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Summary of Fiscal Year 1999 Findings for the Long Term Resource Monitoring Program of the Upper Mississippi River System

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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 Upper Midwest Environmental Sciences Center, a U.S. Geological Survey science center, in cooperation with the five Upper Mississippi River System (UMRS) States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The U.S. Army Corps of Engineers provides guidance and has overall Program responsibility. The mode of operation and respective roles of the agencies are outlined in a 1988 Memorandum of Agreement.

The UMRS encompasses the commercially navigable reaches of the Upper Mississippi River, as well as the Illinois River and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers. Congress has declared the UMRS to be both a nationally significant ecosystem and a nationally significant commercial navigation system. The mission of the LTRMP is to provide decision makers with information for maintaining the UMRS as a sustainable large river ecosystem given its 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 summarizes monitoring activities of the Long Term Resources Monitoring Program during 1999. Selected, notable findings pertaining to annual results for hydrology, water quality, fish, macroinvertebrates, and vegetation are summarized and interpreted. This report satisfies, for 1999, Goal 2, *Monitor Resource Change*, Objective 2.3, *Synthesize and Evaluate Monitoring Data*, as specified in the Operating Plan for the Long Term Resource Monitoring Program (U.S. Fish and Wildlife Service 1993).
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Abstract

This report summarizes monitoring activities of the Long Term Resource Monitoring Program (LTRMP) during 1999 and highlights selected results and accomplishments pertaining to hydrology, water quality, fish, macroinvertebrates, and vegetation.

Mean discharge in 1999 was above average in the Upper Mississippi and Illinois Rivers, but spring flooding was relatively minor. Total nitrogen concentration has declined in the upper reaches of the LTRMP study area (Pools 4 and 8) from highs of about 4 mg/L in 1993 to present levels of about 1.5 mg/L. Mass balance budgets indicate that little nitrogen is lost (denitrified) as water moves through the LTRMP study pools on the Mississippi River. La Grange Pool on the Illinois River also shows little denitrification, but does trap sediments.

Submersed aquatic vegetation was sampled by stratified random sampling in 1999 for the second year. The maximum depth for locating sample sites was changed from 3 to 2.5 m in 1999 because in 1998 little vegetation was found at depths >2.5 m. Vegetation patterns during 1999 were similar to 1998 and no pool-scale changes were detected. Vegetation abundance in 1998 was at or near the highest abundance recorded since 1991. The presence of vegetation was negatively correlated with water depth, current velocity, and wind fetch.

Densities of macroinvertebrates varied among pools in 1999 and showed no systemwide trends. Zebra mussel (*Dreissena polymorpha*) densities were highest in Pools 13 and 8 with Pool 8 showing a substantial increase from earlier years.

Fish collections in 1999 yielded 66 to 76 species per study area, including 14 state-listed threatened or endangered species. In addition, a new invasive species—rudd (*Scardinius erythrophthalmus*)—was collected in Pool 13. The abundance of bluegills (*Lepomis macrochirus*) >150 mm in total length has increased recently in all pools except Pool 26.

Key words: Aquatic vegetation, bluegill, discharge, fish, Illinois River, invertebrates, Mississippi River, nitrogen, water quality

Introduction

The Long Term Resource Monitoring Program (LTRMP), a component of the Environmental Management Program for the Upper Mississippi River System, is administered by the U.S. Geological Survey's Upper Midwest Environmental Sciences Center (Center) in La Crosse, Wisconsin. The LTRMP supports six field stations operated by state agencies in Illinois, Iowa, Minnesota, Missouri, and Wisconsin (Figure 1) to collect most of the monitoring data. Data on important ecosystem components, including water quality, vegetation, macroinvertebrates, and fish, are obtained using standardized operating procedures. Monitoring activities focus primarily on six study areas: Navigation Pools 4, 8, 13, and 26 and the Open River reach on the Mississippi River and La Grange Pool on the Illinois River. Information from monitoring activities and a variety of other sources are available at the Center's Data Library Web site http://www.umesc.usgs.gov/data_library/data_library.html. This report summarizes activities, results, and highlights of the LTRMP during 1999 for hydrology, water quality, vegetation, macroinvertebrates, and fish.

Figure 1. Field stations operated by the Long Term Resource Monitoring Program on the Upper Mississippi River System.

Interpretation of Ecological Conditions

The Upper Mississippi River Basin has been implicated as contributing disproportionately to nitrate delivery and subsequent environmental degradation in the Gulf of Mexico. In addition, high loading of nitrogen, phosphorus, and sediment to streams, lakes, and reservoirs within the Upper Mississippi River Basin may adversely affect local and regional resources. To manage sediment and nutrient movement within the basin, information is needed on the present and historical levels of these constituents and the mechanisms that control their movement. The LTRMP is uniquely qualified to contribute to such investigations.

During 1988–89, the abundance of submersed aquatic vegetation declined precipitously in extensive reaches of the Upper Mississippi River, coincident with a severe midwestern drought. This decline continued through 1994 (Wiener et al. 1998). The causes of this decline are unknown, but may include decreased light availability because of phytoplankton blooms, depletion of nutrients during low flows, herbicides, and grazing by fish (Wiener et al. 1998). The recovery of aquatic vegetation was hindered by high turbidity in backwaters, which reduced light availability (Kimber et al. 1995; Owens and Crumpton 1995), and by high water levels during the 1993 flood.

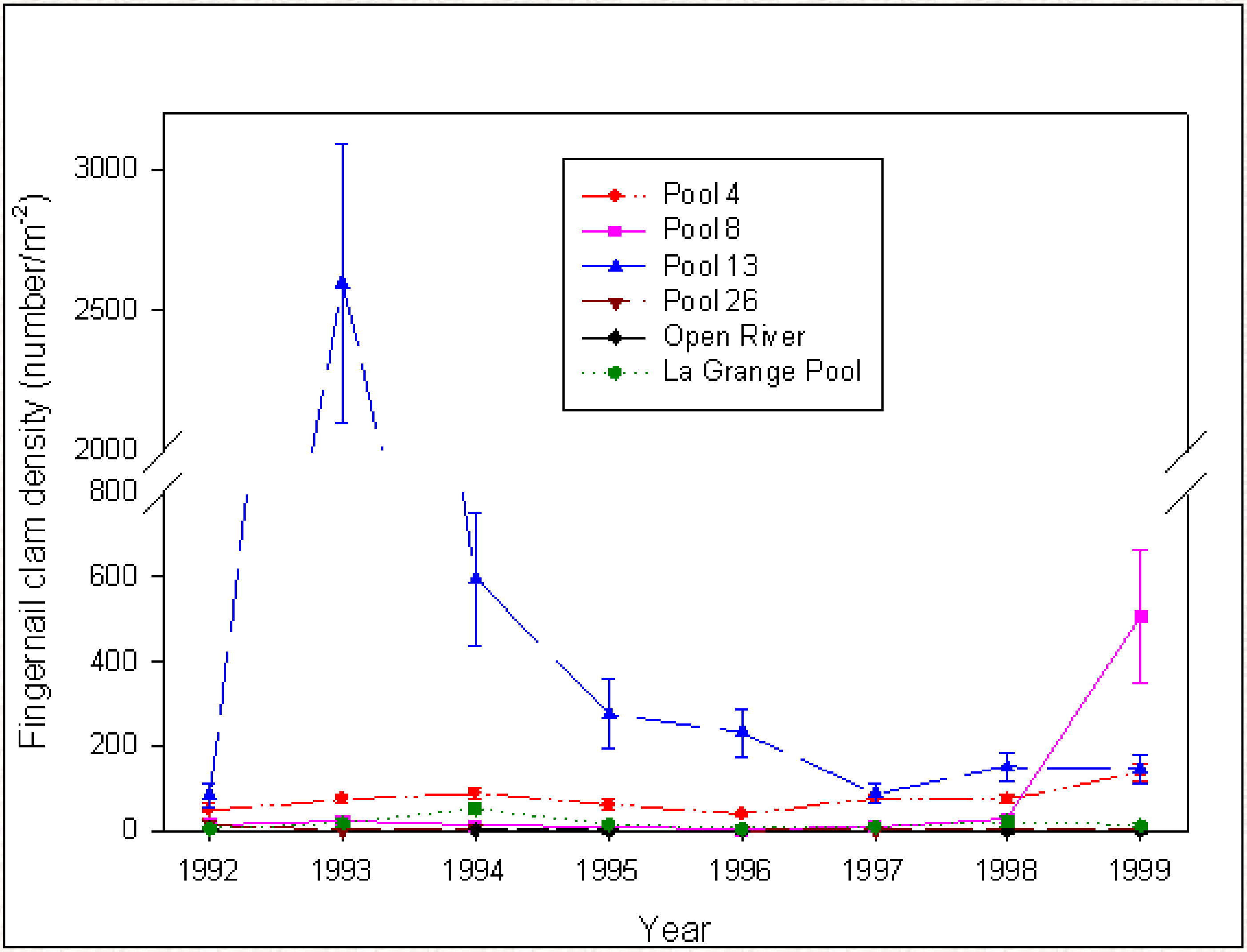
Yin et al. (2000a) concluded that in 1998 submersed aquatic vegetation was at or near the peak abundance recorded since 1991. The abundance of submersed aquatic vegetation was similar between 1998 and 1999 in Pools 4, 8, and 13. Collectively, these observations indicate that the Upper Mississippi River above Dam 13 has rebounded from the severe declines in aquatic vegetation that occurred during the drought of 1987–89 and the flood of 1993.

Estimated mean densities of fingernail clams in 1999 increased in Pools 4 and 8, relative to 1998, but decreased in Pools 13 and 26 and La Grange Pool (Figure 8). The reason for the pronounced increase in the mean densities of fingernail clams in Pool 8 is unknown, but could be related to improved conditions within the sediments. The abundance, standing crop, and taxonomic composition of benthic macroinvertebrates declined in some reaches during recent decades (reviewed by Wiener et al. 1998). In particular, populations of the fingernail clam declined significantly along a 700-km stretch of river from Minneapolis, Minnesota, to Keokuk, Iowa (Wilson et al. 1995). These declines and the subsequent slow recovery of fingernail clams may have been caused in part by the periodic buildup of toxic concentrations of ammonia in bottom sediments (Wilson et al. 1995; Wiener et al. 1998).

Increases in the abundance of zebra mussels may adversely affect certain native biota in the Upper Mississippi River. In particular, the river's unionid mussel fauna is seriously threatened by the zebra mussel, which attaches to the shells of native mussels. Since 1991, the frequency and intensity of unionid mussel infestation by zebra mussels have increased greatly in many areas of the Mississippi River. In other North American waters, unionid mussels have suffered severe mortality (up to 100%) within 1 to 2 years after heavy infestation by zebra mussels (Nalepa 1994; Schloesser and Nalepa 1994; Ricciardi et al. 1995; Whitney et al. 1995).

High densities of zebra mussels can also degrade water quality, indirectly harming other organisms. In particular, zebra mussels have caused major depletion of dissolved oxygen in affected reaches of the Seneca River in New York (Effler and Siegfried 1994) and the Illinois River (Sparks et al. 1994) where populations exceeded 30,000 mussels per square meter. The abundances of certain other exotic (nonnative) species has also increased in the river, posing potential threats to native fauna and flora (Wiener et al. 1998).

Figure 8. Estimated mean densities of fingernail clams *(Musculium transversum)* in each study area of the Long Term Resource Monitoring Program, weighted by area of strata. Bars indicate 1 standard error.



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Monitoring Activities and Highlights

Hydrology Water Quality Vegetation Macroinvertebrates Fish

Hydrology

Hydrologic analyses were performed on daily discharge data collected at St. Paul, Minnesota; Keokuk, Iowa; and St. Louis, Missouri, for the Upper Mississippi River and at Kingston Mines, Illinois, for the Illinois River (Table). Discharge values are usually obtained from elevation gage readings through an elevation-discharge relation. The period of record for the four stations ranged from 60 to 122 years. Watershed areas for the four stations vary from about 2 to 99% of the total watershed of the Upper Mississippi River, including the Missouri River watershed (Table). Other information concerning the discharge database is provided in Wlosinski et al. (1995).

Table 1. Watershed and discharge statistics for four gages in the Upper Mississippi River System.

River	Gaging station	Watershed area at gaging station (km^2)	Watershed area at gaging station as a percent of entire river watershed	Number of years of record for gage	Mean discharge		Mean discharge in 1999 as a percent of the mean for the period of record
					During period of record m^3sec^{-1} ft^3sec	During 1999 m^3sec^{-1} ft^3sec	
Illinois	Kingston Mines, Illinois	40,969	2	60	491 17,329	532 18,805	109
Mississippi	St. Paul, Minnesota	95,312	5	94	375 13,227	588 20,748	157
Mississippi	Keokuk, Iowa	308,210	17	122	2,050 72,404	2,842 100,377	139
Mississippi	St. Louis, Missouri	1,805,230	99	67	5,915 208,903	7,787 274,989	132

Mean daily discharge (m^3/sec) was calculated for each station from January 1 through September 30 for all years of available data (Table). Compared to historical means, 1999 was a relatively wet year. The discharge for the first 9 months of 1999 ranged from 32 to 55% higher than the historical means for the three stations on the Upper Mississippi River and was 9% higher for the Illinois River station (Table). Based on ranked data, 1999 was above the 82rd percentile for the three Mississippi River stations and at the 67th percentile for the Illinois River station.

Although 1999 was relatively wet (Figure 2), the maximum water elevations at Kingston Mines, St. Paul, and Keokuk were 0.3 to 0.6 m below flood stage. At St. Louis, the maximum stage was about 1 m higher than flood stage for 14 days, but was about 7 m lower than the maximum stage measured during the record flood of 1993.

Water Quality

Water quality monitoring within the Long Term Resource Monitoring Program (LTRMP) focuses on variables that significantly affect aquatic habitats, including physicochemical features, suspended sediment, and major plant nutrients, in the Upper Mississippi River and its major tributaries. Sampling in 1999 followed the design established in 1993. This design uses quarterly sampling episodes and uses a stratified random sampling design, with fixed-site sampling conducted at tributaries, major inflows and outflows from the navigation pools, and other locations of interest. Stratified random sampling provides unbiased, seasonal information on water quality across broad areas, such as entire navigation pools. Fixed-site sampling provides continuous information at specific locations.

The transport of sediment and major plant nutrients within the Upper Mississippi River System is an important management concern. For example, mass balance budgets for navigation pools in the LTRMP study area (Figure 3) showed little change in nitrogen from inflows to outflows within a given pool. This suggests that little nitrogen is being removed by denitrification. Thus, most nitrogen is passing through these pools, which may contribute to the problem of Gulf hypoxia.

After the 1993 flood, a decline in total nitrogen was observed in the upper reaches (Pools 4 and 8) of the LTRMP study area, but further decline was not evident in 1998–99. Total nitrogen concentrations in Pools 4 and 8 declined from about 4.0 mg/L in 1993 to about 1.5 mg/L in fall 1998, but did not decline further in 1999.

In the Illinois River, a spring peak in concentrations of nitrate + nitrite occurred again in 1999 (Figure 4). The similarity in nitrogen concentrations above and below La Grange Pool (Figure 4) suggests (and loading calculations verify) that this reach of the Illinois

River does not remove significant amounts of the nitrate.

In examining habitat suitability within the Upper Mississippi River, one constituent of particular interest has been dissolved oxygen in off-channel areas under winter ice cover. In Pools 4, 8, and 13, dissolved oxygen under the ice is lower when deep snow covers the ice (Figure 5). This is mainly because of reduced light penetration through deep snow and a resulting decrease in photosynthesis under the ice. This relation seemed to weaken in 1999 mainly because of high variability in snow depth during that winter. Factors other than snow depth also can influence oxygen concentration under the ice (e.g., water movement), but the effects of these factors can be masked by variable snow depths over time.

Vegetation

Submersed aquatic plants are an important component of the Upper Mississippi River ecosystem. They provide food for migratory waterfowl, improve water quality by stabilizing sediments and assimilating nutrients, provide spawning and nursery areas for fish, and support invertebrate populations by providing structure and surface area.

Sampling of submersed aquatic vegetation in the Upper Mississippi River System was conducted with two protocols in 1999. The primary protocol, referred to as "stratified random sampling" (Yin et al. 2000b), has been used since 1998 to sample aquatic vegetation in June and July. This protocol was used in all LTRMP focal areas except the Open River reach because this reach lacks backwaters and its channels do not support submersed aquatic plants because of high turbidity and current velocity. Sampling points were distributed in areas <3.0 m deep during 1998 and <2.5 m during 1999. We reduced the sampling depth because in 1998 little vegetation was found at depths >2.5 m. Areas deeper than these cutoff depths would not support aquatic vegetation given the turbidity in the river; thus, they were considered nonvegetated and not sampled. The second protocol, referred to as "transect sampling" (Rogers and Owens 1995), has been used since 1991 to sample aquatic plants during May–June and August–September in about 32 selected backwaters within Pools 4, 8, 13, and 26 and La Grange Pool.

Unless stated otherwise, results presented here were from stratified random sampling, which provides statistically sound estimates. In 1999 between 538 to 647 randomly selected points were sampled in each study reach. When comparing 1998 and 1999 data, the 1998 data were limited to those points with depths <2.5 m.

In 1999, the percentage frequency of occurrence of submersed aquatic vegetation in Pools 4, 8, 13, and 26 and La Grange Pool was 38, 58, 42, 0.6, and 0, respectively, and the number of plant species recorded in each pool was 15, 16, 14, 2, and 0, respectively

(Figure 6). The most abundant species in Pools 4, 8, and 13 were coontail (*Ceratophyllum demersum*), Canadian waterweed (*Elodea canadensis*), sago pondweed (*Potamogeton pectinatus*), and wild celery (*Vallisneria americana*). Sago pondweed and coontail were the most common species in Pool 26.

The results fit a longitudinal pattern observed during much of the past three decades that submersed aquatic plants are abundant upstream of Lock and Dam 13 and sparse elsewhere in the Upper Mississippi River System (Rogers and Theiling 1999). Deviations from this pattern occurred after the drought of 1987–89 and the flood of 1993 when little submersed aquatic vegetation was present in the entire Upper Mississippi River System.

The distribution of submersed aquatic vegetation was highly heterogeneous within each pool. The presence of submersed aquatic vegetation was negatively correlated with water depth, current velocity, and fetch. In paired comparisons, submersed aquatic vegetation was more abundant in the lower half than the upper half of a pool, more abundant along side channels than along the main channel, and more abundant in isolated backwaters than in contiguous backwaters.

In comparing 1999 with 1998, patterns were similar and no pool-scale changes were detected. However, some smaller scale changes were noted. Contiguous backwaters in Pool 8 had more submersed aquatic vegetation in 1999 than in 1998. Water stargrass (*Heteranthera dubia*) increased in both contiguous backwaters and in the impounded areas in Pool 8. In Pool 26, submersed aquatic vegetation decreased in an isolated backwater known as Stump Lake.

Macroinvertebrates

Macroinvertebrates are an important food for a variety of fish and waterfowl within the river system. Collectively, the river's macroinvertebrate fauna performs an important ecological function by digesting organic material and recycling nutrients. Mayflies (Ephemeroptera), fingernail clams (Sphaeridae; *Musculium transversum*), and midges (Chironomidae) are monitored because of their ecological significance in the food web. Moreover, macroinvertebrates can be useful as biological indicators of water and sediment quality.

Annual monitoring of macroinvertebrates began in 1992. Substrate samples were collected with standard operating procedures (Thiel and Sauer 1999) using Ponar grab samplers. All mayflies, fingernail clams, midges, Asiatic clams (*Corbicula*), and zebra mussels, an exotic invader, were counted and the presence or absence of several other macroinvertebrates (Odonata, Plecoptera, Trichoptera, Diptera, Bivalvia, Oligochaeta, Decapoda, Amphipoda, and Gastropoda) were recorded.

In 1999, samples were collected at both stratified random and fixed-site sampling locations in all six LTRMP study areas yielding a total of 748 samples. These samples contained 3,604 mayflies, 5,944 fingernail clams, 3,348 midges, 9,629 zebra mussels, and 19 *Corbicula* clams.

On a poolwide basis, the estimated mean densities of mayflies increased between 1998 and 1999 in Pools 8, 13, and 26 and La Grange Pool (Figure 7). Estimated mean densities of fingernail clams increased in Pools 4 and 8, but declined in Pools 13 and 26 and La Grange Pool (Figure 8). No fingernail clams were found in the Open River reach. Estimated mean densities of midges increased in Pools 13 and 26 and in the Open River reach. Estimated mean densities of zebra mussels were highest in Pools 8 and 13 (Figure 9), where some samples contained more than 500 individuals. In Pool 8, zebra mussel densities were much higher than in earlier years, whereas in La Grange Pool densities decreased substantially from 1998 to 1999. Only one zebra mussel was found in 98 samples from La Grange Pool. Asiatic clams were uncommon in all study areas.

Based on within-pool distributions, we concluded that Lake Pepin (a natural lake in Pool 4) and the impounded areas in Pool 13 supported the highest densities of mayflies. Fingernail clam densities were highest in Lake Pepin and in the impounded areas of Pools 8, 13, and 26, but fingernail clams were most abundant in side channels in La Grange Pool. Midge densities were highest within backwater contiguous areas in Pools 13 and 26 and La Grange Pool, and Lake Pepin in Pool 4. Zebra mussel densities were highest in impounded areas. In general, fine-grained substrates composed largely of silt and clay supported the highest numbers of mayflies, fingernail clams, and midges, whereas zebra mussels were most abundant on substrates composed of gravel and rock.

Fish

The Upper Mississippi River System supports important recreational and commercial fisheries. Fish species and communities are monitored with standard operating procedures (Gutreuter et al. 1995; Burkhardt et al. 2000) in all six LTRMP study reaches (Figure 1). In 1999, fish were sampled at stratified random and fixed-site locations with electrofishing, hoop nets, fyke nets, gill nets, seines, and trawls. No deviations from the established sampling design occurred in 1999.

Over all study reaches, 2,614 samples were collected during 1999, yielding 363,046 fish and 66 to 76 species per reach. Several state-listed threatened and endangered species were collected including blue sucker (*Cycleptus elongatus*; Pool 8 and Open River),

river redhorse (*Moxostoma carinatum*; Pool 8), speckled chub (*Macrhybopsis aestivalis*; Pool 8), bluntnose darter (*Etheostoma chlorosomum*; Pool 13), chestnut lamprey (*Ichthyomyzon castaneus*; Pool 13), western sand darter (*Ammocrypta clara*; Pool 13), pugnose minnow (*Opsopoeodus emiliae*; Pool 13), paddlefish (*Polyodon spathula*; Open River), mooneye (*Hiodon tergisus*; Open River), Mississippi silvery minnow (*Hybognathus nuchalis*; Open River), plains minnow (*H. placitus*; Open River), silver chub (*M. storeriana*; Open River), trout-perch (*Percopsis omiscomaycus*; Open River), and river darter (*Percina shumardi*; Open River). Trout-perch were last documented in the Open River reach about 30 to 50 years ago. In addition, two specimens of an invasive species—rudd (*Scardinius erythrophthalmus*)—were collected in the impounded shoreline area of Pool 13. Rudd is a Eurasian species that was imported into the southeastern United States as a bait fish.

We examined trends in the abundance of quality-sized bluegills (*Lepomis macrochirus;* >150 mm in total length; Anderson 1978), the species that ranks first in angler harvest in the Upper Mississippi River. We analyzed electrofishing data from backwater contiguous shorelines in all study areas except the Open River reach, which lacks this habitat. Since 1995, the abundance of quality-sized bluegills has increased in all pools except Pool 26 (Figure 10). This increase may be in response to increased aquatic vegetation in backwaters (Aggus and Elliot 1975; Yin et al. 2000a). Pool 26 may be less favorable for bluegills because it has less backwater contiguous habitat (17% of total aquatic habitat) than other pools (21% to 52%; Laustrup and Lowenberg 1994) and little aquatic vegetation. In addition, summer water levels are more variable in Pool 26 than in other pools (Burkhardt et al. 2000), which may reduce recruitment of shoreline-dwelling species, such as bluegills (Miranda et al. 1984). La Grange Pool also contains little aquatic vegetation (Yin et al. 2000a) and the increase in bluegills in this pool may be related to the use of logjams, which are common in side channels, as spawning habitat (Drake et al. 1997).

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Figure 2. Average daily discharge of the Mississippi River at St. Louis, Missouri, for the 67-year period of record (*blue line*) and for the first 9 months of 1999 (*red line*).

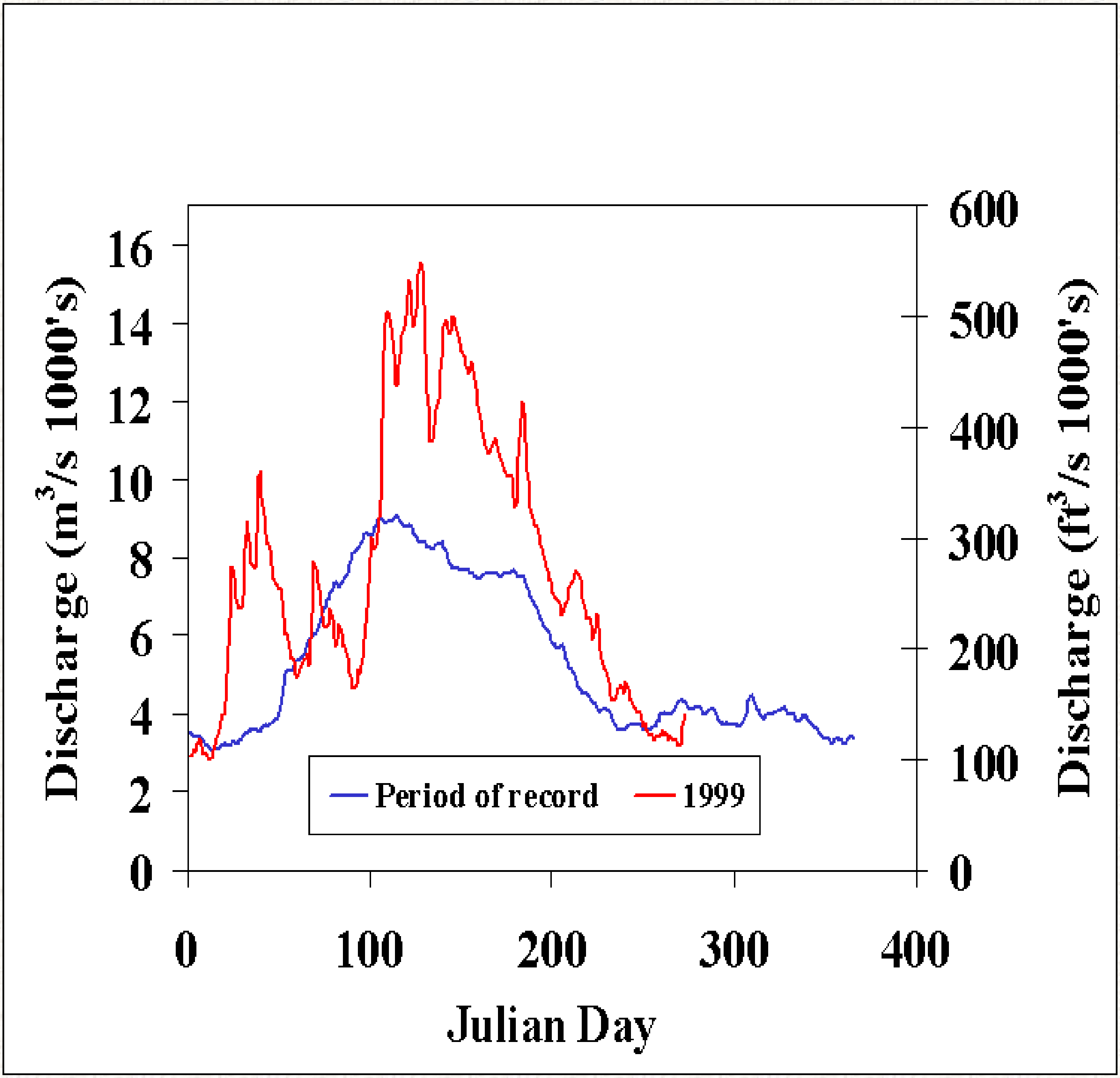

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Figure 3. Transportation of total nitrogen load (Nox-N) in Navigation Pool 13 of the Upper Mississippi River and discharge at Dam 13, 1993–1997.

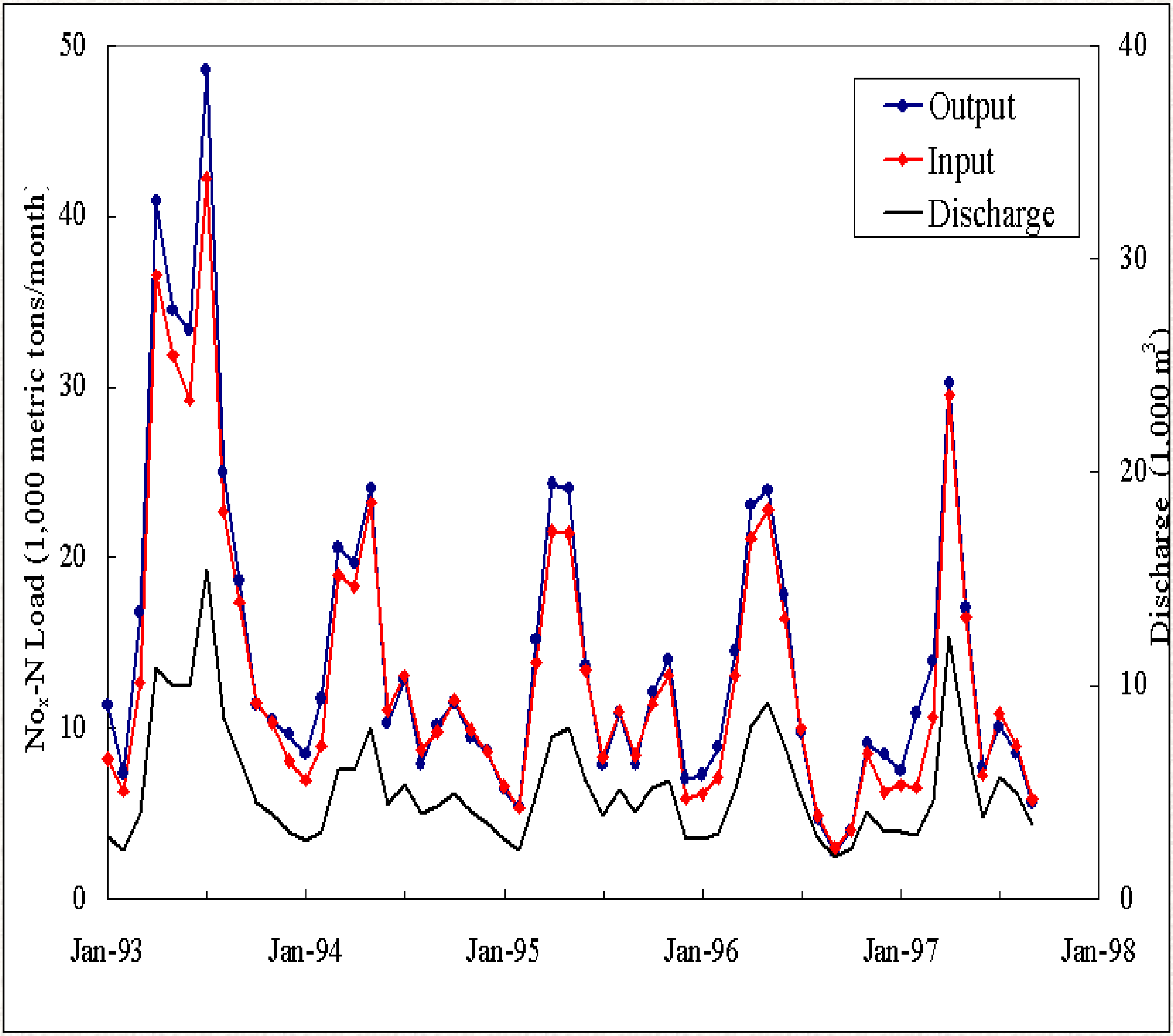

Figure 4. Concentrations (mg/L) of nitrate + nitrite above (*red dots*) and below (*black line*) La Grange Pool of the Illinois River, 1993–1999.

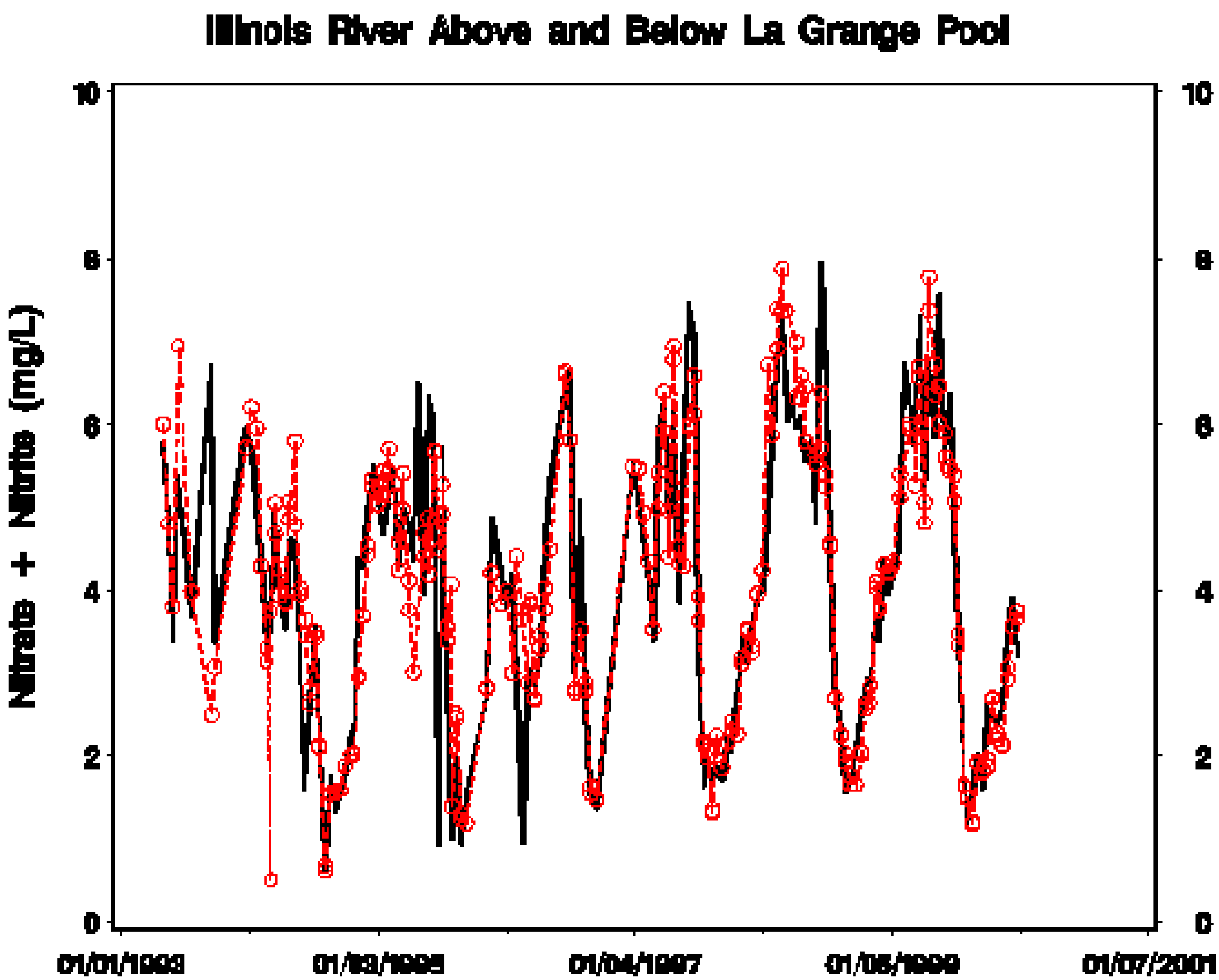

Figure 4. Concentrations (mg/L) of nitrate + nitrite above (*red dots*) and below (*black line*) La Grange Pool of the Illinois River, 1993–1999.

the Illinois River, 1993–1999.

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Figure 5. Winter dissolved oxygen concentration (*solid black line*, left axis) and snow cover (*dashed grey line*, right axis) in Pools 4, 8, and 13 combined for winter stratified random sampling episodes, 1994–1999. Points show the mean, ± 1 standard deviation, and the range. The data show an inverse relation between snow depth and dissolved oxygen concentration.

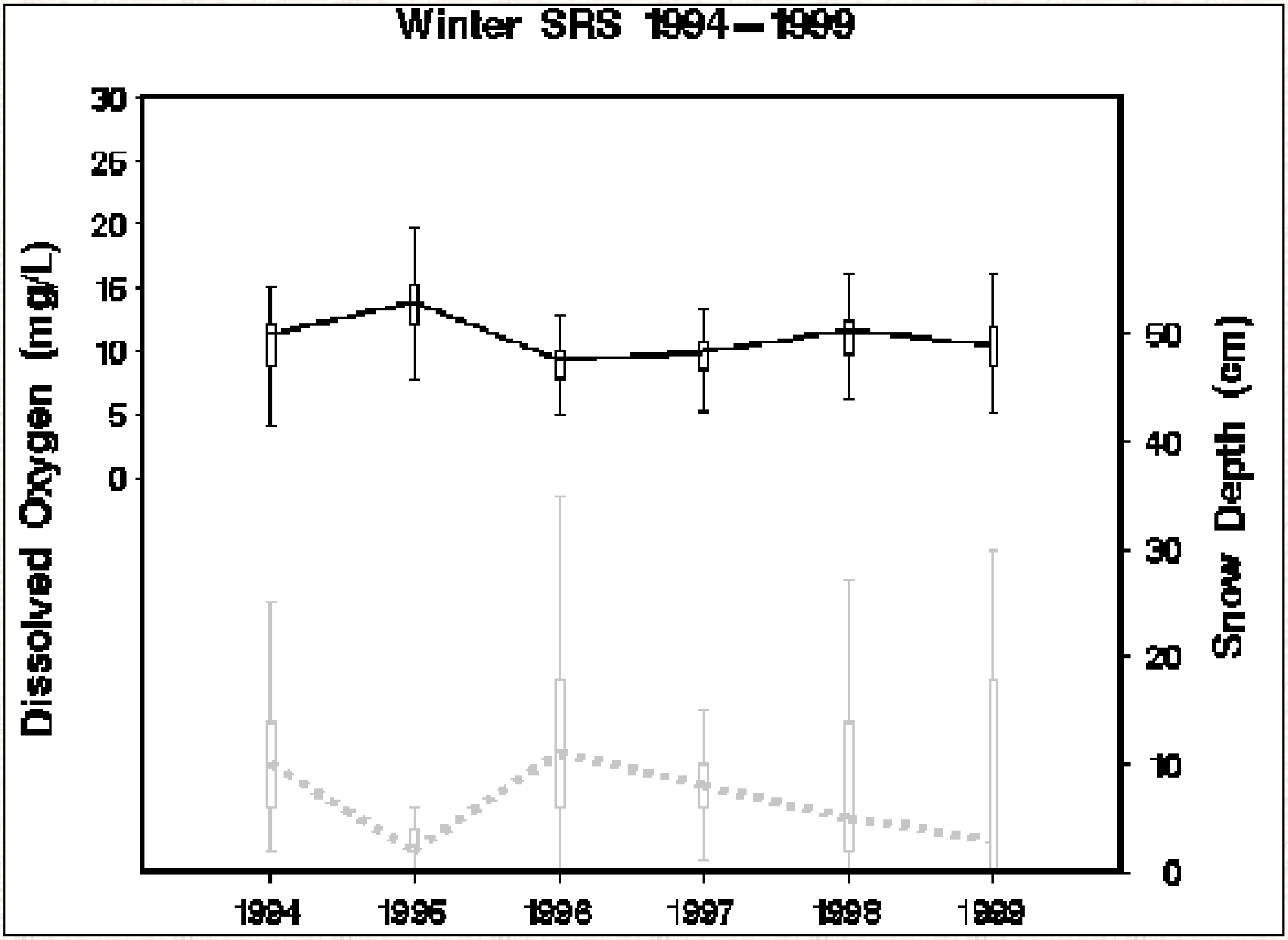

Figure 6. Percentage frequency of occurrence and number of species of submersed aquatic vegetation in areas <2.5 m deep in study pools of the Long Term Resource Monitoring Program, 1998–1999.

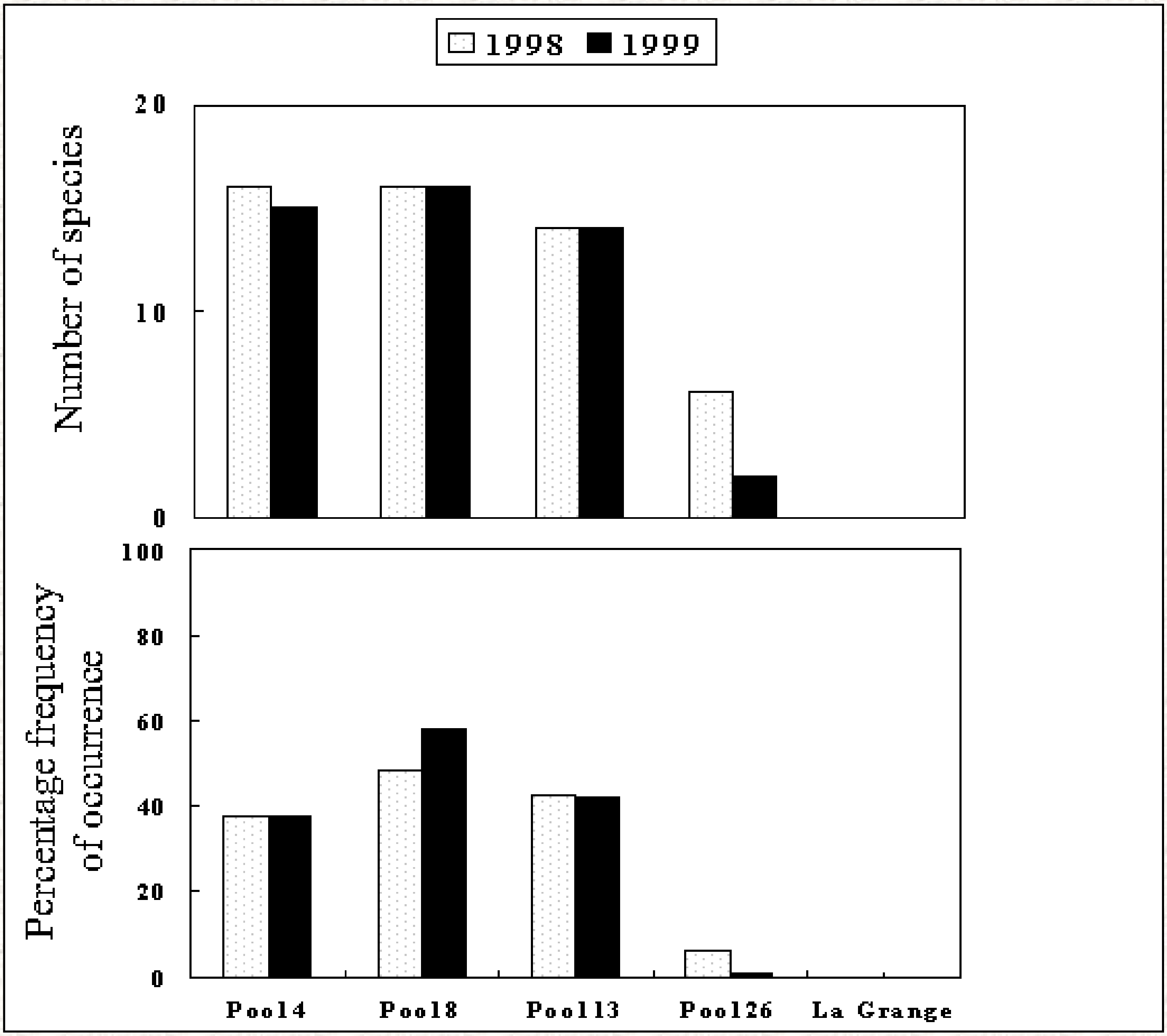

Figure 7. Estimated mean densities of mayflies in each study area of the Long Term Resource Monitoring Program, weighted by area of strata. Bars indicate ± 1 standard error.

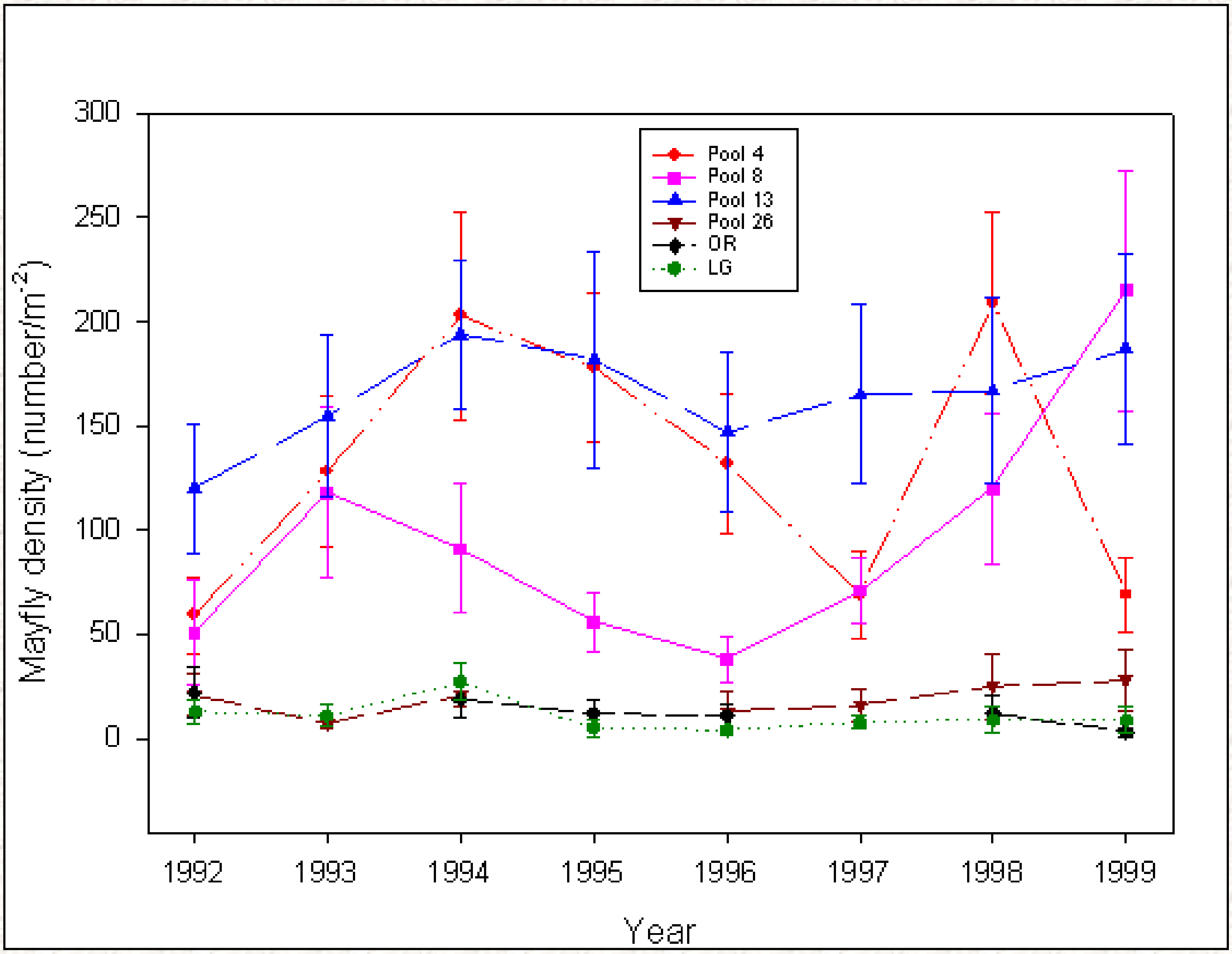

Figure 9. Estimated mean densities of zebra mussels (*Dreissena polymorpha*) in each study area of the Long Term Resource Monitoring Program, weighted by area of strata. Bars indicate ± 1 standard error.

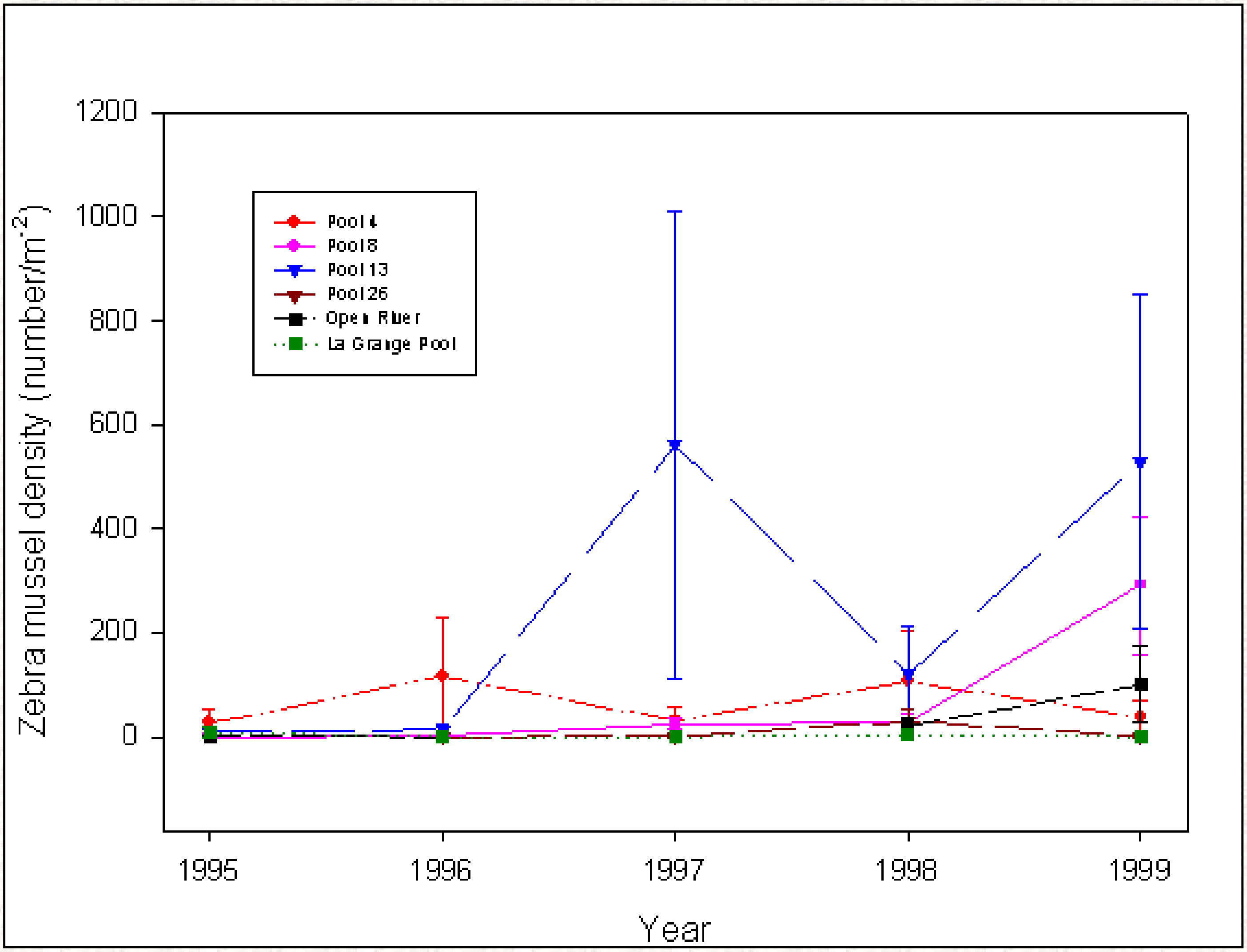

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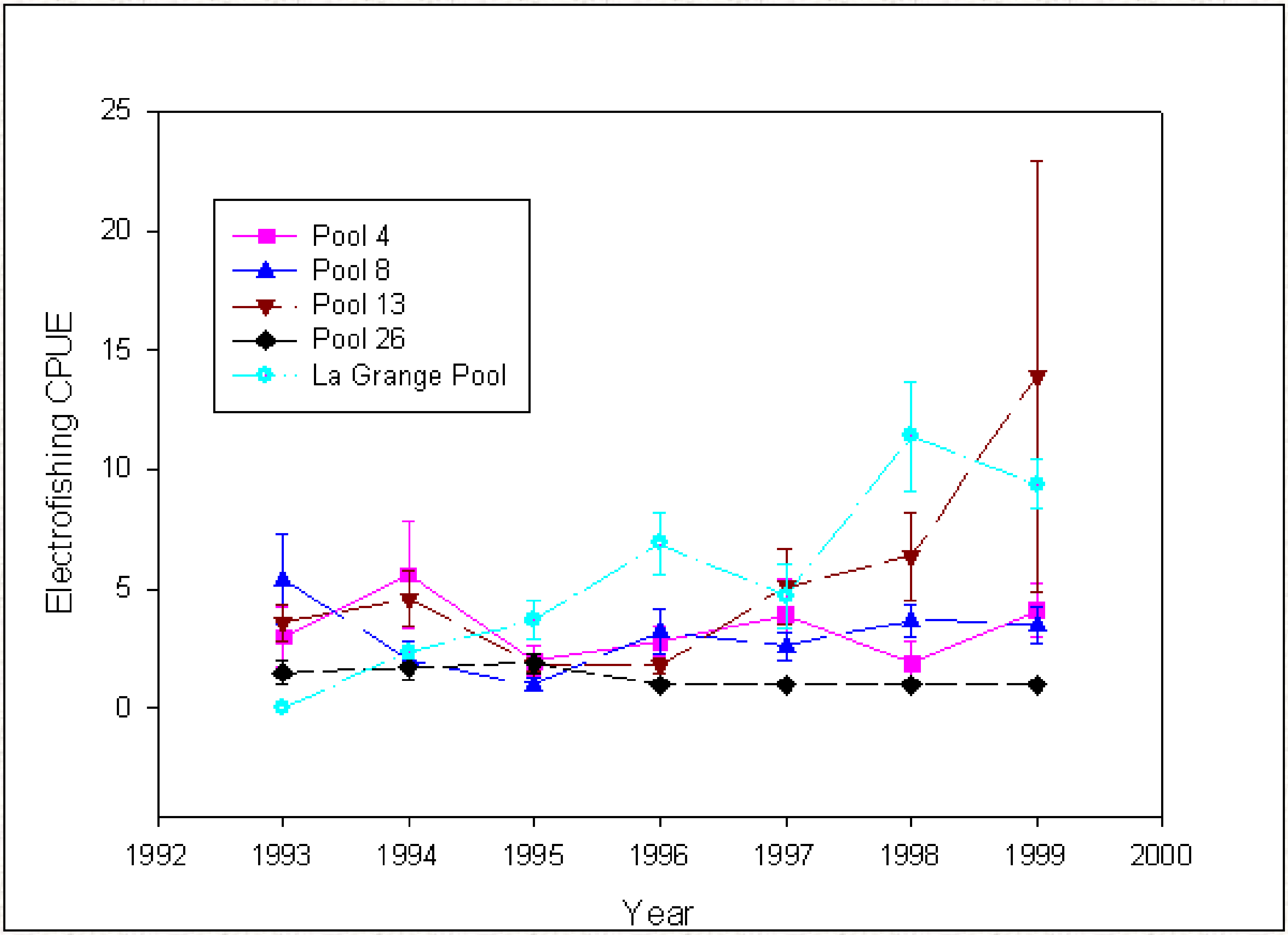
Figure 10. Mean catch per 15 min of electrofishing (CPUE) ± 1 standard error for bluegills (*Lepomis macrochirus*) >150 mm total length sampled from backwater contiguous shorelines in study pools of the Long Term Resource Monitoring Program, 1993–1999.



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