Assessing Risks to Aquatic Resources of the Fox River Drainage: Availability of Aquatic Resources Data and Refining Predicted Distributions of Aquatic Species

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This report is a compilation of information gleaned from agency websites, reports, databases, and through email requests, and phone and in-person interviews. Descriptions were taken nearly verbatim from these sources, although in some instances we made editorial changes as deemed necessary and appropriate. We have made every attempt to cite and acknowledge those references. Only the maps (with the exception of the BSC map) and associated summaries, analysis of ammonia concentrations on the Fox River, development of predicted distributions for aquatic species, and the compilation of the information contained herein represent original works by the authors.

This report represents part of a larger project co-funded by the Illinois Waste Management and Research Center and the Division of Resource Review and Coordination of the Office of Realty and Environmental Planning, Illinois Department of Natural Resources.
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Introduction

A need exists for information which would facilitate rapid assessment of risks to aquatic life. This is especially time critical in areas such as the Fox River drainage where an expanding human population and rapid development threaten aquatic systems. We have been developing a GIS user interface created using GIS technology and expertise to enhance the ecological risk assessment by allowing rapid access to information on species distributions and ancillary information such as location of nature preserves, wetlands and streams, Toxic Release Inventory and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or “Superfund”) sites. To date this pilot effort has involved the creation of predicted species distribution databases for a number of terrestrial and aquatic species known to occur in Kane, Du Page, Will, Kendall, Grundy, and Kankakee counties. The predicted distributions are based on locational data such as records from museum collections and habitat associations determined from scientific literature for each species. For terrestrial species, the habitat associations for each species were assigned to appropriate land cover categories from our most current vegetation classifications for determining predicted distributions.

Through the development of this pilot project and discussions with Illinois Department of Natural Resources Division of Resource Review and Coordination staff, it became apparent that there is a need to further refine aquatic species predicted distributions (e.g. below the sub-watershed level) to facilitate rapid assessment of potential risks to aquatic life in the event of a contaminant release or should a permitting issue arise. A comprehensive streams classification would allow the refinement the predicted distribution of aquatic species below the hydrologic unit level (1:250,000 scale). Our objectives in this portion of the pilot study were to 1) locate and map the locations of water quality monitoring stations and aquatic animal specimen collection sites in the Fox River drainage, 2) identify streams classification systems and utilize an existing classification to attempt to refine the predicted distribution of selected aquatic species inhabiting the Fox River drainage in our pilot area, 3) test the accuracy of predicted distributions for selected aquatic species using existing locality information from Illinois Natural History Survey (INHS) aquatic collections, and 4) determine whether existing data are adequate to be incorporated into an eco-risk tool designed to predict the occurrence of aquatic species.

There is continuing concern about degradation of water quality and related threats to the aquatic resources of the Fox River, amid increased development pressures in this area. Ammonia discharge and permitting issues pertaining to the Fox River and other Illinois waterways are controversial (e.g. see http://www.elpc.org/forest/water/ammonia.htm). We evaluated ammonia nitrogen and unionized ammonia concentrations recorded in 1997 and 1998 at two water quality monitoring stations in the Fox River drainage. These concentrations were compared with critical concentrations of ammonia protective of aquatic life and allowable concentrations of ammonia nitrogen per state statute.
Water Quality Monitoring

a) The Illinois Environmental Protection Agency maintains 125 stations in the Fox River drainage in Illinois (Fig 1). These stations were established under the programs described below (see Surface Water Quality Monitoring and Assessment Programs, River and Stream Monitoring at www.epa.state.il.us/water/surface-water/river-stream-mon.html). A variety of water quality data are collected at these stations, and may include standard water quality/quantity measurements such as discharge and velocity, temperature, turbidity, dissolved oxygen, pH, hardness, dissolved solids, N, Ca, and P, contaminants such as ammonia, elements from As to Zn, fecal bacteria, oils and grease, polynuclear aromatic hydrocarbons, radioactive isotopes, and a variety of organic solvents and other compounds in water and/or sediments. Additionally, fish tissues are analyzed for 20 pesticides and PCB isomers, and in some cases mercury and dioxins. Selected sites may include habitat parameters such as substrate and instream cover, channel morphology, and riparian features, a Macroinvertebrate Biotic Index which reflects the presence and abundance of macroinvertebrate taxa and their tolerance to pollution and other impacts on water/habitat quality, and an Index of Biotic Integrity, a measure of fish community structure, trophic guilds, health, and environmental tolerance.

The parameters measured at each station depends on the program under which that station was established and perceived need at a particular site. Water quality and related data collected under these programs are stored at http://www.epa.gov/storet/.

Ambient Water Quality Monitoring Network
Illinois EPA operates an Ambient Water Quality Monitoring Network (AWQMN) consisting of 213 fixed stations to support surface water chemistry data needs. Integrated water column samples are collected on a six week sampling frequency and analyzed for a minimum of 55 universal parameters including field pH, temperature, specific conductance, dissolved oxygen, suspended solids, nutrients, fecal coliform bacteria, and total and dissolved heavy metals. Additional parameters specific for the station, watershed, and/or subnetwork within the ambient network are also analyzed. Major subnetworks include a pesticide monitoring subnetwork, an industrial solvents subnetwork, and a mining subnetwork. Where stream flow is available from the US Geological Survey water quality data are analyzed for flow-adjusted water quality trends.


Pesticide Monitoring Subnetwork
Since October 1985, Illinois EPA has operated a Pesticide Monitoring Subnetwork to expand screening for toxic organic substances. Fifteen common herbicides and organophosphate insecticides currently used in agricultural production practices are included for water column analysis. The Pesticide Monitoring Subnetwork consists of 30 AWQMN stations that are
adjusted annually to provide additional monitoring coverage in conjunction with the Intensive Basin Survey program. Sampling is conducted during three of the nine AWQMN sampling cycles and consists of one pre-application collection (March to mid-April) and two samples collected in the post application period (mid-April to July). Post pesticide application collections are coordinated with farming activities occurring locally near the AWQMN collection site.

**Facility-Related Stream Surveys**
Illinois EPA conducts Facility-Related Stream Surveys consisting of the collection of macroinvertebrate, water chemistry, stream flow and habitat data upstream and incrementally downstream from municipal and industrial wastewater treatment facility discharges. Facility-
Related Stream Survey information is used to evaluate water quality impacts and the need for additional wastewater treatment controls. Data are also used to characterize the existing and potential aquatic resource of the receiving stream, determine whether there is significant biological impact on the receiving stream and to support the Bureau of Water's National Pollutant Discharge Elimination System permit reissuance activities.

**Intensive River Basin Surveys**

Intensive river basin surveys are conducted on a five-year rotational basis in cooperation with the Illinois Department of Natural Resources (IDNR). These intensive river basin surveys are a major source of information for annual 305(b) assessments. Illinois has 33 major river basins within its borders. Stations sampled by Illinois EPA (IEPA) and IDNR are selected on the basis of where intensive data are currently lacking or historical data need updating. Water chemistry and biological (fish and macroinvertebrate) data along with qualitative and quantitative instream habitat information including stream discharge are collected to characterize stream segments within the basin, identify water quality conditions, and evaluate aquatic life use impairment. Fish tissue contaminant and sediment chemistry sampling are also conducted to screen for the accumulation of toxic substances.

**Toxicity Testing Program**

The Agency has used toxicity testing as a form of environmental exposure and physiological toxicity monitoring for approximately 15 years. The Bureau of Water (BOW) utilizes toxicity/bioassay information for identifying municipal and industrial wastewaters that have potential for toxic chemical contaminants and toxicity to aquatic life in receiving waters. Toxicity testing also supports BOW Permitting and emergency response activities, and assists in the identification of streams selected for biological monitoring in conjunction with the Agency's Facility Related Stream Survey program.

**Fish Contaminant Monitoring Program**

Fish samples collected at intensive river basin survey stations are analyzed for 14 chemical contaminants as part of the Fish Contaminant Monitoring Program. Fish samples are collected and analyzed from approximately 50 stations on Illinois' rivers and streams on an annual basis.

**Biocriteria Development**

Biocriteria are numerical values or narrative expressions that set the standard or attainment goals for biological communities. In Illinois these biocriteria or "biological expectations" are based on a regional reference site approach that enables within-region comparisons between the aquatic community at any stream site and the reference expectation. The regional reference site approach is a key component of biocriteria which ensures reasonably attainable biological goals that recognize and account for the unique combination of regional land form, land use, and physical habitat characteristics which influence the distribution of fish, macroinvertebrates and other aquatic organisms. Illinois is currently developing this framework, which includes refinement of existing biological assessment tools and, where needed, development of new state-of-the-art monitoring approaches. Illinois EPA is working with the Illinois Department of Natural
Resources (IL DNR), US EPA, members of the agricultural, industrial, academic and regulated communities as well as outside contractors and other interested parties to develop biological criteria (biocriteria) for streams and rivers. This approach to biocriteria will enable Illinois EPA to better assess the ecological/environmental quality of Illinois rivers and streams and should allow the Agency to continue to update and refine the stream use designations contained in Illinois' water quality standards.

b) The US Geological Survey’s National Water-Quality Assessment Program (http://water.usgs.gov/nawqa/NAWQA_OFR94-70.html) is designed to assess historical, current, and future water-quality conditions in representative river basins and aquifers nationwide. One of the primary objectives of the program is to describe relations between natural factors, human activities, and water-quality conditions and to define those factors that most affect water quality in different parts of the Nation. The linkage of water quality to environmental processes is of fundamental importance to water-resource managers, planners, and policy makers. It provides a strong and unbiased basis for better decision making by those responsible for making decisions that affect our water resources, including the United States Congress, Federal, State, and local agencies, environmental groups, and industry. Information from the NAWQA Program also will be useful for guiding research, monitoring, and regulatory activities in cost effective ways. The NAWQA Program's unique design provides consistent and comparable information on water resources in 60 important river basins and aquifers across the Nation. Together, these areas account for 60 to 70 percent of the Nation's water use and population served by public water supplies and cover about one-half of the land area of the Nation. Investigations of these 60 areas, referred to as "study units," are the principal building blocks of the NAWQA Program. Illinois contains 2 such Study Units, the Upper (URB) and Lower (LRB) Illinois River Basins (http://infothek erased.usgs.gov/pls/nawqa/nawqa_web_main_gohome).

In the National Water Quality Assessment (NAWQA) program, surface water activities focus on assessing physical and chemical characteristics of streamwater, including physical parameters, suspended sediment, dissolved solids, major ions and metals, nutrients, organic carbon, and dissolved pesticides, and relating these characteristics to hydrologic conditions, sources, and transport. The program also includes selected studies of other water-quality conditions, such as dissolved oxygen and pathogenic bacteria, where they are likely to be important. Bed-Sediment and Fish Tissue Studies are the primary means by which trace elements and hydrophobic (not dissolved in water) organic contaminants are initially assessed in NAWQA. Concentrations of these compounds and their areal distribution are assessed to identify potential sources and needs for more detailed study. Data for concentrations in bed sediment and fish tissue collected at the same sites are used for an initial assessment of biological availability. When a compound is found in both the bed sediment and the fish tissue, the compound is considered biologically available.

The Upper Illinois River Basin study unit is one of 14 NAWQA studies that began in Federal Fiscal Year 1997. Study-unit planning and design, and analysis of available data will be completed during the first 2 years. After the 2-year planning and retrospective analysis period,
surface-water, ground-water, and biological data are collected intensively for 3 years (termed the high-intensity phase). A low-intensity phase follows for 6 years, during which water quality is monitored at fewer sites and areas than were assessed during the high-intensity phase. This combination of high- and low-intensity monitoring phases allows the NAWQA Program to examine trends in water quality and biota over time.

During the planning period, available data and results from previous studies in the study unit are reviewed to understand the primary physical, chemical, and biological factors that affect water quality in the study unit and to identify gaps in the available data. Descriptions of how land use and land cover, soils, geology, physiography, climate, and drainage characteristics may affect water quality are to be included in reports. Information obtained from reviews of previous studies, field checks of available monitoring stations and candidate sampling sites, and field reconnaissance data are used to design a sampling program for the study unit.

During the high-intensity phase, chemical, physical, and biological data are collected at local and regional scales to describe the water quality throughout the study unit. Measurements are made to determine water chemistry in streams and aquifers; the quantity of suspended sediment and the quality of bottom sediments in streams; the variety and number of fish, benthic invertebrates, and algae in streams; and the presence of any contaminants in fish tissues. Specific streams and aquifers, chemical compounds, and biological species are selected for sampling to represent the important water resources and water-quality concerns in the study unit and the Nation. A series of reports describing results of retrospective, and high- and low-intensity-phase data collection and analysis are planned.

The national study design for surface waters focuses on water-quality conditions in streams using three interrelated components: water-column studies, bed-sediment and fish-tissue studies, and ecological studies. Water-column studies monitor physical and chemical characteristics, which include suspended sediment, major ions, nutrients, organic carbon, and dissolved pesticides, and their relation to hydrologic conditions, sources, and transport. Most surface water is monitored at sites termed either basic-fixed sites or intensive-fixed sites according to the frequency of the sampling. The sampling sites are selected to determine the water quality in relation to important environmental settings in the study unit. Most NAWQA study units have 8-10 basic-fixed and 2-3 intensive-fixed sites. Basic-fixed sites are sampled monthly and at high stream flows for 2 years of the 3-year high-intensity phase. The intensive-fixed sites are monitored more frequently (as often as weekly during key time periods) for at least 1 year to characterize short-term variations of water quality. Basic-fixed or intensive-fixed sites can be either indicator or integrator sites. Indicator sites represent relatively homogeneous, small basins (less than 100 square miles) associated with specific environmental settings, such as a particular land use that substantially affects water quality in the study unit. Integrator sites are established at downstream points in large (thousands of square miles), relatively heterogeneous drainage basins with complex combinations of environmental settings. Indicator sites typically are located in the drainage basins of integrator sites. Water samples also are collected as part of synoptic (short-term) investigations of specific water-quality conditions or issues during a specific hydrologic
period (for example, during low streamflow) to provide greater spatial coverage and to allow investigators to assess whether the basic-fixed or intensive-fixed sites are representative of streams throughout the study unit. Bed-sediment and fish-tissue studies assess trace elements and hydrophobic organic contaminants at 15-30 sites to determine their occurrence and distribution in the study unit. (from http://il.water.usgs.gov/nawqa/uirb/pubs/reports/FS-072-98/index.html)

There are a total of 24 NAWQA sites in the Fox River drainage (Fig. 2). Most of these are water quantity measurement stations, with data on discharge, water stage, and precipitation going back nearly to the turn of the 20th century in some cases. During the high intensity phase of the NAWQA program (1999-2001), fish and macroinvertebrate communities, contaminants in fish tissue and bed sediments, and physical and chemical measures of water quality are collected at

![USGS National Water Quality Assessment Sites](image)
one station in the Fox River drainage, Nippersink Creek above Wonder Lake (Fig. 2), as well as on the Illinois River at Ottawa, near its confluence with the Fox River. The Nippersink Creek site will not be sampled as part of the low intensity phase (2002-2007), when fewer sites within study units are sampled. A second high-intensity phase is scheduled for 2008-2010. Data collected at monitoring stations in the UIRB and LIRB Study Units can be accessed at (http://infotrek.er.usgs.gov/pls/nawqa/nawqa.wwv_main.gohome or http://il.water.usgs.gov/annrep_2000/start.htm.

c) The Critical Trends Assessment Program (CTAP) (http://dnr.state.il.us/orep/inrin/ctap/) is an on-going process to evaluate the state of the Illinois environment. It also provides scientific support for the Ecosystems Program under Conservation 2000, a multi-year initiative to preserve and restore Illinois ecosystems. The primary goal of CTAP is to conduct statewide & regional assessments of environmental conditions. But when CTAP's first statewide assessment was completed in 1994, scientists reported that there was not enough data available to adequately assess ecosystem health. To rectify this situation CTAP has developed methods such as land cover mapping and scientist and volunteer monitoring to systematically collect data and monitor ecosystems throughout the state.

Intensive sampling of invertebrate and fish communities using CTAP protocols was conducted by INHS scientists on 30 randomly-selected stream segments each year during 1997-2000; this included 4 sites in the Fox River drainage (Fig. 3). Monitoring is conducted on a 5-year cycle, e.g. 30 segments sampled in 1997 will again be sampled in 2002. Mayfly, stonefly, caddisfly, and fish specimens are preserved, identified, vouchered, and deposited into the appropriate INHS collections. Water quality parameters such as temperature, dissolved oxygen, turbidity, and algal growth, and aquatic and streamside habitat parameters such as bottom substrate, streamside vegetation, channel characteristics, and important watershed components are also recorded. Data are available through appropriate INHS scientists and collections managers.

Illinois RiverWatch (http://dnr.state.il.us/orep/inrin/ecowatch/river/intro.htm) is the stream monitoring component of the Illinois EcoWatch Network, a volunteer monitoring initiative coordinated through the Illinois Department of Natural Resources (IDNR). As Citizen Scientists, RiverWatch (RW) volunteers conduct biological monitoring and stream habitat surveys on wadeable Illinois streams. Citizen Scientists not only learn about the ecology of stream ecosystems, but play a direct role in monitoring the health of their local river or stream.

RW uses several indices to estimate the quality of Illinois streams. The RW Macorinvertebrate Biotic Index (MBI) is an index that rates stream health using 1) an organism's tolerance to pollution and 2) sample density. The lower the MBI value the better the stream quality. Other stream indices that are utilized by RW include sample density, taxon richness, EPT taxa (the number of mayfly, stonefly and caddisfly taxa), and the percent of selected indicator organisms, which is comprised of the EPT taxa mentioned previously but also includes bloodworm and aquatic worm taxa. Taxon richness is an important measurement of stream biodiversity.
Typically, as taxon richness increases so does stream quality. EPT taxa are generally considered to be intolerant to pollution and habitat degradation while bloodworms and aquatic worms are highly tolerant of pollution and habitat degradation. Therefore, streams with high numbers of EPT taxa and low numbers of bloodworms and aquatic worms tend to have greater biological integrity and health compared to streams with low EPT taxa richness and a high incidence of pollution tolerant taxa. Finally, volunteers collect valuable information on the statewide occurrence and distribution of species of special interest including native mussels and exotic species, such as the zebra mussel.

During the period 1995-2000, RiverWatch Citizen Scientists conducted monitoring of 51 sites in the Fox River drainage (Fig.3); these data are available at http://dnr.state.il.us/orep/inrin/ecowatch/river/data1.htm

![Critical Trends Assessment Project Riverwatch Sites](image)
Streams Classifications

a) Assessment of Streams and Watersheds in Illinois: Development of a Stream Classification System and Fish Sampling Protocols - Illinois Department of Natural Resources and Illinois Environmental Protection Agency

The Illinois Natural History Survey and the Watersheds Management Program of the Illinois Department of Natural Resources, along with the Illinois Environmental Protection Agency, are currently developing a statewide streams classification system based on a model used in Michigan (see Seelbach et al., 1997). This classification system is based on the identification of river valley segment units, determination of physical and biological attributes of segments, and development of a GIS database for the classification system. Objectives are to develop a system to delineate segments of Illinois streams and classify those segments (R. Smoger and S. Kohler, INHS, funded research proposal). Stream segment boundaries are delineated based on physical characteristics such as stream junctions, changes in slope, physiographic or land cover unit boundaries, changes in meander, and groundwater source. Physical (e.g. catchment size, water chemistry, channel character) and biological (e.g. fish assemblages) attributes are then assigned to each segment. This information will then be stored in a GIS format.

At the time of this report, project personnel have attributed each arc with upstream and downstream connectivity, gradient, and average elevation. The next step is to define catchments (i.e. watersheds) which can be used to clip out geology and landcover. Once clipped these would then be attributed to each arc as well. It was anticipated that most of the attributes would be generated in the next few months. After the attributes are generated, project staff will investigate the relationships between attributes and fish community data. As this is to be an ecological classification, streams will be classified using the variables that most relate to fish. All other attributes will remain in the attribute table for further stratification of stream types. Key project staff will meet with agency experts this winter to assign meaningful cuts to each attribute class (e.g., what is low, medium, high gradient) (A. Holtrop, INHS, personal communication).

For more information pertaining to this project contact Ann Holtrop, Streams Ecologist, INHS, 217/785-4325 ahogan@dnrmail.state.il.us


The aquatic communities of the Illinois River watershed were classified and used in a conservation planning effort undertaken by The Nature Conservancy of Illinois. Aquatic communities were described within a physical and biological framework. Stream reaches, or valley segments, were delineated and characterized using existing mapped information and GIS. For each valley segment, descriptive information including geology, size, connectivity, hydrology, gradient, and valley type were recorded. In the Illinois River watershed, four attributes (size, connectivity, hydrology, and gradient) were characterized based on existing variation and perceived biological significance. These categories were then combined for a total of 103
macrohabitat types. Lakes (>10 ha) were described by the categories of genesis, hydrology, size, and connectivity. A total of 36 lake macrohabitat types were identified. Patterns in stream fish distributions were assessed using iterative cluster analysis resulting in the identification of seven biological communities. Comparison of the macrohabitat classification showed that fish were primarily distributed along gradients of hydrology, size, and connectivity. Priority zones were delineated around aggregations of diverse, high quality stream segments. These zones were refined based on expert review and additional information including the distributions of targeted species and terrestrial communities. These zones became the basis for conservation planning in the Illinois River watershed. (taken from Miller et al., 1998).

The Illinois River basin was one of the first of the nation’s watersheds to be classified. Since its completion in 1998, the classification has been applied to watersheds throughout North America using improved methods available through new technology. The current Illinois River classification is similar to the original, although improvements have been made to the way the attributes (gradient, size, etc.) are assigned to the stream arcs that allow the classification to be much more flexible and user friendly, using a combination of ArcInfo scripts and Visual Basic programs (Michele DePhilip, personal communication). They are publicly available at www.freshwaters.org (TNC Freshwater Initiative site); contact Tom FitzHugh (tfitzhugh@tnc.org) for more information.

For more information about TNC’s Illinois River Watershed streams classification contact Jonathan Higgins, (312) 759-8017, jhiggins@tnc.org

c) Biological Streams Classification: Biological Assessment of Illinois Stream Quality through 1993. Biological Streams Characterization Work Group, Illinois Department of Natural Resources and Illinois Environmental Protection Agency

The Biological Streams Characterization (BSC) is a multi-tiered stream quality classification based primarily on the attributes of lotic fish communities. The predominant stream quality indicator used in this process is the Index of Biotic Integrity (IBI), comprising of 12 metrics, which form a basis for describing the health or integrity of the fish community. When insufficient fishery data are available for calculating an IBI value, BSC criteria allow the use of sport fish information or macroinvertebrate data to rate streams.

BSC provides a uniform process of characterizing streams statewide and is used by a variety of sources for stream protection, restoration, and planning efforts. It is a key component for defining Illinois stream quality and has a role in the development of subecoregions for the implementation of biocriteria by the Illinois EPA. The ongoing activities of the BSC Work Group constitute an integral element of stream assessment and protection efforts in Illinois.

As of 1993, a total of 13,522 stream miles had been rated. Of these streams, 612 miles have been classified as Unique Aquatic Resource (Class A) streams. Based upon the fish community, these streams are considered to be of exceptional quality. Highly Valued Aquatic Resource streams...
(Class B) totaled 4,545 miles; these areas of high biodiversity typically function as sources for recolonization of lower quality areas such as Class C streams (6,748 miles). Streams rated as Class D (1,551 miles) or Class E (65 miles) are impaired by some combination of water quality or habitat degradation.

The BSC process and statewide streams ratings serve as a valuable tool for natural resource management by state natural resource and regulatory agencies. The increasing demands placed upon our aquatic systems require that stream quality information be readily available for a wide range of management decisions. The BSC process provides a means of integrating the relative quality of aquatic resources to planners, engineers, and non-fisheries biologists, as well as a standard by which stream quality can be measured. This process requires the continued collection of high-quality, quantitative, community-based fisheries data for the most comprehensive stream quality assessments. BSC ratings of streams in northeastern Illinois, including the Fox River drainage, are depicted in Figure 4; the Fox River watershed contains one A- and numerous B- and C-rated streams.

For more information on the Illinois BSC contact Bob Hite, Illinois IEPA (EPA1426@epa.state.il.us), or Dave Day, IDNR (DDAY@dnrmail.state.il.us).
The Illinois Streams Information System (ISIS) project collected data associated with Illinois streams that drain 10 square miles or more. Various types of data were collected, locations of data points along the stream channels were determined, and the data were recorded into a computer database. The database and a mapping facility combine to provide the user with a powerful search, analysis, and visualization tool.

For the purposes of ISIS, the State of Illinois was divided into 10 river basins. In addition, three major rivers (Mississippi, Illinois, and Wabash) were classified as separate basins for data collection purposes. Data were originally collected basin by basin across the state and across a 10-year period of time (1981-91). Some data types were collected statewide, and others were collected for only some of the basins. Key data types were updated in 1995-97. This ISIS user's manual serves as a reference tool for anyone interested in requesting information from the database. It describes each type of data and includes a discussion of collection procedures, an annotated list of data elements collected for the data type, and a list of rivers for which the data type was collected. With this information in hand, the potential user should be familiar enough with the data to describe a knowledgeable query that can be answered by the database.

Data collection methods varied somewhat for each data type, however some procedures were quite standard for nearly all types of data. Unless otherwise noted, all data collection, entry, and verification were carried out by ISIS staff at the University of Illinois. Data were only collected for areas inside the state boundaries. For most data types, an original source (aerial photos, survey forms, National Register of Historic Sites, etc.) was located for the data and site locations were recorded on one of two mylar overlays of U.S. Geological Survey 7.5 minute topographic maps (one overlay for banks land cover and one for the other data types). River mileages (to the nearest 0.1 mile) were determined for the sites on the overlays and then data were entered into the computerized database. Information was based on the original source and the topographic map. Computer output was verified (usually twice) by comparing it to the data source.

Another feature of the ISIS project is the ability to map occurrences of the various data types along each stream. The mapping portion of ISIS combines the information from the ISIS database with a cartographic database of stream center line coordinates. The resulting plotting information is then mapped through the aid of the ArcView program. ISIS is capable of mapping point data as well as reach data. Each map can display multiple data types and intersections of information between data types.

As with all natural systems, streams are constantly changing. Channels change. Streams are dammed. Other streamside sites (natural areas, recreation areas, etc.) may have been abandoned, reshaped, or newly built since the data were collected. Source dates were collected with most data types so the user can determine the age of the data.
Data included in ISIS: boat access sites, bankside land cover, cross index between fish species data from IDNR Streams Database and US EPA STORET database, highway and railroad bridges, BSC A-rated stream segments, channelized stream segment data, county boundaries, dams, elevations, data on fish kills, historic sites, lake endpoints, levees, descriptive information about each stream (e.g. stream ID, watershed numbers, basin codes, stream name, divide, and length), natural areas, stream order, state entry and exit points, USGS topo quads, public recreation sites, actual and potential recreational use of streams, IEPA, IDNR, USGS sampling stations, tributaries, township, range, and section, segments recognized by Nationwide Rivers Inventory.

For additional information about the Illinois Streams Information System project, contact the Project Coordinator, David Day, IDNR Watershed Management Section, at 217/785-5907.


The objective of this study was to identify the state's most biologically significant streams so that protection efforts can be concentrated on a reasonable number of streams and the objective of protecting 100% of Illinois' stream-dependent biodiversity can be realized. In this effort, the state was divided into 25 regions encompassing one large river, a river system, or several small river systems. To identify the most biologically significant streams, the authors located those supporting populations of federal or state threatened, endangered, and "watch list" species, and those with the highest fish (Biological Streams Classification "A" streams) and mussel diversity. Threatened and endangered species lists and watch lists are based on statewide surveys of organisms, and the only aquatic groups for which recent statewide surveys had been conducted (or are being conducted) are fishes, mussels, crayfishes, and vascular plants. Although data on additional groups would refine their analysis, the authors argued that healthy streams tend to have high diversity in many groups of organisms and that protecting the streams identified through this effort will have the effect of protecting a majority of the aquatic biodiversity of Illinois.

To identify streams supporting populations of threatened, endangered, and watch list species, the authors identified streams and stream segments from which one or more threatened, endangered, or watch list species have been observed since 1950 or, for lotic plants, since 1900. The exact locations of known populations of these species are stored on computerized databases at the Illinois Natural History Survey. Streams on this list were assumed still to support threatened, endangered, or watch list species if the species have been observed there since 1980. If a threatened, endangered, or watch list species was recorded from the stream but has not been observed there since 1980, the stream was resampled in 1990-91 in an effort to determine whether the population still existed. If a species has been recorded since 1980, the stream in which it is found is placed on the list of biologically significant streams. In addition to the consideration of threatened, endangered, and watch list species, some stream segments were identified as biologically significant based on mussel diversity. However, recent diversity data
(post-1976) on mussel populations have been collected for only eight of the 25 drainage regions: Kankakee River, Kaskaskia River, Vermilion River, Embarras River, Mackinaw River, Little Wabash River, Wabash River, and Sangamon River. One hundred and eight streams supporting populations of endangered, threatened and watch list species or supporting a high diversity of mussels were identified. These streams plus the 24 streams identified as "A" streams in the BSC classification brings to 132 the number of biologically significant streams recognized in this report.

Locations for collections and historical observations of threatened and endangered lotic plant species were obtained from herbarium data compiled by the Natural Land Institute in 1977 during the preparation of the original list of threatened and endangered species. Files compiled by the Illinois Natural Areas Inventory during 1975-1978 and maintained by the Illinois Department of Conservation Natural Heritage Division were used, as was the Illinois Plant Information Network (ILPIN). ILPIN is a data base developed by the Illinois Natural History Survey on the ecology, biology, distribution, taxonomy, and literature of 3200 plant species in Illinois. Using records back to 1900, each location known for threatened and endangered lotic plant species was visited during 1990 and 1991 to search for extant populations.

The distributional data on mussels were based only on specimens vouched in the Mollusk Collection of the Illinois Natural History Survey (INHS), Champaign, Illinois, or the following collections: the Academy of Natural Science of Philadelphia (ANSP), Chicago Academy of Science (CHAS), Field Museum of Natural History, Chicago (FMNH), Illinois State Museum (ISM), Museum of Comparative Zoology - Harvard University (MCZ), Ohio State University Museum of Zoology (OSUM), University of Illinois Museum of Natural History (UIMNH), University of Michigan Museum of Zoology (UMMZ), and the United States National Museum (USNM).

Biologically significant streams in the Fox River watershed are identified in Figure 5. These included the Fox River from Morgan Creek to its confluence with the Illinois River, an unnamed tributary at Yorkville, North Branch Nippersink Creek, Buck Creek (a BSC "A" rated stream), and 14 lakes. Although this study was directed at streams of Illinois, lakes in the Fox River system are included because of the many connections between the lakes and streams. Through their course, the Fox River and its tributaries wind through many of the lakes, and it is obvious that populations in the lakes have immediate access to the streams.

For more information on Biologically Significant Illinois Streams contact Kevin Cummings at the Illinois Natural History Survey (kscummin@uiuc.edu); for copies of the report, contact Angie Young (ayoung@inhs.uiuc.edu).
Biologically Significant Illinois Streams

Figure 5.

f) Fisheries Analysis System - Illinois Department of Natural Resources

The Fisheries Analysis System for Streams contains data collected as part of regularly scheduled basin surveys, monitoring and special projects (e.g., habitat or stocking programs) (D. Day, IDNR, personal communication). Currently the system holds 2,871 samples (243,508 records) collected from the Illinois River and interior streams, between 1952 and 1999. An additional 1,607 samples containing 158,997 records are available from the boundary rivers (Mississippi, Wabash and Ohio Rivers), collected from 1959-1997. (Note: A record may represent more than one fish as in the following example: Blunt-nose minnow N=5, L=45-55 mm; Total weight 5 grms.). Data from 46 stations in the Fox River basin are contained in 100 samples collected from 1974-1996. Cumulatively, these samples contain comprising 91 fish species.

For more information about FAS, contact Dave Day, IDNR Watershed Management Section, at 217/785-5907.
Aquatic Animal Collections

a) Fish

A large part of the Illinois Natural History Fish Collection (http://www.inhs.uiuc.edu/cbd/collections/fish.html) comes from specimens collected from 1880 to 1905 for S.A. Forbes and R.E. Richardson's "The Fishes of Illinois" published in 1908 and from specimens collected from 1950 to 1978 for P.W. Smith's "The Fishes of Illinois" published in 1979. The collection contains approximately 800,000 catalogued specimens, which makes it about the 15th largest collection of preserved fishes in North America. The geographic scope of the collection is about 51% from Illinois, 30% from elsewhere in North America, 18% from South America, and 1% from the rest of the world.

As of March 10, 2001, the INHS fish collection contained 45,232 lots from Illinois, representing 278 species. This included 2,090 lots of 108 species collected at 214 locations in the Fox River Drainage (Fig. 6).
A searchable online database is available at http://www.inhs.uiuc.edu/cbd/collections/fish.html. In addition to material collected by INHS scientists, the INHS fish collection contains voucher species from NAWQA activities, as well as more recent specimens from IDNR Fisheries regularly scheduled basin surveys, monitoring efforts, and special projects. For more information regarding the INHS Fish Collection contact Mike Retzer, Collections Manager (mretzer@mail.inhs.uiuc.edu), or Chris Mayer, Collections Database Manager (cmayer@mail.inhs.uiuc.edu)

Other fish collections containing a substantial amount of Illinois material include:

**Southern Illinois University at Carbondale Fluid Vertebrate Collection, Division of Fishes**

At the time of this report the SIUC collection housed 42,648 fish lots containing approximately 426,000 specimens and 1,470 species. This included 11,976 computerized lots representing 130,000 to 150,000 specimens collected from throughout Illinois. This collection contained 191 lots containing 570 specimens representing 69 species collected at 25 locations in the Fox River Drainage (Fig. 7).
For more information on this collection contact Brooks Burr, Curator (bburr@siu.edu), or Jeff Stewart, Manager (jstewart@siu.edu).

Field Museum of Natural History
The searchable online fish collection database (http://www.fmnh.org/fishes/fish_search.asp) contains ~ 88,000 records, including 3,892 records from Illinois and 18 from the Fox River drainage. For more information contact Mary Anne Rogers at rogers@fieldmuseum.org

Illinois State Museum
The ISM collection contains 2,563 fish skeletons, including 1,362 from Illinois. For more information contact Rick Purdue at purdue@museum.state.il.us

National Museum of Natural History
The US National Museum of Natural History Fish Collection database can be searched at http://www.nmnh.si.edu/vert/fishcat/. This database contains 250,000 records, 311 of which are older (pre-1972) records from Illinois. For more information contact Jeff Williams at williams.jeff@nmnh.si.edu

b) Mollusks

The Illinois Natural History Survey Mollusk Collection contains over 105,400 catalogued specimens, most of which were collected in Illinois and the southeastern United States. The collection is 90% freshwater species (mussels, fingernail clams, and snails) and 10% terrestrial species (snails). Most of the specimens were collected as a result of various faunal surveys conducted by INHS biologists from the late 1800's until the present. The early collections were made by such naturalists as John W. Powell, Robert Kennicott, Richard E. Call, William A. Nason, Frank C. Baker, Robert E. Richardson, and Charles A. Hart.

The freshwater mussels number over 88,100 catalogued specimens (>25,000 lots). Most of the specimens were collected in Illinois (60%), making it one of the largest state collections of freshwater mussels in the United States. The collection includes mussels from a statewide survey by Max R. Matteson conducted in the 1950's and mussels from William C. Starrett's "A Survey of the Mussels (Unionacea) of the Illinois River: A Polluted Stream" published by INHS in 1971.

The snails are divided between terrestrial (13%) and freshwater (5%) species, most of which were collected more than 50 years ago. The largest and best documented collection of snails at the Survey was compiled by Thural D. Foster and organized by Frank C. Baker as part of his study on the "Landsnails of Illinois" published in 1939. The Baker snail collection numbers 1632 lots containing 11,970 specimens.
In March 1998 curation of the mollusk collection of the University of Illinois Museum of Natural History was transferred to the Illinois Natural History Survey (INHS). The combined INHS and UIMNH Mollusk Collection contains over 300,000 catalogued specimens in approximately 65,000 lots. An online searchable database is available at http://www.inhs.uiuc.edu/cbd/collections/mollusk.html.

The Mollusk Collection Database contained records for 23,788 Illinois specimens representing 118 species, and 1,512 specimens of 43 species collected at 178 locations in the Fox River drainage (Fig. 8). This database contains records from records from the Illinois Natural History Survey, University of Illinois Museum of Natural History, Illinois State Museum, Field Museum of Natural History, National Museum of Natural History, Carnegie Museum of Natural History, Academy of Natural Sciences of Philadelphia, University of Michigan Museum of Zoology, University of Colorado Museum, Chicago Academy of Sciences, Ohio State University Museum of Biological Diversity, and the Harvard University Museum of Comparative Zoology.

Mollusk Collection Sites

![Map of Mollusk Collection Sites]

Figure 8.

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For more information about the INHS Mollusk Collection or the Mollusk Collection Database, contact Kevin Cummins, Curator (ksc@mail.inhs.uiuc.edu) or Chris Mayer, Collections Database Manager (camayer@mail.inhs.uiuc.edu)

c) Aquatic Insects- Ephemeroptera, Plecoptera, and Trichoptera

The Illinois Natural History Survey (INHS), a National Systematics Research Resource Center, maintains some of the largest and most historically significant collections of the aquatic insect orders Ephemeroptera, Plecoptera, and Trichoptera (EPT) in North America, groups that have long been recognized as containing some of the most sensitive indicators of biotic integrity in flowing water ecosystems. Efforts to build the collection began in the 1860's and continue to the present. Information on the EPT collections can be found at http://www.inhs.uiuc.edu/cbd/EPT/index.html.

The Ephemeroptera collection currently contains 11,370 total Illinois records totaling 94,578 specimens and 102 species and subspecies in 15 families; this includes 916 specimens of 20 species from 57 sites in Fox River watershed (Fig. 9).

Illinois Natural History Survey
Ephemeroptera Sites

Figure 9.

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The Plecoptera collection contains 4,902 Illinois records totaling 29,114 specimens and 75 species in 8 families; this includes 1,631 specimens of 31 species from 54 sites on the Fox River watershed (Fig. 10). The Tricoptera database is under construction at the time of this writing and figures are tentative: the Tricoptera collection contains 11,550 Illinois records totaling 129,502 specimens and 204 species in 17 families. Ephemeroptera and Plecoptera records are available in an online searchable database available at http://ellipse.inhs.uiuc.edu/INHSCollections/ephemsearch.html and http://ellipse.inhs.uiuc.edu/INHSCollections/plecopterasearch.html

![Illinois Natural History Survey Plecoptera Sites](image)

Figure 10.

For more information on the INHS EPT collections contact Don Webb, Curator (dwebb@mail.inhs.uiuc.edu), Chris Dietrich, Curator (dietrich@mail.inhs.uiuc.edu), or Colin Favret, Manager (c-favret@life.uiuc.edu). For information on the EPT databases contact Ed
DeWalt (edewalt@mail.inhs.uiuc.edu) or Colin Favret (c-favret@life.uiuc.edu). See also Favret, C. and R. E. DeWalt. 2002. Comparing the Ephemeroptera and Plecoptera specimen databases at the Illinois Natural History Survey and using them to document changes in the Illinois fauna. Annals of the Entomological Society of America: In press

Other collections containing EPT specimens from Illinois:

**Chicago Academy of Sciences Entomology Collection:** This collection may contain Illinois EPT specimens, but is not currently in an electronic database. Thus, this information was not available at the time of this report. For more information on this and other CAS collections contact Steve Sullivan, Collections Manager, at sullivan@chias.org.

d) Crustaceans

The **Illinois Natural History Survey Crustacean Collection** is one of the largest state collections of crustaceans in North America. A few specimens now housed in the collection were collected in the late 1800's by Stephen A. Forbes. More specimens were collected during the first half of the 1900's in conjunction with the insect surveys organized by Herbert H. Ross. A large part of the collection comes from specimens collected from 1972 to 1982 for Lawrence M. Page's "The Crayfishes and Shrimps (Decapoda) of Illinois" published in 1985.

The collection contains about 85,200 specimens (8500 lots) of approximately 260 species in 21 families. Almost all are from North America. About 70% of the collection is from Illinois; the remainder is mostly from the southeastern United States. The best represented groups are crayfishes, shrimps, scuds, slaters, and pill bugs. A searchable online database is available at [http://www.inhs.uiuc.edu/cbd/collections/crustacea.html](http://www.inhs.uiuc.edu/cbd/collections/crustacea.html).

As of March 10, 2001, the INHS crustacean collection (which includes Amphipods, Isopods, Crayfishes, and Shrimps) contained 4,608 lots of 67 species from Illinois. This included 92 records representing 16 species collected at 58 locations in the Fox River drainage (Fig. 11).

For more information about the INHS Crustacean Collection contact Chris Taylor, Curator (ctaylor@mail.inhs.uiuc.edu), or Chris Mayer, Collections Database Manager (cmayer@mail.inhs.uiuc.edu).

Other crustacean collections containing Illinois crustacean material include:

**United States National Museum, Smithsonian Institution,** Invertebrate Zoology Collection. This collection contains 422 Illinois specimens. Contact Karen Reed, Museum Specialist, (Reed.Karen@nmnh.si.edu), for more information.
Refining Predicted Distributions of Aquatic Species

We utilized the TNC classification system to refine the predicted distributions of aquatic species in our pilot project, e.g., to generate predicted distributions at the stream-segment level. Point locations for each species were plotted and layered over stream segments designated by “type” or classification ranking. We assumed that a particular species could be expected (i.e. predicted) to occur in all stream segments of the types in which it is known to occur. These stream segments were then highlighted to represent the predicted distribution of each species (Fig. 12).
The methodology we used to derive predicted distributions is conservative from a resource conservation/protection standpoint, in that a species is assumed to be present in all stream segments of the "type" or classification in which it is known to exist. The appropriate microhabitat conditions and water quality need also be present for that stream segment to be suitable habitat for a particular aquatic species. Existing information on stream habitat parameters and water quality, available through programs outlined in this report, could be used to predict occurrences on a site-specific scale. However, the availability of such information is limited by the locations of existing monitoring stations and previous efforts to collect aquatic biota specimens. Field investigations may be necessary to supplement this information if a finer level of resolution is required.
Alternatively, some stream types within a watershed may not have been sampled, or, if so, may not have been sampled extensively enough to encounter a particular species. However, more comprehensive predicted distributions may be developed by utilizing known species occurrences on a larger geographic scale (e.g. multiple watersheds, statewide). In this way predicted distributions for some species may include additional stream types available within the targeted watershed. For example, by utilizing the known ecological distribution of the Wabash Pigtoe throughout the entire Illinois River watershed (included in the TNC streams classification), additional stream segments were included in the predicted distribution of that species within the Fox River watershed (Fig. 13). The Wabash Pigtoe is a common and widespread species, and thus would be expected to occur in a variety of stream segment types in the Fox River watershed.

Predicted Distribution of the Wabash Pigtoe Using Specimens from the Illinois River Watershed

Figure 13.
Utilizing the known occurrences of a species across a broad geographic scale produces a predicted distribution that can be expected to reflect the ecological distribution of well-sampled taxa reasonably well. A wealth of data exists on the aquatic resources of Illinois, due in part to a long history of scientific collecting, monitoring, and research activities and the management and curation of large biological collections and associated databases by INHS scientists. Additionally, activities such as streams monitoring and surveys by IDNR and IEPA biologists and others (e.g. Eco-Watch), and active collecting and research by scientists at other institutions (e.g. SIU-C) have made a significant contribution. This information, coupled with the streams classification being developed by the INHS for the IDNR and IEPA, would allow for the development of comprehensive predicted distributions for aquatic species. Such distributions are essential to the expansion of the aquatic component of Eco-Risk and the development of Aquatic GAP.

**Ammonia Concentrations in the Fox River**

Ammonia toxicity to aquatic organisms is a complex interaction of pH, temperature, ionic composition, ammonia form and concentration, duration of exposure, life stage, and taxon (e.g. US EPA, 1999; Reinhold and Pescitelli, 1982; Roseboom and Richey, 1977). In water, ammonia exists primarily as two forms, unionized ammonia and the ammonium ion. Temperature and pH are the primary factors that affect the equilibrium between these two forms, of which the unionized form is more toxic. As temperature and pH increase the unionized fraction increases, and ostensibly so does toxicity. However, fish are more sensitive to ammonia at lower temperatures (US EPA, 1999, Reinhold and Pescitelli, 1982; Roseboom and Richey, 1977), presumably due to lower metabolism and decreased ammonia regulation (e.g. a buildup occurs in tissues) (Kieffer and Tufts, 1996; Alsop et al., 1999). Conversely, stressors occurring at higher temperatures (e.g. reduced dissolved oxygen) could also increase ammonia toxicity (Merkens and Downing, 1957). Fish are also more sensitive to ammonia at lower pHs; pH affects the proportion of total ammonia present as unionized ammonia and ammonium ion. Invertebrates are generally less sensitive to acute ammonia exposure than fish (US EPA 1999); however, filter feeders such as clams may be impacted by low-level, chronic exposures.

We examined ammonia nitrogen concentrations at two Illinois Environmental Protection Agency Ambient Water Quality Monitoring stations in the Fox River drainage; one located at South Elgin on the main stem of the Fox River, the other on Blackberry Creek near its confluence with the Fox River at Yorkville (Fig. 14).
Ammonia nitrogen concentrations recorded at South Elgin in 1997 exhibited a gradual decline during late winter/early spring and increased dramatically by mid-May, before declining again by mid-July (Fig. 15). No data were available for April and June of that year. Ammonia concentrations then began to increase during late-summer/autumn through November, before declining precipitously between November and December. Ammonia concentrations recorded at South Elgin in 1998 showed a similar pattern to 1997, in that there was a decline during late winter, and an increase in late summer (Fig. 15). However, ammonia levels remained relatively stable from March through mid-July of 1998.
We also graphed ammonia nitrogen concentrations at Blackberry Creek near Yorkville, a tributary to the Fox River, in 1997 and 1998 (Fig. 16). Except for a large spike in January and a smaller increase in June, ammonia concentrations were relatively stable at around 2 mg/L in 1997. Total ammonia concentrations fluctuated between 0.2 and 0.3 mg/L for most of 1998, with slightly increased concentrations in spring and late summer; ammonia levels decreased during fall and early winter of that year. Interestingly, the mean ammonia nitrogen concentrations were similar between the Blackberry Creek and S. Elgin sites in each given year, and were higher at both sites in 1997 than 1998 (for 1997, South Elgin $\bar{x} = 0.34$ mg/L, Blackberry Creek $\bar{x} = 0.35$ mg/L; for 1998, South Elgin $\bar{x} = 0.26$ mg/L, Blackberry Creek $\bar{x} = 0.22$ mg/L. We also graphed unionized ammonia concentrations recorded at these same stations in 1997.
Not coincidentally, unionized ammonia peaked in June at South Elgin during 1997 (Fig. 17), at the same time as total ammonia nitrogen. The proportion of total ammonia nitrogen as unionized ammonia is dependent on pH and temperature. Unionized ammonia concentrations were highest at Blackberry Creek in June, which coincided with an increase in total ammonia nitrogen concentrations (Fig. 18). Unionized ammonia concentrations did not increase at Blackberry Creek in February, as did total ammonia nitrogen concentrations. The proportion of total ammonia that is unionized is lower at colder temperatures, as this may explain why a concomitant increase was not observed during the winter. The highest unionized ammonia concentration observed at S. Elgin (0.136 mg/L) was much higher than recorded at Blackberry Creek (0.0299 mg/L).
Figure 17.

Figure 18.
We examined concentrations observed at the South Elgin station in 1998 to determine if the peak concentration observed in 1997 was anomalous; a relatively high peak value (0.08 mg/L) was also recorded in 1998. Unfortunately no unionized ammonia concentrations were recorded for April and June of 1997, which would have provided some indication of the duration of increased ammonia levels.

Title 35, Section 302.212 of the Illinois Administrative Code sets an upper limit of 15 mg/L total ammonia nitrogen concentration. The acute and chronic standards for unionized ammonia during April through October are 0.33 mg/L and 0.057 mg/L, respectively. For the months of November through March the acute and chronic standards are lower; the acute and chronic standards for this time period are 0.14 mg/L and 0.025 mg/L, respectively. Illinois statute also provides for allowable concentrations under differing conditions of pH and temperature. Water temperatures at the South Elgin and Blackberry Creek stations ranged from a low of 0.3 to a high of 28°C, and the pH typically exceeded 8.0, sometimes reaching nearly 9.0. Under conditions of warmer water temperatures and higher pH, the allowable total ammonia nitrogen concentration is greatly reduced.

For example, at a temperature of 26.7°C and pH 8.9, the allowable total NH3-N under the Acute Standard (e.g. any length of exposure) is 0.8 mg/L; under these conditions the Chronic Standard would be 0.1 mg/L. Utilizing this combination of pH and temperature, the average concentrations at both sites exceeded the Chronic Standard for the warmer months of April to October. The Acute Standard was exceeded at the South Elgin station in May (and perhaps April and June). Total ammonia nitrogen concentrations did not exceed the allowable levels for the Acute Standard at Blackberry Creek during April - October of 1997 or 1998.

In 1998, unionized ammonia concentrations approached or exceeded the Chronic Standard in June (0.046 mg/L), July (0.08 mg/L), and August (0.05 mg/L). The Chronic Standard for April to October, as provided by Illinois statute, of 0.057 mg/L unionized ammonia shall not be exceeded by an average of 4 samples over any period of 4 days. The data for the summer of 1998 suggests that this standard was likely exceeded for a prolonged period. There is some indication that low-level chronic exposure to ammonia may be more harmful to fish than acute exposures to higher levels (Flis, 1968).

In winter, with a water temperature of 1.7°C and pH of 9.0, the allowable total ammonia nitrogen under the Acute Standard is 1.5 mg/L, while the Chronic Standard is 0.3 mg/L. Using this combination of temperature and pH, the observed ammonia nitrogen concentration at Blackberry Creek reached the maximum allowable concentration under the Acute Standard in January of 1997.

The Chronic Standard was exceeded in late winter of 1996, November (and possibly October) of 1997, and November/December of 1998 at South Elgin, and December 1996 to February 1997 at Blackberry Creek. It is important to reiterate here that in order to have exceeded the Chronic
Standard, the critical value must be exceeded by an average of 4 samples collected over at least 4 days; the data presented suggest that this was likely during these time periods.

Anderson, Sparks, and Paparo (1978) found unionized ammonia concentrations of 0.08-0.09 mg/L produced sublethal effects (e.g. filtering performance and growth) in fingernail clams, and growth was reduced at concentrations of 0.20-0.34 mg/L. Subsequently, Sparks and Sandusky (1981) reported an Environmental Concentration 20 for fingernail clams of 0.77 mg/L at pH 8.0 and 25°C, and Zischke and Arthur (1987) noted reproductive effects in this species at 1 mg/L (24-26°C and pH 7.8-8.2). Roseboom and Richey (1977) summarized ammonia toxicity studies that used fish. Twenty-four hour Lethal Concentration 50 (LC50) were as low as 0.072 mg/L unionized ammonia for rainbow trout fry. The authors determined a 96-hour tolerance limit (TL50) of as low as 0.40 mg/L for small (0.072 g) bluegills, and recommended that unionized ammonia concentrations in Illinois streams not exceed 0.04 mg/L (1/10th of 96-hour TL50). Reinhold and Pescitelli (1982) found that bluegill were more sensitive to unionized ammonia than rainbow trout and fathead minnows, and recorded a 96-hr LC50 of 0.42 mg/L at cold water temperatures (4.0-4.5°C), and 1.58 mg/L at warmer water temperatures (25°C). Sublethal effects and low mortality were observed at the lowest concentrations tested, 0.15 mg/L at the colder water temperature, and 0.86 mg/L at the higher temperature.

Based on the data and published critical concentrations and criteria we examined, the aquatic resources of the Fox River are at risk of exposure to ammonia concentrations which may produce sublethal effects or mortality. Sediment porewater may contain much higher concentrations of ammonia than the water column (Sparks and Ross, 1992), thus benthic invertebrates are likely at even greater risk than indicated here. Ammonia availability and toxicity are governed by complex interactions involving factors such as pH, temperature, dissolved oxygen and carbon dioxide levels, organic matter, and other contaminants. Thus, such factors need to be considered in any detailed investigation into risks associated with ammonia exposure in aquatic life.

Nitrogen inputs may include agricultural (fertilizer and manure), municipal and industrial point sources, atmospheric deposition, and nonagricultural runoff (Smith and Alexander, 2000). Point sources contribute a relatively small proportion of total watershed nitrogen export (e.g. median 0.8% in the Upper Mississippi water-resources region), while fertilizers and animal waste are the major contributing factors (55% and 21%, respectively). Large, rapid increases in ammonia concentrations in the Fox River during late spring and again in autumn likely coincide with increased precipitation and associated runoff events following application of nitrogen fertilizer to crop fields; non-farm applications represent a small proportion (1-4%) of fertilizer application in this region (D. Lorenz, USGS, pers. comm.). Mean unionized ammonia concentrations in the Fox River during 1986-1996 did in fact reflect trends in nitrogen consumption in Illinois during that period (Fig. 19).
Variation in the timing and duration of increased ammonia nitrogen concentrations may result from annual differences in the timing of application and runoff events. Unfortunately missing data did not allow us to determine the extent or duration of increased concentrations of ammonia during some periods. We recommend that every effort be made to collect samples in every month, and more frequently when the Chronic Standard may be exceeded, e.g. during periods of increased runoff.

The environmental chemistry and toxicokinetics of ammonia are complex, and this is not meant to be an exhaustive or definitive study of ammonia concentrations in the Fox River drainage and potential effects on aquatic life there. It does, however, demonstrate that concentrations may exceed recommended thresholds identified in the scientific literature or mandated by law, and indicates the need for further investigation. Regulations designed to restrict ammonia nitrogen inputs by point sources alone may not adequately protect aquatic life in agricultural regions, highlighting the need to reduce agricultural nitrogen inputs. Additional inputs from municipal sources in this rapidly developing area undoubtedly add to periodically high ammonia loads. Protection and restoration of the aquatic resources of the Fox River drainage will necessitate the implementation of programs designed to reduce the input of ammonia nitrogen into streams, particularly from agricultural sources.

For a detailed review of the current knowledge of ammonia toxicity to aquatic organisms and development of ambient water quality criteria for ammonia, see http://www.epa.gov/ost/standards/ammonia/99update.pdf.
Acknowledgments

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