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Annual Status Report, 1998: Macroinvertebrate Sampling



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Annual Status Report, 1998: Macroinvertebrate Sampling

by

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July 1999

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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 (formerly 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 document is an annual summary for 1998, containing a synthesis of target macroinvertebrate populations in the UMRS. This report satisfies, for 1998, Task 2.2.7.4, *Evaluate and Summarize Annual Results* under Goal 2, *Monitor Resource Change*, as specified in the Operating Plan for the LTRMP (U.S. Fish and Wildlife Service 1993). This report was developed with funding provided by the LTRMP.

Annual Status Report, 1998: Macroinvertebrate Sampling

by

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Abstract. In 1992, macroinvertebrate sampling was initiated in Pools 4, 8, 13, 26, 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. Long-term monitoring is needed to detect population trends and local changes in aquatic ecosystems. Mayflies (Ephemeroptera), fingernail clams (Sphaeriidae), and the exotic *Corbicula* species were selected for monitoring. Midges (Chironomidae) were added to the sampling design in 1993 and zebra mussels (*Dreissena polymorpha*) were added in 1995. Mayflies, fingernail clams, and midges, 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 taxa were weighted by strata for extrapolation purposes. Pool 4 reported the highest estimated mean densities of mayflies and midges (208.9 and 253.0 m⁻², respectively). Pool 13 had the highest estimated mean number of fingernail clams (150.1 m⁻²). Overall, the impounded areas, including Lake Pepin, and the contiguous backwaters tended to support the highest densities of mayflies, fingernail clams, and midges. Substrates with predominantly a silt clay constituent supported the highest mean densities of mayflies, fingernail clams, and midges. The presence or absence of Amphipoda, Bivalvia, Decapoda, Diptera, Gastropoda, Odonata, Oligochaeta, Plecoptera, and Trichoptera was also recorded.

Key words: Benthic aquatic macroinvertebrates, *Corbicula*, fingernail clams (Sphaeriidae), mayflies (Ephemeroptera), midges (Chironomidae), Mississippi River, zebra mussels (*Dreissena polymorpha*)

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 a nationally significant ecosystem and a nationally significant navigation system. In 1992, macroinvertebrate sampling was initiated in Pools 4, 8, 13, 26, 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 (Ephemeroptera), fingernail clams (Sphaeriidae), and the exotic *Corbicula* species were selected for monitoring. Midges (Chironomidae) were added to the sampling design in 1993 and zebra mussels (*Dreissena polymorpha*) in 1995. These taxa, found in the soft-sediment substrate, were chosen because they play an important ecological role in the UMRS. The exotic *Corbicula* species and zebra mussels were chosen for sampling because of possible detrimental effects they may have on the economy and biology of the UMRS (Sauer 1996).

The objective of the LTRMP macroinvertebrate component is to annually monitor and report trends in the status and distribution of select macroinvertebrate populations. The publicly available data and annual status reports are the most basic LTRMP products. These annual status reports provide more detailed summaries of macroinvertebrate data than are included in trend reports (Sauer 1998). 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 studies will integrate more narrowly focused analyses of data from all LTRMP monitoring components (limnology,

bathymetry, sediments, aquatic plants, and fisheries) with results of experimental studies to identify causes of problems and opportunities for improved management. The resulting syntheses will be the ultimate products of the LTRMP.

Methods

Sampling Procedures

The sampling of mayflies, fingernail clams, midges, *Corbicula* sp., and zebra mussels was conducted during 1998 in Pools 4, 8, 13, 26, the Open River reach of the Mississippi River, and La Grange Pool of the Illinois River (Figure 1). The presence or absence of Amphipoda, Bivalvia, Decapoda, Diptera, Gastropoda, Odonata, Oligochaeta, Plecoptera, and Trichoptera was also recorded.

Sampling was conducted at about 125 sites per study reach per year (Table 1; Figures 2–7). Sample allocation was based on several criteria: surface area of the aquatic area in each study reach, field station input on accessibility, and the productivity of the taxa in each aquatic area. All sites were sampled in spring 1998 (Table 2).

Sites included locations where benthic samples were collected historically and randomly selected sites distributed among key aquatic areas, which are based on enduring geomorphic features (Wilcox 1993): contiguous backwaters (BWC), areas that have 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), large, mostly open-water areas located in the downstream portion of the navigational pools; and side channels (SC), channels that carry less flow than the navigational channel. For Pool 4, the IMP is in the form of Lake Pepin, a tributary delta lake formed by the Chippewa River. For the present report, only randomly selected sites are discussed.

The LTRMP developed a spatial database of aquatic areas (Owens and Ruhser 1996) on the basis of aerial photography made in 1989; this database is used for randomized selection of sampling sites and the quantification of sampling strata reported herein. Ongoing change detection requires that this database be updated at appropriate intervals. The LTRMP Operating Plan (U.S. Fish and Wildlife Service 1993) prescribes future repetition of aerial photography. Additionally, the LTRMP updates sampling maps, as needed, from direct observations made by the sampling crews.

Macroinvertebrate sampling procedures are described in detail in the LTRMP Procedures Manual (Thiel and Sauer 1995). Benthic samples were collected with a winch-mounted 23- × 23-cm (0.052-m²) standard Ponar grab sampler (Ponar Grab Dredge, Wildlife Supply Company, Saginaw, Michigan). The sieve size of the Ponar wash frame was U.S. Standard No. 16 (1.18 mm). Thus, inferences in macroinvertebrate numbers made from the data for this report are restricted to the larger taxa of the population whole (i.e., adults). Mayflies, fingernail clams, midges (greater than 1 cm), *Corbicula* sp., and zebra mussels were counted and picked in the field.

Site Information

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 percentage of submersed and floating-leaved 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. Water depth was also measured at each site.

Statistical Analyses

Total catch is recorded for each target taxa from individual Ponar samples. Whenever a species is not collected in a sample, the catch for that species in that sample is zero.

The areawide estimated mean number of taxa in the present report are based on estimates of mean densities obtained by pooling data over all strata selected for macroinvertebrate sampling (Sauer 1998). In this way, the analyses track the broadest possible spatial scale in relative densities. The pooling probably presents a truer image of areawide trends in true densities because it does not rely only on particularly favorable habitats. If the quantity of preferred habitats declines through time while densities in those preferred habitats remains constant, then these pooled mean density statistics should also reflect that decline, whereas mean density statistics from only the preferred habitats would not. The LTRMP monitors both the composition of aquatic areas and macroinvertebrates. Therefore, if the quantity of that aquatic area class preferred by a particular species declines through time while the abundances within each aquatic area remain constant, then the pooled mean density 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 mean densities 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 densities), the pooled mean, denoted \bar{y}_{st} (st for stratified) is given by

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

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

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

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 $s(\bar{y}_{st})$. Equation (1) is used to obtain estimates of overall mean densities for stratified random sampling. In random samples, equation (1) yields unbiased estimates of the pooled means regardless of the probability distribution of y (Cochran 1977). For LTRMP macroinvertebrate monitoring, the sampling units are the 50-m² sampling grids.

Summary

- Measured depths at sampling sites ranged from 0.3 to 18.5 m with a mean of 3.3 m.
- In all study reaches, more than 80% of the Ponar grabs contained no submersed or floating-leaved vegetation (Table 3). The majority of samples taken in all reaches were in open water surrounded by little vegetation (Tables 4–7). The lack of vegetation at sites cannot be correlated with macroinvertebrate absence or presence because samples are taken in early spring before visible vegetation growth occurs.
- Macroinvertebrate samples ($N = 627$) in 1998 produced a total of 3,021 mayflies, 1,491 fingernail clams, 2,479 midges, 15 *Corbicula* sp., and 1,746 zebra mussels.
- Mean densities of target taxa were weighted by strata selected for macroinvertebrate sampling (Sauer 1998) to estimate poolwide or reachwide means (Table 8; Figures 8–10). Pool 4 had the highest estimated mean numbers of mayflies and midges. Pool 13 had the highest densities of fingernail clams. All study areas showed an increase in the estimated mean number of mayflies between 1997 and 1998. Positive increases in fingernail clam densities were seen in Pools 8, 13, 26, and La Grange Pool. Increases in midge densities were seen in Pools 4, 8, and 13.
- Low numbers of *Corbicula* species were reported for all study reaches. Zebra mussel densities were highest in Pools 4 and 13 with some samples containing more than 250 individual zebra mussels.
- Visual classification of sediments indicated that sample sites in Pools 4, 8, 13, 26, and La Grange Pool were dominated by silt clay (Table 9). Sample sites in the Open River study area were dominated by sand.
- The BWC and IMP aquatic areas supported the highest mean numbers of mayflies in all study areas except the Open River reach (Table 10).
- Mean densities of fingernail clams were greatest in Lake Pepin (Pool 4) and the IMP area of Pools 8, 13, and 26. The greatest densities of fingernail clams in La Grange Pool were found in the SC aquatic areas (Table 11).
- The BWC areas had the highest densities of midges in all study areas except Pool 4, Lake Pepin (Table 12).
- The MCB areas had the highest densities of zebra mussels in Pools 4, 8, 13, and the Open River. The IMP area had the highest densities in Pool 26, and the SC areas had the highest densities in La Grange Pool (Table 13).
- The silt clay substrate supported the highest mean numbers of mayflies in the study areas (Table 14), followed closely by silt clay with sand. Not surprisingly, the highest densities of zebra mussels were found on the sand and gravel rock substrates.
- Oligochaeta (aquatic worms and leeches) and Sphaeriidae (fingernail clams) were the only taxa that were present more times than they were absent; 52.7% of the samples contained Oligochaeta and 50.4% contained fingernail clams (Figure 11).

Acknowledgments

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Table 1. Macroinvertebrate random sample sites by study reach and aquatic area. Numbers in parentheses are historical (fixed) sites.

Study reach	Contiguous backwater	Impounded	Side channel	Main channel border
Pool 4	55 (3)	44 (1) ^a	10	11
Pool 8	34 (3)	49 (11)	19 (2)	10
Pool 13	43 (2)	46 (1)	14 (4)	15
Pool 26	12	28	30 (3)	15 (4)
Open River	—	—	66 (16)	44 (2)
La Grange Pool	24 (18)	—	35 (7)	40 (1)

^aPool 4 Impounded = Lake Pepin, Tributary Delta Lake.

Table 2. Sampling dates for 1998 macroinvertebrate sampling.

Study reach	Beginning date	Ending date
Pool 4	May 4	May 13
Pool 8	April 30	May 11
Pool 13	May 11	May 20
Pool 26	May 18	May 27
Open River	May 26	June 3
La Grange Pool	May 4	May 18

Table 3. Number of sites, reported as percentages, with submersed and floating-leaved vegetation in the column of water and sediment that the Ponar fell through. *N* = number of samples.

Study reach (<i>N</i>)	Vegetation present				
	0%	1%–20%	21%–50%	51%–90%	91%–100%
Pool 4 (121)	87.6	8.3	3.3	—	0.8
Pool 8 (109)	85.3	9.2	2.8	1.8	0.9
Pool 13 (118)	89.0	10.2	—	—	0.8
Pool 26 (72)	93.0	7.0	—	—	—
Open River (108)	96.3	3.7	—	—	—
La Grange Pool (99)	100.0	—	—	—	—

Table 4. Number of sites, reported as percentages, with submersed vegetation within a 15-m radius from the boat. *N* = number of samples.

Study reach (<i>N</i>)	Vegetation present				
	0%	1%–20%	21%–50%	51%–90%	91%–100%
Pool 4 (121)	84.3	7.4	4.1	4.1	—
Pool 8 (109)	83.5	11.0	2.8	2.8	—
Pool 13 (118)	84.7	11.9	2.5	0.8	—
Pool 26 (72)	100.0	—	—	—	—
Open River (108)	100.0	—	—	—	—
La Grange Pool (99)	100.0	—	—	—	—

Table 5. Number of sites, reported as percentages, with floating-leaved vegetation within a 15-m radius from the boat. *N* = number of samples.

Study reach (<i>N</i>)	Vegetation present				
	0%	1%–20%	21%–50%	51%–90%	91%–100%
Pool 4 (121)	93.4	1.7	2.5	2.5	—
Pool 8 (109)	95.4	3.7	0.9	—	—
Pool 13 (118)	88.1	10.2	1.7	—	—
Pool 26 (72)	91.7	8.3	—	—	—
Open River (108)	100.0	—	—	—	—
La Grange Pool (99)	100.0	—	—	—	—

Table 6. Number of sites, reported as percentages, with emergent vegetation within a 15-m radius from the boat. *N* = number of samples.

Study reach (<i>N</i>)	Vegetation present				
	0%	1%–20%	21%–50%	51%–90%	91%–100%
Pool 4 (121)	85.1	11.6	2.5	0.8	—
Pool 8 (109)	100.0	—	—	—	—
Pool 13 (118)	98.3	0.8	0.8	—	—
Pool 26 (72)	100.0	—	—	—	—
Open River (108)	100.0	—	—	—	—
La Grange Pool (99)	100.0	—	—	—	—

Table 7. Number of sites, reported as percentages, with open water within a 15-m radius from the boat. *N* = number of samples.

Study reach (<i>N</i>)	Open water present				
	0%	1%–20%	21%–50%	51%–90%	91%–100%
Pool 4 (121)	—	—	—	6.6	93.4
Pool 8 (109)	1.8	0.9	4.6	—	92.7
Pool 13 (118)	—	0.8	0.8	2.5	95.8
Pool 26 (72)	—	—	—	—	100.0
Open River (108)	—	—	—	0.9	99.1
La Grange Pool (99)	—	—	—	—	100.0

Table 8. Reachwide estimated mean number of mayflies, fingernail clams, midges, *Corbicula* sp., and zebra mussels per square meter by year and study area, weighted by areas of strata. Numbers in parentheses are ± 1 standard error. *N* = number of samples.

Study area and year (<i>N</i>)	Mayflies (m ²)	Fingernail clams (m ²)	Midges (m ²)	<i>Corbicula</i> sp. (m ²)	Zebra mussels (m ²)
Pool 4					
1992 (122)	59.1 (± 18.2)	47.0 (± 18.5)	—	0.0 (± 0.03)	—
1993 (121)	128.1 (± 36.2)	73.8 (± 10.8)	317.5 (± 39.0)	0.0 (± 0.0)	—
1994 (126)	203.1 (± 50.0)	88.2 (± 12.2)	184.6 (± 32.5)	0.0 (± 0.1)	—
1995 (120)	178.4 (± 35.9)	60.9 (± 13.3)	81.5 (± 13.9)	0.0 (± 0.0)	26.6 (± 26.6)
1996 (121)	131.9 (± 33.9)	39.4 (± 7.3)	37.7 (± 11.5)	0.0 (± 0.0)	115.8 (± 113.3)
1997 (120)	69.1 (± 20.7)	75.5 (± 8.7)	151.9 (± 35.0)	0.0 (± 0.0)	30.8 (± 27.5)
1998 (121)	208.9 (± 43.5)	72.6 (± 10.1)	253.0 (± 39.8)	0.0 (± 0.0)	107.1 (± 97.7)
Pool 8					
1992 (109)	50.9 (± 24.6)	15.3 (± 11.4)	—	0.0 (± 0.0)	—
1993 (109)	117.8 (± 40.9)	22.2 (± 11.0)	50 (± 9.4)	0.0 (± 0.0)	—
1994 (110)	90.7 (± 30.9)	11.4 (± 5.0)	27 (± 15.8)	0.0 (± 0.0)	—
1995 (109)	55.9 (± 14.2)	6.4 (± 3.0)	11 (± 3.9)	0.0 (± 0.0)	0.2 (± 0.2)
1996 (109)	38.3 (± 11.2)	2.2 (± 0.9)	15 (± 4.1)	0.0 (± 0.0)	0.6 (± 0.4)
1997 (112)	71.0 (± 16.4)	8.5 (± 3.6)	26 (± 6.3)	0.0 (± 0.0)	24.5 (± 11.1)
1998 (109)	119.8 (± 35.6)	26.5 (± 8.4)	82.2 (± 18.5)	0.0 (± 0.0)	25.7 (± 16.7)
Pool 13					
1992 (118)	120.3 (± 30.5)	84.0 (± 27.6)	—	0.0 (± 0.0)	—
1993 (119)	154.5 (± 39.3)	2,596.3 (± 494.3)	509.3 (± 94.8)	0.2 (± 0.2)	—
1994 (125)	193.9 (± 35.8)	593.7 (± 156.5)	74.5 (± 34.1)	0.0 (± 0.0)	—
1995 (118)	181.6 (± 51.7)	276.3 (± 81.9)	39.8 (± 9.4)	0.0 (± 0.0)	10.1 (± 6.8)
1996 (118)	146.6 (± 38.0)	231.4 (± 58.2)	21.2 (± 7.0)	0.0 (± 0.0)	14.0 (± 8.2)
1997 (118)	165.0 (± 42.5)	87.4 (± 23.1)	79.0 (± 36.0)	0.0 (± 0.0)	562.2 (± 448.3)
1998 (118)	167.4 (± 45.1)	150.1 (± 33.5)	79.5 (± 27.5)	0.0 (± 0.0)	120.1 (± 92.8)
Pool 26					
1992 (117)	20.9 (± 9.5)	15.2 (± 9.4)	—	1.6 (± 1.1)	—
1993 (66)	7.0 (± 1.9)	1.3 (± 0.5)	10.4 (± 2.1)	0.0 (± 0.0)	—
1994 (124)	20.9 (± 6.3)	4.8 (± 2.9)	14.3 (± 7.7)	0.7 (± 0.7)	—
1995 (69)*	—	—	—	—	—
1996 (112)	13.0 (± 10.4)	0.2 (± 0.1)	18.2 (± 8.5)	0.0 (± 0.0)	0.3 (± 0.3)
1997 (85)	15.8 (± 7.9)	1.0 (± 0.7)	13.3 (± 6.1)	0.0 (± 0.0)	1.3 (± 1.2)
1998 (72)	25.2 (± 16.1)	3.7 (± 3.7)	4.6 (± 2.2)	4.2 (± 3.0)	28.7 (± 23.8)

Table 8. Continued.

Study area and year (N)	Mayflies (m ⁻²)	Fingernail clams (m ⁻²)	Midges (m ⁻²)	Corbicula sp. (m ⁻²)	Zebra mussels (m ⁻²)
Open River					
1992 (92)	22.0 (±12.0)	5.0 (±3.4)	—	0.9 (±0.6)	—
1993 ^b	—	—	—	—	—
1994 (84)	19.2 (±8.6)	0.5 (±0.5)	7.7 (±3.6)	1.7 (±1.2)	—
1995 (112)	11.7 (±5.5)	0.0 (±0.0)	13.9 (±5.0)	1.4 (±1.1)	2.4 (±2.0)
1996 (107)	10.9 (±6.1)	0.0 (±0.0)	5.0 (±2.4)	1.2 (±0.8)	0.3 (±0.2)
1997 ^b	—	—	—	—	—
1998 (108)	11.6 (±8.6)	0.0 (±0.0)	3.8 (±2.4)	0.9 (±0.6)	19.9 (±16.8)
La Grange Pool					
1992 (102)	13.0 (±6.3)	3.7 (±2.4)	—	0.4 (±0.4)	—
1993 (98)	10.7 (±4.8)	17.4 (±9.5)	52.0 (±14.3)	0.0 (±0.0)	—
1994 (126)	26.6 (±8.5)	50.5 (±12.5)	57.0 (±9.9)	10.1 (±2.9)	—
1995 (98)	5.7 (±3.5)	15.2 (±8.2)	31.7 (±12.1)	1.4 (±0.7)	9.3 (±9.3)
1996 (98)	3.6 (±1.5)	4.7 (±2.7)	150.0 (±49.7)	1.2 (±0.7)	0.4 (±0.4)
1997 (99)	7.7 (±3.3)	9.3 (±4.8)	100.8 (±33.0)	0.0 (±0.03)	0.0 (±0.0)
1998 (99)	8.6 (±5.6)	20.5 (±11.7)	91.3 (±25.1)	0.6 (±0.6)	2.5 (±1.2)

^aSampling not completed because of high water.

^bNot sampled because of flooding.

Table 9. Percentage of predominant substrate type found in Ponar grab samples by study reach. N = number of samples.

Study reach (N)	Predominant substrate (%)					
	Hard clay	Silt clay	Silt clay with sand	Sand with silt clay	Sand	Gravel rock
Pool 4 (121)	1.7	51.2	15.7	6.6	19.8	5.0
Pool 8 (109)	2.8	35.8	20.2	18.3	22.9	—
Pool 13 (118)	1.7	36.4	28.0	12.7	19.5	1.7
Pool 26 (72)	4.2	30.6	4.2	12.5	37.5	11.1
Open River (108)	2.8	9.3	3.7	4.6	50.9	28.7
La Grange Pool (99)	17.2	28.3	21.2	9.1	23.2	1.0

Table 10. Mean number of mayflies per square meter by study reach and aquatic area. *N* = number of samples.

Study reach (<i>N</i>)	Aquatic areas			
	BWC ^a (±1 SE)	MCB ^b (±1 SE)	IMP ^c (±1 SE)	SC ^d (±1 SE)
Pool 4 (121)	145.4 (±26.1)	181.6 (±179.2)	242.1 (±42.9) ^e	1.7 (±1.7)
Pool 8 (109)	111.3 (±32.2)	7.7 (±7.7)	146.1 (±33.5)	115.4 (±58.3)
Pool 13 (118)	219.1 (±47.7)	19.2 (±12.7)	181.4 (±41.3)	140.1 (±91.6)
Pool 26 (72)	73.7 (±49.2)	18.1 (±10.1)	38.5 (±22.6)	26.1 (±19.4)
Open River (108)	—	11.2 (±8.4)	—	15.1 (±10.1)
La Grange Pool (99)	12.0 (±6.8)	7.0 (±5.2)	—	8.5 (±4.1)

^aBWC = contiguous backwater.

^bMCB = main channel border.

^cIMP = impounded.

^dSC = side channel.

^ePool 4 IMP = Lake Pepin, tributary delta lake.

Table 11. Mean number of fingernail clams per square meter by study reach and aquatic area. *N* = number of samples.

Study reach (<i>N</i>)	Aquatic areas			
	BWC ^a (±1 SE)	MCB ^b (±1 SE)	IMP ^c (±1 SE)	SC ^d (±1 SE)
Pool 4 (121)	24.0 (±6.5)	8.5 (±8.5)	94.0 (±11.8) ^e	0.0 (±0.0)
Pool 8 (109)	22.7 (±6.3)	13.5 (±13.5)	34.0 (±7.9)	18.2 (±10.4)
Pool 13 (118)	177.5 (±44.8)	34.6 (±26.2)	194.4 (±30.2)	37.1 (±21.5)
Pool 26 (72)	3.2 (±3.2)	4.5 (±4.5)	11.2 (±9.6)	1.2 (±1.2)
Open River (108)	—	0.0 (±0.0)	—	0.0 (±0.0)
La Grange (99)	8.0 (±3.5)	25.3 (±15.6)	—	33.9 (±10.4)

^aBWC = contiguous backwater.

^bMCB = main channel border.

^cIMP = impounded.

^dSC = side channel.

^ePool 4 IMP = Lake Pepin, tributary delta lake.

Table 12. Mean number of midges per square meter by study reach and aquatic area. *N* = number of samples.

Study reach (<i>N</i>)	Aquatic areas			
	BWC ^a (±1 SE)	MCB ^b (±1 SE)	IMP ^c (±1 SE)	SC ^d (±1 SE)
Pool 4 (121)	95.8 (±11.7)	2.1 (±2.1)	324.3 (±51.0) ^e	24.5 (±1.9)
Pool 8 (109)	99.7 (±17.6)	32.7 (±14.9)	81.8 (±11.3)	83.3 (±39.6)
Pool 13 (118)	148.0 (±36.7)	33.3 (±22.4)	61.5 (±28.6)	2.7 (±1.9)
Pool 26 (72)	33.7 (±11.4)	1.1 (±1.1)	30.4 (±12.2)	1.2 (±0.9)
Open River (108)	—	3.6 (±2.4)	—	5.5 (±1.9)
La Grange Pool (99)	244.4 (±68.2)	25.3 (±6.2)	—	21.5 (±8.8)

^aBWC = contiguous backwater.

^bMCB = main channel border.

^cIMP = impounded.

^dSC = side channel.

^ePool 4 IMP = Lake Pepin, tributary delta lake.

Table 13. Mean number of zebra mussels per square meter by study reach and aquatic area. *N* = number of samples.

Study reach (<i>N</i>)	Aquatic areas			
	BWC ^a (±1 SE)	MCB ^b (±1 SE)	IMP ^c (±1 SE)	SC ^d (±1 SE)
Pool 4 (121)	1.3 (±0.8)	609.0 (±396.1)	109.7 (±109.7) ^e	19.2 (±17.4)
Pool 8 (109)	0.6 (±0.6)	55.8 (±39.4)	42.6 (±28.8)	1.1 (±1.1)
Pool 13 (118)	25.0 (±24.6)	202.6 (±148.4)	156.8 (110.6)	158.0 (±158.0)
Pool 26 (72)	0.0 (±0.0)	24.9 (±22.5)	418.3 (±309.8)	0.0 (±0.0)
Open River (108)	—	22.4 (±19.0)	—	0.6 (±0.4)
La Grange (99)	0.0 (±0.0)	3.3 (±1.5)	—	8.0 (±4.2)

^aBWC = contiguous backwater.

^bMCB = main channel border.

^cIMP = impounded.

^dSC = side channel.

^ePool 4 IMP = Lake Pepin, tributary delta lake.

Table 14. Mean number of select taxa per square meter by predominant substrate type, all study areas combined. *N* = number of samples.

Predominant substrate (<i>N</i>)	Mayflies (m⁻²)	Fingernail clams (m⁻²)	Midges (m⁻²)	<i>Corbicula</i> sp. (m⁻²)	Zebra mussels (m⁻²)
Hard clay	3.2 (±1.6)	6.4 (±3.2)	10.9 (±3.8)	1.3 (±0.9)	4.5 (±2.0)
Silt clay	207.7 (±20.0)	89.0 (±12.2)	170.9 (±18.0)	0.4 (±0.4)	29.5 (±25.2)
Silt clay with sand	138.8 (±23.1)	87.0 (±14.0)	67.5 (±11.4)	0.6 (±0.3)	46.2 (±25.0)
Sand with silt clay	22.7 (±6.5)	16.0 (±3.7)	55.9 (±11.5)	0.3 (±0.3)	32.9 (±17.8)
Sand	0.5 (±0.2)	2.7 (±1.0)	11.5 (±2.4)	0.3 (±0.2)	48.9 (±30.1)
Gravel rock	1.6 (±0.8)	0.0 (±0.0)	0.8 (±0.6)	0.8 (±0.6)	248.4 (±109.9)

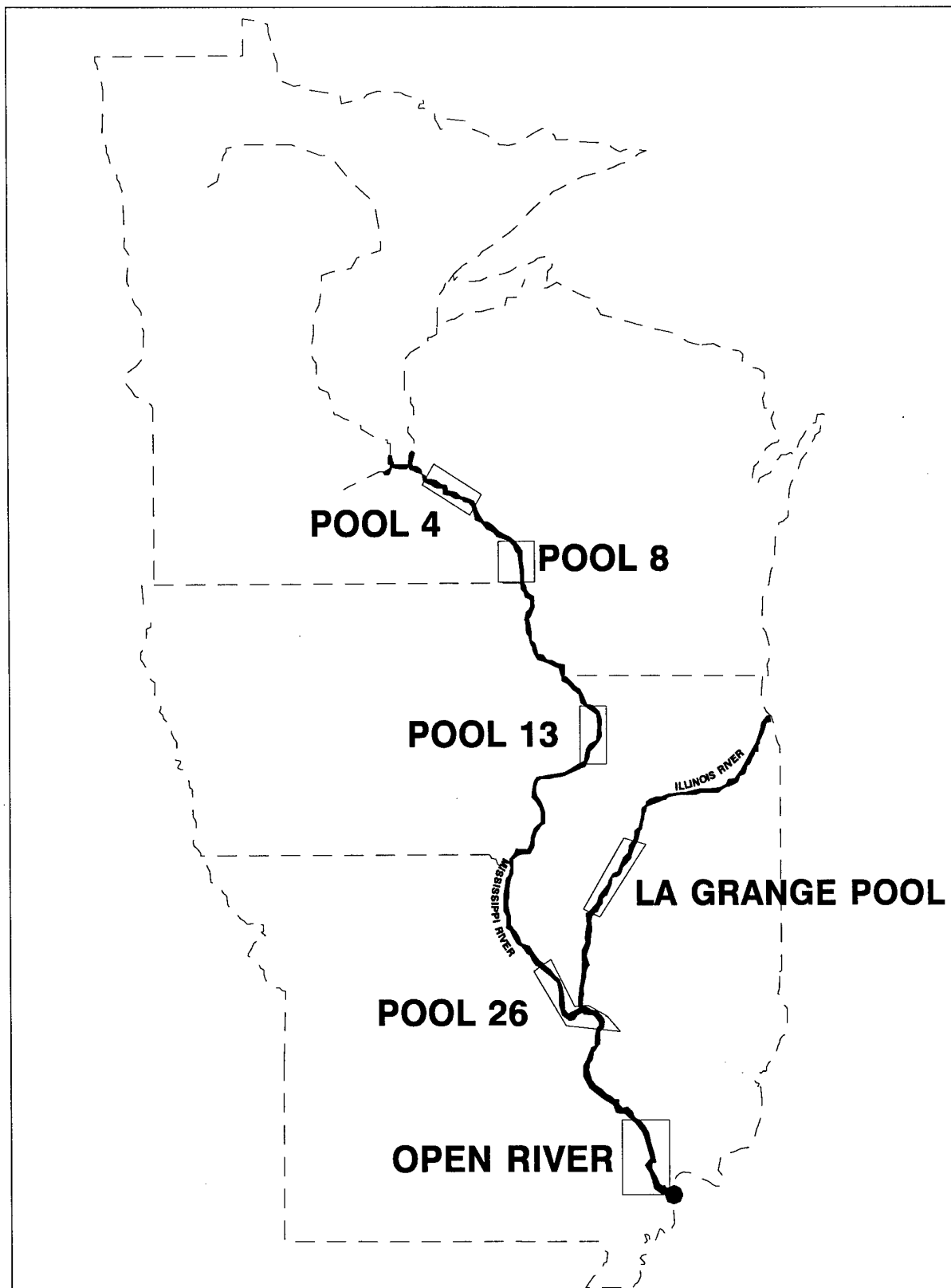


Figure 1. Long Term Resource Monitoring Program study reaches for macroinvertebrate sampling.

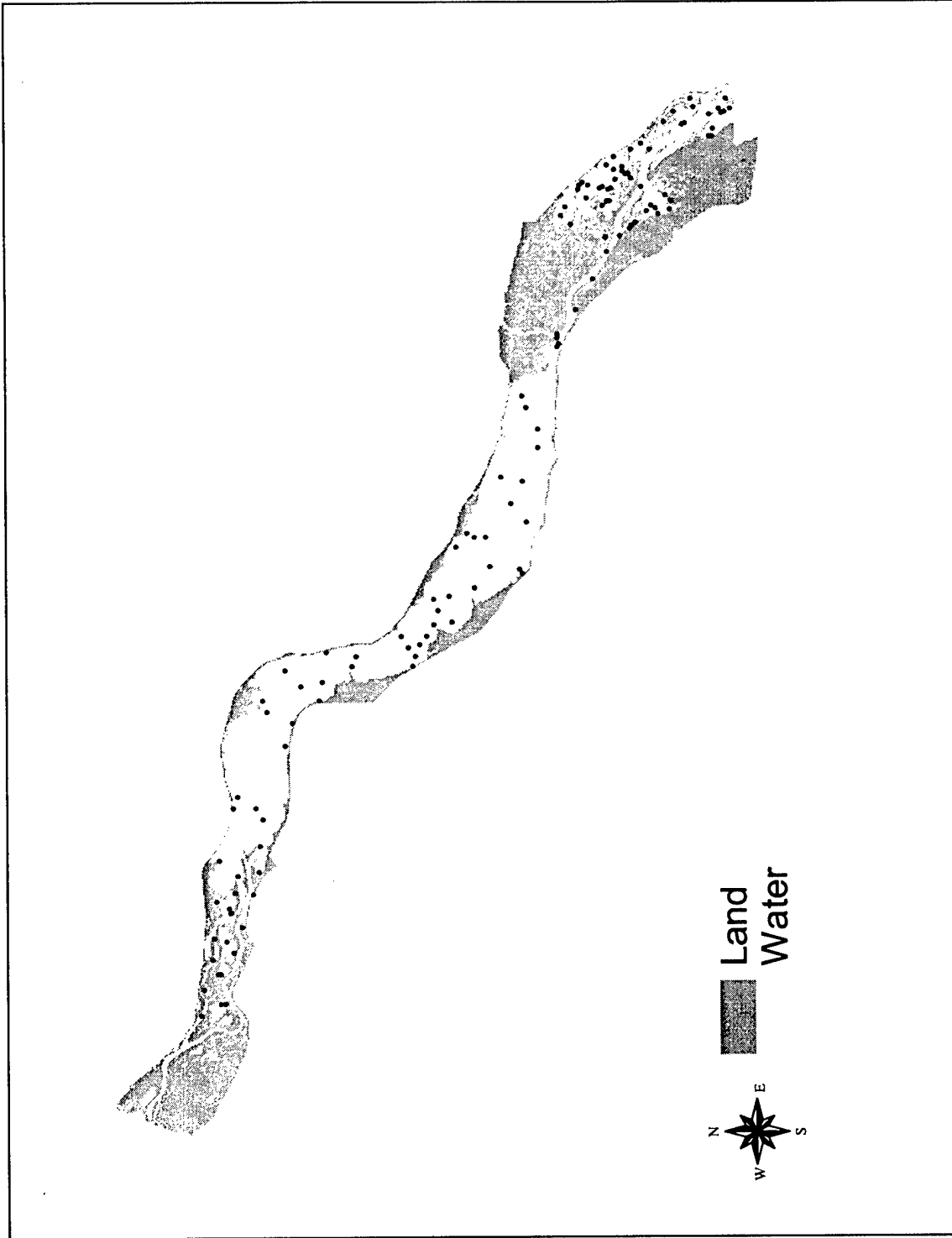


Figure 2. Pool 4 (Mississippi River miles 753–797)—1998 Long Term Resource Monitoring Program macroinvertebrate random sample points.

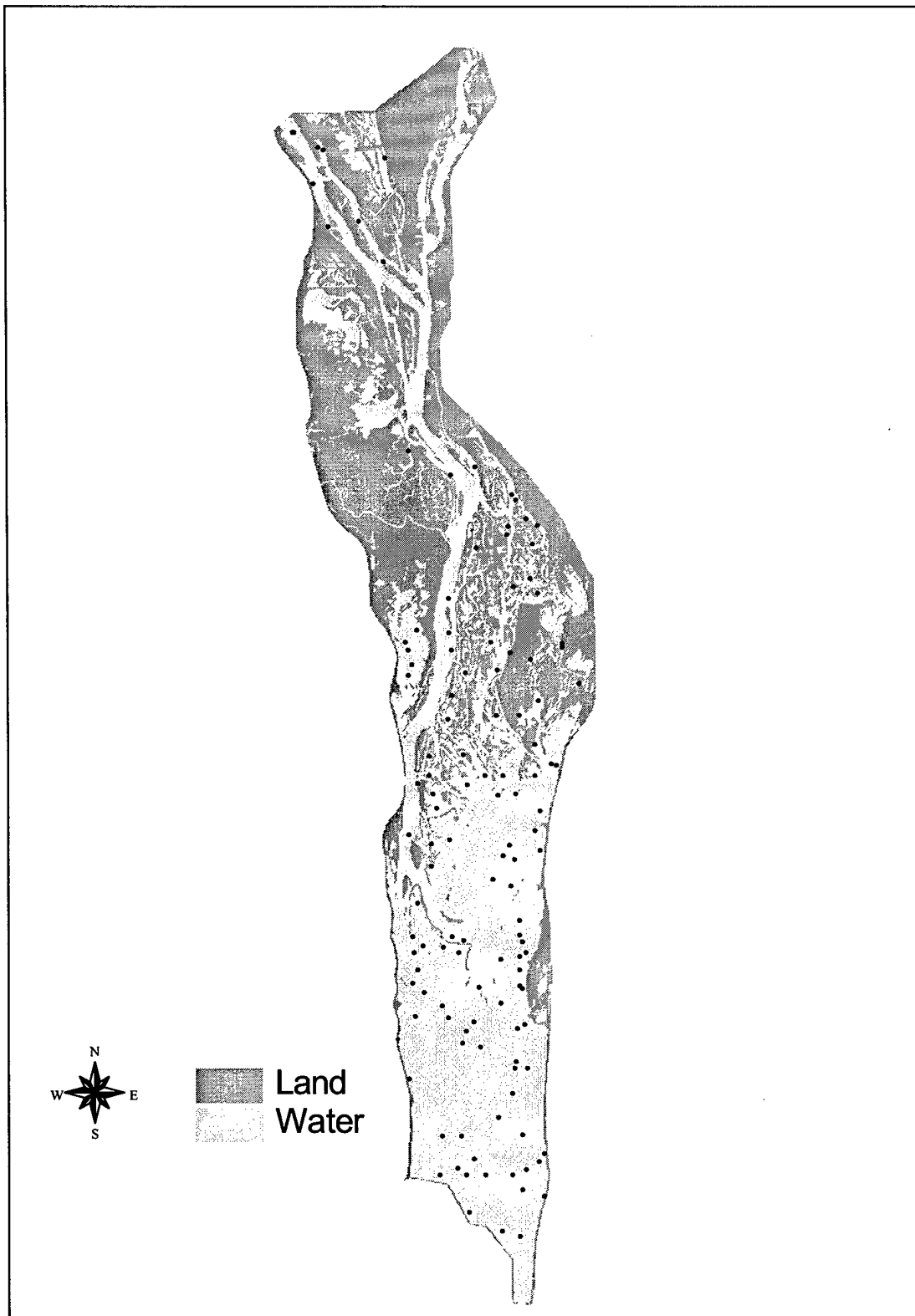


Figure 3. Pool 8 (Mississippi River miles 679–703)—1998 Long Term Resource Monitoring Program macroinvertebrate random sample points.

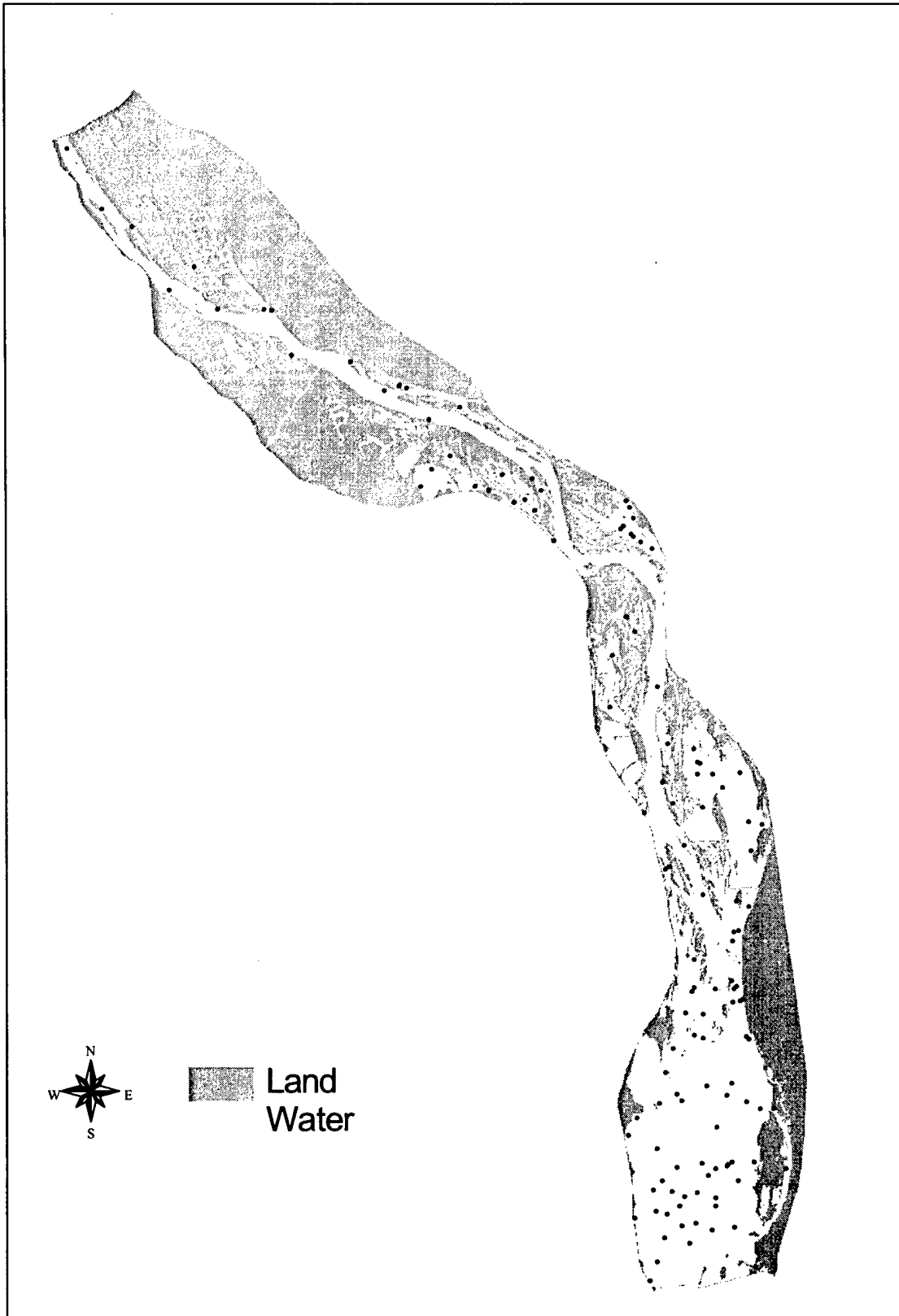


Figure 4. Pool 13 (Mississippi River miles 522.5–557)—1998 Long Term Resource Monitoring Program macroinvertebrate random sample points.

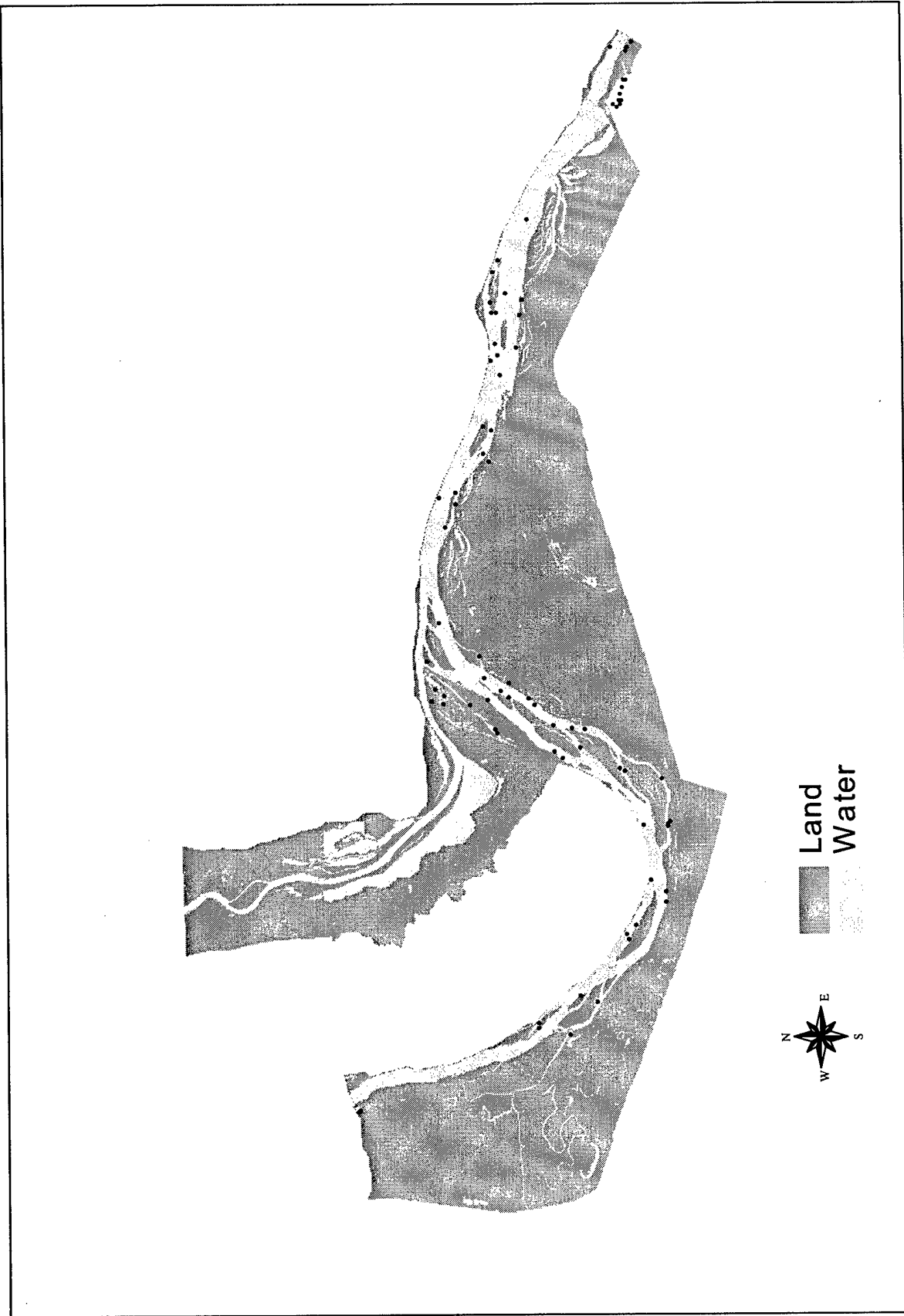


Figure 5. Pool 26 (Mississippi River miles 203-241.5)—1998 Long Term Resource Monitoring Program macroinvertebrate random sample points.

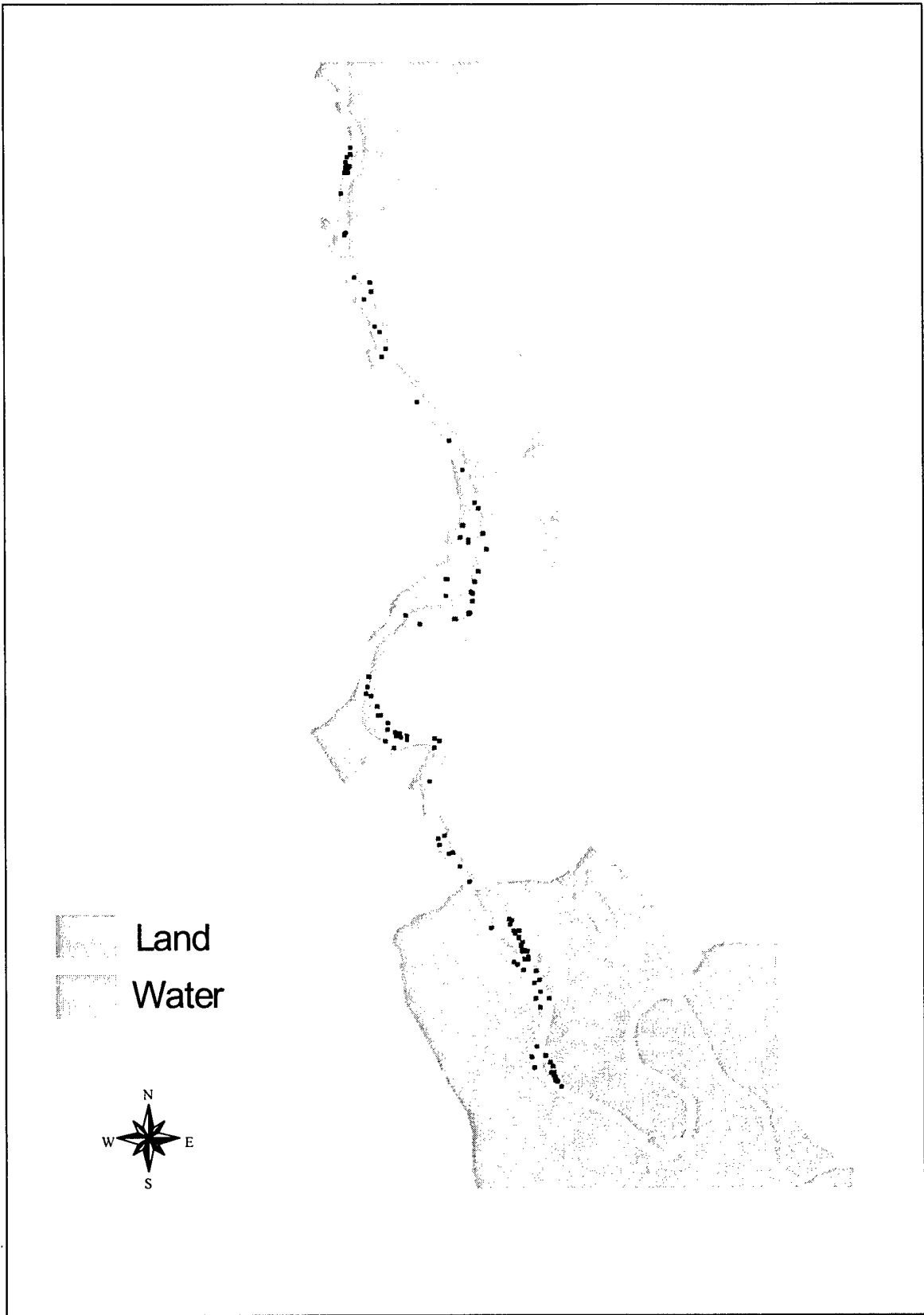


Figure 6. Open River (Mississippi River miles 0–80)—1998 Long Term Resource Monitoring Program macroinvertebrate random sample points.

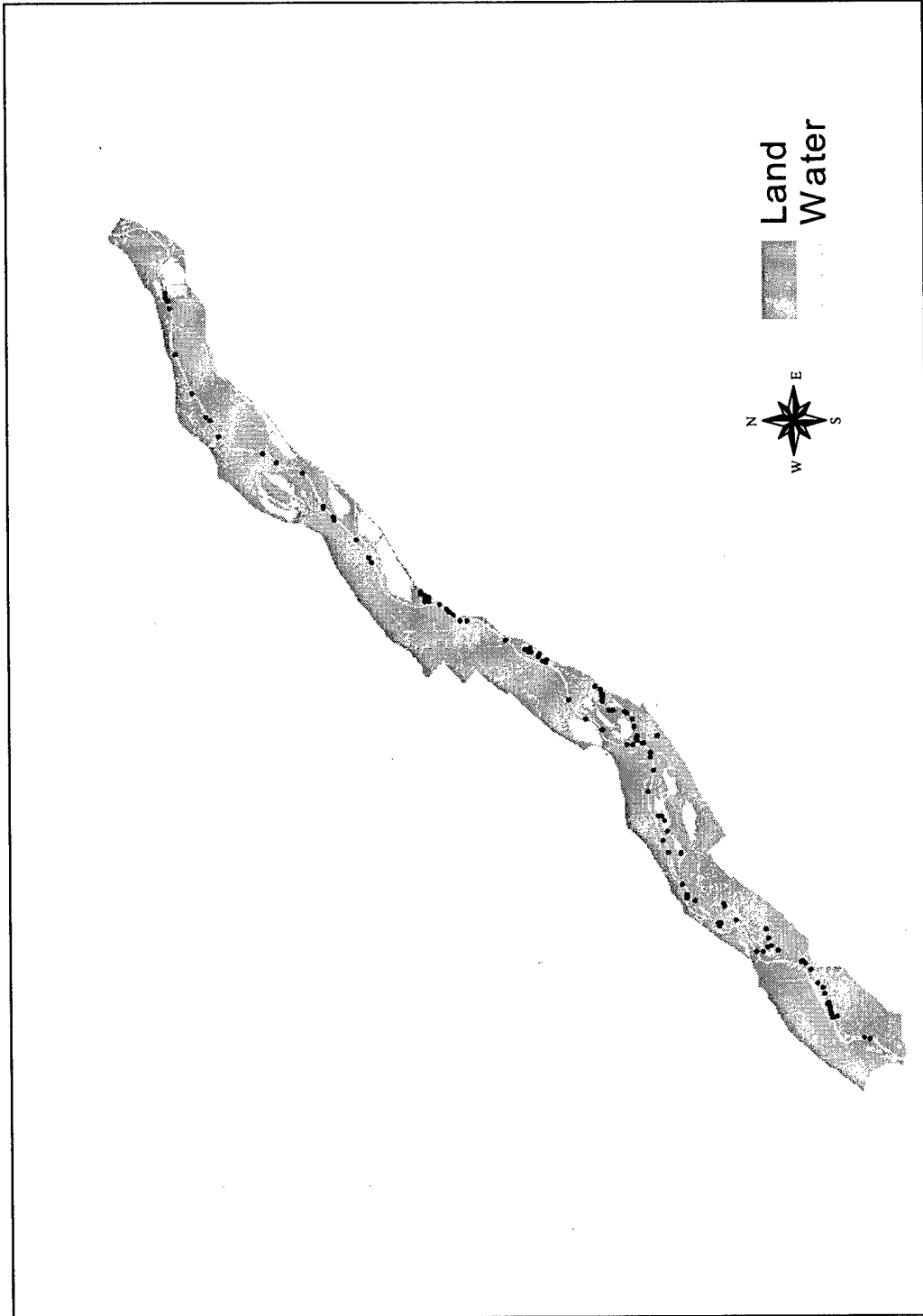


Figure 7. La Grange Pool (Illinois River miles 80–158)—1998 Long Term Resource Monitoring Program macroinvertebrate random sample points.

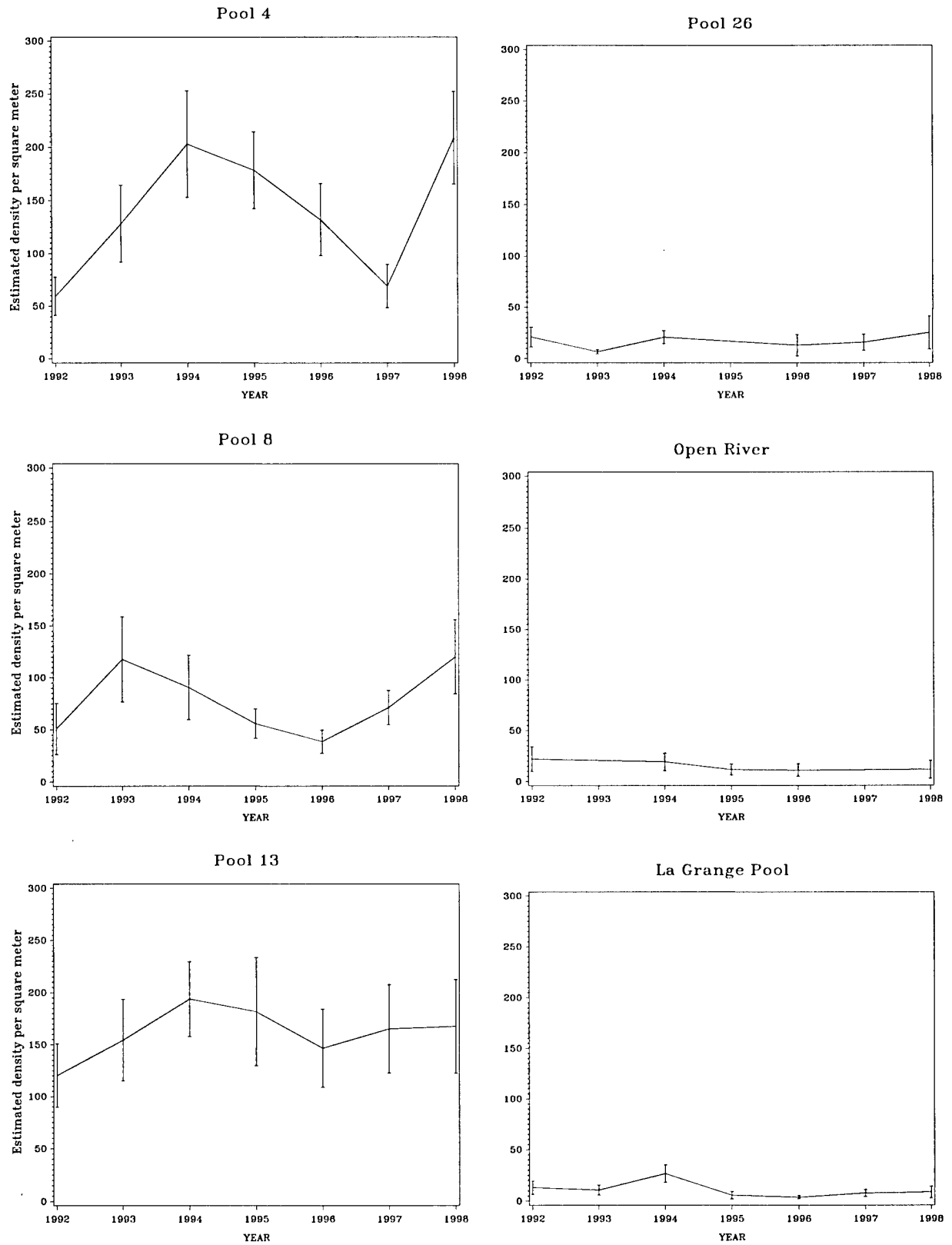


Figure 8. Estimated mean number of Ephemeroptera per square meter by study area, weighted by area of strata. Bars indicate ± 1 standard error.

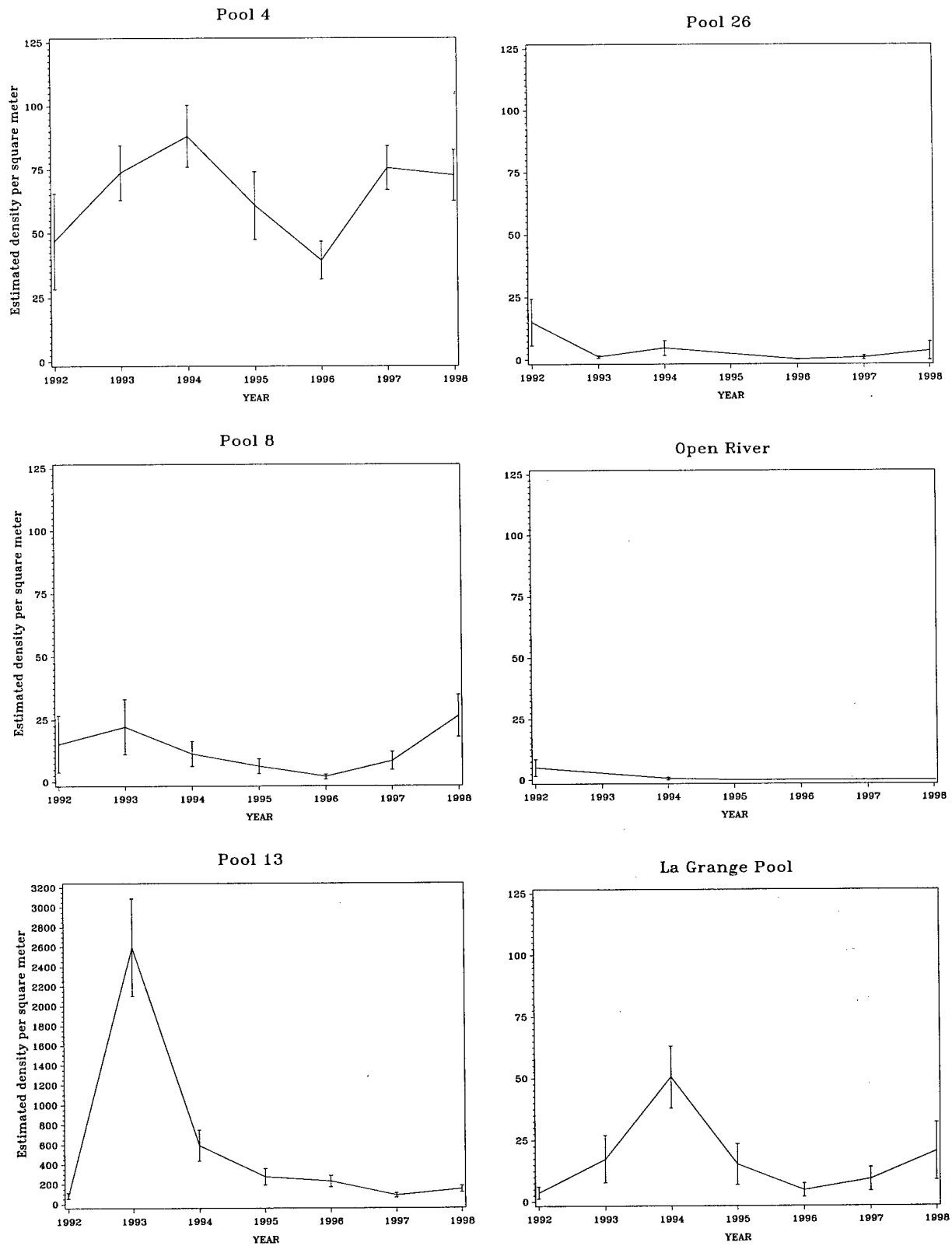


Figure 9. Estimated mean number of Sphaeriidae per square meter by study area, weighted by area of strata. Bars indicate ± 1 standard error.

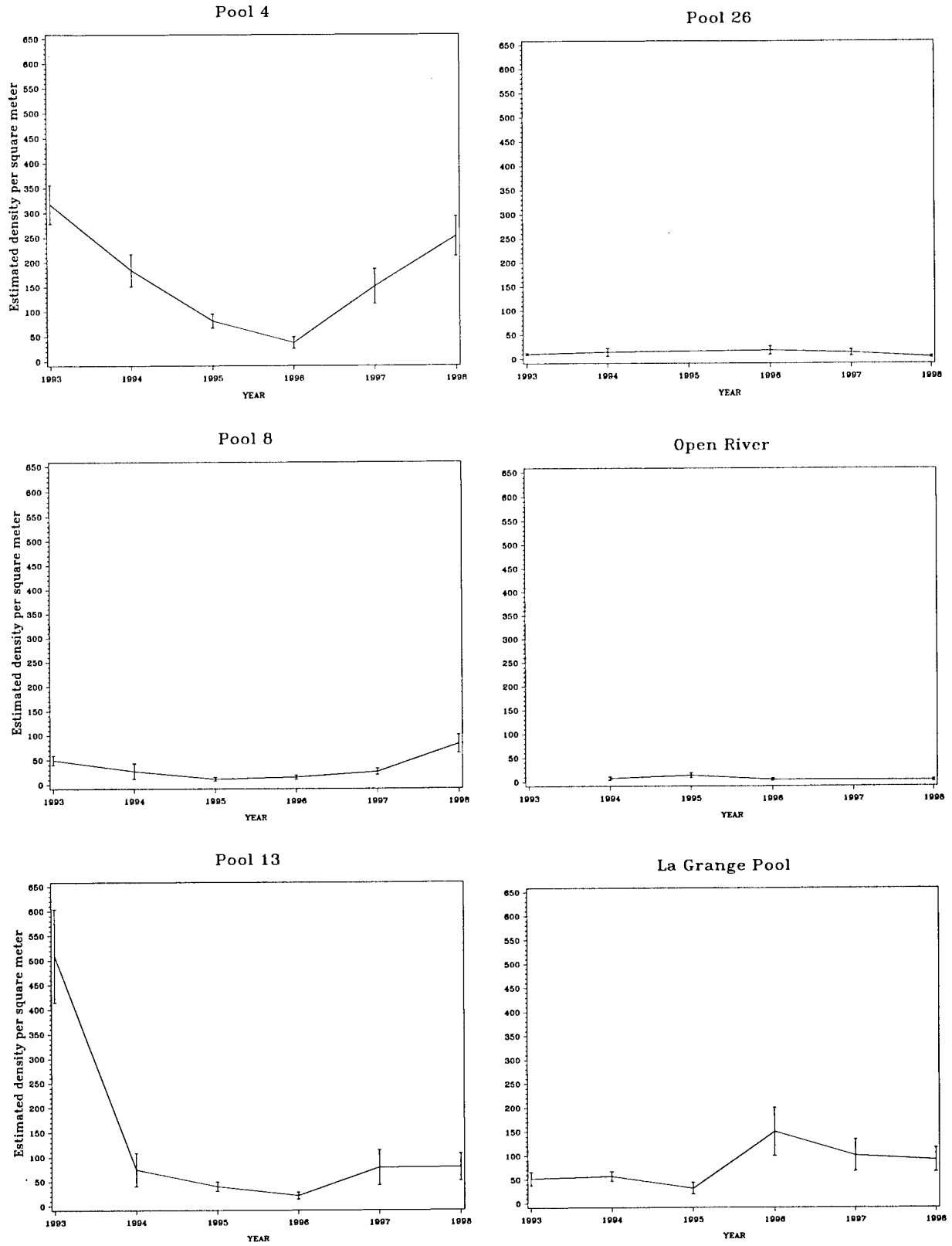


Figure 10. Estimated mean number of Chironomidae per square meter by study area, weighted by area of strata. Bars indicate ± 1 standard error.

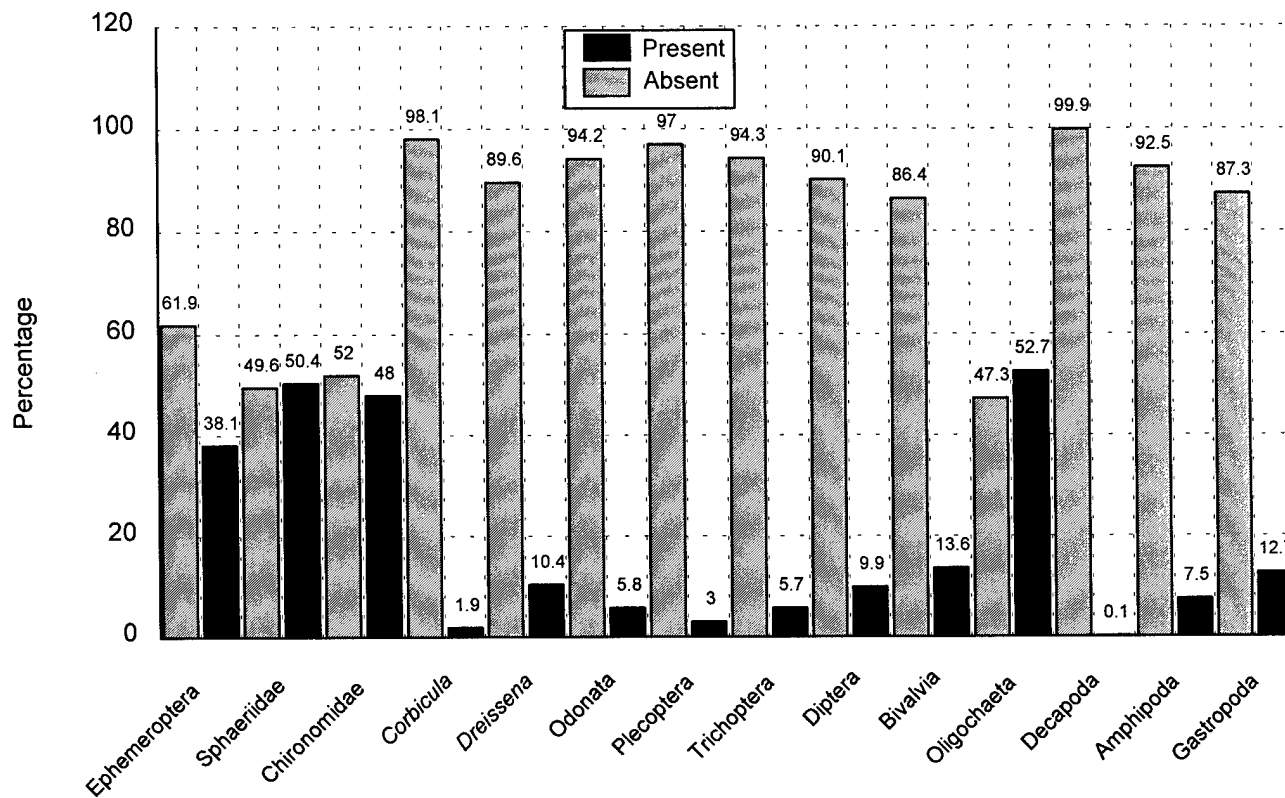


Figure 11. Percentage of times (all sample sites) that the taxa were recorded.

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13. ABSTRACT (Maximum 200 words) 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. Long-term monitoring is needed to detect population trends and local changes in aquatic ecosystems. Mayflies (Ephemeroptera), fingernail clams (Sphaeriidae), and the exotic <i>Corbicula</i> species were selected for monitoring. Midges (Chironomidae) were added to the sampling design in 1993 and zebra mussels (<i>Dreissena polymorpha</i>) were added in 1995. Mayflies, fingernail clams, and midges, 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 taxa were weighted by strata for extrapolation purposes. Pool 4 reported the highest estimated mean densities of mayflies and midges (208.9 and 253.0 m ⁻² , respectively). Pool 13 had the highest estimated mean number of fingernail clams (150.1 m ⁻²). Overall, the impounded areas, including Lake Pepin, and the contiguous backwaters tended to support the highest densities of mayflies, fingernail clams, and midges. Substrates with predominantly a silt clay constituent supported the highest mean densities of mayflies, fingernail clams, and midges.				
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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.

