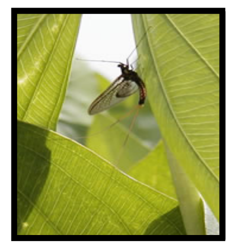
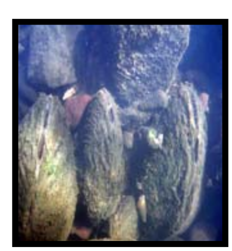
UPPER MISSISSIPPI RIVER AQUATIC LIFE DESIGNATED USES

IMPROVING PROTECTION UNDER THE CLEAN WATER ACT

February 2012

Upper Mississippi River Basin Association





Upper Mississippi River
Aquatic Life Designated Uses:
Improving Protection under the Clean Water Act

February 2012

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Executive Summary

BACKGROUND

Designated uses (e.g., aquatic life support, drinking water, and contact recreation) are a foundational component of Clean Water Act (CWA) water quality standards. Under the CWA, water quality criteria are developed, monitoring is conducted, and assessments are made to determine whether designated uses are being attained. Therefore, the assignment and definition of designated uses plays a central role in characterizing and protecting waterbody health under the CWA.

The states of Illinois, Iowa, Minnesota, Missouri, and Wisconsin assign a number of designated uses to the Upper Mississippi River (UMR). UMR designated uses vary among the states, though there are some similarities in the major uses (i.e., aquatic life, drinking water, and contact recreation) assigned. However, the application of current designated uses does not always reflect the UMR's unique character as a large, diverse, modified, floodplain ecosystem – nor does it capture the River's diversity in water chemistry, physical conditions, and biological communities. As a result, these uses may not provide for optimized, or even adequate, UMR water quality protection. Therefore, the Upper Mississippi River Basin Association (UMRBA) Water Quality Executive Committee (WQEC) directed the UMRBA Water Quality Task Force (WQTF) to examine UMR designated use approaches in order to identify opportunities for improving interstate consistency and water quality protection.

The WQTF's designated use work began with a detailed examination of aquatic life uses, as described in this report. The aquatic life focus was chosen because: 1) all the states assign an aquatic life use to the UMR, 2) aquatic life use assessments are typically the most broadly-based CWA waterbody assessments and therefore often act as drivers of water quality assessments in general, and 3) this appears to be where the greatest need exists to better reflect the diverse characteristics of the UMR in the states' regulatory approaches, and therefore where there is the greatest potential benefit from any modifications.

This report documents the WQTF's aquatic life uses investigation and includes findings and recommendations related to these uses and other CWA program components. It is intended primarily for use by the states, as well as US EPA, in their ongoing efforts to improve water quality protection on the UMR. Others with an interest in the River's water quality and ecosystem health may also find value in this report.

PROJECT APPROACH

The WQTF took a stepwise approach in its examination of aquatic life uses as follows:

- **Review the states' current approaches** to designated uses generally and aquatic life uses specifically, as well as the related CWA components of criteria, monitoring, and assessment. This step addressed the question: *"Are there shortcomings in the states' current approaches to aquatic life uses on the UMR and, if so, are there opportunities to improve those approaches?"*
- **Identify major considerations** regarding any potential modifications to aquatic life designated uses. This step asked the question: *"What factors should be kept in mind when examining UMR aquatic life uses and in making recommendations for their modification?"*
- **Examine chemical, physical, and biological data** to detect patterns relevant to aquatic life uses. This step asked the question: *"Are the aquatic life communities on the UMR distinct enough in their characteristics to merit differentiation of aquatic life uses in a Clean Water Act context?"*
- **Make recommendations for next steps related to UMR aquatic life uses**, based on the information gathered in the preceding steps.

FINDINGS

1) Regarding States' Current Approaches and Opportunities for Improvement:

- The states do not share common aquatic life use definitions, water quality criteria, monitoring strategies, or assessment protocols on the UMR.
- Although there are some similarities among the states, accumulated differences in use definitions, criteria, monitoring, and assessment methodology frustrate the ability to comprehensively and consistently characterize UMR aquatic life health. This also creates challenges in communication among agencies and with the public at large.
- The states' CWA impaired waters lists indicate relative agreement that much of the UMR main channel is attaining its assigned aquatic life use. However, because the states' approaches are not adapted to the unique characteristics of the UMR and biological measures are largely absent from UMR CWA assessment, this may not be an accurate characterization of the health of the River's aquatic life.
- Opportunities for improvement include:
  - Seeking greater consistency in states' UMR aquatic life use definitions and more explicit aquatic life protection goals in these definitions.
  - Addressing spatial and temporal distinctions in chemical, physical, and biological characteristics within UMR aquatic life designated uses. This would facilitate the states' adoption of criteria, including biological metrics, specifically suited to protect certain river habitats.
  - Evaluating the ability of existing monitoring programs to support assessment of current and potentially revised aquatic life uses and considering how modified aquatic life uses might impact monitoring needs.

2) Regarding Major Considerations in Examining UMR Aquatic Life Uses:

- Readily available information indicates significant physical, chemical, and biological diversity on the UMR, in both spatial and temporal contexts.
- Information sources most relevant for examining UMR aquatic life uses are the US Army Corps of Engineers' (USACE) Environmental Management Program Long Term Resource Monitoring (LTRM) component and US Environmental Protection Agency's (US EPA) Environmental Monitoring and Assessment Program – Great Rivers Ecosystems (EMAP-GRE) survey.
- Approaches used to designate and assess aquatic life uses in the Chesapeake Bay, Delaware River, and Ohio River contain elements relevant for consideration in regard to UMR aquatic life uses.

3) Regarding Patterns Demonstrated in Chemical, Physical, and Biological Data:

- Longitudinal distinctions exist for a number of chemical and physical parameters on the UMR, including temperature, dissolved oxygen, total suspended solids, turbidity, and nutrients. Longitudinal distinctions also exist for biological communities, including fish and vegetation. Specific observations include:
  - Upper LTRM study reaches (Pools 4, 8, and 13) are distinct from lower LTRM study reaches (Pool 26 and Open River) with regard to several water quality and biological parameters.
  - Lake Pepin has a unique effect in reducing suspended solids and associated contaminants due to settling, creating a notable discontinuity in longitudinal water quality gradients.

- Excursions from "threshold values" (i.e., currently applicable water quality criteria and other values used for comparison purposes within this report) for parameters including temperature, turbidity, total suspended solids, and total phosphorus, become more common in the UMR's lower reaches, though the thresholds selected for this report may not necessarily be the most relevant benchmarks in the lower river.
- Ordination and cluster analyses of chemical, physical, and biological data indicate three to four longitudinal groupings for the UMR.

- There are differences across lateral strata for a number of chemical and physical parameters, and in some cases between groups of strata (e.g., contiguous backwater and impounded versus main channel and side channel). Biological communities, both fish and vegetation, also show differences among strata for several metrics (e.g., species richness, frequency of occurrence). Specific observations include:
  - Excursions from threshold values for some parameters (e.g., temperature, dissolved oxygen, pH) occur most frequently in backwaters and impounded areas.
  - Cluster analyses of LTRM chemical/physical data and ordination analyses of LTRM biological data indicate some distinctions among UMR strata (main channel, side channel, contiguous backwater, and impounded). Therefore, these strata should be considered separately in a CWA context, at least as a starting point for future work.
  - Of the strata, the main channel and side channel demonstrate the most similarities, particularly in terms of chemical and physical parameters.
- Temporal patterns, both seasonal and year-to-year, are prominent. Of note:
  - Water quality characteristics and trends can vary greatly by season and flow condition.
  - Extreme and periodic events such as floods and droughts can temporarily and markedly affect water quality condition. Many of the UMR's biological assemblages have adapted to this type of periodic disturbance. These dynamics are relevant in developing and using water quality criteria to assess UMR aquatic life use attainment.
  - Long term system changes (e.g., due to invasive species or climate change) may trigger a need to revisit aquatic life use expectations regarding biological assemblages and associated water quality criteria.
- Several key parameters (e.g., suspended solids, transparency, temperature, velocity, nutrients, depth, and dissolved oxygen) greatly influence the occurrence and health of UMR biological communities. The most important parameters may vary by the type of community and longitudinal/lateral strata. Observations regarding key parameters include:
  - Some commonly-monitored water quality parameters (e.g., suspended solids, transparency) correlated with biological community health often do not have numeric criteria in state water quality standards.
  - However, in some cases, the water quality criteria that do exist are not necessarily accurate predictors of biological community health. For example, several UMR locations demonstrate excursions from water quality criteria in some seasons and strata (e.g., pH and dissolved oxygen in backwaters and impounded areas), but biological monitoring indicates that these same locations often support a relatively natural and healthy fish community.
- **Overall, UMR aquatic life communities, as well as associated chemical and physical parameters, are distinct enough in their spatial and temporal variations to merit differentiation of aquatic life use designations in a Clean Water Act context.**

RECOMMENDATION: UMR CWA CLASSIFICATION STRUCTURE

The UMRBA WQTF recommends a new UMR classification structure to address the distinctions identified in chemical, physical, and biological data. This structure is a framework to aid states in defining aquatic life expectations, developing a monitoring strategy, setting criteria, and conducting assessments.

The proposed UMR CWA classification structure is illustrated in the following figure. This structure includes four longitudinal reaches that reflect the "floodplain reach" definitions used in other UMR programs, while adding a reach to address considerable water quality changes at the base of Lake Pepin. The classification structure also includes four lateral strata, which match LTRM aquatic sampling strata. Isolated backwaters/wetlands are not addressed in this structure, but may be considered in future work.

UMR CWA Classification Structure Recommendation

	Lateral Strata				
Longitudinal Reaches		**Main Channel**	**Side Channel**	**Impounded**	**Contiguous Backwater**
	St. Croix River				
	Upper Impounded to Chippewa River *CWA Assessment Reach 1[*]*				
	Chippewa River (base of Lake Pepin)				
	Upper Impounded below Chippewa River *CWA Assessment Reaches 2-6*				
	Lock and Dam # 13				
	Lower Impounded *CWA Assessment Reaches 7-11*				
	Missouri River				
	Unimpounded (Open River) CWA Assessment Reaches 12-13			*(Not Applicable)*	
	Ohio River				

[*] The UMR states have agreed to a minimum set of 13 UMR CWA assessment reaches defined by eight-digit hydrologic unit codes.

NEXT STEPS

The WQTF recommends the following next steps to implement the UMR CWA classification structure:

- **Incorporate the Classification Structure.** Each state should consider how best to incorporate this structure into its CWA program, and into its water quality standards specifically.
- **Design and Implement a Monitoring Strategy.** Developing a comprehensive CWA monitoring strategy is a top priority for the states in the context of a UMR classification system. A monitoring strategy should address all of the identified UMR classes and include chemical, physical, and biological metrics. It should support not only CWA assessment and listing, but also water quality criteria development.

- **Identify Water Quality Criteria.** Chemical, physical, and biological criteria will need to be identified for each class that are both protective of aquatic communities and, in the case of biological criteria, descriptive of the expectations for aquatic life.
- **Develop an Assessment Methodology.** An assessment methodology is needed that reflects the classification structure and describes how monitoring results will be compared to criteria to determine attainment. This methodology can then support comprehensive and consistent UMR aquatic life assessment.

CONSIDERATIONS IN MOVING FORWARD

As the states move forward, the following should be considered:

- **Need to Revisit and Revise.** This report documents initial steps to aid the states in improving their approaches to aquatic life protection on the UMR. It is fully anticipated that, as the states gain experience in implementation, and obtain new information, they may wish to revisit their approaches, including the classification structure. However, the fact that future changes may be needed should not deter the states from moving forward with the report's recommendations at this time.
- **Differences Among States.** As the states proceed in integrating a UMR classification structure, and implementing related changes in monitoring, criteria, and assessment, they may be at different levels of readiness to proceed. Therefore, the pace at which individual states integrate modifications will vary.
- **Resource Needs and Constraints.** The recommendations and next steps presented here represent an ambitious, but attainable, reinvention of the states' approaches to CWA aquatic life use protection on the UMR. The states and US EPA will need to consider whether current resources are adequate to carry out these efforts. If they are not, it will be critical to identify resource needs and suggest options to address them.

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Chapter 1:
Introduction

THE UPPER MISSISSIPPI RIVER: THE NATURAL RESOURCE

The River and Its Importance

The Mississippi River, one of the world's great rivers and its third largest, fulfills a number of important environmental, recreational, economic, and cultural roles. This complex interstate waterbody starts at Lake Itasca in northern Minnesota and flows over 2,300 miles along 10 states to the Gulf of Mexico, drawing 41 percent of the land mass of the continental United States into its basin.

Figure 1-1: The Upper Mississippi River Basin and Tributaries

The Upper Mississippi River (UMR) is that portion of the Mississippi River above the confluence with the Ohio River, which includes an 812-mile interstate segment along the border of five states – Illinois, Iowa, Minnesota, Missouri, and Wisconsin. The UMR was recognized by Congress as "a nationally significant ecosystem and a nationally significant commercial navigation system" in the Water Resources Development Act of 1986. In addition, the Upper Mississippi River Floodplain Wetlands were recognized in January 2010 by the Ramsar Convention as a Wetland of International Importance.

Along its length, the UMR changes dramatically in physical structure, flow, and water quality. It is also greatly influenced by land use throughout its 189,000 square mile basin. Above the Quad Cities the UMR has a complex floodplain structure including the main channel, side channels, backwaters, and impounded areas. Further downstream there is less channel diversity, and levees separate much of the river from its floodplain. Twelve major UMR tributaries, including the Illinois, Iowa, Missouri, and Wisconsin rivers, as well as numerous smaller tributaries, significantly influence UMR water quality and flow. UMR nutrient, sediment, and other pollutant levels are directly affected by contributions from tributaries, which in turn are influenced by land use basin-wide. As tributaries and runoff add to the river's flow, average annual discharge increases from approximately 9,200 cubic feet per second (cfs) at St. Paul, Minnesota to 205,000 cfs at Thebes, Illinois.

The UMR hosts many wildlife species, including over 300 migratory bird, 150 fish, 50 mammal, and 30 mussel species. In addition, the UMR provides critical habitat for 36 federally-listed or candidate species of rare, threatened or endangered plants and animals. Approximately 300,000 floodplain acres are within the National Wildlife Refuge System, and states manage roughly 140,000 additional acres.

These abundant natural resources help draw over 12 million people annually to fish, swim, boat and recreate on the UMR.

In addition to being a vital natural resource, the UMR is also a critical commercial corridor and irreplaceable water source. Twenty-nine locks and dams help support the shipping of over 110 million tons of commodities per year. Well over 2 million people rely directly on the UMR as a source for drinking water and the river also supplies water to numerous power plants and other industrial operations along its banks. Approximately 50-60% of the UMR floodplain is in agricultural production, providing food for people and livestock locally, nationally, and internationally.

Modifications to the River and Its Floodplain

Over the last 150 years, the UMR and its floodplain have been substantially altered for navigational, agricultural, industrial and economic purposes. Alterations have included the construction of navigational locks and dams, maintenance of a 9-foot navigation channel, levee construction, installation of channel training structures, connection to the Great Lakes via the Illinois River, point source discharges, urban growth, and the conversion of floodplain to agricultural use. While these modifications support a variety of important river and floodplain uses, they have also adversely impacted the river and its ecosystem. Impacts have included a modified hydrologic regime, loss of floodplain forests, increased nutrient loading, altered sediment flow, and the introduction of invasive species

Ongoing Water Quality and Ecosystem Challenges

In recent decades, UMR water quality has benefited from implementation of the Clean Water Act (CWA), including improved control and treatment of point source pollution, and enhanced agricultural conservation practices. Ecosystem restoration projects managed by the US Army Corps of Engineers (USACE) have also been put in place to help restore the river's ecosystem functions. However, a number of significant challenges remain. The condition of the river is often characterized as improved compared to pre-CWA conditions, but still threatened on a number of fronts (National Academy of Sciences 2008, Johnson and Hagerty 2008, UMRCC 2000).

Frequently-cited UMR water quality concerns include: 1) elevated nutrient levels throughout the system, and 2) excess sediment in the river's upper reaches, including elevated suspended sediment levels and high sedimentation rates in some backwaters and side channels (National Academy of Sciences 2008, Johnson and Hagerty 2008, UMRCC 2000). Additionally, water quality problems associated with "legacy" contaminants (e.g., PCBs) and metals (e.g., mercury) continue to be identified in a number of areas on the river, particularly in regard to their accumulation in fish tissue. Finally, emerging contaminants such as personal care products, pharmaceuticals, and perfluorochemicals present potential challenges to UMR water quality.

In sum, while the water quality of the UMR has improved in recent decades, there remains much important work to be done in addressing unresolved and emerging issues while protecting the water quality gains made to date. Additionally, some factors contributing to ongoing UMR water quality challenges, such as locks and dams and nonpoint source pollution, may be outside the direct purview of CWA programs. It is important for UMR water quality managers to be aware of these factors, as well as the constraints and opportunities they present in protecting and improving UMR water quality.

THE UMR AND THE CLEAN WATER ACT

CWA History and Framework

For both interstate and intrastate waters, the CWA is the regulatory cornerstone of water quality protection nationwide. According to CWA Section 101, the statute's objective is to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." Since 1972, the CWA has led to the establishment of water quality standards, control of point source discharges, tracking of water quality changes over time, and identification of polluted areas in need of additional protection. Much of the improvement in UMR water quality, and the nation's waters generally, since 1972 can be attributed to the implementation of the CWA.

Under the CWA, US EPA and the states share responsibility for protecting, maintaining, and restoring water quality. In general, states designate specific uses for their waters, establish criteria designed to protect those uses, control various pollution sources through both regulatory and non-regulatory measures, and monitor and assess water quality on an ongoing basis. States must also submit biennial water quality assessment reports under CWA Section 305(b) and lists of impaired waters under Section 303(d), then taking appropriate actions to protect and restore those impaired waters. US EPA's role includes state program oversight, establishing minimum national standards and approval authority over state standards and 303(d) impaired waters lists. State water quality agencies in Illinois, Iowa, Minnesota, Missouri, and Wisconsin, along with US EPA Regions 5 and 7, are responsible for CWA implementation on the UMR.

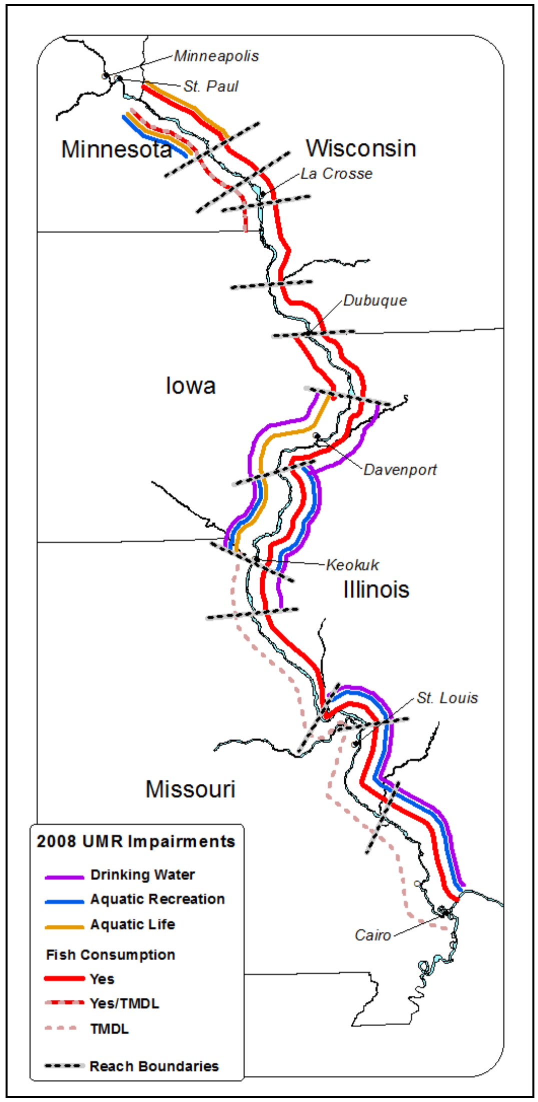

Figure 1-2: Comparison of States' 2008 UMR Impairment Listings

Challenges in Interstate CWA Implementation on the UMR

The UMR's enormous scale, complexity, and diversity, as well as basin-wide influences and system modifications, present numerous challenges in water quality management. Adding to this is the River's status as a boundary among five states, which increases the difficulty of implementing the CWA. The cross-jurisdictional issues raised in this context are inherent in a regulatory system that is designed to establish a national framework while also providing the states flexibility to implement that framework in a manner that meets their individual needs and circumstances.

Each state implements the CWA independently on the UMR. While there are many commonalities among the states' in their CWA implementation on the UMR, there are also significant differences in designated uses, water quality criteria, monitoring, assessment methodologies and impairment listings. As a result, bordering states may characterize the condition of a shared river reach quite differently. This is illustrated in a comparison of the states' CWA impairment listings for the UMR (see Figure 1-2). Disparities in impairment listings can create a mixed message for stakeholders and the public at large, as well as disparate regulatory expectations (e.g., for TMDLs and permits) among states and for regulated entities.

Importance of Collaboration in CWA Implementation

In light of the challenges posed by interstate waters, the CWA includes provisions for interstate consultation and coordination regarding specific actions in several instances. Additionally, CWA Section 103 offers the following general guidance, directing US EPA to:

> *"…encourage cooperative activities by the State for the prevention, reduction, and elimination of pollution, encourage the enactment of improved and, so far as practicable, uniform State laws relating to the prevention, reduction, and elimination of pollution; and encourage compacts between States for the prevention and control of pollution."*

UMRBA's Water Quality Task Force (WQTF) and Water Quality Executive Committee (WQEC) – working under UMRBA's Board of Directors – provide important, ongoing forums for interstate collaboration in CWA implementation on the UMR. UMRBA was established in 1981 by the UMR Governors to facilitate dialogue and cooperative action among the five states and to work with federal agencies on inter-jurisdictional river programs and policies, including water quality programs.

The UMR Governors articulated their vision for CWA collaboration via UMRBA in an August 2007 statement as follows:

> *"We are committed not only to the protection of the River's water quality, but we are also committed to doing so in a coordinated manner….We are therefore supporting the coordination of water quality monitoring, assessment, and standards for the Upper Mississippi River by the States of Illinois, Iowa, Minnesota, Missouri, and Wisconsin and the Upper Mississippi River Basin Association. This approach will allow the Clean Water Act to be implemented on the Upper Mississippi River in a more coordinated and consistent fashion than has ever been possible previously."*

In keeping with the Governors' vision, the WQTF and WQEC have sought to improve both interstate consistency and water quality outcomes through their collaborative efforts.

Opportunities for Improving Consistency and Protection via Designated Uses

There are several areas within state CWA water quality programs where greater consistency and protection for the UMR could be achieved, including water quality criteria, designated uses, monitoring, assessment methodology, and impairment listing decisions. The WQTF has addressed a number of these elements in its work, including establishing minimum assessment reaches, examining states' approaches to fish consumption advisories and reviewing sediment-related water quality criteria, as well as ongoing consultations regarding 303(d) impairment listings (see Table 1-1).

Table 1-1: UMRBA Water Quality Task Force Recent Projects

CWA Element	Component	Project	Completed
Water Quality Standards	Designated Uses	Aquatic Life Designated Uses	Current
	Water Quality Criteria	Review of Sediment-Related Water Quality Criteria	2007
		Biological Assessment	2011
Methodology	Data Standards/ Data Sharing	Review of Fish Consumption Advisories	2005
		Ongoing Consultation	Ongoing
	305(b) Assessment	Setting Uniform Minimum Assessment Reaches	2003
		Review of Fish Consumption Advisories	2005
		Biological Assessment	2011
	303(d) Listing	Review of Fish Consumption Advisories	2005
		Ongoing Consultation	Ongoing

In 2007, the WQEC asked the WQTF to begin an examination of the designated uses assigned to the UMR. The WQEC felt that addressing this foundational component of water quality standards would not only promote interstate consistency, but also provide the opportunity to best protect the UMR by improving the fit of water quality standards to the resource. The remainder of this report summarizes the WQTF's subsequent examination of aquatic life designated uses in particular.

Chapter 2:
Why Examine UMR Aquatic Life Designated Uses?

ROLE OF DESIGNATED USES IN CWA WATER QUALITY STANDARDS

Water Quality Standards Framework

US EPA issued water quality standards regulations in 1983 to implement objectives of the CWA and provide water quality capable of supporting “the protection and propagation of fish, shellfish and wildlife, and provide for recreation in and on the water” whenever attainable, per CWA §101(a)(2). States and authorized Indian tribes have the primary responsibility for developing and implementing water quality standards that protect public health and welfare, enhance water quality, and define water quality goals for their waterbodies. US EPA provides guidance to states, and reviews and has approval authority for new and revised state water quality standards.

Water quality standards must contain the following three major elements: 1) designated uses for waterbodies, 2) numeric or narrative criteria to protect those uses, and 3) anti-degradation policies. In brief, the components play the following roles in water quality standards[1]:

- **Designated uses** are those uses that states and US EPA determine should be attained in a waterbody. Designated uses reflect the public’s answer to the question, “To what uses do we, or might we want to, put this waterbody?” The uses therefore set the goals for the waterbody in the most general sense, even though the uses may already be attained. Examples of designated uses include aquatic life, drinking water, contact recreation, and fish consumption.
- **Water quality criteria** are descriptions of the conditions needed to support the designated uses for a waterbody. These can be expressed as numeric concentrations of pollutants or physical characteristics (such as temperature or pH), biological indices, or other quantitative measures. They can also be expressed as narrative statements.
- **Anti-degradation policies** set the rules to be followed when a proposed activity could lower the quality of a high quality water (one which are already exceeds conditions necessary to meet designated uses).

Foundational Role of Designated Uses

Of the three major components of water quality standards, designated uses can be seen as perhaps the most foundational. US EPA’s publication, *Use of Biological Information to Better Define Designated Aquatic Life Uses in State and Tribal Water Quality Standards* (US EPA 2005), states:

> *“The use of a waterbody is the most fundamental description of its roles in the aquatic and human environments. All of the water quality protections established by the CWA follow from the waterbody’s designated use. As designated uses are critical in determining the water quality criteria that apply to a given waterbody, determining the appropriate designated use is of paramount importance in establishing criteria that are appropriately protective of that designated use.”*

Accordingly, the UMRBA WQEC and WQTF identified designated uses as a primary area to examine opportunities for greater consistency and improved UMR water quality protection.

[1] Descriptions adapted from US EPA Watershed Academy presentations.

STATES' APPROACHES TO UMR DESIGNATED USES

States' Current Approaches to UMR Designated Uses

The states, with US EPA approval, assign designated uses to the waters within their jurisdiction. Generally, states will designate all waters for aquatic life and recreation uses unless those uses are proven unattainable. This approach derives from the goal stated in CWA §101(a)(2) of "water quality which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water." In addition, CWA §303(c)(2)(A) says that water quality standards "…shall be such as to protect the public health or welfare, enhance the quality of water and serve the purposes of this Act" and that other uses including public water supply and navigation need to be considered in setting standards. The states therefore often assign several uses to a waterbody in addition to aquatic life and recreation.

States have generally followed the approach described above in assigning designated uses to the UMR. Each state has designated the length of the UMR for aquatic life use and contact recreation uses[2], with specific descriptions of these major uses varying by state. Other uses widely assigned to the UMR are drinking water and fish consumption. However, only three states assign a drinking water use and fish consumption is not always an explicitly defined use and may be part of aquatic life or public health designated uses. Table 2-1 lists the uses assigned to the UMR using generic terminology for the major uses of aquatic life, contact recreation, drinking water, and fish consumption.

Table 2-1: Comparison of Major Designated Uses for the Upper Mississippi River[a]

State	Reach of UMR within State	Aquatic Life	Contact Recreation	Drinking Water	Fish Consumption[d]
Illinois	Entire UMR	X	X[c]	X	X
Iowa[b]	Minnesota Border — Lock and Dam 14	X	X		X
	Lock & Dam 14 — Lock & Dam 15	X	X	X	X
	Lock & Dam 15 — Iowa River	X	X		X
	Iowa River — Burlington water intake	X	X	X	X
	Burlington water intake — Skunk River	X	X		X
	Skunk River — Missouri Border	X	X	X	X
Minnesota	Entire UMR	X	X		X
Missouri	Entire UMR	X	X[c]	X	X
Wisconsin	Entire UMR	X	X		X

a The designated use descriptions are generalized and thus vary somewhat from the specific language used by states to define uses.
b Iowa assigns its drinking water use only to points of drinking water intake.
c Primary contact recreation is not currently designated for a 7-mile segment in IL and 28-mile segment in MO.
d Fish consumption is not always a stand-alone use, but can be part of aquatic life or human health protection use. However, all UMR states assess for fish consumption, and it is therefore listed here as a "major use."

As indicated by Table 2-1, the UMR states are in general agreement in the assignment of several major uses to the river. However, when the specific terms used to define each state's designated uses are considered, differences between states emerge. Table 2-2 summarizes designated uses assigned by the UMR states as written in their respective water quality standards.

[2] Finalization of the primary contact recreation use in the St. Louis area (28 miles) for Missouri is pending. Primary contact use is not applied in a seven-mile segment on the Illinois side of the river near Sauget due to a state approved disinfection exemption.

Table 2-2: Current Designated Uses on UMR, as Listed in State Standards and Rules

State and Designated Uses (right descending)		State and Designated Uses (left descending)
Minnesota - Aquatic life and recreation - Industrial consumption - Agriculture and wildlife - Aesthetic enjoyment and navigation - Other	MISSISSIPPI RIVER	**Wisconsin** - Fish and other aquatic life (warm water sport fishery) - Recreation - Public health and welfare - Wildlife
Iowa - General use (includes livestock and wildlife watering, aquatic life, non-contact recreation, crop irrigation, industrial, domestic and other water withdrawal uses) - Primary contact recreation - Warm water aquatic life - Human health protection (fish consumption and drinking water) - Drinking water supply (intake areas only)		**Illinois** - General (includes aquatic life, agricultural, secondary contact, industrial, primary contact where physical configuration permits such use – note disinfection exemptions at some permitted outfalls) - Public and food processing water supply
Missouri - Irrigation - Livestock and wildlife watering - Protection of aquatic life (general warm water fishery) - Human health protection (fish consumption) - Whole body contact recreation - Secondary contact recreation - Drinking water supply - Industrial process and cooling water		

Consistency in UMR Designated Uses

As illustrated in Table 2-1 and Table 2-2, evaluating the consistency of UMR designated uses among the states is not a simple matter. While the states do share common, broad categories for major uses, each state names or incorporates these uses in a slightly different manner and also has additional uses. Moreover, as will be discussed later in this chapter, each applies differing criteria and assessment methodologies to evaluate use attainment, which accentuates any differences already present in use definitions.

Application of Designated Uses to the UMR

Two other important aspects regarding the states' application of designated uses by to the UMR are:

- The designated uses assigned by the states to the UMR are typically among those applied to waters statewide. The uses are not defined with the specific conditions or diversity of the UMR in mind.

- States currently base their CWA 305(b) assessments and 303(d) impairment listings for the UMR primarily on monitoring data from the main channel. States typically do not attempt to assess other UMR aquatic areas. There has not been an explicit system-wide attempt, until this project, to determine whether the states' existing designated uses and criteria are appropriate for other UMR aquatic areas.

Summarized Observations Regarding States' Current Approaches to UMR Designated Uses

The following summary observations can be made regarding the states' approaches to UMR designated uses:

- All of the states assign aquatic life, contact recreation, and fish consumption uses to the UMR. However, differing terminology is used to describe these uses in each state's standards.
- Fish consumption is not explicitly named as a separate designated use in all states, though all states assess the degree to which their fish consumption uses are supported.
- Drinking water use is applied river-wide for in Illinois and Missouri, at intake locations in Iowa, and not at all in Minnesota and Wisconsin (which do not have potable water intakes on the UMR).
- UMR designated uses assigned to the UMR are drawn from categories applied statewide (i.e., there are no uniquely defined uses for the UMR).
- The effective applicability of the designated uses for CWA reporting purposes is typically for the main channel of the UMR only.
- The application of differing criteria and assessment methodologies to designated uses within each state can accentuate discrepancies among states.

Implications of the States' Current Approaches to CWA Designated Uses

Although the major designated uses assigned to the UMR are generally similar, there are a significant number of disparities that result not only in definitional differences, but also in differences in CWA outcomes. While variations in designated uses are not the only cause of inconsistency between states in UMR CWA assessment outcomes (for example, different water quality criteria and assessment methodologies also contribute), any differences in state specific terminology and use assignment can ultimately contribute to inconsistencies in the assessment of the UMR in terms of meeting CWA goals.

The variety of terminology and assessment methodologies can also frustrate the ability of the states and US EPA to communicate clearly amongst themselves and with the public about UMR water quality, even if the states' CWA assessments are in general agreement regarding its condition. As such, the current approaches to designated uses on the UMR do not effectively encourage interstate consistency and transparency.

Moreover, the current, state-specific designated uses applied to the UMR were not developed with the River's unique character as a large, diverse, modified floodplain ecosystem in mind. Therefore, they may not provide optimized or even adequate protection of the resource and its multiple uses. For example, current use assignments may not recognize important longitudinal trends in water quality or aquatic community composition along the length of the River. Also, the current set of designated uses do not account for any lateral differences in water quality and ecosystem function between flowing channel, off-channel, and impounded areas of the UMR.

FOCUSING ON UMR AQUATIC LIFE DESIGNATED USES

Rationale for Focusing on Aquatic Life Designated Uses

As described in the preceding section, there are a number of uses assigned by the states to the UMR. There could be benefit in examining any or all of these to improve interstate assessment consistency and water quality protection. However, the WQTF chose to focus initially on aquatic life designated uses for the following reasons:

- An aquatic life use is currently assigned in some form to the entire UMR.
- Aquatic life use assessments are generally the most broadly-based CWA waterbody assessments and therefore often act as the drivers of CWA water quality assessments.
- This appears to be the use where the greatest need exists to better match the diverse characteristics of the UMR to the states' regulatory approaches, and therefore where there might be the greatest benefits from any potential modifications in aquatic life use approaches.

Some of the potential benefits of examining and modifying the state's aquatic life use on the UMR include:

- Identifying shared UMR aquatic life protection goals among the states.
- Adapting water quality standards to the unique nature and diversity of the river, leading to better protection of the resource (e.g., better ability to identify and address water quality problems in habitats other than the main channel, such as backwaters).
- Improving the ability of the states to accurately assess whether UMR aquatic life goals are being attained.
- Improving the ability to communicate to the public regarding the UMR's condition and how the CWA helps protect valued UMR resources.
- Facilitating the use of improved, spatially and seasonally appropriate water quality criteria, including biological criteria, for aquatic life use protection.
- Improving connections to UMR ecosystem restoration efforts and data collected under these efforts, such as Long Term Resource Monitoring (LTRM) data; possibly leading to greater congruence in the characterization of the UMR between ecosystem restoration and CWA programs.
- Enhancing the understanding of the UMR's diversity and dynamics among state and federal water quality program staff.
- Contributing to greater consistency in the states' 303(d) impaired waters listings for the UMR as related to aquatic life use attainment.

Timeliness of Examining Aquatic Life Designated Uses

State's designated uses have been in place on the UMR for many years. However, with an ever increasing volume of data and information becoming available for the UMR, and a number of new assessment tools being developed, it is now possible to describe and assess aquatic life uses in a more meaningful way than previously achievable.

US EPA's *Use of Biological Information to Better Define Designated Aquatic Life Uses in State and Tribal Water Quality Standards* (US EPA 2005), states the need for aquatic life uses to evolve with improved availability of information as follows:

"During the 1970s, the biological goals adopted into State or Tribal water quality standards as designated aquatic life uses may have been appropriately general (e.g., "aquatic life as naturally occurs") given the limited data available and the state of the science. However, while such general use classifications meet the requirements of the CWA and the implementing federal regulations, they may constitute the beginning, rather than the end, of appropriate use designations. Improved precision may result in more efficient and effective evaluation of attainment of condition and utilization of restored services."

The timing of this examination of aquatic life uses also dovetails with two other recent projects of the WQTF; one to examine biological assessment tools and the other to review UMR nutrient occurrence, monitoring, and impacts.

STATES' APPROACHES TO UMR AQUATIC LIFE DESIGNATED USES

In order to best understand how the states approach aquatic life protection under the CWA, it is necessary to examine not only designated uses, but also the water quality criteria, monitoring, and assessment methodologies used to determine if uses are attained. Accordingly, all of these elements are addressed in the following sections.

State Aquatic Life Use Definitions and Assignments to the UMR

Each state assigns an aquatic life use to the UMR and these uses are generally applied to the entirety of the UMR adjacent to that state. Table 2-3 lists the definitions of aquatic life uses assigned by the states to the UMR, as given in their respective regulations.

In each of the states' regulatory definitions, some description of the aquatic community to be protected is given. Table 2-4 extracts these specific references for easier comparison across the states. In general, the states share a focus on warm water communities and sport fisheries. Typically, each state adds more breadth to its definition via references to game, nongame, or forage fish, habitat, or other aquatic community types (e.g., macroinvertebrate). However, none of the definitions list specific habitats, species or groups to be protected.

Table 2-3: States' Definitions for Aquatic Life Uses Applied to the UMR

State	Use Name	Definition/Description in State Rule	Details/Comment	State Rule
Illinois	General (includes Aquatic Life)	*Purpose*: The **General Use** standards will protect the State's water for aquatic life (except as provided in Section 302.213), wildlife, agricultural use, secondary contact use and most industrial uses and ensure the aesthetic quality of the State's aquatic environment. Primary contact uses are protected for all General Use waters whose physical configuration permits such use. "Aquatic Life" means native populations of fish and other aquatic life.	The UMR is assigned to the General Use category as default (i.e., it has not been assigned to a different use category). Aquatic life use is a subset of the General Use category.	Illinois Administrative Code Section 301.220 and 302.202
Iowa	Aquatic Life (Warm Water Class B (WW-1))	**Warm water—Type 1 (Class "B(WW-1)").** Waters in which temperature, flow and other habitat characteristics are suitable to maintain warm water game fish populations along with a resident aquatic community that includes a variety of native nongame fish and invertebrate species. These waters generally include border rivers, large interior rivers, and the lower segments of medium-size tributary streams.	Also, at 61.2(2)"d" - The Mississippi River and the Missouri River do not meet the criteria of 61.2(2)"c" but nevertheless constitute waters of exceptional state and national significance. Water quality management decisions will be made in consideration of the exceptional value of the resource.	Iowa Administrative Code 567-61
Minnesota	Aquatic Life and Recreation (Class 2B waters)	**Class 2 waters, aquatic life and recreation**. Aquatic life and recreation includes all waters of the state that support or may support fish, other aquatic life, bathing, boating, or other recreational purposes and for which quality control is or may be necessary to protect aquatic or terrestrial life or their habitats or the public health, safety, or welfare. **Class 2B waters.** The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life, and their habitats.	Per Minnesota Rule 7050.0430, all waters not otherwise classified are placed in Class 2B for aquatic life and recreation.	Minnesota Rules 7050.0140, 7050.222 and 7050.0430
Missouri	Protection of Aquatic Life (Warm Water Fishery)	**Protection of aquatic life (General warm-water fishery**)—Waters in which naturally occurring water quality and habitat conditions allow the maintenance of a wide variety of warm-water biota, including naturally reproducing populations of recreationally important fish species.		Missouri Code of State Regulations 10 CSR 20-7.031 (also Table H)
Wisconsin	Fish and Other Aquatic Life	This subcategory includes surface waters capable of supporting a community of fish and aquatic life which includes cold water, warm water sport fishery, warm water forage fishery, and limited forage fishery.	Wisconsin DNR interprets that "warm water sport fishery" applies to the UMR as it is not placed explicitly in a "higher" or lower category. However, other subcategories could potentially apply in certain aquatic areas. Also, at NR 104.21, a statement that the Mississippi River "…shall meet the standards and requirements for recreational use and fish and aquatic life."	Wisconsin Administrative Code NR 102.04 NR 104.21

Table 2-4: Language Describing Aquatic Life in State Regulations (excerpted from Table 2-3)

State	Description of Aquatic Life/Aquatic Community Given in Use Definition
Illinois	…native populations of fish and other aquatic life.
Iowa	…maintain warm water game fish populations along with a resident aquatic community that includes a variety of native nongame fish and invertebrate species.
Minnesota	…propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life, and their habitats.
Missouri	…maintenance of a wide variety of warm-water biota, including naturally reproducing populations of recreationally important fish species.
Wisconsin	…supporting a community of fish and aquatic life.

Water Quality Criteria Applicable for Aquatic Life Uses

The states' aquatic life use definitions provide a description of *what* to protect but do not address *how* it is protected. The states' water quality criteria help define *how* uses are protected under the CWA, as they describe the conditions needed to support aquatic life. Table 2-5 shows key chemical and physical criteria, as well as narrative criteria, that apply to aquatic life uses assigned to the UMR. While Table 2-5 does not capture the entirety of water quality criteria potentially applicable to aquatic life use protection (i.e., it focuses on parameters for which data is most often available and for which assessments most often done), it does illustrate the following:

- There is no single set of criteria applied by the states to the UMR as a whole or to shared UMR segments.
- Aquatic life use is generally assessed using physical and chemical criteria. There are no specific numeric measures of biological condition, although the narrative criteria of most states do consider biological condition generally.
- There is fairly close agreement in the values used for some criteria (e.g., for dissolved oxygen and pH). However, there are also cases where criteria are not congruent or, more often, where criteria for a certain parameter are in place for one or two states, but not for others (e.g., for aluminum and arsenic).
- Criteria are generally not designed to account for seasonal, lateral, or longitudinal water quality variations on the UMR.

Monitoring

Among the UMR states' CWA agencies, there is a great diversity in the extent of monitoring conducted for CWA assessment purposes. Illinois EPA conducts water quality monitoring at 11 main channel stations on its portion of the UMR. Minnesota PCA and Wisconsin DNR each have three water quality monitoring stations on the UMR and also conduct numerous special studies. Missouri DNR operates one station in conjunction with USGS. Iowa DNR does not have any dedicated CWA water quality monitoring on the UMR. The parameters monitored at each of these main channel stations vary by state, but are generally focused on chemical and physical measurements. The states also share data from these monitoring efforts amongst themselves. However, there is no River-wide, CWA assessment-focused monitoring program or strategy.

Table 2-5: Summary of Key Numeric and Narrative Water Quality Criteria that Apply to Aquatic Life Uses on UMR

Pollutant	Illinois	Iowa	Minnesota	Missouri	Wisconsin
Ammonia Nitrogen	Acute and chronic criteria vary with temperature and pH	Acute and chronic criteria vary with temperature and pH	Acute and chronic criteria vary with temperature and pH	Acute and chronic criteria vary with temperature and pH	Acute and chronic criteria vary with temperature and pH (new rule pending)
Dissolved Oxygen (DO)	3.5 to 5.0 mg/l minimum depending on reach and season	5.0 mg/l minimum	5.0 mg/l daily minimum	5.0 mg/l minimum	5.0 mg/l minimum
Total Mercury	2.6 µg/l acute 1.3 µg/l chronic	1.64 µg/l acute 0.9 µg/l chronic	2.4 µg/l acute 0.69 µg/l chronic 0.20 mg/kg fish tissue	2.4 µg/l acute 0.5 µg/l chronic	0.83 µg/l acute 0.44 µg/l chronic
pH	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0	6.0-9.0
Total Phosphorous	(0.05 mg/l for lakes greater than 20 acres only)	--	--	--	100 µg/L (applicable to main channel and side channel only)
TSS	--	--	32µg/L (site specific, from confluence with Minnesota River to Upper Lake Pepin only -near Minneapolis / St. Paul)	--	--
Turbidity	--	turbidity of the receiving stream shall not be increased by more than 25 NTUs by any point source discharge	25 NTU	--	--
Temperature	Specific for 3 UMR zones by month (August 30-32C)	Specific for 2 UMR zones by month (August 29-30C)	Daily avg. cannot exceed 86F	Specific for 3 UMR zones by month (August 88-89F)	Specific for UMR by month (August 86F)
Narrative	free from sludge, bottom deposits, floating debris, oil, odor, plant or algal growth, color or turbidity other than natural	free from sludge deposits, floating debris, oil, grease, scum, floating material, objectionable color or odor or other aesthetically objectionable conditions, not acutely toxic to human, animal or plant life, undesirable or nuisance aquatic life	not degraded, no increase in slime or aq. plants, no harmful pesticides or residues, fishery and biota not impaired or endangered, species composition not altered, propagation or migration of biota not prevented or hindered, no floating solids, scum, oil, excessive suspended solids, discoloration, odors, gas ebullition, sludge, slimes, fungus growth, habitat degradation, excessive aquatic plants, or other harmful effects	free from harmful bottom deposits, oil, scum, floating debris, unsightly color or turbidity, offensive odor, toxic, impairment to biological community, tires, cars, appliances, debris or equipment	free from objectionable deposits, floating or submerged debris, oil, scum, color, odor, taste or unsightliness, not toxic to humans, not acutely harmful to animal, plant or aquatic life

In addition to data from their own monitoring efforts, UMR state CWA programs rely on data from a number of other monitoring programs, including state fish tissue monitoring programs, fixed site data from the Long Term Resource Monitoring (LTRM), and the USGS' National Stream Quality Accounting Network (NASQAN). While these programs provide very valuable data for CWA assessments, it is important to note that they were not designed to fulfill CWA objectives and therefore do not always provide the exact information sought by CWA programs in terms of parameters monitored, spatial or temporal coverage, or analytical methods. Further discussion regarding the use of data from these non-CWA programs is found in the following section regarding assessment methodologies.

Assessment Methodology

Assessment methodology refers to how states compare available data and information to water quality criteria to determine if designated uses are attained as part of their CWA Section 305(b) assessments. A state's methodology can include an assessment reach segmentation scheme for a water body, determinations of what data will be used, how data are compared to criteria, and the role of best professional judgment in the process. While US EPA has issued Integrated Report (assessment and impairment listing) guidance to the states for CWA assessments (US EPA 2005), this guidance is non-binding and thus each state has its own specific assessment process.

Each state independently performs a UMR CWA assessment (i.e., there is no unified UMR assessment). The states have, however, agreed to a minimum set of 13 interstate UMR assessment reaches delineated by 8-digit hydrologic unit codes. These allow the states to communicate about assessments more easily and compare results more readily (see Table 2-6). However, each state applies its own methodology to assess the portion of the UMR along its border within the 13 reaches.

Each state must determine what data to incorporate into its assessments. US EPA's regulations require that states "assemble and evaluate all existing and readily available water quality-related data and information" in developing their impairment listings (40 CFR 130.7(b)(5)). Also of note for the UMR, US EPA guidance (US EPA 2002) suggests that "if a state shares a waterbody with another state, it must consider existing and readily available data from the state that shares the waterbody." Accordingly, each state seeks out and solicits data for its biennial water quality assessment. Each state then incorporates the data received into its assessments, subject to state credible data rules, and in consideration of whether the state has water quality criteria in place against which the data can be compared. Ultimately, each state uses data from a variety of sources in conducting its CWA assessments. As an example, Table 2-7 summarizes the data sets the states used in their 2008 UMR water quality assessments.

Once a state identifies the data it will use to perform its water quality assessments, it utilizes its assessment methodology to determine whether the aquatic life use is being supported. Often, this includes specifying a percentage of samples that must meet a criterion in order for the waterbody to be placed in a use support category. Table 2-8 summarizes how the states determined aquatic life use support for the 2008 assessment cycle. This table shows similar, though not identical, approaches among the states.

Table 2-6: Minimum UMR Assessment Reaches, per 2003 Memorandum of Understanding

Physical Feature	Minimum Assessment Reaches (by 8-digit HUC code)	River Miles
St. Croix River	**Assessment Reach 1 (Rush-Vermillion)** (St. Croix River to Chippewa River/ HUC 07040001)	**812-763**
Lock and Dam #3		
Chippewa River		
Lock and Dam #4	**Assessment Reach 2 (Buffalo-Whitewater)** (Chippewa River to Lock and Dam 6/ HUC 07040003)	**763-714**
Lock and Dam # 5		
Lock and Dam #5a		
Lock and Dam #6		
Lock and Dam #7	**Assessment Reach 3 (La Crosse-Pine)** (Lock and Dam 6 to Root River/HUC 07040006)	**714-694**
Root River		
Lock and Dam #8	**Assessment Reach 4 (Coon-Yellow)** (Root River to Wisconsin River/HUC 07060001)	**694-631**
Lock and Dam #9		
Wisconsin River		
Lock and Dam #10	**Assessment Reach 5 (Grant-Maquoketa)** (Wisconsin River to Lock and Dam 11/ HUC 07060003)	**631-583**
Lock and Dam #11		
Lock and Dam #12	**Assessment Reach 6 (Apple-Plum)** (Lock and Dam 11 to Lock and Dam 13/ HUC 07060005)	**583-523**
Lock and Dam #13		
Lock and Dam #14	**Assessment Reach 7 (Copperas-Duck)** (Lock and Dam 13 to Iowa River/ HUC 07080101)	**523-434**
Lock and Dam #15		
Lock and Dam #16		
Lock and Dam #17		
Iowa River		
Lock and Dam #18	**Assessment Reach 8 (Flint-Henderson)** (Iowa River to Des Moines River/ HUC 07080104)	**434-361**
Lock and Dam #19		
Des Moines River		
Lock and Dam #20	**Assessment Reach 9 (Bear-Wyaconda)** (Des Moines River to Lock and Dam 21/ HUC 07110001)	**361-325**
Lock and Dam #21		
Lock and Dam #22	**Assessment Reach 10 (The Sny)** (Lock and Dam 21 to Cuivre River/ HUC 07110004)	**325-237**
Lock and Dam #24		
Lock and Dam #25		
Cuivre River		
Lock and Dam #26 (Mel Price)	**Assessment Reach 11 (Peruque-Piasa)** (Cuivre River to Missouri River/ HUC 07110009)	**237-196**
Missouri River		
Kaskaskia River	**Assessment Reach 12 (Cahokia-Joachim)** (Missouri River to Kaskaskia River/ HUC 07140101)	**196-118**
Thebes Gap	**Assessment Reach 13 (Upper Miss-Cape Girardeau)** (Kaskaskia River to Ohio River/ HUC 07140105)	**118-0**
Ohio River		

Table 2-7: State Utilization of Data Sets for UMR 2008 Assessment and Listing Cycle

State	Data Sets Utilized by States in 2008 Assessment and Listing Cycle				
	Own Program-Specific CWA Water Quality Monitoring	Other States' Data	LTRM Water Quality Data (Fixed Site)	USGS NASQAN Data	Other
Illinois	**Yes** (11 stations)	No	**Yes**	**Yes**	
Iowa	No (0 stations)	**Yes**	**Yes**	**Yes**	US EPA/Iowa DNR fish tissue data
Minnesota	**Yes** (3 stations)	**Yes**	**Yes**	N/A	
Missouri	**Yes** (1 station)	**Yes**	**Yes**	**Yes**	USACE, MDC, Fish Tissue, Municipal Water Cos.
Wisconsin	**Yes** (3 stations)	**Yes**	**Yes**	N/A	

Table 2-8: Guidelines for Determining Degree of Aquatic Life Use Support for UMR

State	Full	Full/ Threatened	Partial	Not Supported
Illinois	*Conventional pollutants[1]:* ≤10% of samples exceed standards *Toxic pollutants[2]:* ≤1 violation of acute standards; or <11% of samples exceed chronic standards and sample means do not exceed standards *If <10 samples:* ≤1 violation for all pollutants; 0 violations of acute toxics		*Conventional pollutants:* 11-25% of samples exceed standards *Toxic pollutants:* 2 violations of acute standards; or ≥11% of samples exceed chronic standards and sample means do not exceed standards *If <10 samples:* 2 violations for all pollutants; ≤1 violation of acute toxics	*Conventional pollutants:* >25% of samples exceed standards *Toxic pollutants:* ≥3 violations of acute standards; or ≥11% of samples exceed chronic standards and sample means exceed standards *If <10 samples:* ≥3 violations for all pollutants; ≥2 violation of acute toxics
Iowa	*Conventional and toxic pollutants:* Up to one violation of acute toxicity criteria. Chronic criteria for toxics and criteria for conventional pollutants exceeded in ≤ 10% of samples. *Fish kills:* no pollutant-caused fish kills in most recent 3-year period	Criteria for conventional pollutants or chronic toxicity criteria are exceeded in no more than 10% of samples but levels are trending such that future impairment is likely	*Conventional and toxic pollutants:* Criteria for conventional pollutants or chronic toxicity criteria exceeded in from 11-25% of samples (90% confidence level). *Fish kills:* 1 pollutant-caused fish kill in most recent 3-year period	*Conventional and toxic pollutants:* More than one violation of acute toxicity criteria; or, criteria for conventionals or chronic toxicity criteria exceeded in more than 25% of samples *Fish kills:* >1 pollutant-caused fish kill in most recent 3-year period
Minnesota	*Conventional pollutants:* ≤10% of samples exceed chronic standard *Toxic pollutants:* ≤1 sample in 3 years or <2.8% of samples exceed chronic standard, and no samples in 3 years exceed maximum standard	Not applicable	*Conventional pollutants:* 10-25% of samples exceed chronic standard	*Conventional pollutants:* ≥25% of samples exceed chronic standard *Toxic pollutants:* ≥2 samples in 3 years or ≥2.8% of samples exceed chronic standard; or 1 exceedance of the maximum standard in 3 years
Missouri	**Impairment thresholds as follows:** *Conventional pollutants:* ≥ 10% of values exceed standards *Toxic pollutants (acute):* Maximum daily concentration exceeded more than once every three years *Toxic pollutants (chronic):* Maximum 4-day concentration exceeded more than once every three years			
Wisconsin	**Impairment thresholds as follows:** *Conventional pollutants:* ≥ 10% of values exceed standards *Toxic pollutants (acute):* Maximum daily concentration exceeded more than once every three years *Toxic pollutants (chronic):* Maximum 4-day concentration exceeded more than once every three years			

[1]Examples of conventional pollutants are BOD, TSS, and pH.
[2]Examples of toxic pollutants are PCBs and mercury. See 40 CFR 401.15 for a complete list of toxic pollutants identified under the Clean Water Act.

Aquatic Life Use Assessment Outcomes

The states' assessments of aquatic life use attainment are ultimately communicated in their CWA Section 303(d) impairment listings. If a designated use is not attained in CWA Section 305(b) assessment, then the use is identified as impaired in the state's 303(d) listing. Table 2-9 shows how aquatic life use attainment was reflected in the states' 2008 303(d) impairment listings for the UMR.

The table shows that the states consider much of the UMR main channel to be attaining the aquatic life use, with the exception of turbidity and suspended solids-related impairments in the uppermost reach and some metals and a localized nutrient impairment in lower reaches.

Table 2-9: Attainment of UMR Aquatic Life Use As Reflected in States' 2008 303(d) Impairment Listings

State	Aquatic Life Use Attained? (If no, cause of impairment)	UMR Minimum Assessment Reach	Aquatic Life Use Attained? (If no, cause of impairment)	State
MN	No (Turbidity)	**Reach1** St. Croix River to Chippewa River	No (Suspended Solids)	WI
MN	Yes	**Reach 2** Chippewa River to Lock & Dam 6	Yes	WI
MN	Yes	**Reach 3** Lock & Dam 6 to Root River	Yes	WI
MN IA	Yes Yes	**Reach 4** Root River to Wisconsin River	Yes	WI
IA	Yes	**Reach 5** Wisconsin River to Lock & Dam 11	Yes	WI
IA	Yes	**Reach 6** Lock & Dam 11 to Lock & Dam 13	Yes Yes	WI IL
IA	No (Aluminum, localized nutrients)	**Reach 7** Lock & Dam 13 to Iowa River	Yes	IL
IA	No (Aluminum)	**Reach 8** Iowa River to Des Moines River	Yes	IL
MO	Yes	**Reach 9** Des Moines River to Lock & Dam 21	Yes	IL
MO	Yes	**Reach 10** Lock & Dam 21 to Cuivre River	Yes	IL
MO	Yes	**Reach 11** Cuivre River to Missouri River	Yes	IL
MO	No (Localized lead and zinc)	**Reach 12** Missouri River to Kaskaskia River	Yes	IL
MO	Yes	**Reach 13** Kaskaskia River to Ohio River	Yes	IL

Observations regarding aquatic life use assessment outcomes for the UMR include:

- The states are largely in agreement that the UMR main channel is generally attaining the aquatic life use. The states agree in 9 of the 13 reaches that chemical and physical monitoring of the main channel do not indicate aquatic life use impairment. In one reach, states agree there is a turbidity/ suspended solids impairment. For three reaches, there is inconsistency in impairment listings, although two of these stem from localized issues.
- Overall, while there is some inconsistency between states in assessment outcomes, there is close enough agreement that *consistency alone may not* be the most compelling reason to examine aquatic life designated uses.

- Current UMR CWA assessments are limited by a lack of specificity in aquatic life use definitions, little ability to address off-channel areas, a reliance almost solely on chemical/physical data, and the absence of biological criteria. Therefore, the question of whether the current suite of CWA tools (uses, criteria, monitoring, and assessment methodologies) accurately characterize UMR aquatic life use attainment *clearly is* a compelling reason to examine aquatic life designated uses.
- Put another way, while the states currently assess UMR aquatic life use attainment with similar results, it is not clear that these assessments are an accurate reflection of the current health of UMR aquatic life. This question becomes particularly important in light of reports from UMR restoration programs (e.g., Johnson and Hagerty 2008), that have indicated degraded ecological conditions on the UMR.

SUMMARY OBSERVATIONS REGARDING STATES' APPROACHES TO UMR AQUATIC LIFE USES

The following summary observations can be made regarding the states' current approaches to UMR aquatic life uses:

- Generally:
  - There are no unified or shared aquatic life use definitions, water quality criteria sets, monitoring strategies, or aquatic life use assessment protocols among UMR CWA programs.
  - Although there are similarities in the states' implementation of the CWA on the UMR regarding aquatic life uses, accumulated differences in use definitions, criteria, monitoring, and assessment methodology frustrate the ability of the states to comprehensively and consistently characterize the condition of the UMR's water quality and aquatic life. This can contribute to problems in communication both among regulatory agencies and with the public at large.
  - The interrelated nature of designated uses, water quality criteria, monitoring, and assessment must be considered as modifications to aquatic life designated uses are being examined. Therefore, even though this report is most focused on aquatic life designated uses, by necessity it also includes discussion of these related elements.
- Regarding Designated Uses:
  - All the states assign an aquatic life use to the UMR, and these uses generally share a focus on warm water communities and sport fisheries, but are not otherwise explicit about protection goals.
  - The aquatic life uses assigned to the UMR are selected from use categories applied statewide (i.e., there are not specific uses for the UMR).
  - Existing designated uses are legally applicable to the river as a whole both laterally and longitudinally for each state, though in a practical sense data from only the main channel is typically used for CWA water quality assessments.
- Regarding Water Quality Criteria:
  - Criteria used to assess UMR aquatic life use attainment are primarily chemical/physical criteria. There currently are no numeric biological criteria, though some recognition of biology is present in existing narrative criteria.
  - There is commonality in some water quality criteria applied to the river (e.g., for dissolved oxygen). However, there are also a number of cases where criteria are not consistent among states or where criteria are present for one state but missing entirely for another.

- Criteria generally do not reflect the UMR's diversity in terms of water quality, habitats, and aquatic communities.

- Regarding Monitoring:
  - While there are many monitoring programs on the UMR, there is no River-wide, CWA-focused monitoring program or strategy.
  - There is great variability in the amount of UMR water quality monitoring conducted by state CWA programs, with some states having very limited monitoring. No state CWA programs regularly monitor off-channel areas.
- Regarding Assessment Methodology and Outcomes:
  - States use some non-CWA program (e.g., LTRM, USGS/NASQAN) data in their CWA assessments. However, their ability to utilize this data can be limited by the lack of monitoring for parameters for which the states have established criteria, spatial coverage, sampling design, analytical method, and states' limited familiarity with the data.
  - There is no single UMR CWA assessment or assessment methodology. Each state assesses independently. Outcomes, as expressed in 303(d) impairment lists, vary among the states.
  - The states' CWA impaired waters lists indicate relative agreement that much of the UMR main channel is attaining its assigned aquatic life use. However, **it is not clear that this agreement reflects an accurate characterization of the health of the river's aquatic life**. In fact, this project in part resulted from the WQTF's concern that main channel physical/chemical data are inadequate to accurately and fully assess the UMR's aquatic life health.

OPPORTUNITIES PRESENTED FOR UMR AQUATIC LIFE DESIGNATED USES

The preceding discussion identified a number of issues and limitations regarding the states' current approaches to UMR aquatic life use designations and related CWA program components. However, this should not be seen simply as a critique of current approaches. Rather, it highlights opportunities regarding UMR aquatic life designated uses, including:

- Exploring ways to make aquatic life designated uses more explicit about protection goals.
- Addressing lateral and longitudinal differences in chemical, physical, and biological characteristics among the UMR's aquatic habitats.
- Encouraging greater consistency in the definition of aquatic life for the UMR among the states.
- Facilitating the implementation of consistent CWA biological assessment and condition class thresholds through habitat-based definitions of UMR aquatic life uses, which will allow for the development of appropriate biological condition expectation(s) for the River.
- Evaluating the compatibility of existing monitoring programs with current and potentially revised aquatic life uses, and considering how refined aquatic life use definitions might impact monitoring needs.

Chapter 3:
Considerations in Examining UMR Aquatic Life Designated Uses

IMPORTANT CONSIDERATIONS IN EXAMINING UMR AQUATIC LIFE USES

The preceding chapter detailed the states' current approaches to aquatic life uses, criteria, monitoring and assessment. It described the limitations in current approaches and highlighted opportunities for potential improvement. Given these discussions, the next questions to consider are regarding *if*, *how*, and *to what extent* UMR aquatic life designated uses should be modified. It is apparent that current approaches to assigning and assessing UMR aquatic life uses are not ideal – but important questions moving forward include:

- Is there an improved way to approach aquatic life designated uses on the UMR?
- How do we determine what this improved approach might be?

In answering these questions, the following issues should be considered:

- How do the UMR's physical, temporal, and ecosystem characteristics vary among its aquatic habitats and reaches?
- How can existing biological, chemical, and physical water quality data inform decision-making?
- What UMR programs and data sources are most relevant to defining aquatic life designated uses?
- What are the connections between this effort to examine UMR aquatic life uses and other WQTF projects?
- What approaches have been used to define aquatic life designated uses in other large, diverse aquatic ecosystems?

This chapter explores each of the above considerations in detail.

UMR PHYSICAL, BIOLOGICAL, AND TEMPORAL DIVERSITY

As discussed in this report's first chapter, there is a great deal of aquatic diversity in the UMR as it is a large, modified, floodplain river system. The River displays diversity in physical characteristics both longitudinally and laterally, in changes over time in response to season/flow, and in its different ecological characteristics and biological communities. This diversity results from geomorphology, natural water cycles, hydrological alteration due to locks and dams and floodplain uses, sedimentation due to impounding and floodplain uses. The dimensions and causes of UMR diversity should be kept in mind when the River's aquatic life designated uses are being considered.

Physical Diversity

Longitudinal Diversity
Longitudinal diversity on the UMR exists both at the system scale as well as within individual impounded pools. At the system scale, the river can be considered in three major "floodplain reaches," which divide the UMR longitudinally into segments with roughly similar physical features. These floodplain reaches are commonly referred to as the Upper Impounded, Lower Impounded, and Unimpounded (or Open River) reaches (see Figure 3-1). In the impounded reaches, there is also considerable physical variation along the length of pools. The river is more likely to retain a relatively

complex channel structure in areas most distant from a dam, while nearer to a dam the river becomes more lake-like in nature.

Longitudinal changes occur in water chemistry, physical characteristics and biological communities in the UMR system. These longitudinal changes can be observed in UMR water quality and biological data, as is discussed in more detail in Chapter 4.

Lateral Diversity
Lateral diversity is also present on the UMR. Figure 3-2 illustrates the types of lateral diversity that exist on the UMR. While lateral diversity is most prominent in the UMR's upper reaches, it exists to some degree throughout much of the system.

Water quality often varies among different lateral areas of the UMR, especially in regard to physical and chemical parameters such as flow, total suspended solids, temperature, and dissolved oxygen. This lateral variation in water quality characteristics is discussed in greater detail in Chapter 4.

The LTRM has long used categorizations of UMR aquatic habitats in its monitoring program. Figure 3-3 is a detailed layout of UMR habitats presented in the LTRM publication *An Aquatic Habitat Classification System for the UMR* (Wilcox, 1993). In practice, LTRM sampling strata include main channel, side channel, backwater contiguous, impounded, backwater isolated, and tributary delta lakes. Strata delineations are based on interpretation of 1989 summer aerial photos, and thus do not consider dynamic on-site factors such as depth and water velocity. Strata have been mapped and associated GIS information is available. Figure 3-4 shows LTRM sampling strata for UMR Pool 8.

The following, taken from the 1998 and 2008 LTRM Status and Trends reports, further describe UMR aquatic areas as reflected in the LTRM sampling strata:

- ***Main channel:*** Substrates are typically shifting sand; the undeveloped river included a series of runs, pools, and channel crossings providing a diversity of depth along the main channel. A section of the main channel is maintained as a nine foot deep navigation channel for commercial navigation.
- ***Secondary/side channel:*** Aquatic channel connected to the main channel and separated from the main channel by an island; usually has flowing water. Some are stable, others are transient and may fill causing the island to join the bank. They may form smaller interconnected tertiary channels.
- ***Impoundment:*** The volume of standing water that is maintained behind a dam.
- ***Backwater (including floodplain lakes):*** Small, generally shallow body of water attached to a main or side channel, with little or no current of its own; shallow, slow-moving water associated with a river but outside the river's main channel. Tend to accumulate fine-grained sediment. The difference between isolated and contiguous backwaters is the presence of a permanent connection between the backwater and river, all may be inundated during floods.

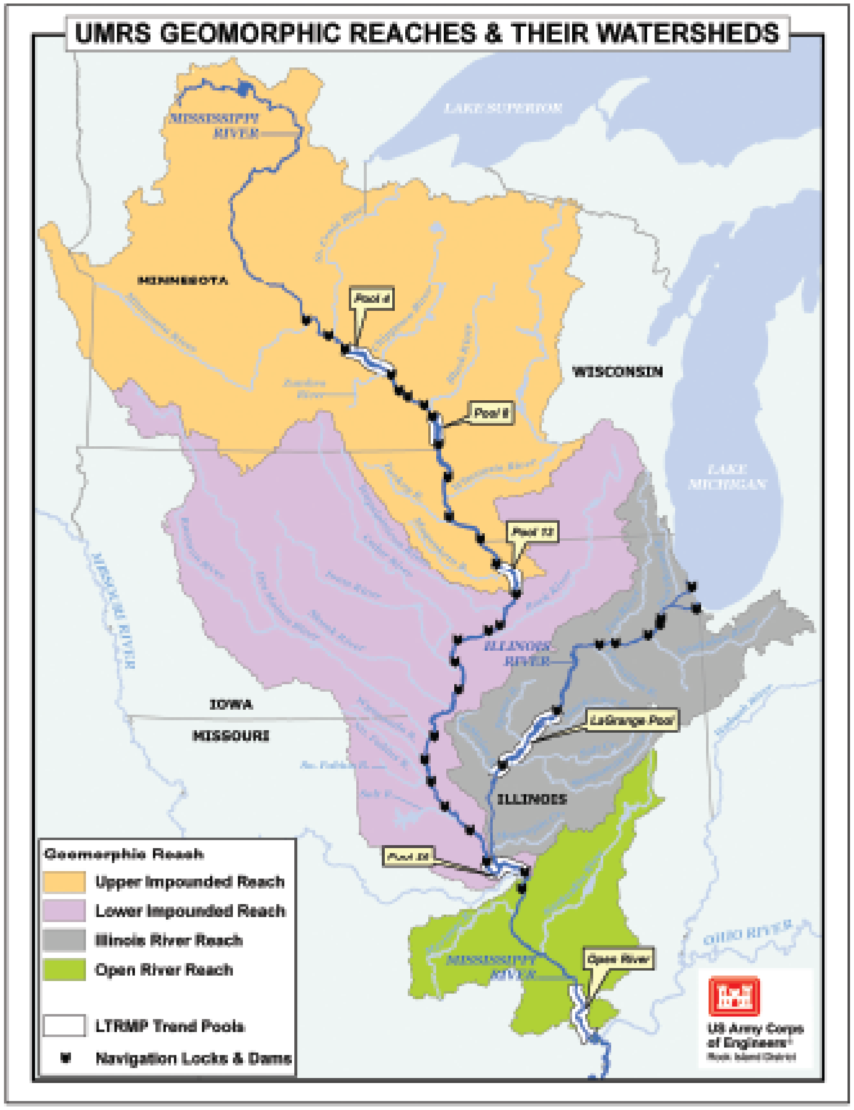

Figure 3-1: UMR Floodplain Reaches. Note that this study does not include the Illinois River portion of the UMRS, shown here in grey (image courtesy of the US ACE-Rock Island District).

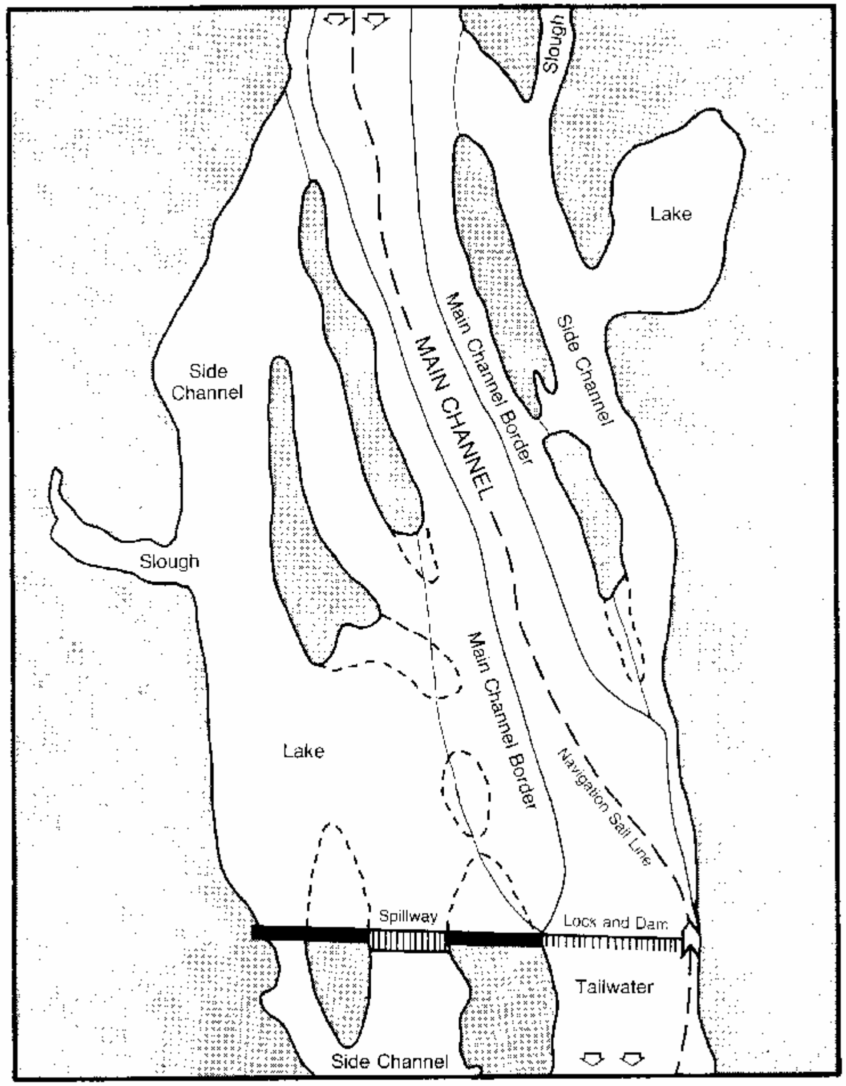

Figure 3-2: Generalized Depiction of UMR Lateral Diversity (from UMRBC, 1982).

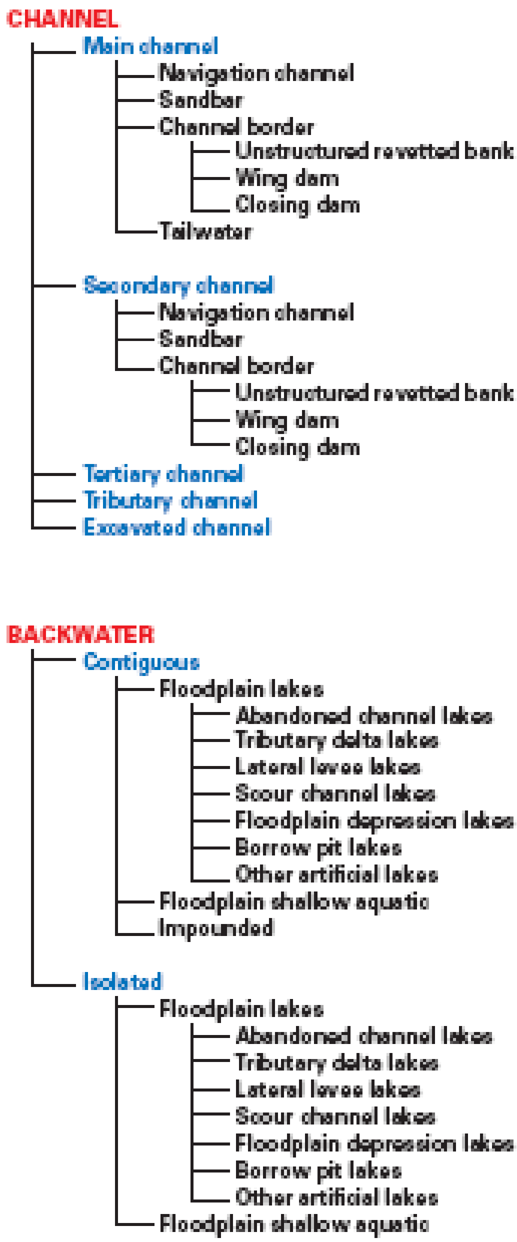

Figure 3-3: UMR Aquatic Habitats (from Wilcox, 1993).

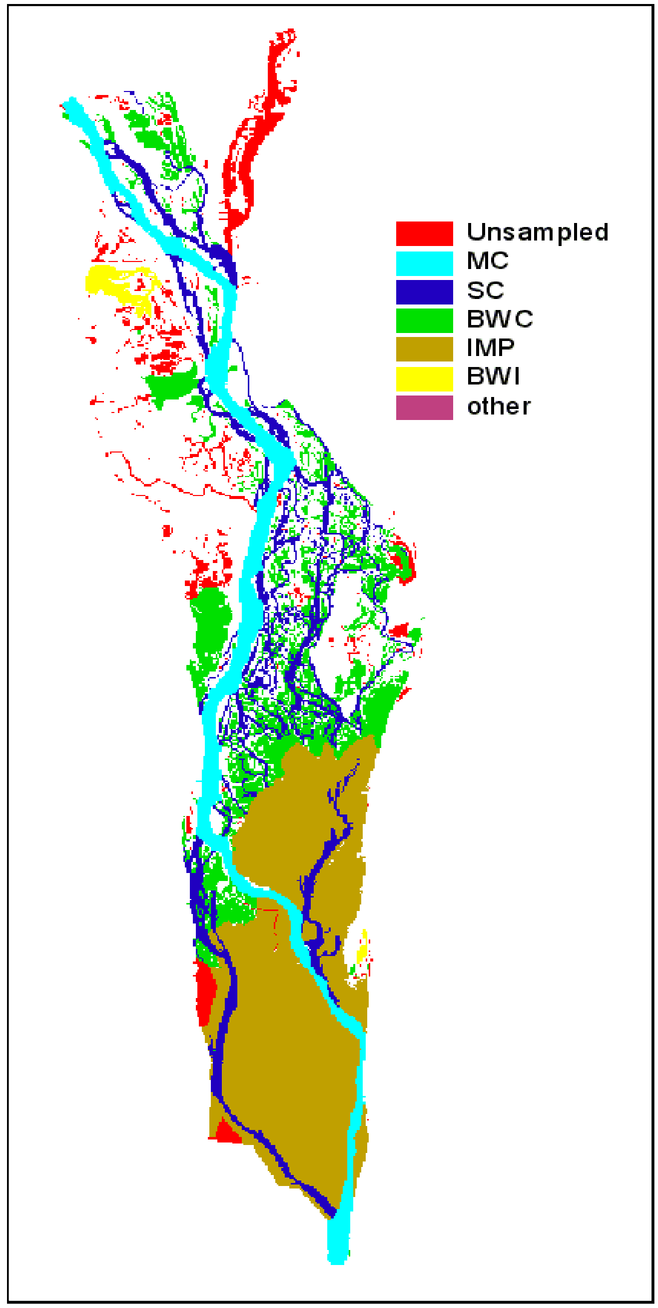

Figure 3-4: LTRM Aquatic Sampling Strata for UMR Pool 8. MC = Main Channel, SC = Side Channel, BWC =Backwater Contiguous, BWI = Backwater Isolated, IMP = Impounded (image courtesy of USACE -LTRM).

Table 3-1 is adapted from the *Upper Mississippi River and Illinois Waterways Cumulative Effects Study* (WEST Consultants, 2000) and also describes the characteristics of aquatic areas analogous to four of the common LTRM sampling strata.

Table 3-1: Comparison of UMR Aquatic Areas and Generalized Depth, Substrate, and Current Velocity (adapted from Table 2-1 of Cumulative Effects Study Volume 2, WEST Consultants 2000).

Aquatic Area	Depth Characteristics	Substrate Characteristics	Velocity Characteristic*
Main Channel	> 9 foot channel bordered by shallower areas	Shifting sand with some silt and clay laterally toward bank	High = 12% Med. = 75% Low = 10%
Secondary Channel	< or > 9 foot channel connected to the main channel	Sand, sand/silt or silt/clay	High = 16% Med. = 66% Low = 18%
Contiguous Backwater	Typically <6 feet connected to main channel by one or more openings	Silt/clay	High = 0% Med. = 13% Low = 87%
Isolated Backwater	Typically <6 feet and not connected to the main channel	Silt/clay	Low = 100% (by definition)

* Average current velocity calculated from RMA2 model results from five Mississippi River reaches, where High => 0.45 m/s (1.8 ft/sec), Medium = 0.15 to 0.45 m/s (0.5 to 1.8 ft/sec), and Low<0.15 m/sec (<0.5 ft/sec).

As mentioned earlier in the chapter, lateral diversity is most prominent in the UMR's upper reaches and declines in its lower reaches. Figure 3-5 illustrates the relative occurrence of main channel, side channel, contiguous backwater, and impounded strata as a percentage of surface area in the 13 minimum UMR CWA assessment reaches. Additionally, Table 3-2 depicts the occurrence of strata in LTRM study reaches.

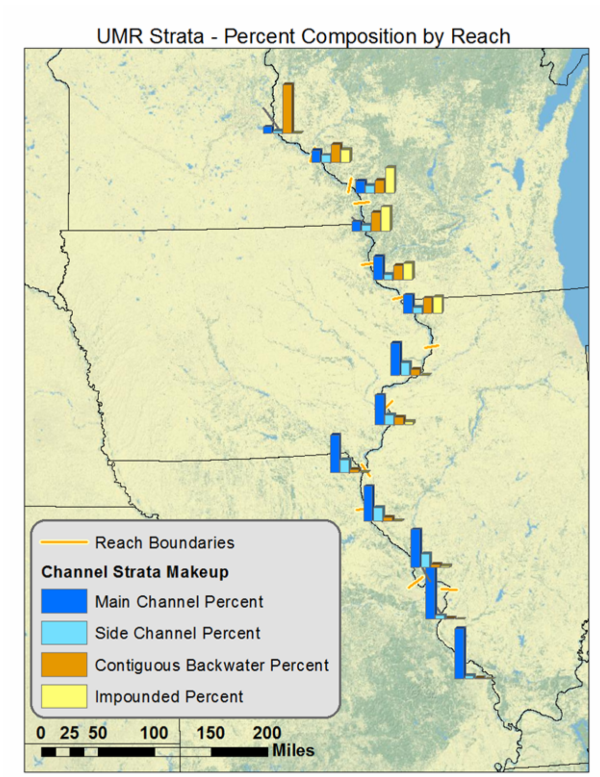

Figure 3-5: Relative Occurrence of Strata in UMR Minimum CWA Assessment Reaches. (UMRBA – generated image, using USACE-LTRM data)

Table 3-2: Area of Each Strata on the UMR per LTRM Study Reach (in ha, adapted from Ickes 2005).

Strata	Pool 4	Pool 8	Pool 13	Pool 26	Open River
Main Channel Border	564 (16%)	597 (9%)	1110 (16%)	3308 (64%)	3148 (87%)
Side Channel Border	722 (21%)	1037 (16%)	690 (10%)	1418 (27%)	468 (13%)
Backwater Contiguous	2233 (63%)	1354 (21%)	2403 (35%)	281 (5%)	0
Impounded	0*	3425 (53%)	2611 (38%)	190 (4%)	0

*Lake Pepin is classified as a Tributary Deltaic Lake by LTRM, so Pool 4 has no Impounded stratum in this characterization.

Biological Diversity - Variation in Aquatic Community Composition

The UMR hosts a diversity of aquatic communities and the specific communities utilizing particular pools, reaches, or strata will need to be considered in possible refinements of aquatic life use designations. The presence of aquatic organism guilds and species in various pools, reaches and strata is determined in part by physical habitat characteristics, including substrate and flow. Table 3-3 is adapted from the Cumulative Effects Study (WEST, 2000) and reflects the habitat requirements and velocity preferences for a number of plant and animal guilds on the UMR. Two important points illustrated by this table are:

- Individual UMR species and guilds have differing habitat requirements and velocity preferences. Therefore, aquatic life expectations/ use designations may be different among pools, reaches, and strata.

- Individual species and guilds may utilize more than one pool, reach or stratum and this may also vary by life stage and season. This interdependence means that aquatic life use designations may need to include multiple pools, reaches and/or strata.

Table 3-3: Habitat Requirements and Velocity Preferences of UMR Plant and Animal Guilds. Illustrates general habitat requirements and velocity preferences for some UMR species and guilds. For the fish species, preferences represent conditions required for adult fishes during summer, low-flow conditions. MC=main channel, SC=secondary channel, CB=contiguous backwater, IB=isolated backwater. Velocities: High => 0.45 m/s (1.8 ft/sec), Medium = 0.15 to 0.45 m/s (0.5 to 1.8 ft/sec), and Low<0.15 m/sec (<0.5 ft/sec) (adapted from Cumulative Effects Study, Volume 2, WEST Consultants 2000).

Biological Community	Guild	Habitat Requirements*	Velocity Preference**
Aquatic Vegetation	Rooted submersed aquatics	MC, SC, CB, IB	Low, Med
	Unrooted submersed aquatics	CB, IB	Low
	Floating perennials	CB, IB	Low, Med
	Floating annuals	CB, IB	Low
	Perennial emergent aquatics	CB, IB	Low
	Annual emergent aquatics	CB, IB	Low
Macroinvertebrates	Lotic-erosional (running-water riffles)	MC, SC	Med, High
	Lotic-depositional (running-water pools and margins)	MC, SC, CB	Low
	Lentic limnetic (standing water)	CB, IB	Low
	Lentic-littoral (standing water, shallow shore area)	CB, IB	Low
	Lentic profundal (standing water, basin)	CB, IB	Low
Freshwater mussels	Lotic	MC, SC	Med, High, Low
	Lentic	CB	Med, High, Low
Fish	Rheophil (e.g., walleye, channel catfish)	MC, SC	Med, High
	Rheophil-limnophil (e.g., emerald shiner, sauger)	MC, SC, CB	Med, Low, High
	Pelagic rheophil-limnophil (e.g., white bass)	MC, SC, CB	Med, Low, High
	Limnophil-rheophil (e.g., paddlefish, smallmouth bass)	CB, SC, MC	Med, Low
	Pelagic limnophil-rheophil (e.g., bigmouth buffalo, smallmouth buffalo)	CB, SC, MC	Med, Low
	Limnophil (e.g., largemouth bass, bluegill, green sunfish, warmouth)	CB, IB	Low
Amphibians and Reptiles	Lotic	MC, SC	Low
	Lentic	CB, IB	Low
Waterfowl	Diving ducks	MC, SC, CB	Med, Low
	Dabbling ducks, geese, and swans	CB, IB, SC, MC	Low

Temporal Diversity - Seasonal Considerations

Seasonal variations affect water chemistry, physical characteristics, and biological responses on the UMR and in other rivers. Examples of seasonal water chemistry variations include decreased temperature and dissolved oxygen levels in the winter, especially in the backwaters; and increased temperature and primary productivity in backwaters in summer months. Ultimately, designated uses may best be refined not only in terms of chemical, physical, and/or biological differences, but also in terms of seasonal variation. Seasonal variations will also be important considerations for water quality criteria and monitoring approaches associated with any new or revised aquatic life designated uses.

Additionally, while a particular area is classified in a specific stratum for LTRM sampling purposes, the actual conditions in that area may be dramatically affected by flow and water level in a given year or season. While some areas may consistently demonstrate the attributes of their assigned stratum regardless of flow and water level condition (e.g., the main channel), the characteristics of other areas may change under different conditions (e.g., a backwater's seasonal/high water connection to a flowing channel). Therefore, any definitions of aquatic life use based on specific aquatic strata should recognize this potential for that stratum's defining characteristics to temporarily break down due to extremes in depth, flow and water level caused by factors such as droughts, floods, or water level draw-downs. However, it is anticipated that aquatic life use assessments will likely not use data collected during extreme events that fundamentally affect the strata characteristics.

IMPORTANCE OF WATER QUALITY DATA IN DECISION-MAKING

The preceding discussion described the UMR's diversity in terms of lateral and longitudinal physical characteristics, distribution of aquatic communities, and temporal variations. These spatial, as well as temporal, distinctions are not captured in the states' current one-size-fits-all aquatic life use designations. Some form of CWA water quality standards distinction between these pools, reaches, and/ or strata may be appropriate. Therefore, a key question in moving forward regarding potential refinement of aquatic life use designations is, **"Are the aquatic life communities on the UMR distinct enough in their characteristics to merit differentiation of aquatic life uses in a Clean Water Act context?"**

Any decisions regarding CWA distinctions require a detailed review of UMR data and literature. In this water quality standards context, it is essential that water quality data, including biological data, be examined. Examination of strata-specific water quality data can help illustrate the conditions present or needed to support aquatic life uses on the UMR. Biological data in particular help illustrate where and when meaningful differences in aquatic communities exist, and hence where expectations for the aquatic life use may need to be adjusted or biological criteria developed. These data can serve as the basis for strata-specific water quality criteria that may ultimately need to be assigned to support any revised aquatic life designated uses. Evaluations of strata-specific water quality data may also reveal instances where existing water quality criteria may or may not be appropriate for the protection of UMR aquatic life uses. A detailed examination of these data should help determine how to make important distinctions in aquatic life designated uses, while avoiding segmenting beyond what is biologically meaningful and practical to implement.

Accordingly, this project has included a specific focus on the review of UMR water quality data and related literature. This data and literature analysis is presented in Chapter 4 and includes information from LTRM, US EPA's EMAP-GRE, and other UMR monitoring programs.

UMR PROGRAMS AND DATA SOURCES MOST RELEVANT TO AQUATIC LIFE DESIGNATED USES

State CWA water quality programs are not alone in their efforts to monitor, assess, and protect the UMR. Several non-CWA UMR programs have a wealth of data relevant to this examination of UMR aquatic life uses. Collaborating with and being informed by other UMR programs and entities, including ecosystem restoration and monitoring efforts, is essential in any potential refinement of UMR aquatic life designated uses. Perhaps more importantly, working with these programs may ultimately lead to more congruent characterizations of the UMR and its ecological condition across program areas, and greater harmonization of assessment tools such as biological indicators and assessment strategies.

Among the many programs in place on the River, the following appear to be most relevant for this examination of UMR aquatic life designated uses:

US Army Corps of Engineers Restoration Programs

US Army Corps of Engineers programs provide for ecosystem restoration on the Upper Mississippi River System, including the Illinois River. Through these programs – primarily the Environmental Management Program (EMP) – over 86,000 acres of habitat have been restored, 60 projects have been completed, and 23 projects are in design and construction currently to restore 24,000 additional acres. Projects are built to restore or preserve habitat for aquatic and floodplain communities as well as endangered species. These restoration programs have also produced extensive documentation regarding the UMR, its characteristics, habitats, biota, and dynamics. Importantly, the EMP includes the Long Term Resource Monitoring Program (LTRM), as described in the following section.

Also of significance to this investigation of aquatic life uses, USACE restoration programs have recently engaged in UMR "reach planning." This process involved setting objectives and performance measures – addressing water quality, habitat, and biota, among other factors – for 11 geomorphic reaches on the UMR system, which provide for some potential commonality with CWA aquatic life designated uses and water quality criteria. Several WQTF members participated in the reach planning process in order to gain a better understanding of the effort, develop cross-program connections, and gather information relevant for CWA purposes.

EMP - Long Term Resource Monitoring Program

USACE funds work at the USGS' Upper Midwest Environmental Sciences Center (UMESC) in La Crosse, Wisconsin and five state-based field stations to implement the LTRM on the UMR. LTRM monitoring components include aquatic vegetation, water quality, fish, macroinvertebrates (through 2004), land-cover, water levels, bathymetry, and sedimentation. LTRM sampling is conducted in five study reaches on the UMR - Pools 4, 8, 13, 26, and the Open River. The water quality component consists of 25 metrics, sampled quarterly for stratified random sampling (SRS) sites, and sampled at fixed sites year round. LTRM scientists assess status and trends of the data at several spatial scales, including habitat or strata, pool or reach, geomorphic reach, floodplain reach, and system levels (see USGS 1999 and Johnson and Hagerty 2008). For this examination of aquatic life designated uses, LTRM is of foremost importance because it is the dominant ongoing, systemic UMR monitoring program, providing many years of data for the study reaches, including lateral strata, and for multiple seasons from 1993 to the present.

Despite its very extensive nature, LTRM does have the limitation of having data available only for the five UMR study reaches. LTRM also does not include monitoring for indicator bacteria or toxics commonly assessed by CWA programs. Additionally, specific parameters measured by LTRM and analytical methods used may not always match what is needed by state CWA programs.

In sum, although LTRM does not provide all the data needed for UMR CWA water quality assessments and impairment listings, it is an extensive and extremely helpful dataset that can greatly aid this investigation of aquatic life use designations.

US EPA Environmental Monitoring and Assessment Program-Great Rivers Ecosystems Survey

As part of the Environmental Monitoring and Assessment Program (EMAP), US EPA conducted a Great Rivers Ecosystem (GRE) monitoring survey from 2004 through 2006, including the Upper Mississippi, Missouri and Ohio Rivers. EMAP is a research program focused on developing indicators and unbiased statistical designs for assessing the condition of aquatic ecosystems at a variety of spatial scales. EMAP-GRE was a demonstration project designed to help states develop methods to assess large rivers. Parameter sampling included water chemistry, plankton, aquatic vegetation, riparian physical habitat, fish, fish tissue contaminants, benthic macroinvertebrates, periphyton, and sediment.

EMAP-GRE sampling took place on the UMR main channel, along its entire length, in mid-summers from 2004-2006. Single samplings (and re-sampling) of chemical/physical water quality parameters, fish, aquatic macroinvertebrates, and aquatic vegetation were conducted at randomly-selected sites along the UMR main channel. EMAP-GRE data is important for this project because it provides longitudinal data for the entire length of the UMR and the monitoring approach was explicitly designed to work within the CWA framework.

Other Programs

There are numerous other programs and efforts that may also produce data, information, and insights of relevance to the examination of aquatic life uses for CWA purposes. These include the US EPA's National Rivers and Streams Assessment (NRSA), state resource management programs, local monitoring efforts, and special studies conducted by state and federal agencies. However, this project focused on LTRM and EMAP-GRE as primary data sets due to their extensive, system-wide nature.

RELATIONSHIP TO OTHER WQTF EFFORTS

This examination of aquatic life designated uses took place concurrently with two other major efforts of the UMRBA WQTF: 1) developing a UMR CWA biological assessment implementation guidance document, and 2) reporting on UMR nutrient monitoring, occurrence, and local impacts to CWA designated used. Both projects of these projects were completed in September 2011 and have connections to the aquatic life designated uses effort.

The aquatic life designated use project and the biological assessment guidance document project are closely related and mutually supportive of each other. As the aquatic life use project investigated potential modifications to designated uses, the biological assessment project evaluated tools that could be employed to better assess attainment of aquatic life uses. Ultimately, biological assessment tools are needed to better assess UMR aquatic life use attainment under any set of aquatic life designated uses, whether existing or revised.

There may be a less direct relationship between the nutrient project and the aquatic life use project. However, nutrients are frequently mentioned as a pollutant adversely affecting UMR aquatic life and therefore, to the extent that the nutrient project identified with greater specificity how aquatic life is impacted by nutrients on the UMR, it may help in eventually characterizing the nutrient conditions needed to support UMR aquatic life uses.

APPROACHES TO AQUATIC LIFE USES IN OTHER LARGE AQUATIC ECOSYSTEMS

While there are no exact analogs to the UMR among other large aquatic ecosystems in the United States, lessons can be learned from how aquatic life designated uses have been addressed elsewhere. These lessons may help focus and expedite efforts on the UMR. The three large aquatic ecosystems were examined for this project: the Ohio River, the Delaware River and Bay, and the Chesapeake Bay. Descriptions of how aquatic life uses are addressed in these systems follow.

Ohio River

The Ohio River is 981 miles long, starting at the confluence of the Allegheny and the Monongahela Rivers in Pittsburgh, Pennsylvania, and ending in Cairo, Illinois, where it flows into the Mississippi River. The Ohio River watershed encompasses portions of 14 states and drains nearly 190,000 square miles (Figure 3-6).

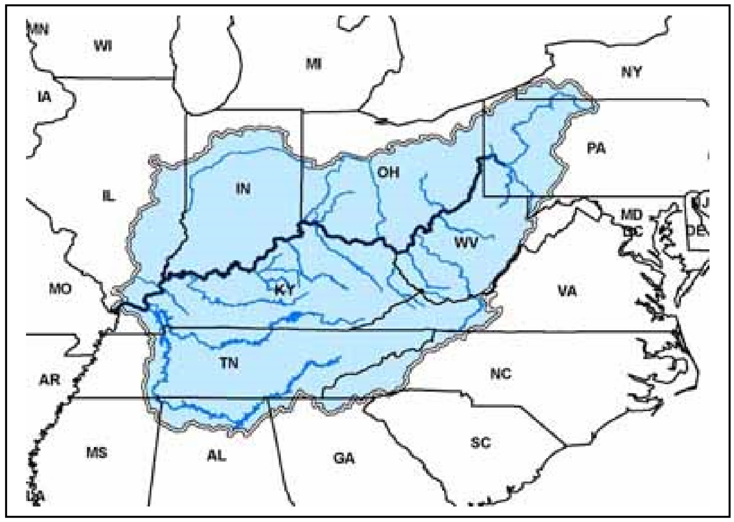

Figure 3-6: Ohio River Basin (map courtesy ORSANCO).

The Ohio River Valley Water Sanitation Compact of 1948 was signed by Governors of eight states (Illinois, Indiana, Kentucky, New York, Ohio, Pennsylvania, Virginia, and West Virginia), following the consent of Congress. This created the Ohio River Valley Water Sanitation Commission (ORSANCO) and mandated that all waters of the Ohio River shall be maintained in a satisfactory, sanitary condition, available for certain beneficial uses.

ORSANCO's water quality standards apply to all compact states. They contain designated uses to be protected in the Ohio River, establish minimum water quality criteria to assure the uses are achieved, and set waste water discharge requirements to attain the water quality criteria. Standards also allow for individual states to develop and implement more stringent regulations.

The entirety of designated use definitions for the Ohio River in ORSANCO's water quality standards is as follows:

> "*The Ohio River, as hereinbefore defined, has been designated by the Compact as available for safe and satisfactory use as public and industrial water supplies after reasonable treatment, suitable for recreation usage, capable of maintaining fish and other life, and adaptable to such other uses as may be legitimate*."

ORSANCO's general definition of the aquatic life use, "…capable of maintaining fish and other life…" has some similarity to the aquatic life uses defined by UMR states (see Table 2-4).

ORSANCO has narrative general water quality criteria for the Ohio River similar to those of most UMR states, "free from objectionable sludge deposits, floating debris, scum, oil and other floating material, material causing color or odors, aesthetic nuisances, and toxics." There is also a narrative aquatic life protection criterion, "biological integrity shall be safeguarded, protected and preserved," and numeric aquatic life protection criteria (e.g., for dissolved oxygen, temperature, pH, ammonia, and metals). Specialized criteria include dissolved oxygen and temperature criteria adjusted for different seasons, and distinct ammonia criteria for acute, chronic, and early life stages of fish. In addition, similar to most UMR states, numeric bacteria criteria exist for the contact recreation use to protect human health.

At first glance, ORSANCO's approach to the Ohio River may appear quite similar to what currently is being done by the states for the UMR. However, there are at least three important distinctions to keep in mind:

- Since there is only one baseline set (ORSANCO's) of water quality standards for the Ohio River, issues of interstate consistency are minimized.
- The Ohio River does not have the complex off-channel structure found on the UMR. Therefore, there is less need to develop uses and criteria applicable along a lateral gradient.
- ORSANCO has developed an extensive biological monitoring and assessment program to assess attainment of the aquatic life use and determine whether "…the biological integrity of the Ohio River is being safeguarded, protected, and preserved."

Delaware River and Bay

The Delaware River is the longest un-dammed river east of the Mississippi River. It is fed by 26 tributaries, in a basin covering about 13,000 square miles. The basin drains parts of Pennsylvania, New Jersey, New York, and Delaware and includes river, tributary, estuary, bay, tidal, wetland, reservoir, and lake areas. The basin is composed of four regions, each with unique characteristics: the Upper Region (headwaters and contributing watersheds), the Central Region (the remaining freshwater river and contributing watersheds), the Lower Region (area of tidal influx from Trenton, NJ to the head of the bay and contributing watersheds), and the Bay Region (includes bay and surrounding watersheds). Major land use in the basin includes forest (55%), agriculture (26%), developed (14%), and wetlands/water (4%). Of note, the Delaware River basin is much smaller than the UMR basin, has different land use demographics (more forest and half the agricultural land), a higher natural gradient, and no dams.

The Delaware River and Bay are subject to water quality programs administered by the Delaware River Basin Commission (DRBC), formed via a compact in 1961. The DRBC establishes federally codified Water Quality Regulations to meet the program requirements of the CWA. The DRBC and stakeholders have also developed a Basin Plan for the watershed including desired outcomes, goals, objectives, and milestones for protecting, preserving, and enhancing water resources. The Basin Plan sets a direction for water policy and management through 2030, and seeks to involve a broad range of governmental and non-governmental entities.

The general designated use categories to be protected within the Delaware Basin include: agricultural, industrial, and public water supply where salinity allows; wildlife, fish and aquatic life; recreation; navigation; waste assimilation; other uses as provided in the comprehensive plan. The DRBC has defined ten water quality management zones for assessment purposes; named 1A-E, 2, 3, 4, 5 and 6 (see Figure 3-7). The designated uses assigned in each zone vary somewhat among zones reflecting expectations for use in regard to water supply, fish propagation, navigation, etc. (see Table 3-4). For each designated use, in each assessment unit, a number of water quality parameters, relevant to the use, are compared to chemical water quality criteria and some of these criteria also vary by zone. The designated uses assigned by DRBC are similar to many of the current designated uses that are assessed by states in the UMR.

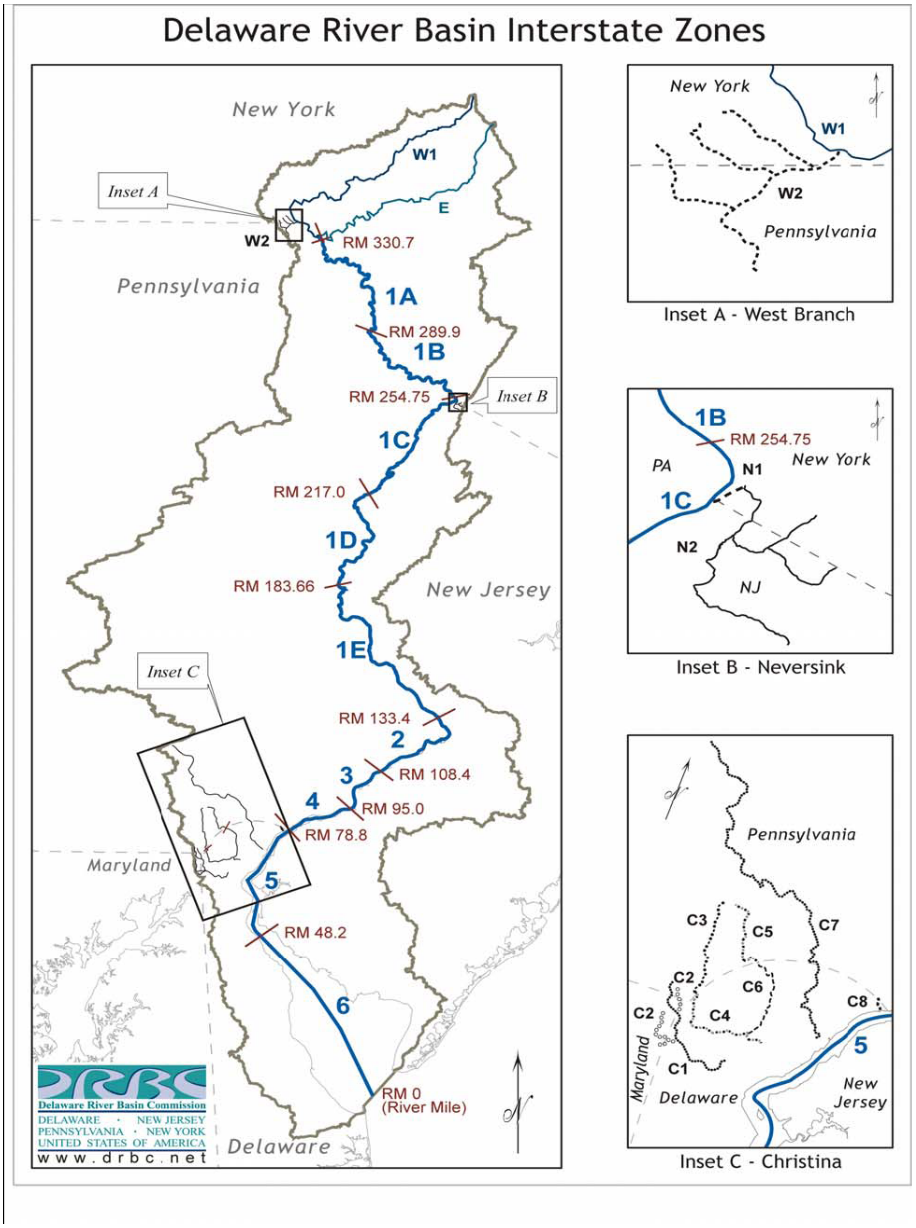

Figure 3-7: Delaware River Interstate Zones (figure courtesy DRBC).

The DRBC has established zone-specific water quality criteria for parameters including dissolved oxygen, temperature, pH, fecal coliform, dissolved solids, turbidity, and alkalinity. The DRBC does not use biological criteria for assessments or for identifying CWA Section 303(d) impaired waters, other than for fish-tissue toxics analyses. The DRBC is currently in the process of developing a biomonitoring program and establishing biocriteria for the non-tidal Delaware River.

For CWA Section 303(d) and 305(b) purposes, only the main stem of the Delaware River is assessed by the DRBC. Intrastate tributaries are included in each basin state's integrated assessment report.

Table 3-4: Uses Assigned to Delaware River Basin Interstate Zones (image courtesy DRBC).

Use	Zone 1A	Zone 1B	Zone 1C	Zone 1D	Zone 1E	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6
Public water supplies after reasonable treatment	X	X	X	X	X	X	X			
Industrial water supplies after reasonable treatment	X	X	X	X	X	X	X	X	X	X
Agricultural water supplies	X	X	X	X	X	X	X			
Maintenance and propagation of resident game fish and other aquatic life	X	X	X	X	X	X	X	X	X (propagation only applied for RM 70 to 48.2)	X
Maintenance and propagation of trout	X									
Maintenance and Propagation of Shellfish										X
Spawning and nursery habitat for anadromous fish	X	X	X	X	X					
Passing of anadromous fish		X	X	X	X	X	X	X	X	X
Wildlife	X	X	X	X	X	X	X	X	X	X
Primary Contact Recreation	X	X	X	X	X	X		X (below RM 81.8)	X	X
Secondary Contact Recreation							X	X (above RM 81.8)		
Navigation						X	X	X	X	X

Beyond 303(d) reporting, the DRBC produces a "State of the Basin" report. Basin reporting includes indicators assembled into four categories: hydrology, water quality, living resources, and landscape. Water quality indicators include nutrients, dissolved oxygen, water clarity, metals (especially copper), fish consumption advisories, pesticides, toxics and PCBs in support of designated uses (separate for tributaries and the river/bay). Living resource indicators include macroinvertebrates, freshwater mussels, oysters, horseshoe crabs, shorebirds (red knot), Louisiana waterthrush, bald eagle, striped bass and weakfish, Atlantic sturgeon, shad, brook trout, and invasive species.

The approaches taken to aquatic life designated uses, criteria, and assessment in the Delaware River and Bay may be of interest to this examination of UMR aquatic life uses because:

- They provide examples of longitudinal division of an interstate waterbody, with consistent assignment of uses and criteria within these longitudinal segments. These uses and criteria are adjusted along the length of the waterbody to reflect changing use expectations, aquatic communities, physical properties, and water quality characteristics.
- They are currently being implemented using primarily chemical/physical criteria, similar to the current approach on the UMR. Additionally, efforts on the Delaware River also reflect an attempt to begin incorporating biological assessment, similar to recent work on the UMR.

Chesapeake Bay

The Chesapeake Bay is the largest estuary in the nation and third largest in the world. It is approximately 200 miles long and between 3 and 35 miles wide depending on location. The Bay averages 21 feet deep, and its basin covers 64,000 square miles. About 80 percent of the Bay's fresh water comes from three major tributaries: the Susquehanna River, the Potomac River, and the James River. The six states in the basin include Delaware, Maryland, New York, Pennsylvania, Virginia and West Virginia, as well as the District of Columbia. The Bay watershed is home to over 17 million people, and its population is growing rapidly. Current major land uses include forest (58%), agriculture (25%), and urban / suburban lands. The Bay is home to 29 waterfowl species, 173 shellfish species, 348 finfish species, and more than 2,700 species of plants. Over 500 million pounds of seafood are produced in the Bay annually, with commercial and recreational fishing having stressed blue crab and oyster populations in particular.

The Bay and its tributaries face water quality challenges from excess nitrogen, phosphorus, and sediment. Pollutant sources include agriculture, urban runoff, wastewater, and airborne contaminants. High turbidity and algal blooms block sunlight from reaching aquatic bay grasses and create low dissolved oxygen available for aquatic biota. In addition to poor water quality, the Bay suffers from degraded habitats, low populations of many fish and shellfish species, and over 200 invasive species.

The Chesapeake Bay Program (CBP) is a regional watershed partnership that has coordinated and conducted restoration efforts in the Bay since 1983. Partners include the six basin states, the District of Columbia, the Chesapeake Bay Commission, academic institutions, US EPA, USACE, USGS, USDA-NRCS and many others. Over 90 staff work for the Program, which is based in Annapolis, Maryland. Since 1986, US EPA and the CBP partners have been engaged in efforts to identify the water quality requirements of the Bay's aquatic life communities. This process has been guided by the 1987 and 2000 Chesapeake Bay Agreements and has resulted in a series of synthesis and technical support documents.

The US EPA Chesapeake Bay Program Office (CBPO) issued a guidance document in May 2003 identifying aquatic life water quality criteria for the Bay and tidal tributaries. This document was intended to help the basin states and the District of Columbia adopt revised criteria in their respective water quality standards to address nutrient and sediment pollution. Until that time, basin states and the District of Columbia applied water quality criteria to the entire bay, and not specifically to various aquatic areas. The 2003 criteria are not only spatially specific, but also seasonally adjusted as needed.

CBPO released a technical support document in October 2003 identifying refined aquatic life uses for the Bay and providing assistance to the states in developing use attainability analyses (UAAs). These refined uses were the culmination of work begun in the 1980s including extensive research regarding key species and analyses of data relating to water quality, biota, endangered and threatened species.

The designated uses recommended in the October 2003 document reflect the habitats of several commercially, recreationally, and ecologically important species and aquatic communities. Vertical and horizontal boundaries are recommended based on natural factors, historical records, physical features, hydrology, and scientific reasons. The five designated uses outlined in the October 2003 document are: 1) migratory fish spawning and nursery, 2) shallow-water bay grass, 3) open-water fish and shellfish, 4) deep-water seasonal fish and shellfish, and 5) deep-channel seasonal refuge.

Figure 3-8 gives a visual depiction of these uses and Table 3-5 describes the uses in more detail. Attainability for the shallow-water use was assessed based on comparison of historical and recent bay grass distribution, as well as water clarity and chlorophyll a data. Attainability for all other uses was assessed based on dissolved oxygen modeled responses.

CBPO also released a Bay segmentation scheme in 2004 to assign designated uses within specific Bay segments. Table 3-6 is an excerpt from this segmentation scheme. Figure 3-9 and Table 3-7 provide an example of how criteria, in this case for dissolved oxygen, are selected applied for the protection of aquatic life use.

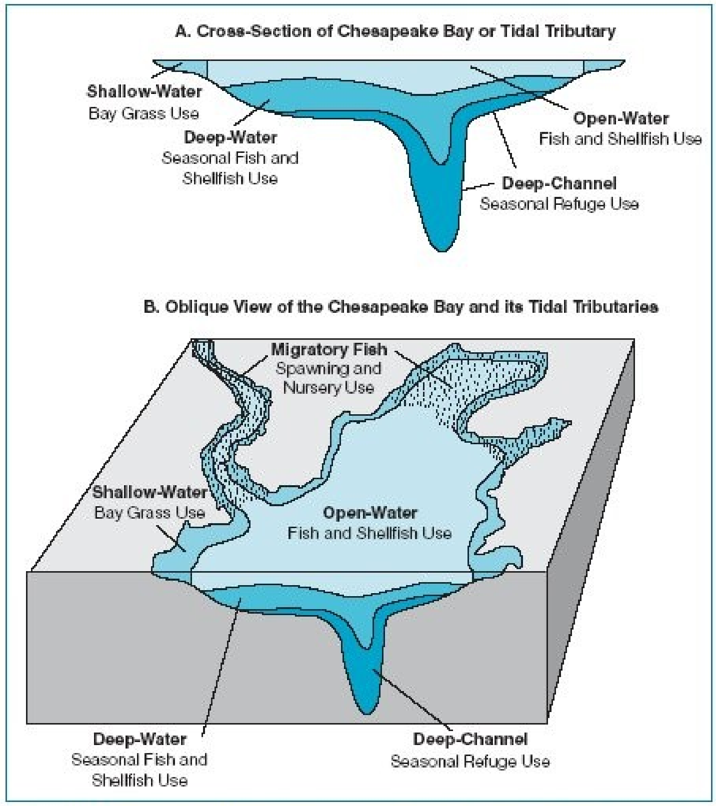

Figure 3-8: Conceptual Diagram of Chesapeake Bay Designated Use Zones (image courtesy US EPA Chesapeake Bay Program Office).

The 2003 and 2004 documents, along with several addenda, provide guidance to the states in adopting revised water quality standards for the Bay. Delaware, the District of Columbia, Maryland and Virginia have all subsequently adopted jurisdiction-specific Chesapeake Bay water quality standards consistent with the US EPA guidance documents.

Table 3-5: Five Chesapeake Bay Tidal Waters Uses (source: US EPA Chesapeake Bay Program Office).

Tidal water designated use	Chesapeake Bay habitats and communities protected
Migratory fish spawning and nursery	Migratory and resident tidal freshwater finfish during the late winter/spring spawning and nursery season in tidal freshwater to low-salinity habitats.
Shallow-water Bay grass	Underwater Bay grasses and fish and crab species that depend on the shallow-water habitat provided by underwater Bay grass beds.
Open-water fish and shellfish	Diverse populations of sport fish, including striped bass, bluefish, mackerel and sea trout, as well as important bait fish such as menhaden and silversides in surface water habitats within tidal creeks, rivers, embayments, and the mainstem Chesapeake Bay year-round.
Deep-water seasonal fish and shellfish	Animals inhabiting the deeper transitional water column and bottom habitats between the well-mixed surface waters and the very deep channels during the summer months (e.g., bottom-feeding fish, crabs and oysters, as well as other important species, including the Bay anchovy).
Deep-channel seasonal refuge	Bottom-sediment-dwelling worms and small clams that serve as food for bottom-feeding fish and crabs in the very deep channels in summer.

Table 3-6: Current Tidal Water Designated Uses by Chesapeake Bay Segment (excerpt only)* (source: US EPA Chesapeake Bay Program Office).

CB segment name	CB segment	Juris.	Migratory fish spawning & nursery	Open water fish & shellfish	Deep water seasonal fish & shellfish	Deep channel seasonal refuge	Shallow water Bay grasses
			Feb. 1–May 31	Year-round	June 1–Sept. 30	June 1–Sept. 30	SAV growing season
Northern Chesapeake Bay	CB1TF	MD	X	X			X
Upper Chesapeake Bay	CB2OH	MD	X	X			X
Upper Central Chesapeake Bay	CB3MH	MD	X	X	X	X	X
Middle Central Chesapeake Bay	CB4MH	MD	X	X	X	X	X
Lower Central Chesapeake Bay , MD	CB5MH_MD	MD		X	X	X	X
Lower Central Chesapeake Bay, VA	CB5MH_VA	VA		X	X	X	X
Western Lower Chesapeake Bay	CB6PH	VA		X	X		X
Eastern Lower Chesapeake Bay	CB7PH	VA		X	X		X
Mouth of the Chesapeake Bay	CB8PH	VA		X			X

*Only bay segments shown. There are also over 80 riverine segments with these uses assigned in the Chesapeake Basin.

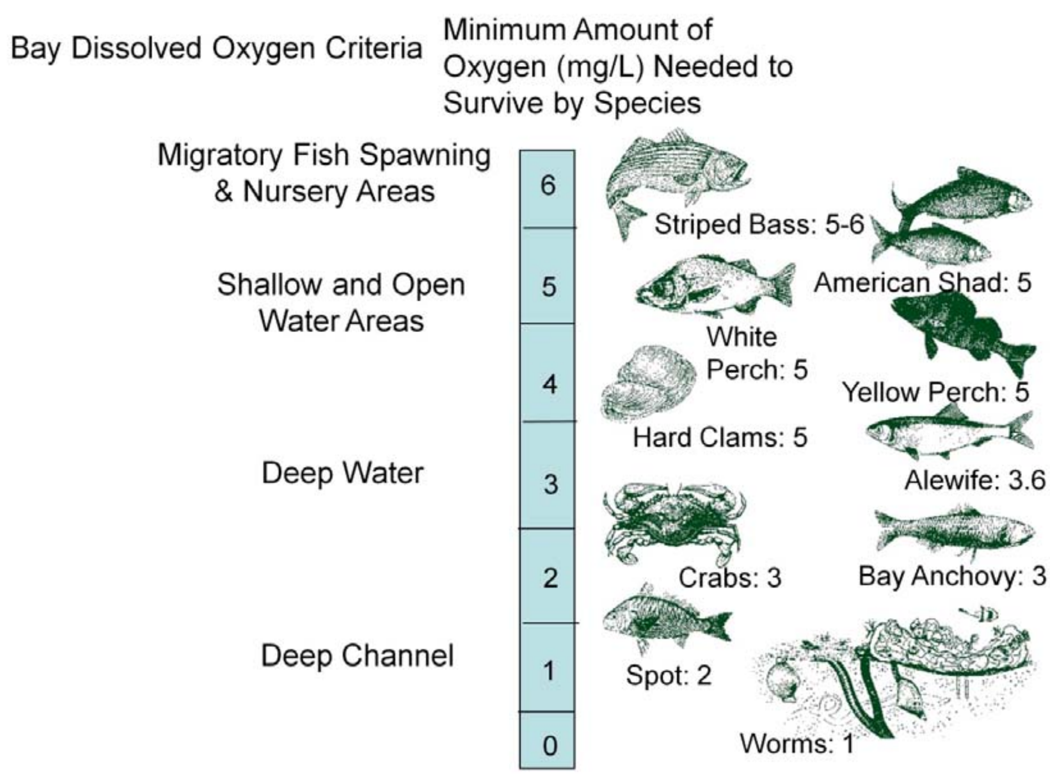

Figure 3-9: Dissolved Oxygen Concentrations (mg/L) Required by Different Chesapeake Bay Species and Biological Commmunities (from US EPA 2003).

Table 3-7: Current Chesapeake Bay DO Criteria (source: US EPA Chesapeake Bay Program Office).

Designated use	Criteria concentration/duration	Protection provided	Temporal application
Migratory fish spawning and nursery use	7-day mean ≥ 6 mg/L (tidal habitats with 0–0.5 ppt salinity)	Survival and growth of larval/juvenile tidal-fresh resident fish; protective of threatened/endangered species	February 1–May 31
	Instantaneous minimum ≥ 5 mg/L	Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species	
	Open-water fish and shellfish designated use criteria apply		June 1–January 31
Shallow-water Bay grass use	Open-water fish and shellfish designated use criteria apply		Year-round
Open-water fish and shellfish use	30-day mean ≥ 5.5 mg/L (tidal habitats with 0–0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species	Year-round
	30-day mean ≥ 5 mg/L (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile, and adult fish and shellfish; protective of threatened/endangered species	
	7-day mean ≥ 4 mg/L	Survival of open-water fish larvae	
	Instantaneous minimum ≥ 3.2 mg/L	Survival of threatened/endangered sturgeon species[a]	
Deep-water seasonal fish and shellfish use	30-day mean ≥ 3 mg/L	Survival and recruitment of Bay anchovy eggs and larvae	June 1–September 30
	1-day mean ≥ 2.3 mg/L	Survival of open-water juvenile and adult fish	
	Instantaneous minimum ≥ 1.7 mg/L	Survival of Bay anchovy eggs and larvae	
	Open-water fish and shellfish designated use criteria apply		October 1–May 31
Deep-channel seasonal refuge use	Instantaneous minimum ≥ 1 mg/L	Survival of bottom-dwelling worms and clams	June 1–September 30
	Open-water fish and shellfish designated use criteria apply		October 1–May 31

Notes: mg/L = milligrams per liter; ppt = parts per thousand salinity
a. At temperatures considered stressful to shortnose sturgeon (> 29 degrees Celsius), DO concentrations above an instantaneous minimum of 4.3 mg/L will protect survival of this listed sturgeon species.

Also in 2004, the Bay basin states agreed on 88 water quality and biota monitoring stations as well as sampling methods. Water quality indicators monitored and assessed include dissolved oxygen, water clarity (Secchi depth), chlorophyll a, and chemical contaminants (including metals, PCBs and tributyltin). Habitat and food web indicators include bottom / benthic habitat, bay grasses, phytoplankton, and wetlands. Fish and shellfish indicators include blue crab, oysters, striped bass, American shad, and menhaden. States and USGS perform the monitoring, and the CBP provides data summaries via annual basin reports. States then create their own CWA 303(d) lists and 305(b) reports.

Summary of Observations Regarding Approaches in Other Large Aquatic Ecosystems

While none of the three large aquatic ecosystems examined here are an exact analog to the UMR, some observations of potential relevance to UMR aquatic life uses are:

- Each has addressed some component of spatial diversity in aquatic life designated uses and assessment.
- In two cases, the Delaware River and Chesapeake Bay, spatial diversity has been addressed by creating spatially-specific designated use or waterbody classification schemes. These two programs have also adapted their water quality criteria to address spatial, as well as seasonal, diversity.
- ORSANCO has taken a different approach of using more general designated uses and criteria but then making adjustments in biological assessments to accommodate for spatial differences.
- In all three programs, there is a much more significant institutional structure and financial investment supporting CWA waterbody-specific programs than currently exists on the UMR.

Chapter 4:
Data Analysis and Literature Synthesis to Examine UMR Water Quality and Aquatic Life

GOAL OF DATA ANALYSIS AND LITERATURE REVIEW

As stated in Chapter 3, analysis of water quality data, including biological data, is critical to answering the question: **"Are the aquatic life communities on the UMR distinct enough in their characteristics to require differentiation of aquatic life uses in a Clean Water Act context?"** This chapter presents a data analysis and literature review focused on answering this question. The subsequent chapter (Chapter 5) addresses how CWA approaches may need to change to reflect any identified distinctions.

APPROACH TO DATA AND LITERATURE REVIEW

Selection of Data Sets and Literature for Review

The WQTF identified the following data and literature as those of most relevance to UMR aquatic life designated uses:

- Water quality data, including biological data, from the USACE's Long Term Resource Monitoring (LTRM), as well as recent literature utilizing these data.
- Water quality data, including biological data, from the US EPA's Environmental Monitoring and Assessment Program – Great Rivers Ecosystems (EMAP-GRE) survey.

These two programs each have extensive data sets, though each have differing degrees of spatial and temporal coverage on the UMR. They have different goals and objectives for their data collection, but similar sampling methods for some parameters. Both programs have rigorous quality assurance and quality control procedures in place. Both have extensive databases, have produced technical reports, and have expert scientific staff available to offer data review and interpretation assistance. Of note, these two programs have also been a primary focus of the WQTF's recent UMR CWA biological assessment guidance document development.

Other programs, including the US EPA National Rivers and Streams Assessment (NRSA) and state-specific monitoring efforts, have potentially relevant data for the consideration of UMR aquatic life uses. However, these data were either not yet available (i.e., NRSA) or limited in spatial coverage. As such, they were not included in this project's analyses.

General Approaches to Examining Data and Literature

LTRM and EMAP-GRE data, as well as LTRM literature, were examined in several ways to help reveal any important distinctions and patterns, including:

- Compilation of data and creation of basic summary statistics such as means and ranges, for key chemical and physical parameters identified by the WQTF.
- Review of data compilations for spatial trends and patterns. This included visual evaluation of data trends and patterns, as well as some statistical "clusters" analyses.
- Comparison of means and ranges to selected "threshold" values for certain chemical and physical parameters. The selection and use of threshold values is discussed in detail later in this chapter.

- Extraction and synthesis of relevant analyses and conclusions from published literature utilizing LTRM data.

DATA SETS REVIEWED

LTRM Water Quality

Examination of LTRM data was a priority because of the program's intensive monitoring of UMR aquatic strata. Specifically, quarterly stratified random sampling[3] (SRS) data exists from 1994 to the present for five UMR study reaches – Pool 4, Pool 8, Pool 13, Pool 26, and the Open River (see Figure 4-1). These study reaches cover portions of the UMR CWA assessment reaches 2, 4, 6, 11, and 13 respectively (see Table 2-6).

LTRM chemical and physical data were examined for three seasons to capture varied conditions on the UMR: winter (maximum ice and snow cover), spring (maximum discharge), and summer (typically minimum discharge, highest temperature). Parameters reviewed were temperature, dissolved oxygen, conductivity, pH, turbidity, total suspended solids, chlorophyll-a, total nitrogen, and total phosphorus (see Appendix C).

LTRM biological data for fish, macroinvertebrate, and aquatic vegetation communities were also examined (see Appendix E). Biological metrics reviewed included richness, community composition and structure, number of individuals for particular species / functional groups, percent frequency of occurrence, and abundance index. LTRM biological monitoring occurs only in the summer, so review was limited to just this season. Data availability was limited in part as LTRM macroinvertebrate sampling ended in 2004, and aquatic vegetation is currently not sampled at Pool 26 or the Open River.

LTRM data were examined in four prominent sampling strata[4] as follows:

- ***Main channel***: the navigation channel and its border
- ***Side channels***: channels other than the main channel
- ***Contiguous backwaters***: off-channel areas with apparent surface water connection to the main channel
- ***Impounded***: large, mostly open-water off-channel areas located in the downstream portion of the navigation pools, upstream of a lock and dam

Isolated backwaters were not included in these analyses as very few data are available for this stratum, except in Pool 8. Of note, the distinctions between strata may be approximate because strata delineations are based on interpretations of 1989 aerial photography, and thus do not incorporate variable on-site factors such as depth and water velocity.

Strata-specific means, by pool and season, for selected chemical and physical parameters were calculated and examined, as were maximum and minimum values per season and stratum in each pool. The means, maximums, and minimums were compared to threshold values as described later in this chapter.

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[3] Only LTRM SRS data were was examined as part of this analysis. Fixed site LTRM data were not included as they cannot not be directly merged with strata-focused SRS data analyses.

[4] Strata definitions taken from 2006 LTRM Water Quality Component Update (Houser and Rogala 2006).

Figure 4-1: Map of LTRM Study Reach Locations on the UMR. Note Illinois River station in the LaGrange Pool is not being considered as part of this UMR aquatic life designated use project (image courtesy USACE-LTRM).

LTRM Reports

Several recent reports utilizing LTRM data were incorporated into this project's literature review. Water quality reports reviewed were those recommended by LTRM staff as best addressing UMR spatial and seasonal variations. Fish- and vegetation-focused reports selected for review included those providing insight into study reach, pool, strata, or seasonal patterns in UMR aquatic communities. Reports giving insight into the dynamics of water quality as related to aquatic communities were also reviewed. In all, two water quality reports (Houser 2005 and Houser, et al. 2010), six fisheries reports (Barko et al. 2005, Chick et al. 2005, Ickes et al. 2005, Irons et al. 2009, Kirby and Ickes 2006, and Knights et al. 2008), three aquatic vegetation related reports (Langrehr and Moore 2008, Yin and Langrehr 2005, and Yin et al. 2010), and the comprehensive 2008 LTRM "Status and Trends" report (Johnson and Hagerty 2008) were reviewed for this project.

EMAP-GRE Water Quality Data

The US EPA EMAP-GRE data set includes chemical, physical, and biological information collected on the UMR in 2004-2006. Main channel border sampling took place in mid-summer each of these three years. 144 locations were monitored using a random sampling approach, with multiple (from 3 to 19) sample sites in each of the 13 CWA assessment reaches (see Figure 4-2). EMAP-GRE's data is unique and valuable for this project as it covers the entire length of the UMR.

This project reviewed EMAP-GRE data for the 13 UMR CWA assessment reaches. Water quality parameters examined included temperature, dissolved oxygen, conductivity, pH, turbidity, total suspended solids, chlorophyll-a, total nitrogen, and total phosphorus. Several fish community metrics were also reviewed, including richness, biomass, and abundance of non-native species.

Additionally, EMAP-GRE developed the Great Rivers Fish Index (GRFIn) of biological integrity. GRFIn scores were also among the parameters examined in this project.

Figure 4-2: Map of UMR EMAP-GRE Sampling Locations. Stations on the UMR are pink; some stations on the Ohio and Missouri Rivers are also shown in yellow (image courtesy US EPA).

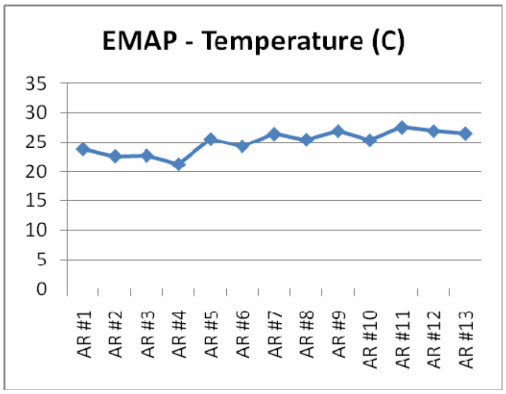
LONGITUDINAL PATTERNS IN WATER QUALITY DATA

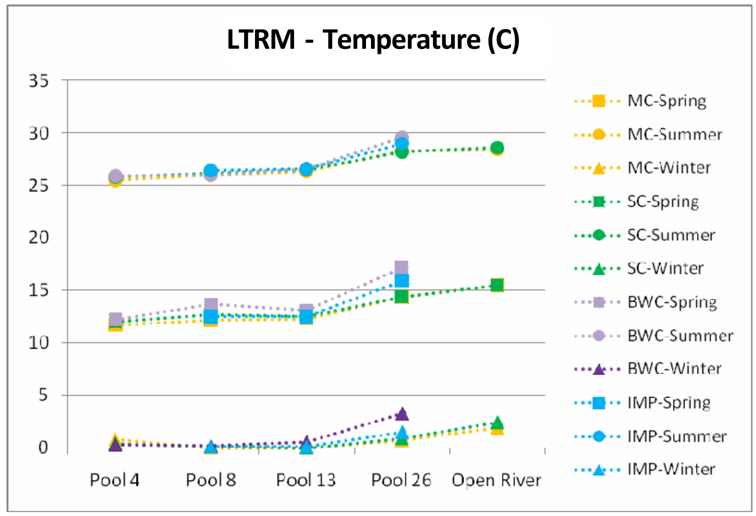
Longitudinal Patterns in Chemical and Physical Data

Trends and Patterns

Summarized findings from water quality data and literature examination for longitudinal patterns follow. For further details, see Appendix C for comprehensive tables addressing LTRM water quality data and Table 4-1 on page 4-10 for a summary regarding EMAP-GRE water quality parameters of interest.

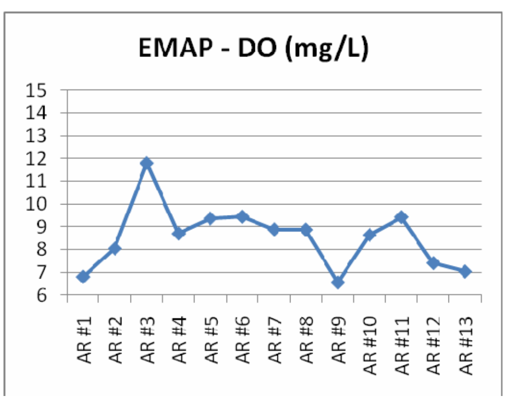
- ***Temperature***: Water temperature generally increases downstream for all strata in the spring and summer. In summer, there are maximum water temperature values above 30º C more than 10% of the time in some strata of the lower LTRM study reaches, including all strata of Pool 26 (22-41% of the time) and the main channel of the Open River (21% of the time).

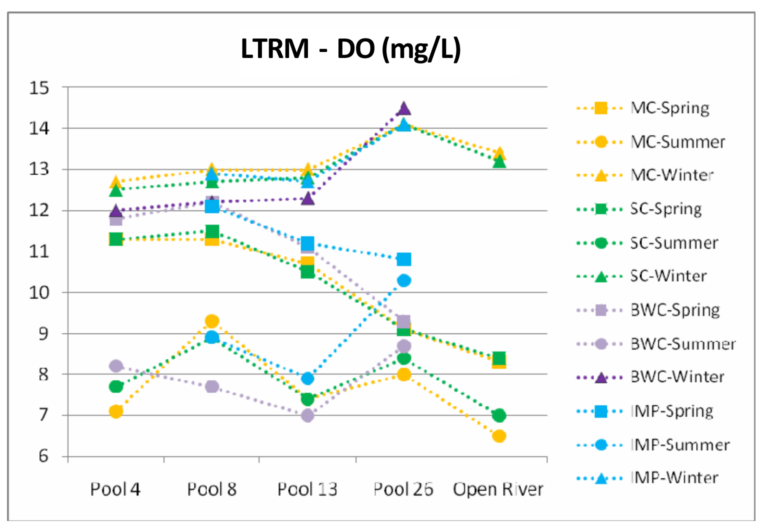




Figures 4-3 and 4-4: Mean Temperatures in Celsius from EMAP-GRE (2004-2006) and LTRM (1994-2008) by reach[5]

- ***Dissolved Oxygen (DO)***: Longitudinal patterns for DO are seasonally dependent. In the spring values are higher upstream and in the winter values are higher downstream. Spring means for all LTRM strata are between 8.3-12.1 mg/L and winter means for all strata are between 12.0-14.5 mg/L. In the summer, there are no distinct longitudinal dissolved oxygen patterns. These observations are generally consistent with the findings presented in Houser (2005).

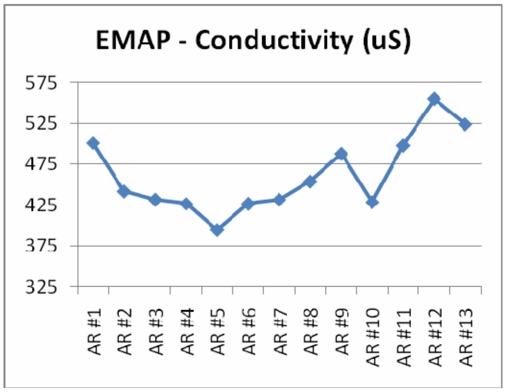


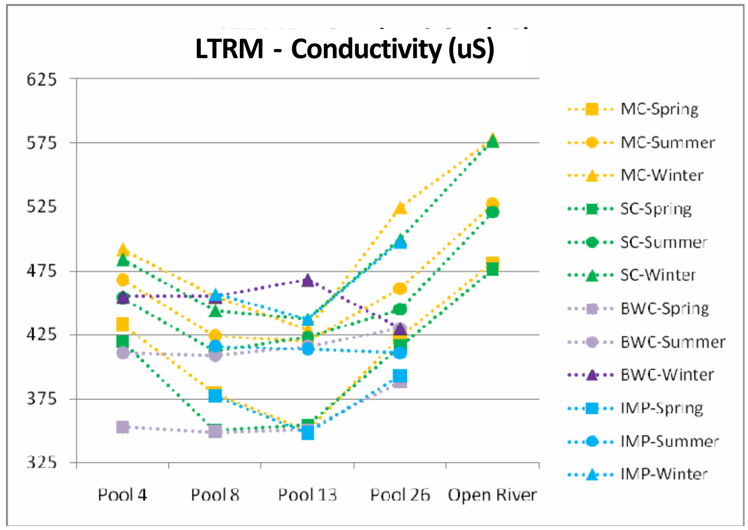


Figures 4-5 and 4-6: Mean Dissolved Oxygen (DO) concentrations from EMAP-GRE (2004-2006) and LTRM (1994-2008) by reach

5 For Figures 4-3 through 4-21, the term "reach" means CWA assessment reaches (AR) for EMAP graphs and study reaches for LTRM graphs.

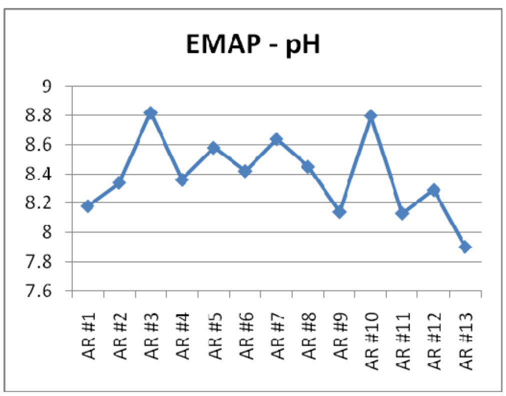
- ***Conductivity:*** Conductivity generally declines from Pool 4 to approximately Pool 13, then increases through the Open River. River-wide, mean values range from 348 – 578 µS when all seasons are considered.

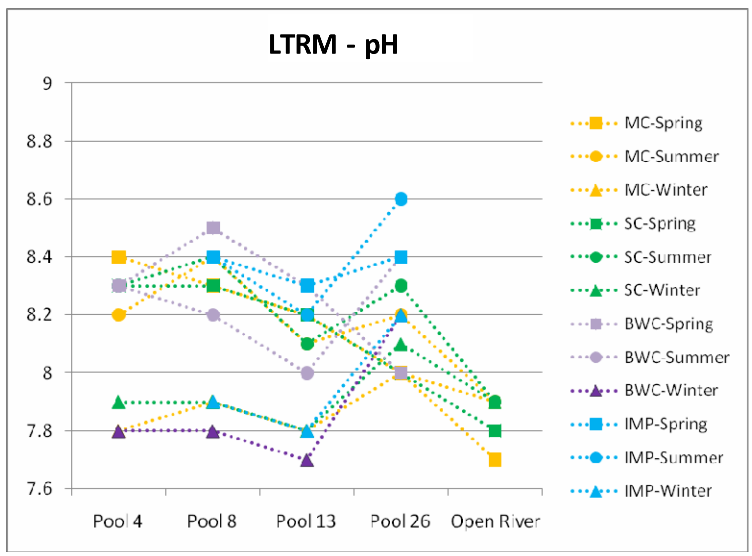




Figures 4-7 and 4-8: Mean Conductivity levels from EMAP-GRE (2004-2006) and LTRM (1994-2008)by reach

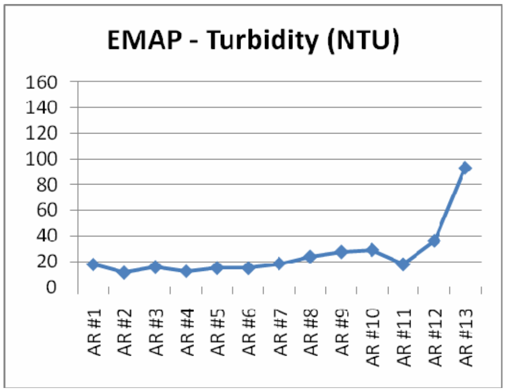
- ***pH:*** No longitudinal patterns are apparent in pH data, though there is some indication of generally decreasing levels moving downstream for all seasons, with the prominent exception of Pool 26.

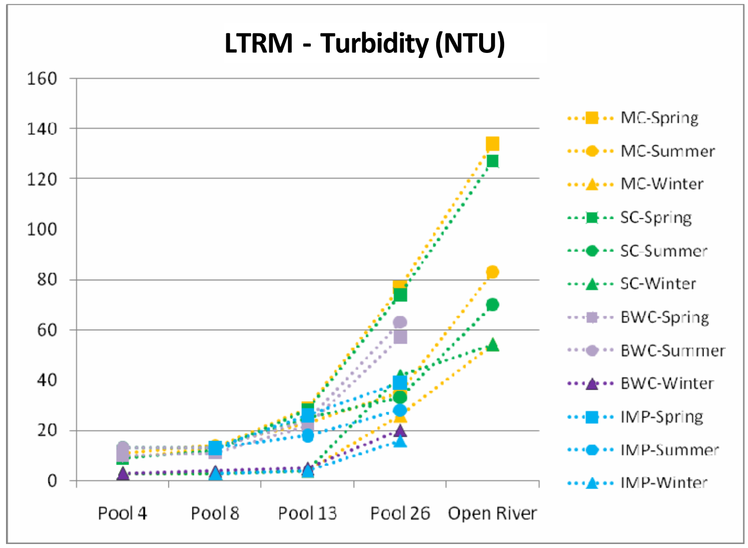




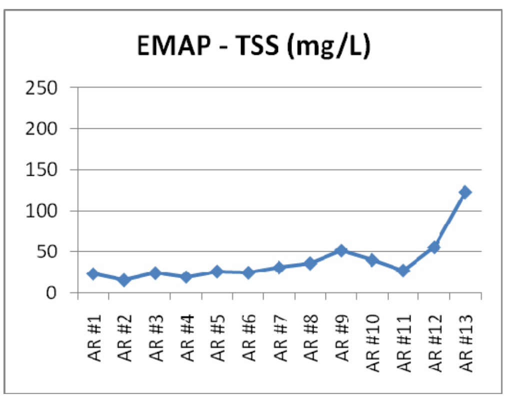
Figures 4-9 and 4-10: Mean pH levels from EMAP-GRE (2004-2006) and LTRM (1994-2008) by reach

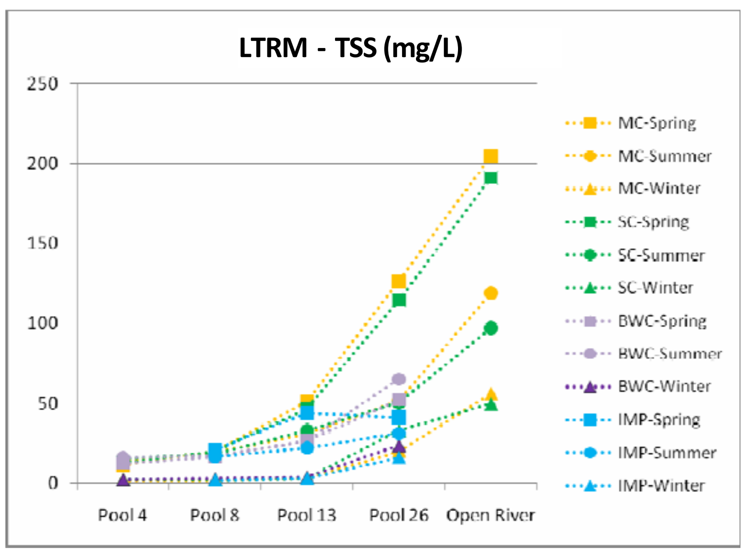
- ***Turbidity and Total Suspended Solids (TSS)***: There are dramatic longitudinal increases in turbidity (from 3 to 134 NTU) and TSS (from 2.0 to 204 mg/L) for all study pools moving downstream in all seasons. Many seasonal averages and ranges are above threshold values for turbidity and TSS in Pool 13, Pool 26, and the Open River. However, thresholds for these parameters may not necessarily be relevant in the River's lower reaches, as these reaches historically had higher levels of suspended materials, particularly below the Missouri River (Meade 1995).





Figures 4-11 and 4-12: Mean Turbidity from EMAP-GRE (2004-2006) and LTRM (1994-2008) by reach





Figures 4-13 and 4-14: Mean Total Suspended Solids (TSS) concentrations from EMAP-GRE (2004-2006) and LTRM (1994-2008) by reach

The graphs above do not identify the effect of Lake Pepin on longitudinal TSS and turbidity gradients. Houser (2005) and Houser, et al. (2010) spilt Pool 4 data into to Upper and Lower Pool 4 groupings to better illustrate this effect. When this is done, the impact of suspended materials settling in Lake Pepin can clearly be seen (Figure 4-15) as a notable discontinuity in an otherwise increasing gradient.

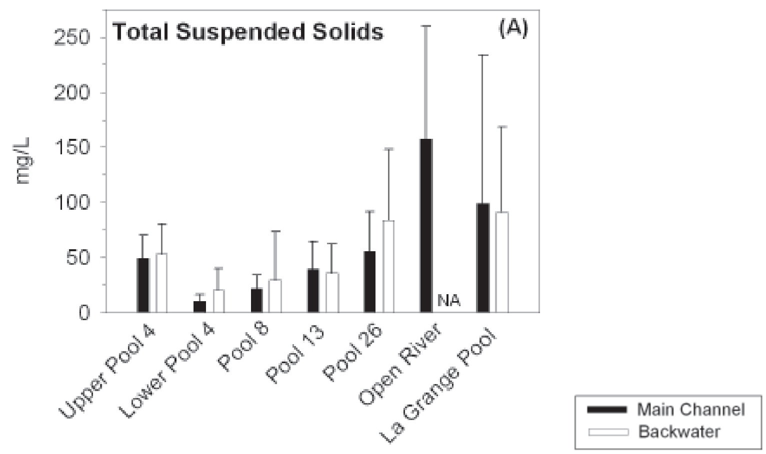
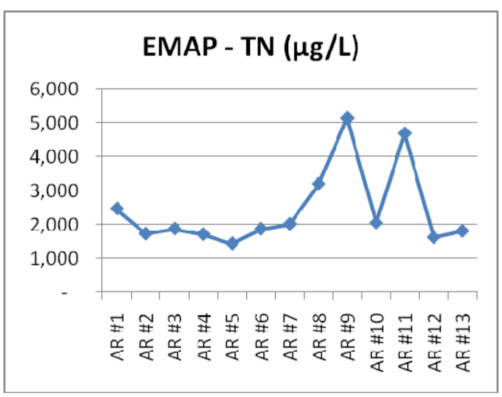


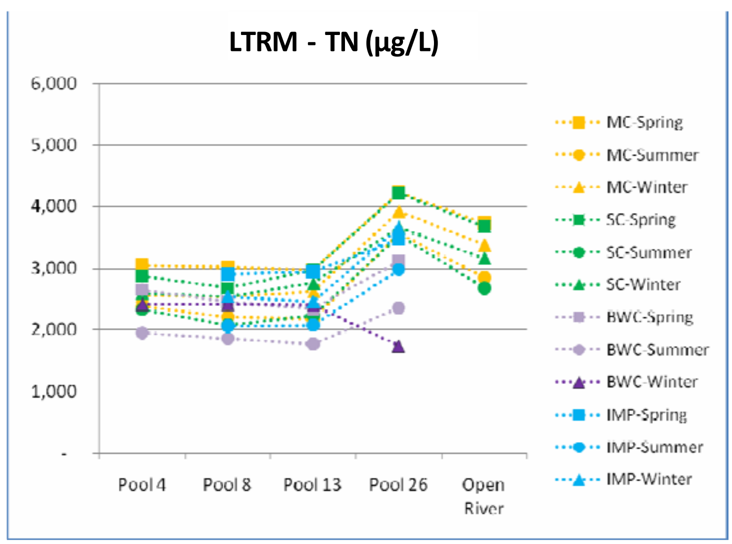
Figure 4-15: Mean Total Suspended Solids (mg/l) in Main Channel and Backwater Strata. Summer LTRM stratified random sampling (1993-2001). Note that La Grange Pool is on the Illinois River. Error bars represent +/- one standard deviation (from Houser 2005).

- ***Nitrogen and Phosphorus***: Nitrogen and phosphorus both appear in higher concentrations in the UMR's lower reaches than in its upper reaches. However, these parameters demonstrate differing specific longitudinal patterns. Total nitrogen (means from 1.62 – 5.13 mg/L) is roughly constant moving downstream through Pool 13, increases from Pool 13 to Pool 26, and then declines in the Open River. Total phosphorus (means from 68 – 360 µg/L) generally increases moving downstream, reaching it highest levels in Pool 26 and the Open River.

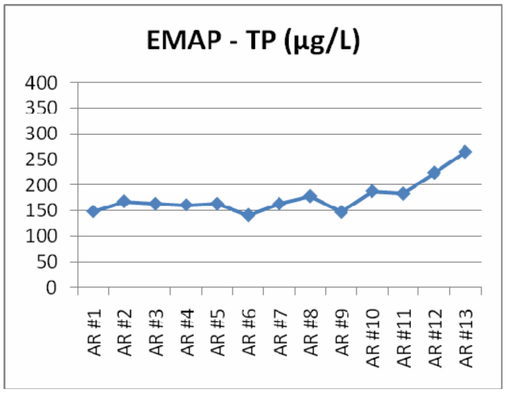
  Houser, et al. (2010) characterized changes in phosphorus as an increasing gradient. For nitrogen, they described the pattern as a difference between northern and southern pools rather than a gradient *per se*. These authors also found Lake Pepin's settling process to have a notable impact in reducing total phosphorus concentrations (due to phosphorus' affinity for particles) and relatively less effect on nitrogen (Houser, et al. 2010).

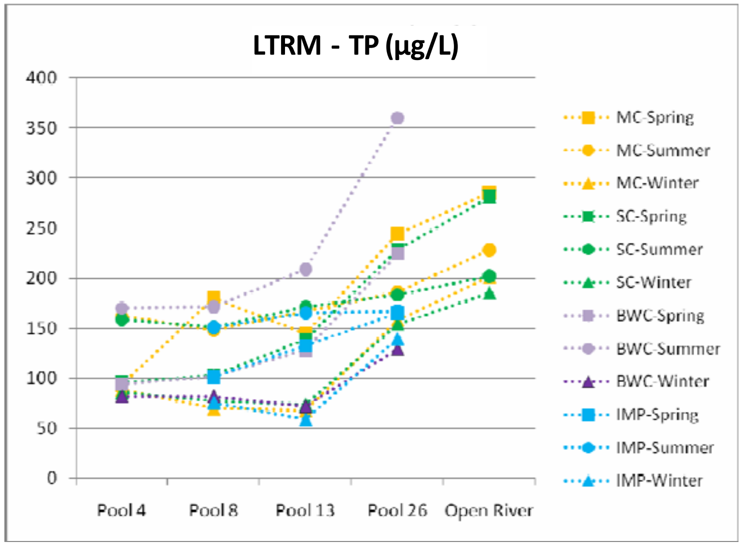
  Nutrient concentrations are also strongly influenced by the season. In spring and summer, means and ranges for most pools and strata are above the 100 µg/L phosphorus threshold. In winter, only Pool 26 and the Open River have total phosphorus averages above 100 µg/L.





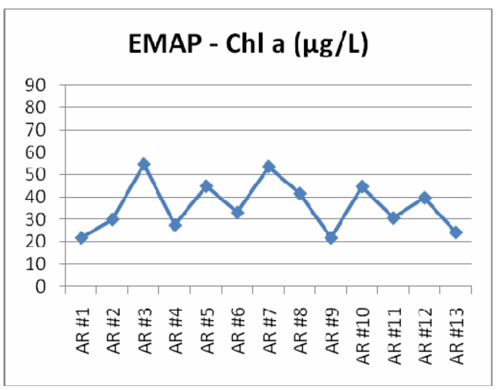
Figures 4-16 and 4-17: Mean Total Nitrogen (TN) concentrations from EMAP-GRE (2004-2006) and LTRM (1994-2008) by reach

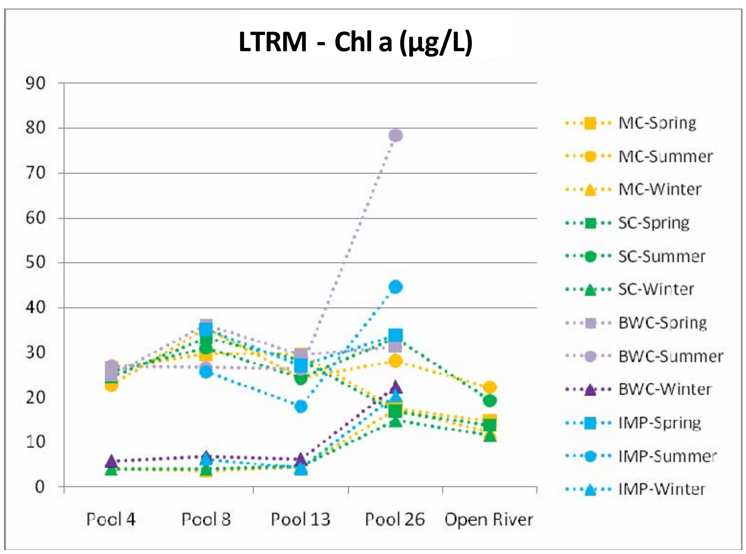




Figures 4-18 and 4-19: Mean Total Phosphorus (TP) concentrations from EMAP-GRE (2004-2006) and LTRM (1994-2008) by reach

- ***Chlorophyll-a***: Chlorophyll-a is a nutrient-related parameter indicative of algal biomass that displays seasonally-dependent longitudinal patterns. For example, in spring it is highest in the upper LTRM reaches (Pool 4, 8, 13) and decreases downstream; but in winter the inverse is true as chlorophyll-a is lowest in the upper LTRM reaches (Pool 4, 8, 13) and increases downstream. In summer, chlorophyll-a levels do not show distinct longitudinal patterns, with summer main channel means per CWA assessment reach ranging from 21.9 – 54.7 µg/L. Houser (2005) noted similar seasonal dependence in longitudinal patterns of chl-a in backwaters (see Figure 4-22). Houser et al. (2010) noted that chl-a concentrations in the Open River may be limited by reduced light availability, due to higher suspended solids concentrations in this reach.





Figures 4-20 and 4-21: Mean Chlorophyll-a (chl-a) concentrations from EMAP-GRE (2004-2006) and LTRM (1994-2008) by reach

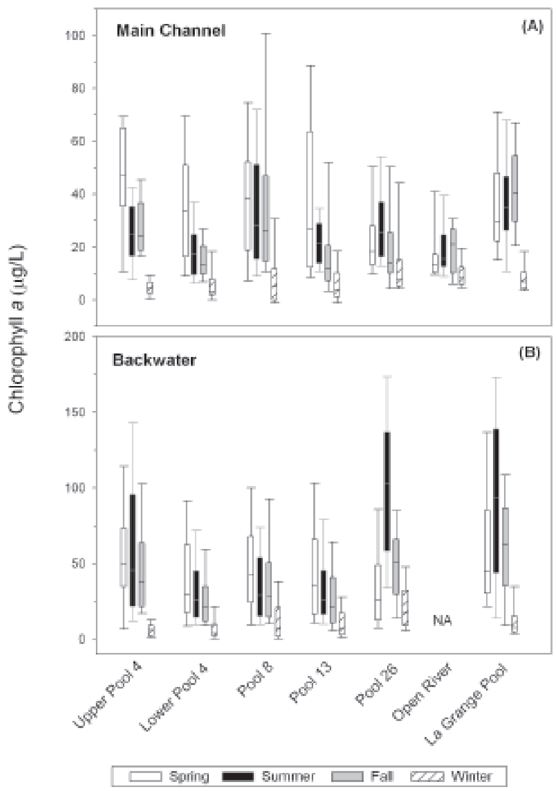


Figure 4-22: Box Plots of Winter, Spring, Summer, and Fall Chlorophyll-a (µg/l) Concentrations in Main Channel and Backwaters. LTRM stratified random sampling (1993-2001). Box plots represent the 10^{th}, 15^{th}, 50^{th}, 75^{th}, and 90^{th} percentiles (from Houser 2005).

Table 4-1: EMAP-GRE Chemical and Physical Data. Means per CWA assessment reach are provided. Samples were collected in summers 2004-2006, from UMR main channel.

	Temp (^oC)	DO (mg/L)	Conductivity (µS)	pH	Turbidity (NTU)	TSS (mg/L)	TN (µg/L)	TP (µg/L)	Chl a (µg/L)
AR #1	23.8	6.81	501	8.18	17.6	23.4	2467	148	21.9
AR #2	22.6	8.05	442	8.34	11.2	15.7	1726	168	30.1
AR #3	22.7	11.79	432	8.82	15.7	24.3	1875	163	54.7
AR #4	21.2	8.70	427	8.36	12.3	19.6	1711	161	27.5
AR #5	25.5	9.36	395	8.58	14.9	26.2	1438	163	44.9
AR #6	24.3	9.44	427	8.42	14.8	24.8	1870	141	33.1
AR #7	26.4	8.88	432	8.64	18.3	31.0	2009	163	53.6
AR #8	25.4	8.87	454	8.45	23.7	36.2	3192	178	41.6
AR #9	26.9	6.56	488	8.14	27.4	51.9	5130	147	21.9
AR #10	25.3	8.64	429	8.80	29.0	40.2	2043	188	44.7
AR #11	27.5	9.42	498	8.13	17.7	27.4	4681	183	30.7
AR #12	26.9	7.41	555	8.29	36.2	55.8	1615	224	39.7
AR #13	26.5	7.04	524	7.90	93.3	123.1	1804	265	24.3

Summarized Longitudinal Trends and Patterns in Chemical and Physical Data

A summary of the longitudinal water quality patterns seen in LTRM and EMAP-GRE chemical and physical data, as well as LTRM water quality reports, appears in Table 4-2.

Table 4-2: Summary of Longitudinal Patterns in LTRM and EMAP-GRE Chemical and Physical Data

Parameter	General Longitudinal Patterns
Temperature	Generally increases downstream, during all seasons
Dissolved Oxygen	Seasonally dependent, where: - In winter, greater downstream - In spring, greater upstream - No longitudinal gradient in the summer
Conductivity	For all seasons, generally declines from Pool 4 through approximately Pool 13, then increases through the Open River
pH	No prominent pattern, though some decrease in values moving downstream for all seasons, with the exception of Pool 26.
Turbidity	After decline at Lake Pepin, generally increases downstream for all seasons
Total Suspended Solids	After decline at Lake Pepin, generally increases downstream for all seasons
Total Nitrogen	For all seasons, roughly constant through Pool 13, increases through Pool 26, and then declines in the Open River
Total Phosphorus	Generally increases downstream during all seasons
Chlorophyll a	Seasonally dependent, where: - In winter, increases downstream - In spring, relatively constant with slight decline downstream - No gradient in the summer

Cluster Analyses for Longitudinal Patterns

To further analyze longitudinal water quality patterns, cluster analyses were performed by UMRBA staff on the EMAP-GRE chemical and physical data presented in Table 4-1. In these analyses, CWA assessment reaches where water quality is similar across parameters will cluster together. To conduct the clustering, an algorithm was used that required both a data set and a selection of the number of clusters desired. Preliminary statistical analysis indicated that three or four clusters would be most likely to identify meaningful distinctions in these data (see Appendix D for details). As such, analyses were run on these data, and subsequent data sets, using three and four clusters. The analyses' results are presented in Table 4-3.

The results of these cluster analyses indicate a longitudinal transition occurring between CWA assessment reaches 6 and 7 (between Pool 13 and 14), as well as another longitudinal distinction somewhere between assessment reaches 10 and 12 (between Pool 22 and the Kaskaskia River confluence). While there are no obvious lines that divide the River neatly into sections, there is a definite distinction apparent between the upper, middle, and lower reaches of the UMR.

Additionally, cluster analyses were run to compare intrapool variation (i.e., from upper pool reaches to lower pool reaches) to variation between reaches (see Appendix D). These analyses showed that between-reach variations in water quality are more prominent that intrapool variations.

Table 4-3: Cluster Analyses of EMAP-GRE Chemical and Physical Data. Showing which CWA assessment reaches are most similar to each other when longitudinal patterns are analyzed.

Assessment Reach Number (Name)	3 Clusters	4 Clusters
AR #1 (Rush - Vermillion)	1	1
AR #2 (Buffalo - Whitewater)	1	1
AR #3 (La Crosse – Pine)	2	2
AR #4 (Coon – Yellow)	1	1
AR #5 (Grant - Maquoketa)	2	2
AR #6 (Apple – Plum)	1	1
AR #7 (Copperas – Duck)	2	2
AR #8 (Flint – Henderson)	2	2
AR #9 (Bear – Wyaconda)	2	3
AR #10 (The Sny)	2	2
AR #11 (Peruque – Piasa)	2	3
AR #12 (Cahokia – Joachim)	2	3
AR #13 (Upper Miss – Cape Girardeau)	3	4

Longitudinal Patterns in Fish Communities

Patterns Identified in LTRM Literature and Data

Longitudinal patterns in UMR fish communities are well documented in LTRM reports. In Chick et al. (2005), fish community composition (presence/absence) and fish community structure (relative abundance) were shown to vary among study reaches. Ordination figures 4-23 and 4-24 are taken from this paper and provide a visual representation of the variations between and similarities among fish communities in LTRM study reaches. These figures illustrate distinctions between upper reaches and lower reaches generally, as well as some difference between Pool 8 and the other upper reaches, as seen in Figure 4-24. Note that the LaGrange pool, abbreviated LG in the figures, is on the Illinois River and not part of this project.

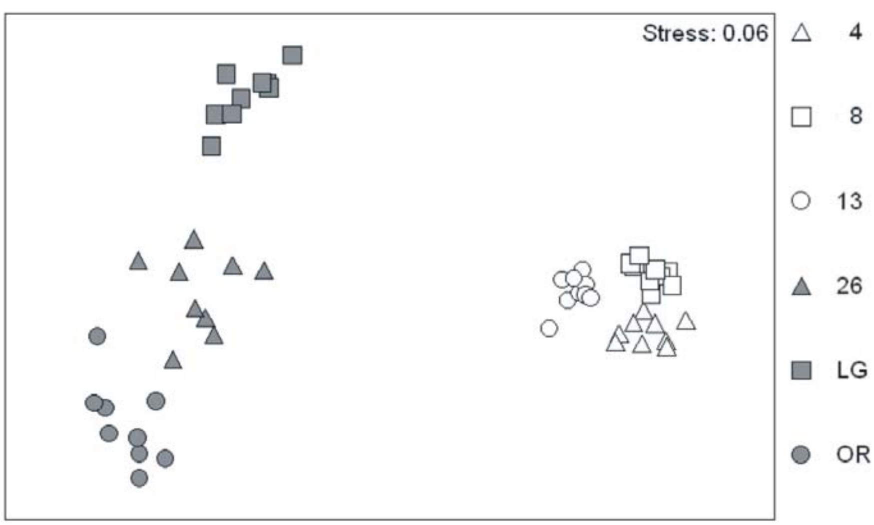


Figure 4-23: Ordination Analysis of Fish Community <u>Composition</u> Data (presence/absence) for the UMR collected by LTRM, 1994–2002. Data were from a combination of day electrofishing, large and small hoop nets, fyke nets, and mini-fyke nets. Each point represents community composition for a single year within the designated study reach. The upper study reaches (Pools 4, 8, and 13) are represented by open symbols whereas the lower study reaches (Pool 26, La Grange Pool, and Open River Reach) are represented by shaded symbols (from Chick et al. 2005).

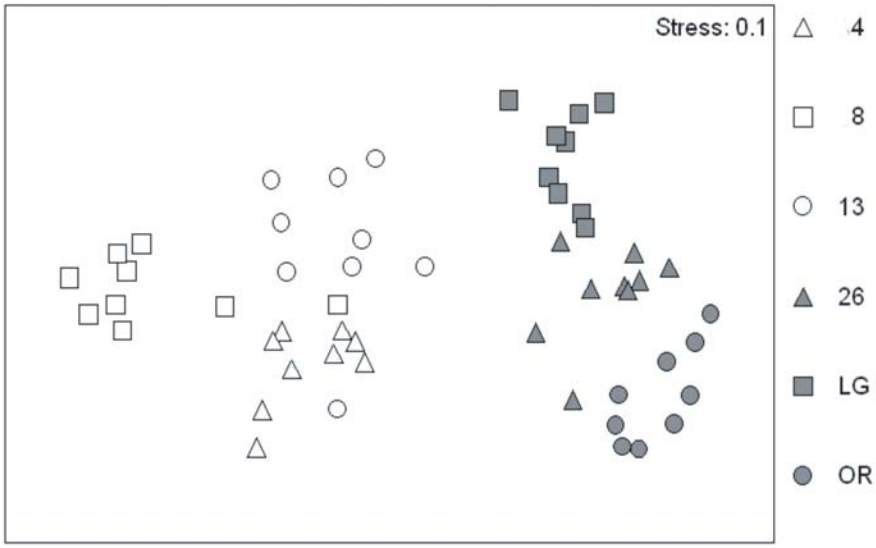


Figure 4-24: Ordination Analysis of Fish Community Structure Data (relative abundance, as square root catch/15 min of day electrofishing) for the UMR collected by LTRM, 1994–2002. Each point represents community structure (based on poolwide means) for a single year within the designated study reach. The upper study reaches (Pools 4, 8, and 13) are represented by open symbols whereas the lower study reaches (Pool 26, La Grange Pool, and Open River Reach) are represented by shaded symbols (from Chick et al. 2005).

In Kirby and Ickes (2006), significant differences in length-weight ratios were noted among the UMR study reaches in regard to five fish species: black crappie (*Pomoxis nigromaculatus*), channel catfish (*Ictalurus punctatus*), common carp (*Cyprinus carpio*), sauger (*Sander canadensis*), and walleye (*S. vitreus*). They also observed a higher proportion of large fish in Pool 4, and a lower proportion of large fish in the southern study reaches. In addition, Kirby and Ickes note that out of 136 fish species the LTRM program has collected to date, 47 fish species were common and collected in each of the five study reaches; 24 fish species were only collected in one study reach (rare or uncommon); and 33 species were collected in 2 or 3 study reaches.

In Ickes et al. (2005), the lowest proportion of non-native fish biomass was found in Pool 8, suggesting a healthier fish community in that study reach. Johnson and Hagerty (2008) noted that recreational fish are declining in the Open River, and this could potentially be an indicator of declining health in the fish community in that reach. Finally, Knights et al. (2008) reported that results of sampling off-channel fish assemblages showed degraded fish communities in upper Pool 4, and good recreational fisheries in upper and middle Pool 8 and Pool 13.

Several LTRM fisheries reports further reveal longitudinal patterns in terms of groups of study reaches, sometimes referred to as upper (Pools 4, 8, 13) and lower (Pool 26 and Open River) reaches. In Chick et al. (2005), fish community composition (presence/absence) was noted to be most different between upper and lower reaches. Five fish species were exclusively found in upper study reaches (Table 4-4), and 19 species were found only in lower study reaches (Table 4-5). They reported little overlap between upper and lower reaches in terms of fish community structure (relative abundance).

Ickes et al. (2005) noted that fish species richness is highest in upper study reaches, and lower richness is observed in lower reaches. They also reported fewer non-native fish species and a lower proportion of non-native biomass in the upper reaches, and more non-native species in the lower reaches, thus suggesting degraded aquatic communities and habitat conditions in the lower UMR. Johnson and Hagerty (2008) noted non-native fish are declining and recreational fish are increasing in the upper study reaches. These elements indicate a healthier ecosystem in the upper reaches. Knights et al. (2008), reported that among upper study reaches the off-channel fish assemblages are similar to each other, and that among lower study reaches the off-channel fish assemblages resemble each other.

Overall, these studies demonstrate that there are significant fish community differences among the LTRM study reaches. They show that potentially the healthiest UMR fish communities exist in Pool 8 (followed by Pool 13) among the study reaches, in regard to richness, community structure and composition, native biomass and other metrics. A number of the studies also emphasized the distinction between fish communities in the upper study reaches and the lower study reaches.

Table 4-4: Five Fishes Found Only in Upper LTRM Study Reaches (Pool 4, Pool 8, and Pool 13) (from Chick et al. 2005).

Common Name	Scientific Name
Burbot	*Lota lota*
Spotted sucker	*Minytrema melanops*
Weed shiner	*Notropis texanus*
Western sand darter	*Ammocrypta clara*
Central mudminnow	*Umbra limi*

Table 4-5: Nineteen Fishes Found Only in Lower LTRM Study Reaches (Pool 26, Open River, and LaGrange Pool) (from Chick et al. 2005).

Common Name	Scientific Name
Bighead carp	*Hypopthalmichthys nobilis*
Blue catfish	*Ictalurus furcatus*
Blacktail shiner	*Cyprinella venusta*
Blackstripe topminnow	*Fundulus notatus*
Freckled madtom	*Noturus nocturnus*
Goldfish	*Carassius auratus*
Grass carp	*Ctenopharyngodon idella*
Inland silverside	*Menidia beryllina*
Longear sunfish	*Lepomis megalotis*
Western mosquitofish	*Gambusia affinis*
Red shiner	*Cyprinella lutrensis*
Redear sunfish	*Lepomis microlophus*
Silverband shiner	*Notropis shumardi*
Striped bass	*Morone saxatilis*
Skipjack herring	*Alosa chrysochloris*
Spotted bass	*Micropterus punctulatus*
Silver carp	*Hypothalmichthys molitrix*
Threadfin shad	*Dorosoma petenense*
White perch	*Morone americana*

In addition to the review of LTRM reports, LTRM fish data was summarized for the purposes of this project by study pool, season and strata for indicator species including those considered of recreational value, commercial value, and forage value to aquatic communities (see Appendix E and Table 4-6). Patterns displayed in these summaries are generally are congruent with the findings of LTRM reports.

Table 4-6. Fish Species Richness and Top Ten Species per LTRM Study Reach in 2010. Queried for this project from LTRM online data browser.

	Average Species Richness (2006-2010)	Total Species All Years (2006-2010)	Most Abundant Fish Caught in 2010	
Pool 4	64	86	Emerald shiner (44,496) Mimic shiner (7,395) Bluegill (5,632) Gizzard Shad (3,633) Weed shiner (2,420)	Yellow perch (951) Largemouth Bass (839) Pumpkinseed (528) Spotfin shiner (515) Black crappie (478)
Pool 8	70	89	Bluegill (12,026) Weed shiner (4,887) Largemouth bass (2,215) Yellow perch (1,321) Un-id sunfishes (1219)	Emerald shiner (932) Pumpkinseed (715) Mimic shiner (594) Common carp (537) Black crappie (534)
Pool 13	60	83	Mimic shiner (2,227) Emerald shiner (1,476) Bluegill (1,158) Gizzard shad (873) Spottail shiner (608)	Common carp (533) Channel catfish (529) Yellow perch (503) Largemouth bass (456) Pumpkinseed (416)
Pool 26	55	89	Gizzard shad (2,207) W. Mosquitofish (1,312) Silver carp (1,018) Freshwater drum (618) Channel catfish (616)	Bluegill (570) White bass (519) Common carp (461) Emerald shiner (379) Black crappie (183)
Open River	63	98	Gizzard shad (672) Channel catfish (489) Smallmouth buffalo (487) Common carp (403) Freshwater drum (392)	Emerald shiner (369) Silver carp (257) Bluegill (225) Channel shiner (221) White bass (203)

Longitudinal Patterns in EMAP-GRE Data

EMAP-GRE fish community data metrics examined for this project included Great Rivers Fish Index (GRFIn) scores, richness, numbers of individuals, and biomass for native and non-native species. Table 4-7 includes displays EMAP-GRE fish community metrics as means per CWA assessment reach. Patterns apparent here are as follows:

- GRFIn scores were highest in CWA assessment reaches 2-4 (Chippewa River confluence to the Wisconsin River confluence), and lowest in CWA assessment reaches 1 (St. Croix River confluence to Chippewa River confluence) and 11-13 (below the Cuivre River confluence).
- Fish community richness was highest in CWA assessment reaches 2-5 (Chippewa River confluence through Pool 11).
- The number of fish individuals collected was highest in CWA assessment reaches 3-5 (Pool 7 through Pool 11), and lowest in CWA assessment reaches 11-12 (Lock & Dam 26 to the Kaskaskia River confluence).
- Biomass of native species was highest in CWA assessment reaches 1-4 (St. Croix River confluence to the Wisconsin River confluence), and lowest in CWA assessment reach 11 (Cuivre River confluence to Missouri River confluence).

Table 4-7: EMAP-GRE Fish Community Data. Presented as means per interstate CWA assessment reach for multi-metric index score (GRFIn), community richness, number of individuals, biomass to examine longitudinal patterns. Reaches are numbered north to south along the river's flow.

CWA Interstate Assessment Reach	GRFIn Score*	Richness	Native Richness	Number of Individuals	Number of Native Individuals	Biomass	Native Biomass
AR #1	4.82	19.43	18.33	481.9	448.8	150.0	64.6
AR #2	7.37	24.16	23.14	548.1	536.3	89.2	55.6
AR #3	8.21	27.87	26.45	698.9	678.9	125.9	101.9
AR #4	7.69	22.51	21.56	1197.7	1186.4	86.4	57.8
AR #5	6.68	22.81	21.81	701.4	691.0	50.6	24.3
AR #6	6.07	19.88	19.03	295.2	285.5	38.1	21.3
AR #7	5.00	19.19	18.19	598.7	579.3	75.6	23.6
AR #8	5.59	21.33	20.17	549.1	525.4	104.8	34.5
AR #9	4.91	19.42	17.85	338.5	327.2	61.6	34.1
AR #10	5.07	21.98	20.71	513.6	478.6	101.9	22.7
AR #11	3.37	16.00	14.25	256.8	241.3	51.1	19.9
AR #12	3.19	15.67	13.33	253.3	211.7	73.2	26.0
AR #13	4.78	17.92	16.01	441.1	362.8	75.5	35.9

*Different sets of metrics are used to calculate impounded (AR 1- 11) and unimpounded (AR 12-13) GRFIn scores.

Cluster Analyses of EMAP-GRE Fish Data for Longitudinal Patterns

Cluster analyses of EMAP-GRE fish data were performed as part of this project to compliment the ordination analyses of LTRM fish data (Figures 4-23 and 4-24). Cluster analyses of EMAP-GRE data (Table 4-8) indicate a longitudinal gradient with:

- A cluster of similar fish communities for CWA assessment reaches 2-4 (Chippewa River confluence to Wisconsin River confluence)
- A second cluster including reaches 1 (St. Croix River confluence to Chippewa River confluence) and 5-10 (Wisconsin River confluence to Cuivre River confluence)
- A third cluster for reaches 11-13 (below the Cuivre River confluence)

The above results align with the observed greater fishery quality in Pool 8 (assessment reach 4) documented in LTRM reports, as well and the structural and compositional differences observed in assessment reaches 12 and 13 that led EMAP-GRE researchers to develop a separate set of metrics for GRFIn calculations in the Open River. Also, the improvement in GRFIn scores and multiple metrics beginning in assessment reach 2 (below the Chippewa River confluence) may reflect an improvement in water quality conditions due to the settling out of suspended materials in Lake Pepin.

Table 4-8: Cluster Analyses of EMAP-GRE Fish Community Data. Showing which CWA assessment reaches are most similar to each other when longitudinal groupings analyzed.

Assessment Reach Number (Name)	3 Clusters	4 Clusters
AR #1 (Rush - Vermillion)	1	1
AR #2 (Buffalo - Whitewater)	2	2
AR #3 (La Crosse – Pine)	2	3
AR #4 (Coon – Yellow)	2	2
AR #5 (Grant - Maquoketa)	1	1
AR #6 (Apple – Plum)	1	1
AR #7 (Copperas – Duck)	1	1
AR #8 (Flint – Henderson)	1	1
AR #9 (Bear – Wyaconda)	1	1
AR #10 (The Sny)	1	1
AR #11 (Peruque – Piasa)	3	4
AR #12 (Cahokia – Joachim)	3	4
AR #13 (Upper Miss – Cape Girardeau)	3	4

Summarized Longitudinal Trends and Patterns in Fish Community Data
In general, the following longitudinal patterns are observed in UMR fish communities:

- There are differences in fish community composition and structure among LTRM study reaches.
- There are differences in EMAP-GRE multi-metric scores, richness, and biomass along a longitudinal gradient.
- There are differences in fish community composition and structure between groups of LTRM study reaches, namely between the upper study reaches (Pools 4, 8, and 13) and the lower study reaches (Pool 26 and Open River).
- Among LTRM study reaches, Pool 8, and then Pool 13 appear to have the most diverse and healthy fish communities, as indicated by a variety of metrics.
- EMAP-GRE data reveals differences among fish communities in CWA assessment reaches in three clusters (assessment reaches 2-4, 1 with 5-10, and 11-13).
- In EMAP-GRE data, assessment reaches 2-4 have the highest fish multi-metric scores, assessment reaches 2-5 have highest fish richness, assessment reaches 3-5 have highest number of native fish individuals, and assessment reaches 1-4 have the highest native fish biomass.
- Improvements seen in EMAP-GRE metrics beginning with assessment reach 2 may be a result of improved water quality conditions below Lake Pepin.

Longitudinal Patterns in Aquatic Vegetation

Patterns Identified in LTRM Literature and Data
LTRM aquatic vegetation reports were also reviewed to identify longitudinal patterns. Report review focused on submersed aquatic vegetation (SAV) as opposed to rooted-floating leaf or emergent vegetation, as there appear to be more data analyses and reporting on SAV, and more research into the correlation between SAV and water quality parameters. Also, SAV is the most abundant aquatic vegetation type on the UMR. LTRM collected SAV data in four study reaches on the UMR (not Open River due to historical SAV absence there) until 2004. After 2004, Pool 26 sampling was eliminated from the protocol due to low occurrence of SAV. Also, SAV was sampled in Pools 5, 7, 11, and 12 (outside of the LTRM study reaches) in 2001 and 2002.

Yin et al. (2005), reported widespread SAV occurrence in lower Pool 4 (46-70%), Pools 5, 7, 8 (48-75%), and 13 (41-61%); while SAV was common to infrequent in upper Pool 4 (7-25%), Pools 11, and 12; and it was extremely rare in Pool 26 (0-0.5%). These authors considered the deeper and faster flow in the upper sections of each pool a major limiting factor to SAV occurrence relative to the shallower and slower flow in the middle and lower sections of each pool. The same paper shows that the dominant SAV species in Pools 4, 8, and 13 include *Vallisneria americana* (American wildcelery), *Heteranthera dubia* (water stargrass), *Ceratophyllum demersum* (coontail), *Elodea canadensis* (Canadian waterweed), and *Stuckeniapectinata pictinata* (sago pondweed). Lower Pool 4 and Pools 5, 7, and 8 had very similar SAV results, seen as a tight cluster when displayed on an ordination chart (Figure 4-25). Also, upper Pool 4, and Pools 11, 12, and 13 had similar SAV results, but not as tight of an ordination cluster.

Table 4-9: LTRM Aquatic Vegetation Summary. Mean percent frequency of occurrence, and mean abundance index or mean percent cover by study reach, weighted by the areas of the aquatic strata. (Frq = percent frequency of occurrence, AI = abundance index, Cov = percent cover). Data from 2005-2009, except for Pool 26 from 2000-2004 (from Yin et al. 2010). Open River study area is not monitored for aquatic vegetation as vegetation did not historically occur there.

	Submersed aquatic vegetation		Rooted, floating-leaf vegetation		Emergent vegetation	
Study Reach	**Frq**	**AI**	**Frq**	**Cov**	**Frq**	**Cov**
Upper Pool 4	20.2	2.74	1.58	0.58	6.10	2.76
Lower Pool 4	66.9	16.3	29.0	8.92	18.2	10.2
Pool 8	73.6	16.2	34.5	13.0	22.2	11.4
Pool 13	60.1	13.7	30.3	14.6	9.00	5.02
Pool 26	0.08	<0.1	2.06	0.60	6.86	3.96

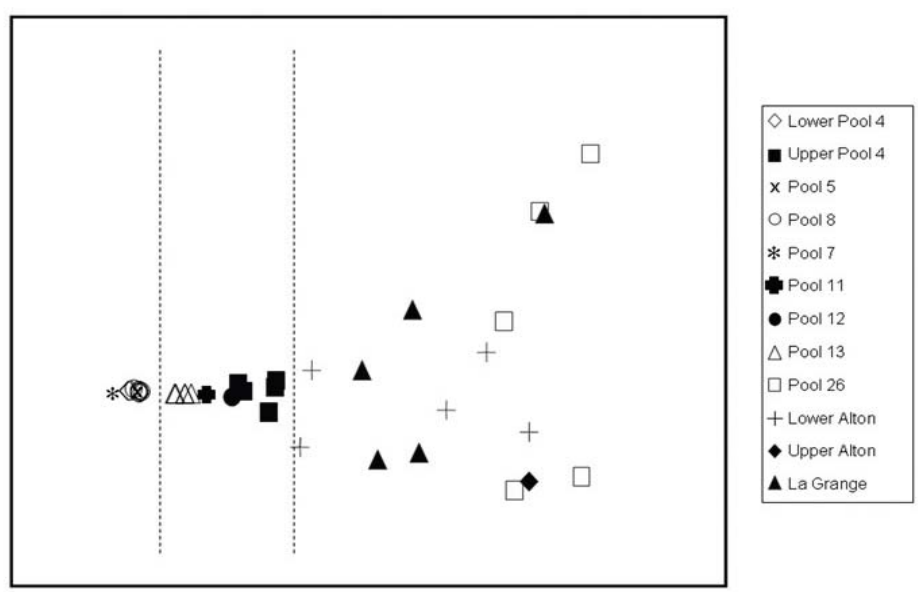


Figure 4-25: Ordination Analysis of LTRM Aquatic Vegetation Data. Study reaches and out-pool sample areas based on frequency of occurrence of all aquatic vegetation species from 1998 to 2002. Pool 4 was divided into upper (above river mile 775) and lower (below river mile 775) sections due to the presence of Lake Pepin in the middle of the pool. The Alton and La Grange Pools are in the Illinois River and not being considered in this project. Note that symbols in closest proximity to each other represent pools with similar aquatic vegetation communities. Vertical dashed lines are used to separate the communities that are most related from the other communities (from Yin et al 2005).

Langrehr and Moore (2008) focused on main and side channels in Pools 4, 8, and 13, finding that SAV diversity and percent frequency is greater in lower portions of pools than in upper portions of pools. They found the highest percent frequency of SAV occurrence (55%), the highest percent frequency for an individual species (38%), and the highest mean abundance scores in lower Pool 4 side-channel areas. Further they found sensitive SAV species to be rare, while tolerant SAV species, including *C.demersum* (coontail), *E.canadensis* (Canadian waterweed), *Myriophyllum spicatum* (Eurasian watermilfoil), *Potamogeton crispus* (curly pondweed), *S. pectinatus* (sago pondweed), composed a large portion of the SAV community in all study reaches. The same report states that Aquatic Macrophyte Community Index and Floristic Quality Index scores indicate lower portions of pools have higher quality aquatic vegetation communities, especially Pools 4 and 8. The maximum number of species found at any one site was 10 in lower Pools 4 and 8 side channels; maximum species richness for one study reach was 12 species in lower Pool 8 side channels.

In summary, the studies of LTRM SAV data indicate that some aquatic vegetation metrics show strong correlation to groups of study reaches, meaning upper study reaches (Pools 4, 8, and 13) have similar observations, which are different than the lower study reach (Pool 26). However, upper Pool 4 is very distinct from the other upper pools, in that it has generally lower quality SAV community. These studies also indicate intrapool variation in SAV communities throughout the study pools, though none as distinct as the variation in Pool 4, which is likely a result of Lake Pepin's effect on water quality via the settling of suspended materials.

Cluster Analyses of LTRM Vegetation Data for Longitudinal Patterns
Using frequency of occurrence and abundance index parameters for SAV, and frequency of occurrence and percent cover parameters for rooted and emergent vegetation, two- and three-cluster analyses were performed on LTRM vegetation data presented in Table 4-9. In both scenarios, Upper Pool 4 and Pool 26 were divided from Lower Pool 4, Pool 8, and Pool 13.

Table 4-10: Cluster Analyses of LTRM Vegetation Data

Study Reach	2 Clusters	3 Clusters
Upper Pool 4	1	1
Lower Pool 4	2	2
Pool 8	2	2
Pool 13	2	3
Pool 26	1	1

Summarized Longitudinal Trends and Patterns in Vegetation Data
In summary, the following are notable longitudinal patterns in aquatic vegetation on the UMR:

- There are differences in SAV percent frequency of occurrence between upper and lower LTRM study reaches.
- There are differences in SAV diversity and percent frequency of occurrence between upper and lower sections in the same pool. Lower sections of each pool have higher quality aquatic vegetation communities, with the division between upper and lower Pool 4 being the most predominant example.
- Deeper and faster moving water in upper sections of each pool is a likely limiting factor for SAV occurrence.

LATERAL PATTERNS IN WATER QUALITY DATA

Lateral Patterns in Chemical and Physical Data

Trends and Patterns

A summary of findings from the examination of LTRM chemical and physical data for lateral patterns follows. See Appendix C for comprehensive tables of regarding LTRM water quality parameters of interest. Houser (2005) and Houser, et al. (2010) were also reviewed to gain additional insight into lateral distinctions. EMAP-GRE data are only available for the main channel border, so those data were not examined for lateral patterns.

- ***Temperature***: Water temperature means increase slightly when moving laterally from main channel, to side channel, to backwater contiguous areas in spring and summer. Impounded area temperatures do not display a consistent relationship to other strata temperatures during these seasons. Pool 26 maximum temperature readings in the summer are greater than 30º C for all strata - main channel (25% of data points), side channel (22%), contiguous backwaters (41%) and impounded (29%). In winter, there are no clear patterns in water temperature differences among strata (see Figure 4-4).
- ***Dissolved Oxygen***: In spring, when flow is high and water is mixing well in flowing channels, mean dissolved oxygen (DO) values are very similar in main channels and side channels in each pool. In summer, contiguous backwater areas in Pools 8 and 13 have lower DO means than the channel areas, and the summer minimum DO values in the backwaters have been below 5.0 mg/l with some frequency in Pool 8 (12% of data points), Pool 13 (21%), and Pool 26 (13%). Winter mean DO values in contiguous backwaters are lower than those in channel areas for Pools 4, 8, and 13, likely due to low flow and thick ice cover; and winter minimum DO values in the backwaters have been below 5.0 mg/L in Pool 4 (14% of data points), Pool 8 (13%), and Pool 13 (10%) (see Figure 4-6 and Appendix C).

  In all seasons, backwater contiguous areas display a much greater range of DO values than main or side channel strata (see Appendix C). This variation in ranges may be more important in an aquatic life context than the variation in mean values described above.

  Houser (2005) presents a detailed examination of spatial and temporal patterns in UMR DO concentrations. The authors note that, while the overall occurrence of low daytime, surface, DO concentrations was infrequent on the UMR system as a whole (about 4% of sites monitored were less than 5 mg/L), backwaters in the summer and winter displayed the most frequent occurrence of low DO (see Table 4-11).
- ***Conductivity***: Conductivity values are slightly lower in backwater and impounded areas than in channel areas, across all seasons (see Figure 4-8).
- ***pH***: Mean pH values are generally similar among strata per pool each season with some very slight increases in backwater and impounded areas in some seasons. Spring and summer pH ranges in off-channel areas have the highest percentage of data points outside of the 6.5 – 9.0 range, including spring for Pool 8 (backwaters 15%, impounded 13%) and Pool 13 (backwaters 12%), and summer for Pool 26 (backwaters 17%, impounded 18%), with all excursions resulting from values above 9 (see Figure 4-10 on page 4-6).

Table 4-11: Mean Proportion of Stratified Sampling Sites with Dissolved Oxygen Concentrations <5.0 mg/L in Winter and Summer from 1993 to 2001. One standard deviation is shown parenthetically. Bold font indicates where the proportion of sites with low dissolved oxygen is > 10%. Note that the LaGrange Pool is on the Illinois River and therefore outside the focus of this report (from Houser 2005).

Study reach	Strata				
	Main channel	Side channel	Backwater	Lake[a]	Impounded
Winter					
Pool 4	0.004 (0.013)	0.008 (0.02)	**0.14 (0.14)**	0.007 (0.015)	—[b]
Pool 8	0	0.005 (0.014)	**0.13 (0.09)**	—	0
Pool 13	0	0	**0.1 (0.05)**	—	0.004 (0.01)
Pool 26	0	0.003 (0.008)	0.006 (0.02)	0	0
Open River	0	0	--	—	—
La Grange Pool	0	0	0.009 (0.03)	—	—
Summer					
Pool 4	0.008 (0.3)	0.013 (0.03)	0.058 (0.07)	0.003 (0.01)	
Pool 8	0.008 (0.02)	0.013 (0.02)	**0.12 (0.08)**		0
Pool 13	0.003 (0.01)	0.023 (0.05)	**0.21 (0.14)**		0.057 (0.1)
Pool 26	0.014 (0.04)	0.022 (0.05)	**0.13 (0.1)**	0.14 (0.2)	0.022 (0.05)
Open River	0.013 (0.04)	0.032 (0.06)			
La Grange Pool	**0.25 (0.24)**	0.35 (0.27)	0.067 (0.067)		

[a]Lake Pepin in Pool 4; Swan Lake in Pool 26.
[b]— indicates that stratum was not present in that reach.

- ***Turbidity and Total Suspended Solids (TSS)***: Turbidity and total suspended solids means show only very slight lateral patterns, often with slightly higher values in channel areas than in other strata. However, in summer, backwaters may demonstrate higher levels than channel areas (Figure 4-26). This seasonal relationship is likely a result of changes in flow condition, where more suspended solids end up in channel areas during higher flow periods while, in summer, backwaters may experience more phytoplankton abundance and sediment resuspension (Houser 2005).

  An examination of ranges reveals that turbidity in summer is above 25 NTU for Pool 4 backwater data points 21% of the time. In Pool 13, spring averages for the main channel, side channel, and impounded strata are above 25 NTU. Mean values are above 25 NTU for Pool 26 and the Open River in most strata and seasons. Similarly, Pool 13 main channel, side channel, and impounded strata averages are above 32 mg/L TSS in the spring; while this threshold is exceeded for most strata and seasons in Pool 26 and the Open River. However, as mentioned previously, these thresholds may not be appropriate benchmarks for the UMR's lower reaches (see Figures 4-12 and 4-14).

- ***Nitrogen and Phosphorus***: Notable lateral patterns are observed in these nutrient parameters. Mean total nitrogen values (2.08 – 4.24 mg/L) for main and side channel areas are higher than contiguous backwater means (1.74 – 3.11 mg/L) in spring, summer, and winter. The highest total nitrogen mean seasonal values are in Pool 26 main channel and side channels in spring.

  Spring values for total phosphorus are typically higher in the main (93 – 285 µg/L) and side (96-281 µg/L) channels, and lower in contiguous backwaters (94 – 224 µg/L). However, in the summer the opposite is true, with lower values in the main (148 – 228 µg/L) and side (151-202 µg/L) channels, and higher values in contiguous backwaters (170 – 360 µg/L). The highest seasonal mean for total phosphorus is in Pool 26 contiguous backwaters in summer. In spring and summer, most strata means are in excess of 100 µg/L total phosphorus (see Figure 4-16 and Figure 4-18).

- ***Chlorophyll-a:*** Mean chlorophyll-a spring patterns show a slight increase in Pools 8 and 26 backwaters (36.1 and 31.2 µg/L) over main channel areas (29.6 and 17.5 µg/L); and summer means in Pools 4, 13, and 26 backwaters (27.0, 26.3, 78.3 µg/L) are greater than main channel means (22.6, 24.3, 28.1 µg/L). Houser (2005) also found higher backwater chl-a levels in the summer, as compared to the main channel (see Figure 4-26). The highest seasonal mean for chlorophyll-a is in the backwaters of Pool 26 in summer (78.3 µg/L) (see Figure 4-20).

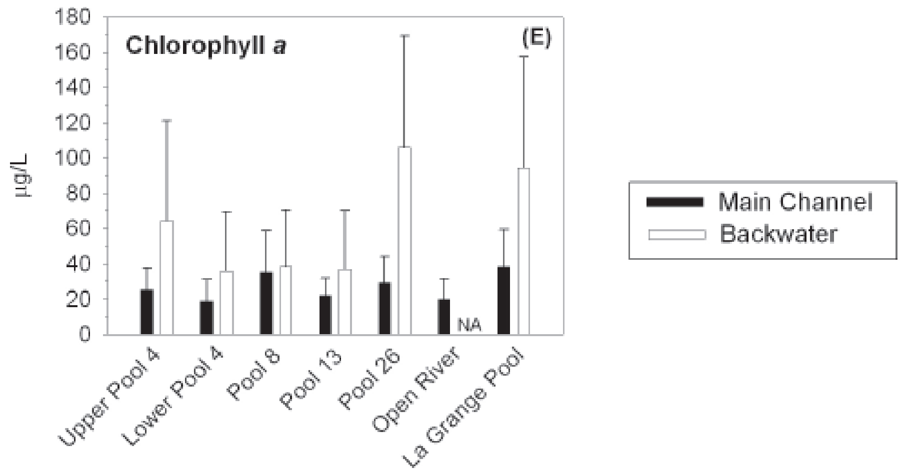


Figure 4-26: Mean Chlorophyll-a (mg/l) in Main Channel and Backwater Strata. Summer LTRM stratified random sampling (1993-2001). Note that La Grange Pool is on the Illinois River. Error bars represent +/- one standard deviation (from Houser 2005).

Summarized Lateral Trends and Patterns in Chemical and Physical Data

A summary of the longitudinal patterns seen in LTRM data is presented in Table 4-12.

Table 4-12: Summary of Lateral Patterns in LTRM Chemical and Physical Data

Parameter	General Lateral Patterns
Temperature	Seasonally dependent, where: - In spring and summer, slight increases as moving laterally from main channel to side channel to contiguous backwaters - No lateral pattern in winter
Dissolved Oxygen	Seasonally dependent, where: - In spring, similar values for main channel and side channel - In summer, Pool 8 and 13 contiguous backwaters have lower means than main and side channel areas - In winter, Pools 4, 8, and 13 contiguous backwaters have lower means than main and side channel areas For all seasons, greater ranges in values for contiguous backwater than in main and side channels
Conductivity	Slightly lower in backwater and impounded areas than in main and side channel areas, across all seasons
pH	Similar across strata, some elevated values seen in contiguous backwater and impounded strata in the spring and summer.
Turbidity	Slightly higher means in main and side channel areas than off channel areas, except in summer, where means may be higher in backwaters than in channels
Total Suspended Solids	Slightly higher means in main and side channel areas than off channel areas, except in summer, where means may be higher in backwaters than in channels
Total Nitrogen	Main and sides channel areas have higher mean values than contiguous backwaters in winter, spring, and summer.
Total Phosphorus	Seasonally dependent, where: - Main and side channels have higher mean values than contiguous backwaters in spring - Contiguous backwaters have higher mean values than the main and side channels in summer
Chlorophyll a	Backwater contiguous concentrations are typically higher than main and side channel concentrations, across seasons.

Cluster Analyses of LTRM Chemical and Physical Data for Lateral Patterns

Cluster analyses were performed on LTRM data to examine similarities and groupings among strata. These results showed that there is no consistent set of associations among strata. The lotic strata (main channels and side channels) were generally the most closely associated, but the trend did not hold for all study reaches and seasons. Figure 4-27 is a dendrogram of this analysis which illustrates how closely related the strata are based on LTRM water quality means per strata. See Appendix D for further discussion of these cluster analyses.

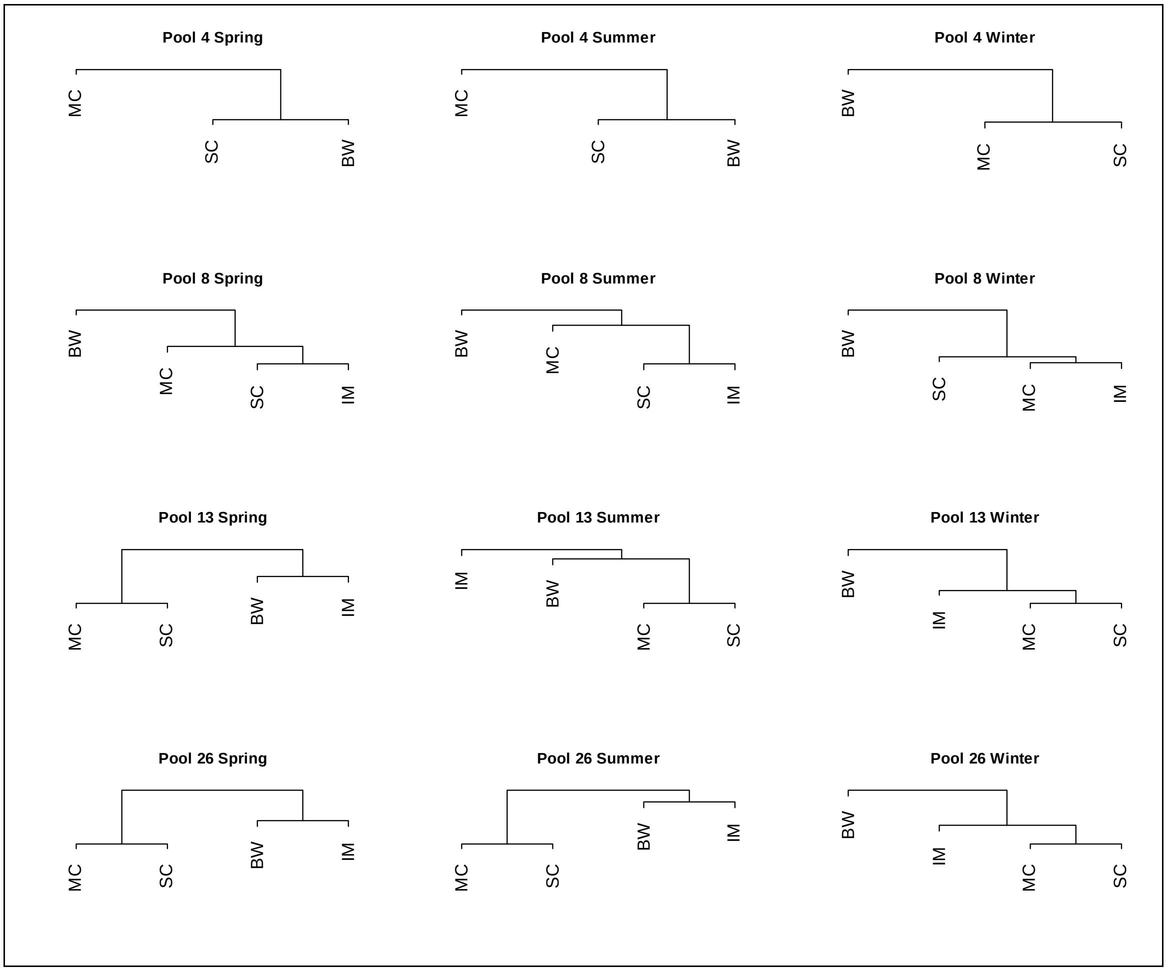


Figure 4-27: Dendrogram of Lateral Cluster Analysis of LTRM Water Quality Data

Lateral Patterns in Fish Communities

Patterns Identified in LTRM Literature and Data

Several LTRM fisheries researchers have identified lateral patterns in fish community data. Ickes et al. (2005) found species richness to be highest in backwater contiguous areas, followed by side channels, and then main channel borders. Chick et al. (2005) found community structure (relative abundance) varies among strata and fish community structure in backwaters is distinctly different than other strata, but that main channel and side channel community structure overlap (see Figures 4-28 and 4-29). Barko et al. (2005) and Chick et al. (2005) both found that fish structure in contiguous backwaters is dominated by centrarchids (i.e., sunfishes). Chick et al. (2005) also found:

- The most abundant backwater species are gizzard shad, bluegill, largemouth bass, common carp, smallmouth buffalo, black crappie, bullhead minnow, and freshwater drum.
- Main channel border wing dam areas in upper pools are dominated by catastomids (e.g., buffalo, redhorse, suckers), and in lower pools these areas are dominated by green sunfish and blue catfish.
- Abundant main channel border/side channel species include emerald shiners, spotfin shiners, white bass, and shorthead redhorse.
- No significant patterns were observed in regard to fish community in impounded areas.

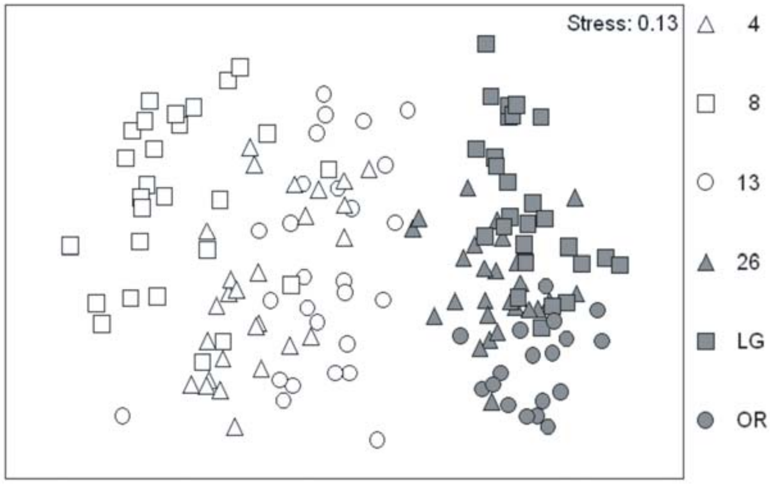


Figure 4-28: Ordination Analysis of Fish Community Structure Data (square root of catch per 15 min of day electrofishing) for the UMR collected by LTRM, 1994–2002. Each point represents fish community structure for a combination of year and habitat strata for each study reach. The upper study reaches (Pools 4, 8, and 13) are represented by open symbols whereas the lower study reaches (Pool 26, La Grange Pool, and Open River Reach) are represented by shaded symbols (from Chick et al. 2005).

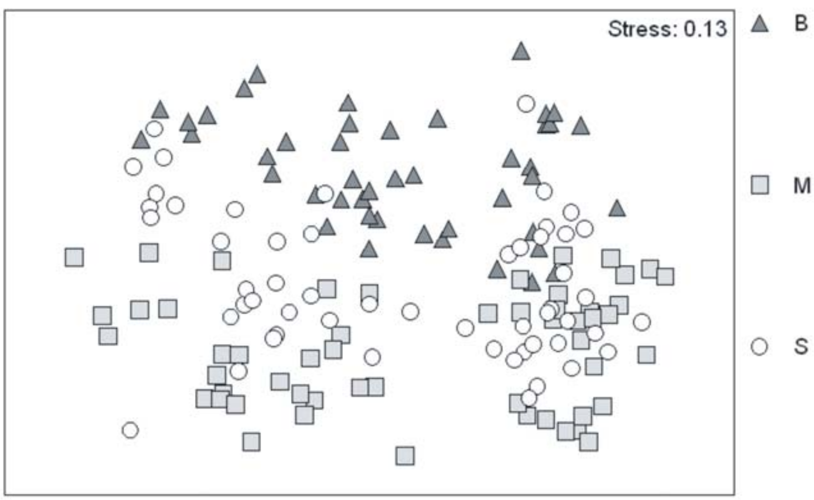


Figure 4-29. Ordination Analysis of Fish Community Structure Data (square of root catch per 15 min of day electrofishing) for the UMR collected by LTRM, 1994–2002. Each point represents fish community structure for a combination of year and habitat strata within the designated study reach. The ordination is identical to Figure 4-28 (year × habitat strata × resource trend area) but with points coded by habitat strata (B = backwaters, M = main channel, and S = side channel) rather than resource trend area (from Chick et al. 2005).

Additionally, LTRM fish data were summarized for purposes of this project by study pool and strata for indicator species including those which are considered of recreational, commercial, and forage value (see Appendix E). While these data have not been subjected to statistical examination, they do illustrate differential occurrence across strata for a number of key species.

Summarized Lateral Trends and Patterns in Fish Community Data
In general, the following lateral patterns in UMR fish communities were identified in LTRM reports:

- Fish species richness is highest in contiguous backwaters, followed by side channels, and then main channel-border areas
- Fish community structure varies among strata, with contiguous backwaters most distinctly different than other strata, and main channel and side channel community structure overlapping.

Lateral Patterns in Aquatic Vegetation

Yin et al. (2005) found SAV occurrence was highest in isolated backwater areas (i.e., areas with low depth and low velocity), followed by contiguous backwater areas, then side channels, and finally main channel borders. Additionally, LTRM SAV data queried for this report (Table 4-13) also demonstrates higher frequency and abundance scores for side channels and backwaters as compared to the main channel. Therefore, it appears that increased connectivity to the main channel has a net negative influence on SAV frequency of occurrence (i.e., the strata which are further away and less influenced by the main channel have a better chance for SAV growth).

Additionally, species composition also varies among strata. The most prominent SAV species in impounded areas, where current is moderate, include American wildcelery and water stargrass. The most prominent SAV species in contiguous backwaters and isolated backwaters, where there is little or no current, include coontail, Canadian waterweed, and sago pondweed (Langrehr and Moore 2008). These authors also stated that Aquatic Macrophyte Community Index and Floristic Quality Index scores indicate that side channels have higher quality SAV communities than main channel border area SAV communities.

Table 4-13. SAV Percent Frequency of Occurrence and Abundance Index. Mean percent frequency of occurrence and mean abundance index by study reach, and strata (Frq = percent frequency of occurrence, AI = abundance index) Data from 2006-2010,, except that data for pool 26 were from 2000-2004, as SAV monitoring was eliminated after 2004 in that study reach (as extracted from LTRM online data browser for this project).

	MC Border		Side Channel		Contiguous Backwater		Impounded	
	Frq	AI	Frq	AI	Frq	AI	Frq	AI
Upper Pool4	15.0	1.74	8.66	0.96	34.9	5.94	n/a	n/a
Lower Pool 4	36.7	7.06	59.5	11.7	88.7	22.1	n/a	n/a
Pool 8	32.3	5.96	52.9	10.3	88.0	19.6	81.2	20.4
Pool 13	19.2	3.46	18.5	3.42	72.3	16.1	66.0	15.8
Pool 26	0	0	0	0	0	0	0	0

Summarized Lateral Trends and Patterns in Vegetation Data
In general, the following are lateral patterns in UMR SAV communities:

- SAV percent frequency of occurrence is highest in isolated backwaters, followed by contiguous backwaters, then impounded areas, side channels, and lowest in main-channel border areas.
- Low depth and low velocity have positive influences on SAV frequency of occurrence.
- Increased connectivity to main channel has negative influence on SAV occurrence.
- Higher quality SAV communities exist in side channels than main channels.

TEMPORAL PATTERNS IN WATER QUALITY DATA

Temporal patterns in UMR water quality data, including biological data, can be observed both in terms of seasonal and year-to-year variations. Flood years, spring runoff, droughts, water level drawdowns, and nutrient processing are all factors that influence temporal patterns. The ability to measure seasonal variation is largely limited to chemical and physical parameters, as this data is collected year-round on the UMR. Seasonal variations in biological parameters are not typically quantified, outside of special projects, as vegetation and fish sampling is typically conducted only in the summer months.

Seasonal and Year-to-Year Patterns in Chemical and Physical Data

Seasonal Variations

Chemical and physical data show seasonal patterns, as may expected due to changes in temperature, precipitation, flow, and other factors that vary throughout the course of the year. Many of these seasonal patterns have already been mentioned in the preceding discussions of longitudinal and lateral patterns, though some of the most prominent seasonal patterns include:

- Temperature values above 30º C in *summer* in Pool 26 and Open River
- Dissolved oxygen values below 5 mg/L in *summer* and *winter* in contiguous backwater areas in some study pools
- pH values above 9.0 in the *spring* and *summer* in certain strata
- Elevated main channel turbidity and TSS values in the *spring*, particularly in the lower river

Additionally, Houser (2005) found that nitrogen and soluble reactive phosphorus concentrations follow differing seasonal patterns, with nitrogen concentration highest in the spring and early summer and phosphorus concentrations highest in the late summer and early fall. This pattern was seen in both the main channel and backwater strata.

See Appendix C for details by parameter, pool, and strata for each season reviewed (winter, spring, and summer).

Year-to-Year Variations

Year to year variations are seen in a number of water quality parameters. While not all of the mechanisms underlying year-to-year variations are yet fully understood, variations in a number of parameters, such as nitrogen and chlorophyll-a, are likely driven by differences in precipitation and river discharge among years (Houser 2005). Other factors can be important for specific parameters, such as the effect of ice and snow cover on backwater DO levels (Houser 2005).

Year-to-Year Patterns in Fish Community Data

Year-to-year temporal patterns in fish community structure were observed by Chick et al. (2005) to vary slightly among years. A multigear index revealed a stronger year to year variance for annual poolwide catch-per-unit-effort averages. Barko et al. (2005) report significant variation in young-of-the-year fish communities among years for Pool 13 (50%), Pool 4 (34%), Pool 8 (32%), Open River (27%), and Pool 26 (19%). Floods appear to affect both young-of-the-year and adult fish communities for the flood year and the following year. For example, fish communities from 1994 are disassociated from other years perhaps due to the 1993 flood (Figure 4-30).

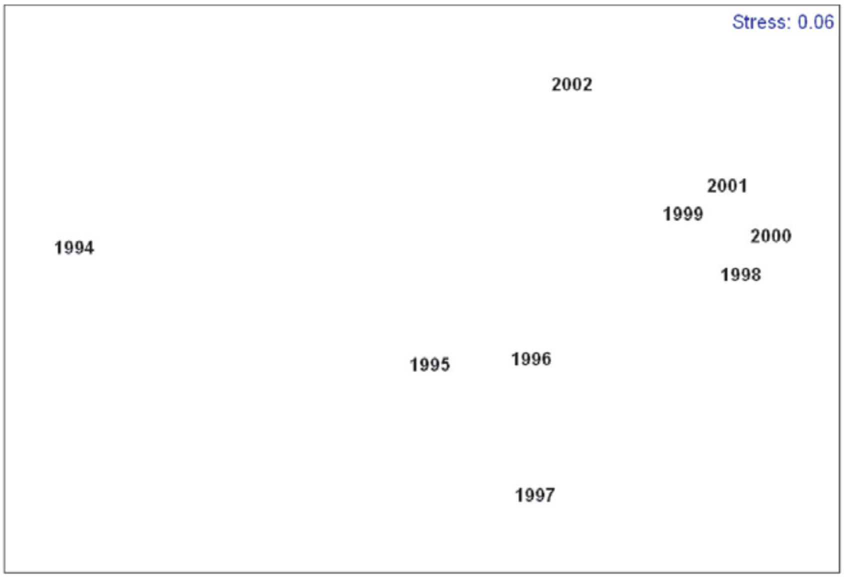
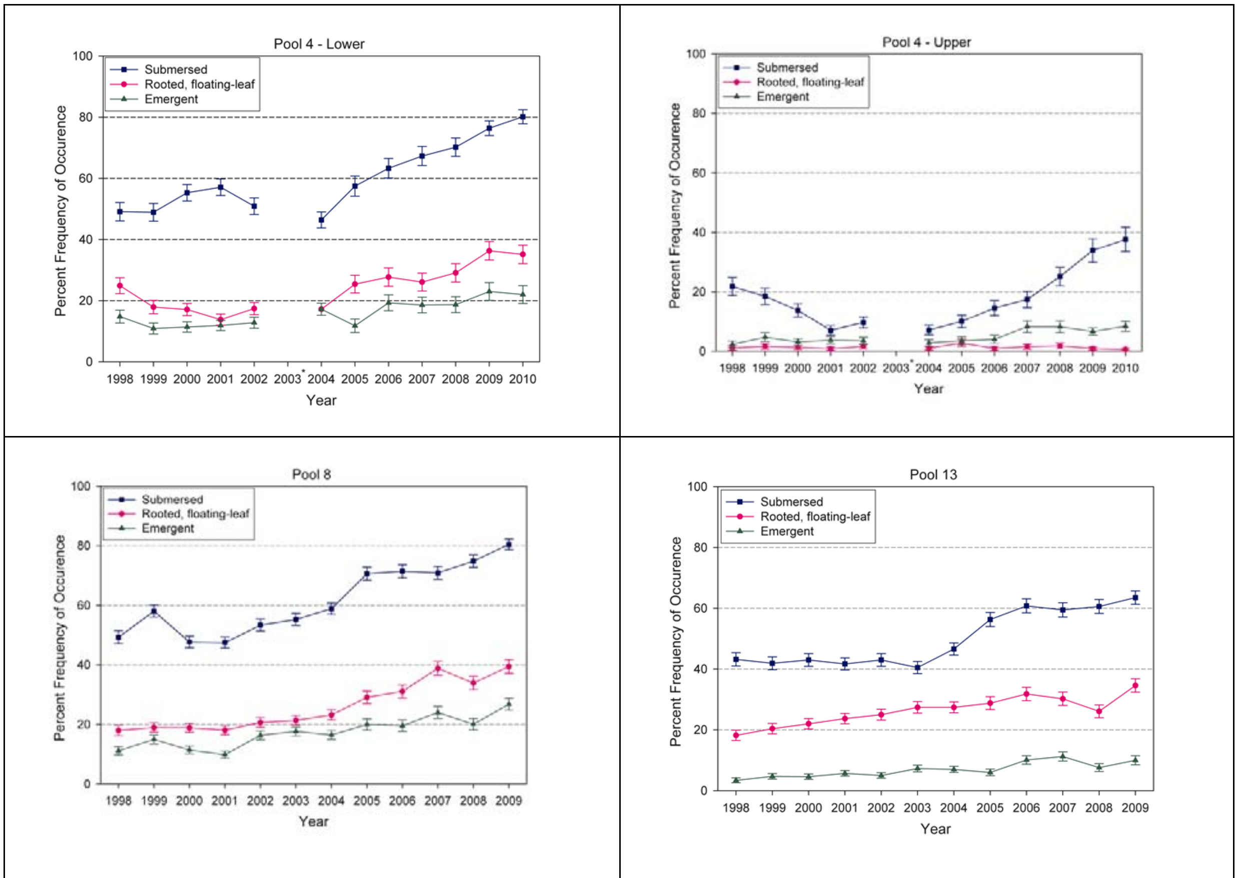


Figure 4-30: Ordination Analysis of Fish Community Structure Data by Year. Indexed by multiple gears, and averaged by year across all resource trend areas for the UMR collected by LTRM, 1994–2002. Labels reflect the averaged community structure for each year (from Chick et al 2005).

Year-to-Year Patterns in Aquatic Vegetation Communities

Aquatic vegetation temporal patterns between years have been observed. Overall, aquatic vegetation frequency is increasing in several study reaches (Figure 4-31) over the period of 1998 to 2010. Some year-to-year differences in frequency may be attributed to various environmental, physical or water quality factors. In particular, the distribution of submersed aquatic vegetation is limited by water depth and transparency (Johnson and Hagerty 2008). Events that impact these parameters, such as floods and water level drawdowns, can therefore affect the extent of vegetation present in the current or following year.



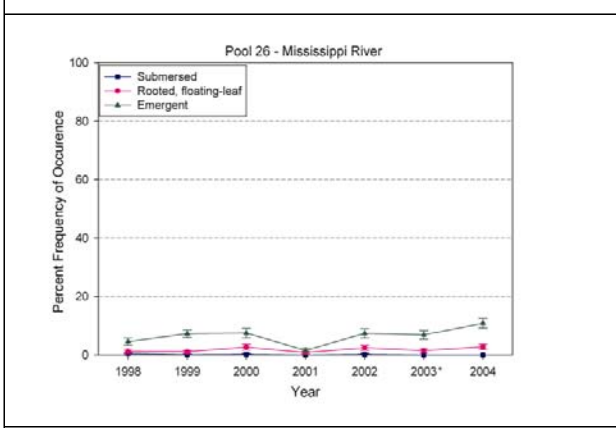


Figure 4-31: Aquatic Vegetation Percent Frequency of Occurrence by Year and Reach. Submersed aquatic, rooted, floating-leaf, and emergent vegetation by study reach, weighted by the areas of the aquatic strata. *In Pool 4, analysis was not calculated in 2003 because no data were collected for the isolated backwater and Lake Pepin strata (from Yin et al. 2010).

In general, the following are temporal trends of note on the UMR:

- Several water quality parameters, including temperature, DO, pH, TSS, and turbidity vary by season within strata. A number of water quality parameters, including nitrate, phosphorus, chlorophyll-a, and DO also vary among years. Precipitation and river discharge, among other factors, influence both seasonal and year-to-year variations in parameter concentrations.
- Fish structure varies slightly by year, and varies the most for young-of-the-year fish.
- Floods appear to affect fish communities for the flood year and the year following the flood.
- Year-to-year differences in vegetation occurrence may be explained in part by changes in water depth and transparency resulting from events including floods and water level drawdowns.

COMPARISON OF CHEMICAL AND PHYSICAL DATA TO THRESHOLD VALUES

The preceding discussion focused on spatial, and temporal, patterns emerging from this project's data and literature review. Additionally, LTRM and EMAP chemical and physical data were compared to selected "threshold values," which include both currently applicable water quality criteria and other water quality values for the UMR (see Table 4-14).

Threshold comparisons are included to highlight particular issues and patterns for consideration in a CWA aquatic life use context. The intent of including these comparisons is not to imply regulatory decisions, but to highlight circumstances relevant for designated uses, and, ultimately, criteria-setting. Threshold comparisons were not attempted for biological data, though this was done for the main channel in the WQTF's recently completed biological assessment project (Yoder, et al. 2011).

Table 4-14: Threshold Values Used for UMR Water Quality Comparisons

Parameter	Threshold Value	Reason for Use
Temperature	30° C	Temperature criterion used by several states.
Dissolved Oxygen	5.0 mg/L	Dissolved oxygen criterion used by several states.
pH	6.5 min and 9.0 max	pH criteria used by several states.
Turbidity	25 NTU	Turbidity criterion used by Minnesota.
Total suspended solids	32 mg/L	Pool 2 to Lake Pepin site specific criteria (summer average) used by Minnesota.
Total phosphorus	100 µg/L	Wisconsin criterion applicable to UMR main and side channels.

Mean Excursions

Parameter means for strata, calculated by pool and season (see Appendix C), were compared threshold values. "Mean excursions" were observed in the LTRM and EMAP data as follows:

- ***Turbidity and TSS***: For the LTRM SRS water quality data reviewed, turbidity and TSS showed numerous seasonal mean excursions from threshold values in various strata, particularly in reaches from Pool 13 and downriver. EMAP-GRE data demonstrated similar patterns. However, the threshold values used here may not appropriate benchmarks for the lower River as turbidity and TSS demonstrate a generally increasing gradient along the length of the river due to both anthropogenic and historic features (Meade 1995).
- ***Total Phosphorus***: In spring and summer, total phosphorus means were above 100 µg/L for all strata and pools, with the exception of Pool 4. In the winter, however, only Pool 26 and the Open River had mean total phosphorus excursions. EMAP-GRE data displayed similar results. While 100 µg/L is an adopted water quality criterion in Wisconsin, its relevance is not as clear for the lower River, where factors including reduced light availability and residence time may limit eutrophication even when nutrient levels are elevated (Houser, et al. 2010).

Range Excursions

Ranges were calculated only for LTRM SRS data and not for EMAP-GRE data. LTRM SRS data demonstrated several *minimum* and *maximum* value, or "range excursions" from thresholds. In particular, this analysis focused on instances where more than 10% of values were excursions from a threshold. This percentage was selected because, for many non-toxic parameters, states identify aquatic life uses as "not fully supported" when greater than 10% of values do not meet a criterion. Identified range excursions in the LTRM SRS data were as follows:

- ***Temperature***: All excursions were in the summer, with greater than 10% of values above 30°C in Pool 26 (all strata) and Open River (main channel only). Most other pools and strata exhibited at least some values above 30°C in the summer.
- ***Dissolved Oxygen***: All instances of excursions with greater than 10% values below 5 mg/L were in backwater contiguous areas. These occurred in Pools 4, 8, and 13 in the summer and Pools 4 and 8 in the winter. In the summer, several pools and strata had some values below 5 mg/L. In winter, all pools with backwater contiguous strata had some values below 5 mg/L in this stratum.
- ***pH***: Excursions where greater than 10% of values were above 9.0 occurred in the spring in Pool 8 (backwater contiguous and impounded strata) and Pool 13 (main channel and backwater contiguous strata). Also, in summer, more than 10% of values were above 9.0 in Pool 26 (backwater contiguous and impounded strata). In the spring and summer, all non-main channel strata (except in Pool 4) show at least some values above 9.0.
- ***Turbidity***: In addition to the range excursions described above, more than 10% of spring values were above 25 NTU in Pool 4's backwater contiguous stratum. Additionally, in the spring and summer, all pools and strata had some values above 25 NTU.
- ***TSS:*** In addition to the numerous lower river mean excursions (which are also range excursions) described previously, a number of results were above 32 mg/l in spring and summer, particularly in impounded and backwater contiguous strata.
- ***Total Phosphorus***: In addition to the mean excursions described previously, all other pools and strata had some values above 100 µg/L, across all seasons.

Summary

Table 4-15 summarizes observed excursions from threshold values as seen in LTRM data. As noted above, EMAP-GRE data gave similar results for mean excursions in the main channel.

Table 4-15: Summary of Water Quality Excursions from Thresholds in 1994-2008 LTRM SRS Data

Parameter	Threshold Value	Mean Excursions	Range Excursions (>10% of values do not meet threshold)
Temperature	30° C	None	Pool 26: All strata during the summer. Open River: Main channel during the summer.
Dissolved Oxygen	5.0 mg/L	None	Pools 8, 13, and 26: Contiguous backwaters in summer. Pools 4 and 8: Contiguous backwaters in winter.
Conductivity	*Not applicable/no threshold selected.*		
pH	6.5 to 9.0 (range)	None	Pool 8: Backwater contiguous and impounded areas during the spring. Pool 13: Main channel and backwater contiguous areas in the spring. Pool 26: Backwater contiguous and impounded areas during the summer. *(Note: In all cases, excursions were due to values greater than 9.0.)*
Turbidity	25 NTU	Pool 13: Main channel, side channel, and impounded areas in spring. Pool 26 and Open River: All existent strata, across all seasons (except Pool 26 backwater contiguous and impounded areas in winter).	*In addition to mean excursions:* Pool 4: Backwater contiguous areas in summer.
TSS	32 mg/L	Pool 13: Main channel, side channel, and impounded areas in spring. Side channels in the summer. Pool 26: All strata in spring. All strata except impounded in summer. Only side channel in winter. Open River: All existent strata, all seasons.	*In addition to mean excursions:* Pools 13 and 26: Appear to be range excursions in other strata in all seasons, but specific percentages were not calculated.
TN	*Not applicable/no threshold selected.*		
TP	100 µg/L	Pool 4: All strata in summer. Pool 8 and Pool 13: All strata in spring and summer. Pool 26 and Open River: All strata, all seasons.	*In addition to mean excursions:* All Reaches: Appear to be likely range excursions in all other pools, strata, and seasons, but specific percentages were not calculated.
Chlorophyll a	*Not applicable/no threshold selected.*		

DYNAMICS BETWEEN CHEMICAL, PHYSICAL, AND BIOLOGICAL PARAMETERS

The preceding discussion has focused on spatial and temporal patters in chemical, physical, and biological communities. Additionally, the dynamics between physical conditions, water quality, and biological communities are key in understanding aquatic life on the UMR. Several LTRM reports describe how aquatic communities, both fish and vegetation, are influenced by environmental factors and water quality parameters. Some of these relationships have been discussed in the preceding text, but other others have not been previously described and therefore are summarized in this section.

Fish Communities, Physical Conditions, and Water Quality Relationships

Barko et al. (2005) examined the ability of habitat and physical/chemical variables to explain fish assemblage variation in the LTRM study reaches. They also examined interannual variability as explanatory of assemblage variation (i.e., the ability of sample year to predict variation). Among their findings are the following:

- Habitat (i.e., strata) explained assemblage variation for adults as follows: Pool 4 (22% of variation), Pool 8 (23%), Pools 13 (19%), Pool 26 (19%) and Open River (3%). Somewhat less variation for young-of-the-year fish assemblages was explained by habitat as follows: Pool 4 (10%), Pool 8 (20%), Pool 13 (15%), Pool 26 (17%), and Open River (3%).
- Six physical and chemical variables (temperature, velocity, water clarity, conductivity, depth, and surface elevation) explained the following amount of variation in fish abundance in LTRM study reaches: Pool 4 (23% of variation), Pool 8 (23%), Pool 13 (17%), Pool 26 (31%), and Open River (30%). The most important explanatory variables among reaches as follows: water temperature Pools 8 and 13;velocity in Pools 4, 8, 13, and 26; water clarity (measured via Secchi depth) in Pool 4; depth (indicated by depth of gear deployment) in Pools 8, 26, and Open River; and water surface elevation in the Open River.
- Young-of-the-year abundance was much more influenced by the sampling year that adult abundance. The percent of variation explained for young of the year was between 19% and 50% (depending on reach), while only between 9% and 12% for adults.

In sum, Barko et al. showed that habitat and physical/chemical parameters have some correlation to fish population characteristics, but are not complete or necessarily strong predictors, and that the relative importance of the various factors varies among pools. They also showed that interannual variation has the greatest effect on young-of-the year populations, indicating that extreme events (e.g., flood and drought years) may have the most impact on young-of-the year fish.

Other LTRM studies have examined the linkages between fish communities and physical/chemical variables. Knights et al. (2008) concludes that the environmental variables best explaining variation in off-channel area fish assemblages are total suspended solids, total nitrogen, proportion of moderately deep water, and dissolved oxygen levels, with these four variables accounting for 58% of the variation in fish assemblages. Johnson and Hagerty (2008) note that sediment and nutrient levels in the UMR affect fish communities through much of the system.

In addition to the literature findings summarized above, the summaries of water quality and biological data presented earlier in this chapter reveal cases where excursions from threshold values occur, but biological communities appear to be successful. Perhaps the leading example of this is that Pools 8 and 13 have among the most healthy UMR fish communities (as demonstrated by a number of metrics), but dissolved oxygen levels in the backwaters of these pools fall below 5 mg/L with some regularity in the summer and winter. This indicates that, at least in the case of dissolved oxygen, water quality values may not need to meet certain “minimums” at all places and times in order to maintain a healthy community. Possible explanations for this seemingly counterintuitive result include: 1) lower dissolved oxygen levels may be indicative of the presence of vegetation, a key component of healthy backwater ecosystems, and/or 2) periodic low dissolved oxygen levels may perform an integral role as an ecosystem disturbance contributing to the maintenance of biodiversity by providing a competitive advantage for certain species, as has been observed for other periodic disturbances such as flow conditions (Ward 1998, Meffe 1984).

Vegetation Communities, Physical Conditions, and Water Quality Relationships

Dynamics between aquatic vegetation communities, physical conditions, and water quality are also described in LTRM reports. Yin et al. (2005) reports a negative correlation between percent frequency of SAV and both turbidity and water level fluctuation. Together the two variables accounted for 82% of the variance in SAV occurrence, with turbidity being a stronger predictor of SAV than water level fluctuation. Both of the variables are good predictors of longitudinal SAV variation (see Figure 4-32).

Langrehr and Moore (2008) found that the mean number of SAV species is the aquatic vegetation attribute most correlated with water quality. They also found that SAV is correlated with and limited by light availability and not typically limited by nutrients, at least in terms of ambient water concentrations (see Table 4-16).

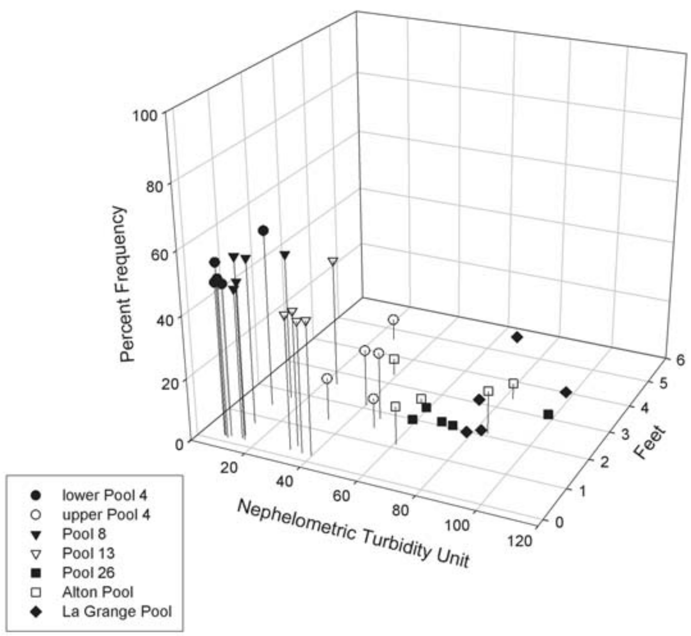


Figure 4-32: Correlation Between Percent Frequency of SAV and Two Physical Factors. Mean water turbidity (calculated from measurements taken between May 1 and August 31 from one Long Term Resource Monitoring Program fixed site near the main channel at the upper end of each pool or section) and water level fluctuations (standard deviation of daily water levels), by pool (r^2 = 0.82). For analysis, Pool 4 was divided into upper (above river mile 775) and lower (below river mile 775) sections due to the presence of Lake Pepin in the middle of the study pool (from Yin et al. 2005).

Summary of Interactions and Dynamics

The LTRM studies described above indicate the following as important relationships between aquatic communities, physical factors, and water quality in the UMR:

- Fish communities appear to be most affected by temperature, velocity, depth, transparency, suspended solids, nutrients, and dissolved oxygen.
- Vegetation communities appear to be most affected by turbidity, water level fluctuation, and depth.

Of note, several of these factors (e.g., velocity, depth, water level fluctuation) are not typically considered in a CWA context for water quality assessments and impaired waters listings. Turbidity/suspended solids and nutrients are currently addressed in some, but not all, state water quality standards. Temperature and dissolved oxygen are the only factors discussed above where water quality criteria are in place for all UMR states.

Table 4-16: Correlation of Macrophyte Attributes to Water Quality Characteristics. All data from side channel and main channel border strata. Analyses did not include species with less than 20 occurrences; all pools and years are combined; and species represent percent frequency (from Langrehr and Moore 2008).

Attribute	Water quality measurement	Strata	r^2 value	p value
Vallisneria Americana	Secchi transparency	Side channel	0.5025	<0.0001
Potamogeton crispus	Secchi transparency	Side channel	0.4385	<0.0001
Heteranthera dubia	Secchi transparency	Side channel	0.3675	<0.0001
Mean number of species recorded at a site	Secchi transparency	Side channel	0.3599	<0.0001
Maximum number of species recorded at a site	Secchi transparency	Side channel	0.3018	<0.0001
Percent frequency of submersed vegetation	Secchi transparency	Side channel	0.2905	<0.0001
Potamogeton crispus	Secchi transparency	Main channel border	0.2875	<0.0001
Elodea canadensis	Secchi transparency	Side channel	0.2819	<0.0001
Mean plant abundance	Secchi transparency	Side channel	0.2762	0.0001
Ceratophyllum demersum	Secchi transparency	Side channel	0.2711	0.0001
Vallisneria americana	Suspended solids	Side channel	0.2561	0.0002
Aquatic Macrophyte Community Index	Secchi transparency	Side channel	0.2403	0.0003
Myriophyllum spicatum	Secchi transparency	Side channel	0.2322	0.0005
Potamogeton crispus	Suspended solids	Side channel	0.2171	0.0006
Ceratophyllum demersum	Suspended solids	Side channel	0.2146	0.0006
Mean number of species recorded at a site	Suspended solids	Side channel	0.2102	0.0007
Total number of species recorded	Secchi transparency	Side channel	0.2062	0.0010
Potamogeton zosteriformis	Dissolved oxygen	Side channel	0.2049	0.0009
Potamogeton nodosus	Secchi transparency	Side channel	0.1750	0.0028
Floristic Quality Index	Secchi transparency	Side channel	0.1738	0.0029
Potamogeton foliosus/pusillus	Secchi transparency	Side channel	0.1511	0.0058
Mean Coefficient of Conservatism	Secchi transparency	Main channel border	0.1424	0.0075
Stuckenia pectinatus	Secchi transparency	Side channel	0.1375	0.0087
Relative frequency of exotic species	Secchi transparency	Side channel	0.1272	0.0119
Relative frequency of tolerant species	Ammonium nitrogen	Side channel	0.1145	0.0187

SUMMARY OF OBSERVATIONS FROM DATA ANALYSES AND LITERATURE REVIEW

Limitations in Drawing Conclusions

Conclusions drawn from this data and literature review need to be made in recognition of the constraints of review performed, the limits of the data, and in light of UMR ecosystem function as follows:

- Much of the data review presented in this report relies on simple visual comparison. More rigorous approaches could be employed to further understand the significance of distinctions observed.
- Currently, extensive lateral data is only available in LTRM study reaches. Reaching systemic conclusions regarding lateral patterns therefore requires the extrapolation of LTRM findings to non-study reaches. Further data collection in all CWA assessment reaches may be helpful in resolving uncertainties.
- Complexity and variability of the system must also be kept in mind. For example, yearly variation in water quality parameters is expected due to factors such as drought or flood years. Another example is that the presence or absence of certain fish species may be due to the geographic limitations of the species, and not due to immediate water quality influences. Also, changes in flow regime and season may affect the distribution of some highly mobile fish species.

In addition, the UMR is an altered system and this affects water quality and biological patterns. The building of locks and dams changed the UMR ecosystem by creating fast moving areas below dams and slow moving areas above dams, wider and deeper impounded areas, and more expansive shallow backwater areas. Each of these ecosystem changes in turn affected chemical, physical, and biological conditions of the river system. These changes should be kept in mind while making summary observations about UMR water quality.

Strongest Patterns and Most Important Considerations

Based on water quality data, including biological community information, presented in this chapter, it is apparent that considerable longitudinal and lateral diversity exists in the UMR. Additionally, as with most rivers and streams in the Midwest, the UMR exhibits both seasonal and year-to-year, variations in water quality.

As states work on water quality standards, as well as monitoring and assessment protocols, for the UMR, it is critical to recognize these spatial and temporal variations. A primary challenge is to determine which distinctions are most meaningful, recognizing that no two areas of river will have identical chemical, physical, and biological characteristics. As such, it is helpful to identify the strongest and potentially most important patterns emerging from this report’s data and literature review as follows:

- Longitudinal Patterns and Considerations
  - Longitudinal distinctions exist among reaches for a number of water quality parameters, including temperature, dissolved oxygen, total suspended solids, turbidity, and nutrients, as observed in both LTRM and EMAP-GRE data.
  - Longitudinal distinctions also exist among reaches for biological communities (both fish and vegetation) as seen in cluster analyses of LTRM and EMAP-GRE data.
  - There are similarities among the upper study reaches (Pools 4, 8, and13) for some chemical, physical, and biological parameters. Separately, the lower study reaches (Pool 26 and Open River) shared similarities in some chemical, physical, and biological parameters.

- Lake Pepin has a unique effect in reducing suspended material concentrations due to settling, as well as on associated contaminants (e.g., phosphorus), creating a notable discontinuity in longitudinal gradients for these water quality parameters.
- Ordination and cluster analyses of water quality data indicate that three to four longitudinal groupings emerge for the UMR. Also, cluster analyses show that variations in water quality between reaches are stronger than intrapool variations.
- Excursions from threshold values for some parameters (temperature, turbidity, total suspended solids, total phosphorus) are more common in lower reaches of the UMR. However, the thresholds applied in this report for these parameters may not necessarily be appropriate benchmarks in these reaches.
- Overall, longitudinal patterns in water quality data, including biological communities, are indicative of a need to make longitudinal distinctions in UMR CWA aquatic life designated uses, as well as in water quality criteria used to assess aquatic life use attainment.

▪ Lateral Patterns and Considerations

- For certain water quality parameters (e.g., dissolved oxygen, total nitrogen, total phosphorus) there are differences among strata and sometimes differences between groups of strata (e.g., contiguous backwater and impounded strata versus main channel and side channel). Often, these lateral patterns are dependent on season and flow conditions.
- Excursions from thresholds values for some parameters (e.g., temperature, dissolved oxygen, pH) occur most frequently in backwaters and impounded areas.
- Biological communities, both fish and vegetation, show differences among strata for several metrics (e.g., richness, frequency of occurrence). Of note, fish are able to move and may utilize more than one stratum over different seasons and life stages, while submersed aquatic vegetation (SAV) is rooted in the substrate. As such, SAV may be more indicative of long term water quality conditions.
- Lateral distinctions in water quality often occur on a seasonal and/or year-to-year gradient. Therefore, the ability to define strata with a set of fixed lines over time is limited. The temporal dynamics of flow condition, water depth, and factors such as summer vegetation should be considered in any recognition of lateral variation within designated uses.
- Cluster analyses of LTRM chemical and physical data do not reveal a consistent grouping of strata as most similar, though main channel and side channel are most frequently grouped together. As such, each strata should likely be considered separately in a CWA aquatic life designated use context, at least as starting point for future work.

▪ Seasonal and Year-to-Year Patterns

- Seasonal patterns are extremely important to consider. Water quality characteristics and trends can vary greatly by season and flow condition. Water quality criteria associated with any new or revised aquatic life designated uses should account for naturally occurring temporal variability and/or be explicit about the conditions under which criteria are to be applied.
- Extreme events such as floods and droughts which periodically occur on a large and dynamic system such as the UMR, can temporarily and markedly affect water quality conditions. For example, floods typically not only increase flows but also raise suspended sediment levels on temporary basis. Further, many of the River's biological assemblages have adapted to this type of periodic disturbance. As such, considerations of exceedance frequency and duration, as well as the role of periodic disturbance in ecosystem function, are relevant in developing and using water quality criteria to assess UMR aquatic life use attainment.

- Also, long term trends of system change (e.g., invasive species, climate change) may trigger a need to revisit aquatic life use expectations regarding biological assemblages and associated water quality criteria.

- Relationships Between Chemical, Physical, and Biological Parameters
  - Several key parameters that greatly influence the occurrence and health of UMR biological communities (i.e., suspended solids, transparency, temperature, velocity, nutrients, aquatic vegetation, depth, and dissolved oxygen). Which of these parameters are most important varies by community type and aquatic strata.
  - Commonly-monitored and water quality parameters (e.g., suspended solids, transparency) that are correlated with the health of biological communities frequently do not have numeric criteria in state water quality standards.
  - In some cases, existing state water quality criteria are not fully accurate or sole predictors of biological community health. For example, data from several UMR locations demonstrates excursions from water quality criteria in some seasons and strata (e.g., pH and dissolved oxygen in backwaters and impounded areas). Although the excursions suggest impairment of aquatic life uses, biological monitoring indicates that these locations often support a relatively natural and healthy fish community.
  - The evidence of successful fish populations in areas where water quality thresholds are not always met indicates that currently identified “minimal” conditions may not be reflective of aquatic life needs in all times, in all places on the UMR. For example, as discussed earlier in this chapter, reduced dissolved oxygen concentrations may actually be linked to beneficial conditions (i.e., the presence of vegetation) and/or play a role in a disturbance regime that helps promote biodiversity. As such, the identification of location- and season-appropriate thresholds for some water quality parameters, as well as the potential role of certain variations (e.g., changes in dissolved oxygen levels) in ecosystem function, are important considerations in developing and applying aquatic life criteria on a complex ecosystem like the UMR.

Summary

In all, the data and literature analyses presented here give strong indication that **UMR aquatic life communities, as well as associated water quality characteristics, are distinct enough in their spatial and temporal variation to merit differentiation in Clean Water Act aquatic life use designations.** The next chapter proposes how the states might proceed to begin incorporating such distinctions into their UMR CWA water quality use designations, criteria, assessments, and impaired waters listings.

Chapter 5:
Recommendations & Next Steps

ADDRESSING UMR DIVERSITY IN CWA CONTEXT

Chapter 4 examined existing UMR data and literature, identifying numerous important distinctions in UMR aquatic communities and water quality conditions. These patterns were observed in both longitudinal and lateral gradients. Important temporal variations, both seasonal and year-to-year, were also observed. Additionally, a number of instances were identified where states' current water quality criteria are: 1) inadequate to fully assess aquatic life conditions (e.g., due to lack of criteria for biology and key chemical/physical parameters), and/or 2) may not provide an accurate indication of the River's aquatic life use attainment (e.g., when criteria do not reflect expected seasonal variations or variations among strata). **In sum, the data analyses and literature review indicate that the states' current CWA approaches are very limited in their ability to fully and accurately asses the UMR's aquatic life condition.**

SCOPE AND CONSIDERATIONS FOR REPORT RECOMMENDATIONS

Given the identified limitations in current CWA approaches, the UMRBA WQTF believes it is important for the states to adapt multiple program elements (e.g., designated uses, monitoring, criteria, and assessments) to improve aquatic life protection and consistency on the UMR. As such, the recommendations made in this final chapter go beyond the report's designated use scope *per se*. The WQTF recognized and considered the following in making recommendations:

- The complexity of the UMR, including the considerable data already available, as well as the possible need for even more specific information to support improved CWA aquatic life use assessments.
- The need to focus on only the most CWA-relevant elements of the UMR's diversity.
- A CWA-focused monitoring strategy, water quality criteria (including biological criteria), and an assessment methodology should accompany any UMR designated use refinements. Therefore, any first step regarding designated uses should help set the stage for further work on these related elements.
- New or revised CWA components may be developed and implemented on different timelines among states. As such, recommendations should be relevant to all UMR states, regardless of how their CWA program is current structured or what their readiness to adopt changes may be.
- Any changes may need to be modified as further information is gathered and synthesized, and as program components (e.g., monitoring strategy) are developed and implemented. As such, flexibility and adaptability in any recommendations are also important.

RECOMMENDED ACTION – ESTABLISH A UMR CLASSIFICATION STRUCTURE

In recognition of the above, **the most productive next step appears to be the establishment of a UMR classification structure**. A classification structure provides an initial framework to capture major variations in UMR aquatic communities and water quality conditions. Moreover, it establishes an architecture to aid states in describing aquatic life expectations for specific areas of the river, developing a monitoring strategy, setting criteria, and conducting assessments.

Classification is a commonly-employed technique in dealing with waterbody diversity under the CWA's water quality standards and assessment programs. In fact, some UMR states currently implement a classification structure for their intrastate surface waters that recognizes differences in waterbody types and sizes (e.g., shallow versus deep lakes), and also recognizes longitudinal gradients in headwaters streams and rivers. See example in Figure 5-1, where the classification step is noted as "waterbody class" and highlighted in gold.

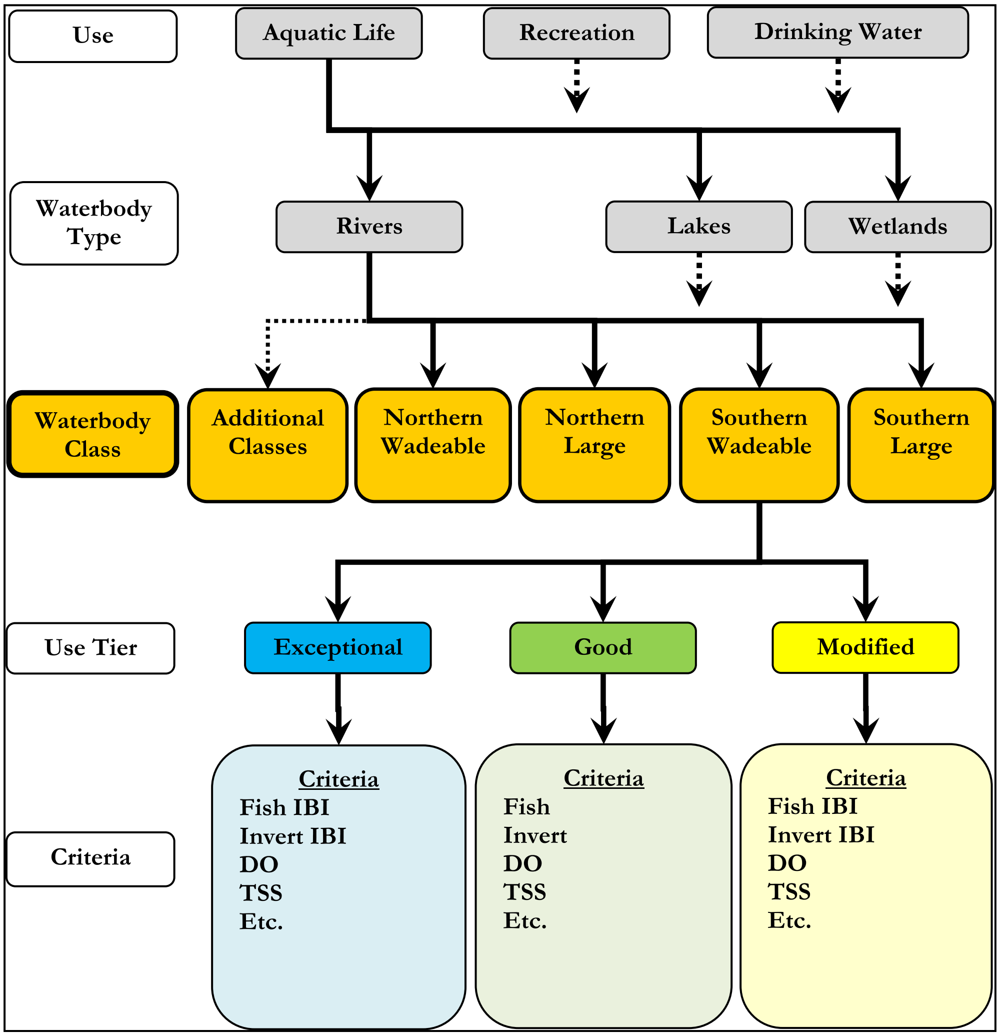


Figure 5-1: Generalized (Non-UMR Specific) Example State Framework for Designated Uses and Waterbody Classification

As described in Chapter 3, CWA programs addressing other large aquatic ecosystems, such as the Chesapeake Bay and the Delaware River, have incorporated habitat-informed waterbody classification approaches. Additionally, "natural classification" is an important first step in the development of biological assessment under a tiered aquatic life use (TALU) approach (US EPA 2005). The WQTF's recent biological assessment project and several states' biological assessment programs are informed by the TALU approach. Therefore, the WQTF's recommendation for a UMR classification is informed by the approaches already used in UMR states, other large aquatic ecosystem programs, and the UMR biological assessment project. **Moreover, such a structure can address longitudinal and lateral components of the UMR's aquatic life and water quality diversity.**

Importantly, the recommendations given here must be considered as an <u>initial</u> classification structure. Classification will likely need to be revisited as more information becomes available and as other UMR CWA program elements are further refined and implemented.

SPECIFIC UMR CLASSIFICATION RECOMMENDATIONS

The WQTF's specific recommendations for a UMR classification structure are based on this report's data and literature review, as well as discussions with state and federal resource and water quality experts. These recommendations reflect the most prominent distinctions identified in UMR water quality and aquatic communities (see pages 4-39 to 4-41).

Longitudinal Component of Classification

Recommendation: Recognize four longitudinal reaches on the interstate UMR. Details, considerations, and limitations regarding this recommendation are described below.

- Define the four longitudinal reaches as follows (see also Table 5-1):
  - ***Upper Impounded Reach (above the Chippewa River)***. This reach starts at the St. Croix River and goes downstream to the Chippewa River (base of Lake Pepin). It includes CWA assessment reach 1 and encompasses river miles 812-763.
  - ***Upper Impounded Reach (below the Chippewa River)***. This reach starts at the Chippewa River (base of Lake Pepin) and goes downstream to Lock and Dam 13. It includes CWA assessment reaches 2-6 and encompasses river miles 763-523.
  - ***Lower Impounded Reach***. This reach starts at Lock and Dam 13 and goes downstream to the confluence with the Missouri River. It includes CWA assessment reaches 7-11 and encompasses river miles 523-196.
  - ***Unimpounded Reach***. This reach starts at the Missouri River confluence and goes downstream to the Ohio River confluence. It includes CWA assessment reaches 12-13 and encompasses river miles 196-0. This is also known as the Open River reach.

  Table 5-1 provides further context and details regarding these longitudinal distinctions.
- This approach acknowledges longitudinal gradients in water quality and aquatic communities seen in LTRM and EMAP-GRE data, reported in LTRM publications, and demonstrated in ordination and cluster analyses. While these lines of evidence do not point to precise or identical cutoffs in all cases, the recommended reach boundaries reflect the most predominant demarcations demonstrated.
- This longitudinal classification accounts for the major discontinuity in chemical, physical, and biological data within the Upper Impounded Reach at Lake Pepin by dividing this reach at the Chippewa River. However, it does not accommodate less prominent longitudinal discontinuities in data within other floodplain reaches, as none of these appeared as pronounced as the changes between flood plain reaches or at Lake Pepin.
- This recommendation accounts for and includes reference to the 13 minimum interstate reaches (see Table 5-1), which are currently used by the UMR states for purposes of CWA assessments and impaired waters listings.
- This approach also provides some alignment with floodplain reach definitions used by UMR ecosystem restoration programs (see Table 5-1).
- Additional data will eventually be needed for lateral strata in pools outside of the LTRM study reaches, to provide a better understanding of aquatic communities and water quality along the full length of the UMR.

Table 5-1: UMR Reach Comparison and Longitudinal Classification Recommendation

Floodplain Reach	Physical Feature	CWA Interstate Assessment Reach	River Miles	Recommended Longitudinal Reach
Upper Impounded	*St. Anthony Falls*	Non-Interstate UMR		
	Lock and Dam #1			
	Lock and Dam #2			
	St. Croix River	**Assessment Reach 1 (Rush-Vermillion)** (St. Croix River to Chippewa River/ HUC 07040001)	**812-763**	**Upper Impounded (above Chippewa River)**
	Lock and Dam #3			
	Chippewa River			
	Lock and Dam #4	**Assessment Reach 2 (Buffalo-Whitewater)** (Chippewa River to Lock and Dam 6/ HUC 07040003)	**763-714**	**Upper Impounded (below Chippewa River)**
	Lock and Dam # 5			
	Lock and Dam #5a			
	Lock and Dam #6			
	Lock and Dam #7	**Assessment Reach 3 (La Crosse-Pine)** (Lock and Dam 6 to Root River/HUC 07040006)	**714-694**	
	Root River			
	Lock and Dam #8	**Assessment Reach 4 (Coon-Yellow)** (Root River to Wisconsin River/HUC 07060001)	**694-631**	
	Lock and Dam #9			
	Wisconsin River			
	Lock and Dam #10	**Assessment Reach 5 (Grant-Maquoketa)** (Wisconsin River to Lock and Dam 11/ HUC 07060003)	**631-583**	
	Lock and Dam #11			
	Lock and Dam #12	**Assessment Reach 6 (Apple-Plum)** (Lock and Dam 11 to Lock and Dam 13/ HUC 07060005)	**583-523**	
	Lock and Dam #13			
Lower Impounded	*Locks and Dam #14*	**Assessment Reach 7 (Copperas-Duck)** (Lock and Dam 13 to Iowa River/ HUC 07080101)	**523-434**	**Lower Impounded**
	Locks and Dam #15			
	Lock and Dam #16			
	Lock and Dam #17			
	Iowa River			
	Lock and Dam #18	**Assessment Reach 8 (Flint-Henderson)** (Iowa River to Des Moines River/ HUC 07080104)	**434-361**	
	Lock and Dam #19			
	Des Moines River			
	Lock and Dam #20	**Assessment Reach 9 (Bear-Wyaconda)** (Des Moines River to Lock and Dam 21/ HUC 07110001)	**361-325**	
	Lock and Dam #21			
	Lock and Dam #22	**Assessment Reach 10 (The Sny)** (Lock and Dam 21 to Cuivre River/ HUC 07110004)	**325-237**	
	Lock and Dam #24			
	Lock and Dam #25			
	Cuivre River			
	Lock and Dam #26 (Melvin Price)	**Assessment Reach 11 (Peruque-Piasa)** (Cuivre River to Missouri River/HUC 07110009)	**237-196**	
	Missouri River			
Unimpounded	*Kaskaskia River*	**Assessment Reach 12 (Chaokia-Joachim)** (Missouri River to Kaskaskia River/ HUC 07140101)	**196-118**	**Unimpounded (Open River)**
	Thebes Gap	**Assessment Reach 13 (Upper Miss-Cape Girardeau)** (Kaskaskia River to Ohio River/HUC 07140105)	**118-0**	
	Ohio River			

Lateral Component of Classification

<u>Recommendation</u>: Recognize four lateral strata on the interstate UMR. Details, considerations, and limitations regarding this recommendation are described below.

- Specify four lateral aquatic strata on the UMR based on current LTRM strata definitions and delineations as follows:
  - ***Main channel***: The navigation channel and its border.
  - ***Side channels:*** Channels other than the main channel.
  - ***Contiguous backwaters:*** Off-channel areas with apparent surface water connection with the main channel and side channels.
  - ***Impounded:*** Large, mostly open-water off-channel areas located in the downstream portion of the navigation pools, upstream of a dam.
- This approach recognizes various distinctions observed in LTRM data among these four strata. While the main channel and the side channel strata demonstrate similarities in chemical and physical characteristics, they are kept separate in this recommended structure. This approach is intended to preserve flexibility and the ability to examine these strata further during monitoring strategy and criteria development processes. It also recognizes that some biological communities (i.e., vegetation) may differ appreciably between main and side channels.
- For a particular river reach, only those lateral strata present would be used (i.e., some reaches do not have all four lateral strata).
- Implicit in this approach is an understanding that lateral strata classifications may be revisited as implementation proceeds and to better integrate factors including as water level, velocity, flow regime, and biological features/expectations.
- This lateral classification structure does not specifically address isolated backwaters/wetlands and tributary deltaic lakes (i.e., Lake Pepin). In the case of Lake Pepin, extensive work is already underway to address this segment of the river via the Lake Pepin TMDL and this is the only tributary deltaic lake on the UMR mainstem. Isolated backwaters/wetlands may be addressed in future work, but their exclusion at this time should not affect decision and actions regarding the four specified mainstem strata.

Summarized Recommendation

The following is the summarized recommendation for a UMR classification structure that incorporates the previously described longitudinal and lateral elements:

	Lateral Strata				
Longitudinal Reaches		**Main Channel**	**Side Channel**	**Impounded**	**Contiguous Backwater**
	St. Croix River				
	Upper Impounded to Chippewa River *CWA Assessment Reach 1*[*]				
	Chippewa River (base of Lake Pepin)				
	Upper Impounded below Chippewa River *CWA Assessment Reaches 2-6*				
	Lock and Dam # 13				
	Lower Impounded *CWA Assessment Reaches 7-11*				
	Missouri River				
	Unimpounded (Open River) CWA Assessment Reaches 12-13			*(Not Applicable)*	
	Ohio River				

[*] The UMR states have agreed to a minimum set of 13 UMR CWA assessment reaches defined by eight-digit hydrologic unit codes.

Figure 5-2: Recommended UMR CWA Classification Structure

NEXT STEPS: INCORPORATE THE UMR CLASSIFICATION STRUCTURE INTO STATE PROGRAMS; ADDRESS MONITORING, CRITERIA, AND ASSESSMENT

Implementation of the recommended classification structure will drive additional UMR CWA program modifications. Therefore, adopting the classification structure is not a stand alone activity, but rather a part of an interrelated series of steps. Along with the incorporation of the classification structure itself, three areas of related activity are: 1) developing and implementing a comprehensive CWA monitoring strategy, 2) identifying water quality criteria (including biological criteria) applicable to different classes, and 3) creating a CWA assessment methodology. These activities are all part of an ongoing and likely iterative process of continued improvements in UMR CWA assessments.

Incorporate Classification Structure

With the initial step of identifying a classification structure completed, each state should consider how best to incorporate this structure into its water quality standards and CWA assessment/listing process. The states have all indicated their intent to use the recommendations of this report as a guiding framework, but each state's specific process for incorporating these recommendations may vary.

Figure 5-3 shows a generic example of a how a state might structure waterbody classifications within its aquatic life use to accommodate UMR classes. As indicated here, an individual state may need to address several CWA waterbody classes, depending on the strata and longitudinal reaches present on the UMR within its borders.

The UMRBA WQTF anticipates that the states' efforts to integrate the classification structure may reveal the need for further refinements. Should this happen, the states will need to collaborate amongst themselves regarding adjustments. The WQTF is providing its initial guidance to the states through this report and is prepared to provide a forum for consideration of additional changes as needed.

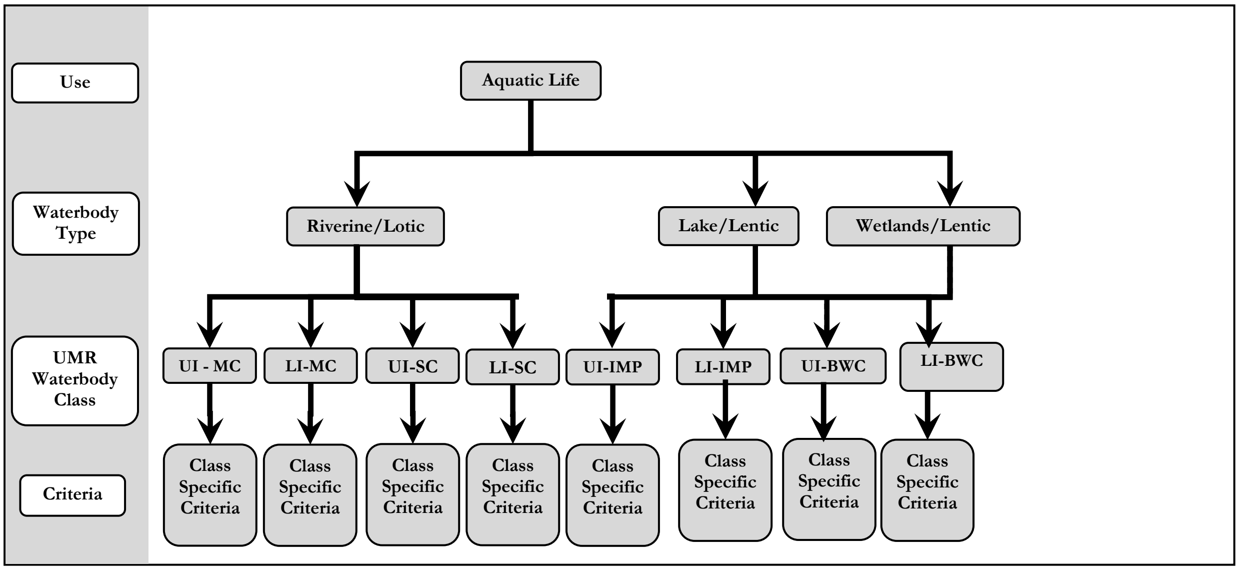


Figure 5-3: Conceptual Diagram Illustrating How the UMR Classification Structure Could be Integrated into State Water Quality Standards. Only generic Upper Impounded (UI) Reach and Lower Impounded (LI) Reach Classes shown for brevity.

Design and Implement Monitoring Strategy

Developing a comprehensive CWA assessment-focused monitoring strategy for the UMR is a top priority for the states. Such a strategy is a critical element if this report's recommendations are to have their desired effect in improving the UMR assessment and protection. In fact, the WQTF has already scoped a process and identified funding to support the development of a UMR CWA monitoring strategy. This project is slated to be completed by September 2013.

Chemical, physical, and biological metrics should all be considered within a monitoring strategy, as they are all key components of ecosystem function. The states will also need to specifically address the type and extent of monitoring that is appropriate to fully assess all of the proposed UMR classes. This should include consideration of probabilistic monitoring (as was done by EMAP-GRE and is done by LTRM), intensive strata monitoring (as is done by LTRM), and fixed-site monitoring (as done currently in some state programs as well as LTRM). Further, the monitoring strategy should be developed and implemented not only for purposes of CWA assessment and impairment listing, but to support other CWA management functions, including further criteria development. In addition, sample collection and analytical methods, frequency of sampling, and data storage all need to be considered in developing a comprehensive monitoring strategy for the UMR.

One example to consider is the draft monitoring framework prepared by US EPA, Office of Research and Development and presented to the WQTF in 2008 (Bolgrien 2008). This framework incorporates a stratified random sampling approach in each of the 13 CWA assessment reaches and for each of the four lateral strata.

Identify Aquatic Life Criteria

Water quality criteria, including biological criteria, must be identified for each class if needed, that are protective of aquatic communities and, in the case of biological criteria, descriptive of the expectations for aquatic life. Presently, most UMR states have chemical and physical water quality criteria that apply to the full length of the UMR mainstem within their state boundaries. These criteria, however, do not address the spatial and temporal variability of the UMR. As demonstrated in the review of LTRM and EMAP-GRE data, there are some cases where the states' existing water quality criteria may not provide an accurate representation of aquatic life needs. Moreover, in some cases, the states' current criteria do not address the parameters most closely tied to aquatic community health (e.g., key physical parameters such as flow, light availability, total suspended solids) or are absent altogether (i.e., biological criteria). Therefore, criteria development will need to take into account what the most critical parameters are and the appropriate values (or range of values) for these parameters, in each of the recommended classes. In some cases, multiple criteria may be considered or bundled together to show the relationship or response between the different parameters. In addition, criteria should consider temporal variability due to seasonal change, velocity, and water level.

Of note, the WQTF's recent UMR CWA biological assessment guidance document specifically addresses the question of applying biological criteria and assessment to the UMR's main channel. Additionally, the WQTF's UMR nutrients report can help inform nutrient criteria development.

Develop a UMR Aquatic Life Assessment Methodology

Employing the recommended classification structure, with it more nuanced approach to life use designation is foundational to the goal of enhancing interstate consistency in assessing aquatic life use attainment on the UMR. The states' assessment methodology for the UMR should reflect the classification structure and describe how monitoring results will be compared to criteria to determine aquatic life use attainment.

A shared UMR assessment methodology will allow states to interpret and analyze water data in a consistent manner river-wide. This will require recognizing the longitudinal and lateral classes in the assessment methodology and defining threshold levels of attainment for each class. In addition, an assessment period needs to be defined. If states can come to agreement on how to assess UMR aquatic life uses, this will lead to more consistent impairment decisions and water quality/aquatic life protection efforts. In addition, a common UMR aquatic life assessment could be used to prepare reports on the overall health of the River, similar to the report card formats used by other large aquatic ecosystems. It could also be utilized by other UMR programs (e.g., ecosystem restoration) to measure progress towards meeting goals.

CONSIDERATIONS MOVING FORWARD

Revisit and Refine Classification Structure as Needed

As has been previously stated, the recommended classification structure is an *initial* step to aid the states in revising approaches to aquatic life protection on the UMR. The UMRBA WQTF fully anticipates that, with some experience in implementation, and availability of new information, the states may wish to revise the structure. However, the fact that future changes may be needed should not deter the states from proceeding with the WQTF's recommendations at this time. Rather, this is simply a recognition of the iterative, ongoing nature of this work. Some considerations during implementation regarding potential future modifications include:

Main Channel/Side Channel Separation
One particular distinction that the states may wish to consider is the separation of the main channel and side channel into distinct lateral strata. As has been noted previously and raised in several comments on this report, these two strata often share similar water quality characteristics. Therefore, they are the lateral strata most likely to be considered for combination in future classification refinements. As such, the states may want to consider questions including the following as they proceed with implementation: 1) How are monitoring needs similar or different between these strata? 2) How distinct are the biological communities between these strata? and 3) Does additional water quality data reveal more differences or similarities between these strata?

Augment Strata Definitions with Physical Descriptors
The delineations taken from the LTRM to define lateral strata could be augmented with specific descriptors of physical condition (e.g., depth, velocity, and vegetation cover). Such additional descriptors may aid in capturing the dynamic characteristics of certain areas, particularly how off-channel areas may change over time. This would also respond to the limitation of LTRM strata delineations being tied to a single year of aerial photography.

Consider Isolated Backwaters/Wetlands
This report did not include isolated backwaters due to lack of monitoring data for this stratum. Additionally, these areas are the least connected to interstate waters. However, the states may wish to extend the UMR classification structure to include isolated backwaters/wetlands as implementation proceeds.

An alternate approach to UMR classification is displayed in Figure 5-4, that addresses all three of the above considerations to a certain extent. While this figure does not follow directly from the recommended structure, it does capture the ideas of main channel/side channel combination, incorporation of additional physical descriptors, and the addition of isolated backwaters/wetlands (as well as the assignment of criteria to particular lateral classes). As states proceed with implementation, they may wish to revisit the issues described above as well as Figure 5-4 when considering potential modifications to the classification structure. Note that the criteria listed in Figure 5-4 are illustrative only and are not a recommendation from the UMRBA WQTF for specific criteria.

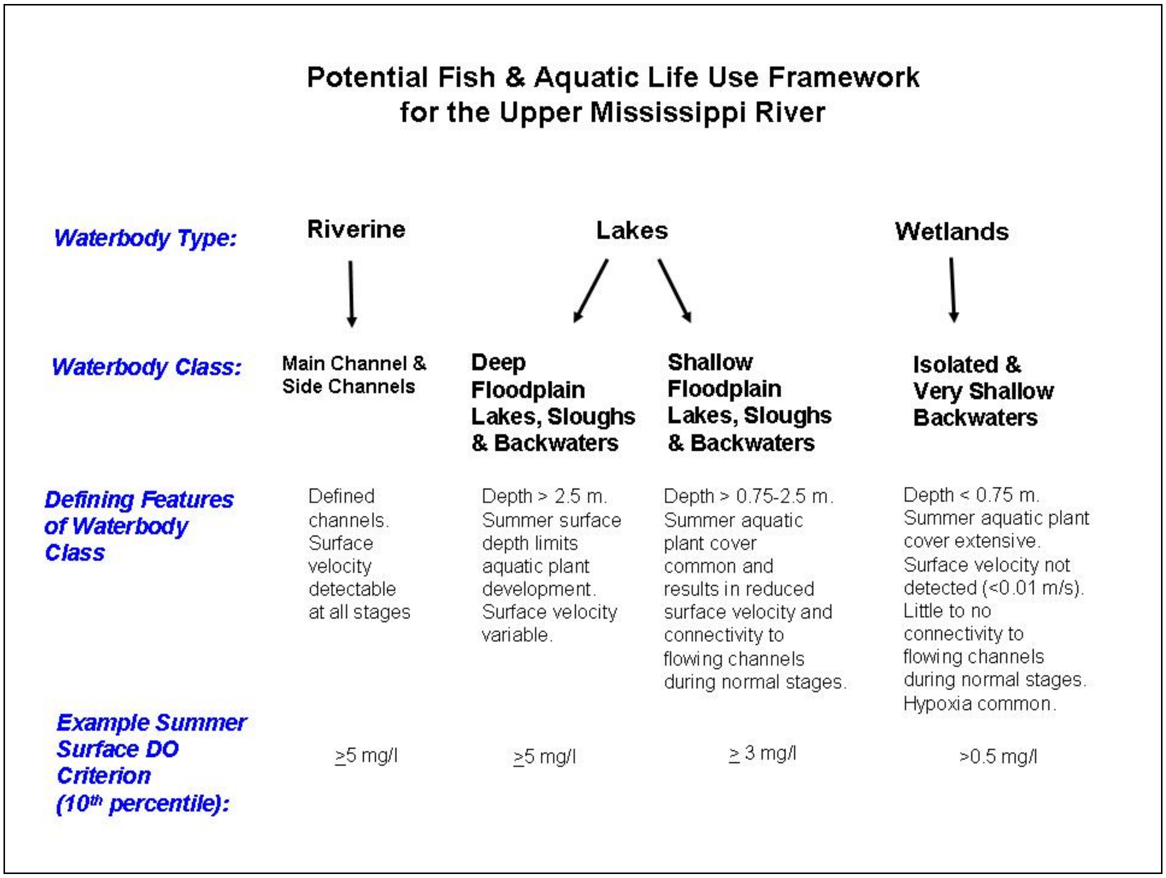


Figure 5-4: Alternate Example of State Framework for Designated Uses and Lateral Waterbody Classification (courtesy John Sullivan, WI DNR).

Recognize Differences Among States

As the states move forward in integrating a UMR classification structure and implementing related changes in monitoring, criteria, and assessment methodologies, it is important to recognize that the states may differ in their readiness to adopt these changes. Reasons include differing procedural requirements and resource availability. Therefore, the pace at which individual states integrate modifications will vary. Regardless, the classification structure recommended in this report provides the states with a common framework to pursue a shared goal, even if they reach it on different timelines.

Moreover, as is always the case with the WQTF, the recommendations made here are not intended to impede the progress of any individual state. Therefore, if a particular state wishes to proceed with any of the elements described above, it need not wait for the others states. Additionally, if a state wishes to use a more detailed classification scheme, it can do so without undermining the intent of the classification scheme proposed here, just as the UMR *minimum* assessment reaches are designed to allow a state to make further distinctions.

Consider Resource Needs and Constraints

The recommendations and next steps outlined above represent an ambitious, but attainable, revision to the states' approaches to water quality standards and aquatic life assessment/listing on the UMR. It will, however, be necessary for the states, and US EPA, to consider whether current resources are adequate to carry out the criteria development, monitoring, and assessment needed to adequately characterize aquatic life conditions on the UMR in a CWA context. If current resources are inadequate, the states and US EPA will need to identify the resource gaps and consider options for obtaining necessary resources.

References

Angradi, T.R., editor. 2006. Environmental Monitoring and Assessment Program: Great River Ecosystems, Field Operations Manual. EPA/620/R-06/002. U. S. Environmental Protection Agency, Washington, D.C.

Barko V. A., B. S. Ickes, D. P. Herzog, R. A. Hrabik, J. H. Chick, and M. A. Pegg. 2005. Spatial, Temporal, and Environmental Trends of Fish Assemblages within Six Reaches of the Upper Mississippi River System. US Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, February 2005. Technical Report LTRMP 2005-T002.

Bolgrien, D. 2008. A multiple habitat design for assessing the Upper Mississippi River. U.S. Environmental Protection Agency. Office of Research and Development. Duluth, Minnesota.

Chick, J. H., B. S. Ickes, M. A. Pegg, V. A. Barko, R. A. Hrabik, and D. P. Herzog. 2005. Spatial Structure and Temporal Variation of Fish Communities in the Upper Mississippi River System. US Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, May 2005. LTRMP Technical Report 2005-T004.

Delaware River Basin Commission (DRBC). 2008a. Delaware River and Bay Integrated List, Water Quality Assessment. DRBC Report. West Trenton, NJ. 2008.

Delaware River Basin Commission (DRBC). 2008b. Delaware River, State of the Basin Report. DRBC Report. West Trenton, NJ. December 2008.

Houser, J. N., editor. 2005. Multiyear synthesis of limnological data from 1993 to 2001 for the Long Term Resource Monitoring Program. Final report submitted to the US Army Corps of Engineers from the US Geological Survey, Upper Midwest Sciences Center, La Crosse, Wisconsin, March 2005. LTRMP Technical Report 2005-T003.

Houser, J. N. et al. 2010. Longitudinal trends and discontinuities in nutrients, chlorophyll, and suspended solids in the Upper Mississippi River: implications for transport, processing, and export by large rivers. Hydrobiologia 651:127-144.

Houser, J.N. and J. Rogala. 2006. Water quality component update. US Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, March 2006. (web-based report)

Ickes, B. S., M. C. Bowler, A. D. Bartels, D. J. Kirby, S. DeLain, J. H. Chick, V. A. Barko, K. S. Irons, and M. A. Pegg. 2005. Multiyear Synthesis of the Fish Component from 1993 to 2002 for the Long Term Resource Monitoring Program. US Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, June 2005. LTRMP 2005-T005.

Irons, K. S., DeLain, S. A., Gittinger, E., Ickes, B. S., Kolar, C. S., Ostendorf, D., Ratcliff, E. N., and Benson, A. J. 2009. Nonnative Fishes in the Upper Mississippi River System. U. S. Geological Survey, Scientific Investigations Report 2009-5176.

Johnson, B. L., and K. H. Hagerty, editors. 2008. Status and Trends of Selected Resources of the Upper Mississippi River System. U. S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, December 2008. Technical Report LTRMP 2008-T002.

Kirby, D. J., and B. S. Ickes. 2006. Temporal and Statial Trends in the Frequency of Occurrence, Length-frequency Distributions, Length-weight Relationships, and Relative Abundance of Upper Mississippi River Fish. U. S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, July 2006. LTRMP 2006-T002.

Knights, B.C, B.S. Ickes, and J.N. Houser. 2008. Fish Assemblages in Off-Channel Areas of the Upper Mississippi and Illinois Rivers: Implications for Habitat Restoration at Management-Relevant Scales. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, September 2008. Completion Report 2007APE07, submitted to the U.S. Army Corps of Engineers, Rock Island, Illinois. LIMITED DISTRIBUTION.

Langrehr, H., and M. Moore. 2008. Assessment of the Use of Submersed Aquatic Vegetation Data as a Bioindicator for the Upper Mississippi River. U. S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, December 2008. LTRMP Technical Report 2008-T003.

Meade, H., editor. 1995. Contaminants in the Mississippi River, 1987-1992. US Geological Survey Circular 1133. United States Government Printing Office. 1995.

Meffe, G.K. 1984. Effects of a biotic disturbance on coexistence of predator-prey fish species. Ecology 65(5):1525-1534.

National Academy of Sciences. 2008. Mississippi River Water Quality and the Clean Water Act: Progress, Challenges, and Opportunities. National Academies Press. Washington, DC. March 2008.

Ohio River Valley Water Sanitation Commission (ORSANCO). 2006. Pollution Control Standards for Discharges to the Ohio River. ORSANCO 2006 Revision.

US Army Corps of Engineers. 2009. Draft Title VIII of the Water Resources Development Act of 2007, Upper Mississippi River and Illinois Waterway System, Navigation and Ecosystem Sustainability Program, 2009 Implementation Report.

US Geological Survey. 1999. Ecological Status and Trends of the Upper Mississippi River System 1998: A Report of the Long Term Resource Monitoring Program. U. S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. April 1999

US Environmental Protection Agency. 2002. Consolidated Assessment and Listing Methodology. U.S EPA, Office of Wetlands, Oceans, and Watersheds. July 2002.

US Environmental Protection Agency. 2003. Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability. EPA/903-R-03-004. US EPA, Region III, Chesapeake Bay Program Office. October 2003.

US Environmental Protection Agency. 2005. Use of Biological Information to Better Define Designated Aquatic Life Uses in State and Tribal Water Quality Standards. EPA/822-R-05-001. U.S EPA, Office of Water, Washington, DC. August 2005.

Upper Mississippi River Basin Association (UMRBA). 2009. Examining Biological Indicators for the Upper Mississippi River: Applications in Clean Water Act and Ecosystem Restoration Programs. UMRBA Final Report from May 2009 Workshop. St. Paul, Minnesota.

Upper Mississippi River Basin Association (UMRBA). 2007. Issue Paper: Sediment-Related Water Quality Criteria for the Upper Mississippi River. UMRBA Report. St. Paul, Minnesota.

Upper Mississippi River Basin Association (UMRBA). 2005. Upper Mississippi River Fish Consumption Advisories: State Approaches to Issuing and Using Fish Consumption Advisories on the Upper Mississippi River. UMRBA Report. St. Paul, Minnesota.

Upper Mississippi River Basin Association (UMRBA). 2004. Upper Mississippi River Water Quality: The State's Approaches to Clean Water Act Monitoring, Assessment, and Impairment Decisions. UMRBA Report. St. Paul, Minnesota.

Upper Mississippi River Basin Commission (UMRBC). 1982. Comprehensive Master Plan for the Management of the Upper Mississippi River System. Upper Mississippi River Basin Commission, St. Paul, Minnesota.

Upper Mississippi River Conservation Committee (UMRCC). 2002. Upper Mississippi River Water Quality Assessment. UMRCC, Water Quality Technical Section Report, March 2002.

Upper Mississippi River Conservation Committee (UMRCC). 2000. A Strategy For the Natural Resources of the Upper Mississippi River System, A River That Works and a Working River. UMRCC, Editor: Dan McGuiness. Rock Island, Illinois. January 2000.

WEST Consultants. 2000. Upper Mississippi River and Illinois Waterway Cumulative Effects Study, Volume 2: Ecological Assessment. Submitted to the Department of the Army, USACE, Rock Island District. ENV Report 40-2. June 2000.

Ward, J.V. 1998. Riverine landscapes biodiversity patterns disturbance regimes, and aquatic conservation. Biological Conservation 83(3):269-278.

Yin, Y. and H. A. Langrehr. 2005. Multiyear Synthesis of the Aquatic Vegetation Component from 1991-2002 for the Long Term Resource Monitoring Program. U. S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin**,** January 2005. LTRMP 2005-T001.

Yin, Y. H., H. Langrehr, T. Shay, T. Cook, R. Cosgriff, M. Moore, and J. Petersen. 2010. Vegetation Sampling in the Upper Mississippi River System: Annual Update. U. S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin**,** February 2009. An LTRMP Web-based report available on-line.

Yoder, C. O., et al. 2011. Improving Water Quality Standards and Assessment Approaches for the Upper Mississippi River: UMR Clean Water Act Biological Assessment Implementation Guidance. Midwest Biodiversity Institute. Columbus, Ohio. September 2011.

Appendix A

Definitions and Acronyms

DEFINITIONS

Lotic	Surface waters with significant or moderate flow, riverine
Lentic	Surface waters or those with little or no flow, lake-like
Limnophilic	Preferring slower moving waters
Pelagic	Zone in a waterbody neither close to the shore nor close to the bottom
Rheophilic	Preferring faster moving waters
Study Reaches	Areas of the UMR regularly sampled by LTRM – Pools 4, 8,13, 26 and the Open River

ACRONYMS

ALDU	Aquatic Life Designated Use
BWC	Backwater Contiguous
BWCS	Backwater Contiguous Shoreline
BWI	Backwater Isolated
CHL-A	Chlorophyll-a
CFS	Cubic feet per second
CPUE	Catch Per Unit Effort
CWA	Clean Water Act
DNR	Department of Natural Resources
DRBC	Delaware River Basin Commission
EMAP	Environmental Monitoring and Assessment Program
EMERG	Emergent (aquatic vegetation)
EMP	Environmental Management Program
GRE	Great River Ecosystems
GRFIn	Great Rivers Fish Index of Biological Integrity
IMP	Impounded
LTRM	Long Term Resource Monitoring (of USACE EMP)
MC	Main Channel
MCB	Main Channel Border
MCBU	Main Channel Border Unstructured
MCBW	Main Channel Border Wingdam
NESP	Navigation and Ecosystem Sustainability Program
NTU	Nephelometric Turbidity Unit
ORSANCO	Ohio River Valley Water Sanitation Commission
PCA	Pollution Control Agency
RFL	Rooted Floating Leaf (aquatic vegetation)
SAV	Submersed Aquatic Vegetation
SC	Side Channel
SCB	Side Channel Border
SRS	Stratified Random Sampling
SSP	Species

TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
UMR	Upper Mississippi River
UMRBA	Upper Mississippi River Basin Association
UMRCC	Upper Mississippi River Conservation Committee
USACE	US Army Corps of Engineers
US EPA	US Environmental Protection Agency
USGS	US Geological Survey
WRDA	Water Resources Development Act
WQEC	Water Quality Executive Committee (within UMRBA)
WQTF	Water Quality Task Force (within UMRBA)

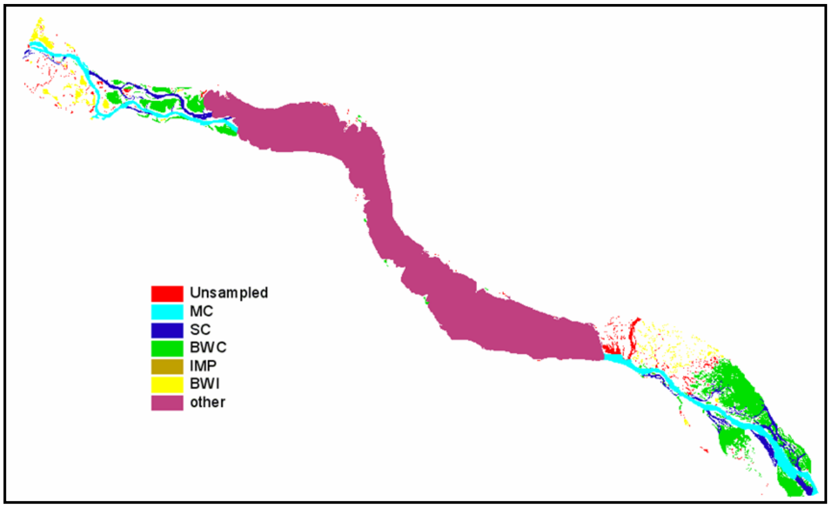
Appendix B

LTRM Sampling Strata Maps

1) LTRM Study Reach Aquatic Strata Maps

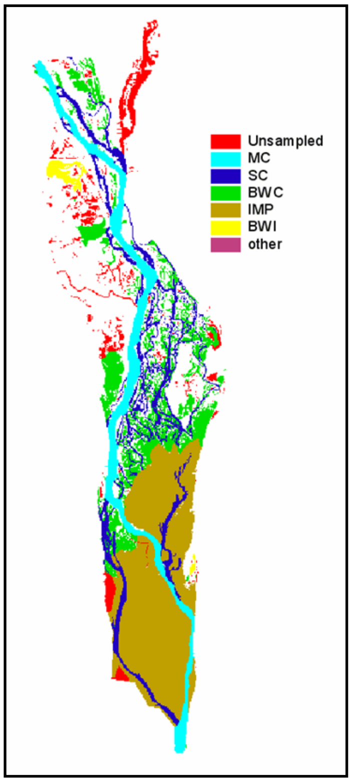
(where MC = main channel, SC = side channel, BWC = backwater contiguous, IMP = impounded, and BWI = isolated backwater)

Pool 4*

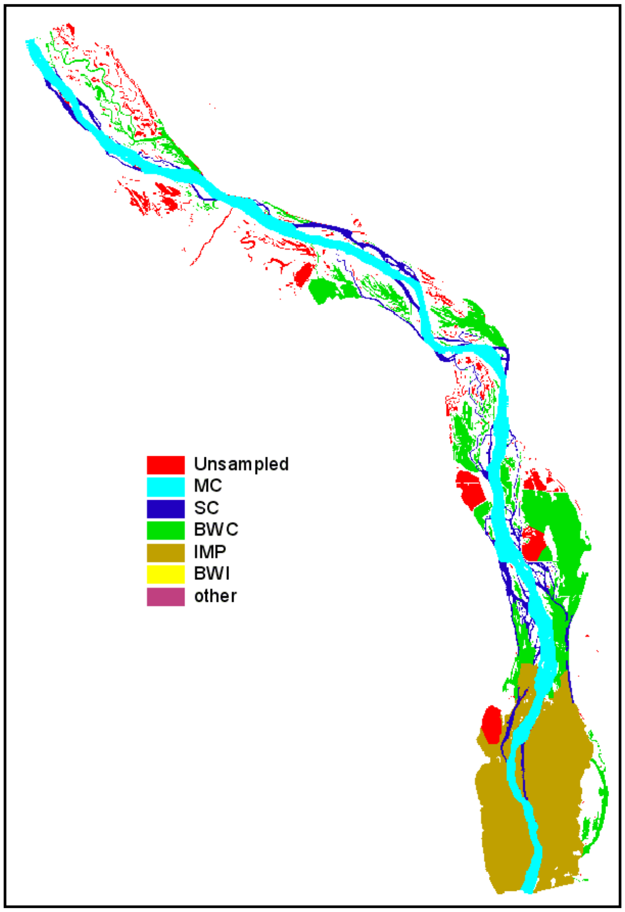


* Note that "other" is Lake Pepin, which is classified as tributary deltaic lake (TDL) stratum.

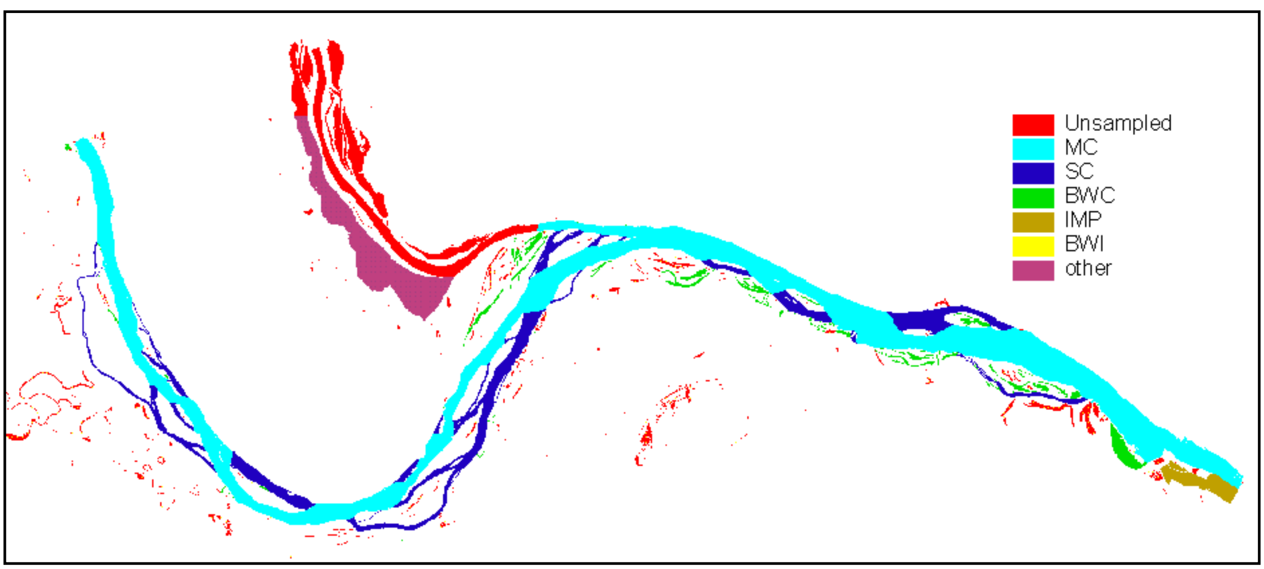
Pool 8



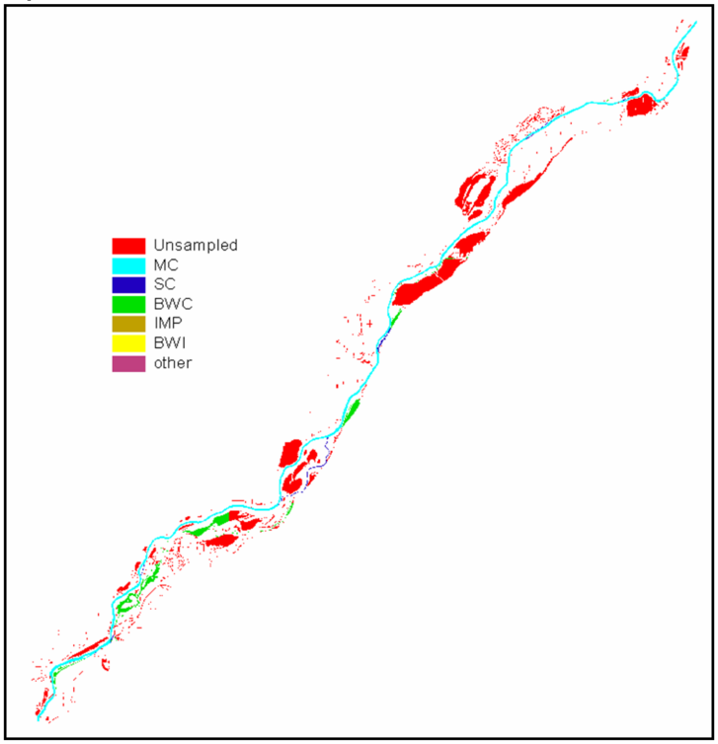
Pool 13



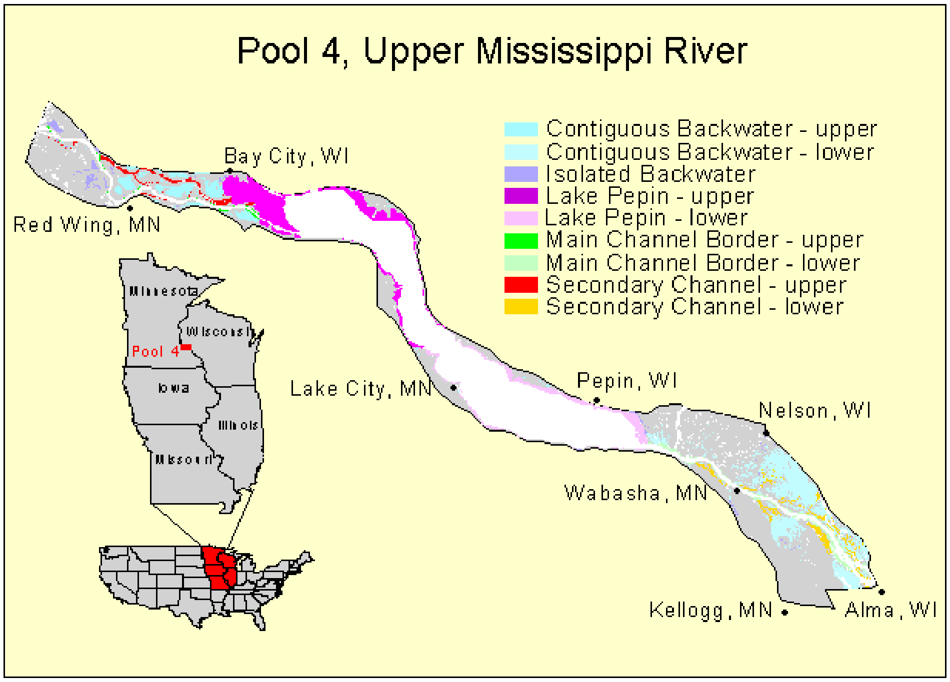
Pool 26

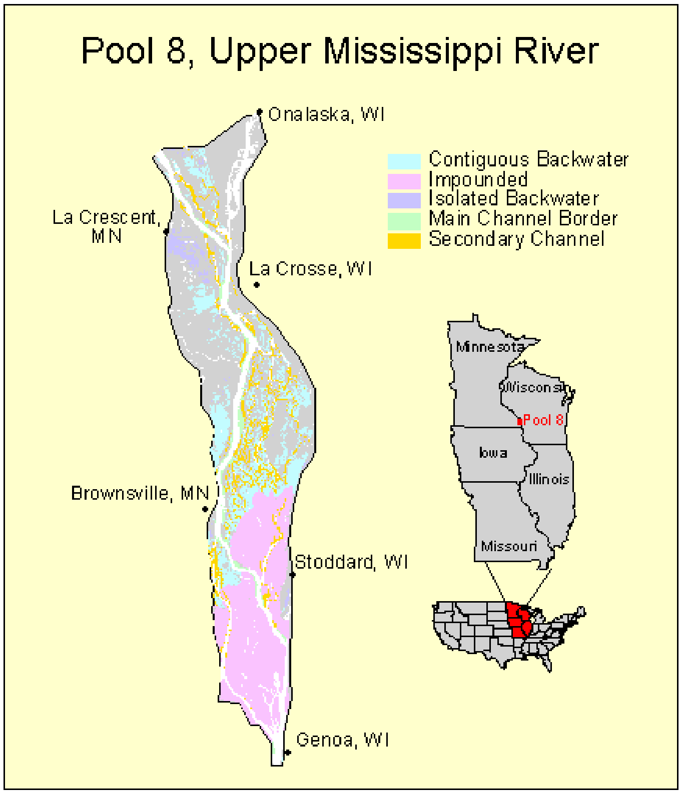


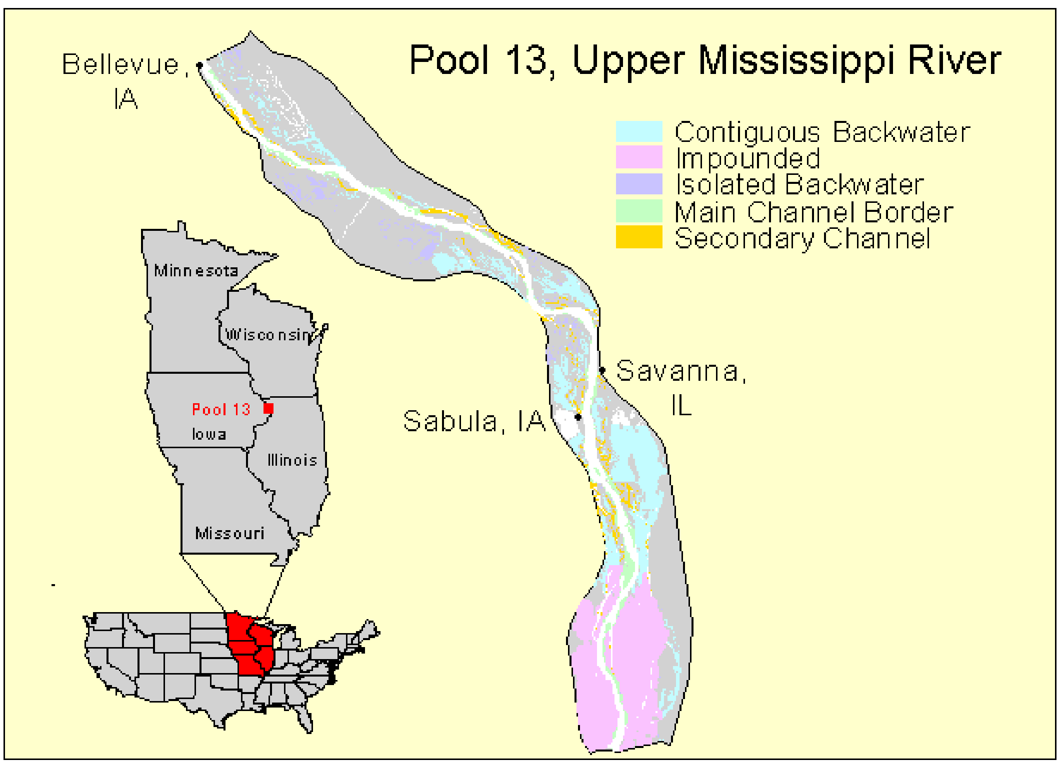
Open River

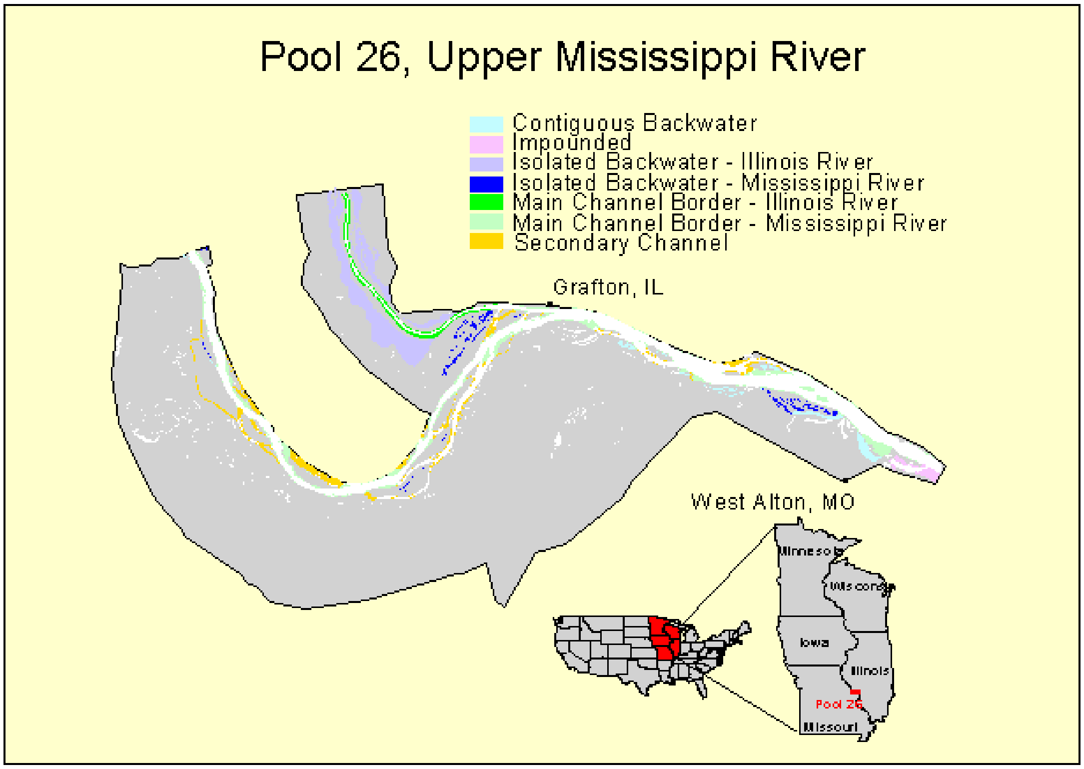


2) LTRM Study Reach Biological Sampling Strata Maps




Pool 8, Upper Mississippi River
Onalaska, WI
Contiguous Backwater
Impounded
Isolated Backwater
Main Channel Border
Secondary Channel
La Crescent, MN
La Crosse, WI
Minnesota
Wisconsin
Pool 8
Iowa
Illinois
Missouri
Brownsville, MN
Stoddard, WI
Genoa, WI


Pool 13, Upper Mississippi River
Bellevue, IA
Contiguous Backwater
Impounded
Isolated Backwater
Main Channel Border
Secondary Channel
Minnesota
Wisconsin
Pool 13
Iowa
Illinois
Missouri
Savanna, IL
Sabula, IA


Pool 26, Upper Mississippi River
Contiguous Backwater
Impounded
Isolated Backwater - Illinois River
Isolated Backwater - Mississippi River
Main Channel Border - Illinois River
Main Channel Border - Mississippi River
Secondary Channel
Grafton, IL
West Alton, MO
Minnesota
Wisconsin
Iowa
Illinois
Pool 26
Missouri

Appendix C

LTRM Water Quality Data Summary

The following tables summarize LTRM water quality data gathered for UMRBA WQTF aquatic life designated use project. Data is provided for all five LTRM study reaches on the Upper Mississippi River: Pools 4, 8, 13, 26, and the Open River, and for each of the four main strata which have extensive water quality data available: main channel (MC), side channel (SC), backwater contiguous (BWC), and impounded. Isolated backwaters are were not examined for this project, as the LTRM SRS data includes only 10 sites for isolated backwaters, and all 10 sites are in Pool 8. Data is summarized for three seasons as follows:

- Spring: Sampling occurs from late April thru early May for 14 days, and represents a period of maximum discharge.
- Summer: Sampling occurs from late July thru early August for 14 days, and typically represents low-flow conditions.
- Winter: Sampling occurs from late January thru early February for 14 days, and represents maximum ice and snow cover conditions.

The first three tables show: 1) LTRM field station information; 2) number of sample sites assigned per strata, per pool for each season for non-nutrient water quality parameters; and 3) number of sites for nutrient parameters (TN and TP). When an * is indicated after the n value, the actual number of sites sampled varies for some years by a few more or less locations. For nutrient parameters, n varies considerably over the years 1994-2000) and after 2000 is more constant. The fourth table shows the water quality threshold values used for comparison purposes.

Data is summarized as an average of annual medians per strata and per pool per season (spring, summer, and winter) from 1994 (the first full year of collecting all water quality parameters) thru 2008, excluding 2003 when no data was collected. Ranges given represent the 5th and 95th percentile for all years considered. Yellow highlighted areas indicate that at some results are excursions from threshold values. The percentage of data points from the last five years that violate thresholds or criteria are noted in parenthesis in the range column where appropriate. Red highlighted areas indicate >10% of the values were excursions from thresholds in the last five years. Grey highlighted areas indicate means which are excursions from threshold values, and the associated range of results.

Table C-1: Location of LTRM field stations, states which border the study reach, and which CWA Assessment Reach encompass the study reach

	LTRM Field Station Location	States which border sampling locations	CWA Assessment Reach Number
Pool 4	Lake City, MN	MN, WI	2
Pool 8	La Crosse, WI	MN, WI	4
Pool 13	Bellevue, IA	IA, IL	6
Pool 26	Brighton, IL	MO, IL	11
Open River	Jackson, MO	MO, IL	13

Table C-2: Number of LTRM sample locations per study reach, per strata, per season for non-nutrient water quality parameters

	MC	SC	BWC	Impounded
Pool 4	n=25	n=30	n=50	- -
Pool 8	n=25	n=30*	n=60*	n=25
Pool 13	n=30	n=30*	n=60*	n=30
Pool 26	n=20*	n=42*	n=29*	n=15*
Open River	n=75*	n=75*	- -	- -

Table C-3: Number of LTRM sample locations per study reach, per strata, per season for nutrient water quality parameters

	MC	SC	BWC	Impounded
Pool 4	n=8	n=10	n=18	- -
Pool 8	n=8	n=10	n=21	n=8
Pool 13	n=10	n=10	n=21	n=10
Pool 26	n=7	n=14	n=10	n=5
Open River	n=26	n=26	- -	- -

Table C-4: Threshold Values Used for UMR Water Quality Comparisons

Parameter	Threshold Value	Reason for Use
Temperature	30° C	Temperature criterion used by several states.
Dissolved Oxygen	5.0 mg/L	Dissolved oxygen criterion used by several states.
pH	6.5 min and 9.0 max	pH criteria used by several states.
Turbidity	25 NTU	Criterion used by Minnesota.
Total suspended solids	32 mg/L	Pool 2 to Lake Pepin site specific criteria used as summer average by Minnesota.
Total phosphorus	100 µg/L	Wisconsin criterion applicable to UMR main and side channels.

Table C-5a: LTRM Spring Temperature Data, by Pool, and by Strata, in degrees Celsius (1994-2008, excluding 2003)

SPRING TEMP.	**MC**		**SC**		**BWC**		**Impounded**	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	11.7	7.9-15.4	12.0	7.8-16.3	12.2	7.4-20	- -	- -
Pool 8	12.2	7.9-18.1	12.7	8.4-18.2	13.7	8.25-21.3	12.5	9.1-19.2
Pool 13	12.3	6.9-17.5	12.5	6.9-17.7	13.1	7.1-20.25	12.5	7.4-19.4
Pool 26	14.4	8.5-20.1	14.4	9.2-18.6	17.2	10.7-27.2	15.9	10.8-24.3
Open River	15.5	12.2-18.9	15.5	12.2-23.6	- -	- -	- -	- -

Table C-5b: LTRM Summer Temperature Data, by Pool, and by Strata, in degrees Celsius (1994-2008, excluding 2003)

SUMMER TEMP.	**MC**		**SC**		**BWC**		**Impounded**	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	25.5	22.9-30.2 (4.0%)	25.8	22.9-30.9 (7.1%)	25.9	20.8-33.1 (4.4%)	- -	- -
Pool 8	26.0	22.5-29.2	26.2	21.7-31.7 (0%)	26.0	20.3-32.1 (1.3%)	26.4	22.8-30.8 (0%)
Pool 13	26.3	23.6-29.7	26.5	23.4-31.9 (1.3%)	26.6	21.9-32.2 (5.4%)	26.6	22.2-31.7 (5.6%)
Pool 26	28.3	25.4-33.1 (25%)	28.2	24.8-32.1 (22%)	29.6	23.2-37.1 (41%)	29.0	22.9-33.5 (29%)
Open River	28.4	25.6-32.3 (21%)	28.6	25.6-33.0 (10%)	- -	- -	- -	- -

Table C-5c: LTRM Winter Temperature Data, by Pool, and by Strata, in degrees Celsius (1994-2008, excluding 2003)

WINTER TEMP.	**MC**		**SC**		**BWC**		**Impounded**	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	0.8	0.0-2.9	0.4	-0.1-2.8	0.3	-0.2-4.6	- -	- -
Pool 8	0.0	-0.2-1.2	0.1	-0.1-2.4	0.2	-0.2-4.6	0.1	-0.2-1.4
Pool 13	0.0	-0.3-1.6	0.0	-0.3-1.4	0.6	-0.2-4.7	0.1	-0.2-2.0
Pool 26	0.7	-0.3-3.6	0.9	-0.3-5.8	3.3	0.0-14.1	1.5	-0.3-5.7
Open River	1.9	0.1-5.8	2.4	0.1-14.5	- -	- -	- -	- -

OBSERVATIONS:

- Longitudinal differences all seasons (increases downstream)
- Some lateral differences
- Seasonal differences (lowest in winter, highest in summer)
- All seasonal averages meet threshold (30° C)
- Red and yellow highlighted ranges above threshold (% of data points above threshold)

Table C-6a: LTRM Spring Dissolved Oxygen Data, by Pool, by Strata, in mg/L (1994-2008, excluding 2003)

SPRING D.O.	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	11.3	9.0-18.0	11.3	7.6-17.6	11.8	7.5-25	- -	- -
Pool 8	11.3	8.4-15.5	11.5	7.8-17.0	12.2	6.9-25.0	12.1	8.0-19.3
Pool 13	10.7	7.3-14.9	10.5	7.0-15.4	11.1	6.8-19.8	11.2	8.1-17.2
Pool 26	9.1	6.6-12.4	9.1	7.2-12.0	9.3	4.7-19.2 (0.7%)	10.8	7.0-20.0
Open River	8.3	6.0-11.5	8.4	5.9-15.3	- -	- -	- -	- -

Table C-6b: LTRM Summer Dissolved Oxygen Data, by Pool, by Strata, in mg/L (1994-2008, excluding 2003)

SUMMER D.O.	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	7.1	4.8-14.8 (0.8%)	7.7	4.7-14.8 (1.3%)	8.2	0.3-20.0 (5.8%)	- -	- -
Pool 8	9.3	5.5-15.2 (0.8%)	8.9	4.0-16.4 (1.3%)	7.7	0.3-15.8 (12%)	8.9	4.5-15.1 (<0.1%)
Pool 13	7.4	5.0-11.7 (0.3%)	7.4	4.7-15.7 (2.3%)	7.0	0.4-15.1 (21%)	7.9	2.5-17.0 (5.7%)
Pool 26	8.0	3.1-13.2 (1.4%)	8.4	3.8-13.2 (2.2%)	8.7	2.1-19.8 (13%)	10.3	4.0-20.5 (2.2%)
Open River	6.5	4.9-8.3 (1.3%)	7.0	4.5-17.2 (3.2%)	- -	- -	- -	- -

Table C-6c: LTRM Winter Dissolved Oxygen Data, by Pool, by Strata, in mg/L (1994-2008, excluding 2003)

WINTER D.O.	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	12.7	9.9-17.9	12.5	7.0-16.8	12.0	0.2-20.7 (14%)	- -	- -
Pool 8	13.0	9.1-16.4	12.7	8.7-17.9	12.2	0.0-21.4 (13%)	12.9	8.5-17.1
Pool 13	13.0	10.2-16.0	12.8	10.0-16.4	12.3	0.9-20.0 (10%)	12.7	0.7-19.0 (4%)
Pool 26	14.1	11.2-18.9	14.1	10.7-22.0	14.5	2.3-25.0 (6%)	14.1	9.2-20.0
Open River	13.4	11.6-16.2	13.2	7.6-18.8	- -	- -	- -	- -

OBSERVATIONS:

- Longitudinal differences in spring (decreases downstream)
- Lateral differences, especially in summer and winter
- Seasonal differences (lowest in summer)
- All seasonal averages meet threshold (5.0 mg/L)
- Red and yellow highlighted ranges below threshold (% of data points below threshold in all years)

Table C-7a: LTRM Spring Conductivity, by Pool, by Strata, in µS/cm (1994-2008, excluding 2003**)**

SPRING CONDUCT.	**MC**		**SC**		**BWC**		**Impounded**	
	avg.	range	avg.	range	avg.	range	avg.	Range
Pool 4	433	139-620	420	87-604	353	73-599	- -	- -
Pool 8	379	209-547	350	199-551	349	129-542	377	192-551
Pool 13	350	220-494	354	240-509	351	217-502	348	215-502
Pool 26	423	289-723	416	308-660	388	188-910	393	287-468
Open River	481	312-614	476	338-599	- -	- -	- -	- -

Table C-7b: LTRM Summer Conductivity, by Pool, by Strata, in µS/cm (1994-2008, excluding 2003)

SUMMER CONDUCT.	**MC**		**SC**		**BWC**		**Impounded**	
	avg.	range	avg.	range	avg.	range	avg.	Range
Pool 4	468	149-596	454	213-586	411	199-612	- -	- -
Pool 8	424	297-513	412	294-503	409	254-519	416	308-508
Pool 13	420	341-517	423	346-523	416	264-531	414	304-496
Pool 26	461	312-672	445	272-625	430	280-948	411	298-524
Open River	527	384-629	521	382-667	- -	- -	- -	- -

Table C-7c: LTRM Winter Conductivity, by Pool, by Strata, in µS/cm (1994-2008, excluding 2003)

WINTER CONDUCT.	**MC**		**SC**		**BWC**		**Impounded**	
	avg.	range	avg.	range	avg.	range	avg.	Range
Pool 4	492	204-656	484	305-647	455	252-798	- -	- -
Pool 8	455	369-591	444	334-620	455	338-948	457	186-623
Pool 13	429	367-509	437	365-553	468	261-784	437	370-758
Pool 26	525	298-1104	500	224-981	430	142-940	498	260-679
Open River	578	399-814	577	406-801	- -	- -	- -	- -

OBSERVATIONS:

- Slight longitudinal differences (increases downstream)
- Slight lateral differences (decreases laterally)
- Slight seasonal differences (lower in spring)
- No threshold value applied

Table C-8a: LTRM Spring pH, by Pool, by Strata, in standard units (1994-2008, excluding 2003)

SPRING pH	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	8.4	7.4-9.2 (0%)	8.3	7.0-9.0	8.3	6.8-9.7 (6.2%)	- -	- -
Pool 8	8.3	7.4-9.0	8.3	7.1-9.3 (8.9%)	8.5	7.0-9.6 (15%)	8.4	7.2-9.4 (13%)
Pool 13	8.2	7.5-9.6 (11%)	8.2	7.5-9.4 (6.6%)	8.3	7.5-9.7 (12%)	8.3	7.6-9.5 (8.4%)
Pool 26	8.0	7.6-9.2 (0%)	8.0	7.6-9.2 (0%)	8.0	7.1-9.4 (5.2%)	8.4	7.7-9.4 (8.8%)
Open River	7.7	7.0-8.3	7.8	7.1-9.1 (0%)	- -	- -	- -	- -

Table C-8b: LTRM Summer pH, by Pool, by Strata, in standard units (1994-2008, excluding 2003)

SUMMER pH	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	8.2	7.7-9.0	8.3	7.6-9.1 (2.0%)	8.3	6.7-9.3 (3.5%)	- -	- -
Pool 8	8.4	7.6-9.1 (5.2%)	8.4	7.6-9.1 (5.8%)	8.2	6.6-9.2 (3.1%)	8.4	7.5-9.2 (4.4%)
Pool 13	8.1	7.7-8.7	8.1	7.6-9.1 (1.3%)	8.0	6.9-9.3 (3.9%)	8.2	7.3-9.6 (8.6%)
Pool 26	8.2	7.5-9.0	8.3	7.6-9.1 (1.8%)	8.4	7.5-9.3 (17%)	8.6	7.5-9.3 (18%)
Open River	7.9	7.4-8.5	7.9	7.4-8.9	- -	- -	- -	- -

Table C-8c: LTRM Winter pH, by Pool, by Strata, in standard units (1994-2008, excluding 2003)

WINTER pH	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	7.8	7.3-8.6	7.9	7.2-8.4	7.8	6.9-8.7	- -	- -
Pool 8	7.9	7.0-8.5	7.9	6.7-8.6	7.8	6.8-8.7	7.9	6.8-8.6
Pool 13	7.8	7.0-8.5	7.8	7.0-8.4	7.7	6.9-8.7	7.8	7.0-8.6
Pool 26	8.0	6.7-8.8	8.1	7.3-9.3 (0.6%)	8.2	6.8-9.8 (8.7%)	8.2	7.4-9.0
Open River	7.9	6.0-8.5 (0%)	7.9	6.0-8.5 (0.3%)	- -	- -	- -	- -

OBSERVATIONS:

- Longitudinal differences (decreases downstream)
- Lateral differences (increases laterally)
- Some seasonal differences (lower in winter)
- All seasonal averages meet threshold (6.5-9.0)
- Red and yellow highlighted ranges outside threshold range (% of data points outside threshold), all of these are instances where pH > 9

Table C-9a: LTRM Spring Turbidity, by Pool, by Strata, in nephelometric turbidity units (1994-2008, excluding 2003)

SPRING TURBID.	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	9	4-37 (8.0%)	9	4-34 (6.6%)	10	3-79 (4.0%)	- -	- -
Pool 8	13	7-48 (0%)	12	6-26 (0.7%)	11	3-53 (3.3%)	13	6-28 (2.4%)
Pool 13	29	15-98	28	13-140	22	5-81	26	7-91
Pool 26	77	15-306	74	18-300	57	5-280	39	15-210
Open River	134	26-680	127	10-555	- -	- -	- -	- -

Table C-9b: LTRM Summer Turbidity, by Pool, by Strata, in nephelometric turbidity units (1994-2008, excluding 2003)

SUMMER TURBID.	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	Range
Pool 4	11	4-96 (10%)	13	3-106 (6.6%)	13	1-86 (21%)	- -	- -
Pool 8	14	4-66 (1.6%)	13	3-93 (2.0%)	13	1-131 (6.0%)	13	1-38 (1.6%)
Pool 13	23	10-66	25	11-67	24	2-80	18	1-50
Pool 26	35	7-209	33	11-280	63	11-230	28	10-79
Open River	83	16-296	70	6-600	- -	- -	- -	- -

Table C- 9c: LTRM Winter Turbidity, by Pool, by Strata, in nephelometric turbidity units (1994-2008, excluding 2003)

WINTER TURBID.	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	Range
Pool 4	3	2-6	3	2-7	3	1-35 (0.4%)	- -	- -
Pool 8	3	2-5	3	2-10	4	2-96 (3.0%)	3	2-8
Pool 13	4	2-6	4	2-29	5	2-24	4	2-21
Pool 26	26	3-400	42	3-408	20	2-208	16	4-336
Open River	54	16-354	54	5-335	- -	- -	- -	- -

OBSERVATIONS:

- Longitudinal differences (increases downstream)
- Some lateral differences
- Seasonal differences (higher in spring and summer; lowest in winter)
- Grey highlighted averages, and associated ranges, above threshold (25 NTU)
- Red and yellow highlighted ranges above threshold (% data points above threshold, where calculated)

Table C-10a: LTRM Spring Total Suspended Solids, by Pool, by Strata, in mg/L (1994-2008, excluding 2003, and 1994 for P4)

SPRING TSS	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4 +	11.7	5.3-60.1	12.9	2.5-59.9	12.5	2.1-116.7 (1.2%)	- -	- -
Pool 8	20.0	10.0-22.2	20.1	7.6-51.7	16.8	2.5-92.7 (1.3%)	21.0	6.6-69.2 (0.8%)
Pool 13	51.0	18.3-194.8	46.5	17.5-155.7	26.6	5.8-141.8	44.1	8.7-229.0
Pool 26	126.7	20.7-439.9	114.8	22.4-381.4	52.3	6.9-33.4	41.3	17.5-288.9
Open River	204.3	49.4-767.1	191.4	13.1-743.1	- -	- -	- -	- -

Table C-10b: LTRM Summer Total Suspended Solids, by Pool, by Strata, in mg/L (1994-2008, excluding 2003)

SUMMER TSS	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4 +	13.8	2.8-116.6 (0.8%)	15.5	3.1-166.4 (2.0%)	16.0	1.5-101.9 (4.4%)	- -	- -
Pool 8	19.3	4.5-85.6 (0%)	18.4	2.2-132.9 (0.7%)	17.1	1.2-351.5 (2.0%)	16.5	0.8-59.0
Pool 13	30.8	12.0-97.5	33.0	14.2-103.4	26.3	1.8-150.1	22.2	0.8-73.9
Pool 26	51.6	6.8-266.4	50.4	15.0-322.9	65.1	10.0-477.1	31.2	11.1-208.9
Open River	118.9	21.3-426.9	97.0	10.7-475.7	- -	- -	- -	- -

Table C-10c: LTRM Winter Total Suspended Solids, by Pool, by Strata, in mg/L (1994-2008, excluding 1996 and 2003)

WINTER TSS	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4 +	2.1	0.6-5.0	2.2	0.8-9.9	2.4	0.4-23.3	- -	- -
Pool 8	2.0	0.4-5.3	2.3	0.6-19.7	2.8	0.7-91.6 (0.3%)	2.1	0.8-18.9
Pool 13	3.0	0.5-6.8	3.1	0.6-10.8	3.9	1.0-34.3	3.0	0.6-27.1
Pool 26	20.0	2.3-456.6 (?%)	32.9	2.9-447.3	23.7	2.9-251.1 (?%)	16.2	3.2-239.5 (?%)
Open River	56.2	23.3-385.2	49.8	4.7-392.2	- -	- -	- -	- -

OBSERVATIONS:

- Longitudinal differences (increases downstream)
- Lateral differences (sometimes lower in BWC and IMP)
- Seasonal differences (highest in spring, lowest in winter)
- Grey highlighted averages, and associated ranges, above threshold (32 mg/L)
- Highlighted ranges above threshold; (% of data points above threshold)

Table C-11a: LTRM Spring Chlorophyll-*a*, by Pool, by Strata, in µg/L (1995-2008, excluding 2003 and 1994)

SPRING Chl-*a*	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	26.55	5.88-61.22	24.50	3.78-68.53	24.97	1.76-122.30	- -	- -
Pool 8	29.59	3.70-76.62	33.26	4.24-93.81	36.06	1.00-115.30	35.07	5.88-96.59
Pool 13	29.55	5.39-91.23	28.21	5.16-73.33	29.38	4.47-97.46	27.09	5.23-91.84
Pool 26	17.46	3.53-46.45	16.91	5.35-43.12	31.21	5.55-148.8	33.75	4.69-155.1
Open River	14.65	5.44-53.77	13.75	2.00-60.24	- -	- -	- -	- -

Table C-11b: LTRM Summer Chlorophyll-*a*, by Pool, by Strata, in µg/L (1994-2008, excluding 2003 and 2006)

SUMMER Chl-*a*	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	22.66	1.30-53.56	25.69	1.50-89.22	26.93	1.00-200.80	- -	- -
Pool 8	35.29	4.86-95.02	30.95	3.73-85.44	26.61	1.00-117.90	25.60	1.00-81.03
Pool 13	24.33	4.34-79.08	24.31	3.85-72.95	26.27	1.00-175.30	17.92	1.00-70.45
Pool 26	28.06	9.23-99.53	33.10	7.35-105.40	78.29	7.49-366.90	44.67	6.94-148.60
Open River	22.22	7.74-63.73	19.31	2.78-87.82	- -	- -	- -	- -

Table C-11c: LTRM Winter Chlorophyll-*a*, by Pool, by Strata, in µg/L (1994-2008, excluding 2003)

WINTER Chl-*a*	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	4.04	1.00-23.12	3.94	1.00-26.94	5.77	1.00-74.05	- -	- -
Pool 8	3.60	1.00-38.20	4.06	1.00-44.42	6.79	1.00-96.62	6.24	1.00-40.27
Pool 13	4.37	1.00-24.72	4.58	1.00-21.26	6.19	1.00-72.64	4.14	1.00-33.74
Pool 26	17.18	1.82-79.79	14.82	2.10-51.18	22.34	1.27-122.40	20.35	2.27-104.90
Open River	12.32	2.41-51.11	11.51	2.44-87.59	- -	- -	- -	- -

OBSERVATIONS:

- Longitudinal differences (lower downstream in spring, higher downstream in winter)
- Lateral differences (higher laterally in P8 and P26)
- Seasonal differences (lowest in winter)
- No threshold value applied

Table C-12a: LTRM Spring Total Nitrogen, by Pool, by Strata, in mg/L (1994-2008, excluding 2003)

SPRING TN	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	3.05	0.73-5.92	2.88	0.95-8.27	2.65	0.65-5.70	- -	- -
Pool 8	3.01	1.14-6.53	2.68	1.00-6.16	2.45	0.67-6.18	2.90	0.90-5.93
Pool 13	2.98	0.68-8.57	2.97	1.30-5.54	2.34	0.82-5.56	2.94	0.61-5.49
Pool 26	4.24	1.63-8.74	4.22	1.65-7.22	3.11	0.97-8.76	3.47	1.78-7.39
Open River	3.73	1.89-6.60	3.68	1.09-5.74	- -	- -	- -	- -

Table C-12b: LTRM Summer Total Nitrogen, by Pool, by Strata, in mg/L (1994-2008, excluding 2003)

SUMMER TN	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	2.38	0.76-5.25	2.33	0.53-5.45	1.95	0.48-5.95	- -	- -
Pool 8	2.21	0.86-4.75	2.08	0.89-6.19	1.86	0.59-4.72	2.06	0.49-4.42
Pool 13	2.17	1.21-3.97	2.23	1.21-3.56	1.77	0.65-3.49	2.08	0.63-3.79
Pool 26	3.56	1.66-7.94	3.54	0.94-7.45	2.36	0.56-8.62	2.98	1.37-4.97
Open River	2.85	1.30-4.67	2.68	0.56-4.47	- -	- -	- -	- -

High values for 2004 for most strata and pools.

Table C-12c: LTRM Winter Total Nitrogen, by Pool, by Strata, in mg/L (1994-2008, excluding 2003)

WINTER TN	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	2.56	1.56-4.66	2.60	1.73-4.15	2.42	0.65-4.80	- -	- -
Pool 8	2.54	1.90-3.78	2.54	1.70-4.12	2.42	0.46-3.72	2.54	1.27-5.94
Pool 13	2.63	1.81-4.54	2.76	1.87-5.46	2.40	0.24-5.72	2.46	1.84-5.47
Pool 26	3.93	2.57-6.67	3.66	0.94-6.93	1.74	0.26-5.14	3.66	2.58-5.60
Open River	3.38	1.88-6.73	3.16	0.55-7.63	- -	- -	- -	- -

OBSERVATIONS:

- Longitudinal differences (increases P26 and OR; always highest P26 MC/SC)
- Lateral differences (decreases laterally)
- Seasonal differences (highest in spring)
- No threshold value applied

Table C-13a: LTRM Spring Total Phosphorus, by Pool, by Strata, in mg/L (1994-2008, excluding 2003)

SPRING TP	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	0.093	0.035-0.347	0.096	0.031-0.327	0.094	0.037-0.310	- -	- -
Pool 8	0.180	0.047-0.224	0.103	0.028-0.173	0.102	0.020-0.279	0.101	0.013-0.208
Pool 13	0.145	0.064-0.631	0.139	0.076-0.400	0.128	0.066-0.365	0.133	0.052-0.475
Pool 26	0.244	0.109-0.567	0.228	0.124-0.575	0.224	0.074-0.972	0.165	0.107-0.470
Open River	0.285	0.063-0.742	0.281	0.024-0.677	- -	- -	- -	- -

Table C-13b: LTRM Summer Total Phosphorus, by Pool, by Strata, in mg/L (1994-2008, excluding 2003, and 1996 for P13 and OR)

SUMMER TP	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	0.162	0.079-0.307	0.159	0.049-0.807	0.170	0.025-1.544	- -	- -
Pool 8	0.148	0.082-0.302	0.151	0.049-0.501	0.171	0.047-1.087	0.151	0.055-0.865
Pool 13	0.167	0.018-0.492	0.171	0.044-0.415	0.209	0.076-1.058	0.165	0.026-0.523
Pool 26	0.186	0.044-0.623	0.183	0.041-0.723	0.360	0.036-1.686	0.167	0.036-0.640
Open River	0.228	0.132-0.423	0.202	0.046-0.447	- -	- -	- -	- -

Table C-13c: LTRM Winter Total Phosphorus, by Pool, by Strata, in mg/L (1994-2008, excluding 2003)

WINTER TP	MC		SC		BWC		Impounded	
	avg.	range	avg.	range	avg.	range	avg.	range
Pool 4	0.089	0.035-0.169	0.086	0.036-0.247	0.082	0.011-0.272	- -	- -
Pool 8	0.070	0.038-0.126	0.077	0.040-0.337	0.082	0.023-0.355	0.076	0.029-0.152
Pool 13	0.068	0.030-0.207	0.074	0.032-0.351	0.072	0.023-0.389	0.059	0.002-0.212
Pool 26	0.158	0.088-0.517	0.154	0.044-0.581	0.129	0.020-0.465	0.140	0.040-0.331
Open River	0.201	0.098-0.501	0.185	0.058-0.453	- -	- -	- -	- -

OBSERVATIONS:

- Longitudinal differences (increases downstream)
- Lateral differences (decreases laterally in spring, increases laterally in summer)
- Seasonal differences (lower in spring)
- Yellow highlighted ranges above threshold of 100 µg/L (percentages not calculated)
- Grey highlighted means, and associated ranges, above threshold (percentages not calculated)

Appendix D

Longitudinal and Lateral Classification with Clustering

The R statistical package[1] was used to cluster data[2] from both the EMAP and LTRM programs, which aided in identifying lateral and longitudinal distinctions in water quality and biological data.

LTRM DATA BY POOL, SEASON AND STRATA

LTRM chemical data were used to help determine differences and similarities between main channel, side channel, contiguous backwater, and impounded UMR strata. Clustering was performed on seasonal means of chlorophyll-a, conductivity, dissolved oxygen, pH, temperature, total nitrogen, total phosphorus, total suspended solids, and turbidity.

Except in Pool 4 (which has only three of the examined strata), all combinations of season and pool were grouped into two and three clusters. Tables D-1 through D-4 indicate pool-by-pool differences in grouping, as well as differences between the seasons. Generally the main channel and side channel are most closely associated with each other, but pools 4 and 8 don't necessarily follow that pattern.

Table D-1:	Pool 4 Spring	Pool 4 Summer	Pool 4 Winter
MC	1	1	1
SC	2	2	1
BW	2	2	2
IP	N/A	N/A	N/A

Table D-2:	Pool 8 Spring (2)	Pool 8 Spring (3)	Pool 8 Summer (2)	Pool 8 Summer (3)	Pool 8 Winter (2)	Pool 8 Winter (3)
MC	1	1	1	1	1	1
SC	1	2	1	2	1	2
BW	2	3	2	3	2	3
IP	1	2	1	2	1	1

Table D-3:	Pool 13 Spring (2)	Pool 13 Spring (3)	Pool 13 Summer (2)	Pool 13 Summer (3)	Pool 13 Winter (2)	Pool 13 Winter (3)
MC	1	1	1	1	1	1
SC	1	1	1	1	1	1
BW	2	2	1	2	2	2
IP	1	3	2	3	1	3

Table D-4:	Pool 26 Spring (2)	Pool 26 Spring (3)	Pool 26 Summer (2)	Pool 26 Summer (3)	Pool 26 Winter (2)	Pool 26 Winter (3)
MC	1	1	1	1	1	1
SC	1	1	1	1	1	1
BW	2	2	2	2	2	2
IP	2	3	1	3	2	3

[1] R 2.11.1 for MS Windows

[2] Clustering was performed with the pam() command – Partitioning Around Medoids. All values were scaled with the scale() command prior to clustering.

Figure D-1 is a hierarchical clustering approach to the same dataset[3], an alternate clustering technique that can indicate how closely any given item is related to any other item in the clustering scheme. The distance between each of the four strata and the way they are related to one another changes between seasons and pools; again, main channel and side channel are usually closest to one another, but not always.

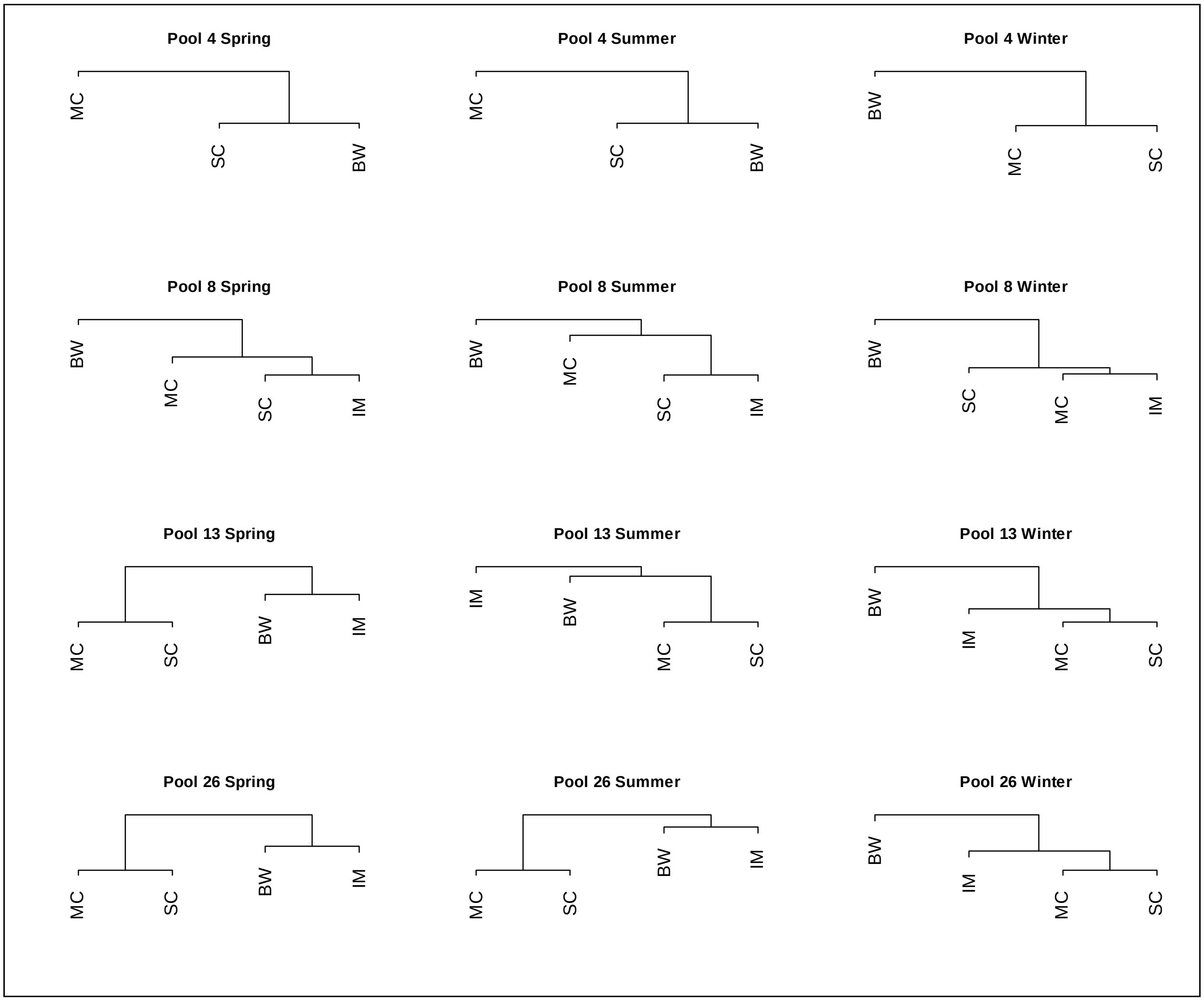


Figure D-1: Hierarchical Clustering (LTRM Chemical Data)

EMAP AVERAGES PER ASSESSMENT REACH

The first round of longitudinal clustering was performed with chemical and biological EMAP data, averaged by assessment reach. The chemical parameters were DO, pH, conductivity, temperature, turbidity, TSS, TP, TN, and Chl-A summer averages.

Table D-5 represents how the assessment reaches were divided. The longitudinal trend is most distinct in the 4 cluster scenario, but is visible in both. Neither scenario seems to show a distinct divide between upper, middle, and lower sections of the UMR, but rather a gradual change.

[3] Hierarchical clustering created by calculating the Euclidean distance between reaches with the dist() command, then clustering using the Ward algorithm with the hclust() command.

Table D-5: EMAP Chemical/Physical Clustering

	3 Clusters	4 Clusters
AR #1	1	1
AR #2	1	1
AR #3	2	2
AR #4	1	1
AR #5	2	2
AR #6	1	1
AR #7	2	2
AR #8	2	2
AR #9	2	3
AR #10	2	2
AR #11	2	3
AR #12	2	3
AR #13	3	4

Figure D-2 shows the hierarchical dendrogram for EMAP chemical data. This reinforces the longitudinal distinctions seen in Table D-1, with three distinct groups evident that are nearly equivalent to three of the four clusters in the four cluster scenario.

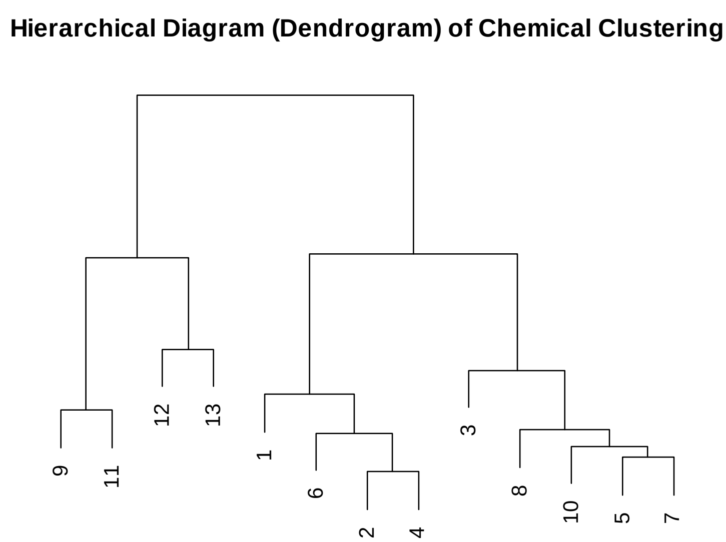


Figure D-2: Hierarchical Clustering (Chemical Data). Numbers indicate assessment reaches

After clustering assessment reaches using chemical data, they were clustered using biological data, including fish IBI, biomass, and richness scores[4]. Table D-6 shows that these results are similar to the chemical clustering, in that the UMR is clearly divided longitudinally. Unlike the chemical data, distinct dividing lines are visible in this analysis, particularly between reaches 10 & 11 and 4 & 5. Also distinct from the chemical clustering is that reach 1 remains separate from other upper UMR reaches under all three clustering scenarios.

Table D-6: EMAP Fish Clustering

	2 Clusters	3 Clusters	4 Clusters
AR #1	1	1	1
AR #2	2	2	2
AR #3	2	2	4
AR #4	2	2	2
AR #5	1	1	1
AR #6	1	1	1
AR #7	1	1	1
AR #8	1	1	1
AR #9	1	1	1
AR #10	1	1	1
AR #11	2	3	3
AR #12	2	3	3
AR #13	2	3	3

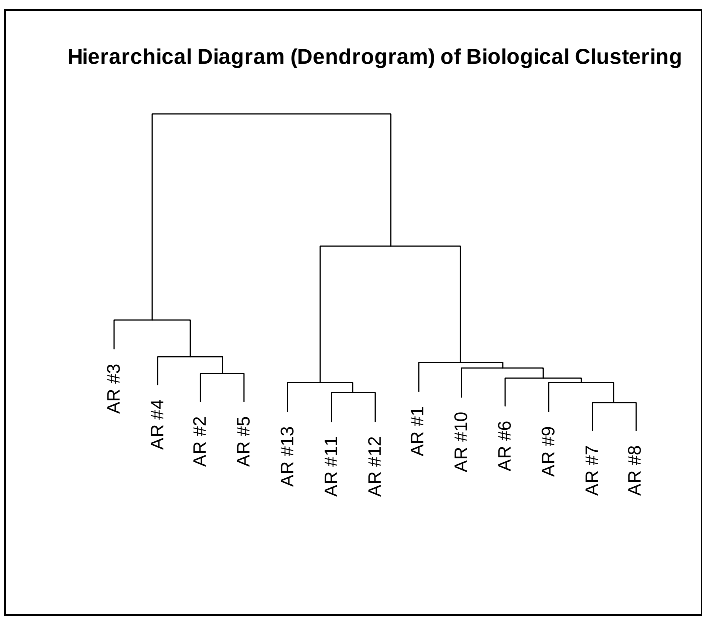


Figure D-3: Hierarchical Clustering (Biological Data)

[4] Specifically, the values "GRFIN", "NAT_RICH_ALL", "VERT_RICH_EXC2_ALL", "NONINDIG_RICH_ALL", "NAT_NIND_ALL", "VERT_NIND_EXC2_ALL", "PROP_NAT_NIND_EXC1", "NAT_BIO_ALL", "VERT_BIO_EXC2_ALL", and "PROP_BIO_NAT_NO_EXC1_ALL" were used to cluster the reaches.

Figure D-3 is a hierarchical clustering like Figure D-2 except using the biological data mentioned above, and as with Figure D-2, the groups evident in the dendrogram are largely equivalent to the clusters in the table. One notable exception is that reach 5 is grouped with 2, 3, and 4 in the dendrogram, while it is generally grouped with reaches 6 – 10 in the table.

EMAP INDIVIDUAL SITES

Cluster analyses were performed on individual EMAP sites for the chemical data. The goal of these analyses was to see whether trends identified using data aggregated over assessment reaches were evident in data that were not aggregated.

All Sites (144)

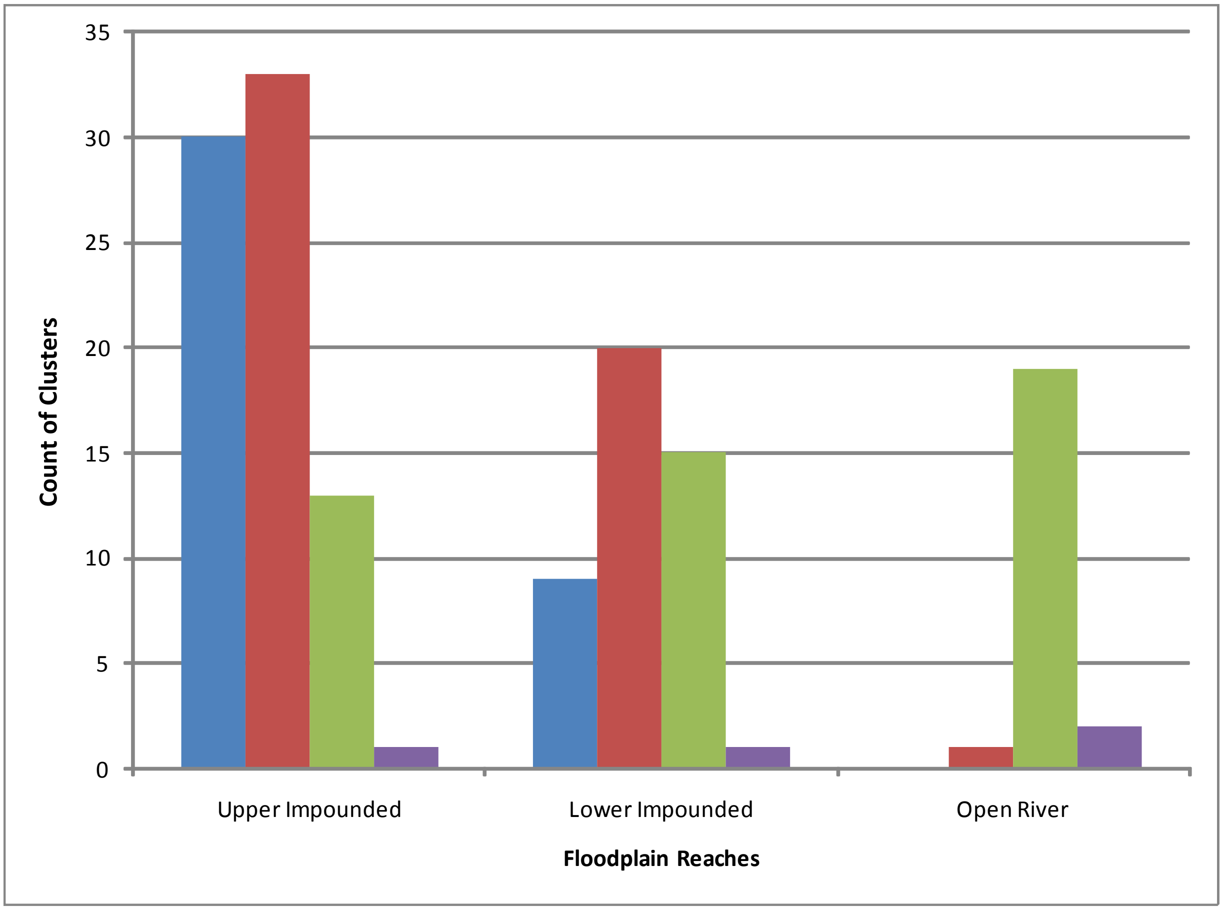


Figure D-4: Count of clusters within each floodplain reach. Each color represents a cluster – blue, red, green, and purple.

All 144 sample locations from the EMAP-GRE program on the Mississippi River were examined, using the same parameters that were used to analyze assessment reach summer means. Figure D-4 shows the number of sites in each of the four clusters, aggregated by floodplain reach. The longitudinal pattern is clear – the proportion of sites in the blue and red clusters declines from north (Upper Impounded) to south (Open River), while the proportion in the green cluster increases. Running the regression command on the site dataset[5] confirms this trend; the clusters explained about 15% of the variation in the floodplain reaches[6].

[5] lm()

[6] R^2 = 0.146 and p-value <0.001 with the floodplain reach of each site as the independent variable and the cluster as the dependent variable.

It has been noted that the upstream to downstream, within-pool variation of water quality parameters can be greater than the between-pool variation. Figure D-5 shows the count of clusters aggregated by distance from the nearest downstream dam (OR indicates open river, where there are no downstream dams; numbers are in kilometers). The figure doesn't appear to reveal any trends related to distance from dams (which serves as an indicator of whether the sample was taken in an impounded area or not). A regression indicating that none of the variation in clusters is explained by distance from downstream dams[7] supports this interpretation.

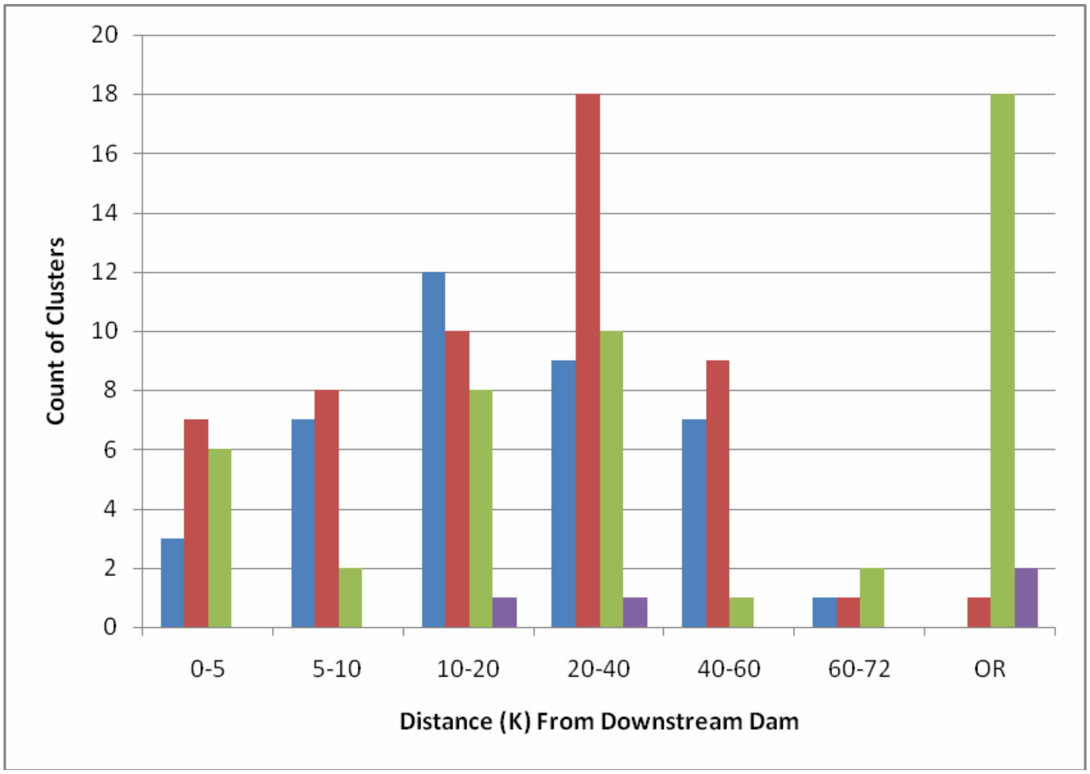


Figure D-5: Number of clusters (colored as in Figure D-1) aggregated by distance from nearest downstream dam

[7] R^2 = -0.005 and p-value > 0.1 with the distance from the dam at each site as the independent variable and the cluster as the dependent variable.

The LTRM UMR strata GIS shapefile was examined to determine distances between dams and the furthest upstream extent of their associated impounded areas. While the variation was great (0 – 17 kilometers), the median was established at 7 K. The sites were filtered to remove all those less than 8 K distant from the closest downstream dam and clustering was performed on the new dataset.

As Figure D-6 below shows, little changed by removing near-dam sites. The proportions of the blue and red clusters decreased and the proportion of the green cluster increased from upstream to downstream.

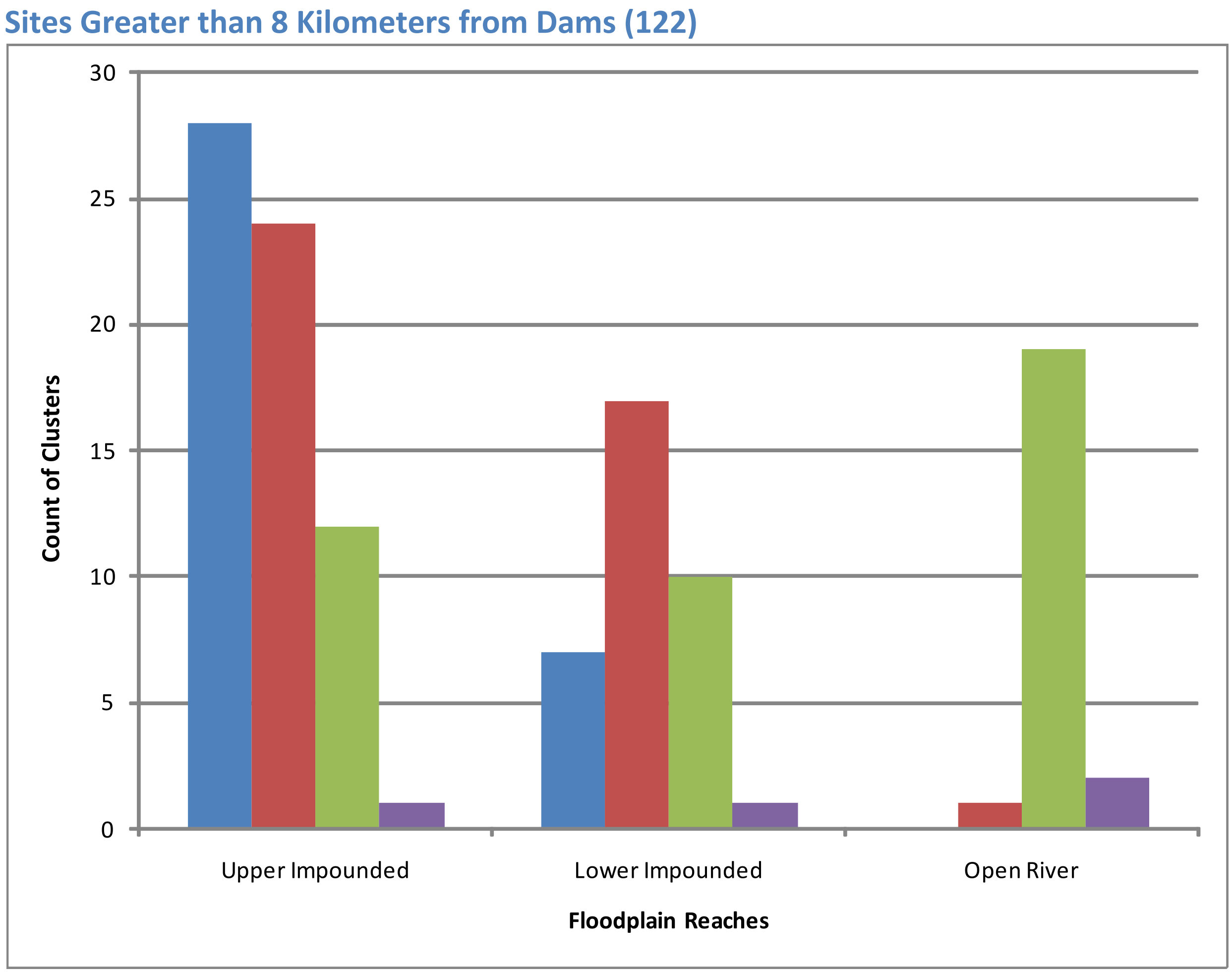


Figure D-6: Count of clusters within floodplain reaches, excluding sites less than 8 kilometers from the nearest downstream dam

Summary

The clustering analyses, taken independently and as a whole, support the classification of the river into three floodplain reaches and four lateral strata. They also support the conclusion that main channel water quality characteristics vary much more strongly over the entire longitudinal reach of the river than longitudinally within pools.

Appendix E

LTRM Biological Data Summary Tables

MCBU = main channel border unstructured
MCBW = main channel border wingdam
SCB = side channel border
BWCS = backwater contiguous shoreline
IMP = impounded shoreline

FISH: (shading indicates pools and strata where species most prevalent)

Bluegill (recreational ssp), 5-year mean 2006-2010, day electrofishing CPUE.
Appear dominant in BWC, upper reaches (low flow).

	MCBU	MCBW	SCB	BWCS	IMP	Total Catch 2010
Pool 4	5.36	0.75	11.7	24.7	n/a	5,632
Pool 8	29.7	10.7	37.8	56.7	23.4	12,026
Pool 13	6.09	1.50	10.0	29.8	3.73	1,158
Pool 26	2.35	2.62	1.81	14.7	18.4	570
Open River	0.08	0.24	0.63	n/a	n/a	225

Sauger (recreational ssp), 5-year mean 2006-2010, day electrofishing CPUE.
Appear dominant in SC upper / IMP lower (moderate flow and depth).

	MCBU	MCBW	SCB	BWCS	IMP	Total Catch 2010
Pool 4	0.416	0.050	0.716	0.212	n/a	55
Pool 8	0.292	0.056	0.488	0.184	0.176	15
Pool 13	0.434	0.198	0.800	0.278	0.516	52
Pool 26	0.158	0	0.258	0.090	0.832	19
Open River	0.084	0.098	0.156	n/a	n/a	5

Channel catfish (commercial ssp), 5-year mean 2006-2010, day electrofishing CPUE.
Appear dominant in channels, lower reaches (high flow and depth).

	MCBU	MCBW	SCB	BWCS	IMP	Total Catch 2010
Pool 4	0.280	0.250	0.332	0.034	n/a	289
Pool 8	0.168	0.252	0.244	0.156	0.102	310
Pool 13	1.00	1.24	1.78	0.722	0.050	529
Pool 26	2.82	4.01	3.02	1.20	1.48	616
Open River	1.36	2.41	1.02	n/a	n/a	489

Smallmouth buffalo (commercial ssp), 5-year mean 2006-2010, day electrofishing CPUE. Appear
Appear dominant in BWC and IMP, lower reaches (low flow).

	MCBU	MCBW	SCB	BWCS	IMP	Total Catch 2010
Pool 4	0	0.084	0.242	0	n/a	40
Pool 8	0	0.034	0.024	0.024	0	15
Pool 13	0.594	0.298	0.234	0.495	0.084	178
Pool 26	0.924	0.356	1.032	3.71	2.92	174
Open River	0.660	0.720	0.494	n/a	n/a	487

Largemouth bass, 5-year mean 2006-2010, day electrofishing CPUE.
Appear dominant in BWC and IMP, upper reaches (low flow).

	MCBU	MCBW	SCB	BWCS	IMP	Total Catch 2010
Pool 4	4.93	0.592	9.64	18.1	n/a	836
Pool 8	20.8	5.88	25.7	20.7	30.3	2,215
Pool 13	7.55	1.36	7.22	14.2	14.8	456
Pool 26	0.880	1.24	0.550	1.22	2.84	33
Open River	0.058	0.104	0.164	n/a	n/a	50

Black crappie, 5-year mean 2006-2010, day electrofishing CPUE.
Appear dominant in SC and BWC, upper reaches (low to moderate flow).

	MCBU	MCBW	SCB	BWCS	IMP	Total Catch 2010
Pool 4	0.906	0.192	1.64	1.79	n/a	478
Pool 8	0.810	0.154	1.92	1.88	0.918	534
Pool 13	0.194	0	0.434	1.57	0.150	147
Pool 26	0.100	0.264	0.100	0.318	0.594	183
Open River	0.016	0.198	0.046	n/a	n/a	104

Yellow perch, 5-year mean 2006-2010, day electrofishing CPUE.
Appear dominant all unstructured strata, upper reaches only.

	MCBU	MCBW	SCB	BWCS	IMP	Total Catch 2010
Pool 4	3.00	0.076	4.05	5.05	n/a	951
Pool 8	8.28	0.704	6.76	6.25	3.14	1,321
Pool 13	0.532	0	0.766	2.98	2.79	503
Pool 26	0	0	0	0	0	0
Open River	0	0	0	n/a	n/a	0

Additional LTRM Fish Data Summarized

	Richness 5-Year Mean, 2006-2010, all gears	Richness / total ssp all years	Total Catches 2010	Emerald Shiner and Gizzard Shad (Forage fish) Catch 2010	Total Catches Minus ES and GS 2010
Pool 4	60.8	82	70,775	44,496 / 3,633	22,646
Pool 8	59.2	89	29,311	932 / 107	28,272
Pool 13	59.6	82	11,517	1,476 / 873	9,168
Pool 26	57.6	89	9,645	379 / 2207	7,059
Open River	60.2	108	5,039	369 / 672	3,998

Additional LTRM Fish Data Summarized

	Bluegill Catch 2010	Sauger Catch 2010	Largemouth Bass Catch 2010	Channel Catfish Catch 2010	Smallmouth Buffalo Catch 2010
Pool 4	5,632	55	836	289	40
Pool 8	12,026	15	2,215	310	15
Pool 13	1,158	52	456	529	178
Pool 26	570	19	33	616	174
Open River	225	5	50	489	487

SUBMERSED AQUATIC VEGETATION: (shading indicates pools and strata where species most prevalent)

American wildcelery, % frequency of occurrence, mean 2006-2010 except for P26 2000-2004
Appear dominant in IMP (moderate current), highest poolwide P8 and P13.

	MCB	SC	BWC	IMP	Pool wide
Pool 4 Upper	0	0	0.220	n/a	14.8
Pool 4 Lower	24.7	26.5	31.3	n/a	
Pool 8	18.0	19.1	8.82	58.0	**34.9**
Pool 13	11.6	4.44	7.54	50.1	**26.1**
Pool 26	0	0	0	0	0.16

Water stargrass, % frequency of occurrence, mean 2006-2010 except for P26 2000-2004
Appear dominant in SC and IMP (moderate current), highest poolwide P8.

	MCB	SC	BWC	IMP	Pool wide
Pool 4 Upper	0	0	1.12	n/a	20.1
Pool 4 Lower	26.7	42.0	41.7	n/a	
Pool 8	23.2	27.4	24.8	56.3	**40.0**
Pool 13	8.32	6.82	10.4	22.1	14.6
Pool 26	0	0	0	0	0.16

Sago pondweed, % frequency of occurrence, mean 2006-2010 except for P26 2000-2004
Appear dominant in BWC (little / no current), highest poolwide P13.

	MCB	SC	BWC	IMP	Pool wide
Pool 4 Upper	12.0	4.00	23.9	n/a	16.0
Pool 4 Lower	10.7	17.0	9.66	n/a	
Pool 8	11.4	13.8	20.2	11.2	14.0
Pool 13	10.8	9.66	30.7	14.5	**20.7**
Pool 26	0	0	0	0	2.76

Coontail, % frequency of occurrence, mean 2006-2010 except for P26 2000-2004
Appear dominant in BWC (little / no current), highest poolwide P8.

	MCB	SC	BWC	IMP	Pool wide
Pool 4 Upper	3.00	3.98	19.9	n/a	38.3
Pool 4 Lower	14.0	42.5	84.5	n/a	
Pool 8	18.9	40.0	81.0	61.4	**62.6**
Pool 13	7.54	12.9	65.4	29.7	41.4
Pool 26	0	0	0	0	1.00

Canadian waterweed, % frequency of occurrence, mean 2006-2010 except for P26 2000-2004
Appear dominant in BWC (little / no current), highest poolwide P8.

	MCB	SC	BWC	IMP	Pool wide
Pool 4 Upper	2.00	1.32	8.04	n/a	35.6
Pool 4 Lower	24.0	44.0	81.4	n/a	
Pool 8	20.6	38.8	74.3	64.7	**61.6**
Pool 13	8.06	11.7	34.8	32.9	30.0
Pool 26	0	0	0	0	0.32*

***Occurred only in isolated backwaters of this pool.**

Aquatic Vegetation Richness (all years) for SAV, RFL, and EMERG; and Top Ten SAV Species per LTRM Study Reach (2010) (for Pool 26, 2004, last year of sampling)

SAV Submersed Aquatic Vegetation
RFL Rooted Floating Leaf (aquatic vegetation**)**
EMERG Emergent (aquatic vegetation)

	SAV	RFL	EMERG	Top Ten Species (relative frequency)	
Pool 4	21	3	24	Canadian waterweed (18.9) coontail (17.9) leafy / small pondweed (12.2) water stargrass (10.2) curly pondweed (7.6)	sago pondweed (7.5) flatstem pondweed (6.6) wildcelery (5.2) Eurasian watermilfoil (4.6) nodding waternymph (3.5)
Pool 8	17	3	22	Canadian waterweed (20.2) coontail (19.5) water stargrass (13.0) leafy/small pondweed (11.8) wildcelery (10.2)	Eurasian watermilfoil (6.4) flatstem pondweed (5.7) curly pondweed (5.1) sago pondweed (1.7) nodding waternymph (1.6)
Pool 13	16	2	20	coontail (22.1) Canadian waterweed (18.8) wildcelery (12.0) leafy/small pondweed (9.7) Eurasian watermilfoil (8.1)	water stargrass (6.8) sago pondweed (6.1) southern waternymph (4.5) longleaf pondweed (4.3) curly pondweed (4.1)
Pool 26	8	3	90	coontail (100)	

MACROINVERTEBRATES:

(Data for P8 and P13 from 2000-2004, P4 and P26 from 1999-2004 excluding 2003, and OR from 1995-2000 excluding 1997. P4 impounded area is Lake Pepin, a tributary delta lake.)

Mayflies, 5-year mean, # / square meter

	MCB	SC	BWC	IMP
Pool 4	0.80	41.1	68.6	139
Pool 8	40.4	106	68.8	173
Pool 13	75.2	80.0	120	175
Pool 26	25.0	16.2	9.2	36.4
Open River	8.8	12.4	n/a	n/a

Fingernail clams, 5-year mean, # / square meter

	MCB	SC	BWC	IMP
Pool 4	1.6	11.2	33.8	133
Pool 8	36.2	203	91.4	522
Pool 13	123	60.8	129	467
Pool 26	0.2	1.0	8.0	15.8
Open River	0	0	n/a	n/a

Midges, 5-year mean, # / square meter

	MCB	SC	BWC	IMP
Pool 4	39.4	47.4	80	114
Pool 8	15.8	44.6	86.4	36
Pool 13	1.6	8.4	666	47.6
Pool 26	12.2	17.4	153	207
Open River	6.4	37.6	n/a	n/a

Zebra mussels, 5-year mean, # / square meter

	MCB	SC	BWC	IMP
Pool 4	97.6	7.8	12.2	76.8
Pool 8	52.6	344	5.6	560
Pool 13	160	118	54.2	895
Pool 26	36.2	4.8	0	2.6
Open River	43.2	4.2	n/a	n/a