Long Term Resource Monitoring Program

Program Report

96-P001

## Annual Status Report:

# 1992 Macroinvertebrate Sampling

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February 1996

# Annual Status Report:
# 1992 Macroinvertebrate Sampling

by

Jennifer S. Sauer
National Biological Service
Environmental Management Technical Center
575 Lester Avenue
Onalaska, Wisconsin 54650

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*The Environmental Management Technical Center issues LTRMP Program Reports to provide Long Term Resource Monitoring Program partners with programmatic documentation, procedures manuals, and annual status reports.*



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*The National Biological Service . . . gathering, analyzing, and sharing the biological information necessary to support the wise stewardship of the Nation's natural resources.*

# 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, an office of the National Biological Service, in cooperation with the five Upper Mississippi River System (UMRS) States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin, with guidance and Program responsibility provided by the U.S. Army Corps of Engineers. 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.

The mission of the LTRMP is to provide decision makers with information to maintain 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 impacts, develop management alternatives, manage information, and develop useful products.

This document is an annual status report for 1992, containing a synthesis of target macroinvertebrate populations in the UMRS. This report satisfies, for 1992, Task 2.2.7.4, *Evaluate and Summarize Annual Results* under Goal 2, *Monitor Resource Change* as specified in the Operating Plan for the Long Term Resource Monitoring Program (USFWS 1992). This report was developed with funding provided by the Long Term Resource Monitoring Program.

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**By Jennifer S. Sauer**

**Abstract**

In 1992, as part of the Long Term Resource Monitoring Program, macroinvertebrate sampling was initiated in Pools 4, 8, 13, 26, and the open river reach of the Mississippi River, and La Grange Pool of the Illinois River. Long-term monitoring is needed to detect population trends and detect local changes in aquatic ecosystems. Mayflies (Ephemeridae), fingernail clams (Sphaeriidae), and the exotic *Corbicula* species were selected for monitoring. These three members of the soft-substrate community were chosen because they play an important ecological role in the Upper Mississippi River System. Sampling was based on a stratified random design and was conducted at approximately 125 sites per study area. Mean densities of organisms were weighted by strata for study reach estimates. Pool 13 had the highest mean number of mayflies (124 $m^{-2}$) and fingernail clams (90 $m^{-2}$). The lowest mean number of mayflies and fingernail clams (10 and 3 $m^{-2}$, respectively) was encountered in La Grange Pool. Silt/clay substrates supported the highest mean densities of mayflies in all reaches except for Pool 26 and La Grange. Silt/clay substrates also supported the highest densities of fingernail clams except for Pool 13 and La Grange.

## Introduction

In 1992, macroinvertebrate sampling was initiated in Pools 4, 8, 13, 26, and the open river reach of the Mississippi River and La Grange Pool of the Illinois River as part of the Long Term Resource Monitoring Program (LTRMP). Mayflies (Ephemeridae), fingernail clams (Sphaeriidae), and the exotic *Corbicula* species were selected for monitoring. These three organisms found in the soft-sediment substrate were chosen because they play an important ecological role in the Upper Mississippi River System (UMRS). The exotic *Corbicula* species was chosen for sampling because of possible detrimental impacts it may have on the economy and biology of the UMRS. Conversely, mayflies and fingernail clams were chosen because they are important components of the aquatic food web, and declines could have adverse effects on a variety of riverine fish and wildlife. Thompson (1973) found that in the fall, lesser scaup (*Aythya affinis*) gizzard contents contained 76% sphaeriids and about 13% mayflies. Thompson also found both organisms to be important to canvasbacks (*A. valisneria*), ring-necked ducks (*A. collaris)*, and American coots (*Fulica americana*) feeding in open water. A number of fish, including commercial and recreational fish, use both organisms (Hoopes 1960; Jude 1968; Ranthum 1969).

Macroinvertebrates are useful as indicators because of their ability to retain contaminants, their relatively large size, and their limited mobility (Myslinski and Ginsburg 1977). Thus, changes in mayfly and fingernail clam densities could indicate trends, and perhaps account for spatial variations of various wildlife and fish as well. 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 in the Illinois River.

Long-term monitoring is needed to detect population trends and local changes in aquatic ecosystems. Few long-term studies have been conducted on the distribution and abundance of mayflies and fingernail clams, although several areas of the UMRS have been sampled sporadically (Fremling 1964; Carlander et al. 1967; Gale 1969; Hubert et al. 1983; Brewer 1992; Hornbach et al. 1993). Between 1976 and 1989 through 1991, Eckblad and Lehtinen (1991) found significant declines in Sphaeriidae populations from backwater lakes, while Brewer (1992) reported the largest declines of Sphaeriidae from open water areas in Pool 8 between 1975 and 1990 (from 86,910 to 110 $m^{-2}$). Mayflies

(*Hexagenia*) showed the greatest declines (from 3,940 to 20 $m^{-2}$) in bay areas. A mean density of 40,000 *Sphaerium transversum* $m^{-2}$ was recorded by Gale (1973) in Pool 19. Although these studies contain valuable information, they were collected using different methods and over short periods, making it difficult to predict long-term trends.

# Objectives

The objective of the LTRMP macroinvertebrate component is to annually monitor and report trends in the status and distribution of target macroinvertebrate populations. Because 1992 was the first year of macroinvertebrate sampling, our short-term objectives were to (1) evaluate the methods selected and (2) document spatial patterns among reaches and aquatic areas.

# Methods

## *Spatial Design*

Pools 4, 8, 13, 26, and the open river reach of the Mississippi River and La Grange Pool of the Illinois River were sampled for mayflies (Ephemeridae), fingernail clams (Sphaeriidae), and *Corbicula* sp. during 1992 (Fig. 1; USFWS 1992). Sampling was based on a stratified random design and was conducted at 125 sites per reach. Sites included locations where benthic samples were collected historically (Appendix A). Sampling was also conducted at randomly selected sites distributed among the five types of aquatic areas outlined by Wilcox (1993): contiguous backwaters (BWC), which are areas having apparent surface water connection with the rest of the river; channel border unstructured (CBU) areas, the area between the navigational buoys and the riverbank, not including revetments and channel-training structures; contiguous floodplain shallow (CFS) aquatic areas, portions of the floodplain inundated by the navigation dams that are not part of any floodplain lakes or channels; impounded areas (IMP), large, mostly open water areas located in the downstream portion of the navigational pools; and side channels (SC), which carry less flow than the navigational channel (Table 1; Thiel 1993). Only 96 sites were sampled in the open river because of sampling difficulty. All sites were sampled in June before mayfly emergence (Table 2).

## *Sampling Methods*

### Macroinvertebrates

Macroinvertebrate sampling procedures are described in detail in the LTRMP Procedures Manual (Thiel 1993). Benthic samples were collected using a winch-mounted 23- x 23-cm, (0.052-$m^2$) standard Ponar grab sampler (Ponar™ Grab Dredge, Wildlife Supply Company, Saginaw, Michigan). The samples were sieved through a U.S. standard sieve No. 30 (595 µm). Mayflies, fingernail clams, and *Corbicula* sp. were counted and picked in the field from the sample and preserved in 10% formalin. Once a sample was picked *in situ*, the remaining material in the wash frame also was preserved in 10% formalin.

### QA/QC

Ten percent of the samples collected were sorted in the laboratory. Results were compared with samples sorted in the field to determine sorting efficiency. Laboratory analyses also provided additional data on the benthic community (midges and aquatic worms). The laboratory sample was stained with a rose bengal solution (Thiel 1993) and allowed to sit for at least 48 h. Macroinvertebrates were removed and sorted into six broad taxonomic categories: mayflies, fingernail clams, *Corbicula* sp., midges, aquatic worms, and "others." The organisms were counted and preserved in 70% ethanol.

Mayflies and fingernail clams found in the field and laboratory were measured to the nearest

millimeter. Measurements aided in determining field sorting efficiency and whether a larger sieve size could be used to simplify field sorting.

## Site Information

A sediment sample was collected at each site using a 15- x 15-cm petite Ponar grab sampler. Five categories of substrate composition were used: muck/organic, silt clay, sandy silt, sand, gravel rock, and hard clay. Substrate composition was based on subjective characterization. The sediment samples were analyzed at the Environmental Management Technical Center (EMTC) for moisture content, bulk density, and percent organic material.

At each site, the percentage of submersed and floating-leaf aquatic vegetation in the column of water and sediment that the Ponar dredge fell through was recorded. Also, the type and percentage of vegetation and open water in a 15-m radius from the boat were characterized and water depth was measured.

Absolute abundance of the three target organisms was derived from the Ponar grabs. Data were analyzed with the Statistical Analysis System (SAS; SAS Institute, Inc., Cary, NC). For statistical analysis, random and historical sites were combined to increase the power of the test. Absolute abundance was not normally distributed; therefore, a general linear model (GLM) was used on log-transformed data to determine significant differences in the number of organisms found within the study reaches. Potential differences in densities of the three target organisms between aquatic areas and substrate types also were tested with a GLM procedure on log-transformed data. Estimation of Pool/Reach-wide mean densities was derived using the following formula, where the subscript *st* indicates that simplified random sampling was used, *N* equals the number of hectares in an aquatic area, and *y* equals the mean densities of organisms within that aquatic area (Schaeffer et al. 1979).

$$\overline{y}_{st} = \frac{1}{N}[N_1\overline{y}_1 + N_2\overline{y}_2 + \ldots N_L\overline{y}_L]$$

# Results

## *Pool 4*

### Site Features

Pool 4 begins at river mile (RM) 796.9 at Red Wing, Minnesota, and ends at RM 752.8 at Alma, Wisconsin, a distance of 44.1 m. The study area encompasses about $1.34 \times 10^4$ hectares. Measured depths at sampling sites ranged from 0.2 to 10.5 m with a mean of 2.2 m. Approximately 80% of the sites were unvegetated. Sampled aquatic areas in Pool 4 included CFS, CBU, BWC, impounded lake (IMP-L), and SC.

### Macroinvertebrate Abundance and Distribution

Macroinvertebrate samples (*N*=126) in Pool 4 in 1992 produced a total of 409 mayflies, 171 fingernail clams, and 1 *Corbicula* sp., with 57% of the sites containing at least one of the target organisms. The highest mean density of mayflies was found in the BWC aquatic area (116 $m^{-2}$), with CBU having the lowest mean density (32 $m^{-2}$; Fig. 2). Lake Pepin (IMP-L) had the highest mean densities of fingernail clams (59 $m^{-2}$; Fig. 3).

The silt/clay substrate was the most frequently sampled substrate in Pool 4. Of the 126 sampling sites, 57 (45%) had silt/clay as the predominant substrate. The highest mean densities of 104 mayflies $m^{-2}$ (Fig. 4) and 49 fingernail clams $m^{-2}$ were found in silt/clay substrate (Fig. 5).

## *Pool 8*

### Site Features

Pool 8 begins at RM 702.5 at Dresbach, Minnesota, and ends at RM 679.2 at Genoa, Wisconsin, a distance of 23.3 m. The study area encompasses about $6.73 \times 10^3$ hectares. Measured depths at sampling sites ranged from 0.2 to 7.4 m with a mean of 1.5 m. About 90% of the sites were unvegetated. Sampled aquatic areas in Pool 8 included CFS, CBU, BWC, IMP, and SC.

### Macroinvertebrate Abundance and Distribution

Macroinvertebrate samples (*N*=125) in Pool 8 in 1992 produced a total of 313 mayflies, 82 fingernail clams, and 0 *Corbicula* sp., with 46% of the sites containing at least one of the target organisms. The highest mean density of mayflies was found in the IMP aquatic area (102 $m^{-2}$), with CBU having the lowest mean density (15 $m^{-2}$; Fig. 2). The impounded area had the highest mean densities of fingernail clams (25 $m^{-2}$; Fig. 3).

The silt/clay substrate was the most frequently sampled substrate in Pool 8. Of the 125 sampling sites, 52 (42%) had silt/clay as the predominant substrate. Mean densities of 97 mayflies $m^{-2}$ (Fig. 4) and 28 fingernail clams $m^{-2}$ were found in silt/clay substrate (Fig. 5).

## *Pool 13*

### Site Features

Pool 13 extends from RM 556.7 at Bellevue, Iowa, to RM 522.5 at Clinton, Iowa, a distance of 34.2 m. The study area encompasses about $8.74 \times 10^3$ hectares. Measured depths at sampling sites ranged from 0.20 to 8.3 m with a mean of 1.8 m. About 90% of the sites were unvegetated. Sampled aquatic areas in Pool 13 included CFS, CBU, BWC, IMP, and SC.

### Macroinvertebrate Abundance and Distribution

Macroinvertebrate samples (*N*=125) in Pool 13 in 1992 produced a total of 641 mayflies, 607 fingernail clams, and 0 *Corbicula* sp., with 69% of the sites containing at least one of the target organisms. The highest mean density of mayflies was found in the IMP aquatic area (191 $m^{-2}$), with CBU having the lowest mean density (35 $m^{-2}$; Fig. 2). The side channel aquatic area had the highest mean densities of fingernail clams (148 $m^{-2}$; Fig. 3).

Sandy silt substrate was the most frequently sampled substrate in Pool 13 with 42 of the 125 sampling sites (34%) having sandy silt as the predominant substrate. Mean densities of 223 mayflies $m^{-2}$ were found in a silt/clay substrate (Fig. 4), and 234 fingernail clams $m^{-2}$ were found in the muck/organic substrate (Fig. 5).

## *Pool 26*

### Site Features

Pool 26 begins at RM 241.4 at Winfield, Missouri, and ends at RM 202.9 at Alton, Illinois, a distance of 38.5 m. The study area encompasses about $5.32 \times 10^3$ hectares. Measured depths at sampling sites ranged from 0.1 to 12 m with a mean of 3.1 m. About 99% of the sites were unvegetated. Aquatic areas in Pool 26 included CBU, BWC, IMP, and SC.

### Macroinvertebrate Abundance and Distribution

Macroinvertebrate samples (*N*=124) in Pool 26 in 1992 produced a total of 199 mayflies, 184

fingernail clams, and 15 *Corbicula* sp., with 32% of the sites containing at least one of the target organisms. The highest mean density of mayflies was found in the SC aquatic area (53 $m^{-2}$), with BWC having the lowest mean density (1 $m^{-2}$; Fig. 2). The impounded aquatic area had the highest mean densities of fingernail clams (95 $m^{-2}$; Fig. 3).

The sand substrate was the most frequently sampled substrate in Pool 26. Sand was the predominant substrate at 44 of the 124 sampling sites (35%). Mean densities of 79 mayflies $m^{-2}$ were found in the sandy silt substrate (Fig. 4), and 109 fingernail clams $m^{-2}$ were found in silt/clay substrate (Fig. 5).

## *Open River*

### Site Features

The open river study area encompasses about 3.85 x $10^3$ hectares, from RM 85 to RM 0 at Cairo, Illinois. Measured depths at sampling sites ranged from 0.2 to 8.4 m with a mean of 2.6 m. None of the sampling sites were vegetated. Sampled aquatic areas in the open river included CBU and SC.

### Macroinvertebrate Abundance and Distribution

Macroinvertebrate samples (*N*=96) in the open river in 1992 produced a total of 158 mayflies, 43 fingernail clams, and 6 *Corbicula* sp., with 26% of the sites containing at least one of the target organisms. The highest mean density of mayflies was found in the SC aquatic area (46 $m^{-2}$), with CBU having the lowest mean density (18 $m^{-2}$; Fig. 2). The SC aquatic area had the highest mean densities of fingernail clams (14 $m^{-2}$; Fig. 3).

The sand substrate was the most frequently sampled substrate in the open river. Sand was the predominant substrate at 43 of the 96 sampling sites (45%). The highest mean densities of 173 mayflies $m^{-2}$ (Fig. 4) and 44 fingernail clams $m^{-2}$ were found in silt/clay substrate (Fig. 5).

## *La Grange*

### Site Features

La Grange Pool extends from RM 157.8 at Peoria, Illinois, to RM 80.2 at La Grange, Illinois, a distance of 77.6 m. The study area encompasses about 4.63 x $10^3$ hectares. Measured depths at sampling sites ranged from 0.3 to 4.5 m with a mean of 1.8 m. About 98% of the sites were unvegetated. Sampled aquatic areas in La Grange Pool included CBU, BWC, and SC.

### Macroinvertebrate Abundance and Distribution

Macroinvertebrate samples (*N*=125) in La Grange Pool in 1992 produced a total of 62 mayflies, 32 fingernail clams, and 3 *Corbicula* sp., with 26% of the sites containing at least one of the target organisms. The highest mean density of mayflies was found in the BWC aquatic area (13 $m^{-2}$), with CBU and SC having the lowest mean densities (8 $m^{-2}$; Fig. 2). The SC aquatic area had the highest mean densities of fingernail clams (10 $m^{-2}$; Fig. 3).

The silt/clay substrate was the most frequently sampled substrate in La Grange Pool. Of the 125 sampling sites, 73 (58%) had silt/clay as the predominant substrate. The largest mean densities of 39 mayflies $m^{-2}$ were found in the muck/organic substrate (Fig. 4), and 29 fingernail clams $m^{-2}$ were found in the hard clay substrate (Fig. 5).

# Summary

Macroinvertebrate samples ($N$=721) in 1992 produced a total of 1,782 mayflies, 1,119 fingernail clams, and 25 *Corbicula* sp., with 43.6% of the sampling sites containing at least one of the target organisms. Pool 13 had the highest number of samples with at least one mayfly or fingernail clam (68.8%). The open river reach (20.8%) and La Grange Pool (24.8%) had the lowest percentage of samples, with at least one mayfly or fingernail clam (Table 3). The exotic Asiatic clam (*Corbicula* sp.) was found in small numbers in Pool 4, 26, the open river reach, and La Grange Pool.

Mean densities of target organisms were weighted by strata to estimate pool/reach wide means (Schaeffer et al. 1979). The number of mayflies and fingernail clams captured by Ponar sampling differed significantly between reaches ($P$ <0.05; Table 4). Pool 13 had the highest mean number of mayflies (124 $m^{-2}$) and fingernail clams (90 $m^{-2}$). The lowest mean number of mayflies (10 $m^{-2}$) and fingernail clams (3 $m^{-2}$) were from La Grange Pool. *Corbicula* sp. were found in the greatest mean numbers in Pool 26 and the open river (1 $m^{-2}$), with Pools 4, 8, and 13 reporting zero (Table 4).

Visual classification of sediments indicated that sites in Pools 4, 8, and La Grange Pool were dominated by silt/clay. All aquatic areas except CBU and SC were dominated by silt/clay. Laboratory sediment analyses supported the findings of the subjective classifications. Moisture was predictably related to density ($y$=75.81-39.26x, $r^2$=0.95); therefore, it will not be discussed further. Bottom deposits had densities ranging from 0.30 to 1.74 g/mL and percent organic matter from 0.18 to 34.55. Sediments found in BWC, CFS, IMP, and Lake Pepin, Pool 4 (IMP-L) aquatic areas were dominated by low densities and relatively high percent organic matter.

Significant differences in densities of mayflies and fingernail clams were found among aquatic areas and substrate type within study reaches ($P$ <0.05). The highest mean densities of mayflies and fingernail clams were found in BWC, IMP, and SC aquatic areas (Figs. 2 and 3). Silt/clay substrates supported the highest mean densities of mayflies in all reaches except for Pool 26 and La Grange (Fig. 4). Silt/clay substrates also supported the highest densities of fingernail clams except for Pool 13 and La Grange (Fig. 5).

## *Laboratory Sorting*

Ten percent of the samples from each reach were randomly selected for a second laboratory sorting. A mean of 3.78 mayflies and 3.59 fingernail clams per quality control sample was found. Overall, organisms found in the laboratory samples were smaller than those picked in the field (mayflies=6.4 mm, laboratory, versus 24.2 mm, field; fingernail clams=2.7 mm, laboratory, versus 5.6 mm, field). The largest numbers of other benthic organisms found in the laboratory sorting were aquatic worms (Table 5).

# Discussion

Many spatial patterns on biological populations are contagious (Elliot 1977). This clumping or patchiness can cause low organism densities to be common in a random sampling approach while high organism densities are a rare event. This phenomenon was seen in 1992 LTRMP macroinvertebrate sampling (Figs. 6 and 7).

Aquatic areas and sediment type differed among the six study reaches (Tables 1 and 6). Greater densities of fingernail clams and mayflies were found in the impounded areas of the Upper Mississippi River. Gravel rock, hard clay, and sand supported relatively few mayflies and fingernail clams. Silt/clay, sandy silt, and muck/organic substrates are more well suited for burrowing organisms. These softer substrates tend to generally support greater benthic densities and diversity (Colbert et al. 1975; Johnson et al. 1974; Solomon et al. 1974).

Densities of fingernail clams in Pool 13 were over three times the densities of fingernail clams in the other study reaches. Pool 13 also had the highest numbers of mayflies, which in part could be attributed to the low percentage of sand found in the Pool 13 sampling areas. Other factors such as low river discharge or high amounts of un-ionized ammonia (Anderson et al. 1978) could be involved in the low numbers of organisms found in the La Grange Pool.

The data from this first year of macroinvertebrate sampling by the LTRMP will serve as a baseline for future years. Also, this first year of sampling will assist in making methodology changes for future years (i.e., sample size, site locations, and mesh size). Continued LTRMP macroinvertebrate sampling and integration with other LTRMP sampling (i.e., water quality sampling) may answer questions: (1) Can the low numbers of fingernail clams and mayflies be attributed to poor water quality? and (2) Are the low numbers due to loss of fingernail clam- and mayfly-preferred habitat?

## Acknowledgments

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**Table 1.** Numbers of randomly distributed macroinvertebrate samples by study reach and aquatic area. Numbers in parentheses are historical sites.

| | Aquatic area | | | | | |
|---|---|---|---|---|---|---|
| **Study reach** | **BWC** | **CBU** | **CFS** | **IMP** | **SC** | **Totals** |
| Pool 4 | 22 (3) | 25 | 27 | 24 (1)a | 24 | 122 (4) |
| Pool 8 | 23 (2) | 25 | 24 (1) | 14 (11) | 23 (2) | 109 (16) |
| Pool 13 | 23 (2) | 25 | 25 | 24 (1) | 21 (4) | 118 (7) |
| Pool 26 | 30 | 27 (4) | - | 31 | 29 (3) | 117 (7) |
| Open river | - | 46 (2) | - | - | 46 (2) | 92 (4) |
| La Grange | 26 (15) | 41 (1) | - | - | 38 (2) | 107 (18) |
| All reaches | 124 (22) | 189 (7) | 76 (1) | 93 (13) | 183 (13) | 665 (56) |

BWC = contiguous backwater (vegetated and unvegetated)
CBU = channel border unstructured
CFS = contiguous floodplain shallow
IMP = impounded (vegetated and unvegetated)
SC = side channel
[a]Pool 4 IMP = Lake Pepin

**Table 2.** Sampling dates for 1992 macroinvertebrate sampling

| **Study reach** | **Beginning date** | **Ending date** |
|---|---|---|
| Pool 4 | June 13, 1992 | June 30, 1992 |
| Pool 8 | June 15, 1992 | June 26, 1992 |
| Pool 13 | June 10, 1992 | June 23, 1992 |
| Pool 26 | June 2, 1992 | June 26, 1992 |
| Open river | June 1, 1992 | June 12, 1992 |
| La Grange | June 8, 1992 | June 24, 1992 |

**Table 3.** Percent of samples containing at least one species.

| Study reach (*N*) | Mayflies | Fingernail clams | *Corbicula* sp. | Mayflies or fingernail clams | All organisms |
|---|---|---|---|---|---|
| Pool 4 (126) | 48.4 | 34.1 | 0.8 | 56.3 | 57.1 |
| Pool 8 (125) | 40.8 | 20.0 | 0.0 | 46.4 | 46.4 |
| Pool 13 (125) | 58.4 | 52.8 | 0.0 | 68.8 | 68.8 |
| Pool 26 (124) | 22.6 | 16.1 | 4.8 | 31.5 | 32.3 |
| Open river (96) | 15.6 | 10.4 | 5.2 | 20.8 | 26.0 |
| La Grange (125) | 20.0 | 8.8 | 2.4 | 24.8 | 26.4 |

*N*=number of samples

**Table 4.** Mean number of mayflies, fingernail clams, and *Corbicula* sp. per square meter by study reach. Weighted by areas of strata.

| Study reach (*N*) | Mayflies (SE) | Fingernail clams (SE) | *Corbicula* sp. (SE) |
|---|---|---|---|
| Pool 4 (126) | 57 (±17.5) B | 48 (±17.8) B | 0 (±0.0) A |
| Pool 8 (125) | 85 (±22.9) B | 22 (±10.3) C | 0 (±0.0) A |
| Pool 13 (125) | 124 (±31.8) A | 90 (±29.1) A | 0 (±0.0) A |
| Pool 26 (124) | 29 (±15.4) C | 14 (±8.5) C | 1 (±1.0) A |
| Open river (96) | 21 (±11.5) C | 5 (±3.3) C | 1 (±0.6) A |
| La Grange (125) | 10 (±4.6) C | 3 (±1.9) C | 0.2 (±0.2) A |

*N*=number of samples

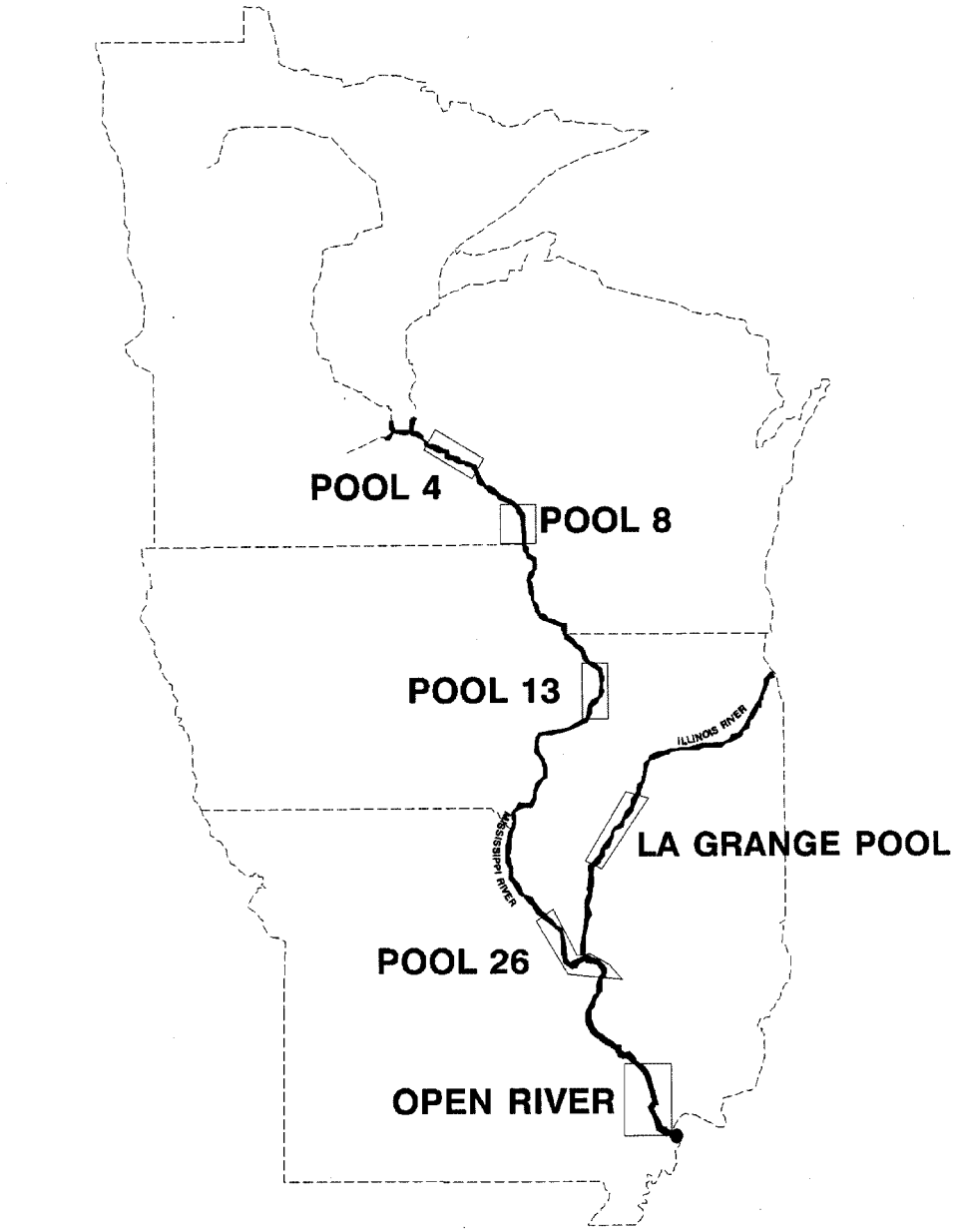
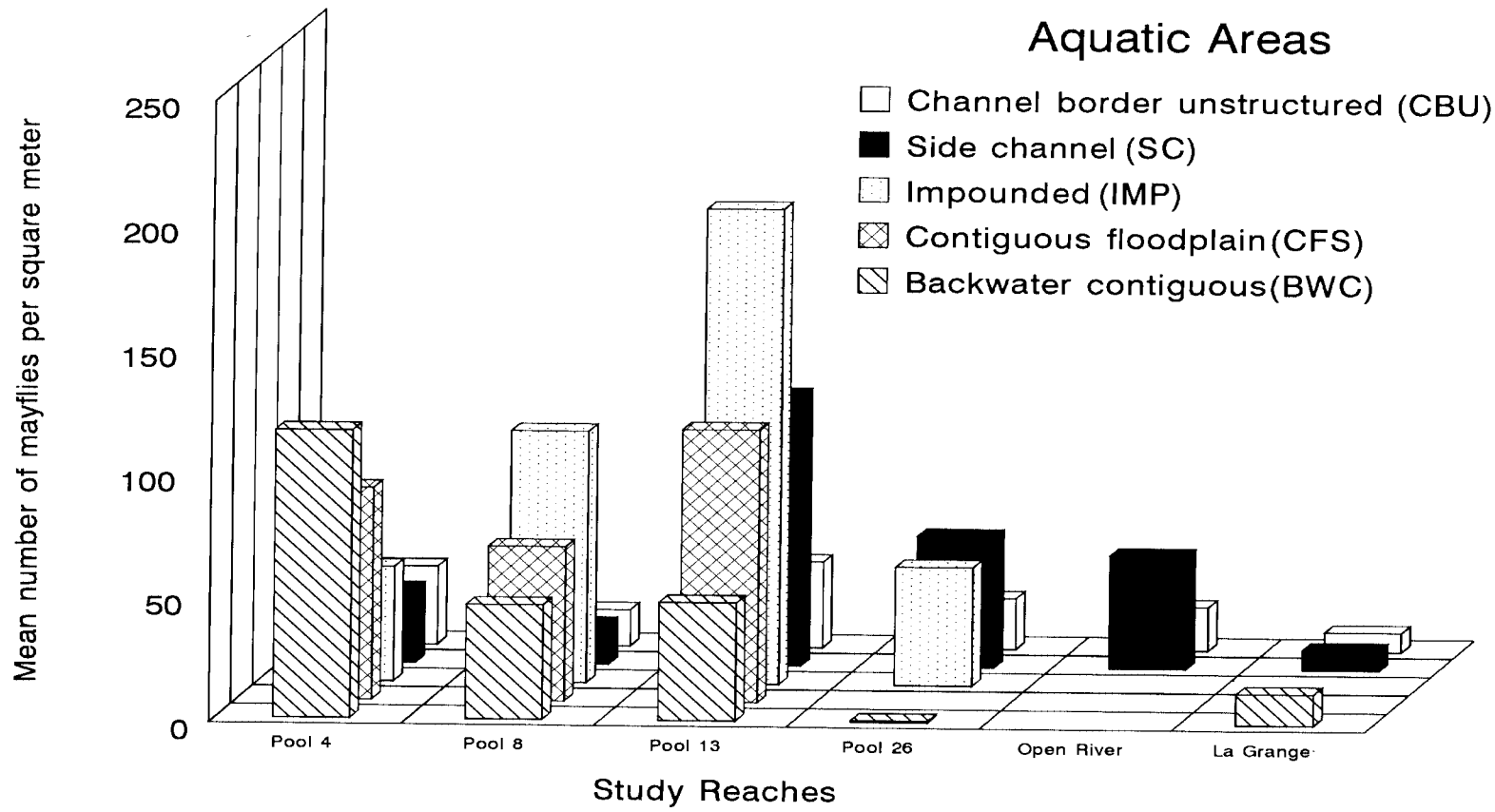
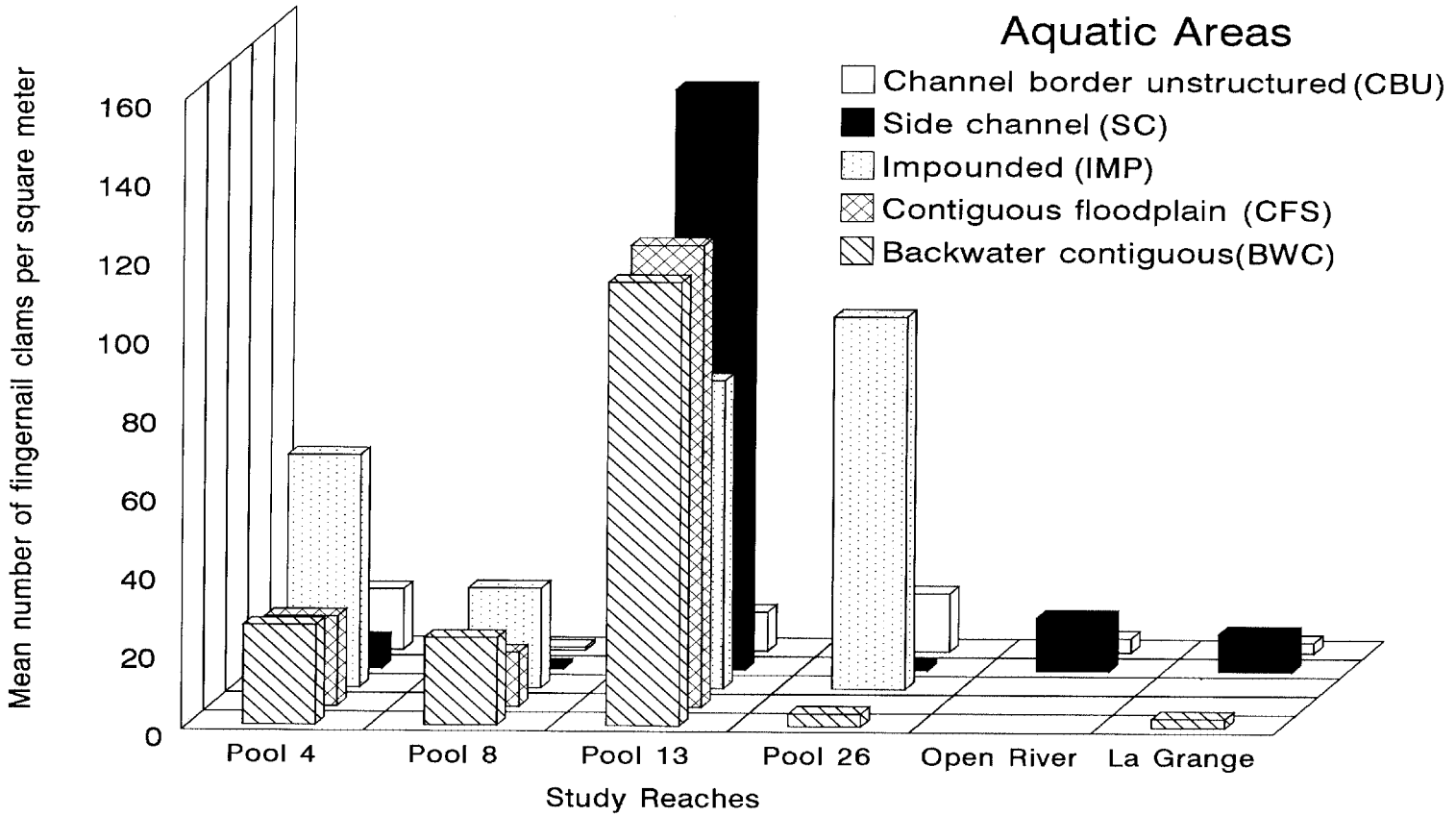



**Figure 1.** Long Term Resource Monitoring Program study reaches for macroinvertebrate sampling



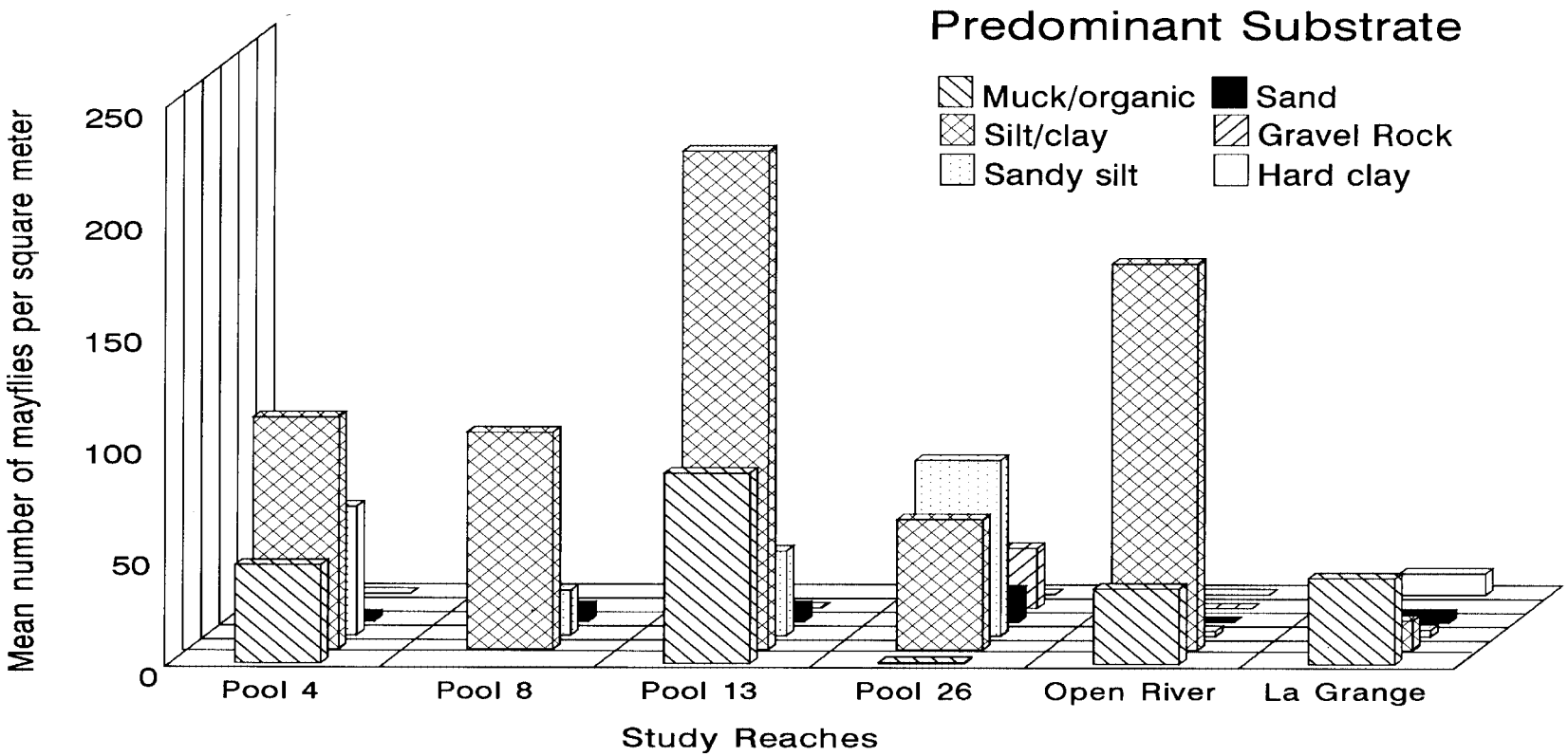

| | | | | | | |
|---|---|---|---|---|---|---|
| Channel border unstructured | 32 (±27.6) C | 15 (±6.3) C | 35 (±15.2) B | 20 (±8.3) A | 18 (±10.4) A | 8 (±4.0) A |
| Side channel | 30 (±10.7) CB | 16 (±8.1) C | 109 (±40.7) AB | 53 (±33.0) A | 46 (±19.5) A | 8 (±2.7) A |
| Impounded | 46 (±15.1) AB | 102 (±23.6) A | 192 (±44.0) A | 48 (±23.2) A | - | - |
| Contiguous floodplain | 85 (±22.0) A | 62 (±19.4) B | 110 (±25.6) A | - | - | - |
| Backwater contiguous | 116 (±35.9) A | 46 (±18.3) BC | 48 (±15.3) B | 1 (±0.6) B | - | 13 (±5.7) A |

**Figure 2.** Mean number of mayflies for study reaches (per square meter) by aquatic area



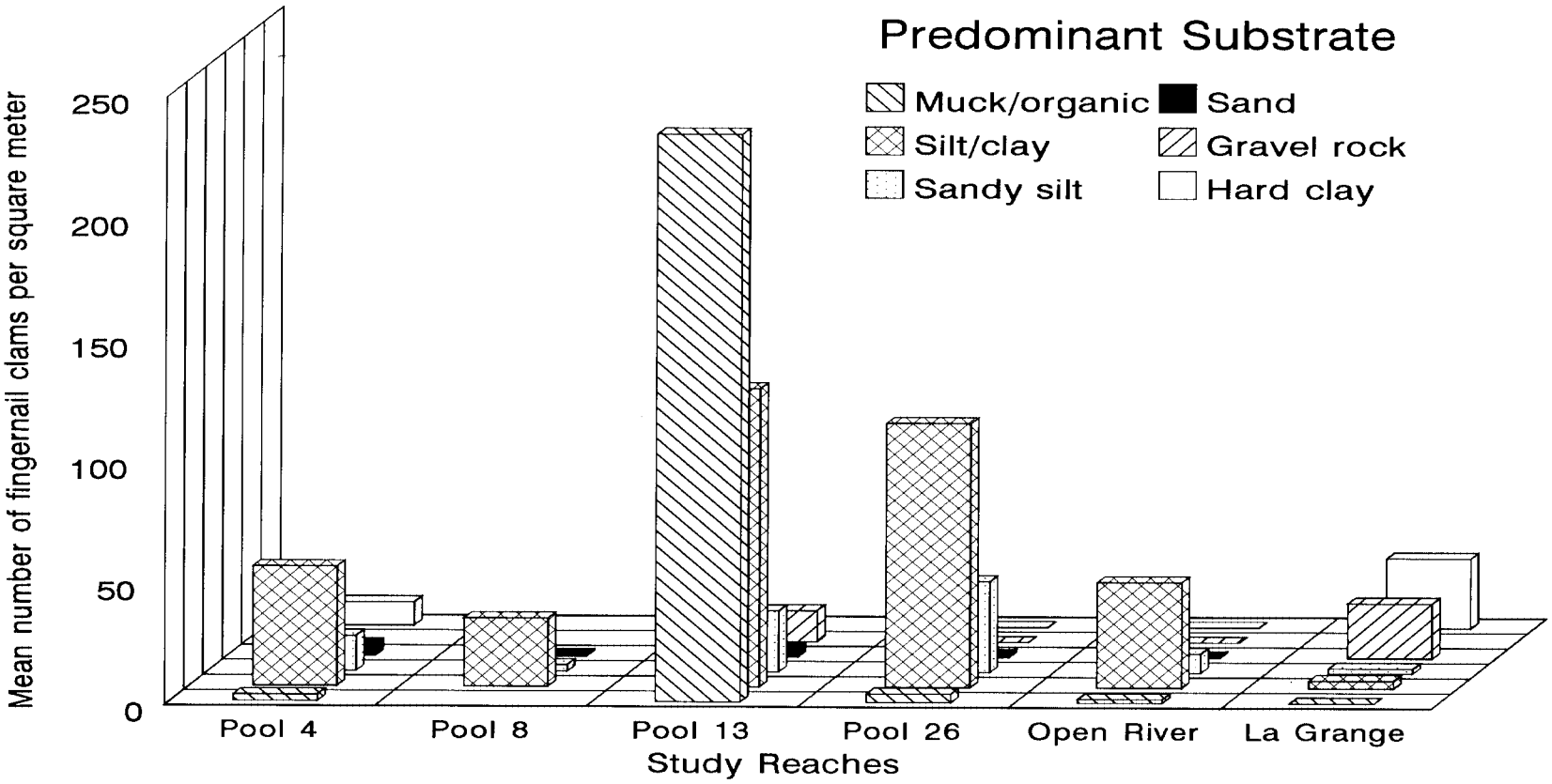

| | | | | | | |
|---|---|---|---|---|---|---|
| Channel border unstructured | 15 (±9.2) C | 1 (±0.8) B | 10 (±5.0) C | 15 (±10.5) B | 4 (±2.8) A | 3 ( 1.7) A |
| Side channel | 7 (±3.4) BC | 1 (±0.8) B | 148 (±63.0) AB | 1 (±0.8) B | 14 (±6.6) A | 10 ( 5.7) A |
| Impounded | 59 (±22.5) A | 25 (±10.2) A | 78 (±15.7) A | 95 (±39.1) A | - | - |
| Contiguous floodplain | 23 (±6.6) ABC | 14 (±6.8) A | 118 (±41.0) AB | - | - | - |
| Backwater contiguous | 25 (±8.7) AB | 22 (±14.8) A | 113 (±46.7) B | 3 (±2.1) B | - | 2 ( 1.7) A |

**Figure 3.** Mean number of fingernail clams for study reaches (per square meter) by aquatic area




| | Pool 4 | Pool 8 | Pool 13 | Pool 26 | Open River | La Grange |
|---|---|---|---|---|---|---|
| Hard clay | 0 (±0.0) B | - | - | 0 (±0.0) B | 0 (±0.0) B | 10 (±9.6) AB |
| Gravel Rock | - | - | 0 (±0.0) D | 27 (±26.9) AB | 0 (±0.0) B | - |
| Sand | 3 (±1.2) B | 7 (±2.9) B | 7 (±4.9) CD | 14 (±5.7) AB | 0 (±0.0) B | 4 (±3.5) B |
| Sandy silt | 58 (±14.8) A | 20 (±6.4) B | 38 (±10.1) BC | 79 (±49.6) A | 2 (±1.5) B | 3 (±1.7) B |
| Silt/clay | 104 (±19.9) A | 97 (±16.0) A | 223 (±35.2) A | 58 (±29.7) AB | 173 (±58.2) A | 13 (±4.0) B |
| Muck/organic | 44 (±35.3) AB | - | 85 (±24.9) B | 1 (±4.0) AB | 34 (±17.4) B | 39 A |

**Figure 4.** Mean number of mayflies for study reaches (per square meter) by predominant substrate type




| | Pool 4 | Pool 8 | Pool 13 | Pool 26 | Open River | La Grange |
|---|---|---|---|---|---|---|
| Hard clay | 10 (±9.6) A | - | - | 0 (±0.0) B | 0 (±0.0)B | 29 (±28.8) A |
| Gravel rock | - | - | 13 (±12.8) B | 0 (±0.0) B | 0 (±0.0)B | - |
| Sand | 5 (±2.2) A | 1 (±0.5) B | 3 (±1.8) B | 1 (±0.6) B | 0.5 (±0.0)B | 23 (±20.9) AB |
| Sandy silt | 14 (±9.4) A | 3 (±1.2) B | 25 (±7.0) B | 38 (±18.2) AB | 8 (±7.9)B | 2 (±1.6)B |
| Silt/clay | 49 (±11.1) A | 28 (±8.9) A | 123 (±36.6) A | 109 (±49.6) A | 44 (±19.4) A | 3 (±1.3)B |
| Muck/organic | 3 (±2.7) A | - | 234 (±61.7) A | 4 (±2.3) B | 2 (±1.6)B | 0 (±0.0)B |

**Figure 5.** Mean number of fingernail clams for study reaches (per square meter) for predominant substrate type

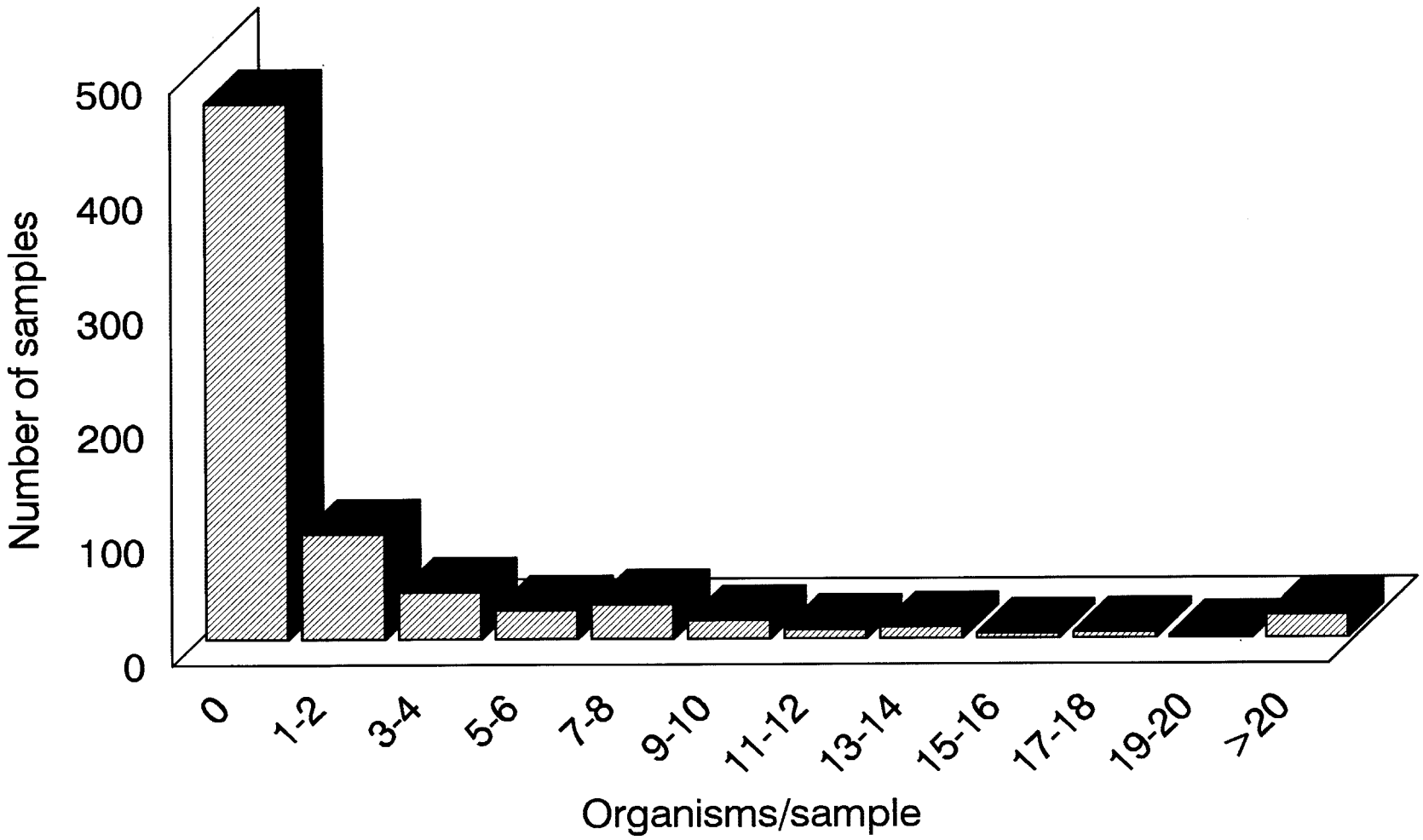



**Figure 6.** Frequency of mayflies in Ponar samples

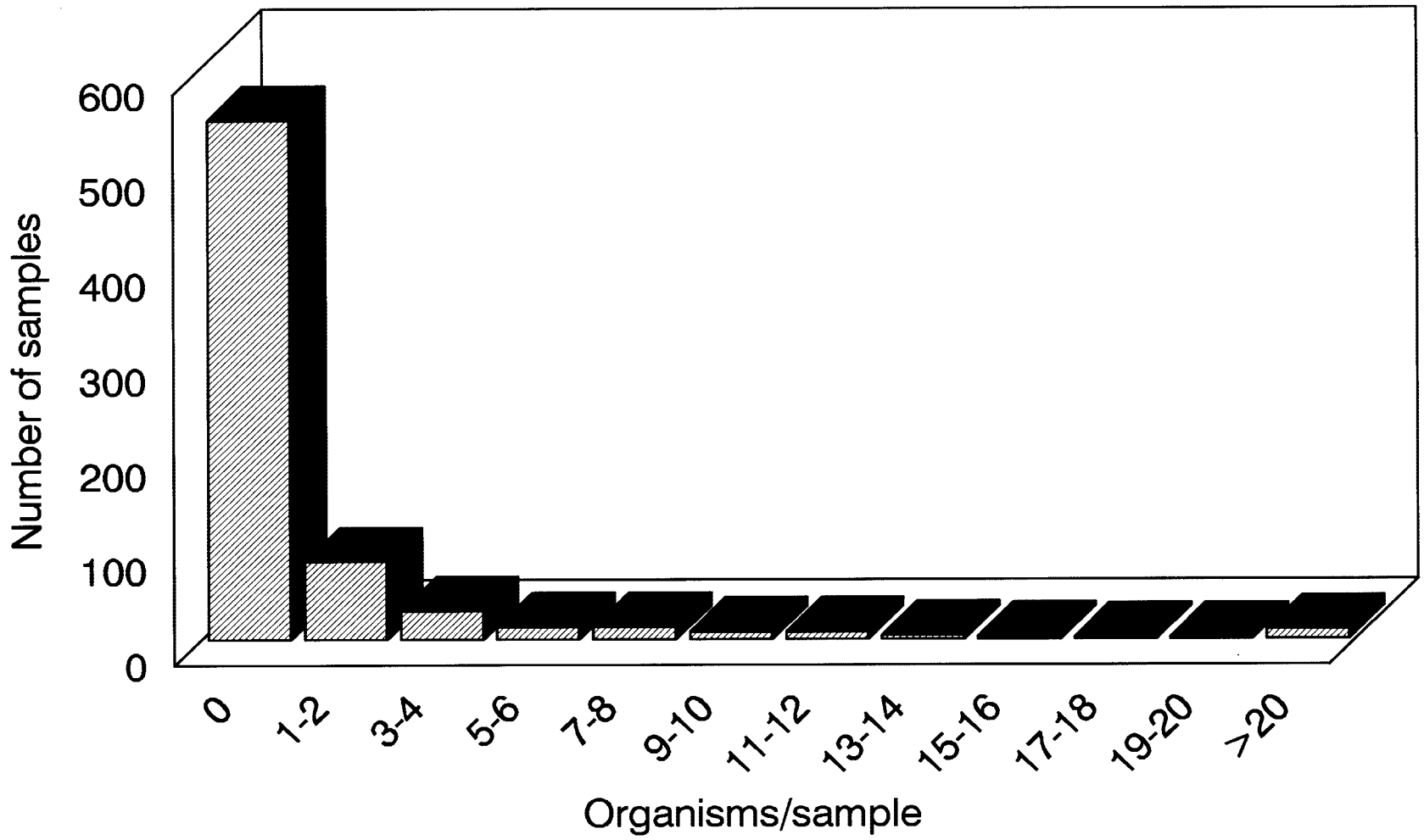



**Figure 7.** Frequency of fingernail clams in Ponar samples

# Appendix A

## *References for locations of historical sites*


*Pool 4*

Fremling, C. R., D. V. Gray, and D. N. Nielson. 1973. Environmental Impact Assessment Study, Pool 4 of the Northern Section of the Upper Mississippi River. U.S. Army Corps of Engineers, St. Paul District.

*Pool 8*

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Brewer, S. 1992. Community structure of benthic macroinvertebrates in Navigation Pool No. 8, Upper Mississippi River: Comparisons between 1975 and 1990. M.S. Thesis, University of Wisconsin-La Crosse, La Crosse, Wisconsin. 47 pp.

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*La Grange*

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Anderson, K. B. 1977. Musculium transversum in the Illinois River and an acute bioassay method for the species. M.S. Thesis, Western Illinois University. 79 pp.

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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 to maintain the Upper Mississippi River System as a sustainable large river ecosystem given its multiple-use character. The LTRMP is a cooperative effort by the National Biological Service, the U.S. Army Corps of Engineers, and the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin.