AN INVENTORY AND EVALUATION OF BIOLOGICAL INVESTIGATIONS THAT RELATE TO STREAM-WATER QUALITY IN THE UPPER ILLINOIS RIVER BASIN OF ILLINOIS, INDIANA, AND WISCONSIN

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CONVERSION FACTORS

In this report measurements are given in inch-pound units only. The following table contains factors for converting to metric units:

Multiply inch-pound unit	*By*	*To obtain metric unit*
foot	0.3048	meter
mile	1.609	kilometer
square mile	2.59	square kilometer

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ABSTRACT

Results of studies of the aquatic biology of the upper Illinois River basin provide a historical data source from which inferences can be made about changes in the quality of water in the main stem river and its tributaries. The results of biological investigations that have been conducted throughout the basin since 1900 are summarized and their relevance to stream-water-quality assessment is described, particularly their relevance to the upper Illinois River basin pilot project for the National Water-Quality Assessment Program. Four general categories of biological investigations were identified: Populations and community structure, chemical concentrations in tissue, organism health, and toxicity measurements. Biological investigations were identified by their location in the basin and by their relevance to each general investigation category. The most abundant literature was in the populations and community structure category. Tissue data were limited to polychlorinated biphenyls, organochlorine pesticides, dioxin, and several metals. The most cited measure of organism health was a condition factor for fish that associates body length with weight or body depth. Toxicity measurements included bioassays and the Ames Test. The bioassays included several testing methods and test organisms.

INTRODUCTION

Organisms and the biotic communities that they comprise are affected by the qualitative and quantitative aspects of their physical and chemical surroundings and are useful for evaluation of the environments in which they live. Many aquatic organisms are sensitive to small changes in the environment and can function as continuous monitors of change in water quality. For example, Berkman and others (1986) concluded that in agricultural areas benthic invertebrates were more sensitive than fish to changes in stream-water quality because benthic invertebrates are directly affected by sediments, whereas fish are more indirectly affected. In large ecosystems, trends in contaminant levels have been assessed by analyses of fish tissues (Lowe and others, 1985; Schmitt and others, 1985; Devault and others, 1986). The incidence of tumors in fish has been used to compare polluted and nonpolluted watersheds (Brown and others, 1973; Baumann and others, 1982, 1987). Bioassays are commonly regarded as indicators of existing sediment-quality and water-quality effects on biota and have been used widely in a variety of studies on aquatic systems.

The use of biological information to assess water quality is usually less quantitative than more traditional assessment methods such as measurement of water and sediment chemistry. Variability occurs in the number and kinds of species present and in movements of individuals along stream reaches in response to environmental conditions. Because of the variability of biological data, a single biological assessment method cannot be used to unilaterally evaluate water quality. For instance, aquatic organisms are influenced by factors other than water quality. Watershed manipulation can degrade aquatic habitats and affect populations without necessarily changing the chemical quality of water. Biological organisms can have dissimilar contaminant-uptake rates based on habitat preference, food preference and feeding habits, or lipid levels. Bioaccumulation of contaminants in tissue is another assessment tool; however, tissue concentrations of contaminants do not necessarily relate directly to effects on biotic populations. Bioassay tests are simplistic compared to actual environments; extrapolation of laboratory data to existing conditions is difficult.

Although individual biological assessment methods vary, common trends in information collected by several methods are meaningful. Long and Chapman (1985) recommend an integration of methods and conclude that bioassays are best used in combination with ecological and chemical surveys; Herricks and Schaeffer (1987) recommend integration of physical, chemical, and ecological parameters for assessments. Integration of a variety of biological methods for assessing water quality is fairly common (Cairns and Dickson, 1973; Ryder and Edwards, 1985) and has resulted in the development of several biological indices to evaluate water quality (Wojcik and Butler, 1977; Jones and others, 1981; Hilsenhoff, 1982; Karr and others, 1987). Although such indices may not consistently apply for all geographic situations, various modifications have increased their applicability (Hilsenhoff, 1982).

The National Water-Quality Assessment Program (NAWQA) was initiated to: (1) Provide a nationally consistent description of current water-quality conditions for a large part of the Nation's water resources, (2) define long-term trends (or lack of trends) in water quality, and (3) identify, describe, and explain, as possible, the major factors that affect observed water-quality conditions and trends (Hirsch and others, 1988). The NAWQA program is in a pilot phase that began in 1986 and will continue through 1991. Seven pilot projects, which represent a diversity of hydrologic environments and water-quality conditions, were selected to test and further develop the assessment concepts. Four of the pilot projects focus on surface water; three focus on ground water. The surface-water project areas are the upper Illinois River basin in Illinois, Indiana, and Wisconsin; the Kansas River basin in Kansas and Nebraska; the Kentucky River basin in Kentucky; and the Yakima River basin in Washington. The ground-water project areas are the Carson basin in Nevada and California; the Central Oklahoma aquifer in Oklahoma; and the Delmarva Peninsula in Delaware, Maryland, and Virginia.

Purpose and Scope

This report is part of the initial information identification and evaluation process for the NAWQA pilot project for the upper Illinois River basin. Its purposes are to identify the sources of biological data for the upper Illinois River basin that relate to four general assessment categories and to summarize their relevance to water-quality assessment in the context of the NAWQA program. Biological data from published and unpublished reports from the late 1800's to 1988 are described, and obvious common trends that are indicated by the data are denoted. The data are divided into four general assessment categories for comparative purposes: (1) Populations and community structure, (2) chemical concentrations in tissue, (3) organism health, and (4) toxicity measurements. The data are evaluated for completeness relative to temporal continuity, geographic sufficiency, and overall quality; and the potential usefulness of the data for assessing water quality is discussed.

Description of the Upper Illinois River Basin

The upper Illinois River basin drains 10,949 square miles in northeast Illinois, northwest Indiana, southeast Wisconsin, and southwest Michigan (fig. 1). The basin has three major river systems: The Kankakee, Des Plaines, and Fox. The Des Plaines and Kankakee Rivers join near Morris, Ill., to form the Illinois River, which flows westward to join the Fox River at Ottawa, the downstream limit of the study area.

The Kankakee River drains about 48 percent of the project area (Mades, 1987). Its headwaters are in southwest Michigan, about 150 miles northeast of its confluence with the Des Plaines River. The Iroquois River is the largest tributary to the Kankakee River. Originally, the Kankakee River flowed through an extensive wetland area known as the "Grand Marsh." Most of the wetlands have been drained, and the river is now channelized in Indiana (Meyer, 1936; Ivens and others, 1981). Three low-head dams have been constructed on the Kankakee River in Illinois; however, most of this section of the river remains a naturally meandering stream (Ivens and others, 1981).

The Des Plaines River originates in southeastern Wisconsin about 130 miles north of its confluence with the Kankakee River and drains about 19 percent of the project area (Mades, 1987). Major tributaries of the Des Plaines River include the Du Page River, the Chicago Sanitary and Ship Canal, and the Calumet Sag Channel. A navigation channel of at least 9 feet in depth is maintained on the Calumet Sag Channel, the Calumet and Little Calumet Rivers, the Chicago Sanitary and Ship Canal, and the South Branch of the Chicago River (Bellrose and others, 1977). The Calumet River system originally drained exclusively to Lake Michigan (Crawford and Wangsness, 1987). Because of recontouring of the drainage, sections of the Grand Calumet and Little Calumet Rivers are now in the Des Plaines River basin. Three locks and dams and 34 low-head dams are located on the Des Plaines River and its tributaries (Butts and Evans, 1978).

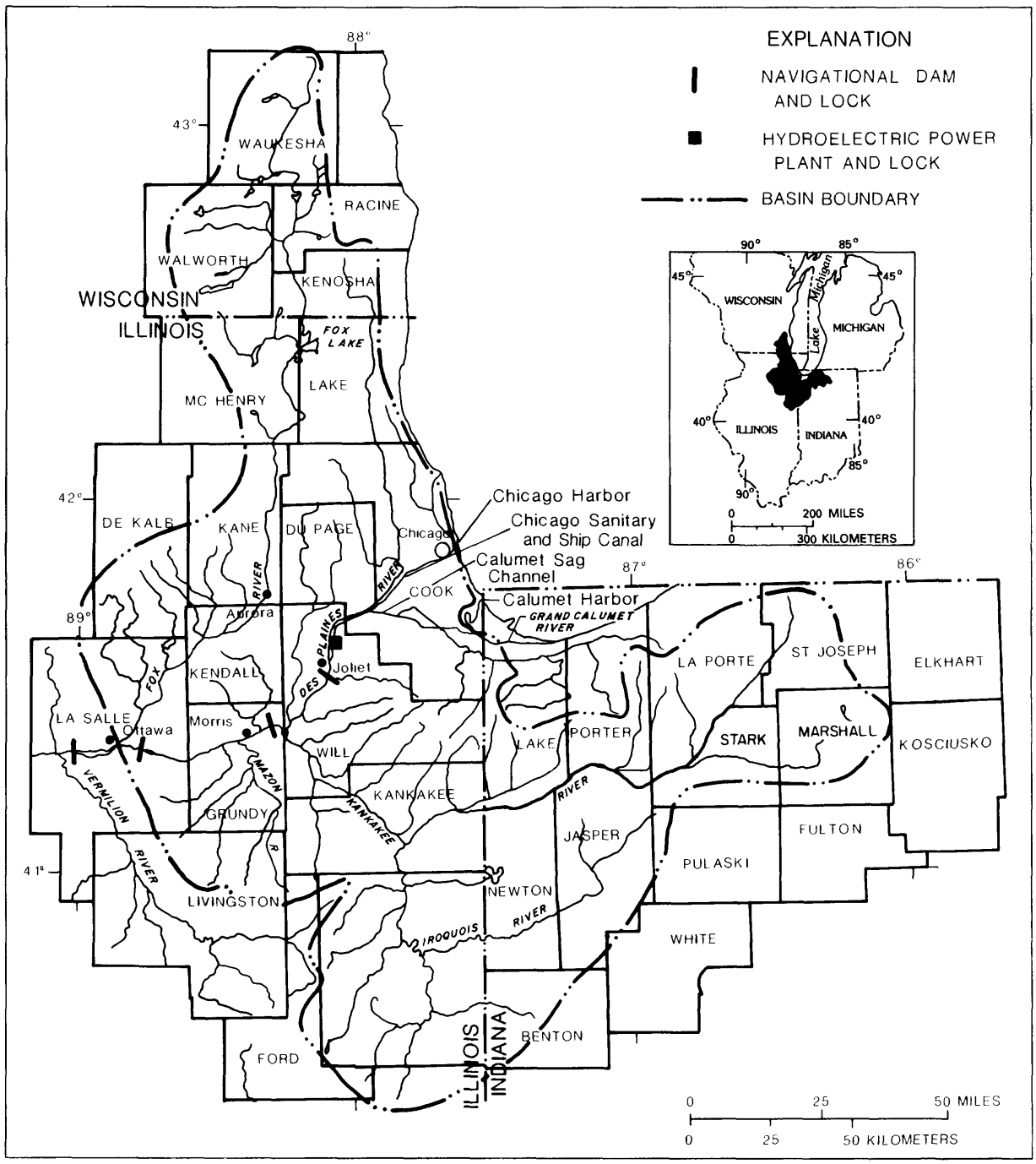

Figure 1.--Upper Illinois River basin study area.

The Fox River drains about 24 percent of the study area (Mades, 1987). The headwaters are in southeastern Wisconsin, and the river flows southward 180 miles to its confluence with the Illinois River. The Fox River has no major tributaries; it drains a series of glacial lakes in southern Wisconsin and northern Illinois. Fourteen low-head dams are located on the Fox River (Butts and Evans, 1978).

The mainstem of the Illinois River drains about 9 percent of the study area (Mades, 1987). The distance between the confluence of the Des Plaines and Kankakee Rivers and the end of the study area at Ottawa is approximately 33 miles. Major tributaries flowing into that reach include the Mazon River and Aux Sable Creek. A navigation channel of at least 9 feet in depth is maintained on the Illinois River; two locks and dams are located on the Illinois River in the study area (Bellrose and others, 1977).

Land use in the upper Illinois River basin is predominantly agricultural; about 75 percent of the basin is cultivated for agricultural row crops, primarily corn and soybeans. About 13 percent of the basin is urbanized. The area most adversely affecting water quality is the greater Chicago metropolitan area. The population of the upper Illinois River basin is about 7 million, of which an estimated 6 million people live in the Des Plaines basin (Mades, 1987).

General Description of Historical Water Quality and Biological Conditions

Early explorers in the study area were impressed by the productivity of the Illinois River area. In 1673, following his ascension of the Illinois River, Marquette wrote that: "We have seen nothing like this river that we enter, as regards to its fertility of soil, its prairies and woods, its cattle, elk, deer, wildcats, bustards, swans, ducks, parroquets, and even beaver," (Mills and others, 1966; University of Illinois Water Resources Center, 1977). The Illinois River was described as clear in 1798 and infested with wild beasts in 1838 (Mills and others, 1966). The "Grand Marsh" of the Kankakee River was described by French explorers; marsh prairies and swamp forest held "countless" waterfowl, "were full of game," and the "meandering river teemed with fish" (Meyer, 1936). In the late 1890's, the waters of the Illinois River remained comparatively clear (Bellrose and others, 1979). The bottomland lakes associated with the Illinois River were described by Kofoid (1903) as being transparent at that time and having bottom materials composed of decaying vegetation rather than mineral silts. An abundance of submergent and emergent vegetation was documented at the beginning of the 20th century (Bellrose and others, 1983). The general habitat types and backwater areas of the Des Plaines River and Illinois River from Chicago downstream were documented on maps prepared for the U.S. Army Corps of Engineers (Woermann, 1902-1904). Associated aquatic organisms were abundant. Aquatic insects and snails associated with aquatic plants were prevalent; invertebrates associated with aquatic plants were found to have, on average, eight times the biomass of benthic invertebrates in Illinois River bottomland lakes downstream from the study area (Bellrose and others, 1977). In 1900, the dollar value of the commercial fishery of the Illinois River was ranked third nationally behind the salmon fishery of the Pacific coast and the Great Lakes fishery. The commercial turtle fishing and mussel industries also were substantial along the Illinois River in the early 1900's (Bellrose and others, 1977).

Major factors currently affecting water quality in the basin include municipal and industrial point-source discharges and nonpoint discharges from urban and agricultural areas. Sediment, nutrients, microorganisms including bacteria and viruses, and potentially toxic inorganic and organic chemicals are associated with many of the discharges.

Man's effects on water quality and associated natural resources in the basin have occurred mainly in the last 150 years and have been fairly well documented (Mills and others, 1966; Starrett, 1972; Bellrose and others, 1979, 1983; Sparks, 1984). Extreme changes in water quality and aquatic biota occurred in the lower Des Plaines and upper Illinois Rivers following the opening of the Chicago Sanitary and Ship Canal in 1900. The canal was built to allow diversions of large volumes of Lake Michigan water to dilute and transport untreated waste from the Chicago area downstream (Reynolds, 1902; Boruff, 1930; Bellrose and others, 1979; Blodgett and others, 1984). Although earlier attempts to dispose of sewage into the Illinois River through the Illinois and Michigan Canal were initiated (Bartow, 1913), aquatic biota were relatively unaffected prior to the completion of the Sanitary and Ship Canal. Industrialization and subsequent waste disposal resulted in the loss of wetland habitats and severe aquatic degradation from pollutants (Chicago Metropolitan Sanitary District, 1914, 1921; Colten, 1985, 1986). The effects on aquatic life were documented by the Illinois Natural History Survey (Forbes and Richardson, 1913, 1919; Richardson, 1928; Starrett, 1971). Fish consumption advisories in the upper Illinois River basin have been issued for reaches of the Des Plaines River, Illinois River, and Grand Calumet River (Illinois Environmental Protection Agency, 1986b; Indiana State Board of Health, 1986) because of elevated levels of PCB's (polychlorinated biphenyls).

Most point-source discharges and municipal wastewaters currently are treated; however, numerous sources exist in the upper Illinois River basin (Jackson and others, 1981). Urban nonpoint sources of chemical constituents also are numerous. For example, more than 700 abandoned hazardous waste sites have been identified in the upper Illinois River basin (Illinois Environmental Protection Agency, 1987c; Indiana Department of Environmental Management, 1987b).

Implementation of a Federal navigation project resulted in the construction of a series of locks and dams in the upper Illinois River basin. These structures, and the associated commercial traffic, have caused increased turbidity and sedimentation; sediment deposition has degraded habitat, adversely affecting biota (Bellrose and others, 1977). Agricultural practices, particularly drainage of wetlands, channelization of streams, and row-cropping, have increased soil erosion and sediment deposition in downstream areas (Griswold and others, 1978; Bellrose and others, 1983). In addition, the presence of agricultural pesticides associated with sediment has increased as agricultural production and soil erosion have increased.

The aquatic biology in the upper Illinois River basin depends, in part, on the kinds and number of habitats present. For this discussion, lotic habitats that occur in the study area were divided into three groups: (1) Tributary streams affected primarily by agricultural practices; (2) river main stems not directly affected by the Chicago metropolitan area, including the Kankakee, upper Des Plaines, and Fox Rivers; and

(3) tributary streams and rivers affected by pollutants from the Chicago area, including the manmade canal system, the lower Des Plaines River, and the Illinois River.

Tributary Streams

Tributary streams in the project area have primarily been affected by soil erosion, channelization, drainage of wetlands, and other factors associated with row-crop agriculture. A comparison of fish population data collected before 1900 and between 1950 and 1970 (Smith, 1971) concludes that the major factors responsible for the loss or decimation of native fish species in Illinois were siltation, drainage of wetlands, desiccation during drought, species interaction, and pollution. In that comparison, Smith (1971) rated the quality of streams by their composition of fish species, concluding that the Fox River system, Kankakee-Iroquois River system, and Mazon River system were generally "good" to "excellent." The tributaries to the Fox and Kankakee Rivers continue to have a diverse variety of habitats and high species richness. Mining and agricultural practices have affected the Mazon River system, but appreciable damage apparently has not occurred. Smith (1971) rated the quality of the Des Plaines River system as "poor" overall, noting extensive modification of streams and problems from pollution. He also noted that some reaches of the system have "good" species diversity. Similar conclusions were reached in a study of northeastern Illinois watersheds that was based on diversity indices for fish populations, a toxicity index, and integration of water quality and demographic information (Brigham and others, 1978). They considered tributaries of the Des Plaines River in the northern part of the watershed to be of "good" quality. In general, "high-quality" aquatic habitats were in the Fox and Kankakee watersheds, and "low-quality" habitats were associated with the more urbanized areas (Brigham and others, 1978). In a study of tributary streams of the Fox River, Sallee and Bergman (1986) concluded that the tributaries maintained diverse fish populations despite urbanization. Sule and Skelly (1985) rate the Kankakee River tributary, Horse Creek, as having "good" water quality, habitat, and fish populations. Water quality in the Little Kankakee River is adequate to support a stocked trout population (Robertson, 1979). Relative to downstream areas, the upper Des Plaines River, Du Page River, and some tributaries of the lower Des Plaines River have "good" fish populations (Dorkin, 1980). However, even where habitat quality is good, fish populations are less diverse in the Des Plaines River system than in other Illinois streams, probably because of poorer water quality (Bertrand, 1984).

River Main Stems

The same general trends in stream biology that exist for the tributary streams also occur in the main river stems of the Kankakee, Des Plaines, and Fox Rivers. The Kankakee River in Illinois was rated "excellent" by Smith (1971), having 72 fish species present; Brigham and others (1978) reported 79 species of fish in the watershed. In 1979, 44 species of fish were collected from seven stations in the Illinois portion of the Kankakee River including six species considered endangered, threatened, or rare in Illinois (Ivens and others, 1981). More recently, 70 species of fish were collected from the Illinois portion of the Kankakee River by Sule and Skelly (1985). In a

survey of the Kankakee River in Indiana, Robertson and Ledet (1981) collected 48 species of fish, and Ivens and others (1981) collected 13 species of mussels and 143 species of nonmussel macroinvertebrates.

The Des Plaines River generally has less fish-species diversity than the Kankakee and Fox Rivers. Bertrand (1984) identified 50 species of fish from 56 stations in the Des Plaines River watershed; 39 of the species were collected in the main stem of the river. He concluded that fish habitat in the Des Plaines River basin ranges from "adequate to superior" and that fish populations are limited by "poor" water quality. The Des Plaines River in Wisconsin maintains diverse fish populations; downstream from Wheeling, Ill., the fish populations indicate a degraded environment (Brigham and others, 1978).

The Fox River, which has some domestic and industrial pollution problems, was rated as "good" to "excellent" by Smith (1971), having 63 fish species present. However, the incidence of tumors in fish from the Fox River was elevated as compared to the tumor incidence in a similarly sized Canadian watershed (Brown and others, 1973). By comparing data from other studies for similar sites, Sallee and Bergman (1986) concluded that fish populations have improved in the Fox River basin; they collected a total of 50 species from 23 sampling locations in 1982. In a more extensive survey, 76 species of fish were collected from 70 sampling locations in the Fox River basin in 1976 (Brigham and others, 1978). The main river channels commonly have the greatest degradation; however, diverse fish populations commonly are maintained in the Fox River (Brigham and others, 1978).

Streams Affected by the Chicago Metropolitan Area

The Illinois River was severely affected by domestic and industrial pollution following the opening of the Sanitary and Ship Canal in 1900. Pollution problems peaked in about 1920, resulting in the loss of vascular aquatic plants, benthic organisms, and fish throughout the project area of the Illinois River and 160 miles downstream to Peoria (Richardson, 1928; Starrett, 1972). In addition, extensive filling of wetlands for waste disposal in the Chicago metropolitan area adversely affected biological resources by eliminating habitat and causing pollution of streams by surface runoff, leachate, and contaminated ground water (Colten, 1986).

Beginning in the 1920's and continuing to the present, the concentrations of pollutants draining to the Chicago Sanitary and Ship Canal and the Illinois River have been reduced by waste treatment. However, in the 1970's, the aquatic habitats affected by the Chicago metropolitan area remained in a degraded condition compared to preurbanization conditions (Starrett, 1971; Havera and others, 1980). This was evidenced from observations of the populations of fish, mussels, other invertebrates, and macrophytes.

Because of pollution, the fish in the upper Illinois River have been considered unfit for commercial use since the early 1950's (Starrett and Parr, 1951). Between 1959 and 1974, few fish species were found in the upper Illinois River and lower Des Plaines River; only carp, goldfish, and hybrids of these pollution-tolerant species commonly were collected (Sparks and

Starrett, 1975). In the late 1970's, the fish populations in the Chicago River, Chicago Sanitary and Ship Canal, Calumet Sag Channel, and the Calumet River system were degraded, and some reaches in the watershed were devoid of fish (Brigham and others, 1978).

At least 38 species of mussels are known to have occurred in the upper Illinois River between 1870 and 1900. By 1912, pollution from the Chicago metropolitan area had virtually eliminated all mussel species from this portion of the Illinois River (Starrett, 1971). A comprehensive survey of the upper Illinois River in 1966 indicated that no mussels had recolonized the area (Starrett, 1971).

An abundance of aquatic oligochaetes (Annelida: Clitellata) relative to other benthic invertebrates can indicate areas of sediment pollution. Aquatic oligochaetes are the dominant group of benthic invertebrates in many of the Chicago area watersheds. In the mid-1970's, the total benthic biomass attributable to aquatic oligochaetes for several watersheds in the Chicago area was from 73 percent to more than 90 percent (Brigham and others, 1978). In 1974, macroinvertebrates in the upper Illinois River included only pollution-tolerant oligochaetes and midge larvae (Diptera: Chironomidae); the only exception was a small number of clams from the exotic genus *Corbicula*, collected near Marseilles (Havera and others, 1980). In that study, distribution of drift macroinvertebrate organisms indicated that tributary streams to the upper Illinois River contained balanced communities but that the main stem contained an unbalanced community of pollution-tolerant species (Havera and others, 1980).

Generally, the biota in streams affected by the Chicago metropolitan area have undergone severe degradation caused by the toxic and oxygen-demanding effects of domestic and industrial waste disposal. Since the late 1970's, a period of limited recovery has occurred. Reappearance of small stands of aquatic plants and increased diversity of fish species, especially in areas farthest downstream from the Chicago area, indicate that water quality and substrate conditions have improved (Havera and others, 1980).

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EVALUATION OF BIOLOGICAL INVESTIGATIONS RELATIVE TO WATER QUALITY

Biological investigations that relate to water quality in the upper Illinois River basin were grouped into four categories for the purpose of this report: Populations and community structure, chemical concentrations in tissues, organism health, and toxicity measurements.

Populations and Community Structure

Surveys to determine populations and community structure of aquatic organisms were the most common type of biological study in the upper Illinois River basin (table 1). A total of 169 studies that included population data were identified. The Des Plaines River basin had the most studies completed, and the Fox River basin had the least. Fish are the most surveyed taxa of organisms, followed by macroinvertebrates and plankton. Data on vascular plants and terrestrial vertebrates were few.

The information available for the upper Illinois River basin on biological populations and community structure is extensive temporally and geographically. However, the many studies that have been completed are essentially a medley of unrelated site-specific data. In the sections that follow, the data available for the study area are summarized for the kinds of organisms studied and for the dates and locations of studies. Comparability among the various studies is discussed.

Kinds of Organisms Studied

The groups of organisms investigated are summarized in table 1. Generally, each study focuses on a relatively limited portion of the ecosystem. Several studies were designed to summarize the data available for a variety of organisms (Mills and others, 1966; Emge and others, 1974; Bellrose and others, 1977; Dan McGuiness and Associates, 1981; Jackson and others, 1981; U.S. Army Corps of Engineers, 1983). However, these studies were limited to parts of the project area and mainly are compilations of existing data rather than comprehensive ecosystem surveys.

Plankton are an important part of the ecosystem. These organisms are the base of production of the aquatic food webs. As observed by Forbes and Richardson (1913) "...the economic importance of the plankton is largely in the predominance of these minute animals and plants in the food of the young of our most important fishes--a predominance which may be expressed, without serious exaggeration, in the aphorism: no plankton, no fish..." Several plankton studies have been conducted in the upper Illinois River basin. The early work of Kofoid (1903, 1905) on the Illinois River downstream from the project area is extensive.

Table 1.--*Studies of the populations and structure of aquatic communities in the upper Illinois River basin*

[F, Fox River; D, Des Plaines River; K, Kankakee River; I, Illinois River]

Literature citation	Basin				Biota investigated									
	F	D	K	I	Plankton	Floodplain vegetation	Emergent and submersed plants	Macroinvertebrates	Mussles	Fish	Amphibia and reptiles	Birds	Mammals	Endangered species
Anderson, K.B. (1977)		X		X				X	X					
Anderson, R.V. (1977)	X								X					
Atwood (1984)				X						X				
Barker and others (1967)			X			X								
Bartow (1913)		X		X						X				
Bell (1975)		X				X								
Bell (1976a)		X				X								
Bell (1976b)		X				X								
Bell and del Moral (1977)		X				X								
Bellrose (1941)	X	X		X			X							
Bellrose and others (1977)		X		X			X	X	X	X	X	X	X	
Bellrose and others (1987)	X	X		X								X		
Belonger (1969)	X						X							
Bertrand (1975)				X						X				
Bertrand (1984)		X				X				X				
Bertrand and others (1982)	X									X				
Bland (1976)		X								X				
Bode (1988a)	X							X						
Bode (1988b)	X				X									
Boland and others (1979)	X	X		X	X									
Boronow and McNelly (1986)	X									X				
Brack and Holmes (1982)			X											X
Brice and Lewis (1977)			X						X					
Brigham and others (1981)			X					X	X	X				X
Brigham and others (1978)	X	X	X					X		X				
Butts (1974)		X		X	X			X						
Butts and others (1975)		X		X	X			X						
Chay and others (1977)		X								X				
Cima (1980)		X								X				
Dan McGuiness and Associates (1981)		X		X			X	X	X	X		X	X	X
Danglade (1914)				X					X					
Dennison (1978)	X	X								X				
Dennison and others (1978, 1982)		X			X			X		X				
Dennison and others (1984)	X	X								X				
Dorkin (1980)		X								X				

Table 1.--*Studies of the populations and structure of aquatic communities in the upper Illinois River basin*--Continued

Literature citation	Basin				Biota investigated									
	F	D	K	I	Plankton	Floodplain vegetation	Emergent and submersed plants	Macroinvertebrates	Mussles	Fish	Amphibia and reptiles	Birds	Mammals	Endangered species
Dorkin (1987)		X						X		X				
Dreher (1977)		X						X						
Ecological Analysts, Inc. (1980a)		X								X				
Ecological Analysts, Inc. (1980b)				X						X				
Ecological Analysts, Inc. (1981a)		X								X				
Ecological Analysts, Inc. (1981b)				X						X				
Ecological Analysts, Inc. (1981c)		X								X				
Ecological Analysts, Inc. (1982a)				X	X			X	X	X				
Ecological Analysts, Inc. (1982b)				X						X				
Ecological Analysts, Inc. (1982c)			X						X					
Ecological Analysts, Inc. (1983a, 1983b)		X								X				
Ecological Analysts, Inc. (1984a)		X						X						
Ecological Analysts, Inc. (1984b)		X		X						X				
Emge and others (1974)		X		X	X	X	X	X	X	X	X	X	X	X
Environmental Consultants and Planners (1980)		X				X	X	X	X	X	X	X	X	
Environmental Science and Engineering (1984)		X		X						X				
Environmental Science and Engineering (1985a, 1985b)		X								X				
Environmental Science and Engineering (1986a)		X		X						X				
Environmental Science and Engineering (1986b)		X								X				
Environmental Science and Engineering (1987a, 1987b)		X		X						X				
Fago (1984a)	X	X								X				X
Fago (1984b)	X	X				X				X				
Forbes and Richardson (1905)	X	X	X	X		X	X			X				
Forbes and Richardson (1913)		X	X	X	X		X	X	X	X				
Forbes and Richardson (1919)		X		X	X					X				

Table 1.--*Studies of the populations and structure of aquatic communities in the upper Illinois River basin*--Continued

Literature citation	Basin				Biota investigated									
	F	D	K	I	Plankton	Floodplain vegetation	Emergent and submersed plants	Macroinvertebrates	Mussles	Fish	Amphibia and reptiles	Birds	Mammals	Endangered species
Forbes and Richardson (1920)	X	X	X	X		X	X			X				
Gerking (1945)		X	X							X				
Graber and others (1978)	X	X	X	X								X		
Graham and others (1984)			X							X				
Gromme (1963)	X	X										X		
Havera and others (1980)		X		X	X	X	X	X	X	X	X	X	X	X
Herricks and Himelock (1981)		X		X						X				
Hill and Hullinger (1981)		X						X						
Illinois Environmental Protection Agency (1986a, 1987a)	X	X	X	X				X		X				
Illinois Environmental Protection Agency (1987d)	X						X	X	X	X				
Illinois Environmental Protection Agency (1988a, 1988b)		X					X	X	X	X				
Indiana Department of Environmental Management (1986)			X					X		X				
International Environmental Consultants (1981)		X		X	X	X	X	X	X	X	X	X	X	X
Ivens and others (1981)			X					X	X	X				
Iverson (1985)			X									X		
Jackson and others (1981)		X		X				X		X	X	X	X	
Jackson (1961)	X	X											X	
Keup and others (1965)		X						X		X				
Kofoid (1903)[1]				X	X		X							
Kofoid (1905)[1]				X	X									
Kothandaraman and others (1977)	X				X			X						
Kothandaraman and others (1981)				X	X									
Kurz (1978)			X			X	X							
Kwak and Larimore (1987)			X							X				
Langbein and Wight (1976)		X								X				
Larimore and Skelly (1981)			X		X			X	X	X				
Larimore and Kwak (1986)			X							X				
Leighton (1907)		X			X									
Lin and Evans (1974)		X		X	X									
Lin and others (1975, 1978)	X	X	X		X									

Table 1.--*Studies of the populations and structure of aquatic communities in the upper Illinois River basin*--Continued

Literature citation	Basin				Biota investigated									
	F	D	K	I	Plankton	Floodplain vegetation	Emergent and submersed plants	Macroinvertebrates	Mussles	Fish	Amphibia and reptiles	Birds	Mammals	Endangered species
Lin and others (1979)	X				X									
Lopinot (1965)	X	X	X	X			X							
Matsunaga and Murphy (1979)		X						X		X				
Metropolitan Sanitary District of Chicago (1986)		X						X		X				
Meyer (1936)			X			X	X			X		X	X	
Mills and others (1966)	X		X	X		X	X	X	X	X	X			
Minton (1972)		X	X								X			
Mitsch and others (1979)			X			X	X			X		X	X	
Mitsch and Urbikas (1980)		X				X		X		X				
Muench (1964a)			X							X				
Muench (1964b)	X				X		X			X				
Muench (1965)	X	X			X					X				
Muench (1968)		X								X				
Mumford and Whitaker (1982)		X	X										X	
Nelson (1878)		X		X						X				
Page and others (1979)			X					X	X	X				
Poff (1957)	X									X				
Polls and Spielman (1977)		X						X						
Polls and others (1980)		X						X						
Purdy (1930)		X	X	X	X			X						
Rabenold (1988)		X											X	
Reilly (1976)		X						X						
Richardson (1928)				X				X	X	X				
Robertson (1972)			X			X				X				
Robertson (1979)			X							X				
Robertson and Ledet (1981)			X							X				
Sallee and Bergman (1986)	X						X	X		X				
Sallee and others (1987)			X							X				
Schacht and Matsunaga (1975a, 1975b)		X						X		X				
Schmeelk and others (1983, 1984, 1985, 1986a, 1986b)		X			X					X				
Seegert (1987)			X							X				
Shelford (1911)		X								X				
Skelly and others (1982)			X							X				
Skelly and Sule (1983)			X							X				
Skelly and others (1984, 1985)			X							X				

Table 1.--*Studies of the populations and structure of aquatic communities in the upper Illinois River basin*--Continued

Literature citation	Basin				Biota investigated									
	F	D	K	I	Plankton	Floodplain vegetation	Emergent and submersed plants	Macroinvertebrates	Mussles	Fish	Amphibia and reptiles	Birds	Mammals	Endangered species
Small and Antipa (1969)			X						X					
Smith (1961)	X	X	X	X							X			
Smith (1965, 1971, 1979)	X	X	X	X						X				
Sparks (1977)		X		X						X				
Sparks (1984)		X		X			X	X	X	X				
Sparks and Starrett (1975)		X		X						X				
Sparks and others (1986)		X					X	X						X
Spielman and others (1978)		X			X			X		X				
Spielman and others (1979)		X	X		X			X		X				
Sporre (1987)			X									X		
Starrett (1971)				X					X	X				
Starrett (1972)		X		X	X		X	X	X	X				
Starrett and Parr (1951)				X						X				
Stinauer (1974)				X						X				
Striegl and Cowan (1987)		X			X			X		X				
Sule and Larimore (1978, 1979, 1980)			X		X			X	X	X				
Sule and Skelly (1985)			X							X				
Suloway (1981)			X						X					
Tazik and Sparks (1987)		X					X							
Tessen (1976)	X	X										X		
U.S. Army Corps of Engineers (1979)		X		X	X			X						
U.S. Army Corps of Engineers (1983)		X				X	X	X	X	X	X	X	X	X
U.S. Fish and Wildlife Service (1986)			X							X		X		X
U.S. Geological Survey (1982)	X	X			X									
Wilson and Clark (1912)			X						X					
Woermann (1902-1904)		X		X		X								
Woods (1959)		X								X				
Total for Fox River--37 studies					9	3	8	7	2	19	1	4	1	1
Total for Des Plaines River--111 studies					28	15	19	41	14	73	10	14	11	7
Total for Kankakee River--54 studies					9	7	7	14	13	36	2	6	3	3
Total for Illinois River--55 studies					16	6	14	19	14	38	7	9	6	4
Total for basin--169 studies					40	20	26	55	29	113	10	19	12	10

[1]Data collected downstream from the study area.

Few surveys of submergent, emergent, and floodplain vegetation have been conducted in the basin. Comprehensive discussions of the taxa of vegetation that occur in the Illinois River valley are found in Mills and others (1966) and Havera and others (1980). An extensive description of vegetation near Hickory Creek, in the Des Plaines River basin, is presented by Bell (1975, 1976a, 1976b), Bell and del Moral (1977), and the U.S. Army Corps of Engineers (1983). The aquatic and floodplain vegetation of the upper Des Plaines River is described in Environmental Consultants and Planners, Inc. (1980). Sparks and others (1986) and Tazik and Sparks (1987) document the areal coverage of submergent and emergent vegetation for the lower Des Plaines River. Reinvasions of algal species and aquatic macrophytes in the Chicago metropolitan area of the Des Plaines River basin have been observed in the late 1980's. Possible reasons for this increase in aquatic plants are: (1) The reduction of suspended solids and chlorine discharge at wastewater treatment facilities of the Metropolitan Water Reclamation District of Greater Chicago, (2) a decrease of suspended sediments and, thus, an increase in water clarity associated with the partial completion of the Tunnel and Reservoir Project, a large urban-runoff control project (Irwin Polls, Metropolitan Water Reclamation District of Greater Chicago, oral commun., 1987). The vegetation associated with the Kankakee River near the Illinois-Indiana State line is described in Kurz (1978) and Mitsch and others (1979). The vegetation of the former large wetland area associated with the Kankakee River is discussed in Meyer (1936) and Forbes and Richardson (1905, 1920).

Data for aquatic macroinvertebrates and mussels are relatively extensive. The streams affected by pollution from the Chicago metropolitan area generally exhibit low species diversity for macroinvertebrates and an extirpation of mussels, although pollution-tolerant organisms are sometimes abundant (Starrett, 1971; Butts and others, 1975; Bellrose and others, 1977; Dennison and others, 1978; Hill and Evans, 1978; Spielman and others, 1978, 1979; Havera and others, 1980; Sparks and others, 1986). Surveys for macroinvertebrate species in the Fox River basin are incomplete. The data for the Kankakee River basin generally are localized in the Kankakee River drainage of Illinois. There is extensive documentation of macroinvertebrate species (Sule and Larimore, 1978, 1979, 1980; Page and others, 1979; Brigham and others, 1981; Ivens and others, 1981; Larimore and Skelly, 1981) and mussel populations (Wilson and Clark, 1912; Brice and Lewis, 1977; Suloway, 1981; Ecological Analysts, Inc., 1982c).

Fish sampling data are the most abundant biota information available. All of the basins have adequate fish species diversity information. However, most of the collections were made using electrofishing techniques, which are not efficient for small fish and ictalurids. Several studies in the 1970's and 1980's provide information on species present in the Fox River basin (Brigham and others, 1978; Bertrand and others, 1982; Dennison and others, 1984; Fago, 1984a; Sallee and Bergman, 1986). Information on fish populations in the Des Plaines River basin is abundant, especially the general surveys by the Metropolitan Water Reclamation District of Greater Chicago (University of Illinois Water Resources Center, 1976; Dennison, 1978; Dennison and others, 1978, 1982, 1984; Spielman and others, 1978, 1979; Schmeelk and others, 1983, 1984, 1985, 1986a, 1986b) and the more specific surveys done for Commonwealth Edison Company (University of Illinois Water Resources Center, 1976; Cima,

1980; Ecological Analysts, Inc., 1980a, 1981a, 1981c, 1983a, 1983b, 1984a, 1984b; Environmental Science and Engineering, Inc., 1984, 1985a, 1985b, 1986b, 1987a, 1987b). Additional fish information for the Des Plaines River basin is given in Emge and others (1974), Schacht and Matsunaga (1975a, 1975b), Sparks and Starrett (1975), Brigham and others (1978), Smith (1979), Dorkin (1980), Environmental Consultants and Planners, Inc. (1980), Havera and others (1980), U.S. Army Corps of Engineers (1983), Bertrand (1984), and Fago (1984a). Similarly, numerous fish studies have been completed in the Kankakee River basin. The studies for Commonwealth Edison Company were very thorough but were geographically limited (Sule and Larimore, 1978, 1979, 1980; Larimore and Skelly, 1981; Skelly and others, 1982, 1984, 1985; Larimore and Kwak, 1986; Kwak and Larimore, 1987). Additional surveys for fish populations in the Kankakee basin include Muench (1964a), Robertson (1972, 1979), Brigham and others (1978), Mitsch and others (1979), Page and others (1979), Smith (1979), Brigham and others (1981), Ivens and others (1981), Robertson and Ledet (1981), and Sallee and others (1987). Data for the Illinois River basin are also extensive. These include site-specific surveys done for Commonwealth Edison Company (Ecological Analysts, Inc., 1980b, 1981b, 1982a, 1982b, 1984b; Environmental Science and Engineering, Inc., 1984, 1986a, 1987a, 1987b). More general information is included in Forbes and Richardson (1905, 1913, 1919, 1920), Mills and others (1966), Stinauer (1974), Bertrand (1975), Sparks and Starrett (1975), Bellrose and others (1977), Smith (1979), Havera and others (1980), Herricks and Himelock (1981), Atwood (1984), and Sparks (1984).

Most information on aquatic-associated terrestrial vertebrates is limited in quantity and is of general scope. Limited information is available for the Fox River basin. Mitsch and others (1979) and Sporre (1987) document the only substantial information for the Kankakee River basin. Several of the large, general reports for the Illinois River and Des Plaines River contain some information on vertebrates; these include Mills and others (1966), Emge and others (1974), Bellrose and others (1977), Environmental Consultants and Planners, Inc. (1980), Havera and others (1980), Jackson and others (1981), and U.S. Army Corps of Engineers (1983). Bellrose and others (1987) presented data on waterfowl from the Illinois, Des Plaines, and Fox River basins for the period of 1976 to 1985. Additional data are available from regional work (Kumlien and Hollister, 1951; Smith, 1961; Hoffmeister and Mohr, 1972; Minton, 1972; Mumford and Whitaker, 1982; Mumford and Keller, 1984).

There are only 10 known studies that contain discussions on endangered and threatened species (table 1). These species potentially could be used to evaluate water-quality conditions over time by correlating the decrease or increase in range or population of a species to possible causal effects. However, this information could not be unilaterally used to evaluate water quality but would need to be combined with other ecosystem data to develop a comprehensive view of biological conditions.

Dates and Locations of Studies

Historical records for biological populations in the study area exist for a variety of organisms. Seventeen studies that took place prior to 1950 are listed in table 1. In addition, a number of studies published after 1950 have references to earlier data.

The early data for plankton is limited to the lower Des Plaines River and the Illinois River. However, the historical data for these two rivers are extensive, as described in the works of Kofoid (1903, 1905) and Purdy (1930). Additional references include Forbes and Richardson (1913), Mills and others (1966), Starrett (1972), Emge and others (1974), and Havera and others (1980). Plankton studies completed after 1950 are available for all the basins and are listed in table 1.

Studies that document aquatic and floodplain vegetation prior to 1950 are relatively rare. General discussions concerning vegetation are presented in Meyer (1936) and Forbes and Richardson (1905, 1920) for the Kankakee River basin. Forbes and Richardson (1913) and Kofoid (1903) discuss aquatic plant vegetation for the Illinois River. Woermann (1902-1904) mapped much of the floodplain of the Des Plaines and Illinois Rivers and described some of the vegetation. Discussions on the vegetation that occurred historically in the study area also are included in Mills and others (1966), Emge and others (1974), Bellrose and others (1977), Mitsch and others (1979), Havera and others (1980), U.S. Army Corps of Engineers (1983), and Sparks (1984). Studies done since 1950 that address aquatic and terrestrial vegetation are listed in table 2 but are not definitive from a basinwide perspective. In 1988, the U.S. Fish and Wildlife Service (FWS) and the States of Illinois and Indiana had ongoing mapping studies of all wetland habitats in the two-State part of the upper Illinois River basin as part of the FWS National Wetland Inventory project. The State of Wisconsin initiated an inventory of wetlands independent of the national effort. In 1988, the Wisconsin inventory was completed for most of the counties in the study area. Additionally, aerial photographs of vegetation in the study area have been made by the Chicago District of the U.S. Army Corps of Engineers and by the Agricultural Conservation and Stabilization Service, U.S. Department of Agriculture.

Macroinvertebrate and mussel data from pre-1950 studies are limited to the lower Des Plaines River and Illinois River (Forbes and Richardson, 1913; Danglade, 1914; Richardson, 1928; Purdy, 1930) and a single study on the Kankakee River (Wilson and Clark, 1912). Suloway (1981) discusses the historical record for mussels in the Kankakee River including observations of population trends. Other studies that include discussions on the historical record for this group of organisms are Mills and others (1966), Starrett (1971, 1972), Emge and others (1974), Bellrose and others (1977), Hill and Evans (1978), Page and others (1979), Havera and others (1980), Brigham and others (1981), Ivens and others (1981), and U.S. Army Corps of Engineers (1983). Studies that include discussions on the post-1950 status of macroinvertebrate and mussel populations are listed in table 1.

Pre-1950 studies of fish in the study area are concentrated in the Des Plaines and Illinois River basins (Nelson, 1878; Forbes and Richardson, 1905, 1913, 1919, 1920; Shelford, 1911; Richardson, 1928); some general information is available for the Kankakee River (Forbes and Richardson, 1905, 1920; Meyer, 1936). A number of additional studies include discussions on the history of fish-species data for the study area (Keup and others, 1965; Mills and others, 1966; Smith, 1971; Starrett, 1971; Emge and others, 1974; Sparks and Starrett, 1975; Bellrose and others, 1977; Mitsch and others, 1979; Page and others, 1979; Dorkin, 1980; Havera and others, 1980; Brigham and others, 1981; Ivens and others, 1981; U.S. Army Corps of Engineers, 1983; Atwood, 1984; Fago,

1984a; Sparks, 1984). Studies that include discussions on post-1950 fish data are cited by basin in table 1.

Data prior to 1950 for aquatic-associated amphibia, reptiles, birds, and mammals are extensive; however, distinguishing specific species that are affected directly by water quality is difficult. Although general references to the organisms present are made (Meyer, 1936; Kumlien and Hollister, 1951; Smith, 1961; Graber and Graber, 1963; Hoffmeister and Mohr, 1972; Minton, 1972; Mumford and Whitaker, 1982; Mumford and Keller, 1984), collections of specimens, documentation of species, and data on abundance of organisms affected directly by water quality are few. Graber and Graber (1976) and Holmes and others (1986) used bird populations to evaluate environmental conditions. Waterfowl and other bird populations have been correlated to changes in the quality of aquatic habitats for the Illinois River, mainly downstream from the study area (Mills and others, 1966; Bellrose and others, 1979; Havera and others, 1980). Some data are available from the study area for aquatic-dependent species such as herons (Graber and others, 1978; Iverson, 1985) and waterfowl (Bellrose and others, 1987). No comprehensive studies exclusively using aquatic-associated vertebrates to evaluate water-quality conditions have been completed. However, these organisms are potentially useful as biological evaluation tools.

The general locations of investigations completed in each basin are listed in figures 2 through 5. All of the investigations listed in figures 2 through 5 are cross-listed in table 1 for information on the kinds of organisms studied. The several investigations completed for Commonwealth Edison Company (Ecological Analysts, Inc., 1980-84; Environmental Science and Engineering, Inc., 1984-87) are mostly localized: (1) In the lower Des Plaines River; (2) near the Dresden Station at the confluence of the Des Plaines and Kankakee Rivers; and (3) near the Braidwood Station on the Kankakee River between Wilmington and Kankakee, Ill. The Illinois Environmental Protection Agency (1987d, 1988a, 1988b) completed intensive surveys for the Fox, Des Plaines, and Du Page Rivers. Many of the reports completed for the State agencies have been done for specific stream reaches. Few regionwide or statewide studies are cited.

Extensive data for fish, macroinvertebrates, and plankton exist for the Illinois part of the Kankakee River basin (fig. 2; table 1); information for vascular plants and vertebrates is more general and less extensive than for other organisms. Data for the Indiana part of the Kankakee River and the Iroquois River are few relative to the Kankakee River in Illinois. The Iroquois River is especially lacking in specific data.

The data for the Des Plaines River (fig. 3; table 1) are extensive for fish throughout the basin. Fish population studies are especially extensive for Hickory Creek because this area has been used for academic research since the early 1900's. The data for plankton, vascular plants, macroinvertebrates, and vertebrates are less extensive than for fish, but a substantial amount of information is available, especially for the lower part of the basin.

Literature citation	Iroquois River	Kankakee River	
		Lower	Upper
Barker and others, 1967	X	X	X
Brack and Holmes, 1982			X
Brice and Lewis, 1977		X	
Brigham and others, 1978, 1981		X	
Ecological Analysts, Inc., 1982c		X	
Forbes and Richardson, 1905, 1920	X	X	X
Forbes and Richardson, 1913		X	
Gerking, 1945			X
Graber and others, 1978	X	X	
Graham and others, 1984		X	
Illinois Environmental Protection Agency, 1986b		X	
Illinois Environmental Protection Agency, 1987a	X	X	
Indiana Department of Environmental Management, 1986			X
Ivens and others, 1981		X	
Iverson, 1985			X
Kurz, 1978		X	
Kwak and Larimore, 1987		X	
Larimore and Skelly, 1981		X	
Larimore and Kwak, 1986		X	
Lin and others, 1975, 1978		X	
Lopinot, 1965	X	X	
Meyer, 1936		X	X
Minton, 1972			X
Mitsch and others, 1979		X	
Muench, 1964a	X	X	
Mumford and Whitaker, 1982			X
Page and others, 1979		X	
Purdy, 1930		X	
Rabenold, 1988			X
Robertson, 1972, 1979			X
Robertson and Ledet, 1981			X
Sallee and others, 1987		X	
Seegert, 1987			X
Skelly and others, 1982		X	
Skelly and Sule, 1983		X	
Skelly and others, 1984, 1985		X	
Small and Antipa, 1969		X	
Smith, 1961, 1965, 1971, 1979	X	X	
Spielman and others, 1979		X	
Sporre, 1987			X
Sule and Larimore, 1978, 1979, 1980		X	
Sule and Skelly, 1985		X	
Suloway, 1981		X	
U.S. Fish and Wildlife Service, 1986			X
Wilson and Clark, 1912	X	X	X

Figure 2.--Kankakee River basin with list of population and community structure studies.

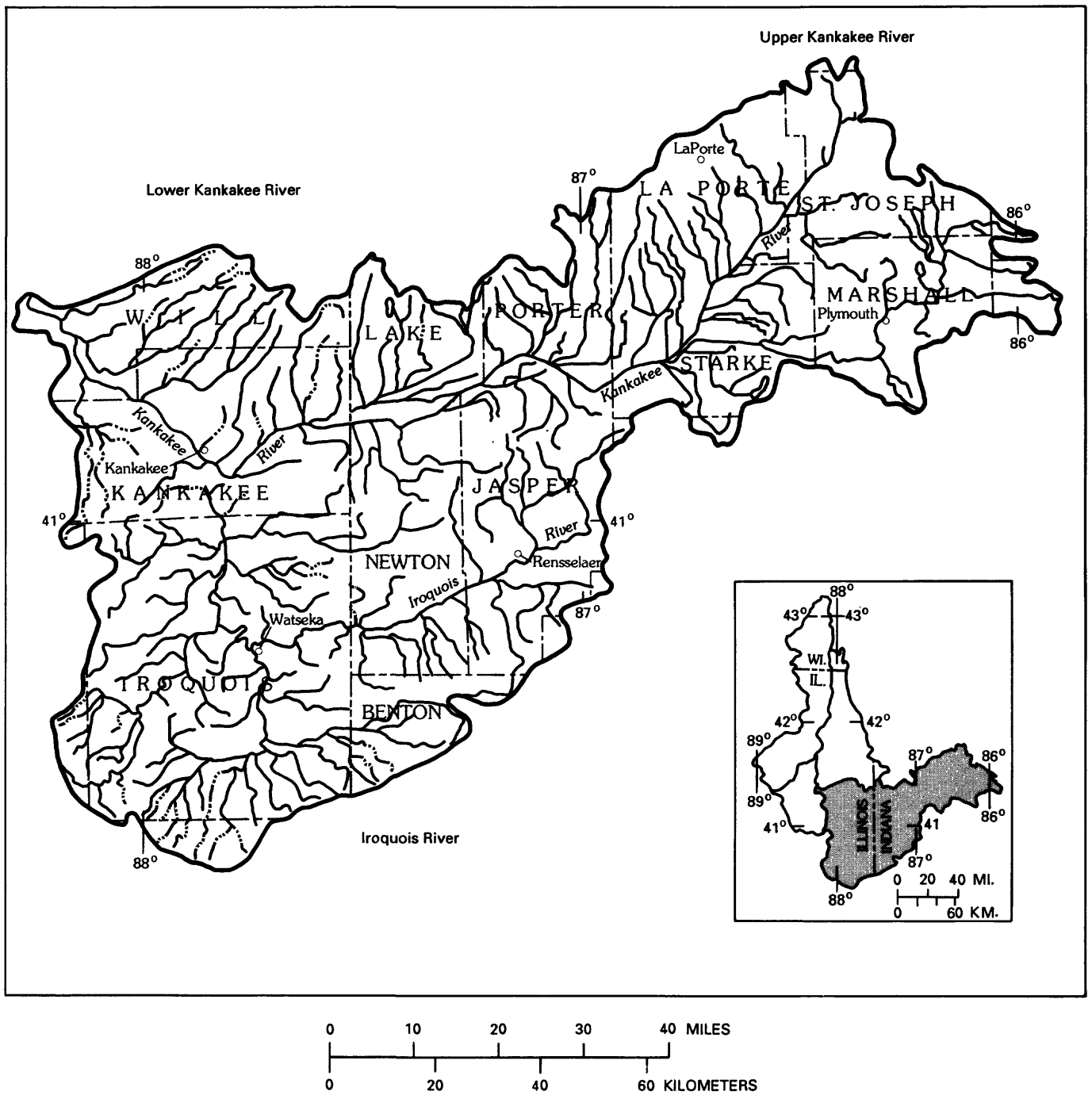

Figure 2.--Kankakee River basin with list of population and community structure studies--Continued

Literature citation	Des Plaines River Upper	Lower
Anderson, K.B., 1977		X
Bartow, 1913		X
Bell, 1975, 1976a, 1976b		X
Bell and del Moral, 1977		X
Bellrose, 1941		X
Bellrose and others, 1977, 1987		X
Bertrand, 1984	X	X
Bland, 1976		X
Boland and others, 1979		X
Brigham and others, 1978	X	X
Butts, 1974		X
Butts and others, 1975		X
Chay and others, 1977		X
Cima, 1980		X
Dan McGuiness and Associates		X
Dennison, 1978	X	X
Dennison and others, 1978		X
Dennison and others, 1982, 1984	X	X
Dorkin, 1980, 1987		X
Dreher, 1977		X
Ecological Analysts, Inc., 1980a, 1981a, 1981c, 1983a, 1983b, 1984a, 1984b		X
Emge and others, 1974		X
Environmental Consultants and Planners, Inc., 1980	X	
Environmental Science and Engineering, Inc., 1984, 1985a, 1985b, 1986a, 1986b, 1987a, 1987b		X
Fago, 1984a, 1984b	X	
Forbes and Richardson, 1905, 1920	X	X
Forbes and Richardson, 1913, 1919		X
Graber and others, 1978	X	X
Havera and others, 1980		X
Herricks and Himelock, 1981		X
Hill and Evans, 1978		X
Hill and Hullinger, 1981		X
Illinois Environmental Protection Agency, 1986b		X
Illinois Environmental Protection Agency, 1987a	X	X
International Environmental Consultants, 1981		X
Jackson, 1961	X	
Jackson and others, 1981		X
Keup and others, 1965		X
Langbein and Wight, 1976	X	X

Figure 3.--Des Plaines River basin with list of population and community structure studies.

Literature citation	Des Plaines River	
	Upper	Lower
Leighton, 1907		X
Lin and Evans, 1974		X
Lin and others, 1975, 1978		X
Lopinot, 1965	X	X
Matsunaga and Murphy, 1979	X	X
Metropolitan Sanitary District of Greater Chicago, 1986		X
Mills and others, 1966		X
Minton, 1972		X
Mitsch and Urbikas, 1980		X
Muench, 1965		X
Muench, 1968	X	X
Mumford and Whitaker, 1982		X
Nelson, 1878		X
Polls and Spielman, 1977		X
Polls and others, 1980		X
Purdy, 1930		X
Reilly, 1976	X	X
Schacht and Matsunaga, 1975a		X
Schacht and Matsunaga, 1975b	X	X
Schmeelk and others, 1983	X	X
Schmeelk and others, 1984, 1985, 1986a, 1986b		X
Shelford, 1911		X
Smith, 1961, 1965, 1971, 1979	X	X
Sparks, 1984		X
Sparks and Starrett, 1975		X
Sparks and others, 1986		X
Spielman and others, 1978, 1979		X
Starrett, 1972		X
Striegl and Cowan, 1987		X
Tazik and Sparks, 1987		X
Tessen, 1976	X	
U.S. Army Corps of Engineers, 1979, 1983		X
U.S. Geological Survey, 1982	X	X
Woermann, 1902-1904		X
Woods, 1959		X

Figure 3.--Des Plaines River basin with list of population and community structure studies--Continued

(p. 25 follows)

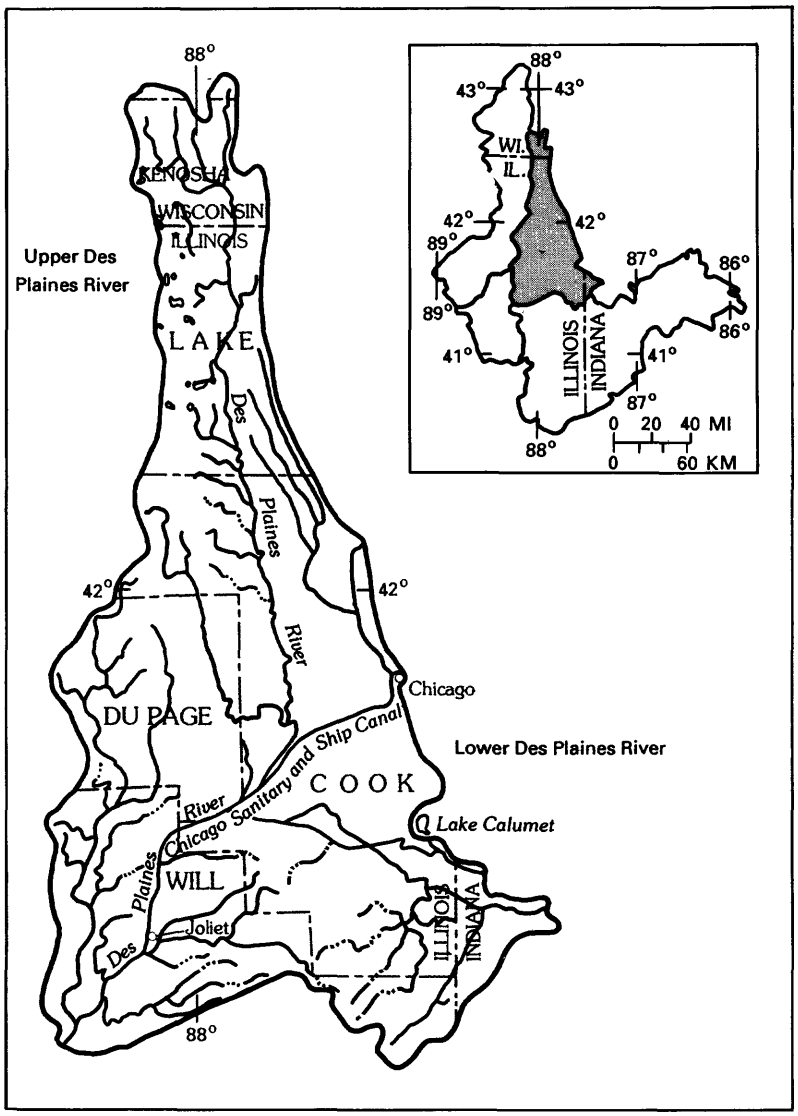

Figure 3.--Des Plaines River basin with list of population and community structure studies--Continued

Literature citation	Fox River		
	Upper	Middle	Lower
Bellrose, 1941	X		
Bellrose and others, 1987	X		
Belonger, 1969		X	
Bertrand and others, 1982		X	X
Bode, 1988a, 1988b	X		
Boland and others, 1979		X	X
Boronow and McNelly, 1986	X		
Brigham and others, 1978		X	X
Dennison, 1978		X	X
Dennison and others, 1984		X	X
Fago, 1984a, 1984b	X		
Forbes and Richardson, 1905, 1920		X	X
Graber and others, 1978		X	X
Gromme, 1963	X		
Illinois Environmental Protection Agency, 1986b, 1987a		X	X
Jackson, 1961	X		
Kothandaraman and others, 1977		X	
Lin and others, 1975, 1978, 1979		X	
Lopinot, 1965		X	X
Muench, 1964b		X	
Muench, 1965		X	X
Poff, 1957	X		
Sallee and Bergman, 1986		X	X
Smith, 1961, 1965, 1971, 1979		X	X
Tessen, 1976	X		

Figure 4.--Fox River basin with list of population and community structure studies.

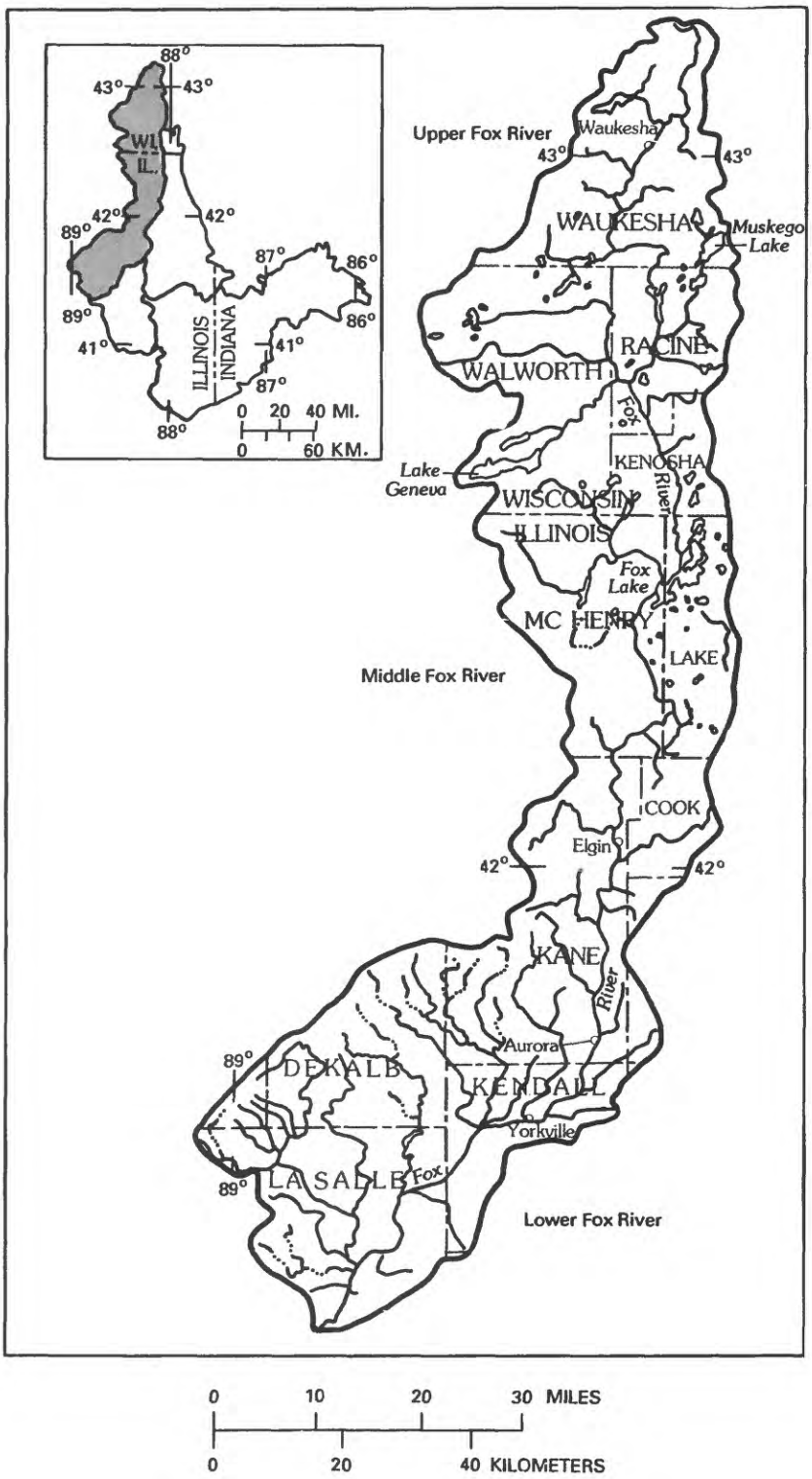

Figure 4.--Fox River basin with list of population and community structure studies--Continued

Literature citation

Anderson, K.B., 1977
Atwood, 1984
Bartow, 1913
Bellrose, 1941
Bellrose and others, 1977, 1987
Bertrand, 1975
Boland and others, 1979
Butts, 1974
Butts and others, 1975
Dan McGuiness and Associates, 1981
Danglade, 1914
Ecological Analysts, Inc., 1980b, 1981b, 1982a, 1982b, 1984b
Emge and others, 1974
Environmental Sciences and Engineering, Inc., 1984, 1986a, 1987a, 1987b
Forbes and Richardson, 1905, 1913, 1919, 1920
Graber and others, 1978
Havera and others, 1980
Herricks and Himelock, 1981
Hill and Evans, 1978

Literature citation

Illinois Environmental Protection Agency, 1986b, 1987a
International Environmental Consultants, 1981
Jackson and others, 1981
Kofoid, 1903, 1905
Kothandaraman and others, 1981
Lin and Evans, 1974
Lopinot, 1965
Mills and others, 1966
Nelson, 1878
Purdy, 1930
Richardson, 1928
Smith, 1961, 1965, 1971, 1979
Sparks, 1977, 1984
Sparks and Starrett, 1975
Starrett, 1971, 1972
Starrett and Parr, 1951
Stinauer, 1974
U.S. Army Corps of Engineers, 1979
Woermann, 1902-1904

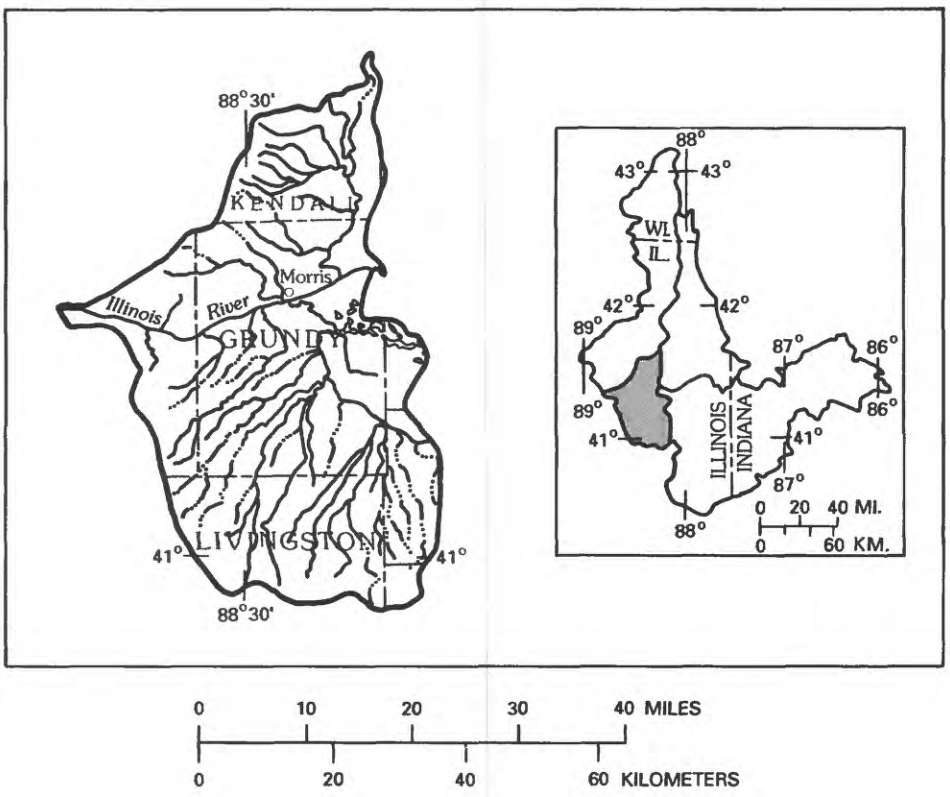

Figure 5.--Illinois River basin with list of population and community structure studies.

Data for fish populations are extensive for the Fox River basin (fig. 4; table 1). Plankton, vegetation, and macroinvertebrate data are more limited; data for aquatic-associated terrestrial vertebrates are general in nature.

The data for the Illinois River basin are relatively extensive for fish, macroinvertebrates, and plankton (fig. 5; table 1). More general data on vascular plants and vertebrates also have been collected.

Baseline Studies

In order to determine if changes in biological populations have occurred in response to changes in water quality, the background or baseline populations must first be described from previous data or from sampling of a nearby, physiographically similar and undisturbed watershed. Once the baseline ecosystem is known, then changes from the baseline can be compared to water-quality changes. The numerous surveys of various biological populations that have been conducted in the upper Illinois River basin have been either geographically or taxonomically limited, or both. There are an abundance of data for some groups of organisms, especially fish. However, no comprehensive study to document the plant and animal community in the project area as a whole has been completed. Additional information is needed for some of the basins and for some taxonomic groups to clearly delineate the ecosystem structure. However, the available information indicates that adverse water-quality conditions have affected biological communities, especially in the Chicago metropolitan area and the Illinois River. Additional data collection needs to be coordinated in order to establish the existing biological conditions throughout the upper Illinois River basin. Such a data-collection effort also requires that a standard data-collection protocol be adhered to. Continued data collections will result in accumulation of a data source from which trends in populations can be determined.

Chemical Concentrations in Tissues

Studies of chemical concentrations in tissue were relatively few, with 18 studies completed (table 2). Three of the studies listed were completed downstream from the study area (Mathis and Cummings, 1973; Lowe and others, 1985; Schmitt and others, 1985). The Des Plaines River basin had the most studies; fish were the group most extensively studied. One study evaluated vascular aquatic plants (Tazik and Sparks, 1987). Total PCB's were the contaminant group most frequently analyzed in these tissue studies; dioxin was cited in the fewest reports. Most of the studies that included data for chemical constituents in biological tissues were done by or in cooperation with State or Federal agencies.

The use of biological tissues to determine or monitor levels of biologically available chemical constituents in the aquatic environment is a relatively new technique in the upper Illinois River basin. All of the studies identified have occurred after 1970 (table 2); no longer-term historical information on potential changes in bioaccumulation of various chemical constituents is available. Future analysis of properly archived specimens may provide an opportunity to trace the occurrence of selected constituents through time.

Table 2.--*Studies of the concentrations of chemicals in organism tissues in the upper Illinois River basin*

[F, Fox River; D, Des Plaines River; K, Kankakee River; I, Illinois River; OC, organochlorine pesticides; PCB, polychlorinated biphenyls; Dioxin, 2,3,4,8-tetrachlorodibenzo-p-dioxin]

Literature citation	Basin				Taxa of tissue			Contaminant			
	F	D	K	I	Emergent and submersed plants	Macro-inverte-brates	Fish	OC	PCB	Metals	Dioxin
Anderson, R.V. (1977)	X					X				X	
Dorkin (1987)		X				X	X		X		
Illinois Environmental Protection Agency (1985)	X	X	X	X			X	X	X		
Illinois Environmental Protection Agency (1986a)	X	X		X			X	X	X		X
Illinois Environmental Protection Agency (1986b)	X	X	X	X			X	X	X		X
Illinois Environmental Protection Agency (1987b)	X	X	X	X			X	X	X	[1]X	
Indiana Department of Environmental Management (1986)			X				X	X	X	X	
Indiana Department of Environmental Management (1987a)			X				X	X	X	X	
Indiana State Board of Health (1986)		X					X		X		
Indiana State Pollution Control Board (1984)			X				X	X	X	X	
Indiana State Pollution Control Board (1985)		X	X			X	X	X	X	X	X
Lowe and others (1985)			[2]X				X			X	
Mathis and Cummings (1973)			[2]X			X	X			X	
Matsunaga and Murphy (1979)		X					X	X	X		
Pietz and others (1984)		X				X				X	

Table 2.--*Studies of the concentrations of chemicals in organism tissues in the upper Illinois River basin*--Continued

Literature citation	Basin				Taxa of tissue			Contaminant			
	F	D	K	I	Emergent and submersed plants	Macro-inverte-brates	Fish	OC	PCB	Metals	Dioxin
Schacht and Matsunaga (1975b)		X					X	X	X		
Schmitt and others (1985)			[2]X				X	X	X		
Tazik and Sparks (1987)		X			X			[3]X	X	X	
Wisconsin Department of Natural Resources (1987)	X	[4]X					X	X	X	X	
Total for Fox River-- 6 studies					0	1	5	5	5	3	2
Total for Des Plaines River-- 12 studies					1	3	10	9	11	5	3
Total for Kankakee River -- 7 studies					0	0	7	7	7	5	1
Total for Illinois River-- 7 studies					0	1	7	5	5	3	2
Total for basin-- 19 studies					1	5	16	13	15	11	3

[1]Mercury only.
[2]Sampling location downstream from study area.
[3]Dieldrin only.
[4]PCB's only.

Most data for chemical concentrations in tissues are for various species of fish. Only 6 of the 19 studies identified in table 2 contain tissue data for other organisms. The States of Illinois and Indiana generally attempt to collect fish from groups that are predators, omnivores, and bottom feeders (Illinois Environmental Protection Agency, 1985; Indiana Department of Environmental Management, 1986). Common carp (*Cyprinus carpio*) is the most commonly used species for tissue analysis. However, most studies do not rely exclusively on carp. Information is available for species from the families Lepisosteidae (gar), Esocidae (pike), Umbridae (mudminnow), Cyprinidae (minnow), Catostomidae (sucker), Ictaluridae (catfish), Perchichthyidae (white bass), Centrarchidae (sunfish), Percidae (perch), and Sciaenidae (drum). Hence, the tissue data available for the study area represent a diverse group of species and a variety of habitats and feeding habits. Additionally, the data for fish tissues are diverse geographically, limiting direct comparisons among species for the various basins and tributaries. No concerted effort has been made to collect fish from specific age, sex, size class, or reproductive condition; all these factors contribute to variability in the tissue concentration data.

The data for macroinvertebrates are few compared to those for fish. Only five studies were identified for the study area, and those include analyses of several different invertebrate species. Analyses of plant tissues have been completed in a single location using submergent and emergent species (table 2).

Sampling locations for tissue concentration data are distributed throughout the study area; most studies were done in the Des Plaines basin. Comparisons among the basins are possible for some chemicals in fish tissues; interbasin comparisons of chemical concentrations in tissues of macroinvertebrates and plants are not possible. Turtles, earthworms, and small mammals are alternative organisms that can be used to evaluate environmental effects from tissue analysis (Stone and others, 1980; Beyer and others, 1982; Minnesota Pollution Control Agency, 1982; Rowley and others, 1983; Mac and others, 1985); however, data on these organisms have not been reported for the basin.

The groups of chemicals for which tissue concentration data are available are relatively limited. The most commonly reported data are for total PCB's, which are the sum of a mixture of structurally similar specific PCB congeners (Schwartz and others, 1987). Organochlorine pesticides, which include a number of related compounds (Schmitt and others, 1985), were the second most analyzed group of compounds. The number of organochlorine compounds analyzed in specific tissues varies by study. Therefore, comparisons among all basins for all organochlorine compounds are not possible, but comparisons for a limited number of compounds are possible. In the mid-1980's, a relatively small number of tissue samples were analyzed for TCDD (2,3,7,8-tetrachlorodibenzo-p-dioxin) as part of a national study sponsored by the U.S. Environmental Protection Agency (USEPA) in cooperation with the various State agencies. Studies of trace metals in biological tissues are few (table 2). Analyses for specific metals vary among studies but generally include some combination of cadmium, chromium, copper, lead, mercury, nickel, selenium, or zinc; arsenic also is commonly analyzed.

The USEPA was mandated by the Clean Water Act of 1977, section 307(a)(1), to establish a list of priority pollutants. That list includes 129 compounds; however, many additional compounds are toxic or have the potential to bioaccumulate. Besides the aforementioned PCB's, organochlorine pesticides, TCDD, metals, and arsenic, there are virtually no data for other chemical contaminants in biological tissues for the study area. Examples of contaminants that need to be considered for future analyses are chlorinated styrenes, which are highly toxic, bioaccumulative, and are commonly present in industrialized areas (Tarkpea and others, 1985), and biocides. Biocides are used for a variety of industrial and manufacturing purposes, and some are subsequently discharged into surface waters (North Carolina Department of Natural Resources and Community Development, 1983). Many of the biocides contain the highly toxic and relatively persistent compounds known as organotins. No data on chlorinated styrenes or biocides in biological tissues were located for the upper Illinois River basin.

The accuracy of data for biological tissues is a major concern when evaluating bioavailability or comparing spatial or temporal differences in concentrations. Because the use of tissues for evaluation purposes is relatively new, laboratory procedures and quality-control and quality-assurance procedures for tissue analyses are commonly less standardized than are procedures for determination of water and sediment chemistry. In addition, sample-collection methods may vary. For example, some fish tissue data are comprised of analyses of whole fish, whereas some data are only for filleted muscle tissue. Also, the species, size, age, and number of organisms in composite samples may vary and affect results. To facilitate comparisons among data and ensure accurate concentration measurements, standard methods for laboratory analyses and sample collection need to be followed. Many of the agencies collecting biological tissue for tissue analyses have developed their own internal guidelines; establishment of methods having basinwide consistency is needed.

Organism Health

Degradation of the health of organisms living in the aquatic environment may indicate a change in water quality that predates more extreme effects like extirpation. Evaluators of organism health include the study of physical malformations, behavioral changes, disease, changes in rate of growth, mortality, reproductive success, and condition factor. In more recent studies, organisms also are evaluated for biochemical and physiological measurements such as blood cell counts, blood chemistry, bone development, oxygen consumption, acetylcholinesterase inhibition, osmoregulation, and tumor frequency (Baumann and others, 1982; Mehrle and Mayer, 1985). The methods that have been used to evaluate organism health in the study area are listed in table 3. A total of 42 studies included data on organism health (table 3). The Illinois River basin had the most studies; only one study was conducted in the Fox River basin. The taxa most commonly assessed were fish; only one study evaluated other organisms, aquatic macrophytes.

Table 3.--*Studies of the health of organisms in the upper Illinois River basin*

[F, Fox River; D, Des Plaines River; K, Kankakee River; I, Illinois River]

Literature citation	Basin				Taxa assessed		Effect assessed					
	F	D	K	I	Fish	Aquatic macrophytes	Disease	Condition factor	Physical malformation	Tumor incidence	Other	
Atwood (1984)				X	X				X			
Atwood (1987)				X	X		X		X			
Brown and others (1973)	X				X					X		
Cima (1980)		X			X		X	X	X		[1]X	
Ecological Analysts, Inc. (1980a)		X			X		X	X	X		[1]X	
Ecological Analysts, Inc. (1980b)				X	X		X	X	X		[1]X	
Ecological Analysts, Inc. (1981a)		X			X		X	X	X		[1]X	
Ecological Analysts, Inc. (1981b)				X	X		X	X	X		[1]X	
Ecological Analysts, Inc. (1981c)		X			X		X	X	X		[1]X	
Ecological Analysts, Inc. (1982a, 1982b)				X	X		X	X	X		[1]X	
Ecological Analysts, Inc. (1983a, 1983b)		X			X		X	X	X		[1]X	
Ecological Analysts, Inc. (1984b)				X	X		X	X	X		[1]X	
Emge and others (1974)		X		X	X			X	X			
Environmental Science and Engineering (1984)				X	X		X	X	X		[1]X	
Environmental Science and Engineering (1985a, 1985b)		X			X		X	X	X		[1]X	
Environmental Science and Engineering (1986a)				X	X		X	X	X		[1]X	
Environmental Science and Engineering (1986b)		X			X		X	X	X		[1]X	
Environmental Science and Engineering (1987a, 1987b)			X		X		X	X	X		[1]X	
Forbes and Richardson (1913)		X		X	X		X					
Havera and others (1980)				X	X		X		X			

Table 3.--*Studies of the health of organisms in the upper Illinois River basin*--Continued

Literature citation	Basin				Taxa assessed		Effect assessed					
	F	D	K	I	Fish	Aquatic macrophytes	Disease	Condition factor	Physical malformation	Tumor incidence	Other	
Jackson and others (1981)		X		X	X		X		X			
Kwak and Larimore (1987)			X		X		X	X	X		[1]X	
Langbein and Wight (1976)		X			X		X				[1]X	
Larimore and Skelly (1981)			X		X			X			[1]X	
Larimore and Kwak (1986)			X		X			X			[1]X	
Lubinski and Jackson (1985)				[2]X	X			X				
Mills and others (1966)		X		X	X		X	X	X			
Sallee (1987)				X	X			X				
Skelly and others (1982, 1984)			X		X			X			[1]X	
Skelly and others (1985)			X		X			X			[1]X	
Sparks (1984)		X		X	X			X				
Sparks and others (1986)		X				X					[3]X	
Sule and Larimore (1978)			X		X			X				
Sule and Larimore (1979)			X		X			X				
Sule and Larimore (1980)			X		X			X			[1]X	
Sule and Skelly (1985)			X		X			X			[1]X	
Thompson (1928)				X	X				X			
Total for Fox River--1 study					1	0	0	0	0	1	[1]0, [3]0	
Total for Des Plaines River--16 studies					15	1	13	12	12	0	[1]10, [3]1	
Total for Kankakee River--10 studies					10	0	1	10	1	0	[1]8, [3]0	
Total for Illinois River--20 studies					20	0	14	14	16	0	[1]9, [3]0	
Total for basins--42 studies					41	1	24	33	26	1	[1]27, [3]1	

[1]Incidence of parasitism.
[2]Downstream from study area.
[3]General condition.

The most commonly determined measure of fish health was condition factor, a measure of relative plumpness. This generally is a ratio between the standard length of a fish and its depth or weight. One method divides the depth into the length (Mills and others, 1966). An alternative condition factor (Skelly and others, 1985) is determined using the equation:

$$\frac{\text{weight (grams)} \times 100{,}000}{\text{total length (millimeters)}^3} \quad .$$

Mills and others (1966) conclude that pollution causes thinner fish, which reduces the commercial value. In addition to the studies listed in table 3, the Metropolitan Water Reclamation District of Greater Chicago has extensive data that could be used to calculate condition factor for fish collected in the Des Plaines and Fox River basins during the 1970's and 1980's. A large data base for temporal and geographic comparison of condition factor could be established if all existing data were compiled.

The frequency of tumors in fish has been compared for polluted watersheds and less polluted areas (Brown and others, 1973; Baumann and others, 1982). Because tumors are external and internal, comprehensive examinations of fish are required to evaluate tumor incidence. Histopathological examination also is required to determine if tumors are caused by cancer or other disease. Although external physical malformations have been noted in many studies in the study area (table 3), tumor incidence studies, as described, were only completed by Brown and others (1973) for the upper Illinois River basin. Tumor frequency surveys may be a valuable tool for assessing potential contaminant effects in and among basins or tributaries. A standard field and histological methodology for this assessment technique needs to be developed to facilitate interbasin comparisons.

The incidence of the physical malformation of carp termed "knothead" (Thompson, 1928) is an additional potential evaluation tool. This condition appears to be somewhat limited geographically to the lower Des Plaines and Illinois Rivers. However, exact causes for knothead are not known.

Toxicity Measurements

The toxicity studies completed in the study area are of two general types. The bioassay study subjects a test organism to a given environmental condition and measures short- or long-term effects that can vary from acute toxicity to no effect. The second type is the Ames salmonella/microsome bacterial reversion assay that measures mutagenesis and correlates this to carcinogenic potential (McCann and others, 1975; Ames, 1977; McCann and Ames, 1977; Johnson and Herron, 1979).

Bioassays have been completed for the study area using fish, fingernail clams, zooplankton, and algae (table 4). Static and flow-through bioassays have been completed by a number of researchers to assess water quality; toxicity to sediment has also been measured (Blodgett and others, 1984). The toxicity index using bluegill (Lubinski and others, 1974) also has been used by Brigham and others (1978) and by Lubinski and Sparks (1981).

Bioassays have been used to correlate biological effect, which is presumably associated with water-quality changes in the study area, with specific chemical constituents (Sandusky and others, 1979; Sparks and others, 1981; Sparks and Sandusky, 1983). Various agencies also use bioassays to measure effects of specific effluents on biological organisms (Roseboom and Richey, 1977; Illinois Environmental Protection Agency, 1986b; Indiana Department of Environmental Management, 1986; Schreiber, 1986; Simon, 1987). The majority of the studies cited in table 4 are for the Illinois River in and downstream from the study area; interbasin comparisons cannot be made at this time. Bioassays have potential as assessment devices; however, existing programs need to be coordinated, and specific goals for bioassay need to be identified before a basinwide bioassay assessment can be implemented.

The Ames test has been used in each of the major basins to measure the mutagenicity of the water (table 4). Relatively few samples in each basin have been completed, too few data to allow a comparison among geographical areas in the upper Illinois River basin. However, this testing methodology is practical for collecting a relatively large number of samples over a short period of time.

CONCLUSION

Although the results of various biological assessment measures that are used to evaluate water quality may vary, common trends among several methods may transcend inherent variability problems allowing for determination of relations between change in water quality and change in aquatic biology. Four general biological assessment categories were identified: Populations and community structure; chemical concentrations in tissue; organism health; and toxicity measurements. The upper Illinois River basin has a rich and diverse biological literature available that documents many biological effects related to water quality. However, because the data for the studies were collected and analyzed by a variety of methods, quantitative ecosystem-wide or basinwide evaluations are difficult to make.

Populations and community structure data are the most abundant for the study area. Population data for fish are more common than for any other taxon. Plankton, macroinvertebrate, and mussel data are also relatively common.

Chemical concentrations in fish tissue have been determined for PCB's, organochlorine pesticides, TCDD, and some metals. Tissue analyses are less extensive for other organisms. Testing for other contaminants has not been completed. Data on PCB's in fish are the most prevalent. Comparisons of concentrations of contaminants among basins for TCDD or metals are not possible because of insufficient data.

Condition factor of fish is the only organism health parameter having sufficient data for evaluation among basins at this time. Additional calculations of condition factor of fish can be made from length and weight data collected in other studies. Tumor incidence data are potentially valuable, but existing data are few. Other measures of organism health have potential for water-quality assessment but have not been widely used in the study area.

Table 4.--*Toxicity studies conducted in the upper Illinois River basin*

[F, Fox River; D, Des Plaines River; K, Kankakee River; I, Illinois River]

Literature citation	Basin				Organism tested			Fish kill	Laboratory test	Field test	Mutagenicity (Ames) test
	F	D	K	I	Fish	Fingernail clam	Other				
Anderson, K.B. (1977)				[1]X		X			X		
Anderson and others (1978)				[1]X		X			X		
Blodgett and others (1984)		X		X		X			[2]X		
Brigham and others (1978)	X	X	X		[3]X				X		
Clark and Johnston (1982)		X		X			[4]X		X		X
Illinois Environmental Protection Agency (1986b)	X		X	X	X			X		X	
Indiana Department of Environmental Management (1986)			X				[5]X		X		
Indiana Stream Pollution Control Board (1984)			X					X			
Indiana Stream Pollution Control Board (1985)		X	X				[5]X		X		
Johnston and Herron (1979)	X			[1]X			[4]X		X		X
Langbein and Wight (1976)		X						X			
Lubinski and others (1974)		X	X	X	[3]X				X	X	
Lubinski and Sparks (1981)		X		X	[3]X				X		
Metropolitan Sanitary District of Greater Chicago (1986)		X					[4]X				X
Paparo and Sparks (1977)				X		X			X		

Table 4.--*Toxicity studies conducted in the upper Illinois River basin*--Continued

Literature citation	Basin				Organism tested			Fish kill	Laboratory test	Field test	Mutagenicity (Ames) test
	F	D	K	I	Fish	Fingernail clam	Other				
Sandusky and others (1979)				[1]X		X			X		
Schreiber (1986)	X	X			X		[4,6]X		X		X
Simon (1987)		X	X	X	X		[4,5,7]X		X		X
Sparks (1984)				X		X			X		
Sparks and Sandusky (1983)				[1]X		X			X		
Sparks and others (1981)				[1]X		X			X		
Total for Fox River--4 studies					3	0	2	1	3	1	2
Total for Des Plaines River--10 studies					5	1	5	1	8	0	3
Total for Kankakee River--7 studies					4	0	3	2	6	2	1
Total for Illinois River--14 studies					4	8	3	1	13	1	3
Total for basin--21 studies					6	8	7	3	16	2	5

[1]Downstream from study area.
[2]Sediment toxicity measured.
[3]Bluegill toxicity index, described in Lubinski and others (1974).
[4]Bacteria used in Ames test.
[5]*Daphnia magna* or *Daphnia pulex*.
[6]*Ceriodaphnia* sp.
[7]Algal assay.

Toxicity studies in the upper Illinois River basin consist of various acute and chronic bioassay tests and the Ames test for mutagenicity. Bioassays have been used to evaluate water-quality impacts on biota but need to be more fully coordinated for an overall basinwide assessment. Ames tests are potentially useful, but there currently are few data for the study area.

Basinwide assessment of the response of aquatic biological communities to change in water quality is one aspect of NAWQA. An effectual biological assessment program will require expansion of current biological data-collection programs and cooperation among concerned agencies to develop and use consistently standardized data-collection methodologies.

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