TRANSACTIONS of the ILLINOIS STATE ACADEMY OF SCIENCE

Volume 89, Numbers 1 and 2 1996

ILLINOIS STATE ACADEMY OF SCIENCE
Founded 1907
Affiliated with the
ILLINOIS STATE MUSEUM, Springfield

ISSN 0019-2252
PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

* * * * *

The Transactions of the Illinois State Academy of Science will publish papers that contain the results of original research in all aspects the areas listed above.

The current Transactions may be obtained by payment of annual dues. To obtain previous issues of Transactions or for additional information, contact the Executive Secretary at the Illinois State Museum, Springfield, Illinois 62706.

Transactions of the Illinois State Academy of Science
(1996), Volume 89, 1 and 4, pp. 1, 2, and *163-166 corrected*

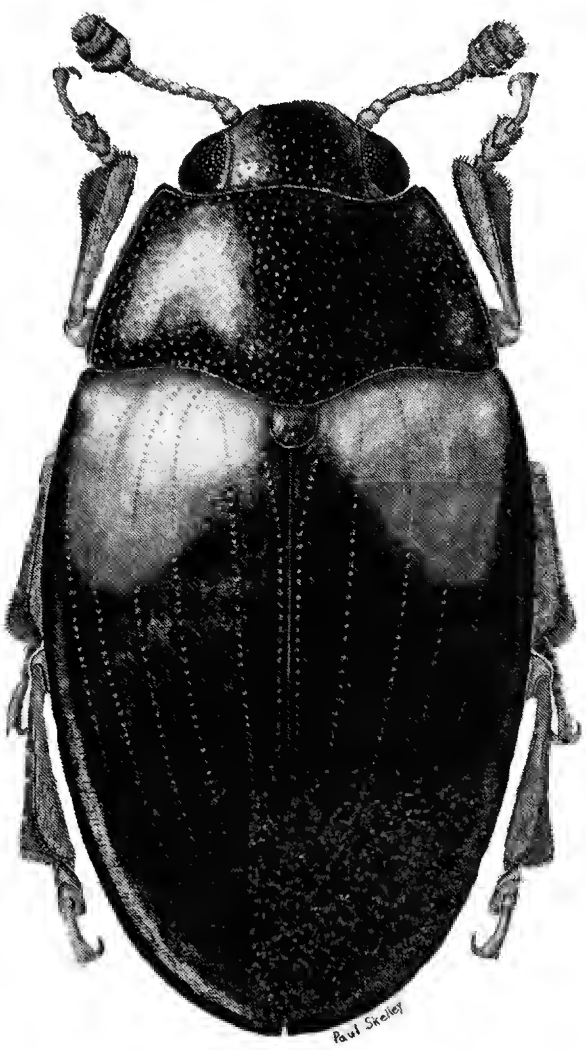
Erratum

Listed below is a correction to a manuscript which was previously published in the Transactions of the Illinois State Academy of Science. The correction is printed on the following **originally numbered pages** for easy replacement in the original publication.

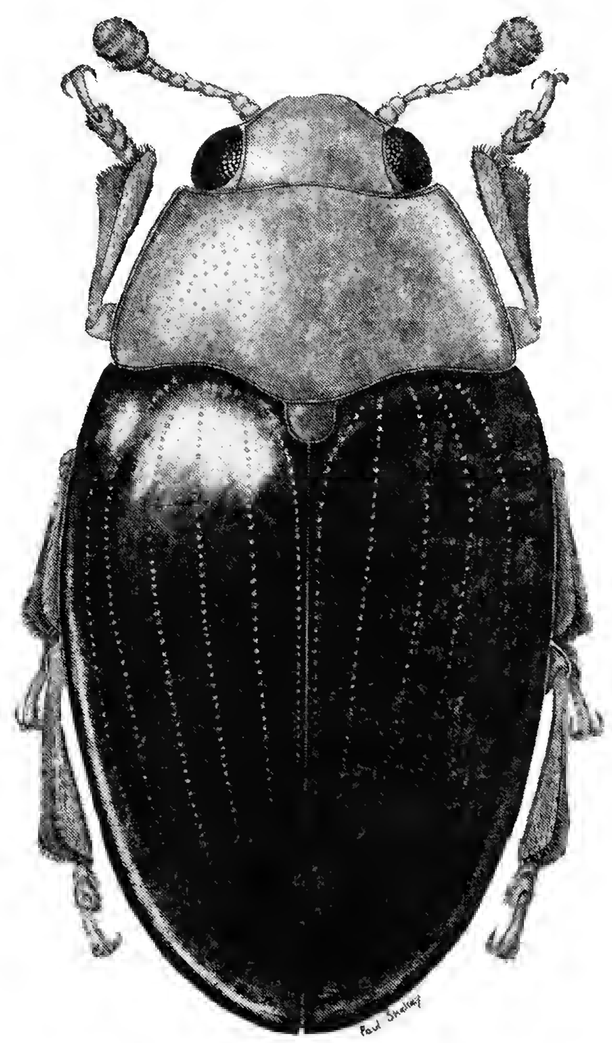
Goodrich, Michael A. and Paul E. Skelley 1995. The Pleasing Fungus Beetles of Illinois (Coleoptera: Erotylidae) Part III. Trans. Ill. State Acad. Sci. 88 (3&4): 145-168

The quality of the drawing reproductions printed as Figures 13-18 on pp.163-166 was insufficient to identify the characteristics referred to in the article. Thus they are reprinted on the following pages.

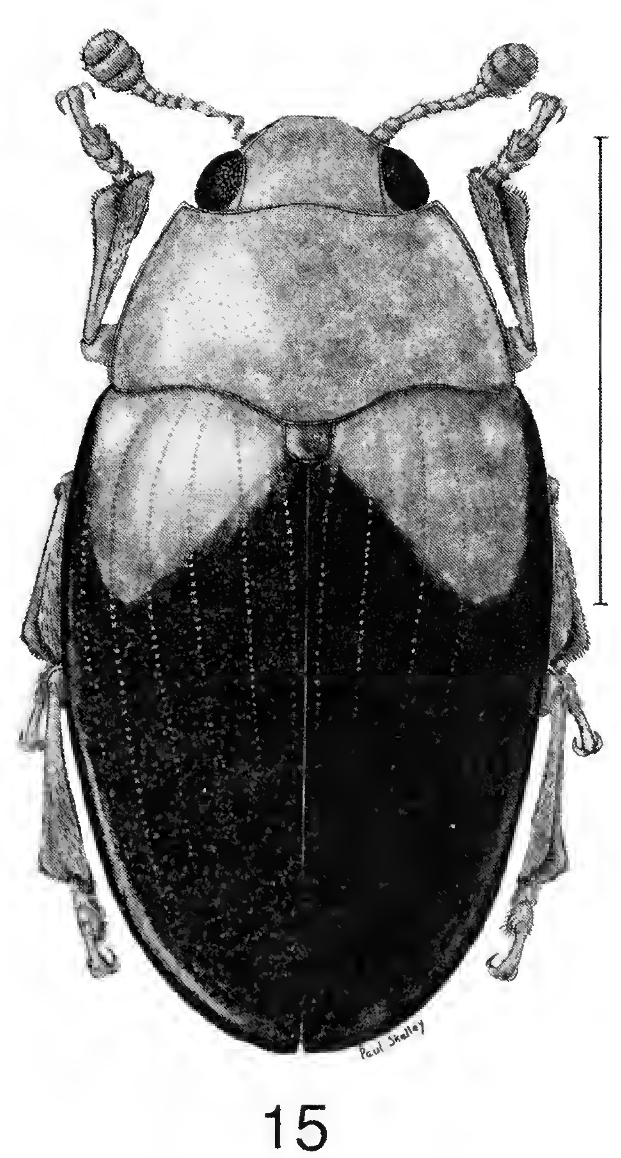
Figs. 13-15 Dorsal habitus of *Tritoma biguttata* (Say) sspp. 13. *Tritoma biguttata biguttata* (Say). 14. *Tritoma biguttata affinis* Lacordaire. 15. *Tritoma biguttata* "hybrid". Line = 2.00 mm.



13



14



15

Fig. 16 Dorsal habitus of *Tritoma humeralis* Fabricius. Line = 0.66 mm.

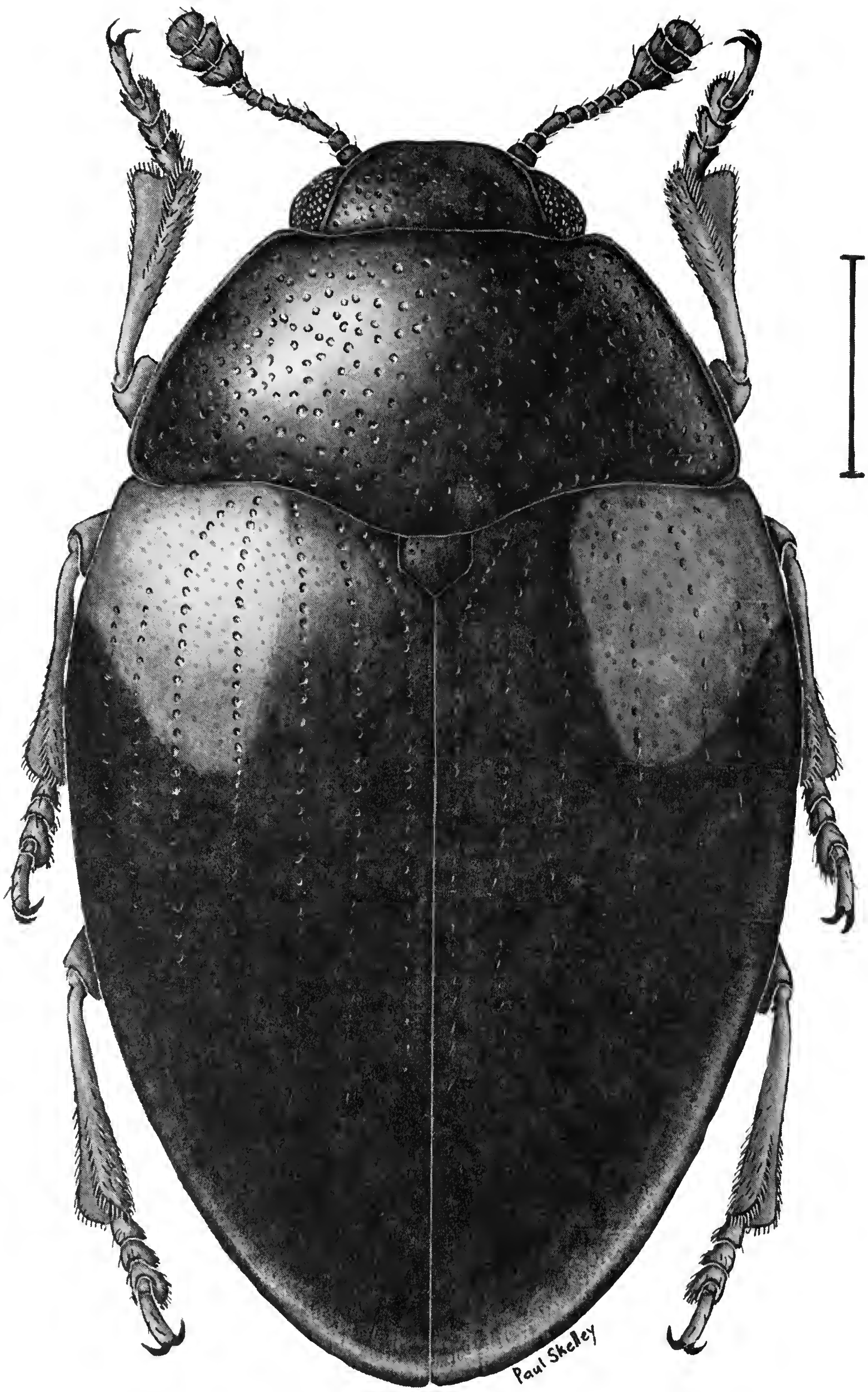


Fig. 17 Dorsal habitus of *Tritoma mimetica* (Crotch). Line = 1.00 mm.

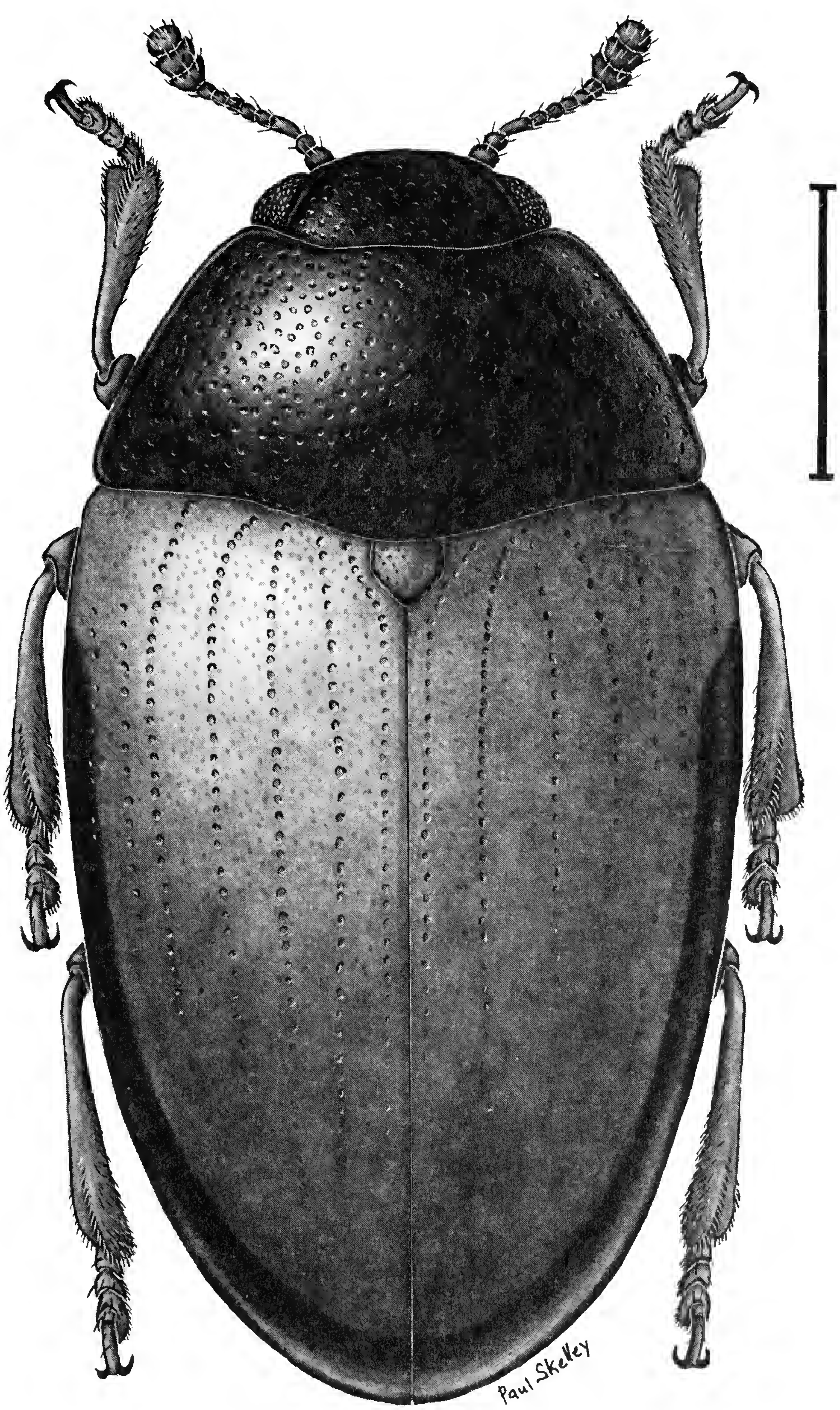
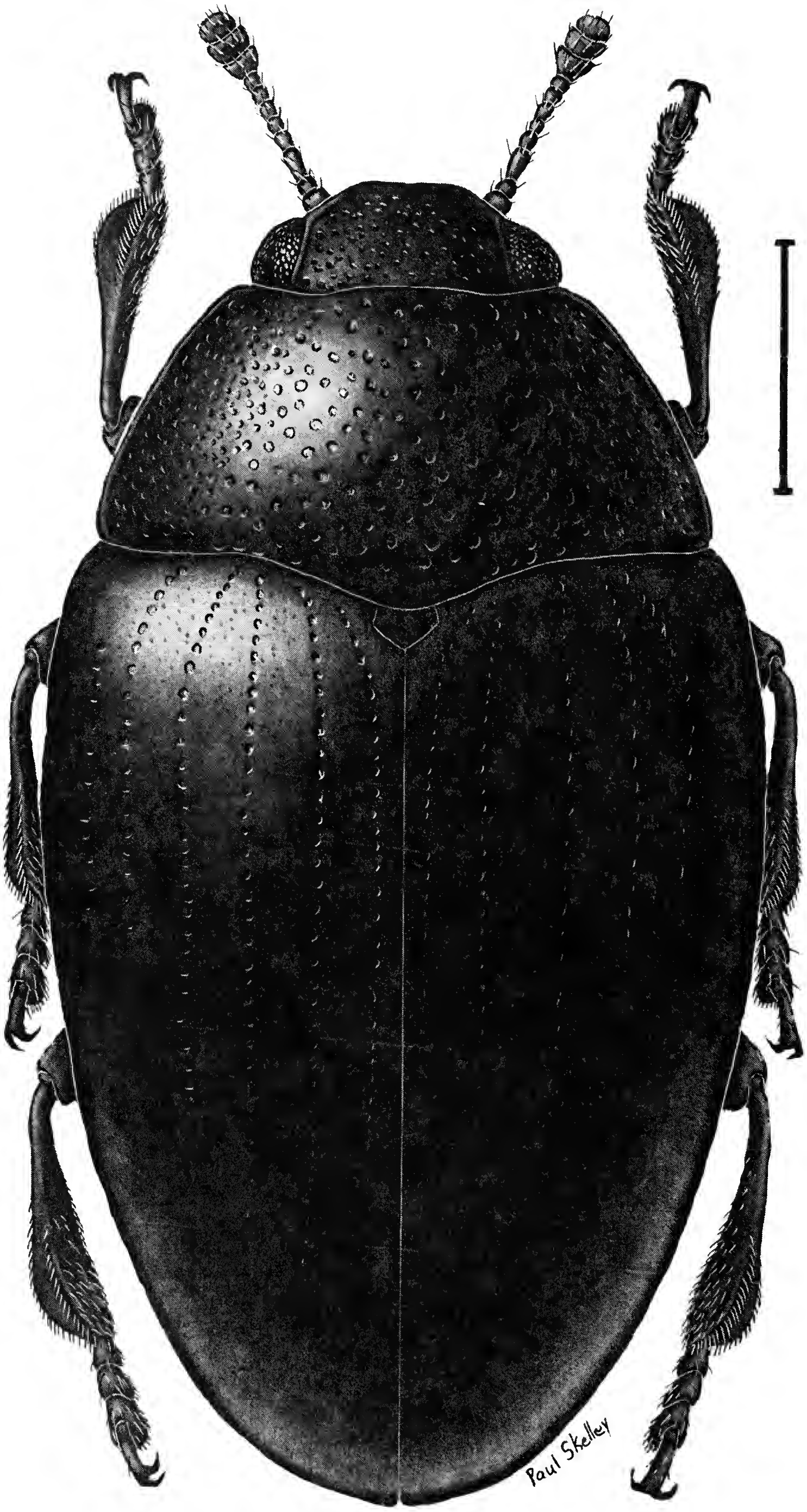


Fig. 18 Dorsal habitus of *Tritoma unicolor* (Say). Line = 1.00 mm.



Transactions of the Illinois State Academy of Science
(1996), Volume 89, 1 and 2, pp. 7-19

Inheritance of Variegation in *Collinsia heterophylla*

J. Gorsic and K. Kerby
Elmhurst College
Department of Biology
Elmhurst, IL 60126-3296

ABSTRACT

Three types of variegation of *Collinsia heterophylla* Buist. (2N = 14), all controlled by recessive nuclear genes, and all transferable to the offspring through the female and male gametes, are reported: (1) Orange variegation, controlled by the reversible vao gene producing orange and green sectored or true breeding wholly orange plants. The orange phenotype is the result of significantly fewer chloroplasts in the cells of these plants. (2) White variegation (vaw), which is characterized by yellow sectors that turn white as the leaves mature; survivalship of white and green variegated plants is greatly reduced. (3) Blending variegation (vab), with indistinct (blending) borders between yellow-green and green sectors of the leaves; the yellow-green areas tend to expand as the variegated plant matures.

INTRODUCTION

The first record of variegation in the genus *Collinsia* is found in the earliest report on the hybridization experiments with *C. bicolor* (synonym for *C. heterophylla*) and *C. tinctoria* conducted by Rasmuson (1920).

The yellow variegation of *C. tinctoria* behaved in crosses as a monogenic recessive trait transferable to offspring through the female and male gametes. Leaves of the variegated plants varied from pure yellow, through variable mixtures of yellow and green, to green with small spots and/or stripes of yellow. Rasmuson attributed the increase of green sectors in the leaves of yellow plants to the operation of a dominant gene I. The I/I and I/i variegated plants having leaves with green sectors were viable, but the homozygous recessive i/i variegated plants, being yellow or nearly so, were dying prematurely. Rasmuson did not exclude the possibility of a wild type individual appearing among the offspring of a self-pollinated variegated plant.

Orange variegation of *C. heterophylla* Buist. (Scrophulariaceae) reported below, exhibited a great degree of similarity in the phenotypic expression, as well as in the inheritance pattern, with the variegation of *C. tinctoria* described by Rasmuson.

MATERIALS AND METHODS

Seeds used in these investigations were of the same source as the seeds used in previous studies (Gorsic 1973, 1977). Greenhouse cultural practices, hybridization methods and statistical tests employed for genetic analysis of *C. heterophylla* have been recently outline by Gorsic (1994).

The chloroplast counts were made from epidermal peels using the abaxial surface of mature leaves. The leaves were taken from the 8-10th node of each plant. Guard cells were observed under a 100X objective lens. The number of chloroplasts and their relative size were observed. Ten guard cells from each of three leaves of each phenotype were analysed.

RESULTS

Phenotypes of the three variegation types of *C. heterophylla*, reported in this article, are compared in Table 1.

Orange variegation, vao. Two self-pollinated sibling plants of the culture h79301 produced a total of 44 green and 12 variegated offspring. The coloration of leaves of the 12 variegated plants varied from pure orange, through combinations of predominantly orange with some green, to predominantly green with some orange streaks.

The self-pollinated orange plants produced offspring whose leaves were pure orange or orange with some green sectors (Fig. 1A). Many of these second generation orange plants died prematurely. In progenies of the self-pollinated orange-green variegated plants a correlation was observed: plants having a higher proportion of green sectors in the leaves produced a higher number of the wild type individuals among their offspring.

The reciprocal crosses between the wild type and any orange variegated plant produced non-variegated offspring, indicating that the orange variegation was a recessive trait transferable through the female and male gametes. The F_2 and backcross progenies segregated into green and variegated (including few pure orange) plants in erratic ratios: most cultures deviated but little from the classical monohybrid ratio, whereas in some cultures the deviations were significant or highly significant (Table 2).

Plants of the recessive class of some F_2 cultures were all pure orange leaved (lack of vao reversion in all plants), or all had orange-green sectored leaves (vao reversions in all plants), whereas in F_2 cultures of other hybrids the recessive class contained both aforementioned phenotypes (vao reversions in some plants, none in others). Two cultures (h9384, h9385), a selfing and an intercross of two heterozygous (Vao/vao) sibling plants produced a total of 191 plants, of which 144 were wild type, 32 had orange-green sectored leaves, and 15 plants had pure orange leaves. The number of individuals in these phenotypic classes fit the modified F_2 ratio of 12 (143 vs. 144) : 3 (36 vs. 32) : 1 (12 vs. 15) indicative of a dihybrid with a dominant epistatic gene (X^2 = 1.192, P = .5). The vao gene reversion to the wild type allele, it appears, required an activator (Ac) gene independent of the vao gene: Vao/vao Ac/ac - 9 Vao–Ac-- (green) : 3 Vao –ac/ac (green) : 3 vao/vao Ac -- (orange-green sectored) : 1 vao/vao ac/ac (pure orange). A self-fertilized orange variegated plant having orange-green sectored leaves (culture h94227) produced 38 plants. Of these, 31 were either green (2) or orange-green sectored (29), and 7 plants which had pure orange leaves. The likely genotype of this orange variegated plant was: vao/vao

Ac/ac. Further studies of the Ac gene's role in variegations in *C. heterophylla* are under way.

Chloroplast analysis indicates that Vao controls the number of chloroplasts in the cells. Pure orange plants contain a mean of 3.9 chloroplasts per guard cell compared with 12.1 chloroplasts per guard cell in wild type plants. In variegated plants, 3.0 per guard cell were observed in the orange-yellow sectors whereas 10.2 chloroplasts per guard cell were detected in the green sectors of the leaves. In addition to the mean number of chloroplasts differing between the green and orange-yellow tissue, the overall morphology of the chloroplasts were qualitatively different. The chloroplasts in the orange-yellow tissue appeared smaller and lighter in color when compared to chloroplasts in the green sectors of the leaves. The color may reflect differences in the number of thylakoids, the number of light traps, or the number of chlorophyll molecules per chloroplast.

White variegation, vaw. In the culture h8741 a variegated plant appeared whose leaves had yellow stripes that turned white as the leaves aged (Fig. 2B). Flowers produced in the axils of variegated bracts of this plant were self-pollinated and reciprocally hybridized with an orange variegated plant (vao/vao) and a wild type (Vaw/Vaw) plant.

Seeds of the self-pollinated flowers produced the wild type and white variegated plants in about equal proportion. The hybrid seeds, however, produced only the wild type offspring, indicating that the white variegation (vaw) and orange variegation (vao) genes were both recessive and nonallelic. The F_2 and the backcross progenies of the Vaw/vaw hybrids segregated in typical monohybrid ratios, and the selfings of dihybrids Vao/vao Vaw/vaw produced plants of four phenotypes: wild type, orange variegated, white variegated, and an orange-white-green sectored type in a 9:3:3:1 ratio (Table 3).

The white variegation trait, then, was controlled by a mutated nuclear gene vaw, nonallelic to vao, and transferable through gametes to the offspring.

The reversibility of the vaw allele has not been investigated because of the very low viability of plants with the vaw/vaw genotype.

Blending variegation, vab. In the progeny of a self-pollinated plant (culture h88105) six out of 19 plants had leaves displaying yellow-green patches or stripes. These variegated plants resembled the orange variegated (vao) plants except for having indistinct (blending) borders between the yellow-green and green areas (Fig. 2C).

The reciprocal crosses of wild type (Vab/Vab) plants and blending variegation (vab/vab) mutants produced wild type offspring. The F_2 and backcross progenies segregated in statistically acceptable monohybrid ratios (Table 3). The segregation data of cultures revealing a lack of independent assortment of vab and vao genes are given in Table 4.

The phenotypic expression of the vab/vab plants varied considerably. Some of these plants could be identified only by examining their leaves in the translucent light: variable shades of green indicated a differential transmission of light due to an uneven concentration of chlorophyll (chloroplasts) in the leaves of mildly variegated plants.

In contrast to the orange variegated (vao) seedlings, whose emerging cotyledons were partly to completely orange, the cotyledons of vab plants appeared wild type and stayed green for about two weeks after emerging from the soil when the characteristic fading of green signaled the onset of yellow-green symptoms of blending variegation.

As in the orange variegation, discussed above, the yellow-green and green sectoring of leaves followed the pattern seemingly set by the color distribution on cotyledons and the first pair of leaves. The green sectors appeared to have been produced by mitotic divisions of reverted cells of the seedling's apical meristem, rather than arising from random reversions of vab genes in cells of the leaves.

DISCUSSION

In this current investigation of genetic variability and gene linkage studies in *C. heterophylla*, four different variegation types have been encountered. The basic genes involved in the chlorophyll and/or chloroplast formation for three of these variegations have been identified.

The experimental results indicate that the primary hereditary components controlling variegations were located in the nuclear chromosomes rather than in the DNA of cytoplasmic organelles. Of the three variegation types investigated, only the orange (vao) and blending (vab) type have been afforded a closer look.

Orange variegation, vao. Reciprocal crosses indicate that orange variegation is a recessive trait controlled by a nuclear gene. The F_2 and backcross progenies included green and variegated plants. Most cultures deviated little from the classical monohybrid ratio, whereas in some cultures the deviations were significant (Table 2). These results are most easily explained by assuming that the recessive vao allele is subject to gene reversion, likely by a transposable element. Presumably, pure orange plants were produced by vao/vao individuals lacking a specific transposable element or an activator for it (Table 2).

By the close observation of the distribution pattern of the orange and green areas in stems and leaves of the variegated plants, the time of the vao gene reversion may be surmised. In the vao/vao seedlings displaying large areas of green on their cotyledons, the vao reversion to the wild type Vao allele must have occurred at an early precotyledonous stage of embryonic development. Leaves of these plants were predominantly green exhibiting some patches or stripes of orange color (Fig. 1B). In plants having both the cotyledons and the lowermost leaves predominantly orange, and patterned sectors of green on the leaves higher-up the stem, the vao reversions must have occurred either (1) at the inception of cotyledon and epicotyl differentiation of the embryo, and the green tissues of cotyledons and stem (leaves) resulted from mitotic propagation of the reverted chlorophyllous cells of the chimeric embryo by the sorting out process during the organogenesis of cotyledons and leaves, or (2) the gene reversions may have occurred after the inception of primordia in the embryonic cotyledons and leaves themselves. The localization of leaves with green sectors in one or two rows on the same side of the stem (Collinsias have decussate leaf arrangement), and the retention of approximately the same proportion of orange to green areas in the leaves and bracts along the stem, indicate that vao reversions occurred in the apical meristem, rather than in the growing leaves.

Variegated plants having leaves that exhibited green patches and small green spots scattered all over the predominantly orange blade (Fig. 2A), suggested gene reversions are taking place in the developing leaves themselves. However, the scattering pattern may be the result of transposition of transposable elements occurring during the mitotic chromosomal replications (in young embryo) affecting only one of the newly formed chromatids (Fedoroff 1984). This reversion would produce revertant and nonrevertant daughter cells that would give rise to the chimeric apices with a more or less even distribution of revertant cells. The leaf primordia of such apical chimeras would reflect the same mixture of cells and would develop into mature leaves exhibiting a scattered distribution of the patches and spots of green over the orange blade (Fig. 2A).

Appearance of the wild type individuals among the offspring of the self-pollinated variegated (vao/vao) plants can be explained by the production of revertant Vao gametes in the flowers of chimeric (Vao/vao vao/vao) peduncular apices, or by gene reversions occurring in the zygotes.

Lower than the expected number of the variegated plants counted among the F_2 progenies of some hybrids (Table 2) were attributed, in part, to the change in gene frequency in favor of the Vao allele, due to the reversion of vao genes. The absence of variegated plants from the F_2 progenies of other hybrids (e.g. sample h89416, Table 2) can be ascribed to either (1) the virtual homozygosity (Vao/Vao) of "hybrids", brought about by the donation of revertant Vao gametes by the recessive parents at the time of fertilization, or (2) to the reversion of the vao genes taking place in the heterozygous zygotes themselves or in the very young embryos.

Apparently only the recessive vao alleles were amenable to reversion. In hundreds of the Vao/vao hybrids examined not one variegated plant appeared that would indicate the reverse allelic change. The revertant Vao alleles appeared as stable as their wild type counterparts.

Blending variegation, vab. Plants with well expressed blending variegation (vab) bred true, and, when crossed with the orange variegated (vao) plants, produced the wild type offspring. The F_2 progenies of these hybrids segregated into the wild type and variegated plants of the blending and orange type in an approximate ratio of 2:1:1. It was later demonstrated by backcrosses that the absence of the double recessive plants from the F_2 progeny was due to a tight linkage of vab and vao genes in repulsion phase (Vabvao/vabVao), which resulted in a 2:1:1 ratio for the wild type and the two variegation types, blending and orange (Table 4).

Results from reciprocal crosses between homozygous wild type plants and blending variegation mutants, and between orange variegated mutants and blending variegated mutants indicate that blending variegation was controlled by a mutated nuclear gene vab, nonallelic with vao, and transferable to the offspring through the female and male gametes. The allelic relationshp between the white variegation gene vaw and blending variegation gene vab has not been investigated.

The yellow-green areas of leaves of the blending variegation plants showed a distinct tendency to expand - apparently by diffusion of a vab controlled substance - rendering entirely yellow-green plants of low fertility.

To explain these results, the bidirectional gene conversion of the whole-chromatid and half-chromatid conversion type (à la *Neurospora crassa*), demonstrable in heterozygotes, was excluded from the consideration as being a possible mechanism of the vao and vab restoration to the wild type alleles, because in the orange and blending variegation mutants no bidirectional change has been observed in heterozygotes.

The gene reversion by a transposable element agreed best with the behavior of the vao and vab alleles in their mutability as reflected in the coloration patterns observed in stems and leaves of the variegated plants.

Plants with orange and green (vao) and yellow-green and green (vab) sectored leaves represented those homozygous recessive (vao/vao and vab/vab) individuals in which somatic vao and vab reversions occurred either during embryogenesis or after the active growth has been resumed at germination of seed - or both. Random gene reversions, occurring during the postgermination period would render a random distribution of color sectors on the leaves. In *C. heterophylla* this has not been observed. Observations supporting the pregermination reversions in variegated plants are: (1) coloration pattern of cotyledons and the first pair of leaves (presence vs. absence and the proportion of colored sectors) seem to set the coloration pattern for the remaining vegetative leaves and bracts, (2) the restriction of a specific color to leaves of one or two rows on one side of stem, and (3) the alternate leaf pairs (positioned one upon the other in the same plane) mimicking one another in amount and/or localization of sectors (left vs. right side of leaf blade). Factors favoring gene reversion during embryogenesis are not known. The influence of maternal genotype may be one of them.

The orange variegation of *C. heterophylla* is an unstable mutant similar to flavostriata of *Antirrhinum majus* investigated by Delool et al. (1986) except that in *C. heterophylla* a stable recessive, true breeding, orange mutant has been isolated. The reversibility of vao gene appears to follow the controlling (transposable) element model of a defective structural gene component (vao) as the receptor and an autonomous regulator component (Ac) (Nevers *et al.* 1986). Rasmuson's (1920) I gene of *C. tinctoria* may also have been such a regulator.

The yellow-green areas of leaves of the blending variegation (vab) mutants showed a clear tendency to expand (on account of green sectors) during the vegetative growth, which makes the vab gene suspect of being involved in chlorophyll (chloroplast) destruction in addition to being a defective gene involved in its synthesis. If so, then the yellow-green patches of leaves may have been simply the areas of vab-guided synthesis of a diffusable substance capable of speeding up the breaking down of chlorophyll (chloroplasts) or slowing down its synthesis. In young mildly variegated plants (with high vab reversion rate) having less than 1/4 of leaf area yellow-green, the symptoms did not seem to expand to the deleterious level, and plants matured properly. In young plants (with low vab reversion rate) with more than 1/2 of the surface area of leaves yellow-green the leaf discoloration was enhanced, so that at the flowering time the upper vegetative leaves and bracts of the peduncle were devoid of nearly all green color. Such plants produced mostly nonviable seed. At this stage of investigation it is not clear whether the diffusible substance acted directly on the anabolic or catabolic processes of chlorophyll metabolism or indirectly via nuclear and/or cytoplasmic DNA.

No stable, true breeding, wholly yellow-green (vab) plants have as yet been isolated.

Orange (vao) and blending (vab) variegation mutants were crossed with yellow, another recessive leaf pigmentation mutant of *C. heterophylla* controlled by the nonreversible gene y (Gorsic 1994). Fertile yellow plants (yy) were produced and the coloration pattern of the double homozygous recessives, vao/vao y/y and vab/vab y/y, were examined. Seedlings of these double recessives exhibiting no vao or vab gene reversions had bright yellow cotyledons which turned gradually pale yellow, became albino-like and died within 10 days after emerging from the soil. The double recessives having reverted vao^R or vab^R alleles respectively produced greenish-yellow and bright-yellow sectored cotyledons and leaves having sharp borders between the color sectors in vao^R/vao y/y individuals and with blending borders in vab^R/vab y/y plants (bright-yellow sectors turning pale-yellow and white with age). A triple homozygous recessive vao^R/vao vab^R/vab y/y produced intensely greenish-yellow and bright-yellow sectored cotyledons and leaves with sharp borders between some color sectors and blending between others.

In all these double and triple homozygotes, the lower the rate of vao and/or vab gene reversion, the larger were the bright-yellow (pale-yellow and white) areas of cotyledons and leaves and the lower was the survivalship; and vice versa, the greater the rate of reversion, the larger were the greenish-yellow areas of cotyledons and leaves and the higher was the survivalship of plants.

From these observations it can be concluded that the double and triple recessive plants regarding the y, vao and vab genes (vao/vao y/y, vab/vab y/y, vao/vao vab/vab y/y) without reversion of either of the variegation genes cannot produce chlorophyll (chlorplasts) and die after they exhaust the food supply of their cotyledons. That means that the y gene is controlling a certain step in chlorophyll synthesis (chloroplast formation) which requires the products of the dominant Vao and Vab alleles that their recessive counterparts are unable to provide. The same applies - mutatis mutandis - to the vao and vab alleles in their relation to the y gene. The decreased number of chloroplasts in the guard cells and their altered morphology supports this hypothesis.

If a transposon was involved in evoking the original vao allele (of this investigation), which behaves as a stable gene in some genotypes, then the question may be raised: Is the transposition of transposable elements one of the routine processes of generating new alleles in natural populations?

LITERATURE CITED

Delool, R.A.H., and R.A.E. Tilney-Basset. 1986. Germinal reversion in three variegated-leaf mutants of *Antirrhinum majus* L. Jour. Her. 77: 236-240.

Federoff, N.V. 1984. Transposable genetic elements in maize. Scien. Am. 250: 85-98.

Gorsic, J. 1994. Inheritance of eleven new variants of *Collinsia heterophylla*. Jour. Her. 85: 314-318

Gorsic, J. 1977. Inheritance of five new characters in *Collinsia heterophylla*. Ill. State Acad. Sci., Transactions 69: 461-466.

Gorsic, J. 1973. The genus *Collinsia*. XXX. Further genetic studies in *C. heterophylla*. Bot. Gaz. 134: 255-266.

Nevers, P., N.S. Shepherd, and H. Saedler. 1986. Plant transposible elements. Adv. Bot. Res. 12: 103-203.

Rasmuson, H. 1920. On some hybridisation experiments with varieties of *Collinsia*. Hereditas 1: 178-185.

Table 1. Types of variegation in *Collinsia heterophylla*

Name and Genotype	Phenotype
1. Orange, vao/vao	Stems and leaves either (1) uniformly orange, (2) predominantly orange with some green patches or stripes, (3) predominantly green with some orange-yellow patches or stripes, or (4) orange-yellow with scattered green patches and spots. The last three patterns are expressed in individuals with vao gene reversions.
2. White, vaw/vaw	Stems and leaves of young plants green with yellow patches and/or stripes turning white with age. The vigor of these plants is greatly reduced.
3. Blending, vab/vab	Stems and leaves exhibiting yellow-green pathces or stripes having blending borders with green; yellow-green sectors tend to expand, occasionally rendering entirely yellow-green leaves. The growth rate of the predominantly yellow-green plant is reduced.

Table 2. Phenotypic segregation of F_2 and backcross (BC) progenies of orange variegated hybrids of *Collinsia heterophylla* (Ratios: F_2 3:1, BC 1:1, * Seed parent vao/vao)

Culture	Progeny	# green	# variegated	Total	Chi-square	P
86181	F_2	100	29	129	0.436	.5
8851	F_2	89	22	111	1.588	.2
8882	F_2	61	9	70	5.505	.02
8884	F_2	26	9	35	0.007	.95
89395	F_2	24	2	26	3.283	.1
89397	F_2	45	10	55	1.364	.2
89398	F_2	66	6	72	10.667	.001
89399	F_2	35	8	43	0.939	.3
89456	F_2	28	7	35	0.549	.4
90111	F_2	72	17	89	1.650	.2
9219	F_2	29	4	33	2.272	.1
9220	F_2	50	6	56	5.356	.02
9221	F_2	39	11	50	0.106	.7
9222	F_2	25	9	34	0.000	—
9238	F_2	27	5	32	1.041	.3
9247	F_2	148	47	195	0.083	.8
9349	F_2	18	3	21	0.777	.3
9378	F_2	27	8	35	0.009	.95
9380	F_2	51	13	64	0.520	.4
93108	F_2	24	9	33	0.009	.95
93109	F_2	41	10	51	0.529	.5
94109	F_2	20	4	24	0.500	.5
94126	F_2	17	3	20	0.600	.4
94246	F_2	37	6	43	2.797	.1
8107*	F_2	174	48	222	1.352	.2
8673*	F_2	98	26	124	1.074	.3
89416*	F_2	47	0	47	14.235	<.001
89418*	F_2	53	3	56	11.524	<.001
89423*	F_2	14	4	18	0.000	—
93176*	F_2	116	31	147	1.198	.25
8814	BC	6	5	11	0.000	—
89386	BC	7	9	16	0.062	.7
89387	BC	7	9	16	0.062	.7
89461	BC	11	8	19	0.210	.5
9426	BC	10	13	23	0.172	.2
9429	BC	11	13	24	0.040	.7
94147	BC	12	13	25	0.000	—
94148	BC	13	16	29	0.137	.7
83107-8	BC*	7	3	10	0.900	.25
8403	BC*	5	5	10	0.000	—
89404	BC*	3	3	6	0.000	—
9432	BC*	4	4	8	0.000	—

Table 3. Phenotypic segregation of monohybrids and dihybrids of white (vaw) and blending (vab) variegation mutants of *Collinsia heterophylla*.

Culture	Genotype/Cross	Progeny[a]	Green	Varie-gated	Varie-gated	Double Reces.	Total	Chi-Square	P
8844	Vaw/vaw	F_2	9	1	–	–	10	0.533	0.5
89546	Vaw/vaw	F_2	7	3	–	–	10	0.000	—
89548	Vaw/vaw	F_2	9	2	–	–	11	0.029	0.7
8850	Vaw/vawxvaw/vaw	BC	6	10	–	–	16	0.562	0.4
89544-48	Vao/vao Vaw/vaw	F_2[b]	29	10	9	1	49	0.839	0.8
86114	Vab/vab	F_2	9	–	1	–	10	0.533	0.4
88105	Vab/vab	F_2	13	–	6	–	19	0.680	0.4
9223	Vab/vab	F_2	21	–	7	–	28	0.000	—
9240	Vab/vab	F_2	36	–	4	–	40	4.033	0.02
9247	Vab/vab	F_2	47	–	1	–	48	12.249	<0.001
94122	Vab/vab	F_2	24	–	6	–	30	0.177	0.7
94362	Vab/vab	F_2	12	–	3	–	15	0.016	0.9
94365	Vab/vab	F_2	11	–	4	–	15	0.129	0.7
93254*	Vab/vab	F_2	6	–	2	–	8	0.000	—
9459*	Vab/vab	F_2	9	–	5	–	14	0.380	0.5
94367*	Vab/vab	F_2	6	–	3	–	9	0.286	0.6
94368*	Vab/vab	F_2	8	–	2	–	10	0.000	—
9368	Vab/vabxvab/vab	BC	4	–	4	–	8	0.000	—
94301	Vab/vabxvab/vab	BC	4	–	4	–	8	0.000	—
94396	Vab/vabxvab/vab	BC	30	–	23	–	53	0.924	0.35
94397	Vab/vabxvab/vab	BC	4	–	3	–	7	0.000	—
94398	Vab/vabxvab/vab	BC	8	–	7	–	15	0.000	—

[a] Expected ratios: F_2 3:1; BC 1:1; [b] Dihybrid F_2 9:3:3:1 * Maternal parent vab/vab

Table 4. Phenotypic segregation of F_2 progenies of dihybrids (Vao/vao Vab/vab) of orange (vao) and blending (vab) variegation mutants of *Collinsia heterophylla* indicating vao-vab linkage[a].

Culture	Green	Orange varieg.	Blending varieg.	Double varieg.	Total	Chi-square	P
89440-5	21	8	6	---	35	1.099	0.5
9441	9	3	3	---	15	0.165	0.5
9460	23	9	9	---	41	0.825	0.7
9365	8	2	5	---	15	0.565	0.7

[a] The absence of double recessives due to vao-vab linkage in repulsion phase (Vaovab/vaoVab) rendering a 2:1:1 ratio instead of the expected 9:3:3:1 ratio.

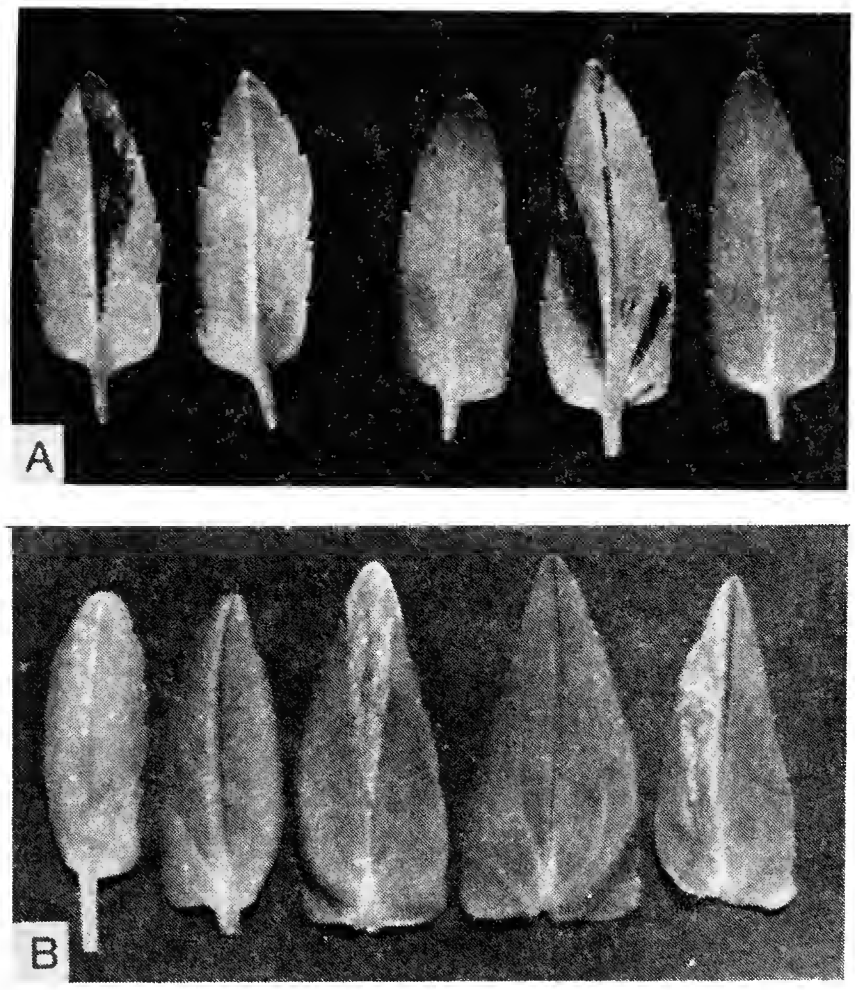


Figure 1.
Orange variegation (vao) in *Collinsia heterophylla.*
A. Pure orange (no vao reversion) and orange green sectored leaves (with vao reversion) - two (left) from lower, three (right) from upper node.
B. Leaves from 3-4-5-6-7th node from same side of stem (notice orange sectors on alternate leaves).

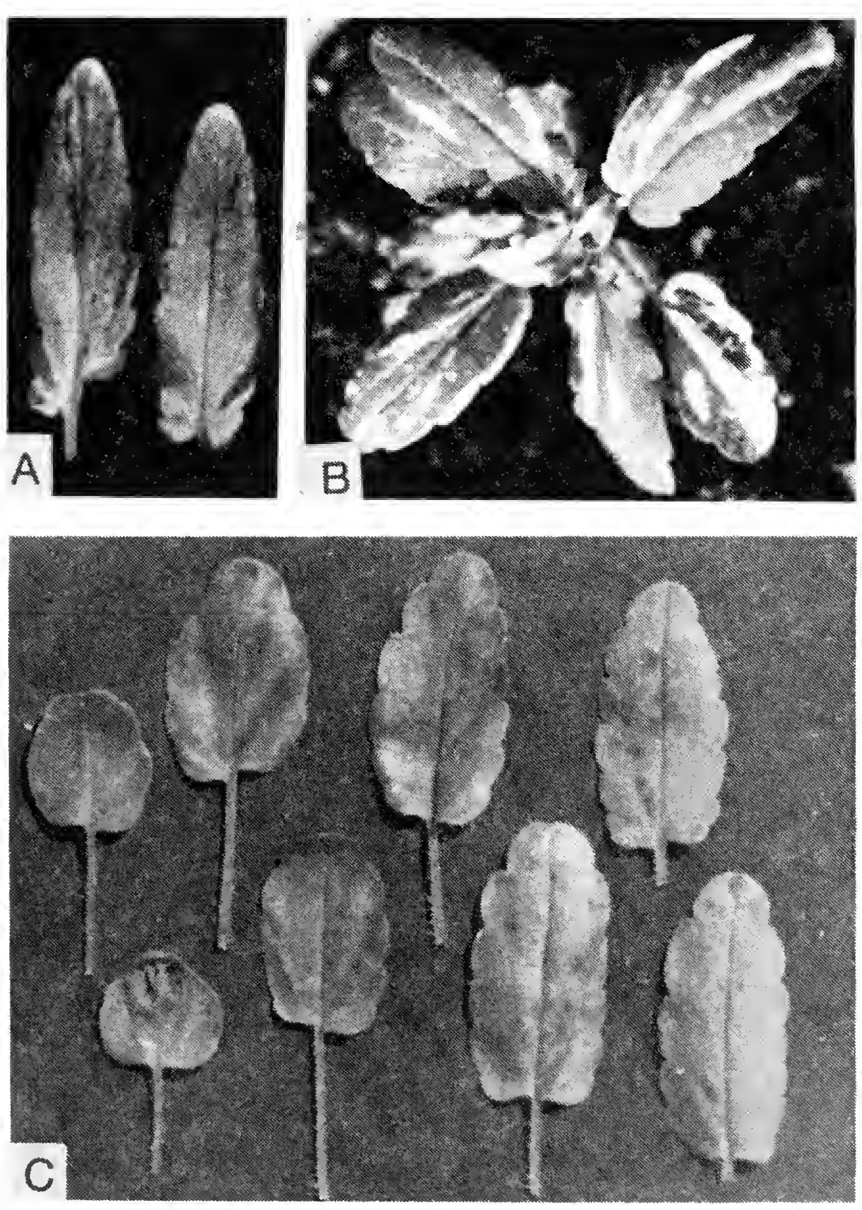


Figure 2.
Three variegation types of *Collinsia heterophylla.*
A. Orange variegated (vao) leaves with patches and spots of green in orange blades.
B. a white green variegated (vaw) mutant.
C.Blending variegation (vab). Leaf pairs (left to right) of the 1-2-3-4th node exhibiting reduction of green areas and expanding of yellow-green areas.

Transactions of the Illinois State Academy of Science
(1996), Volume 89, 1 and 2, pp. 21-23

Crepis pulchra (Asteraceae) and *Moenchia erecta* (Caryophyllaceae) in Illinois

David M. Ketzner
Illinois Natural History Survey
Center for Wildlife Ecology
607 East Peabody Drive
Champaign, IL 61820

ABSTRACT

The occurrence of the Eurasian weeds *Crepis pulchra* L. (Asteraceae) and *Moenchia erecta* (L.) Gaertn., Mey. & Scherb. (Caryophyllaceae) are reported in Illinois for the first time. A key to the Illinois species of *Crepis* is provided.

INTRODUCTION

During botanical exploration of southern Illinois in 1993 two taxa of vascular plants were found which were not previously reported for the state. The two taxa, *Crepis pulchra* L. (Asteraceae) and *Moenchia erecta* (L.) Gaertn., Mey. & Scherb. (Caryophyllaceae) are both Eurasian weeds that were found in disturbed habitats. The collection of *Moenchia* vouchers a new genus for Illinois. Acronyms for herbaria used in this paper follow Holmgren *et al.* (1990).

RESULTS AND DISCUSSION

SPECIMEN: *Crepis pulchra* L. Illinois. Alexander County. Southwest of Unity along State Route 3 at east entrance to Horseshoe Lake Conservation Area. SE 1/4, SE 1/4, sec. 11, T16S, R2W. Roadside. 20 May 1993. David Ketzner & Mark Basinger 1493 (ILLS, ISM); South of Unity along State Route 127. SE 1/4, NE 1/4, sec. 12, T16S, R2W. Roadside. 31 May 1993. David Ketzner & Mark Basinger 1506 (ILLS, ISM); North of Unity along State Route 127. SE 1/4, SE 1/4, sec. 25, T15S, R2W. Roadside. 31 May 1993. David Ketzner & Mark Basinger 1508 (ILLS, ISM, SIU).

Crepis pulchra is locally established in waste places in the United States from Virginia to Ohio and Indiana, southward to Georgia, Alabama, Mississippi, and Louisiana (Cronquist, 1980; Gleason and Cronquist, 1991). In states adjacent to Illinois it is apparently uncommon. Deam (1940) reports it as a roadside weed from Jefferson County in Indiana. In Missouri it is known from a freight yard in St. Louis County (Steyermark, 1963). Browne and Athey (1992) report it from the Mississippian Plateau and Bluegrass Regions of Kentucky.

At the Illinois sites, all on roadsides, *C. pulchra* is associated with common weeds such as *Festuca pratensis* Huds., *Bromus commutatus* Schrad., *Melilotus alba* Desr., *M. officinalis* (L.) Lam., *Campsis radicans* (L.) Seem., *Vicia cracca* L., and *Trifolium campestre* Schreb.

Until this report, two species of *Crepis* were known from Illinois, both from northeastern counties (Mohlenbrock, 1986). The following key is provided to distinguish *C. pulchra* from the other Illinois species.

KEY TO *CREPIS* IN ILLINOIS

1. Inner involucral bracts pubescent within; mature achenes dark purplish-brown .... *C. tectorum* L.
1. Inner involucral bracts glabrous within; mature achenes pale 2
   2. Involucre entirely glabrous, 8-12 mm high; achenes 4-6 mm long .... *C. pulchra* L.
   2. Involucre pubescent on outer surface, 5-8 mm high; achenes 1.5-2.5 mm long .... *C. capillaris* (L.) Wallr.

Crepis pulchra is the only Illinois species in the genus with entirely glabrous involucral bracts.

SPECIMEN: *Moenchia erecta* (L.) Gaertn., Mey. & Scherb. Illinois. Clay County. Charley Brown Park, west of Flora. NE 1/4, NW 1/4, sec. 33, T3N, R6E. Lawn. 17 May 1993. David Ketzner 1487 (ILLS, ISM, MICH).

In Illinois, *M. erecta* would most likely be confused with *Sagina decumbens* (Ell.) Torr. & Gray which it somewhat resembles with its wiry habit. In *S. decumbens* flowers are pentamerous and styles are alternate with the sepals. *M. erecta* has tetramerous flowers and styles opposite the sepals (Clapham, 1964). Also the capsule of *Moenchia* opens by eight short, revolute teeth, while in *Sagina* the capsule opens by four-five valves. In the British Isles *M. erecta* is known as "upright chickweed" (Clapham *et al.*, 1962).

Moenchia erecta is apparently rather rare in North America. Britton (1901) reported it in waste grounds near Philadelphia and Baltimore. It has more recently been collected in Oregon (Peck, 1961), British Columbia (Szczawinski and Harrison, 1972), California (Taylor and Ahart, 1983), and South Carolina (Rabeler, 1991). At the Illinois site *M. erecta* occurs in a lawn in a city park that is frequently mowed. The lawn is dominated by *Festuca pratensis* Huds., *Poa pratensis* L., and *Trifolium dubium* Sibth. Other common associates are *Plantago lanceolata* L., *P. pusilla* Nutt., *P. virginica* L., *Dactylis glomerata* L., *Galium pedemontanum* (Bellardi) All., *Hedyotis crassifolia* Raf., *Cerastium vulgatum* L., *Trifolium repens* L., *Veronica arvensis* L., and *Rumex acetosella* L.

The Illinois collection site is very near the Clay County Fairgrounds where farm animals are displayed yearly. The lawn where *M. erecta* was collected is used as a parking area for vehicles and animal trailers during the fair. *Moenchia erecta* may have been introduced at this site from the fur of farm animals or possibly from hay used as bedding or fodder. Rabeler (1991) speculates that *M. erecta* arrived at the South Carolina station, which is near a former wool combing mill, in imported wool.

ACKNOWLEDGMENTS

I thank Mr. Mark Basinger who was present during the initial discovery of *C. pulchra* and who later brought the northernmost site to my attention. Dr. Richard K. Rabeler confirmed the identity of *M. erecta.* Dr. Loy R. Phillippe, Dr. Steven R. Hill, Dr. Allen Plocher, and three anonymous reviewers read the manuscript and provided helpful suggestions. Financial support was provided by a grant from the Illinois Department of Transportation, Bureau of Design and Environment.

LITERATURE CITED

Britton, N. L. 1901. Manual of the flora of the northern states and Canada. Henry Holt and Company, New York. 1080 pp.

Browne, E. T., Jr. and R. Athey. 1992. Vascular plants of Kentucky: an annotated checklist. The University Press of Kentucky, Lexington. 180 pp.

Clapham, A. R. 1964. *Moenchia* Ehrh. Pp. 145-146 *in* T. G. Tutin, V. H. Heywood, N. A. Burges, D. H. Valentine, S. M. Walters, and D. A. Webb, eds. Flora Europaea: volume 1. Lycopodiaceae to Platanaceae. Cambridge University Press.

Clapham, A. R., T. G. Tutin, and E. F. Warburg. 1962. Flora of the British Isles. 2nd Edition. Cambridge University Press. 1269 pp.

Cronquist, A. 1980. Vascular flora of the southeastern United States: volume 1. Asteraceae. The University of North Carolina Press, Chapel Hill. 261 pp.

Deam, C. C. 1940. Flora of Indiana. Department of Conservation, Division of Forestry, Indianapolis. 1236 pp.

Gleason, H. A., and A. Cronquist. 1991. Manual of vascular plants of northeastern United States and adjacent Canada. 2nd Edition. The New York Botanical Garden, Bronx, New York. 910 pp.

Holmgren, P. K., N. H. Holmgren, and L. C. Barnett, eds. 1990. Index Herbariorum. Part 1: The Herbaria of the World. 8th edition. Regnum Vegetabile volume 120. New York Botanical Garden, New York. 693 pp.

Mohlenbrock, R. H. 1986. Guide to the vascular flora of Illinois. Southern Illinois University Press, Carbondale. 507 pp.

Peck, M. E. 1961. A manual of the higher plants of Oregon. 2nd Edition. Binfords & Mort, Portland, Oregon. 936 pp.

Rabeler, R. K. 1991. *Moenchia erecta* (Caryophyllaceae) in Eastern North America. Castanea 56 (2): 150-151.

Steyermark, J. A. 1963. Flora of Missouri. The Iowa State University Press, Ames. 1725 pp.

Szczawinski, A. F. and A. S. Harrison. 1972. Flora of the Saanich Peninsula: annotated list of vascular plants. Occasional Papers of the British Columbia Provincial Museum No. 16. 114 pp.

Taylor, M. S. and L. Ahart. 1983. Noteworthy collections: California. *Moenchia erecta* (L.) Gaertn., Mey. & Schreb. (Caryophyllaceae). Madrono 30 (2): 129-130.

Transactions of the Illinois State Academy of Science
(1996), Volume 89, 1 and 2, pp. 25-36

Impact of Dormant Season Herbicide Treatment on the Alien Herb Garlic Mustard (*Alliaria petiolata* [Bieb.] Cavara and Grande) and Groundlayer Vegetation

Victoria A. Nuzzo
NATIVE LANDSCAPES
1947 Madron Road
Rockford IL 61107

ABSTRACT

Experimental control of *Alliaria petiolata* was conducted in three sites over two years, testing three herbicides at various concentrations, and monitoring response of both *A. petiolata* and groundlayer flora. Glyphosate (trade name Roundup) significantly reduced *A. petiolata* by >93% when applied at 1% and 2%, but not at 0.5%, concentrations. Glyphosate at all concentrations had little effect on herbaceous species, which were primarily dormant at the time of application, but at 0.5% concentration significantly reduced cover of sedges (*Carex jamesii* and *C. laxiflora*) from a pretreatment mean of 13.1% to a post-treatment mean of 2.2%. Bentazon (trade name Basagran) non-significantly reduced *A. petiolata* cover by >90% (compared to a 70% reduction in the control plots) when applied at 0.56 kg and 1.12 kg AI/ha. Bentazon did not affect cover of groundlayer species, nor species density. Acifluorfen (trade name Blazer) killed all *A. petiolata*, inhibited *A. petiolata* seedling germination, and significantly reduced cover of native herbs by >70%, and appeared to have a strong soil residual.

INTRODUCTION

Alien species threaten the integrity of natural areas (Drake et al. 1989, Wagner 1993), and are often implicated in the loss of native flora (Mack 1989, Mooney and Drake 1986). Attempts to reduce or eliminate alien species with herbicides poses risks to the natural community, as both target and non-target species may be damaged. The decision to use an herbicide is based on the real or potential threat posed by the alien species, anticipated reduction in the target alien species following treatment, and sensitivity of non-target native flora to the herbicide. In general, little is known about the response of native vegetation to various herbicides.

In the Midwest, the alien biennial herb garlic mustard (*Alliaria petiolata* [Bieb.] Cavara & Grande; hereafter referred to as *Alliaria*) is considered a severe threat in deciduous forests (Nuzzo 1994a, White et al. 1993). This cool-season herb overwinters as a basal rosette, and continues to grow on snow-free days when temperatures are above freezing (Cavers et al. 1979). Thus, control efforts are usually conducted in late fall and early spring, when *Alliaria* is physiologically active and most native species are dormant.

Research indicates that a 3% glyphosate spray is an effective dormant season control agent for *A. petiolata* (Nuzzo 1991). Fall treatment significantly reduced adult density the following June, while spring treatment significantly reduced both adult density and seedling frequency in June, as treatment was conducted during the period of germination. Impact on native herbs was not monitored, but spring treatment appeared to sharply reduce cover of native herbs (Nuzzo pers. obs.). Bentazon reduced *Alliaria* cover by 94%, and acifluorfen reduced *Alliaria* by 34-46%, when applied during the growing season (Nuzzo 1994b).

The impact of these three herbicides on community structure and species composition is unknown. Glyphosate (trade name Roundup) is a non-selective systemic herbicide that kills all vegetation green at the time of application. Bentazon (trade name Basagran) is a post-emergent contact herbicide that targets dicots and some species of sedges (*Cyperaceae*), but does not impact graminoid species. Acifluorfen (trade name Blazer), also a post-emergent contact herbicide, targets dicots and some grass species. Native sedges (*Carex* sp.), forbs that are evergreen or semi-evergreen, and early spring ephemereals that emerge at the same time *Alliaria* seedlings germinate, are potential targets of dormant season treatment with any of these herbicides.

This research was undertaken to 1) investigate the relative effectiveness of three herbicides (glyphosate, bentazon, and acifluorfen) as control agents for *Alliaria*, and 2) to assess the associated herbicide impact on groundlayer community structure.

METHODS

Study sites

Three study sites were selected that had low to moderate infestation of *Alliaria*, natural quality rank of B to C (lightly to moderately disturbed; White and Madany 1978), relatively intact, diverse herbaceous layer, and absence of state or federal endangered or threatened plant species.

Hall Memorial Woods is a 16.2 hectare Grade B dry-mesic and mesic upland forest on the southwest side of Rockford, Winnebago County, Illinois, in the Freeport Section of the Rock River Hill Country Natural Division. The overstory is dominated by slippery elm (*Ulmus rubra*), white oak (*Quercus alba*) and white ash (*Fraxinus americana*), and the sapling layer is dominated by yellowbud hickory (*Carya cordiformis*), basswood (*Tilia americana*) and slippery elm. The understory is moderately dense, and dominated by wild plum (*Prunus americana*). Plots were established in the mesic portion of the forest, in an area dominated by trilliums (*Trillium flexipes* and *T. recurvatum*) in spring, and wild geranium (*Geranium maculatum*) and false solomon seal (*Smilacina racemosa*) in summer.

Maple Grove Forest Preserve is a 20 hectare Grade B mesic upland forest in Downer's Grove Illinois, located in the Morainal Section of the Northeastern

Morainal Natural Division. The overstory is dominated by sugar maple (*Acer saccharum*), white ash and white oak. The sapling layer is dominated by sugar maple, and the understory is open with few shrubs. Groundlayer is composed of spring ephemereals and perennials, which produce moderate cover in spring, and low cover in August.

Pecatonica Bottoms Nature Preserve is a 17 hectare Grade B mesic floodplain forest 23 km northwest of Rockford on the north bank of the Pecatonica River, Winnebago County, Illinois, located within the Freeport Section of the Rock River Hill Country Natural Division. The overstory is dominated by black maple (*Acer nigrum*), basswood, and black walnut (*Juglans nigra*). The understory is very open with few saplings or shrubs, and the groundlayer is extremely rich, with high herbaceous cover throughout the growing season.

Data Collection

Permanent plots (4m x 4m) were established in early spring (after *Alliaria* seedling germination), in areas where *Alliaria* seedlings were fairly abundant and herbaceous flora was diverse. Twelve plots were established in Hall Woods and 12 in Maple Grove in 1990, and 26 in Pecatonica Bottoms in 1991. Four $1m^2$ quadrats were randomly chosen as permanent quadrats within each 16 m^2 plot. Plots were paired on the basis of initial *Alliaria* cover (low and high cover plots paired), and pairs were randomly assigned to receive treatment or control.

Data were collected in May and August the year prior to dormant season treatment, and again the year after treatment. Phenological indicators were recorded, and data were collected at the same phenological date each spring at each site. Collected data consisted of: *Alliaria* adult density, adult cover, and seedling cover, all recorded in May, and rosette cover recorded in August; and presence and percent cover by seven cover classes (<1%, 1-7%, >7-25%, >25-50%, >50-75%, >75-93%, and >93%) of all herbaceous and graminoid species, and all woody species <1m tall, rooted in the quadrat.

Data Analysis

May and August data for all species, excluding *Alliaria*, were combined by overlaying data sheets; the higher cover class assigned to each species within each quadrat was recorded on the master data sheet. Because the quadrats were located in the same positions in May and August, selection of the higher of the two values accurately reflected maximum growth of each species within that quadrat. Data were used to calculate total species density, and cover of all individual species, based on cover class midpoints. Cover values were then summed by life-form group (herbaceous, graminoid, and woody species) within each quadrat.

A single "percent change" value was obtained for each variable by dividing post-treatment data by pre-treatment data, within each quadrat. This method eliminated the problem of auto-correlation due to permanent quadrats, and also relativized among sites and years. Mean percent change within quadrats reflected actual change over time, and often varied from average change within treatments.

Change in *Alliaria* cover was assessed by dividing adult cover in spring by immature rosette cover the preceding summer. Under normal conditions, rosettes that survive the winter increase substantially in cover the following spring. Other measures of *Alliaria* abundance -- seedling cover and adult density -- were tested for significant differences using spring (post-treatment) data. Seedling cover is highly variable depending on the seed bank, and differences in seedling cover among plots do not necessarily reflect impact of treatment.

Preliminary analysis of data from Hall Woods and Maple Grove indicated no differences between season of treatment, nor between plots within treatments. Data were subsequently combined and tested for significant differences (0.05 s.l.) by two-way ANOVA using site and treatment as grouping variables. No differences were detected between plots within treatments at Pecatonica Bottoms (1991/1992), and community data were combined and tested by two-way ANOVA using treatment and season as the grouping variables. *Alliaria* data (seedling, rosette and adult cover, and adult density) at Pecatonica Bottoms did not follow normal distributions, and were tested for significant differences by Kruskal-Wallis.

Treatments

Glyphosate (1% and 2% v:v concentrations) was applied in Maple Grove and Hall Woods in fall 1990/spring 1991. Based on the results of the 1990/91 applications, a 0.5% concentration of glyphosate was tested at Pecatonica Bottoms, along with acifluorfen at 1.12 kg AI/ha (1.0# AI/acre), and bentazon at 0.28, 0.56, and 1.12 kg/ha (0.25, 0.5 and 1.0 #AI/acre).

Herbicides were mixed with distilled water and 10 ml of water-soluble blue dye/l a few hours prior to application. Ten ml/l of crop oil concentrate was added to acifluorfen and bentazon. Herbicide was applied in overlapping bands with a two-nozzle (flat spray tip) boom attached to a CO^2 powered sprayer unit, calibrated to deliver 93.5 liters of water/ha (10 gallons/acre) at 19 psi, 35 m/min.

Herbicide was applied after the majority of native plants were dormant, on days with low wind and above-freezing temperatures. Applications were made 12 November 1990 and 3 March 1991 in Hall Woods, 13 November 1990 and 21 March 1991 in Maple Grove, and 13 November 1991 and 1 March 1992 in Pecatonica Bottoms. Spring treatments were made prior to *Alliaria* seedling germination and emergence of native ephemeral herbs.

RESULTS

1% and 2% Glyphosate (1990/1991)

Glyphosate significantly reduced adult *Alliaria* cover at both sites (Table 1), regardless of season of application or concentration. At Hall Woods, *Alliaria* cover more than doubled in control plots between fall 1990 and spring 1991, from 6.8% to 16.3%, but declined from 8.0-10.1% to <0.25% in treated plots (Table 2). Similar declines were recorded in Maple Grove, from pretreatment means of 23-28% cover to <2% cover after treatment (Table 2).

Reflecting the decrease in adult cover, adult density was significantly lower in treated plots than in controls at both sites (Tables 1 and 2). Density was higher at Maple Grove than Hall Woods, averaging $31.1/m^2$ and $8.8/m^2$, respectively, in untreated plots. In treated plots density ranged from a mean of $0.06\text{-}3.8/m^2$ (Table 2).

Alliaria seedling cover was not affected by herbicide application, as treatment was made prior to germination. Seedling cover varied significantly between sites, but within sites was similar in all plots regardless of treatment (Tables 1 and 2).

Total herbaceous cover and woody vegetation cover were not significantly affected by glyphosate treatment. The two test sites differed significantly in groundlayer cover, but the response of vegetation to herbicide treatment was similar in both sites. At Hall Woods, herbaceous cover increased in all plots by 20-30% between years, ranging from 102-119% in 1991, and from 130-139% in 1992. At Maple Grove, herbaceous cover declined in all plots, from 80-99% in 1991 to 65-97% in 1992. At both sites, changes in treated plots were comparable to those recorded in control plots. While glyphosate did not reduce total herb cover, two herbaceous species appeared sensitive to this herbicide; the perennial semi-evergreen white avens (*Geum canadense*) and the annual bedstraw (*Galium aparine*). Woody cover increased and decreased similar to herbaceous cover at both sites. Species density (number of species/m^2) was similar in all plots before and after treatment at both sites.

0.5% Glyphosate, bentazon, and acifluorfen (1991/1992)

Alliaria underwent high natural mortality in the control plots, and seedling cover, adult density, adult cover, and percent change from 1991 rosette cover to 1992 adult cover, were similarly low in control, glyphosate, and bentazon treated plots (Table 4).

Bentazon at 0.56 kg and 1.12 kg AI/ha nonsignificantly reduced *Alliaria* cover within individual quadrats; within plots (4 quadrats/plot) *Alliaria* cover declined >90%, from pretreatment means of 31% and 55% cover, to post treatment means of 2% and 5% cover (Table 4). In the control plots, *Alliaria* cover declined 71%, from 22% to 6%. Glyphosate at 0.5% concentration, and bentazon at 0.28 kg AI/ha had no significant effect on *Alliaria* cover.

In contrast, acifluorfen at 1.12 kg/ha eliminated all adult *Alliaria*, and reduced seedling cover to <0.1% (Table 4), significantly lower than in the control plots (sl <0.001). Acifluorfen also eliminated most forb vegetation, including species dormant at the time of application. Average cover declined 72%, from 232% prior to treatment, to just 48% 6-9 months after treatment (Table 4). The majority of cover was produced by wood nettle (*Laportea canadensis*), with a minor contribution by *Viola* sp.. Other forbs had very low cover, and usually occurred as seedlings or as diminutive plants with few leaves. Acifluorfen did not affect cover of woody species, nor of cyperoid species (Tables 3 and 4). Species density declined significantly in the acifluorfen-treated plots (Table 3), from a mean of 13.6 to $10.0/m^2$, reflecting the impact on herbaceous species (Table 4).

Glyphosate at 0.5% concentration did not affect *Alliaria* cover, but did significantly reduce cyperoid cover by 63%, from 13.1% cover pre-treatment to 2.2% cover post-treatment (Tables 3 and 4). Most abundant, and therefore most affected, species were the sedges *Carex jamesii* (declined from 5.4% to 0.8%), and *C. laxiflora* (7.2% to 0.4%). Glyphosate had no significant effect on cover of woody species (Table 3). Herbaceous cover was slightly and nonsignificantly lower in the glyphosate-treated plots, indicating that some species may have been impacted by this herbicide. Two annual species, *Chaerophyllum procumbens* and *Galium aparine*, had lower frequency and cover after treatment. Woodland phlox (*Phlox divaricata*) and wild ginger (*Asarum canadense*), both perennial and semi-evergreen species, did not appear affected by treatment.

Native groundlayer vegetation was unaffected by an application of bentazon (Table 3). Cover of herbaceous, cyperoid and woody species, and mean species density, were comparable before and after treatment at all concentrations of Bentazon.

DISCUSSION

Cover of adult *Alliaria* was sharply reduced >93% by applications of both 1% and 2% glyphosate (but not 0.5%) to dormant rosettes, similar to the reduction obtained with a 3% solution (Nuzzo 1991). Because immature rosettes were killed, adult density was also significantly reduced by 95-99%, relative to the control. Glyphosate is equally effective when applied in late fall as in very early spring, as *Alliaria* rosettes remain semi-evergreen through the winter months. Seedlings germinated several weeks to several months after the herbicide was applied, and were therefore not affected, as glyphosate has virtually no soil residual. When glyphosate is applied during the germination period, seedlings are significantly reduced (Nuzzo 1991).

Use of glyphosate, particularly in spring, resulted in some species loss, as the herbicide is non-selective; herbaceous species that were green at the time of application were reduced or killed by the herbicide. Species most noticeably affected were sedges (*Carex jamesii* and *C. laxiflora*), and white avens (*Geum canadense*), a semi-evergreen early successional forb. Surprisingly, two other semi-evergreen herbs, phlox and wild ginger, did not appear affected by this herbicide. The annual bedstraw *Galium aparine* appeared to decline with glyphosate treatment. *G. aparine* is a winter annual that germinates in early fall and overwinters as a small plant, and may have been physiologically active at the time of herbicide application.

Dormant season application of bentazon at 0.56 kg and 1.12 kg AI/ha produced a nonsignificant reduction in *Alliaria* cover in this study. When applied during the growing season, bentazon significantly reduced *Alliaria* cover, comparable to glyphosate (Nuzzo 1994). While it is possible that bentazon is primarily effective as a growing season treatment, it is also possible that dormant season treatment impact was obscured by natural over-winter *Alliaria* mortality, which can exceed 78% (Nuzzo 1993). Additional study is needed to determine if this herbicide can effectively reduce *Alliaria* presence when applied during the dormant season.

Acifluorfen removed all *Alliaria* and most herbaceous vegetation. Although listed as a post-emergent herbicide, acifluorfen had a long-lasting soil residual that prevented *Alliaria* germination, and killed numerous herbaceous species that were completely dormant at the time of treatment.

Seedlings were not affected by either glyphosate or bentazon, because herbicides were applied prior to seedling germination.

RECOMMENDATIONS

Application of 1% or 2% glyphosate applied during the dormant season at above-freezing temperatures effectively kills *Alliaria* rosettes, but also damages other species that are green at the time of application, particularly sedges. Glyphosate is a suitable management tool for small *Alliaria* populations, and the problem of non-target species loss may be balanced against the benefit of removing *Alliaria*.

Where sensitive species are present in the groundlayer, application of bentazon at 0.56 kg/ha may be an acceptable substitute for glyphosate. Bentazon has none of the drawbacks of glyphosate, but may be less effective than glyphosate in controlling *Alliaria*. Neither herbicide affected seedling germination, and depending on the seedbank, repeated dormant season applications may be needed to control *A.petiolata*.

ACKNOWLEDGEMENTS

This research was supported by a grant from the Illinois Department of Energy and Natural Resources. I would like to thank the Rockford Park District, the Winnebago County Forest Preserve District, and the DuPage County Forest Preserve District for permission to use their facilities. John Alesandrini, Scott Kobal, Michael Jones, Wayne Lampa, and Matt Paulson provided valuable field assistance.

LITERATURE CITED

Cavers, P.B., M.I. Heagy and R.F. Kokron. 1979. The biology of Canadian weeds. 35. *Alliaria petiolata* (M. Bieb.) Cavara and Grande. Canadian Journal of Plant Science 59:217:229.

Drake, J.A., H.A. Mooney, F. di Castri, R.H. Groves, F.J. Kruger, M. Rejmanek, and M. Williamson (eds.). 1989. Biological invasions: a global perspective. John Wiley and Sons. NY. 525 p.

Mack, R.N. 1989. Temperate grasslands vulnerable to plant invasions: characteristics and consequences. pp 155-179 *in* Drake, J.A., H.A. Mooney, F. di Castri, R.H. Groves, F.J. Kruger, M. Rejm¨nek, and M. Williamson (eds.). 1989. Biological invasions: a global perspective. John Wiley and Sons. NY. 525 p.

Mooney, H.A. and J.A. Drake (eds.). 1986. Ecology of biological invasions on North America and Hawaii. Springer-Verlag. NY 321 p.

Nuzzo, V.A. 1991. Experimental control of garlic mustard [*Alliaria petiolata* (Bieb.) Cavara & Grande] in northern Illinois using fire, herbicide and cutting. Natural Areas Journal 11:158-167.

Nuzzo, V.A. 1993. Natural mortality of garlic mustard (*Alliaria petiolata* (Bieb.) Cavara & Grande) rosettes. Natural Areas Journal 13:132-133.

Nuzzo, V.A. 1994a. Element stewardship abstract for *Alliaria petiolata* (*Alliaria officinalis*) garlic mustard. The Nature Conservancy. Arlington VA. 20 p.

Nuzzo, V.A. 1994b. Response of garlic mustard (*Alliaria petiolata* Bieb [Cavara and Grande]) to summer herbicide treatment. Natural Areas Journal 14:309-310.

Wagner, W.H., Jr. 1993. Problems with biotic invasions: a biologist's viewpoint. pp 1-8 *in* McKnight, B.N. (ed.) Biological pollution: the control and impact of invasive exotic species. Indiana Academy of Science. Indianapolis, IN. 261 p.

White, D.J., E. Haber, and C. Keddy. 1993. Invasive plants of natural habitats in Canada. Canadian Museum of Nature. Ottawa, Canada. 121 p.

White, J. and M.H. Madany. 1978. Classification of natural communities in Illinois. pp 309-405 *in* Illinois natural areas inventory technical report, volume 1: Survey methods and results. Illinois Natural Areas Inventory. Urbana IL. 426 pp.

Table 1. Summary tables of two-way ANOVA for percent change in cover of herbaceous and woody vegetation, and species density, at Hall Woods and Maple Grove, 1990 - 1991.

Source of Variation	df	SS	MS	F	P
***Alliaria* Cover, 1991/1990**					
Site	1	56.01	56.01	2.837	0.096
Treatment	2	331.64	165.82	8.397	<0.001
Site X Treatment	2	115.45	57.73	2.923	0.059
Error	87	1717.92	19.75		
Adult Density 1991					
Site	1	2016.67	2016.67	10.116	0.002
Treatment	2	7321.58	3660.79	18.362	<0.001
Site X Treatment	2	2070.08	1035.04	5.192	0.007
Error	90	17942.63	199.36		
Seedling Cover 1991					
Site	1	4320.17	4320.17	7.090	0.009
Treatment	2	1515.77	757.89	1.244	0.293
Site X Treatment	2	3355.90	1677.95	2.754	0.069
Error	90	54841.16	609.35		
Herbaceous Cover 1991/1990					
Site	1	2.146	2.146	10.043	0.002
Treatment	2	0.322	0.161	0.754	0.473
Site X Treatment	2	0.494	0.247	1.155	0.320
Error	90	19.235	0.214		
Woody Cover 1991/1990					
Site	1	13.626	13.626	4.853	0.030
Treatment	2	10.790	5.395	1.921	0.153
Site X Treatment	2	7.624	3.812	1.357	0.263
Error	88	247.115	2.808		
Species Density 1991/1990					
Site	1	0.028	0.028	0.280	0.598
Treatment	2	0.373	0.186	1.882	0.158
Site X Treatment	2	0.584	0.292	2.945	0.058
Error	90	8.918	0.099		

Table 2. Mean cover of *Alliaria petiolata*, herbaceous species (excluding *Alliaria*), and woody species, and mean species density, before (1990) and after (1991) herbicide treatment at Hall Woods and Maple Grove.

		HALL WOODS			MAPLE GROVE		
		Control	Glyphosate 1%	Glyphosate 2%	Control	Glyphosate 1%	Glyphosate 2%
ALLIARIA							
Rosette Cover	(1990)	6.81	8.00	10.09	22.75	28.22	23.53
Adult Cover	(1991)	16.03	0.06	0.25	26.84	1.91	1.38
Seedling Cover	(1991)	54.25	52.69	36.41	26.00	40.00	37.09
Adult Density	(1991)	8.81	0.19	0.06	31.06	3.81	1.69
COMMUNITY							
Herb Cover	(1990)	101.63	118.84	105.41	79.47	81.78	98.81
	(1991)	130.72	139.34	130.66	64.84	74.53	97.13
Woody Cover	(1990)	36.41	13.53	17.19	7.09	6.25	6.63
	(1991)	32.06	17.44	17.53	3.38	3.88	5.31
Species/m^2	(1990)	7.38	8.13	8.50	7.88	8.69	9.44
	(1991)	7.63	7.31	7.19	7.13	6.56	8.50

Table 3. Summary tables of two-way ANOVA for percent change in cover of herbaceous, cyperoid, and woody vegetation, and species density, at Pecatonica Bottoms, 1991 - 1992.

Source of Variation	df	SS	MS	F	P
Herbaceous Cover, 1992/1991					
Treatment	5	1.723	0.345	9.176	<0.001
Season	1	0.132	0.132	3.526	0.064
Treatment X Season	5	0.325	0.065	1.730	0.137
Error	84	3.154	0.038		
Cyperoid Cover, 1992/1991					
Treatment	5	60.920	12.184	1.190	0.357
Season	1	22.764	22.764	2.090	0.152
Treatment X Season	5	42.563	8.513	0.782	0.566
Error	84	914.563	10.891		
Woody Cover, 1992/1991					
Treatment	5	298.192	59.638	1.835	0.117
Season	1	9.433	9.433	0.290	0.592
Treatment X Season	5	481.429	96.286	2.963	0.017
Error	72	2339.828	32.498		
Species Density 1992/1991					
Treatment	5	1.271	0.254	8.615	<0.001
Season	1	0.009	0.009	0.307	0.581
Treatment X Season	5	0.292	0.058	1.980	0.090
Error	84	2.479	0.030		

Table 4. Mean cover of *Alliaria petiolata*, herbaceous species (excluding *Alliaria*), cyperoid species, and woody species, and mean species density, before (1991) and after (1992) herbicide treatment at Pecatonica Bottoms.

		Control	Glyphosate	Bentazon			Acifluorfen
			0.5%	0.28kg	0.56 kg	1.12 kg	1.12 kg
ALLIARIA							
Rosette Cover	(1991)	21.81	21.22	36.34	31.44	55.47	23.97
Adult Cover	(1992)	6.34	6.19	13.53	2.44	5.22	0.00
Seedling Cover	(1992)	5.13	15.16	6.88	9.13	15.44	0.09
Adult Density	(1992)	8.88	7.88	11.13	3.81	8.25	0.00
COMMUNITY							
Herb Cover	(1991)	205.34	120.38	169.69	185.06	135.69	221.78
	(1992)	138.34	66.34	102.88	103.31	83.78	63.91
Cyperoid Cover	(1991)	18.78	13.06	12.00	17.66	15.44	10.09
	(1992)	23.75	2.21	13.16	16.59	17.91	11.66
Woody Cover	(1991)	2.63	4.19	5.41	1.56	2.31	2.25
	(1992)	4.06	3.34	6.31	3.78	3.34	7.66
Species/m^2	(1991)	13.81	12.63	13.31	14.63	13.06	13.67
	(1992)	13.56	13.44	14.44	13.88	12.88	10.00

Transactions of the Illinois State Academy of Science
(1996), Volume 89, 1 and 2, pp. 37-40

The Syntheses of Phencyclone and Dihydrophencyclone

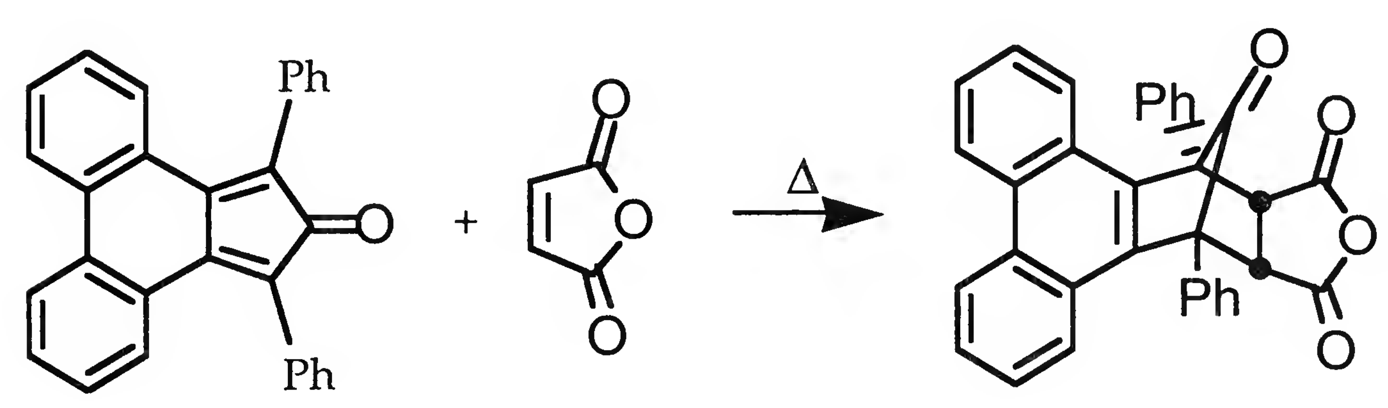
William R. Forsyth, Gerald A. Weisenburger, and Kurt W. Field*
Department of Chemistry, Bradley University
Peoria, IL 61625
*Author to whom correspondence should be addressed.

ABSTRACT

The base promoted condensation of 1,3-diphenylacetone and phenanthrenequinone can be used to synthesize either phencyclone or dihydrophencyclone. When the condensation is performed at room temperature using solid potassium hydroxide and approximately equimolar quantities of the ketone and quinone in ethanol solvent, high purity phencyclone is produced in moderate yield. However, in refluxing ethanol and a 2:1 molar ratio of the quinone:ketone, the dropwise addition of ethanolic potassium hydroxide affords high purity dihydrophencyclone in moderate yield.

INTRODUCTION

The formation of Diels-Alder adducts from substituted cyclopentadienones (cyclones) and alkenes is well documented (Allen et al. 1964; Dilthey et al. 1937; Harrison 1991; Mackenzie 1960; Sasaki et al. 1976; Yasuda et al. 1980; Yasuda et al. 1981). Phencyclone, **1**, has been shown to form endo [4 + 2] π-cycloadducts with various dienophiles including styrenes and a number of cyclic alkenes, e.g. eq 1. The high reactivity and high regio- and periselectivity make phencyclone an ideal diene for Diels-Alder reactions (Sasaki et al. 1976; Yasuda et al. 1980; Yasuda et al. 1981).

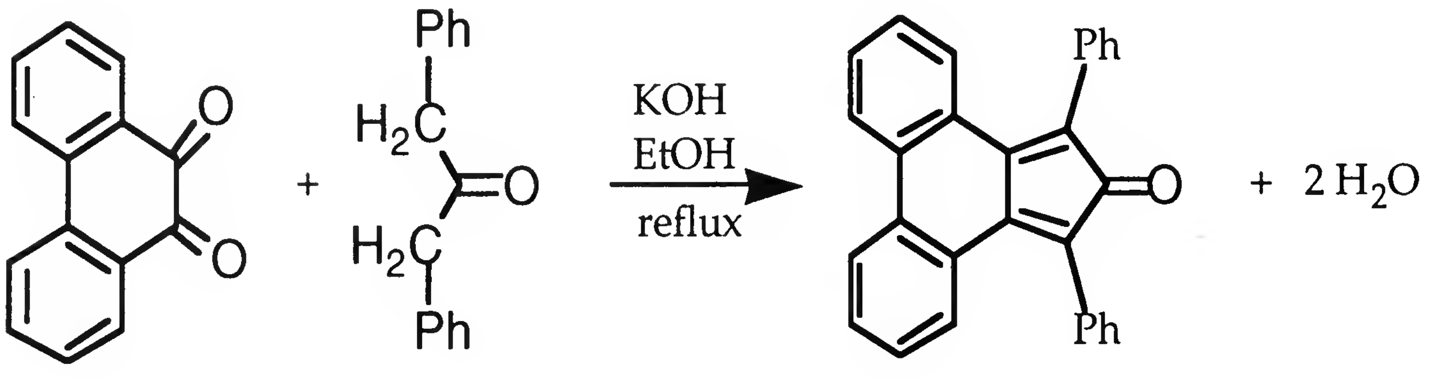


(1)

Phencyclone
1

Maleic Anhydride

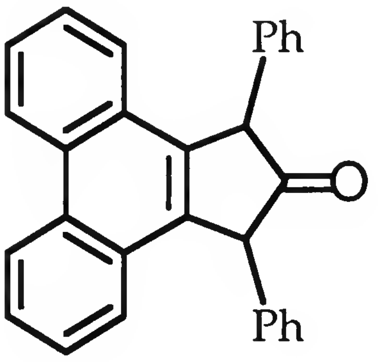
Phencyclone is usually synthesized via a base promoted aldol condensation, eq 2 (Dilthey et al. 1935). Experimental difficulties and yield inconsistencies encountered



(2)

1

during these syntheses are also well documented. For example, Harrison (1992) reports that the preparation of **1** as suggested by Vaughn-Williams (1971) does not lead to the formation of **1** but instead yields dihydrophencyclone, **2**. Perhaps Allen's



Dihydrophencyclone

2

(1964) statement, "phencyclone is not easy to prepare", accurately summarizes the utility of the published synthetic sequences leading to **1**.

Previous preparations of **1** require scrupulous temperature control coupled with the lengthy addition of the alcoholic base solution (Allen et al. 1964; Dilthey et al. 1935; Harrison 1992). We report, herein, a preparation of **1** that is very reproducible, affords reasonable yields, and avoids the necessity of temperature control and the dropwise addition of base.

RESULTS AND DISCUSSION

A systematic investigation of the experimental parameters associated with the preparation of phencyclone confirmed that reaction temperature is the critical variable. By running the reaction at room temperature, we have found that the preparation of **1** is easy to execute and very reproducible. Above ca. 60 °C dihydrophencyclone becomes the predominant product (Harrison 1991). A second experimental modification involved the introduction of the potassium hydroxide. The need for dropwise addition of the alcoholic base was eliminated by combining the phencyclone precursors and solvent before adding solid potassium hydroxide. Note, literature methods used potassium hydroxide-alcohol solutions; however, these solutions degrade upon standing and must be prepared just prior to use. Finally, using the conditions described above, we optimized two additional experimental parameters, base concentration and reaction time, which ultimately led to the procedure described below.

EXPERIMENTAL SECTION

General.
Infrared absorption (IR) spectra were recorded on a Nicolet Model 205 instrument. Steady-state ultraviolet-visible (UV-vis) absorption spectra were recorded on a Perkin-Elmer Model 552 spectrometer and are expressed as λ_{max} in nm (log ε). The ^{1}H and ^{13}C NMR spectra were obtained on a Bruker Instruments Inc. ARX 400. Analytical high-performance liquid chromatography (HPLC) was performed with a Gilson Medical Electronics instrument equipped with a Model 112 UV/vis detector and an Alltech 5 μm 4.6 x 250 mm Econosphere C_{18} column with 25% water in acetonitrile as eluant at 1.0 mL/min. Melting points, determined on a Thomas-Hoover capillary apparatus, were not corrected. 1,3-Diphenylacetone and phenanthrenequinone (99%) were used as received (Aldrich).

Phencyclone, 1, (1,3-Diphenyl-2-cyclopenta[l]-phenanthrene-2-one) [5660-91-3].
1,3-Diphenylacetone (0.584 g, 2.78 mmol), phenanthrenequinone (0.532 g, 2.58 mmol), and 25 mL of 95% ethanol were combined. Upon the addition of solid potassium hydroxide pellets (1.0 g, 17.8 mmol) the initially orange heterogeneous mixture darkened. After stirring at room temperature for 30 min., the black precipitate was isolated by vacuum filtration and washed with 2 x 5 mL of cold ethanol. The solid was dried in vacuo to give 0.720 g (1.88 mmol, 73%) of the title compound: mp 206.8-208.4 °C; IR (KBr) 1700 cm^{-1} (C=O); UV (cyclohexane) 300.5 (4.4); ^{13}C NMR ($CDCl_3$) δ 200.16 ($\underline{C}$=O). HPLC analysis revealed that **1** did not contain dihydrophencyclone and was of greater purity than **1** prepared by other methods. Multiple preparations of **1**, via this procedure, performed by several individuals averaged 73% (high 81%, low 68%).

Dihydrophencyclone, 2.
1,3-Diphenylacetone (0.262 g, 1.25 mmol), phenanthrenequinone (0.503 g, 2.42 mmol), and 25 mL of 95% ethanol were heated to reflux with stirring. A freshly prepared solution of 10% ethanolic KOH (1 mL) was then added dropwise over a five minute period, after which the heterogeneous mixture was stirred for an additional 60 min. After cooling the solution, the desired material was isolated by vacuum filtration, washed with 3 x 10 mL of cold ethanol, and dried in vacuo yielding a dull ivory solid (0.368 g, 0.957 mmol, 77%): IR (KBr) 1746 cm^{-1} (C=O); UV (cyclohexane) 258.2 (4.3); ^{1}H NMR ($CDCl_3$) δ 5.19 (sp^3 C$\underline{H}$); ^{13}C NMR ($CDCl_3$) δ 58.92 (sp^3 $\underline{C}$H), 123.37, 126.51, 126.94, 127.11, 127.27, 128.16, 128.55, 128.75, 131.20, 135.53, 137.37, 210.55 ($\underline{C}$=O). HPLC analysis of **2** confirmed its high purity and the absence of **1**.

CONCLUSION

A systematic investigation of the experimental variables associated with the base promoted condensation of 1,3-diphenylacetone and phenanthrenequinone afforded a much improved preparation of phencyclone. Similar studies revealed that dihydrophencyclone was best prepared by a procedure similar to that described by Dilthey (1935).

ACKNOWLEDGMENT

Miss Denise Flynn and Mr. Jeffrey Hurley are recognized for their initial experimental assistance. Mr. Stan Abel and Dr. David Weisleder of the National Center for Agricultural Utilization Research, USDA, Agricultural Research Service, Peoria, IL (NCAUR USDA ARS), graciously assisted with translation of the German manuscripts and acquisition of NMR spectra, respectively. Financial support was provided, in part, by the Dow Chemical Company Foundation.

LITERATURE CITED

Allen, C. F. H. and Ning, R. Y. 1964. New Phencyclone Adducts from Ethylenic Compounds. Can. J. Chem. 42:2151-2152.

Dilthey, W., ter Horst, I., and Schommer, W. 1935. Tieffarbige aromatische Funfringketone [Heteropolare, XXVII]. J. prakt. Chem. 143:189-210.

Dilthey, W., ter Horst, I., and Schaefer, A. 1937. Maleinsaureaddukte an Phencyclon. J. prakt. Chem. 148:53-71.

Harrison, E. A. 1991. Synthesis of a Bicyclo[2.2.1heptene Diels-Alder Adduct. J. Chem. Educ. 68:426-427.

Harrison, E. A. 1992. The Importance of Temperature Control in the Preparation of Phencyclone. J. Chem. Educ. 69:571.

Mackenzie, K. 1960. Bicyclo[2,2,1]heptadiene in the Diels-Alder Reaction. J. Chem. Soc. 473-483.

Sasaki, T., Kanematsu, K., and Iizuka, K. 1976. Molecular Design by Cycloaddition Reactions. XXV. High Peri- and Regiospecificity of Phencyclone. J. Org. Chem. 41:1105-1112.

Vaughn-Williams, H. R. 1971. Two Syntheses for the Organic Undergraduate. J. Chem. Educ. 48:259.

Yasuda, M., Harano, K., and Kanematsu, K. 1980. High Peri- and Regiospecificity of Phencyclone: Kinetic Evidence of the Frontier-Controlled Cycloaddition Reaction and Molecular Structure of the Cycloadduct. J. Org. Chem. 45:659-664.

Yasuda, M., Harano, K., and Kanematsu, K. 1980. Frontier-Controlled Cycloaddition Reactions of Phencyclone with 1 H-Azepine. Remarkably Accelerated Aromatic Cope Rearrangement of an Endo-[4 + 2]-Cycloadduct. J. Org. Chem. 45:2368-2372.

Yasuda, M., Harano, K., and Kanematsu, K. 1981. Frontier-Controlled Cycloaddition Reactions of Phencyclone with Electron-Rich Dienophiles via Charge-Transfer Complexes: Kinetic Study and Its Mechanistic Aspects. J. Org. Chem. 46:3836-3841.

Transactions of the Illinois State Academy of Science
(1996), Volume 89, 1 and 2, pp. 41-52

Metals Concentrations in Periphyton and Sediments of the Embarras River and Brushy Fork, Douglas County, Illinois

Charles L. Pederson* and David L. Vaultonburg
Environmental Biology Program
Eastern Illinois University
Charleston, Illinois 61920
*corresponding author

Key Words: heavy metal, biological monitoring, streams, algae

ABSTRACT

The Embarras River is used as a water supply by several municipalities in east-central Illinois. This study was initiated because industrialization in the area could potentially contribute to the metal burden of Brushy Fork and the Embarras River - streams already subject to agricultural runoff, wastewater plant effluent, and landfill leachate. Our purpose was to evaluate the potential use of attached algae (periphyton) as a biological monitor of heavy metal pollution in streams and to establish baseline concentrations of metals in periphyton of the Embarras River Basin for future comparisons. Periphyton was collected using artificial substrates which were deployed for successive 2-week intervals from 30 May 1990 through 22 September 1990. Sampling sites were located in the Embarras River, upstream and downstream of the mouth of Brushy Fork, and in Brushy Fork, upstream and downstream of the mouth of Newman Drain #2. Analysis of periphyton and stream sediments by inductively coupled plasma-atomic emission spectroscopy revealed the presence of several potentially toxic metals (Al, Ba, Co, Cr, Fe, Mn, Ni, V and Zn). Comparison of these data with previously reported aqueous concentrations of these metals in the Embarras River suggests that monitoring protocols which involve sediment and periphyton may facilitate detection of metals pollution in streams and that the Embarras River drainage may be subject to chronic but relatively low levels metals pollution.

INTRODUCTION

Metals released into terrestrial and aquatic systems from natural and anthropogenic sources may alter the structure of biotic communities as well as pose a threat to public health. Algae and aquatic macrophytes are potentially useful as biological monitors of metal pollution because they concentrate metals from their surroundings such that metals content of their tissues may be measured even when ambient concentrations are so low as to be undetectable by routine analyses (Friant and Koerner, 1981; Bailey and Stokes, 1985; Smith and Kwan, 1989). In addition, biomonitors provide an integrated picture of metals pollution within a given system, particularly if the system is subject only to intermittent or low-level contamination (Whitton, 1985).

Algae which grow attached to various substrata in aquatic systems have been referred to as periphyton, and because of the immediacy of their association with the aqueous medium they may serve as indicators of perturbations in lakes and streams. Metal concentrations in periphyton have been found to be directly related to aqueous concentrations of zinc (Cushing and Rose, 1970), vanadium, chromium, selenium, and nickel (Patrick *et al.*, 1975). Subsequently, Friant and Koerner (1981) found chromium concentrations to be higher in periphyton collected at a site impacted by industrial discharge than at an upstream reference site. Uptake of metals by periphyton also may be a function of sediment metals concentrations (Bailey and Stokes, 1985).

Although ambient concentrations of metals in the waters of the Embarras River drainage were determined in 1987 (Ettinger, 1989), no detailed studies had been undertaken to determine baseline metals content of the periphyton in this drainage. Since current land use in the watershed is primarily agricultural, we believed it necessary to obtain these data before the potential for metals pollution increases. This paper reports on concentrations of metals present in periphyton and sediments of the Embarras River and its tributary, Brushy Fork, and evaluates the potential for use of periphyton as a biological monitor for assessment of water quality in the Embarras River drainage.

MATERIALS AND METHODS

Study Site

The Embarras River drains an area of approximately 4500 km^2 in east-central Illinois, USA (Fig. 1), receiving largely agricultural runoff along with some municipal and industrial waste effluents (Ettinger, 1987). Sampling sites were established in the Embarras River, 3.7 km upstream (UPEMB) and 4.7 km downstream (DNEMB) of the mouth of Brushy Fork, and in Brushy Fork, 3.0 km upstream (UPBFK) and 1.1 km downstream (DNBFK) of the mouth of Newman Drain #2 (Fig. 1). These sites were selected based upon the siting of a heavy metals reclamation facility in Newman, Illinois and its potential to impact water quality in the Embarras River basin.

Sampling Regime

The periphyton community indigenous to each site was sampled using artificial substrates consisting of 35.5 X 24.4 cm plexiglas sheets. Substrates were exposed just below the stream surface by attachment to a flotation device (71 X 15 X 1.5 cm PVC-pipe frame with a styrofoam block at either end) which was anchored to maintain its position within the stream reach. Substrates were exposed at each site for successive two week periods from 30 May 1990 to 22 September 1990. At the end of each two week period, substrates were collected, air dried, and replaced with clean plexiglas sheets. Sediment samples were collected from each site on 13 June, 8 August, and 22 September and stored frozen. Field measurements of stream flow, conductivity, dissolved oxygen, temperature and pH were made on each sampling date.

Laboratory Analyses
Air-dried periphyton was removed from a 185 cm^{-2} area of the upper surface of each substrate. Periphyton samples were placed into separate, preweighed, acid-washed 10 mL glass vials and net dry mass determined after drying at 105 C for 24 hr. Oven-dried periphyton samples were stored in a desiccator and sediment samples were stored frozen prior to elemental analysis.

Periphyton and sediment samples were analyzed by the Illinois Natural History Survey Laboratory in Urbana, Illinois for total cations analysis. Sediment samples were freeze-dried. Oven-dried periphyton and freeze-dried sediment samples were ground to pass through a 100-mesh nylon fabric sieve before being subjected to similar digestion procedures. Dry samples (sediments = 0.015 g; periphyton = 0.050 g) were placed in 150-mL round bottom flasks with 10 mL of HNO_3 and 4.25 mL of 70% $HClO_4$. Flasks were heated until the HNO_3 had volatilized and dense, white $HClO_4$ fumes appeared, at which time another 5 mL of HNO3 was added. Heating with subsequent addition of HNO_3 was repeated until only a small amount of undigested residue (silicon dioxide) remained. This residue was transferred to a PTFE-lined Parr acid digestion bomb and final digestion was accomplished by addition of 3 mL HF with heating to 140 C in a muffle furnace for 2 hr. Individual samples were brought to an appropriate volume with deionized water and aliquots were analyzed for silver, aluminum, arsenic, boron, barium, beryllium, calcium, cadmium, cobalt, chromium, copper, iron, potassium, magnesium, manganese, molybdenum, sodium, nickel, phosphorus, lead, antimony, selenium, silicon, tin, vanadium, and zinc by inductively coupled plasma-atomic emission spectroscopy (ICP-AES) using a Jarrell-Ash 975 Plasma AtomComp spectrophotometer (Sue Wood, personal communication).

Statistical Analyses
Two-factor analysis of variance (ANOVA) without replication (Sokal and Rohlf, 1995) was used to determine significant differences ($p < 0.05$) among sampling dates and sites. Metals concentrations which did not show significant differences by site were considered replicates, and a single factor (sample date) ANOVA was performed along with the Scheffe method to test for significant differences between individual means by date (Sokal and Rohlf, 1995). Because substrates were not replicated at sampling sites, it was not possible to test for interaction of independent variables. Correlation analysis was used to relate periphyton metals concentrations with sediment metals content, as well as with stream physical and chemical variables (Sokal and Rohlf, 1995).

RESULTS

Artificial substrates were recovered from all four sampling sites every two weeks from 13 June through 22 September 1990, with the exception of 27 June. Substrates deployed on 13 June were lost, apparently due to flooding, at all but the UPEMB site. Previously, it was determined that material removed from these substrates consisted primarily of diatoms, but also contained other algae, bacteria, protozoans, aquatic insect larvae, and trapped sediments (Vaultonburg and Pederson, 1994). However, material removed from the artificial substrates will be referred to consistently as periphyton for the sake of clarity.

Seven metals which are either essential plant nutrients or which are generally not toxic that were detectible in sediments and periphyton included boron, calcium, potassium, magnesium, sodium, phosphorus, and silicon. Because these nutrient elements were not the focus of our study, they have been omitted from statistical analyses and are not considered further in this paper. Concentrations of ten metals in sediments ([S]) and periphyton ([P]), including some of the more toxic metals, were at or below the detection limits of ICP-AES at all four sampling sites on all dates. These were silver ([S] < 33.0 ppm; [P] < 10.0 ppm), arsenic ([S] < 100 ppm; [P] < 30.0 ppm), beryllium ([S] < 3.33 ppm; [P] < 1.00 ppm), cadmium ([S] < 13.3 ppm; [P] < 4.00 ppm), copper ([S] < 13.3 ppm; [P] < 4.00 ppm), molybdenum ([S] < 20.0 ppm; [P] < 6.00 ppm), lead ([S] < 50.0 ppm; [P] < 15.0 ppm), antimony ([S] < 43.3 ppm; [P] < 13.00 ppm), selenium ([S] < 103 ppm; [P] < 31.0 ppm), and tin ([S] < 110 ppm; [P] < 33.00 ppm).

Aluminum (Al), barium (Ba), chromium (Cr), iron (Fe), manganese (Mn), nickel (Ni), and zinc (Zn) are potentially toxic and were present in measurable concentrations in periphyton (Table 1) as well as sediments (Table 2). Cobalt (Co) and vanadium (V) were detected consistently in periphyton (Table 1) but not in sediments (Table 2). Periphyton concentrations of these nine metals were subjected to two-factor ANOVA (sample date, sample site). Nickel concentrations did not vary significantly by date or site over the course of the study. Therefore, the mean concentration was calculated and is reported as 39.1 ppm. Two-factor ANOVA of Cr concentrations detected significant differences between site and date. However, if data are grouped such that UPEMB and DNEMB are considered replicates as are UPBFK and DNBFK, then the mean Cr concentration in periphyton of the Embarras River (51.7 ppm, n=14) is greater than in periphyton of Brushy Fork (41.7 ppm, n=14).

Concentrations of Al, Ba, Co, Fe, Mn, V, and Zn in periphyton did not differ by site but did differ by date. On this basis, sampling sites were considered to be replicates and data were subjected to one-factor ANOVA (sample date) which identified significant variation between sampling dates for all of these metals. Concentrations increased temporally, with periphyton collected in September bearing a significantly higher metals concentration than periphyton collected earlier in the sampling season (Table 3). Periphyton concentrations of Al, Ba, Cr and Ni were not correlated with any of the physical and chemical variables, while significant negative correlations were observed between stream flow and concentrations Co, Fe, Mn, V, and Zn.

Sediment concentrations of Al, Ba, Cr, Fe, Mn, and Zn did not differ by site or date. Nickel concentrations in sediment differed significantly by site but not date, although Scheffe's test identified differences only between UPBFK and DNEMB. While V was present in measurable amounts in some sediment samples collected from both Embarras River sites as well as DNBFK, Co was not detected in any sediment samples (Table 2). Of the nine potentially toxic metals identified in periphyton, only Ni was always present in greater concentrations in sediment (Table 4). Barium and Zn were detected at slightly higher maximum concentrations in sediment than in periphyton, however values did not vary by orders of magnitude. Otherwise, metals were present in equal or greater concentrations in periphyton when compared to concentrations in sediments. No correlation was detected between periphyton and sediment concentrations of these nine metals.

DISCUSSION

Detection of metals pollution in streams may be facilitated by using periphyton as a biological monitor, rather than by attempting to directly assess metals concentrations of water or sediments (Friant and Koerner, 1981). Concentrations of heavy metals in water may be below the analytical limit of detection as exemplified in the data obtained during an intensive study of the Embarras River basin (Ettinger, 1989). Potentially toxic metals such as Co, Cr, Ni, V, and Zn often were not detected or were found only in very low aqueous concentration, leading to the conclusion that water quality in the Embarras River was very good or even excellent with regard to metals content. However, even if aqueous concentrations are high enough to permit detection, one time "grab" samples may not intercept pulses of pollution which can be considerably greater than background levels.

Our work suggests that metals can be detected more reliably through monitoring of sediments and periphyton as compared to monitoring of aqueous concentrations alone. Of the toxic metals not detected by water analysis in 1987 (Ettinger, 1989), only Co remained undetected in sediments during 1990 (Table 4). Furthermore, Bailey and Stokes (1985) found sediment metals concentrations of 1,000-10,000 times concentrations found in water. If aqueous metals concentrations in the Embarras River are presumed to have changed little since 1987, then our data suggest sediment concentration factors ranging from nearly 500 times the probable aqueous concentration of Mn in water to more than 8000 times that for Al (Table 4).

Since periphyton metals concentrations provide an integrated picture of metals pollution over time while demonstrating bioavailability, our data indicate that the Embarras River drainage may be subject to chronic but relatively low level metals pollution. This is supported by the fact that we found concentrations of some potentially toxic metals in sediments of the Embarras River and Brushy Fork to be greater than those found in other regions of the United States. Concentrations of Al in sediments of the Embarras drainage exceed those found in sediments of Clark Fork River in Montana which is heavily contaminated with Cu mining and smelting wastes (Moore *et al.*, 1989). Barium, Cr, Fe, Mn, and Ni are more concentrated in Embarras River and Brushy Fork sediments than in those of the South Dry Sac and Little Sac Rivers in southwest Missouri which are subject to leachate from landfills and wastewater treatment plant effluent (Mantei and Foster, 1991), and Cr concentrations were higher than the average reported for sediments in 63 Illinois lakes (Kelly and Hite, 1981). In addition, concentrations of Al, Cr, Fe, Mn, Ni and Zn in Embarras River and Brushy Fork sediments tended to be higher than the average concentrations in 1318 soil samples collected throughout the United States (Shacklette and Boerngen, 1984).

Although pH has been found to be inversely correlated with metals concentrations in water and algal material (Bailey and Stokes, 1985), pH tended to be higher on September sampling dates during our study. Thus, our observation of a temporal increase in periphyton metals concentration is somewhat difficult to explain. Possible explanations include seasonal changes in algal community structure (Vaultonburg and Pederson, 1994) since concentrations of metals in algae vary between genera and within a genus (Trollope and Evans, 1976). Alternatively, qualitative changes in sediment accumulated along with periphyton on artificial substrates may have resulted in perception of increased metals concentrations. Metal concentrations are affected by the size and composition of sediment particles (Combest, 1991) as well as the type of other metal sequestering materials (e.g., organics) which are attached to those particles (Mantei and Foster, 1991). Work by Bailey and Stokes (1985) demonstrated sediment metals to be correlated with organic content. Combest (1991) found a near linear relationship between the percentage of clay present in sediment and the quantity of Cu, Cr, and Zn detected. He also observed an inverse relationship between the quantity of metal present and the percent of sand. However, it is worth noting that metal concentration does not always increase in proportion to decreasing particle size and, on occasion, higher metal concentrations are found in association with larger particles (Gibbs, 1977; Feltz, 1980). Seasonal changes in community structure and quality of sediment associated with the periphyton may ultimately have been determined by flow regime.

We believe that use of artificial substrates to collect periphyton for monitoring metals pollution in streams provides a viable alternative to monitoring protocols which include analysis of only water or sediments. In our study, not only were more metals detected in periphyton, but concentrations were generally much higher than aqueous concentrations reported by Ettinger (1989). Furthermore, concentrations in periphyton were at least equal to those of sediments. Although we detected a greater number of metals in sediments than were detected in water by Ettinger (1989), Friant and Koerner (1981) point out that physical and chemical processes are required to sequester metals into sediments. In contrast, algae (periphyton) have been demonstrated to concentrate metals by active as well as passive uptake. Therefore, periphyton provides a more realistic representation of spatial and temporal variation in ambient metals concentrations while demonstrating which metals are available for uptake by the aquatic and riparian plants that form the basis of freshwater food webs.

The metals burden of Brushy Fork and the Embarras River already may be substantial with sources including agricultural runoff, municipal and industrial effluent, and landfill leachate. Our data provide a valuable baseline for assessing future impacts on the Embarras River system while demonstrating a method with potential for broad application. However, further research is required regarding the influence of various physical and chemical factors on metals uptake by periphyton.

ACKNOWLEDGEMENTS

The contributions of J. Carlson, C. Mueller, M. Vaultonburg, and W. Weiler are gratefully acknowledged. This work was supported in part by a grant from the Eastern Illinois University Council for Faculty Research.

LITERATURE CITED

Bailey, R.C., and P.M. Stokes. 1985. Evaluation of filamentous algae as biomonitors of metal accumulation in softwater lakes: a multivariate approach. Pages 5-26 in R.D.

Cardwell, R. Purdy and R.C. Bahner, editors. Aquatic toxicology and hazard assessment: 7th symposium, ASTM STP 854. American Society for Testing Materials, Philadelphia, PA, USA.

Combest, K.B. 1991. Trace metals in sediment: spatial trends and sorption processes. Water Res. Bull. **27**:19-28.

Cushing, C.E., and F.L. Rose. 1970. Cycling of zinc-65 by Columbia River periphyton in a closed lotic microcosm. Limnol. Oceanogr. **15**:762-767.

Ettinger, W.H. 1989. An intensive study of the Embarras River basin. Illinois Environmental Protection Agency, Springfield, IL, USA.

Feltz, H.R. 1980. Significance of bottom material data in evaluating water quality. Pages 271-286 in R.A. Baker, editor. Contaminants and sediments, Vol 1. Ann Arbor Science Publishers, Inc., Ann Arbor, MI, USA.

Friant, S.L., and H. Koerner. 1981. Use of an in situ artificial substrate for biological accumulation and monitoring of aqueous trace metals: a preliminary field investigation. Water Res. **15**:161-167.

Gibbs, R.J. 1977. Transport phases of transition metals in the Amazon and Yukon Rivers. Geol. Soc. Amer. Bull., **88**:829-843.

Kelley, M.H., and R.L. Hite. 1981. Chemical analysis of surficial sediments from 63 Illinois lakes, summer 1979. Illinois Environmental Protection Agency, Springfield, IL, USA.

Mantei, E.J., and M.V. Foster. 1991. Heavy metals in stream sediments: Effects of human activities. Environ. Geol. Water Sci. **18**:95-104.

Moore, J.N., E.J. Brook, and C. Johns. 1989. Grain size partitioning of metals in contaminated, coarse-grained river floodplain sediment: Clark Fork River, Montana, USA. Environ. Geol. Water Sci. **14**:107-115.

Patrick, R., T. Bott, and R. Larson. 1975. The role of trace elements in management of nuisance growths. USEPA Rept. 660/2-75-008. Corvallis, OR, USA.

Shacklette, H.T., and J.G. Boerngen. 1984. Element concentrations in soils and other surficial materials of the conterminous United States. United States Government Printing Office, Washington, D.C., USA.

Smith, S., and M.K.H. Kwan. 1989. Use of aquatic macrophytes as a bioassay method to assess relative toxicity, uptake kinetics and accumulated forms of trace metals. Hydrobiologia **188/189**:345-351.

Sokal, R.R., and F.J. Rohlf. 1995. Biometry: the principles and practice of statistics in biological research, 3rd edition. W.H. Freeman and Company, San Francisco, CA, USA.

Trollope, D.R., and B. Evans. 1976. Concentrations of copper,iron, lead, nickel and zinc in freshwater algal blooms. Environ. Poll., **11**:109-116.

Vaultonburg, D.L., and C.L. Pederson. 1994. Spatial and temporal variation of diatom community structure in two east-central Illinois streams. Trans. Il. Acad. Sci. **87**:9-27.

Whitton, B.A. 1984. Algae as monitors of heavy metals in freshwaters. Pages 257-280 in L.E. Shubert, editor. Algae as ecological indicators. Academic Press, Inc., London, England, UK.

Table 1. Metals concentrations (ppm) in periphyton removed from artificial substrates exposed for successive two-week periods in the Embarras River and Brushy Fork during 1990.

Site ExposureDates	Elements Al	Ba	Co	Cr	Fe	Mn	Ni	V	Zn
UPEMB									
5/30-6/13	40000	472	14.3	51.6	14200	406	27.5	54.6	51.2
6/27-7/11	34900	419	19.0	53.8	16600	826	72.8	95.0	77.0
7/11-7/25	57800	418	16.2	50.0	14400	546	32.2	38.8	45.0
7/25-8/08	46200	493	24.8	41.6	18200	808	33.8	40.2	70.2
*8/08-8/25	39700	476	20.6	51.2	15800	984	45.6	68.0	59.0
8/25-9/08	41000	430	36.2	66.6	29300	1670	47.2	108	108
9/08-9/22	56800	530	31.4	62.0	29400	1790	45.8	104	114
DNEMB									
5/30-6/13	33500	402	11.4	58.6	12800	391	27.9	54.5	49.7
6/27-7/11	29300	272	11.0	38.2	11000	405	24.8	29.5	48.2
7/11-7/25	38500	422	15.2	42.6	14100	799	37.2	60.1	61.2
7/25-8/08	39000	476	13.8	48.3	18000	889	38.3	63.6	73.0
*8/08-8/25	38400	460	22.6	54.8	16700	1840	48.2	34.8	68.6
8/25-9/08	49600	502	35.2	48.6	25400	1380	41.2	83.4	98.0
9/08-9/22	48800	529	41.0	55.7	25800	1760	42.0	94.0	101
UPBFK									
5/30-6/13	33600	334	16.2	41.3	16800	596	33.7	53.5	87.6
6/27-7/11	32900	345	18.1	38.8	16100	642	31.6	68.2	64.2
7/11-7/25	44400	473	19.0	44.6	17900	684	41.2	63.0	76.0
7/25-8/08	38400	424	21.4	33.6	17400	833	37.0	82.2	76.0
*8/08-8/25	44900	501	32.7	42.4	23400	1270	39.8	86.6	97.6
8/25-9/08	35800	449	33.3	36.4	18600	2010	35.0	74.5	82.1
9/08-9/22	50800	533	35.2	42.9	25800	4260	49.4	95.4	95.4
DNBFK									
5/30-6/13	35000	386	14.8	43.1	15200	628	34.7	42.5	73.8
6/27-7/11	28800	463	15.1	31.4	10400	554	55.4	53.4	64.8
7/11-7/25	44600	460	15.2	46.9	19100	956	29.0	66.0	73.4
7/25-8/08	43300	458	28.1	33.4	19000	1380	33.8	61.5	80.3
*8/08-8/25	41200	476	24.4	41.4	17200	1220	29.9	56.6	63.0
8/25-9/08	49600	479	38.1	54.2	24400	1100	38.4	87.4	97.5
9/08-9/22	44800	477	48.1	52.8	27800	2690	40.6	104	125

* Substrates deployed on 8/08/90 were recovered after a 17-day incubation period rather than the standard two week period due to logistical problems.

Table 2. Metals concentrations (ppm) in sediments of the Embarras River and Brushy Fork during 1990.

Site ExposureDates	Elements Al	Ba	Co	Cr	Fe	Mn	Ni	V	Zn
UPEMB									
6/13	19800	395	<6.7	62.2	11400	760	57.5	26.0	50.2
8/08	22100	400	<6.7	57.2	15600	424	84.6	46.8	142
9/22	17200	290	<6.7	32.8	8460	377	65.3	<23.3	38.1
DNEMB									
6/13	14700	318	<6.7	44.0	17000	1090	52.6	59.0	82.6
8/08	15400	240	<6.7	48.0	4530	220	51.0	44.0	25.5
9/22	18100	320	<6.7	40.4	10100	488	40.6	64.8	49.2
UPBFK									
6/13	21300	390	<6.7	39.4	8980	446	67.2	<23.3	32.8
8/08	15300	353	<6.7	49.0	18700	2170	84.6	<23.3	114
9/22	18600	383	<6.7	37.0	17000	1010	75.8	<23.3	51.8
DNBFK									
6/13	24900	590	<6.7	43.4	22000	1140	58.0	34.0	53.4
8/08	19900	360	<6.7	39.2	11600	456	55.6	24.4	51.0
9/22	16900	352	<6.7	29.8	13200	467	53.4	<23.3	67.4

< Indicates metal concentrations below detection limits of ICP-AES.

Table 3. Mean concentrations (ppm) of potentially toxic metals in periphyton collected from 4 sites in the Embarras River and Brushy Fork during 1990. Mean concentrations for exposure periods which differ significantly ($p < 0.05$) from a given value are shown in parentheses.

Exposure	Elements						
(Period) Date	Al	Ba	Co	Fe	Mn	V	Zn
(1) 5/30-6/13	35500 (7)	399	14.2 (6,7)	14800 (6,7)	505 (7)	51.3 (7)	65.6 (7)
(2) 6/27-7/11	31500 (3,7)	375 (7)	15.8 (6,7)	13500 (6,7)	607 (7)	61.5	63.6 (7)
(3) 7/11-7/25	46300 (2)	443	16.4 (6,7)	16400 (6,7)	746 (7)	57.0	63.9 (7)
(4) 7/25-8/08	41700	463	22.0 (6,7)	18200 (7)	978 (7)	61.9	74.9
(5) 8/08-8/25	41100	478	25.1 (7)	18300 (7)	1330	61.5	72.1
(6) 8/25-9/08	44000	465	35.7 (1,2,3,4)	24400 (1,2,3)	1540	88.3	96.4
(7) 9/08-9/22	50300 (1,2)	517 (2)	38.9 (1,2,3,4,5)	27200 (1,2,3,4)	2630 (1,2,3,4)	99.4 (1,2,3)	109.0 (1,2,3)

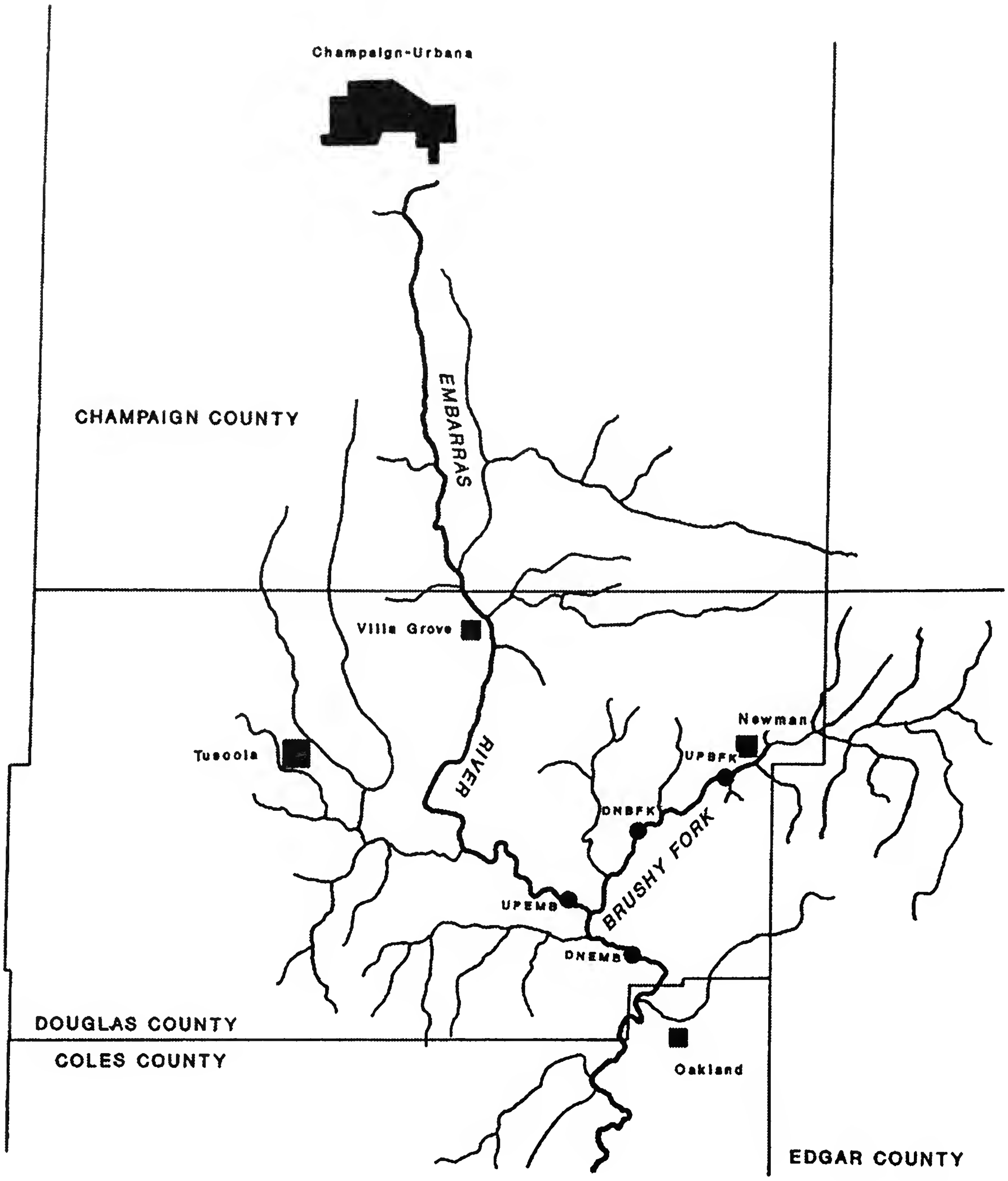
Table 4. Minimum and maximum metals concentrations (ppm) observed in sediments and periphyton of the Embarras River and Brushy Fork during 1990. Minimum and maximum metals concentrations observed in 1987 in water samples collected from Brushy Fork and the Embarras River near the mouth of Brushy Fork are from Ettinger (1989).

	Aqueous Concentration (1987)		Sediment Concentration (1990)		Periphyton Concentration (1990)	
Element	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Al	0.46	2.91	14700	24900	28800	57800
Ba	0.041	0.074	240	590	272	533
Co	---	---	<6.7	<6.7	11.4	48.1
Cr	0.005	0.006	29.8	62.2	31.4	66.6
Fe	0.57	3.47	4530	22000	10400	29400
Mn	0.082	0.464	220	2170	391	4260
Ni	<0.005	0.020	40.5	84.6	24.8	72.8
V	<0.005	0.007	<23.3	64.8	29.5	108
Zn	<0.005	<0.005	25.5	142	45.0	125

--- Indicates metals for which concentrations were not determined

< Indicates metal concentrations which were below detection limits with regard to the material tested

Figure 1. Embarras River and Brushy Fork drainage in Champaign, Edgar and Douglas Counties showing the locations of sampling sites in the Embarras River, upstream (UPEMB) and downstream (DNEMB) of the mouth of Brushy Fork, and in Brushy Fork, upstream (UPBFK) and downstream (DNBFK) of the mouth of Newman Drain #2.



Transactions of the Illinois State Academy of Science
(1996), Volume 89, 1 and 2, pp. 53-62

Characterization of Proteins from Continuous Ambulatory Peritoneal Dialysis (CAPD) Fluids

Paula D. Eason and Marjorie A. Jones
Department of Chemistry
Illinois State University
Normal, Il 61790

Key Words: Peritoneal Dialysis, Proteins, Electrophoresis

Presented in part at the 203rd Annual Meeting of the American Chemical Society, San Francisco, CA., April, 1992 and the 85th Annual Meeting of the Illinois State Academy of Sciences, Springfield, Il, October 1992.

ABSTRACT

Peritoneal dialysis fluids originally devoid of protein were collected from Continuous Ambulatory Peritoneal Dialysis (CAPD) volunteers. Dwell samples were collected in early morning, mid-day, mid-afternoon and evening. These fluids were found to contain substantial amounts of proteins (90 mg/100 ml for n = 5 patients). Following SDS-polyacrylamide gel electrophoresis, some 16 to 44 different proteins could be detected in the CAPD fluid. The number of protein bands was significantly higher in the morning dwell compared to the last dwell collected in the evening. Albumin was identified as the protein found in highest amounts for all patients. These data suggest that peritoneal dialysis places additional metabolic stresses on patients due to the movement of proteins into the peritoneal cavity from the blood.

INTRODUCTION

Kidney diseases are often life threatening and are increasingly being treated by peritoneal dialysis. However, this type of dialysis may have subsequent detrimental effects on patients and the mesothelial cells that line the peritoneal cavity may be stressed and damaged during long term peritoneal dialysis. This stress could then allow increased leakage of materials into and out of the peritoneal cavity. Peritonitis, a severe bacterial infection, is also a common consequence of peritoneal dialysis treatment. Gram negative bacteria that release lipopolysaccharide (LPS) into the peritoneal cavity as part of the infective process may have some role in further damage to the kidney. The kidney seems especially sensitive to LPS insult. However, the biochemical mechanisms by which the LPS reaches the kidney are not well understood. Mesothelial cells, which line the peritoneal cavity, are thought to form a barrier between the peritoneal cavity and the blood stream. These cells, if damaged during long term dialysis treatments, could allow increased movement of materials such as LPS from the cavity into the blood. Since LPS has such potent effects on body temperature and membrane permeability as well as a number of other physiological responses, movement of LPS from the peritoneal cavity to the blood can lead to wide spread effects.

Proteins, such as albumin, IgG, C3 and transferrin, have been reported in peritoneal dialysis fluid [1,2,3]. Concentrations of these proteins range from 1 to 50 mg/100 ml of fluid [1,3]. DeVecchi et al. (1990) reported the mean dialysate concentration of IgG was 6.9 $\pm$ 4.2 mg/100 ml with no difference between men and women and no correlation with time from the last peritonitis episode[4]. Lee et al. (1990) reported that the amount of drained protein ranged from 20 to 50 mg/100 ml fluid[5]. Kagen et al. (1990) reported that all lipoproteins (VLDL, IDL, LDL, and HDL) were present in peritoneal effluent. They also reported that HDL loss into the effluent may account for the lower HDL levels in CAPD patients[6] However, little work has been done evaluating time of day of fluid collection. We have extended these previous studies in this pilot study using Continuous Ambulatory Peritoneal Dialysis (CAPD) fluids collected from five volunteers. The amounts of total protein and the numbers of types of proteins in each fluid are reported and compared within the same patient at different times during a day and between patients for fluids collected at the same time of day.

METHODS

Unless otherwise stated, all reagents were obtained from Sigma Chemical Co., St. Louis, MO. The peritoneal dialysis fluid used (Dianeal PD-2) was obtained from Baxter Healthcare Corp., Il., Round Lake, Il. The Dianeal PD-2 contains mineral salts and glucose but is devoid of protein. The CAPD was collected from the peritoneal cavity of volunteers after 4-8 hours in vivo and frozen in aliquots at -80°C in sterile polypropylene tubes. For each patient, four dwells were collected (morning, mid-day, late afternoon, and evening). The volume of each dwell was determined using a 2 L graduate cylinder. Protein was determined by the Bio-Rad Micro Assay[7]. Five patients were evaluated whose age and sex are as follows: 22 year old female, 31 year old female, 35 year old male, 81 year old male, and 83 year old female. For each patient a CAPD volume containing 450 ug of protein was lyophilized. The resulting pellets were resuspended in 6 mM Tris-phosphate, 7% sodium dodecyl sulfate (SDS) in a final volume of 50 ul. The entire samples were loaded onto SDS polyacrylamide gels for electrophoresis. Samples were evaluated by one dimensional slab gels (9%) using the method of Laemmli[8] or by a gradient gel using the method of Anderson et al.[9] The gradient gel consisted of 3 cm of 15% acrylamide at the bottom of the gel, overlayered by 5 cm of 12%, 4 cm of 9% and 3.5 cm of 4.5% acrylamide. Preliminary work indicated better protein separation using the gradient system. Following electrophoresis, the gels were stained with 0.03% Coomassie Blue[10]. Bio-Rad Low Molecular Weight Standards were used for determination of apparent molecular weights of CAPD proteins and standard MW proteins migrated as a linear function with a correlation coefficient of 0.993. An image analyzer (Visage 100, BioImage, Ann Arbor, MI) was used to spectrophotometrically scan the gels and determine relative concentrations of proteins. For some samples, antiserum which recognizes human albumin (Sigma Chemical Company, St. Louis, MO) was used to immunoprecipitate a protein found in large amounts in the CAPD. Following incubation (overnight at 4°C) of CAPD fluid with the antiserum, the immunoprecipitate was collected using glass fiber filters. After filtration, the filters were incubated for 4 hours at room temperature in 1 ml of 30% SDS to solubilize the proteins. Both the filtrate and the retentate were lyophilized and prepared for electrophoresis as above. Data are reported as mean ± SD or SEM and were compared using analysis of variance (ANOVA) and Fisher's Least Significant Difference (LSD) post test. Differences were considered significant at $p < 0.05$. In some cases, the coefficient of variation was also calculated.

RESULTS AND DISCUSSION

Following peritoneal dialysis, the CAPD fluid contained substantial amounts of protein, approximately 90 ± 50 mg/100 ml fluid (n = 20 dwells). This value is approximately 2-3 fold higher than the values reported by Lee et al.[5] The average total volumes of each dwell was 2235 ± 328 ml (mean ± SD for 20 dwells). Therefore the average dwell contained a total of approximately 2 g of protein. This value is similar to that of Steinhauer et al. (1992) who reported total dialysate protein of 2.62 g using dialysis fluid containing glucose. They also reported that addition of amino acids (2.6%) in the dialysis fluid increased the amount of protein (about 30%) found in the dialysate[14]. Figure 1 shows the average amount of total protein per dwell relative to the sequence in which samples were collected. The dwells were in sequence with # 1 being the first dwell collected for the day and dwell #4 being the last dwell sample of the day. There was no significant difference in total amount of protein per dwell at any time of the day. This differs from the report by Kagen et al. (1990) who concluded that long dwell times (6-8 hours) result in continuous loss of protein throughout the dwell time so that an apparent equilibrium is not reached[11].

Table I shows the range of times for dwell collections for the 5 patients and average length in hours of dwell residence. Dwell sequences 1 through 4 correspond with those in Figure 1. Three of the dwell resident times were constant with an average value of 5 hours. Dwell 1 was about 38% longer since the dwell remained in the peritoneal cavity overnight.

Table I: Time of dwell collection and dwell residence

Dwell Sequence	Dwell Length (hours)*	Time of Collection (range)
#1: morning	8.2 ± 1.0[a]	5:30am - 8:15am
#2: mid-day	5.2 ± 0.3[b]	11:00am - 2:25pm
#3: late afternoon	4.8 ± 0.3[b]	3:30pm - 7:00pm
#4: night	5.1 ± 0.6[b]	8:30pm - 11:15pm

* mean ± SEM for 5 patients; values with the same letter are not significantly different at $P < 0.05$.

Figure 2 shows the average daily protein for all 4 dwells for each individual patient. Between patients there is approximately a two fold variation in the amount of protein removed during the peritoneal dialysis procedure with the values ranging from about

1.5 to 3.0 g of protein per dwell. There was no statistical difference between any of the 5 patients, between males and females or between the different age groups. The coefficient of variation (Cv)`for each patient was calculated at 0.5, 0.2, 0.4, 0.3, and 0.4 for patients # 1,2,3,4, and 5 respectively. This value is very similar for 4 of the 5 patients and the average Cv is 0.3. The source of this large variation within and between individuals is not obvious but is interesting. The data suggest that the average CAPD patient loses about 8 grams of protein per day during peritoneal dialysis.

Using SDS polyacrylamide gel electrophoresis which separates proteins by apparent MW, a number of different proteins in the CAPD were observed. The number and relative concentration of the proteins depended on the patient and time of day collected as shown in Figure 3a and b. For Figure 3a, the same volume of sample (0.5 ml) for dwell # 1 of each patient was lyopholized and then prepared for electrophoresis. Lane 1 contains the molecular weight standards. Figure 3b is the same dwell from the same patients; however, each lane contains the same amount of protein (450 ug). Lane 1 again is molecular weight markers. A comparison of these two gels shows the same relative patterns of protein bands between patients whether using a consistent amount of protein per lane or volume of CAPD fluid per lane. However, all subsequence work was done using the same amount of protein per lane so that the proportion of each protein relative to total protein applied could be estimated. Most of the same proteins as determined by relative migration distance (Rf) are seen in all 5 patients as shown in Figures 3a and b. However, some bands appear to be more prevalent than others and this observation was more evident than when the same volume of sample was applied to the gel.

One protein (Rf = 0.49) was found in such substantial concentrations that it could have masked other proteins. Using the standard curve, an apparent MW was calculated at 64,000 to 68,000 suggesting that this is serum albumin. The width of this band makes Rf determinations difficult. Immunoprecipitation with human albumin antiserum tentatively identified this protein but was not completely effective since about 30% of the human albumin was still detectable in the filtrate and 70% in the precipitate. The immunoprecipitates were not used to obtain quantitative data since the antiserum itself contributed a substantial amount of protein which was visible on gels and thereby obscured the data which we wanted to obtain. Future work might use a highly purified monoclonal antibody for the immunoprecipitation procedure.

There were five major proteins which were found in the highest proportions on the gradient gels as judged from the Image Analyzer data (Figure 3b). An overlay plot of authentic standards tentatively identified protein #1 as IgG, protein #3 as transferrin, and protein #4 as serum albumin. Proteins #2 and #5 (with apparent molecular weights of 106 and 24 kD respectively) were not identified.

To compare the number of proteins found in the CAPD fluids within and between patients, gradient gels were run using the same total amount of protein (450 ug) for each lane. The gels were scanned with the image analyzer to determine the number of bands per patient per dwell and data are show in Table II. The average number of proteins was fairly constant between patients and within a single patient. The mean number of protein bands for dwell #1 (37.6 ± 5.0) was significantly higher than dwell # 4 (28.2 ± 4.3). In dwell #4 there was an apparent decrease of about 25% in the number of detectable proteins on the gel. The large error bar found in dwell #4 in Figure 1 could be partly due to this lower detectability. Other techniques have resulted in detection by electrophoresis of at least 30 serum proteins[12].

Table II: Number Of Proteins Detected In CAPD

Patient #	Dwell #1	Dwell #2	Dwell #3	Dwell #4	Patient mean±sd
1	30	40	37	33	35 ± 4
2	38	37	38	32	36 ± 3
3	38	34	23	28	31 ± 7
4	44	24	32	25	31 ± 9
5	38	16	31	23	27 ± 10
Dwell mean± sd	38 ± 5	30 ± 10	32 ± 6	28 ± 4	

Table III represents the 5 specific proteins labeled on the gel in Figure 3b. The detectable range is from approximately 2% of the total (protein #5) to 26% of total (protein #4) protein of the lane. Of the 450 ug protein loaded, 113 ug was estimated to be protein #4 which is tentatively identified as serum albumin.

Table III: Specific proteins (1-5) as mean ± sd percent of total detected/lane/patient for 4 dwells

Patient #	Protein 1	Protein 2	Protein 3	Protein 4	Protein 5
1	4.2±0.7	8.2±1.8	2.9±0.8	23.0±4.4	1.2
2	4.7±1.8	6.2±2.0	3.0	19.7±5.3	2.1±0.1
3	4.3±1.1	6.3±4.6	4.2±2.6	29.7±9.5	1.8±0.1
4	3.2±1.3	5.1±1.5	3.6±3.3	29.9±6.9	1.7
5	4.6±1.1	6.4±1.2	3.5	26.5±13.5	2.5±0.4
Total Group mean±sd	4.2±0.6	6.4±1.1	3.4±0.5	25.8±4.4	1.9±0.5
Cv	0.14	0.17	0.12	0.12	0.26

Since the quantitative technique used here is able to detect relative amounts, this value of 26% is reasonable. Albumin accounts for some 47-60% of the total serum protein[12]. Due to the width of the gel band, we may have exceeded the linear response region of the Image Analyzer for this protein. The value of 26% is therefore likely to be an underestimate of actual amount of this protein. Also since the protein band found in this region of the gel is so large, this protein could have masked other proteins with a similar Rf but present in smaller amounts. Proteins such as HLA class I and II antigens (with MW of 50,000 and 60,000 respectively) have been reported by Gelder et al. (1990)[13].

In some cases, all protein bands were not found in every patient. For example, protein #3 was not detected in all dwells of all patients. Therefore, there is individual variation which is yet not easily correlated with other physiological or biochemical factors. These 5 proteins account for approximately 42% of the total number of individual bands on the gels. The coefficient of variations in Table III for proteins 1-4 were fairly consistent indicating a relatively small range of variability in the population. The Cv for protein #5 is larger suggesting a less consistent biological response to the stress of peritoneal dialysis. This small MW protein may represent a breakdown product.

Table IV represents the 5 specific proteins labeled on the gel in Figure 3b. There was no significant difference in the percent of each protein as a function of the time of day. However, protein #3 was only detected in one patient in dwell #4, the last dwell of the day collected. Also protein #5 was not detected in any of the patients in the last dwell. In other dwells, the average percent value of the sum of proteins #3 and #5 constitutes about 5% of the total protein loaded onto the gel. From this it is evident that even though the dwells have approximately the same total amount of protein, not all types of proteins are found in each dwell. Kagent et al. (1990) reported that higher molecular weight proteins, such as albumin and immunoglobulins, were lost into the dialysate faster than smaller molecular weight species[11].

Table IV: Specific proteins (1-5) as percent of total protein detected/lane as a mean ±sd for group/dwell

Dwell Time	Protein 1	Protein 2	Protein 3	Protein 4	Protein 5	Total
Morning	5.0±1.0	5.1±2.1	3.7±2.4	22.4±11.3	2.1±0.5	38.3
Noon	4.7±1.3	6.6±1.6	3.0±0.9	26.8±8.4	1.7±0.5	42.8
Afternoon	3.1±0.8	9.0±1.7	4.7±1.7	28.2±11.7	2.0±0.4	47.0
Night	3.9±0.9	5.2±2.5	1.9	25.6±6.2	0	36.6
Mean±sd	4.2±0.8	6.5±1.8	3.3±1.2	25.8±2.5	1.9±0.2	41.7

Peritoneal dialysis has been shown to be an important treatment for kidney failure yet it is not without long term consequences. How much of these consequences is due to the loss of protein in the dialysis fluid as well as stress of the mesothelial cells lining the peritoneal cavity is not well understood at this time. Since a substantial amount of the protein found in the peritoneal dialysis fluid is serum albumin, there clearly is a transport of protein from serum to peritoneal cavity during dialysis. Serum exudate likely accounts for some or most of the other proteins found in the CAPD fluid. The mechanism of this migration may be passive or active. The results from this study suggest that at least some of the proteins found in the CAPD are in apparent equilibrium with blood since there was no significant difference in the amount of protein per dwell with shorter (about 5 hours) or longer dwell times (about 8 hours). With longer dwell time, the coefficient of variation was smaller however. There also was no statistical difference relative to age or gender of the patients suggesting that the mechanism of translocation is common and that an apparent equilibrium between the blood and peritoneal cavity can easily be established. The average 70 kg person contains about 2.8 L of blood which is very similar to the average volume of dwell fluid (2.2 L) recovered from the 5 patients. If the movement of protein from blood to peritoneal cavity is only diffusion controlled, a larger amount of protein is predicted for the CAPD fluid at equilibrium since average serum levels of total protein range from 65-80g per L[12] and we find approximately 1.0g per L in the fluid. We calculate that about 3-4% of the total serum protein is lost per day by peritoneal dialysis patients. This may add a substantial metabolic stress to the system. Clearly, other forces are involved which specifically decrease the flux of protein from blood to CAPD or increased reabsorption through the lymphatics. This is emphasized by the observation that the last dwell of the day (#4) contained little detectable amounts of some specific proteins (# 3 and #5) as judged by electrophoresis. It is apparent that there are substantially different amounts of these two proteins later in the day relative to early dwells. Also, there was approximately 25% fewer protein bands evident by electrophoresis in the last dwell relative to the first dwell. This pilot study should now be extended to evaluate a larger population of CAPD patients to substantiate our results. A future study to determine the effects of diurnal rhythms on these two proteins or a possible transport system specific for these two proteins would be of interest. Clearly more work remains to determine the source of all of the proteins found in CAPD as well as determining the rate of specific protein influx into the CAPD. The presence of serum proteins in CAPD may stress the mesothelial cells which could result in movement of solutes from the peritoneal cavity to the blood. Further work using mesothelial cells in culture should be considered.

ACKNOWLEDGMENTS

This research was supported in part by grants from The Council of Undergraduate Research (CUR) Academic-Industrial Undergraduate Research Partnership (AIURP) Summer Fellowship and The Illinois State Academy of Sciences Research Grant (to PDE). Dr. J.T. Hjelle, Dept. of Basic Sciences, University of Illinois College of Medicine at Peoria, Peoria, Il 61656 generously provided the CAPD fluids. The work by Kevin Steidley and Mark Welsh in collecting and storing the CAPD is gratefully acknowledged.

REFERENCES

1. Holmes C., Lewis S. Host defense mechanisms in the peritoneal cavity of continuous dialysis ambulatory patients. 2. Humoral defenses. Peritoneal Dialysis Int 1991;**11**:112-17.
2. Krediet RT, Struijk DG, Koomen GC, Hoek FJ, Arisz L. The disappearance of macromolecules from the peritoneal cavity during continous ambulatory peritoneal dialysis (CAPD) is not dependent on molecular size. Peritoneal Dialysis Int 1990;**10**:147-52.
3. Young GA, Taylor A, Kendall S, Brownjohn AM. Longitudinal study of proteins in plasma and dialysate during continuous ambulatory peritoneal dialysis (CAPD). Peritoneal Dialysis Int 1990;**10**:257-61.
4. DeVecchi AF, Kopple JD, Young GA, Nolph KD, Vonesh EF, Castelnovo C, Dichiro J, Nissenson A, Brownjohy AM, Prowant B, et al. Plasma and dialysate immunoglobulin C in continuous ambulatory peritoneal dialysis patients: a multicenter study. Am J Nephrol 1990;**10**:451-6.
5. Lee HD, Park MS, Chung SH, Lee YB, Kim KS, Hwang SD, Moon C. Peritoneal solute clearances in diabetes. Peritoneal Dialysis Int 1990;**10**:85-88.
6. Kagen A, Bar-Khayim Y, Schafer Z, Fainaru M. Kinetics of peritoneal protein loss during CAPD. Kidney Int 1990;**37**:980-90.
7. Bradford M. A rapid method for quantitation of microgram quantities of protein utilizing the principle of protein-dye binding. Analyt Biochem 1976;**72**:248-54.
8. Laemmli U.K. Cleavage of structural proteins during the assembly of the head of bacteiophage T4. Nature 1970;**227**:680-85.
9. Anderson TL, Olson GE, and Hoffman LH. Stage-specific alterations in the apical membrane glycoproteins of endometrial epithelial cells related to implantation of rabbits. Biol Reprod 1986;**34**:701-20.
10. Fairbanks G, Steck TL, Wallach DFH. Electrophoretic analysis of the major prolypeptides of the human erythrocyte membrane. Biochemistry 1971;**10**:2606-17.
11. Kagan A, Bar-Khayim Y, Schafer Z, Fainaru M. Kinetics of peritoneal protein loss during CAPD: I. Different characteristics for low and high molecular weight proteins. Kidney Int 1990; **37**:971-9.
12. Diem K, Lentner C. (eds) 1973. Scientific Tables. 7th Edition. Ciba-Geigy, Basle, Switzerland.
13. Gelder FB, McDonald JC, Landreneau MD, McMillan RM, Aultman DF. Identification, characterization, and quantitation of soluble HLA antigens in the circulation and peritoneal dialysate of renal patients. Ann Surg 1991;**213**:591-7.
14. Steinhauer HB, Lubrich-Birkner I, Kluthe R, Baumann G, Schollmeyer P. Am J Nephrol 1992;**12**:61-7.

Figure 1. Average mg protein/dwell for 5 patients as a function of time. Error bars are the SEM values.

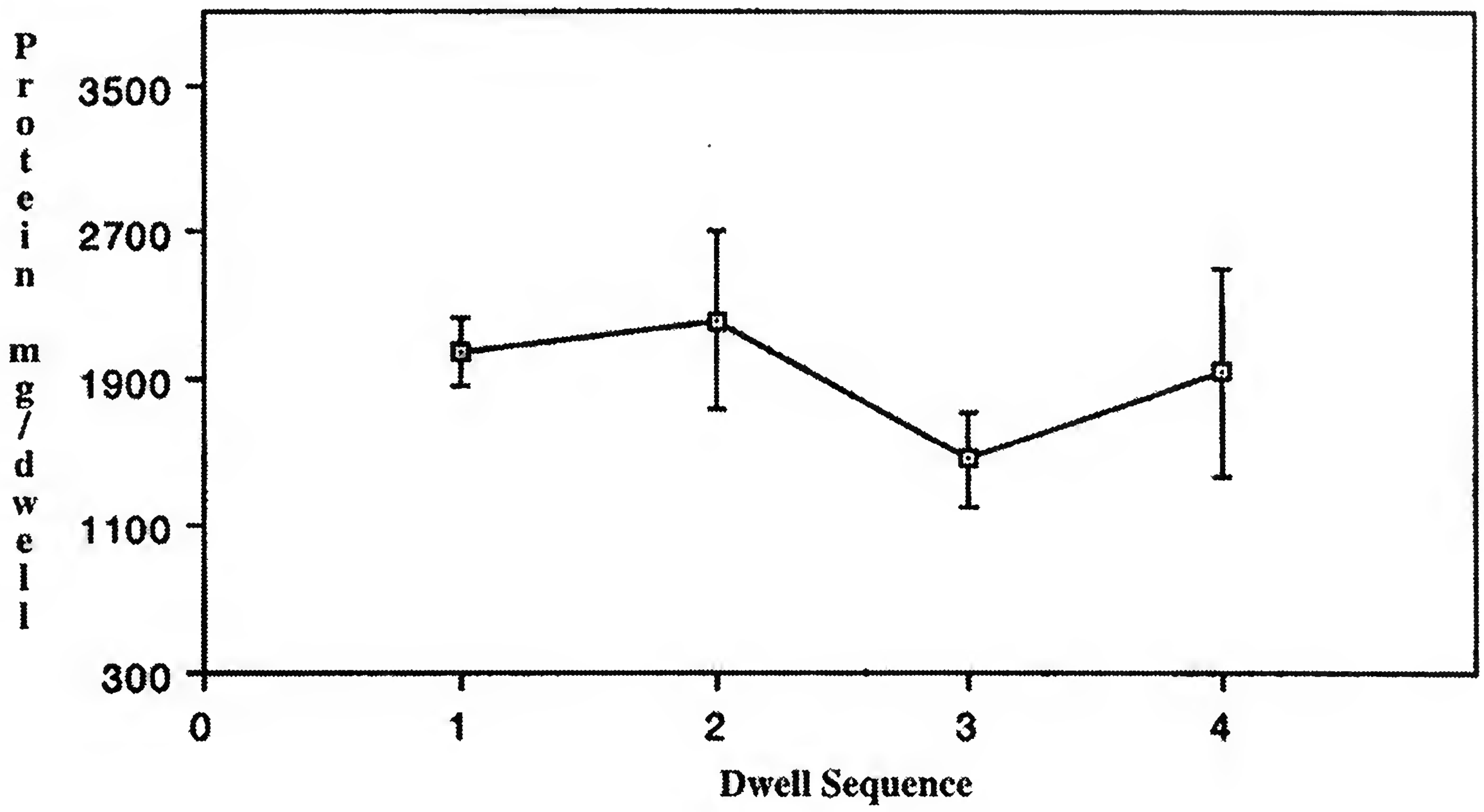


Figure 2. Average daily protein for all 4 dwells for each individual patient is shown. Error bars are the SEM values.

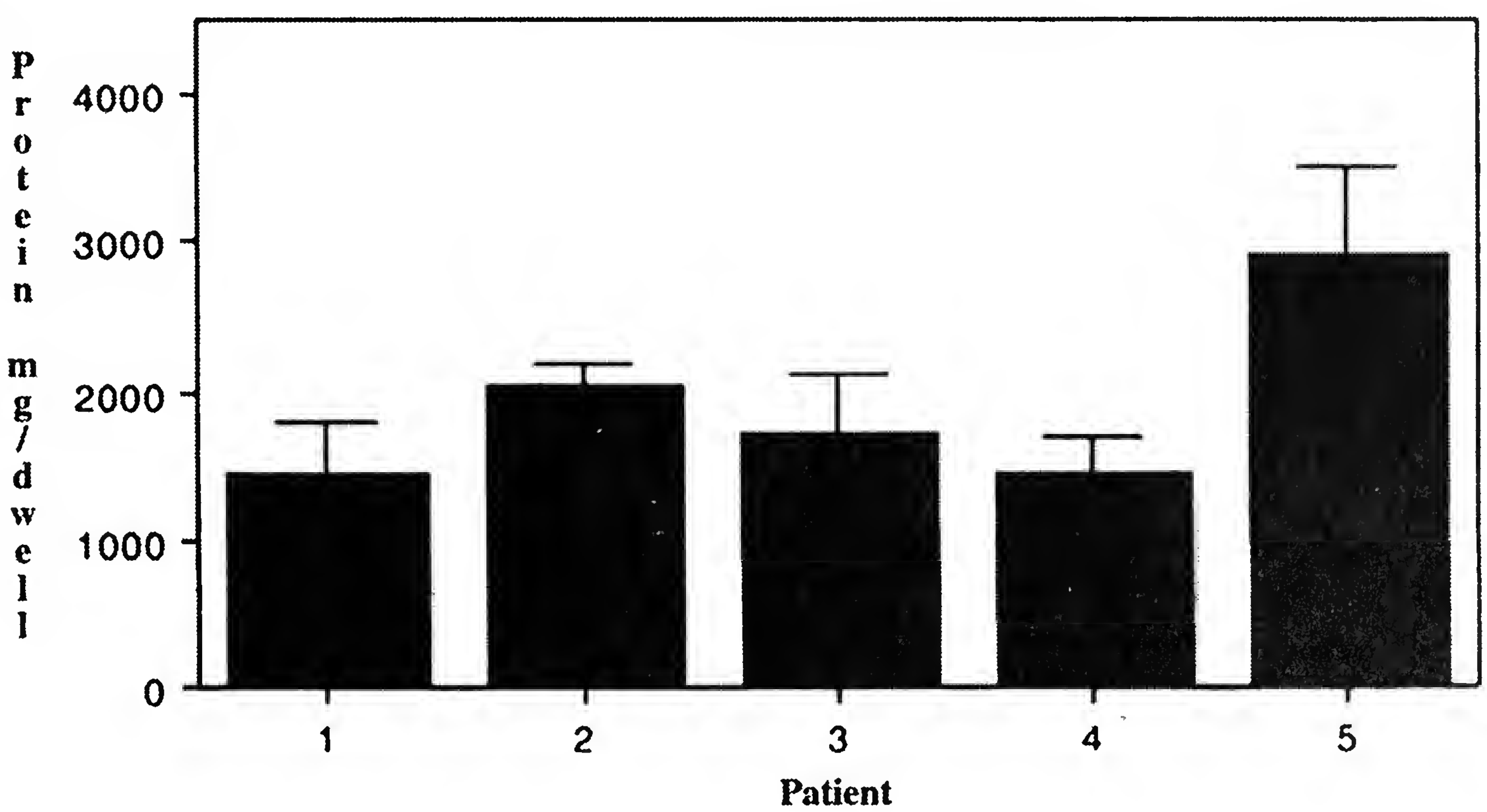
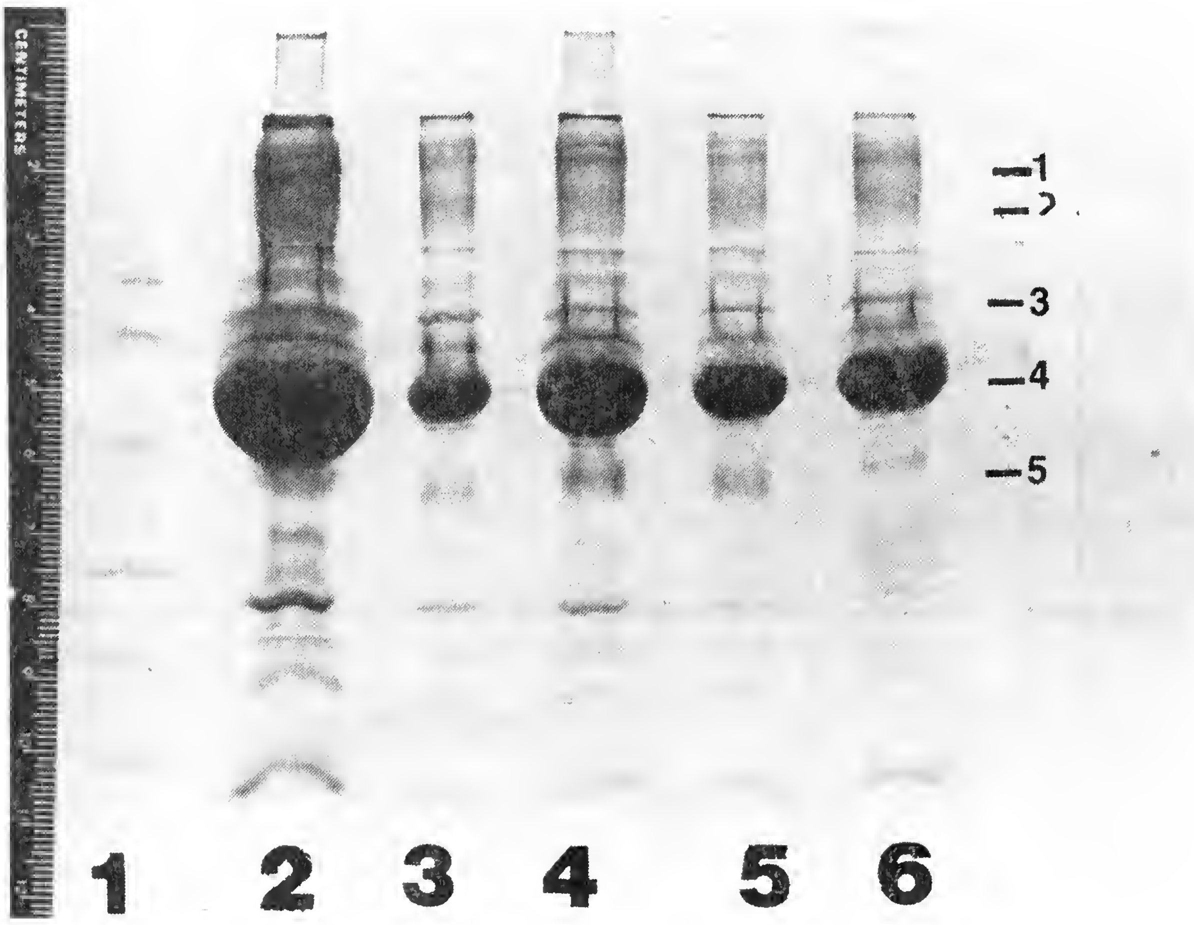
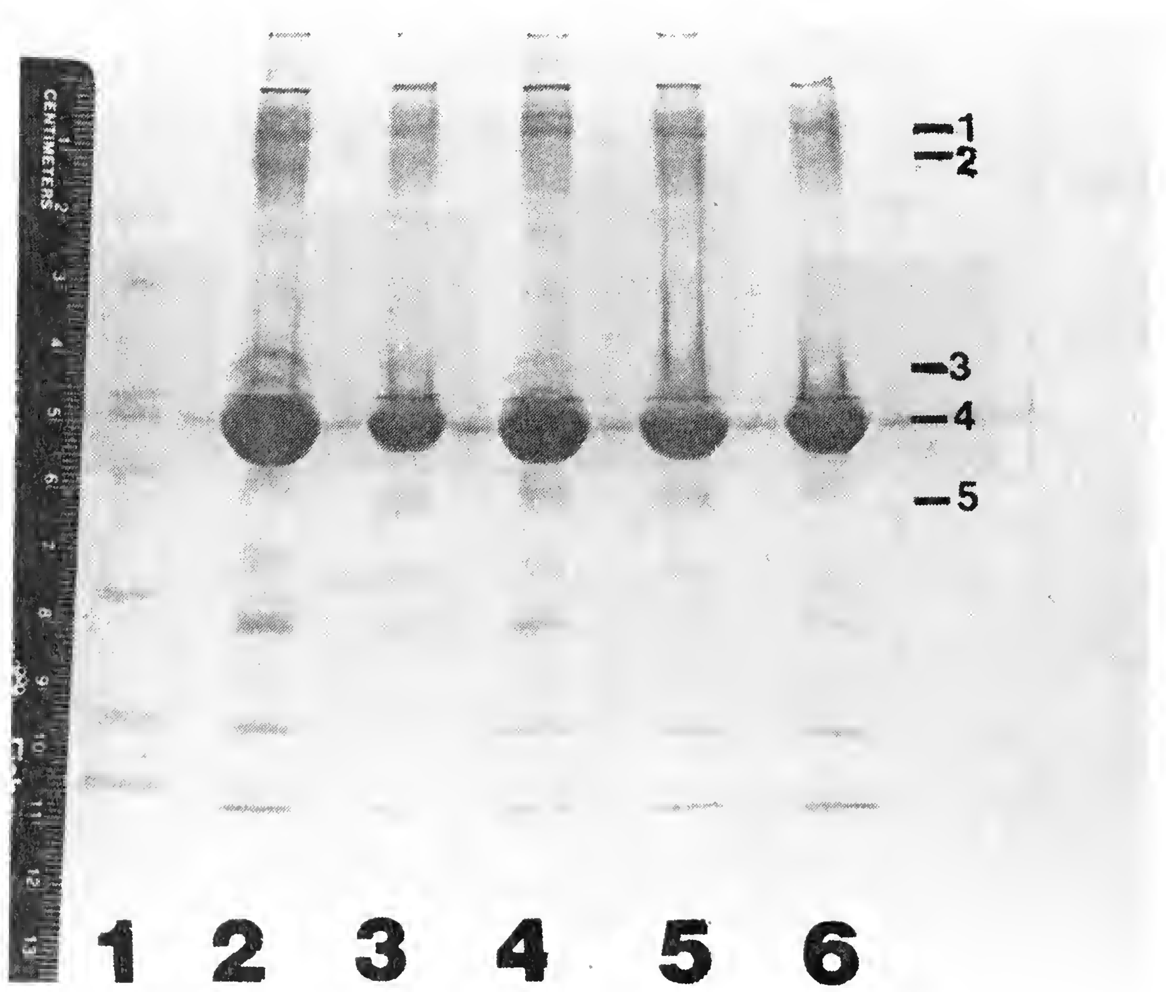


Figure 3. a) A representative gel showing protein profiles from all 5 patients using the same dwell and using the same volume of CAPD fluid per lane. Lane 1 is MW standards. Lanes 2-6 are from patient number 1,2,3,4,and 5 respectively



b) A representative gel showing protein profiles from all 5 patients using the same dwell and using the same amount of CAPD protein per lane. Lane 1 is MW standards. Lanes 2-6 are from patient number 1,2,3,4,and 5 respectively



Transactions of the Illinois State Academy of Science
(1996), Volume 89, 1 and 2, pp. 63-71

Modelling Deer Harvest Alternatives in Indiana

Louis C. Bender[1]
Division of Fish and Wildlife
Indiana Department of Natural Resources
300 West First Street
Bloomington, Indiana 47403

and

Gary J. Roloff
Boise-Cascade Corporation, Timberland Resources
One Jefferson Square
P.O.Box 50
Boise, Idaho 83728

[1]Present address
Washington Department of Wildlife
5405 NE Hazel Dell Avenue
Vancouver, Washington 98663

ABSTRACT

To assess strategies for increasing trophy buck production, we used Indiana's deer population management model, which follows the dynamics of each distinct sex and age cohort, to model alternative deer population management strategies. Harvest strategies modeled included (1) aselective buck harvest, (2) limited buck harvest with emphasis on yearlings, and (3) 2-point or better buck harvests; each strategy was modeled using four different buck:doe ratios. Trophy management strategies increased the numbers of older age-class bucks, at the expense of overall harvest. Harvest strategies aimed solely at providing certain age-class harvest percentages, popular among trophy management adherents, provide little insight into the true age structure of the population being harvested.

INTRODUCTION

Trophy white-tailed deer (*Odocoileus virginianus*) management is becomingly increasingly popular among hunting groups (Fleming 1983, Weigand and Mackie 1987, Carpenter and Gill 1987, Langenau 1988). Many midwestern states utilize sex-age-kill (SAK) or other population reconstruction models, in which the annual yearling buck harvest percentage (AYBP) is used as an indicator of buck population structure (Lang and Wood 1976, Creed et al. 1978, Gladfelter 1980). In an age-stable, stationary population, the AYBP equals the overall annual buck mortality rate; thus, population managers use this value to determine how intensively the buck population is being harvested. Since the AYBP is an indicator of buck survival into older age-classes, it is popularly used to assess the trophy potential of a population as well (J. Stahl, Indiana Whitetail Lobby, pers. commun.).

In Indiana, dissatisfaction has been expressed over the age-structure of the buck white-tailed deer harvest, and the numbers of older age-class bucks in the herd. Trophy management adherents favor population management strategies which they believe increase the proportion of bucks in the population in general, and older age-class bucks in particular. In Indiana, such groups espouse a "65% rule", believing that if the AYBP exceeds 65%, too few older age-class bucks are present in the population (J. Stahl, Indiana Whitetail Lobby, pers. commun.). Most Indiana deer management units exceed this value.

Modelling allows the evaluation of differing harvest strategies on deer demographics. Deer population management requires knowledge of both herd numbers and sex and age structure to accurately predict the effects of harvests on the deer population. Indiana's deer population model allows the tracking of individual sex and age cohorts. We used Indiana's deer population model to assess total harvest and buck age structure under the current (~37 bucks per 100 does) and three alternative (50, 75, and 100 bucks per 100 does) buck:doe ratios using three buck harvest strategies. Our objective was to evaluate trophy buck production under the various harvest scenarios.

METHODS

Population Modelling
The dynamics of Indiana's deer herd are modelled using the computer simulation model Pop-II, Version 6.03 (Fossil Creek Software, Ft. Collins, CO) (Bartholow 1986). Pop-II is an accounting model which follows each sex- and age-class individually. Initial inputs of Pop-II include sex-specific initial population age-structure, age-, sex-, and season-specific mortality rates, and age-specific natality rates (Table 1). Additional information which can be added to the model include annual sex- and age-specific harvests, sex- and age-specific harvest efforts, and an environmental severity index. Pop-II models population dynamics for each individual sex- and age-class based on a biological year, beginning just after fawn drop, using the formula:

$$P_{N+1} = P_N - M_S - M_H - M_W + R,$$

where P_{N+1}=population the following June, P_N=current June population, M_S=summer mortality, M_H=harvest mortality, M_W=winter mortality, and R=recruitment. The model begins at the start of the biological year (approximately early June for Indiana deer) and proceeds with the following steps (from Bartholow 1986): (1) subtraction of age- and sex-specific pre-harvest mortality (e.g., poaching, predation, accidents, disease, and emigration. This period follows from just after fawn drop until the hunting season); (2) subtraction of harvest mortality (including a pre-selected wounding loss); (3) subtraction of age- and sex-specific post-harvest mortality (e.g., starvation, accidents, predation, poaching, disease, and emigration. The postseason period covers the time from the end of the hunting season to immediately prior to fawn drop, late May through early June); and (4) addition of recruitment based on age-specific natality rates. The final model step is to advance all surviving individuals 1 age-class and place the recruitment into the initial age-class.

Mortality and natality rates (Table 1) used in Indiana's model were derived from consultation with regional deer biologists and by iteration. Consultations were used to select a range of possible rates. Iteration was used to fine tune these rates until the model provided the best fit to observed herd parameters. Harvest check station age data were used to derive the proportion of yearling and adult deer in the harvest, and this was extrapolated to the population. Adult buck:doe ratios were derived from comparison of yearling buck and doe harvest percentages (Creed et al. 1978). Adult deer were partitioned into individual age-classes based on herd age structure data collected from Indiana Department of Natural Resources biological check stations.

Alternative Management Simulations

The relative-effort- value option of Pop-II allows the simulation of differing harvest strategies. Effort values allow the partitioning of the harvest among different age-classes. We modeled a hypothetical deer population with a constant post-harvest population of 1000 individuals under a variety of differing management scenarios. Management options modeled included (1) maintaining current herd mean sex and age parameters (post-harvest herd ratios of ~37 adult bucks per 100 adult does, and ~135 fawns per 100 adult does), (2) increasing the relative proportion of adult bucks in the population (to post-harvest levels of 50, 75, and 100 per 100 adult does, respectively), and (3) subjecting the above populations to 3 differing buck harvesting strategies: The current strategy, with harvest proportional to age-class numbers (C strategy); a "trophy only" strategy, with increased effort on age-class 2.5 and older bucks (T strategy); and a "yearling" strategy, with heavy emphasis on yearling buck harvest and decreased vulnerability to harvest among older age-class bucks (Y strategy) (Table 2). Each management scenario modeled was projected for 13 years, and compared in terms of (1) base population (post-fawning) necessary to sustain a post-harvest population of 1000 deer, (2) sustained yield, (3) harvest percentages, and (4) harvest and population age-structure.

RESULTS AND DISCUSSION

Increasing the proportion of bucks in the population resulted in declining harvests (from 6-26%) and decreased production as the relative proportions of does declined in the populations (Table 3). Concurrently, buck age-structure was shifted upward, resulting in increased numbers of older (age 4.5 and up) age-class bucks and hence greater "trophy buck" production from the population (Tables 4-5). Managing for increased proportions of adult bucks in the population can result in increased trophy buck production, but at the expense of reduced overall deer harvest and hunting opportunity.

In the above, hunter effort was assumed to be independent of deer age-class. However, as trophy animals become more common, and hunter access more limited, increased hunter selection is focused on the trophy animals in the population (Bender

1992, Langenau 1988). Simulations evaluating the effects of age-specific harvest using 3 alternative buck harvesting strategies demonstrate that trophy production from a harvested population can vary greatly with hunter selectivity (Tables 4-5). Also, as often demonstrated in the field, systems aimed at producing trophy animals by protecting younger age-classes (strategy T) usually fail to increase the numbers of trophy animals in a population (Carpenter and Gill 1987, Hernbrode 1987, Weigand and Mackie 1987). Conversely, trophy management systems aimed at harvesting a large percentage of the younger, more vulnerable animals, thereby increasing survival probabilities for mature animals (strategy Y), are often very effective in producing older age class individuals (Fleming 1983, Ueckermann 1987, Bender 1992). Strategy C, where harvest is proportional to numbers in an age-class, is seldom observed in populations with large numbers of trophy animals; exceptions include intensively managed European red deer (*Cervus elaphus*) populations (Ueckermann 1987). In these populations, harvest is apportioned by age-class via selective culling of animals with inferior inherent antler development qualities.

Finally, a common belief among many trophy-oriented deer hunting constituents is that the AYBP in the harvest is a good indicator of the trophy quality of the herd. In Indiana, such groups espouse a "65% rule," believing that as the percentage of yearlings in the antlered buck harvest exceeds 65%, too few older age-class bucks are present in the population, while below 65%, adequate numbers are present. Several shortcomings are present in this argument. Firstly, the argument holds merit only if harvesting is proportional to herd age-structure. However, as older age-class bucks become more common in populations, harvest pressure tends to shift to these older age-classes unless otherwise regulated (i.e., a C strategy will shift to a T strategy simply by changes in hunter behavior). This change in hunter behavior actually results in fewer trophy animals being present in a population until a 1:1 adult sex ratio is approached. However, T strategies show significantly lower yearling buck harvest percentages than C strategies, despite producing fewer trophy age-class animals (T strategies do produce the greatest overall numbers of ≥2.5 year old bucks, however) (Tables 3-5). Type Y strategies, in contrast, have the highest yearling buck harvest percentages, yet produce the greatest numbers of trophy age-class deer until a 1:1 adult sex-ratio is approached. Thus, population management strategies focusing on yearling buck harvest percentages alone are simplistic, being tied to a critical assumption that is often violated as a population shifts towards increasing older-age class animals. Focus on yearling buck harvest percentage alone does not provide any confident insights into the buck age structure present in a deer population.

CONCLUSIONS

Buck harvest strategies aimed at increasing buck:doe ratios can result in increased proportions of older age-class bucks, but only at the expense of decreased population production and hunting opportunity. Despite popular belief, yearling buck harvest percentages tell little about the age structure of the buck population being harvested, especially as the proportion of bucks in the population increases. Harvest strategies aimed solely at providing certain yearling buck harvest percentages, without concurrent evaluation of hunter selectivity, have little biological basis as a legitimate white-tailed deer population management tool.

ACKNOWLEDGEMENTS

Funding for this projected was provided by the Indiana Department of Natural Resources, Division of Fish and Wildlife, through Pittman-Robertson Project W-26-R-23 (13B). We thank John Olson, Jim Mitchell, and Lou Cornicelli, IDNR, for their contributions to this project.

LITERATURE CITED

Bartholow, J. 1986. POP-II system documentation. Fossil Creek Software, Ft. Collins, CO. 59pp.

Bender, L.C. 1992. The Michigan elk: Ecology of a heavily exploited population. Ph.D. Dissertation, Michigan State Univ., East Lansing. 199pp.

Carpenter, L.H., and R.B. Gill. 1987. Antler point regulations: the good, the bad, and the ugly. Trans. West. Assoc. Game Fish Comm. 67:94-107.

Creed, W.A., B.E. Kohn, and K.R. McCaffery. 1978. Deer population measurements in management units. Wis. Dep. Nat. Res. Perf. Rep. No. 209. 25pp.

Fleming, K.M. 1983. Quality white-tailed deer management on an east Texas hunting club. Proc. Annu. Conf. Southeast. Assoc. Fish Wildl. Agencies 37:118-126.

Gladfelter, L. 1980. Deer population estimators in the midwest farmland. Pages 5-11 in R.L. Hine and S. Nehls (eds.). White-tailed deer population management in the north central states. North Central Section, The Wildl. Soc.

Hernbrode, B. 1987. Elk harvest management--meeting the challenges of quantity and quality. Trans. West. Assoc. Game Fish Comm. 67:88-93.

Lang, L.M., and G.W. Wood. 1976. Manipulation of the Pennsylvania deer herd. Wildl. Soc. Bull. 4:159-165.

Langenau, E. 1988. Managing Michigan deer herds for trophy bucks. Mich. Dep. Nat. Res. Wildl. Div. Rep. No.3080. 16pp.

Ueckermann, E. 1987. Managing German red deer (*Cervus elaphus* L.) populations. Pages 505-516 in C.M. Wemmer (ed). Biology and management of the Cervidae. Smithsonian Institute Press, Washington D.C.

Weigand, J.P., and R.J. Mackie. 1987. What's working and what's not: an overview to approaches to management for quality hunting. Trans. West. Assoc. Game and Fish Comm. 67:69-76.

Table 1. Initial inputs of Indiana's generalized Pop-II deer population model.

AGE	Population Proportions M	Population Proportions F	Preseason Mortality M	Preseason Mortality F	Postseason Mortality M	Postseason Mortality F	Young per 100 Does
0.5	0.251	0.206	0.15	0.15	0.11	0.11	68
1.5	0.135	0.118	0.07	0.07	0.11	0.11	174
2.5	0.051	0.082	0.07	0.07	0.11	0.11	195
3.5	0.006	0.044	0.07	0.07	0.11	0.11	195
4.5	0.004	0.032	0.07	0.07	0.11	0.11	195
5.5	0.002	0.014	0.07	0.07	0.12	0.12	195
6.5	0.002	0.012	0.07	0.07	0.13	0.13	195
7.5	0.001	0.010	0.07	0.07	0.14	0.13	195
8.5	0.001	0.009	0.07	0.07	0.15	0.15	195
9.5	0.001	0.007	0.07	0.07	0.17	0.17	195
10.5	0.001	0.006	0.07	0.07	1.00	1.00	---

SEX RATIO AT BIRTH: 110 MALES PER 100 FEMALES

Table 2. Relative effort values used to mimic differing hunter selectivity using Pop-II's hunter effort option.

	Harvest strategy					
	C (Aselective)		T (Trophy)		Y (Yearling)	
AGE	M	F	M	F	M	F
0.5	1	1	1	1	1	1
1.5	1	1	1	1	2	1
2.5	1	1	2	1	1	1
3.5	1	1	2	1	1	1
4.5	1	1	2	1	1	1
5.5	1	1	2	1	1	1
6.5	1	1	2	1	1	1
7.5	1	1	2	1	1	1
8.5	1	1	2	1	1	1
9.5	1	1	2	1	1	1
10.5	1	1	2	1	1	1

Table 3. Comparisons among alternative harvest simulations. Simulations were based on a post-harvest population size (after pre-season natural mortality and harvest mortality) of 1000 deer at the herd sex- and age-compositions shown. A final sex- and age-composition of 37 adult bucks per 100 adult does, and 135 fawns per 100 adult does, represents mean current conditions across Indiana.

Ratio Goal[1]	Pop Size[2]	Tot Harvest[3]	% YEAR[4]	% AB[5]
37:100:135	1639	421 (0%)	66	53
50:100:135	1603	395 (- 6%)	59	46
75:100:135	1546	350 (-17%)	49	34
100:100:135	1496	311 (-26%)	42	26

[1] Ratio Goal: Desired herd ratios immediately after harvest (# adult bucks:100 adult does: # of fawns).

[2] Pop Size: Stabilized population size immediately after fawning that produces desired herd ratio.

[3] Tot Harvest: Stabilized sustained harvest produced by simulated population. Percent difference from current strategy is shown in parentheses.

[4] % YEAR: Percent yearling bucks in simulated buck harvest.

[5] % AB: Percent adult bucks harvested.

Table 4. Population structure of a deer population with a post-harvest population level of 1000 animals and final sex- and age-structure as indicated (# bucks:100 adult does: # fawns).

	37:100:135				50:100:135			
AGE	C[1] B[2]	T B	Y B	D	C B	T B	Y B	D
0.5	393	393	393	357	375	375	375	341
1.5	231	231	231	210	221	221	221	184
2.5	79	108	56	129	91	118	68	123
3.5	27	12	30	79	38	29	38	75
4.5	9	1	16	48	16	7	22	46
5.5	3	0	9	29	6	2	12	28
6.5	1	0	5	18	3	0	7	17
7.5	0	0	2	11	1	0	4	10
8.5	0	0	1	6	0	0	2	6
9.5	0	0	1	4	0	0	1	3
10.5+	0	0	0	2	0	0	1	2

	75:100:135				100:100:135			
AGE	C B	T B	Y B	D	C B	T B	Y B	D
0.5	345	345	345	313	319	319	319	290
1.5	203	203	203	184	187	187	187	170
2.5	105	126	83	113	110	127	92	104
3.5	54	52	51	69	65	67	61	64
4.5	28	22	32	42	38	35	41	39
5.5	14	9	20	26	23	18	27	24
6.5	7	4	12	16	13	10	17	14
7.5	4	2	7	9	8	5	11	9
8.5	2	1	4	6	4	2	7	5
9.5	1	0	3	3	2	1	4	3
10.5+	0	0	1	2	1	1	3	2

[1] C=Harvest proportional to age-class (i.e. aselective); T=Harvest selective towards older age-class (trophy) bucks; Y=Harvest selective towards younger (yearling) age-class bucks.

[2] B=Numbers of bucks; D=Numbers of does.

Table 5. Harvest structure from a deer population with a post-harvest population level of 1000 animals and final sex- and age-structure as indicated (# bucks:100 adult does: # fawns).

	37:100:135				50:100:135			
AGE	C[1] B[2]	T B	Y B	D	C B	T B	Y B	D
0.5	67	67	67	61	64	64	64	58
1.5	114	85	138	46	93	66	118	44
2.5	39	80	17	28	39	71	18	27
3.5	14	9	9	17	16	17	10	17
4.5	5	1	5	11	7	4	6	10
5.5	2	0	3	6	3	1	3	6
6.5	1	0	1	4	1	0	2	4
7.5	0	0	1	2	0	0	1	2
8.5	0	0	0	1	0	0	1	1
9.5	0	0	0	1	0	0	0	1
10.5	0	0	0	0	0	0	0	0
TOTAL[3]	174	174	174	247	159	159	159	235
% YR[4]	66	49	79		59	42	74	
% TR[5]	5	0	6		7	3	8	

	75:100:135				100:100:135			
AGE	C B	T B	Y B	D	C B	T B	Y B	D
0.5	59	59	59	54	55	55	55	50
1.5	65	43	87	41	46	29	64	37
2.5	33	53	18	25	27	39	16	23
3.5	17	22	11	15	16	21	10	14
4.5	9	9	7	9	9	11	7	9
5.5	5	4	4	6	6	6	5	5
6.5	2	2	3	3	3	3	3	3
7.5	1	1	2	2	2	2	2	2
8.5	1	0	1	1	1	1	1	1
9.5	0	0	1	1	1	0	1	1
10.5+	0	0	0	0	0	0	0	0
TOTAL	133	133	133	217	111	111	111	201
% YR	49	32	66		42	26	59	
% TR	14	12	14		20	21	17	

[1] C = Harvest proportional to age-class (i.e. aselective); T=Harvest selective towards older age-class (trophy) bucks; Y=Harvest selective towards younger (yearling) age-class bucks.

[2] B = Numbers of bucks; D=Numbers of does.

[3] Total antlerless harvest (does + fawns). The other TOTAL (i.e., 133 or 111) is the number of adult bucks only.

[4] Percent yearling bucks in harvest.

[5] Percent of bucks age 4.5 or older in harvest.

Transactions of the Illinois State Academy of Science
(1996), Volume 89, 1 and 2, pp. 73-91

Nonnative Fishes in Illinois Waters: What Do the Records Reveal?

Brooks M. Burr[1], David J. Eisenhour[1], Kenneth M. Cook[1], Christopher A. Taylor[2], Gregory L. Seegert[3], Randy W. Sauer[4], and Elmer R. Atwood[4]

Department of Zoology, Southern Illinois University, Carbondale, Illinois 62901-6501[1]
Illinois Natural History Survey, Champaign, Illinois 61820[2]
EA Midwest, 444 Lake Cook Road, Suite 18, Deerfield, Illinois 60015[3]
Division of Fisheries, Illinois Department of Conservation, Hazlet State Park Office, Carlyle, Illinois 62231[4]

ABSTRACT

Recent collections (late 1980s, early 1990s) in Illinois waters demonstrate convincingly that the State's fish faunal diversity is expanding rapidly from introductions of nonnative fishes through purposeful (e.g., stockings, transplantations, release of aquarium pets) and unintentional means (e.g., release of ship ballast water, dispersal of fishes from flooded aquaculture ponds, mixed stockings), by the natural invasion of Illinois waters from stockings in other states, or by movement of fishes made possible by changing environmental conditions. Two Asian exotics (Grass Carp [*Ctenopharyngodon idella*] and Bighead Carp [*Hypophthalmichthys nobilis*]) are now established in Illinois waters and the White Perch (*Morone americana*) has dispersed rapidly and probably is now established in the state. In addition, vouchered specimens indicate a somewhat widespread but sporadic occurrence in Illinois of two other exotics, the Rudd (*Scardinius erythrophthalmus*) and Silver Carp (*Hypophthalmichthys molitrix*). Collections from 1993-1994 made in the Chicago Sanitary and Ship Canal reveal that the exotic Oriental Weatherfish (*Misgurnus anguillicaudatus*) probably is established and its occurrence there may be the result of pet releases. Recent records also indicate that southern Illinois has been invaded by the Inland Silverside (*Menidia beryllina*), almost certainly established; the Striped Mullet (*Mugil cephalus*), a largely marine species spreading northward in the Mississippi River from the Gulf Coast; the Pirapatinga (*Piaractus brachypomus*), a neotropical exotic probably being released by disregarding hobbyists; and the Goldfish (*Carassius auratus*), now common in southern Illinois after the recent flooding of the Mississippi River. The Rainbow Smelt (*Osmerus mordax*) continues to be collected in the Mississippi River of southern Illinois, although somewhat more sporadically than in previous years.

INTRODUCTION

The history of introductions of nonnative fishes into Illinois waters mirrors the general history of introductions into North America. The Goldfish, *Carassius auratus*, was probably the first exotic fish to be introduced into North America (late 1600s). It was also the first nonnative species reported from Illinois (Nelson 1876), although it was not considered established until many years later (O'Donnell 1935). The only known established exotic in Illinois at the time the first "Fishes of Illinois" was completed was the Common Carp, *Cyprinus carpio* (Forbes and Richardson 1908). By the late 1970s, six nonnative species were known to be reproducing (i.e., established) in Illinois waters (Smith 1979). Since Smith's (1979) survey of Illinois fishes, in which 13 species were considered to be nonnative, an additional seven species have become a part of the State's fish fauna either by accidental or purposeful introduction or by recent invasion of Illinois waters from both more southern or northern latitudes (Burr 1991). Because fish introductions into Illinois waters clearly have accelerated in recent years, documentation of the current status of several species is warranted. The potential ecological effects of nonnative fishes on native aquatic communities include habitat alterations (e.g., removal of vegetation); degradation of water quality; introduction of parasites and diseases; trophic alterations (e.g., increased predation, competition for food resources); hybridization; and spatial interactions (e.g., overcrowding, competition for spawning sites) (Taylor et al. 1984). On the positive side, the Asian carps reach large sizes and are a potential food source, especially for commerical markets; their potential as sportfishes is dubious.

Since the most recent review (Burr 1991) of nonnative fishes in Illinois, Johnston (1991) has provided records of the Threespine Stickleback (*Gasterosterus aculeatus*) in the Lake Michigan drainage; Page and Laird (1993a) and Laird and Page (in press) provided a summary and key to the identification of nonnative fishes in Illinois; Raibley et al. (1995) demonstrated reproduction of Grass Carp (*Ctenopharyngodon idella*) in the Illinois and upper Mississippi rivers; and in the gray literature, Raibley (1995) and the Long Term Resource and Monitoring Program at the Havana Field Station (1993) reported records for the White Perch (*Morone americana)* and the Grass Carp (*Ctenopharyngodon idella*) from the Illinois River and documented their probable establishment in Illinois. Reports of the Round Goby (*Neogobius melanostomus*) and presumably the Tubenose Goby (*Proterorhinus marmoratus*) as abundant in the Illinois waters of Lake Michigan have appeared recently on the national news and as major articles in Chicago newspapers. Both species are native to the Black and Caspian seas and apparently were introduced with ballast water into the Great Lakes (Robins et al. 1991). The Oriental Weatherfish (*Misgurnus anguillicaudatus*), an exotic ornamental fish, commonly kept in home aquaria and backyard ponds, is apparently established in streams of northeastern Illinois (Page and Laird 1993a,b; this report). The status of the Ruffe (*Gymnocephalus cernuus*), an additional European exotic introduced with ballast water into the Great Lakes and now established in Wisconsin and Minnesota, is uncertain in the Illinois portion of the Lake Mighican drainage.

The objectives of this paper are to: 1) document the relatively recent invasion and circumstantial evidence for reproduction in both the Grass Carp (*C. idella*) and the Bighead Carp (*Hypophthalmichthys nobilis*) in the inland waters of Illinois; 2) record the rapid 5-year dispersal and spread of the White Perch (*M. americana*) from Lake Michigan to Horseshoe Lake and its almost certain establishment in Illinois; 3) provide voucher records of the Striped Mullet (*Mugil cephalus*), a largely marine species, in Illinois waters; 4) provide vouchered records for the occurrence of the Oriental Weatherfish (*M. anguillicaudatus*) in the Chicago region and note the species' probable establishment there; 5) document the recent post-flood invasion of Goldfish (*C. auratus*) into southern Illinois; 6) provide the first records of the exotic Pirapatinga (*Piaractus brachypomus*), a neotropical characoid, in southern Illinois; 7) note the occurrence of several introductions of the Rudd (*Scardinius erythrophthalmus*), an exotic native to Europe, not yet known to be established in Illinois; 8) provide evidence for the recent abundance and reproduction of the Inland Silverside (*Menidia beryllina*) in the Ohio and Mississippi River drainages of Illinois; 9) note the beginnings of probable establishment of the Silver Carp (*Hypophthalmichthys molitrix*) in Illinois; and 10) call attention to the continued persistence during the winter of the Rainbow Smelt (*Osmerus mordax*) in the Mississippi River.

METHODS AND MATERIALS

Records are based on collections made by the authors or collections deposited at the Illinois Natural History Survey (INHS), Southern Illinois University at Carbondale (SIUC), and a reference collection maintained at EA Midwest. Collections were made using 10 or 20 foot minnow and bag seines and (rarely) a boat-mounted electofishing unit and gill nets. Measurements are in mm standard length (SL) unless otherwise indicated. Most records reported here are from the late 1980s and early 1990s and are meant to demonstrate the rapid invasion that often occurs once a nonnative species gains access to continuous drainage systems. The use of common and scientific names of fishes follows the recommendations of Robins et al. (1991). Species accounts include catalog number, locality (legal locality in parentheses when available), major drainage (in parentheses), county, date of capture, and also in parentheses the number of specimens followed by their range in SL. Genera and species are treated alphabetically within the general phylogenetic scheme presented by Robins et al. (1991).

We have endorsed here the use of the term nonnative to encompass any fish species that is either an exotic, a transplant, or a recently invading species from outside of Illinois. Terminology and definitions associated with nonnative fishes follow Shafland and Lewis (1984) and Hocutt (1985).

RESULTS

Goldfish
Carassius auratus
SIUC 22651 (4, 113.0 - 131.0 mm), pool (Old Clear Creek channel) at culvert (Clear Cr. Dr.) on Tamms Rd., 1.5 mi. E McClure (T14S, R3W, Sec. 11NW), Alexander Co., 11 November 1993; SIUC 22609 (2, 121.0 - 149.0 mm), ditch adjacent to Clear Creek levee (Mississippi R. Dr.), 1.5 mi. NNW Gale (T14S, R3W, Sec. 27SW), Alexander Co., 4 December 1993; SIUC 22626 (3, 106.1 - 111.0 mm), ditch (Clear Cr. Dr.) next to road, 2.0 mi. SE McClure (T14S, R3W, Sec. 22SW), Alexander Co., 4 December 1993; SIUC 22918 (2, 111.8-124.9 mm), Mississippi River (Gulf of Mexico Dr.), at Grand Tower, Devil's Backbone Park (T10S, R4W, Sec. 23SE), Jackson Co., 24 February 1994; SIUC 22959 (12, 100.0-132.00 mm), Mississippi River (Gulf of Mexico Dr.), at Grand Tower aerial pipeline crossing (T10S, R4W, Sec. 23SE), Jackson Co., 23 April 1994; SIUC 24527 (1, 86.5 mm), Horseshoe Lake spillway (Cache R. Dr.), 1.0 mi. E of Miller City (T16S, R2W, Sec. 21NE), Alexander Co., 19 July 1995.

Remarks: Smith (1979) recorded the exotic *C. auratus* as common, especially in the Illinois River drainage, but had no records of the species from southern Illinois, although Gunning (1954) captured a specimen from Horseshoe Lake, Alexander County, in 1953 (SIUC 13962). Sporadic occurrences of the species are reported from western Kentucky (Burr and Warren 1986) and southern Missouri (Pflieger 1975). Numerous recent specimens appeared in our collections from various points in southwestern Illinois following the receding floodwaters of 1993, demonstrating that a number of source pools are now available in the area. All specimens were wild type in color and morphology and almost certainly do not represent the recent release of aquarium stock. It is likely the species invaded southern Illinois with the 1993 flood and took advantage of shallow flooded fields for reproduction and recruitment.

Grass Carp
Ctenopharyngodon idella
SIUC 21436 (4, 38.9 - 75.7 mm), Horseshoe Lake spillway [west side ditch] (Cache R. Dr.), 1.0 mi. E of Miller City (T16S, R2W, Sec. 21NE), Alexander Co., 17 April 1993; SIUC 22956 (1, 307 mm), Horseshoe Lake (Cache R. Dr.), west arm and near dam (T16S, R2W, Sec, 21NE), Alexander Co., 13 April 1994; SIUC 24458 (1, 32.8 mm), Horseshoe Lake spillway (Cache R. Dr.), 1.0 mi. E of Miller City (T16S, R2W, Sec. 21NE), Alexander Co., 14 June 1995; SIUC 24528 (1, 106.0 mm), same location as SIUC 24458, 19 July 1995; SIUC 23044 (2, 244-276 mm), Lake Creek (Cache R. Dr.), at Illinois Hwy. 3/127 crossing (T16S, R2W, Sec. 13), Alexander Co., 11 September 1994; SIUC 19962 (15, 12.6 - 29.6 mm), Cache River (Ohio R. Dr.), just E of jct. Hwy. 3 & 127, 1.5 mi. S Unity (T16S, R16E, Sec. 12SE), 4 August 1992; SIUC 20294 (1, 27.1 mm), Big Muddy River (Mississippi R. Dr.), at Rattlesnake Ferry (T10S, R3W, Sec. 27NW), Jackson Co., 4 August 1992; SIUC 20537 (1, 32.6 mm), Main Ditch Clear Creek (Mississippi R. Dr.), 4 mi. NNE Gale (T14S, R3W, Sec. 27NE), near mouth of Sexton Creek, Alexander Co., 20 September 1992; SIUC [pharyngeal arches examined and returned], Kaskaskia River, Pelican Pouch, about 4 mi. SSW Carlyle (T2N, R2W, Sec. 31), Clinton Co., summer 1991; SIUC 23897 (1, 49.6 mm), Mississippi River (Gulf of Mexico Dr.), Pool 25, Cockerill Hollow Access at Batchtown, RM 243.5, Calhoun Co., 11 September 1993.

Remarks: *Ctenopharyngodon idella*, a native of Asia, was introduced as a means of vegetation control in 1963 into experimental ponds in Arkansas and soon thereafter into impoundments in that state. It escaped almost immediately and dispersed throughout the Missouri-Mississippi mainstem (Pflieger 1978). By 1987 it was established in the Missouri River drainage, Missouri (Brown and Coon 1991). Greenfield (1973) and Stanley et al. (1978) reviewed the literature on the biology of *C. idella* and noted that it randomly spawns in strong currents of large rivers, apparently in response to rising water levels. Eggs must remain suspended in current for at least two days (approximate hatching time), so long reaches of flowing water are required for successful reproduction. These conditions were apparently enhanced during the recent floodings of the Mississippi River.

For years, triploid *C. idella* have been stocked into Illinois farm ponds and some lakes (e.g., SIUC Campus Lake) in an effort to control aquatic vegetation. Commercial fishermen have been catching adults and juveniles from the Illinois portion of the

Mississippi River for over 15 years (Paul Kimmel, pers. comm.). In the gray literature, Jennings (1989) reported four post-larval specimens (6 mm total length) from the Ohio River, near RM 945, in the vicinity of Metropolis, Illinois, collected in July 1987 by personnel of Hunter Environmental Services, St. Louis, Missouri. In addition, one of us (GLS) has collected two individuals (40 mm, 685 mm) from the Ohio River near Metropolis, in 1991-1992. A majority of the vouchered specimens reported here represent recent post-hatchlings or young-of-the-year and to our knowledge document the first evidence of spawning and recruitment of the species in the inland waters (i.e., waters other than the bordering big rivers) of Illinois [probable reproduction in the Big Muddy River was noted recently by Burr and Warren (1993) and in the Illinois and upper Mississippi rivers by Raibley et al. (1995)]. IDOC personnel captured 13 adult or subadult specimens (423-558 mm TL) from the Cache River at Perks bridge (T14S, R1E, Sec. 15), Pulaski County, on 27 September 1994. Grass Carp were not captured at this station or 25 others in a 1992 Cache River survey; these individuals almost certainly represent 1993 post-flood dispersal. As judged from the collection localities, the lower reaches of four river systems (Illinois, Big Muddy and Cache rivers, Clear Creek) in southern Illinois are all serving as apparent spawning or nursery sites. Because triploid *C. idella* are presumably incapable of producing viable offspring, we conclude that big river diploid stocks are now utilizing Illinois waters for some reproduction. Since the floods of 1993 and 1994, adult *C. idella* are common in both Horseshoe Lake and its outlet, Lake Ceek, Alexander County. We captured and released numerous subadults in Lake Creek during late summer 1994. In the approximately 23 years since *C. idella* was first reported from Illinois (Smith 1979), evidence for reproduction has occurred only in the last few years, indicating a somewhat lengthy period prior to establishment, especially when compared to *Morone americana* and *Menidia beryllina.*

Staff of the Long Term Resource Monitoring Program at the Havana, Illinois, field station recently (1994) collected juvenile *C. idella* less than 30 mm long from La Grange Reach, Illinois River, Beebe Lake near Banner (RM 135.7), and Quiver Lake near Havana (RM 122.2) (Raibley 1995). A 60-mm juvenile was taken at the Reach 26 field station on the Mississippi River. Gravid females also have been collected from the Illinois River. According to Raibley (1995) and Raibley et al. (1995) ploidy testing revealed diploid individuals. With all of these records taken together, there seems little doubt that *C. idella* is firmly established in Illinois.

Aquatic macrophytes dominate the diet of subadult and adult *C. idella,* although a few studies show consumption of animal matter (Laird and Page in press). While the impact of this species in Illinois waters remains to be seen, the potential for reducing cover used by a variety of fish species is certainly a potential adverse effect. In addition, excessive removal of aquatic macrophytes from large backwaters could impact waterfowl populations and restructure forage fish communities (Bettoli 1987). On the other hand, commercial fishermen in southern Illinois report *C. idella* to be a popular food fish and markets have developed for the sale of this species.

Silver Carp
Hypophthalmichthys molitrix
SIUC 17716 (1, 465 mm), Mississippi River (Gulf of Mexico Dr.), RM 160 at Merrimac (T2S, R11W, Sec. 8), Monroe Co., 25 March 1990; SIUC 23043 (1, 470 mm), Big

Muddy River (Mississippi R. Dr.), at Rattlesnake Ferry (T10S, R3W, Sec. 27NW), Jackson Co., 15 August 1994; SIUC 23046 (1, 492 mm), Horseshoe Lake (Cache R. Dr.), (T16S, R2W, Sec, 21NE), Alexander Co., August 1994; SIUC 24415 (2, 37.7-43.5 mm), ditch at Horseshoe Lake (Cache R. Dr.), 0.25 mi. W of spillway on Promised Land Road (T16S, R2W, Sec. 21), Alexander Co., 14 June 1995.

Remarks: This carp, a native of Asia, and first introduced into Arkansas in 1973, was then raised and stocked into municipal sewage lagoons, and by the early 1980s was reported from the natural waters of that state (Robison and Buchanan 1988). Sporadic records of this fish were known in Illinois beginning in about 1983, and only occasional specimens have begun to appear in our collections and the catches of commercial fishermen. With its spongelike gill rakers, *H. molitrix* is capable of straining organisms as small as 4 microns in diameter and is apparently efficient at digesting green and blue-green algae (Robison and Buchanan 1988). Its spawning requirements are similar (i.e., spawning occurs when water rises after heavy rains) to that of *H. nobilis* and *C. idella*, and recent capture of young-of-the-year in a ditch near Horseshoe Lake is the first evidence of successful spawning in Illinois waters and the United States. Considering that both *H. nobilis* and *C. idella* are now established in Illinois and have spawning requirements similar to *H. molitrix*, it is likely that this species will become established within the next ten years. Its impact on natural fish communities and the aquatic environment in general are unknown.

Bighead Carp
Hypophthalmichthys nobilis
SIUC 21715 (1, 232 mm), Horseshoe Lake spillway (Cache R. Dr.), 1.0 mi. E of Miller City (T16S, R2W, Sec. 21NE), Alexander Co., 29 June 1993; SIUC 23042 (1, 244 mm), same location as SIUC 21715, 21 July 1994; SIUC 23045 (1, 370 mm), same location as SIUC 21715, 11 September 1994; SIUC 24414 (2, 41.4-43.0 mm), ditch at Horseshoe Lake (Cache R. Dr.), 0.25 mi. W of spillway on Promised Land Road (T16S, R2W, Sec. 21), Alexander Co., 14 June 1995. SIUC 24403 (1, 44.5 mm), trib., Lake Creek (Cache R. Dr.), at Hwy. 3 crossing (T16S, R2W, Sec. 12SW), Alexander Co., 29 June 1995; SIUC 24003 (1, 250 mm), backwater of Cache River Ohio-Mississippi R. Dr.), just E of Sandusky (T15S, R1W, Sec. 18-19), Alexander Co., March 1995; SIUC 19280 (1, 535 mm), Big Muddy River (Mississippi R. Dr.) at Hwy. 3 crossing near Aldridge (T11S, R4W, Sec. 17SW), Union Co., 23 February 1992; SIUC 19282 (1, 446 mm), Horseshoe Lake (Mississippi R. Dr.), S of Granite City (T3N, R9W, Sec. 22-27), Madison Co., April 1992; SIUC 20308 (1, 23.4 mm), Big Muddy River (Mississippi R. Dr.), at Rattlesnake Ferry (T10S, R3W, Sec. 27NW), Jackson Co., 4 August 1992; SIUC 22240 (1, 670 mm), Cache River [diversion canal] (Ohio R. Dr.), 0.5 mi. upstream from Hwy. 3 in diversion canal near confluence of Cache & Mississippi rivers (T16S, R17E, Sec. 30NE), Alexander Co., 20 April 1993; SIUC 23040 (2, 476-506 mm), Big Muddy River (Mississippi R. Dr.), just S of Murphysboro (T9S, R2W, Sec. 7SW, NE), Jackson Co., 24 June 1994 ; SIUC 23919 (1, 210 mm), Kaskaskia River (Mississippi R. Dr.), near Covington (no precise legal locality available), Washington Co., 28 February 1994.

Remarks: According to Jennings (1988) this species was first introduced into Arkansas in 1972 for use in combination with other phytophagous fishes to improve water quality and increase fish production in culture facilities. It first began to appear in open waters in the early 1980s in both the Ohio and Mississippi rivers (Jennings 1988). Probable spawning in Illinois was first documented by Burr and Warren (1993) in the lower Big Muddy River as judged from capture of a postlarval specimen (SIUC 20308). Recent capture of additional specimens representing young-of-the-year, subadults, and adults strongly suggests that reproduction and recruitment are occurring in Illinois waters. This is the most recent and rapidly invading exotic carp in southern Illinois. It appears to be using the lower reaches of the Big Muddy, Cache, and Kaskaskia rivers as spawning areas.

Additional specimens, not all vouchered in museum collections, indicate that the species may be relatively common in some southern Illinois waters. A commercial fisherman captured eight specimens (one vouchered as SIUC 22240) in the range of 13.6-18.1 kg in hoop nets on the lower Cache River in April 1993. Don Garver, IDOC District Fishery Biologist, examined and released 31 specimens ranging in total length from 427 to 594 mm and in weight from 0.86 to 2.8 kg caught by a commercial fisherman on the Big Muddy River in May 1994 (two vouchered as SIUC 23040). The fisherman had released a similar number of fish caught the previous day (he was not certain that what he caught was legal). Four adults ranging in length from 280 to 345 mm were captured and released by one of us (DJE) on two different dates in July 1994 from Lake Creek, Alexander County. Anglers have caught this species in the Kaskaskia River since 1992 and IDOC District Fishery Biologist Charlie Marbut identified a 533 mm-TL specimen in January 1994 from the tailwaters of Carlyle Lake.

Spawning of *H. nobilis* occurs in swift channels of large rivers (Jennings 1988). Flooding of lowland areas is a necessary requirement as these become the nursery areas for larvae and juveniles (Jennings 1988). These fundamental conditions and others summarized in Jennings (1988) were clearly met by the recent major flooding events in the Midwest and almost certainly account for the recent appearance of postlarvae and juveniles. The large numbers of adults appearing recently in commercial fishing harvests are presumably also related to flooding which probably redistributed adults in such a manner as to make them more accessible to fishermen. It would appear that this species is now established in Illinois waters and is capable of using the lower reaches of major Mississippi River tributaries as spawning reaches and/or nursery areas for larvae and juveniles.

The potential impact of this species is not adequately known. Markets for *H. nobilis* apparently have not become well established. Confusion over the correct identity of this species and the legality of taking this fish in commercial harvests has resulted in its consideration as a nuisance by some fishermen we have interviewed. The biological interaction of *H. nobilis* with other filter-feeding native fishes such as the Paddlefish (*Polyodon spathula*) warrants future investigation.

Rudd
Scardinius erythrophthalmus
INHS 64739 (1, 124.1 mm), Avon-Fremont Ditch (Illinois R. Dr.), at Grayslake (T45N, R10E, Sec. 26SE), Lake Co., 19 July 1988; INHS 64740 (1, 165.1 mm), Twin Lake (Fox R. Dr.), at Silver Springs State Park (T36N, R6E, Sec. 2/3), Kendall Co., 20 September 1988; INHS 28470 (3, 255.0-268.0 mm), Foli Dark Pond (Fox R. Dr.), at Plano (T37N, R6E, Sec. 27NE), Kendall Co., 15 September 1992; INHS 64430 (1, 80.0 mm),

Kankakee River (Illinois R. Dr.), 0.5 mi. N Custer Park (T32N, R9E, Sec. 13), Will Co., 1 August 1988; SIUC 22873 (1, 111 mm), Kankakee River (Illinois R. Dr.), 500 m downstream confluence with Horse Creek, E bank (T32N, R9E, Sec. 12), Will Co., 1 August 1989; SIUC 22874 (1, 121 mm), same location as SIUC 22873, 10 August 1989; INHS 65512 (1, 68.9 mm), Kankakee River (Illinois R. Dr.), 5.5 mi. ESE Ritchie (T32N, R10E, Sec. 36), Will Co., 17 May 1989; INHS 65419 (1, 82.2 mm), same location as INHS 65512, 31 May 1989; INHS 29751 (1, 175.0 mm), Des Plaines River (Illinois R. Dr.), at RM 273.3, 4 mi. S Minooka at mouth (T34N, R8E, Sec. 36NE), Grundy Co., 5 July 1990; SIUC 17614 (170, 39.7 - 58.4 mm), Carlyle Lake [bait dealer] (Kaskaskia R. Dr.), near Carlyle, Clinton Co., 21 July 1989.

Remarks: *S. erythrophthalmus* is native to Europe, Asia Minor, and interior Russia; beginning in the 1980s it underwent an explosive anthropogenic dispersal by the Arkansas fish farming industry "as a new, hardy, and colorful bait minnow" (Burkhead and Williams 1991). According to Burkhead and Williams (1991), the species has been distributed to at least 14 states and captured in the public waters of eight states. As indicated, a large number of individuals (SIUC 17614) were obtained from a bait dealer at Carlyle Lake and scattered records are available from several locations in northern Illinois beginning in 1988, with at least one record as recent as 1992 (INHS 28470). There is no evidence that this minnow is established in Illinois. The bulk of the records are of single fish, probably of subadult and adult age.

This species is primarily an inhabitant of lentic habitats and primarily occupies mid and surface waters. According to Wheeler (1969) the species is omnivorous, with adults feeding principally on insects and crustaceans, occasionally fish. Eggs are laid on submerged vegetation, along the shoreline, and on reed banks. It apparently reaches a large enough size (41 cm; 2 kg) to be popular with anglers in Europe (Wheeler 1969). Should this species become established in Illinois it will undoubtedly compete for limited resources in managed lakes, but it could provide a forage base for piscivorous sportfishes.

Oriental Weatherfish
Misgurnus anguillicaudatus
INHS 61129 (1, 113.0 mm), North Shore Channel (Lake Michigan Dr.), Dempster St., in Skokie (T41N, R13E, Sec. 14SE), Cook Co., 16 July 1987; INHS 61130 (1, 38.1 mm), same locality as INHS 61129, 19 September 1990; INHS 61131 (1, 55.5 mm), same locality as INHS 61129, 31 October 1990; SIUC 24002 (2, 131.0-138.0 mm), Chicago Sanitary and Ship Canal (Illinois R. Dr.), RM 321, Cook Co., 6 November 1994.

Remarks: *Misgurnus anguillicaudatus* is native to eastern Asia, principally northern China and Japan (Robins et al. 1991). In North America, this fish is established in several flood control channels in southern California, the headwaters of the Shiawassee River, Michigan, and the Boise River system, Idaho (Courtenay et al. 1986, Courtenay et al. 1987). One of us (GLS) has collected 13 specimens during 1993-1994, all from the upper reaches of the Illinois River drainage. As of 1994, vouchered records at SIUC and EA Midwest indicate the species is confined to the Des Plaines River/Ship Canal upstream of Brandon Road Lock and Dam (between RM 286 and 321). Page and Laird (1993a) and records at INHS indicate a wider range in northeastern Illinois including the

North Shore Channel in Skokie and perhaps Lake Michigan. We presume the source of this species in Illinois is via aquarium hobbyists releasing unwanted pets.

Captured specimens from the Sanitary and Ship Canal range in total length from 137 to 169 mm, the equivalent of adult size in the species native range (Sterba 1966). Smaller specimens from the North Shore Channel possibly represent release of small individuals or circumstantial evidence for recruitment. *M. anguillicaudatus* takes part in a rather elaborate spawning tryst that results in eggs being attached to the bases of aquatic plants (summarized in Breder and Rosen 1966). In its native range and also in Illinois this species occupies sluggish waters over mud substrates into which it commonly burrows. Due to an intestinal accessory respiratory organ it can survive low oxygen conditions. Hensley and Courtenay (1980) reported the species to be omnivorous. Considering these various life requisites, the number of specimens captured over a recent two-year period, and the latitude at which it occurs natively, *M. anguillicaudatus* is almost certainly established in northeastern Illinois. In Michigan, California, and Idaho, its established range has not expanded appreciably and we assume that only localized populations will continue in Illinois. If it does expand its range in Illinois, studies of the species reproductive biology and diet may help to determine its potential impact on native fishes.

Pirapatinga
Piaractus brachypomus
SIUC 19835 (1, 218 mm), Little Grassy Lake (Big Muddy R. Dr.) near Girl Scout Camp (T 10S, R1E, Sec. 19), Williamson Co., 15 June 1992; SIUC [examined and returned to angler, about same size as SIUC 19835], Southern Illinois University at Carbondale Campus Lake (Big Muddy R. Dr.) (T9S, R1W, Sec. 16), Jackson Co., 22 June 1992.

Remarks: *Piaractus* is native to South American freshwaters and serves as a valuable food fish as well as being a part of the ornamental fish trade. Burr and Warren (1993) reported this species from the Big Muddy River drainage as *Colossoma* sp. [pacu]. Since that paper was written, a taxonomic expert on pacus and their relatives has examined the specimens and provided us with the correct scientific name. More recently (1993) we obtained another specimen (SIUC 22241) from Lake Barkley, Kentucky. We know of no fish farms in the vicinity that raise this species nor of any state or federal agency that would be releasing this exotic into public waters. Apparently, humans have released their aquarium pets, which were probably too large for their aquaria, into nearby lakes rather than destroying them. This tropical fish almost certainly winterkills at this latitude and there is no reason to expect it to become established in north temperate waters. A single fish taken on a trotline, Mississippi River, south of Chester, Randolph County, September 1988 (Chester Herald Tribune, 1988), was reported as a piranha, but the accompanying photograph shows it to be *Piaractus.* An additional newspaper account (Randolph County Herald Tribune, 1994) of an angler catch of this fish (reported as a 14-inch piranha) in September 1994 is from Lake Baldwin (Kaskaskia R. Dr.), Randolph/St. Clair counties, a power-plant cooling lake that stays relatively warm throughout the year. It is possible that this species could survive and become established in lakes of this type.

Because the species strongly resembles some species of piranha (e.g., *Serrasalmus* and *Pygocentrus*), the capture of specimens by anglers often is reported in newspaper accounts and causes undue alarm among swimmers and boaters. The coincidental appearance of four specimens of *Piaractus* from four different lakes within a three-year period seems unusual, especially that out of the thousands of fish caught over this time period, anglers would improbably catch one of the few specimens someone had released.

Rainbow Smelt
Osmerus mordax
SIUC 22804 (5, 54.0 - 61.4 mm), Mississippi River (Gulf of Mexico Dr.) at Grand Tower aerial pipeline crossing (T10S, R4W, Sec. 23SW), Jackson Co., 20 March 1987; SIUC 24087 (39, 45.6-66.8 mm), same location as SIUC 22804, 1 April 1995; SIUC 22803 (1, 64.0 mm), Mississippi River (Gulf of Mexico Dr.) at Venice boat ramp (T3N, R10W, Sec. 35), Madison Co., 20 March 1987; SIUC 22801 (2, 54.6 - 57.2 mm), Mississippi River (Gulf of Mexico Dr.) at Chester boat ramp (T7S, R7W, Sec. 30), Randolph Co., 20 March 1987; SIUC 23604 (18, 34.5-47.0 mm), Mississippi River (Gulf of Mexico Dr.), just downstream of mouth of Marys River (T7S, R6W, Sec. 33), Randolph Co., 12 November 1994.

Remarks: Mayden et al. (1987) reviewed the records and literature on the distributional history of *O. mordax* in the Mississippi River basin. They concluded that this species, otherwise unknown from the Mississippi River basin prior to 1978, reached the lower Missouri River mainstem and lower Mississippi River mainstem from escaped forage stockings in Lake Sakakawea, North Dakota, and possibly some may have originated from Lake Michigan stock. Approximately seven years elapsed from the initial stock of *O. mordax* in Lake Sakakawea until they were first captured in the free-flowing lower Mississippi River (Mayden et al. 1987). During winter months on the Mississippi River at Grand Tower from the late-1970s to the mid-1980s, *O. mordax* was the most common species along the shoreline (Klutho 1983). We report here the most recent (1994-1995) records of *O. mordax* from the Mississippi River and note that our survey work in the Mississippi River over the past several years has until recently revealed few specimens. The status of *O. mordax* in the Mississippi River basin remains uncertain, but its sporadic occurrence over the past six years in the mainstem suggests that it might best be considered an occasional winter transient.

Inland Silverside
Menidia beryllina
SIUC 20177 (47, 26.5 - 52.3 mm), Ohio River (Mississippi R. Dr.), 3 mi. ENE Olmstead at Lock & Dam 53 (T15S, R2E, Sec. 19), Pulaski Co., 4 August 1992; SIUC 20173 (55, 23.8 - 46.2 mm), Ohio River (Mississippi R. Dr.), near Joppa (T15S, R3E, Sec. 26), Massac Co., 4 August 1992; SIUC 20307 (9, 33.0 - 43.5 mm), Big Muddy River (Mississippi R. Dr.), at Rattlesnake Ferry (T10S, R3W, Sec. 27NW), Jackson Co., 4 August 1992; SIUC 23595 (139, 22.6-77.2 mm), Kincaid Creek (Big Muddy R. Dr.) at Kincaid Lake spillway (T9S, R3W, Sec. 4NW), Jackson Co., 12 November 1994; SIUC 19119 (25, 59.1 - 74.7 mm), Ohio River (Mississippi R. Dr.), at Paducah (T16S, R5E, Sec.19), McCracken Co., Kentucky, 17 September 1991; SIUC 19167 (36, 56.3 - 62.7 mm), Ohio River (Mississippi R. Dr.), RM 944-948, near Shawnee Steam Plant, McCracken Co., Kentucky, August 1991.

Remarks: In a footnote, Smith (1979) stated that *M. beryllina* had been recently found in the Mississippi River of southern Illinois [INHS 26962, from Grand Tower in 1978, captured by one of us (BMB)], indicating that he was unaware of any previous records of this fish in Illinois waters. Pflieger (1975) reported the species to be common in the Mississippi River from the mouth of the Ohio River southward. Since Smith's (1979) report, no *M. beryllina* had been taken in Illinois waters until the 1990s, when the species was found to be common in the lower Ohio River by several independent investigators. The Ohio River records are the first to be reported (outside of the gray literature) for the mainstem. We also document the presence of this species in the lower Big Muddy River. The latter record was noted by Burr and Warren (1993) and appears to represent the northernmost record of this species in the Mississippi River basin. Size ranges of individuals indicate that reproduction has occurred (Stoeckel and Heidinger 1989), although it is unknown if the fish is established permanently in Illinois.

Menidia beryllina is abundant in Gulf Coastal waters and is frequently found established in pure freshwater rivers and lakes. We assume the Ohio River population of *M. beryllina* has only recently entered the lower mainstem, although it is abundant along the shoreline on both sides of the river. It is possible that *M. beryllina* entered the Ohio River via the Tennessee-Tombigbee waterway which now connects Gulf Coast drainages to the Ohio River, especially because of recent (1991) records from both Kentucky and Barkley reservoirs (Etnier and Starnes 1993). It is equally possible that the lower Mississippi River population expanded its range after the low water levels of the late 1980s created water-quality conditions (e.g., high dissolved solids) favorable for this species to disperse. Stockings in power-plant cooling reservoirs (i.e., Lake Baldwin and Lake of Egypt) for purposes of forage for sportfishes has occurred in the past few years but both of these reservoirs are a long distance (in terms of river miles) from capture sites reported here. Other fish biologists (Shute and Etnier 1994) have suggested that *Menidia* is invading the region from the lower Ohio-Mississippi rivers and not through the Tennessee-Tombigbee waterway.

Striped Mullet
Mugil cephalus
SIUC 21346 (1, 253 mm), Ohio River (Mississippi R. Dr.), at RM 944.2, 1 mi. downstream of Metropolis (T16S, R4E, Sec. 34), Massac Co., 18 July 1992; SIUC 17665 (1, 356 mm), Mississippi River (Gulf of Mexico Dr.), at Angelo Towhead, 1.0 mi. W of bridge at Cairo (T17S, R1w, Sec. 36), Alexander Co., 7 September 1989; INHS 57769 (1, 335.0 mm), Mississippi River (Gulf of Mexico Dr.), at RM 145.8, 5 mi. SW Maeystown (T4S, R11W, Sec. 22), Monroe Co., 20 September 1989.

<u>Remarks</u>: Burr et al. (1990) and Burr (1991) reported records of *M. cephalus* for the upper Mississippi River basin, noting that this species was known previously only as far north in the Mississippi River as southern Arkansas (Robison and Buchanan 1988). The record from the Mississippi River at mile 145.8 is the northernmost record known for this otherwise familiar resident of estuaries, salt marshes, and shoreline areas of the Atlantic and Gulf coasts (Etnier and Starnes 1993). Again we speculate that low water levels in the Mississippi River in 1988 and 1989 created water-quality conditions favorable for *M. cephalus* to reach the upper Mississippi River basin. A recent record (1993) from Kentucky Lake, Tennessee (Etnier and Starnes 1993), suggests that the Tennessee-Tombigbee waterway might possibly be another route of dispersal for this species to reach the mainstems of the Ohio and Mississippi rivers.

Because this species spawns offshore in marine waters, it will never be a persistent component of the Illinois fish fauna. *M. cephalus* is probably best considered a transient or periodic southern invader of Illinois waters.

White Perch
Morone americana
INHS 61096 (2, 121.3-141.4 mm), Lake Calumet (Lake Michigan Dr.), 1 mi. N Calumet City (T37N, R14E, Sec. 3-11), Cook Co., 20 June 1991; INHS 61097 (2, 112.1-106.8 mm), Calumet River (Lake Michigan Dr.), 130th Street in Calumet (T37N, R14E, Sec. 36), Cook Co., 26 June 1991; INHS 61098 (5, 81.9-127.3 mm), Little Calumet River (Lake Michigan Dr.), at I-94 bridge in Calumet (T36N, R14E, Sec.2NE), Cook Co., 21 June 1991; INHS 27890 (6, 89.0-128.5 mm), Wolf Lake (Calumet R. Dr.), William Powers Conservation Area (T37N, R15E, Sec. 20), 4 September 1990; INHS 29750 (1, 118.9 mm), Illinois River (Mississippi R. Dr.), RM 272.2, 3 mi. S Minooka, upstream of Dresden Island Lock & Dam (T34N, R8E, Sec. 26NE), Grundy Co., 2 August 1990; INHS 27889 (1, 54.9 mm), Illinois River (Mississippi R. Dr.), RM 170.7, Upper Peoria Lake, Lambie's Boat Harbor, Mossville (T9N, R8E, Sec. 3), Peoria Co., 20 September 1991; INHS 61171 (1, 55.4 mm), Illinois River (Mississippi R. Dr.), RM 180.8, Chillicothe (T28N, R3W, Sec. 5), Woodford Co., 10 September 1991; SIUC 21434 (1, 136 mm), mouth of Swan Lake at Illinois River mile 6 (Mississippi R. Dr.), 6.0 mi. N Grafton (T13S, R1W, Sec. 10), Calhoun Co., 19 November 1992; SIUC 22960 (3, 69.5-76.2 mm SL), Mississippi River (Gulf of Mexico Dr.), at Grand Tower aerial pipeline crossing (T10S, R4W, Sec. 23SW), Jackson Co., 23 April 1994; SIUC 23052 (1, 43.9 mm), Big Muddy River (Mississippi R. Dr.), at Rattlesnake Ferry (T10S, R3W, Sec. 27NW), Jackson Co., 22 August 1994; SIUC 24411 (1, 28.8 mm), Lake Creek (Cache R. Dr.), at 2nd bridge below Horseshoe Lake spillway (T16S, R2W, Sec. 14SW), Alexander Co., 29 June 1995. SIUC 23051 (4, 81.0-112.0 mm), Lake Creek (Cache R. Dr.), at Horseshoe Lake spillway (T16S, R2W, Sec. 21), Alexander Co., 25 June 1994; SIUC 21906 (4, 63.2 - 87.5 mm), culvert between formerly flooded fields (Mississippi R. Dr.), just SE Miller City (T16S, R2W, Sec. 20), Alexander Co., 6 November 1993.

Remarks: *M. americana* is an anadromous euryhaline species originally restricted to the North American Atlantic Coast where it is established in many freshwater lakes and rivers. Scott and Christie (1963) reviewed the spread of *M. americana* into the lower Great Lakes by movement of the species through the Mohawk River Valley and the Erie Barge Canal into Lake Ontario. By 1975, the species was established in western Lake Erie (Busch et al. 1977). Johnson and Evans (1990) hypothesized that above-average temperatures during the middle of the 20th century provided a window for *M. americana* to enter the Great Lakes and spread from there. Smith (1979) did not report this species from the Illinois waters of Lake Michigan; the first record for Illinois was of a single specimen captured in Belmont Harbor in 1988 (Savitz ét al. 1989). By 1990-1991 *M. americana* had dispersed into the upper Illinois River and the Lake Calumet system and by 1992 was captured near the mouth of the Illinois River (Fig. 1). One of us (GLS) has collected *M. americana* annually from the upper reaches of the Illinois River drainage (RM 270.2-323.1) from 1990 through 1994. During this period, 46 specimens have been collected including several < 30 mm SL, which undoubtedly are young of the year (Mansuetti 1964). From 2 September to 4 October 1994, 10 adult and one juvenile *M.*

americana were collected from the Calumet River (RM 328-330), Cook County. In 1994, two larval (7.5 and 10.5 mm SL) *Morone* were collected from the Des Plaines River near Romeoville. Meristic features and other characteristics suggest that these two larvae represent *M. americana*, the most common *Morone* in the area; however, positive separation from the Yellow Bass (*Morone mississippiensis*) at this size is not possible. As of 1993-1994 *M. americana* reached extreme southern Illinois via the mainstem Mississippi River, with recent records from the Horseshoe Lake drainage, Alexander County.

Other than the Great Lakes, another possible source of the presence of *M. americana* in the Mississippi River is via the Missouri River as a result of introductions made into Nebraska lakes beginning in 1964 (Hergenrader and Bliss 1971, Zuerlein 1981). Cross et al. (1986) reported records from the Platte-Niobrara rivers and Hesse et al. (1982) reported the species from the middle Missouri River. However, we are unaware of any recent records of *M. americana* farther downstream in the Missouri River.

Lengths of specimens (individuals less than 70 mm SL are considered young of the year according to Marcy and Richards [1974]) captured and vouchered in research or reference collections (i.e., EA Midwest, INHS, and SIUC) indicate convincingly that *M. americana* is reproducing in Illinois waters and is almost certainly an established member of the Illinois fish fauna. The species is known to spawn in shallow fresh water over a variety of bottom types and often increases rapidly in numbers despite the presence of other established species (Scott and Crossman 1973). We predict that *M. americana* will continue to spread southward in the Mississippi River and will reach large enough population levels in Illinois to compete with native *Morone* and other species for various resources. In addition, the presence of four species of *Morone* (two native, and two nonnative) together with stockings of *Morone* hybrids in Midwest rivers (e.g., the Ohio River), is likely to complicate indentification of juvenile and subadult representatives of the genus.

In five years *M. americana* has dispersed nearly the entire length of Illinois, and represents an outstanding example of how quickly a newly-invading species can spread and become established. Only *O. mordax* has been shown to have moved more rapidly downriver in the Mississippi River basin (Mayden et al. 1987) from points of introduction in the upper Missouri River and possibly the Great Lakes.

DISCUSSION

When Forbes and Richardson (1908) published their classic work on Illinois fishes only one nonnative species was known to be established in the state, the Common Carp, *C. carpio*. By the late 1970s, 13 nonnative fish species were present in Illinois waters (Smith 1979). By 1990, 22 nonnative species (including southern invaders) were known from Illinois, although not all were documented as established at that time (Burr 1991). We add here evidence in the form of young-of-the-year and/or age class variation that circumstantially demonstrates that *C. idella*, *H. nobilis*, *M. anguillicaudatus*, *M. beryllina*, and *M. americana* are reproducing and established in Illinois waters; we predict that *H. molitrix* will become established within the next decade.

In general, nonnative species, especially those introduced into the Southwest, have had an adverse effect on native fishes (Becker 1983, Courtenay and Robins 1989); however, the feeding niches (i.e., vegetation, plankton) of the Asian carps are somewhat different than most of the fishes native to North America. In addition, all of the Asian carps reach a large size and are relatively more fecund than many native species. The widespread distribution of these species in Illinois streams makes it impractical to eradicate them from known areas of occurrence. Direct effects of introduced species on native species include: 1) elimination, 2) reduced growth and survival, 3) changes in community structure, and 4) no effect (Moyle et al. 1986). Perhaps of greatest concern are species such as *M. americana* that have spread rapidly, and which tend to become overpopulated and stunted, thereby competing for food resources and reducing the growth rates of other more desirable sportfishes (Zuerlein 1981). In fact, Zuerlein (1981) traces the history of purposeful (starting in 1964) and inadvertent introductions of *M. americana* in Nebraska and presents an alarming case for a species that has few desirable qualities in the Midwest. Early sexual development, ability to spawn in a variety of habitats, high reproductive potential, die-offs before reaching a desirable angling size, and difficulty and expense of eradication are questionable qualities in terms of human welfare, sportfishing, and native fish communities.

Of notable interest is the preponderance of nonnative species (e.g., *O. mordax*, *M. cephalus*, *M. beryllina*, and *M. americana*) that are principally euryhaline or inhabitants of marine environments. All of these species except *M. cephalus* are now established in Illinois and other Midwestern states. These ecologically labile species perhaps represent the extreme in colonizing species, with each exhibiting traits that demonstrate their tolerance for a variety of variable environmental conditions.

The source of nonnative fishes in Illinois waters is varied and perhaps more complicated than we are aware. Of the species reported here, three have dispersed after having been introduced into other states (e.g., *O. mordax*) or by recent changes in enviromental conditions (i.e., warming, drought) that have allowed their (e.g., *M. beryllina*, *M. cephalus*) movement northward. Others (e.g., *C. auratus*, *H. molitrix*), not certainly established in southern Illinois but introduced originally as food fishes or for aquaculture studies, appear to have become more widely distributed after the recent Mississippi River flooding. Still others (e.g., *C. idella*, *H. nobilis*) have become established after earlier introductions for other purposes (i.e., weed control, improvement of water quality in culture ponds). One species (*S. erythrophthalmus*) has been introduced via bait bucket and two others (*M. anguillicaudatus*, *P. brachypomus*), probably through release of aquarium stock. *M. americana* has spread rapidly from the Great Lakes to southern Illinois because of its tolerance for varying ecological conditions. The exotic carps and *C. auratus* are of some use to humans as food or for control of weeds in small water bodies, but few would argue for their desirability as sportfish. Moreover, the well documented impacts of the Common Carp (*C. carpio*) on both aquatic habitats and native species does not bode well for those concerned with further establishment of these large and ecologically aggressive cyprinids. Others (*O. mordax*, *M. cephalus*, *S. erythrophthalmus*, *M. anguillicaudatus*, *P. brachypomus*) would appear to be relatively harmless because they are either not established or are only occasional transients in Illinois waters. Only time and careful study will allow us to understand the long-term ecological effects of the established *M. americana*.

It is clear that both purposeful and unintentional introductions can lead to undesirable results, especially in terms of sportfishing, human welfare, and ecological interactions. Moyle et al. (1986) introduced the concept of the "Frankenstein Effect" suggesting that if broad scale consequences of each introduction are not considered, they may ultimately cause more problems than they solve. While it may be too early in the history of invasion of nonnative Illinois fishes to detect a demonstrable effect on native communities, studies in other parts of North America allow us to conclude that further introductions are not warranted in most bodies of water and that more targeted education is needed to prevent accidental or unintentional introductions (i.e., mixed stockings, release of aquarium pets) into Illinois.

Courtenay and Moyle (1992) provide an instructive overview of the legacy of fish introductions into the United States and note that success of introductions depends on whether they are defined mainly in terms of economics or angler satisfaction. It is not our purpose to re-review that material but only to point out that the American Fisheries Society has adopted policy statements on intentional introductions (e.g., Kohler and Courtenay 1986), yet no state seems to have adopted these policies or protocols as their policy. Li and Moyle (1993) present ecological concepts important for understanding the effects of introductions, suggest some management alternatives to introducing new species, and provide guidelines for evaluating proposed introductions. Changes in values, an expanding human population, and a decline in natural habitats provide an opportunity for reconsideration of old policies and values. Illinois could become a model for the nation by adopting a proactive and progressive set of policies and protocols for introductions. There is now considerable public concern for endangered species, maintaining water quality, preserving natural areas and biodiversity, and protecting the limited wild areas we have left in Illinois. Keeping all possible options open when considering the future of Illinois' natural resources is vital.

ACKNOWLEDGMENTS

We appreciate the field assistance of Brett J. Dunn, Ed Walsh, and the 1993-1994 SIUC ichthyology classes. Larry Vaughn apprised us of the appearance of Silver Carp in Horseshoe Lake. Don Garver, IDOC fishery biologist, brought specimens of the Bighead Carp to our attention. June McIlwain, U.S. Fish and Wildlife Service, brought two records of the Pirapatinga to our laboratory, and Leo G. Nico, National Biological Service biologist, helped in the correct identification of that species. Jim Smithson, Illinois Power Company, located the newspaper account of the Pirapatinga from Lake Baldwin. William L. Pflieger, Missouri Department of Conservation, provided a record of the Striped Mullet from the Mississippi River.

LITERATURE CITED

Becker, G. C. 1983. Fishes of Wisconsin. The University of Wisconsin Press, Madison. 1052 pp.

Bettoli, P. W. 1987. The restructuring of a forage fish community following large scale aquatic vegetation control. Unpubl. Ph.D. Dissertation, Texas A & M University, College Station. 148 pp.

Breder, C. M., Jr. and D. E. Rosen. 1966. Modes of reproduction in fishes. Natural History Press, Garden City, New York. 941 pp.

Brown, D. J. and T. G. Coon. 1991. Grass carp larvae in the lower Missouri River and its tributaries. N. Amer. J. Fish. Manage. 11:62-66.

Burkhead, N. M. and J. D. Williams. 1991. An intergeneric hybrid of a native minnow, the golden shiner, and an exotic minnow, the rudd. Trans. Amer. Fish. Soc. 120:781-795.

Busch, W. D. N., D. H. Davies, and S. J. Nepszy. 1977. Establishment of white perch, *Morone americana*, in Lake Erie. J. Fish. Res. Board Can. 34:1039-1041.

Burr, B. M. 1991. The fishes of Illinois: an overview of a dynamic fauna, pp. 417-428 in L.M. Page and M. R. Jeffords (editors). Our Living Heritage: the Biological Resources of Illinois. Bull. Ill. Nat. Hist. Surv. 34.

Burr, B. M. and M. L. Warren, Jr. 1986. A distributional atlas of Kentucky fishes. Kentucky Nature Preserves Comm. Sci. Tech. Ser. 4. 398 pp.

Burr, B. M. and M. L. Warren, Jr. 1993. Fishes of the Big Muddy River drainage with emphasis on historical changes, pp. 186-209 in L. W. Hesse, C. B. Stalnaker, N. G. Benson, and J. R. Zuboy (editors). Proceedings of the Symposium on Restoration Planning for the Rivers of the Mississippi River Ecosystem. Natl. Biol. Surv. Biol. Rep. 19.

Burr, B. M., M. L. Warren, Jr., G. K. Weddle, and R. R. Cicerello. 1990. Records of nine endangered, threatened, or rare Kentucky fishes. Trans. Ky. Acad. Sci. 51:188-189.

Courtenay, W. R., Jr. and P. B. Moyle. 1992. Crimes against biodiversity: the lasting legacy of fish introductions. Trans. 57th N. Amer. Wildl. & Nat. Res. Conf. (Special Session 6): 365-372.

Courtenay, W. R., Jr. and C. R. Robins. 1989. Fish introductions: good management, mismanagement, or no management? CRC Critical Reviews in Aquatic Sciences 1:159-172.

Courtenay, W. R., Jr., D. A. Hensley, J. N. Taylor, and J. A. McCann. 1986. Distribution of exotic fishes in North America, pp. 675-698 in C. H. Hocutt and E. O. Wiley (editors). The zoogeography of North American freshwater fishes. John Wiley and Sons, Inc., New York.

Courtenay, W. R., Jr., C. R. Robins, R. M. Bailey, and J. E. Deacon. 1987. Records of exotic fishes from Idaho and Wyoming. Great Basin Nat. 47:523-526.

Cross, F. B., R. L. Mayden, and J. D. Stewart. 1986. Fishes in the western Mississippi basin (Missouri, Arkansas and Red rivers), pp. 363-412 in C. H. Hocutt and E. O. Wiley (editors). The zoogeography of North American freshwater fishes. John Wiley & Sons, Inc., New York.

Etnier, D. A. and W. C. Starnes. 1993. The fishes of Tennessee. The University of Tennessee Press, Knoxville. 681 pp.

Forbes, S. A. and R. E. Richardson. [1908]. The fishes of Illinois. Illinois State Laboratory of Natural History. cxxxi + 357 pp. plus separate atlas of 103 maps.

Greenfield, D. W. 1973. An evaluation of the advisability of the release of grass carp, *Ctenopharyngodon idella*, into the natural waters of the United States. Trans. Ill. State Acad. Sci. 66:47-53.

Gunning, G. E. 1954. The fishes of Horseshoe Lake, Illinois. Unpubl. M. A. Thesis, Southern Illinois University at Carbondale. 37 pp.

Hensley, D. A. and W. R. Courtenay, Jr. 1980. *Misgurnus anguillicaudatus* (Cantor), Oriental Weatherfish, p. 436 in D. S. Lee et al. (editors). Atlas of North American freshwater fishes. North Carolina State Museum of Natural History, Raleigh.

Hergenrader, G. L. and Q. P. Bliss. 1971. The white perch in Nebraska. Trans. Amer. Fish. Soc. 100:734-738.

Hesse, L. W., G. L. Hergenrader, H. S. Lewis, S. D. Reetz, and A. B. Schlesinger (editors). 1982. The middle Missouri River. A collection of papers on the biology with special reference to power station effects. Missouri River Study Group, Norfolk, Nebraska. 301 pp.

Hocutt, C. H. 1985. Standardized terminology--politics or biology? in Letters to the Editor. Fisheries 10:49.

Jennings, D. P. 1988. Bighead carp (*Hypophthalmichthys nobilis*): biological synopsis. U.S. Fish Wild. Serv., Biol. Rep. 88:1-35.

Jennings, D. P. 1989. Exotic species update. National Fisheries Research Center, Gainesville, Florida. 3 pp.

Johnson, T. B. and D. O. Evans. 1990. Size-dependent winter mortality of young-of-the-year white perch: climate warming and invasion of the Laurentian Great Lakes. Trans. Amer. Fish. Soc. 119:301-313.

Johnston, C. E. 1991. Discovery of the threespine stickleback (*Gasterosteus aculeatus*) (Pisces: Gasterosteidae) in Lake Michigan drainage, Illinois. Trans. Ill. State Acad. Sci. 84:173.

Klutho, M. A. 1983. Seasonal, daily, and spatial variation of shoreline fishes in the Mississippi River at Grand Tower, Illinois. Unpubl. M. A. Thesis, Southern Illinois University at Carbondale. 84 pp.

Kohler, C. C. and W. R. Courtenay, Jr. 1986. American Fisheries Society position on introductions of aquatic species. Fisheries 11:39-42.

Laird, C. A. and L. M. Page. in press. Nonnative fishes inhabiting the streams and lakes of Illinois. Ill. Nat. Hist. Surv. Bull.

Li, H. W. and P. B. Moyle. 1993. Management of introduced fishes, pp. 287-307 in C. C. Kohler and W. A. Hubert (editors). Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Long Term Resource Monitoring Program Havana Field Station. 1993. Exotic species in the Illinois River. Ill. Chapter Amer. Fish. Soc. [Newsletter] 7:5.

Mansuetti, R. 1964. Eggs, larvae, and young of the year white perch (*Roccus americanus*), with comments on its ecology in the estuary. Chesapeake Sci. 5:3-45.

Marcy, B. C., Jr. and F. P. Richards. 1974. Age and growth of the the white perch *Morone americana* in the lower Connecticut River. Trans. Amer. Fish. Soc. 103:117-120.

Mayden, R. L., F. B. Cross, and O. T. Gorman. 1987. Distributional history of the rainbow smelt, *Osmerus mordax* (Salmoniformes:Osmeridae), in the Mississippi River basin. Copeia 1987:1051-1054.

Moyle, P. B., H. W. Li, and B. A. Barton. 1986. The Frankenstein effect: impact of introduced fishes on native fishes in North America, pp. 415-426 in R. H. Stroud (editor). Fish culture in fisheries management. American Fisheries Society, Bethesda, Maryland.

Nelson, E. W. 1876. A partial catalog of the fishes of Illinois. Ill. Mus. Nat. Hist. Bull. 1:33-52 [also Ill. State Lab. Nat. Hist. Bull. 1:33-52.]

O'Donnell, D. J. 1935. Annotated list of the fishes of Illinios. Ill. Nat. Hist. Surv. Bull. 20:473-500.

Page, L. M. and C. Laird. 1993a. The identification of the nonnative fishes inhabiting Illinois waters. Final report to Illinois Department of Conservation, Springfield. 39 pp.

Page, L. M. and C. Laird. 1993b. Exotic fishes in Illinois. Ill. Nat. Hist. Surv. Rept. No. 324:3-5.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City. 343 pp.

Pflieger, W. L. 1978. Distribution and status of the grass carp (*Ctenopharyngodon idella*) in Missouri streams. Trans. Amer. Fish. Soc. 107:113-118.

Raibley, P. 1995. More juvenile grass carp collected in the Illinois River. Ill. Chapter Amer. Fish. Soc. [Newsletter] 8:9.

Raibley, P. T., D. Blodgett, and R. E. Sparks. 1995. Evidence of grass carp (*Ctenopharyngodon idella*) reproduction in the Illinois and upper Mississippi rivers. J. Freshwater Ecol. 10:65-74.

Robins, C. R., R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea, and W. B. Scott. 1991. World fishes important to North Americans exclusive of the species from the continental waters of the United States and Canada. American Fisheries Society Special Publication 21. American Fisheries Society, Bethesda, Maryland. 243 pp.

Robison, H. W. and T. M. Buchanan. 1988. Fishes of Arkansas. University of Arkansas Press, Fayetteville. 536 pp.

Savitz, J., C. Aiello, and L.G. Bardygula. 1989. The first record of the white perch (*Morone americana*) in Illinois waters of Lake Michigan. Trans. Ill. State Acad. Sci. 82:57-58.

Scott, W. B. and W. J. Christie. 1963. The invasion of the lower Great Lakes by the white perch, *Roccus americanus* (Gmelin). J. Fish. Res. Board Can. 20:1189-1195.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Bull. Fish. Res. Board Can. 184:1-966.

Shafland, P. L. and W. M. Lewis. 1984. Terminology associated with introduced organisms. Fisheries 9:17-18.

Shute, P. W. and D. A. Etnier. 1994. Regional SFC reports, region III - North-Central. Southeast. Fishes Council Proc. 30:14-15.

Smith, P. W. 1979. The fishes of Illinois. University of Illinois Press, Urbana. 314 pp.

Stanley, J. G., W. W. Miley II, and D. L. Sutton. 1978. Reproductive requirements and likelihood for naturalization of escaped grass carp in the United States. Trans. Amer. Fish. Soc. 107:119-128.

Sterba, G. 1966. Freshwater fishes of the world. Studio Vista Limited, London. 879 pp.

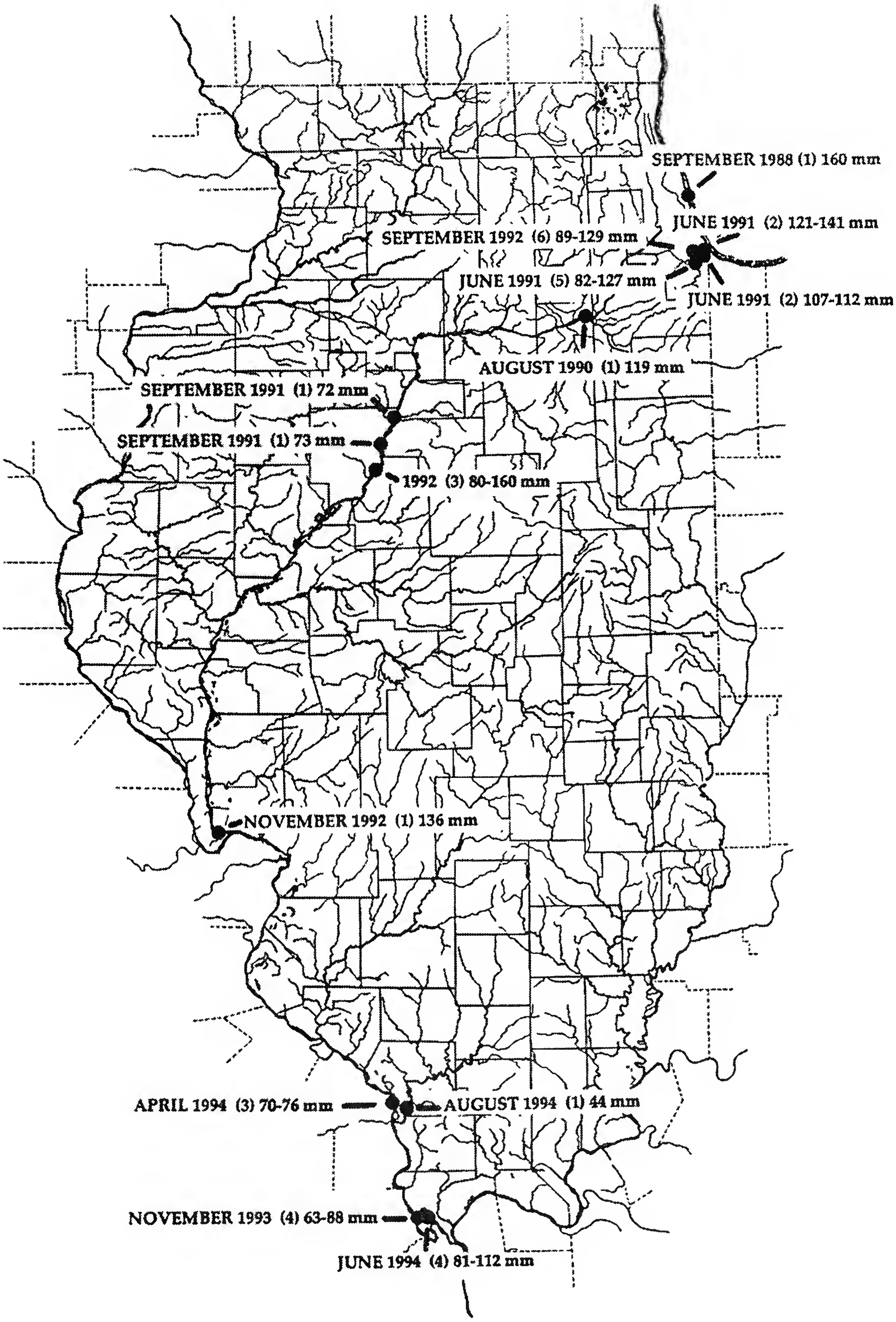
Stoeckel, J. N. and R. C. Heidinger. 1989. Reproductive biology of the inland silverside, *Menidia beryllina*, in southern Illinois. Trans. Ill. State Acad. Sci. 82:59-69.

Taylor, J. N., W. R. Courtenay, Jr., and J. A. McCann. 1984. Known impacts of exotic fishes in the continental United States, pp. 322-373 in W. R. Courtenay, Jr. and J. R. Stauffer, Jr. (editors). Distribution, biology, and management of exotic fishes. Johns Hopkins University Press, Baltimore.

Wheeler, A. 1969. The fishes of the British Isles and north-west Europe. Michigan State University Press, East Lansing. 613 pp.

Zuerlein, G. 1981. The white perch, *Morone americana* (Gmelin), in Nebraska. Nebraska Tech. Ser. 8:1-108.

Figure 1. Record stations and dates of capture for the White Perch (*Morone americana*) demonstrating the rapid spread of this species in Illinois from Lake Michigan to the Mississippi River in extreme southern Illinois. Numbers of individuals captured are in parentheses; range in size of specimens captured is in mm SL.



Transactions of the Illinois State Academy of Science
(1996), Volume 89, 1 and 2, pp. 93-103

White-Tailed Deer Use of a Suburban Environment in Southern Illinois

Louis Cornicelli[1], Alan Woolf, and John L. Roseberry
Cooperative Wildlife Research Laboratory
Southern Illinois University at Carbondale
Carbondale, Illinois 62901

[1] Present address: Department of Natural Resources, 553 E. Miller Dr., Bloomington, IN 47401.

ABSTRACT

Female white-tailed deer (*Odocoileus virginianus*) were studied in a suburban setting to determine whether they altered their behavior to adapt to living in close proximity to humans and human-associated disturbances. Although deer had opportunity for egress, a marked animal was never detected leaving the study area. Study animals were predominantly crepuscular and used woodlots as primary diurnal bedding sites. Woodlots provided the most secure cover, and their distribution generally dictated deer distribution throughout the study area. Activity budgets did not differ from published data, which suggests suburban deer met life requisites in their small home ranges without additional effort. Origin of the suburban herd apparently coincided with a rapidly expanding county deer population in the early-mid 1980's. Once established however, reproduction was the primary mode of population recruitment. Suburban habitats may serve as refuges that buffer efforts to regulate deer numbers by hunting in surrounding areas. Suburban herds should be identified and managed in association with surrounding rural populations.

INTRODUCTION

White-tailed deer use many natural and human-created habitats (Marchinton and Hirth 1984). One such habitat is the suburban interface between urban and rural landscapes. Use of these areas by white-tailed deer is a relatively recent, but increasingly common phenomenon that has created new challenges for deer managers (Roseberry and Woolf 1991, Curtis and Richmond 1992). Several studies have focused on the human dimensions of suburban deer management (Decker and Gavin 1985, 1987; Connelly et al. 1987; Witham and Jones 1987, 1989; Cornicelli et al. 1993), but little research has been conducted on the basic ecology of deer in these habitats. For example, it is not clear whether deer alter their patterns of habitat use, social behavior, or activity to exploit suburban habitats. Such information is necessary to identify management issues and select appropriate management options (Decker 1987).

Radio telemetry and visual observations were used to study white-tailed deer in a suburban habitat in southern Illinois. The objective was to determine whether home range, movements, and activity of the suburban deer differed from animals in rural Midwestern habitats.

STUDY AREA

The study was conducted October 1990 through May 1992 on a 41.6 km^2 area that comprised the community of Carbondale, Southern Illinois University at Carbondale (SIUC), and some adjacent areas in Jackson County, southern Illinois. Carbondale is a moderately-sized community (17.6 km^2, 27,000 people) in a rural setting that has experienced a dramatic deer population increase during the past decade (Ill. Dept. Conserv., unpubl. data). Carbondale is essentially an island of developed land surrounded by high-quality rural deer habitat. Sufficient undeveloped land remains within Carbondale to support a resident deer population.

METHODS

Distribution and Abundance

All wooded and oldfield habitats were searched for sign of deer use (e.g., trails, beds, pellet groups) to assess general distribution of deer on the Carbondale study area (CSA). To supplement ground searches, a 55-km roadside survey was conducted twice weekly near sunset from 5 to 25 June 1990. Incidental sightings by research personnel, local cooperators, and the Carbondale and SIUC Police departments also were solicited and recorded.

Capture and Radio Telemetry

Deer were baited into open fields and captured with rocket nets or projectile syringes (Hawkins et al. 1968). A combination of 6.7 mg/kg ketamine hydrochloride (HCL) and 1.7 mg/kg xylazine HCL was used for immobilization. Captured deer were sexed, aged by tooth replacement and wear (Severinghaus 1949) as fawn (≤1 yr), yearling (>1 but <2 yrs), or adult (≥2 yrs), and eleven females were affixed with motion-sensitive radio-collars (Wildlife Materials, Carbondale, IL). Effects of the chemical immobilization were reversed with a 0.3 mg/kg intravenous injection of yohimbine HCL (Mech et al. 1985).

Radio-marked deer were located by triangulation ≤10 times/week using a directional 2-element antenna, portable receiver-scanner, and compass. The network of roads on the CSA afforded opportunity to obtain 2 bearings that were approximately 90° apart at distances ≤300 m. Because of the close proximity between the observer and deer and frequent visual observations, estimates of error polygons were not calculated.
Habitat Composition and Use

A high-altitude, color-infrared photograph (27 Mar 1988, 1:14,000) and ground surveys were used to identify 18 land-use types, which were then condensed into 5 classes: urban, residential, woodland/oldfield, agriculture/grassland, and water (Table 1). A transparency of the infrared photograph was digitally scanned into a computerized file and converted into a raster image. Map and Image Processing

System software (MIPS; MicroImages Inc., Lincoln, NE.; Skrdla 1992) was used to outline and classify the image to determine total area and relative proportion of each habitat type.

Home Range

Home ranges for autumn (Sep-Nov), winter (Dec-Feb), spring (Mar-May), and summer (Jun-Aug) were computed for each study year. Two non-parametric home range estimators, the harmonic mean (Dixon and Chipman 1980) and Fourier (Anderson 1982), and one non-statistical estimator, the modified minimum area polygon (Harvey and Barber 1965) were tested to see which provided the most realistic fit for the data. Due to heterogeneity of the CSA, both non-parametric estimators produced home ranges that did not accurately reflect deer use of the suburban situation. For example, the harmonic mean estimator frequently generated circular home ranges that encompassed large urban areas that deer did not use. Therefore, the modified minimum area polygon was used in all home range calculations.

Behavior

Diel activity patterns were determined using motion-sensitive features of the radio-collars. Three 4-hour intervals (e.g., 0001-0400, 0401-0800, . . . ,2001-2400) were sampled each week, which yielded complete coverage of one 24-hour period every two weeks. Activity levels for all collared deer were assessed during each 4-hour interval. Individuals were sampled for 6 minutes (Beier and McCullough 1988) after which the scanner would move to the next frequency. If the transmitter pulse rate was constant for the entire period, activity was coded as 0 (inactive); otherwise it was coded as 1 (active).

Statistical Analyses

Analysis of Variance (ANOVA) and Tukey's multiple range test were used to compare seasonal home range sizes. ANOVA was also used to evaluate seasonal differences in activity. Differences were considered significant at $\underline{P} < 0.05$.

RESULTS

Distribution and Abundance

Deer on the CSA formed six distinct groups containing from 9 to 50 animals; the estimated total population was 125 to 150. Other deer occupied the area, but they were not studied because they did not represent a suburban situation (Fig. 1).
Habitat Composition and Use

Habitat composition and degree of development varied within the study area and accounted for both deer distribution (the group units) and abundance. The CSA consisted of 48% developed lands, 27% woodland/oldfield, 24% agriculture/grassland, and 1% water. Potential habitat for deer consisted mainly of small patches of woods and fields bordered or surrounded by developed areas (Fig. 1). These areas were remnants of farmland converted to residential and commercial expansion during the early 1970's.

As indicated by telemetry, wooded areas were a critical habitat component of the study area because they served as primary diurnal bedding sites. Of the 574 wooded hectares on the CSA, 95% were within the core of at least one animal's home range. Oldfields also served as bedding sites, especially if they included a woody component. Agricultural fields and grasslands served as the primary foraging areas.

Home Range

Seasonal.--Seasonal home ranges were calculated for 11 does tracked $\leq$ 20 months. Winter and spring home ranges were 60% larger than those in summer and fall ($F = 3.73$; $P = 0.018$; Table 2). Average home range increased during late winter 1991 when several does used a newly-emergent winter wheat field (*Triticum aestivum*). During summer, average home range decreased with the onset of fawning and several weeks post-partum.

Annual.--Average annual home range ($n = 7$) averaged 50.8 ± 23 ha and did not differ among does ($P = 0.169$). There was a strong correlation ($r = 0.77$) between available habitat (patch size that the deer inhabited) and annual home range, which indicated deer used all available areas within their respective group location. There was no evidence that deer used areas outside their identified group locations for periods longer than 1 to 2 days. Unlike other deer telemetry studies, the characteristic "wanderings" that are the basis for exclusion of 5% of telemetry locations typically did not occur. None of four does monitored $\geq$ 15 months were observed leaving the study area.

Fidelity

Fidelity was expressed as the percentage of overlap between home range among consecutive seasons (e.g., spring-summer) and between years (e.g., winter 1991, 1992). In all but three cases marked deer ($n = 11$) displayed strong site-specific fidelity between season and between years; one deer had only 1% overlap between winter 1991 and winter 1992, while a second deer had no overlap between fall 1991 and winter 1992, and between winter 1991 and winter 1992. When these were removed from the analysis, mean overlap averaged 40% (range = 10.8% to 75.3%) between seasons and 28.2% (range = 14.4% to 48.4%) between years. Differences in degree of overlap between females were attributed to seasonal changes in vegetative composition and annual changes in agricultural practices. To illustrate, the relocations of one doe were concentrated toward north during summer (the area of heaviest cover within her home range) and south in winter (the portion of her home range that contained agricultural crops). Conversely, a doe who inhabited an area that remained constant throughout the study period exhibited little deviation in overlap (Fig. 2).

Movements

Marked deer were sedentary and remained within 1 km of their capture sites. Average daily distances traveled increased with increases in home range (e.g., winter/spring vs. summer/fall), although only marginally ($P = 0.06$) (Table 2). Although deer altered use patterns seasonally depending on changing food supplies, they basically inhabited the same areas throughout the year (see Fidelity, above).

Mean distance from the geometric center of activity (GCA) to the outermost edge of the home range averaged 528.6 m (range = 194.7 to 1,145.7 m). The GCA moved an average of 238.8 m between winter and summer (the largest and smallest average home ranges, respectively). These movements represented a shift from communal bedding and feeding groups in winter to individualism exhibited during summer parturition. Distance between seasonal GCA averaged 151.8 m (range 3.6 to 481.5) and did not vary during consecutive seasons ($\underline{P}$ = 0.428).

Activity

Marked deer maintained a predominantly crepuscular activity schedule throughout the study period. Greatest activity (percent of time active ± SE) occurred in early morning (68.4% ± 2.6%; 0400 - 0800 hrs) and around dusk (60.4% ± 3.3%; 1600 - 2000 hrs in winter-spring and 2000 - 2400 hrs in summer) ($\underline{P}$ = 0.019). There was no difference in activity levels (hours of activity ± SE) between winter (12.7 ± 0.04), spring (11.9 ± 0.05), or summer (11.7 ± 0.05) ($\underline{P}$ = 0.926).

DISCUSSION

Emerging Phenomena of Suburban Deer

The habitation of deer on the CSA is a relatively recent occurrence. An urban wildlife inventory conducted in Carbondale during 1978-79 reported only two deer sightings in 2 years (Jenkusky 1979). One lifetime resident indicated that deer were not common until 1985 (R. Parrish, pers. comm.). Additionally, deer-vehicle collisions on the CSA showed a 200% increase in the number of reported accidents during the period 1981-1989, with the greatest increase occurring in 1987 (Cornicelli 1992).

Factors contributing to the establishment and growth of the suburban deer herd inhabiting the CSA are likely related to a rapid increase in the Jackson County deer population as evidenced by harvest data (Ill. Dep. Conserv., unpubl. data). Increasing deer densities in rural habitats most likely resulted in higher dispersal rates and an increased probability that dispersing deer would find vacant, suitable habitats such as offered by the CSA. Once immigrants became established on the CSA, resident herds formed that appeared to have strong fidelity to their home ranges. The availability of travel corridors suggests that herds on the CSA are not trapped in isolated habitats, yet we found no indications that they would attempt to emigrate.

The herd clearly is not a "sink"; rather, it may well be a "source" population for surrounding areas. If true, the CSA and similar suburban habitats serve as refuges and source populations that, depending on size, may buffer the effects of exploitation on surrounding hunted herds.

Behavior and Ecology of Suburban Deer

Telemetry data indicated that deer on the CSA had smaller home ranges than a herd in rural habitat. Hawkins (1967), working on Crab Orchard National Wildlife Refuge less than 10 km east of the CSA, reported home ranges for females up to 10 times larger than was observed during the present study. Smaller home ranges indicate that suburban areas, such as the CSA, can provide the necessary resources for deer in relatively small areas. Although development has removed larger expanses of contiguous habitat (Cornicelli 1992), high interspersion within smaller patches allow deer to obtain such resources without excessive travel between areas.

Although deer habitat on the CSA was limited and often close to human developments, their predominantly crepuscular activity rhythms were consistent with other studies of deer activity (Montgomery 1963, Kammermeyer and Marchinton 1977, Beier and McCullough 1990). This is interesting because it has been suggested that the behavioral flexibility of deer should enable them to modify activity periods to avoid humans (Marchinton and Hirth 1984). This apparently was not the case on this study area.

MANAGEMENT IMPLICATIONS

The emerging phenomena of suburban deer populations present two basic problems for wildlife managers. The most immediate of these is control of the size and growth of these non-traditional herds. Deer in suburban habitats are generally not amenable to conventional management strategies (Jones and Witham 1990). Historical control methods involving hunter harvests are usually not a viable option due to safety considerations and opposition by urban/suburban residents. In the Carbondale area, 82% of survey respondents wanted the deer population stabilized or decreased, yet only 46% supported some type of lethal control (Cornicelli et al. 1993). Clearly, suburban deer populations present wildlife management with a challenge to develop proactive, innovative strategies to balance public needs and concerns with the ultimate welfare of the resource (Curtis et al. 1993).

The second problem involves harvest management of the rural segment of the deer population. Essentially immune from harvest and natural predation, suburban herds can be expected to increase rapidly and, if suitable corridors exist, may act as effective source populations for surrounding areas via annual dispersal of juveniles. Depending on the relative size and number of suburban sanctuaries, normal harvest strategies may be compromised. When planning future harvests to attain population goals, we recommend that predictive models and other management planning tools take into account the potential refuging effects of suburban areas.

LITERATURE CITED

Anderson, D. J. 1982. The home range: a new non-parametric estimation technique. Ecology. 63:103-112.

Beier, P., and D. R. McCullough. 1988. Motion-sensitive radio collars for estimating white-tailed deer activity. J. Wildl. Manage. 52:11-13.

Beier, P., and D. R. McCullough. 1990. Factors influencing white-tailed deer activity patterns and habitat use. Wildl. Monogr. 109:1-51.

Connelly, N. A., D. J. Decker, and S. Wear. 1987. Public tolerance of deer in a suburban environment: Implications for management and control. Proc. East. Wildl. Damage Control Conf. 3:207-218.

Cornicelli, L. 1992. White-tailed deer use of a suburban area in southern Illinois. M.S. Thesis. Southern Ill. Univ. at Carbondale, Carbondale, Ill. 112pp.

Cornicelli, L., A. Woolf, and J. L. Roseberry. 1993. Residential attitudes and perceptions toward a suburban deer population in southern Illinois. Trans. Ill. Acad. Sci. 86:23-32.

Curtis, P. D., and M. E. Richmond. 1992. Future challenges of suburban white-tailed deer management. Trans. N. Am. Wildl. Nat. Resour. Conf. 57:104-114.

Curtis, P. D., R. J. Stout, B. A. Knuth, L. A. Myers, and T. M. Rockwell. 1993. Selecting deer management options in a suburban environment: a case study from Rochester, New York. Trans. N. Am. Wildl. Nat. Resour. Conf. 58:102-116.

Decker, D. J. 1987. Management of suburban deer: an emerging controversy. Proc. East. Wildl. Damage Control Conf. 3:344-345.

Decker, D. J., and T. A. Gavin. 1985. Public tolerance of deer in a suburban environment: Implications for control. Proc. East. Wildl. Damage Control Conf. 2:192-204.

Decker, D. J. and T. A. Gavin. 1987. Public attitudes toward a suburban deer herd. Wildl. Soc. Bull. 15:173-180.

Dixon, K. R., and J. A. Chapman. 1980. Harmonic mean measure of animal activity areas. Ecology. 61:1040-1044.

Hawkins, R. E. 1967. Social Organization of the White-tailed Deer on Crab Orchard National Wildlife Refuge. M. A. Thesis. Southern Ill. Univ. at Carbondale, Carbondale, Ill. 180 pp.

Harvey, M. J., and R. W. Barbour. 1965. Home range of *Microtus ochrogaster* as determined by a modified minimum area method. J. Mammal. 46:398-402.

Hawkins, R. E., L. S. Martoglio, and G. G. Montgomery. 1968. Cannon-netting deer. J. Wildl. Manage. 32:191-195.

Jenkusky, S. M. 1979. Wildlife and habitat components of an urban area. M.A. Thesis. Southern Ill. Univ. at Carbondale, Carbondale, Ill. 95pp.

Jones, J. M., and J. H. Witham. 1990. Post-translocation survival and movements of metropolitan white-tailed deer. Wildl. Soc. Bull. 18:434-441.

Kammermeyer, K. E., and R. H. Marchinton. 1977. Seasonal change in circadian activity of radio-monitored deer. J. Wildl. Manage. 41:315-317.

Marchinton, R. L., and D. H. Hirth. 1984. Behavior. Pages 129-168 in L. K. Halls, ed. The Ecology and management of white-tailed Deer. Stackpole Books, Harrisburg, Pa.

Mech, L. D., G. D. DelGuidice, P. D. Karns, and U. S. Seal. 1985. Yohimbine hydrochloride as an antagonist to xylazine hydrochloride-ketamine hydrochloride immobilization of white-tailed deer. J. Wildl. Dis. 21:405-410.

Montgomery, G. G. 1963. Nocturnal movements and activity rhythms of white-tailed deer. J. Wildl. Manage. 27:422-427.

Roseberry, J. L., and A. Woolf. 1991. A comparative evaluation of techniques for analyzing white-tailed deer harvest data. Wildl. Monogr. 117:1-59.

Severinghaus, C. W. 1949. Tooth development and wear as criteria of age in white-tailed deer. J. Wildl. Manage. 13:195-216.

Skrdla, M. P. 1992. A guide to map and image processing. MicroImages, Inc., Lincoln, Neb. 292pp.

Witham, J. H., and J. M. Jones. 1987. Deer-human interactions and research in the Chicago metropolitan area. pages 155-159. in L. W. Adams and D. L. Leedy, eds. Integrating man and nature in the metropolitan environment. Natl. Inst. for Urban Wildl. Columbia, Md.

Witham, J. H., and J. M. Jones. 1989. Managing urban deer in Illinois: The role of state government. pages 81-84 in Ninth Great Plains wildlife damage control workshop, Fort Collins, Co.

Table 1. Aggregated land-use types.

Category	Includes
Urban	Business/commercial properties, apartment complexes, roadways
Residential	Residential sub-divisions (single-family housing)
Woodland/Oldfield	Woodland, hedgerow, oldfield
Agriculture/Grassland	Row crops, hay/alfalfa, pasture, orchards, other grasslands
Water	Lake, pond, stream

Table 2. Seasonal home range size (ha) and average distance (m) between geometric center and outermost edge of the home range for radio-collared white-tailed deer in Carbondale, IL, 1990-92.

			Home Range		Movements		
Season	n[1]	N[2]	Mean	SE	Mean	Min	Max
Autumn	11	11	16.7	10.3	404.3	147.9	651.9
Winter	11	17	37.1	24.0	602.1	316.5	935.4
Spring	9	15	40.1	30.2	592.6	230.4	1,145.7
Summer	7	9	16.5	9.2	408.1	274.6	781.7

[1] Number of female deer radio-collared during that season.

[2] Number of home ranges used in analysis (several deer were monitored during consecutive years).

Figure 1. Map of the Carbondale, Illinois study area showing distribution of cover types. Enclosed solid lines indicate primary deer herds. Areas outside dashed lines indicate property within city limits, but not representative of a suburban setting.

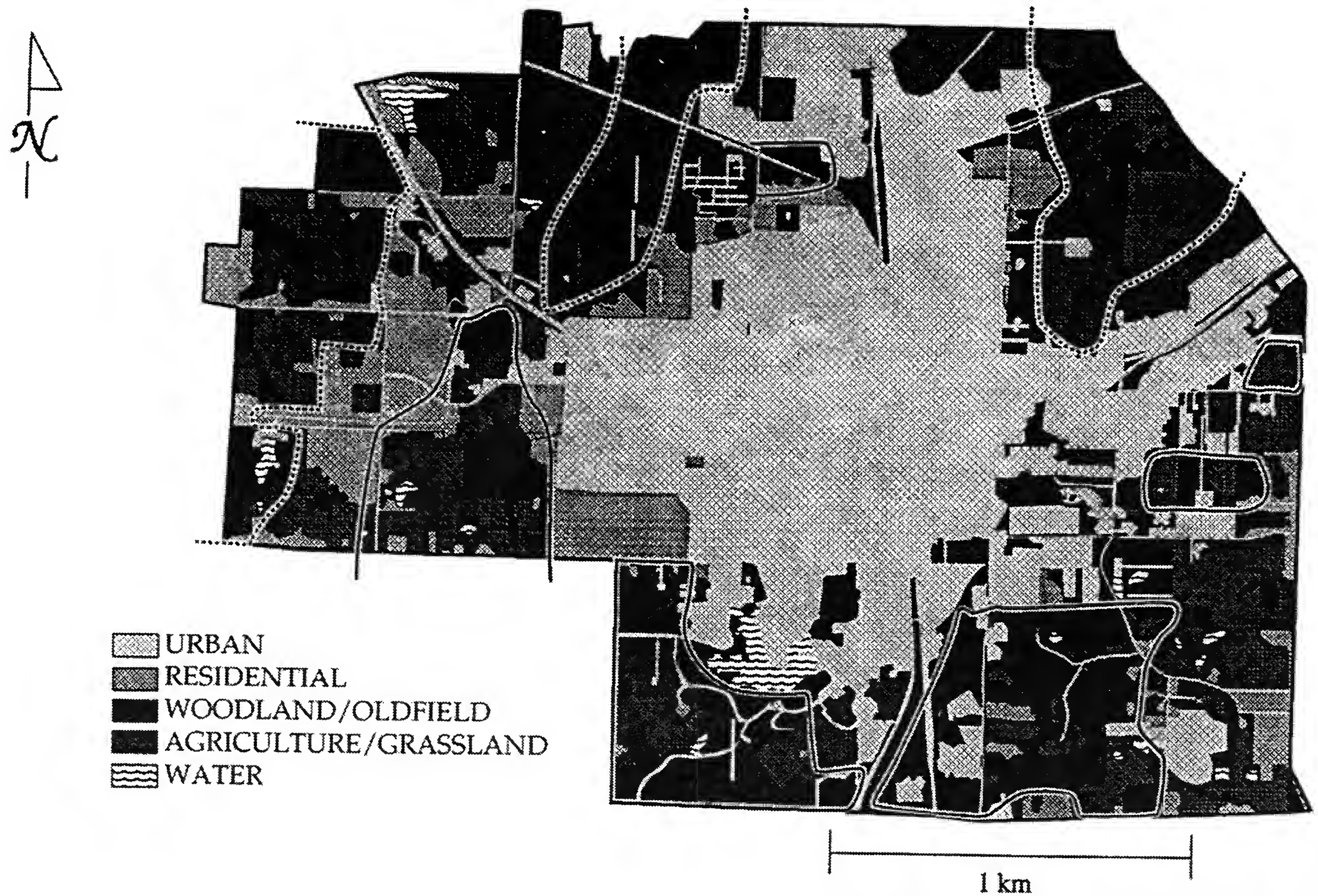


Figure 2. Differences in degree of seasonal home range overlap between a doe that inhabited changing vegetation (A) and one whose habitat did not vary (B).

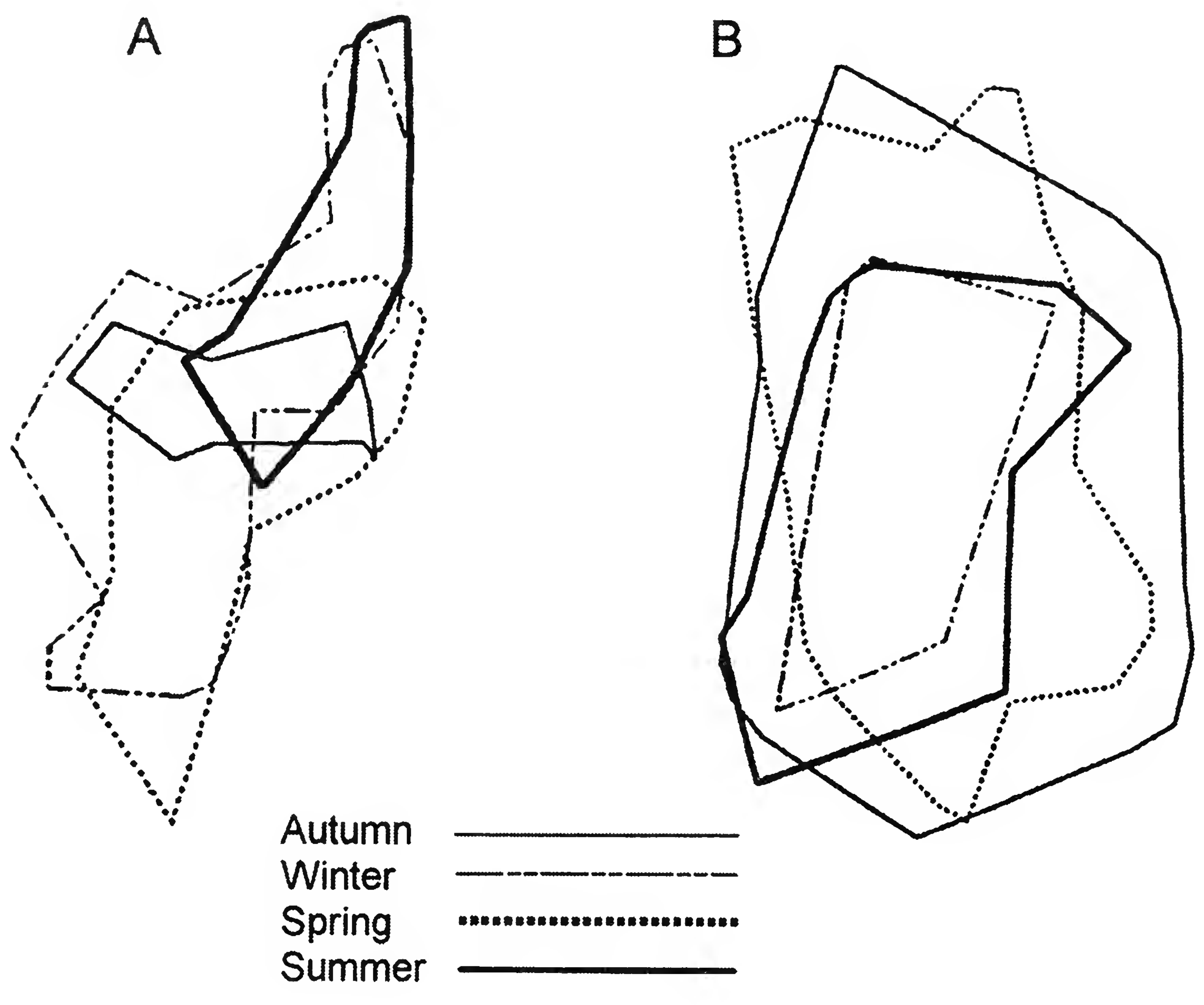
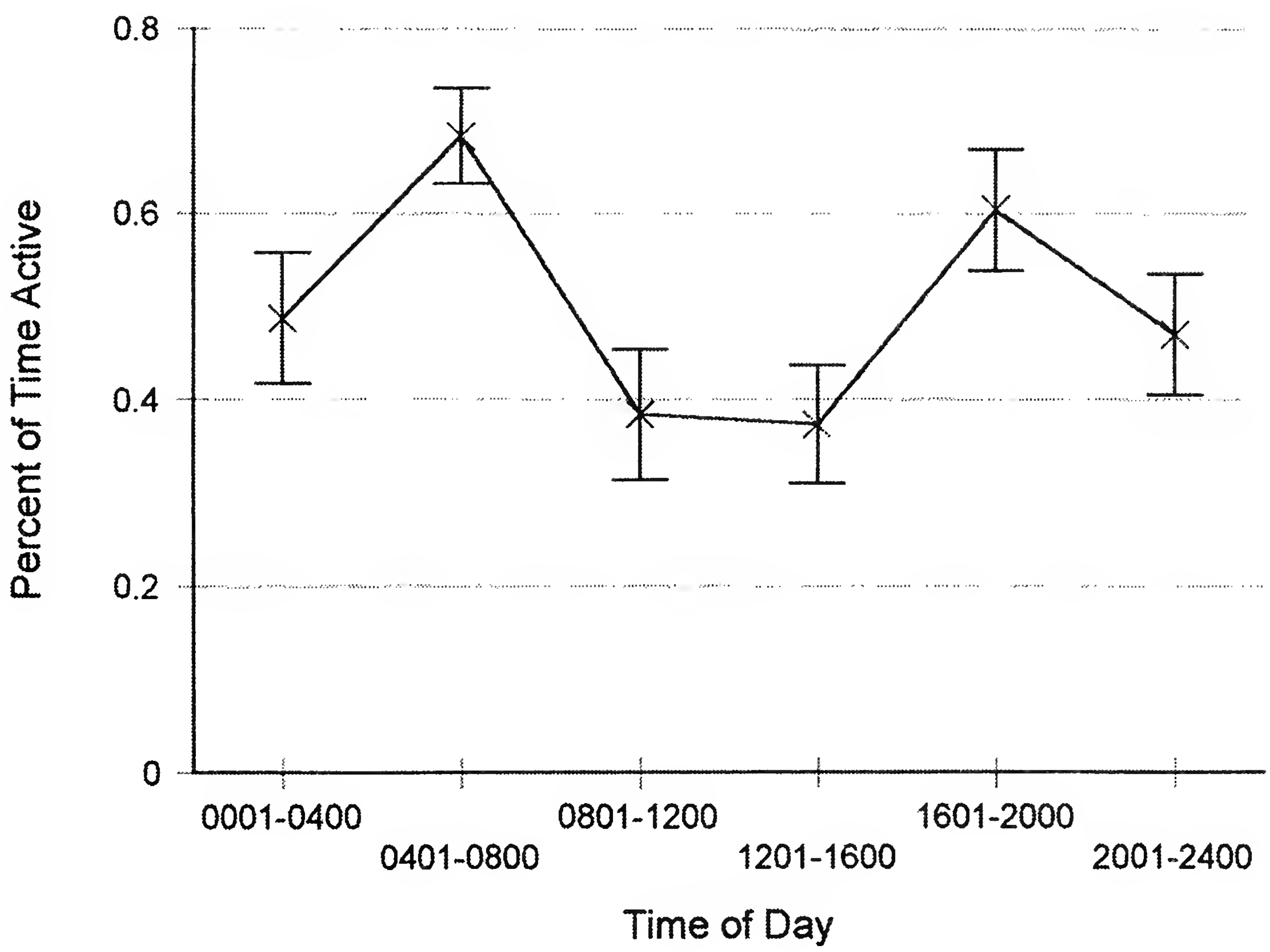


Figure 3. Percent of time active (± 95%) for radio-collared white-tailed deer in Carbondale, Illinois, Nov. 1990 - June 1991.



Transactions of the Illinois State Academy of Science
(1996), Volume 89, 1 and 2, pp. 105-111

Comparative Survival and Growth of Various Size Channel Catfish Stocked Into a Lake Containing Largemouth Bass

Michael Dudash and Roy C. Heidinger
Cooperative Fisheries Research Laboratory
and Department of Zoology
Southern Illinois University
Carbondale, Illinois 62901-6511

ABSTRACT

Channel catfish (*Ictalurs punctatus*) ranging in total length from 76 to 203 mm were divided into five size classes (76-102; 103-127; 128-152; 153-178; and 179-203 mm) and stocked into a 17 ha lake. Three hundred catfish in each size class were group marked with silver nitrate. The catfish were sampled fourteen months after stocking. Relative survival increased with the increase in size class. If the largest size class was scaled to 100 percent, relative survival from smallest to largest size class was 02, 04, 42, 78, and 100%, respectively.

INTRODUCTION

In the U.S. new or renovated impoundments are frequently stocked with channel catfish (*Ictalurus punctatus*), largemouth bass (*Micropterus salmoides*), and bluegill (*Lepomis macrochirus*) (Flickinger and Bulow 1993). In many of these impoundments there is little or no recruitment by the channel catfish and supplemental stocking of hatchery reared fish is required to maintain the fishery (Finnell and Jenkins 1954). The introduction of channel catfish into ponds and small lakes is widespread. At least 35 states have channel catfish stocking programs (Smith and Reeves 1986). Both biological and economic success of such a stocking is largely determined by the survival rate of the channel catfish.

In lakes with established fish populations, the stocking of small fingerling channel catfish results in low survival due primarily to predation by piscivorous fishes (Mestle 1983; Storck and Newman 1988). Higher densities of smaller fish are stocked to try to compensate for losses due to predation. However, this practice is usually ineffective because catch rates remain low. Stocking programs using 20 cm and larger channel catfish fingerlings can produce fisheries in bass-bluegill lakes (Adair 1981; Broach 1967; Santucci et al. 1994). Higher survival provides partial justification for stocking larger fish, however, the increase in survival of larger fingerlings may be of limited economic advantage if production costs are high.

In many small lakes, the largemouth bass is well recognized as the primary predator of the stocked channel catfish (Crance and McBay 1966; Dillon et al. 1971). Based on an aquarium and pond study without any other forage species present, Krummrich and Heidinger (1973) concluded that one must stock channel catfish of at least 178 to 203 mm to avoid loss to predation by a 0.9 kg largemouth bass. Spinelli et al. (1985) in another aquarium study found that predation of channel catfish by largemouth bass was reduced when other vulnerable prey were present. The objective of our study is to determine if it is economically more advantageous to stock small fingerlings at higher stocking densities or large fingerlings at lower stocking rates.

MATERIALS AND METHODS

Channel catfish ranging in total length from 76 to 203 mm were divided into five size classes: 76-102, 103-127, 128-152, 153-178, and 179-203 mm. In June, 300 channel catfish in each size group were marked with silver nitrate (Thomas 1975) and stocked into Campus Lake. Cost per fish within each size group was based on retail prices of local commercial producers. Campus Lake is a shallow (maximum depth 3 m) 17 ha impoundment located in Jackson County on the Southern Illinois University campus in Carbondale, Illinois. The spillway was screened with a 1.2 cm bar mesh metal screen during this experiment.

Each size group was distinctly marked. Only one fish was marked with each applicator. Fingerlings were marked, measured to the nearest millimeter and held in a raceway for twenty-four hours prior to stocking. Mortality was less than 1% and the dead fish were replaced. One hundred similarly marked channel catfish were held in a rearing pond to validate mark retention. Total stocking density was equivalent to 88 fish per hectare.

The fish community in campus lake is composed primarily of bluegill (*Lepomis macrochirus*), redear (*L. megalotis*), and largemouth bass. Channel catfish are present but natural recruitment is very low.

The largemouth bass population was evaluated in terms of numbers and length frequency. The Chapman modification of the Schnabel mark and recovery method was used to estimate the largemouth bass population (Ricker 1975). Largemouth bass were sampled by electrofishing with a three-phase, 220 volt AC, balanced electrode array, boat mounted unit. Largemouth bass 200 mm or larger in total length were measured to the nearest millimeter and marked with a small caudal (dorsal end) fin clip.

Proportional stock density (PSD) of the largemouth bass population was calculated using 200 mm as stock size and 300 mm as quality size (Anderson 1977). PSD is defined as the number of fish equal to or larger than quality size divided by the number of fish equal to or greater than stock size. Other parameters that could affect vulnerability such as turbidity and vegetative cover were also monitored. Turbidity was measured with a Secchi disc and percent vegetative cover was estimated visually.

Fourteen months after stocking the one-plus year old channel catfish were sampled using five panel experimental gill nets (12.7, 19.0, 25.4, 32.0, 38.0 mm bar mesh), trotlines, and electrofishing. All sampling devices were used throughout the lake. The trotlines used 1/0 hooks and were baited with worms, chicken liver, small crayfish, and small pieces of fish.

Statistical tests were performed with the SAS system computer programs (SAS Institute 1988). Regression analysis was used to correlate size of fish at stocking with the percentage of each size class recovered and with the size of the recovered fish. Fisher's exact test was used to test for significant differences between the size of fish stocked and the number recovered.

RESULTS AND DISCUSSION

Fourteen months after stocking 121 (8.1%) of the 1500 stocked channel catfish were recovered. Most (91%) were obtained from the trotlines. Assuming that trotlines do not select for different size channel catfish within the size range in this study, there was a positive correlation (r^2=0.9513; p=0.0046) between the size of fish at stocking and the percentage of each size class recovered. Fisher's exact test indicated no statistically significant difference at the alpha 0.05 level between the smallest two size classes and between the largest two size classes (Table 1). Channel catfish stocked between 103-203 mm showed a linear relationship between size of channel catfish stocked and their relative survival (Figure 1).

After 14 months in Campus Lake the mean final total length of the 76-102 mm size group was 251 mm whereas the mean final total length of the 179-203 mm size group was 398 mm (Table 2). Final size was positively correlated (r^2=0.9505; p=.0047) with initial size. Mean growth rates ranged from 11.6 to 15.7 mm per month.

The largemouth bass population in Campus Lake is characterized by a large number of small fish (Figure 2) yielding a relatively low PSD value of 17 percent. At the time the channel catfish were stocked we estimated that the lake contained 73 ±29 (95% CI) bass per hectare.

Throughout this study grass carp (*Ctenopharyngodon idella*) reduced aquatic vegetation to less than 1.0% surface area. Secchi disc readings ranged from 51 to 125 cm.

If the percent of stocked channel catfish recovered are rescaled so that the 179-203 size group is 100%, then the survival of the four smaller size groups relative to the largest size group can be calculated (Table 3). Thus for every 100 fish of the 179-203 mm size group that survives only 2 of the smallest (76-102 mm) and 42 of the 128-152 mm size group survive. When the cost of fingerlings range from 0.06 cent each for the small size group to 0.32 cents each for the largest size group the relative cost per 100 large size group equivalence ranges from $300 for the smallest fish to $32 for the largest fish (Table 3). In general relative cost decreased with an increase in size stocked. However, the largest change occurred between the 103-127 mm size group and the 128-152 mm size group (Table 3).

Stocking cost per channel catfish returned to creel is dependent upon the initial production cost of the fish and their relative survival. It cost more to produce a large fingerling for stocking than it does a small fingerling at least within the size range used in this study. Within the ranges of sizes stocked in this study, relative survival also increased with the size of fish stocked. Based on the trend in number of fish recovered from each size class, under the environmental and predator conditions found in Campus Lake at the time of stocking, it would have been most economical to stock the largest size group (179-203 mm). Statistically, however, there was no difference in the recovery rate of the two largest size classes, therefore, it would have been most economical to stock the smaller 153-178 mm size class. Santucci et al. (1994) found that there is no difference in recovery rates between 200-mm and 250-mm channel catfish. When the economics of stocking is based on survival the cost to produce each size group is a very important consideration. Actual production cost depends upon many factors such as type of hatchery, food cost, personnel cost, production technique, etc. Based on the relative survival in this study, the cost of the smaller size groups as a percentage of the largest size group would have to be 0.02, 0.04, 0.42, and 0.78, respectively, in order to be as economical to stock as smaller sized fish.

This study has provided needed information on the survival and relative cost of stocking various sizes of channel catfish into an established largemouth bass-bluegill community. Studies on other lakes are needed before relative survival can be modeled with respect to the predator population and other variables that affect vulnerability to predation such as vegetation and turbidity.

LITERATURE CITED

Adair, B. 1981. Open-water creel survey at Lake Anita, 1979-1981 with emphasis on effectiveness of channel catfish maintenance stockings. Iowa Conservation Commission, Des Moines, Iowa.

Anderson, R.O. 1977. Management of small warm water impoundments. Fisheries1(6):5-7, 26-28.

Broach, D. 1967. Arkansas' catchable channel catfish, *Ictalurs punctatus*. (Rafinesque), program. Proceedings South Eastern Association Game and Fish Commissioners. 21:445-452.

Crance, J.H., and L.B. McBay. 1966. Results of tests with channel catfish in Alabama ponds. Prog. Fish-Cult. 28:193-200.

Dillon, O.W., W.W. Neely, V.E. Davison, and L.V. Compton. 1971. Warm water fishponds. Farmers Bulletin 22J7, U.S. Dept. of Agriculture, Washington, D.C.

Finnell, J.C., and R.M. Jenkins. 1954. Growth of channel catfish in Oklahoma waters: 1954 revision. Oklahoma Fish. Res. Lab. Rep. No. 41, Oklahoma City.

Flickinger, S.A., and F.J. Bulow. 1993. Small impoundments. Pages 469-492 in C.C. Kohler and W.A. Hubert, editors. Inland fisheries management in North America. American Fisheries Society, Bethesda, Maryland.

Krummrich, J.R., and R.C. Heidinger. 1973. Vulnerability of channel catfish to largemouth bass predation. Prog. Fish-Cult. 35:173-175.

Mestle, G.E. 1983. Survival of stocked channel catfish in small ponds. M.S. Thesis, Oklahoma State University, Stillwater. 69 pp.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Bd. Can. Bull. 191:97-99.

Santucci, Jr. V.J., D.H. Wahl, and T.W. Storck. 1994. Growth, mortality, harvest and cost-effectiveness of stocked channel catfish in a small impoundment. North American Journal of Fish Management 14:781-789.

SAS Institute. 1988. SAS/STAT user's guide. SAS Institute, Cary, North Carolina. 1028 pp.

Smith, B.W., and W.C. Reeves. 1986. Stocking warmwater species to restore or enhance fisheries. Pages 17-29 in R.H. Stroud, editor. Fish culture in fisheries management. Fish. Culture Section and Fisheries Management Section of the American Fisheries Society, Bethesda, Maryland.

Spinelli, A.J., B.G. Whiteside, and D.G. Huffman. 1985. Aquarium studies on the evaluation of stocking various sizes of channel catfish with established largemouth bass. North American Journal of Fish Management 5:138-145.

Storck, T., and D. Newman. 1988. Effects of size at stocking on survival and harvest of channel catfish. North American Journal of Fish Management 8:98-101.

Thomas, A.E. 1975. Marking channel catfish with silver nitrate. Prog. Fish-Cult. 37(4):250-252.

Table 1. Number and total length of channel catfish stocked and number recaptured 14 months later.

Size Class (mm)	Number Stocked	Stocking Density (per ha)	Number [1] Recaptured	Percent Recovered
76-102	300	18	1[a]	0.3
103-127	300	18	2[a]	0.6
128-152	300	18	22	7.3
153-178	300	18	42[b]	14.0
179-203	300	18	54[b]	18.0
TOTAL	1500	88	121	

[1] / Numbers with similar superscripts are not statistically different at alpha =0.05.

Table 2. Growth of channel catfish fingerlings recaptured after 14 months in Campus Lake.

Size Class Stocked (mm)	Mean Initial Length (mm)	Mean Final Length (mm)	Growth Rate (mm/month)
76-102	89	251	11.6
103-127	115	286	12.2
128-152	140	353	14.8
153-178	165	385	15.7
179-203	191	398	14.8

Table 3. Relationship between cost survival and relative cost of channel catfish.

Size (mm)	Relative [a] Survival (%)	Relative [b] Number Needed	Unit Cost ($)	Relative Cost ($)
76-102	2	5000	0.06	300
103-127	4	2500	0.10	250
128-152	42	238	0.25	60
153-178	78	128	0.29	37
179-203	100	100	0.32	32

[a] Relative survivals among size groups have been rescaled so that the 179-203 mm size group equals 100 percent.
[b] Number required per 100 of the largest size group (179-203 mm) recovered.

Figure 1. Relationship between the size of channel catfish stocked and the relative frequency of recapture.

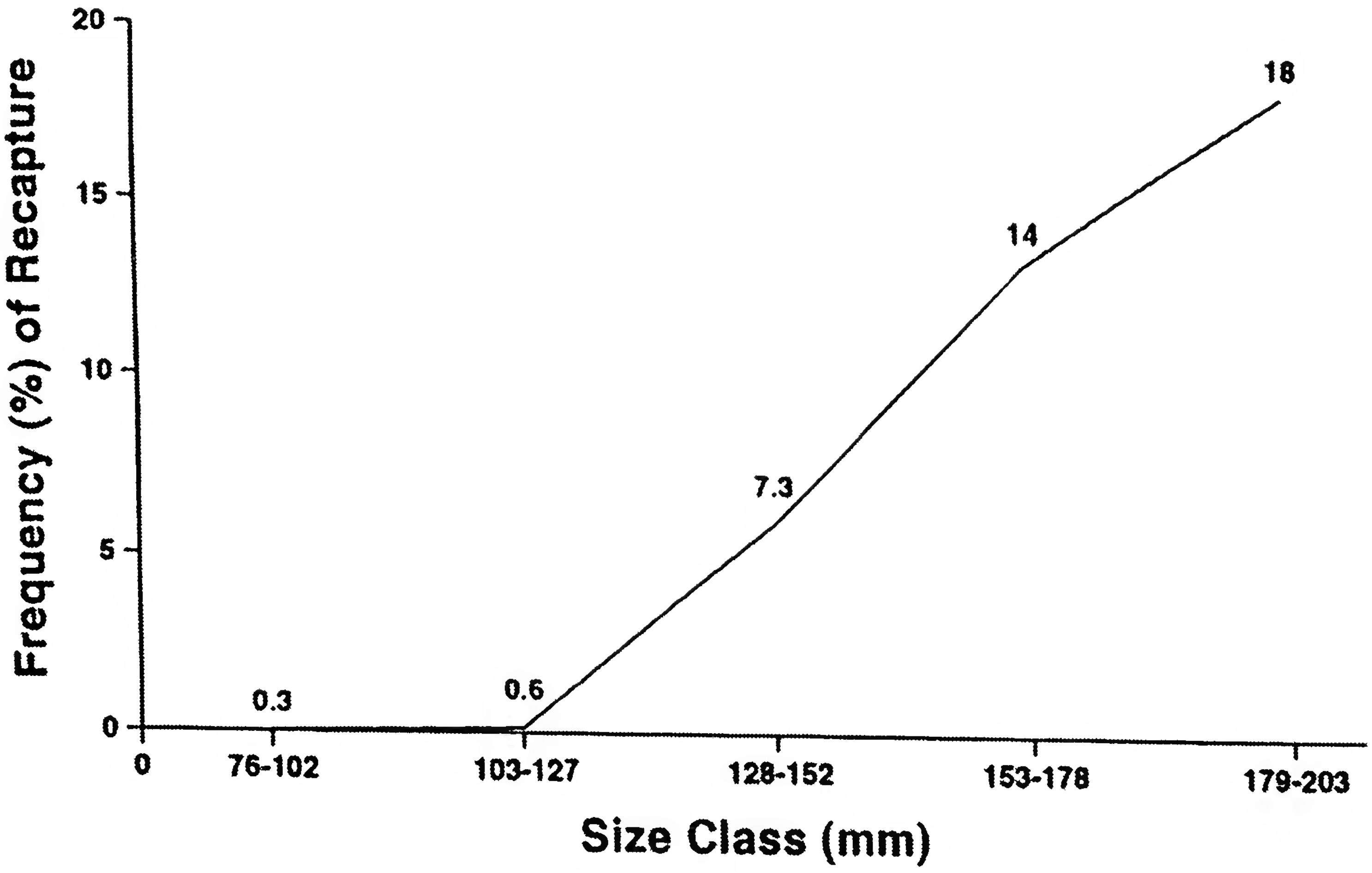
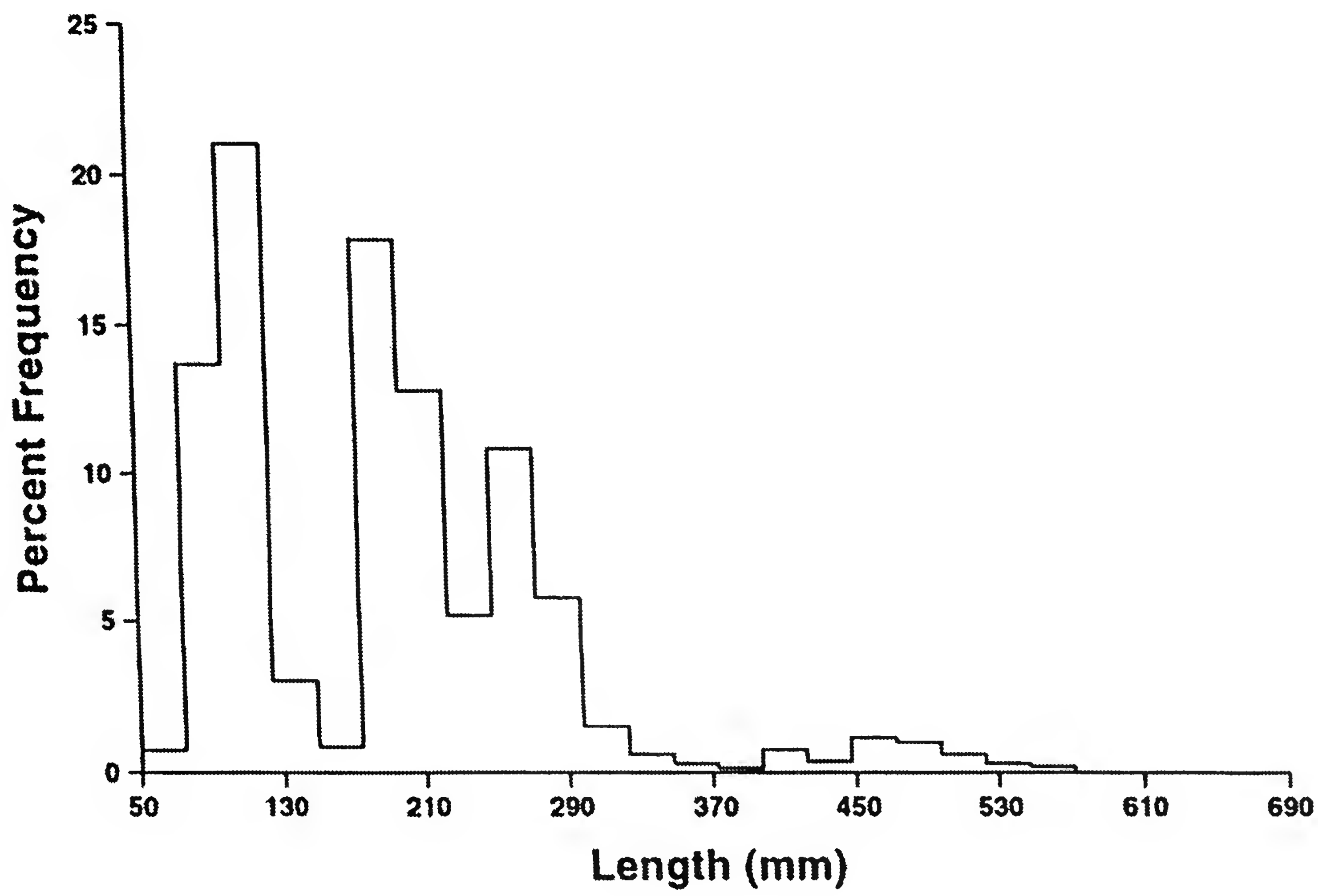


Figure 2. Length-frequency distribution for largemouth bass in Campus Lake.



Transactions of the Illinois State Academy of Science
(1996), Volume 89, 1 and 2, pp. 113-122

Utilization of Backwater Habitats by Unionid Mussels (Bivalvia: Unionidae) on the Lower Illinois River and in Pool 26 of the Upper Mississippi River

John K. Tucker, Charles H. Theiling, and James B. Camerer
Illinois Natural History Survey
Long Term Resource Monitoring Program Pool 26
4134 Alby Street, Alton, Illinois 62002, USA

ABSTRACT

Samples of the unionid faunas from two contiguous and five isolated backwaters of the lower Illinois River and Pool 26 of the Upper Mississippi River revealed differences in species composition between the two habitat types. Contiguous backwaters supported diverse faunas (7 to 14 species) near their connections with the river, whereas isolated backwaters supported only three or four species. Species diversity decreased within contiguous backwaters suggesting that the river-backwater interaction is important in maintaining unionid species diversity in these habitats. The common practice of isolating backwaters from the river using levees to prevent siltation may lead to reduced unionid diversity.

INTRODUCTION

Little is known about the extent unionid mussels utilize backwater habitats along the lower Illinois River and the Upper Mississippi River. In the last extensive review of the unionid fauna of the Illinois River, Starrett (1971) reported no unionids from Meredosia Lake, a bottomland lake, one species from Lake Matanzas, a contiguous backwater, and seven species from Quiver Lake, another contiguous backwater. The near absence of information on unionid faunas in backwaters of large rivers stands in sharp contrast to the much more extensively studied faunas of the mainstems of large (e.g., Hornbach et al., 1992; Siemsen, 1993) and small rivers (e.g., Schanzle and Cummings, 1991; Miller, 1993).

Characterizing unionid faunas in contiguous and isolated backwaters is important because some contiguous backwaters such as Swan Lake are candidates or currently scheduled for impoundment as Habitat Rehabilitation and Enhancement Projects (HREPS). Little is known of the effect of such projects on nontarget species such as unionids. Although impoundments of rivers are known to affect mussel faunas (Bates, 1962), no studies have reported species compositions of unionid faunas from contiguous backwaters before and after isolation. With the arrival of the zebra mussel (*Dreissena polymorpha*) in the lower Illinois and Upper Mississippi Rivers (Tucker et al., 1993; Tucker, 1994) complicating conservation of unionid species diversity (Neves, 1993), an understanding of unionid faunal composition in various habitats is critical. Herein, we report on the unionid faunas of Swan Lake and Brick House Slough, both contiguous backwaters, and of five nearby isolated backwaters (Fig. 1).

MATERIALS AND METHODS

We used two collecting methods. Qualitative collections (timed samples) were made by collecting every mussel found in a unit time. Quantitative collections were made by removing all mussels found in 30 randomly placed 0.25 m^2 quadrats at each location (Tucker et al., 1993).

Collecting effort as measured by man hours varied among the stations sampled using qualitative methods. We collected all specimens found in one-half man hour at the Brick House Slough sites (Table 1). We collected all specimens found in two man hours at all other locations (Tables 2 and 3). Because collecting effort differed among stations, the number of individual specimens for all sites are converted to the number of specimens collected for each one-half man hour (Tables 1-3). We made all collections in water shallow enough for wading. Specimens were located by touch.

Quantitative samples were made at Brick House Slough station 1 and Swan Lake station 1 so that more objective comparisons could be drawn between those two locations. Mussels were too infrequent at the interior and isolated stations to employ quantitative sampling.

Collecting areas are outlined in Fig. 1. Swan Lake and Brick House Slough are contiguous with the Illinois and Mississippi Rivers, respectively, whereas all other sites are isolated by levees. We collected at seven stations within Swan Lake and four stations within Brick House Slough. Of the seven stations inside Swan Lake, three of them (1-3) are within 800 meters of the mouth of the lake and are classified as exterior stations, whereas the other four (4-7) are classified as interior stations. Of the four stations in Brick House Slough, two are within 400 meters of the mouth and are classified as exterior stations, whereas the other two (3-4) are classified as interior stations. We made collections at single station in all of the isolated backwaters (= isolated stations). All sampling occurred between 1 July and 22 July, 1994.

We identified all specimens (Cummings and Mayer, 1992) in the field and returned them to the collecting station immediately after identification. Only living specimens are included in the samples.

We used the SAS system of statistical programs (SAS Institute, 1988) for statistical evaluation of results. We selected the GLM procedure, which is appropriate for unbalanced sample sizes, to perform analysis of variance (ANOVA).

RESULTS

Qualitative samples.
We collected a total of 16 unionid species from the 16 stations we sampled. Only one species, *Anodonta grandis*, occurred at every station. Of the remaining species, only *Amblema plicata* (11 of 16), *Quadrula quadrula* (13 of 16), and *Potamilus ohiensis* (9 of 16) were collected at more than half of the stations. Half of the species (8 of 16) were collected at either a single station or two stations. Eight species (*Megalonaias nervosa, Quadrula nodulata, Anodonta imbecilis, Arcidens confragosus, Lasmigona complanata, Obliquaria reflexa, Potamilus alatus,* and *Truncilla truncata*) were collected only at stations we classified as exterior stations in the contiguous backwaters (Tables 1 and 2). The remaining species occurred in two or more station classifications.

We used ANOVA to compare the number of species found in contiguous backwaters (exterior and interior stations) and isolated backwaters as well as the number of specimens found. The model for the comparison of the number of species is significant (mean square = 47.68, $F = 13.58$, $p = 0.0007$) as is the model for the number of specimens (mean square = 14212.11, $F = 11.09$, $p = 0.0015$). For the number of species, exterior stations (mean number of species = 8.8, n = 5) had significantly more species ($p < 0.05$) than did interior stations (mean number of species = 4.2, n = 6) or isolated stations (mean number of species = 3.0, n = 5). Interior and isolated stations did not differ ($p > 0.05$) from each other. Exterior stations also had more ($p < 0.05$) specimens per unit of collecting effort (mean = .105.25 specimens / half-hour) than did either interior stations (mean = 14.58 specimens / half-hour) or isolated stations (mean = 14.0 specimens / half-hour). Again, interior and isolated stations did not differ significantly ($p > 0.05$).

Individual comparisons within station classifications found no statistically significant differences in the number of species between the stations classified as interior stations nor for those classified as isolated stations. The exterior stations for Swan Lake and Brick House Slough did not differ statistically in the number of species (10.3 and 6.5, respectively) found ($F = 2.50$, $p = 0.2120$) but did differ ($F = 13.34$, $p = 0.0354$) in the number of specimens (64.08 and 167.0, respectively) found per half-hour of collecting effort.

Quantitative samples.
The mussel faunas at Brick House Slough station 1 and Swan Lake station 1 are similar in most respects (Table 4). Both are dominated by a few species and in particular by *Amblema plicata*. Likewise, *Quadrula quadrula, Anodonta grandis,* and *Obliquaria reflexa* are important contributors to the faunas. However, we did find significantly more specimens per meter ($F = 4.77$, $p = 0.0330$) at Brick House Slough than at Swan Lake (Table 4) consistent with the results of the qualitative sampling (Tables 1 and 2).

DISCUSSION

The species and number of specimens found in our study vary by habitat. Stations that are near to the river/backwater connection contained more species and larger numbers of individuals. Such stations (e.g., Brick House 1-2 and Swan Lake 1-3) have faunas that are typically riverine. For instance, species lists recently published for the Illinois River near Swan Lake and for the Mississippi River in Pool 26 (Tucker et al., 1993; Tucker, 1994) are similar to the species that we found at stations we classify as exterior ones. However, samples from interior and isolated stations are not riverine and are more similar to other lake faunas (e.g., Parmalee, 1955; Starrett, 1971). Apparently, the interactions at the river/backwater interface is important in maintaining the riverine nature of faunas from exterior stations.

At this point, it should be noted that the number of species collected is related to the collecting effort expended regardless of the technique employed (i.e., Lubinski, 1987). Therefore, statistical comparisons of the number of species collected among sites with differing collecting effort is questionable. However, in this instance, collecting effort was greatest in the locations (i.e., isolated backwaters) with the lowest numbers of species collected. The differences between isolated and contiguous backwater species numbers should be reduced yet species numbers from contiguous backwater samples were still statistically greater than those from isolated backwaters where collecting effort was as much as four times greater. If anything, the difference in collecting effort minimized the differences between isolated and contiguous backwaters.

Although the proximal causes of the differences between exterior stations and interior/isolated stations are not known, the importance of river/backwater interaction is underscored by the change from a riverine fauna to a lentic fauna within both of the contiguous backwaters we studied. The role of contiguous backwaters in transporting resources to the river has been investigated for invertebrates (Shaeffer and Nickum, 1986a) and fish (Shaeffer and Nickum, 1986b). In both instances, the authors have concluded that backwaters export resources to the river; we believe that Swan Lake exports and imports resources between the river and the lake.

Currents in the vicinity of the mouth of Swan Lake have been observed to change direction on a daily basis, probably due to differencial diurnal heating and cooling of the river and backwater. Other water exchanges probably occur due to mechanical eddies in the vicinity of the mouth of Swan Lake. We believe inflowing currents transport resources originating in the river into the lake and it's resident mussels. Outflowing currents likely transport resources originating in the lake over the mussels and out to the river. Both water movement and energy transport are factors assumed to be important in the distribution of unionid species in contiguous backwaters.

Our study has important ramifications where maintenance of unionid species diversity is a consideration in management activities. Programs such as levee construction that isolate backwaters from the river will likely significantly reduce unionid species diversity. Such habitat modification programs are justified by the desire to reduce sedimentation rates and increase numbers of 'preferred' species such as waterfowl and centrarchid fishes.

At present, little concern exists about maintaining unionid faunal diversity within backwaters due in part to the widespread belief that 'better quality' faunas are found in the adjoining channel borders of the two rivers that we studied. The report that contiguous backwaters may serve as refugia from the adverse effects of the zebra mussel, *Dreissena polymorpha* (Tucker and Atwood, 1995), suggests that maintenance of the river/backwater connection may become an important tool for preserving unionid diversity in North American rivers. Prior to the introduction of *D. polymorpha*, the diversity and abundance of unionid mussels had been greatly challenged by human disturbance of their habitats (Starrett, 1971; Lubinski, 1987). For instance, Starrett (1971, Table A-21) reported that 21 species of unionids apparently had been extirpated in the Alton Pool of the Illinois River since 1870. William et al. (1992) found that roughly 55% of North America's mussel species were extinct or endangered. However, the importance of habitat destruction may pale in contrast to the future effects on unionid diversity caused by the introduction of exotic species such as the Asiatic clam, *Corbicula fluminea* (e.g., Belanger et al., 1990; Leff et al., 1990) and the zebra mussel, *Dreissena polymorpha* (e.g., Mackie, 1991; Hunter and Bailey, 1992; Mackie, 1993; Tucker, 1994; Gillis and Mackie, 1994).

ACKNOWLEDGMENTS

We thank J. B. Hatcher for assistance with collecting. K. D. Blodgett read the manuscript. G. L. Mackie provided a copy of the Gillis and Mackie paper prior to its publication. This work was partially supported by the Illinois Natural History Survey and the Upper Mississippi River System Long Term Resource Monitoring Program.

LITERATURE CITED

Bates, J. M. 1962. The impact of impoundment on the mussel fauna of Kentucky Reservoir, Tennessee River. Am. Midl. Nat. 68:232-236.

Belanger, T. V., C. G. Annis and D. D. VanEps. 1990. Growth rates of the Asiatic clam, *Corbicula fluminea*, in the upper and middle St. Johns River, Florida. Nautilus 104:4-9.

Cummings, K. S. and C. A. Mayer. 1992. Field guide to freshwater mussels of the midwest. Illinois Nat. Hist. Surv. Man. 5:i-xiii + 1-194.

Gillis, P. L. and G. L. Mackie. 1994. Impact of the zebra mussel, *Dreissena polymorpha*, on populations of Unionidae (Bivalvia) in Lake St. Clair. Can. J. Zool. 72:1260-1271

Hornbach, D. J., A. C. Miller and B. S. Payne. 1992. Species composition of the mussel assemblages in the upper Mississippi River. Malacol. Rev. 25:119-128.

Hunter, R. D. and J. F. Bailey. 1992. *Dreissena polymorpha* (zebra mussel): Colonization of soft substrata and some effects on unionid bivalves. Nautilus 106:60-67.

Leff, L. G., J. L. Burch and J. V. McArthur. 1990. Spatial distribution, seston removal, and potential competitive interactions of the bivalves *Corbicula fluminea* and *Elliptio complanata*, in a coastal plain stream. Freshwater Biol. 24:409-416.

Lubinski, K. S. 1987. Community and population characteristics of mussels in the bed at Illinois River Mile 3.0-L. Pp. 104-114 *In* Proceedings of the workshop on die-offs of freshwater mussels in the United States. U.S. Fish and Wildlife Service, UMR Conservation Committee.

Mackie, G. L. 1991. Biology of the exotic zebra mussel, *Dreissena polymorpha*, in relation to native bivalves and its potential impact in Lake St. Clair. Hydrobiol. 219:251-268.

Mackie, G. L. 1993. Biology of the zebra mussel (*Dreissena polymorpha*) and observations of mussel colonization on unionid bivalves in Lake St. Clair of the Great Lakes. Pp. 153-165 *In* Nalepa, T. E. and D. W. Schloesser (eds.). Zebra mussels biology, impacts, and control. Lewis Publishers, Boca Raton, Florida.

Miller, E. J. 1993. Evaluation of Verdigris River, Kansas, Freshwater mussel refuge. Pp. 56-60 *In* Cummings, K. S., A. C. Buchanan and L. M. Koch (eds.). Conservation and management of freshwater mussels. Proceedings of a UMRCC symposium. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Neves, R. J. 1993. A state-of-the-unionids address. Pp. 1-9. *In* Cummings, K. S., A. C. Buchanan and L. M. Koch (eds.). Conservation and management of freshwater mussels. Proceedings of a UMRCC symposium. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Parmalee, P. W. 1955. Some ecological aspects of the naiad fauna of Lake Springfield, Illinois. Nautilus 69:28-34.

SAS Institute. 1988. SAS/STAT user's guide. SAS Institute, Cory, North Carolina. 1028 pp.

Schanzle, R. W. and K. S. Cummings. 1991. A survey of the freshwater mussels (Bivalvia: Unionidae) of the Sangamon River Basin, Illinois. Illinois Nat. Hist. Surv. Biol. Notes 137:1-25.

Shaeffer, W.A. and J.G. Nickum. 1986a. Relative abundance of macroinvertebrates found in habitats associated with backwater area confluences in the Upper Mississippi River. Hydrobiol. 136:113-120.

Shaeffer, W.A. and J.G. Nickum. 1986b. Backwater areas as nursery habitat for fishes in Pool 13 of the Upper Mississippi River. Hydrobiol. 136:131-140.

Siemsen, T. S. 1993. Detailed inventory of freshwater mussels in the lower Ohio River, miles 918.0-981.0. Pp. 106-108 *In* Cummings, K. S., A. C. Buchanan and L. M. Koch (eds.). Conservation and management of freshwater mussels. Proceedings of a UMRCC symposium. Upper Mississippi River Conservation Committee, Rock Island, Illinois.

Starrett, W. C. 1971. A survey of the mussels (Unionacea) of the Illinois River: a polluted stream. Illinois Nat. Hist. Surv. Bull. 30:267-403.

Tucker, J. K. 1994. Colonization of Unionid Bivalves by the Zebra Mussel, *Dreissena polymorpha,* in Pool 26 of the Mississippi River. J. Freshwater Ecol. 9:129-134.

Tucker, J. K. and E. R. Atwood. 1995. Contiguous backwater lakes as possible refugia for unionid mussels in areas of heavy zebra mussel (*Dreissena polymorpha*) colonization. J. Freshwater Ecol. 10:43-47.

Tucker, J. K., C. H. Theiling, K. D. Blodgett and P. A. Thiel. 1993. Initial occurrences of zebra mussels (*Dreissena polymorpha*) on freshwater mussels (Family Unionidae) in the upper Mississippi River System. J. Freshwater Ecol. 8:245-251.

Williams, J. D., M. L. Warren, Jr., K. S. Cummings, J. L. Harris and R. J. Neves. 1992. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18:6-22.

Table 1. Numbers and species of unionids collected from contiguous and isolated backwaters of the Mississippi River including Brick House Slough, the contiguous backwater, and Dresser Island and Spadderdock Lake, the isolated backwaters, for 0.5 manhours of picking.

	Isolated backwaters		Brick House Slough stations			
	Spadderdock	Dresser	1	2	3	4
Species	n	n	n	n	n	n
Amblema plicata	0	1	154	111	10	9
Megalonaias nervosa	0	0	2	0	0	0
Quadrula nodulata	0	0	0	2	0	0
Quadrula quadrula	1	0	7	5	10	3
Anodonta grandis	4	14	2	15	14	10
Anodonta suborbiculata	4	12	0	0	1	0
Arcidens confragosus	0	0	6	0	0	0
Leptodea fragilis	0	0	0	0	0	1
Obliquaria reflexa	0	0	22	2	0	0
Potamilus ohiensis	5	0	0	2	1	0
Truncilla truncata	0	0	4	0	0	0
Number of species	4	3	7	6	5	4

Table 2. Numbers and species of unionids collected in Swan Lake, a contiguous backwater of the Illinois River. Number of specimens (n) collected adjusted to number collected per 0.5 manhours collecting for each site.

	Exterior stations			Interior stations			
	1	2	3	4	5	6	7
Species	n	n	n	n	n	n	n
Amblema plicata	58.50	35.50	34.0	3	0	1	4.25
Megalonaias nervosa	0.25	0	0	0	0	0	0
Quadrula nodulata	0.75	0	0	0	0	0	0
Quadrula quadrula	6.75	3.25	5	7	0.50	2	0.25
Anodonta grandis	10.50	5.25	5.75	3	3.50	0.25	0.25
Anodonta imbecillis	0.50	0.75	0	0	0	0	0
Anodonta suborbiculata	0	0	0.25	0	0	0.25	0
Arcidens confragosus	0.50	0.75	0.50	0	0	0	0
Lasmigona complanata	0.25	0	0.25	0	0	0	0
Lampsilis teres	0.75	0	0	2	0	0	0
Leptodea fragilis	0.75	0.25	0	0	0	0	0
Obliquaria reflexa	8.75	2.25	1.25	0	0	0	0
Potamilus alatus	0.25	0	0	0	0	0	0
Potamilus ohiensis	0.75	0.50	0.50	0	0.50	0.25	0.50
Truncilla truncata	0.50	0	0	0	0	0	0
Toxolasma parvus	0	0	0.75	0	0	0	0
Number of species	14	8	9	4	3	5	4

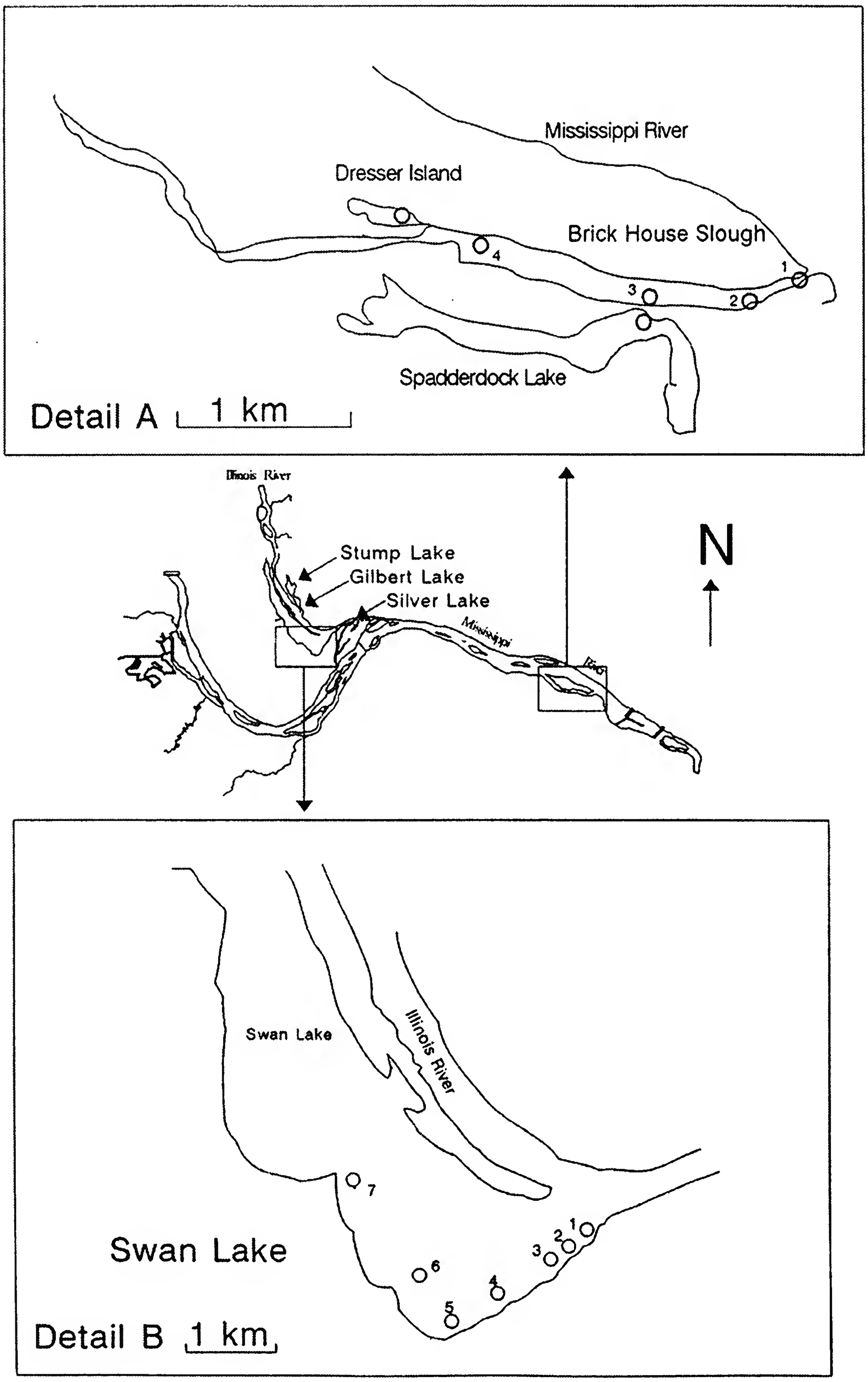
Table 3. Number and species of unionids collected in three isolated backwaters of the Illinois River. Number of specimens (n) collected adjusted to number collected per 0.5 manhours collecting for each site.

Species	Stump Lake n	Silver Lake n	Gilbert Lake n
Anodonta grandis	8.25	11.50	3.50
Anodonta suborbiculata	0	3.50	1.50
Toxolasma parvus	0.75	0	0
Quadrula quadrula	0	0	0.50
Leptodea fragilis	0	0	0.50
Number of species	2	2	4

Table 4. Number and species of unionids collected in quantitative samples from Swan Lake (station 1) and Brick House Slough. n = total number of specimens collected in 30 0.25 m^2 samples.

Species	Swan Lake n	Brick House Slough n
Amblema plicata	55	103
Megalonaias nervosa	0	3
Quadrula pustulosa	0	1
Quadrula quadrula	11	21
Anodonta grandis	6	12
Anodonta imbecillis	1	0
Arcidens confragosus	1	2
Lasmigona complanata	0	3
Lampsilis teres	8	0
Leptodea fragilis	8	3
Obliquaria reflexa	16	12
Potamilus alatus	2	0
Potamilus ohiensis	2	0
Truncilla truncata	5	2
Number of species	11	10
Number specimens/m^2	15.3	21.6

Figure 1. Upper Mississippi and lower Illinois Rivers showing location of study sites at Stump, Gilbert, and Silver Lakes and collecting stations within Brick House Slough (Detail A) and Swan Lake (Detail B).



Academy Notes

Future Meetings of the Academy

ILLINOIS WESLEYAN UNIVERSITY
October 18 & 19, 1996

meetings return to Spring in 1998

Student Competition Award Recipients

Annual Meeting - October 1995

Botany Division - Best Student Paper

1st Place

Paige A. Mettler-McClure, Southern Illinois University - Carbondale
Mettler-McClure, Paige A. and Marion Smith.
Changes in Site Characteristics for a Threatened Fugitive Floodplain Species, *Boltonia decurrens*, as a Result of the Flood of 1993

2nd Place

Karia E. Readel, University of Illinois - Urbana
Redel, Karia E., D.S. Seigler, J.E. Ebinger, and H.D. Clark.
Variation in Tannin Production in Populations of Mexican *Acacia* Species

Health Science Division - Best Student Presentation

1st Place

Michael Parks, Southern Illinois University - Edwardsville
A New Method to Obtain Fibrin-Platelet Matrices in the Continued Study of Candidal Endocarditis

Student Research Grant Recipients

October 1995

Matthew Biggs, University of Illinois - Urbana/Champaign
Lowest Cost Launch System for Competitive Return on Investment by 2010.

Robert Brady, Southern Illinois University - Carbondale
The Quantitative Characterization of Quality Parameters and Material Flaws via Pulsed Video Thermography

Zareefa Burki, Loyola University - Chicago
A Physical Map of the Short Arm/Telomeric Region of Human Chromosome 21

Matthew Dystra, Trinity Christian College
Estimating Global Diversity

Margaret Przybysz, Loyola University - Chicago
A Physical Map of the Distal Centromere Region of Human Chromosome 21

Craig Stevens, Loyola University - Chicago
A Physical Map of the Centromere Region of Human Chromosome 21

James Therrien, Southern Illinois University - Carbondale
The Systematics of Porella (L.): the *Porella platyphylla* (L.) Pfelff. and *P. platyphylloidea* (Schwein.) Lindb. Species Complex

Information for Contributors

Submission Information

1. Original communications may be sent to: Transactions of the Illinois State Academy of Science, Illinois State Museum, Springfield, Illinois 62706.

2. Submission of a paper to the Editors will be held to imply that it has not been published previously except in Abstract form and, if accepted, will not be published elsewhere in the same form, without written consent of the Editors.

3. The format for manuscripts should follow a form appropriate to the specific discipline; most commonly, e.g., Abstract (no more than 250 words), Introduction, Materials and Methods, Results, Discussion, and Summary.

4. Manuscripts should be typewritten, double-spaced on one side of bond paper (8.5" x 11") with a left hand margin of not less than 1.5 inch. The author must submit one original and two copies of the manuscript, and should retain a copy.

5. Tables and figures may be incorporated within the manuscript or included at the end of the manuscript. Tables must be numbered consecutively in the order in which they are referred to in the text. Likewise for figures.

6. Both genus and species must be given for all organisms used in the investigation.

7. In the text, references should be quoted by the author's name and date, e.g., (Smith, 1960). Footnotes are to be avoided.
   a. At the end of the manuscript, full references, in alphabetical order, must be listed and include the names of the authors, date of publication, full title of the paper, title of the journal, volume number, and the first and last page numbers. References to books must include the number of the edition, publisher, and place of publication.

Acceptance Information

8. Each manuscript will be reviewed by no less than two anonymous reviewers.

9. For manuscripts deemed acceptable for publication, authors must address the reviewers comments and provide a revised manuscript copy to the Editor.

Publication Information

10. Upon final acceptance of manuscripts for publication the author shall provide a computer disk and hard copy version of the manuscript to the Editor containing all text and tables.

11. All graphs, charts, and diagrams will be reproduced by photo-offset means directly from the author's final manuscript. These must be submitted in a camera ready form.
   a. The entire printed area must fit within a centered 8 inch by 5 inch area, including room for legend, positioned either vertically or horizontally. More than figure may appear on each page as long as appearance of the page is not cluttered.

12. Photographs and photomicrographs should be glossy prints. Each should have, lightly written on the back, the author's name, the figure number, and an indication of the plane of the picture. Lines or lettering to appear on the photographs should be in Letraset.

13. Galley proofs will be sent to the author, first-mentioned author, or designee for correction. Corrections to the page proofs must be restricted to printer's error only. Other alterations will be charged to the author.

14. The page charge for members is $25.00 per page. The charge for non-members is doubled. Twenty-five reprints will be provided to the author by the Academy.

Transactions of the Illinois State Academy of Science
Volume 89 (1996)

CONTENTS

TRANSACTIONS of the ILLINOIS STATE ACADEMY OF SCIENCE

Volume 89, Numbers 3 and 4 1996

ILLINOIS STATE ACADEMY OF SCIENCE
Founded 1907

Affiliated with the
ILLINOIS STATE MUSEUM, Springfield

ISSN 0019-2252
PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

* * * * *

The Transactions of the Illinois State Academy of Science will publish papers that contain the results of original research in all aspects the areas listed above.

The current Transactions may be obtained by payment of annual dues. To obtain previous issues of Transactions or for additional information, contact the Executive Secretary at the Illinois State Museum, Springfield, Illinois 62706.

Transactions of the Illinois State Academy of Science
(1996), Volume 89, 3 and 4, pp. 125-141

Application of a Geographic Information System to Mapping Presettlement Vegetation in Southwestern Illinois

Richard B. Brugam[1] and Mary James Patterson[2]
[1]Department of Biological Sciences
[2]Environmental Studies Program
Southern Illinois University
Edwardsville, Ill. 62026

ABSTRACT

Presettlement tree distributions from two Southwestern Illinois counties were compared with physiographic regions using maps created on MAPINFO, a Geographic Information System. The ecotone between the forests of the Mississippi Borderland bluffs and the Illinoisan Till Plains is clearly shown on the GIS maps. The ecotone follows a creek valley that divides the sharply dissected bluffs from the flat till plains. Fire intolerant taxa such as *Ulmus* spp., *Celtis* spp., *Populus deltoides*, *Acer negundo*, and *Fraxinus* spp. grew in the complex of wetlands nearest to the Mississippi River. The bluffs along the river had a moderately fire tolerant forest of *Quercus alba*, *Q. velutina* / *Q. rubra*, and *Carya* spp. The Illinoisan-aged till plains of the eastern part of the study area supported a mixture of prairie, *Quercus palustris*, and *Q. stellata* on soils that were occasionally waterlogged.

Keywords: Illinois, Public Land Survey, pre-settlement vegetation, Prairie Peninsula, Oak-Hickory Forest

INTRODUCTION

The Prairie Peninsula (Transeau 1935) is a large area of mixed forest and prairie in the American Midwest that extends eastward across the state of Illinois from the Mississippi River. It is interrupted near the river by a narrow strip of forested land along the river referred to as the "Mississippi Valley Section of the Oak-Hickory Forest Region" by Braun (1964). Although this strip of land shares a climate similar to that of the Prairie Peninsula, it was heavily forested before European settlement (Transeau 1935).

The Government Land Office Survey can be used to determine the relationship of the western boundary of the Prairie Peninsula with topography. U.S. government lands were surveyed before they were sold to pioneer farmers. The survey used locations of "bearing" trees, identified to species, as markers for survey plots. These trees represent a low-density vegetation survey that can be used to reconstruct the natural vegetation before European settlement.

Many investigators have reconstructed pre-settlement vegetation of parts of Illinois using the land survey records (Anderson 1991). Anderson and Anderson (1975) and Rodgers and

Anderson (1979) used the surveys to reconstruct the distributions of prairie and forest in three Illinois counties. King and Johnson (1974) examined the distributions of tree species with respect to slope and proximity to streams. More recently, Shotola et al. (1992) used the pre-settlement survey in a comparison with modern forest composition in southwestern Illinois. Fralish et al. (1991) used the surveys to compare the distributions of particular tree species and community types with site characteristics and with modern vegetation to examine changes in forest composition since pre-settlement times.

Geographic Information Systems are computer programs which use geographically organized data to construct maps. They can be used to examine the relationship between geographic data and landforms. In particular, a Geographic Information System can be used to summarize the relationship between the distribution of trees in the U.S. Government Land Office Survey and topography.

With the exception of Grimm (1984) and Schwartz (1994), few previous investigators have used computer mapping techniques to study the Public Land Survey data. We have applied these techniques to the land survey data from southwestern Illinois to compare distributions of the tree species with major topographic features.

STUDY AREA

Location

The area of this study is Madison and St. Clair counties in Illinois with small portions of adjacent Bond, Clinton, Washington and Monroe counties (Fig. 1).

Madison and St. Clair counties were chosen for this study because of their location at the interface of the Prairie Peninsula (mapped by Transeau 1935) and the oak/hickory forest that extends northward along the Mississippi (Braun 1964). This is an ecotonal area (Fig 1) which is not associated with any sharp difference in climate. Precise maps of forest distributions along the ecotone would reveal the relationship between the distributions of particular trees and landforms along the east side of the Mississippi River.

Geology

Southwestern Illinois was covered by the Illinoisan glacier (Schwegman 1973) which has been dated between 170,000 and 125,000 B.P. (Curry and Follmer 1992). The Illinoisan glacial till plain covers most of the eastern half of the study area.

Although the Wisconsinan glacier did not reach Southwestern Illinois, the wind-blown, glacially-derived silt from the Mississippi River during Wisconsinan times forms a thick loess covering over most of the area. With the exception of the alluvial plains of the major rivers, all soils in our study area are derived from loess (Wallace 1978; Goddard and Sabata 1986).

Climate

Southwestern Illinois has a continental climate with a maximum average July temperature of 31.4 °C (88.6 °F.) and a minimum average January temperature of -7.6 °C (19.3 °F.; Wallace 1978). In most years there are strong summer droughts broken by occasional frontal storms. Total rainfall averages 14.7 cm per year (36.82 inches) but the actual amount varies greatly from year to year (Wallace 1978).

Native American Occupation

Our study area was the location of the largest settlement of Native American people north of Mesoamerica (Fowler 1989). This ceremonial center, named Cahokia, dates from 1100 to 1300 A.D. and had an estimated population of between 10,000 and 30,000. Although the landscape was much modified by the Cahokian people, by the time of European contact the impact of the Cahokians probably was no longer evident. By then, native American populations at the site had declined (Fowler 1989).

Natural Divisions

The study area includes several environmental divisions described by Schwegman (1974) and classified on the basis of topography.

The environmental division nearest the Mississippi River is the Mississippi Bottomlands (Fig 1). In pre-settlement time, this region, also called the "American Bottoms" contained many lakes and wetlands developed in old river channels (Fowler 1989). Soils in this region have developed from river alluvium (Wallace 1978; Goddard and Sabata 1986).

The Mississippi Borderlands division (Fig 1) is characterized by river bluffs on its western border. This division has a dissected topography with deeply incised valleys.

The eastern part of our study area lies within the Southern Till Plains division, which extends over a large portion of Southern Illinois. It is characterized by loess-covered Illinoisan till plains crossed by major rivers (e.g. the Kaskaskia; Fig 1). The till plain is level to gently rolling except near streams where erosion has produced shallow valleys. The soils of this division are poorly drained (Wallace 1978; Goddard and Sabata 1986). Before European settlement large areas of the till plain were covered with shallow water in spring. These "wet prairies" dried by summer (Schwegman 1974).

A small part of the Western Forest and Prairie division enters the northern part of the study area (Fig. 1). As with the Southern Till Plains division, the Western Forest and Prairie division is underlain by Illinoisan glacial till plain.

The Ozark division along the southwestern edge of the study area (Fig. 1) is characterized by loess-covered karst topography with many sink holes, a few of which contain lakes. The modern flora of this division has many similarities with the eastern edge of the Missouri Ozarks (Schwegman 1974).

METHODS

Field Methods

The survey data used here are drawn from the U.S. Government Land Office Survey. The study area was surveyed in 1812 (Patterson 1989). Our data are drawn from the microfilm copies of the survey notes archived at the Illinois State Library in Springfield. These surveys were completed on public lands throughout the U.S. before the lands were sold to settlers. This survey created a grid of square "townships" which were 6 miles on a side.

Each township contains 36 square "sections" a mile on a side. The sections are further subdivided into four 1/4 square mile "quarter sections". In the land surveys two or four "bearing trees" (sensu Grimm 1984) were blazed with an axe at each section and quarter section corner throughout the survey area to mark the land for later sale to pioneer farmers. The trees were identified, measured, and located with respect to the quarter section corner. More complete descriptions of the survey methods are presented in Bourdo (1956) and Grimm (1984). Only bearing trees (sensu Grimm 1984) were used in this study.

The surveyors of Southwestern Illinois only recorded 2 bearing trees at each section corner. In addition to species, the surveyors recorded the size of the tree, and the distance and direction from the corner.

The surveyors identified the trees by common English names in use at the time. The Southwestern Illinois surveyors did not differentiate hickory species. Furthermore, the references of the surveyors to "black" oak probably included both *Quercus velutina* and large numbers of individuals which we would today classify as red oak, *Quercus rubra.* Fralish et al. (1991) encountered similar problems in interpreting the distributions of red and black oak in the land survey of the Shawnee Hills of southern Illinois.

The use of vernacular names by the surveyors means that the distributions of some species were obscured. For example, *Celtis laevigata* exists in the study area in modern times, but is likely to have been included with *C. occidentalis* under the name "hackberry" (Mohlenbrock1982). The surveyors also did not differentiate among species of oaks which are important in localized areas (*Q. muehlenbergii* on the river bluffs). These problems of tree identification increase our difficulties in interpreting the survey results but do not reduce the value of the distribution data that we do have.

Computer Methods

For our study the latitude and longitude of each quarter section corner was entered into a computer file. This file was used in MAPINFO, version 4, a commercially available geographic information system, to locate the trees to be mapped. Borders of physiographic regions were digitized from Schwegman (1974) and overlaid on the map of tree locations. Soil types were digitized from the soil map of Illinois and overlain on the tree maps.

Statistical Methods

The association between tree species and physiographic region were tested using a chi-squared test on a 5 by 2 contingency table.

RESULTS

Distribution of Forest and Prairie

In the Southern Till Plains division, trees were primarily along stream beds (Fig. 2). On the dry uplands surveyors found no bearing trees. These areas were covered with prairie. Toward the west, trees became more numerous and every quarter section corner in the Mississippi Borderlands division had trees. The Mississippi Bottomlands by contrast, had large treeless areas which extended to the bluff edge.

Tree Species Distributions

Southern Till Plain Division

Although the Southern Till Plain division had prairie vegetation on the uplands, it also had a distinctive assemblage of trees along stream channels and in isolated upland locations. The most common species in this division are pin oak and post oak (Fig. 3). Some specimens of overcup oak (*Q. lyrata*) occurred in this division along Sugar Creek in the eastern part of the area (Fig. 3).

The western boundary of pin, post, and overcup oak distributions does not correspond with the western boundary of the Southern Till plains division as mapped by Schwegman (1974). Our maps show this western boundary to follow an arc (labeled "Ecotone" on Fig. 3) from the northwestern to the southeastern corner of the study area. The boundary follows Silver Creek and Mud Creek (Figs 3 and 4). There is a clear demarcation of vegetation types along these streams. To the east are large expanses of prairie bordered by pin, post, and overcup oak trees along streams (Fig. 3). To the west of Silver Creek are more heavily forested areas of white, red, black and black jack oak and hickory (Figs 4 and 5).

The boundary between forest types is not an artifact of poor identifications by surveyors because the boundary transects many townships. Each township was surveyed by a single survey crew. Thus, tree identifications on both sides of the boundary within a township can be expected to be consistent.

Mississippi Borderlands

The Mississippi Borderlands supported an oak/hickory forest including white and "black" oaks (Fig. 4). Hickory was also common in this division near the bluff edge (Fig 5). As mentioned above, this classical "Oak-Hickory" forest extended beyond the mapped boundary of this division to Silver Creek in the east.

Mississippi Bottomlands

The Mississippi Bottomlands, an alluvial plain subject to frequent flooding, supported forests that were very different from the oak/hickory forests of the surrounding uplands.

The major species found in the land survey in the Mississippi American Bottomlands are elm , willow, cottonwood (Fig 6), sycamore, boxelder, hackberry, and ash (Fig 7). Nearly all of the box elder and cottonwood were close to the Mississippi. In contrast, elm was found both in the Mississippi Bottomlands and in many upland sites.

Western Forest and Prairie Division

This division supported white oak, "black" oak (Fig 4), hickory (Fig. 5). The quarter section corners from the center of this division all contain black jack oak (Fig. 5). This latter species has an unusual distribution because it also occurs in a small area to the west of Silver Creek and in scattered sites throughout the study area (Fig. 5).

Ozark Division

The Ozark Division had a forest similar to the Mississippi Borderlands division. In the Ozark Division white oak was found at nearly every quarter section corner (Fig. 4). "Black" oak was also common (Fig. 4)

Sugar Maple

Sugar maple (*Acer saccharum*; Fig. 6) was not confined to a particular environmental division but was found in greatest abundance along the Kaskaskia River. The surveyors found a few isolated specimens of these species in other locations.

Statistical Analyses of Tree Distributions

The chi-squared test (Table 1) was used to determine if the most abundant tree species in the data set were distributed randomly with respect to Schwegman's (1974) physiographic divisions. Most tree species show a significantly non-random distribution with respect to division. A few species, like sugar maple and black jack oak, had distributions among divisions which did not differ significantly from random.

When the percentage of tree species occupying particular regions is examined (Fig. 8), the affinities of species for particular regions is apparent. These percentages represent the proportion of particular species compared with the total number of trees in the physiographic division. White oak, black oak, and hickories are found in all physiographic divisions. Pin oak is most abundant in the Southern Till Plains. Elm, ash, hackberry, boxelder and cottonwood are most abundant in the Bottomlands. Post oak is most abundant in the Western Prairie and Forest division.

DISCUSSION

Ecotone Between the Mississippi Borderlands and Southern Till Plain

This pre-settlement vegetation survey reveals an ecotone between a forest of hickory, white oak, red oak and black oak and a forest of pin oak, post oak, and overcup oak dividing the study area (Fig 3). For most of its length in our area the ecotone follows Silver Creek. This creek also separates areas of contrasting topography. To the west of the creek the land has highly dissected loess ravines. To the east it is flat, loess-covered glacial till plain. The creek itself follows a meandering course through a relatively broad, shallow valley.

A likely explanation for the existence of the ecotone at Silver Creek is contrasting fire frequency on either side of the creek. The flat areas to the east of the creek were covered by prairie. They are marked by the Piasa soil association (Fig. 3) which developed under grasslands. The Piasa soil is also poorly permeable having ponded water on it in spring (Goddard and Sabata 1986). The areas of prairie were surrounded by a fire-tolerant woodland of pin oak, post oak, and overcup oak. Presumably, prairie fires burned into these areas. Silver Creek probably functioned as an efficient fire break. To the west of the creek the dissected topography provided additional firebreaks allowing the growth of a forest of less fire tolerant trees -- white oak, red oak, black oak, and hickory.

King and Johnson (1977) also emphasized the association among topography, fire frequency and the geographic distributions of tree species in Illinois. In their study of the pre-settlement vegetation of the Sangamon River drainage in Illinois, they found that forested survey corners were more likely to be found on sloping sites. Flat land supported prairie. We found a similar relationship. The Ozark, Mississippi Borderlands, and Western Prairie and Forest divisions all have areas of steep slopes whereas the Southern Till

Plains division has large areas of flat land of the type that supported prairie in the Sangamon River drainage (King and Johnson 1974).

Telford (1926) noted the prevalence of post oaks on well-drained soils and pin oaks on poorly drained soils in the Southern Till Plains. These forests called the "Illinois flatwoods" have a tree density intermediate between savanna and forest (Taft et al. 1995). Taft et al. (1995) find the post oak flatwoods to be associated with poorly permeable soils with clay pans and frequent fires. Our maps show the natural distribution of the flatwoods. Guyette and Cutter (1991) emphasize in their study of fire history in southern Missouri that post oak is very resistant to scarring by ground fires. Their observation suggests that the flatwoods were very fire tolerant.

The ecotone between the Mississippi Borderlands that we have found from the land survey data marks the western border between the Prairie Peninsula and Braun's (1964) Mississippi Valley Section of the Oak-Hickory Forest. Our location for the boundary is somewhat to the east of Schwegman's (1974) location, but consistent with his interpretation of the physiographic regions of Southern Illinois.

Flood Plain Forests

The Mississippi Bottomlands, in contrast with the surrounding uplands, contained species that are either common in flood-plains (e.g. *Salix* and *Populus*) or fire intolerant, moisture demanding genera (e.g. *Fraxinus* and *Ulmus*). Their presence in the Bottomlands suggests that fire frequencies there were low. Fowler's (1989) map of the pre-settlement Mississippi Bottomlands shows it to have been a complex of wetlands and oxbow lakes. In modern times, levee construction and draining have erased most of these wetland types.

The Geographic Distribution of Sugar Maple

One result of the European colonization of southwestern Illinois has been a sharp decline in fire frequency (Ebinger 1986). A number of investigators (Anderson and Adams 1978; Ebinger 1986; Shotola et al. 1992) have suggested that a major result of this change is enhanced survival of sugar maple and the eventual replacement of oak/hickory forest by sugar maple at many sites. Sugar maple is rare as a bearing tree in our data set. It occurs in abundance only along the Kaskaskia River. In modern times, it has colonized old-growth woods. Grimm (1984) suggested that sugar maple is susceptible to periodic ground fires because its seedlings survive for a long time in the forest understory until a light gap releases them. The seedling population of maples would be susceptible to even a small ground fire that would not affect larger oaks. An anthropogenic decrease in fire frequency would enhance the survival of the seedlings.

CONCLUSION

The presettlement land survey data for Southwestern Illinois show a strong relationship between tree species distributions and topography. The computer-generated maps show a clear ecotone between the oak-hickory forests on the uplands adjacent to the Mississippi River and the pin oak and post oak woodlands surrounding the prairies to the east of the river. The distributions of these forest types are consistent with the hypothesis that differences in fire frequency influenced by topography controlled tree species distributions in pre-settlement Southwestern Illinois.

LITERATURE CITED

Anderson, R.C. 1991. Presettlement forests of Illinois. Proceedings of the Oak Woods Management Workshop. G.V. Burger, J. Ebinger and G.S. Wilhelm eds. Eastern Illinois University, Charleston, Ill. pp 9-19.

Anderson , R.C. and D.E. Adams 1978. Species replacement patterns in Central Illinois white oak forests. In P.E. Pope ed. Central Hardwoods Conference II Purdue University, West Lafayette, Indiana. pp 284-301.

Anderson, R.C. and M.R. Anderson 1975. The presettlement vegetation of Williamson County, Illinois. Castanea 40:345-363.

Bourdo E.A., Jr. 1956. A review of the General Land Office Survey and of its use in quantitative studies of former forests. Ecol. 37:754-768.

Braun, E.L. 1964. Deciduous Forests of Eastern North America Hafner Publishing Co., New York. 596 pp.

Curry, B. and L.R. Follmer 1992. The last interglacial-glacial transition in Illinois 123-25 ka. In Clar, P.V. and Lea P.D. eds. The Last Interglacial-Glacial Transition in North America. Geological Society of America Special Paper 270

Ebinger, J. 1986. Sugar maple, a management problem in Illinois forests. 79:25-30.

Fowler, M. L. 1989. The Cahokia Atlas: A Historical Atlas of Cahokia Archaeology. Studies in Illinois Archaeology 6. Illinois Historic Preservation Agency, Springfield, Ill. 243 pp.

Fralish, J.S., F.B. Crooks, J.L. Chambers, and F.M. Harty. 1991. Comparison of presettlement, second-growth and old-growth forest on six site types in the Illinois Shawnee Hills. Amer. Midl. Nat. 125:294-309.

Goddard, T.M. and L.R. Sabata. 1986. Soil Survey of Madison County, Illinois. United States Department of Agriculture, Soil Conservation Service. Washington, D.C. 254 pp.

Grimm, E.C. 1984. Fire and other factors controlling the Big Woods vegetation of Minnesota in the mid-nineteenth century. Ecol. Monogr. 54:291-311.

Guyette, R.P. and B.E. Cutter. 1991. Tree-ring analysis of fire history of a post oak savanna in the Missouri Ozarks. Natural Areas Journal 11:93-99

King, F.B. and J.B. Johnson. 1977. Presettlement forest composition of the central Sangamon River basin, Illinois. Trans. Ill. Acad. Sci. 70:153-163.

Mohlenbrock R.H. 1982. Illustrated Flora of Illinois: Flowering Plants, Basswoods to Spurges. Southern Illinois University Press, Carbondale. 234 pp.

Patterson, M.J. 1989, Pre-settlement Vegetation of Madison and St. Clair Counties, Illinois. M.S. Thesis, Southern Illinois University, Edwardsville, 140 pp.

Rodgers, C. and R.C. Anderson 1979. Presettlement vegetation of two prairie peninsula counties. Bot. Gaz. 140:232-240.

Schwartz, M.W. 1994. Nautral distribution and abundance of forest species and communities in Northern Florida. Ecol. 75:687-705.

Schwegman, J.E. 1974. Comprehensive Plan for the Illinois Nature Preserves System, Part 2: The Natural Divisions of Illinois. Illinois Nature Preserves Commission. 32 pp.

Shotola, S.J., G.T. Weaver, P.A. Robertson, and W.C. Ashby. 1992. Sugar maple invasion of an old-growth oak-hickory forest in southwestern Illinois. Am. Midl. Nat. 127: 125-138.

Taft, J.B., M.W. Schwartz and L.R. Phillippe 1995. Vegetation ecology of flatwoods on the Illinoisan till plain. J. of Veg. Sci. 6:647-666.

Telford, C.J. 1926. Third report of a forest survey of Illinois. Illinois Natural History Survey Bulletin 16:1-102.

Transeau, E. N. 1935. The prairie peninsula. Ecol. 16: 99-112.

Wallace, D.L. 1978. Soil Survey of St. Clair County, Illinois. United States Department of Agriculture, Soil Conservation Service. Washington, D.C. 114 pp.

Table 1: Chi-squared results. The null hypothesis is that individuals of a species are evenly distributed among the 5 physiographic regions. The degrees of freedom vary because some regions had < 5 individuals of a particular species.

Species	degrees of freedom	chi squared	Probability
Celtis spp.	1	98.4	P<.1%
Q.alba	4	87.0	P<.1%
Q.stellata	2	81.9	P<.1%
P.deltoides	1	81.5	P<.1%
A.negundo	1	75.5	P<.1%
Q.velutina /rubra	4	73.4	P<.1%
Q.palustris	2	59.1	P<.1%
Fraxinus spp.	2	48.3	P<.1%
Ulmus spp.	3	46.1	P<.1%
Carya spp.	4	34.2	P<.1%
Q.marilandica	2	3.3	P>5%
A.saccharum	1	1.5	P>5%

Figure 1. Environmental divisions of southwestern Illinois Redrawn from Schwegman (1974). Inset shows location of study area.

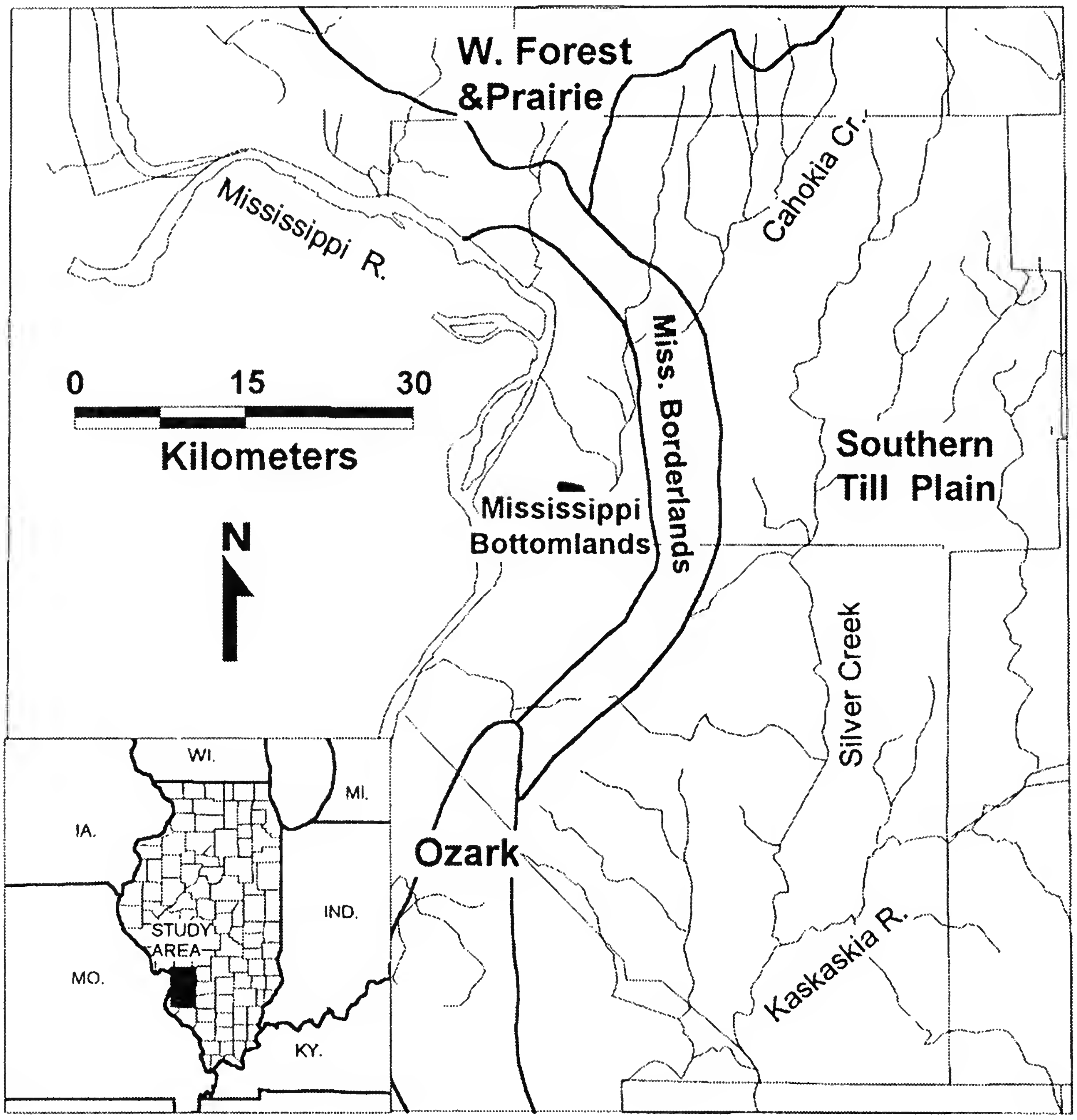


Figure 2. Location map of all quarter section corners with trees.

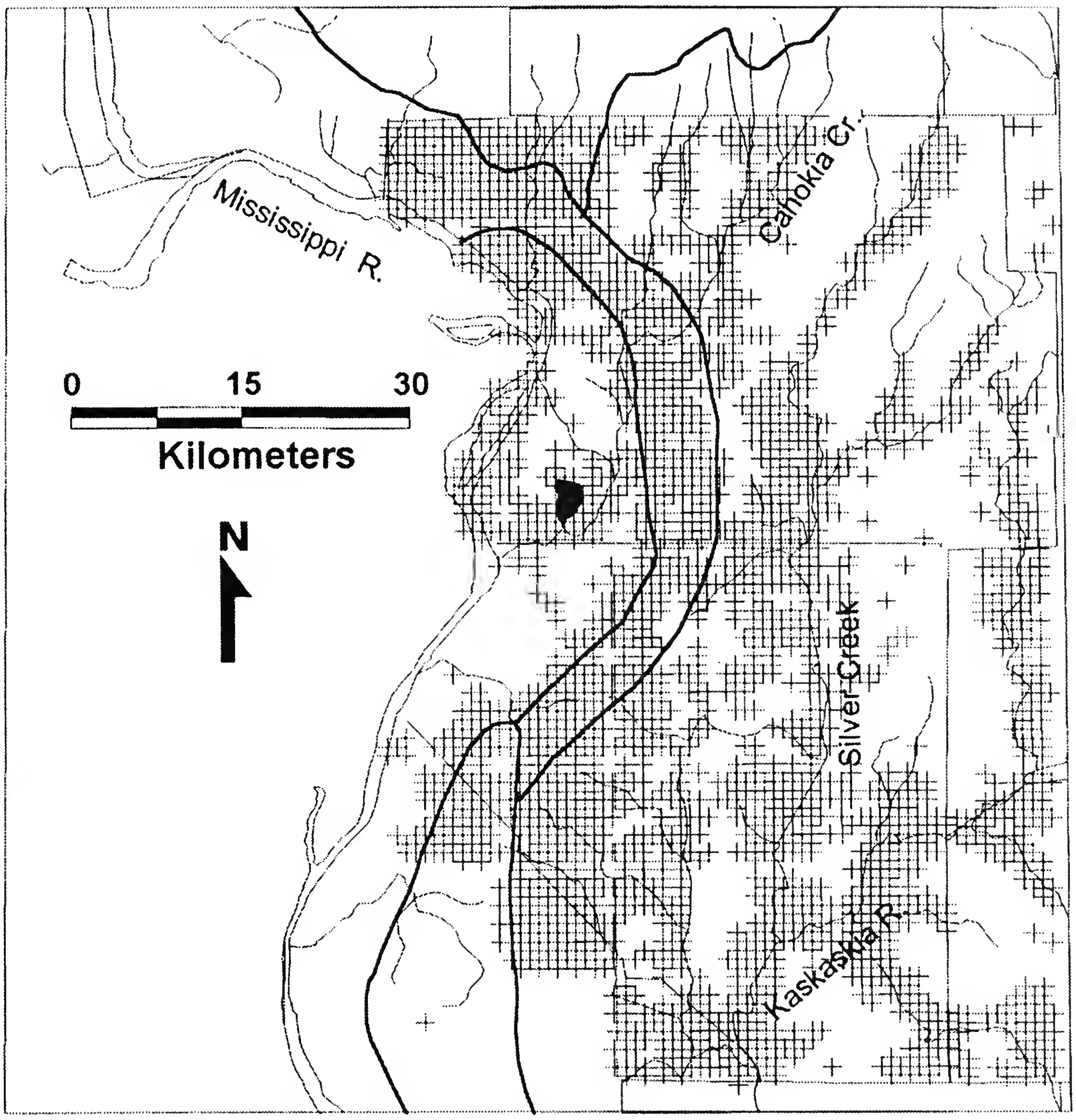


Figure 3. Location map of all , post oak (*Q. stellata*), overcup oak (*Q. lyrata*) and pin oak (*Quercus palustris*) trees in the study area. Ecotone between pin oak-post oak-overcup oak woodlands and white oak-red oak-black oak forest indicated by heavy line. Piasa soil association shown by shaded regions.

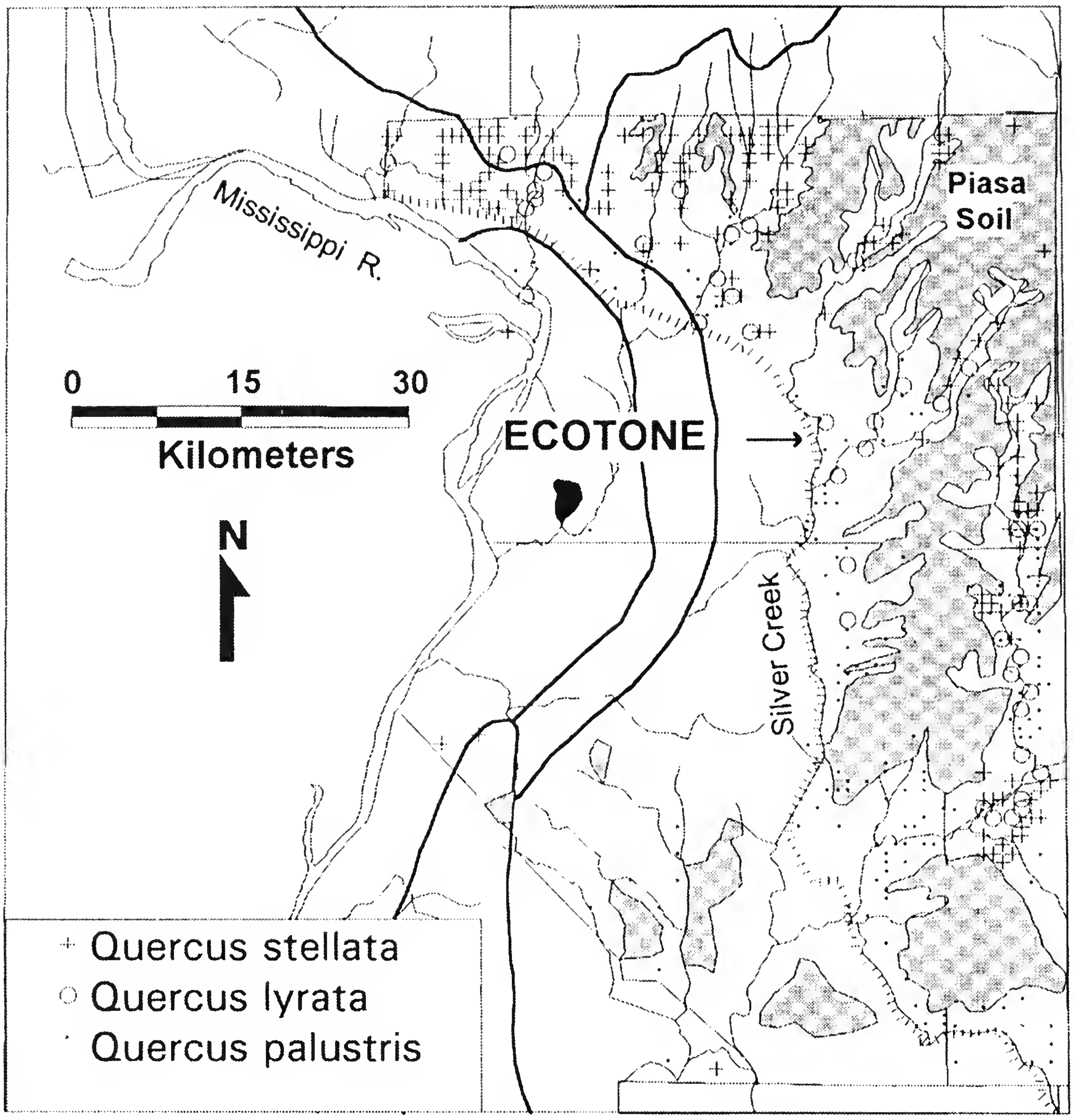


Figure 4. Location map of all black or red oak (*Q. rubra* /*Q. velutina*), and white oak (*Quercus alba*) trees in the study area.

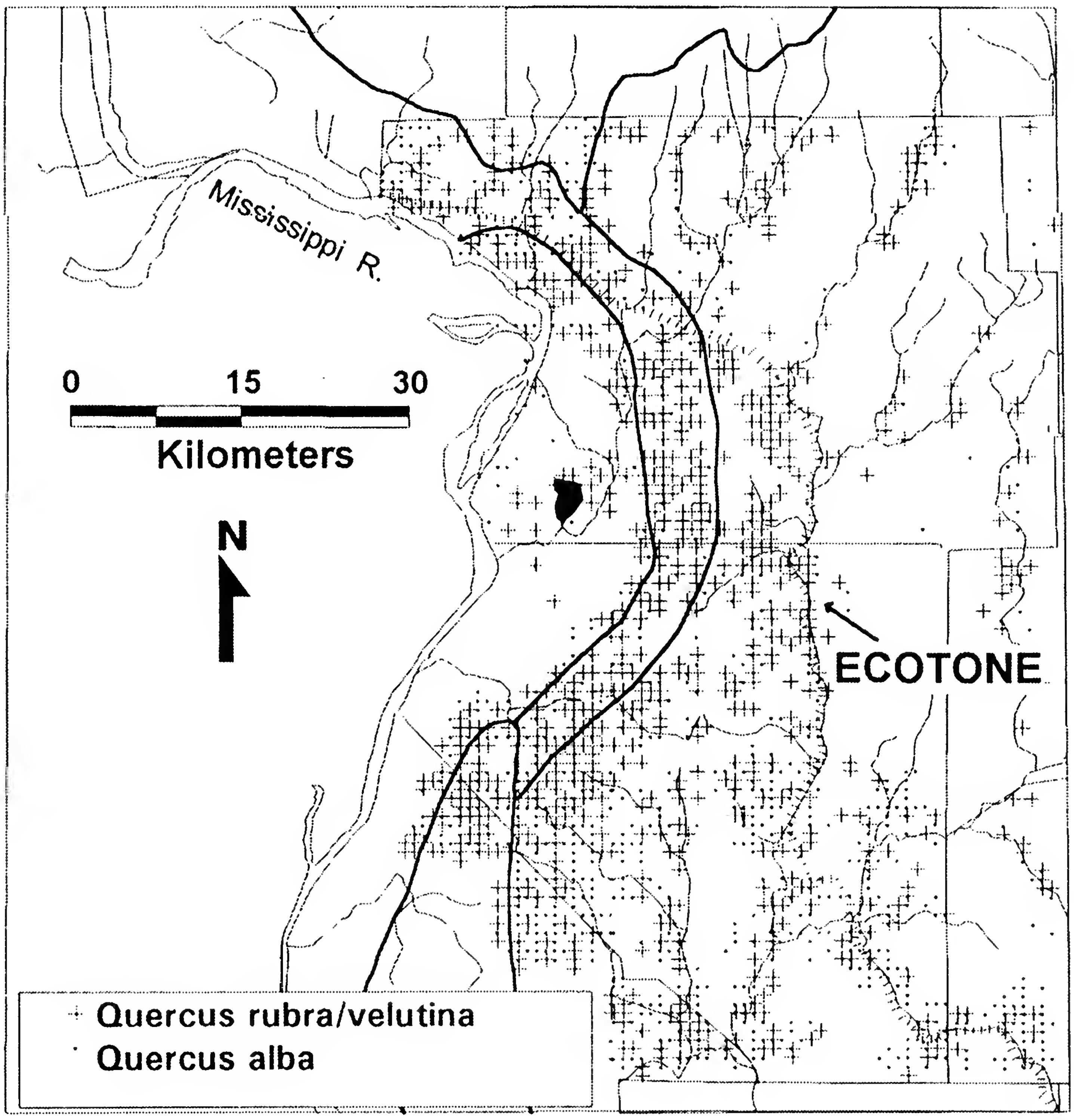


Figure 5. Location map of all black jack oak (*Quercus marilandica*) and hickory (*Carya* spp.) trees in the study area.

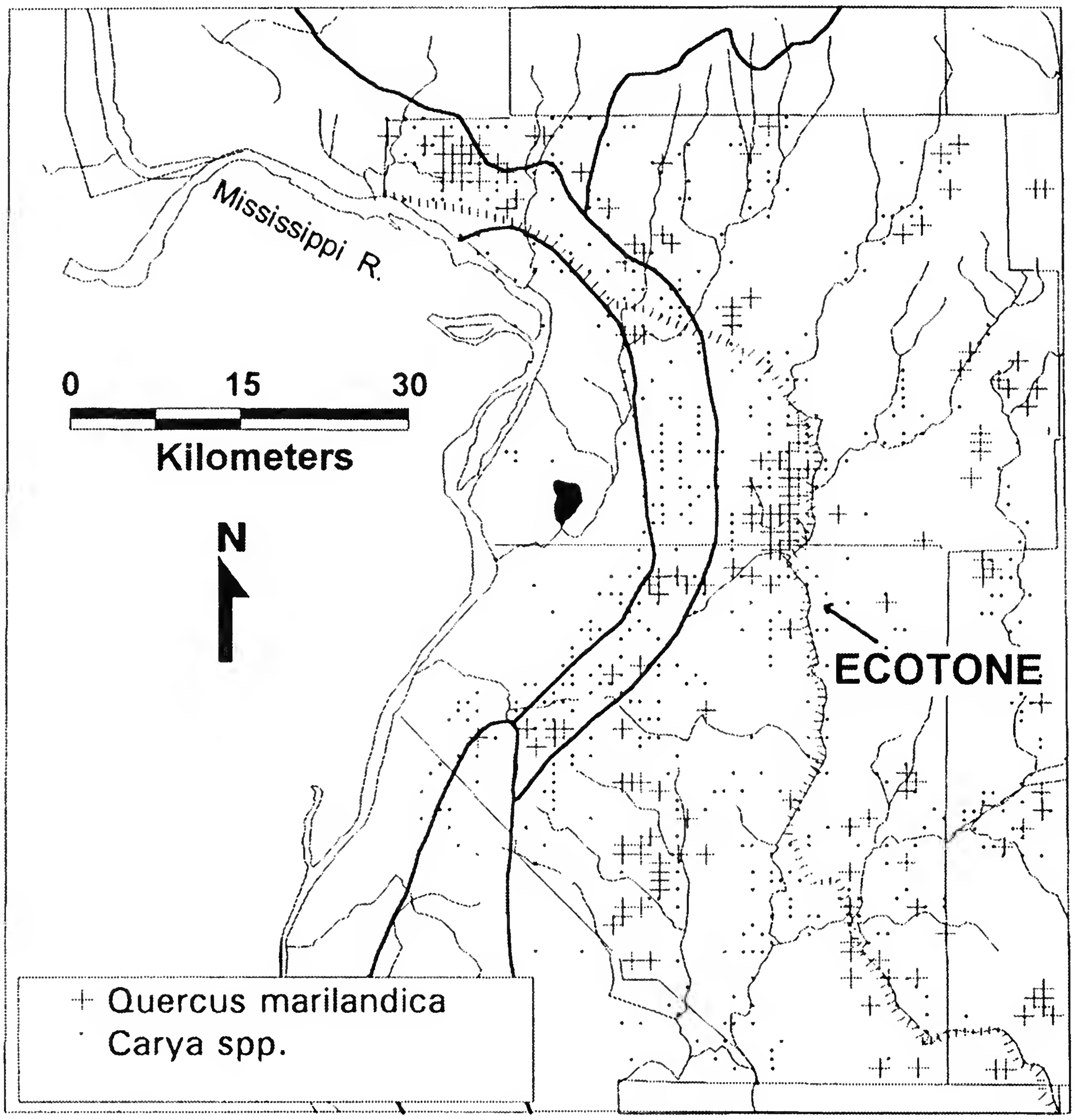


Figure 6. Location map of all sugar maple (*Acer saccharum*), cottonwood (*Populus deltoides*), willow (*Salix* spp.) and elm (*Ulmus* spp.) trees in the study area.

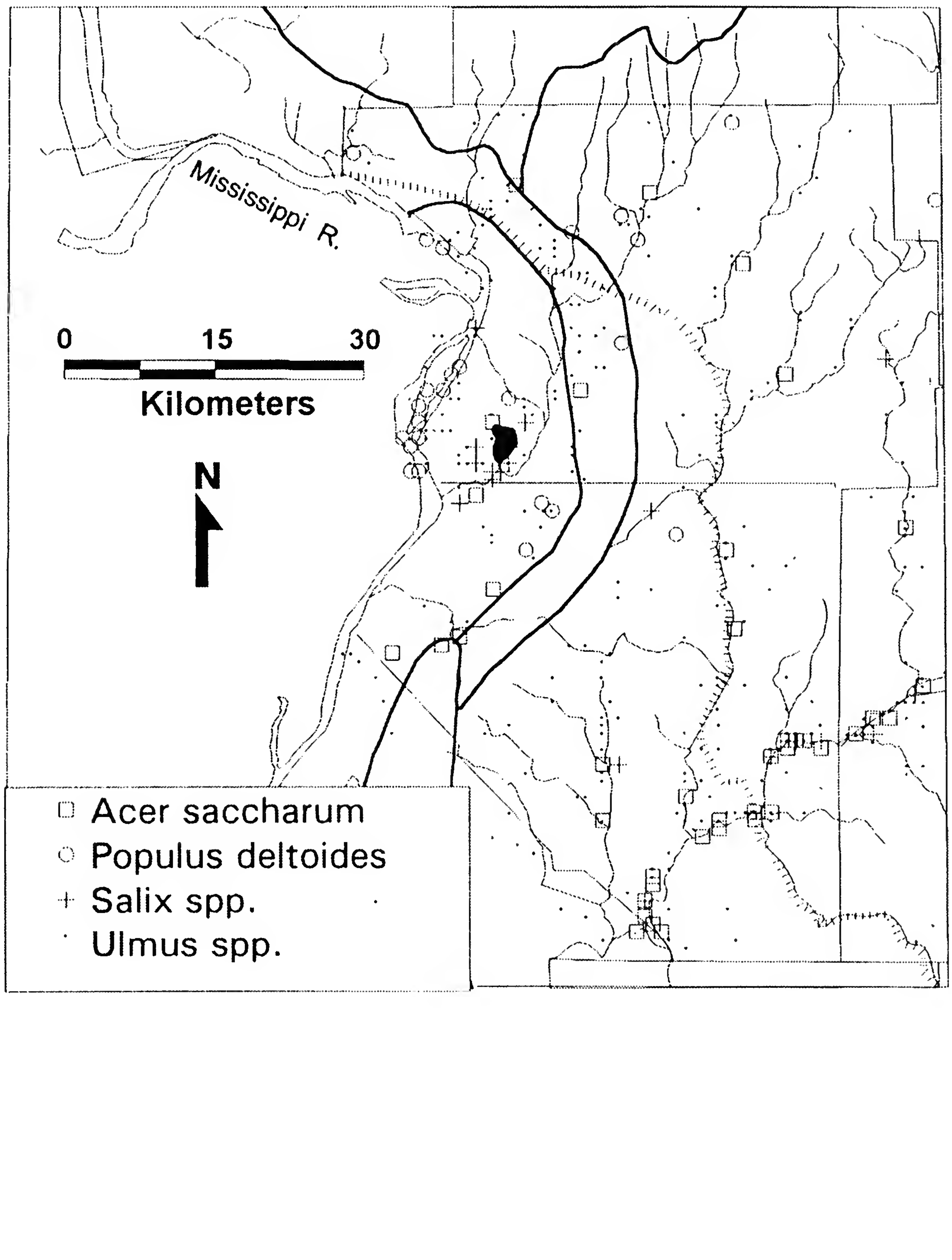


Figure 7. Location map of all sycamore (*Platanus occidentalis*), ash (*Fraxinus*), hackberry (*Celtis* spp.), and box elder (*Acer negundo*) trees in the study area.

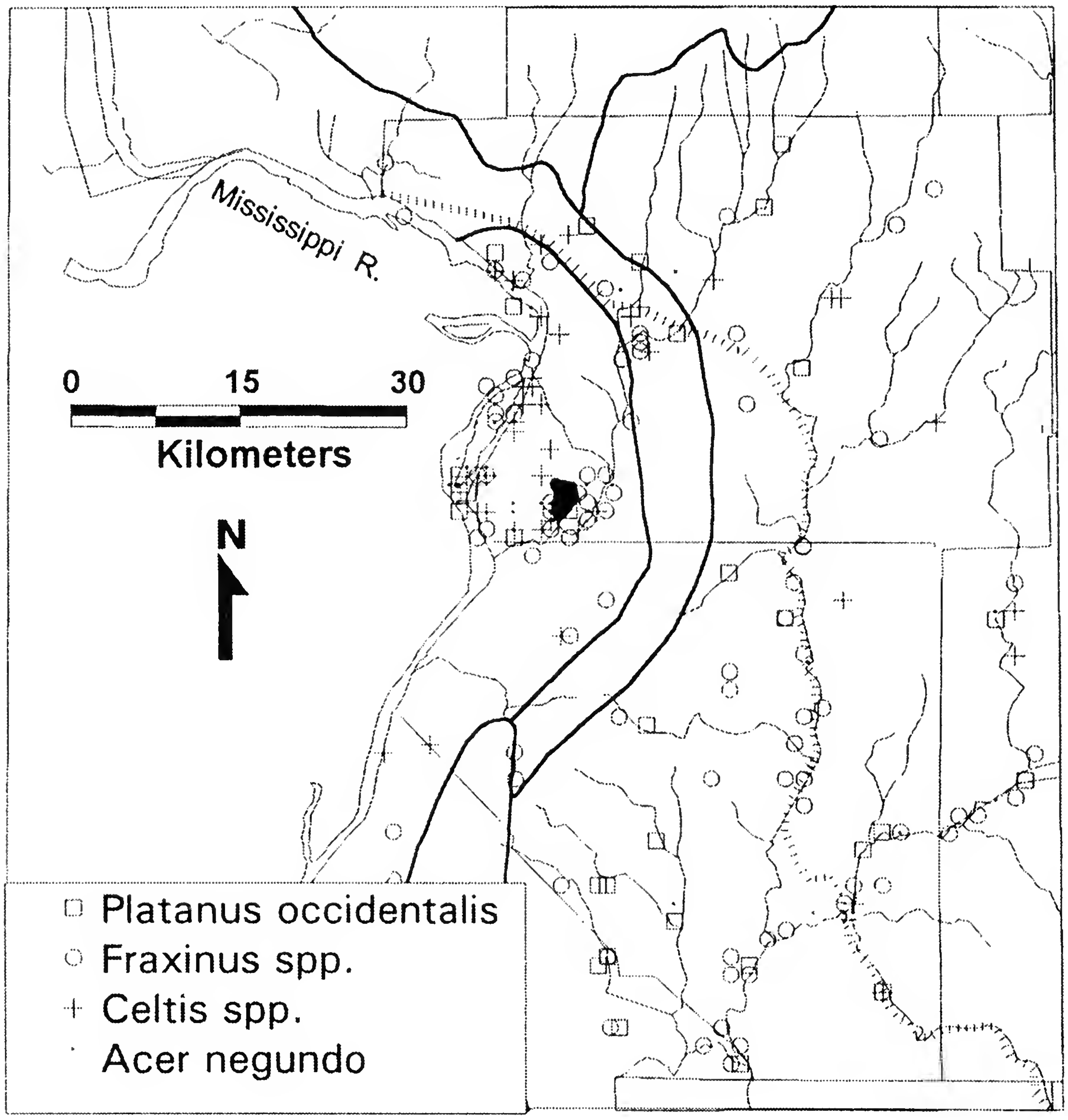
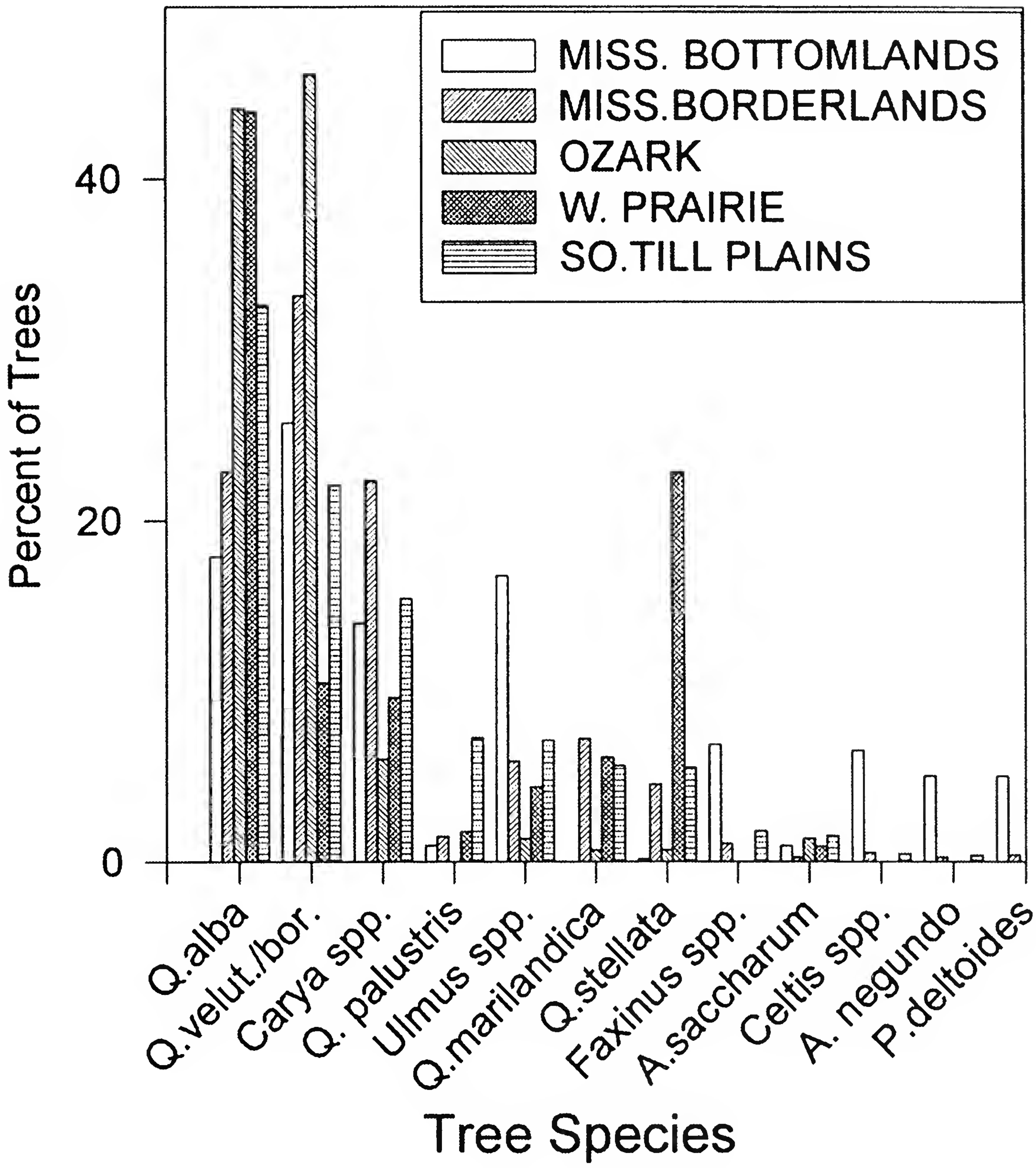


Figure 8. Percent abundances of trees in the physiographic regions.



Transactions of the Illinois State Academy of Science
(1996), Volume 89, 3 and 4, pp. 143-156

The Lichen Flora of Putnam County, Illinois

Richard D. Hyerczyk
The Nature Conservancy
Volunteer Stewardship Network
Chicago, IL 60603

ABSTRACT

Seventy-seven species of lichens are reported from Putnam County, Illinois. An annotated species list along with growth forms, habitats and relative frequency of each taxon is provided.

INTRODUCTION

Putnam County, is located in north-central Illinois approximately 194 km (120 miles) southwest of Chicago (Figure 1). With an area of 414 square kilometers (159 square miles) it is the smallest county in Illinois.

Most of the county is located in the Grand Prairie Division (the Grand Prairie Section) of the natural divisions of Illinois (Schwegman 1973). The county is generally characterized by level or gently rolling topography with elevations averaging 200 meters (660 feet) above sea level. Along the bluff areas of the Illinois River, elevations drop to 130 meters (425 feet) above sea level, representing the Upper Mississippi & Illinois River Bottom Lands Division (the Illinois River Section) and the Illinois River & Mississippi River Sand Area Division (the Illinois River Section).

Other than the work of Jones (1993) who reported 47 species of lichens, no other lichenological studies are known from Putnam County.

MATERIALS AND METHODS

This project was conducted from April of 1991 until August of 1995 to study the habitats and determine the number of lichens from Putnam County, Illinois. All substrates were considered, including corticolous (on tree bark), saxicolous (on concrete and stone), lignicolous (on rotten stumps and wood rail fencing) and terricolous (on weathered clay till and sand).

Collections were made from 13 named locations (State- and County-owned Conservation areas and private cemeteries). Collections from unnamed locations were put in a "miscellaneous" group, for a total of 14 study sites (Table 1). Study sites were visited year-round and each site was visited at least five times.

Specimens were identified using keys by Brodo (1968 and 1988), Hale (1979) and Wilhelm (1995). Tests for color changes of lichen chemical substances were done with the following reagents: sodium hypochlorite (**C**) and potassium hydroxide (**KOH**). Thin-layer chromatography (**TLC**) following Culberson (1972) was used to verify secondary-product chemistry.

The relative frequency of the lichens reported here was determined by the number of sites at which each lichen was observed, and was not based on collections (Table 2). **Rare**: one site; **Occasional**: two to five sites; **Frequent**: six to ten sites; **Common**: eleven to fourteen sites.

It was brought to my attention by an anonymous reviewer that two additional lichen species had been located in the collection of the Illinois Natural History Survey. I have not included these lichens in this paper because I was not able to examine the vouchers for these plants

RESULTS

Seventy-seven species of lichens in 39 genera representing 18 families are reported from Putnam County, Illinois (Table 2). Forty lichens (52%) are of the crustose growth form, 23 (30%) are foliose and 14 (18%) are fruticose.

Three lichens (4%) are considered to be common, and of these only *Candelaria concolor* and *Physcia millegrana* were found at every site surveyed. Twenty-seven (35%) are rare, known only from a single collection. Forty (52%) are occasional and seven (9%) are frequent.

The Natural Lands Area (NLA) (Figure 1, Site number 1), with 38 species, and Lake Sennachwine Conservation Area (LSCA) (Figure 1, Site number 2), with 32 species, had the highest number of lichens observed. The diversity of habitats (open oak woodlands and sand deposits at NLA and a gravel pit at LSCA) may explain the higher numbers of species found at these sites.

The remaining State- and County-owned preserves consisted of shaded woodlands. Many of the lichens observed at these sites were found in only sunnier locations along the perimeter of these preserves.

Fewer species were found at the seven cemeteries, a fact that may be attributed to their smaller land area and reduced diversity of habitats (marble headstones and a few trees).

Of the 47 lichen species reported by Jones (1993) I was able to find 38 (80%) in the field. I have not included the remaining nine species because I was unable to locate or examine vouchers for these plants.

ANNOTATED SPECIES LIST

What follows is an annotated list of lichens that were collected by the author and Michael D. Jones. Nomenclature and authority follow Esslinger and Egan (1995). The growth form and substrate are also listed after the name of each lichen. At least one specimen of each species reported has been deposited in the herbarium at the Morton Arboretum (MOR) in Lisle, Illinois.

Family ACAROSPORACEAE

SARCOGYNE Flotow

Sarcogyne regularis Körber [CRUSTOSE] [SAXICOLOUS]

Rare; known only from a single collection from dolomite in a gravel pit at Lake Sennachwine Preserve. Hyerczyk 338.

THELOCARPON Nyl. *ex* Hue

Thelocarpon laureri (Flotow) Nyl. [CRUSTOSE] [LIGNICOLOUS]

Rare; known only from a single collection from a wooden fence post at Lake Sennachwine Preserve. Hyerczyk 1262.

Family ARTHONIACEAE

ARTHONIA Ach.

Arthonia caesia (Flotow) Körber [CRUSTOSE] [CORTICOLOUS]

Frequent; on *Gleditsia triacanthos* near Hennepin (Hyerczyk 27), on *Gleditsia triacanthos* at the Donnelly State Wildlife Area (Hyerczyk 26) and on *Acer saccharum* at the Fox Run Conservation Area (Hyerczyk 31).

Family BACIDIACEAE

BACIDIA De Not.

Bacidia granosa (Tuck.) Zahlbr. [CRUSTOSE] [SAXICOLOUS]

Occasional; on dolomite at the Donnelly State Wildlife Area (Hyerczyk 427) and on limestone rubble at the Natural Lands Area (Hyerczyk 1168).

BACIDINA Vêzda

Bacidina inundata (Fr.) Vêzda [CRUSTOSE] [SAXICOLOUS]

Occasional; on an igneous boulder on a forested slope near Magnolia. Jones 3933.

Family CLADONIACEAE

CLADINA Nyl.

Cladina subtenuis (Abbayes) Hale & Culb. [FRUTICOSE] [TERRICOLOUS]

Rare; known only from a single collection from sand at the Natural Lands Area. Jones 3912.

CLADONIA P. Browne

Cladonia chlorophaea (Flörke *ex* Sommerf.) Sprengel [FRUTICOSE] [TERRICOLOUS]

Occasional; on clay at the Donnelly State Wildlife Area (Hyerczyk 396) and the Fox Run Conservation Area (Hyerczyk 417).

Cladonia coniocraea (Flörke) Sprengel [FRUTICOSE] [LIGNICOLOUS]
Occasional; on rotten logs in shaded woods at the Fox Run Conservation Area (Hyerczyk 29) and the George S. Park Nature Preserve (Hyerczyk 390).

Cladonia cristatella Tuck. [FRUTICOSE] [LIGNICOLOUS, TERRICOLOUS]
Occasional; on rotten logs and on sand at the Natural Lands Area. Jones 3909a.

Cladonia cylindrica (A. Evans) A. Evans [FRUTICOSE] [LIGNICOLOUS]
Occasional; on rotten logs at the Natural Lands Area (Hyerczyk 409) and the George S. Park Nature Preserve (Hyerczyk 391).

Cladonia grayi G. K. Merr. *ex* Sandst. [FRUTICOSE] [TERRICOLOUS]
Rare; known only from a single collection from sand at the Natural Lands Area. Jones 3914.

Cladonia humilis (With.) J. R. Laundon [FRUTICOSE] [TERRICOLOUS]
Rare; known only from a single collection from weathered clay at the Fox Run Conservation Area. Hyerczyk 52.

Cladonia macilenta var. ***bacillaris*** (Genth) Schaerer [FRUTICOSE] [LIGNICOLOUS]
Occasional; on rotten logs near Putnam (Hyerczyk / Kierny 37), at the Donnelly State Wildlife Area (Hyerczyk 1169), the Fox Run Conservation Area (Hyerczyk 419), Lake Sennachwine Preserve (Hyerczyk 116) and the Natural Lands Area (Hyerczyk 400).

Cladonia peziziformis (With.) J. R. Laundon [FRUTICOSE] [TERRICOLOUS]
Occasional; on sand at the Donnelly State Wildlife Area (Hyerczyk 399) and the Natural Lands Area (Jones 3915).

Cladonia piedmontensis G. Merr. [FRUTICOSE] [TERRICOLOUS]
Rare; known only from a single collection from sand at the Natural Lands Area. Jones 3911.

Cladonia polycarpoides Nyl. [FRUTICOSE] [TERRICOLOUS]
Occasional; on sandy soil in an open field at the Fox Run Conservation Area (Hyerczyk 416) and on sand at the Natural Lands Area (Jones 3910).

Cladonia ramulosa (With.) J. R. Laundon [FRUTICOSE] [CORTICOLOUS]
Rare; known only from a single collection from *Prunus serotina* at the Natural Lands Area. Hyerczyk 1345.

Cladonia rei Schaerer [FRUTICOSE] [LIGNICOLOUS, TERRICOLOUS]
Occasional; on rotten logs at the Donnelly State Wildlife Area (Hyerczyk 424) and on sand at the Natural Lands Area (Jones 3909).

Cladonia subulata (L.) F. H. Wigg. [FRUTICOSE] [LIGNICOLOUS]
Rare; known only from a single collection from a dead tree at the Donnelly State Wildlife Area. Hyerczyk 48.

Family **CYPHELIACEAE**

CYPHELIUM Ach.

Cyphelium tigillare (Ach.) Ach. [CRUSTOSE] [LIGNICOLOUS]
Occasional; on a wood rail fence at the Donnelly State Wildlife Area. Hyerczyk 425.

Family **GRAPHIDACEAE**

GRAPHIS Adans.

Graphis scripta (L.) Ach. [CRUSTOSE] [CORTICOLOUS]

Occasional; on *Acer saccharum* at the George S. Park Nature Preserve. Hyerczyk 47.

Family **LECANORACEAE**

ASPICILIA A. Massal.

Aspicilia caesiocinerea (Nyl. *ex* Malbr.) Arnold [CRUSTOSE] [SAXICOLOUS]

Rare; known only from a single collection from granite at the Fox Run Conservation Area. Hyerczyk 381. This species has also been found on granite in southwestern Cook County.

CANDELARIELLA Müll. Arg.

Candelariella reflexa (Nyl.) Lettau [CRUSTOSE] [CORTICOLOUS]

Rare; known only from a single collection from *Quercus rubra* at the George S. Park Nature Preserve. Hyerczyk 1181.

Candelariella xanthostigma (Ach.) Lettau [CRUSTOSE] [CORTICOLOUS]

Occasional; on *Populus deltoides* (Jones 3907e) at the Natural Lands Area and on *Quercus* sp. (Hyerczyk 426) at the Donnelly State Wildlife Area.

LECANORA Ach.

Lecanora dispersa (Pers.) Sommerf. [CRUSTOSE] [SAXICOLOUS]

Frequent; on dolomite (Hyerczyk 336) at Lake Sennachwine Preserve and on concrete (Hyerczyk 50) near Granville.

Lecanora strobilina (Sprengel) Kieffer [CRUSTOSE] [LIGNICOLOUS]

Rare; known only from a single collection from a wood fence post at Lake Sennachwine Preserve. Hyerczyk 1263.

Lecanora symmicta (Ach.) Ach. [CRUSTOSE] [CORTICOLOUS]

Occasional; on *Quercus* sp. near Standard. Hyerczyk 49.

Family **MONOBLASTACEAE**

ANISOMERIDIUM (Müll. Arg.) Choisy

Anisomeridium nyssigenum (Ellis&Everh.) R.C.Harris [CRUSTOSE] [CORTICOLOUS]

Occasional; on *Acer saccharum* at the Fox Run Conservation Area. Hyerczyk 33.

Family **OPEGRAPHIDACEAE**

OPEGRAPHA Ach.

Opegrapha atra Pers. [CRUSTOSE] [CORTICOLOUS]

Occasional; on *Ulmus americana* (Hyerczyk 332) near Putnam and on *Ulmus americana* (Hyerczyk 1162) at the Fox Run Conservation Area.

Family **PARMELIACEAE**

CANDELARIA A. Massal.

Candelaria concolor (Dickson) Stein [FOLIOSE] [CORTICOLOUS, LIGNICOLOUS, SAXICOLOUS]

Common; on wood fences, boulders and a variety of trees throughout the county, including *Crataegus mollis*. Hyerczyk 22.

Candelaria concolor var. ***effusa*** (Tuck.)G.Merr.&Burnham[FOLIOSE] [LIGNICOLOUS]
Occasional; on a wooden fence post near Putnam. Hyerczyk 1170.

FLAVOPARMELIA Hale
Flavoparmelia caperata (L.) Hale [FOLIOSE] [CORTICOLOUS]
Occasional; on *Quercus rubra* at the George S. Park Nature Preserve. Hyerczyk 1179.

FLAVOPUNCTELIA (Krog) Hale
Flavopunctelia soredica (Nyl.) Hale [FOLIOSE] [CORTICOLOUS]
Rare; known only from a single collection from an open grown *Quercus* sp. near Standard. Hyerczyk 20.

PARMELIA Ach.
Parmelia sulcata Taylor [FOLIOSE] [CORTICOLOUS]
Occasional; on *Crataegus mollis* (Hyerczyk 43) at the Donnelly State Wildlife Area and on *Quercus rubra* (Hyerczyk 1182) at the George S. Park Nature Preserve.

PUNCTELIA Krog
Punctelia bolliana (Müll. Arg.) Krog [FOLIOSE] [CORTICOLOUS]
Occasional; on *Populus deltoides* (Jones 3905), on *Quercus alba* (Jones 3761) and on *Quercus macrocarpa* (Hyerczyk 326).
Punctelia missouriensis Wilhelm & Ladd [FOLIOSE] [CORTICOLOUS]
Occasional; on *Quercus rubra* (Hyerczyk 1180) at the George S. Park Nature Preserve and on *Acer* sp. at Friends Cemetery (Hyerczyk 1358).
Punctelia rudecta (Ach.) Krog [FOLIOSE] [CORTICOLOUS, LIGNICOLOUS]
Occasional; on a dead tree (Hyerczyk 45) at the Donnelly State Wildlife Area and on *Quercus rubra* (Hyerczyk 1183) at the George S. Park Nature Preserve.

Family **PELTIGERACEAE**

PELTIGERA Willd.
Peltigera didactyla (With.) J. R. Laundon [FOLIOSE] [TERRICOLOUS]
Rare; known only from a single collection from clay at the Donnelly State Wildlife Area. Hyerczyk 392.

Family **PERTUSARIACEAE**

PERTUSARIA D C.
Pertusaria pustulata (Ach.) Duby [CRUSTOSE] [CORTICOLOUS]
Rare; known only from a single collection from *Carya ovata* at the Natural Lands Area. Jones 3939.

Family **PLEOMASSARIACEAE**

JULELLA Fabre
Julella sericea (Massal.) Coppins [CRUSTOSE] [CORTICOLOUS]
Occasional; on *Quercus rubra* at the Natural Lands Area. Jones 3895.

Family **PYRENULACEAE**

LICHENOTHELIA D. Hawksw.

Lichenothelia sp. [CRUSTOSE] [SAXICOLOUS]
Occasional; on granite at the Fox Run Conservation Area. Hyerczyk 1161.

Family **PYXINACEAE**

AMANDINEA Choisy *ex* Scheid. & H. Mayrh.

Amandinea punctata (Hoffm.) Coppins & Scheid. [CRUSTOSE] [LIGNICOLOUS]
Occasional; on wood rail fences (Hyerczyk 327), (Jones 3766).

BUELLIA De Not.

Buellia dakotensis (H. Magn.) Sheard, *in ed.* [CRUSTOSE] [CORTICOLOUS]
Rare; known only from a collection from an *Acer* sp. branch at Union Grove Cemetery near Granville. Hyerczyk 1361.

HYPERPHYSCIA Müll. Arg.

Hyperphyscia adglutinata (Flörke) H. Mayrh. & Poelt [FOLIOSE] [CORTICOLOUS]
Occasional; on *Acer negundo* (Hyerczyk 328) near McNabb and on *Populus deltoides* at the Natural Lands Area (Jones 3906).

PHAEOPHYSCIA Moberg

Phaeophyscia cernohorskyi (Nádv.) Essl. [FOLIOSE] [SAXICOLOUS]
Occasional; on a marble headstone at Magnolia cemetery. Hyerczyk 1174.

Phaeophyscia ciliata (Hoffm.) Moberg [FOLIOSE] [SAXICOLOUS]
Occasional; on a marble headstone (Hyerczyk 1173) at Magnolia Cemetery and on a marble headstone (Hyerczyk 1349) at St. Joseph Cemetery.

Phaeophyscia orbicularis (Necker) Moberg [FOLIOSE] [CORTICOLOUS]
Rare; known only from a single collection from *Ulmus americana* near Putnam. Hyerczyk 34.

Phaeophyscia rubropulchra (Degel.) Essl. [FOLIOSE] [CORTICOLOUS]
Frequent; on tree bases in damp, shaded woods, including *Quercus rubra* (Hyerczyk 44) at the Donnelly State Wildlife Area and *Quercus rubra* at the Natural Lands Area (Jones 3894).

PHYSCIA (Schreber) Michaux

Physcia adscendens (Fr.) H. Olivier [FOLIOSE] [SAXICOLOUS]
Frequent; on marble headstones at Mount Palatine Cemetery Nature Preserve. (Hyerczyk 329), (Jones 3880).

Physcia aipolia (Ehrh. *ex* Humb.) Fürnr. var. ***aipolia*** [FOLIOSE] [CORTICOLOUS]
Occasional; on *Ulmus americana* (Hyerczyk 53) near Putnam and on *Fraxinus americana* (Hyerczyk 1348) at St. Joseph Cemetery near McNabb.

Physcia millegrana Degel. [FOLIOSE] [CORTICOLOUS, LIGNICOLOUS]
Common; on a variety of trees, including *Quercus muhlenbergii* (Hyerczyk 21), (Jones 3926) and wood rail fences throughout the county.

Physcia stellaris (L.) Nyl. [FOLIOSE] [CORTICOLOUS]
Common; on a variety of trees throughout the county, including *Acer saccharum* (Hyerczyk 19, 23) near Granville.

PHYSCIELLA Essl.

Physciella chloantha (Ach.) Essl. [FOLIOSE] [CORTICOLOUS]

Frequent; on a variety of trees, including *Ulmus americana* (Hyerczyk 418) at the Fox Run Conservation Area and *Ulmus americana* (Hyerczyk 28) near Putnam.

PHYSCONIA Poelt

Physconia detersa (Nyl.) Poelt [FOLIOSE] [CORTICOLOUS, SAXICOLOUS]

Occasional; on a variety of trees, including *Populus deltoides*, *Quercus muhlenbergii* (Jones 3925) and *Ulmus rubra* and on marble headstones in cemeteries.

Physconia kurokawae Kashiw. [FOLIOSE] [CORTICOLOUS]

Occasional; on *Populus alba* (Hyerczyk 333) near Putnam and *Quercus rubra* (Hyerczyk 1178) at the George S. Park Nature Preserve.

RINODINA (Ach.) Gray

Rinodina papillata H. Magn. [CRUSTOSE] [CORTICOLOUS]

Rare; known only from a single collection from *Populus deltoides* at the Natural Lands Area. Jones 3907b.

"Sterile Lichens"

LEPRARIA Ach.

Lepraria lobificans Nyl. [CRUSTOSE] [CORTICOLOUS, SAXICOLOUS]

Occasional; on granite boulders and tree bases in damp woods, including *Quercus rubra* at the Fox Run Conservation Area (Hyerczyk 30) and *Quercus rubra* at the Natural Lands Area (Jones 3901, 3902).

Lepraria sp.# 1 [CRUSTOSE] [CORTICOLOUS]

Rare; known only from a single collection from the base of *Prunus serotina* at the Natural Lands Area. Hyerczyk 408.

Family **TELOSCHISTACEAE**

CALOPLACA Th. Fr.

Caloplaca feracissima H. Magn. [CRUSTOSE] [SAXICOLOUS]

Frequent; on concrete at Magnolia Cemetery. Hyerczyk 1171.

Caloplaca holocarpa (Hoffm. *ex* Ach.) M. Wade [CRUSTOSE] [LIGNICOLOUS]

Rare; known only from a single collection from a wood rail fence near Putnam. Hyerczyk 339.

Caloplaca lithophila H. Magn [CRUSTOSE] [SAXICOLOUS]

Rare; known only from a single collection from dolomite at Magnolia Cemetery. Hyerczyk 1359.

Caloplaca luteominia (Tuck.) Zahlbr. var. ***luteominia*** [CRUSTOSE] [SAXICOLOUS]

Rare; known only from a single collection from pebbles in a gravel pit at Lake Sennachwine Preserve. Hyerczyk 39.

Caloplaca microphyllina (Tuck.) Hasse [CRUSTOSE] [LIGNICOLOUS]

Occasional; on wood rail fences near Magnolia. Hyerczyk 42.

Caloplaca sideritis (Tuck.) Zahlbr. [CRUSTOSE] [SAXICOLOUS]

Rare; known only from a single collection from granite at the Fox Run Conservation Area. Hyerczyk 1165.

Caloplaca squamosa (de Lesd.) Zahlbr. [CRUSTOSE] [SAXICOLOUS]
Occasional; on dolomite at Granville Cemetery (Hyerczyk 1353), on a marble headstone at Mount Palatine Cemetery Nature Preserve (Jones 3882) and on dolomite at Sacred Heart Cemetery (Hyerczyk 1357).

Caloplaca ulmorum (Fink) Fink [CRUSTOSE] [SAXICOLOUS]
Occasional; on marble headstones at Friends Cemetery (Hyerczyk 1354), Magnolia Cemetery (Hyerczyk 1360) and St. Joseph Cemetery (Hyerczyk 1352).

Caloplaca vitellinula (Nyl.) H. Olivier [CRUSTOSE] [SAXICOLOUS]
Occasional; on concrete near Granville (Hyerczyk 24) and on marble headstones at Mount Palatine Cemetery Nature Preserve (Jones 3881) and at Union Grove Cemetery (Hyerczyk 1356).

XANTHORIA (Fr.) Th. Fr.

Xanthoria fallax (Hepp.) Arnold var. ***fallax*** [FOLIOSE] [CORTICOLOUS]
Occasional; on *Acer negundo* near Granville. Hyerczyk 25.

Xanthoria sp.#1 [FOLIOSE] [SAXICOLOUS]
Occasional; on marble headstones at Magnolia Cemetery (Hyerczyk 1175) and St. Joseph Cemetery (Hyerczyk / Kierny 36).

Family **TRAPELIACEAE**

PLACYNTHIELLA Elenkin

Placynthiella uliginosa (Schrader) Coppins & P. James[CRUSTOSE] [TERRICOLOUS]
Rare; known only from a single collection from sand near McNabb at the Natural Lands Area with *Cladonia* spp. Hyerczyk 1344.

TRAPELIOPSIS Hertel & Gotth. Schneider

Trapeliopsis flexuosa (Fr.) Coppins & P. James [CRUSTOSE] [LIGNICOLOUS]
Occasional; on wood rail fences. Hyerczyk 331.

Trapeliopsis granulosa (Hoffm.) Lumbsch. [CRUSTOSE] [LIGNICOLOUS]
Rare; known only from a single collection from a wood rail fence at the Donnelly State Wildlife Area. Hyerczyk 46.

Family **VERRUCARIACEAE**

ENDOCARPON Hedwig

Endocarpon pusillum Hedwig [CRUSTOSE] [SAXICOLOUS]
Frequent; on concrete and dolomite throughout the county. Hyerczyk 38, 1176.

THELIDIUM A. Massal.

Thelidium microcarpum (Leight.) A. L. Sm. [CRUSTOSE] [SAXICOLOUS]
Rare; known only from a single collection from sandstone at the Fox Run Conservation Area. Hyerczyk 420.

VERRUCARIA Schrader

Verrucaria calkinsiana Servít [CRUSTOSE] [SAXICOLOUS]
Occasional; on dolomite at the Fox Run Conservation Area (Hyerczyk 330, 1163), on marble headstones at Mount Palatine Cemetery Nature Preserve (Jones 3883) and on a dolomite outcrop near Magnolia (Jones 3929).

Verrucaria muralis Ach. [CRUSTOSE] [SAXICOLOUS]
Rare; known only from a single collection from dolomite at the Fox Run Conservation Area. Hyerczyk 335.

Verrucaria sordida Servít [CRUSTOSE] [SAXICOLOUS]
Rare; known only from a single collection from pebbles in a gravel pit at Lake Sennachwine Preserve. Hyerczyk / Kierny 40.

ACKNOWLEDGMENTS

I would like extend my to thanks to the following people for their assistance in this project: Dr. Gerould Wilhelm and Linda Masters for doing TLC on several specimens and for their help in identification and verification of specimens; Michael D. Jones for the information he provided on lichens he collected in Putnam County; Greg Rajsky, as well as two anonymous reviewers, for their comments and suggestions on an earlier draft of this paper; and Darcia Ferrari and the Putnam County Conservation District for permission to do this study on County owned lands.

LITERATURE CITED

Brodo, I.M. 1968. The lichens of Long Island, New York: A vegetational and floristic analysis. New York State Museum and Science Service Bulletin 410: 1-330.

Brodo, I.M. 1988. Lichens of the Ottawa region. 2nd ed. National Museum of Natural Sciences, Ottawa, Canada.

Culberson, C.F. 1972. Improved conditions and new data for the identification of lichen products by a standardized thin-layer chromatography method. Journal of Chromatography 72: 113-125

Esslinger, T. L. & R. C. Egan. 1995. A Sixth Checklist of the Lichen-forming, Lichenicolous and Allied Fungi of the Continental United States and Canada. The Bryologist 98(4): 467-549.

Hale, M.E. Jr. 1979. How to know the lichens. 2nd ed. Wm. C. Brown Co. Dubuque, Iowa.

Jones, M.D. 1993. Lichen flora of the middle Illinois river counties. Unpublished report to the Illinois Department of Conservation.

Schwegman, J.E. 1973. Comprehensive plan for the Illinois Nature Preserves System. Part 2. The natural divisions of Illinois. Illinois Nature Preserves Commission, Rockford, Illinois.

Wilhelm, G. 1995. Lichens of the Chicago Region. 14 October revision. Unpublished.

Table 1. List of study sites in Putnam County, Illinois. Size of study site: ***HEC*** = Hectares. Growth forms of lichens observed: ***CRU*** = crustose; ***FOL*** = foliose; ***FRU*** = fruticose. ***TOTAL***: Total number of lichens found at study site.

NAME OF SITE	HEC	CRU	FOL	FRU	TOTAL
Donnelley State Wildlife Area	250.0	9	8	5	22
Fox Run Conservation Area	108.0	11	5	6	22
Friends Cemetery	0.6	3	11	0	14
George S. Park Woods Nature Preserve	32.0	8	12	2	22
Granville Cemetery	2.4	3	5	0	8
Lake Sennachwine Conservation Area	174.0	19	11	2	32
Magnolia Cemetery	1.2	7	8	0	15
Miller-Anderson Woods Nature Preserve	104.0	5	6	0	11
Mount Palatine Cemetery Nature Preserve	0.6	10	5	0	15
Natural Lands Area	109.0	16	12	10	38
Sacred Heart Cemetery	1.2	5	4	0	9
St. Joseph Cemetery	0.4	2	8	0	10
Union Grove Cemetery	0.8	4	4	0	8
miscellaneous locations	------	1	5	0	6

Table 2. Growth Forms, Habitats and Status of the Putnam County Lichen Flora. GROWTH FORMS: ***Cr*** = crustose; ***Fo*** = foliose; ***Fr*** = fruticose. HABITATS: ***Co*** = corticolous; ***Lig*** = lignicolous; ***Sax*** = saxicolous; ***Ter*** = terricolous. Number of study sites that a lichen was observed at: ***Nss***. Status: ***Sta.*** [1 site : ***R*** = rare; 2-4 sites: ***O*** = occasional; 6-10 sites: ***F*** = frequent; 11+ sites: ***C*** = common.]

NAME OF LICHEN	Cr	Fo	Fr	Co	Lig	Sax	Ter	Nss	Sta
Amandinea punctata	X				X			4	O
Anisomeridium nyssigenum	X			X				5	O
Arthonia caesia	X			X				7	F
Aspicilia caesiocinerea	X					X		1	R
Bacidia granosa	X					X		4	O
Bacidina egenula	X					X		4	O
Buellia dakotensis	X			X				1	R
Caloplaca feracissima	X					X		8	F
Caloplaca holocarpa	X				X			1	R
Caloplaca lithophila	X					X		1	R
Caloplaca luteominia var. luteominia	X					X		1	R
Caloplaca microphyllina	X				X			2	O
Caloplaca sideritis	X					X		1	R
Caloplaca squamosa	X					X		3	O
Caloplaca ulmorum	X					X		3	O
Caloplaca vitellinula	X					X		3	O
Candelaria concolor		X		X	X	X		14	C
Candelaria concolor var. effusa		X			X			2	O
Candelariella reflexa	X			X				1	R
Candelariella xanthostigma	X			X				2	O
Cladina subtenuis			X				X	1	R
Cladonia chlorophaea			X				X	2	O
Cladonia coniocraea			X		X			2	O
Cladonia cristatella			X		X		X	2	O
Cladonia cylindrica			X		X			2	O
Cladonia grayi			X				X	1	R
Cladonia humilis			X				X	1	R
Cladonia macilenta var. bacillaris			X		X			4	O
Cladonia peziziformis			X				X	3	O
Cladonia piedmontensis			X				X	1	R
Cladonia polycarpoides			X				X	2	O
Cladonia ramulosa			X	X				1	R
Cladonia rei			X		X		X	2	O
Cladonia subulata			X		X			1	R
Cyphelium tigillare	X				X			2	O
Endocarpon pusillum	X					X		10	F
Flavoparmelia caperata		X		X				3	O
Flavopunctelia soredica		X		X				1	R
Graphis scripta	X			X				4	O
Hyperphyscia adglutinata		X		X				3	O
Julella sericea	X			X				2	O
Lecanora dispersa	X					X		9	F
Lecanora strobilina	X				X			1	R
Lecanora symmicta	X			X				2	O
Lepraria lobificans	X			X		X		5	O
Lepraria sp. # 1	X			X				1	R

Table 2. continued

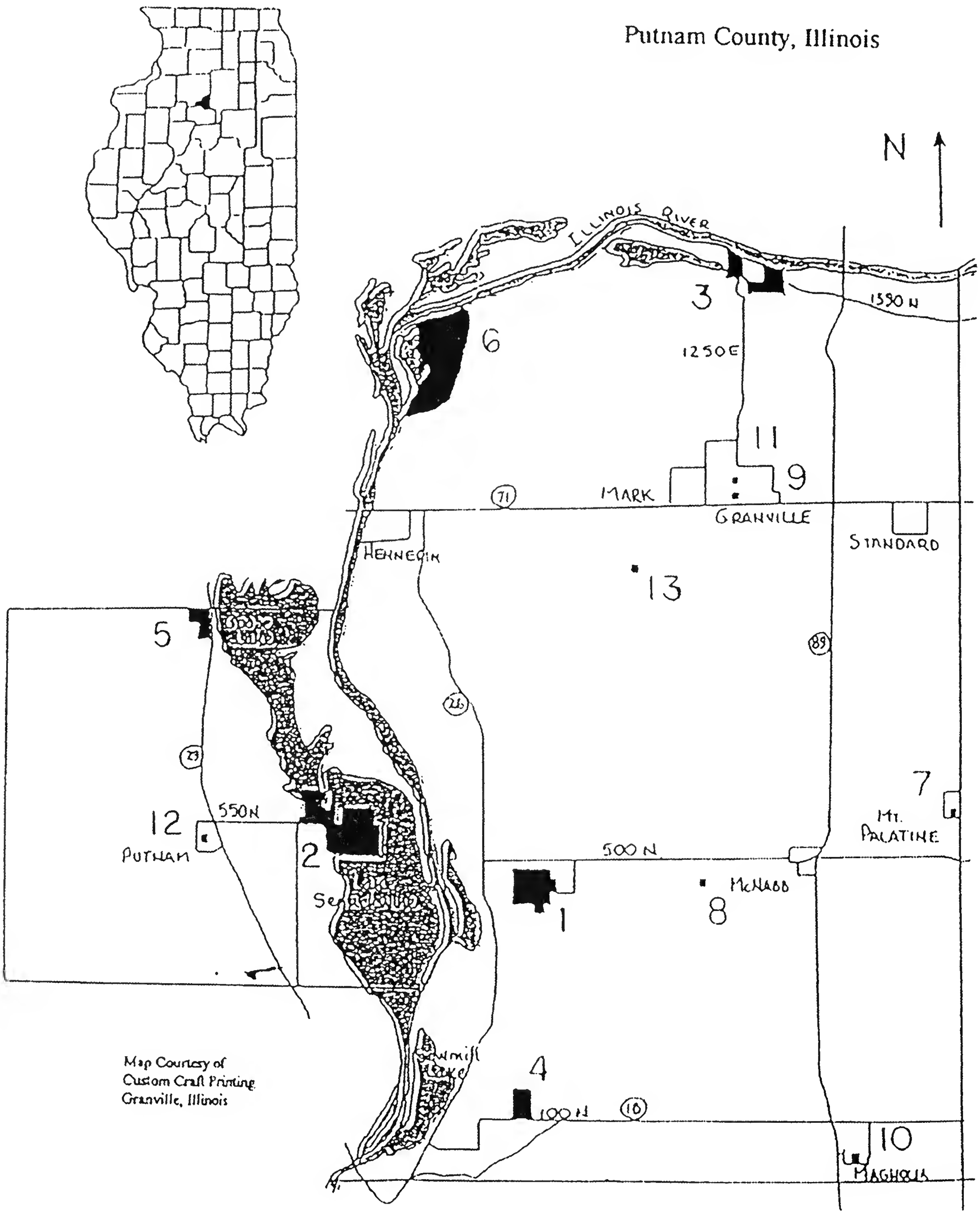
NAME OF LICHEN	Cr	Fo	Fr	Co	Lig	Sax	Ter	Nss	Sta
Lichenothelia sp.	X					X		2	O
Opegrapha atra	X			X				4	O
Parmelia sulcata		X		X				3	O
Peltigera didactyla		X					X	1	R
Pertusaria pustulata	X			X				1	R
Phaeophyscia cernohorskyi		X				X		3	O
Phaeophyscia ciliata		X				X		3	O
Phaeophyscia orbicularis		X		X				1	R
Phaeophyscia rubropulchra		X		X				6	F
Physcia adscendens		X				X		6	F
Physcia aipolia		X		X				2	O
Physcia millegrana		X		X	X			14	C
Physcia stellaris		X		X				12	C
Physciella chloantha		X		X				9	F
Physconia detersa		X		X		X		5	O
Physconia kurokawae		X		X				2	O
Placynthiella uliginosa	X						X	1	R
Punctelia bolliana		X		X				4	O
Punctelia missouriensis		X		X				2	O
Punctelia rudecta		X		X	X			5	O
Rinodina papillata	X			X				1	R
Sarcogyne regularis	X					X		1	R
Thelidium microcarpum	X					X		1	R
Thelocarpon laureri	X				X			1	R
Trapeliopsis flexuosa	X				X			2	O
Trapeliopsis granulosa	X				X			1	R
Verrucaria calkinsiana	X					X		4	O
Verrucaria muralis	X					X		1	R
Verrucaria sordida	X					X		1	R
Xanthoria fallax var. fallax		X		X				3	O
Xanthoria sp.#1		X				X		3	O

Summary of the Putnam County, Illinois lichen flora:

CRUSTOSE	40	52%
FOLIOSE	23	30%
FRUTICOSE	14	18%

TOTAL SPECIES	77	
RARE	27	35%
OCCASIONAL	40	52%
FREQUENT	7	9%
COMMON	3	4%

Figure 1. Study sites in Putnam County, Illinois.



1. Natural Lands Area
2. Lake Sennachwine Conservation Area
3. Fox Run Conservation Area
4. George Park Memorial Forest Nature Preserve
5. Miller-Anderson Woods Nature Preserve
6. Donnelley State Wildlife Area
7. Mount Palatine Cemetery Nature Preserve
8. Friends Cemetery
9. Granville Cemetery
10. Magnolia Cemetery
11. Sacred Heart Cemetery
12. St. Joseph Cemetery
13. Union Grove Cemetery

Transactions of the Illinois State Academy of Science
(1996), Volume 89, 3 and 4, pp. 157-167

The Impact of a Commercially Prepared Science Program on Science Instruction and Scientific Literacy among Elementary Students

James A. McGaughey
Botany Department
Eastern Illinois University
Charleston, Illinois 61920

ABSTRACT

The Illinois State Board of Education (ISBE) has provided funds through the Scientific Literacy Grant Program to improve curriculum and instruction in science, mathematics and technology. This summative evaluation describes some of the impact a commercially prepared science program, Windows on Science, had on science curriculum for K-6 students in fourteen elementary school buildings in east-central Illinois. The Grant was administered by Educational Service Center #15, Charleston, Illinois. The major elements of Windows on Science include Level 1 videodisc technology, supporting laboratory materials and an ancillary language laboratory. Results from surveys, interviews and observations indicate: i) teachers utilized the videodisc more than the other two major elements, ii) the program was used as a supplement to existing curricula rather than as the sole curriculum, iii) most teachers believe that science instruction is improved through implementation of the program.

Key Words: videodisc, scientific literacy, elementary science, technology

---

INTRODUCTION AND PURPOSE

Measures to improve science curriculum and instruction in elementary and secondary schools have continued since the flurry of activity during the 1960's to develop new science programs. Kyle, Shymansky and Alport (1982) report that during 1963 alone there were 412 federally funded in-service institutes earmarked for curriculum development in science and math. Only a few of these programs continue to be a part of science curriculum in elementary and secondary schools today. As the "economic sputnik" (Marcuccio, 1987) emerged in 1984 with the publication of A Nation at Risk: The Imperative for Educational Reform (The National Commission on Excellence in Education, 1983) new demands from private and public interest groups emerged. This new directive for science education has emphasized scientific literacy among students to enhance their ability to become functional, productive citizens in a technological society. Concurrently, the expanded use of technological advancements in instruction took place in many schools. Advancements in videodisc technology, computer networking, and interfacing conventional laboratory equipment with computers began to find a niche among current methods and tools of instruction for science education in schools throughout the country.

To address the public and private demand for increased scientific literacy among students enrolled in elementary and secondary schools in Illinois, the Illinois State Board of Education (ISBE) began in 1989 the Scientific Literacy Grant program. Schools and government agencies submitted competitive grant proposals for money provided by the State Legislature. To date, recipients of these grants have used the funds "to support staff development projects for K-12 public school teachers to improve their literacy levels in science, mathematics and technology" (Illinois State Board of Education, 1995). As one of the annual recipients of these grants, Educational Service Center #15 (ESC 15), Charleston, Illinois, has provided programs designed to fulfill the mandates outlined by ISBE for elementary schools in its geographic area.

The purpose of this project was to evaluate how elementary teachers incorporated and utilized one particular program provided by ESC 15 to improve students' scientific literacy. This paper represents a portion of the evaluation report submitted to ESC 15 in August, 1995.

DESCRIPTION OF THE PROGRAM EVALUATED

The program evaluated during this project was Windows on Science (WOS) an elementary science program developed by Optical Data Corporation, Warren, New Jersey, in 1981. It is described as being a "complete curriculum resource that can be used throughout the year, either alone or to supplement an existing program" (Optical Data Corporation, 1994). The program features a videodisc with each of the 11 volumes of instruction and is organized in four titles: i) Primary Science, 3 Volumes, ii) Earth Science, 3 Volumes, iii) Life Science, 2 Volumes, iv) Physical Science, 3 Volumes. The three volumes of Primary Science are suggested for use by primary (first, second and third) grades. The Earth, Life and Physical Science volumes are intended to be used by intermediate (fourth, fifth and sixth) grades. Each volume contains three major elements for instruction, i) a 12 inch double-sided videodisc, ii) equipment and supplies for supportive laboratory activities, iii) an ancillary Language Laboratory.

Teacher Resources Booklets and Videodiscs

Teacher Resources Booklets are written for each unit of instruction. Each booklet provides the following information: i) instructions for first time videodisc users, ii) timelines for lesson and activity presentations, iii) content and process skills associated with each lesson, iv) articulation suggestions for other curricular arenas, v) student assessment, vi) barcodes and lesson notes for the videodisc, vii) equipment and supply lists, viii) procedures for activities, ix) ideas for critical thinking and enrichment exercises. Each volume contains a videodisc validated for Level 1 use i.e., the videodisc player is used without an external computer and is driven by remote control (Peterson, Hofmeister, Lubke, 1988). The videodisc can store up to 54,000 unique analog still images, film or videotape segments or computer generated graphics. Narrations for videotape segments, if present, are in English and Spanish.

Laboratory Equipment

Complementary to each volume is a set of materials, equipment and supplies for manipulative or hands-on activities. The original set of supplies from the manufacturer contains consumable as well as non-consumable materials. The initial quantity of lab equipment provided is such that activities can be performed by pairs of students or at least by small groups of 3 to 4 students. The laboratory supplies are designed to provide supportive hands-on activities associated with other elements of the program.

Language Laboratory

The Language Laboratory is a set of booklets with reading passages intended to provide supplemental reading material. In some cases, writing prompts and suggestions for activities are provided to be coordinated with other subjects, such as math or social studies. Pictures, diagrams and concept maps are a part of each booklet.

METHODS OF EVALUATION

Population

The population of interest was the self-contained and/or departmentalized kindergarten through sixth grade teachers from the fourteen buildings that participated in ESC 15's Scientific Literacy Grant for the last two years. Specifically faculty and staff who had or were utilizing WOS were included in the study.

Instrumentation

A survey was constructed to examine attitudes and reactions of faculty who used WOS. The survey consisted of two parts. Questions from the first part of the survey were used to determine: i) faculty demographics, ii) faculty definition of scientific literacy, iii) the role of WOS in addressing faculty's definition of scientific literacy, iv) which portion(s) of WOS were deemed important by the faculty, v) the extent to which the three major elements of the program were used, vi) the extent to which the program supports, supplements and/or replaces existing science curricula, vii) changes that have occurred in science education as a result of implementing WOS, and viii) how WOS compares with other science programs utilized. A 5-point Likert scale (Murphy and Likert, 1938) was used to rate opinions and attitudes. The scale included the following dimensions: 1=Strongly Disagree, 2=Disgaree, 3=Undecided, 4=Agree, 5=Strongly Agree. Written comments also were solicited. The second part of this survey was used to gather specific information regarding which primary and/or intermediate WOS units have been used by teachers for science lessons. This portion of the survey is not discussed in this report.

Data Analysis

Results of the survey were hand tallied. Statistical analysis was done using the Statistical Package for the Social Sciences (SAS). Frequencies, mean values, standard deviations, number of respondents, and percentages of category responses were data provided by this computer program. As WOS is divided into volumes for primary and intermediate grades, comparisons of results from primary (kindergarten through third grade) and intermediate (fourth through sixth grade) teachers were made for some questions. A Kruskal-Wallis test was used to determine if significant differences existed.

RESULTS

One hundred and five K-6 teachers have access to Windows on Science in their buildings and were asked to complete the survey. Eighty surveys were returned. All but one building returned at least one survey. At all grade levels, the majority of time devoted to science instruction takes place in the afternoon. Eighty-four percent of the K-3 teachers reported teaching science in the afternoon and eighty percent of 4-6 teachers reported the same.

Teachers were asked to rate statements that could be included as part of a definition for scientific literacy. Primary grade teachers rated "Correct use of lab tools" and "Ability to determine several ways of finding a solution to a problem" highest (Table 1). Intermediate teachers rated these statements along with "Ability to conduct simple research projects" as highest (Table 1). The history of science was least important for both groups (Table 1).

Teachers were asked to what extent WOS provided adequate instruction for their definition(s) of scientific literacy. The first choice for both groups was "Concepts and science vocabulary" (Table 2). Primary teachers rated "Relating science and technology" as second and intermediate teachers rated "Conducting simple research projects", "Use of lab tools" and "Role of science in society" as second (Table 2). Both groups of teachers rated WOS as providing the least adequate instruction in "History of science" and "How scientists work" (Table 2).

Teachers were asked how WOS was used in conjunction with current and/or previous curricula and textbooks. Primary teachers rated the program highest regarding use to supplement units they teach and secondarily as a supplement to their science text (Table 3). Intermediate teachers rated WOS highest as a supplement to units they teach (Table 3).

Teachers responded to which of the three major elements of the program were most important, the videodisc, the Language Laboratory or the laboratory materials (Table 4). The Kruskall-Wallis test revealed that K-3 teachers differed with respect to their rank of the three components ($H = 86.2$, $P<0.0004$); similarly 4-6 teachers' attitudes differed statistically ($H = 15.7$, $P<0.001$). Both groups rated the videodisc most important in for instruction followed by the laboratory equipment and the Language Laboratory.

Teachers were asked to indicate how often they used the three major elements of the program when science lessons were taught. Table 5 shows that primary and intermediate teachers used the videodisc most frequently. Intermediate teachers used the hands-on equipment the least while primary teachers used the Language Laboratory the least.

Questions about changes in instruction show primary and intermediate teachers feel science instruction has changed since implementing WOS (Table 6). Both groups agreed that their instruction is better now than prior to using WOS. Both primary and intermediate teachers rated the impact of WOS on their science curriculum as positive (Table 6). Questions dealing with issues that define generally accepted improvement in science instruction had median values of 3.0 or better. These questions addressed the amount of time spent on science since using the program, the amount of time spent reading relative to hands-on activities, and change in the units of science included in the curriculum. Sixty-five percent of all teachers disagreed or strongly disagreed that the videodisc player was a replacement for the textbook. Overall, primary teachers gave higher ratings to this set of questions than did intermediate teachers.

DISCUSSION

Survey responses revealed that teachers feel science education should involve an activity-based, hands-on approach. Concepts rated highest in teacher definitions of scientific literacy were: i) correct use of lab tools, ii) multiple solutions to problems, iii) conduct simple research, and iv) correct use of scientific terms. Survey results also demonstrated that definitions of scientific literacy by K-3 and 4-6 teachers did not differ remarkably. However teachers' definitions of scientific literacy (Table 1) differed from their views on how Windows on Science (WOS) addresses these definitions (Table 2). Rated by teachers in the top 50% of how well WOS addresses components of scientific literacy were: i) concepts and vocabulary, ii) relating science to technology, iii) role of science in society, and iv) use of lab tools. What teachers feel is important in scientific literacy is not necessarily what they feel is the best part of this program.

Responses show that teachers believe improvement in science instruction has taken place as a result of WOS. Table 6 shows that all faculty gave one of the highest ratings to "I think science instruction is better than prior to having WOS." Since no pre- and post-testing was conducted with regard to the impact of WOS on science instruction, transcriptions from interviews with teachers were examined for reasons why teachers believe science instruction is better now than before. References to the multitude of visuals that are now available to teachers through the videodisc are replete throughout the interviews. Similarly, teachers assert how much more interesting these visuals make their lessons and note that these visuals (including short video clips) appear to enhance student enjoyment of classroom presentations. With this in mind, improvements in scientific literacy and science instruction attributable to WOS may result from an increased capacity to illustrate biological, physical and environmental phenomena.

Though science textbooks are still available for student use in many classrooms and reading assignments from these texts remain a part of science instruction for some classes, faculty stated their students spend less time reading science and more time with hands-on activities since use of WOS began (Table 6). However, reports that students are spending more time with activities are contradicted by data in Table 5. Approximately 64% of K-3 faculty used the videodisc more than half of the time in science instruction. This is supported by results which show primary teachers rated the videodisc player as the most important part of the program followed by the laboratory equipment and Language Laboratory (Table 4). Hands-on activities were used by only 12% of K-3 teachers more than half of the time, and there is no record of any primary teacher using the Language Lab more than half of the time (Table 5). Intermediate teachers favored the videodisc, as 66% used it more than half of the time they taught science (Table 5). In contrast, the percentage of teachers who reported use of the other two elements more than half of the time for science instruction was relatively low (laboratory equipment: 20%, Language Laboratory: 13%). It is possible that students may be using materials from WOS along with activities from another text or curriculum guide, or from supplemental material provided by the teacher. The survey did not discriminate between various sources for supporting activities. Additional interviews and review of total science curricula may reveal various sources of supportive hands-on activities.

Observations of science lessons in the participating schools confirm the extensive use of the videodisc player as reported in the results. As an example, still frames of graphs, charts or photographs along with video segments have provided background information enabling students to ask questions, formulate hypotheses from their questions, and test hypotheses by collecting information about natural phenomena. In turn these may stimulate students to analyze information collected from the visual display and draw conclusions. Without the teacher blatantly stating "today's lesson will be a method for scientific investigation", some of the frame and video sequences could be used to trace the steps of the scientific method. Accordingly the videodisc may be seen by teachers as a replacement for a traditional hands-on laboratory activity which was used to demonstrate the steps in the scientific method and it may be viewed as a way of simulating activities that require materials and equipment unavailable to the class. Consequently teachers may regard the videodisc as an alternative to presenting laboratory activities without students actually performing manipulations. Videodiscs may present students with opportunities to observe activities that normally cannot be conducted in an elementary science classroom. Teachers may equate use of the videodisc with actively engaging students in something other than traditional activities such as reading a text or writing answers to questions hence the perception of spending less time reading and more time engaged in alternative activities. This new tool for instruction may indeed be engaging students in activities heretofore unavailable.

In summary, teachers perceive that Windows on Science enhances their instruction. Primary and intermediate teachers use the videodisc extensively and perhaps as a substitute for other hands-on activities. Apparently, WOS has resulted in somewhat of a redefinition of activity-based science instruction. What remain to be distinguished are teachers' perceptions of "activity- oriented" lessons for science. A more precise explanation of what constitutes activity-based or hands-on science is needed from elementary teachers. Additional observations of science lessons and interviews with teachers, staff and students could clarify their definition and provide further evidence of how a program such as Windows on Science is incorporated into instruction.

LITERATURE CITED

Gardner, M. and Likert, R. (1938). Public Opinion and the Individual. Harper and Brothers Publishers, New York.

Illinois State Board of Education. (1995). Scientific Literacy Grant Program. FY96 Staff Development Request for Proposals. Author, Springfield, IL.

Kyle, W.C., Shymansky, J.A., and Alport, J.M. (1982). Alphabet soup science. Science Teacher 49(8), pp.49-53.

Marcuccio, P. (1987). Forty-five years of elementary school science: a guided tour. Science and Children 24(4), pp.12-14.

Murphy, G. and Likert, R. (1938). Public Opinion and the Individual. Harper and Brothers Publishers, New York.

National Commission on Excellence in Education. (1983) A Nation at Risk: The Imperative for Education Reform. U.S. Department of Education, Washington, DC.

Optical Data Corporation. (1994). Windows on Science. Author, Trenton, NJ.

Peterson, L., Hofmeister, A.M., and Lubke, M. (1988). A videodisc approach to instructional productivity. Educational Technology 28(2), pp.16-22.

Table 1. Primary (K-3) and intermediate (4-6) teacher definitions (Mean/Median) of scientific literacy.

	K-3	4-6
Correct use of lab tools	4.4/5.0	4.5/5.0
Multiple solutions to problems	4.4/4.0	4.5/5.0
Conduct simple research	4.2/4.0	4.5/5.0
Correct use of science terms	4.3/4.0	4.4/4.0
Relationship between science and technology	3.9/4.0	4.3/4.0
Role of science in society	3.8/4.0	4.2/4.0
How scientists work	4.0/4.0	4.1/4.0
Science history	3.5/4.0	3.6/4.0

Table 2. Survey response to the question "To what extent does Windows on Science (WOS) provide adequate instruction with respect to your definitions of scientific literacy?" Values are expressed as mean/median on a 5-point Likert Scale.

	K-3	4-6
Concepts and Vocabulary	4.1/4.0	4.5/4.0
Relating science and technology	3.9/4.0	3.5/4.0
Role of science in society	3.8/4.0	3.7/4.0
Use of lab tools	3.8/4.0	3.7/4.0
Science process skills	3.8/4.0	3.6/4.0
How scientists work	3.7/4.0	3.5/4.0
Conducting simple research projects	3.7/4.0	3.7/4.0
History of science	3.1/3.0	3.5/4.0

Table 3. Survey response to the question "How is Windows on Science (WOS) used in conjunction with existing curricula?" Values are expressed as mean-median on a 5-point Likert scale.

	K-3	4-6
WOS supplements units I teach	3.7/4.0	3.1/4.0
WOS supplements my science text	3.6/4.0	2.9/4.0
WOS is supplemented by my science text	3.3/4.0	2.9/2.5
WOS is thorough enough to stand alone	3.0/3.0	2.9/3.0

Table 4. Response to survey question "What elements of Windows on Science (WOS) are most important for science instruction?" Values are expressed as mean/median on a 5-point Likert scale.

	K-3	4-6
Videodisc player	4.4/5.0	4.2/4.0
Laboratory materials	3.3/3.0	3.5/4.0
Language laboratory	2.3/2.0	2.3/2.0

Table 5. Response to survey question "When teaching science how often (percent of time) do you use the videodisc, hands-on lab activities, and/or Language Lab with your instruction?" Values expressed as percentages.

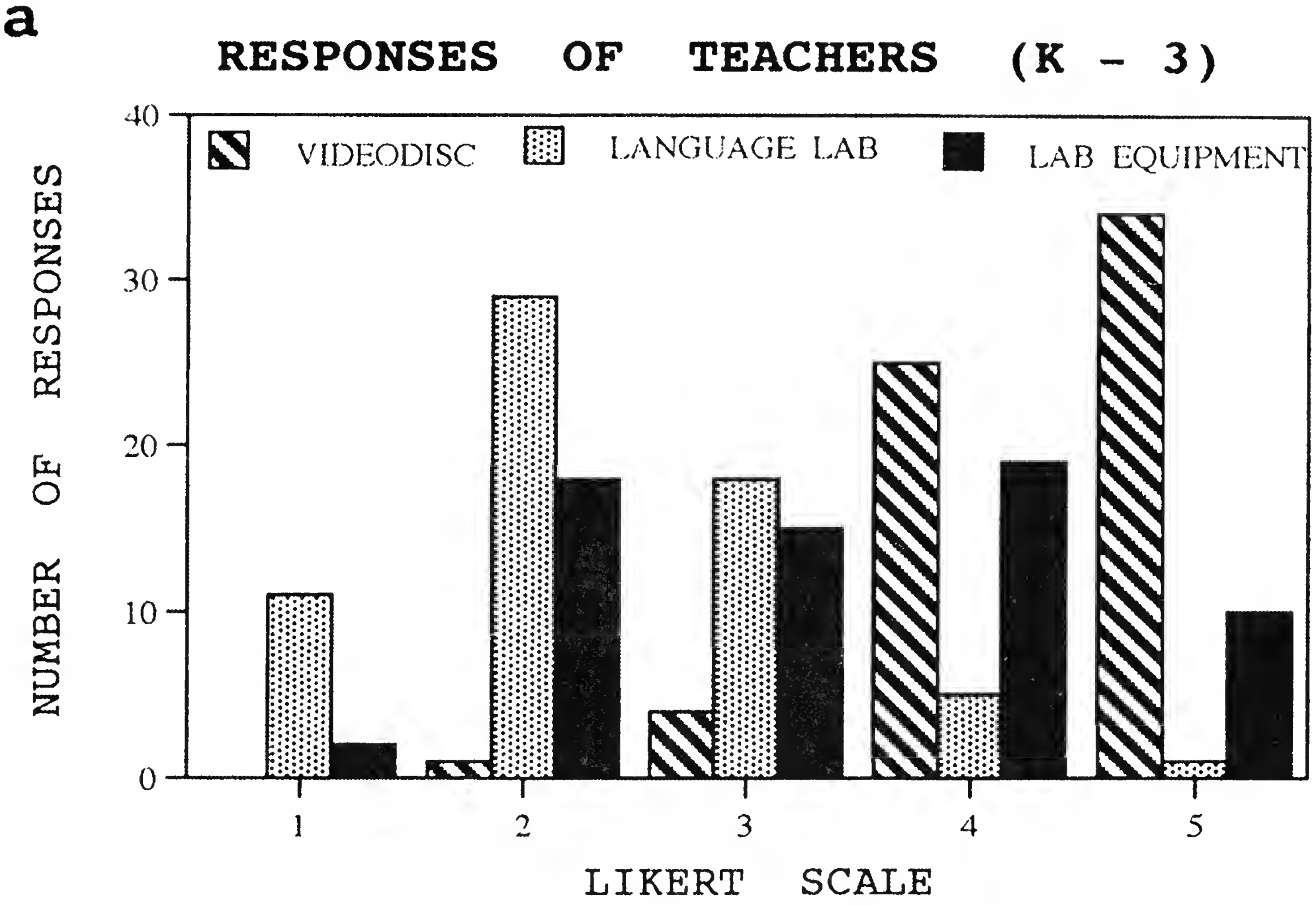
		100%	75%	50%	25%	0%	
Videodisc	K-3	27.7	36.9	23.1	12.3	-	(n=65)
	4-6	33.3	33.3	20.0	13.3	-	(n=15)
Hands-On Lab	K-3	1.6	11.1	33.9	45.2	6.5	(n=62)
	4-6	-	20.0	20.0	46.7	13.3	(n=15)
Language Lab	K-3	0.0	0.0	4.8	35.5	59.7	(n=62)
	4-6	6.7	6.7	20.0	40.0	26.7	(n=15)

Table 6. What impact has Windows on Science (WOS) had on science instruction? (Mean/median)

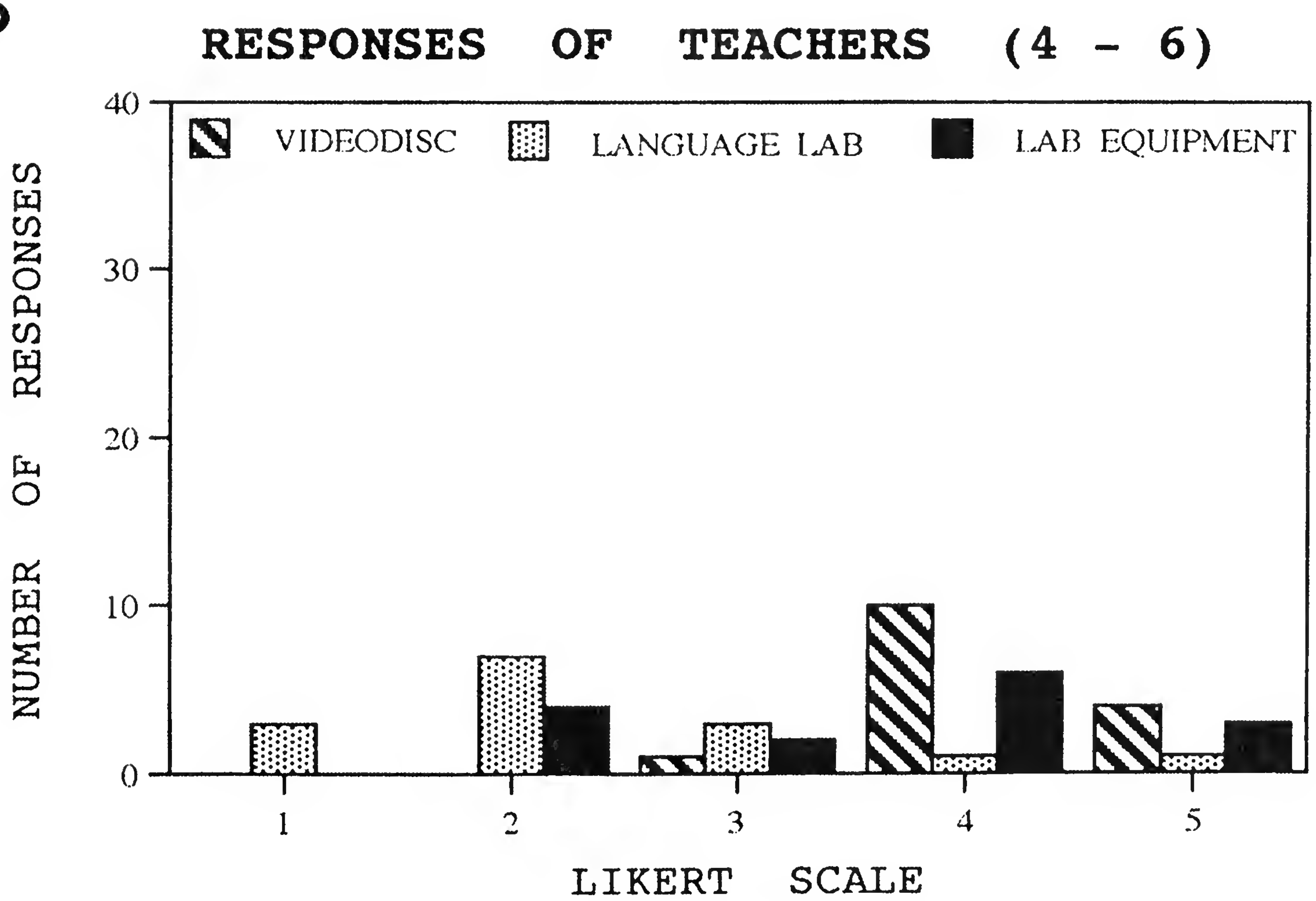
	K-3	4-6
When I use a WOS unit, my students are involved in more hands-on activities than direct teacher instruction from me.	3.5/4.0	3.1/3.5
My class spends more time with hands-on activities since using WOS.	3.4/4.0	2.9/3.0
Overall I think science instruction is better than prior to having WOS.	4.0/4.0	3.5/3.0
More time is spent each week teaching science since using WOS.	3.4/4.0	3.0/3.0
I have included more units of science since using WOS.	3.3/4.0	2.7/2.0
My students spend less time reading and more time with activities since using WOS.	3.7/4.0	3.5/4.0
WOS gives me the chance to teach more about the effects of science and technology on society.	3.6/4.0	2.9/3.0
My students get more instruction on science "facts and figures" since using WOS.	3.3/3.0	3.2/3.0
WOS simply replaces the textbook with video and TV to teach science.	2.6/2.0	2.3/2.0
My science instruction has not changed since we acquired the WOS material.	1.7/2.0	2.2/2.0

Figure 1. a) A comparison of the importance of the three major elements of Windows on Science (WOS) for Primary (K-3) teachers. b) A comparison of the importance of the three major elements of Windows on Science (WOS) for Intermediate (4-6) teachers.

a



b



Transactions of the Illinois State Academy of Science
(1996), Volume 89, 3 and 4, pp. 169-186

Selected Illinois Fishes in Jeopardy: New Records and Status Evaluations

Brooks M. Burr[1], Kenneth M. Cook[1], David J. Eisenhour[1], Kyle R. Piller[1], William J. Poly[1], Randy W. Sauer[2], Christopher A. Taylor[3], Elmer R. Atwood[2], and Gregory L. Seegert[4]

Department of Zoology, Southern Illinois University, Carbondale, Illinois 62901-6501[1]
Division of Fisheries, Illinois Department of Natural Resources,
Hazlet State Park Office, Carlyle, Illinois 62231[2]
Illinois Natural History Survey, Champaign, Illinois 61820[3]
EA Midwest, 444 Lake Cook Road, Suite 18, Deerfield, Illinois 60015[4]

ABSTRACT

Recent collections (late 1980s, early 1990s) in Illinois waters by resource management and university personnel conducting status surveys of jeopardized fishes, drainage-wide biotic integrity studies, and routine sampling have documented significant new vouchered records for 15 fish species that have been variously placed on lists of rare, threatened, or endangered species. Three species (Sturgeon Chub [*Macrhybopsis gelida*], Blue Sucker [*Cycleptus elongatus*], Greater Redhorse [*Moxostoma valenciennesi*]) are candidates for listing as federally endangered or threatened by the U.S. Fish and Wildlife Service and are restricted to large rivers. Specifically, we document: 1) the threatened Least Brook Lamprey (*Lampetra aepyptera*) in Lusk and Bay creeks; 2) photographic and anecdotal accounts from the 1950s and 1960s of the presumably extirpated Alligator Gar (*Atractosteus spatula*) in the Mississippi River and Horseshoe Lake; 3) the first records in over 30 years of the Alabama Shad (*Alosa alabamae*) from two locations in the Mississippi River; 4) extension of the northern limits of the Blacktail Shiner (*Cyprinella venusta*) in the Clear Creek system upstream to Dutch Creek; 5) the continued occurrence of the endangered Cypress Minnow (*Hybognathus hayi*) in the middle Cache River and below Horseshoe Lake dam; 6) the first record in just over 30 years of the endangered Bigeye Chub (*Hybopsis amblops*) from the Little Vermilion River; 7) the sporadic occurrence of the endangered Sturgeon Chub in the Mississippi River at Grand Tower; 8) numerous records of the endangered Bigeye Shiner (*Notropis boops*) indicating its localized abundance in the Clear Creek system and the Little Vermilion River; 9) the continued occurrence of the River Chub (*Nocomis micropogon*) in the Little Vermilion River, perhaps the only spawning stream known for this fish in Illinois; 10) several records of young-of-the-year Blue Sucker from the mainstem Mississippi and Wabash rivers, the first evidence of spawning in Illinois waters in decades; 11) five new records of the endangered Greater Redhorse from the Fox, Vermilion, and Illinois rivers; 12) the first records of the distributionally restricted Spring Cavefish (*Forbesichthys agassizi*) and threatened Bantam Sunfish (*Lepomis symmetricus*) from the middle Cache River drainage; 13) the sporadic occurrence of the endangered Western Sand Darter (*Ammocrypta clara*) in the Mississippi River; and 14) the first record of the Harlequin Darter (*Etheostoma histrio*) from the

Wabash River of Illinois in over 90 years. We recommend legal protection for three species (i.e., Alabama Shad, Blue Sucker, and Blacktail Shiner) that presently lack any formal conservation status.

INTRODUCTION

At least 187 fishes have been reported over the past century as native to Illinois waters (Burr 1991), with at least 20% of these having been considered rare, endangered, or threatened (Table 1). Some of these jeopardized species are now considered extirpated, while others disappeared so many years ago that they never made it onto any list of imperiled species. Since the early 1970s, a number of workers have compiled lists or accounts of jeopardized Illinois fishes, including Lopinot and Smith (1973), Smith and Page (1981), Herkert (1992, 1994), and the Illinois Endangered Species Protection Board [IESPB] (1989, 1990, 1994). These reports document that at least 39 native Illinois fishes have for various reasons warranted some form of legal protection. The historical data base on Illinois fishes (Forbes and Richardson 1908, Smith 1979) continues to be enlarged by personnel working for agencies charged with protecting and managing the State's natural resources as well as by university and other personnel interested in rare fishes. As a consequence, new records of rare species accrue annually but seldom are reported in any formal manner. New information on potentially rare or jeopardized fishes assists resource management personnel in making informed decisions regarding protection status and fiscal needs.

Since the most recent reviews (Herkert 1992, 1994) of endangered and threatened fishes have appeared, status surveys of seven potentially jeopardized fishes have been completed (EA Engineering, Science, and Technology 1994, Taylor et al. 1994). In addition, Page et al. (1992) summarized data on aquatic biodiversity for Illinois streams and provided drainage by drainage accounts of rare fishes with the ultimate goal of identifying Illinois' most biologically significant streams.

We report here records for 15 potentially jeopardized Illinois fish species and evaluate their conservation status in light of recent discoveries. Additionally, we confirm the presence in Illinois of several fishes known only to a few specialists and of a few species thought to have been extirpated from the State.

METHODS AND MATERIALS

Records are based on collections made by the authors, the Illinois Department of Natural Resources (IDNR), and collections deposited at the Illinois Natural History Survey (INHS) and Southern Illinois University at Carbondale (SIUC). Collections were made using minnow and bag seines, a boat-mounted electrofishing unit or gill nets. Measurements are in mm standard length (SL) for all species, except *Lampetra aepyptera*, which are in mm total length (TL). Most records reported here are from the late 1980s and early 1990s and are meant to show recent effort in searching for and finding rare Illinois fishes. A number of the new records result from incidental capture during routine surveys of drainages, surveys targeted for particular species, or from general collecting in poorly worked areas. The use of common and scientific names of fishes is somewhat eclectic, but generally follows the recommendations of Robins et al. (1991) or Page and Burr

(1991). Species accounts include catalog number, number of specimens followed by their range in SL or TL (in parentheses), stream or lake name, major drainage (in parentheses), common locality (legal locality in parentheses when available), county, and date of capture. Genera and species are treated alphabetically within the general phylogenetic scheme presented by Robins et al. (1991).

RESULTS

Least Brook Lamprey
Lampetra aepyptera
SIUC 22207 (1, 120 mm), Bay Creek (Ohio R. Dr.), 0.5 mi. W Robbs (T12S, R5E, Sec. 19NW), Pope Co., 4 September 1991; SIUC 22224 (1, 121 mm), Sugar Creek (Saline R. Dr.), at Rt. 166 bridge, 0.5 mi. SE Creal Springs (T10S, R3E, Sec. 25), Williamson Co., 16 September 1993; SIUC 22218 (1, 149), Sugar Creek (Saline R. Dr.), 1.0 mi. SSE Creal Springs (T10S, R3E, Sec. 36SW), Williamson Co., 16 September 1993; SIUC 21234 (1, 127 mm), Big Grande Pierre Creek (Ohio R. Dr.), 0.5 mi. upstream of confluence with Rose Creek (T11S, R7E, Sec. 15S), Pope Co., 11 August 1986; SIUC 22880 (1, 166 mm), Big Creek (Ohio R. Dr.), 3.5 airmi. NNW Elizabethtown at Iron Furnace (T12S, R8E, Sec. 3), Hardin Co., 12 February 1994; SIUC 11907 (1, 136 mm), Lusk Creek (Ohio R. Dr.), at Co. Rd. 5 bridge, 2.8 mi. SE Eddyville (T12S, R6E, Sec. 16SE), Pope Co., 22 March 1985; SIUC 18935 (1, 131.2 mm), same location as SIUC 11907, 26 October 1991.

Remarks: Smith (1979) reported *Lampetra aepyptera* from small streams draining into the Ohio River in southeastern Illinois including Big Creek, Big Grande Pierre Creek, and Sugar Creek. Our records confirm that this species occurs in Big Grande Pierre Creek where it was previously known only from a 26-mm ammocoete (Smith 1979). Also confirmed is the occurrence of this species in Sugar Creek where the previous record was based on a sample taken in the mid-1950s. In addition, the range of this species is now known to include Lusk Creek and Bay Creek, with Lusk Creek records based on pre-spawning males. Smith's (1979:7) suggestion that this species "probably occurs throughout the eastern portion of the Shawnee Hills of southern Illinois" is now substantiated (Fig. 1). As judged from its limited range and few high-quality spawning streams, *L. aepyptera* is considered threatened in Illinois. Information is needed on spawning sites, spawning dates, population size, and threats to continued existence before a more informed status evaluation can be made. The proposed impoundment of Sugar Creek, Williamson County, will almost certainly remove a known population from the species' limited range in Illinois.

Alligator Gar
Atractosteus spatula
SIUC [photograph record] (1, ca. 1,750 mm), Mississippi River (Gulf of Mexico Dr.), in Nine-Mile Shute at Grand Tower, Jackson Co., 1955.

Remarks: As Smith (1979) noted, *Atractosteus spatula* has apparently always been rare in Illinois waters, and the only voucher specimen known from the state is a juvenile collected in 1935 from the Illinois River, locality unknown (INHS 64422). In 1944, 85 *A. spatula* were netted at five stations on the Mississippi River between Grafton and

Cairo (Barnickol and Starrett 1951); 80 of these were captured at Cairo. Additional records of this species are based on literature reports and personal communications judged to be reliable, or of photographs of large adults that are unmistakable as another gar species. The photographic record reported here is of a large adult caught by Mr. C. E. Nickles, formerly of Jonesboro. Roy C. Heidinger, SIUC Fisheries Biologist, caught on hook and line a large adult (>2 m) from the Mississippi River below Windfield Lock & Dam 25 near Batchtown, Calhoun County, in 1963. The huge size of this individual rules out all other gar species known from the Midwest. In 1964, Ora M. Price, then an IDOC Fisheries Biologist, reported a 67 inch (1.7 m) individual captured in a trammel net by a commercial fisherman from Horseshoe Lake, Alexander County (Burr and Heidinger 1994). No post-1970 records of this fish are known from Illinois waters, and these records serve to further document the historical occurrence of this fish in Illinois. *Atractosteus spatula* has declined precipitously in the upper Mississippi basin (Burr and Page 1986) and only occasional waifs from more southerly regions might be expected in Illinois. The species is considered extirpated in Illinois.

Alabama Shad
Alosa alabamae
SIUC 23596 (1, 76.9 mm), Mississippi River (Gulf of Mexico Dr.), just downstream from mouth of Marys River [near Chester] (T7S, R6W, Sec. 33), Randolph Co., 12 November 1994; SIUC 24824 (1, 75.4 mm), Mississippi River (Gulf of Mexico Dr.), at Grand Tower, Devils Backbone Park (T10S, R3W, Sec. 22SW), Jackson Co., 29 September 1995.

Remarks: *Alosa alabamae*, one of the few remaining anadromous species in the Midwest, is one of the most poorly known fishes in Illinois. Smith (1979) reported only a single juvenile (62.2 mm) from the Mississippi River, Monroe County, collected 21 August 1962 (INHS 20096). In the early 1900s, prior to the construction of numerous dams on rivers, this fish spawned near the Keokuk region of the Mississippi River (Coker 1930). Since that time, the only known spawning reaches in the entire upper Mississippi basin are in a few streams in east-central Missouri (Pflieger 1975). Spawning occurs in May and June and young about 100 mm TL (lengths of our specimens are SL) captured in the fall "are presumably making their way back to the sea" (Smith 1979:28). Our specimens, both captured during the fall, are the first records in over 30 years of the Alabama Shad in the Mississippi River and confirm the occasional presence of juveniles presumably en route to the sea. This species has never been placed on Illinois' rare fishes list. It is possible that the species still spawns in Illinois waters. If so, some level of protection should be accorded the species.

Blacktail Shiner
Cyprinella venusta
SIUC 25012 (1, 26.7 mm), Mississippi River at Thebes Access, RM 43.8 (T15S, R3W, Sec. 8SW), Alexander Co., 18 September 1986; SIUC 22639 (1, 53.8 mm), Clear Creek (Mississippi R. Dr.), at mouth (T14S, R3W, Sec. 3SW), Alexander Co., 11 November 1993; SIUC 22378 (4, 41.8 - 48.0 mm), Dutch Creek (Clear Cr. Dr.), near mouth of Caney Fork, 2.75 mi. ENE Ware (T12S, R2W, Sec. 20SE), Union Co., 28 September 1993; SIUC 23054 (1, 37.8 mm), Lake Creek (Cache R. Dr.), at 2nd bridge below Horseshoe Lake spillway (T16S, R2W, Sec. 14), Alexander Co., 25 June 1994; SIUC

21165 (1, 49.5 mm), Lusk Creek (Ohio R. Dr.), 0.8 mi. E of Wattersburg (T13S, R6E, Sec. 16SE), Pope Co., 1986.

Remarks: Taylor et al. (1994) reviewed the historical records and conservation status of *Cyprinella venusta* in Illinois. They pointed out that the narrow Illinois range of this fish, with spawning reaches limited to southwestern Illinois (Clear Creek drainage), low numbers of individuals, and evidence of continued hybridization with the Red Shiner, *C. lutrensis*, has placed the species in a more precarious position than previously known; threatened status was recommended. Our records extend the range of the species in the Clear Creek system to Dutch Creek, perhaps the northernmost extent of this species' range. A post-flood individual is available from Horseshoe Lake, Alexander County. Cook (1994) recently identified specimens (SIUC 22419, 22383, 22282, 22376) as morphological intermediates between *C. venusta* and *C. lutrensis* from throughout the Clear Creek drainage. An additional hybrid involving these two parental species was also identified from Lake Creek, Alexander County, in 1994 (SIUC 23090). We concur that this species should be provided threatened status in Illinois.

Cypress Minnow
Hybognathus hayi
SIUC 21694 (10, 31.3 - 37.0 mm), Horseshoe Lake spillway (Cache R. Dr.), 1.0 mi. E of Miller City (T16S, R2W, Sec. 21NE), Alexander Co., 29 June 1993; SIUC 20187 (1, 67.7 mm), Cypress Creek (Cache R. Dr.), 1.5 mi. W of White Hall (T14S, R1E, Sec. 1SE), Pulaski Co., 9 June 1992.

Remarks: Warren and Burr (1989) reviewed the status of *Hybognathus hayi* in Illinois and recorded its historical occurrence from the Big Muddy River, Clear Creek, Horseshoe Lake, and Cache River drainages. Their status survey revealed that the species was extirpated from the Big Muddy River and Clear Creek drainages. Our records confirm the continued existence of this species in the middle reach of the Cache River (Muir et al. 1995) and the Horseshoe Lake drainage. Specimens from Horseshoe Lake represent young-of-the-year and indicate spawning prior to the flood of 1993. Extensive sampling of the Clear Creek drainage by Cook (1994) and monitoring of the Horseshoe Lake drainage over the past two years has not revealed additional occurrences of the species, nor were any found in a recent survey of the middle Cache River (Cook et al. 1995). The sporadic distribution, general rarity, and extirpation of known historical populations argues for this species' continued status as endangered in Illinois.

Bigeye Chub
Hybopsis amblops
SIUC 20608 (1, 55.5 mm), Little Vermilion River (Wabash R. Dr.), at Peabody Coal property, 3 mi. ESE Georgetown (T17N , R11W, Sec. 2), Vermilion Co., 2 September 1992.

Remarks: Warren and Burr (1988) reviewed the status of *Hybopsis amblops* in Illinois and agreed with Smith (1979) that the species was extirpated from the state, having been last collected in 1961. Their study included searches at 20 sites historically known to harbor the species, including sampling of suitable habitat in the Little Vermilion River. In a recent study by IDOC stream biologists a single adult *H. amblops* was discovered among several thousand cyprinids collected from the Little Vermilion River representing the first collection of this species from Illinois in over 30 years. Although suitable habitat is present there and in other locations in Vermilion County, the lack of additional specimens despite considerable effort expended to find the species, indicates its extreme rarity. Additional searches are warranted to help locate a viable (i.e., reproducing) population of this state endangered species in Illinois waters.

Sturgeon Chub
Macrhybopsis gelida
SIUC 22921 (3, 26.2 - 28.0 mm), Mississippi River (Gulf of Mexico Dr.), at Grand Tower [aerial pipeline crossing] (T10S, R4W, Sec. 23SE), Jackson Co., 24 February 1994; SIUC 24086 (1, 23.9 mm), Mississippi River (Gulf of Mexico Dr.), at Grand Tower [Devil's Backbone Park] (T10S, R4W, Sec. 23SE), Jackson Co., 1 April 1995.

Remarks: As Smith (1979) noted, *Macrhybopsis gelida* is one of the rarest of Illinois fishes, being restricted to the Mississippi River mainstem below the mouth of the Missouri River. In a one-year study of the composition of Mississippi River shoreline fishes at Grand Tower, Klutho (1983) collected only five individuals of this species in swift water over gravel and sand. Annual sampling of the Mississippi River shoreline for over 10 years by IDOC fisheries biologists has not yielded this species. Our recent records demonstrate the continued occurrence of this species in the Illinois portion of the lower Mississippi River, although it appears to be localized and extremely rare. The recent appearance of this species may be correlated with several years of spring/summer floods, as a closely related species, *Macrhybopsis aestivalis*, spawns during flood events (Bottrell et al. 1964). The decline of this species over much of its range in the Missouri River basin has lead to its consideration as a candidate for listing (i.e., a C1 species) as an endangered or threatened species by the U.S. Fish & Wildlife Service (Werdon 1993) and recent addition of the species to the list of endangered Illinois fishes (Table 1).

Bigeye Shiner
Notropis boops
SIUC 20610 (6, 40.0 - 58.7 mm), Little Vermilion River (Wabash R. Dr.), at Peabody Coal property, 3.0 mi. ESE Georgetown (T17N, R11W, Sec. 2), Vermilion Co., 2 September 1992; SIUC 20636 (6, 49.5 - 64.5 mm), Little Vermilion River (Wabash R. Dr.), at Fliermans Nature Preserve (T17N, R11W, Sec. 5), Vermilion Co., 2 September 1992; SIUC 20620 (4, 54.2 - 67.5 mm), Little Vermilion River (Wabash R. Dr.), above Hwy. 150, 1.0 mi. S Georgetown (T17N, R11W, Sec. 6), Vermilion Co., 1 September 1992; SIUC 20721 (6, 44.0 - 64.8 mm), Little Vermilion River (Wabash R. Dr.), above steel bridge, 1.5 mi. N Humrick (T17N, R11W, Sec. 12N), Vermilion Co., 2 September 1992; SIUC 20591 (1, 48.5 mm), Little Vermilion River (Wabash R. Dr.), above Humrick Rd., 0.5 mi. SE Georgetown (T18N, R11W, Sec. 33SW), Vermilion Co., 1 September 1992; SIUC 22256 (5, 41.7 - 61.7 mm), Green Creek (Clear Cr. Dr.), at Hwy. 146 pull-off, 3.5 mi. E of Ware T12S, R2W, Sec. 21SE), Union Co., 1 July 1993; SIUC 22380 (19, 42.7 - 59.6 mm), Dutch Creek (Clear Cr. Dr.), near mouth of Caney Fork, 2.75 mi. ENE of Ware (T12S, R2W, Sec. 20SE), Union Co., 28 September 1993; SIUC 22367 (18, 23.6 - 54.5 mm), Dutch Creek (Clear Cr. Dr.), S of Hwy. 146 bridge, 3.25 mi. E of Ware (T12S, R2W, Sec. 28NW), Union Co., 9 September 1993; SIUC 22359 (2, 55.5 - 62.2 mm), Hutchins Creek (Clear Cr. Dr.), at U. S. Forest Service

property, 2.5 mi. NE (town of) Wolf Lake (T11S, R3W, Sec. 25SW), Union Co., 4 August 1993; SIUC 22384 (1, 43.9 mm), Clear Creek (Mississippi R. Dr.), at U. S. Forest Service access rd., off Co. Rd. 19, 1.75 mi. W of Mountain Glen (T11S, R2W, Sec. 27SW), Union Co., 21 September 1993; SIUC 22423 (9, 36.9 - 53.0 mm), Clear Creek (Mississippi R. Dr.), 2.5 mi. WNW Mountain Glen (T11S, R2W, Sec. 28S), Union Co., 5 October 1993; SIUC 22263 (19, 35.9 - 57.4 mm), Sexton Creek (Clear Cr. Dr.), near ford in creek, 2.5 mi. NE Gale (T14S, R3W, Sec. 25NE), Alexander Co., 23 June 1993; SIUC 22311 (17, 33.4 - 58.7 mm), Miller Creek (Clear Cr. Dr.), at bridge 1 mi. E of Thebes (T15S, R3W, Sec. 9SE), Alexander Co., 23 June 1993; SIUC 22420 (5, 36.3 - 52.4 mm), Seminary Fork (Clear Cr. Dr.), at bridge on Co. Rd. 19, 2.25 mi. NW of Mountain Glen (T11S, R2W, Sec. 21SE), Union Co., 5 October 1993; SIUC 22841 (2, 28.2 - 30.7 mm), Mississippi River (Gulf of Mexico Dr.) at Picayune Chute, 2.75 mi. WNW McClure (T14S, R3W, Sec. 6N), Alexander Co., 25 October 1993.

Remarks: Smith (1979) documented the sporadic distribution and rarity of *Notropis boops* noting that it was probably never abundant in Illinois except in the Vermilion and Little Vermilion River systems. Lack of population knowledge of this species and its presumed extirpation from stream reaches in the Kaskaskia and Little Wabash Rivers led to its upgrading from threatened to endangered between 1990 and 1994 (Table 1). Our recent collections from the Little Vermilion River confirm its historical abundance there. In addition, Cook (1994) found that this species had expanded its range northward in the Clear Creek system of southwestern Illinois where it is now common in streams (e.g., Green, Dutch, and Hutchins creeks) where it had never been previously reported despite intensive sampling over a period of years by several investigators. We also document this species from a side channel (Picayune Chute) of the Mississippi River. Although the status of historically known populations in the Illinois, Kaskaskia, and Little Wabash rivers remains poorly known, the species is thriving in the Little Vermilion River and Clear Creek. *Notropis boops* is sporadic and rare, but much more common than several other endangered species (e.g., *E. histrio*, *H. amblops*, *H. hayi*) discussed here. This species should be considered for downgrading to the threatened category.

River Chub

Nocomis micropogon

SIUC 20609 (1, 130 mm), Little Vermilion River (Wabash R. Dr.), at Peabody Coal property, 3.0 mi. ESE Georgetown (T17N, R11W, Sec. 2), Vermilion Co., 2 September 1992; SIUC 20720 (2, 110 - 111 mm), Little Vermilion River (Wabash R. Dr.), above steel bridge, 1.5 mi. N Humrick (T17N, R11W, Sec. 12N), Vermilion Co., 2 September 1992.

Remarks: Burr et al. (1988) reported the first records of *Nocomis micropogon* from the Little Vermilion River; prior records included only two localities from the mainstem Wabash River in Clark and Lawrence counties (Smith 1979). Our recent records document the continued occurrence of this species in the Little Vermilion River and strongly suggest that this may be the only potential spawning stream known in Illinois. Abundant rocky substrate in the Little Vermilion River provides appropriate nesting habitat for the species. *Nocomis micropogon* was recently added to the Illinois endangered list.

Blue Sucker

Cycleptus elongatus

All vouchered records are Mississippi River, Gulf of Mexico Drainage. SIUC 23892 (1, 21.3 mm), Pool 24, RM 296.1 at Cincinnati Landing (T5S, R7W, Sec. 26SE), Pike Co., 10 June 1993; SIUC 23935 (1, 21.3 mm), Pool 24, RM 280.5 at Delair Access (T7S, R5W, Sec. 20), Pike Co., 10 June 1993; SIUC 23931 (1, 22.4 mm), Pool 24 about 7.5 mi. SW Pleasant Hill [in Pike County], Calhoun Co., 11 June 1993; SIUC 24948 (1, 28.1 mm), RM 244.7, 3 mi. NW Batchtown (T12S, R2W, Sec. 6), Calhoun Co., 10 June 1992; SIUC 25460 (1, 15.7 mm), at Piasa Harbor, RM 209.5, Jersey Co., 17 June 1994; SIUC 23923 (1, 34.0 mm), RM 125.2 at Little Rock Ferry, Randolph Co., 11 June 1993; SIUC 24945 (1, 152 mm), at rock dikes, 4 mi. NW Chester (T7S, R7W, Sec. 15SE), Randolph Co., 29 August 1995; SIUC 24886 (1, 22.4 mm), at Grand Tower aerial pipeline (T10S, R4W, Sec. 23SE), Jackson Co., 16 June 1994; SIUC 23934 (1, 24.4 mm), RM 43.9 at Thebes Public Access (T15S, R3W, Sec. 8SE), Alexander Co., 11 June 1992.

Remarks: According to Smith (1979), *Cycleptus elongatus* had been declining in abundance for many years due in part to dams on navigable rivers, deterioration of water quality, excessive catches of adults in spawning runs, and gradually decreasing depths of river channels from sedimentation. Prior to 1993, the only vouchered young-of-the-year specimen known from Illinois had been collected in 1972 from the Mississippi River, Rock Island Co., RM 506. Seven vouchered collections of young-of-the-year from the Mississippi River in Alexander County (Thebes) north to Pike County (Cincinnati Landing) (Fig. 1) demonstrate recent reproduction, strongly correlated with the 1993 and 1994 floods. Recent (1995) capture of a 152-mm individual demonstrates that some recruitment is occurring in Illinois. The Illinois Department of Natural Resources (IDNR) Streams Database contains a number of records of young-of-the-year/juvenile (sensu Moss et al. 1983) *Cycleptus* from the mainstem Mississippi and Wabash rivers (Fig. 1) between 1972 and 1992 indicating that reproduction has occurred sporadically in these large rivers over the past 20 years. We accept these records as valid even though they are not vouchered. Most records of adults of this species are from the Wabash River, probably not coincidentally the longest free-flowing (i.e., unimpounded) river in the eastern United States. One of us (GLS) collected 16 *C. elongatus* ranging in size from 148 to 675 mm from the Wabash River, Clark County, in 1988 (Fig. 1). Rupprecht and Jahn (1980) reported on the biology of *C. elongatus* in Pool 20 of the Mississippi River. They found adult males in breeding condition in April, but no ripe females. A recent article in *Fisheries* (Anonymous 1993) reported the capture of many young-of-the-year in the upper Mississippi River suggesting that it is a species, along with many others, that reproduces in large numbers in response to a "flood pulse." This species has never been placed on Illinois' rare or endangered fishes lists (Table 1), but is a candidate for listing (i.e., a C2 species) as a federally endangered species by the U.S. Fish & Wildlife Service (Elstad and Werdon 1993). We recommend this species be considered for listing as threatened in Illinois.

Greater Redhorse

Moxostoma valenciennesi

INHS 65239 (1, 382 mm), Illinois River (Mississippi R. Dr.), 3.5 mi. SSW Channahon, Dresden Island Lock and Dam (T34N, R8E, Sec. 25), Grundy Co., 1987-1989;

INHS 30925 (1, 435 mm), Fox River (Illinois R. Dr.), at Mooseheart, just below mouth of Mill Creek, 0.75 mi. upstream Route 56 (T39N, R8E, Sec. 33NE), Kane Co., 26 October 1993; INHS 61192 (1, 292 mm), Fox River (Illinois R. Dr.), at Yorkville, Hwy. 47 crossing (T37N, R7E, Sec. 32NE), Kendall Co., 29 August 1991; INHS 59345 (1, 385 mm), Mud Creek (Vermilion-Illinois R. Dr.), 2.0 mi. NW Cornell (T30N, R4E, Sec. 33SE), Livingston Co., 2 August 1990; SIUC 19736 (2, 306 - 345 mm), Vermilion River (Illinois R. Dr.) at Hummiston Woods, 5.0 mi. NW Pontiac (T29N, R4E, Sec. 36), Livingston Co., 9 July 1991.

Remarks: This species, known historically from one specimen collected in Salt Creek, DuPage County, 1901, was considered extirpated from the State (Smith 1979). Seegert (1986) reported the first modern record of this species, a single adult from the upper Illinois River, Mile 249, taken with electrofishing equipment. Since his report, *Moxostoma valenciennesi* has been captured on five different occasions from five new localities in the Fox, Vermilion, and mainstem Illinois rivers (Fig. 1). All specimens were collected with electrofishing gear, probably the most effective method of sampling for species of *Moxostoma*. Similarly, electrofishing surveys revealed previously unknown populations of *M. valenciennesi* and the River Redhorse, *M. carinatum,* in Ohio streams (Yoder and Beaumier 1986). All vouchered specimens are adults suggesting that either reproduction or recruitment is low in Illinois, or that young are more difficult to collect than adults. Seegert (1991) captured 18 juveniles and adults (ca. 300-550 mm TL) from three of seven locations on the Vermilion River and one of its tributaries (Rooks Creek). Searches for spawning reaches in the Fox, Vermilion, and adjacent rivers are needed. This species is still the rarest of the six species of *Moxostoma* recorded from the state and is considered endangered in Illinois. It is a candidate for listing (i.e., a C2 species) as a federally endangered species by the U.S. Fish & Wildlife Service.

Spring Cavefish

Forbesichthys agassizi

SIUC 24816 (1, 40 mm), Cypress Creek (Cache R. Dr.), 2 mi. N Perks (T13S, R1E, Sec. 35), Pulaski Co., 13 April 1995.

Remarks: Smith (1979) reported this species (as *Chologaster agassizi*) from springs in the Clear Creek drainage and from springs and spring outlets in Hardin and Johnson counties (Big and Bay Creek drainages). Our record is the first from the Cache River drainage and fills a distributional gap between the populations known from southeastern and southwestern Illinois across the Shawnee Hills. Prior to population studies conducted in southern Illinois (Smith and Welch 1978), *Forbesichthys agassizi* was considered endangered (Lopinot and Smith 1973). A clearer understanding of its population size, mostly subterranean existence, and predilection for isolation in caves, springs, spring outlets, and swamp margins resulted in its removal from consideration as endangered or threatened in Illinois. Research presently underway on caves, springs, and groundwater pollution in Illinois waters (e.g., Webb et al. 1993) will allow for a more informed decision regarding future status of and threats to this unusual species.

Bantam Sunfish

Lepomis symmetricus

SIUC 25847 (1, 27.1 mm), Running Lake Ditch, 0.5 mi. W Ware (T12S, R3W, Sec. 26), Union Co., 30 March 1996; SIUC 22661 (2, 32.1 - 43.0 mm), pool (Clear Cr. Dr.), at culvert on Tamms Rd., 1.5 mi. E McClure (T14S, R3W, Sec. 11NW), Alexander Co., 11 November 1993; SIUC 22678 (4, 28.5 - 55.1 mm), Clear Creek (Mississippi R. Dr.), 2.0 mi. SE Reynoldsville (T13S, R2W, Sec. 30SE), Union Co., 4 September 1993; SIUC 22582 (1, 23.5 mm), Clear Creek (Mississippi R. Dr.), 2.25 mi. ENE of McClure (T14S, R3W, Sec. 1SW), Alexander Co., 23 October 1993; SIUC 22601 (1, 42.5 mm), Clear Creek (Mississippi R. Dr.), 3.25 mi. NE Gale (T14S, R3W, Sec. 22NE), Alexander Co., 11 November 1993; SIUC 22697 (1, 25.5 mm), backwaters (Mississippi R. Dr.), near mouth of Clear Creek (T14S, R3W, Sec. 33), Alexander Co., 11 November 1993; SIUC 24402 (1, 19.9 mm), Lake Creek (Cache R. Dr.) at first bridge below spillway of Horseshoe Lake (T16S, R2W, Sec. 22), Alexander Co., 29 June 1995; SIUC 26054 (3, 49.3 - 52.1 mm), flooded ditches east of picnic area, adjacent Horseshoe Lake spillway (T16S, R2W, Sec. 22), Alexander Co., 15 May 1996; SIUC 24798 (3, 20.8 - 51.5 mm), Buttonland Swamp (Cache R. Dr.), 1.5 mi SE Perks (T14S, R1E, Sec. 13), Pulaski Co., 21 July 1995; SIUC 24809 (4, 27.0 - 49.0 mm), Limekiln Slough (Cache R. Dr.), 4.0 mi. E Ullin (T14S, R1E, Sec. 21), Pulaski Co., 29 July 1995.

Remarks: Smith (1979) considered the range of *Lepomis symmetricus* to be limited in Illinois to the LaRue Pine Hills - Wolf Lake region of Union County. The species reaches its greatest abundance in Illinois in swamps. Burr et al. (1988) provided records that extended the Illinois range of this species south through the Clear Creek drainage to Horseshoe Lake, Alexander County. Records reported here demonstrate a nearly continuous occurrence of *L. symmetricus* in the Clear Creek drainage, including three records from the mainstem. The flood of 1993 presumably contributed to the spread of this species and to its occurrence in atypical mainstem stream habitats (Cook 1994). The surprising recent records are from the Cache River drainage in Buttonland Swamp and Limekiln Slough where previous collections (e.g., Smith 1979, Phillippi et al. 1986, Warren and Burr 1989, Muir et al. 1995) made in suitable habitat failed to produce the species. At least two age classes are represented in the Cache River samples indicating successful reproduction has occurred in the drainage. This species is considered threatened in Illinois.

Western Sand Darter

Ammocrypta clara

SIUC 22884 (1, 43.5 mm), Mississippi River (Gulf of Mexico Dr.), RM 234 at Martins Landing (T13S, R2W, Sec. 21SE), Calhoun Co., 19 May 1988; SIUC 22808 (1, 32.5 mm), Mississippi River (Gulf of Mexico Dr.), RM 125 at Little Rock Ferry, Randolph Co., 1 September 1989. SIUC 24085 (4, 49.0 - 50.5 mm), Mississippi River (Gulf of Mexico Dr.), RM 223, Pool 26, at Royal Landing (T13S, R1W, Sec. 22NW), Calhoun Co., 4 August 1994; SIUC 24951 (1, 27.7 mm), Mississippi River (Gulf of Mexico Dr.), RM 183.2 at Merchants RR bridge (T3N, R12W, Sec. 26), Madison Co., 16 September 1994.

Remarks: Smith (1979) reported *Ammocrypta clara* from the Mississippi River above the mouth of the Missouri River and from the Kaskaskia and Sugar rivers in inland Illinois. Dimmick (1988) reported the first records in Illinois of this species from the Mississippi River below the mouth of the Missouri River. Tucker and Cronin (1996) noted a new locality in the Mississippi River at Hat Island, Calhoun County, with all specimens taken over sand in swift water. Our records document a somewhat more continuous range of this species in the Mississippi River on the Illinois side in Randolph, Madison, and Calhoun counties. Numerous collecting trips to the large sand bar on the Mississippi River at Grand Tower where Dimmick (1988) captured specimens in 1985 and 1987 have not resulted in additional records. A small, highly localized population exists in the Kankakee River. A single juvenile was collected near Custer Park in 1988, a single subadult was collected downstream of Wilmington in 1990, and three adults were collected downstream of Wilmington in 1992 (Seegert 1992). This species is very rare in Illinois and is not easily sampled unless abundant clean sand habitat in swift water is available and fine mesh nets are used. The lack of suitable habitat in the Mississippi River and elsewhere in Illinois is certainly a factor in this species' rarity as well as the degradation of former habitat in the Kaskaskia River. *Ammocrypta clara* is considered endangered in Illinois. Although our few records and those of Tucker and Cronin (1996) document a wider range for this species than formerly known, it warrants endangered status because of largescale habitat loss.

Harlequin Darter
Etheostoma histrio
SIUC 24444 (1, 27.8 mm), Wabash River (Ohio R. Dr.), 1.0 mi. NW of Mount Carmel (T1S, R12W, Sec. 16NE), Wabash Co., 29 July 1995; SIUC 24861 (1, 59 mm), Wabash River (Ohio R. Dr.), at downstream end of Mink Island, 5.0 mi. NE Maunie (T5S, R14W, Sec. 27NW), White Co., 30 October 1995.

Remarks: According to Smith (1979) the only extant population of *Etheostoma histrio* occurred in a 20-mile reach of the Embarras River in Cumberland and Jasper counties, and represents the northernmost known occurrence of the species. Recent records (post-1984) of *E. histrio* from the Embarras River are lacking. There is general concern that the Embarras River population may be at very low population levels or extinct, in part because the dam on the Embarras River below Charleston breached in 1985 releasing an excessive silt load downstream (P. A. Ceas, pers. comm.). Smith (1979) also suggested that an unvouchered record of *Etheostoma zonale* reported from the Wabash River, White County, by Forbes and Richardson (1908) in actuality represented *E. histrio*. Our records are the first known occurrences of *E. histrio* on the Illinois side of the Wabash River in nearly a century, and confirm the existence of this species in Illinois outside of the Embarras River population. One record is very near the presumed Forbes and Richardson locality, and the other is about 60 river miles north of it . Our specimens document that adults and young-of-the-year occupy parts of the lower Wabash River, but may not represent a viable population. The chronology of this species in the lower Wabash River is remarkably similar to that in adjacent Indiana. In Indiana, over 100 years elapsed between the time when Jordan (1890) collected *E. histrio* and when it was next collected in the state by one of us (GLS). We recommend continued endangered status for this species.

DISCUSSION

During the approximately 150 years since Europeans actively colonized Illinois, changes in the fish fauna have been profound. For example, since the late 1970s over 20 nonnative fishes have been reported in Illinois, a number of which are now reproducing in State waters (Burr et al. 1996). Of the 187 native species, a few have expanded their ranges and are now more abundant and more generally distributed than formerly, but many more have been decimated to some degree by the widespread modification of habitats and deterioration of water quality. Prior to the passage of the federal Endangered Species Act in 1973, attempts had been made (e.g., Lopinot and Smith 1973) to list species as rare or endangered on the basis of their natural rarity, restricted distribution, and paucity of habitat as well as on the basis of immediate or potential threats to their existence within Illinois (Smith 1979). After implementation of the act, terminology was revised to include the categories endangered and threatened. Because the Longjaw Cisco, *Coregonus alpenae* (see Table 1), is no longer considered a valid species (Smith and Todd 1984) and was never officially reported from the Illinois waters of Lake Michigan, only one Illinois species (Pallid Sturgeon [*Scaphirhynchus albus*)] qualifies as federally endangered (actively threatened with extinction) throughout all or a significant portion of its range.

The Illinois Endangered Species Act of 1972 (amended in 1977) provides for some protection of rare fishes. Lists and accounts (Lopinot and Smith 1973, Smith and Page 1981, IESPB 1989, 1990, 1994, Herkert 1992, 1994) of rare, endangered, or threatened species have continued to be revised and updated (Table 1); however, potential threats to jeopardized fishes are always present, and the status of each species is constantly subject to change. A change in status can occur quickly, particularly in a peripheral or relict population or when new information on naturally rare species becomes available.

Since 1973, 39 native fishes have been placed on the various lists of rare, threatened, or endangered species for Illinois (Table 1). Some of these (e.g., Alligator Gar, Alabama Shad, Blackfin Cisco [*Coregonus nigripinnis*], Round Whitefish [*Prosopium cylindraceum*], Cypress Minnow, Bigeye Chub, Greater Redhorse) were formerly so poorly known in Illinois that they were presumed extirpated (Smith 1979) or probably so. Records and surveys in the 1980s and 1990s have revealed that the Alabama Shad, Cypress Minnow, Bigeye Chub, and Greater Redhorse are still present in Illinois, although the Alabama Shad and Bigeye Chub are extremely rare and have not been shown to be reproducing in Illinois.

Of the 15 jeopardized species for which additional records are reported here, three (Sturgeon Chub, Blue Sucker, Greater Redhorse) are candidates for listing as federally endangered or threatened by the U.S. Fish and Wildlife Service and are restricted to large rivers. We agree that the Sturgeon Chub and Greater Redhorse warrant state protection as endangered species, and recommend that because of recent evidence of reproduction, the Blue Sucker be considered for state threatened status. One species, Alligator Gar, has not been seen in Illinois since the 1960s, and our photographic record and anecdotal accounts emphasize the rarity and almost certain extirpation from Illinois; except for the vouchered juvenile specimen, there is no evidence that this species ever reproduced in State waters. Seven of the species are state endangered and occupy a variety of stream sizes. One (Bigeye Shiner) is locally abundant in two stream reaches of both southern and central

Illinois, and is demonstrating successful reproduction in a manner that far exceeds the other species placed in the endangered category. Therefore, we recommend the Bigeye Shiner be downgraded to threatened status. The other six species (Cypress Minnow, Bigeye Chub, River Chub, Greater Redhorse, Western Sand Darter, Harlequin Darter) clearly warrant endangered status, some (e.g., Harlequin Darter) being so rare as to have been considered extirpated (Burr 1991) only a few years ago. Two of the species are state threatened, which seems to be the appropriate category, and one additional species, Blacktail Shiner, is recommended for threatened status. One species, Spring Cavefish, with a restricted range, was found for the first time in the middle Cache River drainage, a location between known sites in southwestern and southeastern Illinois. It has not been listed in any jeopardized category since 1973, and perhaps should be considered as sporadic, but locally common in springs and their outflows (Smith and Welch 1978). We note, however, that there is much present concern for water quality in groundwater habitats (Webb et al. 1993) and that localized pollution problems could severely decimate this species. The Alabama Shad, so rare in Illinois that it was presumed extirpated by some researchers, was found at two locations in the Mississippi River. The Alabama Shad presently receives no formal protection in Illinois and should be considered for such in the future.

Recently, Warren and Burr (1994) reviewed the status of imperiled fishes in the United States and noted that imperilment apparently is not confined to particular taxonomic groups, which is an indication of the widespread and pervasive degradation of aquatic habitats that has occurred over the past century. The same pattern appears to hold for Illinois. We reiterate and emphasize the growing call among aquatic resource professionals that Illinois' fishes and the streams they inhabit need: 1) proactive protective efforts in the form of watershed-wide management plans that manage and conserve our finest remaining streams as identified by Page et al. (1992) rather than just individual species; 2) establishment of a statewide network of aquatic preserves; 3) restoration of our degraded hydrologic units; and 4) continued long-term research programs on fish communities aimed at inventories of abundance and distribution, ecosystem recovery, and riparian-riverine interactions (Warren and Burr 1994). Illinois, with its long history of aquatic research, has made great strides in meeting the goals of points 1 and 4, and we urge the need for concern and prompt action in meeting the objectives of points 2 and 3 in the very near future.

ACKNOWLEDGMENTS

Melody Meadows, SIUC Cooperative Fisheries Research Laboratory, brought to our attention the photograph of the Alligator Gar caught by her grandfather, C. E. Nichols. Roy C. Heidinger shared his information on the capture of an Alligator Gar in 1963. IDNR records for the Blue Sucker were provided by Dave Day. K. J. Woodruff, D. Henry, and others assisted in field work.

LITERATURE CITED

Anonymous. 1993. Mississippi flooding could benefit fisheries. Fisheries 18(10):48-49.

Barnickol, P. G. and W. C. Starrett. 1951. Commercial and sport fishes of the Mississippi River. Ill. Nat. Hist. Surv. Bull. 25:267-350.

Bottrell, C. E., R. H. Ingersol, and R. W. Jones. 1964. Notes on the embryology, early development, and behavior of *Hybopsis aestivalis tetranemus* (Gilbert). Trans. Amer. Microsc. Soc. 83:391-399.

Burr, B. M. 1991. The fishes of Illinois: an overview of a dynamic fauna, pp. 417-428 in L. M. Page and M. R. Jeffords (editors). Our Living Heritage: the Biological Resources of Illinois. Bull. Ill. Nat. Hist. Surv. 34.

Burr, B. M. and R. C. Heidinger. 1994. Fish, unionid mussel, crayfish, and shrimp species of Horseshoe Lake and Lake Creek, pp. 7-1--7-40 in R. A. Brandon et al. (principal investigators). Potential effects of increased water levels on flora and fauna at Horseshoe Lake, Alexander County, Illinois. Final Report to Division of Natural Heritage, Illinois Department of Conservation, Springfield.

Burr, B. M. and L. M. Page. 1986. Zoogeography of fishes of the lower Ohio-upper Mississippi basin, pp. 287-324 in C. H. Hocutt and E. O Wiley (editors). The zoogeography of North American freshwater fishes. John Wiley & Sons, Inc., New York.

Burr, B. M., M. L. Warren, Jr., and K. S. Cummings. 1988. New distributional records of Illinois fishes with additions to the known fauna. Trans. Ill. State Acad. Sci. 81:163-170.

Burr, B. M., D. J. Eisenhour, K. M. Cook, C. A. Taylor, G. L. Seegert, R. W. Sauer, and E. R. Atwood. 1996. Nonnative fishes in Illinois waters: what do the records reveal? Trans. Ill. State Acad. Sci. 89:73-91.

Coker, R. E. 1930. Studies of common fishes of the Mississippi River at Keokuk. U.S. Department of Commerce. Bureau of Fisheries Document 1072:141-225.

Cook, K. M. 1994. Fishes of the Clear Creek drainage, Illinois: faunal composition, biotic integrity, and historical overview. Unpublished M. S. Thesis, Southern Illinois University, Carbondale. 179 pp.

Cook, K. M., D. J. Eisenhour, and B. M. Burr. 1995. Status of the cypress minnow (*Hybognathus hayi*) at the Cache River historical site Illinois Route 37 bridge, Johnson/Pulaski Co., Illinois. Final Report to Illinois Department of Natural Resources, Springfield. 7 pp.

Dimmick, W. W. 1988. Discovery of the western sand darter, *Ammocrypta clara*, in the Mississippi River below the confluence of the Missouri River. Trans. Ill. State Acad. Sci. 81:211-212.

EA Engineering, Science, and Technology, Inc. 1994. Status of *Notropis nubilus*, *Hybognathus hankinsoni*, *Rhinichthys cataractae*, and *Campostoma oligolepis* in Illinois. Final Report to Illinois Endangered Species Protection Board, Springfield, Illinois. [6 unnumbered pp.]

Elstad, S. A. and S. J. Werdon. 1993. Status report on blue sucker (*Cycleptus elongatus*), a candidate endangered or threatened species. Draft Report, U. S. Fish and Wildlife Service, Ecological Services, North Dakota State Office, Bismark. 55 pp.

Forbes, S. A. and R. E. Richardson. [1908]. The fishes of Illinois. Illinois State Laboratory of Natural History. cxxxi + 357 pp. plus separate atlas of 103 maps.

Herkert, J. R. 1992. Endangered and threatened species of Illinois: status and distribution, Volume 2: Animals. Illinois Endangered Species Protection Board, Springfield. 142 pp.

Herkert, J. R. (editor). 1994. Endangered and threatened species of Illinois: status and distribution, Volume 3: 1994 changes to the Illinois list of endangered and threatened species. Illinois Endangered Species Protection Board, Springfield. 33 pp.

IESPB, Illinois Endangered Species Protection Board. 1989. Checklist of endangered and threatened animals and plants of Illinois. Endangered Species Protection Board, Springfield, Illinois. 24 pp.

IESPB, Illinois Endangered Species Protection Board. 1990. Checklist of endangered and threatened animals and plants of Illinois. Endangered Species Protection Board, Springfield, Illinois. 26 pp.

IESPB, Illinois Endangered Species Protection Board. 1994. Checklist of endangered and threatened animals and plants of Illinois. Endangered Species Protection Board, Springfield, Illinois. 20 pp.

Jordan, D. S. 1890. Report of explorations made during the summer and autumn of 1888, in the Allegheny region of Virginia, North Carolina, and Tennessee, and in western Indiana, with an account of the fishes found in each of the river basins of those regions. Bull. U.S. Fish Comm. 8:97-173.

Klutho, M. A. 1983. Seasonal, daily, and spatial variation of shoreline fishes in the Mississippi River at Grand Tower, Illinois. Unpubl. M. A. Thesis, Southern Illinois University, Carbondale. 84 pp.

Lopinot, A. C. and P. W. Smith. 1973. Rare and endangered fish of Illinois. Illinois Department of Conservation, Division of Fisheries, Springfield. 53 pp.

Moss, R. E., J. W. Scanlan, and C. S. Anderson. 1983. Observations on the natural history of the blue sucker (*Cycleptus elongatus* Le Sueur) in the Neosho River. Amer. Midl. Nat. 109:15-22.

Muir, D. B., R. L. Hite, M. M. King, M. R. Matson. 1995. An intensive survey of the Cache River basin. Illinois Environmental Protection Agency, Bureau of Water, Springfield, IEPA/WPC/95-013. 126 pp.

Page, L. M. and B. M. Burr. 1991. A field guide to freshwater fishes of North America north of Mexico. Houghton Mifflin Co., Boston. 432 pp.

Page, L. M., K. S. Cummings, C. A. Mayer, S. L. Post, and M. E. Retzer. 1992. Biologically significant Illinois streams. An evaluation of the streams of Illinois based on aquatic biodiversity. Illinois Natural History Survey, Center for Biodiversity Technical Report 1992(1):1-485. Final Report to Illinois Department of Conservation and Illinois Department of Energy and Natural Resources, Springfield.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Department of Conservation, Jefferson City. 343 pp.

Phillippi, M. A., B. M. Burr, and R. A. Brandon. 1986. A preliminary survey of the aquatic fauna of the Cache River in Johnson and Pulaski counties, Illinois. Final Report to Illinois Department of Conservation, Division of Natural Heritage, Springfield. 414 pp.

Robins, C. R., R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea, and W. B. Scott. 1991. Common and scientific names of fishes from the United States and Canada. American Fisheries Society Special Publication 20. American Fisheries Society, Bethesda, Maryland. 183 pp.

Rupprecht, R. J. and L. A. Jahn. 1980. Biological notes on blue suckers in the Mississippi River. Trans. Amer. Fish. Soc. 109:323-326.

Seegert, G. 1986. Rediscovery of the greater redhorse (*Moxostoma valenciennesi* Jordan) (Cypriniformes: Catostomidae) in Illinois. Trans. Ill. State Acad. Sci. 79:293-294.

Seegert, G. 1991. A survey of the greater redhorse in the Vermilion River. Final Report to Illinois Department of Conservation, Springfield. 5 pp.

Seegert, G. 1992. Status survey of the western sand darter (*Ammocrypta clara*) in the Kankakee River. Final Report to Illinois Department of Conservation, Springfield. 4 pp.

Smith, G. R. and T. N. Todd. 1984. Evolution of species flocks of fishes in north temperate lakes, pp. 45-68 in A. A. Echelle and I. Kornfield (editors). Evolution of fish species flocks. University of Maine at Orono Press, Orono.

Smith, P. W. 1979. The fishes of Illinois. University of Illinois Press, Urbana. 314 pp.

Smith, P. W. and L. M. Page. 1981. Endangered and threatened fishes, pp. 5-20 in M. L. Bowles (coordinating editor). Endangered and threatened vertebrate animals and vascular plants of Illinois. Illinois Department of Conservation, Springfield.

Smith, P. W. and N. M. Welch. 1978. A summary of the life history and distribution of the spring cavefish, *Chologaster agassizi* Putnam, with population estimates for the species in southern Illinois. Ill. Nat. Hist. Surv. Biol. Notes 104:1-8.

Taylor, C. A., B. M. Burr, and K. M. Cook. 1994. Status and distribution of three rare Illinois fishes: blacktail shiner (*Cyprinella venusta*), northern starhead topminnow (*Fundulus dispar*), and cypress darter (*Etheostoma proeliare*). Trans. Ill. State Acad. Sci. 87:71-82.

Tucker, J. K. and F. A. Cronin. 1996. The western sand darter (*Ammocrypta clara*) in Pool 26 of the Mississippi River in Missouri and Illinois. Trans. Ill. State Acad. Sci. in press.

Warren, M. L., Jr. 1992. Variation of the spotted sunfish, *Lepomis punctatus* complex (Centrarchidae): meristics, morphometrics, pigmentation and species limits. Bull. Ala. Mus. Nat. Hist. 12:1-47.

Warren, M. L., Jr. and B. M. Burr. 1988. Reassessment of the Illinois ranges of the bigeye chub, *Hybopsis amblops*, and the pallid shiner, *Notropis amnis*. Ohio J. Sci. 88:181-183.

Warren, M. L., Jr. and B. M. Burr. 1989. Distribution, abundance, and status of the cypress minnow, *Hybognathus hayi*, an endangered Illinois species. Natural Areas J. 9:163-168.

Warren, M. L., Jr. and B. M. Burr. 1994. Status of freshwater fishes of the United States: overview of an imperiled fauna. Fisheries 19:6-18.

Webb, D. W., S. J. Taylor, and J. K. Krejca. 1993. The biological resources of Illinois caves and other subterranean environments. Illinois Natural History Survey, Center for Biodiversity Technical Report 1993(8):1-157. Final Report to The Environmental Protection Trust Fund Commission and Illinois Department of Energy and Natural Resources, Springfield.

Werdon, S. J. 1993. Status report on sturgeon chub (*Macrhybopsis gelida*), a candidate endangered or threatened species. Draft Report, U. S. Fish and Wildlife Service, Fish and Wildlife Enhancement, North Dakota State Office, Bismark. 60 pp.

Yoder, C. O. and R. A. Beaumier. 1986. The occurrence and distribution of river redhorse, *Moxostoma carinatum* and greater redhorse, *Moxostoma valenciennesi* in the Sandusky River, Ohio. Ohio J. Sci. 86:18-21.

Table 1. History of Rare (R), Endangered (E), Threatened (T), and Extirpated (Ex) fish species in Illinois according to various authorities. Common names follow Page and Burr (1991) and Warren (1992).

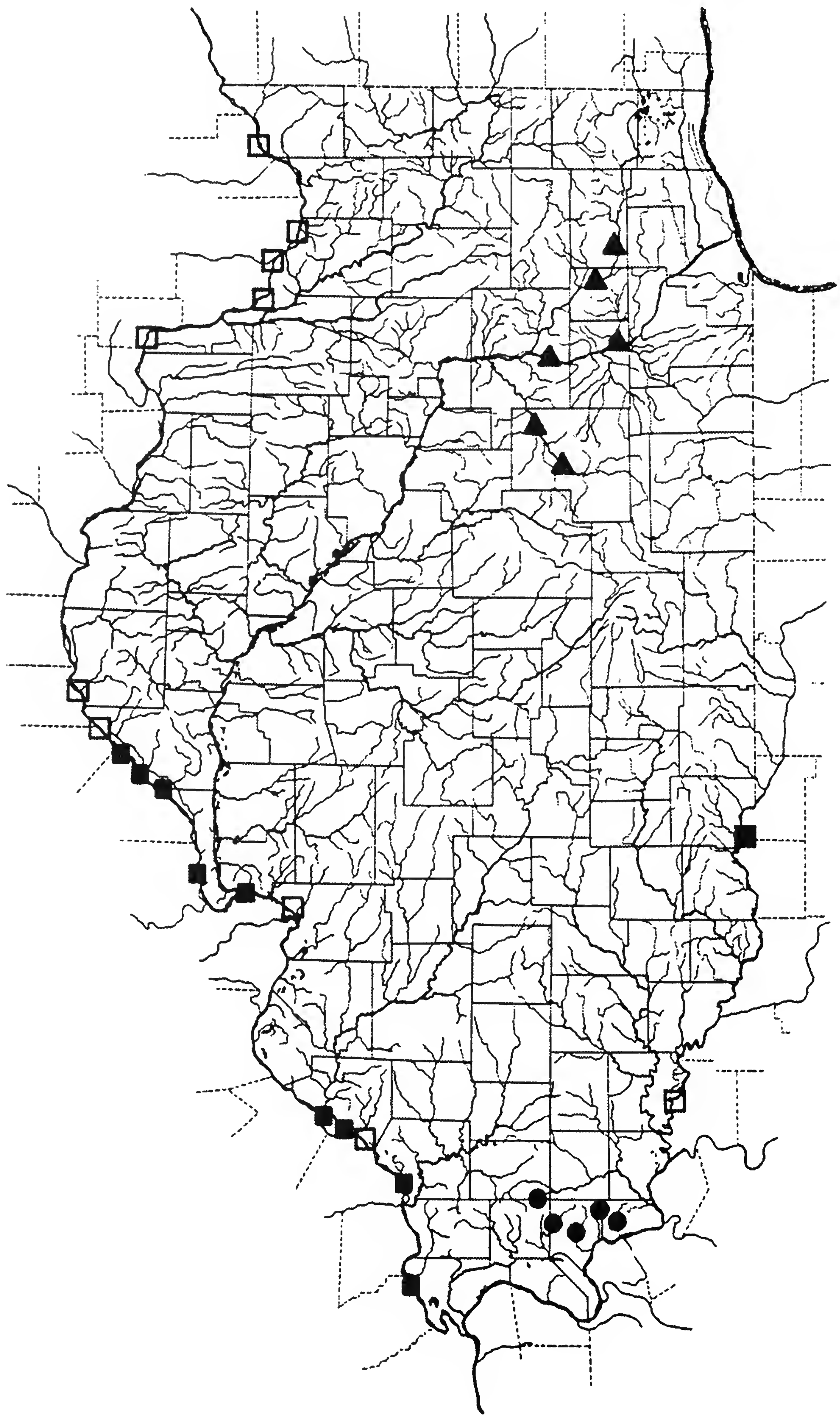
		Lopinot & Smith (1973)[1]	Smith & Page (1981)	IESPB (1989)	IESPB (1990)	IESPB (1994)
1.	Northern Brook Lamprey	-	-	E	E	E
2.	Least Brook Lamprey	-	-	T	T	T
3.	Pallid Sturgeon	R	-	-	-	E
4.	Lake Sturgeon	R	T	T	T	E
5.	Alligator Gar	R	T	T	T	Ex[2]
6.	Alabama Shad	R	-	-	-	-
7.	Longjaw Cisco	-	E	Ex[3]	Ex[3]	Ex[3]
8.	Cisco	R	T	T	T	T
9.	Lake Whitefish	Ex	T	T	T	-
10.	Blackfin Cisco	Ex	-	-	-	-
11.	Round Whitefish	Ex	-	-	-	-
12.	Cypress Minnow	-	-	E	E	E
13.	River Chub	-	-	-	-	E
14.	Bigeye Chub	Ex	E	E	E	E
15.	Sturgeon Chub	R	-	-	-	E
16.	Sicklefin Chub	R	-	-	-	-
17.	Pallid Shiner	E	-	E	E	E
18.	Pugnose Shiner	R	T	E	E	E
19.	Bigeye Shiner	R	-	T	T	E
20.	Ironcolor Shiner	-	-	T	T	T
21.	Blackchin Shiner	R	-	T	T	T
22.	Blacknose Shiner	R	T	T	T	E
23.	Bluehead Shiner	-	E	E	E	E
24.	Taillight Shiner	-	-	-	-	E
25.	Weed Shiner	-	-	E	E	E
26.	Longnose Sucker	-	T	T	T	T
27.	River Redhorse	R	-	T	T	T
28.	Greater Redhorse	-	-	E	E	E
29.	Northern Madtom	R	-	E	E	E
30.	Spring Cavefish	E	-	-	-	-
31.	Banded Killifish	R	-	T	T	T
32.	Banded Pygmy Sunfish	R	-	-	-	-
33.	Redspotted Sunfish	-	-	T	T	T
34.	Bantam Sunfish	E	T	T	T	T
35.	Western Sand Darter	R	-	E	E	E
36.	Eastern Sand Darter	-	-	E	E	E
37.	Bluebreast Darter	E	E	E	E	E
38.	Harlequin Darter	R	E	E	E	E
39.	Iowa Darter	-	-	T	T	E

[1] The definition of "endangered" as used in Lopinot and Smith (1973) is not equivalent to that used by the U.S. Fish and Wildlife Service

[2] Presumed extirpated by Illinois Endangered Species Technical Advisory Committee on Fishes and deleted from IESPB listings

[3] Presumed extinct throughout range; taxonomic validity in question

Figure 1. Record stations in Illinois (1985-1995) based on vouchered specimens of: *Lampetra aepyptera* (●); post-larval and young-of-the-year *Cycleptus elongatus* (■); and *Moxostoma valenciennesi* (▲). We have included the record from Seegert (1986) for *M. valenciennesi*. Open squares (□) are unvouchered IDNR reports (1972-1992) of young-of-the-year/juvenile *C. elongatus* from the Mississippi and Wabash rivers.



Transactions of the Illinois State Academy of Science
(1996), Volume 89, 3 and 4, pp. 187-196

Summer Distribution of the Federally Endangered Indiana Bat (*Myotis sodalis*) in Illinois

James E. Gardner, Joyce E. Hofmann, and James D. Garner*
Illinois Natural History Survey
Champaign, IL 61820
and
*Illinois Department of Natural Resources
Springfield, IL 62701

Present address of JEG: Missouri Highway and Transportation Department
Jefferson City, MO 65102

ABSTRACT

During the summers of 1985 through 1994, mist netting was conducted at 191 sites in 71 Illinois counties to determine the summer distribution of the federally endangered Indiana bat (*Myotis sodalis*). A total of 115 Indiana bats was captured at 35 sites in 21 counties in the southern three-fourths of Illinois. Adult male Indiana bats were also found to be using two caves and one mine during the summer. Because one cave was located in an additional county, summer records were obtained for 22 counties. Captures of reproductively active females or juveniles at 24 sites in 16 counties indicated that maternity colonies of this species occur throughout its range in Illinois. Recaptures of banded individuals in the same area during different summers demonstrated that Indiana bats displayed loyalty to their summer ranges.

INTRODUCTION

The federally endangered Indiana bat (*Myotis sodalis*) is a migratory species that congregates in caves and abandoned mines during the winter, but is more widely dispersed during the summer (Barbour and Davis 1969). The majority of this species hibernates in a few caves and one mine in Missouri, southern Indiana, and Kentucky (Brady et al. 1983). During the summer, the Indiana bat has a fairly extensive range in the midwestern and eastern United States -- from Arkansas north to Iowa and southern Michigan, through the Appalachian region to Vermont, and south to North Carolina and Tennessee (Barbour and Davis 1969, Thomson 1982). Until recently, relatively little was known about the actual summer distribution or habitat requirements of this species (Barbour and Davis 1969, Thomson 1982). Barbour and Davis (1969) felt that information was limited because Indiana bats roosted singly or in small groups in hollow trees or underneath loose bark during the summer. The first maternity colony (reproductively active females and their young) of Indiana bats to be studied was not discovered until 1971 when its roost tree in Indiana was bulldozed (Cope et al. 1973).

In Illinois, many of the early records (prior to 1970) of Indiana bats were specimens collected during hibernation from caves in southern (Union and Hardin counties) and western (Pike and Madison counties) portions of the state, an abandoned lead mine in Jo Daviess County, and Blackball Mine, an abandoned limestone mine in La Salle County (Miller and Allen 1928, Smith and Parmalee 1954, Layne 1958, Hall 1960, Hoffmeister 1989). Spring or autumn records of migrating individuals exist for Adams, Christian, Cook, Franklin, Jackson, Madison, McDonough, Morgan, and Sangamon counties (Clark and Clark 1987; Hoffmeister 1989; Illinois Natural History Survey, unpublished data). Prior to 1985 there were summer records of reproductively active female or juvenile Indiana bats only for Jackson (Gardner and Taft 1984), Perry (Kirkpatrick 1980), Pike (Gardner and Gardner 1980; Gardner and Taft 1984; Clark and Clark 1987), Union (Brack 1979), and the border of Wabash and Edwards counties (Kessler and Turner 1980). In addition, three male Indiana bats had been collected in Blackball Mine in La Salle County in May (Hoffmeister 1989) and an adult male and adult female (reproductive condition unknown) from Adams County were examined by the Illinois Department of Public Health during summer months (Illinois Natural History Survey, unpublished data).

A cooperative research project of the Illinois Natural History Survey, Illinois Department of Conservation (now Natural Resources), Illinois Department of Transportation, and Shawnee National Forest (U.S. Forest Service) was initiated in 1985 to study the statewide distribution and summer habitat requirements of the Indiana bat. This paper presents findings on the summer distribution of this species in Illinois.

METHODS

The primary method used to determine the summer distribution of the Indiana bat was mist netting at surface sites, nearly all of which were along intermittent and perennial streams and small rivers. Netting sites were established at locations where overhanging branches of riparian trees formed a canopy above the stream channel; such a situation creates a tunnel through which bats can fly to drink or feed on aquatic insects.

Bats were captured in black, 38-mm mesh, monofilament mist nets; these nets range from 5.5 to 18.5 m in length and can be spread to a height of 2.2 m. A pair of metal poles either 6.1 or 9.2 m high was positioned under overhanging tree branches on opposite sides of the stream (or river) channel. Nets of equal length were stacked vertically and suspended above the stream between rope and pulley systems attached to both poles. With this system it was possible to raise the top of the uppermost net to the canopy and block most of the flyway above the stream. An additional mist net was frequently spread across the channel just above water level to catch low-flying bats. A complete description of the netting system can be found in Gardner et al. (1989).

Mist netting was conducted primarily between 1 May and 30 August on nights when environmental conditions were favorable (i.e., no precipitation or strong winds, limited moonlight, and temperatures above 9°C). Nets were raised at dusk and checked at 10- to 15-minute intervals until 2400 h or later. Bats were removed from the net and examined to determine species, sex, age (juvenile or adult), and reproductive condition. Age class was determined by the degree of closure of the phalangeal epiphyses; juveniles (i.e., less than one year old) are recognizable by the incomplete ossification of the epiphyses (Barbour and Davis 1969). The reproductive condition of males was assessed by the size of the epididymides; sexually mature males have enlarged or distended epididymides which can be seen through the interfemoral membrane (Racey 1988). Pregnant females were recognized by gently palpating the fetus through the abdomen, and lactating and post-lactating females by examination of the teats. Weights were determined to the nearest 0.1 g by suspending the bats from a Pesola scale. One size XCL consecutively-numbered, color-coded, plastic split-ring bird band (A.C. Hughes, England) was placed on a forearm of each Indiana bat for individual identification. Bats were released at the capture site after examination.

More than two dozen caves and mines were visited during the summer to determine if they were used by roosting Indiana bats. Bats were also captured at some cave entrances using a portable harp trap similar to one described by Tidemann and Woodside (1978). The trap consists of an aluminum frame that has a double rank of monofilament lines strung vertically under tension; a large canvas bag is suspended below the frame to catch bats that hit the lines. After the trap had been placed in a cave's entrance, coarse nylon netting was used to cover the remainder of the entrance and direct emerging bats into the trap. The trap was checked periodically from dusk until bats were no longer emerging.

RESULTS AND DISCUSSION

From May through August during the years 1985 through 1994, 299 nights of mist netting were conducted at 191 surface sites in 71 Illinois counties (Figure 1, Appendix). A total of 1856 bats was captured at these locations, 115 (6.2%) of which were Indiana bats. This greatly increased the number of summer records for this species in Illinois. Indiana bats were caught at 35 surface sites in 21 counties (Figure 2, Table 1). Adult male Indiana bats were also found to be using two caves and one mine in three counties during the summer (Figure 2). Seven adult males were trapped at the entrance to Cave Spring Cave in Hardin County during June and July 1985; three males were caught there in June 1986. This cave had been a known hibernation site for Indiana bats (Layne 1958, Hall 1960, Whitaker 1975), but these were the first summer records of the species using the cave. However, this cave may no longer be a suitable roost site because of alterations caused by nearby quarrying activity. A cluster of bats in an Adams County cave examined in June 1987 included 13 adult male Indiana bats as well as 47 little brown bats (*Myotis lucifugus*). Five male Indiana bats were found in this cave in July 1988. Three adult males were caught at the entrance of an abandoned silica mine in Alexander County in June 1991; 750 Indiana bats were observed roosting within the mine at that time.

In all, summer records for the Indiana bat were collected in 22 of the 71 Illinois counties sampled during this study. No previous summer records had existed for 17 of these counties and additional summer records were obtained for Adams, Jackson, Perry, Pike, and Union counties. The only other previous summer localities for this species were Blackball Mine (three males) in La Salle County (Hoffmeister 1989) and Bonpas Creek (lactating female and juvenile female), the boundary between Wabash and Edwards counties (Kessler and Turner 1980). Five nights of mist netting on Bonpas Creek during 1986, 1987, and 1991 yielded no Indiana bats, suggesting that a maternity colony may no longer occur in that area. Prior to 1985, mist netting had been conducted in five additional counties (Bureau, Christian, Clinton, Stephenson, and Warren), but no Indiana bats were captured in any of them (Gardner and Taft 1983, 1984). Thus, 76 of Illinois' 102 counties have been sampled for bats since 1980.

Captures of reproductively active females and/or juveniles at 24 sites during this study indicated the presence of Indiana bat maternity colonies in 16 counties (Figure 2, Table 1). A maternity colony was discovered in an additional county (Cass) by Kurta et al. (1993) in 1992. These records indicate that Indiana bat breeding colonies occur throughout the species' range in the state.

Most of the Indiana bats were captured at sites in west-central and southern portions of the state where mist netting effort was greatest. Despite the fact that mist netting has been conducted in more northerly Illinois counties during this study and previously by Gardner and Taft (1983), no Indiana bats have been caught north of Henderson and Ford counties. Except for the hibernaculum (Blackball Mine) in La Salle County, the only Indiana bat records north of 41°N latitude are for three specimens collected at a mine in Jo Daviess County in December 1953 (Smith and Parmalee 1954) and a migratory individual in Cook County in September 1928 (Hoffmeister 1989). Similarly, the only record for Wisconsin is a specimen collected in an abandoned lead mine in Grant County (adjacent to Jo Daviess County) in November 1954 (Davis and Lidicker 1955). Thus, it appears that the summer range of the Indiana bat does not extend into the northern quarter of Illinois.

In Iowa, reproductively active female and juvenile Indiana bats have been captured only in the southern third of the state, south of 42°N (Clark et al. 1987) and no more than 50 km north of Henderson County, Illinois. Clark et al. (1987) suggested that climatic factors and distance to major hibernacula limit the summer distribution of this species in Iowa. A female captured in Marion County, Iowa, had been banded at Pilot Knob Mine in Missouri, 463 km to the southeast (LaVal and LaVal 1980). East of Illinois, the summer range of Indiana bats extends considerably farther north; maternity colonies occur throughout Indiana (3D/Environmental Services, Inc. 1993) and in lower Michigan, south of 43°N (Kurta 1980). Five Indiana bats captured in Michigan (at five separate locations) had been banded at two caves in Kentucky (Kurta 1980); the greatest linear distance between these southern Michigan locations and the cave at which the individual had been banded is approximately 520 km. Any location in northern Illinois is within 520 km of at least one of the Priority 1 hibernacula in Missouri, southern Indiana, and Kentucky (as designated by the Indiana Bat Recovery Team). This suggests that Indiana bats could occur farther north than Henderson and Ford counties. The Chicago metropolitan region may not provide suitable habitat for Indiana bats, but their absence (or scarcity) elsewhere in northern Illinois is probably a reflection of declining population levels for this species (Clawson 1995).

The recapture of banded individuals at sites during more than one year demonstrated that Indiana bats are loyal to their summer ranges. Repeated mist netting was conducted at a cluster of sites along Fishhook Creek in Pike and Adams counties for an intensive study of Indiana bat summer habitat requirements. Indiana bats were captured in this area every summer from 1985 through 1989 and three individuals banded there were recaptured during subsequent summers. An adult male was caught at two sites approximately 1 km apart during the summers of 1986 and 1987. A pregnant female banded in 1987 was recaptured at a site 250 m away during the same summer and recaptured, again pregnant, at the latter site in the summer of 1988. A female banded as a juvenile in 1986 was caught at a location approximately 900 m from her original capture site two years later. In addition, an adult male banded at Cave Spring Cave (Hardin County) in 1985 was recaptured there in 1986 and another male was found occupying the same cave in Adams County during the summers of 1987 and 1988. Similarly, Cope et al. (1973) and Humphrey et al. (1977) found that a maternity colony occupied the same area along the Noland Fork River in Indiana for five consecutive summers.

ACKNOWLEDGMENTS

Major financial support for this project was provided by the Bureau of Design and Environment, Illinois Department of Transportation. Vital cooperation and additional financial support were provided by the U.S. Fish and Wildlife Service (Region 3), the Indiana/Gray Bat Recovery Team, and the Shawnee National Forest, U.S. Forest Service (especially Mike Spanel). Work at some locations was funded by the Lake County Forest Preserve District; Wetlands Research, Inc.; City Water, Light and Power (Springfield); U.S. Army Corps of Engineers, Rock Island District; and the Freeman Coal Company. Dr. Thomas Griffiths and his students at Illinois Wesleyan University sampled bats in ten counties during 1988. Many individuals assisted with field work. We especially wish to recognize the contributions of Maggie Cole, Raymond Smith, Karen Tyrell, Barbara Ver Steeg, Randall Collins, Bob Lindsay, Jean Krejca, Beccy Porter, Curt Condon, Tap Sangpan, and Shawn Robinson.

LITERATURE CITED

Barbour, R.W. and W.H. Davis. 1969. Bats of America. The University Press of Kentucky, Lexington. 286 pp.

Brack, V., Jr. 1979. Determination of presence and habitat suitability for the Indiana bat (*Myotis sodalis*) and gray bat (*Myotis grisescens*) for portions of three ditches, Big Five Levee and Drainage District, Union and Alexander counties, Illinois. Unpubl. report, St. Louis District, U.S. Army Corps of Engineers. 23 pp.

Brady, J.T., R.K. LaVal, T.H. Kunz, M.D. Tuttle, D.E. Wilson, and R.L. Clawson. 1983. Recovery plan for the Indiana bat. U.S. Fish and Wildlife Service, Washington, D.C. 23 pp.

Clark, B.K. and B.S. Clark. 1987. Distribution notes of bats for west-central Illinois. Trans. Ill. St. Acad. Sci. 80:207-212.

Clark, B.K., J.B. Bowles, and B.S. Clark. 1987. Summer status of the endangered Indiana bat in Iowa. Am. Midl. Nat. 118:32-39.

Clawson, R.L. 1995. Report on the status of Priority 1 Indiana bat hibernacula. Unpubl. report, Indiana Bat Recovery Team. 8 pp.

Cope, J.B., A.R. Richter, and R.S. Mills. 1973. A summer concentration of the Indiana bat, *Myotis sodalis*, in Wayne Co., Indiana. Proc. Indiana Acad. Sci. 58:93-95.

Davis, W.H. and W.Z. Lidicker, Jr. 1955. *Myotis sodalis* in Wisconsin. J. Mamm. 36:567.

Gardner, J.E. and T.L. Gardner. 1980. Determination of presence and habitat suitability for the Indiana bat (*Myotis sodalis*) and gray bat (*Myotis grisescens*) for portions of the lower 6.6 miles of McKee Creek, McGee Creek Drainage and Levee District, Pike County, Illinois. Unpubl. report, St. Louis District, U.S. Army Corps of Engineers. 22 pp.

Gardner, J.E. and J.B. Taft. 1983. Determination of presence and habitat suitability for the Indiana bat (*Myotis sodalis*) and gray bat (*Myotis grisescens*) at nine Illinois Department of Transportation project areas. Unpubl. report, Bureau of Location and Environment, Illinois Department of Transportation, Springfield. 133 pp.

Gardner, J.E. and J.B. Taft. 1984. A limited survey and assessment of the bat fauna occurring in twenty-six selected Illinois Department of Transportation study areas in eight Illinois counties. Unpubl. report, Bureau of Location and Environment, Illinois Department of Transportation, Springfield. 205 pp.

Gardner, J.E., J.D. Garner, and J.E. Hofmann. 1989. A portable mist netting system for capturing bats with emphasis on *Myotis sodalis* (Indiana bat). Bat Research News 30:1-8.

Hall, J.S. 1960. A life history and taxonomic study of the Indiana bat, *Myotis sodalis*. Ph.D. thesis, University of Illinois, Urbana. 129 pp.

Hoffmeister, D.F. 1989. Mammals of Illinois. University of Illinois Press, Urbana and Chicago. 348 pp.

Humphrey, S.R., A.R. Richter, and J.B. Cope. 1977. Summer habitat and ecology of the endangered Indiana bat, *Myotis sodalis*. J. Mammal. 58:334-346.

Kessler, J.S. and W.M. Turner. 1980. Survey for the Indiana bat, *Myotis sodalis*, Bonpas Creek, Illinois. Unpubl. report, Louisville District, U.S. Army Corps of Engineers. 4 pp.

Kirkpatrick, R.D. 1980. Determination and habitat suitability for the Indiana bat (*Myotis sodalis*) and gray bat (*Myotis grisescens*) for a portion of Pipestem Creek, Perry County, Illinois. Unpubl. report, AMAX Coal Co., Indianapolis, IN. 8 pp.

Kurta, A. 1980. Status of the Indiana bat, *Myotis sodalis*, in Michigan. Mich. Acad. 13:31-36.

Kurta, A., J. Kath, E.L. Smith, R. Foster, M.W. Orick, and R. Ross. 1993. A maternity roost of the endangered Indiana bat (*Myotis sodalis*) in an unshaded, hollow sycamore tree (*Platanus occidentalis*). Am. Midl. Nat. 130:405-407.

LaVal, R.K. and M.L. LaVal. 1980. Ecological studies and management of Missouri bats, with emphasis on cave-dwelling species. Terrestrial Series No. 8, Missouri Department of Conservation, Jefferson City. 53 pp.

Layne, J.N. 1958. Notes on mammals of southern Illinois. Am. Midl. Nat. 60:219-254.

Miller, G.S. and G.M. Allen. 1928. The American bats of the genera *Myotis* and *Pizonyx*. U.S. Nat. Mus. Bull. 144:1-218.

Racey, P.A. 1988. Reproductive assessment in bats. Pp. 31-45 *in* T.H. Kunz (ed.) Ecological and behavioral methods for the study of bats. Smithsonian Institution Press, Washington, D.C.

Smith, P.W. and P.W. Parmalee. 1954. Notes on distribution and habits of some bats from Illinois. Trans. Kans. Acad. Sci. 57:200-205.

Thomson, C.E. 1982. *Myotis sodalis*. Mamm. Species 163:1-5.

3D/Environmental Services, Inc. 1993. A model of summer habitat use by the federally endangered Indiana bat (*Myotis sodalis*) in Indiana: compilation of data from 1990-1992 field studies. Unpubl. report, Indiana Department of Natural Resources, Division of Fish and Wildlife, Endangered Species Program.

Tidemann, C.R. and D.P. Woodside. 1978. A collapsible bat-trap and a comparison of results obtained with the trap and with mist-nets. Aust. Wildl. Res. 5:355-362.

Whitaker, J.O., Jr. 1975. Bats of the caves and mines of the Shawnee National Forest of southern Illinois with particular emphasis on *Myotis sodalis*, the Indiana bat. Pp. 25-64 *in* Distributional studies of the Indiana bat (*Myotis sodalis*) on three national forests of the eastern region. Unpubl. report, Eastern Region Forest Service, U.S. Department of Agriculture.

Table 1. Mist netting records for Indiana bats (*Myotis sodalis*) in Illinois, 1985-1994

County	Location	No.	Maternity colony*
Adams	Fishhook Creek (5 sites)	19	X (3 sites)
	Ursa Creek	2	
	Long Island Lake (Mississippi River)	5	X
Alexander	Lake Creek	2	
	Black Creek	2	X
Bond	East Fork Shoal Creek	7	X
Cass	Panther Creek	1	
Ford	Middle Fork Vermilion River	1	X
Henderson	Jinks Hollow Creek	1	X
Jackson	Cedar Creek (2 sites)	6	X (1 site)
Jersey	Piasa Creek	2	X
Johnson	Cache River (Boss Island)	1	X
Lawrence	Brushy Creek	1	
Macoupin	Macoupin Creek	1	X
McDonough	Camp Creek	1	X
Perry	Galum Creek	1	
Pike	Fishhook Creek (4 sites)	39	X (4 sites)
	Beebe Creek (2 sites)	3	X (1 site)
Pope	Big Grand Pierre Creek	1	
Pulaski	Cache River	6	X
Saline	Bankston Fork	2	X
Schuyler	Missouri Creek	4	X
Scott	Sandy Creek	2	X
Union	Clear Creek	1	
Vermilion	Little Vermilion River (2 sites)	4	X (2 sites)

* pregnant, lactating, or post-lactating females and/or juveniles captured at site(s)

APPENDIX

Locations of mist netting sites in Illinois, 1985-1994

SITE	COUNTY
Fishhook Creek (7 sites)	Adams
Ursa Creek	Adams
Long Island Lake (2 sites)	Adams
Black Creek (Horseshoe Lake)	Alexander
Cooper Creek No. 5	Alexander
Lake Creek (3 sites)	Alexander
Sandy Creek	Alexander
East Fork Shoal Creek	Bond
Kingsbury Creek	Bond
Kishwaukee River	Boone
Kishwaukee River Slough	Boone
Carroll Creek	Carroll
Panther Creek (2 sites)	Cass
Sangamon River (2 sites)	Champaign
Lincoln Trail State Park Lake	Clark
Dismal Creek	Clay
Greasy Creek	Coles
Little Embarras River	Coles
Whetstone Creek	Coles
Brushy Creek	Crawford
Hurricane Creek	Cumberland
North Fork Salt Creek	Dewitt
Embarras River (2 sites)	Douglas
Lyman Woods	DuPage
Waterfall Glen	DuPage
West Fork Big Creek	Edgar
Bonpas Creek (2 sites)	Edwards
Bishop Creek	Effingham
Ramsey Creek	Fayette
Middle Fk Vermilion R (2 sites)	Ford
Big Muddy River	Franklin
Rice Lake	Fulton
Eagle Creek (2 sites)	Gallatin
Ohio River tributary	Gallatin
Robinette Creek	Gallatin
West Fork Mazon River	Grundy
Waupecan Creek	Grundy
Big Creek (2 sites)	Hardin
Hogthief Creek	Hardin
Wallace Branch	Hardin
Jink's Hollow Creek	Henderson
Smith Creek	Henderson
Mud Creek	Henry
Mineral Creek	Henry
Iroquois River (2 sites)	Iroquois
Cave Creek	Jackson
Cedar Creek (2 sites)	Jackson
Piles Fork	Jackson
Otter Creek	Jersey
Piasa Creek	Jersey
Apple River	Jo Daviess
Smallpox Creek (2 sites)	Jo Daviess
Yellow Creek	Jo Daviess
East Fork Galena River	Jo Daviess
Furnace Creek	Jo Daviess
Irish Hollow Creek	Jo Daviess
Bay Creek	Johnson
Cache River (Boss Island)	Johnson
Little Black Slough	Johnson
Sugar Creek (4 sites)	Johnson
Davis Creek	Kankakee
Momence Wetlands	Kankakee
Des Plaines River (4 sites)	Lake
Mill Creek/Des Plaines River	Lake
Little Vermilion River	La Salle
Brushy Creek	Lawrence
Franklin Creek	Lee
Rooks Creek (2 sites)	Livingston
Kickapoo Creek	Logan
Sugar Creek	Logan
Joe's Creek	Macoupin
Macoupin Creek	Macoupin
East Fork Wood River	Madison
Slough at Cahokia Creek	Madison
West Fork Wood River	Madison
Dumms Creek	Marion
Skillet Fork	Marion
Crow Creek	Marshall
Sandy Creek	Marshall
Prairie Creek (2 sites)	Mason
Main Ditch	Massac
Massac Creek	Massac
Sevenmile Creek (2 sites)	Massac
Camp Creek	McDonough
Willow Creek	McDonough
Mackinaw River (3 sites)	McLean

(Appendix concluded on next page)

APPENDIX (concluded)

SITE	COUNTY
North Henderson Creek	Mercer
Camp Creek	Mercer
Dry Fork Horse Creek	Monroe
Fountain Creek	Monroe
Rock River tributary	Ogle
Galum Creek	Perry
Sangamon River	Piatt
Beebe Creek (3 sites)	Pike
Fishhook Creek (5 sites)	Pike
Bay Creek	Pope
Big Grand Pierre Creek (3 sites)	Pope
Flat Lick Branch	Pope
Hunting Branch Creek	Pope
Lusk Creek	Pope
Pond (south Millstone Bluff)	Pope
Robnette Creek (2 sites)	Pope
Cache River (3 sites)	Pulaski
Mill Creek	Randolph
Silver Creek (2 sites)	St. Clair
Little Silver Creek	St. Clair
Silver Creek tributary	St. Clair
Bankston Fk (2 sites)	Saline
Rock Branch	Saline
Brush Creek	Sangamon
Horse Creek (3 sites)	Sangamon
Spring Creek	Sangamon
Missouri Creek	Schuyler
Willow Creek	Schuyler
Little Sandy Creek	Scott
Sandy Creek	Scott
Jordon Creek	Shelby
Lake Shelbyville	Shelby
Richland Creek	Shelby
Prairie Creek	Tazewell
Alloway Creek	Tazewell
Clear Creek	Union
Clear Creek Ditch	Union
Line C Ditch	Union
Lingle Creek	Union
Wolf Lake tributary	Union
Little Vermilion River (2 sites)	Vermilion
Middle Fork Vermilion River	Vermilion
Vermilion River	Vermilion
Bonpas Creek (2 sites)	Wabash
Coffee Creek	Wabash

SITE	COUNTY
Greathouse Creek	Wabash
Beaver Creek	White
Deer Creek	Whiteside
Lynn Creek	Whiteside
Forked Creek	Will
Plum Creek	Will
Grant Creek	Will
Prairie Creek	Will
Crab Orchard NWR (2 sites)	Williamson
Sugar Creek	Williamson
Sugar Creek	Williamson
Mackinaw River	Woodford

Figure 1.
Locations of mist netting sites, 1985-1994.

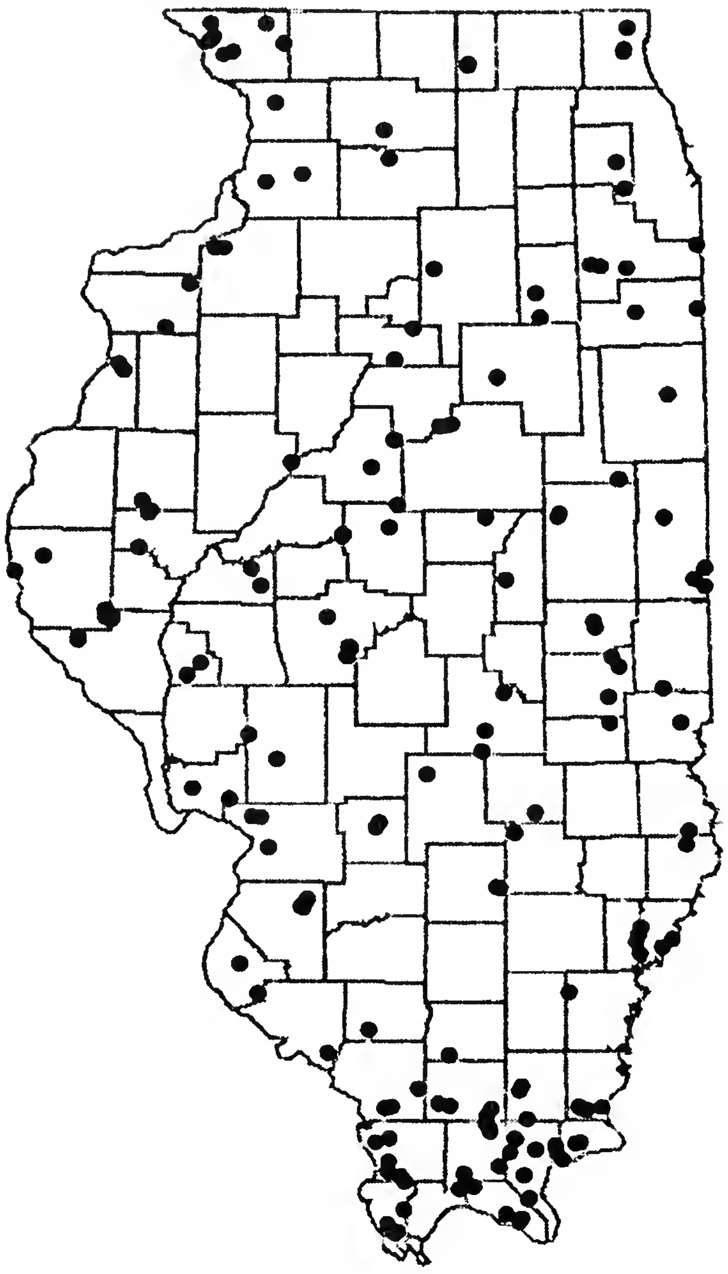
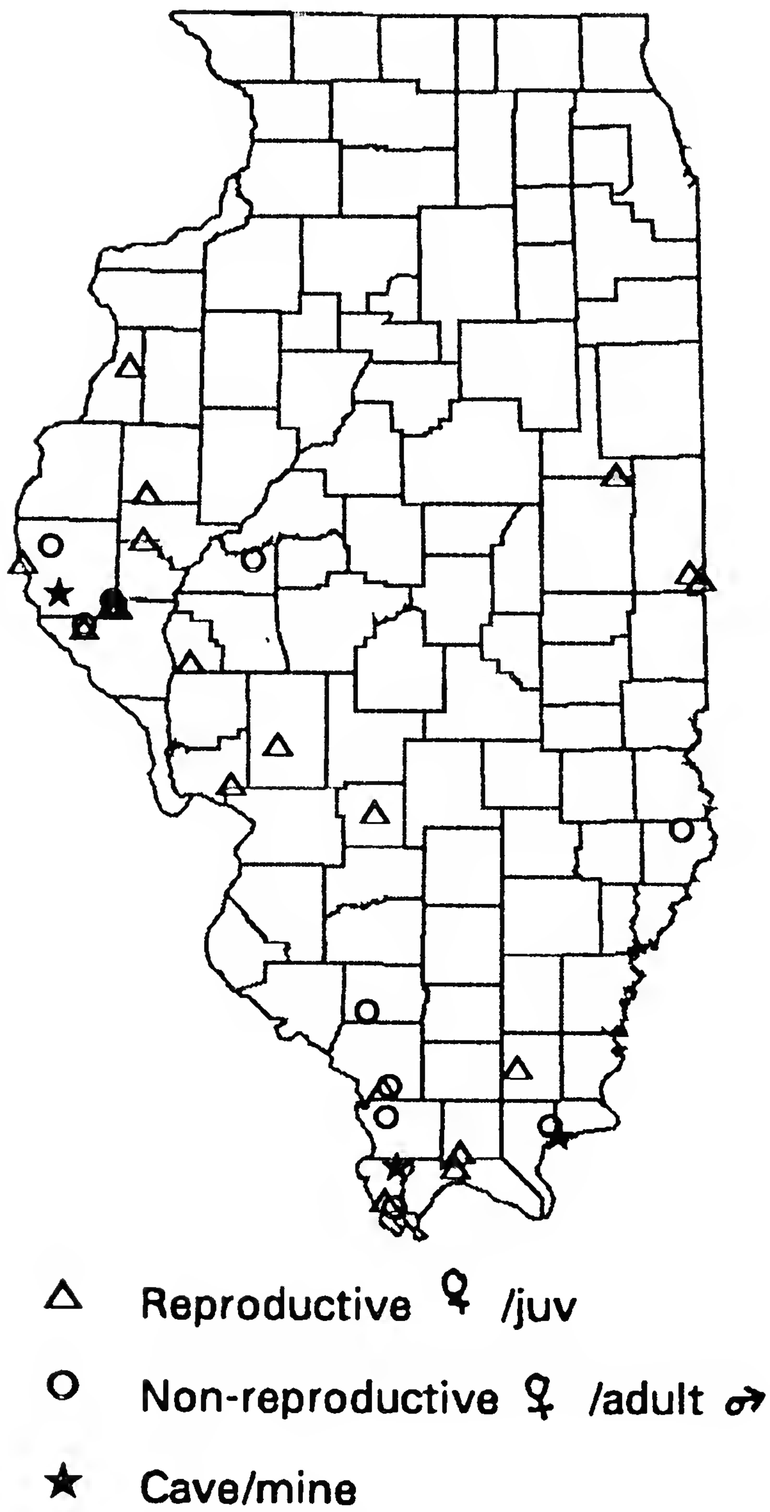


Figure 2.
Summer records of the Indiana bat (*Myotis sodalis*) in Illinois, 1985-1994.



Transactions of the Illinois State Academy of Science
(1996), Volume 89, 3 and 4, pp. 197-213

Fall and Spring Body Weights and Condition Indices of Ducks in Illinois

Christopher S. Hine and Stephen P. Havera
Illinois Department of Natural Resources
Illinois Natural History Survey
Forbes Biological Station
Havana, IL 62644

Richard M. Whitton
Illinois Department of Natural Resources
Union County Refuge
Jonesboro, IL 62952

Jerome R. Serie
U.S. Fish and Wildlife Service
Patuxent Environmental Science Center
12100 Beech Forest Road
Laurel, MD 20708-4038

ABSTRACT

Body weights and condition indices are used in physiological and ecological studies to measure the health of individual birds. Body weights and condition indices for many species of ducks during fall and spring are lacking for mid-migration areas, such as Illinois, and are desirable for examining various aspects of waterfowl biology and management.

We recorded body weights and wing chord measurements of harvested dabbling (*Anas* spp.) and diving ducks (*Aythya* spp.) during fall 1985 and 1989-1991 along the Illinois and Mississippi rivers. Body weights and wing chord measurements were also examined from diving ducks livetrapped during spring 1977 and 1981-1988 on Keokuk Pool (Pool 19) of the Mississippi River.

Comparisons of body weights collected in the Illinois River valley during fall revealed that adult male and immature female mallards (*Anas platyrhynchos*), immature male gadwalls (*A. strepera*), and immature male green-winged teals (*A. crecca*) were heavier ($\underline{P} \leq 0.05$) in 1938-1940 than in 1985 and 1989-1991. Fall body weights (1985, 1989-1991) of males were greater ($\underline{P} < 0.05$) than females for all species examined. Likewise, adults weighed more ($\underline{P} < 0.05$) than immatures except for wood ducks (*Aix sponsa*). Adult males were the heaviest cohort ($\underline{P} < 0.05$) for all species during fall. Differences among fall condition indices (1985, 1989-1991) of males and females varied by species. Condition indices were higher ($\underline{P} < 0.05$) for adults than for immatures in all species except wood ducks. Body weights and condition indices increased ($\underline{P} < 0.05$) with advancing fall

Julian date for adult male mallards in 1989 and most age and sex classes of lesser scaups (*Aythya affinis*) in 1985.

In spring, male diving ducks were heavier ($\underline{P} < 0.05$) and had greater ($\underline{P} < 0.01$) condition indices than females. Adult canvasbacks (*A. valisineria*) were heavier and had higher condition indices ($\underline{P} < 0.001$) than immatures, and adult males were the heaviest ($\underline{P} < 0.001$) cohort among canvasbacks. Also, adult male canvasbacks with large body weights appeared early during spring migration of most years.

INTRODUCTION

Bellrose and Hawkins (1947) first studied body weights of ducks in the Illinois River valley during fall, 1938-1940. Their objectives were to determine the weights of various species and to investigate the contention of hunters that ducks were in poor physical condition. Since then, the wetlands, rivers, and agricultural landscapes of Illinois have undergone many changes. However, there have been no subsequent studies on body weights of ducks during fall in the Illinois River valley and only one study, which examined canvasbacks, in the Mississippi River valley bordering Illinois (Serie and Sharp 1989). Similarly, there are few data on body weights and condition of ducks in the Midwest during spring migration. Besides Whitton (1987), whose data we include, just one study has focused on the body weights of ducks in or near Illinois in spring, and that study involved canvasbacks on Pool 19 of the Mississippi River (Barzen 1989).

In this study, we recorded body weights and condition indices from hunter-harvested ducks during fall, compared their weights with those reported 50 years earlier by Bellrose and Hawkins (1947), and investigated changes in these parameters during migration. In addition, we documented body weights and condition indices of diving ducks livetrapped in spring on Pool 19 of the Mississippi River and investigated changes in these parameters during migration.

METHODS

Canvasbacks, lesser scaups, and ring-necked ducks (*Aythya collaris*) were captured from 2 March through 6 April, 1977 and 1981-1988 in swim-in traps baited with corn. The actual period of capture varied among years and was dependent upon the timing of migration and duration of stay with spring phenology. Trap sites were located on the Illinois side of Pool 19 of the Mississippi River from the lock and dam at Hamilton north to Niota. Age determination of lesser scaups and ring-necked ducks by wing plumage in spring is unreliable (Carney 1964); therefore, samples of lesser scaups and ring-necked ducks in spring were pooled for each sex. Body weight was measured with a spring-loaded Homs Model 4 scale ($\pm$10 g). Wing chord length ($\pm$1 mm) was determined as described by Carney (1964).

Hunter-harvested lesser scaups and ring-necked ducks (canvasbacks were protected) were also obtained from this same stretch of Pool 19 in the fall of 1985. The ages of canvasbacks, lesser scaups, and ring-necked ducks in fall were determined by wing plumage (Serie et al. 1982). During fall 1989-1991, samples of hunter-harvested ducks were examined at public hunting areas and commercial waterfowl picking operations throughout the

Illinois River valley. The hunting seasons for 1985 and 1989-1991 occurred for 30 to 40 days ranging between 24 October and 3 December. Harvested ducks were aged by wing plumage (Carney 1964, Serie et al. 1982), by tail feather characteristics (Larson and Taber 1980), and by cloacal examination (Larson and Taber 1980). Body weights of harvested ducks were measured with the Homs Model 4 scale in 1985 and with an Ohaus Port-O-Gram electronic balance Model C3001 ($\pm$1 g) in 1989-1991. Condition indices (body weight [g]/wing chord [mm]) were calculated for both live-trapped and hunter-harvested ducks (Ringelman and Szymczak 1985).

Differences in body weight and condition indices were assessed between age classes, sex classes, and age and sex classes for all species with sufficient sample sizes ($n \geq 5$). Two sample t-tests were used to compare body weights between age and sex classes of ducks (i.e., adult male, immature female) collected in 1938-1940 and those collected in 1989-1991. Two-way analysis of variance (ANOVA) was used to test for differences in body weight and condition indices between sex classes, age classes, and sex/age interaction using PROC GLM and type III sums of squares of the Statistical Analysis System (SAS) (SAS Inst. Inc. 1988a). Tukey/Kramer post hoc multiple comparison tests were employed to detect differences in body weights and condition indices among age and sex classes. Pearson product-moment correlations were utilized to detect relationships of body weights and condition indices with advancing Julian date where sample sizes, distribution of the samples over time, and length of the collection period in fall (15 to 38 days) and trapping period in spring (8 to 22 days) permitted. Statistical tests were computed using SAS (SAS Inst. Inc. 1988a, 1988b) and BMDP Statistical Software (BMDP 1992). All statistical tests were considered significant at $P \leq 0.05$.

RESULTS

I. Fall Body Weights

1938-1940 vs. 1989-1991

Because of small sample sizes, comparisons between body weights collected during the present study and those collected by Bellrose and Hawkins (1947) were limited to mallards, green-winged teals, and gadwalls (Table 1). Differences in body weights for these three species indicated that ducks collected during 1938-1940 were heavier ($P \leq 0.05$) than those collected during 1989-1991. We found differences in body weights for adult male mallards ($t = 2.354$, 378 df, $P < 0.01$) and a smaller sample of immature female mallards ($t = 1.833$, 11 df, $P < 0.05$). However, weights of adult female and immature male mallards did not differ ($P > 0.05$) between time periods (Table 1). Other comparisons revealed differences between body weights of immature male green-winged teals ($t = 2.336$, 6 df, $P < 0.05$) and immature male gadwalls ($t = 3.106$, 9 df, $P < 0.01$).

Age Classes, Sex Classes, Age & Sex Classes, and Dates Within Years

Mallards

Differences occurred in the body weights of male ($\bar{x} = 1{,}223$ g, SE = 7, $n = 281$) versus female mallards ($\bar{x} = 1{,}066$ g, SE = 11, $n = 117$) ($F = 90.12$; 1, 394 df; $P < 0.001$) as well as for adult ($\bar{x} = 1{,}187$ g, SE = 8, $n = 325$) versus immature mallards ($\bar{x} = 1{,}130$ g, SE = 14, $n = 73$) ($F = 24.90$; 1, 394 df; $P < 0.001$). Differences in body weights existed between mallard age and sex classes ($F = 65.05$; 3, 394 df; $P < 0.001$). Adult male mallards were heavier than adult females, immature males, and immature females (Table 1).

Also, immature male mallards weighed more than both adult and immature females, and adult females were heavier than immature females. Weights of adult male mallards increased with Julian date as the fall progressed ($r_{xy} = 0.555$, $P < 0.001$) in 1989, but not in 1990 and 1991.

Wood Ducks

Male wood ducks ($\bar{x} = 710$ g, SE = 10, $n = 43$) were heavier ($F = 8.12$; 1, 72 df; $P = 0.006$) than females ($\bar{x} = 654$ g, SE = 9, $n = 35$), but adult and immature wood ducks did not differ in weight ($P > 0.05$). Age and sex classes were different ($F = 5.15$; 3, 72 df; $P = 0.003$), which indicated that adult males weighed more than adult females (Table 1).

Green-winged Teals

Body weights of male green-winged teals ($\bar{x} = 372$ g, SE = 7, $n = 38$) exceeded ($F = 6.54$; 1, 49 df; $P = 0.014$) those of females ($\bar{x} = 349$ g, SE = 7 $n = 14$). Also, adult body weights ($\bar{x} = 369$ g, SE = 6, $n = 46$) were greater ($F = 5.64$; 1, 49 df; $P = 0.022$) than immatures ($\bar{x} = 340$ g, SE = 13, $n = 6$). The only difference found between age and sex classes ($F = 5.00$; 2, 49 df; $P = 0.011$) of green-winged teals revealed that adult males weighed more than adult females (Table 1).

Gadwalls

Male gadwalls ($\bar{x} = 933$ g, SE = 46, $n = 12$) weighed more ($F = 7.09$; 1, 19 df; $P = 0.015$) than females ($\bar{x} = 759$ g, SE = 33, $n = 11$) and adults ($\bar{x} = 997$ g, SE = 54, $n = 8$) weighed more ($F = 10.49$; 1, 19 df; $P = 0.004$) than immatures ($\bar{x} = 771$ g, SE = 26, $n = 15$). There were also differences detected between age and sex classes of gadwalls ($F = 10.08$; 3, 19 df; $P < 0.001$). Body weights of adult males exceeded those of immature males and immature females (Table 1).

Lesser Scaups

Male lesser scaups ($\bar{x} = 853$ g, SE = 5, $n = 182$) weighed more ($F = 47.99$; 1, 295 df; $P < 0.001$) than females ($\bar{x} = 780$ g, SE = 9, $n = 117$) and adults ($\bar{x} = 877$ g, SE = 6, $n = 139$) were heavier ($F = 117.55$; 1, 295 df; $P < 0.001$) than immatures ($\bar{x} = 779$ g, SE = 6, $n = 160$). Body weight comparisons of age and sex classes of lesser scaups also revealed differences ($F = 67.21$; 3, 295 df; $P < 0.001$). Adult males outweighed adult females, immature males, and immature females. Also, adult females and immature males were heavier than immature females (Table 1).

Sufficient sample sizes were available for 1985 to examine changes in body weight over time. Body weight increased with Julian date during fall for adult male ($r_{xy} = 0.230$, $P = 0.029$), immature male ($r_{xy} = 0.279$, $P = 0.010$), and immature female lesser scaups ($r_{xy} = 0.357$, $P = 0.003$).

Ring-necked Ducks

Male ring-necked ducks ($\bar{x} = 765$ g, SE = 8, $n = 42$) outweighed ($F = 6.03$; 1, 65 df; $P = 0.017$) females ($\bar{x} = 653$ g, SE = 19, $n = 27$), and adults ($\bar{x} = 786$ g, SE = 11, $n = 23$) weighed more ($F = 15.99$; 1, 65 df; $P < 0.001$) than immatures ($\bar{x} = 688$ g, SE = 13, $n = 46$). Age and sex classes of ring-necked ducks differed in body weights ($F = 20.26$; 3, 65 df; $P < 0.001$). Adult and immature males were heavier than immature females (Table 1).

II. Fall Condition Indices

Age Classes, Sex Classes, Age & Sex Classes, and Dates Within Years

Mallards

Male mallards ($\bar{x}$ = 4.27, SE = 0.02, n = 281) had higher condition indices (F = 39.92; 1, 394 df; $P < 0.001$) than females ($\bar{x}$ = 3.98, SE = 0.04, n = 117), and adults ($\bar{x}$ = 4.22, SE = 0.02, n = 325) were in better condition (F = 20.75; 1, 394 df; $P < 0.001$) than immatures ($\bar{x}$ = 4.04, SE = 0.05, n = 73). Differences in condition between age and sex classes of mallards (F = 24.63; 3, 394 df; $P < 0.001$) indicated that adult males had higher condition indices than adult females, immature males, and immature females (Table 1). Both adult female and immature male mallards were in better condition than immature females. The condition indices of adult male mallards increased ($r_{xy} = 0.449$, $P < 0.001$) with fall Julian date in 1989, but not in 1990 and 1991.

Wood Ducks

Condition values for male wood ducks ($\bar{x}$ = 3.18, SE = 0.04, n = 43) exceeded (F = 4.17; 1, 72 df; $P = 0.045$) those of females ($\bar{x}$ = 2.99, SE = 0.04, n = 35), but there were no differences ($P > 0.05$) between adult and immature wood ducks. Comparisons of condition indices between age and sex classes (F = 2.91; 3, 72 df; $P = 0.040$) showed that adult males were in better physical condition than adult females (Table 1).

Green-winged Teals

Condition indices for male and female green-winged teals did not differ ($P > 0.05$). However, adults ($\bar{x}$ = 2.03, SE = 0.03, n = 46) were in better condition (F = 6.20; 1, 49 df; $P = 0.016$) than immatures ($\bar{x}$ = 1.84, SE = 0.06, n = 6). There was also a difference in condition between age and sex classes (F = 3.33; 2, 49 df; $P = 0.044$) of green-winged teals, which showed that adult males had higher condition values than immature males (Table 1).

Gadwalls

Differences between condition indices for male ($\bar{x}$ = 3.51, SE = 0.14, n = 12) and female gadwalls ($\bar{x}$ = 3.04, SE = 0.12, n = 11) were nearly significant (F = 4.33; 1, 19 df; P = 0.051). Adult gadwalls ($\bar{x}$ = 3.69, SE = 0.17, n = 8) were in better condition (F = 6.17; 1, 19 df; $P = 0.023$) than immatures ($\bar{x}$ = 3.06, SE = 0.09, n = 15). Comparisons of gadwall condition indices between age and sex classes revealed differences (F = 6.13; 3, 19 df; $P = 0.004$), which indicated that adult males had higher condition indices than both immature males and immature females (Table 1).

Lesser Scaups

Male lesser scaups ($\bar{x}$ = 4.18, SE = 0.03, n = 182) were in better physical condition (F = 11.50; 1, 295 df; $P < 0.001$) than females ($\bar{x}$ = 3.98, SE = 0.04, n = 117), and adults ($\bar{x}$ = 4.32, SE = 0.03, n = 139) had higher condition index values (F = 97.71; 1, 295 df; $P <$ 0.001) than immatures ($\bar{x}$ = 3.91, SE = 0.03, n = 160). Differences also existed in condition indices between age and sex classes of lesser scaups (F = 42.49; 3, 295 df; $P <$ 0.001). Both adult males and adult females had higher condition indices than immature males and immature females (Table 1). Immature males were also in better condition than immature females. In 1985, condition indices increased with fall Julian date for immature male ($r_{xy} = 0.267$, $P = 0.014$) and immature female lesser scaups ($r_{xy} = 0.355$, P = 0.003).

Ring-necked Ducks

Condition indices for male and female ring-necked ducks did not differ ($P > 0.05$). However, adult condition indices ($\bar{x} = 3.99$, SE = 0.06, $n = 23$) surpassed ($F = 13.14$; 1, 65 df; $P < 0.001$) those of immatures ($\bar{x} = 3.59$, SE = 0.06, $n = 46$). Condition indices varied between age and sex classes of ring-necked ducks ($F = 12.97$; 3, 65 df; $P < 0.001$). Adult and immature males were in better condition than immature females (Table 1).

III. Spring Body Weights

Age Classes, Sex Classes, Age & Sex Classes, and Dates Within Years

Canvasbacks

Male canvasbacks ($\bar{x} = 1{,}323$ g, SE = 3, $n = 1{,}728$) weighed more ($F = 73.10$; 1, 444 df; $P < 0.001$) than females ($\bar{x} = 1{,}175$ g, SE = 5, $n = 672$), and adults ($\bar{x} = 1{,}307$ g, SE = 3, $n = 1{,}721$) outweighed ($F = 22.83$; 1, 444 df; $P < 0.001$) immatures ($\bar{x} = 1{,}218$ g, SE = 5, $n = 679$). Body weights varied considerably between age and sex classes of canvasbacks ($F = 303.36$; 3, 2,396 df; $P < 0.001$). Adult males were heavier than adult females, immature males, and immature females (Table 2). Adult females outweighed immature females. Immature males were heavier than either adult females or immature females.

There was an inverse relationship ($P \leq 0.05$) between weights of adult male canvasbacks and Julian date during five (1977, 1981, 1983, 1986, 1988) of the seven years that data permitted examination. This indicated that there was a tendency for heavier adult males to arrive on Pool 19 earlier than lighter-weight individuals during spring migration. Body weights of adult female canvasbacks were also inversely related to Julian date ($r_{xy} = -0.346$, $P < 0.001$) in 1977, but weights of adult females increased ($r_{xy} = 0.312$, $P = 0.039$) with Julian date during the spring migration of 1981. No trends were observed between body weight and Julian date for adult female canvasbacks in 1983, 1984, 1987, and 1988. Weights of immature male canvasbacks were greater earlier in the spring migrations of 1977 ($r_{xy} = -0.343$, $P < 0.001$) and 1984 ($r_{xy} = -0.449$, $P < 0.001$); however, no trends existed between body weight and Julian date in 1981 or 1988. Body weights of immature female canvasbacks increased ($r_{xy} = 0.389$, $P = 0.003$) with Julian date in 1981. No relationship existed between body weight and Julian date for immature females in 1977, 1987, and 1988.

Lesser Scaups

Male lesser scaups were heavier ($F = 126.97$; 1, 461 df; $P < 0.001$) than females (Table 2). Sufficient data were available to examine body weight changes over time for male and females in 1977, 1987, and 1988. In 1987, weights of male lesser scaups decreased as Julian date increased ($r_{xy} = -0.208$, $P < 0.001$); however, the opposite occurred in 1988 when weights were the greatest during later dates of the trapping period ($r_{xy} = 0.091$, $P < 0.028$). No trend was observed between weights of male lesser scaups and Julian date in 1977. The only significant relationship between body weight and Julian date for females occurred in 1988 when weight increased with Julian date ($r_{xy} = 0.208$, $P = 0.009$).

Ring-necked Ducks

Male ring-necked ducks were heavier ($F = 20.57$; 1, 47 df; $P < 0.001$) than females during spring (Table 2).

IV. Spring Condition Indices

Age Classes Sex Classes, Age & Sex Classes and Dates Within Years

Canvasbacks

Male canvasbacks ($\bar{x}$ = 5.56, SE = 0.03, n = 312) had higher condition indices (F = 36.41; 1, 444 df; $P < 0.001$) than females ($\bar{x}$ = 5.20, SE = 0.04, n = 136), and adults ($\bar{x}$ = 5.53, SE = 0.03, n = 323) had higher (F = 11.79; 1, 444 df; $P < 0.001$) condition indices than immatures ($\bar{x}$ = 5.26, SE = 0.05, n = 125). Variances in condition indices of canvasbacks also occurred among age and sex classes (F = 22.03; 3, 444 df; $P < 0.001$). Adult males were in better condition than adult and immature females (Table 3). Immature male canvasbacks had higher condition indices than immature females. Comparisons of Julian dates and condition indices of adult male canvasbacks were examined for 1986 and 1988; the indices declined (r_{xy} = -0.221, P = 0.004) as Julian date increased in 1988 but not in 1986. The condition of adult females, immature males, and immature females did not differ by Julian date ($P > 0.05$) in 1986 and 1988 when sample sizes permitted comparisons.

Lesser Scaups

Male lesser scaups had higher (F = 73.32; 1, 461 df; $P < 0.001$) condition indices than females (Table 3). Condition indices for males (r_{xy} = 0.147, P = 0.012) and females (r_{xy} = 0.170, P = 0.036) increased with Julian date in spring 1988 but not in 1985.

Ring-necked Ducks

Male ring-necked ducks were in better condition (F = 11.22; 1, 47 df; P = 0.002) than females (Table 3).

DISCUSSION

Fall body weights of adult male and immature female mallards, immature male gadwalls, and immature male green-winged teals in the Illinois River valley were less during the present study (1989-1991) than during 1938-1940. Several factors, such as weather, deteriorating habitat conditions, food availability, or accuracy of the scales, could have caused these differences. Wetlands and their flora and fauna associated with the Illinois River have been detrimentally affected by sedimentation and unnatural water level fluctuations during the past 50 years (Bellrose et al. 1983, Havera and Bellrose 1985). Consequently, the abundance and diversity of wetland plants important as food sources for ducks in the Illinois Valley have decreased in recent decades (Bellrose et al. 1979). Hier (1989) also found weights of ring-necked ducks collected in Minnesota to be less in 1984-1986 than 30 years earlier, and Afton et al. (1989) stated that weights of lesser scaup in Louisiana were less in 1986 than 20 years earlier. Afton et al. (1989) suggested that these differences could be attributed to annual variation in reproductive effort, deterioration of food resources, increased disturbance on fall migration and winter areas, or a reflection of a long-term decline in the condition of lesser scaups. Human disturbances, primarily associated with boating activities, on Pool 19 of the Mississippi River also presented a problem for waterfowl attempting to fulfill energy requirements during fall and spring migrations (Havera et al. 1992).

Analyses of fall body weights (1985, 1989-1991) revealed that males and adults (except wood ducks) were heavier than their counterparts in all species of ducks examined. Also, adults were in better condition than immatures in all species with the exception of wood ducks. These results were consistent with many other studies on duck body weights (Owen and Cook 1977, Afton and Hier 1986, Delnicki and Reinecke 1986, Ringelman 1988, Hier 1989, Krementz et al. 1989, Lokemoen et al. 1990, Hohman and Weller 1994). Ringelman (1988) suggested that immature mallards may be in poorer condition because of being displaced to suboptimal foraging areas by dominant birds (i.e., adult males and pairs), particularly during severe weather when competition for food is intense. Afton and Hier (1986) reported that during fall, immature lesser scaups weighed less than adults, but weight increases for immatures were greater than for adults. They attributed these differences to the possibility that immatures may be growing in addition to accumulating nutrient reserves for migration. Serie and Sharp (1989) found that immature male canvasbacks accumulated fat reserves during fall migration and did not reach peak weights until arrival on the wintering areas, whereas adults reached their highest levels of fat storage earlier in migration. In south Florida, immature ring-necked ducks were lower in weight than adults during fall migration, but the two age groups were equivalent in weight by late winter (Hohman et al. 1988).

Fall body weights and condition indices for adult male mallards increased with Julian date in 1989. Fall body weights and condition indices for adult male, immature male, and immature female lesser scaups increased with Julian date in 1985. Sanderson and Anderson (1981) also found that mean body weights of hunter-harvested mallards increased during the season on Lake Sangchris in central Illinois. Takekawa (1987) stated that in many species of waterfowl, fluctuations in body weight follow similar patterns where weights peak as individuals arrive on the wintering areas, decrease through winter, and rebound in the spring. Austin and Fredrickson (1987) reported that female lesser scaups increased lipid reserves during fall migration, and late migrants were generally fatter than early migrants in southwestern Manitoba. Also, Serie and Sharp (1989) reported mean weights increased within age and sex classes by date during fall for migrating canvasbacks.

Analyses of spring body weights and condition indices (1977, 1981-1988) produced results similar to those for fall. Body weights and condition indices for males were higher than those for females, and adults had greater weights and condition indices than immature canvasbacks, lesser scaups, and ring-necked ducks. Evidence from other studies indicates that male diving ducks weigh more than females during spring migration (Lovvorn 1987, Gammonley and Heitmeyer 1990). By the time they reached the breeding grounds in southwest Manitoba, however, Barzen (1989) found that paired female canvasbacks were heavier and contained more fat than males. Other investigators (Hohman 1986, Barzen and Serie 1990, Afton and Ankney 1991) presented body weight data for male and female diving ducks on breeding areas that appeared to support Barzen (1989). Differences occurred when weights of females increased during ovarian follicle development, and males lost weight as time devoted to feeding decreased and time spent guarding their mates from intruding males and predators increased (Hohman 1986, Hohman et al. 1988, Afton and Ankney 1991).

Analyses of our spring body weight data for adult male canvasbacks on Pool 19 indicated that heavier birds generally appeared earlier than lighter individuals. No other investigations of body weights for diving ducks in Illinois or any other spring staging area have documented similar results. Barzen (1989) reported that body weights for male and female canvasbacks on their northward spring migration changed among sites (Pools 19, 9, 8, 7, North Dakota, and Manitoba), but they did not increase with the Julian date of their collection among these sites. Early spring migration by heavier adult male canvasbacks may indicate that birds in good condition migrate earlier to increase reproductive success (Ankney and MacInnes 1978, Raveling 1979, Krapu 1981, Moller 1994). Thornburg et al. (1988) suggested that declines in spring weights of Canada geese (*Branta canadensis*) in southern Illinois may have been attributed to geese that were in better physiological condition initiating migration at the earliest opportunity. Canvasbacks in poor condition may not be able to endure long-distance flights, thereby causing them to remain in an area longer to increase body reserves or to make shorter flights and delay their migration (Korschgen et al. 1988).

There is strong evidence that body weights and condition are related to waterfowl survival (Burnham and Nichols 1985, Haramis et al. 1986, Takekawa 1987, Pollock et al. 1989, Hohman et al. 1995). Ducks that were heavier and in good condition withstood longer periods of food shortage and cold stress (Calder 1974), and were less vulnerable to natural (Weatherhead 1985) and hunting mortality (Greenwood et al. 1986, Hepp et al. 1986, Blohm et al. 1987, Reinecke and Shaiffer 1988, Heitmeyer et al. 1993) than ducks that were lighter and in poorer physical condition. Several researchers reported that body weight and condition were positively related to winter and annual survival rates of canvasbacks (Haramis et al. 1986, Takekawa 1987, Hohman et al. 1995). Similar relationships were also found for mallards (Hepp et al. 1986, Blohm et al. 1987) and American black ducks (*Anas rubripes*) (Pollock et al. 1989, Longcore et al. 1991).

For waterfowl to maintain sufficient body weight and condition, which may increase survival and reproductive probabilities, high-quality habitats must be provided on migration, wintering, and breeding areas. Greater body weights were associated with the quality of wetlands used by mallards and wood ducks on wintering areas (Delnicki and Reinecke 1986) and for mallards, blue-winged teals (*A. discors*), and gadwalls during the breeding season (Lokemoen et al. 1990). Loesch and Kaminski (1989) also reported that wetland conditions on the wintering grounds affected body condition, survival, and recruitment rates of mallards. Barzen (1989) stated that protection of key staging areas along migration routes may influence recruitment rates of canvasbacks. Many species of waterfowl incur the energy demanding activities of migration, courtship, and molt simultaneously (Weller 1965, Bellrose 1980, Hepp and Hair 1983, Gammonley and Heitmeyer 1990, Hohman et al. 1990). Accordingly, the availability of high-quality habitats throughout the annual range of waterfowl (Korschgen et al. 1988, LaGrange and Dinsmore 1988, Loesch and Kaminski 1989), including the important fall and spring migration areas in Illinois and elsewhere in the heart of the Mississippi Flyway, is imperative to sustain healthy populations.

ACKNOWLEDGMENTS

We thank Illinois Department of Natural Resources personnel at the public hunting areas for their cooperation and B. Redman and L. O'Hara for use of their commercial picking facilities. R.L. Hager, K.L. Hills, F.H. Roetker, and R.A. Williamson provided logistical support for trapping operations. M.M. Georgi and P.H. Soboroff assisted in field operations. J.D. Brawn and A.P. Yetter provided statistical assistance. G.C. Sanderson, W.L. Anderson, A.P. Yetter, W.L. Hohman, P.W. Brown, and C.E. Warwick reviewed and edited the manuscript. M.M. Georgi assisted with data manipulation and L.L. Anderson and K.E. Roat typed the manuscript. Some of the data in this manuscript were collected as partial fulfillment of a Master of Science degree from Western Illinois University for the third author with the financial support provided by R.V. Anderson. This study was funded in part by Pittman Robertson Federal Aid Project W-43-R, with cooperation from the Illinois Department of Natural Resources, Illinois Natural History Survey, and U.S. Fish and Wildlife Service.

LITERATURE CITED

Afton, A.D., and C.D. Ankney. 1991. Nutrient reserve dynamics of breeding lesser scaup: a test of competing hypothesis. Condor 93:89-97.

Afton, A.D., and R.H. Hier. 1986. Fall migration ecology of lesser scaup in Minnesota. DNR Progress Report. Unpublished information.

Afton, A.D., R.H. Hier, and S.L. Paulus. 1989. Nutrient reserves of lesser scaup in mid-winter in southwestern Louisiana. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 43:404-411.

Ankney, C.D., and C.D. MacInnes. 1978. Nutrient reserves and reproductive performance of female lesser snow geese. Auk 95:459-471.

Austin, J.E., and L.H. Fredrickson. 1987. Body and organ mass and body composition of postbreeding female lesser scaup. Auk 104:694-699.

Barzen, J.A. 1989. Patterns of nutrient acquisition in canvasbacks during spring migration. M.S. Thesis, University of North Dakota, Grand Forks. 74 p.

Barzen, J.A., and J.R. Serie. 1990. Nutrient reserve dynamics of breeding canvasbacks. Auk 107:75-85.

Bellrose, F.C. 1980. Ducks, geese and swans of North America. Third ed. Stackpole Books, Harrisburg, PA. 540 p.

Bellrose, F.C., and A.S. Hawkins. 1947. Duck weights in Illinois. Auk 64(3):422-430.

Bellrose, F.C., F.L. Paveglio, Jr., and D.W. Steffeck. 1979. Waterfowl populations and the changing environment of the Illinois River valley. Ill. Nat. Hist. Surv. Bull. 32(1):1-54.

Bellrose, F.C., S.P. Havera, F.L. Paveglio, Jr., and D.W. Steffeck. 1983. The fate of lakes in the Illinois River valley. Ill. Nat. Hist. Surv. Biol. Notes No. 119. 27 p.

Blohm, R.J, R.E. Reynolds, J.P. Bladen, J.D. Nichols, J.E. Hines, K.H. Pollock, and R.T. Eberhardt. 1987. Mallard mortality rates on key breeding and wintering areas. Pages 246-257 in Trans. 52nd N. Amer. Wildl. and Nat. Resour. Conf. 748 p.

BMDP. 1992. Statistical software manual, 7.0 release. BMDP Statistical Software Inc., Los Angeles, CA.

Burnham, K.P., and J.D. Nichols. 1985. Comments on condition bias and band recovery data from waterfowl banding programs. Wildl. Soc. Bull. 13(3):345-349.

Calder, W.A. 1974. Consequences of body size for avian energetics. Pages 86-144 in R.A. Paynter, Jr., ed. Avian energetics. Publ. Nuttall Ornithological Club No. 15.

Carney, S.M. 1964. Preliminary keys to waterfowl age and sex identification by means of wing plumage. U.S. Dep. Inter. Spec. Sci. Rep. 82. 47 p.

Delnicki, D., and K.J. Reinecke. 1986. Mid-winter food use and body weights of mallards and wood ducks in Mississippi. J. Wildl. Manage. 50(1):43-51.

Gammonley, J.H., and M.E. Heitmeyer. 1990. Behavior, body condition, and foods of buffleheads and lesser scaup during spring migration through the Klamath Basin, California. Wilson Bull. 102(4):672-683.

Greenwood, H.R., R.G. Clark, and P. J. Weatherhead. 1986. Condition bias of hunter-shot mallards (*Anas platyrhynchos*). Can. J. Zool. 64:599- 601.

Haramis, G.M., J.D. Nichols, K.H. Pollock, and J.E. Hines. 1986. The relationship between body mass and survival of wintering canvasbacks. Auk 103:506-514.

Havera, S.P., and F.C. Bellrose. 1985. The Illinois River: a lesson to be learned. Wetlands 4:29-41.

Havera, S.P., L.R. Boens, M.M. Georgi, and R.T. Shealy. 1992. Human disturbance of waterfowl on Keokuk Pool, Mississippi River. Wildl. Soc. Bull. 20:290-298.

Heitmeyer, M.E., L.H. Fredrickson, and D.D. Humburg. 1993. Further evidence of biases associated with hunter-killed mallards. J. Wildl. Manage. 57(4):733-740.

Hepp, G.R., and J.D. Hair. 1983. Reproductive behavior and pairing chronology in wintering dabbling ducks. Wilson Bull. 95:675-682.

Hepp, G.R., R.J. Blohm, R.E. Reynolds, J.E. Hines, and J.D. Nichols. 1986. Physiological condition of autumn-banded mallards and its relationship to hunting vulnerability. J. Wildl. Manage. 50(2):177-183.

Hier, R.H. 1989. Fall weights of redheads and ring-necked ducks in northern Minnesota. Prairie Nat. 21(4):229-233.

Hohman, W.L. 1986. Changes in body weight and body composition of breeding ring-necked ducks (*Aythya collaris*). Auk 103:181-188.

Hohman, W.L., and M.W. Weller. 1994. Body mass and composition of ring-necked ducks wintering in southern Florida. Wilson Bull. 106(3):494-507.

Hohman, W.L., T.S. Taylor, and M.W. Weller. 1988. Annual body weight change in ring-necked ducks (*Aythya collaris*). Pages 257-269 in Milton W. Weller, ed. Waterfowl in winter. University of Minnesota Press, Minneapolis. 624 p.

Hohman, W.L., D.W. Woolington, and J.H. Devries. 1990. Food habits of wintering canvasbacks in Louisiana. Can. J. Zool. 68:2605-2609.

Hohman, W.L., J.L. Moore, and J.C. Franson. 1995. Winter survival of immature canvasbacks in inland Louisiana. J. Wildl. Manage. 59(2):384-392.

Korschgen, C.E., L.S. George, and W.L. Green. 1988. Feeding ecology of canvasbacks staging on Pool 7 of the Upper Mississippi River. Pages 237-249 in Milton W. Weller, ed. Waterfowl in winter. University of Minnesota, Minneapolis. 624 p.

Krapu, G.L. 1981. The role of nutrient reserves in mallard reproduction. Auk 98:29-38.

Krementz, D.G., J.E. Hines, P.O. Corr, and R.B. Owen, Jr. 1989. The relationship between body mass and annual survival in American black ducks. Ornis Scand. 20(2):81-85.

LaGrange, T.G., and J.J. Dinsmore. 1988. Nutrient dynamics of female mallards during spring migration through central Iowa. Pages 287-297 in Milton W. Weller, ed. Waterfowl in winter. University of Minnesota Press, Minneapolis. 624 p.

Larson, J.S., and R.D. Taber. 1980. Criteria of sex and age. Pages 143-202 in S.D. Schemnitz, ed. Wildlife management techniques manual. Fourth ed. The Wildl. Soc., Washington, D.C.

Loesch, C.R., and R.M. Kaminski. 1989. Winter body-weight patterns of female mallards fed agricultural seeds. J. Wildl. Manage. 53(4):1081-1087.

Lokemoen, J.T., D.H. Johnson, and D.E. Sharp. 1990. Weights of wild mallard *Anas platyrhynchos*, gadwall *A. strepera*, and blue-winged teal *A. discors* during the breeding season. Wildfowl 41:122-130.

Longcore, J.R., D.G. McAuley, and C. Frazer. 1991. Survival of postfledging female American black ducks. J. Wildl. Manage. 55(4):573-580.

Lovvorn, J.R. 1987. Behavior, energetics, and habitat relations of canvasback ducks during winter and early spring migration. M.S. Thesis, University of Wisconsin, Madison. 172 p.

Moller, A.P. 1994. Phenotype-dependent arrival time and its consequences in a migratory bird. Behav. Ecol. and Sociobiol. 35:115-122.

Owen, M., and W.A. Cook. 1977. Variations in body weight, wing length and condition of mallard *Anas platyrhynchos* and their relationship to environmental changes. J. Zool. (London) 183:377-395.

Pollock, K.H., S.R. Winterstein, and M.J. Conroy. 1989. Estimation and analysis of survival distributions for radio-tagged animals. Biometrics 45:99-109.

Raveling, D.G. 1979. The annual cycle of body composition of Canada geese with special reference to control of reproduction. Auk 96:234-251.

Reinecke, K.J., and C.W. Shaiffer. 1988. A field test for differences in condition among trapped and shot mallards. J. Wildl. Manage. 52(2):227-232.

Ringelman, J.K. 1988. Examining waterfowl condition: skewed ideas on the normal procedure. Pages 277-285 in Milton W. Weller, ed. Waterfowl in winter. University of Minnesota Press, Minneapolis. 624 p.

Ringelman, J.K., and M.R. Szymczak. 1985. A physiological condition index for wintering mallards. J. Wildl. Manage. 49(3):564-568.

Sanderson, G.C., and W.L. Anderson. 1981. Waterfowl studies at Lake Sangchris, 1973-1977. Ill. Nat. Hist. Surv. Bull. 32(4):656-690.

SAS Institute, Inc. 1988a. SAS/STAT user's guide release. 6.06 ed. SAS Institute Incorporated, Cary, NC. 1028 p.

SAS Institute, Inc. 1988b. SAS user's guide: basics. Version 6.06 ed. SAS Institute Incorporated, Cary, NC. 1290 p.

Serie, J.R., and D.E. Sharp. 1989. Body weight and composition dynamics of fall migrating canvasbacks. J. Wildl. Manage. 53(2):431-441.

Serie, J.R., D.L. Trauger, H.A. Doty, and D.E. Sharp. 1982. Age class determination of canvasbacks. J. Wildl. Manage. 46:894-904.

Takekawa, J.Y. 1987. Energetics of canvasbacks staging on an Upper Mississippi River pool during fall migration. Ph.D. dissertation, Iowa State University, Ames. 189 p.

Thornburg, D.D., T.C. Tacha, B.C. Estel, and J.W. Spitzkeit. 1988. Spatial and temporal variation in winter weights of Mississippi Valley Canada geese. Pages 271-276 in Milton W. Weller, ed. Waterfowl in winter. University of Minnesota Press, Minneapolis. 624 p.

Weatherhead, P.J. 1985. Condition bias and band recovery data: a reply to Burnham and Nichols. Wildl. Soc. Bull. 13(3):349-351.

Weller, M.W. 1965. Chronology of pair formation in some nearctic Aythya (Anatidae). Auk 82:227-235.

Whitton, R.M. 1987. Blood lead, ingested shot, and migrational energetics in canvasbacks, lesser scaup and ring-necked ducks on Pool 19, Mississippi River. M.S. Thesis, Western Illinois University, Macomb. 118 p.

Table 1. Body weights, length of wing chords, and condition indices of hunter-harvested ducks in the Illinois and Mississippi river valleys during fall, 1938-1940, and 1985, 1989-1991.

			1938-1940[a]			1985[b], 1989-1991						
				Body wt[c] (g)			Body wt[cd] (g)		Wing chord (mm)		Condition index[d] (g/mm)	
Species	Sex	Age	n	$\bar{x}$	SE	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Dabbling Ducks												
Mallards	M	Ad	631	1,261A	5	220	1,240AB	8	288	0.6	4.31B	0.03
		Im	730	1,175	5	61	1,163B	12	282	0.6	4.13B[e]	0.04
	F	Ad	402	1,084	9	105	1,078B	11	268	0.8	4.02B[e]	0.04
		Im	671	1,034A	5	12	966AB	37	267	1.4	3.62B	0.14
Wood ducks	M	Ad	4	694		37	712B	9	223	1.0	3.19B	0.03
		Im	5	712		6	702	49	223	2.0	3.14	0.20
	F	Ad				20	652B	11	218	1.6	2.99B	0.05
		Im	4	553		13	666	14	218	1.7	3.05	0.07
Green-winged teals	M	Ad	21	390	5	32	378B	7	184	1.1	2.05B	0.04
		Im	38	372A	5	6	340A	13	185	3.7	1.84B	0.06
	F	Ad	10	354	9	14	349B	7	176	1.1	1.98	0.04
		Im	31	336	9							
Gadwalls	M	Ad	16	989	27	6	1,046B	58	272	2.5	3.84B	0.19
		Im	68	907A	14	6	821AB[e]	24	258	0.4	3.18B[e]	0.09
	F	Ad	14	848	18	2	851	40	262	6.4	3.25	0.07
		Im	66	807	14	9	739B[e]	36	247	1.3	2.99B[e]	0.14
Northern pintails	M	Ad	237	1,034	9	4	1,088	31	274	3.0	3.98	0.09
		Im	403	975	5	4	950	70	262	3.0	3.63	0.23
	F	Ad	60	889	14	1	813		255		3.19	
		Im	219	835	9	3	664	69	250	1.7	2.66	0.30

Table 1. Continued.

			1938-1940[a]			1985[b], 1989-1991						
				Body wt[c] (g)			Body wt[cd] (g)		Wing chord (mm)		Condition index[d] (g/mm)	
Species	Sex	Age	n	$\bar{x}$	SE	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
American wigeons	M	Ad	19	807	23	3	744	42	260	0.6	2.86	0.17
		Im	82	780	14	2	739	99	258	0.0	2.86	0.39
	F	Ad	16	753	23							
		Im	92	717	9	4	711	52	241	1.0	2.95	0.21
Northern shovelers	M	Ad	16	689		4	702	24	247	1.0	2.84	0.11
		Im	45	671								
	F	Ad	6	621								
		Im	35	590		2	651	6	227	5.7	2.87	0.11
American black ducks	M	Ad	12	1,202	45	2	1,180	97	295	6.4	4.01	0.43
		Im	18	1,175	32							
	F	Ad	10	1,089	41	2	1,017	64	271	4.2	3.76	0.30
		Im	29	1,066	23							
Diving Ducks												
Lesser scaups	M	Ad	9	839		96	893B	6	205	0.6	4.36B[e]	0.03
		Im	26	780		86	809B[e]	6	203	0.6	3.99B	0.03
	F	Ad	6	780		43	842B[e]	11	198	0.7	4.25B[e]	0.06
		Im	27	785		74	744B	10	195	0.7	3.82B	0.05
Ring-necked ducks	M	Ad	9	862		20	787B[e]	12	198	0.8	3.98B[e]	0.06
		Im	9	735		22	744B[e]	10	196	0.9	3.80B[e]	0.05
	F	Ad	5	694		3	780	35	193	3.2	4.04	0.22
		Im	6	658		24	637B	18	187	1.1	3.40B	0.09

Table 1. Continued.

			1938-1940[a]			1985[b], 1989-1991						
				Body wt[c] (g)			Body wt[cd] (g)		Wing chord (mm)		Condition index[d] (g/mm)	
Species	Sex	Age	n	$\bar{x}$	SE	n	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Buffleheads	M	Ad				4	504	16	175	3.0	2.88	0.11
		Im										
	F	Ad				2	470	77	169	4.2	2.78	0.39
		Im										
Ruddy ducks	M	Ad	3	612		2	479	105	153	0.0	3.14	0.68
		Im				2	523	20	148	2.1	3.55	0.20
	F	Ad	2	549								
		Im										

[a] Data from Bellrose and Hawkins (1947).
[b] Data for 1985 from Whitton (1987).
[c] Values in each row followed by the same letter differ significantly ($\underline{P} \leq 0.05$).
[d] Values in each column followed by the same letter differ significantly ($\underline{P} \leq 0.05$) unless noted otherwise.
[e] Values are not significantly different ($\underline{P} > 0.05$).

Table 2. Body weights by sex and age class of canvasbacks, lesser scaups, and ring-necked ducks livetrapped on Pool 19 of the Mississippi River during springs 1977, 1981-1988[a].

Species	Sex	Age	n	Years	Body weight[b] (g) x̄	SE
Canvasbacks						
	M	Ad	1,322	1977, 1981-1984, 1986-1988	1,339A	3
		Im	403	1977, 1981-1984, 1986-1988	1,276A	6
	F	Ad	396	1977, 1981-1984, 1986-1988	1,205A	6
		Im	271	1977, 1981-1984, 1986-1988	1,136A	8
Lesser scaups						
	M	–	1,090	1977, 1985, 1987, 1988	770B	3
	F	–	373	1977, 1985, 1987, 1988	679B	4
Ring-necked ducks						
	M	–	71	1977, 1985, 1987, 1988	744C	7
	F	–	29	1977, 1985, 1987, 1988	651C	16

[a] Data for 1985 and 1986 from Whitton (1987).
[b] Values followed by the same letter differ significantly ($\underline{P} \leq 0.05$).

Table 3. Condition indices of canvasbacks, lesser scaups, and ring-necked ducks livetrapped on Pool 19 of the Mississippi River in spring 1985[a], 1986[a], and 1988.

Species				Body weight (g)		Wing chord (mm)		Condition Indices[b] (g/mm)	
Sex	Age	Years	n	x̄	SE	x̄	SE	x̄	SE
Canvasbacks									
M	Ad	1986, 1988	249	1,360	8	243	0.4	5.60AB	0.03
	Im	1986, 1988	63	1,286	16	237	0.9	5.43C	0.06
F	Ad	1986, 1988	74	1,235	15	233	0.9	5.29A	0.06
	Im	1986, 1988	62	1,177	16	231	0.7	5.09BC	0.07
Lesser scaups									
M	--	1985, 1988	308	778	4	207	0.3	3.77D	0.02
F	--	1985, 1988	157	697	7	201	0.3	3.48D	0.03
Ring-necked ducks									
M	--	1985, 1988	40	735	10	200	0.6	3.67E	0.05
F	--	1985, 1988	11	628	22	190	2.0	3.30E	0.09

[a] Data for 1985 and 1986 from Whitton (1987).

[b] Values followed by the same letter differ significantly (P ≤ 0.05).

Transactions of the Illinois State Academy of Science
(1996), Volume 89, 3 and 4, pp. 215-219

Locality Records of the Northern Leopard Frog, *Rana pipiens*, in Central and Southwestern Illinois

Michael Redmer
Department of Zoology
Southern Illinois University at Carbondale
Carbondale, Illinois 62901

ABSTRACT

Three new localities for *Rana pipiens* in central and southwestern Illinois are reported, and several explanations are proposed for these records. Previous records of *R. pipiens* were limited primarily to the northern third of Illinois. *Rana pipiens*, and the southern leopard frog, *R. sphenocephala*, previously were believed to be allopatric in Illinois. However, parapatric populations of *R. pipiens* and the plains leopard frog, *R. blairi* have been reported from several northcentral and northeastern Illinois counties.

INTRODUCTION

The taxonomy of North American leopard frogs has been subject of study throughout much of the 20th century. Results of morphological studies and hybridization experiments led Moore (1944, 1946) to conclude that "*Rana pipiens*" was a single wide-ranging species. In his work on the amphibians and reptiles of Illinois, Smith (1961) recognized "*Rana pipiens*" as the only leopard frog species in Illinois. Smith recognized two subspecies of *R. pipiens* in Illinois: *R. p. pipiens* (northern leopard frog), and *R. p. sphenocephala* (southern leopard frog), and depicted a wide zone of intergradation across the middle of the state. Brown and Brown (1972) later showed that at least three call types existed within the *R. pipiens* complex in Illinois. In addition, several significant morphological characters were recognized, and now three leopard frog species (*R. pipiens*, *R. sphenocephala*, and the plains leopard frog, *R. blairi*) are known to occur in Illinois (Mecham, et al., 1973; Brown and Morris, 1990).

Rana pipiens, *sensu stricto*, can be distinguished from *R. blairi* by continuous dorsolateral folds (one or both of which are broken posteriarly and medially displaced on *R. blairi*). Male *R. pipiens* possess Müllerian ducts (vestigial oviducts), a feature not shared with either *R. blairi* or *R. sphenocephala* (Mecham, et al. 1973; Brown and Morris, 1990). The range maps of Pace (1974) and Morris (1994; Fig. 1) show records of *R. pipiens* from the northern one-third of Illinois, as far south as Kankakee County on the east, and Henderson County on the west. The maps also showed an isolated record from McLean County, in central Illinois, which may represent an introduced locality or misidentification. The distributions of *R. pipiens* and *R. blairi* overlap in several northern counties in which *R. blairi* occurs (Brown and Morris, 1990). Previously, *R. pipiens* and *R. sphenocephala* were not reported together in any county in the state.

The pickerel frog, *Rana palustris*, has been confused with *R. pipiens* in some Illinois collections (Redmer and Mierzwa, 1994). *Rana palustris* differs from *R. pipiens* by possessing the following characters (which *R. pipiens* lacks): a) usually square spots arranged in parallel rows between wide dorsolateral folds, b) rounder snouts, and c) yellow-gold flash coloration on the thighs and groin in life; and d) lack of male Müllerian ducts.

Recently, five *R. pipiens* specimens identified as *R. palustris* were found in the herpetology research collection of the Department of Biological Sciences, Southern Illinois University at Edwardville (SIUE). These specimens bear field tags which indicate the frogs were collected outside of the previously known Illinois range of *R. pipiens*. The objective of this paper is to report these specimens.

MATERIAL AND METHODS

While examining preserved specimens in the SIUE collection, (in a jar labeled "*Rana palustris*") five specimens not identifiable as that species were found. The collection data attached to these specimens are as follows:

> **Madison County**: SIUE 1588 and 1589. Elevation 540' [166 m] in grassy pond area. 89° 59' 30" N, 38 47'. 28 April 1964. W. A. Armistead. SIUE 1590. Bank of Indian Creek 3 miles [4.9 km] SE of Roxana. 17 April 1963. J. Lynch.
> **Sangamon County**: SIUE 1616. Springfield, 6.0 miles [9.8 km] due S on Route 66. Alt. 600'+ [=elevation 185 m], along Lake Springfield shoreline. 28 April 1963. L. Fencel. SIUE 1617. Six miles [9.8 km] S of Springfield, Route 66. Found under highway bridge. Elevation 600' [185 m]. 28 April 1963. J. and L. Leitner.

The specimens were dissected and examined to determine sex and the presence or absence of Müllerian ducts. The general external appearance of each specimen (especially dorsolateral folds, spot pattern, and external secondary sex characters such as vocal sacks and articular nuptual pads) were noted. All other preserved leopard frogs in the SIUE collection were examined in a similar fashion.

RESULTS AND DISCUSSION

All five specimens were male, and had dorsolateral folds continuous to the thigh. All possessed Müllarian ducts, and lacked external vocal sacks. Dorsal spots are round or oblong, and randomly distributed between the dorsolateral folds. This character combination supports the identity of each specimen as *R. pipiens*, thus possibly extending considerably the range of this species in the state (Fig 1). However, this small sample does not necessarily indicate that populations of *R. pipiens* occur in Madison and Sangamon counties. There are three possible explanations for these records:

1) Intentional or accidental release of captive specimens of unknown origin. Live individuals of the *R. pipiens* complex have for many years been commercially available through the biological supply industry. Pentecost and Vogt (1976) reported that, in

Wisconsin, approximately 160,000 *Rana pipiens* were harvested annually by biological supply houses. Two Madison County specimens (SIUE 1588-1589) were collected on the campus of SIUE, and may have been former captives that were released or that escaped. *Rana pipiens*, and other frog species, are sometimes used as fishing bait and tadpoles may be translocated as a by-product of fish stocking operations. Both Sangamon County specimens were collected in the vicinity of Lake Springfield, and may have been released or escaped bait animals. Although ranid frogs are not usually considered popular pet species, it is possible that any or all of the examined specimens were released or escaped pets.

2) Erroneous locality data or errors in cataloging. It is possible that any or all of the specimens were collected or obtained somewhere other than the locations indicated on the field tags, and that errors were made on the field tags, and/or during the process of cataloging them into the SIUE collection.

3) Possibility of disjunct populations. It is possible that these specimens represent disjunct and/or relict populations. Elsewhere in the midwest (e.g., Indiana and Ohio), *R. pipiens* occurs at latitudes as far south as Madison County (Conant and Collins, 1991). Also, in Illinois, four snake species (fox snake, *Elaphe vulpina*; smooth green snake, *Opheodrys vernalis*; bull snake, *Pituophis melanoleucus*; plains gater snake, *Thamnophis radix*) known primarily from the northern half of the state also occur in disjunct populations along the Illinois River drainage, or in counties on the east side of the Mississippi River crescent north and east of St. Louis, Missouri (Smith, 1961; McNaughton, 1976; Tucker, 1994 a, b). Blanding's turtle, *Emydoidea blandingii*, has a mostly northern distribution in Illinois and Missouri, but recently it has been documented from St. Charles County, Missouri (Powell, et al., 1993). The Madison and Sangamon county *Rana pipiens* specimens may represent similar relicts.

Both *Rana blairi* and *Rana sphenocephala* previously have been reported from Madison County (Axtell, 1976; Brown and Morris, 1990). Only *R. sphenocephala* has been reported previously from Sangamon County (Pace, 1974). If the *R. pipiens* specimens reported in this paper represent natural populations, these records are the first to document the occurrence of this species in Illinois counties where *R. sphenocephala* also occurs, and Madison County would be the first Illinois County in which all three leopard frogs are known to occur.

ACKNOWLEDGMENTS

I thank J. Capps (Southern Illinois University at Edwardsville) for calling my attention to the specimens reported herein. R. W. Axtell (Southern Illinois University at Edwardsville) granted permission to examine specimens in his care. R. W. Axtell and R. A. Brandon (Southern Illinois University at Carbondale) and three anonymous reviewers commented on drafts of the manuscript.

LITERATURE CITED

Axtell, C. B. 1976. Comparisons of morphology, lactate dehydrogenase, and distribution of *Rana blairi* and *Rana utricularia* in Illinois and Missouri. Transactions of the Illinois State Academy of Science 69: 37 - 48.

Brown, L. E., and J. R. Brown. 1972. Call types of the *Rana pipiens* complex in Illinois. Science 176: 928 - 929.

Brown, L. E., and M. A. Morris. 1990. Distribution, habitat, and zoogeography of the plains leopard frog (*Rana blairi*) in Illinois. Illinois Natural History Survey Biological Notes 136: 1 - 6.

Conant, R., and J.T. Collins. 1991. A field guide to the amphibians and reptiles of eastern and central North America. Houghton Mifflin, Boston. 450 p.

McNaughton, G. 1976. Relict populations of *Pituophis melanoleucus* and *Thamnophis radix* in Illinois. Herpetological Review 7: 124.

Mecham, J. S., M. J. Littlejohn, R. S. Oldham, L. E. Brown, and J. R. Brown. 1973. A new species of leopard frog (*Rana pipiens* complex) from the plains of the central United States. Occasional Papers, Museum of the Texas Technical University 18: 1 - 11.

Moore, J. A. 1944. Geographic variation in *Rana pipiens* Schreber of eastern North America. Bulletin of the American Museum of Natural History 82: 345 - 370.

Moore, J. A. 1946. Incipient intraspecific isolating mechanisms in *Rana pipiens*. Genetics 31: 304 - 326.

Morris, M. A. 1994. Ranges of amphibians and reptiles in Illinois. Pp. 65-90. In: R. A. Brandon. Herpetology Laboratory Notebook. 710 Books, Carbondale, Illinois.

Pace, A. E. 1974. Systematic and biological studies of the leopard frogs (*Rana pipiens* complex) of the United States. University of Michigan Museum of Zoology Miscellaneous Publications 148: 1 - 140.

Pentecost, E. D., and R. C. Vogt. 1976. Amphibians and reptiles of the Lake Michigan Drainage Basin. Environmental Status of the Lake Michigan Drainage System, Argonne National Laboratory 16: 1 - 69.

Powell, R., T. R. Johnson, and D. D. Smith. 1993. New records of amphibians and reptiles in Missouri for 1993. Missouri Herpetological Association Newsletter 6:3-26.

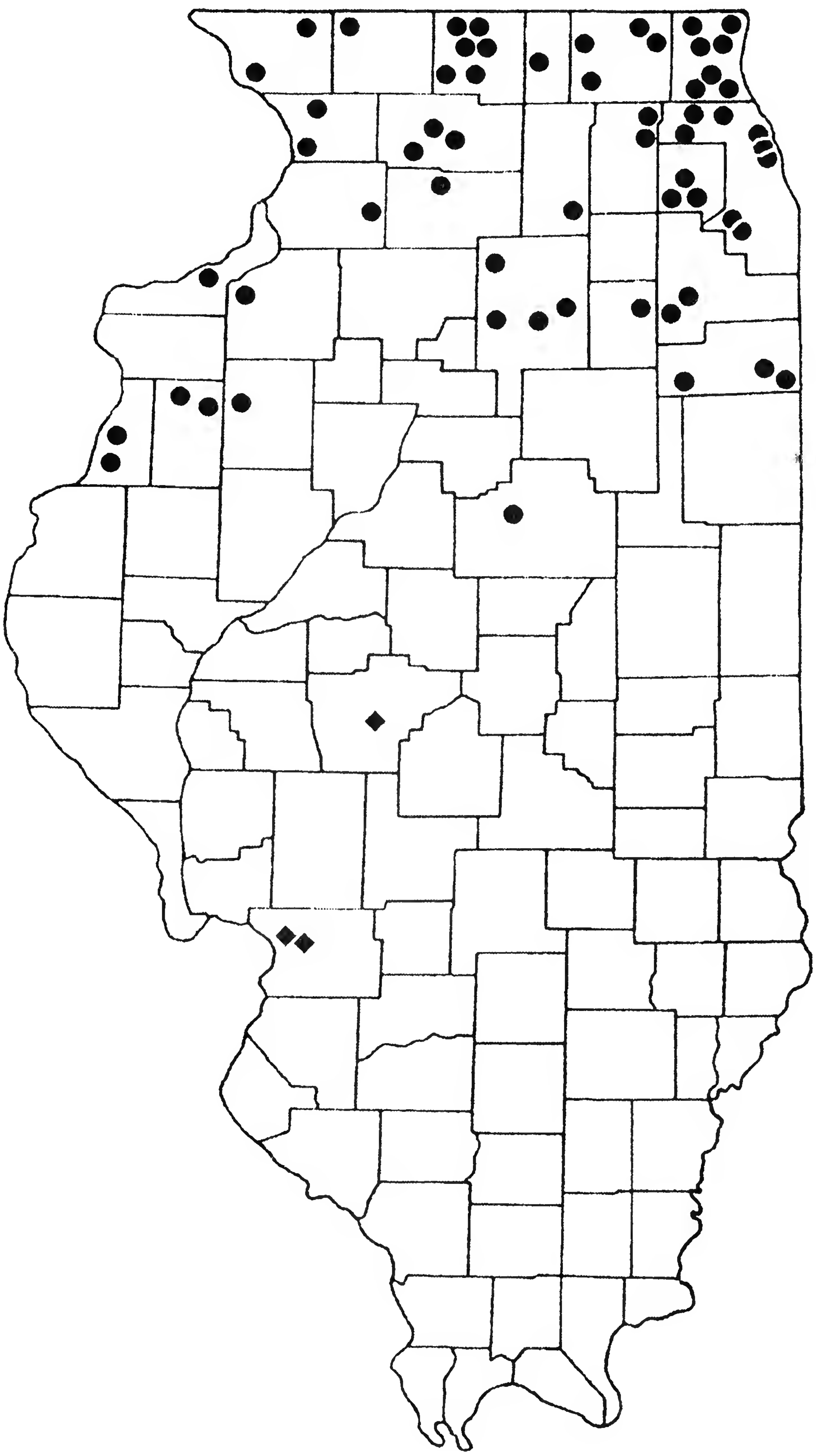
Redmer, M., and K. S. Mierzwa. 1994. A review of the distribution and zoogeography of the pickerel frog, *Rana palustris*, in northern Illinois. Bulletin of the Chicago Herpetological Society 29: 21 - 30.

Smith, P. W. 1961. The amphibians and reptiles of Illinois. Illinois Natural History Survey Bulletin 28: 1 - 298.

Tucker, J. K. 1994 a. Noteworthy distributional records for some snakes from Jersey and Madison counties, Illinois. Herpetological Review 25: 79 - 80.

Tucker, J. K. 1994 b. Geographic Distribution: *Thamnophis radix* (plains garter snake). Herpetological Review 25: 168

Figure 1. The distribution of *Rana pipiens* in Illinois, based on maps by Pace (1974), and Morris (1994). Diamonds indicate localities reported herein. Circles indicate previous records.



Transactions of the Illinois State Academy of Science
(1996), Volume 89, 3 and 4, pp. 221-224

The Western Sand Darter (*Ammocrypta clara*) in Pool 26 of the Mississippi River in Missouri and Illinois

John K. Tucker and Frederick A. Cronin
Illinois Natural History Survey
Long Term Resource Monitoring Program Pool 26
4134 Alby Street
Alton, Illinois 62002 USA

ABSTRACT

Two new localities from Pool 26 of the Mississippi River are reported for the western sand darter (*Ammocrypta clara*) for Missouri and Illinois. One locality is at River Mile 219.4, Perry Island, St. Charles County, Missouri; the other is at River Mile 235.0-236.0, Hat Island, Calhoun County, Illinois. Specimens were collected at the first locality in one year (1992) out of five years (1989-1993) of sampling and at the second in two years (1989, 1992) out of five. The specimens of this species accounted for 0.4% of all fish collected in 1989, and 0.07% of all fish collected in 1992. All collecting sites had a sand substrate with significant current.

INTRODUCTION

The western sand darter (*Ammocrypta clara* Jordan and Meek, 1885) is listed as endangered in Illinois (Herkert, 1993). Smith (1979) reported it from several Illinois counties and noted that it formerly occurred sparingly over the entire state except for the Wabash-Ohio drainage. He noted that the species had decreased in abundance due to habitat loss (Smith, 1979). He provided only eight relatively recent records for the species (Smith, 1979: p. 272). Herkert (1993) listed eight counties in Illinois where the species has been found since 1980. The species is uncommon in Missouri (Pflieger, 1975) but not listed as endangered or threatened.

The present distribution of *A. clara* in the Mississippi River are based on pre-1980 records. Dimmick (1988) reported on specimens from below the confluence of the Missouri and Mississippi rivers. Smith (1979) and Pflieger (1975) mapped scattered records along the Mississippi River upriver of the confluence with the Missouri River. For Pool 26 of the Mississippi River, Herkert (1993) listed Calhoun County but did not note specific localities, and the species was not reported from the county by Smith (1979). Because the distribution of this species is poorly known for Pool 26, we report localities where we collected the species between 1989 and 1994.

MATERIALS AND METHODS

We collected specimens by trawling, night electrofishing, and seining using Long Term Resource Monitoring Program (LTRMP) methods (Gutreuter et al., in press). Seines (3-mm "Ace" netting) were 10.7 m long and 1.8 m high with a 0.9-m square bag located at the center of the net. Trawls were two seam, 4.8 m wide and 4.5 m long, slingshot balloon trawls. The body of the trawl is made of #9 nylon with 18-m diameter stretch mesh. The bag contains a 1.8-m liner consisting of 3-mm diameter mesh. At each collecting site, water temperature and depth, current velocity, and conductivity were measured using LTRMP methods (Gutreuter et al., in press). For each specimen, we measured total length to the nearest 1 mm. Except for voucher specimens deposited in the collections of the Illinois Natural History Survey (INHS 33870-33876 and 60798), we released all other fish caught at the collecting sites.

RESULTS

In 1989, we collected 55 specimens (Table 1). Except for one fish trawled at the north end of Hat Island, Calhoun County, Illinois (NE1/4 sec. 17, T13S, R2W), at Mississippi River mile (MRM) 236.0, we seined all others in Hat Island side channel, Calhoun County, Illinois (NW1/4, sec. 21, T13S, R2W) at MRM 235.0. In 1992, we caught 25 specimens (Table 1). One each of these was collected by trawling off Hat Island, Calhoun County, Illinois (NW1/4 sec. 21, T13S, R2W), at MRM 235.0 and off Perry Island, St. Charles County, Missouri (NE1/4 sec. 4, T48N, R5E) at MRM 219.4. Night electrofishing at the latter location also yielded a single specimen. We collected the remaining 22 by seining. One came from the Perry Island location in Missouri, 18 from the southern end of Hat Island, Calhoun County, Illinois (NW1/4, sec. 21, T13S, R2W), and 3 from the Hat Island side channel location. None were collected in 1990, 1991, 1993, or 1994.

DISCUSSION

Although specimens have been collected in two of the six years (1989-1994) of LTRMP sampling, the species was not commonly encountered. For instance, in 1989, we collected 13,853 specimens of 47 other species, and in 1992, we caught 36,435 specimens of 66 other species. *Ammocrypta clara* thus accounted for 0.4% of all fish in 1989 and 0.07% of all fish in 1992.

In part, the rarity of the species in our collections reflects the difficulty of collecting it. The species is known to be nocturnal and presumably it buries itself in the sand during day-light hours (Smith, 1979). The fact that LTRMP sampling has produced no specimen since 1992 may reflect a decline in this species' abundance in Pool 26. However, collections in 1989 and 1992 occurred during years with relatively low water levels. Thus, we were able to sample areas not accessible by seining at normal pool levels. Therefore, the species, which is uncommon under any circumstances, could easily have been missed in the other years.

Furthermore, suitable sand habitats (Dimmick, 1988) are mostly limited to the portion of Pool 26 upriver of the mouth of the Illinois River (MRM 217). Our sampling confirms habitat descriptions published by several authors (e.g., Pflieger, 1975; Smith, 1979; Dimmick, 1988; Page and Burr, 1991). At each site, the substrate is sand with significant current velocity (Table 1). Except for three specimens, all came from main channel border sites. We found the species at shallow (0.5 m) as well as deep (8 + m) water sites. Because seining produced the bulk of the specimens (57 of 61) and is effective only in shallow water, our sampling likely underestimates the extent to which the species occurs in Pool 26.

ACKNOWLEDGMENTS

We thank M. A. Morris, R. J. Maher, B. J. Kerans, and D. W. Soergel for assistance in the field. R. J. Maher and S. Gutreuter made helpful comments on the manuscript. This work was partially supported by the Illinois Natural History Survey and the Upper Mississippi River System Long Term Resource Monitoring Program.

LITERATURE CITED

Dimmick, W. W. 1988. Discovery of the western sand darter, *Ammocrypta clara*, in the Mississippi River below the confluence of the Missouri River. Trans. Illinois State Acad. Sci. 81:211-212.

Gutreuter, S., R. Burkhardt, and K. Lubinski. in press. Chapter 1: Fish, p. 1.11.70. *In*: Procedures manual of the Long Term Resource Monitoring Program for the Upper Mississippi River System. U. S. Fish and Wildlife Service, Environmental Management Technical Center, Onalaska, Wisconsin.

Herkert, J. R. 1993. Endangered and threatened species of Illinois: Status and distribution. Volume 2 - Animals. Illinois Endangered Species Protection Board, Springfield. 142 pp.

Page, L. E., and B. M. Burr. 1991. A field guide to freshwater fishes [of] North America north of Mexico. Houghton Mifflin Co., Boston. 432 pp.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Dept. Conservation, Jefferson City. 343 pp.

Smith, P. W. 1979. The fishes of Illinois. University of Illinois Press, Urbana. 314 pp.

Table 1. Specimens of the western sand darter (*Ammocrypta clara*) collected from Mississippi River Pool 26.

Location MRM	date	water temp °C	water depth m	conductivity µmhos/cm	current velocity m/sec	n	Habitat type
235.0	8/14/89	25.6	0.5	354	0.05	54	side channel
236.0	9/20/89	19.7	8.48	369	0.31	1	channel
235.0	7/22/92	25.2	4.0	454	0.83	1	channel
219.4	8/12/92	25.0	0.5	390	0.22	1	channel border
235.5	8/12/92	28.0	0.4	407	0.11	3	side channel
219.4	8/31/92	24.0	0.4	447	0.14	1	channel border
219.4	9/29/92	18.0	4.3	426	0.85	1	channel
235.0	10/05/92	20.5	0.5	402	0.08	18	channel border

Transactions of the Illinois State Academy of Science
(1996), Volume 89, 3 and 4, pp. 225-231

Laboratory Survivorship of Aerially Exposed Pond Snails (*Physella integra*) from Illinois

John K. Tucker
Illinois Natural History Survey
Long Term Resource Monitoring Program Pool 26
4134 Alby Street
Alton, Illinois 62002, USA

Fredric J. Janzen
Department of Zoology and Genetics
Iowa State University
Ames, Iowa 50011, USA

Gary L. Paukstis
2489 Quail Court
Aurora, Illinois 60504, USA

ABSTRACT

Many aquatic snails occupy ephemeral habitats that are occasionally subjected to severe environmental conditions. To investigate the physiological capacity of these animals to resist extreme environmental changes, we aerially exposed aquatic pond snails (*Physella integra*) to temperatures of 5°C and 20°C for 6, 8, 12, 24, 36, 48, and 60 hours. Survivorship varied with temperature and exposure times. At 20°C, survivorship was 0% for snails aerially exposed for 24 hours or longer. At 5°C, 0% survivorship was attained at 60 hours exposure. Sensitivity to aerial exposure was related to shell size of individuals, with larger specimens (shell length greater than 7 mm) significantly more likely to survive exposure than smaller specimens at temperatures and intervals with incomplete mortality. These results suggest that epiphragm development and size-specific survivorship predispose these animals to rapid population recovery following severe, short-term environmental fluctuations.

INTRODUCTION

Rapid, dramatic climate change is expected by the end of the 21st century and may have a profound biological impact (reviewed by Root and Schneider, 1993). Although average global temperatures may rise as little as 1°C over the next 100 years, the most significant side effect of even the most modest change in global temperatures is increased variation in local temperatures and precipitation (Knox, 1993; Root and Schneider, 1993). This increased environmental stochasticity and its unpredictability may select strongly against organisms that cannot adapt to or avoid this rapid change (Wyman, 1991; Peters and Lovejoy, 1992; Kareiva et al., 1993).

Throughout history, of course, organisms have experienced environmental variation and basically have evolved or gone extinct in response to the most coarse-grained changes. Many taxa that survive severe environmental fluctuations possess general traits (e.g., a broad temperature tolerance) or specific adaptations (e.g., seed dormancy) (Futuyma, 1986). For example, recent extirpations of populations of the terrestrial snail *Arianta arbustorum* in Switzerland have been linked to the inability of eggs to hatch because the climate has warmed (Baur and Baur, 1993). Sympatric populations of the snail *Cepaea nemoralis*, a species with greater thermal tolerance, have not suffered the same fate. Generally, however, the ability to survive such stochastic conditions is unclear even for organisms that possess presumptive adaptations for weathering severe environmental fluctuations.

Therefore, we selected *Physella integra* (Family Physidae), a basommatophoran pulmonate snail, to investigate the extent to which such snails are able to withstand aerial exposure. This species and other species of this important North American family of aquatic snails occupy both permanent and ephemeral aquatic habitats (Clampitt, 1974; Te, 1978; Brown, 1979). This common Illinois snail is frequently found in habitats subject to drying and possesses adaptations such as greater temperature tolerance that are not present in snails occupying permanent aquatic habitats (Brown, 1979; Paukstis et al., in press). Since *P. integra* is an aquatic species, it must either possess adaptations to resist desiccation or face extirpation each time such ephemeral habitats dry. One recognizable adaptation in this species is the epiphragm, a membranous covering over the aperture formed from dried body secretions (Cheatum, 1934). An epiphragm is formed whenever the snail is exposed to air and cannot immediately return to water. The effectiveness of epiphragm formation in this species has not been investigated. Herein, we report on the abilities of Physella integra to resist desiccation when exposed to air under two temperature regimes in the laboratory.

MATERIALS AND METHODS

Physella integra were collected 6 and 11 January 1994 from a ditch near the junction of Old Poag Road and Wanda Road, SW1/4 Sec. 12, T4N, R9W, 0.3 km W of Poag, Madison County, Illinois. All experimental trials were conducted or initiated within 2 days of collection. Snails were refrigerated at 5°C prior to use. Voucher specimens are deposited in the collections of the Illinois Natural History Survey.

We gently tamped dry snails with a paper towel and randomly assigned them to experimental and control containers. Experimental and control snails were kept in open cylindrical plastic containers 21 cm in diameter and 16 cm tall. We placed experimental animals into containers so that individual snails were not in contact with each other and so that the aperture of each snail faced the bottom of the container to allow epiphragm formation. Snails remained immobile once placed into experimental containers.

Containers were then assigned to experimental treatments as follows: seven time intervals (6 hr, 8 hr, 12 hr, 24 hr, 36 hr, 48 hr, and 60 hr) completely crossed with two temperatures (5°C and 20°C). Relative humidity for the 5°C trials was 47% whereas it was 58% for the 20°C trials. Initially, we subjected two replicates of 20 snails each to each of these 14 treatments. For both temperatures, one control replicate of 20 snails each was kept in an identical container for 60 hours, but was covered by 5 cm of water from the collecting site.

After determining survivorship among treatments for this experiment, we repeated the experiment for treatments with either few survivors or few fatalities. Thus, we gathered data in a second experiment for one other replicate for the 6 and 8 hr 20°C treatment and the 8 hr 5°C treatment, two others for the 36 and 48 hr 5°C treatment, four others for the 24 hr 5°C treatment, and five others for the 12 hr 20°C and 12 hr 5°C treatments. These additional replicates were necessary to increase sample sizes sufficiently to allow statistical comparison of shell lengths among treatments with few survivors or few fatalities, while still reducing the number of snails killed to the minimum necessary to achieve statistical relevance. In the second experiment, replicate size varied from 19 to 23 snails per container. Because survivorship did not vary between the first and second experiment, results were combined. We also maintained two control replicates with one at each temperature for 60 hours during the second experiment. In all, we used a total of 1029 individual snails in the two experiments along with 80 further individuals as controls.

At the end of each time interval, the replicates for each temperature in both experiments were covered with fresh water from the collecting site. This water was either at 5°C or 20°C whichever was appropriate to match the treatment temperature. The containers were then moved to 15°C. Mortality was assessed after 12 hr at 15°C. At this time, each snail was measured to the nearest 1 mm and preserved in 70% ethanol. Snails that did not extend the body and crawl or those that failed to retract into the shell after mechanical stimulation were considered dead.

Because sample sizes were unbalanced in the combined data for the two experiments, we used statistical methods appropriate to such an unbalanced design. We used SAS (SAS Institute 1988) to perform ANOVA with the GLM procedure, correlation analysis, and regression analysis. *G* tests were used to compare survivorship of snails among treatments (Sokal and Rohlf, 1981). The *G* test evaluates the goodness of fit of the observed data relative to the expected result. The *G* test is an appropriate statistical test to apply to mortality data (Sokal and Rohlf, 1981). Values for *p* were obtained by comparing the resulting *G* value to the corresponding chi-square value using SAS functions. We used the sequential Bonferroni procedure to adjust *p* values for multiple comparisons (Rice, 1989).

RESULTS

All four controls had 100% survivorship. However, survivorship in experimental treatments varied depending on temperature and exposure time (Table 1). Survivorship of snails at 5°C was significantly greater at 6 ($G = 10.949, p < 0.001$), 8 ($G = 50.689, p < 0.001$), 12 ($G = 111.240, p < 0.001$), 24 ($G = 62.407, p < 0.001$), 36 ($G = 10.386, p < 0.002$), and 48 ($G = 4.178, p < 0.05$) hr than that of snails at 20°C for the same time intervals. No snails survived in the 24, 36, 48, and 60 hr treatments at 20°C or in the 60 hr treatment at 5°C.

Percent survivorship at 5°C was related to the duration of aerial exposure (r = -0.94997, p < 0.0001). The relationship can be expressed as % surviving = -2.16 * exposure time in hours + 110.44 (F = 240.536, p < 0.0001). At 20°C, percent survivorship was also related to duration of aerial exposure (r = -0.69613, p < 0.0002). This relationship can be expressed as % surviving = -1.07 * exposure time in hours + 49.69 (F = 19.745, p < 0.0001). The slopes of these lines differ (F = 31.05, p < 0.0001), which was consistent with G test results. Overall, survivorship decreased faster with exposure interval at 20°C than at 5°C.

Survivorship of snails was also related to shell length, with larger specimens being more likely to survive than smaller ones in any treatment with survivorship less than 100%. Mean shell length of surviving snails was significantly greater than that of snails that died (Table 1). Mean shell lengths of snails included in each treatment were not significantly different from each other (p > 0.05 in every case), indicating that the initial assignment of snails to treatments was not a factor in the results of this experiment.

Because larger specimens were more likely to survive than smaller ones, mean shell length of snails surviving and dying was related to exposure times at 5°C. The relationship (r = 0.8668, p < 0.0001) at 5°C is Mean Shell Length Survivors = 0.09 * exposure time in hours + 5.72 (F = 46.778, p < 0.0001). Exposure time was also related to mean shell length of snails that died (r = 0.72599, p < 0.0001). The relationship can be expressed as Mean Shell Length Dead = 0.09 * exposure time in hours + 3.14 (F = 24.257, p < 0.0001). At 20°C, absence of survivors in exposure times exceeding 12 hours made correlation and regression analysis meaningless (Table 1).

DISCUSSION

Cheatum (1934) described the results of an uncontrolled experiment with *Physella integra* (incorrectly identified as *Physa sayi crassa*; see Clampitt, 1974, for corrected identification of Cheatum's snails). He found that 3 of 24 (12.5%) individuals (shell length not given) survived aerial exposure from 3 July to 10 September in a shaded outdoor enclosure that was periodically sprinkled with lake water. However, in this experiment, the snails were buried to a depth of 3 cm and were not aerially exposed.

Of course, the conditions that we subjected the snails to are much harsher than those used by Cheatum (1934), and this is reflected in the relatively short time (24 to 60 h) needed to reach 100% mortality. Even so, our data suggest that *Physella integra* from Illinois is moderately resistant to desiccation even under extreme circumstances. However, it is apparently less resistant than the gastropods placed under similar conditions by Dudgeon (1982). In his dry pan experiments conducted at 24-26°C and 60-70% relative humidity, 100% mortality took from 7 days in *Thiara scabra* to 22 days in *Sinotaia quadrata.*

We also believe that our data indicate the importance of epiphragm formation in this species. Every snail tested formed an epiphragm, with the result that the aperture was firmly glued to the plastic substratum. Once wetted, survivors rapidly became mobile.

We presume that death was due to desiccation, but we cannot eliminate the possibility that oxygen deprivation was a factor as well (e.g., Dudgeon, 1982). This species and other pulmonates respire by taking air or water into the lung chamber in the mantle (Cheatum, 1934). Once the epiphragm is formed, aerobic respiration is probably precluded and the snails must respire anaerobically. Von Brand et al. (1950) reported that *Physa* (= *Physella*) *gyrina*, a species closely related to *P. integra*, could tolerate exposure to anoxic water through anaerobic metabolism for 6 hours at 30°C with 100% survivorship and with 3% survivorship after 16 hours at 30°C. Comparison of our results to those of Von Brand et al. (1950) suggest that the mortality we observed was due to water loss rather than to inability to respire anaerobically for a sufficient time interval to survive the treatment. This explanation is probably correct because the snails that Von Brand et al. (1950) exposed to anoxia but not to dehydration survived longer durations of exposure at higher temperatures as compared to our snails at 20°C.

Our results are important because they clearly indicate that larger individuals are more likely to survive relatively short periods of drying under harsh conditions than are smaller specimens (Table 1). These larger snails are more likely to be reproductive than are smaller individuals (Brown, 1979). Consequently, populations exposed to periodic drying may quickly recover because reproduction could recommence immediately.

The ecological relevance of our experiments is uncertain because field studies comparing size-specific effects of aerial exposure on aquatic mollusks are unavailable for any species of *Physella*. Our conclusion that larger individuals are more likely to survive short-term aerial exposure may be obviated if size-specific behavioral differences are present. For instance, small snails may be more likely or better able to seek shelter in cracks in the substrate or under cover objects than larger snails. Field studies of species that occupy ephemeral habitats would be necessary to evaluate the existence and importance of such behaviors. Regardless, our experimental results will be important in interpreting the ecological context of behavior of snails in the field.

The findings of our study are particularly relevant to the current debate over environmental scenarios expected under incipient global climate change. The epiphragm adaptation in *Physella* permits these aquatic snails to endure short periods of extreme dehydration, an environmental condition that may increase in frequency as global and local climates change (Root and Schneider, 1993). In this light, more experiments of the adaptive significance of traits linked to tolerance of environmental stochasticity would be valuable to conservation biologists.

ACKNOWLEDGMENTS

We thank J. B. Hatcher and M. M. Tucker for help in making collections. This work was partially supported by the Illinois Natural History Survey and the Upper Mississippi River System Long Term Resource Monitoring Program. Journal Paper No. J-16763 of the Iowa Agricultural and Home Economics Experiment Station, Ames, Iowa, Project No. 3369, and supported by the Hatch Act and State of Iowa funds.

LITERATURE CITED

Baur, B. and A. Baur. 1993. Climatic warming due to thermal radiation from an urban area as possible cause for the local extinction of a land snail. Journal of Applied Ecology 30:333-340.

Brown, K. M. 1979. The adaptive demography of four freshwater pulmonate snails. Evolution 33:417-432.

Cheatum, E. P. 1934. Limnological investigations on respiration, annual migratory cycle, and other related phenomena in fresh-water pulmonate snails. Transactions of the American Microscopical Society 53:348-407.

Clampitt, P. T. 1974. Seasonal migratory cycle and related movements of the fresh-water pulmonate snail, *Physa integra*. American Midland Naturalist 92:275-300.

Dudgeon, D. 1982. Aspects of desiccation tolerance of four species of benthic mollusca from Plover Cove Reservoir, Hong Kong. Veliger 24:267-271.

Futuyma, D. J. 1986. Evolutionary Biology, second edition. Sinauer, Sunderland, Massachusetts. 600 pp.

Kareiva, P. M., J. G. Kingsolver, and R. B. Huey. 1993. Biotic Interactions and Global Change. Sinauer, Sunderland, Massachusetts. 559 pp.

Knox, J. C. 1993. Large increases in flood magnitude in response to modest changes in climate. Nature 261:430-432.

Paukstis, G. L., F. J. Janzen, and J. K. Tucker. in press. Comparative survivorship of sympatric native North American gastropods (*Anguispira, Mesodon, Physella, Pleurocera*) and an introduced bivalve (*Dreissena*) exposed to freezing temperatures. Veliger

Peters, R. L. and T. E. Lovejoy. 1992. Global Warming and Biological Diversity. Yale University Press, New Haven, Connecticut. 386 pp.

Rice, W. R. 1989. Analyzing tables of statistical tests. Evolution 43:223- 225.

Root, T. L. and S. H. Schneider. 1993. Can large-scale climatic models be linked with multi-scale ecological studies? Conservation Biology 7:256-270.

SAS Institute 1988. SAS/STAT user's guide. SAS Institute, Cory, North Carolina. 1028 pp.

Sokal, R. R. and F. J. Rohlf. 1981. Biometry, Second edition. W. H. Freeman, New York. 859 pp.

Te, G. A. 1978. The systematics of the family Physidae (Basommatophora: Pulmonata). Ph.D. Dissertation, University of Michigan, Ann Arbor, Michigan. 325 pp.

Von Brand, T., H. D. Baernstein, and B. Mehlman. 1950. Studies on the anaerobic metabolism and the aerobic carbohydrate consumption of some fresh water snails. Biological Bulletin 98:266-276.

Wyman, R. L. 1991. Global Climatic Change and Life on Earth. Routledge, Chapman and Hall, New York. 282 pp.

Table 1. Aerial exposure of a pond snail, *Physella integra*, and its relationship to shell length of surviving and dying snails.

Treatments		Snails				Results of ANOVA	
exposure duration (hours)	temp (C°)	survivors mean shell length (mm)	n	fatalities mean shell length (mm)	n	*F*	*p*
6	5	6.20	40	------	0	------	------
8	5	6.89	56	5.25	4	10.42	< 0.0021
12	5	6.68	125	3.60	20	98.27	< 0.0001
24	5	7.68	75	5.73	45	75.25	< 0.0001
36	5	8.75	12	6.65	68	32.64	< 0.0001
48	5	10.00	3	6.67	78	32.79	< 0.0001
60	5	------	0	6.70	40	---	---
6	20	7.34	50	5.50	10	15.78	< 0.0002
8	20	7.81	21	6.10	40	33.52	< 0.0001
12	20	7.67	38	6.07	104	36.36	< 0.0001
24	20	------	0	6.88	40	------	------
36	20	------	0	6.20	40	------	------
48	20	------	0	6.89	80	------	------
60	20	------	0	6.33	40	------	------

Academy Notes

Meetings of the Academy

ILLINOIS WESLEYAN UNIVERSITY
October 18 & 19, 1996

The Importance and Value of Biological Diversity

Keynote Address

Using Marine Biodiversity Research to Establish Conservation Priorities in Coral Reef Ecosystems

by
Dr. Jim Thomas
Research Zoologist and Curator of Crustaceans
National Museum of Natural History
Smithsonian Institution

Special Symposium in Conjunction with Annual Meeting

Endangered Species / Ecosystems and Private Lands

Student Competition Award Recipients

Annual Meeting - October 1995

Cell, Molecular, and Developmental Biology Division

1st Place

Paul Vordtriede, Southern Illinois University - Edwardsville

The Construction of Binary Vectors Containing the cDNAs Coding for Human Fibrinogen

2nd Place

Paul Benson, Knox College

Messenger RNA Stability and Membrane Phospholipid Composition in Heat Stressed Barley Aleurone Cells

Teresa Veith, Knox College

Are Urns from Different Sipunculan Genera Functionally Similar? A Comparison of the Urns of *Phascolosoma perhicens* with those of *Sipunculus nudus* (Phylum Sipuncula)

1995 Science Talent Awards

Frank Reed Award

Omar Latif, Illinois Mathematics and Science Academy, Aurora, IL

Interleukin 12 Regulation in Ethanol - Consumer C57/BL6 Mice

State Winners

Tayo Akinyemi, Lincoln Park High School, Chicago, IL

Molecular Weight Determination of Siderophore Hydrase

Elizabeth Gewurz, Evanston Township High School, Evanston, IL

Mapping Impulses of Collisions of a Tennis Ball with a Racket in Order to Determine Sweetspot

Michael Adam Greene, Evanston Township High School, Evanston, IL

Evolving a Neural Network for Controlling Locomotion

Graeme Rohn, Evanston Township High School, Evanston, IL

Complex Collisions Involving Three Disks

Earl Zaromb, Illinois Mathematics and Science Academy, Aurora, IL

Theoretical Determination of the Geometrics of Ammonia Clusters

Honorable Mention

Eileen Adler, Mother Theodore Guerin High School, River Grove, IL

The Effects of Vitamins A, C, and E on *Agrobacterium tumefaciens*

Tina Cheuk, Downers Grove North High School, Downers Grove, IL

Characterization and Analysation of the Biosynthetic Pathways of Prodigiosin in *Serratia marcescens*

Bridget McNicholas, Montini Catholic High School, Lombard, IL

Composting: The Silent Recycler and Producer

Jeremiah Nehmelman, Delavan Community High School, Delavan, IL

Bioremediation: Crude as a Source of Energy for Bacterial Proliferation

Information for Contributors

Submission Information

1. Original communications may be sent to: Transactions of the Illinois State Academy of Science, Illinois State Museum, Springfield, Illinois 62706.

2. Submission of a paper to the Editors will be held to imply that it has not been published previously except in Abstract form and, if accepted, will not be published elsewhere in the same form, without written consent of the Editors.

3. The format for manuscripts should follow a form appropriate to the specific discipline; most commonly, e.g., Abstract (no more than 250 words), Introduction, Materials and Methods, Results, Discussion, and Summary.

4. Manuscripts should be typewritten, double-spaced on one side of bond paper (8.5" x 11") with a left hand margin of not less than 1.5 inch. The author must submit one original and two copies of the manuscript, and should retain a copy.

5. Tables and figures may be incorporated within the manuscript or included at the end of the manuscript. Tables must be numbered consecutively in the order in which they are referred to in the text. Likewise for figures.

6. Both genus and species must be given for all organisms used in the investigation.

7. In the text, references should be quoted by the author's name and date, e.g., (Smith, 1960). Footnotes are to be avoided.
   a. At the end of the manuscript, full references, in alphabetical order, must be listed and include the names of the authors, date of publication, full title of the paper, title of the journal, volume number, and the first and last page numbers. References to books must include the number of the edition, publisher, and place of publication.

Acceptance Information

8. Each manuscript will be reviewed by no less than two anonymous reviewers.

9. For manuscripts deemed acceptable for publication, authors must address the reviewers comments and provide a revised manuscript copy to the Editor.

Publication Information

10. Upon final acceptance of manuscripts for publication the author shall provide a computer disk and hard copy version of the manuscript to the Editor containing all text, tables, and figure headings.

11. All graphs, charts, and diagrams will be scanned directly from the author's final manuscript. Photographs and photomicrographs should be black and white glossy prints as they will be reproduced via gray-scale photo-offset. All items must be submitted in a camera ready form with appropriate legend.
    a. The entire printed area must fit within a centered 8 inch by 5 inch area, including room for figure heading. More than figure may appear on each page as long as appearance of the page is not cluttered.

12. Galley proofs will be sent to the author, first-mentioned author, or designee for correction. Corrections to the page proofs must be restricted to printer's error only. Other alterations will be charged to the author.

13. The page charge for members is $25.00 per page. The charge for non-members is doubled. Twenty-five reprints will be provided to the author by the Academy.

Transactions of the Illinois State Academy of Science
Volume 89 (1996)

CONTENTS