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Temporal and Spatial Trends in the Frequency of Occurrence, Length-frequency Distributions, Length-weight Relationships, and Relative Abundance of Upper Mississippi River Fish

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Cover photo: Shovelnose sturgeon (*Scaphirhynchus platorynchus*) by Kevin Mauel, Wisconsin Department of Natural Resouces

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by

Daniel J. Kirby

Iowa Department of Natural Resources
206 Rose Street
Bellevue, Iowa 52031

and

Brian S. Ickes

U.S. Geological Survey
Upper Midwest Environmental Sciences Center
2630 Fanta Reed Road
La Crosse, Wisconsin 54603

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U.S. Geological Survey
Upper Midwest Environmental Sciences Center
2630 Fanta Reed Road
La Crosse, Wisconsin 54603

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Executive Summary

This report focuses on fisheries information colleted by the Long Term Resource Monitoring Program (LTRMP) in 1993–2002. In 10 years of sampling, more than 24,000 fish community samples from six study areas in the Upper Mississippi River System (UMRS) were collected for the LTRMP. More than three million individual fish composing 136 species were collected. Data gathered from this extensive effort were used to address the following four questions: (1) What fish species are present in the UMRS and how are species distributed within the basin? (2) What is the size structure of commercially and recreationally important species and does size structure vary within the system? (3) How does the physical condition of species vary from year to year and spatially within the system? and (4) In what way does the abundance of species within the system vary temporally and spatially? These topics were chosen because they take advantage of the extensive temporal and spatial characteristics of the LTRMP fisheries database and address important management-oriented questions not easily answered with short-term or local-scale research. Most of the findings in the report are not revolutionary, but rather provide quantified proof or support for existing ideas regarding population ecology within the UMRS. The following is a summary of key findings:

1. From 1993 to 2002, the LTRMP collected 136 of the 163 species (83%) found in the UMR since the late 19th century.
    a. Of these 136 species, 47 species were collected in all six LTRMP study areas, 32 species were collected in 4 or 5 study areas, 33 species were collected in 2 or 3 study areas, and 24 species were collected in 1 study area.
    b. Fifty-six species always occurred or frequently occurred within sampling years (1993–2002), 47 species commonly occurred or occasionally occurred within sampling years, and 33 species uncommonly occurred or rarely occurred within sampling years.
    c. Cyprinidae was the dominant family in terms of species richness and composed 30% of the species collected from the UMRS. Five families (Catostomidae, Centrarchidae, Cyprinidae, Ictaluridae, and Percidae) composed 72% of the species collected from the UMRS.
2. Spatial differences in length-frequency distributions were more pronounced for commercially exploited species (e.g., channel catfish [*Ictalurus punctatus*] and smallmouth buffalo [*Ictiobus bubalus*]) than for species exploited solely by recreational angling (e.g., black crappie [*Pomoxis nigromaculatus*] and sauger [*Sander canadensis*]).
    a. In Pool 4, all 12 species investigated exhibited a relative length frequency composed of a high proportion of long fish when compared to average length frequencies for LTRMP study areas.
3. Rate of gain (i.e., increase in $\log_{10}$ weight per unit increase in $\log_{10}$ length) was significantly different among LTRMP study areas for all five of the species investigated (i.e., black crappie, channel catfish, common carp [*Cyprinus carpio*], sauger, and walleye [*Sander vitreus*]) and was significantly different among years for four of the five species (i.e., black crappie, channel catfish, common carp, and walleye).
    a. La Grange Pool of the Illinois River was the only study area that contained species (black crappie, channel catfish, and sauger) exhibiting a rate of gain significantly greater than the overall UMRS rate of gain trend.

4. The relative abundance of 75 study groups (50 fish species, 25 of which were split into 2 length groups) varied significantly among LTRMP study areas, 72 of 75 study groups exhibited significant variation in relative abundance among 3 types of aquatic areas (contiguous backwater shorelines, main channel border, and side channel border), and 59 of 75 study groups exhibited significant interannual variation in relative abundance.
   a. Spatial variation proved more important than temporal variation for separating species based upon relative abundance patterns.
   b. Centrarchid species exhibited high levels of variation in relative abundance among contiguous backwater shoreline, main channel border, and side channel border areas.
   c. For substock-length fish, temporal variation in relative abundance was, in general, most pronounced for species in channel habitats that exhibit low parental care (e.g., common carp, sauger, smallmouth buffalo, walleye, and white bass [*Morone chrysops*]) and was least pronounced for species exhibiting high parental care (e.g., bluegill [*Lepomis macrochirus*], channel catfish, flathead catfish [*Pylodictis olivaris*], green sunfish [*Lepomis cyanellus*], longnose gar [*Lepisosteus osseus*], and white crappie [*Pomoxis annularis*]).
   d. Analysis of variance suggests that centrarchid species, bowfin (*Amia calva*), emerald shiners (*Notropis atherinoides*), flathead catfish, golden shiners (*Notemigonus crysoleucas*), longnose gar, river shiners (*Notropis blennius*), and yellow perch (*Perca flavescens*) are most likely to respond to habitat rehabilitation and enhancement projects applied to macrohabitats.

Contents

Tables

Figures

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 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 as 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 multiple-use 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.

This report supports Strategy 2.2.8 as specified in Goal 2, Monitor Resource Change, of the LTRMP Operating Plan (U.S. Fish and Wildlife Service 1993). This report was developed with funding provided by the LTRMP.

Temporal and Spatial Trends in the Frequency of Occurrence, Length-Frequency Distributions, Length-Weight Relations, and Relative Abundance of Upper Mississippi River Fish

Daniel J. Kirby[1] and Brian S. Ickes[2]

[1]Iowa Department of Natural Resources
206 Rose Street
Bellevue, Iowa 52031

[2]U.S. Geological Survey
Upper Midwest Environmental Sciences Center
2630 Fanta Reed Road
La Crosse, Wisconsin 54603

Abstract: The Long Term Resource Monitoring Program (LTRMP) collected more than 24,000 fish community samples from six study areas on the Upper Mississippi River System in 1993–2002. More than three million fish composed of 136 fish species were collected. These data were used to assess length-weight relationships and size structure of commercial (i.e., commercially harvested) and recreational (i.e., recreationally harvested) species, and the distribution, frequency of occurrence, and abundance patterns of commercial, nongame (i.e., not commercially or recreationally harvested), and recreational species. Forty-seven species were collected in all 6 LTRMP study areas, 32 species were collected in 4 or 5 study areas, 33 species were collected in 2 or 3 study areas, and 24 species were collected in 1 study area. Spatial differences (i.e., differences among study areas) in size structure were more pronounced for commercial species than for recreational species. Rate of gain (increase in $\log_{10}$ weight per unit increase in $\log_{10}$ length) was assessed for five species, and was significantly different among study areas for all five species and significantly different among years for four species. Assessment of longitudinal-spatial (among study area), lateral-spatial (among aquatic area types) and temporal (among 10 years) patterns in abundance showed that species were most similar with respect to temporal variation in abundance, and least similar with respect to longitudinal-spatial variation in abundance. These fisheries population assessments, derived from the spatially and temporally expansive LTRMP dataset, will provide river resource managers with decision support tools for managing UMRS fisheries.

Key words: Abundance patterns, fish populations, Illinois River, length-weight relationships, size structure, species richness, Upper Mississippi River.

Chapter 1. Introduction, Study Area, and Fish Sampling Methods

Introduction

The Upper Mississippi River (UMR) is an important aquatic resource supporting a variety of uses including recreational and commercial fishing (Rasmussen 1979; U.S. Geological Survey 1999). In a 1990 recreational-use survey, fishing accounted for 29% of reported activity on the UMR and recreational users (e.g., anglers, boaters, sightseers) spent approximately $340 million on durable goods and trip-related expenses (Carlson et al. 1995). The UMR commercial fishery harvest averages about 11 million pounds annually with a wholesale value of about $2 million dollars (Upper Mississippi River Conservation Committee 1998, 1999, 2000). The UMR supports a rich fish assemblage, with more than 150 species reported in collections from the UMR during the past century (Pitlo et al. 1995). The ecological, social, and economic importance of UMR fishes provides support for monitoring UMR fish population trends.

The Water Resource Development Act of 1986 (Public Law 99-662) established the Upper Mississippi River System (UMRS) as the only river system in the United States to be formally recognized as a nationally significant ecosystem and commercial navigation system. As part of this recognition, the U.S. Congress authorized the Environmental Management Program in 1986, which includes the Long Term Resource Monitoring Program (LTRMP). The LTRMP is implemented by the U.S. Geological Survey Upper Midwest Environmental Sciences Center in cooperation with the five Upper Mississippi River System states of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The U.S. Army Corp of Engineers has overall responsibility for the LTRMP and provides guidance to the program. The mode of operation and the roles of agencies are outlined in a 1988 Memorandum of Agreement. The LTRMP fisheries component is charged with monitoring and reporting trends of selected fish populations and communities in the UMRS (U.S. Fish and Wildlife Service 1993). In 1993–2002, the LTRMP collected fish community samples at sites in five UMR study areas (Pools 4, 8, 13, and 26, and Open River) and one Illinois River study area (La Grange Pool). Fisheries data collected as part of the LTRMP are used to quantify the status and trends of fish populations and communities, and to address fisheries management concerns in a multiuse large-river resource (Gutreuter and Theiling 1999).

This report focuses on the population ecology of fishes in the Upper Mississippi and Illinois Rivers. The data analyses presented address several fisheries management questions. Chapter 2 defines the "commonness" and spatial distribution of the 136 fish species collected by the LTRMP. Chapter 3 focuses on the length-frequency distribution of 12 common and widespread species (i.e., species collected from all 6 LTRMP study areas in 1993–2002) with importance to recreational or commercial fisheries. Chapter 4 investigates the length-weight relationships of five species with importance to recreational and commercial fisheries. Chapter 5 defines the spatial and temporal variation of 50 widespread species (i.e., collected from all LTRMP study areas, excluding the Open River study area, in at least 1 year of sampling). The central theme linking these four chapters is the quantification of trends in population indices both within study areas and across the UMRS. The topics and theme of this report were chosen because they use the extensive temporal and spatial characteristics of the LTRMP fisheries database to address management questions not easily answered with short-term and local-scale research.

Chapters 3 through 5 used standardized length categories to define size classes of fish before analyses. Length categories were used to identify size classes of populations that may exhibit unique temporal or spatial variation. Length categories were used for common recreational and commercial species. Incremental length categories (Gabelhouse 1984), provided by Anderson and Neumann (1996) and Bister et al. (2000), were used in Chapters 3 and 4. Incremental length categories place fish into substock, stock-quality, quality-preferred,

preferred-memorable, memorable-trophy, and trophy length categories based on percentages of world record length for each species (Anderson and Neumann 1996). Minimum lengths for stock, quality, preferred, memorable, and trophy length categories correspond to near 20–26%, 36–41%, 45–55%, 59–64%, and 74–80% of world record lengths, respectively (Anderson and Neumann 1996). Traditional length categories (Gabelhouse 1984) were used in Chapter 5 to place fish into substock (i.e., less than stock length) and stock length (i.e., greater than or equal to stock length) categories. Stock length, as defined above, equates roughly to the size where fish reach maturity and the minimum length of fish that provide recreational value (Anderson and Neumann 1996).

Study Area

The LTRMP study areas include six river sections within the UMRS. Five of the study areas are on the Mississippi River and one is on the Illinois River (Figure 1.1). Study areas are referred to by navigation pool designations (e.g., Pool 4 is the area between Lock and Dam 4 and Lock and Dam 3), or by river mile (river mile 0 is at the confluence of the Ohio and Mississippi Rivers). Mississippi River study areas include Pools 4 (river mile 752–797; excluding Lake Pepin), 8 (river mile 679–703), 13 (river mile 523–557), and 26 (river mile 202–242) and the Open River study area (river mile 29–80, hereafter referred to as Open River). The Illinois River study area is La Grange Pool (river mile 80–158). These study areas were chosen, in part, to reflect differences in geomorphology, floodplain land-use practices, and navigation management practices within the UMRS (Burkhardt et al. 2001). Pools 4, 8, and 13 are characterized by high percentages of open water and aquatic vegetation and low agricultural use within the floodplain (Table 1.1). Pools 4, 8, and 13 are geomorphically complex with a high percentage of total aquatic area composed of backwater and side channels. Pool 26 and Open River contain a relatively high percentage of agricultural land use within the floodplain, and a comparatively high percentage of the total aquatic area is main channel (Table 1.1). The floodplain composition of La Grange Pool is similar to Pool 26 and Open River, but aquatic area composition within La Grange Pool is similar to Pools 4, 8, and 13 (Burkhardt et al. 2001).

Figure 1.1. The Upper Mississippi River System and the six study areas that compose the Long Term Resource Monitoring Program.

Fish Sampling Methods

Standardized LTRMP sampling procedures (Gutreuter et al. 1995) were used to collect community fish samples from LTRMP study areas in 1993–2002. Fisheries sampling was conducted using a stratified random sampling regime. The strata were based on enduring geomorphic and physical features, called aquatic areas, that help define aquatic habitats (Gutreuter et al. 1995). The following nine strata types were used:

backwater contiguous-offshore, backwater contiguous-shoreline, side channel borders, main channel border-unstructured area, tailwater zone, impounded-offshore, impounded-shoreline, tributary mouth, and tributary delta lake. Within each study area, sampling effort was equally allocated in three periods: June 15–July 31, August 1–September 15, and September 16–October 31. Realized effort within each year (i.e., the number of completed collections) was contingent upon river conditions and was reduced in 2002 when three gear types (seines, tandem fyke nets, tandem mini-fyke nets) were eliminated from standard sampling allocations (Table 1.2).

The following sampling gears, in standardized dimensions and effort, were used to collect community samples: day electrofishing, night electrofishing, fyke nets, mini-fyke nets, seines, trawls, gill nets, tandem fyke nets, and tandem mini-fyke nets (Gutreuter et al. 1995; Table 1.2). Not all strata were represented in each study area and not all gears were deployed in each stratum. Sampling sites (50- x 50-m cells) were randomly selected from a database of accessible sampling sites and referenced by Universal Transverse Mercator coordinates. Randomly selected alternate sites were also generated to provide collection teams with alternates to primary sites that were deemed inaccessible (e.g., too shallow). Fisheries sampling was augmented with limited sampling at a few permanently fixed sites. Fixed-site samples were included in analyses for Chapters 2–4, but were not included in analyses for Chapter 5.

Collected fish were identified to species to the extent reasonably possible and counted. Individual fish were measured for total length to the nearest millimeter. However, when large catches were encountered, fish were placed into 1- or 2-cm length groups. Observations of hybrids and fish identified only to genus were excluded from analysis for this report. Weight measurements to the nearest gram were recorded for subsamples of black crappie (*Pomoxis nigromaculatus)*, channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*), highfin carpsucker (*Carpiodes velifer*), sauger (*Sander canadensis*), and walleye (*Sander vitreus*) collected from September 16 to October 31 of each monitoring year.

Table 1.1. Floodplain and aquatic area compositions of the Long Term Resource Monitoring Program (LTRMP) study areas in the Mississippi (Pools 4, 8, 13, and 26 and Open River) and Illinois Rivers (La Grange Pool).

		Floodplain composition (%) [a]			Aquatic area composition (%) [b]	
Study area	Floodplain area (ha)	Open water	Aquatic vegetation [c]	Agriculture	Contiguous backwater	Main channel [d]
Pool 4	25,155	47.1	15.9	5.7	21.3	10.5
Pool 8	15,408	36.4	25.7	0.7	30.6	14.2
Pool 13	23,965	25.7	23.6	7.3	28.5	24.7
Pool 26	48,467	13.4	1.6	33.5	17.3	54.4
Open River	107,142	9.8	0.6	70.4	1.8	79.0
La Grange Pool	89,529	15.7	2.2	59.6	52.2	21.3

[a] Data on floodplain composition were from Theiling et al. (2000). Open River floodplain composition was for river mile 0 to 80 (Ohio River confluence to Grand Tower).
[b] Data on the composition of aquatic areas were from the LTRMP aquatic areas spatial database. Aquatic area composition was for river mile 29 to 80 (Open River).
[c] Aquatic vegetation included submersed aquatic beds, floating-leaved aquatic beds, permanently flooded emergent annuals, and permanently flooded emergent perennials.
[d] Main channel included navigation channel and main channel border areas.

Table 1.2. Number of fish collections made by year, study area, and gear in the Long Term Resource Monitoring Program study areas in the Upper Mississippi River System in 1993–2002.

Year	Gear[a]												Completed collections[b]	Allocated collections[c]
	D	F	G	HL	HS	M	N	S	T	TA	TF	TM		
Pool 4														
1993	71	22	30	54	55	48	12	40	8	NC[d]	23	24	387	390
1994	84	30	12	61	60	59	12	58	12	12	24	24	448	474
1995	82	32	12	65	66	62	12	55	12	12	24	24	458	474
1996	84	36	12	66	66	64	12	58	12	12	24	24	470	474
1997	82	36	11	48	46	65	12	70	8	12	30	30	450	462
1998	82	35	12	47	48	66	11	72	10	12	30	30	455	462
1999	84	36	12	48	48	66	12	72	12	12	30	30	462	462
2000	84	24	NC	36	36	53	12	72	12	NC	24	24	377	378
2001	80	24	NC	36	36	54	12	72	12	NC	24	24	374	378
2002	82	24	NC	36	36	54	NC	NC	4	NC	NC	NC	236	246
Pool 8														
1993	86	52	20	66	66	84	54	116	12	NC	12	12	580	580
1994	93	60	14	66	66	79	54	118	12	NC	12	12	586	592
1995	96	60	7	66	66	84	54	72	12	5	12	12	546	546
1996	96	60	NC	66	66	84	54	72	12	NC	18	18	546	546
1997	102	60	NC	66	66	84	54	72	12	NC	18	18	552	552
1998	102	60	NC	65	66	84	54	72	12	NC	18	18	551	552
1999	102	60	NC	66	66	84	54	70	12	NC	18	18	550	550
2000	72	42	NC	30	30	66	48	60	12	NC	18	12	390	390
2001	84	48	NC	41	42	66	48	60	12	NC	18	12	431	432
2002	84	48	NC	30	30	66	NC	NC	12	NC	NC	NC	270	270
Pool 13														
1993	52	39	NC	39	40	55	14	80	4	NC	18	19	360	486
1994	60	42	NC	49	49	70	22	108	16	NC	21	21	458	486
1995	59	42	NC	54	54	75	24	108	24	NC	21	21	482	486
1996	63	42	NC	54	54	75	24	108	24	NC	21	21	486	486
1997	61	42	NC	54	54	75	19	108	24	NC	21	21	479	486
1998	63	42	NC	54	54	75	24	108	24	NC	21	21	486	486
1999	63	42	NC	54	54	75	24	108	24	NC	21	21	486	486
2000	63	42	NC	54	54	75	24	108	24	NC	21	21	486	486
2001	63	42	NC	54	54	75	24	108	24	NC	21	21	486	486
2002	63	42	NC	48	48	75	NC	NC	24	NC	NC	NC	300	300
Pool 26														
1993	33	12	NC	22	22	13	NC	4	NC	NC	5	5	116	387
1994	78	24	NC	53	55	47	6	84	12	NC	12	12	383	387
1995	77	24	NC	56	55	45	6	84	12	NC	12	12	383	387
1996	78	24	NC	57	57	45	6	84	12	NC	12	12	387	387
1997	77	24	NC	56	57	45	6	84	12	6	12	12	391	387
1998	76	23	NC	54	51	42	6	76	12	6	12	12	370	387
1999	76	24	NC	52	54	45	6	78	12	NC	12	12	371	387
2000	78	24	NC	56	57	43	6	84	8	6	12	12	386	387
2001	77	24	NC	56	57	43	6	84	12	NC	12	12	383	387
2002	77	25	NC	56	57	45	NC	NC	12	NC	NC	NC	272	273
Open River														
1993	14	10	1	13	13	27	NC	NC	1	NC	NC	NC	79	336
1994	37	18	7	53	55	60	NC	24	6	NC	NC	NC	260	336
1995	47	16	7	51	52	57	NC	22	4	NC	NC	NC	256	336
1996	46	17	NC	49	49	61	NC	32	49	NC	NC	NC	303	336
1997	50	17	11	54	55	64	NC	44	57	NC	NC	NC	352	336
1998	33	12	9	50	51	58	NC	9	4	NC	NC	NC	226	354
1999	45	11	NC	52	55	54	NC	32	NC	NC	NC	NC	249	318
2000	47	14	17	47	47	48	NC	63	1	NC	NC	NC	284	318
2001	51	15	24	51	50	51	NC	56	NC	NC	NC	NC	298	318
2002	51	15	NC	50	50	51	NC	NC	NC	NC	NC	NC	217	219
La Grange Pool														
1993	66	23	53	54	54	65	42	60	10	NC	12	12	451	426
1994	66	24	NC	59	59	64	67	84	14	30	12	12	491	384
1995	127	42	NC	71	72	92	17	96	24	NC	12	12	565	564
1996	126	41	NC	69	72	90	18	94	24	NC	12	12	558	564
1997	122	42	NC	59	59	89	18	94	24	NC	18	18	543	552
1998	124	42	NC	60	60	90	16	96	24	NC	18	18	548	552
1999	123	42	NC	60	60	89	13	96	24	NC	18	18	543	552
2000	125	41	NC	60	60	88	18	92	24	NC	18	18	544	552
2001	126	42	NC	60	60	90	18	96	24	NC	18	18	552	552
2002	126	42	NC	60	60	90	NC	NC	24	NC	NC	NC	402	402

[a]Gear types are abbreviated as follows: D = day electrofishing, F = fyke nets, G = gill nets, HL = large hoop nets, HS = small hoop nets, M = mini-fyke nets, N = night electrofishing, S = seines, T = trawling, TA = trammel nets, TF = tandem fyke nets, and TM = tandem mini-fyke nets.

[b]Completed collections are the number of successfully completed fish collections in each study area and year.

[c]Allocated collections are the number of collections that were allocated in each study area and year using the LTRMP study design.

[d]NC = no collections made.

Chapter 2. Species Distribution and Frequency of Occurrence

Introduction

The Upper Mississippi River (UMR) is a diverse assemblage of aquatic habitats (e.g., secondary channels, backwaters, and main channel) subject to environmental conditions that can vary substantially over time (e.g., drought, flood, and ice). This spatial and temporal habitat diversity supports a fish community with high species richness (Smith et al. 1971; Rasmussen 1979; Fremling et al. 1989, Pitlo et al. 1995). Rasmussen (1979), Fremling et al. (1989), and Pitlo et al. (1995) subjectively assessed the relative abundance of UMR species based upon collection data from field biologists, defined species distributions, and placed species into rare, uncommon, occasional, common, or abundant categories. As acknowledged by Pitlo et al. (1995), the amount and type of data available about individual species may depend upon the ease of collecting a species and the importance of the species to commercial and recreational fisheries.

In this chapter, the "commonness" of fish species is assessed using the number of years each species was found in each study area during 1993–2002. Species distribution and frequency of occurrence data provide insight into systemic processes that shape fish communities. Fish communities are a reflection of the habitat available and the habitat requirements of individual species. The presence of a species in a study area suggests that the species habitat requirements are being met and the absence of a species in a study area suggests that the species habitat requirements are not being met. Sometimes, habitat management and rehabilitation can modify available habitat to influence the distribution or relative abundance of a species.

Methods

We analyzed fish community data collected from the Long Term Resource Monitoring Program (LTRMP) in 1993–2002 from Pools 4, 8, 13 and 26 and Open River study area (Open River; river mile 29–80) of the Mississippi River, and La Grange Pool of the Illinois River. Within each study area and for each study year, a species was considered present if it was captured with any gear (Table 2.1). Species were assigned to distribution categories and frequency of occurrence categories based upon the number of study areas the species was collected in and the average frequency (percentage of years) the species was collected within study areas of occurrence (Table 2.1). The scientific names (genus and species), common names, and phylogenic sequence of families that we used were provided by Nelson et al. (2004).

Results

One hundred thirty-six species from 27 families were collected for the LTRMP as part of standard monitoring (Table 2.1). Of these 136 species, 47 species were collected in all study areas, 32 species were collected in 4 or 5 study areas, 33 species were collected in 2 or 3 study areas, and 24 species were collected in 1 study area (Table 2.2). Fifty-six species always occurred or frequently occurred within sampling years (1993–2002), 47 species commonly occurred or occasionally occurred within sampling years, and 33 species uncommonly occurred or rarely occurred within sampling years (Table 2.2). In general, species with the most widespread distributions had the highest frequency of occurrence, and species with the smallest distributions had the lowest frequency of occurrence (Table 2.2). Eighteen fish species were collected in all study areas and in all years, and included 2 lepisosteids (gar), 1 amiid (bowfin), 1 clupeid (herring), 3 cyprinids (carp or minnows), 2 catostomids (suckers), 2 ictalurids (catfish), 1 percichthyid (temperate bass), 4 centrarchids (sunfish), 1 percid (perch) and 1 sciaenid (drum). Fifteen species rarely occurred within sampling years, and included 5 cyprinids, 1 esocid (pike), 1 osmerid (smelt), 1 cyprinodontid (killfish), 1 centrarchid, and 3 percids (Table 2.1).

Species richness for 1993–2002 was highest in Open River (101 species), and was similar in Pools 8 and 26 (89 species), Pool 4 (86 species), La Grange Pool (85 species) and

Pool 13 (83 species). The high species richness in Open River was largely attributable to the collection of 5 cyprinids (bigeye chub, blacktail shiner, bleeding shiner, plains minnow, sicklefin chub), 3 centrarchids (flier, spotted bass, spotted sunfish), and 3 percids (dusky darter, greenside darter, slough darter) with primary distributions in the Lower Mississippi River, Missouri Ozarks, Missouri River Basin, or Ohio River Basin (Table 2.1). Cyprinidae was the dominant family in terms of species richness and composed 30% of the species collected from the UMRS (Table 2.3). Five families (Catostomidae, Centrarchidae, Cyprinidae, Ictaluridae, and Percidae) composed 72% of the species collected from the UMRS (Table 2.3). Open River and Pool 26 had a high richness of cyprinids when compared to La Grange Pool and the three upriver study areas (Pools 4, 8, and 13), whereas Open River and Pool 26 had a low richness of catostomids when compared to La Grange Pool and upriver study areas (Table 2.3).

Two species, brook stickleback (*Culaea inconstans*) and central mudminnow (*Umbra limi*), were collected in all three upriver study areas (Pools 4, 8, and 13), but were absent in the lower three study areas (Pool 26, Open River, La Grange Pool). Ten species were collected in all three of the lower study areas, but were absent from samples in the three upriver study areas. These species included bighead carp (*Hypopthalmichthys nobilis*), blackstripe topminnow (*Fundulus olivaceus*), blue catfish (*Ictalurus furcatus*), goldfish (*Carassius auratus*), red shiner (*Cyprinella lutrensis*), redear sunfish (*Lepomis microlophus*), silverband shiner (*Notropis shumardi*), silver carp (*Hypophthalmichthys molitrix*), threadfin shad (*Dorsoma petenense*), and western mosquitofish (*Gambusia affinis*).

The LTRMP collected seven species of fish that are not native to North America in 1993–2002. Common carp (*Cyprinus carpio*) was the only invasive exotic species captured in all study areas, whereas goldfish, silver carp, and bighead carp were collected exclusively in the lower three study areas. Grass carp (*Ctenopharyngodon idella*) were frequently collected in the lower three study areas, but only a single collection was made from the upper three study areas. Brown trout (*Salmo trutta*) were collected in Pools 8 and 13, where they most likely occur as tributary strays from coldwater stream stockings. A single specimen of rudd (*Scardinius erythrophthalmus*) was collected in Pool 13, and was most likely introduced from a baitfish bucket.

Discussion

Pitlo et al. (1995) documented the presence of 155 species in the UMR since recordkeeping commenced in the late 19th century. Since the publication of Pitlo et al (1995) the LTRMP collected eight additional species, resulting in 163 species observations for the UMR. The following species caught in the UMR by the LTRMP were not listed by Pitlo et al. (1995): bigeye chub (*Notropis amblops*), bleeding shiner (*Luxilus zonatus*), greenside darter (*Etheostoma blennioides*), rudd, spotted sunfish (*Lepomis punctatus*), silver carp, slough darter (*Etheostoma spectabile*), and white perch (*Morone americana*). Twenty-seven of the species listed by Pitlo et al. (1995) were not collected through standard LTRMP sampling in 1993–2002, but these species were primarily tributary strays or species that existed in the UMR based on historical records, but may no longer be present. Exceptions (i.e., known species found since 1985, not considered tributary strays, and not caught by the LTRMP) included Alabama shad (*Alosa alabamae*), flathead chub (*Platygobio gracilis*), greater redhorse (*Moxostoma valenciennesi*), pallid sturgeon (*Scaphirhynchus albus*), sturgeon chub (*Macrhybopsis gelida*), and western silvery minnow (*Hybognathus argyritis*).

The 18 species collected from all LTRMP study areas in all years represent taxa with the ability to survive in a wide variety of habitat conditions. The loss of any of these species from a reach of the UMR would be indicative of major habitat alteration or degradation. Most ubiquitous species in the Mississippi River are representatives of “old” ichthyofauna such as sturgeon, gar, bowfin, goldeye, a few cyprinids, a few ictiobine suckers, bullhead, crappie, and two larger percids, whereas less widely distributed species represent “new” adaptively-radiating faunas including the shiners, moxostomine suckers, madtoms, topminnows, sculpins, small darters, and lepomine sunfishes (Fremling et al. 1989). Common carp was the only exotic invasive species found to be ubiquitous within the system, but bighead carp, grass carp, and silver carp were commonly collected in lower study areas and are widely considered to have an expanding distribution within the UMRS.

The continuation of the LTRMP will ensure that shifts in species composition and relative abundance can be detected—providing an opportunity to address and mitigate for species losses. The LTRMP data set also provides the ability to identify changes in the distribution and relative abundance of species exhibiting a limited range within the basin and to detect the occurrence of new species (e.g., silver carp). Before the LTRMP, it was difficult to discern how the distribution of a species has changed over time because effort within river reaches was sporadic and unequal. As the UMRS continues to change, the value of LTRMP species distribution and frequency of occurrence information will increase. For example, it is believed that the distributions of species, such as blue catfish (*Ictalurus furcatus*), lake sturgeon (*Acipenser fulvescens*), and skipjack herring (*Alosa chrysochloris*), has been reduced in the basin since the completion of the lock and dams, but it is difficult to quantify this change using historical data. Tracking changes in species distribution and frequency of occurrence provides a means for assessing present and future ecosystem health.

Table 2.1. Total years of occurrence (i.e., the number of sampling years where at least one specimen of a species was caught), by study area, for fish species collected for the Long Term Resource Monitoring Program in the Upper Mississippi River System in 1993–2002 [a].

Species	Study area							
	Pool 4	Pool 8	Pool 13	Pool 26	LG Pool	Open River	Dist.[b]	Occur.[c]
Family Petromyzontidae—lampreys								
American brook lamprey (*Lampetra appendix*)	2	6	0	0	0	0	R	O
Chestnut lamprey (*Ichthyomyzon castaneus*)	8	10	3	3	3	10	A	C
Silver lamprey (*Ichthyomyzon unicuspis*)	10	10	9	2	0	0	W	C
Family Acipenseridae—sturgeons								
Lake sturgeon (*Acipenser fulvescens*)	6	1	1	5	0	0	W	U
Shovelnose sturgeon (*Scaphirhynchus platorynchus*)	10	10	10	9	1	10	A	F
Family Polyodontidae—paddlefishes								
Paddlefish (*Polyodon spathula*)	4	0	0	6	4	8	W	O
Family Lepisosteidae—gars								
Longnose gar (*Lepisosteus osseus*)	10	10	10	10	10	10	A	A
Shortnose gar (*Lepisosteus platostomus*)	10	10	10	10	10	10	A	A
Spotted gar (*Lepisosteus oculatus*)	0	0	1	10	10	10	W	C
Family Amiidae—bowfins								
Bowfin (*Amia calva*)	10	10	10	10	10	10	A	A
Family Hiodontidae—mooneyes								
Goldeye (*Hiodon alosoides*)	5	4	2	10	9	10	A	C
Mooneye (*Hiodon tergisus*)	10	10	10	10	2	6	A	F
Family Anguillidae—freshwater eels								
American eel (*Anguilla rostrata*)	10	2	0	7	5	10	W	C
Family Clupeidae—herrings								
Gizzard shad (*Dorosoma cepedianum*)	10	10	10	10	10	10	A	A
Skipjack herring (*Alosa chrysochloris*)	1	1	0	10	10	10	W	C
Threadfin shad (*Dorosoma petenense*)	0	0	0	10	10	9	R	F
Family Cyprinidae—carps and minnows								
Bigeye chub (*Notropis amblops*)	0	0	0	0	0	1	L	R
Bigeye shiner (*Notropis boops*)	0	0	0	3	0	3	R	U
Bighead carp (*Hypopthalmichthys nobilis*)	0	0	0	10	7	9	R	F
Bigmouth shiner (*Notropis dorsalis*)	4	0	1	3	0	0	R	U
Blacknose dace (*Rhinichthys atratulus*)	1	0	0	0	4	0	R	U
Blacktail shiner (*Cyprinella venusta*)	0	0	0	0	0	9	L	F

Table 2.1. (continued)	Study area							
Species	Pool 4	Pool 8	Pool 13	Pool 26	LG Pool	Open River	Dist.[b]	Occur.[c]
Bleeding shiner (*Luxilus zonatus*)	0	0	0	0	0	1	L	R
Bluntnose minnow (*Pimephales notatus*)	8	7	5	7	10	8	A	C
Brassy minnow (*Hybognathus hankinsoni*)	0	2	0	0	0	0	L	U
Bullhead minnow (*Pimephales vigilax*)	10	10	10	10	10	10	A	A
Central stoneroller (*Campostoma anomalum*)	1	0	1	5	8	6	W	O
Channel shiner (*Notropis wickliffi*)	0	0	8	10	0	10	W	F
Common carp (*Cyprinus carpio*)	10	10	10	10	10	10	A	A
Creek chub (*Semotilus atromaculatus*)	0	1	3	3	4	2	W	U
Emerald shiner (*Notropis atherinoides*)	10	10	10	10	10	10	A	A
Fathead minnow (*Pimephales promelas*)	5	10	9	2	9	1	A	C
Ghost shiner (*Notropis buchanani*)	0	0	0	1	0	0	L	R
Golden shiner (*Notemigonus crysoleucas*)	9	10	10	8	10	3	A	F
Goldfish (*Carassius auratus*)	0	0	0	6	10	2	R	C
Grass carp (*Ctenopharyngodon idella*)	1	0	0	9	9	10	W	C
Hornyhead chub (*Nocomis biguttatus*)	1	0	0	0	0	0	L	R
Mimic shiner (*Notropis volucellus*)	10	10	4	0	0	2	W	C
Mississippi silvery minnow (*Hybognathus nuchalis*)	0	6	8	7	0	9	W	C
Pallid shiner (*Notropis amnis*)	1	2	0	0	0	0	R	R
Plains minnow (*Hybognathus placitus*)	0	0	0	0	0	3	L	U
Pugnose minnow (*Opsopoeodus emiliae*)	10	10	10	0	0	5	W	F
Red shiner (*Cyprinella lutrensis*)	0	0	0	10	10	10	R	A
River shiner (*Notropis blennius*)	10	10	10	10	7	10	A	F
Rudd (*Scardinius erythrophthalmus*)	0	0	1	0	0	0	L	R
Sand shiner (*Notropis stramineus*)	8	9	4	10	6	3	A	C
Sicklefin chub (*Macrhybopsis meeki*)	0	0	0	0	0	3	L	U
Silver carp (*Hypophthalmichtyhs molitrix*)	0	0	0	5	4	3	R	O
Silver chub (*Macrhybopsis storeriana*)	10	10	10	10	10	9	A	F
Silverband shiner (*Notropis shumardi*)	0	0	0	9	10	10	R	F
Southern redbelly dace (*Phoxinus erythrogaster*)	0	0	2	0	0	0	L	U
Speckled chub (*Macrhybopsis aestivalis*)	10	4	10	8	0	10	W	F
Spotfin shiner (*Cyprinella spiloptera*)	10	10	10	10	0	6	W	F

Table 2.1. (continued) Species	Study area Pool 4	Pool 8	Pool 13	Pool 26	LG Pool	Open River	Dist.[b]	Occur.[c]
Spottail shiner (*Notropis hudsonius*)	10	10	10	8	10	3	A	F
Striped shiner (Luxilus chrysocephalus)	0	0	0	1	0	1	R	R
Suckermouth minnow (*Phenacobius mirabilis*)	0	0	5	5	4	0	R	O
Weed shiner (*Notropis texanus*)	8	10	0	0	0	0	R	F
Family Catostomidae—suckers								
Bigmouth buffalo (*Ictiobus cyprinellus*)	10	10	10	10	10	10	A	A
Black buffalo (*Ictiobus niger*)	6	2	8	10	10	10	A	C
Blue sucker (*Cycleptus elongatus*)	10	8	6	8	1	10	A	C
Golden redhorse (*Moxostoma erythrurum*)	10	10	10	6	10	3	A	F
Highfin carpsucker (*Carpiodes velifer*)	4	10	10	0	10	0	W	F
Northern hog sucker (*Hypentelium nigricans*)	6	7	1	0	3	0	W	O
Quillback (*Carpiodes cyprinus*)	10	10	10	8	10	4	A	F
River carpsucker (*Carpiodes carpio*)	10	9	10	10	10	10	A	F
River redhorse (*Moxostoma carinatum*)	10	10	0	0	0	1	R	C
Shorthead redhorse (*Moxostoma macrolepidotum*)	10	10	10	10	10	9	A	F
Silver redhorse (*Moxostoma anisurum*)	10	10	9	0	9	0	W	F
Smallmouth buffalo (*Ictiobus bubalus*)	10	10	10	10	10	10	A	A
Spotted sucker (*Minytrema melanops*)	10	10	10	1	0	0	W	C
White sucker (*Catostomus commersoni*)	10	10	8	1	5	0	W	C
Family Ictaluridae—bullhead catfishes								
Black bullhead (*Ameiurus melas*)	7	10	10	7	10	5	A	F
Blue catfish (*Ictalurus furcatus*)	0	0	0	10	2	10	R	C
Brown bullhead (*Ameiurus nebulosus*)	3	9	0	7	10	0	W	C
Channel catfish (*Ictalurus punctatus*)	10	10	10	10	10	10	A	A
Flathead catfish (*Pylodictis olivaris*)	10	10	10	10	10	10	A	A
Freckled madtom (*Noturus nocturnus*)	0	0	1	5	3	10	W	O
Stonecat (*Noturus flavus*)	2	6	8	3	5	6	A	O
Tadpole madtom (*Noturus gyrinus*)	10	10	10	4	7	2	A	C
Yellow bullhead (*Ameiurus natalis*)	10	9	10	7	10	3	A	F

Table 2.1. (continued) Species	Study area Pool 4	Pool 8	Pool 13	Pool 26	LG Pool	Open River	Dist.[b]	Occur.[c]
Family Esocidae—pikes								
Grass pickerel (*Esox americanus vermiculatus*)	0	0	1	3	9	0	R	O
Muskellunge (*Esox masquinongy*)	0	0	0	0	0	1	L	R
Northern pike (*Esox lucius*)	10	10	10	2	7	0	W	C
Family Umbridae—mudminnows								
Central mudminnow (*Umbra limi*)	2	9	2	0	0	0	R	O
Family Osmeridae—smelts								
Rainbow smelt (*Osmerus mordax*)	0	1	0	0	0	0	L	R
Family Salmonidae—trouts								
Brown trout (*Salmo trutta*)	0	5	1	0	0	0	R	U
Family Percopsidae—trout-perches								
Trout perch (*Percopsis omiscomaycus*)	9	8	0	0	0	1	R	C
Family Aphredoderidae—pirate perches								
Pirate perch (*Aphredoderus sayanus*)	2	4	0	2	8	3	W	U
Family Gadidae—cods								
Burbot (*Lota lota*)	8	9	0	0	0	0	R	F
Family Cyprinodontidae—killifishes								
Blackspotted topminnow (*Fundulus olivaceus*)	0	0	0	0	0	4	L	O
Blackstripe topminnow (*Fundulus notatus*)	0	0	0	3	10	10	R	C
Starhead topminnow (*Fundulus dispar*)	0	0	0	1	0	0	L	R
Family Poeciliidae—livebearers								
Western mosquitofish (*Gambusia affinis*)	0	0	0	10	10	10	R	A
Family Atherinidae—silversides								
Brook silverside (*Labidesthes sicculus*)	9	10	10	10	10	9	A	F
Inland silverside (*Menidia beryllina*)	0	0	0	0	0	3	L	U
Family Gasterosteidae—sticklebacks								
Brook stickleback (*Culaea inconstans*)	3	4	2	0	0	0	R	U
Family Percichthyidae—temperate basses								
Striped bass (*Morone saxatilis*)	0	0	0	0	7	7	R	C
White bass (*Morone chrysops*)	10	10	10	10	10	10	A	A
White perch (*Morone americana*)	0	0	0	1	10	0	R	O
Yellow bass (*Morone mississippiensis*)	0	7	10	9	10	6	W	F

Table 2.1. (continued) Species	Study area Pool 4	Pool 8	Pool 13	Pool 26	LG Pool	Open River	Dist.[b]	Occur.[c]
Family Centrarchidae—sunfishes								
Black crappie (*Pomoxis nigromaculatus*)	10	10	10	10	10	10	A	A
Bluegill (*Lepomis macrochirus*)	10	10	10	10	10	10	A	A
Flier (*Centrarchus macropterus*)	0	0	0	0	0	2	L	U
Green sunfish (*Lepomis cyanellus*)	10	10	8	10	10	10	A	F
Largemouth bass (*Micropterus salmoides*)	10	10	10	10	10	10	A	A
Longear sunfish (*Lepomis megalotis*)	0	0	0	0	2	8	R	O
Orangespotted sunfish (*Lepomis humilis*)	7	10	10	10	10	10	A	F
Pumpkinseed (*Lepomis gibbosus*)	10	10	10	0	2	0	W	F
Redear sunfish (*Lepomis microlophus*)	0	0	0	4	8	3	R	O
Rock bass (*Ambloplites rupestris*)	10	10	10	0	1	0	W	C
Smallmouth bass (*Micropterus dolomieu*)	10	10	10	4	8	2	A	C
Spotted bass (*Micropterus punctulatus*)	0	0	0	0	0	10	L	A
Spotted sunfish (*Lepomis punctatus*)	0	0	0	0	0	1	L	R
Warmouth (*Lepomis gulosus*)	0	10	10	10	10	10	W	A
White crappie (*Pomoxis annularis*)	10	10	10	10	10	10	A	A
Family Percidae—perches								
Banded darter (*Etheostoma zonale*)	3	3	0	0	0	0	R	U
Blackside darter (*Percina maculata*)	2	5	0	0	2	1	W	U
Bluntnose darter (*Etheostoma chlorosomum*)	0	0	4	0	0	4	R	O
Crystal darter (*Ammocrypta asprella*)	3	3	0	0	0	0	R	U
Dusky darter (*Percina sciera*)	0	0	0	0	0	6	L	C
Fantail darter (*Etheostoma flabellare*)	0	3	1	0	0	0	R	U
Greenside darter (*Etheostoma blennioides*)	0	0	0	0	0	1	L	R
Iowa darter (*Etheostoma exile*)	0	7	0	0	0	0	L	C
Johnny darter (*Etheostoma nigrum*)	10	10	10	0	7	3	W	C
Logperch (*Percina caprodes*)	10	10	10	10	10	9	A	F
Mud darter (*Etheostoma asprigene*)	8	10	9	7	9	6	A	F
Orangethroat darter (*Etheostoma spectabile*)	0	0	0	0	0	1	L	R
River darter (*Percina shumardi*)	10	10	10	9	0	6	W	F
Sauger (*Sander canadensis*)	10	10	10	10	10	10	A	A
Slenderhead darter (*Percina phoxocephala*)	9	10	9	5	6	2	A	C

Table 2.1. (continued)	Study area							
Species	Pool 4	Pool 8	Pool 13	Pool 26	LG Pool	Open River	Dist.[b]	Occur.[c]
Slough darter (*Etheostoma gracile*)	0	0	0	0	0	1	L	R
Walleye (*Sander vitreus*)	10	10	10	8	10	2	A	F
Western sand darter (*Ammocrypta clara*)	8	10	6	3	0	2	W	O
Yellow perch (*Perca flavescens*)	10	10	10	1	2	0	W	C
Family Sciaenidae—drums								
Freshwater drum (*Aplodinotus grunniens*)	10	10	10	10	10	10	A	A
Family Mugilidae—mullets								
Striped mullet (*Mugil cephalus*)	0	0	0	0	0	1	L	R

[a] Species were assigned to distribution categories (Dist.) and frequency of occurrence categories (Occur.) based upon the number of study areas in which collected and the average frequency (percentage of years) collected within study areas of occurrence. The table shows a phylogenic sequence of families of fishes, with species listed alphabetically by common name within family groups. The phylogenic sequence, scientific names (family, genus, and species), and common names followed that of Nelson et al. (2004).

[b] Distribution categories

A— Collected in all LTRMP study areas during 1993–2002.
W— Widespread distribution, collected in 4 or 5 LTRMP study areas during 1993–2002.
R— Regional distribution, collected in 2 or 3 LTRMP study areas during 1993–2002.
L— Local distribution, collected in 1 LTRMP study area during 1993–2002.

[c] Frequency of occurrence categories

A— always collected within a sampling year, collected in all years within study areas of occurrence.
F— frequently collected within a sampling year, collected on average in 80–99% of years within study areas of occurrence.
C— commonly collected within a sampling year, collected on average in 60–79% of years within study areas of occurrence.
O— occasionally collected within a sampling year, collected on average in 40–59% of years within study areas of occurrence.
U— uncommonly collected, collected on average in 20–39% of years within study areas of occurrence.
R— rarely collected, collected on average in 1–19% of years within study areas of occurrence.

Table 2.2. Species counts within distribution and frequency of occurrence categories for fish species collected for the Long Term Resource Monitoring Program in the Upper Mississippi River System in 1993–2002.

	Frequency of occurrence[b]					
Distribution[a]	Always	Frequent	Common	Occasional	Uncommon	Rare
All study areas	18	18	10	1	0	0
Widespread	1	9	13	5	4	0
Regional	2	6	6	9	8	2
Local	1	1	2	1	6	13

[a]Distribution categories were as follows:
all study areas = collected in all six Long Term Resource Monitoring Program study areas,
widespread = collected in four or five study areas,
regional = collected in two or three study areas, and
local = collected in one study area.

[b]Frequency of occurrence categories were as follows:
always = collected in all years within study areas of occurrence,
frequent = collected on average in 80–99% of years within study areas of occurrence,
common = collected on average in 60–79% of years within study areas of occurrence,
occasional = collected on average in 40–59% of years within study areas of occurrence,
uncommon = collected on average in 20–39% of years within study areas of occurrence, and
rare = collected on average in 1–19% of years within study areas of occurrence.
(For example, 13 species of fish commonly occurred within a widespread distribution in the UMRS.)

Table 2.3. Total species richness by study area and family, for fishes collected for the Long Term Resource Monitoring Program in the Upper Mississippi River System in 1993–2002.

Family[a]	Study area						All Areas
	Pool 4	Pool 8	Pool 13	Pool 26	LG Pool[b]	Open River	
Family Petromyzontidae (lampreys)	3	3	2	2	1	1	3
Family Acipenseridae (sturgeons)	2	2	2	2	1	1	2
Family Polyodontidae (paddlefishes)	1	0	0	1	1	1	1
Family Lepisosteidae (gars)	2	2	3	3	3	3	3
Family Amiidae (bowfins)	1	1	1	1	1	1	1
Family Hiodontidae (mooneyes)	2	2	2	2	2	2	2
Family Anguillidae (freshwater eels)	1	1	0	1	1	1	1
Family Clupeidae (herrings)	2	2	1	3	3	3	3
Family Cyprinidae (carps and minnows)	21	19	22	27	20	31	41
Family Catostomidae (suckers)	14	14	13	10	12	9	14
Family Ictaluridae (bullhead catfishes)	7	7	7	9	9	8	9
Family Esocidae (pikes)	1	1	2	2	2	1	3
Family Umbridae (mudminnows)	1	1	1	0	0	0	1
Family Osmeridae (smelts)	0	1	0	0	0	0	1
Family Salmonidae (trouts)	0	1	1	0	0	0	1
Family Percopsidae (trout-perches)	1	1	0	0	0	1	1
Family Aphredoderidae (pirate perches)	1	1	0	1	1	1	1
Family Gadidae (cods)	1	1	0	0	0	0	1
Family Cyprinodontidae (killifishes)	0	0	0	2	1	2	3
Family Poeciliidae (livebearers)	0	0	0	1	1	1	1
Family Atherinidae (silversides)	1	1	1	1	1	2	2
Family Gasterosteidae (sticklebacks)	1	1	1	0	0	0	1
Family Percichthyidae (temperate basses)	1	2	2	3	4	3	4
Family Centrarchidae (sunfishes)	9	10	10	9	12	13	15
Family Percidae (perches)	12	14	11	8	8	14	19
Family Sciaenidae (drums)	1	1	1	1	1	1	1
Family Mugilidae (mullets)	0	0	0	0	0	1	1
All Families (total species richness)	86	89	83	89	85	101	136

[a]The phylogenic sequence, scientific names, and common names followed that of Nelson et al. (2004).

[b]LG pool is La Grange Pool.

Chapter 3. Spatial Patterns in Length-frequency Distributions

Introduction

Length-frequency distributions are commonly used by fisheries managers to assess the size structure of fish populations and can identify problems such as low recruitment, slow growth, or excessive annual mortality (Anderson and Neumann 1996). The length-frequency distributions of 12 species with recreational or commercial importance are displayed and evaluated in this chapter. Categorical (length-based) catch-per–unit-effort (CPUE) is also provided for each species to supplement the information provided by length-frequency distributions. The objective of this evaluation was to visually and quantitatively assess spatial differences in length frequencies among Long Term Resource Monitoring Program (LTRMP) study areas.

Methods

Twelve fish species with direct commercial or recreational importance were identified as being common and widespread in LTRMP study areas (i.e., collected in all study areas in all years 1993–2002) and were chosen for length-frequency distribution analysis. The commercially harvested species were bigmouth buffalo (*Ictiobus cyprinellus*), common carp (*Cyprinus carpio*), channel catfish (*Ictalurus punctatus*), flathead catfish (*Pylodictis olivaris*), freshwater drum (*Aplodinotus grunniens*), and smallmouth buffalo (*Ictiobus bubalus*), and the noncommercially harvested species were black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), sauger (*Sander canadensis*), white bass (*Morone chrysops*), and white crappie (*Pomoxis annularis*). For each species, the sampling gear having the highest total catch of stock-length fish among study areas was used for analysis (stock-length designations, Anderson and Neumann 1996; Bister et al. 2000). Analysis was limited to the single gear with the highest total catch to maximize sample size and to avoid bias associated with combining multiple gears.

For each species and study area, a five-cell relative length frequency was calculated for data from 1993 to 2002 combined—where the value in each cell was the proportion of the total catch falling within the length category represented by the cell. Only species with a sample size of >40 from each study area for selected gears were included in analyses. The length categories used for the five cells were determined by the following criteria: (1) Gabelhouse (1984) incremental length categories (i.e., stock-quality, quality-preferred, preferred-memorable, memorable-trophy, and greater than or equal to trophy) were used if at least one specimen of trophy length had been captured and (2) if no trophy-length specimens had been captured, five categories of equal increment were constructed beginning with stock length and ending with a category including the length of the largest individual captured.

The relative length-frequency technique (Bonar 2002) was used to visually evaluate the length-frequency distribution of selected species in study areas. This technique uses the average length frequency (ALF) as a reference distribution that can be compared to length-frequency distributions of interest. For each species, the ALF is the average of the relative length-frequency distribution in the six LTRMP study areas.

A Kolmogorov-Smirnov statistic (KS; NPAR1WAY procedure, empirical distribution function [EDF] option; SAS Institute 1999) was used to quantify differences among the length-frequency distributions of study areas. Continuous length data for stock-length fish, rather than categorical data were applied to the Kolmogorov-Smirnov test (i.e., data sets were composed of “raw” length values for each fish collected). The additive inverse of the maximum deviation between the pooled EDF and the EDF from study areas was used to quantify the magnitude of the difference between the pooled and study area distributions. Positive values for the maximum deviation between the pooled EDF and the EDF from a study area represent length-frequency distributions composed of a higher than average proportion of long fish. Negative values for the maximum deviation between the pooled EDF and the EDF from a study area represent length-frequency distributions composed of a higher than average proportion of short fish.

For each study area, estimates of pooled (all sampling strata) areawide mean CPUE were calculated for each length category of each of the selected species for 1993–2002. Mean CPUE data supplements relative frequency information as an index of categorical abundance, within each length group and study area, that is independent of the total catch in other length groups and study areas (i.e., relative frequency within a category is dependent upon total catch within other length categories, and mean CPUE is not dependent upon total catch in other categories). This analysis was limited to the same sampling gears used in length-frequency analyses from random stratified monitoring. Statistical methods for estimates of areawide mean CPUE and associated standard error followed that of Gutreuter et al. (1995). Inferential statistics were not used to test the significance of differences among study area CPUE.

Results

Length frequency histograms are displayed for each study area in the following figures: Figure 3.1, bigmouth buffalo; Figure 3.2, black crappie; Figure 3.3, bluegill; Figure 3.4, channel catfish; Figure 3.5, common carp; Figure 3.6, flathead catfish; Figure 3.7, freshwater drum; Figure 3.8, largemouth bass; Figure 3.9, sauger; Figure 3.10, smallmouth buffalo; Figure 3.11, white bass; Figure 3.12, white crappie. Spatial differences in length-frequency distributions were most pronounced (KS > 0.200, Table 3.1) for common carp (Figure 3.5), flathead catfish (Figure 3.6), and smallmouth buffalo (Figure 3.10), and least pronounced (KS < 0.100, Table 3.1) for black crappie (Figure 3.2), bluegill (Figure 3.3), largemouth bass (Figure 3.8), sauger (Figure 3.9), and white bass (Figure 3.11). No commercially harvested species exhibited a KS value of <0.100, and only one noncommercially harvested species (i.e., white crappie) exhibited a KS value of >0.100 (Table 3.1).

In Pool 4, all species exhibited a length-frequency distribution composed of a high proportion of long fish when compared to the pooled distributions (Table 3.1). In Pool 8, all commercially harvested species, black crappie, and white crappie exhibited a length-frequency distribution composed of a high proportion of long fish when compared to the pooled distributions. In Pool 13, 6 out of 12 species exhibited a length-frequency composed of a high proportion of long fish when compared to the pooled distributions. In Pool 26, only white crappie exhibited a length-frequency distribution composed of a high proportion of long fish when compared to the pooled distribution. In the Open River study area (Open River; river mile 29 to 80), 9 out of 12 species exhibited a length-frequency distribution composed of a high proportion of long fish when compared to the pooled distributions. In La Grange Pool, 4 out of 12 species exhibited a length-frequency distribution composed of a high proportion of long fish when compared to the pooled distributions.

Pooled areawide CPUE point estimates (hereafter referred to as CPUE estimates or catch rates) generally reflected size-structure patterns revealed through the analysis of relative length frequency (Tables 3.2–3.13). Catch rates were low (<0.15 fish/unit effort) for the longest length groups (fifth category) of all species in all years and study areas and are not presented. La Grange Pool was the only study area to catch long (580–679 mm) bigmouth buffalo in all 10 sampling years and exhibited the highest catch rates for shorter (280–579 mm) bigmouth buffalo in most years (Table 3.2). Pool 4 had the highest CPUE estimates for long (300–379 mm) black crappie in 6 of 10 sampling years, and Open River consistently exhibited the lowest catch rates for all intermediate size classes (130–299 mm) of black crappie (Table 3.3). Pool 13 had the highest CPUE estimates for long (185–219 mm) bluegill in 7 out of 10 sampling years. The highest CPUE estimates for intermediate-sized bluegill (115–184 mm) were exclusively within upriver study areas (Pools 4, 8, and 13) or La Grange Pool (Table 3.4). Channel catfish CPUE estimates were low (<0.5 fish/net night) for long fish (> 480 mm) in all study areas, were highest in upriver study areas for intermediate-sized fish

(380–479 mm), and were highest for short fish (280–379 mm) in Pools 8 and 26 (Table 3.5). The highest CPUE estimates for long common carp (> 530 mm) were in upriver study areas in all years, whereas the highest CPUE estimates for short (280–409 mm) common carp were in Pool 26 or La Grange Pool in all years (Table 3.6). Flathead catfish CPUE estimates were low (≤0.3 fish/net night) for all size categories in all study areas and all years (Table 10). Catch-per-unit-effort estimates for long (510–629 mm) freshwater drum were low (≤0.2 fish/net night) in all study areas and years, were highest for intermediate-sized (380–509 mm) fish in Pool 26 for 7 out of 10 years, and were highest for short (200–299 mm) fish in lower study areas (Pool 26, Open River, La Grange Pool) in all years (Table 3.8). Pool 13 had the highest CPUE estimates for long (350–424 mm) largemouth bass in 7 out of 10 years, and the highest CPUE estimates for shorter (200–349 mm) largemouth bass were in Pools 8 and 13 or La Grange Pool in 9 out of 10 years (Table 3.9). Sauger CPUE estimates were low (≤0.9 fish/15 min) for all size categories in all study areas and years (Table 3.10). Pools 4 or 26 had the highest CPUE estimates for intermediate-sized (500–609 mm) smallmouth buffalo in all years, and Pool 26 or La Grange Pool had the highest CPUE point estimates for short (280–499 mm) smallmouth buffalo in all years (Table 3.11). Pool 4 or La Grange Pool had the highest CPUE estimates for intermediate-sized (300–379 mm) white bass in 9 out of 10 years, and La Grange Pool had the highest CPUE estimates for short (150–229 mm) white bass in 7 out of 10 years (Table 3.12). Pool 13 had CPUE estimates for long (300–379 mm) white crappie greater than or equal to all other pools in all years, and Pool 13 or La Grange Pool had the highest CPUE estimates for shorter (130–299 mm) white crappie in all years (Table 3.13).

Discussion

Observed length-frequency distributions of fish populations are a product of the populations dynamic rate functions (i.e., reproduction, recruitment, growth, and mortality), gear bias, and sampling bias (Anderson and Neumann 1996). The LTRMP uses standardized gears and sampling procedures to help ensure that biases are similar when comparing indices among study areas. Therefore, we assumed that among study area differences in length-frequency distributions reflect differences in dynamic rate functions. The factors determining reproduction, recruitment, and growth of fish stocks in rivers are generally related to physical habitat, hydrology, or climate (Meals and Miranda 1991; Maceina and Betolli 1998; Sheehan and Rasmussen 1999; Pitlo 2002). Mortality of stock-length fish is also influenced by environmental factors, but exploitation can contribute significantly to total annual mortality, particularly in commercial fisheries (Pitlo 1997; Maceina et al. 1998; Mestl 1999; Timmons and Hughbanks 2000).

Spatial differences in length-frequency distributions were more pronounced for commercially exploited fish species than for species exploited solely by recreational angling. The following two mechanisms could explain the observed differences between commercial and recreational species: (1) the commercial species generally obtain a larger maximum length and maximum age when compared to recreational species, which magnifies the effects of subtle environmental differences that effect reproduction, recruitment, growth, and mortality among study areas and (2) commercial exploitation rates are different among study areas, which influences the length-frequency distribution of populations, but recreational exploitation either has comparatively little influence on size structure or is relatively similar among study areas. One or both of these mechanisms could explain the observed spatial differences in size structure. Previous studies suggest that commercial fishing can truncate size structures in large river populations (Mestl 1999; Timmons and Hughbanks 2000; Travnichek and Clemons 2001). Reach-specific growth rates can also contribute to spatial differences in size structure within a river system (Kirby 2001). Additional research into the reproduction, recruitment, growth, mortality, and exploitation of species exhibiting significant spatial variability in size structure will help provide answers.

It is important to consider abundance when comparing relative length-frequency distributions among areas because the abundance of long fish may be low even in situations where length-frequency distributions are composed of a high proportion of long fish (or vice versa). For example, bigmouth buffalo in La Grange Pool had a relative length frequency composed of a low proportion of long fish when compared to other study areas, but also had highest CPUE estimates for long fish in most years. Furthermore, the recreational or commercial value of a fishery is dependent upon size structure, as well as abundance.

This observational investigation identified spatial patterns in the length-frequency distributions and categorical (length-based) relative abundance of recreational and commercial fishes, but does not provide factors responsible for patterns. Future research should strive to identify factors driving spatial patterns to supply resource managers with mechanisms for improving the abundance and size structure of fish stocks. Factors driving UMR spatial patterns in fish abundance and size structure are most likely tied to habitat dynamics. For example, centrarchid species (black crappie, bluegill, largemouth bass) in Pools 4, 8, and 13, and La Grange Pool exhibited high CPUE estimates and length frequencies composed of proportionally more long fish when compared to Pool 26 and Open River. This trend is probably caused by the increased availability of suitable backwater habitat in Pools 4, 8, and 13, and La Grange Pool when compared to Open River and Pool 26. Chapter 5 provides a detailed analysis of fish species abundance variation and identifies the relative importance and spatial scale of factors affecting abundance.

Bigmouth buffalo (*Ictiobus cyprinellus*)

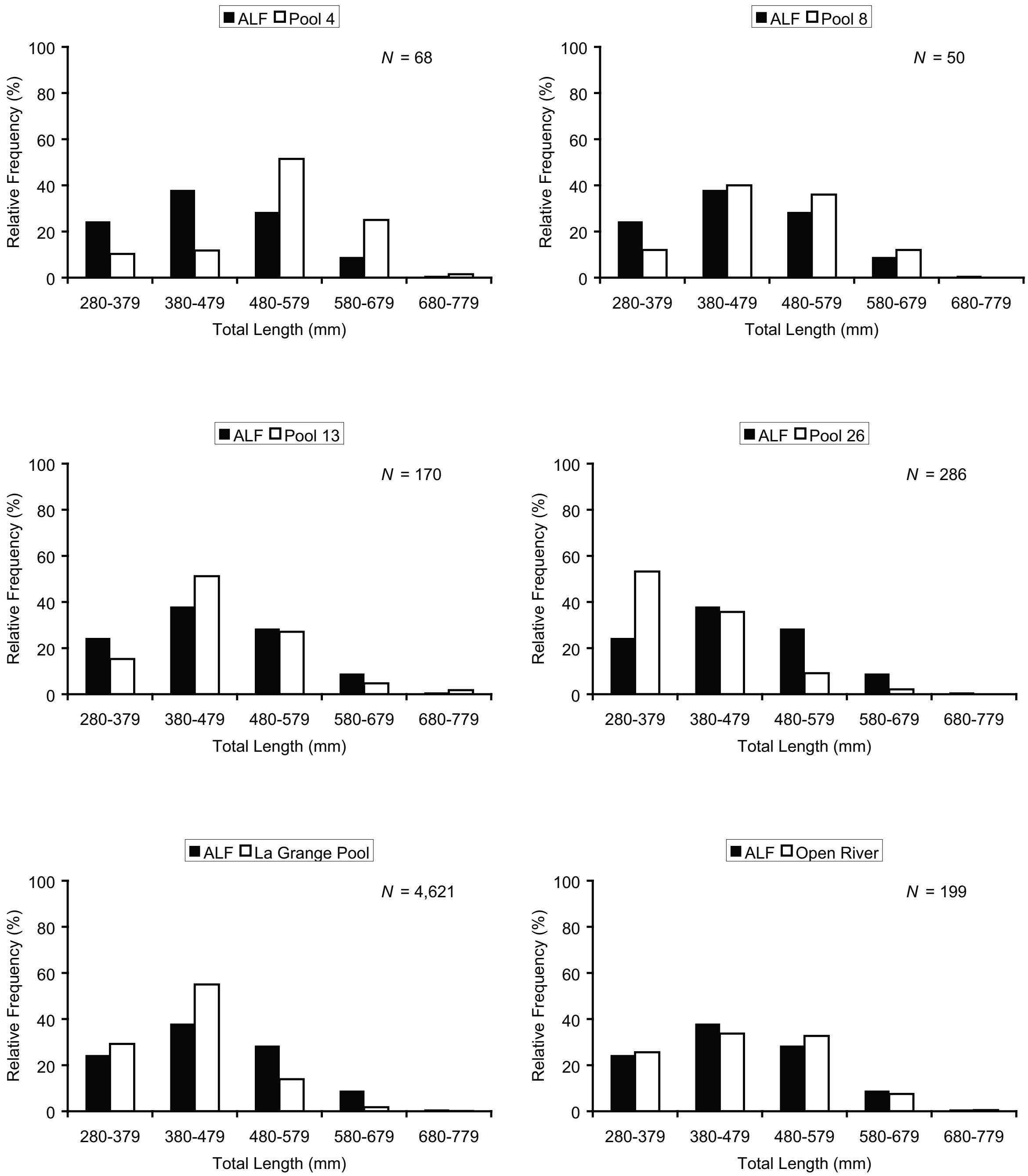

Figure 3.1. Relative length-frequency distributions of bigmouth buffalo (*Ictiobus cyprinellus)* collected by day electrofishing in the Long Term Resource Monitoring Program study areas in 1993–2002. The average length frequency (ALF; Bonar 2002) is the average of relative length frequencies for the six study areas in 1993–2002.

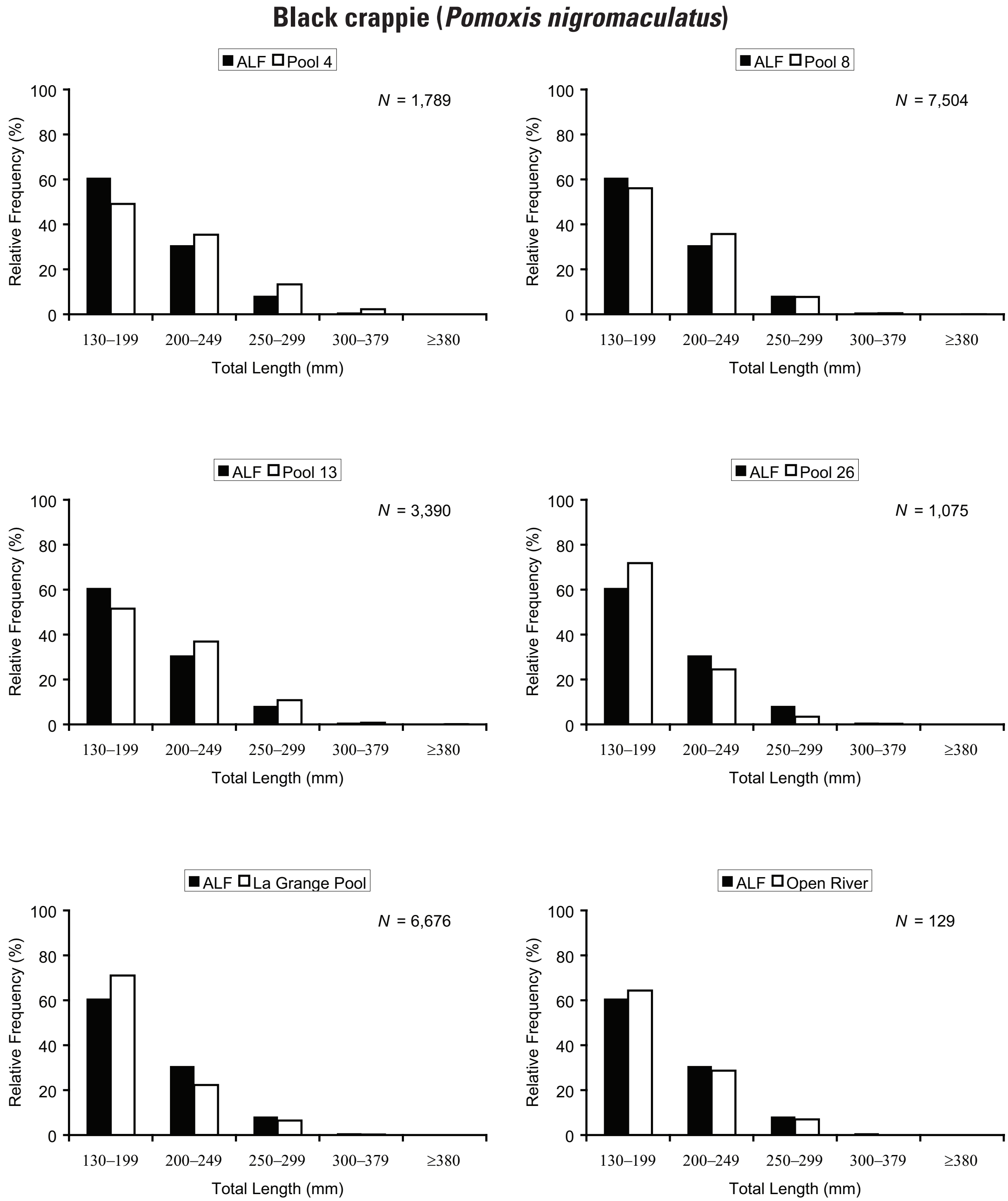

Figure 3.2. Relative length-frequency distributions of black crappie (*Pomoxis nigromaculatus*) collected by fyke nets (1.8-cm bar measure mesh, 0.9-m x 1.8-m frame) in the Long Term Resource Monitoring Program study areas in 1993–2002. The average length frequency (ALF; Bonar 2002) is the average of relative length frequencies for the six study areas in 1993–2002.

Bluegill (*Lepomis macrochirus*)

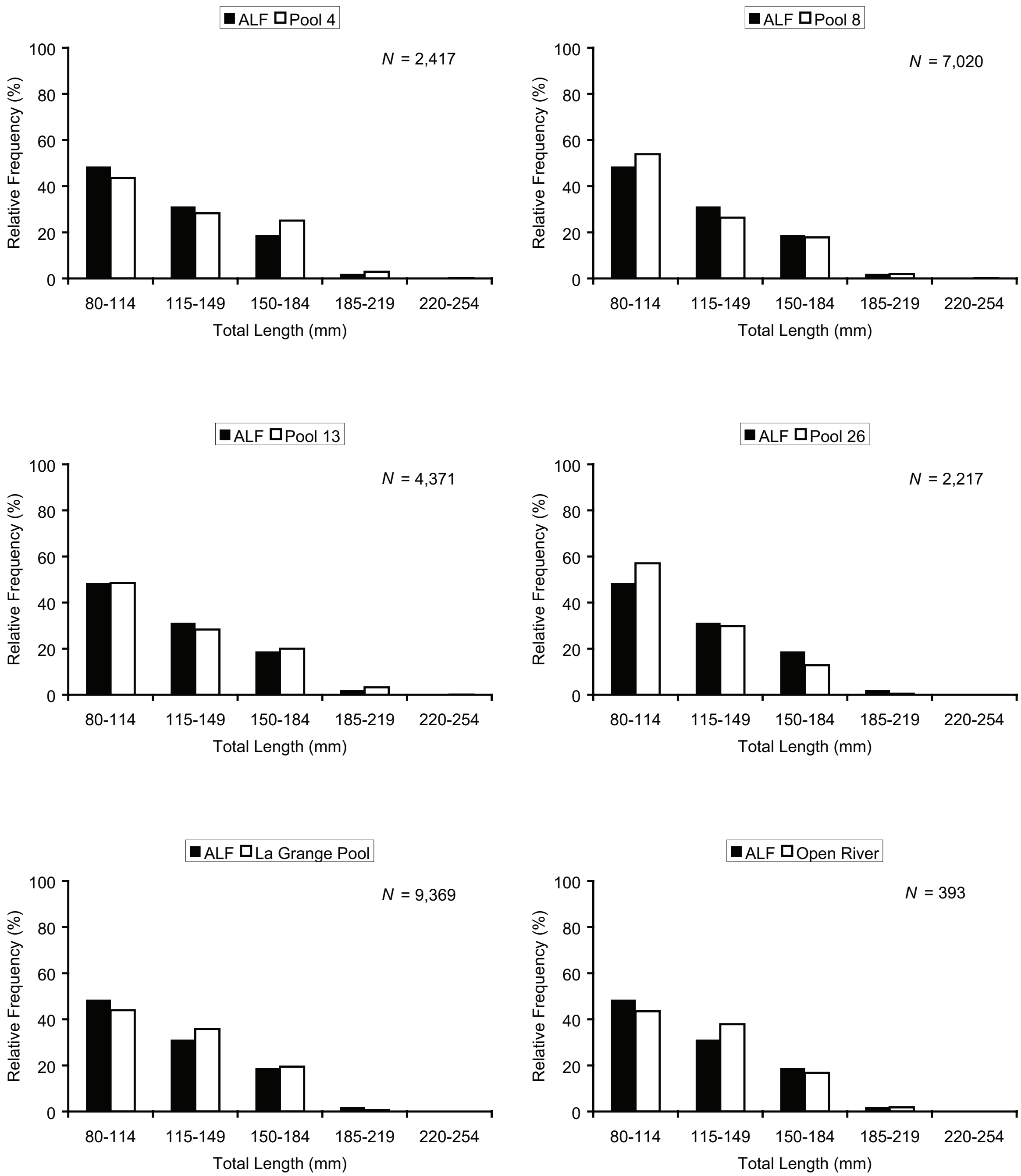

Figure 3.3. Relative length-frequency distributions of bluegill (*Lepomis macrochirus*) collected by day electrofishing in the Long Term Resource Monitoring Program study areas in 1993–2002. The average length frequency (ALF; Bonar 2002) is the average of relative length frequencies for the six study areas in 1993–2002.

Channel catfish (*Ictalurus punctatus*)

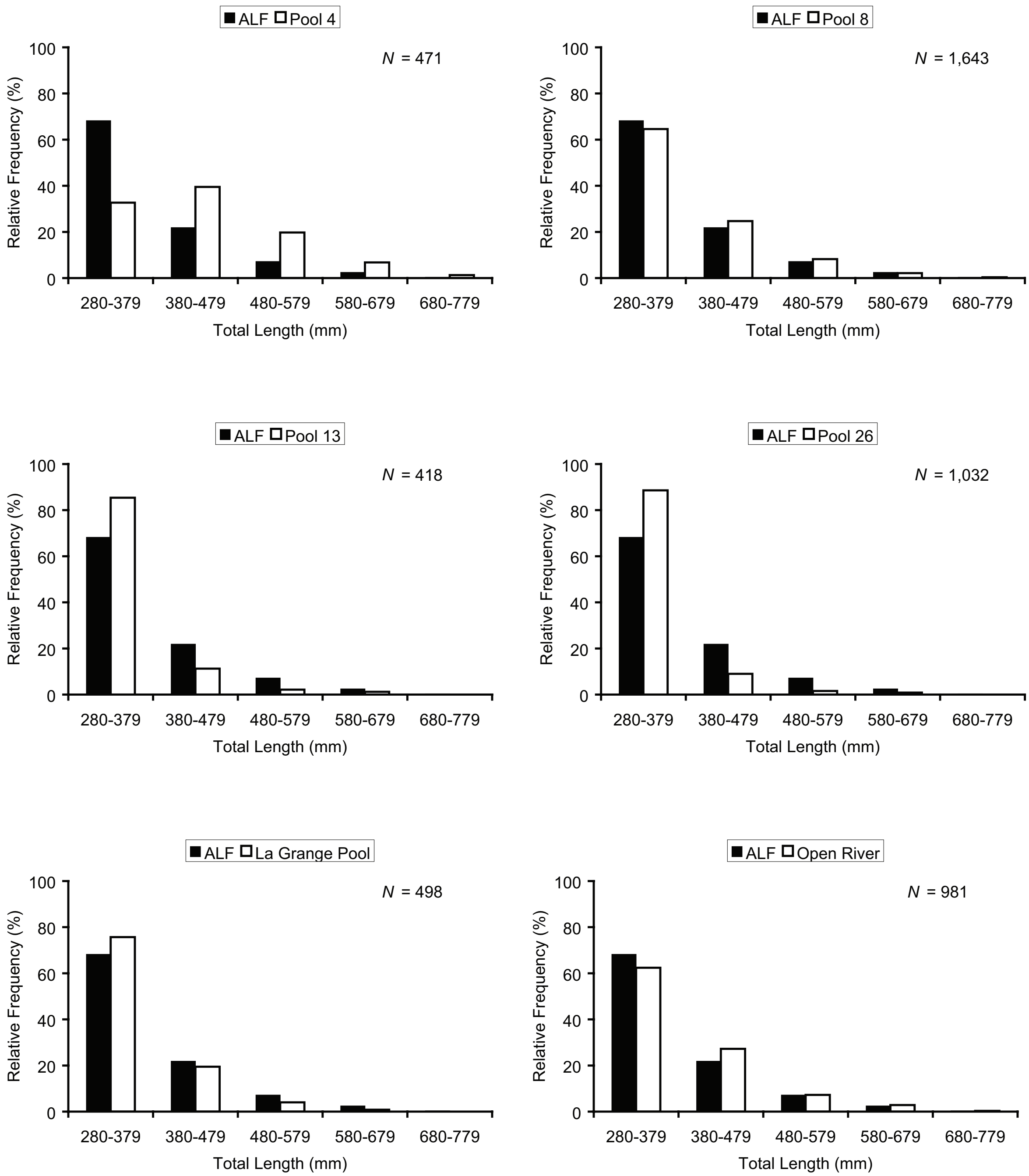

Figure 3.4. Relative length-frequency distributions of channel catfish (*Ictalurus punctatus*) collected by small hoop nets (1.8-cm bar measure mesh, 0.6-m hoop diameter) in the Long Term Resource Monitoring Program study areas in 1993–2002. The average length frequency (ALF; Bonar 2002) is the average of relative length frequencies for the six study areas in 1993–2002.

Common carp (*Cyprinus carpio*)

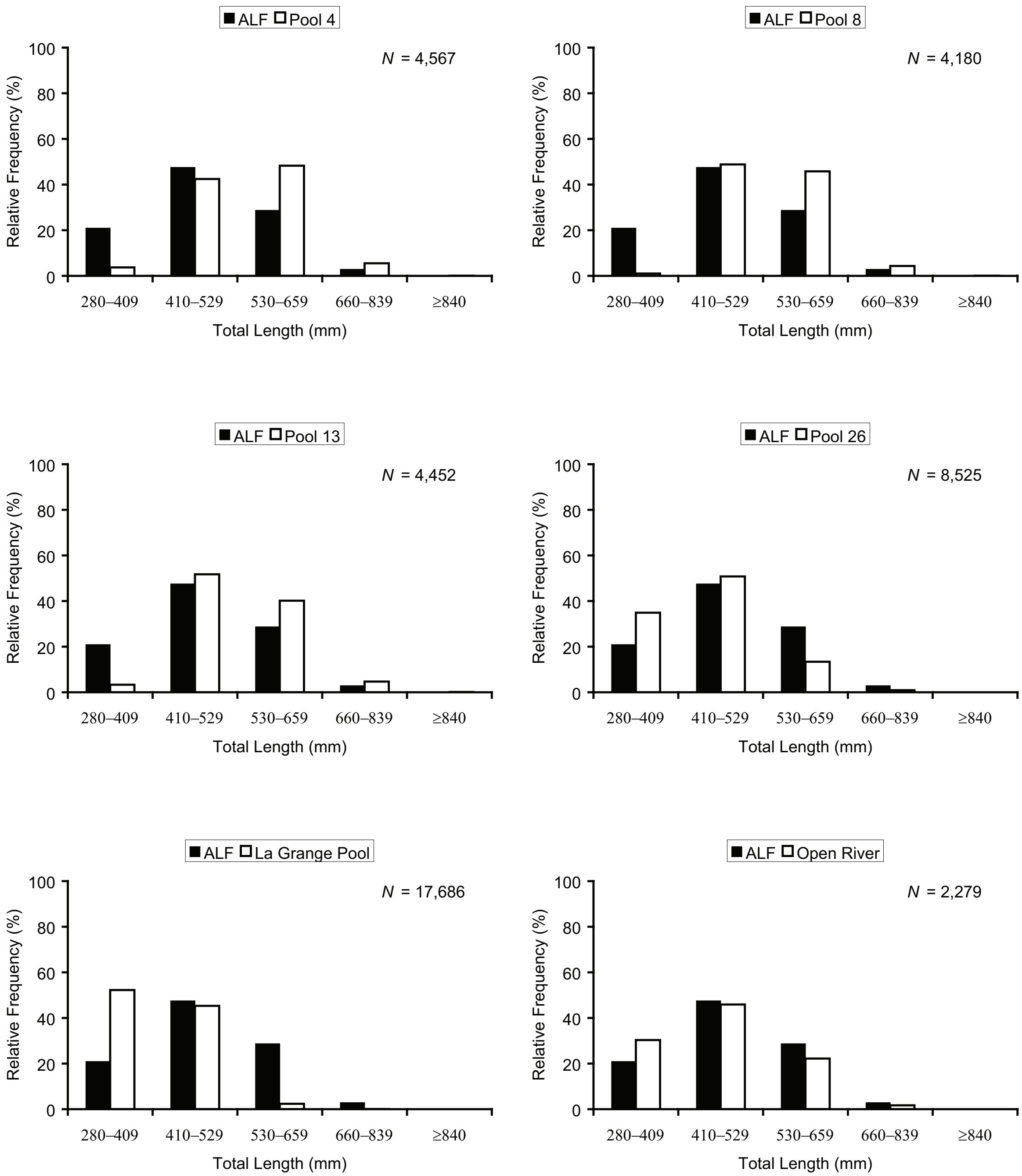

Figure 3.5. Relative length-frequency distributions of common carp (*Cyprinus carpio*) collected by day electrofishing in the Long Term Resource Monitoring Program study areas in 1993–2002. The average length frequency (ALF; Bonar 2002) is the average of relative length frequencies for the six study areas in 1993–2002.

Flathead catfish (*Pylodictis olivaris*)

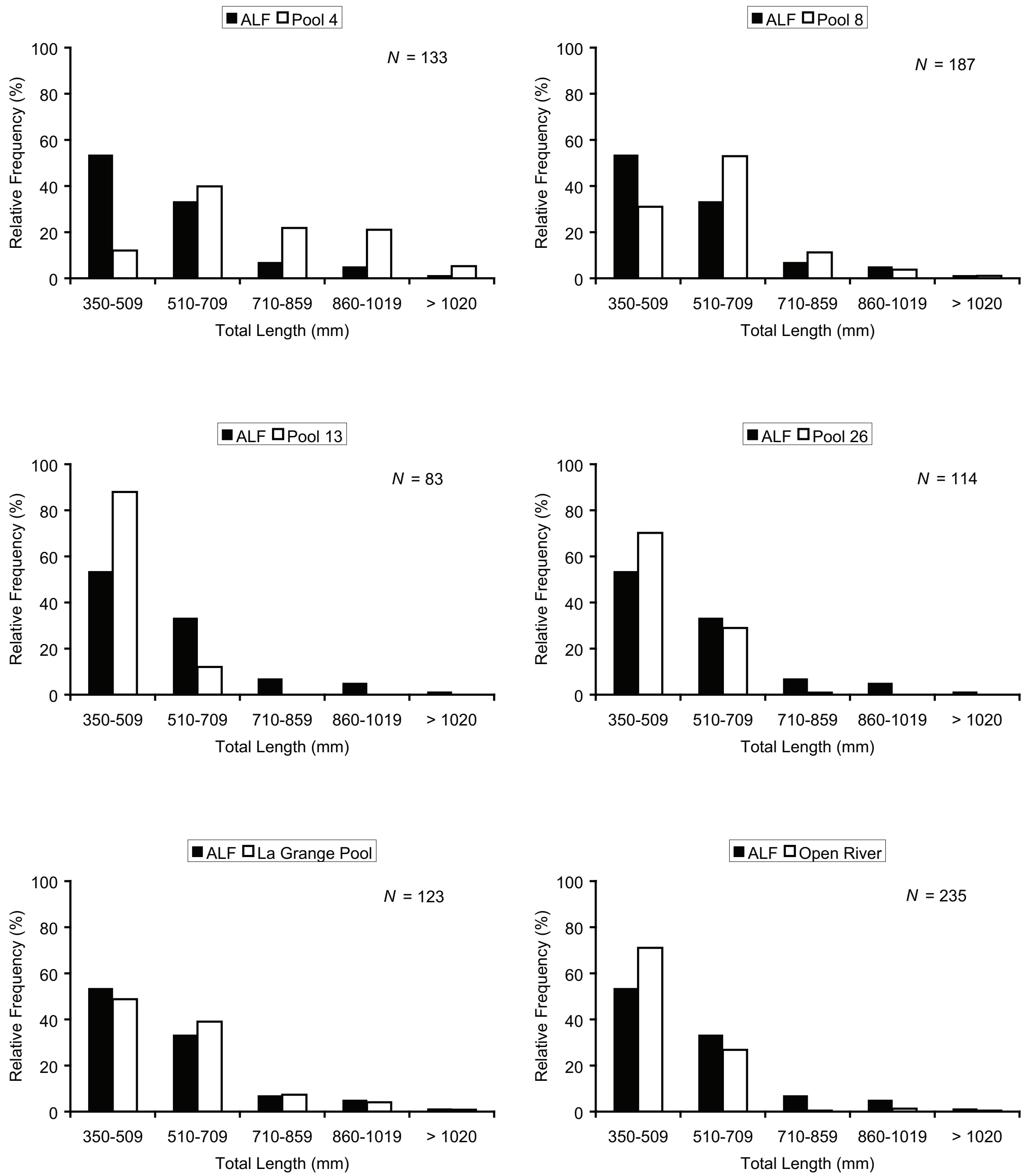

Figure 3.6. Relative length-frequency distributions of flathead catfish (*Pylodictis olivaris*) collected by large hoop nets (3.7-cm bar measure mesh, 1.2-m hoop diameter) in the Long Term Resource Monitoring Program study areas in 1993–2002. The average length frequency (ALF; Bonar 2002) is the average of relative length frequencies for the six study areas in 1993–2002.

Freshwater drum (*Aplodinotus grunniens*)

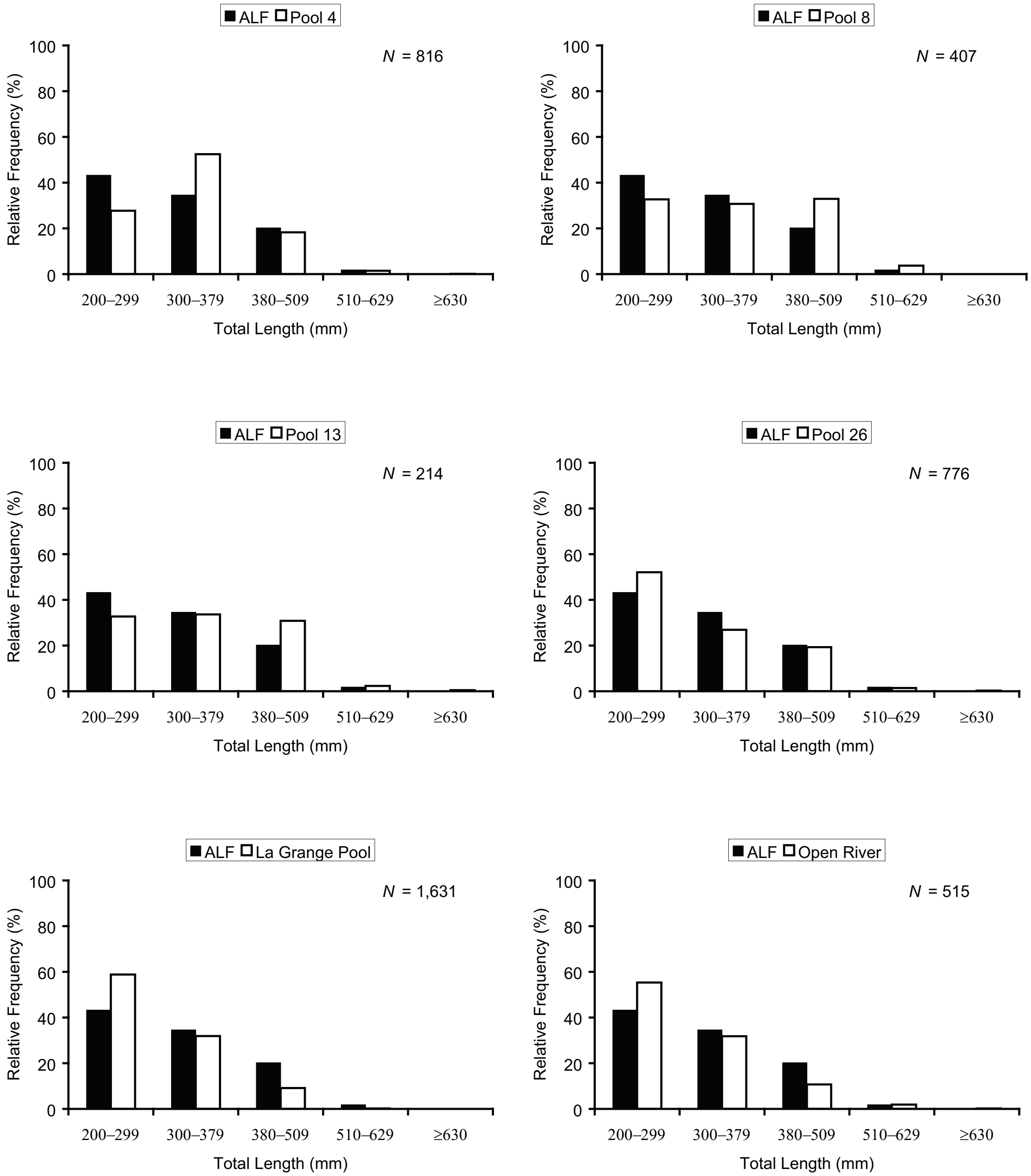

Figure 3.7. Relative length-frequency distributions of freshwater drum (*Aplodinotus grunniens*) collected by day electrofishing in the Long Term Resource Monitoring Program study areas in 1993–2002. The average length frequency (ALF; Bonar 2002) is the average of relative length frequencies for the six study areas in 1993–2002.

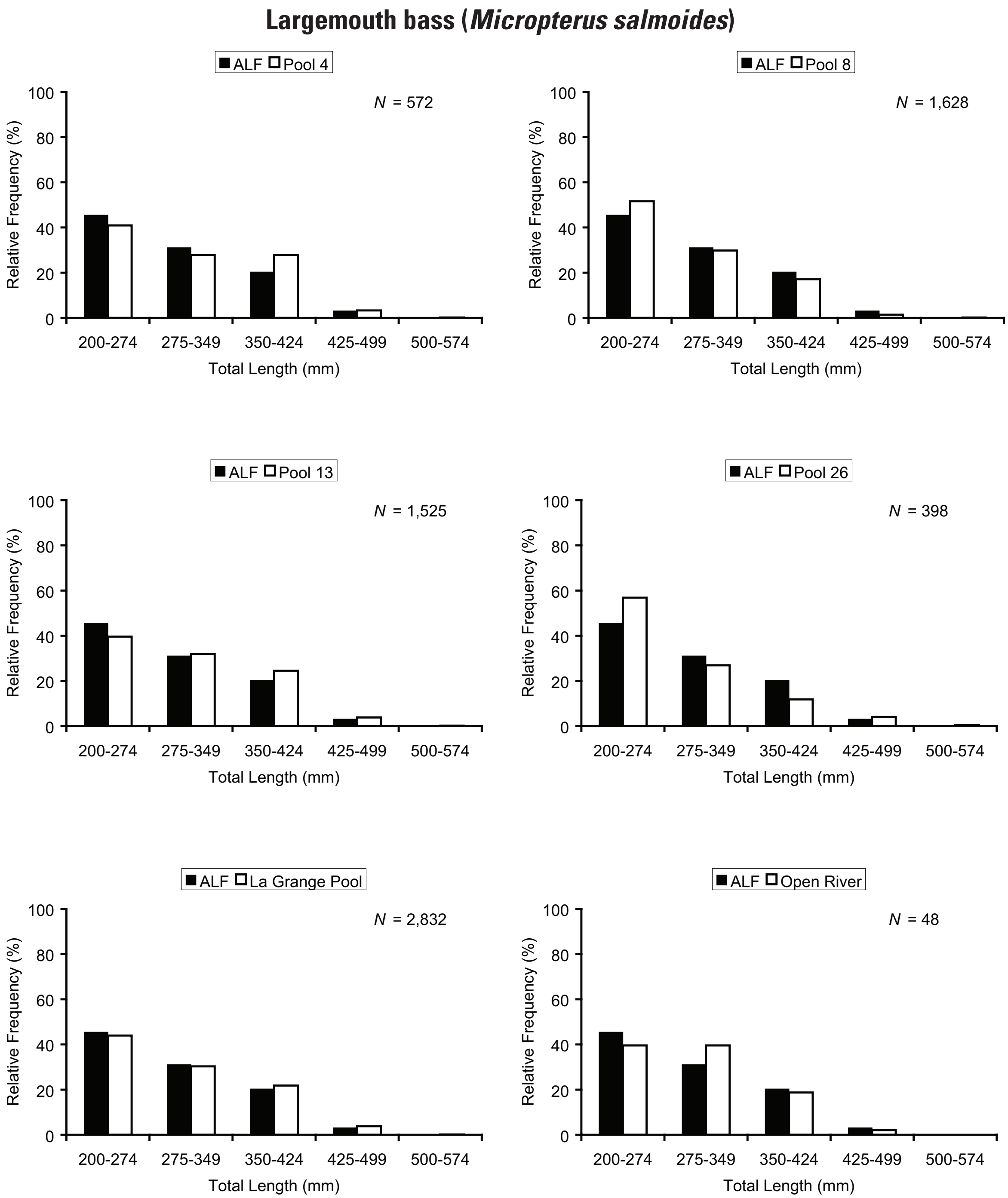

Figure 3.8. Relative length-frequency distributions of largemouth bass (*Micropterus salmoides*) collected by day electrofishing in the Long Term Resource Monitoring Program study areas in 1993–2002. The average length frequency (ALF; Bonar 2002) is the average of relative length frequencies for the six study areas in 1993–2002.

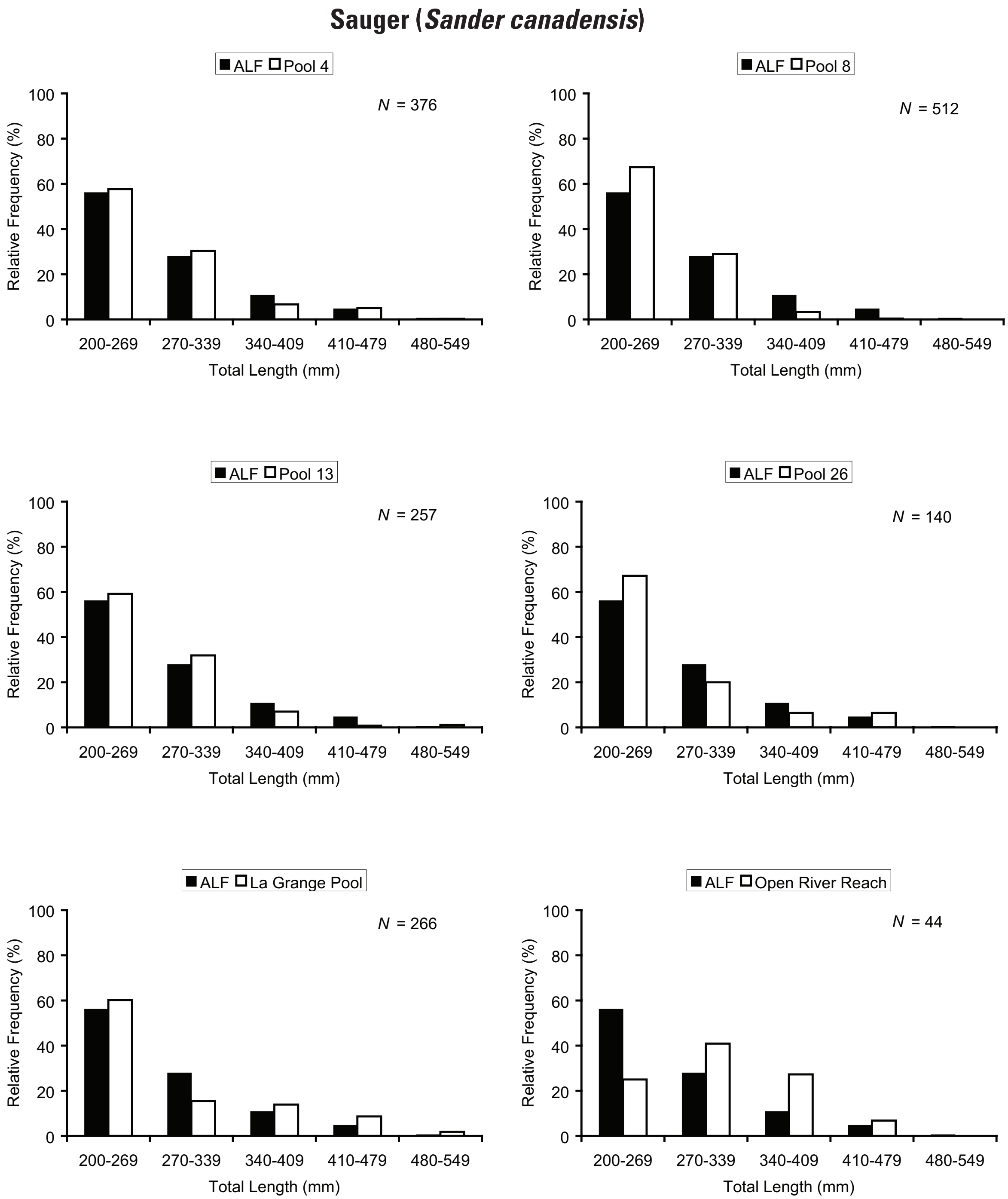

Figure 3.9. Relative length-frequency distributions of sauger (*Sander canadensis*) collected by day electrofishing in the Long Term Resource Monitoring Program study areas in 1993–2002. The average length frequency (ALF; Bonar 2002) is the average of relative length frequencies for the six study areas in 1993–2002.

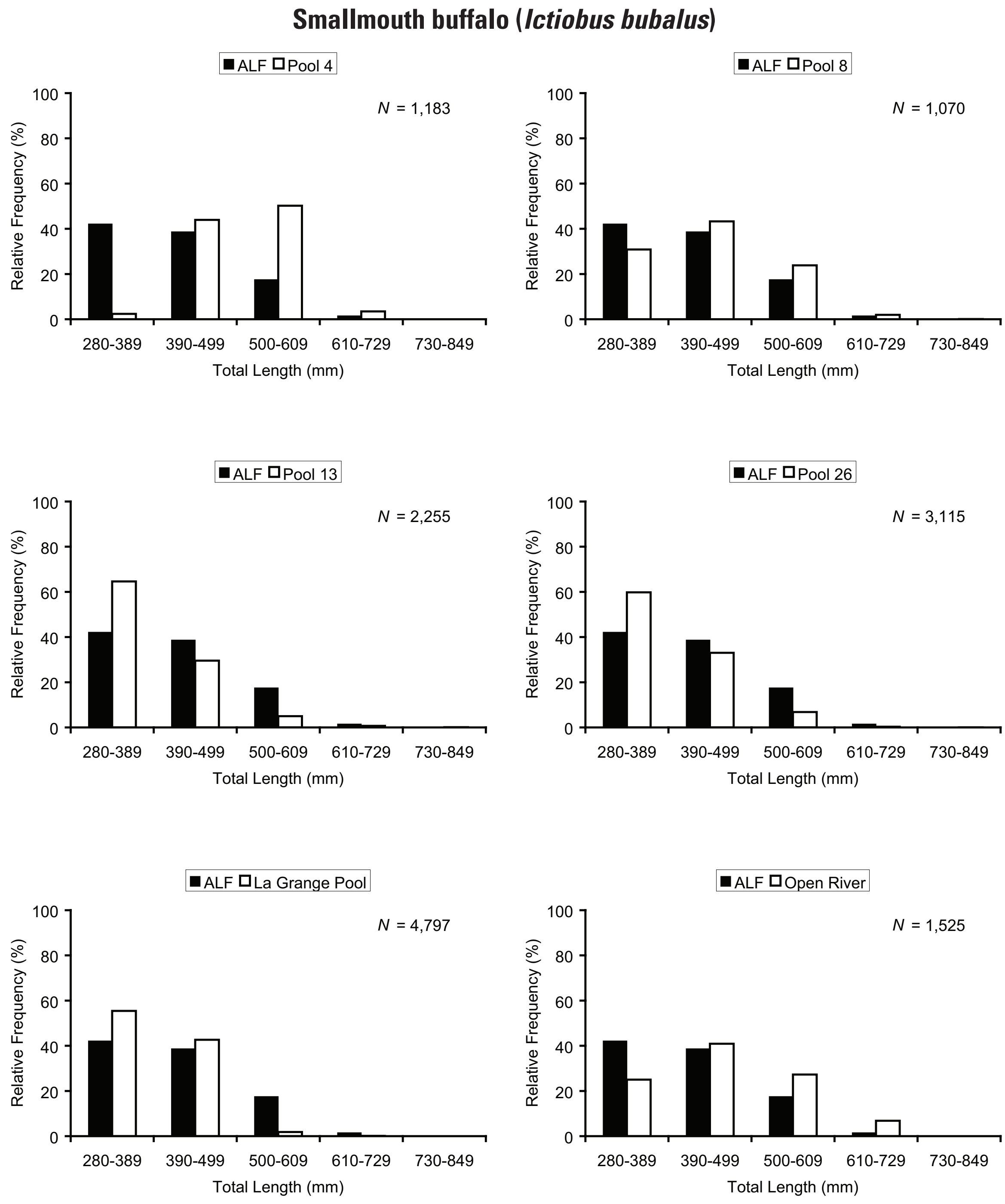

Figure 3.10. Relative length-frequency distributions of smallmouth buffalo (*Ictiobus bubalus*) collected by large hoop nets (3.7-cm bar measure mesh, 1.2-m hoop diameter) in the Long Term Resource Monitoring Program study areas in 1993–2002. The average length frequency (ALF; Bonar 2002) is the average of relative length frequencies for the six study areas in 1993–2002.

White bass (*Morone chrysops*)

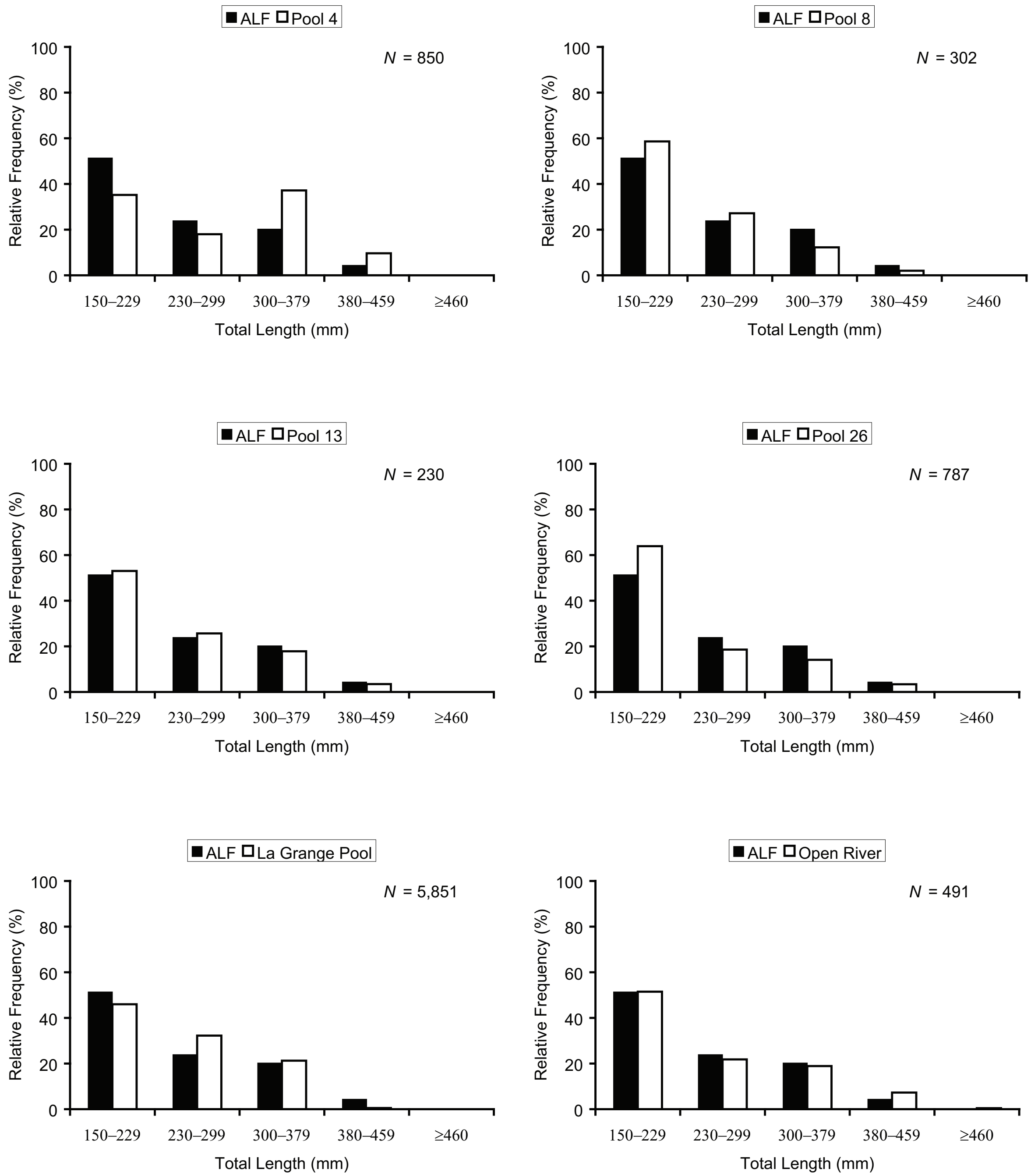

Figure 3.11. Relative length-frequency distributions of white bass (*Morone chrysops*) collected by day electrofishing in the Long Term Resource Monitoring Program study areas in 1993–2002. The average length frequency (ALF; Bonar 2002) is the average of relative length frequencies for the six study areas in 1993–2002.

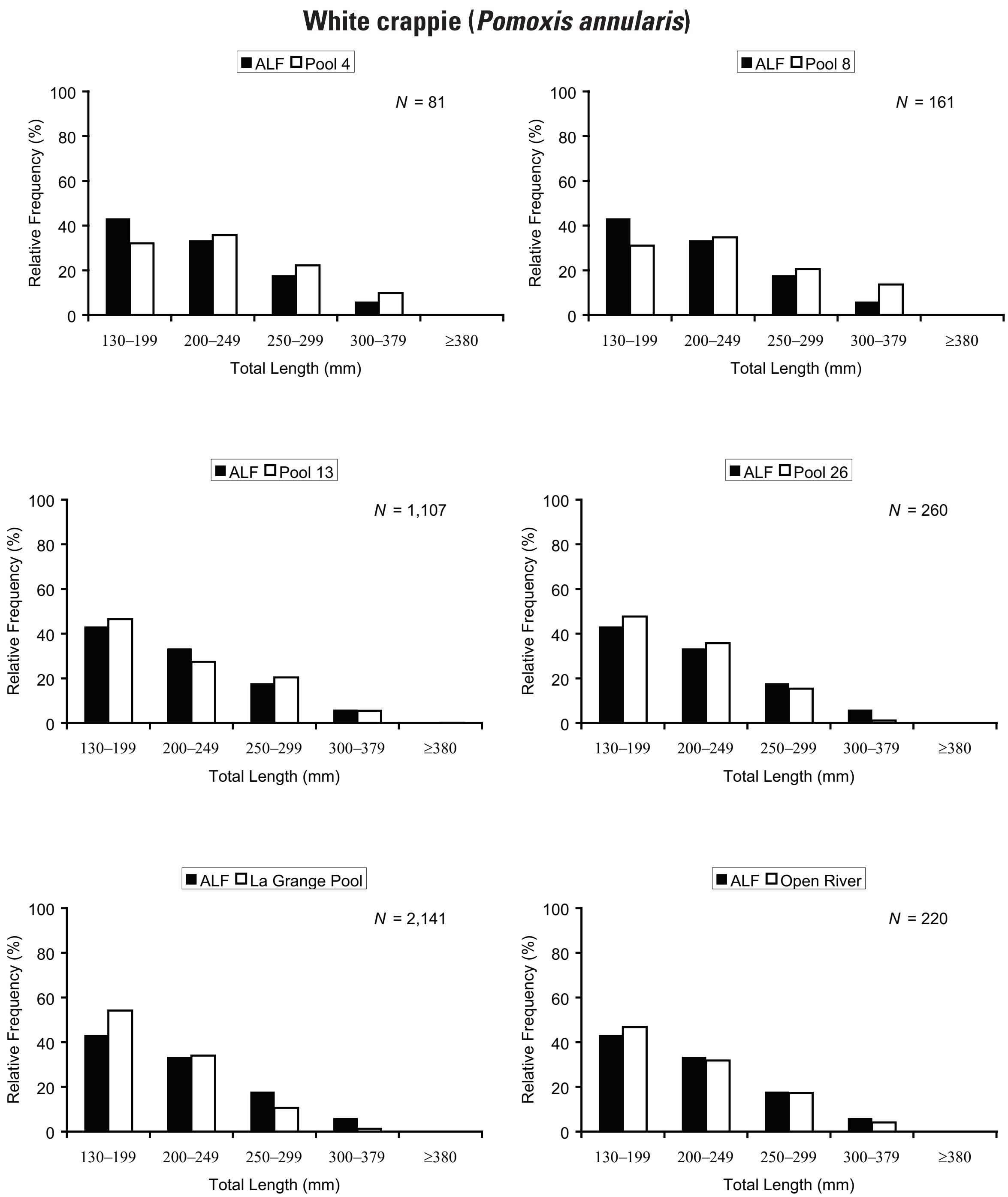

Figure 3.12. Relative length-frequency distributions of white crappie (*Pomoxis annularis*) collected by fyke nets (1.8-cm bar measure mesh, 0.9-m x 1.8-m frame) in the Long Term Resource Monitoring Program study areas in 1993–2002. The average length frequency (ALF; Bonar 2002) is the average of relative length frequencies for the six study areas in 1993–2002.

Table 3.1. Kolmogorov-Smirnov (KS) statistics for differences in length-frequency distributions of stock-length fish among study areas of the Long Term Resource Monitoring Program in 1993–2002.

Study area[a]	Gear[b]	N	EDF at maximum[c]	Additive inverse of the deviation from the mean at maximum[d]	KS[e]
Bigmouth buffalo (*Ictiobus cyprinellus*)					
4	D	68	0.176	5.045	
8	D	50	0.440	2.463	
13	D	170	0.529	3.375	
26	D	286	0.855	-1.156	
LG	D	4,621	0.818	-2.020	
OR	D	199	0.520	3.819	
Pooled	D	55,394	0.788		0.108
Black crappie (*Pomoxis nigromaculatus*)					
4	F	1,789	0.477	4.398	
8	F	7,504	0.526	4.795	
13	F	3,390	0.475	6.213	
26	F	1,075	0.707	-4.119	
LG	F	6,676	0.705	-10.097	
OR	F	129	0.605	-0.265	
Pooled	F	20,563	0.581		0.099
Bluegill (*Lepomis macrochirus*)					
4	D	2,417	0.223	1.360	
8	D	7,020	0.333	-6.926	
13	D	4,371	0.272	-1.396	
26	D	2,217	0.311	-2.830	
LG	D	9,369	0.174	7.454	
OR	D	393	0.206	0.883	
Pooled	D	25,787	0.251		0.067
Channel catfish (*Ictalurus punctatus*)					
4	HS	471	0.251	7.198	
8	HS	1,643	0.524	2.357	
13	HS	418	0.718	-2.771	
26	HS	1,032	0.813	-7.414	
LG	HS	498	0.671	-1.975	
OR	HS	981	0.493	2.782	
Pooled	HS	5,043	0.582	.	0.162
Common carp (*Cyprinus carpio*)					
4	D	4,567	0.124	29.834	
8	D	4,180	0.094	30.461	
13	D	4,452	0.137	28.613	
26	D	8,525	0.612	-4.310	
LG	D	17,686	0.883	-42.186	
OR	D	2,279	0.516	2.379	
Pooled	D	41,689	0.565		0.327
Flathead catfish (*Pylodictis olivaris*)					
4	HL	133	0.188	5.239	
8	HL	187	0.460	2.494	
13	HL	83	0.952	-2.820	
26	HL	114	0.842	-2.133	
LG	HL	123	0.634	0.090	
OR	HL	235	0.843	-3.070	
Pooled	HL	875	0.642		0.252
Freshwater drum (*Aplodinotus grunniens*)					
4	D	816	0.208	5.635	
8	D	407	0.251	3.127	
13	D	214	0.252	2.242	
26	D	776	0.464	-1.625	
LG	D	1,631	0.527	-4.890	
OR	D	515	0.433	-0.622	
Pooled	D	4,359	0.406		0.131

Table 3.1. (continued)

Study area[a]	Gear[b]	N	EDF at maximum[c]	Additive inverse of the deviation from the mean at maximum[d]	KS[e]
Largemouth bass (*Micropterus salmoides*)					
4	D	572	0.456	1.235	
8	D	1,628	0.584	-3.076	
13	D	1,525	0.450	2.243	
26	D	398	0.651	-2.849	
LG	D	2,832	0.486	1.173	
OR	D	48	0.479	0.199	
Pooled	D	7003	0.508		0.060
Sauger (*Sander canadensis*)					
4	D	376	0.710	0.819	
8	D	512	0.842	-2.024	
13	D	257	0.774	-0.352	
26	D	140	0.786	-0.395	
LG	D	266	0.673	1.295	
OR	D	44	0.318	2.880	
Pooled	D	1,595	0.752		0.097
Smallmouth buffalo (*Ictiobus bubalus*)					
4	HL	1,183	0.089	21.498	
8	HL	1,070	0.505	6.841	
13	HL	2,255	0.814	-4.767	
26	HL	3,115	0.790	-4.237	
LG	HL	4,797	0.867	-10.639	
OR	HL	1,525	0.559	6.057	
Pooled	HL	13,945	0.713	.	0.224
White bass (*Morone chrysops*)					
4	D	850	0.558	7.166	
8	D	302	0.874	-1.229	
13	D	230	0.813	-0.146	
26	D	787	0.844	-1.130	
LG	D	5,851	0.834	-2.329	
OR	D	491	0.754	1.105	
Pooled	D	8,511	0.803		0.085
White crappie (*Pomoxis annularis*)					
4	F	81	0.494	1.200	
8	F	161	0.342	3.624	
13	F	1,107	0.529	3.255	
26	F	260	0.596	0.501	
LG	F	2,141	0.716	-4.110	
OR	F	220	0.550	1.145	
Pooled	F	3,970	0.627		0.105

[a]Study areas are abbreviated as 4 = Pool 4, 8 = Pool 8, 13 = Pool 13, 26 = Pool 26, LG = La Grange Pool, and OR = Open River.

[b]Gear types are abbreviated as D = day electrofishing, F = fyke nets, HL = large hoop nets, and HS = small hoop nets.

[c]The KS test measures the maximum difference between the pooled empirical distribution function (EDF) and empirical distribution functions from each study area.

[d]Positive values for the additive inverse of the deviation from the mean indicate a distribution comprised of proportionally longer fish when compared to the pooled distribution, and negative values are indicative of a distribution comprised of proportionally shorter fish. The value for the deviation from the mean indicates the magnitude of the difference between the study area and the pooled length-frequency distributions.

[e]A KS statistic <0.1 indicates little difference in length-frequency distributions, whereas values >0.2 indicate substantial difference among study areas.

Table 3.2. Areawide mean catch-per–unit-effort (fish/15 min) and standard error (in parentheses) estimates by length group for bigmouth buffalo (*Ictiobus cyprinellus*) collected by day electrofishing in Long Term Resource Monitoring Program study areas in 1993–2002.

Length category (mm)	Study area	Year 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		Bigmouth buffalo (*Ictiobus cyprinellus*)									
280–379	Pool 4	0	0	0.1	0	0	0	0	0	0	0
		–[a]	–	(0.0)	–	–	–	–	–	–	–
	Pool 8	0	0	0.0	0.0	0	0.0	0	0	0	0
		–	–	(0.0)	(0.0)	–	(0.0)	–	–	–	–
	Pool 13	0.0	0.0	0.0	0.3	0.2	0	0	0.0	0	0.0
		(0.0)	(0.0)	(0.0)	(0.1)	(0.2)	–	–	(0.0)	–	(0.0)
	Pool 26	0.1	0	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0
		(0.1)	–	(0.0)	(0.0)	(0.1)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
	LG[b]	0.1	0.5	0.6	0.3	1.6	1.1	0.7	1.7	1.3	0.5
		(0.1)	(0.1)	(0.1)	(0.1)	(0.5)	(0.3)	(0.1)	(0.5)	(0.3)	(0.0)
	OR[c]	0.0	0	0	0	0	0	0	0.1	0.0	0
		(0.0)	–	–	–	–	–	–	(0.1)	(0.0)	–
380–479	Pool 4	0	0.0	0	0.0	0.0	0.0	0	0	0	0
		–	(0.0)	–	(0.0)	(0.0)	(0.0)	–	–	–	–
	Pool 8	0	0	0	0.1	0.0	0	0.0	0	0	0
		–	–	–	(0.1)	(0.0)	–	(0.0)	–	–	–
	Pool 13	0.2	0.2	0.0	0.1	0.6	0.2	0.0	0.2	0.0	0.0
		(0.1)	(0.2)	(0.0)	(0.1)	(0.3)	(0.1)	(0.0)	(0.1)	(0.0)	(0.0)
	Pool 26	.4	0.0	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.0
		(.3)	(0.0)	(0.0)	(0.0)	(0.1)	(0.0)	(0.0)	(0.1)	(0.0)	(0.0)
	LG	0.3	3.5	0.8	1.5	1.3	1.0	0.9	0.9	1.7	1.4
		(.1)	(1.0)	(0.2)	(0.3)	(.4)	(0.2)	(0.2)	(0.3)	(0.4)	(0.5)
	OR	0	0.0	0.0	0	0	0	0	0.1	0	0.1
		–	(0.0)	(0.0)	–	–	–	–	(0.1)	–	(0.1)
480–579	Pool 4	0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0
		–	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	–
	Pool 8	0	0.0	0.0	0.0	0	0.0	0.0	0	0	0
		–	(0.0)	(0.0)	(0.0)	–	(0.0)	(0.0)	–	–	–
	Pool 13	0.2	0.1	0	0.0	0.2	0.0	0.0	0.2	0.1	0.0
		(0.2)	(0.1)	–	(0.0)	(0.2)	(0.0)	(0.0)	(0.2)	(0.1)	(0.0)
	Pool 26	0.0	0.0	0.0	0	0.0	0	0.0	0.0	0.0	0
		(0.0)	(0.0)	(0.0)	–	(0.0)	–	(0.0)	(0.0)	(0.0)	–
	LG	0.0	0.7	0.2	0.5	0.4	0.2	0.2	0.2	0.3	0.4
		(0.0)	(0.3)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1	(0.1)	(0.3)
	OR	0.2	0.1	0	0	0	0	0.1	0.0	0	0.0
		(0.2)	(0.1)	–	–	–	–	(0.1)	(0.0)	–	(0.0)
580–679	Pool 4	0	0.0	0.0	0	0.0	0	0.0	0.0	0.0	0.0
		–	(0.0)	(0.0)	–	(0.0)	–	(0.0)	(0.0)	(0.0)	(0.0)
	Pool 8	0	0	0.0	0.0	0.0	0	0	0	0	0
		–	–	(0.0)	(0.0)	(0.0)	–	–	–	–	–
	Pool 13	0.1	0	0	0	0	0.0	0	0.0	0.0	0
		(0.1)	–	–	–	–	(0.0)	–	(0.0)	(0.0)	–
	Pool 26	0	0	0.0	0	0.0	0	0	0.0	0.0	0.0
		–	–	(0.0)	–	(0.0)	–	–	(0.0)	(0.0)	(0.0)
	LG	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
	OR	0	0	0.1	0	0	0	0	0	0	0
		–	–	(0.1)	–	–	–	–	–	–	–

[a]– = no fish collected, no estimate
[b]LG = La Grange Pool
[c]OR = Open River

Table 3.3. Areawide mean catch per unit effort (fish/net day) and standard error (in parentheses) estimates by length group for black crappie (*Pomoxis nigromaculatus*) collected by fyke nets in Long Term Resource Monitoring Program study areas in 1993–2002.

Length category (mm)	Study area	Year 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		Black crappie *(Pomoxis nigromaculatus)*									
		2.1	1.1	6.6	0.3	2.0	1.9	5.0	8.2	3.9	1.3
130–199	Pool 4	(1.0)	(0.6)	(2.4)	(0.2)	(0.6)	(0.7)	(1.4)	(4.2)	(1.2)	(0.8)
		16.0	5.9	6.5	15.1	5.0	4.7	8.1	2.5	4.6	2.6
	Pool 8	(3.7)	(1.6)	(2.0)	(4.2)	(1.0)	(1.0)	(1.9)	(0.9)	(1.5)	(0.7)
		8.3	1.1	4.5	14.6	3.3	1.7	3.8	4.6	7.3	4.0
	Pool 13	(2.1)	(0.4)	(1.1)	(3.8)	(1.1)	(0.4)	(1.9)	(2.6)	(2.1)	(1.0)
		0.2	3.9	2.1	0.5	0.5	0.4	0.4	0.2	2.2	2.5
	Pool 26	(0.2)	(2.2)	(0.5)	(0.2)	(0.4)	(0.2)	(0.2)	(0.1)	(0.9)	(0.7)
		0.3	9.9	15.3	14.3	22.5	3.3	28.3	0.8	4.0	10.2
	LG[a]	(0.2)	(2.4)	(4.2)	(4.4)	(7.0)	(0.8)	(7.2)	(0.3)	(2.6)	(3.9)
		0	0	2.5	0	0	0	0	0	0	0
	OR[b]	–[c]	–	(2.5)	–	–	–	–	–	–	–
		1.1	2.7	1.4	1.7	7.9	1.5	2.5	5.4	1.6	0.5
200–249	Pool 4	(0.4)	(1.2)	(0.9)	(0.7)	(0.7)	(0.7)	(0.7)	(1.6)	(0.5)	(0.4)
		4.3	3.9	2.7	4.8	6.8	4.1	3.5	3.4	2.8	1.3
	Pool 8	(1.2)	(0.8)	(1.4)	(1.2)	(1.5)	(0.7)	(0.8)	(0.6)	(0.7)	(0.3)
		10.3	6.2	1.5	2.8	4.5	2.2	1.3	3.7	4.0	2.0
	Pool 13	(4.0)	(2.2)	(0.4)	(0.9)	(1.3)	(0.6)	(0.5)	(1.3)	(1.2)	(0.5)
		0.2	0.2	1.4	0.4	0.0	0.0	0.0	0.2	0.8	0.7
	Pool 26	(0.1)	(0.1)	(0.5)	(0.2)	(0.0)	(0.0)	(0.0)	(0.1)	(0.2)	(0.3)
		1.6	8.1	10.1	6.4	3.3	8.8	4.0	2.0	1.7	2.4
	LG	(1.0)	(3.4)	(2.7)	(1.6)	(1.2)	(2.8)	(1.4)	(0.6)	(0.5)	(0.7)
		0	0	0.1	0	0	0	0	0	0	0
	OR	–	–	(0.1)	–	–	–	–	–	–	–
		0.8	1.3	0.6	0.2	1.2	1.5	1.1	1.2	2.0	0.7
250–299	Pool 4	(0.3)	(0.5)	(0.2)	(0.1)	(0.3)	(0.7)	(0.4)	(0.4)	(0.9)	(0.3)
		1.8	1.0	0.7	0.6	1.2	1.3	0.7	0.3	1.0	0.8
	Pool 8	(0.4)	(0.4)	(0.3)	(0.1)	(0.3)	(0.2)	(0.2)	(0.1)	(0.3)	(0.2)
		1.6	2.8	2.0	0.9	0.6	0.6	0.4	0.8	0.8	0.7
	Pool 13	(0.7)	(1.3)	(0.6)	(0.5)	(0.2)	(0.2)	(0.2)	(0.2)	(0.3)	(0.3)
		0.0	0.0	0.0	0.1	0	0.0	0.0	0	0.4	0.2
	Pool 26	(0.0)	(0.0)	(0.0)	(0.0)	–	(0.0)	(0.0)	–	(0.1)	(0.2)
		0.4	5.1	0.7	2.6	2.2	0.9	2.5	0.2	0.8	0.5
	LG	(0.2)	(1.9)	(0.2)	(0.8)	(1.0)	(0.2)	(0.8)	(0.1)	(0.2)	(0.2)
		0	0	0	0	0	0	0	0	0	0
	OR	–	–	–	–	–	–	–	–	–	–
		0.1	0.2	0.5	0.5	0	0.4	0.3	0.1	0.4	0.1
300–379	Pool 4	(0.1)	(0.1)	(0.2)	(0.2)	–	(0.3)	(0.1)	(0.1)	(0.2)	(0.1)
		0.1	0.1	0.1	0.1	0.0	0.1	0.0	0	0.1	0
	Pool 8	(0.1)	(0.0)	(0.1)	(0.1)	(0.0)	(0.0)	(0.0)	–	(0.1)	–
		0.0	0.1	0.2	0.1	0	0	0.1	0.1	0.1	0.0
	Pool 13	(0.0)	(0.1)	(0.1)	(0.1)	–	–	(0.1)	(0.1)	(0.0)	(0.0)
		0	0	0	0	0.0	0	0	0	0.1	0
	Pool 26	–	–	–	–	(0.0)	–	–	–	(0.1)	–
		0	0	0	0	0.0	0.0	0.3	0.0	0.1	0
	LG	–	–	–	–	(0.0)	(0.0)	(0.1)	(0.0)	(0.0)	–
		0	0	0	0	0	0	0	0	0	0
	OR	–	–	–	–	–	–	–	–	–	–

[a]LG = La Grange Pool
[b]OR = Open River
[c] – = no fish collected, no estimate

Table 3.4. Areawide mean catch per unit effort (fish/15 min) and standard error (in parentheses) estimates by length group for bluegill (*Lepomis macrochirus*) collected by day electrofishing in Long Term Resource Monitoring Program study areas in 1993–2002.

Length category (mm)	Study area	Year 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		Bluegill (*Lepomis macrochirus*)									
80–114	Pool 4	0.6	0.7	1.4	0.6	1.5	1.5	3.7	2.6	1.2	1.1
		(0.3)	(0.3)	(0.6)	(0.2)	(0.5)	(0.4)	(0.9)	(0.8)	(0.7)	(0.3)
	Pool 8	0.3	0.4	3.5	7.0	4.3	5.4	4.3	5.5	5.9	1.5
		(0.2)	(0.2)	(1.0)	(3.3)	(1.3)	(1.2)	(0.8)	(0.9)	(1.2)	(0.6)
	Pool 13	0.7	0.2	3.1	6.8	4.2	6.8	5.9	1.4	0.6	1.1
		(0.2)	(0.1)	(0.9)	(2.0)	(1.0)	(1.6)	(3.0)	(.04)	(0.2)	(0.30
	Pool 26	0.3	1.1	0.3	0.2	0.3	0.7	0.9	0.5	1.2	0.3
		(0.2)	(0.3)	(0.1)	(0.1)	(0.1)	(0.2)	(0.5)	(0.3)	(0.6)	(0.2)
	LG[a]	0.3	2.8	2.4	3.4	2.6	5.1	2.4	1.5	1.3	1.5
		(0.1)	(0.6)	(0.5)	(0.8)	(0.6)	(1.3)	(0.5)	(0.4)	(0.3)	(0.3)
	OR[b]	0.9	0.0	0	0.0	0	0	0	0.0	0.1	0.0
		(0.9)	(0.0)	–[c]	(0.0)	–	–	–	(0.0)	(0.1)	(0.0)
115–149	Pool 4	0.1	0.7	0.7	0.4	0.5	1.2	3.2	1.8	0.6	0.3
		(0.1)	(0.3)	(0.3)	(0.1)	(0.2)	(0.4)	(1.0)	(0.5)	(0.1)	(0.1)
	Pool 8	0.6	0.1	1.1	2.8	1.7	2.4	2.7	2.9	2.2	0.6
		(0.3)	(0.1)	(0.4)	(0.8)	(0.4)	(0.4)	(0.6)	(0.6)	(0.4)	(0.4)
	Pool 13	1.2	0.4	1.1	2.6	2.6	2.0	5.9	0.8	0.7	0.5
		(0.3)	(0.2)	(0.4)	(0.9)	(0.7)	(0.4)	(2.6)	(0.2)	(0.3)	(0.1)
	Pool 26	0.2	1.4	0.3	0.1	0.1	0.2	0.5	0.3	1.6	0.2
		(0.1)	(0.4)	(0.2)	(0.1)	(0.1)	(0.1)	(0.3)	(0.2)	(0.6)	(0.1)
	LG	0.1	2.4	2.0	1.2	2.8	2.7	3.0	1.7	0.9	0.5
		(0.1)	(0.5)	(0.5)	(0.3)	(0.6)	(0.7)	(0.5)	(0.5)	(0.3)	(0.2)
	OR	0.4	0.0	0	0.0	0	0	0	0.0	0.3	0
		(0.4)	(0.0)	–	(0.0)	–	–	–	(0.0)	(0.2)	–
150–184	Pool 4	0.7	0.6	0.2	0.4	0.8	0.7	2.3	1.8	0.7	0.5
		(0.2)	(0.3)	(0.1)	(0.1)	(0.3)	(0.2)	(0.5)	(0.4)	(0.1)	(0.1)
	Pool 8	0.7	0.4	0.1	1.5	1.0	1.1	2.1	3.2	1.7	0.4
		(0.3)	(0.1)	(0.1)	(0.6)	(0.3)	(0.2)	(0.3)	(0.5)	(0.4)	(0.2)
	Pool 13	1.2	0.8	0.3	0.8	1.0	2.0	4.8	0.9	0.5	0.3
		(0.3)	(0.2)	(0.1)	(0.2)	(0.3)	(0.5)	(3.0)	(0.2)	(0.2)	(0.1)
	Pool 26	0.1	0.6	0.2	0.0	0.0	0.0	0.1	0.1	0.5	0.0
		(0.10	(0.2)	(0.1)	(0.0)	(0.0)	(0.0)	(0.0)	(0.1)	(0.2)	(0.0)
	LG	0.1	0.9	1.1	1.0	1.0	2.4	1.5	1.4	0.7	0.4
		(0.1)	(0.2)	(0.2)	(0.3)	(0.4)	(0.6)	(0.3)	(0.3)	(0.2)	(0.1)
	OR	0	0.0	0	0	0.0	0	0	0	0.1	0.0
		–	(0.0)	–	–	(0.0)	–	–	–	(0.1)	(0.0)
185–219	Pool 4	0.1	0.0	0.1	0.0	0.1	0.2	0.1	0.1	0.1	0.0
		(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.1)	(0.1)	(0.0)	(0.0)	(0.0)
	Pool 8	0.1	0.1	0.0	0.0	0.1	0.2	0.1	0.1	0.3	0.1
		(0.0)	(0.0)	(0.0)	(0.0)	(0.1)	(0.1)	(0.0)	(0.0)	(0.1)	(0.1)
	Pool 13	0.2	0.3	0.1	0.1	0.1	0.4	0.2	0.2	0.1	0.3
		(0.1)	(0.1)	(0.0)	(0.0)	(0.1)	(0.1)	(0.1)	(0.1)	(0.0	(0.1)
	Pool 26	0.0	0.0	0	0	0	0	0	0	0	0.0
		(0.0)	(0.0)	–	–	–	–	–	–	–	(0.0)
	LG	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
		(0.0)	(0.0)	(0.0)	(0.0)	(0.1)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
	OR	0	0	0	0	0	0	0	0	0	0
		–	–	–	–	–	–	–	–	–	–

[a]LG = La Grange Pool.
[b]OR = Open River.
[c]– = no fish collected, no estimate

Table 3.5. Areawide mean catch-per-unit-effort (fish/net day) and standard error (in parentheses) estimates by length group for channel catfish (*Ictalurus punctatus*) collected by small hoop nets in Long Term Resource Monitoring Program study areas in 1993–2002.

Length category (mm)	Study area	Year									
		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		Channel catfish (*Ictalurus punctatus*)									
280–379	Pool 4	0.3 (0.2)	0.1 (0.0)	0.1 (0.0)	0.1 (0.1)	0.2 (0.1)	0.1 (0.1)	0.2 (0.1)	0.1 (0.0)	0.2 (0.1)	0.2 (0.1)
	Pool 8	0.4 (0.4)	1.0 (0.4)	1.7 (0.5)	1.1 (0.3)	0.7 (0.2)	0.1 (0.0)	0.2 (0.1)	0.4 (0.2)	0.1 (0.1)	0.1 (0.1)
	Pool 13	0.0 (0.0)	0.1 (0.0)	0.4 (0.2)	0.2 (0.1)	0.3 (0.2)	0.1 (0.1)	0.1 (0.0)	0.3 (0.1)	0.5 (0.3)	0.1 (0.0)
	Pool 26	0.4 (0.2)	1.6 (0.6)	1.0 (0.3)	0.9 (0.7)	1.4 (0.4)	1.0 (0.7)	0.4 (0.1)	0.6 (0.2)	1.8 (0.4)	0.4 (0.1)
	LG[a]	0.2 (0.1)	0.8 (0.4)	0.3 (0.1)	0.1 (0.1)	0.1 (0.0)	0.8 (0.4)	0.2 (0.1)	0.3 (0.1)	0.3 (0.1)	0.5 (0.3)
	OR[b]	0.1 (0.1)	0.3 (0.1)	0.1 (0.1)	0.2 (0.2)	0.4 (0.2)	0.2 (0.1)	0.0 (0.0)	0.4 (0.2)	0.1 (0.1)	0.3 (0.2)
380–479	Pool 4	0.2 (0.1)	0.1 (0.0)	0.1 (0.0)	0.1 (0.1)	1.2 (0.6)	0.5 (0.2)	0.2 (0.1)	0.1 (0.0)	0.1 (0.1)	0.1 (0.0)
	Pool 8	0.1 (0.1)	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)	0.6 (0.2)	0.6 (0.2)	0.1 (0.0)	0.4 (0.1)	0.2 (0.1)	0.3 (0.1)
	Pool 13	0.0 (0.0)	0 –[c]	0 –	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.2)	0.0 (0.0)
	Pool 26	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.1)	0.2 (0.1)	0.2 (0.1)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.2 (0.1)
	LG	0.1 (0.0)	0.1 (0.1)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.1)
	OR	0.3 (0.2)	0.3 (0.2)	0.0 (0.0)	0.2 (0.1)	0.3 (0.1)	0.3 (0.1)	0.0 (0.0)	0.2 (0.2)	0.1 (0.1)	0.1 (0.1)
480–579	Pool 4	0.0 (0.0)	0.1 (0.1)	0.1 (0.0)	0.0 (0.0)	0.4 (0.2)	0.2 (0.1)	0.2 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)
	Pool 8	0.0 (0.0)	0.1 (0.1)	0.1 (0.1)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.1)	0.1 (0.0)	0.2 (0.1)
	Pool 13	0.0 (0.0)	0 –	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0 –	0 –
	Pool 26	0 –	0.0 (0.0)	0.1 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	LG	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0 –	0.0 (0.0)
	OR	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0 –	0 –	0.1 (0.1)	0.1 (0.1)	0.2 (0.1)
580–679	Pool 4	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.1)	0.1 (0.1)	0.1 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)
	Pool 8	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)
	Pool 13	0 –	0.0 (0.0)	0 –	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0 –	0 –
	Pool 26	0 –	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)
	LG	0 –	0 –	0 –	0.0 (0.0)	0 –	0 –	0.0 (0.0)	0 –	0 –	0 –
	OR	0 –	0 –	0 –	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0 –	0 –	0.1 (0.1)	0 –

[a]LG = La Grange Pool.
[b]OR = Open River.
[c]– = no fish collected, no estimate

Table 3.6. Areawide mean catch-per-unit-effort (fish/15 min) and standard error (in parentheses) estimates by length group for common carp (*Cyprinus carpio*) collected by day electrofishing in Long Term Resource Monitoring Program study areas in 1993–2002.

Length category (mm)	Study area	Year 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		Common carp (*Cyprinus carpio*)									
280–409	Pool 4	0.5 (0.2)	0.2 (0.1)	0.1 (0.0)	0.4 (0.1)	0.1 (0.0)	0 –[a]	0.7 (0.2)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
	Pool 8	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0 –	0.1 (0.0)	0 –
	Pool 13	0.1 (0.1)	0.2 (0.1)	0.7 (0.3)	0.7 (0.3)	0.1 (0.0)	0.2 (0.1)	0.2 (0.0)	0.0 (0.0)	0.1 (0.0)	0.2 (0.1)
	Pool 26	3.0 (1.2)	4.0 (0.8)	10.3 (1.7)	10.3 (1.7)	7.7 (1.5)	3.2 (0.9)	3.4 (0.7)	1.6 (0.4)	0.3 (0.1)	0.7 (0.2)
	LG[b]	1.6 (0.4)	11.0 (1.6)	7.5 (1.3)	7.5 (1.3)	8.5 (1.5)	3.7 (0.6)	2.4 (0.3)	3.3 (0.5)	3.0 (0.4)	1.3 (0.2)
	OR[c]	0.1 (0.1)	2.2 (0.6)	3.1 (1.2)	3.1 (1.2)	0.8 (0.3)	0.0 (0.0)	0.1 (0.1)	0.3 (0.1)	0.0 (0.0)	0.0 (0.0)
410–529	Pool 4	3.7 (0.6)	2.9 (0.4)	2.9 (0.3)	1.5 (0.3)	3.6 (0.6)	1.8 (0.3)	2.5 (0.5)	1.9 (0.3)	1.7 (0.4)	0.7 (0.1)
	Pool 8	6.4 (1.4)	5.5 (0.9)	3.8 (0.6)	4.7 (0.9)	2.3 (0.4)	1.3 (0.3)	1.3 (0.3)	0.9 (0.3)	0.7 (0.2)	0.0 (0.0)
	Pool 13	6.5 (1.4)	8.6 (2.0)	6.3 (1.0)	7.8 (1.3)	7.3 (1.5)	4.5 (0.8)	2.5 (0.5)	4.1 (1.0)	1.0 (0.3)	2.0 (0.6)
	Pool 26	3.3 (1.0)	5.0 (1.1)	3.9 (0.6)	8.4 (1.6)	10.7 (2.0)	8.8 (2.5)	11.7 (2.0)	6.2 (1.3)	7.6 (1.6)	5.5 (1.5)
	LG	1.4 (0.4)	4.8 (0.8)	3.5 (0.5)	4.4 (0.6)	6.2 (0.9)	5.0 (0.5)	3.4 (0.4)	5.4 (0.7)	6.5 (0.8)	3.6 (0.5)
	OR	0.1 (0.1)	0.6 (0.4)	1.0 (0.4)	2.1 (0.8)	2.5 (0.8)	1.2 (0.2)	1.7 (0.7)	1.0 (0.3)	2.1 (1.0)	1.0 (0.4)
530–659	Pool 4	2.0 (0.4)	1.3 (0.2)	1.7 (0.2)	1.5 (0.3)	3.2 (0.4)	3.4 (0.6)	4.7 (0.6)	4.3 (0.6)	3.3 (0.8)	1.9 (0.4)
	Pool 8	2.4 (0.5)	3.1 (0.6)	2.3 (0.3)	2.2 (0.5)	2.5 (0.5)	4.1 (0.7	2.7 (0.4)	2.2 (0.5)	1.4 (0.2)	0.1 (0.1)
	Pool 13	3.5 (0.7)	5.9 (1.3)	4.1 (0.7)	4.7 (1.1)	3.8 (0.8)	4.4 (0.9)	3.2 (0.5)	3.5 (0.8)	1.2 (0.3)	2.4 (0.7)
	Pool 26	2.4 (0.8)	3.1 (0.6)	1.4 (0.3)	2.7 (0.6)	2.0 (0.5)	1.6 (0.4)	2.8 (0.4)	1.1 (0.3)	2.3 (0.7)	1.2 (0.4)
	LG	0.2 (0.1)	0.2 (0.1)	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)	0.2 (0.1)	0.3 (0.1)	0.3 (0.1)	0.4 (0.1)
	OR	0.6 (0.3)	0.6 (0.3)	0.6 (0.2)	1.9 (0.4)	0.5 (0.2)	0.8 (0.5)	0.5 (0.4)	2.2 (1.6)	2.2 (1.6)	0.8 (0.4)
660–839	Pool 4	0.2 (0.1)	0.2 (0.1)	0.2 (0.1)	0.1 (0.0)	0.3 (0.1)	0.3 (0.1)	0.4 (0.1)	0.4 (0.1)	0.6 (0.1)	0.2 (0.1)
	Pool 8	0.1 (0.0)	0.2 (0.1)	0.2 (0.1)	0.1 (0.0)	0.2 (0.1)	0.4 (0.1)	0.2 (0.1)	0.2 (0.1)	0.1 (0.1)	0.1 (0.0)
	Pool 13	0.2 (0.1)	1.0 (0.4)	0.5 (0.1)	0.4 (0.1)	0.2 (0.1)	0.3 (0.1)	0.4 (0.1)	0.4 (0.1)	0.2 (0.1)	0.3 (0.2)
	Pool 26	0.1 (0.1)	0.3 (0.1)	0.1 (0.0)	0.1 (0.0)	0.1 (0.1)	0.1 (0.0)	0.2 (0.1)	0.1 (0.1)	0.1 (0.0)	0.1 (0.0)
	LG	0 –	0 –	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)
	OR	0 –	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.1)	0.3 (0.3)	0.0 (0.0)

[a]– = no fish collected, no estimate

[b]LG = La Grange Pool.

[c]OR = Open River.

Table 3.7. Areawide mean catch-per–unit-effort (fish/net day) and standard error (in parentheses) estimates by length group for flathead catfish (*Pylodictis olivaris*) collected by large hoop nets in Long Term Resource Monitoring Program study areas in 1993–2002.

Length category (mm)	Study area	Year 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		Flathead catfish (*Pylodictis olivaris*)									
350–509	Pool 4	0 –[a]	0.0 (0.0)	0 –	0 –	0 –	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0 –
	Pool 8	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.1)
	Pool 13	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)
	Pool 26	0.2 (0.1)	0.3 (0.1)	0.1 (0.1)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)
	LG[b]	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0 –
	OR[c]	0.2 (0.1)	0.1 (0.1)	0.3 (0.1)	0.1 (0.1)	0.0 (0.0)	0.1 (0.1)	0.1 (0.1)	0.2 (0.1)	0.1 (0.1)	0.0 (0.0)
510–709	Pool 4	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0 –	0 –	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)
	Pool 8	0.0 (0.0))	0.1 (NA)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.1 (0.1)
	Pool 13	0.0 (NA	0 –	0 –	0 –	0.1 (0.1)	0 –	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	Pool 26	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	LG	0.0 (0.0)	0 –	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	OR	0 –	0.0 (0.0)	0.1 (0.1)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0 –	0.0 (0.0)
710–859	Pool 4	0.0 (0.0)	0.0 (0.0)	0 –	0 –	0.1 (0.1)	0 –	0 –	0.0 (0.0)	0.0 (0.0)	0 –
	Pool 8	0 –	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	Pool 13	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –
	Pool 26	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0.0 (0.0)
	LG	0.0 (0.0)	0 –	0 –	0.0 (0.0)	0 –	0 –	0 –	0.0 (0.0)	0 –	0 –
	OR	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –
860–1019	Pool 4	0.0 (0.0)	0 –	0 –	0 –	0.1 (0.1)	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0 –
	Pool 8	0.0 (0.0)	0 –	0 –	0.0 (0.0)	0.0 (0.0)	0 –	0 –	0 –	0 –	0 –
	Pool 13	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –
	Pool 26	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –
	LG	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0.0 (0.0)	0 –	0 –
	OR	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0.0 (0.0)	0.0 (0.0)

[a]– = no fish collected, no estimate

[b]LG = La Grange Pool.

[c]OR = Open River.

Table 3.8. Areawide mean catch-per-unit-effort (fish/15 min) and standard error (in parentheses) estimates by length group for freshwater drum (*Aplodinotus grunniens*) collected by day electrofishing in Long Term Resource Monitoring study areas in 1993–2002.

Length category (mm)	Study area	Year 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		Freshwater drum (*Aplodinotus grunniens*)									
200–299	Pool 4	0.3	0.4	0.2	1.0	0.4	0.2	0.3	0.2	0.3	0.1
		(0.1)	(0.2)	(0.1)	(0.5)	(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.0)
	Pool 8	0.0	0.2	0.1	0.1	0.1	0.0	0.1	0.2	0.2	0.0
		(0.0)	(0.1)	(0.1)	(0.0)	(0.1)	(0.0)	(0.1)	(0.1)	(0.1)	(0.0)
	Pool 13	0.1	0	0.1	0.3	0.3	0.1	0.2	0.3	0.0	0.1
		(0.1)	–[a]	(0.0)	(0.1)	(0.1)	(0.0)	(0.2)	(0.1)	(0.0)	(0.1)
	Pool 26	0.4	0.3	2.2	1.2	0.1	1.2	1.7	0.2	0.6	0.3
		(0.2)	(0.1)	(1.1)	(0.7)	(0.1)	(0.5)	(0.6)	(0.1)	(0.3)	(0.1)
	LG[b]	0.6	0.1	0.9	0.6	1.4	0.8	0.7	0.7	0.3	0.2
		(0.4)	(0.1)	(0.2)	(0.2)	(0.1)	(0.2)	(0.3)	(0.2)	(0.1)	(0.1)
	OR[c]	0.1	0.9	0.4	2.3	1.0	0.5	0.4	0.5	0.4	0
		(0.1)	(0.4)	(0.3)	(1.1)	(0.6)	(0.3)	(0.2)	(0.3)	(0.4)	–
300–379	Pool 4	1.3	0.5	0.3	0.5	0.3	0.8	1.0	0.6	0.4	0.2
		(0.2)	(0.2)	(0.1)	(0.1)	(0.1)	(0.2)	(0.2)	(0.2)	(0.1)	(0.1)
	Pool 8	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0	0.2	0.0
		(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.1)	(0.0)	(0.0)	(0.1)	(0.0)
	Pool 13	0.3	0.0	0.0	0.0	0.1	0.3	0.1	0.2	0.1	0.1
		(0.2)	(0.0)	(0.0)	(0.0)	(0.0)	(0.1)	(0.0)	(0.1)	(0.1)	(0.1)
	Pool 26	0.6	0.3	0.3	0.6	0.2	0.4	1.2	0.1	0.3	0.1
		(0.2)	(0.1)	(0.2)	(0.3)	(0.1)	(0.1)	(0.6)	(0.1)	(0.1)	(0.1)
	LG	0.1	0.2	0.3	0.5	0.4	0.7	0.4	0.3	0.2	0.2
		(0.1)	(0.1)	(0.1)	(0.1)	(0.1)	(0.2)	(0.1)	(0.1)	(0.1)	(0.1)
	OR	0.4	0.8	0.5	0.4	0.9	0.3	0.6	0.6	0.1	0.0
		(0.3)	(0.3)	(0.3)	(0.2)	(0.3)	(0.2)	(0.4)	(0.4)	(0.1)	(0.0)
380–509	Pool 4	0.3	0.1	0.2	0.0	0.2	0.1	0.2	0.1	0.1	0.3
		(0.1)	(0.0)	(0.1)	(0.0)	(0.1)	(0.0)	(0.1)	(0.1)	(0.0)	(0.2)
	Pool 8	0.2	0.1	0.1	0.1	0.1	0.6	0.1	0.1	0.1	0.0
		(0.0)	(0.0)	(0.1)	(0.0)	(0.0)	(0.3)	(0.0)	(0.0)	(0.1)	(0.0)
	Pool 13	0.2	0.1	0.1	0.1	0.0	0.1	0.2	0.3	0.0	0.1
		(0.1)	(0.1)	(0.1)	(0.0)	(0.0)	(0.0)	(0.1)	(0.2)	(0.0)	(0.0)
	Pool 26	0.3	0.2	0.3	0.5	0.2	0.3	0.4	0.1	0.5	0.2
		(0.2)	(0.1)	(0.2)	(0.2)	(0.1)	(0.1)	(0.2)	(0.1)	(0.3)	(0.1)
	LG	0.0	0.0	0.0	0.0	0.1	0.2	0.1	0.1	0.1	0.2
		(0.0)	(0.0)	(0.0)	(0.0)	(0.1)	(0.0)	(0.0)	(0.0)	(0.0)	(0.1)
	OR	0.1	0.1	0.0	0.0	0.3	0	0.3	0.3	0.0	0
		(0.1)	(0.1)	(0.0)	(0.0)	(0.1)	–	(0.2)	(0.2)	(0.0)	–
510–629	Pool 4	0.0	0.0	0	0	0	0	0.0	0.0	0.0	0.0
		(0.0)	(0.0)	–	–	–	–	(0.0)	(0.0)	(0.0)	(0.0)
	Pool 8	0	0.0	0	0.0	0.0	0.0	0	0.0	0.0	0.0
		–	(0.0)	–	(0.0)	(0.0)	(0.0)	–	(0.0)	(0.0)	(0.0)
	Pool 13	0.0	0	0	0	0	0.0	0	0	0.0	0.0
		(0.0)	–	–	–	–	(0.0)	–	–	(0.0)	(0.0)
	Pool 26	0.1	0.0	0.0	0	0.0	0.0	0	0	0.0	0
		(0.1)	(0.0)	(0.0)	–	(0.0)	(0.0)	–	–	(0.0)	–
	LG	0	0	0	0	0.0	0	0	0	0	0.0
		–	–	–	–	(0.0)	–	–	–	–	(0.0)
	OR	0	0	0	0	0.1	0	0.2	0.2	0	0.0
		–	–	–	–	(0.1)	–	(0.1)	(0.2)	–	(0.0)

[a]– = no fish collected, no estimate
[b]LG = La Grange Pool.
[c]OR = Open River.

Table 3.9. Areawide mean catch-per-unit-effort (fish/15 min) and standard error (in parentheses) estimates by length group for largemouth bass (*Micropterus salmoides*) collected by day electrofishing in Long Term Resource Monitoring Program study areas in 1993–2002.

Length category (mm)	Study area	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		Largemouth bass (*Micropterus salmoides*)									
200–274	Pool 4	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.2 (0.1)	0.3 (0.1)	0.2 (0.1)	0.8 (0.2)	0.5 (0.1)	0.2 (0.1)	0.5 (0.1)
	Pool 8	0.3 (0.2)	0.2 (0.1)	0.6 (0.2)	1.9 (1.3)	0.5 (0.1)	0.5 (0.1)	1.3 (0.3)	0.8 (0.1)	0.4 (0.1)	0.1 (0.1)
	Pool 13	1.0 (0.2)	0.2 (0.1)	1.0 (0.3)	1.6 (0.3)	1.1 (0.2)	0.7 (0.2)	1.8 (0.5)	1.3 (0.5)	0.3 (0.1)	0.8 (0.3)
	Pool 26	0.0 (0.0)	0.5 (0.1)	0.2 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.2)	0.0 (0.0)	1.0 (0.3)	0.3 (0.1)
	LG[a]	0.0 (0.0)	0.3 (0.1)	0.7 (0.1)	0.4 (0.1)	0.5 (0.1)	0.8 (0.2)	2.7 (0.7)	0.6 (0.1)	0.3 (0.1)	0.4 (0.1)
	OR[b]	0 –[c]	0 –	0 –	0.0 (0.0)	0.0 (0.0)	0 –	0 –	0 –	0.0 (0.0)	0.0 (0.0)
275–349	Pool 4	0.2 (0.1)	0.1 (0.1)	0.0 (0.0)	0.1 (0.1)	0.2 (0.1)	0.1 (0.0)	0.5 (0.2)	0.5 (0.1)	0.3 (0.1)	0.2 (0.1)
	Pool 8	0.1 (0.1)	0.2 (0.0)	0.2 (0.1)	1.0 (0.5)	0.5 (0.1)	0.3 (0.1)	0.6 (0.1)	1.0 (0.2)	1.0 (0.2)	0.1 (0.0)
	Pool 13	0.8 (0.2)	0.6 (0.1)	0.3 (0.1)	0.8 (0.2)	1.0 (0.2)	1.0 (0.2)	1.4 (0.3)	1.5 (0.5)	0.5 (0.2)	0.2 (0.1)
	Pool 26	0.0 (0.0)	0.1 (0.1)	0.3 (0.1)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.2 (0.1)	0 –
	LG	0.1 (0.1)	0.7 (0.1)	0.3 (0.1)	0.4 (0.1)	0.3 (0.1)	0.7 (0.1)	0.9 (0.2)	0.9 (0.2)	0.3 (0.1)	0.1 (0.0)
	OR	0 –	0 –	0 –	0 –	0.0 (0.0)	0 –	0 –	0 –	0 –	0 –
350–424	Pool 4	0.2 (0.1)	0.2 (0.1)	0.2 (0.1)	0.1 (0.1)	0.3 (0.1)	0.1 (0.0)	0.2 (0.1)	0.2 (0.1)	0.2 (0.1)	0.2 (0.1)
	Pool 8	0.2 (0.1)	0.1 (0.0)	0.1 (0.1)	0.3 (0.1)	0.2 (0.1)	0.3 (0.1)	0.4 (0.2)	0.4 (0.1)	0.6 (0.1)	0.0 (0.0)
	Pool 13	0.5 (0.1)	0.6 (0.2)	0.4 (0.1)	0.6 (0.2)	0.7 (0.1)	0.5 (0.1)	0.9 (0.3)	0.6 (0.2)	0.4 (0.1)	0.7 (0.2)
	Pool 26	0.0 (0.0)	0.1 (0.1)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)
	LG	0.0 (0.0)	1.1 (0.2)	0.5 (0.1)	0.3 (0.1)	0.3 (0.1)	0.5 (0.1)	0.4 (0.1)	0.4 (0.1)	0.2 (0.1)	0.2 (0.1)
	OR	0 –	0 –	0.0 (0.0)	0 –	0.0 (0.0)	0 –	0 –	0 –	0 –	0 –
425–499	Pool 4	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	Pool 8	0.0 (0.0)	0 –	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0 –	0.0 (0.0)	0 –
	Pool 13	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.1 (0.0)	0.1 (0.1)	0.0 (0.0)	0.1 (0.1)	0.2 (0.1)	0.1 (0.1)	0.0 (0.0)
	Pool 26	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0 –	0 –	0 –	0 –
	LG	0 –	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.1)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)
	OR	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –

[a]LG = La Grange Pool.
[b]OR = Open River.
[c]– = no fish collected, no estimate

Table 3.10. Areawide mean catch-per-unit-effort (fish/15 min) and standard error (in parentheses) estimates by length group for sauger (*Sander canadensis*) collected by day electrofishing in Long Term Resource Monitoring Program study areas in 1993–2002.

Length category (mm)	Study area	Year									
		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
						Sauger (*Sander canadensis*)					
200–269	Pool 4	0.1 (0.0)	0.0 (0.0)	0.3 (0.1)	0.1 (0.1)	0.3 (0.1)	0.3 (0.1)	0.9 (0.2)	0.2 (0.1)	0.0 (0.0)	0.3 (0.1)
	Pool 8	0.4 (0.1)	0.2 (0.1)	0.3 (0.1)	0.3 (0.1)	0.1 (0.1)	0.9 (0.1)	0.5 (0.1)	0.5 (0.1)	0.0 (0.0)	0 –[a]
	Pool 13	0.4 (0.2)	0.2 (0.1)	0.4 (0.2)	0.1 (0.0)	0.2 (0.1)	0.6 (0.2)	0.5 (0.1)	0.4 (0.1)	0.1 (0.0)	0.3 (0.1)
	Pool 26	0 –	0.8 (0.2)	0.1 (0.1)	0.0 (0.0)	0.3 (0.1)	0.0 (0.0)	0.2 (0.1)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)
	LG[b]	0.1 (0.1)	0.8 (0.2)	0.1 (0.0)	0.2 (0.1)	0.3 (0.1)	0.3 (0.1)	0.1 (0.0)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)
	OR[c]	0 –	0.1 (0.1)	0.1 (0.1)	0 –	0 –	0.1 (0.1)	0 –	0 –	0.0 (0.0)	0.1 (0.1)
270–339	Pool 4	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.2 (0.1)	0.1 (0.0)	0.3 (0.1)	0.4 (0.1)	0.1 (0.0)	0.1 (0.0)
	Pool 8	0.0 (0.0)	0.2 (0.1)	0.1 (0.0)	0.3 (0.1)	0.2 (0.0)	0.2 (0.0)	0.2 (0.0)	0.4 (0.1)	0.2 (0.1)	0 –
	Pool 13	0.1 (0.1)	0.1 (0.1)	0.0 (0.0)	0.3 (0.1)	0.2 (0.1)	0.3 (0.1)	0.2 (0.1)	0.3 (0.1)	0.1 (0.1)	0.0 (0.0)
	Pool 26	0 –	0.1 (0.0)	0.1 (0.1)	0.1 (0.0)	0 –	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	LG	0 –	0.1 (0.0)	0.1 (0.1)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0 –	0.0 (0.0)
	OR	0 –	0.0 (0.0)	0.2 (0.1)	0.1 (0.1)	0 –	0 –	0.1 (0.1)	0.1 (0.1)	0 –	0 –
340–409	Pool 4	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)
	Pool 8	0 –	0 –	0 –	0 –	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0 –
	Pool 13	0 –	0 –	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.1 (0.0)	0 –	0.0 (0.0)	0.1 (0.1)	0 –
	Pool 26	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0 –	0 –
	LG	0 –	0 –	0.1 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	OR	0 –	0 –	0.1 (0.1)	0 –	0 –	0.0 (0.0)	0 –	0.1 (0.1)	0.1 (0.1)	0 –
410–479	Pool 4	0.1 (0.1)	0 –	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0 –	0.0 (0.0)	0.0 (0.0)
	Pool 8	0 –	0 –	0.0 (0.0)	0 –	0 –	0 –	0 –	0 –	0 –	0 –
	Pool 13	0 –	0 –	0 –	0.0 (0.0)	0 –	0 –	0.0 (0.0)	0 –	0 –	0 –
	Pool 26	0 –	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0 –	0 –	0.0 (0.0)
	LG	0 –	0 –	0 –	0.0 (0.0)	0 –	0.1 (0.0)	0 –	0.0 (0.0)	0 –	0.0 (0.0)
	OR	0 –	0 –	0 –	0.0 (0.0)	0 –	0.2 (0.1)	0 –	0 –	0 –	0 –

[a]– = no fish collected, no estimate

[b]LG = La Grange Pool.

[c]OR = Open River.

Table 3.11. Areawide mean catch-per-unit-effort (fish/net day) and standard error (in parentheses) estimates by length group for smallmouth buffalo (*Ictiobus bubalus*) collected by large hoop nets in Long Term Resource Monitoring Program study areas in 1993–2002.

Length category (mm)	Study area	Year 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
					Smallmouth buffalo (*Ictiobus bubalus*)						
280–389	Pool 4	0 –[a]	0 –	0 –	0.2 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –
	Pool 8	0.1 (0.0)	0 –	0.1 (0.0)	0.6 (0.2)	0.6 (0.2)	0 –	0.0 (0.0)	0.0 (0.0)	0 –	0 –
	Pool 13	0.0 (0.0)	0.1 (0.0)	0.3 (0.1)	0.5 (0.2)	3.0 (0.8)	0.5 (0.1)	0.6 (0.2)	0.6 (0.2)	0.4 (0.2)	0.0 (0.0)
	Pool 26	0.4 (0.2)	0.2 (0.1)	2.1 (0.6)	5.3 (1.8)	5.0 (1.4)	1.5 (0.4)	1.2 (0.4)	1.2 (0.4)	0.7 (0.3)	0.4 (0.1)
	LG[b]	2.5 (1.3)	0.3 (0.1)	1.3 (0.3)	0.9 (0.2)	2.8 (0.9)	3.5 (0.7)	1.8 (0.5)	1.8 (0.5)	5.6 (1.7)	2.4 (0.8)
	OR[c]	0 –	0 –	0.0 (0.0)	2.5 (2.2)	1.0 (0.5)	1.3 (0.7)	0.1 (0.1)	0.1 (0.1)	0 –	0.1 (0.0)
390–499	Pool 4	0.6 (0.3)	0.3 (0.1)	0.5 (0.2)	0.2 (0.1)	0.4 (0.2)	0.9 (0.3)	0.5 (0.2)	0.9 (0.3)	0.6 (0.2)	0.1 (0.1)
	Pool 8	0.5 (0.1)	0.1 (0.1)	0.3 (0.1)	0.3 (0.1)	1.1 (0.3)	0.1 (0.1)	0.1 (0.1)	0.0 (0.0)	0.1 (0.0)	0 –
	Pool 13	0.0 (0.0)	0.3 (0.1)	0.3 (0.1)	0.1 (0.0)	0.9 (0.5)	0.2 (0.1)	0.6 (0.2)	0.4 (0.1)	0.6 (0.3)	0.1 (0.0)
	Pool 26	1.0 (0.7)	1.1 (0.3)	1.1 (0.3)	1.0 (0.3)	1.3 (0.4)	0.7 (0.2)	1.0 (0.2)	1.9 (0.4)	1.2 (0.2)	0.9 (0.2)
	LG	1.1 (0.5)	0.8 (0.2)	0.8 (0.2)	0.4 (0.2)	0.9 (0.3)	2.4 (0.6)	0.9 (0.2)	2.3 (0.6)	4.0 (1.0)	4.1 (1.2)
	OR	0.1 (0.1)	0.0 (0.0)	0.7 (0.3)	1.2 (0.7)	0.8 (0.3)	1.4 (0.4)	0.9 (0.3)	1.7 (0.5)	0.6 (0.3)	0.6 (0.3)
500–609	Pool 4	0.1 (0.1)	0.1 (0.1)	0.3 (0.1)	0.1 (0.0)	0.4 (0.1)	0.9 (0.3)	0.8 (0.2)	1.2 (0.4)	0.9 (0.2)	0.5 (0.2)
	Pool 8	0.2 (0.1)	0.1 (0.1)	0.1 (0.0)	0.2 (0.1)	0.6 (0.2)	0.1 (0.0)	0.1 (0.0)	0.2 (0.1)	0.2 (0.1)	0 –
	Pool 13	0 –	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.2 (0.1)	0.1 (0.0)	0.1 (0.1)	0.1 (0.0)	0.1 (0.1)	0.0 (0.0)
	Pool 26	0.3 (0.3)	0.2 (0.1)	0.3 (0.1)	0.5 (0.2)	0.2 (0.1)	0.2 (0.1)	0.3 (0.1)	0.2 (0.1)	0.1 (0.0)	0.3 (0.1)
	LG	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.2 (0.1)	0.0 (0.0)	0.1 (0.0)	0.1 (0.1)	0.0 (0.0)
	OR	0.1 (0.1)	0.1 (0.0)	0.6 (0.3)	0.2 (0.1)	0.3 (0.1)	0.4 (0.2)	0.6 (0.3)	0.9 (0.3)	0.0 (0.0)	0.1 (0.1)
610–729	Pool 4	0 –	0.0 (0.0)	0.0 (0.0)	0 –	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0.1 (0.0)
	Pool 8	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –
	Pool 13	0 –	0 –	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0 –	0 –
	Pool 26	0 –	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0 –	0.0 (0.0)
	LG	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –
	OR	0.2 (0.2)	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0 –	0.0 (0.0)

[a]– = no fish collected, no estimate
[b]LG = La Grange Pool.
[c]OR = Open River.

Table 3.12. Areawide mean catch-per-unit-effort (fish/15 min) and standard error (in parentheses) estimates by length group for white bass (*Morone chrysops*) collected by day electrofishing in Long Term Resource Monitoring Program study areas in 1993–2002.

Length category (mm)	Study area	Year 1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		White bass (*Morone chrysops*)									
150–229	Pool 4	0.2 (0.1)	0.0 (0.0)	1.6 (0.8)	0.0 (0.0)	0.1 (0.0)	0.3 (0.2)	0.5 (0.2)	0.1 (0.0)	0.1 (0.0)	0.1 (0.1)
	Pool 8	0.0 (0.0)	0.0 (0.0)	0.2 (0.1)	0.2 (0.1)	0.0 (0.0)	0.4 (0.3)	0.3 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
	Pool 13	0.2 (0.1)	0.7 (0.7)	0.5 (0.2)	0.1 (0.1)	0.1 (0.0)	0.2 (0.1)	0.3 (0.1)	0.4 (0.1)	0.4 (0.1)	0.1 (0.1)
	Pool 26	6.9 (2.2)	3.0 (0.8)	0.4 (0.1)	0.1 (0.1)	0.8 (0.2)	0.7 (0.2)	0.5 (0.1)	0.1 (0.0)	0.1 (0.0)	0.2 (0.1)
	LG[a]	0.8 (0.7)	4.4 (0.9)	0.8 (0.4)	1.7 (0.4)	0.7 (0.2)	2.5 (0.5)	0.5 (0.2)	1.2 (0.6)	1.2 (0.6)	0.4 (0.1)
	OR[b]	2.5 (0.9)	1.5 (0.9)	0.4 (0.3)	0.4 (0.3)	0.3 (0.1)	0.4 (0.2)	0 –[c]	0.7 (0.3)	0.7 (0.3)	0.1 (0.1)
230–299	Pool 4	0.2 (0.1)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.2)	0.3 (0.1)	0.2 (0.0)	0.0 (0.0)
	Pool 8	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0 –
	Pool 13	0.1 (0.1)	0.2 (0.1)	0.1 (0.1)	0.2 (0.1)	0.1 (0.1)	0.2 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.1)
	Pool 26	0.0 (0.0)	0.3 (0.1)	0.9 (0.3)	0.1 (0.0)	0.0 (0.0)	0.4 (0.2)	0.6 (0.1)	0.1 (0.0)	0.1 (0.1)	0.0 (0.0)
	LG	0.2 (0.1)	0.2 (0.1)	0.4 (0.2)	0.6 (0.2)	0.8 (0.2)	1.1 (0.3)	2.0 (0.6)	0.3 (0.1)	0.2 (0.1)	0.1 (0.1)
	OR	0.3 (0.2)	0.4 (0.2)	0.6 (0.3)	0.2 (0.2)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.0 (0.0)	0 –	0.1 (0.1)
300–379	Pool 4	0.5 (0.2)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.4 (0.1)	0.3 (0.1)	0.3 (0.1)	0.3 (0.1)	0.7 (0.1)	0.3 (0.1)
	Pool 8	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.3 (0.1)	0 –	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)
	Pool 13	0 –	0.1 (0.1)	0.0 (0.0)	0.1 (0.1)	0.1 (0.1)	0.0 (0.0)	0.1 (0.0)	0.2 (0.1)	0.0 (0.0)	0.1 (0.0)
	Pool 26	0 –	0.1 (0.0)	0.0 (0.0)	0.3 (0.1)	0.2 (0.1)	0.2 (0.1)	0.4 (0.1)	0.2 (0.1)	0.1 (0.0)	0.2 (0.0)
	LG	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.5 (0.1)	0.3 (0.1)	1.2 (0.4)	0.5 (0.1)	0.4 (0.1)	0.2 (0.1)	0.3 (0.1)
	OR	0 –	0.1 (0.1)	0.0 (0.0)	0.3 (0.1)	0.2 (0.1)	0.0 (0.0)	0.2 (0.1)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)
380–459	Pool 4	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.1 (0.1)	0.1 (0.0)	0.2 (0.1)
	Pool 8	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0 –	0 –	0 –	0.0 (0.0)	0 –	0 –
	Pool 13	0 –	0.1 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0 –	0 –
	Pool 26	0 –	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)
	LG	0 –	0 –	0 –	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –
	OR	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –

[a]LG = La Grange Pool.
[b]OR = Open River.
[c]– = no fish collected, no estimate

Table 3.13. Areawide mean catch-per-unit-effort (fish/net day) and standard error (in parentheses) estimates by length group for white crappie (*Pomoxis annularis*) collected by fyke nets in Long Term Resource Monitoring Program study areas in 1993–2002.

Length category (mm)	Study area	Year									
		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
		White Crappie (*Pomoxis annularis*)									
130–199	Pool 4	0 –[a]	0 –	0.1 (0.1)	0 –	0.5 (0.4)	0 –	0.1 (0.1)	0.1 (0.1)	0.3 (0.2)	0 –
	Pool 8	0.3 (0.2)	0.0 (0.0)	0.1 (0.0)	0.1 (0.1)	0.1 (0.1)	0.0 (0.0)	0.2 (0.1)	0 –	0.1 (0.1)	0.0 (0.0)
	Pool 13	0.5 (0.2)	0.0 (0.0)	1.4 (0.4)	1.1 (0.3)	0.8 (0.4)	0.6 (0.2)	0.9 (0.4)	2.7 (1.2)	4.8 (1.8)	3.0 (1.2)
	Pool 26	0.2 (0.1)	0.4 (0.2)	0.3 (0.2)	0.0 (0.0)	0.0 (0.0)	0.1 (0.0)	0.0 (0.0)	0.2 (0.1)	1.3 (0.6)	0.4 (0.2)
	LG[b]	0.1 (0.1)	5.0 (1.5)	2.7 (1.2)	1.3 (0.4)	3.9 (0.9)	1.6 (0.9)	2.3 (0.9)	0.6 (0.2)	0.5 (0.2)	1.2 (0.4)
	OR[c]	0 –	0 –	0 –	0 –	0 –	0 –	0.0 (0.0)	0 –	0 –	0 –
200–249	Pool 4	0.1 (0.1)	0 –	0.2 (0.1)	0 –	0.2 (0.1)	0 –	0 –	0.2 (0.1)	0.1 (0.1)	0 –
	Pool 8	0.2 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.0 (0.0)	0.1 (0.1)	0.4 (0.3)	0.1 (0.1)	0.0 (0.0)	0.0 (0.0)
	Pool 13	1.6 (0.6)	0.3 (0.1)	0.1 (0.1)	1.2 (0.6)	0.5 (0.2)	0.3 (0.1)	1.8 (1.5)	0.4 (0.2)	1.2 (0.5)	1.8 (0.8)
	Pool 26	0.3 (0.1)	0.3 (0.1)	0.2 (0.1)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)	0.6 (0.2)	0.3 (0.1)
	LG	0.2 (0.1)	0.7 (0.3)	5.8 (2.0)	1.1 (0.4)	1.0 (0.4)	2.1 (0.1)	2.2 (0.7)	1.6 (0.6)	0.6 (0.3)	0.7 (0.2)
	OR	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –
250–299	Pool 4	0.1 (0.1)	0 –	0.1 (0.1)	0 –	0 –	0.3 (0.2)	0 –	0.3 (0.2)	0 –	0 –
	Pool 8	0.1 (0.1)	0.2 (0.1)	0.0 (0.0)	0 –	0.1 (0.0)	0.1 (0.1)	0.1 (0.0)	0 –	0.1 (0.1)	0 –
	Pool 13	0.5 (0.2)	1.0 (0.5)	0.6 (0.3)	0.2 (0.1)	0.2 (0.1)	0.5 (0.2)	0.7 (0.3)	1.1 (0.5)	0.8 (0.3)	1.3 (0.5)
	Pool 26	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0.0 (0.0)	0.0 (0.0)	0 –	0 –	0.0 (0.0)	0.4 (0.2)	0.1 (0.1)
	LG	0.1 (0.1)	0.1 (0.0)	0.8 (0.3)	0.8 (0.3)	0.6 (0.2)	0.8 (0.2)	0.7 (0.3)	0.4 (0.2)	0.1 (0.0)	0.4 (0.1)
	OR	0 –	0.0 (0.0)	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –
300–379	Pool 4	0 –	0.1 (0.1)	0 –	0 –	0.0 (0.0)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0 –
	Pool 8	0.1 (0.1)	0.0 (0.0)	0.1 (0.0)	0.1 (0.0)	0 –	0.1 (0.0)	0.1 (0.1)	0 –	0.0 (0.0)	0 –
	Pool 13	0.1 (0.1)	0.3 (0.1)	0.5 (0.3)	0.1 (0.1)	0.1 (0.1)	0.1 (0.1)	0 –	0.1 (0.1)	0.1 (0.1)	0.4 (0.2)
	Pool 26	0 –	0.0 (0.0)	0.1 (0.1)	0 –	0 –	0 –	0 –	0 –	0.1 (0.1)	0 –
	LG	0 –	0.1 (0.1)	0.3 (0.1)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)	0.0 (0.0)	0.1 (0.0)	0 –	0.1 (0.1)
	OR	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –	0 –

[a]– = no fish collected, no estimate
[b]LG = La Grange Pool.
[c]OR = Open River.

Chapter 4. Temporal and Spatial Trends in Length-weight Relationships

Introduction

Length-weight relationships of fish populations are helpful for determining body condition or general "well-being" and can be a robust predictor of growth (Anderson and Neumann 1996). When length and weight data for a fish population are logarithmically transformed, the relation between length and weight is linear and can be viewed as the population rate of gain on the log scale (i.e., increase in $\log_{10}$ weight per unit increase in $\log_{10}$ length; hereafter referred to as rate of gain). Populations with a high rate of gain are adding weight at a faster rate than populations with a low rate of gain. Length-weight regression parameters can be used to estimate the weight of fish at a given length for the population. Length-weight regression provides a means for comparing fish plumpness or body condition among populations while controlling for length. Increased predicted weight for a population at a given length suggests increased fat reserves are available for somatic growth and gonad development. Factors affecting population length-weight relationships include physiological stress, competition for resources, habitat suitability, and prey availability. This chapter compares length-weight relationships among study areas and study years 1993–2002 for the Long Term Resource Monitoring Program (LTRMP). Spatial differences in length-weight relationships may provide insight into mechanisms responsible for variability in population parameters among study areas. Temporal differences in length-weight relationships may provide insight into how environmental conditions (e.g., water levels, climate) can affect fish growth and health.

Methods

Total length (nearest millimeter) and weight (nearest gram) data were collected for individual black crappie (*Pomoxis nigromaculatus*), channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*), highfin carpsucker (*Carpiodes velifer*), sauger (*Sander canadensis*), and walleye (*Sander vitreus*) in third period (September 16–October 31) LTRMP fish collections. Annually, weight data were screened for outliers based on the percent deviation from LTRMP derived length-weight regression models. Weight data were considered outliers if the observed weight differed from predicted weight (calculated using length-weight regression models) by <-70% or >150% for fish ≤125 mm, <-60% or >120% for fish from 126 to 249 mm, and <-50% or >100% for fish ≥250 mm. Weight data flagged as outliers were reviewed by field collection staff and removed if deemed unreliable. Length-weight regression analyses were limited to fish of stock length through quality length (see Anderson and Neumann 1996 for length designations). Highfin carpsucker data were excluded from analyses because they were not collected in all study areas or years. There were no stock length to quality length walleye collected from the Open River study area (Open River; river mile 29–80) in 1993–2002, so Open River was excluded from analysis for walleye. Length and weight data were $\log_{10}$ transformed before analyses to provide a linear relation between fish length and weight. Field-collected weight data inherently have error associated with them that affect the ability to precisely define length-weight relationships (Gutreuter and Krzoska 1994). Error associated with field-collected weight measurements reduces the likelihood that significant trends in rate of gain will be detected, but should not increase the likelihood of Type I error.

For each species, linear regression was used to describe the relation between $\log_{10}$ weight (dependent variable) and $\log_{10}$ length (independent variable) for each year and study area. Regressions were tested for parallel slopes and equal *Y*-intercepts using analysis of variance (GLM procedure; SAS Institute 1999). To determine which years and study areas were significantly different, the slope from individual year and study area length-weight regressions were tested for significant difference against a composite length-weight regression (i.e., length-weight regression constructed from all years and study areas) using a *t*-test. Year regression slopes were considered significantly different than the composite regression slope at $P < 0.005$ (Bonferroni corrected for $N = 10$ year comparisons), and study area regression line slopes were considered significantly different than the composite regression line slope at $P < 0.008$ (Bonferroni corrected for N = six study areas).

For each species, length-weight regressions were calculated for each study area and year. These regressions were used to predict weight upon entering stock length (PW_1) and upon leaving quality length (PW_2), using length designations from Anderson and Neumann (1996). Inferential statistics were not used to test the significance of differences among predicted weights—they are meant to serve as descriptive guides for interpreting rate of gain results.

Results

The rate of gain was significantly different among areas (test for parallel slopes, $P < 0.05$, Table 4.1) for all species tested (i.e., black crappie, channel catfish, common carp, sauger, and walleye). In La Grange Pool, the rate of gain for black crappie, channel catfish, and sauger was significantly higher (*t*-tests, $P < 0.005$) than the overall rate of gain trend (Table 4.2). La Grange Pool was the only study area to contain populations with a rate of gain significantly higher than the overall rate of gain trend. High rate of gain for black crappie, channel catfish, and sauger in La Grange Pool was caused by a decreased plumpness of small fish and an increased plumpness of large fish (predicted weights, Table 4.2). Pools 4, 13, and 26, and La Grange Pool contained at least one species exhibiting a rate of gain significantly lower than the overall rate of gain trend.

The rate of gain was significantly different among years for black crappie, channel catfish, common carp, and walleye (test for parallel slopes, $P < 0.05$, Table 4.1), but was not significantly different among years for sauger (test for parallel slopes, $P = 0.0791$, Table 4.1). In 1993, the rate of gain for black crappie and common carp was significantly lower (*t*-tests, $P < 0.005$) than the overall rate of gain trend (Table 4.3). Low rate of gain for black crappie and common carp in 1993 was caused by an increased plumpness of small fish (predicted weights, Table 4.3). In 1997, the rate of gain for black crappie and common carp was significantly higher (*t*-test, $P < 0.005$) than the overall rate of gain trend (Table 4.3). High rate of gain for black crappie and common carp in 1997 was caused by an increased plumpness of large fish (predicted weights, Table 4.3). In 1993, channel catfish exhibited increased plumpness across all lengths, causing rate of gain to be near average despite an increased body condition for small and large fish (Table 4.3). In 1996 and 1998, no species exhibited a rate of gain significantly lower or higher than the overall rate of gain trend and in 1994, 1995, 1999, 2000, 2001, and 2002 only a single species exhibited a significantly reduced or increased rate of gain.

Discussion

La Grange Pool of the Illinois River was the only study area containing species exhibiting an increased rate of gain when compared to overall rate of gain trends (for three out of five species). For these species, smaller fish were less plump and larger fish were more plump in the Illinois River than in main-stem Upper Mississippi River (UMR) areas. This spatial trend suggests the presence of biological factors (e.g., food availability, competition, climate, hydrology) in La Grange Pool that differ from the main-stem UMR. The Illinois River became degraded because of human effects (levees, pollution, sediment contamination) in the 1950s through the early 1970s, coinciding with a decreased condition factor in common carp (Theiling 1999). Our investigation indicates that the condition of common carp in the Illinois River remains below average. However, for the other species studied, condition compared favorably between La Grange Pool and main-stem UMR sites. Further investigation into bioenergetics and growth of these species could identify specific causes for the observed spatial patterns in length-weight relationships.

Black crappie and common carp were the only two species that exhibited a similar rate of gain response to temporal variability (down in 1993 and up in 1997). Black crappie and common carp are most closely associated with backwater and side channel habitats in the Upper Mississippi River System, whereas the other three study species are most closely associated with main channel and side channel habitats. The Mississippi and Illinois Rivers surpassed flood stage in all study areas in 1993 and 1997, but the timing of the flood events differed. The 1993 flood event occurred in late June and early July (with a smaller flood in April), but the 1997 flood event occurred primarily in April. This suggests that the timing of flood events may be as important to fish productivity as is the flood itself. Future conceptual models for fish productivity in large rivers may be improved by incorporating flood frequency and flood predictability (as done for community structure in smaller rivers by Poff and Ward [1989]), as well as a measure of flood timing.

Table 4.1. Results of tests for parallel slopes and equal *Y*-intercepts for length-weight regressions of fish collected in September 16–October 31, 1993–2002, from the six Long Term Resource Monitoring Program study areas within the Upper Mississippi River System.

	Slope			Intercept		
Comparison	**df**	***F***	***P*[a]**	**df**	***F***	***P*[a]**
Black crappie (*Pomoxis nigromaculatus*)						
Among years	9, 4461	10.76	**<0.0001**	9, 4461	10.69	**<0.0001**
Among areas	5, 4469	16.85	**<0.0001**	5, 4469	17.15	**<0.0001**
Channel catfish (*Ictalurus punctatus*)						
Among years	9, 2789	2.95	**0.0017**	9, 2789	2.96	**0.0017**
Among areas	5, 2797	4.36	**0.0006**	5, 2797	4.19	**0.0009**
Common carp (*Cyprinus carpio*)						
Among years	9, 7602	5.87	**<0.0001**	9, 7602	6.55	**<0.0001**
Among areas	5, 7610	8.74	**<0.0001**	5, 7610	8.74	**<0.0001**
Sauger (*Sander canadensis*)						
Among years	9, 2123	1.72	0.0791	9, 2123	1.65	0.0968
Among areas	5, 2131	9.96	**<0.0001**	5, 2131	9.77	**<0.0001**
Walleye (*Sander vitreus*)						
Among years	9, 1177	5.86	**<0.0001**	9, 1177	5.93	**<0.0001**
Among areas	4, 1187	14.88	**<0.0001**	4, 1187	15.47	**<0.0001**

[a]Significant *P* values are in bold text. Significant *P* values indicate significantly different slopes for tests of parallel slopes and indicate significantly different intercepts for tests of equal intercepts.

Table 4.2. Length-weight regression statistics by study area and species for fish collected from the Upper Mississippi River System for the Long Term Resource Program in 1993–2002 [a].

Study area [b]	N	Slope (a)	Intercept (b)	r^2	PW_1 (g)	PW_2 (g)	t	P [c]
Black crappie (*Pomoxis nigromaculatus;* 130–199 mm total length)								
P4	1,393	3.236	-5.356	0.972	31	250	-2.06	0.0392
P8	466	3.277	-5.447	0.970	30	254	-0.00	0.9974
P13	1,352	3.240	-5.369	0.962	30	248	-1.90	0.0581
P26	306	3.258	-5.409	0.956	30	250	-0.49	0.6251
LG	916	3.505	-5.981	0.937	27	262	8.02	**<0.0001**
OR	48	3.340	-5.590	0.945	30	259	0.71	0.4785
All	4,481	3.277	-5.452	0.963	30	251		
Channel catfish (*Ictalurus punctatus;* 280–409 mm total length)								
P4	242	3.466	-6.287	0.905	157	2,315	-0.28	0.7806
P8	478	3.518	-6.416	0.976	156	2,400	0.90	0.3679
P13	181	3.479	-6.305	0.963	162	2,414	-0.08	0.9360
P26	752	3.489	-6.334	0.938	160	2,407	0.17	0.8666
LG	518	3.616	-6.672	0.971	150	2,496	3.59	**0.0003**
OR	638	3.406	-6.137	0.938	158	2,225	-2.25	0.0243
All	2,809	3.484	-6.328	0.953	158	2,364		
Common carp (*Cyprinus carpio;* 280–409 mm total length)								
P4	724	2.885	-4.557	0.848	318	1,996	-2.75	**0.0060**
P8	299	2.883	-4.514	0.902	348	2,176	-1.89	0.0588
P13	654	2.872	-4.514	0.873	327	2,031	-2.86	**0.0043**
P26	2,732	3.002	-4.858	0.954	308	2,079	0.01	0.9893
LG	2,307	2.898	-4.637	0.922	285	1,801	-4.47	**<0.0001**
OR	906	3.061	-5.010	0.920	303	2,121	2.04	0.0418
All	7,622	3.002	-4.873	0.928	297	2,008		
Sauger (*Sander canadensis;* 200–299 mm total length)								
P4	754	3.460	-6.242	0.975	52	479	1.75	0.0795
P8	442	3.384	-6.060	0.950	53	464	-0.81	0.4196
P13	724	3.300	-5.855	0.957	55	451	-3.39	**0.0007**
P26	86	3.132	-5.435	0.876	59	438	-3.51	**0.0004**
LG	130	3.656	-6.709	0.960	50	523	3.90	**<0.0001**
OR	7	3.181	-5.529	0.982	61	472	-1.21	0.2282
All	2,143	3.412	-6.123	0.963	53	473		
Walleye (*Sander vitreus;* 250–379 mm total length)								
P4	536	3.180	-5.499	0.964	134	1,283	-5.52	**<0.0001**
P8	470	3.396	-6.067	0.984	119	1,334	2.14	0.0326
P13	165	3.431	-6.159	0.984	117	1,342	2.39	0.0168
P26	10	3.593	-6.531	0.964	122	1,564	1.54	0.1244
LG	16	3.042	-5.119	0.954	150	1,302	-1.42	0.1571
OR								
All	1,197	3.338	-5.912	0.977	124	1,327		

[a] Length-weight regression parameters include (a) slope, (b) intercept, and (r^2) coefficient of determination, as well as predicted weight upon entering stock length (PW_1) and upon leaving quality length (PW_2) based upon regression parameters. P-values and t statistics of comparisons between study area slopes and the slope of the overall length-weight regression line are included. Slopes were considered significantly different at $P < 0.008$ (Bonferroni correction). Stock and quality length designations are from Anderson and Neumann (1996).

[b] P4 = Pool 4, P8 = Pool 8, P13 = Pool 13, P26 = Pool 26, LG = La Grange Pool, and OR = Open River.

[c] Significant P values are in bold.

Table 4.3. Length-weight regression statistics by year and species for fish collected from the Upper Mississippi River System by the Long Term Resource Program in 1993–2002 [a].

Year	*N*	Slope (*a*)	Intercept (*b*)	r^2	PW_1 (g)	PW_2 (g)	*t*	*P* [b]
Black crappie (*Pomoxis nigromaculatus;* 130-199 mm total length)								
1993	292	3.097	-5.029	0.938	33	247	-4.97	**<0.0001**
1994	471	3.164	-5.212	0.969	30	234	-4.12	**<0.0001**
1995	690	3.403	-5.730	0.968	29	266	4.68	**<0.0001**
1996	377	3.384	-5.703	0.928	28	259	2.68	0.0074
1997	295	3.390	-5.709	0.962	29	259	2.96	**0.0030**
1998	374	3.218	-5.310	0.972	31	252	-1.78	0.0752
1999	567	3.303	-5.510	0.969	30	254	0.78	0.4362
2000	486	3.291	-5.487	0.974	30	251	0.51	0.6087
2001	553	3.322	-5.558	0.975	29	252	1.50	0.1347
2002	376	3.262	-5.421	0.953	30	249	-0.41	0.6794
All	4,481	3.277	-5.452	0.963	30	251	.	.
Channel catfish (*Ictalurus punctatus;* 280-409 mm total length)								
1993	208	3.514	-6.370	0.971	170	2,601	0.59	0.5539
1994	285	3.582	-6.586	0.961	151	2,446	2.17	0.0303
1995	147	3.469	-6.302	0.915	154	2,279	-0.23	0.8157
1996	233	3.517	-6.413	0.966	156	2,402	0.65	0.5145
1997	559	3.540	-6.488	0.956	150	2,342	1.50	0.1334
1998	232	3.508	-6.397	0.968	154	2,352	0.45	0.6544
1999	210	3.493	-6.355	0.966	156	2,353	0.15	0.8777
2000	228	3.473	-6.289	0.955	162	2,410	-0.19	0.8465
2001	312	3.505	-6.382	0.947	157	2,388	0.47	0.6367
2002	395	3.332	-5.934	0.939	166	2,210	-3.83	**0.0001**
All	2,809	3.484	-6.328	0.953	158	2,364	.	.
Common carp (*Cyprinus carpio;* 280-409 mm total length)								
1993	558	2.890	-4.543	0.921	338	2127	-3.37	**0.0007**
1994	1415	2.997	-4.852	0.965	303	2043	-0.23	0.8166
1995	661	3.035	-4.978	0.934	281	1939	0.91	0.3611
1996	462	2.993	-4.846	0.904	301	2020	-0.20	0.8441
1997	887	3.117	-5.160	0.924	294	2,133	3.48	**0.0005**
1998	712	2.984	-4.811	0.848	310	2,069	-0.40	0.6891
1999	780	3.031	-4.962	0.927	285	1,962	0.77	0.4386
2000	688	3.168	-5.310	0.855	277	2,079	3.62	**0.0003**
2001	795	3.140	-5.264	0.884	263	1,939	3.56	**0.0004**
2002	664	3.056	-5.038	0.913	276	1,927	1.34	0.1810
All	7,622	3.002	-4.873	0.928	297	2,008	.	.

Table 4.3. (Continued)

Year	*N*	Slope (*a*)	Intercept (*b*)	r^2	PW_1 (g)	PW_2 (g)	*t*	*P* [b]
Sauger (*Sander canadensis;* 200-299 mm total length)								
1993	233	3.356	-5.988	0.954	54	463	-1.20	0.2316
1994	194	3.332	-5.928	0.901	55	461	-1.39	0.1654
1995	239	3.483	-6.285	0.980	54	497	1.80	0.0724
1996	163	3.352	-5.976	0.911	55	465	-0.95	0.3423
1997	164	3.461	-6.228	0.969	54	497	0.84	0.4030
1998	276	3.392	-6.093	0.976	52	451	-0.45	0.6542
1999	387	3.353	-5.991	0.970	53	452	-1.47	0.1416
2000	214	3.435	-6.181	0.972	53	475	0.51	0.6125
2001	231	3.348	-5.944	0.968	58	489	-1.36	0.1741
2002	42	3.195	-5.602	0.972	56	433	-1.64	0.1002
All	2,143	3.412	-6.123	0.963	53	474		
Walleye (*Sander vitreus;* 250-379 mm total length)								
1993	103	3.407	-6.096	0.982	119	1,336	1.51	0.1323
1994	91	3.535	-6.419	0.987	114	1,410	3.44	**0.0006**
1995	200	3.281	-5.745	0.958	133	1,367	-1.53	0.1265
1996	129	3.448	-6.189	0.978	120	1,392	2.06	0.0396
1997	72	3.446	-6.198	0.980	116	1,347	1.81	0.0701
1998	149	3.423	-6.146	0.987	115	1,316	2.09	0.0368
1999	148	3.189	-5.548	0.983	126	1,213	-3.27	**0.0011**
2000	126	3.247	-5.686	0.980	126	1,267	-1.56	0.1181
2001	166	3.257	-5.690	0.983	132	1,336	-1.72	0.0856
2002	12	3.209	-5.575	0.977	132	1,291	-0.79	0.4273
All	1,197	3.338	-5.912	0.977	124	1,327		

[a]Length-weight regression parameters include (*a*) slope, (*b*) intercept, and (r^2) coefficient of determination, as well as predicted weight upon entering stock length (PW_1)and upon leaving quality length (PW_2) based upon regression parameters. *P* values and *t* statistics of comparisons between year slopes and the slope of the overall length-weight regression line are included. Slopes were considered significantly different at $P < 0.005$ (Bonferroni correction). Length designations are from Anderson and Neumann (1996).

[b] Significant P values are in bold.

Chapter 5. Temporal and Spatial Trends in Relative Abundance

Introduction

This chapter contains an investigation of variation in abundance of fish populations among years, study areas, and aquatic areas (e.g., backwater shorelines, main channel borders, and side channel borders) in the Upper Mississippi River (UMR). Relative abundance data (typically defined as catch-per–unit-effort) are routinely collected to index the density of fish populations in inland waters (Ney 1999). The Long Term Resource Monitoring Program (LTRMP) fish sampling design provides an opportunity to assess variation in the relative abundance of fish species among study areas (longitudinal-spatial variation), aquatic areas (lateral-spatial variation), and among years (temporal variation). Quantifying how fish populations vary across space and time can isolate factors responsible for observed patterns in fish abundance. Identifying the primary factors responsible for population abundance patterns will help fisheries managers determine species most likely to respond to local habitat modifications, climatic variability, or degradation of specific types of aquatic areas.

This investigation used analysis of variance (ANOVA) to identify trends in the relative abundance of 50 UMR species. Analysis of variance is based on the premise that an increase in the difference among factor level means is associated with an increase in variability when comparing among factor levels (Rao 1998; Zar 1999). For example, if the mean abundance of bluegill (*Lepomis macrochirus*) is similar in backwaters and channel habitats, low levels of variance will be associated with samples from the two habitats. Conversely, if the mean abundance of bluegill is dissimilar in backwater and channel habitats, high levels of variance will be associated with samples from the two habitats. Analysis of variance is most commonly applied to determine if a response variable differs significantly among factor levels (as with fish abundance in channel habitats and backwater habitats in the above example). In this investigation, ANOVA was used to measure variability associated with spatial and temporal factors, then these measurements of variability were used to contrast and compare species relative abundance patterns. These variance partitioning techniques should be viewed as data exploration.

We present results as visual representations of how fish species relate to one another based on longitudinal-spatial, lateral-spatial, and temporal variance. This was an observational investigation because no specific a priori hypotheses are tested. The visual representations of variation in relative abundance represent a 10-year period of field collection composed of 3,324 electrofishing samples. These figures can be used as guides by resource managers for applied habitat management or for formulating hypothesis concerning UMR fish abundance dynamics. The goal of this investigation was to classify groups of species that share similar spatial and temporal variance patterns, and are likely to respond in a similar manner to habitat modifications or habitat change. Our results provide a starting point for the development of statistical models for relating abundance patterns to environmental characteristics.

Methods

In 1993–2002, standard LTRMP protocols were used to collect fish samples (N = 3,324) using day electrofishing at randomly selected shoreline sites in contiguous backwater, main channel, and side channel aquatic areas of Pools 4, 8, 13, and 26 of the UMR and La Grange Pool of the Illinois River. Collection crews consisted of three persons (i.e., a pilot and two persons operating dip nets). Electrofishing runs were approximately 15 min and covered approximately 200 m of shoreline. Dip netters collected fish as they appeared, regardless of size and species. Voltage and amperage were adjusted to achieve a uniform base power of 3,000 watts after correcting for on-site conductivity and temperature variation (Burkhardt and Gutreuter 1995). A pulse frequency of 60 Hz and a duty-cycle of 25% were used for all runs.

Within each study area, nearly equal electrofishing effort was applied among three open-water study periods (June 15–July 31, August 1–September 15, September 16–October 31). The number of samples per aquatic area (i.e., contiguous backwater shorelines, main channel borders, and side channel borders) was based on the proportional contribution of each aquatic area type to the total aquatic area of each study area (Gutreuter et al. 1995). The Open River study area was excluded from analysis because it did not contain sites in backwater aquatic areas.

Fish abundance is not typically normally distributed, both spatially and temporally, resulting in non-normally distributed and right-skewed samples for low-density fish populations (Bannerot and Austin 1983; Hubert 1996; Counihan et al. 1999). The distribution of catch-per-unit-effort (CPUE, catch/effort) data is affected by population density and, therefore, no single data transformation can be applied in all cases to generate a more normal distribution (Hubert 1996; Counihan et al. 1999). Previous researchers have suggested that for low-density populations an index based on the presence or absence of organisms in samples may be superior to indexes based on the arithmetic mean (Bannerot and Austin 1983; Counihan et al. 1999). In this study we used the proportion of electrofishing runs containing a given species, or size group of a species, to index abundance.

Analysis was limited to those species present in LTRMP samples from all five study areas in at least 1 year during 1993–2002 ($N = 50$). To assess relations between size-classes within species, fish were grouped based upon stock and substock length designations for those species with proposed length designations in peer-reviewed literature ($N = 25$, size designations from Anderson and Neumann 1996 and Bister et al. 2000). This resulted in 75 study groups (50 species with 25 species split into stock and substock length).

For each sampling year, the proportion of positive electrofishing runs was calculated independently for each fish species and size class of interest for each study area, sampling period, and aquatic area type using the following formula: $PPR = p/n$; where PPR = the proportion of positive runs, p = the number of runs where the species and size group of interest was present, and n = the total number of electrofishing runs completed. This study design resulted in equal effort for each study area and aquatic area type within years. Proportion data have a binomial distribution; therefore, the proportion of positive electrofishing runs data was transformed using a modified Freeman and Tukey arcsine transformation (Zar 1999) before further analysis.

We considered two primary spatial factors (aquatic area type and study area) and one temporal factor (year), as well as all higher order interactions, resulting in seven model factors. Among groups variation at the study area, aquatic area, year, and interaction factor levels was measured as Type III sums of squares using a three-factor unbalanced ANOVA (GLM procedure; SAS Institute 1999). The ratio of factor sum of squares (factor SS) to total sum of squares (total SS) for each ANOVA factor was derived for each of the 75 study groups. Factor SS/total SS served as a measure of the relative importance of each factor to the total variation in relative abundance (e.g., the percentage of variation in bluegill abundance explained by variation among aquatic areas). Principal components analysis (PCA; CANOCO v.4.5; ter Braak and Smilauer 2002) and two-dimensional plots were used to ordinate species based upon factor SS/total SS for the model factors.

Visual representations of variation among study areas (longitudinal-spatial variation), aquatic areas (lateral-spatial varitation), and years (temporal variation) constructed through PCA and two-dimensional plots were used to assess which species and size groups exhibited similar temporal and spatial abundance patterns. Principal components analysis was done separately for substock-length groups, stock-length groups, and species with no size designation to allow easier interpretation of figures. Two-dimensional plots were divided into quadrants based upon median values for factor SS/total SS. For select species, pie charts were constructed to visually represent variance decomposition into factor SS/total SS for the seven model factors. F values (within factors mean square/error mean square) and P values derived from ANOVA were used to quantitatively describe the significance of factors.

Results

Three-factor (study area, aquatic area, year) ANOVA models explained from 39% to 90% of the variation in study group relative abundance with a mean of 63% for the 75 study groups. The proportion of total SS accounted for by study area, aquatic area, year, and interaction factors varied among study groups, as did subsequent *F* values (Figure 5.1 provides examples of variance decomposition and among group variation in the proportion of total SS explained by model factors).

Ranges in factor SS/total SS were sufficient to ordinate fish species using two-dimensional plots and PCA. The proportion of total SS accounted for by the study area factor ranged from a low of 5.4% ($F = 12.737$, df = 4,296, $P < 0.0001$) for substock-length black crappie, to a high of 67.4% ($F = 231.64$, df = 4,296, $P < 0.0001$) for golden redhorse (i.e., relative to other factors, the abundance variation associated with differences among study areas was lowest for stock-length black crappie and highest for golden redhorse). The proportion of total SS accounted for by the aquatic area factor ranged from a low of <0.1% ($F = 0.002$, df = 2,296, $P = 0.9985$) for substock-length sauger, to a high of 32.9% ($F = 142.568$, df = 2,296, $P < 0.0001$) for substock-length bluegill. The proportion of total SS accounted for by the year factor ranged from a low of 0.4% ($F = 0.429$, df = 9,296, $P = 0.9188$) for shortnose gar, to a high of 20.3% ($F = 18.728$, df = 9,296, $P < 0.0001$) for substock-length common carp. *F*-values indicated significant differences among study areas ($P < 0.05$) for all study groups (i.e., all species and size groups), significant differences among aquatic areas ($P < 0.05$) for 72 of 75 study groups, and significant differences among years ($P < 0.05$) for 59 of 75 study groups.

Significant interactions were present for many species and size groups. This suggests that UMR abundance patterns are spatially and temporally complex (i.e., year differences were dependent upon aquatic area and study area, aquatic area differences were dependent upon study area). Significant year ×study area interaction ($P < 0.05$) was present for 63 of 75 study groups, significant year × aquatic area interaction was present for 8 of 75 study groups, and significant aquatic area × study area interaction was present for 63 of 75 study groups. Significant three-way (year × aquatic area × study area) interaction was present for 8 of 75 study groups.

Two-dimensional plots of factor SS/total SS for aquatic area, study area, and year factors are shown in Figures 5.2–5.4. Table 5.1 contains six-letter codes used to identify fish species and length groups of species in figures. Stock-length and substock-length centrarchids (i.e., black crappie, bluegill, largemouth bass, orangespotted sunfish, smallmouth bass, and white crappie) exhibited high levels of variation in relative abundance when comparing among aquatic area types (Figures 5.2–5.3). Bowfin, emerald shiner, substock-length flathead catfish, golden shiner, stock-length longnose gar, river shiner, and yellow perch also varied considerably among aquatic area types. Broadcast and pelagic spawning species associated with main channel habitats (e.g., common carp, freshwater drum, sauger, smallmouth buffalo, walleye and white bass) exhibited high levels of temporal variability in substock-length abundance (Figures 5.2 and 5.4). Similarly, the abundance of stock-length common carp, gizzard shad, smallmouth buffalo, and sauger showed high levels of temporal variability (Figures 5.2 and 5.4). Species exhibiting high levels of variation in abundance among study areas for both stock-length and substock-length fish included channel catfish, gizzard shad, northern pike, shorthead redhorse, smallmouth bass, smallmouth buffalo, yellow perch, and walleye (Figures 5.3–5.4). Additionally, bullhead minnow, golden redhorse, logperch, quillback, river shiner, shortnose gar, shovelnose sturgeon, and stonecat exhibited high variability when comparing among study areas (Figures 5.3–5.4).

Temporal abundance patterns were highly dependent upon study area (i.e., year × study area interaction) for substock-length black buffalo, green sunfish, sauger, and white bass. Lateral-spatial abundance patterns were highly dependent upon year (i.e., year × aquatic area interaction) for stock-length channel

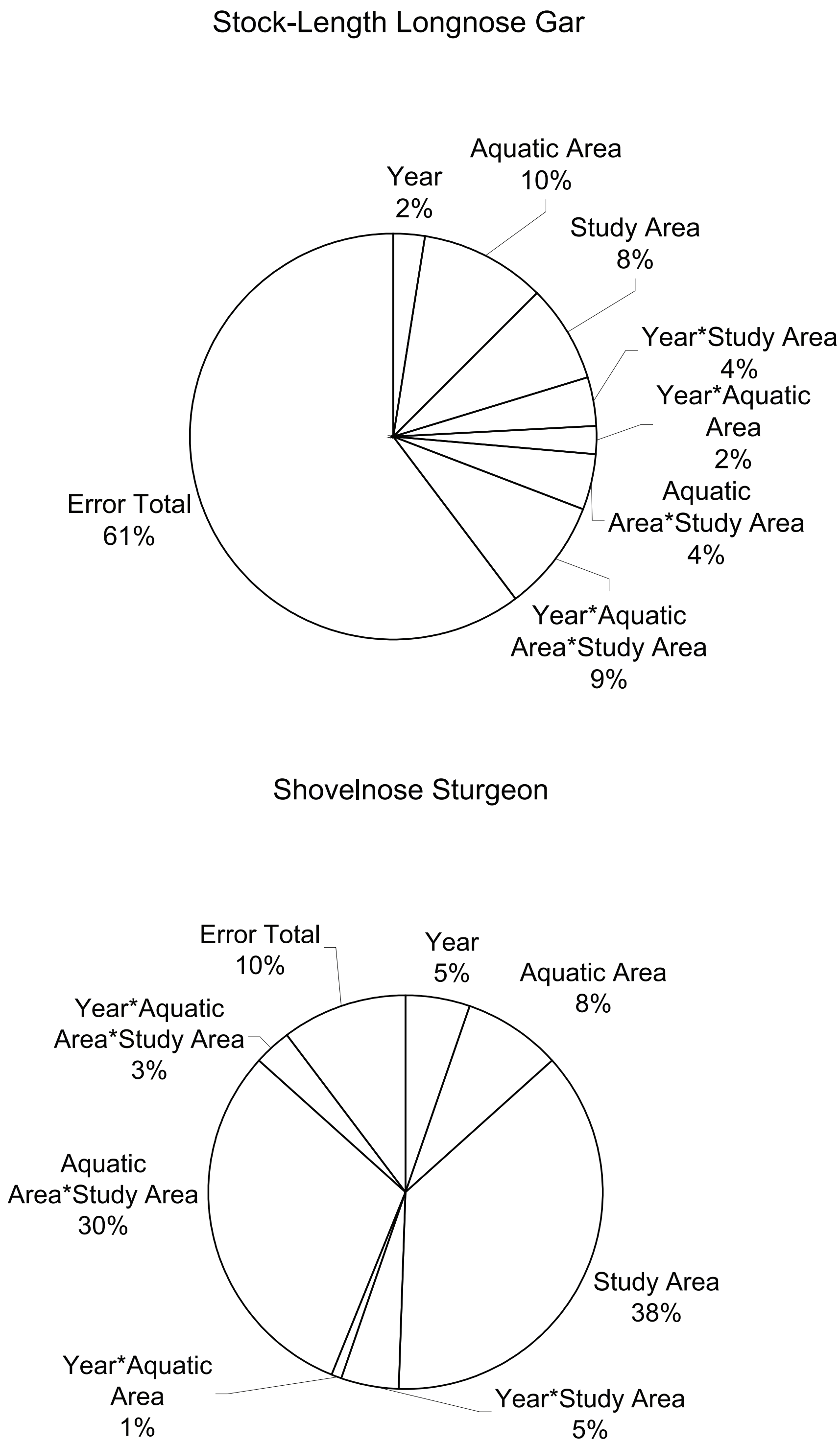

Figure 5.1. Pie charts representing the results of variance decomposition for the relative abundance (proportion of positive electrofishing runs) of stock-length longnose gar (*Lepisosteus osseus*) and shovelnose sturgeon (*Scaphirhynchus platorynchus*) collected by electrofishing from five study areas in the Upper Mississippi River System. The proportion of total sum of squares by model factors, as visually depicted in pie charts, was used to ordinate and group species based on lateral-spatial (aquatic area), longitudinal-spatial (study area), and temporal (year) variance patterns.

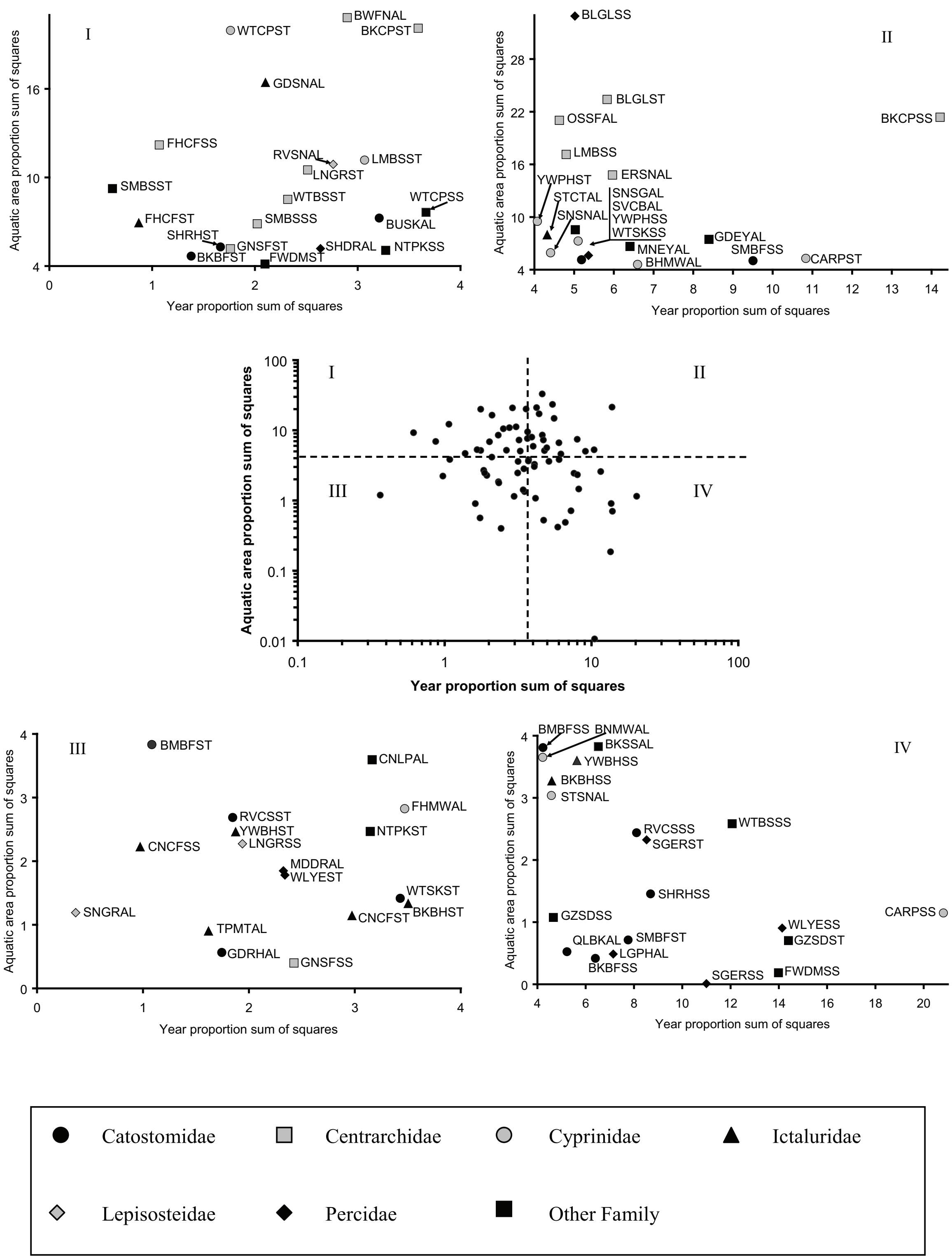

Figure 5.2. Proportion of total variation in abundance explained by year and aquatic area factors for 75 fish study groups collected with day electrofishing from the Upper Mississippi River System in 1993–2002. The overall view (center) displays all 75 study groups with dashed lines representing medians for the axes. Median values were used to separate study groups into quadrants I (top left), II (top right), III (bottom left), and IV (bottom right). Six-letter codes represent species and length groups of study groups (Table 5.1).

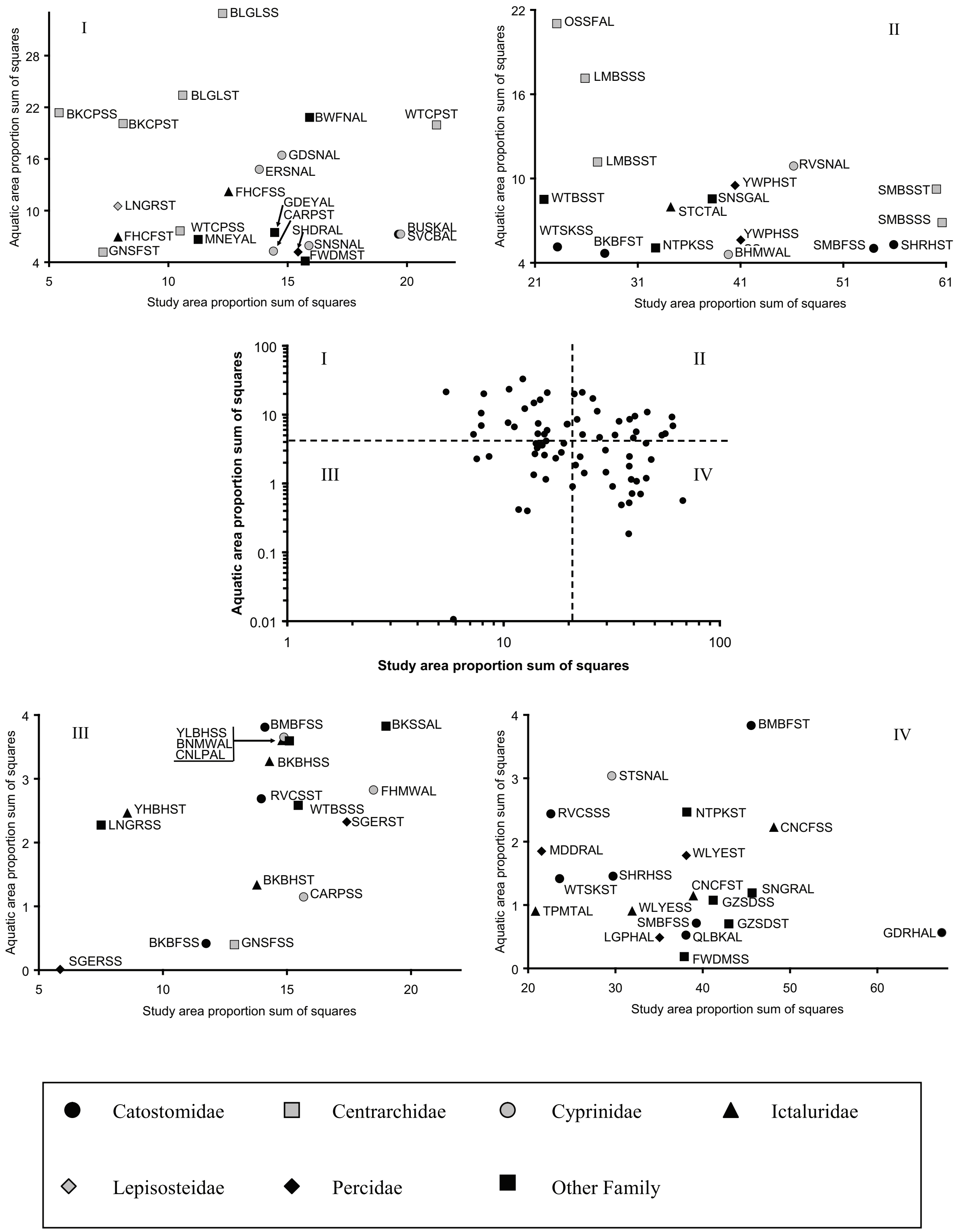

Figure 5.3. Proportion of total variation in abundance explained by study area and aquatic area factors for 75 fish study groups collected with day electrofishing from the Upper Mississippi River System in 1993–2002. The overall view (center) displays all 75 study groups with dashed lines representing medians for the axes. Median values were used to separate study groups into quadrants I (top left), II (top right), III (bottom left), and IV (bottom right). Six-letter codes represent species and length groups of study groups (Table 5.1).

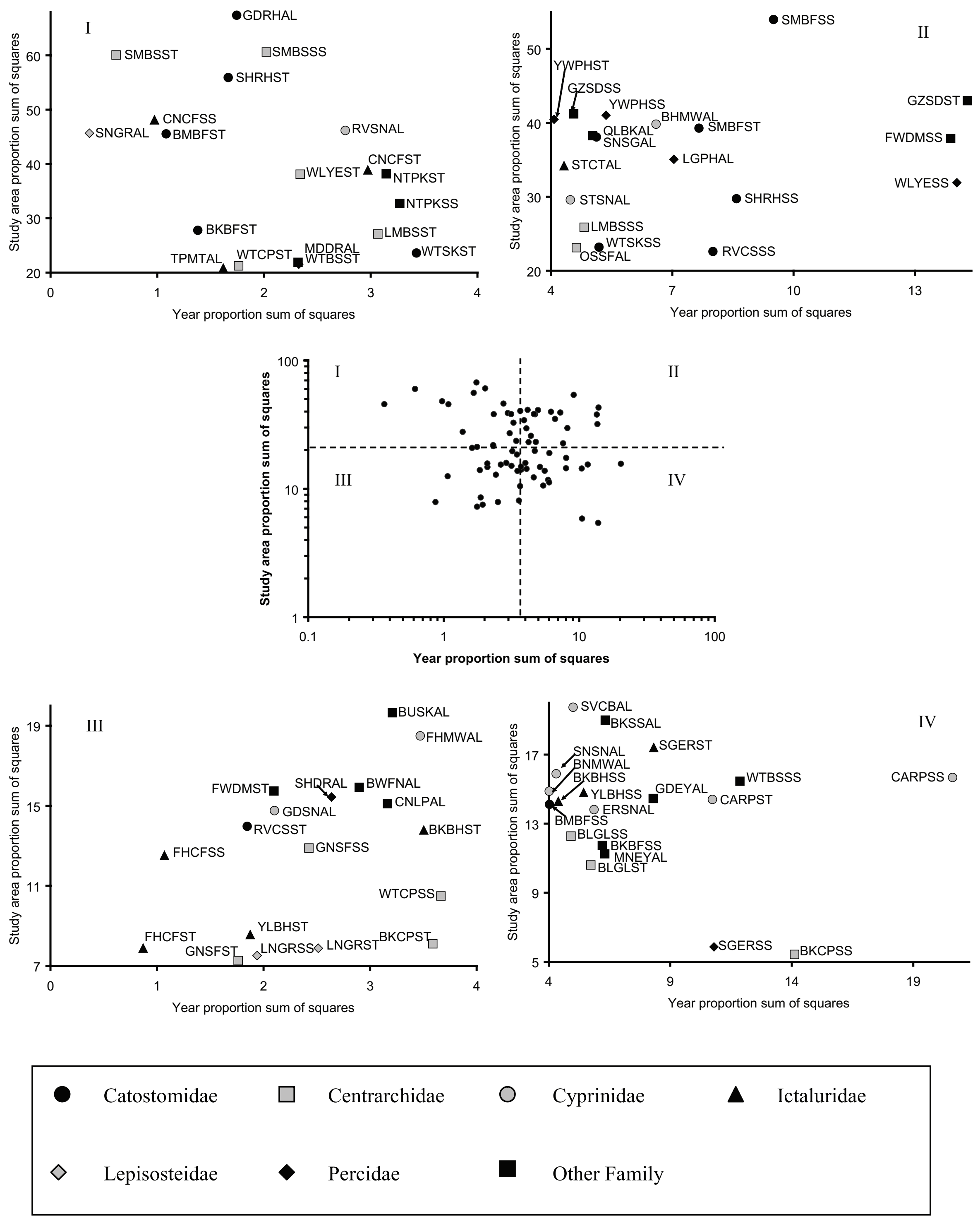

Figure 5.4. Proportion of total variation in abundance explained by year and study area factors for 75 fish study groups collected with day electrofishing from the Upper Mississippi River System in 1993–2002. The overall view (center) displays all 75 study groups with dashed lines representing medians for the axes. Median values were used to separate study groups into quadrants I (top left), II (top right), III (bottom left), and IV (bottom right). Six-letter codes represent species and length groups of study groups (Table 5.1).

catfish, bluntnose minnows, substock-length black crappie, and substock-length bigmouth buffalo. Lateral-spatial abundance patterns were dependent upon study area (i.e., aquatic area × study area interaction) for stock- and substock-length black bullheads, yellow bullheads, and white suckers, as well as shovelnose sturgeon and stonecat.

Graphical PCA results for substock-length fish, stock-length fish, and species with no size designation are in Figures 5.5–5.7, respectively. The first two principal components axes captured 80% of the total variance in the proportions of total SS for substock-length fish (Table 5.2), 86% for stock-length fish (Table 5.3), and 87% for species without size designations (Table 5.4).

Species varied considerably with respect to the proportion of total variation in relative abundance explained by differences among study areas (long vector length in Figures 5.5–5.7). That is, some species were distributed evenly throughout study areas whereas other species had a much higher or lower relative abundance in an individual study area or study areas. For example, smallmouth bass relative abundance varied considerably when comparing among study areas, but black crappie relative abundance was similar when comparing among study areas. Species varied comparatively little with respect to the proportion of total variation explained by differences among years (short vector length in Figures 5.5–5.7). In other words, all species varied in relative abundance on a year-to-year basis, but when comparing among species, differences in temporal variation were slight when compared to differences in longitudinal-spatial variation. The proportion of total variation in relative abundance explained by differences among aquatic areas was important for separating substock-length groups of species (Figure 5.5), but was comparatively unimportant for stock-length groups and species without size designations. Species exhibiting high proportions of variation explained by year × aquatic area interaction generally had high proportions of variation explained by year × study area and year × study area × aquatic area interaction (similar vector directions in Figures 5.5–5.7). The proportion of variance explained by aquatic area × study area interaction was an important component for separating adult fishes (i.e., stock-length and no size designation groups), but was comparatively unimportant for substock-length fish.

Discussion

The abundance dynamics of fish populations inhabiting the UMRS are complex. In a large river system, species abundance varies temporally (i.e., from year to year), longitudinally (i.e., from upstream to downstream), and laterally (i.e., among aquatic areas at the same latitude). Risotto and Turner (1985) suggested that factors affecting fish catch on the UMR could be divided into two groups (i.e., short- and long-term factors) on the basis of the type of influence imposed by the factor. Short-term factors, such as rainfall and water temperature, affect fish catch on an annual basis, and long-term factors, such as latitude and geomorphology, determine overall productivity, which influences long-term trends in abundance (Risotto and Turner 1985). Our investigation quantified short-term variation (i.e., year to year) and sought to distinguish differences among species in the relative importance of factors affecting long-term abundance. Recognizing the responses of species to long-term factors can help identify appropriate management actions and realistic goals.

Species differed markedly in the amount of relative abundance variation caused by longitudinal-spatial factors, differed to a lesser extent in variation caused by lateral-spatial factors, and were most similar with respect to temporal variation. Fish management on large rivers is often centered on improving the abundance of desirable fish populations by minimizing temporal variability (e.g., water level management and harvest regulations), enhancing lateral habitats (e.g., increasing connection between channel and off-channel habitats, and improving backwater overwintering habitat), or addressing longitudinal-spatial factors (e.g., optimizing hydrology and land-use practices). Thus, the success of a management initiative is contingent on addressing factors responsible for variation in abundance. Longitudinal-spatial variation is usually a

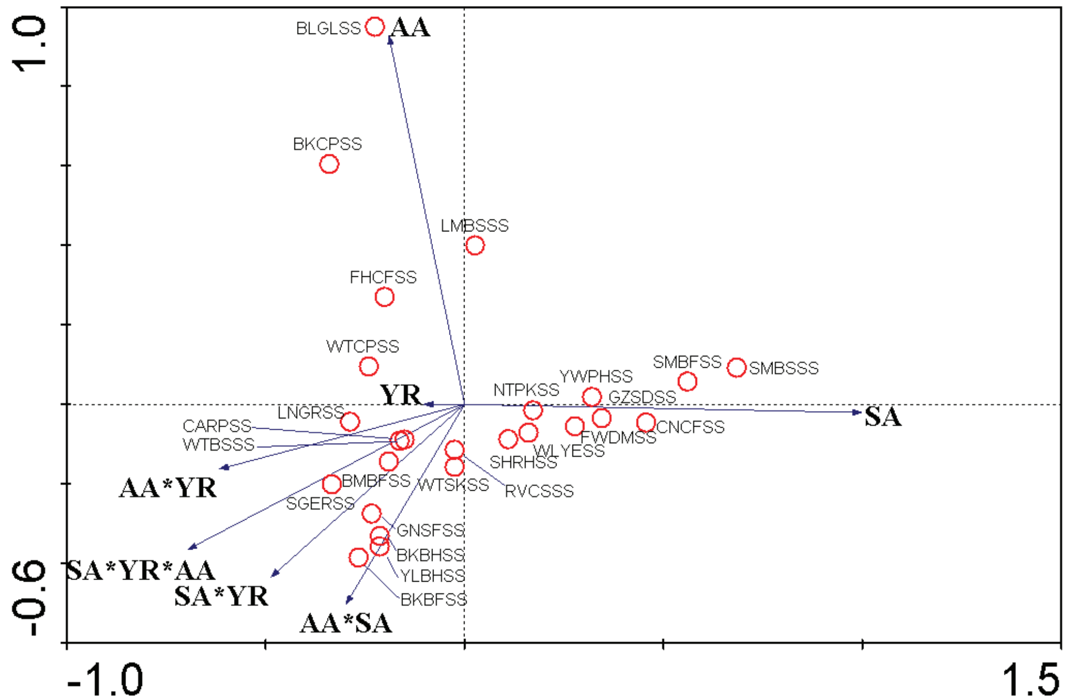

Figure 5.5. Biplot showing the first two principal component axes and demonstrating the loadings of each species on the seven analysis of variance (ANOVA) factors for substock-length fish. The ordination was based on a species x ANOVA factor matrix where the proportion of total sum of squares accounted for by each model factor comprised the data. The first two axes explained 80% of the variation in the univariate ANOVA results. AA = Aquatic area, SA= Study area, and YR = Year on axes labels. Six-letter codes represent species and length groups of study groups (Table 5.1).

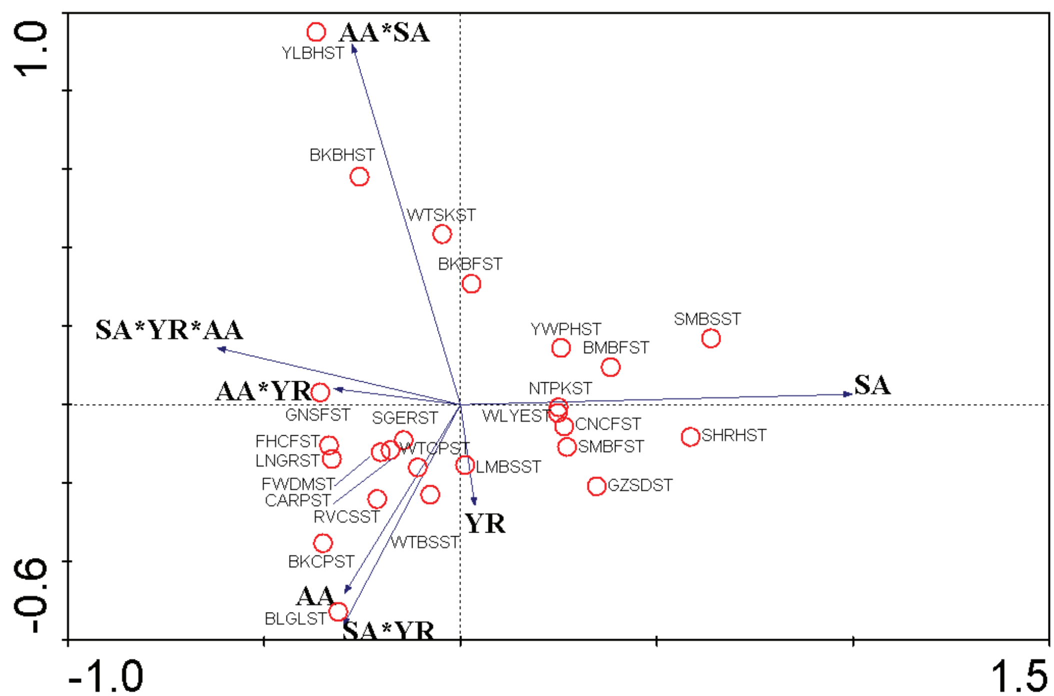

Figure 5.6. Biplot showing the first two principal component axes and demonstrating the loadings of each species on the seven analysis of variance (ANOVA) factors for stock-length fish. The ordination was based on a species x ANOVA factor matrix where the proportion of total sum of squares accounted for by each model factor comprised the data. The first two axes explained 80% of the variation in the univariate ANOVA results. AA = Aquatic area, SA = Study area, and YR = Year on axes labels. Six-letter codes represent species and length groups of study groups (Table 5.1).

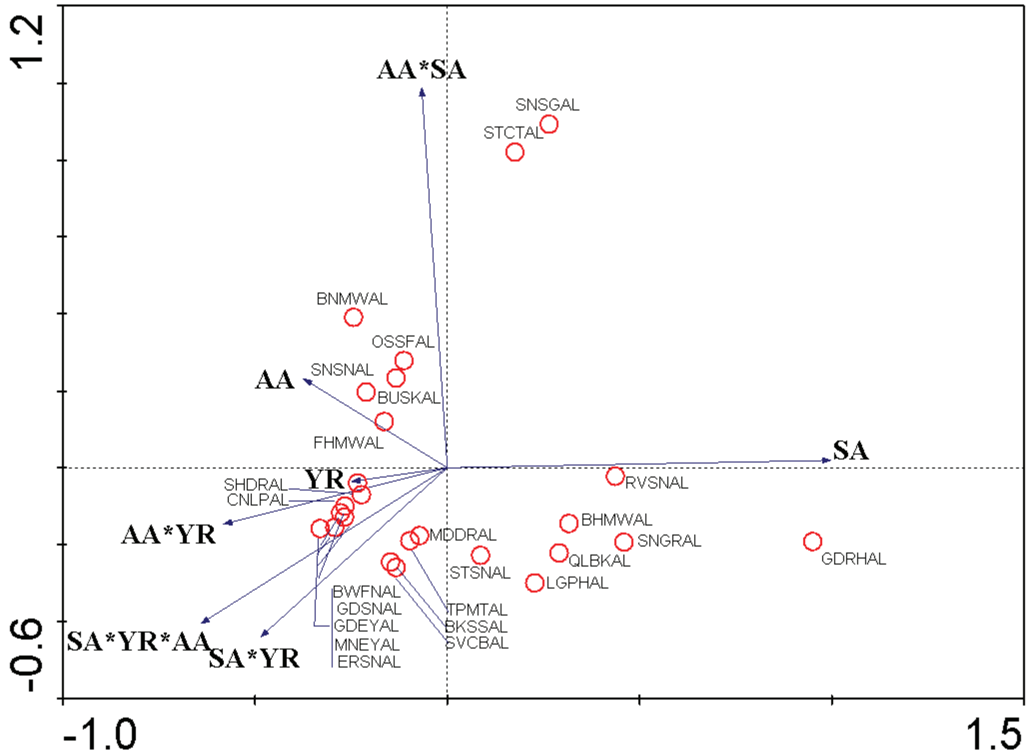

Figure 5.7. Biplot showing the first two principal component axes and demonstrating the loadings of each species on the seven analysis of variance (ANOVA) factors for fish species without length designations. The ordination was based on a species x ANOVA factor matrix where the proportion of total sum of squares accounted for by each model factor comprised the data. The first two axes explained 80% of the variation in the univariate ANOVA results. AA = Aquatic area, SA = Study area, and YR = Year on axes labels. Six-letter codes represent species and length groups of study groups (Table 5.1).

reflection of systemic factors (e.g., hydrology, water chemistry, floodplain morphology) that are not easily controlled through direct management intervention for the obvious reasons of scope and cost. For this reason, management actions typically focus on controlling year-to-year variation and lateral habitat improvements in an effort to mitigate for undesirable systemic factors.

Species that exhibited the highest levels of variation among aquatic area types would be most likely to show a relative abundance response to habitat improvements focusing on specific types of macrohabitats. Not surprisingly, centrarchid species exhibited high levels of variation among aquatic areas. Centrarchids remain a primary target of many aquatic habitat rehabilitation and enhancement projects (HREPs) on the UMR and have shown positive abundance responses to HREPs focused on backwater habitat (Gent et al. 1995). This investigation suggests that bowfin, emerald shiners, substock-length flathead catfish, golden shiners, stock-length longnose gar, river shiners, and yellow perch would also respond positively to HREPs applied to key macrohabitats in river reaches at hospitable latitudes. Conversely, important recreational species—such as channel catfish, sauger, and walleye—exhibited comparatively low levels of variation among aquatic areas, which suggests that HREPs focused on single macrohabitats are less likely to initiate an abundance response for these species.

When considering substock-length groups, temporal variation was in general most pronounced for species associated with channel habitats and low parental care (e.g., common carp, freshwater drum, sauger, smallmouth buffalo, walleye, white bass) and least pronounced for species associated with high parental care (e.g., channel catfish, flathead catfish, green sunfish, smallmouth bass). Those species exhibiting the highest levels of temporal variation generally exhibited low levels of variation among aquatic areas (black crappie is a notable exception). For this reason, species exhibiting high levels of temporal variation may pose difficulties for managers attempting to manipulate their abundance through local habitat modifications.

Longitudinal-spatial variation (i.e., upstream to downstream) was an important factor for separating UMR fish species. Those species with low levels of variation among study areas (e.g., bluegill, black crappie, flathead catfish, green sunfish) can be viewed as having an even presence or absence throughout the UMRS. These species may or may not be in high abundance, but must be adaptable to a wide range of chemical and physical constituents. Marked long-term declines or increases in the abundance of these species would be indicative of broad systemic change.

Longitudinal-spatial variation in relative abundance also provides insight into how the UMRS changes when traveling from upstream to downstream. Species with high levels of variation in relative abundance when comparing among study areas (e.g., bigmouth buffalo, golden redhorse, shorthead redhorse, smallmouth bass, smallmouth buffalo) can be viewed as more reach-specific. Assuming that abundance is a reflection of success, these species found conditions more favorable in a particular study area or study areas. For redhorse species and smallmouth bass, relative abundance was greater in Pools 4 and 8, whereas the abundance of the buffalo species was greater in Pool 26 and La Grange Pool of the Illinois River. Buffalo species are well suited for turbid large river conditions, whereas redhorse and smallmouth bass are more suited to clear-water and moderate size streams (Pflieger 1997). In this way, the life histories and adaptations of individual species can determine the fish community at a given latitude on the UMR, as well as the abundance of a given species.

Interaction among lateral-spatial, longitudinal-spatial, and temporal factors was common within study groups. Interaction terms identify species that exhibited different responses to levels of a factor dependent upon levels of another factor. This complexity in relative abundance patterns is not surprising given the size and dynamic nature of the UMR. It serves not only as a measure of complexity, but identifies species with unique relative abundance patterns warranting further study. For example, stock-length channel catfish exhibited temporal (i.e., year to year) variation in aquatic area use. This suggests that channel and off-channel habitat use by some species is dependent upon short-term factors (e.g., rainfall), which makes it important to consider the affect of temporal variability in river conditions when assessing lateral-spatial abundance patterns.

Longitudinal, lateral, and spatial processes serve as the cornerstone of current conceptual models regarding large river form, function, and community structure. The river continuum concept (Vannote et al. 1980) stresses the importance of longitudinal processes to community structure, whereas the flood pulse concept (Junk et al. 1989) centers around the importance of lateral (floodplain) processes to overall productivity. Temporal variability is considered a primary force behind population abundance and community structure in lotic systems (Grossman et al. 1982; Poff and Ward 1989). Ward (1989) suggested a four-dimensional (i.e., lateral, longitudinal, vertical, temporal) conceptual model of lotic ecosystems was necessary to achieve ecosystem-level understanding of the dynamics in natural lotic systems. Likewise, it is necessary to quantify how the abundance of fish populations vary in lateral-space, longitudinal-space, and across time to achieve a holistic perspective of factors affecting fish abundance. When considering a river system as large as the UMR, the impact of systemic longitudinal change upon species abundance and community structure is large (as evidenced by high among study area abundance variability in this investigation). However, when viewed from a smaller, pool-level scale (35–100 river km), lateral-spatial and temporal factors are primarily responsible for short-term abundance patterns. Despite this, river managers must remain cognizant that the long-term abundance of fish populations is ultimately confined by systemic processes and the longitudinal placement of a river reach.

Table 5.1. Study group codes in alphabetical order. Listing includes the common name, scientific name, and length group represented by the study group code. Superscript letters indicate the source of length-based size designations.

Code	Common name	Scientific name	Length group (mm) [a]
BHMWAL	Bullhead minnow	*Pimephales vigilax*	All lengths
BKBFSS	Black buffalo	*Ictiobus niger*	≤ 279 [b]
BKBFST	Black buffalo	*Ictiobus niger*	≥ 280 [b]
BKBHSS	Black bullhead	*Ameiurus melas*	≤ 149 [c]
BKBHST	Black bullhead	*Ameiurus melas*	≥ 150 [c]
BKCPSS	Black crappie	*Pomoxis nigromaculatus*	≤ 129 [c]
BKCPST	Black crappie	*Pomoxis nigromaculatus*	≥ 130 [c]
BKSSAL	Brook silverside	*Labidesthes sicculus*	All lengths
BLGLSS	Bluegill	*Lepomis macrochirus*	≤ 79 [c]
BLGLST	Bluegill	*Lepomis macrochirus*	≥ 80 [c]
BMBFSS	Bigmouth buffalo	*Ictiobus cyprinellus*	≤ 279 [d]
BMBFST	Bigmouth buffalo	*Ictiobus cyprinellus*	≥ 280 [d]
BNMWAL	Bluntnose minnow	*Pimephales notatus*	All lengths
BUSKAL	Blue sucker	*Cycleptus elongatus*	All lengths
BWFNAL	Bowfin	*Amia calva*	All lengths
CARPSS	Common carp	*Cyprinus carpio*	≤ 279 [c]
CARPST	Common carp	*Cyprinus carpio*	≥ 280 [c]
CNCFSS	Channel catfish	*Ictalurus punctatus*	≤ 279 [c]
CNCFST	Channel catfish	*Ictalurus punctatus*	≥ 280 [c]
CNLPAL	Chestnut lamprey	*Ichthyomyzon castaneus*	All lengths
ERSNAL	Emerald shiner	*Notropis atherinoides*	All lengths
FHCFSS	Flathead catfish	*Pylodictis olivaris*	≤ 349 [c]
FHCFST	Flathead catfish	*Pylodictis olivaris*	≥ 350 [c]
FHMWAL	Fathead minnow	*Pimephales promelas*	All lengths
FWDMSS	Freshwater drum	*Aplodinotus grunniens*	≤ 199 [c]
FWDMST	Freshwater drum	*Aplodinotus grunniens*	≥ 200 [c]
GDEYAL	Goldeye	*Hiodon alosoides*	All lengths
GDRHAL	Golden redhorse	*Moxostoma erythrurum*	All lengths
GDSNAL	Golden shiner	*Notemigonus crysoleucas*	All lengths
GNSFSS	Green sunfish	*Lepomis cyanellus*	≤ 79 [c]
GNSFST	Green sunfish	*Lepomis cyanellus*	≥ 80 [c]
GZSDSS	Gizzard shad	*Dorsoma cepedianum*	≤ 179 [c]
GZSDST	Gizzard shad	*Dorsoma cepedianum*	≥ 180 [c]
LGPHAL	Logperch	*Percina caprodes*	All lengths
LMBSSS	Largemouth bass	*Micropterus salmoides*	≤ 199 [c]
LMBSST	Largemouth bass	*Micropterus salmoides*	≥ 200 [c]
LNGRSS	Longnose gar	*Lepisosteus osseus*	≤ 409 [c]
LNGRST	Longnose gar	*Lepisosteus osseus*	≥ 410 [c]
MDDRAL	Mud darter	*Etheostoma asprigene*	All lengths
MNEYAL	Mooneye	*Hiodon tergisus*	All lengths
NTPKSS	Northern pike	*Esox lucius*	≤ 349 [c]
NTPKST	Northern pike	*Esox lucius*	≥ 350 [c]
OSSFAL	Orangespotted sunfish	*Lepomis humilis*	All lengths
QLBKAL	Quillback	*Carpiodes cyprinus*	All lengths

Table 5.1. (Continued)

Code	Common name	Scientific name	Length group (mm) [a]
RVCSSS	River carpsucker	*Carpiodes carpio*	≤179 [d]
RVCSST	River carpsucker	*Carpiodes carpio*	≤180 [d]
RVSNAL	River shiner	*Notropis blennius*	All lengths
SGERSS	Sauger	*Sander canadensis*	≤199 [c]
SGERST	Sauger	*Sander canadensis*	≤200 [c]
SHDRAL	Slenderhead darter	*Percina phoxocephala*	All lengths
SHRHSS	Shorthead redhorse	*Moxostoma macrolepidotum*	≤149 [d]
SHRHST	Shorthead redhorse	*Moxostoma macrolepidotum*	≤150 [d]
SMBFSS	Smallmouth buffalo	*Ictiobus bubalus*	≤179 [d]
SMBFST	Smallmouth buffalo	*Ictiobus bubalus*	≤180 [d]
SMBSSS	Smallmouth bass	*Micropterus dolomieu*	≤179 [c]
SMBSST	Smallmouth bass	*Micropterus dolomieu*	≤180 [c]
SNGRAL	Shortnose gar	*Lepisosteus platostomus*	All lengths
SNSGAL	Shovelnose sturgeon	*Lepisosteus platostomus*	All lengths
SNSNAL	Sand shiner	*Notropis stramineus*	All lengths
STCTAL	Stonecat	*Noturus flavus*	All lengths
STSNAL	Spottail shiner	*Notropis hudsonius*	All lengths
SVCBAL	Silver chub	*Macrhybopsis storeriana*	All lengths
TPMTAL	Tadpole madtom	*Noturus gyrinus*	All lengths
WLYESS	Walleye	*Sander vitreus*	≤ 249 [c]
WLYEST	Walleye	*Sander vitreus*	≤250 [c]
WTBSSS	White bass	*Morone chrysops*	≤149 [c]
WTBSST	White bass	*Morone chrysops*	≤150 [c]
WTCPSS	White crappie	*Pomoxis annularis*	≤129 [c]
WTCPST	White crappie	*Pomoxis annularis*	≤130 [c]
WTSKSS	White sucker	*Catostomus commersoni*	≤149 [d]
WTSKST	White sucker	*Catostomus commersoni*	≤150 [d]
YLBHSS	Yellow bullhead	*Ameiurus natalis*	≤99 [c]
YLBHST	Yellow bullhead	*Ameiurus natalis*	≤100 [d]
YWPHSS	Yellow perch	*Perca flavescens*	≤129 [c]
YWPHSS	Yellow perch	*Perca flavescens*	≤130 [c]

[a]Superscript letters indicate the source of length-based size designations.
[b]Bister et al. (2000) does not include black buffalo, but does include the same designation for smallmouth buffalo and bigmouth buffalo. This designation was used for black buffalo.
[c]Anderson and Neumann (1996)
[d]Bister et al. (2000)

Table 5.2. Eigenanalysis results for substock-length study groups principal components analysis.

Axes	Eigenvalues	Cumulative percentage of study-group variance explained
1	0.628	63
2	0.170	80
3	0.130	93
4	0.042	97

Table 5.3. Eigenanalysis results for stock-length study groups principal components analysis.

Axes	Eigenvalues	Cumulative percentage of study-group variance explained
1	0.688	69
2	0.167	86
3	0.091	95
4	0.034	98

Table 5.4. Eigenanalysis results for study groups without size designations principal components analysis.

Axes	Eigenvalues	Cumulative percentage of study-group variance explained
1	0.645	65
2	0.220	87
3	0.099	96
4	0.021	99

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13. ABSTRACT (Maximum 200 words)

The Long Term Resource Monitoring Program (LTRMP) collected more than 24,000 fish community samples from six study areas on the Upper Mississippi River System in 1993–2002. More than three million fish comprised of 136 fish species were collected. These data were used to assess length-weight relations and size structure of commercial (i.e., commercially harvested) and recreational (i.e., recreationally harvested) species, and the distribution, frequency of occurrence, and abundance patterns of commercial, nongame (i.e., not commercially or recreationally harvested), and recreational species. Forty-seven species were collected in all six LTRMP study areas, 32 species were collected in 4 or 5 study areas, 33 species were collected in 2 or 3 study areas, and 24 species were collected in 1 study area. Spatial differences (i.e., differences among study areas) in size structure were more pronounced for commercial species than for recreational species. Rate of gain (increase in $\log_{10}$ weight per unit increase in $\log_{10}$ length) was assessed for five species, and was significantly different among study areas for all five species and significantly different among years for four species. Assessment of longitudinal-spatial (among study area), lateral-spatial (among aquatic area types) and temporal (among 10 years) patterns in abundance showed that species were most similar with respect to temporal variation in abundance, and least similar with respect to longitudinal-spatial variation in abundance. These fisheries population assessments, derived from the spatially and temporally expansive LTRMP dataset, will provide river resource managers with decision support tools for managing UMRS fisheries.
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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.