Long Term Resource Monitoring Program

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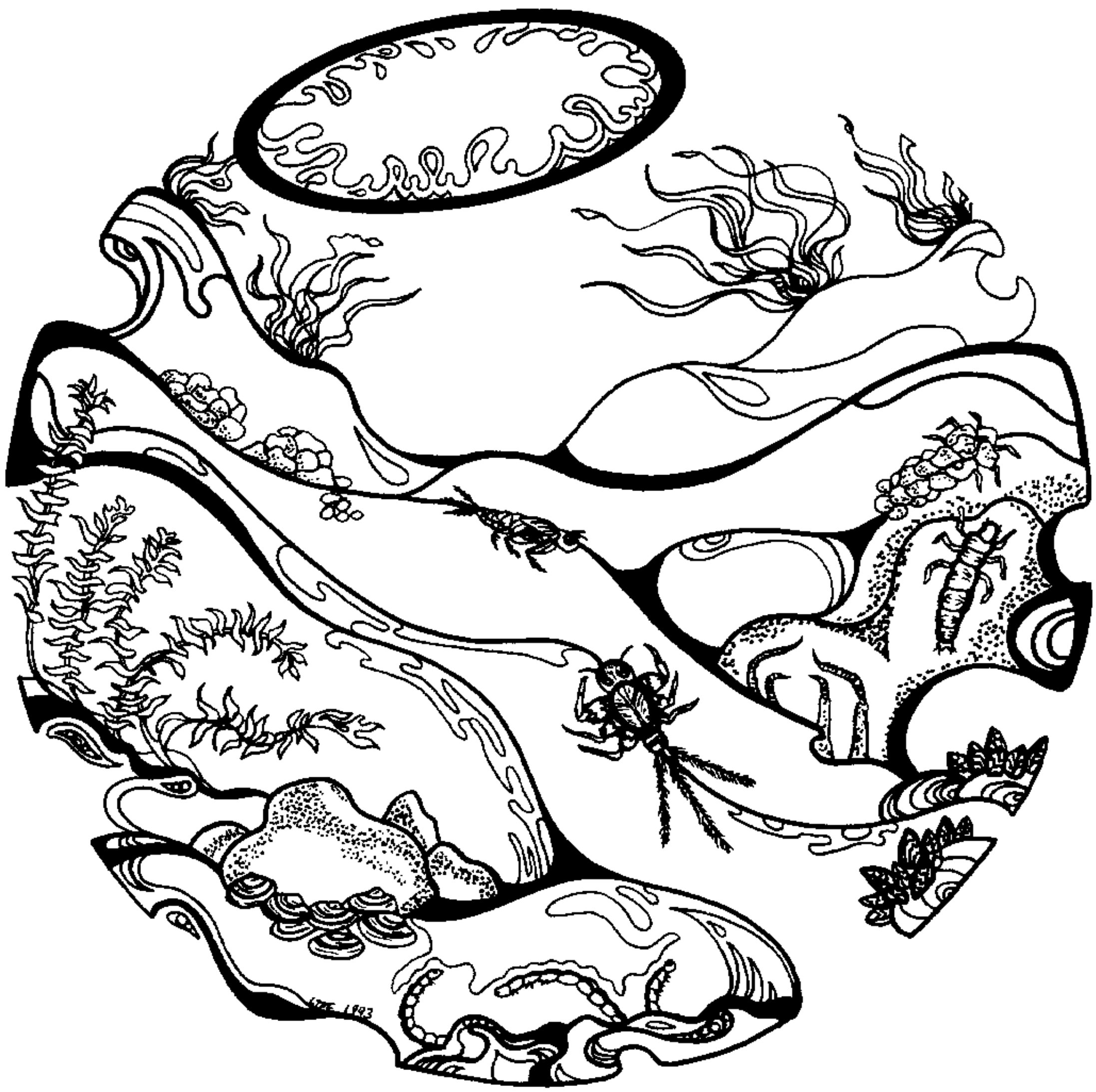
Evaluation of the Macroinvertebrate Component of the Long Term Resource Monitoring Program



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Preface

The Long Term Resource Monitoring Program (LTRMP) was authorized under the Water Resources Development Act of 1986 (Public Law 99-662) as an element of the U.S. Army Corps of Engineers' Environmental Management Program. The LTRMP is being implemented by the Upper Midwest Environmental Sciences Center, a U.S. Geological Survey science center, in cooperation with the five Upper Mississippi River System (UMRS) States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The U.S. Army Corps of Engineers provides guidance and has overall Program responsibility. The mode of operation and respective roles of the agencies are outlined in a 1988 Memorandum of Agreement.

The UMRS encompasses the commercially navigable reaches of the Upper Mississippi River, as well as the Illinois River and navigable portions of the Kaskaskia, Black, St. Croix, and Minnesota Rivers. Congress has declared the UMRS to be both a nationally significant ecosystem and a nationally significant commercial navigation system. The mission of the LTRMP is to provide decision makers with information for maintaining the UMRS as a sustainable large river ecosystem given its multiuse character. The long-term goals of the Program are to understand the system, determine resource trends and effects, develop management alternatives, manage information, and develop useful products.

This report supports Task 2.2.7.5 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 LTRMP.

Evaluation of the macroinvertebrate component of the Long Term Resource Monitoring Program

by

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Abstract: The need for effective monitoring programs to detect population status and trends and to measure the effectiveness of management actions has been voiced by a number of management agencies. It is prudent for any long-term monitoring program to periodically undergo evaluation. In 2002, an evaluation of the Long Term Resource Monitoring Program's (LTRMP) macroinvertebrate component was begun to determine whether its current design was still appropriate based on LTRMP objectives, partner needs, and expected funding levels. The following report discusses the history and sampling design of the component and the results of an evaluation survey and workshop conducted with LTRMP partners. The survey and workshop were the first steps to help assess general support and identify issues or concerns about the macroinvertebrate component. Suggestions for a future design of the macroinvertebrate component include the continuation of monitoring soft-sediment macroinvertebrates and the addition of long term monitoring of native mussels.

Key words: Benthic aquatic macroinvertebrates, Corbicula, evaluation, fingernail clams (Pisidiidae), Illinois River, Long Term Resource Monitoring Program, mayflies (Ephemeroptera), midges (Chironomidae), Mississippi River, zebra mussels (*Dreissena polymorpha*)

Introduction

The need for effective monitoring programs and the information they provide has been voiced by a number of agencies (Davis 1989; Interagency Ecosystem Management Task Force 1995). Long-term ecosystem monitoring is needed to detect population status and trends and to measure the effectiveness of management actions (LaRoe et al. 1995; Mac 1998; Wenche and Semb 2001).

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 (EMP; Program). Congress recognized the Upper Mississippi River System (UMRS) as a nationally significant ecosystem and a nationally significant commercial navigation system—the only river in the United States to be formally recognized as such. 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 further recognized that the system provides a diversity of opportunities and experiences and should be administered and regulated in recognition of its several purposes.

Recognizing that knowledge of ecosystem conditions and trends was critical for effective administration, the original authorization provided for a 10-year EMP starting in 1987. Section 405 of the Water Resources Development Act of 1990 (Public Law 101-640) extended the Program an additional 5 years, and Section 509 of the Water Resources Development Act of 1999 (Public Law 106-53) authorized the EMP as a continuing program. The LTRMP is conducted by the U.S. Geological Survey (USGS) in cooperation with the five UMRS states (Illinois, Iowa, Minnesota, Missouri, and Wisconsin), with guidance and overall Program responsibility provided by the U.S. Army Corps of Engineers. The ultimate goal of the LTRMP is not simply to report status and trends, but to improve the understanding and management of the UMRS.

From 1992 to 2004, LTRMP staff collected data on select macroinvertebrate populations in six study areas on the UMRS (Figure 1). The LTRMP macroinvertebrate 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.

It is prudent for any long-term monitoring program to periodically undergo review (Hirst 1983; McDonald et al. 1998; Strayer et al. 1986). In fact, Congress recognized the need for periodic assessment of the EMP by requiring a report (U.S. Army Corps of Engineers 1997) containing

- an evaluation of the Program,
- description of the accomplishments of the Program,
- updates on a systemic habitat needs assessment, and
- identification of any needed adjustments in the authorization of the Program.

Over its history, the LTRMP has undergone various reviews including scientific and management reviews (Church 1996; International Science Review Committee 1990; Weaver 1997). In 2002, we undertook an evaluation of the Macroinvertebrate Component to determine if its current design is still appropriate based on LTRMP objectives, partner needs, and expected funding levels. The LTRMP Macroinvertebrate Component is one of four LTRMP field components and has accounted for about 5% of the annual LTRMP funding from 1992 to 2004, compared to 18–34% for other field components (aquatic vegetation, water quality, and fisheries).

Planning History

The first step in designing any monitoring program is to set clear objectives. The objectives for macroinvertebrate monitoring were set out in a series of LTRMP planning documents.

The first long-term monitoring planning document was written by the Upper Mississippi River Conservation Committee (1980). This document laid out two goals for a monitoring

Figure 1. The six study areas of the Long Term Resource Monitoring Program on the Upper Mississippi River System.

program—to document changes in the physical and chemical components of the habitat and to document plant and animal changes in the UMRS. Invertebrate monitoring variables would include zooplankton, macroinvertebrates, and periphyton. Planning for the LTRMP and subsequent macroinvertebrate component became more specific in 1981 with the Comprehensive Master Plan (Jackson et al. 1981). The plan recommended weekly sampling of zooplankton in spring and early summer with bi-monthly Ponar grab samples and artificial substrate samplers. In 1987, an Action Plan prepared by the U.S. Fish and Wildlife Service (USFWS 1987) became more explicit and suggested three major tasks, (1) characterization of selected benthos, (2) population demography and density of fingernail clams and burrowing mayflies, and (3) annual changes in density, physical condition, and population demography of native mussels.

Finally, the 1992 Operating Plan (USFWS 1993), because of budget constraints, narrowed the scope of invertebrate monitoring to target benthic macroinvertebrates, specifically the soft-substrate invertebrates. The soft-substrate macroinvertebrates were chosen as an important component of the ecosystem and because of their importance as food resources for waterfowl and fish (Ken Lubinski, USGS, pers. comm.). Burrowing mayflies (Ephemeridae), fingernail clams (Sphaeriidae), and the nonnative Asiatic clam (*Corbicula* spp.) were selected for monitoring initially. Midges (Chironomidae) were added to the sampling design in 1993 and the nonnative zebra mussel (*Dreissena polymorpha*) in 1995. Mayflies, fingernail clams, and midges were chosen as target organisms for the LTRMP because of their important ecological role in the UMRS, especially as a source of food for waterfowl and fish. The Asiatic clam (*Corbicula fluminea*) and zebra mussel (*Dreissena polymorpha*), both nonnative freshwater clams, were chosen for monitoring because of their possible detrimental effects on the economy and biology of the UMRS. The main objective of the LTRMP macroinvertebrate component is to document spatial and temporal trends in select benthic macroinvertebrates.

Sampling Design for the Long Term Resource Monitoring Program Macroinvertebrate Component

Sampling in a large river is difficult (Resh and Rosenberg 1989; Flotemersch et al. 2000). In 1991, the LTRMP initiated a pilot study to determine an efficient and cost-effective sampling design for the macroinvertebrate component, taking into consideration the study design, sample size, and cost of sampling benthic macroinvertebrates in a large river (Bartsch et al. 1998). Bartsch et al. (1998) sampled in two strata: backwater areas and channel borders. They found that using one Ponar grab per site produced abundance estimates for Oligochaeta, Chironomidae, and total invertebrates similar to those derived from averaging three grabs while reducing the cost by 63%. Their design, unfortunately, was ineffective in determining statistical differences in abundance between the two strata for mayflies and fingernail clams. They suggest caution in using their design under different environmental conditions such as abundance and spatial distribution, which will affect sample size and precision.

A number of researchers prescribe a simple strategy when designing a monitoring program (Likens 1989; Manly 2001; Wenche and Semb 2001). Densities of benthic invertebrates are highly variable and extremely patchy making it difficult to obtain accurate estimates of mean densities. The macroinvertebrate component addresses this problem in two ways. First, the component's stratified random design is intended to estimate unbiased mean densities of target macroinvertebrates within aquatic area strata of each study area. Stratified random sampling involves splitting the population into groups, or strata, and choosing a random sample from each stratum. This is appropriate when population units are more similar within each stratum than they are across strata. This approach also can increase precision and lower the error associated with population estimates within each stratum (Elliot 1977; Manly 2001).

Second, a standard Ponar grab was chosen as sampling gear because it has the best precision (lowest mean variance) and accuracy (highest mean density) when sampling soft-substrates compared to other gears (Schloesser and Nalepa 2002). The depth of penetration of a Ponar is about 16 cm in soft-substrate (Schloesser and Nalepa 2002). Mayflies burrow to maximum depths of 13 cm (Hunt 1953; Ericksen 1968) and fingernail clams have been found at depths of 16.9 cm with smaller clams burrowing deeper than larger clams (Gale 1971, 1973, 1976), thus, the vast majority of target taxa fall within the reach of a standard Ponar. The Ponar also has screens on top of the grab to decrease hydraulic shock (Schloesser and Nalepa 2002). The heavy weight (23 kg) of the Ponar is needed in a large flowing river.

Use of standardized protocols is essential in any monitoring program. Standardized macroinvertebrate data collection began in 1992. Sampling protocols are documented in Thiel and Sauer (1999). Benthic samples were collected with a winch-mounted 0.052-m^2 standard Ponar grab sampler (Ponar Grab Dredge, Wildlife Supply Company, Saginaw, Michigan) and sorted in the field. The wash frame sieve size was a U.S. Standard Sieve no. 30 (595 m) in 1992, but was changed to a U.S. Standard Sieve no. 16 (1.18-mm) in 1993 to increase sorting efficiency. Thus, inferences on macroinvertebrate numbers from these data (1993–present) are restricted to larger individuals (Dukerschein et al. 1996). Identification of the target taxa is to the Family level because this level of detail is generally sufficient for management decisions (Fredrickson and Reid 1988).

Laboratory costs add substantially to macroinvertebrate monitoring and research. Also, the premature release of juvenile fingernail clams from the branchial chambers of adults, caused by traumas such as washing, transport, and the addition of preservatives (Gale 1969) can occur. Therefore, it was decided to field sort samples. Quality assurance (QA) samples are periodically examined in the laboratory to determine field-sorting efficiency. After the picking process is completed in the field, it is determined by random draw whether the sample will be taken to the laboratory for QA/QC procedures. About 10% of the samples in each aquatic area were retained. Negative binomial regression models were used to analyze the QA data for the years 1993, 1995, 1997, and 1999. There was a positive relation between numbers of organisms found in the field and numbers found in the lab. In other words, the higher the number of organisms found in the field, the more likely organisms would be found in the lab. Sorting efficiency for mayflies and fingernail clams in the field was consistent over time ($P = 0.2395$ and $P = 0.0733$; respectively). These results emphasize the importance for standardization in methods to get consistency of results over the years. Mayflies were most likely missed in the field if detritus ($P = 0.0124$) was present in the samples whereas fingernail clams were most likely missed in the field if shells ($P = 0.0205$) were present in the sample. Those organisms missed in the field were usually smaller individuals. In 1992, the average length of mayflies found in the field was 25.7 mm versus 5.7 mm in the lab. For fingernails clams, the average length found in the field was 6.6 mm versus 2.7 mm in the lab. Lab results for fingernail clams need to be interpreted with caution because premature release of juvenile fingernail clams by adult clams can occur under stress. Juvenile clams average less than 5 mm in size (Gale 1969; Dietz and Stern 1977; Heard 1977).

Lubinski et al. (2001) used power analysis to assess how well the LTRMP field components (fisheries, water quality, submersed aquatic vegetation, and macroinvertebrates) could detect change from one period (year for macroinvertebrates) to the next at existing levels of effort. Data on macroinvertebrate density were not normally distributed, and frequent zero values were recorded. Therefore to reduce the influence of these zero values on the analyses, initial power analyses were on presence/absence of mayfly and fingernail clam data. Power to detect a 20% annual change ($\alpha = 0.2$) was consistently greater in Navigation Pools 4, 8, and 13 than Pool 26, Open River Reach, and La Grange Pool because of the greater frequencies of occurrence of macroinvertebrates in the nonchannel aquatic areas (contiguous backwaters and impounded area) of these study areas. Low power to detect annual changes of this magnitude (20% change) is expected with macroinvertebrates with life cycles of 1 year or less that exhibit large annual changes in abundance. Also, using presence-absence data usually yields lower power to detect changes in populations if declines are modest (<20–50%; Strayer 1999).

Sauer (2004) found that variance component estimates indicate that, on average, the majority of the variance seen among mayfly, fingernail clam, and midge annual means is derived from real changes in those means. A minority of the year-to-year variance (approximately 20%) was attributed to sampling or error variance.

The ability to detect long-term trends for macroinvertebrates is comparable (even greater) to other biotic and abiotic LTRMP components (http://www.umesc.usgs.gov/ltrmp/power_plots.html). For example, under the current sampling program, power to detect a 5% change per year in mayfly relative abundance in Pool 13 reaches 80% after approximately 13 years. More than 20 years are needed to detect a 5% change per year in bluegill catch-per-unit effort (CPUE) in Pool 13. Power to detect a 5% change per year in log-transformed suspended solids levels in the backwater stratum of Pool 13 in summer under the current sampling intensity is ~11 years. Preliminary analysis on mayflies shows that given some minimal sample size per year, the sample size that really matters is the number of years sampled given that temporal trends are estimated across annual averages.

Data Management and Delivery

We are committed to making data readily accessible to river managers and the public in a timely manner. Because of the volume alone, collecting, processing, managing, and reporting of field data is a significant investment of time and money. The volume and demands to quickly disseminate LTRMP data lead us to use computer technology to capture and deliver the data in a timely manner. The component began Web-based reporting and automation of electronic field data collection in 2001.

Many steps were taken before field data automation could begin. A computer was selected that would hold up under a variety of field and weather conditions—heat, cold, vibrations, rain, snow. These rugged systems were designed to meet Military Standard 810E. A touchscreen design was chosen to allow users to navigate the electronic data sheet (Figure 2) by touching icons or links. The aim was to reduce the amount of keypunching in the field. Before the automated field data collection system was fully

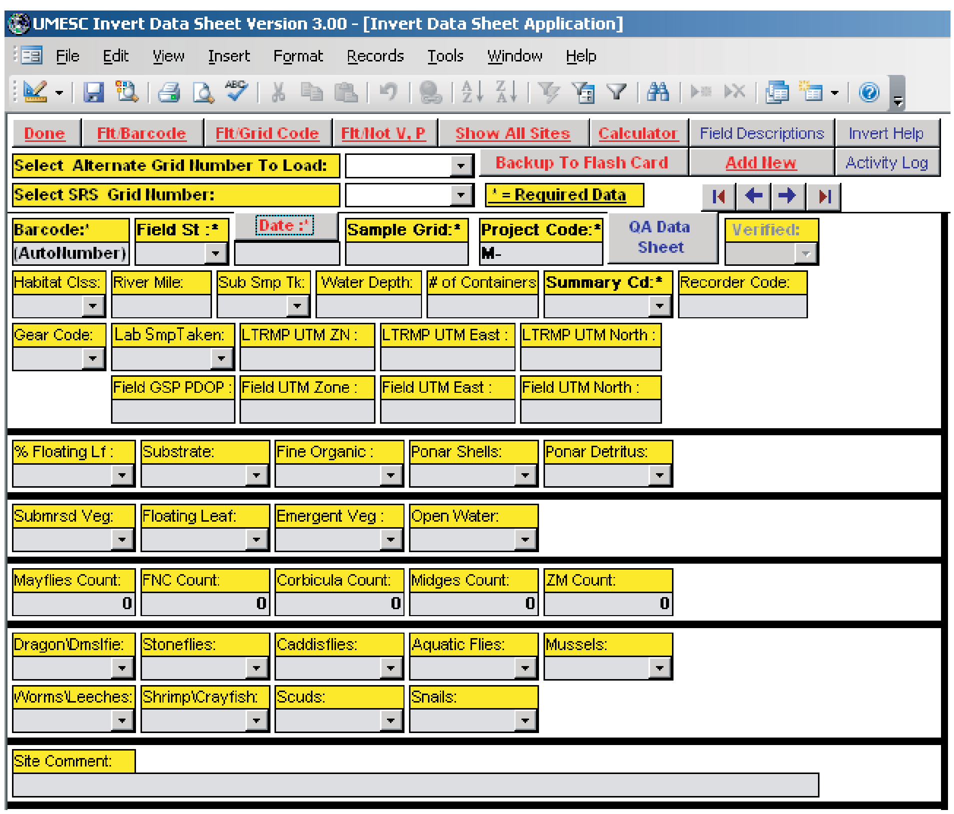

Figure 2. Macroinvertebrate electronic data sheet.

implemented, the system was fully tested by the Pool 13 field station. A number of factors were evaluated during testing including correctness of the data entry application, computer durability, and ease of use. To determine if the electronic data sheet was recording correctly, paper data sheets were also filled out during the testing period. This enabled staff to determine if any errors were occurring during data entry.

Two goals of the electronic data sheet are to increase data entry efficiency by preloading as much data as possible and reduce errors in data recording. Sometimes a single error would require several hours to research and correct. By using electronic data capture, most of the errors can be captured at the source (i.e., in the field) by use of syntax, contextual, and range checks made by data capture software run on a laptop computer, thus preventing most errors from ever entering the system. Errors are much easier to prevent than to correct (Oakley et al. 2001).

Overall, the automation of field data entry was a success. There were timesavings in data recording, entry, and verification in the field and office and cost savings with the data entry contractor. Delivery time for Web-based reporting was also improved.

Workshop Overview and Survey Results

In spring 2002, an on-line survey form was generated and sent out to 216 LTRMP partners. The survey was the first step to help assess general support and identify issues or concerns about the Macroinvertebrate Component. There was a 21% return rate. Because some of the questions were open-ended questions, answers were paraphrased for clarity. The results of the survey can be found in Appendix A.

The majority of the respondents to the on-line survey consider the macroinvertebrate component important in understanding the river ecosystem. The data are used in a variety of ways from assessing and planning habitat and rehabilitation projects to classroom use and outreach.

Respondents to the survey had a number of issues, concerns, or questions relating to invertebrates on the UMRS. These include the role of invertebrates on the river ecosystem, impact of exotics, lack of analysis, and lack of funding. While they noted the strengths of the component such as coverage of multiple pools, consistency in sampling design, tracking of trends, length of record, and importance of macroinvertebrates, there are also a number of weaknesses. A recurring theme in the on-line survey was the gaps in spatial coverage. Despite the importance of benthic invertebrates, little information is available on the occurrence and densities of these animals outside of key LTRMP study areas; especially in Pools 14–25. To address this issue a systemic design enhancement could be implemented (see recommendations below). The lack of information on other invertebrate taxa (i.e., native mussels, zooplankton) was also seen as a data gap. While respondents considered the soft-substrate community the most important community to monitor, they considered monitoring of native mussels a close second.

Another limitation seen of the component was the limited analysis of the data to date. The occurrence of many zeroes made analysis for macroinvertebrates challenging. In 2002, efforts began to predict macroinvertebrate abundances in space and time through statistical models. The work stems from the management focus of the LTRMP. Resource managers are concerned with the abundance of macroinvertebrates as it relates to migratory waterfowl and a number of game and sport fish including shovelnose sturgeon, walleye, and bluegills. Once macroinvertebrate abundance and distribution patterns are better understood, management actions can be undertaken. Analysis efforts under the Macroinvertebrate Component can be referenced in Sauer (2004), Gray (2005), and Gray et al. (2005).

In September of 2002, a panel of LTRMP Partners met to review the Macroinvertebrate Component. Presentations from the Macroinvertebrate Component Coordinator included a multiyear data report and a summary of the survey results. A list of questions was developed that the panel considered critical to improving our understanding of aquatic macroinvertebrates in the UMRS (Appendix B). These questions developed by the LTRMP and

Partners can help establish annual projects and activities in a way that strives toward addressing larger science and management issues within budgetary constraints and opportunities. A list of research ideas that could be explored using the current LTRMP macroinvertebrate data was developed by the panel (Appendix C). Presentations also were given by Robert Hrabik, Missouri Department of Conservation on the Open River study design and Dr. Brian Gray, USGS-UMESC on modeling efforts.

The workshop panel participants agreed that the expectations of the LTRMP macroinvertebrate component—baseline and trend monitoring of soft-substrate macroinvertebrates—are being achieved.

Conclusions

Depending on what questions you want the macroinvertebrate data to help you answer (and the investment of time and resources available), a wide range of possibilities exist for the future direction of the Macroinvertebrate Component. Whereas management issues are the top consideration when designing a monitoring program, issues of today should not limit monitoring since they will change (McDonald 1998).

Fancy (2000) states the “best” sampling design depends on the questions being asked. As mentioned above, the management objective of the LTRMP’s Macroinvertebrate Component is to provide a better understanding of the conditions needed to support viable macroinvertebrate populations at levels adequate for sustaining native fish and migrating waterfowl. Macroinvertebrate population status and trend data are required to reach this objective.

The macroinvertebrate data set currently contains 13 years of data and is just now reaching sufficient length to provide reasonable power to detect long term changes. The current design gives unbiased annual estimates at pool/strata level and provides the ability to detect long-term trends and develop “management action” levels. Also, estimates of interannual variation for both strata and pools improve as the number of years macroinvertebrates are monitored increases. The magnitude of interannual variation will help managers characterize (statistically) what constitutes an important “change in status”.

A system as large as the UMRS contains a mixture of spatial attributes that can influence the abundance and distribution of biota within the river system. A reduction in the spatial coverage will impair the ability to provide data for investigating how the spatial structure of physical, chemical, and biotic components of the UMRS influence the abundance and distribution of macroinvertebrate resources. Given adequate number of years, status and trend information can help managers make informed decisions on systemic sampling design issues, will allow inferences about changes to biota at higher trophic levels (fish and waterfowl), and will provide the most cost-effective measure of biotic integrity for the UMRS.

However, gathering only status and trend information on select benthic invertebrates is limiting. There are many needs and questions not addressed with the current design (Appendix B and C). To address the specific issue of the lack of spatial coverage in the component and going under the assumption that we are interested in the status and trends for these areas, one method of sampling is a serially alternating design with augmentation. This design should be better suited for detecting long-term trends (Manly 2001). Under this design, Pools 4, 8, 13, and 26 and La Grange Pool would be sampled annually and a sub-sample of remaining pools would be sampled each year, thus the entire system would be sampled over a period of 5 years (Appendix D). This type of design would still allow us to track status and trends, plus investigate different dynamics and potential drivers in each pool.

There also is a demonstrated need to monitor the status and trends of the native mussel community of the UMRS (Appendix A, National Strategy for the Conservation of Native Freshwater Mussels, and Conservation Plan for Freshwater Mussels of the Upper Mississippi River System). Management agencies need to know the condition of the resource (i.e., species richness, relative abundance, density, and recruitment measurements) in order to modify harvest regulations, evaluate threats, and determine levels of management effort required to maintain viable populations (Miller and Payne 1988). Unfortunately, the scientifically valid data needed to describe the resource's current status and predict its response to future stressors or management actions are lacking. The most urgent short-term question expressed by many managers, especially in downstream pools, is "What's out there"?

A program needs to be formulated not only to answer several basic and urgent short-term management and science questions, but also to provide the initial data needed to begin answering long-term questions through the development and refinement of a scientifically sound long-term monitoring program for native mussels.

The Open River Reach field station staff is investigating new study designs for the Open River Reach because the current design is not practical for the habitat or taxa in that area. Other designs and methods need to be explored because there are many areas of the UMRS where little is known about the invertebrate fauna. Areas such as isolated backwaters, major tributaries, or dike fields are not sampled under the current design. Beckett et al. (1983) found dike fields important in the lower Upper Mississippi River. Because of the unique nature of these areas, the best way to address this issue may not be to just add them into the current design, but rather attack them with focused studies or short-term monitoring.

The long-term monitoring design should be coordinated with necessary experiments and management action evaluations to quantify causal mechanisms. Focused research topics could answer questions such as "What is the effectiveness of HREP efforts on macroinvertebrates?"; "Are patches with high density of organisms consistent through time? If so, are they predictable by other co-variables? Can we then change the sampling design to emphasize these areas?", and "What role do macroinvertebrates play in the nitrogen cycle?"

The LTRMP Macroinvertebrate Component has produced a high-quality, consistent data set on macroinvertebrate distribution and abundance over many years. It is only one of a few long-term databases on large river macroinvertebrates nationwide. The LTRMP macroinvertebrate monitoring framework is well suited to provide a better understanding of the long-term changes in the UMRS' natural resources. More years of monitoring are necessary to understand apparent temporal pattern. A combination of long-term monitoring with applied research to understand changes in the UMRS ecosystem is needed.

Funding Plans

In 2005, a 5-year plan was developed for the LTRMP assuming a static budget of about $5 million per year over the period. Within this plan, the data collection portion of the Program was reduced to a level that could be accomplished annually over the 5-year period given the budget constraint. This effort, called the "minimum sustainable program," required about $3.7 million in 2005, which will inflate (based on a projected 4.1 % annual inflation rate) to about $4.3 million in 5 years. As part of this restructuring, which was based on guidance from the LTRMP Analysis Team and Environmental Management Program Coordinating Committee, the macroinvertebrate component was dropped from the minimum sustainable program. Future work on invertebrates within LTRMP can be funded as focused research projects to address specific issues of interest to the Partnership.

Acknowledgments

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Appendix A. Macroinvertebrate Evaluation Survey Results

Part I

Question	Yes	No
Are you aware of the existence of the LTRMP macroinvertebrate database for the Upper Mississippi River?	36	3
Have you personally used this information?	22	16

Part II

Question	Frequency of responses
For what purpose(s) have you used the LTRMP macroinvertebrate data?	
Tracking exotics	3
Assessing waterfowl use areas and walleye condition	3
Assessing and planning COE projects	4
Detecting spatial patterns and trends	8
Classroom use	2
Water quality assessment reports	1
Bioindicators	2
Outreach	3
Hypothesis generation, planning studies	2
How often do you use LTRMP macroinvertebrate data?	
Have not used data	6
Once a year	8
Few times a year	15
As necessary for Project Proposals	2
How do you access LTRMP data?	
Only paper reports	7
Paper reports, Web database	1
Paper reports, Web reports	5
Paper reports, Web reports, Web database	10
Only Web database	5
Web reports	2
Web reports, Web database	1

Question (cont.)	Frequency of responses (cont.)
What do you see as the management utility of the current LTRMP macroinvertebrate component?	
Water quality indicator, indicator of river health	7
Assessing waterfowl and fish use	4
Detect invasives	3
Baseline data	2
Detect spatial patterns and temporal trends	6
Environmental review	1
Help explain inter-relationships	3
Has little actual management value	2
What limits your use of the data in your own activities?	
Limited spatial coverage on river	4
Sampling only once a year	2
Lack of production data	1
Methodology not useful in Open River	1
Limited meta-data	1
Unfamiliar with database	3
Time to use database	5
What do you see as strengths of the current LTRMP macroinvertebrate component?	
Coverage of multiple Pools	1
Indicator of river health, IBI	2
Consistency in sampling design	9
Tracking of trends, length of record	7
Importance of macroinvertebrates	2
What do you see as weaknesses of the current LTRMP macroinvertebrate component?	
Lack of spatial coverage over UMRS	8
Neglecting other taxa (e.g., mussels, zooplankton)	7
Low funding	3
Low sampling frequency (i.e., only sampled once a year)	2
No biomass data	3
Lack of adjusting for changing strata (read aquatic area)	1
No direct physical measurements taken at site	1
Lack of analysis	1

Part III

	Most important	Very Important	Important	Somewhat important	Not very important
How important is the LTRMP macroinvertebrate component as an aspect of understanding the river ecosystem?		16	19	3	1
In your opinion, what are the most important macroinvertebrate taxa to sample?					
Soft-substrate taxa	24	3	3	2	3
Taxa on rock and rip-rap	6	2	5	7	15
Drift	4	4	5	3	19
Native mussels	21	6	3	4	1
Exotics	8	7	7	5	7
Zooplankton	5	10	7	2	11
Taxa on woody debris or vegetation	6	2	4	11	12
Please specify the importance of each of the following types of macroinvertebrate information:					
Total abundance		7	15	10	5
Community composition		18	13	4	1
Total Biomass		7	15	10	5
Presence/Absence Frequency		6	13	13	4

Part IV

Other taxa you consider important?

- All, should be community level
- The most important in the Open River Reach are those that use sand and sand/gravel.
- Terrestrial insect species that could threaten bottom land forest (e.g., gypsy moth)

Other information you consider important?

- Age/length class structure (native mussels)
- Annual production
- Productivity to address total contribution of multivoltine species

Part V

What issues, problems, or questions related to invertebrates on the UMRS concern you the most? (All replies listed)

- Impacts of exotics
- Continuing availability of abundant and diverse, interdependent food chain links
- Species losses, particularly those that change the energetics of the river food webs
- Causal relations between invertebrates and material cycling and movement
- Abundance of mayflies, abundance of fingernail clams, what are the zebra mussels doing, how are the native mussels coping with the zebra mussels
- Are we losing the ability to support fish and wildlife through this thread of the food web?
- Correlate above data to other physical and chemical factors to develop prescriptions for restoration in historically good invert habitat areas
- Effects of zebra mussel invasion on overall ecology of the river and on native mussels, effects of ammonia and other pollutants on sensitive inverts important for food to fish and waterfowl (mayflies, fnc), and the fact that we are losing many of our native mussels
- How critical is abundance and composition in determining fish and wildlife populations (abundance and diversity)?
- In the Open River Reach we know nothing about community composition and how disturbance affects relative abundance and distribution of these organisms. Hence, we know nothing about how invertebrates or which ones may be important ecosystem drivers.
- Loss of the soft and hard substrate taxa
- Unionids (native mussels)—we don't sample them well
- Need better understanding of the diversity and the role as indicators of river health
- Production of macroinvertebrates is a big driver in the river ecosystem affecting materials processing, fish production, etc. We don't yet have a good handle on macroinvertebrate production, or how to manage to influence it. I am concerned about the declines in abundance of fingernail clams, mayflies, etc., as well as the effects of zebra mussels.
- Their role in food webs
- We are not tracking macroinvertebrates as well as we should; somehow need to increase the importance of this component.
- What are the impacts of exotics (i.e., zebra mussels) on fish, native mussels, and other invertebrates in the UMR? How do natural disturbances (floods droughts) impact the invertebrate community? How do changes in SAV influence the macroinvertebrate community?
- What is the importance of macroinvertebrate drift to the fisheries of the UMR? What are the interconnections between macrophytes and macroinvertebrates (refugia, regulation, etc)?
- Why do populations fall or increase? What effect do zebra mussels have on native mussels, reducing the invertebrate populations used by other animals? What are the effects of water quality, particularly DO, turbidity, light penetration. What conditions over which we have some control can influence the micro and macro habits of these creatures to influence the base of the food chain and the health of the river. Currently we have little information on where, how many, life cycles etc. of these animals.
- Zebra mussel population dynamics—if numbers boom, we need to monitor our endangered native mussel populations more closely because we may need to move them to refugia. Any info I can get to help me track this would be very helpful, because we lack staff to monitor Mississippi River.
- Exotic species relationships
- Freshwater mussel decline
- Long-term trends of native mussels and species diversity, long-term changes in water quality and effects on invertebrate diversity and abundance
- Relating value of a habitat created/lost to loss/gain of macroinvertebrates, and consequently if there are tangible systemic gains
- What species, numbers and biomass are available for migratory waterfowl food in fall?

What suggestions do you have for improving the LTRMP macroinvertebrate component? (All replies listed)

- Actively promote research of the data set beyond federal scientists. Look at the work that has been done on the Mid-Atlantic Highlands Macroinvertebrate data set for EMAP.
- Add a diversity element.
- As for nearly all LTRMP components, there should be time spent on a synthetic analysis of long term spatial and temporal trends of the extant data set. While the raw data set is extremely useful, I think clients and user groups would benefit greatly from a more thorough analysis (like that being done for fisheries and water quality) as well as a set of predictions or recommendations relating to the effects of HREPS on lower trophic levels.
- Correlate above data to other physical and chemical factors to develop prescriptions for restoration in historically good invert habitat areas. Suggestions: Evaluate the existing data to determine the survey levels needed before which additional collections become redundant (within an acceptable risk level for missing minute levels of change in short periods of time). Use any effort savings to survey additional pools, additional habitats, or conduct additional research.
- Expand sampling to consider the complete suite of invertebrate guilds and species.
- Expand the number a parameters recorded at the site (i.e., water velocity at various depths, strata of site based on field observations, etc). In other words, collect information about the sample site and nearby features that would allow someone to further analyze the data not strictly relying on potentially incorrect pre-sampling strata identification.
- Experiment on where and how to construct habitat for native mussels that is somehow protected from zebra mussel invasions. Look at zooplankton data from past studies and see what else we need to really answer questions about the effects of exotic zooplankton and other exotics on productivity at that level, which is important for survival of larval fish and other organisms higher in the food chain. Look at the productivity contribution of invertebrates on plants, rock, etc. as well.
- Funding. We will go from there.
- How about a guide to the most common inverts by river reach?
- Increase level of importance.
- More quantitative measurement of sediment particle size (ie silt, clay sand) and organic matter (LOI) during sample collections.
- Nothing to offer other than try to find a way to conduct some samples in the lower pools of the UMR.
- Publish reports, anecdotal letters, and stories in community, regional, and national papers explaining the vital roles of the macroinvertebrate communities to support the rest of the aquatic, wetland, and riverine ecosystems.
- Sample Unionids.
- We have not yet developed and calibrated predictive model(s) for the river ecosystem. Macroinvertebrate monitoring could be oriented to calibration and validation of such a model system.
- You would have to do the stats but I think we could get better coverage of the habitats with more sites
- Do some analysis with the WQ data and see if the factors correlate with increases or decreases in abundance. Sample more and different guilds.
- Include sampling for native mussels and zooplankton
- Sample more taxa.
- Sample in fall.

Additional comments? (All replies listed)

- Good luck with your survey — and the future of the macroinvert component!
- Get at it! Politicians paying the bills don't understand why the frogs are dying or why, where, or how the exotics are important (e.g. so it's a different species or genus filling the niche—what's the difference?).
- I have re-read the Technical Report (98-T001) Temporal Analysis of Select Macroinvertebrates in the Upper Mississippi River System, 1992–1995, printed in April, 1998. It would seem that perhaps it is an unreachable goal to intend this data for any management utilization. The report conclusion is high variability occurs in all locations for unknown reasons, and that only long-term trend documentation can be achieved. Is this a fair reading of the conclusion? If so, is that still our assessment?
- I haven't explored LTRMP data much. It is of interest because it is so difficult to sample large systems. I would like to see large river sampling strategy discussion with representatives in my program—USGS WRD National Water-Quality Assessment Program (NAWQA).
- I think some form of macroinvertebrate sampling needs to be continued. It is the only program on the river that does this — develop population trend data that no one else does
- I've said it many times before, having a partial invert program as we have currently may be more detrimental than having none because funders may think expansion of an existing program is not necessary, but starting a new comprehensive program (filling a data gap) might be necessary.
- Invertebrates are expensive to study, but I don't think we can get adequate information to really understand the productivity dynamics of our fish without filling in some of the blanks in their food chain. I think if invertebrates crashed on any one of the substrates mentioned above for any reason, we would see some noticeable changes in fauna up the food chain.
- It works, it is simple, we quantify several important species, soft substrate taxa pick up the same info as hard substrate taxa with less effort and also pick up sediment problems because of their close association to the substrate.
- Again, not being active in larger river management, I have limited understanding and use of this data.
- Keep your data coming to managers; I've never used the database. Maybe there needs to be some type of "LTRMP Data Retrieval Workshop?" I don't have much expertise about macroinvertebrates. Continue to do good work and be the macroinvertebrates expert for the river.
- Need to prepare integrated reports/models looking at the relationships between the macroinvertebrates community and other LTRM monitoring components. Also, is it possible to develop some type of "simple" index for the monitored invertebrates that would indicate the "relative of health" of the habitat/areas sampled?
- Please make every effort to continue this valuable series.
- Please do not cut this component!
- Thank you for making the data and reports readily available on the Web.
- Thanks for the opportunity to complete the survey.
- This is a critical need and one of the lesser understood aspects of river health to the general public. Let’s work on an invertebrate guide for the river that weaves in their importance.
- Keep up the good work on this important component of the river!

Appendix B. Brainstorming Session: Questions About Upper Mississippi River System Macroinvertebrates

1. Are burrowing mayfly populations cyclical or temporal?
2. Have zebra mussels affected ecology of the river and what can we do about it?
3. What is the abundance and distribution of nonindigenous invertebrates?
4. How are watersheds/tributaries affecting invertebrates on the river?
5. What are trends and abundances of native mussels?
6. What are we mandated by Congress to do and is it flexible enough to do one organism or do we need everything?
7. What factors affect the production and abundance of invertebrates and how does that relate to the distribution of waterbird?
8. Is abundance of upper level biota affected by or correlated with invertebrates?
9. What are the major biological and abiotic factors that contribute to variance?
10. How do population/community metrics co-vary across space and time?
11. Community dynamics of invertebrates. No management in Open River. Food items for rare/endangered species. Seasonal distribution/abundance. What do they have for invertebrates?
12. As pools age then sediment, what changes in invertebrates can we expect?
13. What are the relative contribution of invertebrates in terms of drift, etc. to the fisheries, especially sport and game fish?
14. What are the midges in “Swan Lake” eating to make them so big?
15. Are there *refugia* in the Upper Mississippi River where mussels are surviving and where are they?
16. What proportion of invertebrates contributes to overall production?
17. How does invertebrate production co-vary with vegetation production?
18. How important are other components, e.g., drift, flood pulse, rock structure, terrestrial insects released during flood pulse?
19. Is snail production in the spring flood pulse beneficial to waterfowl egg production and/or is *Vallisneria* tuber production as beneficial to waterfowl migration?
20. Is there an actual reported food web for a large river?
21. Are there linkages between invertebrates and fish? Parasites and general health of fisheries.
22. Cycling varies between pools—are pools operating independently or is there a set point so cycles cascade? Is hydrology setting the cycle?
23. What hydraulic, water depth, stage, flow, chemical variables (i.e., DO, pH), food and other factors control patchiness?
24. What do we know about the adult invertebrates—how do they contribute to abundance and distribution?
25. How do gypsy moths affect the bottomland forest?
26. When and where is invertebrate biomass limited by predation?
27. Which is a better indicator: biomass, abundance, or production?
28. What effects do aquatic invertebrates have on terrestrial ecosystems?
29. Do over-wintering factors affect invertebrates?
30. Can episodic toxic events affect community structure/abundance—ammonia, DO.
31. Can we map systematically the relative importance of the HNA functional Guilds?
32. Would it be more useful to gather information on total biomass (invertebrates as a whole)

instead of numbers—possible way to increase sample size.

33. Where are the bottlenecks in the invertebrates?
34. Has the ban on mussel harvest affected mussel abundance?
35. Which species are at greatest risk?
36. Come up with a listing of invertebrates on the river.
37. Does timing and density of zooplankton relate to y-o-y (paddlefish) fish production?
38. What factors determine the timing and density of zooplankton?
39. What zooplankton is out there?
40. What is the role of exotics (rusty crayfish, spiny waterflea, zebra mussels) on the UMRS?
41. What is the role of the annual hydrograph and water levels (floods/droughts) on year-to-year abundance and production?
42. Is there greater waterfowl predation in lower Pool 8 compared to Upper Pool 8?
43. Is there a longitudinal variance related to invertebrates. (i.e., why more mayflies in Pool 13 than Pool 26 if they both have similar sediment types or do the WQ parameters differ between these large regions?
44. What is the role of invertebrates as a whole?
45. Do we need to continue monitoring invertebrates or are there other ways to understand the system?
46. Invertebrates as fish food—night drift vs. day benthic grazing
47. Does navigation have an effect on invertebrate abundance?
48. Are we interested in pool-wide estimates or aquatic areas?
49. What is the abundance and distribution of mayflies/fnc in Pool 5? Do we care?
50. What causes the variability of invertebrates in aquatic areas?
51. What are the causal relations between invertebrates and material cycling and movement?
52. How are the native mussels coping with the zebra mussels?
53. How critical is abundance and composition in determining fish and wildlife populations (abundance and diversity)?
54. We don't yet have a good handle on macroinvertebrate production, or how to manage to influence it.
55. Can we relate the value of a habitat created/lost to loss/gain of macroinvertebrates, and consequently if there are an tangible systemic gains?
56. What are zebra mussel population dynamics?
57. What species, numbers, and biomass are available for migratory waterfowl food in the fall?
58. Do we need to broaden the suite of WQ parameters at each invertebrate sample site?

Appendix C. Brainstorming Session: Research Ideas from the Long Term Resource Monitoring Program Partners

1. Overlay areas of waterfowl usage from US Fish and Wildlife Service with invertebrate abundance.
2. Are patches with high density of organisms (mayflies) consistent through time? If so, are they predictable by other co-variables? Can we then change the sampling design to emphasize these areas? (Comment by Dr. Haro about several presentations at NABS regarding benthic association with mayflies).
3. If yes to #2, what is the appropriate number of samples to be collected?
4. Perform analyses for fingernail clams and midges that have been done for mayflies.
5. Can we expand upon USGS Pool 7 fingernail clam work? Expand it to other pools? Is the report finished? If so, get it out for review. If not, finish it.
6. Are we interested in Pool-wide estimates or at the strata level? Consensus seemed to be both. Under current design we can say something about Pool-wide estimates; but, do we need to increase sample size to get at strata level?
7. Can we reduce variance by "re-stratifying" samples based on substrate?
8. Overlay areas of persistent vegetation growth and invertebrate abundance for the same year. Use aerial photographs and/or vegetation specialist knowledge.
9. Can we take the means of water quality parameters (turbidity, secchi, nutrients, silica, suspended solids, chlorophyll, etc.) and infer anything about invertebrates?
10. Are there other modeling exercises that could be tested or meshed with invertebrate data?
11. Explore historical data in more depth. Examine the difference between the clusters of sites in upper versus lower Pool 8. Does it relate to closed waterfowl area in lower pool? Check in to obtaining Cal Fremling's historical data.
12. Are there "hot spots" for macroinvertebrates (mayflies) in other key pools as there appears to be in Pool 4?
13. Do the fixed water quality sites help explain temporal variation or abundance of macroinvertebrates? While a given invertebrate site may not fall exactly on a water quality fixed site, or be sampled on the same day, several appear relatively close. Can this be of use?
14. Using the current data would be able to see if there are any cross channel differences in invertebrate abundance as seen in the water quality data?
15. Does the LTRMP spring data show the same trends as Refuge fall data?

Appendix D. A potential 5-year Rotating Panel Design With Augmentation for Macroinvertebrate Sampling on the Upper Mississippi River System

	Pool/Study area																										
Year	**2**	**3**	**4**	**5**	**5a**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**24**	**25**	**26**	**Open River Reach**	**La Grange Pool**
N	125	125	**125**	125	125	125	125	**125**	125	125	125	125	**125**	125	125	125	125	125	125	125	125	125	125	125	**125**	125	**125**
2004			X					X					X												X		X
2005			X					X					X												X		X
2006			X					X					X												X		X
2007			X					X					X												X		X
2008			X					X					X												X		X
2009			X					X					X												X		X
2010			X					X					X												X		X
2011			X					X					X												X		X
2012			X					X					X												X		X
2013			X					X					X												X		X
2014			X					X					X												X		X
2015			X					X					X												X		X
2016			X					X					X												X		X
2017			X					X					X												X		X
2018			X					X					X												X		X
2019			X					X					X												X		X
2020			X					X					X												X		X
2021			X					X					X												X		X
2022			X					X					X												X		X
2023			X					X					X												X		X
2024			X					X					X												X		X
2025			X					X					X												X		X
2026			X					X					X												X		X

An “X” or gray box indicates sampling in that pool and year at the sample size (N) indicated in the first row.

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13. ABSTRACT (Maximum 200 words) The need for effective monitoring programs to detect population status and trends and to measure the effectiveness of management actions has been voiced by a number of management agencies. It is prudent for any long-term monitoring program to periodically undergo evaluation. In 2002, an evaluation of the Long Term Resource Monitoring Program (LTRMP) macroinvertebrate component was begun to determine whether its current design was still appropriate based on LTRMP objectives, partner needs, and expected funding levels. The following report discusses the history and sampling design of the component and the results of an evaluation survey and workshop conducted with LTRMP partners. The survey and workshop were the first steps to help assess general support and identify issues or concerns about the macroinvertebrate component. Suggestions for a future design of the macroinvertebrate component include the continuation of monitoring soft-sediment macroinvertebrates and the addition of long term monitoring of native mussels.			
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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.