UPPER MISSISSIPPIAN) OF NORTHERN ARKANSAS. The upper Fayetteville Formation is a good example of the type of rhythmic bedding that may result from cyclic sedimentation, but that has also been suggested to result from "diagenetic unmixing" of carbonate and clay minerals. Field work, thin section description, x-ray diffraction and the SEM are used to determine primary and diagenetic features. Uniformity and continuity of the limestone beds in outcrop indicate that they are primary. Carbonate grain sizes are generally in the microspar range. Lack of significant compaction is evident in the limestones, yet almost all pore space is filled. Dolomitization and silicification have been observed. Criteria used to establish the interbedded calcareous shales as the source of the pore-filling and replacement minerals are not as evident here as in other studied stratigraphic units. Continued study is needed to determine a more complete diagenetic history.

Cocke, J. M. and R. Heese, Department of Earth Science, Central Missouri State University, Warrensburg, MO 64093. NEW GENUS OF BOTHROPHYLLIDIDAE FROM DESMOINESIAN LIMESTONE OF WESTERN MISSOURI. The Myrick Station Member of the Pawnee Formation and the Houx Limestone have yielded abundant rugose corals including aulophyllidids, geyerophyllidids, lophophyllidids and a new genus of the Family Bothrophyllididae Fomichev, 1953. These American corals show typical bothrophyllidid characters: thickening of major septa that thin first in counter quadrants, a distinct cardinal fossula, well-developed dissepimentarium and a loose columella composed variously of median plate, sagging tabulae and radiating lamellae. The new genus differs from other bothrophyllidids in lacking minor septa and possessing well-developed but local lonsdaleoid dessepimentaria.

Nold, J. L., Department of Earth Science, Central Missouri State University, Warrensburg, MO 64093. THE IDAHO COBALT BELT-A REMOBILIZED STRATABOUND ORE DISTRICT. The Idaho Cobalt Belt is located in Lemhi County about 50 km west of Salmon, ID. The most important deposit in the district is the Blackbird Mine which produced copper-cobalt-gold ore sporadically from the early 1900's until 1960. In the belt, originally stratiform ores have undergone increasing degrees of remobilization toward the northwest, in the direction of increasing regional metamorphic grade. The Iron Creek deposit at the southeast end of the belt is the least remobilized; zones of disseminated and massive sulfides lie parallel to bedding. At the Blackpine Mine remobilization has concentrated the mineralization into relatively thin concordant and discordant veins. Further northwest at the Blackbird Mine, the veins are thicker and more continuous. The highest grade of metamorphism in the belt is on the northwest end at the Salmon Canyon deposit. However, in spite of the higher grade of metamorphism, and presumably greater volumes of metamorphically generated fluids, little remobilization has occurred. Apparently no fluid-controlling structures were near the mineralized zones at this location.

Laudon, R. C., R. D. Hagni and B. Biere, Department of Geology and Geophysics, University of Missouri, Rolla, MO 65401. COMPUTER PROGRAM TO CALCULATE AND PLOT QUANTITATIVE COLOR AND SPECTRAL REFLECTANCE FOR ORE MINERALS. Data on reflectance values for specific wavelengths of light are available in the literature for many ore minerals. Data for approximately 575 minerals have been collected and combined into 1 database. The computer program calculates the quantitative color values x, y, Y, λ_d and Pe(%), for all the minerals and stores the values on floppy disk. The program has an option that plots reflectance versus λ_{um} on the screen for any of the minerals. These plots can also be printed out on a dot-matrix printer. The database and programs are written for the IBM-PC and can be obtained at no cost by sending a blank diskette and self addressed, stamped envelope to any of the authors.

Hagni, J. E., Scientific Computer Systems, Inc., PO Box 783, Arlington, VA 22216, and Richard D. Hagni, Department of Geology and Geophysics, University of Missouri, Rolla, MO 65401. A SYSTEM OF AUTOMATED ORE MINERAL IDENTIFICATION BY MICROCOMPUTER PROGRAM. Most systems of ore mineral identification have been limited in scope, cumbersome, slow, ineffective and best used by expert microscopists. We have developed a computer program that is rapid, easy-to-use and effective for both novice and expert alike. It contains a data base consisting of the principal identification properties for 649 ore minerals. The data base includes average Vickers hardness number, reflectance, Talmage hardness, strength of anisotropism, quantitative color, qualitative color and tint of the ore mineral and color and tint of the internal reflections. Although the principal purpose of the program is to narrow the possible minerals for a given unknown to a small number that can then be compared more closely to those in standard descriptive texts, in many instances the program provides an immediate selection of a single most probable mineral.

Cocke, J. M. and M. Rogers, Department of Earth Science, Central Missouri State University, Warrensburg, MO 64093. SELECTED MICHELINID CORALS OF TEXAS AND OKLAHOMA. Two types of michelinids have been collected from Pennsylvanian Missourian units in Texas and Oklahoma. The first, *Michelinia*, has numerous complete and incomplete tabulae that fill each corallite and are collected from shallow water (regressive) limestones and shales. The second, a thick walled undescribed genus, has few tabulae concentrated in the upper few millimeters of each corallite. Below those tabulae, the corallite is filled with dense skeletal material. Specimens of the undescribed genus are found in the (transgressive) "core" shale with ammonoids, nautiloids, conularids and paragassizocrinids.

Moeglin, T. D., Geosciences Department and **H. R. James**, Department of Agriculture, Southwest Missouri State University, Springfield, MO 65804. CLAY MINERAL ASSEMBLAGES OF TWO FRAGIPANS ON THE SPRINGFIELD PLATEAU. Soil samples from the fragipan layers of the Hoberg and Keeno soils in Lawrence County, MO, were chemically treated to achieve maximum dispersion and identified on a General Electric XRD-700 defractometer. Clay minerals associated with the fragipan are kaolinite, illite (the $2M_1$ and possibly IM polytype), montmorillonite, regularly interstratified illite-montmorillonite and randon interstratified illite-montmorillonite. Relative abundance calculations indicate that kaolinite increases through the fragipan, montmorillonite decreases and illite varies throughout the layer. This assemblage is interpreted within the framework of low hydraulic conductivity at fragipan boundaries, low leaching rates and a complex geomorphic history.

Lojko, F. B., Springfield Public Schools, 940 North Jefferson Avenue, Springfield, MO 65802. BEACH SAND GRAIN SIZE ON THE COLORADO RIVER IN THE GRAND CANYON. Beach sand samples from selected beach sites were collected, sieved, analyzed and measured for the past 4 summers during the same frame of time. The purpose of the study was to calculate effects of the Glen Canyon Dam and regulation of flow of the Colorado River being discharged from the dam on physical characteristics, composition and phi size of the sandy beaches. Comparison of sand grain size from different locations on the same beach, and from the same locations in different years, yields information about deposition and erosion of the beaches through time. The sand was found to be generally fine- to medium-grained. A river current velocity of 22-25 cm/sec would be sufficient to initiate erosion of any beach sands sampled. Mean grain size was larger in samples taken closer to the water's edge than in samples collected at areas farther from the river. The sand grains were moderately- to well-sorted. The trend of increased mean sand grain size between 1982 and the years 1983 and 1984 supports evidence of a resorting of beach sands by the high water flow in 1983.

Freund, M., R. C. Laudon, and J. R. Carr, Department of Geology and Geophysics and Department of Geological Engineering, University of Missouri, Rolla, MO 65401. AN EVALUATION OF 4 DIFFERENT GRIDDING TECHNIQUES USED IN CONTOURING PROGRAMS. Single data points were eliminated from a grid of x, y, z data points. The x and y values of the single data points were fed back into 4 computerized gridding procedures and the calculated z values were then compared to the actual (eliminated) z values. Cokriging, using either of 2 equation solutions, produced more accurate results than either ordinary kriging or trend surface analyses.

Herpetology

Kangas, D. A., Science Division, Northeast Missouri State University, Kirksville, MO 63501. POPULATION SIZE AND SOME STATISTICAL PREDICTORS OF ABUNDANCE OF *KINOSTERNON FLAVESCENS* IN NORTH MISSOURI. A 5-year study of *K. Flavescens* in north Missouri yielded 3 sites where turtles could be trapped. The largest population was estimated to be 932 turtles (range = 655-1610; Schnabel method). The second largest population was estimated to be 61 turtles (range = 43-101). The third site had 3 turtles. Two additional sites were selected which did not yield *Kinostemon* to search or to trapping. Stepwise multiple regression was used to assess particle size as a predictor of turtle abundance. The Schnabel estimates were used as the dependent variable. Ninety percent of the variation in turtle abundance could be accounted for by the regression on the percentage of very coarse sand in the soil of the sites. A second stepwise multiple regression was run on 9 independent variables which describe land use. Three of these: acres in marsh ($r = 0.949$), acres under human influence ($r = 0.183$) and acres in pasture ($r = 0.081$) were significant predictors of turtle abundance. Their slopes were different from 0.

Scheibe, J. S., Department of Biology, Southeast Missouri State University, Cape Girardeau, MO 63701. EFFECTS OF RESOURCE LIMITATION ON THE COEXISTENCE OF AGE STRUCTURED LIZARD POPULATIONS IN THERMALLY UNPREDICTABLE ENVIRONMENTS. The hypothesis that interspecific competition can prevent coexistence of lizard species in thermally unpredictable environments was tested using a computer simulation model. Population growth was modeled using renewal equations incorporating age specific fecundity and survival parameters. The results show that lizards in thermally unpredictable environments can coexist under conditions of resource limitation that would not be possible for lizards in more predictable environments.

Aldridge, R., Biology Department, St. Louis University, St. Louis, MO 63103. OVIDUCAL SPERM STORAGE IN THE SOUTHEASTERN CROWNED SNAKE (*TANTILLA CORONATA*). The left oviduct of *T. coronata* is vestigial. The right oviduct has 3 morphologically distinct regions: vagina, middle region and glandular region. Mating occurs in the spring and late summer. In April and May during vitellogenesis, sperm are abundant in the lumen of the middle portion. Following oviposition (June and July), sperm are present only in the seminal recepticle of the glandular region. In late summer when copulations resume, sperm are again present in the middle segment. Some females that had mated in the spring, or previous summer, are non-reproductive.

Trautwein, S. N., Department of Biology, Southeast Missouri State University, Cape Girardeau, MO 63701, and **B. L. Johns,** Indiana University School of Medicine, Ft. Wayne, IN 46805. VASCULAR ANATOMY OF THE FENCE LIZARD, *SCELOPORUS UNDULATUS*. Previous work by Trautwein and others indicates that the extent of brain cooling of the fence lizard which occurs during exercise is not explained merely by passive convective processes. An active mechanism of blood shunting between alternative venous drainages from the head may account for the differential cooling. The present study looks for such a venous shunt by injection of microfil cast medium into the vascular system, followed by staining of the skeleton with alcian blue and alizarin red and clearing with trypsin digestion. Anatomical evidence is given for the presence of an arterio-venous counter-current in the neck. Vessels in the head, neck and limbs, including microvasculature in muscles and skin, are also shown.

Kangas, D. A., Science Division, Northeast Missouri State University, Kirksville, MO 63501. SURVIVORSHIP AND LIFE TABLE CALCULATIONS FOR *KINOSTERNON FLAVESCENS*. Survivorship of 2 populations of *K. flavescens* was estimated by 2 methods. Using age-frequency distributions, overall survivorship was estimated to be 0.50, 0.54 and 0.55 for turtles 5 years old and older. These estimates correspond to a range of mortalities from 0.69 to 0.60. From 1983 data it was possible to estimate survivorship for each age group. These estimates ranged from 0.17 for hatchlings (1980-1981) to 1.0 for several age groups in several years. Mortalities ranged from 1.77 to 0. The pattern of survivorship was type III with non-age-specific mortality. Reproductive abilities of the turtle suggest a population capable of maintaining itself. Field observation and assessment of age distributions support this conclusion.

Oncology

Papermaster, B. W. and R. D. Reynolds, Cancer Research Center, Columbia, MO 65203. EARLY DETECTION AND CANCER PREVENTION. While there have been major advances in the treatment of cancer, the principles of cost effectiveness are best served through efforts in early detection and prevention. Tobacco usage and environmental exposure factors are readily recognized by the general population, but recommended changes in lifestyle have been resisted. Third party payment of early detection has not been supported and large population research studies are expensive. Efforts to prove whether early detection leads to improved survival of study populations and whether treatment costs can be reduced through intervention studies are currently underway. Initial funding, long-term followup and analysis of interventional methods will be high cost items that require financial grant support. The Missouri population is ideal for these studies. Combined institutional efforts with singleness of purpose and review of quality assurance are recommended. Interval cancers, overall survival and comparative therapy costs should be included in both prevention and early detection programs.

Smith, M. E., J. E. McEntire, R. D. Reynolds and B. W. Papermaster, IMBIC Corporation and Cancer Research Center, Columbia, MO 65203. PLATELET DERIVED GROWTH FACTORS. Growth factors (GF) represent cellular products which react with cell receptors. GF stimulate cell receptors to signal the growth of the cell. While GF are small molecular weight proteins with a simplistic mechanism of action, receptors are larger molecules which have complex mechanisms of action that involve oncogenes. Platelet derived growth factors (PDGF) represent a family of GF with similar chemical structures that are released during the clotting process. PDGF originate from the alpha granules of platelets and bind with the receptors of the fibroblasts and smooth muscle cells in connective tissue that are exposed at the time of injury. While the healing process normally results in a platelet release of PDGF and other factors, there is increasing evidence that mesenchymal tumors produce their own GF that autostimulate malignant growth through increased receptor numbers and sensitivity as well as by an increased strength of the signal mechanism within the malignant cell.

McEntire, J. E., M. E. Smith, R. D. Reynolds, J. Wibbenmeyer and B. W. Papermaster, Cancer Research Center and IMBIC Corporation, Columbia, MO 65203. THE BROAD FUTURE OF LYMPHOKINES. The term lymphokines refers to those products generated by normal lymphocytes which represent modulation of the immune system. Molecules thus far identified have been glycoproteins. The amino acid structure has received the majority of recent attention, but it has become apparent that lipids and carbohydrates are also important. While

benefits in cancer have been the primary area of investigation, the lymphokines may be effective in the management or prevention of viral diseases, malaria, radiation injury, aging, autoimmune disorders and other medical conditions. Central nervous system effects and changes in the classic neuroendocrine axis have also been demonstrated. Using the normal human lymphoblastoid B-cell RPMI-1788 cell line grown in RPMI 1640 medium with 2% human serum, responses in human cancer have been demonstrated. Identified factors produced by this cell line include lymphotoxin macrophage activation factor, macrophage migration inhibition factor and leukocyte migration inhibition factor.

Patterson, W. P. and C. W. Caldwell, Department of Medicine and Pathology, University of Missouri, Columbia, MO 65212, and **R. D. Reynolds**, Ellis Fischel State Cancer Center, Columbia, MO 65203. DECREASED IMMUNOGLOBULIN PRODUCTION IN NORMAL B CELLS DUE TO DEFECTIVE T CELL FUNCTION IN MALIGNANT LYMPHOMA. Disordered T cell function in malignant lymphomas has been described in various *in vitro* mitogen stimulated systems as both abnormal suppressor and enhanced helper function. This study examines the effect of T cells (T_{1ym}) from 5 patients with B cell lymphomas on normal B cells IgG production in a mixed lymphocyte culture. Normal splenic B cells purified by a panning procedure were cocultured with T_{1ym} or normal T cells in a 1:1 ratio for 72 hrs with or without tetradecanoyl phorbol acetate. Supernatants were assayed for IgG by an ELISA technique. Controls consisted of normal B cells and normal allogeneic T cells. T_{1ym} plus B cells produced significantly less ($p<0.00001$) IgG (mean = 9.1 ± 3.82 ng/ml) than controls (mean = 66.2 ± 3.68 ng/ml). These results suggest enhanced suppressor or defective helper activity of T_{1ym} on normal B cells; this defect may be primary to these disorders.

Morrison, C. M., Q. S. Ringenberg, V. Gerhard and R. D. Reynolds, Department of Medicine and the Tumor Registry, University of Missouri School of Medicine, Columbia, MO 65212. IMPROVING THE COLLECTION OF REPORTABLE INFORMATION IN PATIENTS WITH CANCER. To improve the collection of information on cancer patients, the Cancer Patient Questionnaire (CPQ) was developed. One hundred nineteen cancer patients at the University of Missouri Hospital & Clinics (UMHC) completed the CPQ. Information obtained was then compared with information recorded by the UMHC Tumor Registry (TR). The CPQ agreed with data collected by the TR in 65% of cases for family history, 98% of cases for place of birth, 84% of cases for occupational history, 91% of cases for tobacco use and 88% of cases for number of pregnancies or live births. The CPQ was able to collect more extensive family history, occupational and demographic data than the TR. The CPQ is accurate, complete and easy to use and may replace the TR chart review in the collection of these data. Supported by the Scholarships for Research in Medicine Program, Department of Medicine, University of Missouri-Columbia School of Medicine.

Khojasteh, A., R. D. Reynolds and A. R. Garcia, Ellis Fischel Cancer Center, Columbia, MO 65203. CHANGES OF THE IMMUNOLOGIC PHENOTYPE OF LEUKEMIC CELLS DURING THE COURSE OF THERAPY. Development of various types of lymphoproliferative disorders or their transformation to each other in a single patient has increasingly been reported. We have followed a case of chronic lymphocytic leukemia (CLL) with circulating lymphocytes having a null-cell immunologic phenotype. In 1983, we demonstrated disease progression associated with morphologic changes predominated by lymphocytes, resembling lymphosarcoma cell leukemia. The cells were carrying B_1 markers as defined by monoclonal antibodies. In 1985, following a course of macrophage activating factor obtained from RPMI-1788 B-cell line, a significant shift from B_1 to B_2 phenotype was noted. Then an abrupt resolution of lymphocytosis and improvement of other hemotologic parameters and appearance of lymphocytes immunoglobulin characteristics of CLL cells were detected. These cells were carrying concurrently B_1 (B-cell marker) and leuk-1 (T-cell marker). The changes represent emergence of either 2 clones of malignant lymphocytes or back and forth transformation of a single clone of lymphocyte.

Garcia, A. R., A. Khojasteh and R. D. Reynolds, Ellis Fischel Cancer Center, Columbia, MO 65203. STERNAL METASTASES IN CARCINOMA OF THE BREAST. There is a paucity of published information regarding sternal metastasis in carcinoma of the breast, particularly about its behavior. We have observed a group of 9 patients, detected during bone scintigraphy, which developed sternal metastases a median of 7.6 years (range 0.25-23.5 yrs) after diagnosis. Moreover, these lesions have remained stable during a followup period for a median of 3.1 yrs (range 0.66-7.5 yrs). Even after specific treatment, such as 2000 or 3000 rads to the sternum, the lesions remained relatively unchanged both by x-rays (lytic) and by scintigraphy for up to 4 yrs. The median age at diagnosis was 55 yrs (range 34-77 yrs). Confirmation of the metastatic disease suggested by the scintigrams was often delayed from 6 to 18 months, in part because of the difficulties in obtaining good roentgenograms of the sternum. Xerograms of the sternum did not prove to have any advantage over plain x-rays. Patients with a positive E.R. had a longer time interval between time of diagnosis and development of the sternal metastasis which was statistically significant ($p < 0.05$).

Chaudhary, S., R. Reynolds, A. Khojasteh, A. Garcia, K. Ruble and T. Madden, Ellis Fischel State Cancer Center, Columbia, MO 65203. A PRELIMINARY CROSSOVER STUDY OF THE COMPARISON OF THE EFFICACY OF HIGH DOSE PROCHLORPERAZINE AND METHOCHLOPRAMIDE IN CIS-PLATIN INDUCED NAUSEA AND VOMITING. In this ongoing study comparing the effectiveness of prochlorperazine to methochlopramide in controlling emesis associated with chemotherapy containing cis-platinum. Prochlorperazine was given intravenously at a dosage of 20 mg/m^2 starting half an hour before DDP infusion and then every 3 hrs for 24 hrs. Pts were then crossed over to the other regimen with the second course of chemotherapy and received methochlopramide 1 mg/kg q 2° for 24 hrs starting ½ hr before DDP infusion. Benadryl was given prophylactically with both types of regimen at a dosage of 25-50 mg q 6 hr. DDP infusion was given over a period of 8 hrs and

patients received a mean of 75-100 mg/m^2 dosage of DDP. Pts were monitored for at least 24 hrs by physicians and nursing personnel. Toxicities were mild and acceptable in both arms. Overall characteristics of beneficial effects appear to favor prochlorperazine.

Reynolds, R., A. Khojasteh, A. Garcia, S. Chaudhary, M. Gohel, D. Vowell, M. R. Dugan, K. Ruble and C. Gay. Ellis Fischel State Cancer Center, Columbia, Missouri, 65203. HIGH-DOSE CONTINUOUS 5-DAY INFUSION OF 5-FLUOROURACIL AUGMENTED WITH ALLOPURINOL. Twenty-five patients with metastatic adenocarcinoma of the colon were treated with 5-day continuous infusions of 5-Fluorouracil (FU) with and without allopurinol (AP). AP was tested for its ability to permit larger doses of chemotherapy without added toxicity. Eight males and 17 females were entered. Age range was 40-75; median 61 years. Median age for FU alone was 62 and FU + AP was 60. There were 4 males in each group. Dose range for FU alone was 2,150-7,500 mg (mean 4,370), and for FU + AP was 6,000-15,000 mg (mean 10,250). Toxicity in FU group was leukopenia - 33%, thrombocytopenia - 7%, anemia - 13% and stomatitis - 7%; for FU + AP was leukopenia - 30%, thrombocytopenia - 20% and anemia - 10%. Stable disease or tumor response was observed in 27% (range 2-4 mo) of FU and in 90% of FU + AP group (range 2-13 mo).

Reynolds, R. D., A. Khojasteh, A. R. Garcia, K. Ruble, M. R. Dugan and C. Gay. Department of Medicine, Ellis Fischel State Cancer Center, Columbia, MO, 65203. THE ENDOCRINE MILEAU OF BREAST CANCER. Two hundred nine consecutive breast cancer patients were questioned with regard to cancer history and endocrine disorders. Fifty-one (28%) had second primaries, 21 (10%) of which were bilateral breast cancers; 51 (28%) had prior hysterectomies, 21 (10%) had prior thyroid disease, 15 (7%) had prior D&C, 8 (3.8%) had diabetes mellitus and 1 had Cushing's syndrome. The overall associated endocrine abnormality was therefore 117/209 (56%). Hysterectomy was more likely (45/168, 27%) to have been performed in T_1 and T_2 disease than in T_3 and T_4 disease (6/41, 15%). Hysterectomy had been performed more often in node positive (34/120, 28%) than node negative (17/89, 19%) patients. From these data, it appears likely that the development of breast cancer is associated with an underlying disorder in the individual endocrine mileau.

Garcia, A. R., R. D. Reynolds, A. Khojasteh and S. Chaudhary, Ellis Fischel Cancer Center, Columbia, MO 65203. TUMORS OF THE STERNUM. During the past 30 years we have observed 32 neoplasms of the sternum. All 32 were metastatic, perhaps reflecting the referring patterns to our Institution. Twenty-four of these neoplasms were metastatic from carcinoma of the breast. The remaining 8 metastatic neoplasms included: colon adenocarcinoma (2), and 1 each of—cervix epidermoid carcinoma, testicular Sertoli cell, thyroid medullary carcionoma, unclassified carcinoma, unclassified sarcoma and plasma cell dyscrasia. Excluded from the above, were 3 cases referred for a "sternal mass," which proved to have benign changes, consistent with congenital deformity (1), diffuse fibrosis (1) and a histologically suspected osteochondroma.

Physics

Whitaker, R. J., Department of Physics, Southwest Missouri State University, Springfield, MO 65804, L. R. WILBERFORCE AND THE WILBERFORCE PENDULUM. In 1894 Lionel Robert Wilberforce published a paper entitled, "On the Vibrations of a Loaded Spiral Spring." This device has come to be known as the "Wilberforce Pendulum." A number of writers have since discussed this device, including Arnold Sommerfeld. A history of this discussion will be presented along with a brief biography of Wilberforce. The pendulum will also be demonstrated.

Stacey, L. M., Department of Physics, St. Louis University, St. Louis, MO 63103. THE FIRST ANNUAL SLU PHYSICS COMPETITION. On April 19, 1986, the Physics Department of St. Louis University sponsored a physics competition (which will become an annual event on our campus) for all high school physics students in the St. Louis metropolitan area including adjacent counties in Illinois. I will describe the purposes of such a competition, how we organized this event and how our event differs from other regional physics competitions described in the literature. At the time of this writing we have had a good response from local high school teachers, but I will report on the final outcome in this talk.

Kapoor, Y. M., Department of Natural Sciences and Mathematics, Lincoln University, Jefferson City, MO 65101. PHOTOREFLECTANCE STUDY OF INTERBAND TRANSITIONS IN GaAS/A1GaAs MULTIPLE QUANTUM WELLS. Modulation spectroscopy is discussed. The optical modulation technique of photoreflectance is described, as well as experimental details used for photoreflection. Multiple quantum wells and their properties are discussed. Using photoflectance method, preliminary measurements show a large number of levels in quantum wells in GaAs/A1GaAs. The low and high level optical transitions from various levels of multiple quantum wells in GaAs/A1GaAs superlattices are studied at room temperature.

Science Education

Granger, C. R., C. A. Dickerson and E. P. Ortleb, University of Missouri-St. Louis, 8001 Natural Bridge, St. Louis, MO 63121. A PARTNERSHIP OUTREACH PROGRAM IN SCIENCE EDUCATION (POPSE). Historically, the infusion of pedagogical philosophy and methods into the science classroom has been difficult. Without a sound

philosophy and a scientifically derived instructional strategy, excellence in the classroom is a hit-or-miss occurrence. POPSE was developed to provide direct physical and pedagogical classroom assistance for life science teachers of selected high schools. Through this program teachers are able to borrow equipment or request technical assistance from the University of Missouri in St. Louis. Of most importance, teachers can request the preparation and presentation of an instructional unit for their specific classes and students. All units are modeled in accordance with Piagetian learning theory and follow the Learning Cycle instructional strategy. POPSE provides both the philosophical and physical components to aid in the development of excellence in science education. The POPSE program model will be presented. Supported by St. Louis School District, University of Missouri-St. Louis, Monsanto Fund, Emerson Electric and the Coordinating Board for Higher Education, Title II program.

Dickerson, C. A., University of Missouri-St. Louis, 8001 Natural Bridge, St. Louis, MO 63121. THE PARTNERSHIP CLASSROOM AS AN EQUILIBRATING MECHANISM FOR A PARADIGM SHIFT IN A COMMUNITY OF PRACTICING SCIENCE EDUCATORS. Traditional methods for instructional change have not always been successful. The perception of the Piaget learning theory and the Learning Cycle Strategy, is the behavioral technique of approach for successful learner and instructional change. Timing the introduction of a different technique is crucial for its formation. Teachers are provided with information of the services that the Partnership Outreach Program in Science Education offers from the University of Missouri-St. Louis. Teachers then have the option to address their life science concerns and needs directly in the high school classroom with the human dynamics of interaction with science materials. Resolutions are provided from a technical and modeled instructional experience which is cooperative in preparation, presentation and feedback. An example of exemplary materials will be included. Supported by St. Louis School District, University of Missouri-St. Louis, Monsanto Fund, Emerson Electric, Coordinating Board for Higher Education Title II.

Granger, C. R., L. D. Friedman and A. O. Wilke, Department of Biology, University of Missouri-St. Louis, St. Louis, MO 63121, RESTRUCTURING INTRODUCTORY BIOLOGY ACCORDING TO THE LEARNING CYCLE INSTRUCTIONAL STRATEGY. Students entering college vary greatly in their academic backgrounds. Unique curriculum materials for introductory biology for majors have been developed that seek to provide equal opportunity of success for students with a history of low achievement as well as successful students. Integrated laboratory/lecture/discussion units have been developed based on the learning theory of Piaget and designed according to the Learning Cycle format. The new materials utilize exposure to concrete experiences followed by the development of formal concepts. The program philosophy, administration and model will be presented and sample materials shared. Preliminary classroom testing is currently underway. Supported in part by a grant from the Fund for the Improvement of Postsecondary Education and the University of Missouri-St. Louis.

C. C. Young, A. R. P. Journet, C. M. Stanley and J. S. Scheibe, Department of Biology, Southeast Missouri State University, Cape Girardeau, MO 63701. PERFORMANCE, GENDER AND COGNITIVE LEVEL OF STUDENTS IN GENERAL BIOLOGY LABORATORY. Several studies have suggested that there is a relationship between the gender of students and performance in science courses. Meanwhile, unrelated studies on the relationship between student performance in science courses and student cognitive level have produced conflicting results. However, it is not always clear whether the science courses used for such studies are designed to achieve higher cognitive skills or to test higher cognitive skills. This casts doubt on the meaning of interpretations that relate science performance to gender. General Biology Laboratory at Southeast Missouri State University is a course in the process of science. As such, it teaches and tests formal reasoning. A pencil and paper test of cognitive level (in the sense of Piaget) supported the hypothesis that the course promotes an advance in the student reasoning ability. This study tests the hypothesis that cognitive level and gender are predictors of student performance in the course.

Journet, A. R. P., Southeast Missouri State University, Cape Girardeau, MO 63701. TEACHING SCIENCE: NON-MAJORS INTRODUCTORY BIOLOGY LABORATORY. If scientific literacy is measured by information less than by an understanding of the process of science, the general education science laboratory seems the obvious place to address the problem. Since the hypothetico-deductive process of scientific investigation is often equated with formal operational thought, teaching the process of science may have broader cognitive significance even than attacking scientific literacy. The non-majors biology course that addresses this problem must take students, many of whom are concrete operational (in the sense of Piaget) and respond to science by memorization (in the sense of Bloom), to the higher cognitive level and higher learning objectives that successful scientific investigation demands. This presentation will discuss how this is undertaken in BS 101, General Biology Laboratory at Southeast Missouri State University, Cape Girardeau.

Hart, R. A. and W. Minter, Department of Biology, Northwest Missouri State University, Maryville, MO 64468. ESSAY TESTING USING MULTIPLE CHOICE QUESTIONS. How can you grade a multiple choice test to yield results as if you were reading an Essay? A program for machine scoring tests has been developed at Northwest Missouri State University for use in large "BioScience" classes. A student writing an essay will write down what he knows; however, he will do a lot of guessing when answering multiple guess questions. If we allow the student to leave blank answers for what he does not know and score accordingly, then with a test analysis we have asked the student to exercise judgement.

Hoggard, F. R., Department of Chemistry, Southwest Missouri State University, Springfield, MO 65804. APPLYING TECHNIQUES OF INFORMATION THEORY TO PROBLEM SOLVING. Information concepts including acquisition, coding, classification, storage, processing and decision making will be illustrated using typical chemistry verbal problems.

Lojko, F. B., Springfield Public Schools, 940 N. Jefferson Avenue, Springfield, MO 65802. GEOLOGY AND BIOLOGY RESEARCH IN THE GRAND CANYON—A UNIQUE WORKSHOP FOR SCIENCE TEACHERS. Classwork in geology and biology coupled with participation in basic research projects conducted on the Colorado River in the Grand Canyon afford a unique learning experience for science teachers. Two weeks of course work are followed by intensive data gathering along the River corridor of the Grand Canyon. The data acquired are analyzed as part of on-going research investigations relative to managing the Colorado River as a recreational and industrial resource. The topics of investigation include some of the following areas: changes in beach profiles, human impact on the beaches, insect density and diversity on Colorado River beaches, small mammal populations in riparian vegetation, study of beach and sand grain size and electrofishing studies. Gathering and interpretation of data provide a learning experience for teachers; the results of the study provide a data base used by the Park Service/Bureau of Reclamation in resource management of the Grand Canyon. Research results are incorporated into existing secondary science curricula as enrichment science activities and special learning units.

Berkland, T. and J. M. Cocke, Department of Earth Science, Central Missouri State University, Warrensburg, MO 64093. PREPARING SMALL MACROFOSSILS FOR THIN SECTIONING. The mounting of small macrofossils on slides for making transverse and longitudinal thin sections can cause great difficulty. The authors have devised a solution to the problem by orienting the fossil in a base of epoxy putty on a horizontal surface before encasing the fossil in a dental plaster plug. This procedure establishes a permanent plane of orientation that will allow grinding of the fossil to the desired plane. This procedure has been used on several classes of fossils: 1) fusiform and cylindrical, 2) spherical, 3) bivalves, 4) conispiral and 5) planispiral.

Poster Section

Elkins, L., D. Yourtee and T. Luke, Toxicology Program, University of Missouri, Kansas City, MO 64108. THE EFFECT OF COPPER ION ON THE CYTOTOXICITY AND MUTAGENICITY OF ADRIAMYCIN. Adriamycin (doxorubicin) and copper ion were studied in the Ames *Salmonella* Mutation Assay to evaluate changes in mutagenesis resulting from the interaction of these compounds. *Salmonella typhimurim* strain TA98 was used. Doxorubicin reacts as a strong mutagen in this strain, producing up to 1500 revertant colonies per plate. But at a concentration of 58 μg/plate, mutagenesis is repressed due to significant cytotoxicity. However, with the addition of 3.5×10^{-7} moles/plate of cupric acetate, the number of revertant colonies rises by approximately 300 colonies. Copper appears to suppress cytotoxicity while allowing mutagenesis to be expressed. This observation has possible clinical significance since patients with Hodgkin's Disease and certain other cancers often have highly elevated serum copper levels.

Gilbertson, R. E. and N. Babrakzai, Department of Biology, Central Missouri State University, Warrensburg, MO 64093. PRELIMINARY OBSERVATIONS ON THE KARYOTYPE OF *ANGUISPIRA ALTERNATA*. Preliminary cytological studies on 2 populations of *A. alternata* from Warrensburg, MO, and Rhode Island revealed a diploid number of 64 chromosomes for this species. The chromosomes are biarmed (meta- and submeta-centrics). The karyotype has 2 chromosomes with nucleolar organizer regions (NOR's). The possibility of NOR heterozygosity in both populations is indicated. The occurance of supernumeraries is suspected in 1 population (Rhode Island).

Kunze, J. F., Nuclear Engineering, University of Missouri, Columbia, MO 65211. GEOTHERMAL ENERGY POTENTIAL IN MISSOURI. Despite the general belief that Missouri has virtually no potential to utilize geothermal energy, ground water heat pumps that extract heat or "cool" from the subsurface water could substantially reduce heating and cooling energy bills in this state, and reduce both summer and winter peak power demands on the electrical grid of the state. Missouri's abundance of ground water at relatively shallow depth and the environmentally benign aspects of extracting water from these aquifers to supply ground water heat pumps leads to the conclusion that introduction of these devices to half of the residences and commercial buildings in the state would result in a reduction of $200 million/yr in current electricity consumption, and could reduce the present natural gas consumption by $600 million (most of those receipts leave the state's economy). This implementation will require pumping and reinjecting approximately 8 million acre-ft of water per year throughout the state. The potential for utilizing higher temperature aquifers than 60°F is also significant.

Peery, L., Central Methodist College, Fayette, MO 65248 and Missouri Senate Research Staff; and **D. Valentine**, Missouri Senate Research Staff, Capitol Building, Jefferson City, MO 65101. SOLID WASTE MANAGEMENT—OPTIONS FOR MISSOURI. A review of solid waste management in Missouri is presented. Future management alternatives are analyzed from a technical and economic standpoint. Related legislative policy issues and options are also explored.

Babrakzai, N. and S. H. Mills, Department of Biology, Central Missouri State University, Warrensburg, MO 64093. A SIMPLE PHOTOGRAPHIC TECHNIQUE FOR THE PRODUCTION OF A "CELL-FINDER" SLIDE WITH THE HELP OF A MICROCOMPUTER. An AppleWorks Spreadsheet file for the Apple IIe was developed using copy and calculate options to produce a numbered grid. The printed 49.6 × 38.4 cm grid with 2976 individually labeled 8mm squares was photographed with a Nikon F_2 camera and 55mm Micro Nikor lens. Five brands of commercially available 35mm films were shot at various shutter speeds with a f-5.6 lens aperture. After

developing, fixing, washing and drying, suitable negatives were mounted in euparol on microscope glass slides, using 24 × 50 mm coverslips. A study under the compound microscope with 100× magnification indicated the potential suitability of all the films to make a "cell-finder" slide. Very specific (i.e., 30 um^2) regions on microscope slides can be relocated with the help of the "cell-finder" slide for recording in a microcomputer data base or notebook for subsequent retrieval and data analysis of histochemical, histological and cytogenetic material.

Ashley, D. C., and T. Rachow, Biology Department, Missouri Western State College, St. Joseph, MO 64507. A SIMPLE, COMPUTER-GRADABLE HUMAN GENETICS QUESTIONNAIRE. A simple genetics questionnaire dealing with approximately 20 human traits will be displayed. This questionnaire has been completed by over 1000 students at MWSC. For each of the traits listed, students mark their appropriate phenotype on a standard, computer-readable answer sheet. These answer sheets are optically scanned and compared to a key as if they are student exams. This method allows for collection and computer processing of large amounts of survey data without the need for extensive programming skills. We collect data from all of our introductory biology laboratory sections 1 week and then give the students the frequency summaries the next week so that they can compute Hardy-Weinberg Equilibrium values. Ninety percent of the students who have completed the survey indicated they had enjoyed the exercise and also learned something about human genetics.

COLLEGIATE DIVISION

Biology

Garrison, R. C., D. J. Robbins and D. C. Ashley, Biology Department, Missouri Western State College, St. Joseph, MO 64507. A REPORT ON THE PREVALENCE OF THE PARASITE *PARELAPHOSTRONGYLUS TENUIS* IN WHITE-TAILED DEER (*ODOCOILEUS VIRGINIANUS*) IN NORTHWESTERN MISSOURI. Little is known about *Parelaphostrongylus tenuis* in deer in Missouri. A study was initiated during the 1985 deer season to determine the prevalence of this meningeal worm in northwestern Missouri. Eighty-five deer brains were examined. These came from 9 different counties and were obtained from hunters, taxidermists, abattoir owners or conservation personnel. Of the 85 deer examined, 13 (15.2%) were infected with adult meningeal worms. The infected deer contained from 1 to 5 worms. The mean number of worms recovered per infected deer was 1.64, with a standard deviation of 1.38. This is the first report of *P. tenuis* in northwest Missouri and constitutes a new distribution record.

Moyer, C. J., Department of Biology, Missouri Western State College, St. Joseph, MO 64506. A PLANT SURVEY 2 YEARS AFTER REESTABLISHMENT OF A TALLGRASS PRAIRIE. This paper evaluates the status of a 1-acre reestablished prairie approximately 2 years after the area was plowed and planted. During the fall of 1985, a survey using quadrat sampling technique was completed on the plants in the area. The results from this study were compared with other studies completed both before and after prairie reestablishment in the same area.

Chemistry-Geology

Hufford, K., R. N. Roy and D. A. Johnson, Department of Chemistry, Drury College, Springfield, MO 65802. PRECISE EMF STUDIES OF THE SYSTEM: BORIC ACID + KBORATE + KCl AT DIFFERENT TEMPERATURES. The ionization of boric acid in aqueous solutions of KCl and in water have been determined at 5, 15, 25, 35, 45 and 55°C employing a cell of the type Pt; H_2 (g, 1 atm) / H_3BO_3 (m_1) + $KB(OH)_4$ (m_2) + KCl / AgCl,Ag. The values of pK_1 thus obtained were fitted to the Ives-Moseley equation, pK = A/T + B + C 1n T; and to the Harned and Robinson equation pK = A/T + B + CT. From these temperature coefficients, the thermodynamic quantities ($\Delta G°$, $\Delta H°$, $\Delta S°$ and $\Delta Cp°$) were evaluated. The results will be compared with the literature data, if available. The simple interpretation by extrapolation of pK′ (apparent dissociation constant) to zero ionic strength will be made.

Connole, J., R. N. Roy, D. A. Johnson and L. N. Roy, Department of Chemistry, Drury College, Springfield, MO 65802. DETERMINATION OF IONIZATION CONSTANT OF CARBONIC ACID IN PRESENCE OF NH_4Cl AT 5, 25, AND 45°C. The electrochemical cell without liquid junction: Pt; / H_2 + CO_2 / NH_4HCO_3 (m_1), NH_4Cl (m_2), CO_2 (m_3) / AgCl, Ag has been employed to determine the first ionization constant of carbonic acid in NH_4Cl solutions and in water at 5, 15, 25, 35 and 45°C. The molality ratios m_1/m_2 were approximately 1,2,3,4. The range of molality for NH_4HCO_3 varied from 0.015 to about 1 mo1o-kg^{-1}, whereas for NH_4Cl, the molality ranged from

0.01 to about 0.3 mol-kg^{-1}. The results of the study will be reported at 5, 25 and 45°C and will be compared with those of previously studied similar systems such as $KHCO_3$ + KCl + H_2O and $NaHCO_3$ + NaCl + H_2O.

Orscheln, A., Chemical Engineering Department, University of Missouri, Columbia, MO 65211. ELECTRO-CHEMICAL MEASUREMENTS OF TRANSPORT NUMBERS FOR ION-EXCHANGE MEMBRANES. The purpose of this research is to experimentally determine transport numbers for various types of ion-exchange membranes in accordance with the Nernst equation. The form of the Nernst equation which applies to membrane potentials is: $\Delta \phi_m = -(RT/F)(t_+ - t_-) \ln(c_2/c_1)$. Where $\Delta \phi_m$ is the membrane potential, R is the Ideal Gas constant, T is the temperature, F is Faraday's Constant, t_+ and t_- are the transport numbers of the monovalent ions and c_1 and c_2 are the electrolyte concentrations on either side of the membrane. Cell potentials are measured at room temperature as a function of a wide range of electrolyte concentrations while keeping the ratio of c_2/c_1 constant. Both anion and cation exchange membranes were tested. The data were reduced to find the transport numbers as a function of concentration (c_1). The correlation obtained is exponential in form. Supported by Monsanto Honors Project.

Hughes, R. W., Chemical Engineering Department, University of Missouri, Columbia, MO 65211. AIRBORNE RADON MEASUREMENTS. Airborne particulates were collected at various distances from a rural 25-megawatt coal burning power plant. The samples were then analyzed for radon and the results presented. Data from the literature are compared to measured values; an attempt is made to calculate risks to the public from radon exposures. Finally, various methods are described that can be used to monitor radon. Supported by Monsanto Honors Project.

R. E. Popham and R. Readnour, Chemistry Department, Southeast Missouri State University, Cape Girardeau, MO 63701. COMPARISON OF ANODIC STRIPPING VOLTAMMETRY (ASV) AND GRAPHITE FURNACE ATOMIC ABSORPTION (GFAA) FOR Pb^{2+} AND Cd^{2+} IN MISSISSIPPI RIVER WATER. Samples were analyzed over a 10-week period by both techniques. For Pb^{2+} the average concentration was 31.4±5.09 ppb and 12.3±7.34 ppb for ASV and GFAA, respectively. For Cd^{2+} the average concentration was 15.0±3.42 ppb and 12.3±2.47 ppb for ASV and GFAA, respectively. Statistical analysis showed no significant difference between the standard deviations of the 2 techniques for Pb^{2+} or Cd^{2+}. The analysis of the means showed no significant difference at a confidence level of below 90% for Pb^{2+} and 95% for Cd^{2+}. The results show the comparability of the 2 techniques as a means to develop confidence in the values of Pb^{2+} and Cd^{2+} in water samples at very low concentrations.

K. R. Evans and V. E. Kurtz, Geosciences Department, Southwest Missouri State University, Springfield, MO 65802. TRILOBITE AND ACROTRETID (INARTICULATE) BRACHIOPOD FAUNAL ZONATION OF SHELF SEDIMENTS OF THE DAVIS AND BONNETERRE FORMATIONS FROM SOUTH-CENTRAL MISSOURI. Examination of 2 cores from south-central Shannon County, MO, reported as possibly exhibiting shelf to basin transition facies, do show a thickening of the Late Cambrian Davis and Bonneterre Formations to the south. However, there is no evidence that these cores reach the shelf edge. Core sampling and processing reveals abundant trilobite and acrotretid (inarticulate) brachiopod faunas which demonstrate the typical faunal successions for Missouri. Over 900 acrotretid specimens were recovered, including 3 genera and 6 species. Corresponding trilobite faunas range from the *Aphelaspis* to the *Taenicephalus* zones.

Engineering

Pulse, D. L. and C. D. Geilker, Department of Electrical Engineering, University of Missouri-Columbia/Kansas City, Truman Campus, Independence, MO 64050 and Department of Physics, William Jewell College, Liberty, MO 64068. ANALOG MULTIPLEXER FOR USE WITH A SINGLE CHANNEL CHART RECORDER. The Rustrak impact chart recorder is an inexpensive laboratory chart recorder. The price, however, increases with the number of channels. Thus, a circuit for multiplexing 2 analog channels onto a single channel recorder would not only be more economical, but would make the recorder a more versatile instrument. The key to the circuit function is the method used by the recorder to log the data. A synchronous-motor-driven hammer strikes a meter needle every 2 seconds and the needle removes a spot of wax from the chart paper. By counting the number of hammer strikes the circuit can change analog channels at preselected time intervals. Uses for temperature data acquisition will be discussed.

Index to Authors

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