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Development of a Life History Database for Upper Mississippi River Fishes



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Development of a Life History Database for Upper Mississippi River Fishes

by

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Summary

Life history theory can help identify where attention may be most profitably focused in monitoring and research. By incorporating life history information, researchers can explore and test associations at different levels of ecological organization and recast standard monitoring observations to gain new perceptions into population and community dynamics. A database of fish life history information was therefore developed from peer-reviewed literature sources and standardized Long Term Resource Monitoring Program (LTRMP) data sources for Upper Mississippi River System (UMRS) fishes. Presently, this database presents life history data on 108 life history traits for 230 fish species and hybrids. Data were compiled under standards developed by the authors. These standards define the type and quality of information to be incorporated in the future; in effect, the database will be a living product, receiving enhancements as new data become available. The database is constructed to permit seamless interface to the LTRMP fisheries database maintained at the Upper Midwest Environmental Sciences Center in La Crosse, Wisconsin. The life history database and fisheries data browser are available at http://www.umesc.er.usgs.gov/data_library/fisheries/graphical/fish_front.html.

The fish life history database will prove an important resource for testing prevailing ecological and river theories with existing empirical data, investigating anthropogenic controls on functional attributes of ecosystems, developing indicators of ecosystem health, identifying and assessing fish passage alternatives, ascribing ecosystem service values to UMRS fisheries resources, and serving LTRMP data in ways meaningful to managers, scientists, and the public. This report summarizes the development of this database, including database standards and metadata, and provides some examples of its utility.

Contents

	<i>Page</i>
Summary	iii
Preface	vii
Introduction	1
Background	1
Rationale	2
Objectives	3
Methods	3
Database Development Strategy	3
Database Quality Assurance Standards	4
Data Sources	4
Database Format	5
Metadata	5
Attribute Classes	5
Attribute Class Membership	6
Demonstration of the Database	7
Functional Feeding Guilds	7
Proportional Biomass of Nonnative Species	8
Conclusions	8
References	9
Appendix A. Attribute Definitions and Codes	A-1
Appendix B. Data Citations	B-1

Figures

<i>Number</i>	<i>Page</i>
1. Composition (<i>A</i> , Presence/Absence) and structure (<i>B</i> , Abundance) of fish community sampled based on feeding guilds present in total catch by regional trend area of the Long Term Resource Monitoring Program, Upper Mississippi River System	8
2. Percentage of total number (<i>A</i>) and percentage of total biomass (<i>B</i>) of fish collected annually that were nonnative fish species from Long Term Resource Monitoring Program fish sampling, 1989–2002	9

Preface

The Long Term Resource Monitoring Program (LTRMP) was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program. The LTRMP is being implemented by the Upper Midwest Environmental Sciences Center, a U.S. Geological Survey science center, in cooperation with the five Upper Mississippi River System (UMRS) States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The U.S. Army Corps of Engineers provides guidance and has overall Program responsibility. The mode of operation and respective roles of the agencies are outlined in a 1988 Memorandum of Agreement.

The UMRS encompasses the commercially navigable reaches of the Upper Mississippi River, as well as the Illinois River and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers. Congress has declared the UMRS to be both a nationally significant ecosystem and a nationally significant commercial navigation system. The mission of the LTRMP is to provide decision makers with information for maintaining the UMRS as a sustainable large river ecosystem given its multiuse character. The long-term goals of the Program are to understand the system, determine resource trends and effects, develop management alternatives, manage information, and develop useful products.

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Development of a Life History Database for Upper Mississippi River Fishes

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Introduction

Background

Life history traits can be defined as a suite of characteristics particular to a species that describe its association to the environment in which it evolved or currently exists. These

characteristics can be conceptualized as particular to the physiology, behavior, and general ecology of the species. Examples of general life history trait categories include reproductive strategies, habitat associations, feeding affinities, phylogenetic associations, and physiological tolerances.

Generally, species exhibit physiological adaptations and behavioral associations that define a niche, or suite of conditions meeting

critical life history needs and characterize the general association of a species to its environment. When suites of species share particular classes of life history traits, ecologists can group these species into guilds, allowing investigations into functional, structural, and compositional patterns and associations. Because life history traits are fundamental determinants of population performance, the investigation of life history strategies is central to both theoretical ecology and resource management (Winemiller and Rose 1992).

This report summarizes the development of a life history database for Upper Mississippi River System (UMRS) fishes. In the following sections, we provide a rationale for its development within the Long Term Resource Monitoring Program (LTRMP), describe it, outline standards for its development, and demonstrate how it can be linked to the LTRMP fisheries database and used to address a host of new questions relevant to management and science in the basin. The life history database and fisheries data browser are available at http://www.umesc.er.usgs.gov/data_library/fisheries/graphical/fish_front.html

Rationale

The LTRMP fish component has been collecting fish data for more than a decade on the Upper Mississippi and Illinois Rivers. A standardized probabilistic sampling design (Gutreuter et al. 1995) yields species occurrence, abundance estimates, and length observations to assess ecological status and trends in relative abundance for more than 130 fish species over 1,200 km of river (U.S. Geological Survey 1999; Ickes et al. 2005b).

Data and publications from the LTRMP support the information needs of a diverse federal and state natural resource agency partnership. The partnership uses LTRMP data to

1. detect trends in population and community level responses (Ickes et al. 2005b; Kirby and Ickes 2006);
2. assess ecosystem integrity (U.S. Geological Survey 1999) and biotic responses to management activities (Gutreuter 2004);
3. inform game and nongame conservation initiatives (Ickes et al. 2005b);

4. evaluate changes in the presence, distribution, and population dynamics of exotic species (Chick and Pegg 2001; Chick et al. 2005; Ickes et al. 2005b);
5. develop and test models (Barko et al. 2005; Ickes et al. 2005b; Kirby and Ickes 2006); and
6. plan targeted research (e.g., Gutreuter 2004; Koel 2004).

To date, however, LTRMP fisheries data have been limited in how they can meet the many management and scientific challenges they are expected to address. This is because the monitoring program measures only the most basic population and community responses. What is needed is a way to recast existing and future data to inform a wider set of applied management and scientific perspectives.

To meet the many needs of natural resource management agencies and scientists within the UMRS, we identified the development of a central life history database as a crucial need for the LTRMP. Such a database would serve several important functions.

First, the compilation of life history information will open new windows for addressing applied management and research questions within the UMRS. For example, by linking the life history database to the LTRMP fisheries database, we can investigate spatiotemporal patterns in functional, structural, and compositional traits of UMRS fish communities, and associations of such traits to habitat characteristics and rehabilitation efforts within the UMRS. Such investigations require recasting relative abundance data into alternative metrics that may be more sensitive to the question being asked of the data. For example, growth models coded in the life history database can be used to convert abundance and length observations into biomass. Biomass is arguably a more sensitive indicator of production responses to extreme events such as floods and droughts, habitat losses, and habitat rehabilitation efforts. Converted biomass observations can be used in single species research or can be further categorized into functional (e.g., feeding, reproductive) guilds to model community responses to changes in the river system.

Second, life history information will provide a foundation for the initial development and testing of a large river Index of Biological Integrity (Karr

1994; Lyons et al. 2001) or other tools designed to assess ecosystem condition. For example, species observations can be reclassified based on physiological performance or tolerance criteria coded within the life history database. Thus recast, biological indicators of environmental conditions could be further refined and developed.

Third, the compilation of life history information will have several direct and immediate management applications. For example, managers will have access to an information source that can be used in designing, testing, and implementing longitudinal and lateral fish passage technologies (Ickes et al. 2001; 2005a).

Finally, the life history database will allow the LTRMP to more effectively serve program data to a wider audience in conjunction with the recently developed Graphical Fish Database Browser (http://www.umesc.usgs.gov/data_library/fisheries/graphical/fish_front.html). Life history attributes can be linked to summarized status and trends information served by the Graphical Fish Database Browser, providing a biological context for trend interpretation. Effectively serving program data in multiple formats that communicate resource status and trends to diverse audiences is a key priority within the LTRMP.

Compiling accurate and reliable life history data can be difficult. Care must be taken to ensure that ascribed life history attributes and classes reflect the traits of the species. Several factors make constructing a life history database challenging.

First, life history data can be found in many readily accessible media formats, but data quality can vary substantially among data sources. Thus, care must be taken and assurances made that any assembled data reflect the ecological traits of the species in the system under consideration. Second, whereas some life history traits are effectively immutable across systems, many others can be system-specific (Leggett and Carscadden 1978). For example, a species trophic status could be much different in a species-poor northern lake compared to a species-rich temperate river, whereas swimming performance at a given temperature may be largely the same regardless of the system in which the observation was made. Thus, for many life history traits, care must be taken to avoid simply adopting data from another system.

Finally, popular species (e.g., game fish) tend to be studied much more than rare or nongame species. Consequently, data are often fundamentally lacking for many species. Gaps in the database indicate species in need of life history research.

Objectives

Recognizing these limitations, we sought to develop a database with a robust set of life history traits. We established standards for data sources and data quality to provide the best possible assurance that traits coded in the database closely reflect the ecological attributes of UMRS fish species. These standards will allow us to continually add new information over time, resulting in an ever-expanding, consistent, and high-quality source of life history information for UMRS fishes. Specific objectives of this project are

1. develop guidelines describing the types and quality of data to be entered into the database;
2. identify, compile, and incorporate quality data sources into the database;
3. document data types, formats, and codes (e.g., metadata); and
4. demonstrate how the life history database can be used in concert with the central LTRMP fisheries database.

Methods

Database Development Strategy

Our objectives in developing data standards were to

1. create guidelines describing the type and quality of data to be put in the database,
2. assure that qualifiers and classifiers in data from divergent sources could be reliably combined, and
3. enable building a consistent living document that can be augmented through time as new information becomes available.

Database Quality Assurance Standards

Because of difficulties in accurately ascribing life history traits, we identified two primary types of data as robust sources of life history information that should be used to develop the initial database. We identified the first source as any database generated from peer-reviewed field or lab studies with documented data management protocols covering the UMRS. For the database documented in this report, we derived life history attributes directly from the LTRMP fisheries database, but potentially any data source with broad coverage of the UMRS and generated under these standards could be used in the future. Such databases were viewed to have greatest utility for a wide variety of system-variant life history attributes. We believed UMRS databases should be a primary source of information initially because data from the system under study should best reflect such system-variant life history traits. Developing data for such life history traits requires analysis and summarization of the LTRMP or other qualifying data. One example used in the compilation of the life history database was the development of growth models (length/weight regressions) for every species in the LTRMP fisheries database for which it was possible. The resulting model coefficients were then coded into the life history database.

We determined that the second qualifying source of information should be peer-reviewed scientific literature. We agreed that primary scientific literature would provide the best and most reliable data for system-invariant life history traits, such as swimming performance indicators, phylogenetics, and chemical tolerances.

After determining qualifiers about where the information should come from and the types of information needed, the next step was to develop and standardize a process of integrating qualifying information into one consistent life history database for UMRS fishes.

Within the quality control constraints described above, we proceeded to compile, code, and incorporate life history data, such as taxonomic nomenclature, feeding and reproductive guilds, distributional associations, population metrics, and habitat preferences into a UMRS fish life history database. In a series of discussions occurring over several months, the team determined a suite of

attributes to include in the life history database (Appendix A, Tables A-1–A-9).

Data Sources

Previously, researchers gathered assorted life history data with relevance to UMRS fish species for use in particular research projects. We assembled data from these sources and requested authorization for their use in our effort. Life history data for UMRS species presented in Winemiller and Rose (1992) served as the original broad base of information for our database. Dr. Mark Pegg (Illinois Natural History Survey, Illinois River Biological Station, Havana) provided additional data from doctoral work conducted on the Missouri River. Dr. Pegg's data were available in spreadsheet form and contained life history attribute data assembled from various peer-reviewed scientific sources for most UMRS fish species. Life history data from Dr. Todd Koel (National Park Service, Yellowstone National Park) and Dr. David Galat (U.S. Geological Survey, University of Missouri, Columbia), subsequently cited in peer-reviewed publications, were also incorporated to the database (Galat and Zweimuller 2001; Koel 2004).

As an initial assessment of the above data sources, we created a cross-linked data table to assess redundant life history attributes and data. Combining these sources resulted in numerous redundant data fields, which we subsequently evaluated for concurrency. This was done by cross-comparing data values in all redundant fields. Data fields with missing values were omitted from the cross-comparison. In >90% of the cases, data from the various sources were identical or closely concurrent and redundant data fields were consolidated. We defined concurrence as a <10% difference in attribute value for any given species. Finally, if species data were absent from all but one data source for a given attribute, we chose to accept the nonmissing data from the relevant data source for our database. Such instances were rare.

In addition to data sources cited previously, many additional attributes were derived directly from LTRMP data sources. Attribute names, methods of calculation, and additional details are outlined in the Metadata section of this report.

Database Format

We used Microsoft Access 2003 to develop the database because this program permits the user to make customized database queries and facilitates data export to a variety of programs. Access 2003 also facilitates data entry by permitting the user to import a variety of software formats that can be linked to the database.

Initially, data were imported to the life history database in tabular form from each assembled data source. Attributes were organized into nine tables, each representing a data theme. These themes include distribution, growth, economic value, phylogeny, photos, reproduction, preference and guild, miscellaneous, and references. In total, 108 life history attributes are represented in the database (Appendix A, Tables A-1–A-9). Each theme table contains 230 rows of data, 1 row for each species represented by the full database. Additionally, each table contains a data field titled “Fishcode,” a 4-digit alphanumeric field that provides the relational link among all database tables. “Fishcode” is a unique fish species code used in standard LTRMP monitoring protocols (Gutreuter et al. 1995). Use of “Fishcode” in the life history database provides a common relational link not only among tables in the life history database but also to the entire LTRMP fisheries component database. In this way, all life history attributes and data in the life history database can be relationally linked to the LTRMP fisheries database, comprising greater than 4 million fish observations from 1993 to present.

Metadata

The LTRMP fish life history database is represented by a series of tables in a Microsoft Access 2003 database. Tables within the database can be dichotomized into two types; data tables and data legends. When viewing data tables within the database, membership in either the data tables or data legends category is determined by a naming prefix of the form XXXXX_YYYYYYYY, where XXXXX represents either “Legend” or “Data table,” and “_” represents a naming convention divider. The naming suffix YYYYYYYY represents the name of the attribute class to which the data

table belongs when the prefix is “Data table,” or the name of the data attribute the data legend supports when the prefix is “Legend.” “Data table” contains life history data organized into classes containing similar life history attributes. Nine “Data tables” are represented in the database and are collectively comprised of 108 individual life history attributes. Each “Data table” is common in that 230 fish species are represented in each table and each table contains the attribute “Fishcode” as a common linking field. “Legends” contain text translations for numeric codes representing categorical attributes within “Data tables.” Thirteen attribute “Legends” are represented along with a “Master_Legend” that describes each attribute, associated legends, acceptable data codes, and data class membership.

Attribute Classes

Data attributes are organized into nine attribute classes with each attribute class represented by a single table within the database. Attributes within each attribute class are similar in the types of life history traits they describe. Below, we identify and briefly outline each attribute class. In the following sections, we identify individual attributes within each class, describe each attribute, and document coding standards.

Distribution: (seven attributes represented; Appendix A, Table A-1) To relate information on the known historical and contemporary distribution of fishes in the UMRS.

Economic Value: (two attributes represented; Appendix A, Table A-2) To provide data to recast LTRMP observations into economic valuation units. Economic valuation criteria were derived from Southwick and Loftus (2003).

Growth: (22 attributes; Appendix A, Table A-3) Collectively these attributes are meant to represent population performance and societal preference. Growth attribute class include growth model coefficients, maximum observed lengths, juvenile and adult growth rates, and proportional stock size designations.

LTRMP Fish Photos: (11 attributes; Appendix A, Table A-4) To document type specimens from the UMRS and to facilitate and compliment LTRMP data serving initiatives.

Attributes within this class photographically document species, track photo attributions, and aid in photographic database management.

Taxonomy: (10 attributes; Appendix A, Table 5) To provide information on phylogenetic and taxonomic associations, and species status in the UMRS.

Preference and Guild: (27 attributes; Appendix A, Table A-6) To provide data on species physiological performance, tolerance to environmental conditions, environmental preferences, and ecological guild memberships (Balon 1975).

Reproduction: (eight attributes; Appendix A, Table A-7) To provide data on species reproductive capacity, timing, and mode.

Miscellaneous: (seven attributes; Appendix A, Table A-8) To present data on attributes that are not easily categorized. This attribute class contains information on species exploitation status in the UMRS, species migratory behavior and affinity, conservation status, and rank abundance.

References: (three attributes; Appendix A, Table A-9) To document and cross-reference data and literature sources used to populate the LTRMP life history database.

Attribute Class Membership

Individual attributes in the “Distribution” attribute class provide information on geographic distribution for UMRS fish species. Specifically, “Distribution” attributes include midrange latitude, mean range latitude, and ubiquity. (Appendix A, Table A-1). Attributes for historical distributions, contemporary distribution, species description, and historical distribution reference are under development and will be added to the database later.

Individual attributes in the “Economic Value” attribute class provide information on monetary values for UMRS fish species. The data are presented in US dollar amounts. Specifically, “Economic Value” attributes include replacement value mass and replacement value counts (Appendix A, Table A-2).

Individual attributes in the “Growth” attribute class provide information on growth parameters at various life stages for UMRS

fish species. Specifically, “Growth” attributes include length × weight regression intercept, length × weight slope coefficient, length × weight equation source, number of observations used to fit length × weight models, minimum length used to fit length × weight models, maximum length used to fit length × weight models, larval growth rates, young-of-the-year growth rate, adult growth rate, mean annual growth, length at maturity, maximum age, juvenile length cutoff, maximum observed LTRMP length, maximum literature length, substock, stock, quality, preferred, memorable, and trophy size classes (Appendix A, Table A-3).

Individual attributes in the “LTRMP Fish Photos” attribute class provide a photo and its documentation for UMRS fish species. Specifically, “LTRMP Fish Photos” attributes include “have photo,” photo filename1, photo filename2, photo type locality, photo date, photo credit, photo credit affiliation, photo credit phone, photo credit e-mail, photo description, and photo copyright. Each of these parameters is described in detail, including acceptable codes when applicable and data source, in the Attribute Definitions and Codes section (Appendix A, Table A-4).

Individual attributes in the “Taxonomy” attribute class provide information on phylogenetic and taxonomic associations for UMRS fish species. Specifically, “Taxonomy” attributes include common name, taxonomic order, family name, family rank, scientific name, taxonomic rank, LTRMP, animal, native, and identification status. Each of these parameters is described in detail, including acceptable codes when applicable and data source, in the Attribute Definitions and Codes section (Appendix A, Table A-5).

Individual attributes in the “Preference and Guild” attribute class provide information on species physiological performance, tolerance to environmental conditions, environmental preferences, and ecological guild memberships. Specifically, “Preference and Guild” attributes include r-guild, r-guild1, r-guild2, r-guild3, f-guild1, f-guild2, f-guild3, trophic guild, fluvial dependence, migratory, ecological tolerance, large river species, current preference, substrate preferences, silt tolerance, spawning substrate, turbidity tolerance, swim factor, shape factor, water column preference, adult habitat, freshwater/marine, adult trophic level, relative anadromy,

egg buoyancy habitat guild, and The Nature Conservancy global rank. Each of these parameters is described in detail, including acceptable codes when applicable and data source, in the Attribute Definitions and Codes section (Appendix A, Table A-6).

Individual attributes in the “Reproduction” attribute class provide information on reproductive capacity, timing and mode for UMRS fish species. Specifically, “Reproduction” attributes include maximum fecundity, mean fecundity, mean ovum diameter, range ovum diameter, spawning duration, spawning bouts, parental care, and mean incubation. Each of these parameters is described in detail, including acceptable codes when applicable and data source, in the Attribute Definitions and Codes section (Appendix A, Table A-7).

Individual attributes in the “Miscellaneous” attribute class provide information on species exploitation, species migratory behavior and affinity, conservation status, and rank abundance for UMRS fish species. Specifically, “Miscellaneous” attributes include exploit rank, Wilcox migratory, Wilcox pass dams, Wilcox U_{crit} , conservation status and LTRMP 10-year rank. Each of these parameters is described in detail, including acceptable codes when applicable and data source, in the Attribute Definitions and Codes section (Appendix A, Table A-8).

Individual attributes in the “References” attribute class documentation, cross-reference data and literature sources used to populate the LTRMP life history database. Specifically, “References” attributes include reference identification number, point of contact, and source citation (Appendix A, Table A-9).

Demonstration of the Database

Besides giving researchers and managers a quick reference to life history traits of UMRS fishes, this database’s main contribution is to integrate life history information with basic monitoring data, permitting a wider array of analytical and data modeling perspectives. By incorporating life history information into LTRMP analyses, researchers can explore and test associations at different levels of ecological organization and can recast standard monitoring observations to gain new insights into fisheries

population and community dynamics across the UMRS. In this section, we provide two brief examples of ways the life history database has recently been used to gain new insights into fisheries dynamics in the UMRS.

Functional Feeding Guilds

Our first example used the life history database to recast standardized monitoring observations into functional feeding guilds. Thus, each species in the central LTRMP database was reclassified according to its functional feeding guild class, as represented in the life history database, and patterns among LTRMP study reaches were explored. The question at hand concerns identifying spatial patterns in functional feeding traits, expressed as differences in total abundance, as an integrated descriptor of spatial differences in energy sources and food web pathways. In other words, are there spatial differences in the functional composition (presence/absence) or functional structure (abundance) of UMRS fish communities that may reflect different energy pathways in the system? To investigate this question, we used the life history database to ascribe functional feeding traits to each species in the central LTRMP database and then produced plots of percent composition and abundance of each feeding guild class by LTRMP study area. Feeding guild composition results are presented in Figure 1a, whereas feeding guild structure results are presented in Figure 1b.

From a compositional perspective, Figure 1a shows the six study reaches monitored by the LTRMP are remarkably similar in their functional feeding guild composition. Similar proportions of each guild class are observed across all six study reaches, which span nearly 1,200 km of river. Conversely, Figure 1b shows spatial patterns in feeding guild structure (proportional abundance) and demonstrates pronounced spatial differences. Invertivory dominates in the northern study reaches, whereas planktivory dominates in the southern study reaches. These differences may reflect variations in local or regional energy sources, energy pathways (e.g., food webs and trophic linkages), or differences in habitat integrity. Factors correlated with these differences are yet to be identified, but this example demonstrates how

Proportional Biomass of Nonnative Species

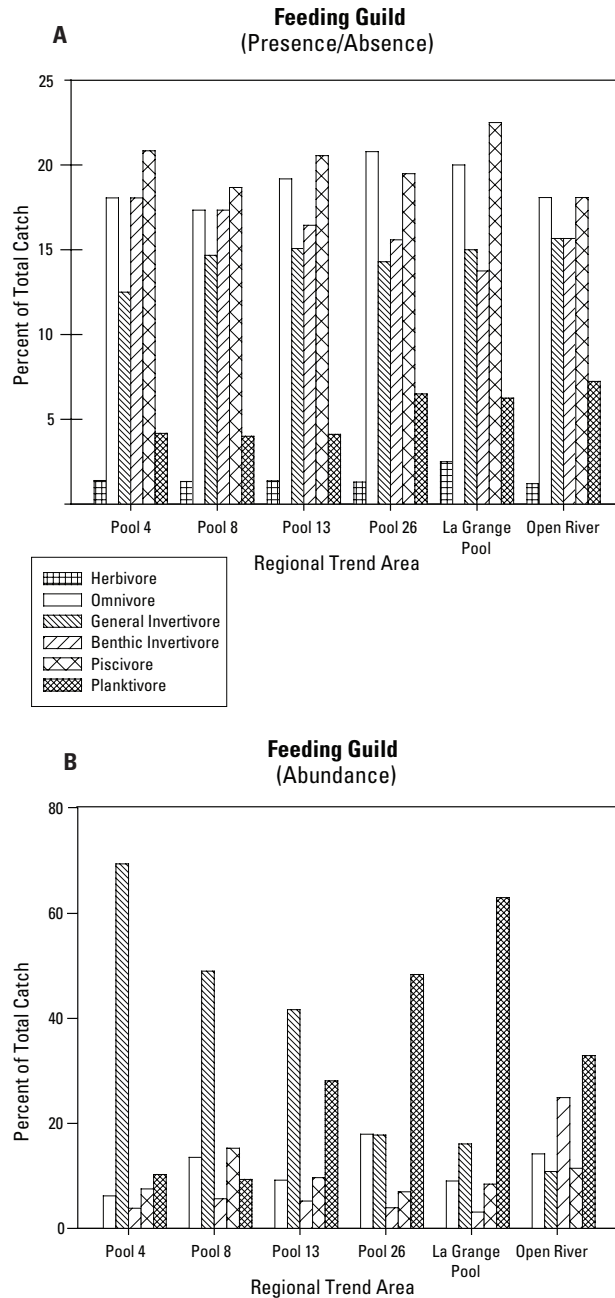


Figure 1. Composition (A, Presence/Absence) and structure (B, Abundance) of fish community sampled based on feeding guilds present in total catch by regional trend area of the Long Term Resource Monitoring Program, Upper Mississippi River System.

Our second example uses the life history database to investigate spatial differences and trends in the proportion of nonnative species that comprise the UMRS fish community. Two perspectives are pursued. The first reclassifies UMRS species as either native or nonnative based on data in the life history database. Abundance was tallied by class and the proportion of nonnative abundance per year was calculated and plotted for each LTRMP study reach (Figure 2a). The second also reclassifies UMRS species as either native or nonnative based on data in the life history database, but first converts abundance into biomass using regression models for each species that are coded into the life history database. Relative biomass was tallied for each class, used to calculate the proportion nonnative fish for each year, and plotted for each LTRMP study reach (Figure 2b).

Based on abundance, Figure 2a suggests that nonnative species are typically a small proportion of the UMRS fish community. Interannual variability is evident though, and the proportion of nonnatives has been as high as 60% over the period of observation for all trend areas combined. From an abundance perspective, nonnative species are typically a small proportion of total fish abundance (<10%; Figure 2a). From a biomass perspective, however, a substantially different story emerges (Figure 2b). As a fraction of total biomass, nonnative species are observed annually to represent 30% to 60% of the fish community observed by LTRMP standardized sampling protocol. Moreover, Pool 8 appears to have a notably smaller portion of its fish biomass sequestered in nonnative species, whereas other study areas have proportionally greater nonnative biomass comprising their fish communities. Finally, since 1993, the proportion of nonnative biomass to total fish biomass has been declining in all six LTRMP study reaches.

the life history database can be used to open new insights and identify new questions.

Conclusions

The examples presented above represent just the most basic ways in which the life history database can be used to extend the scope and utility of standardized LTRMP monitoring data, but also

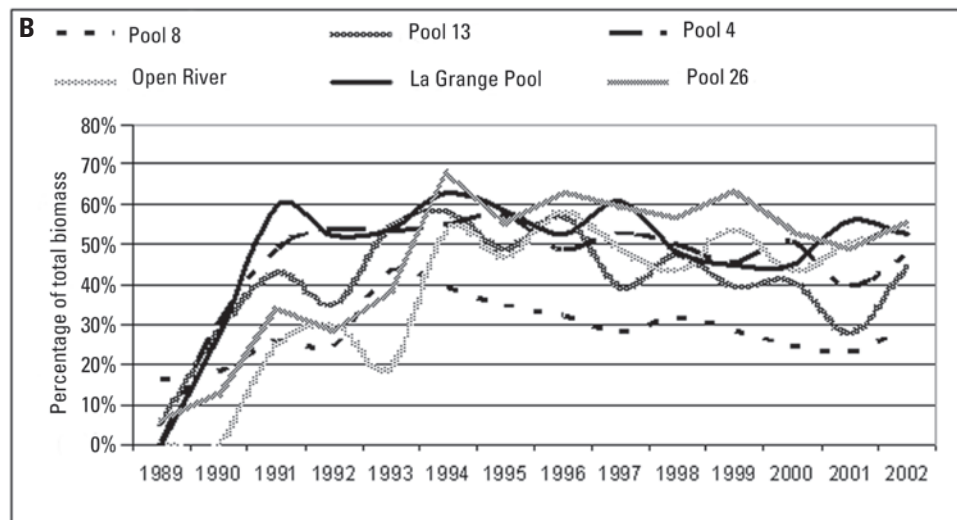
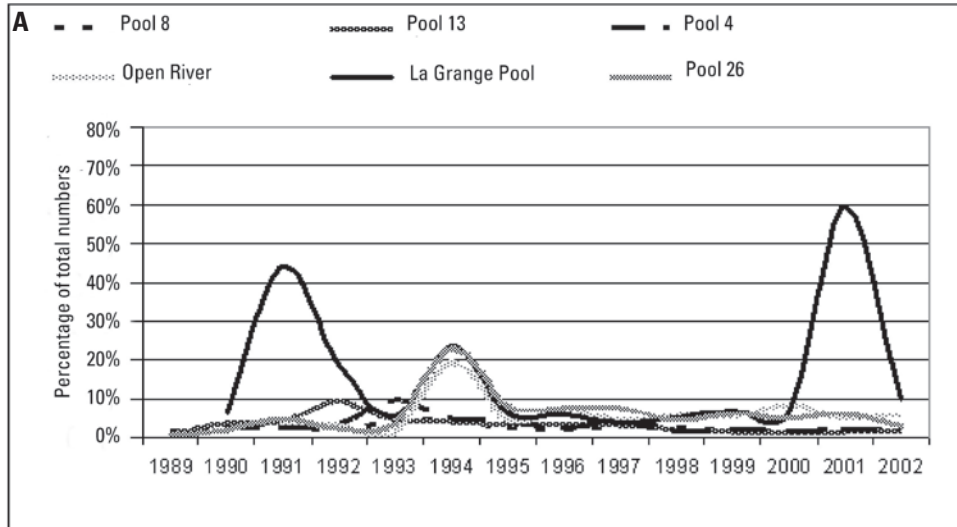


Figure 2. Percentage of total numbers (A) and percentage of total biomass (B) of fish collected annually that were nonnative fish species from Long Term Resource Monitoring Program fish sampling, 1989–2002. Pre-1993 data collected using fixed-site design, whereas post-1992 data collected using stratified random sampling design. Data from these two sampling periods may not be directly comparable. Total biomass was calculated by converting abundance into biomass using regression models for each species.

suggest such uses are potentially promising for extending our understanding of fish population and community dynamics in the UMRS. We suspect that this database will play a prominent role in future program research, as well as in developing new and novel ways to serve program data. Finally, we expect this database to have immediate utility for UMRS managers as they seek information relevant to the day-to-day management of diverse UMRS fisheries resources.

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Appendix A

Attribute Definitions and Codes

Table A-1. Attribute name, description, and source citation for data attributes in the Distribution Attribute Class for the Long Term Resource Monitoring Program (LTRMP) fish life history database. Data source is identified in Appendix B.

Attribute name	Description	Data source
Historical Distribution	Map of historical distribution from non-LTRMP data sources	Under development
Contemporary Distribution	Map of contemporary distribution from LTRMP data sources	Under development
Species Description	Text description of the species (ecology, biology, social significance)	Under development
Historical Distribution Reference	Reference source for historical distribution map	Under development
Midrange Latitude	Midrange latitude based on range maps or verbal accounts	Pegg and Pierce (1)
Mean Range Latitude	Mean range in latitude based on range maps or verbal accounts	Winemiller and Rose (2)
Ubiquity	Closed ratio numeric index of the species ubiquity in LTRMP samples 1993–2002 (10-year period)	Ickes (3)

Table A-2. Attribute name, description, and data source for data attributes in the Economic Value Attribute Class for the Long Term Resource Monitoring Program (LTRMP) fish life history database. Data source is identified in Appendix B.

Attribute name	Description	Data source
Replacement Value Mass	Dollar amount of replacement valuation during investigation of fish kill by pounds (year 2004 US dollars)	Southwick et al. (9)
Replacement Value Counts	Dollar amount of replacement valuation during investigation of fish kill by each fish (year 2004 US dollars)	Southwick et al. (9)

Table A-3. Attribute name, description, and data source for data attributes in the Growth Attribute Class for the Long Term Resource Monitoring Program (LTRMP) fish life history database. Data source is identified in Appendix B.

Attribute name	Description	Data source
LW Intercept	Parameter for standard length/weight equations - also known as the size of squamation	Ickes (4)
LW Slope	Parameter for standard length/weight equations - the rate of weight gain per unit length	Ickes (4)
LW Source	Source of growth model	Ickes (4) or Gutreuter et al. (10)
LW Nobs	For empirically derived models, the number of observations (individual fish) used in the linear regression	Ickes (4)
LW Min Length	For empirically derived models, the minimum length used in the development of regression models	Ickes (4)
LW Max Length	For empirically derived models, the maximum length used in the development of regression models	Ickes (4)
Larval Growth	Mean increment during the first month following hatching	Pegg and Pierce (1)
YOY Growth	Mean increment during the first year following hatching or independent life for viviparous fishes	Pegg and Pierce (1)
Adult Growth	Mean annual length increment over an average adult life span	Pegg and Pierce (1)
Mean Annual Growth	Mean calculated fraction (in millimeters Total Length) gained per year in a normal adult life span	Pegg and Pierce (1)
Age at Maturity	The mean age at maturation	Simon (5)
Length at Maturity	The modal length (mm) at maturation	Pegg and Pierce (1)
Maximum Age	Maximum age	Pegg and Pierce (1)
Juvenile Length Cutoff	Length, in mm, below which an individual is considered a juvenile	Barko et al. (6)
Maximum Observed LTRMP Length	Maximum length observed over the period of record by the LTRMP	Ickes (7)
Maximum Literature Length	The maximum length reported	Pegg and Pierce (1)
Substock	Length (mm) below which an individual is classified as “Substock” size	Anderson and Neumann (8)
Stock	Length (mm) below, but above Substock size, at which an individual is classified as “Stock” size	Anderson and Neumann (8)
Quality	Length (mm) below, but above Stock size, at which an individual is classified as “Quality” size	Anderson and Neumann (8)
Preferred	Length (mm) below, but above Quality size, at which an individual is classified as “Preferred” size	Anderson and Neumann (8)
Memorable	Length (mm) below, but above Preferred size, at which an individual is classified as “Memorable” size	Anderson and Neumann (8)
Trophy Size Classes	Length (mm) above which an individual is classified as “Trophy”	Anderson and Neumann (8)

Table A-4. Attribute name, description, and codes and meanings for data attributes in the Fish Photos Attribute Class for the Long Term Resource Monitoring Program (LTRMP) fish life history database. "N/A" means that the information is not applicable to that attribute.

Attribute name	Description	Codes and meanings
Have Photo	Is there a photo in the archives for this species?	Y = Yes N = No
Photo Filename1	Directory path and file name of primary photo	N/A
Photo Filename2	Directory path and file name of secondary photo	N/A
Photo Type Locality	Where primary photo was taken	N/A
Photo Date	Date primary photo was taken	N/A
Photo Credit	Who took the primary photo or who is otherwise accredited?	N/A
Photo Credit Affiliation	Agency affiliation of photo credit	N/A
Photo Credit Phone	Phone number of individual credited with the primary photo	N/A
Photo Credit E-mail	Email address of person credited with the photo	N/A
Photo Description	Brief text description of the primary photo	N/A
Photo Copyright	Is the photo copyright protected?	Y = Yes N = No

Table A-5. Attribute name, description, codes and meaning, and data source for data attributes in the Taxonomy Attribute Class for the Long Term Resource Monitoring Program (LTRMP) fish life history database. "N/A" means that the information is not applicable to that attribute. Data source is identified in Appendix B.

Attribute name	Description	Codes and meanings	Data source
Common Name	Common name used in LTRMP Fish Component procedures	N/A	Gutreuter et al. (10)
Taxonomic Order	Taxonomic order	N/A	Nelson et al. (13)
Family Name	Taxonomic family	N/A	Nelson et al. (13)
Family Rank	Taxonomic rank of phylogenetic Family	N/A	Nelson et al. (13)
Scientific Name	Binomial (genus and species) taxonomy	N/A	Nelson et al. (13)
Taxonomic Rank	Taxonomic rank of phylogenetic species	N/A	Nelson et al. (13)
LTRMP	Species collected by the LTRMP	Y = Yes N = No	Gutreuter et al. (10)
Animal	Type of animal	Fish	Simon (5)
Native	Native or nonnative species	Native Nonnative	Simon (5)
ID Status	Status of the identification (Species or Hybrid)	Species Hybrid	N/A

Table A-6. Attribute name, description, codes and meaning, data source, and source citation for data attributes in the Preference and Guild Attribute Class for the Long Term Resource Monitoring Program (LTRMP) fish life history database. "N/A" means that the information is not applicable to that attribute. Data source is identified in Appendix B.

Attribute name	Description	Codes and meanings	Data source
R-Guild	Balon's Reproductive Guild	(A.) Nonguarders (A.1) Open Substratum Spawners (A.2) Brood Hiders (A.1.1) Pelagophils (A.1.2) Lithopelagophils (A.1.3) Lithophils (A.1.4) Phytolithophils (A.1.5) Phytophils (A.1.6) Psammophils (A.2.3) Lithophils (A.2.4) Speleophils (B.) Guarders (B.1) Substratum Choosers (B.1.3) Lithophils (B.1.4) Phytophils (B.2) Nest (B.2.3) Lithophils (B.2.4) Ariadnophils (B.2.5) Phytophils (B.2.7) Speleophils (C.) Bearers (C.1) External Bearers (C.1.4) Gill Chamber brooders (C.2) Internal Bearers (C.2.4) Viviparous	Simon (5)
R-Guild1	Reproductive Guild (Does this species guard its eggs?)	N/A	Simon (5)
R-Guild2	Reproductive Guild (How are eggs dispersed?)	N/A	Simon (5)
R-Guild3	Reproductive Guild (Substrate eggs dispersal mode)	N/A	Simon (5)
F-Guild1	Adult Feeding Guild (Feeding preferences)	N/A	Simon (5)
F-Guild2	Adult Feeding Guild (Area of river system in which primary feeding mode occurs)	N/A	Simon (5)
F-Guild3	Adult Feeding Guild (Feeding mode)	N/A	Simon (5)
Trophic Guild	Trophic guild	N/A	Pegg and Pierce (1)
Fluvial Dependence	Is this species dependent upon on a flowing water environment as its habitat?	N/A	Simon (5)
Migratory	Is this species migratory?	0 = No 1 = Yes	Simon (5)
Ecological Tolerance	Relative Ecological Tolerance	N/A	Simon (5)
Large River Species	Is the species classified as a Large River Species?	0 = No 1 = Yes	Winemiller and Rose (2)

Table A-6. (continued)

Attribute name	Description	Codes and meanings	Data source
Current Preference	Water current preference	1 = Fast 2 = Moderate 3 = Slow-none 4 = General	Winemiller and Rose (2)
Substrate Preference	Substrate preference as a component of adult habitat (not reproduction)	1 = Cobble 2 = Gravel 3 = Sand 4 = Silt 5 = General 6 = Vegetation 7 = Structure 8 = Pelagic	Winemiller and Rose (2)
Silt Tolerance	Relative tolerance to silt	1 = High 2 = Medium 3 = Low	Winemiller and Rose (2)
Spawning Substrate	Spawning substrate preference	1 = Cobble 2 = Gravel 3 = Sand 4 = Silt 5 = General 6 = Vegetation 7 = Structure 8 = Pelagic	Winemiller and Rose (2)
Turbidity Tolerance	Relative tolerance to turbidity	1 = High 2 = Medium 3 = Low	Winemiller and Rose (2)
Swim Factor	Swim factor	N/A	Winemiller and Rose (2)
Shape Factor	Shape factor	N/A	Winemiller and Rose (2)
Water Column Preference	Water column preference of adult fishes	1 = Benthic 2 = Epibenthic 3 = Pelagic	Winemiller and Rose (2)
Adult Habitat	Adult habitat preference	1 = Caves or Springs 2 = Small cold water streams 3 = Small warm water streams 4 = River backwater and lakes 5 = Estuaries 6 = Marine benthic 7 = Marine pelagic	Winemiller and Rose (2)
Freshwater/Marine	Marine or freshwater classification	F = Freshwater M = Marine	Winemiller and Rose (2)
Adult Trophic Level	Trophic status based on summarized diet information for adult fish	1 = Detrivore/Herbivore 2 = Omnivore 3 = Invertivore 4 = Piscivore	Winemiller and Rose (2)
Relative Anadromy	Relative migratory behavior (fractional numbers accepted)	1 = Anadromous 2 = Sedentary -1 = Catadromous	Winemiller and Rose (2)

Table A-6. (continued)

Attribute name	Description	Codes and meanings	Data source
Egg Buoyancy	Relative buoyancy of eggs in the environment	N/A	Winemiller and Rose (2)
Habitat Guild	Adult habitat guild (see report for source data and descriptions of guild traits)	N/A	West Consultants (13)
TNC Global Rank	The Nature Conservancy's (TNC) Global Rank	G1 = the species is globally and critically imperiled G2 = the species is globally or nationally imperiled G3 = the species is either rare or uncommon G4 = the species is globally widespread, abundant, or apparently secure, but with cause for long-term concern G5 = the species is demonstrably, widespread, abundant, and secure globally	Simon (5)

Table A-7. Attribute name, description, codes and meaning, and data source for data attributes in the Reproduction Attribute Class for the Long Term Resource Monitoring Program (LTRMP) fish life history database. "N/A" means the information is not applicable to that attribute. Data source is identified in Appendix B.

Attribute name	Description	Codes and meanings	Data source
Maximum fecundity	Largest batch fecundity reported	N/A	Winemiller and Rose (2)
Mean fecundity	Mean batch fecundity for a local population	N/A	Winemiller and Rose (2)
Mean ovum diameter	The mean diameter of mature (fully yolked) ovarian oocytes	N/A	Winemiller and Rose (2)
Range ovum diameter	The range of diameters for mature ovarian oocytes reported for a local population	N/A	Winemiller and Rose (2)
Spawning duration	Number of days that spawning or early larvae were reported	N/A	Winemiller and Rose (2)
Spawning bouts	The mean number of times an individual female was reported to spawn during a year	N/A	Winemiller and Rose (2)
Parental care	Relative amount of parental care provided to larvae and juveniles	0 = No special placement of zygotes, no parental care of zygotes or larvae, no nutritional contribution to larvae 1 = zygote are placed in a special habitat (i.e., scattered on vegetation or buried in gravel), a brief period of protection by one sex (<1 month) 2 = both zygotes and larvae are maintained in nest, a long period of protection by one sex (>1 month) or brief care by both sexes, brief period of nutritional contribution to larvae (= brief gestation [<1 month]) with nutritional contribution in viviparous 3 = Lengthy protection by one of the sexes 4 = Lengthy protection by both sexes	Winemiller and Rose (2)
Mean incubation	Mean time to hatch (hours)	N/A	Winemiller and Rose (2)

Table A-8. Attribute name, description, codes and meaning, data source, and source citation for data attributes in the Miscellaneous Attribute Class for the Long Term Resource Monitoring Program (LTRMP) fish life history database. "N/A" means that the information is not applicable to that attribute. Data source is identified in Appendix B.

Attribute name	Description	Codes and meanings	Data source
Exploit Rank	Exploitation rank (relative intensity of exploitation)	0= Not exploited 1 = Primary target 2 = Exploited as by catch	Ickes et al. (12)
Wilcox Migratory	Is this species known or suspected to be migratory in the Upper Mississippi River System (UMRS)?	0 = No 1 = Yes 2 = Likely	Wilcox et al. (11)
Wilcox Pass Dams	Has this species been observed to migrate through UMRS navigation dams?	0 = No 1 = Yes	Wilcox et al. (11)
Wilcox U _{crit}	Critical swimming velocity estimated or compiled from numerous peer-reviewed studies	N/A	Wilcox et al. (11)
Conservation Status	Does this species possess federal or state conservation status in the UMRS Basin?	0 = No 1 = Yes	Ickes et al. (12)
LTRMP 10-year rank	Rank abundance (total program catch) over all six LTRMP study reaches during the 10-year period from 1993 to 2002	1 = Most abundant species	Ickes et al. (12)

Table A-9. Attribute name and description for data attributes in the References Attribute Class for the Long Term Resource Monitoring Program (LTRMP) fish life history database.

Attribute name	Description
ID	Unique ID number for reference
Point of Contact	Contact accountable for data
Source Citation	Original source for data

Appendix B

Data Citations

Table B-1. Expanded citation and bibliographic data for data citations used in Appendix A tables.

Identifier	Citation
Pegg and Pierce (1)	Pegg, M. A., and Pierce, C. L. 2002. Fish community structure in the Missouri and Yellowstone rivers in relation to flow characteristics. <i>Hydrobiologia</i> 479:155–167.
Winemiller and Rose (2)	Winemiller, K. O., and K. A. Rose. 1992. Patterns of life history diversification in North American fishes: Implications for population regulation. <i>Canadian Journal of Fisheries and Aquatic Sciences</i> 49(10):2186–2218.
Ickes (3)	Calculated from the Long Term Resource Monitoring Program (LTRMP) database as $N_{obs} / N_{pot} * P_{obs} / P_{pot}$; where N_{obs} is the total number of years a species was observed in the six LTRMP study reaches between 1993 and 2002 (range: 0–60), N_{pot} is the total number of years x reach combinations in which a species was potentially observed (=60), P_{obs} is the number of LTRMP study reaches in which a species was observed at least once over the period 1993–2002 (range: 0–6), and P_{pot} is the number of LTRMP study reaches in which a species could potentially be observed (=6).
Ickes (4)	Parameters for log-log ordinary least squares length-weight regression derived from the Long Term Resource Monitoring Program. $\text{Log}_{10}(\text{length}) = \text{Intercept} + \text{Slope} * \text{Log}_{10}(\text{weight})$.
Simon (5)	Simon, T. P., editor. 1999. Assessing the sustainability and biological integrity of water resources using fish communities. Boca Raton, Florida. CRC Press. 671 pp.
Barko et al. (6)	Barko, V. A., B. S. Ickes, D. P. Herzog, R. A. Hrabik, J. H. Chick, and M. A. Pegg. 2005. Spatial, temporal, and environmental trends of fish assemblages within six reaches of the Upper Mississippi River System. U.S Geological Survey, Upper Midwest Sciences Center, La Crosse, Wisconsin, February 2005. Technical Report LTRMP 2005-T002. 27 pp.
Ickes (7)	Calculated as the maximum observed length observed by the Long Term Resource Monitoring Program over the period of record (1989 to 2004).
Anderson and Neumann (8)	Anderson, R. O., and R. M. Neumann. 1996. Length, weight, and associated structural indices. Pages 447–482 <i>in</i> B. R. Murphy and D. W. Willis, editors. <i>Fisheries techniques</i> , second edition. American Fisheries Society, Bethesda, Maryland.
Southwick et al. (9)	Southwick, R. I., and A. J. Loftus. 2003. Investigation and monetary values of fish and freshwater mussel kills. American Fisheries Society, Bethesda, Maryland. 177 pp.
Gutreuter et al. (10)	Gutreuter, S., R. Burkhardt, and K. Lubinski. 1995. Long Term Resource Monitoring Program Procedures: Fish Monitoring. National Biological Service, Environmental Management Technical Center, Onalaska, Wisconsin, July 1995. LTRMP 95-P002-1. 42 pp. + Appendixes A–J.
Wilcox et al. (11)	Wilcox, D. B., E. L. Stefanik, D. E. Kelner, M. A. Cornish, D. J. Johnson, I. J. Hodgins, S. J. Zigler, and B. L. Johnson. 2004. Improving fish passage through navigation dams on the Upper Mississippi River System. Upper Mississippi River-Illinois Waterway System Navigation Study ENV Report 54. U.S. Army Corps of Engineers, Rock Island District. 110 pp. + Appendixes A–D.
Ickes et al. (12)	Ickes, B. S., M. C. Bowler, A. D. Bartels, D. J. Kirby, S. DeLain, J. H. Chick, V. A. Barko, K. S. Irons, and M. A. Pegg. 2005. Multiyear synthesis of the fish component from 1993 to 2002 for the Long Term Resource Monitoring Program. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. LTRMP 2005-T005. 60 pp. + Appendixes A–E + CD-ROM.
West Consultants (13)	West Consultants, Inc. 2000. Upper Mississippi River and Illinois Waterway cumulative effects study. Volume 2: Ecological Assessment. Contract Number DACW25-97-R-0012. Final report to the Department of Army Corps of Engineers, Rock Island District. 295 pp.
Nelson et al. (14)	Nelson, J. S., E. J. Crossman, H. Espinosa-Pérez, L. T. Findley, C. R. Gilbert, R. N. Lea, and J. D. Williams. 2004. Common and scientific names of fishes from the United States, Canada, and Mexico, Sixth Edition. American Fisheries Society, Bethesda, Maryland. 386 pp.

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The Long Term Resource Monitoring Program (LTRMP) for the Upper Mississippi River System was authorized under the Water Resources Development Act of 1986 as an element of the Environmental Management Program. The mission of the LTRMP is to provide river managers with information for maintaining the Upper Mississippi River System as a sustainable large river ecosystem given its multiple-use character. The LTRMP is a cooperative effort by the U.S. Geological Survey, the U.S. Army Corps of Engineers, and the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin.

