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Our Living Heritage: The Biological Resources of Illinois

Edited by
Lawrence M. Page
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Foreword

We live in a world of near continuous monitoring. In our automobiles we monitor the status of fuel, oil pressure, temperature, and seat belts through gauges, lights, and electronic voices. The consumption of electricity and fuel in our homes is monitored as is the chlorine in our drinking water and the alcohol in our beer. Manufacturers retain quality assurance inspectors and issue warrantees and guarantees to convince us that all is well. We monitor our schools and measure our own progress through grades and proficiency scores. It seemed appropriate, therefore, that the Illinois Natural History Survey should take a measure of the living natural resources of Illinois by bringing together a knowledgeable group of persons to summarize the state of the State. In order to share this information and to provide an opportunity for discussion, a symposium, "Our Living Heritage: The Biological Resources of Illinois," was sponsored by the Illinois Department of Energy and Natural Resources and organized by the Survey. The event, timed to coincide with Earth Day 1990 celebrations, was held on April 23 and 24 on the campus of the University of Illinois at Urbana-Champaign. It was attended by nearly 250 professional scientists from some 50 agencies and institutions along with a number of interested and dedicated citizens. To share the results of that symposium with an even larger audience, we have issued this publication of its proceedings.

To address the salient features of the living resources of Illinois in an ordered fashion, the symposium was presented in five sessions: forests, prairies and barrens, wetlands, streams and caves, and agro-urban ecology. When we consider that only 0.5% of Illinois remains in undisturbed natural areas, that Illinois ranks 46th among states in publicly owned open space per person, that forest acreage has decreased by 73% in the past century and tallgrass prairie by over 99%, that 85% of our wetlands have been lost, that soil erosion proceeds at the rate of 200 million tons per year, and that approximately 30,000 tons of herbicide and 3,500 tons of insecticides are used annually on agricultural crops in Illinois, we can scarcely imagine the tone of the symposium to have been anything but pessimistic. In part, there was discouragement, but it was tempered by positive developments, including the designation of the Middle Fork of the Vermilion River as a National Wild and Scenic River, the acquisition of the Cache River Basin, the initiation of a study to identify high-quality Illinois streams based on biodiversity, and the ever quickening actions of the Nature Preserves Commission.

Preservation/conservation has been in conflict with consumption/development since the days of Theodore Roosevelt. At times one side seems to prevail over the other, but the balance has been clearly on the side of consumption. Special interest groups have to a considerable extent managed to give the word *environmentalist* a pejorative cast and the word *development* a positive ring. During the past decade, the executive branch of the federal government has determinedly downplayed environmental concerns, and that stance has been translated into inertia in a number of federal agencies with responsibility for natural resources. The focus of the United States Environmental Protection Agency, for example, has until very recently ignored the living components of the environment. At the same time, public sensitivity to environmental concerns has dramatically increased, primarily through public service television and other media-generated presentations on tropical deforestation, extinction of species, depletion of the ozone layer, agro-chemical contamination of groundwater, and the effects of acid rain. Some of this concern is now being transformed into political action. Polls suggest that the public understanding of environmental matters is quite high, and some believe that it exceeds the perceptions of elected officials. A Green Party has emerged in this country only very recently, but Greens are a part of both major political parties and the trend in federal legislation may soon begin to sway in favor of conservation/preservation and away from consumption/development. The National Institutes for the Environment may well become a reality within the next several years. Within this tentatively encouraging national picture, the symposium was timely indeed.

One symposium event of special interest cannot be documented in these proceedings—the "citizens respond" program of Monday evening, April 23—and I would like to note it here. Michael Jeffords and Susan Post of the Survey opened that session with a mulitmedia presentation on the biodiversity of Illinois. Their slides of representative plants and animals and habitats of the natural divisions of Illinois brought home to us the beauty and fragility that can yet be discovered in the landscape of our state. A panel presentation by five environmental activists followed: Clark Bullard, Office of Energy Research at the University of Illinois at Urbana-Champaign; Max Hutchison, Natural Land Institute of The Nature Conservancy; Lawrence Page of the Illinois Natural History Survey; Donna Prevedell, farmwife and contributing editor to the *Progressive Farmer*; and Michael Reuter, Volunteer Stewardship Network of The Nature Conservancy. They spoke briefly but openly on preservation activities in which they had been closely involved. The discussion was then turned over to the audience, who asked questions and shared their experiences—successes and failures—with preservation efforts.

I urge you to read on in order to understand the status of the biological resources of Illinois and to appreciate how much remains to be accomplished to secure their future—and ours. I would be remiss, however, if I did not conclude by acknowledging the committee of Survey staff who planned and conducted the symposium: Lawrence Page, Michael Jeffords, Joyce Hofmann, Susan Post, Louis Iverson, and Audrey Hodgins. Their efforts included developing the program, arranging for speakers and facilities, producing and mailing promotional materials, and welcoming the audience. Without their enthusiasm and hard work, the symposium would not have materialized and our understanding of the biological resources of Illinois would be much diminished.

Lorin I. Nevling, Chief
Illinois Natural History Survey

Contents

Introduction

The term *biodiversity* has not yet made its way into most dictionaries, but the word is generally accepted to mean the organisms that inhabit the Earth and the ecosystems in which they live. Lying at the junction of the eastern forest, western great plain, southern coastal plain, Ozark uplift, and northern forest biomes, Illinois provides habitat for an extremely varied native flora and fauna. Scientists at the Illinois Natural History Survey recently compiled data on the biodiversity of Illinois and conservatively estimated that more than 53,000 species are native to the state (Appendix I). The largest groups are insects with about 17,000 species and fungi with about 20,000 species. In addition, Illinois is home to 2,068 species of vascular plants and 649 species of vertebrates (mammals, birds, reptiles, amphibians, and fishes).

The biodiversity of Illinois is more readily appreciated when it is compared to that of other regions. Consider, for example, that the Pine Hills–LaRue Swamp region of southwestern Illinois contains about 1,000 native species of plants. The Great Smoky Mountains National Park, an area of wilderness about 260 times larger, contains only 1,200 native plant species. That same region of southwestern Illinois also has more amphibian and reptile species (61) than are found in any region of comparable size in the United States. Perhaps equally surprising, one-fourth of all the freshwater fishes and mussels of North America north of Mexico are found in Illinois.

The destruction of tropical rainforests, which are thought to contain over half the total species of organisms, has been widely publicized, but all ecosystems are threatened as human populations and their support systems expand. Illinois, one of the most altered regions on Earth, is experiencing an ongoing and accelerating loss in variety as well as absolute numbers of organisms. At least 115 species are known to have been extirpated in recent decades (Appendix I), and another 497 are officially listed in Illinois as threatened or endangered. Unless circumstances change dramatically, Illinois will soon have lost 1 in 5 of its native species of fishes, 1 in 5 of its native flowering plants, 1 in 5 of its native birds, 1 in 4 of its native mammals, and a startling one-half of its native freshwater mussels!

Historical accounts of Illinois noted huge trees, vast grasslands, and extensive wetlands. Illinois was chiefly a combination of flat, mesic, "marshy" prairies and forested hilly country. Interspersed in these habitats were sand dunes, bogs, fens, sedge meadows, savannas, and swamps. Unfortunately, little of that original landscape remains. In fact, Illinois ranks an unenviable 49th among states in the percentage of natural areas surviving. Of the original 22 million acres of prairie, only 2,300 acres (0.01%) remain. Of the 14 million acres of forest present in Illinois in 1820, only 13,500 acres of primary (undisturbed) forest survive (0.10%). Many of our wetlands have been, and continue to be, drained before they can be biologically inventoried and their value determined. Our streams are polluted and increasingly degraded by the influx of soil from surrounding farmland. A significant portion of the biodiversity of Illinois will soon disappear unless the remaining species-rich areas are protected.

Several factors contribute to the global loss of biodiversity: the explosive growth of the human population, widespread and extreme poverty and malnutrition, and a notable lack of sustainable, productive agricultural and forest systems in many regions of the world. This loss is of paramount importance because human existence depends on the biological resources of the planet. Our prosperity and well-being are based largely on our ability to take advantage of the properties of plants, animals, and microorganisms for food, clothing, medicine, and shelter. As species are lost, we reduce our options for future development of vital commodities. As habitats and ecosystems are lost, we lose the recreational potential of wild places, and we disturb the balance of atmospheric gases, including oxygen, carbon dioxide, and ozone. Although the link between biodiversity and human survival is clear, we must also learn to value the biodiversity of our planet and state for its own sake, quite apart from direct benefits to us.

The loss of biodiversity is a global problem, but the loss of Illinois biodiversity is of special concern to Illinoisans. In our state, the major cause of the loss of species is the destruction and degradation of habitat. The anthropogenic changes associated with agriculture and urbanization cause environmental degradation and lead to the extinction of species. If the loss of its native biodiversity is not halted, Illinois could become a biological desert unable to respond to the need for new products and incapable of developing resource-based solutions to human problems. At issue is how we will protect the natural habitats that remain, restore some of the natural areas that have been lost, and balance the protection of biodiversity against conflicting social and economic interests. If we are to make informed decisions, we must first complete the following tasks.

Inventory the biological resources of Illinois. Our knowledge about the biodiversity of Illinois is incomplete. This lack of information hampers our ability to estimate the size and nature of the problem and to recommend remedial measures. We are unable to identify all the biological resources at risk because no inventory of all life forms exists. Although our knowledge of some taxa is extensive, other groups are largely unknown. Species are lost before they are discovered and studied. Even in groups that are well studied (e.g., birds and fishes), changes are occurring so rapidly that additional data are needed if wise decisions relative to development and management are to be made.

Develop the scientific base on which the emerging fields of conservation biology, restoration ecology, and environmental management can be built. Recent global and regional environmental changes and the inevitability of future modifications underscore the need for prudent decisions regarding the protection and use of natural resources. Indices are needed that will enable us to compare habitats and select outstanding natural areas for management and protection.

Educate Illinoisans regarding the importance of biological diversity. Biodiversity is of particular interest to biologists and ecologists, but all citizens must be informed about the global biodiversity crisis if protective legislation is to be enacted and funding ensured.

Encourage socio-economic research related to the wise use of biodiversity. We need theoretical and empirical studies on the economic and social causes of the biodiversity crisis, its consequences, and its remedies.

Sponsored by the Department of Energy and Natural Resources and the Illinois Natural History Survey, the symposium "Our Living Heritage: The Biological Resources of Illinois" was held in celebration of Earth Day 1990 on the Urbana-Champaign Campus of the University of Illinois. Two days, April 23 and 24, were spent reviewing present information about the biodiversity of Illinois and identifying actions necessary to understand and conserve the remaining resources of our state. Sessions were arranged by ecosystem (forests, prairies and barrens, wetlands, streams, caves, and agro-urban habitat), and contributors discussed what is known about how these ecosystems function, how they have been modified, and how various decisions are likely to affect their survival. The proceedings that follow summarize information on the biodiversity of Illinois and suggest where additional research is needed. Nineteen of the twenty-two presentations delivered at the symposium are included here, either as abstracts or papers.

Although the audience agreed that more information on certain subjects and groups of organisms is needed, they also acknowledged that we know enough to conclude that we have already drastically altered most of our native landscape and that we are rapidly losing native species. Without greater protection and more extensive management of natural areas, the loss of habitats and species can only accelerate.

Session One: Forests

Like the first farmsteads, towns of the frontier were built in stumpland meadows. The trees were gone. The civic landscapes sweltered in the sun. Never so quick an afterthought: fast-growing black locust trees were imported and planted everywhere, from college campuses to courthouse squares, to provide a promise of shade. What irony—the sons of the world's most incredible axemen planting seedlings in the shadow of stumps five feet across.—Robert O. Petty

In 1820, approximately 13.8 million acres of Illinois were forested. The midcontinental location of the state and its north to south distance of nearly 400 miles allowed an unusual variety of forest types to exist. The presettlement forests of Jo Daviess County covered nearly 80% of the land surface and were noted for their rugged topography and the presence of Pleistocene relic species. In 1830, a U.S. Government geologist surveying the Grand Prairie Division in central Illinois observed, "Sometimes the woodland extends along this river for miles continuously, again it stretches in a wide belt off into the country, marking the course of some tributary streams, and sometimes in vast groves of several miles in extent, standing alone, like islands in the wilderness of grass and flowers." Robert Ridgway, a Smithsonian naturalist, noted the immense size and diversity of the trees along the lower Wabash Valley in the 1870s. With photographs and measurements, he documented the extraordinary nature of the bottomlands. In the Shawnee Hills the relatively broad, flat-bottomed ravines, originally cut by the melt-waters of the Illinoian glacier, were verdant, damp jungles filled with trees—beech, sugar maple, and tulip—that reached and overtopped the sandstone bluffs. South of the Shawnee Hills the terrain flattened and a distinctly southern forest grew in the past and present Ohio River valleys. Great expanses of bald cypress–water tupelo swamps filled the lowlands along the Cache and Ohio rivers. Rare species like willow oak, silverbell, water hickory, and American chestnut occupied river terraces, flatwoods, and ravines.

We know of these magnificent forests for several reasons. Early settlers to Illinois, while greatly impressed with the vast expanse of prairie, chose to live in the woodlands, a landscape with which Europeans felt more familiar. Thus the nature of these forests came to be better documented than that of other landscape types. In addition, early biologists like Ridgway and the St. Louis physician George Engelmann described the presettlement condition of Illinois forests in considerable detail.

To begin to understand the current condition of Illinois forests we must reflect upon their past and on what has been lost. Robert Ridgway, writing in the *American Naturalist* in the 1870s, described the forests along the Wabash River. "If the forest is viewed from a high bluff, it presents the appearance of a compact, level sea of green, apparently endless . . . the tree-tops swaying with the passing breeze, and the general level broken by occasional giant trees which rear their massive heads so as to overlook the surrounding miles of forest . . . while the occasional, and by no means infrequent, 'monarchs' which often tower apparently for one-third their height above the tree-top line, attain an altitude of more than one hundred and eighty feet, or approach two hundred feet." In the visitor center of Beall Woods, an Illinois Nature Preserve in Wabash County, an immense yellow outline painted on the floor represents one of these last great trees. The circle is seventeen feet in diameter.

Today nearly 4.3 million acres of trees can be found in Illinois, not too startling a decline in acreage from 1820 if we consider the agricultural and urban development that now blankets the state. Lest we are too complacent, however, we should recall that much of the forest acreage of today is second- or third-growth timber or pine plantations; only 13,500 acres of relatively undisturbed forests remain—a shockingly small percentage of our rich, forested heritage. Fortunately, fragments remain of nearly all forest types found in presettlement times and these, in conjunction with land survey records, early written accounts, and good biological detective work, allow us to mentally reconstruct, and sometimes physically restore, the various forest habitats. These efforts, to some extent, provide a glimpse of what was once Illinois.

The three papers given at this session help us to conceptualize the forests that were once so integral to the Illinois landscape and to understand how the forests that exist today came to be. In addition, they enable us to appreciate the role that forests play in the economy of the state, in preserving biodiversity and habitat for wildlife, in controlling erosion and improving the quality of surface water, and in conserving energy and slowing global warming.

Forest Resources of Illinois: What Do We Have and What Are They Doing for Us?

Louis R. Iverson, Illinois Natural History Survey

Forests occupy only a relatively small proportion (12%) of the land area of Illinois (Figure 1), yet they provide tremendous benefits to the citizens of the state. We need only walk through the woods to be aware of some of these benefits: aesthetic beauty, habitat for specialized plants and for birds and other wildlife, recreational opportunities, and high-quality hardwood. The more subtle but equally important benefits that forest ecosystems provide, however, are not so readily perceived. Forested acres, for example, dramatically inhibit soil erosion, thereby reducing the sediment load that eventually finds its way into our water courses; no forest benefit is more important when we consider that 3.3 pounds of soil are lost for each pound of grain produced in Illinois (Iverson et al. 1989). Global warming, due largely to the excessive buildup of carbon dioxide in the atmosphere, is also counteracted to some degree by our forests because plants convert tremendous quantities of carbon dioxide into plant tissue and oxygen each day. Then too, our forests contribute greatly to the maintenance of biological diversity, a benefit of crucial importance in Illinois where the landscape is dominated by a row-crop monoculture.

The purpose of this paper is to review the historic trends that shaped the Illinois forest, to document its present status, and to summarize the benefits it currently provides. The material is largely condensed from a more detailed and complete document, *Forest Resources of Illinois: An Atlas and Analysis of Spatial and Temporal Trends* (Iverson et al. 1989). Readers are encouraged to consult that book and the map (Iverson and Joselyn 1990) that accompanies it for a great deal more information regarding the forests of Illinois, including data specific to the counties in which they may be particularly interested. Both the book and map are available as Special Publication 11 from the Illinois Natural History Survey.

Much of the story of the Illinois forests can be understood by comparing the earliest systematic vegetation data available for the state, data recovered from the original land surveys made during the first half of the nineteenth century, with recent land-use information taken via remote sensing from airplanes and satellites.

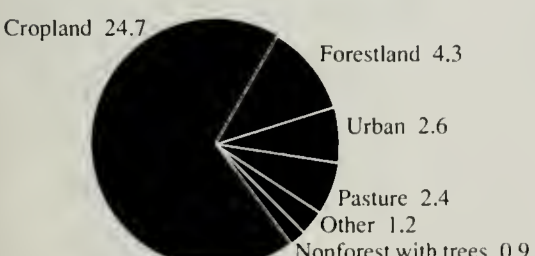

Figure 1. Major land use in Illinois in millions of acres, 1985. Total acres in Illinois = 36,061,000. Source: Hahn 1987.

FORESTS OF 1820

Illinois was surveyed by the United States General Land Office between 1807 and 1844. Starting from southern Illinois and working northward, surveyors divided the land into townships and sections, prepared plat maps, and made notes on the vegetation they encountered. These records provide a fairly complete picture of the landscape prior to the massive disturbance caused by European settlement. Anderson (1970) published a map showing the statewide distribution of forest and prairie as deduced from these data (Figure 2). Large expanses of forest existed, primarily in the south and west. Approximately 38.2% of the state (13.8 million acres) was forested at the time of the European settlement, 61.2% was prairie, and 0.6% was water. Fifteen counties were at least 80% forested, and only 21 counties had less than 20% forest cover.

FOREST TRENDS 1820–1980

Illinois forests have undergone drastic changes in the decades since European settlement. Only 31% of the forest area present in 1820 exists today (Figure 3). The lowest percentage of forest occurred about 1920 when only 22% of the land forested in 1820 remained in forest (Telford 1926; U.S. Forest Service 1949; Essex and Gansner 1965; Hahn 1987). Although forest area has increased in recent decades, most of today's forest is secondary forest, and only about 11,600 acres exist in a relatively undisturbed condition (Illinois Natural Areas Inventory as reported in Iverson et al. 1989). Illinois ranks 49th, next to Iowa, in percent of the state converted from its "potential" vegetation type (Küchler 1964); only 11 percent of the state remains in its "potential" vegetation type and essentially all of that is forest (Klopatek et al. 1979).

The pattern of deforestation of the primary (i.e., "virgin") forests of Illinois can be deduced to some degree by relying on estimates of forestland in 1820 and 1924 and on other written accounts (especially Telford 1926). From initial settlement in the early 1800s to 1860, agriculture was the only important industry associated with wooded lands. Until 1830, forests were the sole source of potential agricultural land; however, when settlers realized that the prairies made good cropland and after the invention of the moldboard plow, the prairies were converted to cropland at an astonishing rate of approximately 3.3% per year (Table 1). Over 300,000 people settled the prairies during the decade of the 1830s, and this burgeoning population created an enormous demand for housing material, fuel, and fence posts. Railways were not yet in place to import lumber, and most of the timber in the prairie counties rapidly disappeared.

Figure 2. Forests in Illinois about 1820. Source: Anderson 1970.

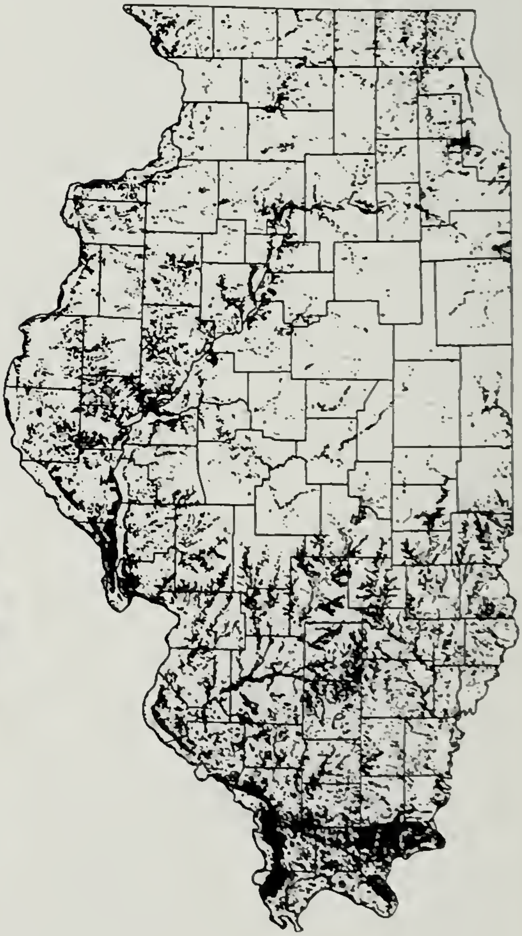

Figure 3. Forests in Illinois about 1980. Source: U.S. Geological Survey land-use data, 1973–1981.

By 1860, a timber industry had begun to flourish in Illinois. Ninety-two of the 102 counties had industries based on wood products by 1870, and forestland had dwindled to 6.02 million acres (Telford 1926). During the 1880s, annual lumber production exceeded 350 million board feet, 2.2 times the present production, and continued to increase until 1900, when it began to decrease as the resource itself declined. By 1923, only 22,000 acres of the original 13.8 million acres of primary forest remained.

A useful comparison can be made between deforestation in Illinois in the nineteenth century and the deforestation presently under way in the tropics. The primary forests of Illinois went from 13.8 million acres in about 1820 to 6 million acres in about 1870, to 22,000 acres in about 1920 (Figure 4), an overall deforestation rate of 1% per year (1.13% of the original primary forest lost during the first half of the century, 0.87% during the second half). Deforestation rates, however, were not a constant during the period and probably followed a curve such as that shown in Figure 5, with maximum deforestation in the late 1800s. Rates of deforestation have also been compiled for Rondônia in Brazil (Malingreau and Tucker 1988), for Costa Rica (Sader and Joyce 1988), and for Malaysia (Iverson et al. 1990) and are shown in Table 1. The fastest rate, 2.47% annually, was found from 1972 to 1982 in peninsular Malaysia, even though more forestland was being removed in Rondônia. This rate was probably equaled in Illinois in the late 1800s (Figure 5). A similar curve is currently found in the other countries, with Malaysia at the apex of the curve, Rôndonia on the upward slope with increasing rates, and Costa Rica on the downward slope with a declining resource and a dropping rate. History does indeed repeat itself, and we Americans should acknowledge our own history of deforestation as we now attempt to curb the destruction of tropical forests.

FOREST TRENDS 1962–1985

Forest area increased by 10% from 1962 through 1985, from 3.87 to 4.26 million acres. This increase is partially explained by the reduced number of cattle raised in Illinois and the conversion of pastures and hayland to secondary forest. Total net volume of growing stock has also increased 40% since 1962 (Table 2). Pine plantations have shown the highest percentage of increase in volume (up to 375%), but the largest absolute increase in volume was shown by oaks (an increase of 0.64 million cubic feet).

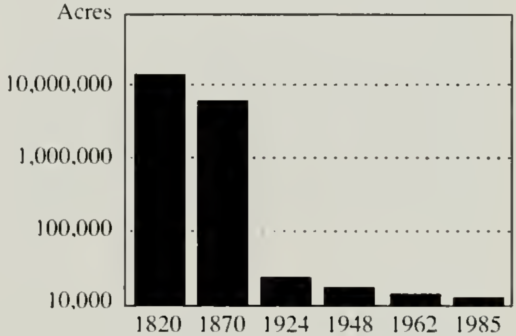

Figure 4. Extent of Illinois primary forests, 1820–1985. Interpreted from Telford 1926; U.S. Forest Service 1949; and Anderson 1970.

Table 1. Recent rates of land clearing in three tropical countries compared with rates of land clearing in Illinois from 1820 to 1923.

Location	Land use	Year	Sq km of land	Percent cleared per year
Rondônia, Brazil	Forest	1978	239,800	
		1987	208,000	1.47
Malaysia	Forest	1972	48,970	
		1982	36,870	2.47
Costa Rica	Forest	1940	34,210	
		1983	8,710	1.73
Illinois	Forest	1820	55,870	
		1870	24,290	1.13
		1923	90	0.87
Illinois	Prairie	1830	87,550	
		1860	10	3.33

Compositional changes during 1962–1985 were especially profound, with vast percentage increases in commercial acreage of white, red, and jack pines, oak–gum–cypress, and especially maple–beech forest types (Figure 6). Maples increased 41-fold in the past 25 years—from 0.025 million acres to 1.046 million acres! Concomitantly, oak–hickory decreased by 337,000 acres (14%), and over half of the state's elm–ash–soft maple disappeared. The loss of oak–hickory is largely from maple "take-over" as shade-tolerant maples replace oak–hickory stands following mortality or harvest. A documented case of the maple take-over of a forest in east-central Illinois is presented later in these proceedings (Ebinger and McClain, page 375) and elsewhere (Ebinger 1986). The reduction of elm–ash–soft maple is due to mortality from Dutch elm disease and the conversion to cropland of bottomland forests that once supported this forest type. These data make clear that although forest acreage and volume have increased since 1962, the quality and value of the timber resource has diminished, at least by today's standards. Maple-dominated forests also support a somewhat different array of wildlife than that supported by oak-dominated forests, and such "hard mast" (acorns and hickory nuts) feeders as squirrels and woodpeckers are less abundant in maple-dominated forests.

ILLINOIS FORESTS TODAY

A closer look at the current status of the Illinois forests reveals some interesting and on occasion surprising information.

Area

Estimates of current forestland compiled from the 1985 U.S. Forest Service inventory indicate that about 12% (4.27 million acres) of the land area of Illinois is forested (Hahn 1987). The extent of this forestland can be seen in Figure 3 (as well as in several forms on the 1:500,000 scale map of Iverson and Joselyn 1990). The importance of the southern and western counties is clear. At one extreme is Ford County with only 3,000 acres of forestland; at the other is Pope County with 149,200 acres, Jackson with 134,500, and Pike with 122,500. Included in this 4.27 million acres are 4,029,900 acres of commercial (capable of and potentially available to produce commercially valuable trees) forestland and 235,600 acres of reserved or protected timberland.

Wooded strips less than 120 feet wide and land on which at least one tree (5 inches in diameter at breast height) occurs per acre make up a category that has been designated "nonforestland with trees." Included in this category are wooded strips (178,500 acres), wooded pastures (162,400), urban and other built-up land (139,500), windbreaks (133,100), improved pastureland with trees (103,600), urban forest (102,800), and several miscellaneous classes. Taken together, 900,800 acres of nonforestland with trees are found in Illinois.

Composition

The composition of many Illinois forests has changed over the past several decades. Today, about one-half of the commercial forest acreage

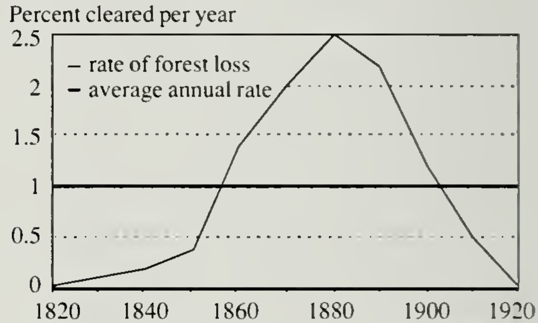

Figure 5. Rate of forest clearing in Illinois, 1840–1920. Interpreted from Telford 1926; U.S. Forest Service 1949; and Anderson 1970.

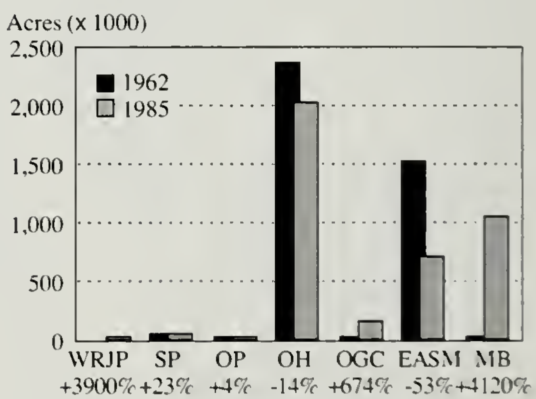

Figure 6. Composition of Illinois commercial forests, 1962–1985. Percent change is given below each pair of bars. Abbreviations are decoded as follows: WRJP = white–red–jack pine, SP = shortleaf pine, OP = oak–pine, OH = oak–hickory, OGC = oak–gum–cypress, EASM = elm–ash–soft maple, MB = maple–beech. Source: Hahn 1987.

Table 2. Net volume of growing stock on commercial forestland in Illinois by species group for 1962 and 1985, percent change between those dates, and net annual growth estimated from 1985 data.

Species group	1962 (thousand cubic feet)	1985 (thousand cubic feet)	Percent change	Net annual growth (thousand cubic feet)
Softwoods				
Loblolly–shortleaf pine	15,200	64,700	+327	1,891
White pine[1]	—	16,800	—	393
Red pine[1]	—	12,000	—	310
Eastern red cedar	2,400	11,400	+375	445
Bald cypress	6,800	8,900	+31	13
Jack pine[1]	—	700	—	36
Other softwoods	700	3,000	+329	110
Total	25,100	117,500	+368	3,224
Hardwoods				
Red oak	701,800	1,062,400	+51	18,352
White oak	739,700	1,017,600	+38	15,075
Hickory	343,900	522,500	+52	7,443
Soft maple	259,200	341,600	+32	14,144
Elm	367,700	267,400	-27	-5,106
Green–white–black ash	218,200	261,000	+20	6,932
Hard maple	99,800	163,100	+63	3,717
Cottonwood	114,100	157,800	+38	1,976
Sycamore	123,300	134,600	+9	2,412
Black walnut	77,500	119,100	+54	2,279
Hackberry[2]	—	93,500	—	5,683
Black cherry[2]	—	87,700	—	3,663
Basswood	25,800	54,100	+110	1,215
Yellow poplar	26,400	51,800	+96	1,609
Willow[2]	—	50,300	—	1,427
Sweetgum	58,600	45,100	-23	1,163
River birch[2]	—	36,800	—	1,257
Tupelo	13,900	28,000	+101	209
Beech	14,500	12,100	-17	242
Butternut[2]	—	5,700	—	105
Aspen	9,100	1,900	-79	28
Other hardwoods	223,100	203,500	-9	8,966
Total	3,416,600	4,717,600	+38	92,791
Total all species	3,441,700	4,835,100	+40	96,015

[1] Tabulated only in 1985 survey, included with other softwoods in 1962.
[2] Tabulated only in 1985 survey, included with other hardwoods in 1962.
Source: Hahn 1987; reprinted from Iverson et al. 1989.

(2.03 million acres) is oak–hickory, one-fourth is maple–beech (1.05 million acres, almost exclusively sugar maple), and one-sixth is elm–ash–soft maple (0.72 million acres) (Figure 6). Together, the remaining forest types (white–red–jack pine, loblolly–shortleaf pine, oak–pine, and oak–gum–cypress) account for an additional 216,800 acres of commercial forestland.

The location of these various forest types has been mapped (Iverson et al. 1989; Iverson and Joselyn 1990). Oak–hickory is found throughout the state with maximum levels in the western and southern counties. Maple–beech, a forest type also found throughout Illinois, has the highest average number of acres per county in western Illinois but is proportionally most prominent in the central Grand Prairie counties. Elm–ash–soft maple is found in bottomland forests, and these forests are more frequently located in the southern counties. Oak–pine, oak–gum–cypress, and shortleaf pine types are confined to the southern counties, but the white pine type is most common in the western part of the state.

According to the Illinois Plant Information Network (Iverson and Ketzner 1988), 508 woody taxa have been recorded in Illinois, a high diversity of woody plant species considering the extensive agricultural acreage. Trees account for 261 taxa, shrubs 284, and lianas 47 (some taxa include more than one type). These woody plants account for a diversity of cover types and occupy a variety of habitats. On average, 70 tree taxa and 54 shrub taxa have been recorded from each county (Iverson et al. 1989). Southern counties have the largest number of tree taxa (Jackson has 145 taxa, Pope 129, and Union 128), and northeastern counties have the most shrub taxa (Cook has 153 and Lake 136).

Volume, Annual Growth, and Number

Net volume estimates for 1985 showed the prominence of oak and hickory in commercial forests, with considerable amounts of ash, black walnut, cottonwood, elm, maple, and sycamore as well (Figure 7). The data shown in Figure 7 may have greater immediacy if we consider that 1 million board feet provide enough lumber to build an estimated 73 wood houses. The total net volume of Illinois timber in 1985—17.5 billion board feet—would theoretically build 1.3 million wood houses!

Total net volume estimates of growing stock were 4.8 billion cubic feet, an average of 47.4 million cubic feet per county or 1,200 cubic feet per acre of commercial forestland in the state. Hard hardwoods (predominately oak, hickory, and ash) accounted for 68% of total volume; soft hardwoods (e.g., elm and soft maple) accounted for 30% and softwoods (e.g., pine) made up 2%.

According to annual growth estimates for 1985 (Hahn 1987), growing stock showed 96 million cubic feet of growth, or 437 million board feet of sawtimber growth. Over 42% of net annual sawtimber growth was accounted for by oaks, with another 10% from soft maple, 6.3% from ashes, 3.7% from black cherry, 3.3% from hard maple, and 3.2% from black walnut. Only elm and black ash showed negative growth rates between 1962 and 1985, and these are attributed to Dutch elm disease and the clearing of bottomlands.

The estimated number of trees in Illinois commercial forests revealed a somewhat surprising statistic: the elms, with 344 million trees, were the most common group. Most of these, however, are small slippery (or red) elms with little commercial value (Figure 8). Overall, white oaks (99 million), red oaks (136 million), hickories (185 million), hard maples (117 million), and soft maples (91 million) were very abundant.

Age

Illinois forests are reasonably well distributed among age classes, with 61-year to 80-year classes most prevalent; however, certain trends appear when the ages of major forest types are considered (Figure 9). Oak–hickory forests show a very uneven age distribution, with the majority older than 60 years. A predominance of maple–beech is found in younger age classes (<30 years) relative to oak–hickory and elm–ash–soft maple. This pattern again illustrates, as it did in the data on acreage trends (Figure 6), two important aspects of Illinois forests today: maples are rapidly increasing in younger age classes and forest types dominated by oaks and elms are declining and have relatively fewer trees in younger age classes. Among the other forest types, white

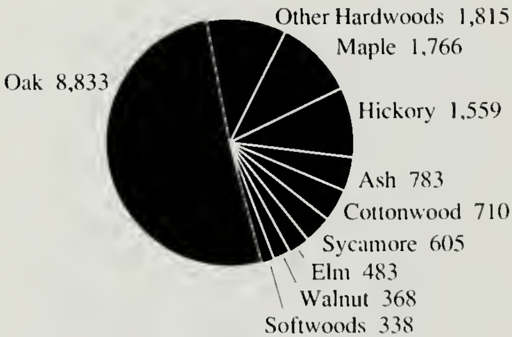

Figure 7. Total volume of Illinois commercial forestland in 1985 in million board feet. Total net volume of sawtimber was 17.5 billion board feet. Source: Hahn 1987.

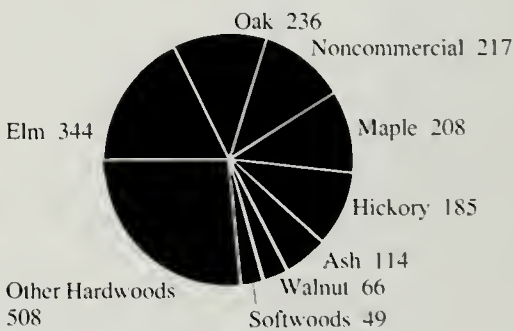

Figure 8. Number of live trees in 1985 in Illinois commercial forestland in millions of trees. Total number of trees was 1.93 billion. Source: Hahn 1987.

and shortleaf–loblolly pine peak in the 21- to 30-year class with very little stand acreage under 10 years of age. Pine plantations are no longer being planted to the extent they were from 1930 to 1960, primarily because of changes in the management of the Shawnee National Forest (U.S. Forest Service 1986).

Site

Forest stands can also be classified according to an index that measures the quality of a site based on the height its trees attain after 50 years of growth. The soils of Illinois are superior for forest growth compared to the relatively shallow or infertile soils of neighboring states like Missouri or Kentucky. According to this index, fully 84% of the trees in the commercial forestlands of Illinois are capable of supporting growth of 61 to more than 100 feet during a 50-year interval.

Mortality

In 1985, the forests of Illinois experienced an annual mortality of over 200 million board feet of sawtimber (67 million cubic feet of growing stock) (Hahn 1987). In contrast, 161 million board feet of timber were cut in 1983 (Blyth et al. 1987); at that time, therefore, more timber was dying than was being cut. These mortality data represent an annual death rate of 1.36% of the total inventory and 69% of the annual growth of growing stock. These rates are quite high in comparison to the mortality rate (0.9%) in Illinois in 1962 and to rates in neighboring states—central Wisconsin, for example, had an average mortality rate of only 0.8% of its total inventory in 1983 (Raile and Leatherberry 1988). The Illinois secondary forests are aging, with concomitant increasing mortality. Disease accounted for 38% of the mortality, but weather, suppression, and unknown causes were also important (Hahn 1987). Elms suffered the greatest mortality and accounted for 26% of total mortality; 56% of the elm mortality was due to disease.

Ownership

Over 90% (3.64 million acres) of the commercial forests in Illinois are privately owned, mostly by farmers (45.3%) and other individuals (38.1%) (Figure 10). The remaining 10% is publicly owned, primarily by the federal government (7.2%) in the form of the Shawnee National Forest. The Cooperative Extension Service of the U.S. Department of Agriculture estimated that Illinois had 169,073 private

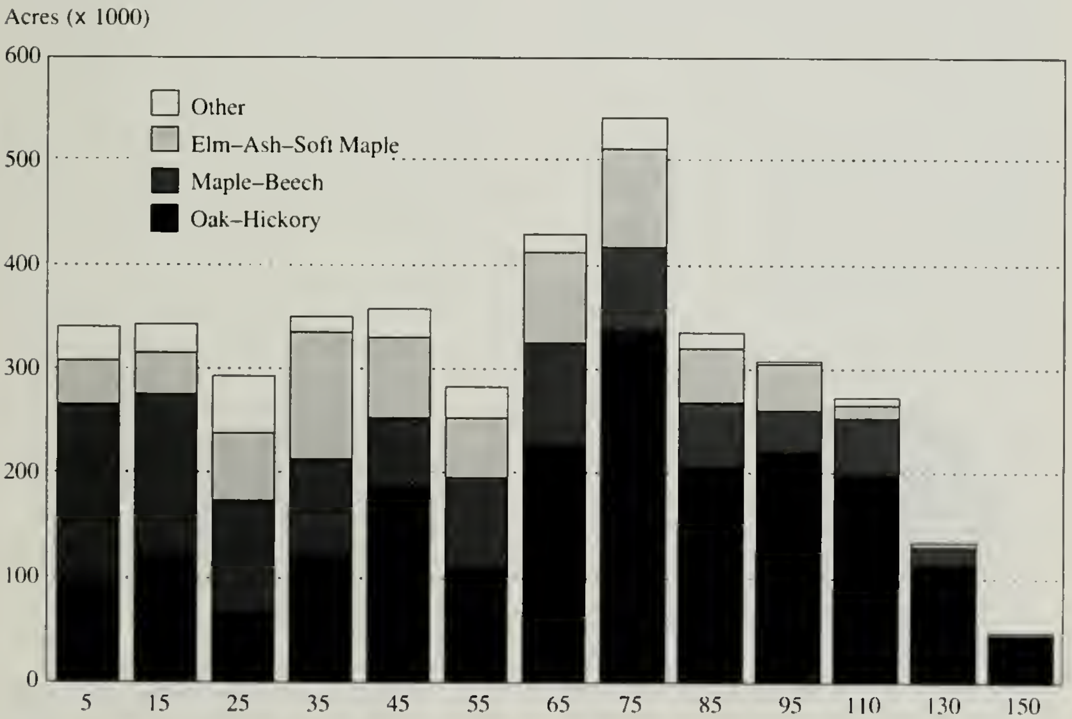

Figure 9. Acreage by age classes (in years) of the three major forest types in Illinois in 1985. Source: Hahn 1987.

forestland owners, each of whom owned an average of 21.5 acres of forest. The primary reasons for forest ownership given by the holders of small parcels were wildlife habitat and aesthetic value (Young et al. 1984); income was of greater importance for those who owned large forest parcels (McCurdy and Mercker 1986).

BENEFITS OF ILLINOIS FORESTS

Although Illinoisans would undoubtedly respond in different ways if queried on the benefits of the forests of our state, probably none of them would be in error. The forests of Illinois truly offer multiple benefits and perhaps one of the most encouraging aspects of management is that plans can be designed to accommodate and enhance these varied benefits.

Natural Communities

In the late 1970s, a search for natural communities relatively undisturbed by human activity was undertaken throughout the state (White 1978). Of the 1,089 natural areas selected for inclusion in the Natural Areas Inventory, 392 (36%) contained forestland; however, only 149 natural areas, a mere 11,593 acres of forestland, were classified as Grade A (relatively undisturbed) or Grade B (some disturbance). Of that total, about a third was classified as Grade A. Since that inventory, a few additional high-quality sites have been added, for a total of 157 areas from 62 counties. Lake and St. Clair counties contain the largest number of forested natural areas (12 and 11, respectively); Peoria has 7, Washington and Mason 6 each, and Massac 5. Adams County has the most extensive acreage of high-quality forestland, 1,950 acres, followed by St. Clair (963 acres), Lake (635 acres), Johnson (622 acres), McLean (450 acres), Saline (447 acres), Cook (444 acres), and Pike (431 acres).

Many high-quality forests in Illinois are undergoing degradation because of the invasion of exotic plants. Over much of the state, forests are threatened by garlic mustard (*Alliaria petiolata*), Amur honeysuckle (*Lonicera maackii*), tatarian honeysuckle (*L. tatarica*), Japanese honeysuckle (*L. japonicus*), multiflora rose (*Rosa multiflora*), autumn olive (*Elaeagnus umbellata*), and other introduced species. These exotics reduce the diversity of forest communities by eliminating native understory species. Management strategies must be adopted within the few remaining high-quality forests if they are to be protected from aggressive species. Control measures include recruiting volunteers for hand weeding, the cautious application of pesticides, and the implementation of biological controls. Perhaps most important is an educational program to teach the public how to identify and control these dangerous invaders.

Botanical Diversity

Illinois forests provide habitat for an exceptional diversity of plant species and are the natural home for most trees and other woody species. The 508 taxa of trees, shrubs, and lianas found in Illinois represent 15.9% of the state's reported flora, and 346 (69%) of them are associated with forest habitats (ILPIN data: Iverson and Ketzner 1988) (Figure 11). Most of the remaining taxa are cultural (escaped from cultivation). Of the 508 taxa, 370 (73%) are native to Illinois; the remaining are introduced. A relatively high proportion of the state's woody taxa are listed as rare in Illinois (40%); 15% occur commonly, 33% occur occasionally (common in localized patches), and 12% are

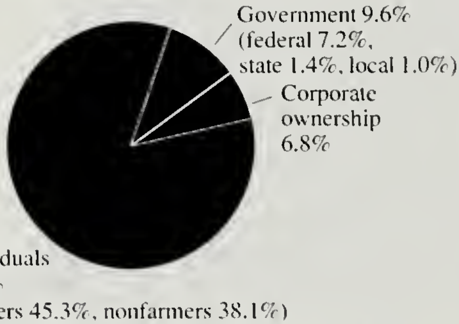

Figure 10. Ownership of Illinois commercial forests, 1985. Source: Hahn 1987.

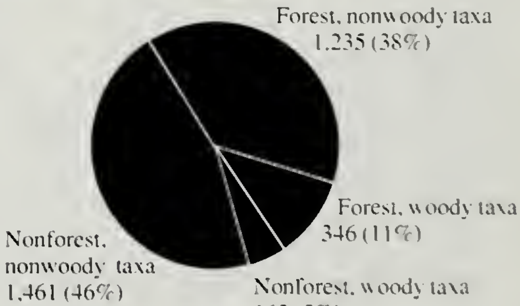

Figure 11. Number of plant taxa by habitat and habit (woody and nonwoody). Total taxa in Illinois = 3,204. Source: Iverson and Ketzner 1988.

uncommon (localized distribution or sparse throughout).

Illinois forests also provide habitat for an amazing number of nonwoody taxa. Including the woody taxa, fully 1,414 native taxa (61% of the native Illinois flora) are associated with forest habitats (Figure 11). Thus Illinois forests, which occupy only 12% of the area of the state, provide habitat for over half of its native flora. If we are to protect this irreplaceable biological diversity, we must maintain and restore forest communities. Beyond the importance of forestland as habitat for total plant diversity, rare plant species are frequently found in forest habitat, for example, 166 taxa (47%) of the 356 plants listed as threatened or endangered in Illinois are forest inhabitants. The importance of high-quality forests as refuges for these taxa cannot be overemphasized, especially in the face of extreme pressures from urban and agricultural growth.

Wildlife Habitat

Illinois forests provide the major habitat for numerous wildlife species, and losses in the quality and quantity of that habitat severely affect wildlife populations (Illinois Wildlife Habitat Commission 1985). Game species—gray squirrel, eastern wild turkey, quail, and white-tailed deer—depend on woodlands as do many more nongame animals—thrushes, warblers, woodpeckers, nuthatches, kinglets, and whippoorwills—to mention only a few bird species. But some relationships between wildlife and forests are more subtle. Most of us recognize the dependence of wood ducks on natural cavities in the trees of bottomland forests, but bottomland forests also provide food and habitat for fish, mitigate the effects of floods, restrain the movement of harmful chemicals into lakes and streams, and provide shade, thereby lowering water temperatures during stressful summer months.

One method of summarizing the value of Illinois wildlife habitat is based on land use. Complete details are presented in Graber and Graber (1976), and revised calculations based on current data are given in Iverson et al. (1989). The habitat evaluation index devised by Graber and Graber is based on the relative amount of a particular habitat type within a given area, the availability of that habitat type within the state or region, the changing availability of that habitat (Is it increasing or decreasing over time?), and the "cost" of a given habitat measured in years required to replace the ecosystem. A summary of habitat factors for Illinois as a whole is presented in Table 3. By this calculation, over three-quarters of the wildlife habitat (88 of 115.7 habitat factor points) is derived from forests. Elm–ash–cottonwood rates highest because this forest type has been disappearing so quickly over the past two decades (Figure 6). Oak–hickory values would be higher except that numbers in older age classes are increasing as secondary forests mature, even though numbers in younger age classes are decreasing (Figure 9). A very minor rating was earned by maple–beech because this forest type has increased so dramatically in recent years (Figure 6).

This method can be used to evaluate wildlife habitat on parcels of various size (see examples in Iverson et al. 1989). In the final calculation, the habitat factor for a given site or region is divided by a regional or statewide habitat factor (115.7 for the state). An index of 1.0, therefore, means that the value of the habitat under consideration is about average for the state or region as a whole. Thus, a habitat evaluation index of 1.5, the value calculated for the 16 southern counties, indicates a much higher wildlife value than the value of the state overall. Similarly, the value of 0.66 for the 60 northern counties indicates a relatively poor

Table 3. Habitat factors for Illinois, 1985, calculated according to Graber and Graber (1976).

Land type	Habitat factor	Percent of habitat factor
Forest		
Pine	5.70	4.9
Oak–hickory	30.07	26.0
Oak–gum–cypress	11.97	10.3
Elm–ash–cottonwood	40.19	34.7
Maple–beech	0.14	0.1
Subtotal		76.0
Nonforest		
Cropland	0.29	0.3
Pasture/hayland	10.01	8.7
Prairie	1.46	1.3
Marsh	15.28	13.2
Water	0.38	0.3
Urban, residential	0.03	0.0
Fallow	0.19	0.2
Subtotal		24.0
Total	115.73	100.0

habitat for wildlife, and the value of 1.09 for the 26 south-central counties indicates wildlife habitat somewhat above that of the state as a whole.

Fragmentation of forest habitat has negative implications for wildlife, especially for neotropical migrant birds that need large blocks of uninterrupted forest for successful nesting (Harris 1984; Blake and Karr 1987; Robinson 1988). As large tracts of forest are broken into small, isolated woodlots, more forest edge is created and more opportunities exist for edge-adapted species, most importantly the cowbird, to invade the area and parasitize the nests of many forest songbirds.

The extent of fragmentation in Illinois forests was made clear in a recent examination of forest parcels by size. Relying on the Illinois Geographic Information System and data from the U.S. Geological Survey, researchers determined that 10,121 forested parcels exist in the state and that the average size per parcel is 358 acres (Iverson et al. 1989). About 44% of the parcels are less than 100 acres in size and about 10% are larger than 600 acres (Figure 12). Perhaps the density of forest parcels can be pictured more clearly if we envision an area the size of a township—36 square miles. On average, 6.1 parcels exist per township-sized area, with 69% of them roughly 40 (limit of resolution of the data) to 200 acres in size. This perspective makes clear that Illinois forests are extremely fragmented and that a concentrated effort must be made to protect larger forest patches and to aggregate smaller ones.

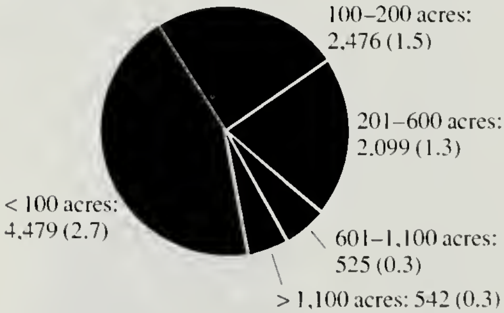

Figure 12. Number of forested parcels in Illinois by size and average number of parcels per township equivalent (36 square miles). Total number of parcels in Illinois of a given size is the number immediately following the size (e.g., <100-acre parcel: 4,479). Average number of parcels of a given size per township equivalent is given in parentheses. Source: Iverson et al. 1989.

Soil and Water Quality Protection

Soil erosion with its accompanying degradation of surface water is indeed a serious threat to the future of an agricultural state: for every pound of corn, soybeans, wheat, or oats grown in Illinois, 3.3 pounds of soil are lost (Iverson et al. 1989). In contrast to cropland, forest vegetation protects against excessive soil loss. Average erosion of cropland proceeds at about four times the annual rate of nongrazed forestland—7 tons per acre compared to 1.6 tons, respectively. The difference in soil loss is even greater on sloping, highly erodible soils. Soils with land capability ratings of IVe to VIIe lose 24.2 to 39.4 more tons per acre each year they are under cultivation than they would lose if they were forested. In 1982, 1.75 million acres of cropland had these capability ratings. Had those acres been converted to nongrazed forestland, 36.5 million of the 157.8 million tons of soil lost annually from cropland would have been saved. Figure 13 shows that the soil savings that would result from converting cropland with higher capability ratings to nongrazed forest would be disproportionately higher than conversions from cropland with lower ratings.

The Conservation Reserve Program is designed to remove marginal cropland from cultivation, and it is helping; however, over 96% of the cropland currently being removed from production in Illinois is going into grass rather than trees. The U.S. Department of Agriculture and the Illinois Council on Forestry Development are working together to alter this percentage in favor of trees.

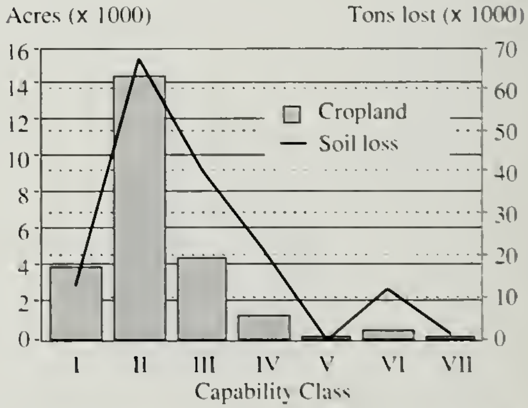

Figure 13. Cropland acreage and annual soil loss by capability class. Class I soils are most productive: Class VII soils are least productive. Source: U.S. Soil Conservation Service data base 1982.

Heavy grazing, and especially feedlot operations, in forestlands largely negates the benefits of soil protection. Average soil loss from forestland that is heavily grazed or under feedlot operations is 13.1 tons per acre per year in contrast to only 1.6 tons per acre per year on nongrazed forest. Thus, 66% of the 12.6 million tons of soil lost annually from forestland is lost from these areas, even though only 19% of Illinois forests are categorized as grazed. Light grazing of forestland generally does not increase soil loss significantly and is certainly to be preferred over cultivation of marginal lands.

According to estimates by the U.S. Forest Service, 133,100 acres of windbreaks existed in Illinois in 1985 (Hahn 1987). Windbreaks retard soil loss due to wind erosion, but they also provide shade for livestock and shelter for wildlife. Their aesthetic qualities are not to be overlooked, but their role in the conservation of energy is growing in importance. Back in 1981, the Soil Conservation Service estimated that 124,000 buildings in rural Illinois needed windbreaks. Had they been planted, energy equivalent to 941 million kilowatt-hours of electricity could have been saved (USDA Soil Conservation Service 1982).

Recreation and Scenic Values

In 1987, surveys by the Illinois Department of Conservation indicated that Illinoisans spent about 240 million days or portions of days pursuing recreation on or near forestlands; in the process they spent approximately $6.3 billion (Illinois Department of Conservation 1989). Activities closely aligned with forest recreation (picnicking, observing nature, cross-country skiing, backpacking, hiking, camping, canoeing, horseback riding, snowmobiling, riding off-road vehicles, trapping, and hunting) accounted for 206 million of those days, an average of 18.7 days per resident (Figure 14).

The majority (93%) of the 4,528 areas developed for recreation in Illinois (almost 900,000 acres) are publicly owned and operated. Total land available for recreation totals roughly 2.7% of the state's land and water area, a per capita outdoor recreation acreage of less than 0.1 acre. Among states, Illinois rates 46th in total public open space per capita. In addition, most of the publicly owned land available for recreation is located in the southern part of the state; the majority of Illinoisans, however, live in the north.

Urban Forests

Most Illinoisans (83%) live in urban centers, and urban forests are often their only exposure to a natural environment. Urban forests provide many benefits beyond those normally associated with rural forests, including temperature modification and energy conservation; the abatement of air, water, and noise pollution; the masking of unpleasing urban views; and physical and psychological benefits to city dwellers. Because the urban forest exists in such a heterogeneous environment, an accurate assessment of its extent and function is difficult. The U.S. Forest Service, however, has estimated that 102,800 acres of urban forest and 139,500 acres of urban areas with trees existed in Illinois in 1985 (Hahn 1987). Cook County alone has over 67,000 acres of forest preserves, and much of this land is available for recreation. A recent remote-sensing study revealed that 21.3% of the land area in the six-county Chicago area had tree cover in 1988 (Cook and Iverson 1991). Yet less than 0.01 acre per capita of publicly owned forestland exists in that six-county area, and Chicago ranks last among the nation's ten largest urban centers in this regard.

Urban forests face three problems. First, maintenance and management are inadequate. A recent survey by the Illinois Council on Forestry Development (1988) estimated that 6.5 million municipal street trees exist in Illinois with an estimated value of $3 billion. These trees are generally not adequately maintained because of inadequate budgets and the lack of trained foresters. In addition, less than half the potential number of street trees are presently in place, and removals outstrip plantings (American Forestry Association 1988). Second, forestlands are jeopardized by

Figure 14. Days (in thousands) spent in recreational pursuits on or near forestlands in Illinois, 1987. Source: Illinois Department of Conservation 1989.

development and population pressures. Tremendous growth is now occurring in the six collar counties around Chicago. Information from the Northeastern Illinois Planning Commission (1987) shows that 867 quarter sections (about 5.6% of the area) were urbanized (population density exceeding 1,000 per square mile) between 1970 and 1980. Much of this growth was at the expense of forestland. A third problem is the absence of a policy for using wood waste. Until recently, much of the debris from tree removals and large amounts of other wood wastes were deposited in landfills, an enormous waste of wood and leaf mulch and the needless use of costly landfill space. Better uses for this material must be developed and marketed.

Timber Products

Illinois ranks fifth in the nation in demand for wood but 32nd in production. As a result, Illinois imports much of the wood it uses from neighboring states. In addition, 14.2% of the wood harvested in Illinois is processed in neighboring states and then often imported back into the state. Currently, the annual growth of timber (96 million cubic feet) exceeds timber removals (68.6 million cubic feet removed for timber products, logging residues, and changing land uses), and a higher proportion of the state's demand for wood could be met within its own boundaries if the processing facilities were at hand. With judicious management, harvesting could be increased, negative effects on the environment minimized, and multiple benefits achieved.

In 1983, 161 million board feet of timber (mbf) were harvested in Illinois (Blyth et al. 1987); 146 mbf were processed in 178 Illinois sawmills. Red oak (29%), pin oak (19%), white oak (16%), and cottonwood (10%) accounted for the majority of sawlogs processed in the state. Of the 4 mbf of veneer and other high-quality logs (mostly white oak, walnut, and red oak) cut in Illinois during 1983, only 0.3% remained in the state. Additionally, all pulpwood (7.2 million cubic feet) produced in the state were processed elsewhere. The veneer and pulpwood statistics are not surprising because virtually no plants for either veneer or pulpwood are found in Illinois.

An enormous quantity of fuelwood is harvested from Illinois woodlands. In 1982, nearly 2 million cords of firewood were cut or gathered, a figure that represents 43% of the total trees utilized that year! The major harvest of fuelwood takes place in the heavily populated northeastern counties. Cook, McHenry, and Will counties, for example, each harvested over 150,000 cords of fuelwood in 1983 (Blyth et al. 1985). The majority of firewood (97%) was cut from private lands, and 75% was gleaned from dead trees.

According to U.S. Department of Commerce figures, forest-related industries in Illinois employ 55,000 people with an average payroll of $965 million. These firms contribute more than $2 billion annually to the state's economy through value added by manufacture; in addition, they invest more than $144 million in capital improvements annually (U.S. Department of Commerce 1982–1985).

According to 1984 data from Dun & Bradstreet, 166,900 employees work for 957 Illinois firms that are primarily involved in the manufacture of wood products. If the paper industry is included, an additional 576 firms and 367,450 persons are involved (Figure 15). The Dun & Bradstreet numbers are much higher than those released by the U.S. Department of Commerce because Dun & Bradstreet include the total number of employees, even those not directly associated with the wood-manufacturing component. Nonetheless, a large number of employees work in forest-related industries, most of which are located in the Chicago region.

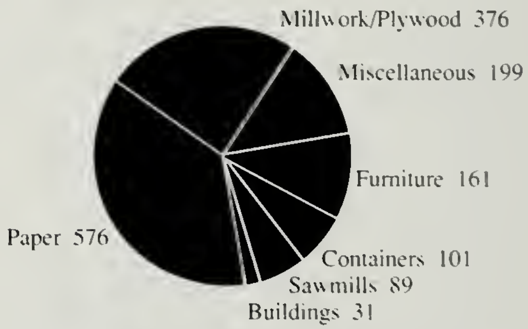

Figure 15. Forest-related industries in Illinois, 1984. These 1,533 sites employed 534,342 workers. Source: Dun & Bradstreet data base 1984.

CONCLUSIONS

A great deal of information has been presented to establish the initial contention of this paper: the Illinois forests provide numerous important benefits to the citizens of the state. Nevertheless, considerable improvement in the quantity and quality of these benefits could be achieved if forestlands were better managed. Over most of the state, little forest management is underway, and the potential of our forests to provide wildlife habitat, preserve biodiversity, and extend wood production has not been tapped. Even in "wilderness" areas, management is often necessary to maintain the status quo (e.g., remove exotic invaders). Ecosystems are not static entities; change is inevitable, but only with management can change benefit the resource as well at its human guardians.

We need to manage the forest resources we currently possess, but we also need to plant more forests if we are to assure continuing benefits from our forests. Recent political developments have and may continue to support tree planting programs; however, caution is in order. Planting trees requires more than seedlings and a spade. Species most appropriate to a given site must be selected, follow-up care must be available, and long-term management must be provided if the success of these programs is to be ensured.

The environmental problems facing Illinois, the nation, and the planet are grave indeed. Yet we are learning the important role that forests can play in mitigating some of these problems. We have, however, only begun to realize the enormity of the task. We have only begun to take the actions needed to create a sustainable world.

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Forest Succession in the Prairie Peninsula of Illinois

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Presently most of central Illinois is in the Grand Prairie Natural Division (Schwegman 1973), classified as a part of the prairie peninsula of the oak–hickory forest region by Braun (1950), as a mosaic of bluestem prairie and oak–hickory forest by Küchler (1964), and as a part of the prairie–deciduous forest ecotone by Davis (1977). At the time of settlement by Europeans, prairie dominated most of Illinois. Forests were common, however, occurring on rough terrain such as moraines and dissected valleys of streams and rivers and as isolated groves on the flat to gently rolling prairie.

During postglacial times, the vegetation of Illinois changed extensively (King 1981). Pollen diagrams from the prairie peninsula in Illinois record the climatically related vegetation shifts that have occurred since the late Pleistocene. The pollen record for Chatsworth Bog, Livingston County, in the center of the prairie peninsula, suggests that a mosaic of open spruce woodlands and tundra existed there from 14700 to 13800 BP. This cover type in turn was replaced by an ash/tundra assemblage that reflected the slowly increasing temperatures of the late-glacial from 13800 to 11600 BP. After 11600 BP, pollen from deciduous trees and shrubs increased dramatically, starting with cool-climate species (birch, hazel, black ash) and followed by such warm-tolerant taxa as elms, oaks, and hickories. By 8300 BP, prairie dominated the area as indicated by a dramatic decrease in tree pollen and a corresponding increase in the amount of pollen from herbaceous plants. Oak pollen was still present, however, suggesting that prairie vegetation was probably common on the drier flat uplands while the lowlands and river valleys retained their forest cover. These open expanses of prairie with savanna and forest communities restricted to the more dissected lands were what the early European settlers found when they entered the prairie peninsula of Illinois in the early 1800s.

The presettlement distribution of the major vegetation types in Illinois (prairie, savanna, and forest) was determined largely by firebreaks such as lakes and rivers and by topographic relief that controlled the frequency and intensity of fire (Gleason 1913; Wells 1970; Grimm 1984). Gleason (1913) found that forests were more extensive on the east side of firebreaks, while prairie tended to be more extensive on the west side. This distribution pattern was the result of prevailing westerly winds that carried fires to the western sides of firebreaks, thus encouraging the development of prairies. In contrast, the eastern sides were protected from fires, and forest developed at these locations.

PRESETTLEMENT FORESTS

In presettlement times, according to survey records of the General Land Office, prairie occupied 61.2% of Illinois and forest and savanna accounted for 38.2% (Iverson et al. 1989). In general, prairie vegetation was most common on flat to gently sloping ground; savanna and forest were most common in dissected areas. The segregation of forest, savanna, and prairie on the basis of topography apparently occurred because dissected landscapes do not readily carry fire. For the most part, these dissected landscapes have well-developed drainage systems that support permanent or temporary streams, which serve as firebreaks. In addition, fires in hilly areas tend to move up slope relatively rapidly due to rising convection air currents, but convection currents work against fires when they move down hill, not uncommonly causing them to burn themselves out.

A great deal of vegetation information can be obtained from survey records of the General Land Office (Bourdo 1956). The job of the surveyors was to establish a grid system of township, range, and section lines by the placement of section and quarter section corner posts. In prairie and marsh areas, only posts were used. In timbered areas, however, two (or four) witness trees were blazed, and the distance and direction of these trees from the corner posts were recorded along with their species and estimated diameter at breast height (dbh). Because the placement of the corner posts and the selection of witness trees were essentially random, the principles of the distance method (Cottam and Curtis 1956) can be applied to the witness tree data and the composition and tree density of the presettlement savannas and forests determined.

In Illinois, several researchers have used survey records of the General Land Office to determine the extent, composition and densities of tree species for various counties. Some of their studies are summarized here and indicate the extent and composition of the presettlement vegetation of the prairie peninsula.

Kilburn (1959) found that the original forest in Kane County consisted largely of oak openings composed of pure bur oak or bur/white oak stands. Lowlands and swamp forests were found along rivers and streams, but a more mesic forest occurred on the heavier soils of the Big Woods area. Overall, three-fifths of the county was prairie. Topography accounted for most of the vegetation pattern: level areas were in prairie vegetation; protected ravines, valleys, steep bluffs, and hills were largely forested. Overall, 87% of the witness trees recorded by the surveyors were oaks and hickories.

In Lake County, the situation was similar. Oak and hickory species accounted for 95% of the trees recorded (Moran 1976). In this county, however, savanna was the dominant vegetation type, occupying 51% of the area. It was found mostly on rolling uplands that were frequently broken by small wetlands or streams; bur oak was by far the most common species with black and white oaks in lesser numbers. Prairie, wet prairie, and marsh occupied 33% of the county while forests occurred in the remaining 16%. For the most part, prairies were situated on flat terrain and forests were restricted to areas of rough topography or where natural firebreaks afforded some protection.

In McLean County, located in west-central Illinois, the presettlement vegetation was 89.5% prairie, 5.4% savanna, 1.8% open forest, and 3.3% closed forest (Rodgers and Anderson 1979). The forested areas occurred on the more rugged topography associated with rivers, streams, and glacial moraines. White and black oaks were the most numerous species recorded, but in the closed forests (273 trees/ha) the more mesic species (i.e., sugar maple, elm, red oak, buckeye) accounted for about one-third of the trees present. These more shade-tolerant, mesic species, which for the most part are fire-sensitive, occupied sheltered ravines and areas adjacent to streams where fires occurred infrequently. In contrast, the relatively shade-intolerant oaks, which depend on periodic fires to maintain their dominance, were more common on less dissected uplands.

In adjacent Mason County, similar results were obtained (Rodgers and Anderson 1979). Located in the Illinois River Sand Area Section (Schwegman 1973), on soils developed from deep sand deposits laid down by glacial meltwater during the Pleistocene (Willman and Frye 1970), prairie was the dominant vegetation type, occupying 67.7% of the county. Savanna (14.4%) and forest (13.3%) occurred on most of the remaining land and 4.6% was covered by lakes and swamps. The dominant tree species in the presettlement forests and savannas were shade-intolerant, fire-tolerant black and blackjack oaks. In the closed forests (263 trees/ha), the oaks and hickories were still the most numerous species. The more mesic, shade-tolerant, fire-sensitive tree species (i.e., sugar maple, elm, walnut) were also found in the closed forests, particularly in areas of rough topography.

In Douglas County, near the southern edge of the Grand Prairie Natural Division (Schwegman 1973), prairie was the most widespread plant community (85%). Closed forest, which was generally restricted to the major river systems, accounted for the remaining 15%. These forests were dominated by white and black oaks and hickories, species that accounted for 70% of the witness trees recorded by the surveyors. Mesic, shade-tolerant, fire-sensitive species were present but restricted to areas of rough topography and river valleys (Ebinger 1986a).

Prairie was the most widespread vegetation type (60%) in Coles County, the southern half of which is located on the Shelbyville Moraine, the terminal moraine of Wisconsin glaciation. Prairie was most common on the flat to gently rolling uplands in the northern and central parts of the county. Forests, which accounted for most of the remaining 40%, were restricted to the rough topography of the terminal moraine and to the valleys of the Kaskaskia and Embarras rivers. More than 80% of the witness trees recorded were oaks and hickories, with white, black, and red oaks most numerous. Again, more mesic species were restricted to rough topography (Ebinger 1987).

Information extrapolated from the records of early surveyors indicates that prairie vegetation dominated most of Illinois in presettlement times and was found on the flat to gently rolling uplands throughout most of the state. Savannas and forests, in contrast, were more common in rough topography, especially in the driftless areas, along major waterways, and where morainal systems provided topographic relief. For the most part, savannas developed on sites where the frequency of fire was reduced, thereby permitting the establishment of fire-tolerant tree species (Anderson 1970; Anderson and Anderson 1975; Grimm 1984; Anderson and Brown 1986). Forests, particularly closed forests, developed in places of rough relief, in river valleys, and in other protected areas where fires were less likely to occur. Oaks and occasionally hickories dominated the open savannas. In the forests, oaks and hickories were also the dominant species, but more mesic, shade-tolerant, fire-sensitive tree species were common forest components. Furthermore, the transition from forest to prairie varied from being rather abrupt in some locations in the prairie peninsula to others where savannas formed a broad transition between forest and prairie (Nuzzo 1986). This transition was probably determined by topographic relief, firebreaks, fuel loads, and other edaphic and climatic factors that controlled the frequency and intensity of fires.

PRESENT SUCCESSION TRENDS

During the past century and a half of agricultural development, periodic fires have ceased in the prairie peninsula, and the oak savannas and open oak forests on the uplands have become closed-canopy forests. As a result, these woodlots have been changing to forests dominated by such mesic, shade-tolerant, fire-sensitive species as sugar maple, American and red elms, white and green ashes, and ironwood (Anderson and Adams 1978; Adams and Anderson 1980; Ebinger 1986b).

In particular, sugar maple has increased in importance in most Illinois forests (Iverson et al. 1989). If this trend continues, many of the oak–hickory forests, their understories, and the wildlife that depends upon them will be in serious trouble in the near future. Even the best quality oak–hickory communities are apparently undergoing an irreversible change as sugar maple and other mesic, shade-tolerant species replace many of the original forest components. Almost no work has been done concerning methods to reverse this trend, and the problem now concerns many ecologists and managers of natural areas.

Many of the better quality forests that presently exist in the prairie peninsula have been surveyed during the past thirty years. In a few of them, sugar maple is not an important component, though other mesic species are sometimes common. At Walnut Point State Park in Douglas County (Ebinger et al. 1977), sugar maple is rarely encountered, and oaks and hickories are by far the most numerous species. In the forests and savannas of the Kankakee Sand Area Section (McDowell et al. 1983) and the Illinois River Sand Area Section (Rodgers and Anderson 1979) oaks dominate and mesic species are rarely encountered. In most of the stands studied, however, mesic species, particularly sugar maple, are relatively important components. These mesic species are also well represented in the seedling and sapling categories and in the smaller diameter classes. Oaks and hickories, in contrast, are poorly represented in these categories.

Mesic, shade-tolerant, fire-sensitive species are common components of many recently surveyed forests in the prairie peninsula. Two "prairie grove forests" in Champaign County have been surveyed at various times in the past, and sugar maple is an important component in both. In Trelease Woods (Boggess 1964; Pelz and Rolfe 1977), sugar maple dominates the seedling and sapling categories as well as most of the diameter classes. Similar results were obtained for Brownfield Woods by Boggess and Bailey (1964) and Miceli et al. (1977).

An inventory of the woody vegetation of Funks Forest Natural Area in McLean County was conducted by Boggess and Geis (1966). This forest is an example of a mesophytic forest that is transitional between the upland oak–hickory cover type and the "prairie grove forest." Sugar maple, the dominant species in Funks Forest, is followed closely by white oak and elm. Sugar maple and white oak, however, represent two distinct age classes. White oak, which predominates in the 30-inch-diameter class, is a "pioneer" species; and sugar maple, which predominates in the 16-inch-diameter class, has perhaps been increasing steadily in importance during the past century.

One recently documented example of the increase in importance of sugar maple is at Baber Woods Nature Preserve in Edgar County. This 16-ha forest is located on the flat to gently rolling ground just north of the Shelbyville Moraine, the terminal moraine of Wisconsin glaciation. Two decades ago, McClain and Ebinger (1968) reported that sugar maple ranked second in importance in the woods and dominated the seedling, sapling, and smaller diameter classes. In a more recent survey of the same area, Newman and Ebinger (1985) found that this trend had continued. Sugar maple was now first in importance, and the number per acre had almost doubled. Further, sugar maple continued to dominate the seedling and sapling categories and accounted for nearly half of the individuals in smaller diameter classes. Sugar maple and oaks represent two distinct age classes in Baber Woods, as shown in Figure 1. These curves show that oaks predominate the larger diameter classes and suggest that these species have been an important forest component for an extended period of time. Sugar maple, in contrast, predominates the smaller diameter classes and has probably been increasing steadily during the past century. The large number of sugar maple seedlings, saplings, and smaller diameter trees suggests a continuation of this trend.

Table 1 indicates when sugar maples began to increase in importance in Baber Woods. In nearly every quadrat, sugar maple increased in number, size, and importance from 1965 to 1983. In addition, the number, size, and importance of sugar maple decreased from the northwestern corner of the woods, becoming smaller and less common toward the southeastern corner. This pattern suggests that sugar maple probably occurred in the ravines that exist just to the north and west of the woods, where in presettlement times it was probably protected from fire due to the rough topography. With the cessation of fire, this fire-sensitive species has been able to invade the upland forests that still exist in the area.

Another indication of the increase of sugar maple in Baber Woods is the distribution of this species and the oak species by diameter classes for the 1965 and 1983 surveys (Table 2). Sugar maple increased in all diameter classes between 1965 and 1983, particularly in two diameter classes, 10–19 and 20–29 cm. Sugar maple showed an overall increase of nearly 30 trees per hectare between the two surveys. In contrast, oak species decreased in numbers, dramatically so in the lower diameter classes, with increases occurring only in classes 60–69 cm in diameter and above (Table 2). Overall, species density increased in the woodlot, from 258.6 stems/ha in 1965 to 277.3 stems/ha in 1983. Most of this increase is due to sugar maple and other mesic species that are tolerant of shade and sensitive to fire. Presently the oaks are common in the larger diameter classes because of recruitment from the smaller diameter classes. Oak reproduction is sparse (McClain and Ebinger 1968; Newman and Ebinger 1985), and as the veteran trees die, fewer oaks are available to fill the canopy gaps. In contrast, sugar maple, with its high gap-

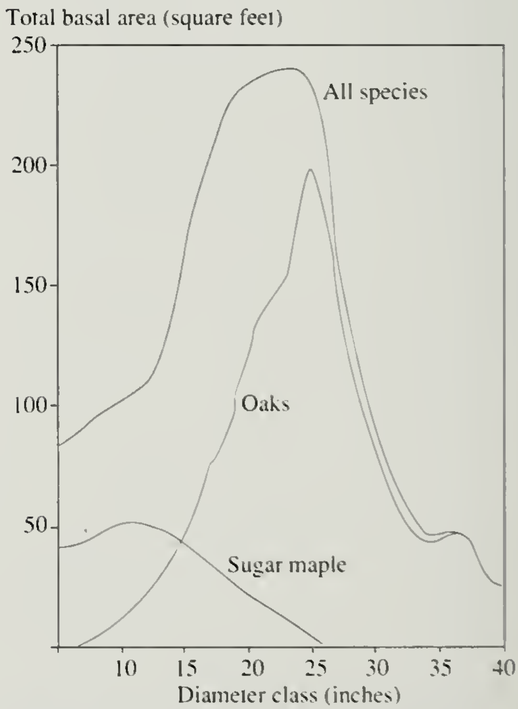

Figure 1. Smooth curves of basal area by diameter class for sugar maple, all oak species combined, and all species combined at Baber Woods, Edgar County, Illinois. Source: Ebinger 1986b.

phase replacement potential, is able to take advantage of these canopy openings (Ebinger 1986).

Within Baber Woods are a number of large open-grown white oaks. In a walk-through survey conducted during the early spring of 1990, twenty-six large, open-grown white oaks were observed. All have open, round crowns and large lower branches, some within 4 m of the ground. They are probably remnants from a time when this forest was an open, upland savanna. The average diameter of these open-grown white oaks is 101.6 cm dbh, and two that had died recently were cut and aged at 313 years. Both had fire scars at 65 and 77 years, indicating that in the past fires were probably common in the area. Five other oaks that had died recently were also cut and aged.

Table 1. Distribution of sugar maple in Baber Woods Nature Preserve, Edgar County, Illinois, for the surveys of 1965 (McClain and Ebinger 1968) and 1983 (Newman and Ebinger 1985). The following information is given for each quadrat (1 ha): the number of stems present (above 10 cm dbh), the number of stems exceeding 40 cm dbh, the average diameter (cm), and the importance value (relative density and relative dominance) for sugar maple. Highest possible importance value is 200. The northern edge of the woods is represented in quadrats 1 through 4.

	Quadrat 1		Quadrat 2		Quadrat 3		Quadrat 4	
	1965	1983	1965	1983	1965	1983	1965	1983
Number of individuals	140	153	158	152	104	124	82	102
Number <40 cm dbh	8	14	12	17	3	4	2	9
Average diameter (cm)	23.1	23.6	22.1	25.3	19.3	20.9	20.1	22.7
Importance value	78.1	86.2	82.4	98.6	52.6	68.1	42.1	57.5
	Quadrat 5		Quadrat 6		Quadrat 7		Quadrat 8	
	1965	1983	1965	1983	1965	1983	1965	1983
Number of individuals	98	134	91	138	90	100	45	70
Number <40 cm dbh	7	9	5	6	3	6	1	4
Average diameter (cm)	20.6	20.5	19.1	19.4	18.9	21.6	19.5	20.4
Importance value	51.2	71.9	45.9	66.7	45.8	58.3	25.1	37.8
	Quadrat 9		Quadrat 10		Quadrat 11		Quadrat 12	
	1965	1983	1965	1983	1965	1983	1965	1983
Number of individuals	60	95	29	101	38	74	34	58
Number <40 cm dbh	9	14	—	1	—	2	—	1
Average diameter (cm)	23.5	21.1	15.6	15.5	19.8	20.2	18.5	20.9
Importance value	40.8	53.2	13.8	39.2	25.4	45.8	20.4	34.5

Table 2. Density (number/ha) in broad diameter classes for sugar maple, oak species, and all other species in Baber Woods Nature Preserve, Edgar County, Illinois, for the surveys of 1965 (McClain and Ebinger 1968) and 1983 (Newman and Ebinger 1985).

	Sugar maple		Oak species		Other species		Totals	
Diameter class	1965	1983	1965	1983	1965	1983	1965	1983
10–19 cm	42.6	58.9	7.6	3.7	50.0	62.1	100.2	124.7
20–29 cm	17.8	24.7	10.9	4.9	17.0	17.7	45.7	47.3
30–39 cm	7.3	10.6	14.7	8.3	19.0	13.2	41.0	32.1
40–49 cm	2.4	4.6	17.7	11.6	15.4	12.6	35.5	28.8
50–59 cm	0.6	1.0	16.2	13.0	5.6	7.9	22.4	21.9
60–69 cm	0.1	0.3	7.5	11.1	0.9	2.1	8.5	13.5
70–79 cm	–	–	2.7	4.4	0.3	0.6	3.0	5.0
80–89 cm	–	–	1.1	2.3	0.1	0.2	1.2	2.5
90+ cm	–	–	1.1	1.5	–	–	1.1	1.5
Total	70.8	100.1	79.5	60.8	108.3	116.4	258.6	277.3

These were forest-grown trees with straight trunks, no low branches, and an average diameter of 68.2 cm. They varied in age from 140 to 158 years, with an average age of 148 years. In contrast were the increment cores obtained from 30 sugar maples in various parts of the woodlot. Those from the northwestern part of the woods, where the largest individuals occurred, averaged 44.7 cm dbh and had an average age of 107.6 years. Sugar maples from the northeastern and southeastern corners of the woodlot were smaller and younger (Table 3).

The data suggest that before European settlement, the area now known as Baber Woods was an open, white oak savanna maintained by periodic fires. This community was probably parklike with an understory of prairie grasses and forbs. With the cessation of fire, the number of seedlings increased and began to fill the gaps in the canopy between the large open-grown oaks. As shade increased, moisture levels within the forest probably increased, creating a habitat for more mesic, shade-tolerant, fire-sensitive species such as sugar maple.

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Table 3. Tree rings and diameters (dbh) of sugar maples at selected sites in Baber Woods Nature Preserve, Edgar County, Illinois.

	Diameter (cm)		Growth ring	
Area	Range	Average	Range	Average
Northwest corner	37.4–59.7	44.7	101–116	107.6
Northeast corner	26.0–35.8	30.4	52–91	70.6
Southeast corner	17.5–35.5	25.7	51–71	61.1

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Effects of Forest Fragmentation on Illinois Birds

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Abstract. The forests in Illinois are among the most fragmented in North America. Most remaining tracts are small, isolated, and dominated by "edge" habitats. Populations of many forest species, especially those that breed in the forest interior, have been declining, and many characteristic forest species do not occur in woodlots below a certain minimum size. Data from small woodlots (<65 ha; 170 acres) in the Lake Shelbyville area of central Illinois suggest that reproductive failure may be at least partly responsible for these trends, especially among the neotropical migrants that breed in Illinois but winter in the tropics. Most nests fail because of brood parasitism by brown-headed cowbirds (*Molothrus ater*) (76% of all nests of neotropical migrants) or because of nest predation (80% of all nests).

Brown-headed cowbirds, which are abundant throughout Illinois, pose a particularly severe threat because they lay their eggs in the nests of host species, which go on to raise cowbirds instead of their own young. Parasitized nests in the Lake Shelbyville area averaged 3.3 cowbird eggs per parasitized nest. All 19 wood thrush (*Hylocichla mustelina*) nests were parasitized with an average of 4.6 cowbird eggs per nest. Only about 10% of the birds of all species caught in midsummer were juveniles. These data strongly suggest that the reproduction of neotropical migrants in very small woodlots is insufficient to compensate for adult mortality, a result consistent with the population declines observed in the Shelbyville area.

Birds nesting in much larger tracts (up to 2,024 ha; 5,000 acres) in the Shawnee National Forest appear to face similar problems. A crew of 14 workers located over 400 nests in 1989 and discovered that cowbird parasitism and nest predation rates were high, even deep in the forest interior. In contrast to studies elsewhere, cowbirds were found throughout each study area, regardless of the proximity of edges. Over 55% of all nests were parasitized and an average of 60% of all nests were destroyed by predators. As in Shelbyville, wood thrushes suffered most from cowbirds: 90% of all nests parasitized and an average of 3.2 cowbird eggs per nest. Other species that suffered high (>70%) parasitism rates were the red-eyed vireo (*Vireo olivaceus*) and the scarlet (*Piranga olivacea*) and summer tanagers (*P. rubra*). A few species reproduced successfully in spite of the abundance of nest predators and cowbirds. Worm-eating (*Helmitheros vermivorus*) and Kentucky warblers (*Oporornis formosus*) hide their nests effectively, and for these species young outnumbered adults in midsummer samples of birds caught in mist nests.

These results suggest that management decisions will have to take into account differences among species in susceptibility to forest fragmentation. The cowbird situation is more serious than has been anticipated and apparently cannot be solved simply by minimizing edges as has been proposed elsewhere in the Midwest. At least a few species, for example, the wood thrush, may be in serious trouble throughout the Midwest and should receive special management attention.

Session Two: Prairies and Barrens

The chance to find a pasque-flower is a right as inalienable as free speech.—Aldo Leopold

The first Europeans to see the Illinois country had crossed a vast ocean, snaked their way through a nearly impenetrable mountain range, and forged a path through a thousand miles of dense, primeval forest. They did it with indomitable spirit and by sheer force of will. Yet when they reached the edge of the eastern deciduous forest, approximated today by the Indiana–Illinois border, they stopped in wonder. Here was a landscape so different from those with which they were familiar that they had no word for it. In time this landscape came to be known as "prairie," a word derived from the French word for *meadow*.

At first, early settlers avoided living on the prairie because the treeless grasslands were thought to be infertile. They did not provide much needed building materials, fuel, and water. Instead, they offered the prospect of menacing prairie fires and howling winter storms. Soon, however, the settlers realized that prairie made excellent cropland, especially after John Deere invented the moldboard plow that allowed virgin prairie soil to be broken. The wild prairies became cropland at an astonishing rate—approximately 3.3% per year. Over 300,000 people settled on the prairie during the decade of the 1830s, and by 1860 nearly all the prairies had disappeared.

At least 23 different kinds of prairies are found in Illinois—add barrens, savannas, and glades and the list increases to over 30. These various prairies once occupied nearly 22 million acres of the state. Today they are confined to about 3,000 acres, less than 0.01% of their original extent. Unfortunately, it is easier to find examples of the prairie's influence in the "prairie" state—Prairie Street, Prairie State Games, Prairie Farms Dairy, Prairieview Estates, Prairie Technology—than it is to find an actual prairie. Prairie remnants persist, however, along railroad lines, in pioneer cemeteries, even on the grounds of industrial complexes, growing in a forgotten corner of some storage yard yet to be developed.

Over 200 species of plants characteristically inhabit Illinois prairies. Although this number is relatively low compared with a typical undisturbed woodland, a small prairie remnant—as little as five acres—can be surprisingly diverse with more than 120 species of plants. All present-day Illinois prairies, however, are incomplete, fragmented ecosystems and lack the large herbivores that were so important in their development.

What if Illinoisans had had the foresight to preserve only 100 square miles of virgin prairie in central Illinois? What a tremendous natural resource and botanical laboratory that would be today! Inevitable though the destruction of the prairie may have been, it is truly unfortunate that prairies will be visualized by future generations as isolated pockets of native vegetation, persisting in a world that passed them by. Ironically, the French word for meadow, so incongruous when applied to this once vast grassland, now seems totally appropriate.

The session opened with a broad historical perspective of the tallgrass prairie. The papers that followed focused tightly on two aspects of that prairie—the remnant-restricted prairie and savanna insects of the Chicago region and the response of prairie birds to habitat fragmentation.

Illinois Prairies: A Historical Perspective

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The grasslands of central North America originated in the Miocene–Pliocene transition, about 7–5 million years before present (YRBP) and were associated with the beginning of a drying trend. The Miocene uplift of the Rocky Mountains created a partial barrier between moist Pacific air masses and the interior portion of the continent. The spread of the Antarctic ice sheet, by tying up atmospheric moisture, also contributed to increased aridity. Woody plants are generally less well adapted to drought than most grass species, and the spread of grasslands consequently occurred at the expense of forests. As the grassland expanded, numbers of grazing and browsing animals increased, an indication that the association of grasses and grazers occurred over a long period of time (Stebbins 1981; Axelrod 1985).

The prairies of Illinois are part of the central grassland, a large triangular-shaped area that has its base along the foothills of the Rocky Mountains from the Canadian provinces of Saskatchewan and Manitoba southward through New Mexico into Texas. The apex of the triangle, the prairie peninsula (Transeau 1935), extends eastward into the Midwest and includes the prairies of Illinois, Iowa, Indiana, Minnesota, Missouri, and Wisconsin with scattered outliers in southern Michigan, Ohio, and Kentucky. Because the Rocky Mountains intercept moist air masses moving westward from the Pacific Coast, the grassland lies in the partial rain shadow to the east. From west to east within the central grasslands, annual precipitation increases from 25–38 cm to 75–100 cm and becomes more reliable; potential evapotranspiration decreases, the number of days with rainfall increases, and periods of low humidity and periodic droughts in July and August decrease (Risser et al. 1981). Associated within this climatic gradient is a shift in the grassland species dominating the vegetation.

Ecologists traditionally have separated the central grassland into three major west–east divisions. The arid western shortgrass prairie is dominated by such species as buffalo grass (*Buchloe dactyloides*), blue grama (*Bouteloua gracilis*), and hairy grama (*B. hirsuta*) that reach heights of only 30–45 cm. The mixed-grass prairie occupies the middle sector of the central grassland and is dominated by grasses that are 60–120 cm tall, including little bluestem (*Schizachyrium scoparium*), needle-grasses (*Stipa spartea* and *S. comata*), and wheatgrasses (*Agropyron smithii* and *A. dasystachyum*). The prairies of Illinois are in the eastern portion of the remaining division of the central grassland, the tallgrass prairie (Figure 1). In this area of relatively high rainfall, the dominant grasses on mesic sites include big bluestem (*Andropogon gerardi*), Indian grass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*)—grasses that reach heights of 1.8–3.6 m. On poorly drained sites supporting wet prairies, prairie cordgrass (*Spartina pectinata*) and bluejoint grass (*Calamagrostis canadensis*) are dominant species; little bluestem and sideoats grama (*Bouteloua curtipendula*) are important grasses on dry sites (Weaver 1954; Risser et al. 1981; Bazzaz and Parrish 1982). Figure 2 indicates how these major grass species follow a soil moisture gradient.

Illinois prairies, which dominated about 60% of the state prior to the extensive settlement and alteration of the landscape by Europeans, developed since the last glacial advance. According to King (1981), as the last of the Wisconsinan age ice sheet retreated from the northeastern portions of the state, mesic deciduous forests dominated most of the landscape. A drying and warming trend began about 8,700–7,900 YRBP, and prairie began to replace deciduous forests in southern Illinois. Prairie influx into central Illinois occurred about 8,300 YRBP and concomitantly oak–hickory forest began to replace mesic forest in the northern portion of the state. Prairies occupied much of the state during the Hypsithermal Period (8,000–6,000 YRBP), which was the hottest and driest part of the Holocene. The climate became cooler and more moist following the Hypsithermal, but prairie stabilized throughout much of Illinois (King 1981).

Because of increased rainfall and reduced evapotranspiration, the climate is increasingly favorable for the growth of trees from west to east in the central grassland. Consequently, in Illinois and the rest of the prairie peninsula, the average climate for approximately the past 5,000 years appears to have been more favorable for forest than for grassland. However, this region has had periodic droughts during which the forest retreated and the grasslands advanced or were maintained. To understand factors influencing the persistence of grasslands in this region, we must consider the extremes of climate and not the average. Britton and Messenger (1970) suggested that the droughts that are most detrimental to woody species are those that do not permit deep recharge of soil moisture during the winter months. On soils without drainage restrictions, trees generally root at greater depths than grasses and rely on moisture stored deep in the soil during droughty periods in midsummer. Interestingly, Britton and Messenger (1970) presented data showing that areas of the Midwest that did not experience deep soil moisture recharge during the drought of 1933–1934 approximately corresponded to the prairie peninsula (Figure 3).

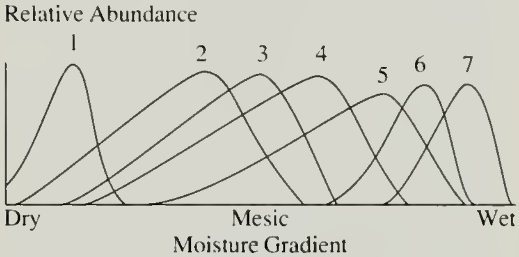

Figure 2. Generalized distribution of major grass species across a soil moisture gradient: (1) sideoats grama, *Bouteloua curtipendula*; (2) little bluestem, *Schizachyrium scoparium*; (3) Indian grass, *Sorghastrum nutans*; (4) big bluestem, *Andropogon geradi*; (5) switchgrass, *Panicum virgatum*; (6) bluejoint grass, *Calamagrostis canadensis*; (7) prairie cordgrass, *Spartina pectinata*. Adapted from Parrish and Bazzaz 1982.

Figure 1. Presettlement distribution of the tallgrass prairie. Adapted from National Geographic (1980) 157(1):43.

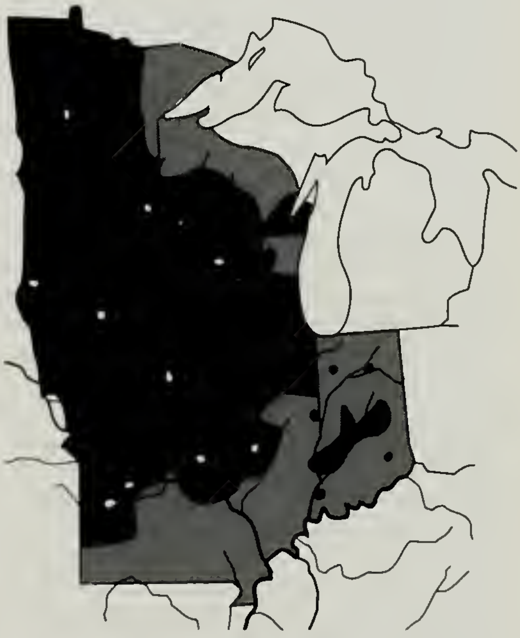

Figure 3. Area in which complete recharge of soil moisture did not occur between the summer of 1933 and the summer of 1934 is shown in dark grey; light grey indicates the area of complete recharge. From Britton and Messenger 1970.

Ecologists generally recognize that climate is the most important factor influencing the distribution of vegetation. However, most ecologists believe that prairie vegetation in the eastern United States would have largely disappeared during the past 5,000 years had it not been for the nearly annual burning of the prairies by the North American Indians and the prairie fires set by lightning (Komarek 1968). The role of Indians in maintaining the prairies and the reasons they burned these grasslands have been discussed and documented by various authors (e.g., Stewart 1951, 1956; Curtis 1959; Pyne 1986).

Although many woody species, for example, oaks (*Quercus* spp.), readily resprout after being top-killed by fire, prairie species are generally better adapted to burning than are most woody plants. The adaptation that protects grasses and forbs from fire is their annual growth habit: the plant dies back to its underground organs each year, exposing only dead material above ground (Gleason 1922). Prairie fires become very hot above ground and on the surface of the soil (83 to 680 C) (Wright 1974; Rice and Parenti 1978) but because they move quickly and soil is a good insulator, little heat penetrates the soil. The same adaptation that protects prairie plants from fire also protects them from drought and grazing. Growing points beneath the surface of the soil permit regrowth after intense grazing and protect perennating organs from desiccation during periods of drought or from fire at any time of the year (Gleason 1922; Tainton and Mentis 1984; Anderson 1982,1990).

Grasses generally produce more biomass annually than can be decomposed in a year. This production of excess herbage probably evolved in response to grazing; however, the productivity of grasslands declines when excess plant litter is not removed by fire or grazing (Golley and Golley 1972). Thus, grasslands evolved under conditions of periodic drought, fire, and grazing and are adapted to all three (Owen and Wiegert 1981; McNaughton 1979, 1984; Anderson 1990).

In presettlement Illinois, the vegetation was primarily a shifting mosaic of prairie, forest, and savanna that was largely controlled by the frequency of fire under climatic conditions that were capable of supporting any of these vegetation types. The frequency of fire was largely determined by topography and the occurrence of such natural firebreaks as waterways and dissected landscapes. Fires carry readily across landscapes that are level to gently rolling, but in hilly and dissected landscapes the spread of fire is more limited (Wells 1970; Grimm 1984). Fire tends to carry well uphill because rising convection currents encourage its spread. But as fire moves down slopes, the convection currents tend to retard it by rising upward and working against the downward direction of the moving fire.

The importance of waterways in determining the distribution of forest and prairie in presettlement Illinois was demonstrated by Gleason (1913) through the use of the Government Land Office Records for selected Illinois counties. He found that prairies were more associated with the west sides of streams and bodies of water than with the east sides, and forests were generally found bordering the east sides. Gleason attributed this pattern to prevailing westerly winds that carried fires from west to east; the west sides of waterways, therefore, burned more frequently than the east sides. Forests were most abundant in presettlement Illinois in the northeast Morainal Section (Schwegman 1973) and in the three unglaciated areas of Illinois (driftless area of Jo Daviess and Carroll counties in northwest Illinois, Calhoun County and portions of Pike County in west-central Illinois, and the far southern portion of the state) (Figure 4). In these areas, the dissected nature of the topography and/or the presence of waterways decreased the frequency of fire and encouraged the growth of forests and savannas. Similarly, the Illinoian till plain, which is older and more dissected than the Wisconsinan till plain, supported more forest than the Wisconsinan till plain, especially in the southern portion (Figure 4).

The relationship between topographic relief and vegetational patterns in Illinois has been recently reexamined. Using a map showing the distribution of prairies and timber (forest and savanna) for Illinois, based on the Government Land Office Records (Anderson 1970), and a map of the average slope range for the state (Fehrenbacher et al. 1968), Anderson (1991) determined the simultaneous occurrence of slope categories and vegetation. Most of the prairie vegetation (82.3%) occurred on landscapes with slopes of 2–4%; only 23.0% of the timbered land, usually on floodplains, was associated with this slope category. In contrast, 77% of the timbered land occurred on sites that had slopes greater than 4% (4–7% slope = 35.2% timber and >7% slope = 41.8% timber) (Figure 5). Iverson (1988) also showed that presettlement forests were positively correlated with sloping landscapes.

The relationship between vegetational patterns and topography is illustrated by the presettlement vegetation of McLean County, which is located in the Grand Prairie Division (Schwegman 1973). That relationship is shown in Figure 6 (Rogers and Anderson 1979). Prior to settlement by Europeans, the county was 90% tallgrass prairie, which occupied relatively level landscapes. Savannas and open forests that were dominated by relatively shade-intolerant but moderately fire-resistant oaks (burr, *Quercus macrocarpa*; white, *Q. alba*; and black, *Q. velutina*) occurred on slopes and ridges of glacial moraines. These areas were subject to periodic fires but less frequently than the prairies. Sheltered areas, such as ravines and stream valleys, contained oaks and hickories but also a high component of mesophytic, shade-tolerant, and fire-susceptible tree species—elms (*Ulmus* spp.), ashes (*Fraxinus* spp.), and maples (*Acer* spp.).

Figure 4. Areal distribution of the dominant till formations and unglaciated portions of Illinois. Adapted from Willman and Frye 1970.

The presettlement prairies of Illinois were drastically altered by the influx of European settlers who converted essentially all of the prairie lands to agriculture. The earliest settlers entered the unglaciated southern portion of the state. This was a familiar landscape for these people who were mostly hunters and trappers from forested regions of Tennessee, Kentucky, and West Virginia. As they migrated northward, they followed the fingerlike traces of forest along the major waterways and initially avoided the larger tracts of prairie. For a variety of reasons, the larger tracts of prairie were avoided in favor of smaller tracts of prairie adjacent to waterways and timber. The settlers needed water for their livestock and to turn waterwheels, and timber was needed for fuel and building materials. In addition, the large tracts of prairie exposed the settlers to the force of winter storms. Timber was considered such an important commodity on the prairie that counties were not allowed to form as governmental units until residents could demonstrate that they had access to timber to support development (Prince and Burnham 1908).

Ironically, some of the earliest settlers believed that prairie soils were infertile. They had been familiar with life in the forest and thought that soil incapable of supporting trees would not be productive for crops. Furthermore, turning over the thick prairie sod was an almost insurmountable obstacle to early prairie farmers until John Deere invented the self-scouring steel plow in 1836. Even after settlers had learned of the fertility of the prairie soil and could raise large crops, many of the larger tracts of prairie remained unsettled because the lack of transportation to get crops to distant markets inhibited expansion onto the prairie. With the coming of the railroads in the 1850–1860s, however, prairies were rapidly converted to cropland (Anderson 1970).

As the prairies were converted to an agricultural landscape, fires, which had swept nearly annually across the prairie in presettlement times, were actively stopped by settlers who viewed them as a threat to economic security. According to Gerhard (1857: 278), "The first efforts to convert prairies into forest land were usually made on the part of the prairie adjoining to the timber. . . . three furrows were ploughed all round the settlements in order to stop the burning of the prairies . . . ; whereupon the timber quickly grows up." The settlers also indirectly stopped the fires by creating plowed fields and roads that acted as firebreaks.

Cessation of these nearly annual prairie conflagrations furthered the demise of the prairies, and many of them were converted to forests or savanna by invading tree species, the distribution of which was no longer restricted by periodic fires. Prairies continued to persist along railroad rights-of-way. Railroads had been in place before the landscape was extensively disturbed and the rights-of-way, which usually extended for 100 feet on either side of the track, were fenced to keep off livestock. In addition, the rights-of-way were managed with fire. Those fires along with many accidental fires prevented the invasion of woody species and exotic weeds. In the last 10 to 20 years, however, many of the remnant prairies along railroads have disappeared because herbicides are used to manage rights-of-way rather than fire. Then too, abandoned rights-of-way, which often contained the only example of native prairie vegetation in areas as large as a county, have frequently been purchased by an adjacent landowner and converted to cropland.

Within Illinois, tallgrass prairie was the dominant grassland community. Variation in topography, drainage patterns, and soil texture resulted in a variety of prairie community

Figure 5. The distribution of native forest–savanna vegetation and prairie (left) compared to average slope categories (right) in Illinois. Native prairie vegetation is shown as black; native forest-savannah vegetation is shown as white. A slope of 2–4% is shown as white, 4–7% as stripes, and >7% as black. From Anderson 1991.

types. Hill prairies occur in scattered locations along the generally forested bluffs of the major river systems, especially the Illinois and Mississippi. These prairies are relatively small, occupying areas from less than a fraction of an acre to as many as 12 or 13 acres. These xeric prairies often occur on west to southwest facing slopes and are dominated by species such as little bluestem and sideoats grama that are dominant components of the arid mixed-grass and shortgrass prairies to the west of Illinois (Evers 1955). Despite the xeric nature of these sites, many presettlement hill prairies have been eliminated or greatly reduced in area as a result of the exclusion of fire and the subsequent encroachment of woody plants (Kilburn and Warren 1963; Anderson 1972; Ebinger 1981; McClain 1983). Many hill prairies have also experienced a decline in quality as a result of grazing by cattle (Evers 1955).

Sand prairies occur on the deep Pleistocene sand deposits along the Illinois River that were laid down by glacial meltwaters during the Woodfordian substage of the Wisconsinan glacial advance (Willman and Frye 1970). These coarse textured sandy soils have little water-holding capacity and favor the growth of plant species adapted to the droughty conditions that characterize this habitat (Gleason 1907; Vestal 1913). Dominant plant species on sand prairies include little bluestem grass, sand lovegrass (*Eragrostis trichodes*), and sand reedgrass (*Calamovilfa longifolia*). The sand prairie community is more resistant to disturbance than the tallgrass prairie. Many agricultural weeds are adapted to mesic sites and are not effective competitors on sand prairie sites. When weeds become established on tallgrass prairie, however, they can prevent recolonization by tallgrass prairie species (Curtis 1959). Until the expanded use of fertilizers and irrigation, sustained agriculture had not been possible on these droughty, low-nutrient sites and as they were abandoned, the native sand prairie flora frequently became reestablished.

Of the 22 million acres of tallgrass prairie that once covered the Illinois landscape, only about 2,300 acres of high-quality prairie remain (White 1978). The prairie community inadvertently provided the incentive for its own demise. In a grassland community, about two-thirds of the plant mass is located beneath the surface of the soil in the form of roots and other underground organs. As these belowground portions of the plant die, they decay in place and greatly enrich the soil with organic matter. The rich and productive soils of most of the Midwest cornbelt, some of the most agriculturally productive soils in the world, had their genesis under prairies. Once the European settlers learned of the fertility of the prairie soil, had the plow that could effectively turn the sod, and could transport their crops to distant markets, the prairies of Illinois disappeared quickly.

Today, however, there is growing interest by the scientific community and the general public in saving and restoring the prairie. The esthetic values of prairie landscapes are being appreciated by a growing number of persons and the potential value of prairie plants in a system of sustainable agriculture is drawing attention from several sources. Efforts are being made to develop one of the native grasses (eastern gama grass, *Tripsacum dactyloides*) into a perennial grain crop (Eisenberg 1989) and to expand the use of warm-season native grasses as a source of forage in combination

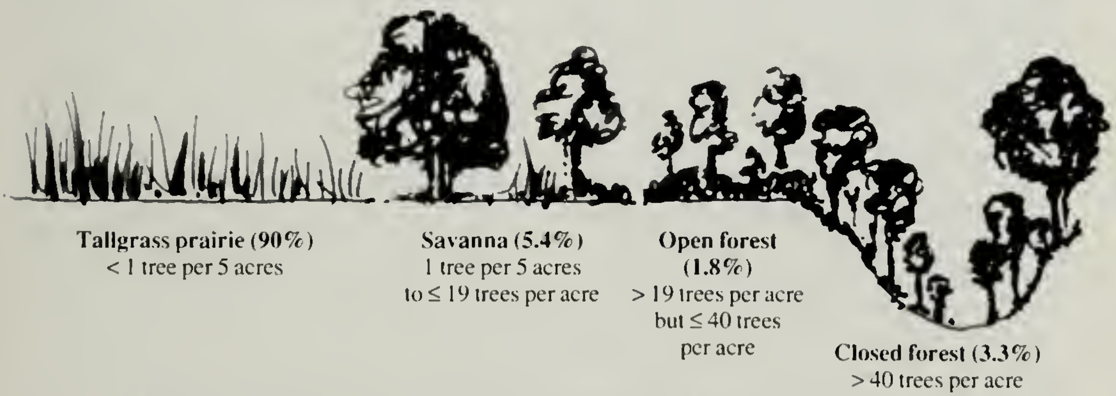

Figure 6. Presettlement vegetation of McClean County, Illinois, in relation to topography about 1820. Adapted from Anderson 1990.

with cool-season domestic grasses. The cool season domestic grasses, such as orchard grass (*Dactylis glommeratus*) and smooth brome (*Bromus inermis*), provide forage during the early and late (cool) portions of the growing season. The warm-season prairie grasses, which maximize growth in July and August, produce a high-quality forage in the middle of the summer when the productivity of the cool-season species is low. As a result, cattle are provided with abundant, good-quality forage throughout the growing season.

It is interesting to note that such cool-season grasses as the exotic Kentucky bluegrass (*Poa pratensis*) were favored over native grass species by the European settlers as forage for livestock. Bluegrass provided forage a month earlier in the spring and a month later in the fall than the native species and was favored for this reason (Prince and Burnham 1908). Because the native grasses had evolved under a system of intermittent grazing pressure, they were eliminated when exposed to continuous grazing. After a couple of years of continuous grazing, native species declined, and the Kentucky bluegrass invaded and dominated.

In Illinois, the tallgrass prairie ecosystem is gone. Yet, the interest in preserving the remaining remnant prairies is strong, including the efforts of such private groups as the Grand Prairie Friends and The Nature Conservancy and such governmental agencies as the Illinois Department of Conservation and the Department of Transportation. Plantings of prairie grasses now diversify the vegetation along many interstate highway rights-of-way. An increasing number of native prairie forbs, the nongrass plants ("flowers") of the prairie, and prairie grasses are being sold by commercial nurseries and seed growers. These forbs include blazing star (*Liatris* spp.), purple cone flowers (*Echinacea pallida* and *E. purpurea*), yellow cone flower (*Ratibida pinnata*), and others. These efforts ensure that future generations of Illinoisans, like the earliest visitors to the state, will have the opportunity to observe prairie life and be inspired by the pleasant colors of tall prairie grasses in the fall and shooting stars (*Dodecatheon media*) and lavender phlox (*Phlox pilosa*) in the spring.

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Prairie and Savanna-restricted Insects of the Chicago Region

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Abstract. Numerous remnants of the presettlement prairies and savannas of the Chicago region have survived. Unfortunately, most are very small and degraded. Nearly all are isolated within vast expanses of human-dominated landscape. For the past nine years, I have surveyed grasshopper, katydid, froghopper, leafhopper, treehopper, butterfly, and macro moth (in part) communities on a variety of these remnants in an attempt to gauge the status and site size requirements of the remnant-restricted members of these groups.

Few of the species considered in this study (probably less than 5%) have been extirpated. Most, perhaps as many as 80–90%, have adapted to our degraded modern landscape and can be found in a variety of human-dominated settings. Among the 10 to 20% that are restricted to native grassland remnants, roughly half are seemingly secure, surviving on at least a dozen protected sites. Approximately one-fifth of the remnant-restricted species are known from fewer than six sites and may be endangered within this area.

Most of the remnant-restricted insects considered in this study have survived on relatively small sites. One-third have been found on sites smaller than 5 hectares. Two-thirds have been found on sites of less than 40 hectares. More than four-fifths have been recorded on two or more sites of less than 300 hectares. (Even sites as small as 1 hectare can support a few restricted species.) Site size is clearly an important determinant of butterfly diversity on smaller remnants (1–60 ha) in this region.

Prairie Birds of Illinois: Population Response to Two Centuries of Habitat Change

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The landscape of Illinois has changed considerably over the last two hundred years. The once extensive, unbroken stretches of prairie have given way to agricultural crops, and this shift has had a substantial impact on the state's bird fauna. The purpose of this paper is twofold: to examine how the prairie bird fauna of Illinois has responded to changes in the state's landscape and to discuss how a highly fragmented landscape may be affecting prairie bird populations.

POPULATION STUDIES 1800–1900

Prior to European settlement, prairie occupied approximately 8.5 million hectares in Illinois, nearly two-thirds of the state (Anderson 1970). The area of prairie was over 1.5 times that of forests. which at approximately 5.5 million hectares was the next most abundant habitat type (Graber and Graber 1963). The composition of the presettlement bird fauna in Illinois is not well known. Current data, however, show that prairies support relatively low densities of breeding birds. Bird densities in tallgrass prairie habitat average roughly 1.8 pairs per hectare (Cody 1985). Comparable densities for eastern deciduous forests are 8.7 pairs per hectare (obtained from 87 breeding bird studies published in *American Birds*, volumes 37 and 38). Because of the low density of birds in prairie habitat, Graber and Graber (1963) estimated that only 35–40% of the presettlement bird fauna of Illinois was composed of prairie birds; forest birds, however, may have accounted for as much as 55–60%.

Unfortunately, by the time much of the early ornithological work was conducted within Illinois (1850–1900), considerable losses of prairie habitat had already occurred. By 1850 prairie habitat had been reduced to 2.1 million hectares (Graber and Graber 1963), a reduction of almost 75% or roughly 3.5% per year since 1810. We can, therefore, reasonably assume that some changes in the prairie bird fauna had occurred prior to any detailed study. Nevertheless, the works of Ridgway (1873, 1889, 1895) for central and southern Illinois and Nelson (1876) for northern Illinois can be used to estimate prairie bird abundances in the state prior to 1900 (Table 1).

A number of prairie bird species initially benefited from the conversion of prairie to farmland. Those that benefited most include the horned lark, vesper sparrow, and greater prairie-chicken. The increase in horned larks and vesper sparrows was largely due to their ability to colonize and breed in cultivated habitats, which by 1900 had become the most abundant habitat type in the state (Graber and Graber 1963). The initial opening of the prairies and forests to agriculture produced an intermixed pattern of food and cover that was beneficial to many species of upland game, including the greater prairie-chicken (Westemeier and Edwards 1987). This shift in habitat coupled perhaps with a reduction in the abundance of predatory animals (due to fur trapping and hunting) allowed the prairie-chicken to reach a peak abundance within Illinois of approximately 10 million birds by 1860 (Westemeier 1986; Westemeier and Edwards 1987). Prairie-chickens started to decline soon after reaching their peak abundance. Nelson (1876) listed them as once excessively abundant but now rather scarce in the Chicago region and as less numerous in all the more settled areas of the state due to egg collection by humans, unrestricted hunting, and loss of habitat.

POPULATION STUDIES 1900–1950

During 1906–1909, a systematic survey of the state's birds was conducted by Alfred Gross and Howard Ray of the Illinois State Laboratory of Natural History (Forbes 1913; Forbes and Gross 1922). These surveys provided the first quantitative estimates of breeding bird populations within Illinois. A summary of the relative abundances of the most common grassland species encountered by Gross and Ray in ungrazed grass, mixed-hay, and pasture from the north and central regions of Illinois are shown in Table 1. Gross and Ray found bobolinks and meadowlarks (eastern and western) to be the most common bird species, accounting for more than 50% of all birds encountered in these habitats. Of the birds listed as abundant or very common by Ridgway (1889, 1895) and Nelson (1876), the greater prairie-chicken, upland sandpiper, and Henslow's sparrow apparently experienced the greatest declines between the mid-1800s and the censuses of Gross and Ray. All three of these species were uncommon or rare by 1906 (Table 1).

In the first paper addressing changes in the bird fauna of Illinois, Ridgway (1915) discussed changes that had taken place in the half century preceding 1915. He cites three prairie birds—the greater prairie-chicken, upland sandpiper, and dickcissel—as experiencing serious declines during this period. The greater prairie-chicken and upland sandpiper were considered on the verge of elimination within Illinois because of shooting and destruction of nests by dogs and cats. The dickcissel had also dramatically declined during this period for "unknown reasons" (Ridgway 1915). Ridgway first noted the dickcissel's decrease around 1885 and stated that by 1915 this species never reached more than one-fourth and usually less than one-tenth its former numbers. Coincidentally, Fretwell (1986) documented a sevenfold increase in grazing pressure between 1870 and 1884 on the dickcissel's primary wintering grounds in Venezuela, a factor that he believed could significantly affect winter resources and, in turn, dickcissel numbers.

POPULATION STUDIES 1950–1989

In 1956–1958, the census routes of Gross and Ray were repeated by Graber and Graber (1963) of the Illinois Natural History Survey

Table 1. Relative abundance of prairie birds within Illinois 1850–1989.

		1906–1909[2]		1956–1958[3]		1987–1989[4]		USFWS[5]
Species	Prior to 1900[1]	%	Rank	%	Rank	%	Rank	% change
Eastern meadowlark[6]	Abundant	25.5	2	20.0	2	11.8	2	–67.0
Dickcissel	Abundant	13.1	3	8.7	4	7.7	5	–46.7
Grasshopper sparrow	Abundant	5.9	5	5.3	6	8.6	4	–56.0
Bobolink	Abundant	25.8	1	9.7	3	11.4	3	–90.4
Henslow's sparrow	Abundant	<1.0	15	<1.0	14	1.6	12	*
Red-winged blackbird	Very common	9.9	4	36.2	1	26.8	1	–18.8
Greater prairie-chicken	Very common	<1.0	13	0.0	16	0.0	16	*
Upland sandpiper	Very common	2.3	9	<1.0	12	<1.0	13	–16.8
Vesper sparrow	Common	1.3	11	1.4	10	<1.0	15	+12.1
Horned lark	Common	4.9	6	4.8	7	<1.0	14	0.0
Field sparrow	Common	4.0	7	2.9	9	5.6	7	–52.6
Song sparrow	Common	2.6	8	1.0	11	3.3	10	–29.3
Savannah sparrow	Common	2.3	10	5.8	5	3.5	9	–58.9
American goldfinch	Common	1.2	12	3.1	8	4.7	8	–42.8
Common yellowthroat	Common	<1.0	14	<1.0	15	5.8	6	– 8.8
Sedge wren	Common	<1.0	16	<1.0	13	2.8	11	–22.5

[1] Relative abundance prior to 1900 based on the works of Nelson (1876) and Ridgway (1873, 1889, 1895).
[2] Relative abundance 1906–1909 based on the censuses of Gross and Ray from approximately 380 ha of ungrazed grass, mixed-hay, and pasture, located in northern and central Illinois (Forbes 1913; Forbes and Gross 1922).
[3] Relative abundance 1956–1958 based on the censuses of Graber and Graber (1963) from approximately 290 ha of ungrazed grass, mixed-hay, and pasture, located in northern and central Illinois.
[4] Relative abundance from the present study (1987–1989) based on censuses of approximately 400 ha of ungrazed prairie and agricultural grasslands in northeastern and east-central Illinois.
[5] Estimated population change within Illinois between 1967–1989 based on United States Fish and Wildlife Service's breeding bird survey (USFWS, unpublished data).
[6] For 1906–1909 and 1956–1958, relative abundance estimates are for eastern and western meadowlarks combined.
*Present on too few routes for accurate trend analysis.

(Table 1). The Grabers believed that the red-winged blackbird, horned lark, and dickcissel had shown large statewide population increases between 1909 and 1956.

Red-winged blackbird numbers had almost doubled since the earlier censuses of Gross and Ray due to the ability of this species to invade nearly all terrestrial habitats within the state (Graber and Graber 1963). Ridgway (1889) noted that although very common, the nests of red-winged blackbirds were always in or in very close proximity to a swamp or marsh. Gross and Ray, however, found red-winged blackbirds in all the grassland habitats they censused in 1906–1909, although 60% of the state's population of these birds still nested in marshes (Graber and Graber 1963). From 1909 to 1956, red-winged blackbird densities within grassland habitats in Illinois increased nearly tenfold. The species had become far more common in grasslands than in marshes, with individuals inhabiting marshes accounting for less than 3% of the state's population (Graber and Graber 1963).

The statewide increase in horned larks between 1909 and 1956 corresponded to their shift from primarily grassland to cultivated habitats, especially row-cropped fields. This switch from a rapidly declining to a rapidly increasing habitat greatly benefited the horned lark, which Graber and Graber (1963) recognized as the species that had increased most dramatically between 1909 and 1956. The Grabers attributed the dickcissel's statewide increase to an expansion in acreage of agriculturally disturbed grasslands, a type of habitat that this species may prefer over true prairie (Kendeigh 1941; Graber and Graber 1963; Zimmerman 1971). Most species of prairie birds, however, had shown either little or no statewide population change between 1909 and 1956 (Graber and Graber 1963). The bobolink, song sparrow, and savannah sparrow showed slight increases, the upland sandpiper and field sparrow slight decreases, and the vesper sparrow, grasshopper sparrow, and American goldfinch no change.

Between 1987 and 1990, I conducted research on the breeding birds of Illinois grasslands; however, my field methods differed from those used by Gross and Ray and the Grabers and direct comparisons are therefore not possible (see Herkert 1991 and Graber and Graber 1963 for descriptions of methods). Nevertheless, a comparison of relative abundances of these species indicates that the current composition of grassland bird fauna is probably very similar to that of the late 1950s (Table 1). Red-winged blackbirds remain the most common species, outnumbering the next most abundant species, the eastern meadowlark, by more than two to one. In fact, four of the five most abundant species are the same in my censuses and in those of Graber and Graber (Table 1).

An estimate of how prairie bird numbers have changed since the Grabers' census can be obtained from data collected by the United States Fish and Wildlife Service's cooperative breeding bird survey (unpublished data). These data from Illinois for 1967–1989 show that nearly all prairie bird species have experienced population declines during this 23-year interval (Table 1). Some of the formerly most abundant prairie bird species, for example, the bobolink, have shown declines as high as 90% during this period. The causes of these recent population declines are not well understood but probably are a consequence of continued loss of grassland habitat within Illinois.

Although the initial loss of prairie habitat within Illinois was rapid and extensive, the reduction of prairie habitat has continued in recent decades. By 1978, less than 1,000 hectares of high-quality prairie remained in the state (Schwegman 1983). The loss of prairie habitat was originally offset by the creation of secondary grasslands such as hayfields and pastures, habitats which the majority of prairie birds found suitable for breeding (Graber and Graber 1963). In fact, none of the characteristic birds of the eastern tallgrass prairie region are considered endemic to prairie habitat (Risser et al. 1981). Acreage of these secondary grassland habitats, however, has also recently declined. For example, the amount of hay within Illinois was reduced by more than half, from 850,000 to 400,000 hectares, between 1960 and 1989 (Illinois Agricultural Statistics Service 1988, 1989). The amount of pasture within Illinois has also been greatly reduced, with pasture occupying only 607,000 hectares in 1987 (U.S. Department of Commerce Bureau of the Census 1989) compared with 2.5 million hectares in 1906. The continued loss of both native and agricultural grassland habitats in Illinois has contributed to an increasingly fragmented landscape.

HABITAT FRAGMENTATION

The process of habitat fragmentation sets off a series of events that can ultimately have a major effect on breeding bird communities. Changes associated with increased fragmentation include a decrease in the total amount of habitat, a decrease in the average size of habitat patches, increased patch isolation, and an increase in the ratio of edge to interior habitat, all of which may have important consequences for breeding birds (Wiens 1989).

The most important consequence of habitat fragmentation is the loss of large amounts of habitat and the resulting losses of individuals, local populations, and possibly even species. Surprisingly, only three species of prairie birds have been extirpated from Illinois despite the extensive loss of prairie habitat (Table 2). Bowles et al. (1980) originally listed four species as extirpated from Illinois, but the sandhill crane has returned to the state as a breeding species (Kleen 1988). The remaining three species (sharp-tailed grouse, swallow-tailed kite, and whooping crane) were extirpated prior to or very shortly after 1900 (Bowles et al. 1980). Another 13 prairie bird species are now considered to be threatened or endangered within Illinois (Table 2), primarily as a direct result of extensive habitat loss. A number of these endangered and threatened species may be on the verge of extirpation within Illinois. The greater prairie-chicken, for example, once one of our most abundant prairie birds, now has a statewide population of less than 100 individuals (R. Westemeier, pers. comm.).

The reduction of the average patch size that accompanies habitat fragmentation also has serious consequences for breeding birds. Small patches may be too small to meet the minimum territory requirements for a species or may lack essential resources necessary for the establishment of populations (Diamond 1975). The responses of individual species to reductions in patch size are variable, but nearly all bird species exhibit a minimum area threshold below which they never occur (e.g., Lynch and Whigham 1984; Hayden et al. 1985; Robbins et al. 1989). Six prairie bird species were never encountered during my research within Illinois on areas of less than 10 hectares (Table 3), despite the fact that the average territory for four of these species (bobolink, savannah sparrow, grasshopper sparrow, and Henslow's sparrow) is typically less than 2.5 hectares (Wiens 1969). Many prairie bird species avoid small areas, and small grasslands have been shown to support impoverished breeding bird faunas (Samson 1980; Howe et al. 1985; Herkert 1991). The number of breeding bird species in grassland fragments is strongly related to fragment size, with large fragments supporting significantly more species than small fragments (Samson 1980; Herkert 1991). In addition, small habitat patches generally support small numbers of individuals, thus greatly increasing the influence of stochastic events on population demography. As a result, small isolated bird populations have been shown to exhibit relatively high turnover rates (e.g., Diamond 1969; Diamond and May 1977; Morse 1977) and therefore a higher probability of local population extinction.

In Illinois, the natural areas inventory (1975–1978) identified only 253 remnants, totaling 950 hectares, of high-quality prairie

Table 2. Extirpated, endangered, and threatened birds of Illinois prairies (from Bowles et al. 1980).

Endangered	Threatened
American bittern	Loggerhead shrike
Yellow rail	Henslow's sparrow
Black rail	Brewer's blackbird
Bachman's sparrow	
Greater prairie-chicken	Extirpated
Swainson's hawk	Sharp-tailed grouse
Short-eared owl	Whooping crane
Northern harrier	Swallow-tailed kite
Upland sandpiper	
Sandhill crane	

Table 3. Minimum areas of encounter for 17 grassland bird species from 24 grassland fragments located in northeastern and east-central Illinois (1987–1989). Grasslands ranged from 0.5 to 650 hectares.

<10 hectares	10–30 hectares
Field sparrow	Bobolink
American goldfinch	Savannah sparrow
Song sparrow	Grasshopper sparrow
Dickcissel	Henslow's sparrow
Ring-necked pheasant	
Sedge wren	>30 hectares
Common yellowthroat	Upland sandpiper
Red-winged blackbird	Northern harrier
Northern bobwhite	
Eastern meadowlark	
Vesper sparrow	

within the state (Schwegman 1983). The majority of these remnants were small, most less than 20 hectares, and would therefore be expected to support very few, if any, prairie bird species. Grasslands of 100 hectares or more may be necessary to support just five prairie interior species (Herkert 1991).

Increases in patch isolation can also increase the probability of local population extinctions due to decreased immigration rates. Island biogeography theory predicts that immigration rates will be affected by both patch isolation and size, with the lowest immigration rates occurring on patches that are small and well isolated from a colonizing source (MacArthur and Wilson 1967). Whether mainland fragments act as true islands with respect to immigration, however, is open to question because mainland fragments are not surrounded by totally inhospitable habitat as are true islands and therefore might not show immigration rates that are strongly dependent on patch isolation. A number of studies conducted in the eastern deciduous forests of North America have demonstrated that isolation does have a significant effect on species richness within forest fragments (Robbins 1980; Howe 1984; Lynch and Whigham 1984; Askins et al. 1987). Researchers working in forests on other continents, however, have found no evidence supporting isolation as a significant factor affecting species richness within fragments (Kitchener et al. 1982; Howe 1984; Opdam et al. 1985). The effects of isolation on immigration rates in midwestern grasslands have not been studied to date.

Harris (1984) points out that island biogeography theory assumes that islands always have a mainland source pool for immigration; for terrestrial fragments, however, the "mainland" source may be lost as a result of the fragmentation process. In this case, the recolonization of mainland fragments must occur between habitat patches. The integrity of the whole system would then depend on the existence of areas large enough to produce enough surplus individuals to provide dispersers as well as maintain stable populations within a particular preserve.

Another consequence of habitat fragmentation is an increase in the ratio of edge to interior habitat as patch size decreases (Butcher et al. 1981; Temple 1986). This increase may result in the loss of species that require interior habitats and an increase in the abundance of edge species (Whitcomb et al. 1981; Ambuel and Temple 1983; Temple 1986). Small grasslands are usually dominated by such nonprairie species as red-winged blackbirds and common yellowthroats and support few prairie interior bird species (Herkert 1991). Moreover, the increase in the ratio of edge to interior habitat may lead to lower reproductive success for nesting grassland birds. Levels of both nest predation and parasitism have been shown to be higher in edge habitats than in grassland interiors, especially if the edge is a field–woodland or field–shrubland border (Best 1978; Gates and Gysel 1978; Johnson and Temple 1986, 1990; Burger 1988).

Finally, we must remember that loss of prairie and grassland habitat in Illinois, and throughout the Midwest, affects birds primarily during the breeding season. The majority of prairie bird species are migratory and spend only a fraction of any given year on the breeding grounds. Similar alterations of wintering and possibly migratory habitat may also significantly affect these bird species. The degree to which events off of the breeding grounds affect prairie birds are not well known. For such species as the dickcissel, however, events on the wintering grounds and migratory routes may be the most important factors affecting distribution and abundance patterns on the breeding grounds in the Midwest (Fretwell 1986). The fact that processes operating outside the boundaries of Illinois affect bird populations within the state does not excuse us from being concerned about events occurring within Illinois, but rather should alert us to the year-round needs of these species. If conservation efforts to preserve prairie birds are to succeed, management efforts must address not only processes operating on the breeding grounds within Illinois but the migratory and wintering needs of these species as well.

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Session Three: Wetlands

What would the world be, once bereft
Of wet and wildness? Let them be left,
O let them be left, wildness and wet;
Long live the weeds and the wilderness yet.

—Gerard Manley Hopkins

While most Illinois residents may not consider their state to be particularly wet, early settlers had a very different impression. Writing in 1833, the year Chicago was incorporated as a village, Colbee Benton observed that Chicago "stands on the highest part of the prairie, and in the wet part of the season the water is so deep that it is necessary to wade from the town for some miles to gain the dry prairie. Notwithstanding the water standing on the prairie and the low, marshy places, and the dead-looking river, it is considered a healthy place."

The retreat of the glaciers left numerous large and small streams with many associated wet areas. Much of northeastern Illinois had abundant diverse wetlands, and central Illinois was a montage of wet prairies and marshes. Extensive tracts of tupelo–cypress swamps could be found in the far southern part of the state.

Wetlands are diverse and complex places. The most common wetlands in Illinois are marshes and sedge meadows, although ponds, fens, seeps, wet prairies, swamps, and bogs are also present. Marshes form where water is above the soil surface for all or nearly all of the year—along the margins of ponds, lakes, or rivers, in places sheltered from strong currents and waves. Sedge meadows are usually associated with fens. Here the water level is near or just below the surface most of the year, and this habitat often merges into marshes as the water depth increases. The surface of the vegetation hides countless tussocks or humps formed by the tussock sedge, and these vary in height from a few inches to over a foot. The terms *bog* and *fen* are often used inconsistently, even interchangeably, and considerable confusion has been the result. In general, bogs are acidic and poor in minerals, with most of the water coming from rainfall and surface runoff and most of the new peat developing from sphagnum moss. Fens range from acidic to alkaline and are rich in minerals; much of the water comes from groundwater that has percolated through calcareous bedrock or gravel. Peat is produced primarily by sedges and grasses. Seeps are characterized by groundwater that has reached the surface in a diffuse rather than a concentrated flow. Seeps form when groundwater that has percolated down through porous sand or gravel reaches a layer of impermeable material and flows outward, usually at the base of a bluff or ravine. Swamps are areas where the soil is saturated or covered with surface water for most of the growing season; woody vegetation dominates.

What was formerly looked upon as sources of disease and pestilence, "sacred to the ague and fever," are currently viewed in a new light. The importance of wetlands is only now being realized: they store runoff after major rains and slowly release it; they filter silt and pollutants from water; and they are tremendously productive, providing habitat for a diversity of plants and animals.

Illinois originally had an estimated 8 million acres of wetlands. Since Illinois became a state in 1818, more than 95% of these have been drained with a concomitant loss in the natural processes that wetlands provide. High-quality wetlands that reflect presettlement conditions are exceedingly rare today; only about 6,000 acres remain.

The papers presented at this session reviewed the state of our wetlands, documenting what has been lost as well as what must be restored or preserved. Particular attention was given to the plants and animals that depend on the unique habitats of wetlands.

Aquatic and Wetland Plants of Illinois

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Abstract. Over 100 of the 172 families of vascular plants growing without cultivation in Illinois have species adapted to aquatic or moist soil habitats. These wetland plants range from ferns and their allies to conifers to flowering plants. Growth forms include herbs, shrubs, and trees, any of which may function as the dominant species of a plant community or as minor components. Some important wetland plant families in Illinois are the sedge family (Cyperaceae), grass family (Poaceae), pondweed family (Potamogetonaceae), duckweed family (Lemnaceae), smartweed family (Polygonaceae), and sunflower family (Asteraceae). In providing for their own growth and reproduction, these plants make up the vegetation component of wetlands and provide much of the food, nesting cover, and escape cover for wetland animals.

Common aquatic and emergent species of wetland communities in Illinois include coontail (*Ceratophyllum demersum*) beneath the surface of calm waters, duckweeds (*Lemna* sp.) floating on the surface, bulrushes (*Scirpus* sp.) and cattail (*Typha latifolia*) in marshes, buttonbush (*Cephalanthus occidentalis*) in shrub swamps, and bald cypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*) in wooded swamps. A wider variety of species occupy moist soil communities as opposed to aquatic communities.

Breeding Biology and Larval Life History of Four Species of *Ambystoma* (Amphibia: Caudata) in East-central Illinois

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Abstract. Temporary aquatic habitats, whether roadside ditches, flooded fields, or woodland ponds are essential in maintaining the biodiversity of Illinois. Nineteen species of Illinois amphibians (50% of the state's species) depend on such habitats for breeding. Two species of reptiles breed in those habitats, and 8 to 10 more use them as foraging areas. In addition, these temporary aquatic habitats are important for many invertebrate species.

Kickapoo State Park, located in Vermilion County, Illinois, provides just such temporary aquatic habitats, and this paper records my observations of the breeding biology and larval history of four species of salamanders, genus *Ambystoma* (Amphibia: Caudata) in that setting from 1973–1984.

Ambystoma opacum migrated to the dry beds of two vernal hilltop ponds at Kickapoo State Park in late September or October. The females oviposited under the mat of leaf litter that covered the pond beds and abandoned the eggs in late fall. *Ambystoma platineum*, *A. texanum*, *A. maculatum*, and *A. platineum* x *A. texanum* hybrids migrated to the ponds under stimulus of rains in February and March, provided groundwater was sufficient to fill the ponds to a depth of at least 25 cm. *Ambystoma maculatum* migrated 3–7 days later than the other spring-breeding species. In years when no standing water was present in the ponds, spring migration was prolonged or involved few animals. *Ambystoma texanum* and *A. maculatum* males deposited beds of spermatophores in different locations on the pond bottoms. The gynogenetic *A. platineum* used sperm from the *A. texanum* spermatophores to initiate cleavage of their eggs, and fertilization occasionally occurred. *Ambystoma platineum* and *A. texanum* laid eggs in water less than 30 centimeters deep; *A. maculatum* laid eggs in water at least as deep as 30 centimeters.

Ambystoma opacum larvae hatched within 24 hours after the ponds filled in the spring. Eggs of the other species hatched in 3–6 weeks. Larvae grew little for 2 weeks and then grew rapidly for about 1.5 months. Little further growth occurred before transformation.

Larvae usually transformed in late May (*A. opacum*) or late June (the other species). *Ambystoma opacum* larvae were always able to transform, but in most years the ponds dried before most, if not all, of the larvae of the other species could transform. Larvae are opportunistic feeders, and their food included volvocids, ostracods, branchiopods, annelids, insects, and in the case of *A. opacum*, the larvae of other salamanders.

Ecological Integrity of Two Southern Illinois Wetlands

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Palustrine and riverine wetlands in Illinois are increasingly rare ecosystems. Unfortunately, the declining wetland habitat in Illinois is not an isolated phenomenon (Mitsch and Gosselink 1986; Illinois Department of Conservation 1988). Wetlands across this country are in jeopardy due to drainage for a variety of human endeavors, primarily agriculture, or to the associated and chronic but less dramatic threat, soil erosion.

The presettlement area of wetlands in this country is difficult to ascertain, and estimates vary from 51 to 87 million hectares (Greeson et al. 1979). The rapidity with which our wetlands disappeared is difficult to comprehend. By the early 1950s, 35% of the wetlands in this country had already been drained. Federal bureaucracies were given unbridled authority to drain any wetland deemed a nuisance. In the eastern United States, the U.S. Army Corps of Engineers and the USDA Soil Conservation Service played major roles in the destruction of wetlands. The Army Corps destroyed large wetlands while the Soil Conservation Service destroyed smaller ones. Drainage tiles were installed throughout wetlands and quit discharging only when no more water was left to drain. Large and small ditches were dug to expedite drainage and are dramatically illustrated on most topographic maps of southern Illinois. Many of the largest ditches were given quaint yet telling names, for example, Post Creek Cutoff, which was dug in the early 1900s and continues to disrupt the natural hydrological dynamics of the wetlands along the Cache River of southern Illinois. Smaller ditches generally remain unnamed, such as the one dug in an as yet incomplete effort to drain Lovets Pond, a remnant of the once vast Mississippi River floodplain wetlands of southern Illinois. That ditch was most likely dug overnight during the fall of 1986. From 1950 to 1970 another 8.5% of the nation's wetlands were lost, approximately 186,000 hectares per year over the twenty-year period and an area almost twice the size of the Shawnee National Forest.

Most (95%) of the wetlands in the United States are inland and those are incredibly diverse, ranging from the upland, subalpine swamp-meadows of Yosemite to the lowland pitcher-plant bogs of southern Alabama. Of all wetland types (see Cowardin et al. 1979), none is more threatened than the emergent wetlands, those characterized by erect, rooted, herbaceous hydrophytes (excluding mosses and lichens), or the forested wetlands, those characterized by woody vegetation at least 6 meters tall. The former is found in Lovets Pond, and the latter along the Cache River. Nationwide these two wetland types disappeared at a rate approaching 10% each year from 1950 to 1970. This rate has diminished but not nearly enough.

Illinois has the regrettable distinction of having lost more of its wetlands than most other states, and only 5% of our original wetlands are left. Obviously, Illinois needs to preserve all of its remaining wetlands. To do so would provide greater assurance that the state's biodiversity would not decrease to exclude even fairly common but uncelebrated species like the crawling water beetles (*Peltodytes* and *Haliplus* spp.). One cannot be optimistic about future preservation efforts because federal and state laws and their implementation are "too little too late" to prevent even state agencies from destroying wetland habitat. To illustrate, the Illinois Department of Conservation is currently entertaining a proposal to destroy an old-growth bottomland forest wetland in Horseshoe Lake Conservation Area in Alexander County. Public opposition to the project may prevail, but current law and regulation would make that destruction legal.

An immediate response is essential. We need to identify and prioritize the Illinois wetlands in greatest jeopardy, a task not easily accomplished. Many practical and theoretical questions must be answered in the process, for example, "What size do wetlands need to be to assure their integrity and to preserve maximum biodiversity?" Given present understanding and adequate financial resources, the best answer is to preserve the largest areas possible. In Illinois, however, most of the remaining wetlands are small, isolated islands such as Lovets Pond. Small as these are, they cannot be ignored, and we cannot allow ecological theory to be used as an excuse for not preserving or protecting them. If we accept that only large, nearly pristine areas should be placed on a priority list, we assure further decreases in the state's biodiversity because small wetlands do harbor diverse communities, and in many cases those communities appear to be stable. In fact, small wetlands like Lovets Pond may presently have greater ecological integrity than larger, heavily silted ones like those along the Cache River. By ecological integrity I mean the relative disparity between the abundance and diversity of the aquatic fauna in a given system relative to that which could reasonably be expected to occur in the same system if it were undisturbed. A close look at the macroinvertebrate communities of Lovets Pond and the Cache River wetlands (Figure 1) provides evidence for this contention. Acknowledging the value of small wetlands does not of course mean that we should not fight for the greatest protection possible for larger areas such as the Cache wetlands. Although these areas may be seriously compromised, they nevertheless contain pockets of diversity that might serve as epicenters of re-invasion for an entire area if allowed to do so.

Lovets Pond was once part of a wetland system that covered a large area of the Mississippi River bottoms of southern Illinois

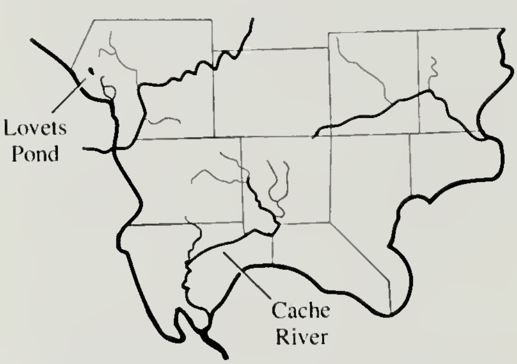

Figure 1. Location of Lovets Pond and the Cache River, the two Southern Illinois sites in this study.

(Jackson County and others). Now, this once vast ecosystem is reduced to a 16-ha remnant that is surrounded by a lowland forest that increases its size to 65 ha. This island is totally enclosed by intensive agriculture. When I began to investigate the ecological integrity of Lovets Pond, I shared the bias of many biologists who are convinced that preserving small areas does not protect enough biodiversity to justify the cost. This contention may be true for large organisms but what about small ones? In long- and short-term scenarios, many species not in need of large areas may perhaps be protected within small, isolated systems.

The Cache River wetlands were also once part of a much larger system (114,000 ha). Only 1% of this vast wetland complex remains, with Heron Pond, a beautiful state nature preserve, the best-known area. At the present time, about 14,000 ha are being considered for inclusion in the proposed Cypress Creek National Wildlife Refuge. The area is an important wintering ground for migrating waterfowl and contains other unique features, including several bald cypress trees over 1,000 years old that represent the oldest living organisms east of the Mississippi River. Agricultural activity occurs throughout the area and forms the borders of most of the remaining wetlands.

SITE DESCRIPTIONS AND METHODS

Lovets Pond. The investigation of the macroinvertebrate communities of Lovets Pond during 1986 focused on two questions (Phillippi and Peterson 1986). Are the communities diverse and distinct from one another? And if so, are the communities distributed to correspond to the vascular plant communities? Because vascular plants are the major substrate for the attachment of nonbenthic macroinvertebrates, distinctiveness among the macroinvertebrate communities might well be realized along a gradient similar to that observed for the vascular plants.

In order to answer these questions, one site was selected for investigation in each of the four major plant communities: open pond, shrub swamp, true swamp, and marsh (Figures 2–5). During 1986, these communities were connected by water for varying amounts of time. The open pond and the shrub swamp were connected the longest, and the true swamp was connected to the previous two for a shorter period. The marsh was isolated from the other three for most of the year. The open pond community is edged with buttonbush (*Cephalanthus occidentalis*), and by early summer the surface is almost totally covered with yellow pond lily (*Nuphar luteum*). Water in the open pond community was about 1–2 m deep. The shrub swamp community surrounds the open pond and is dominated by an impenetrable thicket of buttonbush with a few black willows (*Salix nigra*) scattered throughout. Thick stands of lizard's-tail (*Saururus cernuus*) occur along its edge. In general, 20–30 cm of water covered this community during the winter and spring. The true swamp is fully forested with a variety of tree species, including pumpkin ash (*Fraxinus profunda*), red maple (*Acer rubrum*), and water locust (*Gleditsia aquatica*). Water covered the forest floor (10–12 cm) only during the winter. The marsh, dominated by graminoid plants, is the smallest (1 ha) and most isolated of the four communities. It is maintained by periodic fires set by farmers to prevent the lowland forest from encroaching onto their fields. The amount of silt covering the bottom of each of the four communities was minimal.

Two unit-effort dipnet samples of the macroinvertebrate community were taken from each plant community on six dates at four- to

Figure 2. Open pond community of Lovets Pond in mid-April 1986. The thick growth of yellow pond lily (*Nuphar luteum*) obscures the coontail (*Ceratophyllum demersum*) and pondweed (*Potamogeton* spp.) that are scattered throughout. Photo by author.

Figure 3. Shrub swamp community of Lovets Pond in mid-June 1986. The almost impenetrable growth of buttonbush (*Cephalanthus occidentalis*) in the background is surrounded primarily by lizard's tail (*Saururus cernuus*). Photo by author.

Figure 4. True swamp community of Lovets Pond in mid-June 1986. New growth of arrow arum (*Peltandra virginica*), foreground, covers the lowest points in this community. A variety of tree species are seen in the background, including pumpkin ash (*Fraxinus profunda*), water locust (*Gleditsia aquatica*), and red maple (*Acer rubrum*). Photo by author.

Figure 5. Marsh community of Lovets Pond in mid-May 1986. Such graminoid plants as bur reed (*Sparganium eurycarpum*), giant bulrush (*Scirpus tabernaemontanii*), and common cattail (*Typha latifolia*) surround the marsh edge. Duckweeds (*Spirodela* spp. and *Lemna* spp.), water meal (*Wolffia* sp.), and sponge plant (*Limnobium spongia*) cover the surface by summer. Photo by author.

six-week intervals, January through June 1986. Samples were preserved and later sorted and identified to the lowest practical taxon.

Cache River and Wetlands. During the summer of 1986 a team of biologists (Phillippi et al. 1986) surveyed the aquatic fauna at 23 sites within the Cache River drainage (Figure 6). Two dipnet samples were taken from a representative portion of each of the sites and the organisms sorted and identified to the lowest practical taxon.

Figure 6. Large bald cypress (*Taxodium distichum*) along the Cache River and its wetlands provide a major attraction for canoeists. Photo by Marti Crothers.

RESULTS AND DISCUSSION

Lovets Pond. The true swamp and marsh communities of Lovets Pond contained the highest number of macroinvertebrate taxa; the lowest number was found in the open pond (Table 1). Samples taken from the true swamp and shrub swamp communities yielded the largest number of individuals; once again, the open pond yielded the lowest number (Table 1).

The number of taxa and individuals in each community fluctuated in a roughly similar fashion across the seasons; however, no pattern within or across the four communities in regard to the diversity (H') of macroinvertebrates was discernible (Figure 7). No single plant community always harbored the highest or lowest species diversity. Even so, the four plant communities contained distinct macroinvertebrate assemblages, at least qualitatively, and this distinction was demonstrated using Jaccard's similarity coefficients and group average clustering (Figure 8). Cluster 1 is predominated by the shrub swamp macroinvertebrate community, cluster 2 by the true swamp, and cluster 4 by the open pond community. The macroinvertebrate community inhabiting the marsh is indistinct from those of the other three communities even though the marsh is the most isolated of the four communities. These data suggest that this small wetland harbors distinct and diverse macroinvertebrate communities—communities that are known to be dramatically affected by human-caused changes in substrate and water quality (Greeson et al. 1979). From the practical viewpoint of conservation biology, the ecological integrity of Lovets Pond can be considered good and thus worthy of protection.

Cache River and Wetlands. Approximately 230 aquatic and semiaquatic macroinvertebrate taxa were collected from the 23 sites. The number of taxa and individuals at

Table 1. Total number of taxa and individuals for the four major plant communities of Lovets Pond. Ranges are given in parentheses.

	Open pond	Shrub swamp	True swamp	Marsh
Total number of taxa	37	52	58	59
(Number per sample)	(8–20)	(14–30)	(10–30)	(11–26)
Total number of individuals	1,042	4,034	4,807	2,200
(Number per sample)	(113–241)	(526–982)	(257–1,259)	(113–769)

each site ranged from 21–66 and 212–2,735, respectively. Only 7% (17 taxa) were found at 10 or more sites. Of those 17 taxa, 6 were crustaceans (aquatic sowbugs, sideswimmers, shrimps, and crayfishes) and 6 were surface or water-column dwelling beetles (Coleoptera) or bugs (Heteroptera). Over 20,500 individuals were examined, excluding those taken from qualitative samples. The clubtail dragonfly (*Ariogomphus maxwelli*) was observed and/or collected at 4 of 23 sites. This species was known from only a few Gulf Coast states until June of 1985 when a single adult male was collected at Mermet Lake in Massac County, Illinois. Thus, the Cache population may be the only viable one in the state. Sampling also yielded such rare to uncommon bugs as the water scorpion (*Nepa apiculata*) and such common but hard to collect bugs as the marsh treader or water measurer (*Hydrometra martini*). In the sites most disturbed with a heavy silt load, at least a few surface-dwelling insects (for example, *Gerris marginatus* and *Trepobates* spp.) were found. *Gerris marginatus* is perhaps the most common strider in the Cache system.

To assess the ecological integrity of the various Cache sites, species diversity measurements (H') were calculated and can be compared with those found at Lovets Pond. Four sites have a relatively high species diversity (0.898–1.131): the Cache River at Highway 37, Snake Hole, Eagle Pond, and Long Reach. The Cache River at Highway 37 is a highly disturbed site. The north bank has been cleared and a levee built. The channel has been dredged and carries a very heavy silt load. Long Reach is also a heavily silted portion of the main channel. Snake Hole is a well-shaded pond located at the base of a rocky-boulder cliff in an area known as Little Black Slough. This state-owned site is generally the least silted of any of the Cache wetlands. Eagle Pond, also heavily silted, is a popular canoeing destination because of its picturesque cypress knees and buttonbush thickets. Sites with moderate macroinvertebrate species diversity (0.651–0.834) are heavily silted, including Wildcat Bluff/Watson Pond and Short Reach, both owned by the Illinois Department of Conservation. The other 5 sites with moderate diversity are privately owned. The remaining 12 sites have low species diversities

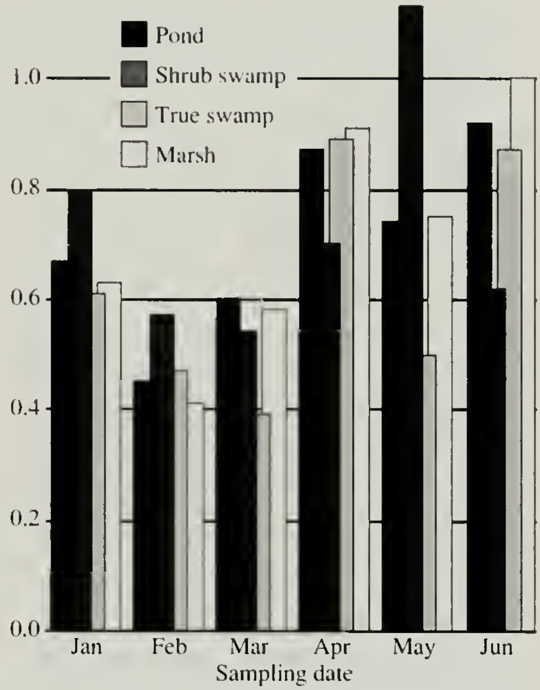

Figure 7. Shannon diversity (H') values (N=2) for the macroinvertebrate communities inhabiting the four major plant communities of Lovets Pond.

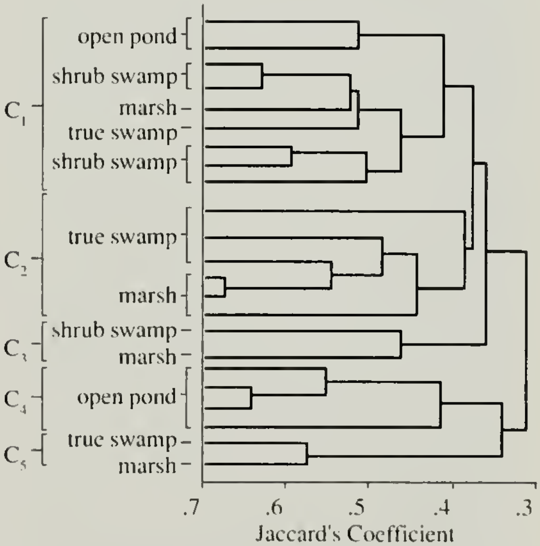

Figure 8. A clustering of the macroinvertebrate communities inhabiting the four major plant communities of Lovets Pond using group average clustering of the Jaccard's coefficients of similarity.

(0.170–0.612), including Limekiln Spring and Slough which is owned by The Nature Conservancy and is generally considered "protected." That site exemplifies the major threat to all the remaining Cache wetlands—excessive habitat destruction due to siltation from agricultural endeavors. Even the integrity of the areas "protected" by the state, by The Conservancy, or by other private groups is being threatened by siltation, which is obliterating most of the available aquatic habitat. The quality of the adjacent terrestrial habitat is variable; some sites are cleared of all vegetation and others have mature, high-quality forests or swamps. Sites with the most disturbed terrestrial component generally have the least diverse aquatic component. Even though the data reveal that macroinvertebrate species diversity is generally low, enough islands of diversity seem to exist to reclaim the area if it were protected from further siltation and other degrading influences. The ecological integrity of the Cache and its wetlands cannot, however, be considered good, especially in light of the excessively silted substrate of the areas I visited.

CONCLUSIONS

I have examined the ecological integrity of two southern Illinois wetlands: one small, Lovets Pond, and a much larger one, the Cache. I have concluded that if drastic measures are not immediately initiated (such as the proposed Cypress Creek National Wildlife Refuge), the future of the Cache River system is bleak, primarily due to excessive siltation. On the other hand, Lovets Pond appears adequately protected from siltation by a forest buffer.

We should act now to preserve both systems and all other Illinois wetlands, regardless of size. Large, disturbed systems such as the Cache may recover, thereby preserving a large portion of the biodiversity of Illinois. Small systems such as Lovets Pond also serve to preserve their share of biodiversity.

ACKNOWLEDGMENTS

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Status and Distribution of Wetland Mammals in Illinois

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Wetlands are highly productive and diverse habitats that supply important resources for many mammalian species (Fritzell 1988). The objectives of this paper are to list the mammals that are found in the wetlands of Illinois, to identify species that are threatened or endangered, and to discuss the distribution of wetland mammals within the state, especially those restricted to wetland habitats. Only palustrine wetlands, rather than riverine or lacustrine systems, are considered. These shallow water habitats are categorized as palustrine emergent (sedge meadow, marsh, bog, and fen), palustrine scrub-shrub, and palustrine forested (swamp and seasonally or temporarily flooded forested wetland) wetlands (Cowardin et al. 1979). Illinois mammals that inhabit these types of wetlands are listed in Table 1.

Most of the mammals in Table 1 are terrestrial or semiaquatic. Bats are not typically considered wetland mammals, although any Illinois species might well forage above marshes or bogs or along the edges of swamps. Research conducted by the Illinois Natural History Survey and the Illinois Department of Conservation revealed that forested wetlands in southern Illinois provide roosting sites for three species of bats. In May 1988, a radio-tagged pregnant Indiana bat was found roosting behind loose bark on a dead American elm (*Ulmus americana*) in a wetland created by subsidence in Saline County. A lactating southeastern bat was radio-tracked to the hollow base of a living tupelo gum (*Nyssa aquatica*) in Little Black Slough in Johnson County during the summer of 1989; she shared this roost with at least 100 other individuals. Four Rafinesque's big-eared bats were also found roosting in a tupelo gum in the slough during that summer. To stress the importance of palustrine forested wetlands to these three endangered species, I have listed them in Table 1. Other species of bats also roost in trees during the summer, although little is known about their specific habitat preferences (Barbour and Davis 1969; Hoffmeister 1989). Species likely to roost in forested wetlands include the silver-haired bat (*Lasionycteris noctivagans*), northern long-eared bat (*Myotis septentrionalis*), and evening bat (*Nycticeius humeralis*).

Table 1 includes one federally endangered species, the Indiana bat (Endangered Species Act, 16th U.S. Congress, docket 1531); three state endangered species, the southeastern bat, Rafinesque's big-eared bat, and river otter; and three state threatened species, the marsh rice rat, golden mouse, and bobcat (Illinois Administrative Code, Title 17, Chapter I, subchapter c, part 1010.30, as amended March 17, 1989). These seven species and the swamp rabbit (Kjolhaug et al. 1987) are uncommon in Illinois; all other species in Table 1 range from relatively common to abundant (Hoffmeister 1989). The beaver and white-tailed deer are now common even though both species had been nearly extirpated from the state by the end of the 19th century (Pietsch 1954; Pietsch 1956; Hoffmeister 1989).

Some of the species in Table 1 have restricted ranges within Illinois. The southern short-tailed shrew, big-eared bat, southeastern bat, swamp rabbit, marsh rice rat, and golden mouse occur only in the southern portion of the state (Ellis et al. 1978; Feldhamer and Paine 1987; Kjolhaug et al. 1987; Hoffmeister 1989; Illinois Natural Heritage Database). The main breeding population of river otters is along the Mississippi River north of Rock Island (Jo Daviess, Carroll, Whiteside, and Rock Island counties); a smaller population may occur in the Heron Pond–Little Black Slough area of the Cache River drainage (Johnson County) in southern Illinois (Anderson 1982). Most bobcats probably occur in the northwestern and southernmost portions of Illinois where relatively large expanses of suitable habitat remain (Illinois Natural Heritage Database). The Virginia opossum, southern flying squirrel, beaver, white-footed mouse, woodland vole, muskrat, house mouse, meadow jumping mouse, gray fox, raccoon, mink, and white-tailed deer, on the other hand, occur throughout the state (Hoffmeister 1989). The remaining species in Table 1 have ranges that cover much of Illinois. The meadow vole and least weasel occur in the northern half of the state, and the northern short-tailed shrew is found primarily in the northern two-thirds (Hoffmeister 1989). The southeastern shrew and southern bog lemming occur in the southern two-thirds of Illinois, although bog lemmings have been caught in Carroll County (Hoffmeister 1989). The Indiana bat, though rare, has been found in 20 counties in central and southern Illinois during the summer (Illinois Natural Heritage Database). The masked shrew may have a discontinuous distribution in Illinois, occurring primarily in the northern third of the state but also in at least two southern counties (Hoffmeister 1989).

Many species of mammals are habitat generalists. The home ranges of larger mammals, such as the bobcat and white-tailed deer, typically consist of a mosaic of forested areas interspersed with open areas that could include wetlands (Schwartz and Schwartz 1981). Many smaller mammals may be found in a variety of habitats. The masked shrew, for example, is

Table 1. Wetland mammals of Illinois. Terrestrial and semiaquatic species are included if their activities (e.g., foraging, nesting) are conducted entirely or partly within palustrine wetlands; bats are included if they are known to roost in wetlands.

Common name	Scientific name	Habitat[1]
Virginia opossum	*Didelphis virginiana*	FW
Masked shrew	*Sorex cinereus*	M SM B FW
Southeastern shrew	*Sorex longirostris*	M SW FW
Northern short-tailed shrew	*Blarina brevicauda*	M SM B
Southern short-tailed shrew	*Blarina carolinensis*	M
Indiana bat	*Myotis sodalis*	SW FW
Southeastern bat	*Myotis austroriparius*	SW
Rafinesque's big-eared bat	*Plecotus rafinesquii*	SW
Swamp rabbit	*Sylvilagus aquaticus*	SS SW FW
Southern flying squirrel	*Glaucomys volans*	FW
Beaver	*Castor canadensis*	M SW FW
Marsh rice rat	*Oryzomys palustris*	M SS SW
White-footed mouse	*Peromyscus leucopus*	M SM SS FW
Golden mouse	*Ochrotomys nuttalli*	SS SW FW
Meadow vole	*Microtus pennsylvanicus*	M SM
Woodland vole	*Microtus pinetorum*	M FW
Muskrat	*Ondatra zibethicus*	M SW
Southern bog lemming	*Synaptomys cooperi*	M
House mouse	*Mus musculus*	M FW
Meadow jumping mouse	*Zapus hudsonius*	M SM
Gray fox	*Urocyon cinereoargenteus*	FW
Raccoon	*Procyon lotor*	M SS SW FW
Least weasel	*Mustela nivalis*	M
Mink	*Mustela vison*	M FW
River otter	*Lutra canadensis*	SW FW
Bobcat	*Felis rufus*	SS SW FW
White-tailed deer	*Odocoileus virginianus*	M SS SW FW

[1] Palustrine wetland habitats used by these species are coded as follows:
M = marsh
SM = sedge meadow
B = bog
SS = scrub-shrub wetland
SW = swamp
FW = seasonally or temporarily flooded forested wetland
Sources on habitat use: Barbour and Davis 1974; Schwartz and Schwartz 1981; Mumford and Whitaker 1982; Jones and Birney 1988; and Hoffmeister 1989.

abundant in sedge meadows and marshes in northern Illinois but also inhabits sand prairies, flatwoods, fencerows, pastures, and successional fields (Mumford and Whitaker 1982; Mahan and Heidorn 1984; Szafoni 1989). The white-footed mouse has been trapped in sedge meadows and marshes (Mahan and Heidorn 1984; Szafoni 1989) but is more typically an inhabitant of upland forests and shrublands. In fact, few species of mammals are specifically adapted for living in wetland environments (Fritzell 1988). Most of the species listed in Table 1 are not restricted to wetlands and, therefore, their distribution and abundance are not indicative of or significantly limited by the status of wetlands in Illinois. The swamp rabbit and marsh rice rat are the Illinois mammals that are most limited to palustrine wetlands. The beaver, muskrat, and river otter are also closely associated with wetlands but are more aquatic in their habits and could be considered species of rivers, streams, lakes, or ponds. The swamp rabbit and rice rat are uncommon and have limited distributions within the state; the remainder of this paper will discuss their distribution and status in more detail.

The swamp rabbit is a representative of the Eastern-Austral faunal element, the group of mammalian species whose distributions are centered in the southeastern United States (Jones and Birney 1988). Its northern limit is in Illinois and Indiana and coincides with that of the southern swamp forest community at approximately the 24°C temperature isoline (Chapman and Feldhamer 1981). Swamp rabbits rarely occur far from water and inhabit floodplain forests, cypress swamps, and canebrakes (Cory 1912; Layne 1958; Barbour and Davis 1974; Sealander 1979; Chapman and Feldhamer 1981; Hoffmeister 1989). In Indiana, swamp rabbits were found in areas where low ridges were interspersed with small wooded sloughs and grassy marshes (Terrel 1972).

In the early 1900s, the swamp rabbit was known to occur in swamps along the Mississippi and Ohio rivers in Illinois; its northern limits were thought to be a few miles south of Grand Tower in Jackson County and 5 miles below Golconda in Pope County (Howell 1910). The earliest specimens were collected in Alexander and Johnson counties (Cory 1912) and Williamson County (Necker and Hatfield 1941). Cockrum (1949) believed that the swamp rabbit had extended its range during the early twentieth century as far north as Jefferson County. He reported that hunters had killed swamp rabbits in Franklin County during 1935–1936 and in Jefferson County during 1936. More recently, specimens and possible sightings have been recorded in several other counties: Marion, Massac, Perry, Randolph, and Union (Layne 1958); Bond, Calhoun, Gallatin, Lawrence, Wabash, Washington, and Wayne (Klimstra and Roseberry 1969); and Edwards and White (Terrel 1969). These findings indicate a range extending northward to Calhoun, Bond, and Lawrence counties (Figure 1). Whether these new records represent a range expansion or improved reporting is, however, uncertain.

Kjolhaug et al. (1987) of the Cooperative Wildlife Research Laboratory conducted intensive searches for swamp rabbits or their sign (pellets on logs, vegetation clippings, tracks) in 11 southern Illinois counties and limited searches in three others during 1984–1985. Sign was recorded at 22 sites along the Bay Creek and Big Muddy, Cache, Mississippi, and Ohio River drainages in Alexander, Franklin, Jackson, Johnson, Massac, Pope, Pulaski, and Union counties (Figure 1). No sign was found in Gallatin, Lawrence, Saline, Wabash, Wayne, and Williamson counties, although all but Saline had earlier records. Other counties for which previous records exist were not searched during the study by Kjolhaug et al. (1987).

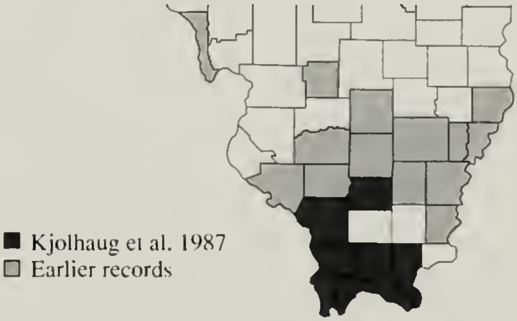

Figure 1. Southern Illinois counties in which swamp rabbit sign was found by Kjolhaug et al. (1987) and earlier records for this species (Howell 1910; Cory 1912; Necker and Hatfield 1941; Cockrum 1949; Layne 1958; Klimstra and Roseberry 1969; Terrel 1969).

The results of the study by Kjolhaug and his colleagues suggest that Alexander, Johnson, Massac, Pulaski, and Union counties support several secure populations of swamp rabbits, whereas this species is present at low densities and with limited distributions in Franklin, Jackson, and Pope counties. Only 12,585 ha in southern Illinois were found to support swamp rabbits, although approximately 2,000 additional hectares of suitable habitat were identified. The state of Illinois was the most important owner of swamp rabbit habitat. The potential habitat for this species in Illinois and neighboring states has been drastically reduced by the construction of levees and drainage ditches and the conversion of bottomlands to agricultural use (Terrel 1972; Barbour and Davis 1974; Korte and Fredrickson 1977; Whitaker and Arbell 1986; Kjolhaug et al. 1987; Hoffmeister 1989). In Indiana, for example, swamp rabbits are now restricted to a single county (Whitaker and Arbell 1986). Fragmentation of bottomland forest and swamp has created islands surrounded by unsuitable habitat, a condition limiting successful dispersal and reestablishment of extirpated local populations. Kjolhaug et al. (1987) concluded that swamp rabbits were unlikely to colonize vacant areas of habitat and that existing populations will continue to be extirpated.

The marsh rice rat (Figure 2) is the only member of this predominantly Neotropical genus with an extensive range in the United States (Honacki et al. 1982). The southern portion of Illinois is at the northern limit of its range, although rice rats once occurred as far north in the state as Peoria County, where their remains have been found at an archeological site (Baker 1936). Rice rats are common throughout much of their range, where they inhabit coastal and freshwater marshes and swamps and areas along lakes, rivers, and streams (Wolfe 1982).

The first modern specimens from Illinois were collected at Olive Branch and Cache in Alexander County (Cory 1912; Necker and Hatfield 1941). McLaughlin and Robertson (1951) collected two specimens in Johnson County and concluded that rice rats were limited to swampy areas within the Coastal Plain Division of the state (Schwegman 1973). More recently, rice rats have also been reported from Franklin, Jackson, Massac, Pulaski, Union, and Williamson counties (Klimstra and Scott 1956; Klimstra 1969; Klimstra and Roseberry 1969; Rose and Seegert 1982; Urbanek and Klimstra 1986; Illinois Natural Heritage Database). In addition, the remains of a rice rat were found in the stomach of a mink collected from an unspecified location in Washington County (Casson 1984). The recent range of the rice rat, inferred from these limited records, extends through the Ozark, Mississippi River Bottomlands, and Shawnee Hills divisions into the Mt. Vernon Hill Country Section of the Southern Till Plain Division.

During 1986–1987 staff members of the Illinois Natural History Survey live-trapped in 17 southern Illinois counties to assess the current distribution of the rice rat (Figure 3; Hofmann et al. 1991). A total trapping effort of 3,517 trap-nights resulted in 1,111 captures of small mammals representing 13 species. Rice rats were captured at 13 sites in 10 counties (Figure 3). They were found for the first time in Hamilton, Pope, Saline, and White counties and were also trapped at new localities in Alexander, Franklin, Jackson, Johnson, Massac, and Williamson counties. Rice rats were not caught in Pulaski, Union, and Washington counties, although earlier records existed. Despite recent trapping efforts, no rice rats have been captured in Gallatin, Hardin, Perry, and Randolph counties. These results suggest that rice rats occur farther to the northeast in the state than indicated by previous records (into the Wabash Border Division). Rice rats may have expanded their range within the state, perhaps using waterways and wet areas along highway and railroad rights-of-way as dispersal corridors; more likely, they were present in Hamilton,

Figure 2. A rice rat live-trapped in Franklin County during the distribution study of 1986–1987. Photo by Marilyn Morris.

Pope, Saline, and White counties but unreported due to limited sampling. Although some potentially suitable habitat for rice rats occurs in Perry, Randolph, and Washington counties, their primary range appears to extend only as far north as Franklin and Jackson counties in southwestern Illinois. In addition to the 10 counties in which rice rats were captured during the Survey's study, they may also occur in Pulaski and Union counties. Existing records, however, do not suggest that they would be common in either county. The only specimen known from Pulaski County was found dead in a field in January 1987 (Illinois Natural Heritage Database), and no rice rats have been reported from Union County since 1958 (Klimstra and Roseberry 1969; Illinois Natural Heritage Database).

During the Survey's study, 132 rice rats were captured, a number that includes at least 99 individuals. Nearly half (45–49 individuals) were trapped at the Saline County site and more than 70% (72–76 individuals) were caught at just four sites in Alexander, Jackson, Pope, and Saline counties. At the nine remaining sites, the number of individuals trapped was

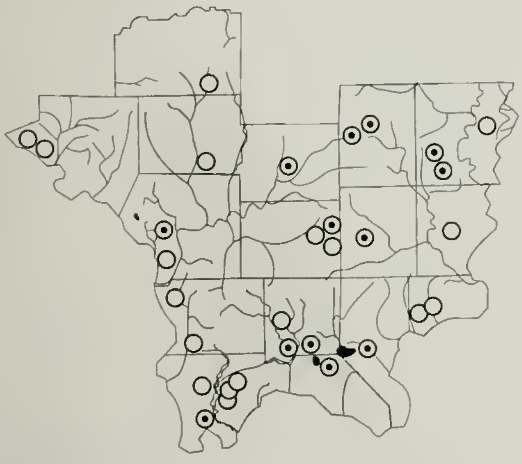

Figure 3. Trapping sites in southern Illinois, 1986–1987 are shown as circles; sites at which captures of rice rats occurred contain dots (Hofmann et al. 1990). The range of this species based on earlier records is indicated in gray (Cory 1912; Necker and Hatfield 1941; McLaughlin and Robertson 1951; Klimstra and Scott 1956; Klimstra 1969; Klimstra and Roseberry 1969; Rose and Seegert 1982; Casson 1984; Urbanek and Klimstra 1986; Illinois Natural Heritage Database).

5 or fewer. Despite the fact that their range within the state is more extensive than had been thought, rice rats do not appear to be common in Illinois and their continued status as a threatened species appears to be warranted.

Areas where rice rats were captured were characterized by standing water and a dense cover of emergent herbaceous vegetation, specifically sedges (*Carex* spp.), rushes (*Juncus* spp.), bulrushes (*Scirpus* spp.), spike rushes (*Eleocharis* spp.), or cattails (*Typha* spp.). Trapping was most successful in roadside ditches along county or state highways and along the shores of ponds and lakes. Since many extensive wetlands in southern Illinois no longer exist, rice rats occupy islands of original or manmade wetland habitat that are often small and widely scattered. Such areas cannot support large populations, and small populations are especially vulnerable to extirpation due to environmental changes, disease, or predation. As with the swamp rabbit, recolonization of a site could be hampered by the large expanses of unsuitable habitat separating it from other populations.

The remaining wetland habitat of the swamp rabbit and marsh rice rat needs to be protected. Such protection should be the highest priority, but habitat enhancement and recreation may also warrant consideration. State and federally owned forested bottomlands could be managed to increase their quality as swamp rabbit habitat (Kjolhaug et al. 1987). Modern surface-mining reclamation techniques have the potential to create habitat suitable for rice rats (Ohlsson et al. 1982; Klimstra and Nawrot 1985). There is no guarantee, however, that such areas would be colonized because existing populations are widely dispersed. Relocation of animals to newly created or existing wetlands may be a useful management procedure. Whitaker and Arbell (1986) recommended reintroduction of swamp rabbits into areas with suitable habitat in Indiana, and the feasibility of relocating rice rats is currently being studied by the Illinois Natural History Survey in southern Illinois. Finally, the fact that most other mammals that use wetlands are flexible in their habitat choices does not mean that there is reason for complacency about the loss of remaining Illinois wetlands.

ACKNOWLEDGMENTS

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Session Four: Streams and Caves

Who hears the fishes when they cry?—Henry David Thoreau

More than half of the 13,200 miles of streams in Illinois have been dredged, channelized, dammed, or altered in other ways. Our rivers and streams suffer from pollution, siltation, and the introduction of exotic organisms. The Illinois River, described by Thomas Jefferson as "a fine river, clear, gentle, and without rapids," has served as Chicago's sewer, a waterway for untold numbers of barges made navigable only by numerous dams, and a repository for much of the eroded topsoil from central Illinois farmland. The "typical" stream in east-central Illinois is a narrow ditch lined with mowed grass, weeds, or row crops, stretching across the landscape and disappearing into the distance. The Cache River in southern Illinois was diverted in 1916 via the Post Creek Cutoff. Designed to alleviate flooding, it cut the river in two, allowing a portion to drain directly into the Ohio River. As a result, the Lower Cache has become a sluggish trickle that even flows backwards upon occasion.

Surprisingly, a few high-quality streams remain in Illinois. The Biological Stream Characterization, an index of stream quality completed in 1989, identified 24 stream segments of excellent quality throughout the state. These total somewhat less than 500 miles, about 4% of the stream mileage in Illinois. Included in this group are segments of the Kishwaukee in northern Illinois, the Vermilion in east-central Illinois, and Lusk and Big creeks in the Shawnee National Forest.

Caves in Illinois have fared somewhat better. Four areas where caves are typically found correspond to major outcroppings of calcareous rocks. More than 480 caves were identified during the 1988 inventory conducted by the Illinois State Museum.

The remarkably stable, insulated environments of caves support a unique biota. For the most part, these organisms are adapted to little or no light and limited food resources. Caves are regarded as natural zoological laboratories where, because of the relative simplicity of the ecosystem, important biological and evolutionary questions can be studied.

One presentation at this session surveyed the nature of Illinois streams—what we have, what we have lost, and what can yet be done by way of restoration and preservation. Two speakers focused on inhabitants of that stream system, the surprisingly diverse and dynamic Illinois fish fauna and the varied mussel populations. The fourth paper described the cave environment and ecosystem, noting the often overlooked values of this unique natural resource.

The Fishes of Illinois: An Overview of a Dynamic Fauna

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Just over ten years ago, Smith (1979) published the most recent comprehensive summary of the Illinois fish fauna. His review revealed 199 fish species, 186 of which were considered native to the state. A major finding was that the Illinois fish fauna is dynamic and that the distributions of many species have changed considerably since the first comprehensive survey of Illinois fishes by Forbes and Richardson ([1908], 1920). Because of introductions of alien species, discoveries of species new to Illinois, and rediscoveries of species formerly thought to be extirpated, the composition of the Illinois fish fauna is in need of clarification.

In the past decade, the greater redhorse, *Moxostoma valenciennesi* (Seegert 1986), and the cypress minnow, *Hybognathus hayi* (Burr and Mayden 1982; Warren and Burr 1989), which were thought to have been extirpated from Illinois, were rediscovered. Examination of collections made prior to Smith's survey and recent collecting have documented previously unreported records for the bluehead shiner, *Pteronotropis hubbsi* (Burr and Warren 1986), and the pallid shiner, *Hybopsis amnis* (Warren and Burr 1988). Three fishes were recently added to the state fauna; in addition, new localities for ten other uncommon species were reported by Burr et al. (1988) and by Dimmick (1988). The introduced rainbow smelt, *Osmerus mordax*, has recently and rapidly extended its range in Illinois (Burr and Mayden 1980). The white perch, *Morone americana*, previously unrecorded from Illinois, has dispersed into the Illinois portion of Lake Michigan (Savitz et al. 1989a). The bighead carp, *Hypophthalmichthys nobilis*, silver carp, *Hypophthalmichthys molitrix*, and rudd, *Scardinius erythrophthalmus*— three Eurasian exotics unknown in Illinois streams during Smith's (1979) survey— are being captured at a number of localities, particularly big rivers and reservoirs.

My purpose here is to review briefly the Illinois fish fauna and record some of the changes that have occurred in the composition of Illinois fishes since Smith's (1979) comprehensive study. I have used the term 'alien' to encompass any fish species "of foreign origin" that is either an exotic, a transplant, or a recently invading species from more southern latitudes.

HISTORICAL PERSPECTIVE

The history of ichthyological investigations in Illinois is a rich one. At the time the Illinois Natural History Society was established in 1858, approximately three-fourths of the Illinois fish fauna had been named and described by such distinguished ichthyologists as Samuel L. Mitchill (1764–1831), Charles A. Lesueur (1778–1846), Constantine S. Rafinesque (1783–1840), Jared P. Kirtland (1793–1877), Louis Agassiz (1807–1873), and Charles F. Girard (1822–1895). Fourteen of the species described were first discovered in Illinois.

The first regional list of Illinois fishes was prepared by Robert Kennicott (1855), who treated the fishes of the Chicago area. Comprehensive catalogs of fishes of the entire state later appeared by Edward W. Nelson (1876), David Starr Jordan (1878), Stephen A. Forbes (1884), and Thomas Large (1903).

Intensive Illinois ichthyology, however, began with Stephen Forbes (1844–1930; Figure 1), the first Director of the State Laboratory of Natural History then in Normal, Illinois, and later moved to Urbana-Champaign in 1885. Sometime in the 1870s, Forbes developed the idea of producing a well-illustrated and detailed account of Illinois fishes. Year after year horse-drawn wagon parties were sent to explore and collect in different streams of the state until finally records were available for virtually every river in Illinois. The monumental effort that went into the project represented the patience and toil of 30 years. The final report, *The Fishes of Illinois*, appeared in 1908

Figure 1. Stephen Alfred Forbes (1844–1930). Photo courtesy of Illinois Natural History Survey.

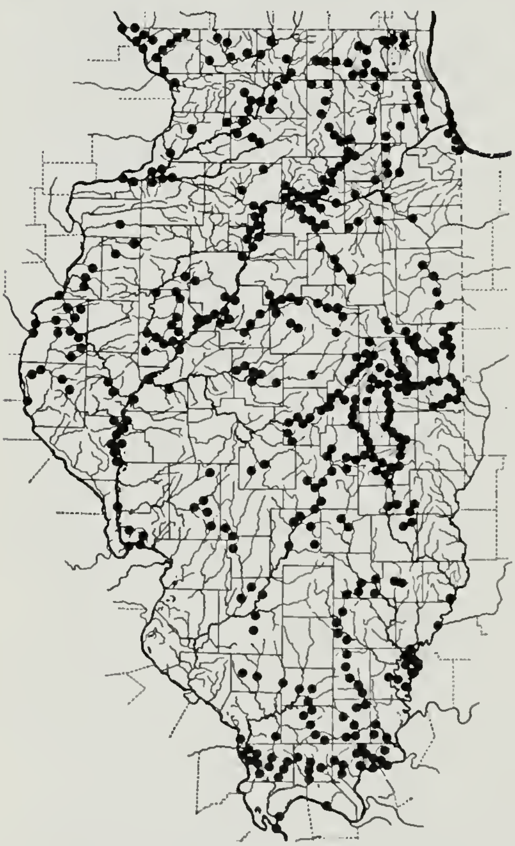

Figure 2. Location of collections of fishes made from 1876 to 1903. From Forbes and Richardson [1908].

(although no publication date is given in the volume) and was authored by Forbes and his colleague Robert Earl Richardson (1877–1935). A separate atlas of 103 range maps accompanied the volume. At that time, *The Fishes of Illinois* was considered by many to be the best regional ichthyology ever published on fishes in North America. Exceptionally skillful water colors of many species (52 in the 1908 edition, 68 in the 1920 edition), some never before published in color, were included and helped to make the book an immediate classic. Most of the copies of the initial edition were burned in a warehouse fire, and a second edition was produced in 1920.

The Forbes and Richardson data base (Figure 2) included over 200,000 fish specimens and 1,545 collections made from about 475 localities representing all major drainages and 93 of the 102 counties of Illinois. A total of 142 presently valid species (Table 1) was recorded from Illinois waters by Forbes and Richardson [1908], and only one (common carp, *Cyprinus carpio*) of those was an alien species. About 20,000 specimens used in the original *Fishes of Illinois* are vouchered in the collection of the Illinois Natural History Survey. Clearly, the superb historical data base for Illinois fishes is unique and unsurpassed by that of any other state or province in North America.

Subsequent to the masterful Forbes and Richardson treatise appeared works by Meek and Hildebrand (1910) on fishes of the Chicago region and another list of Illinois fishes by O'Donnell (1935), which added a few species to the known fauna of the state. A large number of collections made during the 1940s by Aden C. Bauman, a student of Carl L. Hubbs, contributed many significant records of Illinois fishes, particularly from the southern half of the state. Bauman's collections are at the University of Michigan Museum of Zoology and have only recently been used (Lee et al. 1980; Burr and Mayden 1982; Warren and Burr 1989).

In about 1950, Philip W. Smith (1921–1986; Figure 3), former head of one of the Illinois Natural History Survey's scientific sections and author of *The Amphibians and Reptiles of Illinois* (1961), undertook to resurvey the fishes of the state. This task provided a unique opportunity for comparing modern-day distributional data with the classic work of Forbes and Richardson. The bulk of

Smith's fieldwork began in the summer of 1962 and continued until the mid-1970s. During this period Smith published an account of the fishes of Champaign County (Larimore and Smith 1963), an annotated preliminary list of Illinois fishes (Smith 1965), an assessment of Illinois streams based on fish distribution data (Smith 1971), a key to Illinois fishes (Smith 1973), and finally, a new *Fishes of Illinois* (Smith 1979) that summarized the identification, biology, and distribution of the Illinois fish fauna.

Smith and his colleagues found 199 species in Illinois (Table 1), made over 3,000 collections from over 2,000 localities in all of the drainages of the state and in all of the 102 counties (Figure 4), and preserved as vouchers approximately 400,000 specimens deposited at the Illinois Natural History Survey. When he compared his data with those of Forbes and Richardson, Smith (1971:8) found that about 70 Illinois fishes clearly showed patterns of range decimation or extirpation from the state and that 13 alien species occupied Illinois waters.

Since the publication of Smith's (1979) treatise, state fish biologists have continued to collect data on the Illinois ichthyofauna. Particularly active have been ichthyologists and fish biologists from the state's universities, the Illinois Natural History Survey, the Illinois Department of Conservation, and several consulting firms. Additional discoveries of exotic species, native species previously unreported, and the invasion of more southerly species into Illinois waters emphasize the dynamic nature of the Illinois fauna and the need for continued collections of fishes even in presumably well-surveyed areas.

DYNAMIC NATURE OF THE ILLINOIS FAUNA

Illinois has many drainage systems and is bounded on the west by the Mississippi River, on the south by the Ohio River, on the east by the Wabash River, and on the northeast by Lake Michigan. The numerous interior streams, glacial lakes in Lake County, and cypress–tupelo swamps in southern Illinois account for the richness of the fauna. Illinois has the lowest average elevation of the north-central states. More than 90% of the state lies within the Central Lowlands Province, all of which was glaciated except the Driftless Area in extreme northwestern Illinois. Although well-watered, Illinois has lost many aquatic habitats to agriculture, stream impoundments, industrial and domestic pollution, and other modifications of watersheds.

Disappearance of Native Species

As noted previously, Smith (1971:8) documented range decimation or rarity for approximately 70 Illinois fishes; later, Smith (1979:xviii–xix) revised this number to include 52 species, some of which probably were rare even prior to European settlement. For about 120 species, no range change was detected. According to Smith (1971), several factors are primarily responsible for the disappearance of native Illinois fishes: 1) excessive siltation has caused the extinction or decimation of at least 16 species through loss of water clarity, disappearance of aquatic vegetation, and deposition of silt over rocky or sandy substrates; 2) drainage of wetlands has shrunk the ranges of at least 13 species; 3) desiccation

Table 1. Composition of Illinois fishes over the past century.

	Total no. of species	No. of aliens	No. extirpated
Forbes and Richardson [1908]	142[1] (141 native)	1	Not applicable
Smith (1979)	199 (186 native)	13	9
Present Information (1990)	209[2] (187 native)	22[3]	12[4]

[1] Forbes and Richardson [1908] recognized 150 species, 142 of which are considered valid today.
[2] Additions since Smith (1979) include Atlantic salmon, bighead carp, silver carp, rudd, taillight shiner, inland silverside, threespine stickleback, striped mullet, white perch, and Rio Grande cichlid.
[3] The number of alien species also includes three relatively recent invaders from the south (threadfin shad, inland silverside, and striped mullet); the first two of these are also stocked as forage in Illinois reservoirs.
[4] Extirpations since Smith (1979) include bluehead shiner, bigeye chub, harlequin darter, northern madtom, and alligator gar. The cypress minnow and greater redhorse, both included as extirpated by Smith (1979), have been rediscovered recently in Illinois, as noted in the text.

during drought, which has dried up once permanently flowing streams, stopped the flow in seeps and springs, and temporarily reduced the size of formerly larger rivers, has shrunk the ranges of at least 12 species; 4) interactions between species, including the effects of introduced species on native ones, competitive supplantation, and aggressive dispersal by ecologically labile species, has caused the extinction or decimation of at least 9 species; 5) industrial, domestic, and agricultural pollution has caused the decimation of at least 5 species; 6) dams and impoundments are responsible for the decimation of at least 4 species through the loss of a large variety of habitats and the blocking of natural migration; 7) higher water temperatures now than formerly, chiefly the result of stream channelization and the removal of marginal vegetation, have caused the decimation of at least 1 species. No single factor has as yet been identified for the extirpation of the muskellunge, *Esox masquinongy*, from northern Illinois or the saddleback darter, *Percina ouachitae*, from the Wabash River.

Since the publication of Smith's book (1979), the continued decline of several species has been documented. Examples include the pallid shiner, *Hybopsis amnis*, a species now known to have been much more widespread in Illinois than indicated on Smith's (1979) distribution map. It has disappeared from seven major Illinois drainages where it was known to occur from the late 1800s through the 1940s (Warren and Burr 1988). It remains in the Kankakee River drainage (Skelly and Sule 1983) and in the upper Mississippi River (Warren and Burr 1988). The Mississippi silvery minnow, *Hybognathus nuchalis*, was not taken in the recent (late 1980s) survey of the fishes of Champaign County and was rarely taken in several recent surveys in southern Illinois where suitable habitat was present. The bigeye shiner, *Notropis boops*, continues to disappear from sites of former occurrence but survives in the Little Vermilion River and the Clear Creek drainage of southern Illinois. Major impoundments (Carlyle and Shelbyville reservoirs) on the Kaskaskia River have severely limited the habitat of the western sand darter, *Etheostoma clarum*, which is now very rare (if not extinct) in the drainage. The species has, however, been taken recently in the Mississippi River below the mouth of the Missouri River (Dimmick 1988).

Figure 3. Philip Wayne Smith (1921–1986). Photo courtesy of Illinois Natural History Survey.

Figure 4. Location of collections of fishes made from 1950 to 1978. From Smith 1979.

Another striking discovery emanating from Smith's (1979) survey and subsequent work was the relatively large number of Illinois fishes that have been extirpated since the original Forbes and Richardson (1908) survey. As of this writing, these include eight species: Ohio lamprey, *Ichthyomyzon bdellium*; blackfin cisco, *Coregonus nigripinnis*; muskellunge, *Esox masquinongy*; rosefin shiner, *Lythrurus ardens*; gilt darter, *Percina evides*; saddleback darter, *Percina ouachitae*; crystal darter, *Crystallaria asprella*; and spoonhead sculpin, *Cottus ricei*.

Even more alarming is the number of species that have disappeared since Smith (1979) began his survey in the 1960s. Examples include the bluehead shiner, *Pteronotropis hubbsi*, last collected in Illinois waters in 1974 (Burr and Warren 1986) and the bigeye chub, *Hybopsis amblops*, last collected in 1961 (Smith 1979; Warren and Burr 1988). In addition, the harlequin darter, *Etheostoma histrio*, known previously from the Embarrass River, Cumberland and Jasper counties, is almost certainly extinct in Illinois, probably because of drainage alterations below Lake Charleston dam. My recent attempts (1987, 1988) to collect the northern madtom, *Noturus stigmosus*, in the Wabash drainage of Illinois have been unsuccessful. The alligator gar, *Atractosteus spatula*, has not been taken in Illinois since 1965, although sufficient effort has not been expended recently to clarify its status.

On a positive note, at least two species thought to have been extirpated at the time of Smith's (1979) survey have been rediscovered in Illinois. The cypress minnow, *Hybognathus hayi*, is now known with certainty to be reproducing in the middle Cache River drainage (and possibly in Horseshoe Lake) in southern Illinois but is still considered extirpated from former sites of occurrence in the Big Muddy River drainage (Warren and Burr 1989). The drainage of wetlands that are used as nursery areas by the species is thought to be the main factor responsible for extirpation from the Big Muddy River. The greater redhorse, *Moxostoma valenciennesi*, thought to have been extinct in Illinois since 1901, was collected in 1985 from the Illinois River, rivermile 249 (Seegert 1986) and again in 1989 from the Illinois River, rivermile 270.5. These two individuals must be part of a population residing somewhere in the upper basin.

Native Species Previously Unrecorded

One native fish has been added to the state ichthyofauna since Smith's (1979) report. The taillight shiner, *Notropis maculatus*, was discovered for the first time in Illinois in a wetland in Massac County in 1987 (Burr et al. 1988). This species was captured at only 1 of 22 wetlands sampled on the lower Wabash and Ohio rivers (Burr and Warren 1987) and should be recognized as endangered in Illinois and given highest priority for protection.

Species Expanding Their Ranges

Because the Illinois fish data base is extensive, covers two broad historical periods, and is well vouchered, it allows us to be reasonably confident of the ranges of most native, nongame fishes within the confines of Illinois. While many species have experienced range reductions in the last 90 years, a few others have expanded their ranges in response to widespread modification of habitats. An outstanding example is the red shiner, *Cyprinella lutrensis*, a species tolerant of wide fluctuations in pH, dissolved oxygen, and thermal shock (Matthews and Hill 1977). Additionally, its adaptable feeding habits and reproductive capability (Matthews and Hill 1977) in combination with its tolerance for the above-mentioned parameters undoubtedly account for its success in Illinois. This species has expanded its range north into Wisconsin, up the Ohio River drainage of southern Illinois into Kentucky and the lower Wabash River, and beginning in the 1960s crossed over from Mississippi River drainages into the upper Vermilion River drainage (Page and Smith 1970), where it has continued to move downstream to Champaign County. Another example is the silverjaw minnow, *Ericymba buccata*, which has expanded its range chiefly in the Illinois River drainage. This pioneering species quickly disperses into newly dredged ditches with sandy substrates. Because Illinois streams tend to be wider and shallower than formerly (Larimore and Smith 1963), suitable habitat for species tolerant of these conditions has increased.

Nearly all game/sport fishes and some forage species (e.g., golden shiner, *Notemigonus crysoleucas*, and fathead minnow, *Pimephales promelas*) have had their ranges expanded by numerous introductions which continue unabated in Illinois. The mosquitofish, *Gambusia affinis*, has been widely transplanted in efforts to control mosquito outbreaks. The inland silverside, *Menidia beryllina*, was collected in 1978 from the Mississippi River at Grand Tower (a record included in a footnote by Smith [1979:211]). Beginning in 1980, this fish has been stocked as a forage species in several southern Illinois ponds and impoundments (Stoeckel and Heidinger 1989). Examples of game/sport fishes recently captured in the Illinois waters of Lake Michigan and not reported in Smith (1979) include the channel catfish, *Ictalurus punctatus*, and the black crappie, *Pomoxis nigromaculatus* (Savitz et al. 1990). Smith (1971:8) lists another five native species whose ranges have expanded in recent times.

New Records of Rare or Geographically Limited Species

Collections of Illinos fishes made during the 1940s by A.C. Bauman and those made during the 1980s have revealed new records for rare or geographically limited Illinois species that expand the information in Smith (1979). For example, the lake sturgeon, *Acipenser fulvescens*, not reported from the Mississippi River since 1966, is known from three recent records in the Mississippi (Burr et al. 1988) and Ohio rivers (Burr et al. 1990). New localities for eight other uncommon Illinois fishes were included in Burr et al. (1988). Dimmick (1988) reported the first Illinois records of the western sand darter, *Etheostoma clarum*, from the Mississippi River south of the mouth of the Missouri River; Savitz et al. (1989b) recorded the first record of the quillback, *Carpiodes cyprinus*, in the Illinois waters of Lake Michigan. Examination of voucher specimens from several U.S. museums has resulted in a reassessment of the ranges of the bigeye chub and pallid shiner (Warren and Burr 1988) as originally presented in Smith (1979).

The Alien Component and Recent Southern Invasions

Since Smith's (1979) survey, three exotics, the bighead carp, silver carp, and rudd, in addition to the four Smith reported, have been found at several localities in Illinois and, if not already established, almost certainly will be within a few years. The potential ecological effects of introduced and exotic 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., predation, competition for food); hybridization; and spatial alterations (e.g., overcrowding) (Taylor et al. 1984).

Twenty-two (10.5 %) of the total of 209 fish species in Illinois are not native to the state (Table 2). Of these, at least 13 were probably intentionally introduced, 5 spread through manmade canals in the Great Lakes drainage to the Illinois portion of Lake Michigan, 1 was an unintentional introduction, and 3 euryhaline species recently invaded from more southern latitudes.

The presence of new species raises questions as to their source, their ecological role in Illinois, and their importance to human welfare. Among the 22 species, 7 are introductions from Europe or Asia; 3 are from western North America; 8 are from eastern fresh waters of the Atlantic Coast, of which 3 are introduced and 5 used canals; 3 are native to the lower Mississippi basin or Gulf Coast and have entered the state naturally or by human transfer; and 1 (the cichlid) was presumably introduced accidentally with other sport fishes. Several, probably many, additional species have in the past been introduced into Illinois waters but are not known to persist. Thousands of Atlantic salmon, *Salmo salar*, were introduced into the Mississippi River in the late 1800s (Carlander 1954). Apparently the stockings were not successful, although several individuals collected in 1986 from the Mississippi River near Chester (Burr et al. 1988) indicate that illegal stockings have apparently occurred in the river in recent decades. Grass, silver, and bighead carps have been encountered at many localities in Illinois, and the grass and bighead carps are known to be reproducing in the upper Mississippi River basin (Pflieger and Grace 1987; Pflieger 1989; Jennings 1989). A plethora of tropical and subtropical aquarium fishes have surely been released into Illinois waters (see Smith [1965] for examples) only to perish in the ensuing winter. One exception is the Rio Grande cichlid, *Cichlasoma cyanoguttatum*, released accidentally in the mid-1980s into Powerton Lake near Pekin; individuals have been observed setting up territories in that thermally treated lake during summer months (Rich Monzingo, pers. comm.). The threespine stickleback, *Gasterosteus aculeatus*, captured twice in 1988 from the Illinois portion of Lake Michigan (at Trident Harbor and Cicero), is apparently spreading rapidly through the upper Great Lakes. It was first taken in Lake Huron in

1982 (C. L. Smith 1985:276), but whether the species is self-sustaining in Illinois waters is not known.

Some of the alien species are localized geographically, rare, or small and apparently unimportant ecologically. In contrast, the salmonids, striped bass, and recently introduced carps are much valued as recreational species or for weed control, and some are common and becoming widespread. Another group of species includes the locally abundant alewife and goldfish, the widespread common carp, and the rapidly spreading rainbow smelt and white perch. These species are more or less controversial, being variously valued as sources of food or recreation but with negative ecological attributes (e.g., periodic alewife die-offs, predation, unfavorable ecological interactions with native species). The rainbow smelt, the most numerous small species in some winter seine samples from the Mississippi River for over 10 years, has not been collected from June through October and is probably not self-sustaining in the Illinois portion of the Mississippi River. The sea lamprey, an alien in Lake Michigan, has played a major role in the history and fisheries of the Great Lakes Basin.

One of the most surprising invasions in Illinois was the appearance during the fall of 1989 of the striped mullet, *Mugil cephalus*, in the Mississippi and Ohio rivers. This principally marine species had not been reported previously from Illinois waters and was known only in the published literature as far north in

Table 2. General distribution in Illinois of alien fish species and recent invaders from southern latitudes. Numbers in parentheses indicate (1) exotics introduced directly into Illinois, (2) transplants from elsewhere in North America, (3) species colonized after introduction elsewhere or through manmade access, and (4) species that have recently invaded.

Fish species by family	General distribution in Illinois
Petromyzontidae	
Petromyzon marinus, sea lamprey (3)	L. Michigan
Clupeidae	
Alosa pseudoharengus, alewife (3)	L. Michigan
Dorosoma petenense, threadfin shad (2, 4)	Ohio R., Mississippi R., Wabash R., southern Illinois reservoirs
Salmonidae	
Oncorhynchus kisutch, coho salmon (2)	L. Michigan
Oncorhynchus mykiss, rainbow trout (2)	northern half of Illinois
Oncorhynchus tshawytscha, chinook salmon (2)	L. Michigan
Salmo salar, Atlantic salmon (2)	Mississippi R.
Salmo trutta, brown trout (1)	northern Illinois, L. Michigan
Osmeridae	
Osmerus mordax, rainbow smelt (3)	L. Michigan, Illinois R., Mississippi R., Ohio R.
Cyprinidae	
Carassius auratus, goldfish (1)	Illinois and Rock R. drainage
Ctenopharyngodon idella, grass carp (1)	big rivers, reservoirs, ponds
Cyprinus carpio, common carp (1)	statewide
Hypophthalmichthys molotrix, silver carp (1)	big rivers, reservoirs, ponds
Hypophthalmichthys nobilis, bighead carp (1)	big rivers, reservoirs, ponds
Scardinius erythrophthalmus, rudd (1)	northern Illinois; sporadic
Ictaluridae	
Ameiurus catus, white catfish (2)	Illinois R., Mississippi R., Kaskaskia R.
Moronidae	
Morone americana, white perch (3)	L. Michigan
Morone saxatilis, striped bass (2)	Illinois reservoirs
Atherinidae	
Menidia beryllina, inland silverside (2, 4)	southern Illinois reservoirs, Mississippi R.
Gasterosteidae	
Gasterosteus aculeatus, threespine stickleback (3)	L. Michigan
Mugilidae	
Mugil cephalus, striped mullet (4)	Ohio R., Mississippi R.
Cichlidae	
Cichlasoma cyanoguttatum, Rio Grande cichlid (2)	Powerton L., Pekin

the Mississippi River as southern Arkansas (Robison and Buchanan 1988). According to William L. Pflieger (pers. comm.), striped mullets were obtained from the Mississippi River at New Madrid in 1983 and at Cape Girardeau in 1988. The lower water levels in the Mississippi River in 1989 may have created water quality conditions (e.g., high dissolved solids) favorable for striped mullet and allowed them to reach the upper Mississippi River basin (Burr et al. 1990).

ENDANGERED, THREATENED, AND WATCH LIST SPECIES

In the approximately 150 years since Europeans actively colonized the state of Illinois, changes in the fish fauna have been profound. Of the 187 native species (Table 1), 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. Since the longjaw ciscoe, *Coregonus alpenae*, is no longer considered a valid species and was never officially reported from the Illinois waters of Lake Michigan, none of the Illinois species qualifies as endangered (actively threatened with extinction) in the sense of the federal definition.

The Illinois Endangered Species Act of 1972 (amended in 1977) provides for some protection of rare fishes. Lists (Smith and Page 1981; Illinois Endangered Species Protection Board 1990) of endangered and threatened fishes have continued to be revised and updated; however, potential threats to rare fishes are always present and the status of each is constantly subject to change. A change in status can occur quickly, particularly in a peripheral or relict population.

Thirteen of the 187 native species are endangered and 15 are threatened (Table 3). Eleven species have been placed on a watch list (Table 4), an action that suggests they may be recategorized as endangered or threatened depending on changes that take place in Illinois. A significant concern to conservation biologists and others is the status and protection of those species that are restricted to big, free-flowing rivers (i.e., the Mississippi River). Some of the species on the watch list are big river fishes; however, because these species do not occur generally within the "inland" waters of state boundaries, they are not receiving the protection they warrant. Examples of big river fish needing more formal protection in Illinois include the pallid sturgeon, *Scaphirhynchus albus*, the flathead chub, *Platygobio gracilis*,

Table 3. Fishes categorized as endangered or threatened in Illinois according to the Illinois Endangered Species Protection Board (1990). Nomenclature has been modified where appropriate to follow Page and Burr (1991) and Warren (1989).

Endangered	Threatened
Northern brook lamprey, *Ichthyomyzon fossor*	Least brook lamprey, *Lampetra aepyptera*
Bigeye chub, *Hybopsis amblops*	Lake sturgeon, *Acipenser fulvescens*
Pallid shiner, *Hybopsis amnis*	Alligator gar, *Atractosteus spatula*
Pugnose shiner, *Notropis anogenus*	Cisco, *Coregonus artedii* (or *artedi*)
Weed shiner, *Notropis texanus*	Lake whitefish, *Coregonus clupeaformis*
Bluehead shiner, *Pteronotropis hubbsi*	Bigeye shiner, *Notropis boops*
Cypress minnow, *Hybognathus hayi*	Ironcolor shiner, *Notropis chalybaeus*
Greater redhorse, *Moxostoma valenciennesi*	Blackchin shiner, *Notropis heterodon*
Northern madtom, *Noturus stigmosus*	Blacknose shiner, *Notropis heterolepis*
Western sand darter, *Etheostoma clarum*	River redhorse, *Moxostoma carinatum*
Eastern sand darter, *Etheostoma pellucidum*	Longnose sucker, *Catostomus catostomus*
Bluebreast darter, *Etheostoma camurum*	Banded killifish, *Fundulus diaphanus*
Harlequin darter, *Etheostoma histrio*	Redspotted sunfish, *Lepomis miniatus*
	Bantam sunfish, *Lepomis symmetricus*
	Iowa darter, *Etheostoma exile*

the sturgeon chub, *Macrhybopsis gelida*, and the sicklefin chub, *Macrhybopsis meeki*. These four species are restricted in Illinois to the main channel of the Mississippi River below the mouth of the Missouri River. Intermittent sampling in the Mississippi River below the mouth of the Missouri River over a 12-year period indicates that the three chub species are naturally rare and sporadic in occurrence. Small numbers of the sicklefin chub are still being captured, but the flathead and sturgeon chubs have been taken once each since 1985. The pallid sturgeon is so rare throughout its range that it is being considered for listing as a federally endangered species.

If species that are considered extirpated from Illinois and those on the endangered, threatened, or watch lists are included, 46 species or 24% of the native fauna are experiencing trouble maintaining viable populations in Illinois. The addition of the taillight shiner, flathead chub, and sicklefin chub, which are presently not on any formal list, brings the total to 49 species or 26%.

RECOMMENDATIONS

Illinois is a model state in view of its excellent data base on fish distributions over time. Although we have learned a great deal about the effects of human activities on the aquatic environment in Illinois, we must continue to conduct basic survey work on Illinois fishes and document long-term changes in the fauna. Because fishes are sensitive indicators of environmental quality, continued collection of data will aid in monitoring a variety of stream-quality parameters and assist state agencies in identifying high-quality aquatic habitats in need of protection.

Because of the number of species extirpated or endangered in Illinois, we need to establish a monitoring program and status surveys of species on the watch list. Several of the species on the Illinois endangered list are probably already extirpated (e.g., bigeye chub, bluehead shiner) and the most effective course of action might be to allocate funds and efforts on species that may be realistically recoverable.

Over the last several years, we have come to recognize that we know comparatively little about the fundamental life histories of nongame fishes in contrast to the voluminous literature on the biology of game or sport fishes. If we are ever going to manage nongame species effectively, more funding is needed for studies on basic fish biology, especially those emphasizing reproductive biology, trophic ecology, predator-prey interactions, and parasites and diseases.

The purchase of critical habitat by The Nature Conservancy, the Illinois Department of Conservation, and other agencies has provided islands of habitat where some rare fish species can survive. For the taillight shiner, the purchase of critical habitat may be the best measure for protecting this rare and highly localized species. Several rare Illinois fishes that occur in relatively undisturbed and protected areas (e.g., LaRue–Pine Hills Swamp) continue to maintain viable populations. Efforts to purchase critical stream and wetland habitats in Illinois need to increase.

Game and sport fishes have been stocked in Illinois waters for many years. Within reason, state agencies should now consider stocking certain nongame fishes in an attempt to restore viable populations. Pond culture of endangered and threatened species should be continued in Illinois because it has provided a useful environment for studying aspects of the fundamental life histories of rare species; this information in turn leads to more effective management.

Because siltation is still considered to be the number one factor in decimation of native fish populations, we must continue to work creatively with farmers and others in protecting the valuable prairie topsoil of Illinois. The removal of gravel from headwater streams should be discouraged because the process increases erosion and destroys breeding sites of headwater creek fishes. Reservoir construction

Table 4. Fishes placed on the watch list by the Illinois Endangered Species Technical Advisory Committee on Fishes. These species do not receive protection under federal or state laws.

Pallid sturgeon, *Scaphirhynchus albus*
Round whitefish, *Prosopium cylindraceum*
Lake chub, *Couesius plumbeus*
River chub, *Nocomis micropogon*
Gravel chub, *Erimystax x-punctatus*
Sturgeon chub, *Macrhybopsis gelida*
Blacktail shiner, *Cyprinella venusta*
Northern starhead topminnow, *Fundulus dispar*
Fourhorn sculpin, *Myoxocephalus quadricornis*
Spoonhead sculpin, *Cottus ricei*
Cypress darter, *Etheostoma proeliare*

and stream channelization should also be discontinued in Illinois because of the detrimental effects these practices have on large expanses of aquatic habitat.

Finally, basic survey work on the big rivers of Illinois is badly needed. While we know comparatively little about the biology of small stream species, we know next to nothing regarding nongame, big river fishes. Unusual Illinois species (e.g., the pallid sturgeon) may disappear before we learn anything substantial about them or can protect them.

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The Aquatic Mollusca of Illinois

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Illinois has historically supported a diverse aquatic molluscan fauna, numbering over 175 species and occupying almost every type of aquatic habitat from the Great Lakes to wetlands, temporary woodland ponds, seeps, springs, and streams. Two classes of mollusks are represented in the waters of Illinois: Bivalvia, which includes the clams and mussels, and Gastropoda, represented by the snails and limpets. The native bivalves of Illinois are members of three families: the Margaritiferidae and Unionidae (the freshwater mussels) and the Sphaeriidae (the fingernail clams and peaclams). The gastropods are divided into two subclasses, Prosobranchia and Pulmonata. The Prosobranchs or the operculated, gill-breathing snails are represented in Illinois by 37 species in six families. The Pulmonates or the nonoperculated, lung-breathing snails contain 37 species in four families. A list of the species for each of the families reported from the state is given on pages 435–438. For the unionids, aspects of their biology, commercial use, and status are discussed. Information on identification, distribution, and biology of the aquatic molluscan fauna of Illinois will appear in forthcoming publications. An excellent monograph on the freshwater snails of North America has been published (Burch 1989) and should be consulted for keys and figures of most of the species found in Illinois.

The list of the freshwater mussels of Illinois (pages 435–436) is based on the examination of specimens in collections housed in the following museums: Academy of Natural Sciences, Philadelphia; Chicago Academy of Sciences; Field Museum of Natural History; Illinois Natural History Survey; Illinois State Museum; Museum of Comparative Zoology, Harvard; Ohio State University Museum of Zoology; University of Illinois Museum of Natural History; University of Michigan Museum of Zoology; and the United States National Museum. The list for Sphaeriidae and Gastropoda (pages 436–438) were compiled from the literature on Illinois Mollusca, primarily the publications of Baker (1900, 1901, 1902, 1906, 1922); Basch (1963); Burch (1989); Dexter (1956); Ulffers (1855); and Zetek (1918). Additional work is planned to verify the sphaeriid and gastropod lists by examining specimens in museum collections.

Nomenclature in this paper, with three exceptions, follows a list of common and scientific names of mollusks prepared by the Committee on Scientific and Vernacular Names of Mollusks of the Council of Systematic Malacologists, American Malacological Union (Turgeon et al. 1988). Subspecies are not recognized, nomenclature for members of the *Pleurobema cordatum* species complex follows Stansbery (1983), and nomenclature for the family Hydrobiidae follows Hershler and Thompson (1987) and Hershler et al. (1990).

The aquatic mollusks of Illinois have been studied for over 150 years. Thomas Say, the first scientist to work on mollusks in Illinois, was one of America's earliest naturalists. Say traveled to the Midwest as early as 1817 and in 1826 moved from Philadelphia to the utopian community of New Harmony, Indiana (Van Cleave 1951). While there, he collected and described many of the mollusks found in the Wabash River and its tributaries, some of which are are still recognized today.

Few attempts have been made to compile a list of the mollusk species found in Illinois. In 1906, Frank C. Baker published an annotated checklist of the Mollusca of Illinois in which he summarized the available data on the distribution of the species within the state. A prolific writer, Baker published over 400 papers, including many important works on the molluscan fauna of Illinois (Baker 1897, 1898, 1899, 1900, 1901, 1902, 1906, 1922, 1926). Baker's papers remain the best source of published information on the biology and distribution of aquatic mollusks in the state. Other early workers on the freshwater mollusks of Illinois included Kennicott (1855); Ulffers (1855); Calkins (1874a, 1874b, 1874c); Strode (1891, 1892); Wilson and Clark (1912); Danglade (1912, 1914); Zetek (1918); and Hinkley (1919).

Few papers were published on the aquatic Mollusca of Illinois in the 1930s and 1940s. During the late 1940s and 1950s, Dr. Max R. Matteson of the University of Illinois collected mussels at over 200 sites in Illinois and amassed one of the largest and best documented collections that exists for any state in the nation. Matteson's surveys provided both distribution and abundance data on mussels from Illinois streams, many of which had not been previously sampled. His collections, now at the Illinois Natural History Survey, provide an invaluable data set and serve as the benchmark for mussel surveys conducted today.

In 1967, Paul W. Parmalee of the Illinois State Museum published *The Fresh-water Mussels of Illinois*, which included many original observations on the distribution and habitat of unionids. This monograph, one of the most frequently cited regional works on freshwater mussels, is still the best guide available on the mussels of the state. Other papers on aquatic mollusks of Illinois in the 1950s and 60s include van der Schalie and van der Schalie (1950); Dexter (1953, 1956); Parmalee (1955, 1956); Matteson (1961); Matteson and Dexter (1966); and Fechtner (1963).

In the 1970s and 1980s, stream surveys were conducted on the Illinois (Starrett 1971), Kankakee (Lewis and Brice 1980; Suloway 1981), Kaskaskia (Suloway et al. 1981), and Wabash rivers (Meyer 1974; Clark 1976). These and current studies document the rapid decline of the freshwater mussels of Illinois and provide data on the status of rare species.

BIVALVIA: MUSSELS AND CLAMS

Freshwater mussels in the families Margaritiferidae and Unionidae are found throughout the holarctic region but reach their greatest diversity in eastern North America, where they number about 285 species (Turgeon et al. 1988). A total of 78 species in two families and four subfamilies has been recorded from Illinois and boundary waters (pages 435–436).

Biology. Mussels filter-feed on plankton, which they remove from the water as it circulates through the animal via incurrent and excurrent aperatures. In most freshwater mussel species, the sexes are separate. Sperm are released into the water and taken into the female via the incurrent aperature. The eggs are fertilized and develop into an intermediate stage, the glochidium. Glochidia are stored in the female's gills, which function as brood chambers. Nearly all unionids must pass through a parasitic phase in order to complete their life cycle. In the spring or summer, glochidia are expelled into the water and must come in contact with the appropriate host, usually a fish, to which they attach and metamorphose into a juvenile mussel. Glochidia are either internal parasites on the gills or external parasites on the fins. Some species are host specific, but others are generalists and use a wide variety of fishes as hosts. Mussels are long lived. Many species live as long as 25 years, and some are reported to live more than 50 years.

Commercial Use. In 1891 a German immigrant, J.F. Boepple of Petersburg, Illinois, realized that the mussels of the United States could be used, as they had been in Europe, to manufacture buttons. In the early part of the twentieth century, enormous quantities of mussels were harvested for the button industry, with some beds in Illinois producing over 700 tons in a single year (Coker 1919). Mussel shells were collected, cooked out, and shipped to factories where they were cut into blanks, sorted, polished, and finished into buttons. Today freshwater mussel shells are exported to Japan where they are converted into beads and inserted into oysters where they serve as nuclei for cultured pearls. The oysters are maintained in cages under water, and over a period of about a year, a layer of mother-of-pearl is secreted around the bead to form the pearl.

From 1912 to 1914, roughly 15,000 tons of shells were taken in Illinois and boundary waters and sold at a price that varied from $4 to $10 a ton. The increase in price over the last 75 years has been astronomical. In the 1940s, the price of shells was about $25 a ton and remained at that level until the button industry collapsed in the late 1950s due to the advent of plastics. As the demand for shells to manufacture cultured pearls increased, so did the price, from $45 a ton in the 60s, $800 in the 70s, and

$1,800 in the 80s, to $2,400 a ton this year (N. Cohen, pers. comm.). At current prices, the estimated harvest of 1912 to 1914 would be worth about $36 million.

Status. Surveys across North America have documented significant declines in freshwater mussel populations. Recent surveys for mussels in Illinois using the same methods as those of previous studies have documented a reduction in the fauna for all streams sampled (Table 1). In 1966, William C. Starrett of the Illinois Natural History Survey conducted an in-depth study of the Illinois River. He collected only 23 of the 47 species previously reported from the Illinois (Starrett 1971). Two of the 24 extirpated species were the butterfly, *Ellipsaria lineolata* (Rafinesque 1820), a species that has declined statewide in recent years; and the Higgins eye, *Lampsilis higginsi* (Lea 1857), now on the federally endangered species list. Similar results were obtained in the Kankakee River where Suloway (1981) reported only 24 of the 32 species historically known to inhabit the river. The Kankakee River drainage continues to support some of the richest mussel populations of the state, including the state threatened bullhead, *Plethobasus cyphyus* (Rafinesque 1820), and the ellipse, *Venustaconcha ellipsiformis* (Conrad 1836). In the Kaskaskia River, the decline in diversity has been pronounced. Only 32 of the 39 species recorded from the drainage were found in 1956, and that number was reduced to 24 by 1978 (Suloway et al. 1981). In addition, the number of individuals dropped from 2,595 to 498, an 80% reduction in just over 20 years. A survey of the Sangamon River in 1988–1989 recovered all of the species found in 1956–1960; however, overall numbers collected per unit of effort were much lower, and some, for example, *Elliptio dilatata* (Rafinesque 1820) and *Megalonaias nervosa* (Rafinesque 1820) have been nearly extirpated (Schanzle and Cummings 1991).

Table 1. Selected streams in Illinois where recent surveys have documented declines in the freshwater mussel fauna. Data from Starrett 1971; Suloway et al. 1981; Suloway 1981; and Cummings et al. unpublished.

	Number of mussel species	
	Pre-1960	Post-1960
Mississippi River drainage		
Illinois River	47	23
Kaskaskia River	39	24
Kankakee River	32	24
Wabash River drainage		
Embarras River	44	27
Vermilion River	41	25
Little Wabash River	41	31

In the Wabash River drainage, even the relatively undisturbed Vermilion River has suffered a serious decline, with almost 40% of the mussel species extirpated by the 1970s. Although its species richness has declined, this river supports the only known populations of at least two state endangered species: the wavy-rayed lampmussel, *Lampsilis fasciola* Rafinesque 1820, and the rabbitsfoot, *Quadrula cylindrica* (Say 1817). The pattern is the same in the Embarras River, where the number of species has dropped from 44 to 27. A comparison of surveys done in 1956 and 1986 revealed that the Embarras River continues to support a fairly diverse fauna; however, the number of individuals has declined over 80% in the last 30 years. Two state endangered species are found in Illinois only in the Embarras: the kidneyshell, *Ptychobranchus fasciolaris* (Rafinesque 1820), and the snuffbox, *Epioblasma triquetra* (Rafinesque 1820). The Little Wabash River has suffered a similar decline, and a 1988 survey revealed that only 31 of the 41 species known to have occurred in the drainage are extant.

A variety of factors are responsible for the decline of mussel populations. Foremost is siltation from agricultural run-off due to poor land management. Mussels are sedentary and particularly susceptible to the smothering effects of siltation. Channelization is detrimental because it eliminates habitat for mussels as well as potential host fishes. Impoundments often create good habitat directly below the dam, but they also inundate large areas of the stream and impede the migration of host species. Herbicides, pesticides, and petroleum-related pollution also have negative effects, and competition from exotics has been implicated in the decline of native mussels, although the mechanisms involved are not entirely understood.

One result of the status surveys conducted in Illinois and other states in recent years has been the addition of many mussel species to state and federally endangered species lists. Thirteen species are now considered to be globally extinct, including four once found in Illinois (Turgeon et al. 1988; see listing on pages 435–436, this publication). On the federal level, 37 mussels are listed as endangered and another 56 are proposed or candidates for listing (U.S. Department of the Interior, Fish and Wildlife Service 1989a, 1989b). The Illinois Threatened and Endangered Species List now contains 33 mussels (29 endangered and 4 threatened), slightly over 40% of the species ever recorded from Illinois (Illinois Endangered Species Protection Board 1990). Another 11 species are candidates or species of special concern that may be listed in the future. These bring the total number of rare, endangered, or extirpated species in Illinois to 44 species—56% of the state's known mussel fauna. Other states have similar problems. North Carolina, for example, recently reported that half of its mussel species are disappearing and in need of protection (Venters 1990). This national decline has received some much needed attention and funding has been provided in recent years to begin to document and address the problem.

The fingernail clams and peaclams of the family Sphaeriidae are holarctic in distribution and occupy a wide variety of habitats. Thirty-eight species in four genera are found in North America, and 26 species in three genera are reported from Illinois (pages 436–437). Although little has been published on the distribution and status of these animals in Illinois since Baker's list of 1906, unpublished reports make clear that many species have disappeared from the streams in which they formerly occurred and are declining throughout their range. Sphaeriids are hermaphroditic and, unlike freshwater mussels, have direct development, with about 2 to 20 young produced per female. Although sphaeriids have no direct economic value, they are an important food source for many animals, including fishes and diving ducks.

The family Corbiculidae is represented in Illinois by the exotic Asian Clam, *Corbicula fluminea* (Müller 1774). Introduced in North American in the 1920s (Counts 1981), this species was first reported in Illinois from the Ohio River in southern Illinois in the early 1960s (Fechtner 1962). Since then it has spread at least as far north as Rock Island and is present in most if not all drainages in the state. As is the case with most established exotics, *Corbicula* has had serious negative effects on the environment. This extremely prolific clam has caused major problems associated with the fouling of cooling water intakes of power plants (Isom 1986) and may outcompete native species (Clarke 1988).

The family Dreissenidae is represented in North American freshwaters by the zebra mussel *Dreissena polymorpha* (Pallas 1771). Although the zebra mussel is not currently established in Illinois waters, it was recently discovered in the Indiana portion of Lake Michigan and its arrival here is imminent. This exotic is causing tremendous economic problems in Lake Erie and Lake St. Clair and will negatively affect our native mussels by smothering and suffocating them as it has in the Great Lakes.

GASTROPODA: FRESHWATER SNAILS

Freshwater snails are basically herbivores and detritivores and use their radulae to scrape algae and diatoms from plants and rocks. About 500 species of freshwater snails are found in North America, 350 Prosobranchs and 150 Pulmonates (Burch 1989). Of those, 85 or about one-fifth of the species are candidates for federal protection (U.S. Department of Interior, Fish and Wildlife Service 1989b). A review of the literature suggests that there are or were about 74 species of freshwater snails in Illinois, two of which were introduced and three that are under consideration for federal listing (pages 437–438).

The subclass Prosobranchia is represented in Illinois by 37 species in six families: Valvatidae, Viviparide, Bithyniidae, Hydrobiidae, Pomatiopsidae, and Pleuroceridae.

The shells of North American Valvatidae are relatively small (up to 5 mm) and flattened in shape. Valvatids are egg layers and, unlike most Prosobranchs, hermaphroditic. Five species, all in the genus *Valvata*, have been reported from Illinois.

The family Viviparidae is found on all continents except Antarctica and South America and occurs throughout eastern North America. The sexes are separate, and as their name implies, they are "live bearers" as opposed to egg layers. Six species in three genera are found in Illinois.

The family Bithyniidae is represented in Illinois by the Mud Bithynia, *Bithynia tentaculata* (Linnaeus 1758). This species also occurs in Europe, and populations have been introduced into North America where the species has spread widely (Burch 1989). *Bithynia tentaculata* has been reported from Pleistocene deposits in Chicago, and it may, therefore, have been present in North America before Europeans arrived.

The family Hydrobiidae is one of the most common and widely distributed snail families in the world. These small- to medium-sized snails are a major component of the North American fauna and number about 35 genera and 170 species (Hershler and Thompson 1987; Turgeon et al. 1988). Most live in fresh water, although a few have been found in brackish water. Twelve species in seven genera have been reported from Illinois.

The family Pomatiopsidae is represented in North America by six species, two of which are found in Illinois. These snails are usually regarded as amphibious, inhabiting river banks or moist areas near streams.

The Pleuroceridae are widely distributed, occurring in North, Central, and South America and in Africa and Asia. They reach their greatest diversity, however, in the southeastern United States. Pleurocerids are extremely sensitive to the effects of pollution and siltation. At least 23 species are presumed extinct, and many others are candidates for threatened or endangered status (Turgeon et al. 1988; U.S. Department of the Interior, Fish and Wildlife Service 1989b). Eleven species in four genera have been found in Illinois, three of which are candidates for federal listing (page 437). Their current status in Illinois is unknown and needs investigation.

The subclass Pulmonata is represented in Illinois by four families. Like the pleurocerids, members of the family Lymnaeidae are found worldwide but reach their greatest diversity in North America. Fourteen species (1 introduced) in six genera have been reported from Illinois.

The family Physidae is mainly a New World family with a few species found in Eurasia and Africa. Physids are found in a wide variety of habitats and are the most widespread and abundant snails in North America. They appear to be the most pollution tolerant of all freshwater mollusks and may be the only species found in highly degraded waters.

The family Planorbidae is restricted to fresh water and is worldwide in distribution. Planorbids vary widely in size from about 1 to 30 mm. A few species are known to serve as intermediate hosts for human parasites and have been studied extensively; most others are relatively unknown ecologically. Twelve species (1 introduced) in six genera have been found in Illinois.

The Ancylidae, or freshwater limpets, are worldwide in distribution and are found in many freshwater habitats. The family, revised in 1963, is currently thought to contain about 13 species in four genera (Basch 1963; Turgeon et al. 1988). Ancylids can usually be found attached to aquatic vegetation or living on stones or other debris. Little is known about the biology of freshwater limpets, but they are reported to be fairly intolerant of chemical pollution (Basch 1963). Six species in three genera have been found in Illinois.

The current distribution and status of gastropods in Illinois are poorly understood, and as a result we are unable to compile a list of threatened or endangered freshwater snail species for the state. Given the documented decline in freshwater mussels and other aquatic organisms, however, there can be little doubt that Illinois has lost and is likely in danger of losing many species of snails as well.

Conservation efforts in Illinois and other states have thus far concentrated on preserving or protecting terrestrial ecosystems and their inhabitants. While the protection of prairies, bogs, fens, glades, and forests is an extremely important and worthwhile endeavor, we need to protect aquatic habitats as well or we will most certainly lose many of the fascinating and unique species that are found in the fresh waters of North America.

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The Aquatic Mollusca of Illinois. Species are arranged alphabetically within each family or in the case of Unionidae within each subfamily. Abbreviations for status are as follows: (†) = extinct, X = extirpated from Illinois, FE = federally endangered, FC = federal candidate, SE = state endangered, ST = state threatened, SC = state candidate (watch list), I = introduced.

Scientific Name	Common Name	Status[1]
CLASS BIVALVIA		
ORDER UNIONOIDA		
Family Margaritiferidae (1 species)		
Subfamily Cumberlandinae		
Cumberlandia monodonta (Say 1829)	Spectaclecase	FC, SE
Family Unionidae (77 species)		
Subfamily Ambleminae		
Amblema plicata (Say 1817)	Threeridge	
Cyclonaias tuberculata (Rafinesque 1820)	Purple wartyback	
Elliptio crassidens (Lamarck 1819)	Elephant-ear	ST
Elliptio dilatata (Rafinesque 1820)	Spike	SC
Fusconaia ebena (Lea 1831)	Ebonyshell	SC
Fusconaia flava (Rafinesque 1820)	Wabash pigtoe	
Fusconaia subrotunda (Lea 1831)	Long-solid	FC, SC, X
Hemistena lata (Rafinesque 1820)	Cracking pearlymussel	FE, SE, X
Megalonaias nervosa (Rafinesque 1820)	Washboard	
Plethobasus cicatricosus (Say 1829)	White wartyback	FE, SE, X
Plethobasus cooperianus (Lea 1834)	Orange-foot pimpleback	FE, SE
Plethobasus cyphyus (Rafinesque 1820)	Sheepnose	ST
Pleurobema clava (Lamarck 1819)	Clubshell	FC, SE
Pleurobema cordatum (Rafinesque 1820)	Ohio pigtoe	SC
Pleurobema plenum (Lea 1840)	Rough pigtoe	FE, SE, X
Pleurobema rubrum (Rafinesque 1820)	Pyramid pigtoe	SC
Pleurobema sintoxia (Rafinesque 1820)	Round pigtoe	
Quadrula cylindrica (Say 1817)	Rabbitsfoot	SE
Quadrula fragosa (Conrad 1835)	Winged mapleleaf	FC, SC, X
Quadrula metanevra (Rafinesque 1820)	Monkeyface	
Quadrula nodulata (Rafinesque 1820)	Wartyback	
Quadrula pustulosa (Lea 1831)	Pimpleback	
Quadrula quadrula (Rafinesque 1820)	Mapleleaf	
Tritogonia verrucosa (Rafinesque 1820)	Pistolgrip	
Uniomerus tetralasmus (Say 1831)	Pondhorn	ST
Subfamily Anodontinae		
Alasmidonta marginata Say 1818	Elktoe	
Alasmidonta viridis (Rafinesque 1820)	Slippershell	SE
Anodonta grandis Say 1829	Giant floater	
Anodonta imbecillis Say 1829	Paper pondshell	
Anodonta suborbiculata Say 1831	Flat floater	
Anodontoides ferussacianus (Lea 1834)	Cylindrical papershell	
Arcidens confragosus (Say 1829)	Rock-pocketbook	
Lasmigona complanata (Barnes 1823)	White heelsplitter	
Lasmigona compressa (Lea 1829)	Creek heelsplitter	ST
Lasmigona costata (Rafinesque 1820)	Fluted-shell	
Simpsonaias ambigua (Say 1825)	Salamander mussel	FC, SE
Strophitus undulatus (Say 1817)	Squawfoot	
Subfamily Lampsilinae		
Actinonaias ligamentina (Lamarck 1819)	Mucket	
Cyprogenia stegaria (Rafinesque 1820)	Fanshell	FE, SE
Ellipsaria lineolata (Rafinesque 1820)	Butterfly	SC
Epioblasma flexuosa (Rafinesque 1820)	Leafshell	(†), SE, X
Epioblasma obliquata (Rafinesque 1820)	Catspaw	FE, SE, X.
Epioblasma personata (Say 1829)	Round combshell	(†), SE, X

Scientific Name	Common Name	Status
Epioblasma propinqua (Lea 1857)	Tennessee riffleshell	(†). SE. X
Epioblasma rangiana (Lea 1839)	Northern riffleshell	FC. SC. X
Epioblasma sampsonii (Lea 1861)	Wabash riffleshell	(†). SE. X
Epioblasma torulosa (Rafinesque 1820)	Tubercled blossom	FE. SE. X
Epioblasma triquetra (Rafinesque 1820)	Snuffbox	SE
Lampsilis abrupta (Say 1831)	Pink mucket	FE. SE. X
Lampsilis cardium Rafinesque 1820	Plain pockethook	
Lampsilis fasciola Rafinesque 1820	Wavy-rayed lampmussel	SE
Lampsilis higginsi (Lea 1857)	Higgins eye	FE. SE
Lampsilis ovata (Say 1817)	Pocketbook	SC
Lampsilis siliquoidea (Barnes 1823)	Fatmucket	
Lampsilis teres (Rafinesque 1820)	Yellow sandshell	
Leptodea fragilis (Rafinesque 1820)	Fragile papershell	
Leptodea leptodon (Rafinesque 1820)	Scaleshell	FC. SE. X
Ligumia recta (Lamarck 1819)	Black sandshell	
Ligumia subrostrata (Say 1831)	Pondmussel	
Obliquaria reflexa Rafinesque 1820	Threehorn wartyback	
Obovaria olivaria (Rafinesque 1820)	Hickorynut	
Obovaria retusa (Lamarck 1819)	Ring Pink	FE. SE. X
Obovaria subrotunda (Rafinesque 1820)	Round hickorynut	SE
Potamilus alatus (Say 1817)	Pink heelsplitter	
Potamilus capax (Green 1832)	Fat pocketbook	FE. SE
Potamilus ohiensis (Rafinesque 1820)	Pink papershell	
Potamilus purpuratus (Lamarck 1819)	Bleufer	SC
Ptychobranchus fasciolaris (Rafinesque 1820)	Kidneyshell	SE
Toxolasma lividus (Rafinesque 1831)	Purple lilliput	FC. SE
Toxolasma parvus (Barnes 1823)	Lilliput	
Toxolasma texasensis (Lea 1857)	Texas lilliput	
Truncilla donaciformis (Lea 1828)	Fawnsfoot	
Truncilla truncata Rafinesque 1820	Deertoe	
Venustaconcha ellipsiformis (Conrad 1836)	Ellipse	SC
Villosa fabalis (Lea 1831)	Rayed bean	FC. SE. X
Villosa iris (Lea 1829)	Rainbow	SE
Villosa lienosa (Conrad 1834)	Little spectaclecase	SE
ORDER VENEROIDA		
Family Sphaeriidae (26 species)		
Musculium lacustre (Müller 1774)	Lake fingernailclam	
Musculium partumeium (Say 1822)	Swamp fingernailclam	
Musculium securis (Prime 1852)	Pond fingernailclam	
Musculium transversum (Say 1829)	Long fingernailclam	
Pisidium adamsi Prime 1851	Adam peaclam	
Pisidium casertanum (Poli 1791)	Ubiquitous peaclam	
Pisidium compressum Prime 1852	Ridged-beak peaclam	
Pisidium conventus Clessin 1877	Alpine peaclam	
Pisidium cruciatum Sterki 1895	Ornamented peaclam	
Pisidium dubium (Say 1817)	Greater eastern peaclam	
Pisidium equilaterale Prime 1852	Round peaclam	
Pisidium fallax Sterki 1896	River peaclam	
Pisidium ferrugineum Prime 1852	Rusty peaclam	
Pisidium idahoense Roper 1890	Giant northern peaclam	
Pisidium lilljeborgi (Clessin 1886)	Lilljeborg peaclam	
Pisidium nitidum Jenyns 1832	Shiny peaclam	
Pisidium punctatum Sterki 1895	Perforated peaclam	
Pisidium punctiferum (Guppy 1867)	Striate peaclam	
Pisidium rotundatum Prime 1852	Fat peaclam	
Pisidium variabile Prime 1852	Triangular peaclam	
Pisidium walkeri Sterki 1895	Walker peaclam	
Sphaerium fabale (Prime 1852)	River fingernailclam	

Scientific Name	Common Name	Status[1]
Sphaerium occidentale (Lewis 1856)	Herrington fingernailclam	
Sphaerium rhomboideum (Say 1822)	Rhomboid fingernailclam	
Sphaerium simile (Say 1817)	Grooved fingernailclam	
Sphaerium striatinum (Lamarck 1818)	Striated fingernailclam	
Family Corbiculidae (1 species)		
Corbicula fluminea (Müller 1774)	Asian clam	I
Family Dreissenidae (1 species)		
Dreissena polymorpha (Pallas 1771)	Zebra mussel	I
CLASS GASTROPODA (74 species)		
SUBCLASS PROSOBRANCHIA		
ORDER MESOGASTROPODA		
Family Valvatidae (5 species)		
Valvata bicarinata Lea 1841	Two-ridge valvata	
Valvata lewisi Currier 1868	Fringed valvata	
Valvata perdepressa Walker 1906	Purplecap valvata	
Valvata sincera Say 1824	Mossy valvata	
Valvata tricarinata (Say 1817)	Threeridge valvata	
Family Viviparidae (6 species)		
Campeloma crassulum Rafinesque 1819	Ponderous campeloma	
Campeloma decisum (Say 1817)	Pointed campeloma	
Lioplax sulculosa (Menke 1827)	Furrowed lioplax	
Viviparus georgianus (Lea 1834)	Banded mysterysnail	
Viviparus intertextus (Say 1829)	Rotund mysterysnail	
Viviparus subpurpureus (Say 1829)	Olive mysterysnail	
Family Bithyniidae (1 species)		
Bithynia tentaculata (Linnaeus 1758)	Mud bithynia	
Family Hydrobiidae (12 species)		
Amnicola limosa (Say 1817)	Mud amnicola	
Amnicola pilsbryi Walker 1906	Lake duskysnail	
Amnicola walkeri Pilsbry 1898	Canadian duskysnail	
Birgella subglobosus (Say 1825)	Globe siltsnail	
Fontigens aldrichi (Call & Beecher 1886)	Hoosier amnicola	
Fontigens antroecetes (Hubricht 1940)		
Fontigens nickliniana (Lea 1838)	Watercress snail	
Hoyia sheldoni (Pilsbry 1890)	Storm hydrobe	
Probythinella lacustris (Baker 1928)	Delta hydrobe	
Pyrgulopsis lustrica (Pilsbry 1890)	Boreal marstonia	
Pyrgulopsis scalariformis (Wolf 1870)	Moss pyrg	
Somatogyrus depressus (Tryon 1862)	Sandbar pebblesnail	
Family Pomatiopsidae (2 species)		
Pomatiopsis cincinnatiensis (Lea 1840)	Brown walker	
Pomatiopsis lapidaria (Say 1817)	Slender walker	
Family Pleuroceridae (11 species)		
Elimia costifera (Reeve 1861)	Corded elimia	
Elimia livescens (Menke 1830)	Liver elimia	
Elimia semicarinata (Say 1829)	Fine-ridged elimia	
Leptoxis praerosa (Say 1821)	Onyx rocksnail	FC, SC
Leptoxis trilineata (Say 1829)	Broad mudalia	
Lithasia armigera (Say 1821)	Armored rocksnail	FC, SC
Lithasia obovata (Say 1829)	Shawnee rocksnail	
Lithasia verrucosa (Rafinesque 1820)	Verrucose rocksnail	FC, SC
Pleurocera acuta Rafinesque 1831	Sharp hornsnail	
Pleurocera alveare (Conrad 1834)	Rugged hornsnail	
Pleurocera canaliculata (Say 1821)	Silty hornsnail	

Scientific Name	Common Name	Status [1]
SUBCLASS PULMONATA		
ORDER BASOMMATOPHORA		
Family Lymnaeidae (14 species)		
Acella haldemani (Binney 1867)	Spindle lymnaea	
Fossaria dalli (Baker 1907)	Dusky fossaria	
Fossaria humilis (Say 1822)	Marsh fossaria	
Fossaria obrussa (Say 1825)	Golden fossaria	
Fossaria parva (Lea 1841)	Pygmy fossaria	
Fossaria tazewelliana (Wolf 1870)	Tazewell fossaria	
Lymnaea stagnalis Linnaeus 1758	Swamp lymnaea	
Pseudosuccinea columella (Say 1817)	Mimic lymnaea	
Radix auricularia (Linnaeus 1758)	Big-ear radix	I
Stagnicola caperatus (Say 1829)	Wrinkled marshsnail	
Stagnicola catascopium (Say 1817)	Woodland pondsnail	
Stagnicola elodes (Say 1821)	Marsh pondsnail	
Stagnicola exilis (Lea 1834)	Flat-whorled pondsnail	
Stagnicola woodruffi (Baker 1901)	Coldwater pondsnail	
Family Physidae (5 species)		
Aplexa elongata (Say 1821)	Lance aplexa	
Physella gyrina (Say 1821)	Tadpole physa	
Physella heterostropha (Say 1817)	Pewter physa	
Physella integra (Haldeman 1841)	Ashy physa	
Physella virgata (Gould 1855)	Protean physa	
Family Planorbidae (12 species)		
Biomphalaria glabrata (Say 1818)	Bloodfluke planorb	I
Gyraulus deflectus (Say 1824)	Flexed gyro	
Gyraulus parvus (Say 1817)	Ash gyro	
Helisoma anceps (Menke 1830)	Two-ridge rams-horn	
Micromenetus dilatatus (Gould 1841)	Bugle sprite	
Micromenetus sampsoni (Ancey 1885)		
Planorbella armigera (Say 1821)	Thicklip rams-horn	
Planorbella campanulata (Say 1821)	Bellmouth rams-horn	
Planorbella pseudotrivolvis (Baker 1920)		
Planorbella trivolvis (Say 1817)	Marsh rams-horn	
Planorbella truncata (Miles 1861)	Druid rams-horn	
Promenetus exacuous (Say 1821)	Sharp sprite	
Family Ancylidae (6 species)		
Ferrissia fragilis (Tryon 1863)	Fragile ancylid	
Ferrissia parallela (Haldeman 1841)	Oblong ancylid	
Ferrissia rivularis (Say 1817)	Creeping ancylid	
Laevapex diaphanus (Haldeman 1841)	Cymbal ancylid	
Laevapex fuscus (Adams 1840)	Dusky ancylid	
Rhodacmea hinkleyi (Walker 1908)	Knobby ancylid	

[1] Readers may be puzzled by such dual designations for a species as endangered and extirpated or endangered and extinct. The current Illinois list of threatened and endangered mussels was compiled in 1987. Since that time, surveys have determined that some of the species on that list are probably no longer extant. Future lists will reflect such changes and species thought to be extirpated or extinct will be removed. At the present time, however, a species may continue to be listed as endangered but considered by researchers to be extirpated or extinct.

Streams of Illinois

Lawrence M. Page, Illinois Natural History Survey

The recent increased interest in protecting streams (Phillippi and Anderson 1989) is an extremely welcome development. Until now, little effort has been directed toward protecting flowing bodies of water in Illinois, largely because of the difficulties of the task. In contrast, completion of a natural areas inventory in Illinois and excellent efforts by the Illinois Nature Preserves Commission and The Nature Conservancy have resulted in safeguarding a number of prairies and other terrestrial ecosystems.

To protect our streams, we need to gather data and develop appropriate methodologies. To organize this process, we need to address the following questions in relation to streams: What does Illinois have? What should we protect? What are the major causes of stream degradation? How do we protect streams?

WHAT DOES ILLINOIS HAVE?

Because Illinois has a large and complex drainage pattern (Figure 1), it is considered a well-watered state, particularly in relation to most western states. It is bounded on the west by the Mississippi River, on the south by the Ohio, on the northeast by Lake Michigan, and on the southeast by the Wabash. An excellent discussion of the drainages of Illinois and their characteristics at the turn of the century was undertaken by C.W. Rolfe in Forbes and Richardson's *The Fishes of Illinois* [1908]. The biogeography of the fishes of Illinois and other states of the lower Ohio and upper Mississippi River basins is discussed by Burr and Page (1986).

The geological characteristics of Illinois strongly influence the diversity and distributions of its aquatic biota, and the streams of Illinois can be classified physiographically according to Fenneman's physiographic provinces (Fenneman 1938):

I. Great Lakes: Lake Michigan Section
II. Mississippi River
- A. Wisconsin Driftless Section
- B. Till Plains Section
  1. Wisconsin Glacial Till
  2. Illinoian Glacial Till
- C. Shawnee Hills–Ozark Plateaus Section
- D. Coastal Plain Section

The streams over most of Illinois are relatively recent products of glaciation. Those flowing into Lake Michigan and those on the Till Plains Section developed after Pleistocene glaciers had receded and are less than 100,000 years old; those north of the Shelbyville moraine, the southern terminus of the Wisconsin glaciation, are less than 10,000 years old. In contrast, streams in the unglaciated areas of Illinois—the Wisconsin Driftless, Shawnee Hills, and Coastal Plain sections—traverse much older areas. Unglaciated areas exhibit more topographic relief and have more bedrock; their streams are characterized by higher gradients, and they often sustain unique aquatic communities.

The Illinois portion of the Wisconsin Driftless Section is found mostly in Jo Daviess County. It escaped glaciation, and the streams there are the product of millions of years of geological evolution. Relict populations of species otherwise eliminated from Illinois by the glaciers (e.g., the Ozark minnow, *Notropis nubilus*) remain there. The major stream of the area is the Apple River.

The Till Plains Section is the vast area of the state covered during the Pleistocene by one or more glacial advances. During glaciation, old river channels were filled with glacial drift. As the glaciers receded, drift was laid down in ridges that acted as dams holding back meltwater and creating large lakes. Later, over long periods of time, the lakes filled with depositional materials, drainage outlets formed in the moraines, and the lakes transformed into marshes and prairies. Water flowing through the marshes and prairies eventually cut the drainage patterns that exist today. Nearly the entire region covered by glacial till (Till Plains Section) is drained by tributaries flowing southwest into the Mississippi River (mainly, the Rock, Illinois, Kaskaskia, and Big Muddy rivers) and by tributaries flowing southeast into the Wabash and Ohio rivers (the Vermilion, Embarras, Little Wabash, and Saline rivers).

The Shawnee Hills are composed almost entirely of Mississippian limestone and sandstone and stand an average of about 400 feet above the surrounding land. Several of the most interesting streams and aquatic organisms, including species endemic to Illinois, such as the Illinois crayfish (*Orconectes illinoiensis*), occur in this region. The streams of the Shawnee Hills—including Big, Lusk (Figure 2), Big Grand Pierre, and Clear creeks—are small, clear rocky streams that are among the most scenic in the state.

The Coastal Plain lies south of the Shawnee Hills. Flat, sandy, and covered by residual soils, it is drained almost entirely by the Cache River and small tributaries of the Ohio. Aquatic organisms found on the Illinois Coastal Plain tend to be restricted to this region in Illinois, although they are also characteristic of the Coastal Plain to the south of Illinois. Because the Illinois portion of the Coastal Plain is small, many species found there are rare and restricted and therefore protected in Illinois.

The present character of the streams of Illinois is as much a function of human activities as it is of the evolution of drainage patterns. What we have done to the streams in the last 200 years has had a major impact on the distributional patterns and community structure established during the millions of years of geological history that preceded our arrival. The questions now are, what does Illinois have left and what should be protected and from what?

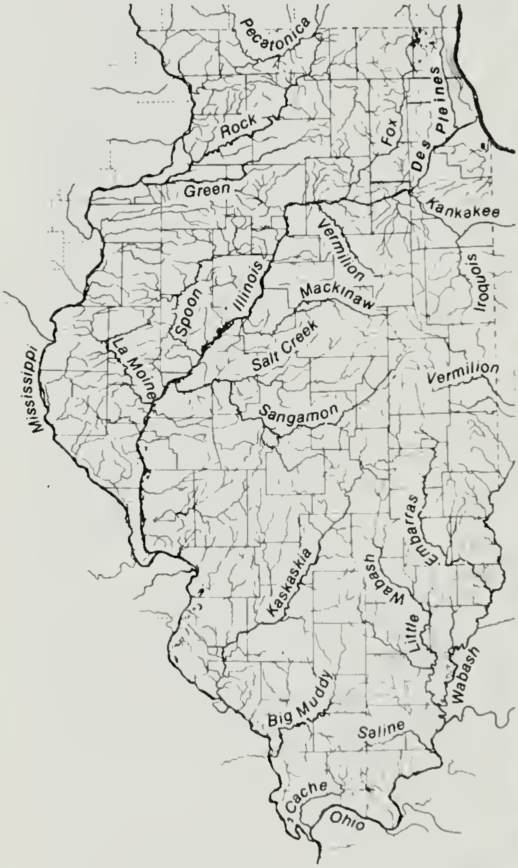

Figure 1. Major streams of Illinois.

Figure 2. Lusk Creek Canyon, Pope County, Illinois. Photo by Michael Jeffords.

WHAT SHOULD WE PROTECT?

An element of scenic beauty apart from living organisms is certainly worth preserving, but generally we are interested in protecting life. In deciding what to protect, we can concentrate on biodiversity. The species that remain are of interest and of value to us for a number of reasons, and it seems clear that we as a society, through the establishment of environmental protection agencies and endangered species lists, have stated emphatically that we want to protect them. The reasons for protecting species include vital as well as aesthetic and economic considerations. Living organisms provide the oxygen we breathe and the food we eat and are the source of many of our medicines. We enjoy the beauty and diversity of life and acknowledge that our lives without wild places and wild plants and animals would be much less interesting and enjoyable. By maintaining a diversity of plants and animals, we are also maintaining a variety of choices for the biological control of noxious species; surely that option is more likely to result in a healthy environment than is resorting to potentially dangerous pesticides.

Because of the enormous modifications of the Illinois landscape, we are faced with protecting large numbers of species. Our present list of endangered and threatened animals and plants includes nearly 500 species. In addition to these, which are considered to be in risk of extirpation from the state, thousands of others have disappeared or declined significantly in abundance in the past 200 years. In a sense, because Illinois is so highly modified, we are faced with protecting almost all native species. Unfortunately, it is too late to protect complete watersheds and other large areas (the exception being Heron Pond–Little Black Slough Preserve in southern Illinois), and thus we need to concentrate on identifying and protecting streams with high species diversity and those with rare species. Other parameters that might be used to select streams to protect, for example, water quality, land use, unusual habitats, naturalness of the ecosystem, and natural divisions, are reflected in the biodiversity. If many species or rare species are present, it is because the water quality has remained good for a long time, because unusual habitats are present, and so on.

How do we recognize streams with high diversity and rare diversity? The best way is to obtain data from large geographic, in this instance statewide, data bases and compare various localities with one another. Fortunately, Illinois has more complete statewide data bases on the diversity of aquatic organisms than any other state. Burr (pages 417–427, this volume) has discussed the surveys of fishes (Forbes and Richardson [1908]; Smith 1979), and Cummings (pages 428–438, this volume) has discussed past (Parmalee 1967; Starrett 1971) and ongoing surveys of the mussels of Illinois. A third important data base is that on crustaceans, part of which was published (crayfishes and shrimps) by Page (1985). Combined, these data bases can be used to identify outstanding streams by locating those that have the highest diversity (most species) of fishes, crayfishes, and mussels, and those that have the rarest diversity (i.e., those that support populations of threatened and endangered species).

Outstanding streams can also be identified by using the Biological Stream Characterization (BSC), a stream-quality classification developed by the Illinois Department of Conservation and the Illinois Environmental Protection Agency (Hite and Bertrand 1989). The classification is based on fish community characteristics and the potential of a stream to function as a fishery resource. Stream segments are categorized from "A" (highest quality) to "E" (lowest). Currently, 24 stream segments are considered to belong in the "A" category and about 184 in the "B" category.

This year, the Center for Biodiversity at the Illinois Natural History Survey initiated a study to enlarge and enhance the BSC with statewide data on biodiversity. Fieldwork will update existing statewide data bases, specifically those on endangered and threatened species and on the diversity of mussel species. These data, in turn, will be used to identify outstanding streams in addition to those already recognized by the BSC. The end product will be a list of streams to be protected and managed for their outstanding biological characteristics. Although data continue to be gathered, 20 aquatic ecosystems, including 13 streams, were identified as outstanding by Page, Burr, and Cummings (1989) (Table 1), and they seem certain to appear on subsequent lists of streams in Illinois most deserving of protection.

WHAT ARE THE MAJOR CAUSES OF STREAM DEGRADATION?

The recognition of streams worthy of protection is a major accomplishment, but ultimately it becomes a meaningless exercise unless we identify the sources of degradation and initiate actions to eliminate them. Smith (1971) identified factors primarily responsible for the disappearance of some and the decline of other species of fishes in Illinois (Table 2). These factors negatively affect other aquatic species as well and are probably the principal threats to stream biodiversity.

Because of the pervasive nature of agriculture in Illinois, siltation is undoubtedly the major cause of stream degradation and has affected at one time or another nearly every stream in the state. Silt negatively affects stream organisms in several ways and benefits only a few species that are able to tolerate the silt-laden habitats left behind when other species die out. Silt inhibits the ability of organisms to breathe by covering their gills and preventing effective oxygen exchange. High turbidity (silt suspended in water) for prolonged periods results in the suffocation of many aquatic organisms—plants as well as animals. When the primary producers (plants) and primary consumers (e.g., many insect larvae) are eliminated, fishes and other organisms dependent on them for food die or perhaps produce fewer offspring, and eventually species disappear. Silt is unsuitable as a spawning substrate for most fishes because eggs laid in silt are unable to obtain an adequate oxygen supply. Instead, fishes commonly lay their eggs on gravel or among plants, where they are hidden from predators and at the same time remain in actively flowing water and thus in a continuous supply of oxygen. In heavily silted streams where gravel and plants are covered with silt, reproductive success is reduced for many species, and they disappear after a few seasons. Mussels are especially vulnerable because of their sessile habits and, as noted by Cummings (pages 428–438, this volume), the loss of mussel diversity in Illinois has been extraordinarily large (21% of the species have been extirpated and another 35% are in danger of extirpation.)

"Drainage" as a factor contributing to the loss of fishes (Smith 1971) refers to the drainage of bottomland lakes that serve many fishes as nurseries and some stream-dwelling fishes as overwintering refuges and spawning areas. In their natural condition, these lakes are extraordinarily productive (Dodge 1989) and favored areas for the growth and development of small fishes. In Illinois, most of these lakes were found along large rivers such as the Mississippi and Illinois. Their loss resulted from drainage to produce more farmland and from filling with silt as sediment-laden rivers overflowed during periods of flooding. If we are to protect stream organisms, the remaining bottomland lakes must be protected and, where possible, others should be restored.

As more water is consumed in Illinois, primarily for agricultural purposes, water tables

Table 1. Outstanding streams of Illinois based on aquatic biodiversity.

1. Middle Fork Vermilion River, Vermilion County
2. Kankakee River, Kankakee and Will counties
3. Big Creek, Hardin County
4. Embarras River, Jasper, Cumberland, and Coles counties
5. North Fork Vermilion River, Vermilion County
6. Little Vermilion River, Vermilion County
7. Crane Creek, Mason County
8. Lusk Creek, Pope County
9. Kishwaukee River, Winnebago, Boone, and McHenry counties
10. Little Wabash River, Clay, Effingham, and Shelby counties
11. Mississippi River, Rock Island County
12. Wabash River, White County
13. Clear Creek, Union County

Source: Page, Burr, and Cummings 1989.

Table 2. Factors primarily responsible for the extirpation of 8 and decimation of 60 native species of Illinois fishes.

	Number of species extirpated	Number of species decimated
Siltation	2	14
Drainage	0	13
Desiccation during drought	0	12
Species interaction	2	7
Pollution	2	5
Dams and impoundments	0	4
Temperature	0	1
Unknown causes	2	4

Source: Smith 1971.

are lowered in many places and stream desiccation has become a major problem. Springs that were formerly perennial are now ephemeral, and species restricted to them die during periods of drought. The disappearance of the southern redbelly dace, *Phoxinus erythrogaster*, from southern Illinois is thought to be a result of the lower water table and the increased frequency with which springs dry.

Detrimental interactions between exotic and native species include competition, predation, disease, and parasitism. Although some species introduced into Illinois have produced results perceived as beneficial (e.g., certain crops adopted from Europe), the vast majority have proved detrimental to native species. Familiar aquatic examples include the common carp (*Cyprinus carpio*), which is notorious for its ability to stir up stream substrates and destroy otherwise suitable feeding or spawning grounds for other fishes, and the rusty crayfish (*Orconectes rusticus*), which displaces native crayfishes in amazingly short periods of time by means that are not entirely understood. The most recent invader, the zebra mussel (*Dreissena polymorpha*), is now in the Great Lakes and likely to negatively affect native mussels. It is already causing major problems in water treatment and power plants (Cummings 1990).

Much has been written about stream pollution (e.g., Hynes 1960), and it is unnecessary to detail that discussion here. Briefly, pollutants poison aquatic organisms. Major progress has been made recently in reducing point sources of pollution (Illinois Environmental Protection Agency 1990), but such nonpoint sources as the agricultural runoff of pesticides remain a major problem.

Dams and impoundments convert large segments of flowing water into standing water. A few species are favored by the conversion, but many more are eliminated. The pre-impoundment list of species present in a medium to large river in Illinois commonly includes 30–40 species of fishes and 10–20 species of mussels. In contrast, an impoundment typically supports only 8–12 species of fishes and 4–6 species of mussels. The negative impact of an impoundment on biodiversity is compounded by the fact that species in the impoundment are always common, for example, largemouth bass (*Micropterus salmoides*), gizzard shad (*Dorosoma cepedianum*), and common carp (*Cyprinus carpio*); the species lost, however, can include threatened and endangered species. The battle in Illinois over a proposed reservoir on the Middle Fork of the Vermilion River (Figure 3) was in part related to protection of the state-endangered bluebreast darter (*Etheostoma camurum*), and the battle in Tennessee over the proposed Tellico Dam was in part related to the perceived threat to the federally endangered snail darter (*Percina tanasi*). Exacerbating the negative impact of impoundments on biodiversity is their tendency to fill with sediments carried by the streams flowing into them. Because they fill in, they are short-lived relative to the potential life of a stream.

Figure 3. Middle Fork of the Vermilion River, Vermilion County, Illinois. Photo by Lawrence Page.

Dams negatively affect stream communities in addition to the direct effects of inundation. Many species of fishes migrate upstream to spawn; when a dam blocks their passage, they cannot reach suitable spawning areas. In a relatively short time, populations decline and sometimes disappear. A dam impedes and often stops the flow of water downstream and causes major alterations in the stream ecosystem.

In many streams, temperature elevation results in the removal of riparian vegetation that once shaded flowing water. With direct sunlight for prolonged periods, the water is warmed and becomes unsuitable for many species. Another cause of warming is the continuous lowering of the water table, with the result that less groundwater reaches surface streams. Fishes that generally prefer cool water and species adversely affected by this warming trend include trouts, nearly absent from Illinois, and sculpins, which are becoming less common and more restricted in distribution.

Channelization (or canalization) of streams converts them from a series of riffles and pools of varying characteristics into a ditch of nearly uniform width, depth, velocity, and substrate. Instead of providing the variety of habitats available in an unchannelized stream, a channelized stream offers only one habitat and only those species capable of living in that habitat persist. In addition, bankside vegetation is usually removed to enable the large equipment needed for channelization to gain access to the stream. Loss of vegetation further reduces biodiversity. The diversity of species in a ditch is usually much lower than that in a meandering stream.

HOW DO WE PROTECT STREAMS?

Given the major causes of degradation (Table 2) and the multiple uses of streams in Illinois, a multifaceted approach to their protection is imperative. Our goal is to keep the native biota intact, and all approaches aimed at stream protection must have as their objective to keep the stream ecosystem as natural as possible. Broadly considered, protection means that we must prevent the harmful development of the stream and the watershed and the deterioration of the water quality.

A third alternative, restoration (e.g., eliminating the source of a pollutant or allowing a channelized stream to return to a meandering stream) is a reasonable and highly desirable objective and is usually relatively inexpensive. Such massive projects as the restoration of wetlands, although desirable, can be extremely expensive and inevitably fall short of the goal of ecosystem restoration because of the intervening loss of many species previously present. Although a great deal of interest and enthusiasm is being devoted to restoration, if we must choose between protecting the remaining "natural" ecosystems (i.e., those least disturbed by man) and restoring areas, the wiser course is to protect what we have left rather than to devote limited resources to restoring abused ecosystems.

Preventing development. Following the enhancement of the Biological Stream Characterization and the more complete listing of outstanding Illinois streams, I anticipate that the Illinois Nature Preserves Commission, The Nature Conservancy, and other conservation organizations will purchase easements, dedicate preserves, or otherwise move to protect these outstanding aquatic ecosystems. Designation of streams and key portions of watersheds (particularly headwaters) as nature preserves by the Illinois Nature Preserves Commission, the procurement of land by The Nature Conservancy, and similar protective measures would be major steps in keeping stream ecosystems intact because the kinds of development that negatively affect these systems would be prevented.

In addition, when outstanding streams appear on an official list (in this instance, the list generated by the BSC), regulatory agencies can require that development that might negatively affect a stream or its watershed be undertaken in ways that minimize these effects. The identification of healthy and degraded streams will result in a data base that can be extremely useful in other studies on the patterns and causes of stream degradation (e.g., land-use studies).

Protecting water quality. Water quality is protected by preventing the introduction of contaminants such as pesticides and sewage. One extremely important way to reduce the most detrimental nonpoint pollutant, silt, is to keep riparian vegetation intact. In central Illinois, the recent practice of plowing to the stream bank has resulted in stream bank failure and permitted large amounts of silt to enter streams. In addition to its value as a filter of silt, riparian vegetation shades the stream from direct sunlight during the hottest part of the year, thereby benefiting the many cool-water species characteristic of Illinois streams. Legislation is needed in Illinois to reduce nonpoint pollution.

Other approaches to protecting streams include the development of methods and legislation to restrict introductions of exotic species and to control the amount of water diverted from streams for municipal, industrial, and agricultural uses.

SUMMARY

The present characteristics and biota of the streams of Illinois are the results of geological and evolutionary history and the recent modifications of streams and watersheds by human activities. To protect Illinois streams, we need to determine what aquatic biodiversity remains, where it is located, and what components need to be protected and from what. Then we must develop the most effective means of protection. By supplementing stream quality ratings and statewide data bases on aquatic organisms with fieldwork, we can identify streams with outstanding (i.e., high and rare) biodiversity. After outstanding streams appear on an official state list (the BSC), regulatory agencies can act to minimize environmental damage.

Major threats to the integrity of Illinois streams can be identified and protective measures implemented even though streams, which are affected by activities throughout their watersheds, are clearly more difficult to protect than are many terrestrial ecosystems. Major threats to streams include siltation, drainage of bottomland lakes, desiccation, introductions of exotic species, pollution, artificial impoundments, elevated temperatures, and channelization. Protective measures include the purchase of easements and the dedication of preserves to prevent harmful development of the stream and the watershed. Water quality can be protected by preventing the introduction of detrimental substances such as silt, pesticides, and sewage. One extremely important way to reduce siltation, the most detrimental nonpoint pollutant of streams in Illinois, is to leave riparian vegetation intact. Legislation is needed in Illinois to reduce nonpoint pollution, to restrict introductions of exotic species, and to control the amount of water diverted from streams for municipal, industrial, and agricultural uses.

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Illinois Caves: A Unique Resource

James E. Gardner, Illinois Natural History Survey

Unlike neighboring Missouri with over 5,000 caves, Illinois is not known as a cave state. The many glacial advances that extended far south into the state buried the limestone bedrock that is so conducive to the formation of caves. Nevertheless, according to Oliver and Graham (1988), at least 480 caves are found in Illinois. They noted that the largest and most hydrologically active caves occur in the Sinkhole Plain area of St. Clair and Monroe counties, one of the four major cave areas in Illinois (Figure 1). They also observed that biological activity appears greatest in caves in the Shawnee Hills Section.

The study of caves (speleology) encompasses a unique and intriguing world of darkness, one that often extends far below the earth's surface. Because caves are devoid of sunlight and green plants, they may appear foreboding to any form of life. This perception, combined with the difficult and oftentimes hazardous obstacles for intrepid scientists to overcome, would appear to make speleology an unattractive field of study. To the contrary, speleology is an exciting and rewarding pursuit.

The study of cave life (biospeleology) has not been avoided simply because of potential hazards to investigators. Scientific studies of caves began as early as the 17th century in Europe, when theories on cave hydrology were introduced. Early biospeleology was limited primarily to very general faunal surveys and to descriptions of unpigmented animals (initially thought to be albino) with degenerative eye structures. In the United States, the first cave studies were spearheaded by Europeans. Constantine Rafinesque studied and named cave animals in Mammoth Cave and other caves near Lexington, Kentucky, during his visits around 1822. However, it wasn't until the late 1800s that interest in North American caves and cave life were made fully manifest.

The history of biospeleology in Illinois reaches back over a century when the founder of the Illinois Natural History Survey, Stephen A. Forbes, wrote on blind cave fishes and their allies (Forbes 1881, 1882). The studies that followed much later (Layne and Thompson 1952; Gunning and Lewis 1955; Weise 1957; Smith and Welch 1978) were indirectly associated with caves and springs and focused on the spring cavefish (*Chologaster agassizi*). By 1950, the mass of data that had been collected by nonprofessional biospeleologists, cave explorers, and surveyors encouraged more complete systematic descriptions of taxonomic groups of cave animals and their distribution. Encouraged by a rapidly growing interest in cave ecology and the physiology of cavernicoles (animals found in caves), researchers grew more interested. Peck and Lewis (1977) provided the first and presently only comprehensive information on the occurrence of more than 200 invertebrate species collected from caves in Illinois. The only other studies of invertebrate cave fauna in Illinois focused on taxonomic descriptions (Yeatman 1964; Liang 1970; Steeves and Seidenberg 1971; Lewis and Bowman 1981). Other Illinois studies involving caves (or abandoned mines) did not consider the larger subterranean ecosystem or its inhabitants, but focused on bats that used caves as roosts.

We gained a better understanding of cave ecosystems through studies by Poulson and White (1969), Barr (1968), Caumartin (1963), and Poulson (1972). Perhaps the most comprehensive publication concerning natural cave resources was *The Life of the Cave* by Mohr and Poulson (1966). Biospeleology has now become a recognized field of study. Universities offer degrees with emphasis on aspects of biospeleology, and a number of nonprofit state and national cave research and conservation organizations actively promote the study and conservation of cave resources. State and federal land management agencies have undertaken studies involving cave resources and the unique life forms associated with them(Gardner 1984, 1986; Oliver and Graham 1988; J.D. Garner, pers. comm.).

There is a great need for more information concerning Illinois caves and their associated fauna. It is my intent to introduce the reader to the rich heritage of our unique cave resources in the hope of fostering appreciation and stimulating continued work. Lipman (1965) commented that "speleology has a definite place on the national conservation scene," and I share his hope that "as the need for more detailed information about underground conditions increases, the science of speleology will grow."

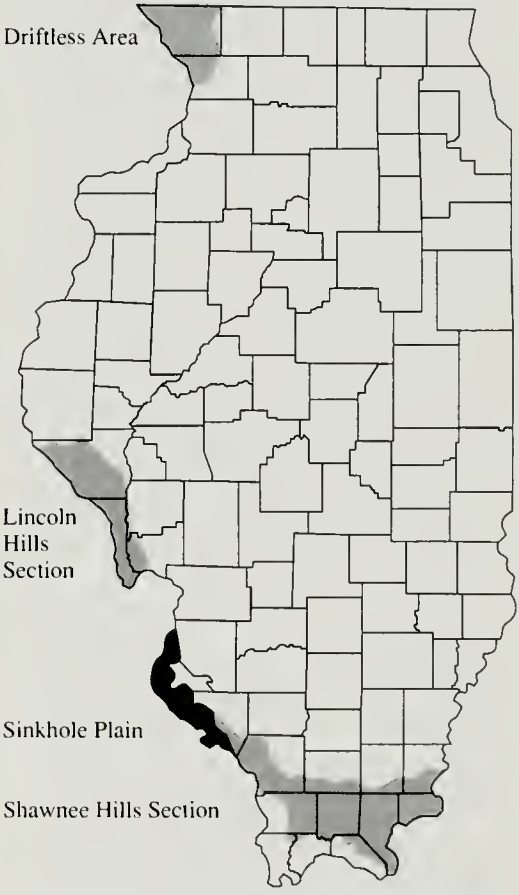

Figure 1. The four major cave areas of Illinois. Adapted from Oliver and Graham 1988.

THE VALUE OF CAVE RESOURCES

Our unique cave habitats and the diversity of life they support are subjected to environmental pressures that threaten their very existence. The delicate balance of many cave ecosystems has been needlessly destroyed by human activities. Caves, springs, and other subterranean features are a valuable part of our natural resources; yet pollution of our subterranean water systems is becoming increasingly evident, damaging the resource and in the process threatening our health and well-being. Cave explorers (spelunkers) must learn to be even more conscientious in order to lessen the impact of their visits. There must be caves left in Illinois free from detrimental impacts, thereby conserving their natural state for future studies.

Caves, like other more traditional natural resources, have four basic values:

Intrinsic. In the most literal sense, caves are a viable and important link in the great environmental chain that binds our planet together. Caves and the resources they contain have an inherent value.

Aesthetic and cultural. Caves provided dwellings for humankind long before recorded history. Often they were sacred places associated with rites and ceremonies. Caves are important historically and aesthetically. Their mystery exists even today and the beauty of untouched cave formations (speleothems) cannot be denied. Caves are a valuable part of our heritage.

Recreational. Spelunking is an increasingly popular recreational sport. As cave locations become known, explorers flock to see them. Anyone who has met the challenge of exploring passageways rarely or never seen will have a memorable and deeply moving experience. Caves have a recreational value but they are also an economic asset, as documented by the millions of tourists who buy tickets yearly for commercial cave tours.

Scientific. Perhaps the most precious value of our caves is found in the knowledge we gain from studying them. Caves, like pages in a history book, provide information on past climate, paleontology, and archaeology.

Caves have perhaps been studied longest by geologists, fascinated by the natural processes of caves (Bretz 1938; Harris and Allen 1952). Hydrologists and engineers have recognized the need to study caves and the secrets of their formation (speleogenesis). Caves provide a barometer whereby we can measure environmental quality. Dye tracing studies, with their subsequent determination of water courses, have averted serious pollution catastrophes and ensured water quality to many communities. Finally, cave environments and the animals associated with them provide living systems to study. Many cave animals have provided solutions to environmental and medical problems; others serve as examples for the study of basic ecological principles.

BIOSPELEOLOGICAL OBJECTIVES

Howarth (1981) argued that if cave invertebrates were to be targeted for conservation, top priority should be given to conducting thorough biological inventories and ecological studies in threatened caves. He further emphasized that the long-term goal in the conservation of cave invertebrates must be the protection of suitable cave habitats. Poulson (1975) addressed cave management problems and their solutions, noting the importance of baseline biological data. Poulson and Kane (1976) provided an excellent outline for the biological inventory of caves, pointing out that most detrimental impacts could be understood only if a baseline inventory had been conducted before disturbances occurred. The prime objectives of a biological resource inventory according to Poulson and Kane (1976) are summarized below.

Identifying species. As many species of cave animals as possible should be identified and recorded from each cave under investigation. This task is achieved by three methods.

1. A review of the literature. Investigators must be familiar with the work that has preceded their own if they are to conduct inventories efficiently.

2. Identifications in the field. Recorded observations provide a substantial amount of data with minimum impact to the cave environment. Cave invertebrates are among the most difficult life forms to discover, observe, and identify. Specific determinations of invertebrate cave fauna often require a taxonomic specialist. Identifications of vertebrates do not usually require detailed knowledge of microscopic taxonomic characteristics. Bats, salamanders, and certain fishes can be readily identified by trained observers. Collecting and preserving cave vertebrates for the sole purpose of identification is an unacceptable method of inventory. Several species of cave-dwelling vertebrates are protected by state and federal legislation that prohibits their collection.

3. Identification through established collections. Identifications of most cave invertebrates are usually made through reference to existing collections. Specific determinations of fauna are often based on microscopic morphological characteristics (i.e., legs, antennae, mouth parts, reproductive organs). Such identifications are usually well beyond the capabilities of most investigators, and taxonomic specialists need to be consulted.

Documenting cave fauna. Unfortunately, budget constraints significantly limit the extent to which cave resources can be studied. As a result, threatened or endangered species usually receive priorities for study. This limitation should not, however, restrict the gathering of information to only those species. If an ecosystem or habitat approach is followed, all faunal elements in a cave protected for listed species can be studied.

Noting species associations and ecologically related information. The identification of individual elements of a cave's fauna provides insight into the entire ecosystem. Often the occurrence of a particular species can be anticipated by the presence of another species.

Identifying future study areas. Inventories of biological resources are important in identifying caves where more detailed studies are needed. Priorities can then be set since a detailed study of each cave is impossible in terms of time, labor, and money.

Developing recommendations. Cave resources are an integral part of our natural resources, but responsible management or enhancement of any resource cannot be accomplished without first identifying its elements. Cave resources require very special management.

THE CAVE ENVIRONMENT

The cave environment affects the behavior, development, and evolution of the organisms living there. The absence of light, near-constant temperatures, and the amount of humidity all influence the animals found in caves and their positions within the cave relative to the entrance. Cave climates vary little compared to surface climates. The cave environment is cool and humidity is usually high; evaporation rates, therefore, are very low. Air currents in caves (cave breathing) are normal events in response to surface barometric pressure and can markedly affect temperature and humidity within a cave.

Caves can be divided into zones based on the amount of light and the degree of changes in temperature and humidity.

Twilight zone (cave entrance). The twilight zone extends into the cave as far as unaided human vision is possible. This zone is usually damp and cool, but temperature and humidity fluctuations are close to those found outside the cave. Some green plants may invade the entrance area, and this zone contains the largest and most diverse fauna in the cave. Animals found in the twilight zone include surface species of birds, mammals, snakes, frogs, and many different species of invertebrates that are commonly associated with the surface.

Middle zone. This zone lies just beyond the twilight zone and is characterized by total darkness. Temperature and humidity vary somewhat with seasonal changes at the surface. Animals found in this zone include bats, crickets, millipeds, and surface species of amphipods and isopods.

Zone of total darkness and nearly constant temperature. This zone, like the middle zone, is devoid of light; however, temperatures fluctuate only slightly from the average annual mean temperature of the ground, approximately 13 to 15°C (54 to 58°F) in Illinois. The humidity remains nearly constant, usually near 100%. Animals inhabiting this zone are usually obligative cave-dwelling species such as blind, unpigmented amphipods, isopods, cave fishes, pseudoscorpions, and springtails.

THE CAVE ECOSYSTEM

A cave ecosystem can be defined as all of the living organisms within a given cave bound together by interrelationships and interacting with the physical environment of the cave. Cave animals can be classified by their interaction with the cave environment or by the role they play in the cave ecosystem—their ecological classification (Barr 1963). Some organisms possess highly specialized adaptations that allow them to live in a world of total darkness, extremely low food availability, and relatively constant temperature. The organisms that inhabit caves are divided into two categories: epigean or surface-dwelling organisms and hypogean or subsurface organisms.

Epigean (surface) organisms. These animals usually must complete their entire life cycle on the surface. When found in a cave environment, they are classified as accidentals. Epigeans that wander, fall, or get washed into a cave will either escape or eventually perish there.

Hypogean (subsurface) organisms. These animals normally live below the surface in caves, in subterranean water courses, or in interstitial environments (i.e., between soil particles). The three commonly recognized classes of hypogeans are troglobites, troglophiles, and trogloxenes. The ecological term endogean, or edaphobite, is used to classify species that normally live in soil (e.g., earthworms). Additionally, phreatobite is a term used to describe animals that inhabit the upper layers of groundwater (Holsinger 1969); it is considered synonymous with troglobite. Troglobitic species account for only 20 to 30% of the faunal assemblages of most North American caves. The largest percentages of cave fauna are troglophiles and trogloxenes.

Troglobites, as the derivation of their name suggests (from the Greek for hole and to live), live exclusively in caves, springs, or subterranean water systems; they cannot survive outside these environments. Troglobites are perhaps the most fascinating of all cave species because they possess marked morphological adaptations to subterranean environments. Illinois contains a diversity of troglobitic invertebrates. Peck and Lewis (1977) reported 18 troglobitic invertebrates from Illinois, 14 of which are considered endemic (found nowhere else on earth). However, no populations of troglobitic vertebrates (i.e., true cavefishes and salamanders) are known from the state.

Troglobites possess morphological, physiological, and behavioral adaptations that make them unique. Compared to their surface relatives, troglobites have reduced metabolic rates. Their sensory capabilities are modified, including reduced or absent vision, increased vibration (hearing) reception, increased olfaction (smell or chemo-reception), and increased tactile sensitivity. Their appendages are longer and more slender, and their movements are slower, more deliberate. Their bodies also tend to be more slender. Reproduction periods are acutely tuned to the seasonal availability of food, and fewer and larger eggs are generally laid.

Troglophiles (cave loving) commonly inhabit caves and can complete their entire life cycle there; however, they are also found in cavelike microclimates on the surface (i.e., deep down in surface leaf debris, in crawl spaces beneath buildings, or inside wet, rotting logs). Examples of troglophiles in Illinois are the cave salamander (*Eurycea lucifuga*) and species of isopods and beetles.

Trogloxenes (cave visitors) frequent caves for shelter and favorable microclimates but must return to the surface to complete some portion of their life cycle (i.e., feeding and reproduction). Bats are classified as trogloxenes as are raccoons, birds that nest in the entrance of caves, and certain species of snakes.

THE NEED FOR CONSERVATION

Bretz and Harris (1961) published descriptions and locations of more than 60 caves throughout Illinois. Their section on basic cave formation (speleogenesis) and cave types is complete and educational. Unfortunately, the publication of the exact locations of these caves opened the way for vandalizing the larger, more popular ones. Enticed by descriptions of passageways and the beautiful formations they contained, novice, adventure-seeking explorers trampled through the caves, defacing and destroying some of the finest cave resources of Illinois.

Relatively few caves have been protected, and many are in dire need of protection. In response to this need, the Illinois legislature passed the Cave Protection Act in 1985. Drafted by the Illinois Department of Conservation (J. D. Garner, pers. comm.), the act established measures for the protection of the natural and cultural resources of Illinois caves. An inventory of the natural resources of over 80 Illinois caves was conducted by the Illinois State Museum (Oliver and Graham 1988). Additionally, the Illinois Department of Conservation and the Illinois Natural History Survey conduct investigations of biological cave resources; emphasis is given to endangered bats.

Recent protection measures for Illinois caves were perhaps precipitated by the recognition (White 1973) and classification (White 1978) of these resources during the Illinois Natural Areas Inventory. As a result of that study and the ongoing efforts of the Illinois Department of Conservation, several caves have been identified as having significant natural resource features and are included in the Illinois Natural Areas Inventory. Other caves have been designated as Illinois Natural Heritage Landmarks in order to protect their valuable resources. One Illinois cave, with at least 12 miles of passageway, was purchased in 1987 and dedicated on August 31, 1989, as an Illinois Nature Preserve to protect a hibernating population of the federally endangered Indiana bat (*Myotis sodalis*). Another cave, Illinois Caverns, was purchased in 1986 and classified as an Illinois Natural Area. Six miles of passageway in Illinois Caverns are open to the public for exploration through a permit system designed to protect the cave.

More studies are needed to identify and understand the unique biological resources of Illinois caves. The delicate and intricate natural communities of our caves cannot be protected unless we identify their elements. However, biological collections in caves should never be done without first consulting competent authorities. Over-collecting and improper collecting methods have been extremely harmful to some populations of cave species. The admonition, "Take only pictures and leave only footprints" should have special significance to every Illinoisan if we are to ensure that our unique cave resource is secured for future generations.

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Session Five: Agro-Urban Ecology

The time has long since passed when a citizen can function responsibly without a broad understanding of the living landscape of which he is a part.—Paul B. Sears

Agricultural and urban development practices that take into account the conservation of the remarkable biodiversity of Illinois must be initiated and encouraged. A balance between economic development and the preservation of natural resources must soon be struck, for it seems that "economics" continues to win and very soon there will be little left to preserve. With the conversion of the landscape to intensive row cropping has come the realization that perhaps our system could operate at a somewhat less intense level. With 99.93% of the landscape of Illinois reflecting some degree of development, the point of no return seems imminent.

Although the production of food is of course beneficial and necessary, the maintenance and restoration of our natural heritage—the landscapes that reflect presettlement conditions complete with the organisms they support—also represents a desirable and perhaps even essential course of action. Common ground must be found between these two opposing courses if the requirements of both are to be met. Perhaps agro-ecology will provide that common ground. In retrospect, we seem to have been moving toward agro-ecology for some time. Consider, for example, the interest shown in organic gardening and low-input and sustainable agriculture. Agro-ecology, however, moves a step closer by requiring a balance between the requirements of agriculture and the obligation to preserve our natural heritage. While our agricultural system presently requires vast biological deserts populated by a single species, the same principles need not be applied to the surrounding landscape. Fields do not have to be cultivated to the very edges of rivers and streams; fencerows and windbreaks do not have to be removed to squeeze in a few more rows of corn; railroad rights-of-way that support corridors of native vegetation do not have to be destroyed; streams do not have to be channelized; and species of organisms need not be driven to extinction in the name of short-term economic development.

The next generation of agriculturalists must farm from an ecological perspective and the time has come when all Illinoisans, farmers and city-dwellers alike, must adopt a conservation ethic. To quote Francis Moore Lappe, "Individual well-being is impossible outside of the well-being of others." Ultimately, we can maintain our well-being only if "others" include all species of organisms, not merely *Homo sapiens*.

Papers read at this session introduced long-range perspectives (for example, the movement of biota between natural and managed ecosystems) as well as more immediate ones (for example, the management of urban deer populations). The closing remarks, both disturbing and challenging, concluded this session and the symposium.

The Land Use Controversy: Maintaining and Increasing Biotic Diversity in the Agricultural Landscape of Illinois

Michael E. Irwin, Illinois Natural History Survey

Approximately one hundred years ago our state underwent a rapid and extensive agricultural transformation that converted the rich, fertile soils and relatively flat terrain underlying its prairies and forests into vast tracts of field crops, primarily corn and soybean. With the exception of Iowa, a state with a history similar to that of Illinois, the Great Plains, with its vast expanses of wheat, and a few large tropical countries like Brazil and Indonesia, which have exploited their lands by putting in broad stretches of such perennial crops as rubber and African oil palm, there is perhaps no extensive area on earth that is so heavily cultivated in so few plant species as the state of Illinois. This agricultural transformation has taken, and continues to take, a heavy toll on native biota. With only 11% of our land now left in natural vegetation and over 53% of our woody plant taxa found in cultivated areas, we have cause for concern. Can this trend be reversed? If so, at what price?

Two viewpoints seem in genuine conflict. On the one hand, we have the argument that agricultural production must be sustained to meet our food needs and to offset the nation's balance of payment deficits through expanded exports. Those holding this short–term view make a powerful case that meeting these needs benefits humanity and our citizens in nutritional and economic ways. On the other hand, the persistent exploitation of our natural areas continues to deplete the biotic richness of our lands, diminishing the legacy for future generations and restricting our access to diverse genes for future manipulation. An equally powerful argument, this long-term perspective recognizes that what is exterminated can never be restored.

I propose that these seemingly opposing positions might be resolved in a manner that satisfies both factions. Aspects of natural systems may enhance agriculture; similarly, aspects of managed landscapes may safeguard natural systems and provide a formula for recovering biotic richness in pillaged habitats.

COMPONENTS FOSTERING SYNERGISM

The components that are responsible for fostering potential synergism must be determined, and the interactions among those components examined. All systems could then be managed with a view towards optimizing selected synergistic interactions. Three elements seem of particular importance: refugia, biological diversity, and genetic richness.

Refugia. Parcels of land that for one reason or another retain unique biota during times when that biota would otherwise not be present are referred to as refugia. How agricultural oases and other biotically favorable, artificial environments sustain species locally through times of natural emigration or diapause and how this ability to sustain biota affects both natural systems and managed landscapes are of considerable consequence.

Irrigation in agricultural settings, particularly in semitropical areas that undergo a season of prolonged drought, can provide habitats favorable for the atypical overseasoning of some biota. As a result, these organisms need not emigrate or aestivate. Irrigation could alter the customary overseasoning habits of a variety of organisms, including insects and their natural enemies, especially in dry tropical forest habitats. Irrigation could also alter the time of year during which certain biota invade natural systems from agricultural settings, with a conceivably enormous impact on both systems. Such invasions already occur regularly in Illinois through the introduction of plants grown in greenhouses for propagation in orchards and home gardens.

Just as agricultural systems provide niches for noncrop-related organisms, so do natural areas harbor both pests and beneficial organisms that either plague or safeguard agricultural crops. The role of refugia in sustaining these complex interactions is relatively unknown; the repercussions, however, are undeniably profound.

Biological diversity. A portion of the diversity of life in one system will inevitably invade nearby systems; how this invasion affects a recipient system is of considerable interest to conservationists and agriculturalists alike. If agriculture is considered an invasive system that receives much of its noncrop biotic diversity in the form of colonists from surrounding systems, the long-term monitoring of colonization might help us to formulate models of invasion rates and types of colonists through time.

Similarly, areas where agroforestry and agriculture are practiced could greatly influence the biological integrity of adjoining natural systems. Scott Robinson (page 382, this volume) provided an example at this symposium when he talked about how habitat fragmentation increased nest parasitism among some of our song birds. Another example is the introduction of the honeybee, which has probably had a great, although unmeasured, impact on natural pollinators in some areas. Monitoring herbivorous insects and their natural enemies might help us develop models of biotic interchange—a third case in point.

Genetic richness. Any biological species consists of a number of populations. Each population includes a number of individuals, each with a slightly different genetic makeup or genotype. The genetic richness within a population purportedly equips that population to withstand environmental disruption, although the process itself is not well understood. When a population from one system invades another, a very restricted portion of the invading population may manage to pass successfully from its resident system and colonize the other. Successful invasions of this nature are sometimes referred to as genetic bottlenecking. The result of colonization and the accompanying extinctions has enormous consequences on the sustainability of a given population, especially one in the area being invaded. The genetic richness of invading populations might well be influenced by the proximity and relative sizes and shapes of the systems in question. Such concepts as habitat fragmentation and patch dynamics are very much a part of this process. Natural systems harbor genetically adaptable populations of harmful and beneficial species that continually invade agricultural systems. Similarly, agricultural landscapes probably contain genetically adaptable populations that continually invade natural systems. Understanding the nature of genetic richness and how that richness affects invasion is important in designing sustainable agricultural and forestry systems.

BIOTIC LINKS

An inevitable exchange of biota occurs wherever two ecosystems come into contact. The zone of interchange, called an ecotone, is in a sense a battleground for genetic and biotic dominance and compatibility. When a natural system is ravaged by deforestation or by the introduction of agriculture, the system usually transforms in stages—for example, from pristine forests to high-input row-crop agriculture. An ecotone is established along the spatiotemporal border of this shift and could well govern the rates and types of biotic interchanges between natural and managed systems. The role of a shifting ecotone in the ecological and economic balance of biota in natural and managed systems remains a mystery and demands investigation.

Refugia, biological diversity, and genetic richness are each affected by successful movement of biota across ecotones. The spatial and temporal links between natural systems and agricultural landscapes can influence the nature and, perhaps more importantly, the rate at which these interactions occur. The size and configuration of areas of land where agroforestry and agriculture are practiced in relation to the size and configuration of the remaining natural area, for instance, could be decisive in determining how managed expanses interact with natural systems.

The movement of biota between natural and managed ecosystems can have dramatic effects on both types of systems. As stewards of this earth, we must manage the effects so that a balance is achieved between short-term and longer-term goals. The sobering realization is that we know so little about these interchanges and how they affect both types of systems.

Our ability to sustain high-input agriculture has a limited horizon. Time is running out for earth's rich natural ecosystems. We must set a course that will uncover the biotic relationships between these systems so that they can be wisely managed in the future. I urge a strong, timely research and education agenda that critically addresses this issue.

Farm Programs, Agricultural Technologies, and Upland Wildlife Habitat

Richard E. Warner, Illinois Natural History Survey

Since the late 1800s, the grassland habitat of upland wildlife in Illinois has been modified in one way or another by agriculture. Although the prairie was gone by the early 1900s, much of the farmland in Illinois through the 1950s contained various grasses, including small grains, forage crops (cool-season grasses and forage legumes), and uncultivated areas. These farmland mosaics sustained most small vertebrates that had once been common on the prairie, even though pasturing and haying caused significant mortality. After World War II, however, farm programs and agricultural technologies began to change, gradually leading to greater chemical and mechanical disturbances of farmland and the loss of grassland as row-crop farming expanded. By the late 1970s, even the most common upland wildlife—ring-necked pheasant, cottontail, bobwhite, and ground-nesting sparrows—had registered dramatic declines. During the 1980s, the intensive cultivation of corn and soybeans moderated, and grassland was more widely planted, primarily as part of annual set-aside programs that diverted cropland from production. The response of upland wildlife to the reestablishment of grassland has been minimal, presumably because farm programs require or encourage management practices on set-aside fields that are not conducive to the reproduction and survival of most small animals using grassland in Illinois. Moreover, grasslands on farm landscapes now tend to be small, linear patches unattractive to "interior" species. Such highly fragmented tracts also typically sustain high densities of opportunistic mammalian predators. Further, the intensive chemical and tillage disturbances on cropland have limited the availability of insects and plant seeds, the critical food resources of wildlife.

Evaluating Alternatives for Urban Deer Management

James H. Witham, Illinois Natural History Survey

Deer management in metropolitan areas is complicated by the conflicting values of publics with special interests. Those in charge of developing programs that address site-specific needs are well advised to consider various alternatives during the planning stage. Failure to review management options can result in uninformed or biased decisions, which in turn contribute to further controversy and reduce the credibility of those in charge of the program. Published reviews of deer management alternatives generally point out the limitations and advantages associated with various control methods and include an assessment of the usefulness of each method. Relying on such evaluations can be helpful, but making judgments too early, for example at the stage when potential options are being listed, can result in less efficient methods being censored or eliminated prematurely. Early elimination may be detrimental because less efficient methods often have desirable attributes that can be combined with more efficient management techniques. Relying on a combination of methods for the management of deer in urban areas is appealing because it creates a basis for compromise among diverse interest groups.

In large metropolitan areas, such as Chicago, where deer are abundant and adverse interactions with people are widespread and frequent, the state wildlife agency can facilitate local decision making by maintaining a computerized data base of deer management alternatives. Three categories are useful: an unrestricted list of deer management options, potential strategies that rely on a combination of options or suggest how options can be combined, and field-tested management programs and research that document which methods have worked and which have failed and why. Such an information base is one product of the Urban Deer Study conducted by the Illinois Natural History Survey, and we anticipate that it will be used by the Illinois Department of Conservation and the many airports, arboretums, forest preserves, and municipalities in the Chicago Metropolitan Area that manage local deer populations.

Illinois Railbanking Study

Richard Pietruszka, Greenway Coordinator, Illinois Department of Conservation

The Illinois Railbanking Study was initiated by the Illinois Department of Conservation in 1989 in response to the growing recognition within the state and nation that abandoned railroad corridors should be preserved for multiple public uses. Among the objectives of the study are the exploration and evaluation of the natural and outdoor recreational resources associated with the acquisition and development of greenways and their management.

Detailed analyses of the following issues related to the conversion of abandoned railroad corridors into multipurpose public resources were conducted:

- The concerns of local governments and landowners adjacent to abandoned railroad corridors.
- The identification and evaluation of strategies that might allay local concerns and resolve conflict.
- The evaluation of the economic impact, including the impact on local taxes, of the conversion of abandoned railroad corridors to multipurpose public resources.
- The identification of the potential users of converted corridors.

The principle purpose of the Illinois Railbanking Study, concluded in August of 1990, is to assist the Illinois Department of Conservation with the formulation of policies and planning strategies for a statewide trail system.

Closing Remarks

Brian D. Anderson, Director, Illinois Nature Preserves Commission

I was very pleased to be invited to offer the concluding remarks for this symposium. The Illinois Natural History Survey has developed through the years a world-renowned reputation as a center of scientific inquiry. I've found the presentations of the last two days extremely informative, but also disturbing. It is important, I believe, to look at the information provided on various species groups and community types within the context of the landscape on which they occur. Illinois has led the nation in developing institutions like the Natural History Survey, the Endangered Species Protection Board, the Nature Preserves Commission, and the Division of Natural Heritage of the Illinois Department of Conservation—all dedicated to the identification and preservation of the biodiversity of the state. Unfortunately, the founding of these institutions was not by coincidence. No place in the hemisphere has been more drastically altered by the hand of humankind. I might also mention that the statistics I'm about to present were also largely compiled by the Natural History Survey. Over 80% of Illinois is currently committed to agriculture, and another approximately 5% of its surface acreage is urbanized. That leaves approximately 15% of Illinois as undeveloped land. Of that, only 0.07 of 1% retains to some degree its presettlement condition. The full complement of native plants and animals has been forced to survive on less than 100,000 acres of land. The impact to our biota has been devastating; of the approximately 2,500 species of vascular plants considered to be native to Illinois, 356 (about 14%) are considered to be threatened or endangered. Our vertebrate fauna has been even more severely affected: of 649 native vertebrates, 93 (14%) are listed as endangered or threatened, not to mention the 30 or so species that have already been extirpated from our state.

And the carnage continues, but not through spectacular catastrophic events. We can't point to an Exxon Valdez or a Chernobyl. The greatest threat to the native biodiversity of Illinois isn't apocalyptic; it is simply diminution, the slow but steady erosion of our biological heritage—a road here, a 404 permit there, individual by individual, population by population, species by species.

I spent Earth Day in Springfield, and sprinkled among the rally speakers was the reading of a contest-winning essay. The topic was "What Earth Day Means To Me." It caused me to reflect, and I realized I had only hopes for the meaning of Earth Day. And foremost among these was one. I hoped that Earth Day 1990 was the last day I had to listen to the terms *environmental trade-off* and *environmental compromise*. We have to put a word back into our vocabulary—a little word, an important word, the word ***no***. Where natural areas or habitats of endangered species are involved, we must "just say NO!" If it's a road, take another one. If it's a condo complex, put it somewhere else. If it's an ORV? Well, if it's an ORV, send it back to Japan.

I also listened that day to many speeches heralding our achievements since Earth Day 1970, always with special mention of passage of the Clean Air Act, the Clean Water Act, and the Endangered Species Act. All of these were worthy achievements. They were also all passed in the *first* decade after the *first* Earth Day. And the reauthorization of each was challenged by the Federal Administration in the *second* decade after the first Earth Day Perhaps I am confused, but I thought it was pretty obvious that on Earth Day 1990 we were celebrating the end of a decade of environmental backsliding. It is my hope that Earth Day 1990 was the day that 100 million citizens of the world let the leaders of the western world know that environmental compromise had no place on any political agenda, conservative or liberal. Planetary survival is, in and of itself, a conservative concept.

A couple of years ago I sat with a conservative acquaintance listening to a presentation on the decline of the natural character of our national parks. He commented that the fellow hadn't learned that the gloom and doom message of radical environmentalism had lost its credibility. The world hadn't ended, and no one wanted to hear that message anymore. I guess he'd missed the news of Love Canal, Three-mile Island, Chernobyl, Bhopal, the donut hole in the ozone layer, and global drought perhaps due to global warming.

Well, I just want to assure him that's not my message. I don't intend to sound morose; however, we have wasted a critical decade. Given our technological sophistication, we should be much farther along in solving our environmental problems, including the biodiversity crisis. So don't worry. We no longer have time for hand wringing. I don't intend to depress you, I intend to *press* you; press you on every front where we possess the technology to improve the environment.

So what is the job before us? First, where the preservation of significant extant resources is involved, we must be uncompromising. We can afford to lose no more. Natural areas, habitats of endangered species, and wetlands are just plain off limits from here on. The developers and planners must hear this message from scientists, conservationists, environmentalists, and politicians. And if the latter are raising their voices in the wrong chorus, they should be sent to look for new jobs.

As for specifics: We must pass legislation to extend the consultation provisions of the Illinois Endangered Species Protection Act to natural areas this session. That legislation was recently introduced as House Bill 3991. (Postscript: it never left committee.)

Second, we must pass strong legislation to protect our remaining wetlands. You can help do that by supporting HB 3712 and SB 1907. (Postscript: neither was brought to the floor of the House of Representatives for a vote.)

Third, we can no longer tolerate the narrow interpretation of the definition of public waters employed by the Division of Water Resources of the Illinois Department of Transportation. Governor Thompson should force the division to accept the Attorney General's opinion, which would extend the division's jurisdiction to most of our streams. If the Division of Water Resources hasn't assumed that responsibility by this time next year, we should have those jurisdictions removed entirely from the Illinois Department of Transportation. (Postscript: a compromise measure was drafted but not introduced.)

Fourth, we should hold every one of our elected representatives responsible for seeing that the first of these three objectives is achieved. (Postscript: *none* was achieved.)

Even if we were to lose nothing else, we probably could not ensure the long-term survival of the biodiversity of our state. We must also *restore* Illinois.

The Illinois Nature Preserves System preserves remnants of high-quality natural communities. Most of these, however, are too small to protect wide-ranging or area-sensitive species. We must begin to establish biotic reserves, which are very large preserves having a high-quality core surrounded by degraded but restorable lands. Using the knowledge we will gain in establishing biotic reserves, we must then, through restoration management, begin to restore our open spaces to native natural communities.

I had a dream a couple months ago. I dreamt I was in a village where everyone, small children to the elderly, were preparing for a wedding. Some were scouring the countryside for rocks and metals; more skilled hands were shaping gemstones and cutting jewels; still others were crafting chains of silver and gold. Finally, the bride appeared; she wasn't a young woman. She was tall—a little wide in the middle—and bore the scars of nurturing several generations of offspring. But when she was draped in that cloak of jewels and gems linked by golden and silver chains, she was transformed into an unparalleled beauty. I see some of those hands in our audience; I've seen them in our nature preserves; I have seen them building conservation areas, restoring railroad prairies, and protecting river corridors. We must do a lot more of all of these things, but we must also integrate our efforts.

I would, therefore, call for the establishment of an Institute of Land Use Studies. The objective of this entity would be to apply the most current computer and satellite technology available to the identification, protection, preservation, and restoration of our native landscapes—and thereby our biodiversity. This institute would also allow Illinois to lead the nation as *the* center for land use planning technology. The federal government has abdicated its traditional role as a leader in this area. We should, therefore, help ourselves and at the same time develop the tools to preserve other important centers of biodiversity, for example, those in the tropics.

Secondly, we should begin immediately using the Geographic Information System of the Natural History Survey to integrate statewide natural resource planning efforts. Statewide rails-to-trails conversions, watershed planning, nature preserve and biotic reserve establishment, river corridor preservation, wetland protection, and prairie and savanna restoration should all be coordinated through a statewide protection planning committee hosted and chaired by the Department of Energy and Natural Resources.

Thirdly, we should press immediately for sustained funding for natural history survey work. For far too long the Illinois Natural History Survey has been dependent on contracts from private, profit-motivated interests in order to monitor what is happening in Illinois landscapes. For example, although a great effort is underway to complete basic survey work on the state's streams, we are desperate for recent faunistic surveys of habitats of high endemism such as caves, seeps, and springs.

We must also begin to look carefully at invertebrates, including Illinois arthropods. You will notice I didn't even mention the percentage of currently listed invertebrates. Only well-known groups of invertebrates, like mussels and crayfish, have been addressed, and we are not even sure of the total numbers of species in other groups of arthropods. A beetle found in only one cave in Illinois, one cave in the *whole world*, is a treasure; one that I am not prepared to write off.

While we were all pleased that a portion of the real estate transfer tax was dedicated last legislative session to the acquisition of natural areas, there are important natural areas that will not survive the five years required for phasing in the program. We only get 20% of $4 million over the five-year period, 20%, 40%, 60%, 80%, and 100%, respectively. We desperately need a stopgap appropriation or bond issue of about $15 million to acquire such areas before they are lost. Otherwise, as we look forward to achieving the ability to acquire outstanding natural areas, we may have to watch some of our most important natural areas slip between our fingers.

Finally, we must ensure that resources once acquired or protected are adequately managed. I propose that a dollar be added to the license fee for motor vehicles and that the proceeds be dedicated to maintenance and management of natural lands, thereby helping to compensate for the slaughter of wildlife on our highways. Now I've been told everybody and their brother has tried to get a piece of that action, but the very obvious cause-effect relationship between transportation development and loss of wildlife through habitat conversion and habitat fragmentation, not to mention direct wildlife mortality, is so obvious that I believe the public would embrace the surcharge if given the chance.

Thank you for your attention. Thank you for coming, and I look forward to working with all of you in these efforts in the future. Remember, we have an obligation to be objective, to treat all development interests fairly, that is, equally, but we must refrain from compromise. We've already lost too much.

Appendix One: Native Illinois Species and Related Bibliography

Susan L. Post, Illinois Natural History Survey

The assemblage of living forms native to Illinois . . . are held together as a definitely organized, living whole. —Stephen A. Forbes, 1889

The Illinois State Agricultural Society was formed in 1853 and brought zoologists and botanists together in an organized natural history society. In the first transactions of the Agricultural Society, three Illinois species lists were published: *The Birds of Southern Illinois* by H. Pratten (1855), *The Mollusca of Southern Illinois* by H.A. Ulffers (1855), and *The Animals of Cook County* by R. Kennicott (1855). These were the first attempts to list the species of Illinois.

By the turn of the century, biologists from the State Laboratory of Natural History, later to become the Illinois Natural History Survey, were systematically sampling the state. These early field investigations formed the basis for understanding our ecosystems and the natural histories of the organisms found in them. Because of these early records, comparisons can be made between conditions that exist today and those that existed a century ago. From its first publication in 1876, Stephen A. Forbes' *List of Illinois Crustacea*, to its most recent, the Survey has concerned itself not only with cataloging organisms and their distributions in the state but also with the relationships of these organisms to their environments. The Survey's long existence has allowed continuity. Field studies have been and continue to be repeated at intervals, and long-term changes in populations and natural habitats have thereby been documented.

E.O. Wilson (1988) notes in his recent discussion of biological diversity that we do not know the true number of species on Earth, possibly even to the nearest order of magnitude. The same is true for Illinois. We are fairly certain of the numbers of our more visible fauna in the Phylum Cordata—the reptiles, amphibians, fishes, birds, and mammals. In other phyla, however, we are less certain. Research on many of these groups is at an early stage, and new species are frequently found. Even though we list approximately 17,000 insects, this number is only an approximation. The nematodes, which may outnumber even the insects, are an even more difficult group to estimate. The vast majority of the species in Illinois remain unmonitored. Like the dead in Gray's *Elegy Written in a Country Churchyard*, they may pass from the Earth unnoticed and unknown.

The list of species native to Illinois that follows was not generated by a single biological survey but is the result of a search of the literature and a query of systematists familiar with the organisms of Illinois. Sources are listed in the bibliography and in the acknowledgments. The list is divided into five kingdoms: Monera, Protista, Fungi, Plantae, and Animalia (Whittaker 1959). Classification of the invertebrates follows Brusca and Brusca (1990), and plant nomenclature follows Mohlenbrock (1986).

The numbers of certain groups were impossible to estimate and are listed as unknown—the bacteria, nematodes, and protozoa. According to the Bacteriological Code (1958), bacteria cannot be described as simply as other organisms. Every individual is treated as belonging to a number of categories of consecutive rank. Only the individual is considered "real." Until the taxonomic problems have been solved, no list of species for Illinois can be constructed. Although the protozoa are divided into seven phyla (Levine et al. 1980), we have left them as the generic "protozoa." Much of protozoan systematics is still in the alpha stage, with thousands of species yet to be discovered and classified (Lee et al. 1985). Few invertebrate groups illustrate the diversity in form, habitat, and behavior found in the nematodes. An examination of virtually any organic substrate commonly yields nematode specimens representing undescribed species. The systematics of this group is in an embryonic stage.

Although the class Insecta is very large and new species are continually being described, an estimate was made by consulting specialists for each group. The species number for Coleoptera (J. Bouseman, pers. comm.), Hymenoptera (W. LaBerge, pers. comm.), and Diptera (D. Webb, pers. comm.) are only estimates. The number of Diptera was determined by randomly choosing 1,000 species from *A Catalog of the Diptera of America North of Mexico* (Stone et al. 1965) and determining how many of those occur in Illinois. This process was replicated three times and a homogeneity chi square was used to determine if the three samples could be lumped. A nonsignificant x^2 indicated that the three samples could be combined and the mean determined. The percent of species found to occur in Illinois was multiplied by 17,000 (number of species of Diptera in North America) to estimate the number in Illinois.

Only a small fraction of the Illinois fungi are known, but estimates suggested that Illinois has at least 20,000 species (L. Crane, pers. comm.). The number of species of mites in the order Acari was estimated based on the number of mite species in Canada and the assumption that the total number of mites in Illinois would equal half the number of insect species in the state (J. Kethley, pers. comm.). In the class Aves, the number of species includes native breeding species and migrants.

Determining the numbers of species that are extirpated from the state or extinct is difficult. With the exception of the showiest birds, mammals, and flowering plants, biologists are reluctant to say with finality that a species has come to its end. The possibility always exists that a few individuals or a population will be discovered in some remote habitat. As with species numbers, we know with near certainty that some of the more conspicuous fauna have been extirpated; we are less certain about other species.

Species thought to no longer exist in Illinois are listed in Table 1A along with the source from which the determination was made. The plant list was compiled using Sheviak (1978), Paulson and Schwegman (1976), Paulson et al. (1976), and Bowles et al. (1991), and was reviewed by M.L. Bowles, J.E. Ebinger, D.M. Ketzner, G. Kruse, S. Lauzon, L.R. Phillippe, K.R. Robertson, J. Schwegman, M.K. Solecki, and J.B. Taft. The final list was reviewed by K.R. Robertson.

Included in Table 1A are species listed in the 1990 Illinois Endangered Species Protection Board's *Checklist of Endangered and Threatened Animals and Plants of Illinois* but now considered extirpated. Not included are three species of birds, two species of mammals, and one plant species that disappeared from the state and were successfully reintroduced—peregrine falcon, ruffed grouse, wild turkey, white-tailed deer, beaver, and lakeside daisy. Species that no longer occur in the United States are indicated.

The bibliography that concludes this appendix lists all publications that were used to create the list of native Illinois species and the table of extirpated species.

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LIST OF NATIVE ILLINOIS TAXA (AND NUMBERS OF SPECIES)

Kingdom Monera (112⁺ species)
- Division Schizophyta: bacteria (number of species unknown)
- Division Cyanophyta: blue-green algae (112 species)

Kingdom Protista (1,406⁺ species)
- Division Protozoa: (number of species unknown)
- Division Euglenophyta: euglenoids (30 species)
- Division Chrysophyta: diatoms and golden brown algae (440 species)
- Division Pyrrophyta: fire algae (20 species)
- Division Chlorophyta: green algae (507 species)
- Division Phaeophyta: brown algae (0 species)
- Division Rhodophyta: red algae (5 species)
- Division Myxomycota: plasmodial slime molds (400 species)
- Division Acrasiomycota: cellular slime molds (2 or 3 species)
- Division Plasmodiophoromycota: (1 species)

Kingdom Fungi (~ 20,000 species)
- Division Chytridiomycota: chytrids (~ 300 species)
- Division Oomycota: water molds (~ 300 species)
- Division Zygomycota: bread molds (~ 400 species)
- Division Ascomycota: sac fungi (~ 9,000 species including 500 species of lichens)
- Division Basidiomycota: club fungi (~ 5,000 species)
- Division Deuteromycota: fungi imperfecti (~ 5,000 species)

Kingdom Plantae (2,574 species)
- Division Bryophyta
  - Class Anthocerota: hornworts (3 species)
  - Class Hepaticae: liverworts (118 species)
  - Class Musci: mosses (385 species including 2 extirpated species)
- Division Lycodiophyta: club mosses, quillworts, and spike mosses (12 species including 3 endangered species of clubmosses and 1 extirpated species of quillwort)
- Division Equisetophyta: horsetails (12 species including 3 endangered and 1 extirpated species)
- Division Filicophyta: ferns (75 species including 11 endangered, 3 threatened, and 2 extirpated species)
- Division Coniferophyta: conifers (14 species, including 4 endangered and 3 threatened species)
- Division Anthophyta: monocots and dicots (1,955 species including 275 endangered, 54 threatened, 53 extirpated, 1 extinct, and 1 extirpated but reintroduced species)

Kingdom Animalia (29,662⁺ species)
- Phylum Porifera: sponges (14 species)
- Phylum Cnidaria: polyps and jellyfish
  - Class Hydrozoa: hydra and freshwater jellyfish (<10 species of hydra and 1 species of freshwater jellyfish)
- Phylum Platyhelminthes: flatworms (400 species)
- Phylum Nemertea: ribbon worms (1 species)
- Phylum Nematoda: nematodes (number of species unknown)
- Phylum Nematomorpha: horsehair worms (2 species)
- Phylum Acanthocephala: spiny-headed worms (27 species including 1 species found in the endangered greater prairie-chicken)
- Phylum Gastrotricha (60 species)
- Phylum Rotifera: rotifers (150–175 species)
- Phylum Entoprocta (1 species)
- Phylum Annelida: segmented worms
  - Class Oligochaeta: "earthworms" (20 terrestrial and 83 aquatic species)
  - Class Hirudinea: leeches (32 species)
  - Class Aphanoneura (3 species)
  - Class Branchiobdellida: crayfish worms (9 species)

Phylum Arthropoda
- Class Chelicerata (10,598⁺ species)
  - Subclass Arachnida
    - Order Scorpiones: scorpions (1 species)
    - Order Araneae: spiders (530 species)
    - Order Pseudoscorpionida: pseudoscorpions (28 species)
    - Order Opiliones: daddy long-legs (19 species)
    - Order Acari: mites and ticks (20 species of ticks and ~10,000 species of mites)
- Class Myriapoda (74 species)
  - Subclass Diplopoda: millipedes (29 species)
  - Subclass Pauropoda: pauropods (5 species)
  - Subclass Chilopoda: centipedes (37 species)
  - Subclass Symphyla: symphylans (3 species)
- Class Insecta (~17,000 species)
  - Subclass Myrientomata
    - Order Proturans: proturans (6 species)
  - Subclass Oligoentomata
    - Order Collembola: springtails (73 species)
  - Subclass Diplurata
    - Order Diplura: diplurans (6–10 species)
  - Subclass Zygoentomata
    - Order Thysanura: silverfish (6⁺ species)
  - Subclass Pterygota
    - Order Ephemeroptera: mayflies (126 species)
    - Order Odonata: dragonflies (98 species) and damselflies (44 species)
    - Order Blattodea: cockroaches (9 species)
    - Order Mantodea: mantids (1 species)
    - Order Isoptera: termites (5 species)
    - Order Plecoptera: stoneflies (57 species)
    - Order Orthoptera: grasshoppers, crickets, and katydids (157 species)
    - Order Dermaptera: earwigs (3 species)
    - Order Phasmida: walking sticks (5 species)
    - Order Zoraptera: zorapterans (1 species)
    - Order Psocoptera: book and bark lice (91 species)
    - Order Hemiptera: true bugs (910 species)
    - Order Thysanoptera: thrips (200 species)
    - Order Anoplura: sucking lice (18 native and 19 nonnative [from domestic animals and man] species)
    - Order Mallophaga: biting lice (280 species including 1 extinct species that occurred on the passenger pigeon)
    - Order Homoptera: plant bugs (1,485 species)
    - Order Strepsiptera: twisted-wing insects (15–20 species)
    - Order Coleoptera: beetles (5,000 species)
    - Order Neuroptera: lacewings, antlions, alderflies (45 species including 1 extirpated species)
    - Order Hymenoptera: bees, ants, wasps (2,000⁺ species)
    - Order Mecoptera: scorpionflies (18 species)
    - Order Siphonaptera: fleas (33 species including 1 species that occurs on the endangered Eastern wood rat)
    - Order Diptera: true flies, mosquitoes, and gnats (4,100 species)
    - Order Trichoptera: caddisflies (184 species)
    - Order Lepidoptera: butterflies and moths (2,000 species including 1 endangered, 2 threatened, and 5 extirpated species)
- Subphylum Crustacea
  - Class Branchiopoda (52 species)
    - Order Anostraca: fairy shrimp (4 species)
    - Order Cladocera: water fleas (~43 species)
    - Order Conchostraca: clam shrimp (5 species)
  - Class Maxillopoda (84 species)
    - Subclass Ostracoda: seed shrimp (53 species)
    - Subclass Copepoda (21 species)
    - Subclass Branchiura: fish lice (10 species)

Class Malacostraca (71 species)
Order Decapoda: crayfish (23 species including 4 endangered and 2 extirpated species)
Order Isopoda: pillbugs (28 species including 1 endangered species)
Order Amphipoda: scuds (19 species including 5 endangered and 1 threatened species)
Order Musida: opossum shrimp (1 species)
Phylum Pentastomida: tongue worms (no species found in native fauna)
Phylum Tardigrada: water bears (13 species)
Phylum Mollusca
Class Gastropoda: snails (170 species including 1 endangered species)
Class Bivalvia: mussels and clams (104 species including 29 endangered, 4 threatened, 16 extirpated, and 4 extinct species)
Phylum Ectoprocta (9 species)
Phylum Chordata
Subphylum Vertebrata
Class Agnatha: lampreys and jawless fish (6 species including 1 endangered and 1 threatened species)
Class Osteichthyes: boney fishes (181 species including 12 endangered, 14 threatened, and 12 extirpated species)
Class Amphibia: amphibians (39 species including 2 endangered, 1 threatened, and 1 presumed extirpated species)
Class Reptilia: reptiles (59 species including 5 endangered, 4 threatened, and 1 presumed extirpated species)
Class Aves: birds (297 native breeding and migrant species including 37 endangered, 6 threatened, 8 extirpated, 4 extinct, and 3 extirpated but reintroduced species)
Class Mammalia: mammals (67 species including 7 endangered, 3 threatened, 9 extirpated, and 2 extirpated but reintroduced species)

Total number of species: 53,754+
Total number of extirpated species: 115
Total number of threatened and endangered species: 497

Table 1A. Native Illinois species presumed extirpated.

Scientific name	Common name	Source
KINGDOM PLANTAE		
Division Bryophyta		
Brachylema subulatum (P. Beauvois) Schimper ex Cardot	Moss	McKnight pers. comm.
Neckera pennata Hedwig	Moss	McKnight pers. comm.
Division Lycodiophyta		
Isoetes engelmannii A. Braun	Englemann's quillwort	Mohlenbrock 1967
Division Equisetophyta		
Equisetum palustre L.	Marsh horsetail	Bowles et al. 1991
Division Filicophyta		
Asplenium ruta-muraria L.	Wall-rue spleenwort	Mohlenbrock 1967
Woodwardia virginica (L.) J.E. Smith	Chain fern	Bowles et al. 1991
Divisinn Anthophyta		
Apios priceana Robinson	Price's groundnut	Schwegman pers. comm.
Arabis drummondii Gray	Rock cress	Swink & Wilhelm 1979
Arethusa bulbosa L.	Dragon's mouth	Sheviak 1974
Bacopa acuminata (Walter) B.L. Robinson	Purple hedge-hyssop	Bowles et al. 1991
Baptisia tinctoria (L.) R. Brown	Yellow wild indigo	Bowles et al. 1991
Carex cumulata (Bailey) Fernald	Sedge	Bowles et al. 1991
Carex plantaginea Lamarck	Sedge	Bowles et al. 1991
Cinna latifolia (Treviranus) Grisebach	Drooping wood reed	Bowles et al. 1991
Cirsium pitcheri (Torrey & Eaton) Torrey & Gray	Dune thistle	Bowles pers. comm.
Clintonia borealis (Aiton) Rafinesque	Bluebead lily	Swink 1988
Corallorhiza trifida Chatelain	Pale coral root orchid	Sheviak 1974
Daucus pusillus Michaux	Small wild carrot	Bowles et al. 1991

Scientific name	Common name	Source
Delphinium carolinianum Walter var. *penardii* (Huth) Warnock	Prairie larkspur	Mohlenbrock 1981
Elatine brachysperma Gray	Waterwort	Mohlenbrock 1978
Eleocharis caribaea (Rottboell) Blake	Spike rush	Mohlenbrock 1976
Eleocharis equisetoides (Elliott) Torrey	Horsetail spike rush	Bowles et al. 1991
Epigaea repens L. var. *glabrifolia* Fernald	Trailing arbutus	Swink & Wilhelm 1979
Erianthus brevibarbis Michaux	Brown plume grass	Mohlenbrock 1973
Fuirena scirpoides Michaux	Umbrella grass	Bowles et al. 1991
Gaillardia aestivalis (Walter) Rock	Blanket flower	Mohlenbrock 1986
Geum rivale L.	Purple avens	Bowles et al. 199
Glyceria canadensis (Michaux) Trinius	Rattlesnake manna grass	Bowles et al. 1991
Gnaphalium macounii Greene	Western cudweed	Bowles et al. 1991
Gratiola aurea Muhlenberg	Goldenpert	Swink & Wilhelm 1979
Hippuris vulgaris L.	Mare's tail	Swink & Wilhelm 1979
Hypericum ellipticum Hooker	St. John's wort	Mohlenbrock 1978
Linnaea borealis L. ssp. *americana* (Forbes) Hulten	Twinflower	Swink & Wilhelm 1979
Malaxis monophylla (L.) Swartz	Adder's mouth orchid	Sheviak 1978
Malaxis unifolia Michaux	Adder's mouth orchid	Sheviak 1978
Nemopanthus mucronata (L.) Trelease	Mountain holly	Mohlenbrock 1978
Oryzopsis asperifolia Michaux	Rice grass	Mohlenbrock 1972
Oryzopsis pungens (Torrey) Hitchcock	Rice grass	Mohlenbrock 1972
Paspalum lentiferum Lamarck	Bead grass	Bowles et al. 1991
Plantago heterophylla Nuttall	Small plantain	Bowles et al. 1991
Platanthera (Habenaria) dilatata (Pursh) Hooker	White orchis	Sheviak 1974
Platanthera (Habenaria) hookeri Torrey	Hooker's orchid	Bowles et al. 1991
Platanthera (Habenaria) orbiculata (Pursh) Torrey	Round-leaved orchid	Sheviak 1974
Polygala paucifolia Willdenow	Flowering wintergreen	Swink & Wilhelm 1979
Potamogeton epihydrus Rafinesque	Pondweed	Mohlenbrock 1970a
Potamogeton vaseyi J.W. Robbins	Pondweed	Bowles et al. 1991
Ranunculus ambigens S. Watson	Spearwort	Bowles et al. 1991
Ranunculus gmelinii DC. var. *hookeri* (D. Don) L. Benson	Small yellow crowfoot	Swink & Wilhelm 1979
Schedonnardus paniculatus (Nuttall) Trelease	Tumble grass	Mohlenbrock 1972
Scheuchzeria palustris L. var. *americana* Fernald	Arrow grass	Bowles et al. 1991
Scirpus microcarpus Presl	Bulrush	Bowles et al. 1991
Scirpus pedicellatus Fernald	Bulrush	Bowles et al. 1991
Scirpus subterminalis Torrey	Bulrush	Swink & Wilhelm 1979
Sparganium minimum (Hartman) Fries	Least bur-reed	Mohlenbrock 1970a
Thismia americana N.E. Pfeiffer[1]	Thismia	Mohlenbrock 1983
Trautvetteria caroliniensis (Walter) Vail	False bugbane	Mohlenbrock 1981
Trifolium stoloniferum Eaton	Running buffalo grass	Schwegman 1989
Trillium cernuum L.	Nodding trillium	Bowles et al. 1991
Valerianella patellaria (Sullivant) Wood	Corn salad	Sheviak 1978
KINGDOM ANIMALIA		
Phylum Arthropoda		
Class Insecta		
Columbicola extinctus Malcomson	Chewing louse on passenger pigeon	Malcomson 1937
Hesperia dacotae (Skinner)	Dakota skipper	Sternburg pers. comm.
Notodonta simplaria Graef	Simple promenant	Godfrey pers. comm.
Pieris napi oleracea (Harris)	Mustard white	Irwin & Downy 1973
Schinia indiana (J.B. Smith)	Indiana schinia	Godfrey pers. comm.
Speyeria diana (Cramer)	Diana fritillary	Irwin & Downy 1973
Sympherobius occidentalis Fitch	Brown lacewing	Macleod pers. comm.
Class Malacostraca		
Cambarus robustus Girard	Lusty crayfish	Page 1985
Macrobrachium ohione (Smith)	Ohio shrimp	Page 1985

Scientific name	Common name	Source
Phylum Mollusca		
Class Bivalvia		
Epioblasma flexuosa (Rafinesque)[1]	Leafshell	Cummings 1991
Epioblasma obliquata (Rafinesque)	Catspaw	Cummings 1991
Epioblasma personata (Say)[1]	Round combshell	Cummings 1991
Epioblasma propinqua (Lea)[1]	Tennessee riffleshell	Cummings 1991
Epioblasma rangiana (Lea)	Northern riffleshell	Cummings 1991
Epioblasma sampsonii (Lea)[1]	Wabash riffleshell	Cummings 1991
Epioblasma torulosa (Rafinesque)	Tubercled blossom	Cummings 1991
Fusconaia subrotunda (Lea)	Long-solid	Cummings 1991
Hemistena lata (Rafinesque)	Cracking pearlymussel	Cummings 1991
Lampsilis abrupta (Say)	Pink mucket	Cummings 1991
Leptodea leptodon (Rafinesque)	Scaleshell	Cummings 1991
Obovaria retusa (Lamarck)	Ring pink	Cummings 1991
Plethobasus cicatricosus (Say)	White wartyback	Cummings 1991
Pleurobema plenum (Lea)	Rough pigtoe	Cummings 1991
Quadrula fragosa (Conrad)	Winged mapleleaf	Cummings 1991
Villosa fabalis (Lea)	Rayed bean	Cummings 1991
Phylum Cordata		
Class Osteichthyes		
Atractosteus spatula (Lacépède)	Alligator gar	Burr 1991
Coregonus nigripinnis (Gill)	Blackfin cisco	Smith 1979
Crystallaria asprella (Jordan)	Crystal darter	Smith 1979
Esox masquinongy Mitchill	Muskellunge	Smith 1979
Etheostoma histrio Jordan & Gilbert	Harlequin darter	Burr 1991
Hybopsis amblops (Rafinesque)	Bigeye chub	Burr 1991
Ichthyomyzon bdellium (Jordan)	Ohio lamprey	Smith 1979
Lythrurus ardens (Cope)	Rosefin shiner	Smith 1979
Noturus stigmosus Taylor	Northern madtom	Burr 1991
Percina evides (Jordan & Copeland)	Gilt darter	Smith 1979
Percina uranidea (Jordan & Gilbert)	Stargazing darter	Smith 1979
Pteronotropis hubbsi (Bailey & Robison)	Bluehead shiner	Burr 1991
Class Amphibia		
Cryptobranchus alleganiensis (Daudin)	Hellbender	Morris pers. comm.
Class Reptilia		
Nerodia fasciata (Linnaeus)	Broad-banded watersnake	Morris pers. comm.
Class Aves		
Ajaia ajaja (Linnaeus)	Roseate spoonbill	Bohlen 1989
Campephilus principalis (Linnaeus)[1]	Ivory-billed woodpecker	Bohlen 1989
Conuropsis carolinensis (Linnaeus)[1]	Carolina parakeet	Bohlen 1989
Corvus corax Linnaeus	Common raven	Bohlen 1989
Cygnus buccinator Richardson	Trumpeter swan	Bohlen 1989
Ectopistes migratorius (Linnaeus)[1]	Passenger pigeon	Bohlen 1989
Numenius borealis (Forster)[1]	Eskimo curlew	Bohlen 1989
Tympanuchus phasianellus (Linnaeus)	Sharp-tailed grouse	Bohlen 1989
Class Mammalia		
Bison bison (Linnaeus)	Bison	Hoffmeister 1989
Canis lupus Linnaeus	Gray wolf	Hoffmeister 1989
Cervus elaphus Linnaeus	Elk	Hoffmeister 1989
Erethizon dorsatum (Linnaeus)	Porcupine	Hoffmeister 1989
Felis concolor Linnaeus	Mountain lion	Hoffmeister 1989
Martes americana (Turton)	Marten	Hoffmeister 1989
Martes pennanti (Erxleben)	Fisher	Hoffmeister 1989
Peromyscus gossypinus (Le Conte)	Cotton mouse	Hoffmeister 1989
Ursus americanus Pallas	Black bear	Hoffmeister 1989

[1] This species no longer occurs in the United States.

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Appendix Two

County reference map. Readers who wish to identify counties on maps shown in the text will find this map a convenient reference.

Coffee break allowed time for speaker Joyce Hofmann to continue her advocacy on behalf of those troubled wetland tenants, the swamp rabbit and rice rat.

Brooks Burr's concern over threatened fish and dwindling aquatic habitat answered Thoreau's query, "Who hears the fishes when they cry?" We do.

Louis Iverson's use of satellite data piqued interest in INHS Special Publication 11: *Forest Resources of Illinois* with its 67 computer-generated maps.

James "Gene" Gardner's research on caves introduced us to the fragility and fascination of that dark and silent habitat.

Survey support staff set up exhibits for the symposium and rolled posters for mailing. In an economy drive, staff collected the 450 paper towel tubes used to mail the posters!

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