United States
Department of
Agriculture

Forest
Service

North Central
Research Station

General
Technical Report
NC-244

# The Hoosier-Shawnee Ecological Assessment

**Frank R. Thompson, III, Editor**

Thompson, Frank R., III, ed
2004. **The Hoosier-Shawnee Ecological Assessment.** Gen. Tech. Rep. NC-244. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 267 p.

This report is a scientific assessment of the characteristic composition, structure, and processes of ecosystems in the southern one-third of Illinois and Indiana and a small part of western Kentucky. It includes chapters on ecological sections and soils, water resources, forest, plants and communities, aquatic animals, terrestrial animals, forest diseases and pests, and exotic animals. The information presented provides a context for land and resource management planning on the Hoosier and Shawnee National Forests.

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**Key Words:** crayfish, current conditions, communities, exotics, fish, forests, Hoosier National Forest, mussels, plants, Shawnee National Forest, soils, water resources, wildlife.

**Cover photograph:** Camel Rock in Garden of the Gods Recreation Area, with Shawnee Hills and Garden of the Gods Wilderness in the background, Shawnee National Forest, Illinois.

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Published 2004

www.ncrs.fs.fed.us

# Preface

Initiated by the Hoosier and Shawnee National Forests, this report is a scientific assessment of the characteristic composition, structure, and processes of ecosystems in the southern one-third of Illinois and Indiana and a small part of western Kentucky. Data and findings from the assessment should provide a helpful context for land and resource management planning on the two national forests; however, the assessment makes no management decisions or recommendations.

The report is organized into nine chapters; the introduction and chapters addressing ecological sections and soils, water resources, forests, plants, aquatic animals, terrestrial wildlife, forest diseases and pests, and exotic animals.

# Acknowledgments

The following individuals made contributions to the Hoosier-Swanee Ecological Assessment as members of the Steering Committee, authors, reviewers, or in other roles.

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Matthew Nicholson, U.S. Envirnmental Protection Agency

George Parker, Purdue University

J.C. Randolph, Indiana University

Charles Ruffner, Southern Illinois University

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# The Hoosier-Shawnee Ecological Assessment

**Frank R. Thompson, III, Editor**

# The Hoosier-Shawnee Ecological Assessment: Objectives, Approach, and Major Findings

**Frank R. Thompson, III**

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The landscapes of southern Illinois and Indiana consist of a mix of private, State, and federally owned land used in a variety of ways. The area is comprised of nearly equal proportions of forest and open or agricultural lands. It includes species and communities that contribute significantly to global biodiversity and other communities that exist in small remnants of their former distribution or in a highly degraded state. Keystone species such as the American chestnut have disappeared, and now abundant species such as oaks may be threatened by exotic pest species and alteration of historic disturbance regimes. Nearby urban areas put large recreational demands on these landscapes. The way in which these lands are managed will affect the benefits people derive from them.

The USDA Forest Service initiated the Hoosier-Shawnee ecological assessment and collaborated with other agencies, universities, and individuals to review the information available on ecological conditions in the assessment area. The purpose of an assessment is to gain an understanding of current conditions and trends regarding the land, resources, and people and to place this within a relevant historical context. Assessments focus on measures of ecosystem integrity because ecosystems with high integrity maintain their characteristic species diversity and ecological processes, such as productivity, soil fertility, and rates of biogeochemical cycling (Committee of Scientists 1999). Regional assessments provide valuable information for land management planning and may discuss consequences of various management actions; however, they make no land management decisions or even recommendations.

## OBJECTIVES

This report is a scientific assessment of the characteristic composition, structure, and processes of ecosystems in the southern one-third of Illinois and Indiana and a small part of western Kentucky. It describes the ecological integrity of the area under current policies and across ownerships but focuses on information most likely to be relevant to land management planning on the Hoosier and Shawnee National Forests, the area's two national forests (fig. 1). The assessment area is defined by 16 ecological subsections within the Ozark Highlands Section; the Upper Gulf Coastal Plain Section; the Interior Low Plateau, Shawnee Hills Section; and Interior Low Plateau, Highland Rim Section (fig. 2). This report should be of interest, however, to all landowners and citizens interested in land management and conservation in the assessment area.

Assessment authors reviewed and synthesized existing knowledge; there was neither funding nor time to discover new information or develop new knowledge. For the same reason the scope of this assessment is significantly narrower than either the Southern Appalachian Assessment or the Ozark-Ouachita Highlands Assessement (USDA Forest Service 1996, 1999). The assessment reports on current and historical ecological conditions, but does not address social and economic conditions. The assessment does not make management decisions or even management recommendations, nor does it provide any formal analyses of possible management actions. Some sections of the assessment do, however, discuss the consequences of various land management activities based on existing knowledge.

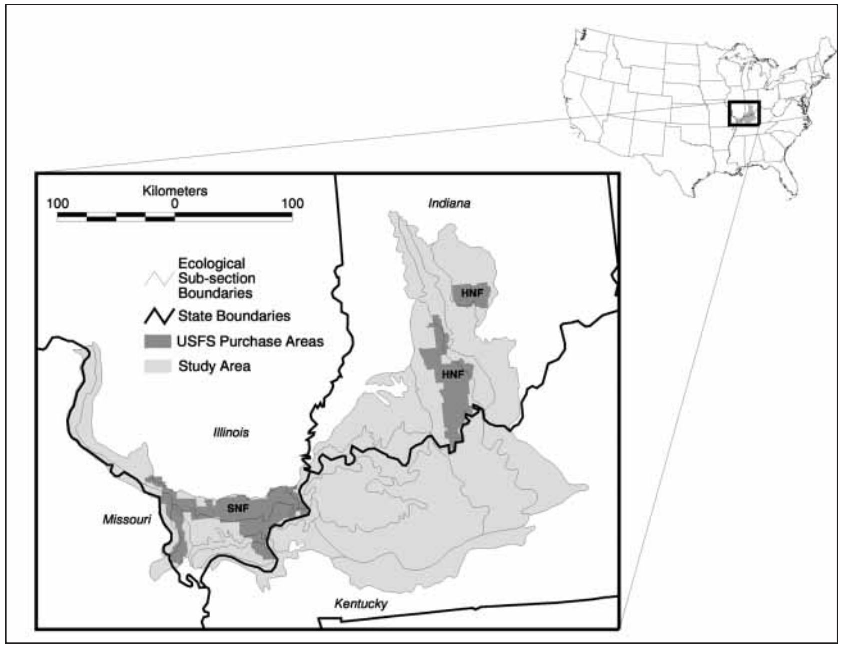


**Figure 1.** Location of the Hoosier and Shawnee National Forests within the ecological assessment area.

## APPROACH

A charter for the Hoosier-Shawnee Ecological Assessment, established by the supervisors of the Hoosier and Shawnee National Forests, identified a team to conduct the assessment as well as tentative questions to answer. The team was composed of individuals from universities and Federal and State agencies with scientific expertise in subject areas to be addressed by the assessment. The team met to refine the scope and objectives of the assessment, and a subset of the team along with additional coauthors wrote the chapters in this report. Authors were selected based on their expertise and availability and represent university and Federal and State agency scientists and land managers. Drafts of each chapter were reviewed anonymously by experts not affiliated with the Hoosier or Shawnee, as well as by the appropriate resources staff from each national forest. The editor oversaw the review process and ensured that authors adequately addressed reviewer comments. Participants, including steering team members, authors, and reviewers, are listed on the acknowledgments

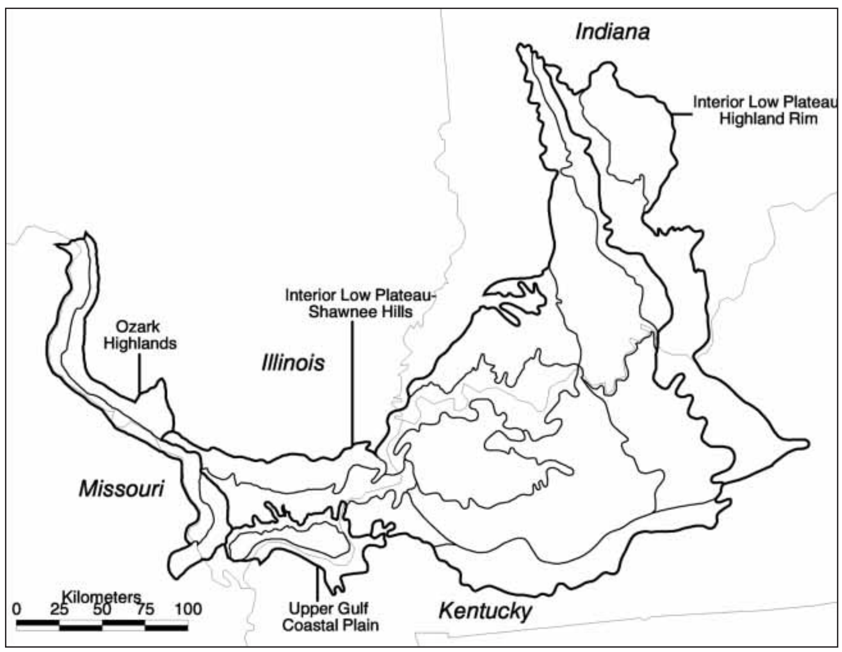


**Figure 2.** Ecological sections and subsection boundaries (Keys et al. 1995) within the Hoosier-Shawnee Ecological Assessment Area.

page of the assessment (Thompson 2004). I especially thank Kelle Reynolds (Hoosier National Forest), and Steve Widowski (Shawnee National Forest) for their key role as my primary liaison with the national forests and who acted in many ways as co-editors, and Lucy Burde (Technical Publications Editor, North Central Research Station) for her work in copy-editing the assessment.

## SUMMARY OF MAJOR FINDINGS

The following sections summarize findings reviewed in the individual chapters or present findings particularly relevant to conservation issues. Each section references a chapter in the assessment; readers should see the chapters for original sources of the information reported.

### Ecological Regions and Soils (Ponder 2004)

The assessment area is located in the unglaciated southern one-third of Illinois and Indiana and a small part of western Kentucky. The assessment area includes 16 subsections within the Ozark Highlands Section; the Upper Gulf Coastal Plain Section; the Interior Low Plateau, Shawnee Hills Section; and the Interior Low Plateau, Highland Rim Section.

Water in the assessment area drains to the Mississippi, Ohio, and Wabash Rivers. Among ecological sections, mean rainfall varies from 44 to 61 inches, mean temperature from 55 to 61°F, and length of growing season from 180 to 200 days. Bedrock is typically limestone, shale, and sandstone. Some areas have soluble bedrock primarily composed of limestone that has resulted in karst landforms. Deep alluvial soils are present in floodplains of major rivers; otherwise, soils are generally well drained to moderately well drained and many have silt loam or loam textures. On steep slopes, soils are typically thin with gravelly or cherty textures. There are areas of thin, very droughty soils over bedrock that is often exposed in places, and these soils support barren or transitional vegetation.

Management practices such as logging, fire or its exclusion, water, human-made drainage, and conversion to agricultural uses have led to much change in soil productivity and forest cover type since presettlement times. Private agricultural lands purchased by the National Forest System in the 1930s through the 1950s were reforested; abandoned crop fields in the uplands were planted to non-native pine plantations while floodplain fields were primarily planted to tulip-poplar. These plantations helped control further erosion for watershed protection. Most of the once eroded forest soils planted to trees are in better condition now than they have been in decades, and many now support native tree species.

### Current and Historical Forest Conditions (Parker and Ruffner 2004)

Forest covers 43 percent of the assessment area and agriculture occupies 48.9 percent. The remaining 8 percent is in urban (1.8%), wetlands (3.0%), water (2.5%), and barren or transitional land (0.6%).

The aerial extent of major forest types in assessment area is 37 percent oak/hickory, 16 percent beech/maple, 25 percent mixed upland hardwoods, 10 percent bottomland hardwoods, 4 percent pine/cedar, 4 percent pine/hardwoods, and 4 percent post oak/scrub oak.

Most of the timberland within the assessment area is less than 100 years old, reflecting the major logging that was done around the turn of the 19th/20th century. The acreage of forests in older age classes is expected to dramatically increase, and forests less than 10 years old are expected to decrease under current land use trends.

Fire was an important historical factor throughout the region. Fire return intervals in at least a portion of the area averaged 12 and 4 years during periods of Native American and European settlement, respectively.

By 1900 most forests had been cut and all had been subjected to fire and grazing by domestic livestock during 100 years of European occupation. Some of the cut-over forest land was allowed to regrow, but most was permanently cleared for row crop agriculture. Clearing steeply sloping lands led to severe erosion and eventual abandonment. Forest abuse began to decline in the 1930s as severely eroded lands were transferred from private to public ownership and better management practices were established.

The long history of disturbance by Native Americans and European settlers from the 1400s to the early 1900s followed by better management and greater protection of forests from the 1940s to the present has resulted in the forests we find today.

## Native and Exotic Plants

(Olson et al. 2004)

Natural communities in the assessment area include forests, barrens, cliffs, wetlands, and streams. Based on global and state heritage ranks, 360 plant species are a conservation concern in at least one of the three States covered by the assessment.

Twenty invasive, exotic plants are described that potentially threaten native plants and ecosystems in the assessment area.

## Aquatic Resources

(Whiles and Garvey 2004)

The Shawnee National Forest includes parts of six major drainages in Illinois: the Upper Mississippi-Cape Girardeau, Big Muddy, Cache, Saline, Lower Ohio, and Lower Ohio Bay. The Hoosier National Forest includes parts of the Lower Ohio-Little Pigeon, Blue Sinking, Patoka, and Lower East Fork White drainages. There are at least portions of 40 major watersheds in the assessment area.

Approximately 69,000 miles of streams flow through the assessment area, of which 60 percent are perennial and 14 percent are artificial or greatly altered (e.g., drainage ditches). Most stream riparian zones are either urban or agricultural; only 22 percent of watersheds in the assessment area contain streams with abundant forested riparian areas.

More than 8,000 reservoirs have been constructed in the region. These provide important water supplies, recreational opportunities, and economic benefits, but also potentially influence the ecological integrity of streams.

Wetland habitats are some of the most degraded and diminished freshwater resources in the region, with only 2.8 percent woody and 0.3 percent herbaceous wetland vegetation remaining in the assessment area.

Water quality varies greatly across the region, with elevated nutrients and contaminants (e.g., heavy metals and organic compounds) exceeding USEPA regional standards in many of the systems. Increased surface water and groundwater contamination and rising public and industrial demand may continue to compromise water quality and quantity within much of the assessment area.

## Aquatic Animals

(Burr et al. 2004)

The assessment area includes 194 native fish species, 76 native mussel species, and 34 native crayfish species. Five of the subregions (e.g., Mississippi Embayment) that make up the assessment area were recently ranked as either globally or bioregionally outstanding aquatic resource areas.

At least 12 fish species are of conservation concern within the Shawnee and Hoosier National

Forest boundaries, and another 10 species are poorly known, need status surveys, or other forms of conservation evaluation. Nearly 30 mussel species and 10 crayfish species are of conservation concern in the area, but fewer than 10 of these actually occur within national forest boundaries or would be directly affected by national forest activities.

Commercial and recreational fisheries are popular in the region, and commercial exploitation of both mussels and crayfishes occurs in the assessment area.

The most valuable and unique aquatic habitats in the area include springs, spring runs, karst aquifers, wetlands, swamps, mainstem large rivers, and upland, gravel-bottomed streams in both the Shawnee and Hoosier National Forests.

### **Wildlife** (McCreedy et al. 2004)

Five species are federally listed as threatened or endangered: the bald eagle (threatened), the interior least tern (endangered), the gray bat (endangered), the Indiana bat (endangered), and the American burying beetle (endangered).

There are 173 species of global viability concern; 14 are vertebrates, 159 are either terrestrial invertebrates or cave-associated aquatic invertebrates. These species are considered rare to critically imperiled throughout their global ranges. An additional 172 terrestrial species are of viability concern at the State level; 81 of these species are birds. These species are considered rare to critically imperiled within at least one of the States of the assessment area.

In the assessment area, 161 species of viability concern are cave or karst-associated species. Four cave and karst systems within the assessment area are globally significant from the standpoint of their obligate subterranean fauna.

In addition, 160 species of birds are a conservation concern. Data from the North American Breeding Bird Survey are adequate to evaluate trends from 1966 to 2000 for 40 species; 14 species increased in abundance and 27 species decreased in abundance.

Neotropical migrant birds make up approximately a third of the avian species of conservation concern in the assessment area. Sixteen species declined in numbers and five species increased in numbers from 1966 to 2000.

White-tailed deer and eastern wild turkey are common to abundant throughout the assessment area. Ruffed grouse and woodcock populations are locally restricted, and numbers of both species have declined substantially across the assessment area. Northern bobwhite quail populations vary from locally stable to declining across the assessment area; current populations are a third of those present in the early 1980s.

### **Native and Exotic Forest Insects and Diseases** (Scarbrough and Juzwik 2004)

Defoliating insects have had the greatest effects in forests where oak species predominate. Increases in oak decline are expected with the imminent establishment of the European gypsy moth. Insects and diseases of the pine forests are artifacts of stand origin and age. Chestnut blight and Dutch elm disease have had the greatest broad-ranging and historical effects on the non-oak, broad-leaved forests.

Oak decline and mortality were associated with defoliation of looper complex outbreaks between 1978 and 1981 in the assessment area. In southern Indiana, mortality levels exceeded 10 percent in oak-hickory stands (P. Marshall, personal communication). Scattered oak decline and mortality also occurred following a severe drought in 1987-88.

Although oak wilt is a serious problem in the more northern areas of Indiana and Illinois, it is just a minor problem in the southern areas because infection centers usually do not become very large. Species in the assessment area are susceptible to Sudden Oak Death, a recently discovered and newly described fungal species found on the west coast of North America, but it has not been detected in the assessment area. Diseases of non-oak hardwoods include Dutch elm disease, butternut canker, ash yellows, dogwood anthracnose, and chestnut blight.

Potential insect pest problems in oak forests in the assessment area include the forest tent caterpillar, two-lined chestnut borer, red oak borer, jumping oak gall, looper complex, walkingstick, and Asiatic oak weevil. Insect pests of non-oak hardwoods include the emerald ash borer and Asian longhorned beetle.

European gypsy moth (*Lymantria dispar*) is a major defoliator of hardwood trees in both forest and urban landscapes and has caused much damage to forests in the Northeastern United States. It will likely have a major effect on the oak forests of the assessment area in the near future.

### Exotic Aquatic and Terrestrial Animals (Burr et al. 2004)

The origin, status, trends, habitat associations, and distribution of 43 exotic fish or invertebrate species, 5 exotic hybrid fish species, and 9 exotic terrestrial vertebrates are reviewed. Nineteen exotic aquatic species originated from elsewhere in the Midwest through stocking programs, six came from Asia or Eurasia, five from the Gulf coast, three from the Atlantic coast, four from South America, two from the Pacific coast, and one from the Southeastern United States. The majority of exotic terrestrial vertebrates found within the assessment area originated in Europe, Asia, and Africa. Terrestrial exotics species are generally well adapted to human habitation.

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# Ecological Regions and Soil Conditions in the Hoosier-Shawnee Ecological Assessment Area

**Felix Ponder, Jr.**

## ABSTRACT

I present information on the ecological sections, subsections, and soils within the Hoosier-Shawnee Ecological Assessment Area. The assessment area falls within the Ozark Highlands Section, the Upper Golf Coastal Plain Section, and the Shawnee Hills and Highland Rim Sections of the Interior Low Plateau. I reviewed physical, chemical, and biological soil properties; soil loss; compaction; and productivity. Management practices such as logging, fire or its exclusion, water drainage, and conversion to agricultural uses have led to much change in soil productivity and forest cover type since presettlement times. Although fire appears to have had little or no direct long-term impacts on soils in these forests, its use can significantly impact vegetation growth and composition. Private landowners within the Shawnee and Hoosier National Forest Purchase Areas are taking advantage of State and Federal programs to improve their land; their goals are similar to the goals of the two national forests, which include enhancing timber production, watershed protection, and wildlife habitat.

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The assessment area is located in the unglaciated southern one-third of Illinois and Indiana and a small part of western Kentucky and is in the Ozark Highlands Section, the Upper Gulf Coastal Plain Section, and the Shawnee Hills and Highland Rim Sections of the Interior Low Plateau. Landscapes range from xeric to mesic. Water drains from the Shawnee National Forest to the Mississippi and Ohio Rivers and from the Hoosier National Forest to the Wabash and Ohio Rivers. Soils within these forests have a wide range of moisture levels, depths, internal physical characteristics, and fertility levels. Both national forests have many acres of private land within their purchase boundaries. These lands have been subjected to some of the same natural occurrences and poor management activities that previously occurred on lands now in national forest ownership.

## ECOLOGICAL SECTIONS AND SOIL CONDITIONS

The information I present on the ecological sections, and subsections, and soils within the Hoosier-Shawnee Ecological Assessment Area is based on McNab and Avers (1994) and Keys et al. 1995.

### Ozark Highlands Section

The portion of the assessment area in the Ozark Highlands Section includes the Illinois Ozarks

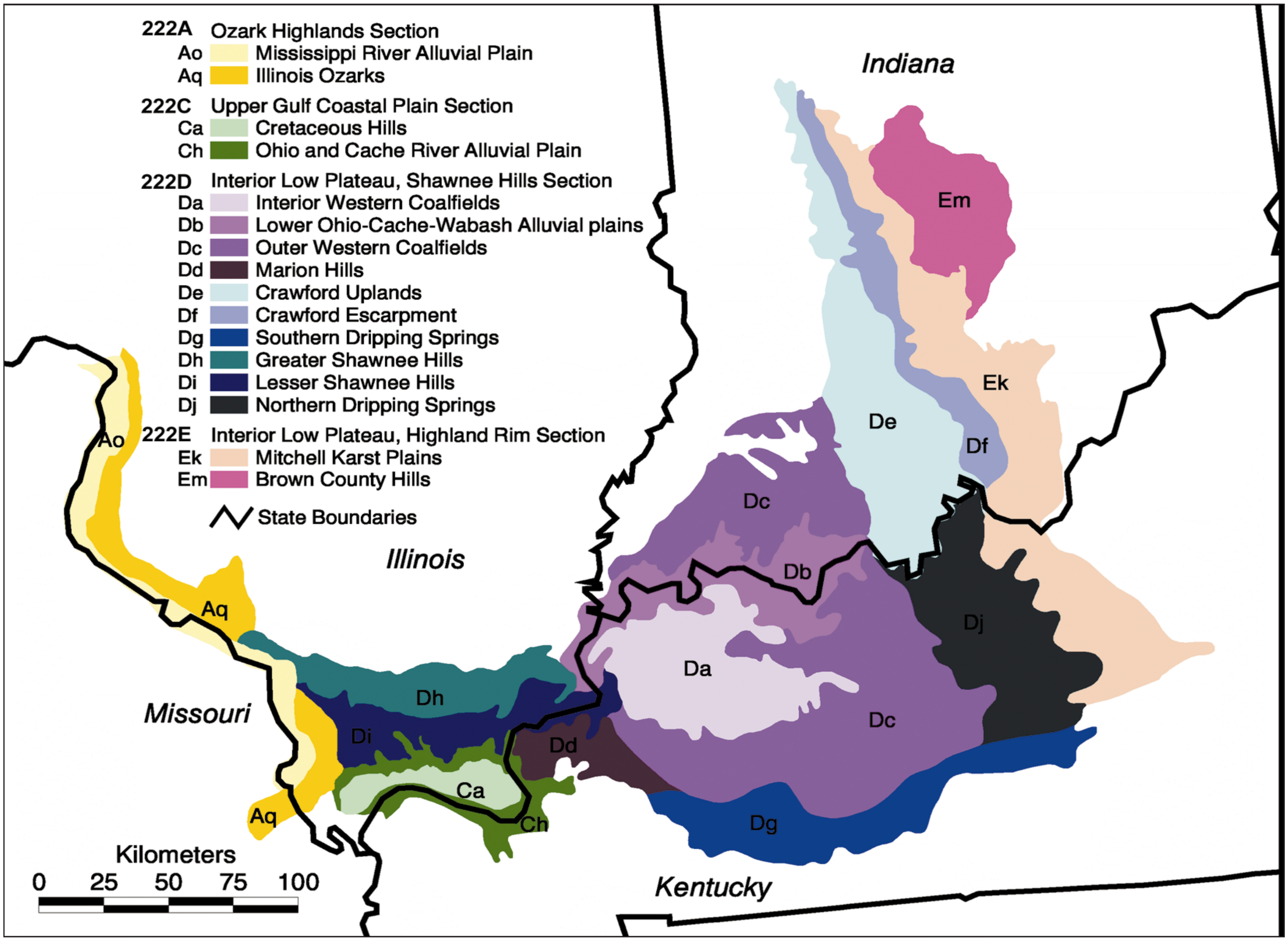


**Figure 1.** Ecological sections and subsections within the Hoosier-Shawnee Ecological Assessment Area (Adapted from Keys et al. 1995). Alpha-numeric designations of subsections refer to names and descriptions in table 1 and the Map Unit Tables in Keys et al. (1995).

(222Aq, fig. 1) and Mississippi River Alluvial Plain (222Ao, fig. 1) Subsections. These are very ancient landscapes, much older than the Rockies. The bedrock is Devonian and Silurian in age. Over the years, weathering has reduced their height by many hundreds of feet. The mean annual precipitation varies from 40 to 48 inches from northwest to southeast. Snow averages about 10 inches. Mean annual temperature is 55 to 60°F. The growing season lasts 180 to 200 days.

The soils in this section are primarily Alfisols, Entisols, Inceptisols, Mollisols, and Ultisols with mesic temperature regime. The soils are mostly cherty, developed in loess mantle. Most ridgetops with gentle slopes (3 to 8 percent) have about 2 feet of loess or loess-like silty mantle compared to ridgetops with moderate slopes (8 to 15 percent), which have soils with gravelly subsoils. The Illinois Ozarks Subsection has a thicker loess mantle due to its proximity to the Mississippi River. The Mississippi River Valley was a historic source for loess during the Pleistocene age. Mineralogy is siliceous or mixed, generally fine loamy, fine silty, loamy-skeletal, or clayey-skeletal in texture. Soils are of variable depth to bedrock, but are generally shallow, stony, and acidic, except on broad ridges and bottomlands.

### Upper Gulf Coastal Plain Section

This section includes the Cretaceous Hills (222Ca, fig. 1) and the Ohio and Cache River Alluvial Plain (222Ch, fig. 1) subsections. Upland soils developed in loess, sands, and gravels; flood plain soils in alluvium; and terrace soils along the Cache River system in Ohio River sediments. Soils in the Upper Gulf Coastal Plain are mostly Alfisols (Menfro, Hosmer), Inceptisols (Belknap, Burnside) with some Entisols, Mollisols, and Ultisols (Anonymous 1982, Keys

1982, Keys et al. 1995). Uplands are dominated by well-drained and moderately well drained soils on side slopes and ridgetops. Alluvial soils are present on floodplains of the Ohio River and Cache Rivers and their tributaries. These alluvial soils are generally deep and medium textured, and they have adequate moisture during the growing season. Well-drained Haymond and Sharon series and the somewhat poorly drained Belknap and Wakeland series occupy relatively narrow floodplains. High bedrock summits occur in northeast Johnson, Pope, and Hardin Counties. The annual precipitation averages 48 to 52 inches. Average temperature ranges from 61 to 68ºF. The growing season lasts 190 to 220 days.

### Interior Low Plateau, Shawnee Hills Section

This is the largest portion of the assessment area and includes the following subsections: Interior Western Coalfields (222Da), Lower Ohio-Wabash Alluvial Plains (222Db), Outer Western Coal Fields (222Dc), Marion Hills (222Dd), Crawford Uplands (222De), Crawford Escarpment (222Df), Southern Dripping Springs (222Dg), Greater Shawnee Hills (222Dh), Lesser Shawnee Hills (222Di), and Northern Dripping Springs (222Dj) (fig. 1). Soils in the Greater Shawnee Hills Subsection were derived from Pennsylvanian sandstone and shale with some Mississippian limestone, while soils in the Lesser Shawnee Hills were derived from Mississippian sandstone, shale, and limestone. Soils in the Lower Ohio-Wabash Alluvial Plains Subsection were derived from Pleistocene outwash of the late Paleozoic shale-sandstone.

The Crawford Escarpment Subsection is characterized by limestone of the middle Mississippian age overlain by regolith and colluvium as thick as 5 feet, with areas where bedrock is commonly exposed and massive limestone cliffs. Sandstone, shale, and limestone of late Mississippian and early Pennsylvanian age composed most of the surface bedrock in the Crawford Upland Subsection. Bedrock is exposed in many places or is very near the surface except in stream valleys.

The mean annual precipitation averages 44 inches. The average annual temperature is about 55ºF in southern Indiana. The growing season is approximately 195 days.

Major soils include Alfisols, Entisols, Inceptisols, Mollisols and Ultisols. These soils were formed under deciduous forests from loess, residuum, and alluvium. Alfisols (Zanesville, Grantsburg, Elkinsville, Wellston, and Bartle series) dominate the section with inclusions of Inceptisols (Haymond, Belknap, and Huntington series). Soils are generally well drained to moderately well drained, and many have silt loam or loam textures. On steep slopes, soils are typically thin with gravelly or channery textures. Subsoil permeability for upland soils is generally slow to very slow while floodplain soils typically have slow to moderately slow permeability. The soils occur on gently sloping to very steep topography, often on narrow ridges bordered by steep slopes and bedrock outcrops. Zaneville, Wellston, and Muskingum series also occur in association with other soils on the steep side slopes. Moderately well drained Grantsburg and the somewhat poorly drained Robbs series are the main soils occupying ridgetops. Permeability is slow to very slow because of a moderately to strongly developed fragipan in the lower subsoil. Many rock outcrops also are present on the steeper slopes. Some wetlands occur throughout this section mainly on floodplains.

Also, some parts of this section contain soluble bedrock strata composed primarily of limestone, made of calcium carbonate. Because limestone is somewhat more soluble than dolomite (calcium-magnesium carbonate), sinkholes and other karst landforms are common.

(See a description of karst in the paragraph just before the section on soil productivity limitations.) Because recharge to the water table is rapid, it can carry contaminants from the surface. Contaminants may include effluent from private septic systems, agricultural chemicals, animal and livestock wastes, motor oil, industrial waste, and garbage. Consequently, in karst landscapes, the risk of groundwater contamination from residential, agricultural, or industrial development is very high.

Both the Ozark Highlands and the Shawnee Hills Sections contain areas of thin, very droughty soils over bedrock that is often exposed in places. Because these soils contain little moisture or plant nutrients, many of the trees growing on them are stunted or gnarled. Further, the plant communities supported on these xeric forest soils have been characterized as "barren or transitional vegetation," usually having no more than 50 percent woody cover and a codominant understory of grasses or other plants. Barren or transitional land areas occur mostly along ridgetops and south and southwest facing slopes. Acreages of these lands are present in the Greater Shawnee Hills, Lesser Shawnee Hills, Illinois Ozarks, and the Cretaceous Hills subsections on the Shawnee and in the Crawford Escarpment and the Crawford Uplands subsections on the Hoosier.

### Interior Low Plateau, Highland Rim Section

The eastern portion of the assessment area is in the Interior Low Plateau, Highland Rim Section and includes the Brown County Hills (222Em, fig. 1) and Mitchell Karst Plain (222Ek, fig. 1) Subsections. The sandstone-shale region occurs as two main bodies in southern Indiana. The eastern portion is separated by deep stream valleys, and it is mostly wooded hillside land, with little suitable cropland, which occurs in small stream bottoms. The western area has stony hillside land with rock bluffs, but more areas of productive land. A large percentage of the land has been worked as strip mines and is now in forest. The Brown County Hills Subsection is composed of siltstone and shale of early to middle Mississippian age. This subsection is very rugged, with deep entrenchments by streams that drain into the Wabash River basin. The area has had long-term fluvial erosion, resulting in a noticeable dendritic drainage pattern. Fluvial erosion, transport, and deposition are the predominant geomorphic processes in the subsection. Derived from middle Mississippian age carbonate bedrock, regolith as much as 30 feet thick over limestone is the predominant surface material in the Mitchell Karst Plain Subsection. Stream entrenchment has, in some places, produced limestone outcrops. Terra rossa, a red clayey regolith from 5 to 50 feet thick, is a distinctive feature of this subsection.

Annual precipitation in the Highland Rim Section averages 44 to 54 inches. Temperature averages 55 to 61°F. The growing season lasts 180 to 200 days.

The Brown County Hills Subsection is dominated by well-developed udic Ultisols, udic Alfisols, and acidic, udic Inceptisols. Other Alfisols have both aquic and udic soil moistures, and some have fragipans. Along streams, Entisols dominate and have both udic and aquic moisture regimes. There are also some sandy Entisols near the West Fork of the White River. In addition, udic Entisols may occur on steeper slopes and on recently exposed loess. Although acidic Inceptisols are more common, basic Inceptisols are also present. Also occurring are aquic Inceptisols. Mollisols are common in some areas having both aquic and udic soil moisture regimes.

The Mitchell Karst Plain Subsection is characterized as a region of irregular topography. Soils were formed in a thin layer of discontinuous loess and silty clayey residuum-colluvium. Well-developed udic Alfisols on stable surfaces is the dominant soil type in this region. Fragipans have developed in some areas. Other common well-developed soils are the udic Ultisols, some with fragipans. The Alfisols in this region can also have aquic soil moisture, and some have a fragipan. Inceptisols with an udic moisture regime appear with both acidic and basic characteristics. Udic Mollisols are common. Paleudults (Frederick series), Fragiuldults (Zaneville series), Hapludalfs (Wellston series), and Dystrochrepts (Berks series) are representative soils in these two subsections.

The term "karst" refers to a landscape that typically is marked with sinkholes, that may be underlain by caves, and that has many large springs that discharge into stream valleys. Once these underground drainage pathways become established in bedrock, surface-water drainage is diverted underground. As a result, karst areas, such as the Mitchell Karst Plain, generally lack the network of surface streams seen in most other areas. It is generally a rolling plain pocked with sinkholes, but in areas of stream entrenchment, steep hillsides and cliffs occur. Streams, however, are uncommon because of the sinkholes. Drainage, which is commonly subterranean, flows into the Wabash or Ohio River basins. Most of the surface landscape consists of regolith. Bedrock outcrops, mostly limestone, occur on steep slopes bordering streams and at the crests of some hills. The breakdown of limestone beds (to form sinkholes) is important in shaping the landscape.

## SOIL PRODUCTIVITY LIMITATIONS

### Soil Loss

Considerable soil loss had occurred over the landscapes in both national forests before Forest Service ownership. Estimates of surface horizon loss range from 25 percent to over 75 percent for some areas. Timber cutting and farming had peaked and begun to decline by 1900 and had caused widespread soil erosion. Soils erode when soil porosity is reduced, especially when there is a lack of good vegetative cover. Preserving topsoil is important because deep surface layers generally translate into higher productivity. Topsoil material is usually enriched with organic matter. Organic matter provides soil with large pores, thus reducing soil density and enhancing water infiltration. Thin topsoil usually means lower organic matter content, because this is where nearly all soil organic matter is located, except for roots and other buried biomass. Soil organic matter increases soil water storage. In addition, approximately 50 percent of the plant available phosphorus (P) and potassium (K) reside in the topsoil. Thin topsoil means less rooting depth and plant available water capacity. Losing topsoil, therefore, contributes to a loss of nitrogen (N), P, and K and subsequent decline in productivity.

Growing trees increase soil porosity by providing litter in the form of leaves and other plant materials used by burrowing soil organisms that feed on dead organic matter. Thus, the potential for soil erosion lies with activities associated with tree removal rather than just with the temporary absence of tree cover.

Erosion is also affected by the steepness and length of the slope. Greater slope lengths increase the runoff velocity and the movement of sediments carried in runoff. In many areas, severe and prolonged erosion contributed significantly to reduced soil productivity on the Hoosier and Shawnee.

Wells and Jorgensen (1979) concluded that biomass-harvesting practices that removed more than tree boles could be selected from rotation to rotation without serious risk of decline in soil productivity in forests where the only concern for productivity loss was associated with nutrients removed in harvested biomass, because soil nutrient supply and productivity in forests change relatively slowly. However, an increase in harvest intensity could be expected to increase soluble nutrient losses and increase transport of particulate matter. Increasing the amount of biomass removal reduces the quantity of organic residue that would ordinarily be subjected to decomposition and nutrient release. If forest floor temperature and moisture are increased by biomass removals, there could be a nutrient flush from accelerated forest floor decomposition.

The addition of soil amendments such as animal manure and fertilizers can supply needed nutrients for tree growth and help offset losses in soil fertility caused by soil loss. However, productivity lost by excessive soil erosion cannot be restored through additional nutrient inputs for soils with subsoil material that has unfavorable properties (shallow to bedrock or restrictive layer, poor drainage, and so on) for tree growth.

The conversion of forested land in southern Illinois and southern Indiana to agriculture increased the opportunity for soil erosion, and soon forests and soils were nearing exhaustion. The most important factors in rehabilitating these soils on the national forests were the planting of trees and good forest management.

## Alluviation

The most productive sites on both forests are alluvial land areas in floodplains along rivers such as the Mississippi, Wabash, and Cache, and some of the larger streams. Alluvium is made up of eroded rock particles from hillsides that are ground into finer and finer grains of soil material each time they move downstream. Soil texture and depth for these soils are variable because of the alluvial nature of the materials. These sites are usually readily accessible, so most of them have been heavily cut over and/or farmed. Areas vary in size and shape and are scattered over the landscape.

The bottomlands along the Mississippi River were formed by glacial floodwaters. The floodplain is quite large and reflects the meandering history of the river, which has left many oxbow lakes and sloughs. The soils vary in that some are sandy and well drained while others are clay and poorly drained. Almost all bottomland forests along the Mississippi River floodplain were cleared for agriculture in the past (Groninger and Zaczek 1999). Although much fewer in number compared to less productive soils in national forest ownership, many of these bottomland soils are well drained and fertile. More recent floods (1993 and 1996), especially in areas influenced by the Mississippi River and large streams, caused the abandonment of additional acres within the forest purchase boundary that had been cleared of trees for farming. Efforts are being made to regenerate some of these recently purchased lands to trees (Inahgeh Project: History and Status of the Inahgeh Project, copy in the files at the Forest Service office in Jefferson City, MO).

A large acreage of these floodplain soils also occurs in the southernmost section of Illinois and includes the bottomlands of the Cache River. The area has swampy forest bottomland and is the northernmost extension of the Gulf Coastal Plain Province. Bald cypress-tupelo swamps are unique to this division. Although never glaciated, this area has been affected by glacial floodwaters. Sediments of sands, gravel, and clay in older terraces, as well as more recent alluvium, are quite deep, burying the bedrock. Before the intervention of humans, rivers and streams flooded regularly, increasing productivity and enriching floodplains with sediments and nutrients. Changes in rivers, such as levees, locks, and dams, have diminished the natural flooding cycles and reduced the productivity of alluvial systems.

## Soil Compaction

Compaction, the moving of soil particles closer together by external forces such as falling rain or traffic, can affect forest soil productivity. It can restrict soil drainage and increases the bulk density of soil and its resistance to penetration. Compaction reduces air exchange in the rooting area. All of these can hinder plant growth and yield. Today, more and more land managers are seeing the adverse effects of compaction over the entire range of soil types—from sands to heavy clays. However, more and more compaction problems are showing up in medium-textured soils, such as silt loam—a texture found throughout both forests. The worst compaction occurs on somewhat poorly drained soils and soils having low shrink-swell properties; compaction is often worse there than on poorly drained depressional soils.

Soil compaction can contribute to poor root health and reduce the response time of roots to localized nutrient concentrations (Chaudhary and Prihar 1974, Shierlaw and Alston 1984). It has been shown to reduce soil volume, soil porosity, aeration, water infiltration, and saturated hydraulic conductivity (Greacen and Sands 1980) or to limit bulk density for root growth (Daddow and Warrington 1983).

Sandy soils also compact. Sandy soils tend to remain compacted because the natural processes of shrink-swell and free-thaw have little effect on them. Gomez et al. (2002) indicated that for some coarse-textured soils, seedling performance may be better in compacted soil than in soil not compacted. Early results show that both height growth and diameter at breast height (d.b.h.) were better for shortleaf pine planted in compacted forest plots containing Clarksville cherty silt loam than in plots where the soil was not compacted (Ponder 2004). The reverse was true for northern red oak and white oak planted on the same Missouri site.

Although timber harvesting equipment is getting larger, equipment manufacturers and land managers are becoming more aware of the potential soil damage that can occur during the harvesting process. To reduce soil compaction on highly susceptible soil, timber harvesting is restricted when soil is wet. There is some concern that residual compaction during thinning could, after several entries into the same stand, reduce productivity. Although there are data to show that soils in skid trails and roads are compacted compared to other soil in the stand, controlling traffic during the harvest and reusing major skid trails and roads restrict compaction to the same areas. The natural recovery of compacted soil often takes many years.

All of the answers on how to deal with soil compaction are not yet available. It is hard to rehabilitate compacted forested soil. Conifer species, because of their shallower root systems compared to hardwoods, are more adapted to growing on compacted and shallow soils, and on some sites they should be the species of choice for regeneration. Bedding the planting rows before planting conifers has become the method of choice for private and Federal lands in some locations. However, soil bedding before planting is not widespread in the central hardwood forests.

Some soils in the region have a very slowly permeable fragipan. However, these soils are suitable for trees. Fragipans tend to affect the growth of some trees more than others; thus, selecting the proper species for a site can enhance productivity.

### Other Factors

In general, these forests have been highly disturbed (soil loss, alluvium, and compaction) by fire, grazing, and cutting that occurred in the early decades of the 1900s and consequently lost some productivity because of these activities (Sutherland 1997). Environmental factors constitute the majority of factors used to determine a soil's overall productivity. The relative importance of each factor is interwoven into the influence of the others. None are dominant in all circumstances, although one may have a greater influence. For example, although

**Table 1.** Ecological sections, subsections, and potential vegetation in the Hoosier-Shawnee Ecological Assessment Area. Adapted from Keys et al. (1995)

| Ecological section | Subsection | Potential vegetation |
|---|---|---|
| Ozark Highlands | Mississippi River Alluvial Plain (222Ao) | Cottonwood-willow forest, green ash-elm-hackberry forest, pin oak-swamp white oak forest |
| Ozark Highlands | Illinois Ozarks (222Aq) | White oak-black oak forest, shortleaf pine-oak forest, little bluestem-sideoats gramma glade, beech-sugar maple forest |
| Interior Low Plateau, Highland Rim | Mitchell Karst Plain (222Ek) | White oak-red oak forest, little bluestem-sideoats gramma glade, beech-maple forest |
| Interior Low Plateau, Highland Rim | Brown County Hills (222Em) | Upland oak-hickory forest, beech-maple forest, chestnut oak-mixed oak forest |
| Upper Gulf Coastal Plain | Cretaceous Hills (222Ca) | White oak-red-oak forest, southern red oak-mixed oak forest, post oak-mixed oak woodland-barrens |
| Upper Gulf Coastal Plain | Ohio and Cache River Alluvial Plain (222Ch) | Cypress-tupelo swamps, pin-oak-swamp white oak flatwoods, watercup oak-sweet gum forest |
| Interior Low Plateau, Shawnee Hills | Interior Western Coalfields (222Da) | Southern red oak-white oak-hickory forest, oak forest |
| Interior Low Plateau, Shawnee Hills | Lower Ohio-Wabash Alluvial Plains (222Db) | Oak-sweetgum bottomland forest, cypress-tupelo swamps, bulrush-cattail marsh |
| Interior Low Plateau, Shawnee Hills | Outer Western Coal Fields (222Dc) | Southern red oak-white oak-hickory forest, beech-maple forest |
| Interior Low Plateau, Shawnee Hills | Marion Hills (222Dd) | Chestnut-oak-oak-hickory forest, southern red-oak-white oak-hickory forest |
| Interior Low Plateau, Shawnee Hills | Crawford Uplands (222De) | White oak-red oak forest, beech-maple forest |
| Interior Low Plateau, Shawnee Hills | Crawford Escarpment (222Df) | White oak-red oak forest, beech-maple forest |
| Interior Low Plateau, Shawnee Hills | Southern Dripping Springs (222Dg) | Southern red oak-white oak-hickory forest, American beech-sugar maple-yellow poplar forest |
| Interior Low Plateau, Shawnee Hills | Greater Shawnee Hills (222Dh) | White oak-red oak forest, post oak-blackjack oak forest, blackjack oak-cedar glades |
| Interior Low Plateau, Shawnee Hills | Lesser Shawnee Hills (222Di) | White oak-red oak forest, post oak-blackjack oak forest, blackjack oak-cedar glades |
| Interior Low Plateau, Shawnee Hills | Northern Dripping Springs (222Dj) | Southern red oak-white oak-hickory forest, sugar maple-yellow poplar forest |

approximately 760 mm of precipitation falls in the Shawnee and Hoosier National Forests during the growing season, summer droughts of up to 4 weeks during July and August are not uncommon. Also, because most of the soils in these two forests, excluding alluvial soil, were formed under forest, they have inherent low organic matter content compared with soils formed under grass. Thus, the combination of soil, climatic, and topography has created a variety of physiographic soil types and has a profound influence on the distribution of forest species and communities (table 1). While the aforementioned factors play an important role in determining inherent soil productivity, litter fall is an important internal nutrient cycling mechanism that helps regulate productivity in forest communities. Nutrient inputs from litter fall, dead wood, and reproductive litter in central hardwood forests are generally in the order of calcium (Ca) > N > K > magnesium (Mg) > P (Peterson and Rolfe 1980).

Effective soil depth and available water holding capacity (AWC) are recognized as major factors regulating site productivity and plant community composition (Fralish 1976, George and Fisher 1989). Available water holding capacity integrates effective soil depth with texture, percent stone, and bulk density changes through a particular depth. These variables have a strong effect on soil water, which ultimately determines site potential and tree growth. However, data for estimating AWC are not easily obtained, and thus, for predicting growth on disturbed sites such as forests where productivity may be below potential levels, it is necessary to use other site factors that can be rapidly observed in the field.

Redcedar (*Juniperus* spp.) occurs on the most xeric sites. Such sites have small amount of soil and limited water availability. Redcedar stands are located in a variety of slope positions that range from exposed bluff edges facing a variety of directions. On sites where the soil is somewhat deeper and covers the entire bedrock surface, the forest stands are generally dominated by post oak (*Quercus* spp.) with blackjack oak (*Quercus* spp.), hickory (*Carya* spp.), and white oak (*Quercus* spp.) (table 1). Stands of white oak tend to dominate middle slope positions, on more gently sloping land surfaces near ridgetop sites or on south, southwest, and west slopes. Occurring with white oak are post oak, black oak (*Quercus* spp.), and several species of hickory. Soils are deeper and the available water storage capacity is 5 cm more than for post oak sites. Northern red oak (*Quercus* spp.) stands are found in middle slope positions but on sites that have northwest, north, and northeast aspects. Soils average about 13 cm deeper than for white oak with similar available water storage capacity. Other relatively important species include pignut hickory (*Carya* spp.), shagbark hickory (*C. ovata* (Mill.) K. Koch), white ash (*Fraxinus americana* L.), and sugar maple (*Acer saccharum* Marsh.). These communities rapidly grade into sugar maple communities in lower slope positions. Soils averaging over 100 cm deep to bedrock, usually without a fragipan, and high available water storage capacity (>20 cm) in the profile have a mixture of relatively mesophytic hardwood species (Braun 1964). These hardwoods are designated as mixed hardwoods to distinguish them from the sugar maple community. Fisher and Kershaw (1985) concluded that while site characteristics do influence species composition, net basal area growth as a measure of productivity depends more on average tree size and stocking.

## EFFECTS OF CURRENT AND PAST LAND USE PRACTICES

### Deforestation and Conversion to Agriculture

Practices such as logging, water drainage, and conversion to agricultural uses have led to considerable change since presettlement times. Settlement of much of the land began in the early 1800s, some areas as early as 1763. At the close of the Revolutionary War, the American government encouraged immigration by offering homesteads at small cost, and settlers began to come down the Ohio River or up the Mississippi into southern Illinois where the population remained concentrated until the 1830s. The agricultural economy developed primarily in bottomlands, where people cleared forest for field crops and pastures by tree-girdling and burning. Many people migrated into the area in the 1850s with the development of the charcoal pig iron industry. The demand for this high-quality iron caused rapid deforestation of the area around the smelters. Pig iron production peaked in the 1880s and then declined with the loss of the timber resource for charcoal. Most of the smelters were closed by the turn of the century. The communities that surrounded the smelters were abandoned and the forests regrew. In other areas, the forest was removed because of surface mining for minerals. Over time, these mines closed or were abandoned and the forest regrew. However, from the time these forests were cleared until they redeveloped, many tons of soil were carried from the sites by water in tributary streams of rivers such as the Cache and Mississippi where the soil was deposited.

The area now occupied by the Oakwood Bottoms Greentree Reservoir was intensively farmed before its acquisition by the Federal government between 1933 and 1938. These flatwoods occur on nearly level lacustrine sediments. The soils are Inceptisols that formed in lacustrine sediments with high shrink-swell capability. Clay contents exceed 60 percent leading to vertic characteristics due to montmorillonitic mineralogy. These areas are often wet during the spring and fall. Since its acquisition, the Oakwood Bottoms Greentree Reservoir has been left to reforest itself naturally or through replanting. No tree harvest is planned on Oakwood Bottoms for timber management purposes. However, harvest may be used to regenerate oaks at 60- to 80-year intervals to improve and maintain wildlife habitat. Pin oak (*Quercus* spp.) grows rapidly on these lacustrine soils (McIlwain 1967). Very little of the wetlands and floodplain forests remain in presettlement condition. These physical changes to the landscape, including the mixture of agricultural and forest lands, have had a profound ecological effect.

### Agricultural and Silvicultural Management

Before European settlement, vegetation in the Shawnee and Hoosier National Forests was mainly deciduous forest. In general, deep, well-drained upland soils supported sugar maple, oaks, hickories, beech (*Fagus* spp.), poplar (*Populus* spp.), and oaks. Shallow, well-drained upland soils were covered with scrub oak (*Quercus* spp.) (including blackjack and scarlet), while pin oak grew mostly on poorly drained soils. Farming eliminated forest from relatively level land areas and land surfaces on broad ridges and hills. More forested acres were decreased by mining. Many of these once abandoned fields and mining areas are now in some stage of forest stand development or other successional vegetation. During the 1930s through the 1950s, private agricultural lands that were purchased and put into the National Forest System on the Shawnee and Hoosier National Forest were reforested or maintained as wildlife openings. Much of the abandoned crop fields in the uplands were planted to non-native pine plantations while floodplain fields were primarily planted to tulip-poplar. These plantations helped control further erosion for watershed protection. Through reforestation and rehabilitation, hardwoods have made a comeback and occupy many acres in the Shawnee and Hoosier National Forests. Most of the once eroded forest soils planted to trees are in better condition now than they have been in decades, and many support native tree species such as oak, ash, and black cherry.

Private forests are expected to play an important role in meeting future timber needs. Both the Hoosier and Shawnee have large acreages of private timberland within their purchase boundaries. Private landowners own 85 percent of the forested land in Indiana. Each private landholder owns timberland for a unique reason, which makes it difficult to explain and predict how landowners will manage their forest resources. Public policymakers and industrial planners are concerned that these lands may not meet their potential in fulfilling future needs for timber. Continued division of the forest into smaller parcels and increased development may make harvesting uneconomical. For example, from 1978 to 1996, in just 18 years, the number of Indiana's private timberland owners tripled; however, the amount of private timberland increased by only 30,000 acres.

Planting trees prevents soil erosion and provides habitat for wildlife and recreation. Historical data and the presence of fire-resistant characteristics support the role of fire in the establishment and maintenance of mixed-oak forests in the Central Hardwoods Region. Following the clearcutting of the forests in the 1800s, fire suppression became a dominant forest management technique. Age and species diversity declined and forest stand composition shifted, allowing more vigorous and shade-tolerant species to dominate. As a result, seedlings in oak-dominated forests have become suppressed by vegetative competition, resulting in a decrease in oaks in the midstory. Adams and Rieske-Kinney (1999) concluded that this shift in species composition has resulted in the economic loss of an extremely valuable hardwood group and may also impact forest succession rate, wildlife composition and distribution, and watershed characteristics.

Fire can be a useful way to rejuvenate forested areas. Not only do fires replenish the soil with nutrients vital to plant growth by quickly breaking down dead plant materials, and allowing more sunlight to reach the forest floor to increase plant and animal diversity, but they also cut out disease from plant populations and often facilitate plant production. Rapid plant regrowth is essential to the rehabilitation of a burned area, for plants greatly influence the hydrology of a soil. For plants to grow back on a burned area, they require several nutrients whose concentrations are modified by fires. The degree of modification is determined by a fire's temperature, but there are a few general trends. Levels of P and pH (Kutiel and Shaviv 1993, Marion et al. 1991) both increase during a fire. Conversely, N decreases during a fire (Kutiel and Shaviv 1993, Marion et al. 1991).

Chemical concentrations in burned soils are greatly affected by a fire's intensity. Several studies show how minerals essential for plant growth in the soil are affected by fire intensity. Low-intensity fires (100-250ºC) tend to increase levels of ammonium (Kutiel and Shaviv 1989, 1993), Ca (Weaver and Jones 1987), and Ca, Mg, and K (Kutiel and Shaviv 1989, Marion et al. 1991), while high-intensity fires (>500ºC) tend to decrease them. Kutiel and Shiviv also noted in their study that pH increased with fire intensity and that the highest concentrations of sodium, K, and Mg occurred at a fire temperature of 250ºC.

The highest concentration of essential minerals for plants occurs during low-intensity fires. Low-intensity fires also tend to create patchy burn mosaics on the landscape. These are desirable because N, which is essential to plant growth and is decreased by fires, can easily diffuse from the unburned areas into the burned areas in the form of NO3-N. Nitrogen can also be replaced through the migration of nitrifying plants from the unburned areas to the burned areas (Kutiel and Shaviv 1993). Patchy burning (low-intensity fire) is often a direct function of soil moisture. Therefore, prescribed burns are most effective (i.e., rejuvenating the vegetation and not degrading the soil) during the wetter months of the year.

Fire also has a tendency to change the texture of a soil by aggregating the clays into sand-sized particles (Ulery and Graham 1993). Dobrowolski et al. (1992) showed from their study of fire's effect on sandy soils that a high percent of sand in the top layer of soil and a low depth of clay rich horizons tend to increase the infiltration capacity of a soil. However, the effect is short lived, and in most cases the effect of fires on soils is to increase the erodibility of soils due to a lack of vegetation (Scott and Van Wyk 1990).

Increases in soil nutrient availability following fire have been found in some systems and fire regimes and not in others. So far, what we know about possible detrimental effects of fire on site chemistry suggests that these effects are minimal and of short duration. Intense fires of logging slash in the southern Appalachians have combusted some of the organic layer without significant loss of carbon (C) or N from the O-horizon (Vose and Swank 1993) and have increased available soil N (Austin and Baisinger 1955, Knoepp and Swank 1993). Fire is being reintroduced in the restoration and maintenance of a complex mosaic of woodlands, forests, barrens, and savannas using landscape-scale prescribed fire and other techniques. It will likely require multiple fires to restore the desired oak structure.

Acid deposition from sulfate and nitrate ions over the area included in these two forests diminishes southward and westward from north and northeastern sources (National Atmospheric deposition Program/National Trends Network- http://nadp.sws.uiuc.edu). The most noted effect associated with acid deposition has been a decrease in pH. Hydrogen ion concentration as pH in 1999 was 4.4 in central Indiana compared to 4.5 in southern Indiana and 4.6 in southern Illinois. With few exceptions, sulfate ion deposition followed the same pattern. Nitrate ion deposition as $NO_3$-, however, was higher (15 kg/ha) for the Hoosier than for the Shawnee (13 kg/ha). The region contains four of the Nation's top seven

$NO_x$ emitters and three of the top five $SO_2$-emitters.

Acidification effects on soil have been postulated, but direct causal relationships on the ecosystem are far from clear. All soils are not equally susceptible to acidification. The buffering capacity of soil depends on mineral content, texture, structure, pH, base saturation, salt content, and soil permeability. Studies indicate that increases in acidification due to precipitation lead to a loss of cation exchange capacity and increased rates of mineral loss. Although the potential effects of acidic precipitation on soil could be long lasting, researchers note that many counteracting forces could mitigate the overall final effects, including the release of new cations to exchange sites by weathering or through nutrient recycling by vegetation. Trees appear to be slightly stimulated by acid precipitation, although this effect would be expected to be shortlived because of increased leaching of cationic nutrients and the buildup of toxic concentration of metals in soil water (Bittenbender et al. 2001). Hornbeck (1987) concluded that there were no obvious impacts of atmospheric deposition for red oaks and sugar maple from a 10-year inventory of forest resources in six New England States where acid deposition was high. Therefore, any changes in soil chemistry associated with acid deposition were minimal on tree growth.

### Hardwood Restoration Programs

To aid private landowners in timber management and to demonstrate the importance of private forests in providing wood products, wildlife habitat, and soil and water protection, both Federal and State assistance is available for all phases of timber management from site preparation to harvesting. Although the major incentive for these programs is the protection of the soil and water resources by planting trees or grasses, they encourage farmers to convert highly erodible cropland or other environmentally sensitive acreage to vegetative cover including filter strips or riparian buffers. With new and potential markets for timber, owners of mined land are keenly interested in reforestation with commercially valuable hardwoods.

Both the Conservation Reserve Program and the Wetlands Reserve Program provide assistance to landowners to apply conservation practices to their land through cost-sharing agreements. The inherent value of functional wetlands resides in the benefits provided to society through floodwater mitigation, water quality enhancement, groundwater recharge, habitat for rare and endangered species, forest production, game and nongame species production, and aesthetics. Recent studies have shown that 46 percent of all threatened and endangered U.S. plant and animal species are associated with wetland habitats. Predicting the effectiveness of wetland restoration efforts is difficult due to the longevity of forested systems. For restoration to be considered effective, important wetland functions need to be restored or at least on a path where restoration of those functions is probable and predictable. Functional linkages of restoration success must be designed to allow comparisons of parameters, such as soil organic matter development and characterization, and comparison of C and nutrient fluxes and nutrient pools at different successional stages during system recovery at various stages.

Private landowners' requests for enrollment in the programs greatly exceed allotted funding. When practices under these forest restoration programs are adequately administered, they enhance our ability to produce food and fiber, reduce sedimentation in streams and rivers, improve water quality, establish wildlife habitat, and enhance forest and wetland resources.

## ACKNOWLEDGMENTS

The author thanks Pat Merchant, Bryan Fitch, and Wayne Geyer for their reviews of an earlier version of this manuscript and for their helpful advice and comments.

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# Current and Historical Forest Conditions and Disturbance Regimes in the Hoosier-Shawnee Ecological Assessment Area

**George R. Parker and Charles M. Ruffner**


## ABSTRACT

We review the historical and current status of forests in the Hoosier-Shawnee Ecological Assessment Area. Native American people influenced the vegetation through fire and agricultural clearing across the region until the early 1800s when European settlers arrived.

Clearing of the land for agriculture peaked in the early 1900s after which badly eroded land was abandoned and either planted or naturally regenerated to forest. Many of these abandoned farms were purchased for public parks and forests and managed as timberlands throughout the 20th century.

Today, about 43 percent of the landscape is covered by forest and 49 percent in agriculture. Land use varies across the region depending on its suitability for nonforest use. For instance, much of the uplands across the assessment area, including the Ozark Highlands, Interior Low Plateau, Shawnee Hills (hereafter "Shawnee Hills"), and Interior Low Plateau, Highland Rim (hereafter "Highland Rim") Sections are dominated by forest land. In contrast, much of the best lands are privately held and support agricultural activities.

Forests are mostly temperate deciduous hardwoods with coniferous forests covering only 8 percent of the forest area. Forests are currently dominated by oak and hickory species that cover about 40 percent of the forest area. However, species composition is changing from species established as the result of frequent past disturbances (<1950) to more shade tolerant species as the result of the decreased disturbance regimes of the late 20th century (>1950). There is concern about the loss of landscape diversity and maintenance of oak species as these shifts occur, and current management activities are being implemented to reduce this transition.



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We review the historical and current status and management of forest within the region surrounding the Hoosier National Forest in southern Indiana and the Shawnee National Forest in southern Illinois. The assessment area, encompassing over 12 million acres, has a long history of human activity beginning with Native American peoples 12,000 years before present. Human-caused disturbances including the use of fire, grazing by livestock, and extensive clearing have been important factors in determining the condition of the vegetation in the region today.

We document the rich historical ecology of the Hoosier-Shawnee Ecological Assessment Area by coupling the historical disturbance regimes with the changing vegetation patterns across ecological units. Vegetation is examined within the context of the National Hierarchical Framework of Ecological Units, a classification system that divides landscapes into ecologically significant regions at multiple scales (Keys et al. 1995). Section and subsection names and numbers follow Keys et al. (1995) and are also listed in Ponder (2004). The diversity of history and management is discussed for 4 ecological sections and 16 subsections (fig. 1). As history of resource use, major forest types, and current management activities are examined for each unit, descriptions are limited due to the large spatial area each unit encompasses.

## MAJOR CHANGES IN VEGETATION AND THE INFLUENCE OF HUMANS FOLLOWING GLACIAL RETREAT

### Prehistoric period (before 1650)

During the height of the Wisconsin glaciation (28,000 years BP), ice sheets were located in central Illinois and Indiana, but landscapes were ice free in southern Indiana, southern Illinois, and western Kentucky. The preglacial landscape of this region, however, was greatly influenced by the ice sheets to the north. During the Wisconsin glaciation, a mixture of boreal-northern hardwood/pine forests dominated portions of western Kentucky and southern Illinois alternating with southern pine-prairie species during warm episodes (Franklin 1994, Whitehead 1997). Following the disappearance of the ice sheets by 17,000 years BP, deciduous species migrated into the region and forests were comprised of oak, hickory, elm, and beech species by 11,500 years BP. In the Middle Holocene, a warming trend known as the Hypsithermal period (8,700-5,000 years BP) resulted in prairie expansion into the region; mesophytic tree species retreated to mesic bottomland and cove sites while oak and hickory dominated upland sites (Franklin 1994). Following the Hypsithermal, a cooler, moister climate fostered woody invasion into prairie and open savannas. Through time, these open woodlands were heavily influenced and probably maintained by recurring fire, both natural and human caused (Fralish et al. 1999). By 2,000 years BP, forests of the region were comprised of oak-hickory and mixed mesophytic forests with inclusions of glades, prairies, and savannas. Braun (1950) classified regional forests as oak-hickory in the Ozark Hills of southwestern Illinois and mixed mesophytic across the Shawnee Hills of southeastern Illinois and western Kentucky. Küchler (1964) mapped the potential vegetation of this region as oak-hickory.

Coupled with the natural interactions of vegetation and climate were the interactions of humans and vegetation. By the Middle Holocene, Archaic peoples had settled into the lower Ohio and middle Mississippi River areas. Archaic people (8,000-2,500 years BP) were seminomadic hunter-gatherers who were adept at manipulating their environments (Caldwell 1958; Delcourt 1987; Munson 1986, 1988). Cultural ecologists believe Archaic peoples used fire widely for altering forest composition and

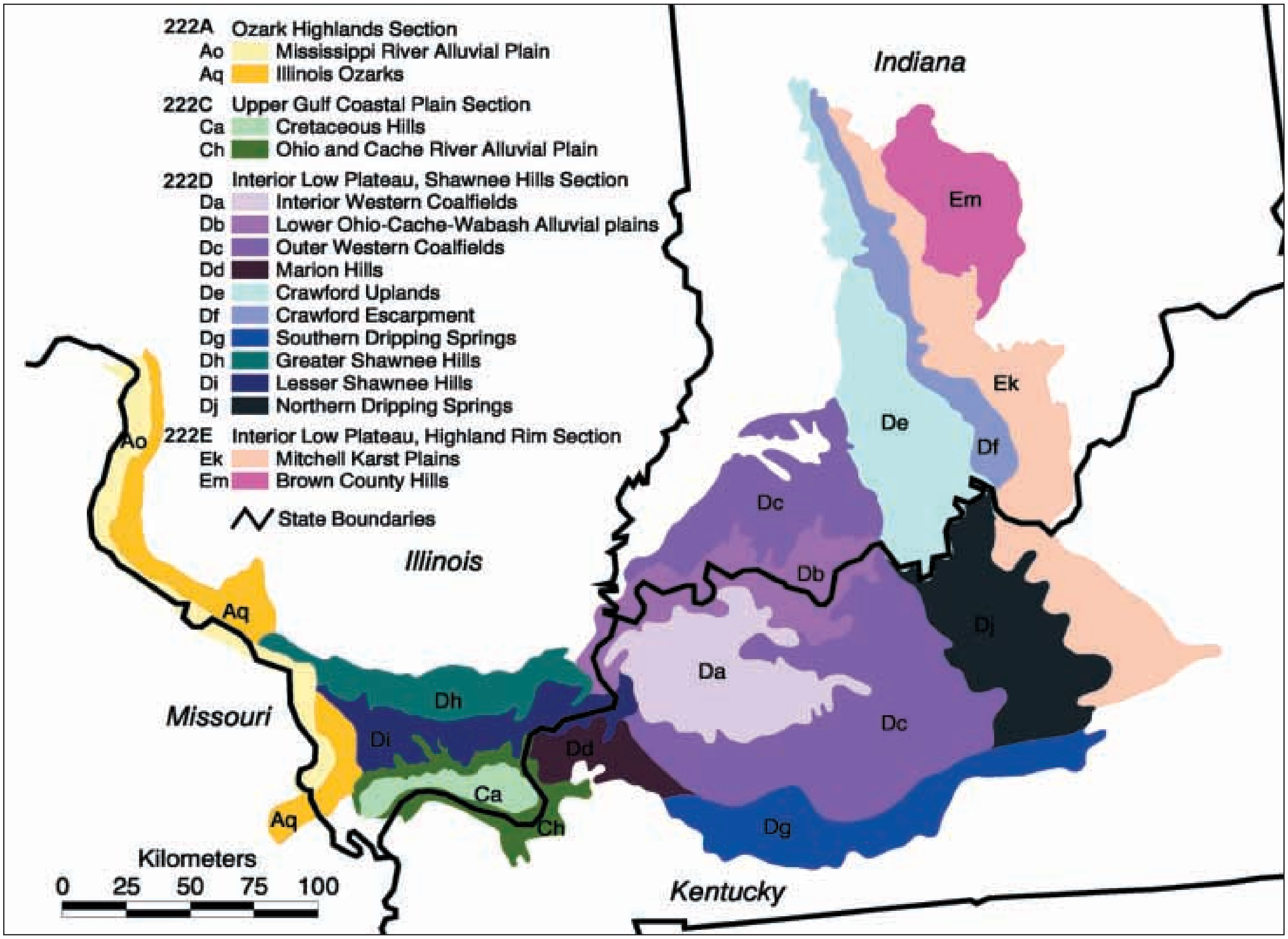


**Figure 1.** Ecological sections and subsections within the Shawnee-Hoosier Ecological Assessment Area.

structure as well as for clearing forest patches, driving game, and other activities (Caldwell 1958, Delcourt et al. 1998, Mellars 1976). Although the overall impact of these activities is equivocal based on uncertain population sizes and shifting demographics, most paleoecologists accept that Archaic peoples altered their local environments to augment their subsistence economy (Gardner 1997, Munson 1986). Later, Woodland period (2,500-1,000 years BP) cultures had an intensified hunting-gathering economy with growing dependence on swidden horticulture. These cultures were dependent on the seasonal availability of collected resources, and thus their occupation sites rotated between bottomland and upland forests. Woodland cultures also used fire to clear forest patches and aid in collecting and processing mast resources of upland forests (Clark and Royall 1995, Ruffner 1999). Paleoecologists recently reported the influence of Woodland cultural activities in the form of "forest gardens" in central hardwood forests (Delcourt et al. 1998). Mississippian period (1,000-500 years BP) natives moved into the region, establishing the earliest agriculture at their large agricultural village sites along river bottoms (Cole 1951, Muller 1985). These villages supported populations as large as 500 persons and were characterized by stockaded enclosures surrounded by cultivated fields where corn, beans, and squash were grown (Cole 1951, Muller 1985). Mississippian communities disintegrated into tribes after 500 years BP and dispersed widely across the landscape with few permanent settlements. Pre-European Native groups of the southern Illinois region consisted of the Kaskaskia, Michigamea, and Shawnee (Brown 1985). As a result of growing hostilities between Native and European groups in the 1700s, numerous migrations moved tribal groups up and down major river drainages. By the mid-1700s, the lower Ohio River Valley was a major thoroughfare for westward movement of displaced tribes from the Mid-Atlantic including the Delaware and Shawnee (McConnell 1992). Population numbers varied during this period, and the effect of humans on the environment is poorly understood.

Historical accounts of the region depict the area as heavily influenced by Native activities (Allen 1945, Brown 1985, Kimmerer and Lake 2001, Temple 1966). Indeed, the anthropogenic landscape encountered by early European settlers in the 18th century reflected a long-term interaction between Native activities and vegetation associations. Native American use of fire and clearing land for agriculture was probably much greater in the 1400s than it was in the 1700s when Europeans started settling in the region (Denevan 1992, Williams 2000). European diseases had greatly reduced Native American populations by the late 1,500s—early 1,600s, reducing their overall impact on vegetation across the landscape, allowing some recovery of forested conditions by the 1700s when Europeans became more active in the region (Olson 1996). However, fire and agriculture continued to be used across the landscape by a smaller number of Native Americans. Research on the barrens of southern Indiana indicates that some areas were burned about every 23 years from 1650 to 1820 (Guyette and Dey 2000). However, fire history across the assessment area needs to be studied more intensively to further elucidate these relationships.

Based on General Land Office survey records, pre-European settlement forests of southern Illinois were loosely characterized into four ecotones: 1) mesic oak-hickory forests dominated by white oak (*Quercus alba*), black oak (*Q. velutina*), and hickory (*Carya* spp.) occurring on thin loess upland soils across the Shawnee Hills, 2) mixed hardwood forests with tulip-poplar (*Liriodendron tulipifera*), American beech *(Fagus grandifolia)*, white oak, black oak, hickory, and sweetgum *(Liquidambar styraciflua)* on thick loess deposits of the Ozark Hills, 3) lowland-depression forests with elm (*Ulmus* spp.), ash (*Fraxinus* spp.), sweetgum, oaks, hickories, bald cypress *(Taxodium distichum)*, and red/silver maple *(Acer rubrum/saccharinum)* on low-lying terraces and bottomlands of the Ohio, Wabash, Cache, Saline, and Mississippi Rivers, and 4) floodplain forest (elms, ashes, hackberry *(Celtis occidentalis)*, eastern cottonwood *(Populus deltoides)*, and American sycamore *(Platanus occidentalus))* in narrow bands along riverbed margins (Leitner and Jackson 1981, Schulte and Mladenoff 2001).

Isolated fragments of savanna and prairie were present across upland north-central portions of the region (Williamson and Johnson Counties, Illinois), the Cretaceous Hills of southeastern Illinois, and the hill prairies along bluffs of the Mississippi River (Anderson and Anderson 1975, Evers 1955, Fralish et al. 1999). Small native populations of shortleaf pine *(Pinus echinata)* occur on extreme, xeric uplands of the Ozark Hills at LaRue-Pine Hills in Union County and the Piney Creek Reserve of Jackson County, Illinois (Ashby and Kelting 1963, Davis and Ruffner 2001, Suchecki 1997, Turner 1936).

The presettlement landscape of southern Indiana was predominantly forested (Lindsey et al. 1965, Potzger et al. 1956) with significant areas of prairie and disturbed and open forest (Eagelman 1981, McCord 1970, Olson 2001). Oak and hickory species were dominant on the Brown County Hills, Crawford Uplands, and Interior Western Coal Fields Subsections, and mixed forests of American beech, sugar maple (*Acer saccharum*), oaks, and hickories were dominant on the limestone soils of the Mitchell Karst Plain and Crawford Escarpment Subsections. The Lower Ohio-Cache-Wabash Alluvial Plains Subsection was dominated by floodplain forests of elm, hackberry, sycamore, and beech (Gordon 1936). Many other species were also present in these areas and will be discussed in more detail later.

Current overstories of old-growth forests are indicative of species present during the presettlement period (Lindsey and Schmelz 1965, 1970; Lindsey et al. 1969, Lindsey 1962; Parker 1989; Ruffner et al. 2002; van de Gevel and Ruffner 2002). Many of these old forests have seral oak species in their overstories due to the disturbance regimes spanning the Native American-European settlement periods (DenUyl 1954). Old-growth studies have attempted to identify key characteristics of forest structure and composition, but few generalizations can be made because of the scarcity of data (<1% of original forest remains) (Parker 1989). Most old-growth forests of this region are small, highly fragmented parcels with older canopies (>150 years) of oak and hickory that developed during periods of frequent fire, and midstories of later seral species such as sugar maple or American beech that developed as a result of fire suppression (Fralish et al. 1991, McCune and Menges 1986, Parker 1989, Ruffner et al. 2002, Schlesinger 1976, van de Gevel 2002, Weaver and Ashby 1971).

### Historic Period (>1650-Present)

Exploration of the lower Ohio and middle Mississippi Valleys was begun by French traders and missionaries in the mid-1600s (Brown 1985). A tannery was established at Grand Chain, Illinois, along the lower Ohio River in 1703, but the enterprise failed by 1704 because of Native American hostilities and disease. Between 1720 and 1750, the first permanent European settlements were founded at Cahokia, Kaskaskia, Prairie du Rocher, and Fort de Chartres (Meyer 1996). Obviously, these settlements were located at key Native American village sites to foster trade networks.

Competition between France and Great Britain for supremacy of the Native American trade culminated in the French and Indian War (1754-1763). Fort Massac, a new French fort on the Ohio River, was completed in 1757, but all French holdings in southern Illinois were in British hands by 1765. Between 1765 and 1778, the British garrison co-existed with the local Kaskaskia and Michigamea Indians. When the American Revolution began, the British garrison departed for Detroit and the region was eventually “conquered” and claimed by George Rogers Clark for the Virginia Colony (Clark [1790] 1920). During his tenure as commander of the Illinois garrison, Clark’s strong leadership guaranteed the growth and stability of the region with ever increasing numbers of emigrating settlers moving through the Cumberland Gap, across Kentucky, and into the Illinois Country. When the conflict ceased and trade routes opened westward, the lower Ohio and middle Mississippi Valleys experienced great population fluxes.

By 1830, the population density of southern Illinois had grown to an average of 6 to 18 persons per square mile (Meyer 1996, Meyers 2000). Settlement patterns in 1830 included incipient agriculture along the Mississippi and Ohio corridors with frontier subsistence across the central portion of the Shawnee Hills. Early European land uses reflected farmstead development such as clearing forest for agricultural patches, grazing livestock in forested areas, and consuming basic fuelwood/fiber for building. Throughout the 19th century, settlers continued to harvest forest lands for timber production, eventually cutting most of the old-growth forests (Fralish 1988).

Active European settlement began in southern Indiana during the early 1800s as Native American tribes ceded their lands to the United States government. Settlers began clearing land for crops and allowed livestock to roam freely through the forest (Latta 1932, Parker 1997). Trees were felled for building materials or simply piled and burned. Fire was a common disturbance in forests and became more frequent following European settlement. For example, the fire return interval in the southern Indiana barrens decreased from 23 years to 5 years after European settlement (Guyette and Dey 2000). While fire became more frequent on certain sites during settlement, it also was more controlled and fragmented as firebreaks were established through roadbuilding and agricultural clearing. Drainage of wetlands and farming of prairies became common practices by the late 1800s.

Logs were floated down streams during spring flows to sawmills by the 1830s. Wooden products were floated on flatboats to New Orleans and shipped to other areas. With the advent of railroads in the mid-1800s, forests could be logged and shipped to markets throughout the Eastern United States. Railroads also used large quantities of wood for ties and fuel to produce steam (Brundage 1934). Steam-powered engines were also responsible for numerous fires. Increased logging allowed more rapid settlement of sites less suited to agriculture, resulting in resource degradation.

By 1900, most of the forest had been cut and all forests had been subjected to fire and grazing by domestic livestock during the 100 years of European settlement (DenUyl 1947, DenUyl and Day 1939). Some of the cut-over forest land was allowed to regrow, but most was permanently cleared for rowcrop agriculture. More land was permanently cleared in the relatively level areas of the landscape than in the areas of more hilly topography. Clearing steeply sloping lands led to severe erosion and eventual abandonment (Freeman 1908, Sieber and Munson 1994). Settlers farmed “ten year” land, so called because erosion quickly rendered it unsuitable for agriculture (Sieber and Munson 1994). Selective harvesting of forests for specialty products in the 1920s and 1930s led to degraded forest structure (Brundage 1936, 1937).

Burning of woodland understories continued to be a common practice for maintaining open woodlands for pasture, controlling insects, and improving appearance into the early 1900s (Skinner 1939). However, with modern agriculture and reduced woodland grazing, intentional burning of woodlands has declined since the 1950s. Reduced grazing and burning resulted in regrowth of forest understories (Den Uyl 1961). Aerial photography in 1939 shows many open forest canopies without woody subcanopies due to fire and grazing.

After 1900, there was increasing concern about soil erosion and resource abuse (Freeman 1908). Forest abuse began to decline in the 1930s as severely eroded lands were transferred from private to public ownership and better management practices were established. Programs to control soil erosion and fire were begun in the 1930s with the formation of the Civilian Conservation Corps. During the middle to late 20th century, forests across the assessment area were primarily managed first by selection cutting (up to late 1960s-early 1970s) and then by clearcutting (on national forests into 1980s). Single tree and group selection was used primarily on State and private lands into the 1990s. However, on many Federal and State forest lands, the importance of timber management has been reduced while the scope and importance of other forest uses including recreation, education, and interpretation have increased.

## HISTORIC CHANGES BY ECOLOGICAL SECTION

The following discussion describes the general site conditions, past disturbance regimes, and forest types occurring within each section (see fig. 1). The disturbance history is similar across all sections: fire, grazing, and agricultural clearing occurring as common human activities, and wind and ice storms representing frequent natural disturbances. Species composition is driven by climate changes from north to south and east to west interacting with the local disturbance regimes across the assessment area.

### Ozark Highlands Section—Mississippi River Alluvial Plain Subsection (222Ao) and Illinois Ozarks Subsection (222Aq)

The Ozark Hills region in southwestern Illinois is characterized by mature dissected topography capped with loess deposits underlain with cherty limestone (Fralish 1997). Ridgetop sites are relatively narrow spur ridges capped with loess above steep sideslopes of colluvial materials that descend to narrow riparian zones comprised of alluvial soils. Pre-European settlement forests were dominated by oak-hickory species with increased numbers of American beech, sugar maple, and tulip-poplar across more mesic sites (McArdle 1991). McArdle argued that these forests developed under a moderate to infrequent disturbance regime based on the increase in oak-hickory importance after European settlement in response to the more intense disturbance regime of logging and clearing for conversion to agriculture lands, and increased grazing and burning. Indeed, much of the region's forests were extensively logged between 1880 and 1920 and frequent fire was identified as a major problem for forest development in the 1920s (Fralish 1997, Miller 1920, Miller and Fuller 1922). Although much of the Ozark Hills were purchased by the USDA Forest Service in the late 1930s and effective fire control measures were implemented, fires continued through the 1940s.

Despite this disturbance regime, forests of the Ozarks today appear wholly transitional towards sugar maple-beech domination (Fralish 1997, Helmig 1997, Ozier 2001). During the more infrequent disturbances of the 20th century, an understory of maple-beech developed that is slowly coming to dominate forests as the overmature oak-hickory overstory begins to break up (Groninger et al. 2002, Oliver and Larson 1990, Ozier 2001, van de Gevel 2002). Recent management efforts in State forests of this region include prescribed burning of sugar maple understories to top-kill maples and increase advanced regeneration of oak-hickory individuals (Ruffner and Davis 2002, Ruffner et al. 2002).

One important forest type not found elsewhere in the region is the shortleaf pine *(Pinus echinata)*-blackjack oak *(Q. marilandica)* found on the bluffs overlooking the Mississippi floodplain. Turner (1936) described the status of shortleaf pine as "waning" in southern Illinois due to competition from deciduous species and the absence of fire. Suchecki (1997) reported the shortleaf pine overstories at LaRue-Pine Hills were changing to more mesic black oak, white oak, pignut hickory *(Carya glabra)*, and sugar maple. Forest Service attempts to use prescribed burning to increase pine recruitment have unfortunately resulted in a proliferation of oak sprouts across the sites with a near failure of pine recruitment (Suchecki 1997). Davis and Ruffner (2001) reported that pine recruitment appears tied to large overstory gaps at LaRue-Pine Hills.

Infrequent vegetation communities include the numerous hill prairie and barrens on xeric, southwestern ridge sites, notably the Ozark Hill Prairie Research Natural Area, Shawnee National Forest (Perkins 2002), and the Browns Barrens, Union County, managed by the Illinois Department of Natural Resources Natural Heritage Program (McCall and Gibson 1999).

### Upper Gulf Coastal Plain Section—Cretaceous Hills Subsection (222Ca) and Ohio and Cache River Alluvial Plain Subsection (222Ch)

Across the southern tip of southern Illinois lies the northernmost extension of the Gulf Coastal Plain Province (Fenneman 1938). Topography varies from gently rolling uplands to flat, poorly drained bottomlands (Fralish 1997). Presettlement upland forests were largely similar to those of surrounding provinces with oak-hickory dominating dry exposed sites (Schildt 1995). However, due to the predominance of moist sites and lower elevations across the coastal plain, more mesophytic species were reported (Fralish 1997, Schildt 1995). Alluvial sites and northern exposures were nearly dominated by such mesophytes as sugar maple, red maple, American beech, elms, and various ash species. In addition, numerous cypress swamps are located within this region and have been dendrochronologically dated to the mid-1400s.

Small local inclusions of barrens communities occur in the extreme southeastern portion of this subsection and are managed by State and Federal agencies with prescribed fire to maintain the open character of these unique communities (Anderson et al. 2000). Over 25 years, the authors documented vegetation change in relation to altered burning regimes. Many prairie species increased following initial burning of these sites between 1968 and 1973. However, fire cessation has reduced the occurrence of most prairie species while increasing the density and basal area of encroaching tree species. Unfortunately, despite the recent reintroduction of prescribed fire, many prairie species have been lost on these sites and species composition has shifted toward more closed canopy woodland (Anderson et al. 2000).

Major ecological changes across this province include the widespread cutting of forest land in the late 1800s for agricultural lands due to the fine soils and level topography (Fralish 1997). Selective logging of certain species for cooperage and transportation boxes reduced the amount of oak and cypress across the area. With the reduction of oak and the removal of fire from the landscape in the middle of the 20th century, mesophytic species increased in importance even on the driest sites (Fralish 1997).

### Shawnee Hills Section—

#### Southern Indiana and western Kentucky Crawford Escarpment Subsection (222Df), Crawford Upland Subsection (222De), Outer Western Coalfields Subsection (222Dc), and Lower Ohio-Cache-Wabash Alluvial Plains Subsection (222Db)

The Crawford Upland and Crawford Escarpment Subsections are areas of great diversity with steep slopes and narrow valleys (Homoya 1997, Schneider 1966). Oaks and hickory species dominate the uplands, and other species occur on more mesic sites of north slopes and stream valleys. Massive sandstone cliffs occur in the upland and are unique sites for many specialized plant species. The Hemlock Cliffs area on the Hoosier National Forest is an outstanding example of these unique sites where disjunct species such as eastern hemlock *(Tsuga canadensis)* and mountain-laurel *(Kalmia latifolia)* occur. American chestnut *(Castanea dentata)* was also found in this area before being eliminated by the introduced chestnut blight *(Endothia parasitica)*. The Crawford Escarpment Subsection is an area of limestone cliffs that provide unique habitat for specialized species of plants and animals. Other unique communities found in these subsections include limestone and sandstone glades and springs including acid seeps (Bacone and Casebere 1983, Olson 2001).

The Crawford Upland and Escarpment Subsections have a history of clearing for agriculture, grazing by domestic livestock, and human-caused fires. Forests are recovering from these disturbances and are changing in species composition due to recent protection from disturbance. Many specialized communities such as barrens and glades were maintained by past disturbance regimes, but are quickly transitioning to closed canopy forests with protection from fire (Bacone and Casebere 1983, Olson 2001). Prescribed burning has been used since the 1980s to arrest these changes.

The Outer Western Coal Fields Subsection is relatively flat undulating topography with wide valleys (Hedge 1997). This landscape was originally covered with a variety of forest communities with many species of more southern affinity. Southern red oak *(Q. falcata),* post oak *(Q. stellata),* and blackjack oak *(Q. marilandica)* were common on upland drier sites. Poorly drained, acid soils supported a southern flatwoods community dominated by post oak and a mixture of southern bottomland species such as sweetgum and cherrybark oak *(Q. pagodaefolia)*. Fire was probably a factor in maintaining barrens in some of these flatwoods (Olson 2001). Several large tributaries of the Ohio River extend into this subsection with bottomland forest species such as pecan *(Carya illionensis)*, sugarberry *(Celtis laevigata)*, green ash *(Fraxinus pennsylvania),* and American sycamore.

The relatively level topography of the Outer Western Coalfields Subsection has largely remained in private ownership with 47 percent of the landscape in forest cover today. This subsection had vast deposits of coal, which resulted in historic changes different from other parts of the region. Coal extraction began in 1915 and underground mining dominated until the 1930s. Surface mining of coal began in the 1920s, and Indiana led the Nation in surface-mined coal in 1926 and 1927 (Unpublished data, Indiana Department of Natural Resources, Division of Reclamation). Approximately 100,000 acres of land (4%) were disturbed by mining within this subsection from 1941 to 1982. Most of this land (89,934 acres) was in Pike and Warrick Counties. The land mined before 1968 (47,738 acres) was primarily planted to forest species with no soil replacement, grading, or drainage control. From 1968 to 1977, grading of strip-mined lands to approximate original contours was required and much of the acreage was returned to rangeland. After 1977, the Federal Surface Mining and Reclamation Control Act was passed requiring replacement of topsoil and more diversification of restored conditions including criteria for wildlife habitat and wetland uses. Since 1982, 55,834 acres have been strip mined in southwestern Indiana including counties outside the subsections being considered in this report. Some of the restored land has been transferred to public ownership for State parks, forests, and fish and wildlife areas.

## Shawnee Hills Section—

### Southern Illinois (Greater Shawnee Hills Subsection (222Dh) and Lesser Shawnee Hills Subsection (222Di))

The Shawnee Hills make up 950,495 acres of unglaciated east-west escarpment bisecting southern Illinois (Fralish 1997). Topography of this section is characterized by broad ridgetops bearing deep loess deposits dissected by moderately steep sideslopes opening onto broad flat valleys (Fenneman 1938). Pre-European settlement forests of this region were dominated by xerophytic species such as post oak, black oak, white oak, and northern red oak *(Q. rubra)*; mesophytic species such as tulip-poplar, American beech, and sugar maple had low importance values across most sites (Fralish 1997).

Of particular interest were the open savanna woodlands on exposed south-southwestern facing ridges maintained by recurring fire and intermittent droughts (Fralish et al. 1999). At presettlement, a matrix of small isolated patches of post oak, chestnut oak, and eastern redcedar *(Juniperus virginiana)* woodlands was found on uniquely xeric, edaphic sites within the surrounding oak-hickory forest (Fralish et al. 1999). The open canopy structure of these xeric woodlands was probably maintained by recurring fire across this region resulting from Native American burning and lightning fires (Abrams 1992, Fralish 1997, Ruffner and Abrams 1998a).

Following European settlement, the number of fires increased in the forests as did selective cutting and clearcutting of forested areas.

Recurring cutting of oak and hickory species encouraged these species due to their resprouting abilities (Abrams 1992, Fralish 1997, Ruffner et al. 2002). By the early 1910s, long-term harvesting and poor farming practices on highly erodible lands caused many farmers to abandon their farms; much of the land was then sold through the Weeks Act of 1911 and the Clark-McNary Act of 1924 (Conrad 1978, USDA 2000). Original reports of forest conditions in the 1930s suggest that the area had been farmed for over 100 years and that most forest stands had been logged from 1 to 10 times with nearly all the original timber removed and replaced by second-growth forest (USDA 2000). Forest products for the region were listed as "few saw logs, much mining material such as props, ties, lagging, and considerable fruit basket veneer" that supported the numerous orchards (USDA 2000). Clearly, by the mid-1920s, timber quality had been reduced to the point that low value outputs were the only viable products.

Stands disturbed during the early 20th century by harvesting, fire, or grazing are 58 to 84 percent similar to presettlement oak hickory forests, suggesting compositionally stable forests (Fralish 1997, Harty 1978). However, the reduction of harvesting and the eventual near removal of fire from the landscape during the 20th century have caused a shift in importance particularly across northern aspects and low slope positions (Fralish 1997, Hall and Ingall 1910, Miller 1920). Reduced disturbances have resulted in a distinct increase in sugar maple and American beech recruitment into the midstory and understory (Fralish 1997, Ruffner et al. 2002, Schlesinger 1976). The current management objectives of Illinois Department of Natural Resource agencies across this section focus on increasing oak-hickory advanced regeneration while reducing mesophytic stem density with experimental prescribed burns coupled with timber stand improvement cuttings (Allen 2001, Ruffner and Davis 2002). Justification for this rests on the assertion that anthropogenic disturbances (either Native American or Euro-American) have been the driving force influencing forest structure and function across this region for at least the last 400 years (Fralish 1997, Ruffner et al. 2002).

## Highland Rim Section—
### Brown County Hills Subsection (222Em) and Mitchell Karst Plain Subsection (222Ek)

The Brown County Hills Subsection is predominantly a forested landscape with different mixtures of deciduous species occurring on sites due to variation in physiography and soil parent material (Homoya and Huffman 1997, Van Kley et al. 1995). Mixed species forests of sugar maple, American beech, tulip-poplar, northern red oak, and hickory occupy north facing slopes and minor stream valleys. White, black, and scarlet oak *(Quercus cocinea)* and shagbark hickory *(Carya ovata)* species along with red maple are dominant on ridges and south facing slopes. Chestnut oak *(Q. prinus)* occupies the highest and driest ridges. Black maple *(Acer nigrum)*, chinkapin oak *(Q. muehlenbergii)*, and Ohio buckeye *(Aesculus glabra)* are common on sites where limestone soils occur.

The Brown County Hills Subsection is a landscape of steep topography with narrow ridges and valleys (Homoya and Huffman 1997). Although Native Americans were present in the area, they are not believed to have been a major influence on vegetation, so the landscape was likely in forest cover at the time of European settlement in the early 1800s. Early settlers were subsistence farmers, clearing forests on ridges to grow corn, running hogs in the forest, and using native plants and animals for food and shelter. These people also used fire to help them clear forests. Most of the large trees were burned in the early 1800s due to a lack of technology to produce lumber. Tanneries were important in this subsection due to the need for bark from the chestnut oak (Eagleman 1981).

Increased logging due to railroads allowed more land to be settled and farmed in the late 1800s. With most of the flat, alluvial land occupied, settlers either cultivated or grazed livestock on steeply sloping lands. These practices continued into the 1930s when economic conditions and degraded resources forced many farmers from the area. An examination of land use in the Charles C. Deam Wilderness of the Hoosier National Forest using 1939 aerial photography found 33 percent of the 13,000 acres in agriculture or old fields, 26 percent in open canopy forest (indicating livestock grazing), and the remaining 41 percent in closed canopy forest. Upland flats and stream bottoms were most heavily cleared for agriculture, although nearly 20 percent of the slopes were also cleared (Jenkins and Parker 2000). Declining productivity due to widespread topsoil erosion and changing agricultural technology better suited to more level topography placed these farms in a less economically competitive position.

Much of the Brown County Hills area was transferred from private to public ownership as farmlands were abandoned or willingly sold beginning in the early 1900s. Land first purchased for the Brown County Game Preserve in 1924 later became Brown County State Park (Eagleman 1981). The Hoosier National Forest was established in 1935. With farm abandonment and conversion to public ownership, much of the area has returned to forest cover. Many of the badly degraded areas were planted to pine species by the Civilian Conservation Corps during the depression years in the 1930s and 1940s. Today, approximately 67 percent of the Brown County Hills landscape is covered by forest.

The Mitchell Karst Plain Subsection was the largest area of western mesophytic forest found in Indiana (Lindsey et al. 1969). A rich mixture of deciduous tree species on more productive soils characterized the area. Donaldson Woods in Spring Mill State Park is a good example of presettlement forest (Lindsey and Schmelz 1965). Much of this forest is dominated by seral tree species, such as white oak, probably the result of Native American activities. Native Americans are believed to have used fire in this area on an annual basis. The shallow, droughty soils and limited surface streams in this karst topography allowed fires to spread widely across the landscape and were an important factor affecting the native vegetation (Homoya and Huffman 1997). For example, eastern redcedar, a common species throughout the landscape today, was probably much less common during this period of annual burning. Barrens were common in the southern part of this subsection on dry, infertile soils. This community, maintained by fire, was a mixture of scattered post oak and blackjack oak with understories of prairie grasses and forbs (Homoya 1994, Olson 2001).

The history of the Mitchell Karst Plain Subsection is similar to that of the Brown County Hills except settlement occurred more rapidly in the former due to the less rugged topography. Although the soils are shallow in the Mitchell Karst Plain Subsection, the topography was more suitable to permanent clearing for agriculture and livestock grazing. As a result, more of this area has remained in private ownership and nonforest cover. Approximately 29 percent of this subsection is in forest cover. This area has also been the source of limestone rock for buildings, and numerous open pit quarry mines are scattered across the landscape.

## EFFECTS OF NATURAL AND HUMAN DISTURBANCE ON FOREST DEVELOPMENT

Disturbance is widely considered to be important in maintaining diversity of species and community structure and function within landscapes (Attiwil 1994, Loucks 1970). Species composition is constantly changing across the region due to an array of disturbance factors including type, frequency, and intensity. This section focuses on the principal exogenous disturbances including fire (largely human caused) and other natural disturbances such as wind, ice, drought, and biotic factors. These disturbances are discussed in context of their frequency and intensity in relation to influencing species composition across the landscape.

## Disturbance From Fire

There is little doubt that fire was an important historical factor throughout the region based on numerous accounts of early travelers (McCord 1970). However, little information exists on the size, frequency, and intensity of fire on specific sites or sections (Robertson and Heikens 1994). Nonetheless, a growing body of evidence for the region supports the widespread role fire played in forest systems across the assessment area.

### Native American-caused fires

Most of the fires before 1800 were due to Native American activities. Fire was used regularly to clear land for agriculture, aid in hunting, and stimulate plant growth. Early travelers and surveyors reported areas of grassland and barrens in the early 1800s. These communities, with fire-tolerant plant species, were maintained via Native American burning and some natural lightning-caused fire. Although Native Americans may have set fires whenever conditions were suitable, most fire probably occurred in late summer and fall when grasses were dry and forest leaf litter was abundant. Fires were allowed to burn until natural breaks, such as streams, were encountered. During drought years, these fires would have spread over large areas of the landscape. These widespread fires were important in maintaining more open forest understories and in promoting tree species tolerant of periodic fire such as oak, hickory, and shortleaf pine.

Although presettlement fire history data are currently unavailable for the region, fire as a natural component of the ecosystem is widely accepted (Abrams 1992, Fralish 1997, Heikens and Robertson 1995, Robertson and Heikens 1994, Ruffner et al. 2002). Fire histories for the Missouri Ozarks have been widely studied by Guyette and associates. General trends across southern Missouri indicate that during periods of Native American settlement (1701-1820), fire return intervals were longer (11.96 years + 2.4, Mean + SE) than those during European settlement (3.64 years + 0.35) (adapted from Guyette and Cutter 1991). The authors attribute this disparity to the scattered, ephemeral distribution of Native settlements compared to the extensive clearing and agricultural development of European settlers. It must be understood that these data represent the fire history of only the southern Missouri Ozarks. However, we suggest that most forest ecologists would agree with the assumption that similar relationships existed across the region. Because Native settlements were distributed across the Ozarks and Shawnee Hills, forests of this province were probably impacted by burning by Native and European settler. While Woodland Indian cultures of the region probably depended largely on “Three Sisters” agriculture (maize-beans-squash), they continued to practice hunting and gathering of wild faunal and floral resources into the Historic period (Black and Abrams 2001, Delcourt et al. 1998, Gardner 1997, Ruffner 1999, Ruffner and Abrams 2002).

Archaeologists believe these agrarian groups practiced a form of swidden agriculture in which forests were cleared and burned to create open areas. Cultigens included sunflowers, maize, squash, and beans. Crops were cultivated in cleared fields extending out from the central settlement. Fields were cultivated until crop harvests decreased enough (8-12 years) to warrant moving the village to another site (Ritchie and Funk 1973, Sykes 1980). Although it is widely accepted that Native populations had sharply decreased before contact, Indian groups still inhabited and farmed settlements along major riverways. Thus, by the time of European contact (AD 1650), the anthropogenic landscape resembled a mosaic pattern of 1) croplands near settlements, 2) abandoned clearings with early successional taxa, and 3) open forest stands dominated by fire-adapted species such as oak, hickory, and walnut (*Juglans nigra*) (Black and Abrams 2001, Chapman et al. 1982, Delcourt 1987, Delcourt et al. 1998, Ruffner 1999, Ruffner and Abrams 2002).

**Historic period fires**

Although some fires probably started from lightning on dry sites during dry years, fire in this region has mostly been the result of human activities (Skinner 1939). While there is little documented evidence of lightning-caused fire (cf. Ruffner and Abrams 1998b), Martin (1991) speculated these fires most likely occurred in late summer on the top of dry ridges as smoldering embers in hollow trees, and then spread to dry leaf litter.

In this region, lightning-caused fires most likely occur during dry years and, therefore, could spread over large areas of the landscape. Of the 311 fires reported for the Hoosier National Forest from 1973 to 2000 for which a cause was listed, lightning was given as the cause in two fires (USDA 2001). One occurred in July 1976 and the other occurred in April 1996. Both fires were 0.1 acre in size. All other causes were attributed to human activities.

Regional studies reporting Historic period fire histories indicate that fire ignitions were high during this period due to farmers clearing underbrush from the forest (Miller 1920, Robertson and Heikens 1994). Reports during the early 1900s noted that farmers annually burned forests to increase regeneration of grasses and forbs as well as to reduce the understory to ease hunting and travel (Hall and Ingall 1910, Miller 1920). Clearly, forests could not be burned annually for lack of adequate fuels from year to year. However, these early accounts probably describe some portions of the forests being affected by fires each year but not complete burning of the woods (Robertson and Heikens 1994).

Following the frequent burning of the settlement period, fire disturbances were largely controlled or removed after the turn of the 20th century. Numerous local bans on fires and regional laws forbidding this activity led to the overwhelming decrease in ignitions after 1900 (Miller 1920). Major efforts to detect and control wildfires from 1920 to 1940 are reflected in the numerous fire towers erected, the assignment of fire wardens, and to a large extent the efforts of the Civilian Conservation Corps throughout the New Deal years. At the time, foresters suggested that fire control was essential for maintaining forest health and integrity (Miller 1920, Pyne 1982). Thus, the effects of periodic fire in maintaining a healthy oak-hickory forest were removed, and many recent authors cite a significant shift in species composition across much of the region after this (Fralish et al. 1991, Parker 1989, van de Gevel 2002, Weaver and Ashby 1971).

Another way to explore this change in species composition is through investigating the long record (>200 years) of continuous recruitment by oak and hickory species on many sites including the mesic oak woodlands of the Shawnee Hills (Ruffner et al. 2002) and xeric uplands of the Ozark Highlands (van de Gevel 2002) (fig. 2A, B). These age/diameter graphs reflect the date of establishment for each tree cored on a site and can provide insight into the changes in species composition during the history of the stand. From these and many other studies, a clear pattern emerges. Oak and hickory recruitment tended to dominate such sites up until the early 20th century. However, composition changed quickly when between 1920 and 1940 a large cohort of later successional "fire intolerants" established themselves, representing the period when

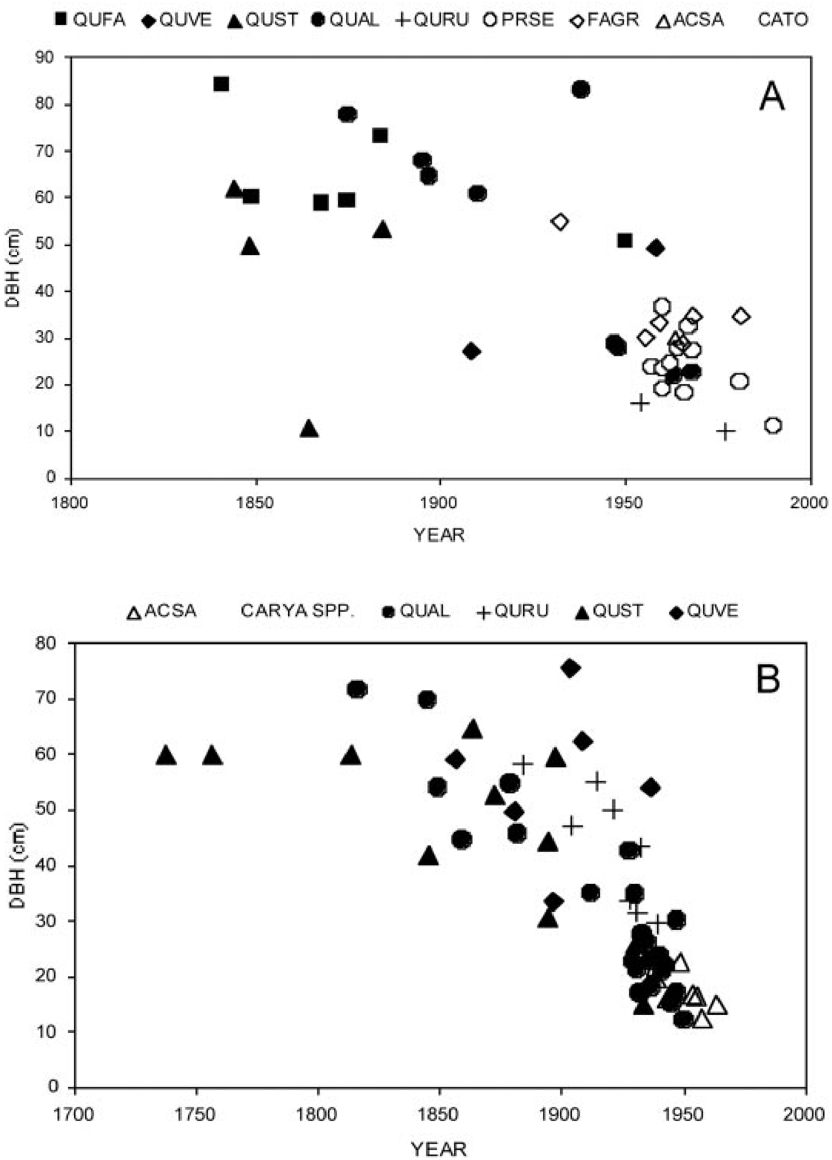


**Figure 2.** Age-diameter relationships for cored trees at selected forest sites in southern Illinois.

A) Thompson Woods, Southern Illinois University Campus, Carbondale.

B) Trail of Tears State Forest, Union County.

QUFA = *Quercus falcata,*
QUVE = *Q. velutina,*
QUST = *Q. stellata,*
QUAL = *Q. alba,*
QURU = *Q. rubra,*
PRSE = *Prunus serotina,*
FAGR = *Fagus grandifolia,*
ACSA = *Acer saccharum,*
CATO = *Carya tomentosa*

effective fire control measures were enacted across the region. It appears that the cessation of fire encouraged recruitment of fire-intolerant species such as sugar maple and American beech at the expense of fire-adapted oak and hickory species (Abrams 1992, Lorimer 1985, Schlesinger 1976).

## Wind

Wind is an important factor in opening forest canopies for more rapid growth of understory trees. Increasing sunlight to the forest floor also allows species intolerant of shade to grow and reproduce. Wind's influence on species composition depends on site condition, species present, and extent of canopy removal. Small openings due to wind may favor shade-tolerant tree species present before canopy removal, whereas large openings may favor a mix of tolerant and intolerant species. Intolerant species are more likely to be favored on drier sites.

Severe windstorms or tornadoes occur frequently, but irregularly throughout the assessment area (NCDC 2001). Severe wind-caused disturbances, in the form of windsheer or tornadoes, can have an intense impact on vegetation, normally felling the overstory and creating large, open areas that typify early successional habitat (Peterson and Pickett 1990). Tornadoes reported across the assessment area from 1950 to 1995 varied largely in intensity and area affected (NCDC 2002).

In Indiana, one of the largest tornadoes occurred in Jackson County in 1963 and had a track 85 miles long and 1,400 yards wide. The data indicate tornadoes are less common in the Highland Rim Section than in the Shawnee Hills Section. Two tornadoes occurred on the Hoosier National Forest from 1990 to present. The first damaged approximately 1,000 acres of the northern part of the Crawford Upland Subsection in 1990. The second occurred on the Brown County Hills Subsection in 1996 and damaged approximately 1,500 acres.

Many notable tornadoes have impacted the southern Illinois region during the past several decades, in particular, the Tri-state Tornado of 1925. This killer tornado devastated a wide swath between the Ozark Hills in southeastern Missouri across the Ozark and Shawnee Hills of southern Illinois and into the Wabash basin of southern Indiana. It appears that tornadoes have always been an important disturbance across the assessment area (NCDC 2002). Indeed, historical accounts taken from Native Americans at Fort Kaskaskia indicate numerous large tornadoes impacting the southern Illinois landscape (Meyer 1996).

Similar in effect, but less intense are windsheer events, or downbursts. Downbursts are generally explained as extreme, localized cells of high intensity winds that are forced downward from storm clouds. Downbursts can also have devastating effects on forest structure, opening large gaps in mature overstory canopies. It appears that these are quite common in southern Illinois and have been responsible for destroying several noted old-growth stands, namely the Weaver tract near Jonesboro and the Thompson Woods tract in Carbondale (Roth, unpublished data; Ruffner et al. 2002). Downburst gaps are characterized by a large hole in the canopy in which many dominant overstory trees have been blown down, resulting in an even-aged patch of species spanning the successional continuum. Advanced regeneration or shade-tolerant species would tend to capture the open gap, but early successional species do seed in portions of the area with the highest amount of light and, with their fast growth rates, can maintain a presence in the canopy (Ruffner et al. 2002). Thus, high-intensity wind disturbances tend to benefit early successional species such as oaks, hickories, black cherry *(Prunus serotina)*, and birches (*Betula* spp.).

Lighter wind disturbances generally cause single-tree mortality or simply blow down an already stressed or dead stem, creating a small canopy gap. These gaps tend to be captured quite quickly by residual trees by way of lateral encroachment of foliage into the open space (Canham 1985). The smaller open area, coupled with the short period of increased light, favors later successional species that may already be present in the understory. Because of the lack of understory fire during the 20th century, species such as sugar maple and beech typically dominate the seedling and sapling layers of many forest stands and generally benefit from these small canopy gaps. It appears certain that small overstory canopy gaps are too small to regenerate oak species (Abrams et al. 1995, Jenkins and Parker 1998, Ozier 2001, Ruffner and Abrams 1998b). Current research is underway to better understand gap dynamics within mature oak-hickory forests of southern Illinois (Ruffner and Groninger, unpublished data). In the Ozark Hills, early data suggest that sugar maple and sweetgum seedlings come to dominate small, single-tree canopy gaps formed by overmature red and white oaks.

### Ice and Snow

Occasional ice (glaze) and snowstorms cause damage to trees such as top breakage and uprooting of species such as eastern redcedar, tulip-poplar, and sweetgum. The National Climatic Data Center reported 14 winter storms from 1993 to 2000 in Brown County, Indiana (Highland Rim Section). Two were reported as heavy snow and one as a sleet/ice storm. The remainder were extreme cold or winter storms. In contrast, Perry County, Indiana, in the southern part of the Crawford Upland (Shawnee Hills Section) had five storms reported from 1970 to 2000. Three of these were heavy snow. In Warrick County, Indiana (Outer Western Coal Field of the Shawnee Hills Section), 15 storms were reported; 1 of these was heavy snow and 6 were freezing rain or ice storms. USDA Forest Service records from 1990 to the present reported snow damage to approximately 300 acres in the southern part of the Crawford Upland Subsection in 1996.

Most glaze ice damage involves large branch breakage without the loss of the whole tree, thus creating scattered canopy openings of varying size. Several glaze storms have been detected in tree rings from forests of the Ozark Hills region of southern Illinois (Davis and Ruffner 2001, van de Gevel 2002, van de Gevel and Ruffner 2002). At the Trail of Tears State Forest, Union County, Illinois, glaze storms damaged fast growing tulip-poplar and sweetgum crowns on bottom sites, which fostered a recruitment pulse of tulip-poplar, hickory, white oak, and sweetgum in the understory (van de Gevel 2002). On exposed cliffs and ridges of the

LaRue Pine Hills Research Natural Area, Union County, Illinois, recruitment of native shortleaf pine appears tied to canopy gaps formed by ice storms that damaged tree crowns (Davis and Ruffner 2001).

Generally, in the Midwest, white oak and shagbark hickory are some of the species considered least susceptible to ice storm damage (Rebertus et al. 1997). Damage severity is highly variable across the Midwest, but trees on lower slopes and mesic aspects tend to have more damage (Rebertus et al. 1997).

## Drought

Although severe drought can kill plants that expanded their range to drier sites during moist years, the combined effect of fire with drought is probably more important than that of drought alone. Visher (1944) reported that drought occurred approximately every 10 years in southern Indiana from 1900 to 1939. Drought has several implications for forests of the region including stress and vulnerability to pest infestation, reduced growth rates, and interactions with fire.

Dendroecological studies have reported the synergistic effects of drought and fire in forests of southern Illinois (Ruffner et al. 2002, van de Gevel 2002, van de Gevel and Ruffner 2002). Analysis of a 275-year-old post oak stand revealed significant relationships between drought severity and radial growth dynamics from 1895 to the present (van de Gevel 2002). Van de Gevel also reported that severe droughts (PDSI >2.5) drastically reduce radial growth for up to 2 years and may increase a tree's susceptibility to insects or pathogens.

## Floods

The influence of flooding on forests depends on the length of time water remains and the time of year that the flood occurs. Winter floods are less damaging than are summer floods. Generally, control of species composition by flooding is more common along the floodplains of larger streams. Flooding along small headwater streams is generally brief enough that species are not killed. Flooding also moves substrate within stream channels and causes erosion of streambanks. In Brown County, Indiana, six floods were reported from 1993 to 2000: two during winter and the other four in April or May. In Perry County, 22 floods were reported from 1970 to 2000: 5 during the winter, 16 during spring (March to May), and 1 in July. In Warrick County, 31 floods occurred from 1970 to 2000: 10 during the winter, 14 in spring (March through June), and 7 during summer (July and August).

## Biotic Disturbance

Although insects and disease occasionally defoliate and kill trees, widespread soil erosion due to clearing for agriculture and free-roaming livestock has been the most important biotic disturbance to occur in the region. Forest Service records on date of initiation of forest stands indicate that 69 percent of the Hoosier National Forest was established between 1800 and 1940. Although stand-replacing events such as tornadoes were occurring during this period, most stands were initiated due to the widespread disturbance by human activities. About 31 percent of the stands on the national forest were begun after 1940 or during the period of transfer from private to public ownership.

Overhunting and habitat destruction had greatly reduced white-tailed deer populations by 1900. Reintroduction programs and management since the 1930s and 1940s have allowed deer populations to recover and even exceed their historic levels. Understories of forests in areas protected from hunting since the 1960s have been negatively impacted by this species (Webster and Parker 1997).

Pathogens such as chestnut blight and Dutch elm disease have changed the structure of forests throughout the assessment area (Parker and Leopold 1982). The American chestnut, a minor component of forest in southern Indiana, has been largely eliminated due to blight introduced in the early 1900s. Elm species, particularly American *(Ulmus americana)* and slippery *(U. rubra)*, have been greatly reduced as canopy trees due to the introduced Dutch elm disease and phloem necrosis.

## CURRENT ECOLOGICAL CONDITIONS

### Forest Types by Ecological Section

For this assessment, area by major forest type is based on Forest Inventory and Analysis data of the USDA Forest Service (FIA Web site). Although the most current data were used (1998), the date of collection varies by State. Forest types have been combined into seven general cover types due to limitations in the number of sample points for any given type within a subsection (table 1). These general types are quite variable across the assessment area due to north-south and east-west changes in species composition. Forest types are named after the dominant species currently present on the landscape. Many of these types are the result of past disturbance and are gradually changing in species composition. For example, the oak-hickory forest type currently covers more of the region than any other forest type but is gradually transitioning to beech-maple or upland mixed hardwoods types on nearly all site types.

#### Pine-cedar forest type

**Highland Rim Section—**This forest type is currently dominated by eastern white pine (*Pinus strobus*), shortleaf pine and loblolly pine (*Pinus taeda*), or eastern redcedar. Some stands of red pine (*Pinus resinosa*) are also present. These forests are primarily the result of the planting of pines on lands that were in agriculture or the natural invasion of eastern redcedar into pasture or croplands. Eastern redcedar is a more common species on limestone soils of the Mitchell Karst Plain Subsection. Hardwoods species such as red oaks, tulip-poplar, black cherry, and other miscellaneous species will gradually replace the current overstory species as they age. Management activities such as logging and prescribed fire will hasten the conversion of this type to native hardwoods.

**Shawnee Hills Section—**The change in this forest type is similar to that described for the Highland Rim Section (primarily within Indiana) except that Virginia pine (*Pinus virginiana*) becomes the dominant species in the extreme southern portion of the Crawford Upland and Escarpment Subsections (table 1). This native pine invades old fields or poor sites after fire and is transitional to hardwood species (Fowells 1965). The western portion of the section in Illinois and Kentucky has native shortleaf pine as well as planted species. Few pure pine stands exist in southern Illinois except where planted for erosion control or reforestation by the Civilian Conservation Corps (CCC) and State forests. Of these, many loblolly pine stands are in an advanced stage of succession with hardwood encroachment. Eastern redcedar has increased across the assessment area in abandoned fields and is generally transitional to hardwoods except in limited redcedar glades on exposed sandstone or limestone outcrops. Illinois Department of Natural Resource heritage biologists also use prescribed fire to maintain cedar glade habitats by reducing hardwood encroachment on sites spanning the Shawnee Hills and Ozark Hills of southern Illinois.

#### Pine-hardwood forest type

**Highland Rim Section—**This forest type is a mixture of planted pine species (primarily white, shortleaf, and loblolly) and various species of native hardwoods. This type is transitional from pine to hardwood species because the pine species were planted and are not regenerating.

**Table 1.** Area of forest land by forest type for each subsection within the Hoosier-Shawnee Ecological Assessment Area based on FIA data (1998).

| FOREST TYPE | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Subsection** | **P/C** | **P/H** | **PO/SSO** | **O/H** | **B/M** | **MUH** | **BH** | **NS** | **Total** |
| *Acres* | | | | | | | | | |
| **Ozark Highland Section** | | | | | | | | | |
| 222Ao | | | | 31,742 | 1,680 | 529 | 47,795 | 1,680 | 83,424 |
| 222Aq | 746 | 5,454 | 6,592 | 128,598 | 44,223 | 9,458 | 17,440 | 289 | 212,800 |
| Total | 746 | 5,454 | 6,592 | 160,340 | 45,902 | 9,986 | 65,235 | 1,969 | 296,224 |
| **Upper Coastal Plain Section** | | | | | | | | | |
| 222Ca | | 3,883 | 2,368 | 27,820 | 9,718 | | 24,861 | | 68,650 |
| 222Ch | | 2,336 | 7,360 | 16,094 | 10,157 | 45,302 | 16,858 | | 98,106 |
| Total | | 6,219 | 9,728 | 43,914 | 19,874 | 45,302 | 41,719 | | 166,756 |
| **Shawnee Hills Section** | | | | | | | | | |
| 222Da | | | | 37,374 | | 102,180 | 51,650 | | 191,204 |
| 222Db | | | | 23,058 | 7,271 | 22,966 | 61,191 | | 114,486 |
| 222Dc | 60,806 | 43,428 | 57,115 | 270,035 | 81,659 | 378,916 | 125,336 | 10,233 | 1,027,527 |
| 222Dd | 8,705 | 6,812 | 17,367 | 39,052 | 6,625 | 42,292 | | | 120,854 |
| 222De | 13,762 | 18,559 | 29,745 | 333,246 | 235,641 | 30,323 | 36,780 | 7,066 | 705,121 |
| 222Df | 10,439 | 14,746 | 3,241 | 102,656 | 79,826 | 16,720 | 6,612 | | 234,238 |
| 222Dg | 21,098 | 12,013 | 25,604 | 90,570 | | 168,472 | 12,104 | | 329,860 |
| 222Dh | 11,360 | 12,943 | 13,291 | 165,003 | 30,991 | 7,139 | 26,801 | | 267,529 |
| 222Di | 9,214 | 7,106 | 7,718 | 122,162 | 32,797 | 12,894 | 22,175 | | 214,066 |
| 222Dj | 19,457 | 31,697 | 28,871 | 93,405 | 45,548 | 278,064 | 17,520 | | 514,563 |
| Total | 154,841 | 147,303 | 182,952 | 1,276,559 | 520,357 | 1,047,072 | 360,170 | 17,299 | 3,719,447 |
| **Highland Rim Section** | | | | | | | | | |
| 222Ek | 29,817 | 26,022 | 9,889 | 129,358 | 113,458 | 92,154 | 17,079 | 171 | 417,947 |
| 222Em | 13,148 | 5,676 | 1,172 | 233,904 | 95,565 | 18,906 | 23,366 | 278 | 392,015 |
| Total | 42,965 | 31,698 | 11,061 | 363,262 | 209,023 | 111,060 | 40,444 | 449 | 809,962 |
| Total | 198,552 | 190,674 | 210,333 | 1,844,075 | 795,156 | 1,213,420 | 507,568 | 19,717 | 4,992,389 |

P/C= Pine/Cedar, P/H= Pine/Hardwoods, PO/SSO= Post Oak/Southern Scrub Oak, O/H= Oak/Hickory
B/M= Beech/Maple, MUH= Mixed Upland Hardwoods, BH= Bottomland Hardwoods, NS= Non-stocked.
For subsection identification and location, see figure 1.

**Shawnee Hills Section—**This forest type in the eastern portion of this section (primarily within Indiana) is similar to that described in the Highland Rim Section except that Virginia pine is an important species in the extreme southern portion of the Crawford Upland and Escarpment Subsections.

**Ozark Highlands Section—**The only stands of native shortleaf pine within this section occur at the Piney Creek reserve in northwestern Jackson County, Illinois, and the LaRue-Pine Hills Research Natural Area of Union County, Illinois. Both these areas appear to be edaphic climax forests on extreme southwest facing bluffs and ridges (Davis and Ruffner 2001, Suchecki 1997). Frankly, these two areas can more accurately be labeled as pine-hardwood forest type due to the high percentage of blackjack and black oak in these stands. At first glance, it appears that these stands may be transitional toward oak domination, but recent research into stand structure suggests that oak has been a component of these forests for several hundred years (Davis and Ruffner 2001, Suchecki 1997). Forest Service prescribed burning in the late 1980s resulted in prolific sprouting of oak and hickory species and little pine regeneration (Suchecki 1997). Most researchers agree that successive, hot fires are required for pine recruitment on these sites. At present, successful shortleaf pine regeneration appears tied to large gap-phase dynamics across bluffs on these sites, but much more research needs to be completed to understand the successional status of these forests.

### Post Oak-Scrub Oak forest type

**Highland Rim Section—**This type is included with the oak-hickory type in this section.

**Shawnee Hills Section—**Post oak barrens of Illinois and Indiana generally occur in one of two unique ecological conditions. The first of these conditions is the post oak flatwoods of the Till Plains and Outer Western Coal Fields Subsections where a soil fragipan prohibits drainage during the wet spring and is exceedingly dry during the late summer. Post oak is the only species that can tolerate these soil extremes and appears successionally stable on these rare sites (Fralish 1997). The other unique post oak sites are the extreme southwest facing, rock strewn hilltops of the Ozarks and Shawnee Hills of southern Illinois (Fralish 1997, van de Gevel 2002). These successionally stable sites are dominated by post oak with small numbers of white and black oak as associates (Fralish 1997).

Chestnut oak barrens in southern Illinois contain nearly pure chestnut oak overstories with shrub and herbaceous species in the understory (Spivey 2000). These barrens sites are considered edaphic climaxes where no potential replacement species are as drought tolerant as the chestnut oak and appear to be compositionally stable (Fralish 1997). In Indiana, this type is found on narrow ridges and south to southwestern slopes on soils, with thin A horizons, that are droughty in summer and fall (Bacone and Casebere 1983, Van Kley 1993). Post oak and white oak, along with black, chinkapin, and chestnut oak, and pignut hickory, dominate the better sites. Understory species include white ash along with sugar maple and black and white oak. Post oak along with blackjack oak, eastern redcedar, and white ash dominates on poorer sites. White ash, eastern redcedar, post and blackjack oak, and persimmon (*Diospyros virginiana*) are common understory species on these poorer sites. Prescribed fire is being used on public lands to maintain the prairie component in these communities.

### Oak-hickory forest type

**Highland Rim Section—**This forest type is a highly variable mixture of species depending on site condition and disturbance history. The type tends to be transitional to more shade tolerant hardwoods species on most sites (Jenkins and Parker 1998, Lindsey and Schmelz 1965, McCune and Menges 1986). Van Kley et al. (1995) sampled forests within this section to develop a habitat classification system for the Hoosier National Forest. They found forest composition was strongly associated with physiographic location, soil pH, and depth of the A soil horizon. This forest type was primarily found on dry-mesic ridges and south to southwest slopes. Chestnut oaks mixed with white oak stands were restricted to dry narrow ridges or middle to upper convex, southwestern slopes. Red maple, sugar maple, and American beech were the most common understory species in these stands. White oak, mixed with black oak and pignut hickory, was common on dry-mesic ridges and steep south slopes. The current understory species composition of this forest type indicates a gradual shift in species composition to more shade tolerant hardwoods if left undisturbed.

**Shawnee Hills Section—**Across the assessment area, oak-hickory is the dominant forest type with most subsections ranging from 45 to 55 percent oak-hickory (table 1). Although the dominant canopy individuals represent this forest type, the sapling and midstory classes are commonly dominated by more mesophytic species such as sugar maple, American beech, and tulip-poplar. This transitional forest is most apparent on north and east facing slopes where evapotranspiration rates are lower, but it is becoming more common on other slopes as well due to the fire exclusion policies and reduced harvesting levels of the 20th century. Thus, according to Fralish (1997), few compositionally stable oak-hickory stands exist across this region and occur only under the most extreme topographic conditions. In Indiana, the oak-hickory forest type is primarily found on convex knobs, dry ridges, and south to southwestern slopes (Van Kley et al. 1995). Species composition shifts with physiographic position and depth of the soil A horizon. Upper elevation convex knobs and nose slopes are dominated by chestnut oak with white, black, and scarlet oaks and pignut hickory as common associates. Chestnut oak and sassafras, along with black, scarlet, and northern red oak and pignut hickory, are major understory species. Upper southwestern slopes are dominated by chestnut and white oak with pignut hickory, and black and scarlet oak as associates. Chestnut oak and sassafras, along with American beech, red maple, blackgum (*Nyssa sylvatica*), sugar maple, black oak, and pignut hickory, are common in the understory. White, black, and chestnut oaks and pignut hickory dominate narrow, convex ridges with occasional fragipans. Sugar maple, a common overstory associate, dominates the understory. White oak, along with black oak and sugar maple as common associates, dominates south slopes. Sugar maple, American beech, and red maple are common understory species. Poorer sites seem to be fairly stable in species composition, while better sites appear to be shifting toward more shade tolerant species.

### Beech-maple forest type

**Highland Rim Section—**Separation of this forest type from the mixed upland hardwoods type is based primarily on how dominant sugar maple and American beech are within the stand (Jenkins and Parker 1998, Van Kley 1993 and 1994). Currently one or both of these two species strongly dominate sites found on steep, convex east and west slopes with limestone soils, headwaters of intermittent streams, and elevated portions of larger streams. East and west slopes are dominated by sugar maple with American beech, northern red oak, and shagbark hickory as common associates. Sugar maple, American elm, and blue ash (*Fraxinus quadrangulata*) are the most common understory species, and American beech, white ash, black maple, and Ohio buckeye are common associates. Headwaters of intermittent streams are dominated by sugar maple and American beech with black and northern red oak and shagbark and pignut hickory as associates. Sugar maple, red maple, and white ash are the most common understory species. Elevated portions of larger streams are dominated by sugar maple, red maple, and American beech. American beech with sugar maple, red maple, and shagbark hickory as associates are common understory species. This type appears to be stable in species composition.

**Shawnee Hills Section—**This forest type is considered late successional due to the high understory tolerance of the principal species and thus is considered the climax forest type for the region (table 1) (Braun 1950, Küchler 1964, Petty and Lindsey 1961). Historically, the highest proportion of this forest type has been found in the northeastern portions of the assessment area in central Indiana where soil nutrient status is higher due to the limestone parent material. In other areas, this forest type dominates mesic footslope and lowland positions where few soil limitations exist and oak-hickory species are outcompeted. In Indiana, this type is primarily found on sheltered northeast slopes of narrow valleys, on benches and lower slopes, or on level footslopes along streams in narrow valleys. This type is dominated by sugar maple and American beech with sugar maple occurring as the most common understory species. As disturbance is reduced across much of the region, this forest type appears to be expanding onto sites previously dominated by disturbance-oriented species.

### Mixed Upland forest type

Highland Rim Section—This type occurs on steep, linear to concave north slopes or along narrow bottoms of intermittent to perennial streams (Jenkins and Parker 2001, Van Kley et al. 1995). It currently includes a mixture of hardwood species such as tulip-poplar, oak and hickory species, sugar maple, and American beech. The understory is usually dominated by sugar maple and American beech indicating that it will transition to the beech-maple type without disturbance.

Shawnee Hills Section—This type appears to be transitional to the beech-maple type and currently has a mixture of species due to past disturbances. It occurs on broad flat ridges with fragipans and on backslopes of varying aspect with limestone soils or concave shapes. A mixture of upland hardwood species occurs in the overstory with sugar maple and American beech the most common understory species.

### Bottomland hardwoods forest type

Highland Rim Section—This type is primarily found along floodplains of major streams. Major species include silver maple, boxelder (*Acer negundo*), green ash, and American sycamore. Boxelder and silver maple are the most common understory species.

Shawnee Hills Section—This type varies in species composition depending on geographic location within the section. Major species include eastern cottonwood, American elm, green ash, silver maple, and sweetgum in the northern areas. Swamp chestnut, cherrybark and overcup (*Quercus lyrata*) oaks, pecan, and water tupelo (*Nyssa aquatica*) occur further south in the section.

## Land Cover Classes and Forest Type Distribution Within Ecological Subsections

The following land cover data are based on an assessment of 1992 Landsat Thematic Mapper Data and ancillary data sources (Vogelmann et al. 1998). Current land use reflects the past history of human activity in relation to topographic variation across the region (table 2, fig. 3). Subsections with the greatest topographic relief have regenerated to forest cover in greater proportion than subsections with more moderate terrain. Land use in the 12.2-million acre assessment area is predominantly forest (43%) or agriculture (49%) (table 2). The remaining 8 percent is in urban (1.8%), wetlands (3.0%), water (2.5%), and barren or transitional land (0.6%). Patterns of land ownership within both national forests are quite similar (fig. 4). Private landowners clearly dominate the landscape in each purchase area. The Shawnee National Forest owns 27 percent of its purchase unit whereas the Hoosier National Forest owns 31 percent of its purchase unit. Other landowners, including some corporate and various State and Federal agencies, hold much of the remaining land.

Fragmentation of the forested area within each subsection is based on an analysis of Advanced Very High Resolution Radiometer (AVHRR) data using FRAGSTATS (table 3). FRAGSTATS is a computer program used to analyze spatial patterns of large land areas (McGarigal and Marks 1994). Thus, subsections with smaller forest patches and thus higher patch density (per 100 acres) are more fragmented by other land uses (note values in each subsection description). The estimated area of forest for each subsection using either AVHRR data or FIA data is compared in table 4 (Zhu and Evans 1994).

**Table 2.** Land use within the Hoosier-Shawnee Ecological Assessment Area based on 1992 National Land Cover Data Analysis.

| Subsection | Total Area | Forest | | Agriculture | | Urban | | Wetlands | | Water | | Other land | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *Acres* | *Acres* | *%* | *Acres* | *%* | *Acres* | *%* | *Acres* | *%* | *Acres* | *%* | *Acres* | *%* |
| **Ozark Highland Section** | | | | | | | | | | | | | |
| 222Ao | 469,537 | 53,367 | 11.4 | 261,237 | 55.6 | 39,594 | 8.4 | 58,099 | 12.4 | 55,948 | 11.9 | 1,292 | 0.3 |
| 222Aq | 546,060 | 199,371 | 36.6 | 310,351 | 56.8 | 12,767 | 2.3 | 15,223 | 2.8 | 7,366 | 1.3 | 983 | 0.2 |
| Total | 1,015,597 | 252,738 | 24.9 | 571,588 | 56.3 | 52,362 | 5.2 | 73,322 | 7.2 | 63,314 | 6.2 | 2,275 | 0.2 |
| **Upper Coastal Plain Section** | | | | | | | | | | | | | |
| 222Ca | 192,877 | 60,448 | 31.3 | 123,525 | 64 | 751 | 0.4 | 7,212 | 3.7 | 939 | 0.5 | 0 | |
| 222Ch | 354,200 | 70,205 | 19.8 | 183,568 | 51.8 | 12,817 | 3.6 | 48,686 | 13.7 | 37,749 | 0.7 | 1,176 | 0.3 |
| Total | 547,078 | 130,653 | 23.9 | 307,093 | 56.1 | 13,568 | 2.5 | 55,899 | 10.2 | 38,688 | 7.1 | 1,176 | 0.3 |
| **Shawnee Hills Section** | | | | | | | | | | | | | |
| 222Da | 830,540 | 163,030 | 19.6 | 605,120 | 72.9 | 16,369 | 2 | 32,088 | 3.9 | 10,535 | 1.3 | 3,404 | 0.4 |
| 222Db | 736,171 | 76,266 | 10.4 | 500,751 | 68 | 35,249 | 4.8 | 66,865 | 9.1 | 54,903 | 7.5 | 2,137 | 0.3 |
| 222Dc | 2,413,998 | 1,125,322 | 46.6 | 1,093,558 | 45.3 | 31,789 | 1.3 | 82,325 | 3.4 | 38,245 | 1.6 | 42,783 | 1.8 |
| 222Dd | 244,135 | 113,289 | 46.4 | 126,444 | 51.8 | 1,551 | 0.6 | 1,702 | 0.7 | 1,000 | 0.4 | 151 | 0.1 |
| 222De | 1,193,640 | 681,903 | 57.1 | 455,424 | 38.2 | 8,220 | 0.7 | 5,755 | 0.5 | 34,116 | 2.9 | 8,220 | 0.7 |
| 222Df | 454,216 | 252,950 | 55.7 | 194,527 | 42.8 | 4,493 | 1 | 321 | 0.1 | 1,284 | 0.3 | 642 | 0.1 |
| 222Dg | 736,663 | 412,754 | 56 | 307,448 | 41.7 | 5,567 | 0.8 | 6,536 | 0.9 | 3,631 | 0.5 | 726 | 0.1 |
| 222Dh | 466,741 | 286,819 | 61.5 | 154,405 | 33.1 | 3,411 | 0.7 | 12,113 | 2.6 | 9,878 | 2.1 | 119 | <0.5 |
| 222Di | 483,754 | 216,011 | 44.7 | 232,017 | 48 | 3,201 | 0.7 | 19,592 | 4 | 12,419 | 2.6 | 511 | 0.1 |
| 222Dj | 931,938 | 552,700 | 59.3 | 352,607 | 37.8 | 5,236 | 2.6 | 5,236 | 0.6 | 15,025 | 1.6 | 1,139 | 0.1 |
| Total | 8,491,796 | 3,881,044 | 45.7 | 4,022,301 | 47.4 | 115,087 | 1.4 | 232,533 | 2.7 | 181,036 | 2.1 | 59,831 | 0.7 |
| **Highland Rim Section** | | | | | | | | | | | | | |
| 222Ek | 1,523,412 | 554,140 | 36.4 | 908,224 | 59.6 | 38,507 | 2.5 | 6,575 | 0.4 | 10,332 | 0.7 | 5,637 | 0.4 |
| 222Em | 647,278 | 435,342 | 67.3 | 166,634 | 25.7 | 4,703 | 0.7 | 2,117 | 0.3 | 14,111 | 2.2 | 235 | <0.5 |
| Total | 2,170,690 | 989,482 | 45.6 | 1,074,858 | 49.5 | 43,210 | 2 | 8,692 | 0.4 | 24,443 | 1.1 | 5,871 | 0.3 |
| Total land area | 12,225,161 | 5,253,917 | 43 | 5,975,839 | 48.9 | 224,227 | 1.8 | 370,446 | 3 | 307,480 | 2.5 | 69,153 | 0.6 |

Other land= barren or transitional lands
For subsection identification and location, see figure 1.

## Ozark Highland Section

**222Ao—**The Mississippi River Alluvial Plain Subsection consists of 469,537 acres of land area with 11.4 percent forested, 55.6 percent agricultural, 8.4 percent urban, and 24 percent in either wetland or water bodies. The high percentage of agricultural land reflects the rich fertile bottoms in proximity to the Mississippi floodplain. Within southern Illinois, 12.5 percent of this subsection occurs within the Shawnee National Forest Purchase Area. Bottomland hardwoods (57%) and oak-hickory (37%) are the dominant forest types. Beech-maple and upland mixed hardwood forest types are of minor importance at 2 percent each. The forests are fragmented due to clearing for agriculture. Forest patches average about 7.5 acres in size and occur at 13 patches per 100 acres.

**222Ag—**The Illinois Ozarks Subsection covers 546,060 acres of land area with 37 percent forested, 57 percent agricultural, and less than 3 percent each of urban, wetlands, and water. The large proportion of forest land reflects the steep upland topography. Still, agricultural land use dominates on the wide valley bottoms of the Ozarks. Within southern Illinois, nearly 18 percent of this subsection occurs within the Shawnee National Forest Purchase Area. Oak-hickory (60%) and beech-maple (21%) forest types are the dominant forest types in this subsection. Historically, oak-hickory forests dominated uplands, particularly south and southwest facing slopes as well as ridges. In contrast, beech-maple forests dominated lower slopes and riparian zones. This pattern is apparently changing with beech-maple forests coming to dominate all sites due to the rich loess deposits. The bottomland hardwood forest type covers about 8 percent of the subsection. The remaining forest types cover less than 4 percent each. Forests are fragmented with an average forest patch area of 14.6 acres and a patch density of 6.8 forest patches per 100 acres.

### Upper Gulf Coastal Plain Section

**222Ca—**The Cretaceous Hills Subsection covers 192,877 acres of land area with 31 percent forested, 64 percent agricultural, and a small percentage of wetland area with virtually no urban lands or water bodies. The high agricultural component represents the rich alluvial soils of the Cache River drainage. In contrast, the other substantial component, forest land, dominates the low upland ridges that span this subsection. Within southern Illinois, nearly 21 percent of this subsection occurs within the Shawnee National Forest Purchase Area. Oak-hickory (41%) and bottomland hardwoods (36%) are the two dominant forest types. The beech-maple forest type covers about 14 percent of the subsection with small areas of pine/hardwood (5%) and post/scrub oak (4%) forest types. Forest patches average about 12.8 acres in area and patch density averages 8 per 100 acres.

**222Ch—**The Ohio and Cache River Alluvial Plain Subsection consists of 354,200 acres of land area with 20 percent forested, 52 percent agricultural, 13 percent wetland and small proportions of urban and water. Again, the high agricultural component represents the rich alluvial deposits of both the Cache and Ohio Rivers with the next most abundant land use being forest. Within southern Illinois, 12 percent of this subsection occurs within the Shawnee National Forest Purchase Area. Mixed upland hardwoods forest type makes up 46 percent of the forest in this subsection. Bottomland hardwoods and oak/hickory forest types are next most important at 17 percent and 16 percent,

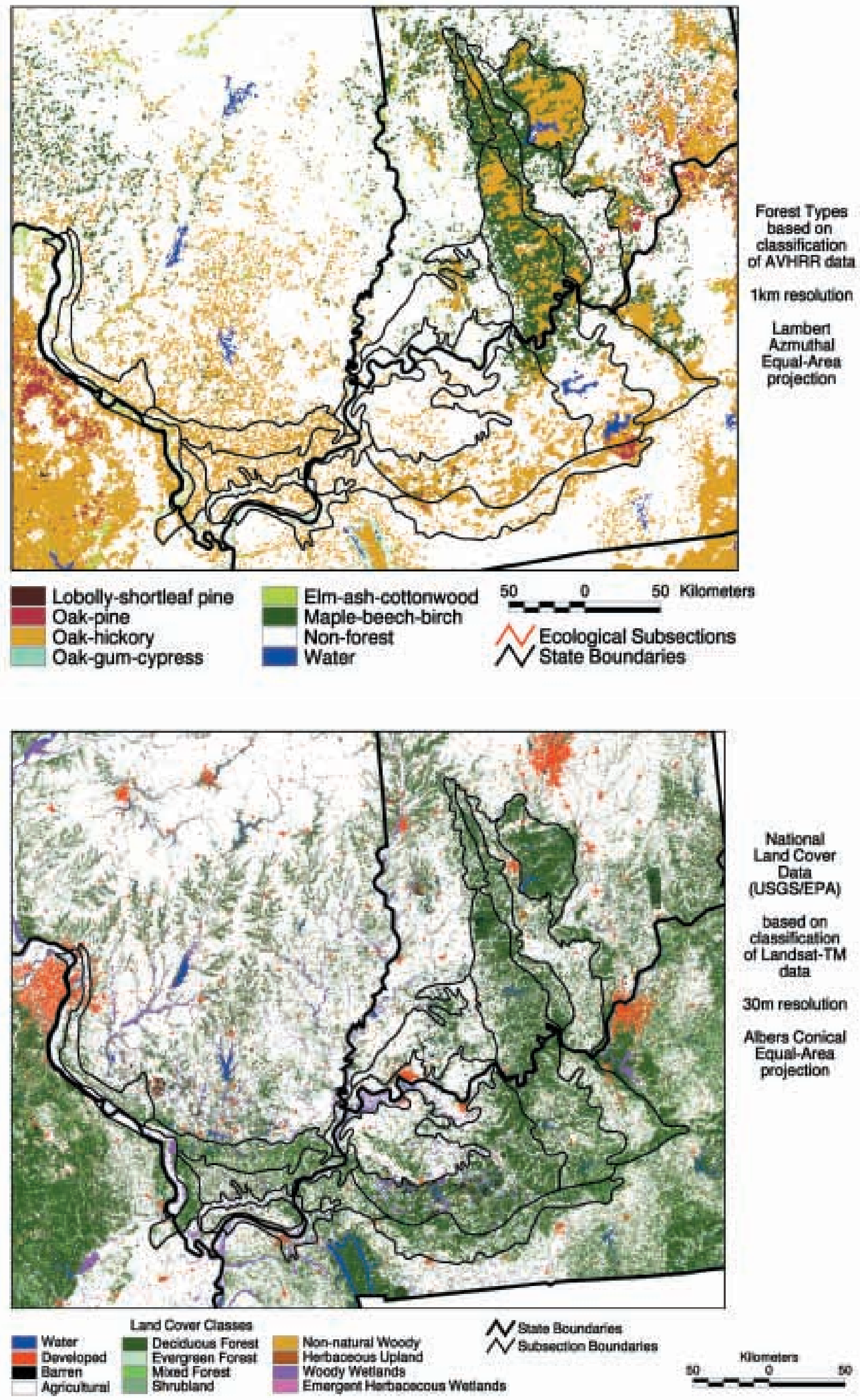


**Figure 3.** Forest types and land cover classes across ecoregion subsections within the Shawnee-Hoosier Ecological Assessment Area.

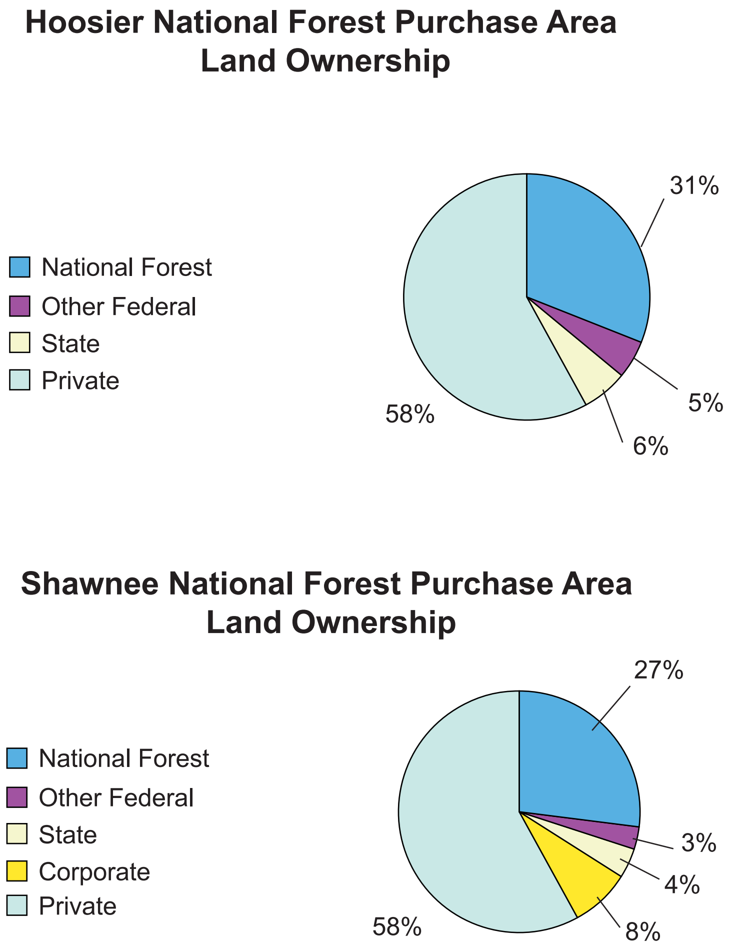


**Figure 4.** Land ownership relationships for lands within the Hoosier and Shawnee National Forest Purchase Units.

respectively. Forest patch area averages about 10 acres and patch density averages about 10 per 100 acres.

### Shawnee Hills Section

222Da—The Interior Western Coalfields Subsection of western Kentucky covers 830,540 acres of land area with 20 percent forested, 73 percent agricultural with less than 3 percent each of urban, wetland, and water. Much of the agricultural lands reflect grazing areas with some rowcropping. None of this subsection occurs within either the Shawnee or Hoosier National Forest Purchase Areas. Mixed upland hardwoods (53%) and bottomland hardwoods (27%) are the two dominant forest types. Oak-hickory covers the remaining 20 percent of the subsection. Forest patches average 7.3 acres in area and patch density averages 13.5 per 100 acres.

222Db—The Lower Ohio-Cache-Wabash Alluvial Plains Subsection covers 736,171 acres of land area with 10 percent forested, 68 percent agricultural, 9 percent wetland, 7.5 percent water, and small quantities of urban and other. Again, agriculture dominates these areas due to the rich alluvial deposits of these river systems. None of this subsection occurs within the Shawnee or Hoosier National Forest Purchase Areas. Bottomland hardwoods (53%) dominate this subsection with the oak-hickory and upland mixed hardwoods forest types each covering about 20 percent of the subsection. Forest patches average about 8.5 acres and patch density averages 11.6 forest patches per 100 acres.

222Dc—The Outer Western Coalfields Subsection covers 2,413,998 acres of land area with nearly equal proportions of forest (47%) and agricultural (45%) land cover. Ninety-two percent of the wetland area is forested. The Outer Western Coalfields Subsection does not include the purchase area of the Hoosier National Forest. Oak/hickory (26%) and mixed upland hardwoods (37%) are the dominant forest types. The other forest types occur in about equal proportions ranging from 4 to 12 percent of the subsection area. Mean forest patch size is 22.4 acres and patch density is 14.5 forest patches per 100 acres.

222Dd—The Marion Hills Subsection covers 244,135 acres of land area, with 46 percent forested, 52 percent agricultural and <1 percent each of urban, wetland, water, and barrens. None of this subsection is within the Shawnee or Hoosier National Forest Purchase Areas. Mixed upland hardwoods (35%) and oak/hickory (32%) are the dominant forest types. The post oak-scrub oak forest type covers 14 percent of the subsection. Other forest types cover less than 7 percent of the subsection each. Mean forest patch area is 17 acres and patch density averages 5.8 forest patches per 100 acres for this subsection.

222De—The Crawford Uplands Subsection covers 1,193,640 acres of land area, with 57 percent in forest cover, 38 percent in agriculture, 3 percent in urban and 3 percent water or wetlands. Ninety-three percent of the wetland area is forested. Thirty-nine percent of the Crawford Uplands Subsection is within the purchase area of the Hoosier National Forest. Of the purchase area, 68 percent is forested, 28 percent is agriculture, 1 percent is urban, 2 percent is water or wetland, and 1 percent is barren or transitional. Oak-hickory (47%) and beech-maple (33%) are the dominant forest types. The five other forest types occurring in this subsection cover less than 5 percent each. Mean forest patch area is 34.9 acres and patch density averages 2.9 forest patches per 100 acres for this subsection.

**222Df—**The Crawford Escarpment Subsection covers 454,216 acres of land area, with 56 percent in forest cover, 43 percent in agriculture, and 1 percent in urban. Less than 1percent is water or wetlands. Twelve percent of the subsection is within the purchase area of the Hoosier National Forest. Of the purchase area, 71 percent is in forest cover, 26 percent is agriculture, and 2 percent is urban. Oak-hickory (44%) and beech/maple (34%) are the dominant forest types. The other five forest types average less than 7 percent each. Mean forest patch area is 37.5 acres and patch density averages 2.6 forest patches per 100 acres.

**Table 3.** Forest area, mean forest patch area, patch area coefficient of variation, largest patch index, total edge, and total core area for each subsection based on FRAGSTATS analysis using AVHRR data.

| Subsection | Total area | Forest area | Mean forest patch area | Patch area coefficient of variation | Largest patch index | Total edge | Total core area |
|---|---|---|---|---|---|---|---|
| | *Acres* | *Acres* | *Acres* | *Percent* | *Percent* | *Miles* | *Acres* |
| **Ozark Highlands Section** | | | | | | | |
| 222Ao | 469,537 | 53,367 | 7 | 2,602 | 17.8 | 6,794 | 70,036 |
| 222Aq | 546,060 | 199,371 | 15 | 5,273 | 41.3 | 9,206 | 147,652 |
| **Upper Gulf Coastal Plain Section** | | | | | | | |
| 222Ca | 192,877 | 60,448 | 13 | 3,556 | 49.3 | 2,943 | 45,156 |
| 222Ch | 354,200 | 70,205 | 10 | 1,490 | 6.8 | 6,645 | 65,143 |
| **Shawnee Hills Section** | | | | | | | |
| 222Da | 830,540 | 163,030 | 7 | 3,126 | 16.6 | 12,812 | 116,830 |
| 222Db | 736,171 | 76,266 | 9 | 1,587 | 8.0 | 9,411 | 84,809 |
| 222Dc | 2,413,998 | 1,125,322 | 22 | 11,661 | 40.1 | 42,334 | 899,073 |
| 222Dd | 244,135 | 113,289 | 17 | 3,933 | 43.2 | 5,411 | 74,885 |
| 222De | 1,193,640 | 681,903 | 35 | 5,208 | 23.3 | 21,941 | 513,775 |
| 222Df | 454,216 | 252,950 | 38 | 2,390 | 16.9 | 8,505 | 196,560 |
| 222Dg | 736,663 | 412,754 | 24 | 6,948 | 42.5 | 13,815 | 323,676 |
| 222Dh | 466,741 | 286,819 | 45 | 5,661 | 63.3 | 7,247 | 244,111 |
| 222Di | 483,754 | 216,011 | 20 | 4,813 | 43.2 | 9,472 | 157,351 |
| 222Dj | 931,938 | 552,700 | 26 | 12,691 | 87.2 | 17,876 | 426,189 |
| **Highland Rim Section** | | | | | | | |
| 222Ek | 1,523,412 | 554,140 | 13 | 5,035 | 22.9 | 26,949 | 358,152 |
| 222Em | 647,278 | 435,342 | 66 | 6,494 | 79.5 | 9,804 | 359,560 |

FRAGSTATS is a software program for determining spatial parameters of land areas.
AVHRR= Advanced Very High Resolution Radiometer.
Largest patch index is the percent of the forest area in the largest patch.
Core area is based on a 30-meter edge.
For subsection identification and location, see figure 1.

**222Dg—**The Southern Dripping Springs Subsection covers 736,663 acres of land area with 56 percent forested, 42 percent agricultural and <1 percent each of urban, wetland, and water. None of this subsection occurs within national forest purchase area boundaries. Mixed upland hardwoods (51%) and oak-hickory (27%) are the most widespread forest types. Post oak-southern scrub oak forest covers about 20 percent of the subsection. The pine-cedar, pine-hardwoods, and bottomland hardwoods forest types each cover 6 percent or less of this subsection. Mean forest patch area is 23.6 acres and patch density averages 4 per 100 acres.

**222Dh—**The Greater Shawnee Hills Subsection covers 466,741 acres of land area with 62 percent forest, 33 percent agricultural, and less than 3 percent urban, wetland, and water each. The high percentage of forest land reflects the steep uplands of the region, which support less agricultural land than the adjacent Lesser Shawnee Hills Subsection. Eighty-six percent of this subsection lies within the Shawnee National Forest Purchase Area. Oak-hickory (62%) is the dominant forest type with beech-maple (12%) and bottomland hardwoods (10%) the next most widespread forest types. The other four forest types present in the subsection

**Table 4.** Comparison of AVHRR and FIA land area data by subsection for the Hoosier-Shawnee Ecological Assessment Area.

| | Total area | | | Forest area | | | Percent forest | | |
|---|---|---|---|---|---|---|---|---|---|
| **Subsection** | **AVHRR** | **FIA** | **Difference** | **AVHRR** | **FIA** | **Difference** | **AVHRR** | **FIA** | **Difference** |
| | *--------- Acres --------* | | *Percent* | *-------- Acres -------* | | *Percent* | *---------------- Percent -------------* | | |
| **Ozark Highland Section** | | | | | | | | | |
| 222Ao | 469,537 | 422,723 | 10 | 53,367 | 83,427 | 36.0 | 11.4 | 19.7 | 8.3 |
| 222Aq | 546,060 | 554,369 | 1.5 | 199,371 | 212,795 | 6.0 | 36.5 | 39.5 | 3.1 |
| **Upper Coastal Plain Section** | | | | | | | | | |
| 222Ca | 192,877 | 173,866 | 9.9 | 60,448 | 68,651 | 12.1 | 31.3 | 39.5 | 8.3 |
| 222Ch | 354,200 | 363,542 | 2.6 | 70,205 | 98,106 | 28.4 | 19.8 | 27.0 | 7.2 |
| **Shawnee Hills Section** | | | | | | | | | |
| 222Da | 830,540 | 815,270 | 1.8 | 163,030 | 191,203 | 14.7 | 19.6 | 23.5 | 3.9 |
| 222Db | 736,171 | 735,665 | 0.1 | 76,266 | 114,485 | 33.4 | 10.4 | 15.6 | 5.2 |
| 222Dc | 2,413,998 | 2,409,332 | 0.2 | 1,125,322 | 1,027,527 | 8.7 | 46.6 | 42.6 | 4 |
| 222Dd | 244,135 | 229,372 | 6 | 113,289 | 120,855 | 6.3 | 46.4 | 52.7 | 6.3 |
| 222De | 1,193,640 | 1,184,125 | 0.8 | 681,903 | 705,121 | 3.3 | 57.1 | 59.5 | 2.4 |
| 222Df | 454,216 | 399,305 | 12.1 | 252,950 | 234,238 | 7.4 | 55.7 | 58.7 | 3.3 |
| 222Dg | 736,663 | 781,399 | 5.7 | 412,754 | 329,859 | 20.1 | 56.0 | 42.2 | 3.8 |
| 222Dh | 466,741 | 480,148 | 2.8 | 286,819 | 267,528 | 6.7 | 61.5 | 55.7 | 5.7 |
| 222Di | 483,754 | 478,827 | 1 | 216,011 | 214,067 | 0.9 | 44.7 | 44.7 | 0.2 |
| 222Dj | 931,938 | 916,921 | 1.6 | 552,700 | 514,563 | 6.9 | 59.3 | 56.1 | 3.2 |
| **Highland Rim Section** | | | | | | | | | |
| 222Ek | 1,523,412 | 1,437,039 | 5.7 | 554,140 | 417,949 | 24.6 | 36.4 | 29.1 | 7.3 |
| 222Em | 647,278 | 594,270 | 8.2 | 435,342 | 392,016 | 10.0 | 67.3 | 66.0 | 1.3 |
| Total land area | 12,225,161 | 11,976,173 | 9.8 | 5,253,917 | 4,992,389 | 9.5 | 43.0 | 41.7 | 1.3 |

AVHRR= Advanced Very High Resolution Radiometer, FIA= Forest Inventory and Analysis.
For subsection identification and location, see figure 1.

cover less than 5 percent each. Mean forest patch area is 45.5 acres and patch density averages 2.2 patches per 100 acres.

**222Di—**The Lesser Shawnee Hills Subsection covers 483,754 acres of land area with 45 percent forested, 48 percent agricultural, and small proportions of wetland and urban areas. Forty-seven percent of this subsection lies within the Shawnee National Forest Purchase Area. Oak-hickory (57%) is the dominant forest type with beech-maple (15%) and bottomland hardwoods (10%) the next most widespread forest types. The other four forest types found in this subsection average less than 6 percent each. Mean forest patch area is 19.6 acres and patch density averages 5 forest patches per 100 acres.

**222Dj—**The Northern Dripping Springs Subsection covers 931,938 acres of land area with 59 percent forest, 38 percent agricultural, and 3 percent urban. None of this subsection occurs within either of the national forest purchase areas. Mixed upland hardwoods (54%) dominate with oak-hickory (18%) and beech-maple (9%) the next most widespread forest types. The other four forest types present average 6 percent or less each. Mean forest patch area is 26.2 acres and patch density averages 3.7 forest patches per 100 acres.

### Highland Rim Section

**222Em—**The Brown County Hills Subsection covers 647,278 acres of land area. Land use in this subsection is 67 percent forest cover, 26 percent agriculture, 2 percent urban, and 2 percent water. Ninety-nine percent of the forest cover is deciduous, and the remainder is in coniferous or mixed deciduous/conifer forest. Twenty-two percent of the Brown County Hills Subsection is within the purchase area of the Hoosier National Forest. Land use within the purchase area is 80 percent forest cover, 13 percent agriculture, less than 1 percent urban, and 6 percent water.

Oak-hickory (31%), beech-maple (27%), and mixed upland hardwoods (22%) are the dominant forest types. The other four forest types cover 7 percent or less of the subsection each. Mean forest patch area is 12.8 acres and patch density averages 8.1 forest patches per 100 acres.

**222Ek—**The Mitchell Karst Plain Subsection covers 1,523,412 acres of land area with 36 percent in forest cover, 60 percent in agriculture, and 2.5 percent urban. Less than 1 percent is water or wetland. Seventy-two percent of the forest cover is deciduous, and the remainder is in coniferous or mixed deciduous/conifer forest. Less than 1 percent (3,676 acres) of the Mitchell Karst Plain Subsection is within the purchase area of the Hoosier National Forest. Land use within the purchase area is 78 percent forested, 22 percent agriculture, and 3 percent urban. Oak-hickory (60%) and beech-maple (24%) are the dominant forest types. The other five forest types average less than 6 percent of the subsection each. Mean forest patch area is 66 acres and patch density averages 1.5 forest patches per 100 acres.

## Forest Age Across the Region

This section examines the current age structure of forests across the region. Although most of the forests in the region are relatively young due to the widespread clearing of the late 1800s and early 1900s, old-growth forests (>150 years in age) are expected to dramatically increase in spatial area under current management practices. Forest patches (>5 acres in size) less than 10 years of age are declining in area across the assessment area.

Most of the timberland within the assessment area is less than 100 years of age, reflecting the major logging activities at the turn of the 20th century (Clark 1987, Schmidt et al. 2000, Tormoehlen et al. 2000). In Indiana, 81 percent of the timberland in the Knobs Unit is between 31 and 100 years of age and 80 percent of the

Lower Wabash Unit falls within this age range. Only 6 percent of the timberland within the Knobs Unit and 2.8 percent of the Lower Wabash Unit exceed 100 years of age. Forests less than 10 years of age account for 2 percent of the Knobs Unit and 1.2 percent of the Lower Wabash Unit. Timberland exceeding 100 years of age is 1.2 percent of the land within the Hoosier National Forest and timberland less than 10 years of age is 1 percent.

The acreage of forests in older age classes within the assessment area is expected to dramatically increase due to current management systems and areas protected from harvest. Old-growth forests on public lands within Indiana are expected to increase from 895 to 136,450 acres over the next 50 years (Parker 1989, Spetich et al. 1997). Most of this additional old forest (99,090 acres) will be within the Hoosier National Forest. Forests less than 10 years of age are expected to decrease under current management systems.

Age structure across the ecological sections of southern Illinois was investigated by stratifying FIA forest type data into 20-year age classes and assigning a midrange age to these stands, i.e., for the 21- to 40-year age class, the median age of establishment would be 30 years ago, approximately 1970. These data revealed that across sections less than 10 percent of the current forest land was established before 1900 indicating very little of the landscape is in old-growth condition (fig. 5). A rough estimate of old growth is 3 to 5 percent of the current forest land (Ruffner, personal observation). Across the region, many stands originated between the 1930s and 1950s with a slight decrease in cutting around 1970 (fig. 5). The Ozark Highlands and the Upper Gulf Coastal Plain Sections have experienced more recent cutting, whereas the Shawnee Hills and Highland Rim Sections have seen a drop in recently established forest stands.

## RECENT TRENDS IN FOREST MANAGEMENT

This section is a review of the literature on the ecological implications of current forest management trends. The general trend in management across the region has been to minimize disturbance through complete protection or drastic reduction in harvest opening size. There has also been an increase in the use of prescribed burning in some fire-dependent communities. Protection from disturbance is likely to hasten the transition of species and will likely result in a loss of biological diversity across the region (Loucks 1970, Thompson and Dessecker 1997).

Major management initiatives of the 20th century are primarily responsible for the forest development pathways that created the current forest cover of the assessment area. At the end of the 19th century, much of the area was recovering from widespread cutting for numerous products (Fralish 1997, Ruffner et al. 2002), rampant grazing and forest burning (Miller 1920), and poor agricultural practices (Fralish 1997). The first major initiative saw the reforestation of many abandoned old fields and pastures, and much of the burned and grazed over lands, with the introduction of nonnative pine species. Reforestation of abandoned lands and reduced grazing of forests have reduced landscape fragmentation, particularly in areas with large public ownership (Spetich et al. 1997) and have generally improved the condition of forests across the region.

Coupled with reforestation and reduced grazing was the control and suppression of fires on the landscape. With the organization of State forestry divisions in the 1920s, the Civilian Conservation Corps (1930-1941), and eventually the full resources of the USDA Forest Service in 1933, an aggressive fire suppression campaign was begun. At the time, managers were acting under accepted concepts and procedures that suggested a healthy vibrant forest must be protected from the damaging scourge of wildfire. Even though numerous people (living at the time) must have experienced and appreciated the long-term effects of introduced fire in the early part of the 20th century, an active fire monitoring system was developed. Fire towers were constructioned, old logging roads were maintained and improved for fire access, and a general public relations campaign was begun to alert the populace to the need for these activities.

At the time of these efforts, the important role of recurring disturbances in the maintenance of oak-hickory forests was poorly understood (Abrams 1992, Lorimer 1985, Schlesinger 1976). These authors, and many others, have contributed greatly to our knowledge of the historical development of these ecosystems. It is generally accepted that the numerous disturbances of the post-European settlement period fostered the expansion of oak-hickory in the eastern deciduous biome (Abrams 1992, Lorimer 1992). Indeed, the frequent cutting regime, coupled with fire and grazing, of southern Illinois, southern Indiana, and western Kentucky that fed stave mills, charcoal iron furnaces, railroad expansions, and the cottage industries that produced fences, fruit containers, clapboards, and building timbers for the rapidly growing region is largely responsible for the mixed oak-dominated forests across the study region.

However, the fire cessation of the early 20th century fostered the expansion of mixed mesophytic species across the region (Fralish et al. 1991). Numerous authors have studied these central hardwood old-growth stands typified by the cessation of cutting, burning, and most forms of management (Barton and Schmelz 1987, Fralish et al. 1991, Fralish 1997, Groninger et al. 2002, Martin 1992, Nelson et al. 1973, Robertson and Heikens 1994, Ruffner et al. 2002, Schlesinger 1976, Spetich 1995, Weaver and Ashby 1971, Zaczek et al. 2002).


**Figure 5.** Stand age classes across ecoregions within the Shawnee-Hoosier Ecological Assessment Area.

Across the spectrum of sites in the assessment area, these studies report significant shifts in species composition and forest structure. Overwhelmingly, sugar maple and American beech are found to be increasing in stand density and basal area at the expense of the oak-hickory overstory. Age-diameter figures suggest that a large cohort of mixed maple, beech, ash, and gum was recruited only a few years after the control of understory fire and the elimination of harvesting across forests of the Ozark Hills, Shawnee Hills, and Highland Rim (Parker 1989, van de Gevel and Ruffner 2002, Zaczek et al. 2002).

Although a complete database of harvest removals for the assessment area does not exist at this time, it is possible to chronicle the major forest management activities of the middle to late 20th century. By the middle to late 1960s, most forest management agencies had adopted clearcutting as the preferred regeneration method for forests of the region (Illinois Technical Forestry Association 1965, Mills et al. 1987). Success of these clearcuts is equivocal based on the variability of site characteristics such as land use history, soils, and species composition (Fralish et al. 1991, Gleason 1926). Depending on the date of fire cessation, many of these clearcuts did not result in regeneration of oak as planned but merely released the advanced regeneration pool in the transitional maple-beech understory (Abrams and Scott 1989, Fralish 1997, Groninger et al. 2002, Heiligmann et al. 1985). In general, clearcutting on upland sites has failed to regenerate oak when adequate advanced regeneration of oak was not in place at the time of harvest (Sanders and Graney 1992). However, oak seedlings and sprouts are usually present in young stands following clearcutting but are overtopped by other faster growing species within a few years (George and Fischer 1991, Jenkins and Parker 1998), indicating the need for additional cultural treatments such as applying herbicide, thinning, or prescribed burning to reduce the competition of these faster growing stems.

The successful regeneration of oak was further reduced by the adoption of group selection cutting in the mid- to late-1980s, despite the reported failure of previous attempts to maintain oak through uneven-aged management options. Under this management scheme, small multistem groups were harvested in an attempt to reduce the visual impact of clearcuts on the landscape. While these altered harvest methods may have reduced the visual impact and quieted clearcutting opponents, many ultimately hastened the replacement of oak-hickory forests by later successional species in the small patches (≤0.5 acre) that were created (Fralish 1997, Groninger et al. 2002, Nelson et al. 1973, Ruffner et al. 2002, Weigel and Parker 1997, Zaczek et al. 2002). Group selection openings may vary from 0.5 to 5 acres in size. The larger openings are capable of providing a light regime more favorable to midtolerant species such as oaks (Jenkins and Parker 1997). Group selection (ranging in size between 1 and 5 acres) is the predominant silvicultural system used in Indiana State Forests (Indiana Department of Natural Resources 2001), but no timber cutting is occurring in the State forests of Illinois.

Because of these preliminary experiments, managers now understand that regeneration methods must be based on an evaluation of the oak regeneration potential (Sanders and Graney 1992). Where oak reproduction is low, stand treatments to enhance oak establishment and growth are needed. Where oak reproduction is adequate, clearcutting is the best method to use (Sanders and Graney 1992). In stands with little or no oak reproduction, the shelterwood method is probably the only one that will succeed in regenerating oaks (Sanders and Graney 1992, Van Lear and Watt 1992). However, success depends on quality of the site and application of additional treatments to reduce competition (Brose et al. 2001).

Perhaps the most successful experiments to date include those in forests of the Piedmont region of Virginia (Brose and Van Lear 1998, Brose et al. 2001, Keyser et al. 1996). Following shelterwood harvests with a 50 percent basal area reduction, these authors conducted repeated prescribed burns to significantly reduce tulip-poplar regeneration and increase advanced oak regeneration. They suggested that this harvest/fire disturbance regime closely mimics the conditions that fostered the development of these oak-dominated systems (Brose et al. 2001). In addition, they reported a critical need for several years between the initial cut and burning. This waiting period allows for several key components including the establishment and growth of vigorous oak seedlings and the regeneration of the buried tulip-poplar seed pool. Although burns were conducted in the winter and summer, spring appeared to be the best time for burning because it presented the most favorable weather conditions such as warm temperatures, lower humidities, and sunny days (Brose et al. 2001).

Within forests of southern Illinois, land managers have been using prescribed fire since the mid-1980s. Although the USDA Forest Service fire management program has largely been forced into a "suppression" mode due to extensive analysis requirements, several Illinois Department of Natural Resources divisions actively manage vegetation with prescribed fire (Ruffner 2001). The Divisions of Forestry and Natural Heritage both use fire to maintain unique vegetation and habitat types in glade and oak savannas, improve wildlife habitat, and foster oak regeneration while reducing competing mesophytic species in forest lands (Ruffner 2001). New research initiatives have been developed to provide empirical data that monitor long-term vegetation dynamics within burned forests of southern Illinois (Allen 2001, Ruffner and Davis 2002). State forestry officials in cooperation with ecologists and silviculturists at Southern Illinois University have begun a landscape-scale study to test the effects of timber stand improvement with fire in upland oak stands of the Shawnee and Cretaceous Hills (Allen 2001; Ruffner, personal observation). These researchers hope that substantial removals of understory and midstory mesophytes, coupled with the application of prescribed fire for 3 to 5 years following removals, will increase advanced oak regeneration at the expense of later successional species.

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# Native Plants and Communities and Exotic Plants within the Hoosier-Shawnee Ecological Assessment Area

**Steven D. Olson, Michael A. Homoya, and Elizabeth L. Shimp**

## ABSTRACT

The diverse natural communities in the Hoosier-Shawnee Ecological Assessment Area include forests, barrens, cliffs, wetlands, and streams. Communities are described based on their dominant and characteristic canopy and understory species as well as abiotic factors. An assessment of the global and state status of plant species is presented; the viability of over 360 species is threatened in the region. A review of 26 exotic plant species in the region is also presented.

The Hoosier-Shawnee Ecological Assessment Area is floristically diverse. Although centered in the Interior Low Plateau, Shawnee Hills (hereafter Shawnee Hills) Section, parts of this region are within the Upper Gulf Coastal Plain, Ozark Highlands and the Interior Low Plateau, Highland Rim (hereafter Highland Rim) Sections. The viability of over 360 plant species is a concern in the assessment area (table 1). Some of these species occur in each of the natural communities within the region. Among the species with viability concerns, 53 are a global concern (table 2) and 21 of those are documented as occurring on National Forest System (NFS) lands (table 3). State heritage ranks are from the States' natural heritage databases and global ranks are from NatureServe (2004). State heritage and global status ranks are a measure of concern for a species' viability and range from critically imperiled (G1/S1) to secure (G5/S5) (tables 1-3). The species with viability concerns are also presented according to the percent occurring within identified habitats (table 4) and land ownership categories (table 5).

The following community classification is a modified version of the Community Classification Hierarchy for the Illinois Natural Areas Inventory (White and Madany 1978). Communities are described based on their dominant and characteristic canopy and understory species, as well as on abiotic factors derived from the authors' and others' field experience, herbaria data, and information obtained from NatureServe (2004). Nomenclature of vascular plants follows the National PLANTS Database (USDA, NRCS 2004) except where noted. Ecological section and subsection names are based on Keys et al. (1995) and are also listed in Ponder (this volume). The community classification used is found in table 6.

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**Table 1.** Plant species within the Hoosier-Shawnee Ecological Assessment Area, which have a viability concern (state rank = S1, S2, or S3 in Illinois, Indiana or Kentucky, global and state ranks as of January 23, 2004) and known habitats.

| | | | State rank | | | |
|---|---|---|---|---|---|---|
| **Scientific name** | **Common name** | **Global rank** | **IL** | **IN** | **KY** | **Habitat** |
| *Acalypha deamii* | Deam's threeseed mercury | G5T4? | S2S3 | S2 | S5? | BL |
| *Aconitum uncinatum* | Southern blue monkshood | G4 | S1 | S1 | S2 | MF, RO |
| *Adiantum capillus-veneris* | Common southern maidenhair | G5 | - | - | S2 | RO |
| *Aesculus pavia* | Red buckeye | G5 | S? | - | S2S3 | BLH, MF |
| *Agalinis skinneriana* | Skinner's false foxglove | G3 | S2 | S1 | S1S2 | BA |
| *Agrimonia gryposepala* | Tall hairy agrimony | G5 | S2 | S1 | S1S2 | MF |
| *Amianthium muscitoxicum* | Flypoison | G4G5 | - | - | S1S2 | W |
| *Amorpha nitens* | Shining false indigo | G3? | S1 | - | S3? | BLH |
| *Amsonia tabernaemontana* var. *gattingeri* | Eastern bluestar | G5T2T3? | - | - | S2S3 | ME |
| *Apios priceana* | Traveler's delight | G2 | SX | - | S1 | RO |
| *Arabis patens* | Spreading rockcress | G3 | - | S1 | - | RO |
| **Aristolochia serpentaria* var. *hastata* | Narrow-leaved snakeroot | G4T? | S2 | S? | S? | BLH |
| *Neobeckia aquatica* | Lakecress | G4? | S3 | S1 | S1S2 | SW, ME |
| *Asclepias meadii* | Mead's milkweed | G2 | S2 | SX | - | BA |
| *Asplenium bradleyi* | Bradley's spleenwort | G4 | S1 | S1 | S3S4 | RO |
| *Asplenium montanum* | Mountain spleenwort | G5 | - | S1 | S4S5 | RO |
| *Asplenium resiliens* | Blackstem spleenwort | G5 | S1 | S1 | S4 | RO |
| *Asplenium ruta-muraria* | Wallrue | G5 | SH | S2 | S4 | RO |
| *Aster drummondii* var. *texanus* | Drummond's aster | G5T? | - | - | SH | W, EH |
| *Aureolaria patula* | Spreading yellow false foxglove | G3 | - | - | S3 | RO |
| *Azolla caroliniana* | Carolina mosquitofern | G5 | S1 | S2 | S4 | AQ |
| *Bacopa rotundifolia* | Disk waterhyssop | G5 | S? | S1 | S3S4 | ME |
| *Baptisia australis* | Wild blue indigo | G5 | S? | S2 | S3 | SS |
| *Baptisia australis* var. *minor* | Blue wild indigo | G5T4T5 | S? | - | S2S3 | BA |
| *Baptisia tinctoria* | Horseflyweed | G5 | SX | S3 | S1S2 | W |
| *Berberis canadensis* | American barberry | G3 | S1 | S1 | S1 | RO |
| *Berchemia scandens* | Alabama Supplejack | G5 | S1 | - | S1S2 | BLH, MF |
| *Boltonia decurrens* | Claspingleaf doll's daisy | G2 | S2 | - | - | ME |
| *Botrychium biternatum* | Sparselobe grapefern | G5 | S1 | S3 | S4 | BLH, BA |
| *Buchnera americana* | American bluehearts | G5? | S3 | S1 | S3S4 | BA |
| *Cabomba caroliniana* | Carolina fanwort | G3G5 | S1S2 | SX | S2 | AQ |
| *Calamagrostis canadensis* var. *macouniana* | Macoun's reedgrass | G5T5? | S1 | SR | SH | ME |
| *Calamagrostis porteri* ssp. *insperata* | Porter's reedgrass | G4T3 | S1 | S1 | S1S2 | W, RO |
| *Calycocarpum lyonii* | Cupseed | G5 | S1S2 | S2 | S4? | BLH, SS |
| *Carex alata* | Broadwing sedge | G5 | S1 | S3 | S1S2 | SW |
| *Carex atlantica* ssp. *atlantica* | Prickly bog sedge | G5T4 | SR | S2 | S4? | SS |
| *Carex atlantica* ssp. *capillacea* | Prickly bog sedge | G5T5? | - | S1 | S1S2 | SS |
| *Carex bushii* | Bush's sedge | G4 | S4? | S1 | S4? | W |
| *Carex communis* | Fibrousroot sedge | G5 | S1 | SR | S5 | MF |
| *Carex crawei* | Crawe's sedge | G5 | S2 | S2 | S2S3 | BA |
| *Carex decomposita* | Cypressknee sedge | G3 | S1 | S2 | S2 | SW |
| *Carex eburnea* | Bristleleaf sedge | G5 | S3? | S2 | S4 | RO, BA |
| *Carex gigantea* | Large sedge | G4 | S1 | S1 | S2 | SW |
| *Carex intumescens* | Greater bladder sedge | G5 | S1 | SR | S5 | BLH |
| *Carex pellita* | Woolly sedge | G5 | S3S4 | SR | SH | ME |
| *Carex lupuliformis* | False hop sedge | G4 | S3 | S2 | S4S5 | BLH |

*(table continued on next page)*

**(table 1 continued)**

| Scientific name | Common name | Global rank | State rank IL | IN | KY | Habitat |
|---|---|---|---|---|---|---|
| *Carex nigromarginata* | Blackedge sedge | G5 | S1 | - | S4? | MF |
| *Carex oxylepis* | Sharpscale sedge | G5? | S1 | - | S4? | BLH |
| *Carex pedunculata* | Longstalk sedge | G5 | S1S2 | S2 | S4? | MF |
| *Carex albicans* var. *australis* | Stellate sedge | G5 | SR | SR | S5? | DF |
| *Carex prasina* | Drooping sedge | G4 | S1 | SR | S5 | SS |
| *Carex reniformis* | Kidneyshape sedge | G4? | S1 | - | S1? | SW |
| *Carex socialis* | Low woodland sedge | G4 | S3 | S2 | S3S4 | BLH |
| *Carex cephaloidea* | Thinleaf sedge | G5 | S3? | SR | S5 | MF |
| *Carex stipata* var. *maxima* | Stalkgrain sedge | G5T5 | S2S3 | SR | SH | SW, BLH |
| *Carex straminea* | Eastern straw sedge | G5 | SR | S2 | S2? | BA, SW |
| *Carex willdenowii* | Willdenow's sedge | G5 | S1 | SR | S4S5 | W |
| *Carya aquatica* | Water hickory | G5 | S1 | SR | S2S3 | SW |
| *Carya pallida* | Sand hickory | G5 | S1 | S2 | S4 | W |
| *Castilleja coccinea* | Scarlet indian paintbrush | G5 | S? | SR | S1 | BA |
| *Catalpa speciosa* | Northern catalpa | G3G4 | S? | S2 | S3S4 | BLH |
| *Chamaelirium luteum* | Fairywand | G5 | S1 | S1 | S4 | MF, BLH |
| *Cheilanthes alabamensis* | Alabama lipfern | G4G5 | - | - | S1 | RO |
| *Cheilanthes lanosa* | Hairy lipfern | G5 | S3 | S2 | S5 | RO |
| *Chimaphila maculata* | Striped prince's pine | G5 | S1 | S3 | S5 | W, MF |
| *Cimicifuga rubifolia* | Appalachian bugbane | G3 | S2 | S1 | S2 | MF, RO |
| *Cirsium carolinianum* | Soft thistle | G5 | S2 | S2 | S3S4 | W |
| *Cladrastis lutea* | Kentucky yellowwood | G4 | S1 | S2 | S3S4 | MF |
| *Clematis crispa* | Swamp leather flower | G5 | S1 | S2 | - | BLH |
| *Clematis pitcheri* | Bluebill | G4G5 | S3S4 | S2 | S3S4 | BLH |
| *Clematis viorna* | Vasevine | G5 | S1 | SR | S4S5 | W |
| *Conyza canadensis* var. *pusilla* | Canadian horseweed | G5T5 | - | SX | S? | BA |
| *Cornus amomum* | Silky dogwood | G5T5 | SR | S1/R | S? | RIP |
| *Corydalis micrantha* ssp.*australis* | Smallflower fumewort | G5T5? | S1? | - | - | BA |
| *Crataegus chrysocarpa* | Fireberry hawthorn | G5 | SR | S1 | - | DF, RO |
| *Crataegus intricata* | Copenhagen hawthorn | G5 | S? | S2 | S5 | DF, BA |
| *Crataegus prona* | Illinois hawthorn | G4G5 | - | S1 | - | DF, RO |
| *Crataegus succulenta* | Fleshy hawthorn | G5 | S? | S2 | - | EH |
| *Crataegus viridis* | Green hawthorn | G5 | S? | S2 | S5? | BLH |
| *Crotonopsis willdenowii* | Willdenow's croton | G5 | S? | S1 | S3S4 | BA |
| *Cyperus lancastriensis* | Mayflower flatsedge | G5 | S1 | - | S3? | DIS, ME |
| *Cyperus pseudovegetus* | Marsh flatsedge | G5 | S3S4 | S2 | S5? | SS |
| *Cypripedium candidum* | White lady's slipper | G4 | S2 | S2 | S1 | BA |
| *Cypripedium parviflorum* | Lesser yellow lady's slipper | G5 | S1 | S2 | S2 | MF |
| *Delphinium carolinianum* | Carolina larkspur | G5 | S? | - | S1S2 | BA, W |
| *Dennstaedtia punctilobula* | Eastern hayscented fern | G5 | S2 | S3 | S4? | RO |
| *Desmodium humifusum* | Eastern trailing ticktrefoil | G1G2? | - | S1 | - | W |
| *Dichanthelium boreale* | Northern panic-grass | G5 | S1 | S2 | S2S3 | DF |
| **Dichanthelium joori* | Panic grass | G? | S1 | - | - | SW |
| **Dichanthelium mattamuskeetense* | A panic-grass | G? | S2S3 | SX | S? | BLH |
| *Dichanthelium ravenelii* | Ravenel's rossette grass | G5 | S1 | - | SR | W, DF |
| *Dichanthelium scoparium* | Velvet panicum | G5 | S1 | S1 | S? | ME, EH |
| **Dichanthelium yadkinense* | Yadkin's panic-grass | G? | S1 | - | - | MF |

*(table continued on next page)*

(table 1 continued)

| Scientific name | Common name | Global rank | State rank IL | IN | KY | Habitat |
|---|---|---|---|---|---|---|
| *Dicliptera brachiata* | Branched foldwing | G5 | S? | S1 | S3S4 | BLH |
| *Didiplis diandra* | Waterpurslane | G5 | S? | S2 | S2S3 | AQ |
| *Diervilla lonicera* | Northern bush honeysuckle | G5 | S? | S2 | - | MF |
| *Diodia virginiana* | Virginia buttonweed | G5 | S? | S2 | S5 | BLH, SS |
| *Dodecatheon frenchii* | French's shootingstar | G3 | S3 | S2 | S3 | RO |
| *Draba cuneifolia* | Wedgeleaf draba | G5 | S1 | - | S1 | BA |
| *Dryopteris celsa* | Log fern | G4 | S1 | S1 | SR | MF |
| *Echinodorus berteroi* | Upright burrhead | G5 | S? | SX | S2 | SW, BLH |
| *Echinodorus tenellus* | Mudbabies | G5? | S1 | SR | SR | ME |
| *Eleocharis wolfii* | Wolf's spikerush | G3? | S1 | S2 | - | BLH |
| *Epilobium ciliatum* | Fringed willowherb | G5 | S2 | S1 | S1? | SS |
| *Eryngium prostratum* | Creeping eryngo | G5 | S1 | - | S4? | ME, DIS |
| *Erysimum capitatum* | Sanddune wallflower | G5 | S? | S2 | - | EH |
| *Euonymus americana* | Strawberry bush | G5 | S1 | SR | S5 | BLH, MF |
| *Eupatorium album* | White thoroughwort | G5 | - | S1 | S5 | BA |
| *Eupatorium incarnatum* | Pink thoroughwort | G5 | S1 | S2 | S5 | W, RO |
| *Euphorbia serpens* | Matted broomspurge | G5 | S? | SX | - | RIP |
| *Euphorbia spathulata* | Warty spurge | G5 | S1 | SR | S2? | RO |
| *Festuca paradoxa* | Clustered fescue | G5 | S3S4 | S1 | SE | BLH, W |
| *Fimbristylis annua* | Annual fimbry | G5 | SX | S1 | S1? | ME |
| *Fimbristylis puberula* | Hairy fimbry | G5 | S? | S1 | S2 | BA |
| *Forestiera ligustrina* | Upland swamp privet | G4G5 | - | - | S2S3 | RO |
| *Dioclea multiflora* | Boykin's clusterpea | G4 | S1 | - | S4 | BLH |
| *Galium virgatum* | Southwestern bedstraw | G5 | S1 | - | - | BA |
| *Gaura filipes* | Slenderstalk beeblossom | G5 | S? | S2 | S5 | BA |
| *Gentiana alba* | Plain gentian | G4 | S? | S2 | S1S2 | BA |
| *Gentiana puberulenta* | Downy gentian | G4G5 | S? | S2 | S1 | BA |
| *Gentiana villosa* | Striped gentian | G4 | - | S1 | S4? | BA, W |
| *Glandularia canadensis* | Rose mock vervain | G5 | S? | SR | S2S3 | BA |
| *Glyceria acutiflora* | Creeping mannagrass | G5 | S4 | S1 | S2 | SW |
| *Glyceria arkansana* | Arkansas mannagrass | G5 | S1 | - | S4? | SW |
| *Gymnopogon ambiguus* | Bearded skeletongrass | G4 | SX | SX | S2S3 | BA |
| *Halesia tetraptera* | Mountain silverbell | G5 | SR | SR | S1S2 | MF |
| *Hedyotis nigricans* var. *nigricans* | Diamond flowers | G5 | S? | S2 | S5 | BA |
| *Helianthemum bicknellii* | Hoary frostweed | G5 | S? | SR | S2? | BA |
| *Helianthus angustifolius* | Swamp sunflower | G5 | S1 | S1 | S4 | BA |
| *Helianthus eggertii* | Eggert's sunflower | G3 | - | - | S2 | BA, W |
| *Heliotropium tenellum* | Pasture heliotrope | G5 | S1 | S2 | S5 | BA |
| *Heteranthera limosa* | Blue mudplantain | G5 | S2S3 | - | S2S3 | ME, SW |
| *Heteranthera reniformis* | Kidneyleaf mudplantain | G5 | S1 | SR | S4? | ME, SW |
| *Heterotheca subaxillaris* | Camphorweed | G5T5 | S? | SR | S2? | RIP |
| *Hexalectris spicata* | Spiked coralroot orchid | G5 | S1 | S2 | S4 | RO, W |
| *Hieracium longipilum* | Hairy hawkweed | G4G5 | S? | SR | S2 | BA |
| *Hottonia inflata* | American featherfoil | G4 | S2S3 | S2 | S4? | AQ, SW |
| *Hydrolea ovata* | Ovate false fiddleleaf | G5 | - | - | SH | SW |
| *Hydrolea uniflora* | Oneflower false fiddleleaf | G5 | S1 | SR | SH | SW |
| *Hypericum adpressum* | Creeping St. John'swort | G3 | S1 | S1 | SH | SW |

*(table continued on next page)*

(table 1 continued)

| Scientific name | Common name | Global rank | State rank IL | IN | KY | Habitat |
|---|---|---|---|---|---|---|
| *Hypericum denticulatum* | Coppery St. John'swort | G5 | S? | S2 | S5 | W, BA |
| *Hypericum dolabriforme* | Straggling St. John'swort | G4 | - | S2 | S4 | BA |
| *Hypericum pyramidatum* | Great St. John'swort | G4 | S1 | S1 | SR | SS, BLH |
| *Iresine rhizomatosa* | Juda's bush | G5 | S1 | S2 | S? | BLH |
| *Isoetes butleri* | Limestone quillwort | G4 | S1 | - | S1 | BA, RO |
| *Isoetes engelmannii* | Appalachian quillwort | G4 | S1S2 | S1 | S? | AQ, RIP |
| *Isoetes melanopoda* | Blackfoot quillwort | G5 | S4S5 | S1 | S1 | BA,RO,BLH |
| *Isotria medeoloides* | Green fiveleaf orchid | G2 | S1 | - | - | MF |
| *Isotria verticillata* | Purple fiveleaf orchid | G5 | S1 | S3 | S? | MF |
| *Itea virginica* | Virginia sweetspire | G4 | S? | S1 | S? | SW, BLH |
| *Juglans cinerea* | Butternut | G3G4 | S2 | S3 | S3 | MF |
| *Juncus filipendulus* | Ringseed rush | G5 | - | - | S2? | BA |
| *Juncus secundus* | Lopsided rush | G5? | S1S2 | S1 | S? | BA |
| *Justicia ovata* | Looseflower waterwillow | G5 | S1 | - | S3 | SW |
| *Koeleria macrantha* | Prairie junegrass | G5 | S3S4 | SR | S1 | W |
| *Krigia caespitos*a | Weedy Dwarfdandelion | G? | S? | SR | S? | EH |
| **Lactuca hirsuta* var. *sanguinea* | Hairy lettuce | G4? | S1 | SR | S? | DF |
| *Lathyrus palustris* | Marsh pea | G5 | S? | SR | S2 | RIP |
| *Lathyrus venosus* | Veiny pea | G5 | S? | S2 | S2S3 | DF, W |
| *Leavenworthia torulosa* | Necklace gladecress | G4 | - | - | S2 | BA, RO |
| *Lechea racemulosa* | Illinois pinweed | G5 | - | S1 | S? | DF,W,BA |
| *Lemna minuta* | Least duckweed | G4 | S2? | S1 | - | AQ |
| *Lesquerella globosa* | Globe bladderpod | G2 | - | S1 | S2 | DIS |
| *Liatris cylindracea* | Ontario blazing star | G5 | S? | SR | S2S3 | BA |
| *Liatris pycnostachya* | Prairie blazing star | G5 | S? | S2 | - | W |
| *Ligusticum canadense* | Canadian licorice-root | G4 | - | S1 | S? | BA |
| *Lilium canadense* | Canada lily | G5 | - | S2 | S? | MF |
| *Lilium superbum* | Turk's-cap lily | G5 | S2 | S3 | S1S2 | MF |
| *Limnobium spongia* | American spongeplant | G4 | S1S2 | SR | S2S3 | AQ, SW |
| *Linum sulcatum* | Grooved flax | G5 | S? | S2 | S3S4 | BA |
| *Lithospermum incisum* | Narrowleaf stoneseed | G5 | S? | S1 | - | BA |
| *Lonicera dioica* var. *glaucescens* | Red honeysuckle | G5 | S1? | SR | S? | RO |
| *Lonicera flava* | Yellow honeysuckle | G5? | S1 | - | S? | RO |
| *Lonicera reticulata* | Grape honeysuckle | G5 | SR | SE | S1 | RO |
| *Ludwigia decurrens* | Wingleaf primrose-willow | G5 | S? | S2 | S? | SW, RIP |
| *Ludwigia glandulosa* | Cylindricfruit primrose-willow | G5 | S? | S2 | S? | SW |
| *Ludwigia hirtella* | Spindleroot | G5 | - | - | S1 | BLH, SW |
| *Lycopodium dendroideum* | Tree groundpine | G5 | S1 | S1 | - | RO |
| *Lysimachia fraseri* | Fraser's yellow loosestrife | G2 | S1 | - | S1 | MF |
| *Lysimachia radicans* | Trailing yellow loosestrife | G4G5 | S1 | - | SH | SW, BLH |
| *Lysimachia terrestris* | Earth loosestrife | G5 | S? | SR | S1 | ME |
| *Magnolia acuminata* | Cucumber-tree | G5 | S? | S1 | S? | MF |
| *Magnolia tripetala* | Umbrella magnolia | G5 | - | S1 | S? | MF |
| *Maianthemum stellatum* | Starry false lily of the valley | G5 | S3? | SR | S1 | MF |
| *Malaxis unifolia* | Green adder's-mouth | G5 | S1 | S1 | S? | DF |
| *Malus angustifolia* | Southern crabapple | G5? | S1 | - | S3 | BLH |
| *Malvastrum hispidum* | Hispid false mallow | G5 | S1 | - | S2? | BA |

*(table continued on next page)*

(table 1 continued)

| Scientific name | Common name | Global rank | State rank IL | IN | KY | Habitat |
|---|---|---|---|---|---|---|
| *Matelea carolinensis* | Maroon Carolina milkvine | G4 | - | - | S1? | EH |
| *Matelea decipiens* | Oldfield milkvine | G5 | S1 | SR | S? | BLH |
| *Matelea obliqua* | Climbing milkvine | G4? | S1 | S2 | S? - | BA, RO |
| *Matteuccia struthiopteris* | Ostrich fern | G5 | S2S3 | S2 | - | BLH, MF |
| *Melanthera nivea* | Snow squarestem | G5 | S1 | - | S3? | BLH |
| *Melanthium woodii* | Wood's bunchflower | G5 | S3 | S3 | S2 | MF |
| *Melica mutica* | Twoflower melicgrass | G5 | S1 | S3 | S? | DF |
| *Melica nitens* | Threeflower melicgrass | G5 | S3S4 | S2 | S3S4 | DF, RO |
| *Melothria pendula* | Guadeloupe cucumber | G5 | S1 | S1 | S? | EH, DIS |
| *Mirabilis albida* | White four o'clock | G5 | SE | SE | S1 | RIP |
| *Monarda bradburiana* | Eastern beebalm | G5 | S? | S1 | S? | DF |
| *Muhlenbergia bushii* | Nodding muhly | G5 | S3 | SR | S1S2 | ME |
| *Muhlenbergia capillaris* | Hairawn muhly | G5 | S2S3 | S1 | S3S4 | BA, RO |
| *Muhlenbergia cuspidata* | Plains muhly | G4 | S2 | S1 | S2 | RO |
| *Muhlenbergia glabriflora* | Inland muhly | G4? | S3S4 | SR | S2S3 | ME, BLH |
| *Najas gracillima* | Slender waternymph | G5? | S2 | S1 | S2S3 | AQ |
| *Nemophila aphylla* | Smallflower baby blue eyes | G5 | - | - | S2? | MF |
| *Nothoscordum bivalve* | Crowpoison | G4 | S4? | S2 | S? | DF, BA |
| *Oenothera linifolia* | Threadleaf evening-primrose | G5 | S? | - | S1S2 | BA, RO |
| *Oenothera perennis* | Little evening-primrose | G5 | S1 | S2 | S1S2 | ME |
| *Oenothera triloba* | Stemless evening-primrose | G4 | S? | SX | S1S2 | RO, BA |
| *Oldenlandia uniflora* | Clustered mille graines | G5 | - | - | S1 | ME, AQ |
| *Onosmodium molle* ssp. *hispidissimum* | Soft hair marbleseed | G4G5T4 | S? | S1 | S1 | BA, W, RO |
| *Onosmodium molle* ssp. *molle* | Soft hair marbleseed | G4G5T3 | SR | - | S1 | BA, W, RO |
| *Onosmodium molle* ssp. *occidentale* | Soft hair marbleseed | G4G5T4? | S? | - | S1 | BA, W |
| *Ophioglossum engelmannii* | Limestone adder'stongue | G5 | S2 | S2 | S? | BA, RO |
| *Orobanche ludoviciana* | Louisiana broomrape | G5 | S1 | S2 | SH | BLH, EH |
| *Oxalis illinoensis* | Illinois woodsorrel | G2G3? | S1 | S2 | S? | MF |
| *Oxydendrum arboreum* | Sourwood | G5 | SE | S2 | S? | DF, RO |
| *Pachysandra procumbens* | Allegheny-spurge | G4G5 | - | S1 | S? | MF |
| *Panicum verrucosum* | Warty panicgrass | G4 | SR | S2 | S? | ME |
| *Paspalum boscianum* | Bull crowngrass | G5 | - | - | S2S3 | RIP |
| *Paspalum dissectum* | Mudbank crowngrass | G4? | S1 | - | S? | ME, EH |
| *Passiflora incarnata* | Purple passionflower | G5 | S? | S2 | S? | EH |
| *Penstemon brevisepalus* | Pale beardtongue | G5 | S1 | SR | S? | DF |
| *Penstemon canescens* | Eastern gray beardtongue | G4 | S1 | S2 | S? | DF |
| *Penstemon deamii* | Deam's beardtongue | G1 | - | S1 | - | DF, W, EH |
| *Perideridia americana* | Eastern yampah | G4 | S? | S1 | S2 | BLH |
| *Phacelia ranunculacea* | Oceanblue phacelia | G4 | S? | S1 | S3 | MF |
| *Phaeophyscia leana* | Wreath lichen | G2 | S1 | S? | S1? | BLH |
| *Philadelphus pubescens* | Hoary mock orange | G5? | - | - | S1 | RO |
| *Phlox amplifolia* | Largeleaf phlox | G3G5 | - | S2 | S? | MF |
| *Phlox bifida* ssp. *stellaria* | Cleft phlox | G5?T3 | SH | S1 | S2 | RO |
| *Pinus echinata* | Shortleaf pine | G5 | S1 | - | S? | DF, RO |
| *Pinus strobus* | Eastern white pine | G5 | S3 | S2 | S? | MF |
| *Piptatherum racemosum* | Blackseed-ricegrass | G5 | S1 | S2 | S3? | RO, MF |
| *Planera aquatica* | Planertree | G5 | S2 | - | S3? | SW, RIP |

*(table continued on next page)*

**(table 1 continued)**

| Scientific name | Common name | Global rank | State rank IL | IN | KY | Habitat |
|---|---|---|---|---|---|---|
| *Plantago cordata* | Heartleaf plantain | G4 | S1 | S1 | SH | RIP |
| *Platanthera clavellata* | Small green wood orchid | G5 | S1 | S3 | S? | SS |
| *Platanthera flava* var. *flava* | Palegreen orchid | G4T4? | S1 | S1 | S? | BLH |
| *Platanthera psycodes* | Lesser purple-fringed orchid | G5 | S1 | S2 | S1 | SS |
| *Pleopeltis polypodioides* ssp. *polypodiodes* | Resurrection fern | G5 | S? | S2 | S? | RO |
| *Poa alsodes* | Grove bluegrass | G4G5 | S1 | S2 | S? | MF |
| *Poa paludigena* | Bog bluegrass | G3 | SX | S3 | - | SS |
| *Poa saltuensis* | Old pasture bluegrass | G5 | SR | SR | S1S2 | BA, MF |
| *Poa wolfii* | Wolf's bluegrass | G4 | S1 | S2 | - | DF, RO |
| *Polygala cruciata* | Drumheads | G5 | S? | SR | S1 | ME |
| *Polygala incarnata* | Procession flower | G5 | S1 | S1 | S? | BA |
| *Polymnia laevigata* | Tennessee leafcup | G3 | - | - | S1S2 | MF |
| *Polytaenia nuttallii* | Nuttal's prairie parsley | G5 | S? | S1 | SX | W, BA |
| *Pontederia cordata* | Pickerelweed | G5 | S3S4 | SR | S1S2 | ME |
| *Potamogeton illinoensis* | Illinois pondweed | G5 | S2S3 | SR | S2 | AQ |
| *Potamogeton pulcher* | Spotted pondweed | G5 | S1 | S1 | S1S2 | AQ |
| *Prenanthes aspera* | Rough rattlesnakeroot | G4? | S? | S2 | S1 | W, BA |
| *Psoralidium tenuiflorum* | Slimflower scurfpea | G5 | S? | SX | S1 | BA |
| *Pteridium aquilinum* var. *pseudocaudatum* | Western bracken fern | G5T5 | S1 | SX | S? | W, BA |
| *Ptilimnium capillaceum* | Herbwilliam | G5 | SR | - | S1S2 | ME |
| *Ptilimnium costatum* | Ribbed mock bishopweed | G3G4 | S3 | - | S3? | ME |
| *Ptilimnium nuttallii* | Laceflower | G5? | S1 | S3 | S1S2 | ME |
| *Pycnanthemum albescens* | Whiteleaf mountainmint | G5 | S1 | - | S1 | DF |
| *Pycnanthemum muticum* | Clustered mountainmint | G5 | S? | - | S2? | DF |
| *Pycnanthemum torrei* | Torrey's mountainmint | G2 | S1 | - | SR | BA, W |
| *Quercus prinus* | Chestnut oak | G5 | S2 | S5 | S? | DF |
| *Quercus texana* | Texas red oak | G4G5 | S1? | - | - | BLH |
| *Quercus phellos* | Willow oak | G5 | S2 | - | S? | BLH |
| *Ranunculus laxicaulis* | Mississippi buttercup | G5? | S4? | S1 | S? | BLH, SW |
| *Ranunculus pusillus* | Low spearwort | G5 | S3 | S1 | S? | BLH, SW |
| *Rhexia mariana* var. *mariana* | Maryland meadowbeauty | G5T5 | Sr | S1 | S? | ME |
| *Rhynchospora corniculata* | Shortbristle horned beaksedge | G5T? | - | S2 | S? | ME, SW |
| *Rhynchospora glomerata* | Clustered beaksedge | G5 | S1 | - | S? | ME |
| *Rhynchospora macrostachya* | Tall horned beaksedge | G4 | - | S2 | S1 | ME |
| *Rubus alumnus* | Oldfield blackberry | G5 | S? | SX | S? | DF, W |
| *Rubus centralis* | Illinois dewberry | G2G4? | - | S1 | - | DF, W |
| *Rubus deamii* | Deam's dewberry | G4? | - | SX | S? | DF, W |
| **Rubus enslenii* | Arching dewberry | G4G5? | S? | S1 | - | DF, W |
| *Rubus odoratus* | Purpleflowering raspberry | G5 | S1 | S2 | S? | RO |
| *Rudbeckia fulgida* var. *fulgida* | Orange coneflower | G5T? | SR | S2 | S? | BA |
| *Rudbeckia fulgida* var. *umbrosa* | Orange coneflower | G5T? | - | S1 | S? | BA |
| *Rudbeckia missouriensis* | Missouri orange coneflower | G4G5 | S1 | - | SR | BA |
| *Rudbeckia subtomentosa* | Sweet coneflower | G5 | S? | SR | S1 | BA, BLH |
| *Saggtitaria latifolia* | Longbeak arrowhead | G? | S1 | S2 | - | ME |
| *Sagittaria australis* | Longbeak arrowhead | G5 | SR | S2 | S? | ME |
| *Sagittaria graminea* | Grassy arrowhead | G5 | S3 | SR | S1S2 | ME |
| *Sagittaria rigida* | Sessilefruit arrowhead | G5 | S4 | SR | S1 | SW |

*(table continued on next page)*

**(table 1 continued)**

| Scientific name | Common name | Global rank | State rank IL | IN | KY | Habitat |
|---|---|---|---|---|---|---|
| *Salvia azurea* ssp. *pitcheri* | Pitcher sage | G4G5T? | S2? | SR | S? | BA |
| *Salvia urticifolia* | Nettleleaf sage | G5 | - | - | S1 | DF |
| *Sanicula smallii* | Small's black snakeroot | G5 | - | S2 | S? | DF, MF |
| *Saxifraga virginiensis* | Early saxifrage | G5 | S1 | S2 | S? | RO, MF |
| *Schoenoplectus hallii* | Hall's bulrush | G2 | S1 | S1 | S1 | ME |
| *Scirpus fluviatilis* | River bulrush | G5 | S3S4 | SR | S1S2 | ME |
| *Scirpus heterochaetus* | Slender bulrush | G5 | S3? | - | S1 | ME |
| *Scirpus polyphyllus* | Leafy bulrush | G5 | S2 | SR | S? | SS |
| *Scirpus verecundus* | Bashful bulrush | G4G5 | S1 | - | S1? | DF, W |
| *Scleria ciliata* var. *ciliata* | Fringed nutrush | G5T? | - | - | S1? | RIP |
| *Scutellaria parvula* var. *australis* | Southern skullcap | G4T? | S? | S2 | S? | BA, DF |
| *Scutellaria parvula* var. *parvula* | Southern skullcap | G4T? | SR | SX | S? | DF |
| *Scutellaria saxatilis* | Smooth rock skullcap | G3 | - | S1 | S2S3 | RO |
| *Sedum telephioides* | Allegheny stonecrop | G4 | S? | S2 | S2 | RO |
| *Selaginella apoda* | Meadow spikemoss | G5 | S3 | S1 | S? | RO,BLH,EH |
| *Setaria geniculata* | Marsh bristlegrass | G5 | S3 | S1 | S? | BA |
| *Sideroxylon lanuginosum* | Gum bully | G4G5 | S1 | - | SR | RO, BA, DF |
| *Sideroxylon lycioides* | Buckthorn bully | G5 | S? | S1 | S? | RO |
| *Silene ovata* | Blue ridge catchfly | G2G3 | S1 | S1 | S1S2 | MF, DF |
| *Silene regia* | Royal catchfly | G3 | S1 | S2 | S1 | BA |
| *Silphium laciniatum* var. *laciniatum* | Compassplant | G5T? | SR | SR | S1S2 | BA |
| *Silphium laciniatum* var. *robinsonii* | Robinson's compassplant | G5T? | - | SR | S2 | BA |
| *Silphium pinnatifidum* | Tansy rosinweed | G3? | - | SR | S3 | BA |
| *Silphium trifoliatum* | Whorled rosinweed | G4? | S1 | SR | S? | BA |
| *Solidago buckleyi* | Buckley's goldenrod | G4 | S? | S1 | S2S3 | W, DF |
| *Solidago puberula* | Downy goldenrod | G5 | - | - | S2 | RO, W |
| *Solidago shortii* | Short's goldenrod | G1 | - | SH | S1 | RIP, RO |
| *Sparganium androcladum* | Branched bur-reed | G4G5 | S3S4 | S2 | S? | SW, ME, SS |
| *Sparganium eurycarpum* | Broadfoot bur-reed | G5 | S4 | SR | S1? | SW, ME |
| *Spigelia marilandica* | Woodland pinkroot | G5 | S? | S1 | S? | BLH, MF |
| *Spiraea alba* | White meadowsweet | G5 | S? | SR | S1 | ME |
| *Spiranthes magnicamporum* | Great plains ladies'-tresses | G4 | S3S4 | S1 | S2 | BA |
| *Spiranthes ochroleuca* | Yellow nodding ladies'-tresses | G4 | - | S2 | - | BA, W |
| *Spiranthes vernalis* | Spring ladies'-tresses | G5 | S1 | S2 | S? | BA |
| *Sporobolus clandestinus* | Rough dropseed | G5 | S3 | SR | S2S3 | BA |
| *Sporobolus heterolepis* | Prairie dropseed | G5 | S2S3 | SR | S1 | BA |
| *Stachys clingmanii* | Clingman's hedgenettle | G2? | - | S1 | - | MF, BLH |
| *Stachys eplingii* | Epling's hedgenettle | G5 | - | - | S1 | BA |
| *Stellaria longifolia* | Longleaf starwort | G5 | S3S4 | SR | S2S3 | ME |
| *Stellaria pubera* | Star chickweed | G5 | S1 | SR | S? | MF |
| *Stenanthium gramineum* | Eastern featherbells | G4G5 | S1 | S1 | S2S3 | MF |
| *Strophostyles leiosperma* | Slickseed fuzzybean | G5 | S? | S2 | S? | BA, EH |
| *Stryax grandifolius* | Bigleaf snowbell | G5 | S1 | S1 | SR | MF |
| *Styrax americanus* | American snowbell | G5 | S2 | S3 | S? | SW |
| *Symphyotrichum oblongifolium* | Aromatic aster | G5 | S? | S2 | S5 | RO |
| *Symphyotrichum priceae* | Lavender old field aster | G5 | - | - | S2 | BA |
| *Synandra hispidula* | Guyandotte beauty | G4 | S1 | S3 | S4 | MF |

*(table continued on next page)*

**(table 1 continued)**

| Scientific name | Common name | Global rank | State rank IL | IN | KY | Habitat |
|---|---|---|---|---|---|---|
| *Talinum calcaricum* | Limestone fameflower | G3 | - | - | S1 | BA, RO |
| *Talinum calycinum* | Largeflower fameflower | G5 | S1 | - | - | BA, RO |
| *Taxodium distichum* | Bald cypress | G5 | S4 | S2 | S? | SW |
| *Thalictrum pubescens* | King of the meadow | G5 | SR | S2 | S? | MF |
| *Thaspium pinnatifidum* | Cutleaf meadowparsnip | G2G3 | - | - | S2S3 | BA |
| *Thelypteris noveboracensis* | New York fern | G5 | S1 | SR | S? | MF |
| *Tilia heterophylla* | American basswood | G5 | S1 | SR | S? | MF |
| *Torreyochloa pallida* | Pale false mannagrass | G5? | S1 | SR | S1 | SW |
| *Trachelospermum difforme* | Climbing dogbane | G4G5 | S? | S2 | S? | BLH, SW |
| *Tradescantia bracteata* | Longbract spiderwort | G5 | S1 | SR | S? | BA |
| *Tragia cordata* | Heartleaf noseburn | G4 | S? | S2 | S? | BA, RO |
| *Trepocarpus aethusae* | Whitenymph | G4G5 | - | - | S3 | RIP, BLH |
| *Trichomanes boschianum* | Appalachian bristle fern | G4 | S2 | S1 | S3S4 | RO |
| *Trichostema dichotomum* | Forked bluecurls | G5 | S? | S2 | S? | BA |
| *Trifolium reflexum* | Buffalo clover | G5 | S1 | S? | S1S2 | BA, DF, W |
| *Trillium nivale* | Dwarf white wakerobin | G4 | S3? | SR | S1 | MF |
| *Trillium pusillum* | Dwarf wakerobin | G3 | - | - | S1 | BLH |
| *Trillium viride* | Wood wakerobin | G4G5 | S2 | - | - | W, BA |
| *Urtica chamaedryoides* | Heartleaf nettle | G4G5 | S1 | - | S? | BLH |
| *Uvularia perfoliata* | Perfoliate bellwort | G5 | - | S1 | S? | DF |
| *Vallisneria americana* | American eelgrass | G5 | S3 | SR | S2S3 | AQ |
| *Verbesina virginica* | White crownbeard | G5 | S? | S1 | S? | EH |
| *Viburnum molle* | Softleaf arrowwood | G5 | S1 | S2 | S3? | MF |
| *Viburnum nudum* | Possumhaw | G5 | SR | SR | S1 | SS, MF |
| *Viola egglestonii* | Glade violet | G4 | - | S1 | S3 | BA |
| *Viola walteri* | Prostrate blue violet | G4G5 | - | - | S2 | RO, BA, DF |
| *Vitis palmata* | Catbird grape | G4 | S? | S2 | S? | SW, BLH |
| *Vitis rupestris* | Sand grape | G3 | S2? | S1 | S2 | RIP |
| *Vittaria appalachiana* | Appalachian shoestring fern | G4 | - | S2 | S? | RO |
| *Waldsteinia fragarioides* | Barren strawberry | G5 | S1 | S2 | S3? | RO, DF |
| *Wisteria frutescens* | American wisteria | G5 | S2 | S2? | S? | RIP, BLH, |
| *Woodwardia areolata* | Netted chainfern | G5 | S2 | S2 | S? | BLH, RO |
| *Zizaniopsis miliacea* | Giant cutgrass | G5 | S1 | - | S1S2 | ME |
| *Zizia aptera* | Meadow zizia | G5 | S? | S2 | S? | BA |

**Key to habitat:** AQ=deep pond, lake, stream pool, submergent and/or floating vegetation; BA=barrens, prairie, glade; BLH=bottomland hardwood forest, wet flatwoods; DF=dry forest, dry flatwoods; DIS=disturbed site, early successional; EH=edge, thicket; ME=wet meadow, marsh, open and shallow pool, ditch, emergent vegetation; MF=mesic forest, dry-mesic forest; RIP=riparian border, bank, bar; RO=rocky slope, cliff, overhang; SS=seep, fen; SW=swamp; W=sparse woodland.

**Key to global and state ranks:** G1/S1=critically imperiled—because of extreme rarity or because of some factor(s) making it especially vulnerable to extirpation from the State. Typically 5 or fewer occurrences or very few remaining individuals (<1,000); G2/S2=imperiled—because of rarity or because of some factor(s) making it very vulnerable to extirpation from the Nation, State. Typically 6 to 20 occurrences or few remaining individuals (1,000 to 3,000); G3/S3=vulnerable—either because rare and uncommon, or found only in a restricted range (even if abundant in some locations), or because of other factors making it vulnerable to extirpation. Typically 21 to 100 occurrences or between 3,000 and 10,000 individuals; G4/S4=apparently secure—uncommon but not rare and usually widespread. Possible cause of long-term concern. Usually more than 100 occurrences and more than 10,000 individuals; G5/S5=secure—common, widespread, and abundant. Essentially ineradicable under present conditions. Typically with considerably more than 100 occurrences and more than 10,000 individuals; G?=questionable; SH=possibly extirpated; SR=reported; SX=presumed extirpated; S?=unranked.

*Nomenclature follows Mohlenbrock (1986).

**Table 2.** Hoosier-Shawnee Ecological Assessment Area plant species with global viability concerns (G1, G2, or G3 and T1, T2, and T3) and known habitats. The T ranks refer to the global status of the trinomial.

| Scientific name | Common name | Global rank | Habitat |
|---|---|---|---|
| *Agalinis skinneriana* | Skinner's false foxglove | G3 | BA |
| *Amorpha nitens* | Shining false indigo | G3? | BLH |
| *Amsonia tabernaemontana* var. *gattingeri* | Eastern bluestar | G5T2T3? | ME |
| *Apios priceana* | Traveler's delight | G2 | RO |
| *Arabis patens* | Spreading rockcress | G3 | RO |
| *Asclepias meadii* | Mead's milkweed | G2 | BA |
| *Aureolaria patula* | Spreading yellow false foxglove | G3 | RO |
| *Berberis canadensis* | American barberry | G3 | RO |
| *Boltonia decurrens* | Claspingleaf doll's daisy | G2 | ME |
| *Calamagrostis porteri* ssp. *insperata* | Porter's reed grass | G4T3 | W |
| *Carex decomposita* | Cypressknee sedge | G3 | SW |
| *Catalpa speciosa* | Northern catalpa | G4 | BLH |
| *Cimicifuga rubifolia* | Appalachian bugbane | G3 | MF |
| *Corydalis micrantha* ssp. *australis* | Smallflower fumewort | GG5T5? | BA |
| *Desmodium humifusum* | Eastern trailing ticktrefoil | G1G2? | W |
| *Dichanthelium boreale* | Northern panic-grass | G5 | DF |
| **Dichanthelium joori* | Panic grass | G? | SW |
| **Dichanthelium mattamuskeetense* | A panic-grass | G? | BLH |
| **Dichanthelium yadkinense* | Panic grass | G? | MF |
| *Dodecatheon frenchii* | French's shootingstar | G3 | RO |
| *Echinodorus tenellus* | Mudbabies | G5? | ME |
| *Eleocharis wolfii* | Wolf's spikerush | G3? | BLH |
| *Helianthus eggertii* | Eggert's sunflower | G3 | BA, W |
| *Hypericum adpressum* | Creeping St. John'swort | G3 | SW |
| *Isotria medeoloides* | Green fiveleaf orchid | G2 | MF |
| *Juglans cinerea* | Butternut | G3G4 | MF |
| *Krigia caespitosa* | Weedy dwarfdandelion | G5 | EH |
| *Lemna minuta* | Least duckweed | G4 | AQ |
| *Lesquerella globosa* | Globe bladderpod | G2 | DIS |
| *Lysimachia fraseri* | Fraser's yellowloosestrife | G2 | MF |
| *Onosmodium molle* ssp *molle* | Soft hair marbleseed | G4G5T3 | BA, W, RO |
| *Oxalis illinoensis* | Illinois woodsorrel | G2G3? | MF |
| *Penstemon deamii* | Deam's beardtongue | G1 | DF, W, EH |
| *Phacelia ranunculacea* | Oceanblue phacelia | G4 | MF |
| *Phaeophyscia leana* | Wreath bog lichen | G2 | BLH |
| *Poa paludigena* | Bog bluegrass | G3 | SS |
| *Polymnia laevigata* | Tennessee leafcup | G3 | MF |
| *Ptilimnium costatum* | Ribbed mock bishopweed | G3G4 | ME |
| *Pycnanthemum torrei* | Torrey's mountainmint | G2 | BA, W |
| *Rubus centralis* | Illinois dewberry | G2G4? | DF, W |
| *Sagittaria australis* | Longbeak arrowhead | G? | ME |
| *Schoenoplectus hallii* | Hall's bulrush | G2 | ME |
| *Scutellaria saxatilis* | Smooth rock skullcap | G3 | RO |

*(table continued on next page)*

## COMMUNITY TYPE—FOREST

Forests are the most widespread and diverse natural communities in the Hoosier-Shawnee Assessment Area. This community type is dominated by trees, with an average canopy cover of 80 percent or greater and has an understory of saplings and shrubs. Forests are subdivided into three subtypes, two of which are defined by their topographic position: upland forest and bottomland (floodplain) forest. Upland and bottomland forests are easily distinguishable because upland forest does not normally flood. Bottomland forests are separated out from upland forest community types because the periodic flooding they receive affects the biotic and abiotic features of their community types. Upland and bottomland forests are divided into natural communities based upon the soil-moisture gradients. The third subtype is flatwoods, which is dependent upon special soil structure.

### Community Subtype: Upland Forest

#### Natural Community—Xeric Upland Forest

Xeric upland forests occur within the Ozark Highlands and Shawnee Hills Sections and are limited to sites of extremely dry exposures, commonly of south and southwest aspects, on shallow or extremely tight soils. This natural community is never extensive and intergrades with barrens and dry forest. This community is characterized by stunted and gnarled trees and a depauperate herbaceous layer.

Xeric upland forests generally form impenetrable thickets of post, blackjack, and scarlet oaks (*Quercus stellata, Q. marilandica,* and *Q. coccinea*), farkleberry (*Vaccinium arboreum*), and eastern redcedar (*Juniperus virginiana*) with a herbaceous layer dominated by little bluestem (*Schizachyrium scoparium*), poverty oat grass (*Danthonia spicata*), and forbs belonging to the aster family. Farkleberry is the only conspicuous shrub. Herbaceous vegetation covers only about 30 percent of the ground; the remainder is rock and gravel. Other characteristic species include prairie wedge scale (*Sphenopholis obtusata*), black hickory (*Carya texana*), twoflower dwarf-dandelion (*Krigia biflora*), common serviceberry (*Amelanchier arborea*), blunt-lobe cliff fern (*Woodsia obtusa*), and Blue Ridge blueberry (*Vaccinium pallidum*). Other associated plants are woman's tobacco (*Antennaria plantaginifolia*), Virginia tephrosia (*Tephrosia virginiana*), elm-leaf goldenrod (*Solidago ulmifolia*), and creeping bush-clover (*Lespedeza repens*).

**(table 2 continued)**

| Scientific name | Common name | Global rank | Habitat |
|---|---|---|---|
| *Silene ovata* | Blue ridge catchfly | G2G3 | MF, DF |
| *Silene regia* | Royal catchfly | G3 | BA |
| *Silphium pinnatifidum* | Tansey rosinweed | G3? | BA |
| *Solidago shortii* | Short's goldenrod | G1 | RIP, RO |
| *Stachys clingmanii* | Clingman's hedgenettle | G2? | MF, BLH |
| *Talinum calcaricum* | Limestone fameflower | G3 | BA, RO |
| *Thaspium pinnatifidum* | Cutleaf meadowparsnip | G2G3 | BA |
| *Trifolium reflexum* | Buffalo clover | G5T2T4? | BA, DF, W |
| *Trillium pusillum* | Dwarf wakerobin | G3 | BLH |
| *Vitis rupestris* | Sand grape | G3 | RIP |

**Key to Habitat:** AQ=deep pond, lake, stream pool, submergent and/or floating vegetation; BA=barrens, prairie, glade; BLH=bottomland hardwood forest, wet flatwoods; DF=dry forest, dry flatwoods; DIS=disturbed site, early successional; EH=edge, thicket; ME=wet meadow, marsh, open and shallow pool, ditch, emergent vegetation; MF=mesic forest, dry-mesic forest; RIP=riparian border, bank, bar; RO=rocky slope, cliff, overhang; SS=seep, fen; SW=swamp; W=sparse woodland.

*Nomenclature follows Mohlenbrock (1986).

## Natural Community—Dry Upland Forest

Dry upland forests occur within the Shawnee Hills, Ozark Highlands, and Highland Rim Sections. This natural community is limited to sites on dry, excessively drained soils that are poorly developed because of steep, exposed slopes, or because of bedrock or gravels at or near the surface. Trees and shrubs grow slowly but are not as stunted as those species encountered in xeric upland forests. Generally, there are well developed herbaceous and understory layers. These communities are most often on ridgetops or high on south- to west-facing slopes. Dry upland forests grade imperceptibly into barrens and xeric forest on more extreme sites and into dry-mesic forests under moderated moisture conditions.

A variety of oaks typically dominate dry upland forests including post oak, blackjack oak, scarlet oak, black oak (*Quercus velutina*), and white oak (*Quercus alba*). Other characteristic trees are mockernut hickory (*Carya tomentosa*), shagbark hickory (*C. ovata*), pignut hickory (*C. glabra*), black hickory, and black gum (*Nyssa sylvatica*). Common serviceberry, farkleberry, and Blue Ridge blueberry are frequent in this habitat. Characteristic herbs include little bluestem, poverty oatgrass, prairie wedgescale, rosy sedge (*Carex rosea*), cypress panic-grass (*Dichanthelium dichotomum*), common dittany (*Cunila origanoides*), creeping bush-clover (*Lespedeza repens*), woodland sunflower (*Helianthus divaricatus*), early blue violet (*Viola palmata*), and twoflower dwarfdandelion.

Boott's sedge (*Carex picta*) is abundant in the Brown County Hills.

Chestnut oak (*Quercus prinus*) stands almost invariably occur on strongly acidic sites with thin soils, particularly in the Brown County Hills and the Crawford Uplands Subsections of the Shawnee Hills. This species is rare in southern Illinois. It often forms solid stands, but black oak or white oak may occupy part of the canopy. The most abundant understory trees are red maple (*Acer rubrum*), common serviceberry, and flowering dogwood (*Cornus florida*). Blue Ridge blueberry can be abundant, and mountain laurel (*Kalmia latifolia*) may form dense stands in the Crawford Uplands. Roundleaf greenbrier and cat greenbrier (*Smilax rotundifolia* and *S. glauca*) form dense mats. Poverty oatgrass is the most abundant grass, but it shares dominance with Boott's sedge (*Carex picta*) in the Brown County Hills. Characteristic herbs are common dittany, violet lespedeza (*Lespedeza violacea*), and queendevil (*Hieracium gronovii*).

On sites with calcareous substrates, chinkapin oak (*Quercus muehlenbergii*) is often common in the canopy. A number of calciphilic herbs are also present in these areas, including American

**Table 3.** Hoosier and Shawnee National Forests plant species that are critically imperiled or imperiled at the state level and their global heritage ranking.

| Scientific name | Common name | Global rank |
|---|---|---|
| **Barrens, prairie, glade** | | |
| *Asclepias meadii* | Mead's milkweed | G2 |
| *Onosmodium molle* ssp. *molle* | Soft hair marbleseed | G4G5T3 |
| *Pycnanthemum torrei* | Mountainmint | G2 |
| *Trifolium reflexum* | Buffalo clover | G5 |
| **Bottomland hardwood forest, wet flatwoods** | | |
| *Phaeophyscia leana* | Wreath lichen | G2 |
| *Stachys clingmanii* | Clingman's hedgenettle | G2? |
| **Dry forest, dry flatwoods** | | |
| *Penstemon deamii* | Deam's beardtongue | G1 |
| *Silene ovata* | Blue ridge catchfly | G2G3 |
| *Trifolium reflexum* | Buffalo clover | G5 |
| **Disturbed site, early successional** | | |
| *Lesquerella globosa* | Globe bladderpod | G2 |
| **Edge, thicket** | | |
| *Penstemon deamii* | Deam's beardtongue | G1 |
| **Wet meadow, marsh, open and shallow pool, ditch, emergent vegetation** | | |
| *Amsonia tabernaemontana* var. *gattingeri* | Eastern bluestar | G5T2T3? |
| *Boltonia decurrens* | Claspingleaf doll's daisy | G2 |
| *Schoenoplectus hallii* | Hall's bulrush | G2 |
| **Mesic forest, dry-mesic forest** | | |
| *Isotria medeoloides* | Green fiveleaf orchid | G2 |
| *Lysimachia fraseri* | Fraser's yellow loosestrife | G2 |
| *Oxalis illinoensis* | Illinois woodsorrel | G2G3? |
| *Silene ovata* | Blue ridge catchfly | G2G3 |
| *Stachys clingmanii* | Clingman's hedgenettle | G2? |
| **Riparian border, bank, bar** | | |
| *Solidago shortii* | Short's goldenrod | G1 |
| **Rocky slope, cliff, overhang** | | |
| *Apios priceana* | Traveler's delight | G2 |
| *Aureolaria patula* | Spreading false foxglove | G3 |
| *Onosmodium molle* ssp. *molle* | Soft hair marbleseed | G4G5T3 |
| *Solidago shortii* | Short's goldenrod | G1 |
| **Swamp** | | |
| *Hypericum adpressum* | Creeping St. John's-wort | G2G3 |
| **Sparse woodland** | | |
| *Calamagrostis porteri* ssp. *insperata* | Porter's reed grass | G4T3 |
| *Desmodium humifusum* | Eastern trailing ticktrefoil | G1G2? |
| *Onosmodium molle* ssp. *molle* | Soft hair marbleseed | G4G5T3 |
| *Penstemon deamii* | Deam's beardtongue | G1 |
| *Pycnanthemum torrei* | Torrey's mountainmint | G2 |
| *Trifolium reflexum* | Buffalo clover | G5 |

columbo (*Frasera caroliniensis*), sicklepod (*Arabis canadensis*), and heartleaf noseburn (*Tragia cordata*).

## Natural Community—Dry-mesic Upland Forest

Dry-mesic upland forests occur throughout the assessment area and are probably the most widespread forest type there. Trees and shrubs grow well because they are less inhibited by poor site conditions associated with xeric and dry upland forest communities. As with the dry upland forest, there are well developed herbaceous and understory layers, but species diversity is greater. These forests are usually found on south- to west-facing slopes, but may also occur in a band high on north- to east-facing slopes, and on ridges. Dry-mesic upland forests grade into dry upland forests higher on slopes and into mesic forests below.

Dry-mesic upland forests can generally be regarded as oak-hickory forests because they are usually dominated by oaks and hickories. Characteristic species include black oak, white oak, northern red oak (*Quercus rubra*), shagbark hickory, and pignut hickory. Additional common trees in this community are bitternut hickory (*Carya cordiformis*), mockernut hickory, American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), and tuliptree (*Liriodendron tulipifera*). Within the Cretaceous Hills, southern red oak (*Quercus falcata*) becomes frequent, and on calcareous sites in the assessment area chinkapin oak and Shumard's oak (*Q. shumardii*) are common. The subcanopy layer has several common small trees and shrubs such as flowering dogwood, eastern redbud (*Cercis canadensis*), rusty blackhaw (*Viburnum rufidulum*), and hophornbeam (*Ostrya virginiana*). Although there is not a complete cover of ground vegetation, there is a fairly diverse list of common herbs. Among these are cutleaf toothwort (*Cardamine concatenata*), rue anemone (*Anemonella thalictroides*), pointed leaf tick-trefoil (*Desmodium glutinosum*), elmleaf goldenrod (*Solidago ulmifolia*), common blue violet (*Viola sororia*), and on calcareous sites, wild comfrey (*Cynoglossum virginianum*). Common graminoids are Bosc's panic-grass (*Panicum boscii*), bearded shorthusk (*Brachyelytrum erectum*), rosy sedge, and James' sedge (*Carex jamesii*).

### Natural Community— Mesic Upland Forest

Mesic upland forests are common throughout the assessment area. Trees are tall, straight trunked, and have few low branches. The canopy is essentially complete, but stands have a well-developed vertical structure of shade-tolerant tree, shrub, and herbaceous species. Under optimal conditions these forests are quite open below the canopy. Herbs are very abundant and diverse, especially early in the growing season. The richest sites tend to be in deep ravines. Mesic upland forests are usually developed in colluvial materials in valleys and ravines or less frequently in deep loess on broad ridges. They are also found low on north- to east-facing slopes and on narrow creek bottoms. These forests grade into mesic floodplain forests where creek bottoms widen and into dry-mesic upland forests higher on the slopes.

The canopy composition of mesic upland forests is variable depending on local relief and depth of soil. In deep ravines surrounded by cliffs, common trees include American beech, sugar maple, northern red oak, white oak, tuliptree, bitternut hickory, white ash (*Fraxinus americana*), and black cherry (*Prunus serotina*). Near intermittent and ephemeral streams, beech and sugar maple are codominant and American sycamore (*Platanus occidentalis*) is found near the streambanks. In areas with limestone bedrock near the surface, black maple (*Acer nigrum*), chinkapin oak, and Shumard's oak are present. Common understory trees in this habitat are American hornbeam (*Carpinus caroliniana*), pawpaw (*Asimina triloba*), flowering dogwood, and on calcareous sites, Ohio buckeye (*Aesculus glabra*). Two common thicket-forming shrubs are northern spicebush (*Lindera benzoin*) and American bladdernut (*Staphylea trifolia*). Eastern leatherwood (*Dirca palustris*) is an infrequent species found associated with limestone.

**Table 4.** Number and percent of species with viability concerns in selected habitat associations of the Hoosier and Shawnee National Forests[1]

| Habitat Association | # Plant Species | *Percent* |
|---|---|---|
| Barrens, prairie, glade | 91 | 25% |
| Rocky slope, cliff, overhang | 62 | 17% |
| Mesic forest, dry-mesic forest | 54 | 15% |
| Bottomland hardwood forest, wet flatwoods | 54 | 15% |
| Sparse woodland | 41 | 11% |
| Wet meadow, marsh, open and shallow pool, ditch, emergent vegetation | 40 | 11% |
| Dry forest, dry flatwoods | 38 | 11% |
| Swamp | 37 | 10% |
| Riparian border, bank, bar | 15 | 4% |
| Edge, thicket | 15 | 4% |
| Seep, fen | 14 | 4% |
| Deep pond, lake, stream, pool, submergent and/or floating vegetation | 12 | 3% |
| Disturbed site, early successional | 4 | 1% |

[1] Total number of species and percentages reflect occurrence of some species in more than one habitat type.

The herbaceous layer can be remarkably diverse, particularly before leaves of canopy trees expand in the spring. Among the more familiar spring ephemerals are shining bedstraw (*Galium concinnum*), white baneberry (*Actaea pachypoda*), dwarf larkspur (*Delphinium tricorne*), Dutchman's breeches (*Dicentra cucullaria*), goldenseal (*Hydrastis canadensis*), Greek valerian (*Polemonium reptans*), and bloodroot (*Sanguinaria canadensis*). Virginia bluebells (*Mertensia virginica*) can form extensive colonies on intermittent stream terraces. Where limestone bedrock is near the surface, twinleaf (*Jeffersonia diphylla*) may be abundant. Ferns are also diverse in this community. Northern maidenhair fern (*Adiantum pedatum*), silver false spleenwort (*Deparia acrostichoides*), glade fern (*Diplazium pycnocarpon*), and Christmas fern (*Polystichum acrostichoides*) are widespread and

**Table 5.** Number of plant species with viability concerns in the Hoosier and Shawnee National Forests found within various landownership categories.

| Ownership Category | Viability Concern Species | Percent of such species |
|---|---|---|
| | | *Percent* |
| Hoosier National Forest | 60 | 17% |
| Shawnee National Forest | 77 | 21% |
| National Forests Combined | 137 | 38% |
| Other Federal Lands | 26 | 7% |
| All Federal Lands | 149 | 41% |
| Illinois State Lands | 48 | 13% |
| Indiana State Lands | 94 | 26% |
| Kentucky State Lands | 35 | 10% |
| All State Lands | 174 | 48% |
| All Public Lands | 251 | 69% |
| Private Lands | 286 | 79% |
| Private Lands Exclusively | 111 | 31% |

common. Lowland bladderfern (*Cystopteris protrusa*) forms large colonies on stream terraces. Common graminoids include Indian woodoats (*Chasmanthium latifolium*), sweet wood-reed (*Cinna arundinacea*), hedgehog woodrush (*Luzula echinata*), and white bear sedge (*Carex albursina*). On stream terraces, eastern bottle-brush grass (*Elymus hystrix*) and eastern woodland sedge (*Carex blanda*) are common.

## Community Subtype: Floodplain Forest

### Natural Community—Mesic Floodplain Forest

Mesic floodplain forests occur along the floodplains of major streams in the assessment area. This forest community occurs on landforms of relatively higher local relief, thereby subject to only short and infrequent flooding. The separation of this natural community from the mesic upland forest is a subtle one; many of the woody overstory and subcanopy species are common to both communities and the differences lie in herbaceous species composition.

Dominant trees of the mesic floodplain forest are white oak, sugar maple, and American beech. Other species characteristically encountered in this habitat include American elm (*Ulmus americana*), black walnut (*Juglans nigra*), white ash, bur oak (*Quercus macrocarpa*), and shellbark hickory (*Carya laciniosa*). American hornbeam is the most frequent understory tree. Spicebush and bladdernut are the most widely seen shrubs. Common herbs are bottomland aster (*Aster ontarione*), golden ragwort (*Senecio aureus*), Virginia spring beauty (*Claytonia virginica*), common blue violet, and smallspike false nettle (*Boehmeria cylindrica*). Other characteristic herbs are Indian woodoats, limestone wild petunia (*Ruellia strepens*), smooth hedgenettle (*Stachys tenuifolia*), sweet wood-reed, groundnut (*Apios americana*), and Canada germander (*Teucrium canadense*).

### Natural Community—Wet-mesic Floodplain Forest

Wet-mesic floodplain forests occur along major streams in the assessment area. Canopy trees are well formed, but generally shorter than those on better-drained sites. There are only scattered shrubs, but the herbaceous layer may be quite thick. Flooding is frequent, but does not last long enough to seriously inhibit tree growth. This community intergrades with other floodplain forests delineated by soil type, average soil moisture, and flooding regime.

This natural community contains the greatest biotic diversity of the floodplain natural community types. The canopy may have several species including American elm, sweetgum (*Liquidambar styraciflua*), honeylocust (*Gleditsia triacanthos*), and black walnut. Giant cane (*Arundinaria gigantea*) occasionally forms dense stands in this community. Bristly greenbrier (*Smilax hispida*) is usually present. Herbaceous species such as groundnut, Gray's sedge (*Carex grayi*), ditch stonecrop (*Penthorum sedoides*), and cutleaf coneflower (*Rudbeckia laciniata*) are indicators of wet-mesic floodplain forest. Poison ivy (*Toxicodendron radicans*) is frequently a dominant ground cover, tree-climbing vine, and occasional shrub.

### Natural Community—Wet Floodplain Forest

Wet floodplain forest occurs along major streams in the assessment area. Diversity and abundance of tree and herbaceous species are low due to prolonged or frequent flooding. The understory is open and frequently the canopy contains numerous gaps. Wet floodplain forest is found in association with swamp and wet-mesic floodplain forest.

River birch (*Betula nigra*), green ash (*Fraxinus pennsylvanica*), silver maple (*Acer saccharinum*), or red maple may form nearly pure even-aged stands. Sometimes these species intermingle with each other and with eastern cottonwood (*Populus deltoides*) and American sycamore. Canadian woodnettle (*Laportea canadensis*) often forms large monotypic colonies. Sweet wood-reed and whitegrass (*Leersia virginica*) are the most common grasses, but a wide variety of sedges such as Gray's sedge (*Carex grayi*), hop sedge (*C. lupulina*), shallow sedge (*C. lurida*), Davis' sedge (*C. davisii*), Muskingum sedge (*C. muskingumensis*), and ravenfoot sedge (*C. crus-corvi*) also occur in this habitat.

### Community Subtype—Flatwoods

Flatwoods is a distinctive forest type found on level terrain. They are vernally wet from cool season precipitation. Internal drainage is very poor because of claypans in the soil. Water stands on these sites for prolonged periods, but the ground is very dry during the summer. There are only scattered understory trees or shrubs. Overall diversity is rather low.

The canopy is often pin oak (*Quercus palustris*) or post oak. Spicebush may occasionally be found. An extensive ground cover of sedges, including Gray's sedge and Muskingum sedge, is often intermixed with little bluestem, white wild indigo (*Baptisia alba*), and rough blazingstar (*Liatris aspera*).

**Table 6.** Natural community classification for the Hoosier-Shawnee Ecological Assessment Area.

| Community type | Community subtype | Natural community |
|---|---|---|
| Forest | Upland forest | Xeric upland forest<br>Dry upland forest<br>Dry-mesic upland forest<br>Mesic upland forest |
| | Floodplain (bottomland) forest | Mesic floodplain forest<br>Wet-mesic floodplain forest<br>Wet floodplain forest |
| | Flatwoods | Flatwoods |
| Savannah | Barrens | Barrens |
| Primary | Cliffs | Sandstone cliff<br>Sandstone overhang<br>Limestone cliff |
| Wetlands (Aquatic) | Seep and spring | Acid seep |
| | Swamp | Swamp<br>Shrub swamp |
| | Open water | Pond<br>Perennial stream |

## COMMUNITY TYPE—SAVANNAH

### Community Subtype and Natural Community—Barrens

Barrens are characterized by species of canopy trees tolerant of xeric conditions, which have a stunted, open-grown appearance. They are also characterized by the dominance of native warm-season grasses and prairie forbs, and, in glades, significant exposures of bedrock. The mix of plants and animals inhabiting these sites varies with the canopy openness, internal structure of the stands, slope, aspect, and other less tangible variables. Barrens are currently recognized at sites within the Brown County Hills, Crawford Escarpment, Crawford Uplands, Cretaceous Hills, Greater Shawnee Hills, and Lesser Shawnee Hills Subsections; the Illinois Ozarks Subsection has more and larger communities.

Sandstone barrens in the Shawnee Hills are dominated by white oak, post oak and black-jack oak, but scarlet oak, pignut hickory, and in Illinois, black hickory are common. Where the soil is deeper, white oak and post oak dominate. Canopy closure is about 60 percent. There are few shrubs, but oak saplings are common.

The only common shrub is farkleberry, which often associates with tangles of cat greenbriar. The ground is well covered by little bluestem, arrowfeather threeawn (*Aristida purpurascens*), cypress panic-grass, and Indiangrass (*Sorghastrum nutans*). Where the canopy is more closed, poverty oatgrass is dominant. Common forbs include clasping Venus' looking-glass (*Triodanis perfoliata*), woodland sunflower, gravelweed (*Verbesina helianthoides*), slender bushclover (*Lespedeza virginica*), waxyleaf aster (*Symphyotrichum undulatum*), common dittany, showy goldenrod (*Solidago speciosa* var. *erecta*), panicled leaf ticktrefoil (*Desmodium paniculatum*), Virginia tephrosia, woman's tobacco, St. Andrew's cross (*Hypericum hypericoides*), and early blue violet (*Viola palmata*).

Nearby sites with less soil development may be dominated by chestnut oak in Indiana or by post and blackjack oaks throughout the assessment area. Roundleaf greenbrier is usually common in these areas. The shrub layer has Blue Ridge blueberry, sassafras (*Sassafras albidum*), and oak shrubs. There are few herbs, mostly poverty oats, with some white edge sedge (*Carex debilis*), Virginia tephrosia, and cypress panic-grass.

Sandstone glades in Illinois are barrens with little more than exposed bedrock and have a variety of lichens and mosses such as reindeer lichen (*Cladina subtenuis*), cup lichens (*Cladonia cristatella* and *C. squamosa*), Dicranum moss (*Dicranum scoparium*), and Leucobryum moss (*Leucobryum glaucum*) covering much of the rock. Vascular plants are poverty oatgrass, orangegrass (*Hypericum gentianoides*), and devil's-tongue (*Opuntia humifusa*). The few trees are mostly blackjack oak, post oak, black hickory, and eastern redcedar.

Limestone barrens are very open, often with less than 20 percent canopy of post oak and chinkapin oak, with a few eastern redcedar trees. Dominant vegetation in the opening consists of Indiangrass, big bluestem (*Andropogon gerardii*), and little bluestem. Flowering dogwood, rusty blackhaw, and New Jersey tea (*Ceanothus americanus*) are present as shrubs. Purple cliffbrake (*Pellaea atropurpurea*) and hairy lipfern (*Cheilanthes lanosa*) occur in fractures of exposed bedrock. Other common herbs include late purple aster (*Symphyotrichum patens* var. *patens*), Virginia wildrye (*Elymus virginicus*), false boneset (*Brickellia eupatorioides* var. *eupatorioides*), eastern purple coneflower (*Echinacea purpurea*), prairie rosinweed (*Silphium terebinthinaceum*), tall blazingstar, pinnate prairie coneflower (*Ratibida pinnata*), false aloe (*Agave virginica*), purpletop tridens (*Tridens flavus*), button eryngo (*Eryngium yuccifolium*), green comet milkweed (*Asclepias viridiflorum*), Mead's sedge (*Carex meadii*), hoary puccoon (*Lithospermum canescens*), and trailing lespedeza (*Lespedeza procumbens*).

The barrens in the Cretaceous Hills Subsection are on the upper slope of gravel knobs. There is a 70-percent canopy of large black oak and southern red oak, with smaller blackjack oak. Post oak is frequently present as a shrub. Farkleberry, flameleaf sumac (*Rhus copallinum*), and flowering dogwood are also found around the barrens. Common herbs include poverty oatgrass, white edge sedge, cypress panic-grass, Virginia tephrosia, St. Andrew's cross, western bracken fern (*Pteridium aquilinum*), little bluestem, hairy lespedeza (*Lespedeza hirta*), Carolina sedge (*Carex caroliniana*), cat greenbrier, and hairy pinweed (*Lechea mucronata*).

Barrens formed on Peoria loess in the Greater Shawnee Hills are dominated by little bluestem and big bluestem. Canopy closure is about 25 percent provided by post oak. Prairie June grass (*Koeleria macrantha*) and prairie dropseed (*Sporobolus heterolepis*) are also common. Conspicuous, but not necessarily common, forbs are woodland sunflower, slender lespedeza, Nuttall's prairie parsley (*Polytaenia nuttallii*), and tall blazingstar.

The bedrock of the Brown County Hills Subsection is mostly acidic siltstones. A few small areas have a barrens-like appearance and species composition. However, many ridges in these hills lack only the prairie species. The siltstone barrens are dominated by chestnut oak trees that with black oak, white oak, and scarlet oak form an 80-percent canopy. The dominant shrubs are Blue Ridge blueberry, northern dewberry (*Rubus flagellaris*), and roundleaf greenbrier. There are also scattered black oak and American beech as shrubs. The ground flora is dominated by Boott's sedge, white edge sedge, poverty oatgrass, and cypress panic-grass. Common forbs include twoflower dwarfdandelion, woman's tobacco, common dittany, violet lespedeza, hairy lespedeza, tall blazingstar, woodland sunflower, nodding ladies'-tresses (*Spiranthes cernua*), Short's aster (*Aster shortii*), elmleaf goldenrod, showy goldenrod, Sampson's snakeroot (*Orbexilum pedunculatum*), and nakedflower ticktrefoil (*Desmodium nudiflorum*). Grasses include Bosc's panic-grass, upland bentgrass (*Agrostis perennans*), and little bluestem.

## COMMUNITY TYPE: PRIMARY

### Community Subtype—Cliffs

Cliff communities are on vertical rock faces and are locally distributed across the assessment area. They have practically no soil, although sand may be deposited at their bases and on small ledges. Most cliffs in this region are composed of sandstone, but there are some of limestone as well. They can be moist to dry depending on their aspect and the surrounding natural communities. The associated plant communities are, for the most part, uniform across the region.

#### Natural Community—Sandstone Cliff

#### Dry Sandstone Cliff

Lichens are found scattered and locally abundant on dry sandstone cliffs, especially *Lepraria finkii*, which give many cliffs a distinct greenish-blue color. Cracks and ledges are often occupied by littleflower alumroot (*Heuchera parviflora*), lobed spleenwort (*Asplenium pinnatifidum*), maidenhair spleenwort (*Asplenium trichomanes*), and common woodsia. In the sand at the base of these cliffs are Standley's goosefoot (*Chenopodium standleyanum*) and Pennsylvania pellitory (*Parietaria pensylvanica*).

#### Moist Sandstone Cliff

Shaded sandstone cliffs retain more moisture and have greater species diversity than drier cliffs. Upland bentgrass, walking fern (*Asplenium rhizophyllum*), shining clubmoss (*Huperzia lucidulum*), rock clubmoss (*H. porophila*), and intermediate woodfern (*Dryopteris intermedia*) occur at scattered locations throughout the assessment area. Wild hydrangea (*Hydrangea arborescens*), marginal woodfern (*Dryopteris marginalis*), littleflower alumroot, and partridgeberry (*Mitchella repens*) are common in the region. Eastern hemlock (*Tsuga canadensis*) is found at a few sites in the Crawford Uplands Subsection.

#### Natural Community—Sandstone Overhang

Sandstone overhang communities have greater moisture and less light than moist sandstone cliffs creating conditions that only a few species can tolerate. At the drip line, a narrow strip (1 to 3 feet wide) where water drips across a shelter entrance is a special ecosystem for certain unique plants. Among these are French's shootingstar (*Dodecatheon frenchii*), Appalachian bristle fern (*Trichomanes boschianum*), and thalloid liverworts (*Conocephalum conicum*).

#### Natural Community—Limestone Cliff

Limestone cliffs occur in the Illinois Ozarks Subsection along the Mississippi River and in the Shawnee Hills Subsection along the Ohio River and its tributaries. These cliffs have a more diverse flora than sandstone cliffs. Frequent species in this community are walking fern, red columbine (*Aquilegia canadensis*), sharplobe hepatica (*Hepatica nobilis* var. *acuta*), bulblet bladderfern (*Cystopteris bulbifera*), and sicklepod.

## COMMUNITY TYPE—WETLANDS (AQUATIC)

Only a few wetland natural areas are known to exist in the bottomlands of the Ohio and Cache River Alluvial Plain and the Mississippi River Alluvial Plain Subsections, and scattered along tributary streams elsewhere in the assessment area. Acid seeps occur within portions of the Cretaceous Hills and Crawford Uplands Subsections.

### Community Subtype—Seep and Spring

#### Natural Community—Acid Seep

Acid seeps are restricted to a small area of the Cretaceous Hills Subsection in Illinois and one site in the Crawford Uplands Subsection in Indiana. These seeps have shallow deposits of peat moss (*Sphagnum* spp.) and exhibit an acidic pH.

The vegetation of seeps in the Cretaceous Hills Subsection is dominated by river birch, red maple or tuliptree; the herbaceous layer is dominated by sedges and ferns including leafy bulrush (*Scirpus polyphyllus*), prickly bog sedge (*Carex atlantica* var. *atlantica*), subarctic lady fern (*Athyrium filix-femina* var. *angustum*), cinnamon fern (*Osmunda cinnamomea*), royal fern (*Osmunda regalis*), and netted chainfern (*Woodwardia areolata*). Several uncommon orchids are also known to occur in association with this rare natural community. The Crawford Uplands Subsection site has a canopy of white oak, sweetgum, American sycamore, American beech, and shagbark hickory, with American hornbeam and red maple in the understory. Herbs present include cinnamon fern, royal fern, Virginia wildrye, (*Elymus virginicus*), wood-reed, bottomland aster, smallspike false nettle, and roundleaf goldenrod (*Solidago patula*).

### Community Subtype—Swamp

#### Natural Community—Swamp

Swamps are freshwater, woody communities with surface water throughout most or all of the year. The water level can vary from several feet in winter to an inch or less in summer; however, it is not unusual for swamps to be up to 5 feet deep in summer. In this natural community type the forest canopy covers at least 50 percent of the water.

Trees characteristic of swamps in southern Illinois are bald cypress (*Taxodium distichum*), water tupelo (*Nyssa aquatica*), water hickory (*Carya aquatica*), pumpkin ash (*Fraxinus tomentosa*), water locust (*Gleditsia aquatica*), and red maple. The shrubby layer consists of Virginia sweetspire (*Itea virginica*), swamp rose (*Rosa palustris*), and common buttonbush (*Cephalanthus occidentalis*). Common herbaceous species include pondweed (*Potamogeton* spp.), naiad (*Najas* spp.), duckweeds (*Lemna* spp.), watermeal (*Wolffia* spp.), and sedges (*Carex* spp.).

#### Natural Community—Shrub Swamp

Shrub swamps are often found in association with ponds in the vegetation mosaic of the floodplain forest in southern Illinois. There is only one small shrub swamp on the Hoosier National Forest. An open canopy of trees may be present, but the shrub layer is clearly dominant. There are aquatic herbaceous plants in these areas.

Tree species include those associated with forested swamps such as bald cypress, pumpkin ash, and red maple. Shrub species include crimsoneyed rosemallow (*Hibiscus moscheutos*), commonbuttonbush, swamp rose, and Virginia sweetspire. The known shrub swamp on the Hoosier is dominated by crimsoneyed rosemallow and common buttonbush. Herbaceous species are similar to those encountered in a forested swamp.

### Community Subtype—Open Water

#### Natural Community—Pond

Ponds are limited to abandoned river meanders (sloughs) in the southern section of the Mississippi River Alluvial Plain. Water must be permanent or semi-permanent, and the community is open. Vegetation is characterized by floating aquatics, submergents, and emergents.

Aquatic species characteristically found in ponds includes watermeal, duckweeds, pondweeds, Mexican mosquito fern (*Azolla mexicana*), American spongeplant (*Limnobium spongia*), naiads, and coon's tail (*Ceratophyllum demersum*). A variety of emergent plants are found in the shallows at the edges of ponds including American lotus (*Nelumbo lutea*), yellow pond-lily (*Nuphar lutea* var. *advena*), green arrow arum (*Peltandra virginica*), pickerelweed (*Pontederia cordata*), and broadleaf arrowhead (*Sagittaria latifolia*).

#### Natural Community—Perennial Streams

Streams are bodies of flowing water in a clearly defined channel. Their character is determined by the amount of water they carry as well as by the bedrock and terrestrial communities through which they flow.

#### High Gradient Creek

Twisted sedge (*Carex torta*), is regularly found along clear streams in Illinois, while fringed sedge (*Carex crinita*) is more common in Indiana. Heartleaf plantain (*Plantago cordata*) is a rare species also found in these areas in southern Illinois.

## EXOTIC PLANTS

Exotic plants pose a serious threat to natural communities by displacing native vegetation and wildlife. Among the native plants and animals that are negatively impacted by exotics are rare and endangered species that already have a precarious existence and may not be able to compete with more aggressive invasive species for space and resources. Thousands of dollars are spent annually to control exotic species. Early treatment and control of invasive species is clearly the ideal and most cost effective approach.

The following is a list of 26 of the most common or problematic nonnative invasive plant species in the assessment area. It is not intended to be a comprehensive list of all invasive plant species found in the assessment area or of all treatment methods. Many publications exist pertaining to identification and control of nonnative invasive plant species. However, two publications are especially helpful summaries with additional specifics on nonnative invasive plants and control methods pertaining to the assessment area: *Invasive Plants of the Southern Tier* (Mortensen 2003) and *Nonnative Invasive Plants of Southern Forests* (Miller 2003).

**Garlic Mustard (*Alliaria petiolata*)** is a biennial mustard that invades riparian and upland mesic forests, particularly those on calcareous soils. If left unchecked, the species threatens more pristine, undisturbed forest communities by forming large colonies and shading out spring wildflowers. As with most exotics, the best control is eradicating plants while populations are small. While plants are flowering in spring, minor infestations may be controlled by pulling the plants or by cutting second-year stems. Prescription fire and herbicide treatment are other methods employed for control.

**Purple Loosestrife (*Lythrum salicaria*)** is a perennial plant that grows 3 to 7 feet tall and sends up several spikes of purple flowers in summer. Although it is a popular ornamental, this species aggressively invades various wetland habitats, displacing native vegetation by forming pure stands. In many States, it is now illegal to buy, sell, or plant this pest species. In this region, it is a problem in many wetlands, especially those bordering the Ohio River. Treatments have included hand pulling of individual plants before seed set or herbicide treatment of large populations. Recently developed biocontrol methods using several insect species that feed on the flowers, foliage, and roots are promising.

**Purple Crownvetch *(Coronilla varia)*** is a sprawling perennial legume that has been widely used in landscaping and roadside erosion control. Forming dense mats of vegetation, this species invades open natural areas, especially barrens communities and stream corridors, smothering native herbaceous plants and climbing over woody species. Herbicide treatment is the primary method of control.

**Cinnamon Vine *(Dioscorea oppositifolia)*** is a twining, perennial vine that climbs over native vegetation including trees and shrubs. Although it favors sunny openings, it can also invade and persist in partial shade. It reproduces asexually by small potato-like structures. These structures, called bulbils, take root and form new plants. Control measures include herbicide treatment.

**Japanese Honeysuckle *(Lonicera japonica)*** is a woody evergreen vine that is most threatening to open, sunny areas although it may impact forest communities. It forms large patches that shade out woody and herbaceous species. Capable of succeeding in almost any soil types, this species may girdle small saplings, climb shrubs and trees, and smother herbaceous plants on the forest floor. Herbicide treatment when most other native species are dormant, typically after the first hard frost in autumn, is recommended.

**Amur Honeysuckle *(Lonicera maackii)*, Tatarian Honeysuckle *(L. tatarica)*, and Morrow's Honeysuckle *(L. morrowii)*** escape into a variety of habitats from open, sunny sites to forest communities. Although they are most prolific in open communities, they invade upland and bottomland forest communities, particularly more disturbed forests. They compete with and shade out native vegetation, and some species release chemicals into the soil that prohibit plant growth. Berry production may be prolific and seeds are readily dispersed by birds. Minor infestations of young seedlings may be hand pulled. Older shrubs are most effectively controlled by cutting and herbicide treatment of stems as well as by fire (in appropriate woodland habitats).

**Yellow Sweet Clover *(Melilotus officinalis)* and White Sweet Clover *(M. alba)*** are used as forage crops and are particularly invasive in open roadsides and natural areas including prairies, barrens, and glades. Control methods include prescribed burning in late spring, hand pulling, and herbicide treatment.

**Nepalese browntop *(Microstegium vimineum)*** is a low-growing Asian grass that invades disturbed sites including roadsides, trails, woodland edges, and streamsides where it forms large colonies and competes with native herbaceous species. It prefers at least partial shade. Suggested controls include hand pulling and cutting or mowing if done late in the growing season before seed production, and selective use of a grass-specific herbicide.

**Reed Canarygrass *(Phalaris arundinacea)*** forms large, dense, monotypic stands. This aggressive grass colonizes various wetland types competing with and shading out native species. It spreads vegetatively by underground stems. Controls include herbicide treatment.

**Tree of Heaven *(Ailanthus altissima)*** is a tree that spreads through root sprout and seed production. It is particularly invasive in openings and clearings and along rock cliffs, but can also occur along streams and in disturbed forest communities. Control methods include basal bark herbicide application or girdling of trees followed by herbicide treatment. Stem cutting followed immediately by herbicide application is another means of control. Cutting alone, however, will result only in resprouting.

**Autumn Olive *(Elaeagnus umbellata)*** is a small tree or large shrub that was once a popular wildlife planting. Individual plants are prolific berry producers, and the seeds are widely spread by birds. It is particularly invasive in open habitats including prairies, but can also spread into forest communities displacing native species. Suggested controls include cutting immediately followed by herbicide application.

**Tall Fescue *(Lolium arundinaceum)*** is a coarse, cool season grass that has been widely used for erosion control and as forage. It forms dense monotypic stands in open areas and threatens native vegetation in prairies and glades as well as stream corridors. Prescription burning and herbicide applications are some of the recommended controls.

**Ground Ivy *(Glechoma hederacea)*** is a creeping mint that invades open areas, roadsides, and floodplain and mesic upland forests. It forms large mats that can outcompete native vegetation, especially the smaller, low growing species. Suggested treatments include herbicide application when other native herbs are dormant.

**Lespedezas (*Lespedeza* spp.)** include several nonnative lespedezas that have been planted in wildlife openings and for erosion control along roadsides. Sericea lespedeza is particularly aggressive and can form large colonies, competing for space with native plants. It poses a serious threat to barrens, glades, and other open communities. Control measures include late spring burning and herbicide application.

**Creeping Jenny (*Lysimachia nummularia*)** is a creeping plant that competes with native vegetation, often forming large carpets in low ground. It has spread widely in floodplain forest communities. Hand pulling of small patches of this plant can be effective. Control of large areas of infestation requires herbicide treatment.

**Fuller's Teasel *(Dipsacus fullonum)*** is a biennial plant often confused with thistles (*Cirsium* spp.). It is an invasive weed of open, sunny areas including roadsides, fields, cemeteries, streambanks, and open woods. This plant is a concern in prairies and open forest communities. Controls include cutting, prescribed burning, and herbicide application.

**Common Periwinkle *(Vinca minor)***, a trailing evergreen, is a popular ornamental that threatens forest communities. It spreads vegetatively and can cover large areas, crowding out all native herbaceous plants and tree seedlings. Controls include herbicide treatment when native forest herbs are dormant.

**Multiflora Rose *(Rosa multiflora)*** is a thorny shrub long used as a wildlife planting, promoted as a hedge, and used for erosion control. This species is now widely recognized as one of our most pernicious, invasive exotics and is listed as a noxious weed in many States. Pasture land and open natural areas are most vulnerable to invasion. Plants can form dense, impenetrable thickets, and landowners have used various methods to control the plant including bush-hogging, grubbing, bulldozing, and application of herbicides. In addition to these measures, several biocontrol agents have been effective controls. The virus rose rosette and a chalcid wasp have shown the greatest potential in controlling this pest.

**Japanese Hop *(Humulus japonicus)*** is a twining, herbaceous vine commercially popular with gardeners. It is an annual or weak perennial found along roadsides and forest edges, but poses a threat to riparian communities. Suggested controls include pulling of plants and removal from the site and herbicide application.

**Johnsongrass *(Sorghum halepense)*** has been used as a pasture or forage plant and has been described as one of the 10 worst weeds in the world. This tall, showy species invades disturbed soils, spreading prolifically by rhizomes and seed production. It is very competitive and invasive and threatens floodplain and bottomland communities, particularly those that have been disturbed. Control methods include mowing, tilling, and herbicide treatment.

**Nodding Musk Thistle (*Carduus nutans*)** is a herbaceous biennial or winter annual that reproduces by seed. It is found in fields, rangelands, open woodlands, bottomlands, and on roadsides and stream or ditch banks. It spreads aggressively and may form dense stands that crowd out desirable plant species. Control measures include close mowing or cutting at intervals to prevent seed production, burning crowns with a propane torch, or spraying with herbicide.

**Phragmites or Common Reed (*Phragmites australis*)** is a large, upright, warm-season perennial grass that spreads mainly by rhizomes but also by seeds. Although native to North America and elsewhere, aggressive colonies may result when native and European strains cross. It is most successful in freshwater areas, marshes, backwaters, pond and lake edges, streambanks, and ditches. Management includes chemical control, annual cutting in late July, grazing, dredging, draining, flooding, or combinations of burning and other methods.

**Kudzu (*Pueraria montana* var. *lobata*)** is a perennial, woody, leguminous trailing vine that can reproduce vegetatively and by seeds. Known as the "vine that ate the South," vines can grow a foot a day, smothering or breaking trees and other vegetation. It infests forest edges, roadsides, old fields, abandoned homesteads, fence rows, and other sunny disturbed areas. Small young patches may be controlled by persistent weeding, mowing, or grazing for 3 to 4 years. Monthly close mowing for two growing seasons or repeated cultivation may work. For heavy infestations, burning, cutting, and herbicide applications may be needed and may take 5 years or more.

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# Freshwater Resources in the Hoosier-Shawnee Ecological Assessment Area

**Matt R. Whiles and James E. Garvey**


## ABSTRACT

The Hoosier-Shawnee Ecological Assessment Area contains 40 major watersheds with unique hydrological, ecological, and socioeconomic features. Depending on the watershed, major groundwater resources are a combination of sandstone, carbonate, and semiconsolidated or unconsolidated sand/gravel aquifers. Approximately 69,000 miles of streams flow through the assessment area, of which 60 percent are perennial and 14 percent are artificial or greatly altered (e.g., drainage ditches). Even though headwater streams represent the majority of stream miles and exert a strong influence on downstream processes, relatively little is known about their extent and condition within the region. Most stream riparian zones are either urban or agricultural; only 22 percent of watersheds in the assessment area contain streams with abundant forested riparian areas. More than 8,000 reservoirs have been constructed in the region; these provide important water supplies, recreational opportunities, and economic benefits, but they also potentially influence the ecological integrity of streams. Consistent with nationwide trends, wetland habitats are some of the most degraded and diminished freshwater resources in the region; only 2.8 percent woody and 0.3 percent herbaceous wetland vegetation remain in the assessment area. Water quality varies greatly across the region, with elevated nutrients and contaminants (e.g., heavy metals and organic compounds) exceeding U.S. Environmental Protection Agency (USEPA) regional standards in many of the systems. Most water in the region is used for power generation and public supply, with 16 times more surface water consumed annually than groundwater. Increased surface water and groundwater contamination and rising public and industrial demand may continue to compromise water quality and quantity within much of the assessment area. Predicted reductions in precipitation associated with global climate change may further compromise the limited water resources of the region.



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## INTRODUCTION

The Shawnee and Hoosier National Forests contain a wide variety of freshwater resources that are vital to the ecological integrity and human population of the region. Freshwater resources in the region provide habitat for a great diversity of plants and animals, as well as recreational, industrial, and domestic goods and services for humans. Across the planet, freshwater resources are imperiled, with more than 50 percent of the world's freshwater runoff already used by humans (Gleick 2000, Jackson et al. 2001) and an even greater percentage adversely influenced by human activities in some manner (Naiman et al. 1995, Naiman and Turner 2000). Currently, the largest threat to freshwater systems in the United States, in terms of number of systems adversely affected, is non-point pollution associated with agriculture (USEPA 1994a). However, urbanization, industrial activities such as mining, exotic species, predicted climate change, and other factors linked to human activities also pose great threats (Cooper 1993; Cushing and Allan 2001; USEPA 1994a, 2001).

No region in the U.S., not even within the boundaries of our national parks and forests, is immune to the variety of problems facing freshwater ecosystems. Hydrological cycles at local or regional scales often are linked, meaning that water use practices and activities that influence water quality within one region may affect hydrological processes and water quality in others. There is also an increasing awareness that atmospheric deposition is a major pathway for the introduction of pollutants into freshwater habitats, even in seemingly pristine regions (Allan 1995, Winter et al. 1999). Projected increases in human population growth, and changes in the hydrological cycle that are linked to predicted climate change, suggest that per capita availability of freshwater will decline in the future (Jackson et al. 2001). This, coupled with water quality issues, demonstrates that prudent management and conservation of remaining freshwater systems are paramount. Conservation of freshwater resources requires an inventory of existing resources and current information about their condition. This inventory of the Hoosier-Shawnee Ecological Assessment Area will provide a benchmark for future assessments of trends in the quantity and quality of freshwater resources and patterns of water use.

Streams, lakes, and wetlands are the lifeblood of a region because freshwater is a vital resource for all organisms, including humans. Additionally, freshwater resources influence local and regional climate, and they have an economic value associated with recreation, industry, and agriculture. Wise management and conservation of freshwater are imperative for maintaining or restoring the ecological and economic well-being of the Hoosier-Shawnee Ecological Assessment Area. This is a particularly challenging task, given the diversity of factors influencing water quantity and quality within the region, including local climate, geology, and human population density and activities.

The boundaries of the Shawnee National Forest include parts of 6 major drainages in Illinois: the upper Mississippi-Cape Girardeau, Big Muddy, Cache, Saline, lower Ohio, and lower Ohio Bay. The Hoosier National Forest boundaries include parts of lower Ohio-Little Pigeon, Blue Sinking, Patoka, and lower East Fork White. At least portions of 40 major watersheds constitute the Hoosier-Shawnee assessment area, and these range in size from 359 square miles (Cache River in Illinois) to 3,174 square miles (upper Green River in western Kentucky) (fig. 1, table 1). Most of these major watersheds include multiple ecological units and numerous subsections of these units. The majority of the watersheds in the study region drain portions of the Interior Low Plateau Shawnee Hills and Highland Rim

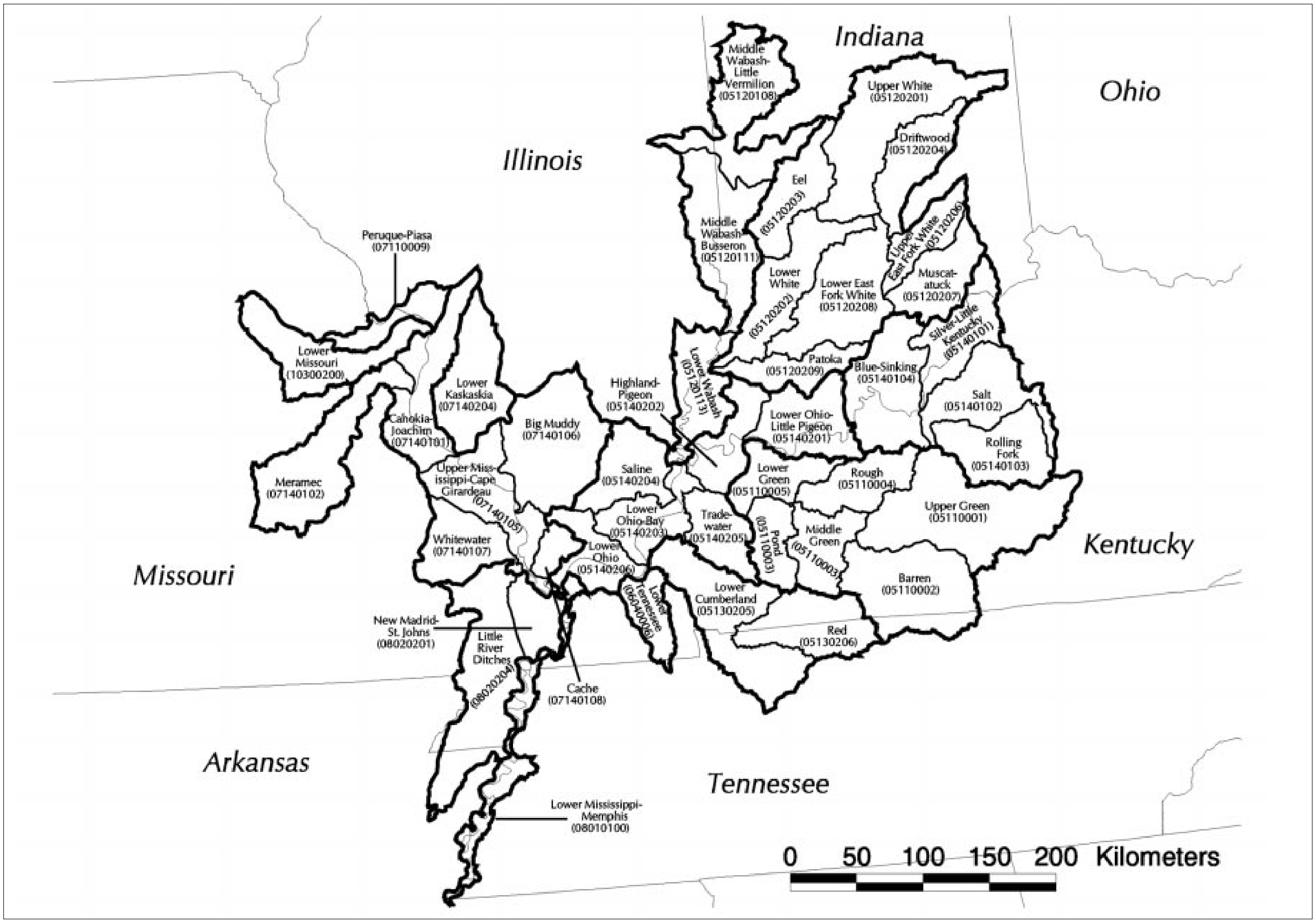



**Figure 1.** Watershed units of the Hoosier-Shawnee assessment area. Numbers are USGS cataloging hydrologic unit codes.

Sections (fig. 1, table 1). Most of these catchments integrate a variety of land cover types, including those with primarily urban, agricultural, and forested land characteristics.

We identified and quantified the major aquatic resources in the Hoosier-Swanee study region, including groundwater resources, lotic surface water habitats, and lentic surface waters and wetlands. We also examined indicators of the ecological integrity of surface water habitats and assessed recent patterns of water use within the region.

## METHODS

Geographic and water use data within the watersheds of the Hoosier-Shawnee assessment area were obtained from a variety of sources, with an emphasis on the most recent and large-scale data sets described below. We approached this effort from the major watershed scale, where watersheds were U.S. Geological Survey (USGS) cataloging units, the finest scale hydrological unit in the USGS classification system (Seaber et al. 1987; fig. 1). Each of these 2,111 units nationwide is comprised of a combination of interconnected surface drainages with unique hydrologic features (Seaber et al. 1987). All 40 cataloging-unit watersheds on which we focused intersect at least a portion of the assessment area, and they represent the major units of analysis in this aquatic resource inventory.

### Watershed Characteristics

Aquifers and their associated geologic composition within each watershed derive from the USGS Principal Aquifers of the 48 contiguous U.S. (Lloyd and Lyke 1995). Stream and river data derive from the USEPA's most recent River Reach File (RF3), a hydrographic database of the surface waters of the continental United

**Table 1.** USGS hydrological units (watersheds) within each ecological unit and subsection of the Hoosier-Shawnee Ecological Assessment Area.

| Watershed | Watershed area (mi$^2$) | Ecological unit | Subsection | Proportion of watershed in subsection |
|---|---|---|---|---|
| Barren | 2,244 | Interior Low Plateau—Shawnee Hills Section | Southern Dripping Springs | 0.054 |
| | | | Outer Western Coal Fields | 0.008 |
| Big Muddy | 2,369 | Interior Low Plateau—Shawnee Hills Section | Greater Shawnee Hills | 0.089 |
| | | | Lesser Shawnee Hills | 0.008 |
| | | Ozark Highlands | Mississippi River Alluvial Plain | 0.022 |
| | | | Illinois Ozarks | 0.004 |
| Blue Sinking | 1,898 | Interior Low Plateau—Highland Rim Section | Mitchell Karst Plain | 0.484 |
| | | Interior Low Plateau—Shawnee Hills Section | Northern Dripping Springs | 0.178 |
| | | | Crawford Upland | 0.176 |
| | | | Crawford Escarpment | 0.097 |
| Cache | 359 | Interior Low Plateau—Shawnee Hills Section | Lesser Shawnee Hills | 0.302 |
| | | Ozark Highlands | Illinois Ozarks | 0.215 |
| | | Upper Gulf Coastal Plain | Ohio and Cache River Alluvial Plain | 0.175 |
| | | | Cretaceous Hills | 0.168 |
| Cahokia-Joachim | 1,660 | Ozark Highlands | Mississippi River Alluvial Plain | 0.221 |
| | | | Illinois Ozarks | 0.154 |
| Driftwood | 1,179 | Interior Low Plateau—Highland Rim Section | Brown County Hills | 0.035 |
| Eel | 1,211 | Interior Low Plateau—Highland Rim Section | Mitchell Karst Plain | 0.048 |
| | | | Brown County Hills | < 0.001 |
| | | Interior Low Plateau—Shawnee Hills Section | Crawford Upland | 0.074 |
| | | | Crawford Escarpment | 0.070 |
| Highland-Pigeon | 1,005 | Interior Low Plateau—Shawnee Hills Section | Lower Ohio-Cache-Wabash Alluvial Plains | 0.373 |
| | | | Interior Western Coal Fields | 0.300 |
| | | | Outer Western Coal Fields | 0.284 |
| Little River Ditches | 2,646 | Ozark Highlands | Illinois Ozarks | 0.014 |
| Lower Cumberland | 2,311 | Interior Low Plateau—Shawnee Hills Section | Southern Dripping Springs | 0.087 |
| | | | Marion Hills | 0.032 |
| | | Upper Gulf Coastal Plain | Ohio and Cache River Alluvial Plain | 0.019 |
| Lower East Fork White | 2,055 | Interior Low Plateau—Highland Rim Section | Mitchell Karst Plain | 0.260 |
| | | | Brown County Hills | 0.239 |
| | | Interior Low Plateau—Shawnee Hills Section | Crawford Upland | 0.234 |
| | | | Crawford Escarpment | 0.132 |
| | | | Outer Western Coal Fields | 0.033 |
| Lower Green | 918 | Interior Low Plateau—Shawnee Hills Section | Interior Western Coal Fields | 0.392 |
| | | | Outer Western Coal Fields | 0.384 |
| | | | Lower Ohio-Cache-Wabash Alluvial Plains | 0.218 |
| | | | Northern Dripping Springs | 0.003 |
| Lower Kaskaskia | 1,617 | Ozark Highlands | Illinois Ozarks | 0.054 |
| | | | Mississippi River Alluvial Plain | 0.001 |
| Lower Missouri | 1,610 | Ozark Highlands | Mississippi River Alluvial Plain | 0.013 |
| Lower Ohio | 936 | Interior Low Plateau—Shawnee Hills Section | Lesser Shawnee Hills | 0.196 |
| | | | Greater Shawnee Hills | 0.057 |
| | | Upper Gulf Coastal Plain | Ohio and Cache River Alluvial Plain | 0.263 |
| | | | Cretaceous Hills | 0.204 |

*(table continued on next page)*

**(table 1 continued)**

| Watershed | Watershed area (mi$^2$) | Ecological unit | Subsection | Proportion of watershed in subsection |
|---|---|---|---|---|
| Lower Ohio Bay | 1,090 | Interior Low Plateau—Shawnee Hills Section | Lesser Shawnee Hills | 0.352 |
| | | | Marion Hills | 0.191 |
| | | | Greater Shawnee Hills | 0.148 |
| | | | Lower Ohio-Cache-Wabash Alluvial Plains | 0.120 |
| | | | Interior Western Coal Fields | 0.058 |
| | | | Outer Western Coal Fields | 0.007 |
| | | Upper Gulf Coastal Plain | Ohio and Cache River Alluvial Plain | 0.080 |
| | | | Cretaceous Hills | 0.047 |
| Lower Ohio-Little Pigeon | 1,395 | Interior Low Plateau—Shawnee Hills Section | Outer Western Coal Fields | 0.390 |
| | | | Lower Ohio-Cache-Wabash Alluvial Plains | 0.277 |
| | | | Crawford Upland | 0.256 |
| | | | Northern Dripping Springs | 0.080 |
| Lower Tennessee | 691 | Upper Gulf Coastal Plain | Ohio and Cache River Alluvial Plain | 0.115 |
| Lower Wabash | 1,315 | Interior Low Plateau—Shawnee Hills Section | Outer Western Coal Fields | 0.125 |
| | | | Lower Ohio-Cache-Wabash Alluvial Plains | 0.031 |
| Lower White | 1,646 | Interior Low Plateau—Highland Rim Section | Brown County Hills | 0.092 |
| | | | Mitchell Karst Plain | 0.065 |
| | | Interior Low Plateau—Shawnee Hills Section | Crawford Upland | 0.151 |
| | | | Crawford Escarpment | 0.082 |
| | | | Outer Western Coal Fields | 0.013 |
| Meramec | 2,143 | Ozark Highlands | Mississippi River Alluvial Plain | <0.001 |
| Middle Green | 1,018 | Interior Low Plateau—Shawnee Hills Section | Outer Western Coal Fields | 0.741 |
| | | | Southern Dripping Springs | 0.209 |
| | | | Interior Western Coal Fields | 0.009 |
| Middle Wabash-Little Vermilion | 2,267 | Interior Low Plateau—Shawnee Hills Section | Crawford Upland | 0.003 |
| Muscatatuck | 1,145 | Interior Low Plateau—Highland Rim Section | Mitchell Karst Plain | 0.013 |
| New Madrid-St. Johns | 707 | Ozark Highlands | Illinois Ozarks | 0.010 |
| Patoka | 868 | Interior Low Plateau—Shawnee Hills Section | Crawford Upland | 0.395 |
| | | | Outer Western Coal Fields | 0.303 |
| | | | Crawford Escarpment | 0.028 |
| Peruque-Piasa | 636 | Ozark Highlands | Mississippi River Alluvial Plain | 0.019 |
| | | | Illinois Ozarks | 0.004 |
| Pond | 785 | Interior Low Plateau—Shawnee Hills Section | Outer Western Coal Fields | 0.449 |
| | | | Interior Western Coal Fields | 0.286 |
| | | | Southern Dripping Springs | 0.271 |
| Red | 1,482 | Interior Low Plateau—Shawnee Hills Section | Southern Dripping Springs | 0.038 |
| Rolling Fork | 1,439 | Interior Low Plateau—Highland Rim Section | Mitchell Karst Plain | 0.074 |
| Rough | 1,095 | Interior Low Plateau—Highland Rim Section | Mitchell Karst Plain | 0.040 |
| | | Interior Low Plateau—Shawnee Hills Section | Northern Dripping Springs | 0.483 |
| | | | Outer Western Coal Fields | 0.450 |
| | | | Interior Western Coal Fields | 0.026 |
| Saline | 1,182 | Interior Low Plateau—Shawnee Hills Section | Greater Shawnee Hills | 0.243 |
| | | | Lower Ohio-Cache-Wabash Alluvial Plains | 0.010 |
| | | | Lesser Shawnee Hills | 0.006 |
| Salt | 1,475 | Interior Low Plateau—Highland Rim Section | Mitchell Karst Plain | 0.021 |
| Silver-Little Kentucky | 1,253 | Interior Low Plateau—Highland Rim Section | Mitchell Karst Plain | 0.010 |

*(table continued on next page)*

(table 1 continued)

| Watershed | Watershed area ($mi^2$) | Ecological unit | Subsection | Proportion of watershed in subsection |
|---|---|---|---|---|
| Tradewater | 949 | Interior Low Plateau—Shawnee Hills Section | Outer Western Coal Fields | 0.402 |
| | | | Interior Western Coal Fields | 0.328 |
| | | | Southern Dripping Springs | 0.120 |
| | | | Marion Hills | 0.112 |
| | | | Lesser Shawnee Hills | 0.038 |
| Upper East Fork White | 806 | Interior Low Plateau—Highland Rim Section | Brown County Hills | 0.036 |
| Upper Green | 3,171 | Interior Low Plateau—Highland Rim Section | Mitchell Karst Plain | 0.160 |
| | | Interior Low Plateau—Shawnee Hills Section | Northern Dripping Springs | 0.153 |
| | | | Southern Dripping Springs | 0.072 |
| | | | Outer Western Coal Fields | 0.034 |
| Upper Mississippi-Cape Girardeau | 1,687 | Interior Low Plateau—Shawnee Hills Section | Greater Shawnee Hills | 0.014 |
| | | Ozark Highlands | Mississippi River Alluvial Plain | 0.215 |
| | | | Illinois Ozarks | 0.006 |
| Upper White | 2,722 | Interior Low Plateau—Highland Rim Section | Brown County Hills | 0.095 |
| | | | Mitchell Karst Plain | 0.008 |
| Whitewater | 1,213 | Ozark Highlands | Mississippi River Alluvial Plain | 0.028 |

States and Hawaii (USEPA 1994b). Data provided by the River Reach File are limited to the resolution (1:100,000) of the digital maps from which the data set derives (Horn et al. 1994). Classifications of streams as natural or unnatural derive from the Multi-Resolution Land Consortium's National Land Cover Database (NLCD). Major drainages within each watershed were identified as the stream or river with the greatest mean annual discharge ($ft^3.s^{-1}$) within the USGS gauging station database (USGS 2001). Riparian vegetation cover percentages derive from 1-km grid cells adjacent to streams in the USGS 1:2,000,000 digital line graph coverage (1990 USGS-EROS). Surface area and numerical data on reservoirs and wetlands derive from the NLCD and the 1992 U.S. Army Corps of Engineers National Inventory of Dams database (Army Corps of Engineers 1992).

## Watershed Condition and Water Use

Our assessment of watershed condition includes the USEPA's Index of Watershed Indicators (IWI; USEPA 1999) that incorporates current watershed condition with vulnerability to future perturbations (table 2). The IWI characterization is based on a scoring procedure accounting for several indicator values including waters that meet designated uses, fish consumption advisories, source water condition, contaminated sediments, water quality, wetland loss, species at risk, pollutant loads over permit levels, urban/agricultural runoff, population change, hydrologic modification, and atmospheric nitrogen deposition (table 2). We determined the proportion of reservoirs and streams within each watershed that failed to meet water quality standards under Section 303D of the Clean Water Act in 1998 (State-USEPA Partnership Program 1998). We also quantified various patterns of water use within each watershed using 1990 and 1995 data sets from the USGS Water Information Coordination Program (see Solley et al. 1998). Data were compiled and are presented in table 2 to reflect current resource conditions and quantities. When possible, we also identified trends of water quality and use.

## OVERVIEW OF FRESHWATER RESOURCES

### Groundwater Resources

Aquifers are continuous groundwater systems that contain water in sufficient quantity for domestic, commercial, industrial, or agricultural uses, and they represent important long-term storage of water in given regions. In most cases, aquifers and other groundwater resources interact with surface waters, and each can have an important influence on the other. Hence, the pollution or depletion of one can adversely affect the other. Aquifers and other groundwaters are primarily used by humans for irrigation, industrial activities, and domestic water supplies, and there is global concern over the long-term implications of groundwater overuse and pollution (Jackson et al. 2001). For example, many aquifers in the Western United States are being depleted more rapidly than they are being recharged.

The source of groundwater in the Hoosier-Shawnee assessment area is precipitation. Average annual precipitation in the region ranges from approximately 36 inches in the northern part of the study area in Illinois to 48 inches in the eastern part of the region in Kentucky. Approximately 50 to 75 percent of this precipitation is returned to the atmosphere via evaporation and transpiration, and much of the remainder represents stream discharge (Lloyd and Lyke 1995). Groundwater recharge is a factor of both precipitation and surface layer permeability, and most recharge goes to shallow groundwater pools. Annual groundwater recharge in the Hoosier-Shawnee study region is estimated at 1 inch/year in relatively drier regions of Illinois and eastern Missouri, but recharge rates increase in the eastern part of the study area to near 3 to 5 inches/year (Lloyd and Lyke 1995). Much of the deepest groundwater (generally >500 feet depth) in the region is classified as saltwater, defined as water with >1,000 mg/L dissolved solids (Lloyd and Lyke 1995).

**Table 2.** Interpretation of Index of Watershed Indicators (IWI; USEPA 1999), an index that incorporates current watershed condition with vulnerability to future perturbations.

| IWI Score | Water quality | Vulnerability |
|---|---|---|
| 1 | Better | Low |
| 2 | Better | High |
| 3 | Less serious | Low |
| 4 | Less serious | High |
| 5 | More serious | Low |
| 6 | More serious | High |
| 7 | Insufficient data | Insufficient data |

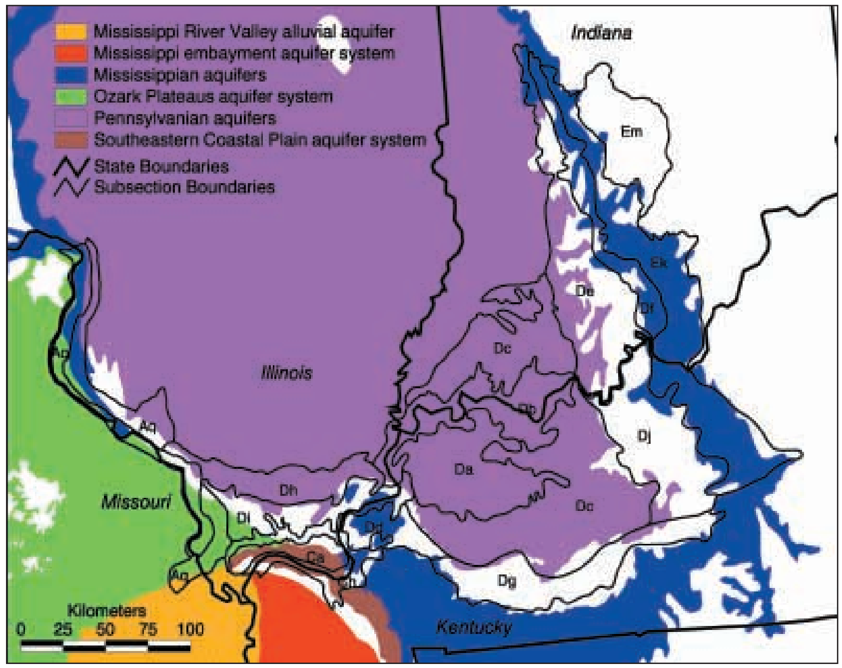



**Figure 2.** Aquifers of the Hoosier-Shawnee assessment area. Letter codes refer to ecoregion subsections in the assessment area (Keys et al. 1995, Ponder 2004).

Most aquifers in the Hoosier-Shawnee study region are associated with sedimentary rock, primarily sandstone (Pennsylvanian systems) and carbonate-rock (Ozark Plateaus aquifer system) or a combination of the two (Mississippian aquifers) (figs. 2, 3). However, the Mississippi River valley alluvial system, which includes parts of the Cache, Little River Ditches, lower Ohio, New Madrid-St. Johns, upper Mississippi, and Whitewater drainages consists of unconsolidated sand and gravel; and the Mississippi Embayment system (parts of the lower Ohio and lower Tennessee drainages) and the Southeastern Coastal Plain system (Cache, lower Ohio, lower Ohio Bay, and lower Tennessee drainages) consist of semiconsolidated sand and gravel (table 3). Combined, these systems represent 19 percent of aquifers in the region that are composed of semiconsolidated or unconsolidated materials (fig. 3). In general, the sand and gravel aquifers in the region are relatively shallow and are associated with the alluvial deposits of the large rivers in the region.

The majority of the major drainage basins in the study area include two to three principal aquifer types, although some drainages are geologically more diverse and include more (fig. 2, table 3). For example, the lower Ohio drainage includes six aquifer types (Mississippi Embayment, Mississippi River valley alluvial, Mississippian, Ozark Plateaus, Pennsylvanian, and Southeastern Coastal Plain), and a substantial portion of its area (about 224 square miles) has no associated aquifer. In contrast, some smaller drainages in more homogenous areas of the study region, such as the Red, Pond, and Saline, include only one aquifer type and have extensive areas with no associated aquifers.

Sandstone aquifers are characterized by having relatively low rates of water movement. However, both carbonate-rock aquifers and those associated with semiconsolidated or unconsolidated materials can have relatively high recharge rates and hydraulic conductivity, indicating that water can move relatively rapidly into and within these types of aquifers. In addition, a large portion of the Hoosier-Shawnee study region, such as the Shawnee Hills and Salem Plateau regions of southern Illinois and the Blue Sinking drainage of south-central Indiana and northwest Kentucky, is karst, with significant networks of caves and associated subterranean aquatic systems (Weibel et al. 1997). Groundwaters in karst regions are particularly vulnerable to pollution from surface activities (e.g., agricultural activities and septic waste) because nutrients, agrochemicals, and other pollutants can move into these systems via percolation of water through thin and porous substrates, sinkholes, and sinking streams (Panno et al. 1996, Taylor and Webb 2000). Further, water movements in karst terrain can be very unpredictable, and groundwater contamination problems that might be localized in some regions can become regional problems in karst areas (Winter et al. 1999). Taylor and Webb (1998) noted that it is common for landowners in the region to use sinkholes as waste dumping sites, exacerbating problems of groundwater pollution. A recent investigation in a cave in St. Clair County, Illinois, demonstrated the linkage between surface activities and groundwater in karst regions by showing major changes in turbidity and assorted water chemistry parameters in a cave stream during a storm on the surface (Taylor and Webb 2000).

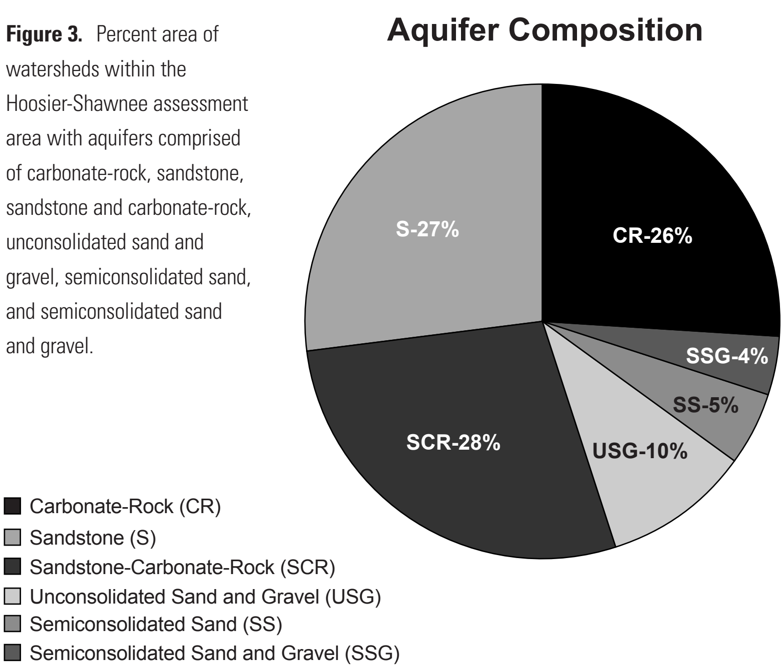



**Figure 3.** Percent area of watersheds within the Hoosier-Shawnee assessment area with aquifers comprised of carbonate-rock, sandstone, sandstone and carbonate-rock, unconsolidated sand and gravel, semiconsolidated sand, and semiconsolidated sand and gravel.

Given the geology of many of the aquifers and other groundwater resources of the Hoosier-Shawnee assessment area, protection of groundwater resources is an important issue for this region. In particular, careful monitoring of land use practices, including farming practices and maintenance of private septic systems will be required to maintain the quality of groundwater resources. Further, much of the groundwater of the region is interconnected, such that careless or destructive practices in even a small area can negatively influence other parts of the region.

**Table 3.** Major aquifer types and associated geologic composition within each USGS hydrological unit (watershed) of the Hoosier-Shawnee Ecological Assessment Area (see Lloyd and Lyke 1995).

| Watershed | Aquifer type | Rock type | Area ($mi^2$) |
|---|---|---|---|
| Barren | Mississippian | sandstone-carbonate-rock | 1,106 |
| | None | NA | 1,027 |
| | Pennsylvanian | sandstone | 11 |
| | Silurian-Devonian | carbonate-rock | 81 |
| Big Muddy | None | NA | 36 |
| | Ozark Plateaus | carbonate-rock | 5 |
| | Pennsylvanian | sandstone | 2,345 |
| Blue Sinking | Mississippian | sandstone-carbonate-rock | 1,161 |
| | None | NA | 726 |
| | Pennsylvanian | sandstone | 6 |
| Cache | Mississippi River Valley Alluvial | unconsolidated sand and gravel | 38 |
| | None | NA | 53 |
| | Ozark Plateaus | carbonate-rock | 224 |
| | Southeastern Coastal Plain | semiconsolidated sand and gravel | 41 |
| Cahokia-Joachim | Mississippian | sandstone-carbonate-rock | 246 |
| | None | NA | 102 |
| | Ozark Plateaus | carbonate-rock | 861 |
| | Pennsylvanian | sandstone | 441 |
| Driftwood | None | NA | 207 |
| | Silurian-Devonian | carbonate-rock | 947 |
| Eel | Mississippian | sandstone-carbonate-rock | 313 |
| | None | NA | 438 |
| | Pennsylvanian | sandstone | 444 |
| Highland-Pigeon | Pennsylvanian | sandstone | 997 |
| Little River Ditches | Mississippi River Valley Alluvial | unconsolidated sand and gravel | 2,378 |
| | Ozark Plateaus | carbonate-rock | 261 |
| Lower Cumberland | Mississippian | sandstone-carbonate-rock | 1,856 |
| | None | NA | 478 |
| Lower East Fork White | Mississippian | sandstone-carbonate-rock | 633 |
| | None | NA | 996 |
| | Pennsylvanian | sandstone | 396 |
| Lower Green | None | NA | 8 |
| | Pennsylvanian | sandstone | 915 |
| Lower Kaskaskia | Mississippian | sandstone-carbonate-rock | 39 |
| | None | NA | 180 |
| | Pennsylvanian | sandstone | 1,386 |
| Lower Missouri | Ozark Plateaus | carbonate-rock | 946 |
| Lower Ohio | Mississippi Embayment | semiconsolidated sand | 113 |
| | Mississippi River Valley Alluvial | unconsolidated sand and gravel | 56 |
| | Mississippian | sandstone-carbonate-rock | 12 |
| | None | NA | 362 |
| | Ozark Plateaus | carbonate-rock | 18 |
| | Pennsylvanian | sandstone | 101 |
| | Southeastern Coastal Plain | semiconsolidated sand and gravel | 276 |
| Lower Ohio Bay | Mississippian | sandstone-carbonate-rock | 247 |
| | None | NA | 469 |
| | Pennsylvanian | sandstone | 374 |
| | Southeastern Coastal Plain | semiconsolidated sand and gravel | 5 |
| Lower Ohio-Little Pigeon | None | NA | 269 |
| | Pennsylvanian | sandstone | 1,134 |
| Lower Tennessee | Mississippi Embayment | semiconsolidated sand | 255 |
| | Mississippian | sandstone-carbonate-rock | 44 |
| | None | NA | 200 |
| | Southeastern Coastal Plain | semiconsolidated sand and gravel | 188 |
| Lower Wabash | Pennsylvanian | sandstone | 1,321 |
| Lower White | Mississippian | sandstone-carbonate-rock | 169 |
| | None | NA | 429 |
| | Pennsylvanian | sandstone | 1,077 |

*(table continued on next page)*

(table 3 continued)

| Watershed | Aquifer type | Rock type | Area ($mi^2$) |
|---|---|---|---|
| Meramec | None | NA | 26 |
| | Ozark Plateaus | carbonate-rock | 2,125 |
| Middle Green | None | NA | 336 |
| | Pennsylvanian | sandstone | 681 |
| Middle Wabash-Little Vermilion | Mississippian | sandstone-carbonate-rock | 68 |
| | None | NA | 1,114 |
| | Pennsylvanian | sandstone | 1,047 |
| | Silurian-Devonian | carbonate-rock | 58 |
| Muscatatuck | Mississippian | sandstone-carbonate-rock | 2 |
| | None | NA | 560 |
| | Silurian-Devonian | carbonate-rock | 582 |
| New Madrid-St. Johns | Mississippi River Valley Alluvial | unconsolidated sand and gravel | 723 |
| Patoka | Mississippian | sandstone-carbonate-rock | 1 |
| | None | NA | 189 |
| | Pennsylvanian | sandstone | 669 |
| Peruque-Piasa | Mississippian | sandstone-carbonate-rock | 331 |
| | Ozark Plateaus | carbonate-rock | 2 |
| | Pennsylvanian | sandstone | 214 |
| | None | NA | 111 |
| | Silurian-Devonian | carbonate-rock | 4 |
| Pond | None | NA | 209 |
| | Pennsylvanian | sandstone | 594 |
| Red | Mississippian | sandstone-carbonate-rock | 1,330 |
| | None | NA | 121 |
| Rolling Fork | Mississippian | sandstone-carbonate-rock | 39 |
| | None | NA | 1,294 |
| | Silurian-Devonian | carbonate-rock | 124 |
| Rough | Mississippian | sandstone-carbonate-rock | 44 |
| | None | NA | 626 |
| | Pennsylvanian | sandstone | 422 |
| Saline | None | NA | 12 |
| | Pennsylvanian | sandstone | 1,168 |
| Salt | Mississippian | sandstone-carbonate-rock | 38 |
| | None | NA | 1,170 |
| | Ordivician | carbonate-rock | 118 |
| | Silurian-Devonian | carbonate-rock | 152 |
| Silver-Little Kentucky | Mississippian | sandstone-carbonate-rock | 7 |
| | None | NA | 914 |
| | Silurian-Devonian | carbonate-rock | 369 |
| Tradewater | Mississippian | sandstone-carbonate-rock | 7 |
| | None | NA | 192 |
| | Pennsylvanian | sandstone | 748 |
| Upper East Fork White | None | NA | 327 |
| | Silurian-Devonian | carbonate-rock | 484 |
| Upper Green | Mississippian | sandstone-carbonate-rock | 1,185 |
| | Pennsylvanian | sandstone | 213 |
| | Silurian-Devonian | carbonate-rock | 1,770 |
| Upper Mississippi | Mississippi River Valley Alluvial | unconsolidated sand and gravel | 91 |
| | Mississippian | sandstone-carbonate-rock | 26 |
| | None | NA | 193 |
| | Ozark Plateaus | carbonate-rock | 1,157 |
| | Pennsylvanian | sandstone | 205 |
| Upper White | Mississippian | sandstone-carbonate-rock | 19 |
| | None | NA | 1,119 |
| | Silurian-Devonian | carbonate-rock | 1,616 |
| Whitewater | Mississippi River Valley Alluvial | unconsolidated sand and gravel | 3 |
| | Ozark Plateaus | carbonate-rock | 1,215 |

## Streams and Rivers

The assessment area includes a great diversity of streams, ranging from ephemeral headwaters, to perennial spring seeps, to large, navigable rivers (fig. 4, table 4). These systems, along with their associated reservoirs, account for the vast majority of surface water and are thus a crucial component of the freshwater resources of the area. Because of their longitudinal, unidirectional, and dynamic nature, streams integrate and reflect the landscapes that they drain (Hynes 1970, Vannote et al. 1980) and are thus vulnerable to all disturbances in their drainage areas. Streams are often a strong bellwether of watershed health, and several indices have been developed to characterize stream condition (e.g., Qualitative Habitat Evaluation Index, Yoder and Rankin 1999).

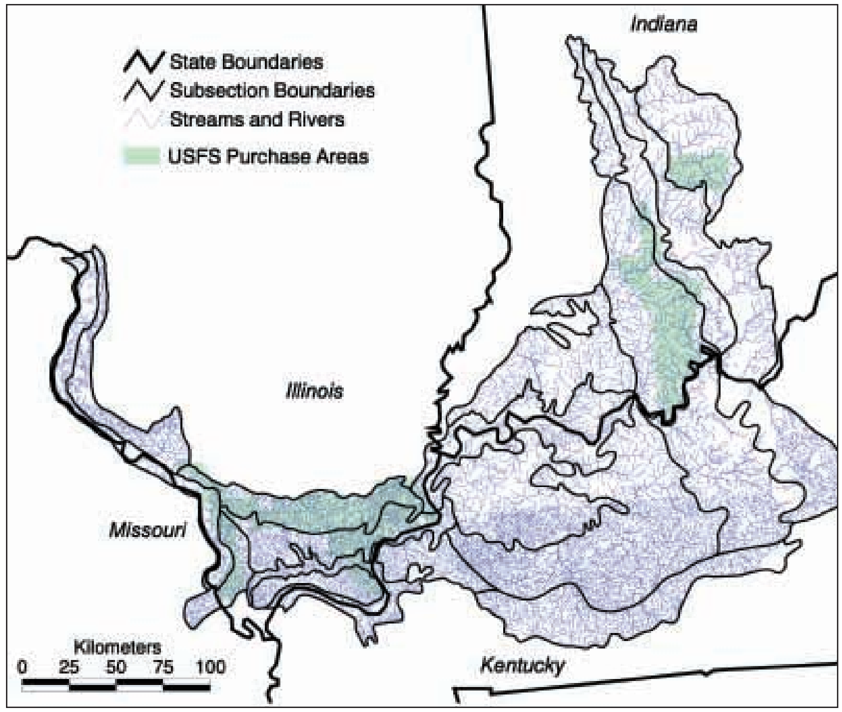



**Figure 4.** Streams of the Hoosier-Shawnee assessment area.

Because small streams, particularly ephemeral and intermittent headwaters, are inevitably underrepresented in data sets derived from maps, data reported in this section do not reflect total streams in the region. Rather, the trends we present are biased to larger streams that appear in the USEPA River Reach File and are included in regional assessments and data sets. Nonetheless, small headwater streams represent the majority of stream reaches in the U.S. (Cushing and Allan 2001, Leopold et al. 1964) and are of great ecological significance (e.g., Cummins 1977, Vannote et al. 1980, Wallace et al. 1992). Further, it has recently been demonstrated that the influence of headwater streams on important processes such as nutrient cycling transcends their relatively small size, and they can potentially influence even large-scale processes such as hypoxia in the Gulf of Mexico (Peterson et al. 2001). Headwater streams also represent some of the most threatened lotic ecosystems because they are often highly modified by human activities such as agriculture and urbanization, sometimes to the point where they are no longer recognizable as streams.

Major watersheds of the assessment area include anywhere from 5 (Cache basin) to 26 (Big Muddy basin) major streams in the basin, and this is proportional to the size of the watersheds (table 4, fig. 4). Likewise, total length of streams ranges from 582 miles (Cache) to 4,716 miles (Little River Ditches), reflecting the sizes of areas drained by watersheds. However, the proportion of stream miles that are perennial varies greatly across the region, as a function of climate, geology, and topography. For the whole region, there are a total of 69,000 miles of streams, and 41,096 miles, or 60 percent of these, are perennial. The proportion of perennial streams in each drainage is highly variable, ranging from only 29 percent in the lower Missouri drainage to 97 percent in the upper East Fork of the White River basin (table 4). As illustrated by these two basins, there is a trend of increasing proportion of perennial miles of streams moving from west to east across the study region, and this is largely related to differences in precipitation.

Along with natural stream channels, there are also a number of unnatural streams in the region. These include drainage ditches that are constructed in agricultural areas and artificial channels constructed to connect bodies of water. In many cases, these unnatural streams

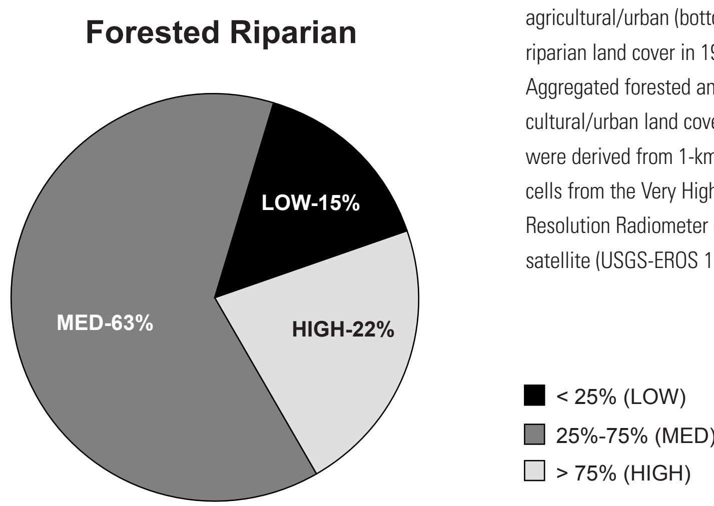
**Table 4.** Surface water characteristics for each hydrologic unit (watershed) of the Hoosier-Shawnee Ecological Assessment Area.

| Watershed | Number of streams | Total river mi | Perennial river mi | Proportion perennial river mi | Proportion natural streams | Major drainage | Mean annual discharge ($ft^3.s^{-1}$) |
|---|---|---|---|---|---|---|---|
| Barren | 16 | 2,299 | 1,741 | 0.76 | 0.96 | Barren River | 2,586 |
| Big Muddy | 26 | 3,349 | 1,059 | 0.32 | 0.94 | Big Muddy River | 710 |
| Blue Sinking | 14 | 1,125 | 972 | 0.86 | 0.90 | Blue River | 327 |
| Cache | 5 | 581 | 272 | 0.47 | 0.81 | Cache River | 300 |
| Cahokia-Joachim | 12 | 2,321 | 730 | 0.31 | 0.92 | Mississippi River | 190,723 |
| Driftwood | 9 | 782 | 718 | 0.92 | 0.91 | Big Blue River | 473 |
| Eel | 7 | 834 | 749 | 0.90 | 0.88 | Eel River | 896 |
| Highland-Pigeon | 13 | 674 | 509 | 0.75 | 0.80 | Ohio River | 132,549 |
| Little River Ditches | 9 | 4,713 | 1,756 | 0.37 | 0.28 | Little River | 2,892 |
| Lower Cumberland | 24 | 2,739 | 1,979 | 0.72 | 0.88 | Cumberland River | 24,494 |
| Lower East Fork White | 16 | 1,403 | 1236 | 0.88 | 0.87 | East Fork White River | 4,900 |
| Lower Green | 7 | 771 | 718 | 0.93 | 0.83 | Green River | 11,229 |
| Lower Kaskaskia | 9 | 2,511 | 926 | 0.37 | 0.96 | Kaskaskia River | 3,761 |
| Lower Missouri | 18 | 2,425 | 693 | 0.29 | 0.93 | Missouri River | 80,985 |
| Lower Ohio | 15 | 1,245 | 540 | 0.43 | 0.84 | Ohio River | 277,541 |
| Lower Ohio Bay | 18 | 4,458 | 2,817 | 0.63 | 0.90 | Ohio River | 1,891,012 |
| Lower Ohio-Little Pigeon | 17 | 1,085 | 962 | 0.89 | 0.83 | Ohio River | 128,839 |
| Lower Tennessee | 8 | 1,201 | 778 | 0.65 | 0.96 | Tennessee River | NA |
| Lower Wabash | 15 | 1,042 | 730 | 0.70 | 0.76 | Wabash River | 28,264 |
| Lower White | 18 | 1,221 | 1,079 | 0.88 | 0.72 | White River | 4,900 |
| Meramec | 16 | 3,663 | 970 | 0.26 | 0.98 | Meramec River | 3,279 |
| Middle Green | 15 | 1,537 | 1,089 | 0.71 | 0.91 | Green River | 8,502 |
| Middle Wabash-Little Vermilion | 12 | 2,492 | 1,373 | 0.55 | 0.90 | Wabash River | 6,672 |
| Muscatatuck | 14 | 953 | 856 | 0.90 | 0.91 | Muscatatuck River | 226 |
| New Madrid-St. Johns | 10 | 957 | 366 | 0.38 | 0.23 | Ohio River | NA |
| Patoka | 7 | 672 | 497 | 0.74 | 0.89 | Patoka River | 1,044 |
| Peruque-Piasa | 7 | 834 | 316 | 0.38 | 0.88 | Mississippi River | 109,182 |
| Pond | 10 | 1,225 | 760 | 0.62 | 0.88 | Pond River | 274 |
| Red | 16 | 919 | 724 | 0.79 | 0.98 | Red River | 1,354 |
| Rolling Fork | 16 | 2,014 | 1,696 | 0.84 | 0.99 | Rolling Fork | 1,818 |
| Rough | 10 | 1,016 | 838 | 0.83 | 0.92 | Rough River | 1,085 |
| Saline | 18 | 1,731 | 602 | 0.35 | 0.94 | South Fork Saline River | 164 |
| Salt | 16 | 1,507 | 1,271 | 0.84 | 0.95 | Salt River | 1,589 |
| Silver-Little Kentucky | 9 | 961 | 844 | 0.88 | 0.90 | Ohio River | 116,408 |
| Tradewater | 13 | 1,533 | 1,231 | 0.80 | 0.90 | Tradewater River | 333 |
| Upper East Fork White | 6 | 631 | 610 | 0.97 | 0.85 | East Fork White River | 2,537 |
| Upper Green | 20 | 3,612 | 2,496 | 0.69 | 0.95 | Green River | 2,741 |
| Upper Mississippi-Cape Girardeau | 20 | 2,131 | 1,085 | 0.51 | 0.87 | Mississippi River | 207,882 |
| Upper White | 15 | 1,774 | 1,591 | 0.90 | 0.87 | White River | 2,533 |
| Whitewater | 13 | 2,001 | 894 | 0.45 | 0.96 | Mississippi River | NA |

are located where natural stream channels occurred historically, but channelized ditches have replaced the natural features. On average, 14 percent of streams in the study region are artificial or highly modified, and this ranges from only 28 percent natural streams in the heavily agricultural region of the Little River Ditches drainage in the "bootheel" of Missouri to 99 percent natural streams in the Rolling Fork basin of western Kentucky. In general, the proportion of unnatural streams is highest in low, flat areas near major rivers where a high proportion of the land is cultivated (table 4). There is little information about the ecological integrity of these unnatural streams in the study region, but evidence from other regions suggests they are highly degraded systems (e.g., Cooper 1993, Whiles et al. 2000).

Discharge data reflect water export from the major stream in each drainage basin, and these values are highly variable across the region. Numerous basins are drained by relatively small rivers (e.g., Saline, Muscatatuck, Cache), whereas others include major rivers such as the Ohio and Mississippi that have substantial discharge (e.g., Cahokia-Joachim, upper Mississippi-Cape Girardeau, lower Ohio Bay). However, it is important to note that basins bisected by large rivers like the Mississippi and Ohio are not exporting all discharge reported. Rather, these values reflect export by the entire landscape drained by these large rivers, and the contribution from areas within the Hoosier-Shawnee study region represent only a fraction of total discharge. Average total discharge for the entire study area (including large rivers that flow through the region) is 87,937 $ft^3.s^{-1}$.

Riparian land use has been shown to be one of the most important determinants of water quality and biotic integrity. Riparian vegetation can influence the movement of water, sediments, and nutrients into streams and also influences instream physical habitat and temperature (Naiman 1997). Riparian vegetation also influences the trophic status of streams by influencing light penetration that fuels instream primary production and by providing energy inputs such as leaf litter (Vannote et al. 1980). Historically, riparian vegetation in this region was primarily forest, but human activities have greatly altered this pattern (fig. 5). Of the 40 major drainages in the assessment area, only 22 percent—including the Blue Sinking and upper Green watersheds—have greater than 75 percent forested riparian vegetation, and 63 percent have between 25 and 75 percent forested riparian zones. Conversely, 75 percent—including the Little River Ditches and Lower Wabash catchments—have >50 percent agricultural and urban riparian zones, and only 15 percent have less than 20 percent agricultural and urban riparian zones.



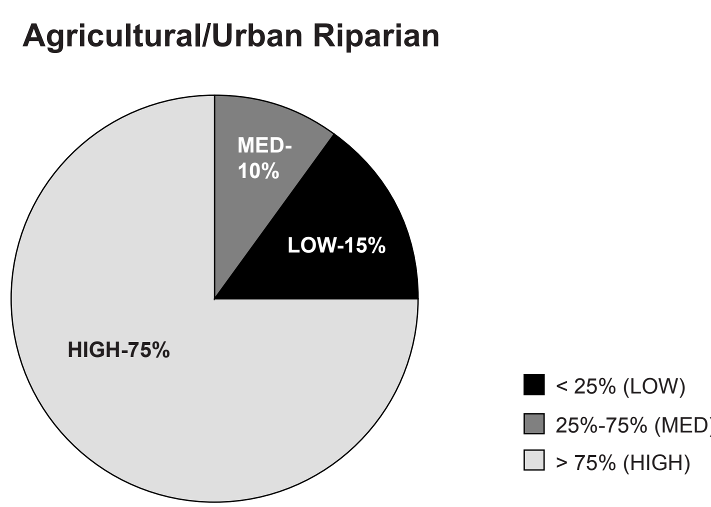




**Figure 5.** Percentage of watersheds (N=40) within the Hoosier-Shawnee assessment area that contained low, moderate, or high forested (top) or agricultural/urban (bottom) riparian land cover in 1990. Aggregated forested and agricultural/urban land cover data, were derived from 1-km grid cells from the Very High Resolution Radiometer (AVHRR) satellite (USGS-EROS 1990).

Aside from occasional studies on individual stream reaches, there is little quantitative information on instream habitats across the assessment area. In one of the few comprehensive studies in the region, Hite et al. (1990) surveyed 14 streams in the Shawnee National Forest during 1986-1987 and found that conditions varied greatly in the region, but that the streams they examined generally had good physical habitat, water quality, and biological integrity. In particular, they noted that streams such as Big, Lusk, and Big Grand Pierre Creeks (lower Ohio-Bay drainage) and upper Clear and upper Miller Creeks (upper Mississippi-Cape Girardeau), which drain forested uplands, were exceptional in quality. In contrast, streams that drained agricultural areas, such as Bay and Cedar Creeks (lower Ohio-Bay drainage) and lower Clear Creek (upper Mississippi-Cape Girardeau), were relatively degraded. Hite et al. (1990) noted that riparian land use was a major determinant of stream quality in the region and cited loss of riparian vegetation, sediment and nutrient inputs from crop fields, and unregulated ATV traffic as threats to stream habitat quality and biological integrity in the region. Similarly, Muir et al. (1995) found better stream conditions in relatively undisturbed uplands of the Cache River basin compared to lower stream reaches draining agricultural areas.

Stream biodiversity, ecosystem function, and overall health are generally maximized when habitat heterogeneity is high (Allan 1995). Habitat heterogeneity in streams is largely a function of substrates (e.g., a mix of substrate particle sizes with some stable substrate types present) and channel morphology and current dynamics (e.g., sinuosity and regular riffle-pool sequences) (Allan 1995). Although high habitat heterogeneity is evident in some stream reaches in the study area, particularly in headwaters and mid-reaches, land use patterns in much of the region and the large number of systems impacted by sediments result in poor physical habitat quality in many stream reaches (Hite et al. 1990, Muir et al. 1995).

A large portion of streams in the assessment area drain agricultural landscapes and have been channelized to maximize drainage of the land. Channelization of streams degrades instream and riparian habitat, including reaches upstream of the channelized segments. Subtle changes in elevation at the upstream end of channelized reaches causes formation of migrating head cuts that result in downcutting and widening of upstream reaches, and thus increases bank erosion and sedimentation. Channelized stream reaches also have reduced capacity to dissipate stream energy, further enhancing erosion and sedimentation.

Streams draining agricultural regions of the assessment area are also vulnerable to sediment inputs from exposed soils in croplands. As an example, Big Creek in Union County, Illinois (Cache drainage) has high quality instream habitat and harbors a high diversity of aquatic species in upper reaches where it is protected by extensive riparian forest. However, stream habitat and the inhabitant community degrade rapidly downstream as it approaches the Cache River where it flows through extensive cropland, including channelized reaches with minimal riparian forest cover. As a result, this stream is a current focus of restoration activities by the Illinois Department of Natural Resources and Illinois Environmental Protection Agency (Guetersloh 2001).

In addition to water quality, instream physical habitat is also important to the integrity of stream ecosystems. Although water quality and instream habitat quality are often related, improvements in water quality without consideration of instream habitat quality may not produce benefits in terms of biodiversity and stream ecosystem function.

## Lakes and Reservoirs

Aside from oxbows associated with larger rivers, and a few sinkhole ponds located in southern Indiana and eastern Missouri, there are no natural lakes in the Hoosier-Shawnee study area. Nonetheless, human activities (i.e., dam construction) have resulted in an abundance of lentic habitats that are used for flood control, recreation, and water supplies (table 5). The Shawnee National Forest alone contains more than 200 small (<5 acre) ponds that were constructed to serve as watering stations for wildlife and provide habitat for birds, fish, aquatic invertebrates, and breeding amphibians. It has also been suggested that these forest ponds are important feeding and watering areas for resident bats, including the federally endangered Indiana bat (*Myotis sodalis*).

The reservoirs within the Hoosier-Shawnee Ecological Assessment Area are primarily warm-water systems with relatively high primary productivity (primarily eutrophic; Bremigan and Stein 1999, DiCenzo et al. 1996), and the general trend is for decreasing fertility from west to east within the study area. High primary productivity has been linked with high standing biomass of fish (Ney 1996). However, detrimental or undesirable species often become disproportionately represented in fish assemblages under these conditions (Stein et al. 1995). Hence, the high productivity in many of the reservoirs within the assessment area may have negative impacts on the recreational quality of the fish resource. Similarly, high productivity can create water quality problems associated with unchecked algal growth and reductions in oxygen concentrations.

Productivity, water clarity, and fish production within reservoirs are strongly influenced by land use practices within their drainage areas. Reservoirs within the study area have drainage areas that are on average 2,178 times larger than their surface area, although roughly half only drain areas 27 times or less of the reservoir surface area (table 6). Management of reservoirs in the study area will require an understanding of the linkages between human activities (e.g., land use) in the drainage area and water quality. Because these systems are strongly linked to the watershed, agricultural practices, urban runoff,

**Table 5.** Number of lakes and total lake surface area within each hydrologic unit (watershed) in the Hoosier-Shawnee assessment area.

| Watershed | Number of lakes | Total lake area (acres) |
|---|---|---|
| Barren | 127 | 16,173 |
| Big Muddy | 742 | 42,236 |
| Blue Sinking | 102 | 1,333 |
| Cache | 33 | 2,060 |
| Cahokia-Joachim | 210 | 4,011 |
| Driftwood | 150 | 2,551 |
| Eel | 383 | 7,905 |
| Highland-Pigeon | 194 | 4,598 |
| Little River Ditches | 186 | 4,606 |
| Lower Cumberland | 357 | 68,209 |
| Lower East Fork White | 242 | 16,845 |
| Lower Green | 70 | 789 |
| Lower Kaskaskia | 385 | 6,174 |
| Lower Missouri | 214 | 3,883 |
| Lower Ohio | 219 | 3,467 |
| Lower Ohio Bay | 202 | 2,302 |
| Lower Ohio-Little Pigeon | 248 | 4,125 |
| Lower Tennessee | 66 | 856 |
| Lower Wabash | 151 | 4,937 |
| Lower White | 229 | 2,966 |
| Meramec | 190 | 2,676 |
| Middle Green | 147 | 2,900 |
| Middle Wabash - Little Vermilion | 155 | 4,279 |
| Muscatatuck | 161 | 3,346 |
| New Madrid- St. Johns | 79 | 1,177 |
| Patoka | 240 | 11,706 |
| Peruque-Piasa | 159 | 2,867 |
| Pond | 153 | 2,275 |
| Red | 111 | 745 |
| Rolling Fork | 99 | 1,251 |
| Rough | 107 | 7,222 |
| Saline | 372 | 6,453 |
| Salt | 229 | 3,414 |
| Silver-Little Kentucky | 174 | 2,110 |
| Tradewater | 119 | 3,136 |
| Upper East Fork White | 101 | 1,591 |
| Upper Green | 149 | 38,917 |
| Upper Mississippi | 277 | 4,931 |
| Upper White | 439 | 11,569 |
| Whitewater | 97 | 1,459 |

**Table 6.** Mean (±1SD) and median surface area of lakes and their drainages in the ecological units of the Hoosier-Shawnee assessment area.

| Statistic | Surface area (acres) | Drainage area ($mi^2$) | Drainage area (acres): surface area (acres) |
|---|---|---|---|
| Mean | 364 | 1,232 | 2,178 |
| Standard Deviation | 2,197 | 12,561 | 6,574 |
| Median | 16 | 1 | 27 |

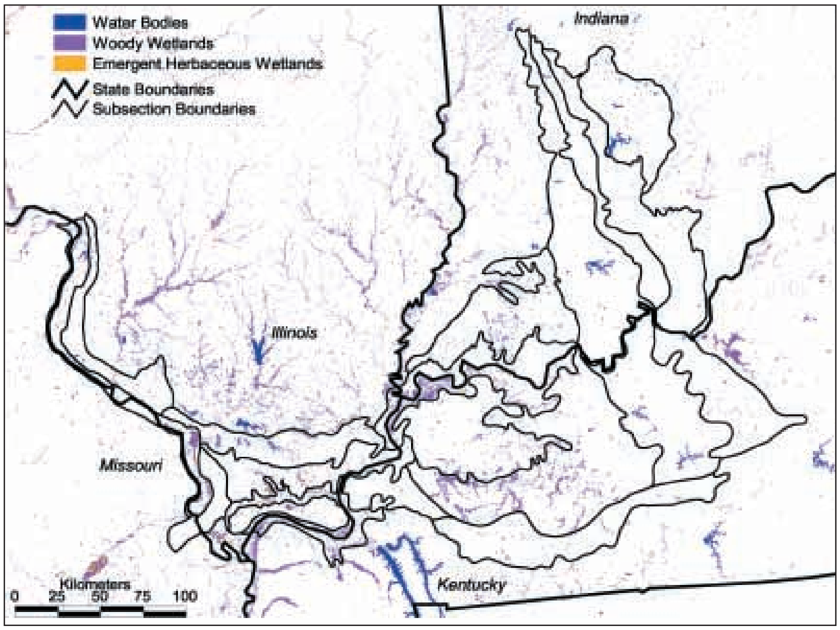



**Figure 6.** Lakes, reservoirs, and wetlands in the Hoosier-Shawnee assessment area.

and wastewater discharge can greatly affect system productivity with detrimental effects to fish assemblages and water quality. Thus, as with other freshwater resources, an awareness of land use patterns is necessary for proper management of lentic resources in the region.

There are a total of 8,068 lakes and reservoirs in the Hoosier-Shawnee study area, totaling 314,048 acres of surface area (table 5, fig. 6). The lower Cumberland, Big Muddy, and upper Green stand out as having much greater total surface areas of reservoirs than the other catchments in the study area. Both the lower Cumberland and upper Green watersheds contain reservoirs with large surface areas (e.g., ranging from 143,137 to 170,924 acres) and high storage capacities including Kentucky Lake, Lake Barkley, and Nolin Lake. The reservoirs within the Big Muddy watershed are only moderately sized (e.g., Cedar and Crab Orchard Lakes at 1,704 and 6,916 acres, respectively), but their high abundance (N=742) generates a high total surface area. Mean surface area of lakes and reservoirs in the assessment area is 364 acres. However, half of the reservoirs are less than 16 acres in surface area (table 6, fig. 6).

Although they can provide numerous benefits, reservoirs can also have negative ecological impacts. In particular, impounding streams changes both the physical (e.g., flow, depth, temperature, sediments) and biological aspects of lotic systems, and can result in isolation of stream reaches. The decline and/or loss of numerous aquatic species is linked to impoundments (Ricciardi and Rasmussen 1999, Richter et al. 1997, Vaughn and Taylor 1999), and Schrank et al. (2001) recently demonstrated that even very small impoundments (e.g., cattle ponds <2 acres) on streams in the Midwest were linked to the absence of a now federally endangered fish species, the Topeka shiner (Notropis topeka). Further, reservoirs can exacerbate regional water quantity problems by enhancing evaporation (Wetzel 2001). Given the number of impoundments that already exist on streams of the assessment area, there have undoubtedly been negative ecological impacts.

For existing impoundments, dam breaching or removal may be an option for reversing deleterious environmental effects. This strategy has been effectively implemented in many states to improve fish passage and to improve instream water quality (Bednarek 2001, Smith et al. 2000). When dams deteriorate, removal may be a particularly viable option if the positive environmental benefits outweigh the high costs of repairs. Water resource managers must carefully consider the consequences of removal projects because community support has not been historically strong, given the loss of impounded waters for recreation (Born et al. 1998). Any planned removal projects in the Hoosier-Shawnee Ecological Assessment Area would likely have socioeconomic and environmental consequences (Bednarek 2001, Born et al. 1998).

## Wetlands and Springs

Wetlands are generally defined as areas where the water table is at or near the land surface, soils are hydric, and dominant plants are hydrophytes. Wetlands may be difficult to define, but they are almost universally regarded as ecosystems that are vital to regional biodiversity and water quality. In Illinois, it is estimated that >40 species of threatened or endangered birds and ~30 threatened or endangered fish species use wetland habitats (CTAP 1994). Further, a large number of amphibian species, a group that is currently of great interest due to massive declines and extinctions across the globe, are associated with wetlands (Stebbins and Cohen 1995). Wetlands also provide important recreational opportunities in the form of waterfowl hunting and fishing. Wetlands are important in hydrological processes and help control flooding during wet periods and maintain base flows during dry periods (Mitsch and Gosselink 1993). Wetlands mediate the impacts of excess nutrients and may facilitate the uptake of pollutants, and it is usually more economically feasible to preserve wetlands than to build water treatment plants (Chichilnisky and Heal 1998). Although the importance of wetlands is now widely accepted, they are one of the most beleaguered ecosystems in North America, and the current extent of wetland habitats across the country is only a fraction (<50 percent) of historical conditions (Vileisis 1997).

Wetland area, and the proportion of catchments classified as wetland, varies considerably across the Hoosier-Shawnee study area (table 7, fig. 6). However, no single catchment in the region has >7 percent woody and >3 percent herbaceous wetland areas. Woody wetlands are characterized by areas where forest or shrubland vegetation accounts for >25 percent of the vegetation cover and the soil is periodically saturated with or covered by water (e.g., swamps). Herbaceous wetlands, the less common of the two, are areas in which perennial herbaceous vegetation accounts for >75 percent of the cover, with the same hydric soil characteristics as the former (e.g., marshes). Wetlands in the study region are fed by precipitation, surface runoff, groundwater, or various combinations of each.

**Table 7.** Total area (square miles) and proportion of watershed area of woody and herbaceous vegetation wetlands within each USGS hydrological unit (watershed) of the Hoosier-Shawnee assessment area.

| | Area ($mi^2$) | | Proportion of watershed area | |
|---|---|---|---|---|
| **Watershed** | **Woody** | **Herbaceous** | **Woody** | **Herbaceous** |
| Barren | 23 | 1.6 | 0.0103 | 0.0007 |
| Big Muddy | 142 | 15.0 | 0.0596 | 0.0063 |
| Blue Sinking | 6 | 0.3 | 0.0033 | 0.0002 |
| Cache | 20 | 7.6 | 0.0571 | 0.0212 |
| Cahokia-Joachim | 40 | 5.6 | 0.0240 | 0.0034 |
| Driftwood | 9 | 0.4 | 0.0076 | 0.0003 |
| Eel | 4 | 0.4 | 0.0032 | 0.0003 |
| Highland-Pigeon | 56 | 4.3 | 0.0564 | 0.0043 |
| Little River Ditches | 58 | 4.3 | 0.0221 | 0.0016 |
| Lower Cumberland | 21 | 2.0 | 0.0090 | 0.0009 |
| Lower East Fork White | 5 | 1.1 | 0.0023 | 0.0005 |
| Lower Green | 35 | 1.9 | 0.0374 | 0.0021 |
| Lower Kaskaskia | 80 | 4.9 | 0.0501 | 0.0031 |
| Lower Missouri | 32 | 4.0 | 0.0198 | 0.0025 |
| Lower Ohio | 56 | 9.7 | 0.0602 | 0.0105 |
| Lower Ohio Bay | 48 | 7.9 | 0.0442 | 0.0073 |
| Lower Ohio-Little Pigeon | 21 | 1.6 | 0.0146 | 0.0012 |
| Lower Tennessee | 43 | 0.4 | 0.0612 | 0.0005 |
| Lower Wabash | 67 | 8.3 | 0.0507 | 0.0063 |
| Lower White | 14 | 0.6 | 0.0084 | 0.0004 |
| Meramec | 12 | 2.6 | 0.0055 | 0.0012 |
| Middle Green | 42 | 1.9 | 0.0411 | 0.0018 |
| Middle Wabash-Little Vermilion | 60 | 5.0 | 0.0264 | 0.0022 |
| Muscatatuck | 22 | 0.4 | 0.0195 | 0.0003 |
| New Madrid- St. Johns | 27 | 3.7 | 0.0369 | 0.0051 |
| Patoka | 14 | 1.8 | 0.0162 | 0.0021 |
| Peruque-Piasa | 24 | 4.5 | 0.0369 | 0.0067 |
| Pond | 52 | 3.6 | 0.0654 | 0.0045 |
| Red | 38 | 3.4 | 0.0272 | 0.0024 |
| Rolling Fork | 27 | 0.7 | 0.0185 | 0.0005 |
| Rough | 19 | 0.3 | 0.0177 | 0.0003 |
| Saline | 50 | 6.1 | 0.0424 | 0.0052 |
| Salt | 23 | 1.1 | 0.0154 | 0.0007 |
| Silver-Little Kentucky | 15 | 1.1 | 0.0117 | 0.0009 |
| Tradewater | 57 | 1.3 | 0.0613 | 0.0014 |
| Upper East Fork White | 7 | 0.1 | 0.0085 | 0.0001 |
| Upper Green | 28 | 0.6 | 0.0090 | 0.0002 |
| Upper Mississippi | 56 | 10.8 | 0.0337 | 0.0065 |
| Upper White | 19 | 1.4 | 0.0069 | 0.0005 |
| Whitewater | 9 | 1.2 | 0.0077 | 0.0010 |

Predictably, most wetlands in the assessment area are located in low, floodplain areas associated with the larger river systems (fig. 6). However, even these areas have only a fraction of their original wetlands remaining, due mostly to agricultural activities that required draining most of the original wetlands. This pattern is of particular concern, as it has been demonstrated that floodplain wetlands are an important component of large river function and productivity (e.g., Junk et al. 1989). The consequences of floodplain wetland loss to large river health in the region are still not fully understood, and this issue certainly deserves more attention.

Currently, the average proportion of woody and herbaceous wetlands in the entire study region is only 2.8 percent and 0.3 percent, respectively, and Illinois ranks as one of the top 10 states in the U.S. in terms of wetland loss (>70 percent loss for the state). There are also indications that many remaining wetland systems in the region are polluted. Historically, wetlands have been used extensively as dumping areas, and thus many may be polluted with a variety of contaminants. For example, a large portion of the >3,000 sites that have been used for waste disposal in Illinois are located in wetlands, and 8 percent of the wetlands in the state are located within 1 mile of a landfill or open dump (CTAP 1994). Clearly, wetlands are limited and imperiled in the study region and could be primary targets for conservation and restoration activities on this basis.

A variety of spring habitats are found throughout the assessment area, but their occurrence is poorly documented and there is little information on the hydrology and biology of these important freshwater habitats in this region. Typically, springs occur where the water table meets the land surface, and they range greatly in size, from small seeps to large features with substantial discharge that contribute greatly to surface waters. The LaRue-Pine Hills Ecological Area in Union County, Illinois (Upper Mississippi Cape Girardeau watershed), is an example of a region within the study area that is rich in wetland and spring habitats. Spring habitats contribute greatly to the high biodiversity of the area, supporting a great diversity of aquatic species, including the spring cavefish (*Forbesicthys agassizi*) and cave salamander (*Eurycea lucifuga*) that are associated with the numerous spring seeps found on the property.

Because both wetlands and springs are closely linked to groundwater dynamics, monitering of groundwater quality and withdrawals is important for their conservation. Even small reductions in groundwater resources can have large impacts on the hydrology of wetland and spring habitats (Carter 1996, Hunt et al. 1999), and groundwater contamination, particularly in karst regions, will also negatively impact wetlands and springs.

## WATER QUALITY PATTERNS

Watershed integrity, as characterized by the USEPA's Index of Watershed Indicators (IWI), in 1999 varied greatly among the watersheds within the Hoosier-Shawnee study area (table 8). These scores are a composite of several factors that influence water quality and vulnerability within each watershed, and lower scores reflect better overall conditions (see Approach section, table 2).

Eight of the forty watersheds were assigned a score of 1, indicating these were areas of high integrity and low vulnerability to perturbations (table 8). These catchments typically contained only a few systems that did not meet water quality standards (table 8). Conversely, 14 watersheds had IWI scores of 5-6, suggesting that water quality was relatively poor in these areas (table 8). An average of 21 lakes and streams failed to meet water quality standards within these watersheds. Drainages that were assigned the highest score of 6 contained lakes and streams with high nutrients, contaminants, and pathogens (table 8). Overall, nutrients and contaminants account for >50 percent of water quality problems within the Hoosier-Shawnee Ecological Assessment Area

**Table 8.** USEPA's index of watershed integrity (IWI) and number of 303d listed streams and lakes (1998) within each hydrologic unit (watershed) of the Hoosier-Shawnee assessment area. Systems with nutrient contamination commonly have high biological oxygen demand and low dissolved oxygen. Common contaminants within streams and lakes are heavy metals (e.g., mercury, lead), PCBs, and pesticides. Habitat alterations include flow changes and channel modification.

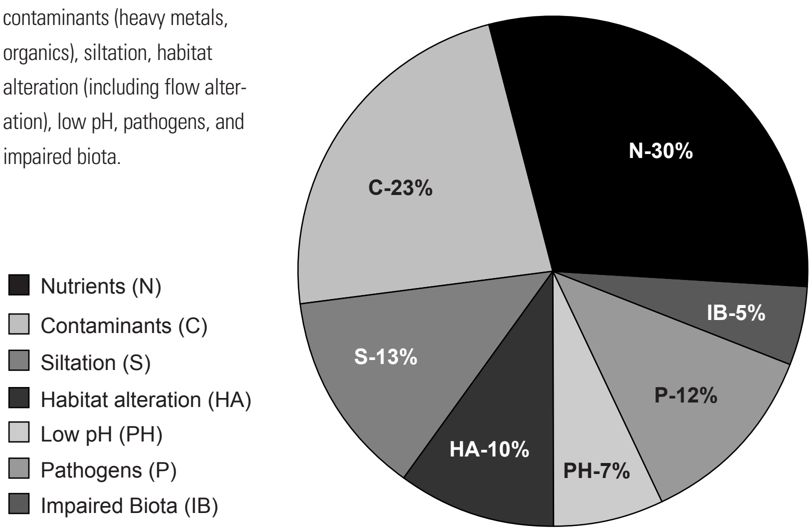
| | | | Proportion of systems | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Watershed | IWI | No. of systems | Nutrients | Contaminants | Siltation | Habitat alteration | Low pH | Pathogens | Impaired biota |
| Barren | 2 | 8 | 0.50 | 0.25 | 0.00 | 0.13 | 0.00 | 0.13 | 0.00 |
| Big Muddy | 5 | 78 | 0.49 | 0.15 | 0.27 | 0.01 | 0.08 | 0.00 | 0.00 |
| Blue Sinking | 4 | 4 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 | 0.50 | 0.00 |
| Cache | 5 | 16 | 0.50 | 0.00 | 0.19 | 0.31 | 0.00 | 0.00 | 0.00 |
| Cahokia-Joachim | 5 | 25 | 0.36 | 0.20 | 0.24 | 0.16 | 0.00 | 0.04 | 0.00 |
| Driftwood | NA | 6 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Eel | 3 | 12 | 0.00 | 0.25 | 0.00 | 0.00 | 0.00 | 0.42 | 0.33 |
| Highland-Pigeon | 6 | 4 | 0.25 | 0.50 | 0.00 | 0.00 | 0.00 | 0.25 | 0.00 |
| Little River Ditches | 1 | 3 | 0.00 | 0.33 | 0.67 | 0.00 | 0.00 | 0.00 | 0.00 |
| Lower Cumberland | 1 | 6 | 0.50 | 0.00 | 0.33 | 0.00 | 0.00 | 0.17 | 0.00 |
| Lower East Fork White | 4 | 12 | 0.00 | 0.58 | 0.00 | 0.00 | 0.00 | 0.08 | 0.33 |
| Lower Green | 3 | 8 | 0.13 | 0.00 | 0.25 | 0.63 | 0.00 | 0.00 | 0.00 |
| Lower Kaskaskia | 5 | 18 | 0.78 | 0.06 | 0.11 | 0.00 | 0.06 | 0.00 | 0.00 |
| Lower Missouri | 3 | 2 | 0.00 | 0.50 | 0.00 | 0.50 | 0.00 | 0.00 | 0.00 |
| Lower Ohio | 5 | 20 | 0.40 | 0.15 | 0.10 | 0.20 | 0.10 | 0.05 | 0.00 |
| Lower Ohio Bay | 3 | 22 | 0.36 | 0.05 | 0.18 | 0.36 | 0.00 | 0.05 | 0.00 |
| Lower Ohio-Little Pigeon | 3 | 5 | 0.20 | 0.60 | 0.00 | 0.00 | 0.00 | 0.20 | 0.00 |
| Lower Tennessee | 1 | 3 | 0.33 | 0.00 | 0.33 | 0.00 | 0.00 | 0.33 | 0.00 |
| Lower Wabash | 5 | 8 | 0.38 | 0.13 | 0.38 | 0.00 | 0.00 | 0.13 | 0.00 |
| Lower White | 4 | 18 | 0.00 | 0.22 | 0.00 | 0.00 | 0.00 | 0.33 | 0.44 |
| Meramec | 1 | 2 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Middle Green | 3 | 11 | 0.36 | 0.09 | 0.09 | 0.09 | 0.18 | 0.18 | 0.00 |
| Middle Wabash-Little Vermilion | 5 | 12 | 0.08 | 0.50 | 0.08 | 0.00 | 0.00 | 0.00 | 0.33 |
| Muscatatuck | 3 | 1 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| New Madrid-St. Johns | 5 | 1 | 0.00 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Patoka | 1 | 3 | 0.00 | 0.67 | 0.00 | 0.00 | 0.00 | 0.00 | 0.33 |
| Peruque-Piasa | 4 | 6 | 0.00 | 0.33 | 0.17 | 0.50 | 0.00 | 0.00 | 0.00 |
| Pond | 3 | 10 | 0.00 | 0.20 | 0.00 | 0.10 | 0.60 | 0.10 | 0.00 |
| Red | 1 | 13 | 0.31 | 0.08 | 0.46 | 0.08 | 0.00 | 0.08 | 0.00 |
| Rolling Fork | 4 | 7 | 0.29 | 0.00 | 0.00 | 0.00 | 0.43 | 0.29 | 0.00 |
| Rough | 1 | 4 | 0.75 | 0.00 | 0.00 | 0.25 | 0.00 | 0.00 | 0.00 |
| Saline | 5 | 45 | 0.29 | 0.27 | 0.09 | 0.16 | 0.20 | 0.00 | 0.00 |
| Salt | 6 | 19 | 0.32 | 0.26 | 0.00 | 0.05 | 0.00 | 0.37 | 0.00 |
| Silver-Little Kentucky | 6 | 17 | 0.29 | 0.47 | 0.00 | 0.06 | 0.00 | 0.18 | 0.00 |
| Tradewater | 3 | 7 | 0.29 | 0.14 | 0.14 | 0.00 | 0.29 | 0.14 | 0.00 |
| Upper East Fork White | 5 | 3 | 0.00 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Upper Green | 3 | 10 | 0.30 | 0.30 | 0.00 | 0.10 | 0.00 | 0.30 | 0.00 |
| Upper Mississippi | 5 | 16 | 0.63 | 0.06 | 0.06 | 0.25 | 0.00 | 0.00 | 0.00 |
| Upper White | 6 | 37 | 0.03 | 0.32 | 0.00 | 0.00 | 0.05 | 0.46 | 0.14 |
| Whitewater | 1 | 0 | NA | NA | NA | NA | NA | NA | NA |

(fig. 7). Siltation, habitat alterations, and pathogens were responsible for an additional 35 percent of water quality problems (fig. 7). Impaired biota and low pH were relatively rare occurrences in the listed systems.

This analysis suggests that nutrient loading, presumably from agricultural activities and wastewater discharges, plus contaminants from industry and sediments from agriculture are the primary factors negatively affecting water quality within much of this region. Agricultural conservation programs (e.g., implementing best management practices such as conservation tillage and vegetated riparian buffers), municipal nutrient abatement, and regulation/monitoring of industrial practices appear to be necessary to prevent further degradation of water quality and to allow current systems to meet federally mandated water quality standards. Unfortunately, many of these problems, particularly nutrient additions from agricultural activities, are non-point source, and these are often more difficult to assess and remediate than point-source issues. In general, non-point pollution issues are best dealt with at the watershed scale and may require relatively long periods of time before improvements to aquatic habitats are evident.

To address management and remediation of non-point threats to water quality and stream integrity at the watershed scale, the Illinois Department of Natural Resources, along with other private, State, and Federal entities, implemented the Pilot Watersheds Program in 1998, with one pair of watersheds (Big Creek and Cypress Creek in the Cache drainage) located in the Hoosier-Shawnee region. This program is designed to monitor changes in hydrology, water quality, instream habitat, and biological integrity in paired watersheds through time as best management practices such as vegetated riparian buffers, conservation tillage agriculture, and instream habitat restorations are implemented.

**Figure 7.** Percentage of USEPA 303d-listed streams and lakes (N= 344) within the ecological units of the Hoosier-Shawnee assessment area in 1998 that have been categorized as failing to meet water quality standards relative to nutrients (including high BOD), contaminants (heavy metals, organics), siltation, habitat alteration (including flow alteration), low pH, pathogens, and impaired biota.




## WATER USE TRENDS

Patterns of water use in the assessment area provide insight into potential sources of water loss and contamination. Trends between 1990 and 1995 provide some sense of past and future changes through time. During 1990 and 1995, the number of wastewater facilities varied among watersheds, largely as a function of resident population density and industrial activity (table 9). The total number of wastewater facilities increased only by 2 percent between 1990 and 1995. If nutrient and contaminant loading from these facilities is roughly proportional to their abundance, we may predict that wastewater point sources of these pollutants are not increasing appreciably.

Average per capita offstream water use within the study region was 3,055 and 3,075 gallons.$d^{-1}$ in 1990 and 1995, respectively (table 10), which is higher than the national average of 2,000 gallons.$d^{-1}$ (Dodds 2002). Offstream use is water diverted or withdrawn from a surface or groundwater source and conveyed to a place of use (Solley et al. 1998). Per capita offstream use for the States of Illinois, Indiana, Kentucky, and Missouri was 1,680, 1,570, 1,150, and 1,320 gallons.$d^{-1}$ during this time (Solley et al. 1998). Thus, average water use per person is generally higher in the assessment area than in the states in which it resides. It is important to note that per capita use varied widely among watersheds within the region; per capita use was less than 376 gallons.d$^{-1}$ in half of the watersheds (table 10). Nationally, per capita water use has declined since the early 1980s due to increased efficiency of use, particularly with agriculture (Dodds 2002, Solley et al. 1998). In comparison, change in per capita use varied widely between 1990 and 1995 within each watershed of the assessment area (table 10).

Total groundwater and surface water use within the entire Hoosier-Shawnee Ecological Assessment Area increased by about 11 percent from 1990 through 1995 (table 11). Surface water use was approximately 16 times greater than groundwater use during both years, primarily due to thermoelectric power generation (fig. 8). Total water use varied greatly among watersheds. Power plants and other factors such as irrigation influenced this variability among catchments. Below, we explore factors influencing differences in total water use.

Water use for irrigation and livestock was particularly important in the Little River Ditches, lower White, and New Madrid-St. Johns watersheds (table 12). Total water use for agriculture increased by an average of 50 percent between 1990 and 1995 but was relatively minor compared to various other water uses (fig. 8). Total domestic water use was relatively low during both years (fig. 8) and changed only 4 percent between years (table 12). Highest domestic use (i.e., for residential use) occurred in upper White, the watershed with the highest human population density. Mining was a relatively minor consumer of total water within the entire region (fig. 8), but use increased by more than 100 percent between 1990 and 1995 (table 12). Watersheds with high water consumption by mining activities typically overlapped subsections such as the Interior and Outer Western Coal Fields of the Shawnee Hills Section. As is typical nationally (Solley et al. 1998), power generation consumed the most water in the region during both years (fig. 8), but total consumption increased by only an average of 5 percent during 1990 through 1995 (table 12). Power generation varied greatly among watersheds, likely due to the availability of cooling sources such as large

**Table 9.** Number of wastewater facilities during 1990 and 1995 within each hydrologic unit (watershed) of the Hoosier-Shawnee assessment area.

| | Number of facilities | |
|---|---|---|
| **Watershed** | **1990** | **1995** |
| Barren | 45 | 41 |
| Big Muddy | 103 | 79 |
| Blue Sinking | 38 | 37 |
| Cache | 8 | 7 |
| Cahokia-Joachim | 190 | 167 |
| Driftwood | 45 | 45 |
| Eel | 28 | 24 |
| Highland-Pigeon | 34 | 34 |
| Little River Ditches | 83 | 59 |
| Lower Cumberland | 36 | 74 |
| Lower East Fork White | 39 | 29 |
| Lower Green | 61 | 61 |
| Lower Kaskaskia | 49 | 39 |
| Lower Missouri | 139 | 150 |
| Lower Ohio | 46 | 39 |
| Lower Ohio Bay | 21 | 23 |
| Lower Ohio-Little Pigeon | 14 | 49 |
| Lower Tennessee | 55 | 54 |
| Lower Wabash | 20 | 20 |
| Lower White | 29 | 29 |
| Meramec | 133 | 141 |
| Middle Green | 25 | 25 |
| Middle Wabash-Little Vermilion | 40 | 45 |
| Muscatatuck | 26 | 19 |
| New Madrid-St. Johns | 15 | 15 |
| Patoka | 10 | 10 |
| Peruque-Piasa | 41 | 42 |
| Pond | 22 | 22 |
| Red | 18 | 9 |
| Rolling Fork | 29 | 29 |
| Rough | 31 | 31 |
| Saline | 14 | 13 |
| Salt | 96 | 96 |
| Silver-Little Kentucky | 177 | 176 |
| Tradewater | 23 | 23 |
| Upper East Fork White | 26 | 25 |
| Upper Green | 63 | 63 |
| Upper Mississippi | 49 | 42 |
| Upper White | 98 | 107 |
| Whitewater | 48 | 38 |

rivers or reservoirs. Public supply (i.e., public source for public and residential use) was another major consumer of water in the entire assessment region during 1990 and 1995 (fig. 8), increasing by 13 percent during this period (table 12). As with domestic use, differences in public use among watersheds varied positively with population density (table 12). Commercial water use changed little (<1 percent) during the 5 years, with high consumption in the Cahokia-Joachim, lower Ohio-Little Pigeon, Salt, and upper White watersheds (table 12). Commercial consumption ranked second to thermoelectric power generation in total consumption (fig. 8).

**Table 10.** Per capita (gallons/day) offstream water use during 1990 and 1995 in each hydrological unit (watershed) of the Hoosier-Shawnee assessment area.

| Watershed | 1990 | 1995 |
|---|---|---|
| Barren | 145 | 199 |
| Big Muddy | 361 | 280 |
| Blue Sinking | 227 | 341 |
| Cache | 66 | 131 |
| Cahokia-Joachim | 1,167 | 1,386 |
| Driftwood | 144 | 167 |
| Eel | 142 | 190 |
| Highland-Pigeon | 310 | 350 |
| Little River Ditches | 1,353 | 2,099 |
| Lower Cumberland | 15,608 | 20,913 |
| Lower East Fork White | 285 | 303 |
| Lower Green | 3,059 | 3,093 |
| Lower Kaskaskia | 3,258 | 3,655 |
| Lower Missouri | 2,878 | 2,513 |
| Lower Ohio | 19,819 | 21,399 |
| Lower Ohio Bay | 169 | 304 |
| Lower Ohio-Little Pigeon | 10,853 | 11,048 |
| Lower Tennessee | 460 | 749 |
| Lower Wabash | 731 | 1,042 |
| Lower White | 3,289 | 3,283 |
| Meramec | 220 | 203 |
| Middle Green | 9,196 | 9,173 |
| Middle Wabash-Little Vermilion | 2,732 | 2,722 |
| Muscatatuck | 135 | 150 |
| New Madrid-St. Johns | 30,184 | 22,666 |
| Patoka | 361 | 255 |
| Peruque-Piasa | 3236 | 2,855 |
| Pond | 2,119 | 2,198 |
| Red | 120 | 177 |
| Rolling Fork | 220 | 199 |
| Rough | 237 | 119 |
| Saline | 1,298 | 224 |
| Salt | 292 | 292 |
| Silver-Little Kentucky | 4,581 | 4,763 |
| Tradewater | 243 | 210 |
| Upper East Fork White | 270 | 347 |
| Upper Green | 201 | 176 |
| Upper Mississippi | 1,545 | 1,981 |
| Upper White | 390 | 444 |
| Whitewater | 283 | 397 |

The surface waters of the assessment region are important for recreational use. In the U.S. in 1991, $15.1 billion was spent on freshwater angling, and 63 percent of non-consumptive outdoor recreation visits in the U.S. included lakeside or streamside destinations (U.S. Department of Interior 1993). In 1996, Illinois waters received about 20 million angling days, and anglers averaged 15 trips.year$^{-1}$ (U.S. Fish and Wildlife Service 1996a). Over $1.6 billion were spent on angling during 1996 in Illinois (U.S. Fish and Wildlife Service 1996a). In Indiana, water use for angling is less than that in Illinois; anglers performing 16.5 million angling days, for an average of about 19 days per angler and $800 million (U.S. Fish and Wildlife Service 1996b). Fishing statistics in Kentucky are similar to those in Indiana, with 15 average days per angler, 10.6 million angling days, and $718 million in revenue (U.S. Fish and Wildlife Service 1996c). These statewide values demonstrate the clear importance of recreational use to the local economy as well as aquatic resources within the Hoosier-Shawnee region. To illustrate, the value of the fishery at Lake Monroe, Indiana, was estimated at $2.16 million during April through October 1991 (Andrews 1992). These statewide statistics suggest that the greatest use of surface waters for fishing should be in the Illinois portion of the study region, but that angling and other nonconsumptive uses are quite important throughout the study region. It also is important to note that some commercial fishing occurs in several rivers within the assessment area, including the Wabash, Ohio, and Cumberland.

**Table 11.** Total groundwater and surface water use (million gallons/day) during 1990 and 1995 within each hydrologic unit (watershed) of the Hoosier-Shawnee assessment area.

| | Groundwater | | Surface water | | Totals | |
|---|---|---|---|---|---|---|
| **Watershed** | **1990** | **1995** | **1990** | **1995** | **1990** | **1995** |
| Barren | 3 | 3 | 22 | 26 | 25 | 29 |
| Big Muddy | 30 | 9 | 1 | 44 | 31 | 54 |
| Blue Sinking | 18 | 19 | 8 | 20 | 26 | 39 |
| Cache | 1 | 2 | 0 | 0 | 1 | 2 |
| Cahokia-Joachim | 62 | 77 | 1,368 | 1,467 | 1,430 | 1,544 |
| Driftwood | 21 | 25 | 3 | 5 | 24 | 30 |
| Eel | 7 | 9 | 3 | 2 | 10 | 12 |
| Highland-Pigeon | 7 | 7 | 70 | 78 | 77 | 85 |
| Little River Ditches | 166 | 277 | 0 | 3 | 166 | 280 |
| Lower Cumberland | 2 | 4 | 1,666 | 2,228 | 1,669 | 2,231 |
| Lower East Fork White | 5 | 6 | 27 | 28 | 33 | 34 |
| Lower Green | 16 | 19 | 251 | 250 | 266 | 270 |
| Lower Kaskaskia | 7 | 9 | 0 | 1,180 | 7 | 1,189 |
| Lower Missouri | 18 | 14 | 1,151 | 1,007 | 1,170 | 1,021 |
| Lower Ohio | 13 | 14 | 1,480 | 1,598 | 1,493 | 1,612 |
| Lower Ohio Bay | 3 | 5 | 2 | 4 | 5 | 9 |
| Lower Ohio-Little Pigeon | 44 | 44 | 1,122 | 1,143 | 1,166 | 1,187 |
| Lower Tennessee | 8 | 11 | 19 | 33 | 27 | 44 |
| Lower Wabash | 12 | 19 | 30 | 39 | 41 | 58 |
| Lower White | 13 | 16 | 541 | 539 | 554 | 554 |
| Meramec | 15 | 16 | 52 | 44 | 67 | 60 |
| Middle Green | 1 | 1 | 396 | 396 | 397 | 397 |
| Middle Wabash-Little Vermilion | 59 | 65 | 469 | 461 | 527 | 526 |
| Muscatatuck | 2 | 2 | 8 | 8 | 9 | 10 |
| New Madrid-St. Johns | 23 | 43 | 1,057 | 767 | 1,080 | 811 |
| Patoka | 3 | 2 | 13 | 9 | 16 | 12 |
| Peruque-Piasa | 32 | 29 | 657 | 579 | 689 | 608 |
| Pond | 2 | 2 | 108 | 110 | 110 | 112 |
| Red | 9 | 2 | 8 | 19 | 17 | 21 |
| Rolling Fork | 6 | 2 | 16 | 17 | 21 | 19 |
| Rough | 9 | 2 | 5 | 6 | 14 | 8 |
| Saline | 11 | 12 | 77 | 3 | 87 | 15 |
| Salt | 17 | 15 | 120 | 123 | 137 | 138 |
| Silver-Little Kentucky | 38 | 39 | 2,310 | 2,402 | 2,348 | 2,441 |
| Tradewater | 3 | 4 | 11 | 9 | 15 | 14 |
| Upper East Fork White | 14 | 18 | 6 | 8 | 21 | 26 |
| Upper Green | 12 | 4 | 22 | 24 | 34 | 28 |
| Upper Mississippi-Cape Girardeau | 9 | 12 | 149 | 187 | 158 | 199 |
| Upper White | 108 | 115 | 425 | 493 | 533 | 608 |
| Whitewater | 7 | 12 | 3 | 2 | 11 | 15 |

**Table 12.** Combined groundwater and surface water (million gallons/day) used for commercial activities, domestic supply, mining, public supply, thermoelectric power generation, and agriculture during 1990 and 1995 within each hydrologic unit (watershed) of the Hoosier-Shawnee assessment area. Agriculture includes water used for irrigation and livestock.

| | Agriculture | | | Domestic | | | Mining | | | Thermoelectric | | | Public Supply | | | Commercial | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Watershed** | **90** | **95** | **Chng** | **90** | **95** | **Chng** | **90** | **95** | **Chng** | **90** | **95** | **Chng** | **90** | **95** | **Chng** | **90** | **95** | **Chng** |
| Barren | 4 | 9 | 1.53 | 2 | 1 | -0.61 | 0 | 0 | NA | 0 | 0 | 0.20 | 18 | 22 | NA | 0 | 1 | s2.07 |
| Big Muddy | 3 | 2 | -0.18 | 2 | 3 | 0.52 | 2 | 14 | 4.81 | 0 | 0 | -0.05 | 25 | 23 | NA | 35 | 10 | -0.73 |
| Blue Sinking | 2 | 2 | 0.14 | 2 | 2 | -0.10 | 1 | 1 | -0.35 | 0 | 0 | 0.06 | 8 | 8 | NA | 13 | 26 | 0.94 |
| Cache | 0 | 1 | 0.51 | 0 | 1 | 0.90 | 0 | 0 | NA | 0 | 0 | -0.08 | 1 | 0 | NA | 0 | 0 | -0.68 |
| Cahokia-Joachim | 2 | 2 | 0.09 | 4 | 11 | 1.80 | 1 | 0 | -1.00 | 1,111 | 1,142 | 0.69 | 249 | 421 | 0.03 | 41 | 96 | 1.35 |
| Driftwood | 2 | 2 | 0.35 | 6 | 5 | -0.01 | 1 | 1 | 0.54 | 0 | 0 | 0.08 | 12 | 13 | NA | 4 | 8 | 0.89 |
| Eel | 1 | 1 | -0.06 | 2 | 2 | 0.09 | 1 | 1 | -0.22 | 0 | 0 | 0.29 | 4 | 6 | NA | 1 | 2 | 0.49 |
| Highland-Pigeon | 1 | 1 | 0.46 | 3 | 2 | -0.43 | 12 | 19 | 0.51 | 14 | 14 | -0.01 | 37 | 37 | -0.01 | 10 | 14 | 0.31 |
| Little River Ditches | 150 | 264 | 0.77 | 1 | 5 | 3.30 | 0 | 0 | NA | 4 | 0 | 0.18 | 16 | 19 | -1.00 | 16 | 2 | -0.89 |
| Lower Cumberland | 1 | 5 | 3.00 | 1 | 0 | -0.70 | 0 | 0 | 6.50 | 1,649 | 2,196 | 0.33 | 17 | 23 | 0.33 | 0 | 11 | 157.00 |
| Lower East Fork White | 2 | 2 | 0.03 | 2 | 2 | -0.07 | 4 | 0 | -0.99 | 0 | 0 | 0.18 | 19 | 23 | NA | 5 | 7 | 0.24 |
| Lower Green | 1 | 1 | 0.36 | 1 | 0 | -0.90 | 1 | 0 | -0.68 | 245 | 245 | 0.15 | 12 | 14 | 0.00 | 6 | 9 | 0.68 |
| Lower Kaskaskia | 3 | 2 | -0.37 | 3 | 5 | 0.50 | 0 | 2 | 4.29 | 1,048 | 1,174 | 0.03 | 5 | 5 | 0.12 | 0 | 0 | 1.00 |
| Lower Missouri | 2 | 3 | 0.53 | 2 | 2 | -0.01 | 0 | 0 | NA | 1,069 | 958 | -0.36 | 89 | 57 | -0.10 | 7 | 1 | -0.89 |
| Lower Ohio | 2 | 3 | 0.82 | 1 | 2 | 1.42 | 0 | 0 | NA | 1,449 | 1,565 | 0.03 | 9 | 10 | 0.08 | 32 | 32 | 0.00 |
| Lower Ohio Bay | 2 | 3 | 0.60 | 0 | 1 | 1.15 | 1 | 3 | 4.31 | 0 | 0 | 0.02 | 2 | 2 | NA | 0 | 0 | 1.00 |
| Lower Ohio-Little Pigeon | 1 | 2 | 0.26 | 2 | 1 | -0.39 | 1 | 3 | 1.00 | 709 | 731 | 0.10 | 11 | 12 | 0.03 | 442 | 438 | -0.01 |
| Lower Tennessee | 1 | 2 | 2.50 | 0 | 0 | -0.17 | 0 | 0 | NA | 0 | 0 | 0.12 | 6 | 7 | NA | 20 | 35 | 0.78 |
| Lower Wabash | 3 | 4 | 0.21 | 1 | 1 | 0.02 | 3 | 3 | 0.06 | 29 | 40 | 1.39 | 4 | 9 | 0.37 | 0 | 0 | 4.50 |
| Lower White | 16 | 16 | 0.01 | 3 | 2 | -0.21 | 2 | 7 | 3.34 | 523 | 517 | 0.09 | 8 | 9 | -0.01 | 2 | 2 | -0.29 |
| Meramec | 1 | 2 | 0.53 | 2 | 3 | 0.43 | 2 | 17 | 8.45 | 0 | 0 | -0.25 | 50 | 38 | NA | 12 | 2 | -0.85 |
| Middle Green | 1 | 1 | 0.36 | 1 | 0 | -0.78 | 2 | 1 | -0.47 | 389 | 389 | 0.06 | 4 | 4 | 0.00 | 0 | 1 | 4.27 |
| Middle Wabash-Little Vermilion | 2 | 2 | 0.17 | 4 | 4 | -0.02 | 1 | 1 | 1.63 | 467 | 458 | -0.03 | 20 | 20 | -0.02 | 34 | 41 | 0.21 |
| Muscatatuck | 1 | 1 | 0.05 | 1 | 1 | -0.08 | 2 | 3 | 0.06 | 0 | 0 | 0.11 | 4 | 4 | NA | 1 | 1 | 0.21 |
| New Madrid-St. Johns | 16 | 37 | 1.33 | 2 | 1 | -0.74 | 0 | 0 | NA | 1,058 | 769 | 0.08 | 4 | 4 | -0.27 | 0 | 0 | -0.76 |
| Patoka | 2 | 2 | 0.02 | 1 | 1 | -0.27 | 7 | 2 | -0.72 | 0 | 0 | 0.04 | 7 | 7 | NA | 0 | 0 | 1.60 |
| Peruque-Piasa | 1 | 1 | 0.46 | 2 | 6 | 2.39 | 0 | 0 | -1.00 | 643 | 565 | 0.05 | 24 | 25 | -0.12 | 19 | 11 | -0.43 |
| Pond | 1 | 1 | 0.32 | 1 | 0 | -0.79 | 1 | 2 | 1.43 | 98 | 98 | 0.08 | 6 | 6 | 0.00 | 1 | 5 | 2.56 |
| Red | 2 | 6 | 2.14 | 4 | 0 | -0.95 | 0 | 0 | NA | 0 | 0 | 0.30 | 11 | 15 | NA | 0 | 4 | 15.30 |
| Rolling Fork | 3 | 4 | 0.32 | 2 | 1 | -0.70 | 0 | 0 | NA | 0 | 0 | 0.12 | 9 | 10 | NA | 7 | 4 | -0.42 |
| Rough | 1 | 1 | 0.51 | 1 | 0 | -0.74 | 1 | 0 | -0.53 | 0 | 0 | 0.17 | 5 | 6 | NA | 6 | 0 | -1.00 |
| Saline | 4 | 4 | -0.12 | 1 | 1 | -0.14 | 9 | 6 | -0.35 | 70 | 0 | 0.24 | 3 | 4 | -1.00 | 0 | 0 | 1.00 |
| Salt | 3 | 5 | 0.45 | 4 | 2 | -0.33 | 0 | 0 | NA | 0 | 0 | 0.14 | 75 | 85 | NA | 55 | 45 | -0.18 |
| Silver-Little Kentucky | 1 | 1 | 0.10 | 2 | 2 | 0.03 | 1 | 13 | 14.27 | 2,208 | 2,282 | 0.10 | 85 | 93 | 0.03 | 51 | 50 | -0.03 |
| Tradewater | 1 | 1 | 0.42 | 1 | 0 | -0.71 | 3 | 4 | 0.62 | 0 | 0 | 0.06 | 8 | 8 | NA | 2 | 0 | -0.92 |
| Upper East Fork White | 3 | 3 | 0.02 | 2 | 2 | -0.15 | 2 | 2 | -0.08 | 0 | 0 | 0.39 | 12 | 17 | NA | 2 | 3 | 0.82 |
| Upper Green | 5 | 7 | 0.30 | 3 | 1 | -0.60 | 0 | 0 | NA | 0 | 0 | 0.02 | 19 | 20 | NA | 6 | 1 | -0.91 |
| Upper Mississippi-Cape Girardeau | 3 | 6 | 0.76 | 1 | 2 | 0.20 | 0 | 0 | -0.44 | 143 | 180 | 0.29 | 8 | 11 | 0.26 | 1 | 1 | -0.20 |
| Upper White | 3 | 3 | 0.09 | 23 | 22 | -0.08 | 34 | 49 | 0.45 | 245 | 292 | 0.12 | 172 | 192 | 0.19 | 56 | 49 | -0.11 |
| Whitewater | 4 | 10 | 1.42 | 1 | 1 | -0.29 | 0 | 0 | NA | 0 | 0 | -0.36 | 5 | 3 | NA | 0 | 0 | -0.46 |

A recent General Circulation Model coupled with a BIOME-BGC ecosystem model predicted that evapotranspiration rates within the assessment region will change relatively little within the next 100 years, although annual precipitation will decline by about 10 percent (Jackson et al. 2001). The model assumed that atmospheric carbon dioxide would increase by 0.5 percent per year, with leaf area of terrestrial vegetation changing as a function of carbon dioxide, climate, water, and nitrogen availability. If this decline in precipitation occurs, the quantity of both surface water and groundwater will decline as a function of decreased recharge rates and increased atmospheric loss. Further, reduced flows in streams often translate into reduced water quality, particularly in regions with moderate to high population density where an appreciable component of baseflow is effluent from wastewater treatment plants. Within the region, the impact of these changes on lentic and lotic aquatic ecosystems and the regional economy is unknown, but is most likely to be adverse.

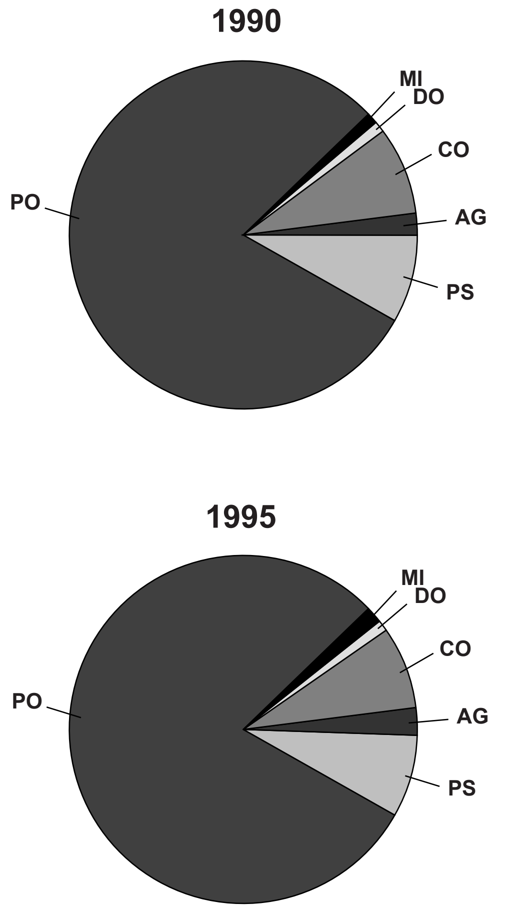



**Figure 8.** Portions of water (millions of gallons/day) within the watersheds of the the the Hoosier-Shawnee aassessment area consumed by agriculture, commercial use, domestic use, mining, power generation, and public supply in 1990 and 1995 (based on data compiled by Solley et al. 1998).

## SUMMARY

Freshwater resources throughout the world are imperiled. Water resources within the Hoosier-Shawnee Ecological Assessment Area are no exception, and this necessitates that current resources and their condition be inventoried and carefully monitored to forge prudent decisions in the future. The 40 watersheds that intersect the region have a diverse array of surface water and groundwater characteristics. The regional aquifers are comprised of several geologic types, and karst areas within the region are potentially problematic because they allow for rapid movement of pollutants into and through groundwater resources. This situation mandates close scrutiny of land use and waste disposal practices, and an understanding of the interrelationships between groundwater and surface water habitats.

The region contains many streams and rivers, including segments of several large systems such as the Ohio and Mississippi Rivers. Little is known about the small headwater streams within this region, although these systems are often gravely affected by land use practices such as rowcrop agriculture, and their importance on a larger scale is just now becoming clear. Assessing the current condition of these headwater systems and understanding how they respond to land use change is necessary for gauging watershed condition. Stream riparian zones have been dramatically transformed in most of the region's watersheds, with a high proportion of streams bounded by relatively little forested vegetation. Because riparian vegetation is closely linked to freshwater resource quality, further losses of these areas will lead to increased water quality problems in both streams and reservoirs. Conversely, riparian restoration practices could result in significant improvements to freshwater resource quality in the region. It is also important that the role of instream habitat quality in promoting stream diversity and ecosystem function be understood, and that future monitoring and management efforts account for this vital component of stream health.

Lentic systems are abundant in the assessment area, although the vast majority have been constructed by humans. Like other freshwater habitats, these systems integrate land use practices, and productivity and sedimentation are often high across the region because of agricultural activities, with concomitant reductions in recreationally important fish and water quality. Improved land use practices such as increasing forested riparian zones of headwaters or installing upstream sediment catch basins may improve conditions in these systems.

Wetland habitats are scarce and fragmented in all watersheds of the assessment region, with less herbaceous than woody wetlands remaining. Remaining wetland areas are critical for maintaining watershed integrity because of ecosystem subsidies they provide. Additionally, wetland restoration activities in the region could produce large, tangible benefits to water quality, flood control, regional biodiversity, and waterfowl hunting.

Watershed integrity, as defined by USEPA, varies greatly among the watersheds within the assessment area. Of the 40 watersheds, 35 percent are in poor condition and 20 percent are in good condition. Watersheds receiving poor scores tended to have a high proportion of streams and reservoirs with high nutrient loads and contaminants (e.g., heavy metals and pesticides).

Average per capita water use within the region is relatively high by State and national standards, although estimates vary widely among watersheds. Most water use is devoted to thermoelectric power generation, with public supply being a distant but still substantive second. Agricultural use is relatively low in most areas, except for a few watersheds in the western region of the assessment area. Surface water use was 16 times greater than that of groundwater, with total use increasing by 11 percent during a recent 5-year period. In addition to serving consumptive needs, surface waters within the assessment area provide economically important recreational resources for fishing and other outdoor activities.

Future challenges for water resource management in the Hoosier-Shawnee Ecological Assessment Area are complex. Important issues include preventing any further degradation of water quality, reversing existing water and habitat quality problems, and preventing depletion of existing freshwater resources by the human population. Factors underlying these problems are similar to those in the rest of the country, primarily non-point source issues affecting water and habitat quality and population growth fueling water use. Fortunately, the human population of the Hoosier-Shawnee region is expected to grow at a lower rate than that of many other regions of the country. However, current global circulation models predict that annual precipitation will decline during the next century, and this could further tax the quantity and quality of freshwater resources, regardless of human population dynamics. A high priority for future research and management is investigations of linkages between land use practices and freshwater resource quality, with a particular focus on small, headwater streams in the region, a component of watershed management that has often been neglected. In particular, there is a need to quantitatively assess the effects of best management practices in agricultural landscapes on both groundwater and surface water habitats.

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# Fishes, Mussels, Crayfishes, and Aquatic Habitats of the Hoosier-Shawnee Ecological Assessment Area

**Brooks M. Burr, Justin T. Sipiorski, Matthew R. Thomas, Kevin S. Cummings, and Christopher A. Taylor**


## ABSTRACT

The Hoosier-Shawnee Ecological Assessment Area, part of the Coastal Plain and Interior Low Plateau physiographic provinces, includes 194 native fish species, 76 native mussel species, and 34 native crayfish species. Five of the subregions (e.g., Mississippi Embayment) that make up the assessment area were recently ranked as either globally or bioregionally outstanding aquatic resource areas. Fish, mussel, and crayfish diversity was analyzed for richness and density within and between the 39 hydrologic units that make up the assessment area. Species richness averaged 76 fish and 26 mussel species per hydrologic unit, and ecological units positioned as ecotones tended to be associated with primary levels of richness. At least 12 fish species are of conservation concern within the Hoosier and Shawnee National Forest boundaries; another 10 species are poorly known and need status surveys or other forms of conservation evaluation. Nearly 30 mussel species and 10 crayfish species are of conservation concern in the area, but fewer than 10 of these actually occur within national forest boundaries or would be directly affected by national forest activities. Commercial and recreational fisheries are popular in the region, and commercial exploitation of both mussels and crayfishes occurs in the assessment area. The most valuable and unique aquatic habitats in the area include springs, spring runs, karst aquifers, wetlands, swamps, mainstem large rivers, and upland, gravel-bottomed streams in both the Hoosier and Shawnee National Forests. The responsibility and challenges the USDA Forest Service shoulders in manageing and protecting the unique aquatic resources on its properties are staggering, especially in regard to the recently acknowledged global need for usable fresh water.



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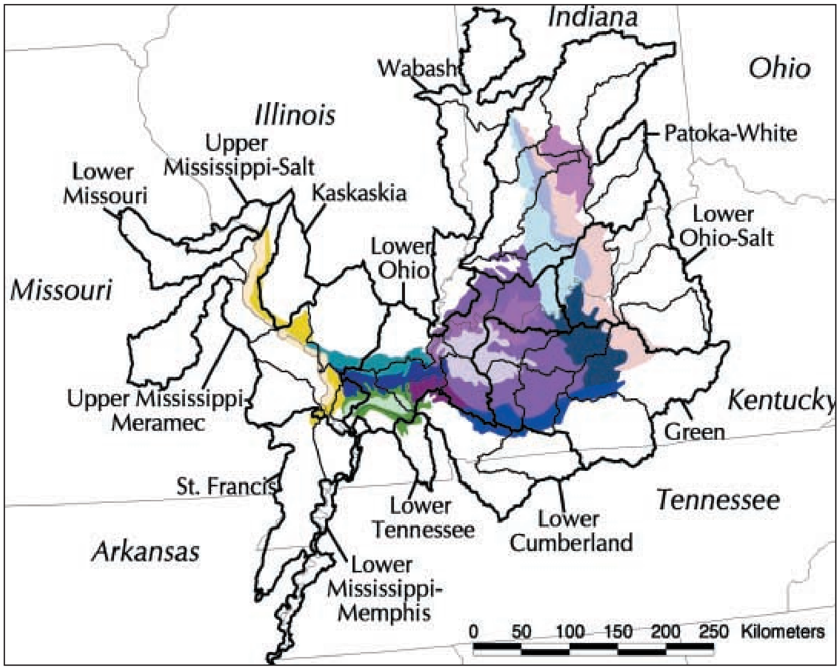


**Figure 1.** The 12 major river basins (divided into hydrologic units–watersheds) in the Hoosier-Shawnee Ecological Assessment Area.

We review the diversity, conservation status, and commercial significance of aquatic species and their habitats within the Hoosier-Shawnee Ecological Assessment Area. For analysis and discussion, aquatic species were restricted to three major taxonomic groups: fishes, unionid mussels, and crayfishes. Rather than use physiographic provinces as a way of analyzing patterns of distribution and diversity, we chose to use hydrological units to provide a more ecologically refined way to examine patterns across the watersheds of the assessment area (as explained in the "Data Sources and Methods of Analysis" subsections).

## DIVERSITY OF FISHES, MUSSELS, AND CRAYFISHES

The fish, mussel, and crayfish fauna of the lower Ohio and middle Mississippi basins, including here portions of the Coastal Plain and Interior Low Plateau Provinces, is part of a region—the Southern and lower Midwestern United States—that harbors a significant portion of the richest temperate aquatic fauna on the North American continent (Warren et al. 2000). The combination of both upland and lowland streams and subterranean waters, along with a large river component, accounts for at least 193 native fish species, 76 native mussels, and 34 native crayfishes. These three aquatic groups represent over 24, 26, and 9 percent, respectively, of all native freshwater fishes, mussels, and crayfishes in the continental United States. The fishes alone represent over 50 percent of the native fauna of the entire Mississippi River basin and about 18 percent of all native freshwater fishes on the North American continent (Burr and Mayden 1992, Warren and Burr 1994, Warren et al. 2000). Illinois, Indiana, and Kentucky each have high to moderately high fish and mussel diversity, falling within the top eight States east of the Mississippi River and surpassing or equaling all States west of the Mississippi River except Missouri and Arkansas (Warren and Burr 1994). A major portion of that diversity is concentrated in the assessment area (Burr and Mayden 1992, Burr and Page 1986, Cummings and Mayer 1992).

The fishes, mussels, and crayfishes documented from the assessment area reside within a much larger natural region that encompasses the lower reaches of large tributaries of the Mississippi alluvial basin (e.g., Kaskaskia and Big Muddy Rivers), and all or significant portions of major drainages of the lower Ohio River basin (e.g., Green, Wabash, and Cache Rivers). It borders or encompasses parts of four ecological sections (see "Data Sources and Methods of Analysis"). Complex drainage histories beginning before the Pleistocene age set the stage for fragmentation, isolation, and mixing of faunas that in large part account for the richness and distinctiveness of the region's fishes, mussels, and crayfishes (Burr and Page 1986; Mayden 1987, 1988; Strange and Burr 1997). The region brings together two major dispersal corridors for fishes and mussels with approximately 330 river miles of the mainstem Ohio River and 165 river miles of the mainstem Mississippi River included in the assessment area.

The Forest Service's national hierarchical framework for classifying and mapping aquatic ecological units (Maxwell et al. 1995) places the Hoosier-Shawnee Ecological Assessment Area in the Arctic-Atlantic Bioregion, Mississippi Region, and Teays-Old Ohio Subregion. Small pieces of the Mississippi, Mississippi Embayment, Central Prairie, and Tennessee-Cumberland Subregions are part of the assessment area. As major rivers flow into the assessment area, most breach or border one or more major ecotones (transitional zones between ecological communities) that influence diversity and composition of fishes (Jenkins and Burkhead 1994). To the north and west, the region is bounded by the Interior Low Plateaus and Ozark Highlands, respectively, and to the south and east, by the Gulf Coastal Plain and the Appalachian Plateaus, respectively. These factors—major river systems with varied histories and ecological settings—provide the backdrop for the uniqueness and high diversity of aquatic species in the assessment area. In fact, the World Wildlife Fund's recent (Abell et al. 2000) conservation assessment of freshwater ecoregions of North America ranks three of the assessment area's subregions as globally outstanding and the remaining two as bioregionally outstanding. These two categories, globally outstanding and bioregionally outstanding, are the highest conservation rankings possible and clearly indicate the uniqueness and natural resource value of the assessment area.

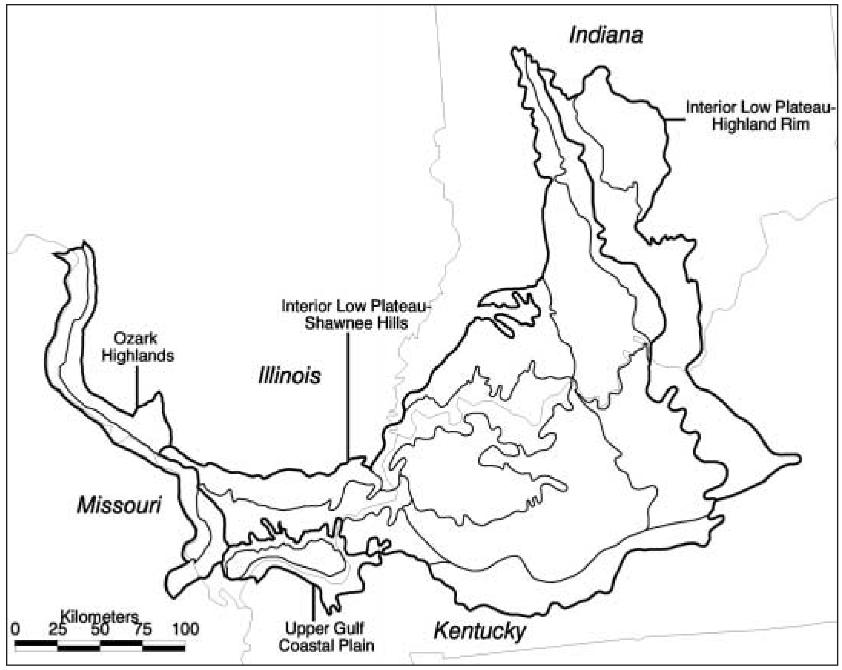


**Figure 2.** The four Ecological Sections of the Hoosier-Shawnee Ecological Assessment Area.

## DATA SOURCES AND METHODS OF ANALYSIS

Within constraints of time and the patterns of diversity in the assessment area, we modeled our summary of aquatic diversity after the excellent chapters on *Diversity of Fishes* (Warren and Hlass 1999), *Diversity of Mussels* (Harris 1999), and *Diversity of Crayfishes* (Warren et al. 1999) as published in Ozark-Ouachita Highlands Assessments Aquatic Condition (General Technical Report SRS-33 (1999) regarding the Ozark-Ouachita Ecological Assessment in Missouri, Arkansas, Kansas, and Oklahoma). To examine the distribution of fish, mussel, and crayfish species, each of the 12 (lower Missouri, upper Mississippi-Salt, Kaskaskia, upper Mississippi-Meramec, St. Francis, lower Tennessee, lower Cumberland, Green, Wabash, Patoka-White, lower Ohio (to Mississippi River confluence), and lower Ohio (to mile 703)) major basins within the assessment area was subdivided into hydrologic units (watersheds) according to standard eight-digit hydrologic unit codes (HUCs) (fig. 1). Only 5 (Rough, Lower Green, Pond, and Tradewater) of 39 hydrologic units fell entirely within the assessment area and represented the entire area ($mi^2$) of their respective HUC (table 1), 16 overlapped between 13 and 99 percent of their total area, and 18 units overlapped the assessment area by 12 percent or less of their total area (fig. 1). Several of the hydrologic units also contain portions of more than one ecological subsection (figs. 1, 2) (e.g., Cache and lower Ohio units share Shawnee Hills and Gulf Coastal Plain Subsections). Only that portion of a HUC that lies within the assessment area was used for tabulation of aquatic diversity.

**Table 1.** Native fish species richness, density, index of relative importance, and overall rank order for watersheds of the Hoosier-Shawnee Ecological Assessment Area.

| River Basin<br>Hydrologic unit name | Watershed code (HUC) | Total area | Area of HUC in assessment | Species richness (rank order) | Species density (rank order) | Index of relative importance (sum rank orders) | Overall rank order * |
|---|---|---|---|---|---|---|---|
| | | *mi²* | *mi²* | *no.* | *no. per mi²* | | |
| **Lower Missouri River Basin** | | | | | | | |
| Lower Missouri | 10300200 | 1,590 | 20.67 | 56 (19) | 2.71 (3) | 22 | 4 |
| **Upper Mississippi-Salt River Basins** | | | | | | | |
| Peruque-Piasa | 07110009 | 633 | 14.559 | 61 (17) | 4.19 (1) | 18 | 2 |
| **Kaskaskia River Basin** | | | | | | | |
| Lower Kaskaskia | 07140204 | 1,600 | 88 | 60 (18) | 0.68 (4) | 22 | 4 |
| **Upper Mississippi-Meramec River Basins** | | | | | | | |
| Cohokia-Joachim | 07140101 | 1,650 | 618.75 | 101 (5) | 0.16 (15) | 20 | 3(3) |
| Upper Mississippi-Cape Girardeau | 07140105 | 1,690 | 397.15 | 129 (1) | 0.32 (7) | 8 | 1(1) |
| Big Muddy | 07140106 | 2,350 | 289.05 | 85 (9) | 0.29 (9) | 18 | 2(2) |
| Whitewater | 07140107 | 1,210 | 33.88 | 23 (27) | 0.68 (4) | 31 | 12 |
| Cache | 07140108 | 352 | 302.72 | 72 (13) | 0.24 (12) | 25 | 7(6) |
| **St. Francis River Basin** | | | | | | | |
| New Madrid-St. Johns | 08020201 | 703 | 7.03 | 2 (33) | 0.28 (10) | 43 | 18 |
| Little River Ditches | 08020204 | 2,620 | 36.68 | 25 (25) | 0.68 (4) | 29 | 10 |
| **Lower Tennessee River Basin** | | | | | | | |
| Lower Tennessee | 06040006 | 689 | 79.235 | 47 (22) | 0.59 (5) | 27 | 8 |
| **Lower Cumberland River Basin** | | | | | | | |
| Lower Cumberland | 05130205 | 2,300 | 317.4 | 65 (16) | 0.20 (13) | 29 | 10 |
| Red | 05130206 | 1,450 | 55.1 | 5 (32) | 0.09 | 32 | 13 |
| **Green River Basin** | | | | | | | |
| Upper Green | 05110001 | 3,130 | 1,311.47 | 87 (8) | 0.07 (20) | 28 | 9(8) |
| Barren | 05110002 | 2,230 | 138.26 | 37 (24) | 0.27 (11) | 35 | 16 |
| Middle Green | 05110003 | 1,010 | 968.59 | 101 (5) | 0.10 (18) | 23 | 5(4) |
| Rough | 05110004 | 1,070 | 1,070 | 51 (21) | 0.05 (22) | 43 | 18(15) |
| Lower Green | 05110005 | 911 | 911 | 83 (11) | 0.09 (19) | 30 | 11(10) |
| Pond | 05110006 | 784 | 784 | 72 (13) | 0.09 (19) | 32 | 13(11) |
| **Wabash River Basin** | | | | | | | |
| Middle Wabash-Little Vermillion | 05120108 | 2,230 | 6.69 | 22 (28) | 3.29 (2) | 30 | 11 |
| Lower Wabash | 05120113 | 1,300 | 202.8 | 76 (12) | 0.37 (6) | 18 | 14 |
| **Patoka-White River Basins** | | | | | | | |
| Upper White | 05120201 | 2,700 | 278.1 | 24 (26) | 0.09 (19) | 45 | 19(16) |
| Lower White | 05120202 | 1,650 | 664.95 | 67 (15) | 0.10 (18) | 33 | 14(12) |
| Eel | 05120203 | 1,200 | 231.6 | 38 (23) | 0.16 (15) | 38 | 17(14) |
| Driftwood | 05120204 | 1,150 | 40.25 | 12 (30) | 0.30 (8) | 38 | 17 |
| Upper East Fork White | 05120206 | 806 | 29.016 | 2 (33) | 0.07 (20) | 53 | 21 |
| Muskatatuck | 05120207 | 1,130 | 14.69 | 0 (34) | 0.00 (23) | 57 | 22 |
| Lower East Fork White | 05120208 | 2,030 | 1,822.94 | 104 (3) | 0.06 (21) | 24 | 6(5) |
| Patoka | 05120209 | 854 | 620.004 | 67 (15) | 0.11 (17) | 32 | 13(11) |

*(table continued on next page)*

(table 1 continued)

| River Basin<br>Hydrologic unit name | Watershed code (HUC) | Total area | Area of HUC in assessment | Species richness (rank order) | Species density (rank order) | Index of relative importance (sum rank orders) | Overall rank order * |
|---|---|---|---|---|---|---|---|
| | | $mi^2$ | $mi^2$ | *no.* | *no. per* $mi^2$ | | |
| **Lower Ohio River Basin (to Miss. R. confl.)** | | | | | | | |
| Lower Ohio-Little Pigeon | 05140201 | 1,370 | 1370 | 90 (7) | 0.07 (20) | 27 | 8(7) |
| Highland-Pigeon | 05140202 | 1,000 | 957 | 84 (10) | 0.09 (19) | 29 | 10(9) |
| Lower Ohio-Bay | 05140203 | 1,090 | 1,079.10 | 107 (2) | 0.10 (18) | 20 | 3(3) |
| Saline | 05140204 | 1,160 | 300.44 | 54 (20) | 0.18 (14) | 34 | 15(13) |
| Tradewater | 05140205 | 936 | 936 | 68 (14) | 0.07 (20) | 34 | 15(13) |
| Lower Ohio | 05140206 | 928 | 668.16 | 103 (4) | 0.15 (16) | 20 | 3(3) |
| **Lower Ohio Rver Basin (to mile 703)** | | | | | | | |
| Silver-Little Kentucky | 05140101 | 1,240 | 12.4 | 0 (34) | 0.00 (23) | 57 | 22 |
| Salt | 05140102 | 1,450 | 30.45 | 18 (29) | 0.59 (5) | 34 | 15 |
| Rolling Fork | 05140103 | 1,430 | 105.82 | 11 (31) | 0.10 (18) | 49 | 20 |
| Blue Sinking | 05140104 | 1,880 | 1,757.80 | 94 (6) | 0.05 (22) | 28 | 9(8) |

* The overall ranks in parentheses have been determined with the small Hydrologic Units (less than 12% proportion of inclusion in the assessment area) removed from the ranking procedure. Small Hydrologic Units have inflated species densities and therefore convey artificailly high indicies of relative importance. See text for further discussion.

## Determination of Fish, Mussel, and Crayfish Distributions

### Fishes

The distribution of fishes within a particular hydrologic unit was determined primarily from spot-distribution maps in Burr and Warren (1986), Gerking (1945), Pflieger (1997), and Smith (1979). The determination of a species occurrence within a unit depended on the temporal (time) coverage, quality, and scale of source distribution maps. Distributions from cited sources (above) were presented as drainage maps for each species with dots indicating the occurrence of a fish species at that point within the drainage. The drainage maps allowed us to make relatively unambiguous interpretations of fish distributions. An unpublished report (i.e., gray literature) on fishes of the Hoosier National Forest (McComish and Brown 1980) is the most recent comprehensive source of written information for fishes in southern Indiana, but questions of quality and sources of distributional data, and accuracy of identifications make it clear that our knowledge of Indiana fishes is inferior to both the Illinois and Kentucky databases. Nevertheless, the scale of these maps, along with textual descriptions of distributions, permitted reasonably accurate delineation of a species' occurrence in a hydrological unit. Pflieger (1997) reported known collections of fishes in Missouri from about 1905 to 1995. Smith (1979) documented fish collections in Illinois from 1876 to 1978. The fish collection database for Kentucky covered records from about 1819 to 1985, with most samples dating from post-1950 (Burr and Warren 1986). Gerking (1945) made collections of fishes in Indiana from 1940 through 1943 and used many literature records from the era of David Starr Jordan and his students (1875-1894).

Information from these primary sources was augmented with fish distributional data presented in Burr and Page (1986), Lee et al. (1980), and Page and Burr (1991). Scientific and common names of fishes generally follow Mayden et al. (1992). Distributions of species described or their distributions clarified subsequent to the previously cited works were obtained from Burr and Page (1993, frecklebelly darter), Ceas and Page (1997, Shawnee darter), Dimmick et al. (1996, rosefin shiner), Eisenhour (1997, channel shiner), Page et al. (1992, guardian darter), and Poly and Wilson (1998, fringed darter). Known but as yet undescribed species of darters that occur only in the Kentucky portion of the assessment area have been included either under orangethroat darter or speckled darter.

Fish faunal composition among drainages of the region was taken from existing works for Kentucky (Burr and Warren 1986), Kentucky and Tennessee (Warren et al. 1991), Illinois and surrounding areas (Burr and Page 1986), and Missouri (Pflieger 1971). Although methods of analysis varied among these authors, each relied on comparing distributions of native fish species and classifying the resulting similarity patterns into fish faunal regions. In a novel approach, Mayden (1988) used major river drainages as analogous to "taxonomic" units and native fish species as analogous to "characters" to produce a "phylogeny" (or evolutionary tree) of drainage units in the Central United States. The fish faunal regions or drainage units recognized by these authors are compatible and generally congruent, and we assumed that sections of drainages not included in these previous works (e.g., some parts of Indiana) are classified in the same fish faunal regions as adjacent drainages in Illinois or Kentucky.

### Mussels

Specific information on mussel distributions within much of the assessment area has not been published. Approximate range maps in Cummings and Mayer (1992) for mussels in Indiana, Illinois, and Missouri do not provide the resolution needed to determine specific distributions within the assessment area. Comprehensive surveys by Baker (1906) and Parmalee (1967), along with unpublished observations of Max Matteson (former zoologist with the University of Illinois, Urbana), have provided the early foundations for mussel distributions in Illinois. A recent summary of mussel distributions in Illinois was provided by Cummings and Mayer (1997). Comprehensive distributional information for mussels in Indiana was provided by Call (1900), Daniels (1903), and Goodrich and van der Schalie (1944). Several more recent studies of mussel distributions in southern Indiana were conducted on the Wabash, White, and East Fork White Rivers (Meyer 1974) and primary tributaries of the East Fork White River (Clarke et al. 1999, Cummings et al. 1992, Harmon 1998, Taylor 1982, Weilbaker et al. 1985). Updated spot-distribution maps compiled by Cummings for mussels of Illinois and Indiana (Cummings 2001, unpublished maps) were used primarily to determine current and historical mussel distributions within the assessment area in those States. Although a considerable body of literature exists on mussels in Kentucky, Cicerello et al. (1991) provided the most recent comprehensive summary of current and historical mussel distributions statewide. Updated spot-distribution maps provided by Cicerello (Cicerello 2001, unpublished maps) for the State of Kentucky served as the primary source of information on specific distributions of mussels within the assessment area in Kentucky. For the small portion of the assessment area that penetrates Missouri, spot-distribution maps in Oesch (1984) served as the primary data source. Scientific and common names of mussels generally follow Williams et al. (1993) except that subspecies are not recognized (Cummings and Mayer 1992).

### Crayfishes

Data sources used to plot historic and recent distribution data of crayfishes onto the 39 watersheds of the assessment area included the following: Page (1985), Page and Mottesi (1995), and Taylor and Anton (1999) for Illinois; Pflieger (1996) for Missouri; the Illinois Natural History Survey (INHS) database (as of August 2001) and Taylor and Schuster (2001, unpublished spot-distribution maps) for

Kentucky; and the INHS database (as of August 2001) for Indiana. The INHS data on crayfish distribution in Kentucky included historic records as well as a relatively larger body of more recent collection records to be used in a future publication. However, aside from older publications—Hay (1896) and Eberly (1955), both with inexact locality information—very little publicly available data exist on the historic or current distribution of Indiana crayfishes. There were relatively few INHS crayfish records for Indiana counties in the assessment area, and those few records were generally concentrated in the Patoka River watershed as well as direct tributaries of the lower Ohio River.

Twenty-one of the thirty-four species in the assessment area have common names that derive from a variety of sources but that have not been uniformly sanctioned by a professional society. For the sake of consistency, we coined common names for the 13 species that lack them. Most of the scientific names of crayfishes in this report agree with those presented in Taylor et al. (1996). The following are exceptions. All *Cambarus bartonii* are of the subspecies *C. b. cavatus,* not *C. b. carinirostris* or *C. b. bartonii.* The subspecies *Orconectes inermis inermis* and *O. i. testii* are both included under the name *O. inermis. Orconectes ronaldi* and *O. margorectus* are newly described species in Taylor (2000) and Taylor (2002), respectively. *Orconectes palmeri palmeri* is the only subspecies recorded in the assessment area (Pflieger 1996) and is referred to here as *O. palmeri.* According to Taylor et al. (1996), both *Cambarus diogenes* and *Procambarus acutus* are comprised of species complexes and warrant further study.

## Analysis of Aquatic Diversity

Fish, mussel, and crayfish species were noted as present or absent within each hydrologic unit and classified as native or endemic. Aquatic species occurring in peripheral (outside the assessment area) hydrologic units were not included. The status of a fish, mussel (i.e., live individual or dead shells), or crayfish species reflects its known historical presence within a unit but does not necessarily indicate its continued present-day occurrence in a unit. Information to account for changes to the fauna is inadequately synthesized for area-wide analysis. Fishes, mussels, and crayfishes were considered native if the assessment area was within their known historical range and no evidence of their having been artificially introduced was available. Depending on scale, biologists define endemic species as those that have a restricted range within one locale (or drainage). Introduced species are defined as those that have been intentionally or accidentally released in a locale. Some species can be described as native and introduced. For example, largemouth bass initially were found in the assessment area and they also have been stocked from hatchery-produced progeny into many farm ponds, impoundments, and artificial lakes in the area. Therefore, largemouth bass occur in two categories at once. Introduced bivalves (i.e., Asian clam and zebra mussel) and sphaeriid clams were not included in our analyses.

Diversity was analyzed using native species richness and native species density. Native species richness is the number of native species (i.e., fish, mussel, or crayfish) within each hydrologic unit. Hydrological units vary in areal extent, and species richness often increases with increases in stream size or area drained. To examine the effect of areal additivity (increases in area may be accompanied by an increase in species), native species richness was divided by the number of square miles in a given hydrologic unit (or partial unit) to produce native species density values for each HUC. In addition, the log of native species richness was regressed on the log area of hydrologic units to examine the relationship between species richness and unit size. Native species richness and a ranked sum of richness and density were plotted on separate hydrologic unit

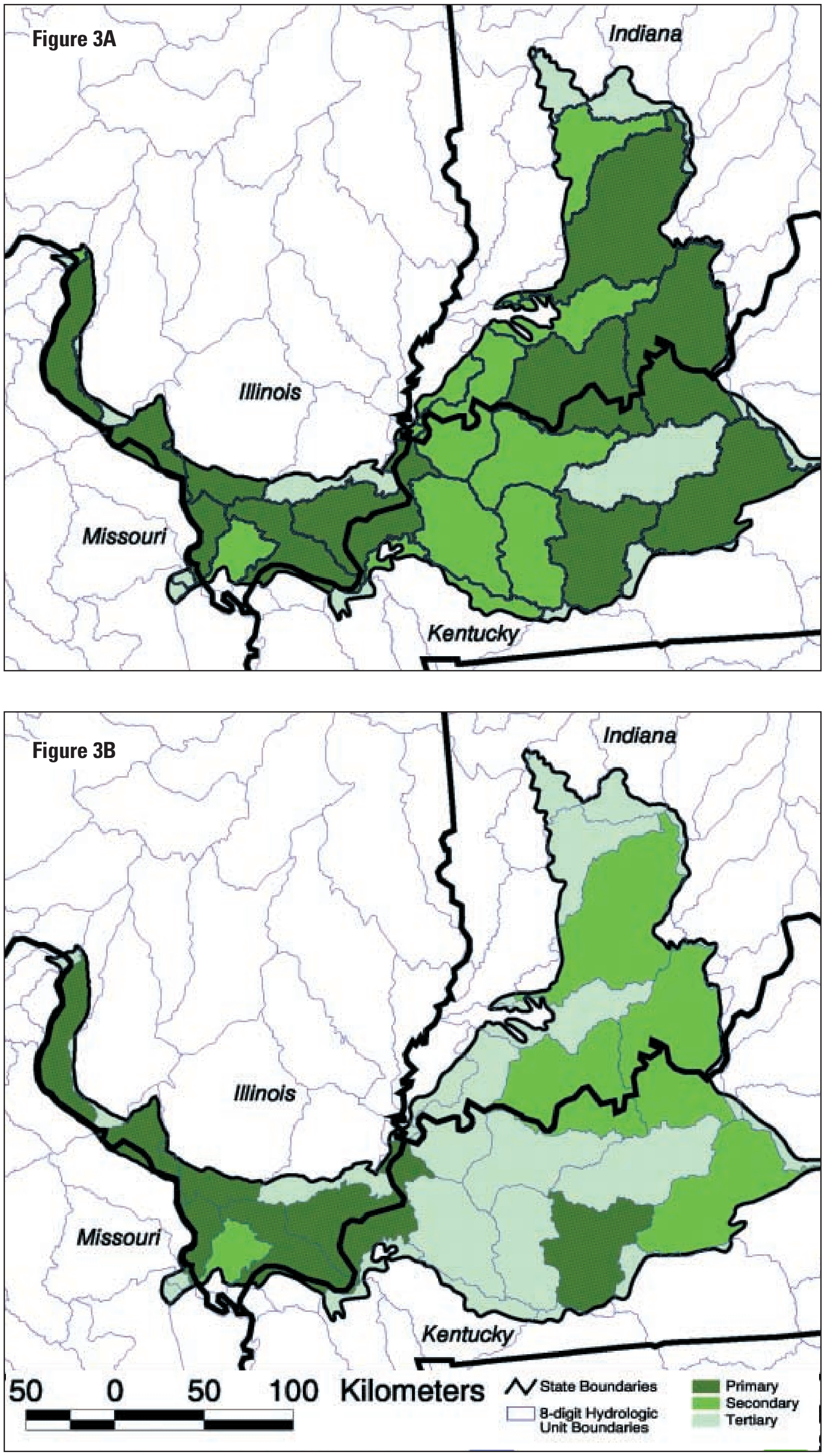


**Figure 3.** Levels of fish species richness (A) and fish species rank of overall importance (B) by watershed in the Hoosier-Shawnee Ecological Assessment Area.

maps. Rank values of species richness in all hydrologic units and ranks of overall importance in hydrologic units with 12 percent or more of their area in the assessment area were divided into quartiles. Three levels of relative richness were recognized among hydrologic units: primary, secondary, and tertiary. Primary levels were assigned to the 9-10 units (depending on tied scores) with the highest values, secondary levels were assigned to the next highest 8-10 units, and tertiary levels were assigned to the remaining units. Hence, primary levels approximate values in the fourth quartile or top 25 percent, secondary levels approximate values in the third quartile or second 25 percent, and tertiary levels approximate values in the first and second quartiles or bottom 50 percent.

Watersheds with less than 12 percent of their total area in the assessment area had artificially high species density values. Therefore, species richness was considered a "real" descriptor of non-random distribution that was not as heavily burdened by watershed size as was species density. For this reason, no figure of species density was included, even though species density values were used in calculating the index of overall importance (but only for watersheds with 12 percent or more of their area in the assessment area).

Individual rank orders of the hydrologic units for native species richness and native species density were summed to create an index of overall relative importance of hydrologic units as freshwater habitats in the assessment area. Species richness and ranked sum of richness and density were plotted on separate hydrologic unit maps to show patterns of richness and relative overall importance (figs. 3-5). All ranking procedures used integer values. The hydrologic units or partial units with lowest ranks were considered the most important with regard to either richness, density, or overall rank. All tied calculated values received the same rank value.

## PATTERNS AND TRENDS

### Composition of Native Freshwater Fishes

Native fish diversity is divided unevenly among families in the assessment area. In the region, 194 native fish species placed in 24 families are represented (table 2). The five richest families—minnows (58 native species), perches (42), suckers (18), sunfishes and basses (16 ), and bullhead catfishes (14),—account for about 76 percent of the fish fauna. Just over 50 percent of the native fish fauna is made up of minnows (Cyprinidae) and darters (Percidae, perch family). Ten families have only one species represented in the assessment area, and other families support a significant number of North American species. For example, 50 percent of all cavefishes (Amblyopsidae) and about 25 percent of lampreys (Petromyzontidae) are recorded from the assessment area (Mayden et al. 1992).

Fish faunal composition has been independently analyzed for Missouri (Pflieger 1971), Kentucky (Burr and Warren 1986), Kentucky and Tennessee (Warren et al. 1991), and Illinois and surrounding areas (Burr and Page 1986). All of these analyses used different units of scale, generally larger drainage units than the eight-digit hydrologic units used here. Three of these studies also were limited to the political boundaries of their respective states and varied in the level of classification achieved. The primary findings relevant to the assessment area are summarized here; for details, the reader is referred to the original studies.

Pflieger (1971) recognized four primary faunal regions in Missouri: Ozark, lowland, prairie, and big river. The Ozark fish faunal region was restricted primarily to the Ozark Highlands or about the southern half of the State. Fish communities here are distinctively fluvial and unique, especially considering the high degree of endemism in the region. Noteworthy are the numbers of geminate pairs of fishes that occur in the Ozark Highlands and that have their next closest relatives occurring in the Appalachian Highlands (Burr and Page 1986). The lowland fish faunal region is a community of fishes restricted primarily to the southeastern corner of Missouri in the “bootheel” of the State. The species and habitats identified for this community in Missouri are similar to what is found in the assessment area in southern Illinois south of the Shawnee Hills continuing through the lower Cumberland-Tennessee region and including the lower Green River drainage. The prairie fish faunal region dominates the northern half of Missouri and is similar to the fish communities recognized in the assessment area in those hydrological units bordering the Mississippi and lower Missouri Rivers. The fourth and final fish faunal region recognized, the big river, includes primarily the mainstem channels of the Mississippi and Missouri Rivers. The assessment area includes about 165 miles of the mainstem Mississippi River and only a few miles of the extreme lower reaches of the Missouri River. The lower Ohio River is different in character (i.e., lower turbidity, narrower unbraided channel, less fluctuation in flow) from the Mississippi and lower Missouri Rivers but is more similar faunistically to the big river faunal region than any of the others recognized.

Burr and Warren (1986) analyzed fish diversity in Kentucky in two ways: 1) on the basis of 28 faunal or watershed units and 2) on the basis of 25 previously recognized physiographic units. Faunal similarity among watershed units was influenced by size, geographic proximity, geological history, and physical and biological characteristics of the units themselves. Three basic faunal groupings were formed: 1) a big river/lowland fauna, 2) an upland fauna, and 3) Terrapin Creek. The first two groupings are relevant to the assessment area and overlap in fish composition with the similar groupings in Missouri. Characteristic of the big river group are the shovelnose sturgeon, paddlefish, skipjack herring, goldeye, river shiner, silverband shiner, flathead chub, and blue sucker. At least four species, pallid sturgeon, sturgeon chub, sicklefin chub, and plains minnow, occur only in the mainstem Mississippi River in the assessment area.

The group most closely associated with the big river assemblage was the lowlands, including the Coastal Plain proper and environmentally similar areas of the lower Green and Tradewater

**Table 2.** Conservation ranks of native fishes of the Hoosier-Shawnee Ecological Assessment Area.

| | | | Occurrence | | Conservation ranks | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Family** | **Species** | **Common name** | **SNF** | **HNF** | **Global** | **Federal** | **AFS** | **HNF** | **SNF** | **MIS HNF** | **MIS SNF** | **IL** | **IN** | **KY** | **MO** |
| Acipenseridae | *Acipenser fulvescens* | Lake sturgeon | X | X | G3 | | T | R | | | | E | E | E | S1 |
| Acipenseridae | *Scaphirhynchus albus* | Pallid sturgeon | X | | G1G2 | E | E | | | | | E | | E | S1 |
| Acipenseridae | *Scaphirhynchus platorynchus* | Shovelnose sturgeon | X | X | G4 | | | | | | | | | | |
| Amblyopsidae | *Amblyopsis spelaea* | Northern cavefish | | X | G3 | T | T | R | | | | | E | S | |
| Amblyopsidae | *Forbesichthys agassizi* | Spring cavefish | X | | G4G5 | | | | | | | | | | S1 |
| Amblyopsidae | *Typhlichthys subterraneus* | Southern cavefish | | X | G4 | | V | | | | | | E | S | S2,S3 |
| Amiidae | *Amia calva* | Bowfin | X | X | G5 | | | | | | | | | | |
| Anguillidae | *Anguilla rostrata* | American eel | X | X | G5 | | | | | | | | | | |
| Aphredoderidae | *Aphredoderus sayanus* | Pirate perch | X | X | G5 | | | | | | | | | | |
| Atherinopsidae | *Labidesthes sicculus* | Brook silverside | X | X | G5 | | | | | | | | | | |
| Atherinopsidae | *Menidia beryllina* | Inland silverside | X | | G5 | | | | | | | | | T | |
| Catostomidae | *Carpiodes carpio* | River carpsucker | X | X | G5 | | | | | | | | | | |
| Catostomidae | *Carpiodes cyprinus* | Quillback | X | | G5 | | | | | | | | | | |
| Catostomidae | *Carpiodes velifer* | Highfin carpsucker | X | X | G4G5 | | | | | | | | | | S2 |
| Catostomidae | *Catostomus commersoni* | White sucker | X | X | G5 | | | | | | | | | | |
| Catostomidae | *Cycleptus elongatus* | Blue sucker | X | X | G3G4 | | V | | | | | | S | | S3 |
| Catostomidae | *Erimyzon oblongus* | Creek chubsucker | X | X | G5 | | | | | | | | | | |
| Catostomidae | *Erimyzon sucetta* | Lake chubsucker | X | X | G5 | | | | | | | | | T | |
| Catostomidae | *Hypentelium nigricans* | Northern hog sucker | X | X | G5 | | | | | | | | | | |
| Catostomidae | *Ictiobus bubalus* | Smallmouth buffalo | X | X | G5 | | | | | | | | | | |
| Catostomidae | *Ictiobus cyprinellus* | Bigmouth buffalo | X | X | G5 | | | | | | | | | | |
| Catostomidae | *Ictiobus niger* | Black buffalo | X | | G5 | | | | | | | | | S | |
| Catostomidae | *Minytrema melanops* | Spotted sucker | X | X | G5 | | | | | | | | | | |
| Catostomidae | *Moxostoma anisurum* | Silver redhorse | | X | G5 | | | | | | | | | | |
| Catostomidae | *Moxostoma carinatum* | River redhorse | | X | G4 | | | | | | | T | S | | |
| Catostomidae | *Moxostoma duquesnei* | Black redhorse | X | X | G5 | | | | | | | | | | |
| Catostomidae | *Moxostoma erythrurum* | Golden redhorse | X | X | G5T4 | | | | | | | | | | |
| Catostomidae | *Moxostoma macrolepidotum* | Shorthead redhorse | X | X | G5T? | | | | | | | | | | |
| Centrarchidae | *Ambloplites rupestris* | Rock bass | X | X | G5 | | | | | M | | | | | |
| Centrarchidae | *Centrarchus macropterus* | Flier | X | X | G5 | | | | | | | | | | S3 |
| Centrarchidae | *Lepomis auritus* | Redbreast sunfish | | | G5 | | | | | | | | | | |
| Centrarchidae | *Lepomis cyanellus* | Green sunfish | X | X | G5 | | | | | | | | | | |
| Centrarchidae | *Lepomis gulosus* | Warmouth | X | X | G5 | | | | | | | | | | |
| Centrarchidae | *Lepomis humilis* | Orangespotted sunfish | X | X | G5 | | | | | | | | | | |
| Centrarchidae | *Lepomis macrochirus* | Bluegill | X | X | G5 | | | | | M | | | | | |
| Centrarchidae | *Lepomis megalotis* | Longear sunfish | X | X | G5 | | | | | | | | | | |
| Centrarchidae | *Lepomis microlophus* | Redear sunfish | X | X | G5 | | | | | | | | | | |
| Centrarchidae | *Lepomis miniatus* | Redspotted sunfish | X | | G5 | | | | | | | T | | T | |
| Centrarchidae | *Lepomis symmetricus* | Bantam sunfish | X | | G5 | | | | R | | | T | S | | S2 |
| Centrarchidae | *Micropterus dolomieu* | Smallmouth bass | X | X | G5 | | | | | M | | | | | |
| Centrarchidae | *Micropterus punctulatus* | Spotted bass | X | X | G5 | | | | | | | | | | |

*(table continued on next page)*

**(table 2 continued)**

| Family | Species | Common name | Occurrence SNF | Occurrence HNF | Conservation ranks Global | Federal | AFS | HNF | SNF | MIS HNF | MIS SNF | IL | IN | KY | MO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Centrarchidae | *Micropterus salmoides* | Largemouth bass | X | X | G5 | | | | | M | | | | | |
| Centrarchidae | *Pomoxis annularis* | White crappie | X | X | G5 | | | | | | | | | | |
| Centrarchidae | *Pomoxis nigromaculatus* | Black crappie | X | X | G5 | | | | | | | | | | |
| Clupeidae | *Alosa alabamae* | Alabama shad | | | G3 | C | V | | | | | | Ex | E | S2 |
| Clupeidae | *Alosa chrysochloris* | Skipjack herring | X | X | G5 | | | | | | | | | | |
| Clupeidae | *Dorosoma cepedianum* | Gizzard shad | X | X | G5 | | | | | | | | | | |
| Clupeidae | *Dorosoma petenense* | Threadfin shad | X | X | G5 | | | | | | | | | | |
| Cottidae | *Cottus bairdi* | Mottled sculpin | | X | G5T? | | | | | | | | | | |
| Cottidae | *Cottus carolinae* | Banded sculpin | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Campostoma anomalum* | Central stoneroller | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Campostoma pullum* | Mississippi stoneroller | | X | G5 | | | | | | | | | | |
| Cyprinidae | *Campostoma oligolepis* | Largescale stoneroller | | | G5 | | | | | | | | | | |
| Cyprinidae | *Cyprinella lutrensis* | Red shiner | X | | G5 | | | | | | | | | | |
| Cyprinidae | *Cyprinella spiloptera* | Spotfin shiner | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Cyprinella venusta* | Blacktail shiner | X | | G5 | | | | | | | | | S | |
| Cyprinidae | *Cyprinella whipplei* | Steelcolor shiner | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Ericymba buccata* | Silverjaw minnow | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Erimystax dissimilis* | Streamline chub | | | G4 | | | | | | | | | | |
| Cyprinidae | *Erimystax x-punctatus* | Gravel chub | | X | G4 | | | | | | | | | Ex | |
| Cyprinidae | *Hybognathus argyritis* | Western silvery minnow | X | | G4 | | | | | | | | | | S2 |
| Cyprinidae | *Hybognathus hayi* | Cypress minnow | X | X | G5 | | | | | | | E | | E | S1 |
| Cyprinidae | *Hybognathus nuchalis* | Mississippi silvery minnow | X | X | G5 | | | | | | | | | | S3,S4 |
| Cyprinidae | *Hybognathus placitus* | Plains minnow | X | | G4 | | | | | | | | | S | S2 |
| Cyprinidae | *Hybopsis amblops* | Bigeye chub | X | X | G5 | | | | | | | E | | | |
| Cyprinidae | *Hybopsis amnis* | Pallid shiner | X | X | G4 | | V | | | | | E | | H | SX |
| Cyprinidae | *Luxilus chrysocephalus* | Striped shiner | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Luxilus cornutus* | Common shiner | | X | G5 | | | | | | | | | | |
| Cyprinidae | *Luxilus zonatus* | Bleeding shiner | | | G5 | | | | | | | | | | |
| Cyprinidae | *Lythrurus fasciolaris* | Scarletfin shiner | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Lythrurus fumeus* | Ribbon shiner | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Lythrurus umbratilis* | Redfin shiner | X | X | G5 | | | | | M | | | | | |
| Cyprinidae | *Macrhybopsis gelida* | Sturgeon chub | X | | G2 | C | V | | | | | E | | H | S3 |
| Cyprinidae | *Macrhybopsis hyostoma* | Speckled chub | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Macrhybopsis meeki* | Sicklefin chub | X | | G3 | C | V | | | | | | | H | S3 |
| Cyprinidae | *Macrhybopsis storeriana* | Silver chub | X | X | G5 | | | | | | | | | | S3 |
| Cyprinidae | *Nocomis biguttatus* | Hornyhead chub | X | X | G5 | | | | | | | | | S | |
| Cyprinidae | *Nocomis effusus* | Redtail chub | | | G4 | | | | | | | | | | |
| Cyprinidae | *Notemigonus crysoleucas* | Golden shiner | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Notropis ariommus* | Popeye shiner | | X | G3 | | V | | | | | | Ex | | |
| Cyprinidae | *Notropis atherinoides* | Emerald shiner | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Notropis blennius* | River shiner | X | X | G5 | | | | | | | | | | |

*(table continued on next page)*

**(table 2 continued)**

| | | | Occurrence | | Conservation ranks | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Family | Species | Common name | SNF | HNF | Global | Federal | AFS | HNF | SNF | MIS HNF | MIS SNF | IL | IN | KY | MO |
| Cyprinidae | *Notropis boops* | Bigeye shiner | X | X | G5 | | | | | | | E | | | |
| Cyprinidae | *Notropis buchanani* | Ghost shiner | X | X | G5 | | | | | | | | | | S2 |
| Cyprinidae | *Notropis chalybaeus* | Ironcolor shiner | | X | G5 | | V | | | | | T | | | S1 |
| Cyprinidae | *Notropis dorsalis* | Bigmouth shiner | X | | G5 | | | | | | | | | | |
| Cyprinidae | *Notropis hudsonius* | Spottail shiner | X | | G5 | | | | | | | | | S | |
| Cyprinidae | *Notropis ludibundus* | Sand shiner | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Notropis maculatus* | Taillight shiner | X | X | G5 | | | | | | | E | | T | S1 |
| Cyprinidae | *Notropis nubilus* | Ozark minnow | X | | G5 | | | | | | | | | | |
| Cyprinidae | *Notropis photogenis* | Silver shiner | | X | G5 | | | | | | | | | | |
| Cyprinidae | *Notropis rubellus* | Rosyface shiner | | X | G5 | | | | | | | | | | |
| Cyprinidae | *Notropis shumardi* | Silverband shiner | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Notropis texanus* | Weed shiner | | | G5 | | | | | | | E | | | |
| Cyprinidae | *Notropis volucellus* | Mimic shiner | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Notropis wickliffi* | Channel shiner | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Opsopoeodus emiliae* | Pugnose minnow | X | X | G5 | | | | | M | | | | | S4 |
| Cyprinidae | *Phenacobius mirabilis* | Suckermouth minnow | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Phenacobius uranops* | Stargazing minnow | | | G4 | | | | | | | | | S | |
| Cyprinidae | *Phoxinus erythrogaster* | Southern redbelly dace | X | X | G5 | | | | | M | | | | | |
| Cyprinidae | *Pimephales notatus* | Bluntnose minnow | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Pimephales promelas* | Fathead minnow | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Pimephales vigilax* | Bullhead minnow | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Platygobio gracilis* | Flathead chub | X | | G5 | | V | | | | | E | | S | S1 |
| Cyprinidae | *Pteronotropis hubbsi* | Bluehead shiner | X | | G3 | | V | | R | | | E | | | |
| Cyprinidae | *Rhinichthys atratulus* | Blacknose dace | X | X | G5 | | | | | | | | | | |
| Cyprinidae | *Rhinichthys cataractae* | Longnose dace | X | | G5 | | | | | | | | | | |
| Cyprinidae | *Semotilus atromaculatus* | Creek chub | X | X | G5 | | | | | | | | | | |
| Elassomatidae | *Elassoma zonatum* | Banded pygmy sunfish | X | | G5 | | | | | | | | | | |
| Esocidae | *Esox americanus* | Grass pickerel | X | X | G5 | | | | | M | | | | | |
| Esocidae | *Esox lucius* | Northern pike | X | X | G5 | | | | | | | | | | |
| Esocidae | *Esox masquinongy* | Muskellunge | | X | G5 | | | | | | | | S | | |
| Esocidae | *Esox niger* | Chain pickerel | | | G5 | | | | | | | | | S | |
| Fundulidae | *Fundulus catenatus* | Northern studfish | X | | G5 | | | | | | | | S | | |
| Fundulidae | *Fundulus dispar* | Starhead topminnow | X | | G4 | | | | | | | | | E | S2 |
| Fundulidae | *Fundulus notatus* | Blackstripe topminnow | X | X | G5 | | | | | | | | | | |
| Fundulidae | *Fundulus olivaceus* | Blackspotted topminnow | X | | G5 | | | | | | | | | | |
| Gadidae | *Lota lota* | Burbot | | | G5 | | | | | | | | | S | |
| Hiodontidae | *Hiodon alosoides* | Goldeye | X | | G5 | | | | | | | | | | |
| Hiodontidae | *Hiodon tergisus* | Mooneye | X | X | G5 | | | | | | | | | | S3 |
| Ictaluridae | *Ameiurus melas* | Black bullhead | X | X | G5 | | | | | | | | | | |
| Ictaluridae | *Ameiurus natalis* | Yellow bullhead | X | X | G5 | | | | | | | | | | |
| Ictaluridae | *Ameiurus nebulosus* | Brown bullhead | X | X | G5 | | | | | | | | | | S3? |

*(table continued on next page)*

**(table 2 continued)**

| Family | Species | Common name | Occurrence | | Conservation ranks | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | SNF | HNF | Global | Federal | AFS | HNF | SNF | MIS HNF | MIS SNF | IL | IN | KY | MO |
| Ictaluridae | *Ictalurus furcatus* | Blue catfish | X | | G5 | | | | | | | | | | |
| Ictaluridae | *Ictalurus punctatus* | Channel catfish | X | X | G5 | | | | | | | | | | |
| Ictaluridae | *Noturus elegans* | Elegant madtom | | | G4 | | | | | | | | | | |
| Ictaluridae | *Noturus eleutherus* | Mountain madtom | | X | G4 | | | | | | | | | | S1,S2 |
| Ictaluridae | *Noturus exilis* | Slender madtom | X | | G5 | | | | | | | | | E | |
| Ictaluridae | *Noturus flavus* | Stonecat | X | X | G5 | | | | | | | | | | |
| Ictaluridae | *Noturus gyrinus* | Tadpole madtom | X | X | G5 | | | | | | | | | | |
| Ictaluridae | *Noturus miurus* | Brindled madtom | X | X | G5 | | | | | | | | | | |
| Ictaluridae | *Noturus nocturnus* | Freckled madtom | X | X | G5 | | | | | | | | | | |
| Ictaluridae | *Noturus stigmosus* | Northern madtom | | X | G3 | | V | | | | | E | | S | |
| Ictaluridae | *Pylodictis olivaris* | Flathead catfish | X | X | G5 | | | | | | | | | | |
| Lepisosteidae | *Atractosteus spatula* | Alligator gar | X | | G5 | | V | | | | | Ex | | E | SX |
| Lepisosteidae | *Lepisosteus oculatus* | Spotted gar | X | | G5 | | | | | | | | | | |
| Lepisosteidae | *Lepisosteus osseus* | Longnose gar | X | X | G5 | | | | | | | | | | |
| Lepisosteidae | *Lepisosteus platostomus* | Shortnose gar | X | X | G5 | | | | | | | | | | |
| Moronidae | *Morone chrysops* | White bass | X | | G5 | | | | | | | | | | |
| Moronidae | *Morone mississippiensis* | Yellow bass | X | X | G5 | | | | | | | | | | |
| Percidae | *Ammocrypta clara* | Western sand darter | X | | G3 | | V | | | | | E | | | S2,S3 |
| Percidae | *Ammocrypta pellucida* | Eastern sand darter | | X | G3 | | V | R | | | | T | | | |
| Percidae | *Crystallaria asprella* | Crystal darter | | | G3 | | V | | | | | Ex | | | S1 |
| Percidae | *Etheostoma asprigene* | Mud darter | X | | G4 G5 | | | | | | | | | | |
| Percidae | *Etheostoma barbouri* | Teardrop darter | | | G4 G5 | | | | | | | | | | |
| Percidae | *Etheostoma bellum* | Orangefin darter | | | G4 G5 | | | | | | | | | | |
| Percidae | *Etheostoma blennioides* | Greenside darter | | X | G5 | | | | | | | | | | |
| Percidae | *Etheostoma caeruleum* | Rainbow darter | X | X | G5 | | | | | | M | | | | |
| Percidae | *Etheostoma camurum* | Bluebreast darter | | X | G4 | | | | | FSOC | | E | | | |
| Percidae | *Etheostoma chlorosoma* | Bluntnose darter | X | X | G5 | | | | | | | | | | |
| Percidae | *Etheostoma crossopterum* | Fringed darter | | | G4 | | | | | | | | | | |
| Percidae | *Etheostoma flabellare* | Fantail darter | X | X | G5 | | | | | | | | | | |
| Percidae | *Etheostoma flavum* | Saffron darter | | | G4 | | | | | | | | | | |
| Percidae | *Etheostoma gracile* | Slough darter | X | X | G5 | | | | | | | | | | |
| Percidae | *Etheostoma histrio* | Harlequin darter | | | G4 | | | | | | | E | | | S2 |
| Percidae | *Etheostoma kennicotti* | Stripetail darter | X | | G4 G5 | | | | | | | | | | |
| Percidae | *Etheostoma maculatum* | Spotted darter | | | G2 | | V | | | | | | | | |
| Percidae | *Etheostoma nigrum* | Johnny darter | X | X | G5 | | | | | | | | | | |
| Percidae | *Etheostoma oophylax* | Guardian darter | | | G4 G5 | | | | | | | | | | |
| Percidae | *Etheostoma proeliare* | Cypress darter | X | | G5 | | | | | | | | | | |
| Percidae | *Etheostoma rafinesquei* | Kentucky darter | | | | | | | | | | | | | |
| Percidae | *Etheostoma smithi* | Slabrock darter | | | G4 | | | | | | | | | | |
| Percidae | *Etheostoma spectabile* | Orangethroat darter | X | X | G5 | | | | | | | | | | |
| Percidae | *Etheostoma squamiceps* | Spottail darter | X | | G4 G5 | | | | | | | | | | |

*(table continued on next page)*

**(table 2 continued)**

| | | | Occurrence | | Conservation ranks | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Family** | **Species** | **Common name** | **SNF** | **HNF** | **Global** | **Federal** | **AFS** | **HNF** | **SNF** | **MIS HNF** | **MIS SNF** | **IL** | **IN** | **KY** | **MO** |
| Percidae | *Etheostoma stigmaeum* | Speckled darter | | | G5 | | | | | | | | | | |
| Percidae | *Etheostoma tecumsehi* | Shawnee darter | | | G1 | | T | | | | | | | | |
| Percidae | *Etheostoma tippecanoe* | Tippecanoe darter | | X | G3 | | V | Ex | | | | | | | |
| Percidae | *Etheostoma variatum* | Variegate darter | | X | G5 | | | | | | | | | | |
| Percidae | *Etheostoma virgatum* | Striped darter | | | G4 | | | | | | | | | | |
| Percidae | *Etheostoma zonale* | Banded darter | | X | G5 | | | | | | | | | | |
| Percidae | *Perca flavescens* | Yellow perch | | X | G5 | | | | | | | | | | |
| Percidae | *Percina caprodes* | Logperch | X | X | G5 | | | | | | | | | | |
| Percidae | *Percina copelandi* | Channel darter | | X | G4 | | | | | | | | | | S3 |
| Percidae | *Percina evides* | Gilt darter | | | G4 | | | | | | | | | | |
| Percidae | *Percina maculata* | Blackside darter | X | X | G5 | | | | | | | | | | |
| Percidae | *Percina phoxocephala* | Slenderhead darter | X | X | G5 | | | | | | | | | | |
| Percidae | *Percina sciera* | Dusky darter | X | X | G5 | | | | | | | | | | |
| Percidae | *Percina shumardi* | River darter | X | X | G5 | | | | | | | | | | S3 |
| Percidae | *Percina stictogaster* | Frecklebelly darter | | | G4 G5 | | | | | | | | | | |
| Percidae | *Percina vigil* | Saddleback darter | | | G5 | | | | | | | | | | |
| Percidae | *Stizostedion canadense* | Sauger | X | X | G5 | | | | | | | | | | |
| Percidae | *Stizostedion vitreum* | Walleye | X | | G5 | | | | | | | | | | |
| Percopsidae | *Percopsis omiscomaycus* | Trout-perch | X | X | G5 | | V | | | | | | | | S1? |
| Petromyzontidae | *Ichthyomyzon bdellium* | Ohio lamprey | | X | G5 | | | | | | | | | | |
| Petromyzontidae | *Ichthyomyzon castaneus* | Chestnut lamprey | X | X | G3 G4 | | | | | | | | | | |
| Petromyzontidae | *Ichthyomyzon fossor* | Northern brook lamprey | | X | G4 | | | | | | | E | | | |
| Petromyzontidae | *Ichthyomyzon unicuspis* | Silver lamprey | X | X | G5 | | | | | | | | | | |
| Petromyzontidae | *Lampetra aepyptera* | Least brook lamprey | X | X | G5 | | | | | | | T | | | |
| Petromyzontidae | *Lampetra appendix* | American brook lamprey | | | G4 | | | | | | | | | | S2 |
| Poeciliidae | *Gambusia affinis* | Western mosquitofish | X | | G5 | | | | | | | | | | |
| Polyodontidae | *Polyodon spathula* | Paddlefish | X | | G4 | | V | | | | | | | | S3 |
| Sciaenidae | *Aplodinotus grunniens* | Freshwater drum | X | X | G5 | | | | | | | | | | |
| Umbridae | *Umbra limi* | Central mudminnow | X | X | G5 | | | | | | | | | | S1 |

E = Endangered
T = Threatened
S = Special concern
V = Vulnerable (American Fisheries Society)
Ex = Extirpated from the area/state in question
C = Candidate for listing federally
G1 = Critically imperiled globally (typically occurs in 5 or fewer counties)
G2 = Imperiled globally (typically occurs in 6 to 20 counties)
G3 = Very rare and local throughout range or found locally in a restricted range
G4 = Widespread, abundant, and apparently secure globally
G5 = Demonstrably widespread, abundant, and secure globally
T4 = Taxonomic subdivision: widespread, abundant, and apparently secure globally
S1 = Missouri-Critically imperiled in the State (typically 5 or fewer occurrences)
S2 = Missouri-Imperiled in the State (typically 6 to 20 occurrences)
S3 = Missouri-Rare and uncommon in the State (21 to 100 occurrences)
S4 = Missouri-Widespread and abundant but of long-term concern
SX = Missouri-Extirpated
H = Historic (Extirpated-Kentucky)
? = Inexact or uncertain
R= Rare within a national forest
FSOC = Forest Species of Concern
M = Management Indicator Species in the national forest
SNF = Shawnee National Forest
HNF = Hoosier National Forest
AFS = American Fisheries Society
MIS = Management Indicator Species

Rivers. Indicative of the lowlands are the spotted gar, cypress minnow, pugnose minnow, ribbon shiner, lake chubsucker, pirate perch, flier, redspotted sunfish, banded pygmy sunfish, mud darter, bluntnose darter, and slough darter. Species more characteristic of the Coastal Plain include the chain pickerel, central mudminnow, blacktail shiner, taillight shiner, bantam sunfish, and cypress darter. The distribution of lowland fishes is strongly associated with a lack of topographic relief and low stream gradients. As a group they inhabit standing waters or sluggish streams and ditches with sand or mud bottoms. Many are also found among or near debris or dense growths of submerged aquatic vegetation. Because parts of the Interior Low Plateaus have aquatic habitats similar to those on the Coastal Plain, especially the floodplains of large streams and rivers, many species primarily distributed on the Gulf Coastal Plain have dispersed to areas far beyond the Mississippi Embayment.

A number of streams in the Ohio basin are representative of fish communities inhabiting upland habitats. Burr and Page (1986) referred to this upland cluster as the "Ohio River Uplands group." Among the most characteristic fishes of this group are the streamline chub, popeye shiner, silver shiner, rosyface shiner, stonecat, Tippecanoe darter, spotted darter, variegate darter, and gilt darter. As a group the upland fauna seems to be intolerant of continuous turbidity and siltation and requires streams with permanent flow, high gradients, and coarse gravel or rock bottoms. The distinctiveness of the upland fauna is probably related to topographic and habitat diversity, a relatively long history of drainage stability, constant base flows, and the isolation associated with inhabiting small streams and rivers. The upland faunal group emphasizes that faunal similarity among the drainages is influenced by geographic propinquity and major drainage basin. These findings are similar to those using physiographic units and others that relied almost exclusively on drainage units (e.g., Burr and Page [1986] for Illinois and surrounding areas, Warren et al. [1991] for Kentucky and Tennessee).

In Mayden's (1988) unique approach to fish faunal assemblages in the assessment area, he used 34 major drainages (e.g., Wabash, Green, Big Muddy Rivers) as analogous to "taxonomic units" and used fish species as the "characters" supporting the branching patterns of the "phylogeny" (estimate of evolutionary history) of the drainage units. His study derived a phylogeny consistent with the known pre-Pleistocene geological history of eastern North American rivers and supported the hypothesis of an ancient ichthyofauna in the Central Highlands region (including the Ouachita, Ozark, and Appalachian Highlands). Among the more intriguing findings of this study and others is that some endemic fish species in the Ozark Highlands have their closest relatives in the Ouachita Highlands, and these two regions together have their next closest relatives in the Appalachian Highlands of eastern Kentucky. For further details on geological and drainage history of the assessment area, see Burr and Page (1986), Burr and Warren 1986), Mayden (1988), Strange and Burr (1997), and Wiley and Mayden (1985).

### Native fish species richness and density

The number of native fish species is not evenly distributed among the hydrologic units (fig. 3A), nor is it oriented to a simple geographic axis or compass point. Species richness averaged 76 fish species per hydrologic unit (after removal of HUCs that have only a small proportion of their area in the assessment area) and ranged from 37 to 129 species. Most units, however, displayed diverse fish faunas; 21 of the 27 units in the assessment area had more than 60 species.

Two separate geographical centers with primary levels of fish species richness (85 to 129 species) are apparent (fig. 3A). One occurs along the southwestern and southern edge of Illinois and the other occurs primarily along the eastern border of the assessment area. The southwestern-southern center is comprised of units within the Mississippi-lower Ohio drainage (Cahokia-Joachim, upper Mississippi-Cape Girardeau, Big Muddy, lower Ohio, and lower Ohio-Bay). The eastern center is comprised of units within the Green, Ohio and Wabash River drainages (lower East Fork White, Blue-Sinking, lower Ohio-Little Pigeon, upper Green, and Pond).

Units with secondary levels of fish species richness (61 to 84 species) are located in the extreme southwest (Cache unit), and the central units (Tradewater, middle Green, lower Green, Highland Pigeon, lower Wabash, Patoka, and lower White) of the assessment area (fig. 3A). Minor secondary units with little space in the assessment area include the lower Cumberland and Piasa (fig. 3A). Those units with tertiary levels (60 or fewer species) were primarily narrow strips of area or incomplete border units. The one exception to this pattern is the Rough unit in the Green River drainage with only 51 recorded species.

Ecological units positioned as ecotones tended to be associated with primary levels of richness. The cluster of hydrological units in the west and south reflects their ecotonal position between the uplands of the Shawnee Hills (in Illinois not Kentucky) and the lowlands of both the Gulf Coastal Plain and the Mississippi Alluvial Plain. These units are enriched by having representatives of both upland and lowland fish communities and the uniqueness of the mainstem Mississippi River's "big river" fauna (Burr and Page 1986, Burr and Warren 1986, Pflieger 1971). The primary richness levels along the eastern edge of the assessment area reflect a dominance of upland habitat, close proximity to the high number of endemic fishes in the Ohio basin, and perhaps an artifact of more thorough sampling efforts in these units. The aggregate of units in the central portion of the assessment area with secondary levels of fish species richness are situated primarily in the lowlands of the lower Green and Tradewater Rivers. Much of this region has been subjected to extensive strip mining, stream channelization, and outdated land-use practices. These kinds of habitat changes and degradation have resulted in a more depauperate fish fauna when compared to surrounding units. The fish fauna in these units is not enriched to the extent of other units that are positioned as ecotones, although as noted this may be an artifact of more extensive historical changes in that region.

The density of native fish species (number of fishes per unit area) was highly variable throughout the assessment area, and small HUCs had inflated species densities that do not accurately reflect density patterns recorded for larger HUCs. We therefore summed the rank order for both richness and density per hydrologic unit and arrived at an overall rank order of importance (table 1, fig. 3B). The overall rank order of importance was identical to native fish species richness in the southwestern and southern units of Illinois. The eastern units that ranked high in richness mostly dropped to secondary levels of overall rank order of importance, except that the middle Green unit maintained its status of primary importance. The number of tertiary units increased in the eastern half of the assessment area.

Small hydrologic units in the assessment area may show high native fish species densities because these units are influenced by the fish fauna of surrounding units. If these units were isolated from their respective surrounding units, we predict that species density would decline. The log of native fish species density in a unit was correlated negatively with the log of unit area ($P < 0.0005$). Regression of the log of native fish species richness with the log of square miles in units was positive and statistically significant ($P < 0.005$). Thus, areal additivity is a factor in consideration of species richness and area, but richness approaches some asymptotic value as area increases. Nevertheless, units with primary and secondary levels of richness and overall rank importance should be considered exceptional areas of fish diversity in the assessment area.

### Endemic fishes

In the strictest sense, only one fish species, the Shawnee darter, is endemic to the assessment area. Its entire range is found in the upper Pond River (Ceas and Page 1997) and the hydrologic unit of the same name. Some 11 additional species are narrow range endemics that in six cases have significant portions of their ranges in the assessment area. Additionally, ongoing studies indicate that several currently recognized species are, in fact, two or more distinct species. For example, Layman (1994) demonstrated that at least two distinct species now masquerading under the name speckled darter have narrow ranges that include the assessment area. Likewise, the orangethroat darter consists of additional distinct, but not yet formally described, species (Ceas 1997) whose ranges fall partially within the assessment area. Several other subspecies of fishes in the area likely will be recognized as distinct endemic species after further study (Mayden et al. 1992, Warren et al. 2000).

Endemic fishes within the assessment area represent four families: the perches, minnows, catfishes, and cavefishes. The perches (darters) have the highest number of endemic species with 9, or 23 percent of all darters recorded in the area. In addition, the assessment area harbors one endemic minnow (Ozark minnow), one endemic madtom catfish (elegant madtom), and one endemic cavefish (northern cavefish).

The primary region of endemicity in the assessment area is the upper Green River and its major tributaries (i.e., Rough, Barren, and Pond Rivers). Four endemics (Kentucky darter, teardrop darter, orangefin darter, and elegant madtom) occur in this region including some combination of the upper Green, Rough, and middle Green hydrologic units. One species (striped darter) is restricted to the Cumberland River including the Red hydrologic unit. Two species (saffron darter, slabrock darter) are restricted range endemics in the Cumberland and Tennessee drainages and found only in the lower Cumberland hydrologic unit in the assessment area. The frecklebelly darter, the only fish species exclusively shared by the Green and Kentucky River drainages in Kentucky and Tennessee, occupies the upper Green and Rough hydrologic units. The guardian darter occurs in tributaries of the lower Tennessee River, including only the lower Tennessee hydrologic unit in the assessment area. The Ozark minnow, an Ozark Highlands-Driftless Area endemic, barely ranges into the assessment area and is found only in the narrow eastern border referred to here as the Cahokia-Joachim and upper Mississippi-Cape Girardeau hydrologic units. Additionally, the cavefish family has three representatives in the assessment area that occupy subterranean waters or surface springs closely connected to karst environments. One of these, the northern cavefish, has nearly its entire hypogean range within the assessment area where it has been recorded in the lower East Fork White, Blue-Sinking, Rough, and upper Green hydrologic units.

On a larger scale the assessment area captures portions of the ranges of big river endemics including the pallid sturgeon, sturgeon chub, and sicklefin chub. All three of these species are found only in the mainstem of the Missouri River and the Mississippi River below the mouth of the Missouri River. None of these species occupy the main channel of the Ohio

River. About 165 river miles of the ranges of these three species are included in the assessment area. No endemic fishes are known in either the Shawnee or Hoosier National Forests, but stable populations of the spring cavefish and northern cavefish occur on Forest Service properties and present unique opportunities for study and protection.

## Composition of Native Mussel Species

Freshwater mussels of the families Unionidae and Margaritiferidae (commonly called naiads, unionids, bivalves, or clams) are found worldwide but achieve their greatest diversity in eastern North America with approximately 297 taxa (281 species and 16 subspecies) currently recognized (Williams et al. 1993). Seventy-six species have been recorded within the boundaries of the assessment area, representing 26 percent of the North American fauna. This includes 92 percent of the species reported to occur or to have occurred in Illinois (Cummings 2001, unpublished data); 97 percent of the species reported in Indiana (Cummings 2001, unpublished data); 71 percent of the species reported in Kentucky (Cicerello 2001, unpublished data); and 39 percent of the species and subspecies reported in Missouri (Oesch 1984).

Many of the mussel species occurring in the assessment area are widely dispersed throughout the Mississippi and Ohio River drainages, whereas others are restricted to a specific stream type (e.g., headwaters and small creeks). Large river drainages traverse different physiographic provinces (ecological subregions) within the assessment area, providing conditions suitable for different aquatic faunal groups, including mussels and fishes. Most mussel species rely on fishes as hosts during the parasitic larval (glochidial) stage of their life cycle. This temporary attachment of the glochidia onto passing fish serves as the means for their dispersal. Pliocene and Pleistocene events affecting zoogeography of fishes in the lower Ohio-upper Mississippi basin have similarly played an important role in the distribution and diversification of freshwater mussels. Mussel species richness (table 3) within the assessment area has resulted from complex drainage histories and varied aquatic habitats, and complex co-evolutionary histories with fish hosts.

The 76 native freshwater mussel species in the assessment area are placed in 36 genera (table 4). The most species-rich genera include *Epioblasma* (8 native species), *Quadrula* (6 species) and *Lampsilis* (6 species). Nineteen genera (25 percent) are represented by a single species. Of the three subfamilies in the Unionidae, 39 lampsilines, 26 amblemines, and 11 anodontines occur within the assessment area. The second family, Margaritiferidae, is represented by a single species *Cumberlandia monodonta* (table 4).

Species richness for hydrologic units within 12 major river basins ranged from a high of 48 in the lower Tennessee to being entirely absent from units in the St. Francis and lower Missouri River basins (table 3). In descending order, average species richness for the remaining nine major river basins was as follows: lower Ohio River (to Mississippi River confluence) (34), Green River (31), lower Cumberland River (19), lower Ohio (to mile 703) (14), Kaskaskia River (13), Patoka-White River (13), upper Mississippi-Meramec River (9), upper Mississippi-Salt River (6), and Wabash River (1).

Roughly half of the native mussel species occurring within the assessment area are representative of a ubiquitous fauna widely dispersed in both the Mississippi and Ohio Rivers (Cummings and Mayer 1992, Johnson 1980). Twenty species are widespread and common within the assessment area—threeridge, Wabash pigtoe, pimpleback, mapleleaf, cylindrical papershell, white heelsplitter, giant floater, creeper, pond papershell, mucket, pocketbook,

**Table 3.** Native fish species richness, density, index of relative importance, and overall rank order for watersheds of the Hoosier-Shawnee Ecological Assessment Area.

| River Basin<br>Hydrologic unit name | Watershed code (HUC) | Total area | Area of HUC in assessment | Species richness (rank order) | Species density (rank order) | Index of relative importance (sum rank orders) | Overall rank order * |
|---|---|---|---|---|---|---|---|
| | | *mi²* | *mi²* | *no.* | *no. per mi²* | | |
| **Lower Missouri River Basin** | | | | | | | |
| Lower Missouri | 10300200 | 1,590 | 20.67 | 0 (24) | 0.000 (28) | 52 | 21 |
| **Upper Mississippi-Salt River Basins** | | | | | | | |
| Peruque-Piasa | 07110009 | 633 | 14.559 | 6 (19) | 0.412 (2) | 21 | 8 |
| **Kaskaskia River Basin** | | | | | | | |
| Lower Kaskaskia | 07140204 | 1,600 | 88 | 13 (17) | 0.148 (5) | 22 | 9 |
| **Upper Mississippi-Meramec River Basins** | | | | | | | |
| Cohokia-Joachim | 07140101 | 1,650 | 618.75 | 12 (18) | 0.019 (23) | 41 | 17(13) |
| Upper Mississippi-Cape Girardeau | 07140105 | 1,690 | 397.15 | 18 (14) | 0.045 (11) | 25 | 11(7) |
| Big Muddy | 07140106 | 2,350 | 289.05 | 2 (22) | 0.007 (25) | 47 | 20(16) |
| Whitewater | 07140107 | 1,210 | 33.88 | 0 (24) | 0.000 (28) | 52 | 21 |
| Cache | 07140108 | 352 | 302.72 | 13 (17) | 0.043 (13) | 30 | 15(11) |
| **St. Francis River Basin** | | | | | | | |
| New Madrid-St. Johns | 08020201 | 703 | 7.03 | 0 (24) | 0.000 (28) | 52 | 21 |
| Little River Ditches | 08020204 | 2,620 | 36.68 | 0 (24) | 0.000 (28) | 52 | 21 |
| **Lower Tennessee River Basin** | | | | | | | |
| Lower Tennessee | 06040006 | 689 | 79.235 | 48 (2) | 0.606 (1) | 3 | 1(1) |
| **Lower Cumberland River Basin** | | | | | | | |
| Lower Cumberland | 05130205 | 2,300 | 317.4 | 37 (5) | 0.117 (7) | 12 | 3(3) |
| Red | 05130206 | 1,450 | 55.1 | 0 (24) | 0.000 (28) | 52 | 21 |
| **Green River Basin** | | | | | | | |
| Upper Green | 05110001 | 3,130 | 1,311.47 | 58 (1) | 0.044 (12) | 13 | 4(4) |
| Barren | 05110002 | 2,230 | 138.26 | 20 (13) | 0.145 (6) | 19 | 6 |
| Middle Green | 05110003 | 1,010 | 968.59 | 37 (5) | 0.038 (14) | 19 | 6(5) |
| Rough | 05110004 | 1,070 | 1,070 | 30 (7) | 0.028 (19) | 26 | 12(8) |
| Lower Green | 05110005 | 911 | 911 | 25 (10) | 0.027 (20) | 30 | 15(11) |
| Pond | 05110006 | 784 | 784 | 16 (15) | 0.020 (22) | 37 | 16(12) |
| **Wabash River Basin** | | | | | | | |
| Middle Wabash-Little Vermillion | 05120108 | 2,230 | 6.69 | 0 (24) | 0.000 (28) | 52 | 21 |
| Lower Wabash | 05120113 | 1,300 | 202.8 | 1 (23) | 0.005 | 23 | 10 |
| **Patoka-White River Basins** | | | | | | | |
| Upper White | 05120201 | 2,700 | 278.1 | 3 (21) | 0.011 (24) | 45 | 18(14) |
| Lower White | 05120202 | 1,650 | 664.95 | 21 (12) | 0.032 (17) | 29 | 14(10) |
| Eel | 05120203 | 1,200 | 231.6 | 14 (16) | 0.060 (9) | 25 | 11(6) |
| Driftwood | 05120204 | 1,150 | 40.25 | 13 (17) | 0.323 (3) | 20 | 7 |
| Upper East Fork White | 05120206 | 806 | 29.016 | 0 (24) | 0.000 (28) | 52 | 21 |
| Muskatatuck | 05120207 | 1,130 | 14.69 | 0 (24) | 0.000 (28) | 52 | 21 |
| Lower East Fork White | 05120208 | 2,030 | 1,822.94 | 48 (2) | 0.026 (21) | 23 | 10(6) |
| Patoka | 05120209 | 854 | 620.004 | 4 (20) | 0.006 (26) | 46 | 19(14) |

*(table continued on next page)*

(table 3 continued)

| River Basin<br>Hydrologic unit name | Watershed code (HUC) | Total area | Area of HUC in assessment | Species richness (rank order) | Species density (rank order) | Index of relative importance (sum rank orders) | Overall rank order * |
|---|---|---|---|---|---|---|---|
| | | $mi^2$ | $mi^2$ | no. | no. per $mi^2$ | | |
| **Lower Ohio River Basin (to Miss. R. confl.)** | | | | | | | |
| Lower Ohio-Little Pigeon | 05140201 | 1,370 | 1370 | 46 (3) | 0.034 (16) | 19 | 6(5) |
| Highland-Pigeon | 05140202 | 1,000 | 957 | 29 (8) | 0.030 (18) | 26 | 12(8) |
| Lower Ohio-Bay | 05140203 | 1,090 | 1,079.10 | 40 (4) | 0.037 (15) | 19 | 6(5) |
| Saline | 05140204 | 1,160 | 300.44 | 14 (16) | 0.047 (10) | 26 | 12(8) |
| Tradewater | 05140205 | 936 | 936 | 26 (9) | 0.028 (19) | 28 | 13(9) |
| Lower Ohio | 05140206 | 928 | 668.16 | 48 (2) | 0.072 (8) | 10 | 2(2) |
| **Lower Ohio Rver Basin (to mile 703)** | | | | | | | |
| Silver-Little Kentucky | 05140101 | 1,240 | 12.4 | 0 (24) | 0.00 (28) | 52 | 21 |
| Salt | 05140102 | 1,450 | 30.45 | 0 (24) | 0.00 (28) | 52 | 21 |
| Rolling Fork | 05140103 | 1,430 | 105.82 | 24 (11) | 0.23 (4) | 15 | 5 |
| Blue Sinking | 05140104 | 1,880 | 1,757.80 | 31 (6) | 0.02 (22) | 28 | 13(9) |

* The overall ranks in parentheses have been determined with the small Hydrologic Units (less than 12% proportion of inclusion in the assessment area) removed from the ranking procedure. Small Hydrologic Units have inflated species densities and therefore convey artificailly high indicies of relativeimportance. See text for further discussion.

fatmucket, fragile papershell, threehorn wartyback, hickorynut, pink heelsplitter, pink papershell, lilliput, fawnsfoot, and deertoe. Although many species have broad distributions, several of these are uncommon or sporadically distributed throughout their range, due to either human-related impacts or specific habitat restrictions (Cummings and Mayer 1992). Eighteen species are broadly distributed but are uncommon or sporadic within the assessment area—purple wartyback, elephant ear, spike, round pigtoe, Ohio pigtoe, pyramid pigtoe, pistolgrip, pondhorn, elktoe, fluted shell, butterfly, wavy-rayed lampmussel, yellow sandshell, black sandshell, round hickorynut, kidneyshell, rainbow, and little spectaclecase. Another 16 species are rare within the assessment area or have been recorded in less than 10 percent of the hydrologic units—crackling pearlymussel, orangefoot pimpleback, clubshell, rough pigtoe, sugarspoon, leafshell, catspaw, Tennessee riffleshell, northern riffleshell, Wabash riffleshell, tubercled blossom, snuffbox, bleufer, purple lilliput, rayed bean, and Kentucky creekshell.

The majority of the native freshwater mussel species within the assessment area are representatives of the rich Interior Basin fauna, which encompasses the entire Mississippi River basin, excluding the Ozarkian and Cumberlandian faunal areas (Parmalee and Bogan 1998, van der Schalie and van der Schalie 1950). One Cumberlandian species (sugarspoon) has been reported to have occurred in the lower Tennessee River (lower Tennessee hydrologic unit), based on an archaeological record (Cicerello et al. 1991). Johnson (1980) subdivided the Interior Basin into Ohioan, Mississippian, and Gulf Coastal regions, based on several species unique to each area. Thus defined, 7 species within the assessment area are characteristic of the Mississippian region and 20 are characteristic of the Ohioan region. Two Gulf coastal species (bleufer and Texas lilliput) reaching the northern limits of their range are represented in only 10 percent of the hydrologic units along the Mississippi and lower Ohio Rivers. The remaining 47 species are uniformly distributed in both the Mississippian and Ohioan regions.

**Table 4.** Conservation ranks of native freshwater mussels of the Hoosier-Shawnee Ecological Assessment Area.

| Family | | | Occurrence | | Conservation ranks | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subfamily | Species | Common name | SNF | HNF | Global | Federal | AFS | HNF | SNF | MIS HNF | MIS SNF | IL | IN | KY | MO |
| Margaretiferidae | *Cumberlandia monodonta* | Spectaclecase | X | | G2G3 | | T | | | | | E | EX | E | S3 |
| **Unionidae** | | | | | | | | | | | | | | | |
| Ambleminae | *Amblema plicata* | Threeridge | X | X | G5 | | | R | | | | | | | |
| Ambleminae | *Cyclonaias tuberculata* | Purple wartyback | X | X | G5 | | SC | | | | | T | | | |
| Ambleminae | *Elliptio crassidens* | Elephant ear | X | X | G5 | | | | | | | T | | | |
| Ambleminae | *Elliptio dilatata* | Spike | X | X | G5 | | | R | | | | T | | | |
| Ambleminae | *Fusconaia ebena* | Ebonyshell | X | X | G4G5 | | | | | | | T | | | E |
| Ambleminae | *Fusconaia flava* | Wabash pigtoe | X | X | G5 | | | | | | | | | | |
| Ambleminae | *Fusconaia subrotunda* | Long-solid | | X | G3 | | SC | | | | | | E | SC | |
| Ambleminae | *Hemistena lata* | Cracking pearlymussel | | | G1 | | E | | | | | | EX | | |
| Ambleminae | *Megalonaias nervosa* | Washboard | X | X | G5 | | | | | | | | | | |
| Ambleminae | *Plethobasus cicatricosus* | White wartyback | | | G1 | | E | | | | | | E | | |
| Ambleminae | *Plethobasus cooperianus* | Orange-foot pimpleback | X | X | G1 | E | E | | | | | E | E | E | |
| Ambleminae | *Plethobasus cyphyus* | Sheepnose | X | X | G3 | | T | | | | | E | E | SC | E |
| Ambleminae | *Pleurobema clava* | Clubshell | | X | G2 | E | E | | | | | | E | E | |
| Ambleminae | *Pleurobema sintoxia* | Round pigtoe | | X | G3 | | | | | | | | | | |
| Ambleminae | *Pleurobema cordatum* | Ohio pigtoe | X | X | G3 | | SC | | | | | E | T | | |
| Ambleminae | *Pleurobema plenum* | Rough pigtoe | | X | G1 | E | E | | | | | | E | E | |
| Ambleminae | *Pleurobema rubrum* | Pyramid pigtoe | | X | G2 | | T | | | | | E | E | E | |
| Ambleminae | *Quadrula nobilis* | Southern mapleleaf | | | G5 | | | | | | | | | | |
| Ambleminae | *Quadrula cylindrica* | Rabbitsfoot | X | X | G3T3 | | T | | | | | E | E | T | S1 |
| Ambleminae | *Qudrula metanevra* | Monkeyface | X | X | G4 | | | | | | | | | | |
| Ambleminae | *Quadrula nodulata* | Wartyback | X | | G4 | | | | | | | | | | S3 |
| Ambleminae | *Quadrula pustulosa* | Pimpleback | X | X | G5 | | | | | | | | | | |
| Ambleminae | *Quadrula quadrula* | Mapleleaf | X | X | G5 | | | | | | | | | | |
| Ambleminae | *Tritogonia verrucosa* | Pistolgrip | X | X | G4 | | | | | | | | | | |
| Ambleminae | *Uniomerus tetralasmus* | Pondhorn | X | X | G4 | | | | | | | | | | |
| Anodontinae | *Alasmidonta marginata* | Elktoe | | | G5 | | SC | | | | | | | T | S2? |
| Anodontinae | *Alasmidonta viridis* | Slippershell | | | G4G5 | | SC | | | | | T | | | |
| Anodontinae | *Anodonta suborbiculata* | Flat floater | X | X | G5 | | | | | | | | | | S2 |
| Anodontinae | *Anodontoides ferussacianus* | Cylindrical papershell | | X | G5 | | | | | M | | | | | S1? |
| Anodontinae | *Arcidens confragosus* | Rock-pocketbook | X | X | G4 | | | | | | | | | | S3 |
| Anodontinae | *Lasmigona complanata* | White heelsplitter | X | X | G5 | | | | | | | | | | |
| Anodontinae | *Lasmigona costata* | Fluted shell | | X | G5 | | | | | | | | | | |
| Anodontinae | *Pyganodon grandis* | Giant floater | X | X | G5 | | | | | | | | | | |
| Anodontinae | *Simpsonaias ambigua* | Salamander mussel | | X | G3 | | SC | | | | | E | T | T | S1 |
| Anodontinae | *Strophitus undulatus* | Squawfoot | | X | G5 | | | | | M | | | | | |
| Anodontinae | *Utterbackia imbecillis* | Paper pondshell | | X | G5 | | | | | | | | | | |
| Lampsilinae | *Actinonaias ligamentina* | Mucket | X | X | G5 | | | | | | | | | | |
| Lampsilinae | *Cyprogenia stegaria* | Fanshell | | X | G1 | E | E | | R | | | E | E | E | |
| Lampsilinae | *Ellipsaria lineolata* | Butterfly | X | X | G4 | | | | | M | | T | | | |
| Lampsilinae | *Epioblasma archaeformis* | Sugarspoon | | | GX | | E* | | | | | | | | |
| Lampsilinae | *Epioblasma flexuosa* | Leafshell | | | GX | | E* | | | M | | | EX | | |
| Lampsilinae | *Epioblasma obliquata* | Catspaw | | | G1 | E | E | | | | | | E | E | |
| Lampsilinae | *Epioblasma propinqua* | Tennessee riffleshell | | X | GX | | E* | | | | | | EX | | |
| Lampsilinae | *Epioblasma rangiana* | Northern riffleshell | | X | G2T2 | | E | | | | | | E | E | |

*(table continued on next page)*

**(table 4 continued)**

| Family Subfamily | Species | Common name | Occurrence SNF | HNF | Conservation ranks Global | Federal | AFS | HNF | SNF | MIS HNF | MIS SNF | IL | IN | KY | MO |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Lampsilinae | *Epioblasma sampsonii* | Wabash riffleshell | | | GX | | E* | | | | | | EX | | |
| Lampsilinae | *Epioblasma torulosa* | Tubercled blossom | | X | G2T2 | E | E | | | | | | E | | |
| Lampsilinae | *Epioblasma triquetra* | Snuffbox | | X | G3 | | T | | | | | E | E | SC | S1 |
| **Unionidae** | | | | | | | | | | | | | | | |
| Lampsilinae | *Lampsilis abrupta* | Pink mucket | X | | G2 | E | E | | | | | E | E | E | E |
| Lampsilinae | *Lampsilis cardium* | Pocketbook | X | X | G5 | | SC | | | | | | | | |
| Lampsilinae | *Lampsilis fasciola* | Wavy-rayed lampmussel | | X | G4 | | | | | | | E | T | | |
| Lampsilinae | *Lampsilis ovata* | Pocketbook | X | | G1 | | SC | | | | | | | E | |
| Lampsilinae | *Lampsilis siliquoidea* | Fatmucket | X | X | G5 | | | | | | | | | | |
| Lampsilinae | *Lampsilis teres* | Yellow sandshell | X | X | G5 | | | | | | | | | | |
| Lampsilinae | Leptodea fragilis | Fragile papershell | X | X | G5 | | | | | | | | | | |
| Lampsilinae | *Ligumia recta* | Black sandshell | X | X | G5 | | SC | | | | | T | | | S1S2 |
| Lampsilinae | *Ligumia subrostrata* | Pondmussel | X | | G4G5 | | | | | | | | | | |
| Lampsilinae | *Obliquaria reflexa* | Threehorn wartyback | X | X | G5 | | | | | | | | | | |
| Lampsilinae | *Obovaria olivaria* | Hickorynut | X | X | G4 | | | | | | | | | | S2S3 |
| Lampsilinae | *Obovaria retusa* | Ring pink | X | | G1 | E | E | | | | | | EX | E | |
| Lampsilinae | *Obovaria subrotunda* | Round hickorynut | X | X | G4 | | SC | | | | | E | T | | |
| Lampsilinae | *Potamilus alatus* | Pink heelsplitter | X | X | G5 | | | | | | | | | | |
| Lampsilinae | *Potamilus capax* | Fat pocketbook | X | X | G1 | E | E | | | | | E | E | E | E |
| Lampsilinae | *Potamilus ohiensis* | Pink papershell | X | X | G5 | | | | | | | | | | |
| Lampsilinae | *Potamilus purpuratus* | Bleufer | X | | G5 | | | | | | | | | E | |
| Lampsilinae | *Ptychobranchus fasciolaris* | Kidneyshell | X | X | G4G5 | | | | | | | E | T | | |
| Lampsilinae | *Toxolasma lividus* | Purple lilliput | | | G2 | | SC | | | | | E | T | E | S2 |
| Lampsilinae | *Toxolasma parvus* | Lilliput | | | G5 | | | | | | | | | | |
| Lampsilinae | *Toxolasma texasensis* | Texas lilliput | X | | G4 | | | | | M | | | | E | S3 |
| Lampsilinae | *Truncilla donaciformis* | Fawnsfoot | X | X | G5 | | | | | | | | | | |
| Lampsilinae | *Truncilla truncata* | Deertoe | X | X | G5 | | | | | | | | | | |
| Lampsilinae | *Villosa fabalis* | Rayed bean | | | G1G2 | | SC | | | | | E | T | E | |
| Lampsilinae | *Villosa iris* | Rainbow | | | G5 | | | | | | | E | | | |
| Lampsilinae | *Villosa lienosa* | Little spectaclecase | | X | G5 | | | | | | | E | T | SC | |
| Lampsilinae | *Villosa ortmanni* | Kentucky creekshell | | | G2 | | SC | | | | | | | T | |
| Unioninae | *Plectomerus dombeyanus* | Bankclimber | | | G4G5 | | | | | | | | | | S3 |

E* = possibly extinct
EX = extirpated from the study area
G1 = Critically imperiled globally (typically 5 or fewer occurrences)
G2 = Imperiled globally (typically 6 to 20 occurrences)
G3 = Very rare and local throughout range or found locally in a restricted range
G4 = Widespread, abundant, and apparently secure globally
G5 = Demonstrably widespread, abundant, and secure globally
T2 = Taxonomic subdivision; imperiled globally (typically 6 to 20 occurrences)
T3 = Taxonomic subdivision; very rare and local throughout range or found locally in a restricted range
S1 = Critically imperiled in the State (typically 5 or fewer occurrences)
S2 = Imperiled in the State (typically 6 to 20 occurrences)
S3 = Rare and uncommon in the State (21 to 100 occurrences)
? = Inexact or uncertain
SC = Species of special concern
E = Endangered
T = Threatened

R= Rare within a national forest
M = Management Indicator Species in the national forest
SNF = Shawnee National Forest
HNF = Hoosier National Forest
AFS = American Fisheries Society
MIS = Management Indicator Species
IL (Herckert 1992)
KY (KSNPC 1996)
IN (www.in.gov/dnr/fishwild 2001)
MO (www.conservation.state.mo.us 2001)

## Native mussel species richness and density

Several of the hydrologic units within the assessment area occupied less than 3 percent of the area of their respective HUCs native freshwater mussels are absent from these units either because it was impossible to determine whether species records fell within the unit boundaries or because the units contained no streams or bodies of water large enough to support freshwater mussels. Species richness averaged 26 species per hydrologic unit (following removal of hydrologic units having only a small proportion of their area in the HUC), but varied considerably between and within major river basins (table 3). For example, within the Patoka-White River basin, only 4 species are known from the Patoka hydrologic unit, whereas 48 are known from the lower East Fork White unit. Primary levels of species richness (31 to 58 species) are concentrated in the southwestern-central (lower Ohio and lower Ohio Bay) units and in the eastern (lower Ohio-Little Pigeon, Blue-Sinking, lower East Fork White, middle Green, and upper Green) units (fig. 4A). Minor primary units having little space within the assessment area include the lower Cumberland and lower Tennessee. Units with secondary levels of mussel species richness (21 to 30 species) are located in the central (Tradewater, Highland-Pigeon, and lower Green) units and in the eastern (Rough, lower White, and Rolling Fork) units. Units with tertiary levels of species richness (20 or fewer species) were primarily those distributed along the borders of the assessment area occupying a small portion of their respective HUCs (fig. 4A).

Hydrologic units in areas that permit a mixture of faunal elements tended to be associated with primary levels of species richness. For example, the southwestern-central units (including the lower Tennessee and lower Cumberland) are enriched by Interior Basin and Cumberlandian species (or Interior Basin species having a Cumberlandian origin) (van der Schalie and van der Schalie 1950). Species-rich units in the Green River basin (middle Green and upper Green) are part of what is recognized to be an important refugium for Ohioan species that repopulated other Ohio River basin tributaries subsequent to Pleistocene glacial events (Johnson 1980). Other hydrologic units (Ohio-Little Pigeon, Blue-Sinking, and lower East Fork

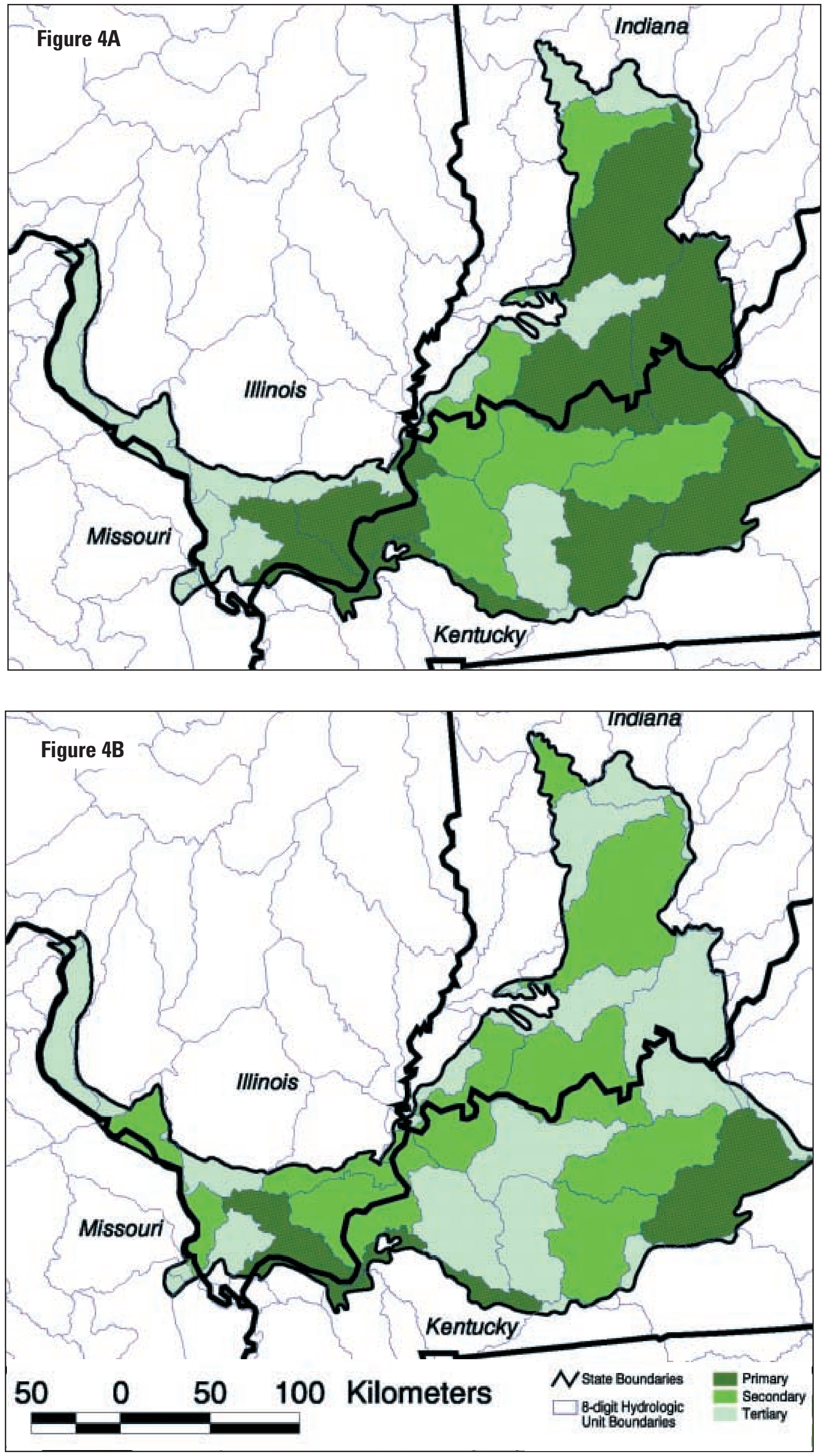


**Figure 4.** Levels of mussel species richness (A) and mussel species rank of overall importance (B) by watershed in the Hoosier-Shawnee Ecological Assessment Area.

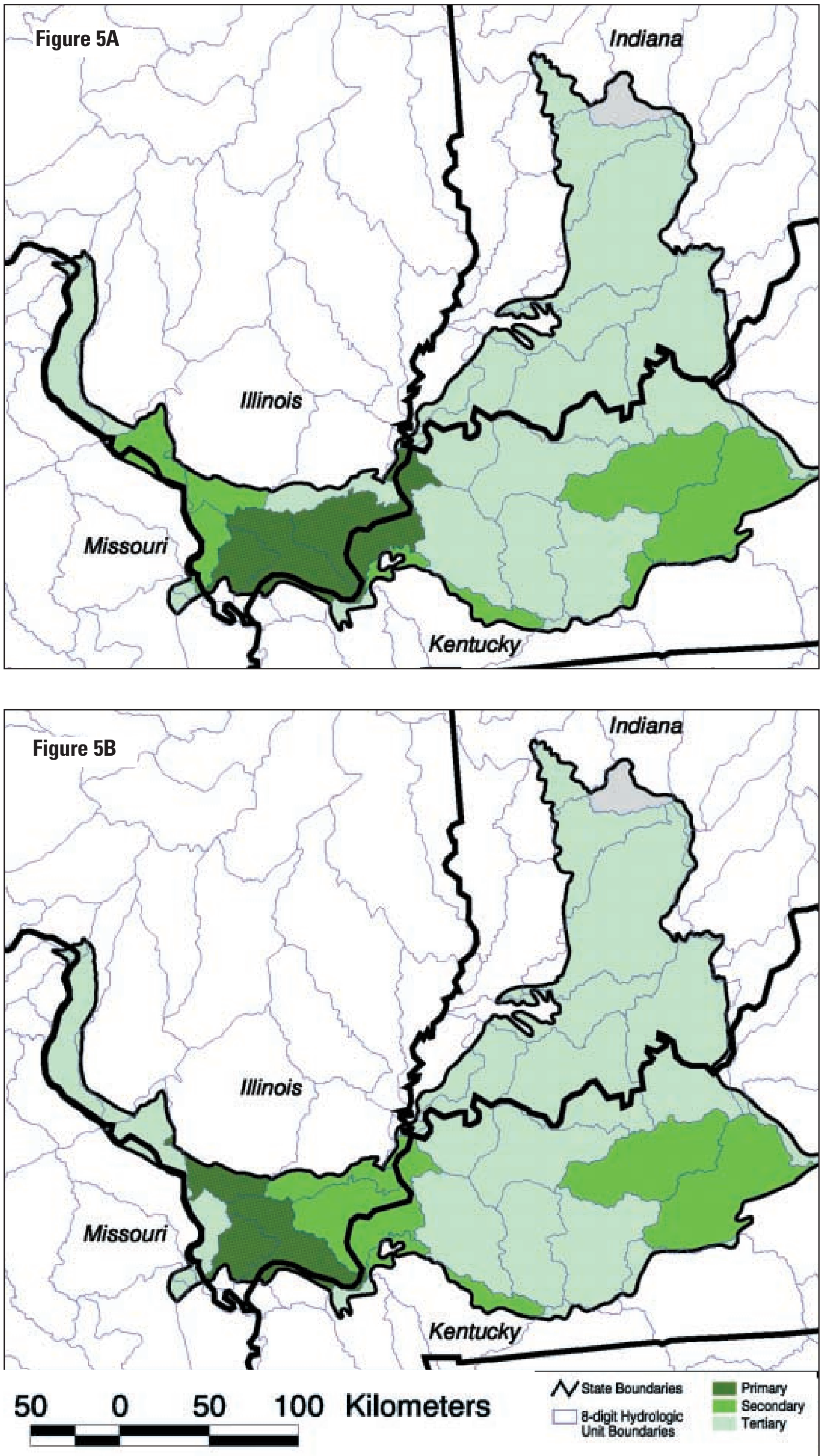


**Figure 5.** Levels of crayfish species richness (A) and crayfish species rank of overall importance (B) by watershed in the Hoosier-Shawnee Ecological Assessment Area.

White) are positioned on ecotones between uplands of the Interior Low Plateau and lowlands of the lower Ohio-Cache-Wabash Alluvial Plains. These units contained species characteristic of both tributaries and larger rivers and thus exhibited higher species richness.

Native mussel species density (number of species per square mile) was highly variable among hydrologic units, ranging from 0.007 to 0.6; average mussel species density was 0.07 species per $mi^2$. Regression of species richness with unit area was significant ($P < 0.05$), but the relationship between species density and unit area was not significant ($P \sim 0.2$). In mussels, therefore, richness increases at a constant rate as area increases at a constant rate (i.e., a linear relationship). Those hydrologic units representing a small portion of the HUCs (peripheral units) had inflated species densities that do not accurately reflect density patterns recorded for larger units. We therefore summed rank order values for species richness and density for each hydrologic unit to give an "index of relative importance" (table 3, fig. 4B). Hydrologic units having primary levels of species richness that also maintained primary rank orders of overall importance were the upper Green and lower Ohio. Eastern units (lower East Fork White, lower Ohio-Little Pigeon, Blue-Sinking, and Pond) ranking high in species richness mostly dropped to secondary levels of overall rank of importance, except that the Blue-Sinking unit dropped to a tertiary level of importance. All peripheral hydrologic units, or those with very small proportions in a particular HUC, were relegated to tertiary importance. The lower Tennessee and lower Cumberland units maintained ranks of primary importance because of their exceptional species richness. Although these units represent small portions of their respective HUCs, species density problems did not inflate their overall ranks. Four hydrologic units were assigned primary levels of relative importance—lower Tennessee, lower Ohio, lower Cumberland, and upper Green. Of these units, the lower Tennessee ranked first in species density (0.6 species per $mi^2$) and the Green ranked first in species richness (58 species). All 10 species federally listed as endangered have been reported from at least one of the units assigned primary levels of relative importance. The upper Green hydrologic unit contains the largest number of species federally listed as endangered—clubshell, rough pigtoe, fanshell, catspaw, northern riffleshell, pink mucket, and ring pink.

## Composition of Native Crayfish Species

Approximately 390 species and subspecies of crayfish are endemic to North America (Lodge et al. 2000a, Taylor et al. 1996). The diversity of crayfish species in the assessment area represents only a small portion of North American diversity, although crayfishes nevertheless are a conspicuous and moderately diverse component of the local aquatic fauna. There are 34 species of crayfish in the assessment area (table 5) and all are members of the family Cambaridae. There are two dwarf species in the genus *Cambarellus*, subfamily Cambarellinae. Otherwise, the assessment area is host to five genera of crayfish all in the subfamily Cambarinae: *Barbicambarus, Cambarus, Fallicambarus, Orconectes,* and *Procambarus*. The largest genus, *Orconectes*, with 19 species, makes up almost 56 percent of the crayfish fauna in the assessment area. The genus *Cambarus* is represented by six species, *Procambarus* by four species, and *Barbicambarus* and *Fallicambarus* each by a single species.

Even though the relative diversity of crayfish species in the assessment area is low compared to other Forest Service assessment areas (e.g., Warren et al. 1999), crayfishes in the region play a significant ecological role and serve as an integral food source for recreationally and commercially important fishes (Lodge et al. 2000a, Taylor et al. 1996). Crayfishes can make up a large portion of the biomass in freshwater ecosystems and may be the largest individual invertebrates present there (Lodge et al. 2000a). Lodge et al. (2000a) also noted that, "Crayfishes are often a central part of freshwater foodwebs and ecosystems. They are dominant consumers of benthic invertebrates, detritus, macrophytes, and algae in streams and lakes, and are themselves important forage for fishes . . . Thus, additions or removals of crayfish species often lead to large ecosystem effects, in addition to changes in fish populations, and losses of biodiversity."

The high numbers of crayfish species supported by the Tennessee-Cumberland and Mississippi Embayment ecoregions are considered globally outstanding by Abell et al. (2000), and the Teays-Ohio and Central Prairie ecoregions also support fairly high numbers of crayfish species. The Tennessee-Cumberland and Mississippi Embayment ecoregions also support the highest number of endemic crayfishes of all North American ecoregions. These major ecoregions and their varied habitats and complexity are primary factors responsible for the crayfish diversity recorded from the assessment area.

### Native crayfish species richness and density

Crayfish species richness, species density, index of relative importance, and rank of overall importance are reported for each hydrologic unit in the assessment area (table 6). Watersheds in the assessment area exhibiting primary, secondary, and tertiary levels of crayfish species richness are shown in figure 5A. The center of primary crayfish species richness occurs in the lower Ohio drainage, from roughly its confluence with the Wabash River to approximately its confluence with the Mississippi River. Nearly the entire Cache River drainage is included in the center of primary richness. There are two centers of secondary crayfish species richness: 1) the entire catchment of the Rough River, the approximately lower half of the upper Green River watershed, and the lower 6 percent of the Barren River watershed; and 2) the lower Mississippi River and its direct Illinois tributaries, from its confluence with the Kaskaskia River to roughly its confluence with the Cache River, and including the lower 12 percent of the Big Muddy River watershed. Secondary richness status also was achieved in two small portions of the lower Cumberland River drainage and its direct tributaries below Lake Barkley, as well as some of its headwater tributaries bordering the Pond and Tradewater River watersheds. No crayfish distribution data were available for the portions of the upper White River and middle White-Little Vermillion watersheds in Indiana. This pattern of species richness has implications for the Shawnee National Forest because all the watersheds making up the assessment area's center of primary species richness either underlie or border the Shawnee.

Watersheds in the assessment area exhibiting primary, secondary, and tertiary ranks of overall importance are shown in figure 5B. The area of primary rank of overall importance includes portions of three watersheds: the lower 12 percent of the Big Muddy River watershed, most of the Cache River watershed, and the lower Ohio River drainage from downstream of Ledbetter, Kentucky, to its approximate confluence with the Mississippi River. There are two centers of secondary overall importance: 1) the lower half of the upper Green and the entire Rough River watershed; and 2) portions of three watersheds including the lower Cumberland River and its direct tributaries below Lake Barkley, as well as some headwater tributaries bordering the Pond and Tradewater River watersheds; the lower Ohio River drainage from its confluence with the Wabash River to Ledbetter, Kentucky; and the southern 26 percent of the Saline River watershed. No distribution data were available for the portions of the upper White River and middle White-Little Vermillion watersheds in Indiana.

### Endemic crayfishes

Six crayfish species are endemic to the assessment area: the Illinois crayfish (*Orconectes illinoisensis*) (Page 1985), the Indiana crayfish (*O. indianensis*) (Page 1985), the Kentucky crayfish (*O. kentuckiensis)* (Page 1985), the Crittenden crayfish (*O. bisectus*) (Taylor and Schuster 2001, unpublished spot-distribution maps), Rafinesque's crayfish (*O. rafinesquei*) (Taylor and Schuster 2001, unpublished spot-distribution maps), and Cobble crayfish (*O. margorectus*) (Taylor 2002).

The range of *O. illinoisensis* is completely contained within Illinois and for the most part coincides with the boundaries of the Shawnee National Forest, except that it also occurs in several rocky, Coastal Plain tributaries of the lower Ohio River. It is considered to be currently stable in the state, is common throughout its range, and can be locally abundant. Although *O. indianensis* is considered endemic to the assessment area, its historic range extends beyond the assessment boundaries, mainly via the North Branch of the Saline River in Illinois and via direct tributaries of the Wabash River north of Greathouse Island to almost its confluence with the White River. Although formerly more widespread in Illinois, the current distribution of *O. indianensis* falls within the assessment area. It is listed as endangered in Illinois (table 5). Except for one collection locality—14 specimens (INHS 112, 4568)—recent collections of *O. indianensis* in Indiana have been within the assessment area, and most of those collections have come from within the Hoosier National Forest. This crayfish species is presumed to be currently stable in Indiana (table 5). Nearly the entire range of *O. kentuckiensis* falls within the assessment area except for a small reach of the lower Cumberland River and its direct tributaries below Lake Barkley. It is listed as endangered in Illinois, occurring only in a few rocky, direct tributaries of the Ohio River in southeastern Illinois. In Kentucky, it occurs in several direct tributaries of the Ohio River in three counties—Crittenden, Livingston, and Union—and is considered to be currently stable.

*Orconectes bisectus* has the most limited range of the six crayfish species endemic to the assessment area. It is found only in Camp and Crooked Creeks, direct tributaries of the Ohio River, in Crittenden County, Kentucky. It is listed as threatened in Kentucky. *Orconectes margorectus*

**Table 5.** Conservation ranks of native freshwater crayfishes of the Hoosier-Shawnee Ecological Assessment Area.

| Family<br>Subfamily | Species | Common name | Occurrence | | Conservation ranks | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | SNF | HNF | Global | Federal | AFS | HNF | SNF | MIS HNF | MIS SNF | IL | IN | KY | MO |
| **Cambaridae** | | | | | | | | | | | | | | | |
| Cambarellinae | *Cambarellus puer* | Cajun dwarf crayfish | X | | G4G5 | | | | | | | | | E | S3? |
| Cambarellinae | *Cambarellus shufeldtii* | Shufeldt's dwarf crayfish | X | | G5 | | | | | | | | | S | S3? |
| Cambarinae | *Barbicambarus cornutus* | Bottlebrush crayfish | | | G3G4 | | | | | | | | | S | |
| Cambarinae | *Cambarus bartonii* | Appalachian brook crayfish | | | G5 | | | | | | | | | | |
| Cambarinae | *Cambarus diogenes* | Devil crayfish | X | X | G5 | | | | | | | | | | |
| Cambarinae | *Cambarus graysoni* | Nashville crayfish | | | G5 | | | | | | | | | | |
| Cambarinae | *Cambarus ortmanni* | Lentic crayfish | | | G4G5 | | | | | | | | | | |
| Cambarinae | *Cambarus rusticiformis* | Riffle crayfish | X | | G4G5 | | | | | | | | | | |
| Cambarinae | *Cambarus tenebrosus* | Spring grayfish | X | X | G5 | | | | | | | | | | |
| Cambarinae | *Fallicambarus fodiens* | Digger crayfish | X | | G5 | | | | | | | | | | S2S3 |
| Cambarinae | *Orconectes barrenensis* | Green River crayfish | | | G4 | | E | | | | | | | | |
| Cambarinae | *Orconectes bisectus* | Crittenden crayfish | | | G2 | | | | | | | | | T | |
| Cambarinae | *Orconectes illinoiensis* | Illinois crayfish | X | | G3 | | SC | | | | | | | | |
| Cambarinae | *Orconectes immunis* | Papershell crayfish | X | X | G5 | | | | | | | | | | |
| Cambarinae | *Orconectes indianensis* | Indiana crayfish | X | X | G2G3 | | SC | | R | | | E | | | |
| Cambarinae | *Orconectes inermis* | Subterranean crayfish | | X | G5T3T4 | | | R | | | | | | | |
| Cambarinae | *Orconectes kentuckiensis* | Kentucky crayfish | X | | G2 | | T | | R | | | E | | | |
| Cambarinae | *Orconectes lancifer* | Shrimp crayfish | | | G5 | | | | | | | E | | E | S1S2 |
| Cambarinae | *Orconectes luteus* | Golden crayfish | | | G5 | | | | | | | | | | |
| Cambarinae | *Orconectes margorectus* | Cobble crayfish | | | ? | ? | ? | | | | | | | | |
| Cambarinae | *Orconectes palmeri* | Gray-speckled crayfish | | | G5 | | | | | | | | | E | |
| Cambarinae | *Orconectes pellucidus* | Eyelash crayfish | | | G3 | | | | | | | | | S | |
| Cambarinae | *Orconectes placidus* | Placid crayfish | X | | G5 | | | | R | | | E | | | |
| Cambarinae | *Orconectes putnami* | Disjunct crayfish | | | G5 | | | | | | | | | | |
| Cambarinae | *Orconectes rafinesquei* | Rafinesque's crayfish | | | G2 | | SC | | | | | | | | |
| Cambarinae | *Orconectes ronaldi* | Mud River crayfish | | | G3 | | | | | | | | | | |
| Cambarinae | *Orconectes rusticus* | Rusty crayfish | X | | G5 | | | | | | | | | | |
| Cambarinae | *Orconectes stannardi* | Little Wabash crayfish | | | G2 | | T | | | | | | | | |
| Cambarinae | *Orconectes tricuspis* | Headwater crayfish | | | G4 | | | | | | | | | | |
| Cambarinae | *Orconectes virilis* | Virile crayfish | X | | G5 | | | | | | | | | | |
| Cambarinae | *Procambarus acutus* | White River crayfish | X | | G5 | | | | | | | | | | |
| Cambarinae | *Procambarus clarkii* | Red swamp crayfish | X | X | G5 | | | | | | | | | | |
| Cambarinae | *Procambarus gracilis* | Prairie crayfish | X | | G5 | | | | | | | | | | |
| Cambarinae | *Procambarus viaeviridis* | Vernal crayfish | X | | G5 | | | | | | | | | T | S3 |

E = Endangered in the State
T = Threatened in the State
S = Special concern in the State
SC = Special concern federally
G1 = Critically imperiled globally (typically occurs in 5 or fewer counties)
G2 = Imperiled globally (typically occurs in 6 to 20 counties)
G3 = Very rare and local throughout range or found locally in a restricted range
G4 = Widespread, abundant, and apparently secure globally
G5 = Demonstrably widespread, abundant, and secure globally
T3 = Taxonomic subdivision: very rare and local throughout range or found locally in a restricted range
T4 = Taxonomic subdivision: widespread, abundant, and apparently secure globally
S1 = Missouri-Critically imperiled in the State (typically 5 or fewer occurrences)
S2 = Missouri-Imperiled in the State (typically 6 to 20 occurrences)
S3 = Missouri-Rare and uncommon in the state (21 to 100 occurrences)
R= rare within a national forest
SNF = Shawnee National Forest
HNF = Hoosier National Forest
AFS = American Fisheries Society
MIS = Management Indicator Species

**Table 6.** Native crayfish species richness, density, index of relative importance, and overall rank order for watersheds of the Hoosier-Shawnee Ecological Assessment Area.

| River Basin<br>Hydrologic unit name | Watershed code (HUC) | Total area | Area of HUC in assessment | Species richness (rank order) | Species density (rank order) | Index of relative importance (sum rank orders) | Overall rank order * | Endemic Species |
|---|---|---|---|---|---|---|---|---|
| | | *mi$^2$* | *mi$^2$* | *no.* | *no. per mi$^2$* | | | |
| **Lower Missouri River Basin** | | | | | | | | |
| Lower Missouri | 10300200 | 1,590 | 20.67 | 1 (12) | 0.048 (7) | 19 | 8 | 0 |
| **Upper Mississippi-Salt River Basins** | | | | | | | | |
| Peruque-Piasa | 07110009 | 633 | 14.559 | 1 (12) | 0.069 (3) | 15 | 4 | 0 |
| **Kaskaskia River Basin** | | | | | | | | |
| Lower Kaskaskia | 07140204 | 1,600 | 88 | 1 (12) | 0.011 (15) | 27 | 13 | 0 |
| **Upper Mississippi-Meramec River Basins** | | | | | | | | |
| Cohokia-Joachim | 07140101 | 1,650 | 618.75 | 4 (9) | 0.006 (19) | 28 | 14(12) | 0 |
| Upper Mississippi-Cape Girardeau | 07140105 | 1,690 | 397.15 | 8 (5) | 0.020 (12) | 17 | 6(7) | 0 |
| Big Muddy | 07140106 | 2,350 | 289.05 | 8 (5) | 0.028 (10) | 15 | 4(5) | 1 |
| Whitewater | 07140107 | 1,210 | 33.88 | 4 (9) | 0.118 (2) | 11 | 2 | 0 |
| Cache | 07140108 | 352 | 302.72 | 10 (3) | 0.033 (9) | 12 | 3(1) | 1 |
| **St. Francis River Basin** | | | | | | | | |
| New Madrid-St. Johns | 08020201 | 703 | 7.03 | 0 (13) | 0.000 (24) | 37 | 17 | 0 |
| Little River Ditches | 08020204 | 2,620 | 36.68 | 5 (8) | 0.136 (1) | 9 | 1 | 0 |
| **Lower Tennessee River Basin** | | | | | | | | |
| Lower Tennessee | 06040006 | 689 | 79.235 | 4 (9) | 0.050 (6) | 15 | 4 | 1 |
| **Lower Cumberland River Basin** | | | | | | | | |
| Lower Cumberland | 05130205 | 2,300 | 317.4 | 8 (5) | 0.025 (11) | 16 | 5 | 1 |
| Red | 05130206 | 1,450 | 55.1 | 2 (11) | 0.036 (8) | 19 | 8 | 0 |
| **Green River Basin** | | | | | | | | |
| Upper Green | 05110001 | 3,130 | 1,311.47 | 8 (5) | 0.006 (19) | 24 | 10(8) | 0 |
| Barren | 05110002 | 2,230 | 138.26 | 7 (6) | 0.051 (5) | 11 | 2 | 0 |
| Middle Green | 05110003 | 1,010 | 968.59 | 6 (7) | 0.006 (19) | 26 | 12(10) | 0 |
| Rough | 05110004 | 1,070 | 1,070 | 9 (4) | 0.008 (17) | 21 | 9(7) | 0 |
| Lower Green | 05110005 | 911 | 911 | 6 (7) | 0.007 (18) | 25 | 11(9) | 0 |
| Pond | 05110006 | 784 | 784 | 5 (8) | 0.006 (19) | 27 | 13(11) | 0 |
| **Wabash River Basin** | | | | | | | | |
| Middle Wabash-Little Vermillion | 05120108 | 2,230 | 6.69 | ND ND | ND ND | ND | ND | ND |
| Lower Wabash | 05120113 | 1,300 | 202.8 | 0 (9) | 0.000 (24) | 33 | 16 | 0 |
| **Patoka-White River Basins** | | | | | | | | |
| Upper White | 05120201 | 2,700 | 278.1 | ND ND | ND ND | ND | ND | ND |
| Lower White | 05120202 | 1,650 | 664.95 | 0 (13) | 0.000 (24) | 37 | 17 | 0 |
| Eel | 05120203 | 1,200 | 231.6 | 0 (13) | 0.000 (24) | 37 | 17(15) | 0 |
| Driftwood | 05120204 | 1,150 | 40.25 | 0 (13) | 0.000 (24) | 37 | 17 | 0 |
| Upper East Fork White | 05120206 | 806 | 29.016 | 0 (13) | 0.000 (24) | 37 | 17 | 0 |
| Muskatatuck | 05120207 | 1,130 | 14.69 | 0 (13) | 0.000 (24) | 37 | 17 | 0 |
| Lower East Fork White | 05120208 | 2,030 | 1,822.94 | 3 (10) | 0.002 (23) | 33 | 16(14) | 0 |
| Patoka | 05120209 | 854 | 620.004 | 4 (9) | 0.006 (19) | 28 | 14(12) | 1 |

*(table continued on next page)*

(table 6 continued)

| River Basin<br>Hydrologic unit name | Watershed code (HUC) | Total area | Area of HUC in assessment | Species richness (rank order) | Species density (rank order) | Index of relative importance (sum rank orders) | Overall rank order * | Endemic Species |
|---|---|---|---|---|---|---|---|---|
| | | $mi^2$ | $mi^2$ | no. | no. per $mi^2$ | | | |
| **Lower Ohio River Basin (to Miss. R. confl.)** | | | | | | | | |
| Lower Ohio-Little Pigeon | 05140201 | 1,370 | 1,370 | 6 (7) | 0.004 (21) | 28 | 14(12) | 1 |
| Highland-Pigeon | 05140202 | 1,000 | 957 | 5 (8) | 0.005 (20) | 28 | 14(12) | 1 |
| Lower Ohio-Bay | 05140203 | 1,090 | 1,079.10 | 11 (2) | 0.010 (16) | 18 | 7(5) | 2 |
| Saline | 05140204 | 1,160 | 300.44 | 6 (7) | 0.020 (12) | 19 | 8(6) | 1 |
| Tradewater | 05140205 | 936 | 936 | 5 (8) | 0.005 (20) | 28 | 14(12) | 1 |
| Lower Ohio | 05140206 | 928 | 668.16 | 12 (1) | 0.018 (14) | 15 | 4(2) | 1 |
| **Lower Ohio River Basin (to mile 703)** | | | | | | | | |
| Silver-Little Kentucky | 05140101 | 1,240 | 12.4 | 0 (13) | 0.000 (24) | 37 | 17 | 0 |
| Salt | 05140102 | 1,450 | 30.45 | 2 (11) | 0.066 (4) | 15 | 4 | 0 |
| Rolling Fork | 05140103 | 1,430 | 105.82 | 2 (11) | 0.019 (13) | 24 | 10 | 0 |
| Blue Sinking | 05140104 | 1,880 | 1,757.80 | 6 (7) | 0.003 (22) | 29 | 15(13) | 0 |

* The overall ranks in parentheses have been determined with the small Hydrologic Units (less than 12% proportion of inclusion in the assessment area) removed from the ranking procedure. Small Hydrologic Units have inflated species densities and therefore convey artificailly high indicies of relative importance. See text for further discussion.

(Taylor 2002) occurs in Crittenden and Livingston Counties in Kentucky, and it is found in Deer Creek and its tributaries, Buck Creek, and the mainstem of the Cumberland River just upstream of Smithland, Kentucky. The description of this species (Taylor 2002) is so recent that no government agency has given *O. margorectus* official conservation status. *Orconectes rafinesquei,* found only in Kentucky, is endemic to the entire Rough River basin, Highland Creek in Henderson and Union Counties, the South Fork of Panther Creek in Ohio County, and two tributaries to the Green River, Pond Creek in Muhlenberg County and Deer Creek in Webster County. Kentucky lists this species as currently stable.

As an aside to crayfish endemicity in the assessment area, if the entire lower Cumberland and lower Tennessee watersheds were included in the assessment area, *O. tricuspis* would also be considered endemic. It occurs in upper Pond River tributaries, tributaries to Lake Barkley, the mainstem of the Cumberland River, and one tributary of Kentucky Lake. Although *O. tricuspis* is not a true endemic to the assessment area, aquatic management plans encompassing that portion of western Kentucky could certainly have an effect on individuals from throughout most of the species' range.

## Implications and Opportunities

We synthesized information on diversity and the geographic patterns of fish, mussel, and crayfish distribution within the assessment area. The synthesis revealed that the assessment area and its surrounding hydrologic units support a large portion of continental, national, and regional fish, mussel, and crayfish species diversity, including a moderate number of endemic species. For example, the eastern half of North America represents the center of diversity for freshwater mussels worldwide. In fact, the World Wildlife Fund's recent (Abell et al. 2000) conservation assessment of freshwater ecoregions of North America ranks three of the assessment area's subregions as globally outstanding and the remaining two as bioregionally outstanding. These two categories, globally outstanding and bioregionally outstanding, are the highest conservation rankings possible on a worldwide scale. The implications of these rankings are almost mind boggling because temperate freshwater faunas in other parts of the world (e.g., Europe, China) have experienced severe degradation and loss of diversity. The Forest Service carries a staggering responsibility for management and protection of this unique resource within the hydrologic units included on its property.

We were able to examine these rich aquatic faunas only on a relatively large and coarse scale (i.e., presence or absence of fishes, mussels, and crayfishes in hydrologic units). The synthesis relied on available literature and did not account for declines in populations in recent times even though abundant evidence is available that several fish and mussel species have experienced a reduction in range or fragmentation of populations within the assessment area (Burr and Page 1986, Burr and Warren 1986, Cummings 1991, Cummings and Mayer 1997, Smith 1979, Warren et al. 2000). For example, of the 297 native freshwater mussels in North America, 213 species (nearly 72 percent) are considered endangered, threatened, or of special concern (Williams et al. 1993). More than 75 percent of these species are believed to be suffering from range reductions, leaving distantly isolated populations that may be functionally extinct—having numbers too low to support a viable population (Watters 2000).

Many aquatic species in the assessment area are found in waters under Federal management (i.e., in national forests), including several hydrologic units of either primary or secondary rank of overall importance. Given the trend toward continued human population growth, the concomitant increase in consumption, and the accompanying modification of aquatic habitats across the assessment area, waters on federally managed lands are becoming increasingly critical for the continued existence of viable populations and communities of native aquatic species. For example, studies are needed to determine how many of the original mussel communities in the assessment area are still viable, but maintenance of stable mussel communities requires an understanding of the factors involved in recruitment, especially the presence of suitable fish hosts.

The effect of forest management practices on fishes, mussels, and crayfishes is a significant, but little understood, component of land management within the assessment area. The response of Pacific salmon and trout to forest disturbance has been examined extensively in the Pacific Northwest. As yet, no comparable body of literature exists for fishes, mussels, or crayfishes of the assessment area, even though the fishes are the best known and most visible members of the aquatic community. Provisional assessments of forest cutting and removal of riparian zones indicate that stream fish and mussel communities generally suffer losses in both diversity and abundance of species (Cummings and Mayer 1997, Smith 1971, Page 1991), but carefully planned experimental studies of these sorts of practices have not yet been done in either the Shawnee or Hoosier National Forests.

The introduction and spread of exotic freshwater bivalve species such as the zebra mussel (*Dreissena polymorpha*) and Asian clam (*Corbicula fluminea*) have had significant impacts on native mussels. These exotic species have established high-density populations and have been implicated in the decline of native mussels (Williams et al. 1993). Efforts are needed to control the spread of these nuisance species and their subsequent impacts on additional native mussel communities.

We consider the synthesis of data about the distribution and diversity of fishes, mussels, and crayfishes to be a starting point for identifying and prioritizing information needs that can then be used to better conserve aquatic diversity.

## ENDANGERED, THREATENED, AND OTHER AQUATIC SPECIES OF SPECIAL CONCERN

North America's freshwater habitats support some of the most extraordinary biotic assemblages in the world (Abell et al. 2000), and yet in a few short decades we have systematically recorded the loss of a significant number of native American fishes and mussels that took the concerted efforts of hundreds of individuals more than 200 years to discover, record, and describe (Warren and Burr 1994). The major proximate causes of declines in fishes, mussels, and crayfishes are (1) physical habitat loss, degradation, or alteration; (2) chemical pollution or alteration; (3) overexploitation; and (4) introduction of competitive nonindigenous organisms (Allan and Flecker 1993, Williams et al. 1993). The process of extinction in the Eastern United States can be related to landscape-scale phenomena that decrease habitat area or quality and ultimately fragment and isolate populations (Angermeier 1995). This process usually takes place gradually with total extinction or extirpation preceded by local losses or regional annihilations (Angermeier 1995). Understanding and eventually preventing local extirpations or total extinctions will surely require greater attention to landscape-level patterns and processes than has been done in the past.

Recent case histories have demonstrated that one of the most powerful defenses against aquatic biodiversity loss, at least in the United States, is the Endangered Species Act (ESA) of 1973, as amended. Additionally, the Clean Water Act (CWA) of 1972, as amended, is another powerful statutory tool for habitat and species conservation that can prevent human-caused endangerment of aquatic communities and environments (Angermeier and Karr 1994). Under the ESA, "species" are interpreted as including species, subspecies, and certain distinctive populations. Those species listed by Federal authority are provided legal protection under specific categories such as endangered, threatened, proposed endangered, and proposed threatened. Species determined as worthy of protection are maintained on official lists by the U.S. Fish and Wildlife Service (1997a, b).

Other private organizations and State agencies are playing increasingly significant roles in the early recognition, listing, and protection of those species potentially at risk of decline or extirpation. Using protocols developed by The Nature Conservancy and State Natural Heritage Programs, listed species have their distributions and conservation statuses monitored. Globally ranked (i.e., G1, G2, or G3) taxa and those considered imperiled at the state level (a variety of categories used here) are also tracked by natural heritage programs and other independent organizations.

More recently, the American Fisheries Society, using panels of professional biologists, has provided additional independent rankings of conservation status for fishes (Warren et al. 2000), mussels (Williams et al. 1993), and crayfishes (Taylor et al. 1996). In this report, we have included rankings from the four State Natural Heritage Programs and the reports by expert panels representing the American Fisheries Society, as well as the Federal listings. The information provided by these varied listings will be an aid to the Fish and Wildlife Service to draw from in considering possible future candidate species for listing and can help with prioritizing and planning of recovery efforts, status surveys, and research on aquatic species.

## DATA SOURCES

Within constraints of time and the patterns and trends in the assessment area, we modeled the following section after the excellent chapter on *Endangered, Threatened, and Other Species of Special Concern* (Warren and Tinkle 1999), in *Ozark-Ouachita Highlands Assessment: Aquatic*

*Conditions* (General Technical Report SRS-33 (1999), regarding the Ozark-Ouachita Ecological Assessment in Missouri, Arkansas, Kansas, and Oklahoma). We synthesized information in tabular format on endangered, threatened, and special concern aquatic organisms including fishes, mussels, and crayfishes. We included species with Federal status (i.e., endangered or threatened under the ESA or candidate species); those ranked globally as G1, G2, or G3 by The Nature Conservancy (Natureserve Web site 2001); and those ranked by State Natural Heritage Programs (Illinois Endangered Species Protection Board 2000, Indiana Department of Fish and Wildlife Web site 2001, Kentucky State Nature Preserves Commission Web site 2001, Missouri Natural Heritage Program 2000). Separate columns were used for the conservation status rankings of the American Fisheries Society (Taylor et al. 1996, Warren et al. 2000, Williams et al. 1993) and the USDA Forest Service (Chad Stinson, Forest Service, personal communication).

We used the latest lists of endangered and threatened animals compiled by the Missouri, Illinois, Indiana, and Kentucky natural heritage or conservation programs and posted on their respective Web sites or their less frequently published lists (e.g., Illinois Endangered Species Protection Board 2000). Some species in the lists may no longer occur where they were once documented, and their listing does not indicate the continued existence of a species in a particular watershed or State. We corrected any inconsistencies between various lists by consulting the most recent species occurrence data available, including that accumulated by several of us actively researching the target aquatic groups. We also included global rankings for all species in the assessment area to provide the status of all taxa at a given point in time (i.e., September 2001).

## PATTERNS AND TRENDS

### Fishes

Only two federally listed fish species, pallid sturgeon and northern cavefish, occur within the assessment area (table 2). The endangered pallid sturgeon is narrowly restricted to the main channel of the Mississippi and Missouri Rivers in the region and has never been reported in the mainstem Ohio or Wabash Rivers. As a big river inhabitant, it is technically outside the boundaries of the Shawnee National Forest; its status and management are being actively studied by a team of aquatic biologists from several states bordering the Mississippi and Missouri Rivers. The range of the threatened northern cavefish falls within some of the property under jurisdiction of the Hoosier National Forest but presents an unusual case because it occurs only in karst habitat where subterranean streams may be difficult to access. A reasonably comprehensive status survey of this species was completed by Pearson and Boston (1995), whose distributional and population estimates indicated the species was stable but subject to decline through vandalism, overcollecting, groundwater pollution, and other factors.

Three candidate species within the assessment area are the Alabama shad, sturgeon chub, and sicklefin chub. All three of these species are denizens of the mainstem Mississippi River, with a few historical records of the Alabama shad available from the mainstem Ohio River (Burr and Warren 1986). The shad appears to have declined precipitously in the last century, at least in the upper Mississippi River basin. It is unique in our area for being the only species that migrates from the Gulf of Mexico up the Mississippi River into freshwater streams to spawn. In fact, the only known spawning reaches in the entire upper Mississippi basin are in the State of Missouri (Pflieger 1997); none are known in Illinois, Indiana, or Kentucky. The two chub species are being studied by both Illinois and Missouri personnel, and a new technique involving trawl nets in water about 12 feet deep or less has revealed more adults and young-of-the-year than expected. The new populational and distributional data indicate that neither species may meet requirements for listing as federally endangered or threatened. Once again, all three of these species are peripheral to either the Shawnee or Hoosier National Forests.

Other species listed by more than one State and known to presently occur within the assessment area include the lake sturgeon and southern cavefish. Lake sturgeon records from the Ohio and Mississippi Rivers were far more frequent in the past 10 years than the previous 20. Both Missouri and Wisconsin have released hatchery stock into public waters, which may account in part for the number of recent records, especially because this species is known to travel long distances in more northern waters (Becker 1983). A probable breeding population of the lake sturgeon is apparently present in the White River, Indiana, where the species is being intensively studied. This is the only known potential site of reproduction in the entire assessment area. The cavefish is an obligate cave dweller (troglobite) and is extremely rare in the southern Indiana karst region. A status survey of the southern cavefish is needed for Kentucky.

### Rare fishes in the Shawnee and Hoosier Forests

Perhaps of greatest relevance to the assessment area is the status of fish species known to presently inhabit streams of the Shawnee and Hoosier National Forests. Of some 140 fish species documented from Shawnee National Forest waters, those with restricted or sporadic ranges or naturally low population numbers include the least brook lamprey, bluehead shiner, bigeye chub, rosefin shiner, slender madtom, starhead topminnow, bantam sunfish, and redspotted sunfish. The least brook lamprey has had one of only five spawning streams in southern Illinois decimated by recent reservoir construction (Burr and Stewart 1999, Weitzell et al. 1998). Other Shawnee populations appear currently stable. The bluehead shiner is probably extinct in Illinois although it once occurred in the LaRue-Pine Hills Research Natural Area (see Burr et al. 1996). The bigeye chub and rosefin shiner were both known historically from Big Creek, Hardin County, within traditional Shawnee National Forest boundaries. Neither species has been found in the southeastern Illinois forest region in decades. The slender madtom is known only from small streams in the upper Clear Creek system in the western region of the Shawnee (e.g., Green and Hutchins Creeks). It is currently stable but highly restricted in range in national forest waters. The starhead topminnow, bantam sunfish, and redspotted sunfish all occur in the LaRue-Pine Hills Research Natural Area where they are currently stable but have very narrow ranges within southern Illinois and the Shawnee boundaries. Additional species worthy of conservation attention in the Shawnee include the southern redbelly dace, lake chubsucker, and spring cavefish. All three occur in sensitive habitats, including springs, spring runs, karst areas, wetlands, and swamps that have been drastically altered in surrounding regions.

Of the 128 native fishes in the Hoosier National Forest, a few are of conservation concern including the muskellunge, northern cavefish, bluebreast darter, and Tippecanoe darter. These four species are all listed by the State of Indiana as either endangered or extirpated. Numerous additional species of conservation concern are known from streams in areas near the Hoosier National Forest boundaries and may occur within the national forest, but the lack of comprehensive sampling data in Indiana waters by competent and well-trained ichthyologists and aquatic biologists has hampered our assessment of aquatic animals at all scales. Nonetheless, status surveys in southern Indiana should target the following rare or restricted (and listed) species: lake sturgeon, popeye shiner, northern studfish, harlequin darter, spotted darter, variegate darter, gilt darter, and eastern sand darter.

According to McComish and Brown (1980), the muskellunge was caught by anglers in different watersheds in the southern portion of Hoosier National Forest up until the 1960s. Apparently no voucher specimens are known and accurate identification is equivocal. The species may be extirpated or at such low population levels that detection by conventional sampling methods has not been forthcoming. Known to anglers as an elusive and challenging sportfish, this species warrants a comprehensive plan for appropriate stocking and management. A thorough and recent field study of the northern cavefish documented reliable records for the species at 44 different sites in southern Indiana (Pearson and Boston 1995). These authors conservatively estimated that there were at least 5,602 individuals of northern cavefish in Indiana and Kentucky combined, the entire known range of this species. Further extrapolations, based on probable phreatic conduits among cave openings and the probable number of cave openings not explored, indicated the population may reach at least 56,000 individuals. For details, the reader is referred to the excellent report by Pearson and Boston (1995). The bluebreast and Tippecanoe darters are both known from the East Fork White River, but published information based on thorough sampling in the drainage is not available. Other fishes that historically occurred in the Hoosier but that are becoming uncommon in the Midwest and need status surveys are the following: all lamprey species, gravel chub, bigeye chub, pallid shiner, trout perch, and channel darter. Searches for the southern cavefish within karst areas of the Hoosier are also desired because Pearson and Boston (1995) found none in the Indiana locations they and others surveyed.

### Extirpated and extinct fishes

Of the nearly 200 native fish species recorded in the assessment area, at least 125 are considered currently stable; with thorough field searches in appropriate habitat an additional 20 or so species could probably be removed from further conservation concern. These numbers are reassuring but could be misleading considering that a number of species have already disappeared from national forest watersheds in both Indiana and Illinois. Over the latter half of the 20th century, three species—alligator gar, pallid shiner, and harelip sucker (*Lagochila lacera* or *Moxostoma lacerum*)—have been documented as extinct or nearly extirpated from waters of the upper Mississippi River basin. The alligator gar has not been recorded in the assessment area since the 1960s (Burr et al. 1996, Poly 2001), and the pallid shiner has virtually disappeared from the region since the 1950s (Burr and Warren 1986, Pflieger 1997, Warren and Burr 1988). The harelip sucker, last observed in 1893, once occurred in Indiana waters (Jenkins in Jenkins and Burkhead 1994) but is considered extinct throughout its range. On a smaller scale, 19th century records (Forbes and Richardson 1909) of the blacknose and longnose daces are available for streams in the western Shawnee; no records since that time are known. The rosefin shiner and bigeye chub once occurred in Spring Branch or Big Creek, Hardin County, in the eastern Shawnee, but neither species has been documented in southern Illinois since 1900 (Smith 1979) and 1935 (B. M. Burr, personal observation), respectively. The popeye shiner once occurred in the East Fork White River, Indiana, in the late 19th century, but appears to be extirpated there (and elsewhere in Indiana) now (Gilbert 1969). This location was near the western edge of the Hoosier.

## Mussels

Conservation ranks assigned to the 76 native mussel species occurring within the assessment area reveal that 42 are currently stable, 13 are of special concern, 5 are threatened, and 16 are either endangered or possibly extinct, according to the assignment of status categories by the American Fisheries Society Endangered Species Committee (Williams et al. 1993). Ten species are federally listed as endangered—orangefoot pimpleback, clubshell, rough pigtoe, fanshell, catspaw, northern riffleshell, tubercled blossom, pink mucket, ring pink, and fat pocketbook (http://ecos.fws.gov). Nearly 70 percent of the species within the assessment area are considered rare, threatened, or endangered in at least one of the States included in the assessment area. Global ranks (Association for Biodiversity www.natureserve.org) assigned to native freshwater mussels occurring within the assessment area show that 48 species are secure or apparently secure, 8 are vulnerable, 16 are either imperiled or critically imperiled, and 4 are presumed extinct (table 4).

## Crayfishes

Four crayfish species (*Orconectes bisectus, O. kentuckiensis, O. rafinesquei*, and *O. stannardi*) in the assessment area are globally imperiled, three (*O. illinoisensis, O. pellucidus,* and *O. ronaldi*) are globally very rare (i.e., locally restricted ranges), and one species (*O. indianensis*) is designated as globally imperiled or at least very rare (table 5). Three of these species (*O. illinoisensis, O. indianensis,* and *O. kentuckiensis*) occur in at least one watershed that drains the Shawnee National Forest, and one species (*O. pellucidus*) occurs in several watersheds of the Hoosier National Forest. All other species are locally abundant throughout their ranges and are considered globally secure. The assessment area harbors no federally listed crayfish species. The American Fisheries Society lists one crayfish species as endangered (*O. barrenensis*), two as threatened (*O. kentuckiensis* and *O. stannardi*), and three species of special concern (*O. illinoisensis, O. indianensis, O. rafinesquei*). The Forest Service lists one species as threatened (*O. indianensis*) and two species (*O. kentuckiensis* and *O. placidus*) of special concern in the Shawnee National Forest, and one species (*O. inermis*) of special concern in the Hoosier National Forest.

## Implications and Opportunities

Increased and coordinated efforts to conduct status surveys and inventories of aquatic species are highly desired for the assessment area. We cannot emphasize enough the lack of available data for the Hoosier National Forest or the State of Indiana, especially for aquatic organisms. For example, Indiana listed no crustaceans as endangered, threatened, or of special concern, even though two crayfishes are listed as globally rare. In comparison to Kentucky, Illinois, and Missouri, where biologists have accumulated nearly comprehensive data sets for fishes, mussels, and crayfishes, Indiana agencies and personnel need to strive for establishing baseline data on aquatic species except those identified as of sport or commercial value. For example, springs and spring runs are among the most valuable of groundwater resources. Both the Shawnee and Hoosier National Forests have numerous springs and spring runs and yet there has been no concerted effort to simply document and describe these unique habitats and examine in some detail their aquatic communities.

The current information available for judging the true status (population sizes, distribution, trends, and threats) of many species is so fragmentary that some species now considered imperiled may not deserve consideration whereas other species may be in jeopardy of extinction but go unrecognized (Williams and Neves 1992). It is apparent from recent work documenting the distribution and status of aquatic species (e.g., Pflieger 1996) that comprehensive inventory efforts in some states are given higher priority and greater support than in others. The ability of natural resource managers to recognize species threatened with extinction or experiencing population declines depends on the timeliness, quality, and comprehensiveness of inventory information available to them. The database assembled for this report provides a basis for increased interstate and Federal-State coordination of efforts to provide up-to-date status information on aquatic species in the assessment area.

## COMMERCIALLY AND RECREATIONALLY IMPORTANT SPECIES

Angling or recreational fishing continues to be a favorite pastime in the United States; nationwide, 17 percent of the population 16 years of age and older have participated in sport fishing activities. Recent figures for Illinois and other states in the assessment area are similar. Angling is also a significant source of revenue; sport fishers spend nearly $40 billion annually pursuing their sport nationwide. In Illinois alone, angler expenditures totaled more than $1.6 billion in 1999. The assessment area is home to thriving musky guide services; popular fishing resorts; major fishing, boat, and tackle manufacturers, large and productive aquaculture facilities and fish farms; and major professional sport fishing tournaments and champions. These activities are highly visible and generate huge revenues for the economies of the assessment area.

The intense level of interest in angling would not have developed if a significant fishery resource had not existed naturally. Historical accounts of early inhabitants indicate that they found a plentiful supply of stream and river fisheries. In the assessment area, however, flowing waters have been altered by construction of dams, levees, channelization and dredging, gravel mining, locks, impoundments, and ponds and by ever increasing demands on the harvest of fishery resources.

Fishery managers respond to the challenge of altered aquatic environments by trying to manage for sustainable yield (through natural fish reproduction) where possible. When necessary, managers supplement or replenish sport fish stocks with fish from either hatcheries or aquaculture facilities. Subsequent yields vary depending on the amount of sport and commercial fishing pressure tempered by habitat quality, the effectiveness of fishing regulations, and the ability of resource agencies to fund improvements in aquatic habitat, increasing demands for stocking, and better hatchery facilities.

In this section, we briefly discuss harvest information and identify differences in legal definitions of sport and commercial fish. More limited information is available on commercial uses and values of crayfish species in the states of the assessment area. The legal harvest of mussel species among assessment area states has been under investigation for several years, especially in the mainstem Ohio River. The recent (1999) collapse in the export market for shells will be beneficial to mussels. For example, no commercial harvest for mussels has been reported in Illinois since the collapse of the market. We also present information on the stocking of nonindigenous fish species and the supplemental stocking of native fish species within the assessment area.

## DATA SOURCES

Within constraints of time and the patterns and trends in the assessment area, we modeled the following section after the excellent chapters on *Commercially and Recreationally Important Species* (Standage 1999a), and *Management Indicator Species* (Standage 1999b) in *Ozark-Ouachita Highlands Assessment: Aquatic Conditions* (General Technical Report SRS-33 (1999), regarding the Ozark-Ouachita Ecological Assessment in Missouri, Arkansas, Kansas, and Oklahoma). We derived lists of species of legal sport and commercial fishes from the Wildlife Codes (hunting and fishing regulations) of each state or from its respective Web page. All of the lists, except Missouri, were vague in terms of taxonomy (e.g., use of the term “sucker” or “redhorse” for several species of *Moxostoma*), and we adjusted the names in table 10 to reflect our best professional judgment (from interviews with commercial fishermen over the last several years and visits to fish markets on the Mississippi and Ohio Rivers) of the species most often caught and sold at market. We found that in many cases fish family groups were listed as sport/game and/or commercial species, when in fact, a particular species in a group does not grow large enough to have angling or commercial value. We identified only those species within a given fish family that might have sport or commercial value. Thus, blue catfish are shown as both a sport and commercial species, whereas the smaller madtom catfish are not.

It is difficult to obtain statistical information on commercial harvest of fishes from natural populations in North America except for the Laurentian Great Lakes. The National Marine Fisheries Service publishes an annual summary entitled *Fisheries of the United States,* but freshwater landings were not listed separately until 1995. Some commercial data from State Natural Resource Agencies can be compared to a survey made in 1975.

We did not make an attempt to tabulate "minnows" that are captured for bait or sold by commercial fishermen because if caught in the wild any number of species might be involved. Sport fish were identified by examining the lists of record size fish caught on hook and line for each of the four states. Some states have listed their stocking records on their respective Web pages. Nearly all included largemouth bass, bluegill, and channel catfish, all of which are ubiquitous in the assessment area and are stocked in nearly all lentic habitats in the region. We have used some information about additional species raised in the State hatchery systems as an indicator of special areas being stocked with specific exotic or nonindigenous species.

General information regarding human consumption of crayfishes was summarized from Huner (1978), Lodge et al. (2000a), and Page (1985). Data on the commercial harvest of mussels were taken from Cummings (1991) for Illinois, Williams and Schuster (1989) for Kentucky, and Oesch (1984) for Missouri.

## PATTERNS AND TRENDS

### Commercial Fish Harvest

More than 50 species of fish make up the freshwater commercial harvest in North America (Heidinger 2000); this figure does not include the bait minnow industry. In North America, less than 1 percent of the total commercial harvest of finfish comes from fresh water. Average yearly harvest of selected freshwater fishes from 1982 to 1984 compared to the average yearly harvest from 1995 to 1997 indicates a 61 percent reduction in harvest in the United States (Heidinger 2000). In a 1994 survey, just over 66 percent of the total United States harvest was from either the Great Lakes (29.2 million pounds) or the State of Arkansas (29 million pounds). To place this freshwater harvest in perspective, one only needs to realize that the 1998 commercial harvest of salmon from Alaska was 713 million pounds (Heidinger 2000) and the channel catfish aquaculture industry produced 507 million pounds in 1996 (USDA 1997). The price paid for fish in the round varies both by species and by location. Prices paid for selected species in, for example, Illinois and Missouri, range from $0.07 to $0.75 per pound (table 7).

Species legally available for harvest in Missouri, Illinois, Indiana, and Kentucky are presented in table 8 which also includes species that some states categorize as "rough" fish (e.g., gars, bowfin, shads, redhorses, freshwater drum). We have observed all of these species in the catches of commercial fishermen in Illinois and Kentucky or being sold in the few fish markets

**Table 7.** Approximate price per pound (round) of selected species (in cents) of commercial fishes of the Hoosier-Shawnee Ecological Assessment Area.

| Species | Illinois 1993 (Dufford 1994) | Missouri 1992 (Robinson 1994) |
|---|---|---|
| American eel | 12-32 | 18 |
| Blue catfish | 36-75 | 54 |
| Bowfin | 7-15 | 7 |
| Buffalofishes | 19-35 | 24 |
| Bullheads | 23-50 | 24 |
| Common carp | 7-35 | 12 |
| Channel catfish | 44-75 | 55 |
| Flathead catfish | 35-75 | 54 |
| Freshwater drum | 9-40 | 15 |
| Gars | 15-50 | 10 |
| Grass carp | 7-25 | 21 |
| Other Asian carp | 7-25 | --- |
| Paddlefish | 20-31 | 30 |
| Quillback carpsucker | 7-50 | 19 |
| Shovelnose sturgeon | 25-60 | 25 |
| Suckers | 7-20 | --- |

still open on the bordering big rivers of the assessment area.

Except for the major rivers (i.e., Mississippi, Ohio, and Wabash) in the assessment area, freshwater commercial fishing often is banned and is usually unpopular with sport anglers. Anglers fear exploitation of sportfishes by commercial fishermen and interference from commercial gear. Sportfishes taken with commercial gear must be returned to the body of water from which they were captured. Sport anglers often destroy commercial fishing gear especially if their lures get entangled by it.

Waters open to commercial fishing in Missouri include the Missouri, Mississippi, and lower St. Francis Rivers (MO DC 1997). From 1993 through 1995, the number of licensed commercial fishers with gear was 340, 319, and 395, respectively. A commercial fish license is also required of mussel harvesters, but their nets and other fishing gear are not regulated. Most commercial fishers (94 percent) have reported harvesting fewer than 5,000 pounds of fish annually since the 1988 license period. This level of harvesting strongly indicates that few fishers make much money from commercial fishing (Robinson 1994). Even at the price of $0.54/pound (the greatest price in 1992 for any commercial fish species), maximum earnings are below the poverty level.

Removal of all catfish species from the commercial fish list on the Missouri River (effective in 1992) is also considered to have caused a drop in the number of commercial fishers (Robinson 1994). The commercial harvest in Missouri for 1993 through 1995 ranged from 541,000 to 668,000 pounds with nearly half of all catches in weight consisting of buffalofishes and common carp. The grass carp harvest grew from 8,787 pounds in 1993 to 15,330 pounds in 1994, and 21,366 pounds in 1995. The majority of the grass carp harvest was from the Missouri and Mississippi Rivers. Undoubtedly, similar increases have occurred for bighead and silver carp, but the data are preliminary at the time of this writing. Commercial fishing is anticipated to remain fairly constant on the big rivers unless: (1) license fees increase significantly; (2) consumption advisories are imposed; (3) further restrictions on the harvest of catfish are imposed; (4) further restrictions on the harvest of sturgeon for caviar are imposed; or (5) the market for fresh fish changes dramatically.

Excluding the bordering rivers and the Great Lakes, Illinois continues to allow commercial fishing in two of the three large U.S. Army Corps of Engineers' reservoirs, Rend and Carlyle Lakes. Rend Lake was open to commercial fishing from January 31 to March 24, 2000. A total of 365,589 pounds of commercial species, primarily bigmouth buffalo, were harvested. Carlyle Lake was opened to commercial fishing from December 28, 1999 to January 28, 2000. A total of 109,519 pounds of commercial species were harvested. Both of these lakes are located to the north and outside of the assessment area. Commercial fishing on the portion of the big rivers (i.e., Mississippi, Ohio, and Wabash Rivers) that lie within the assessment

**Table 8.** Sport and commercial fishes of the Hoosier-Shawnee Ecological Assessment Area, by State. List includes exotic and non-indigenous species.

| | | | Illinois | | Indiana | | Kentucky | | Missouri | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Family** | **Scientific name** | **Common name** | **Sport** | **Comm.** | **Sport** | **Comm.** | **Sport** | **Comm.** | **Sport** | **Comm.** |
| Acipenseridae | *Acipenser fulvescens* | Lake sturgeon | | x | | | x | | | |
| Acipenseridae | *Scaphirhynchus platorynchus* | Shovelnose sturgeon | x | x | x | x | | x | | |
| Amiidae | *Amia calva* | Bowfin | x | x | x | x | x | x | x | x |
| Anguillidae | *Anguilla rostrata* | American eel | | x | | | | x | x | x |
| Catostomidae | *Carpiodes carpio* | River carpsucker | | x | | x | | | | x |
| Catostomidae | *Carpiodes cyprinus* | Quillback | | x | | x | | | | x |
| Catostomidae | *Carpiodes velifer* | Highfin carpsucker | | x | | x | | | | x |
| Catostomidae | *Catostomus commersoni* | White sucker | | x | | | | x | x | x |
| Catostomidae | *Cycleptus elongatus* | Blue sucker | | x | | | | x | x | x |
| Catostomidae | *Hypentelium nigricans* | Northern hog sucker | | x | | | | | x | |
| Catostomidae | *Ictiobus bubalus* | Smallmouth buffalo | x | x | x | x | | x | x | x |
| Catostomidae | *Ictiobus cyprinellus* | Bigmouth buffalo | x | x | x | x | | | x | x |
| Catostomidae | *Ictiobus niger* | Black buffalo | x | x | | x | | | x | x |
| Catostomidae | *Minytrema melanops* | Spotted sucker | | x | | | | | | x |
| Catostomidae | *Moxostoma anisurum* | Silver redhorse | | x | | | | | x | x |
| Catostomidae | *Moxostoma carinatum* | River redhorse | | | | | | x | x | x |
| Catostomidae | *Moxostoma duquesnei* | Black redhorse | | x | | | | | | x |
| Catostomidae | *Moxostoma erythrurum* | Golden redhorse | | x | | | | x | x | x |
| Catostomidae | *Moxostoma macrolepidotum* | Shorthead redhorse | | x | | | | | x | x |
| Centrarchidae | *Ambloplites rupestris* | Rock bass | x | | x | | x | | x | |
| Centrarchidae | *Centrarchus macropterus* | Flier | | | x | | | | x | |
| Centrarchidae | *Lepomis auritus* | Redbreast sunfish | | | | | x | | | |
| Centrarchidae | *Lepomis cyanellus* | Green sunfish | x | | x | | x | | x | |
| Centrarchidae | *Lepomis gulosus* | Warmouth | x | | x | | x | | x | |
| Centrarchidae | *Lepomis humilis* | Orangespotted sunfish | | | | | | | | |
| Centrarchidae | *Lepomis macrochirus* | Bluegill | x | | x | | x | | x | |
| Centrarchidae | *Lepomis megalotis* | Longear sunfish | | | | | x | | | |
| Centrarchidae | *Lepomis microlophus* | Redear sunfish | x | | x | | x | | x | |
| Centrarchidae | *Lepomis symmetricus* | Bantam sunfish | | | | | | | | |
| Centrarchidae | *Micropterus dolomieu* | Smallmouth bass | x | | x | | x | | x | |
| Centrarchidae | *Micropterus punctulatus* | Spotted bass | x | | x | | x | | x | |
| Centrarchidae | *Micropterus salmoides* | Largemouth bass | x | | x | | x | | x | |
| Centrarchidae | *Pomoxis annularis* | White crappie | x | | x | | x | | x | |
| Centrarchidae | *Pomoxis nigromaculatus* | Black crappie | x | | x | | x | | x | |
| Clupeidae | *Alosa chrysochloris* | Skipjack herring | | | | | x | | | |
| Clupeidae | *Dorosoma cepedianum* | Gizzard shad | | x | | | | | | |
| Cyprinidae | *Carassius auratus* | Goldfish | | x | | | | | | |
| Cyprinidae | *Cyprinus carpio* | Common carp | x | x | x | x | x | x | x | x |
| Cyprinidae | *Ctenopharyngodon idella* | Grass carp | x | x | x | x | x | x | x | x |
| Cyprinidae | *Hypophthalmichthys molitrix* | Silver carp | | x | | x | | x | | x |
| Cyprinidae | *Hypophthalmichthys nobilis* | Bighead carp | x | x | x | x | x | x | x | x |
| Esocidae | *Esox americanus* | Grass pickerel | | | | | x | | x | |
| Esocidae | *Esox lucius* | Northern pike | x | | x | | x | | x | |
| Esocidae | *Esox masquinongy* | Muskellunge | x | | x | | x | | x | |
| Esocidae | *Esox masquinongy* x *E. lucius* | Tiger musky | x | | x | | x | | x | |

*(table continued on next page)*

**(table 8 continued)**

| Family | Scientific name | Common name | Illinois | | Indiana | | Kentucky | | Missouri | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Sport | Comm. | Sport | Comm. | Sport | Comm. | Sport | Comm. |
| Esocidae | *Esox niger* | Chain pickerel | | | x | | x | | x | |
| Gadidae | *Lota lota* | Burbot | | | x | | | | | |
| Hiodontidae | *Hiodon alosoides* | Goldeye | x | x | | | | | x | |
| Hiodontidae | *Hiodon tergisus* | Mooneye | | | | | | | | |
| Hiodontidae | *Hiodon tergisus* | Mooneye | | x | | | | | | |
| Ictaluridae | *Ameiurus catus* | White catfish | | | x | | | | x | |
| Ictaluridae | *Ameiurus melas* | Black bullhead | x | x | x | x | x | x | x | x |
| Ictaluridae | *Ameiurus natalis* | Yellow bullhead | x | x | x | x | x | x | x | x |
| Ictaluridae | *Ameiurus nebulosus* | Brown bullhead | x | x | x | x | x | x | x | x |
| Ictaluridae | *Ictalurus furcatus* | Blue catfish | x | x | x | x | x | x | x | |
| Ictaluridae | *Ictalurus punctatus* | Channel catfish | x | x | x | x | x | x | x | |
| Ictaluridae | *Pylodictis olivaris* | Flathead catfish | x | x | x | x | x | x | x | |
| Lepisosteidae | *Atractosteus spatula* | Alligator gar | | | | | | | | x |
| Lepisosteidae | *Lepisosteus oculatus* | Spotted gar | x | x | | x | x | x | x | |
| Lepisosteidae | *Lepisosteus osseus* | Longnose gar | | x | | x | | x | x | x |
| Lepisosteidae | *Lepisosteus platostomus* | Shortnose gar | x | x | | x | | x | | x |
| Moronidae | *Morone chrysops* | White bass | x | | x | | x | | x | |
| Moronidae | *Morone mississippiensis* | Yellow bass | x | | x | | x | | x | |
| Moronidae | *Morone saxatilis* | Striped bass | x | | x | | x | | x | |
| Moronidae | *Morone saxatilisx M. chrysops* | Sunshine or Calico bass | x | | x | | x | | x | |
| Percidae | *Perca flavescens* | Yellow perch | x | | x | | x | | x | |
| Percidae | *Stizostedion canadense* | Sauger | x | | x | | x | | x | |
| Percidae | *Stizostedion vitreum* | Walleye | x | | x | | x | | x | |
| Percidae | *Stizostedion canadense* x *S. viterum* | Saugeye | x | | x | | x | | | |
| Polyodontidae | *Polyodon spathula* | Paddlefish | | x | x | x | x | x | x | x |
| Salmonidae | *Oncorhynchus mykiss* | Rainbow trout | x | | x | | x | | x | |
| Salmonidae | *Salmo trutta* | Brown trout | x | | x | | x | | x | |
| Sciaenidae | *Aplodinotus grunniens* | Freshwater drum | x | x | x | x | x | x | x | x |

area generally target buffalofishes, paddlefish, the large catfishes (channel, blue, and flathead), and all of the Asian carps. A contentious and contemporary issue involves native sturgeon populations and the caviar industry. The black eggs removed from sturgeon and paddlefish are sold to the caviar markets. Because the federally endangered pallid sturgeon may be taken incidentally along with shovelnose and lake sturgeon, various agencies have lobbied for a complete shutdown of any fishing for sturgeon species. At the time of this writing, the issue had not been resolved. Excluding Lake Michigan, Illinois commercial anglers harvested 5.4 million pounds of fish in calendar year 1999 valued at nearly $1.4 million. There was no reported mussel harvest in calendar year 1999 due to a collapse of the export market for shells.

Commercial fishing is allowed or has been allowed on the Ohio and Mississippi Rivers in Kentucky and the largest reservoirs including those near the assessment area—Kentucky Lake and Lake Barkley and Rough River and Nolin River reservoirs (Hoyt and Flynn 1974, Timmons et al. 1989). The commercial fishery of Kentucky Lake is especially important to the economy of western Kentucky. Renaker and Carter (1968) estimated the annual harvest and value of the trotline fishery in the Kentucky section of Kentucky Lake as 136,101 pounds and

$32,740 in 1965 and 575,301 pounds and $166,806 in 1966, whereas Timmons et al. (1985) reported a harvest of 913,560 pounds worth $448,620 in 1984. Bull (1985) estimated a trotline harvest of 379,191 pounds worth $172,000 in 1984 in the same section of Kentucky Lake. Species accounting for the bulk of the harvest included paddlefish, gars, American eels, common carp, buffalofishes, the large catfishes, and freshwater drum. The fate of harvested fish falls into three general categories: 1) fish sold alive, 2) fish sold dressed, and 3) fish for personal use. Few individual fishers or families earn a living above the poverty line if commercial fishing is their only source of income.

**Recreational fisheries**

Designated species of sport fish, by State, are listed in table 8. These listed species reflect named species of sport fish or members of families of sport fish sought by anglers and for which fishing records are maintained on an annual basis in each State. We distinguish between the terms “game” and “sport” fish and maintain that most recreational or “sport” fishing in the assessment area involves the return of individual fish to the body of water soon after capture. “Game” implies exploitation for food and is a term now often restricted to birds and mammals exploited for recreational hunting and consumption. The listings are similar for each State, ranging from 41 to 52 sport fishes depending on definition, angler preferences, geography, angler gear, and other factors. All of the States are maintaining angler records for four different hybrid forms: tiger musky, sunshine bass, calico bass, and saugeye. Some of the hybrids cannot be accurately distinguished from their parental species and require genetic tests for identification and establishment of a record fish. The full suite of sport fish listed for the four States reflects what recreational fishers seek. In addition, many—if not most—of the commercial species are also caught and harvested. While the four States may have different lists of sport fish, in practice, similar species are being managed through statewide creel limits (the number of fish than can be harvested) or more localized size limits.

In addition to the stocking of the standard largemouth bass, bluegill, and channel catfish, each of the States has programs for stocking or releasing exotic or nonindigenous species into reservoirs in or near the assessment area. For example, Illinois operates four hatcheries to annually produce more than 50 million fish of 19 species for stocking into Illinois waters. Indiana operates 6 State hatcheries and Missouri 11 with literally hundreds of thousands of fish produced and released into waters near or in the assessment area. Some fish are also provided by private industry and the Federal government (e.g., Fish and Wildlife Service). Examples of stockings in the assessment area include striped bass, muskellunge, northern pike, brown trout, and rainbow trout, only one (muskellunge) of which is native to the region. The stockings are conducted to 1) develop self-sustaining fisheries; 2) provide unique sport-fishing opportunities; and 3) encourage non-reproducing species to take advantage of unique habitats (e.g., reservoirs and their tailwater fisheries) and/or underutilized forage fish. Trout are stocked into many of the large reservoirs or their cold tailwaters. Striped bass, sunshine bass, and calico bass are stocked in many of the large reservoirs to prey upon shad. Muskellunge are stocked in Lake Kinkaid, Illinois, where a substantial fishery and musky guide livelihood have developed. Some States (e.g., Illinois) in the assessment area allow stocking of triploid grass carp (purportedly sterile) in farm ponds to control aquatic plant growth.

Recent research in the assessment States has concentrated on determining genetic stock of the region’s sport fishes. Information gained provides for more effective management of, for example, largemouth bass that are native to the region rather than introduction of southern or Florida largemouth bass that have their own physiological adaptations for warmer environments. Hatcheries are raising native river-run stocks of walleye to protect their genetic integrity. There is a large and ongoing interstate study of paddlefish in the bordering big rivers emphasizing distribution and abundance. The growing aquaculture industry is having its activities closely monitored in all four States, and a comprehensive aquatic nuisance species management plan has been developed and submitted to the Federal task force dealing with these matters.

### Commercial Mussel Importance

In the early part of the 20th century, large quantities of freshwater mussels were harvested commercially for the pearl button industry from the largest rivers in the Mississippi basin. Once mussels were collected, the soft tissues were cooked and removed, and the shells shipped to factories where they were cut into blanks, sorted, polished, and finished into buttons (Cummings 1991). Species that were most valuable to the button industry were those having white, unblemished nacres that were relatively large and of uniform thickness. The yellow sandshell was used primarily in the early years of the industry, followed by the plain pocketbook and black sandshell. As the industry progressed, additional species were used. For example, Williams and Schuster (1989) inspected several "dumps" on the lower Ohio River where drilled out shells had been discarded and found the following species to be common: ebonyshell, Wabash pigtoe, Ohio pigtoe, mapleleaf, monkeyface, pimpleback, wartyback, and mucket (table 9). Additional species considered valuable to the industry included the pistolgrip and the butterfly (Oesch 1984).

The pearl button industry flourished for nearly 75 years, then collapsed in the early 1950s following the development and widespread use of plastics (Parmalee and Bogan 1998). Although shells are no longer manufactured into buttons, a mussel industry and commercial harvest exists in the assessment area, especially on the mainstem Ohio River. Today, freshwater mussel shells are used in the Japanese cultured pearl industry. Shells harvested from rivers in the United States from Wisconsin to Alabama are exported to Japan where they are cut into small pellets that serve as nuclei for cultured pearls. The following species are most desired for pearl nuclei because of their size, thickness, and hardness: threeridge, washboard, ebonyshell, Wabash pigtoe, Ohio pigtoe, mapleleaf, monkeyface, wartyback, and pimpleback (table 9, Williams and Schuster 1989). Mussel shells are also used to a much lesser extent as specialty items (Oesch 1984). For example, there is still some small demand for the so-called "pinks"—spike, purple wartyback, and elephant ear (table 9), which have pink to purple nacre. These and other species are used primarily in the manufacture of jewelry and other novelty items such as inlaid furniture and knife handles (Williams and Schuster 1989).

### Commercial Crayfish Importance

Except for those species in the genus *Cambarellus,* almost all crayfish species in the assessment area have the potential to reach sizes suitable for human consumption (table 10). However, midwesterners do not consume large quantities of crayfish as is customary among some of the Southern States—mainly Texas and Louisiana (Taylor et al. 1996). No publication summarizes the current crayfish harvest for human consumption in the Midwest, and we therefore judged it to be minimal. Internationally, crayfish are an important product of commerce (Moody 2000). The total annual commercial harvest of crayfish is more than 110,000 metric tons; the United States produces 55 percent of that volume, and the People's Republic of China produces 36 percent. *Procambarus clarkii* is the single most

**Table 9.** Primary habitat and commercial importance of native freshwater mussel species in the Hoosier-Shawnee Ecological Assessment Area.

| Family / Subfamily | Species | Common name | Occurrence: SNF | Occurrence: HNF | Preferred Habitat: *Creek | *Headwater | *Small river | *Medium river | *Large river | *Impoundments | *Mud/ silt | *Sand | *Gravel | *Mixed sand & gravel | **Slow current | **Moderate current | **Swift current | Commercial importance: Cultured Pearl | Button | ***Polished chip |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Margaretiferidae** | *Cumberlandia monodonta* | Spectaclecase | X | | | | | | X | | | X | X | | X | | | | | |
| **Unionidae** | | | | | | | | | | | | | | | | | | | | |
| Ambleminae | *Amblema plicata* | Threeridge | X | X | | | X | X | X | X | X | X | X | | X | X | X | X | X | X |
| Ambleminae | *Cyclonaias tuberculata* | Purple wartyback | X | X | | | | X | X | | | | X | X | X | X | | | | |
| Ambleminae | *Elliptio crassidens* | Elephant ear | X | X | | | | | X | | X | X | X | | | | X | | | X |
| Ambleminae | *Elliptio dilatata* | Spike | X | X | | | X | X | X | X | X | | X | | | X | X | | | X |
| Ambleminae | *Fusconaia ebena* | Ebonyshell | X | X | | | | | X | | | | | X | | X | X | X | X | X |
| Ambleminae | *Fusconaia flava* | Wabash pigtoe | X | X | X | X | X | X | X | | X | X | X | | X | X | X | | X | |
| Ambleminae | *Fusconaia subrotunda* | Long-solid | | X | | | | | X | | | | X | | | | X | ? | ? | ? |
| Ambleminae | *Hemistena lata* | Cracking pearlymussel | | | | | | X | X | | X | X | X | | | X | | | | |
| Ambleminae | *Megalonaias nervosa* | Washboard | X | X | | | | X | X | | X | X | X | | | X | | X | X | |
| Ambleminae | *Plethobasus cicatricosus* | White wartyback | | | | | | | X | | | | X | | | | X | ? | ? | ? |
| Ambleminae | *Plethobasus cooperianus* | Orange-foot pimpleback | X | X | | | | | X | | | | X | X | | | X | | | |
| Ambleminae | *Plethobasus cyphyus* | Sheepnose | X | X | | | | X | X | | | | X | X | | | X | | | |
| Ambleminae | *Pleurobema clava* | Clubshell | | X | | | | X | X | | | | X | X | | | X | ? | ? | ? |
| Ambleminae | *Pleurobema sintoxia* | Round pigtoe | | X | | | | X | X | | X | X | X | | | X | | | X | X |
| Ambleminae | *Pleurobema cordatum* | Ohio pigtoe | X | X | | | | X | X | | | X | X | | | X | | X | X | |
| Ambleminae | *Pleurobema plenum* | Rough pigtoe | | X | | | | X | X | | | X | X | | | ? | | ? | ? | ? |
| Ambleminae | *Pleurobema rubrum* | Pyramid pigtoe | | X | | | | X | X | | | X | X | | | | X | ? | ? | ? |
| Ambleminae | *Quadrula nobilis* | Southern mapleleaf (2) | | | | | | | X | X | | X | X | | X | X | X | ? | ? | ? |
| Ambleminae | *Quadrula cylindrica* | Rabbitsfoot | X | X | | | | X | X | | | | | X | | | X | | | |
| Ambleminae | *Qudrula metanevra* | Monkeyface | X | X | | | | X | X | | | | X | X | | X | X | X | X | X |
| Ambleminae | *Quadrula nodulata* | Wartyback | X | | | | | X | X | | | X | X | | | ? | | X | X | X |
| Ambleminae | *Quadrula pustulosa* | Pimpleback | X | X | | | | X | X | | X | X | X | | X | X | X | X | X | X |
| Ambleminae | *Quadrula quadrula* | Mapleleaf | X | X | | | | X | X | | X | X | X | | X | X | X | X | X | X |
| Ambleminae | *Tritogonia verrucosa* | Pistolgrip | X | X | | | | X | X | | X | X | X | | | X | | X | X | X |
| Ambleminae | *Uniomerus tetralasmus* | Pondhorn | X | X | X | X | | | | X | X | X | | | X | | | | | |
| Anodontinae | *Alasmidonta marginata* | Elktoe | | | | | X | X | | | | | X | X | | X | X | | | |
| Anodontinae | *Alasmidonta viridis* | Slippershell | | | X | X | | | | | X | X | X | | | | X | | | |
| Anodontinae | *Anodonta suborbiculata* | Flat floater | X | X | X | X | | | | X | X | | | | X | | | | | |
| Anodontinae | *Anodontoides ferussacianus* | Cylindrical papershell | | X | X | X | | | | | X | X | | | X | | | | | |
| Anodontinae | *Arcidens confragosus* | Rock-pocketbook | X | X | | | | X | X | | X | X | | | X | | | | | |
| Anodontinae | *Strophitus undulatus* | Squawfoot | | X | | | X | X | X | | X | X | X | | | ? | ? | | | |
| Anodontinae | *Utterbackia imbecillis* | Paper pondshell | | X | X | X | | | | X | X | | | | X | | | | | |
| Lampsilinae | *Actinonaias ligamentina* | Mucket | X | X | | | | X | X | | | | X | X | X | X | X | X | | X |
| Lampsilinae | *Cyprogenia stegaria* | Fanshell | | X | | | | X | X | | | | X | | | | X | | | |
| Lampsilinae | *Ellipsaria lineolata* | Butterfly | X | X | | | | | X | | | X | X | | | | X | X | X | X |
| Lampsilinae | *Epioblasma archaeformis* | Sugarspoon | | | | | | X | X | | | | X | X | | | X | | | |
| Lampsilinae | *Epioblasma flexuosa* | Leafshell (3) | | | | | | | X | | | | X | X | | | X | | | |
| Lampsilinae | *Epioblasma obliquata* | Catspaw | | | | | | X | X | | | | X | | | | X | | | |

*(table continued on next page)*

**(table 9 continued)**

| Family Subfamily | Species | Common name | SNF | HNF | *Creek | *Headwater | *Small river | *Medium river | *Large river | *Impoundments | *Mud/ silt | *Sand | *Gravel | *Mixed sand & gravel | **Slow current | **Moderate current | **Swift current | Cultured Pearl | Button | ***Polished chip |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Occur-rence | | Preferred Habitat | | | | | | | | | | | | | Commercial importance | | |
| **Unionidae** | | | | | | | | | | | | | | | | | | | | |
| Lampsilinae | *Epioblasma propinqua* | Tennessee riffleshell(2) | | X | | | | | X | | | | X | X | | | X | | | |
| Lampsilinae | *Epioblasma rangiana* | Northern riffleshell | | X | | | | X | X | | | | X | | | | X | | | |
| Lampsilinae | *Epioblasma sampsonii* | Wabash riffleshell | | | | | | ? | ? | | | | ? | ? | | | ? | | | |
| Lampsilinae | *Epioblasma torulosa* | Tubercled blossom | | X | | | | X | X | | | | X | | | | X | | | |
| Lampsilinae | *Epioblasma triquetra* | Snuffbox | | X | | | | X | X | | | | X | | | | X | | | |
| Lampsilinae | *Lampsilis abrupta* | Pink mucket | X | | | | | | X | | | X | X | | | | X | | | |
| Lampsilinae | *Lampsilis cardium* | Plain pocketbook | X | X | X | | X | X | X | | X | X | X | | X | X | X | X | X | X |
| Lampsilinae | *Lampsilis fasciola* | Wavy-rayed lampmussel | | X | | | | X | | | | | X | | | X | | | ? | ? |
| Lampsilinae | *Lampsilis ovata* | Pocketbook | X | | | | | | X | | | X | X | | X | X | X | | | |
| Lampsilinae | *Lampsilis siliquoidea* | Fatmucket | X | X | | X | X | X | | X | X | X | X | | X | | | | X | X |
| Lampsilinae | *Lampsilis teres* | Yellow sandshell | X | X | | | | X | X | | | X | X | | X | X | | | X | X |
| Lampsilinae | *Leptodea fragilis* | Fragile papershell | X | X | X | | X | X | X | | X | X | X | | X | X | X | | | |
| Lampsilinae | *Leptodea leptodon* | Scaleshell | | | | | | | X | | X | | | | | | X | | | |
| Lampsilinae | *Ligumia recta* | Black sandshell | X | X | | | | X | X | | | X | X | | | | X | | X | X |
| Lampsilinae | *Ligumia subrostrata* | Pondmussel | X | | X | | | | | X | X | X | | | X | | | | | |
| Lampsilinae | *Obliquaria reflexa* | Threehorn wartyback | X | X | | | | | X | X | | X | X | | X | X | | | | X |
| Lampsilinae | *Obovaria olivaria* | Hickorynut | X | X | | | | | X | | | X | | X | | X | X | | | |
| Lampsilinae | *Obovaria retusa* | Ring pink | X | | | | | | X | | | X | X | | | ? | ? | | | |
| Lampsilinae | *Obovaria subrotunda* | Round hickorynut | X | X | | | | X | | | | X | X | | | X | | | | |
| Lampsilinae | *Potamilus alatus* | Pink heelsplitter | X | X | | | | X | X | | X | X | X | X | X | X | X | | | X |
| Lampsilinae | *Potamilus capax* | Fat pocketbook | X | X | | | | | X | | X | X | | | X | | | | | |
| Lampsilinae | *Ptychobranchus fasciolaris* | Kidneyshell | X | X | | | | X | X | | | | X | | | X | X | | | |
| Lampsilinae | *Toxolasma lividus* | Purple lilliput | | | | | X | X | | X | | | X | | ? | | | | | |
| Lampsilinae | *Toxolasma parvus* | Lilliput | | | X | | X | X | X | X | X | X | X | | ? | | | | | |
| Lampsilinae | *Toxolasma texasensis* | Texas lilliput | X | | | X | X | X | | | X | X | | | X | | | | | |
| Lampsilinae | *Truncilla donaciformis* | Fawnsfoot | X | X | | | | X | X | | | X | X | | X | X | X | | | |
| Lampsilinae | *Truncilla truncata* | Deertoe | X | X | | | | X | X | | X | X | X | | X | X | X | | | |
| Lampsilinae | *Villosa fabalis* | Rayed bean | | | | | X | X | | X | | X | X | | | ? | ? | | | |
| Lampsilinae | *Villosa iris* | Rainbow | | | | | X | X | | | | X | X | | | X | X | | | |
| Lampsilinae | *Villosa lienosa* | Little spectaclecase | | X | | | X | X | | | | X | X | | X | | | | | |
| Lampsilinae | *Villosa ortmanni* | Kentucky creekshell | | | | | ? | ? | | | | ? | ? | ? | ? | ? | ? | | | |
| Unioninae | *Plectomerus dombeyanus* | Bankclimber | | | | | X | X | | | X | | X | | X | X | | | | X |

*Cummings and Mayer (1992)
**Parmalee and Bogan (1998)
***Polished chip (Oesch 1984); jewelry and specialty items (Williams and Schuster 1989)

**Table 10.** Primary habitat and commercial importance of native freshwater crayfish species in the Hoosier-Shawnee Ecological Assessment Area.

| Family Subfamily | Scientific Name | Common Name | Occurence SNF | Occurence HNF | Preferred habitat ∆ | Commercial importance |
|---|---|---|---|---|---|---|
| **Cambaridae** | | | | | | |
| Cambarellinae | *Cambarellus puer* | Cajun dwarf crayfish | X | | 3º burrower | |
| Cambarellinae | *Cambarellus shufeldtii* | Shufeldt's dwarf crayfish | X | | 3º burrower | |
| Cambarinae | *Barbicambarus cornutus* | Bottlebrush crayfish | | | 3º burrower | Potentially consumable |
| Cambarinae | *Cambarus bartonii* | Appalachian brook crayfish | | | 3º burrower & troglophilic | |
| Cambarinae | *Cambarus diogenes* | Devil crayfish | X | X | 1º burrower | Potentially consumable |
| Cambarinae | *Cambarus graysoni* | Nashville crayfish | | | 3º burrower or Open water | |
| Cambarinae | *Cambarus ortmanni* | Lentic crayfish | | | 2º burrower | |
| Cambarinae | *Cambarus rusticiformis* | Riffle crayfish | X | | Open water | Potentially consumable |
| Cambarinae | *Cambarus tenebrosus* | Spring grayfish | X | X | Open water, springs & troglophilic | Potentially consumable |
| Cambarinae | *Fallicambarus fodiens* | Digger crayfish | X | | 1º burrower | Potentially consumable |
| Cambarinae | *Orconectes barrenensis* | Green River crayfish | | | Open water & 3º burrower | |
| Cambarinae | *Orconectes bisectus* | Crittenden crayfish* | | | Open water & 3º burrower | |
| Cambarinae | *Orconectes illinoiensis* | Illinois crayfish* | X | | Open water & 3º burrower | Potentially consumable |
| Cambarinae | *Orconectes immunis* | Papershell crayfish | X | X | 3º burrower | Potentially consumable |
| Cambarinae | *Orconectes indianensis* | Indiana crayfish* | X | X | Open water & 3º burrower | |
| Cambarinae | *Orconectes inermis* | Subterranean crayfish | | X | Troglobitic | |
| Cambarinae | *Orconectes kentuckiensis* | Kentucky crayfish* | X | | Open water & 3º burrower | |
| Cambarinae | *Orconectes lancifer* | Shrimp crayfish | | | Open water & 3º burrower | |
| Cambarinae | *Orconectes luteus* | Golden crayfish | | | Open water & 3º burrower | |
| Cambarinae | *Orconectes margorectus* | Cobble crayfish* | | | Open water & 3º burrower | |
| Cambarinae | *Orconectes palmeri* | Gray-speckled crayfish | | | 3º burrower & Open water | |
| Cambarinae | *Orconectes pellucidus* | Eyeless crayfish | | | Troglobitic | |
| Cambarinae | *Orconectes placidus* | Placid crayfish | X | | Open water & 3º burrower | Potentially consumable |
| Cambarinae | *Orconectes putnami* | Disjunct crayfish | | | Open water & 3º burrower | |
| Cambarinae | *Orconectes rafinesquei* | Rafinesque's crayfish* | | | Open water & 3º burrower | |
| Cambarinae | *Orconectes ronaldi* | Mud River crayfish | | | Open water & 3º burrower | |
| Cambarinae | *Orconectes rusticus* | Rusty crayfish | X | | Open water & 3º burrower | Potentially consumable** |
| Cambarinae | *Orconectes stannardi* | Little Wabash crayfish | | | Open water & 3º burrower | |
| Cambarinae | *Orconectes tricuspis* | Headwater crayfish | | | Open water & 3º burrower | |
| Cambarinae | *Orconectes virilis* | Virile crayfish | X | | Open water & 3º burrower | Potentially consumable*** |
| Cambarinae | *Procambarus acutus* | White River crayfish | X | | 3º burrower | Potentially consumable |
| Cambarinae | *Procambarus clarkii* | Red swamp crayfish | X | X | 3º burrower | Potentailly consumable**** |
| Cambarinae | *Procambarus gracilis* | Prairie crayfish | X | | 1º burrower | |
| Cambarinae | *Procambarus viaeviridis* | Vernal crayfish | X | | 2º burrower | |

See text for full description of the different habitats

1º = primary, 2º = secondary, 3º = tertiary, Troglophilic = lives in caves and surface waters, and Troglobitic = obligate cave dweller

∆ Most crayfish preferring flowing, open-water, burrow either in times of low water, to brood eggs, or to escape below the frost line in winter.

* endemic to the Hoosier-Shawnee Ecological Assessment Area.

** Has historically been sold as bait throughout the midwest and New England which lead to significant range expansion (Page 1985).

*** Has historically been harvested and eaten in Illinois (Page 1985).

**** Continues to be harvested commercially for human consumption and bait in more southern portions of its range (Pflieger 1996).

commercially important species in North America, making up more than 70 percent of all harvested species (Moody 2000). Significant crayfish harvest for human consumption, as well as bait, historically occurred in Wisconsin and Ohio (Huner 1978) with other Midwestern States either not reporting catches or not having significant harvests. Page (1985) mentioned that in Illinois, *Orconectes virilis*, an abundant and ubiquitous species, often was harvested for food historically, but does not appear to be harvested currently. Pflieger (1996) noted that *Procambarus clarkii*, found in the assessment area primarily in southern Illinois, was the most commonly harvested and cultured (for human consumption) species in the United States but largely in the extreme southern portions of its range—Texas and Louisiana. For the most part, however, crayfishes of the assessment area are not commercially harvested for human consumption.

Crayfishes are of potential importance in the commercial bait industry and as a food source for wild sportfish stocks. There is also a small but persistent interest in keeping crayfishes as aquarium pets. Although no literature was found that discussed crayfish harvest for the bait industry in or near the assessment area, harvest certainly occurs. Huner (1978) suggested that most North American crayfish species have been collected for bait historically. On a local level, numerous species are captured for bait throughout the assessment area, in part because the practice of harvesting and selling crayfishes as bait is legal in all four States in the assessment area. Certainly it is common practice for bass and catfish anglers to personally harvest crayfish to be used as bait on fishing outings. As noted earlier, crayfish abundance and species composition can have significant effects on sportfish populations (Lodge et al. 2000a). Crayfishes are indirectly important recreationally in this regard because they make up a significant portion of the biomass in a given aquatic system. This biomass becomes a food source for many life stages of numerous sportfish species, particularly basses and sunfishes (Lodge et al. 2000a).

## Implications and Opportunities

The era of major reservoir construction in the assessment area is about over and it is unlikely that major changes will be made in management of existing reservoirs and their water releases. Species introductions and manipulation will still occur. The success of the introduced muskellunge fishery in southern Illinois may cause other States in the assessment area to consider a similar program. There was some natural reproduction in earlier years of management, but this seems to have disappeared in the most recent years. A major management problem now is escape of introduced sportfishes over the dams of reservoirs into streams that connect to the big rivers. This sort of behavior could pose ecological problems for native stream fishes and other sport fishes unaccustomed to having a large nonindigenous predator (e.g., muskellunge) in their midst. It is also costly to State resource agencies because considerable personnel time and effort are spent retrieving, for example, adult muskellunge, and returning them to the lake in which they were originally stocked.

We anticipate that fisheries managers will increasingly focus on maintaining or restoring significant warm-water and cool-water stream fisheries and improve sport-fish populations and angling in progressively smaller water bodies as time goes on. Most of the large cities now have active urban fishing programs. Emphasis on managing striped bass and other reservoir sport fish is not likely to diminish in the reasonable future. Considerable technical assistance is now available for the landowner with private pond waters. In the assessment area, largemouth, smallmouth, and spotted basses, bluegill, crappie, white and striped basses, walleye, and large catfishes are still the species of choice of most anglers.

Commercial mussel harvesting has been driven by the overseas demand for shell blanks for the cultured pearl industry. Mussel harvesting needs to be carefully monitored to ensure sustainability of the harvested species as well as other species that may be indirectly affected by harvest activities. Uniformity of harvest regulations (including harvest method [i.e., brailing versus diving], minimum shell sizes, season dates, and time of day open for harvest) and uniformity of reporting would support management of harvest within the assessment area and beyond.

Commercial fishing within the assessment area is primarily restricted to the big rivers at this time. Lack of analysis of required commercial fishers reports and lack of close monitoring of fishing are viewed here as a handicap for efficient fisheries management. A shutdown of the caviar industry would halt all fishing for the three sturgeon species and possibly the paddlefish. Commercial fishing is a lifestyle for some families in the region, but none are making a substantial living with fishing alone. Despite fears of sport fishers, commercial fishing is harvesting a renewable resource and can be compatible with general fishery management objectives in the region.

Management of recreational fishing is an ever-changing science. Significant progress has been made in improving habitats and fishery populations, particularly in reservoirs. Continued efforts with private landowners to help assess and manage the hundreds of small water bodies in the assessment area should yield quality fishing. Conserving native genetic stocks of sportfish is an important long-term goal to maintain the integrity of popular species including the largemouth bass, walleye, and bluegill. Development of high quality stream and river fisheries requires more research, attention, and funding in the near future. Some nearly unexploited river catfish fisheries could be developed into new tournaments, especially considering that most fishing records of any size will almost certainly be set with increased catfish angling. Restoration of many streams and rivers in the region would be required to address the degradation of many waters from mining and logging activities, outdated agricultural practices, and chemical pollution. Support of grassroots teams devoted to stream restoration and conservation by government agencies and private corporations (e.g., The Nature Conservancy) could help to restore and protect the fishing quality of assessment area waters.

As mentioned above, because crayfishes can make up a significant portion of the biomass in an aquatic ecosystem, and because they are often "dominant consumers of benthic invertebrates, detritus, macrophytes, and algae in lakes and streams," removals and additions of crayfish species "often lead to large ecosystem effects, in addition to changes in fish populations, and losses in biodiversity" (Lodge et al. 2000a). Although crayfishes naturally expand their ranges by moving both overland and underwater from drainage to drainage, anthropogenic mechanisms for range expansion are much more effective (Lodge et al. 2000a). Lodge et al. (2000a) recognized eight ways humans can expand the ranges of crayfishes: "(1) dispersal into new drainages via canals; …(2) legal and (3) illegal stocking in natural waters; …(4) escapes from aquaculture ponds, (5) live food vendors; …(6) the aquarium and pond trade; …(7) escapes or releases from students after studying live crayfishes obtained from biological supply houses; and (8) escapes from the live bait trade." In the assessment area, crayfishes escaping from the live bait trade are probably the most likely cause of human-induced range expansion. A secondarily important range expansion mechanism is probably escape from aquaculture ponds.

Probably the best North American example of the effects of a nonindigenous crayfish on newly encountered ecosystems is the progressive movement of *Orconectes rusticus* (rusty crayfish) across the upper Midwest, Canada, northern Appalachia, New England, and parts of the Southwestern United States (Lodge et al. 2000a, Page 1985). Rusty crayfish physically and ecologically outcompete smaller, slower growing, less aggressive native crayfish species, destroy macrophyte communities, and decimate benthic invertebrate communities (Lodge et al. 2000a, Page 1985). These detrimental ecosystem-wide changes affect numerous native aquatic species, in addition to crayfishes, and including sport and non-game fishes. Rusty crayfish also hybridize with native crayfish species, in effect genetically eliminating them from the ecosystem in addition to physically and ecologically outcompeting them (Perry et al. 2001). The rusty crayfish is native to the eastern and southern portions of the assessment area (Indiana and Kentucky) and could potentially invade surrounding areas.

An effective way to reduce the threat of nonindigenous crayfishes would be to place a ban on the practice of using live crayfishes as bait for sportfishing within the national forest boundaries. Furthermore, residents and businesses near the national forests could be encouraged to culture and sell bait minnows rather than nonindigenous crayfishes.

## AQUATIC HABITATS

The diversity and abundance of aquatic organisms (e.g., fishes, mussels, crayfishes) and characteristics of their physical habitat (e.g., stream size, substrate type) are primary tools to assess the quality of habitats (Dolloff et al. 1993, Karr et al. 1986). In recent years it has become commonplace to assess aquatic systems by taking a series of measurements and samples at a particular site or series of sites on a stream. Such specific information is unavailable for large portions of the assessment area. The U.S. Environmental Protection Agency (USEPA) and the USEPA programs at the State level have initiated protocols to be used by their field personnel to assess physical and chemical qualities of aquatic habitats. Much of the field work in Illinois and Kentucky has been accomplished in a cooperative and consistent manner with the State Natural Resource Agency or State Nature Preserves Commission. Large-scale analyses in Illinois have linked water quality and other physical variables to fish diversity and abundance and stream ratings for the entire state are available (e.g., Illinois Biological Stream Characterization Work Group 1995). In previous sections, we were able to evaluate diversity of major aquatic groups across the assessment area. No comparable information base exists that can be used to directly examine the status of aquatic habitats in that same area.

The assessment area encompasses a number of major physiographic regions and a diversity of geologic features that, along with an abundance of water bodies, has produced a plethora of aquatic habitats suitable for fishes, mussels, and crayfishes. Habitat occupation varies considerably among the groups of aquatic organisms targeted in this study. For example, several crayfish species are burrowers that may spend much of their lives more than a yard deep in the mud along a stream or wetland. No comparable examples of this kind of habitat occupation are available among fishes or mussels in the area.

## DATA SOURCES AND METHODS OF ANALYSIS

### Fishes

We classified habitat diversity for fishes around a framework and definitions from Cowardin et al. (1979) and Jenkins et al. (1971). The primary purposes of this habitat classification are to allow the user a quick and accurate characterization of fish habitats known to occur in the assessment area and to allow analysis of affinities of groups of fishes to particular habitat types. The following definitions are provided as a guide to our concepts and use of terms in the characterization of major fish habitat systems and subsystems. The *Lacustrine System* includes permanently flooded lakes and reservoirs generally greater than 20 acres in surface area (except sinkhole ponds) with all of the following features: 1) situated in a dammed river channel or topographic depression; 2) lacking trees, shrubs, and emergent vegetation with greater than 30 percent areal coverage; and 3) the deepest part of the basin exceeds 2 m at low water (Cowardin et al. 1979). The subsystems are *Reservoir* (e.g., Lake of Egypt, Illinois), *Floodplain Lake and Oxbow* (e.g., Taylor Lake, Butler County, Kentucky), and Sinkhole Pond (e.g., Dripping Sinks, Lawrence County, Indiana).

The *Palustrine System* includes wetlands dominated by trees, shrubs, and/or emergent vegetation or those lacking such vegetation with both of the following features: 1) surface area less than 20 acres and 2) water depth in the deepest part of the basin less than 2 m at low water. This system includes vegetated wetlands variously known as swamps, oxbows, sloughs, ditches, marshes, or backwaters. It also encompasses a variety of small, shallow impoundments often called ponds (Cowardin et al. 1979). The subsystems are *Floodplain Lake and Oxbow* (e.g., Mud Lake, Hardin County, Illinois), *Pond* (i.e., farm ponds), and *Wetland* (e.g., Cypress Creek Wetland, Muhlenberg County, Kentucky).

The *Riverine System* includes a large majority of the aquatic habitats in the assessment area and is defined as all waters contained within a channel (sensu Cowardin et al. 1979) except for habitats dominated by trees, shrubs, and emergent plants. Water is usually flowing in this system. The modifiers *upland* and *lowland* characterize gradient and velocity in riverine subsystems. Upland is used to describe riverine subsystems in which the gradient is high and the velocity of water is rapid; water generally flows year round; substrates consist of bedrock, boulder, cobble, pebble, and gravel with occasional patches of sand; dissolved oxygen concentrations are near saturation; and the floodplain is little developed (Cowardin et al. 1979). The concept is also partly based on the presence of shoals or riffles within these subsystems constituting 5 to 10 percent or more of the length of the stream (Jenkins and others 1971). In contrast, lowland applies to those subsystems in which gradient and water velocity are low; flow may be negligible in late summer or early fall; substrates consist of sand, mud, or organic debris; oxygen deficits occur; and the floodplain is well developed. The occurrence of riffles and shoals is low, constituting less than 5 to 10 percent of the stream length.

Subsystems in the *Riverine System* are *Cave Stream, Spring, Headwater Creek, Stream and River,* and *Big River*. The distinction between *Cave Stream* and *Spring* subsystems is based on the larger size of a *Cave Stream* and its association with an obvious surface opening; nevertheless, the distinction in some cases may be arbitrary. We regard sinking streams, a common feature of karst topography, as a part of the *Cave Stream* subsystem. The *Headwater Creek* subsystem includes streams ranging up to about 30 feet in width (Jenkins et al. 1971). In forested areas, flow may be present all year; however, many headwater creeks typically consist of isolated pools or lack surface water during seasons of drought. The *Stream and River* subsystem applies to those waters ranging in size from about 30 to 200 feet in width (Jenkins et al. 1971), having water in the channels, and generally flowing year round (e.g., Green River, Kentucky). The *Big River* subsystem includes waters greater than 200 feet wide and follows the concept of Jenkins et al. (1971). This subsystem is used for the largest rivers of the area (e.g., Ohio River, Missouri River, Mississippi River), most of which are impounded by a series of locks and dams or single large dams, but have an admixture of slow-quiet pools and occasional fast-water shoals or tailwater reaches. Substrates are variable and the floodplain is generally well developed. This subsystem also includes the embayed mouths of streams and rivers that empty into big rivers.

### Mussels

We used Cummings and Mayer (1992) and Parmalee and Bogan (1998) for descriptions of aquatic habitats occupied by mussel species in the assessment area. We followed the definitions as used above for fishes when assigning mussel species to specific habitat categories.

### Crayfishes

We relied on Hobbs (1981), Page (1985), and Pflieger (1996) for descriptions, illustrations, and definitions of aquatic habitats of crayfishes, which can occupy smaller bodies of water (e.g., ditches) or more temporary bodies of water (e.g., vernal ponds, flooded backyards) more readily than either fishes or mussels. Definitions of the five major types of crayfish habitats as well as a few individual species accounts of habitat occurrence were thoroughly documented by Hobbs (1981). Habitat occurrence for most species was presented in either Page (1985) or Pflieger (1996).

Information on the ecological role and importance of crayfishes in aquatic and terrestrial habitats came mainly from Lodge et al. (2000a, 2000b) and Taylor et al. (1996). General information on cave ecology and conservation was supplied in the reviews by Culver et al. (1999) and Elliott (2000). Forest Service riparian regulations on logging and recreational activities within national forests were provided by Chad Stinson, Shawnee National Forest.

## PATTERNS AND TRENDS

### Fish Habitat

Flowing waters are the dominant habitat of fishes in the assessment area with nearly 150 species recorded from upland streams and rivers or big rivers. Additionally, most fishes are found over substrates of sand and gravel and in glides or raceways of the riverine system (table 11). Only six species are found in the cave stream subsystem, and a few others would be expected to occasionally enter the twilight zones of caves for limited times. Twelve species have been recorded from springs, but more field efforts are needed to consider this an accurate assessment of this uncommon habitat. Riffle and shoal habitats account for only about 5 to 10 percent of stream length and yet 52 species are recorded from that specific habitat, nearly always over a gravel or pebble substrate. Following definitions of the lacustrine system, it is clear that all "lakes" are artificial in the region and technically are human-made reservoirs that have effectively halted the flow and velocity of riverine systems. As a consequence, the fish communities of reservoirs are depauperate when compared to riverine systems, largely because habitat heterogeneity has been reduced or completely altered. Fish diversity in reservoirs is less than half that of rivers (table 11) and is artificially maintained, in part, by expensive stocking programs to meet the perceived demand of recreational fishers. Most palustrine habitats in the area consist of farm ponds and the few oxbows and wetlands that have not been converted to agricultural land. Nearly all accessible ponds are heavily managed for recreational fishing and have little fish diversity beyond the tailor-made fish populations of channel catfish, bluegill, and largemouth bass. Just over 50 species are associated with aquatic plants, a habitat feature that is rather rare in the assessment area.

**Table 11.** Primary habitat of native freshwater fishes in the Hoosier-Shawnee Ecological Assessment Area.

| | | Occurrence | | Preferred habitat | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Common name** | **SNF** | **HNF** | **Reservoir** | **Floodplain lake & oxbow** | **Sinkhole ponds** | **Ponds** | **Wetlands** | **Cave stream** | **Springs** | **Upland headwater creek** | **Upland stream & river** | **Lowland headwater creek** | **Lowland stream & river** | **Big river** | **Organic debris/mud** | **Sand/gravel (0.08-3 in.)** | **Pebble/cobble (3-24 in.)** | **Boulder/bedrock (>24 in.)** | **Emergent vegetation/cover** | **Aquatic bed** | **Scrub-shrub** | **Forested** | **Instream shelter** | **Riffles** | **Glides** | **Pools** | **Backwaters** | **Embayments** |
| *Acipenser fulvescens* | Lake sturgeon | X | X | | | | | | | | | X | | | X | | X | X | | | | | | | | | | | |
| *Scaphirhynchus albus* | Pallid sturgeon | X | | | | | | | | | | | | | X | | X | X | | | | | | | | | | | |
| *Scaphirhynchus platorynchus* | Shovelnose sturgeon | X | X | | | | | | | | | | | | X | | X | X | | | | | | | | | | | X |
| *Amblyopsis spelaea* | Northern cavefish | | X | | | | | | X | | | | | | | X | X | | | | | | | | | | X | | |
| *Forbesichthys agassizi* | Spring cavefish | X | | | | X | | | X | X | X | | | | | X | X | | | | | | | | | | X | | |
| *Typhlichthys subterraneus* | Southern cavefish | | X | | | | | | X | | | | | | | X | X | | | | | | | | | | X | | |
| *Amia calva* | Bowfin | X | X | | X | | X | | | | | X | | X | X | X | X | | | X | X | | X | X | | | | | X |
| *Anguilla rostrata* | American eel | X | X | | | | | | | | | X | | X | X | X | X | | | | | | | X | | | | | X |
| *Aphredoderus sayanus* | Pirate perch | X | X | | | | | | | X | | X | X | X | | | X | X | | | X | X | X | X | | | | | |
| *Labidesthes sicculus* | Brook silverside | X | X | X | X | | | | | | | X | | X | X | | X | X | | | | | | | | | | | X |
| *Menidia beryllina* | Inland silverside | X | | X | X | | | | | | | | | X | X | X | X | | | | | | | | | | | | X |
| *Carpiodes carpio* | River carpsucker | X | X | X | | | | | | | | X | | X | X | X | X | | | | | | | | | | | X | X |
| *Carpiodes cyprinus* | Quillback | X | | X | | | | | | | | X | | X | X | X | X | | | | | | | | | | | X | X |
| *Carpiodes velifer* | Highfin carpsucker | X | X | X | | | | | | | | X | | X | X | X | X | | | | | | | | | | | X | X |
| *Catostomus commersoni* | White sucker | X | X | | | | | | | X | X | X | X | X | | | X | X | X | X | X | | | X | X | | X | | |
| *Cycleptus elongatus* | Blue sucker | X | X | | | | | | | | | X | | | X | | X | X | | | | | | | | | | | |
| *Erimyzon oblongus* | Creek chubsucker | X | X | | X | | | X | | | X | X | X | X | | X | X | | | X | X | | | X | | | X | | |
| *Erimyzon sucetta* | Lake chubsucker | X | X | | X | | | X | | | | | | | | X | X | | | X | X | X | X | | | | | | |
| *Hypentelium nigricans* | Northern hog sucker | X | X | | | | | | | X | X | X | | | | | X | X | X | | | | | | | | | | |
| *Ictiobus bubalus* | Smallmouth buffalo | X | X | X | X | | | X | | | | X | | | X | X | X | | | | | | | | | | | X | X |
| *Ictiobus cyprinellus* | Bigmouth buffalo | X | X | X | X | | | X | | | | X | | X | X | X | X | | | | | | | | | | | X | X |
| *Ictiobus niger* | Black buffalo | X | | X | X | | | | | | | X | | X | X | X | X | | | | | | | | | | | X | X |
| *Minytrema melanops* | Spotted sucker | X | X | X | X | | | | | | | X | | X | | X | X | | | | | | | | | X | X | | |
| *Moxostoma anisurum* | Silver redhorse | | X | | | | | | | | | X | | X | X | | X | X | | | | | | | | X | | | |
| *Moxostoma carinatum* | River redhorse | | X | | | | | | | | | X | | | X | | X | X | | | | | | | | | | | |
| *Moxostoma duquesnei* | Black redhorse | X | X | | | | | | | | | X | | | | | X | X | | | | | | | | X | X | | |
| *Moxostoma erythrurum* | Golden redhorse | X | X | | | | | | | | X | X | | X | X | | X | X | X | | | | | | | X | X | | |
| *Moxostoma macrolepidotum* | Shorthead redhorse | X | X | X | | | | | | | | X | | X | X | | X | X | | | | | | | | X | X | | |
| *Ambloplites rupestris* | Rock bass | X | X | X | | | | | | | | X | | | | | X | X | X | X | | | | X | | | X | | |
| *Centrarchus macropterus* | Flier | X | X | | X | | | X | | | | | | X | | X | X | | | | X | | | | | | X | | |
| *Lepomis auritus* | Redbreast sunfish | | | X | | | X | | | | | X | | X | | X | X | | | | X | | | X | | | X | X | |
| *Lepomis cyanellus* | Green sunfish | X | X | X | X | | X | X | | | X | X | X | X | X | X | X | X | | | | | | X | | | X | X | X |
| *Lepomis gulosus* | Warmouth | X | X | X | X | | X | X | | | | X | | X | X | X | X | | | X | X | | | X | | | X | | X |
| *Lepomis humilis* | Orangespotted sunfish | X | X | X | X | | | X | | | | X | | X | X | X | X | | | | | | | | | | X | | X |
| *Lepomis macrochirus* | Bluegill | X | X | X | X | | X | X | | | X | X | X | X | X | X | X | X | | | X | | | X | | | X | | X |
| *Lepomis megalotis* | Longear sunfish | X | X | X | X | | X | X | | | X | X | X | X | X | X | X | X | | | | | | X | | | X | | X |
| *Lepomis microlophus* | Redear sunfishes | X | X | X | X | | X | | | | | X | | X | X | X | X | | | X | X | | | X | | | X | | X |
| *Lepomis miniatus* | Redspotted sunfish | X | | | X | | | X | | | | | | X | | X | X | | | X | X | | X | X | | | | | |
| *Lepomis symmetricus* | Bantam sunfish | X | | | X | | | X | | | | | | X | | X | | | | | X | | | X | | | | | |
| *Micropterus dolomieu* | Smallmouth bass | X | X | X | | | | | | | | X | | | X | | X | X | X | | | | | X | | X | X | | X |

*(table continued on next page)*

**(table 11 continued)**

| Species | Common name | Occurrence | | Preferred habitat | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SNF | HNF | Reservoir | Floodplain lake & oxbow | Sinkhole ponds | Ponds | Wetlands | Cave stream | Springs | Upland headwater creek | Upland stream & river | Lowland headwater creek | Lowland stream & river | Big river | Organic debris/mud | Sand/gravel (0.08-3 in.) | Pebble/cobble (3-24 in.) | Boulder/bedrock (>24 in.) | Emergent vegetation/cover | Aquatic bed | Scrub-shrub | Forested | Instream shelter | Riffles | Glides | Pools | Backwaters | Embayments |
| *Micropterus punctulatus* | Spotted bass | X | X | X | X | | | X | | | | X | | X | X | | X | X | | | | | | X | | X | X | | X |
| *Micropterus salmoides* | Largemouth bass | X | X | X | X | | X | X | | | | X | | X | X | X | X | X | | X | X | X | X | X | | | X | X | X |
| *Pomoxis annularis* | White crappie | X | X | X | X | | X | X | | | | X | | X | X | X | X | | | X | X | X | X | X | | | X | X | X |
| *Pomoxis nigromaculatus* | Black crappie | X | X | X | X | | X | X | | | | X | | X | X | X | X | | | X | X | X | X | X | | | X | X | X |
| *Alosa alabamae* | Alabama shad | | | | | | | | | | | | | | X | | X | | | | | | | | | X | | | |
| *Alosa chrysochloris* | Skipjack herring | X | X | X | | | | | | | | X | | X | X | | X | | | | | | | | | | | | X |
| *Dorosoma cepedianum* | Gizzard shad | X | X | X | X | | | | | | | X | | X | X | X | X | | | | | | | | | | | | X |
| *Dorosoma petenense* | Threadfin shad | X | X | X | | | | | | | | X | | | X | X | X | | | | | | | | | | | | X |
| *Cottus bairdi* | Mottled sculpin | | X | | | | | | | | X | X | | | | | X | X | | | | | | | X | X | | | |
| *Cottus carolinae* | Banded sculpin | X | X | | | | | | X | X | X | X | | | | | X | X | | | | | | | X | X | | | |
| *Campostoma anomalum* | Central stoneroller | | X | | | | | | | | X | X | X | X | | | X | X | X | | | | | | X | X | X | | |
| *Campostoma pullum* | Mississippi stoneroller | X | | | | | | | | | X | X | X | X | | | X | X | X | | | | | | X | X | X | | |
| *Campostoma oligolepis* | Largescale stoneroller | X | | | | | | | | | X | X | | | | | X | X | X | | | | | | X | X | | | |
| *Cyprinella lutrensis* | Red shiner | X | | | X | | | | | | | | X | X | X | X | X | | | | | | | | | X | X | | |
| *Cyprinella spiloptera* | Spotfin shiner | X | X | | | | | | | | | X | | X | X | | X | X | | | | | | X | X | X | X | | |
| *Cyprinella venusta* | Blacktail shiner | X | | | | | | | | | | | | X | X | | X | | | | | | | X | | X | X | | |
| *Cyprinella whipplei* | Steelcolor shiner | X | X | | | | | | | | | X | | X | | | X | X | | | | | | X | X | X | X | | |
| *Ericymba buccata* | Silverjaw minnow | X | X | | | | | | | | X | X | X | X | | | X | | | | | | | | | X | X | | |
| *Erimystax dissimilis* | Streamline chub | | | | | | | | | | | X | | | | | X | | | | | | | | X | X | | | |
| *Erimystax x-punctatus* | Gravel chub | | X | | | | | | | | | X | | | | | X | | | | | | | | X | X | | | |
| *Hybognathus argyritis* | Western silvery minnow | X | | | | | | | | | | | | | X | | X | | | | | | | | | X | | | |
| *Hybognathus hayi* | Cypress minnow | X | X | | X | | | X | | | | | | X | | X | | | | | X | X | X | X | | | X | X | |
| *Hybognathus nuchalis* | Mississippi silvery minnow | X | X | | X | | | | | | | X | | X | X | X | X | | | | | | | | | X | X | | |
| *Hybognathus placitus* | Plains minnow | X | | | | | | | | | | | | | X | | X | | | | | | | | | X | | | |
| *Hybopsis amblops* | Bigeye chub | X | X | | | | | | | | | X | | | | | X | | | | | | | | | X | X | | |
| *Hybopsis amnis* | Pallid shiner | X | X | | | | | | | | | X | | X | | X | X | | | | | | | X | | | X | | |
| *Luxilus chrysocephalus* | Striped shiner | X | X | | | | | | | | X | X | | X | X | | X | X | | | | | | | X | X | X | | |
| *Luxilus cornutus* | Common shiner | | X | | | | | | | | X | X | | | | | X | X | | | | | | | X | X | X | | |
| *Luxilus zonatus* | Bleeding shiner | | | | | | | | | | | X | | | | | X | X | | | | | | | X | X | X | | |
| *Lythrurus fasciolaris* | Scarletfin shiner | X | X | | | | | | | | | X | | | | | X | X | | | | | | | | X | X | | |
| *Lythrurus fumeus* | Ribbon shiner | X | X | | | | | | | | | | | X | | X | X | | | | | | | | | | X | X | |
| *Lythrurus umbratilis* | Redfin shiner | X | X | | | | | | | | X | X | X | X | | X | X | | | | | | | X | | X | X | | |
| *Macrhybopsis gelida* | Sturgeon chub | X | | | | | | | | | | | | | X | | X | | | | | | | | | X | | | |
| *Macrhybopsis hyostoma* | Speckled chub | X | X | | | | | | | | | X | | | X | | X | | | | | | | | | X | | | |
| *Macrhybopsis meeki* | Sicklefin chub | X | | | | | | | | | | | | | X | | X | | | | | | | | | X | | | |
| *Macrhybopsis storeriana* | Silver chub | X | X | X | | | | | | | | X | | X | X | | X | X | | | | | | | | X | X | | |
| *Nocomis biguttatus* | Hornyhead chub | X | X | | | | | | | | | X | | | | | X | X | | | | | | | | X | X | | |
| *Nocomis effusus* | Redtail chub | | | | | | | | | | | X | | | | | X | X | | | | | | | X | X | X | | |
| *Notemigonus crysoleucas* | Golden shiner | X | X | X | X | | X | X | | | | X | | X | X | X | X | | | | X | X | X | X | | | | | |
| *Notropis ariommus* | Popeye shiner | | X | | | | | | | | | X | | | | | X | X | | X | | | | | | X | X | | |

*(table continued on next page)*

**(table 11 continued)**

| | | Occurrence | | Preferred habitat | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Common name** | **SNF** | **HNF** | **Reservoir** | **Floodplain lake & oxbow** | **Sinkhole ponds** | **Ponds** | **Wetlands** | **Cave stream** | **Springs** | **Upland headwater creek** | **Upland stream & river** | **Lowland headwater creek** | **Lowland stream & river** | **Big river** | **Organic debris/mud** | **Sand/gravel (0.08-3 in.)** | **Pebble/cobble (3-24 in.)** | **Boulder/bedrock (>24 in.)** | **Emergent vegetation/cover** | **Aquatic bed** | **Scrub-shrub** | **Forested** | **Instream shelter** | **Riffles** | **Glides** | **Pools** | **Backwaters** | **Embayments** |
| *Notropis atherinoides* | Emerald shiner | X | X | X | X | | | | | | X | | | X | X | X | X | X | | | | | | | | X | X | | |
| *Notropis blennius* | River shiner | X | X | X | X | | | | | | | | | | X | X | X | | | | | | | | | X | X | X | X |
| *Notropis boops* | Bigeye shiner | X | X | | | | | | | | | X | | | | | X | X | | X | | | | | | X | X | | |
| *Notropis buchanani* | Ghost shiner | X | X | | | | | | | | | X | | X | X | X | X | | | | | | | | | | X | X | X |
| *Notropis chalybaeus* | Ironcolor shiner | | X | | X | | | | | | | | | X | X | X | X | | | X | X | | | | | | X | X | X |
| *Notropis dorsalis* | Bigmouth shiner | X | | | | | | | | | X | X | | | | | X | | | | | | | | | X | X | | |
| *Notropis hudsonius* | Spottail shiner | X | | | | | | | | | | | | | X | | X | | | | | | | | | X | X | | |
| *Notropis ludibundus* | Sand shiner | X | X | | | | | | | | | X | | X | | | X | | | | | | | | | X | X | | |
| *Notropis maculatus* | Taillight shiner | X | X | | X | | | | | | | | | X | | X | X | | | | X | | X | X | | | X | X | |
| *Notropis nubilus* | Ozark minnow | X | | | | | | | | | | X | | | X | | X | X | | | | | | | | X | X | | |
| *Notropis photogenis* | Silver shiner | | X | | | | | | | | | X | | | | | X | X | | | | | | | | X | X | | |
| *Notropis rubellus* | Rosyface shiner | | X | | | | | | | | | X | | | | | X | X | | | | | | | | X | X | | |
| *Notropis shumardi* | Silverband shiner | X | X | | | | | | | | | | | X | X | | X | | | | | | | | | X | | | |
| *Notropis texanus* | Weed shiner | | | | X | | | | | | | | | X | X | X | X | | | X | X | | | | | | X | X | X |
| *Notropis volucellus* | Mimic shiner | X | X | | | | | | | | | X | | X | | | X | | | X | X | | | | | X | X | | |
| *Notropis wickliffi* | Channel shiner | X | X | | | | | | | | | | | | X | X | X | | | X | | | | | | X | X | X | X |
| *Opsopoeodus emiliae* | Pugnose minnow | X | X | | X | | | X | | | | X | | X | | X | X | | | | X | X | X | X | | | X | X | |
| *Phenacobius mirabilis* | Suckermouth minnow | X | X | | | | | | | | X | X | X | X | X | | X | X | | | | | | | X | X | | | |
| *Phenacobius uranops* | Stargazing minnow | | | | | | | | | | | X | | | | | X | X | | | | | | | X | X | | | |
| *Phoxinus erythrogaster* | Southern redbelly dace | X | X | | | | | | X | X | X | X | | | | X | X | | | | X | | | X | | X | X | | |
| *Pimephales notatus* | Bluntnose minnow | X | X | | | | | | | | X | X | X | X | X | X | X | X | | | X | | | X | | X | X | | X |
| *Pimephales promelas* | Fathead minnow | X | X | | X | | X | | | | X | X | X | X | X | X | X | | | | | | | X | | | X | X | |
| *Pimephales vigilax* | Bullhead minnow | X | X | X | | | | | | | | X | | X | X | | X | X | X | | | | | X | | X | X | | |
| *Platygobio gracilis* | Flathead chub | X | | | | | | | | | | | | | X | | X | | | | | | | | | X | | X | |
| *Pteronotropis hubbsi* | Bluehead shiner | X | | | X | | | | | | | | | | | X | | | | | X | X | X | X | | | | | |
| *Rhinichthys atratulus* | Blacknose dace | X | X | | | | | | | X | X | X | | | | | X | X | | | | | | X | X | X | | | |
| *Rhinichthys cataractae* | Longnose dace | X | | | | | | | | | | X | | | | | | X | | | | | | | X | | | | |
| *Semotilus atromaculatus* | Creek chub | X | X | | | X | | | X | X | X | X | X | X | | X | X | X | X | | X | | | X | | X | X | | |
| *Elassoma zonatum* | Banded pygmy sunfish | X | | | X | | | X | | | | | | | | X | X | | | | X | X | X | X | | | X | | |
| *Esox americanus* | Grass pickerel | X | X | X | X | | X | X | | | | X | | X | | X | X | X | | X | X | X | X | X | | | X | | |
| *Esox lucius* | Northern pike | X | X | X | | | X | | | | | | | | | X | X | | | X | X | | | X | | | X | | |
| *Esox masquinongy* | Muskellunge | | X | X | | | | | | | | X | | | | | X | X | X | X | X | | | X | | | X | | |
| *Esox niger* | Chain pickerel | | | X | X | | | X | | | | | | X | | X | X | | | | X | | X | X | | | X | | |
| *Fundulus catenatus* | Northern studfish | X | | | | | | | | | X | X | | | | | X | X | | X | | | | | | | X | | |
| *Fundulus dispar* | Starhead topminnow | X | | | X | | | X | | | | | | | | X | X | | | | X | | | | | | | | |
| *Fundulus notatus* | Blackstripe topminnow | X | X | | X | | | X | | | X | X | X | X | X | X | X | | | | X | | | | | | X | X | X |
| *Fundulus olivaceus* | Blackspotted topminnow | X | | | X | | | X | | | X | X | X | X | | | X | | | | X | | | | | | X | | |
| *Lota lota* | Burbot | | | | | | | | | | | X | | X | X | X | X | X | | | | | | X | | | X | | X |
| *Hiodon alosoides* | Goldeye | X | | X | | | | | | | | | | X | X | | X | | | | | | | | | X | X | | X |
| *Hiodon tergisus* | Mooneye | X | X | X | | | | | | | | X | | X | X | | X | | | | | | | | | X | X | | X |

*(table continued on next page)*

**(table 11 continued)**

| | | Occurrence | | Preferred habitat | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Species** | **Common name** | **SNF** | **HNF** | **Reservoir** | **Floodplain lake & oxbow** | **Sinkhole ponds** | **Ponds** | **Wetlands** | **Cave stream** | **Springs** | **Upland headwater creek** | **Upland stream & river** | **Lowland headwater creek** | **Lowland stream & river** | **Big river** | **Organic debris/mud** | **Sand/gravel (0.08-3 in.)** | **Pebble/cobble (3-24 in.)** | **Boulder/bedrock (>24 in.)** | **Emergent vegetation/cover** | **Aquatic bed** | **Scrub-shrub** | **Forested** | **Instream shelter** | **Riffles** | **Glides** | **Pools** | **Backwaters** | **Embayments** |
| *Ameiurus melas* | Black bullhead | X | X | X | X | | X | X | | | | X | X | X | X | X | X | | | | X | | | X | | | X | X | X |
| *Ameiurus natalis* | Yellow bullhead | X | X | X | X | | X | X | | | X | X | X | X | X | X | X | | | | X | | | X | | | X | X | X |
| *Ameiurus nebulosus* | Brown bullhead | X | X | X | X | | X | X | | | | X | | X | X | X | X | | | | X | | | X | | | X | X | X |
| *Ictalurus furcatus* | Blue catfish | X | | X | | | | | | | | X | | X | X | X | X | | | | | | | X | | X | X | X | X |
| *Ictalurus punctatus* | Channel catfish | X | X | X | X | | X | | | | | X | | X | X | X | X | X | | | | | | X | | X | X | X | X |
| *Noturus elegans* | Elegant madtom | | | | | | | | | | | X | | | | | X | X | | | | | | | X | X | | | |
| *Noturus eleutherus* | Mountain madtom | | X | | | | | | | | | X | | | X | | X | X | | | | | | | X | X | | | |
| *Noturus exilis* | Slender madtom | X | | | | | | | | | | X | | | | | X | X | | | | | | | X | X | | | |
| *Noturus flavus* | Stonecat | X | X | | | | | | | | | X | | | X | | X | X | X | | | | | | X | X | | | |
| *Noturus gyrinus* | Tadpole madtom | X | X | X | X | | | | | | | X | | X | | X | X | | | X | X | | | X | | | X | | |
| *Noturus miurus* | Brindled madtom | X | X | | | | | | | | | X | | X | | X | X | | | | | | | X | X | | X | | |
| *Noturus nocturnus* | Freckled madtom | X | X | | | | | | | | | X | | X | X | X | X | | | | | | | X | X | | X | | |
| *Noturus stigmosus* | Northern madtom | | X | | | | | | | | | X | | | X | X | X | X | | | X | | | X | X | X | | | |
| *Pylodictis olivaris* | Flathead catfish | X | X | X | | | | | | | | X | | X | X | X | X | X | | | | | | X | | | | | |
| *Atractosteus spatula* | Alligator gar | X | | | X | | | | | | | | | X | X | X | X | | | | | | | | | | | | |
| *Lepisosteus oculatus* | Spotted gar | X | | X | X | | | X | | | | | | X | X | X | X | | | | X | X | X | X | | | X | | |
| *Lepisosteus osseus* | Longnose gar | X | X | X | X | | | | | | | X | | X | X | X | X | | | X | X | | | X | | | X | | |
| *Lepisosteus platostomus* | Shortnose gar | X | X | X | X | | | | | | | | | X | X | X | X | | | X | X | | | X | | | X | | |
| *Morone chrysops* | White bass | X | | X | | | | | | | | X | | X | X | | X | X | | | | | | | | | X | | |
| *Morone mississippiensis* | Yellow bass | X | X | X | X | | | | | | | X | | X | X | | X | X | | | | | | | | | | | |
| *Ammocrypta clara* | Western sand darter | X | | | | | | | | | | X | | | X | | X | | | | | | | | | X | | | |
| *Ammocrypta pellucida* | Eastern sand darter | | X | | | | | | | | | X | | X | | | X | | | | | | | | | X | | | |
| *Crystallaria asprella* | Crystal darter | | | | | | | | | | | X | | | X | | X | | | | | | | | | X | | | |
| *Etheostoma asprigene* | Mud darter | X | | | X | | | X | | | | | | X | X | X | X | | | | | | | X | X | X | | | |
| *Etheostoma barbouri* | Teardrop darter | | | | | | | | | | X | X | | | | | X | X | | | | | | | | X | X | | |
| *Etheostoma bellum* | Orangefin darter | | | | | | | | | | | X | | | | | X | X | | | | | | | X | X | | | |
| *Etheostoma blennioides* | Greenside darter | | X | | | | | | | | | X | | | | | X | X | | X | X | | | | X | X | | | |
| *Etheostoma caeruleum* | Rainbow darter | X | X | | | | | | | | X | X | | | | | X | X | | | | | | | X | X | | | |
| *Etheostoma camurum* | Bluebreast darter | | X | | | | | | | | | X | | | | | X | X | | | | | | | X | | | | |
| *Etheostoma chlorosoma* | Bluntnose darter | X | X | | X | | | X | | | | | X | X | | X | X | | | | X | | | X | | | X | | |
| *Etheostoma crossopterum* | Fringed darter | | | | | | | | | | X | X | | | | | X | X | | | | | | | | X | X | | |
| *Etheostoma flabellare* | Fantail darter | X | X | | | | | | | | X | X | | | | | X | X | | | | | | | X | X | | | |
| *Etheostoma flavum* | Saffron darter | | | | | | | | | | | X | | | | | | X | | | | | | | | X | X | | |
| *Etheostoma gracile* | Slough darter | X | X | | X | | | X | | | | | X | X | | X | X | | | X | X | | | X | | X | X | | |
| *Etheostoma histrio* | Harlequin darter | | | | | | | | | | | X | | X | | X | X | | | | | | | X | X | X | | | |
| *Etheostoma kennicotti* | Stripetail darter | X | | | | | | | | | X | X | | | | | X | X | | | | | | | | X | X | | |
| *Etheostoma maculatum* | Spotted darter | | | | | | | | | | | X | | | | | X | X | X | | | | | | X | | | | |
| *Etheostoma microperca* | Least darter | | | | | | | | | X | X | | | | | X | X | | | | X | | | X | | | X | | |
| *Etheostoma nigrum* | Johnny darter | X | X | | | | | | | | X | X | | | | | X | X | | | | | | X | | X | X | | |
| *Etheostoma oophylax* | Guardian darter | | | | | | | | | | X | X | | | | | X | X | | | | | | | X | X | | | |

*(table continued on next page)*

**(table 11 continued)**

| Species | Common name | Occurrence: SNF | Occurrence: HNF | Preferred habitat: Reservoir | Floodplain lake & oxbow | Sinkhole ponds | Ponds | Wetlands | Cave stream | Springs | Upland headwater creek | Upland stream & river | Lowland headwater creek | Lowland stream & river | Big river | Organic debris/mud | Sand/gravel (0.08-3 in.) | Pebble/cobble (3-24 in.) | Boulder/bedrock (>24 in.) | Emergent vegetation/cover | Aquatic bed | Scrub-shrub | Forested | Instream shelter | Riffles | Glides | Pools | Backwaters | Embayments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Etheostoma proeliare* | Cypress darter | | | | | | | X | | X | | | X | | | X | X | | | | X | | | X | | | | | |
| *Etheostoma rafinesquei* | Kentucky darter | | | | | | | | | | X | X | | | | | X | X | | X | | | | | X | | X | | |
| *Etheostoma proeliare* | Cypress darter | X | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Etheostoma smithi* | Slabrock darter | | | X | | | | | | | X | | | | | | X | X | | | | | | | X | | X | | |
| *Etheostoma spectabile* | Orangethroat darter | X | X | | | | | | | | X | X | X | X | | | X | | | | | | | | X | X | X | | |
| *Etheostoma squamiceps* | Spottail darter | X | | | | | | | | | X | X | | | | | | X | | | | | | | X | | X | | |
| *Etheostoma stigmaeum* | Speckled darter | | | | | | | | | | | X | | | | | X | X | | | | | | | | X | X | | |
| *Etheostoma tecumsehi* | Shawnee darter | | | | | | | | | | X | | | | | | X | X | | | X | | | | X | X | X | | |
| *Etheostoma tippecanoe* | Tippecanoe darter | | X | | | | | | | | | X | | | | | X | X | | | | | | | X | | | | |
| *Etheostoma variatum* | Variegate darter | | X | | | | | | | | | X | | | | | X | X | | | | | | | X | X | | | |
| *Etheostoma virgatum* | Striped darter | | | | | | | | | | X | X | | | | | X | X | | | | | | | | X | X | | |
| *Etheostoma zonale* | Banded darter | | X | | | | | | | | | X | | | | | X | X | | | X | | | | X | X | | | |
| *Perca flavescens* | Yellow perch | | X | X | | | | | | | | | | | X | X | X | | | | X | | | | | | X | X | X |
| *Percina caprodes* | Logperch | X | X | X | X | | | | | | | X | | X | X | X | X | X | | | | | | | | X | X | | |
| *Percina copelandi* | Channel darter | | X | | | | | | | | | X | | | X | | X | | | | | | | | | X | | | |
| *Percina evides* | Gilt darter | | | | | | | | | | | X | | | X | | X | X | | | | | | | X | X | | | |
| *Percina maculata* | Blackside darter | X | X | | | | | | | | X | X | X | X | | X | X | X | | | | | | | | X | X | | |
| *Percina phoxocephala* | Slenderhead darter | X | X | | | | | | | | | X | | | X | | X | X | | | | | | | X | X | | | |
| *Percina sciera* | Dusky darter | X | X | | | | | | | | | X | | X | | X | X | | | | | | | X | | X | X | | |
| *Percina shumardi* | River darter | X | X | | | | | | | | | X | | X | | | X | X | X | | X | | | | X | X | | | |
| *Percina stictogaster* | Frecklebelly darter | | | | | | | | | | | X | | | | | X | X | | X | | | | X | | X | | | |
| *Percina vigil* | Saddleback darter | | | | | | | | | | | X | | X | | | X | | | | | | | | X | X | | | |
| *Stizostedion canadense* | Sauger | X | X | X | | | | | | | | X | | X | X | | X | X | | | | | | X | | X | | | |
| *Stizostedion vitreum* | Walleye | X | | X | | | | | | | | X | | X | X | | X | X | | | | | | X | | X | X | | |
| *Percopsis omiscomaycus* | Trout-perch | X | X | | | | | | | | | X | | | | | X | | | | | | | | | X | X | | |
| *Ichthyomyzon bdellium* | Ohio lamprey | | X | X | | | | | | | | X | | X | | X | X | X | | | | | | X | X | X | X | | |
| *Ichthyomyzon castaneus* | Chestnut lamprey | X | X | X | | | | | | | | X | | X | | X | X | X | | | | | | X | X | X | X | | |
| *Ichthyomyzon fossor* | Northern brook lamprey | | X | | | | | | | | | X | | | | X | X | X | | | | | | X | X | X | X | | |
| *Ichthyomyzon unicuspis* | Silver lamprey | X | X | X | | | | | | | | X | | X | | X | X | X | | | | | | X | X | X | X | | |
| *Lampetra aepyptera* | Least brook lamprey | X | X | | | | | X | | X | X | X | X | X | | X | X | X | | | | | | X | X | X | | | |
| *Lampetra appendix* | American brook lamprey | | | | | | | | | | | X | | | | X | X | X | | | | | | X | X | X | | | |
| *Polyodon spathula* | Paddlefish | X | | X | X | | | | | | | X | | X | X | X | X | X | | | | | | | | | X | X | X |
| *Aplodinotus grunniens* | Freshwater drum | X | X | X | X | | | | | | | X | | X | X | X | X | | | | | | | | | | X | X | X |
| *Umbra limi* | Central mudminnow | X | X | | X | | | X | | X | | | | | | X | X | | | | X | | | X | | | | | |

Unique and rare aquatic habitats for fishes in the area include cave streams, springs, wetlands, and floodplain lakes and oxbows. An outstanding example of all these habitats in one location is the LaRue-Pine Hills Research Natural Area, Union County, Illinois. Other especially scenic sites and those with excellent water quality and high aquatic diversity and found within the two national forests include the middle Blue River system and portions of the East Fork White River in the Hoosier, and the upper Clear Creek system and Big and Lusk Creeks in the Shawnee.

### Mussel Habitat

Most freshwater mussels inhabit permanent flowing bodies of water (i.e., riverine system) but some vary considerably with respect to their microhabitat occurrences (Parmalee 1967, Cummings and Mayer 1992). The aquatic assessment area encompasses a variety of local habitats and environments that support a diverse native freshwater mussel fauna. Those hydrologic units (e.g., lower Ohio, lower Ohio Bay, and lower Ohio-Little Pigeon) that border major ecotones of physiographic regions provide a mixture of hilly upland areas and broad alluvial valleys. Within these areas, habitats ranging from small upland streams to large and small rivers, sloughs, and impoundments (artificial ponds and reservoirs) support a variety of mussel species adapted to different habitat types.

Habitat occurrences of native mussel species recorded within the assessment area are presented in table 9. Species diversity was greatest in those hydrologic units containing portions of medium and large rivers (e.g., lower Tennessee, lower Cumberland, upper Green, and lower Ohio). In fact, 64 percent of the mussel species reported from the assessment area inhabit primarily medium and large rivers. Examples of this riverine mussel fauna include snuffbox, fanshell, plain pocketbook, threehorn wartyback, hickorynut, ring pink, sheepnose, mapleleaf, elephant ear, and ebonyshell. These and other riverine species are generally most successful in sand, gravel, or mixed sand-gravel substrates (table 9). Riverine species (most species in Ambleminae and Lampsilinae, table 9) that live in swift current develop thick shells, heavy hinge teeth, and well-developed muscle insertion scars (Parmalee 1967). In larger rivers, mussel distributions vary with depth, current velocity, substrate composition, and other physical factors affecting their development. For example, according to Parmalee (1967), in fast flowing sections of the Mississippi River, mussels can be found at depths of greater than 15 feet. Williams and Schuster (1989) reported that most mussels in large rivers prefer habitat that has a substrate of sand and fine to coarse gravel in depths of 8 to 20 feet in enough current to prevent excessive siltation.

Native freshwater mussels reported from the assessment area that are particular to creek, headwater, slough, or pond habitats with little or no flow include pondhorn, flat floater, cylindrical papershell, paper pondshell, white heelsplitter, giant floater, and pondmussel (table 9). These species (most species in Anodontinae, table 9) differ morphologically from the riverine species in having thin shells, shallow muscle scars, and reduced or absent hinge teeth (Parmalee 1967). Mussels occurring in lentic habitats in mud or silt substrates also are often limited to shallow water (above the epilimnion) because of their relatively poor tolerance of hypoxia (McMahon 1991). Other mussels are ubiquitous throughout the assessment area and occur in a variety of different habitat types: Wabash pigtoe, threeridge, plain pocketbook, fatmucket, and fragile papershell (table 7). These species have been reported to be adaptable to varying water depths and can tolerate impoundments (Cummings and Mayer 1992, Parmalee 1967).

## Crayfish Habitat

Crayfishes in the assessment area occupy all five major habitat types defined and outlined in Hobbs (1981). The assessment area has species that occupy open water habitats, species exhibiting all three types of burrowing behaviors, and those that dwell in cave streams—both troglobites and troglophiles (table 10).

According to Hobbs (1981), open-water dwellers can be found in permanent or nearly permanent lentic and lotic environments. Most construct simple burrows out of benthic debris or seek cover under rocks or coarse woody debris. Although these crayfishes are generally found in the main body of water, all will burrow in the substrate down to the water table to seek cover in the event of loss of standing water due to drought. They also may burrow to avoid freezing in winter. This burrowing behavior is similar to tertiary burrowers (see below). In the assessment area, 18 species of crayfish occupy open-water habitats: 16 of the genus *Orconectes* and 2 of the genus *Cambarus* (table 10). Eight open-water crayfish species are found in the watersheds that drain the Shawnee National Forest. The watersheds draining the Hoosier National Forest are home to only two crayfish species that have been recorded from open-water habitats.

Primary burrowers are crayfish species that excavate a complex system of tunnels that generally contact the water table in at least one place. These species rarely leave their burrows that seldom come into contact with permanent bodies of surface water. Burrows can be located well inland from such bodies of water, a location that may preclude them from protection by forested filter strips designed to minimize the impacts of logging and recreation on national forest watersheds (see below for description of filter strips). Three primary burrowers occur in the assessment area—*Cambarus diogenes*, *Fallicambarus fodiens*, and *Procambarus gracilis* (table 10). All three of these species are found in the watersheds that drain the Shawnee National Forest. Only *C. diogenes* has been reported in watersheds that drain the Hoosier National Forest.

Secondary burrowers dig simple, straight-shafted tunnels in areas that are prone to flood during certain times of the year such as roadside ditches, borrow pits, swamp pools, and other depressions. These burrowers seldom live in saturated areas where the water table is at or near the soil surface for most of the year. The tunnels of secondary burrowers often do not contact the water table but generally are excavated in moist soils ensuring that the relative humidity of the air in the burrow remains near 100 percent. These species may remain torpid in their burrows during times of drought. They also leave their burrows and spend much of the year in open-water habitats, particularly when the low-lying areas in which they live flood. There are two secondary burrowing species in the assessment area—*Cambarus ortmanni* and *Procambarus viaeviridis* (table 8). The latter species is found in the watersheds that drain the Shawnee National Forest. There are no secondary burrowers in the watersheds of the Hoosier National Forest.

Tertiary burrowing crayfishes are those that spend most of their lives in open water but retreat to burrows during periods of inactivity, to hide from predators, to avoid freezing in the winter, to lay and brood eggs, or to avoid desiccation during low water periods. In contrast to the limited burrowing activities of open-water species, tertiary burrowers may construct elaborate burrows that may or may not come into direct contact with open water. Tertiary burrowers maintain their burrows for most of the year whereas open-water species burrow only when absolutely necessary. The demarcation between open-water species and tertiary burrowers can at times be very narrow, hence most species in table eight are listed as both. Nine tertiary burrowing species are found in the assessment area—two in the genus *Cambarellus*, one in the genus *Barbicambarus*, two in the genus *Cambarus*, two in the genus *Orconectes*, and two in the genus *Procambarus* (table 10). Five of those species are found in watersheds that drain the Shawnee National Forest and two are found in the watersheds of the Hoosier National Forest.

Four species of crayfish in the assessment area either must live in caves (troglobitic) or frequent caves (troglophilic) during their lifetimes (table 10). *Orconectes pellucidus* and *O. inermis* are eyeless, non-pigmented, troglobitic species found in caves of karst formations in western Kentucky and south-central Indiana. *Cambarus tenebrosus* is a troglophilic species that frequents rocky headwater streams and springs, hence its common occurrence in caves. *Cambarus bartonii* is found in a diversity of habitats including caves, springs, riffles, stream pools, and rarely impoundments. *Cambarus tenebrosus* is the only cave-dwelling species found in the Shawnee National Forest. *Cambarus tenebrosus* and *O. inermis* are found in watersheds of the Hoosier National Forest. Eberly (1955) listed *O. pellucidus* as occurring in several counties that overlap the Hoosier National Forest, but Hobbs et al. (1977) reported no valid records of this species in Indiana.

### Implications and Opportunities

Habitat degradation has been a major factor involved in the decline of freshwater mussel and fish populations. For example, construction of dams, channelization, and improper maintenance of riparian zones have resulted in changes to stream environments that are unfavorable to most mussel and some fish species, including increased sedimentation, changed stream hydrology, and reduced habitat heterogeneity. The use of best management practices for timber harvest and road building would minimize impacts to adjacent streams. To be effective, habitat protection and good conservation practices must also extend beyond the boundaries of Federal lands to include entire watersheds. This requires the cooperation of all agencies that share responsibilities for public watersheds and their faunas, as well as riparian landowners. Empirical studies directed at crayfishes are needed to determine the effects of habitat degradation on them.

The activities and home ranges of both primary and secondary burrowing crayfishes can occur great distances from surface bodies of permanent flowing or standing water. Maintenance of vegetative filter strips of varying widths adjacent to lakes, wetlands, perennial streams, and intermittent streams in which logging, road construction, and recreational activities occur will help minimize the potential negative effects those practices might have on aquatic environments and their inhabitants. Primary and secondary burrowing crayfishes, although aquatic species, should perhaps be considered terrestrial species because of their potential to live well beyond the relative protection of designated filter strips. If these species are not considered terrestrial, specific concessions could be made to ensure monitoring and conservation. Restrictions on road building, logging activities, and recreational activities in areas where crayfish burrows are present might benefit these species. Frequent burrow destruction and soil compaction could hinder crayfish burrowing activity, forcing populations to move or trapping them below ground for potentially lethal lengths of time.

As noted earlier, there are no federally listed crayfishes in the assessment area, but three crayfishes in the Shawnee National Forest are listed as endangered in the State of Illinois—*O. indianensis, O. kentuckiensis*, and *O. placidus*. The Forest Service has specific policies for creating stream and river fords (in association with road building and logging activities) within the national forests to minimize the negative effects of the fords on aquatic ecosystems. Crayfishes are relatively immobile compared to other aquatic organisms (e.g., fishes) and are less able to evade fording vehicles.

Much of the assessment area is underlain by karst formations with numerous caves in limestone and other soluble rock (Culver et al. 1999). Cave ecosystems are fragile and complex and can be severely damaged by: (1) water projects such as damming, diverting, and well drilling; (2) land development such as paving, excavating, and filling; (3) nutrient loss from exclusion or loss of important species; (4) nutrient enrichment from sewage, agricultural runoff, slash from forest cutting, and excessive runoff from logged areas; (5) introduction of exotic and pest species; (6) chemical pollution; (7) overcollection; (8) overvisitation; and (9) isolation caused by fragmentation of cave networks from all factors mentioned previously (Elliot 2000). Although many other terrestrial and aquatic organisms depend on cave habitats for survival, the troglophilic and troglobitic fishes and crayfishes in the assessment area could serve as relatively conspicuous and easily monitored indicator species representing the relative health of the caves of the assessment area. Currently, neither of the two cave-associated crayfish species (i.e., *Orconectes inermis* and *O. pellucidus*), only one of which is documented to occur in the Hoosier National Forest, is listed as a Management Indicator Species (MIS) (table 5). These species could be monitored as an indicator of the effects of logging and recreational activities on caves of the assessment area.

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# Terrestrial Animal Species in the Hoosier-Shawnee Ecological Assessment Area

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## ABSTRACT

We reviewed the current status of amphibians, reptiles, birds, mammals, and selected invertebrates within the Hoosier-Shawnee Ecological Assessment Area. Species selected for this evaluation included those most commonly considered with respect to land management, namely threatened and endangered species, those species with viability concerns, the unique community of organisms that use cave and karst habitats, avian species in general, neotropical migrant land birds in particular, and species within the assessment area valued as game species. We evaluated a total of 452 species: 158 birds, 40 mammals, 23 amphibians, 32 reptiles, and 199 invertebrates. Five species listed as either federally threatened or endangered inhabit, or may inhabit, the assessment area. The Hoosier-Shawnee Ecological Assessment Area is particularly notable for its rich cave and karst fauna, and for the diversity of its avian inhabitants.

## INTRODUCTION

The Hoosier-Shawnee Ecological Assessment Area is encompassed by the Central Hardwoods Bird Conservation Region (BCR24) and lies within the Highland Rim and Lexington Plain physiographic regions. The amound of land area held publicly, and the importance of these lands for conservation, have resulted in the designation of 13 internationally Important Bird Areas (IBAs) within or adjacent to the assessment area. In addition to a diverse terrestrial fauna, the area supports rare plant communities and a cave and karst fauna that enlarges with each effort to characterize these species. In contrast, at least with respect to the Hoosier and Shawnee National Forests, private lands are widely interspersed throughout these publicly held natural areas. Population centers adjacent to the assessment area include St. Louis, Missouri; Indianapolis, Indiana; and, Louisville, Kentucky. This cursory picture of the assessment area suggests both the importance and challenge of public land management within the context of regional growth and development, recreational use of public lands, and the subject of this chapter, the conservation of terrestrial wildlife.

This chapter documents the current status of terrestrial animal species that occur, or are likely to occur, within the Hoosier-Shawnee Ecological Assessment Area. This evaluation included those amphibians, reptiles, birds, mammals, and selected invertebrates most commonly considered with respect to land management: namely, threatened and endangered species, those species with viability concerns, the unique community of organisms that use cave and karst habitats, avian species in general, neotropical migrant land birds in particular, and species within the assessment area valued as game species. The first section of this report addresses threatened and endangered species; the remaining species groups follow in turn. We conclude this evaluation with habitat suitability analyses of the assessment area for white-tailed deer (*Odocoileus virginianus*), northern bobwhite quail (*Colinus virginianus*), and bobcat (*Lynx rufus*).

## THREATENED AND ENDANGERED SPECIES

Of the species listed as federally endangered within the assessment area (table 1), the Indiana bat (*Myotis sodalis*) is the most broadly distributed; the interior least tern (*Sterna antillarum*) is likely the most restricted of the endangered vertebrates. Of the endangered species within the assessment area, populations of the gray bat (*Myotis grisescens*) have demonstrated the greatest degree of stability or recovery. The eastern massasauga (*Sistrurus catenatus catenatus*), a candidate for federal listing, may now be extirpated within the assessment area. The American burying beetle (*Nicrophorus americanus*) currently has no known records of occurrence within the assessment area. In spite of the acknowledged rarity of these species, most counties in the region have some current record of occurrence of at least one of the five federally listed species (fig. 1).

**Table 1.** Federally listed threatened or endangered terrestrial animal species present in the Hoosier-Shawnee Ecological Assessment Area.

| Scientific name | Common name | Status | Trend[1] |
|---|---|---|---|
| **Reptiles** | | | |
| *Sistrurus catenatus catenatus* | Eastern massasauga | Candidate | Declining |
| **Birds** | | | |
| *Haliaeetus leucocephalus* | Bald eagle | Threatened | Increasing |
| *Sterna antillarum athalassos* | Least tern (interior) | Endangered | Stable |
| **Mammals** | | | |
| *Myotis grisescens* | Gray myotis | Endangered | Increasing |
| *Myotis sodalis* | Indiana bat | Endangered | Decreasing |
| **Invertebrates** | | | |
| *Nicrophorus americanus* | American burying beetle | Endangered | Stable |

[1] USDI Fish and Wildlife Service (1996).

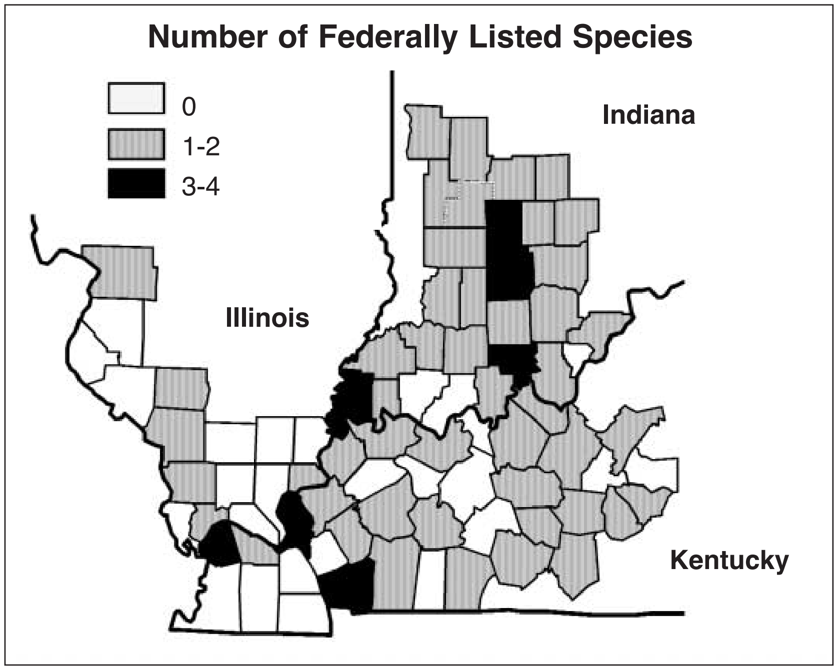


**Figure 1.** The distribution of federally threatened or endangered terrestrial animal species by county in the assessment area.

### Federally Endangered Species

#### Interior least tern

The interior least tern historically inhabited major Midwest river systems that would have included the Arkansas, Missouri, Ohio, Mississippi, Red, Rio Grande, and Wabash Rivers. Early commercial exploitation in the form of plume hunting, habitat loss due to development, and recreational use of gravel bars used as breeding habitats have been principal factors contributing to the endangerment of the interior least tern.

Subspecies of the least tern were apparently abundant through the late 1880s but were regionally extirpated as a consequence of commercial plume hunting. The Migratory Bird Treaty Act of 1918 subsequently provided this and similar species some protection from commercial exploitation. However, the association of the least tern with dry exposed gravel bars as nesting habitat, recreational disturbance of these habitats, and the desirability of adjacent areas for housing development led to a rapid decline of tern populations beginning in the 1940s. Susceptibility to predation, river channelization, irrigation diversion, and the construction of dams in the interior United States have also contributed to the loss of tern nesting habitat.

The status of the interior least tern is unclear within the assessment area. Kentucky records include Ballard, Carlisle, Fulton, Hickman, Livingston, and Union Counties along the Ohio River (Kentucky Department of Fish and Wildlife Resources 2001a, NatureServe 2002); in Illinois, terns may be restricted to Alexander, Gallatin, Jackson, and Pope Counties (Herkert 1992, NatureServe 2002). The single remaining Indiana breeding colony uses the gravel-covered dike of Gibson Lake within the property boundaries of the Cinergy Corporation's Gibson Generating Station (Indiana Division of Fish and Wildlife 2003).

### Indiana bat

Indiana bats occur throughout the Midwestern and Eastern United States; records of occurrence suggest a current distribution encompassing 27 states. Surveys of hibernacula in 2001 suggest a rangewide population of approximately 380,000 Indiana bats (Clawson 2002). This represents a rangewide population decline of 57 percent, down from 880,000 individuals since surveys began after the Indiana bat was listed in 1967 (Clawson 2002).

Numbers of bats have declined across their range, particularly in Kentucky. Between 1960 and 2001, the number of bats observed in Kentucky hibernacula declined by approximately 200,000 individuals. Outside of Kentucky, however, the number of Indiana bats within the Midwest States appears to have increased within the last decade. Indiana populations increased from approximately 160,000 bats in 1960 to an estimated 173,100 bats in 2001. Over the same period, numbers of Indiana bats increased from an estimated 14,800 to 19,300 in Illinois (Clawson 2002). In the 10 years between 1990 population estimates and 2000/2001 surveys, the number of hibernating Indiana bats declined from an estimated 78,700 to 47,900 in Kentucky, while increasing from 14,900 to 19,300 in Illinois, and from 163,500 to 173,100 in Indiana. These most recent trends suggest some degree of stability of Indiana and Illinois populations.

Currently, half of all known Indiana bats occupy hibernacula within the State of Indiana. Indiana and Kentucky each contain three of the nine Priority One Hibernacula, which contain more than 85 percent of the known population of Indiana bats. Illinois, Indiana, and Kentucky all harbor Priority Two and Priority Three Hibernacula (USDI Fish and Wildlife Service 1999a; table 2). Priority One Hibernacula support more than 30,000 wintering bats; Priority Two Hibernacula support between 500 and 30,000 bats; and, Priority Three Hibernacula support fewer than 500 wintering bats.

Persecution, intentional and inadvertent human disturbance of hibernating bats, and vandalism to caves have all contributed to Indiana bat declines. In Kentucky, the exclusion of Indiana bats from caves and changes in airflow due to improper cave gates and structures have also contributed to declines. Bats inhabiting mines have been lost in the collapse of mine ceilings (Brady et al. 1983). In addition to the bats' apparent sensitivity to cave microclimate, and the role of disturbance, simplification of landscapes (USDI Fish and Wildlife Service 1999a), and accumulation of pesticide residues may also influence Indiana bat populations (Brady et al. 1983).

### Gray bat

The gray myotis occurs throughout the cave region of the Eastern and Central United States.

Populations are found in Alabama, northern Arkansas, Kentucky, Missouri, and Tennessee. Fewer populations occur in northwestern Florida, western Georgia, southwestern Kansas, southern Indiana, southern and southwestern Illinois, northeastern Oklahoma, northern Mississippi, and western Virginia.

From the 1960s to early 1980s, this species declined in abundance by at least 50 percent; listing in 1976 arrested its decline (Brady et al. 1982, Tuttle 1979). Although not secure, the rangewide population appears stable and possibly has increased (Bat Conservation International 2001). The status of the gray myotis varies from imperiled to critically imperiled throughout the assessment area, suggesting that the species is particularly vulnerable. Approximately 95 percent of the known population of the gray myotis hibernates in only nine caves. One of these, the Jesse James Cave, is located within the assessment area in southwestern Kentucky. This cave is listed as a Priority One Hibernacula in the Gray Bat Recovery Plan (Brady et al. 1982).

High site fidelity makes the gray myotis particularly vulnerable to the factors that have endangered other bat populations, namely human disturbance and vandalism. The large proportion of the population that now occupies comparatively few sites further endangers this species. Perhaps more so than other bats, the gray myotis may be associated with streams and wetlands (Brady et al. 1982). Consequently, recovery of gray myotis populations may necessitate associated stream and wetland protection or enhancement.

**Table 2.** Kentucky, Illinois, and Indiana counties within or adjacent to the Hoosier-Shawnee Ecological Assessment Area that contain known Indiana bat hibernacula.

| | | |
|---|---|---|
| **Kentucky** | | |
| Adair | Edmonson | Logan |
| Allen | Fulton | McCracken |
| Ballard | Grayson | Meade |
| Barren | Hardin | Taylor |
| Bullitt | Hart | Trigg |
| Caldwell | Henderson | Union |
| Calloway | Hickman | Warren |
| Carlisle | Jefferson | |
| Daviess | Livingston | |
| **Illinois** | | |
| Alexander | Johnson | Pulaski |
| Hardin | Perry | Saline |
| Jackson | Pope | Union |
| **Indiana** | | |
| Clark | Jefferson | Owen |
| Crawford | Lawrence | Washington |
| Greene | Monroe | |
| Harrison | Orange | |

### American burying beetle

The American burying beetle is a large (1.5 inch; 4 cm) strikingly colored member of the carrion beetle family (Silphidae). Adults are a glossy black and bear bright orange wing bands, a similar bright orange shield-like area behind the head, and another bright orange area between their eyes. Carrion beetles function as environmental scavengers that recycle decaying animal material. Reproduction involves the laying of eggs in a chamber formed within a small decaying animal that the beetle subsequently buries. Both sexes attend young. This species formerly occurred throughout temperate eastern North America. American burying beetles once were recorded within at least 150 counties of 35 of the Eastern and Central United States as well as portions of southern Ontario, Quebec, and Nova Scotia. Natural populations of the American burying beetle now occur in only four States: Nebraska, Rhode Island, Oklahoma, and Arkansas. The last known recorded dates of collection for this species within States in the assessment area were 1958 in Illinois, 1965 in Indiana, and 1974 in Kentucky (USDI Fish and Wildlife Service 1991). The American burying beetle is currently thought to be extirpated in the assessment area.

Habitat fragmentation is thought to be a leading cause of extirpation of American burying beetles. Fragmentation of the midwestern landscape has likely resulted in decreased availability of items

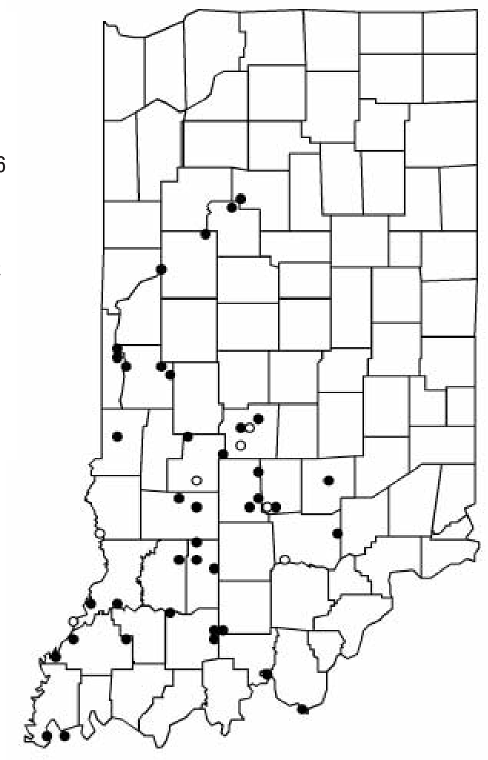

**Figure 2.** The location of bald eagle nests in the State of Indiana during 2002 (Indiana Division of Fish and Wildlife 2003). During 2002, the state's 26 bald eagle nests fledged a total of 45 young. Closed circles represent nests active during 2002; open circles represent inactive nests.

of small carrion (prey) for the American burying beetle, subsequently influencing the reproductive success of this species. Concurrently, as a result of number of factors, the density of vertebrate mesopredators and scavengers that may compete with the American burying beetle for carrion has likely increased. This would include such species as American crow (*Corvus brachyrhynchos*), raccoon (*Procyon lotor*), opossum (*Didelphis marsupialis*), and striped skunk (*Mephitis mephitis*).

## Federally Threatened Species

### Bald eagle

Before European settlement, the bald eagle likely nested throughout the Hoosier-Shawnee assessment area. The dependence of settlers on wood products resulted in widespread deforestation that drastically altered and reduced habitat suitable for eagles. Advancing settlement resulted in the extirpation of nesting eagles within Midwestern States by the early 1900s. The widespread use of industrial pesticides, particularly dichloro-diphenyl-trichloro-ethane (DDT) in the 1950s and 1960s, contributed to the further decline of the eagle. The continental ban of the use of DDT in 1972 resulted in improved reproductive performance of eagles across their range. Indiscriminate persecution by shooting (Herkert 1992) and lead poisoning related to the ingestion of shot (Buehler 2000) remain sources of eagle mortality.

Protection of the species, wetland restoration, and wildlife management efforts directed at reintroduction have resulted in a resurgence of eagles. In Indiana, restoration of the bald eagle began within the assessment area in the Lake Monroe watershed. The Indiana Division of Fish and Wildlife released 73 eaglets between 1985 and 1989 in the effort to re-establish a breeding population in Indiana. All three States within the assessment area now support nesting eagles. The first recent record of nesting in Kentucky occurred in 1989 (Kentucky Department of Fish and Wildlife Resources 2001a) ; nest records now include 32 counties in Kentucky. Eagles now nest in 14 Illinois counties; at least 10 nest records occur within the assessment area in Illinois. In 2002, Indiana bald eagles fledged 45 young from 26 nests (Indiana Division of Fish and Wildlife 2003, fig. 2).

Bald eagles remain particularly associated with major river systems such as the Illinois, Mississippi, and Ohio Rivers; most nests in Indiana are located in the riparian areas of the Wabash and White Rivers. Wetland restoration, including restoration of bottomland and floodplain forests, and land use planning designed to ensure the future viability of wetland and riparian areas will likely provide the best long-term support necessary to maintain the resurgence of the bald eagle within the assessment area.

As a result of rangewide resurgence of bald eagle populations, the status of the bald eagle was downgraded from endangered to threatened in 1995 (USDI Fish and Wildlife Service 1995). In 1999, the Fish and Wildlife Service proposed to delist the bald eagle (USDI Fish and Wildlife Service 1999b).

## Candidate Species

### Eastern massasauga rattlesnake

The range of the eastern massasauga rattlesnake historically extended into southern Illinois and Indiana and included the Midwestern States of Iowa, Michigan, Minnesota, Missouri, Nebraska, New York, Ohio, Pennsylvania, and Wisconsin. There is no current record of occurrence within the assessment area for the eastern massasauga; the most recent record (1986) is that of a declining population in Madison County, Illinois (Szymanski 1998).

Early species accounts suggest that massasaugas were once common throughout the Midwest. Formerly described as extremely abundant in Illinois (Hay 1893), only 7 of 25 historic populations persist. Two of these populations are considered vulnerable, three are declining, and the population trend of the remaining two is unknown (Szymanski 1998). The species occurs across the northern half of Indiana but is no longer known to occur in Indiana's portion of the assessment area. One historical record of occurrence, lacking any supporting documentation, exists for the Hoosier National Forest.

The association of massasaugas with wetlands and wet prairies, combined with the loss of these habitats and fragmentation of remaining habitats, is the greatest contributing factor to the decline of the eastern massasauga rattlesnake. Both Indiana and Illinois have lost at least 85 percent of their presettlement wetlands (Dahl 1990). Upland habitats adjacent to wetlands have also been lost or fragmented, preventing the access to wetland areas necessary to sustain viable massasauga populations. Like other rattlesnakes, this species has also been subject to both persecution and illegal collection.

## TERRESTRIAL SPECIES OF VIABILITY CONCERN

Species were considered to be of viability concern based primarily on their Heritage Status Rank (NatureServe 2002). These ranks estimate the relative imperilment of taxa based on the conservation status ranking system developed by The Nature Conservancy and the Natural Heritage Network (table 3). In general, species were considered to be of viability concern if they ranked of global (G1-G3) or state viability concern (S1-S3).

Generalized habitat associations were reported for all species of global viability concern. Multiple habitat associations were listed for species where appropriate, but no attempt was made to rank the relative importance of multiple habitat associations. Generalized habitat associations included wetland/aquatic, savanna/glade, shrub/sapling, forest, grassland, agriculture, outcrops/cliffs, and cave habitats.

**Table 3.** Conservation status ranking system. Ranks prefaced with G refer to the conservation status of a species across its global range (G1-G5); ranks prefaced with S refer to the conservation status of a species within a state (S1-S5). For example, a species ranked as 'G3S1' would be characterized as globally rare and state critically imperiled.

| Qualifier | Explanation |
|---|---|
| G | Global rank |
| S | State rank |
| 1 | Critically imperiled due to extreme rarity or imperiled due to a biological factor rendering species demonstrably vulnerable to extinction. |
| 2 | Imperiled due to rarity or imperiled due to a biological factor rendering species vulnerable to extinction. |
| 3 | Rare or localized distributions throughout range, vulnerable to local extirpation. |
| 4 | Species apparently secure throughout its range. |
| 5 | Species of widespread distribution, abundant, secure. |
| ? | Rank uncertain |
| U | Unranked |
| T | Rank of recognized subspecies |
| B | Species rank within its breeding range |
| N | Species rank within its non-breeding range |
| Z | Occurs as state migrant |
| X | Presumed extirpated |
| H | Possibly extirpated |
| R | Reported, unverified |
| P | Potential, no record of occurrence |
| A | Accidental occurrence |

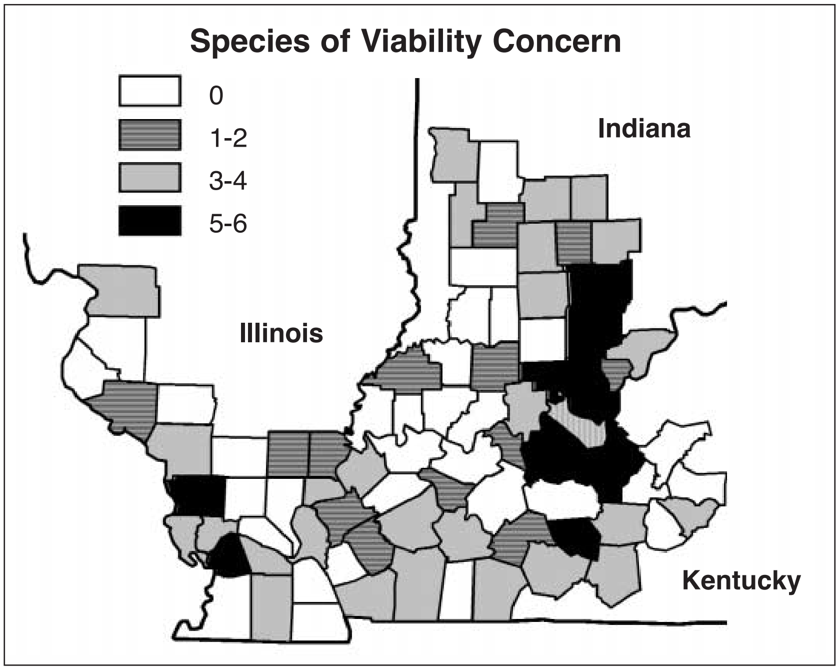


**Figure 3.** The numbers of terrestrial vertebrate species determined to be of global viability concern based on their Heritage Status Ranks by county in the assessment area.

Descriptions of species distributions within and adjacent to the assessment area relied upon State natural heritage databases. Invertebrate distributions were not reported due to lack of available information for these species.

## Species of Global Viability Concern

In total, 41 terrestrial species are considered to be of global viability concern (table 4). These species are ranked as critically imperiled (G1), imperiled (G2), or globally rare (G3). Two amphibians are considered to be of global viability concern: the green salamander (*Aneides aeneus*) and the eastern hellbender (*Cryptobranchus alleganiensis alleganiensis*). Reptiles considered to be of global viability concern include four species associated with wetland habitats: Kirtland's snake (*Clonophis kirtlandii*), alligator snapping turtle (*Macroclemys temminkii*), copperbelly watersnake (*Nerodia erythrogaster neglecta*), and eastern massasauga rattlesnake. Except for the Allegheny woodrat (*Neotoma magister*), all mammals considered to be of global viability concern are bats (tables 4, 5).

Of the 14 vertebrate species of global viability concern, 12 have been recorded in counties that include national forest property (fig. 3). The green salamander occurs only in counties associated with the Hoosier National Forest. Counties associated with the Hoosier contain all but three of the terrestrial vertebrate species considered to be of global viability concern: least tern, eastern small footed myotis (*Myotis leibii*), and alligator snapping turtle. There are no records of occurrence on the Shawnee National Forest for the green salamander, Kirtland's snake, eastern massasauga rattlesnake, Bachman's sparrow (*Aimophila aestivalis*), Allegheny woodrat, interior least tern, or eastern small-footed myotis. Of the 14 vertebrates considered to be of global viability concern, 9 have some association with wetland habitats. Five mammalian species of global viability concern are bats.

More so than any other taxa, invertebrates have historically not been considered in conservation planning largely due to the paucity of data regarding their status. At least 159 invertebrates inhabiting the assessment area are of global viability concern (table 4, 5); 134 of these species are associated with cave and karst habitats. With concerted sampling effort, it is likely that these numbers will increase. Of these 159 terrestrial and cave-associated aquatic invertebrate species of global viability concern, 74 were observed within the proclamation boundaries of the Hoosier and Shawnee National Forests. All but 1 of the 74 invertebrate species were located on the Hoosier National Forest. Ten of those invertebrate species are associated with barrens ecosystems on the Hoosier and 60 species (81%) are associated with cave and karst systems. The predominance of bats and invertebrates as species of global viability concern indicates the relative importance of cave and karst habitats within the assessment area.

## Species of State Viability Concern

An additional 172 terrestrial species are of viability concern at the State level. These species are considered rare (S3) to critically imperiled (S1) within at least one of the States of the assessment area (Illinois, Indiana, Kentucky).

**Table 4.** Terrestrial animal species with global viability concern, their global ranks, and associated habitats in the Hoosier-Shawnee Ecological Assessment Area.

| Scientific name | Common name | Global rank[1] | Habitat |
|---|---|---|---|
| **Amphibians** | | | |
| *Aneides aeneus* | Green salamander | G3G4 | Rock outcrops/Cliffs, Forest |
| *Cryptobranchus alleganiensis alleganiensis* | Eastern hellbender | G3G4T3T4 | Wetland/Aquatic |
| **Reptiles** | | | |
| *Clonophis kirtlandii* | Kirtland's snake | G2 | Wetland/Aquatic |
| *Macroclemys temminckii* | Alligator snapping turtle | G3G4 | Wetland/Aquatic |
| *Nerodia erythrogaster neglecta* | Copperbelly water snake | G5T2T3 | Wetland/Aquatic |
| *Sistrurus catenatus catenatus* | Eastern massasauga | G3G4T3T4 | Wetland/Aquatic |
| **Birds** | | | |
| *Aimophila aestivalis* | Bachman's sparrow | G3 | Savanna/Glade |
| *Sterna anitllarum athalassos* | Least tern (interior) | G4T2Q | Wetland/Aquatic |
| **Mammals** | | | |
| *Myotis austroriparius* | Southeastern myotis | G3G4 | Habitat generalist, Cave habitats |
| *Myotis grisescens* | Gray myotis | G3 | Forest, Wetland/Aquatic, Cave habitats |
| *Myotis sodalis* | Indiana bat | G2 | Forest, Cave habitats |
| *Myotis leibii* | Eastern small-footed myotis | G3 | Forest, Agriculture, Cave habitats |
| *Neotoma magister* | Allegheny woodrat | G3G4 | Rock outcrops/Cliffs, Cave habitats |
| *Plecotus rafinesquii* | Rafinesque's big-eared bat | G3G4 | Forest, Wetland/Aquatic, Cave habitats |
| **Invertebrates** | | | |
| *Amblyscirtes aesculapius* | Laced-wing roadside skipper | G3G4 | Forest, Wetland/Aquatic |
| *Anguispira kochi* | Terrestrial snail | G3[2] | Cave habitats, Forest |
| *Atrytone arogos* | Arogos skipper | G3G4 | Grassland |
| *Calephelis muticum* | Swamp metalmark | G3G4 | Wetland/Aquatic |
| *Campodea plusiochaeta* | Dipluran | G? | |
| *Catocala marmorata* | Marbled underwing moth | G3G4 | Forest |
| *Cicindela patruela* | A tiger beetle | G3 | Forest, Shrub/Sapling, Outcrop/Cliffs |
| *Dorycephalus sp.* | Shovel-headed leafhopper | G3G4 | Savanna/Glade |
| *Dorydiella kansana* | Kansas preacher | G3G4 | Savanna/Glade |
| *Dryobius sexnotatus* | Six-banded longhorn beetle | G? | |
| *Erora laeta* | Early hairstreak | G3G4 | Forest |
| *Erynnis martialis* | Mottled duskywing | G3G4 | Shrub/Sapling, Savanna/Glade |
| *Euphyes dukesi* | Scarce swamp skipper | G3 | Wetland/Aquatic |
| *Fitchella robertsoni* | Robertson's elephant hopper | G2G3 | Savanna/Glade |
| *Flexamia reflexa* | Indian grass flexamia | G2G3 | Savanna/Glade |
| *Hesperia ottoe* | Ottoe skipper | G3G4 | Grassland |
| *Lytrosis permagnaria* | A geometrid moth | G3G4 | Forest |
| *Nicrophorus americanus* | American burying beetle | G2G3 | Shrub/Sapling, Forest, Grassland |
| *Papaipema astute* | Astute stoneroot borer moth | G3G4 | Savanna/Glade |
| *Papaipema beeriana* | Beer's blazingstar borer moth | G3 | Savanna/Glade |
| *Papaipema eryngii* | Rattlesnake-master borer moth | G1G2 | Grassland, Wetland/Aquatic |
| *Paraphlepsius lupalus* | Leafhopper | G? | |
| *Parasa indetermina* | Wild rose slug moth | G4 | Savanna/Glade |
| *Patera laevior* | Terrestrial snail | G3[2] | Cave habitats, Rock outcrops/Cliffs |
| *Pieris virginiensis* | West Virginia white | G3G4 | Forest |
| *Polyamia herbida* | Prairie panic grass leafhopper | G2G3 | Savanna/Glade |
| *Speyeria idalia* | Regal fritillary | G3 | Grassland |

[1] Based upon Heritage Status Rank reported by NatureServe (2002).
[2] Based upon Heritage Status Rank reported by Lewis (2003).

**Table 5.** Cave species with global viability concern, their global ranks, and associated habitats in the Hoosier-Shawnee Ecological Assessment Area.

| Scientific name | Common name | Global rank[1] | Habitat |
|---|---|---|---|
| **Mammals** | | | |
| *Myotis austroriparius* | Southeastern myotis | G3G4 | Habitat generalist, Cave habitats |
| *Myotis grisescens* | Gray myotis | G3 | Forest, Wetland/Aquatic, Cave habitats |
| *Myotis sodalis* | Indiana bat | G2 | Forest, Cave habitats |
| *Myotis leibii* | Eastern small-footed myotis | G3 | Forest, Agriculture, Cave habitats |
| *Neotoma magister* | Allegheny woodrat | G3G4 | Rock outcrops/Cliffs, Cave habitats |
| *Plecotus rafinesquii* | Rafinesque's big-eared bat | G3G4 | Forest, Wetland/Aquatic, Cave habitats |
| **Invertebrates** | | | |
| *Anahita punctulata* | Wandering spider | G3[2] | Cave habitats |
| *Anguispira kochi* | Terrestrial snail | G3[3] | Cave habitats, Forest |
| *Antroselates spiralis* | Shaggy cave snail | G2[2] | Cave habitats, Wetland/Aquatic |
| *Apochthonius undescribed species 1* | Undescribed pseudoscorpion | G1[2] | Cave habitats |
| *Apochthonius undescribed species 2* | Cave pseudoscorpion | G1[3] | Cave habitats |
| *Apochthonius indianensis* | Indiana cave pseudoscorpion | G3 | Cave habitats |
| *Arrhopalites ater* | Black medusa springtail | G2[2] | Cave habitats |
| *Arrhopalites benitus* | Springtail | G3[2] | Cave habitats |
| *Arrhopalites bimus* | Two-year cave springtail | G1[2] | Cave habitats |
| *Arrhopalites carolynae* | Carolyn's cave springtail | G2[3] | Cave habitats |
| *Arrhopalites lewisi* | Lewis' cave springtail | G2[2] | Cave habitats |
| *Arrhopalites undescribed species near lewisi* | Cave springtail | G2[2] | Cave habitats |
| *Arrhopalites undescribed species near marshalli* | Cave springtail | G1[3] | Cave habitats |
| *Arrhopalites whitesidei* | Whiteside's springtail | G2[3] | Cave habitats |
| *Atheta annexa* | Rove beetle | G2/G4 | Cave habitats |
| *Atheta lucifuga* | Light shunning rove beetle | G3[2] | Cave habitats |
| *Bathyphantes weyeri* | Weyers Cave sheet-web spider | G2[2] | Cave habitats |
| *Batriasymmodes undescribed species* | Patton Cave ant beetle | G1[3] | Cave habitats |
| *Batrisoldes undescribed species 1* | Cave ant beetle | G1[2] | Cave habitats |
| *Batrisoldes undescribed species 2* | Cave ant beetle | G1[3] | Cave habitats |
| *Caecidotea jordani* | Jordan's groundwater isopod | G1[2] | Cave habitats, Wetland/Aquatic |
| *Caecidotea teresae* | Teresa's groundwater isopod | G1[2] | Cave habitats, Wetland/Aquatic |
| *Carychium riparium* | Floodplain carych | G3[2] | Cave habitats, Wetland/Aquatic |
| *Cauloxenus stygius* | Northern cavefish commensal copepod | G1[2] | Cave habitats, Wetland/Aquatic |
| *Chitrella undescribed species* | Undescribed cave pseudoscorpion | G1[2] | Cave habitats |
| *Chthonius virginicus* | Virginian pseudoscorpion | G3[2] | Cave habitats |
| *Cicurina arcuata* | Funnel-web spider | G3[2] | Cave habitats |
| *Contyla bollmani* | Bollman's cave milliped | G3[2] | Cave habitats |
| *Crangonxy packardi* | Packard's cave amphipod | G3[2] | Cave habitats, Wetland/Aquatic |
| *Crangonxy undescribed species 1* | Barr's cave amphipod | G3[2] | Cave habitats, Wetland/Aquatic |
| *Crangonxy undescribed species 2* | Indiana cave amphipod | G3[3] | Cave habitats, Wetland/Aquatic |
| *Dactylocythere susanae* | Susan's commensal ostracod | G3[3] | Cave habitats, Wetland/Aquatic |
| *Diacyclops jeanneli jeanneli* | Jeannel's cave copepod | G2[3] | Cave habitats, Wetland/Aquatic |
| *Dicyrtoma flammea* | Flaming springtail | G3[2] | Cave habitats |
| *Entomobrya socia* | Social springtail | G2[3] | Cave habitats |
| *Eperigone indicabilis* | Sheet-web spider | G1[2] | Cave habitats |
| *Erebomaster flavescens* | Golden cave harvestman | G3[2] | Cave habitats |
| *Eumesocampa undescribed species* | Campodeid dipluran | G1[2] | Cave habitats |
| *Folsomia candida* | White springtail | G3[2] | Cave habitats |
| *Folsomia parus* | Small springtail | G3[2] | Cave habitats |
| *Folsomia prima* | Primitive springtail | G2[2] | Cave habitats |

*(table continued on next page)*

**(table 5 continued)**

| Scientific name | Common name | Global rank[1] | Habitat |
|---|---|---|---|
| *Fontigens cryptica* | Hidden spring snail | G1[2] | Cave habitats, Wetland/Aquatic |
| *Glyphyalinia cryptomphala* | Glyph snail | G2[2] | Cave habitats |
| *Glyphyalinia latebricola* | Ledge glyph | G2[2] | Cave habitats, Wetland/Aquatic |
| *Glyphyalinia lewisiana* | Lewis' glyph | G3[2] | Cave habitats, Wetland/Aquatic |
| *Glyphyalinia rimula* | Karst glyph | G2[2] | Cave habitats, Wetland/Aquatic |
| *Hesperochernes mirabilis* | Wonderful pseudoscorpion | G3[2] | Cave habitats |
| *Hypogastrura gibbosus* | Humped springtail | G2[3] | Cave habitats |
| *Hypogastrura helena* | Helen's springtail | G1[2] | Cave habitats |
| *Hypogastrura horrida* | Bristly springtail | G2[2] | Cave habitats |
| *Hypogastrura lucifuga* | Wyandotte cave springtail | G1[2] | Cave habitats |
| *Hypogastrura maheuxi* | Maheux springtail | G2[2] | Cave habitats |
| *Hypogastrura undescribed species near succinea* | Springtail | G1[3] | Cave habitats |
| *Islandiana cavealis* | Iceland cave sheet-web spider | G1[2] | Cave habitats |
| *Isotoma anglicana* | Springtail | G3[2] | Cave habitats |
| *Isotoma caerulatra* | Blue springtail | G1[2] | Cave habitats |
| *Isotoma christianseni* | Christiansen's springtail | G1[2] | Cave habitats |
| *Isotoma nigrifrons* | Dark springtail | G2[2] | Cave habitats |
| *Isotoma nixoni* | Nixon's springtail | G1[2] | Cave habitats |
| *Isotoma torildao* | Springtail | G1[2] | Cave habitats |
| *Isotoma truncata* | Truncated springtail | G2[3] | Cave habitats |
| *Isotoma (Desoria)undescribed species* | Springtail | G1[2] | Cave habitats |
| *Isotomiella minor* | Petit springtail | G3[2] | Cave habitats |
| *Kleptochthonius undescribed species 1* | Undescribed pseudoscorpion | G1[2] | Cave habitats |
| *Kleptochthonius undescribed species 2* | Undescribed pseudoscorpion | G1[2] | Cave habitats |
| *Kleptochthonius undescribed species 3* | Undescribed pseudoscorpion | G1[2] | Cave habitats |
| *Kleptochthonius griseomanus* | Gray-handed pseudoscorpion | G1[3] | Cave habitats |
| *Kleptochthonius packardi* | Pseudoscorpion | G1[3] | Cave habitats |
| *Litocampa undescribed species* | Campodeid dipluran | G2[2] | Cave habitats |
| *Megacyclops undescribed species* | Undescribed copepod crustacean | G1[2] | Cave habitats, Wetland/Aquatic |
| *Megacyclops donnaldsoni donnaldsoni* | Donaldson's cave copepod | G1[2] | Cave habitats, Wetland/Aquatic |
| *Miktoniscus barri* | Barr's terrestrial isopod | G2[2] | Cave habitats, Wetland/Aquatic |
| *Nesticus carteri* | Carter cave spider | G3[3] | Cave habitats |
| *Onychiurus reluctus* | A springtail | G3[2] | Cave habitats |
| *Onychiurus subtenuis* | Slender springtail | G3[2] | Cave habitats |
| *Onychiurus undescribed species 1* | Springtail | G1[3] | Cave habitats |
| *Onychiurus undescribed species 2* | Paradox springtail | G1[3] | Cave habitats |
| *Onychiurus undescribed species near casus* | Springtail | G1[3] | Cave habitats |
| *Onychiurus undescribed species near paro* | Springtail | G1[3] | Cave habitats |
| *Oreonetides undescribed species* | Sheet-web spider | G1[3] | Cave habitats |
| *Patera laevior* | Terrestrial snail | G3[3] | Cave habitats, Rock outcrops/Cliffs |
| *Porhomma cavernicola* | Cavernicolous sheet-web spider | G3[2] | Cave habitats |
| *Proisotoma libra* | Springtail | G2[3] | Cave habitats |
| *Pseudanophthalmus eremita* | Wyandotte Cave ground beetle | G1[2] | Cave habitats |
| *Pseudanophthalmus stricticollis* | Marengo Cave ground beetle | G3[2] | Cave habitats |
| *Pseudanophthalmus tenuis* | Blue River cave ground beetle | G3[2] | Cave habitats |
| *Pseudanophthalmus undescribed species 1* | Undescribed cave ground beetle | G1[2] | Cave habitats |
| *Pseudanophthalmus undescribed species 2* | Undescribed cave ground beetle | G1[3] | Cave habitats |
| *Pseudanophthalmus undescribed species 3* | Undescribed cave ground beetle | G1[3] | Cave habitats |
| *Pseudanophthalmus youngi* | Young's cave ground beetle | G2[2] | Cave habitats |
| *Pseudocandona jeanneli* | Jeannel's cave ostracod | G1[2] | Cave habitats, Wetland/Aquatic |

*(table continued on next page)*

(table 5 continued)

| Scientific name | Common name | Global rank[1] | Habitat |
|---|---|---|---|
| *Pseudocandona marengoensis* | Marengo cave ostracod | G1[2] | Cave habitats, Wetland/Aquatic |
| *Pseudosinella collina* | Hilly springtail | G2[2] | Cave habitats |
| *Pseudosinella fonsa* | Fountain cave springtail | G2[2] | Cave habitats |
| *Pseudosinella undescribed species near fonsa* | Springtail | G1[3] | Cave habitats |
| *Pseudosinella undescribed species* | Springtail | G1[3] | Cave habitats |
| *Pseudotremia conservata* | TNC cave milliped | G1[2] | Cave habitats |
| *Pseudotremia indianae* | Blue River cave milliped | G3[2] | Cave habitats |
| *Pseudotremia reynoldsae* | Reynolds' cave milliped | G1[3] | Cave habitats |
| *Pseudotremia salisae* | Salisa's cave milliped | G1[3] | Cave habitats |
| *Pseudotremia undescribed species 1* | Troglobitic milliped | G1[2] | Cave habitats |
| *Pseudotremia undescribed species 2* | Troglobitic milliped | G1[2] | Cave habitats |
| *Ptomaphagus cavernicola cavernicola* | Cavernicolous fungus beetle | G3[2] | Cave habitats |
| *Rheocyclops indiana* | Indiana groundwater copepod | G1[3] | Cave habitats, Wetland/Aquatic |
| *Rheocyclops undescribed species* | Undescribed copepod crustacean | G1[2] | Cave habitats, Wetland/Aquatic |
| *Sabacon cavicolens* | Cavernicolous harvestman | G3[2] | Cave habitats |
| *Sagittocythere barri* | Barr's commensal cave ostracod | G3[2] | Cave habitats, Wetland/Aquatic |
| *Scoterpes undescribed species* | Troglobitic milliped | G1[2] | Cave habitats |
| *Sensillanura barberi* | Barber's springtail | G2[2] | Cave habitats |
| *Sensillanura caeca* | Blind springtail | G3[2] | Cave habitats |
| *Sensillanura undescribed species near bara* | Springtail | G1[3] | Cave habitats |
| *Sensillanura undescribed species near illina* | Springtail | G1[2] | Cave habitats |
| *Sensillanura undescribed species* | Springtail | G1[3] | Cave habitats |
| *Sinella alata* | Wingless winged cave springtail | G3[2] | Cave habitats |
| *Sinella avita* | Ancestral springtail | G3 | Cave habitats |
| *Sinella barri* | Barr's cave springtail | G3[2] | Cave habitats |
| *Sinella undescribed species* | Cave springtail | G1[2] | Cave habitats |
| *Sminthurides hypogramae* | Springtail | G1[2] | Cave habitats |
| *Sminthurides weichseli* | Weichsel's springtail | G2[2] | Cave habitats, Wetland/Aquatic |
| *Sminthurinus malmgreni* | Malmgren's springtail | G3[2] | Cave habitats, Wetland/Aquatic |
| *Sphalloplana chandleri* | Chandler's cave flatworm | G1[2] | Cave habitats |
| *Sphalloplana weingartneri* | Weingartner's cave flatworm | G2[2] | Cave habitats |
| *Stygobromus subtilus* | Subtle cave amphipod | G2 | Cave habitats |
| *Stygobromus undescribed species 1* | Amphipod crustacean | G1[2] | Cave habitats, Wetland/Aquatic |
| *Stygobromus undescribed species 2* | Amphipod crustacean | G1[2] | Cave habitats, Wetland/Aquatic |
| *Stygobromus undescribed species 3* | Amphipod crustacean | G1[2] | Cave habitats, Wetland/Aquatic |
| *Talanites echinus* | Sac-web spider | G2[2] | Cave habitats |
| *Tomocerus dubius* | Springtail | G3[3] | Cave habitats |
| T*omocerus elongatus* | Elongate springtail | G3[2] | Cave habitats |
| *Tomocerus (Lethemurus) missus* | Relict cave springtail | G2[2] | Cave habitats |
| *Tomocerus undescribed species* | Springtail | G1[3] | Cave habitats |
| *Tychobythinus bythinioides* | Ant beetle | G3[2] | Cave habitats |
| *Veigaia bakeri* | Baker's cave mite | G1[2] | Cave habitats |
| *Veigaia wyandottensis* | Wyandotte cave mite | G1[2] | Cave habitats |

[1] Based upon Heritage Status Rank reported by NatureServe (2002).
[2] Based upon Heritage Status Rank reported by Lewis (1998).
[3] Based upon Heritage Status Rank reported by Lewis et al. (2003).

Not quite half of these species are birds (81 of 172); 22 are reptiles, 12 are amphibians, 18 are mammals, and 39 are invertebrates (table 6).

Among those species determined to be of state viability concern, 73 have some association with wetland or aquatic habitats, 46 have some association with forest habitats, 49 species have some association with early successional habitat types (grassland, savannah/glade, shrub/sapling), and 20 species are associated with caves.

Due to their predominance as species of global or state viability concern, both cave-associated species (table 5) and avian species (tables 7-9) are considered in greater detail below. Detailed assessments of the status of mammals occurring within the assessment area are presented in table 10, reptiles and amphibians are summarized in table 11, and terrestrial invertebrates are summarized in table 12.

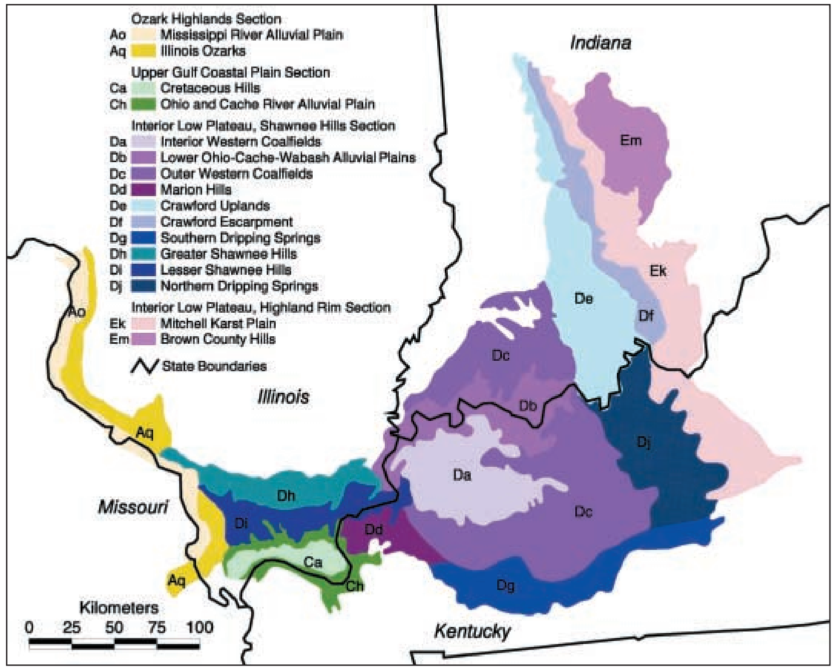


**Figure 4.** Location of ecological subsections that encompass the Hoosier National Forest. The forest resides primarily within three ecological subsections known to contain extensive components of karst: the Mitchell Karst Plains, Crawford Escarpment, and Crawford Uplands Subsections.

## CAVE FAUNA

One of the most striking features of the assessment area is its karst habitat. Karst refers to landscapes characterized by sinkholes, caves, and underground drainages. The majority of this habitat lies within the Mitchell Karst Plain, Crawford Escarpment, and Crawford Uplands subsections of Indiana in which the Hoosier National Forest is located (fig. 4). In addition to the yet unknown number of caves throughout the assessment area, 136 known caves occur on the Hoosier National Forest and 15 occur on the Shawnee National Forest (fig. 5).

The description and inventory of karst fauna within the assessment area is a distinctly recent achievement (Lewis 1994, Lewis 1996, Lewis 1998, Lewis 2002a, Lewis 2002b, Lewis et al. 2002, Lewis et al. 2003). Undertaken to acquire baseline inventories, this work continues to describe species new to the scientific literature and to document new distributions of previously described species. While this work represents

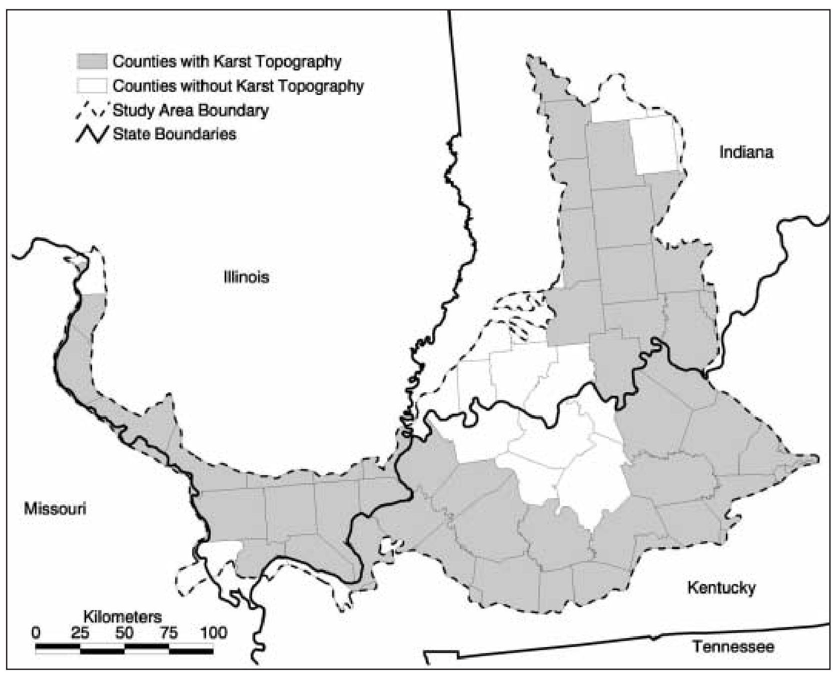


**Figure 5.** Location of known karst features within the Hoosier and Shawnee National Forests. Currently, 136 known caves occur on the Hoosier National Forest and 15 occur on the Shawnee National Forest .

**Table 6.** Terrestrial animal species with state viability concerns, other than those previously identified to be of global viability concern (table 4). Included are global and state Heritage Status Ranks (NatureServe 2002), as well as habitat associations for these species in the Hoosier-Shawnee Ecological Assessment Area.

| Scientific name | Common name | Global rank | State rank IL | IN | KY | Habitat |
|---|---|---|---|---|---|---|
| **Amphibians** | | | | | | |
| *Desmognathus fuscus* | Dusky salamander | G5 | S2 | S4 | S5 | Wetland/Aquatic |
| *Hemidactylium scutatum* | Four-toed salamander | G5 | S2 | S2 | S4 | Wetland/Aquatic |
| *Hyla avivoca* | Bird-voiced treefrog | G5 | S3 | - | S2S3 | Wetland/Aquatic |
| *Hyla cinerea* | Green treefrog | G5 | S3 | - | S3 | Wetland/Aquatic |
| *Hyla gratiosa* | Barking treefrog | G5 | - | - | S3 | Wetland/Aquatic |
| *Hyla versicolor* | Gray treefrog | G5 | S4 | S4 | S2S3 | Wetland/Aquatic |
| *Necturus maculosus* | Mudpuppy | G5 | S5 | S2 | S4 | Wetland/Aquatic |
| *Pseudotriton ruber ruber* | Northern red salamander | G5T5 | - | S1 | S5 | Wetland/Aquatic |
| *Rana areolata circulosa* | Northern crawfish frog | G4T4 | - | S2 | S3 | Grassland, Savanna/Glade, Wetland/Aquatic |
| *Rana blairi* | Plains leopard frog | G5 | S4 | S2 | - | Wetland/Aquatic |
| *Rana pipiens* | Northern leopard frog | G5 | S5 | S2 | S3 | Wetland/Aquatic |
| *Scaphiopus holbrookii holbrookii* | Eastern spadefoot | G5T5 | - | S2 | S4 | Wetland/Aquatic |
| **Reptiles** | | | | | | |
| *Agkistrodon piscivorus leucostoma* | Western cottonmouth | G5T5 | - | S1 | S3S4 | Wetland/Aquatic |
| *Apalone mutica* | Smooth softshell turtle | G5 | S3 | S4 | S3 | Wetland/Aquatic |
| *Cemophora coccinea copei* | Northern scarlet snake | G5T5 | - | S1 | S3S4 | Forest |
| *Crotalus horridus* | Timber rattlesnake | G4 | S3 | S2 | S4 | Outcrops/Cliffs, Forest |
| *Elaphe guttata guttata* | Corn snake | G5T5 | - | - | S3 | Outcrops/Cliffs, Forest |
| *Eumeces anthracinus anthracinus* | Northern coal skink | G5T5 | - | - | S2 | Outcrops/Cliffs, Forest |
| *Eumeces inexpectatus* | Southeastern five-lined skink | G5 | - | - | S3 | Forest, Wetland/Aquatic |
| *Farancia abacura reinwardtii* | Western mud snake | G5T5 | - | SX | S3 | Wetland/Aquatic |
| *Heterodon nasicus* | Western hognose snake | G5 | S2 | - | - | Grassland |
| *Kinosternon subrubrum* | Eastern mud turtle | G5 | S3S4 | S2 | S3S4 | Wetland/Aquatic |
| *Liochlorophis vernalis* | Smooth green snake | G5 | S3S4 | S2 | - | Forest, Grassland, Wetland/Aquatic |
| *Masticophis flagellum* | Eastern coachwhip | G5 | S1 | - | SX | Outcrops/Cliffs, Savanna/Glade, Grassland |
| *Nerodia cyclopion* | Mississippi green water snake | G5 | S1 | - | S1 | Wetland/Aquatic |
| *Nerodia fasciata confluens* | Broad-banded water snake | G5T5 | - | - | S1 | Wetland/Aquatic |
| *Opheodrys aestivus* | Rough green snake | G5 | S5 | S3 | S5 | Forest, Grassland, Shrub/Sapling |
| *Ophisaurus attenuatus* | Slender glass lizard | G5 | S4 | S2 | S2 | Grassland, Savanna/Glade |
| *Pituophis melanoleucus* | Northern pine snake | G4 | - | - | S2 | Forest, Outcrops/Cliffs |
| *Pseudemys concinna* | River cooter | G5 | S1 | S? | S3 | Wetland/Aquatic |
| *Tantilla coronata* | Southeastern crowned snake | G5 | - | S1 | S3S4 | Outcrops/Cliffs, Forest |
| *Tantilla gracilis* | Flathead snake | G5 | S2 | - | - | Outcrops/Cliffs |
| *Thamnophis proximus* | Western ribbon snake | G5 | S4 | S3 | S1S2 | Outcrops/Cliffs, Wetland/Aquatic |
| *Thamnophis sauritus* | Eastern ribbon snake | G5 | S1 | S4 | S3 | Wetland/Aquatic |
| **Birds** | | | | | | |
| *Accipiter cooperii* | Cooper's hawk | G5 | S3 | S3B,SZN | S4B,S4N | Forest |
| *Accipiter gentilis* | Northern goshawk[1] | G5 | SZN | SZN | SZN | Forest |
| *Accipiter striatus* | Sharp-shinned hawk | G5 | S1S2 | S2B,SZN | S3B,S4N | Forest |
| *Actitis macularia* | Spotted sandpiper | G5 | S3S4 | S4B | S1B | Wetland/Aquatic |
| *Ammodramus henslowii* | Henslow's sparrow | G4 | S2 | S3B,SZN | S3B | Grassland |
| *Anas discors* | Blue-winged teal | G5 | S3 | S4B,SZN | S1S2B | Wetland/Aquatic |

(table continued on next page)

**(table 6 continued)**

| Scientific name | Common name | Global rank | State rank IL | IN | KY | Habitat |
|---|---|---|---|---|---|---|
| *Anas platyrhynchos* | Mallard[1] | G5 | S5 | S4 | S3S4B,S4S5N | Wetland/Aquatic |
| *Anas rubripes* | American black duck[1] | G5 | - | S1 | S4N | Wetland/Aquatic |
| *Ardea alba* | Great egret | G5 | S3 | S1B,SZN | S1B | Wetland/Aquatic |
| *Ardea herodias* | Great blue heron | G5 | S4 | S4B,SZN | S3B,S4N | Wetland/Aquatic |
| *Asio flammeus* | Short-eared owl | G5 | S1B,S2S3N | S2 | S1B,S2N | Grassland, Savanna/Glade |
| *Asio otus* | Long-eared owl | G5 | S1B,S2N | S2 | S1B,S1S2N | Forest, Agriculture |
| *Aythya valisineria* | Canvasback[1] | G5 | SZN | SZN | S3N | Wetland/Aquatic |
| *Bartramia longicaud*a | Upland sandpiper | G5 | S2S3 | S3B | SHB | Grassland, Agriculture |
| *Botaurus lentiginosus* | American bittern | G4 | S1S2 | S2B | SHB | Wetland/Aquatic |
| *Bubulcus ibis* | Cattle egret | G5 | S3S4 | SPB,SZN | S1S2B | Agriculture |
| *Buteo lineatus* | Red-shouldered hawk | G5 | S2S3 | S3 | S4B,S4N | Forest, Shrub/Sapling |
| *Buteo platypterus* | Broad-winged hawk | G5 | S3 | S3B,SRFN | S4B | Forest |
| *Buteo swainsoni* | Swainson's hawk | G5 | S1 | - | - | Savanna/Glade, Agriculture |
| *Caprimulgus carolinensis* | Chuck-will's-widow | G5 | S4 | S3B | S4S5B | Forest |
| *Certhia americana* | Brown creeper | G5 | S3 | S2B,SZN | S1S2B,S4S5N | Forest |
| *Chen caerulescens* | Snow goose[1] | G5 | SZN | SZN | S3S4N | Wetland/Aquatic |
| *Chlidonias niger* | Black tern | G4 | S1 | S1B,SZN | SXB,SZN | Wetland/Aquatic |
| *Chondestes grammacus* | Lark sparrow | G5 | S5 | S3B,SZN | S2S3B | Shrub/Sapling, Grassland |
| *Circus cyaneus* | Northern harrier | G5 | S2B,S3N | S2 | S1S2B,S4N | Grassland, Savanna/Glade |
| *Cistothorus palustris* | Marsh wren | G5 | S4 | S3B, SZN | SZN | Shrub/Sapling, Wetland/Aquatic |
| *Cistothorus platensis* | Sedge wren | G5 | S3S4 | S3B,SZN | S3B | Shrub/Sapling, Wetland/Aquatic |
| *Coragyps atratus* | Black vulture | G5 | S3 | S1N,S2B | S4B,S3S4N | Agriculture |
| *Corvus ossifragus* | Fish crow | G5 | S2 | - | S3B | Wetland/Aquatic |
| *Coturnicops noveboracensis* | Yellow rail[1] | G4 | SXB,S2N | SZN | SZN | Wetland/Aquatic |
| *Cygnus buccinator* | Trumpeter swan[1] | G4 | SXB,S2N | SRB | SXN | Wetland/Aquatic |
| *Dendroica caerulescens* | Black-throated blue warbler[1] | G5 | SZN | SZN | S3S4B | Forest, Shrub/Sapling |
| *Dendroica cerulea* | Cerulean warbler | G4 | S3 | S3B | S4S5B | Forest |
| *Dendroica pinus* | Pine warbler | G5 | S3S4 | S3B | S4S5B,SZN | Forest |
| *Dendroica virens* | Black-throated green warbler | G5 | SZN | S2B | S4B | Forest |
| *Dendroica fusca* | Blackburnian warbler[1] | G5 | SZN | - | S1S2B | Forest |
| *Dolichonyx oryzivorus* | Bobolink | G5 | S4 | S4B | S2S3B | Grassland, Agriculture |
| *Egretta caerulea* | Little blue heron | G5 | S1 | SRB,SZN | S1B | Wetland/Aquatic |
| *Egretta thula* | Snowy egret | G5 | S1 | SZN | SZN | Wetland/Aquatic |
| *Elanoides forficatus* | Swallow-tailed kite[1] | G5 | SX | - | - | Forest, Savanna/Glade |
| *Empidonax minimus* | Least flycatcher | G5 | S3 | S3B | S1B | Forest |
| *Falco peregrinus* | Peregrine falcon | G4 | S1 | S2B,SZN | S1B,SZN | Wetland/Aquatic, Grassland |
| *Fulica americana* | American coot | G5 | S4 | S4B,S2N | SHB,SZN | Wetland/Aquatic |
| *Gallinago delicata* | Wilson's snipe[1] | G5 | S3 | S1S2B,SZN | S3S4N | Wetland/Aquatic |
| *Gallinula chloropus* | Common moorhen | G5 | S3 | S3B | S1S2B | Wetland/Aquatic |
| *Gavia immer* | Common loon[1] | G5 | SXB,S2N | SXB,SZN | SZN | Wetland/Aquatic |
| *Grus canadensis* | Sandhill crane[1] | G5 | S3 | S2B,S1N | SZN | Wetland/Aquatic, Grassland |
| *Haliaeetus leucocephalus* | Bald eagle | G4 | S2B,S3N | S2B | S1S2B,S2S3N | Wetland/Aquatic |
| *Helmitheros vermivorus* | Worm-eating warbler | G5 | S4 | S3B | S4S5B | Forest, Shrub/Sapling |
| *Ictinia mississippiensis* | Mississippi kite | G5 | S2S3 | S1B | S2B | Forest |
| *Ixobrychus exilis* | Least bittern | G5 | S2 | S3B | S1S2B | Wetland/Aquatic |
| *Lanius ludovicianus* | Loggerhead shrike | G4 | S3 | S3B,SZN | S4B,S4N | Savanna/Glade, Shrub/Sapling |
| *Laterallus jamaicensis* | Black rail | G4 | S1 | SHB | - | Wetland/Aquatic |
| *Limnothlypis swainsonii* | Swainson's warbler | G4 | S1 | SRB | S3S4B | Shrub/Sapling, Forest |

*(table continued on next page)*

(table 6 continued)

| Scientific name | Common name | Global rank | State rank IL | IN | KY | Habitat |
|---|---|---|---|---|---|---|
| *Lophodytes cucullatus* | Hooded merganser | G5 | S2S3 | S2S3B,SZN | S1S2B,S3S4N | Wetland/Aquatic |
| *Mniotilta varia* | Black-and-white warbler | G5 | S2S3 | S1S2B | S4S5B | Forest |
| *Nyctanassa violacea* | Yellow-crowned night-heron | G5 | S1 | S2B | S2B | Wetland/Aquatic |
| *Nycticorax nycticorax* | Black-crowned night-heron | G5 | S2 | S1B,SAN | S1S2B | Wetland/Aquatic |
| *Pandion haliaetus* | Osprey | G5 | S1 | S1B,SZN | S1S2B | Wetland/Aquatic |
| *Passerculus sandwichensis* | Savannah sparrow | G5 | S5 | S4B,SZN | S2S3B,S2S3N | Grassland, Agriculture |
| *Phalaropus tricolor* | Wilson's phalarope[1] | G5 | S1 | SHB,SZN | SZN | Wetland/Aquatic |
| *Pheucticus ludovicianus* | Rose-breasted grosbeak | G5 | S5 | S4B | S3S4B | Forest, Savanna/Glade |
| *Podilymbus podiceps* | Pied-billed grebe | G5 | S3 | S3B,SZN | S1B,S4N | Wetland/Aquatic |
| *Pooecetes gramineus* | Vesper sparrow | G5 | S5 | S4B,SZN | S1B,SZN | Shrub/Sapling, Savanna/Glade |
| *Porzana carolina* | Sora | G5 | S3 | S4B,SZN | SZN | Wetland/Aquatic |
| *Rallus elegans* | King rail | G4G5 | S2 | S1B,SZN | S1B | Wetland/Aquatic |
| *Rallus limicola* | Virginia rail | G5 | S3 | S3B,SZN | S1B?,SZN | Wetland/Aquatic |
| *Riparia riparia* | Bank swallow | G5 | S5 | S4B | S3B | Wetland/Aquatic |
| *Sitta pusilla* | Brown-headed nuthatch[1] | G5 | SR | SRN | | Shrub/Sapling, Forest |
| *Sterna antillarum* | Least tern[1] | G4 | S1 | S? | S1S2 | Wetland/Aquatic |
| *Sterna forsteri* | Forster's tern[1] | G5 | S1 | SHB,SZN | SZN | Wetland/Aquatic |
| *Sterna hirundo* | Common tern[1] | G5 | S1 | SXB,SZN | SZN | Wetland/Aquatic |
| *Sturnella magna* | Eastern meadowlark | G5 | S5 | S3N,S4B | S5B,S5N | Grassland, Agriculture |
| *Sturnella neglecta* | Western meadowlark | G5 | S5 | S2B | SAB,SZN | Grassland, Agriculture |
| *Thryomanes bewickii* | Bewick's wren | G5 | S1 | S1B,SZN | S3B | Shrub/Sapling |
| *Tyto alba* | Barn owl | G5 | S1S2 | S2 | S3 | Agriculture |
| *Vermivora chrysoptera* | Golden-winged warbler | G4 | S1S2 | S1B | S2B | Shrub/Sapling, Savanna/Glade |
| *Vireo bellii* | Bell's vireo | G5 | S4 | S3B | S2S3B | Shrub/Sapling |
| *Wilsonia citrina* | Hooded warbler | G5 | S3S4 | S3B | S5B | Forest, Wetland/Aquatic, Shrub/Sapling |
| *Wilsonia canadensis* | Canada warbler | G5 | S1 | S2B | S3B | Forest, Wetland/Aquatic |
| *Xanthocephalus xanthocephalus* | Yellow-headed blackbird[1] | G5 | S2 | S1B | SZN | Wetland/Aquatic |
| **Mammals** | | | | | | |
| *Condylura cristata* | Star-nosed mole | G5 | SR | S2? | - | Wetland/Aquatic |
| *Geomys bursarius* | Plains pocket gopher | G5 | S3 | S2 | - | Grassland |
| *Lutra canadensis* | Northern river otter | G5 | S2 | S? | S3S4 | Wetland/Aquatic |
| *Lynx rufus* | Bobcat | G5 | S3 | S1 | S4 | Habitat generalist |
| *Mustela nivalis* | Least weasel | G5 | S3 | S2? | S2S3 | Habitat generalist |
| *Neotoma floridana* | Eastern wood rat | G5 | S1 | - | - | Forest, Wetland/Aquatic, Outcrops/Cliffs |
| *Nycticeius humeralis* | Evening bat | G5 | S3 | S1 | S2S3 | Forest |
| *Ochrotomys nuttalli* | Golden mouse | G5 | S2 | - | S4 | Forest |
| *Oryzomys palustris* | Marsh rice rat | G5 | S2 | - | S4 | Wetland/Aquatic |
| *Reithrodontomys megalotis* | Western harvest mouse | G5 | S4 | S2 | - | Grassland, Agriculture |
| *Sorex fumeus* | Smoky shrew | G5 | - | S2 | S5 | Forest |
| *Sorex hoyi* | Pygmy shrew | G5 | SH | S2 | S4 | Habitat generalist |
| *Sorex cinereus* | Masked shrew | G5 | S5 | S4 | S3 | Habitat generalist |
| *Sorex dispar* | Long-tailed shrew | G4 | - | - | S1 | Forest, Outcrops/Cliffs |
| *Spermophilus franklinii* | Franklin's ground squirrel | G5 | S4 | S2 | - | Grassland |
| *Spilogale putorius* | Eastern spotted skunk | G5 | SR | SX | S2S3 | Forest, Grassland, Outcrops/Cliffs |
| *Sylvilagus aquaticus* | Swamp rabbit | G5 | S3 | S1 | S3S4 | Wetland/Aquatic |

*(table continued on next page)*

(table 6 continued)

| Scientific name | Common name | Global rank | State rank IL | IN | KY | Habitat |
|---|---|---|---|---|---|---|
| *Taxidea taxus* | American badger | G5 | S4 | S2 | SR | Grassland |
| **Invertebrates** | | | | | | |
| *Aleochara lucifiga* | Cave rove beetle | G4[3] | - | S3[3] | - | Cave habitats |
| *Amblyscirtes belli* | Bell's roadside skipper | G4 | S1? | S1S2 | S2S3 | Grassland, Developed |
| *Amblyscirtes hegon* | Salt-and-pepper skipper | G5 | SU | S1S3 | S4 | Savanna/Glade, Forest |
| *Anahita punctulata* | Wandering spider | G4 | - | S1 | - | Cave habitats |
| *Autochton cellus* | Golden-banded skipper | G4 | S1S3 | S1S2 | S3 | Forest, Wetland/Aquatic |
| *Aleochara lucifiga* | Cave rove beetle | G4[3] | S? | S3[3] | - | Cave habitats |
| *Calymmaria cavicola* | Cave funnel-web spider | G4[3] | S? | S3[3] | - | Cave habitats |
| *Cambala annulata* | Annulate millipede | G5 | - | S2 | - | Cave habitats |
| *Cambala minor* | Millipede | G5 | S? | S2 | - | Cave habitats |
| *Carychium exile* | Ice thorn | G5 | S? | S2 | S3S4 | Cave habitats |
| *Catops gratiosa* | Beetle | G4[2] | S? | S2[2] | - | Cave habitats |
| *Celastrina nigra* | Sooty azure | G4 | S2 | S2 | S3 | Forest |
| *Cicurina pallida* | Pallid funnel-web spider | G4[2] | S? | S2 | - | Cave habitats |
| *Cycnia inopinatus* | Unexpected milkweed moth | G4 | - | S2 | - | Savanna/Glade |
| *Cyllopsis gemma* | Gemmed satyr | G5 | SU | S2 | S4 | Savanna/Glade, Forest |
| *Dolomedes scriptus* | Lined nursery web spider | G4[2] | - | S2?[2] | - | Cave habitats, Wetland/Aquatic |
| *Dolomedes vittatus* | Nursery web spider | G4[2] | S? | S1 | - | Cave habitats |
| *Eidmanella pallida* | Pallid cave spider | G5[2] | - | S1 | - | Cave habitats |
| *Eosphoropteryx thyatyroides* | Pinkpatched looper moth | G4G5 | - | S2 | - | |
| *Euphydryas phaeton* | Baltimore checkerspot | G4 | S3 | S2S4 | S3 | Wetland/Aquatic |
| *Euryurus leachii* | Leach's millipede | G4[3] | - | S2 | - | Cave habitats |
| *Fixsenia favonius ontario* | Northern hairstreak | T4 | S1S3 | - | S1 | Savanna/Glade, Forest |
| *Hesperia leonardus* | Leonardus skipper | G4 | SU | S2 | S3 | Savanna/Glade, Forest |
| *Hesperia metea* | Cobweb skipper | G4G5 | S3 | S2S3 | S3 | Shrub/Sapling, Savanna/Glade |
| *Hyperaeschra georgica* | A prominent moth | G5 | - | S2 | - | |
| *Hypogastrura succinea* | Girded springtail | G4[2] | - | S1 | - | Cave habitats |
| *Ligidium elrodii* | Elrod's terrestrial isopod | G4[3] | S? | S4[3] | - | Cave habitats |
| *Necrophilus pettiti* | A carrion beetle | G4[2] | - | S2[2] | - | Cave habitats |
| *Onychiurus casus* | Fallen springtail | G4[2] | - | S2 | - | Cave habitats |
| *Papaipema marginidens* | Margined borer moth | G4 | - | S1 | S? | Savanna/Glade |
| *Papaipema rutila* | Mayapple borer moth | G4 | S? | S1 | - | Savanna/Glade |
| *Polygonia faunus* | Green comma | G5 | - | - | SH | Forest, Savanna/Glade, Outcrops/Cliffs |
| *Quedius spelaeus* | Spelean rove beetle | G5[2] | S? | S2 | - | Cave habitats |
| *Satyrodes appalachia appalachia* | Appalachian eyed brown | G4T5 | - | S1 | - | Wetland/Aquatic |
| *Schinia jaguarina* | Jaguar flower moth | G4 | - | S? | - | Savanna/Glade |
| *Scytonotus granulatus* | Granulated millipede | G5 | - | S3[3] | - | Cave habitats |
| *Sinella cavernarum* | Cavernicolous springtail | G4 | S? | S2 | S? | Cave habitats |
| *Thorybes confusis* | Eastern cloudywing | G4 | - | - | S2S3 | Forest |
| *Tomocerus bidentatus* | Two-toothed springtail | G4[3] | S? | S3 | - | Cave habitats |
| *Tomocerus lamelliferus* | Layered springtail | G4[2] | - | S1 | - | Cave habitats |

[1] This is a species of seasonal importance in the assessment area. These species do not necessarily breed locally but may seasonally inhabit the assessment area.
[2] Based upon Heritage Status Rank as reported by Lewis (1998).
[3] Based upon Heritage Status Rank as reported by Lewis et al. (2003).

**Table 7.** Bird species of management or conservation concern within the Hoosier-Shawnee Ecological Assessment Area, their global and state Heritage Status Ranks, their conservation status within the forests, and their designation as game species within the states of the assessment area.

| Common name | Scientific name | Federal status | Global[1] rank | State status & rank | | | FS | | Game species |
|---|---|---|---|---|---|---|---|---|---|
| | | | | IL | IN | KY | HO[2] | SH[3] | |
| **Loons** | **(Family Gaviidae)** | | | | | | | | |
| Common loon[4] | *Gavia immer* | | G5 | SXB, S2N | SXB, SZN | SZN | | | |
| **Grebes** | **(Family Podicipedidae)** | | | | | | | | |
| Pied-billed grebe | *Podilymbus podiceps* | | G5 | T, S3 | S3B, SZN | S1B, S4N | | FSC | |
| **Cormorants** | **(Family Phalacrocoracidae)** | | | | | | | | |
| Double-crested cormorant | *Phalacrocorax auritus* | | G5 | S2 | SHB, SZN | SHB, SZN | | | |
| **Herons, Bitterns** | **(Family Ardeidae)** | | | | | | | | |
| American bittern | *Botaurus lentiginosus* | | G4 | E, S1S2 | E, S2B | SHB | | FSC | |
| Black-crowned night-heron | *Nycticorax nycticorax* | | G5 | E, S2 | E, S1B, SAN | S1S2B | | FSC | |
| Cattle egret | *Bubulcus ibis* | | G5 | S3S4 | SPB, SZN | S1S2B | | | |
| Great blue heron | *Ardea herodias* | | G5 | S4 | S4B, SZN | S3B, S4N | WL | | |
| Great egret | *Ardea alba* | | G5 | S3 | S, S1B, SZN | S1B | | FSC | |
| Green Heron | *Butorides virescens* | | G5 | S5 | S4B, SAN | S4S5B | | | |
| Least bittern | *Ixobrychus exilis* | | G5 | T, S2 | E, S3B | S1S2B | | FSC | |
| Little blue heron | *Egretta caerulea* | | G5 | E, S1 | SRB, SZN | S1B | | FSC | |
| Snowy egret | *Egretta thula* | | G5 | E, S1 | SZN | SZN | | FSC | |
| Yellow-crowned night-heron | *Nyctanassa violacea* | | G5 | E, S1 | E, S2B | S2B | | FSC | |
| **Ducks, Geese Swans** | **(Family Anatidae)** | | | | | | | | |
| American black duck[4] | *Anas rubripes* | | G5 | - | S1 | S4N | | | IL, IN, KY |
| Blue-winged teal | *Anas discors* | | G5 | S3 | S4B, SZN | S1S2B | | | IL, IN, KY |
| Canada goose - giants | *Branta canadensis* | | G5 | S5 | S5 | S3S4B, S4N | | | IL, IN, KY |
| Canada goose - urban giants[4] | *Branta canadensis* | | | | | | | | IL, IN, KY |
| Canada goose - Southern James Bay Population[4] | *Branta canadensis* | | | | | | | | IL, IN, KY |
| Canada goose - Eastern Prairie Population[4] | *Branta canadensis* | | | | | | | | IL, IN, KY |
| Canvasback[4] | *Aythya valisineria* | | G5 | SZN | SZN | S3N | | | IN, KY |
| Hooded merganser | *Lophodytes cucullatus* | | G5 | S2S3 | S2S3B, SZN | S1S2B, S3S4N | | | IL, IN, KY |
| Mallard[4] | *AnAs platyrhynchos* | | G5 | S5 | S4 | S3S4B, S4S5N | | | IL, IN, KY |
| Snow goose[4] | *Chen caerulescens* | | G5 | SZN | SZN | S3S4N | | | IL, IN, KY |
| Trumpeter swan[4] | *Cygnus buccinator* | | G4 | SXB, S2N | E, SRB | SXN | | | |
| Wood duck | *Aix sponsa* | | G5 | S5 | S4B, S1N | S4S5B, SZN | MIS | MIS | IL, IN, KY |
| **Hawks, Kites, Eagles** | **(Family Accipitridae)** | | | | | | | | |
| Bald eagle | *Haliaeetus leucocephalus* | T | G4 | T, S2B, S3N | E, S2 | T, S1S2B, S2S3N | | | |
| Black vulture | *Coragyps atratus* | | G5 | S3 | S1N, S2B | S4B, S3S4N | | | |
| Broad-winged hawk | *Buteo platypterus* | | G5 | S3 | S, S3B, SRFN | S4B | FSC, MIS | | |
| Cooper's hawk | *Accipiter cooperii* | | G5 | E, S3 | S3B, SZN | S4B, S4N | | FSC | |
| Mississippi kite | *Ictinia mississippiensis* | | G5 | E, S2S3 | S, S1B | S2B | | FSC | |
| Northern goshawk[4] | *Accipiter gentilis* | | G5 | SZN | SZN | SZN | | | |
| Northern harrier | *Circus cyaneus* | | G5 | E, S2B, S3N | E, S2 | S1S2B, S4N | | FSC | |
| Osprey | *Pandion haliaetus* | | G5 | E, S1 | E, S1B, SZN | S1S2B | FSC | FSC | |
| Peregrine falcon | *Falco peregrinus* | | G4 | E, S1 | E, S2B, SZN | S1B, SZN | | | |

*(table continued on next page)*

(table 7 continued)

| Common name | Scientific name | Federal status | Global[1] rank | State status & rank IL | IN | KY | FS HO[2] | SH[3] | Game species |
|---|---|---|---|---|---|---|---|---|---|
| Red-shouldered hawk | *Buteo lineatus* | | G5 | T, S2S3 | S, S3 | S4B, S4N | FSC | FSC | |
| Sharp-shinned hawk | *Accipiter striatus* | | G5 | S1S2 | S, S2B, SZN | S3B, S4N | FSC | FSC | |
| Swainson's hawk | *Buteo swainsoni* | | G5 | E, S1 | - | - | | | |
| Swallow-tailed kite[4] | *Elanoides forficatus* | | G5 | SX | - | - | | | |
| **Partridges, Grouse, Turkeys** | **(Family Phasianidae)** | | | | | | | | |
| Northern bobwhite | *Colinus virginianus* | | G5 | S5 | S4 | S5 | | MIS | IL, IN, KY |
| Ruffed grouse | *Bonasa umbellus* | | G5 | S3 | S4 | S4 | MIS | | IN, KY |
| Wild turkey | *Meleagris gallopavo* | | G5 | S5 | S4 | S4 | MIS | MIS | IL, IN, KY |
| **Rails, Gallinules, Coots** | **(Family Rallidae)** | | | | | | | | |
| American coot | *Fulica americana* | | G5 | S4 | S4B, S2N | SHB, SZN | | | IL, IN, KY |
| Black rail | *Laterallus jamaicensis* | | G4 | E, S1 | E, SHB | - | | | |
| Common moorhen | *Gallinula chloropus* | | G5 | T, S3 | S3B | S1S2B | | FSC | IN, KY |
| King rail | *Rallus elegans* | | G4G5 | E, S2 | E, S1B, SZN | S1B | | | |
| Purple gallinule | *Porphrio martinica* | | G5 | - | - | - | | FSC | KY |
| Sora | *Porzana carolina* | | G5 | S3 | S4B, SZN | SZN | | | IL, IN, KY |
| Virginia rail | *Rallus limicola* | | G5 | S3 | E, S3B, SZN | S1B?, SZN | | | IL, KY |
| Yellow rail[4] | *Coturnicops noveboracensis* | | G4 | SXB, S2N | SZN | SZN | | | |
| **Cranes** | **(Family Gruidae)** | | | | | | | | |
| Sandhill crane[4] | *Grus canadensis* | | G5 | T, S3 | S, S2B, S1N | SZN | | | |
| **Sandpipers, Phalaropes** | **(Family Scolopacidae)** | | | | | | | | |
| American avocet[4] | *Recurvirostra americana* | | G5 | SZN | SXB, SZN | SZN | | | |
| American golden-plover[4] | *Pluvialis dominica* | | G5 | SZN | SZN | SZN | | | |
| American woodcock | *Scolopax minor* | | G5 | S4 | S4B, SZN | S4, S5B, SZN | MIS | | IL, IN, KY |
| Black-bellied plover[4] | *Pluvialis squatarola* | | G5 | SZN | SZN | SZN | | | |
| Buff-breasted sandpiper[4] | *Tryngites subruficollis* | | G4 | SZN | SZN | SZN | | | |
| Wilson's snipe[4] | *Gallinago delicata* | | G5 | S3 | S1, S2B, SZN | S3S4N | | | IL, IN, KY |
| Dunlin[4] | *Calidris alpina* | | G5 | SZN | SZN | SZN | | | |
| Greater yellowlegs[4] | *Tringa melanoleuca* | | G5 | SZN | SZN | SZN | | | |
| Killdeer | *Charadrius vociferus* | | G5 | S5 | S4 | S4S5B, S4N | | | |
| Least sandpiper[4] | *Calidris minutilla* | | G5 | SZN | SZN | SZN | | | |
| Marbled godwit[4] | *Limosa fedoa* | | G5 | SZN | - | - | | | |
| Red knot[4] | *Calidris canutus* | | G5 | SZN | SZN | SZN | | | |
| Red-necked phalarope[4] | *Phalaropus lobatus* | | G4G5 | SZN | SZN | SZN | | | |
| Red phalarope[4] | *Phalaropus fulicaria* | | G5 | - | SZN | - | | | |
| Ruddy turnstone[4] | *Arenaria interpres* | | G5 | SZN | SZN | SZN | | | |
| Sanderling[4] | *Calidris alba* | | G5 | SZN | SZN | SZN | | | |
| Semipalmated sandpiper[4] | *Calidris pusilla* | | G5 | SZN | SZN | SZN | | | |
| Short-billed dowitcher[4] | *Limnodromus griseus* | | G5 | SZN | SZN | SZN | | | |
| Solitary sandpiper[4] | *Tringa solitaria* | | G5 | SZN | SZN | SZN | | | |
| Spotted sandpiper | *Actitis macularia* | | G5 | S3S4 | S4B | S1B | | | |
| Stilt sandpiper[4] | *Calidris himantopus* | | G5 | SZN | SZN | SZN | | | |
| Upland sandpiper | *Bartramia longicauda* | | G5 | E, S2S3 | E, S3B | SHB | | | |
| Western sandpiper[4] | *Calidris mauri* | | G5 | SZN | SZN | SZN | | | |
| Whimbrel[4] | *Numenius phaeopus* | | G5 | - | - | - | | | |

*(table continued on next page)*

(table 7 continued)

| Common name | Scientific name | Federal status | Global[1] rank | State status & rank IL | IN | KY | FS HO[2] | SH[3] | Game species |
|---|---|---|---|---|---|---|---|---|---|
| Willet[4] | *Catoptrophorus semipalmatus* | | G5 | SZN | SZN | SZN | | | |
| Wilson's phalarope[4] | *Phalaropus tricolor* | | G5 | E, S1 | SHB, SZN | SZN | | | |
| **Skuas, Gulls, Terns, Skimmers** | **(Family Laridae)** | | | | | | | | |
| Black tern | *Childonias niger* | | G4 | E, S1 | E, S1B, SZN | SXB, SZN | | | |
| Common tern[4] | *Sterna hirundo* | | G5 | E, S1 | SXB, SZN | SZN | | | |
| Forster's tern[4] | *Sterna forsteri* | | G5 | E, S1 | SHB, SZN | SZN | | | |
| Least tern[4] | *Sterna antillarum* | E | G4 | E, S1 | S? | S1S2 | | | |
| Least tern (interior) | *Sterna antillarum athalassos* | E | G4T2Q | E, S? | E, S1B, SZN | E, S2B | | | |
| **Pigeons, Doves** | **(Family Columbidae)** | | | | | | | | |
| Mourning dove | *Zenaida macroura* | | G5 | S5 | S5 | S5 | | | IL, IN, KY |
| Yellow-billed cuckoo | *Coccyzus americanus* | | G5 | S5 | S4B | S5B | | | |
| **Owls** | **(Families Tytonidae & Strigidae)** | | | | | | | | |
| Barn owl | *Tyto alba* | | G5 | E, S1S2 | E, S2 | S3 | FSC | FSC | |
| Barred owl | *Strix varia* | | G5 | S5 | S4 | S5 | WL | | |
| Long-eared owl | *Asio otus* | | G5 | S1B, S2N | S2 | S1B, S1S2N | | FSC | |
| Short-eared owl | *Asio flammeus* | | G5 | E, S1B, S2S3N | E, S2 | S1B, SZN | | FSC | |
| **Nighthawks, Nightjars** | **(Family Caprimuldigae)** | | | | | | | | |
| Chuck-will's-widow | *Caprimulgus carolinensis* | | G5 | S4 | S3B | S4S5B | | | |
| Whip-poor-will | *Caprimulgus vociferus* | | G5 | S5 | S4B | S5B | | | |
| **Swifts** | **(Family Appodidae)** | | | | | | | | |
| Chimney swift | *Chaetura pelagica* | | G5 | S5 | S5B | S5B | | | |
| **Kingfishers** | **(Family Alcedinidae)** | | | | | | | | |
| Belted kingfisher | *Ceryle alcyon* | | G5 | S5 | S4 | S4S5B, S4N | | | |
| **Woodpeckers** | **(Family Picidae)** | | | | | | | | |
| Hairy woodpecker | *Picoides villosus* | | G5 | S4S5 | S4 | S5 | WL | | |
| Pileated woodpecker | *Dryocopus pileatus* | | G5 | S5 | S4 | S5 | MIS | MIS | |
| Red-headed woodpecker | *Melanerpes erythrocephalus* | | G5 | S5 | S4 | S4B, S4N | | | |
| **Tyrant Flycatchers** | **(Family Tyrannidae)** | | | | | | | | |
| Acadian flycatcher | *Empidonax virescens* | | G5 | S5 | S4B | S5B | MIS | | |
| Eastern kingbird | *Tyrannus tyrannus* | | G5 | S5 | S4B | S5B | | | |
| Eastern wood-pewee | *Contopus virens* | | G5 | S5 | S4B | S5B | | | |
| Great crested flycatcher | *Myiarchus crinitus* | | G5 | S5 | S4B | S5B | | MIS | |
| Least flycatcher | *Empidonax minimus* | | G5 | S3 | S3B | S1B | | | |
| **Shrikes** | **(Family Laniidae)** | | | | | | | | |
| Loggerhead shrike | *Lanius ludovicianus* | | G4 | T, S3 | E, S3B, SZN | S4B, S4N | | RFSC | |
| **Vireos** | **(Family Vireonidae)** | | | | | | | | |
| Bell's vireo | *Vireo bellii* | | G5 | S4 | S3B | S2S3B | | | |
| Red-eyed vireo | *Vireo olivaceus* | | G5 | S5 | S4B | S5B | WL | | |
| White-eyed vireo | *Vireo griseus* | | G5 | S5 | S4B | S5B | | | |

*(table continued on next page)*

(table 7 continued)

| Common name | Scientific name | Federal status | Global[1] rank | State status & rank IL | IN | KY | FS HO[2] | SH[3] | Game species |
|---|---|---|---|---|---|---|---|---|---|
| Yellow-throated vireo | *Vireo flavifrons* | | G5 | S4S5 | S4B | S5B | WL | | |
| **Crows, Jays** | **(Family Corvidae)** | | | | | | | | |
| American crow | *Corvus brachyrhynchos* | | G5 | S5 | S5B | S5B, S5N | | | IL, IN, KY |
| Fish crow | *Corvus ossifragus* | | G5 | S2 | - | S3B | | | |
| **Swallows** | **(Family Hirundinidae)** | | | | | | | | |
| Bank swallow | *Riparia riparia* | | G5 | S5 | S4B | S3B | | | |
| **Chickadees, Titmice** | **(Family Paridae)** | | | | | | | | |
| Tufted titmouse | *Baeolophus bicolor* | | G5 | S5 | S4 | S5 | | | |
| **Nuthatches** | **(Family Sittidae)** | | | | | | | | |
| Brown creeper | *Certhia americana* | | G5 | T, S3 | S2B, SZN | S1S2B, S4S5N | | FSC | |
| Brown-headed nuthatch | *Sitta pusilla* | | G5 | SR | SRN | - | | | |
| White-breasted nuthatch | *Sitta carolinensis* | | G5 | SRN, S4 | S5 | | WL | | |
| **Wrens** | **(Family Troglodytidae)** | | | | | | | | |
| Bewick's wren | *Thryomanes bewickii* | | G5 | E, S1 | E, S1B, SZN | S3B | FSC | FSC | |
| Warner Valley Bewick's wren | *Thryomanes bewickii bewickii* | | G5T? | - | - | - | | | |
| Marsh wren | *Cistothorus palustris* | | G5 | S4 | E, S3B, SZN | SZN | | | |
| Sedge wren | *Cistothorus platensis* | | G5 | S3S4 | E, S3B, SZN | S3B | | | |
| **Gnatcatchers** | **(Family Silviidae)** | | | | | | | | |
| Blue-gray gnatcatcher | *Polioptilla caerulea* | | G5 | S5 | S4B | S5B | | | |
| **Thrushes** | **(Family Turdidae)** | | | | | | | | |
| Eastern bluebird | *Sialia sialis* | | G5 | S5 | S4B, SZN | S5B, S5N | | | |
| Wood thrush | *Hylocichla mustelina* | | G5 | S4 | S4B | S5B | MIS | MIS | |
| **Mockingbirds, Thrashers** | **(Family Mimidae)** | | | | | | | | |
| Brown thrasher | *Toxostoma rufum* | | G5 | S5 | S4B, SZN | S4S5B, SZN | | | |
| **Wood Warblers** | **(Family Parulidae)** | | | | | | | | |
| American redstart | *Setophaga ruticilla* | | G5 | S5 | S4B | S4S5B | WL | MIS | |
| Black-and-white warbler | *Mniotilta varia* | | G5 | S2S3 | S, S1S2B | S4S5B | MIS | | |
| Blackburnian warbler[4] | *Dendroica fusca* | | G5 | SZN | S3N | S1S2B | | | |
| Black-throated blue warbler[4] | *Dendroica caerulescens* | | G5 | SZN | SZN | S3S4B | | | |
| Black-throated green warbler | *Dendroica virens* | | G5 | SZN | S2B | S4B | WL | | |
| Blue-winged warbler | *Vermivora pinus* | | G5 | S4 | S4B | S4S5B | | | |
| Canada warbler | *Wilsonia canadensis* | | G5 | S1 | S2B | S3B | | | |
| Cerulean warbler | *Dendroica cerulea* | | G4 | S3 | S, S3B | S4S5B | RFSS, WL | MIS, RFSS | |
| Golden-winged warbler | *Vermivora chrysoptera* | | G4 | S1S2 | E, S1B | S2B | | | |
| Hooded warbler | *Wilsonia citrina* | | G5 | S3S4 | S, S3B | S5B | FSC | | |
| Kentucky warbler | *Oporornis formosus* | | G5 | S5 | S4B | S5B | WL | MIS | |
| Louisiana waterthrush | *Seiurus Motacilla* | | G5 | S4 | S4B | S5B | MIS | | |
| Northern parula | *Parula americana* | | G5 | S5 | S4B | S4S5B | WL | | |
| Ovenbird | *Seiurus aurocapillus* | | G5 | S4 | S4B | S5B | WL | | |

*(table continued on next page)*

**(table 7 continued)**

| Common name | Scientific name | Federal status | Global[1] rank | State status & rank IL | IN | KY | FS HO[2] | SH[3] | Game species |
|---|---|---|---|---|---|---|---|---|---|
| Pine warbler | *Dendroica pinus* | | G5 | S3S4 | S3B | S4S5B, SZN | MIS | MIS | |
| Prairie warbler | *Dendroica discolor* | | G5 | S4 | S4B | S5B | MIS | MIS | |
| Prothonotary warbler | *Protonotaria citrea* | | G5 | S5 | S4B | S5B | | MIS | |
| Swainson's warbler | *Limnothlypis swainsonii* | | G4 | E, S1 | SRB | S3S4B | | RFSS | |
| Worm-eating warbler | *Helmitheros vermivorus* | | G5 | S4 | S, S3B | S4S5B | FSC, MIS | MIS | |
| Yellow-breasted chat | *Icteria virens* | | G5 | S5 | S4B | S5B | MIS | MIS | |
| Yellow-throated warbler | *Dendroica dominica* | | G5 | S5 | S4B | S4S5B | | | |
| **Tanagers** | **(Family Thraupidae)** | | | | | | | | |
| Scarlet tanager | *Piranga olivacea* | | G5 | S5 | S4B | S5B | MIS | MIS | |
| Summer tanager | *Piranga rubra* | | G5 | S5 | S4B | S5B | | | |
| **Emberizids** | **(Family Emberizidae)** | | | | | | | | |
| Bachman's sparrow | *Aimophila aestivalis* | | G3 | SXB, SHN | E, SXB | S1B | | RFSS | |
| Eastern towhee | *Pipilo erythrophthalmus* | | G5 | S5 | S4B | S5B, S5N | | | |
| Field sparrow | *Spizella pusilla* | | G5 | S5 | S4 | S5B, S5N | | | |
| Grasshopper sparrow | *Ammodramus savannarum* | | G5 | S5 | S4B, SZN | S4B | | | |
| Henslow's sparrow | *Ammodramus henslowii* | | G4 | E, S2 | E, S3B, SZN | S3B | FSC, RFSS | RFSS | |
| Lark sparrow | *Chondestes grammacus* | | G5 | S5 | S3B, SZN | S2S3B | | | |
| Savannah sparrow | *Passerculus sandwichensis* | | G5 | S5 | S4B, SZN | S2S3B, S2S3N | | | |
| Vesper sparrow | *Pooecetes gramineus* | | G5 | S5 | S4B, SZN | S1B, SZN | | | |
| **Cardinals** | **(Family Cardinalidae)** | | | | | | | | |
| Dickcissel | *Spiza americana* | | G5 | S4 | S4B | S4S5B | | | |
| Indigo bunting | *Passerina cyanea* | | G5 | S5 | S4S5B | S5B | | | |
| Painted bunting[4] | *Passerina ciris* | | G5 | SR | - | - | | | |
| Rose-breasted grosbeak | *Pheucticus ludovicianus* | | G5 | S5 | S4B | S3S4B | | | |
| **Blackbirds** | **(Family Icteridae)** | | | | | | | | |
| Bobolink | *Dolichonyx oryzivorus* | | G5 | S4 | S4B | S2S3B | | | |
| Eastern meadowlark | *Sturnella magna* | | G5 | S, S5 | S3N, S4B | S5B, S5N | | | |
| Western meadowlark | *Sturnella neglecta* | | G5 | S5 | S2B | SAB, SZN | | | |
| Yellow-headed blackbird[4] | *Xanthocephalus xanthocephalus* | | G5 | E, S2 | E, S4B | SZN | | | |

[1] Based upon Heritage Status Rank as reported by NatureServe (2002).

[2] Species identified by the Hoosier National Forest as Forest Species of Concern (FSC), Management Indicator Species (MIS), or Regional Forester Sensitive Species (RFSS).

[3] Species identified by the Shawnee National Forest as Forest Species of Concern (FSC), Management Indicator Species (MIS), or Regional Forester Sensitive Species (RFSS).

[4] Species regarded as of seasonal importance in the assessment area. These species may not breed locally but may occur seasonally.

**Table 8.** Bird species of management or conservation concern and their status and trends within the Hoosier-Shawnee Ecological Assessment Area. Management concern is based on presence of the species on various species conservation lists.

| Common name | Federal[1] | State[2] | FWS[3] | FS[4] | GAME | Audubon Watch List | Partners In Flight Priority Tier Score for Breeding[5] | Shorebird Conservation Assessment | Severity of threats on breeding[6] | Importance of Midwest Region to species[7] | Population trends (%/yr) 1966-2000[8] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Highland Rim | Lexington Plain |
| Common loon[9] | | | | X | | | | | | | | |
| Pied-billed grebe | | | | | | | (3) | | | | | |
| Double-crested cormorant | | | X | | | | | | | | | |
| American bittern | | X | X | | | | (3) | | | | | |
| Black-crowned night-heron | | X | | X | | | (3) | | | | | |
| Cattle egret | | | | | | | (3) | | | | | |
| Great blue heron | | | | | | | (1) | | | | + 9.1% | +18.2% |
| Great egret | | X | | | | | (3) | | | | | |
| Green heron | | | | | | | (5), IIA | | | | -2.2% | -3.5% |
| Least bittern | | X | X | X | | | (3) | | | | | |
| Little blue heron | | | | | | | (4) | | | | | |
| Snowy egret | | | | | | | (3) | | | | | |
| Yellow-crowned night-heron | | X | | | | | (3) | | | | | |
| American black duck[9] | | | X | | X | X | | | | | | |
| Blue-winged teal | | | X | | X | | (3) | | | | | |
| Canada goose - giants | | | X | | X | | (1) | | | | +11.9% | 16.3% |
| Canada goose - urban giants[9] | | | X | | X | | | | | | | |
| Canada goose - SJB pop[9] | | | X | | X | | | | | | | |
| Canada goose - EPP pop[9] | | | X | | X | | | | | | | |
| Canvasback[9] | | | X | | X | | | | | | | |
| Hooded merganser | | | | | X | | (3) | | | | | |
| Mallard[9] | | | X | | X | | (1) | | | | +9.3% | +14.9% |
| Snow goose[9] | | | X | | X | | | | | | | |
| Trumpeter swan[9] | | X | X | X | | X | | | | | | |
| Wood duck | | | X | | X | | (1) | | | | | |
| Bald eagle | X | X | X | X | | | (3) | | | | | |
| Black vulture | | | | | | | (1) | | | | +11.7% | |
| Broad-winged hawk | | X | | | | | (2) | | 3 | 4 | | |
| Cooper's hawk | | | | | | | (1) | | | | | |
| Mississippi kite | | X | | | | | (3) | | 4 | 3 | | |
| Northern goshawk[9] | | | X | X | | | | | | | | |
| Northern harrier | | X | | X | | | (3) | | | | | |
| Osprey | | X | | | | | (3) | | | | | |
| Peregrine falcon | | X | X | X | | | (3) | | 3 | 1 | | |
| Red-shouldered hawk | | X | X | X | | | (2) | | | | | |
| Sharp-shinned hawk | | X | | | | | (3), IIA | | | | | |
| Swainson's hawk | | | | | | X | | | 4 | 2 | | |
| Swallow-tailed kite[9] | | | | | | | (5), I | | | | | |
| Northern bobwhite | | | | | X | | (5), IIA | | | | -3.1% | -3.9% |
| Ruffed grouse | | | | | X | | (3) | | | | | |
| Wild turkey | | | | | X | | (1) | | | | +27.2% | +6.68% |
| American coot | | | | | X | | (3) | | | | | |
| Black rail | | X | X | | | X | | | | | | |
| Common moorhen | | | | | X | | (3) | | | | | |
| King rail | | X | | X | | | (3) | | | | | |
| Purple gallinule | | | | | | | | | | | | |
| Sora | | | | | X | | (3) | | | | | |

*(table continued on next page)*

**(table 8 continued)**

| Common name | Federal[1] | State[2] | FWS[3] | FS[4] | GAME | Audubon Watch List | Partners In Flight Priority Tier Score for Breeding[5] | Shorebird Conservation Assessment | Severity of threats on breeding[6] | Importance of Midwest Region to species[7] | Population trends (%/yr) 1966-2000[8] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Highland Rim | Lexington Plain |
| Virginia rail | | X | | | | | (3) | | | | | |
| Yellow rail[9] | | | X | X | | X | | | | | | |
| Sandhill crane[9] | | X | | | | | | | | | | |
| American avocet[9] | | | | | | | | 3 | | | | |
| American golden-plover[9] | | | | | | X | | 4 | | | | |
| American woodcock | | | X | | X | X | (3), I | 4 | | | | |
| Black-bellied plover[9] | | | | | | | | 3 | | | | |
| Buff-breasted sandpiper[9] | | | | | | | | 4 | | | | |
| Common snipe[9] | | | | | X | | (3) | 3 | | | | |
| Dunlin[9] | | | | | | | | 3 | | | | |
| Greater yellowlegs[9] | | | | | | | | 3 | | | | |
| Killdeer | | | | | | | (1) | 3 | | | +1.6% | +1.5% |
| Least sandpiper[9] | | | | | | | | 3 | | | | |
| Marbled godwit[9] | | | | | | | | 4 | | | | |
| Red knot[9] | | | | | | | | 4 | | | | |
| Red-necked phalarope[9] | | | | | | | | 3 | | | | |
| Red phalarope[9] | | | | | | | | 3 | | | | |
| Ruddy turnstone[9] | | | | | | | | 4 | | | | |
| Sanderling[9] | | | | | | | | 4 | | | | |
| Semipalmated sandpiper[9] | | | | | | | | 3 | | | | |
| Short-billed dowitcher[9] | | | | | | | | 4 | | | | |
| Solitary sandpiper[9] | | | | | | | | 4 | | | | |
| Spotted sandpiper | | | | | | | (3) | 2 | | | | |
| Stilt sandpiper[9] | | | | | | | | 3 | | | | |
| Upland sandpiper | | X | | X | | | (3), IIC | 2 | 4 | 5 | | |
| Western sandpiper[9] | | | | | | | | 3 | | | | |
| Whimbrel[9] | | | | | | | | 4 | | | | |
| Willet[9] | | | | | | | | 3 | | | | |
| Wilson's phalarope[9] | | | | X | | X | | 4 | | | | |
| Black tern | | X | X | X | | | | | | | | |
| Common tern[9] | | | X | X | | | | | | | | |
| Forster's tern[9] | | | | | | | | | | | | |
| Least tern[9] | X | | | | | | (3) | | | | | |
| Least tern (interior) | X | X | X | | | | | | | | | |
| Mourning dove | | | | | X | | (2) | | | | | |
| Yellow-billed cuckoo | | | | | | | (4), IIA | | | | -1.8% | -2.8% |
| Barn owl | | X | | | | | (3) | | | | | |
| Barred owl | | | | | | | (2) | | | | | |
| Long-eared owl | | | | | | | | | | | | |
| Short-eared owl | | X | | X | | X | (3), IIC | | | | | |
| Chuck-will's-widow | | | | | | | (2), IIIB | | 2 | 3 | | |
| Whip-poor-will | | | | | | | (4), I | | 3 | 4 | -3.0% | -9.8% |
| Chimney swift | | | | | | | (4), IIA | | | | -2.2% | -2.1% |
| Belted kingfisher | | | | | | | (4), IIA | | | | -2.5% | |
| Hairy woodpecker | | | | | | | (2) | | | | | |
| Pileated woodpecker | | | | | | | (2) | | | | | +5.9% |
| Red-headed woodpecker | | | | | | X | (2), IIIB | | | | | |
| Acadian flycatcher | | | | | | | (2), I | | 3 | 4 | | |

*(table continued on next page)*

**(table 8 continued)**

| Common name | Federal[1] | State[2] | FWS[3] | FS[4] | GAME | Audubon Watch List | Partners In Flight Priority Tier Score for Breeding[5] | Shorebird Conservation Assessment | Severity of threats on breeding[6] | Importance of Midwest Region to species[7] | Population trends (%/yr) 1966-2000[8] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | Highland Rim | Lexington Plain |
| Eastern kingbird | | | | | | | (4), IIA | | 2 | 3 | -0.7% | -1.9% |
| Eastern wood peewee | | | | | | | (4), IIA | | 2 | 4 | -0.9% | -2.0% |
| Great crested flycatcher | | | | | | | (4), IIA | | 2 | 4 | | |
| Least flycatcher | | | | | | | (3) | | 2 | 4 | | |
| Loggerhead shrike | | X | X | | | | (5), IIC | | | | -7.0% | |
| Bell's vireo | | | | | | X | (4), I | | 3 | 3 | | |
| Red-eyed vireo | | | | | | | (2) | | 2 | 4 | | +1.5% |
| White-eyed vireo | | | | | | | (4), I | | 3 | 3 | -0.7% | -3.1% |
| Yellow-throated vireo | | | | | | | (3), I | | 3 | 4 | | |
| American crow | | | | | X | | (2) | | | | | +1.5% |
| Fish crow | | | | | | | (3) | | | | | |
| Bank swallow | | | | | | | (3) | | | | | |
| Tufted titmouse | | | | | | | (2), IIIA | | | | | |
| Brown creeper | | | | | | | (3) | | | | | |
| Brown-headed nuthatch[9] | | | | | | X | (3), I | | | | | |
| White-breasted nuthatch | | | | | | | (1) | | | | +3.8% | +4.9% |
| Bewick's wren | | X | | | | | (5), IIC | | | | -11.4% | -12.0% |
| Marsh wren | | X | | | | | (3) | | | | | |
| Sedge wren | | X | X | | | | (3), IIC | | | | | |
| Blue-gray gnatcatcher | | | | | | | (4), IIA | | 2 | 3 | | -4.1% |
| Eastern bluebird | | | | | | | (2), IIIA | | | | +1.9% | -2.0% |
| Wood thrush | | | X | | | X | (5), I | | 4 | 3 | | |
| Brown thrasher | | | | | | | (4), IIA | | | | -0.9% | |
| American redstart | | | | | | | (5) | | 3 | 3 | -6.0% | |
| Black-and-white warbler | | X | | | | | (3) | | 3 | 4 | -7.7% | |
| Blackburnian warbler[9] | | | | | | | | | 3 | 4 | | |
| Black-throated blue warbler[9] | | | | X | | | | | 3 | 3 | | |
| Black-throated green warbler | | | | | | | (3) | | 3 | 4 | | |
| Blue-winged warbler | | | | | | X | (5), I | | 2 | 4 | -3.1% | -8.6% |
| Canada warbler | | | | | | X | | | 3 | 4 | | |
| Cerulean warbler | | X | X | X | | X | (5), I | | 4 | 5 | -5.3% | -11.5% |
| Golden-winged warbler | | X | X | | | X | | | 3 | 5 | | |
| Hooded warbler | | X | | | | | (2) | | 3 | 3 | | |
| Kentucky warbler | | | | | | X | (2), I | | 3 | 4 | | |
| Louisiana waterthrush | | | | | | | (3), I | | | | | |
| Northern parula | | | | | | | (1) | | 3 | 3 | | |
| Ovenbird | | | | | | | (2) | | 3 | 5 | +3.3% | |
| Pine warbler | | | | | | | (1) | | | | +8.6% | |
| Prairie warbler | | | | X | | X | (5), I | | 3 | 3 | -2.5% | -2.2% |
| Prothonotary warbler | | | | | | X | (3), I | | 3 | 3 | | |
| Swainson's warbler | | | | X | | X | (3), I | | 4 | 2 | | |
| Worm-eating warbler | | X | | | | X | (3), I | | 3 | 3 | | |
| Yellow-breasted chat | | | | | | | (5), I | | 3 | 3 | -2.5% | -4.2% |
| Yellow-throated warbler | | | | | | | (1), IIB | | 3 | 3 | +4.3% | |
| Scarlet tanager | | | | | | | (1) | | 3 | 4 | +2.9% | +4.6% |
| Summer tanager | | | | | | | (2), IIB | | 3 | 3 | | -1.5% |
| Bachman's sparrow | | X | | X | | X | (5), I | | | | | |
| Eastern towhee | | | | | | | (4), IIA | | | | -1.8% | -1.9% |

*(table continued on next page)*

**(table 8 continued)**

| Common name | Federal[1] | State[2] | FWS[3] | FS[4] | GAME | Audubon Watch List | Partners In Flight Priority Tier Score for Breeding[5] | Shorebird Conservation Assessment | Severity of threats on breeding[6] | Importance of Midwest Region to species[7] | Population trends (%/yr) 1966-2000[8] Highland Rim | Lexington Plain |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Field sparrow | | | | | | | (5), I | | | | -2.5% | -4.3% |
| Grasshopper sparrow | | | X | | | | (5), IIA | | 4 | 5 | -4.1% | -11.7% |
| Henslow's sparrow | | X | X | X | | X | (1), I | | | | | |
| Lark sparrow | | | | | | | (5) | | 3 | 2 | | |
| Savannah sparrow | | | | | | | (3) | | | | | |
| Vesper sparrow | | | | | | | (4) | | | | | |
| Dickcissel | | | X | | | X | (3), IIC | | 3 | 5 | | |
| Indigo bunting | | | | | | | (4), IIIA | | 2 | 4 | -1.3% | -2.7% |
| Painted bunting[9] | | | | | | X | (3), IIC | | 2 | 1 | | |
| Rose-breasted grosbeak | | | | | | | (3) | | 2 | 4 | | |
| Bobolink | | | X | X | | | (3), IIC | | 3 | 4 | | |
| Eastern meadowlark | | | X | | | | (4), IIA | | | | -2.3% | -1.9% |
| Western meadowlark | | X | | | | | (3) | | | | | |
| Yellow-headed blackbird[9] | | X | | | | | | | 3 | 4 | | |

[1] Federally listed as endangered and threatened.
[2] State listed as endangered or threatened.
[3] USDI Fish and Wildlife Service Region 3 conservation priority species.
[4] Hoosier or Shawnee National Forest: Forest Species of Concern, Management Indicator species, or Regional Forester Sensitive Species.
[5] Partners In Flight 30-year breeding population trend for the Central Hardwoods Bird Conservation Region (BCR24); rank of 1 corresponds to large increase, rank of 5 corresponds to a large decrease.
[6] Severity of threats on the breeding ground, adapted from Thompson et al. (1992) as follows: 1 = no threats, 2 = minor threats, 3 = moderate threats, 4 = severe threats, and 5 = extirpation or extinction likely.
[7] Importance of the Midwest Region to each species adapted from Thompson et al. (1992) as follows: 1 = <1% of population in region, 2 = 1-10% of population in region, 3 = 11-25% of population in region, 4 = 26-50% of population in region, and 5 = >50%.
[8] Number in parentheses is the estimated trend within the physiographic region, summarized as % change per year from 1966 to 2000 (P < 0.10).
[9] Species regarded as of seasonal importance in the assessment area. These species may not breed locally but may occur seasonally.

**Table 9.** Habitat associations of Midwest neotropical migrant birds, mean Management Concern Score of neotropical migrants, and total number of neotropical migrant species with respect to their habitat asociations (adapted from Thompson et al. 1992). Management Concern was based upon the mean score of seven criteria including global abundance, winter distribution, severity of threats on wintering grounds and migration routes, area of breeding range, severity of threats on the breeding grounds in the Midwest, importance of the Midwest Region to species, and population trend in the Midwest region based upon Breeding Bird Survey data from 1966 to 1991. A score of 5 denotes the greatest management concern and 1 the least.

| Habitat type | Management Concern Score 1 – 1.9 | 2 – 2.9 | 3 – 3.9 | 4 – 5 | Number of species | Mean Mgmt. Concern Score |
|---|---|---|---|---|---|---|
| Lowland deciduous forest—bottomland deciduous forest | 0 | 0 | 4 | 1 | 5 | 3.57 |
| Young coniferous forest—upland coniferous forest 12 to 30 years old | 1 | 0 | 1 | 1 | 3 | 3.19 |
| Mature deciduous forest—upland deciduous forest >30 years old | 0 | 8 | 13 | 1 | 22 | 3.18 |
| Grassland—prairie, hayfield, pasture, cultivated grasses | 0 | 5 | 7 | 0 | 12 | 3.07 |
| Shrub-sapling—shrub swamp, upland old field, seedling–sapling forest <12 years old | 2 | 11 | 10 | 1 | 24 | 3.02 |
| Mature coniferous forest—upland coniferous forest >30 years old | 0 | 10 | 6 | 0 | 16 | 3.00 |
| Young deciduous forest—upland deciduous forest 12 to 30 years old | 0 | 3 | 4 | 0 | 7 | 3.00 |
| Lowland coniferous forest—bottomland coniferous forest | 0 | 3 | 3 | 0 | 6 | 2.88 |
| Developed—urban, suburban, rural development | 0 | 3 | 1 | 0 | 4 | 2.75 |
| Wetland—sedge meadow, fen, cattail marsh | 0 | 1 | 0 | 0 | 1 | 2.71 |
| Agricultural-woodland edge—woody fence-rows, shelterbelts, and forest edge in agricultural landscapes | 0 | 5 | 0 | 0 | 5 | 2.69 |
| Primary—ledges, cliffs, caves, banks, etc. | 0 | 5 | 0 | 0 | 5 | 2.29 |
| **TOTAL** | **3** | **54** | **49** | **4** | **110** | |

a remarkable achievement in the description of karst species and their distribution, little is understood of the life histories and vulnerabilities of karst species. In particular, little work has been conducted within the caves of the Shawnee National Forest or within the Kentucky portion of the assessment area.

Of the 173 species of global viability concern within the assessment area, 140 (81%) use cave and karst habitats. This includes 134 invertebrates and 6 mammals, 5 of which are bats (table 5). Many of these invertebrates are endemic to the karst region of south-central Indiana or to specific river drainages within that area (Lewis 1998, Lewis et al. 2002, Lewis et al. 2003). Examples include the Reynolds' cave millipede (*Pseudotremia reynoldsae*), known from one location within the Hoosier National Forest (Lewis et al. 2003, Lewis 2003), and Young's cave ground beetle (*Pseudanophthalmus youngi*), another endemic of the south-central Indiana karst region (Lewis et al. 2003).

Of the 39 invertebrates determined to be of state viability concern, 21 of these species (54%) are either terrestrial or aquatic cave-associated fauna. In total, 161 species or 36 percent of all of the species identified as of global or State viability concern in the assessment area are cave or karst associated species. In addition, four cave or karst systems within the assessment area are considered global subterranean hot spots: the Binkley Cave System, Wyandotte Cave System, Lost River Cave System, and the Tincher Karst Area (Lewis 1998, Lewis et al. 2002, Lewis et al. 2003). A cave system is given this rating when it contains 20 or more obligate subterranean species. The four areas are located within Indiana; the Lost River Cave System and Tincher Karst Area occur partly within the Hoosier National Forest.

The private ownership of cave and karst areas can further complicate the conservation of cave-associated species. Conservation groups, including The Nature Conservancy and Indiana Karst Conservancy, have partnered with the Hoosier National Forest and Indiana State agencies to actively acquire some of these locations as they become available. Recent acquisitions include the 213-acre Blanton property, purchased by The Nature Conservancy. Adjacent to the Wesley Chapel Special Area on the Hoosier National Forest, these two properties contain multiple entrances and miles of passage of the Lost River Cave System. The Lost River Cave System is currently the third longest in the State of Indiana. It contains the most extensive fauna found in any Indiana cave, among which are a community of obligate subterranean fauna of global significance (Lewis et al. 2003).

The comparatively high number of cave-associated species with global and state viability concerns underscores the importance of this habitat type within the assessment area. Karst ecosystems are perhaps the least understood habitat type within the area. The species inhabiting karst ecosystems are unique, understudied, and to some extent, undiscovered. Many of the cave species within the assessment area are known from only a single or a handful of locations (Lewis 1998, Lewis et al. 2002, Lewis et al. 2003). Some of these caves and their associated fauna are threatened by development, road construction, runoff, sewage, and human visitation (Lewis 2002a, Lewis 2002b, Lewis et al. 2003).

## BIRDS OF CONSERVATION CONCERN

In addition to global and state Heritage Status rankings (table 7), evaluation of birds identified as species of viability concern was expanded to include those species identified as USDI Fish and Wildlife Service Region 3 conservation priority species (USDI Fish and Wildlife Service 2002), species identified in the National Shorebird Conservation Plan (Brown et al. 2001), Audubon Watch List species

(National Audubon Society 2002), and those listed by Partners in Flight as either tier I, II, or III conservation priority species (Panjabi 2001). Avian species identified as Regional Forester Sensitive Species, Forest Species of Concern, and Management Indicator Species were similarly considered (table 8). Neotropical migrant land birds were considered in particular because of the pervading concern for conserving these species.

Population trend data were considered for the Highland Rim and Lexington Plain physiographic regions; both regions encompass portions of the assessment area (fig. 6). Long-term population trends (1966–2000) were based upon the North American Breeding Bird Survey, a standardized survey conducted across North America to provide continental, regional, and route-specific assessment of bird populations (Peterjohn 1994, Sauer et al. 2001).

Thompson et al. (1992) identified 110 neotropical migrants that breed in the Midwest and developed conservation priority rankings for those species based upon seven criteria (table 9). Two of these criteria, breeding ground threats and importance of the Midwest to these species, are listed to provide a broader perspective of conservation issues within the Midwest (table 7). Threats on breeding grounds included habitat loss and fragmentation, cowbird parasitism, predation, contamination, and human disturbance among others. Thompson et al. (1992) determined the importance of the Midwest to each species based upon the extent to which the breeding range of each species was encompassed by the region.

Of the 160 birds identified as of management or conservation concern within the assessment area (tables 7, 8), North American Breeding Bird Survey data were sufficient to identify 40 species with regional long-term population trends. From 1966 to 2000, 14 species increased in abundance in either, or both, the Highland Rim or Lexington Plain physiographic regions; 27 species decreased in abundance (table 8). In the case of the eastern bluebird (*Sialia sialis*), numbers of this species declined within the Lexington Plain but increased in the Highland Rim physiographic region.

The limitations of analyses based upon Breeding Bird Survey data have been previously discussed (Thompson et al. 1992). The inability to identify significant long-term population trends for many of these species is predominantly a function of their current or continued rarity. The inability to calculate population trends for certain species should in no way suggest any measure of species stability or abundance. For example, the Hoosier-Shawnee avifauna include such species as the Henslow's sparrow (*Ammodramus henslowii*) and Bell's vireo (*Vireo bellii*), of which there is insufficient data with which to identify regional population trends, yet these species are recognized to be of conservation concern by multiple organizations or agencies.

### Neotropical Migrant Birds

Neotropical migrant birds make up approximately a third of the avian species of conservation concern in the assessment area. Of the 21 neotropical migrants with sufficient data with which to determine regional population trends, 16 declined while 5 species increased from 1966 to 2000 (table 7). Considering the habitat associations of the 16 regionally declining species (Thompson et al. 1992, table 9), one species is associated with agricultural edge, one with developed lands, one with grasslands, five with shrublands, two with young deciduous forest, and six with mature deciduous forest. Of the five species with increasing populations trends, one species is associated with mature conifer forest (pine warbler, *Dendroica pinus*) and four are associated with mature deciduous forest (red-eyed vireo, *Vireo olivaceus*; ovenbird, *Seiurus aurocapillus*; yellow-throated warbler, *Dendroica dominica*; and scarlet tanager, *Piranga olivacea*).

A growing body of evidence suggests that numerous passerines have declined in abundance over the last 50 years, particularly those species collectively known as neotropical migrants (Askins 1995, Robbins et al. 1989, Robbins et al. 1992, Robinson 1996, Sauer and Droege 1992, Thompson et al. 1996). As many as 143 species of neotropical migrants breed in North America and winter south of the United States. At least 110 of these species breed in the Midwest (Thompson et al. 1992), suggesting the importance of the region in the conservation of neotropical migrant birds.

The American Bird Conservancy has led an effort to identify critical habitats for these species, formally designating these sites as globally Important Bird Areas (IBAs). Sites are designated as Important Bird Areas if they contain significant populations of a federally listed species, species on the Partners In Flight Watch List, or species with restricted ranges, or if the site provides habitat for large concentrations of migratory birds. Relative to the remainder of the Midwest, the assessment area contains a substantial number of globally Important Bird Areas (table 13).

A diverse group, neotropical migrants utilize a variety of habitat types including wetlands, agricultural-woodland edge, grasslands, shrub-sapling, swamp, upland old fields, seedling-sapling forest, lowland coniferous forest, lowland deciduous forest, young deciduous forest, mature deciduous forest, coniferous forest, mature coniferous forest, caves, banks, and even developed areas. Within the Midwest, shrub-sapling habitats, mature upland deciduous forest, mature upland coniferous forests, and grasslands have the highest species richness (Thompson et al. 1992).

Although significant tracts of habitat remain within the assessment area, conservation of neotropical migrants is nonetheless a complex task because of the diverse life history of these species and the multiple threats that likely influence their success.

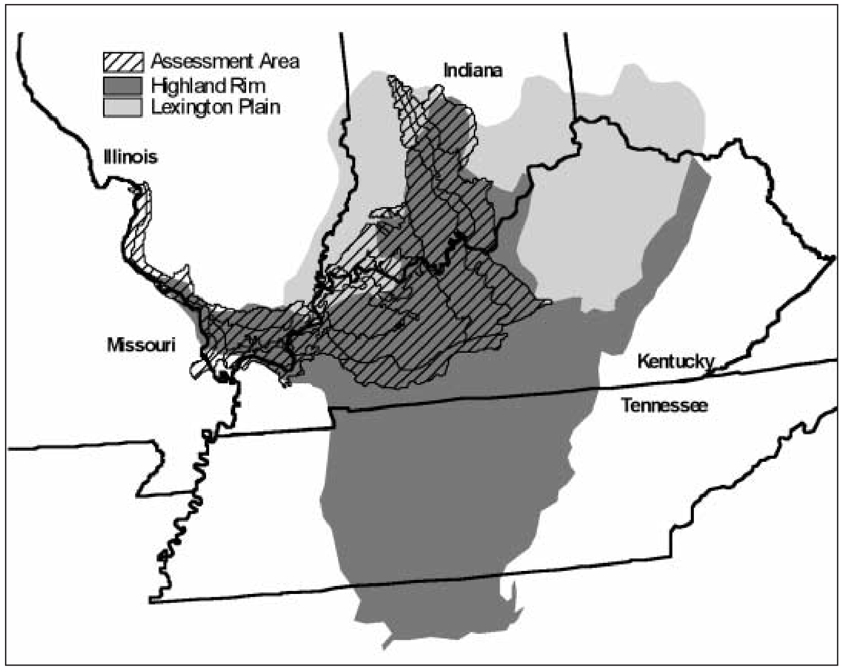


**Figure 6.** Location of the assessment area in relation to the Highland Rim and Lexington Plain physiographic regions. Evaluation of bird population trends was based upon North American Breeding Bird Survey data from these two physiographic regions that encompass the assessment area.

Among the most taxing of issues regarding the conservation of neotropical migrants is the growing recognition that many of these species are dependent upon the use of periodically disturbed habitats. Some of these species are, in fact, obligate early successional species, including such species in the assessment area as the Henslow's sparrow, Bell's vireo, and yellow-breasted chat (*Icteria virens*). The decline of these species is likely related to the loss of grasslands, old fields, and shrublands (Herkert 1991, Herkert et al. 1996). But this should not detract from the effort directed toward species associated with other habitats such as mature deciduous forest; it does, however, reveal the difficulty in managing for diversity within a limited landscape. The association of species with disturbance and the difficulty in managing these habitats has been the subject of recent reviews (Askins 2001, Gobster 2001, Hunter et al. 2001, Thompson and DeGraaf 2001). Not only may some species require multiple habitat types, but the same factors impinging upon forest obligate species may likely influence the

**Table 10.** Mammal species of management or conservation concern found within the Hoosier-Shawnee Ecological Assessment Area.

| | | Federal | Global[1] | State status & rank | | | FS | | Game |
|---|---|---|---|---|---|---|---|---|---|
| **Common name** | **Scientific name** | **status** | **rank** | **IL** | **IN** | **KY** | **HO[2]** | **SH[3]** | **species** |
| Allegheny woodrat | *Neotoma magister* | | G3G4 | - | E, S2 | S4 | RFSS | | |
| American badger | *Taxidea taxus* | | G5 | S4 | E, S2 | SR | RFSS | | IL |
| American beaver | *Castor canadensis* | | G5 | S5 | S4 | S5 | WL | | IL, IN, KY |
| American mink | *Mustela vison* | | G5 | S5 | S4 | S5 | | | IL, IN, KY |
| Bobcat | *Lynx rufus* | | G5 | S3 | E, S1 | S4 | RFSS, MIS | FSC | KY |
| Common gray fox | *Urocyon cinereoargenteus* | | G5 | S5 | S4 | S4 | | | IL, IN, KY |
| Common raccoon | *Procyon lotor* | | G5 | S5 | S4 | S5 | MIS | | IL, IN, KY |
| Coyote | *Canis latrans* | | G5 | S5 | S4 | S5 | | | IL, IN |
| Eastern cottontail | *Sylvilagus floridanus* | | G5 | S5 | S4 | S5 | | | IL, IN, KY |
| Eastern fox squirrel | *Sciurus niger* | | G5 | S5 | S4 | S5 | | | IL, IN, KY |
| Eastern gray squirrel | *Sciurus carolinensis* | | G5 | S5 | S4 | S5 | MIS | MIS | IL, IN, KY |
| Eastern small-footed myotis | *Myotis leibii* | | G3 | - | - | S2 | | | |
| Eastern spotted skunk | *Spilogale putorius* | | G5 | SR | SX | S2S3 | | | |
| Eastern woodrat | *Neotoma floridana* | | G5 | E, S1 | - | - | | RFSS | |
| Evening bat | *Nycticeius humeralis* | | G5 | S3 | E, S1 | S2S3 | RFSS | | |
| Franklin's ground squirrel | *Spermophilus franklinii* | | G5 | S4 | E, S2 | - | | | |
| Golden mouse | *Ochrotomys nuttalli* | | G5 | T, S2 | - | S4 | | FSC | |
| Gray myotis | *Myotis grisescens* | E | G3 | E, S1 | E, S1 | E, S2 | | | |
| Indiana bat | *Myotis sodalis* | E | G2 | S1 | E, S1 | E, S1S2 | | | |
| Least weasel | *Mustela nivalis* | | G5 | S3 | S, S2? | S2S3 | | | IL, KY |
| Long-tailed shrew | *Sorex dispar* | | G4 | - | - | S1 | | | |
| Long-tailed weasel | *Mustela frenata* | | G5 | S4 | S4 | S4 | | | IL, IN, KY |
| Marsh rice rat | *Oryzomys palustris* | | G5 | T, S2 | - | S4 | | FSC | |
| Masked shrew | *Sorex cinereus* | | G5 | S5 | S4 | S3 | | | |
| Muskrat | *Ondatra zibethicus* | | G5 | S5 | S4 | S5 | | | IL, IN, KY |
| Northern river otter | *Lutra canadensis* | | G5 | T, S2 | E, S? | S3S4 | RFSS | FSC | |
| Plains pocket gopher | *Geomys bursarius* | | G5 | S3 | S, S2 | - | | | |
| Pygmy shrew | *Sorex hoyi* | | G5 | SH | S, S2 | S4 | | | |
| Rafinesque's big-eared bat | *Plecotus rafinesquii* | | G3G4 | E, S1 | S, SH | S3 | | FSC | |
| Red fox | *Vulpes vulpes* | | G5 | S5 | S4 | S5 | | | IL, IN, KY |
| Smoky shrew | *Sorex fumeus* | | G5 | - | S, S2 | S5 | | | |
| Southeastern myotis | *Myotis austroriparius* | | G3G4 | E, S1 | E, S1 | S1S2 | RFSS | RFSS | |
| Southern flying squirrel | *Glaucomys volans* | | G5 | S5 | S4 | S5 | | | |
| Star-nosed mole | *Condylura cristata* | | G5 | SR | S, S2? | - | | | |
| Striped skunk | *Mephitis mephitis* | | G5 | S5 | S4 | S5 | | | IL, IN, KY |
| Swamp rabbit | *Sylvilagus aquaticus* | | G5 | S3 | E, S1 | S3S4 | | | IL, KY |
| Virginia opossum | *Didelphis virginiana* | | G5 | S5 | S4 | S5 | | | IL, IN, KY |
| Western harvest mouse | *Reithrodontomys megalotis* | | G5 | S4 | S2 | - | | | |
| White-tailed deer | *Odocoileus virginianus* | | G5 | S5 | S5 | S5 | WL | SRI | IL, IN, KY |
| Woodchuck | *Marmota monax* | | G5 | S5 | S4 | S5 | | | IL, IN |

1 Based upon Heritage Status Rank as reported by NatureServe (2002).

2 Species identified by the Hoosier National Forest as a Forest Species of Concern (FSC), Management Indicator Species (MIS), or Regional Forester Sensitive Species (RFSS).

3 Species identified by the Shawnee National Forest as a Forest Species of Concern (FSC), Management Indicator Species (MIS), or Regional Forester Sensitive Species (RFSS).

**Table 11.** Reptile and amphibian species of conservation concern found within the Hoosier-Shawnee Ecological Assessment Area.

| Common name | Scientific name | Federal status | Global[1] rank | State status & rank IL | IN | KY | FS HO[2] | SH[3] |
|---|---|---|---|---|---|---|---|---|
| **Salamanders** | | | | | | | | |
| Green salamander | *Aneides aeneus* | | G3G4 | - | E, S? | S4 | RFSS | |
| Eastern hellbender | *Cryptobranchus alleganiensis alleganiensis* | | G3G4 T3T4 | E, | E, S1 | S3 | | |
| Dusky salamander | *Desmognathus fuscus* | | G5 | E, S2 | S4 | S5 | | FSC |
| Four-toed salamander | *Hemidactylium scutatum* | | G5 | T, S2 | E, S2 | S4 | | |
| Mudpuppy | *Necturus maculosus* | | G5 | S5 | S, S2 | S4 | | |
| Northern red salamander | *Pseudotriton ruber ruber* | | G5T5 | - | E, S1 | S5 | | |
| **Frogs & Toads** | | | | | | | | |
| Bird-voiced treefrog | *Hyla avivoca* | | G5 | T, S3 | - | T, S2S3 | | RFSS |
| Green treefrog | *Hyla cinerea* | | G5 | S3 | - | S3 | | |
| Barking treefrog | *Hyla gratiosa* | | G5 | - | - | S3 | | |
| Gray treefrog | *Hyla versicolor* | | G5 | S4 | S4 | S2S3 | | |
| Northern crawfish frog | *Rana areolata circulosa* | | G4T4 | - | E, S2 | S3 | | |
| Plains leopard frog | *Rana blairi* | | G5 | S4 | S, S2 | - | | |
| Bullfrog | *Rana catesbeiana* | | G5 | S5 | S4 | S5 | | |
| Green frog | *Rana clamitans* | | G5 | S4 | S? | S5 | | |
| Northern leopard frog | *Rana pipiens* | | G5 | S5 | S, S2 | S3 | | |
| Eastern spadefoot | *Scaphiopus holbrookii holbrookii* | | G5T5 | - | S2 | S4 | | |
| Illinois chorus frog | *Pseudacris streckeri illinoensis* | | | T, - | | | | |
| **Turtles** | | | | | | | | |
| Smooth softshell turtle | *Apalone mutica* | | G5 | S3 | S4 | S3 | | |
| Spiny softshell turtle | *Apalone spiniferus* | | G5 | S5 | S4 | S5 | | |
| Common snapping turtle | *Chelydra serpentina* | | G5 | S5 | S4 | S5 | | |
| Eastern mud turtle | *Kinosternon subrubrum* | | G5 | S3S4 | E, S2 | S3S4 | | |
| Alligator snapping turtle | *Macroclemys temminckii* | | G3G4 | E, S1 | E, S1 | T, S2 | | FSC |
| River cooter | *Pseudemys concinna* | | G5 | E, S1 | E, S? | S3 | | FSC |
| Ornate box turtle | *Terrapene ornata ornata* | | G5T5 | - | E, - | - | | |
| **Lizards** | | | | | | | | |
| Collared lizard | *Crotaphytus collaris* | | G5 | - | - | - | | |
| Northern coal skink | *Eumeces anthracinus anthracinus* | | G5T5 | - | - | S2 | | |
| Southeastern five-lined skink | *Eumeces inexpectatus* | | G5 | - | - | S3 | | |
| Slender glass lizard | *Ophisaurus attenuatus* | | G5 | S4 | S2 | S2 | | |
| **Snakes** | | | | | | | | |
| Western cottonmouth | *Agkistrodon piscivorus leucostoma* | | G5T5 | - | E, S1 | S3S4 | | |
| Northern scarlet snake | *Cemophora coccinea copei* | | G5T5 | - | E, S1 | S3S4 | | |
| Kirtland's snake | *Clonophis kirtlandii* | | G2 | T, S2 | E, S2 | S2 | | |
| Timber rattlesnake | *Crotalus horridus* | | G4 | T, S3 | E, S2 | S4 | RFSS | RFSS |
| Corn snake | *Elaphe guttata guttata* | | G5T5 | - | - | S3 | | |
| Western mud snake | *Farancia abacura reinwardtii* | | G5T5 | - | SX | S3 | | |
| Western hognose snake | *Heterodon nasicus* | | G5 | T, S2 | - | - | | |
| Milk snake | *Lampropeltis triangulum* | | G5 | S? | S? | S5 | | |
| Smooth green snake | *Liochlorophis vernalis* | | G5 | S3S4 | E, S2 | - | | |

*(table continued on next page)*

(table 11 continued)

| Common name | Scientific name | Federal status | Global[1] rank | State status & rank IL | IN | KY | FS HO[2] | SH[3] |
|---|---|---|---|---|---|---|---|---|
| Eastern coachwhip | *Masticophis flagellum* | | G5 | E, S1 | - | SX | | |
| Mississippi green water snake | *Nerodia cyclopion* | | G5 | T, S1 | - | S1 | | FSC |
| Copperbelly water snake | *Nerodia erythrogaster neglecta* | T, (north. pop.) | G5T2T3 | S2 | E, S2 | S3 | | RFSS |
| Broad-banded water snake | *Nerodia fasciata confluens* | | G5T5 | E, - | - | S1 | | |
| Rough green snake | *Opheodrys aestivus* | | G5 | S5 | S, S3 | S5 | | |
| Northern pine snake | *Pituophis melanoleucus* | | G4 | - | - | S2 | | |
| Eastern massasauga | *Sistrurus catenatus catenatus* | | G3G4 T3T4 | E, S2 | E, S2 | - | | |
| Western pygmy rattlesnake | *Sistrurus miliarius streckeri* | | G5T5 | - | - | S3 | | |
| Southeastern crowned snake | *Tantilla coronata* | | G5 | - | E, S1 | S3S4 | | |
| Flathead snake | *Tantilla gracilis* | | G5 | T, S2 | - | - | | |
| Western ribbon snake | *Thamnophis proximus* | | G5 | S4 | S, S3 | S1S2 | | |
| Eastern ribbon snake | *Thamnophis sauritus* | | G5 | E, S1 | S4 | S3 | | FSC |

[1] Based upon Heritage Status Rank as reported by NatureServe (2002).
[2] Species identified by the Hoosier National Forest as a Forest Species of Concern (FSC), Management Indicator Species (MIS), or Regional Forester Sensitive Species (RFSS).
[3] Species identified by the Shawnee National Forest as a Forest Species of Concern (FSC), Management Indicator Species (MIS), or Regional Forester Sensitive Species (RFSS).

**Table 12.** Terrestrial invertebrate species of conservation concern found within the Hoosier-Shawnee Ecological Assessment Area.

| Scientific name | Common name | Federal status | Global[1] rank | State status & rank |  |  | FS |  |
|---|---|---|---|---|---|---|---|---|
|  |  |  |  | IL | IN | KY | HO[2] | SH[3] |
| **Amphipods** |  |  |  |  |  |  |  |  |
| *Crangonyx packardi* | Packard's cave amphipod |  | G3[4] | S1 | S3[4] | S4S5 | RFSS |  |
| *Crangonyx undescribed species* 1 | Barr's cave amphipod |  | G3[4] | - | S3[4] | S? |  |  |
| *Crangonyx undescribed species* 2 | Indiana cave amphipod |  | G3[5] | - | S3[4] | - |  |  |
| *Stygobromus subtilus* | Subtle cave amphipod |  | G2 | S2 | - | - |  | RFSS |
| *Stygobromus undescribed species* 1 | Amphipod crustacean |  | G1[4] | - | S1[4] | - |  |  |
| *Stygobromus undescribed species* 2 | Amphipod crustacean |  | G1[4] | - | S1[4] | - |  |  |
| *Stygobromus undescribed species* 3 | Amphipod crustacean |  | G1[4] | - | S1[4] | - |  |  |
| **Beetles** |  |  |  |  |  |  |  |  |
| *Aleochara lucifiga* | Cave rove beetle |  | G4[5] | - | S3[3] | - | RFSS |  |
| *Atheta annexa* | Beetle |  | G3 | - | S1 | - |  |  |
| *Atheta lucifuga* | Light shunning rove beetle |  | G3[4] | - | S3[4] | - |  |  |
| *Batriasymmodes undescribed species* | Patton Cave ant beetle |  | G1[5] | - | S1[5] | - |  |  |
| *Batrisoldes undescribed species* 1 | Cave ant beetle |  | G1[4] | - | S1[4] | - |  |  |
| *Batrisoldes undescribed species* 2 | Cave ant beetle |  | G1[5] | - | S1[5] | - |  |  |
| *Catops gratiosus* | Beetle |  | G4[4] | S? | S2[2] | - |  |  |
| *Cicindela patruela* | A tiger beetle |  | G3 | - | S3 | - |  |  |
| *Dryobius sexnotatus* | Six-banded longhorn beetle |  | G? | - | T, S? | S1 |  |  |
| *Necrophilus pettiti* | A carrion beetle |  | G4[4] | - | S2[4] | - |  |  |
| *Nicrophorus americanus* | American burying beetle | E | G2G3 | SH | SH | SH |  |  |
| *Pseudanophthalmus eremita* | Wyandotte Cave ground beetle |  | G1[4] | - | S1[4] | - |  |  |
| *Pseudanophthalmus stricticollis* | Marengo Cave ground beetle |  | G3[4] | - | S3[4] | - | RFSS |  |
| *Pseudanophthalmus tenuis* | Blue River cave ground beetle |  | G3[4] | - | S3[4] | - |  |  |
| *Pseudanophthalmus undescribed species* 1 | Undescribed cave ground beetle |  | G1[4] | - | S1[4] | - |  |  |
| *Pseudanophthalmus undescribed species* 2 | Undescribed cave ground beetle |  | G1[5] | - | S1[5] | - |  |  |
| *Pseudanophthalmus undescribed species* 3 | Undescribed cave ground beetle |  | G1[5] | - | S1[5] | - |  |  |
| *Pseudanophthalmus youngi* | Young's cave ground beetle |  | G2[4] | - | S2[4] | - | RFSS |  |
| *Ptomaphagus cavernicola* | Cavernicolous fungus beetle |  | G3[4] | - | S1[4] | - |  |  |
| *Tychobythinus bythinioides* | Ant beetle |  | G3[4] | - | S2[4] | - |  |  |
| *Quedius spelaeus* | Spelean rove beetle |  | G5[4] | S? | S2 | - |  |  |
| **Butterflies and Moths** |  |  |  |  |  |  |  |  |
| *Amblyscirtes aesculapius* | Laced-wing roadside skipper |  | G3G4 |  | S1 |  |  |  |
| *Amblyscirtes belli* | Bell's roadside skipper |  | G4 | S1? | S1S2 | S2S3 | RFSS |  |
| *Amblyscirtes hegon* | Salt-and-pepper skipper |  | G5 | SU | S1S3 | S4 |  |  |
| *Atrytone arogos* | Arogos skipper |  | G3G4 | E, S1 | - | - |  |  |
| *Autochton cellus* | Golden-banded skipper |  | G4 | S1S3 | S1S2 | S3 |  |  |
| *Calephelis mutica* | Swamp metalmark |  | G3G4 | E, S1 | S2S3 | S2 | RFSS |  |
| *Catocala marmorata* | Marbled underwing moth |  | G3G4 | S? | S1 | SU |  |  |
| *Celastrina nigra* | Sooty azure |  | G4 | S2 | S2 | S3 |  |  |
| *Cycnia inopinatus* | Unexpected milkweed moth |  | G4 | - | S2 | - |  |  |
| *Cyllopsis gemma* | Gemmed satyr |  | G5 | SU | S2 | S4 |  |  |
| *Eosphoropteryx thyatyroides* | Pinkpatched looper moth |  | G4G5 | - | T, S2 | - |  |  |
| *Erora laeta* | Early hairstreak |  | G3G4 | - | - | S1 |  |  |
| *Erynnis martialis* | Mottled duskywing |  | G3G4 | S1 | T, S3 | SU | RFSS |  |
| *Euphydryas phaeton* | Baltimore checkerspot |  | G4 | S3 | S2S4 | S3 |  |  |

*(table continued on next page)*

**(table 12 continued)**

| Scientific name | Common name | Federal status | Global[1] rank | State status & rank IL | IN | KY | FS HO[2] | SH[3] |
|---|---|---|---|---|---|---|---|---|
| *Euphyes dukesi* | Scarce swamp skipper | | G3 | S1 | S2 | S1 | | |
| *Fixsenia favonius ontario* | Northern hairstreak | | G4 | S1S3 | S2S4 | S1 | | |
| *Hesperia leonardus* | Leonardus skipper | | G4 | SU | S2 | S3 | | |
| *Hesperia metea* | Cobweb skipper | | G4G5 | T, S3 | T, S2S3 | S3 | | |
| *Hesperia ottoe* | Ottoe skipper | | G3G4 | T, S2 | E, S1 | - | | |
| *Hyperaeschra georgica* | A prominent moth | | G5 | - | T, S2 | - | | |
| *Lytrosis permagnaria* | A geometrid moth | | G3G4 | - | T, S2 | E, S1 | | |
| *Papaipema astute* | Astute stoneroot borer moth | | G3G4 | - | S? | - | | |
| *Papaipema beeriana* | Beer's blazingstar borer moth | | G3 | S? | S? | - | | |
| *Papaipema eryngii* | Rattlesnake-master borer moth | | G1G2 | E, S1 | SX | S1 | | |
| *Parasa indetermina* | Wild rose slug moth | | G4 | - | S? | - | | |
| *Papaipema marginidens* | Margined borer moth | | G4 | - | S1 | S? | | |
| *Papaipema rutila* | Mayapple borer moth | | G4 | S? | S1 | - | | |
| *Pieris virginiensis* | West Virginia white | | G3G4 | S? | S3 | S4 | RFSS | |
| *Polygonia faunus* | Green comma | | G5 | - | - | SH | | |
| *Satyrodes appalachia appalachia* | Appalachian eyed brown | | G4 | - | E, S1 | - | | |
| *Schinia gloriosa* | Glorius flower moth | | G4 | E, - | SU | - | | |
| *Schinia jaguarina* | Jaguar flower moth | | G4 | - | S? | - | | |
| *Speyeria idalia* | Regal fritillary | | G3 | T, S2 | S1 | S2S3 | | |
| *Thorybes confusis* | Eastern cloudywing | | G4 | - | S1? | SU | | |
| **Copepods** | | | | | | | | |
| *Cauloxenus stygius* | Northern cavefish commensal copepod | | G3 | - | S1 | - | RFSS | |
| *Diacyclops jeanneli jeanneli* | Jeannel's cave copepod | | G2[5] | - | S2[5] | - | | |
| *Megacyclops undescribed species* | Undescribed copepod crustacean | | G1[4] | - | S1[4] | - | RFSS | |
| *Megacyclops donnaldsoni donnaldsoni* | Donaldson's cave copepod | | G1[4] | - | S1[4] | - | | |
| *Rheocyclops indiana* | Indiana groundwater copepod | | G1[5] | - | S1[5] | - | | |
| *Rheocyclops undescribed species* | Undescribed copepod crustacean | | G1[4] | - | S1[4] | - | | |
| **Diplurans** | | | | | | | | |
| *Campodea plusiochaeta* | Dipluran | | G1 | - | S1 | - | | |
| *Eumesocampa undescribed species* | Campodeid dipluran | | G1[4] | - | S1[4] | - | | |
| *Litocampa undescribed species* | Campodeid dipluran | | G2[4] | - | S2[4] | - | | |
| **Isopods** | | | | | | | | |
| *Caecidotea jordani* | Jordan's groundwater isopod | | G1[4] | - | S1[4] | - | | |
| *Caecidotea teresae* | Teresa's groundwater isopod | | G1[4] | - | S1[4] | - | | |
| *Ligidium elrodii* | Elrod's terrestrial isopod | | G4[5] | S? | S4[5] | - | | |
| *Miktoniscus barri* | Barr's terrestrial isopod | | G2[4] | - | S2[4] | - | | |
| **Leafhoppers** | | | | | | | | |
| *Dorycephalus sp.* | Shovel-headed leafhopper | | G3G4 | - | S? | - | | |
| *Dorydiella kansana* | Kansas preacher | | G3G4 | - | S1 | - | | |
| *Fitchiella robertsoni* | Robertson's elephant hopper | | G2G3 | - | S1 | - | | |
| *Flexamia reflexa* | Indian grass flexamia | | G2G3 | - | S2S3 | S? | | |
| *Paraphlepsius lupalus* | Leafhopper | | G? | E, S1 | - | - | | |
| *Polyamia herbida* | Prairie panic grass leafhopper | | G2G3 | - | S? | S? | | |

*(table continued on next page)*

(table 12 continued)

| Scientific name | Common name | Federal status | Global[1] rank | State status & rank | | | FS | |
|---|---|---|---|---|---|---|---|---|
| | | | | IL | IN | KY | HO[2] | SH[3] |
| **Millipedes** | | | | | | | | |
| *Cambala annulata* | Annulate millipede | | G5 | - | S2 | - | | |
| *Cambala minor* | Millipede | | G5 | S? | S2 | - | | |
| *Conotyla bollmani* | Bollman's cave milliped | | G3[4] | - | S3[4] | - | RFSS | |
| *Euryurus leachii* | Leach's millipede | | G4[5] | - | S2 | - | | |
| *Pseudotremia conservata* | TNC cave milliped | | G1[4] | - | S1[4] | - | | |
| *Pseudotremia indianae* | Blue River cave milliped | | G3[4] | - | S3[4] | - | | |
| *Pseudotremia reynoldsae* | Reynolds' cave milliped | | G1[5] | - | S1[5] | - | | |
| *Pseudotremia salisae* | Salisa's cave milliped | | G1[5] | - | S1[5] | - | | |
| *Pseudotremia undescribed species* 1 | Troglobitic milliped | | G1[4] | - | S1[4] | - | | |
| *Pseudotremia undescribed species* 2 | Troglobitic milliped | | G1[4] | - | S1[4] | - | | |
| *Scoterpes undescribed species* | Troglobitic milliped | | G1[4] | - | S1[4] | - | | |
| *Scytonotus granulatus* | Granulated millipede | | G5 | - | S3[5] | - | RFSS | |
| **Ostracods** | | | | | | | | |
| *Dactylocythere susanae* | Susan's commensal ostracod | | G3 | - | S3 | S? | | |
| *Pseudocandona jeanneli* | Jeannel's cave ostracod | | G1[4] | - | S1[4] | - | | |
| *Pseudocandona marengoensis* | Marengo cave ostracod | | G1[4] | - | S1[4] | - | | |
| *Sagittocythere barri* | Barr's commensal cave ostracod | | G4 | - | S3 | S? | | |
| **Pseudoscorpions** | | | | | | | | |
| *Apochthonius indianensis* | Indiana cave pseudoscorpion | | G1[5] | - | S1[5] | - | | |
| *Apochthonius undescribed species* 1 | Undescribed pseudoscorpion | | G1[4] | - | S1 | - | | |
| *Apochthonius undescribed species* 2 | Cave pseudoscorpion | | G1[5] | - | S1 | - | | |
| *Chitrella undescribed species* | Undescribed cave pseudoscorpion | | G1[4] | - | S1[4] | - | | |
| *Chthonius virginicus* | Virginian pseudoscorpion | | G3[4] | - | S1[4] | - | | |
| *Hesperochernes mirabilis* | Wonderful pseudoscorpion | | G3[4] | - | S2[4] | S? | RFSS | |
| *Kleptochthonius griseomanus* | Gray-handed pseudoscorpion | | G1[5] | - | S1[5] | - | | |
| *Kleptochthonius packardi* | Pseudoscorpion | | G1[5] | - | S1[5] | - | | |
| *Kleptochthonius undescribed species* 1 | Undescribed pseudoscorpion | | G1[4] | - | S1[4] | - | | |
| *Kleptochthonius undescribed species* 2 | Undescribed pseudoscorpion | | G1[4] | - | S1[4] | - | | |
| *Kleptochthonius undescribed species* 3 | Undescribed pseudoscorpion | | G1[4] | - | S1[4] | - | | |
| **Snails** | | | | | | | | |
| *Anguispira kochi* | Terrestrial snail | | G3[4] | S? | S? | S2 | | |
| *Antroselates spiralis* | Shaggy cave snail | | G2 | - | S2 | S2 | | |
| *Carychium exile* | Ice thorn | | G5 | S? | T, S2 | S3S4 | RFSS | |
| *Carychium riparium* | Floodplain carych | | G3[4] | - | S3[4] | - | | |
| *Fontigens cryptica* | Hidden spring snail | | G1[4] | - | S1[4] | - | | |
| *Glyphyalinia cryptomphala* | Thin glyph | | G4 | - | S1[5] | S2S3 | | |
| *Glyphyalinia latebricola* | Ledge glyph | | G2[4] | - | S1[4] | - | | |
| *Glyphyalinia lewisiana* | Lewis' glyph | | G3[4] | - | S1[4] | - | | |
| *Glyphyalinia rimula* | Karst glyph | | G2[4] | - | S1[4] | - | | |
| *Patera laevior* | Terrestrial snail | | G3[5] | - | S1[5] | SU | | |
| *Stenotrema (Euchemotrema) hubrichti* | Carinate pill snail | | G1 | | | | | RFSS |
| **Spiders** | | | | | | | | |
| *Anahita punctulata* | Wandering spider | | G4 | - | S1 | - | | |
| *Bathyphantes weyeri* | Weyers Cave sheet-web spider | | G2[4] | - | S1[4] | - | | |

*(table continued on next page)*

**(table 12 continued)**

| | | Federal | Global[1] | State status & rank | | | FS | |
|---|---|---|---|---|---|---|---|---|
| **Scientific name** | **Common name** | **status** | **rank** | **IL** | **IN** | **KY** | **HO[2]** | **SH[3]** |
| *Aleochara lucifiga* | Cave rove beetle | | G4[5] | S? | S3[5] | - | | |
| *Calymmaria cavicola* | Cave funnel-web spider | | G4[5] | S2 | S3[5] | - | | |
| *Cicurina arcuata* | Funnel-web spider | | G3[4] | - | S1 | - | | |
| *Cicurina pallida* | Pallid funnel-web spider | | G4[4] | S? | S2 | - | | |
| *Dolomedes scriptus* | Lined nursery web spider | | G4[4] | - | S2[4] | - | | |
| *Dolomedes vittatus* | Nursery web spider | | G4[4] | S? | S1 | - | | |
| *Eidmanella pallida* | Pallid cave spider | | G5[4] | - | S1 | - | | |
| *Eperigone indicabilis* | Sheet-web spider | | G1[4] | - | S1[4] | - | | |
| *Erebomaster flavescens* | Golden cave harvestman | | G3[4] | - | S2[4] | - | RFSS | |
| *Islandiana cavealis* | Iceland cave sheet-web spider | | G1[4] | - | S1[4] | S1 | | |
| *Nesticus carteri* | Carter cave spider | | G3[5] | - | S1[5] | - | RFSS | |
| *Oreonetides undescribed species* | Sheet-web spider | | G1[5] | - | S1[5] | - | | |
| *Porhomma cavernicolum* | Cavernicolous sheet-web spider | | G4 | S? | S2[5] | S? | RFSS | |
| *Sabacon cavicolens* | Cavernicolous harvestman | | G3[4] | - | S1[4] | - | | |
| *Talanites echinus* | Sac-web spider | | G2[4] | - | S1 | - | | |
| **Springtails** | | | | | | | | |
| *Arrhopalites ater* | Black medusa springtail | | G1[4] | - | S1[4] | - | | |
| *Arrhopalites benitus* | Springtail | | G1 | - | S1 | - | | |
| *Arrhopalites bimus* | Springtail | | G3G4 | - | E, S1 | S? | | |
| *Arrhopalites carolynae* | Carolyn's cave springtail | | G2[5] | - | S1[5] | - | | |
| *Arrhopalites lewisi* | Lewis' cave springtail | | G2[4] | - | S2[4] | - | | |
| *Arrhopalites undescribed species near lewisi* | Cave springtail | | G2[4] | - | S2[4] | - | | |
| *Arrhopalites undescribed species near marshalli* | Cave springtail | | G1[5] | - | S1[5] | - | | |
| *Arrhopalites whitesidei* | Whiteside's springtail | | G2[5] | S? | S1[5] | - | | |
| *Dicyrtoma flammea* | Flaming springtail | | G3[4] | - | S1 | - | | |
| *Entomobrya socia* | Social springtail | | G2[5] | - | S2[5] | - | | |
| *Folsomia candida* | White springtail | | G3[4] | S? | S3[4] | - | | |
| *Folsomia parvus* | Small springtail | | G3[4] | - | S1[4] | - | | |
| *Folsomia prima* | Primitive springtail | | G2[4] | S? | S1 | - | | |
| *Hypogastrura gibbosus* | Humped springtail | | G2[5] | - | S1 | - | | |
| *Hypogastrura helena* | Helen's springtail | | G1[4] | - | S1 | - | | |
| *Hypogastrura horrida* | Bristly springtail | | G2[4] | - | S1[4] | - | | |
| *Hypogastrura lucifuga* | Wyandotte cave springtail | | G1[4] | - | S1[4] | - | | |
| *Hypogastrura maheuxi* | Maheux springtail | | G2[4] | - | S1 | - | | |
| *Hypogastrura succinea* | Girded springtail | | G4[4] | - | S1 | - | | |
| *Hypogastrura undescribed species near succinea* | Springtail | | G1[5] | - | S1[5] | - | | |
| *Isotoma anglicana* | Springtail | | G3[4] | - | S1[4] | - | | |
| *Isotoma caerulatra* | Blue springtail | | G1[4] | - | S1[4] | - | | |
| *Isotoma christianseni* | Christiansen's springtail | | G1[4] | - | S1 | - | | |
| *Isotoma nigrifrons* | Dark springtail | | G2[4] | - | S1[4] | - | | |
| *Isotoma nixoni* | Nixon's springtail | | G1[5] | - | S1[5] | - | | |
| *Isotoma torildao* | Springtail | | G1[4] | - | S1[4] | - | | |
| *Isotoma truncata* | Truncated springtail | | G2[5] | - | S2[5] | - | | |
| *Isotoma (Desoria) undescribed species* | Springtail | | G1[4] | - | S1[4] | - | | |
| *Isotomiella minor* | Petit springtail | | G3[4] | - | S2 | - | | |
| *Onychiurus casus* | Fallen springtail | | G4[4] | - | S2 | - | | |

*(table continued on next page)*

**(table 12 continued)**

| Scientific name | Common name | Federal status | Global[1] rank | State status & rank | | | FS | |
|---|---|---|---|---|---|---|---|---|
| | | | | IL | IN | KY | HO[2] | SH[3] |
| *Onychiurus reluctus* | A springtail | | G3[4] | - | S2[4] | - | | |
| *Onychiurus subtenus* | Slender springtail | | G3[4] | - | S1 | - | | |
| *Onychiurus undescribed species* 1 | Springtail | | G1[5] | - | S1[5] | - | | |
| *Onychiurus undescribed species* 2 | Paradox springtail | | G1[5] | - | S1[5] | - | | |
| *Onychiurus undescribed species near casus* | Springtail | | G1[5] | - | S1[5] | - | | |
| *Onychiurus undescribed species near paro* | Springtail | | G1[5] | - | S1[5] | - | | |
| *Proisotoma libra* | Springtail | | G2[5] | - | S1[5] | - | | |
| *Pseudosinella collina* | Hilly springtail | | G2[4] | - | S1[4] | - | | |
| *Pseudosinella fonsa* | Fountain cave springtail | | G2[4] | - | S2[4] | - | RFSS | |
| *Pseudosinella undescribed species* | Springtail | | G1[5] | - | S1[5] | - | | |
| *Pseudosinella undescribed species near collina* | Springtail | | G1[4] | - | S1[4] | - | | |
| *Pseudosinella undescribed species near fonsa* | Springtail | | G1[5] | - | S1[5] | - | | |
| *Sensillanura barberi* | Barber's springtail | | G2[4] | - | S1 | - | | |
| *Sensillanura caeca* | Blind springtail | | G3[4] | - | S1 | - | | |
| *Sensillanura undescribed species* | Springtail | | G1[5] | - | S1[5] | - | | |
| *Sensillanura undescribed species near bara* | Springtail | | G1[5] | - | S1[5] | - | | |
| *Sensillanura undescribed species near illina* | Springtail | | G1[4] | - | S1[4] | - | | |
| *Sinella alata* | Wingless winged cave springtail | | G3[4] | - | S3[4] | - | RFSS | |
| *Sinella avita* | Ancestral springtail | | G3 | S? | S1 | S? | | |
| *Sinella barri* | Barr's cave springtail | | G3[4] | S? | S1[4] | S? | | |
| *Sinella cavernarum* | Cavernicolous springtail | | G4 | S? | S2 | S? | RFSS | |
| *Sinella undescribed species* | Cave springtail | | G1[4] | - | S1[4] | - | | |
| *Sminthurides hypogramae* | Springtail | | G1[4] | - | S1[4] | - | | |
| *Sminthurides weichseli* | Weichsel's springtail | | G2[4] | - | S1[4] | - | | |
| *Sminthurinus malmgreni* | Malmgren's springtail | | G3[4] | S? | S3 | - | | |
| *Tomocerus bidenatus* | Two-toothed springtail | | G4[5] | S? | S3 | - | RFSS | |
| *Tomocerus dubius* | Springtail | | G3[5] | - | S1[5] | - | | |
| *Tomocerus elongatus* | Elongate springtail | | G3[4] | - | S1[4] | - | | |
| *Tomocerus lamelliferus* | Layered springtail | | G4[4] | - | S1 | - | | |
| *Tomocerus (Lethemurus) missus* | Relict cave springtail | | G2[4] | S? | S1[4] | S? | | |
| *Tomocerus undescribed species* | Springtail | | G1[5] | - | S1[5] | - | | |
| **Miscellaneous** | | | | | | | | |
| *Sphalloplana chandleri* | Chandler's cave flatworm | | G1[4] | - | S1[4] | - | | |
| *Sphalloplana weingartneri* | Weingartner's cave flatworm | | G2[4] | - | S2[4] | - | | |
| *Veigaia bakeri* | Baker's cave mite | | G1[4] | - | S1[4] | - | | |
| *Veigaia wyandottensis* | Wyandotte cave mite | | G1[4] | - | S1[4] | - | | |

[1] Based upon Heritage Status Rank as reported by NatureServe (2002).
[2] Species identified by the Hoosier National Forest as a Forest Species of Concern (FSC), Management Indicator Species (MIS), or Regional Forester Sensitive Species (RFSS).
[3] Species identified by the Shawnee National Forest as a Forest Species of Concern (FSC), Management Indicator Species (MIS), or Regional Forester Sensitive Species (RFSS).
[4] Based upon Heritage Status Rank as reported by Lewis (1998).
[5] Based upon Heritage Status Rank as reported by Lewis et al. (2003).

**Table 13.** Globally Important Bird Areas within or adjacent to the Hoosier-Shawnee Ecological Assessment Area.

| | |
|---|---|
| **Illinois** | |
| Crab Orchard National Wildlife Refuge | |
| Lower Cache River Complex | |
| Rend Lake State Fish and Wildlife Area | |
| Shawnee National Forest | |
| Union County Conservation Area | |
| **Indiana** | |
| Big Oaks National Wildlife Refuge | |
| Brown County State Park | |
| Hoosier National Forest | |
| Monroe Reservoir | |
| Morgan-Monroe State Forest | |
| Reclaimed Coal Mine Grasslands | |
| Yellowwood State Forest | |
| **Kentucky** | |
| Fort Campbell | |
| Reelfoot Lake Wildlife Management Area | |

success of disturbance dependent or early successional neotropical migrants as well: habitat fragmentation, composition of habitats within a landscape matrix, area dependence, edge, floral composition of habitat, parasitism, source-sink dynamics, and predation (Ambuel and Temple 1983, Andren 1992, Andren 1995, Angelstam 1986, Askins 1993, Blake and Karr 1984, Bond 1987, Brawn and Robinson 1996, Donovan et al. 1995, Faaborg et al. 1995, Hawrot and Niemi 1996, Heske 1995, Pulliam 1988, Pulliam and Danielson 1991, Robinson 1992, Robinson 1996, Robinson et al. 1995, Thompson 1994).

Neotropical migrants may acquire growing importance as indicators of ecosystem health, exemplifying the need to manage on larger spatial scales than previously recognized (Maurer 1993, Villard and Maurer 1996). Land managers may need to strategically identify habitat areas of sufficient extent, type, and successional stage to maintain a desired composition of neotropical species within the assessment area. This may require the selective acquisition and restoration of areas likely to be detrimental to neotropicals, e.g., agricultural in-holdings, as well as acquisitions designed to extend contiguous acreages.

## KEY GAME SPECIES

### Bobwhite Quail

Bobwhite quail have steadily declined across their range since at least the mid-1950s. From 1980 to 1999, populations of this grassland-old field representative declined by approximately 65 percent within the Central Hardwood Bird Conservation Region (BCR 24), which encompasses the assessment area (Dimmick et al. 2002; figs. 7, 8). The loss of native grasslands, the transition from pastoral land use to clean rowcrop agriculture, and the progressive consolidation of farms into larger, cleaner blocks of land have resulted in the rangewide decline of numerous species dependent on early successional and open-land habitats. This trend, combined with increased rural development, has aggravated habitat loss by further fragmenting open lands (Herkert et al. 1996). Additionally, existing grasslands in the assessment area are pervasively dominated by tall fescue (Kentucky 31, *Festuca arundinacea*), which has limited value as avian habitat (Barnes et al. 1995, Madej and Clay 1991, Roseberry and David 1994, Washburn et al. 2000). A highly invasive exotic species, tall fescue was widely used in CP-1 plantings (Introduced Grasses) of the Conservation Reserve Program throughout the Eastern United States (Osborn et al. 1995).

Bobwhite quail occur in the assessment area where the physical features of the landscape have limited the expansion of rowcrop agriculture and where substantial old fields characterized by woody invasion persist. For example, comparatively stable numbers of quail, albeit low compared to historic levels, occur throughout southern Indiana. The southwest and southeastern areas of the State, however, provide more suitable habitats than do the more heavily forested regions (McCreedy 2002).

Although bobwhite quail are unlikely to approach their historic levels, integrating them into public and private joint grassland recovery efforts may help this and other open-land species (Fenwick and Pashley 2002). In the assessment area, grassland birds may accrue some benefit from the wildlife-related conservation measures of the Farm Bill, the reclamation of minelands, and where appropriate, the restoration of native savannahs and grasslands on public and private lands.

## American Woodcock

In addition to the North American Breeding Bird Survey conducted by the U.S. Geological Survey, the U.S. Fish and Wildlife Service annually evaluates rangewide American woodcock (*Scolopax minor*) breeding populations through the use of a singing ground survey (Kelley 2002). Rangewide, Breeding Bird Survey results suggest a 1.02 percent annual decline in woodcock numbers between 1966 and 2000 (Sauer et al. 2001; figs. 9, 10). Results from the Woodcock Singing Ground Survey, timed to take advantage of the male courtship display, suggest a rangewide annual decline of 1.8 percent from 1968 to 2002 (Kelley 2002). In the Central Management Region, which encompasses Illinois and Indiana, results suggest an annual decline of 1.6 percent over the same period and a 1.5 percent annual decline from 1992 to 2002 (Kelley 2002). The Fish and Wildlife Service does not survey singing ground routes in Kentucky; too few routes, with too few woodcock detected per route, are conducted in either Indiana or Illinois to produce statistically reliable results for these States.

In addition to changes in land use, woodcock have declined in association with the maturation of mesic forests and the loss of periodic disturbance necessary to maintain early successional mesic forest types. In the Central Plains States (Illinois, Indiana, Iowa, Missouri) approximately 15 percent of forested acres

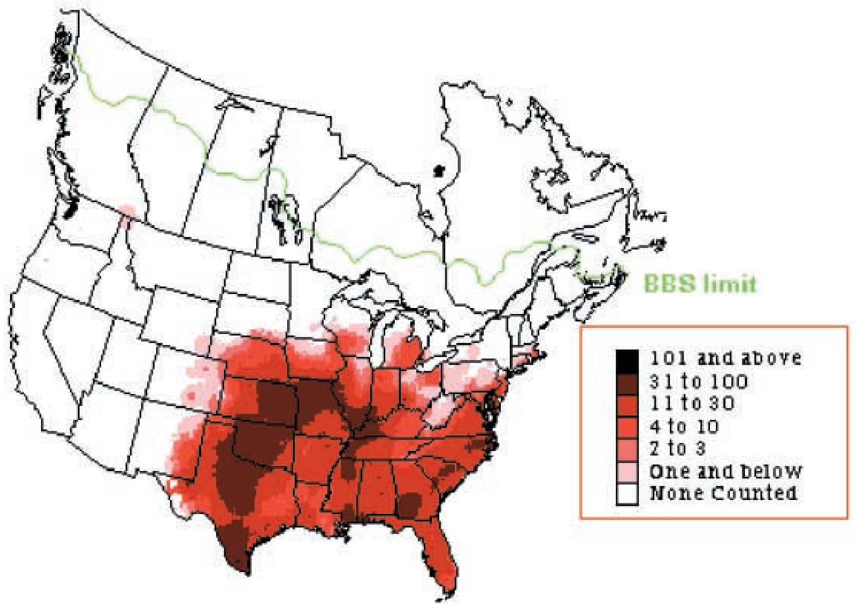


**Figure 7.** Current rangewide distribution and relative abundance of the northern bobwhite quail based on North American Breeding Bird Survey counts between 1982 and 1996 (Sauer et al. 2001).

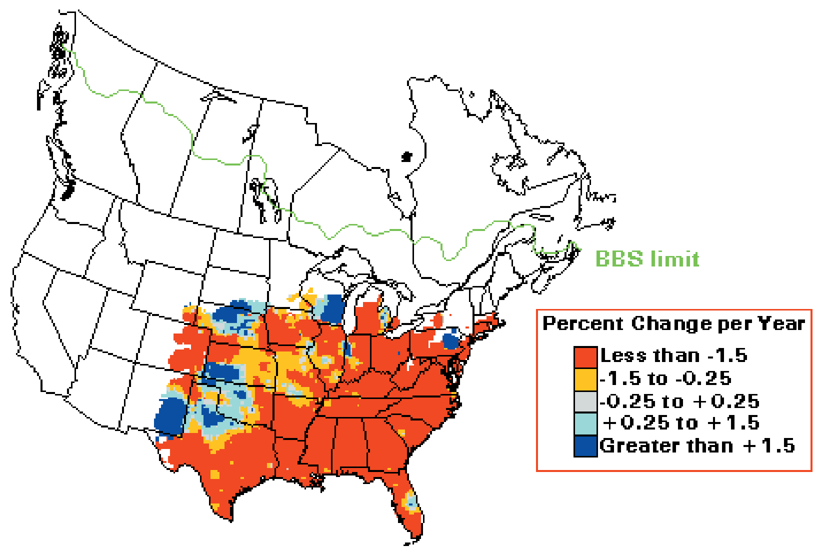


**Figure 8.** Regional population trends of the northern bobwhite quail over 1980 to 1999 based on results of the North American Breeding Bird Survey (Sauer et el. 2001).

were classified as seedling-sapling in the most recent forest inventory (Trani et al. 2001). Only 3 percent of Illinois forests (1998) and 6 percent of Indiana forests (1998) were characterized as seedling-sapling. In the approximately 15 years between forest inventories in Central Plains States, forest acreage increased by 600,000 hectares while early successional forest acreage declined by approximately

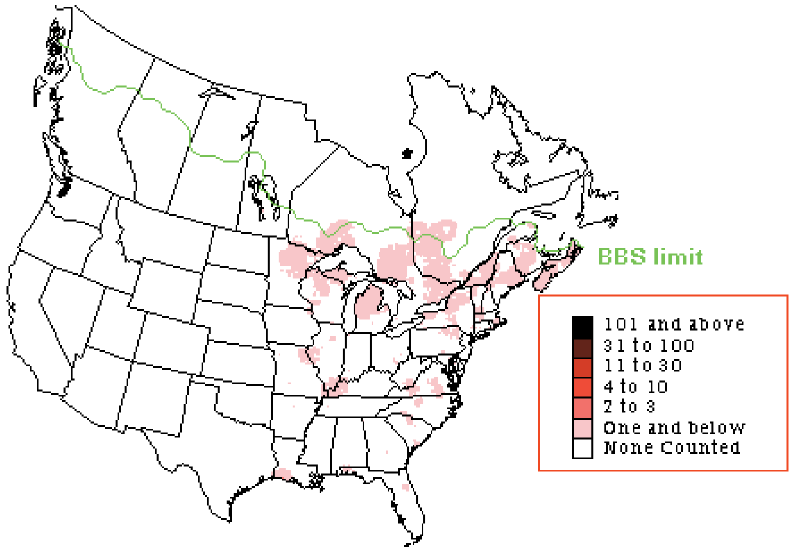


**Figure 9.** Current rangewide distribution and relative abundance of the American woodcock based on North American Breeding Bird Survey counts between 1982 and 1996 (Sauer et al. 2001).

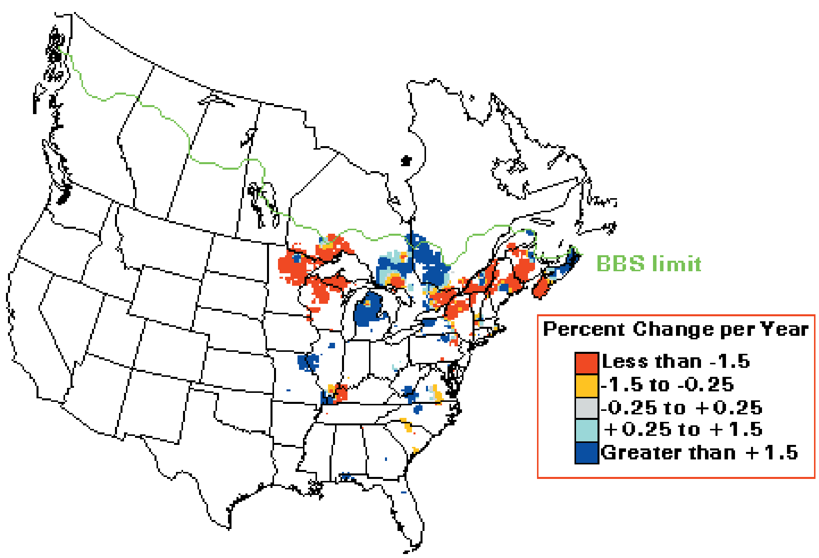


**Figure 10.** Regional population trends of the American woodcock over 1966 to 1996 based on results of the North American Breeding Bird Survey (Sauer et al. 2001).

300,000 hectares. Of those States in the assessment area, the forests of Kentucky, surveyed in 1988, contained the highest percentage of seedling-sapling stage timber (16%; Trani et al. 2001). The vast majority of seedling-sapling timber acreage in these States, however, is in private ownership, approximately two-thirds of which may be contained in average blocks of less than 8 hectares (Birch 1996). Given these considerations, concern for the conservation of woodcock and other disturbance-dependent birds (Hunter et al. 2001, Thompson and Dessecker 1997) has grown as has the appreciation for the difficulty in incorporating disturbance in forest management (Askins 2001, Thompson and DeGraaf 2001).

Historically, at least before wide-scale efforts in flood control, periodic flooding served to maintain early successional bottomland forests. Apart from consideration of either the use of fire or silviculture, the restoration of wetland habitats in the assessment area, ongoing within the national forests, may provide a disturbance regime capable of maintaining a limited acreage of early successional bottomland forest of benefit to the American woodcock.

## Ruffed Grouse

The ruffed grouse (*Bonasa umbellus*) is the most widely distributed of North America's resident game birds, historically occurring throughout Illinois, Indiana, and Kentucky. These birds persist in the assessment area as remnant resident or reintroduced populations of restricted distribution. Only in eastern Kentucky, outside the assessment area, do substantial numbers of grouse now occur. State wildlife agencies in both Illinois and Kentucky have previously attempted reintroductions in the assessment area.

Two of twelve recent western Kentucky reintroductions have been reported as successful: reintroductions at the Pennyrile Forest Wildlife Management Area in Christian and Hopkins Counties and those at the Fort Knox Military Reservation encompassing portions of Bullitt, Hardin, and Meade Counties (Kentucky Department of Fish and Wildlife Resources 2001b; fig. 11). Results of the Illinois Breeding Bird Atlas suggest that grouse possibly persist in Jackson and Union Counties in the Shawnee National Forest. Grouse numbers continue to decline in south-central Indiana counties where they were once trapped for reintroduction in Illinois and Kentucky (fig. 12).

Results of the North America Breeding Bird Survey depict notable heterogeneity in the status and distribution of ruffed grouse across their range (figs. 13, 14), and this most likely reflects the declining availability of early successional forest habitats. In midwestern oak-hickory forest types, ruffed grouse favor 7- to 15-year-old regeneration stands where this type makes up at least 10 to 20 percent of total stand area (Kubisiak 1985, Thompson and Dessecker 1997, Wiggers et al. 1992). The public unpopularity of these habitats and the continued likely loss of early successional acreage on non-industrial private forests suggests that habitats for early successional forest species may continue to decline in the assessment area (Askins 2001, Dessecker and McAuley 2001). Within the assessment area, those species dependent upon early successional upland forest may derive limited benefit from the conversion of nonnative pines to native hardwoods or through silvicultural practices intended to benefit other rare or declining species.

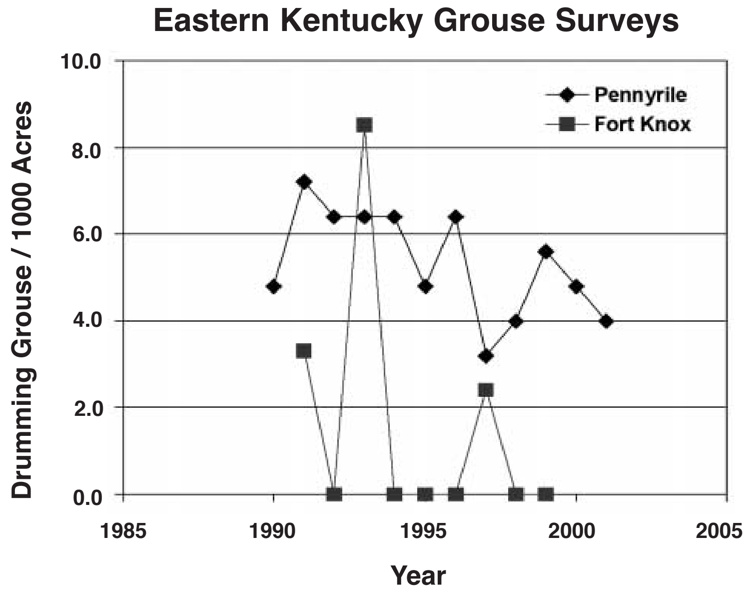


**Figure 11.** Results of ruffed grouse drumming count surveys on two eastern Kentucky sites within the assessment area. Reintroductions at Pennyrile Forest Wildlife Management Area and the Fort Knox Military Reservation represent 2 successes out of 12 attempts to reintroduce grouse to areas of their former range in Kentucky.

### Eastern Wild Turkey

The three States in the assessment area share a common history with respect to the fate and recovery of the eastern wild turkey (*Meleagris gallopavo*). Before European settlement, wild turkeys were widely distributed throughout the forested Eastern United States. As the wave of early settlement advanced across the Midwest, clearing of the eastern deciduous hardwood forest restricted the distribution of them. Concurrently, unregulated subsistence hunting took an increasing toll on them. At the turn of the last century, wild turkeys were reduced to remnant populations inhabiting only those areas unfavorable for settlement, namely the remote Adirondacks, Ozarks, and southern swamps. Public support for harvest regulation, reforestation, and the successional advancement of abandoned lands formed the early foundation for the recovery of this species throughout its former range.

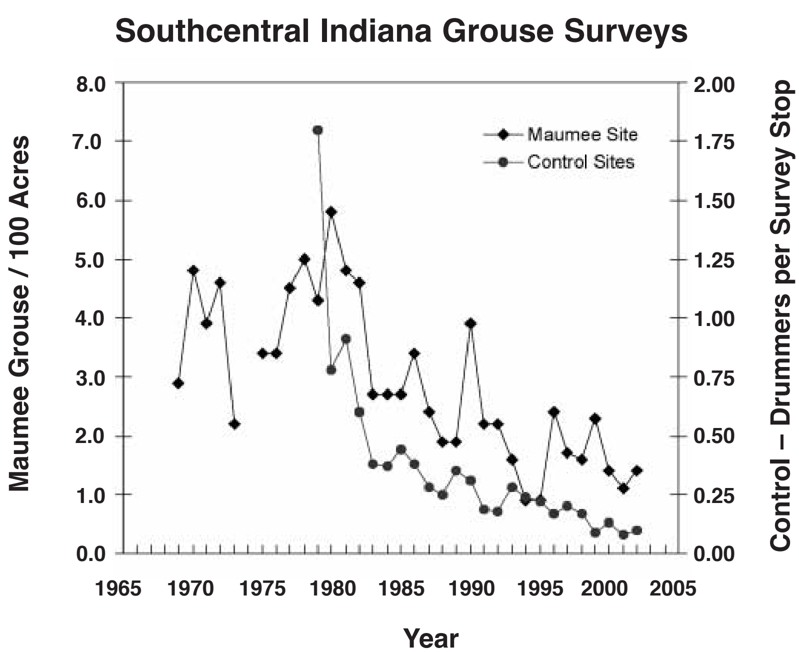


**Figure 12.** Results of ruffed grouse drumming count surveys conducted in south-central Indiana within or near the assessment area (Backs 2002). Results of drumming count surveys on the Maumee Study Area (Jackson and Brown Counties) are expressed as densities of grouse per 100 acres and assume a 1:1 sex ratio. Drumming count surveys on sites that serve as controls for the Maumee study are conducted within Brown, Greene, Jackson, Jefferson, Lawrence, Martin, Monroe, Morgan, Orange, Owen, Perry, and Putnam Counties. Data for control routes are expressed as the number of drumming males per survey stop.

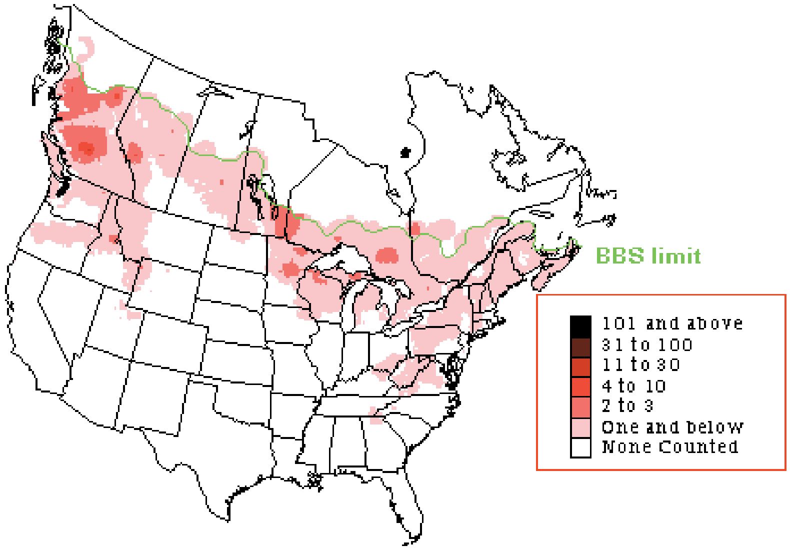


**Figure 13.** Current rangewide distribution and relative abundance of the ruffed grouse as determined by results of the North American Breeding Bird Survey between 1982 and 1996 (Sauer et al. 2001).

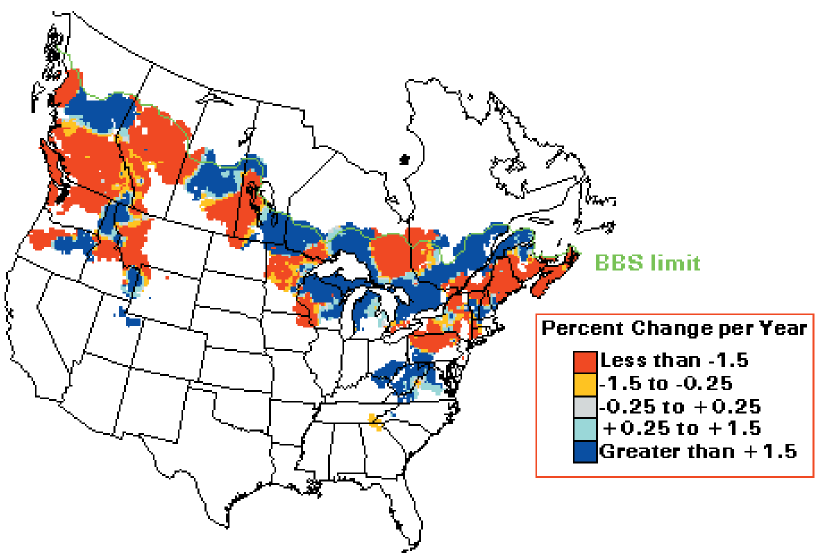


**Figure 14.** Regional population trends of the ruffed grouse over 1966 to 1996 based on results of the North American Breeding Bird Survey (Sauer et al. 2001).

Indiana's effort to restore turkeys to their former range began in 1960 following Illinois' initial restoration effort in 1958 (Backs 1999). Wild turkeys persisted as a remnant population in Kentucky until substantial effort began in 1978 to restore them to their former range. Indiana's Division of Fish and Wildlife has reintroduced a cumulative total of 2,639 turkeys, Illinois has reintroduced a total of 4,768 of these birds, and the Kentucky Department of Fish and Wildlife Resources has released a total of 7,600 turkeys since beginning restoration efforts. Annual hunt harvest of wild turkeys now exceeds 10,000 birds in Indiana, 14,000 in Illinois, and 28,000 in Kentucky.

Hunt participation and harvest of wild turkeys in Indiana is reasonably representative of the recovery and growth of turkey populations within the three-State region as well as the assessment area (fig. 15). Within the nine-county area in which the Hoosier National Forest is located (Brown, Crawford, Dubois, Jackson, Lawrence, Martin, Monroe, Orange, and Perry Counties), hunters harvested 2,451 turkeys of a statewide total of 10,575 in 2002 (Backs and Walker 2002). Within the Purchase and Green River Regions of western Kentucky, approximately 11,550 turkeys, of a statewide total of 28,210, were harvested during the spring 2002 Kentucky turkey season (Kentucky Department of Fish and Wildlife Resources 2003). Southern region hunters in Illinois harvested 5,293 turkeys of a statewide total of 14,314 birds in 2002 (Illinois Department of Natural Resources 2003).

Extensive mature hardwood forest within the assessment area, embedded to some degree within a matrix of agricultural land use, has provided this species with habitat conditions conducive to population growth and range expansion (Lewis 1992, Porter 1992). It is likely that the eastern wild turkey now occupies the majority of suitable habitats in the three-State region as well as the assessment area proper.

## White-tailed Deer

The States of Kentucky, Illinois, and Indiana share much of the history common to midwestern white-tailed deer management. Settlement of the Midwest brought dramatic changes in land use, and unregulated exploitation resulted in near extirpation of white-tailed deer in all three States between 1850 and the turn of the century. Beginning in the 1930s, both the States of Indiana and Illinois sought to restore their deer herds through restocking programs (Indiana Division of Fish and Wildlife 1997, Thomas 2000). The State of Kentucky began a similar effort soon thereafter. Indiana opened its first post-restoration deer hunting season in 1951 and Illinois followed with its first season in 1957. Consistent with the effort to restore deer herds, Indiana and Kentucky hunters were allowed to harvest only bucks during this period of intended herd growth. Beginning in the mid-1980s, managers recognized the need to temper public demand for deer-related recreation with concern for the societal (Hardin 1986) and ecological impacts of growing deer herds (fig. 16). Consequently, management now emphasizes controlling herd growth by shifting harvest to antlerless deer (Indiana Division of Fish and Wildlife 1997, Yancy 2002). All three States within the assessment area now manage deer with localized county harvest quotas intended to influence, increasing where necessary, the proportion of females in the harvest.

The harvest of white-tailed deer throughout the assessment area reflects the adaptability of this species to a forested landscape fragmented by both agriculture and expanding rural development (see below: Habitat Suitability Analyses). Using average county harvests from the 2000 hunt season for comparison, counties within the assessment area had greater per county harvests than did their respective counties outside of the assessment area (fig. 17). In Illinois and Indiana, this likely reflects the regional extent of woody cover compared to that available in the prairie counties of these States. In Kentucky, this may reflect the comparatively greater extent of agricultural land use in this part of an otherwise heavily forested State.

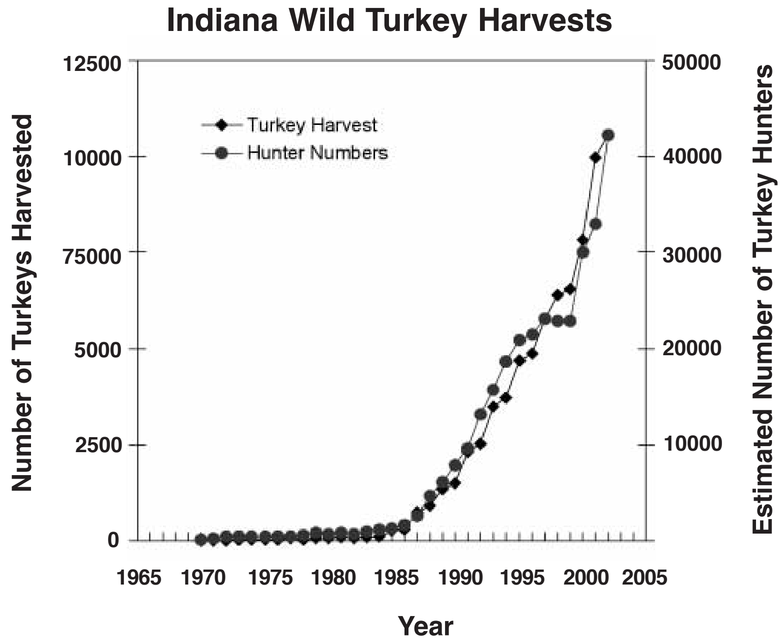


**Figure 15.** Annual wild turkey harvest and growth of hunt participation in Indiana (Backs 2002b). Indiana is representative of the history of turkey restoration and hunt participation in most Midwestern States, including those of the assessment area.

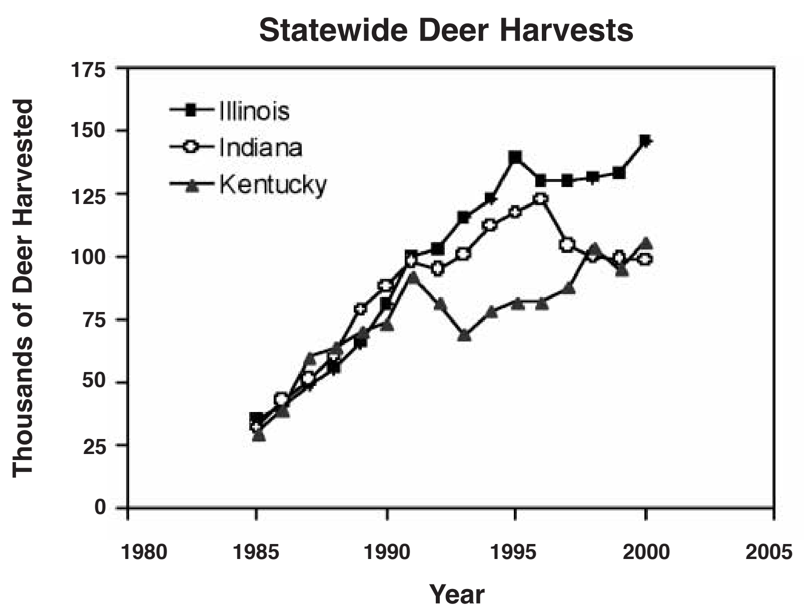


**Figure 16.** Regional white-tailed deer harvests within the States of Illinois, Indiana, and Kentucky. The three states within the assessment area share common histories with respect to deer management: restoration, herd growth, and subsequent localized harvest management intended to control herd growth through harvest of antlerless deer.

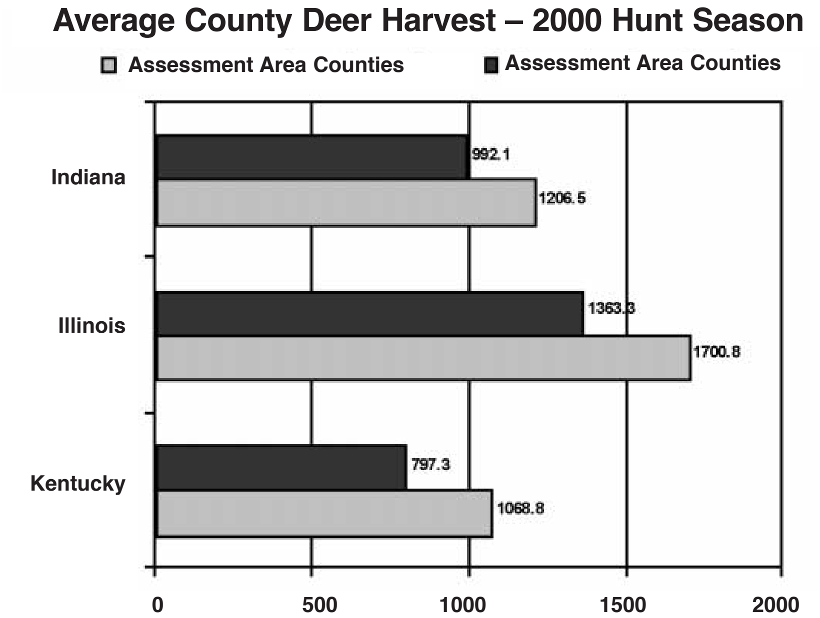


**Figure 17.** Regional comparisons of white-tailed deer harvests within the states of Illinois, Indiana, and Kentucky relative to counties within and outside of the Hoosier-Shawnee Ecological Assessment Area. Greater harvests within assessment area counties reflects suitability of habitat for white-tailed deer relative to other areas of the respective states.

## HABITAT SUITABILITY ANALYSES FOR SELECTED SPECIES

Habitat management remains the most consistently effective means by which land management agencies approach the conservation of terrestrial animal species. The use of Geographic Information Systems (GIS) and the capability to correlate landscape attributes with indices of animal abundance have furthered the ability of land managers to evaluate habitat suitability for any number of species for which these data are available. Spatial habitat suitability was evaluated for three species endemic to the assessment area: the bobcat, the northern bobwhite quail, and the white-tailed deer. These species were selected on the basis of their widespread interest to conservationists, the range of habitats they use, and the availability of regional habitat suitability models for these species.

### Habitat Suitability Analysis: Bobcat

The State of Indiana currently considers the bobcat an endangered species; Illinois recently removed the bobcat from its threatened or endangered species list. The State of Kentucky manages the bobcat as a harvested species. The range and numbers of bobcats in the Midwest appears to have increased in the last decade (Woolf and Hubert 1998), a trend noted in both Illinois (Woolf et al. 2000) and Indiana (Indiana Division of Fish and Wildlife 2003).

#### Habitat model

Habitat suitability analysis for bobcats followed a variation of the model developed by Nielsen and Woolf (2002); this model evaluates landscape similarity to known features of bobcat core range areas. Nielsen and Woolf (2002) constructed this model using data from bobcats in southern Illinois; this sort of explicit spatial model, given that the western portion of the assessment area encompasses southern Illinois, should be reasonably representative of the assessment area.

Woolf et al. (2002) found that bobcats occurred in a variety of habitats, but most often in areas with greater proportional forest cover and larger forest patch size, and in smaller grassland and agricultural areas than were available across the broader landscape. These relationships were mapped by apportioning the assessment area into hexagons equivalent to bobcat home range core areas (4.5 $km^2$). The habitat composition and configuration of each hexagon across the landscape were estimated and compared to bobcat habitat characteristics observed in southern Illinois. Areas that were most similar to actual areas used by bobcats were assumed to be the highest quality habitat for bobcats. High quality bobcat habitat occurs throughout the assessment area; the greatest concentration is in the southwestern portion of the assessment area (fig. 18).

### Habitat Suitability Analysis: Northern Bobwhite Quail

Bobwhite quail primarily occur in open grasslands with interspersed woody edge. These habitats were widespread during the first half of the 20th century as a result of farm abandonment, predominance of pastoral agriculture, and silvicultural practices compatible with the bobwhite's life history. With the advent of clean rowcrop agriculture and the loss of native grasslands, bobwhite quail have steadily declined across their range since at least the mid-1950s (Dimmick et al. 2002). Bobwhite quail currently occur across the assessment area, although populations within the larger Central Hardwoods Region (BCR24) have declined by approximately two-thirds since the early 1980s (Dimmick et al. 2002).

### Habitat model

Northern bobwhite habitat suitability was evaluated using a model developed by Roseberry and Sudkamp (1998). Their model characterizes high quality quail habitat as containing 30 to 65 percent row crops, 15-30 percent grasslands, <30 m/ha of woody edge, and habitat contagion values <65 percent. This latter parameter, habitat contagion, measures the degree of interspersion or juxtaposition of habitat types. The original model by Roseberry and Sudkamp (1998) considered latitude an important component of bobwhite habitat. However, because the critical latitude above which bobwhite are impacted by weather is north of the assessment area, latitude was not considered in this suitability analysis.

The majority of the landscape within the assessment area (75%) appears to be of marginal value to bobwhite quail; 11 percent of the land area could be considered suitable for quail. The majority of these habitats occupy the eastern half of the assessment area, particularly in Kentucky. In Indiana, scattered areas of suitable habitat frame the larger area of the Hoosier National Forest (fig. 19).

If only on a coarse level, it is evident that the proportion and distribution of suitable habitat for quail correspond with patterns of land use across the assessment area. The lack of suitable quail habitat is consistent with the assumption

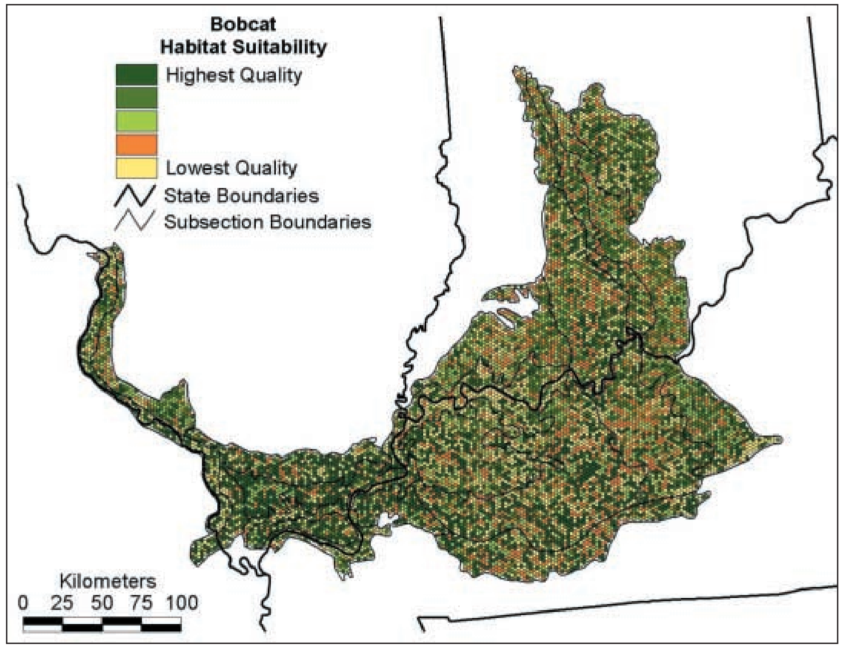


**Figure 18.** Suitability of habitats for bobcat in the assessment area based on a model by C. Nielsen (2000). Figure courtesy of G. Mohr and C. Nielsen, Cooperative Wildlife Research Laboratory, Southern Illinois University, Carbondale, IL.

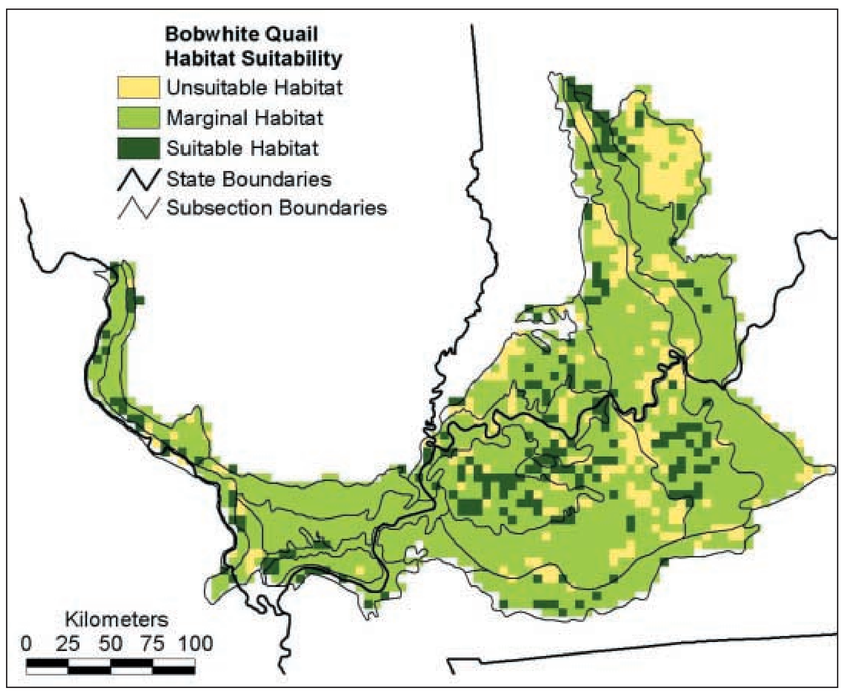


**Figure 19.** Suitability of habitats in the Hoosier-Shawnee Ecological Assessment Area for northern bobwhite based on a model by Roseberry and Sudkamp (1998). Figure courtesy of G. Mohr, Cooperative Wildlife Research Laboratory, Southern Illinois University, Carbondale, IL.

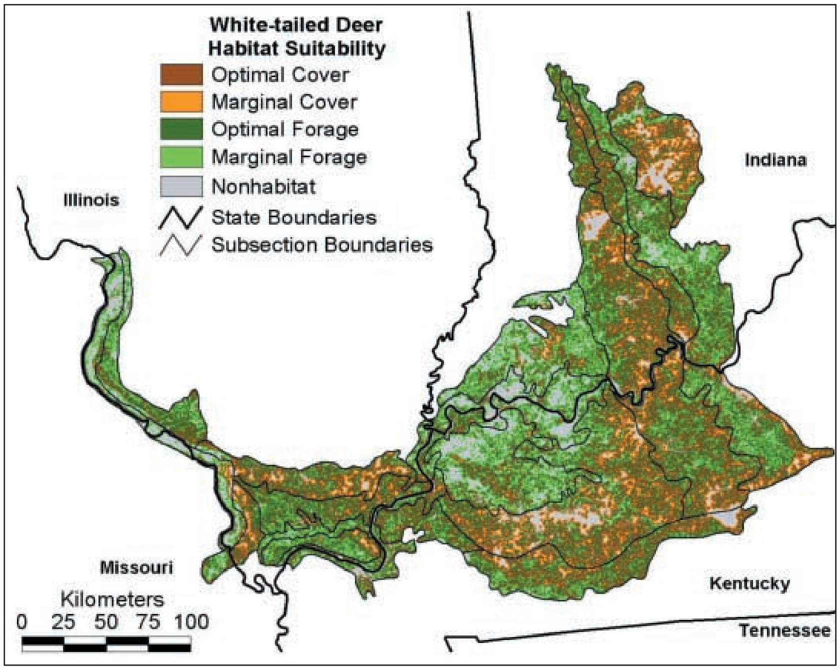


**Figure 20.** Distribution of white-tailed deer habitats in the Hoosier-Shawnee Ecological Assessment Area based on a model by Roseberry and Woolf (1998). Figure courtesy of G. Mohr, Cooperative Wildlife Research Laboratory, Southern Illinois University, Carbondale, IL.

that declining quail populations are related to the availability of suitable habitat.

While the proportion of the land area suitable for grassland species is low relative to other cover types, at least some opportunity exists to pursue the restoration of these native habitats. Given the distribution of the most suitable of these habitats, public–private partnerships that span ownerships may provide some benefit to this declining community of species that has only recently received widespread attention among conservationists (Askins 2001, Hunter et al. 2001).

### Habitat Suitability Analysis: White-tailed Deer

Particularly within the last half century, white-tailed deer have benefited substantially from deliberate efforts to restore the species across its former range, from the protection afforded a publicly desirable game species, and from its apparent tolerance of wide-scale change in patterns of land use across its range. Concurrently, the undeveloped land base suitable for conservation has diminished with the advancement of rural development and human population growth. Consequently, land managers now face the realistic challenge of assessing and managing the ecological impact of deer herds that may approach levels inconsistent with other conservation objectives (deCalesta 1994, McCabe and McCabe 1997, McShea et al. 1997, Waller and Alverson 1997).

White-tailed deer share a common history among the states within the assessment area: near extirpation at the turn of the century as a result of unregulated exploitation and changes in land use associated with settlement; subsequent protection; concerted restoration; and liberalized take to control contemporary herds.

#### Habitat model

A habitat suitability model developed for white-tailed deer in Illinois by Roseberry and Woolf (1998) was used to assess habitat suitability within the assessment area. This model equates row crops, small grains, rural and urban grasslands, orchards, and nurseries as foraging habitat for deer. The model identifies forests, shrublands, and woody wetlands as protective cover for deer. Using proximity to forage to define the relative value of protective cover, optimal deer cover was defined as that occurring less than 200 m from foraging habitats. Marginal protective cover was defined as that occurring from 200 to 500 m from foraging habitats. Similarly, optimal foraging habitat was defined as that occurring within 500 m of protective cover, while marginal foraging habitats occurred from 500 to 1,000 m from protective cover. In other words, the highest quality deer habitats occurred where protective cover and foraging habitats were highly juxtaposed.

Approximately 35 percent of the assessment area is composed of optimal protective cover for white-tailed deer; approximately 26 percent of the land area provides optimal foraging habitats for deer (fig. 20). An additional 19 percent of the assessment area contains marginal deer habitats. As rural development expands, and as the density of human land use increases across rural landscapes, managers will be further challenged to balance the recreational value of white-tailed deer, consumptive and non-consumptive, with societal and ecological concerns related to deer populations perceived to be overabundant.

## KEY FINDINGS

- Five species in the Hoosier-Shawnee Ecological Assessment Area are federally listed as threatened or endangered: the bald eagle (threatened), the interior least tern (endangered), the gray bat (endangered), the Indiana bat (endangered), and the American burying beetle (endangered). Although unlikely, one other species that is a candidate for listing may occur within the assessment area: the eastern massasauga rattlesnake.

- Of global viability concern are 173 species inhabiting the assessment area. Of these species, 14 are vertebrates and 159 are either terrestrial invertebrates or cave-associated aquatic invertebrates. These species are considered rare to critically imperiled throughout their global ranges.

- An additional 172 terrestrial species are of viability concern at the state level; 81 of these species are birds. These species are considered rare to critically imperiled within at least one of the states of the assessment area.

- Cave and karst systems provide habitat for some of the rarest species within the assessment area. Of the 173 species determined to be of global viability concern, 140 (81%) use cave and karst habitats (134 invertebrates and 6 mammals). An additional 21 species determined to be of state viability concern are also associated with cave systems. In total, 161 species of viability concern within the assessment area are cave or karst-associated species. In addition, four cave and karst systems within the assessment area are considered to be globally significant from the standpoint of their obligate subterranean fauna.

- Of the 160 birds identified as of conservation concern within the assessment area, North American Breeding Bird Survey data were sufficient to identify 40 species with regional long-term population trends. From 1966 to 2000, 14 species increased in abundance in either, or both, the Highland Rim or Lexington Plain physiographic regions; 27 species decreased in abundance. In the case of the eastern bluebird, numbers of this species declined within the Lexington Plain but increased in the Highland Rim physiographic region.

- Neotropical migrant birds make up approximately a third of the avian species of conservation concern in the assessment area. Of the 21 neotropical migrants with sufficient data to determine regional population trends, 16 declined while 5 species increased from 1966 to 2000.

- Game species evaluated included the white-tailed deer, eastern wild turkey, ruffed grouse, American woodcock, and northern bobwhite. White-tailed deer and eastern wild turkey populations are common to abundant throughout the assessment area. Ruffed grouse and woodcock populations are locally restricted, and numbers of both species have declined substantially across the assessment area. Northern bobwhite quail populations vary from locally stable to declining across the assessment area; current populations have been reduced to a third of those present in the early 1980s.

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# Native and Exotic Insects and Diseases in Forest Ecosystems in the Hoosier-Shawnee Ecological Assessment Area

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## ABSTRACT

Various native and exotic insects and diseases affect the forest ecosystems of the Hoosier-Shawnee Ecological Assessment Area. Defoliating insects have had the greatest effects in forests where oak species predominate. Increases in oak decline are expected with the imminent establishment of the European gypsy moth. Insects and pathogens of the pine forests are artifacts of stand origin and age. Chestnut blight and Dutch elm disease have had the greatest broad-ranging and historical effects on the non-oak, broad-leaved forests.

Various native and exotic insects and diseases affect the forest ecosystems of the Hoosier-Shawnee Ecological Assessment Area, specifically the Hoosier and Shawnee National Forests. For this analysis, the relative importance of each insect and disease was determined based on the extent and condition of the susceptible resource as well as historical accounts of insect or disease occurrence and potential for future effects.

## DISEASES AND INSECTS OF OAK

Oak-hickory and other oak-type forests predominate in the Hoosier-Shawnee Ecological Assessment Area, accounting for 55 to 70 percent of the total forest cover (USDA Forest Service 2001). These forests include several species of both the red (subgenus *Lobatae*) and white oak (subgenus *Quercus*) groups of oak (*Quercus* spp.). Several pathogens and numerous insects can significantly affect forest ecosystems where oak is an important component (table 1).

### Diseases

#### Oak decline

Oak decline, native to the U.S., affects oaks over broad forest areas of the eastern part of the country (Wargo et al. 1983). Oak decline has been reported for over 130 years and its occurrence is episodic. Currently, large numbers of northern red (*Q. rubra*), southern red (*Q. falcata*), black (*Q. velutina*), and scarlet (*Q. coccinea*) oaks are declining and dying in southern Missouri and northern Arkansas, including oaks in the Mark Twain, Ozark, and Ouachita National Forests in these States (Lawrence et al. 2002). An estimated 100,000 acres of severe decline have occurred in the Mark Twain based on recent surveys (Lawrence et al. 2002). Oak decline and mortality were associated with defoliation of looper complex outbreaks between 1978 and 1981 in the assessment area. In southern Indiana, mortality levels exceeded 10 percent in oak-hickory stands (P. Marshall, personal communication).

Scattered oak decline and mortality also occurred following a severe drought in 1987-88.

Oak decline is a debilitating progression of physical and biological stressors. Initially, environmental, stand, and site factors induce long-term to short-term stress, and then various insects and pathogens may move in. The latter may include borers such as twolined chestnut borer (*Agrilus bilineatus*) and red oak borer (*Enaphalodes rufulus*); defoliators such as European gypsy moth (*Lymantria dispar*); and pathogenic fungi such as *Hypoxylon atropunctatum* and *Armillaria* species. The interaction of these factors results in a slow-acting, yet progressive, disease complex that often leads to tree death. Red oaks are more severely affected by oak decline than white oaks. The occurrence and severity of oak decline are closely associated with the time and location of the triggering factors, such as drought or heavy defoliation by insects. The imminent spread of the European gypsy moth (fig. 1) to the assessment area could therefore trigger more frequent and severe episodes of oak decline.

Declining trees present a safety hazard along roads and trails, and in recreation areas (Lawrence et al. 2002). Often the insects and fungi associated with decline degrade timber because of such factors as sapwood stain and loss of structural integrity. Over larger areas, decline and death of oaks leads to fuel-loading because of increased amounts of coarse woody debris. The disease may increase habitat for some wildlife species but decrease it for others. The quality of recreational experiences such as hiking, camping, and hunting may be reduced by oak decline in oak-hickory forests.

Current oak decline management strategies include harvest of oak stands before they become physiologically overmature. Reproduction in young and middle-aged stands

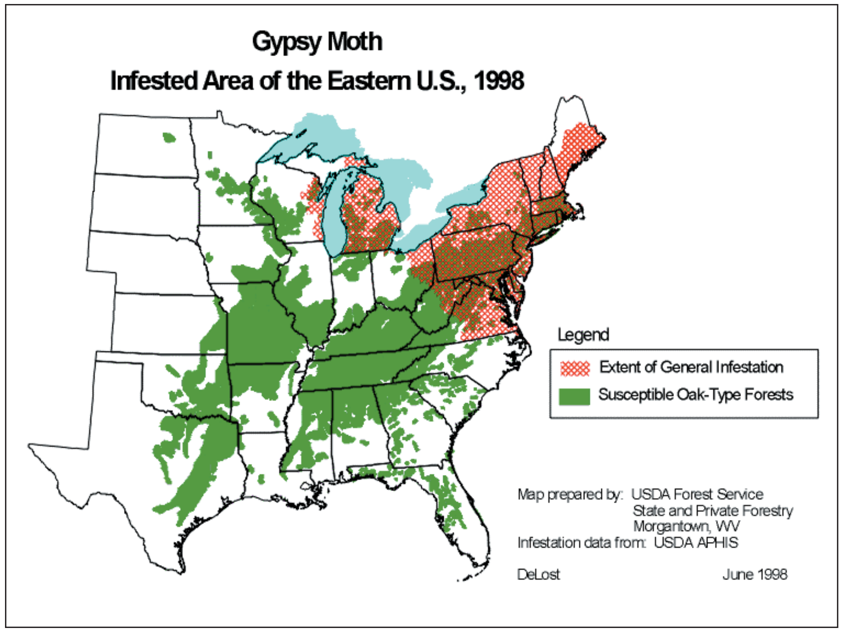


**Figure 1.** European gypsy moth general infestation area and range of potential host species in the Eastern U.S., 1998. (source: http://na.fs.fed.us/wv/gmdigest/maps_charts/maps/gmoak.htm).

**Table 1.** Insects and diseases affecting or with future potential to affect oak forest cover types in the assessment area.

| Pest type | Common name | Scientific name | Status in U.S. native/exotic | Effect of insect or disease on forest resource* Past | Present | Future potential |
|---|---|---|---|---|---|---|
| Disease complex | Oak decline | numerous biological and physical factors | native | XX | X | XX |
| Disease | Oak wilt | *Ceratocystis fagacearum* | native | X | X | X |
| Disease | Sudden Oak Death | *Phytophthora ramorum* | exotic | 0 | 0 | XX |
| Insect | Forest tent caterpillar | *Malacosoma disstria* | native | X | X | X |
| Insect | Wood borers | *Agrilus bilineatus* *Enaphalodes rufulus* | native | X | X | X |
| Insect | Jumping oak gall | *Neuroterus saltorius* | native | XX | XX | X |
| Insect | Looper complex | *Erannis tiliaria* *Phigalia titea* | native | XX | XX | XX |
| Insect | Walkingstick | *Diapheromera femorata* | native | X | ? | ? |
| Insect | European gypsy moth | *Lymantria dispar* | exotic | 0 | 0 | XX |

* Degree or severity of effect: 0 = not established, X = minor, XX = moderate to major, ? = uncertain.

is promoted to ensure regeneration following the harvest. When timber products are of interest, dead and declining trees are removed early and used before the wood degrades.

### Oak wilt

Oak wilt, caused by the fungus *Ceratocystis fagacearum*, is a native tree disease in the Eastern U.S. (Tainter and Baker 1996). Thousands of oaks die every year from infection by the pathogen. Oak wilt has been reported in or near all the counties of the assessment area (O'Brien et al. 2000). Although oak wilt is a serious problem in the more northern areas of Indiana and Illinois, it is considered only a minor problem in the southern areas because infection centers there usually do not become very large (P. Marshall, personal communication). Red oak species are most susceptible to the disease and usually die within the same year they were infected. Infected white oaks, however, die from 2 to 15 or more years later depending on the species. The pathogen is spread in two ways: 1) belowground through grafted roots between diseased and healthy trees, and 2) aboveground by insect vectors.

### Sudden Oak Death

The causal organism of Sudden Oak Death, *Phytophthora ramorum*, is a recent discovery and a newly described species (O'Brien et al. 2002). As of fall 2003, the fungus-like organism (an oomycete) has been found on ornamental and nursery plants on the west coast of North America and in England and a number of European countries, as well as on numerous shrubs and trees in forest and wildland-urban forest ecosytems of California, in a small forest area of southwest Oregon, and on forest trees adjacent to public gardens in England and the Netherlands. The pathogen has caused a serious disease epidemic in oak and tanoak (*Lithocarpus densiflora*) forests of California. Widespread dying of tanoaks was first reported in 1995, but the causal agent was not identified until 2000 (Rizzo et al. 2002). The pathogen causes multiple cankers on the stems and branches of oaks and tanoaks and has killed large numbers of trees in 12 counties of California, increasing fire risk and degrading forest ecosystems.

Eastern oak species including chestnut oak (*Q. prinus*), white oak, and northern red oak have been found to be susceptible to *P. ramorum* based on seedling inoculation tests (Tooley et al. 2003). One possible means of pathogen spread is via infected nursery stock, such as rhododendrons. The pathogen can potentially be spread to the assessment area. Quarantines have been imposed in the U.S. to restrict the movement of lumber, logs, mulch, woodchips, firewood, nursery-related materials, and other items from infested to uninfested areas (USDA Animal and Plant Health Inspection Service 2003). If the disease is detected, affected trees and surrounding buffer trees will likely have to be eradicated.

## Insects

### Forest tent caterpillar

Forest tent caterpillar (*Malacosoma disstria*) is a native defoliator of several hardwood species, but oaks are the main species group affected in the Central States (USDA Forest Service 1989). Other host species fed upon include aspen (*Populus tremuloides*), birch (*Betula* spp.), cherry (*Prunus* spp.), basswood (*Tilia americana*), and ash (*Fraxinus* spp.). The forest tent caterpillar has been considered an important pest of forest trees for many years (Batzer and Morris 1978). Losses in reduced growth following defoliation may be great but tree mortality is generally not common. The pest has historically been a problem in the Oakwood Bottoms Greentree Reservoir of the Shawnee National Forest, particularly on the overmature pin oak resource (D. Haugen, personal communication). Serious defoliation occurred in Lawrence and Martin Counties in Indiana (including the Hoosier National Forest) from 1976 to 1979 (P. Marshall, personal communication).

The forest tent caterpillar has one generation per year. Extensive feeding in tree crowns by the caterpillars (larvae) leads to defoliation. The larvae emerge in spring and begin feeding immediately. They form silken mats on the branches and main stems. Approximately 6 weeks after they emerge, the larvae spin cocoons and pupate. Adult moths emerge about 10 days later and live only a few days. Females lay large numbers of eggs mostly on upper crown branches, and the insect overwinters in the egg stage. Strong winds can carry the moths many miles.

Outbreaks of the pest usually subside after 3 or 4 consecutive years of defoliation (USDA Forest Service 1996). Several adverse environmental factors and natural biological controls are responsible for population decline. Regionwide outbreaks have occurred at intervals varying from 6 to 16 years in northern areas.

The effects of the forest tent caterpillar on the forest ecosystem are both biological and sociological. Besides reducing tree growth and survival, the migrating caterpillars can be a nuisance to recreational forest users. The appearance of defoliated trees during late spring and early summer can also reduce tourism.

### Borers

The twolined chestnut borer (*Agrilus bilineatus*) is a native pest that attacks various hardwoods, but especially several species of oaks in the Central States (Haack and Acciavatti 1992). Trees weakened by drought or defoliation are most susceptible to attack, and the insect is often implicated in oak decline (previously discussed). The larvae tunnel in the phloem and outer sapwood, such that a heavy infestation may girdle and kill the tree (USDA Forest Service 1989).

The red oak borer (*Enaphalodes rufulus*), a long-horned beetle native to North America, is responsible for large annual losses in the hardwood timber industry (Donley and Acciavatti 1980, USDA Forest Service 1989). The loss in lumber grade can amount to 40 percent of the current tree value and is caused by tunneling of the larvae. About 38 percent of the oak wood used for lumber, cooperage, and veneer in the Eastern U.S. is affected by this pest. Species of the red oak group are the preferred host. The pest is an important component of the current oak decline outbreak in Missouri.

### Jumping oak gall

The light-tan, globular galls associated with jumping oak gall are caused by the native cynipid wasp, *Neuroterus saltatorius* (USDA Forest Service 1979). The gall is about the size of a sesame seed and hangs from the underside of the leaf. When the galls mature, they drop from the leaves and carry the wasp to the ground. Larval activity inside the gall causes the gall to jump around on the ground, hence, the name "jumping oak gall." Outbreaks of this pest occurred in Missouri in 1998, and over 1 million acres were affected in Indiana in 1999. Significant levels of infestation were also observed in 2003 (P. Marshall, personal communication).

This small wasp has two generations per year (USDA Forest Service 1989). The first generation emerges in the spring from galls on the ground. This female-only generation lays its eggs on buds and new foliage. Several weeks later, small blister-like galls form on affected leaves as the larvae develop. The male and female wasps that develop from these larvae mate, and the second-generation females lay their eggs on the mature leaves of host trees. The more conspicuous galls created by this second generation then fall to the ground where they overwinter and complete the cycle.

### Looper complex

The linden looper (*Erannis tiliaria*) and half-wing geometer (*Phigalia titea*) feed on and defoliate many hardwood species (USDA Forest Service 1979, 1989). The favored hosts include such trees as red oaks, basswood, maples (*Acer* spp.), and hickories (*Carya* spp.). Although looper-affected stands usually recover, repeated defoliations by either insect can contribute to tree mortality. In general, mortality is confined to trees weakened by drought, disease, or other stresses. Considerable defoliation of oaks and other hardwoods occurred in southern Indiana in 2003 (Sadof and Marshall 2003). This infestation was similar in distribution to that reported in 1979-81. In the earlier epidemic, the defoliation led to 10 percent oak mortality in the area from Morgan-Monroe State Forest south through the Hoosier National Forest to the Ohio River.

Both insect species have one generation per year. The eggs hatch in the spring, and larvae feed on leaves between late April and late June. Entire leaves are consumed except for major veins. Some dispersal of the half-wing geometer occurs when the larvae spin silken threads and are wind-borne to other locations. Both species pupate in the soil. Following emergence and mating by adult moths, eggs are laid. Linden loopers overwinter as eggs, while pupae are the overwintering stage for the geometer. The loopers are managed in forests by selective harvesting of defoliated stands, based on the extent and intensity of the recent defoliation.

### Walkingstick

Walkingsticks (*Diapheromera femorata*) are common defoliators of deciduous trees in North America (USDA Forest Service 1989). Nymphs and adults consume entire leaves, except for parts of major veins. Defoliation may occur twice in one season, and trees over large areas may be defoliated during walkingstick outbreaks. Three or four infestations of individual trees can kill some branches. At times in mixed stands, the insect's selective feeding on black oaks may favor the growth of white oaks or conifers (Wilson 1971). Young nymphs feed on low-growing plants (e.g., beaked hazel, *Cordus corylus*; juneberry, *Amelanchier* spp.), while older nymphs and adult prefer black oak, basswood, and wild cherry.

### European gypsy moth

The European gypsy moth (*Lymantria dispar*), a major defoliator of hardwood trees in both forest and urban landscapes, has caused considerable damage to forests in the Northeastern U.S. (McManus et al. 1992). This exotic insect became established in Massachusetts in 1869 and has since become widespread in the northeastern deciduous forests where its favored hosts, oaks, are common (USDA Forest Service 1989). Its range expands each year; the current southern extent of infestation is Virginia and the western extent is Wisconsin (fig. 1). It will likely have a major effect on the oak forests of the assessment area in the near future because the oak forests of southern Indiana and southern Illinois have been rated as highly susceptible to gypsy moth infestation (Liebhold et al. 1995). Several consecutive years of severe defoliation by the larvae can contribute to oak decline.

Gypsy moth larvae prefer hardwoods but may feed on several hundred different species of trees and shrubs (Liebhold et al. 1995). In the East the insect prefers oaks, apple (*Malus* spp.), sweetgum (*Liquidambar styraciflua*), speckled alder (*Alnus rugosa*), basswood, birch, poplar (*Populus* spp.), willow (*Salix* spp.), and hawthorn (*Crategus* spp.). The host list will undoubtedly expand as the insect spreads further south and west (Liebhold et al. 1995). During heavy infestation, gypsy moth larvae feed on almost all vegetation on a site. However, to date, the insect has avoided ash, yellow-poplar (*Liriodendron tulipifera*), sycamore (*Platanus occidentalis*), butternut (*Juglans cinerea*), black walnut (*Juglans nigra*), catalpa (*Catalpa speciosa*), flowering dogwood (*Cornus florida*), balsam fir (*Abies balsamea*), eastern redcedar (*Juniperus virginiana*), American holly (*Ilex opaca*), and several shrub species (Liebhold et al. 1995). Several interrelated factors (e.g., abundance of favored host, site and stand factors, and tree conditions) determine the vulnerability of forest stands to gypsy moth defoliation.

The gypsy moth has one generation per year. Eggs hatch during late April to early May at approximately the same time as budbreak in oaks. The larvae crawl to the tree crowns to feed until early summer. After feeding, the larvae pupate and emerge as adult moths in about 2 weeks. Shortly after the female emerges, she mates and lays a single egg mass (100 to 1,000 eggs per mass) on trees, rocks, or other objects. These egg masses are the overwintering stage of the insect.

Spread rates for the gypsy moth increased from 1.8 miles/year between 1916 and 1965 to 12.4 miles/year between 1966 and 1990 (Liebhold et al. 1992). In addition to the steady dispersal of the first instar larvae by wind, the insect can be transported over long distances during other life states by human activities. Within infested forests, gypsy moth populations periodically increase to outbreak levels and cause widespread defoliation (McManus et al. 1992). The insects are, however, subject to a number of natural controls that limit their growth potential. For example, cool, wet weather during egg hatch can kill many young caterpillars. Epizootics of a naturally occurring virus (nuclear polyhedrosis virus) and a fungus (*Entomophaga maimaiga*) can cause widespread collapses in gypsy moth populations (Reardon and Hajek 1998). Other natural enemies of the pest exist.

The effects of dying and dead trees resulting from repeated gypsy moth defoliation are numerous. Understory plants dependent on the shade of the affected tree are stressed. Animals depending on the affected tree species for shelter or food are affected. Timber loss occurs in certain areas. Hazard trees are created and fire risk may increase. The larvae themselves are a nuisance and may deter visitors from recreation areas. Lastly, visual quality of the landscape is reduced.

Domestic quarantines are maintained to regulate the human-aided, long-distance transport of gypsy moths from infested to uninfested areas (USDA Animal and Plant Health Inspection Service 2002). Detection programs exist outside the generally infested area. When isolated reproducing populations are detected in such locations, eradication efforts are undertaken. Suppression programs are carried out in the generally infested area to mitigate impacts in selected environments. Specific management strategies for *L. dispar* are covered in detail in the Final Environmental Impact Statement for Gypsy Moth Management in the United States (USDA Forest Service 1995). Detection programs within the assessment area and eradication of isolated reproducing populations should extend the time until the pest ultimately becomes established. In addition, implementation of selected forest management strategies before pest establishment in the assessment area would lessen effects that the pest could have in the future (Gottschalk 1993). Other strategies would likely be considered once the pest becomes established and suppression programs are justified.

## DISEASES AND INSECTS OF PINE AND REDCEDAR

Forest cover types that include pine (*Pinus* spp.) and eastern redcedar account for <15 percent of forests in the assessment area (USDA Forest Service 2001). Plantations of shortleaf (*P. echinata*), loblolly (*P. taeda)*, red (*P. resinosa*), Virginia (*P. virginiana*), and eastern white pine (*P. strobus*) are found in the assessment area. Except for isolated stands of shortleaf pine in Illinois and Virginia pine in Indiana, none of these species of pine are native to the area. Most of the plantations were established during the 1930s and 1940s and their general health is declining because the trees are now overmature and not well suited for the sites on which they are growing.

Several diseases and numerous insect pests can significantly affect forest ecosystems where pine or redcedar are important components (table 2).

## Diseases

### Annosum root disease

Annosum root disease, caused by *Heterobasidion annosum*, is one of the most economically important diseases of conifers in the North Temperate Zone of the world and occurs in most forested areas of the U.S. (Tainter and Baker 1996). The pathogen causes a root and butt rot of affected conifers (Robbins 1984). Infected trees grow more slowly and are susceptible to windthrow and bark beetle attack. Mortality commonly results from infection. Although hardwoods are also susceptible, conifers (including *Juniperus, Larix, Picea,* and *Pinus*) are the major hosts.

New root disease centers are established when spores of the fungus land on freshly cut stump surfaces. Spread from a diseased tree to adjacent healthy trees can occur through root contact. This spread leads to a slowly expanding, somewhat circular disease center. The fungus may survive in infected stumps for 5 to 25 years and produces fruiting bodies and spores. Although quantitative impacts of the disease in the assessment area are not known, the risk of new infection centers developing in pine plantations is high especially following stand thinning (Froelich et al. 1977). Annosum root disease was associated with large pockets of mortality in two red pine stands in the Hoosier National Forest in 1993 (D. Haugen and J. O'Brien 1993).

Clusters of dead trees in pine stands are the most visible effect of the disease. Such openings may be beneficial for wildlife. The disturbed site also may be colonized by invasive plants and the dying trees heavily infested with bark beetles. The primary means of disease control is to prevent infection of freshly cut stumps during thinning.

### Armillaria root disease

In North America, Armillaria root disease is caused by at least 10 different biological species of the fungal genus *Armillaria* (Shaw and Kile 1991). More than 600 woody plant species are hosts for *Armillaria* species. *Armillaria ostoyae* is one of the most important root pathogens of conifers in the Eastern United States (Williams et al. 1986) and is presumed to be the species present in pine stands in the assessment area. *Armillaria* (presumably *ostoyae*) can cause substantial losses in red pine sites originally occupied by oaks and possibly other species such as aspen in the North Central States (Tainter and Baker 1996). Red pine on sites not well suited for its growth is also predisposed to infection. The susceptibility of shortleaf, Virginia, and eastern white pine growing in the assessment area to *A. ostoyae* is not known.

The fungus generally produces clusters of honey-colored mushrooms in the fall. Local spread of the fungus from infected trees, stumps, or other residue occurs through shoe-string like structures called rhizomorphs. Infected red pine usually dies in localized areas scattered across a plantation. Large areas of mortality were observed in two red pine stands of the Hoosier National Forest in 1993; Armillaria root rot and two other root diseases as well as several pine bark beetles were present in declining trees (D. Haugen and J. O'Brien 1993).

*Armillaria* spp. may be beneficial in forested ecosystems by acting as thinning agents in dense stands and coincidently improving stand quality. Small openings created by disease centers may also improve forage for wildlife. The mushrooms of the fungus are eaten by many mammals. The fungus is also considered beneficial as a decomposer of downed and dead timber. The negative effects of Armillaria root disease in pine stands include tree mortality and creation of potential hazard trees in recreational areas.

**Table 2.** Insects and diseases affecting or with future potential to affect pine and redcedar forest cover types in the assessment area.

| Pest type | Common name | Scientific name | Status in U.S. native/exotic | Effect of insect or disease on forest resource* Past | Present | Future potential |
|---|---|---|---|---|---|---|
| Disease | Annosum root disease | *Heterobasidion annosum* | native | X | X | ? |
| Disease | Armillaria root disease | *Armillaria ostoyae* | native | X | X | ? |
| Disease | White pine blister rust | *Cronartium ribicola* | exotic | X | X | X |
| Insect | Pine bark beetles | *Dendroctonus tenebrans* *Ips grandicollis, I. pini* | native | X | X | ? |
| Insect | Pine root collar weevil | *Hylobius radicis* | native | X | X? | ? |
| Insect | Introduced pine sawfly | *Diprion similis* | exotic | XX | X | ? |
| Insect | Pine shoot beetle | *Tomicus piniperda* | exotic | 0 | X | XX? |

* Degree or severity of effect: 0 = not established, X = minor, XX = moderate to major, ? = uncertain.

### White pine blister rust

White pine blister rust is caused by an exotic rust fungus, *Cronartium ribicola* (Nicholls and Anderson 1977, Tainter and Baker 1996)). The fungus causes cankers on the branches and stems of nearly all white pine species, including eastern white pine. The fungus requires an alternate host, *Ribes* species, to complete its life cycle before re-infecting the pine host. The disease is most common in areas where the microclimate favors infections of the foliage by the fungus, i.e., where periods of cool temperature and 100 percent relative humidity for ≥24 hours are common. White pine blister rust is present in the assessment area but does not cause significant damage or mortality.

## Insects

### Pine bark beetles

The black turpentine beetle (*Dendroctonus tenebrans*), a native pest, prefers trees of reduced vigor (Smith and Lee III 1972). All species of southern pines and red spruce (*Picea rubens*) are attacked, but loblolly and slash pines (*P. elliottii*) seem to have higher risk of beetle damage (USDA Forest Service 1989). The beetles are attracted by terpenes released by fresh stumps and injured trees. Trees damaged or weakened by fire, logging, or drought are also highly susceptible. Large pockets of mortality (3-5 acres) were observed in two red pine stands of the Hoosier National Forest in 1993, associated with black turpentine beetles, *Ips* beetles (see below), and three root (D. Haugen and J. O'Brien 1993). Three years of drought preceded the mortality, and the trees were overmature and not well suited for the sites. The pests were likely beneficial in hastening conversion of the stands from non-native pines to native hardwoods. Two native engraver beetles (*Ips grandicollis* and *I. pini*) occur within the assessment area and may contribute to mortality of conifers (USDA Forest Service 1979). These beetles usually prefer trees that have been weakened by lightning or other damage, or they infest and populations increase on fresh slash after logging. Both species attack all pine species found in the assessment area; *I. pini* attacks several spruce (*Picea*) species as well. Besides contributing to mortality in red pine stands on the Hoosier National Forest, these *Ips* species have been associated with disease centers in a shortleaf pine stand (D. Haugen and J. O'Brien 1993).

### Weevils

The ranges of several native weevils that affect regeneration of pines overlap with the assessment area; however, only one of these weevils is considered to be of concern. The pine root collar weevil, *Hylobius radicis*, occurs throughout the north central and northeastern region of the U.S. and in southeastern Canada (USDA Forest Service 1989). It primarily attacks Scotch

(*P. sylvestris*), red, jack (*Pinus banksiana*), Austrian (*Pinus nigra*), and eastern white pine. The insect larvae feed belowground in the root collar, root crown, and on larger roots. Such feeding injury may kill small (<10 cm diameter) trees. Partial girdling of the root collar area in larger trees results in reduced growth rate, increased susceptibility to windthrow, and predisposition to other pests. Pine root collar weevil is scattered through areas of the Hoosier National Forest because of the presence of Scotch pine Christmas tree plantings. Its impact on forest stands is low (P. Marshall, personal communication).

#### Introduced pine sawfly

Eastern white pine is the preferred host of the introduced pine sawfly (*Diprion similis*), an exotic insect first reported in the U.S. (Connecticut) in 1914 (USDA Forest Service 1989). The larvae consume foliage of infested trees. Branches and sometimes entire trees are killed following early season defoliation by the insect (Wilson 1966). Two distinct, widespread outbreaks have been reported in North Carolina, Tennessee, and Virginia. Defoliation of white pine by this sawfly was observed within the assessment area in 1994 and 1995 (D. Haugen, personal communication).

#### Common pine shoot beetle

The common pine shoot beetle (*Tomicus piniperda*) is a serious pest of pines in Europe where it is considered the second most destructive shoot-feeding insect. This beetle was first discovered in Ohio during 1992 (Haack and Kucera 1993). The species now occurs in parts of nine States in the United States (including Illinois and Indiana) and in Ontario, Canada (Ciesla 2001, USDA Animal and Plant Health Inspection Service 2003), and it has the potential to spread over much of the U.S. and Canada. In areas of the United States where this insect has become established, Scotch pine is its preferred host, but Austrian pine, eastern white pine, red pine, and jack pine also have been attacked (Ciesla 2001). The most severe damage caused by *T. piniperda* is the destruction of shoots during maturation feeding. Tree height and diameter growth are reduced when shoot feeding by the beetle is severe. The potential for the common pine shoot beetle to damage pine in forests of the assessment area is low. The insect and associated damage have appeared primarily in Christmas tree plantations and pine tree nurseries.

In cooperation with State officials, the USDA Animal and Plant Health Inspection Service (2003) has quarantined counties in portions of 11 States, including Indiana and Illinois. The Federal quarantine regulates pine logs, stumps, and lumber with bark attached in addition to Christmas trees and pine nursery stock. Several counties in and around the northern end of the assessment area in Indiana are either currently under the Federal quarantine, were added to the quarantine in 2001, or have been surveyed for the pest. Specifically, Brown County (includes part of the Hoosier) and Owen County were added. The close proximity of these quarantined counties and the general quarantined area raises some concerns about management on the Hoosier National Forest.

## DISEASES AND INSECTS OF NON-OAK, BROAD-LEAVED TREES

Non-oak broad-leaved trees (excluding dogwood) account for 19 to 31 percent of forests in the assessment area (USDA Forest Service 2001). Numerous diseases and insect pests occur on elm, maple, ash, birch, aspen, black cherry, and other tree species in these forests (table 3). Dogwood also occurs in two oak cover type forests in the assessment area.

### Diseases

#### Dutch elm disease

Dutch elm disease (DED), caused by exotic pathogens, became established in the U.S. following introduction of the original pathogen (*Ophiostoma ulmi*) in the early 1930s

**Table 3.** Insects and diseases affecting or with future potential to affect non-oak, broad-leaved forest cover types in the assessment area.

| Pest type | Primary forest tree spp. affected | Common name | Scientific name | Status in U.S. native/exotic | Effect of insect or disease on forest resource* | | |
|---|---|---|---|---|---|---|---|
| | | | | | Past | Present | Future potential |
| Disease | Elms | Dutch elm disease | *Ophiostoma ulmi*<br>*Ophiostoma novo-ulmi*<br>*Scolytus multistriatus*** | exotic | XX | XX | X? |
| Disease | Butternut | Butternut canker | *Sirococcus clavigigenentia-juglandacearum* | exotic | X | X | X |
| Disease | Ash | Ash yellows | phytoplasma | native | X? | XX | XX |
| Disease | Dogwood | Dogwood anthracnose | *Discula destructiva* | exotic | X | X | X |
| Disease | Chestnut | Chestnut blight | *Cryphonectria parasitica* | exotic | XX | XX | ? |
| Insect | Ash | Emerald ash borer | *Agilus planipennis* | exotic | 0 | 0 | XX |
| Insect | Maples | Asian longhorned beetle | *Anoplophora glabripennis* | exotic | 0 | 0 | X |

* Degree or severity of effect: 0 = not established, X = minor, XX = moderate to major, ? = uncertain.
** Scolytus multistriatus is an exotic insect vector of the Dutch elm disease pathogen.

(Tainter and Baker 1996, Haugen 1998). An insect vector, the smaller European elm bark beetle (*Scolytus multistriatus*), also was accidentally introduced. A second, closely related, and more aggressive species (*Ophiostoma novo-ulmi*) arrived later and resulted in additional waves of mortality. These exotic pathogens and the exotic beetle are responsible for significantly reducing the populations of elms in the U.S.; losses have been particularly devastating in urban areas. The first wave of DED in the assessment area in the late 1960s and 1970s caused widespread mortality in mature elms. The beetles reproduce in dying elms, and the emerging generation of adults leaving DED-infected trees may carry spores of the causal fungus on their bodies. The infested beetles then transmit the fungus to healthy trees when they feed in twig crotches. The recent increase in DED mortality is likely due to a new cohort of American elms reaching susceptible age. The fungus also is spread from diseased to healthy trees through root grafts.

Mortality of American elms from DED in the assessment area will likely continue. The survival of the elm species, however, is not of concern because young trees can produce several seed crops before they are at risk from bark beetle infestation. There is no feasible, effective control for DED in forests.

### Butternut canker

Butternut grows on rich loamy soils as a minor component in mixed hardwood forests in the Eastern U.S. including parts of the assessment area. Butternut is being killed by *Sirococcus clavigigenenti-juglandacearum*, a fungus considered exotic to North America (Ostry et al. 1996). Multiple perennial stem and branch cankers caused by fungus infection coalesce and lead to tree death. Since it was first identified in 1967, butternut canker has spread throughout the range of the host species. Overall in the Southern U.S., butternut mortality from this disease is estimated at 77 percent. The losses in the assessment area have not been documented, but disease occurrence has been reported. Butternut trees across the range of the species appear to have no resistance, and no risk factors associated with site have been determined. Therefore, butternut on all sites should be considered at risk for the disease. Butternut is a Regional Forester Sensitive Species (RFSS) in the Forest Service's Eastern Region for 13 of the 16 national forests there, including the Shawnee and the Hoosier. It also is listed as a species of current viability concern for the Northern Hardwoods Ecosystem. Currently, harvest of healthy butternut is restricted on Federal lands, and guidelines for retention of living trees are available (Ostry et al. 1994). The effects of the disease are evident in the loss of wood for specialty uses and products, loss of wildlife food, failure of reproduction by the species (i.e., nuts from declining trees are not viable), and imminent loss of this species from the forest. There is no known control for this disease.

### Ash yellows

Ash yellow, a recently discovered (1980s) disease of unknown origin, results in poor growth and gradual decline of ash species (Tainter and Baker 1996, Pokorny and Sinclair 1994). This disease is caused by phytoplasmas (wall-less microbes) that infect and move through the phloem sieve tubes of infected trees. Twelve ash species are reported hosts of the phytoplasma, but white (*F. americana*) and green ash (*F. pennsylvanica*) are the most frequently affected species. The impact of ash yellows on ash populations is not well documented. However, white ash trees that become infected when young do not grow to merchantable size, but merchantable-size trees will survive for 5 to 10 years following infection. Ash yellows may sometimes be a factor in ash decline. In 1995, the State of Indiana reported that approximately 3 percent of the ash population each year showed initial signs of decline due to ash yellows and that tree mortality ranged from 2 to 7 percent annually. The prevalence and long-term effect of the disease on ash in the assessment area, however, is not known. There is no known way to prevent or cure ash yellows.

### Dogwood anthracnose

Dogwood anthracnose, caused by the fungus *Discula destructiva*, was first observed in Washington State in the late 1970s. Following its subsequent appearance in New York in 1978, it has apparently spread rapidly south down the Appalachians to Alabama and as far west as Missouri (Kennard 2001). Flowering dogwood is the principal host in the Eastern U.S. and is not resistant to the disease (Mielke and Daughtrey 1990). The pathogen (most likely an exotic) first infects leaves and causes spots; it then moves through petioles to branches and stems where it causes cankers. In forests, flowering dogwood usually dies within several years of initial infection. Cool moist environments favor infection and disease development. Mortality may be extensive in the landscape. As of 1999, the disease had killed 50 percent of native dogwood trees in 24 western counties of North Carolina (Kennard 2001). Although the disease has been reported within the assessment area, it has not yet caused significant mortality.

Effects of the disease on flowering dogwood in the southern Appalachians have been serious. Aesthetic quality and the tourism industry have been harmed. Dogwood fruits for wildlife food have been lost. Dogwood leaves have also been considered important in maintenance of soil properties, and loss of dogwood leads to deterioration in soil health. Similar effects would be likely for the assessment area if dogwood anthracnose increases in incidence and severity. There are currently no known controls for managing dogwood anthracnose in forests.

### Chestnut blight

Chestnut blight, caused by *Cryphonectria parasitica*, is the most devastating exotic tree disease known in the U.S.. The pathogen has killed all but a small fraction of the original population of American chestnut (*Castnaea dentata*) in that species' natural range (as well as other *Castanea* spp.) since the pathogen's accidental introduction in the early 1900s. The disease causes rapidly growing cankers on branches and stems of trees; stems usually die within 1 to 2 years as these cankers coalesce. Spores of the fungal pathogen are disseminated by wind and wind-driven rain and infect the trees through cracks or wounds in the bark. There is no natural resistance to this exotic pathogen.

American chestnut once grew in one small portion of the assessment area, but this niche has since been occupied by other species. Resistant varieties resulting from backcrossing studies by the American Chestnut Foundation may be available within the decade for deployment in selected areas of the previous range of the species. The USDA Forest Service is currently exploring a partnership with the foundation concerning potential use of such stock for ecosystem restoration on selected portions of Federal lands such as the assessment area.

## Insects

### Emerald ash borer

Emerald ash borer (*Agrilus planipennis*), an exotic insect from northeastern China, was first found to be established in the United States (Michigan) in 2002 (McCullough and Roberts 2002). As of 2003, infestations had been confirmed in 13 Michigan counties; one adjoining county in Ontario, Canada; and two counties in northwestern Ohio (D. Haugen, personal communication). The infestation in the Detroit area had apparently been established for at least 5 years before its discovery. The borer has infested and killed trees in both urban areas and native forests. Extensive feeding galleries of the larvae in the phloem and outer sapwood girdle branches and main stems. In Michigan, the borer has been observed only on ash trees. The borer has attacked both vigorously growing and stressed trees.

The adults are strong fliers and flights of >1 km are possible. In addition, the beetle can be transported in wood products with intact bark moving via international trade. Quarantines have been imposed in North America to restrict the movement of ash trees, firewood, branches, and logs from infested to uninfested areas (Michigan Department of Agriculture 2003). If the emerald ash borer were introduced to forest areas in the assessment area with an ash component, the potential for its establishment would be high (Ciesla 2003).

### Asian longhorned beetle

The Asian longhorned beetle (*Anoplophora glabripennis*), a recent introduction to the United States, is a serious threat to the millions of acres of hardwood trees in forest lands and urban forests, and has no known natural predator in this country (USDA Forest Service 2002). The insect likely arrived in the United States inside solid wood packing material from China. The beetle has the potential to damage such industries as lumber, maple syrup, nursery, commercial fruit, and tourism. To date within the U.S., infestations have been found in metropolitan areas of New York City and Chicago, Illinois ( USDA Forest Service 2003). In these areas, infested trees were removed and the woody material was destroyed by chipping and burning in an attempt to eradicate the insect. There are large areas of forest land with susceptible hosts in and around the southern Indiana portion of the assessment area.

Maples, including boxelder (*A. negundo*), Norway (*A. platanoides*), red (*A. rubrum*), silver (*A. saccharinum*), and sugar (*A. saccharum*), are the preferred host species in the U.S. Other known species include alders, birches, elms, horsechestnut (*Aesculus* spp.), poplars, and willows. Tunneling by beetle larvae girdles tree stems and branches. Repeated attacks lead to dieback of the tree crown and, eventually, death of the tree.

To prevent further spread of the Asian longhorned beetle, Federal quarantines have been established to avoid transporting infested trees and branches from these infested areas (USDA Forest Service 2003). The regulations also attempt to prevent movement of the insect on wood products such as solid wood packing material. The Asian longhorned beetle has not been detected in the year since treatment of the Chicago infestation (Dennis Haugen, personal communication) and, thus, the risk of introducing of the beetle into the assessment area has been greatly reduced.

## ACKNOWLEDGEMENTS

The second author was responsible for reorganizing, editing, updating, and correcting an original manuscript prepared solely by the first author. The second author gratefully acknowledges Dennis Haugen, Kathryn Kromroy, and Phil Marshall for providing helpful technical information during the revision of the manuscript. Technical reviews of the earlier manuscript by two anonymous reviewers and of the revised manuscript by Dennis Haugen and Rob Doudrick were much appreciated.

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# Exotic Aquatic and Terrestrial Animals in the Hoosier-Shawnee Ecological Asessment Area

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## ABSTRACT

We reviewed the impact of exotic aquatic and terrestrial wildlife on ecosystems within the Hoosier-Shawnee Ecological Assessment Area. Recent collections within the assessment area have demonstrated that faunal diversity is expanding rapidly from the intentional and unintentional release of nonindigenous species. We report on the origin, status, trends, habitat associations, and distribution of 58 exotic species including 44 fish or invertebrate species, 5 hybrid fish species, and 9 terrestrial vertebrates. The aquatic species include 19 species from the Midwest used in stocking programs, 6 from Asia or Eurasia, 5 from the Gulf coast, 3 from the Atlantic coast, 4 from South America, 2 from the Pacific coast, and 1 from the Southeastern United States. Five of these species are hybrids that originated in aquaculture facilities or hatcheries. Six non-native species were released or stocked in the assessment area in the 1950s, another three in the 1960s, and another fifteen in the 1970s when the releases peaked in the area. Releases and some natural dispersal from origins along the Gulf coast have continued throughout the 1980s, 1990s, and into the 21st century. The majority of exotic terrestrial vertebrates found in the assessment area originated in Europe, Asia, or Africa. Only one species, the house finch, is native to North America. Three species were intentionally introduced to the Eastern United States, four species were intentionally introduced with subsequent escapes resulting in established feral populations, and two species dispersed naturally into the area. All of the terrestrial exotics reviewed in this chapter are well adapted to, and flourish in association with, human habitation.

**Table 1.** The worldwide number of vertebrate extinctions from major known causes (modified from Cox 1993).

| Group | Human exploitation | Invading species | Habitat disruption | Other | Unknown |
|---|---|---|---|---|---|
| Mammals | 24 | 20 | 19 | 1 | 36 |
| Birds | 11 | 22 | 20 | 2 | 37 |
| Reptiles | 32 | 42 | 5 | | 21 |
| Fishes | 3 | 25 | 29 | 3 | 40 |
| Total | 70 | 109 | 73 | 6 | 134 |
| Total percentage of known causes | 27.1 | 42.3 | 28.3 | 2.3 | |

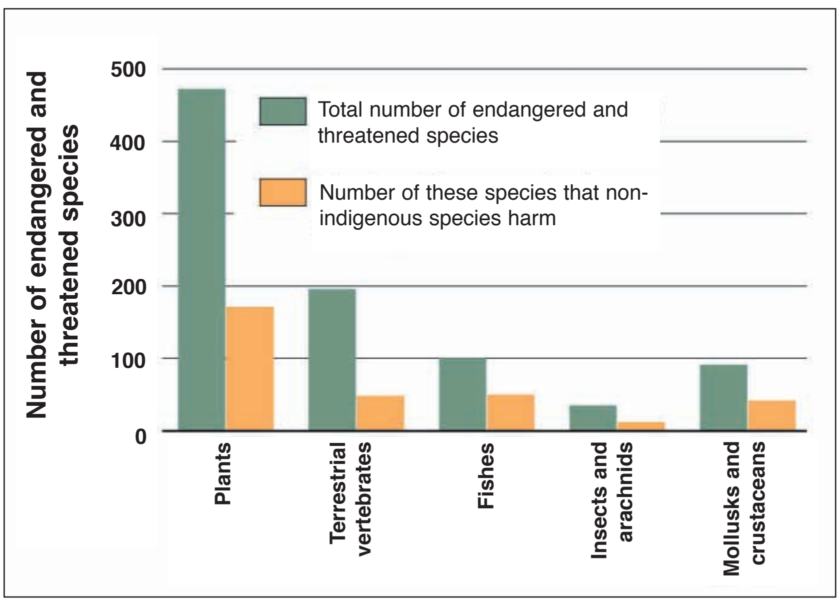
## HISTORY OF EXOTIC SPECIES

An important natural resource issue in the Hoosier-Shawnee Ecological Assessment Area is the invasion of exotic species and their ability to alter population, community, and ecosystem structure and function. Exotic/nonindigenous species were defined by the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 as, "The condition of a species being moved beyond its natural range or natural zone of potential dispersal, including all domesticated and feral species and hybrids." Within the United States, exotics have often been purposefully introduced with little consideration of the long-term negative consequences that these species may eventually have on native biotic communities. Although some introductions have had nominal impacts on native populations and habitats, several have caused devastating damage to natural ecosystems. The Congressional Office of Technology Assessment has recorded at least 4,500 species of foreign origin that have established free-living populations within the United States. Approximately 4 to 19 percent of these species cause severe economic or environmental harm, and 6 to 53 percent are estimated to have neutral or unknown effects. Stein and Flack (1996) estimate that 20 species of exotic mammals, 97 species of exotic birds, and 53 species of exotic reptiles and amphibians now inhabit the United States. Nationwide, about $27.5 billion is spent annually controlling these exotic species (Pimentel et al. 1999).

The outright loss of native species is one of the major effects that invasive exotic species have on biodiversity (Nott et al. 1995); globally, invasive exotic species have caused the extinction of at least 109 vertebrate species (Cox 1993). This is a significant percentage of the overall identified causes of vertebrate extinctions (table 1). Exotic species contribute to a significant proportion of listings of threatened and endangered species within the United States. Exotic species have contributed to the decline of approximately 35 percent of listed taxa (U.S. Congress 1993) (fig. 1). Yet, exotic species also have other serious effects on ecosystems including general decline in abundance of native species, change in ecosystem structure and function, and rearrangement of tropic relations.

Although there are exceptions, successful invasive exotic species seem to exhibit one or more

**Figure 1.** Number of United States species listed under provisions of the U.S. Endangered Species Act of 1973 (U.S. Fish and Wildlife Service 1994) whose status is attributed to threats from nonindigenous species (Office of Technology Assessment 1993).



characteristics that further their establishment and expansion:

**Characteristics of Invasive Species:**

- High rate of reproduction; pioneer species; short generation time
- Long-lived
- Single-parent reproduction (e.g., a gravid or pregnant female can colonize)
- Vegetative or clonal reproduction
- High genetic variability
- Phenotypic plasticity
- Broad native range
- Tolerant of wide range of conditions
- Habitat generalist
- Broad diet (polyphagous)
- Gregarious
- Human commensal

(Characteristics modified from Ehrlich 1989, Lodge 1993, and Meffe and Carroll 1994.) The presence or absence of these characteristics neither precludes the invasion of a species nor guarantees that a particular nonindigenous invader will succeed. Because the success of invasive exotic species is highly variable, these characteristics can serve only as general guidelines for predicting the success of exotic species.

Ecological communities have characteristics that promote invasion by exotic species:

**Characteristics of Communities:**

- Climactically similar to original habitat of invader
- Early successional (recently disturbed)
- Low diversity of native species
- Absence of predators on invading species
- Absence of native species morphologically or ecologically similar to invader
- Absence of predators or grazers in evolutionary history
- Absence of fire in evolutionary history
- Low-connectance food web
- Disturbed by humans

(Characteristics modified from Lodge 1993.) The level of human-induced disturbance is one of the most important features that make a community susceptible to invasion by exotic species (Hobbs 1989). Generally, human disruptions of natural communities, through soil alterations, removal of vegetative cover, or suppression of natural disturbance regimes, seem to promote the invasion of a community by nonindigenous species, whereas intact communities may be more difficult to invade. For example, disturbances stemming from dams, water diversions, destruction of riparian habitat, and other factors have greatly enhanced the ability of many nonindigenous fish species to invade riverine ecosystems within the assessment area. And many nonindigenous bird species, including European starlings (*Sturnus vulgaris*) and house sparrows (*Passer domesticus*), flourish in disturbed areas such as cities, suburbs, and farms.

In the United States, the problem of biological invasion began with European colonization over 500 years ago. Colonists introduced species for aesthetic, economic, and recreational reasons. Livestock and nonindigenous food crops essential to survival were the earliest introductions. Many species such as cats and dogs were introduced as domestic animals, but they escaped and established feral populations that cause significant ecological problems. Although much attention has been focused on the effects of invasive plants and insects, the impacts of introduced aquatic and terrestrial vertebrates have often been as great or even greater.

## METHODS AND DEFINITIONS

We reviewed primary literature (e.g., Burr et al. 1996, Cabe 1993, Laird and Page 1996), secondary literature (e.g., Burr and Warren 1986, Gerking 1945, Hamilton and Wise 1991), as well as aquatic collections deposited at the Illinois Natural History Survey, and Southern Illinois University at Carbondale and Indiana, Illinois, and Kentucky Audubon Society bird records. Most species reported within this chapter were documented within the past two decades and demonstrate the rapid invasion that often occurs once a nonindigenous species gains access to a new environment. When possible, the date (or decade) and location of the first observation (i.e., collection) of each nonindigenous species within the assessment area have been included. The mechanism or vector of introduction is defined as the most probable means by which a species was introduced into the assessment area. Some species have invaded by more than one mechanism and are so noted. Although the precise origins of many of the nonindigenous species in the assessment area are not known, a broad geographic origin has been determined. The native range of a species may not necessarily be the source of the assessment area populations of the species. For example, the Asian clam (*Corbicula fluminea*), a native of Asia, was firmly established in western North America before it was discovered in the Midwest. Therefore, we can reasonably presume that the assessment area populations did not originate in Asia, but from some other part of North America.

Transportation mechanisms of exotic aquatic and terrestrial species can be divided into the following four broad categories: natural dispersal, intentional introduction, intentional introductions with subsequent escape, and unintentional introduction. The first category is a natural biological invasion, which is generally considered a range expansion. The other three categories are dependent on human activities.

## Intentional Introduction

Intentional introductions are those which nonindigenous species have been transported beyond their native range and released into the wild for establishment. Many of the aquatic and terrestrial species introduced within the assessment area were deliberately imported for aesthetic, sport hunting/fishing, or livestock purposes. The early history of intentionally introduced aquatic and terrestrial wildlife species into the assessment area is mostly lost in obscurity. Federal records, however, indicate that deliberate stocking of fish species such as Atlantic salmon (*Salmo salar*) and common carp (*Cyprinus carpio*) by government fish hatcheries had begun by the early 1870s (Heidinger 1999). Accidental release of other species of fishes, in addition to intended species, is a means through which stocking programs can indirectly and unintentionally introduce non-native aquatic organisms. Stocking to enhance sport fishing now includes the release of about 2.5 billion individual sport fishes annually within the United States and Canada (Heidinger 1999). European starlings, house sparrows, ring-necked pheasants, and feral hogs are all examples of intentionally introduced terrestrial species.

## Introduction with Subsequent Escape

Introductions with subsequent escape are those nonindigenous species that are transported beyond their native range under captive conditions from which they later escaped. Subsequently, they may establish reproducing populations; these include the release of aquarium fish, amphibians, and reptiles. The escape of domestic cats and dogs has resulted in free-ranging populations that are widespread throughout the assessment area.

### Aquarium

The intentional release of aquarium pets into the aquatic environment is a practice thought to be more humane than other means of disposal. This practice has increased dramatically in the past decade. Pet owners presumably have not intended to establish self-sustaining populations of their pets, yet they knowingly release them into suitable habitat.

### Cultivation

The accidental escape of fishes and other aquatic organisms cultured in ponds for sport and commercial purposes, especially on the floodplain of large rivers (e.g., Mississippi River), has resulted in the introduction of thousands of exotic fishes. The major flood of 1993 provided a corridor of dispersal for cultured species in the Mississippi River basin.

### Bait

Release of unused bait by anglers and transport of fishes from one drainage to another via fishing vessels are activities through which fish species are introduced into new environments.

## Unintentional Introductions

Unintentional introductions are those nonindigenous species that are transported, often without being detected, beyond their native range in the course of some unrelated activity such as zebra mussels (*Dreissena polymorphia*) released in ship ballast water. Other exotic pests, such as rats and mice, have colonized new areas after being transported in cargo holds, shipping containers, produce, and imported forest products.

### Ships (ballast water)

By the 1880s, the release of ballast water was a common practice, and as a result, exotic species could have been released into North American ports well before 1900 (Mills et al. 1993). In addition, the opening of the enlarged seaway system on the St. Lawrence River in 1959 dramatically increased opportunities for release of ballast water. This event allowed larger ships and a greater frequency of ships sailing directly from Europe. Since the early 1800s, more than 140 exotic aquatic organisms have become established in the Great Lakes. Roughly one-third of these species have been introduced within the past 40 years, a surge coinciding with the opening of the St. Lawrence Seaway (Great Lakes Information Network 2003).

### Canals

In the 1700s, canals began to be built in northeastern North America to help connect adjacent watersheds, dissolving many natural barriers to dispersal of freshwater organisms. Even today the Chicago Sanitary and Ship Canal connects Lake Michigan with the Mississippi River via the Illinois River.

## EXOTIC AQUATIC MACROBIOTA

The fishes (table 2, fig. 2) are the best studied group of introduced freshwater organisms in North America (Fuller et al. 1999). Nonindigenous fishes have been released primarily into reservoirs and ponds in 29 cases, hatcheries or aquaculture facilities in 3 cases (mixed stockings), and mainstem rivers in 14 cases, the latter including some natural dispersal. The mechanism of release includes 1) deliberate stocking for sport fishing, 2) unintentional releases by pet owners, anglers, and aquaculture facilities, 3) natural dispersal into the area by way of new waterway canals or by corridors in mainstream rivers that lack structures (e.g., weirs, major dams) that might impede progress, and 4) release of ship ballast water containing nonindigenous aquatic animals (e.g., zebra mussel). The mechanism of release has been deliberate in 29 cases, mostly stocking for sport fishing, and unintentional in 11 cases by pet owners and fishers. Five putative aquarium releases have been recorded as well as five bait-bucket releases and apparently five releases associated with culture ponds or hatchery facilities.

Eighteen species or hybrids have dispersed into the area naturally by way of new waterway canals or by corridors in mainstem rivers that lack structures (e.g., weirs, major dams) that might impede progress. Fifteen fish species have not established self-sustaining populations in the assessment area, but may be abundant seasonally (e.g., rainbow smelt [*Osmerus mordax*]) or have the potential to become established in the foreseeable future. This is especially true if the number of pet releases and the number of power-cooling reservoirs that have unseasonably warm water throughout the year continue to increase. Only four species are reported from the region as casual or waif occurrences, including valid records for the bull shark (*Carcharhinus leucas*). Three aquatic invertebrate species, rusty crayfish (*Orconectes rusticus*), Asian clam, and zebra mussel, are

**Table 2.** Origin, date, and location of first record, and entry mechanisms and status for nonindigenous aquatic macrobiota of the Hoosier-Shawnee Ecological Assessment Area.

| Family | Species | Common name | Origin | Date | Location | Mechanism[1] | Status |
|---|---|---|---|---|---|---|---|
| Atherinidae | *Menidia beryllina* | Inland silverside | Gulf Coast | 1960s | Mississippi River | Introduction (I); Waterway Canals, Dispersal | Established |
| Belonidae | *Strongylura marina* | Atlantic needlefish | Gulf Coast | 1990 | Lake Barkley tailwaters, KY | Waterway Canals, Dispersal | Casual/Waif Occurrence |
| Carcharhinidae | *Carcharhinus leucas* | Bull shark | Gulf Coast | 1937 | Mississippi River | Dispersal | Casual/Waif Occurrence |
| Centrarchidae | *Lepomis gibbosus* | Pumpkinseed | N. Midwest States | 1970s | Reservoirs, Ponds | Introduction (I) | Reported |
| Centrarchidae | *Lepomis macrochirus* | Bluegill | Midwest States | 1950s | Reservoirs, Ponds | Introduction (I) | Established |
| Centrarchidae | *Lepomis microlophus* | Redear sunfish | Midwest States | 1950s | Reservoirs, Ponds | Introduction (I) | Established |
| Centrarchidae | *Lepomis macrochirus x L. cyanellus* | Bluegill x Green sunfish | Midwest States | 1960s | Reservoirs, Ponds | Introduction (I) | Established |
| Centrarchidae | *Micropterus dolomieu* | Smallmouth bass | N. Midwestern States | 1974 | Goreville Reservoir, IL | Introduction (I) | Reported |
| Centrarchidae | *Micropterus punctulatus* | Spotted bass | SE U.S., Missouri Ozarks | 1974 | Cedar Lake, IL | Introduction (I) | Reported |
| Centrarchidae | *Micropterus salmoides* | Largemouth bass | Midwest States | 1950s | Reservoirs, Ponds | Introduction (I) | Established |
| Centrarchidae | *Pomoxis annularis* | White crappie | Midwest States | 1978 | Reservoirs, Ponds | Introduction (I) | Established |
| Centrarchidae | *Pomoxis nigromaculatus* | Black crappie | Midwest States | 1975 | Reservoirs, Ponds | Introduction (I) | Established |
| Cichlidae | *Cichla ocellatus* | Oscar | South America | 1998 | Campus Lake, SIUC, IL | Introduction (AQ) | Reported |
| Clupeidae | *Dorosoma petenense* | Threadfin shad | Gulf Coast | 1957 | Ohio River | Introduction (I), Dispersal | Established |
| Cyprinidae | *Carassius auratus* | Goldfish | Eurasia | 1953 | Horseshoe Lake, IL | Introduction (I, AQ, B), Dispersal | Reported, possibly established |
| Cyprinidae | *Ctenopharyngodon idella* | Grass carp | Asia | 1971 | Mississippi River | Introduction (I, C), Dispersal | Established |
| Cyprinidae | *Cyprinus carpio* | Common carp | Eurasia | 1885 | Big Muddy River | Introduction (I), Dispersal | Established |
| Cyprinidae | *Hypophthalmichthys molitrix* | Silver carp | Asia | 1983 | Mississippi and Ohio Rivers | Introduction (IE, C), Dispersal | Established |
| Cyprinidae | *Hypophthalmichthys nobilis* | Bighead carp | Asia | 1982 | Mississippi and Ohio Rivers | Introduction (IE, C), Dispersal | Established |
| Cyprinidae | *Hypophthalmichthys molitrix x H. nobilis* | Silver x Bighead carp | Culture ponds, Hatcheries | 1985 | Kentucky Lake, KY | Introduction (IE, C), Dispersal | Reported |
| Cyprinidae | *Luxilus zonatus* | Bleeding shiner | Ozark Uplands or bait shop | 1999 | Kinkaid Creek, IL | Introduction (IE, B), Dispersal | Reported |
| Cyprinidae | *Mylopharyngodon piceus* | Black carp | Asia | 1999 | Missouri culture pond(s) | Introduction (C) | Reported |
| Cyprinidae | *Notemigonus crysoleucas* | Golden shiner | Midwest States | 1970s | Reservoirs, Ponds | Introduction (IE, B) | Established |
| Cyprinidae | *Pimephales promelas* | Fathead minnow | N. Midwest States | 1981 | Reservoirs, Ponds | Introduction (IE, B) | Established |
| Esocidae | *Esox lucius* | Northern pike | N. Midwest States | 1974 | Cedar Lake, IL | Introduction (I) | Reported |
| Esocidae | *Esox masquinongy* | Muskellunge | N. Midwest States | 1980 | Little Cedar Lake, IL | Introduction (I), Limited Dispersal | Reported, possibly established |
| Esocidae | *Esox lucius x E. masquinongy* | Tiger muskellunge | Culture ponds, hatcheries | 1976 | Randolph County Lake, IL | Introduction (I) | Reported (sterile) |
| Gasterosteidae | *Culaea inconstans* | Brook stickleback | N. Midwest States | 2001 | Hatcheries | Introduction (IE, B) | Reported |
| Ictaluridae | *Ameiurus melas* | Black bullhead | Midwest States | 1967 | Ponds | Introduction (I) | Established |
| Ictaluridae | *Ictalurus furcatus* | Blue catfish | Midwest States | 1990s | Reservoirs | Introduction (I) | Established |

*(table continued on next page)*

**(table 2 continued)**

| Family | Species | Common name | Origin | Date | Location | Mechanism | Status |
|---|---|---|---|---|---|---|---|
| Ictaluridae | *Ictalurus punctatus* | Channel catfish | Midwest States | 1950s | Reservoirs, Ponds | Introduction (I) | Established |
| Loricariidae | *Pterygoplichthys disjunctivis* | Amazon sailfin catfish | South America | 1996 | Ohio River | Introduction (IE, AQ) | Reported |
| Moronidae | *Morone americana* | White perch | Atlantic Coast | 1993 | Mississippi River | Waterway Canals, Dispersal | Reported, possibly established |
| Moronidae | *Morone saxatilis* | Striped bass | Atlantic Coast | 1974 | Ohio River, Reservoirs | Introduction (I), Dispersal | Reported, possibly established |
| Moronidae | *Morone saxatilis x M. chrysops* | Sunshine/ Palmetto bass | Culture ponds, hatcheries | 1970s | Ohio River, Reservoirs | Introduction (I), Dispersal | Reported |
| Mugilidae | *Mugil cephalus* | Striped mullet | Gulf Coast | 1989 | Mississippi River | Dispersal | Casual/Waif Occurrence |
| Osmeridae | *Osmerus mordax* | Rainbow smelt | Atlantic Coast | 1978 | Mississippi River | Introduction (I), Dispersal | Casual/Waif Occurrence |
| Percidae | *Etheostoma exile* | Iowa darter | N. Midwest States | 2001 | Culture Ponds, Hatcheries | Introduction (IE, B) | Reported |
| Percidae | *Perca flavescens* | Yellow perch | N. Midwest States | 1977 | Devil's Kitchen Lake, IL | Introduction (I) | Reported, possibly established |
| Percidae | *Stizostedion canadense x S. vitreum* | Saugeye | Culture ponds, hatcheries | 1990s | Ohio River, IN | Introduction (I) | Reported, possibly established |
| Percidae | *Stizostedion vitreum* | Walleye | PA, N. Midwest States | 1974 | Cedar Lake, IL | Introduction (I) | Established |
| Poeciliidae | *Gambusia affinis* | Western mosquitofish | Mississippi River Basin | 1981 | Ponds | Introduction (I), Dispersal | Established |
| Salmonidae | *Oncorhynchus mykiss* | Rainbow trout | Western North America | 1980 | Reservoirs | Introduction (I) | Reported, possibly established |
| Salmonidae | *Oncorhynchus tshawytscha* | Chinook salmon | Pacific Coast | 1978 | Kincaid Lake, IL | Introduction (I) | Reported (smolts) |
| Serrasalmidae | *Piaractus brachypomus* | Redbellied pacu | South America | 1992 | Little Grassy Lake, IL | Introduction (IE, AQ) | Reported |
| Serrasalmidae | *Pygocentrus nattereri* | Red piranha | South America | 2000 | Campus Lake, SIUC | Introduction (IE, AQ) | Reported |
| Cambaridae | *Orconectes rusticus* | Rusty crayfish | Indiana, Ohio | 1960s | Not reported | Introduction (IE, B) | Established |
| Dreissenidae | *Dreissena polymorpha* | Zebra mussel | Eurasia | 1990s | Mississippi and Ohio Rivers | Ships (Ballast Water), Dispersal | Established |
| Corbiculidae | *Corbicula fluminea* | Asian clam | Asia | 1970s | Mississippi and Ohio Rivers | Introduction (IE, AQ), Dispersal | Established |

[1] Introduction (I) = Introduction (Intentional); Introduction (IE) = Introduction with escapes; Introduction (AQ) = Introduction (Aquarium); Introduction (C) = Introduction (Cultivation); Introduction (B) = Introduction (Bait).

established in the assessment area (table 2). Only the crayfish is native to the Eastern United States and has been released via bait buckets by fishers. The two clam species originated from Asia or Eurasia and have used the Mississippi and Ohio Rivers as major corridors of dispersal. The zebra mussel is the only species in the assessment area to have been unintentionally released into North American (i.e., Great Lakes) waters from ship ballast water.

The potential ecological effects of nonindigenous species on native aquatic communities include habitat alterations (e.g., removal of vegetation); degradation of water quality; introduction of parasites and diseases; trophic alterations (e.g., increased predation, competition for food resources); hybridization; and spatial interactions (e.g., overcrowding, competition for spawning sites) (Taylor et. al 1984). Greater oversight of exotic and other nonindigenous introductions will be needed in the future with the increasing demands from a growing human population, an expanding aquaculture industry, and changes in cultural values.

At the beginning of the 20th century, the only known established exotic fish in the assessment area was the common carp, (Burr and Warren 1986, Forbes and Richardson 1909, Gerking 1945, Pflieger 1997). There are now over 536 unique fish taxa (i.e., species, reproducing hybrids) introduced outside their native ranges within U.S. waters (Fuller et al. 1999). Likewise, the number of nonindigenous macrobiota introduced into the assessment area and surrounding aquatic systems has increased dramatically in the past decade. Because fish and other aquatic introductions clearly have accelerated, documentation of their current status is warranted.

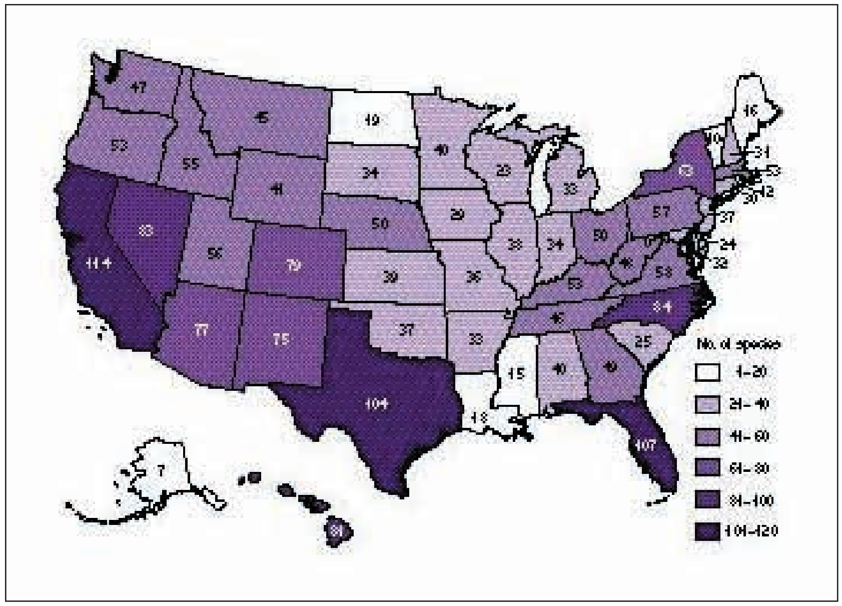



**Figure 2.** Number of nonindigenous fish species introduced into inland waters of the United States, 1850-1995 (data are from the U.S. Geological Survey, Florida Caribbean Science Center, Gainesville, Florida, March 1995).

## Established Non-native and Exoctic Species

### White perch, *Morone americana* [Moronidae]

White Perch, an anadromous euryhaline species originally restricted to the North American Atlantic coast, has now become established in many freshwater lakes and rivers. Scott and Christie (1963) reviewed the spread of White Perch into the lower Great Lakes by movement of the species through the Mohawk River Valley and the Erie Barge Canal into Lake Ontario. Johnson and Evans (1990) hypothesized that above-average temperatures during the middle of the 20th century provided a window for white perch to enter the Great Lakes. By 1990-91, white perch had dispersed into the upper Illinois River and the Lake Calumet system. And by 1992, this species was captured near the mouth of the Illinois River. As of 1993-94, white perch had reached extreme southern Illinois via the mainstem Mississippi River, with recent records from the Horseshoe Lake drainage, Alexander County, Illinois.

Other than the Great Lakes, a possible source of white perch in the Mississippi River is via the Missouri River, a result of introductions made into Nebraska lakes beginning in 1964 (Zuerlein 1981). Cross et al. (1986) reported records from the Platte-Niobrara Rivers, and Hesse et al. (1982) reported the species from the middle Missouri River. However, the authors are unaware of any recent records of white perch farther downstream in the Missouri River (see Pflieger 1997).

White perch have reproduced in assessment area waters and may now be an established member of the local fish fauna. The species is reported to spawn in shallow freshwater over a variety of bottom types and often increases rapidly in numbers despite the presence of other established species (Scott and Crossman 1973). The presence of four species of *Morone* (two native and two nonnative) together with stockings of *Morone* hybrids in midwestern rivers (e.g., the Ohio River), is likely to complicate identification of juvenile and subadult representatives of the genus.

In 5 years, white perch dispersed nearly the entire length of Illinois: an outstanding example of how quickly a newly invading species can spread and become established. Only rainbow smelt has been shown to have moved more rapidly downriver in the Mississippi River basin (Mayden et al. 1987) from points of introduction in the upper Missouri River and possibly the Great Lakes.

**Striped bass, *Morone saxatilis* [Moronidae]**

This anadromous species is native to Atlantic Slope drainages and estuaries of eastern North America and has been widely introduced in the U.S. (Fuller et al. 1999). The striped bass was intentionally stocked by State and Federal agencies in Illinois, Indiana, Kentucky, and Missouri as early as the late 1960s. Beginning in the mid-1970s, adult striped bass were being caught in the Ohio River, some of which escaped over the dams of impoundments. This species is now found in the Wabash and Mississippi Rivers and in a few large reservoirs in or near the assessment area. Although the impact of these stockings has not been established, adults are piscivorous and are capable of getting over the dams of large reservoirs and impacting native fishes in tailwater reaches. There is some evidence that reproduction has occurred in past years, but well-established populations in the assessment area are not known.

**Striped mullet, *Mugil cephalus* [Mugilidae]**

Burr et al. (1996) reported records of striped mullet for the upper Mississippi River and lower Ohio River basins, noting that this species was known previously only as far north in the Mississippi River as southern Arkansas (Robison and Buchanan 1988). A record from the Mississippi River near the mouth of the Missouri River is the northernmost record known for this otherwise familiar resident of estuaries, salt marshes, and shoreline areas of the Atlantic and Gulf coasts (Etnier and Starnes 1993). The authors speculate that low water levels in the Mississippi River in 1988 and 1989 created water-quality conditions favorable for striped mullet to reach the upper Mississippi River basin. A 1993 record from Kentucky Lake, Tennessee (Etnier and Starnes 1993), suggests that the Tennessee-Tombigbee waterway might be another route of dispersal for this species to reach the mainstems of the Ohio and Mississippi Rivers. Because this species spawns offshore in marine waters, it will never be a persistent component of the fish fauna of the assessment area. Striped mullet is probably best considered a transient or periodic southern invader of midwestern waters.

**Rainbow smelt, *Osmerus mordax* [Osmeridae]**

Mayden et al. (1987) reviewed the records and literature on the distributional history of rainbow smelt in the Mississippi River basin. They concluded that this species, otherwise unknown from the Mississippi River basin before 1978, reached the lower Missouri River mainstem and lower Mississippi River mainstem from escaped forage stockings in Lake Sakakawea, North Dakota, and some may have originated from Lake Michigan stock. Approximately 7 years elapsed from the initial stock of rainbow smelt in Lake Sakakawea until they were first captured in the free-flowing lower Mississippi River (Mayden et al. 1987). During winter from the late-1970s to the mid-1980s, rainbow smelt was the most common species along the shoreline of the Mississippi River at Grand Tower (Klutho 1983). The status of rainbow smelt in the Mississippi River basin remains uncertain, but its sporadic occurrence over the past two decades in the mainstem suggests that it might best be considered an occasional winter transient.

**Rainbow trout, *Oncorhynchus mykiss* [Salmonidae]**

The assessment area lacks traditional trout waters, and attempts to develop trout fisheries in the region have typically failed. The most successful rainbow trout fishery is in Devil's Kitchen Lake, Illinois, a Federal property with some deep, cool water. There is no evidence that rainbow trout would survive in the region if they escaped from reservoirs where they are stocked. Limited reproduction and recruitment may occur, but impacts of introduced populations require additional study and evaluation.

### Chinook salmon, *Oncorhynchus tshawytscha* [Salmonidae]

There is apparently only one record of this species having been introduced into a reservoir in the assessment area (table 2). Approximately 4,500 smolts were released in 1978 and there has been no formal record of their status in succeeding years. Because of several life history limitations, the sport fishing potential of this species in relatively warm waters has never been realized.

### Rusty crayfish, *Orconectes rusticus* [Cambaridae]

Within the past 25 years, this species has rapidly expanded its range, and the determination of its historical distribution is difficult. It may have occurred natively in the Ohio River basin of Michigan, Ohio, Kentucky, and Indiana (Taylor and Redmer 1995). Introduced populations in the assessment area have not yet been reported, but are expected because of the rapid expansion in many areas of North America (Lodge et al. 2000). This species has spread primarily through bait-bucket releases and is known to alter native crayfish communities through hybridization and habitat alteration (Perry et al. 2002).

### Bleeding shiner, *Luxilus zonatus* [Cyprinidae]

Hiland and Poly (2000) first reported the occurrence of the bleeding shiner near the assessment area in Kinkaid Creek, downstream of the Kinkaid Lake dam in southeastern Illinois. The bleeding shiner is native to streams in the nearby Missouri Ozarks, but had never been found east of the Mississippi River. They suggested that the species "could have reached Illinois waters naturally because of the proximity of Illinois to the native range of the species, or the minnow could have been a bait-bucket introduction."

### Brook stickleback, *Culaea inconstans* [Gasterosteidae]

Brook stickleback have often been reported in waters far outside their native northern range (Fuller et al. 1999). They are apparently captured incidentally along with fathead minnows in Wisconsin and Minnesota waters and then they are sold in Indiana, Illinois, and Kentucky as part of the bait catch. When anglers are through fishing for the day, they empty their bait buckets, and this species is released unintentionally into the waters being fished. Currently, there are no records of this species spawning in the assessment area, and all records are reports of single individuals.

### Iowa darter, *Etheostoma exile* [Percidae]

There are only two records in the assessement area of the Iowa darter, an otherwise common species in northern Midwestern States. One sample was mixed in with other species to be used by a local fish farm, and the other record is from below the dam of Little Grassy Lake, Illinois. When fathead minnows are collected for bait in the wild in Minnesota and Wisconsin and exported to surrounding States, the samples are invariably mixed with other syntopic species (i.e., brook stickleback, central mudminnow [*Umbra limi*]). The fish are sold to local anglers who release the species in their bait buckets directly into the areas they have been fishing. There are no known established populations of this species in the assessment area, even though there are seemingly few biotic factors that would limit reproduction. At present there is no known ecological impact on the local aquatic fauna as a result of release of this species.

### Yellow perch, *Perca flavescens* [Percidae]

Stockings of sport fish in reservoirs often contain mixed samples. The yellow perch, a species native to more northern regions in the Midwest, has apparently been accidentally introduced into Devil's Kitchen and Crab Orchard Lakes, Illinois, as well as into Monroe Reservoir, southern

Indiana. The release of rainbow trout and walleye was the original aim of the stockings. Yellow perch have survived, particularly in Devil's Kitchen Lake and Monroe Reservoir where reproduction and recruitment have apparently occurred. Yet, there are no known established populations of this species in lotic systems within the assessment area. The impact of this species in the assessment area has not been studied.

### Inland silverside, *Menidia beryllina* [Atherinidae]

In a footnote, Smith (1979) stated that the inland silverside had been found recently in the Mississippi River of southern Illinois from Grand Tower in 1978, indicating that he was unaware of any previous records of this fish in Illinois waters. Pflieger (1975) reported the species to be common in the Mississippi River from the mouth of the Ohio River southward. Since Smith's (1979) report, no additional specimens of the inland silverside were taken in assessment area waters until the 1990s, when the species was found to be common in the lower Ohio River by several independent investigators. The Ohio River records are the first reported for the mainstem. Burr and Adams also recently documented the presence of this species in the lower Big Muddy River. The latter record appears to represent the northernmost extent of this species in the Mississippi River basin. Size ranges of individuals indicate that reproduction has occurred (Stoeckel and Heidinger 1989), and continued capture of this species in free-flowing waters indicates the fish is established permanently in the assessment area.

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

### Goldfish, *Carassius auratus* [Cyprinidae]

Sporadic occurrences of goldfish, a native of Eurasia, are reported from western Kentucky (Burr and Warren 1986), southern Missouri (Pflieger 1997), and southern Indiana (Gerking 1945). Smith (1979) recorded goldfish as common, especially in the Illinois River drainage but had no records of the species from southern Illinois. Yet, Gunning (1954) captured a specimen from Horseshoe Lake in Alexander County, Illinois, in 1953. Numerous specimens appeared in Southern Illinois University at Carbondale collections from various points in southwestern Illinois following the receding floodwaters of 1993, demonstrating that a number of source pools are now available in the area. All specimens were wild type in color and morphology and almost certainly do not represent the recent release of aquarium stock. It is likely the species invaded southern Illinois with the 1993 flood and took advantage of shallow flooded fields for reproduction and recruitment. Goldfish were originally introduced into North America for ornamental purposes (i.e., public aquaria, fountains).

**Grass carp, *Ctenopharyngodon idella* [Cyprinidae]**

Grass carp, a native of Asia, was introduced as a means of vegetation control in 1963 into experimental ponds in Arkansas and soon thereafter into impoundments in that State. It escaped almost immediately and dispersed throughout the Missouri-Mississippi mainstem (Pflieger 1978). By 1987 it was established in the Missouri River drainage, Missouri (Brown and Coon 1991). Greenfield (1973) and Stanley et al. (1978) reviewed the literature on the biology of grass carp and noted that it randomly spawns in strong currents of large rivers, apparently in response to rising water levels. Eggs must remain suspended in current for at least 2 days (approximate hatching time), so long reaches of flowing water are required for successful reproduction. These conditions were apparently enhanced during the 1993-94 floodings of the Mississippi River.

For years, triploid grass carp has been stocked into Illinois, Indiana, and Kentucky farm ponds and some lakes to control aquatic vegetation. Commercial fishermen have been catching adults and juveniles from the Mississippi River for over 20 years. The species is clearly established in Midwestern States and is now impossible to eradicate over such a large area. As judged from sampling localities, the lower reaches of four river systems (Illinois, Big Muddy, and Cache Rivers, Clear Creek) in southern Illinois are all serving as apparent spawning or nursery sites. Because triploid grass carp is presumably incapable of producing viable offspring, we conclude that big river diploid stocks are now using nearby waters for some reproduction. Since the floods of 1993 and 1994, adult grass carp is common in both Horseshoe Lake and its outlet, Lake Ceek, Alexander County, Illinois. In the approximately 23 years since grass carp was first reported from Illinois (Smith 1979), evidence for reproduction has occurred only in the last few years, indicating a somewhat lengthy period before establishment.

Aquatic macrophytes dominate the diet of subadult and adult grass carp, although a few studies show consumption of animal matter (Laird and Page 1996). Although the impact of this species in assessment area waters remains to be seen, carp's potential for reducing cover used by a variety of fish species is certainly a potential adverse effect. In addition, excessive removal of aquatic macrophytes from large backwaters could impact waterfowl populations and restructure forage fish communities (Bettoli 1987).

**Common carp, *Cyprinus carpio* [Cyprinidae]**

The common carp, native to Asia, was transplanted to Europe centuries ago and was eventually introduced to this country as early as 1831 (Fuller et al. 1999). The first stocks were delivered to Midwestern States by government hatcheries in the late-1870s to mid-1880s (Forbes and Richardson 1909). The common carp is now the most successful exotic fish species in North America, occurring in all major river systems, their backwaters, and many ponds, lakes, and reservoirs. This fish is often the dominant species in terms of biomass in many reservoirs and river systems when standard fisheries evaluations are performed. Because this species has been present in the assessment area for well over a century, it has established a reputation for nuisance qualities—bottom feeding in an aggressive manner that fouls water; destroying aquatic vegetation; increasing turbidity; and perhaps eating eggs of other species.

**Silver carp, *Hypophthalmichthys molitrix* [Cyprinidae]**

This carp, a native of Asia and first introduced into Arkansas in 1973, was then raised and stocked into municipal sewage lagoons. By the early 1980s, the species was reported from the natural waters of that State (Robison and Buchanan 1988). Sporadic records of this fish were known in Illinois beginning in about 1983, and only occasional specimens began to appear in Southern Illinois University at Carbondale collections and the catches of commercial fishers. In the past 5 years, the silver carp has increased dramatically in abundance and distribution in the Mississippi, Ohio, and Wabash Rivers, as well as in several of their major tributaries. Silver carp and the three other Asian carps now account for the greatest biomass in the mainstem Mississippi River (Chick and Pegg 2001). With its spongelike gill rakers, silver carp is capable of straining organisms as small as 4 microns in diameter and is apparently efficient at digesting green and blue-green algae (Robison and Buchanan 1988). The spawning requirements of this species are similar to that of bighead and grass carps (i.e., spawning occurs when water rises after heavy rains), and capture of several age classes and young-of-the-year in several locations over the past 7 years in southern Illinois, western Kentucky, and southeastern Missouri, is clear evidence of successful spawning in the assessment area. Impacts on natural fish communities and the aquatic environment in general are unknown, but competition for food resources and space with other valued species (i.e., paddlefish, *Polyodon spathula*) is a likely consequence of its recent establishment.

**Bighead carp, *Hypophthalmichthys nobilis* [Cyprinidae]**

According to Jennings (1988), this native of Asian waters was first introduced into Arkansas in 1972 for use in combination with other phytophagous fishes to improve water quality and increase fish production in culture facilities. It first began to appear in open waters in the early 1980s in both the Ohio and Mississippi Rivers (Jennings 1988). Spawning in Illinois was first documented by Burr and Warren (1993) in the lower Big Muddy River as judged from capture of a postlarval specimen. Recent capture of additional specimens representing young-of-the-year, subadults, and adults strongly suggests that reproduction and recruitment are occurring in the assessment area in the large bordering rivers and their tributaries.

Bighead carp spawn in swift channels of large rivers (Jennings 1988). Flooding of lowland areas is a necessary requirement because these become the nursery areas for larvae and juveniles (Jennings 1988). These fundamental conditions and others summarized in Jennings (1988) were clearly met by major floods in the Midwest and almost certainly account for the recent appearance of postlarvae and juveniles. The large numbers of adults appearing in commercial fishing harvests are also presumably related to flooding, which probably redistributed adults in such a manner as to make them more accessible to fishers. This species is now established in assessment area waters and is capable of using the lower reaches of major Mississippi River tributaries as spawning reaches and nursery areas for larvae and juveniles. The potential impact of this species is not adequately known. The biological interaction of bighead carp with other filter-feeding native fishes such as the paddlefish warrants future investigation.

**Asian clam, *Corbicula fluminea* [Corbiculidae]**

The Asian clam was first observed in North America in British Columbia in 1924 when dead specimens (shells) were found (Counts 1981). The first live specimens were taken in 1938 on the banks of the Columbia River in Washington State. By the 1970s, huge densities of Asian clams were found at many locations in the Southern United States. (Counts 1986). Mechanisms of dispersal were summarized by Counts (1986) and included transport by birds, accidental transport with sand or gravel, and release as bait or as aquarium specimens. The Asian clam could have been introduced into assessment area waters by any of these means. Most records within the assessment area are from the mainstem Ohio and Wabash Rivers and their major tributaries.

### Zebra mussel, *Dreissena polymorpha* [Dreissenidae]

The zebra mussel is native to European waters and was first discovered in North America in Lake St. Clair in June 1988; it was spreading rapidly throughout the Great Lakes basin and the upper Mississippi River by 1991 (Mills et al. 1993). By the mid-1990s, the zebra mussel had spread throughout much of the Mississippi and Ohio River mainstems and the lower reaches of their major tributaries. This species arrived in the ballast water of transoceanic ships from Europe. Major impacts include bio-fouling and bio-filtering, the former resulting in millions of dollars of damage to boat motors and water-intake systems.

## Accidental or Waif Occurrence

### Atlantic needlefish, *Strongylura marina* [Belonidae]

The Atlantic needlefish, primarily a marine-estuarine species, is known to penetrate substantial distances into freshwater (Boschung 1989). On 26 November 1990, a 241-mm-long needlefish was captured in the tailwaters of Barkley Dam, Kentucky. The species was collected again in Kentucky Lake, Tennessee, in 1992 (Etnier and Starnes 1993). It has traversed the Tennessee-Tombigbee Waterway to the Tennessee River in Alabama (Mettee et al. 1996) and probably Tennessee. These records represent casual or waif occurrences but demonstrate the dispersal capability of this species and its tolerance for freshwater systems. Subadults prey on fishes and crustaceans (Ross 2001), and the discovery of early juvenile fish hundreds of miles from saltwater indicates almost certain reproduction in freshwater. An established population in the assessment area would likely compete for food resources with other piscivorous species such as the largemouth bass and muskellunge.

### Bull shark, *Carcharhinus leucas* [Carcharhinidae]

This is the only shark species known to ascend freshwaters in North America (Burgess and Ross 1980). An 84-pound specimen, approximately 5 feet long, was commercially captured on September 6, 1937, in the Mississippi River near Alton, Illinois. Other freshwater records occur much farther south in Louisiana and Florida. All evidence available supports the validity of the Alton record (Thomerson et al. 1977). Indeed, another bull shark was taken in the 1990s off the screen of a power plant intake canal. This report does not appear to be the product of a hoax, but there is little information other than a newspaper report. The Alton record is about 2,800 km from the Gulf of Mexico, the probable source of origin. At that time (1937), the Alton Lock and Dam was the first major obstruction to free transit farther up the Mississippi River. Apparently, water temperatures below 24°C limit the movement of sharks up the river (Thomerson et al. 1977). These records are clearly accidental or waif occurrences.

### Oscar, *Astronotus ocellatus* [Cichlidae]

Oscars, one of the most popular of aquarium fishes, are native to tropical South America where they are used for both subsistence and commercial fishing. The species has been imported into the U.S. for well over 50 years and has been kept by aquarists interested in spawning and feeding behavior of cichlids. In the winter of 1998, Brooks and Adams found two large adults dead in Campus Lake at Southern Illinois University at Carbondale. These oscars were apparently too large to continue to keep in a home aquarium and were released into the lake as a humane way of discarding a pet. No established population is known, although this species is a voracious predator and could survive in a year-round power-cooling lake such as Lake of Egypt, Illinois.

### Threadfin shad, *Dorosoma petenense* [Clupeidae]

The threadfin shad, another primarily marine-estuarine species, first appeared in Tennessee River impoundments in the late 1940s and had been captured at several stations along the Ohio River mainstem from Louisville to Cairo by the late 1950s (Minckley and Krumholz 1960). It is now established in the lower Ohio and Wabash Rivers and occurs above St. Louis, Missouri, in the Mississippi River (Pflieger 1997). It has been and continues to be extensively stocked in reservoirs of the assessment area, primarily as a forage species for piscivorous sport fishes. Young-of-the-year may spawn, but the species winterkills at temperatures below 8°C (Heidinger 1999). The species is planktivorous and competes for food resources with the young of many native species that rely on plankton as their primary food source (Laird and Page 1996). Threadfin shad is an excellent example of a euryhaline species, which by natural dispersal, acclimatization, and stocking, has greatly expanded its historical range and abundance.

### Black carp, *Mylopharyngodon piceus* [Cyprinidae]

Black Carp, another native of Asia, has not been found in the waters of the assessment area. Fuller et al. (1999) reported the escape of at least 30 adults into the Osage River, Missouri, following the flooding of a hatchery pond near Lake of the Ozarks. Yet, none of these black carp were ever recaptured. Southern Illinois University at Carbondale received 13 frozen black carp that had been seized from a pond owner in Missouri, but no other natural occurrences in the Midwest are known. The black carp is superficially similar to grass carp, especially the young, and all grass carp specimens warrant careful examination to be certain that black carp is not present. Black carp has significant potential to negatively impact native aquatic communities by consuming unionid mussels and snails, many of which are endangered (Fuller et al. 1999).

### Amazon sailfin catfish, *Pterygoplichthys disjunctivus* [Loricariidae]

In 1995, fisheries biologists with the State of Kentucky captured and photographed this species from a boat ramp on the Ohio River at New Albany, Indiana (River Mile 608.6). Sailfin catfishes originate from neotropical South America, and this species is common in the ornamental fish trade. There seems little doubt that the captured individual was released by a pet owner at a convenient location. This fish will most likely not survive the low winter temperatures within the assessment area, but the species has established populations in Florida and probably Texas (Fuller et al. 1999).

### Red-bellied pacu, *Piaractus brachypomus* [Serrasalmidae]

*Piaractus* is native to South American freshwaters and serves as a valuable food fish and a significant part of the ornamental fish trade. Since 1993, Southern Illinois University at Carbondale has obtained specimens representing this species from several lakes within the assessment area, yet they know of no fish farms in the vicinity that raise this species or of any State or Federal agency that would be releasing this exotic into public waters. Apparently, humans have released their aquarium pets, which were probably too large for their aquaria, into nearby lakes rather than euthanizing them. Pacu almost certainly winterkill at this latitude, and there is no reason to expect it to become established in north temperate waters. A single fish taken on a trotline, Mississippi River, south of Chester, Randolph County, Illinois, September 1988 (Chester Herald Tribune 1988), was reported as a piranha, but the accompanying photograph shows it to be *Piaractus*. An additional newspaper account (Anonymous 1994) of an angler catch of this fish (reported as a 14-inch piranha) in September 1994 is from Lake Baldwin (Kaskaskia River drainage), Randolph/St. Clair Counties, a power-plant cooling lake that maintains relatively warm water throughout the year. It is possible that this species could survive and become established in lakes of this type. Because the species strongly resembles some species of piranha (e.g., *Serrasalmus* and *Pygocentrus*), the capture of specimens by anglers often is reported in newspaper accounts and causes undue alarm among swimmers and boaters.

**Red piranha, *Pygocentrus nattereri* [Serrasalmidae]**

In fall 2000, a student at Southern Illinois University caught a red piranha on hook and line in Campus Lake. This record and others in newspaper accounts are apparently the result of aquarium releases. As noted above, piranhas are most frequently confused with the seed and fruit-eating pacus. The introduction of a pair of piranhas into one of the power-cooling lakes in the assessment area could result in an ecological disaster because the species'potential for survival, reproduction, and recruitment would be formidable in a warm-water lake.

## Introduction of Native Species

Stocking is a long-standing approach to aquatic resource management within the assessment area. Initially, most fish stockings were undertaken to improve recreational or commercial opportunities, with little or no consideration given to the effect of introduced species on the ecosystem. As our knowledge and understanding of the effects of stocking programs on fishes and aquatic systems have expanded, questions related to fish stocking have become increasingly complex (Li and Moyle 1993, Moyle et al. 1986). Factors such as biodiversity, genetic conservation, and interspecific and intraspecific interactions are now increasingly major components of stocking programs. Within the assessment area, numerous exotic and native species have been introduced and become a vital component of aquatic systems. Although species native to the area are frequently released into water bodies, the stock supplied is often not from local populations. The following species are consistently stocked in the assessment area, but the stock may not be native and could affect genetic level biodiversity.

**Pumpkinseed, *Lepomis gibbosus* [Centrarchidae]**

This species is present in ponds on the Crab Orchard National Wildlife Refuge, Illinois, where at least one population has been established for many years. Pumpkinseeds, native to more northern waters, have appeared in a small number of samples from other ponds in the assessment area and provide a localized fishery. Neither Federal nor State biologists have regularly stocked this species in the assessment area; its origin in the area is not accurately known.

**Bluegill, *Lepomis macrochirus* [Centrarchidae]**

A native species, bluegills have been stocked every year into numerous ponds, lakes, reservoirs throughout much of the assessment area since at least the mid-1950s. Bluegills are native to the Midwest but may become stunted in small ponds and are known to limit recruitment of largemouth bass (Heidinger 1999).

**Redear sunfish, *Lepomis microlophus* [Centrarchidae]**

Similar to the bluegill, redear sunfish have been extensively stocked throughout the assessment area in farm ponds, city lakes, reservoirs, pay lakes, and other standing water bodies. The historical range of this species apparently included much of the assessment area; this species is supplementally stocked into aquatic systems where it occurs naturally.

**Smallmouth bass, *Micropterus dolomieu* [Centrarchidae]**

This species is native to the assessment area in Illinois, Indiana, Kentucky, and Missouri. It has been stocked into reservoirs in southern Illinois and into the Patoka Reservoir in southern

Indiana. A fishery has never developed in southern Illinois. Smallmouth bass stocking is included in the management plans for small ponds in the Hoosier National Forest, Indiana. Natural stream fisheries are known in both the Green River, Kentucky, and a number of streams in southern Indiana.

**Spotted bass, *Micropterus punctulatus* [Centrarchidae]**

Native populations of spotted bass are known from selected stream systems in the assessment area, including southern Illinois, southern Indiana, and western Kentucky. Some stocking of this species has occurred in the past in southern Illinois and probably other parts of the assessment area. Unintentional stockings of hybrids between largemouth and spotted bass have also occurred within the assessment area.

**Largemouth bass, *Micropterus salmoides* [Centrarchidae]**

Probably the most popular sport fish in the assessment area, largemouth bass are native to the region and virtually ubiquitous. They have been stocked consistently every year since at least the mid-1950s into nearly every kind of standing water body available, either officially by both State and Federal agencies or by otherwise well-meaning anglers. The largemouth bass is a major predator in lentic systems and competes with other sport and non-sport fishes for space and food. It is no longer possible to understand the ecological place of this species in natural fish communities because its size, numbers, food base, and space have been manipulated by humans in too many locations for over 50 years.

**White crappie, *Pomoxis annularis* [Centrarchidae]**

White crappie are common and widespread throughout the assessment area, and they are among the most popular of native sport fishes. They have been sporadically stocked into some reservoirs and farm ponds, but they often overpopulate and show poor recruitment (Heidinger 1999). Unintentional stocking of hybrids between the white and black crappie has occurred in some reservoirs.

**Black crappie, *Pomoxis nigromaculatus* [Centrarchidae]**

There are few records of deliberate stocking of black crappie in the assessment area. Black crappie, like white crappie, are native to the region but tend to occur in lower numbers where the two are syntopic. Most crappie anglers pursuit white crappie, but a fishery exists for the black crappie as well.

**Golden shiner, *Notemigonus crysoleucas* [Cyprinidae]**

Golden Shiners are native to the assessment area but are also the most commonly sold bait minnow in the region. The species is commercially produced in ponds and sold as bait throughout the Midwest and as forage for sport fish in farm ponds. Adults may compete for food and space with young sunfish and bass species.

**Fathead minnow, *Pimephales promelas* [Cyprinidae]**

The fathead minnow is a commonly produced bait minnow sold throughout much of the Eastern Unites States. In Midwestern States, it is native to riverine and lacustrine habitats primarily north of the assessment area. Historical, prestocking era records are largely lacking (Burr and Warren 1986, Gerking 1945, Pflieger 1997, Smith 1979) for the assessment area, and the presence of this species may even be the result of bait-bucket release. Illinois State hatchery records indicate that the species has been stocked periodically as forage in reservoirs since at least the 1960s. Fathead minnows are commonly released into fishing waters by anglers who empty their bait buckets after finishing their daily angling.

**Northern pike, *Esox lucius* [Esocidae]**

In the 1970s, northern pike were stocked in a few reservoirs in southern Illinois (i.e., Cedar

Lake, Kinkaid Lake) and southern Indiana (i.e., Monroe Reservoir, Indian Lake) for sport fishing. Reproduction apparently occurred in Kinkaid Lake for the first couple of years, but recruitment was negligible. Some stock has been released in privately owned strip-mine lakes in southern Illinois and western Kentucky. Since the 1970s, there have been no more deliberate State or Federal stockings in Illinois; the authors are unaware of an established population in the assessment area. This species is native to northern Indiana and Illinois in both lakes and streams and is a major predator on other fishes.

**Muskellunge, *Esox masquinongy* [Esocidae]**

Historically, the muskellunge occurred in the Ohio River basin, and a few native populations still exist in the Green River, Kentucky (Burr and Warren 1986). McComish and Brown (1980) indicate that anglers may have taken this species within the Hoosier National Forest boundaries and nearby areas into the 1960s. Stocking programs exist within all the States in the assessment area, but in most cases native Ohio basin muskellunge have not been used as stock.

**Black bullhead, *Ameiurus melas* [Ictaluridae]**

In the 1950s and 1960s, this species was occasionally stocked into farm ponds, city reservoirs, and other urban fishing sites. The black bullhead is native to the Midwest, but in artificial settings it may overpopulate, reproduce at small sizes (15 cm), and develop stunted individuals (Heidinger 1999). Within the assessment area, no known stocking programs are maintained by State or Federal agencies for this species.

**Blue catfish, *Ictalurus furcatus* [Ictaluridae]**

Over the past decade, blue catfish have been stocked in reservoirs within the assessment area. The species is native to the region, and large natural populations are known in the Ohio, Mississippi, and Wabash Rivers where a fishery has developed for anglers and commercial fishers. The success of these stocking programs is not adequately known, and a notable fishery for this species in reservoirs has not yet developed.

**Channel catfish, *Ictalurus punctatus* [Ictaluridae]**

The channel catfish is easily the most widely stocked catfish species in the assessment area. Each year, this catfish has been deliberately released throughout the assessment area into ponds, reservoirs, city lakes, pay lakes, and other sites since at least the 1950s. The recent growth of the aquaculture industry in southern Illinois and southern Missouri now supports hundreds of acres of ponds for channel catfish culture, and cultured stock is often sold in restaurants throughout the region. Channel catfish are native to the assessment area, and many established riverine and lacustrine populations are known.

**Walleye, *Stizostedion vitreum* [Percidae]**

Since the mid-1970s, walleye have been stocked as eggs, fry, or fingerlings into several reservoirs in the assessment area. They continue to be stocked as of this writing, although a notable fishery has not been established in any of the reservoirs (e.g., Kinkaid Lake, Illinois; Patoka Lake, Indiana) that have received continued releases. The species is considered native to the region, but stocked walleyes originated from lakes in Pennsylvania and States other than the Midwest. Adult walleye prey on fishes and crayfishes and may reduce the forage base in large reservoirs or consume the young of other desirable species.

**Western mosquitofish, *Gambusia affinis* [Poeciliidae]**

The western mosquitofish is native to the assessment area and is often abundant in lowland water bodies. The species' reputation for consuming larvae of various mosquito species has resulted in introductions around the world. It has been released annually into urban and rural ponds to help reduce mosquito populations in cities and to provide some forage for predatory fishes. Western mosquitofish have been deliberately released into ponds in the assessment area, but official releases have been minimal. Undocumented introductions have undoubtedly occurred and may account in part for the current abundance of this species.

### Hybrids

At least five hybrid combinations (bluegill x green sunfish, silver carp x bighead carp, northern pike x muskellunge [tiger muskellunge], striped bass x white bass [sunshine bass & palmetto bass], sauger x walleye [saugeye]) of fishes have been stocked or deliberately released into the assessment area or now occur in the assessment area due to dispersal of individuals stocked in other locales. All of these species except for the carp hybrid have been released to improve sport fishing. The bluegill x green sunfish hybrid was released for many years during the 1960s and 1970s into farm ponds and some reservoirs but rarely has been stocked in the past decade. The tiger muskellunge was released into a reservoir in the 1970s, but the success of that stocking is not known and no other deliberate releases have been reported. The sunshine and palmetto bass hybrids have been most successful in the Ohio River and a few reservoirs where large numbers have been released for many years since the mid-1970s. This combination is potentially fertile and will backcross. The saugeye has been released primarily into the Ohio River. Adults are fertile and will backcross (Heidinger 1999). This hybrid may produce a fishery where walleye stocking has failed to do so. Because the hybrid phenotype cannot always be distinguished from the parentals, identification of hybrids to establish fishing records has been problematical, usually involving the taking of tissue samples for genetic analysis. The occurrence of a single carp hybrid is only a report, and there is no indication that more have been released or that this hybrid is established and spreading.

## EXOTIC TERRESTRIAL VERTEBRATES

Exotic terrestrial vertebrates can affect ecosystem-level changes that alter water, nutrient, and energy cycles; productivity; and biomass. Ecosystem-level consequences may directly affect human health. One estimate places the cost of environmental damage and associated control of exotic mammal and bird species in the U.S. at over $36 billion annually (Pimentel et al. 1999). This figure may underestimate the true cost, because this analysis included only the direct “losses and damages” and “control costs;” not the lost ecosystem services. Also, the costs related to invasive species control are increasing as nonindigenous species continue to spread at accelerating rates.

In addition to these economic impacts, ecological impacts such as competition are serious problems associated with exotic species. Nonindigenous species may compete with native species for many things including food and nesting sites. For example, Muscovy ducks introduced into the range of wood ducks may displace them from their tree cavity nests (Bolen 1971). Exotic terrestrial species may also degrade habitat for native wildlife and introduce diseases, pathogens, or parasites that can spread to native wildlife

### European Starling (*Sturnus vulgaris*)

The European starling was intentionally introduced into North America during the 19th century from Europe. Although several early attempts failed, the introduction of approximately 100 birds in Central Park in the 1890s was extremely successful (Laycock 1966). Population growth and range expansion for this species were explosive, and the population of starlings has grown to about 200 million (Cabe 1993). Starling populations now appear to be leveling off or even decreasing throughout most areas of the country (Robbins 2001). The spectacular success of this species is linked to anthropogenic landscape changes. Due to their highly plastic foraging and nesting habits, starlings successfully nest and roost in urban areas and they are also taking greater advantage of agricultural areas than most native birds. In fact, the total agricultural loss due to starlings in the U.S. is estimated at $800 million/year (Pimentel et al. 1999).

Economic losses associated with starling depredation of agricultural crops is only one problem associated with this species. Starlings also compete with native species for food and nesting cavities. The displacement of native bird species by European starlings has been documented in areas of the country with limited nest sites (Weitzel 1988). Starlings aggressively compete with other cavity nesters including woodpeckers, buffleheads, great crested flycatchers, tree swallows, purple martins, eastern blue birds, and others (Cabe 1993). Starlings frequently use nest cavities recently excavated by woodpeckers, driving flickers, red-headed woodpeckers, and red-bellied woodpeckers from their nests. The lower reproduction and fecundity of red-bellied woodpeckers due to nest cavity competition with starlings have been documented (Ingold 1994, 1996). Starlings also usurp nest cavities from native secondary cavity nesting species; the nesting habits of starlings have been linked to declines in bluebird populations (Zeleny 1976).

The spread of disease by starlings is a potential threat within the assessment area. European starlings can carry diseases that are transmissible to livestock and to people, including transmissible gastroenteritis (a swine disease), blastomycosis, and salmonella. Gautsch et al. (2000) found that European starling droppings contained *Campylobacter jejuni*, *Listeria monocytogenes*, and *Chlamydophila psittaci*, all of which are human pathogens. However, the study concluded that the starling droppings were not a significant source of human infection. Within the U.S., starling droppings provide a growth medium for *Histoplasma capsulatum*, the fungus that causes histoplasmosis in humans. Spread of disease among wildlife is another facet of this problem that has not been adequately explored.

The European starling first became established in the assessment area in the 1930s (Cabe 1993). Initially exhibiting explosive population growth, the population levels have been stabilized in the area since the beginning of the Breeding Bird Survey in 1966 (table 3, Sauer et al. 2001). The assessment area falls within the region with the highest number of starling detections per survey route (Sauer et al. 2001). The population levels are most likely due to the high interspersion of agriculture and forests: ideal conditions for breeding starlings.

### House Finch, *Carpodacus mexicanus*

Although the house finch is native to western North America, it is considered an exotic species in the Eastern United States. In fact, the spread of the house finch in the eastern part of its current range has been termed “one of the most notable ornithological events of the twentieth century” (Hill 1993). Shipped from California, a few illegally captured birds were released on Long Island, New York, in 1940 (Elliot and Arbib 1953). The house finch has quickly spread throughout the East, becoming a common bird of urban and suburban areas.

Currently, the exotic house finch breeds throughout most of the Eastern United States in addition to its native range west of the prairies (Hill 1993). In the East, the species is seldom found away from human habitation and is a common sight at back yard bird feeders. The house finch has experienced phenomenal population growth in the assessment area since 1966 with annual increases averaging between 20 and 40 percent (table 3). This remarkable growth rate has been possible due to the fecundity of the species. In addition, house finches have benefited from human alteration of the landscape (Hill 1993). Within its native range, the house finch prefers early successional and edge

**Table 3.** Entry mechanisms and population trends for exotic bird species of the Hoosier-Shawnee Ecological Assessment Area based on Breeding Bird Survey (Sauer et al. 2003) results for two physiographic regions that broadly overlap the assessment area. The number in parentheses is the estimated percent change per year for the entire time period.

| | | Population trends | | |
|---|---|---|---|---|
| **Species** | **Mechanism** | **1966-1979** | **1980-2000** | **1966-2000** |
| European starling | | | | |
| Highland Rim | Introduction (I) | Decrease[3] | Increase[2] | Stable[4] (0.6) |
| Lexington Plain | Introduction (I) | Stable | Stable | Stable (0.9) |
| House finch | | | | |
| Highland Rim | Introduction (I) | --- | Increase[2] | Increase[2] (29.6) |
| Lexington Plain | Introduction (I) | --- | Increase[2] | Increase[2] (15.0) |
| House sparrow | | | | |
| Highland Rim | Introduction (I) | Stable | Decrease[3] | Decrease (-2.5) |
| Lexington Plain | Introduction (I) | Decrease[3] | Decrease[3] | Decrease[3] (-4.2) |
| Rock dove | | | | |
| Highland Rim | Introduction (I) | Increase[2] | Decrease[3] | Stable (-0.8) |
| Lexington Plain | Introduction (I) | Increase[2] | Decrease[3] | Stable (-1.5) |
| Cattle egret | | | | |
| Highland Rim | Dispersal | ---[1] | Increase[2] | Increase[2] (4.2) |
| Lexington Plain | Dispersal | --- | --- | --- |
| Eurasian collared-dove | | | | |
| Highland Rim | Dispersal | ---[1] | Increase[2] | Increase[2] (48.0) |
| Lexington Plain | Dispersal | --- | --- | --- |

[1] Indicates insufficient data to determine trend.
[2] Indicates significant positive trend during the time period.
[3] Indicates significant negative trend during the time period.
[4] Indicates no significant change in relative abundance.

habitats (Salt 1952). This landscape feature is extremely common around human settlements in the East.

Because of their fidelity to human-dominated landscapes, house finches seldom compete with native species away from feeding stations. They dominate American goldfinches at bird feeders; however, this interaction does not appear to impact goldfinch populations in the assessment area (Hamilton and Wise 1991). Interestingly, for house finches, the greatest number of interspecific interactions occurs with another exotic, the house sparrow. House sparrows actively take over house finch nests and dominate back yard feeders (Bergtold 1913, Evenden 1957)

A postscript to the exotic house finch's success in the Eastern United States: a form of conjunctivitis, first reported in eastern populations in 1994, had spread throughout the eastern range of the species by 1997 (Fischer et al. 1997). The gregarious nature of the house finch at feeding stations and its migratory habits in the Eastern United States have been listed as contributing factors in this epizootic (Roberts et al. 2001). The disease is severe and can ultimately lead to death of the infected individual. In fact, the rapid spread of the disease has led to recent declines in eastern house finch populations (Sauer et al. 2001). To date, the only native bird species that appears to be significantly susceptible to this form of conjunctivitis is the American goldfinch, although the disease has been observed much less frequently in this species (Ley et al. 1997). The ultimate implications of this disease for the house finch and native passerines have not yet been determined.

### House Sparrow, *Passer domesticus*

Much like the European starling, the house sparrow was introduced to the U.S. from England. Unlike the starling, the house sparrow, first introduced in 1851 in New York, was aided in its expansion across North America by additional introductions and translocations from established populations (Robbins 1973). By 1910, this species was well established across the continent. The house sparrow now has a nearly global distribution, although in many parts of its range it is seldom seen far from humanmade structures (Lowther and Cink 1992). In North America, some of the highest population levels for house sparrows are attained in the Midwestern U.S. including Illinois and Indiana (Summers-Smith 1988).

The North American population of house sparrows was estimated at 150 million in 1943 (Wing 1943). Yet, the population currently appears to be stable or even decreasing in most areas of the country (Robbins 2001). This decline is also evident within the assessment area (table 3). Lowther and Cink (1992) suggest that the decline of house sparrows is linked to changes in farming practices after World War II from small plots surrounded by hedgerows to large monocultures and clean farming, a change that has also impacted native wildlife.

Many problems associated with the starling are also a concern with house sparrows. House sparrows have been documented to usurp cavities from red-bellied and red-headed woodpeckers (Ingold and Densmore 1992). In addition to native woodpeckers, house sparrows have been known to harass a wide variety of native birds, including robins, Baltimore orioles, yellow-billed cuckoos, and black-billed cuckoos. However, the propensity to displace native bluebirds, wrens, purple martins, and cliff swallows from their nesting sites is perhaps of greater importance (Laycock 1966, Long 1981, Roots 1976).

### Rock Dove, *Columba livia*

The rock dove, a native of Africa and Eurasia, was first domesticated around 4,500 BC with domestics transported around the world by humans (Soccinka 1982). The species was first introduced in North America at Port Royal, Nova Scotia, in 1606 and quickly became established as feral populations (Schorger 1952). Rock doves have flourished in human-dominated areas throughout the world including North, Central, and South America, the Hawaiian Islands, and parts of the West Indies. The rock dove is common throughout the assessment area and is found primarily nesting in or on human structures in human-dominated areas. The rock dove was not included in any formal population census until the BBS began in 1966. In the sixties, the population experienced an increase, but the rock dove population has been stable within the region over the last four decades (table 3).

The primary concern with regard to the rock dove is competition with native cliff nesting species. In addition, their acidic feces eats away gutters and other metal structures, erodes stone buildings, and burns lawns. Rock dove droppings harbor a variety of diseases and parasites that can spread to native wildlife and humans. Amongst the many diseases they carry are aspergillosis, equine encephalitis, influenza, chlamidiosis, toxoplasmosis, and tuberculosis (Schnurrenberger and Hubbert 1981).

### Cattle Egret, *Bubulcus ibis*

Cattle egrets are native to Africa and Asia, and the nature and success of their almost worldwide range expansion has been well documented. Cattle egrets spread from the west coast of Africa in the late 1800s across the Atlantic

Ocean to the coastal area of northeastern South America (Telfair 1994). The species then spread northward into North America. In the United States, cattle egrets were first sighted in southern Florida in 1941 (Owre 1973). Since that time, the species has been observed in all 50 States. Within the assessment area, Indiana is the only State that does not have confirmed breeding. A reasonable explanation for the recent and rapid expansion of the cattle egret in the Western Hemisphere is human conversion of large pasture for livestock production along with the dispersal abilities of the species (Telfair 1994).

Cattle egrets are named because of their habit of feeding on insects disturbed by grazing host animals such as cattle (Telfair 1994). Because of this distinct niche, they do not compete with native wading birds for food. There is potential for nest site competition at breeding colonies, however, especially in the northern part of their range where cattle egrets and native ardeids breed around the same time (Burger 1978). Despite this, cattle egrets may attract other colonial waterbirds to formerly unused inland breeding sites (Telfair 1980), thus expanding potential nesting resources for native species. However, within nesting colonies, the deposition of cattle egret guano changes soil chemistry. Although some plant species such as hackberry (*Celtis occidentalis*) can survive the changes, others such as oak (*Quercus* sp.) are killed.

The cattle egret's diet may be of great economic benefit to cattlemen. There is substantial anecdotal evidence that cattle egrets reduce the numbers of certain species of cattle-associated biting flies thus reducing the incidence of cattle diseases such as bovine anaplasmosis (Telfair 1994). Yet, cattle egrets may propagate the tropical bent tick (*Amblyomma variegatum*), which is a vector of heartwater, a rickettsial disease of cattle and other ruminants (Barre et al. 1995).

Regionally, cattle egrets nest primarily along the Mississippi River, although confirmed breeding has occurred in Williamson County, Illinois, and Trigg County, Kentucky. Although cattle egrets have been detected only on a few survey routes (n=3), the population is generally increasing in the region according to BBS results (Sauer et al. 2001, table 3); however, trends are not significant. Given the history of the species in North America, it will likely continue to extend its range and increase in number.

### Eurasian Collared-Dove, *Streptopelia decaocto*

A native of Asia, the Eurasian collared-dove was apparently imported into the Bahamas during the 1970s; approximately 50 of these doves were released in 1974 as a result of an aviary break-in. The population increased to at least 10,000 birds in less than 10 years, and the population started to spread to other islands. The species reached Florida by the mid-1980s where it continued its rapid range expansion. Populations are now well established in many Eastern and Midwestern States. Nesting records and sightings of the Eurasian collared-dove have occurred throughout the assessment area (fig. 3).

The Eurasian collared-dove was documented in southern Illinois in the mid-1900s and was recently added to the official State checklist (Geiser 2000). The species was first located in Hickman, Kentucky, in late May 1999. The first state record for the Eurasian collared-dove in Indiana was spotted during June 1999 (Gorney 2001). Trend results have been compiled by the BBS only for the Highland Rim physiographic region (table 3) indicating an enormous population increase. The Great Backyard Bird Count, one of the largest citizen-science projects in the world, indicates that the species is increasing and spreading quickly northwestward (fig. 3). The impact of this species has yet to be determined, and it is possible that the

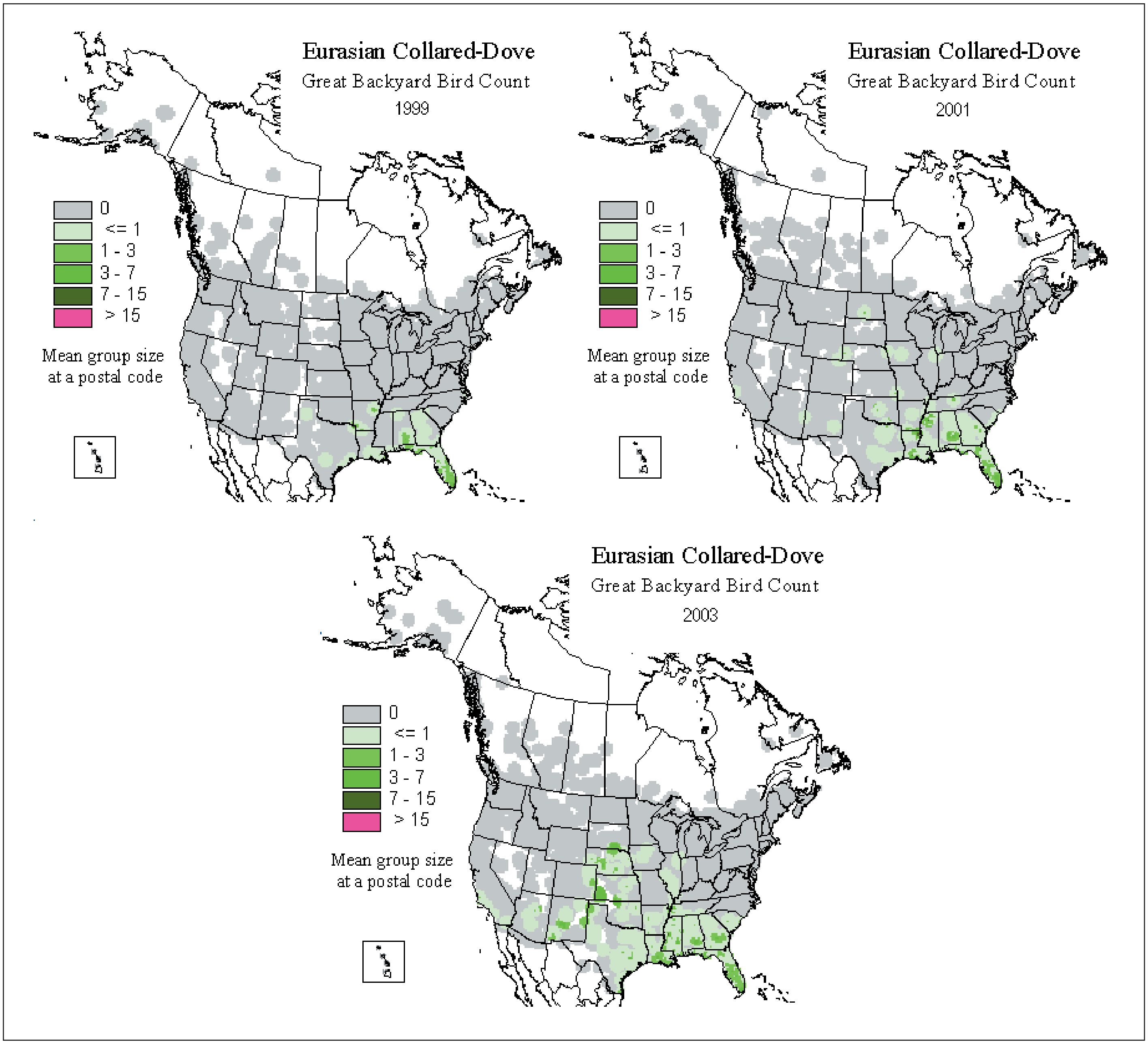



**Figure 3.** Great Backyard Bird Count maps (created by BirdSource) showing the northwestward range expansion of the Eurasian collared-dove from 1999 to 2003 (Great Backyard Bird Count Results 2003).

species will compete with the native mourning dove (*Zenaida macroura*). In Georgia, where the Eurasian collared-dove is well established, the species appears to occupy a niche in the well-developed suburbs somewhere between the rock dove in the city and the mourning dove in open country. The Eurasian collared-dove will provide a unique opportunity to observe the impact of this exotic species on populations of native birds and to learn what ecological/geographical barriers, if any, finally limit their range expansion.

## Feral Cats and Dogs, *Felis domestica* and *Canis familiaris*

The chief characteristic that separates feral cats and dogs from their domestic counterparts is their lack of reliance on humans. Free-roaming pets certainly cause significant ecological damage, most often in fulfilling natural predatory instincts rather than pursuing life requirements. Feral cats and dogs, however, do not directly depend on humans for survival; they must acquire their own food and shelter, often at the expense of native wildlife.

Feral dogs have broad dietary preferences. In addition to scavenging for human garbage, they are known to prey on small and large animals including white-tailed deer and domestic livestock. In a survey, resource managers cited damage to wildlife populations as the primary problem associated with feral dogs (Denny 1974). The impacts of feral dogs on wildlife populations are variable, however, and depend on food availability, number of dogs in an area, and competition with other predators (Green and Gipson 1994).

The size of the feral cat and dog population is unknown, complicated by differing interpretations of the terms, "feral," "unowned," and "stray." There are also no reliable estimates available on the status and trends of feral cat and dog populations, but most agree that cats represent a greater threat to wildlife than dogs. In fact, Ebenhard (1988) found that worldwide, introductions of domestic cats into areas are twice as likely to cause damage as other introduced predators. There are little data on the impact of feral cat predation on wildife, and this is an area that desperately needs to be evaluated. Within the U.S., it is estimated that over a billion small mammals and birds are killed by free ranging rural and feral cats (Ogan and Jurek 1997). This predation by cats may be endangering several bird species including the least tern, piping plover, and logger head shrike (Coleman et al. 1997). In addition to small mammals and birds (especially ground nesting and roosting species), the diets of feral cats include insects, amphibians, and reptiles (Ogan and Jurek 1997). Feral cats compete with natural predators and transmit several diseases including toxoplasmosis (Roelke et al. 1993). In a landmark study in California, Crooks and Soule (1999) determined that habitat fragmentation, coupled with increases in predation pressure from mid-size predators such as feral cats, could quickly drive native prey species locally extinct.

The long-term solution to most problems associated with feral cats and dogs centers on public education that promotes owner responsibility. Programs are needed like the American Bird Conservancy's Cats Indoors! (http://www.abcbirds.org/cats/), which seek to teach cat owners, decisionmakers, and the general public that free-roaming cats pose a significant risk to birds and other wildlife, suffer themselves, and threaten human health. Preventing domestic pets becoming feral is essential and can be accomplished by confining pets and sterilizing them. One study conducted in Massachusetts indicated that 91.5 percent of female cats were spayed and 90 percent of male cats were neutered. Yet, 15 percent of the sterilized females had had an average of two litters before sterilization (Manning and Rowan 1998). When feral populations are significant enough to generate community complaints, targeted control of existing populations may be warranted and many methods exist for this purpose (Green and Gipson 1994). Traditionally, there have been four approaches to controlling feral populations: trap, remove, and euthanize; trap, remove and relocate; trap, neuter, and return to the original site; and wait and see.

### Feral Hog, *Sus scrofa*

Feral hogs descended from domestic farm animals that were first introduced by colonist to North America about 400 years ago (Frankenberger and Belden 1978). In addition, European wild boars were released into Tennessee and North Carolina early in the 20th century for hunting (Jones 1959). Feral hogs within the assessment area are progeny of domestic and wild varieties, as well as their hybrids. Although historically feral hogs have been confined to the Southern United States, they are expanding northward and are found regionally in Illinois and Indiana (Gipson et al. 1998). Throughout the U.S. the feral hog population is estimated to be around 4 million.

Currently, an assessment is underway to determine the status of feral hogs in southern Illinois (G. Feldhammer, personal communication).

Feral hogs are omnivorous, consuming a variety of plants and animals. They directly impact wildlife communities by preying on many species including rodents, birds, amphibians, and invertebrates (Challies 1975, Everitt and Alanis 1980, Henry and Conley 1972, Wood and Roark 1980). Feral hogs carry several important diseases including brucellosis and pseudorabies, which represent a risk to domestic livestock and native wildlife (Peline and Lancia 1990, Van der Leek et al. 1993). This species also hosts a wide variety of parasites that impact native wildlife. In addition, feral hogs potentially compete for food (especially acorn mast) with many wildlife species including white-tailed deer, wild turkey, squirrels, and a variety of waterfowl. The rooting and wallowing of feral hogs are also of consequence. These activities seriously threaten rare plant species, generally disrupt vegetative communities (Tate 1984), increase soil erosion and siltation of aquatic habitats, and may enhance conditions for exotic and invasive plants (Spatz and Mueller-Dombois 1975). Rooting and wallowing also tear up rotten logs that provide habitat for many amphibians and reptiles. During April through August, wild hogs invade high-elevation hardwood communities. A study in the Great Smoky Mountains National Park reported that understory plant cover was reduced by up to 87 percent and that up to 77 percent of all logs and branches were moved in heavily rooted areas (Singer 1981). Red-backed voles and shrews that were normally common in pristine stands were absent in rooted areas.

## DISCUSSION

Exotic aquatic and terrestrial species have changed the structure of eastern forests within the assessment area, as well as the density and composition of wildlife associated with them. Invasive exotic species have disastrous effects on native flora and fauna. In a new environment, exotic species may have fewer predators or diseases, and population growth can be explosive. Since exotic species are self-perpetuating, they can be more permanent problems than other threats to biodiversity including overexploitation and habitat loss. Although the Office of Technology Assessment estimates that 4 to 19 percent of exotic species cause great harm, another 6 to 53 percent are estimated to have neutral or unknown effects. These species, however, should not be viewed as benign biota. For example, purple loosestrife (*Lythrum salicaria*) existed in relatively low numbers for over a century before populations exploded, displacing valuable native wetland plants. Today, more than 190,000 hectares of wetlands are taken over by this invasive nonindigenous plant annually (Thompson et al. 1987). The spread of noninvasive species replaces healthy, diverse ecosystems with biologically impoverished, homogenous landscapes.

Nonindigenous aquatic and terrestrial species found in the assessment area come from varied sources. Of the aquatic species reported here, four (rainbow smelt, grass carp, silver carp, and bighead carp) dispersed after having been introduced into other States. At least five species (e.g., bull shark, threadfin shad, inland silverside, atlantic needlefish, striped mullet) have dispersed upriver from Gulf coastal waters subsequent to presumed changes in environmental conditions (i.e., warming, drought) that allowed their movement northward in the Mississippi River. Others (e.g., goldfish) introduced to the assessment area originally as food fishes or for aquaculture studies, appear to have become more widely distributed after the record 1993-94 Mississippi River flooding. Still other species (e.g., grass carp. silver carp, and bighead carp) have become established after earlier introductions for other purposes (i.e., weed control, improvement of water quality in culture ponds). Three species (fathead minnow, golden shiner, brook stickleback) were introduced via bait bucket, and four others (red bellied pacu, red piranha, oscar, Amazon sailfin catfish) probably through release of aquarium stock. White perch has spread rapidly from the Great Lakes to southern Illinois due to its tolerance for varying ecological conditions. Perhaps the largest contingent of nonindigenous species/stocks and cultured hybrids has been released to enhance and restore sport fishing. At least 19 species and 5 hybrids have been intentionally released, several on an annual basis, into the reservoirs, city lakes, pay lakes, and recreational and farm ponds of the assessment area. Only 11 of these species are native to the area, and the source of brood stock often originates from widely disparate geographic sources. The other eight species are native to either northern North America or originated from either the Atlantic or Pacific slopes of North America.

Many of the terrestrial exotic species present within the assessment area were deliberately introduced for aesthetic, hunting, or livestock purposes. Of the terrestrial species examined in this chapter, only two species—cattle egret and Eurasian collared-dove—have dispersed naturally into the assessment area. Two species of birds (European starling, house sparrow) were introduced by European settlers to help them acclimate to their new setting. The house finch is the only terrestrial exotic discussed here which is native to North America, and the species was introduced from the Western U.S. Four species (rock doves, feral cats, dogs, and hogs) were introduced as pets or livestock and subsequently escaped to establish feral populations.

It is evident that both purposeful and unintentional introductions can lead to undesirable results, especially in terms of sportfishing/hunting, economics, human welfare, and ecological interactions. Moyle et al. (1986) introduced the concept of the "Frankenstein Effect" suggesting that if broad consequences of each introduction are not considered, the introductions may ultimately cause more problems than they solve. Li and Moyle (1999) present ecological concepts important for understanding the effects of introductions, suggest some management alternatives to introducing new species, and provide guidelines for evaluating proposed introductions. Several researchers have published recommendations for dealing with the issue of exotic plants and animals (Campbell 1997, Miller 1997, Stein and Flack 1996). These recommendations include

1. Development of more effective ways to prevent new introductions.
2. Early detection and eradication of new exotics.
3. Better control and management of established invaders.
4. Protection and recovery of native species and ecosystems.
5. Better public education and support for controlling exotics.
6. Better integration of control efforts by responsible government and nongovernmental entities.
7. Support for research aimed at identifying invasive species that could potentially damage our forests.
8. Support for further research aimed at developing effective ways to control exotics.

Changes in values, an expanding human population, and a decline in natural habitats provide an opportunity for reconsidering of old policies and values. And, there is now much public concern for protecting endangered species, maintaining water quality, preserving natural areas and biodiversity, and protecting the limited wild areas we have left in the region. The assessment area could become a model for the Nation by adopting a proactive and progressive set of policies and protocols for introductions.

As highlighted here, many introduced vertebrates were successful, largely due to human alteration of the landscape. This suggests that land management practices may at least limit the impacts of exotic wildlife. Indeed, it appears that broad changes in land use have led to declines in house sparrow populations throughout North America. In addition, management of habitats specifically for native wildlife, may enable native species to better cope with threats presented by exotics. In some circumstances, where the objective is to reduce the population of an exotic species, targeted population control of exotic wildlife may be necessary. However, unless the underlying ecological factors that favor exotic wildlife are addressed, targeted control may not be enough.

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