Summary of Monitoring Findings for Fiscal Year 2002 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 2002. Selected, notable findings pertaining to annual results for hydrology, water quality, fish, macroinvertebrates, and vegetation are summarized and interpreted. This report satisfies, for 2002, 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). Preparation of this report was funded by the Long Term Resource Monitoring Program.

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Abstract

This report summarizes monitoring activities of the Long Term Resources Monitoring Program (LTRMP) during 2002 and highlights selected results and accomplishments pertaining to hydrology, sedimentation, bathymetry, land cover/land use, water quality, fish, vegetation, and macroinvertebrates.

Key words: Aquatic vegetation, Asian carp, bathymetry, chlorophyll-*a*, discharge, fish, hydrology, Illinois River, land cover, macroinvertebrates, Mississippi River, water quality

Introduction

The Long Term Resource Monitoring Program (LTRMP), a component of the Environmental Management Program for the Upper Mississippi River System (UMRS), is administered by the U.S. Geological Survey's Upper Midwest Environmental Sciences Center (UMESC) 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. Information on important ecosystem components, including water quality, fish, vegetation, and macroinvertebrates are obtained annually using standardized procedures. Other data such as land cover/land use and bathymetry are gathered and analyzed periodically. 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 the 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 from the LTRMP during 2002 for hydrology, sedimentation, bathymetry, land cover/land use, water quality, fish, vegetation, and macroinvertebrates.

Figure 1. Long Term Resource Monitoring Program study areas and locations of field stations.


50 0 50 100
Kilometers
Open River
Field Station

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Figures

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Figure 2. Mean discharge (m^3/sec x 1,000) at the St. Louis gaging station, Upper Mississippi River System, 2002.

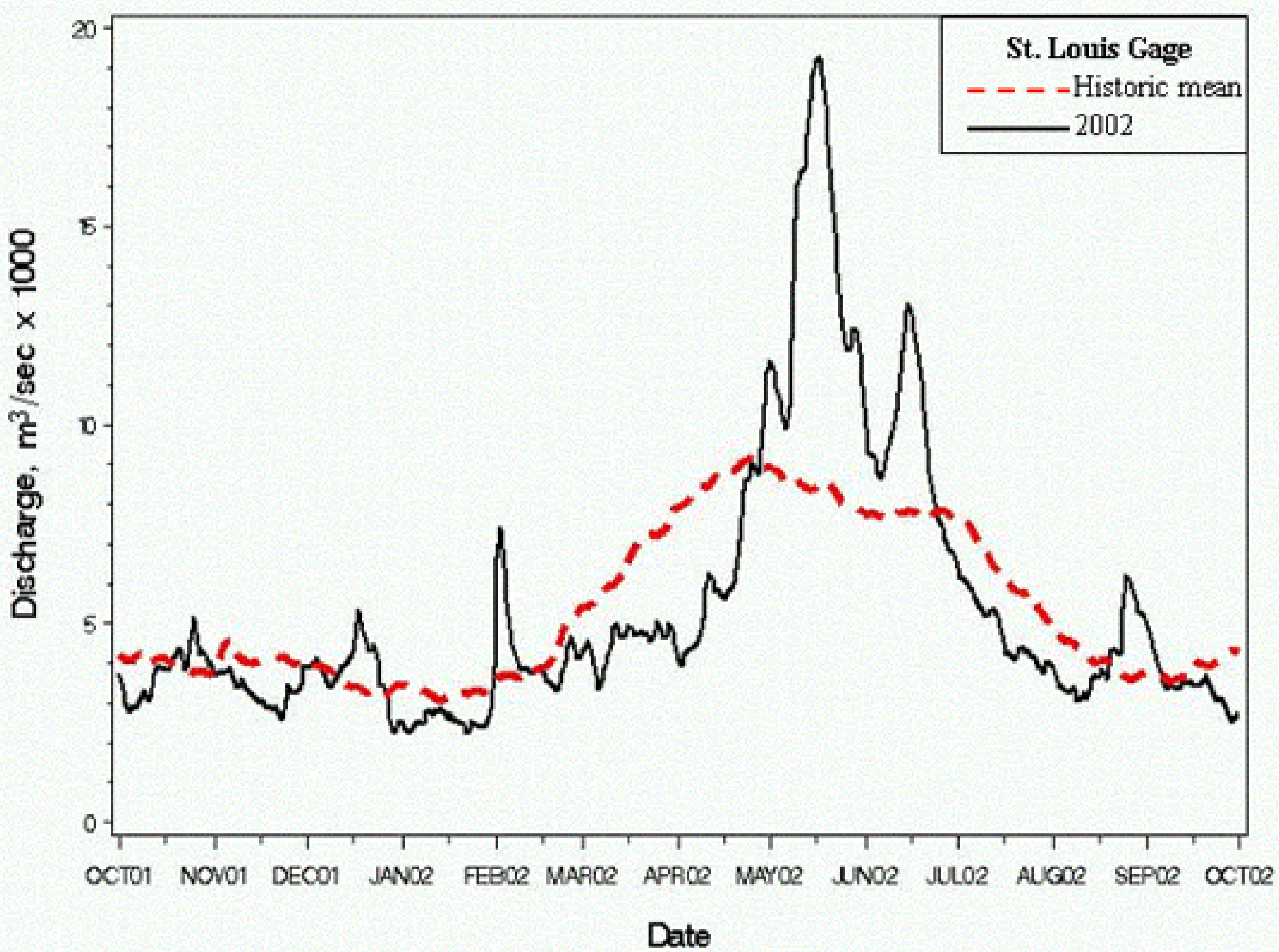


Figure 3. Water elevations (feet above mean sea level) for Pool 4, January 2002–January 2003, Upper Mississippi River System.

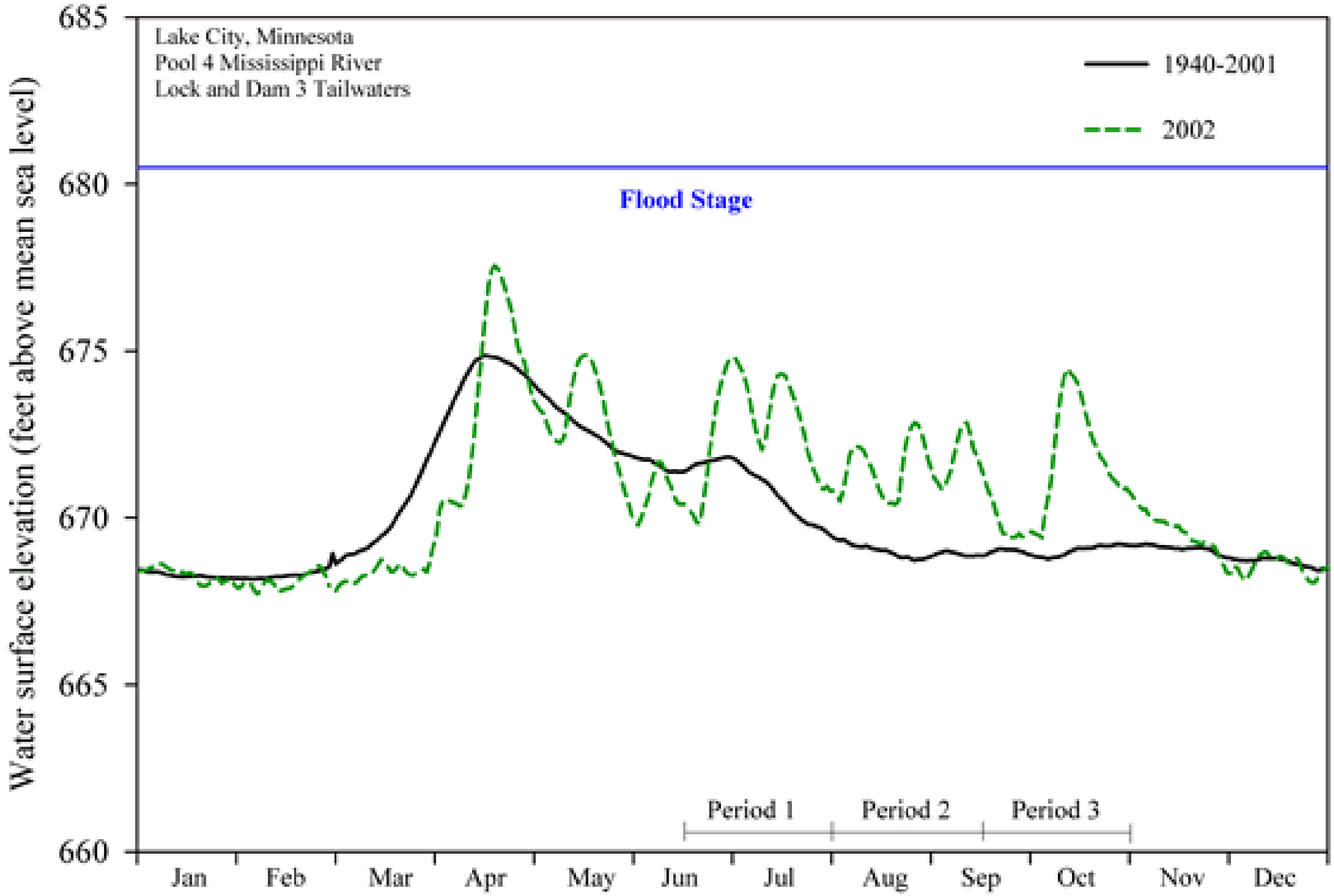


Figure 4. Water elevations (feet above mean sea level) for Pool 8, January 2002–January 2003, Upper Mississippi River System.

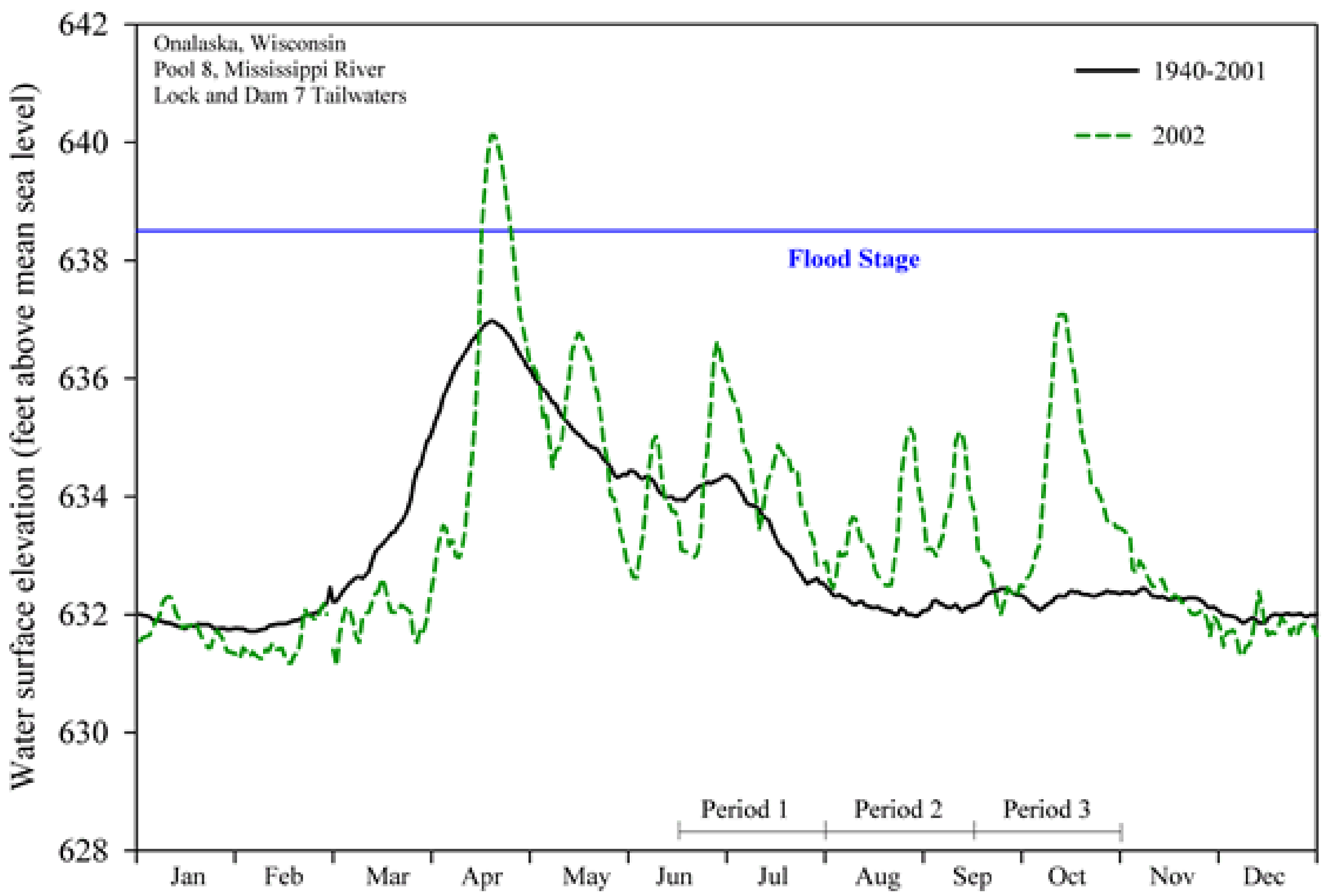


Figure 5. Water elevations (feet above mean sea level) for Pool 13, January 2002–January 2003, Upper Mississippi River System.

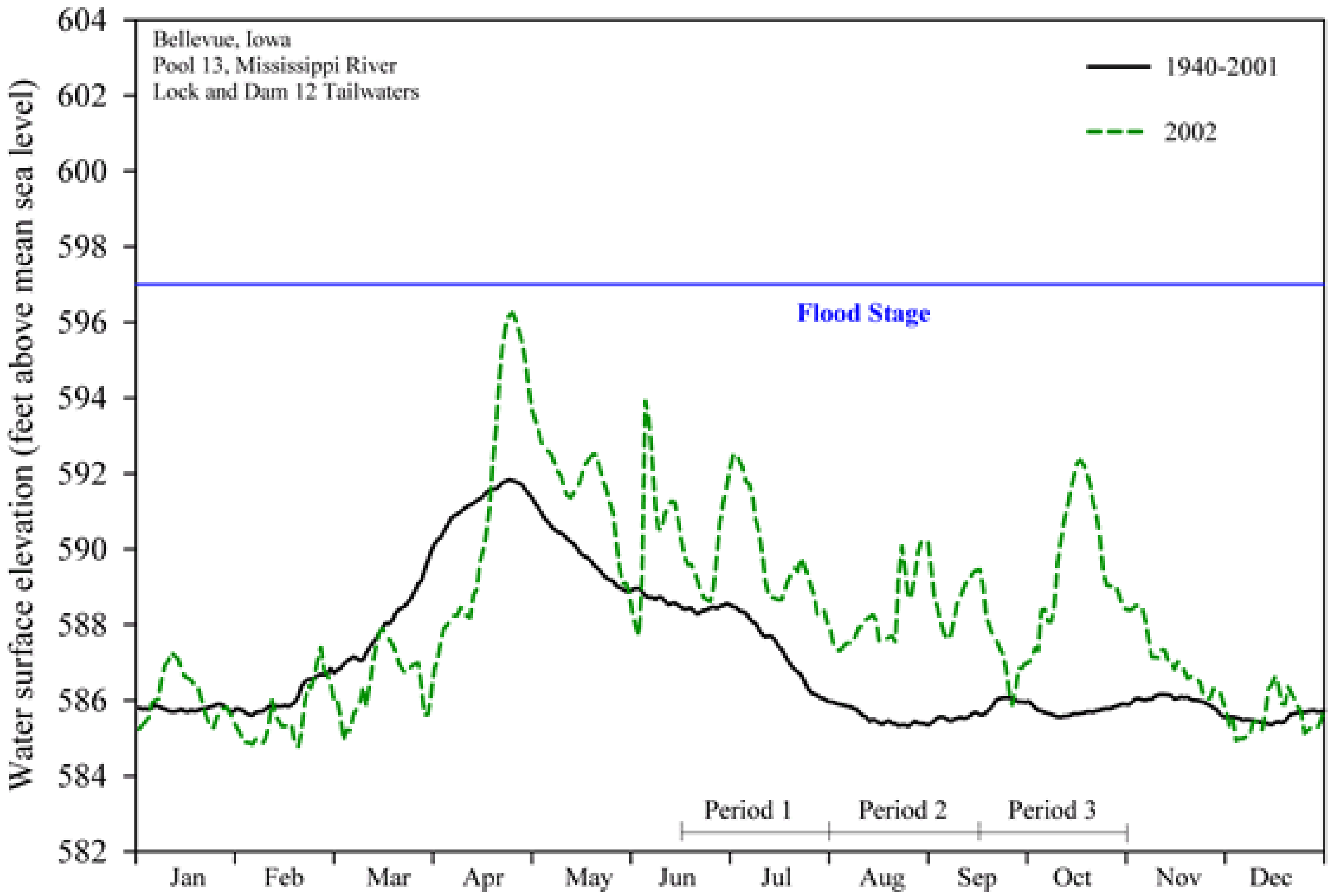
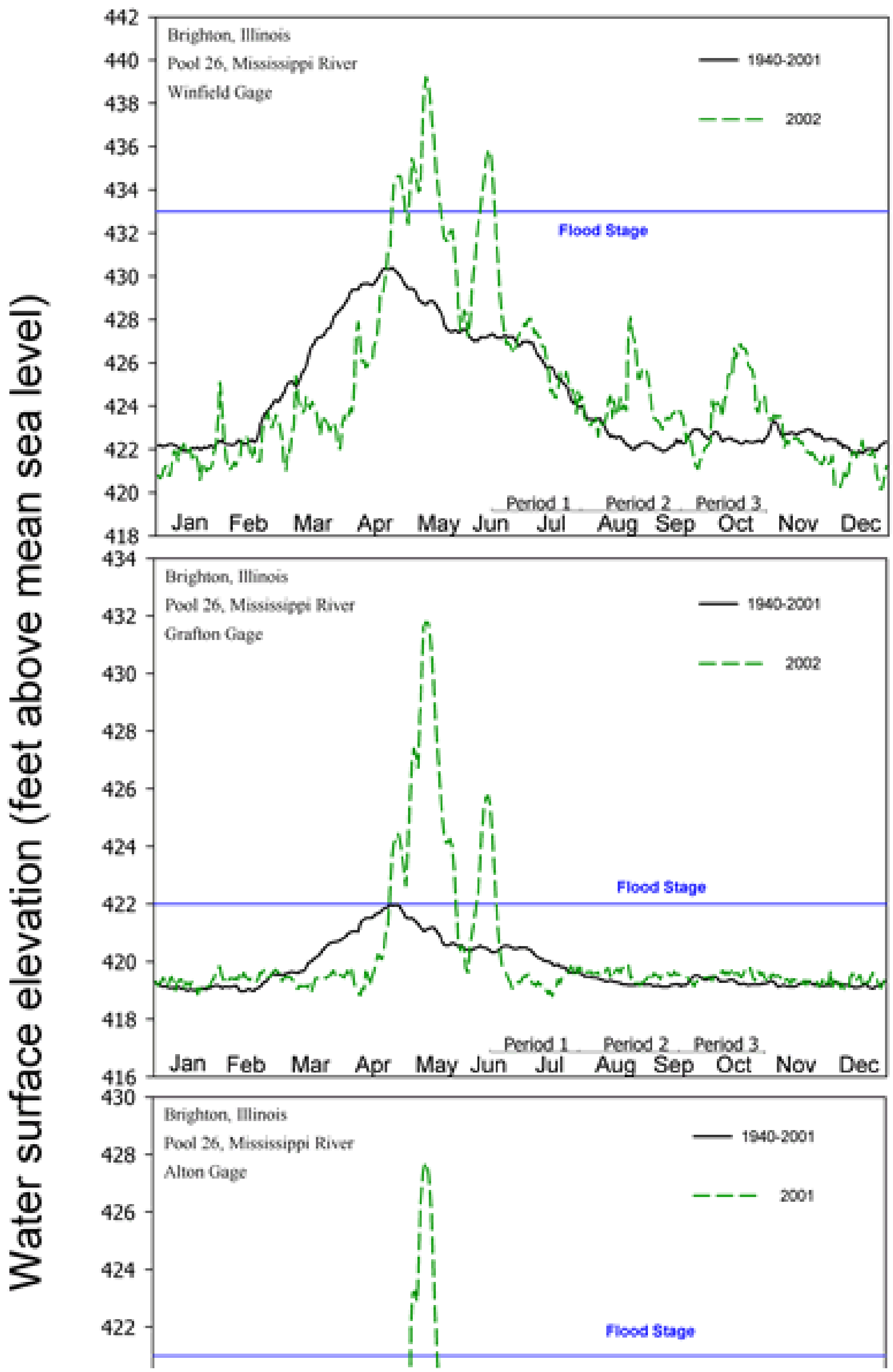
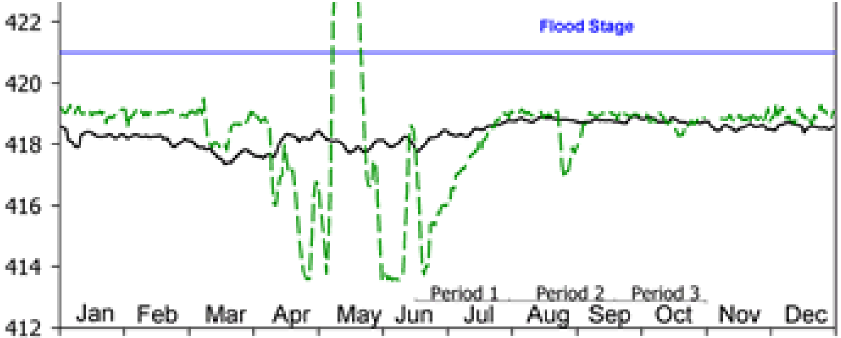


Figure 6. Water elevations (feet above mean sea level) for Pool 26, January 2002–January 2003, Upper Mississippi River System.




422
420
418
416
414
412
Flood Stage
Period 1
Period 2
Period 3
Jan
Feb
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Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 7. Water elevations (feet above mean sea level) for the Open River Reach, January 2002–January 2003, Upper Mississippi River System.

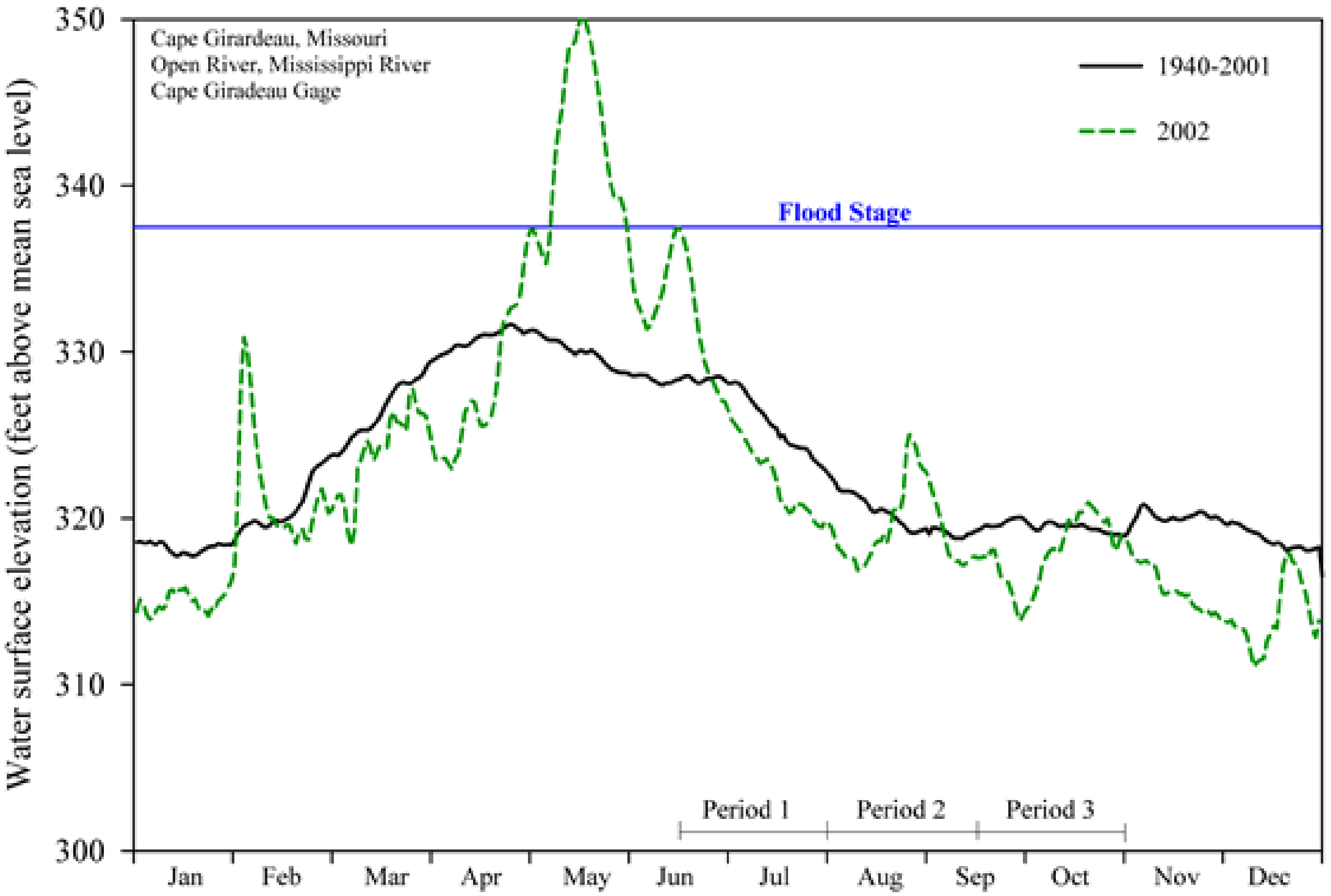


Figure 8. Water elevations (feet above mean sea level) for La Grange Pool, January 2002–January 2003, Upper Mississippi River System.

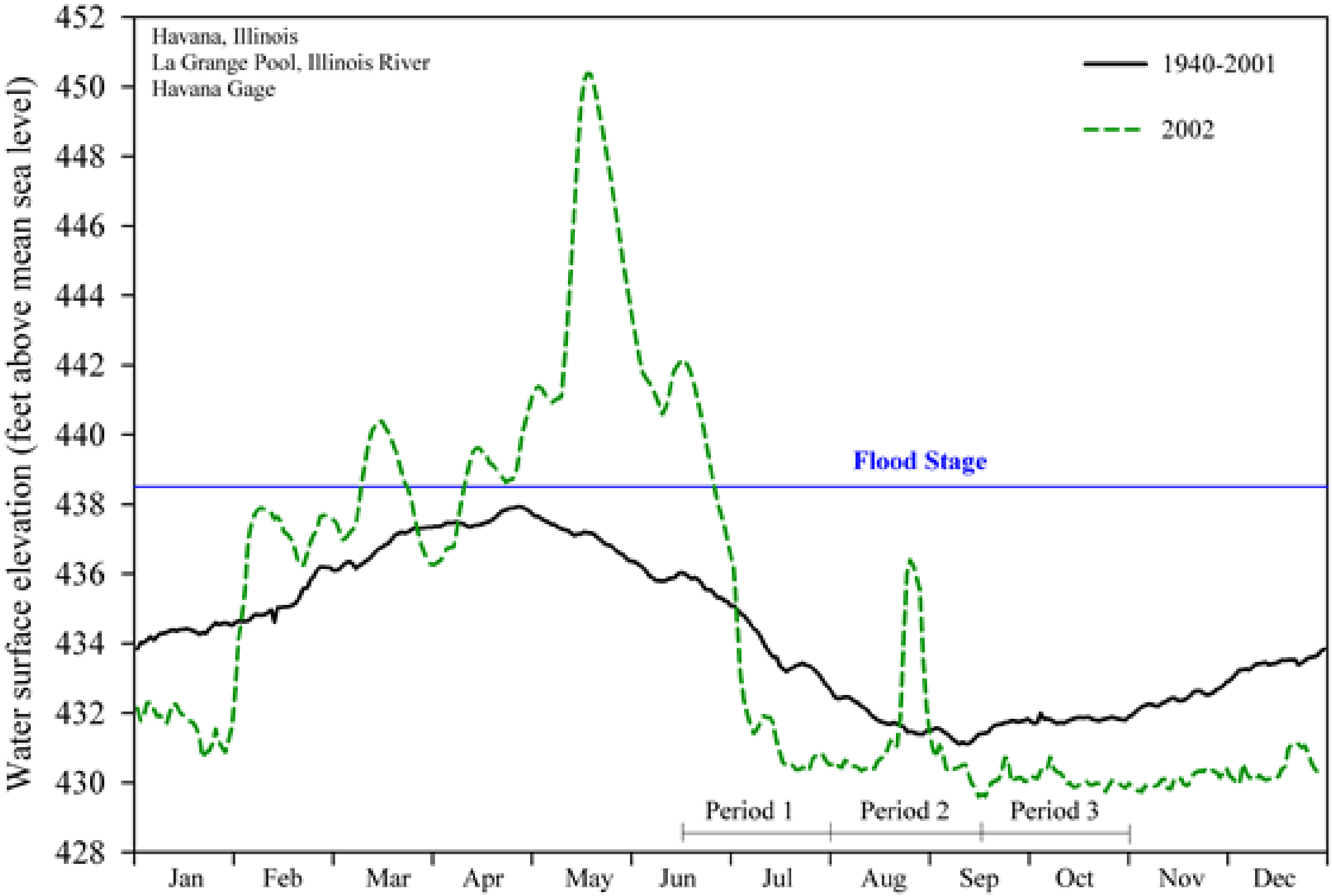


Figure 9. Main channel total suspended solids trends in four of the Long Term Resource Monitoring Program study areas, Upper Mississippi River System. Values are mean concentrations (mg/L) during spring random sampling, 1994–2002.

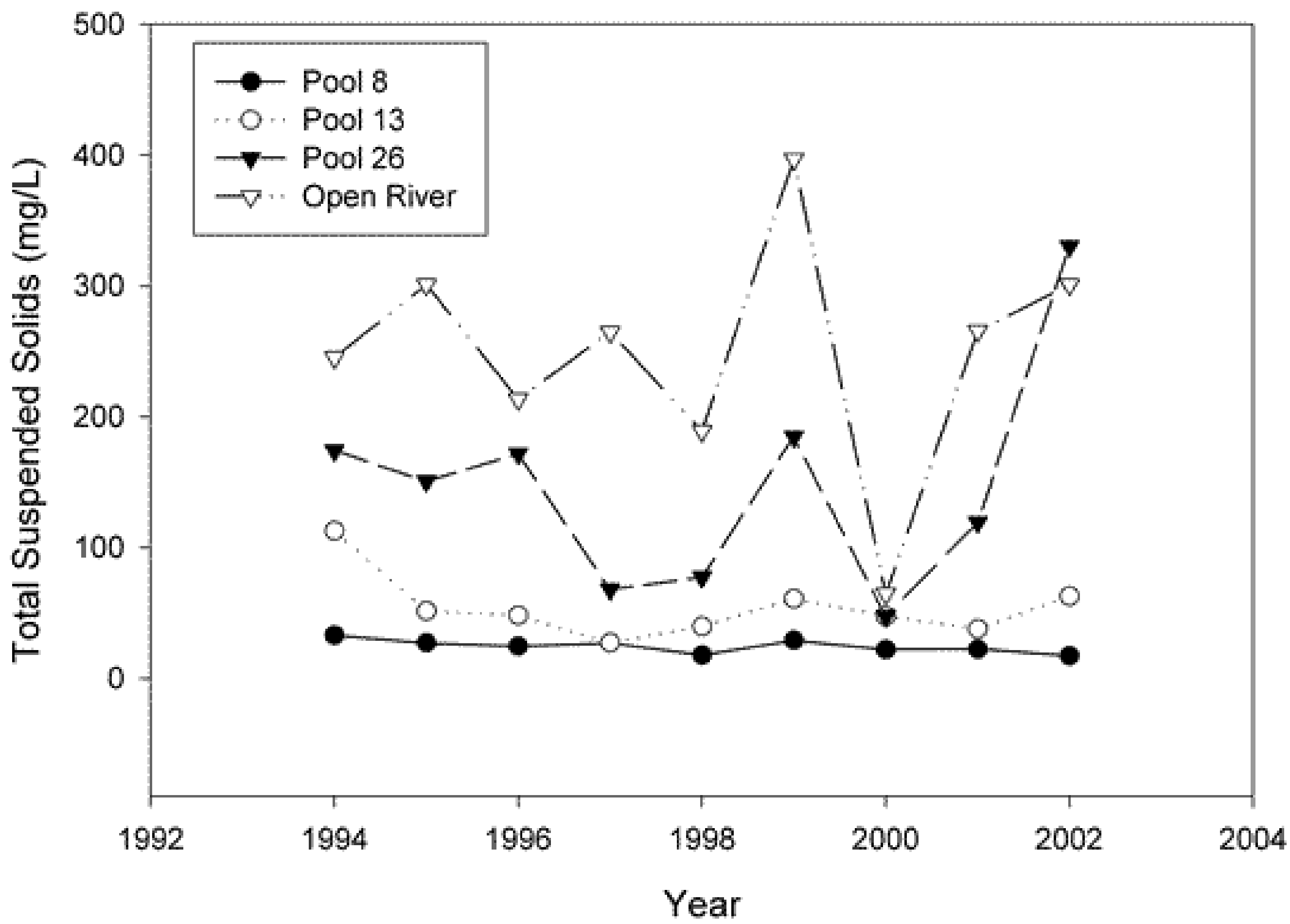
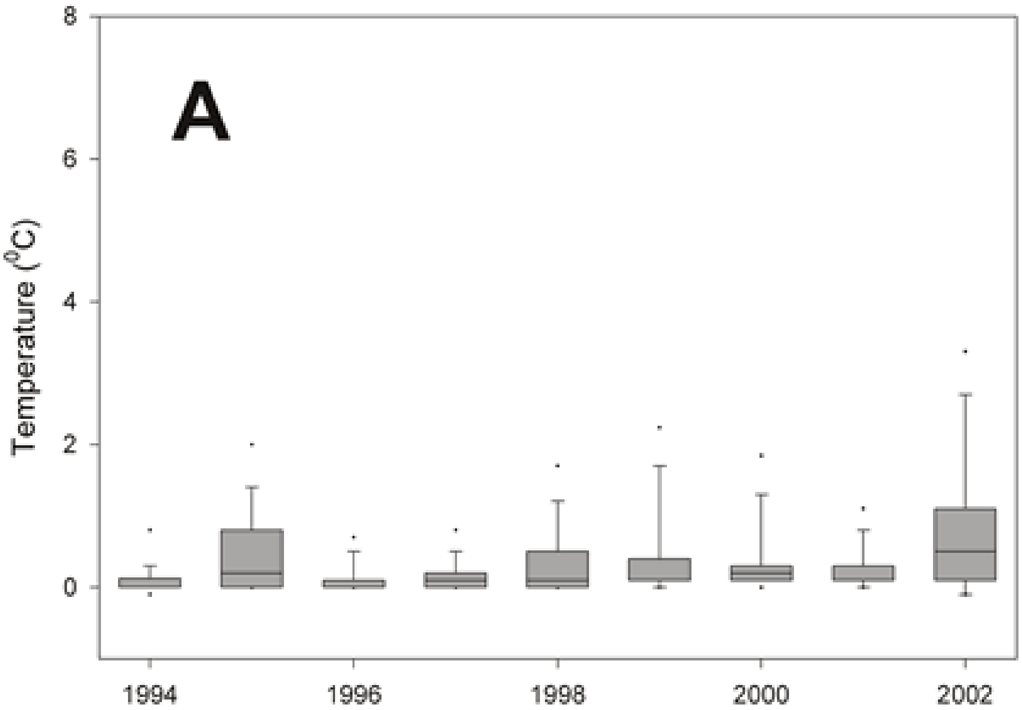
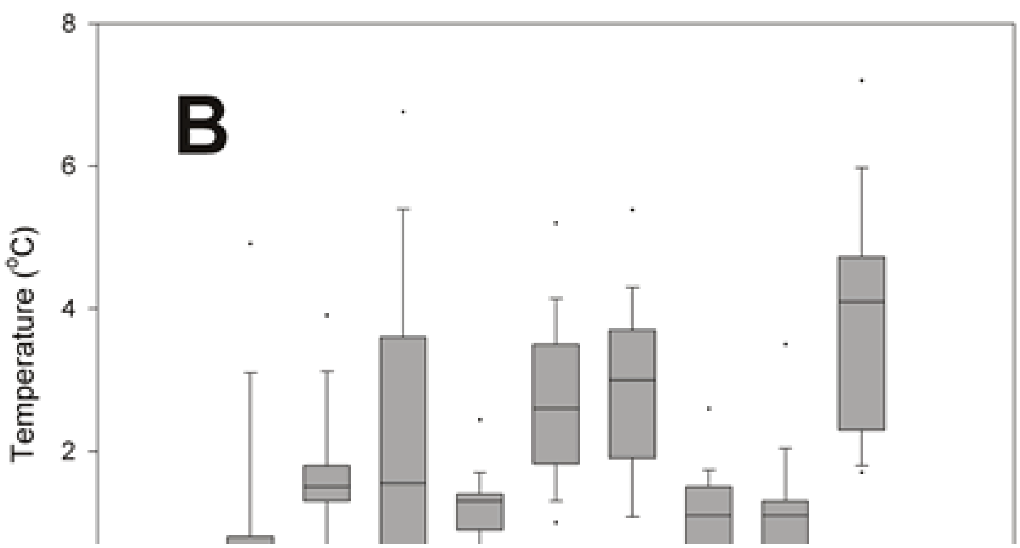
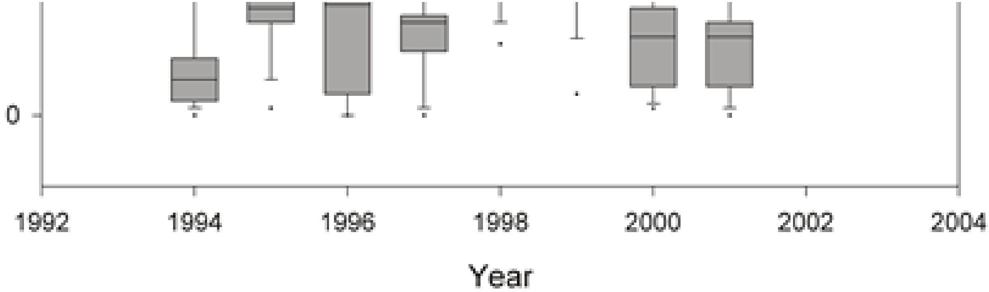


Figure 10. Mississippi River water temperatures (ºC) in northern (*A*: Pools 4, 8, and 13) and southern (*B*: Pool 26 and Open River) Long Term Resource Monitoring Program study areas during winter random sampling, 1994–2002, Upper Mississippi River System. Data are from all strata.



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1992
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2000
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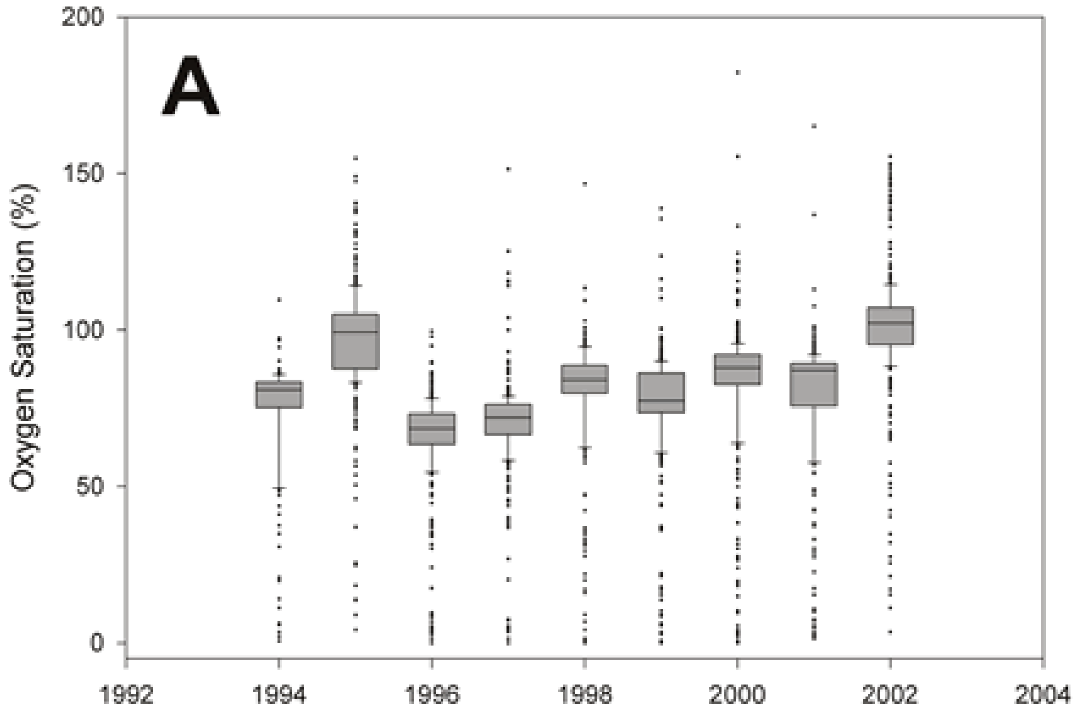
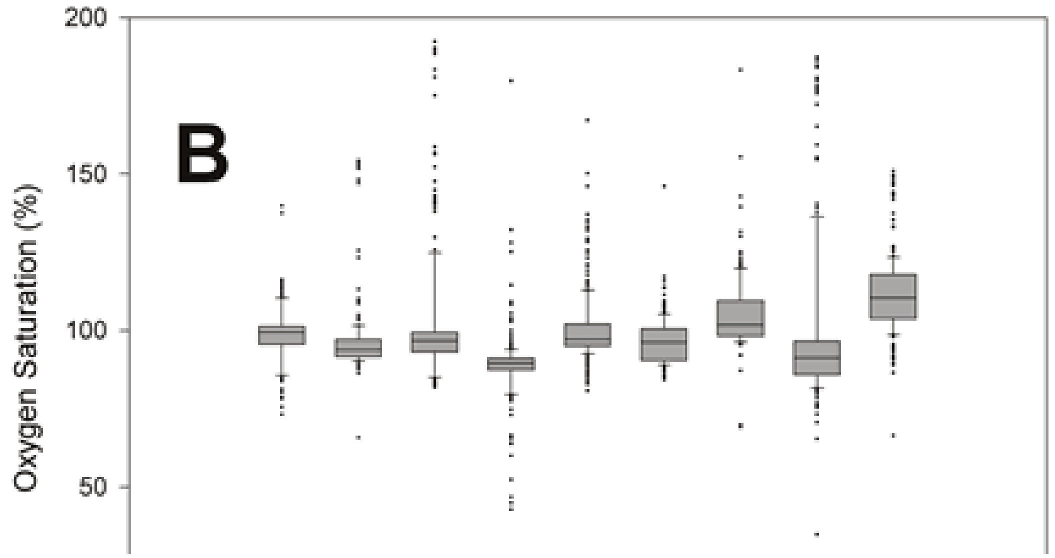
Figure 11. Percent oxygen saturation in the Mississippi River at northern (*A*: Pools 4, 8, and 13) and southern (*B*: Pool 26 and Open River) Long Term Resource Monitoring Program study areas during winter random sampling, 1994–2002, Upper Mississippi River System. Data are from all strata.





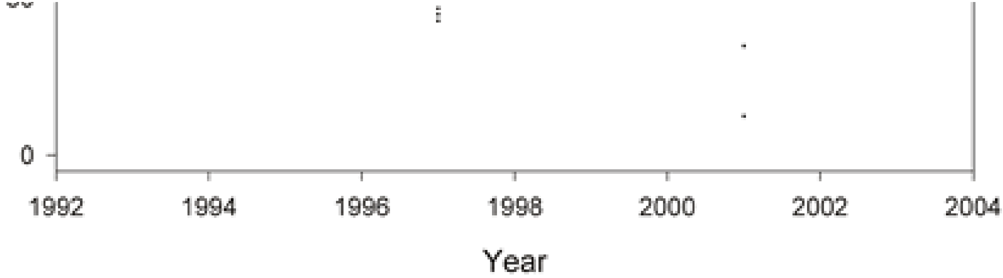

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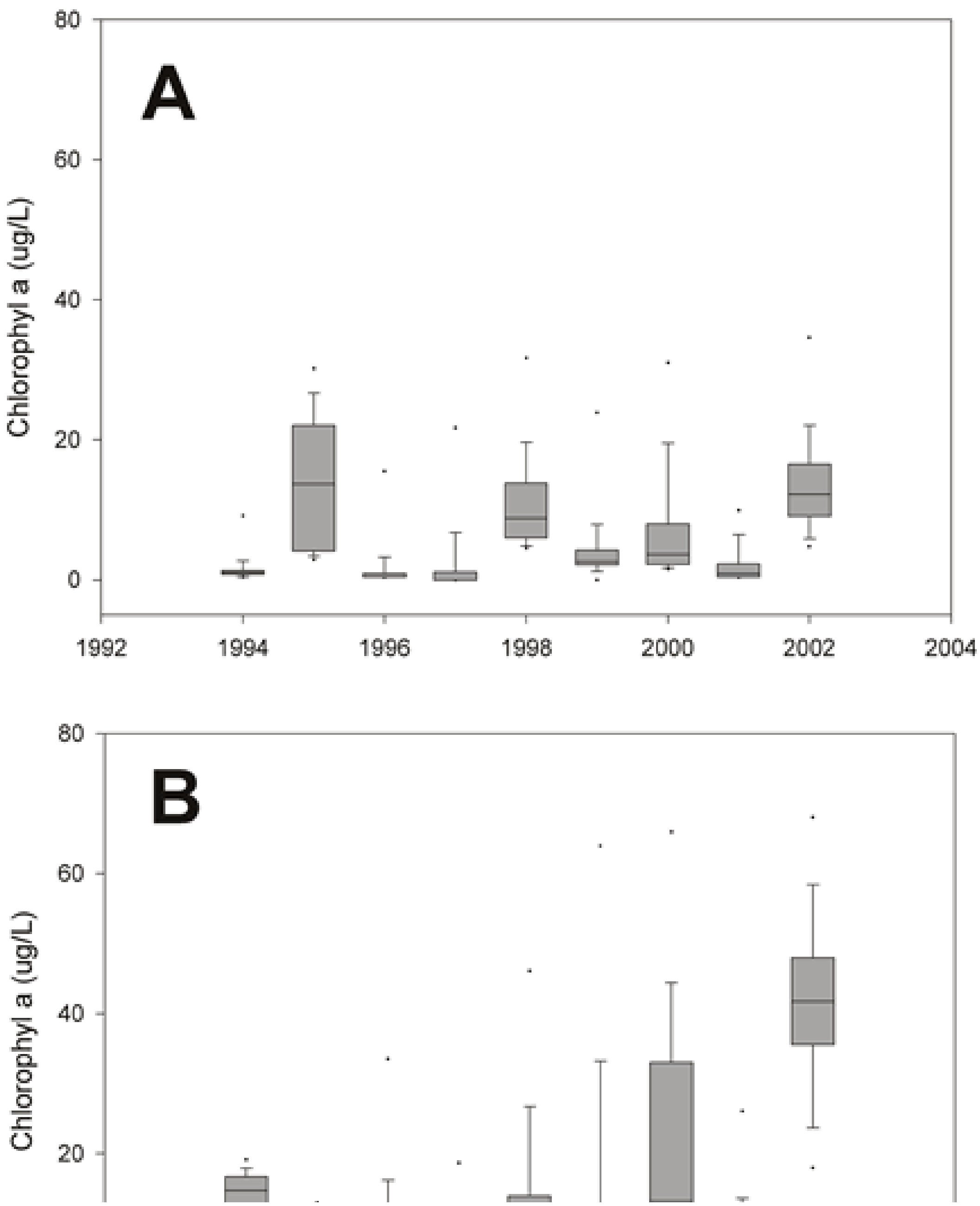
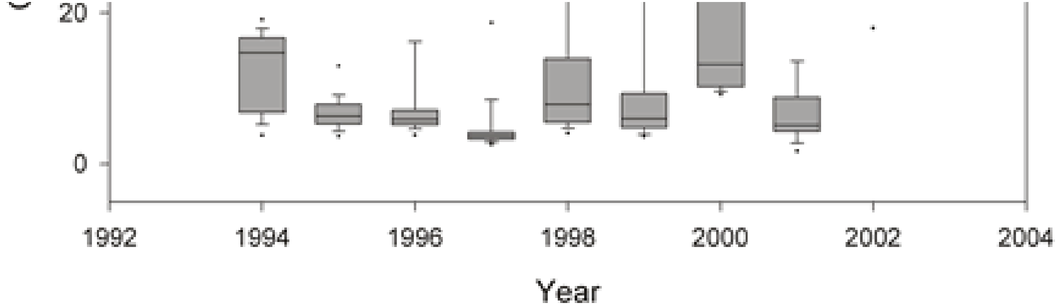
Figure 12. Chlorophyll-*a* concentrations (µg/L) in the Mississippi River at northern (*A*: Pools 4, 8, and 13) and southern (*B*: Pool 26 and Open River) Long Term Resource Monitoring Program study areas during winter random sampling, 1994–2002, Upper Mississippi River System. Data are from all strata.

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1992
1994
1996
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2002
2004
Year

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Figure 13. Percent frequency of occurrence of submersed aquatic vegetation in upper Pool 4, 1991–2001, Upper Mississippi River System.

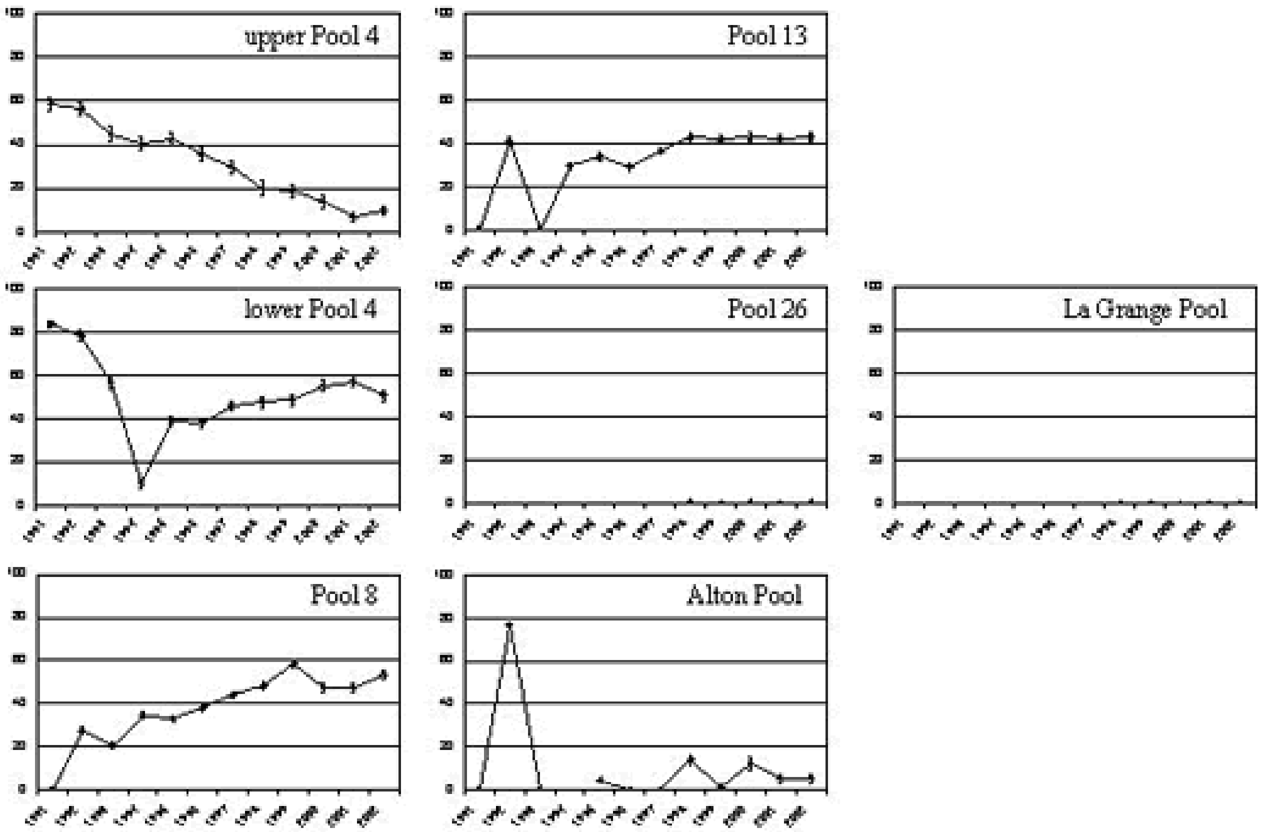

Figure 14. Abundance (rake index) of submersed aquatic vegetation in Pool 13, 1998–2001, Upper Mississippi River System.

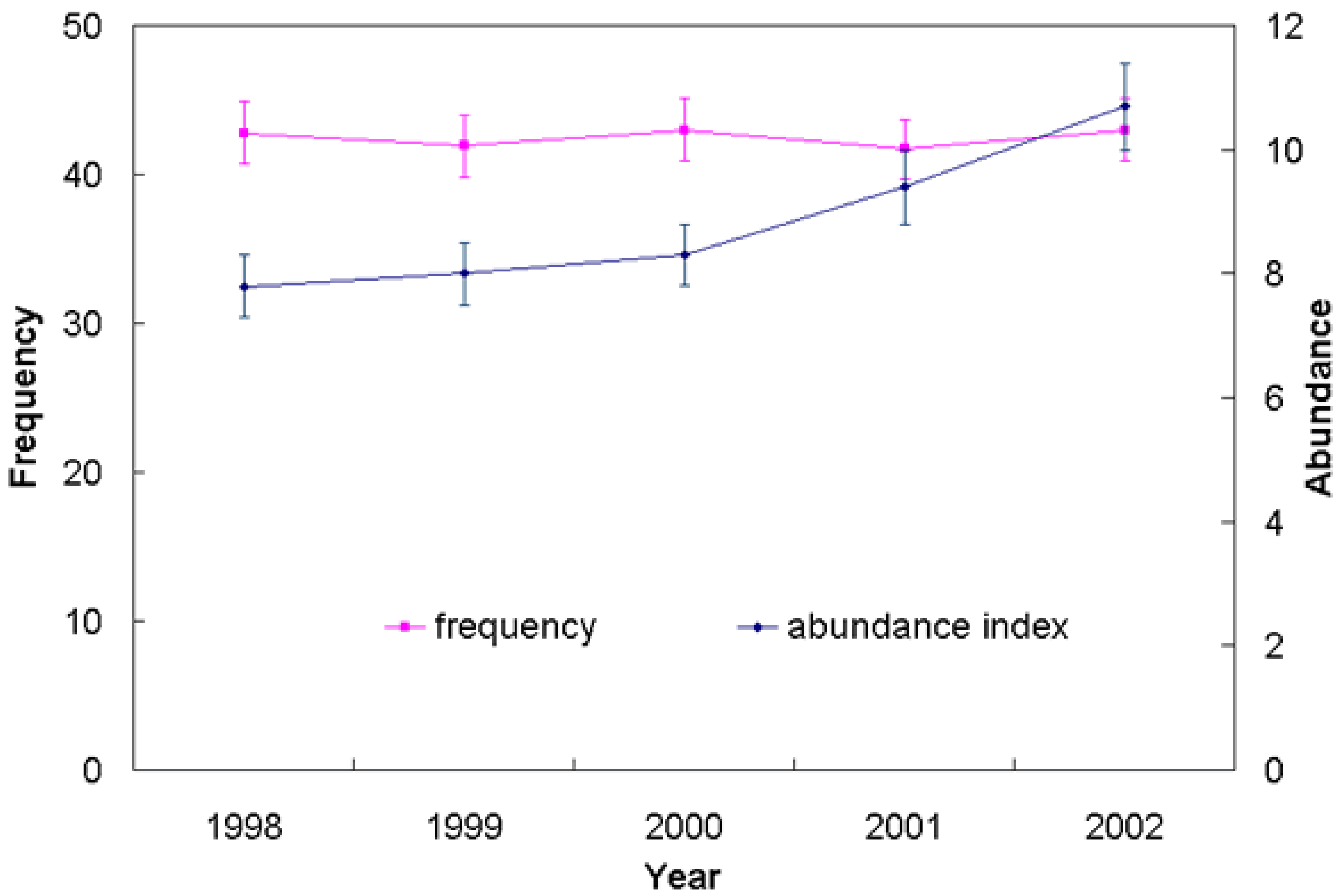

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Figure 15. Canonical ordination of pools based on similarities on vegetation species and abundance, 2002 (Pools 4, 5, 7, 8, 11, 12, 13, and 26 of the Mississippi River and La Grange Pool of the Illinois River).

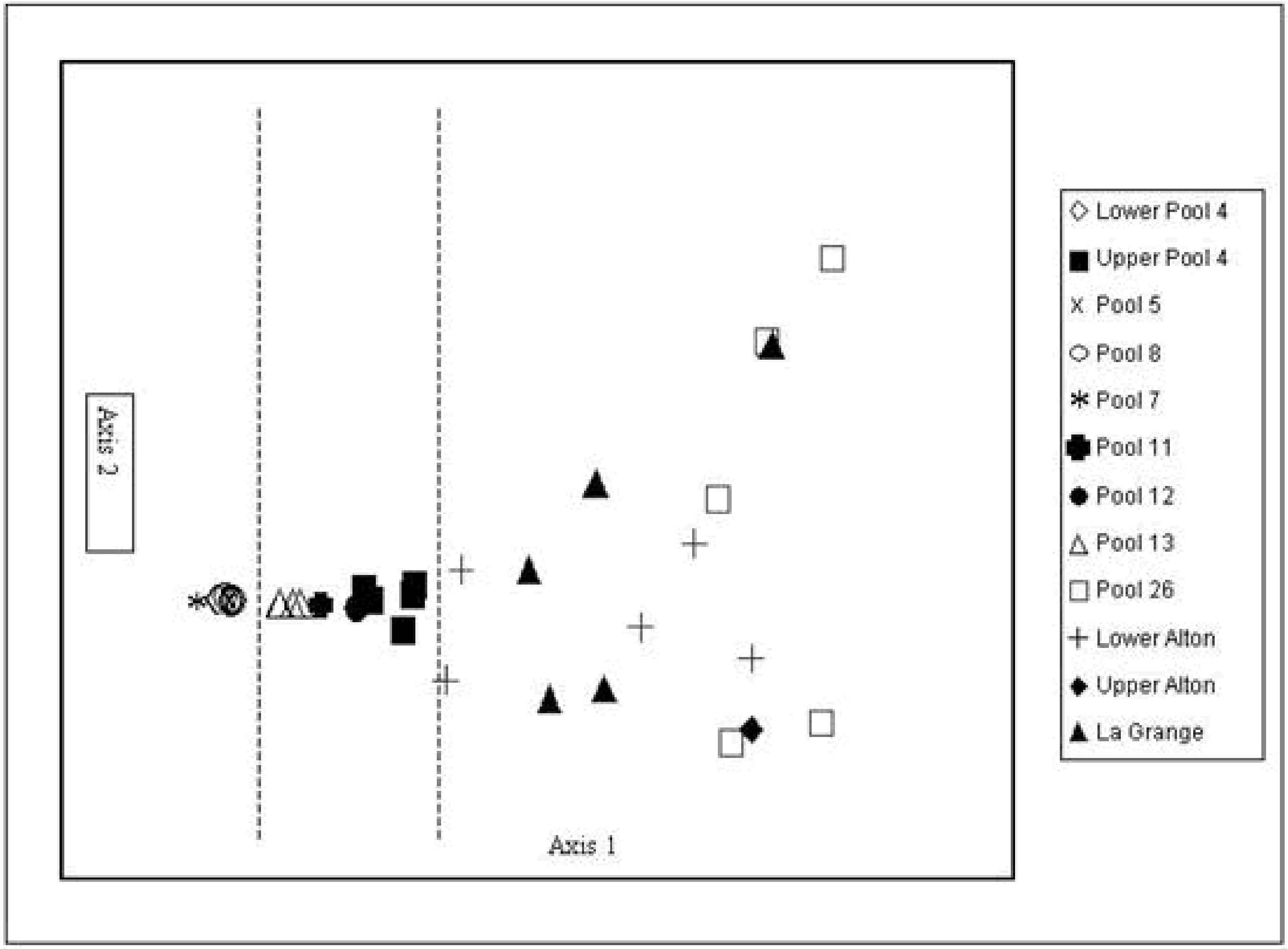

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Figure 16. Mean mayfly (Ephemeridae) abundance from 1992 to 2002, Upper Mississippi River System.

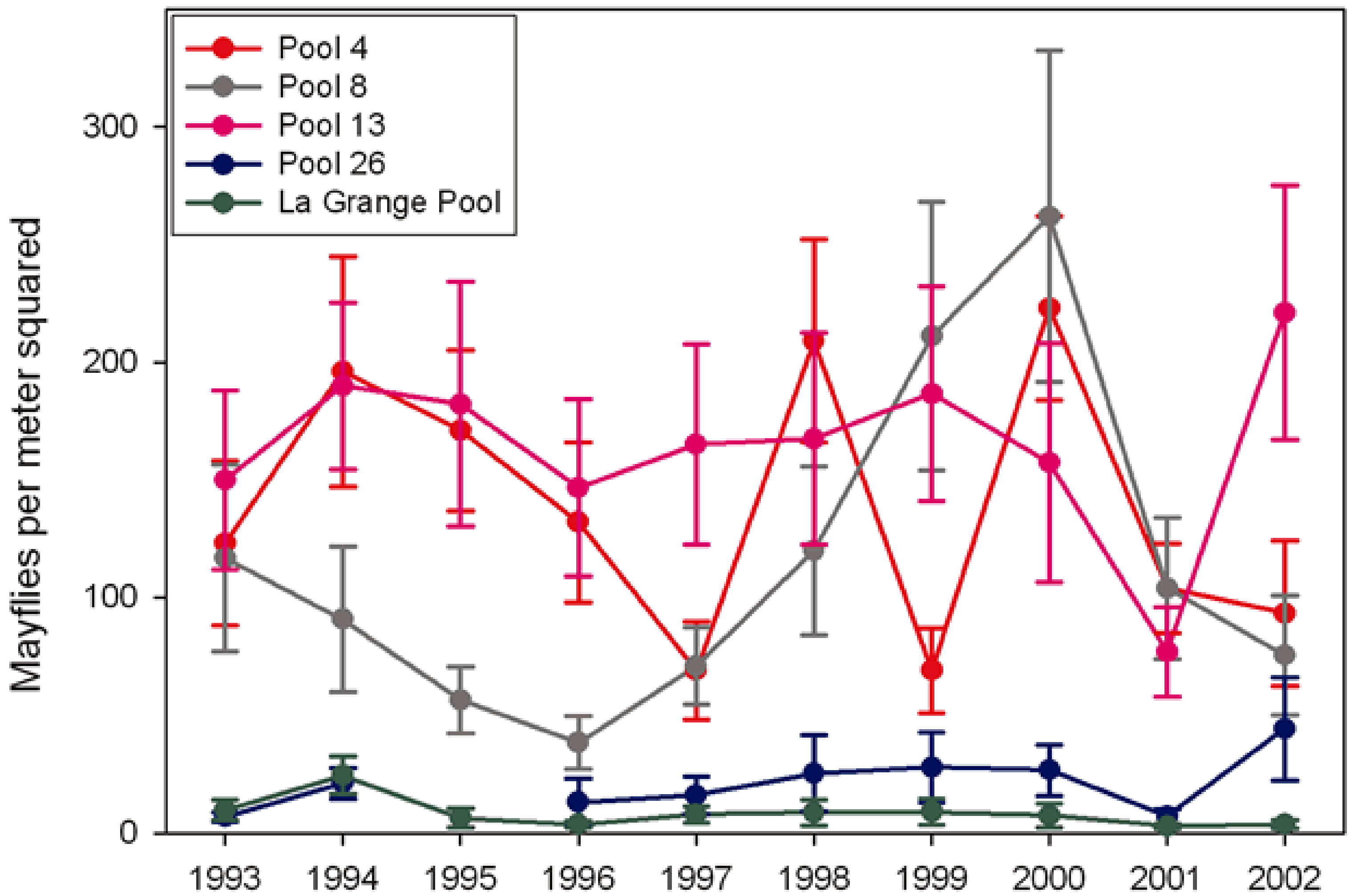

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Figure 17. Mean fingernail clam (Sphaeriidae) abundance from 1992 to 2002, Upper Mississippi River System.

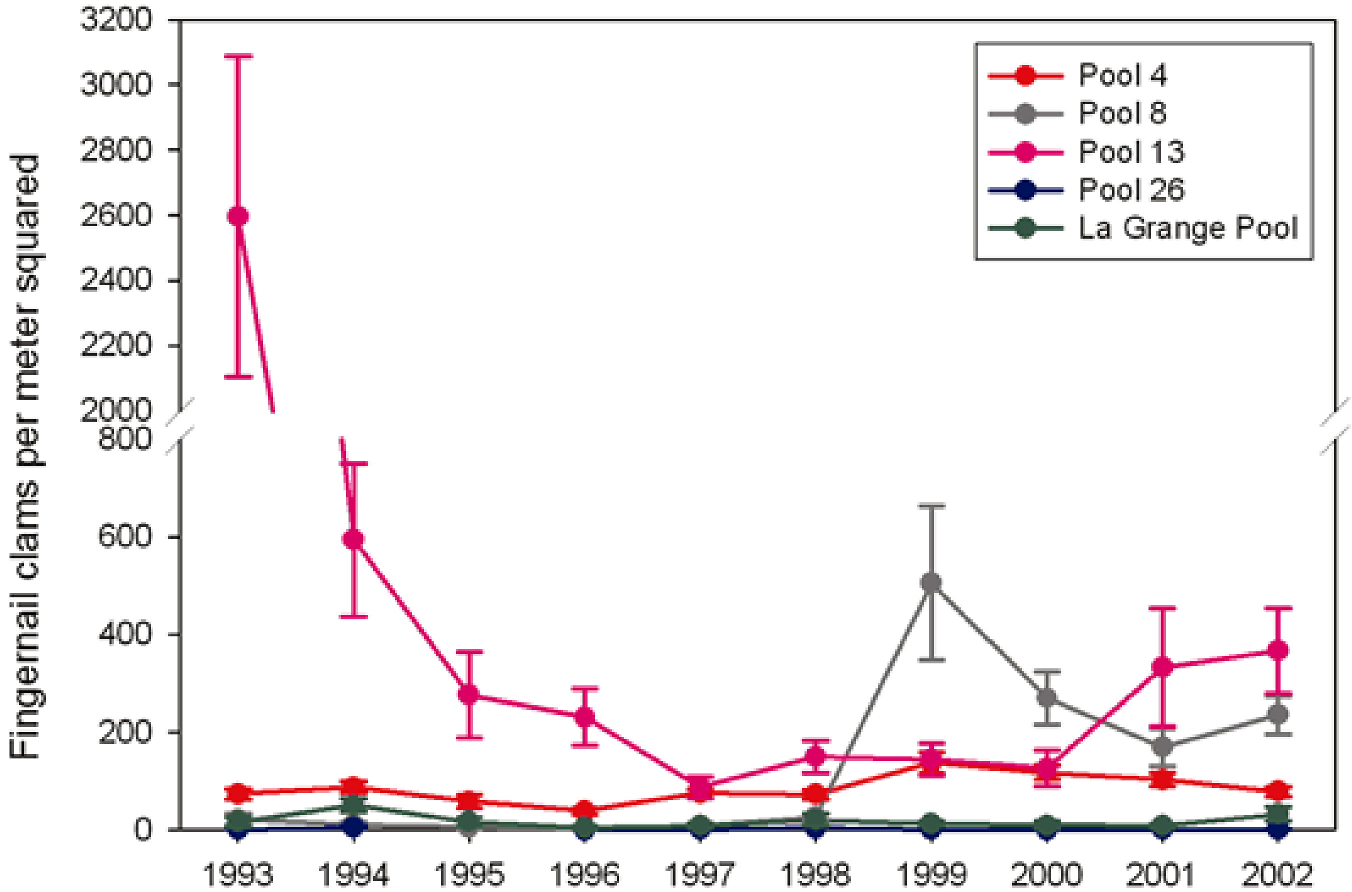

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Figure 18. Mean midge (Chironomidae) abundance from 1992 to 2002, Upper Mississippi River System.

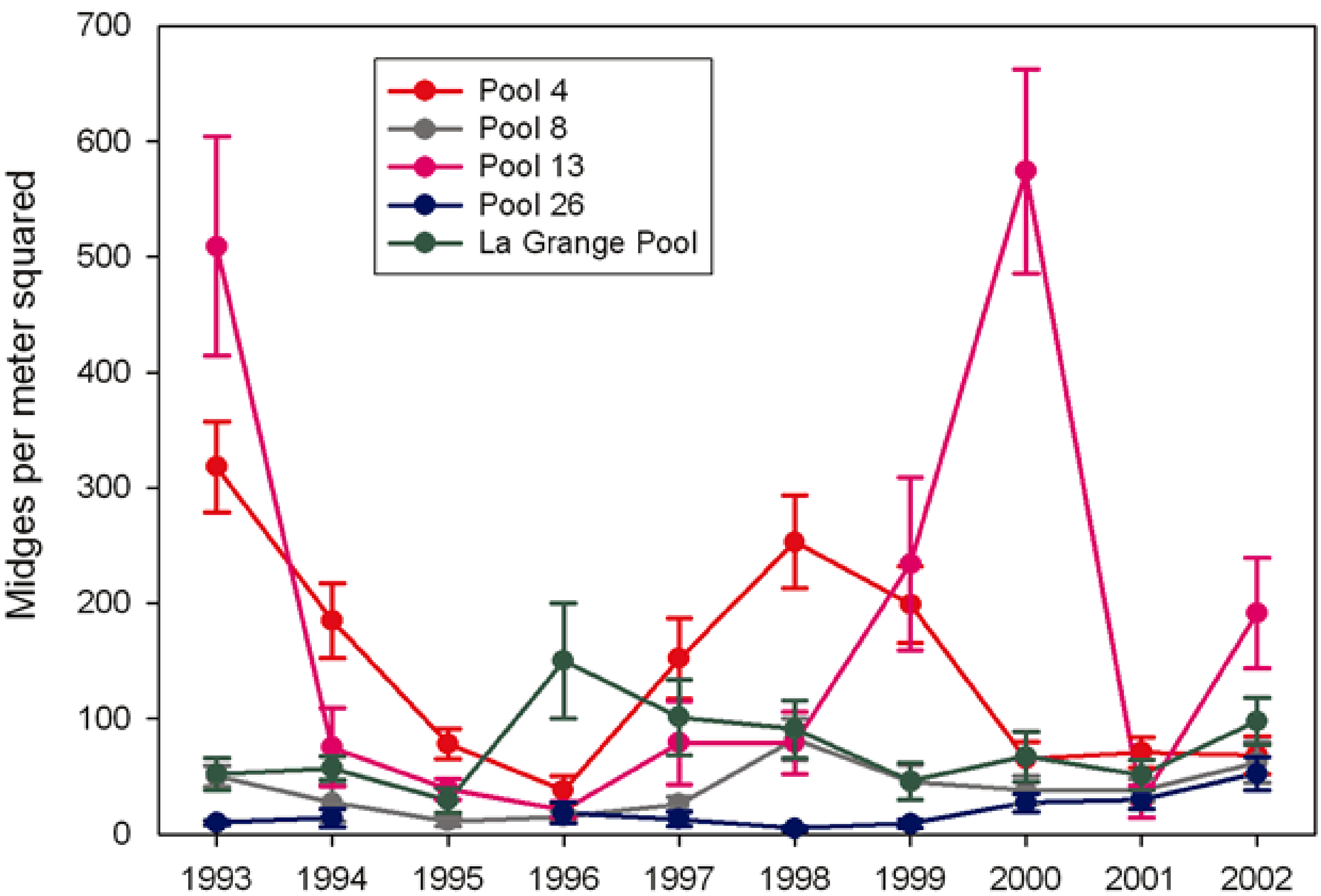
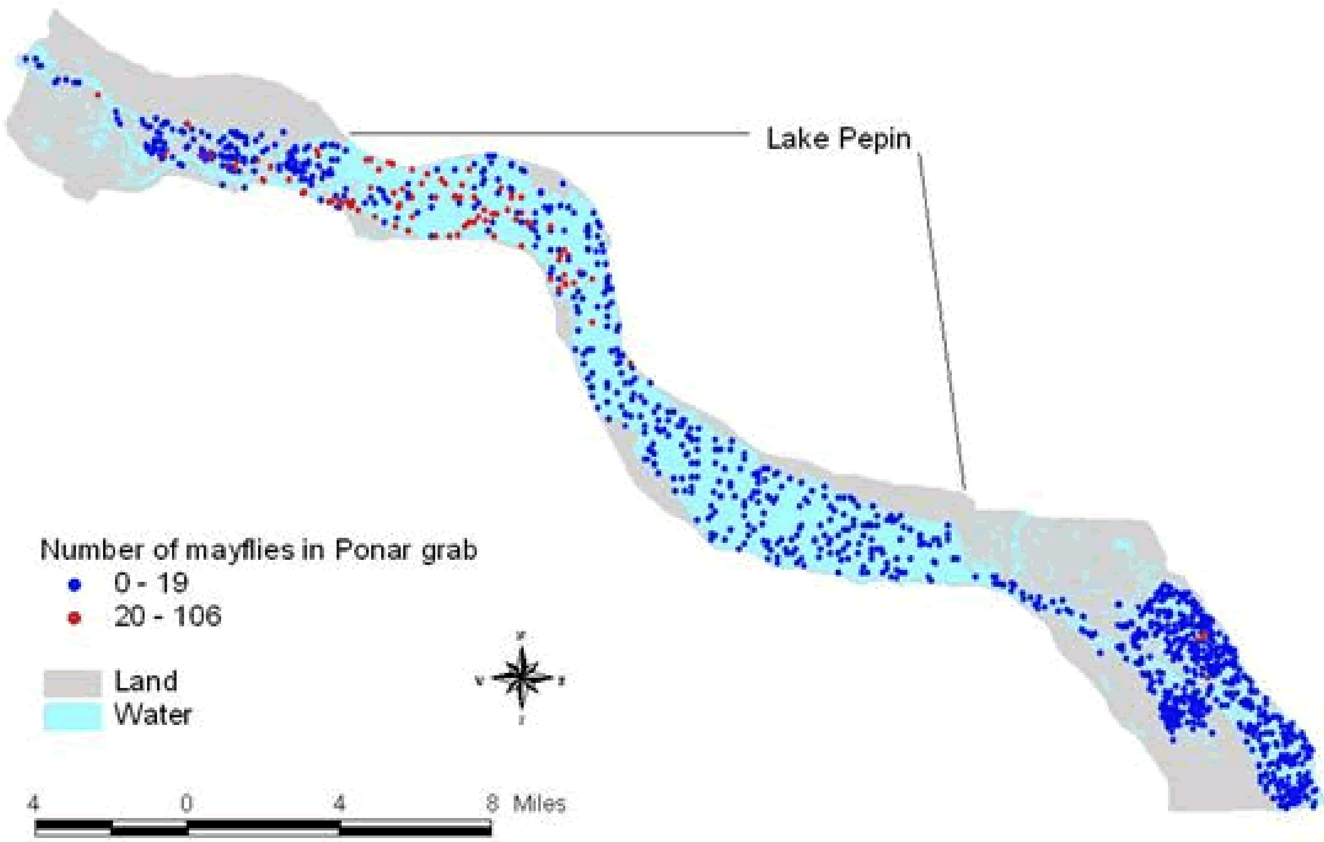


Figure 19. Mayfly abundances in Lake Pepin, Pool 4 of the Upper Mississippi River System (1992–2002).



Monitoring Activities and Highlights

Hydrology

Annual hydrological information provides a simple gage or metric about a primary driving force for the river. Knowing if selected stations were relatively wet or dry, whether there was flood or drought, provides a basis for judging how a given year fits into a longer term picture of the river system. Hydrological 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. Discharge values are usually obtained from elevation gage readings by way of an elevation-discharge model. The period of record for the four stations ranged from 63 to 124 years. Watershed areas for the four stations ranged from about 2% to 99% of the total watershed of the Upper Mississippi River, including the Missouri River watershed. Other information concerning the discharge database is provided in a procedures manual by Wlosinski et al. (1995). Mean daily discharge (in cubic meters per second; m^3/sec) was calculated for each station for each year (defined as the period from October through the following September). Compared to historical means, mean discharge for the 2002 water year was above normal for all stations above St. Louis but normal for St. Louis (Figure 2). Water surface elevations (in feet above mean sea level) for the LTRMP study areas are shown in Figures 3–8.

Land Cover/Land Use

The UMRS is a dynamic ecosystem that has experienced dramatic change over the past 150 years. Its transition from a free-flowing, untrained river to its current impoundment by levees, locks, and dams can be documented through the generation of digital land cover/land use data sets using archival maps and aerial photography. Knowing where and what change has occurred is critical to assessing habitat status and trends. To assist in this effort, UMESC provides detailed systemic land cover/land use data for 1890s, 1975, and 1989.

In 2002, base and over-target funds were used to continue the development of the 2000 systemic land cover/land use data set that is nearing completion. This data set complements the LTRMP baseline land cover/land use developed using 1:15,000 scale aerial photography collected in late summer 1989. Using 1:24,000 scale color infrared aerial photography acquired in late summer 2000 and the LTRMP 31-class vegetation classification system, vegetation coverages for Pools 5–7, 9–12, and 22–25 and the Open River Reach (northern half) and the Alton and Peoria Pools of the Illinois River were completed in 2002. Upper Mississippi River System trend pools (Pools 4, 8, 13, and 26 and Open River Reach (southern half), and La Grange Pool of the Illinois River) were completed in 2001, with the remaining pools scheduled for completion in early 2004. All year 2000 data are referenced in Universal Transverse Mercator Zones 15 and 16 (NAD27 and NAD83) and served on UMESC's Web site as Arc Export files and ArcView shapefiles (http://www.umesc.usgs.gov/data_library/land_cover_use/land_cover_use_data.html).

Bathymetry

Data on water depth, as a function of riverbed elevation and water surface elevation are important for use as habitat predictors, for developing hydrodynamic models, and for estimating sedimentation patterns over time. Bathymetry work was conducted by the U. S. Army Corps of Engineers in collaboration with UMESC in 2002. Over-target funds were used to fill gaps in the LTRMP systemic bathymetric database. The additional surveys enhanced those already planned and funded by the Rock Island and St. Louis Districts of the U.S. Army Corps of Engineers. These additional surveys included Pool 20, the Peoria Pool on the Illinois River, and the Middle Mississippi Reach. Data were delivered to UMESC where they were incorporated into the Geographic Information System (GIS) point data sets for each reach. The GIS coverages of data gaps were updated, and an interpolated map of bathymetry was completed for the Middle Mississippi Reach (http://www.umesc.usgs.gov/data_library/aqa_feat_bath_str/bathymetry.html). The LTRMP will continue to use available funds to expedite the completion of a systemic database. Future surveys will probably be conducted by the U. S. Army Corps of Engineers—Survey Section, as was done in 2002. Cost estimates for completion range between 2 to 3 million dollars.

Sedimentation

Sedimentation is a major concern for resource managers of the Upper Mississippi River (UMR). This process will largely determine the fate of off-channel areas in the UMR (Fremling and Claflin 1984; Nielsen et al. 1984) and the fate of the biota that rely on those habitat conditions. Backwater lakes are of particular interest because they periodically provide a lentic environment in a lotic system. Most backwaters lakes are typically shallow (<1 m) during the low discharge conditions; thus, additional sediment deposition could lead to the loss of these habitats. Studies to determine sedimentation rates and processes were among the recommendations developed by the Sediment Transport and Geomorphology Work Group convened to define informational needs for the UMR (Gaugush and Wilcox 2002).

In 1997, we redesigned the LTRMP short-term sedimentation monitoring study conducted by Rogala and Boma (1996) to overcome problems in the original design. We modified the original protocol to include random sampling and extended the length of transects to include terrestrial banks adjacent to backwaters. Transects in Pools 4, 8, and 13 were surveyed annually between 1997 and 2001. Objectives of this monitoring study included estimating sedimentation rates during a 5-year period beginning in 1997, determining variability in sedimentation rates along transects and among years, and examining spatial and temporal variability to identify variables of interest for future modeling efforts. Overall, we addressed spatial and temporal variability in sedimentation rates at finer scales than previously investigated.

Average sedimentation rates (in centimeters per year; cm/yr) during the 5-year period were lower than most previously reported rates in backwaters in this reach of the river, with estimated means of -0.08 (SE = 0.18) in Pool 4, 0.21 (SE = 0.10) in Pool 8, and 0.47 (SE = 0.26) in Pool 13. Poolwide estimated mean sedimentation rates in the terrestrial areas adjacent to backwaters appeared higher than in aquatic areas, ranging from 0.32 to 0.78 cm/yr (SE = 0.14 and SE = 0.25 cm/yr, respectively), but differences were not significant. When averaged over the study period, sedimentation rates were correlated with bed elevation, but the relations differed between aquatic and terrestrial areas. On an annual basis, the correlation between annual sedimentation rates and bed elevation was similar across aquatic and terrestrial areas, with annual river discharge explaining some of the variability. During the high discharge year of 2001, a positive relation between sedimentation and bed elevation was observed, whereas in low discharge years, such as 2000, there was a negative relation. This relation is reflected in poolwide mean rates for backwaters, that in some pools were significantly higher during low discharge years than in high discharge years.

Water Quality

Water quality monitoring within the LTRMP focused on the UMRS and its major tributaries and included variables, such as physicochemical features, suspended sediment, and major plant nutrients likely to affect aquatic habitats. Sampling in 2002 followed the original 1993 design as modified in 2000 (a 30% reduction in sampling effort was implemented in January 2000). The design combined quarterly stratified random sampling episodes with fixed-site sampling conducted at 2- and 4-week intervals. Tributaries were sampled at 4-week intervals, whereas major inflows/outflows within the study reaches and other selected locations were sampled at 2-week intervals.

Stratified random sampling (about 130 sites per study reach quarterly) provided unbiased, seasonal information on water quality across broad areas, such as entire navigation pools, whereas fixed-site sampling (about 20 sites per study reach) provided more continuous information at specific locations. Severe budget cuts in 2002 forced all water quality monitoring to cease as of September 30, 2002.

The transport of sediment and major plant nutrients within the UMRS is an important management concern. Total suspended solids (mg/L) during spring random sampling episodes have been declining in the upper reaches (i.e., Pools 4 and 8) since 1994, but concentrations in the lower reaches (Pool 26 and Open River) increased during the last 2 years (Figure 9). Spring total suspended solids concentrations peaked in 1999 in the Open River Reach when the river was above flood stage; this was followed in 2000 by lower concentrations that coincided with river stages that were about 10 feet below average. Concentrations returned to previous levels in the Open River during 2002, whereas Pool 26 total suspended solids exceeded those observed during the past eight springs (Figure 9).

Water temperature (^{o}C), the most commonly measured water quality variable, affects a wide range of physical, chemical, and biological phenomena. Because it affects the presence or absence of species, growth rates, oxygen solubility, and chemical equilibria, even subtle changes in temperature have the potential to produce numerous associated changes. Water temperatures were warmer during recent winter random sampling episodes (Figure 10). Median temperatures in both the lower and upper study reaches were greater during 2002 than any of the previously monitored winters. The minimal ice cover that was present in the study reaches during winter 2002 was also indicative of warmer air and water temperatures.

Oxygen concentrations (% O_2 saturation) in the waters of the Mississippi River during winter are a function of numerous factors such as water temperature, ice cover, primary production, and oxygen demand. Historically, wintertime oxygen saturation has been slightly lower in the northern study areas than in the southern study areas, probably because of greater ice and snow cover. Saturation values below 60% are not uncommon during winter in the northern study areas (Figure 11a), but are rare in the southern study areas (Figure 11b). Most years, median winter oxygen saturation in the southern study areas was typically about 100% and was oftentimes supersaturated. However, over the past nine winters, saturation values have generally increased in both the upper and lower Mississippi River (Figures 11a and b). Median values recorded during 2002 exceeded those recorded during the previous eight winters, possibly because of less extensive areas of ice and snow cover (hence greater atmospheric exchange), and higher levels of primary productivity as evidenced by chlorophyll-*a* concentrations (µg/L; Figures 12a and b).

Phytoplankton play a vital ecological role in the UMRS, in that they provide food for filter-feeders, process nutrients, and generate (and consume) oxygen. Algal blooms, often noted during the summertime, also occur during winter particularly when light penetration is not hindered by snow cover. During a period of little snow cover in 1995, a relatively large "bloom" occurred in the northern study reaches (Figure 12a) and was probably responsible for the higher oxygen saturation that also occurred at the same time (Figure 11a). With the exception of the northern study areas in 1995, median chlorophyll-*a* in 2002 was higher than all previous winters monitored. Recent mild winters, with associated warmer temperatures and less snow and ice cover may explain these higher concentrations.

Annual changes in limnological data are strongly influenced by both long-term and episodic changes in weather and hydrology, and limnological response to prevailing conditions are now evident in the LTRMP data. For example, results of recent spring sampling events demonstrate the relation between total suspended solids concentrations and river discharge, much the same as increases in oxygen saturation and chlorophyll-*a* may reflect recent mild winters. The importance of the LTRMP limnological record in documenting changes and relations such as these cannot be overstated, inasmuch as these data will be critical in the interpretation of associated changes in the biological communities of the Mississippi River and other large rivers. The break that occurred in the sampling record beginning in 2002 was ill-timed given the extended period of drought that prevailed over some areas in 2003. Unexpected events (e.g., drought, floods, etc.) contribute significantly to our understanding of UMRS functioning, but their effects will only be recorded with a commitment to long-term, uninterrupted data collection.

Fish

Fish are an important component of the UMRS. Collectively, the river's fish fauna perform several important ecological functions. First, fish are the principal conveyers of matter and energy upstream. As terminal predators in the system, fish also tend to integrate the effects of perturbations to the system, making them excellent indicators of ecosystem integrity. In addition to responding to changes in the river system, fish themselves can affect ecological functions in the river by locally changing water quality characteristics (e.g., bioturbation) and mediating the transport of other biological life forms (e.g., freshwater mussels). Fishes also support socially and economically valuable recreational and commercial fisheries within the UMRS.

Fish monitoring within the LTRMP occurs on six study areas (Pools 4, 8, 13, and 26 and

Open River Reach of the Mississippi River and La Grange Pool of the Illinois River) within the UMRS (Figure 1). Monitoring activities focus on single species and community status and trends, using a multiple sampling gears approach. Sampling in 2002 followed the stratified random sampling design established in 1993, with significant modifications (annual effort was reduced by about 33%) implemented in June 2002. Modifications were implemented in 2002 in the form of gear reductions in consultation with LTRMP partners (Ickes and Burkhardt 2002). Stratified random sampling (about 250-400 sites per study reach) provides unbiased, annual information on single species abundance, community composition, and community structure, within each of the six study areas.

Collections in 2002 provide the opportunity to assess the predicted consequences of gear reductions on annual catch statistics. Ickes and Burkhardt (2002) predicted that annual collections following the gear reductions should produce 0-9% fewer species, based on historical LTRMP data. In 2002, the fish component observed an overall 9% reduction in the total number of species relative to the historical average, in line with predictions. We expect this statistic to vary in future years, as all of the predicted losses were associated with species that were uncommon in the catch, thus making their detection somewhat uncertain for any given year. Surprisingly, whereas Ickes and Burkhardt (2002) predicted a decline of 35% in total catch, 2002 field work actually produced the highest catch on record. Total catch in 2002 was 100,000 more fish than the historical annual average of 350,000 and largely resulted from the largest collections of gizzard shad (*Dorosoma cepedianum*) and threadfin shad (*Dorosoma petenense*) on record for La Grange Pool. We will continue to monitor the effects of the gear reductions on these annual statistics for several more years.

In addition to single species and community status and trends, LTRMP fish data provide critical information on the occurrence, establishment, distribution, and abundance of non-native fish species. For example, silver carp (*Hypopthalmichthys molitrix*) and bighead carp (*H. nobilis*), referred generically as Asian carp (*Hypopthalmichthys* spp.), were introduced as the result of aquaculture activities in the Mississippi River basin and have recently established themselves in the lower reaches of the UMRS. Data from LTRMP have been critical to documenting the spread of these prolific, large species within the UMRS and towards the Great Lake drainage. In 2002, LTRMP Asian carp catches were down and no range expansion was noted (formerly collected in Pool 26, La Grange Pool, and Open River Reach). However, LTRMP fish monitoring gears are inefficient at capturing these species, given their pelagic schooling behavior, and observed declines may be an artifact of inefficient sampling methods.

Vegetation

Aquatic vegetation in the UMRS is desired because of its many values, most notably as food for migratory waterfowl (Korschgen et al. 1988) and habitat for fish. The construction of a series of locks and dams in the 1930s created vast shallow areas where aquatic plants proliferated for nearly 3 decades before symptoms of deterioration associated with permanent impoundment became apparent (Green 1984). A widespread and sudden decline in the distribution and abundance of wild celery (*Vallisneria americana*) from Pools 5 through19 during 1987–89 elevated concern as to whether or not the UMRS was on the verge of a drastic degradation in the aquatic vegetation resources (Rogers and Theiling 1999).

Long-term monitoring of aquatic vegetation was initiated in 1991 with the primary objective of determining trends in submersed and rooted floating-leaf vegetation in the UMRS (Rogers and Theiling 1999). Between 1991 and 2000, submersed aquatic vegetation was sampled along transects in selected backwaters in Pools 4, 8, 13, and 26 of the Mississippi River and La Grange Pool of the Illinois River twice a year, in spring and summer, using a standard protocol (Rogers and Owens 1995). In 1998, a stratified random sampling protocol was initiated (Yin et al. 2000) to allow for estimation of poolwide means. After a 3-year concurrent sampling period wherein both protocols were followed, transect sampling was discontinued and stratified random sampling has been conducted solely since 2001.

Within-pool distribution patterns of submersed aquatic vegetation in the five key pools (4, 8, 13, and 26 and La Grange Pool) were heterogeneous but have remained stable since 1998 when stratified random sampling was initiated. Based on the total number of samples collected within a pool and reported as percent frequency of occurrence (% frequency of occurrence = # of occurrences/total # rake samples), submersed aquatic vegetation in upper Pool 4 has steadily declined from 1991 to 2001 (Figure 13). Submersed aquatic vegetation as measured along transects in lower Pool 4 had steadily declined from 1991 to 1994, followed by a steady increase in vegetation from 1995 to 2001. Submersed aquatic vegetation peaked in Pool 8 in 1999 but experienced a temporary drop in 2001. In 2002, submersed aquatic vegetation increased sharply to a level similar to that observed in 1999. Water level reduction (drawdown) in Pool 8 in summers of 2001 and 2002 contributed to the rebound. The percent frequency of submersed aquatic vegetation in Pool 13 was initially low in 1991 and was low again in 1993. The frequency of occurrence of submersed aquatic vegetation steadily increased between 1994 and 1998 and has since remained stable (Figure 13). Nevertheless, the average amount of vegetation per rake sample, as reflected in an abundance index, has been steadily increasing from 1998 to 2002 (Figure 14). Over the period of record frequency of occurrence for submersed aquatic vegetation in Pool 26 and La Grange Pool was low (Figure 13). Some submersed aquatic vegetation was found in backwaters along the lower 12 miles of the Illinois River. Outpool sampling in Pools 5, 7, and 12 and

Alton Pool revealed that Pools 5 and 7 are similar to lower Pools 4 and 8, Pool 12 is similar to Pool 13, and Alton Pool is similar to La Grange Pool and Pool 26 in aquatic vegetation abundance and species composition (Figure 15).

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. Moreover, macroinvertebrates can be useful as biological indicators of water and sediment quality. Annual monitoring of macroinvertebrates in the UMRS began in 1992.

Mayflies (Ephemeridae), fingernail clams (Sphaeriidae), midges (Chironomidae), the non-native Asiatic clam (*Corbicula* spp.), and the exotic zebra mussel (*Dreissena polymorpha*) are monitored for their ecological significance in the food web or because they are recent non-native invaders to the UMRS. For example, Thompson (1973) reported that in fall, lesser scaup (*Aythya affinis*) gizzard contents contained 76% sphaeriids and about 13% mayflies. Thompson also observed these organisms are important to canvasbacks (*Aythya valisneria*), ring-necked duck (*Aythya collaris*), and American coot (*Fulica americana*). The Waterfowl Handbook also discusses the importance of invertebrates to waterfowl (Eldridge 1988). Shorebirds and wading birds also consume large numbers of invertebrates (Kushlan 1978). A number of fish, including commercial and sport fish such as crappies (*Pomoxis* spp.), shovelnose sturgeon (*Scaphirhynchus platorynchus*), walleye (*Stizostedion vitreum*), bluegill (*Lepomis macrochirus*), freshwater drum (*Aplodinotus grunniens*), and yellow perch (*Perca flavescens*), use the target organisms (Hoopes 1960; Jude 1968; Ranthum 1969; Tyson and Knight 2001).

The high spring flood of 2001—river crests were the second or third highest on record for many areas of the Upper Mississippi River—did not seem to have an adverse effect on macroinvertebrate densities in 2002. In fact, several aquatic areas in Pool 26 and La Grange Pool recorded the highest densities of fingernail clams and midges seen since sampling began in 1992. Previous year flood events can have an effect on the current abundance of the selected macroinvertebrates sampled because of their life cycle. For example, mayfly eggs are laid throughout the summer and after hatch the nymphs will overwinter in the soft substrate. Therefore, various hydrologic and limnological events over the year can affect the next year's abundance and distribution patterns.

Macroinvertebrate sampling in 2002 produced a total of 2,411 mayflies, 3,983 fingernail clams, 3,514 midges, 1 Asiatic clam, and 3,700 zebra mussels from 551 total samples. This is a 50% increase in the total number of mayflies, 21% increase in the total number of fingernail clams, and a 98% increase in midges from 2001, yet these numbers are still within the range of numbers seen since sampling began in 1992. The total number of zebra mussels collected in 2002 decreased 53% from 2001.

The poolwide estimated mean densities of mayflies decreased between 2001 and 2002 in Pools 4 and 8, whereas Pools 13 and 26 and La Grange Pool showed increases (Figure 16). All study areas, except for Pool 4, had increases in the poolwide estimated mean densities of fingernail clams and midges (Figures 17 and 18). Pool 13 was the only study area that had increases in all of the target taxa.

Over the last 9 years of sampling, Lake Pepin has consistently been the "hot spot" for mayflies in Pool 4 (Figure 19). The impounded and backwater contiguous aquatic areas in Pools 8 and 13 supported the highest densities of mayflies. Fingernail clam densities were highest in the impounded aquatic areas in Pools 4 (Lake Pepin), 8, 13, and 26 compared to other aquatic areas.

The backwater contiguous and impounded areas had higher densities of midges than other aquatic areas in all study areas. In Pool 26, midge densities reached their highest recorded level of 313 m^{-2} in the impounded area compared to all other years and aquatic areas. While in La Grange Pool, the backwater contiguous area had the highest ever recorded density of midges since sampling began.

Macroinvertebrate patterns and abundances are distinct among pools and continue to show few trends from year to year. Macroinvertebrates are contingent on a number of biotic and abiotic factors; therefore, large annual variations are expected. Whereas macroinvertebrate densities exhibit boom and bust cycles, the range of variability of annual means is becoming clear. Highly variable data such as the LTRMP data are well suited for monitoring long-term trends (Strayer et al. 1986; Franklin 1988; McEchearn 2000). Long-term monitoring is needed to provide a better understanding of the conditions needed to support viable macroinvertebrate populations at levels adequate for sustaining native fish and migrating waterfowl.

This summary provides a cursory view of the major highlights from the Long Term Resource Monitoring Program in 2002. For more detailed information, we highly recommend the reader review the individual annual reports for 2002 (vegetation and macroinvertebrates). These may be found at http://www.umesc.usgs.gov/reports.html.