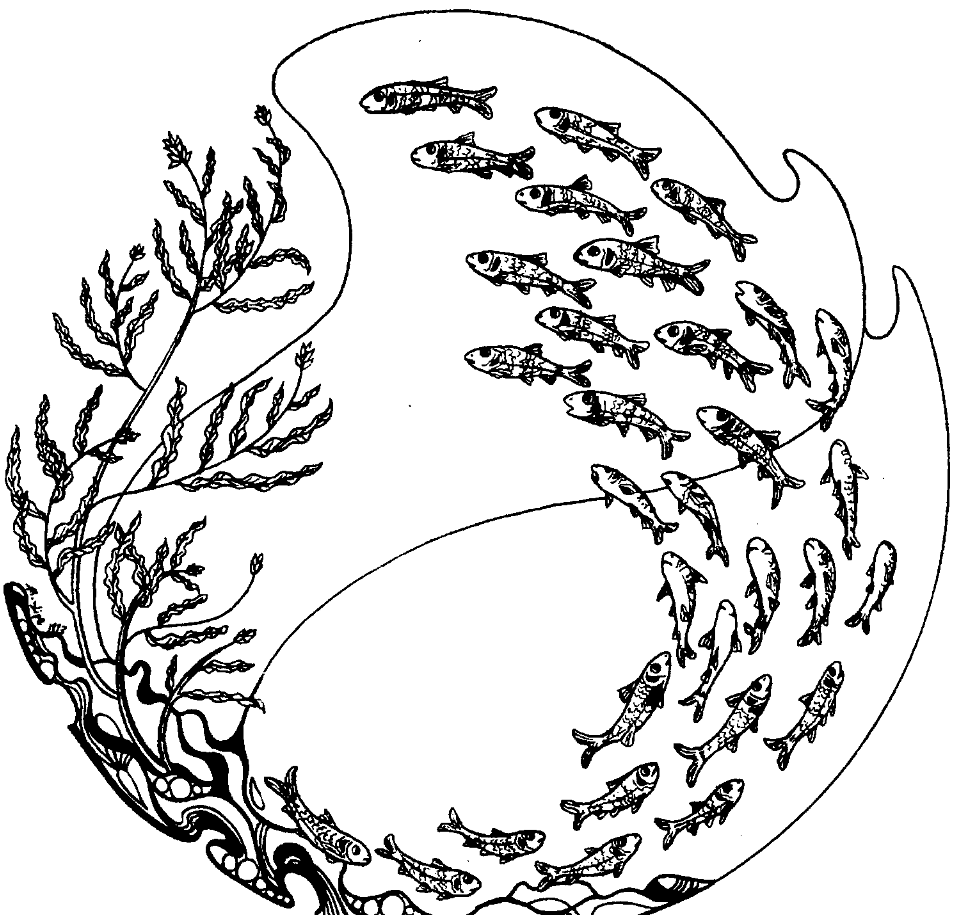
Long Term Resource Monitoring Program

Technical Report
97-T004

Fish Monitoring by the Long Term Resource Monitoring Program on the Upper Mississippi River System: 1990–1994



November 1997

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Fish Monitoring by the Long Term Resource Monitoring Program on the Upper Mississippi River System: 1990–1994

by

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November 1997

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Suggested citation:

Gutreuter, S. 1997. Fish monitoring by the Long Term Resource Monitoring Program on the Upper Mississippi River System: 1990–1994. U.S. Geological Survey, Environmental Management Technical Center, Onalaska, Wisconsin, November 1997. LTRMP 97-T004. 78 pp. + Appendix

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Preface

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

The UMRS encompasses the commercially navigable reaches of the Upper Mississippi River, as well as the Illinois River and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers. Congress has declared the UMRS to be both a nationally significant ecosystem and a nationally significant commercial navigation system. The mission of the LTRMP is to provide decision makers with information for maintaining the UMRS as a sustainable large river ecosystem given its 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 was prepared under Strategy 2.2.8, *Monitor and Evaluate Fish Communities, Guilds, and Populations*, Task 2.2.8.6, *Evaluate and Summarize 5-Year Trends*, as specified in Goal 2 of the Operating Plan (USFWS 1993) and was developed with funding provided by the Long Term Resource Monitoring Program.

Fish Monitoring by the Long Term Resource Monitoring Program on the Upper Mississippi River System: 1990–1994

by

Steve Gutreuter

Abstract

The Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River System (UMRS) conducts highly standardized monitoring of fishes in Pools 4, 8, 13, and 26, in a segment of the unimpounded Mississippi River, and in the La Grange Pool of the Illinois River. The mission of the LTRMP is to provide decision makers with information for managing the UMRS as a sustainable large river ecosystem given its multiple-use character. In this report I summarize the initial 5 years of fish monitoring by the LTRMP. This report documents temporal variability that will be critical to interpretation of future events and trends (consistent temporal changes), and documents important spatial patterns. Because 5 years of data can only provide tenuous trend information and because the LTRMP sampling design was changed between 1992 and 1993, trends reported herein must be interpreted cautiously. No evidence of reduction of fish species richness (number of species) was found from 1990 through 1994 or since recording began in the late 19th century. The abundance of common carp (*Cyprinus carpio*), an exotic but commercially harvested species, and sauger (*Stizostedion canadense*), a recreationally valuable species, increased dramatically from 1990 through 1994. Few species declined in abundance. Spatial patterns in the abundance of certain species, including bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), white crappie (*Pomoxis annularis*), and black crappie (*Pomoxis nigromaculatus*) provide substantial evidence that the availability of backwaters presently limits the abundance of these species in the open river study reach, to a lesser extent in Pool 26, and probably elsewhere. This information could be instrumental in identifying the effects of present river management practices and predicting some biological and economic consequences of future changes in floodplain composition. No evidence was found that the relatively rare lake sturgeon (*Acipenser fulvescens*), shovelnose sturgeon (*Scaphirhynchus platorynchus*), paddlefish (*Polyodon spathula*), and blue sucker (*Cycleptus elongatus*) declined in abundance from 1990 through 1994. The flood of 1993 provided an opportunity for skipjack herring (*Alosa chrysochloris*) to temporarily reenter the uppermost pools of the Mississippi River.

Introduction

The fish monitoring component of the LTRMP is charged, in part, with annual monitoring and reporting of trends in the status of key fish populations and fish communities of the UMRS at 5-year intervals (USFWS 1993). My objectives are to document short-term trends (consistent temporal changes), temporal variability, and spatial patterns for selected fish populations and communities measured by the Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River System (UMRS). This report contains summaries and analyses of key features observed during the first 5 years of the LTRMP.

Fish are the primary biotic object of recreational and commercial use on the UMRS. In 1982, UMRS fisheries provided more than 8.5 million activity days of sport fishing that generated more than $150 million ($234 million in inflation-adjusted 1995 dollars) in direct expenditures (Fremling et al. 1989). Commercial fisheries of the UMRS were valued at more than $2.4 million in 1987 (UMRCC 1989), which is equivalent to $3.1 million in 1995 dollars. Adverse trends in fisheries of the UMRS would undoubtedly have detrimental effects on recreation and the regional economy; therefore, it is important to detect any adverse trends as they occur so that remedial actions can be considered.

The Mississippi River system is noteworthy among the world's large temperate rivers in that it supports an unusually large number of fish species. Historically, at least 150 species of fish have been reported from that portion of the UMRS now monitored by the Long Term Resource Monitoring Program (Fremling et al. 1989). Although many species are somewhat rare and some are strays from adjoining tributaries, the number of species stands in stark contrast to the numbers found in midwestern lakes, which often contain fewer than 15 species. This extraordinary number of fish species makes the Mississippi River one of our nation's greatest biological treasures. Ecological management of the UMRS requires information on trends in species richness, including invasions of exotic species.

The monitoring of and research on fishes are also important because of their effects on other ecosystem elements. Although documentation of the effects of fishes on other biota is derived primarily from lakes and reservoirs (Northcote 1988), and traditional belief maintains that the dynamics of river biota are influenced primarily by abiotic factors, some evidence shows that the dynamics of fish assemblages in temperate rivers are also mediated by biotic factors (Welcomme et al. 1989). Fish may exert influences on other biota in riverine ecosystems and may therefore be of broad ecological importance. For example, there is evidence that common carp (*Cyprinus carpio*), an exotic species that invaded the Mississippi River during the late 1800's and has since become a dominant species, may depress or even eliminate macrophytes either through uprooting or disturbance of substrate (Cahn 1929; Fletcher et al. 1985; Bellrichard 1994). The effects of fishes on benthic macroinvertebrates are well known (Northcote 1988). Therefore, trends in abundance of fishes may prove instrumental in explaining trends in abundance of other riverine biota.

Resource monitoring is an important component of long-term ecological research on processes governing large-scale ecosystems. It is nearly impossible to perform experimental manipulations of the UMRS on large spatial scales and to incorporate replication. Long-term data from standardized sampling programs that span natural or anthropogenic disturbances are essential for gaining adequate understandings of natural background variability, and of large-scale processes governing large river systems (Sparks et al. 1990). Further, the LTRMP fish monitoring will provide support for formulating and investigating research hypotheses concerning smaller scales using focused experimentation. Therefore, the combination of routine monitoring coupled with more intensive investigation of consequences of disturbances and experimentation at reduced spatial and temporal scales is the best means for adequately understanding the UMRS and for identifying viable management alternatives.

The LTRMP is predicated on the hypothesis that resource components, including fishes, have changed and will continue to change in response to changes in sedimentation, navigation, and water-level fluctuation (Rasmussen and Wlosinski 1988; USFWS 1993). Therefore, LTRMP fish sampling focuses on aquatic areas likely to be affected by sedimentation, navigation, and water-level fluctuation. The loss of potentially critical aquatic areas to historic and continued sedimentation is of particular concern. Many fishes, including gizzard shad (*Dorosoma cepedianum*), centrarchids (black basses, crappies, and sunfishes), and freshwater drum (*Aplodinotus grunniens*), require relatively warm standing water for overwinter survival (Shuter et al. 1980; Bodensteiner et al. 1990; Bodensteiner and Lewis 1992, 1994). Among economically important species, the centrarchids may be particularly sensitive to the combination of high current velocity and low temperature (Sheehan et al. 1990; Carlson 1992). For such species, access to relatively deep backwaters may be critical; depth is important for maintenance of winter hypolimnetic temperatures near 4 °C (Wetzel 1975), and backwaters provide isolation from turbulent mixing with colder water. Sediment accumulation and navigation channel management strategies that cause isolation or loss of backwaters may have profound effects on the distribution and abundance of these species. Therefore, it is important to examine spatial patterns in abundance of these fishes and monitor trends to identify any ongoing changes.

This 5-year trend report and those for other LTRMP monitoring components (Rogers [1997]; Sauer [1997]; Soballe [1997]) are examples of intermediate products. The publicly available data and annual status reports

(Gutreuter et al. 1997) are the most basic LTRMP products. The annual status reports provide more detailed summaries of fish data than are included in the present trend report, including size distributions and summaries of relative abundance from each combination of study reach, aquatic area class, sampling gear, and species, but they lack analyses or syntheses. This trend report and the status reports are best used as information sources for the assessment of background variation (Lubinski 1993), identification of management problems, and formulation of hypotheses. The ultimate goal of the LTRMP is not simply to report status and trends, but to improve the understanding and management of the UMRS. The goal can best be achieved by the integration of routine monitoring with experimental research directed at identifying the causes of and solutions to specific problems. Future LTRMP efforts will integrate more narrowly focused analyses of data from all LTRMP monitoring components (limnology, bathymetry, sediments, aquatic plants, and selected macroinvertebrates) with results of experimental studies to identify causes of problems and opportunities for improved management. The resulting syntheses will be the ultimate products of the LTRMP.

The present report contains only analyses of selected temporal trends and spatial patterns. Because of the volume of LTRMP data and possible combinations of features (species, size classes, study reaches, aquatic areas, sampling gears, and others), thousands of combinations of response and explanatory variables are possible. Rather than report all possible combinations of features, I instead focus on: (1) qualitative description of short-term trends and spatial patterns in fish species richness, (2) statistical analyses of short-term trends and spatial patterns in relative abundance of commonly caught species, and (3) qualitative description of short-term trends and spatial patterns of selected rare and exotic species.

Study Areas

The LTRMP has conducted standardized annual fish sampling in Pools 4, 8, 13, and 26 of the Mississippi River and in the La Grange Pool of the Illinois River (Figure 1) since 1990, and has sampled in the open river study reach since 1991. These six LTRMP study reaches were chosen, in part, to reflect important differences in geomorphology, floodplain land-use patterns, and navigation management strategies that exist within the UMRS (Table). Pools 4, 8, and 13 are in an upper impounded reach characterized by high percentages of open water and aquatic vegetation and low agricultural use in the floodplain. Relatively high percentages of the total aquatic area in these study reaches are composed of contiguous (to the main channel) backwaters, and relatively low percentages are composed of main channel. Qualitatively, Pools 4 (Figure 2), 8 (Figure 3), and 13 (Figure 4) are geomorphically complex and richly braided by side channels and backwaters. Pool 26 (Figure 5) is the southernmost navigation pool of a lower impounded reach characterized by relatively low percentages of open water and aquatic vegetation and a high percentage of agriculture in a floodplain that is largely isolated from the river by levees. A low percentage of the total aquatic area is composed of contiguous backwaters, and commensurately a high percentage is composed of the main channel. The open river LTRMP study reach (Figure 6) is characterized by low percentages of open water and aquatic vegetation and 71.5% agriculture in a floodplain that is almost entirely isolated from the river by levees. Of the total aquatic area in the open river study reach, 79% is main channel and there is no longer any permanent contiguous backwater (Table). The La Grange Pool (Figure 7) is similar to Pool 26 in floodplain composition, but is similar to Pools 8 and 13 in composition of the aquatic area (Table). In fact, the La Grange Pool has the greatest percentage (52.2%) of contiguous backwaters among the six LTRMP study reaches.

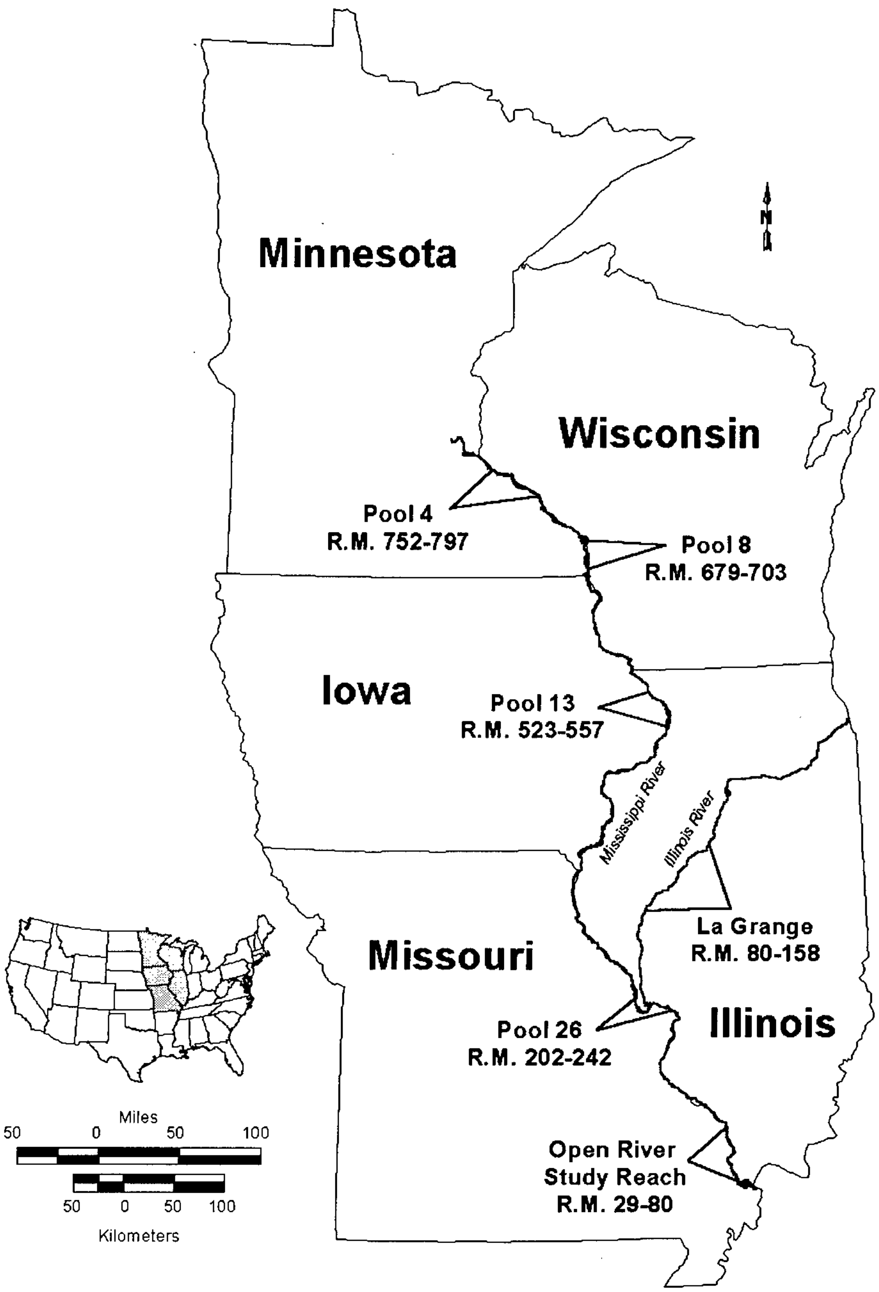

Figure 1. Long Term Resource Monitoring Program study reaches.

Table. Key features of the floodplain and aquatic area compositions of the Long Term Resource Monitoring Program's five Mississippi and Illinois River study reaches. Aquatic area is that portion of the floodplain that is inundated at normal water elevations. Main channel includes area in the navigation channel and main channel border areas. Data on floodplain composition are from Laustrup and Lowenberg (1994). Data on the composition of aquatic areas are from the Long Term Resource Monitoring Program aquatic areas spatial database.

		Floodplain composition (%)			Aquatic area composition (%)	
Study reach	Floodplain area (ha)	Open water	Aquatic vegetation	Agriculture	Contiguous backwater[a]	Main channel
Pool 4	28,358	50.5	10.0	12.1	21.3	10.5
Pool 8	19,068	40.1	14.4	0.9	30.6	14.2
Pool 13	34,528	29.7	8.6	27.9	28.5	24.7
Pool 26	51,688	13.4	1.4	65.4	17.3	54.4
Open River	105,244	9.9	0.6	71.5	1.8	79.0
La Grange Pool, Illinois River	89,554	15.7	2.2	59.6	52.2	21.3

[a]Total area fitting criteria for backwaters (Wilcox 1993) excluding impounded areas and tributary delta lake (Lake Pepin, Pool 4); this area excludes all secondary and tertiary channels.

Methods

Sampling Methods

To properly interpret the results contained in this report one must understand the changes in the LTRMP fish sampling design. The monitoring design was based on subjectively chosen permanently fixed sampling sites from 1990 through 1992 and has been based on statistically valid stratified random sampling since 1993. Statistical theory guarantees that estimates obtained by using stratified random sampling are unbiased for the unknown population means regardless of the stochastic process that generated the data (Cochran 1977), except for any biases that are introduced by the selectivities of the sampling gears. However any gear selectivities are common to data obtained from both subjectively and randomly selected sampling sites. Therefore, the interpretation of trends in the 5-year data series depends on any bias created by the subjective choices of fixed sites. If those data are unbiased for larger areas, then any observed 5-year trends are probably real. If, however, the fixed sites did not represent larger aquatic areas but were biased, then we are left with an initial 3-year series of fixed-site data and a 2-year series of unbiased data. Because of this uncertainty, observed 5-year trends must be interpreted with extreme caution. Details of the LTRMP fish sampling design and protocols, including historic changes, are given in Gutreuter et al. (1995).

The original sampling design and methods of the LTRMP fisheries component were described in detail by Rasmussen and Wlosinski (1988). From 1990 through 1992, the LTRMP fisheries component relied on a fixed-point design wherein a small number of sites were subjectively chosen at the start of the program and were sampled each year. The locations of these fixed sites are displayed in Figures 2–7. The fixed-point design was chosen to avoid high spatial variability that might result from a stratified random sampling design and thereby increase temporal resolution. The 1990–92 LTRMP sampling sites were selected by experienced river biologists, based on personal beliefs and limited observation, from eight habitat classes: unstructured main channel border (MCBU), main channel border wing dam (MCBW), main channel trough (CTR), unstructured

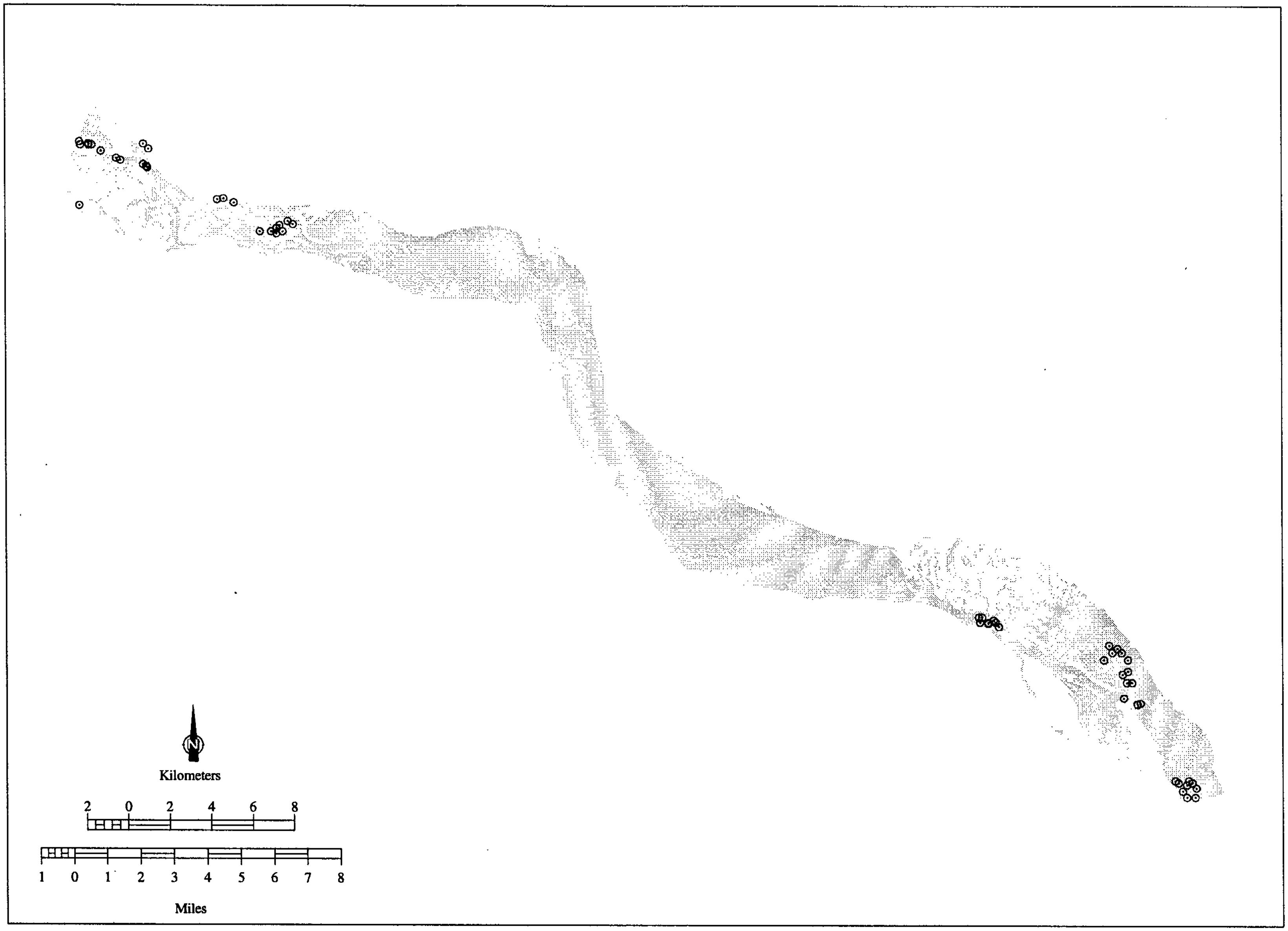

Figure 2. Navigation Pool 4 of the Upper Mississippi River. This pool is dominated by Lake Pepin, a natural tributary delta lake, which is not sampled by the Long Term Resource Monitoring Program fish monitoring component. Approximate locations of fixed sampling sites used from 1990 through 1992 are marked by circles.

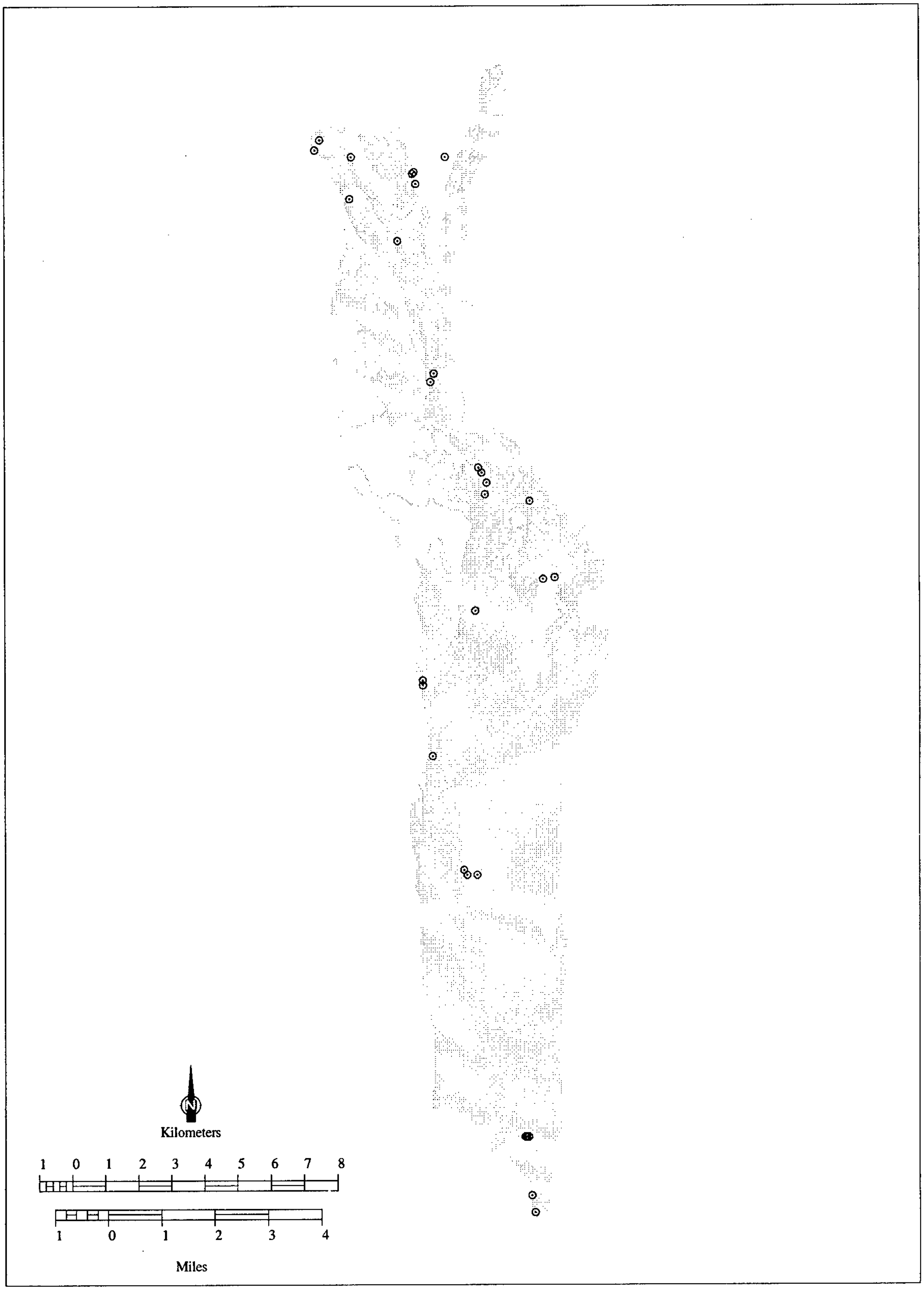

Figure 3. Navigation Pool 8 of the Upper Mississippi River. Approximate locations of fixed sampling sites used from 1990 through 1992 are marked by circles.

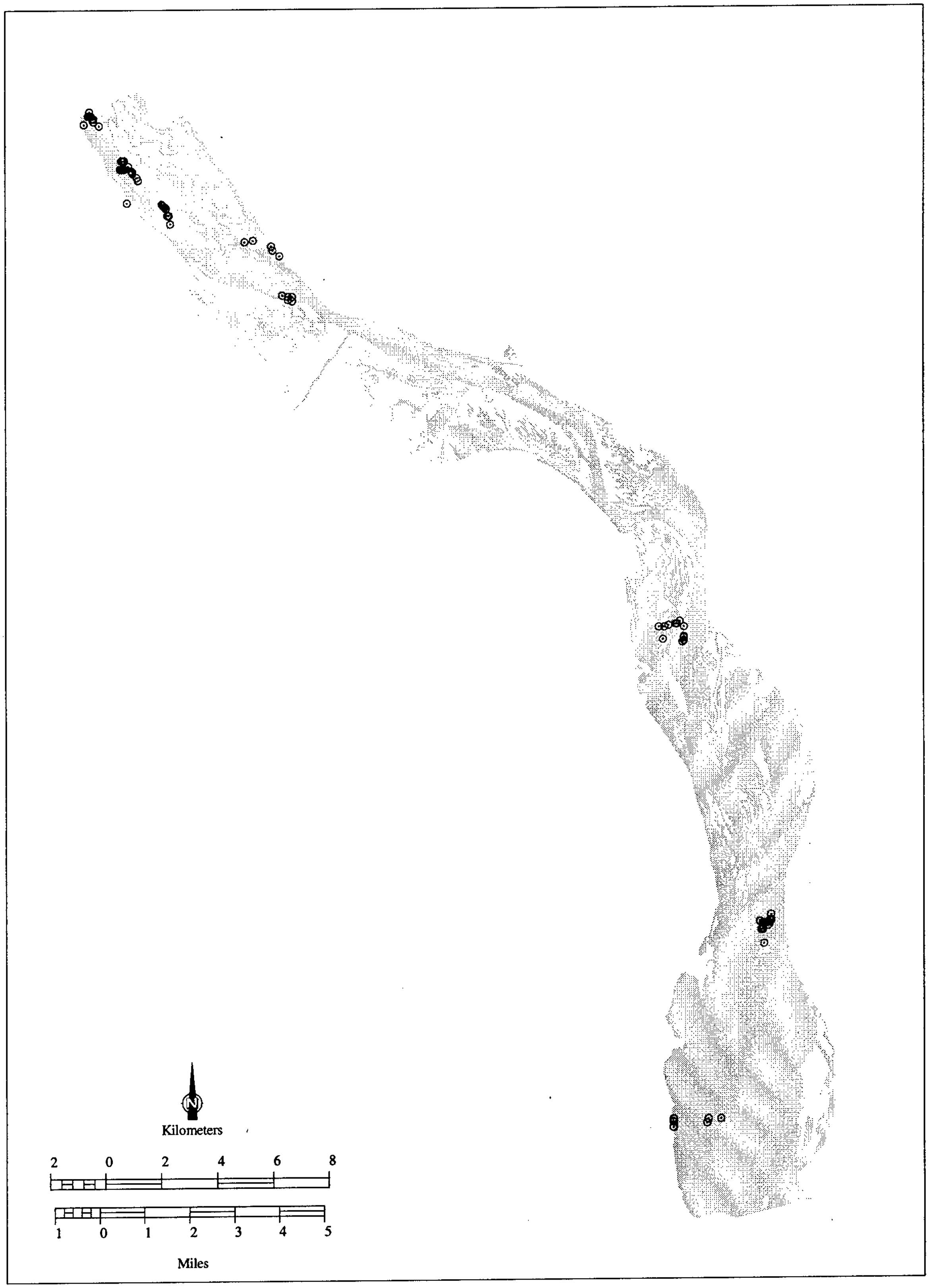

Figure 4. Navigation Pool 13 of the Upper Mississippi River. Approximate locations of fixed sampling sites used from 1990 through 1992 are marked by circles.

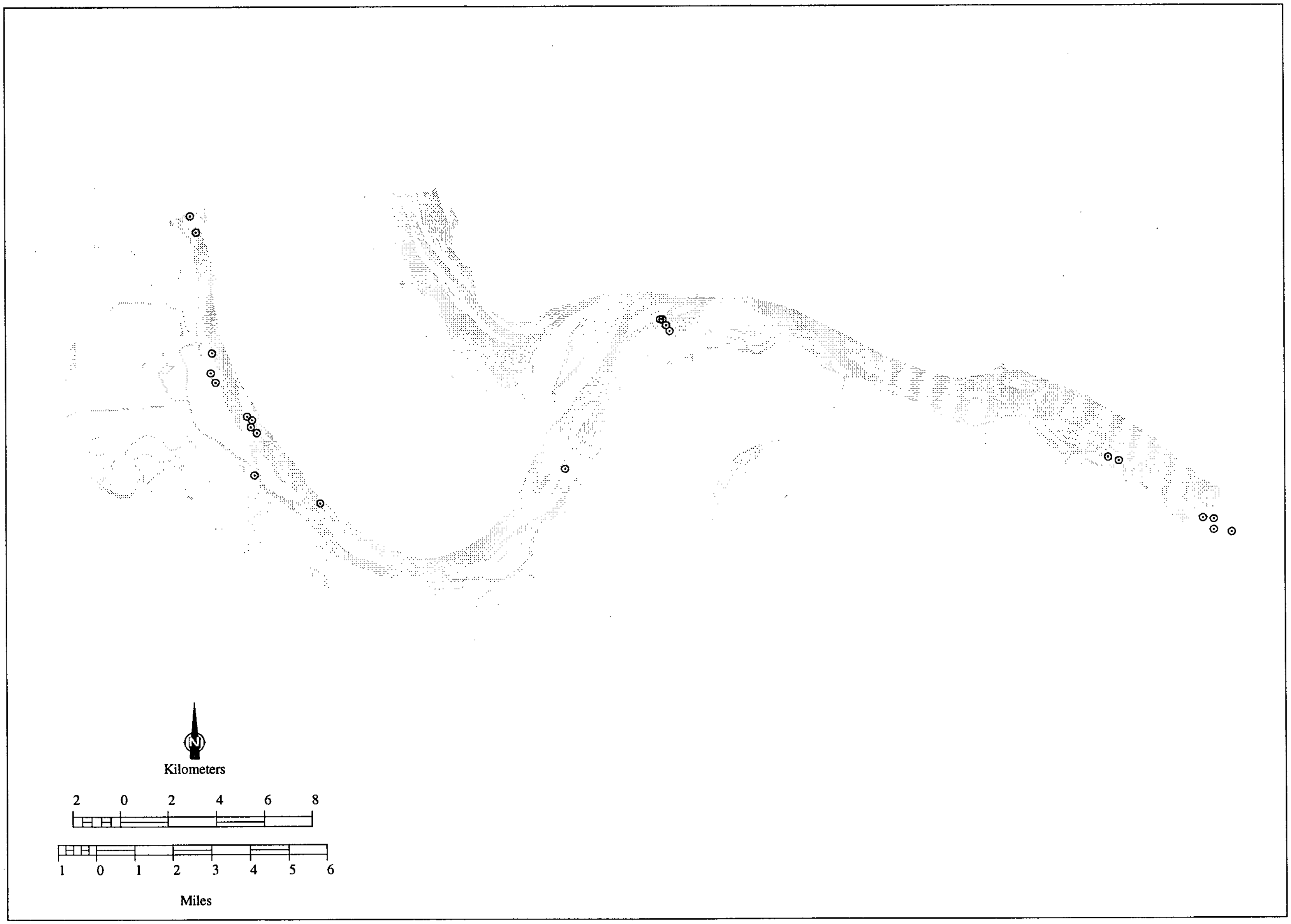

Figure 5. Navigation Pool 26 of the Upper Mississippi River. Approximate locations of fixed sampling sites used from 1990 through 1992 are marked by circles.

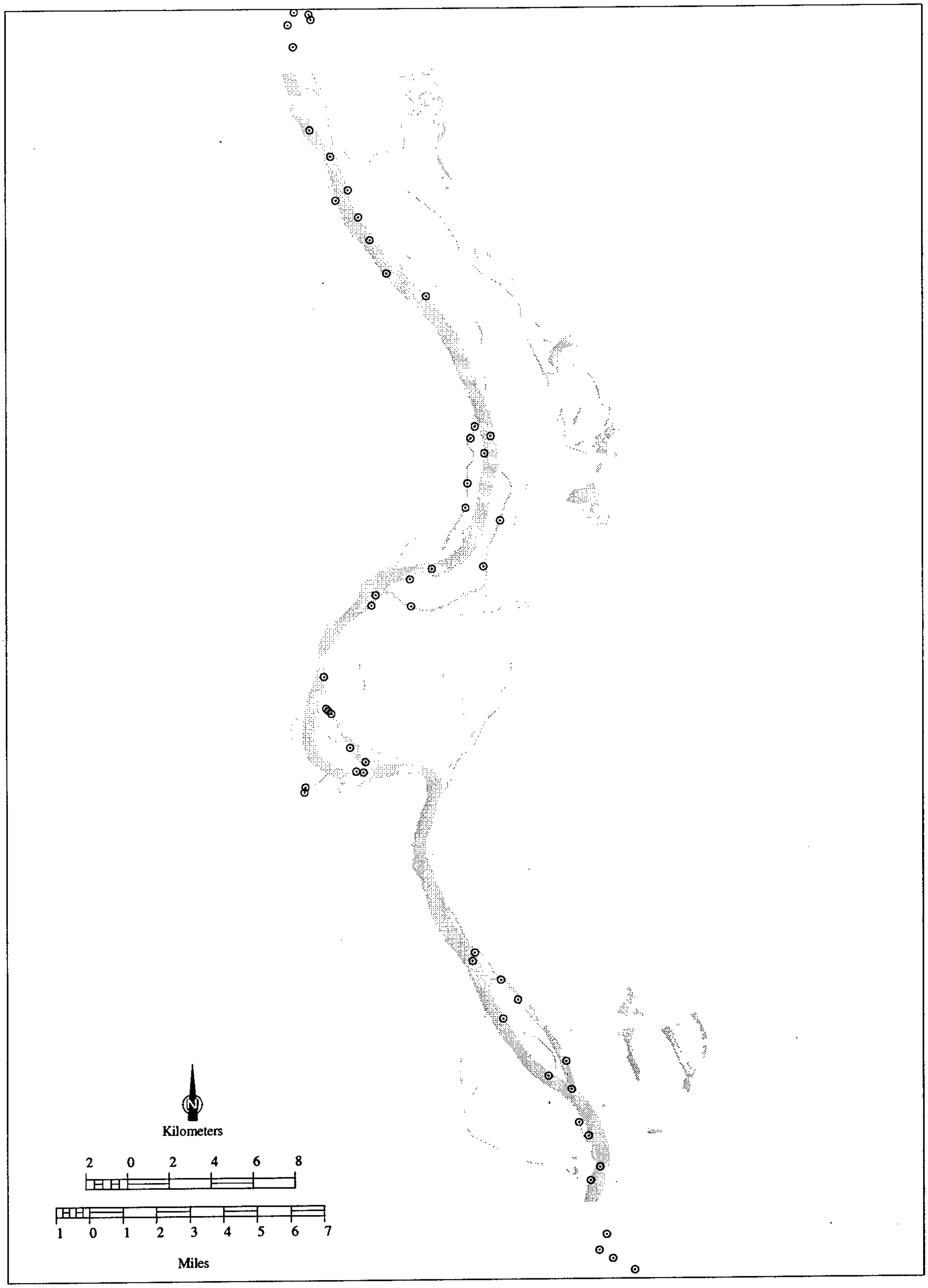

Figure 6. The Long Term Resource Monitoring Program open river study reach of the Mississippi River. Approximate locations of fixed sampling sites used from 1991 through 1992 are marked by circles.

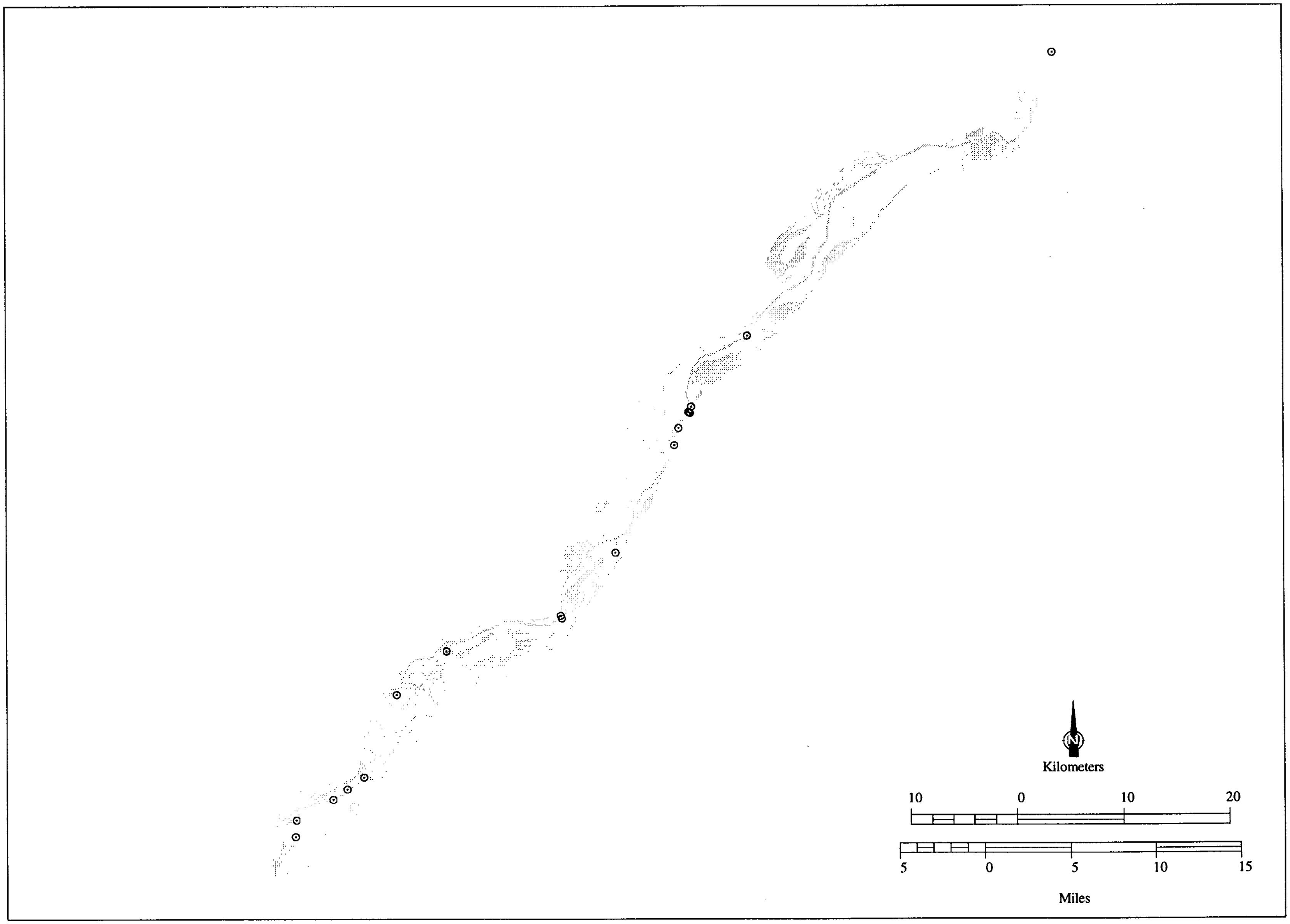

Figure 7. La Grange Pool of the Illinois River. Approximate locations of fixed sampling sites used from 1990 through 1992 are marked by circles.

side channel border (SCB), unvegetated contiguous backwater (BWC-O), vegetated contiguous backwater (BWC-V), open impounded (IMP-O), and vegetated impounded (IMP-V). Four criteria were used to select sampling sites: (1) sites must be representative of corresponding habitat classes within reaches, (2) sampling gear used must be able to sample the site effectively, (3) sites should be near established LTRMP water quality and vegetation sampling sites, and (4) access to sites must be good. Extensive randomized spatial sampling was never conducted to test how well the subjectively chosen LTRMP fish sampling sites actually represented the unsampled areas of corresponding habitat classes within each river reach.

Further, design-based randomness (Cochran 1977) is absent from the fixed-point design. Therefore, inferences and conclusions based on the fixed-point design of 1990–1992 must be restricted to the set of sampling sites rather than generalized to cover all similar habitats in entire LTRMP reaches. The lack of design-based randomness has been cited as a critical shortfall of natural resource monitoring programs that limits the utility of the resulting data to resource management (National Research Council 1990).

The Operating Plan of the LTRMP (USFWS 1993) called for a statistical review of the fish sampling design after 2 years of data had been collected. According to this review (Gutreuter 1993), the original fixed-point sampling design was inadequate to support inferences about entire habitat classes and study reaches that managers and researchers need, and conversion to a statistically valid stratified random sampling design would probably not reduce the precision of resulting estimates but would vastly broaden the interpretation of those estimates. On the basis of that information, the LTRMP converted to a stratified random fish sampling design beginning with the 1993 field season (Gutreuter et al. 1995).

Key aquatic areas chosen for their enduring geomorphic features (Wilcox 1993) are used as sampling strata. These aquatic areas are a useful basis for stratification because fish communities differ among them in consistent ways (Gutreuter 1992). The LTRMP developed a spatial database of aquatic areas (Owens and Ruhser 1996) based on aerial photography made in 1989; this database is used for randomized selection of sampling sites and the quantification of sampling strata reported herein. Ongoing change detection requires that this database be updated at appropriate intervals. The LTRMP Operating Plan (USFWS 1993) prescribes future repetition of aerial photography. Additionally, the LTRMP updates sampling maps, as needed, from direct observations made by the sampling crews.

The LTRMP aquatic areas (Wilcox 1993) are largely compatible with the habitat classes used from 1990 through 1992, with the exception of the 1990–92 classifications based on presence of aquatic vegetation; those fixed sites were reclassified into strata based on aquatic areas. To develop sampling maps, each aquatic area is artificially partitioned into 50-m^2 sampling grids beginning with a random origin for each LTRMP study reach (Gutreuter et al. 1995) using geographic information system software. Beginning in 1993, sampling sites are randomly chosen from this lattice of square grids. Whenever it is discovered that a randomly selected site cannot be sampled for lack of physical access, the nearest accessible site from a list of randomly selected alternate sites is sampled. A few subjectively chosen permanently fixed sampling sites have been monitored since 1993, but data from these special sites are not included in this report.

The distributions of many lotic species may change markedly among seasons (Vadas 1992), and therefore the timing of LTRMP sampling is important for the interpretation of the resulting data. The LTRMP conducts fish sampling from June 15 through October 30. This sampling period was chosen to exclude the spring flooding season and the winter when effective sampling is largely impossible (Rasmussen and Wlosinski 1988). This sampling season is further artificially partitioned into consecutive 6-week sampling periods. Originally, this partitioning was designed in the hope that each year water levels would be stable within at least one of those 6-week periods so that constant gear selectivity could be comfortably assumed during that period (Rasmussen and Wlosinski 1988). However, these sampling periods are now retained primarily as a means to ensure that sampling is not temporally biased in the following way. The LTRMP chose not to randomize sampling dates to give field crews some needed flexibility in scheduling field operations. Unless some method of temporal scheduling was adopted, that choice would entail some risk that sampling could be biased by any latent tendency to sample some aquatic areas early in the sampling season and others later. Therefore, independent random selections of sampling sites from all aquatic areas are made for each 6-week period and all prescribed sampling is completed within each.

Since 1990, the LTRMP has used day and night electrofishing, fyke nets, seines, small "mini" fyke nets, hoop nets, and small trawls to sample fish in various strata. Historical sampling allocations and strata-specific gear deployments are given in Appendix Tables A1–A29. Generally, the number of samples increased greatly after 1990 but has remained relatively constant since 1991, except in 1993 when extreme flooding (NBS 1994) inhibited sampling in most study reaches and precluded standardized sampling during much of the summer in Pool 26 and the open river reach.

The following is a summary of sampling techniques (Gutreuter et al. 1995) used in the LTRMP since 1990.

Electrofishing. Electrofishing is conducted by using pulsed direct current, and boat configuration and power output are standardized (Gutreuter et al. 1995; Burkhardt and Gutreuter 1995). Electrofishing is of 15-min duration and is paced so that the boat samples within rectangle of about 200 m by 30 m.

Hoop netting. The LTRMP uses two sizes of hoop nets. The large nets have seven fiberglass hoops with diameters ranging of 1.1 to 1.2 m. These nets are 4.8 m long, contain two finger-style throats, and are constructed of 3.7-cm (bar measure) nylon mesh. The small nets have seven fiberglass hoops with diameters of 0.5 to 0.6 m. The small nets are 3 m long, contain two finger-style throats, and are constructed of 1.8-cm (bar measure) nylon mesh. From 1990 through 1992 the small and large nets were connected in series—with the large net in front of the small net—and deployed as a single gear. Beginning in 1993, the nets were deployed separately but in pairs within sampling sites. Both nets are baited with 3 kg soybean cake. For this report, the estimates from pairs of nets were pooled and the nets were therefore treated as a single gear for consistency with the 1990–92 data. Hoop net set duration is approximately 48 h. The unit of effort is a net-day, which is 24 h of effort by the pair of nets.

Seining. The LTRMP uses 10.7-m long seines constructed of 3-mm "Ace"-type nylon mesh, except that 4.7-mm mesh is used in the open river reach to accommodate high current velocities. These seines are 1.8 m high and have a 0.9-m^2 bag in the centers. Seines are extended perpendicular to shorelines and then swept in a 90° arc downstream to the shoreline. Specific seining locations within sites were chosen by sampling crews based on suitability of bank slope and bottom characteristics. Only areas that could be waded at full net extension were seined. Generally, four locations were seined within each site, and catch data from these hauls were pooled. The unit of effort is a haul.

Fyke netting. The LTRMP uses Wisconsin-type fyke nets (trap nets) that contain three sections: the lead, the frame, and the cab. All netting is 1.8-cm (bar measure) mesh. Leads are 15 m long and 1.3 m high. The spring steel frames are 0.9 m high and 1.8 m wide, and contain two internal wing throats. The cabs are constructed of six steel hoops (0.9 m in diameter) containing two throats. These nets are fished singly from shoreline or from beds of dense vegetation, or in tandem (with leads connected) offshore. The unit of effort is a net-day, where each frame is one net.

"Mini" or "minnow" fyke netting. Mini-fyke nets are small, Wisconsin-type fyke nets. All mesh is 3-mm "Ace"-type nylon mesh. The leads are 4.5 m long and 0.6 m high. The spring steel frames are 0.6 m high and 1.2 m wide, and contain two internal wing throats. The cabs are constructed of two steel hoops (0.6 m in diameter) containing one throat. These nets are fished singly from shoreline or from beds of dense vegetation, or in tandem (with leads connected) offshore. The unit of effort is a net-day, where each frame is one net.

Species Richness

Species richness (the number of species captured) was tallied for each combination of study reach and year, which provided an observed total count over all combinations of sampling gear and strata within combinations of study reach and year. This aggregation of gears and strata was done because all gears are selective for particular species and sizes, and because there are definite species preferences for particular aquatic areas. Disaggregation would produce many more observed counts (one for each additional combination of gear and stratum), but would not produce clearer observations of any trends. The principal difficulty is that all these observed counts are unreliable measures of true but unknown species richness for which there are presently no satisfactory probability based estimators (Bunge and Fitzpatrick 1993). Species richness is an increasing function of sample size and, without a robust and reliable way to estimate the true but unknown number of species regardless of sample size, there seems to be little purpose in attempting a falsely rigorous analyses of trends. Therefore, the focus in this report is a simple, qualitative assessment of trends in observed species richness from the aggregate of gears and strata within combinations of study reach and year. Because observed species richness may increase to an asymptote in extremely large samples under ideal conditions (e.g., the "species-area curve" or rarefaction method; Sanders 1968), this aggregation across gears and strata should, in principle, produce more accurate estimates of true species richness despite the oversimplicity of the rarefaction approach (Bunge and Fitzpatrick 1993).

Relative Abundance

The LTRMP uses mean catch-per-unit-effort *CPE* as an index of abundance, as is conventional practice (Ricker 1975). The units of effort are specific to particular gears. For electrofishing and seining, effort is a constant, but for other gears it is somewhat variable. For example, the effort goal for fyke nets is 1 day (Gutreuter et al. 1995), but actual effort may vary between about 20 and 30 h. Catch and effort are recorded for each species from individual samples (deployments of particular gears at unique combinations of time and place). Whenever a species is not caught in a sample, the catch for that species in that sample is zero. Although zero catches are not recorded, they are reconstructed for analyses. For each gear, all catch-per-unit-effort data for species that were detected in fewer than 10% of the samples during any year were excluded from the trend analyses. This exclusion of uncommon species precluded zero catches from dominating the analyses.

Analyses of catch-per-unit-effort in this report are based on reachwide estimates of mean *CPE* obtained by pooling data over all strata sampled by a particular gear (Cochran 1977), as is common practice in fishery science (Pennington 1985). Note that this definition of reachwide estimates does not necessarily encompass the entire reach. Rather, this definition restricts all inference to the sets of strata sampled by particular gears within each combination of study reach and year listed in Appendix Tables A1–A26. Because each sampling gear is deployed in all aquatic areas that can be reasonable sampled using that gear, the analyses track the broadest possible spatial scale for trends in relative abundance. Not only does the pooling greatly reduce the volume of data and the number of combinations of conditions that must be analyzed, but it probably presents a truer image of reachwide trends in true abundance because it does not rely only on particularly favorable habitats. The LTRMP monitors both the composition of aquatic areas and fishes. Therefore if the quantity of that aquatic area class preferred by a particular species declines through time while the abundances within each aquatic area remain constant, then the pooled mean *CPE* statistics should also reflect the resulting decline in reachwide abundance, whereas mean *CPE* statistics from only the preferred aquatic area would not. Last, the LTRMP fish database is quite large and the reduction in volume accomplished by the examination of reachwide mean *CPE* statistics was an important asset.

The estimates of pooled reachwide mean *CPE* were obtained from the conventional design-based estimator for stratified random samples (Cochran 1977). For an arbitrary random variable denoted y (in this report y is *CPE*), the pooled mean, denoted $\bar{y}_{st}$ (*st* for stratified) is given by

$$\bar{y}_{st} = \frac{1}{N}\sum_{h=1}^{L} N_h \bar{y}_h, \tag{1}$$

where N_h is the number of sampling units within stratum h, L is the total number of strata, $N = \Sigma_{h=1}^{L} N_h$, and $\bar{y}_h$ denotes the estimator of the simple mean of y for stratum h. The estimator of the variance of $\bar{y}_{st}$ is

$$s^2(\bar{y}_{st}) = \frac{1}{N^2}\sum_{h=1}^{L} N_h(N_h - n_h)\left(\frac{s_h^2}{n_h}\right), \tag{2}$$

where

$$s_h^2 = \frac{\sum_{i=1}^{n_h} (y_{hi} - \bar{y}_h)^2}{n_h - 1}$$

is the usual estimator of the variance of y_h, and n_h is the number of samples taken in stratum h (Cochran 1977). The standard error of $\bar{y}_{st}$ is therefore $s(\bar{y}_{st})$. For LTRMP fish monitoring, the sampling units are the 50-m^2 sampling grids.

Equation (1) is used to obtain estimates of overall mean catch-per-unit-effort from both the 1990–92 fixed-site data and from the 1993–94 random sampling. In random samples—for example, the 1993–94 *CPE* data—equation (1) yields unbiased estimates of the pooled means regardless of the probability distribution of y (Cochran 1977). However, in this report equation (1) is also used to estimate means of the 1990–92 data obtained from fixed-site sampling to maintain computational consistency with the 1993–94 estimates. The pooled means from the 1990–92 fixed-site sampling are not guaranteed unbiased because there is no assurance that the fixed sites were unbiased for the larger aquatic areas. Therefore, the estimates of overall mean catch-per-unit-effort from 1990 through 1992 and from 1993 through 1994 have different interpretations, and these determine proper interpretations of subsequent trend and spatial analyses.

In this report, the presence of differences among LTRMP study reaches and simple linear trends were tested. Because I examine only the first 5 years of data obtained by the LTRMP, it is impossible to perform sophisticated time-series and trend analyses because the existing series are still too brief. However, under some simplifying assumptions, it is possible to test for simple linear trends (straight-line increasing or decreasing trends) over the 5-year period and also to make useful comparisons of these trends among the six LTRMP study reaches. The most important assumption is the continuity of interpretation of the abundance index. Although estimates from the fixed-site sampling of 1990–92 are not guaranteed unbiased as are the estimates from subsequent stratified random sampling, this report combines both types of estimates to form a single 5-year series to comply with the reporting requirements in the LTRMP Operating Plan (USFWS 1993). This discontinuity clouds interpretations of the trend analyses because it cannot be guaranteed that the sampling change is not a partial or total cause of a particular observed trend. Therefore spatial comparisons, which are not affected by this discontinuity, are emphasized in this report. Further, these spatial comparisons of initial 5-year trends may be more valuable to management decision making than are the initial brief time series observed within each study reach.

To reduce the volume of data, and to make reachwide inferences, I used the observed $\overline{CPE}_{rt}$ obtained from equation (1) to make model-based inferences about the unknown true values of reachwide mean catch-per-unit-effort. The statistical tests were constructed assuming the general linear model given by

$$\overline{CPE}_{rt} = \tau_0 + \beta_1 t_r + \tau_{0r} + \beta_{1r} t_r + \epsilon_{rt}, \tag{3}$$

where $\overline{CPE}_{rt}$ denotes reachwide mean catch-per-unit-effort for reach r during year t, τ_0 is the parameter for the overall intercept for all reaches combined, β_1 is the parameter for the overall slope (linear trend) for all reaches combined, the τ_{0r} are five parameters for reach-specific deviations from τ_0, the β_{1r} are five parameters for reach-specific deviations from β_1, and ϵ_{rt} is random error. For these data, it is assumed that the ϵ_{rt} are independently and normally distributed with mean zero and diagonal covariance matrix having elements $s^{-2}(\bar{y}_{st})\sigma^2$, where σ^2 is variance from model-based sources. That is, the observations of $\overline{CPE}_{rt}$ in equation (3) are assumed to be serially independent but are weighted by the reciprocals of their estimated variances from equation (2) to obtain constant model-based variance σ^2. Although *CPE* data are not normally distributed, the Central Limit Theorem (De Groot 1975) implies that the $\overline{CPE}_{rt}$ are approximately normally distributed; however, model assumptions only require that the ϵ_{rt} are approximately normally distributed. Equation (3) can be viewed as a generalization of the analysis of covariance model that accounts for heterogeneity of variance in the response variable $\overline{CPE}_{rt}$ and for the possibility that linear trend slopes differ among LTRMP study reaches.

Three tests based on Type I sums of squares from equation (3) are relevant (Littell et al. 1991). The *F* test for study reach *r* examines the differences due to different intercepts τ_{0r} (adjusted treatment differences), assuming equal trend slopes. The *F* test for the main effect t_r examines the significance of a single linear trend regression of $\overline{CPE}_{rt}$ on t_r that prevails over the six study reaches. Last, the *F* test for the interaction between study reach and time, denoted by the term $\beta_{1r} t_r$ in equation (3), examines the significance of differences in trend coefficients β_{1r} among study reaches. If this last *F* test is not statistically significant, then one concludes that among-reach differences in trend slopes could not be detected.

Uncommon and Exotic Species

In this report I present only qualitative graphical analyses of trends and patterns of catches of selected uncommon and exotic species. Generally, these species are so infrequently captured that most catch data are dominated by zeros and, therefore, the results of analyses described in the previous section would be nearly meaningless. Therefore I present total catch data, for all gears and strata combined, for the selected exotic and uncommon native species. The exotic bighead carp (*Hypopthalmichthys nobilis*) and grass carp (*Ctenopharyngodon idella*) were selected because their status is of concern to river managers. The uncommon native species shovelnose sturgeon (*Scaphirhynchus platorynchus*), lake sturgeon (*Acipenser fulvescens*), paddlefish (*Polyodon spathula*), skipjack herring (*Alosa chrysochloris*), and blue sucker (*Cycleptus elongatus*) were selected because they characteristically are riverine species that are also of special concern.

Results and Discussion

Species Richness

Since the late 19th century, 150 species of fish have been detected from that portion of the Upper Mississippi River (Fremling et al. 1989) now sampled by the LTRMP. The LTRMP has detected 127 species of fish during the first 5 years of standardized monitoring. Because many species are relatively rare and are difficult to detect in species-rich ecosystems, the failure to detect all 150 historical fish species is not evidence of a long-term decline in species richness. Rather, the fact that 127 fish species, a few of which are recently introduced exotics, were detected in only the first 5 years of the LTRMP suggests that overall species richness is probably unchanged since the late 1800s. Within the LTRMP study reaches, there is no evidence of any recent decline in species richness (Figure 8). Species richness increases with increasing sampling size (Bunge and Fitzpatrick 1993). The apparent increasing trend in species richness is therefore probably the result of increased annual sampling effort, particularly from 1990 to 1991 in all study reaches but also from 1992 to 1993 in Pools 4, 8, 13, and the La Grange Pool (Appendix). The apparent decrease in fish species richness from 1992 to 1993 in Pool 26 and the open river study reach is probably the result of reduced sampling intensity; the flood of 1993 precluded normal sampling in these study reaches during much of the summer. Apparent species richness tended to be greatest in Pool 8, which is not surprising given the physical diversity of aquatic areas (Figure 3) and the location in the convergence of the grassland, deciduous forest, and northern coniferous forest biomes (Odum 1971). This pattern in the LTRMP data is consistent with the historic pattern constructed by Fremling et al. (1989).

Relative Abundance

The Gars, Family Lepisosteidae

The abundance of shortnose gar (*Lepisosteus platostomus*), as measured by fyke net sampling, did not show a statistically significant overall LTRMP-wide linear trend ($P = 0.69$) nor statistically significant differences in linear trends among the six LTRMP study reaches ($P > 0.13$). However, mean relative abundance differed significantly among study reaches ($P < 0.01$). The greatest relative abundances of shortnose gar were observed from Pool 26 and the La Grange Pool (Figure 9). This geographic pattern of abundance is entirely consistent with this species' range distribution and preference for low-flow areas (Pflieger 1975); although Pools 4 and 8 contain relatively large proportions of off-channel aquatic area (Table), these study reaches border the northern limit of the natural range for shortnose gar (Pflieger 1975). The relatively low abundance of shortnose gar in the open river study reach is consistent with the relative lack of off-channel aquatic areas (Table).

The Bowfin, Family Amiidae

The abundance of bowfin (*Amia calva*), as measured by fyke net sampling, showed a statistically significant overall LTRMP-wide decreasing linear trend ($P < 0.01$), and there was marginal evidence of differences in linear trends among the six LTRMP study reaches ($P = 0.11$). Overall mean relative abundance of bowfin differed significantly among study reaches ($P < 0.01$). Bowfin require low-flow areas, and particularly backwaters, for habitat (Scott and Crossman 1973; Pflieger 1975). Overall relative abundance estimates for bowfin were greatest in Pools 4, 8, and 13 (Figure 10), which also contain relatively high proportions of backwaters (Table). The relative abundance estimates of bowfin were extremely low from the open river study reach, which contains virtually no backwater area (Table).

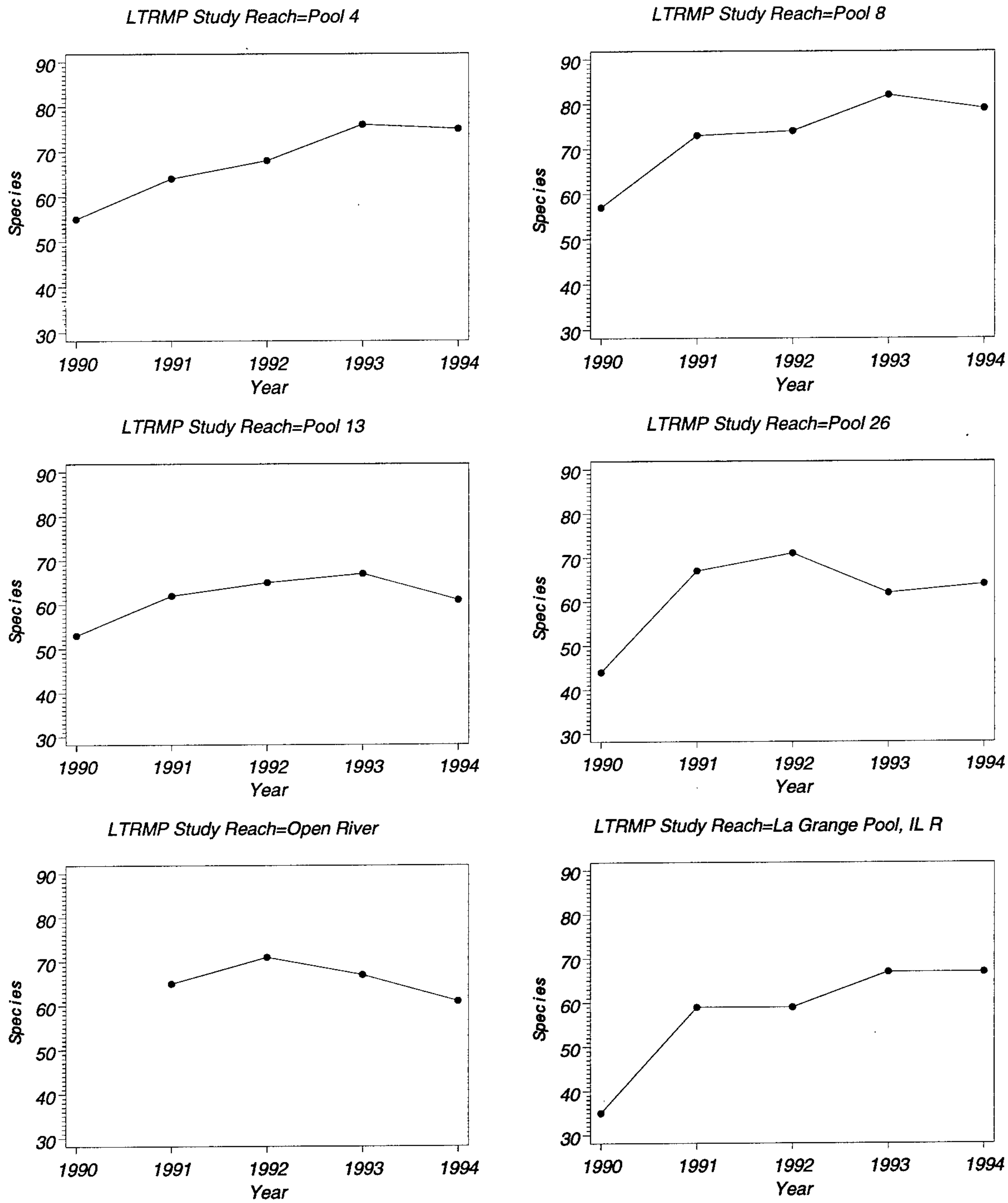

Figure 8. Trends in fish species richness (numbers of species) from Long Term Resource Monitoring Program study reaches, from all sampling gears combined. Samples were collected from subjectively chosen permanaently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

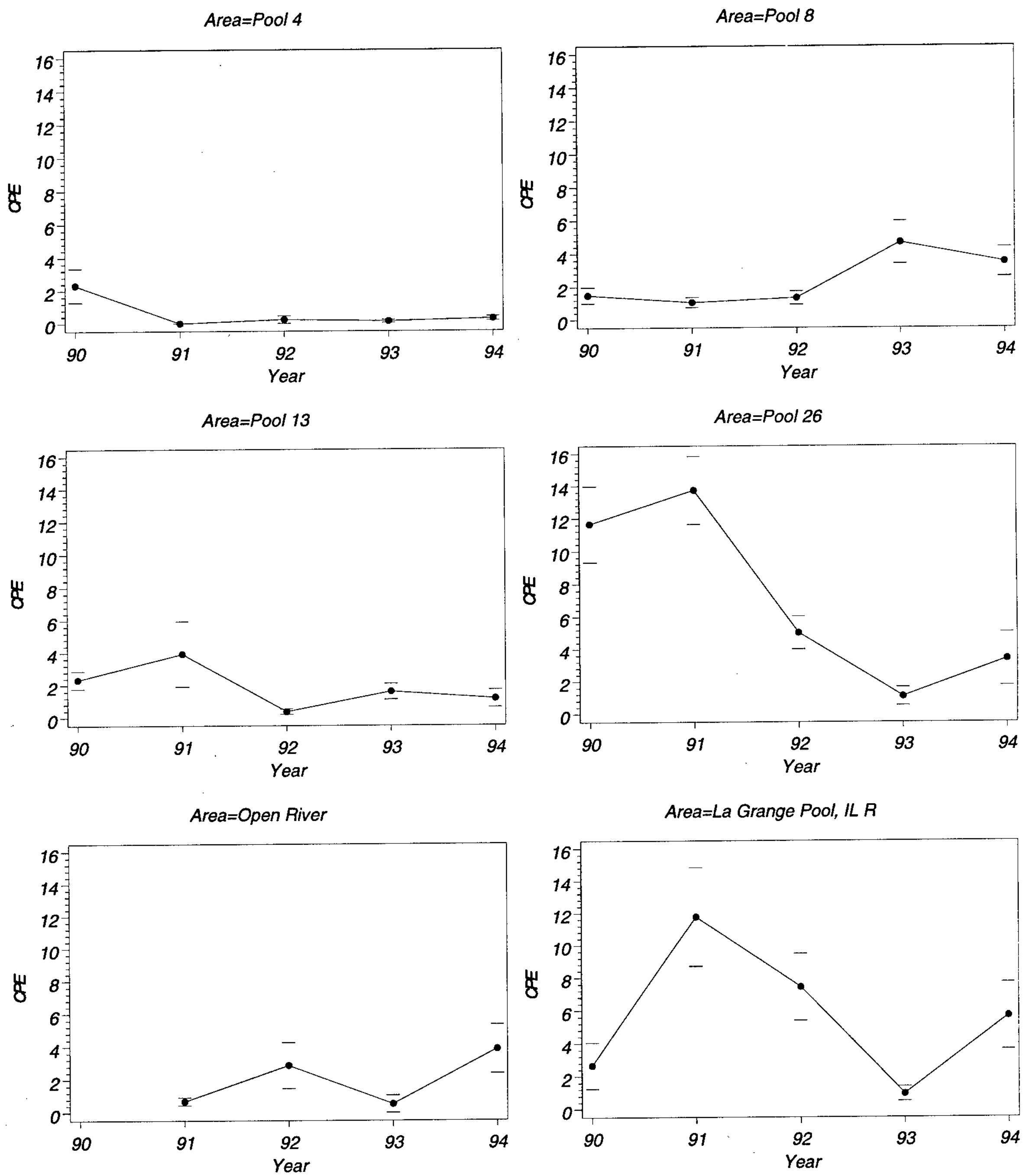

Figure 9. Trends in abundance of shortnose gar (*Lepisosteus platostomus*), as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from fyke net samples. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

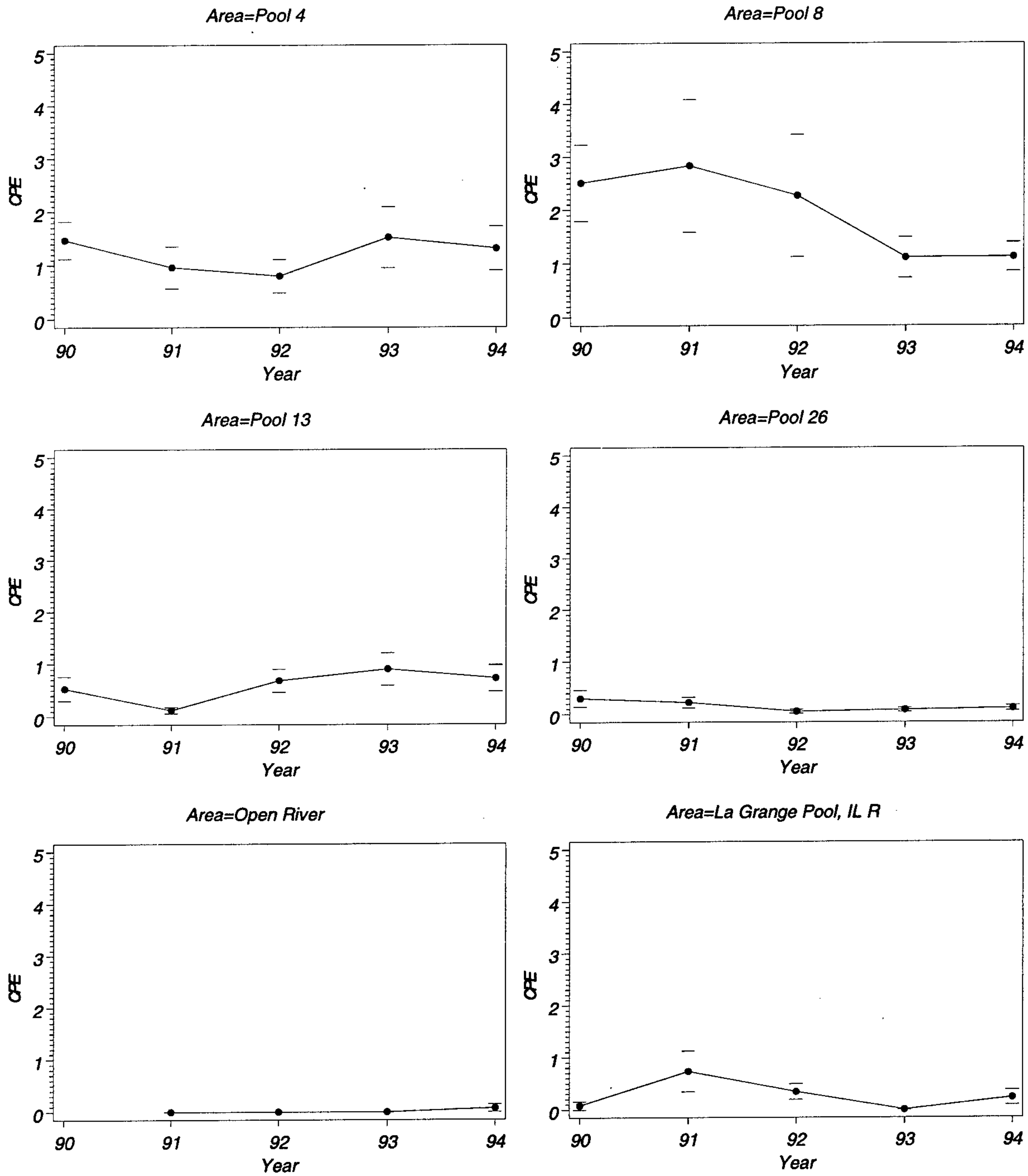

Figure 10. Trends in abundance of bowfin (*Amia calva*), as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from fyke net samples. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

The Herrings, Family Clupeidae

The abundance of gizzard shad (*Dorosoma cepedianum*), as measured by day electrofishing, did not show a statistically significant overall LTRMP-wide linear trend ($P = 0.15$), but linear trends differed significantly among study reaches ($P = 0.05$). Further, overall abundance of gizzard shad from day electrofishing differed significantly among study reaches ($P = 0.03$). Gizzard shad were most abundant in day electrofishing samples from Pool 26, the open river study reach, and the La Grange Pool, which are the three most southerly study reaches of the LTRMP (Figure 11). In those study reaches, relative abundance was highest in 1993, the year of the record flood in the UMRS. However, the peak of abundance in 1993 was followed by a dramatic decline in 1994. Gizzard shad are common in all aquatic areas of the UMRS but are most common in low-flow areas (Scott and Crossman 1973; Pflieger 1975) and may be dependent on the existence of relatively warm backwaters during winters (Lewis and Bodensteiner 1986). These habitat preferences may explain the apparent decline from 1993 to 1994 in the three southerly study reaches, and also the lack of a similar decline in the three northerly reaches where abundance in 1993 was much lower, leaving little room for decline, and where backwaters are more prevalent (Table).

The Minnows, Family Cyprinidae

Common carp (*Cyprinus carpio*) are abundant in all aquatic areas of the UMRS (Pflieger 1975) and typically dominate the commercial harvest (Kline and Golden 1979; Fremling et al. 1989). The abundance of common carp, as measured by *CPE* from day electrofishing, showed a statistically significant linear increase over time among all LTRMP study reaches combined ($P = 0.03$), but differences among linear trends among the study reaches were not apparent ($P = 0.73$); that is, a common increasing trend was apparent among all reaches (Figure 12). Overall mean abundance, regardless of trend, differed among reaches ($P = 0.05$), and common carp were seemingly less abundant in the open river study reach than in other LTRMP study reaches. The reason for the increase in the abundance of common carp from 1992 through 1994 is unknown. Although this exotic species is believed to have some detrimental effects on aquatic vegetation and sediment resuspension when abundance is extremely high (Crivelli 1983; Bellrichard 1994), the recent observation of a high frequency of consumption of zebra mussels (*Dreissena polymorpha*) in Pool 26 (John Tucker, Long Term Resource Monitoring Field Station, Alton, Illinois, personal communication) suggests the possibility that common carp might be an important predator on this nuisance exotic species.

The abundance of spotfin shiner (*Cyprinella spiloptera*), as measured by mini-fyke net sampling, showed no statistically significant overall LTRMP-wide linear trend ($P = 0.68$), trend differences among study reaches ($P = 0.99$), nor overall differences among study reaches ($P = 0.29$). The sample mean *CPE* of spotfin shiner increased in Pool 8 (Figure 13), but that apparent trend could be explained by chance alone in the context of the statistical model for mini-fyke netting encompassing all LTRMP study reaches. Patterns in the abundance of spotfin shiner measured using seining were qualitatively similar to the mini-fyke net data (Figure 14), but differences in variance patterns indicated that trends differed significantly among study reaches ($P = 0.02$) and overall abundance differed significantly among study reaches ($P < 0.01$). Spotfin shiner were essentially undetected from the open river study reach, which is at the extreme southern limit of the range of this species (Pflieger 1975).

Emerald shiners (*Notropis atherinoides*) are an abundant fish in some portions of the UMRS and may be an important prey species (Scott and Crossman 1973). The abundance of emerald shiners, as measured by mean *CPE* from mini-fyke netting, showed a very slight (Figure 15) but statistically significant linearly decreasing trend from all study reaches combined ($P = 0.01$), but linear trend did not differ significantly among study reaches ($P = 0.38$), nor were overall differences in mean abundance significant ($P = 0.50$). The abundance of emerald shiners, as measured by mean *CPE* from seining, showed qualitatively similar patterns

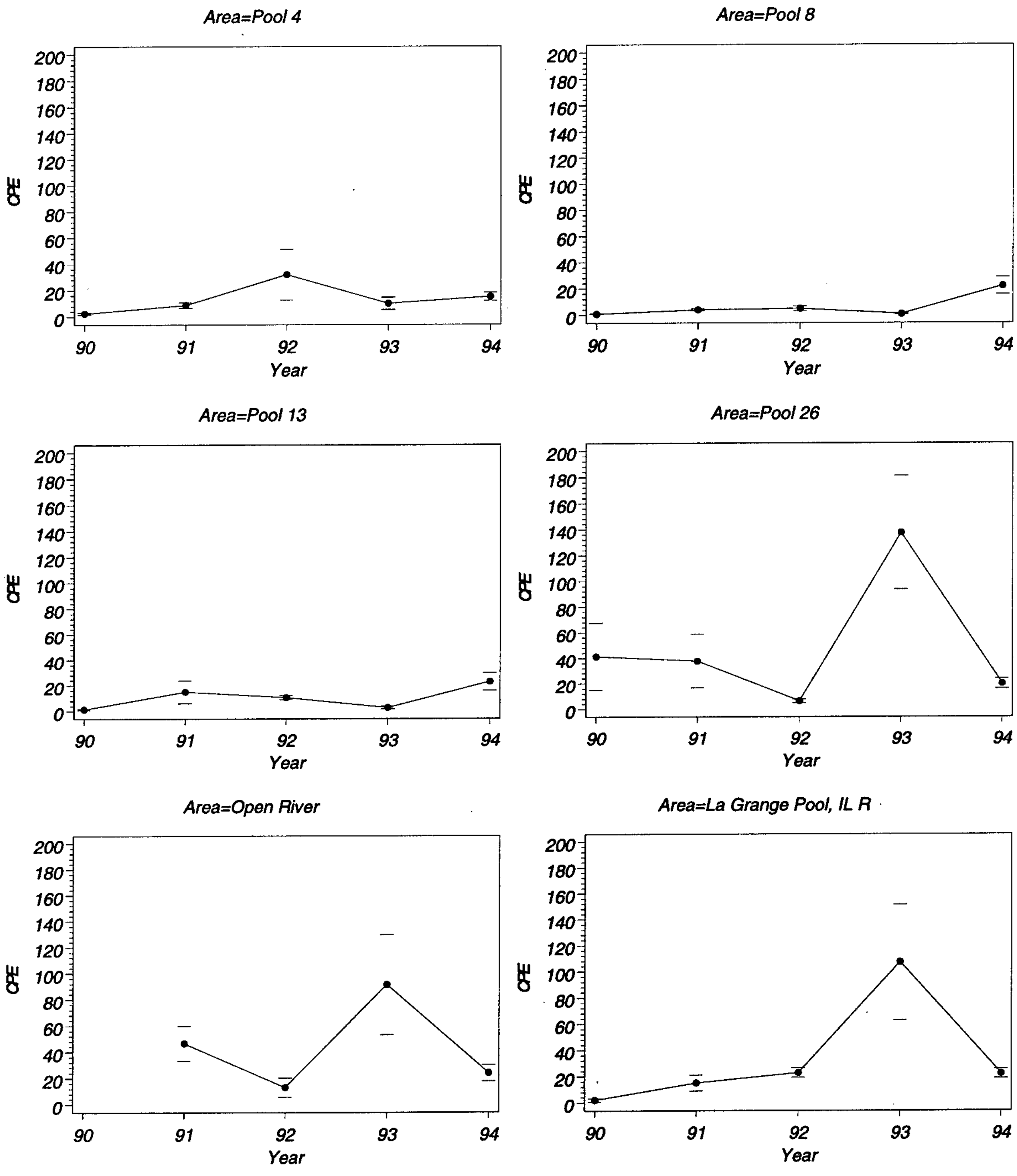

Figure 11. Trends in abundance of gizzard shad (*Dorosoma cepedianum*), as measured by mean catch-per-effort *CPE* ± 1 SE (fish per 15 min) from day electrofishing samples. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

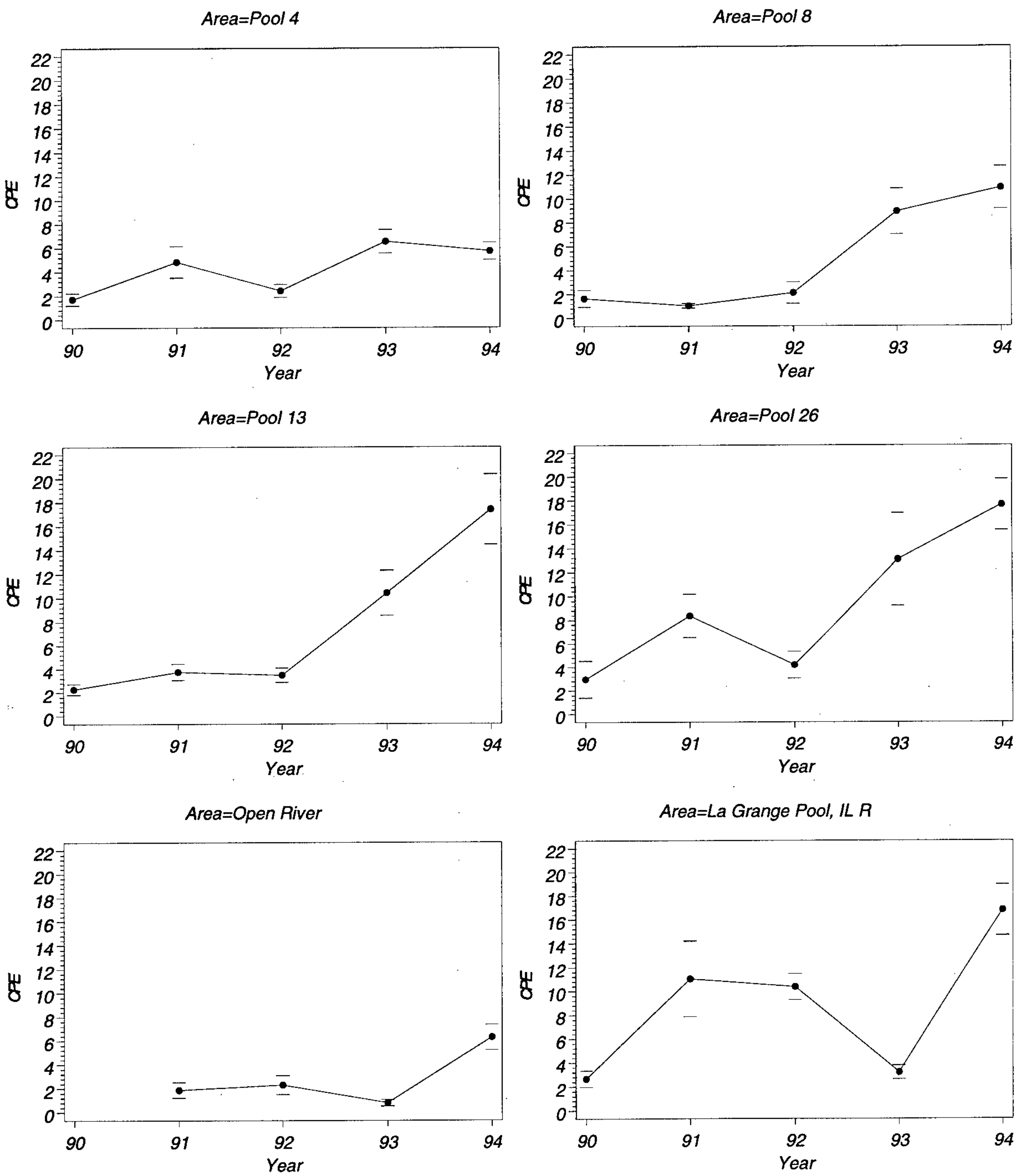

Figure 12. Trends in abundance of common carp (*Cyprinus carpio*) as measured by mean catch-per-effort *CPE* ±1 SE (fish per 15 min) from day electrofishing. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

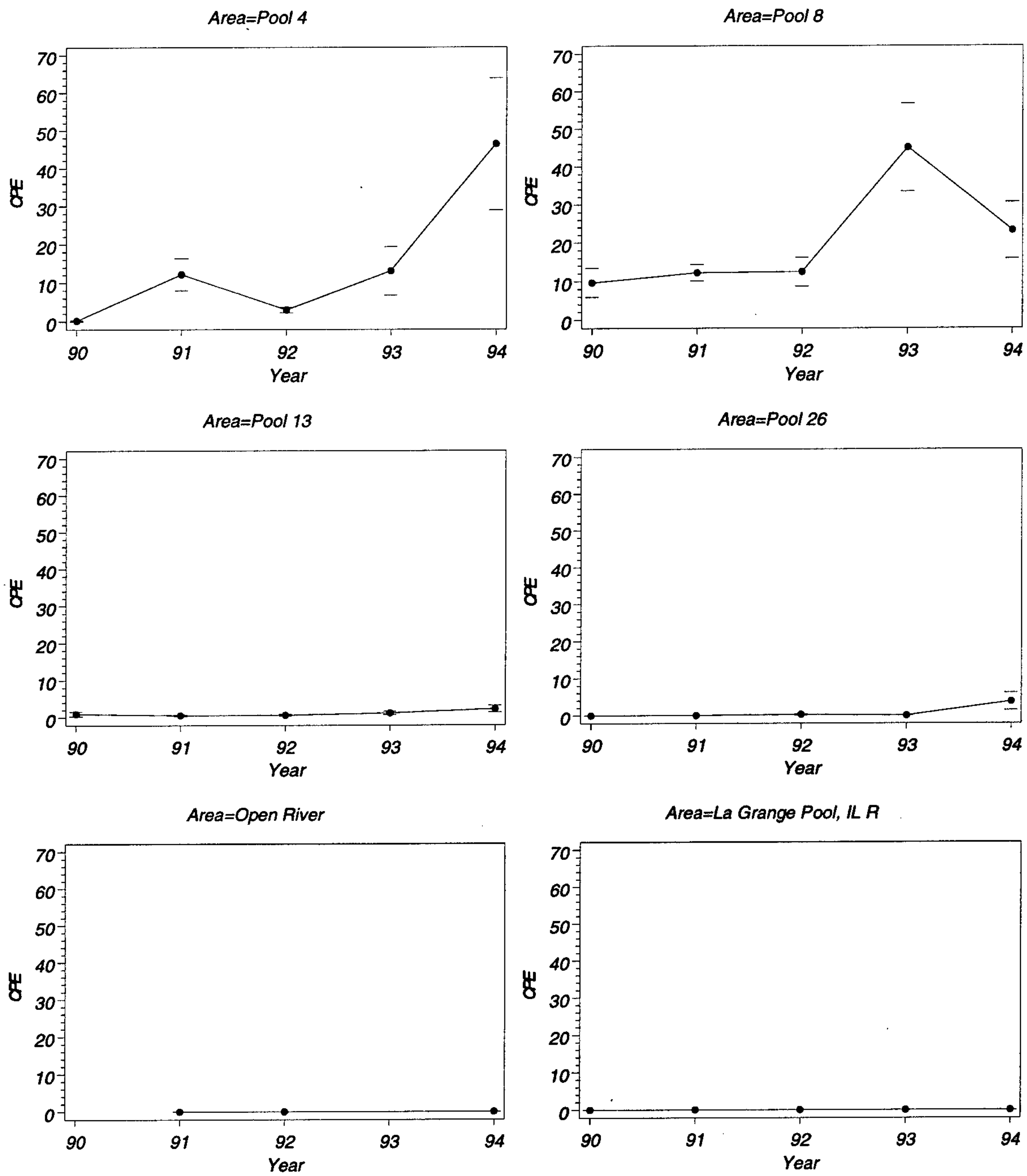

Figure 13. Trends in abundance of spotfin shiner (*Cyprinella spiloptera*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per haul) from seine samples. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

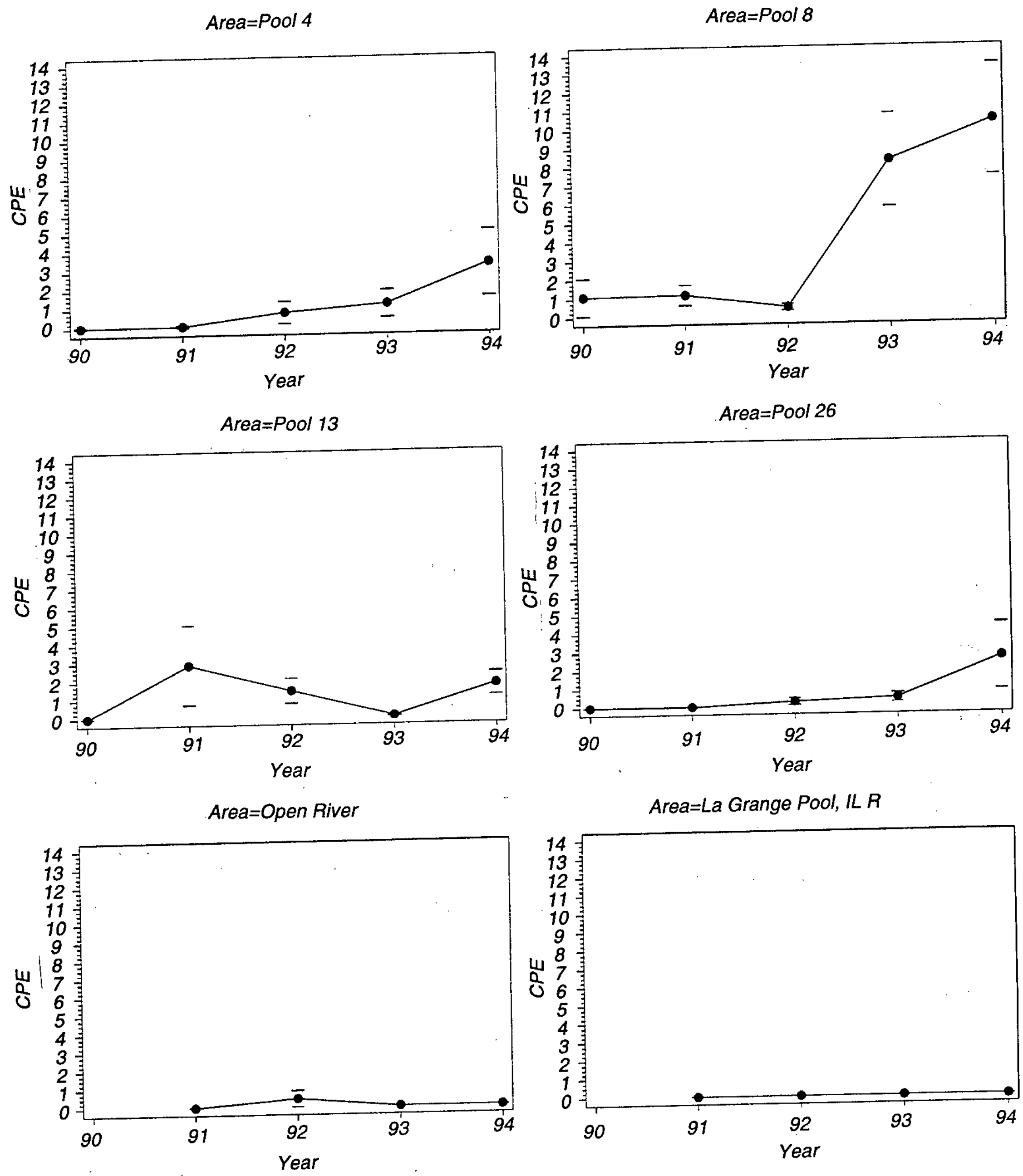

Figure 14. Trends in abundance of spotfin shiner (*Cyprinella spiloptera*) as measured by mean catch-per-effort *CPE*± SE (fish per net-day) from mini-fyke netting samples. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text assumptions necessary for interpretation of trends.

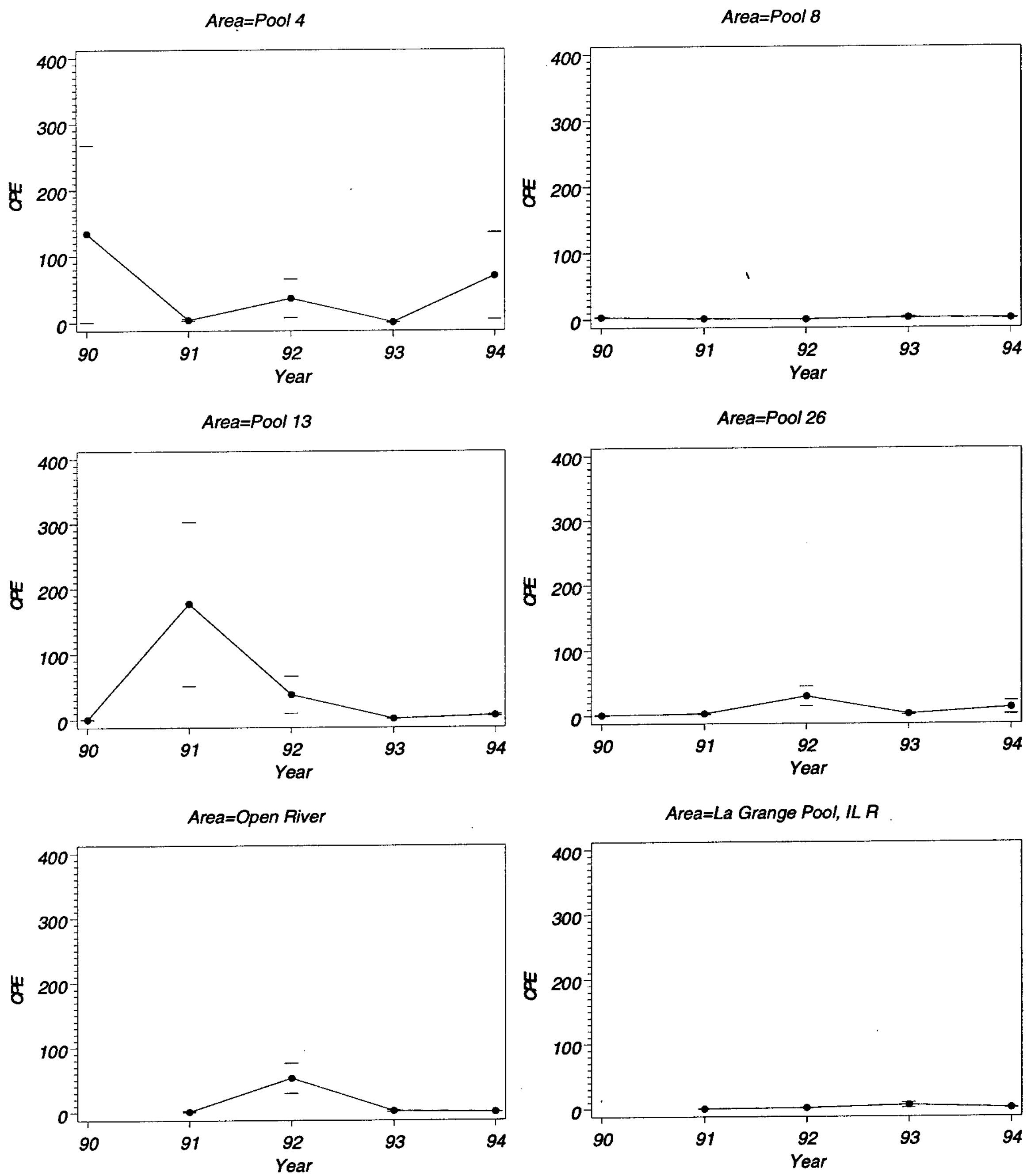

Figure 15. Trends in abundance of emerald shiner (*Notropis atherinoides*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from mini-fyke netting. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

(Figure 16) but, in contrast with the mini-fyke net data, only overall differences in mean *CPE* among study reaches were statistically significant ($P = 0.01$). A reasonable interpretation of both sets of data is that abundance has been somewhat greater in the northern three reaches than in the southern three, and that there may have been a small decline in overall abundance from 1990 through 1994 in the LTRMP study reaches.

The river shiner (*Notropis blennius*), an inhabitant of large rivers, is especially characteristic of the Mississippi, Missouri, and lower Ohio Rivers (Pflieger 1975). The abundance of river shiners, as measured by mean *CPE* from seining, showed a marginally significant linearly decreasing overall LTRMP-wide trend ($P = 0.06$), but linear trend differences among study reaches were not evident ($P = 0.16$). Overall mean abundance of river shiners differed significantly among the LTRMP study reaches ($P = 0.02$), and they were seemingly more abundant in the impounded study reaches of the Mississippi River than in the open river reach. River shiners were not collected from the La Grange Pool of the Illinois River (Figure 17). The apparent lower abundance in the open river study reach may be noteworthy, given that the natural range of this species extends from the Red River system of southern Canada to southern Louisiana (Scott and Crossman 1973). River shiners are believed to prefer channels, at least when observed by biologists during the warm seasons, and to be insensitive to bottom type and turbidity (Pflieger 1975). However, the winter habitat requirements of this species are unknown. If the metabolic scope for activity is constrained by low temperatures so that relatively warm calm water is required in winter, then one might speculate that the river shiner is limited by lack of off-channel habitat, as are several other species (Sheehan et al. 1990).

The spottail shiner (*Notropis hudsonius*) is a northern species for which the southern range limit on the Mississippi River is the confluence of the Ohio River (Pflieger 1975). This species is common in large glacial lakes and rivers in the northern portion of its range, but south of Minnesota and Wisconsin it is primarily restricted to the Mississippi and Illinois Rivers. The abundance of spottail shiners, as measured by mean *CPE* from seining (Figure 18), showed no statistically significant LTRMP-wide linear trend ($P = 0.94$), among-reach differences in linear trends ($P = 0.84$), or overall mean differences among reaches ($P = 0.14$). Spottail shiners were not collected from Pool 26 and the open river study reach of the Mississippi River.

The channel shiner (*Notropis wickliffi*) and the similar mimic shiner (*N. volucellus*) are extremely difficult to distinguish and probably hybridize in portions of the Upper Mississippi River (T. Cavender, The Ohio State University, Columbus, Ohio, personal communication). The taxonomy of these species remains in a state of flux, and therefore discrimination in the LTRMP is somewhat uncertain. The abundance of specimens identified as channel shiners, as measured by mean *CPE* from seining (Figure 19), showed a statistically significant, but slight, LTRMP-wide linear increase ($P < 0.01$), primarily due to trends in Pools 8 and 26. However, differences in linear trends among study reaches ($P = 0.01$) were highly significant and obvious, and abundance decreased within Pool 13 and the open river study reach. Channel shiners were not collected from Pool 4 and the La Grange Pool of the Illinois River.

The bullhead minnow (*Pimephales vigilax*) is a midcontinental species for which the northern range limit is slightly upriver of Pool 4 (Pflieger 1975). The abundance of bullhead minnows, as measured by mean *CPE* from mini-fyke netting (Figure 20), showed a highly significant LTRMP-wide linearly decreasing trend ($P < 0.01$). Overall mean abundance, as measured by mini-fyke netting, differed among study reaches ($P = 0.01$). The abundance of bullhead minnows, as measured by mean *CPE* from seining (Figure 21), showed no statistically significant LTRMP-wide linear trend ($P = 0.33$), nor differences in linear trends among study reaches ($P = 0.24$), but overall mean *CPE* differed among study reaches ($P < 0.01$). A reasonable interpretation of both data sets is that there is no evidence of a linear trend in abundance of bullhead minnows, but that overall mean abundance differed significantly among study reaches. Bullhead minnows are most abundant in areas of low flow—particularly in backwaters (Pflieger 1975). Catch rates tended to be greater from Pools 8, 13, and 26 than from Pool 4 near the species range limit, the open river study reach where backwaters are uncommon (Table), or from the La Grange Pool of the Illinois River where backwaters are common (Figure 20).

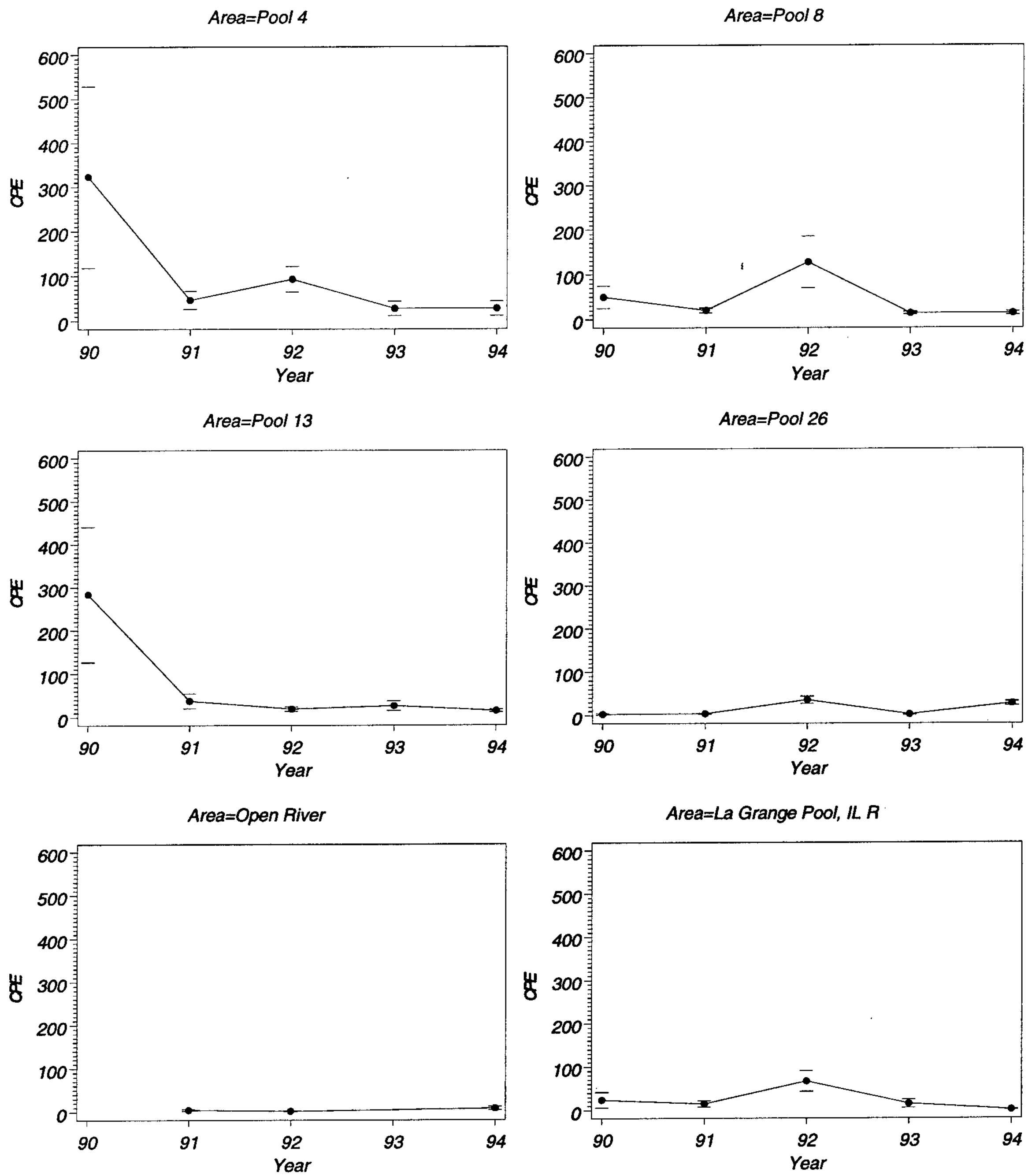

Figure 16. Trends in abundance of emerald shiner (*Notropis atherinoides*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per haul) from seining. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

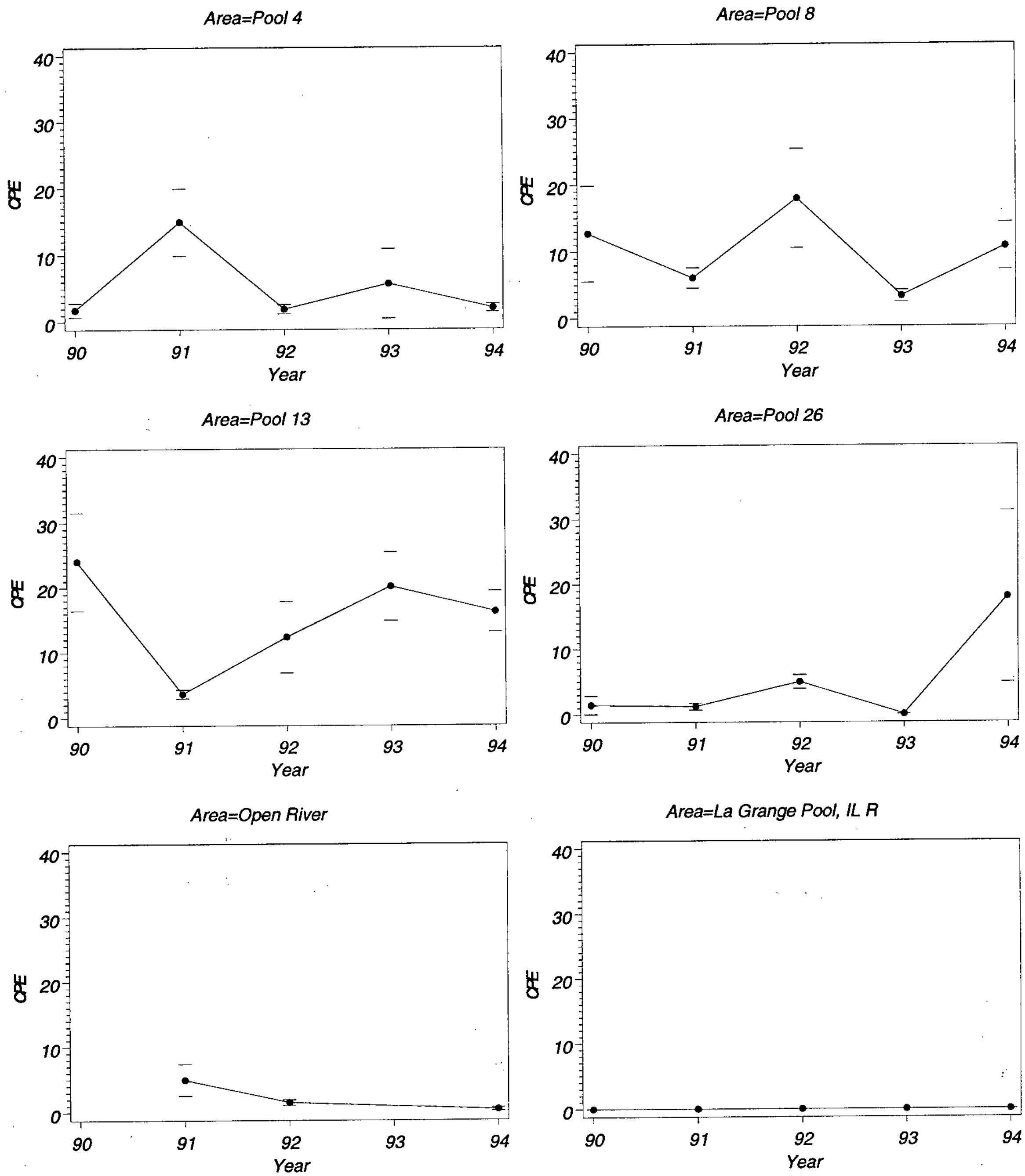

Figure 17. Trends in abundance of river shiner (*Notropis blennius*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per haul) from seine samples. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

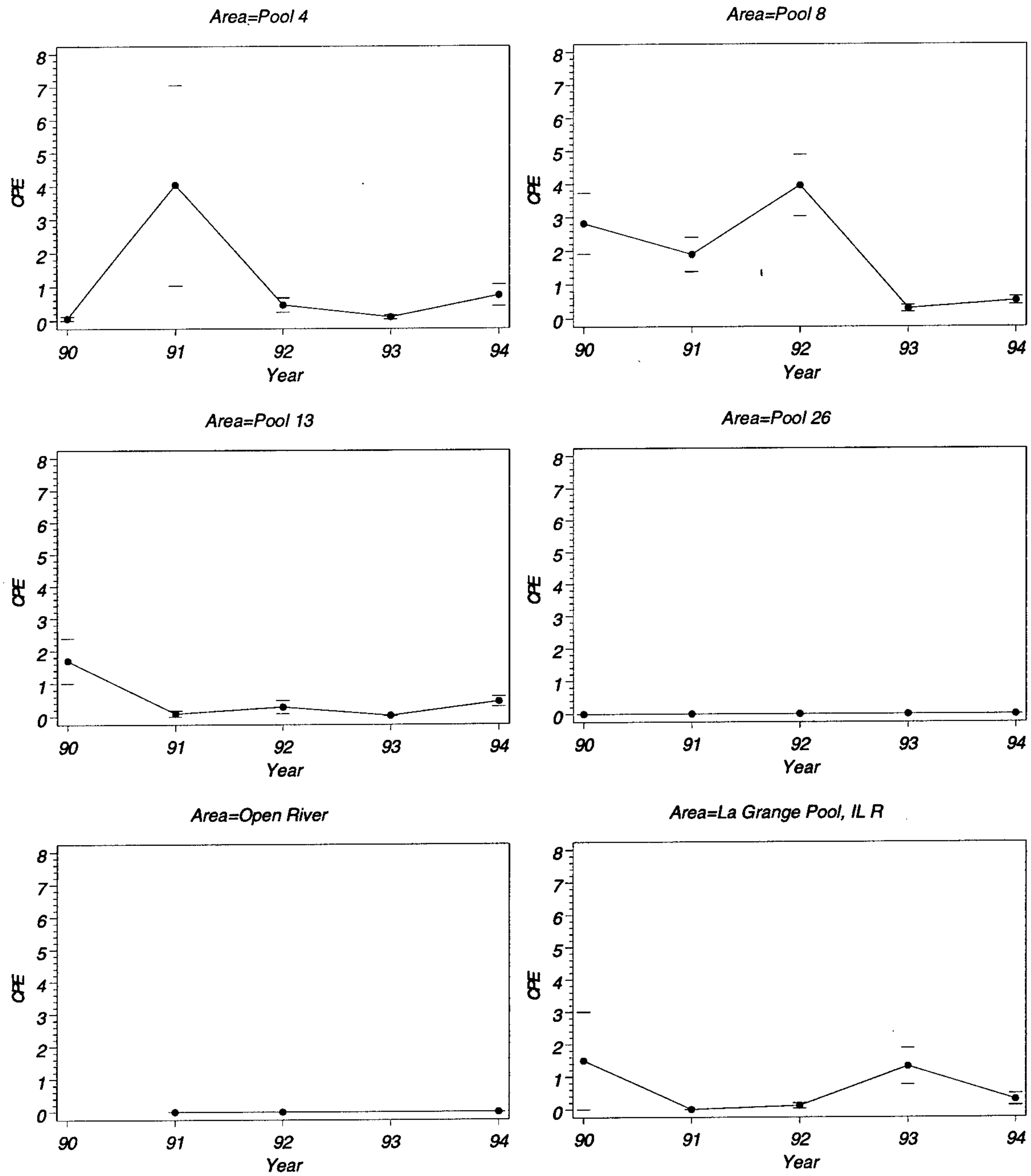

Figure 18. Trends in abundance of spottail shiner (*Notropis hudsonius*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per haul) from seine samples. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

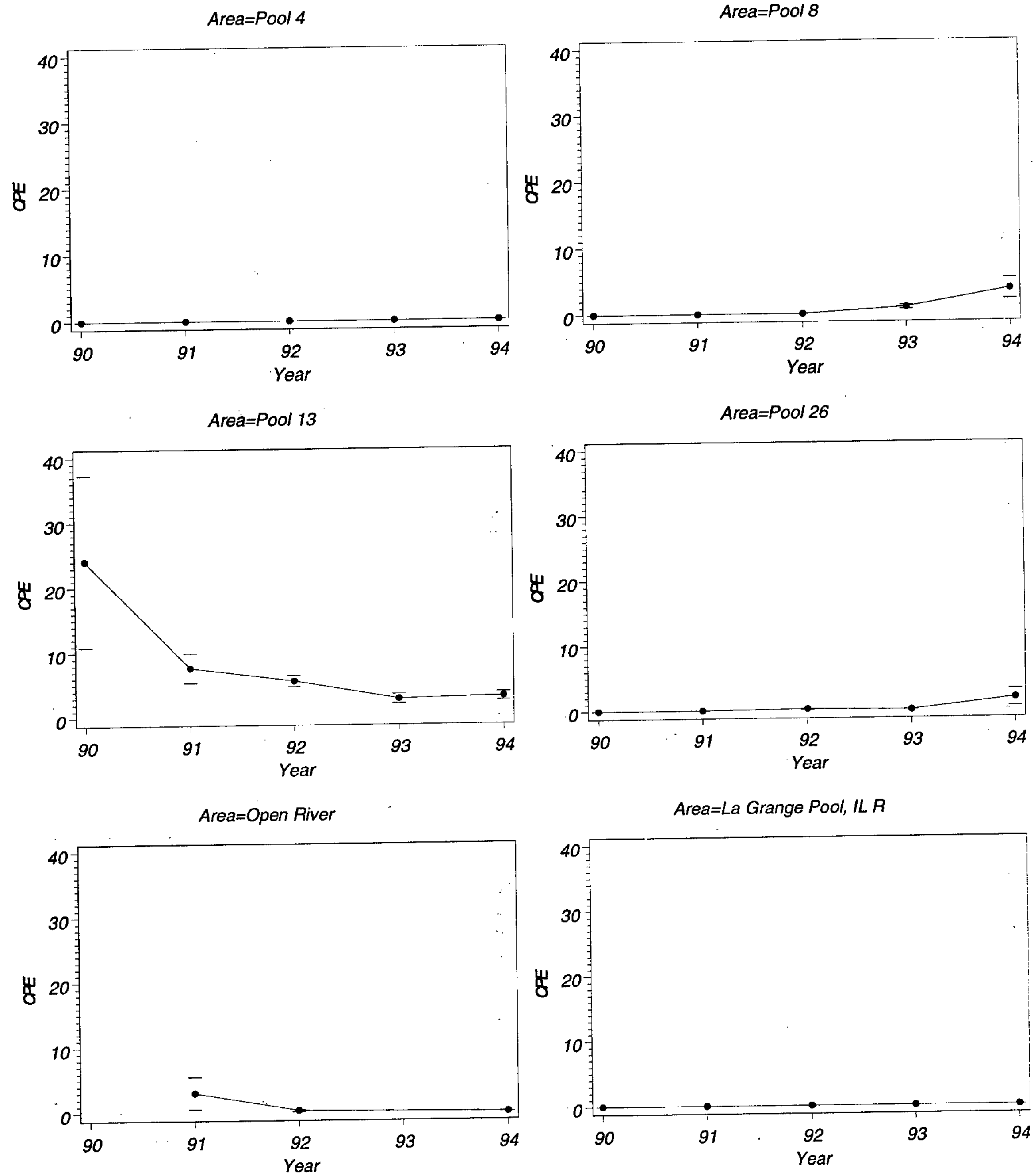

Figure 19. Trends in abundance of channel shiners (*Notropis wickliffi*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per haul) from seining. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

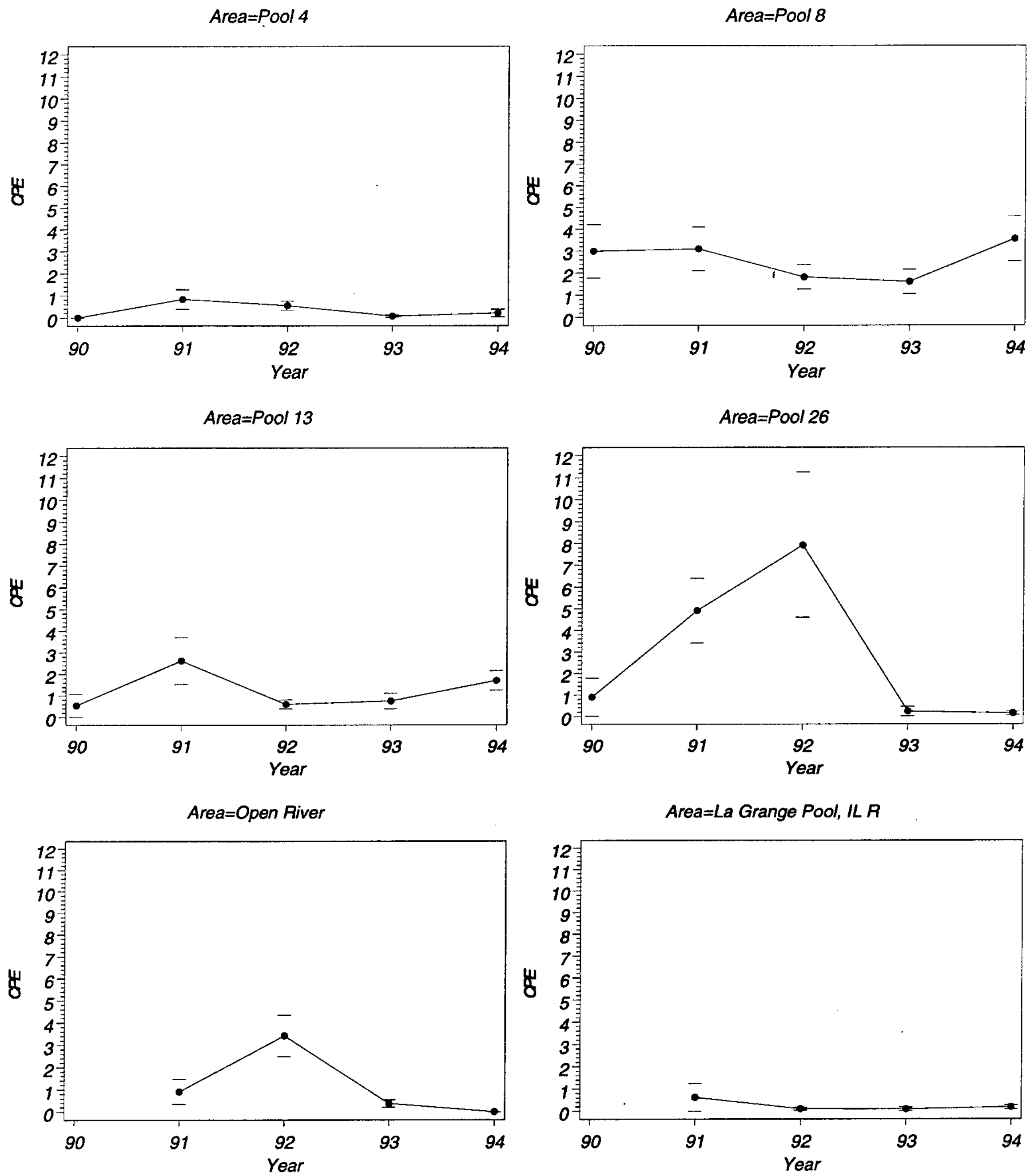

Figure 20. Trends in abundance of bullhead minnows (*Pimephales vigilax*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from mini-fyke netting. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

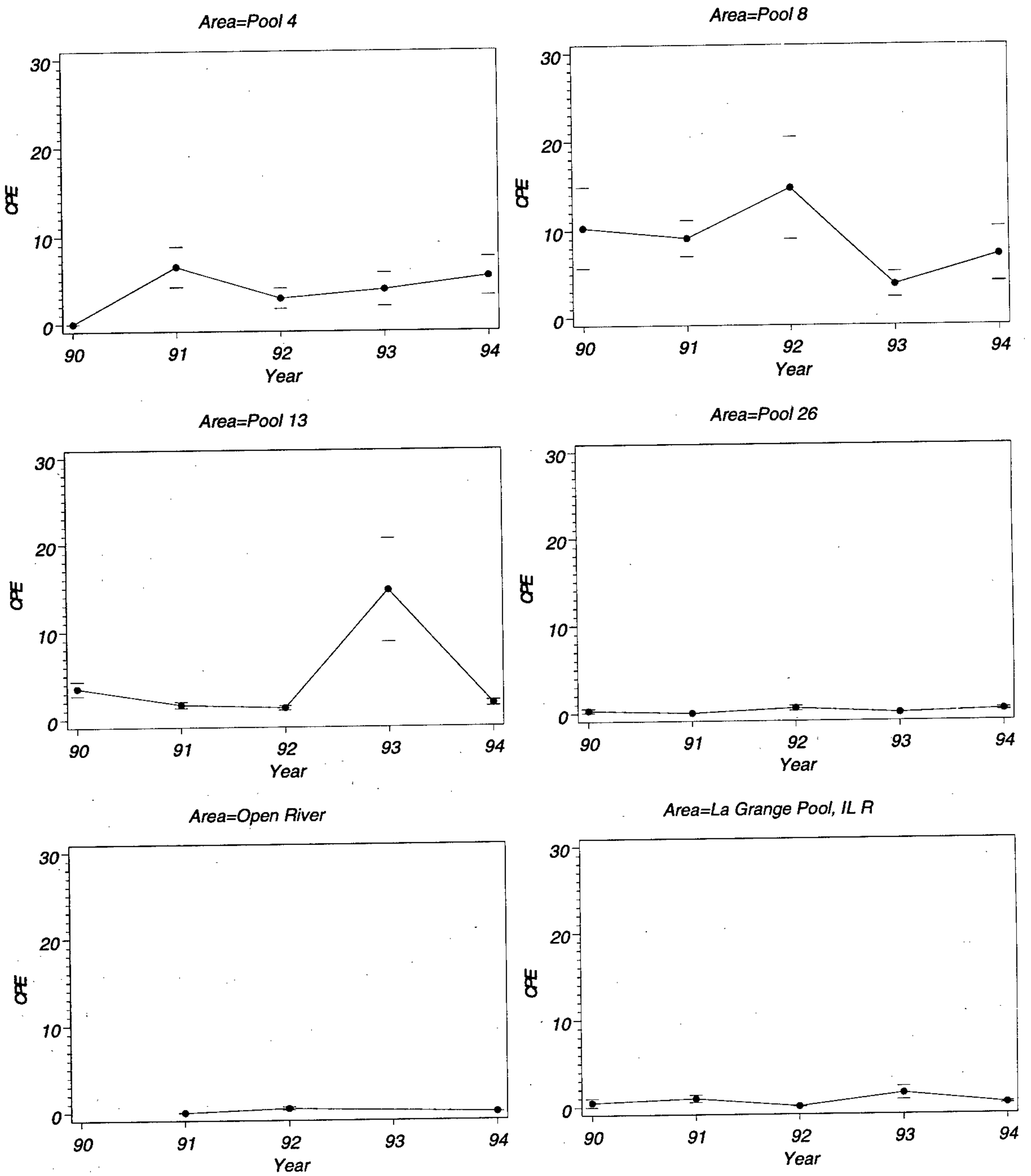

Figure 21. Trends in abundance of bullhead minnows (*Pimephales vigilax*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per haul) from seining. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

Suckers, Family Catostomidae

The river carpsucker (*Carpiodes carpio*) is common in large rivers and prairie streams of south-central Canada and the central United States and seems to prefer turbid, low-flow channels and backwaters (Pflieger 1975). The abundance of river carpsuckers, as measured by mean *CPE* from day electrofishing, showed no LTRMP-wide linear trend or significant differences of linear trends among study reaches ($P = 0.40$), but overall mean abundance differed significantly among study reaches ($P = 0.01$). Catch rates of river carpsuckers were lowest from Pools 4 and 8 (Figure 22).

The smallmouth buffalo (*Ictiobus bubalus*) is an important species in the commercial fishery of the UMRS (Fremling et al. 1989). The abundance of smallmouth buffalo, as measured by mean *CPE* from day electrofishing, showed a statistically significant LTRMP-wide increasing linear trend ($P < 0.01$), and linear trends differed significantly among LTRMP study reaches ($P = 0.02$). Statistically significant differences in overall mean abundance were not found among study reaches ($P = 0.18$). Mean *CPE* of smallmouth buffalo from day electrofishing was highest in the three most southerly study reaches (Figure 23). Because day electrofishing in summer and fall is somewhat selective for small smallmouth buffalo, the electrofishing trends represent primarily juveniles. The LTRMP hoop nets tend to retain relatively large fish. The abundance of smallmouth buffalo, as measured by hoop netting, showed no statistically significant LTRMP-wide linear trend ($P = 0.46$), nor did linear trends differ among study reaches ($P = 0.59$). Nonlinear patterns in mean *CPE*, however, were clearly evident in the data (Figure 24). With the exception of Pool 4, mean *CPE* in the Mississippi River peaked in 1991–92, then declined through 1994. Mean *CPE* in the La Grange Pool seemed to increase during 1993–94 over the previous 3 years. This pattern suggests the passage of a large cohort through the fishery.

The spotted sucker (*Minytrema melanops*) prefers low-flow areas of rivers and small streams, particularly where aquatic vegetation is present; the range of this species extends from east-central Minnesota to the Gulf of Mexico (Pflieger 1975). The abundance of spotted suckers, as measured by mean *CPE* from day electrofishing, showed marginally significant differences in linear trends among study reaches ($P = 0.09$). Sample mean *CPE* increased through time in Pool 4 and decreased slightly in Pool 13 (Figure 25). Overall mean abundance of spotted suckers differed significantly among study reaches ($P = 0.01$), primarily the result of absence of this species from the three southernmost study reaches, where submersed aquatic vegetation is less abundant or absent.

The shorthead redhorse (*Moxostoma macrolepidotum*) inhabits fast-flowing channels of rivers in the northern United States and southern Canada (Scott and Crossman 1973; Pflieger 1975). The open river study reach is barely within the southern range limit of this species on the Mississippi River, although it is common in Ozark streams farther south (Pflieger 1975). The abundance of shorthead redhorse, as measured by mean *CPE* from day electrofishing, showed a statistically significant LTRMP-wide linearly increasing trend ($P < 0.01$), but linear trends differed significantly among the six study reaches ($P = 0.03$). Mean *CPE* of shorthead redhorse was zero from the open river study reach, and the increasing trend was most pronounced in Pool 8 where this species was also most abundant (Figure 26). The increasing trend was slight but measurable in Pool 26 and the La Grange Pool of the Illinois River.

Catfishes, Family Ictaluridae

The channel catfish (*Ictalurus punctatus*) is highly valued by commercial and recreational fishers (Pflieger 1975; Fremling et al. 1989). Among commercially harvested species, channel catfish typically sell for the highest unit price. The abundance of channel catfish, as measured by mean *CPE* from day electrofishing, did not show a statistically significant LTRMP-wide linear trend ($P = 0.16$), nor were there differences in linear

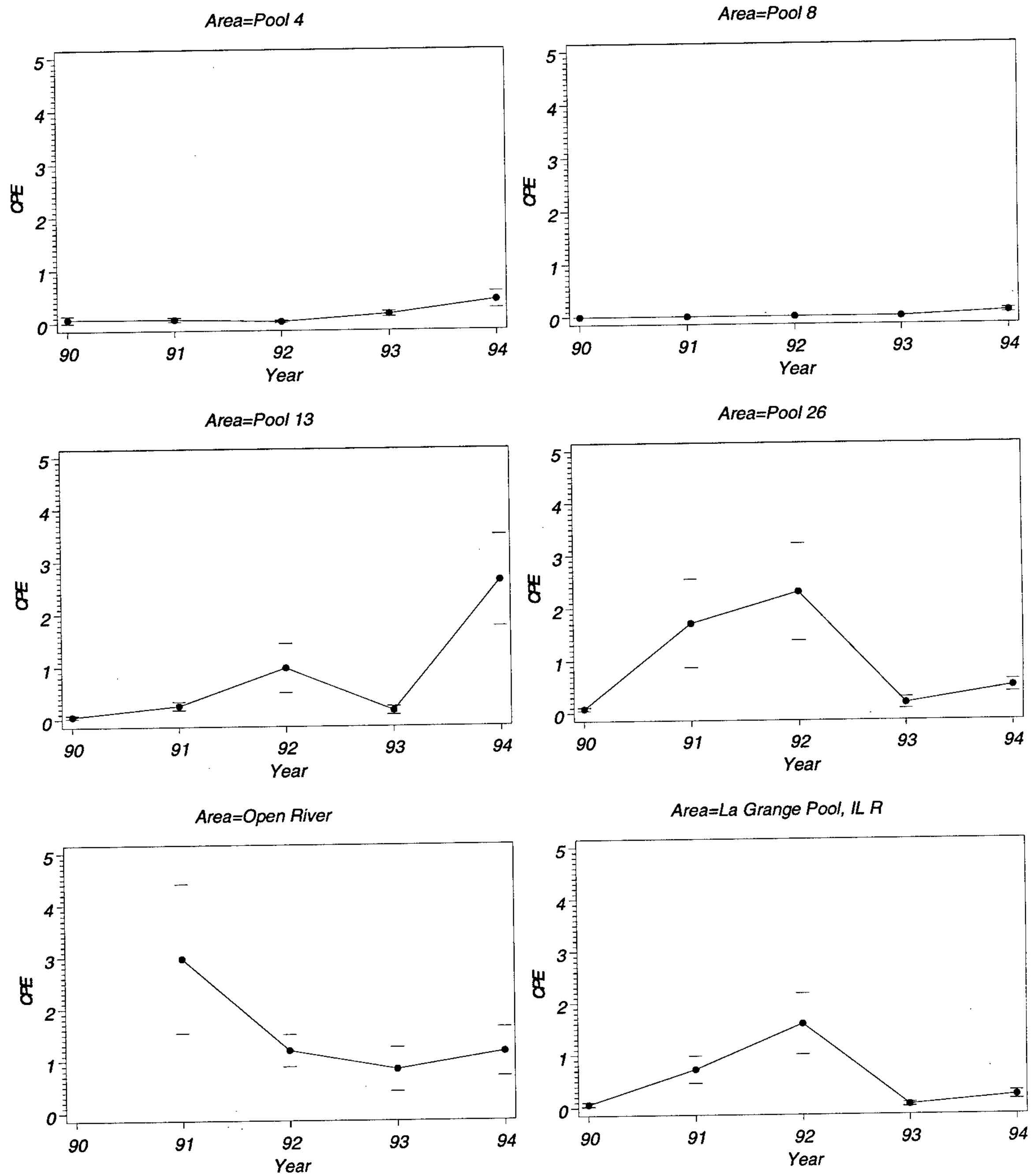

Figure 22. Trends in abundance of river carpsuckers (*Carpiodes carpio*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per 15 min) from day electrofishing. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

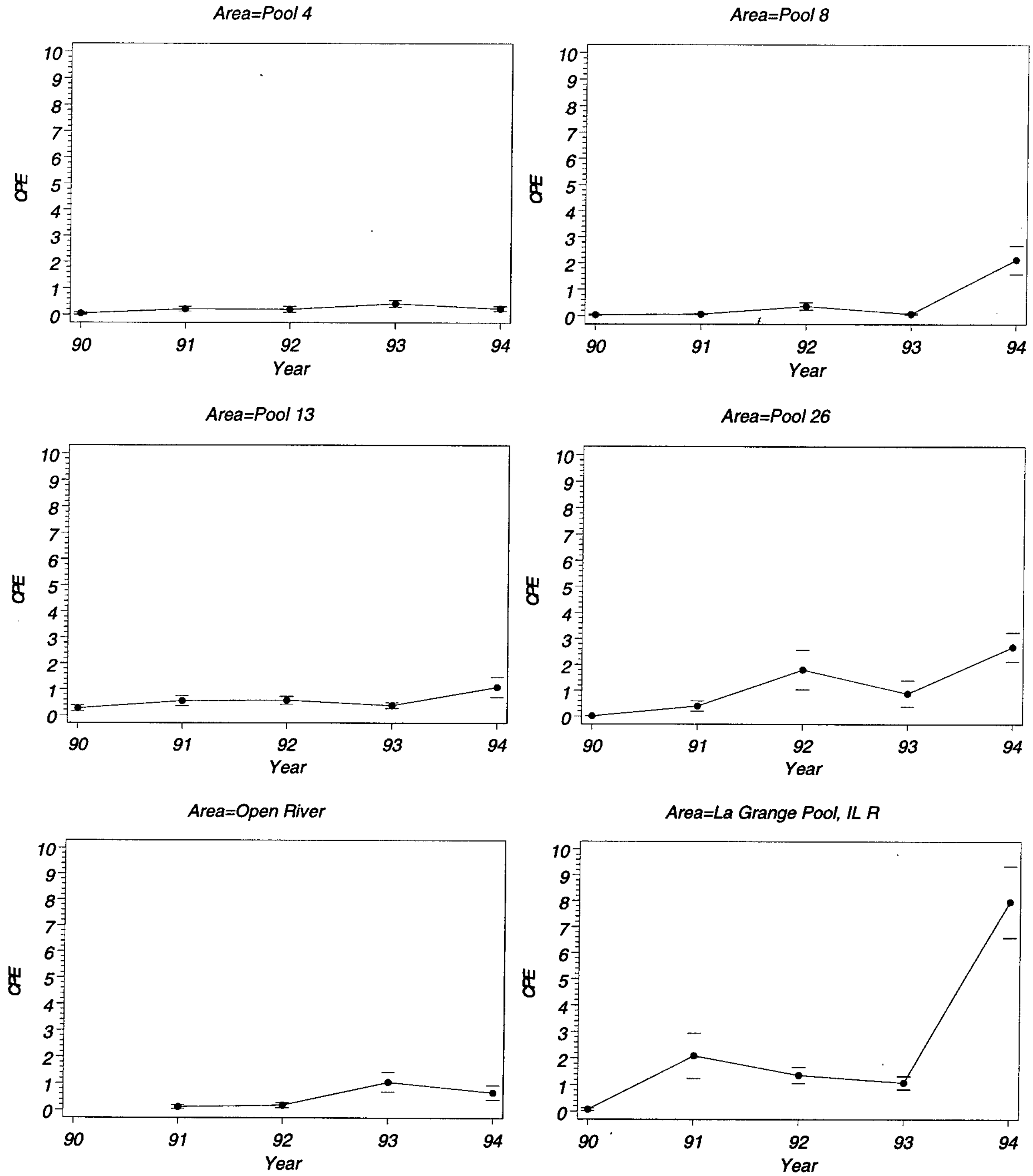

Figure 23. Trends in abundance of smallmouth buffalo (*Ictiobus bubalus*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per 15 min) from day electrofishing. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

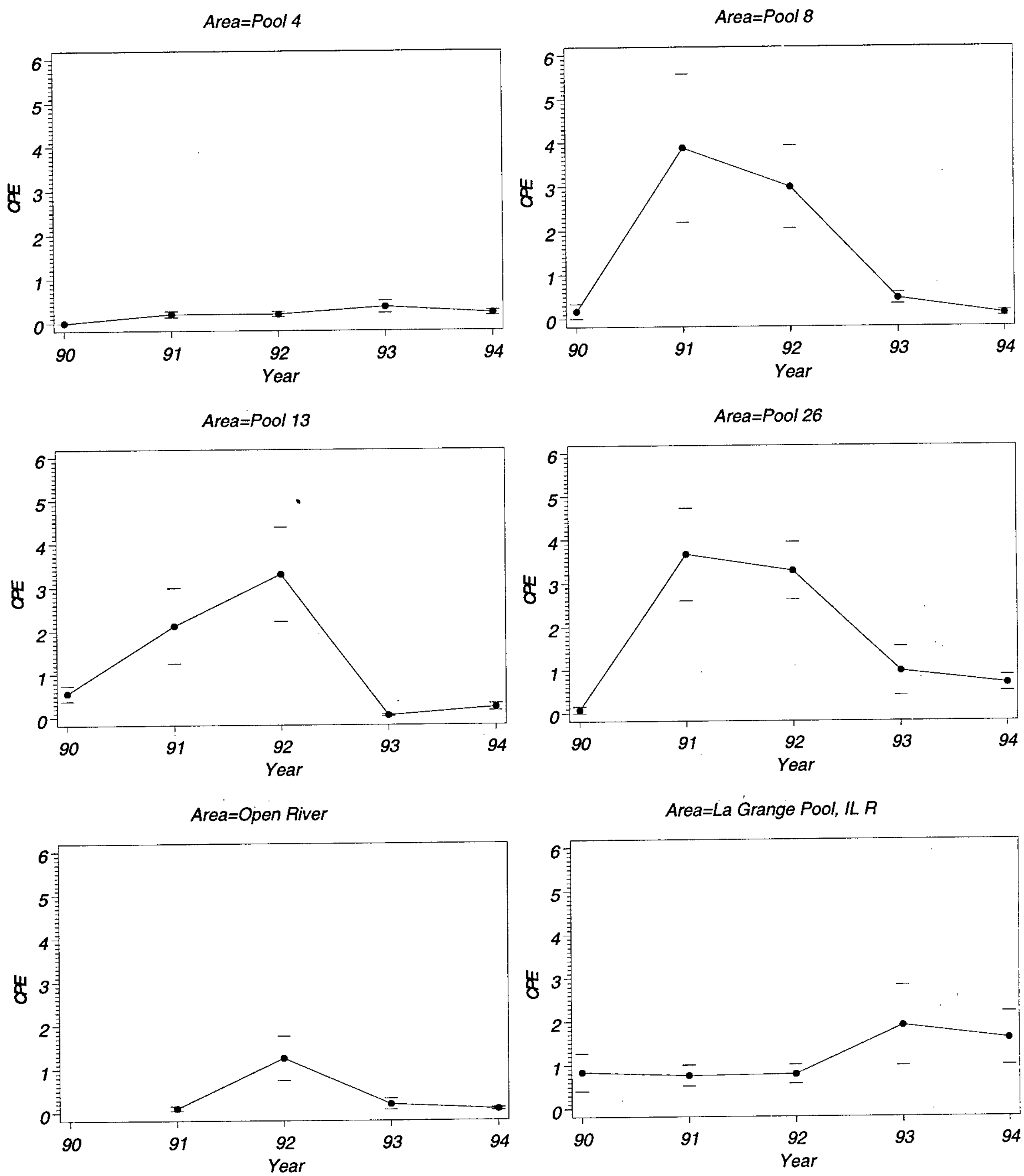

Figure 24. Trends in abundance of smallmouth buffalo (*Ictiobus bubalus*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from hoop netting. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

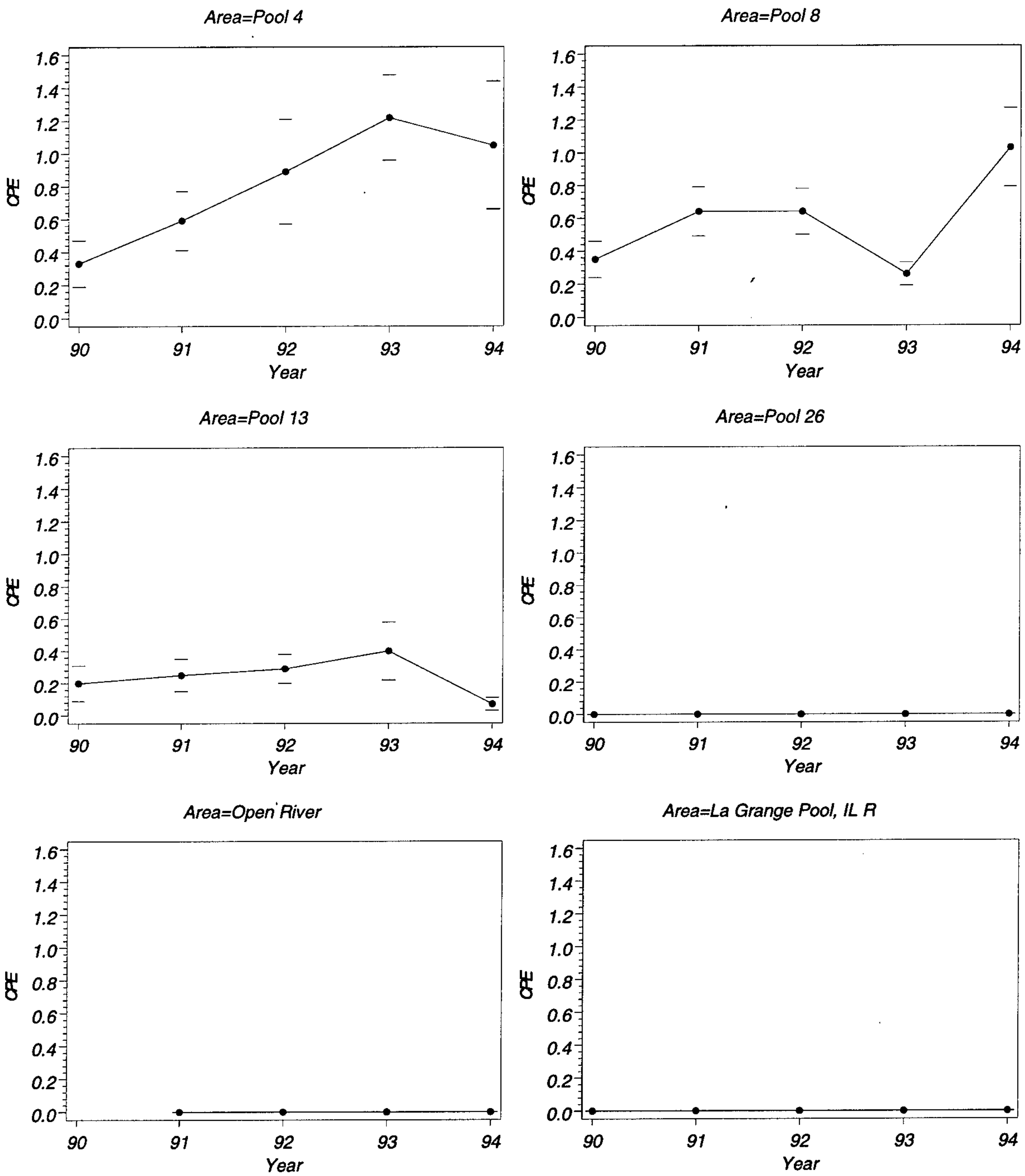

Figure 25. Trends in abundance of spotted suckers (*Minytrema melanops*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per 15 min) from day electrofishing. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

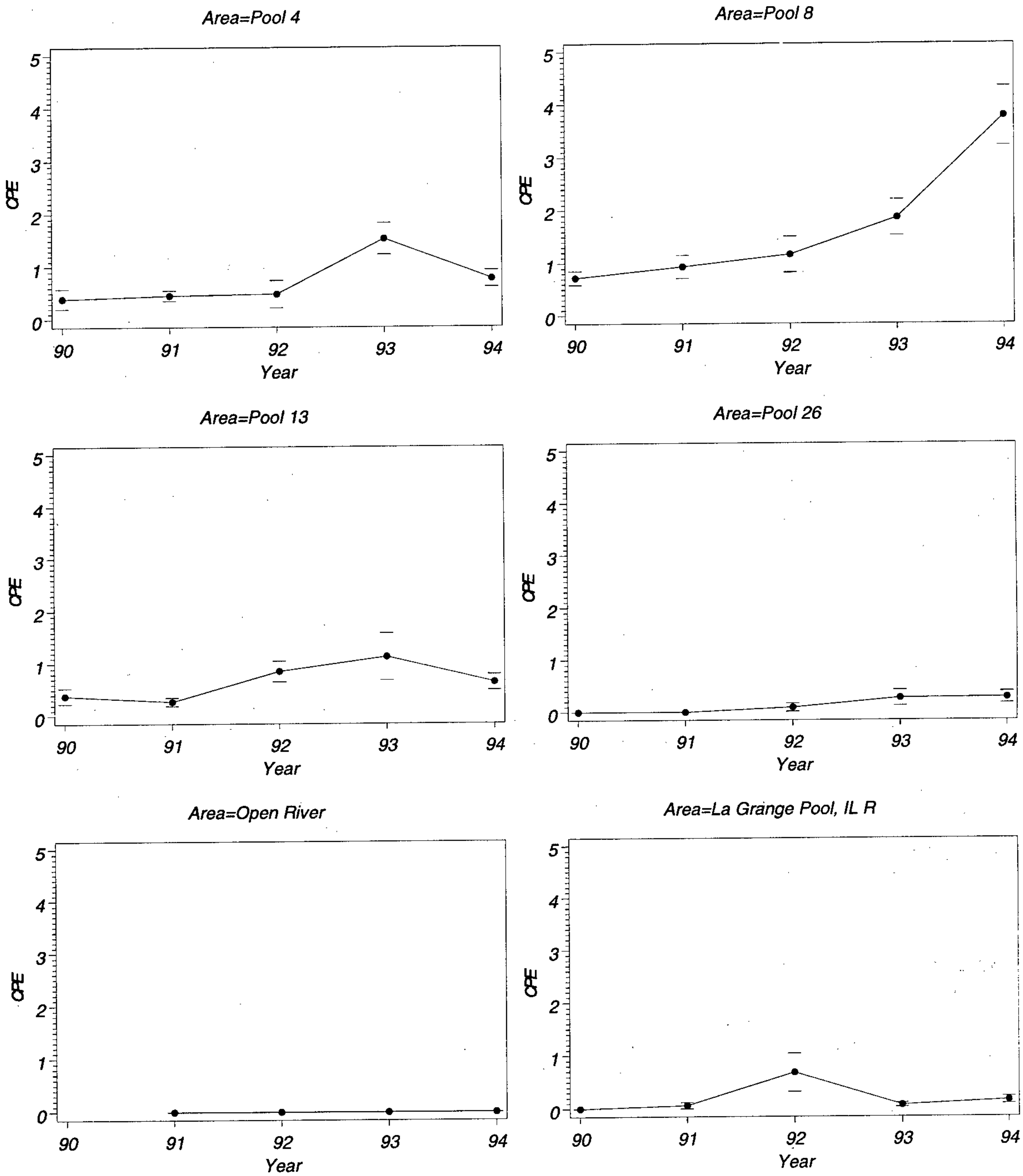

Figure 26. Trends in abundance of shorthead redhorse (*Moxostoma macrolepidotum)* as measured by mean catch-per-effort *CPE* ± 1 SE (fish per 15 min) from day electrofishing. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

trends among study reaches ($P = 0.82$). However, mean overall abundance of channel catfish, as measured by day electrofishing, differed significantly among study reaches ($P = 0.03$). Channel catfish were captured by day electrofishing at much higher rates from Pool 26 and the La Grange Pool than from the other study reaches (Figure 27). Day electrofishing is not a particularly effective method for the capture of benthic fishes such as channel catfish (Reynolds 1983). Commercial fishers use hoop nets, basket trap, and trot lines to capture channel catfish (Starrett and Barnikol 1955). The abundance of channel catfish, as measured by mean *CPE* from hoop netting, also showed no statistically significant LTRMP-wide linear trend ($P = 0.30$) nor did linear trends differ among study reaches ($P = 0.32$). However, the overall mean abundance of channel catfish from hoop netting showed marginally significant differences among study reaches ($P = 0.07$). Like the data from day electrofishing, the mean *CPE* of channel catfish tended to be greatest from Pool 26 and the La Grange Pool, and with the exception of Pool 26, the apparent trend patterns in mean *CPE* from day electrofishing (Figure 27) and hoop netting (Figure 28) were qualitatively similar. The LTRMP hoop netting data evoked some controversy at the fall 1995 meeting of the Upper Mississippi River Conservation Committee Fish Technical Section (Tim Schlagenhaft, Minnesota Department of Natural Resources, Lake City, Minnesota, personal communication). Some members of the Fish Technical Section reported recent increases in commercial harvest of channel catfish and increases in their own fixed-point (nonrandom) sampling. The switch from fixed-point to stratified random sampling by the LTRMP in 1993 may have induced spurious trends in the LTRMP data if the original fixed sites provided particularly favorable habitat for this species. Because some initial LTRMP hoop netting was intended to select for channel catfish, this effect cannot be precluded. Further, commercial fishers are highly successful in identifying those microhabitats from which catch may be maximized; therefore, catch series from commercial fishing might produce different trends than series from stratified random sampling. The qualitative agreement between the mean *CPE* statistics from day electrofishing and hoop netting suggests the LTRMP data may represent true patterns in reachwide abundance; however, given the importance of this species, this issue merits further study.

Flathead catfish (*Pylodictis olivaris*) inhabit rivers and streams of central North America from east-central Mexico north to east-central Minnesota (Pflieger 1975). Flathead catfish are an important top predator in rivers and are prized by commercial and recreational fishers. The abundance of flathead catfish, as measured by mean *CPE* from hoop netting, showed a statistically significant LTRMP-wide decreasing linear trend ($P < 0.01$), and differences in linear trends among LTRMP reaches were not detected ($P = 0.36$). Overall mean abundance of flathead catfish differed among study reaches ($P = 0.02$), and mean *CPE* values tended to be lower from Pool 4, near the northern range limit of this species, than from the other study reaches (Figure 29). The mean *CPE* values showed conspicuous nonlinear trends; in Pool 26, the data suggest the abundance reached a low in 1992 and has increased since (Figure 29).

The Pikes, Family Esocidae

Northern pike (*Esox lucius*) are an important recreational species in the northern United States and throughout most of Canada (Scott and Crossman 1973) and, in the Mississippi River, reach their southern range limit in Pool 26 where they are rare (Pflieger 1975). The abundance of northern pike, as measured by mean *CPE* from fyke netting, did not show a statistically significant LTRMP-wide linear trend ($P = 0.69$), nor were there significant differences in linear trends among study reaches ($P = 0.53$). The overall mean abundance of northern pike differed among study reaches ($P < 0.01$); this species was not detected from Pool 26 and is absent from the open river study reach (Figure 30). In rivers, northern pike are heavily dependent on cool vegetated backwaters, and among the LTRMP study reaches only Pools 4, 8, and 13 provide this habitat. Mean *CPE* of northern pike declined markedly from 1990 through 1994 in Pool 8 (Figure 30), and in this study reach alone a downward linear trend was significant (*t* test on the regression parameter; $P = 0.01$); this trend merits deeper inquiry.

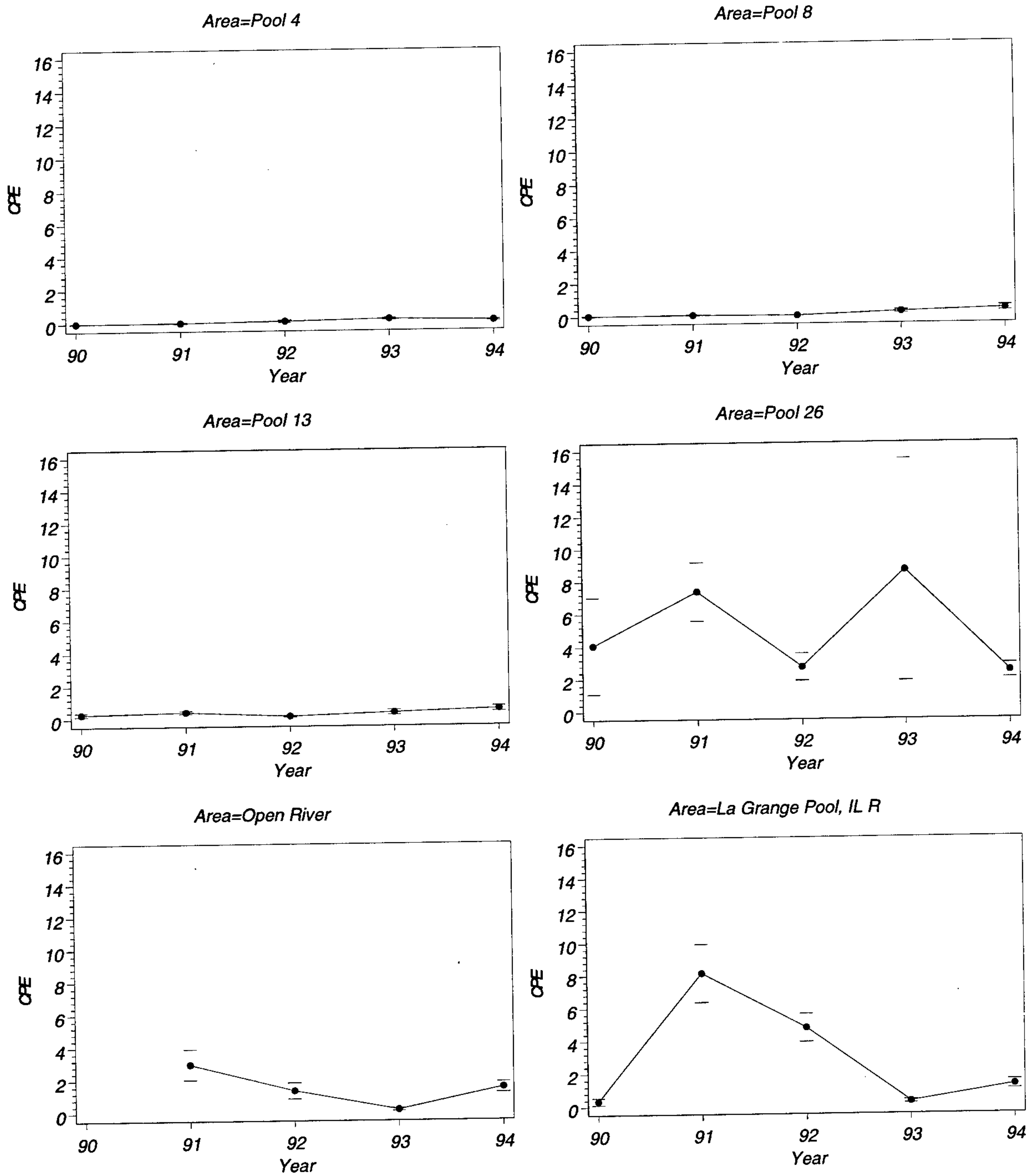

Figure 27. Trends in abundance of channel catfish (*Ictalurus punctatus*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per 15 min) from day electrofishing. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

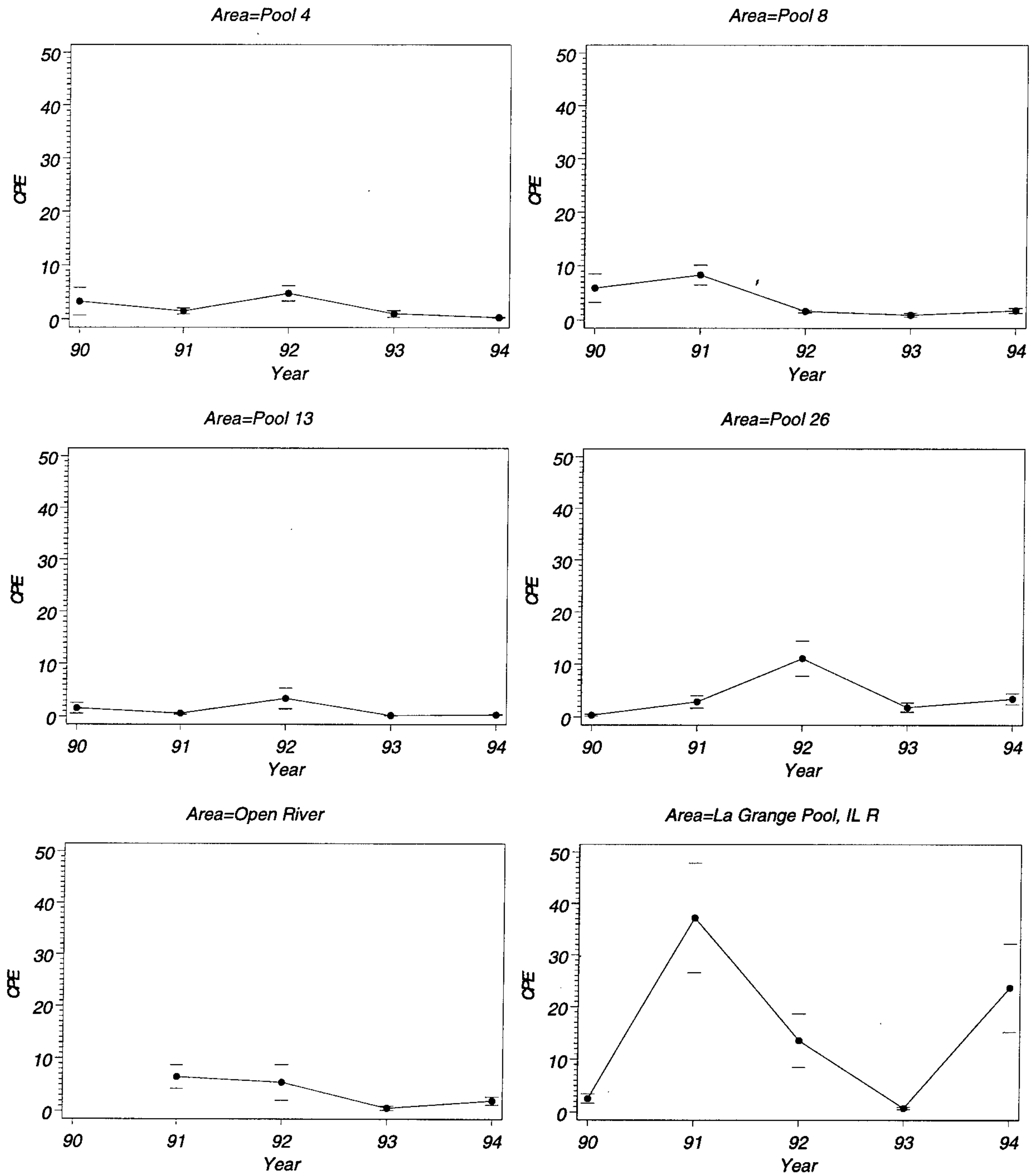

Figure 28. Trends in abundance of channel catfish (*Ictalurus punctatus)* as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from hoop netting. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

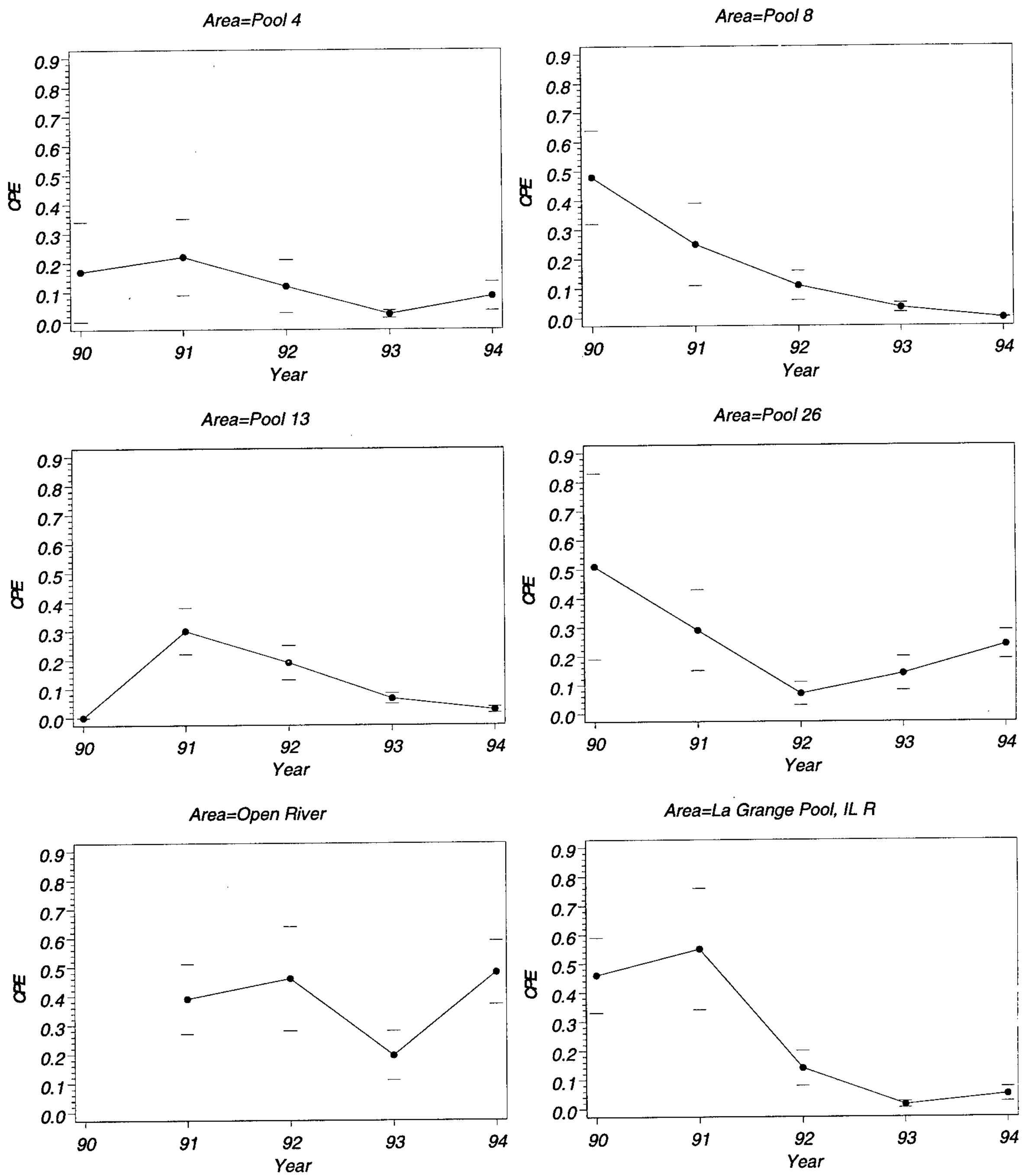

Figure 29. Trends in abundance of flathead catfish (*Pylodictis olivaris)* as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from hoop netting. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

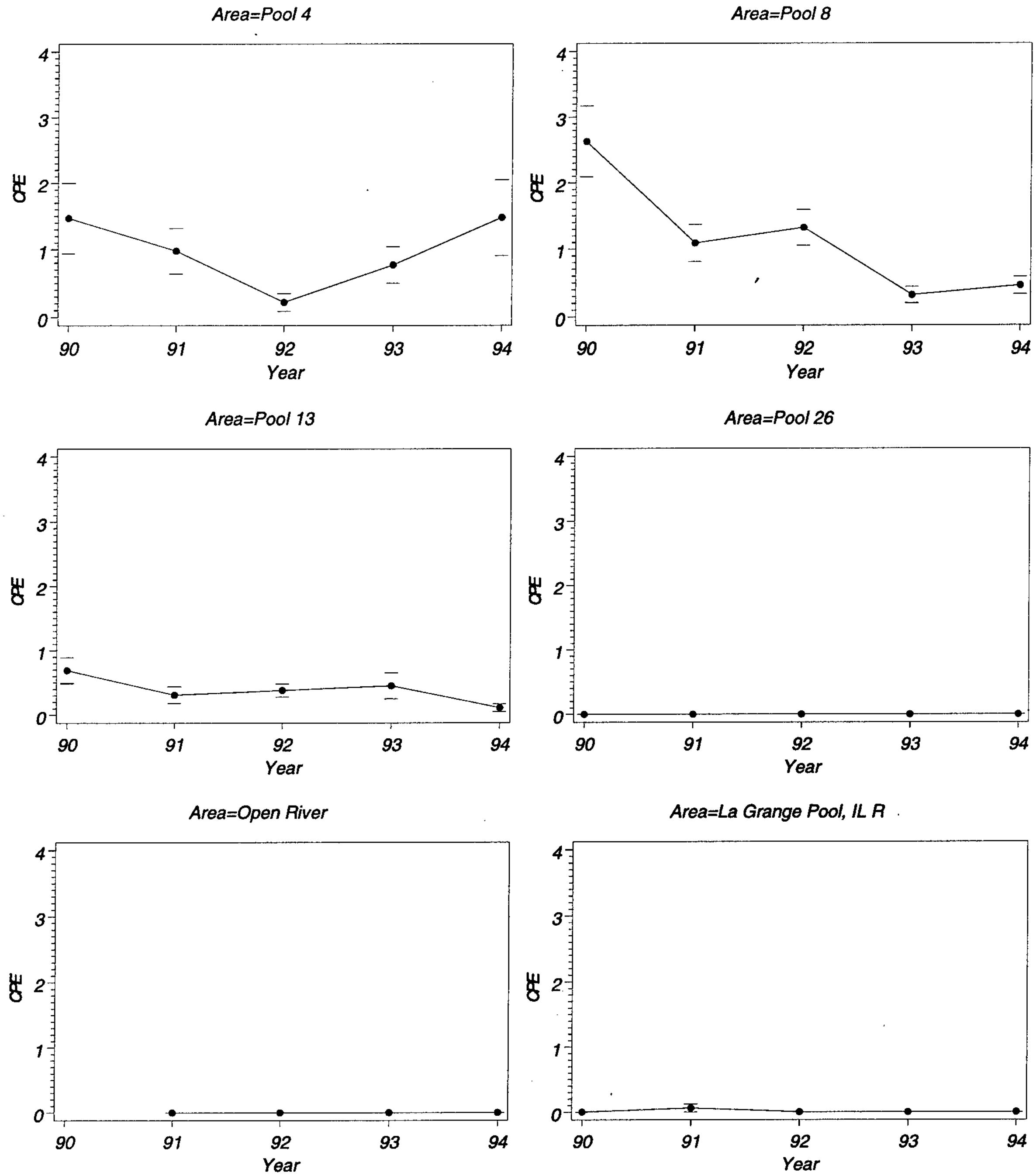

Figure 30. Trends in abundance of northern pike (*Esox lucius*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from fyke netting. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

Temperate basses, Family Percichthyidae

White bass (*Morone chrysops*) are a recreationally important schooling predator; in the Mississippi River drainage they occur from central Minnesota to the Gulf of Mexico (Scott and Crossman 1973; Pflieger 1975). The abundance of white bass, as measured by day electrofishing, showed no statistically significant LTRMP-wide linear trend ($P = 0.83$) or differences in linear trends among study reaches ($P = 0.91$). Overall mean abundance showed marginally significant differences among reaches ($P = 0.07$). The mean *CPE* of white bass in day electrofishing samples was greatest from the three southernmost reaches and least from Pool 4, which is near the northern range limit for this species (Figure 31). The abundance of primarily small white bass, as measured by mean *CPE* from mini-fyke netting, showed marginally statistically significant among-reach differences in linear trend ($P = 0.10$). Pools 4, 8, the open Mississippi River, and the La Grange Pool of the Illinois River showed a linear increase, although most of these trends were too slight to be of much practical importance (Figure 32). The overall mean abundance of small white bass, as measured by mini-fyke netting, differed significantly among study reaches ($P = 0.03$), and abundance tended to be lowest from the open river study reach (Figure 32). Patterns in relative abundance of juvenile white bass, as measured by seining (Figure 33), were qualitatively similar to patterns in mini-fyke netting. The abundance of juvenile white bass, as measured by seining, showed no significant among-reach differences in linear trend ($P = 0.48$). The mean overall abundance showed marginally significant among-reach differences ($P = 0.10$). Both the mini-fyke net data (Figure 32) and the seine data (Figure 33) indicate that large year classes were produced in the La Grange Pool in 1993 and in Pool 4 in 1994.

The Sunfishes, Family Centrarchidae

The bluegill (*Lepomis macrochirus*) is a common species in backwaters and other low-flow areas of the UMRS (Pflieger 1975). The bluegill is native to eastern North America from far southern Canada to the Gulf of Mexico (Scott and Crossman 1973; Pflieger 1975) and supports important recreational fisheries throughout its range. Although this species is often abundant in glacial lakes and reservoirs, the limited fossil evidence suggests that bluegills and other lepomids probably originated in Cenozoic floodplain drainage systems (Cavender 1986; Cross et al. 1986). The abundance of bluegills, as measured by mean *CPE* from day electrofishing, did not show a statistically significant LTRMP-wide linear trend ($P = 0.22$), nor were there statistically significant differences in linear trends among study reaches ($P = 0.28$). However, highly significant among-reach differences existed in overall mean abundance ($P = 0.01$). The mean *CPE* of bluegills from day electrofishing in Pool 26 and the open river study reach tended to less than one-third of the values from the other study reaches, and the greatest mean *CPE* occurred in the La Grange Pool (Figure 34). Fyke netting tends to select for large bluegills (Laarman and Ryckman 1982). The abundance of bluegills, as measured by fyke netting, did not show a statistically significant LTRMP-wide linear trend ($P = 0.84$), but statistically significant linear trend differences among study reaches ($P = 0.01$) were detected. Like the day electrofishing data, overall mean abundance of bluegills from fyke netting differed significantly among study reaches ($P < 0.01$). The fyke netting data showed qualitatively similar patterns to the day electrofishing data, with the exception of mean *CPE* estimates from Pools 8 and 26 in 1990 (Figure 35). With the exception of the 1990 estimates from Pools 8 and 26, the day electrofishing (Figure 34) and fyke netting (Figure 35) series are similar. Mean *CPE* estimates for bluegills from the open river reach, as measured by day electrofishing and fyke netting, were typically less than one-third of the values from the other study reaches. This pattern of abundance starkly contrasts with this species' natural range limit; the open river study reach is near the center of the natural range of this species and Pools 4 and 8 are near the northern range limit. All other factors being equal, greater abundance should be expected in the open river study reach than in the northern reaches. Peak abundance of bluegills was observed in the La Grange Pool, which has the greatest proportion of contiguous backwaters of the LTRMP study reaches. Day electrofishing is somewhat selective for adult bluegills, and fyke netting (Laarman and Ryckman 1982) is selective for the largest fish. Mini-fyke nets are highly selective for juvenile

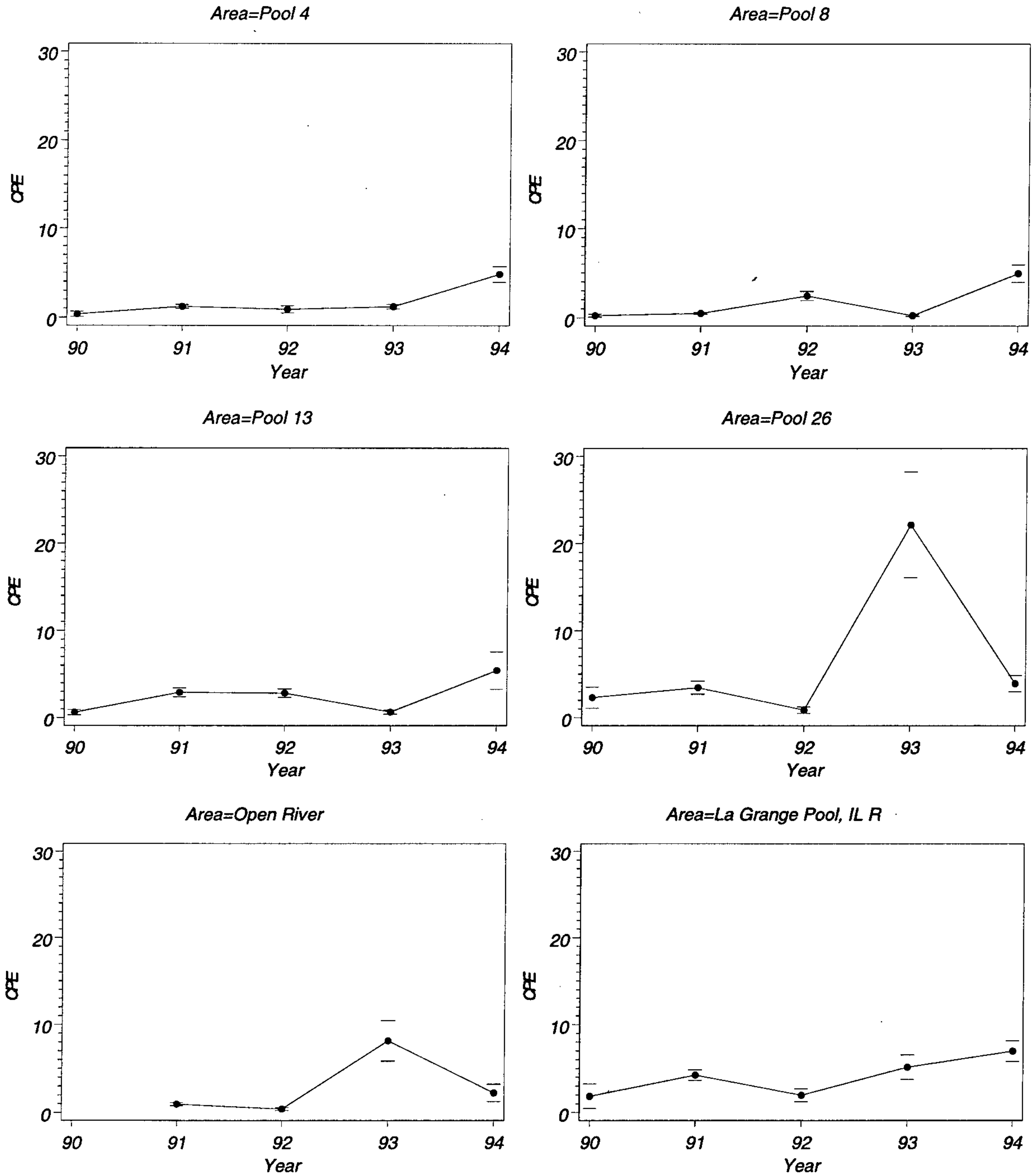

Figure 31. Trends in abundance of white bass (*Morone chrysops*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per 15 min) from day electrofishing. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

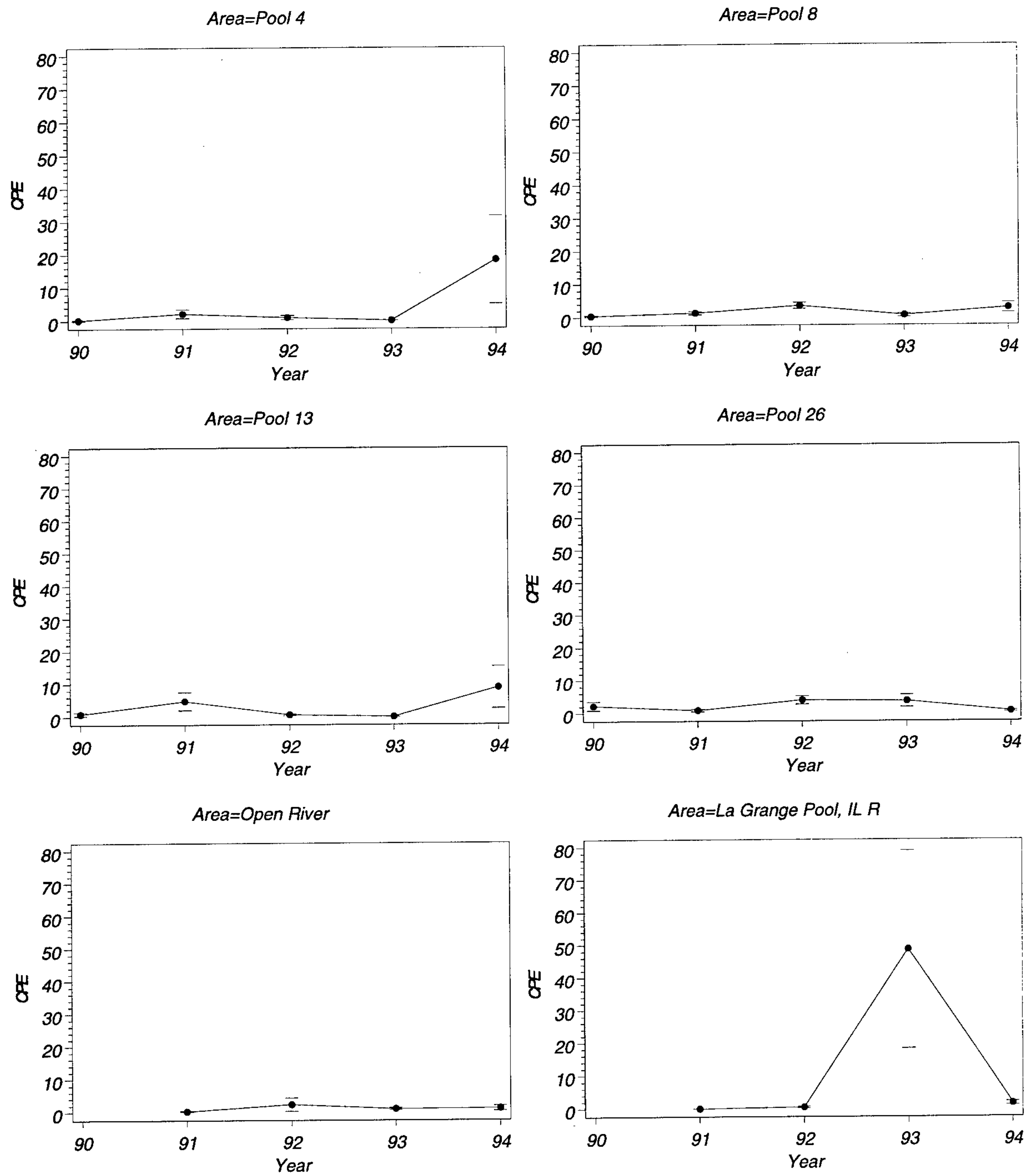

Figure 32. Trends in abundance of white bass (*Morone chrysops*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from mini-fyke netting. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

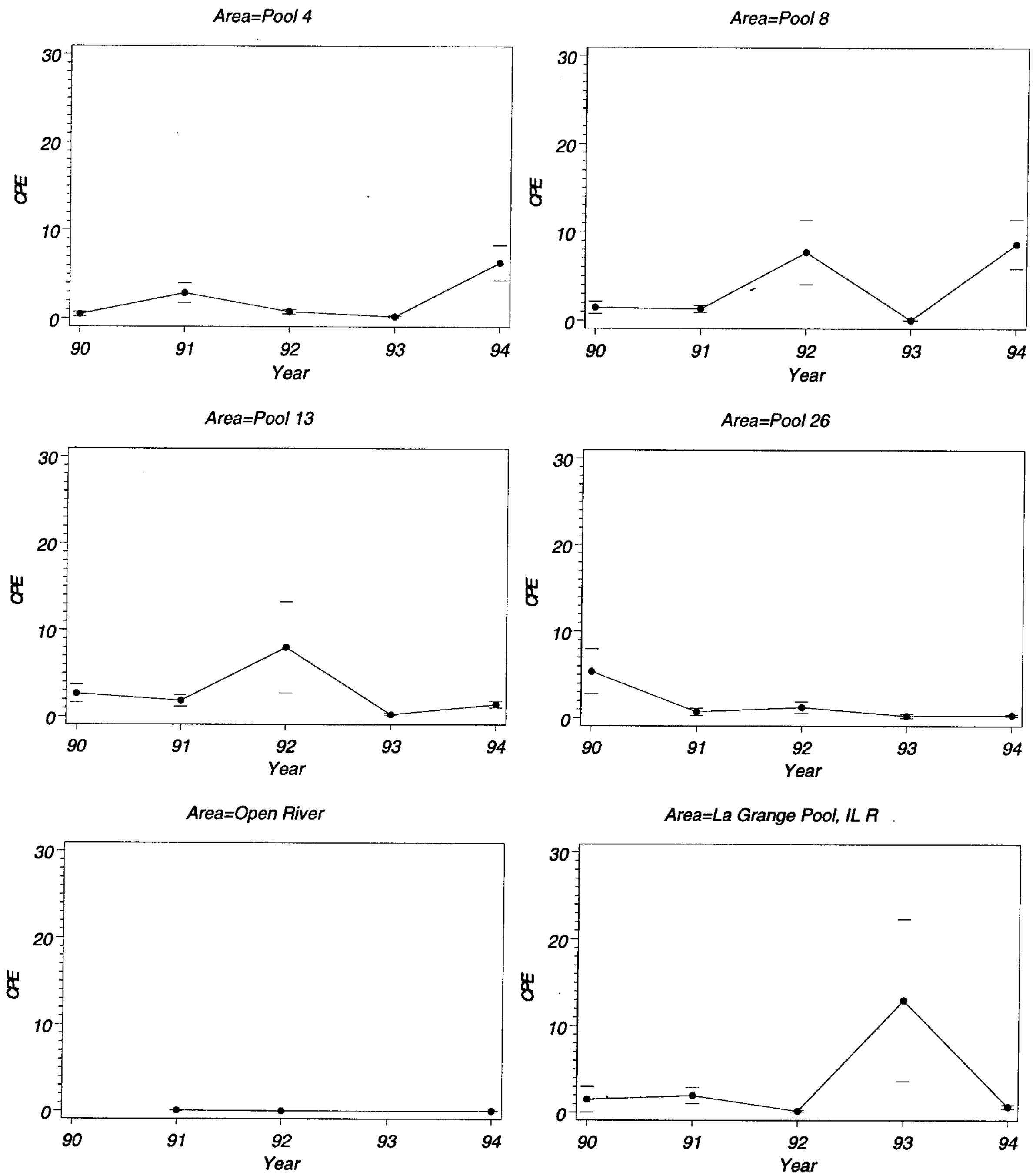

Figure 33. Trends in abundance of white bass (*Morone chrysops*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per haul) from seining. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

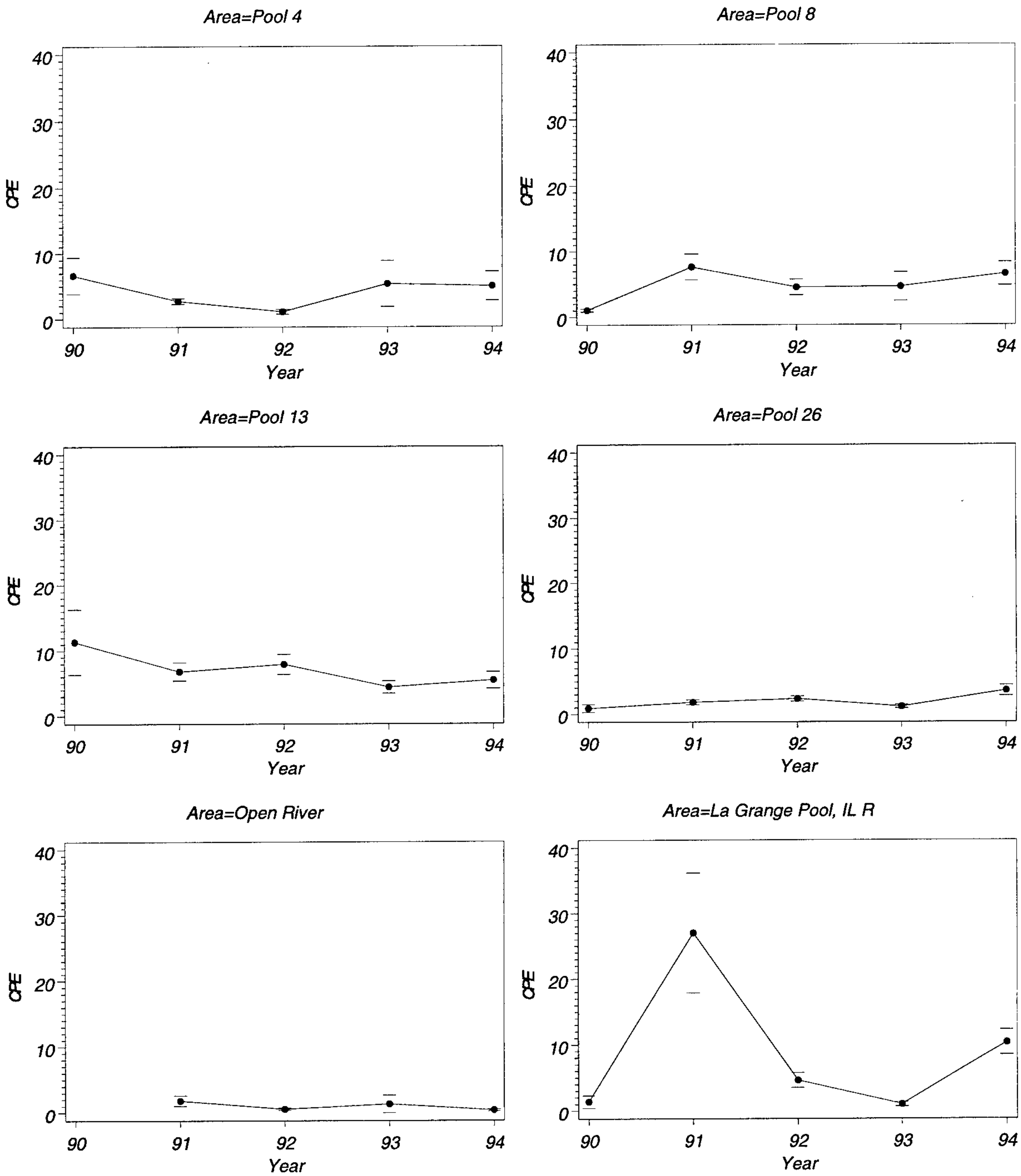

Figure 34. Trends in abundance of bluegill (*Lepomis macrochirus*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per 15 min) from day electrofishing. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

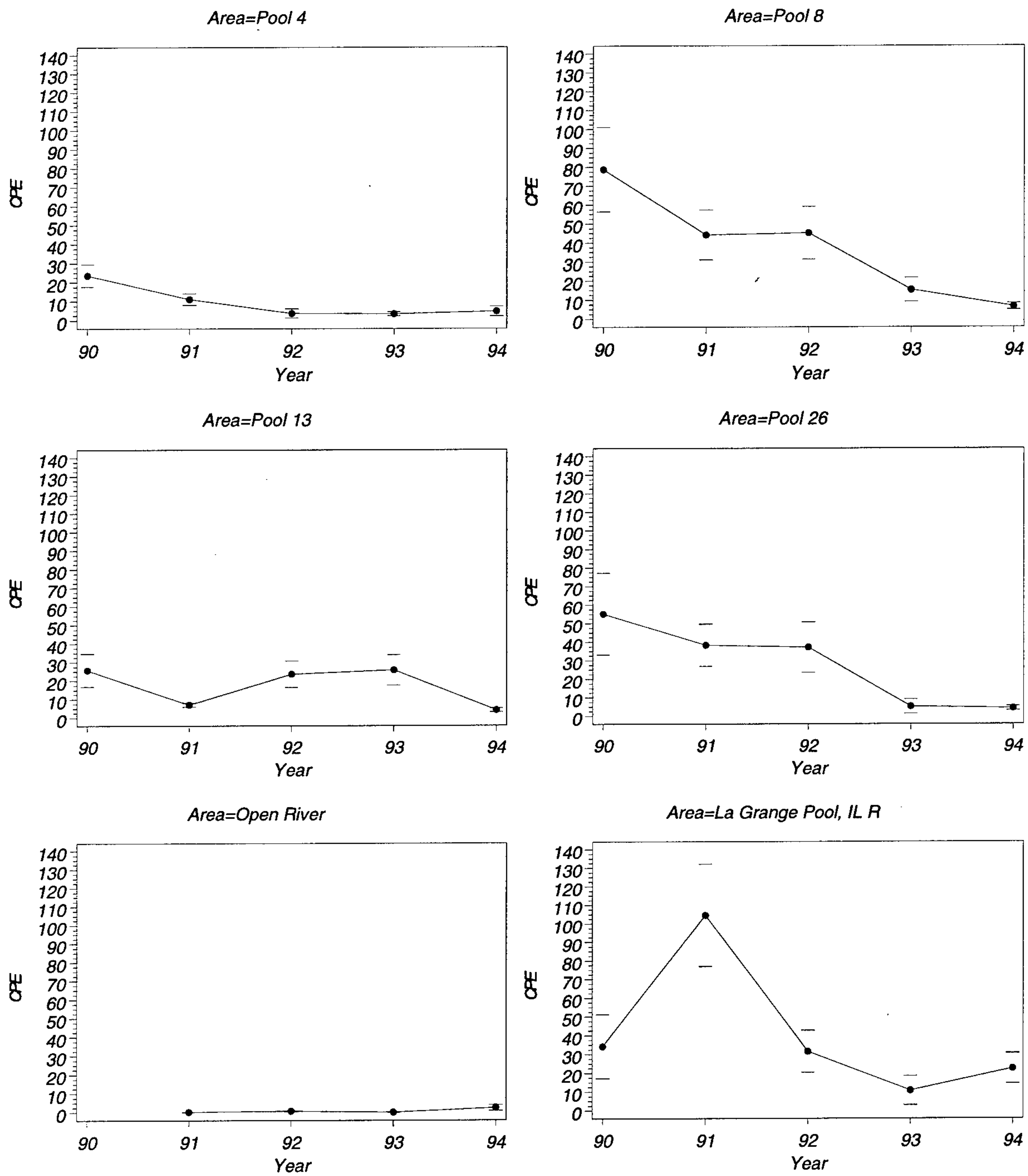

Figure 35. Trends in abundance of bluegill (*Lepomis macrochirus*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from fyke netting. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

bluegills. The abundance of primarily small bluegills, as measured by mini-fyke netting (Figure 36), did not show a statistically significant LTRMP-wide linear trend ($P = 0.57$) or among-reach differences in linear trends ($P = 0.63$). However, there was at least one marginally significant difference in mean overall abundances of primarily small bluegills among study reaches ($P = 0.11$). The mean *CPE* estimates of bluegills from mini-fyke nets tended to be lower from the open river study reach than the other study reaches. Taken together, the composition of aquatic areas (Table) and the day electrofishing, fyke netting, and mini-fyke netting data suggest that, in the open river study reach, abundance of this important species is limited by the availability of backwaters. The electrofishing data further suggest that backwater habitat might be limiting for bluegills in Pool 26.

The smallmouth bass (*Micropterus dolomieui*) is common in glacial lakes and rivers and streams from southern Canada through the Ozark Plateau of Arkansas and Missouri (Pflieger 1975). This species is highly prized by anglers throughout its range. In the Mississippi River, smallmouth bass are common only in the northernmost navigation pools. This species occupies channels and channel borders in summer, and may rely on areas of low current velocity in winter (Munther 1970). The abundance of smallmouth bass, as measured by day electrofishing, did not show a statistically significant LTRMP-wide linear trend ($P = 0.34$) or any among-reach differences in linear trends ($P = 0.45$). However, at least one marginally significant among-reach difference was detected in overall mean abundance ($P = 0.09$). The sample mean *CPE* estimates showed an increasing nonlinear trend in Pools 4 and 8 (Figure 37). The nonlinearity of this empirical trend might explain why a significant among-reach difference in linear trends was not detected. Smallmouth bass were not detected in Pool 26, the open river study reach, or the La Grange Pool (Figure 37).

The largemouth bass (*Micropterus salmoides*) is characteristic of low-flow areas—particularly backwaters—of rivers and has adapted well to reservoirs and warmer glacial lakes (Pflieger 1975). The largemouth bass is among the most valuable of recreationally sought species in North America. Although this recreational value has directed most scientific inquiry to reservoirs and glacial lakes, the largemouth bass is probably an evolutionary product of Pleistocene floodplain drainages (Cross et al. 1986). Although the natural range of this species extends from southeastern Canada to the Gulf of Mexico (Scott and Crossman 1973; Pflieger 1975), it has been successfully introduced elsewhere, including Brazil, Mexico, and Cuba. Pool 4 is near the northern range limit of this species. The abundance of largemouth bass, as measured by day electrofishing, showed no statistically significant LTRMP-wide linear trend ($P = 0.26$), nor were significant among-reach linear trend differences detected ($P = 0.51$). However, among-reach differences in overall mean abundance were highly significant ($P < 0.01$). Mean *CPE* values for largemouth bass were extremely low in the open river study reach, where contiguous backwaters are presently nonexistent (Table); among the LTRMP reaches mean *CPE* values showed peak abundance in the La Grange Pool, where the proportion of aquatic area composed of backwaters was greatest (Figure 38). The mean *CPE* of largemouth bass was about 2–3 times greater in Pools 8 and 13, where backwaters are common, than in Pool 26 (Figure 38) where backwaters are more scarce (Table). The abundance of juvenile largemouth bass, as measured by seining (Figure 39), showed a statistically significant LTRMP-wide declining linear trend ($P < 0.01$), and no among-reach differences in linear trend were detected ($P = 0.99$). Among-reach differences in overall mean abundance of juvenile largemouth bass were marginally significant ($P = 0.06$). Mean *CPE* values for juvenile largemouth bass tended to be extremely low in the open river study reach and Pool 26, where backwaters are scarce (Table), compared with those from the other LTRMP study reaches. The day electrofishing data and the seining data strongly suggest that floodplain composition has major effects on the distribution and abundance of largemouth bass, and hence on the recreational value of the UMRS.

The white crappie (*Pomoxis annularis*) is a common species in low-flow areas of low-gradient rivers and streams from central Minnesota south to the Gulf Coast and east to the Appalachians (Pflieger 1975). The white crappie is an important recreational species, particularly in reservoirs and natural lakes. White crappies prefer relatively deep (4 m or more), calm waters in summer months (Pflieger 1975) and, as judged by their

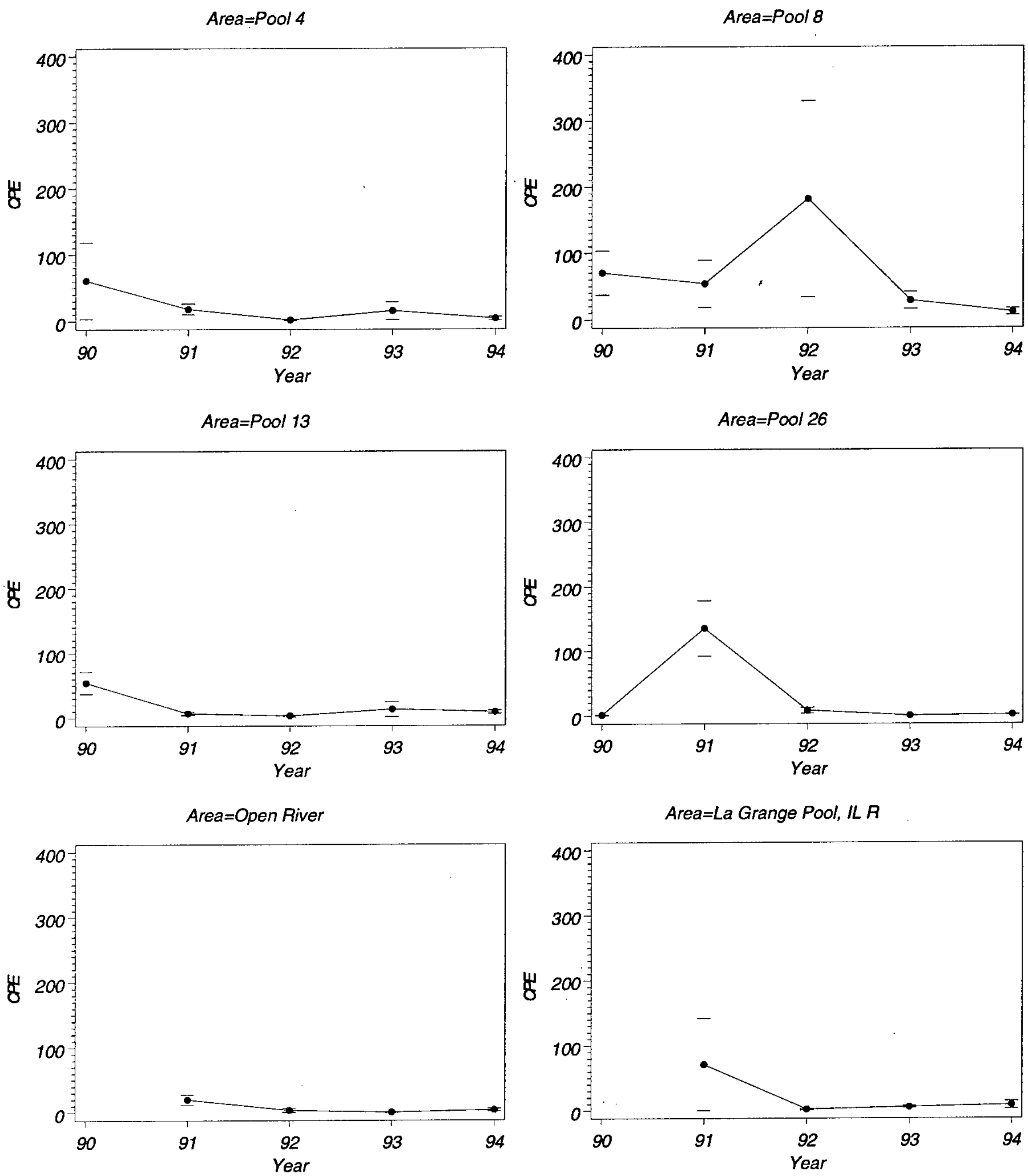

Figure 36. Trends in abundance of bluegill (*Lepomis macrochirus*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from mini-fyke netting. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

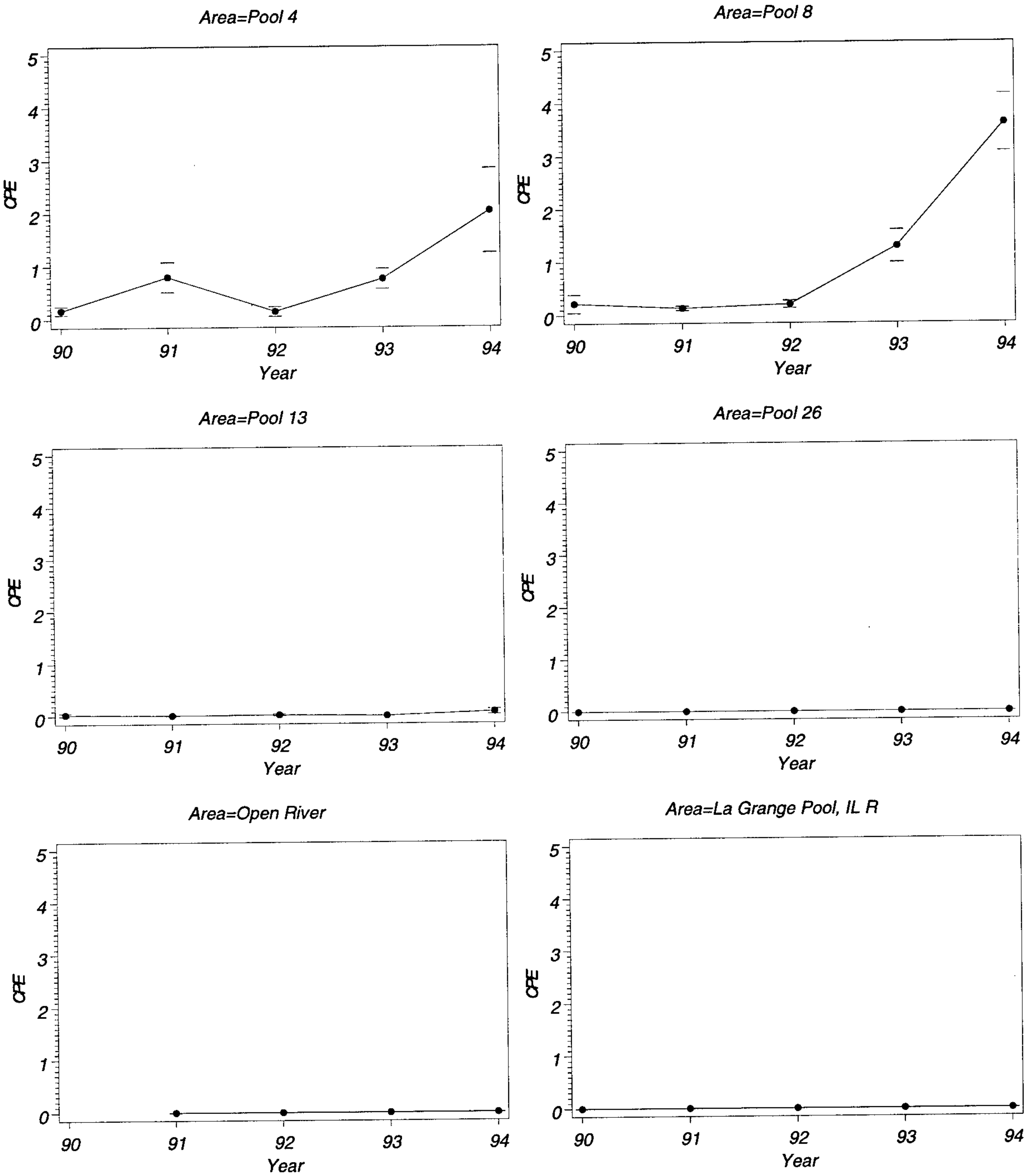

Figure 37. Trends in abundance of smallmouth bass (*Micropterus dolomieui*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per 15 min) from day electrofishing. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

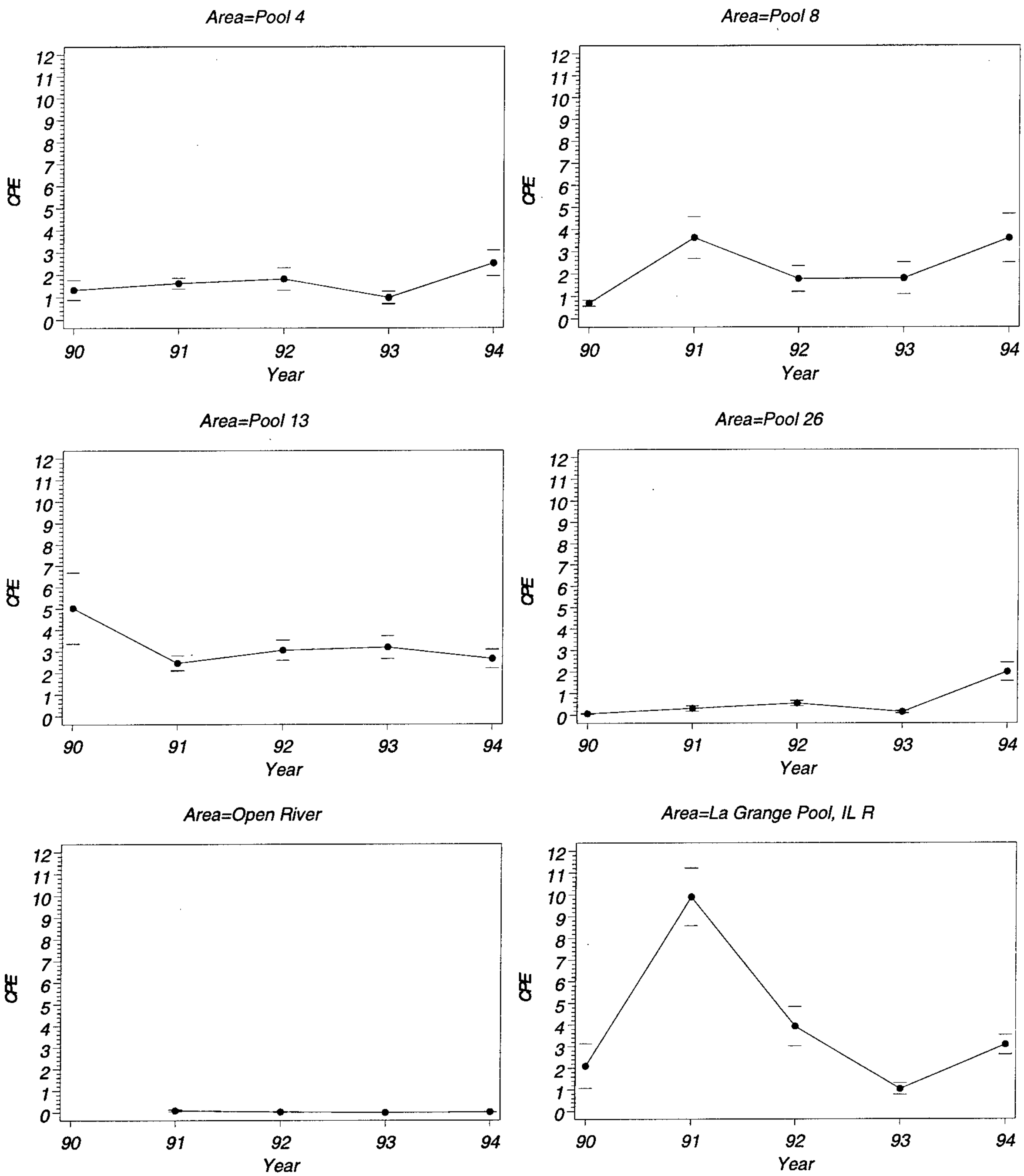

Figure 38. Trends in abundance of largemouth bass (*Micropterus salmoides*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per 15 min) from day electrofishing. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

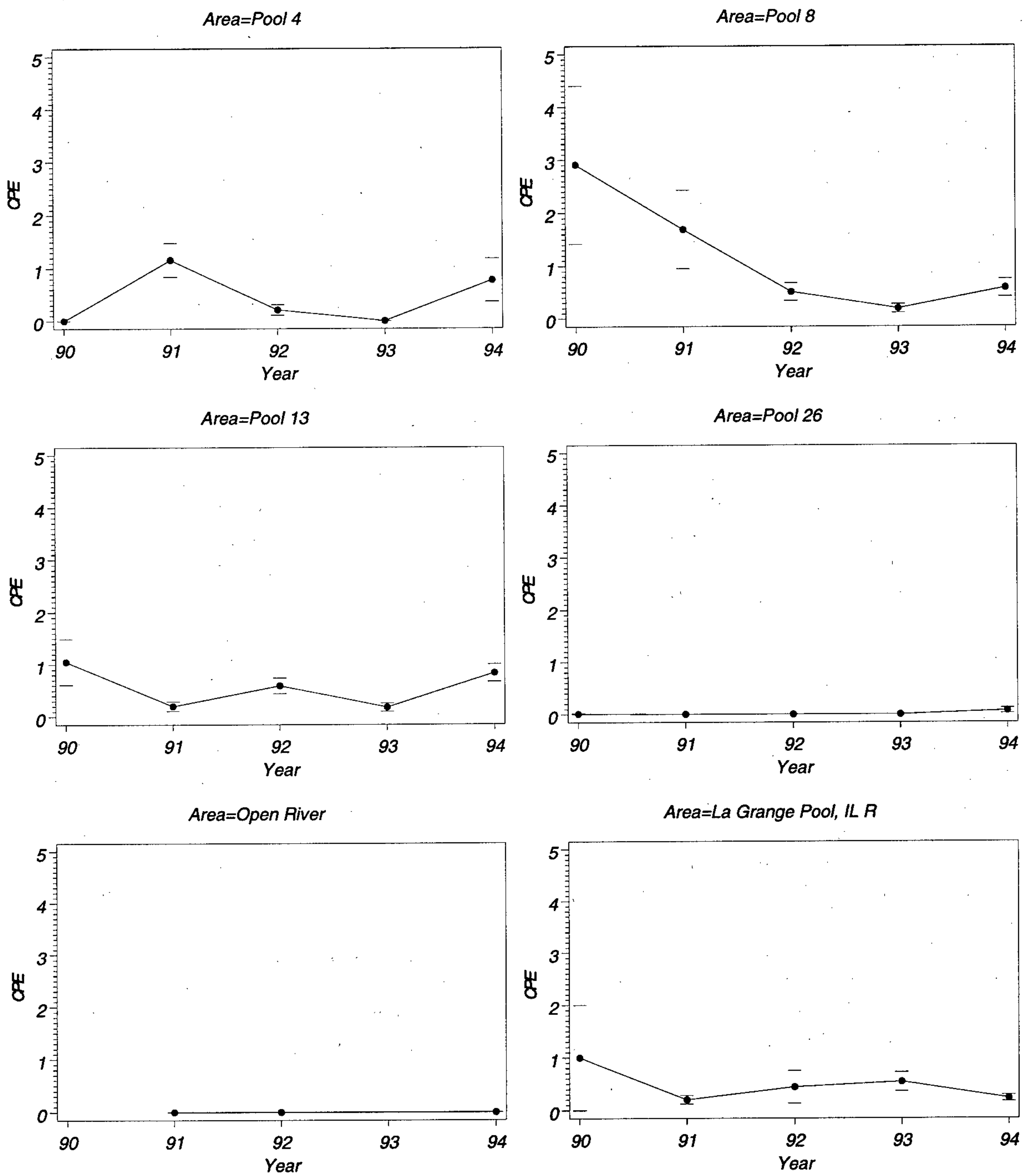

Figure 39. Trends in abundance of primarily small largemouth bass (*Micropterus salmoides*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per haul) from seining. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

similarities to the black crappie (*Pomoxis nigromaculatus*), may require relatively warm, calm water for overwinter survival (Sheehan et al. 1990). The abundance of white crappies, as measured by fyke netting, showed a statistically significant LTRMP-wide decreasing linear trend ($P = 0.01$), and showed marginally significant ($P = 0.13$) among-reach differences in linear trends. Overall mean abundance, regardless of trend, differed significantly among LTRMP study reaches ($P = 0.01$). Mean *CPE* values of white crappies captured by fyke netting tended to be lower in Pool 4 near the northern range limit of this species and in the open river study reach, where backwaters are scarce (Table), than in the other study reaches (Figure 40). Peak values of mean *CPE* were observed from the La Grange Pool, which has the greatest fraction of backwaters among LTRMP study reaches. The declining linear trend was most apparent from Pools 8 and 26 (Figure 40). The abundance of primarily small white crappies, as measured by mini-fyke netting, showed a statistically significant decreasing linear trend ($P < 0.01$), but among-reach differences in linear trend were not detected ($P = 0.64$). However, given the nonlinear patterns in the estimates of mean *CPE* (Figure 41) and the small trend slope, the practical importance of this trend is doubtful. Among-reach differences in the abundance of small white crappies were not apparent ($P = 0.38$). The occurrence of relatively high mean *CPE* values for small white crappies in the open river study reach (Figure 41) is noteworthy given the extremely low abundance of larger, older fish (Figure 40). This may indicate poor survival of white crappies in the open river study reach. Taken together, the fyke netting and mini-fyke netting data suggest that white crappies may be limited by habitat in the open river study reach where backwaters are scarce.

The black crappie (*Pomoxis nigromaculatus*) is largely similar to the white crappie in distribution, ecology, and recreational importance. However, black crappies are less tolerant of turbidity and sediment deposition (Pflieger 1975). Black crappies require relatively warm, calm water for overwinter survival because the swimming ability of this species is extremely limited at temperatures as low as 4° C (Sheehan et al. 1990). The abundance of black crappies, as measured by fyke netting, did not show a statistically significant LTRMP-wide linear trend ($P = 0.21$). However, overall mean abundance, regardless of trend, differed significantly among the LTRMP study reaches ($P < 0.01$). Mean *CPE* estimates tended to be lower from Pool 4 near the northern range limit and from Pool 26 and the open river study reaches (Figure 42), where backwaters are less prominent (Table). Like white crappies, black crappies were scarce in the open river study reach. Conversely, mean *CPE* estimates of black crappies from fyke netting reached peak values in Pool 8 and the La Grange Pool, where backwaters are most prominent among the LTRMP study reaches (Table). The abundance of primarily small black crappies, as measured by mini-fyke netting, showed a statistically significant LTRMP-wide increasing linear trend ($P = 0.01$), but among-reach linear trend differences were not detected ($P = 0.53$). Overall mean abundance, regardless of trend, showed marginally significant differences among LTRMP study reaches ($P < 0.11$). Although the LTRMP-wide linearly increasing trend was statistically significant, the effect was so slight (Figure 43) that the practical significance is doubtful. In fact, an apparent decline in mean *CPE* was evident in Pool 8 following the production of a particularly strong year class in 1991. Low mean *CPE* values of small black crappies were observed from Pool 4, Pool 13, and the open river study reach. Taken together, the fyke netting and mini-fyke netting data suggest that the abundance of black crappies may be limited by the availability of backwaters, particularly in the open river study reach.

The Perches, Family Percidae

The logperch (*Percina caprodes*) is the largest of the darters and is relatively unique among darters in its ability to persist in lakes and reservoirs (Pflieger 1975). Logperch occur from southeastern Canada to the Gulf of Mexico and east to the Florida peninsula. Logperch have been documented from all portions of the UMRS sampled by the LTRMP. The abundance of logperch, as measured by seining, did not show a statistically significant LTRMP-wide linear trend ($P = 0.64$), nor were among-reach differences in linear trends ($P = 0.96$) or in overall mean abundance ($P = 0.72$) detected. However, sample mean *CPE* of logperch tended to be greater in Pools 4 and 8 than elsewhere (Figure 44).

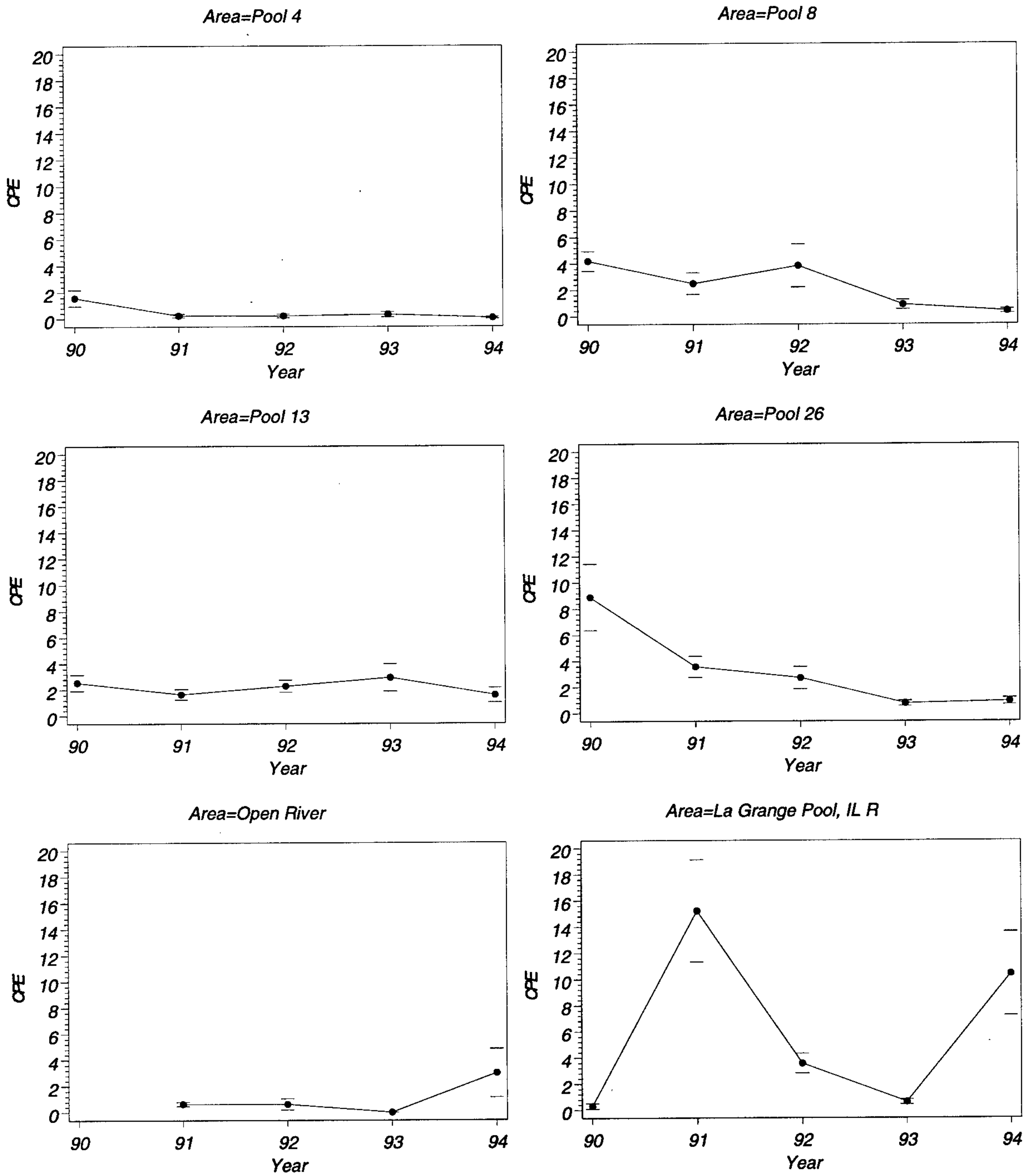

Figure 40. Trends in abundance of white crappie (*Pomoxis annularis*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from fyke netting. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

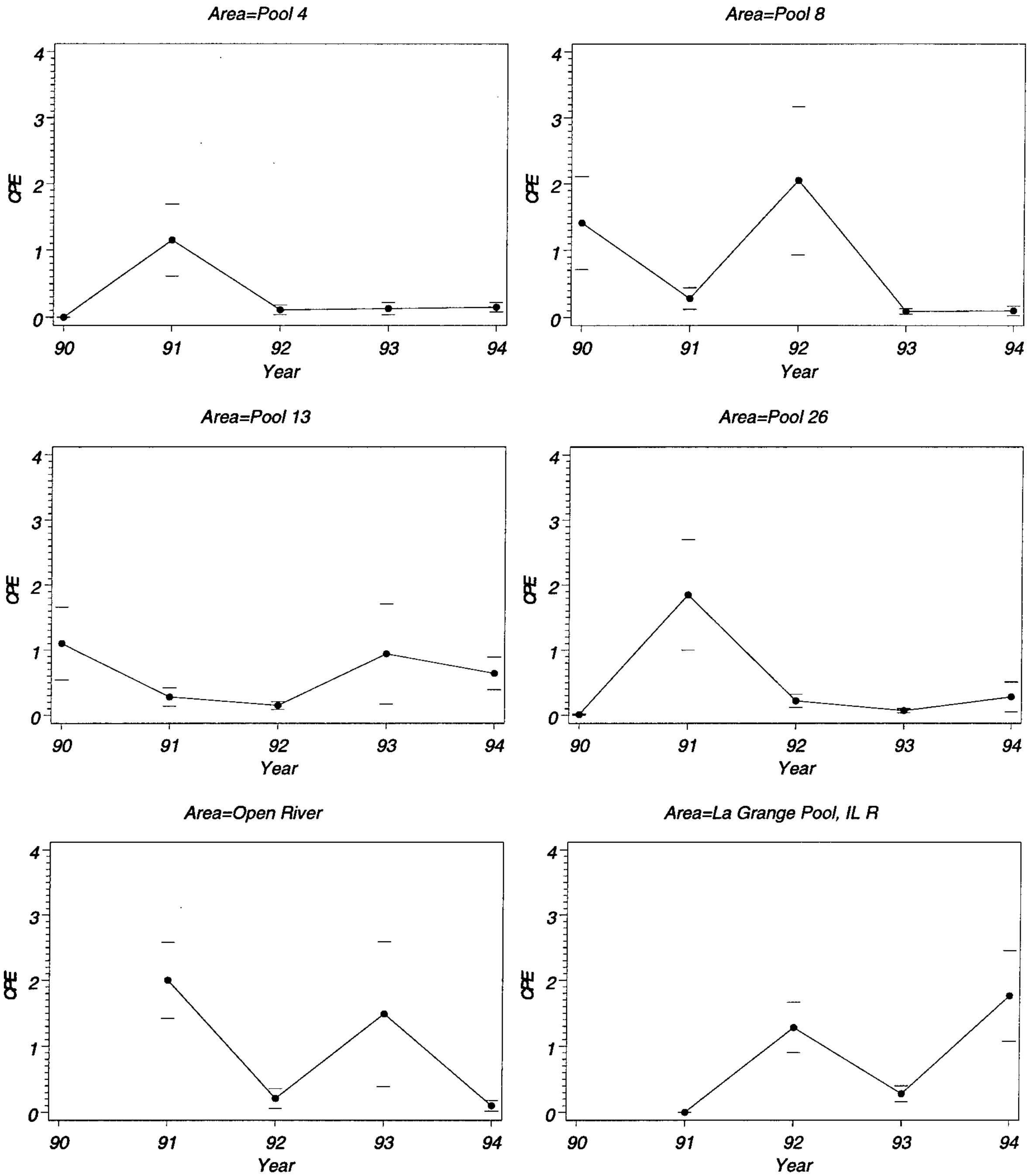

Figure 41. Trends in abundance of white crappie (*Pomoxis annularis*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from mini-fyke netting. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

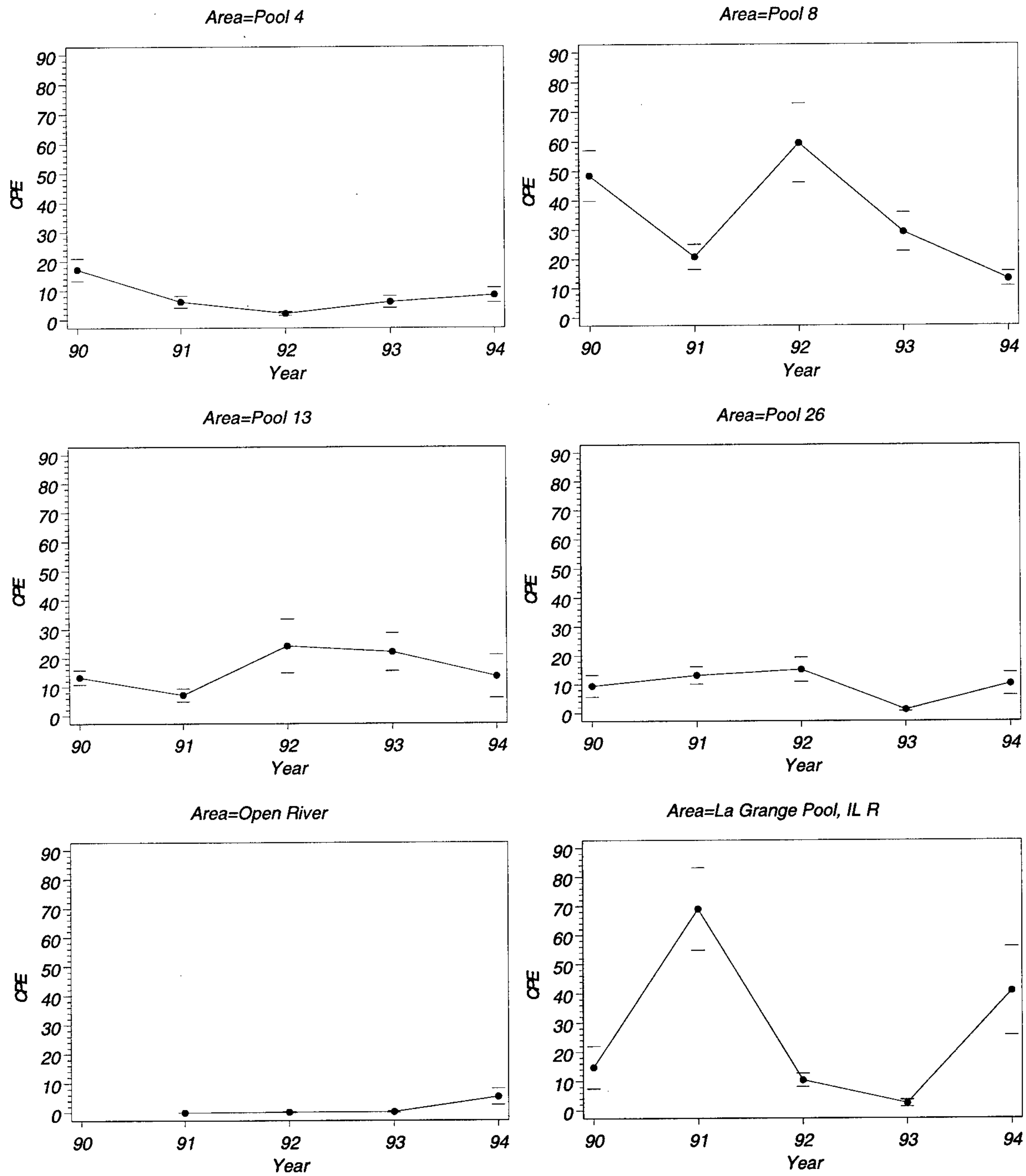

Figure 42. Trends in abundance of black crappie (*Pomoxis nigromaculatus*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from fyke netting. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

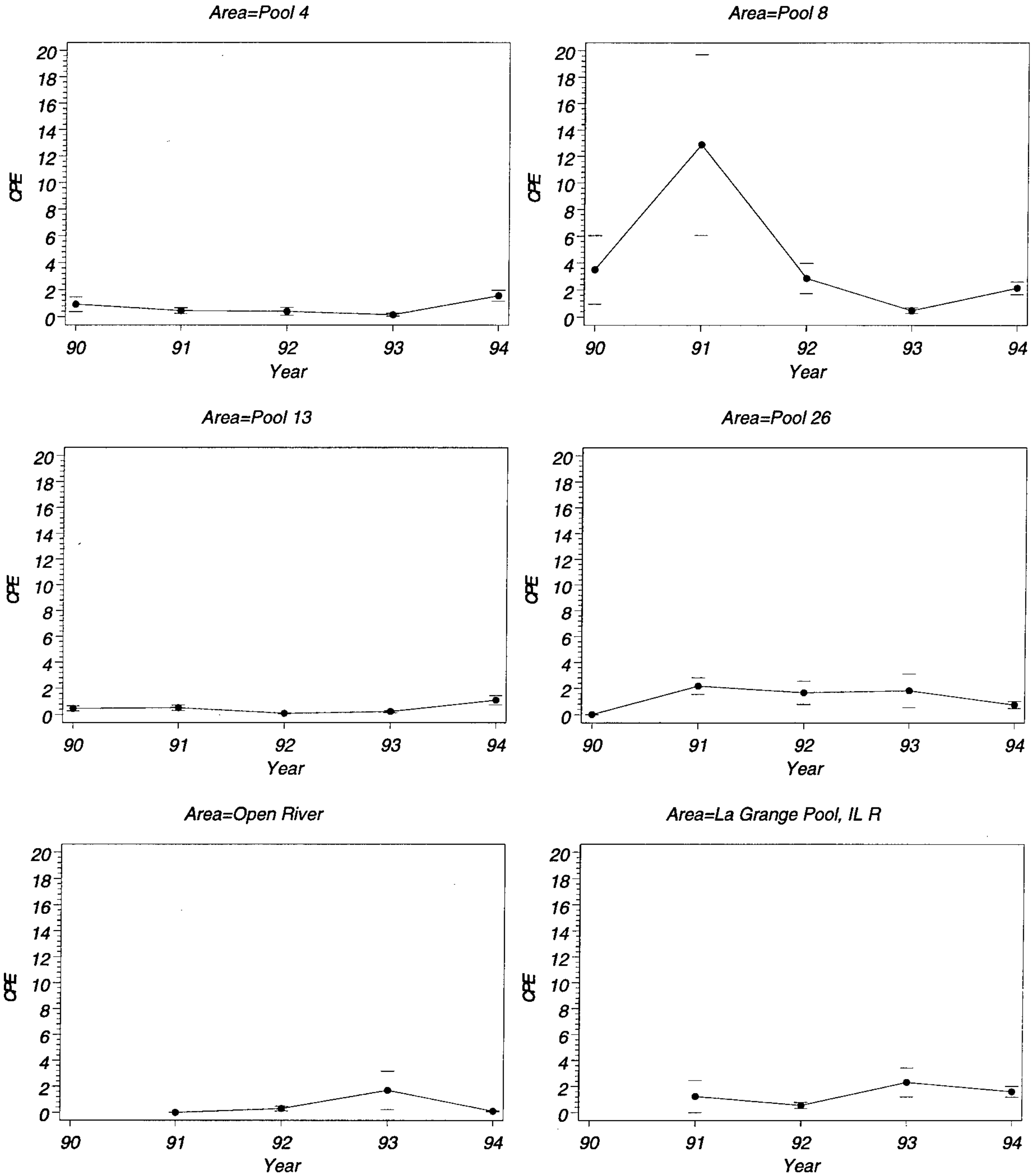

Figure 43. Trends in abundance of black crappie (*Pomoxis nigromaculatus*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per net-day) from mini-fyke netting. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

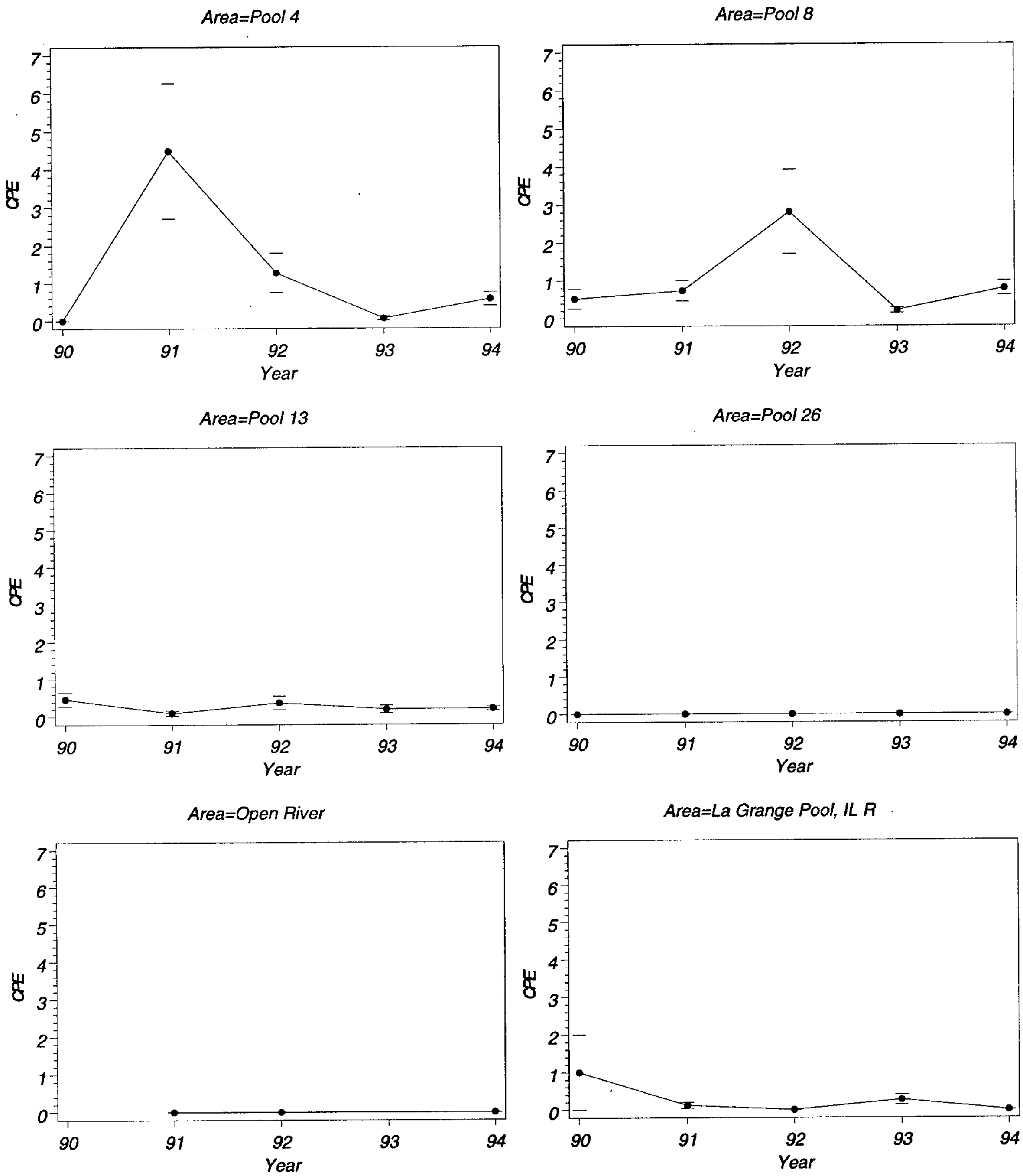

Figure 44. Trends in abundance of logperch (*Percina caprodes*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per haul) from seining. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

The sauger (*Stizostedion canadense*) is a distinctly riverine species that ranges from southern Canada through the greater Mississippi River drainage to the Gulf of Mexico (Pflieger 1975). Where this species is common, including large portions of the UMRS, it is prized by anglers. The larger walleye (*Stizostedion vitreum*) is less riverine and less tolerant of turbidity (Pflieger 1975); in the Mississippi River, it is restricted to the northern pools where it is also recreationally important. The abundance of sauger, as measured by day electrofishing, showed a highly significant LTRMP-wide linearly increasing trend ($P < 0.01$), and linear trends differed significantly among study reaches ($P = 0.01$). Mean overall abundance, regardless of trend, also differed among study reaches ($P = 0.01$). The trend of increasing abundance was apparent in all study reaches except the open river study reach (Figure 45). The magnitude of this increasing trend is large and should be of obvious practical importance.

The Drums, Family Scianidae

The freshwater drum (*Aplodinotus grunniens*) occurs from the Red River drainage of central Canada south to the Yucatan Peninsula of Mexico (Pflieger 1975). The drums are of marine origin, and the freshwater drum is the only species to extend into continental North American fresh waters (Scott and Crossman 1973). This species is abundant in the UMRS and is harvested both commercially and recreationally. The freshwater drum is unique among North American fishes in having molariform pharyngeal teeth on both the top and bottom of the pharynx, which gives this species the ability to crush and consume relatively large mollusks. Further, spawning and egg development occur in open water (Pflieger 1975). The abundance of freshwater drum, as measured by day electrofishing, showed a statistically significant LTRMP-wide linearly increasing trend ($P < 0.01$), and no significant among-reach differences in linear trends ($P = 0.46$) were detected. Overall mean abundance, regardless of trend, differed significantly among study reaches ($P = 0.05$). From a practical perspective, the increasing trend was slight and most apparent in Pools 8, 13, and 26 (Figure 46). Mean *CPE* estimates for freshwater drum were distinctly lower in the northern three study reaches than in the southern three reaches.

Uncommon and Exotic Species

The Lake sturgeon (*Acipenser fulvescens*) is one of the largest fish species in the UMRS, and has been documented as far south as the vicinity of the confluence with the Missouri River (Pflieger 1975). Since 1988, the Missouri Department of Conservation has stocked approximately 80,000 lake sturgeon in Pool 24 (Kenneth L. Brummett, Missouri Department of Conservation, personal communication). During the first 5 years of fish monitoring by the LTRMP, lake sturgeon were detected from Pools 4, 13, and 26 of the Upper Mississippi River (Figure 47). The lack of detection of lake sturgeon elsewhere does not mean this species was absent. These data indicate that lake sturgeon are present in the Mississippi River above the confluence of the Missouri River, but there is no evidence of trends in catches of lake sturgeon.

The shovelnose sturgeon (*Scaphirhynchus platorynchus*) is a characteristic species of the channels of large North American rivers. This species has been documented from the upper reaches of the Mississippi, Missouri, and Ohio Rivers downstream to the Gulf of Mexico (Pflieger 1975). The shovelnose sturgeon is far more abundant than the larger lake sturgeon, but is still a minor component of commercial and recreational landings. Shovelnose sturgeon were detected in all study reaches except the La Grange Pool of the Illinois River (Figure 48). Although there was an apparent 5-year increase in the catches of shovelnose sturgeon from Pools 4, 8, 13, and 26 of the Upper Mississippi River and a drop in catches during 1993 from Pools 13, 26, and the open river study reach, it is likely that changes in total sampling effort explain some of these trends. Total LTRMP fish sampling effort increased from 1990 through 1993, and effort in the more southerly study

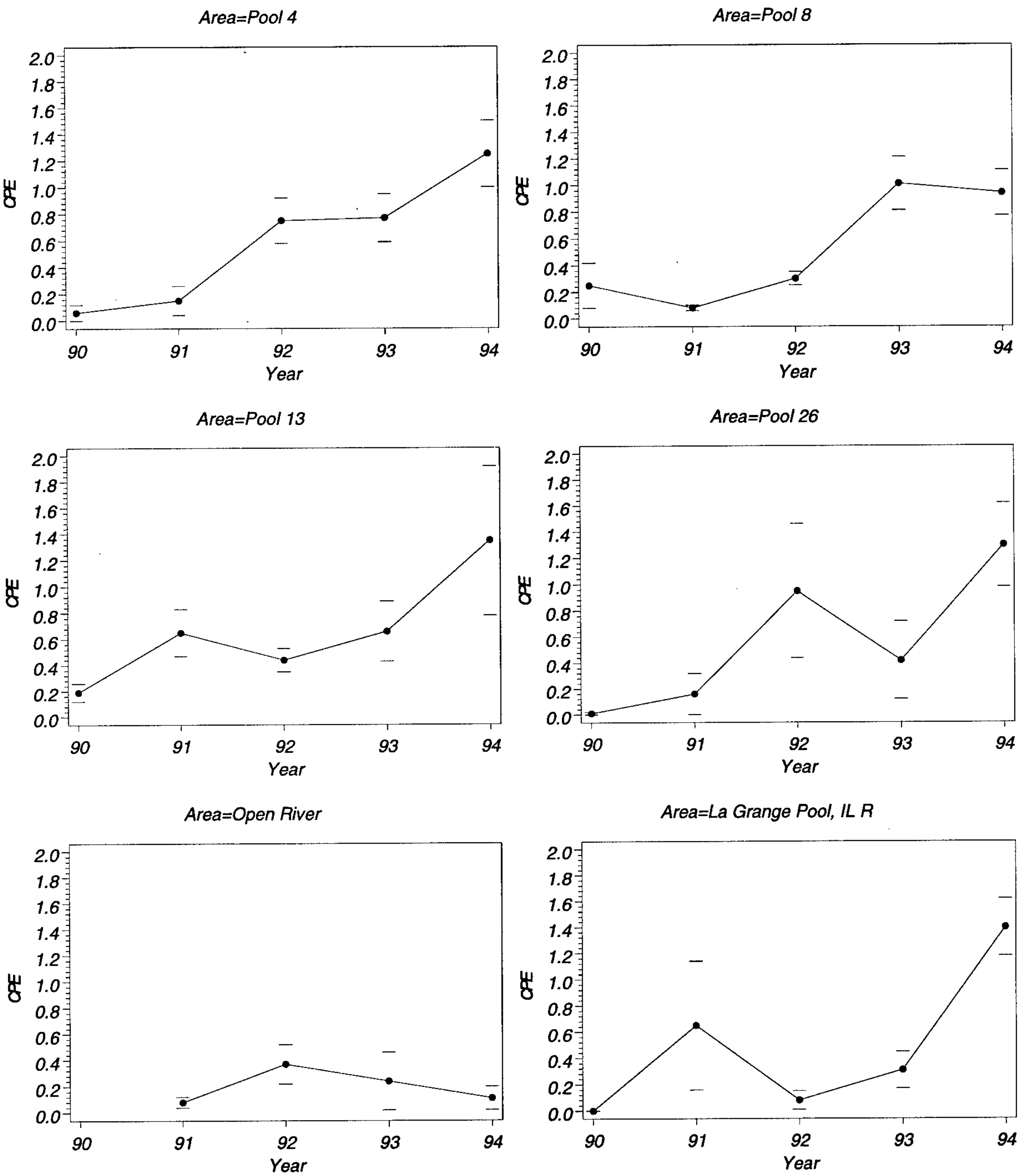

Figure 45. Trends in abundance of sauger (*Stizostedion canadense*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per 15 min) from day electrofishing. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

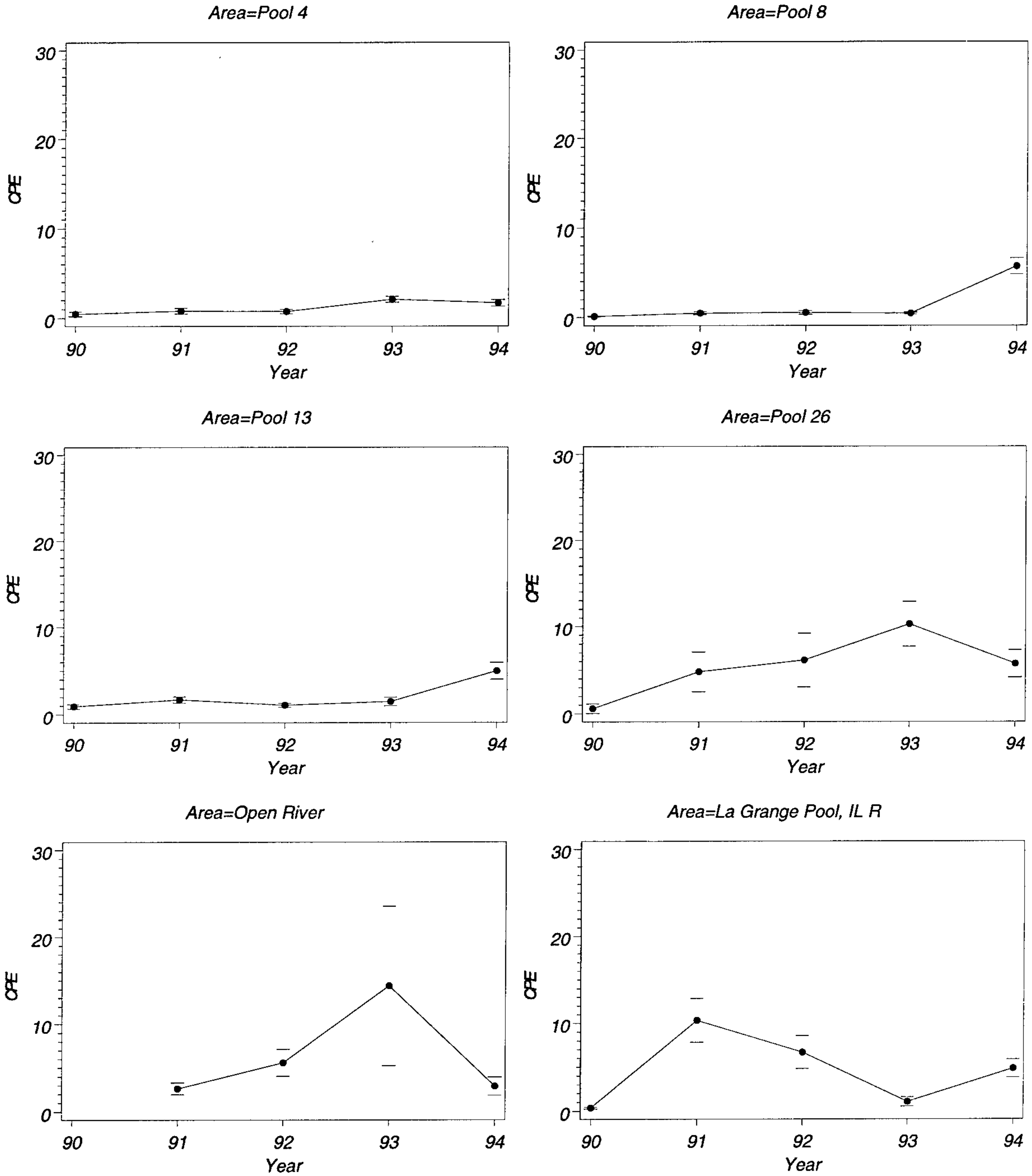

Figure 46. Trends in abundance of freshwater drum (*Aplodinotus grunniens*) as measured by mean catch-per-effort *CPE* ± 1 SE (fish per 15 min) from day electrofishing. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993; see text for assumptions necessary for interpretation of trends.

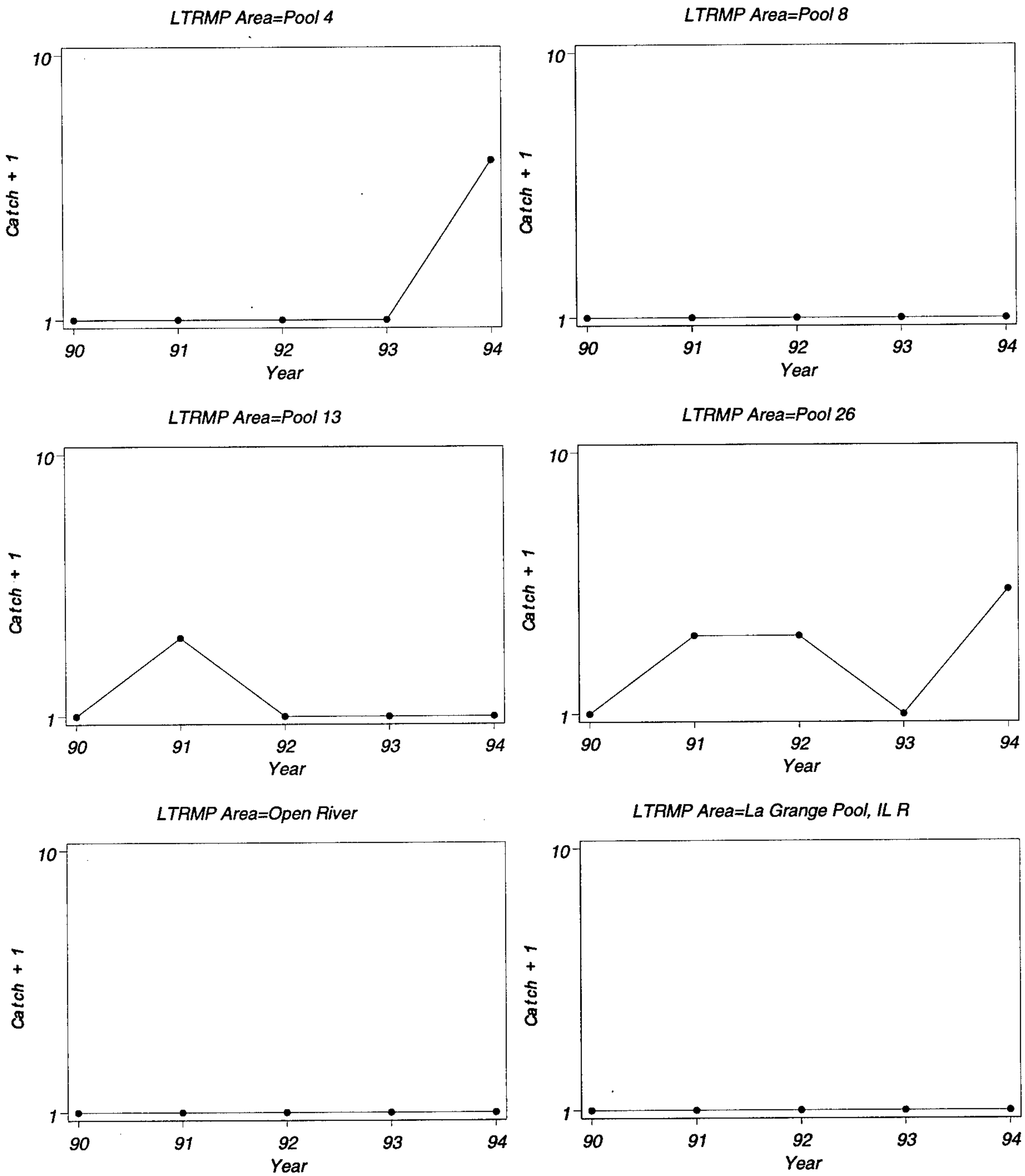

Figure 47. Total catch of lake sturgeon (*Acipenser fulvescens*) from all sampling gears and aquatic areas combined. Catch is plotted on a logarithmic scale. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993. Sampling effort increased through time. See text for assumptions necessary for interpretation of trends.

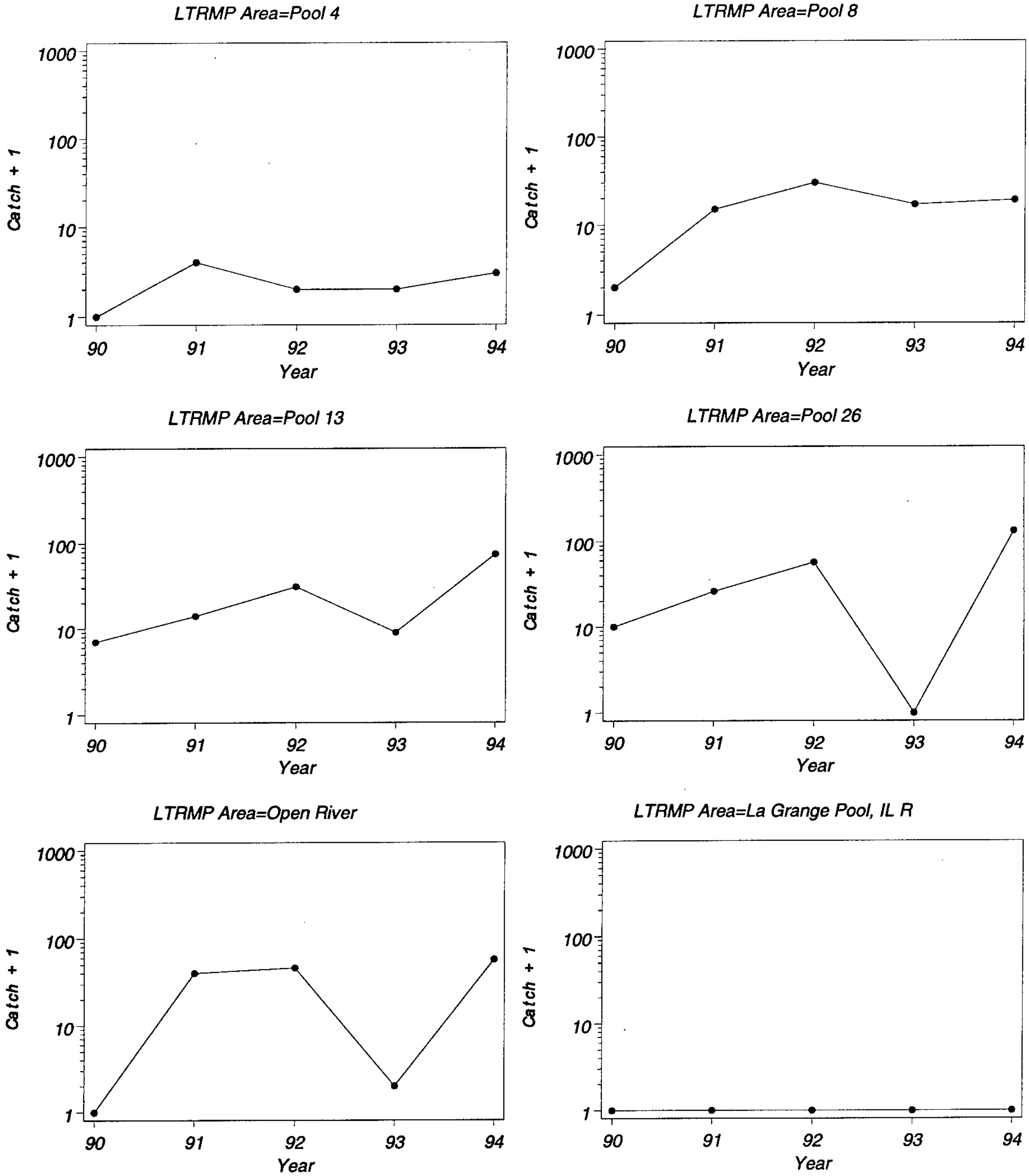

Figure 48. Total catch of shovelnose sturgeon (*Scaphirhynchus platorynchus*) from all sampling gears and aquatic areas combined. Catch is plotted on a logarithmic scale. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993. Sampling effort increased through time. See text for assumptions necessary for interpretation of trends.

reaches was reduced during 1993, when extreme flooding made some sampling impossible (Appendix Tables A1–A29). No evidence exists, therefore, of a recent decline in abundance of shovelnose sturgeon in the LTRMP study reaches.

The paddlefish (*Polyodon spathula*) is striking and immediately identifiable by its long, paddle-shaped snout. This species was reportedly abundant throughout much of the Mississippi River drainage before about 1900; its subsequent decline was believed to be the result of overexploitation and habitat loss (Pflieger 1975). The paddlefish and *Psephurus gladius* of the Yangtze River drainage in China are the only remaining species of the family Polyodontidae. The paddlefish has been listed as a species of concern by many states (Johnson 1987), although they are sufficiently common in others–including Illinois, Iowa, and Missouri–so that limited recreational or commercial harvest is allowed. During the first 5 years of the LTRMP, paddlefish were detected in Pool 26, the open river study reach, and the La Grange Pool (Figure 49). Although paddlefish were not detected in Pools 4, 8, and 13, this species is not absent from the northern pools of the Mississippi River; movements of paddlefish are presently being measured in Pool 5A (P. Thiel, U.S. Fish and Wildlife Service, Onalaska, Wisconsin, personal communication) and in Pool 8 (M. Dewey, U.S. Geological Survey, Upper Mississippi Science Center, La Crosse, Wisconsin, personal communication). The large increase in total catch of paddlefish in the open river study reach during 1994 over the previous 3 years is a notable feature of the data. Sampling effort was essentially unchanged between 1992 and 1994, except for a reduction in 1993 because of record flooding; therefore, this increased catch cannot be explained by sampling effort alone.

Skipjack herring (*Alosa chrysochloris*) is a large potadromous predatory herring indigenous to the Mississippi River and Gulf Coast drainages (Pflieger 1975). The skipjack herring is common in the unimpounded Mississippi River below Lock and Dam 26 and is not rare in the impounded Mississippi River below Lock and Dam 19, but this species is extremely uncommon above Lock and Dam 19 (Fremling et al. 1989), and Becker (1983) listed it as extirpated from Wisconsin. Before 1993, the total LTRMP catch of skipjack herring from the three northern study reaches consisted of two fish from Pool 13, although this species was commonly caught in the three southern study reaches (Figure 50). During the extreme flood of 1993, when the gates at all dams were held open, skipjack herring were detected in Pools 4 and 8. These data suggest that, although the locks and dams have reduced the range persistently occupied by skipjack herring, this species can rapidly but temporarily recolonize its original range when the dam gates are fully opened during floods.

The grass carp (*Ctenopharyngedon idella*) is a large cyprinid that was imported into the United States from Asia in 1963 (Pfllieger 1975) by aquaculturalists who wanted a herbivore capable of controlling noxious aquatic vegetation such as *Hydrilla*. Grass carp soon escaped into the Mississippi River drainage and have spread throughout. During the first 5 years of the LTRMP, grass carp were detected in every study reach except Pools 8 and 13; however, detection in Pool 4 consisted of a single specimen. Total catches of grass carp by the LTRMP have increased markedly in Pool 26, the open river study reach, and in the La Grange Pool (Figure 51), although this species is still uncommon in LTRMP samples. The increasing trend may be explained in part by increased sampling effort from 1990 to 1993, but the trend in total effort cannot explain the increased catch of grass carp from 1992 through 1994. Although this trend might be an artifact of sampling variability, its consistency in the three southernmost study reaches suggests that abundance of grass carp has increased there. This increasing trend should be cause for concern, even though grass carp are probably not now sufficiently abundant to affect native aquatic plants.

The bighead carp (*Hypopthalmichthys nobilis*), another cyprinid introduced by aquaculturalists from eastern Europe and Asia, has since escaped into the Mississippi River drainage. The LTRMP first detected this species in Pool 26 in 1991, and in the Open Mississippi River in 1992 (Figure 52). Although bighead carp were uncommon in LTRMP catches, the LTRMP did not use sampling gear that was particularly effective for capturing this species. Commercial fishers report that bighead carp have become common since 1992, and are often found in close association with paddlefish (Fred Cronin, LTRMP Field Station, Illinois Natural History

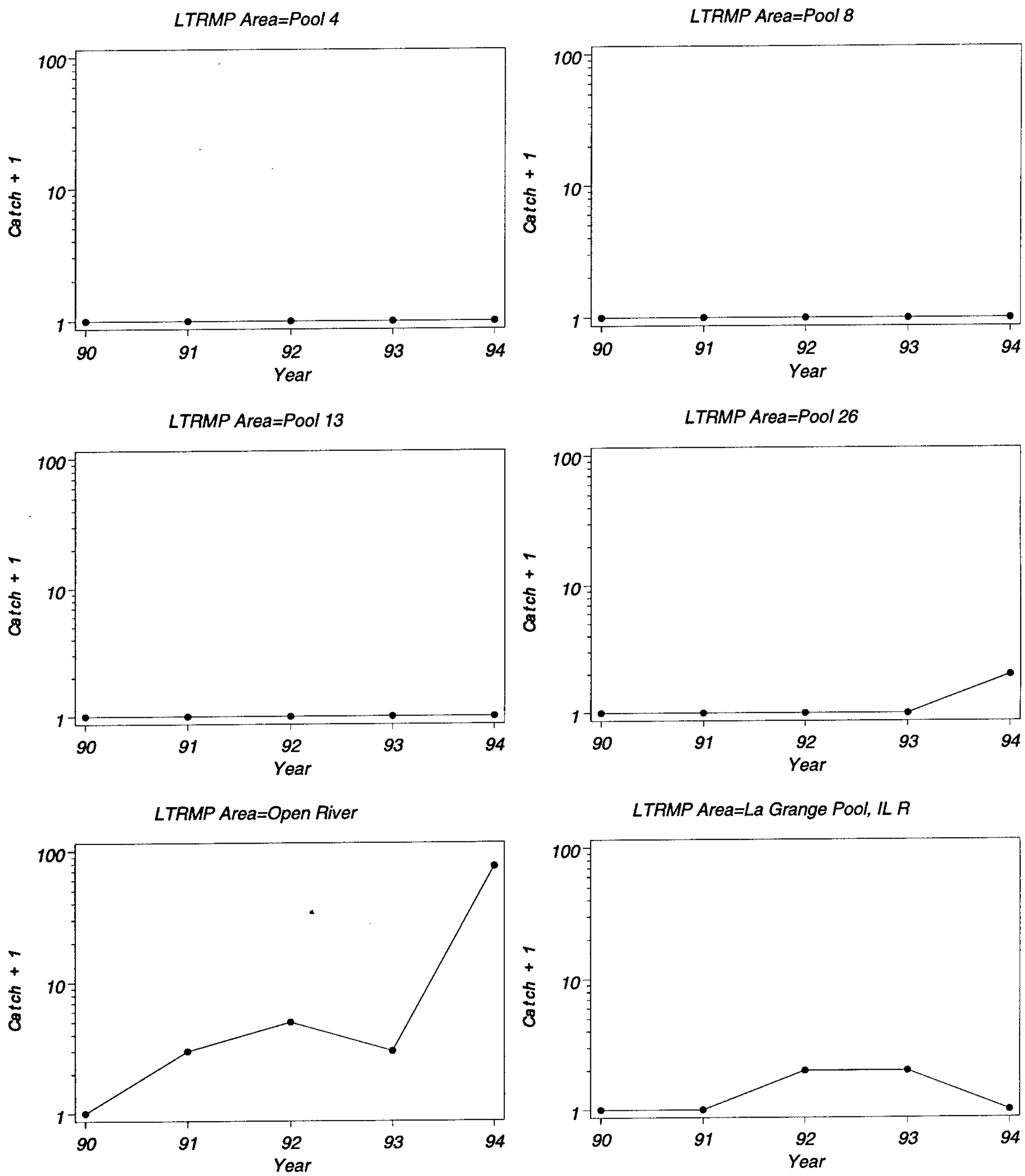

Figure 49. Total catch of paddlefish (*Polyodon spathula*) from all sampling gears and aquatic areas combined. Catch is plotted on a logarithmic scale. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993. Sampling effort increased through time. See text for assumptions necessary for interpretation of trends.

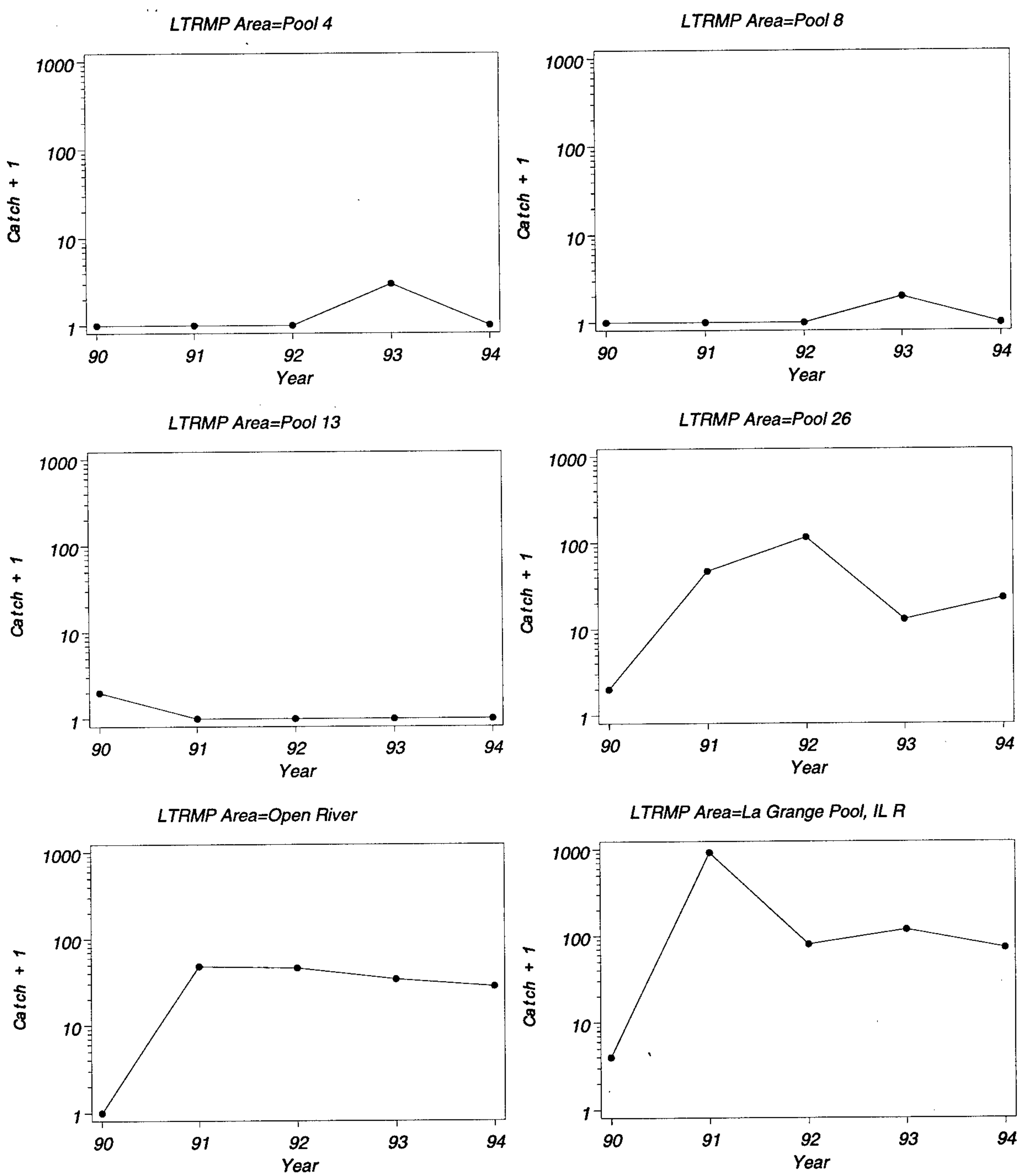

Figure 50. Total catch of skipjack herring (*Alosa chrysochloris*) from all sampling gears and aquatic areas combined. Catch is plotted on a logarithmic scale. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993. Sampling effort increased through time. See text for assumptions necessary for interpretation of trends.

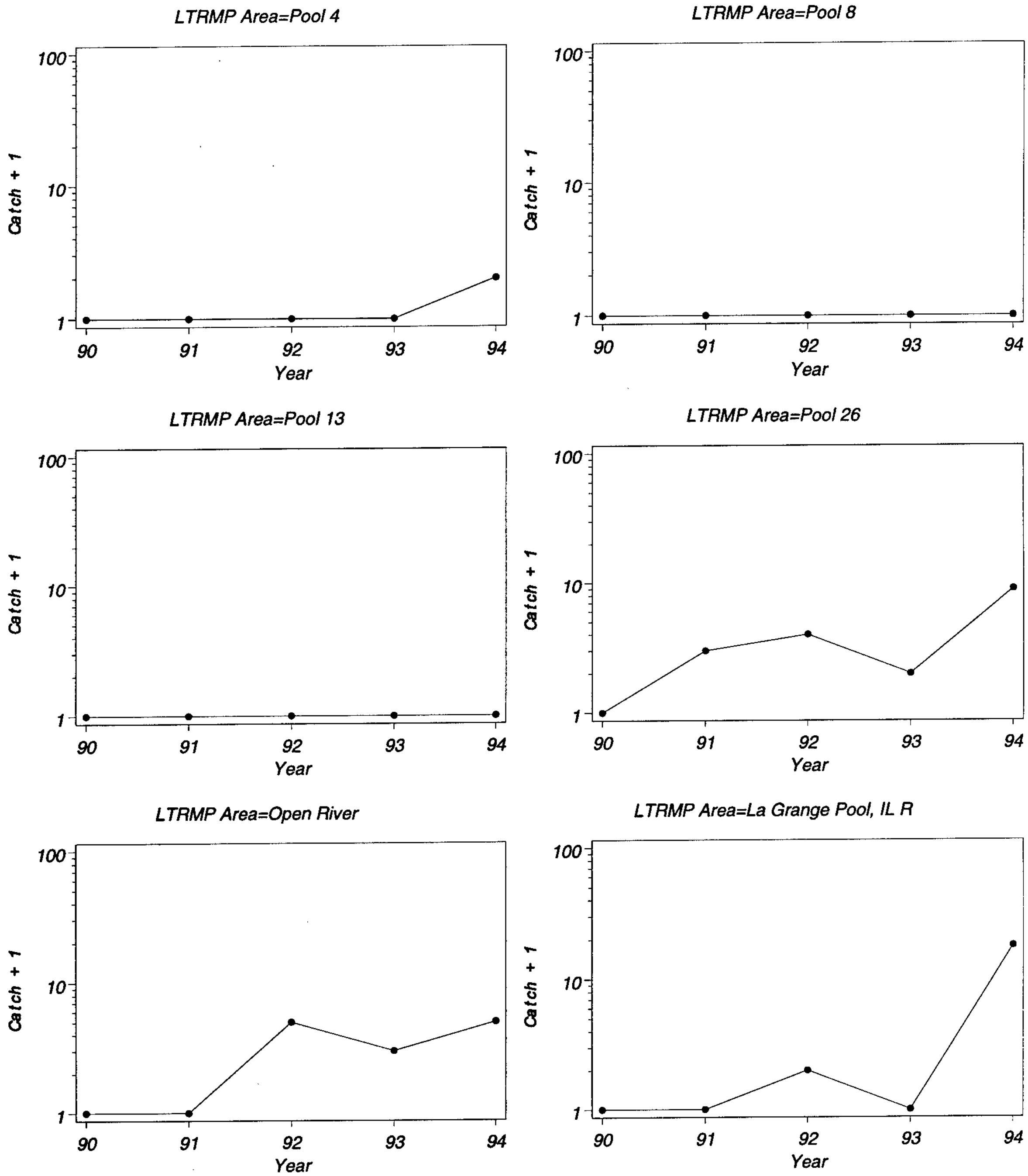

Figure 51. Total catch of grass carp (*Ctenopharyngedon idella*) from all sampling gears and aquatic areas combined. Catch is plotted on a logarithmic scale. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993. Sampling effort increased through time. See text for assumptions necessary for interpretation of trends.

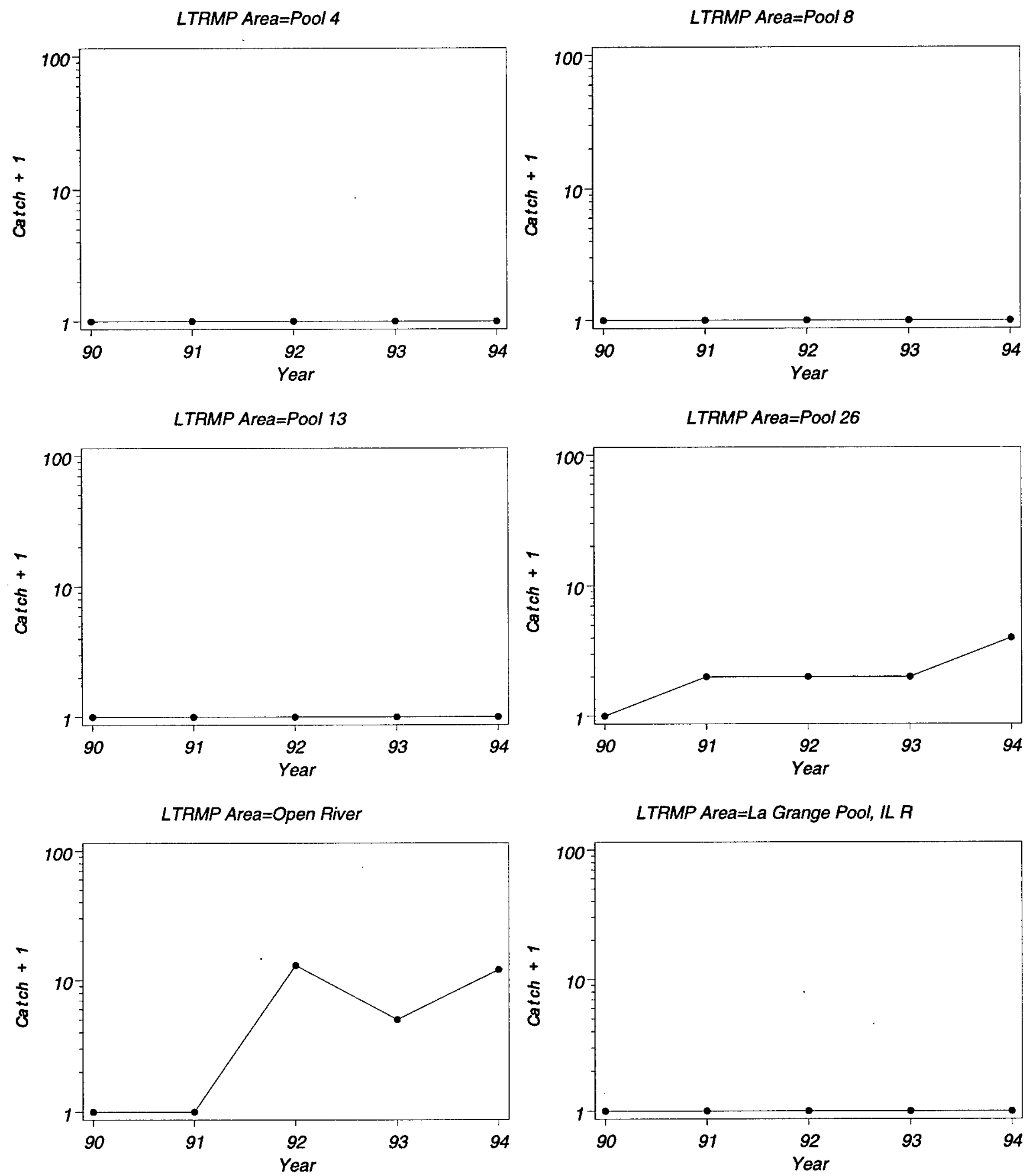

Figure 52. Total catch of bighead carp (*Hypopthalmichthys nobilis*) from all sampling gears and aquatic areas combined. Catch is plotted on a logarithmic scale. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993. Sampling effort increased through time. See text for assumptions necessary for interpretation of trends.

Survey, Alton, Illinois, personal communication). Because nearly all larval fishes and the adults of some species rely on zooplankton for food, the invasion of this exotic planktivore should be cause for concern. If bighead carp become abundant, they could have detrimental effects on indigenous species.

The blue sucker (*Cycleptus elongatus*) inhabits deep, fast-flowing channels of large rivers of the Mississippi and Gulf Coast drainages (Pflieger 1975). Pflieger (1975) reported that blue suckers have declined in abundance since 1900 and attributed that decline to the construction of dams. During the first 5 years of the LTRMP, this species was caught in all study reaches except the La Grange Pool of the Illinois River (Figure 53). Trends in total catches of blue suckers by the LTRMP were not obvious, other than a slight increase from 1990 through 1993, which can be explained by increased total sampling effort over that period (Appendix Tables A1–A29). Although blue suckers are seemingly rare, the LTRMP data suggests that their abundance has probably not declined from 1990 through 1994.

Summary

The LTRMP fish monitoring is relatively unique among efforts to monitor freshwater fishes in that it is conducted according to highly standardized protocols and has been based on stratified random sampling since 1993 (Gutreuter et al. 1995). For the first time in history, managers of the fishery resources of the Upper Mississippi River System have data that are comparable among reaches and that can be extrapolated over entire study reaches, rather than pertaining only to particular sampling locations (Gutreuter 1993). Although the LTRMP is far too new to have developed truly long-term data, the first 5 years of the program produced useful information that was previously unavailable. Important information obtained during the first 5 years of LTRMP fish monitoring includes the following:

There is no evidence that fish species richness or biodiversity has declined from 1990 through 1994, nor since the period of record. The Upper Mississippi River System has been remarkably stable in its biodiversity. As in other species-rich ecosystems, many species are somewhat rare and the present status of several is in question. The LTRMP has proven to be remarkably effective in detecting relatively rare species. The LTRMP detected 127 species of fish during the first 5 years. For perspective, among all historical records before the LTRMP, 150 species of fish had been recorded from areas of the Upper Mississippi River System that are now sampled by the LTRMP (Fremling et al. 1989).

Among species sufficiently common that catch-per-effort should be a reliable index of abundance, relatively few downward trends were observed during 1990–94. Species that showed linearly decreasing trends during that period were shortnose gar (Pool 26 and the La Grange Pool), bowfin, emerald shiner, river shiner, bullhead minnow, flathead catfish, northern pike (in Pool 8), bluegills (in Pools 8, 26, and the La Grange Pool of the Illinois River), small largemouth bass, and white crappies.

Among species sufficiently common that catch-per-effort should be a reliable index of abundance, some noteworthy increasing trends were observed. Species that showed linearly increasing trends of abundance during 1990–94 were common carp, channel shiner, smallmouth buffalo, spotted suckers (in Pools 4 and 8), shorthead redhorse, smallmouth bass (in Pool 8), and sauger. Common carp and sauger showed the greatest increase in abundance. The mean *CPE* of common carp varied as much as two- to ninefold within study reaches and the trend was strongest in Pool 13. Given the potential effects of localized high densities of exotic common carp on submersed aquatic vegetation (Bellrichard 1994), this trend entails unknown risks. However, consumption of exotic zebra mussels by common carp has been documented in Pool 26, and therefore the increased abundance of common carp may have some positive effects. Abundance of the recreationally important sauger increased as much as sevenfold in five of six LTRMP study reaches.

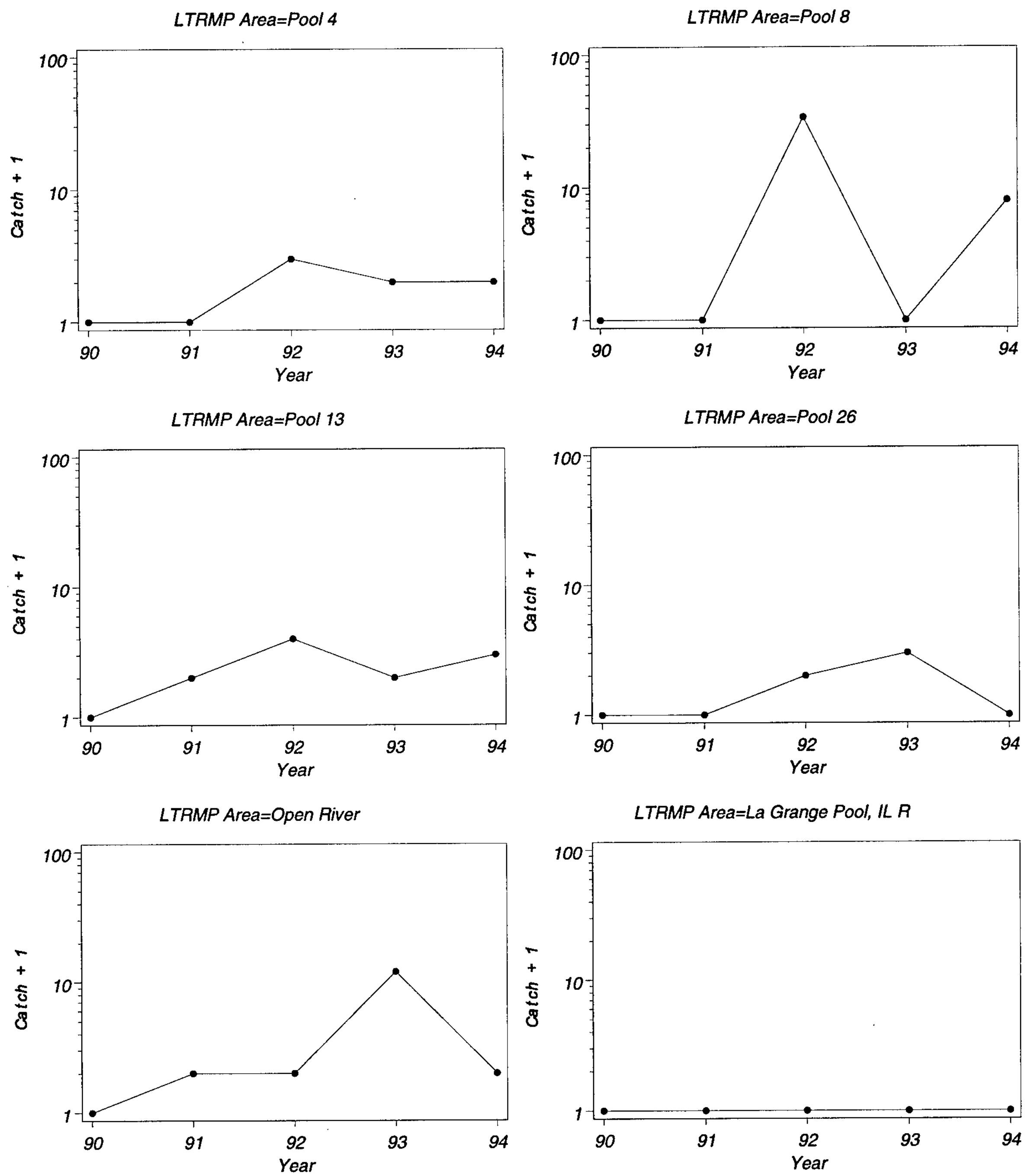

Figure 53. Total catch of blue suckers (*Cycleptus elongatus*) from all sampling gears and aquatic areas combined. Catch is plotted on a logarithmic scale. Samples were collected from subjectively chosen permanently fixed sites from 1990 through 1992, and from randomly selected sites since 1993. Sampling effort increased through time. See text for assumptions necessary for interpretation of trends.

Comparisons of relative abundance among the LTRMP study reaches produced substantial evidence that the quantity of off-channel habitat may be limiting for some species. Bowfin, bullhead minnow, bluegill, largemouth bass, white crappie, and black crappie are all known to prefer or require low-flow areas (Pflieger 1975), and the need for relatively warm low-flow water is greatest in winter for at least several of these species (Sheehan et al. 1990). These species were significantly more abundant from LTRMP study reaches that have large fractions of contiguous backwaters than from reaches in which backwaters are scarce. In the Upper Mississippi River, the fraction of the floodplain composed of backwaters has an approximate longitudinal gradient of decrease from north to south. Therefore the overall pattern of abundance of these species also has an approximate longitudinal gradient. The striking feature of this longitudinal gradient of abundance is that it is opposite of the pattern that should be expected on the basis of the natural geographic ranges of each of these species. Pools 4 and 8 are near the northern natural range limit of each of these species, and all else being equal, we should expect these species to do less well there than near the centers of their ranges in the open river study reach. The abundances of these species in the La Grange Pool of the Illinois River do not fit this longitudinal pattern, perhaps because that pool contains the largest fraction of backwaters among the LTRMP study reaches. This suggests that the patterns of abundance of these species have anthropogenic origins. Navigation management strategies that have reduced the fraction of contiguous backwaters in the unimpounded Mississippi River seem to have measurable consequences for some important fish species. This information also provides a basis from which to predict the future status of certain fishery resources from predictions of the physical configurations of the floodplain and from which to make objective decisions of where habitat restoration is needed most.

The ability to quantify some biological consequences of floodplain composition was only possible because LTRMP sampling is standardized and because the index of fish abundance was computed for all sampled strata rather than within particular strata. That is, monitoring within particular aquatic areas would not be expected to show trends or spatial patterns if abundance within those areas remained constant while the quantities of those areas changed spatially or temporally. Certain fishes might always do well within, say, contiguous backwaters, but their abundance at larger spatial scales should change in response to changes in the quality and quantity of contiguous backwaters. Estimates of reach-wide means from stratified random sampling are unbiased for the true but unknown reachwide means and will change as the fractions of strata change.

Data from the LTRMP suggest that the exotic grass carp and bighead carp are increasing in abundance in portions of the UMRS. Although these species are still uncommon, they have the potential to affect submersed aquatic vegetation (grass carp) and zooplankton (bighead carp), and these trends should be cause for concern. Anecdotal reports from commercial fishers indicate that bighead carp are often captured along with paddlefish, suggesting these species occupy similar habitats.

Although lake sturgeon, shovelnose sturgeon, paddlefish, and blue suckers are species of special concern that are too uncommon to have produced useful estimates of catch-per-effort, trends in total catches suggest that these species are at least stable in most LTRMP study reaches. The total catch of paddlefish increased markedly in the open river study reach from 1991 through 1994.

The skipjack herring is a potadromous species. The available evidence (Fremling et al. 1989) suggests the present-day distribution of skipjack herring in the Mississippi River is limited by the dams, and particularly by Lock and Dam 19. During the flood of 1993, the dam gates were held open and the Mississippi River became free-flowing once again. Concurrently, the LTRMP detected skipjack herring in Pools 4 and 8 suggesting that, although the range of this species is limited by navigation management, it can quickly reenter the upper river when suitable opportunities for upstream passage occur.

These brief initial trends observed by the LTRMP are somewhat compromised by the change from nonrandomized sampling at subjectively chosen permanent sampling locations to stratified random sampling.

Any trends from 1990 through 1994 might be due to that change. However, this change is providing a more solid basis for inference. Stratified randomized sampling will be instrumental in future efforts to integrate different types of data—for example, limnological data and biological data—and to predict the biological consequences of changes in floodplain management and geomorphology.

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Appendix

Appendix Table A1. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 4, Upper Mississippi River during 1990. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	BWCO	MCBU	MCBW	Totals
June15–July 31					
Fyke netting	6			4	10
Minnow fyke netting	2			1	3
Seining	1		2		3
Tandem fyke netting	3	1			4
Gear subtotals	12	1	2	5	20
August 1–September 14					
Day electrofishing	11	1	4	3	19
Fyke netting	6			6	10
Tandem hoop netting			3	3	6
Minnow fyke netting	4			3	7
Night electrofishing	5	1	4	4	14
Seining				4	4
Tandem fyke netting	5				5
Tandem minnow fyke	5	1			6
Gear subtotals	36	3	15	17	71
Annual totals	48	4	17	22	91

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam

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Appendix Table A2. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 4, Upper Mississippi River during 1991. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	BWCO	SCB	MCBU	MCBW	CTR	TWZ	Totals
June 15–July 31								
Day electrofishing	6	6		2				14
Fyke netting	6						2	8
Tandem hoop netting			4	4			2	10
Minnow fyke netting	6						2	8
Night electrofishing		2	2	2				6
Seining			4	4				8
Trawling				8		12	4	24
Tandem fyke netting		6						6
Tandem minnow fyke		6						6
Gear subtotals	18	20	10	20		12	10	90
August 1–September 14								
Day electrofishing	6	6		2	4			18
Fyke netting	6				2		2	10
Tandem hoop netting			2	4	3		1	10
Minnow fyke netting	6				2		2	10
Night electrofishing		4	4	4			2	14
Seining			4	4				8
Trawling				8		12	4	24
Tandem fyke netting		6						6
Tandem minnow fyke		6						6
Gear subtotals	18	22	10	22	11	12	11	106
September 15–October 31								
Day electrofishing	6	6		4	4			20
Fyke netting	6				4		2	12
Tandem hoop netting			4	4	4		2	14
Minnow fyke netting	6				4		2	12
Night electrofishing		4	4	4			2	14
Seining			4	4				8
Trawling				8		12	4	24
Tandem fyke netting		6						6
Tandem minnow fyke		6						6
Gear subtotals	18	22	12	24	16	12	12	116
Annual totals	54	64	32	66	27	36	33	312

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A3. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 4, Upper Mississippi River during 1992. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	BWCO	SCB	MCBU	MCBW	CTR	TWZ	Totals
June 15–July 31								
Day electrofishing	7	5			4			16
Fyke netting	6						2	8
Tandem hoop netting			4	4	4		2	14
Minnow fyke netting	6				4		2	12
Night electrofishing		4	4	4			2	14
Seining			8	8				16
Trawling				8		12	4	24
Tandem fyke netting	1	5						6
Tandem minnow fyke	1	5						6
Gear totals	21	19	16	24	12	12	12	116
August 1–September 14								
Day electrofishing	7	5			4			16
Fyke netting	6						2	8
Tandem hoop netting			4	4	4		2	14
Minnow fyke netting	6				4		2	12
Night electrofishing		4	4	4			2	14
Seining			8	8				16
Trawling				8		12	4	24
Tandem fyke netting	1	5						6
Tandem minnow fyke	1	5						6
Gear totals	21	19	16	24	12	12	12	116
September 15–October 31								
Day electrofishing	7	5			4			16
Fyke netting	6						2	8
Tandem hoop netting			4	4	4		2	14
Minnow fyke netting	6				4		2	12
Night electrofishing		4	4	4			2	14
Seining			8	8				16
Trawling				8		12	4	24
Tandem fyke netting	1	5						6
Tandem minnow fyke	1	5						6
Gear totals	21	19	16	24	12	12	12	116
Annual totals	63	57	48	72	36	36	36	348

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A4. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 4, Upper Mississippi River during 1993. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	BWCO	SCB	MCBU	MCBW	TWZ	Totals
June 15–July 31							
Day electrofishing	6	7	4	6			23
Fyke netting	5						5
Gill net		4	2				6
Large hoop net		4	6	6			16
Small hoop net		4	6	6			16
Minnow fyke netting	5		4	3			12
Night electrofishing						4	4
Seining			8	2			10
Tandem fyke netting		7					7
Tandem minnow fyke		8					8
Gear subtotals	16	34	30	23		4	107
August 1–September 14							
Day electrofishing	5	7	4	6			22
Fyke netting	6					2	8
Gill net		4	4	4			12
Large hoop net		3	7	7		2	19
Small hoop net		3	8	6		2	19
Minnow fyke netting	5	1	6	4		2	18
Night electrofishing						4	4
Seining			10	4			14
Trawling						4	4
Tandem fyke netting		8					8
Tandem minnow fyke		8					8
Gear subtotals	16	34	39	31		16	136
September 15–October 31							
Day electrofishing	4	10	4	6	2		26
Fyke netting	6				1	2	9
Gill net		5	4	3			12
Large hoop net		4	6	4	3	2	19
Small hoop net		4	5	6	3	2	20
Minnow fyke netting	4		7	3	2	2	18
Night electrofishing						4	4
Seining			12	4			16
Trawling						4	4
Tandem fyke netting		8					8
Tandem minnow fyke		8					8
Gear subtotals	14	39	38	26	11	16	144
Annual totals	46	107	107	80	11	36	387

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; TWZ—Tailwater Zone; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough

Appendix Table A5. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 4, Upper Mississippi River during 1994. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	BWCO	SCB	MCBU	MCBW	TWZ	Totals
June 15–July 31							
Day electrofishing	6	9	4	7	3		29
Fyke netting	6				2	2	10
Gill net		4					4
Large hoop net		5	6	5	4	2	22
Small hoop net		4	6	5	4	1	20
Minnow fyke netting	5		6	4	2	2	19
Night electrofishing						4	4
Seining			13	9			22
Trawling						4	4
Trammel net (set)		4					4
Tandem fyke netting		8					8
Tandem minnow fyke		8					8
Gear totals	17	42	35	30	15	15	154
August 1–September 14							
Day electrofishing	8	3	6	6	4		27
Fyke netting	6				3	3	12
Gill net		4					4
Large hoop net		3	6	6	4	2	21
Small hoop net		4	6	6	4	2	22
Minnow fyke netting	6		7	3	4	2	22
Night electrofishing						4	4
Seining			9	7			16
Trawling						4	4
Trammel net (set)		3					3
Trammel net (drift)		1					1
Tandem fyke netting		8					8
Tandem minnow fyke		8					8
Gear totals	20	34	34	28	19	17	152
September 15–October 31							
Day electrofishing	8	4	6	6	4		28
Fyke netting	6					2	8
Gill net		4					4
Large hoop net		4	6	6		2	18
Small hoop net		4	6	6		2	18
Minnow fyke netting	6		6	4		2	18
Night electrofishing						4	4
Seining			13	8			21
Trawling						4	4
Trammel net (set)		4					4
Tandem fyke netting		8					8
Tandem minnow fyke		8					8
Gear totals	20	36	37	30	4	16	143
Annual totals	57	112	106	88	38	48	449

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A6. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 8, Upper Mississippi River during 1990. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	MCBU	MCBW	IMPS	IMPO	Totals
June 15–July 31						
Day electrofishing	8	4	4	2	2	20
Fyke netting	8		4	2		14
Tandem hoop netting		4	4			8
Minnow fyke netting	4		4			8
Night electrofishing	4	4	4		2	14
Seining	4	4				8
Tandem fyke netting					2	2
Tandem minnow fyke					2	2
Gear subtotals	28	16	20	4	8	76
August 1–September 14						
Day electrofishing	8	4	4	2	2	20
Fyke netting	8		4	2		14
Tandem hoop netting		4	4			8
Minnow fyke netting	3		4	2		9
Night electrofishing	4	4	4		2	14
Seining	4	4				8
Tandem fyke netting					2	2
Tandem minnow fyke					2	2
Gear subtotals	27	16	20	6	8	77
Annual totals	55	32	40	10	16	153

Stratum Codes: BWCS—Backwater, Contiguous, Offshore; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; IMPS—Impoundment, Shoreline; IMPO—Impoundment, Open water

Appendix Table A7. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 8, Upper Mississippi River during 1991. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	SCB	MCBU	MCBW	CTR	IMPS	IMPO	TWZ	Totals
June 15–July31									
Day electrofishing	8		4	6		2	2		22
Fyke netting	8			6		2		2	18
Tandem hoop netting		4	4	4				2	14
Minnow fyke netting	4			6		2		2	14
Night electrofishing	4	4	4	6				2	20
Seining	4	4	4						12
Trawling			8		12			4	24
Tandem fyke netting							2		2
Tandem minnow fyke							2		2
Gear subtotals	28	12	24	28	12	6	6	12	128
August 1–September 14									
Day electrofishing	8		4	6		2	2	2	24
Fyke netting	8			6		2		2	18
Tandem hoop netting		4	4	6				2	16
Minnow fyke netting	4			6		2		2	14
Night electrofishing	4	4	4	6				2	20
Seining	4	4	4						12
Trawling			8		12			4	24
Tandem fyke netting							2		2
Tandem minnow fyke							2		2
Gear subtotals	28	12	24	30	12	6	6	14	132
September 15–October 31									
Day electrofishing	8		4	6		2	2		22
Fyke netting	8			6		2		2	18
Tandem hoop netting		4	4	6				2	16
Minnow fyke netting	4			6		2		2	14
Night electrofishing	4	4	4	6				2	20
Seining	4	4	4						12
Trawling			8		12			4	24
Tandem fyke netting							2		2
Tandem minnow fyke							2		2
Gear subtotals	28	12	24	30	12	6	6	12	130
Annual totals	84	36	72	88	36	18	18	38	390

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A8. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 8, Upper Mississippi River during 1992. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	SCB	MCBU	MCBW	CTR	IMPS	IMPO	TWZ	Totals
June 15–July 31									
Day electrofishing	8		4	6		2	2		22
Fyke netting	8					2		2	12
Tandem hoop netting		4	4	6				2	16
Minnow fyke netting	4			6		2		2	14
Night electrofishing	4	4	4	6				2	20
Seining	4	8	8						20
Trawling			8		12			4	24
Tandem fyke netting							2		2
Tandem minnow fyke							2		2
Gear totals	28	16	28	24	12	6	6	12	132
August 1–September 14									
Day electrofishing	8		4	6		2	2		22
Fyke netting	8					2		2	12
Tandem hoop netting		4	4	6				2	16
Minnow fyke netting	4			6		2		2	14
Night electrofishing	4	4	4	6				2	20
Seining	4	8	8						20
Trawling			8		12			4	24
Tandem fyke netting							2		2
Tandem minnow fyke							2		2
Gear totals	28	16	28	24	12	6	6	12	132
September 15–October 31									
Day electrofishing	8		4	6		2	2		22
Fyke netting	8					2		2	12
Tandem hoop netting		4	4	6				2	16
Minnow fyke netting	4			6		2		2	14
Night electrofishing	4	4	4	6				2	20
Seining	4	8	8						20
Trawling			8		12			4	24
Tandem fyke netting							2		2
Tandem minnow fyke							2		2
Gear totals	28	16	28	24	12	6	6	12	132
Annual totals	84	48	84	72	36	18	18	36	396

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A9. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 8, Upper Mississippi River during 1993. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	BWCO	SCB	MCBU	MCBW	IMPS	IMPO	TWZ	Totals
June 15–July 31									
Day electrofishing	9		6	4	4	3			26
Fyke netting	8					4			12
Gill net			2	2			4		8
Large hoop net		4	4	4	4		4	2	22
Small hoop net		4	4	4	4		4	2	22
Minnow fyke netting	8		6	4	4	4		2	28
Night electrofishing	2		4	4	4			4	18
Seining	16		8	8				4	36
Trawling								4	4
Tandem fyke netting		2					2		4
Tandem minnow fyke		2					2		4
Gear subtotals	43	12	34	30	20	11	16	18	184
August 1–September 14									
Day electrofishing	12		6	4	4	4			30
Fyke netting	16					4			20
Gill net			2				4		6
Large hoop net		4	4	4	4		4	2	22
Small hoop net		4	4	4	4		4	2	22
Minnow fyke netting	8		6	4	4	4		2	28
Night electrofishing	2		4	4	4			4	18
Seining	12		8	16				4	40
Trawling								4	4
Tandem fyke netting		2					2		4
Tandem minnow fyke		2					2		4
Gear subtotals	50	12	34	36	20	12	16	18	198
September 15–October 31									
Day electrofishing	12		6	4	4	4			30
Fyke netting	16					4			20
Gill net			2				4		6
Large hoop net		4	4	4	4		4	2	22
Small hoop net		4	4	4	4		4	2	22
Minnow fyke netting	8		6	4	4	4		2	28
Night electrofishing	2		4	4	4			4	18
Seining	12		8	16				4	40
Trawling								4	4
Tandem fyke netting		2					2		4
Tandem minnow fyke		2					2		4
Gear subtotals	50	12	34	36	20	12	16	18	198
Annual totals	143	36	102	102	60	35	48	54	580

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A10. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 8, Upper Mississippi River during 1994. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	BWCO	SCB	MCBU	MCBW	IMPS	IMPO	TWZ	Totals
June 15–July 31									
Day electrofishing	12		6	3	4	4			29
Fyke netting	16					4			20
Gill net							6		6
Large hoop net		4	4	4	4		4	2	22
Small hoop net		4	4	4	4		4	2	22
Minnow fyke netting	7		6	4	4	4		2	27
Night electrofishing	2		4	4	4			4	18
Seining	10		8	16				4	38
Trawling								4	4
Tandem fyke netting		2					2		4
Tandem minnow fyke		2					2		4
Gear subtotals	47	12	32	35	20	12	18	18	194
August 1–September 14									
Day electrofishing	12		8	4	4	4			32
Fyke netting	16					4			20
Gill net							4		4
Large hoop net		4	4	4	4		4	2	22
Small hoop net		4	4	4	4		4	2	22
Minnow fyke netting	8		6	4	4	4			26
Night electrofishing	2		4	4	4			4	18
Seining	12		8	16				4	40
Trawling								4	4
Tandem fyke netting		2					2		4
Tandem minnow fyke		2					2		4
Gear subtotals	50	12	34	36	20	12	16	16	196
September 15–October 31									
Day electrofishing	12		8	4	4	4			32
Fyke netting	16					4			20
Gill net							4		4
Large hoop net		4	4	4	4		4	2	22
Small hoop net		4	4	4	4		4	2	22
Minnow fyke netting	8		6	4	4	4			26
Night electrofishing	2		4	4	4			4	18
Seining	12		8	16				4	40
Trawling								4	4
Tandem fyke netting		2					2		4
Tandem minnow fyke		2					2		4
Gear totals	50	12	34	36	20	12	16	16	196
Annual totals	147	36	100	107	60	36	50	50	586

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A11. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 13, Upper Mississippi River during 1990. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	MCBU	IMPO	Totals
June 15–July 31				
Day electrofishing	8	4	4	16
Fyke netting	8		2	10
Tandem hoop netting		4		4
Minnow fyke netting	4		2	6
Night electrofishing	8	4	4	16
Seining	5	3		8
Tandem fyke netting			2	2
Tandem minnow fyke			2	2
Gear subtotals	33	15	16	64
August 1–September 14				
Day electrofishing	8	4	4	16
Fyke netting	8		2	10
Tandem hoop netting		4		4
Minnow fyke netting	4		2	6
Night electrofishing	8	4	4	16
Seining	4	4		8
Tandem fyke netting			2	2
Tandem minnow fyke			2	2
Gear subtotals	32	16	16	64
Annual totals	65	31	32	128

Stratum Codes: BWCS—Backwater, Contiguous, Offshore; MCBU—Main Channel Border, Unstructured; IMPO—Impoundment, Open water

Appendix Table A12. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 13, Upper Mississippi River during 1991. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	SCB	MCBU	MCBW	CTR	IMPO	TWZ	Totals
June 15–July 31								
Day electrofishing	8	4	4			4		20
Fyke netting	8					2	2	12
Tandem hoop netting		4	4				2	10
Minnow fyke netting	4					2	2	8
Night electrofishing	8	4	4			4	2	22
Seining	4	4	4					12
Trawling			8		12		4	24
Tandem fyke netting						2		2
Tandem minnow fyke						2		2
Gear subtotals	32	16	24		12	16	12	112
August 1–September 14								
Day electrofishing	8	4	4	2		4		22
Fyke netting	8					2	2	12
Tandem hoop netting		4	4				2	10
Minnow fyke netting	4					2	2	8
Night electrofishing	8	4	4			4	2	22
Seining	4	4	4					12
Trawling			8		12		4	24
Tandem fyke netting						2		2
Tandem minnow fyke						2		2
Gear subtotals	32	16	24	2	12	16	12	114
September 15–October 31								
Day electrofishing	8	4	2	2		4		20
Fyke netting	8					2	2	12
Tandem hoop netting		4	4				2	10
Minnow fyke netting	4					2	2	8
Night electrofishing	8	4	4			4	2	22
Seining	4	4	4					12
Trawling			8		12		4	24
Tandem fyke netting						2		2
Tandem minnow fyke						2		2
Gear subtotals	32	16	22	2	12	16	12	112
Annual totals	96	48	70	4	36	48	36	338

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A13. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 13, Upper Mississippi River during 1992. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	SCB	MCBU	MCBW	CTR	IMPO	TWZ	Totals
June 15–July 31								
Day electrofishing	8	4	4			4		20
Fyke netting	8					2	2	12
Tandem hoop netting		4	4	2			2	12
Minnow fyke netting	4			2		2	2	10
Night electrofishing	8	4	4			4	2	22
Seining	4	8	8					20
Trawling			8		12		4	24
Tandem fyke netting						2		2
Tandem minnow fyke						2		2
Gear subtotals	32	20	28	4	12	16	12	124
August 1–September 14								
Day electrofishing	8	4	4	2		4		22
Fyke netting	8					2	2	12
Tandem hoop netting		4	4	2			2	12
Minnow fyke netting	4			2		2	2	10
Night electrofishing	8	4	4			4	2	22
Seining	4	8	8					20
Trawling			8		12		4	24
Tandem fyke netting						2		2
Tandem minnow fyke						2		2
Gear subtotals	32	20	28	6	12	16	12	126
September 15–October 31								
Day electrofishing	8	4	4	2		4		22
Fyke netting	8					2	2	12
Tandem hoop netting		4	4	2			2	12
Minnow fyke netting	4			2		2	2	10
Night electrofishing	8	4	4			4	2	22
Seining	4	8	8					20
Trawling			8		12		4	24
Tandem fyke netting						2		2
Tandem minnow fyke						2		2
Gear subtotals	32	20	28	6	12	16	12	126
Annual totals	96	60	84	16	36	48	36	376

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A14. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 13, Upper Mississippi River during 1993. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	BWCO	SCB	MCBU	MCBW	IMPS	IMPO	TWZ	Totals
June 15–July 31									
Day electrofishing	6		3	3		3			15
Fyke netting	7					4			11
Large hoop net		5	2	2			2		11
Small hoop net		5	2	2			2		11
Minnow fyke netting	7		2	3		4			16
Seining						6			6
Tandem fyke netting		2					2		4
Tandem minnow fyke		3					2		5
Gear subtotals	20	15	9	10		17	8		79
August 1–September 14									
Day electrofishing	8		2	5		4			19
Fyke netting	11					3			14
Large hoop net		6	2	3			2		13
Small hoop net		6	2	3			2		13
Minnow fyke netting	10		1	4		4			19
Night electrofishing	2		1	2				1	6
Seining	12		4	12		8			36
Tandem fyke netting		5					2		7
Tandem minnow fyke		5					2		7
Gear subtotals	43	22	12	29		19	8	1	134
September 15–October 31									
Day electrofishing	8		2	4		4			18
Fyke netting	10					4			14
Large hoop net		4	2	4	3		2		15
Small hoop net		5	2	4	3		2		16
Minnow fyke netting	9		3	4		4			20
Night electrofishing	2		2	2				2	8
Seining	14		6	12		8			40
Trawling								4	4
Tandem fyke netting		5					2		7
Tandem minnow fyke		5					2		7
Gear subtotals	43	19	17	30	6	20	8	6	149
Annual totals	106	56	38	69	6	56	24	7	362

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A15. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 13, Upper Mississippi River during 1994. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	BWCO	SCB	MCBU	MCBW	IMPS	IMPO	TWZ	Totals
June 15–July 31									
Day electrofishing	9		1	4		4			18
Fyke netting	9		1			4			14
Large hoop net		5	5	1			2		13
Small hoop net		5	5	1			2		13
Minnow fyke netting	8		6	2		4			20
Night electrofishing	2		2	2					6
Seining	12		8	8		6	2		36
Tandem fyke netting		5					2		7
Tandem minnow fyke		5					2		7
Gear subtotals	40	20	28	18		18	10		134
August 1–September 14									
Day electrofishing	7		2	4	3	5			21
Fyke netting	10					4			14
Large hoop net		5	2	4	3		2	2	18
Small hoop net		5	2	4	3		2	2	18
Minnow fyke netting	10		2	4	3	4		2	25
Night electrofishing	2		2	2				2	8
Seining	12		4	12		8			36
Trawling								8	8
Tandem fyke netting		5					2		7
Tandem minnow fyke		5					2		7
Gear subtotals	41	20	14	30	12	21	8	16	162
September 15–October 31									
Day electrofishing	8		2	4	3	4			21
Fyke netting	10		1			3			14
Large hoop net		5	2	4	3		2	2	18
Small hoop net		5	2	4	3		2	2	18
Minnow fyke netting	10		2	4	3	4		2	25
Night electrofishing	2		2	2				4	10
Seining	13		4	12		8			37
Trawling								8	8
Tandem fyke netting		5					2		7
Tandem minnow fyke		5					2		7
Gear subtotals	43	20	15	30	12	19	8	18	165
Annual totals	124	60	57	78	24	58	26	34	461

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A16. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 26, Upper Mississippi River during 1990. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	MCBU	MCBW	IMPS	IMPO	Totals
June 15–July 31						
Day electrofishing	2			2		4
Fyke netting	4		2			6
Tandem hoop netting		2	2			4
Seining	2	2				4
Tandem fyke netting					2	2
Gear subtotals	8	4	4	2	2	20
August 1–September 14						
Day electrofishing	5	2	2	2		11
Fyke netting	10		2			12
Tandem hoop netting		4	4			8
Minnow fyke netting	8	2	2	2		14
Night electrofishing	4	4	2			10
Seining		2		2		4
Tandem fyke netting					2	2
Gear subtotals	27	14	12	6	2	61
Annual totals	35	18	16	8	4	81

Stratum Codes: BWCS—Backwater, Contiguous, Offshore; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; IMPS—Impoundment, Shoreline; IMPO—Impoundment, Open water

Appendix Table A17. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 26, Upper Mississippi River during 1991. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	SCB	MCBU	MCWB	CTR	IMPS	IMPO	TWZ	Totals
June 15–July 31									
Day electrofishing	8		4	2		4			18
Fyke netting	8			2		2			12
Tandem hoop netting		4	4	2				2	12
Minnow fyke netting	8			2		2			12
Night electrofishing	4	4	4					2	14
Seining			2						2
Trawling			8		12			4	24
Tandem fyke netting							2		2
Tandem minnow fyke							2		2
Gear subtotals	28	8	22	8	12	8	4	8	98
August 1–September 14									
Day electrofishing	8		4	4		4			20
Fyke netting	8			4		2		2	16
Tandem hoop netting		4	4	4				2	14
Minnow fyke netting	8			2		2		2	14
Night electrofishing	4	4	4					2	14
Seining			4						4
Trawling			8		12			4	24
Tandem fyke netting							2		2
Tandem minnow fyke							2		2
Gear subtotals	28	8	24	14	12	8	4	12	110
September 15–October 31									
Day electrofishing	8		4	2		4			18
Fyke netting	8			4		2		2	16
Tandem hoop netting		4	4	2				2	12
Minnow fyke netting	8			4		2		2	16
Night electrofishing	4	4	4					2	14
Seining			4						4
Trawling			8		12			4	24
Tandem fyke netting							2		2
Tandem minnow fyke							2		2
Gear subtotals	28	8	24	12	12	8	4	12	108
Annual totals	84	24	70	34	36	24	12	32	316

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A18. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 26, Upper Mississippi River during 1992. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	SCB	MCBU	MCBW	CTR	IMPS	IMPO	TWZ	Totals
June 15–July 31									
Day electrofishing	8		4	4		4			20
Fyke netting	8						3	1	12
Tandem hoop netting		4	4	4				2	14
Minnow fyke netting	4			4			4	2	14
Night electrofishing	6	4	4					2	16
Seining	4		7						11
Trawling			8		12			4	24
Gear subtotals	30	8	27	12	12	4	7	11	111
August 1–September 14									
Day electrofishing	8		4	4		4			20
Fyke netting	8						4	2	14
Tandem hoop netting		4	4	4				2	14
Minnow fyke netting	6			3			4	2	15
Night electrofishing	4	4	4					2	14
Seining	2		8						10
Trawling			8		12			4	24
Gear subtotals	28	8	28	11	12	4	8	12	111
September 15–October 31									
Day electrofishing	5		4	4		4			17
Fyke netting	8						3	2	13
Tandem hoop netting		4	4	4				2	14
Minnow fyke netting	6			4			4	2	16
Night electrofishing	6	4	4					2	16
Seining	2		8						10
Trawling			8		12			4	24
Gear subtotals	27	8	28	12	12	4	7	12	110
Annual totals	85	24	83	35	36	12	22	35	332

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A19. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 26, Upper Mississippi River during 1993. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	BWCO	SCB	MCBU	IMPS	IMPO	Totals
June 15–July 31							
Day electrofishing	4			1	4		9
Fyke netting	3				2		5
Large hoop net		2	1	3		2	8
Small hoop net		2		3		2	7
Minnow fyke netting	4				2		6
Tandem fyke netting		1					1
Tandem minnow fyke		1					1
Gear totals	11	6	1	7	8	4	37
September 15–October 31							
Day electrofishing	6		3	11	4		24
Fyke netting	3		2		2		7
Large hoop net		4	4	6			14
Small hoop net		4	4	7			15
Minnow fyke netting	1		4		2		7
Seining			4				4
Tandem fyke netting		2				2	4
Tandem minnow fyke		2				2	4
Gear totals	10	12	21	24	8	4	79
Annual totals	21	18	22	31	16	8	116

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A20. Allocation of Long Term Resource Monitoring Program sampling effort in Pool 26, Upper Mississippi River during 1994. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	BWCO	SCB	MCBU	MCBW	IMPS	IMPO	TWZ	Totals
June 15–July 31									
Day electrofishing	6		6	8	2	4			26
Fyke netting	4		2			2			8
Large hoop net		2	5	8			2		17
Small hoop net		2	5	8			2		17
Minnow fyke netting	4		5	2	4	2			17
Night electrofishing								2	2
Seining			12	16					28
Trawling								4	4
Tandem fyke netting		2					2		4
Tandem minnow fyke		2					2		4
Gear subtotals	14	8	35	42	6	8	8	6	127
August 1–September 14									
Day electrofishing	6		6	8	2	4			26
Fyke netting	4		2			2			8
Large hoop net		2	5	7	2		2		18
Small hoop net		2	5	8	2		2		19
Minnow fyke netting	4		5	2	2	2			15
Night electrofishing								2	2
Seining			11	16					27
Trawling								4	4
Tandem fyke netting		2					2		4
Tandem minnow fyke		2					2		4
Gear subtotals	14	8	34	41	8	8	8	6	127
September 15–October 31									
Day electrofishing	6		6	8	2	4			26
Fyke netting	4		2			2			8
Large hoop net		2	4	8	2		2		18
Small hoop net		2	5	8	2		2		19
Minnow fyke netting	4		5	2	2	2			15
Night electrofishing								2	2
Seining			12	16					28
Trawling								4	4
Tandem fyke netting		2					2		4
Tandem minnow fyke		2					2		4
Gear subtotals	14	8	34	42	8	8	8	6	128
Annual totals	42	24	103	125	22	24	24	18	382

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A21. Allocation of Long Term Resource Monitoring Program sampling effort in the Open River Reach of the Mississippi River during 1991. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	SCB	MCBU	MCBW	CTR	Totals
June 15–July 31					
Day electrofishing	8	9	6		23
Fyke netting	10		3		13
Tandem hoop netting	1	5	2		8
Minnow fyke netting	7		4		11
Night electrofishing	6	6			12
Seining	3	3			6
Trawling	3	19		10	32
Gear subtotals	38	42	15	10	105
August 1–September 14					
Day electrofishing	3	9	5		17
Fyke netting	13		6		19
Tandem hoop netting	1	8	3		12
Minnow fyke netting	12		6		18
Night electrofishing	2	5			7
Seining	5	6			11
Trawling	3	18		11	32
Gear subtotals	39	46	20	11	116
September 15–October 31					
Day electrofishing	5	9	6		20
Fyke netting	11	1	5		17
Tandem hoop netting	2	9	3		14
Minnow fyke netting	11		6		17
Night electrofishing	3	5			8
Seining	6	7			13
Trawling	2	20		12	34
Gear subtotals	40	51	20	12	123
Annual totals	117	139	55	33	344

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A22. Allocation of Long Term Resource Monitoring Program sampling effort in the Open River Reach of the Mississippi River during 1992. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	SCB	MCBU	MCBW	CTR	TRI	Totals
June 15–July 31						
Day electrofishing	10	3	4		2	19
Fyke netting	9	2	2		2	15
Gill net	7				2	9
Tandem hoop netting	7	3	4		2	16
Minnow fyke netting	8	2	5		2	17
Night electrofishing	8	3	3		2	16
Seining	12	2				14
Trawling	3	7		4		14
Gear subtotals	64	22	18	4	12	120
August 1–September 14						
Day electrofishing	9	3	4		2	18
Fyke netting	9	2	4		2	17
Gill net	7		4		2	13
Tandem hoop netting	5	3	4		2	14
Minnow fyke netting	9	2	4		2	17
Night electrofishing	10	3	1		2	16
Seining	24	8				32
Trawling	4	6		4		14
Gear subtotals	77	27	21	4	12	141
September 15–October 31						
Day electrofishing	7	3	4		2	16
Fyke netting	10	2	4		2	18
Gill net	7		4		1	12
Tandem hoop netting	5	3	4		2	14
Minnow fyke netting	10	2	3		2	17
Night electrofishing	8	3	3		2	16
Seining	20	8				28
Trawling	4	6		4		14
Gear subtotals	71	27	22	4	11	135
Annual totals	212	76	61	12	35	396

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A23. Allocation of Long Term Resource Monitoring Program sampling effort in the Open River Reach of the Mississippi River during 1993. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	SCB	MCBU	TRI	Totals
June 15–July 31				
Fyke netting	4	1		5
Minnow fyke netting	8	5		13
Trawling		1		1
Gear totals	12	7		19
September 15–October 31				
Day electrofishing	8	6	3	17
Fyke netting	4	1	4	9
Gill net	1		1	2
Large hoop net	8	5	2	15
Small hoop net	8	5	2	15
Minnow fyke netting	8	6	4	18
Gear subtotals	37	23	16	76
Annual totals	49	30	16	95

Stratum Codes: WCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A24. Allocation of Long Term Resource Monitoring Program sampling effort in the Open River Reach of the Mississippi River during 1994. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	SCB	MCBU	MCBW	TRI	Totals
June 15–July 31					
Day electrofishing	7	5		1	13
Fyke netting	6	1		2	9
Gill net	4			1	5
Large hoop net	10	6		2	18
Small hoop net	10	6		2	18
Minnow fyke netting	14	6		2	22
Seining	8				8
Trawling		2			2
Gear subtotals	59	26		10	95
August 1–September 14					
Day electrofishing	3	5	4	2	14
Fyke netting	5	1		2	8
Gill net	1			1	2
Large hoop net	9	4	4	2	19
Small hoop net	10	5	4	2	21
Minnow fyke netting	12	7	4	2	25
Seining	4	12			16
Trawling		4			4
Gear subtotals	44	38	16	11	109
September 15–October 31					
Day electrofishing	3	3	3	2	11
Fyke netting	4	1		2	7
Gill net	2				2
Large hoop net	9	4	7	2	22
Small hoop net	9	5	6	2	22
Minnow fyke netting	8	4	5	2	19
Gear subtotals	35	17	21	10	83
Annual totals	138	81	37	31	287

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A25. Allocation of Long Term Resource Monitoring Program sampling effort in La Grange reach, Illinois River during 1990. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	SCB	MCBU	Totals
June 15–July 31				
Day electrofishing	3		1	4
Fyke netting	2			2
Tandem hoop netting		2	5	7
Gear subtotals	5	2	6	13
August 1–September 14				
Day electrofishing	4	2	4	10
Fyke netting	8			8
Tandem hoop netting		2	8	10
Night electrofishing	2	2	2	6
Seining	2			2
Gear subtotals	16	6	14	36
Annual totals	21	8	20	49

Stratum Codes: BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured

Appendix Table A26. Allocation of Long Term Resource Monitoring Program sampling effort in La Grange Pool of the Illinois River during 1991. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	SCB	MCBU	CTR	TWZ	Totals
June 15–July 31						
Day electrofishing	3		4			7
Fyke netting	5				2	7
Tandem hoop netting		8	4		2	14
Minnow fyke netting	1				2	3
Night electrofishing	4	8	4		2	18
Seining	4	8	4			16
Trawling			8	6	10	24
Gear subtotals	17	24	24	6	18	89
August 1–September 14						
Day electrofishing			4			4
Fyke netting	4				2	6
Tandem hoop netting		8	4		2	14
Minnow fyke netting					2	2
Night electrofishing	1	8	4		2	15
Seining	4	8	4			16
Trawling			8	13	4	25
Gear subtotals	9	24	24	13	12	82
September 15–October 31						
Day electrofishing			4			4
Fyke netting	10				2	12
Tandem hoop netting		8	4		2	14
Minnow fyke netting	2				2	4
Night electrofishing	4	8	4		2	18
Seining	4	8	4			16
Trawling			8	12	4	24
Gear subtotals	20	24	24	12	12	92
Annual totals	46	72	72	31	42	263

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A27. Allocation of Long Term Resource Monitoring Program sampling effort in La Grange Pool of the Illinois River during 1992. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	SCB	MCBU	CTR	TWZ	Total
June 15–July 31						
Day electrofishing	12		4			16
Fyke netting	12				2	14
Tandem hoop netting		8	6			14
Minnow fyke netting	10				2	12
Night electrofishing	10	8	4		2	24
Seining	2	12	4			18
Trawling			8	12		20
Gear subtotals	46	28	26	12	6	118
August 1–September 14						
Day electrofishing	12		4			16
Fyke netting	12				2	14
Tandem hoop netting		8	4		2	14
Minnow fyke netting	9				2	11
Night electrofishing	8	8	4		2	22
Seining	2	16	8			26
Trawling			8	12	4	24
Gear subtotals	43	32	28	12	12	127
September 15–October 31						
Day electrofishing	12		4			16
Fyke netting	12				2	14
Tandem hoop netting		8	4		2	14
Minnow fyke netting	10				2	12
Night electrofishing	8	8	4		2	22
Seining	2	15	9			26
Trawling			8	12	4	24
Gear subtotals	44	31	29	12	12	128
Annual totals	133	91	83	36	30	373

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A28. Allocation of Long Term Resource Monitoring Program sampling effort in La Grange Pool of the Illinois River during 1993. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	BWCO	SCB	MCBU	TWZ	Totals
June 15–July 31						
Day electrofishing	6		8	6	2	22
Fyke netting	6				2	8
Gill net	6	4	4	4		18
Large hoop net		4	8	6		18
Small hoop net		4	8	5		17
Minnow fyke netting	6		8	5	2	21
Night electrofishing	2		4	2	2	10
Seining	4			8		12
Trawling					4	4
Tandem fyke netting		4				4
Tandem minnow fyke		3				3
Gear subtotals	30	19	40	36	12	137
August 1–September 14						
Day electrofishing	6		8	6	2	22
Fyke netting	6				2	8
Gill net	6	4	4	4		18
Large hoop net		4	8	6		18
Small hoop net		4	8	7		19
Minnow fyke netting	6		8	6	2	22
Night electrofishing	2		4	2	2	10
Seining	8		9	8		25
Trawling					4	4
Tandem fyke netting		4				4
Tandem minnow fyke		5				5
Gear subtotals	34	21	49	39	12	155
September 15–October 31						
Day electrofishing	6		8	6	2	22
Fyke netting	6				1	7
Gill net	6	4	3	4		17
Large hoop net		4	8	6		18
Small hoop net		4	8	6		18
Minnow fyke netting	6		8	6	2	22
Night electrofishing	6		8	6	2	22
Seining	9		8	8		25
Trawling					2	2
Tandem fyke netting		4				4
Tandem minnow fyke		4				4
Gear subtotals	39	20	51	42	9	161
Annual totals	103	60	140	117	33	453

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

Appendix Table A29. Allocation of Long Term Resource Monitoring Program sampling effort in La Grange Pool of the Illinois River during 1994. Table entries are numbers of successfully completed standardized monitoring collections.

Gear	BWCS	BWCO	SCB	MCBU	MCBW	CTR	IMPS	IMPO	TRI	TWZ	Totals
June 15–July 31											
Day electrofishing	6		6	8	2		4				26
Fyke netting	4		2				2				8
Large hoop net		2	5	8				2			17
Small hoop net		2	5	8				2			17
Minnow fyke netting	4		5	2	4		2				17
Night electrofishing										2	2
Seining			12	16							28
Trawling										4	4
Tandem fyke netting		2						2			4
Tandem minnow fyke		2						2			4
Gear subtotals	14	8	35	42	6		8	8		6	127
August 1–September 14											
Day electrofishing	6		6	8	2		4				26
Fyke netting	4		2				2				8
Large hoop net		2	5	7	2			2			18
Small hoop net		2	5	8	2			2			19
Minnow fyke netting	4		5	2	2		2				15
Night electrofishing										2	2
Seining			11	16							27
Trawling										4	4
Tandem fyke netting		2						2			4
Tandem minnow fyke		2						2			4
Gear subtotals	14	8	34	41	8		8	8		6	127
September 15–October 31											
Day electrofishing	6		6	8	2		4				26
Fyke netting	4		2				2				8
Large hoop net		2	4	8	2			2			18
Small hoop net		2	5	8	2			2			19
Minnow fyke netting	4		5	2	2		2				15
Night electrofishing										2	2
Seining			12	16							28
Trawling										4	4
Tandem fyke netting		2						2			4
Tandem minnow fyke		2						2			4
Gear subtotals	14	8	34	42	8		8	8		6	128
Annual totals	42	24	103	125	22		24	24		18	382

Stratum Codes: BWCO—Backwater, Contiguous, Shoreline; BWCS—Backwater, Contiguous, Offshore; SCB—Side Channel Border; MCBU—Main Channel Border, Unstructured; MCBW—Main Channel Border, Wing Dam; CTR—Main Channel Trough; TWZ—Tailwater Zone

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE November 1997	3. REPORT TYPE AND DATES COVERED

4. TITLE AND SUBTITLE Fish monitoring by the Long Term Resource Monitoring Program on the Upper Mississippi River System: 1990-1994	5. FUNDING NUMBERS
6. AUTHOR(S) Steve Gutreuter	
7. PERFORMING ORGANIZATION NAME AND ADDRESS	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Geological Survey Environmental Management Technical Center 575 Lester Avenue Onalaska, Wisconsin 54650	10. SPONSORING/MONITORING AGENCY REPORT NUMBER 97-T004
11. SUPPLEMENTARY NOTES	
12a. DISTRIBUTION/AVAILABILITY STATEMENT Release unlimited. Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 (1-800-553-6847 or 703-487-4650. Available to registered users from the Defense Technical Information Center, Attn: Help Desk, 8725 Kingman Road, Suite 0944, Fort Belvoir, VA 22060-6218 (1-800-225-3842 or 703-767-9050).	12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)

The Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River System (UMRS) conducts highly standardized monitoring of fish species in Pools 4, 8, 13, and 26, in a segment of the unimpounded Mississippi River, and in the La Grange Pool of the Illinois River. The mission of the LTRMP is to provide decision makers with information for managing the UMRS as a sustainable large river ecosystem given its multiple-use character. In this report I summarize the initial 5 years of fish monitoring by the LTRMP. This report documents temporal variability that will be critical to interpretation of future events and trends (consistent temporal changes), and documents important spatial patterns. Because 5 years of data can only provide tenuous trend information and because the LTRMP sampling design was changed between 1992 and 1993, trends reported herein must be interpreted cautiously. No evidence of reduction of fish species richness (number of species) was found from 1990 through 1994 or since recording began in the late 19th century. The abundance of common carp (*Cyprinus carpio*), an exotic but commercially harvested species, and sauger (*Stizostedion canadense*), a recreationally valuable species, increased dramatically from 1990 through 1994. Few species declined in abundance. Spatial patterns in the abundance of certain species, including bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), white crappie (*Pomoxis annularis*), and black crappie (*Pomoxis nigromaculatus*) provide substantial evidence that the availability of backwaters presently limits the abundance of these species in the open river study reach, to a lesser extent in Pool 26, and probably elsewhere. This information could be instrumental in identifying the effects of present river management practices and predicting some biological and economic consequences of future changes in floodplain composition. No evidence was found that the relatively rare lake sturgeon (*Acipenser fulvescens*), shovelnose sturgeon (*Scaphirhynchus platorynchus*), paddlefish (*Polyodon spathula*), and blue sucker (*Cycleptus elongatus*) declined in abundance from 1990 through 1994. The flood of 1993 provided an opportunity for skipjack herring (*Alosa chrysochloris*) to temporarily reenter the uppermost pools of the Mississippi River.

14. SUBJECT TERMS Abundance, biodiversity, fish, flood, floodplain, habitat, river, and trend	15. NUMBER OF PAGES 78 pp. + Appendix
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	