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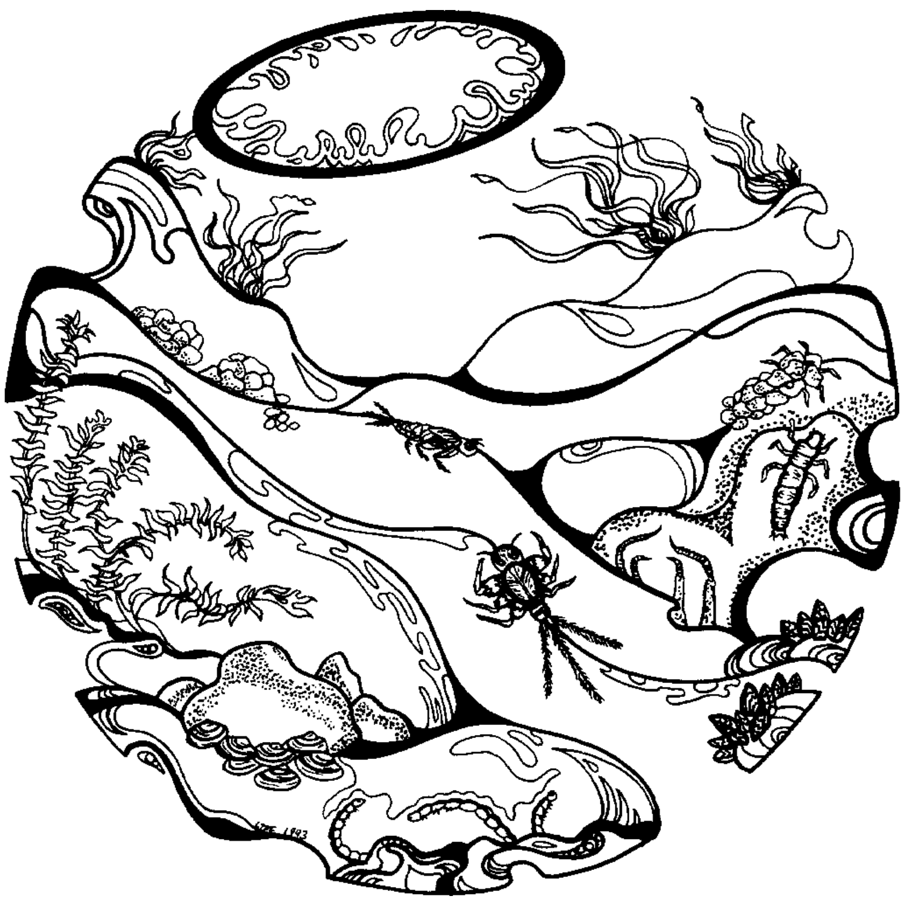
Temporal Analyses of Select Macroinvertebrates in the Upper Mississippi River System, 1992–1995



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by

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April 1998

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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 trend and spatial analysis report supports Task 2.2.7.6, *Evaluate and Summarize 5-Year Trends*, as specified in Goal 2, *Monitor Resource Change* of the LTRMP Operating Plan (U.S. Fish and Wildlife Service 1993). This report was developed with funding provided by the Long Term Resource Monitoring Program.

Temporal Analyses of Select Macroinvertebrates in the Upper Mississippi River System, 1992–1995

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Jennifer S. Sauer

Abstract

The annual variability in mayflies (Ephemeroptera), fingernail clams (Sphaeriidae), and midges (Chironomidae) in six study areas of the Upper Mississippi River System from 1992 to 1995 was examined. Spatial distribution is also discussed for these organisms along with the Asiatic clam (*Corbicula fluminea*) and the zebra mussel (*Dreissena polymorpha*). Sample allocation within each reach was based on a stratified random design where strata were aquatic areas. No significant linear trends across years were found in estimated reachwide mean number of organisms. However, the overall test for differences in intercepts among study areas was statistically significant ($P < 0.05$) for mayflies, fingernail clams, and midges. No statistical difference in trend slopes among reaches were detected. In 1993, the estimated mean density of fingernail clams in Pool 13 was 35 times that found in other study areas. Overall, impounded aquatic areas and silt clay substrates supported higher numbers of the select macroinvertebrates.

Introduction

In 1986, Congress designated the Upper Mississippi River System (UMRS), which consists of the Upper Mississippi and Illinois Rivers and several important tributaries, as both a nationally significant ecosystem and a nationally significant navigation system. Macroinvertebrates and other aquatic organisms play a major role in the aquatic ecosystem. Mayflies (Ephemeroptera), fingernail clams (Sphaeriidae), and midges (Chironomidae), part of the soft-sediment substrate fauna, were chosen as target organisms for the Long Term Resource Monitoring Program (LTRMP) because of their important ecological role in the UMRS. For example, Thompson (1973) found that in fall, lesser scaup (*Aythya affinis*) gizzard contents contained 76% sphaeriids and about 13% mayflies. Thompson also found the target organisms to be important to canvasbacks (*Aythya valisneria*), ring-necked ducks (*Aythya collaris),* and American coots (*Fulica americana*) feeding in open water. A number of fish, including commercial and recreational fish, utilize the target organisms (Hoopes 1960; Jude 1968; Ranthum 1969). Researchers have also traditionally used macroinvertebrates as biological indicators of river water quality (Fremling 1964, 1973, 1989; Myslinski and Ginsburg 1977; Rosenberg and Resh 1993; Steingraber and Weiner 1995). An indicator species can be defined as a species that has particular requirements with regard to a known set of physical or chemical parameters. Macroinvertebrates also perform an important ecological function by digesting organic material and recycling nutrients (Reice and Wohlenberg 1992). The Asiatic clam (*Corbicula fluminea*) and zebra mussel (*Dreissena polymorpha*), both non-native freshwater clams, were chosen for monitoring because of possible detrimental effects they may have on the economy and biology of the UMRS (Tucker 1995a, b), and their status is of concern to river managers.

Few long-term studies on the distribution and abundance of mayflies, fingernail clams, and midges have been published, and the majority of information that is available is scattered in unpublished government reports and theses. Several areas of the UMRS have been sampled sporadically for benthic macroinvertebrates by various researchers (Fremling 1964; Carlander et al. 1967; Gale 1969; Hubert et al. 1983; Eckblad and Lehtinen 1991; Brewer 1992; Hornbach et al. 1993). Although these studies contain valuable information, they were collected by different methods and over relatively short periods, making it impossible to evaluate long-term trends. Long-term monitoring is needed to detect population trends and local changes to direct management actions or measure the effectiveness of management actions.

The objective of this report is to document spatial and temporal patterns in select benthic macroinvertebrates from samples collected from the UMRS by field stations of the LTRMP. This documentation will provide baseline data for future reference on the distribution and abundance of select macroinvertebrates in the UMRS and provide data for other analyses (e.g., synthesis among LTRMP components). Also, these first years of monitoring will be used to establish a scientifically acceptable procedure, using consistent protocols, for the long-term collection of macroinvertebrates in the UMRS.

The publicly available data and annual status reports (Sauer 1996, 1997aSd) are the most basic LTRMP products. Annual status reports provide more detailed summaries of macroinvertebrate data than are included in this trend report, but they lack analyses or syntheses. The 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. That 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 fisheries) with the results of experimental studies to identify causes of problems and opportunities for improved management.

Methods

Study Area and Spatial Design

In 1992, macroinvertebrate sampling was initiated in six study areas on the UMRS. The six LTRMP study areas represent the variety of aquatic areas within the UMRS. They range in size (calculated from geographic information system coverage; Lowenberg 1993) from Pool 8 (19,000 ha) to the Open River (107,000 ha). Long Term Resource Monitoring Program study areas are referred to herein by the navigation pool designations according to the U.S. Army Corps of Engineers lock and dam system and include: Pools 4 (river mile 752 to 797), 8 (679 to 703), 13 (523 to 557), and 26 (202 to 242); the Open River Reach (29 to 80) of the Mississippi River; and La Grange Pool (80 to 158) of the Illinois River (Figure 1). The choice of these study areas was based on several criteria (Jackson et al. 1981):

1. Monitoring locations were either representative of major UMRS habitat types or capable of influencing a significant portion of the system.

2. A historical database was available.

3. Selected pools or reaches were recognized as important fish and wildlife resources.

4. Monitoring locations were established with regard to availability of workers and facilities.

The first year of macroinvertebrate sampling was used to refine the sampling design, and changes have been documented in the Procedures Manual for the LTRMP (Thiel and Sauer 1995). Initially, mayflies, fingernail clams, and *C. fluminea* were selected for monitoring. Midges were added to monitoring in 1993, and zebra mussels were added in 1995.

Sampling was conducted yearly at about 125 sites per study area. Sample allocation was based on a stratified random design, where strata were aquatic areas (Figure 2) as defined by Wilcox (1993):

- contiguous backwaters (BWC), which are areas having apparent surface-water connection with the rest of the river;

- main channel borders (MCB), the area between the navigational buoys and the riverbank (not including revetments and channel-training structures);

- impounded areas (IMP), the large, mostly open water areas located in the downstream portion of the navigational pools;

- side channels (SC), which are channels that carry less flow than the navigational channel; and

- tributary delta lake (TDL), which in Pool 4 is Lake Pepin, an impounded area formed by the Chippewa River.

A spatial database of aquatic areas was developed at the Environmental Management Technical Center (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. This database is updated at appropriate intervals. Sampling maps are updated, as needed, from direct observations made by the sampling crews.

Sample sites also included some historical (fixed) sites, where benthic samples were collected by previous researchers (Paloumpis and Starrett 1960; Fremling 1973; Emge et al. 1974; Colbert et al. 1975; Anderson 1977; Elstad 1977; Hubert et al. 1983; Brewer 1992).

In 1992, stratified random sampling sites were distributed equally in each aquatic area. After analysis of the 1992 data—where 57% of the samples contained no target organisms—it was decided to more heavily sample the particular habitat of the target organisms (i.e., soft-sediment substrate; Table 1). All sites were sampled in spring to characterize the benthic community before mayfly emergence (Table 2).

Sampling Methods

Macroinvertebrate sampling procedures are described in detail in the LTRMP Procedures Manual (Thiel and Sauer 1995). Benthic samples were collected with a winch-mounted 0.052-m^2 standard Ponar grab sampler (Ponar Grab Dredge, Wildlife Supply Company, Saginaw, Michigan). The wash frame sieve size was changed from a U.S. Standard Sieve no. 30 (595 µm), used in 1992, to a U.S. Standard Sieve no. 16 (1.18 mm) in 1993 to increase sorting efficiency in the field. Thus, inferences in macroinvertebrate numbers made from these data are restricted to the larger organisms of the population whole (Dukerschein et al. 1996). Mayflies, fingernail clams, midges, *C. fluminea*, and zebra mussels were picked and counted in the field. After the picking process was complete, leaving only detritus and organisms other than the target organisms, it was determined by random draw whether the sample would be brought back to the laboratory for quality assurance (Norris and Georges 1992). A total of 10% of the sites sampled within each aquatic area were brought back to the laboratory to evaluate field-picking efficiency without the aid of magnification or staining.

Site Information

At each site, substrate composition was noted according to subjective characterization. Six categories of substrate composition were used: hard clay, silt clay, silt clay with sand, sand with silt clay, sand, and gravel rock. The absence or percentage of submersed and floating-leaved aquatic vegetation in the column of water and sediment through which the Ponar dredge fell was estimated. The type and percentage of vegetation and open water in a 15-m radius from the boat were qualitatively characterized. Water depth was measured at each site (Appendix).

Statistical Analysis

Density was recorded for each target taxa from individual Ponar samples. Whenever a taxa was not caught in a sample, the catch for that taxa in that sample is zero.

Analyses of densities (*DS*) were based on estimates of mean densities obtained by pooling data over all strata. In this way, the analyses track the broadest possible spatial scale for trends in relative densities. The pooling probably presents a truer image of reachwide trends in densities because it does not rely only on particularly favorable habitats. If the quantity of preferred habitat declines through time while densities in those preferred habitats remains constant, then these pooled estimated mean densities ($\overline{DS}$) statistics should also reflect that decline, whereas mean density statistics from only the preferred habitats would not. 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 $\overline{DS}$ statistics should also reflect the resulting decline in reachwide abundance, whereas mean density statistics from only the preferred aquatic area would not.

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

$$\bar{y}_{st} = \frac{1}{N} \sum_{h=1}^{L} N_h \bar{y}_h \qquad (1)$$

where N_h is the number of sampling units within stratum *h*, $N = \sum_{h=1}^{L} N_h$, 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

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

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 macroinvertebrate monitoring, random sample sites are selected from grids whose cells are 50 m^2.

Equation (1) is used to obtain estimates of overall mean densities of 1992–95 random sampling. In random samples, equation (1) yields unbiased estimates of the pooled means regardless of the probability distribution of y (Cochran 1977).

For this report, the presence of differences among LTRMP study areas and simple linear trends was tested. Because only the first 4 years of data obtained by the LTRMP were examined in this report, it is impossible to perform sophisticated time-series and trend analyses because the existing series are still too short. However, under some simplifying assumptions, it is possible to test for simple linear trends (straight-line increases or decreases) over the 4-year period and also to make useful comparisons of these trends among the six LTRMP study areas.

To place inference in terms of the reachwide estimates of mean densities, the observed $\overline{DS}_{rt}$ obtained from equation (1) to make inferences about the unknown true values of reachwide mean densities statistical tests were constructed assuming the general linear model given by

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

where $\overline{DS}_{rt}$ denotes reachwide mean abundance 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 six parameters for reach-specific deviations from t_0, the β_{1r} are six 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 $\overline{DS}_{rt}$ in equation (3) are assumed to be serially independent but are weighted by the reciprocals of their variances from equation (2) to obtain constant model-based variance σ^2. Although $\overline{DS}_{rt}$ data are not normally distributed, the Central Limit Theorem (DeGroot 1975) implies that the $\overline{DS}_{rt}$ are approximately normally distributed; however, model assumptions only require that the ε_{rt} are approximately normally distributed. Equation (3) is an extension of the analysis of covariance model that accounts for heterogeneity of variance in the response variable $\overline{DS}_{rt}$ and for the possibility linear trend slopes differ among LTRMP study areas.

Three tests based on Type I sums of squares from equation (3) are relevant (Littell et al. 1991). The F test for study area 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 trend regression of $\overline{DS}_{rt}$ on t_r that prevails over the six study areas. Last, the F test for the interaction between study area 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 areas. If this last F test is not statistically significant, then one concludes that among-reach differences in trend slopes could not be detected.

Results

More than 2,400 Ponar collections were made from the six study areas in summers 1992, 1993, 1994, and 1995. Frequency distributions varied among years; in 1992 low densities (≤20 organisms per sample) were common, and higher densities (>20) occurred in about 4% of the samples (Figure 3). However, after the experimental design was changed in 1993, the number of organisms per sample were more evenly distributed between low and high densities.

Percent composition of target organisms varied among years within study areas. Pool 8 consistently had higher percentages of mayflies than any of the other four target organisms, whereas Pool 13 had high percentages of fingernail clams in 1993, 1994, and 1995 when compared with other target organisms. Pools 4, 8, and 13 had similar temporal patterns for percent composition, but the magnitude of the percentages varied widely (Figure 4).

Measured depths at sampling sites ranged from 0.20 to 8.3 m with a mean of 1.8 m. More than 93% of the sample sites were unvegetated. Visual classification of sediments indicated that sample sites in Pools 4, 8, 13, 26, and La Grange Pool were dominated by silt clay, which constituted 46.6% of the sample sites. The Open River had a predominance of sand at sampling sites. All aquatic areas except main channel borders and side channels (sand) were dominated by silt clay.

Quality Assurance

More than 60% of the samples brought back to the laboratory for quality assurance had zero mayflies, and nearly 60% of the samples had zero fingernail clams. Measurement of the laboratory specimens indicated that 92% of the mayflies and 80% of the fingernail clams were less than or equal to 4 mm in length; mean lengths were 25.3 mm in field-picked mayflies and 6.5 mm in fingernail clams.

Select Macroinvertebrates

No statistically significant linear trend existed in the overall mean densities of mayflies (P = 0.89), fingernail clams (P = 0.79), and midges (P = 0.52) across years or the interation between study areas and years (P = 0.11, P = 0.53, P = 0.13, respectively). However, the overall test for differences in intercepts among study areas was statistically significant (P < 0.05) for all three organisms (Table 3). That is, differences in estimated mean densities of mayflies, fingernail clams, and midges that occurred among study areas were significant. *Corbicula fluminea* and zebra mussels were not included in the trend analyses because of low numbers found during sampling (Table 4).

Ephemeroptera (Mayflies)

Pool 13 contained the highest estimated mean densities ($\overline{DS}$) of mayflies in 1992, 1993, and 1995 followed by Pool 4 (Table 5; Figure 5). In 1994, Pool 4 had slightly higher $\overline{DS}$ of mayflies. The lowest $\overline{DS}$ of mayflies were from Pool 26, the Open River Reach, and La Grange Pool. No estimated mean densities of mayflies were calculated for Pool 26 in 1995; field crews were not able to sample certain sites because of high water. Pool 4 had the largest range in $\overline{DS}$ (143.7 m^{-2}) compared with other study areas.

Although mean densities of mayflies varied over the years among aquatic areas, the IMP aquatic areas, including the naturally impounded Lake Pepin in Pool 4, and BWC areas supported the highest mean number of mayflies in Pools 4, 8, 13, and 26 (Table 6). Side channel areas had the highest mayfly densities in the La Grange Pool study area in 1992–95. Overall, MCB areas supported the lowest densities of mayflies.

The silt clay substrate supported the highest mean numbers of mayflies in all study areas (Table 7). The large-particle substrates (i.e., sand and gravel rock) had the lowest numbers of mayflies.

Sphaeriidae (Fingernail Clams)

Pool 13 contained the highest $\overline{DS}$ of fingernail clams in all years (Table 5; Figure 6). In 1993, the $\overline{DS}$ of fingernail clams in Pool 13 was 35 times that found in other study areas for the same year (Table 5). This wide variability is largely because of the high numbers of fingernail clams found in the impounded area of Pool 13 in 1993 (Table 6). More than 75% of the samples from Pools 8, 26, and the Open River had zero fingernail clams.

Within Pool 8, the BWC aquatic area supported the most fingernail clams, whereas Pools 4, 13, and 26 of the IMP aquatic areas, including the naturally impounded Lake Pepin, supported the highest number of fingernail clams (Table 6). Side channel areas had the highest fingernail clam densities in the Open River. Densities were less than 14.5 m^{-2} in 1992 and dropped to less than 1.0 m^{-2} in 1994 and 1995. Side channel areas also supported the highest number of fingernail clams in the La Grange Pool, although MCB areas had close to the same densities in 1994. In 1993–95, the IMP area of Pool 13 supported 35, 7.2, and 4.6 (respectively) times the number of fingernail clams when compared with the next most productive area.

The silt clay substrate supported the highest number of fingernail clams except in Pool 26 where silt clay with sand had the highest mean densities (Table 7). The large-particle substrates (sand and gravel rock) supported the lowest densities of fingernail clams.

Chironomidae (Midges)

The monitoring of midge densities began in 1993. Although no significant linear trends were detected, Pools 4, 8, and 13 experienced year-to-year declines in midge densities. Pools 4 and 13 contained the highest $\overline{DS}$ of midges (Table 5; Figure 7). The lowest $\overline{DS}$ of midges were from Pool 26 and the Open River. The maximum estimated mean densities found in these study areas were less than 15 m^{-2}. Pool 13 had the largest range in $\overline{DS}$ (469.6 m^{-2}) compared with other study areas.

Midge densities varied widely among aquatic areas over years and study areas. For example, in Pool 8 high midge densities were found in the IMP area in 1993; in 1994, however, the highest midge densities were found in SC areas (Table 6).

The small-particle substrates (silt clay, silt clay with sand, and sand with silt clay) supported the highest mean number of midges in all study areas (Table 7). The large-particle substrates (i.e., sand and gravel rock) along with hard clay had the lowest number of midges.

Corbicula fluminea (Asiatic Clam) and Dreissena polymerpha (Zebra Mussels)

Because of the low number of *C. fluminea* and zebra mussels, no statistical analyses were undertaken (Table 4). Low numbers of *C. fluminea* were found in all study areas. More than 95% of the samples contained zero *C. fluminea* and zebra mussels. No study areas had samples with more than 115 m^{-2} *C. fluminea* (6 individuals). A TDL aquatic area sample site in Pool 4 contained the highest density of zebra mussels (1,500 m^{-2}; 78 individuals). Densities of zebra mussels are most likely under-represented because of the sampling method.

Discussion

The most widespread annual collections of macroinvertebrates in the UMRS are now being made under the LTRMP. The Program's stratified random design is intended to estimate unbiased mean densities of select macroinvertebrates within aquatic area strata of each study area.

To sample such a large geographic area with large sample sizes, field-picking the macroinvertebrates was considered the quickest and most economical process. Evaluation of quality control samples showed that field-picking was adequate for monitoring mayflies and midges and adult fingernail clams greater than 4.0 mm in shell length (Gale 1969; Dukerschein et al. 1996).

Are the target organism densities observed during the 4 years of LTRMP monitoring low or high in relation to long-term means? Although LTRMP data yield adequate mean estimates for the trend analysis reaches, few similar comprehensive inventories were made in the past, and therefore direct comparisons to pre-LTRMP monitoring are difficult. Four years of monitoring indicate that a great deal of temporal and spatial variability exist in mayflies, fingernail clams, and midges populations.

We did not detect statistically significant linear trends across the 4 years within study areas for macroinvertebrates greater than 1.18 mm. Midge densities showed a decline, although not statistically significant, in each study area. Compared with work done by Hornbach et al. (1993) midge densities reported in this study seem low. Hornbach found midge densities greater than 4,000 m^{-2} in a backwater lake in Pool 2. Few studies have examined the abundance and distribution of midges on the UMRS. Midges can constitute a large portion of the benthic community (Eckblad 1986).

Differences between study areas were detectable, especially in the high densities of fingernail clams found in Pool 13. Two possible explanations for Pool 13 having the highest densities of fingernail clams are that (1) Pool 13 is at the lower end of a pollution gradient that extends downstream from Minneapolis–St. Paul (Wilson et al. 1995), or that (2) the substrates of the lower, very broad impounded area—3,555 ha—of Pool 13 are especially suitable for fingernail clams. Clearly, other factors are involved, since Pool 8, which is also downstream from Minneapolis–St. Paul and is more than 3,500 ha, has relatively low densities of fingernail clams (<25 m^{-2}). An explanation of this phenomenon becomes more complicated when one considers that mean densities of fingernail clams at specific sites in Lake Onalaska in Pool 7 and areas in Pool 9 have reached more than 1,000 m^{-2} in the fall of the year (Eric Nelson, U.S. Fish and Wildlife Service, personal communication) while mean densities in Pool 8 fall sampling were below 15 m^{-2}. Gale (1969) reported fingernail clam population densities for Pool 19 at more than 5,000 m^{-2}. Sphaeriidae populations in several backwater lakes in Pool 9 varied from 631.8 m^{-2} in 1976 to 11.3 m^{-2} in 1989 and then increased to 78.0 m^{-2} in 1990 (Eckblad and Lehtinen 1991).

The densities of mayflies collected in LTRMP sampling are well within the ranges reported by past studies. Mayfly densities were highly variable, with concentrations as high as 340 m^{-2} in certain habitats (Fremling and Johnson 1990). Fremling (1989) detected the rebound of *Hexagenia* in Pool 2 and Lake Pepin in Pool 4 during the 1980s and a subsequent population decline in 1988. Carlander et al. (1967) showed how dynamic *Hexagenia* populations can be in Pool 19 from year to year with estimated whole pool populations of 3.6 billion in 1959 to 23.6 billion in 1962. Carlander found *Hexagenia* density ranges in June sampling of zero to 1,292 m^{-2} along his transects.

Some local studies suggest that mayfly and fingernail clam densities have been declining (Eckblad 1991; Wilson et al. 1995). The results from the stratified random sampling of the LTRMP suggest that relatively low densities throughout the river could be the rule rather than the exception. This apparent conflict of findings is likely due in part to differing purposes and spatial scopes of the studies. Local studies are often designed to quantify change—often already under way—in a localized area known for its value as a source for macroinvertebrates and considered at risk because of some destructive event or activity. The stratified random design of the LTRMP macroinvertebrate component ensures that results from every stratum are unbiased, enabling the monitoring of trends over whole strata and study areas (Gutreuter 1993).

Declines in macroinvertebrate densities indicated in the localized studies are a cause for concern. The value of the river macroinvertebrate community as a source of food for fish and waterfowl cannot be overstated. For example, Mills et al. (1966) reported a decline in the number of fingernail clams that coincided with a similar decline in the number of diving ducks utilizing the Illinois River. Long-term monitoring is intended to provide a better understanding of the conditions needed to support viable macroinvertebrate populations at levels adequate for sustaining native fish and migrating waterfowl.

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Table 1. Macroinvertebrate random sample sites by study area and aquatic area—parentheses indicate numbers of historical (fixed) sites.

Study area and year	Contiguous floodplain shallow[a]	Contiguous backwater	Impounded	Side channel	Main channel border
Pool 4					
1992	22 (3)	25	24 (1)[b]	25	25
1993	S	57 (3)	44 (1)	10	10
1994	S	57 (3)	44 (1)	10	10
1995	S	57 (3)	44 (1)	10	10
Pool 8					
1992	24 (1)	23 (2)	14 (11)	23 (2)	25
1993	S	34	49 (11)	19 (2)	10
1994	S	34	49 (11)	19 (2)	10
1995	S	34	49 (11)	19 (2)	10
Pool 13					
1992	25	23 (2)	24 (1)	20 (4)	25
1993	S	43 (2)	46 (1)	14 (4)	15
1994	S	43 (2)	46 (1)	14 (4)	15
1995	S	43 (2)	46 (1)	14 (4)	15
Pool 26					
1992	S	30	31	29 (3)	27 (4)
1993	S	40	27	34 (3)	17 (4)
1994	S	40	27	34 (3)	17 (4)
1995	S	40	27	34 (3)	17 (4)
Open River					
1992	S	S	S	32 (16)	46 (2)
1993	S	S	S	64 (16)	43 (2)
1994	S	S	S	64 (16)	43 (2)
1995	S	S	S	64 (16)	43 (2)
La Grange Pool					
1992	S	23 (18)	S	35 (7)	41 (1)
1993	S	22 (18)	S	35 (7)	40 (1)
1994	S	22 (18)	S	35 (7)	40 (1)
1995	S	22 (18)	S	35 (7)	40 (1)

[a]CFS was reclassified into other aquatic areas in 1993.
[b]Impounded for Pool 4 is defined as Lake Pepin.

Table 2. Sampling dates for macroinvertebrate sampling.

	Sampling period	
Study area and year	**Starting date**	**Ending date**
Pool 4		
1992	June 13	June 30
1993	May 3	May 14
1994	May 2	May 10
1995	May 9	May 11
Pool 8		
1992	June 15	June 26
1993	May 24	June 10
1994	May 23	June 6
1995	May 22	June 2
Pool 13		
1992	June 2	June 23
1993	April 12	June 1
1994	May 10	June 1
1995	May 11	May 19
Pool 26		
1992	June 2	June 26
1993	April 12	June 10
1994	May 10	May 31
1995	May 11	May 19
Open River		
1992	June 1	June 12
1993[a]		
1994	April 4	April 12
1995	April 3	April 17
La Grange Pool		
1992	June 8	June 24
1993	April 28	May 12
1994	May 2	May 12
1995	May 1	May 10

[a]Not sampled because of flooding.

Table 3. Results of analysis of covariance on weighted pool/reachwide means with year, study area, and their interactions as independent variables. Those independent variables shown with an * significantly (P < 0.05) influenced the dependent variables.

	Dependent variables		
Independent variable	**Ephemeroptera**	**Sphaeriidae**	**Chironomidae**
Year	P = 0.89	P = 0.79	P = 0.52
Study area	*P = 0.0001	*P = 0.0095	*P = 0.0341
Year*study area	P = 0.11	P = 0.53	P = 0.13

Table 4. Estimated mean number of *Corbicula fluminea* and zebra mussels per square meter by year and study area, weighted by areas of strata. Numbers in parentheses are ±1 standard error. *N* = sample number.

Study area and year (*N*)	*Corbicula fluminea* (m^{-2})	Zebra mussels (m^{-2})
Pool 4		
1992 (122)	0.3 (±0.03)	S
1993 (121)	0 (±0.0)	S
1994 (126)	0.1 (±0.1)	S
1995 (120)	0 (±0.0)	27.2 (±27.2)
Pool 8		
1992 (109)	0 (±0.0)	S
1993 (109)	0 (±0.0)	S
1994 (110)	0 (±0.0)	S
1995 (109)	0 (±0.0)	0.2 (±0.2)
Pool 13		
1992 (118)	0 (±0.0)	S
1993 (119)	0.2 (±0.2)	S
1994 (125)	0 (±0.0)	S
1995 (118)	0 (±0.0)	10.1 (±6.8)
Pool 26		
1992 (117)	2 (±1.1)	S
1993 (66)	0 (±0.0)	S
1994 (124)	0.7 (±0.7)	S
1995 (69)	S [a]	S [a]
Open River[b]		
1992 (92)	1 (±0.6)	S
1994 (84)	2 (±1.2)	S
1995 (112)	2 (±1.1)	2.4 (±2.0)
La Grange Pool		
1992 (102)	0.4 (±0.4)	S
1993 (98)	0 (±0.0)	S
1994 (126)	10 (±2.9)	S
1995 (98)	1 (±0.7)	9.0 (±9.0)

[a]No estimated mean densities were calculated for Pool 26 in 1995; field crews were not able to sample certain sites because of high water.

[b]No macroinvertebrate monitoring was done in the Open River in 1993 because of high water.

Table 5. Reachwide estimated mean number of Ephemeroptera, Sphaeriidae, and Chironomidae per square meter by year and study area, weighted by areas of strata. Numbers in parentheses are ±1 standard error. *N* = sample number.

Study area and year (*N*)	Ephemeroptera (m^{-2})		Sphaeriidae (m^{-2})		Chironomidae (m^{-2})	
Pool 4						
1992 (122)	59	(±18.2)	47	(±18.5)	S	
1993 (121)	128	(±36.2)	74	(±10.8)	317	(±39.0)
1994 (126)	203	(±50.0)	88	(±12.2)	184	(±32.5)
1995 (120)	178	(±35.9)	61	(±13.3)	81	(±13.9)
Pool 8						
1992 (109)	51	(±24.6)	15	(±11.4)	S	
1993 (109)	118	(±40.9)	22	(±11.0)	50	(±9.4)
1994 (110)	86	(±27.6)	11	(±5.0)	27	(±15.8)
1995 (109)	55	(±14.2)	6	(±3.0)	11	(±3.9)
Pool 13						
1992 (118)	120	(±30.5)	84	(±27.6)	S	
1993 (119)	155	(±39.3)	2,596	(±494.3)	509	(±94.8)
1994 (125)	194	(±35.8)	594	(±156.5)	75	(±34.1)
1995 (118)	182	(±51.7)	276	(±81.9)	40	(±9.4)
Pool 26						
1992 (117)	21	(±9.5)	15	(±9.4)	S	
1993 (66)	7	(±1.9)	1	(±0.5)	10	(±2.1)
1994 (124)	21	(±6.3)	5	(±2.9)	14	(±7.7)
1995 (69)[a]	S		S		S	
Open River						
1992 (92)	22	(±12.0)	5	(±3.4)	S	
1993[b]	S		S		S	
1994 (84)	19	(±8.6)	1	(±0.5)	8	(±3.6)
1995 (112)	12	(±5.5)	0	(±0.0)	14	(±5.0)
La Grange Pool						
1992 (102)	13	(±6.3)	4	(±2.4)	S	
1993 (98)	11	(±4.8)	17	(±9.5)	52	(±14.3)
1994 (126)	27	(±8.5)	51	(±12.5)	57	(±9.9)
1995 (98)	6	(±3.5)	15	(±8.2)	32	(±12.1)

[a]No estimated reach wide densities since sampling was not completed because of flooding.

[b]Not sampled because of flooding.

Table 6. Mean number of organisms per square meter by study area and aquatic area with all years combined. Numbers in parentheses below target organisms are ±1 standard error. *N* = sample number. BWC = contiguous backwaters, MCB = main chanel borders, IMP = impounded areas, SC = side channels, and TDL = tributary delta lake.

Study area	Aquatic area and year (*N*)	Ephemeroptera (m^{-2})		Sphaeriidae (m^{-2})		Chironomidae (m^{-2})		*Corbicula* sp. (m^{-2})		Zebra mussels (m^{-2})	
Pool 4	BWC										
	1992 (25)	116.2	(±35.9)	25.4	(±8.7)	S[a]		0.0	(±0.0)	S[b]	
	1993 (57)	74.2	(±18.4)	12.8	(±2.9)	202.8	(±32.2)	0.0	(±0.0)	S	
	1994 (60)	103.8	(±20.7)	22.8	(±5.8)	233.0	(±61.2)	0.3	(±0.3)	S	
	1995 (56)	55.6	(±12.6)	8.2	(±2.6)	116.1	(±16.5)	0.0	(±0.0)	0.7	(±0.7)
	MCB										
	1992 (25)	31.5	(±27.6)	15.4	(±9.2)	S		0.8	(±0.8)	S	
	1993 (10)	1.9	(±1.9)	1.9	(±1.9)	40.4	(±34.2)	0.0	(±0.0)	S	
	1994 (10)	25.0	(±25.0)	0.0	(±0.0)	23.1	(±21.0)	0.0	(±0.0)	S	
	1995 (11)	57.7	(±57.7)	7.0	(±3.9)	10.5	(±6.0)	0.0	(±0.0)	17.5	(±17.5)
	SC										
	1992 (24)	29.6	(±10.7)	7.2	(±3.4)	S		0.0	(±0.0)	S	
	1993 (10)	28.8	(±20.5)	1.9	(±1.9)	86.5	(±50.3)	0.0	(±0.0)	S	
	1994 (10)	103.8	(±101.7)	1.9	(±1.9)	134.6	(±80.2)	0.0	(±0.0)	S	
	1995 (10)	21.2	(±12.3)	11.5	(±9.6)	11.5	(±5.1)	0.0	(±0.0)	0.0	(±0.0)
	TDL										
	1992 (24)	48.1	(±14.6)	58.4	(±23.5)	S		0.0	(±0.0)	S	
	1993 (44)	149.9	(±42.0)	94.4	(±13.3)	364.1	(±38.4)	0.0	(±0.0)	S	
	1994 (46)	235.4	(±52.4)	111.2	(±14.7)	178.5	(±21.6)	0.0	(±0.0)	S	
	1995 (43)	218.2	(±40.3)	77.4	(±16.0)	79.2	(±13.9)	0.0	(±0.0)	34.9	(±34.9)
Pool 8	BWC										
	1992 (23)	42.6	(±19.3)	6.7	(±3.7)	S		0.0	(±0.0)	S	
	1993 (29)	149.2	(±65.2)	41.1	(±31.1)	39.8	(±10.5)	0.0	(±0.0)	S	
	1994 (32)	105.2	(±30.0)	14.4	(±8.0)	38.5	(±11.0)	0.0	(±0.0)	S	
	1995 (31)	62.0	(±19.5)	9.9	(±6.3)	12.2	(±3.6)	0.0	(±0.0)	0.0	(±0.0)

Table 6. Continued

Study area	Aquatic area and year (*N*)	Ephemeroptera (m^{-2})		Sphaeriidae (m^{-2})		Chironomidae (m^{-2})		*Corbicula* sp. (m^{-2})		Zebra mussels (m^{-2})	
	IMP										
	1992 (14)	46.7	(±26.3)	17.9	(±15.0)	S		0.0	(±0.0)	S	
	1993 (52)	123.5	(±25.4)	20.7	(±3.9)	66.2	(±7.6)	0.0	(±0.0)	S	
	1994 (49)	110.7	(±34.6)	12.2	(±4.4)	12.2	(±6.6)	0.0	(±0.0)	S	
	1995 (49)	82.4	(±16.3)	7.5	(±2.2)	13.3	(±3.5)	0.0	(±0.0)	0.0	(±0.0)
	MCB										
	1992 (25)	14.6	(±6.3)	0.8	(±0.8)	S		0.0	(±0.0)	S	
	1993 (10)	0.0	(±0.0)	3.8	(±2.6)	9.6	(±7.7)	0.0	(±0.0)	S	
	1994 (10)	1.9	(±1.9)	0.0	(±0.0)	3.8	(±2.6)	0.0	(±0.0)	S	
	1995 (10)	1.9	(±1.9)	3.8	(±3.8)	0.0	(±0.0)	0.0	(±0.0)	0.0	(±0.0)
	SC										
	1992 (23)	10.9	(±6.3)	0.8	(±0.8)	S		0.0	(±0.0)	S	
	1993 (18)	111.1	(±61.4)	7.5	(±3.5)	41.7	(±12.8)	0.0	(±0.0)	S	
	1994 (19)	61.7	(±36.1)	10.1	(±4.5)	56.7	(±49.6)	0.0	(±0.0)	S	
	1995 (19)	8.1	(±7.1)	0.0	(±0.0)	9.1	(±7.1)	0.0	(±0.0)	1.0	(±1.0)
Pool 13	BWC										
	1992 (23)	36.0	(±14.1)	109.5	(±50.1)	S		0.0	(±0.0)	S	
	1993 (41)	93.8	(±24.7)	118.2	(±36.2)	264.1	(±59.2)	0.0	(±0.0)	S	
	1994 (48)	392.2	(±60.2)	176.3	(±39.3)	143.8	(±43.3)	0.0	(±0.0)	S	
	1995 (44)	153.8	(±32.4)	117.1	(±29.2)	93.1	(±18.0)	0.0	(±0.0)	1.3	(±1.0)
	IMP										
	1992 (24)	199.5	(±45.2)	81.7	(±16.1)	S		0.0	(±0.0)	S	
	1993 (45)	221.4	(±43.5)	6047.9	(±1104.7)	939.3	(±132.3)	0.4	(±0.4)	S	
	1994 (47)	137.9	(±33.3)	1270.5	(±337.9)	43.4	(±33.0)	0.0	(±0.0)	S	
	1995 (48)	238.4	(±52.8)	536.6	(±154.6)	18.0	(±6.9)	0.0	(±0.0)	16.0	(±9.2)
	MCB										
	1992 (25)	34.6	(±15.2)	10.0	(±5.0)	S		0.0	(±0.0)	S	
	1993 (15)	64.1	(±47.8)	175.6	(±128.9)	189.7	(±135.1)	0.0	(±0.0)	S	
	1994 (15)	1.3	(±1.3)	2.6	(±1.7)	50.0	(±39.8)	0.0	(±0.0)	S	
	1995 (15)	110.3	(±87.7)	59.0	(±37.3)	2.6	(±1.7)	0.0	(±0.0)	17.9	(±15.3)

Table 6. Continued

Study area	Aquatic area and year (*N*)	Ephemeroptera (m^{-2})	Sphaeriidae (m^{-2})	Chironomidae (m^{-2})	*Corbicula* sp. (m^{-2})	Zebra mussels (m^{-2})
	SC					
	1992 (21)	54.0 (±25.1)	80.6 (±43.3)	S	0.0 (±0.0)	S
	1993 (18)	191.2 (±56.0)	157.1 (±48.6)	32.1 (±15.6)	0.0 (±0.0)	S
	1994 (15)	23.1 (±11.1)	43.6 (±20.8)	7.7 (±3.7)	0.0 (±0.0)	S
	1995 (11)	134.6 (±62.3)	47.2 (±24.5)	1.7 (±1.7)	0.0 (±0.0)	5.2 (±5.2)
Pool 26	BWC					
	1992 (30)	0.6 (±0.6)	3.2 (±2.1)	S	0.0 (±0.0)	S
	1993 (32)	37.9 (±10.4)	7.8 (±3.0)	81.1 (±16.6)	0.0 (±0.0)	S
	1994 (40)	151.9 (±32.0)	13.5 (±6.8)	88.0 (±25.6)	0.5 (±0.5)	S
	1995 (41)	5.2 (±2.4)	0.9 (±0.7)	46.0 (±17.6)	0.0 (±0.0)	0.0 (±0.0)
	IMP					
	1992 (31)	47.8 (±23.2)	94.9 (±39.1)	S	7.4 (±4.2)	S
	1993 (27)	121.1 (±36.8)	22.1 (±9.4)	136.0 (±26.4)	0.0 (±0.0)	S
	1994 (27)	118.2 (±36.4)	40.6 (±23.3)	45.6 (±14.7)	0.0 (±0.0)	S
	1995 (27)	21.4 (±11.2)	0.7 (±0.7)	31.3 (±15.0)	0.0 (±0.0)	3.6 (±2.9)
	MCB					
	1992 (27)	21.4 (±9.4)	17.1 (±12.0)	S	2.1 (±1.6)	S
	1993 (3)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	S
	1994 (19)	5.1 (±2.9)	4.0 (±2.8)	9.1 (±8.1)	1.0 (±1.0)	S
	1995	S[c]	S	S	S	S
	SC					
	1992 (29)	21.2 (±9.8)	1.3 (±0.9)	S	0.0 (±0.0)	S
	1993 (4)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	0.0 (±0.0)	S
	1994 (38)	9.1 (±3.7)	0.0 (±0.0)	1.5 (±0.9)	0.0 (±0.0)	S
	1995 (1)	0.0	0.0 (±0.0)	0.0	0.0 (±0.0)	0.0 (±0.0)
Open River	MCB					
	1992 (46)	18.4 (±10.8)	3.8 (±3.0)	S	0.8 (±0.6)	S
	1993	S[d]	S	S	S	S
	1994 (35)	20.9 (±9.4)	0.5 (±0.5)	8.2 (±3.9)	1.6 (±1.2)	S
	1995 (42)	11.9 (±5.8)	0.0 (±0.0)	10.1 (±4.1)	1.8 (±1.1)	2.7 (±2.3)

Table 6. Continued

Study area	Aquatic area and year (*N*)	Ephemeroptera (m^{-2})		Sphaeriidae (m^{-2})		Chironomidae (m^{-2})		*Corbicula* sp. (m^{-2})		Zebra mussels (m^{-2})	
	SC										
	1992 (46)	47.7	(±20.3)	14.2	(±6.9)	S		1.7	(±1.0)	S	
	1993	S		S		S		S		S	
	1994 (49)	7.1	(±2.8)	0.4	(±0.4)	3.9	(±1.6)	2.4	(±1.1)	S	
	1995 (70)	10.4	(±3.5)	0.0	(±0.0)	41.5	(±12.1)	1.6	(±0.9)	0.0	(±0.0)
La Grange Pool	BWC										
	1992 (23)	20.9	(±9.9)	4.2	(±3.0)	S		0.8	(±0.8)	S	
	1993 (25)	16.9	(±7.0)	13.8	(±8.0)	91.5	(±22.4)	0.0	(±0.0)	S	
	1994 (42)	44.0	(±13.0)	39.4	(±13.4)	54.0	(±9.6)	0.5	(±0.5)	S	
	1995 (24)	1.6	(±1.1)	6.4	(±3.0)	54.5	(±24.1)	0.0	(±0.0)	0.0	(±0.0)
	MCB										
	1992 (41)	8.0	(±4.1)	2.8	(±1.7)	S		0.0	(±0.0)	S	
	1993 (38)	5.6	(±3.2)	17.2	(±9.1)	27.3	(±9.6)	0.0	(±0.0)	S	
	1994 (42)	11.4	(±4.9)	57.2	(±12.0)	57.7	(±9.9)	16.5	(±4.6)	S	
	1995 (39)	7.9	(±5.2)	19.7	(±11.5)	14.8	(±3.8)	2.5	(±1.3)	15.8	(±15.8)
	SC										
	1992 (38)	8.6	(±3.0)	10.6	(±6.3)	S		1.0	(±0.7)	S	
	1993 (35)	22.0	(±7.1)	48.9	(±27.8)	26.4	(±5.2)	0.0	(±0.0)	S	
	1994 (42)	67.3	(±14.7)	61.8	(±11.4)	74.6	(±13.7)	11.7	(±3.0)	S	
	1995 (35)	12.6	(±3.9)	33.0	(±11.7)	50.0	(±14.0)	0.5	(±0.5)	1.6	(±1.6)

[a]Chironomidae not sampled in 1992.
[b]Zebra mussels not sampled in 1992–1994.
[c]Pool 26, MCB not sampled in 1995 because of flooding.
[d]Open River not sampled in 1993 because of flooding.

Table 7. Mean number of organisms per square meter by study area and substrate type. Numbers in parentheses below target organisms are ±1 standard error. *N* = sample number.

Study area	Predominant substrate (*N*)	Ephemeroptera (m^{-2})		Sphaeriidae (m^{-2})		Chironomidae (m^{-2})	
Pool 4	Hard clay (6)	16.0	(±16.0)	6.4	(±4.1)	72.1	(±6.0)
	Silt clay (226)	170.9	(±17.0)	57.5	(± 5.8)	164.9	(±21.4)
	Silt clay w/sand (93)	109.6	(±18.5)	48.8	(± 7.4)	265.0	(±27.4)
	Sand w/silt clay (36)	23.0	(±8.6)	7.5	(±2.7)	273.5	(±65.5)
	Sand (113)	1.9	(±0.6)	6.0	(±2.0)	63.9	(±15.8)
	Gravel rock (13)	1.5	(±1.5)	0.0	(±0.0)	23.7	(±14.5)
Pool 8	Hard clay (18)	84.4	(±83.3)	17.1	(±6.2)	22.4	(±10.0)
	Silt clay (142)	159.3	(±18.7)	17.5	(±3.4)	35.8	(±5.6)
	Silt clay w/sand (104)	66.4	(±13.2)	14.8	(±8.8)	49.0	(±14.3)
	Sand w/silt clay (72)	15.0	(±5.2)	10.7	(±2.2)	23.3	(±5.1)
	Sand (100)	2.7	(±1.1)	1.0	(±0.4)	5.7	(±2.0)
	Gravel rock (1)	134.6	(±0.0)	0.0		19.2	
Pool 13	Hard clay (6)	22.4	(±12.6)	2,717.9	(±2,660.4)	22.4	(±18.9)
	Silt clay (253)	248.1	(±19.6)	1,089.2	(±217.3)	260.0	(±38.9)
	Silt clay w/sand (104)	118.0	(±20.9)	836.5	(±274.7)	236.7	(±64.0)
	Sand w/silt clay (50)	5.8	(±1.9)	245.0	(±92.2)	110.8	(±48.6)
	Sand (63)	2.1	(±1.4)	29.3	(±17.1)	0.8	(±0.6)
	Gravel rock (4)	0.0	(±0.0)	9.6	(±9.6)	0.0	
Pool 26	Hard clay (32)	37.3	(±21.8)	2.4	(1.7)	29.8	(±13.0)
	Silt clay (213)	64.1	(±9.4)	23.8	(±6.8)	77.6	(±9.8)
	Silt clay w/sand (33)	61.8	±23.9)	28.0	(±12.2)	30.8	(±25.4)
	Sand w/silt clay (9)	6.4	(±4.5)	4.3	(±4.3)	6.4	(±4.5)
	Sand (82)	7.0	(±3.1)	0.5	(±0.3)	0.0	(±0.0)
	Gravel rock (7)	22.0	(±19.0)	0.0	(±0.0)	6.4	(±6.4)
Open River	Hard clay (20)	11.5	(±3.2)	0.0	(±0.0)	7.5	(±3.9)
	Silt clay (76)	60.0	(±14.3)	9.1	(±4.2)	56.9	(±16.7)
	Silt clay w/sand (28)	7.6	(±4.0)	4.8	(±4.8)	41.4	(±12.5)
	Sand w/silt clay (14)	5.5	(±4.2)	0.0	(±0.0)	0.0	(±0.0)
	Sand (115)	1.8	(±1.4)	0.3	(±0.2)	3.6	(±1.4)
	Gravel rock (35)	1.6	(±0.9)	0.0	(±0.0)	2.7	(±2.1)
La Grange Pool	Hard clay (28)	2.1	(±1.1)	27.5	(±6.5)	48.1	(±18.1)
	Silt clay (225)	30.9	(±4.3)	35.0	(±6.4)	56.8	(±6.2)
	Silt clay w/sand (89)	13.8	(±3.3)	29.2	(±5.9)	50.3	(±7.9)
	Sand w/silt clay (24)	5.6	(±5.6)	18.4	(±7.8)	26.4	(±8.0)
	Sand (56)	1.7	(±0.9)	6.9	(±4.3)	31.2	(±11.3)
	Gravel rock (–)	0.0	(±0.0)	0.0	(±0.0)	0.0	(±0.0)

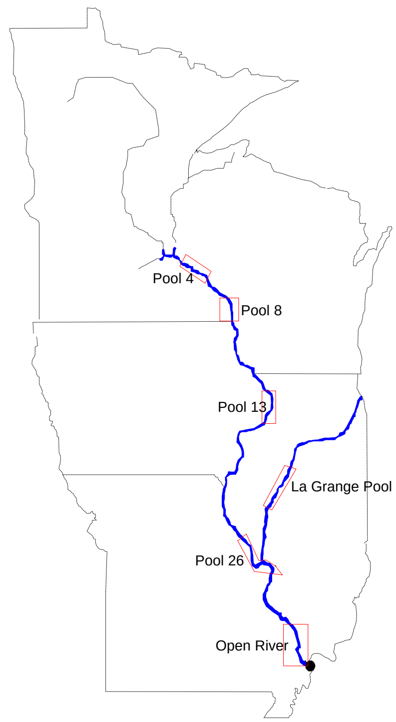

Figure 1. Long Term Resource Monitoring Program study areas for macroinvertebrate sampling.

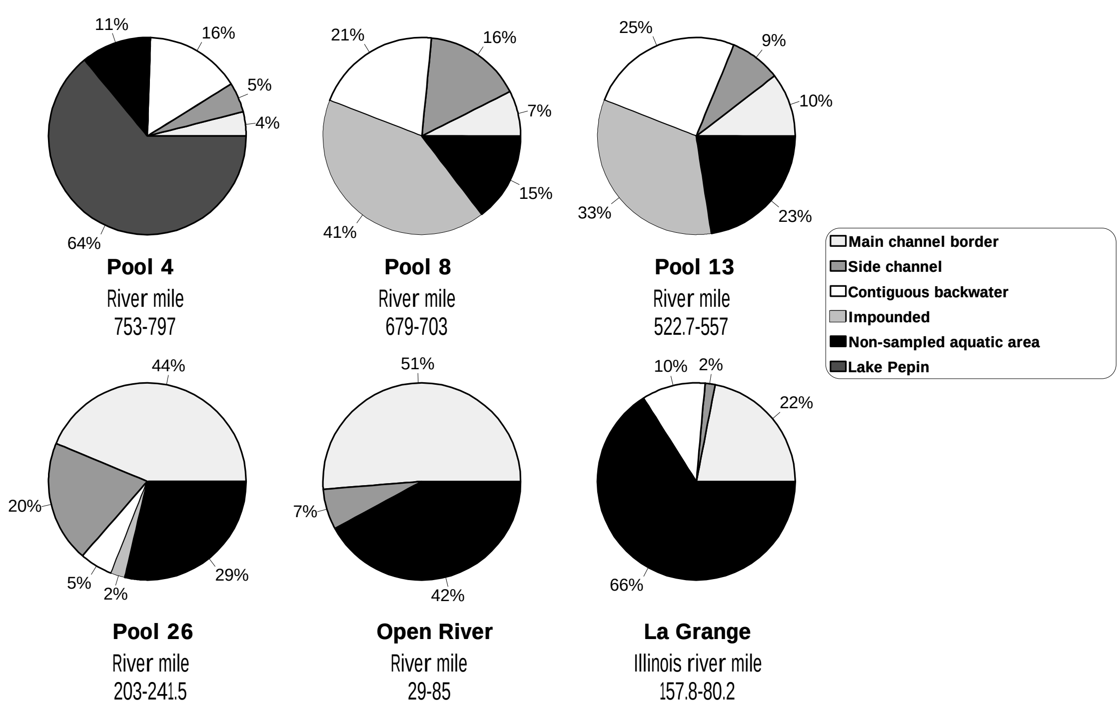

Figure 2. River miles and percentage of aquatic area in each study area.

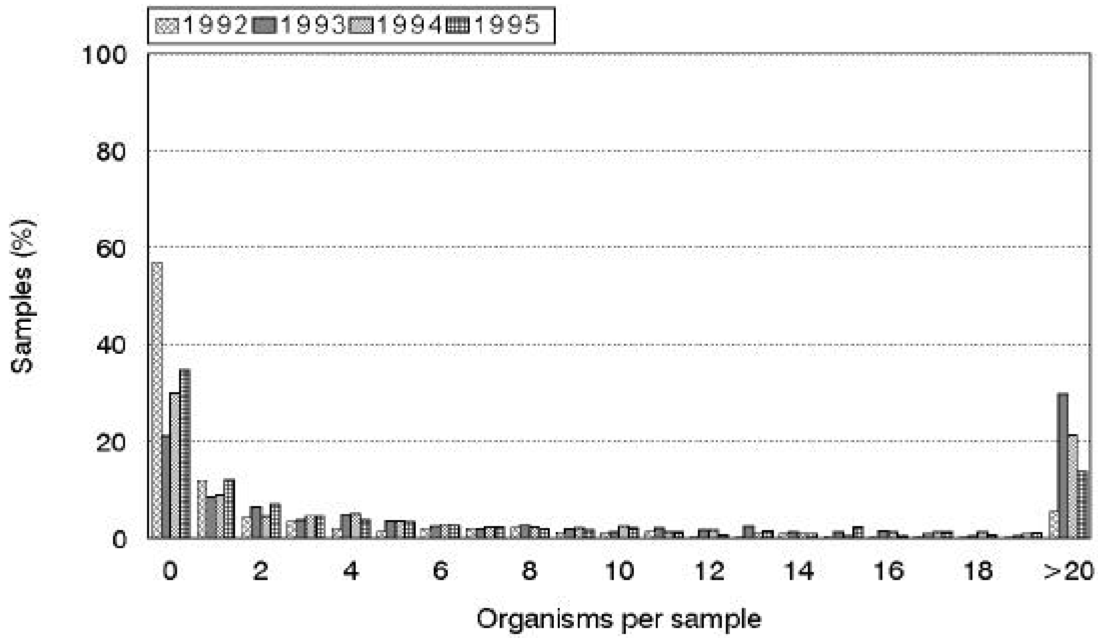

Figure 3. Frequency of target organisms in samples, 1992–1995.

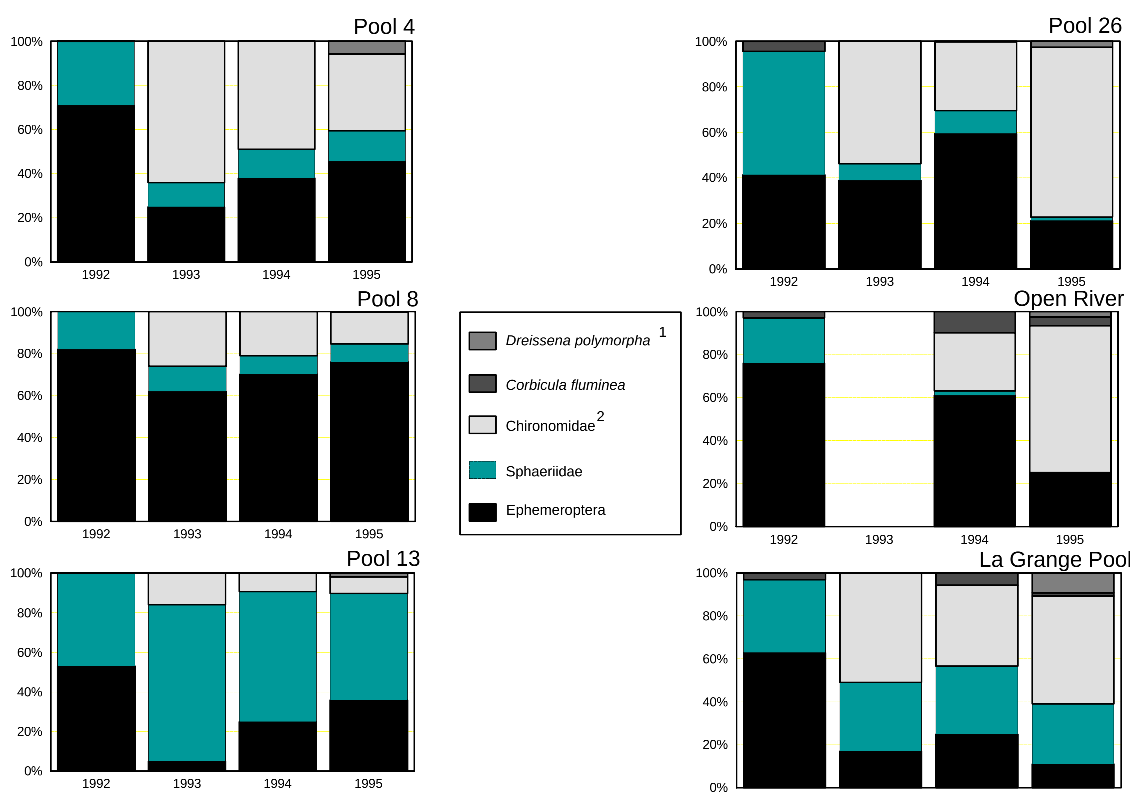

Figure 4. Percent composition of target organisms: 1 = Zebra mussel sampling initiated in 1995, 2 = Midge sampling initiated in 1993.

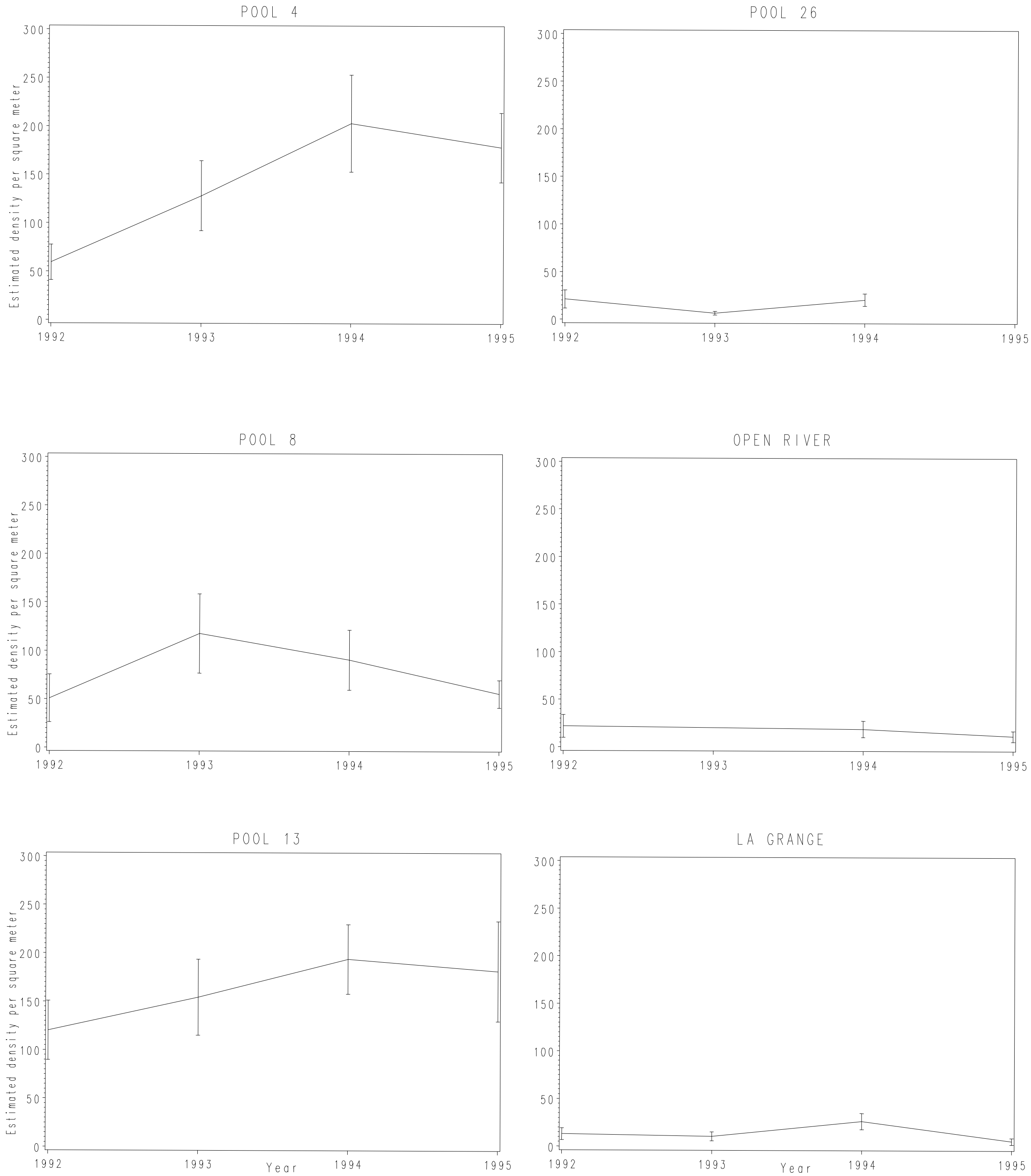

Figure 5. Estimated mean number of Ephemeroptera per square meter by study area, weighted by area of strata. Bars indicate ±1 standard error.

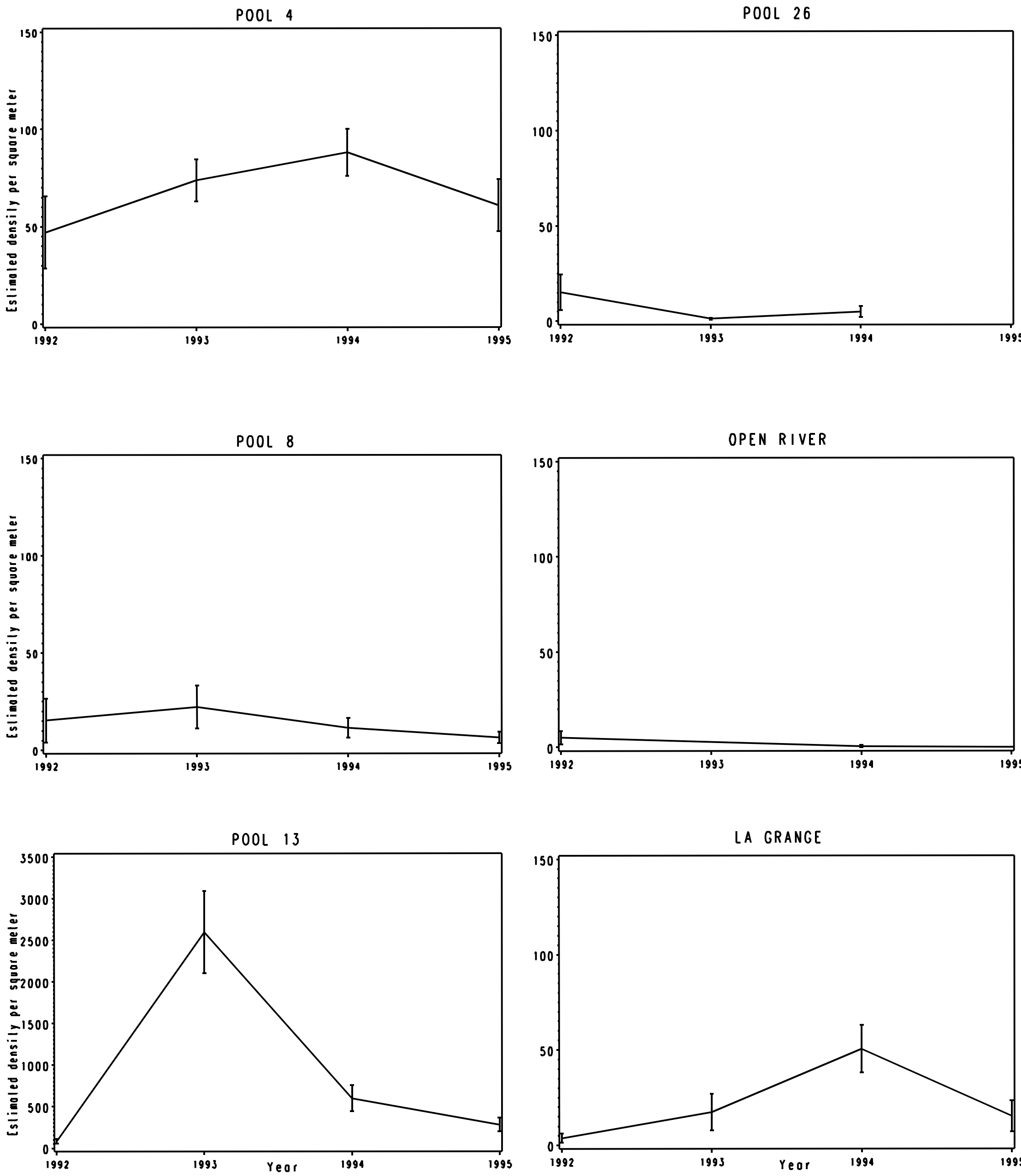

Figure 6. Estimated mean number of Sphaeriidae per square meter by study area, weighted by area of strata. Bars indicate ±1 standard error.

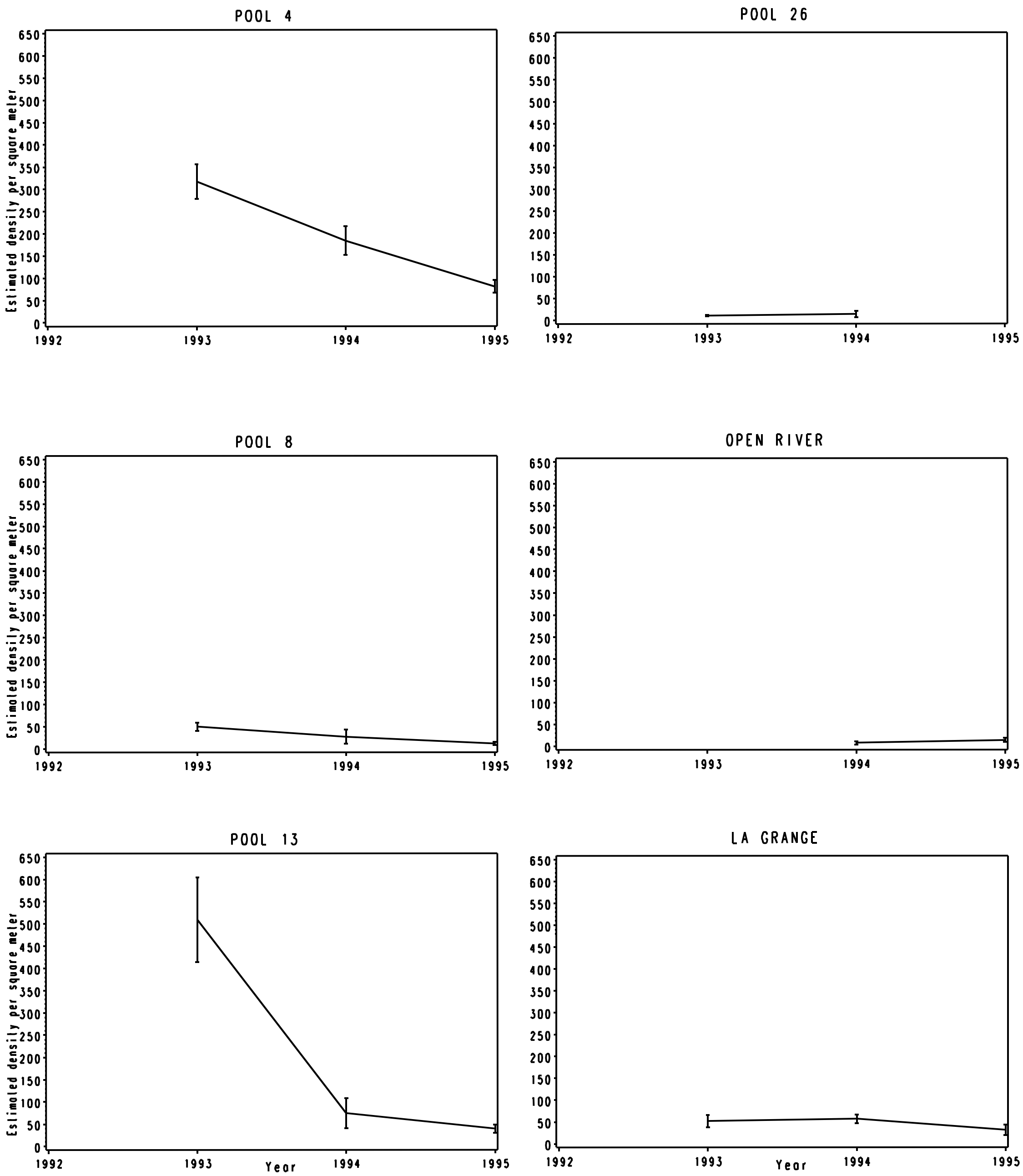

Figure 7. Estimated mean number of Chironomidae per square meter by study area, weighted by area of strata. Bars indicate ±1 standard error.

Appendix. Macroinvertebrate Collection Sheet

Macroinvertebrate Collection Sheet

Long Term Resource Monitoring Program
Environmental Management Technical Center
575 Lester Avenue, Onalaska, WI 54650

Attach Bar Code Here

Field Station

Date
mm dd yy

Sample Grid
Numeric Field

New measured UTM Coordinates
E
N
Zone
PDOP

Project Code
M=RTA Monitoring
B=Bio-Response
E=Experimental
R=Research

Habitat Class
(left justify)
MCB=Main Channel/Border
TDL=Lake Pepin
IMP=Impounded
SC=Side Channel
BWC=Contiguous Backwater

River Mile

Subsample Taken
N=No
A=268 cm^2
B=162 cm^2

Laboratory Sample Taken
(Y or N)

Depth (M)

Containers

Summary Code
1. Sample taken
2. Sample taken but not kept due to hard substrate
3. Sample taken but not kept due to detritus, shells, etc.
4. Other

Gear Code
P=Ponar

Habitat Information

% Submersed and Floating-Leaf Vegetation
(Ponar Only)
0 = 0%
1 = 1% - 20%
2 = 21% - 50%
3 = 51% - 90%
4 = 91% - 100%

Predominant Substrate
1 = Hard Clay
2 = Silt/Clay
3 = Mostly Silt/Clay with Sand
4 = Mostly Sand with Silt/Clay
5 = Sand
6 = Gravel/Rock

Fine Organic Material
(Y or N)

Ponar Sample Description

(Percentage of Whole Tay)

Shells
0 = 0%
1 = 1% - 20%
2 = 21% - 50%
3 = 51% - 90%
4 = 91% - 100%

Detritus
0 = 0%
1 = 1% - 20%
2 = 21% - 50%
3 = 51% - 90%
4 = 91% - 100%

Site Description (Describe 15-m Radius Around Boat)

Submersed Vegetation	Floating-Leaf	Emergent Vegetation	Open Water
0 = 0% 1 = 1% - 20% 2 = 21% - 50% 3 = 51% - 90% 4 = 91% - 100%	0 = 0% 1 = 1% - 20% 2 = 21% - 50% 3 = 51% - 90% 4 = 91% - 100%	0 = 0% 1 = 1% - 20% 2 = 21% - 50% 3 = 51% - 90% 4 = 91% - 100%	0 = 0% 1 = 1% - 20% 2 = 21% - 50% 3 = 51% - 90% 4 = 91% - 100%

Macroinvertebrates

Mayflies | Fingernail Clams | *Corbicula* | Midges | Zebra Mussels

Comments:

Recorder Code

Data collected on this form were collected in compliance with current LTRMP procedures and are to the best of my knowledge complete and free of errors.

Crew Leader Signature: ______________________________

EMTC 08/25/95

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13. ABSTRACT (Maximum 200 words)

The annual variability in mayflies (Ephemeroptera), fingernail clams (Sphaeriidae), and midges (Chironomidae) in six study areas of the Upper Mississippi River System from 1992 to 1995 was examined. Spatial distribution is also discussed for these organisms along with the Asiatic clam (*Corbicula fluminea*) and the zebra mussel (*Dreissena polymorpha*). Sample allocation within each reach was based on a stratified random design where strata were aquatic areas. No significant linear trends across years were found in estimated reachwide mean number of organisms. However, the overall test for differences in intercepts among study areas was statistically significant ($P < 0.05$) for mayflies, fingernail clams, and midges. No statistical difference in trend slopes among reaches were detected. In 1993, the estimated mean density of fingernail clams in Pool 13 was 35 times that found in other study areas. Overall, impounded aquatic areas and silt clay substrates supported higher numbers of the select macroinvertebrates.

14. SUBJECT TERMS

Asiatic clam (*Corbicula fluminea)* benthic aquatic *macroinvertebrates*, *Corbicula*, fingernail claims (Sphaeriidae), mayflies (Ephemeroptera), midges (Chironomidae), Mississippi River, zebra mussel (*Dreissena polymorpha)*

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