Upper Mississippi River Restoration Program

Science in Support of Restoration and Management
FY19 SOW

Enhancing Restoration and Advancing Knowledge of the Upper Mississippi River

Addressing the FY2015–2025 UMRR Strategic Plan

Developing and Applying Indicators of Ecosystem Resilience to the UMRS (FY19-FY21)

Ecological resilience can be defined as the ability of an ecosystem to absorb disturbance and still maintain its fundamental ecological processes, relationships, and structure. The concept of ecological resilience is based on the understanding that most ecosystems can exist in multiple alternative states rather than exhibiting a single equilibrium state to which it is always capable of returning. For example, shallow lakes have been shown to exist in either a clear-water heavily vegetated condition, or a turbid condition with little or no vegetation. The magnitude of disturbance (e.g., change in nutrients or turbidity) a lake in either state could sustain and remain in that state is the ecological resilience of that system.

To support the U.S. Army Corps of Engineers Upper Mississippi River Restoration (UMRR) Program's vision for a "healthier and more resilient ecosystem that sustains the river's multiple uses," the UMRR partnership is currently undertaking an ecological resilience assessment. Broadly, the purpose of the assessment is to gain a deeper understanding of ecosystem dynamics to inform the planning and design of restoration projects. More specifically, the resilience assessment provides insight into how resilience is created, maintained, or broken down within a system and how restoration projects and management actions might influence those processes. In assessing the resilience of the Upper Mississippi River System (UMRS), we have adapted the Resilience, Adaptation and Transformation Assessment Framework, which includes three major elements: 1) a system description, 2) assessment of resilience, and 3) adaptive governance and management. A resilience working group, made up of individuals across the UMRR partner agencies, provides guidance and feedback on the direction and specifics of the assessment.

The goal of the UMRS system description was to simplify a complex system to identify the fundamental characteristics of the system. In doing so, we reviewed the relevant historical context that has shaped the current state of the UMRS, recognized valued uses of and services provided by the UMRS, and identified key ecological resources that are needed to support those valued uses and services. Further, we identified the major controlling variables that are known to influence key ecological resources. Because the resilience assessment is intended to inform restoration decisions and a system description is considered the foundation for a resilience assessment, we engaged UMRR partner agencies throughout the development process, thereby gaining broad acceptance of the completed system description. The system description has been published in a peer-reviewed journal (Bouska et al. 2018).

In the second element of the assessment, assessing the resilience of the system, there are two complementary assessments that occur. The evaluation of general resilience focuses on understanding properties of a system that support its ability to cope with anticipated as well as unforeseen disturbances and changes. More specifically, three properties have been recognized to support the coping capacity of ecosystems to disturbances: 1) diversity and redundancy, 2) connectivity, and 3) slow variables and feedbacks. We applied these principles of general resilience to our understanding of how the UMRS functions (derived from the UMRS system description), to develop broad-scale indicators of general resilience. These indicators provide information about the general adaptive capacity of the river at a floodplain reach scale from which restoration actions can be identified that, in theory, would bolster resilience to future disturbances. Many of these indicators have been integrated into the Indicators of Ecosystem Structure and Function (De Jager et al. *In Press*) that was used to develop the Habitat Needs Assessment II (McCain et al. *In Press*) to support the inclusion of resilience in restoration planning. Further a manuscript has been written and submitted to a peer-reviewed journal.

The second evaluation of the assessing the system element focuses on specified resilience in the context of alternative regimes. A draft manuscript describing plausible alternative regimes is currently underway with accompanying state-and-transition models that characterize biological conditions of the regimes, drivers of transitions, and feedback mechanisms that act to stabilize regimes. The state-and-transition models will be used to identify information gaps that will be compiled into a research framework. Evaluation of trends in driving variable provides information on the range of conditions the system has experienced over monitored time periods and the direction the system is moving and could be incorporated into the third status and trends of the UMRS. The specified resilience assessment will summarize our current state of understanding of the resilience of key ecological resources to changes in controlling variables and develop a framework for evaluating management-relevant relationships for potential thresholds of concern. Given the numerous major resources and controlling variables identified in the system description conceptual models, we plan to identify and evaluate relationships with greatest priority (and data) and focus on one analysis to complete during FY19.

To manage for resilience in a restoration program, an understanding of the effects of various restoration actions on the resilience of the ecosystem is needed. We will build on the existing conceptual models to explore how different types of HREPs likely influence controlling variables or general resilience indicators. This information could substantially inform the selection, design and evaluation of restoration projects within each floodplain reach to affect the coping capacity of the system in the face of future disturbances.

OBJECTIVES (*Note: Objective4 (bold text below) will be the emphasis during FY2019*)

This project will be the primary responsibility of a post-doctoral scientist collaborating with scientists at the U.S. Geological Survey, Upper Midwest Environmental Sciences Center (UMESC) and scientists and managers throughout the UMRR partnership. The objectives are:

1) Establish a resilience working group to capitalize on the diversity of expertise and perspectives that comprise the UMRR partnership. This working group will be substantially involved in the formulation and conduct of this project. *Completed in FY15*.
2) Develop a clear conceptual understanding and definition of ecological resilience as applied to the UMRS.
    a) Small working group will develop a draft ("strawman") conceptual model of ecological resilience in the UMRS.
    b) Convene workshop to discuss and refine this model. Participants will be determined by resilience working group.
    c) Small working group will refine conceptual model based on input from workshop

    Working Draft Conceptual models of UMRS in support of the resilience assessment were completed in FY16. Given the iterative nature of a resilience assessment. These models will continue to be refined throughout the project
3) Use principles of general resilience to guide:
    a) Development of indices of general resilience for the UMRS using data from the UMRR-LTRM.
    b) Description of the current general resilience of multiple reaches of the UMRS.

    Indicators of general resilience were developed in FY17 and was submitted for peer-review publication in FY18.

4) Use the conceptual model to guide:
    a) Development of state and transition models that detail the drivers and responses of potential alternative regimes

b) **Identification of knowledge gaps in our understanding of alternative regimes**
c) Evaluation of the factors contributing to the resilience of the UMRS
   i) Where the UMRS is in a desirable state, what contributes to the resilience of that state and what management actions might maintain or increase that resilience?
   ii) Where the UMRS is in a less desirable state (e.g., lack of vegetation in the lower impounded reach), what contributes to the resilience of that state and how might management actions overcome that resilience?

Conceptualizing alternative regimes using state and transition models to identify research needs related to specified resilience began in FY18 and is ongoing.

WORKPLAN AND DELIVERABLES

In FY19, the next phase of the project will finalize state and transition models that will be used to guide analyses that use UMRR LTRM data to quantify select relationships from the state and transition models and explore the implications for the resilience of the UMRS. Following that, we will begin to examine theoretical and empirical descriptions of the effects management actions have on the resilience of the UMRS.

Results of these efforts will be communicated to the partnership via a seminar or workshop and presentations at various UMRS meetings. We will communicate results to a national and international audience via presentations at scientific conferences and in peer-reviewed publications.

Products and Milestones

Tracking number	Products	Staff	Milestones
2019R1	Updates provided at quarterly UMRR CC meeting and A team meeting	Bouska, Houser	Various
2019R2	Submit research framework for specified resilience to the Resilience Working Group	Bouska, Houser	30 March 2019
2019R3	Submit alternative regimes manuscript for peer-review publication	Bouska	30 March 2019
2019R4	Submit draft manuscript of specified resilience analysis to RWG	Bouska	30 September 2019
Intended for Distribution			
Manuscript: Bouska, K. L., J. Houser, N De Jager, M. Van Appledorn, and J. Rogala. In review. Applying principles of general resilience to large river ecosystems: case study from the Upper Mississippi and Illinois River. Ecological Indicators.			

Modelling and mapping current and projected future habitats of the Upper Mississippi River System (HNA-II; FY17-FY18)

UMRR's Habitat Needs Assessment-II Indicators of Ecosystem Structure and Function for the Upper Mississippi River System Report consists of a series of maps, models, and quantitative measures that provide a system-wide assessment of the hydrogeomorphic and ecological condition of the UMRS. In FY2017, UMESC conducted work related to mapping and modelling aquatic and floodplain habitats (see FY2017 SOW for milestones) as well as developing a draft document summarizing the methods, analyses, and data produced in support of HNA-II (not in FY2017 SOW). In 2018, UMESC completed all work related to data development for HNA-II (see 2017AH9, FH5, GEO1). In addition, a complete draft was developed which includes written summaries of the methods and results of modelling efforts related to aquatic habitats (2017AH8), floodplain habitats (2017FH4), sedimentation (2017FAH3), and forest succession (2017FFH3).

The companion document, Habitat Need Assessment II: Linking Science to Management Perspectives, integrates the quantitative data from the Indicators Report with qualitative assessments that reflected the diverse management philosophies and resources of concern of UMRS stakeholders and management agencies to assess how the structure and function of the UMRS compares to conditions desired by the UMRR partnership. An assessment of current conditions using both quantitative data analysis and qualitative management perspectives was performed at two spatial scales (i.e., navigation pool and clusters of navigation pools that shared similar ecological attributes). In addition, a paired-comparison survey of management agencies was conducted to identify the most important indicators to target with desired future restoration actions.

Products and Milestones

Tracking number	Products	Staff	Milestones
2019HNA1	Final Indicators report (USGS Open File Report)	De Jager, Rogala, Bouska, Houser, Van Appledorn, Rohweder, Fox, Ruhser, Jankowski	December 30, 2018
2019HNA2	Final HNA-II Linking Science to Management Perspectives	McCain, Schmuecker, De Jager	December 30, 2018

Assessing recent rates of sedimentation in the backwaters of Pools 4, 8, and 13 to support river restoration and the Habitat Needs Assessment-II (FY17-18)

In a previous LTRM study between 1997 and 2001, annual bed elevations were measured along a set of backwater transects in Pools 4, 8 and 13 of the Upper Impounded Reach of the UMRS (Rogala et al. 2003). These survey data provided basic information on rates of backwater sedimentation across a gradient of depth and among backwaters that varied in their hydraulic connectivity with channels.

This study will use the same sampling design and survey methodology used in the 1997-2002 study (Rogala et al. 2003).

Conditions were again not suitable for surveys in Pool 13 in the winter of 2017/2018. We will attempt the surveys again in 2018/2019. If surveys cannot be completed in 2018/2019, the completion report will only include analysis of data from Pools 4 and 8.

Products and Milestones

Tracking number	Products	Staff	Milestones
2019ST1	Reestablishment of horizontal and vertical temporary benchmarks, and a data base for horizontal and vertical benchmarks (Continuation of 2017ST1)	Rogala, Moore, Kalas, Bierman	30 March 2019
2019ST2	Open-water nearshore surveys completed and a database (Continuation of 2017ST2)	Rogala, Moore, Kalas, Bierman	31 December 2018
2019ST3	Over-ice surveys completed and a database (Continuation of 2017ST3)	Rogala, Moore, Kalas, Bierman	30 March 2019
2019ST4	Data analysis and completion report on sedimentation rates along transects (Continuation of 2017ST4)	Rogala, Moore, Kalas, Bierman	30 September 2019

Literature Cited:

Rogala, J. T., P. J. Boma, and B. R. Gray. 2003. Rates and patterns of net sedimentation in backwaters of Pools 4, 8, and 13 of the Upper Mississippi River. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. An LTRMP Web-based report available online at:
http://www.umesc.usgs.gov/data_library/sedimentation/documents/rates_patterns/rates_patterns.pdf

Landscape Pattern Research and Application

The goal of landscape pattern research on the Upper Mississippi River System is to develop concepts, maps and indicators that provide both regional-level decision makers and local-level resource managers with information needed to effectively manage the UMRS.

As described in the UMRR Landscape Pattern Research Framework (De Jager 2011), landscape pattern research on the UMRS focuses on linking decisions made at regional scales with restoration actions carried out at local scales. While regional program managers and decision makers are concerned with improving the overall ecological condition of the entire UMRS, local resource managers work to address site specific habitat and resource limitations. Landscape ecology, which focuses on the linkages between patterns visible at broad scales and ecological patterns and processes that occur at local scales, can help to integrate these two scale-dependent management activities. (Strategic Plan Outcome 2, Output 2.2, Outcome 4)

Objectives

1) To develop broad-scale indicators of habitat amount, connectivity and diversity for the purposes of a) identifying areas for ecosystem restoration across the entire system and b) to track status and trends in habitat area, diversity and connectivity.

2) To connect broad-scale landscape pattern indicators with local-scale ecological patterns and processes critical to restoration project development.

Product Descriptions

2018L1: Draft Manuscript: In support of HNA-II, we have developed a spatially explicit model of forest succession that links a newly developed flood inundation model with a model of plant establishment and growth. The methods for this work will be summarize in HNA-II. However, additional scenarios, model validation, sensitivity analyses, and discussion will be provided in this separate document.

Products and Milestones

Tracking number	Products	Staff	Milestones
On-Going			
2016L3	Draft Manuscript: Review of Landscape Ecology on the UMR	De Jager	30 September 2019
Intended for distribution			
Manuscript: De Jager. Modelling Forest succession in the UMRS. (in review)			

Reference

De Jager, N.D. 2011. Scientific Framework for Landscape Pattern Research on the Upper Mississippi and Illinois River Floodplains. Available online: http://www.umesc.usgs.gov/ltrmp/ateam/landscape_patterns_research_framework_final_june2011.pdf

Eco-hydrologic Research

Flooding is believed to be a key driver of form and function of the Upper Mississippi River System (UMRS). Understanding the role of inundation in driving dynamics in both aquatic and terrestrial ecosystems is essential for improving the health and resilience of the UMRS through informed management practices. Only recently, however, have inundation dynamics been characterized and mapped systematically in ecologically meaningful ways. The characterizations of flooding, together with existing geospatial datasets of physical and ecological attributes developed through the UMRRP, offer abundant new opportunities to understand biophysical relationships in the UMRS, especially regarding the role of inundation in shaping forest patterns (composition, structure) and processes (dispersal, regeneration, succession) across multiple spatial and temporal scales.

The goal of this research is to leverage the inundation model along with other existing UMRRP datasets to learn about patterns of floodplain-river connectivity throughout the UMRS, to understand how these patterns may influence ecosystem dynamics, and to contribute to the improved health and resilience of the UMRS by developing concepts, maps, and models relevant to management activities.

Specific Activities for FY2018:

Component 1 – UMRS inundation model completion and support: LTRM will maintain some level of expertise to provide basic model archiving and assistance using the UMRS inundation model. In FY2018, we will:

> 1a. Facilitate the inundation modelling framework's long-term curation by creating an accessible platform for its distribution
> 1b. Continue evaluations of model outputs using empirical data
> 1c. Provide technical assistance on the proper use of model outputs
> 1d. Assist partner agencies on the development of additional uses for the model in HREP project planning

Component 2 – Model application to understand eco-hydrologic patterns and processes: It is a goal of the UMRS management community to restore and sustainably manage floodplain forests to serve as a vital resource for future generations. Ongoing forest management is informed by inventory and monitoring programs that summarize current species distributions and forest conditions. Data from the programs also have the potential to provide novel insights into how and at what spatial and temporal scales forest structure and composition are influenced by environmental conditions (e.g., flooding dynamics, soils, climate), land use history, biotic factors (e.g., dispersal, competition), and their interactions. Research is needed to gain an integrative understanding of how abiotic and biotic factors structure UMRS floodplain forests and to identify environmental conditions suitable for supporting healthy, resilient forests. This research will:

> 2a. Integrate flood inundation model outputs with vegetation data to better understand how multiple aspects of flood regime shape vegetation communities and their dynamics
> 2b. Identify opportunities to apply a better understanding of flood-vegetation interactions at the HREP scale
> 2c. Examine inundation model outputs for spatial and temporal trends in different aspects of flooding regimes that may have impacts on important biophysical patterns and processes

Products and Milestones

Tracking number	Products	Staff	Milestones
2019EH01	Draft manuscript reviewing mapping inundation approaches	Van Appledorn, De Jager,	30 September 2019
2019EH02	Sensitivity analysis of UMRS inundation regimes	Van Appledorn	30 September 2019
2019EH03	Development of UMRS inundation model query tool	Van Appledorn, Fox, Rohweder, De Jager	30 September 2019

On-Going
Manuscript: Van Appledorn, M., De Jager, N.R., Johnson, K. Considerations for improving floodplain research and management by integrating inundation modeling, ecosystem studies, and ecosystem services (2016L5)

Intended for Distribution
Van Appledorn, Molly; DeJager, Nathan R.; Rohweder, Jason. Modeling and mapping inundation regimes for ecological and management applications: a case study of the Upper Mississippi River floodplain, USA (In review)
Van Appledorn, Molly. Data release: UMRS Floodplain Inundation Attribute Raster https://www.sciencebase.gov/catalog/item/5b2a51b9e4b059207627d168
DeJager, Nathan R.;Van Appledorn, Molly;Fox, Timothy J.;Rohweder, Jason;Guyon, Lyle J.;Meier, Andrew R.;Cosgriff, Robert J.;Vandermyde, and Benjamin J. Spatially explicit modeling of floodplain forest succession: A case study in the Upper Mississippi River floodplain, USA (In review)

Aquatic Vegetation, Fisheries, and Water Quality Research

New Projects

2019D12: Expanding the international engagement and recognition of UMRR LTRM (replacing 2014P1)

UMRR has ongoing interests in collaborating and sharing knowledge with other large river monitoring and restoration programs globally. The program has had significant interaction with other large river monitoring and research groups over the years (e.g., Yangtze River in China; Parana-Paraguay and Xingu Rivers in Brazil; USACE 2010) and the 2015-2025 Strategic plan identifies international collaboration as a specific objective for the program.

> "Objective 3.3: Exchange knowledge with other organizations and individuals nationally and internationally" -
> Strategy 1 – Serve as a resource for similar programs nationally and internationally,
> Strategy 2 – Seek knowledge from other organizations and individuals nationally and internationally to enhances UMRR's efforts in advancing its vision

This plan identifies the need to "Focus and enhance knowledge exchange with other organizations and individuals nationally and internationally in a communications plan and implementation framework". Actions identified that are relevant to this effort include: 1) Collaborate with other related large aquatic ecosystem/water resources efforts in the nation and the world, 2) Incorporate insights gained from other national and international programs/efforts as applicable to enhance program implementation, increase knowledge, and create cost-efficiencies, and 3) Promote the program's national and international significance.

The summary paper aims to establish a plan to address these needs. First, it will summarize the scope and status of LTRM's work to date to assist the development of other large river monitoring and restoration efforts. For example, this work has included work in the Amazon and Parana-Paraguay River Basins in Brazil and the Yangtze River in China; and large rivers in PA. Second, it will identify key large river programs globally that collect water quality data and/or do large scale restoration work. We will focus on the following questions:

1. Where do monitoring/restoration programs exist on the world's large rivers? (e.g., Global Rivers Observatory (www.globalrivers.org), UN GEMS/Water Programme Global Water Quality Database (gemstat.org), USGS, National Water Agency of Brazil (ANA), etc)
2. What do they measure? Who does it? Where does the data go? How long have they been in operating? Why were they initiated? Who uses the data? What type of quality control is in place?
3. Does the monitoring program work to inform restoration activities?
4. What type of emerging techniques or technologies exist for monitoring water quality in large rivers?

5. Are there interesting opportunities for cross-system syntheses, learning, knowledge sharing with these programs?

Obtaining this information will assist in developing collaborations between UMRR LTRM and other large river monitoring programs, managers, and researchers that could lead to more data syntheses across river systems, better understanding of how to conceptualize the structure and function of large rivers, and improved predictions of responses to management actions on the UMRS and other large rivers.

USACE 2010. 2010 Report to Congress Upper Mississippi River Restoration Environmental Management Program. U.S. Army Corps of Engineers Rock Island District. 96pp.

2019D13: Ice and snow cover affect winter limnological conditions differently across a connectivity gradient in a large floodplain river (replacing 2018D13)

Much of the Upper Mississippi River (UMR) lies under ice and snow during winter, but we understand little about winter dynamics in this or other large floodplain rivers. In addition, as the climate warms, changes to winter conditions such as warmer water temperatures and altered ice and snow cover could alter the productivity and availability of winter habitat. We will use a 25-year time series of winter data collected from aquatic areas across a lentic-lotic gradient in three navigation pools of the UMR to address these uncertainties and ask the following questions: 1) Have ice and snow cover changed since over time in the UMR? 2) What are the effects of ice and snow cover on limnological conditions in habitats across a lentic-lotic gradient?, and 3) What is the relative importance of snow and ice cover, hydraulic connectivity and other hydrogeomorphic features in affecting conditions in off-channel areas during winter?

Products and Milestones

Tracking number	Products	Staff	Milestones
	On-Going		
Aquatic Vegetation			
2015A7	Data compilation and analysis: Aquatic macrophyte communities and their potential lag time in response to changes in physical and chemical variables	Lund	30 December 2018
2015A8	Draft completion report or manuscript: Aquatic macrophyte communities and their potential lag time response to changes in physical and chemical variables in the LTRM vegetation pools	Lund	30 December 2018
2016A7	Draft completion report: How many years did the effects of the 2001-2002 Pool 8 drawdown on arrowheads (*Sagittaria latifolia* and *S. rigida*) last?	Sauer (Yin)	30 September 2019
Fisheries			
2019B11	Technical support for USACE Fish Community Model	Ickes	30 September 2019
2019B12	Developing a biochronology of smallmouth buffalo growth for the Upper Mississippi and Illinois Rivers (tied to 2018SMBF4)	Ickes with Solomon	30 July 2019
2019B13	Draft Manuscript: Evidence of functionally defined non-random fish community responses over 25 years in a large river system (replacing 2015B17 and 2016B17)	Ickes	30 September 2019

2016B14	Draft completion report: Exploring Years with Low Total Catch of Fishes in Pool 26		Gittinger, Ratcliff, Lubinski, Chick		30 January 2019
Water Quality					
2019D12	Draft Summary Paper: Expanding the international engagement and recognition of UMRR LTRM (replacing 2014P1)		Jankowski		30 September 2019
2019D13	Draft manuscript: Ice and snow cover affect winter limnological conditions differently across a connectivity gradient in a large floodplain river (replacing 2018D13)		Jankowski, Rogala, Houser		30 September 2019
Intended for Distribution					
Burdis, Rob. Manuscript: Trends in water quality and biota in segments of Pool 4, above and below Lake Pepin (2015D16; in review)					

Statistical Evaluation

Statistical support for the UMRR LTRM provides guidance for statistical analyses conducted within and among components, for contributions to management decisions, for identifying analyses needed by the Program, for developing Program-wide statistical projects, and for reviewing LTRM documents that contain statistical content. The statistician is also responsible for ensuring that newly developed statistical methods are evaluated for use by LTRM. Guidance for management includes assistance with modifications to program design and with standardizing general operating procedures.

The statistical component will help identify useful analyses of data within and across components, ensure analytical methods are appropriate and consistent, and, when possible, coordinate multiple analyses to achieve larger program objectives regardless of which group (UMESC, field stations, USACE, etc.) conducts analyses. The statistician is also responsible for reviewing LTRM documents that contain substantial statistical components for accuracy, and for ensuring that quality of analyses is consistent among products. A primary goal of statistical analyses is to draw appropriate conclusions to inform effective management actions. Appropriate statistical analysis and interpretation is critical to making proper inferences from LTRM data. This, in turn, is critical for distinguishing between natural variation and human effects and in evaluating the long-term effects of management actions, such as HREPs, water level manipulations, or increases in navigation.

Products and Milestones

Tracking number	Products	Staff	Milestones
	On-Going		
2016E2	Draft manuscript: How well do trends in LTRM percent frequency of occurrence SAV statistics track trends in true occurrence?	Gray	30 September 2019
	Intended for distribution		
Draft manuscript: Inferring decreases in among- backwater heterogeneity in large rivers using among-backwater variation in limnological variables (2010E1) withdrew the paper from the journal after it had been with the journal for six months, will be re-evaluated in FY19 by BGray			

Advancing our understanding of habitat requirements of fish assemblages using multi-species models

The identification and selection of habitat restoration projects within the UMRR are meant to address ecological needs representing a diversity of native species. The partnership has thus far advanced our understanding of the ecological needs for groups of species such as diving ducks, dabbling ducks, and Centrarchids. This understanding of habitat requirements for particular life history activities (i.e., migratory foraging habitat, overwintering habitat) is critical to maintain sufficient ecological conditions that, if limiting, may negatively influence populations. From a fish assemblage perspective, our understanding of habitat requirements for specific life-history activities is limited, though our understanding of life history guilds allows us to infer broad habitat needs. Yet, specific criteria are required to design rehabilitation projects for the objectives of habitat provision. The issue at hand is then how to identify habitat criteria to develop habitat restoration projects that benefit the broader fish community without undergoing species-specific analyses of all 140+ species?

Species archetype models cluster species based on their response to environmental gradients (Dunstan et al. 2011). We propose the use of archetype models with existing LTRM fisheries data to gain insight into habitat requirements across the fish community, with emphasis on environmental covariates that are commonly manipulated through Habitat Rehabilitation and Enhancement Projects (e.g., depth, velocity, temperature).

Products and Milestones

Tracking number	Products	Staff	Milestones
2019FA1	Draft Manuscript on period-specific inferences on environmental gradients and species-environment associations by period (Expands on 2017FA1-FA2)	Bouska, Gray	1 May 2019

Mapping the thermal landscape of the Upper Mississippi River: A Pilot Study

Temperature is a master variable that controls physical, chemical and biological processes in aquatic ecosystems. For instance, temperature influences fundamental physical characteristics of water such as its density and movement; controls the rates of biogeochemical processes important to river functioning such as nitrogen and carbon cycling (Allen et al. 2005, Yvon-Durocher et al. 2012, Jankowski et al. 2014); and affects all aspects of organism physiology including growth, feeding, and reproduction (Arrhenius 1889, Brown et al. 2004). Thus, shifts in the thermal environment can have effects across all scales of ecological organization.

Understanding the both the natural and anthropogenic drivers of thermal patterns in rivers is fundamentally important to understanding how they will respond to future changes in land use and climate.

Milestones and products:

Tracking number	Products	Staff	Milestones
2017TL2	Final report and data distribution	Jankowski, Robinson, Ruhser	30 March 2019

References:

Allen, A.P., J.F. Gilooly, and J.H. Brown. 2005. Linking the global carbon cycle to individual metabolism. Functional Ecology 19:202-213.

Arrhenius, S. 1889. Uber die Reaktionsgeschwindigkeit bei der Inversion von Rohrzucker durej Sauren. Zeitschrift fur Physik Chemique 4: 226-248.

Brown, J.H., J.F. Gilooly, A.P. Allen, V.M. Savage, and G.B. West. 2004. Toward a metabolic theory of ecology. Ecology 85: 1771-1789.

Caissie, D. 2006. The thermal regime of rivers: a review. Freshwater Biology 51: 1389-1406.

Jankowski, K.J., D.E. Schindler and P.J. Lisi. 2014. Temperature sensitivity of community respiration rates in streams is associated with watershed geomorphic features. Ecology 95: 2707-2714.

Yvon-Durocher, G., J.I. Jones, M. Trimmer, G. Woodward and J.M. Montoya. 2010. Warming alters the metabolic balance of ecosystems. Philosophical Transactions of the Royal Society B-Biological Sciences 365: 2117-2126.

Pool 12 Overwintering HREP Adaptive Management Fisheries Response Monitoring

2019P13: Fisheries Population Monitoring (FY2006-Present)
This is a continuous project that builds on several years of pre-project fisheries monitoring for the Pool 12 Overwintering HREP. We have been performing pool-wide electrofishing in Pool 12 since 2006. We have also been performing fyke netting in backwater lakes that will be rehabilitated, as well as other backwaters in Pool 12 that will not be rehabilitated (as a control). We also perform otolith extraction from bluegills from the lakes we net in to obtain aging, sexing, and mortality information.

Questions still exist as to the most effective longitudinal spacing of fisheries overwintering HREP projects. The Pool 12 Overwintering HREP is unique because four backwater lakes (Sunfish, Stone, Tippy, and Kehough - in order of construction) are being rehabilitated in the same navigation pool (all within roughly eight river miles of each other), in the same window of time, and as part of the same HREP.

Products and Milestones

Tracking number	Products	Staff	Milestones
2019P13a	Collect annual increment of pool-wide electrofishing data	Bierman and Bowler	1 November 2018
2019P13b	Collect annual increment of fyke netting data from backwater lakes	Bierman and Bowler	15 November 2018
2019P13c	Perform otolith extraction from bluegills for aging	Bierman and Bowler	1 December 2018
2019P13d	Age determination of bluegills collected in Fall 2018	Bierman and Bowler	1 February 2019
2019P13e	In-house project databases updated	Bierman and Bowler	31 March 2019
2019P13f	Summary letter compiled and made available to program partners	Bierman and Bowler	30 September 2019

Pool 4 - Peterson Lake HREP Water Quality Monitoring – Pre and Post-Adaptive Management Evaluation (FY17-present)

The Peterson Lake HREP (Habitat Rehabilitation and Enhancement Project) was constructed in 1995 to maintain the lake as a productive backwater resource by reducing the loss of barrier islands to erosion and sand sedimentation in the lake (USACE 1994). One of the specific objectives of the initial project was to create a winter fish refuge in the upper portion of the lake, despite concerns of possible negative effects on summer water quality due to the reduction of flow into the area. While a small area of upper Peterson Lake does currently support a winter fish refuge the project objectives for current velocity (< 1 cm/sec) and water temperature (> 1^{o} C) were considered unsuccessful (USACE 2011). In an effort to increase the area suitable for winter fish use a proposal to shut off a major inlet into the upper lake and partial closures of two other inlets is being proposed. Pre and post water quality monitoring of upper Peterson Lake would determine if this adaptive management strategy is successful. **Based on construction work in Winter 2018.**

Products and Milestones

Tracking number	Products	Staff	Milestones
2017PL3	Collection of post-construction winter water quality data	Burdis, DeLain, Lund, Dawald	February 2019
2017PL4	Collection of post-construction summer water quality data	Burdis, DeLain, Lund, Dawald	August 2019
2017PL5	Summary letter: Tabular and graphical summary of water quality data	Burdis, Lund, Moore	December 2019

References

United States Army Corps of Engineers (USACE). 1994. Upper Mississippi River System Environmental Management Program, Definite Project Report/Environmental Assessment (SP-16), Peterson Lake (HREP). US Army Corps of Engineers, St. Paul District.

United States Army Corps of Engineers (USACE). 2011. Peterson Lake Pool 4 Mississippi River (HREP) Project Evaluation Report. Environmental Management Program for the Upper Mississippi River System. US Army Corps of Engineers, St. Paul District.

UMRR LTRM Component Meetings

To foster communication between USACE, USGS-UMESC and state field station staff, a joint meeting of all staff will be held in FY2019. The primary objectives of the meeting are to help maintain consistency in methods and procedures through time and across field stations, discuss new techniques, instruments, and any issues there may be.

This effort will require participation by all UMRR LTRM staff at USACE, USGS-UMESC, and the state field stations. The meeting location is Muscatine, IA.

Products and Milestones

Tracking number	Product	Staff	Milestone
2019N1	Component Meetings	All LTRM	March 26-27, 2019

Update UMRR LTRM Fact Sheet

To communicate with UMRR LTRM Partners and others on program accomplishments, we will develop a fact sheet highlighting information to knowledge. This will be the 3rd fact sheet in a series highlighting LTRM accomplishments. This effort addresses information relevant to Outcome 4 (Output 1.1) of the Strategic and Operational Plan.

Products and Milestones

Tracking number	Product	Staff	Milestone
2019FS1	Draft UMRR LTRM Fact Sheet	Sauer and All LTRM as needed	30 April 2019
2019FS2	Final UMRR LTRM Fact Sheet	Sauer and All LTRM as needed	30 Sept. 2019

A-Team and UMRR-CC Participation

USGS-UMESC and Field Station staff are often called upon to participate at quarterly A-Team (http://www.umesc.usgs.gov/ltrmp/ateam.html) and UMRR-CC (www.mvr.usace.army.mil/Missions/EnvironmentalProtectionandRestoration/UpperMississippiRiverRestoration/Partnership/CoordinatingCommittee.aspx) meetings. The field station team leaders, component specialists, and UMESC LTRM management staff are expected to participate in the A-Team meetings, if possible. Additional staff may participate as appropriate. Participation at UMRR CC meetings will be by request only. This participation could include sharing of scientific knowledge and/or presentations on current projects. Any participation by LTRM staff at A-Team and/or UMRR CC meetings will be listed in the quarterly activity products.

FY18 Funded Science in Support of Restoration and Management Proposals

Detailed descriptions of the following projects can be found at https://umesc.usgs.gov/ltrmp/documents/fy18Science_sow.pdf

Conceptual Model and Hierarchical Classification of Hydrogeomorphic Settings in the UMRS			
Tracking number	**Products**	**Staff**	**Milestones**
2019CM1	Workshop	Fitzpatrick, Henderson, Rogala, Erwin, Sawyer	30 November 2018
2019CM2	Summary of workshop findings and minutes; internal document	Fitzpatrick, Henderson, Rogala, Erwin, Sawyer	31 December 2018
2019CM3	Presentation to Focal Area 1 workgroup, LTRM researchers, HREP designers, and state resource agency partners	Fitzpatrick, Henderson, Rogala, Erwin, Sawyer, Stone	31 August 2019
2019CM4	GIS data base and query tool	Fitzpatrick, Henderson, Rogala, Erwin, Sawyer, Stone	31 December 2019
2019CM5	Submit draft LTRM Completion report on hydrogeomorphic conceptual model and hierarchical classification system	Fitzpatrick, Henderson, Rogala, Erwin, Sawyer, Stone	31 December 2019
2019CM6	Submit Final LTRM Completion report on hydrogeomorphic conceptual model and hierarchical classification system	Fitzpatrick, Henderson, Rogala, Erwin, Sawyer, Stone	30 June 2020

Develop a better understanding of geomorphic changes through repeated measurement of bed elevation and overlay of land cover data			
2019GC1	Begin Side Channel Surveys (Completed)	Stone, Wallace, Klingman	1 July 2018
2019GC2	Complete geodatabase of previous surveys and begin updating as needed. Begin developing and apply change detection methods.	Stone, Rogala	1 December 2018
NEW	Complete Side Channel Surveys	Stone, Wallace, Klingman	30 September 2019
2019GC3	Submit draft LTRM Completion report	Rogala, Stone	1 March 2020
2019GC4	Begin setting monuments at existing transects. Establish, survey and monument new transects as needed	Kalas, Rogala	1 October 2018

2019GC5	Establish methods. Determine database structure and begin entering data into database (including transect maps, description of monuments, etc.)	Rogala, Kalas	1 December 2018
2019GC6	Complete setting monuments and surveying remaining transects	Kalas	30 September 2020
2019GC7	Complete database for all transects.	Kalas	30 September 2020
2019GC8	Submit draft LTRM Completion Report on recent planform changes using UMRR LCU datasets	Rogala	1 July 2019
Water Exchange Rates and Change in UMRS Channels and Backwaters, 1980 to Present			
2019WE1	Data Analysis	Hendrickson	31 March 2019
2019WE2	Base Maps of Discharge Measurement Location	Le Claire	31 May 2019
2019WE3	Submit draft LTRM Completion Report	Hendrickson	30 September 2019
2019WE4	Submit Final LTRM Completion Report	Hendrickson	30 March 2019
Intrinsic and extrinsic regulation of water clarity over a 950-km longitudinal gradient of the UMRS			
2019IE1	Database complete	Carhart, Drake, others	30 April 2019
2020IE2	Draft analysis and annual progress summary	Drake, Carhart and others	31 December 2019
2020IE2	Submit Draft manuscript	Drake, Carhart and others	30 March 2020
2021IE2	Submit Final manuscript	Drake, Carhart and others	30 December 2020
Effectiveness of Long Term Resource Monitoring vegetation data to quantify waterfowl habitat quality			
2018WF1	Collect data in Pools 4, 8, 13 using LTRM rake and biomass methodology (Completed)	Winter, Lund, Drake, Bales	30 August 2018
2019WF2	Collect data in Pools 4, 8, 13 using benthic core sampling (Completed)	Winter	30 October 2018
2019WF3	Collect data in Pool 8 using benthic core sampling	Winter	30 April 2019
2019WF4	Submit preliminary report with results from data collected in the summer and fall of 2018, and data collected in the spring of 2019	Schmidt, Straub, Schultz	30 July 2019
2019WF5	Collect data in Pools 4, 8, 13 using LTRM methodology	Winter, Lund, Drake, Bales	30 August 2019
2020WF6	Collect data in Pools 4, 8, 13 using benthic core sampling	Winter	30 October 2019
2020WF7	Conduct final analyses, submit draft LTRM Completion report	Schmidt, Straub, Schultz	30 May 2020
2020WF8	Submit Final LTRM Completion Report	Schmidt, Straub, Schultz	30 September 2020

Understanding constraints on submersed vegetation distribution in the UMRS: the role of water level fluctuations and clarity			
2019SVD1	Retrieve existing systemic datasets for elevation gages, topobathy and water clarity.	Kalas, Carhart, Rogala,	30 December 2018
2019SVD2	Estimate/interpolate photic zone and generate predicted SAV bands systemically.	Kalas, Carhart, Rogala,	30 June 2019
2019SVD3	Submit annual progress summary	Kalas, Carhart,	30 September 2019
2019SVD4	Spatial coverages and databases complete, begin draft report.	Kalas, Carhart, Rohweder	30 October 2019
2019SVD5	Submit draft manuscript	Kalas, Carhart, Drake, Rogala, Rohweder	30 September 2020
2019SVD6	Webpage to house database information	Kalas, Carhart, Rogala, Rohweder	30 September 2020

Systemic analysis of hydrogeomorphic influences on native freshwater mussels			
2019FM1	Design pool-wide surveys in Pools 8 and 13, begin assessing patterns in mussel assemblages across a gradient of geomorphic conditions in existing data (Pools 3, 5, 6, and 18), conduct pool-wide surveys for mussels in Pools 8 and 13	Mike Davis, Teresa Newton, Jim Rogala, Jason Rohweder	30 September 2019
2019FM2	Annual progress summary	Teresa Newton	31 December 2019
2019FM3	Calculate pool-wide population estimates of native mussels in Pools 8 and 13, finish assessing patterns in mussel assemblages across a gradient of geomorphic indices (all pools), begin conducting statistical analyses	Catherine Murphy, Teresa Newton, Jim Rogala, Jason Rohweder	30 September 2020
2019FM4	Annual progress summary	Teresa Newton	31 December 2020
2019FM5	Complete statistical analyses, prepare geospatial maps, Submit draft LTRM completion report	Teresa Newton	30 September 2021
2019FM6	Submit Final LTRM completion report	Teresa Newton	30 March 2020

Using dendrochronology to understand historical forest growth, stand development, and gap dynamics			
2019DD1	Annual progress summary	Dr. Harley, Dr. Maxwell, MS students, Ben Vandermyde	31 December 2018
2019DD2	Data collection	Dr. Harley, Dr. Maxwell, MS students, Ben Vandermyde, Robert Cosgriff	31 November 2018
2019DD3	Growth-ring chronologies and forest vegetation demographic and biophysical data	Dr. Harley, MS students	31 July 2019
2019DD4	Plot-level 3-dimensional subsurface floodplain sedimentation maps for each study site	Dr. Maxwell, MS students	31 July 2019

2020DD5	Annual progress summary	Dr. Harley, Dr. Maxwell, MS students, Ben Vandermyde	31 December 2019
2020DD6	Baseline dataset for promoting resilience of hard mast forest communities along the UMRS	Dr. Harley, Dr. Maxwell, MS students	30 June 2020
2020D8	Submit draft manuscript	Dr. Harley, Dr. Maxwell, MS students	30 September 2020
Forest canopy gap dynamics: quantifying forest gaps and understanding gap – level forest regeneration			
2019FG1	Completion of polygon layer of canopy gaps for Study Area with associated tabular and FGDC-compliant metadata	Strassman, Sattler, Hoy	30 April 2019
2020FG2	Annual progress summary	Meier, Strassman	31 December 2018
2020FG3	Data collection	Thomsen, Vandermyde, Guyon	31 October 2019
2020FG4	Annual progress summary	Meier, Strassman	31 December 2019
2020FG5	Submit draft LTRM Completion Report	Guyon, Thomsen, Meier, Strassman	30 September 2020
2020FG6	Baseline dataset complete	Guyon, Thomsen, Meier, Strassman, DeJager	30 September 2020
2020FG7	Submit draft manuscript	Guyon, Thomsen, Meier, Strassman, DeJager	30 September 2021
Investigating vital rate drivers of UMRS fishes to support management and restoration			
2019VR1	Data collection will occur during regular LTRM fish field sampling (Completed)	LTRM Fish Component Leads	15 October 2018
2019VR2	Processing of samples	Quinton Phelps. Greg Whitledge	2018 through 2021
2019VR3	Annual progress summary	Andy Bartels, Kristen Bouska, Quinton Phelps	31 December 2018
2019VR4	Data collection will occur during regular LTRM fish field sampling	LTRM Fish Component Leads	15 October 2019
2019VR5	Annual progress summary	Andy Bartels, Kristen Bouska, Quinton Phelps, Greg Whitledge	31 December 2019
2019VR6	Data collection will occur during regular LTRM fish field sampling	LTRM Fish Component Leads	15 October 2020
2019VR7	Annual progress summary	Andy Bartels, Kristen Bouska, Quinton	31 December 2020

			Phelps, Greg Whitledge		
2019VR8	Data set complete (data delivered to Ben Schlifer, physical structures delivered to BRWFS)		Quinton Phelps		30 September 2021
2019VR9	Submit draft manuscript (Vital rates)		Quinton Phelps, Kristen Bouska		31 December 2021
2019VR10	Submit draft manuscript (Drivers of vital rates)		Quinton Phelps, Kristen Bouska		31 December 2021
2019VR11	Submit draft manuscript (Microchemistry)		Greg Whitledge		31 December 2021

Development of a standardized monitoring program for vegetation and fish response to Environmental Pool Management practices in the Upper Mississippi River System (2019-2020)

Overall project lead investigator. *Provide guidance for overall project and fish component of this project. Provide assistance with data collection, analysis and report writing*
Ben Lubinski, Aquatic Ecologist; Great Rivers Field Station, Illinois Natural History Survey, 918 Union Street, Alton, IL 62002; 217-300-3955; blubinsk@illinois.edu

USACE project lead investigator. *Provide guidance for vegetation component of this project. Provide assistance with data collection, analysis and report writing*
Ben McGuire, Wildlife Biologist; U.S. Army Corps of Engineers, Regional Planning and Environment Division-North, 1222 Spruce Street, St. Louis, MO 63103; 314-331-8478; Benjamin.m.mcguire@usace.army.mil

Collaborators:
Providing field sampling assistance, guidance and training for field work, and overall project review
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Providing support, guidance, and overall review
Shane Simmons, Fisheries Biologist; U.S. Army Corps of Engineers, Regional Planning and Environment Division-North, 1222 Spruce Street, St. Louis, MO 63103; 314-331-8496; Shane.m.simmons@usace.army.mil

Megan Moore, LTRM Team Leader, Mississippi River Coordinator, Minnesota Department of Natural Resources, 1801 S. Oak Street, Lake City, Minnesota 55041; 651-345-3331; megan.moore@state.mn.us

Kristen Bouska, Ecologist, Upper Midwest Environmental Sciences Center, 2630 Fanta Reed Road, La Crosse, WI 54603; 608-781-6344; kbouska@usgs.gov

Gretchen Benjamin, Large River Specialist, The Nature Conservancy, 2525 Sunrise Dr.
La Crosse, WI 54601; 608-397-1140; gbenjamin@tnc.org

Project coordination, oversight of fish-monitoring design and project implementation, lead on analysis of fish and invertebrate data, contribute to report and manuscript preparation.
John Chick, Principal Research Scientist/Field Station Director; Great Rivers Field Station, Illinois Natural History Survey, 918 Union Street, Alton, IL 62002; 217-300-3844; chick@illinois.edu

Introduction/Background:
What's the issue or question?
Environmental Pool Management (EPM) was implemented in 1994 in the US Army Corps of Engineers (USACE) St. Louis District to help promote the growth of wetland vegetation in the navigation pools of the Upper Mississippi River System (UMRS), while still maintaining a safe and dependable navigation channel. Both submersed and emergent aquatic vegetation were abundant in Pool 26 and the lower Illinois River until the mid-1950s, when increased sediment loading and water combined with water level management to maintain navigation led to dramatic decreases in the occurrence and abundance of aquatic vegetation (Mills et al. 1966, Bellrose et al. 1983, Havera and Bellrose 1984). Most backwater lakes lacking the structures necessary for water level management in this area have lacked aquatic vegetation since the 1993 flood.

In 2014, prolonged high flow conditions upstream necessitated a longer than average, 86-day drawdown in lower Pool 26. River biologists observed this atypical condition produced both annual aquatic vegetation and perennial aquatic vegetation, such as arrowhead (*Sagittaria* spp.), American lotus (*Nelumbo lutea*), and spatterdock (*Nuphar lutea*). These observances demonstrated that it is still possible to grow persistent perennial aquatic vegetation along with moist-soil annual vegetation in this portion of the UMRS when EPM produces prolonged drawdowns (USACE 2017). For example, EPM practices from 2014-2018 in Pools 24-26 of the UMRS have proven successful in establishing emergent and moist soil vegetation, such as smartweed (*Polygonum* spp.), millet (*Echinochloa* spp.), and sedges (*Carex* spp.) (USACE 2017). The St. Louis District of the USACE (2016, 2017) has developed and implemented a standardized monitoring program to assess the response of vegetation to EPM. However, no standardized monitoring program has been developed or implemented to assess the responses of fish populations and communities to EPM. The overall goal of this project will be to continue the established monitoring of moist soil and emergent aquatic vegetation growth in Pools 24-26 as a result of EPM, and to develop and implement a standardized monitoring protocol to quantify the use of inundated vegetation by small-bodied fishes and juvenile stages of larger fishes. We will develop and test the protocol for fish sampling in both years of the project in Pool 26, and evaluate its effectiveness in Pool 4 during year 2 of the project. Existing LTRM fish data will be used to test for relationships between the abundance and community composition of fishes with trends in EPM (e.g., drawdown length and timing, vegetation response) in Pool 26.

What do we already know about it?
The goal of EPM, or water-level drawdowns, is to improve ecosystem function in rivers by restoring aspects of the natural flow regime lost as a result of dam construction (Coulter et al. 2018). Regulation of water levels by dams along with increased sediment load has reduced the abundance and occurrence of aquatic vegetation and affected biogeochemistry in the UMRS (Havera and Bellrose 1984; Kenow et al. 2015). EPM seeks to simulate low summer base flows and expose mud flats to allow the growth of emergent and moist soil vegetation (Theiling et al. 1996). EPM has been successful in the lower UMRS pools in creating exposed mud flats and growing emergent and moist soil vegetation, which in turn provides habitat and food for fish and waterfowl after the vegetation is inundated (Garvey et al. 2003; Dugger and Feddersen 2013). In Pool 25, moist soil and emergent vegetation produced through EPM water level management was used by small bodied fishes (e.g. cyprinids and western mosquitofish) and young-of-the-year (YOY) fishes (Garvey et al. 2003). Inundated plant stems that are left the following spring also provide cover and nursery habitat for YOY fishes, as well as habitat for invertebrates consumed by spring migrating waterfowl. In the more northern pooled portion of the UMRS, both annual and perennial plants have responded positively to reduced water level conditions when the reduction is targeted for 90 days of the growing season. Positive vegetation response has been documented within Pool 8 (Kenow and Lyon 2009) and Pool 5 (Kenow et al. 2007) during previous drawdowns. It has also been documented that vegetation would likely respond favorably if a drawdown were to occur in Pool 18 (Schorg et al. 2018).

How will the proposed work improve our understanding of the UMRS?
Work in Pool 25 has demonstrated that small bodied (e.g., cyprinids and wester mosquitofish) and YOY fishes make use of inundated emergent and moist soil vegetation produced by EPM (Garvey et al. 2003; Coulter et al. 2018). Nevertheless, without data from a reach-wide monitoring program, there is no way to know if this finding represents actual increases in the production/abundance of these species or whether this vegetation is simply attracting these fishes from other areas. Our study will document the species of fish using vegetation produced by EPM in Pool 26 and then look for population trends associated with successful EPM drawdowns using Long Term Resource Monitoring (LTRM) data. Additionally, we will develop and evaluate our sampling protocols in both Pool 26 and Pool 4, to assess how well the methods can be used in different reaches of the UMRS. Finally, our proposed sampling methodology (1-m2 throw trap) provides accurate-quantitative data (i.e., number or biomass per m2) for fishes (Kushlan 1981; Chick et al. 1992; Jordan et al. 1997), decapod crustaceans and large bodied insects (Turner and Trexler 1997). This information will be fundamental to future research on the importance of water-level management and may lead to changes in operation of the navigation pools in the UMRS to help maintain ecological health within the UMRS.

Project Goals:

1. **Continue the established monitoring of moist soil and emergent aquatic vegetation growth in Pools 26-24 as a result of EPM (USACE 2016, 2017) in 2019 and 2020**
2. **Develop a standardized monitoring protocol to quantify the use of inundated vegetation by small-bodied and juvenile stages of larger fishes as a result of EPM in the UMRS**
3. **Test for pool-wide relationships between fish abundance in years with and without successful EPM using LTRM data collected in Pool 26**

We will attempt to accomplish these goals through the following objectives:

<u>Year 1 (2019)</u>

Objective 1 – Continue current vegetation monitoring in Pools 26, 25, and 24 to evaluate vegetation response to EPM. (Summer 2019)

Objective 2 –Develop and evaluate a standardized monitoring design to document and quantify fish use of inundated vegetation created by EPM in Pool 26 (Summer/Fall 2019)

Objective 3 – Document and quantify fish use of residual vegetation created by EPM in Pool 26 (Spring)

Objective 4 – Use data from Objective 2 to identify fishes associated with EPM vegetation and initiate an analysis of LTRM fish data to determine and examine fish population trends associated with EPM in Pool 26 (Winter 2019-2020)

Year 2 (2020)

Objective 5 – Document and quantify fish use of residual vegetation created by EPM in Pool 26 during 2019 (Spring 2020)

Objective 6 – Continue vegetation monitoring in Pools 26, 25, and 24 to evaluate vegetation response to EPM (Summer 2020)

Objective 7 – Document and quantify fish use of inundated vegetation associated with EPM in Pool 26 (Summer/Fall 2020)

Objective 8 – Document and quantify fish use of inundated vegetation in Pool 4 using methodology derived from Objective 2 (Summer/Fall 2020)

Objective 9 – Complete analysis of LTRM data examining fish population trends associated with EPM in Pool 26 (Winter 2020-2021)

Relevance of research to UMRR:

This project would support ongoing EPM operations within the St. Louis District (MVS) UMRS and aid in evaluating its effectiveness both for aquatic vegetation production and fish response. This project would also serve as a basis for fish and vegetation monitoring for future UMRR projects implementing water level management in Rock Island District (MVR) and St. Paul District (MVP), i.e., Pool 8 Habitat Restoration and Enhancement Project (HREP) (in feasibility phase) and UMRS EPM fact sheet (currently being developed for Division (MVD) approval). Information and protocols developed from this proposal would also inform feasibility level design as well as be incorporated into Adaptive Management & Monitoring for future HREPs.

EPM has not been incorporated into the restoration measures used for HREPs. Yet, the practice has been demonstrated in multiple locations, Pools 5, 6, 8, 13, 24, 25, and 26 as a method to reinvigorate emergent, rooted floating leaf, and submersed aquatic vegetation communities. The diversity and abundance of these communities are essential ecological elements for aquatic species, including invertebrates, herptiles, fishes and waterbirds. River bank stabilization, nutrient processing, and reduced sediment suspension are also benefits from aquatic vegetation. EPM provides another restoration option that could be used in conjunction with the operation of existing UMRR HREPs and the development of new HREPs and other restoration efforts on the UMRS. LTRM data along with other rigorous data sets should be analyzed to discover the value of this restoration technique within the UMRS. Using existing and newly acquired data this research will help determine the ecological outcomes associated with EPM and will help formulate best management practices and protocols for application of EPM throughout the UMRS.

Addressing the 2018/2019 Focal Areas:

Due to this project's overarching range of topics (water-level management, vegetation, fish, and historical LTRM data) we feel that this project will address multiple information gaps identified in the Focal Areas 2018/2019 document.

Objective 1&6 – 'Vegetation monitoring' will address *THEME 2: UNDERSTANDING ASSOCIATIONS BETWEEN HYDROLOGIC AND GEOMORPHIC CONDITIONS AND THE DISTRIBUTION/ABUNDANCE OF BIOTA IN THE RIVER AND ON THE FLOODPLAIN - Focal area 3: Interactions and associations of hydrogeomorphology with biota and water quality, Subarea 3.1 Interactions between aquatic vegetation and hydrogeomorphology, 3.1, iii. Can water level management be used to increase vegetation growth in pools with high turbidity and limited vegetation?* A main goal of EPM is to increase aquatic vegetation. By continuing to monitor the effects of EPM on vegetation, this project will directly address this Focal Area.

Objective 1&6 will also be able to address *THEME 2: UNDERSTANDING ASSOCIATIONS BETWEEN HYDROLOGIC AND GEOMORPHIC CONDITIONS AND THE DISTRIBUTION/ABUNDANCE OF BIOTA IN THE RIVER AND ON THE FLOODPLAIN. Focal area 4: Understanding relationships among floodplain hydrogeomorphic patterns, vegetation and soil processes, and effects on wildlife habitat and nutrient export, Subarea 4.2: Understand and quantify floodplain vegetation dynamics, i. What aspects of the flood regime are associated with different plant community types?* By continuing to monitor the effects of EPM on vegetation, this project will directly address if varying degrees of EPM have an effect on different types of aquatic vegetation.

Objectives 2-5 and 7-9 'Fish monitoring' will address *THEME 2: UNDERSTANDING ASSOCIATIONS BETWEEN HYDROLOGIC AND GEOMORPHIC CONDITIONS AND THE DISTRIBUTION/ABUNDANCE OF BIOTA IN THE RIVER*

AND ON THE FLOODPLAIN - Focal area 3: Interactions and associations of hydrogeomorphology with biota and water quality, Subarea 3.2 - Associations between hydrogeomorphology and fisheries. By documenting and quantifying fish use of inundated vegetation created by EPM, we will make associations between hydrogeomorphology and fisheries.

Objective 9 will include in-depth analysis of fish population trends associated with EPM in Pool 26. This analysis will potentially address *THEME 3: PHYSICAL, CHEMICAL AND BIOLOGICAL PROCESSES BEHIND THE OBSERVED SPATIAL AND TEMPORAL PATTERNS IN LTRM DATA, Focal area 5: Vital rates of biotic communities, Subarea 5.1: Better quantify rates of recruitment, growth, and mortality of fishes of the UMRS, Subarea 5.2 Better understand the mechanisms behind observed changes in fish populations and implications for UMRS ecosystem and management.* This project and analysis of results will hopefully lend some insight as to how EPM practices affect overall fish populations. For example, does an increase in aquatic vegetation available to fish at various life stages lead to an increase in recruitment to the adult population?

An in-depth analysis of Objective 9 will also address *Theme 2 Focal Area 2: Qualitative assessment of effects of recent (i.e., relatively wet conditions from early 1980s to the present) and projected changes in land use and climate, more specifically, Subarea 2.2. Projected range of hydrologic changes and effects on hydrologic parameters important to habitat and biota.* To accomplish this Objective, we will look at historical hydrographs of Pool 26 to determine if there are any recent trends in the hydrograph that might be influencing aquatic vegetation production and/or fish production.

While this project does not specifically involve an existing HREP, vegetation sampling and fish sampling will be conducted in Piasa and Eagles Nest Islands. The Piasa and Eagles Nest HREP feasibility report was approved in 2018, and is currently in the pre-construction engineering and design phase. EPM sampling as part of this study would occur in areas delineated for aquatic habitat enhancement under the HREP. Therefore data collected as part of this project could potentially serve as 'pre project' data for the approved Piasa and Eagles Nest HREP. This 'pre-project' data would be useful in future evaluations of this HREP.

Methods:

Vegetation monitoring (2019-2020) -Maintain current USACE monitoring of vegetation-
(Objectives 1 &6)
To accomplish these objectives, the areas of EPM vegetation response will be done using three methodologies:

1) Implement the Integrated Waterbird Management and Monitoring (IWMM) protocol (USFWS 2015). A total of six sites in Pool 26, and four sites in Pools 25 and 24.). Only emergent vegetation from the current growing season is assessed. To complete the vegetation surveys while adhering to the protocol, two major steps were completed: 1) an assessment of percent cover of emergent vegetation within the survey unit is completed and 2) a species inventory and species-specific percent cover assessment within the areas of emergent vegetation are completed.

   To complete the first step, the location of all emergent vegetation areas within each survey unit are determined. This is done by a visual assessment throughout each survey unit. Once all areas of emergent vegetation are identified, an estimate of the percent cover of the survey unit by emergent vegetation is completed. Percent cover is defined as the percentage of the survey unit covered by vertical projections from the outermost perimeter of the plants' foliage.

   To complete the second step, a list of all common emergent vegetation species is compiled and an estimate of each species' percent cover is completed. For this estimate, percent cover is defined as above except that it is estimated as a percentage of emergent vegetation area, not as a percentage of the total survey unit area. For example, a survey unit could only contain a single species, Species X across 50% of the total survey unit area, but as an individual plant species it could cover 100% of the emergent vegetation area within the survey unit. So, 100% would be recorded for this measurement. Total cover across species can exceed 100% due to the stratification of plant species with varying heights and growth forms. Mean percent cover would be calculated by pool to compare species composition and densities between pools. Mean percent cover during IWMM surveys would be calculated by site. Species percent frequency of occurrence for would be calculated by pool. Species richness would be calculated by pool. Simpson's diversity indices would be calculated for Pools 26, 25, and 24. Simpson's evenness would be calculated for Pools 26, 25, and 24.

2) Implement transect surveys using the Illinois Natural History Survey, Critical Trends Assessment Protocol for Wetland sites (INHS 2002), at six sites in Pool 26 and four sites in Pools 25 and 24. A transect is placed perpendicular to the long length of the wetland. A random distance along the transect is selected. This baseline is placed along the edge of the wetland vegetation and parallel to the long dimension of the wetland. When lying the transect, the tape measure is pulled taut, but laid upon the ground at all points along its length. Herbaceous vegetation is sampled in ¼ m2 quadrats at an interval of every 2m along the transect, starting 2m from the baseline. A total of 20 quadrats are sampled per site. Quadrats are placed 1m from the transect on alternate sides, starting on the left at the 2m point

(e.g. the first quadrat covers the area from 2-2.5m along the transect, at a distance covering 1-1.5m left of the transect). Average percent cover by site, average species percent cover by site, species richness, and Simpson's diversity index were calculated.

3) Implement the LTRM Vegetation Survey Protocol (Yin et al. 2000) in the lower half of Pool 26 (RM 201-221). Within Pool 26 plot locations would be determined using the LTRM Stratified Random Sampling design, where a 50 x 50 meter grid is generated and overlaid into a GIS map. Nodes of the grid are geo-spatially registered with coordinates generated. Nodes that fall within the sites and 1.5 meters or greater in water depth would be selected as vegetation survey plot locations. This was done for the lower half of Pool 26, RM 201-221. In total, between 70 and 80 plots would be generated. At each plot location, sampling is normally done via a boat and a total of six subplots are located off each corner of the boat and off the port and starboard sides of the boat. Each subplot is assigned a percent cover estimate using a rating of 0 to 5. The cover rating relating to species percent cover is as follows: 0 = None; 1 = 1-20%; 2 = 21-40%; 3 = 41-60%; 4 = 61-8-%; 5 = 81-100%. A cover rating was assigned to each species within each subplot. Average species percent cover, percent frequency of occurrence, and Species richness would be calculated. Simpson's diversity index, Shannon's diversity index, and Simpson's evenness would be calculated.

Fish sampling and monitoring (2019-2020) - Documenting and quantifying fish use of inundated vegetation**- (Objectives 2, 3, 5, 7 & 8)**

1) Study area - The area of EPM response in Pool 26 of the Mississippi River is primarily limited to the lower 10 miles of the pool (river mile 201 – 211). This area has the majority of the contiguous backwaters for the pool and is the most significantly affected by water-level management practices (or drawdowns due to flooding) due to Pool 26 water levels being managed by a hinge point control in the middle of the pool at Grafton, IL. Most of the backwaters are shallow < 1.5 m and have a low gradient, which is ideal for EPM in that a relatively small reduction in water level can expose a relatively large area of mud flats for vegetation growth and sediment compaction.

   Using information from recent assessments of vegetation response to EPM in Pool 26, our goal will be to sample fishes from six sampling areas (Table 1). We will create a grid of potential sampling sites that are 100 m x 25 m, with the 100 m side running parallel to the shore. The number of sites sampled will vary relative to the size of each sampling area, and 5 random sampling locations will be generated within each site. Of those potential sites, when conditions are met: time of the year, vegetation growth or stems present, and water being on the vegetation for a minimum of 3 days, the sampling area will be visited and samples collected. When arriving at a sampling area, crews will have to evaluate the available sites and determine which meet the criteria of having 0.1 – 0.95-m of water and vegetation present. Once the sites are selected, the crews will collect samples from the 5 randomly generated locations within each site. A minimum of 60 and maximum of 120 samples will be collected in the first year, optimally with 60 in the spring (sampling residual stems from last season) and 60 in the late summer.

Pool 26 EPM			
Sampling Area	**Acres**	**Number of Sites**	**Number of Samples**
Dresser	45.4	2	10
Alton Lake	210	3	15
Ellis Bay	39.1	2	10
Mile 210	28.3	2	10
Eagles Nest Island	4.1	1	5
Piasa Island	40.7	2	10
Total		12	60

This design will insure that both the vegetation surveys and fish sampling will occur in the same general areas. Basic water quality data (water depth, Secchi depth, dissolved oxygen, temperature, and specific conductivity) will be taken with each fish sample. A sample will be designated as an "edge" sample in the data if it falls within 5-m of open water.

If conditions cannot be met by EPM for a successful vegetation response in Pool 26, we may move our sampling into another EPM pool such as Pool 25 if it's having successful vegetation growth, or into protected backwaters with vegetation. This will allow us to run a similar sampling protocol, testing the technique and refining the study as needed for the following year/s.

2) Fish sampling in vegetation - Pool 26 – To determine the fish assemblage that is using the vegetation we propose using a widely accepted technique for sampling small bodied fishes in shallow-vegetated habitats, the 1-m^2 throw trap (Kushlan 1981). This technique has been evaluated for accuracy and effectiveness in multiple studies (Kushlan 1981; Chick et al. 1992; Jordan et al. 1997) and has been used to sample fishes and macroinvertebrates in the Florida Everglades (Jordan et al. 1994; Loftus and Ecklund 1994; Dorn and Cook 2015) Lake Okeechobee (Chick and McIvor 1994); coastal mashes (Thom et al. 2004; Dibble et al. 2015) and floodplain-lakes (Florentino et al. 2016). A 1-m^2 by 1 m height, throw trap will be constructed from 14-guage aluminum sheet metal. The throw trap will be thrown into a designated site in a vegetated habitat. The vegetation within the trap will then be pulled, rinsed, and the wet-weight recorded. A 3-mm-mesh bar seine (.99 x 1 m) will be pushed repeatedly through the trap to remove fish and macroinvertebrates. Seining will continue until 5 consecutive seine hauls produce no fish. All fish and macroinvertebrates captured will be preserved in 10% formalin for sorting and identification in the lab. The vegetation removed from the throw trap will be identified and weighed, and percent composition by cover will be estimated.

3) Exploration of Larval fish – As a trial, a small number of larval fish light traps will be deployed at select sites during the spring to test the viability of this technique in vegetated areas of large rivers. Light traps will be placed in areas during the evening and collected the next morning. All fish captured will be preserved in 5% buffered formalin for identification and enumeration in the lab.

4) Fish sampling in vegetation - Pool 4 (2020) - For the second year of the study, these new fish sampling techniques will be evaluated in both Pool 26 and Pool 4 of the Mississippi River to evaluate how this technique works across different regions and environmental conditions throughout the UMRS. It should be noted that we are not evaluating EPM practices in Pool 4, rather just the effectiveness of using a throw trap in vegetated areas to collect small bodied fish in Pool 4.

Evaluating fish response to EPM (2019-2021) –
(Objectives 4 & 8)

1) Fish use of inundated vegetation - We will use data from Objectives 2-3 to identify fishes associated with EPM vegetation and initiate an analysis of LTRM fish data to determine and examine fish population trends associated with EPM in Pool 26. Using Coulter et al. (2018) as a guide, initial species to be evaluated could be Bluegill, Bullhead Minnow, Channel Shiner, Common Carp, Emerald Shiner, Orangespotted Sunfish, River Shiner, Spotfin Shiner and Western Mosquitofish. This list will be refined as we collect our first year of fish samples from inundated vegetation in Pool 26.

2) Overall fish response to EPM practices in Pool 26 – We will use both univariate and multivariate analyses to evaluate whether there have been population and/or community responses to past EPM in Pool 26. Because moderate and major floods are known to influence both the reproductive success of fishes in Pool 26 and the effectiveness of our fish sampling gear, we need to account for these effects in our analysis. Therefore, we will begin by examining trends across our entire periods of record from 1994 to 2018, and then conduct a second analysis comparing recent EPM years to past years omitting years where moderate and major flooding occurred. Univariate analyses will be used to compare CPUE across years for individual species. Multivariate analyses will look for community level responses across the same years looking for differences in the grouping of years with successful EPM to years where no EPM was conducted (or where EPM goals where not achieved). We will then conduct follow up analyses (e.g., SIMPER) to determine if the target species (listed above) contributed to any differences in the groupings among years.

Timeline:

February 2019 – Have throw traps constructed and purchase any other materials needed to begin project.
Spring 2019 – Conduct first Spring fish sampling event in Pool 26. Data collection, entry, and verification. (Objective 3)
Summer 2019 – Conduct vegetation monitoring in Pools 26-24. (Objective 1)
Late Summer/Fall 2019 – Conduct fish sampling in inundated vegetation in Pool 26 (Objective 2)
Winter 2019 – Data entry and verification, initial data analysis (Objective 4).
Spring 2020 – Conduct second Spring fish sampling event in Pool 26. Data collection, entry, and verification. (Objective 5)
Summer 2020 – Conduct vegetation monitoring in Pools 26-24. (Objective 6)
Late Summer/Fall 2020 – Conduct fish sampling in inundated vegetation in Pool 26 and Pool 4 (Objectives 7 and 8)
Winter 2020-21 – Data entry and verification. Complete analysis of fish use of inundated vegetation in Pool 26.

Complete analysis of effectiveness of using a throw trap in Pool 26 and Pool 4. Complete analysis of LTRM data examining fish population trends associated with EPM in Pool 26. (Objective 9)

Spring 2021 - Complete final report on all aspects of project (Objective 10)

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Tracking number	Products	Staff	Milestones
2019epm1	Progress report	Chick and McGuire	30 Dec. 2019
2019epm2	Progress report	Chick and McGuire	30 June 2020
2019epm3	Draft LTRM Completion report on total project	Chick and McGuire	30 June 2021
2019epm4	Final LTRM Completion report on total project	Chick and McGuire	30 Dec. 2021

References:

Bellrose F.C., S.P. Havera, F.L. Paveglio, Jr., and D.W. Steffeck. 1983. The fate of lakes in the Illinois River valley. Ill. Nat. Hist. Surv. Biol. Notes No. 119. 27 p.

Chick J. H., F. Jordan, J. P. Smith, and C. C. McIvor. 1992. A comparison of four enclosure traps and methods used to sample fishes in aquatic macrophytes. *Journal of Freshwater Ecology* 7:353–361.

Chick J.H. and C.C. McIvor. 1994. Patterns in the abundance and composition of fishes among beds of different macrophytes: viewing a littoral zone as a landscape. Canadian Journal of Fisheries and Aquatic Sciences 51: 2873-2882.

Coulter A.A., Adams S.R., Flinn M.B., Whiles M.R., Burr B.M., Sheehan R.J., Garvey J.E. 2018. Extended water-level drawdowns in dammed rivers enhance fish habitat: environmental pool management in the Upper Mississippi River. Environmental Management.

Dibble K.L., Tyrrell, M., and P.S. Pooler. 2015. Factors that drive restoration of nekton communities in impaired salt marshes of northeastern North America. Estuaries and Coasts 38:1304-1316.

Dorn N.J. and M.I. Cook. 2015. Hydrological disturbance diminishes predator control in wetlands. Ecology 96:2984-2993.

Dugger B.D., Feddersen J.C. 2013. Using river flow management to improve wetland habitat quality for waterfowl on the Mississippi River, USA. Wildfowl 59:62-74.

Florentino A.C., M.Petrere, C. Edwarde, C. Freitas, J.J. Toledo, L. Mateus. Y.R. Suarez, and J. Penha. 2016. Environmental Biology of Fish 99:265-274.

Garvey J.E., Dugger B.D., Whiles M.R., Adams S.R., Flinn M.B., Burr B.M., Sheehan R.J. 2003. Responses of Fishes, Waterbirds, Invertebrates, Vegetation, and Water Quality to Environmental Pool Management: Mississippi River Pool 25. Final Report.

Illinois Natural History Survey (INHS). 2002. Critical Trends Assessment Program Monitoring Protocols. Illinois Natural History Survey, Office of the Chief Technical Report: 2002-2.

Havera, S.P., and F.C. Bellrose. 1985. The Illinois River: A lesson to be learned. Wetlands 4:29-41.

Jordan F., S. Coyne, and J.C. Trexler. 1997. Sampling fishes in vegetated habitats: Effects of habitat structure on sampling characteristics of the 1-m^2 throw trap. Transactions of the American Fisheries Society126:1013-1020.

Jordan, F., H. L. Jelks, and W. M. Kitchens. 1994. Habitat use by the fishing spider Dolomedes triton in a northern Everglades wetland. Wetlands 14:239-242.

Kenow K.P., Benjamin G.L., Schlagenhaft T.W., Nissen R.A., Stefanski M., Wege G.J., Newton T.J. 2016. Process, policy, and implementation of pool-wide drawdowns on the Upper Mississippi River: A promising approach for ecological restoration of large impounded rivers. River Research and Applications. 32:295-308.

Kenow KP, Lyon JE. 2009. Composition of the seed bank in drawdown areas of Navigation Pool 8 of the Upper Mississippi River. River Research and Applications 25: 194–207.

Kenow KP, Rogala JT, Boma PJ. 2007. Evaluation of 2006 vegetation response on areas exposed during the 2005 drawdown of Navigation Pool 5, Upper Mississippi River. NESP ENV Report 5, U.S. Army Corps of Engineers, Rock Island, St. Louis, and St. Paul Districts; 10pp. Available at: http://www2.mvr.usace.army.mil/UMRS/NESP/Documents/Evaluation%20of%202006%20vegetation%20on%20Pool%205%20-%20MH%20edit.pdf

Kushlan, J. A. 1981. Sampling characteristics of enclosure fish traps. Transactions of the American Fisheries Society 110:557–562.

Loftus, W.F., and A. Eklund. 1994. Long-term dynamics of an Everglades small-fish assemblage. Pages 461-483 *in* Davis, S.M. and J.C. Ogden. Everglades – The Ecosystem and its Restoration. St. Lucie Press, Boca Raton, FL USA.

Mills, Harlow B„ William C. Starrett, and Frank C. Bellrose. 1966. Man's effect on the fish and wildlife of the Illinois River. Illinois Natural History Survey Biological Notes 57. 24 p.

Shorg, A.J., Romano, S.P. 2018. Shallow and deep water aquatic vegetation potential for a midlatitude pool of the Upper Mississippi River System with drawdown. River Research and Applications. 34:310-316.

Theiling C.H., Maher R.J., Sparks R.E. 1996. Effects of variable annual hydrology on a river regulated for navigation: Pool 26, Upper Mississippi River System. Journal of Freshwater Ecology. 11:101-114.

Thom C.S.B., La Peyre, M.K.G., and J.A. Nyman. 2004. Evaluation of nekton use and habitat characteristics of restored Louisiana marsh. Ecological Engineering 23:63-75.

Turner, A., Trexler, J.C., 1997. Sampling invertebrates from the Florida Everglades: a comparison of alternative methods. Journal of the North American Benthological Society 16, 694–709.

USACE. 2016. St. Louis District Environmental Pool Management 2017 Summary Report.

USACE. 2017. St. Louis District Environmental Pool Management 2017 Summary Report.

USFWS. 2015. Integrated Waterbird Management and Monitoring Approach for Nonbreeding Waterbirds. Monitoring Manual, Version 8: February 2015.

A year of zooplankton community data from the habitats and pools of the UMR

Previous LTRM project:
This project expands on work done in Pool 4 throughout the key LTRM pools. Additionally, this project will assess the potential for using already collected LTRM phytoplankton samples to examine zooplankton community.

Name of Principal Investigator:
Molly Sobotka – lead investigator, zooplankton ID, data analysis, report writing
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Collaborators (Who else is involved in completing the project):
Field sample collection:
Rob Burdis – MN DNR
John Kalas – WI DNR
Travis Knuter – IA DNR
Doyn Kellerhalls – IL NHS
Lori Soeken-Gittinger – IL NHS

Introduction/Background: Please address <u>all</u> of these questions:
What's the issue or question?

Zooplankton are a vital link between the microbial and larger organismal world in aquatic systems. A great deal of research has been done on zooplankton in lakes and reservoirs elucidating community and population dynamics and trophic relationships with zooplankton predators (other zooplankton and planktivorous fish) and prey (phytoplankton). Less information has been collected in rivers, especially over the large scale covered by the UMRR LTRM. However, many fishes are dependent on zooplankton as a food resource during some or all life stages (Nunn et al. 2012). Specifically, in the UMRS Gizzard Shad (*Dorosoma cepedianum;* an important prey fish), Paddlefish (*Polyodon spathula)*, and Bigmouth Buffalo (*Ictiobus cyprinellus;* an important commercial species) are filter feeding planktivores throughout life. White Crappie (*Pomoxis annularis)*, Black Crappie (*P. nigromaculatus)* and Bluegill (*Lepomis macrochirus)*, popular sport fish, all rely heavily on zooplankton during portions of their life. Larval fishes alter their feeding behavior with age, consuming larger zooplankton as their mouth gape increases (Devries et al. 1998). Thus, a diverse zooplankton community is necessary to support larval fish populations to recruitment. The lack of information on the spatial and temporal distribution of zooplankton in the UMRS leaves a gap in our understanding of what and where food resources are available for fish populations.

Currently restoration activities in the UMRS lack standardized assessment protocols and metrics to quantify success. Many of these projects are designed to create habitat and increase the resilience of the system however quantifying results can be difficult. Understanding benefits to the fish community is especially difficult because of their mobility (UMRR HREP Team Meeting, 2016) and potential lag in ecological impact. Zooplankton are sensitive to changes in water quality and hydraulic variables and could provide a useful tool for understanding habitat quality and changes in productivity post-restoration for a variety of fishes. Zooplankton are also sensitive to top-down regulation and so can be used as indicators of the fish community (Jeppesen et al. 2005).

What do we already know about it?

Zooplankton communities differ between habitats and these differences are driven by a variety of factors including turbidity and residence time (Wetzel 2001). Smaller bodied individuals (generally rotifers) tend to be dominant in more lotic habitats while larger bodied crustaceans are more common in lentic areas. These factors could be driving zooplankton dynamics in UMRR LTRM reaches and thus impacting fish communities. No large-scale zooplankton survey has been done within the UMRS however some data has been collected from individual pools. Burdis and Hirsch (2017) found greater zooplankton density in Pool 4 backwaters than the main channel. They also found that rotifers dominated the zooplankton community in both habitats. Off-channel habitats in the UMRS tend to have lower water velocity and greater water clarity. These areas may act as reservoirs and could be a source of zooplankton to the main channel during high water events. Wahl et al. (2008) found in the Illinois River that zooplankton densities in the main channel were greater than could be accounted for by flushing from backwater lakes. That study further concluded that while backwater lakes increased zooplankton densities in the main channel during flood and post-flood periods, the main channel had its own reproducing zooplankton population. However, those authors observed that the Illinois river is highly eutrophic; the main channel of the Mississippi River may be less productive relative to off-channel areas especially in the Open River.

Silver Carp (*Hypophthalmichthys molitrix)* and Bighead Carp (*H. nobilis;* collectively Asian carp), recent invaders to the Mississippi River system, are planktivores and have been found to reduce zooplankton abundance and biomass (Sass et al. 2014, DeBoer et al. 2018) where they are established. Asian carp can impact the entire zooplankton community as they consume large and small bodied individuals (Sampson et al. 2009). Carp are currently abundant in the Mississippi River below Lock and Dam 15 at Davenport, IA and in the Illinois River downstream of Joliet, IL. In the Illinois river Gizzard Shad and Bigmouth Buffalo (*Ictiobus cyprinellus)*, native planktivores, were found to have lower catch per unit effort (CPUE) after invasion of Asian carp (Pendleton et al. 2017). We currently have the opportunity to collect zooplankton data from pools along a gradient of Asian carp abundance. This allows us to collect baseline data for pre-invasion and contrast zooplankton biomass, abundance, and community between these locations.

Finally, collecting samples during the winter, often a bottleneck period for juvenile fish recruitment, will provide data on habitats that are best suited to improve fish over-wintering. Winter zooplankton communities are generally understudied; however, prey availability is considered an important factor in fish overwinter survival (Hurst 2007). Additionally, winter environmental conditions can influence spring plankton blooms (Sommer et al. 2012) and thus prey availability for planktivores.

What are the objective(s) or hypotheses?

Objectives:

Objective 1. Determine if zooplankton communities are measurably different between UMRS strata, key pools, seasons, and pools with/without Asian carp.

Objective 2. Evaluate relationships between zooplankton community and environmental conditions. Compare these relationships to those found previously in the UMRS and in other rivers.

Objective 3. Determine effort required for zooplankton sampling and enumeration by field and lab staff.

Hypotheses:

Hypothesis 1. We hypothesize that small bodied zooplankton that are better suited to turbid conditions (i.e. rotifers) will be dominant in lower UMRS river reaches and larger crustacean taxa will be less abundant than in northern pools.

Hypothesis 2. Main channel zooplankton densities will decrease longitudinally although off-channel communities will be similar.

Hypothesis 3. Zooplankton densities will be lower in winter, however in the upper pools under-ice phytoplankton blooms could support populations larger than those found in open water areas.

Hypothesis 4. The abundance of Asian carp within a pool will be correlated with decreased densities of total zooplankton. Zooplankton in the Illinois River have been depleted by Asian carp; we expect the Open River and Pool 26 to have lower zooplankton abundance than the upper pools as well.

How will the proposed work improve our understanding of the UMRS?

This study will allow comparisons between UMRS LTRM pools and observations of longitudinal and stratum-based differences in zooplankton densities. Further it will begin to establish baselines in UMRS reaches where planktivorous carp are not established. We propose one year of sampling in order to establish protocols and effort. Future multi-year proposals will be considered as an outcome of this project.

Relevance of research to UMRR: Please address all of the following:

How does this work relate to the information needs of UMRR partners? Specifically:

1. *How will the results inform river restoration and management?*
    a. Long term monitoring of zooplankton communities can provide insights into changes in water quality, hydrogeomorphology, and the biological community in aquatic systems. While this study will not provide those insights alone it will allow us to propose a realistic long-term study in the UMR based on zooplankton monitoring.

2. *How will the proposed work contribute to, or improve, the selection or design of Habitat Rehabilitation and Enhancement Projects (HREPs)?*
    a. Zooplankton respond to changes in their physical and biological environment in predictable ways. Monitoring zooplankton community dynamics could be a useful tool to understand how HREPs are changing local water quality and/or how fish communities have responded to an HREP (typically a costlier and time-consuming metric). This work will provide initial community data in different UMRR habitats. Data will be collected from a spectrum of conditions, this will allow us to evaluate relationships that have been observed in other lake and river environments and determine if zooplankton could be used to monitor HREPs in the UMR.

Describe how the research addresses one or more of the 2018/2019 Focal Areas.
If work involves an HREP, name it.

a. Ongoing work in Pool 4 – Lake Pepin
    i. The Minnesota DNR has collected zooplankton from Pool 4 since 1995. This proposal would allow comparisons of zooplankton dynamics between LTRM pools and evaluate correlations observed within Pool 4 on a larger scale.

b. **Focal area 3: Interactions and associations of hydrogeomorphology with biota and water quality. Subarea 3.2: Associations between hydrogeomorphology and fisheries.**

i. Zooplankton dynamics can clarify linkages between major resources (e.g. water quality, fish communities) and controlling variables (e.g. depth, velocity). Understanding these linkages will enhance models predicting system resilience.
ii. While the physiological needs of over-wintering fishes are generally unknown food resources are likely a necessary component for survival. Distribution of food resources during the winter may be an important factor in spatial and community structure. A mismatch between food and other habitat resources (e.g. temperature environment) could lead to decreased over-wintering survival, especially for less mobile juvenile individuals. These data could be used to better predict survival (especially of larval fishes) in different over-wintering locations.

c. **Focal area 5: Vital rates of biotic communities. Subarea 5.2** Better understand the mechanisms behind observed changes in fish populations and implications for UMRS ecosystem and management (from Ickes 2018)
  i. Changes in native species vital rates have been observed, especially in pools where Asian carp are present. Understanding changes in zooplankton dynamics could clarify the reasons behind observed changes and predict impacts in un-invaded pools. Since different species select different sized plankton Asian carp could have variable impacts on different species. Thus, habitat shifts may be occurring that change relative contribution of components related to recruitment, growth, and mortality.

Methods:
Clearly describe methods and how they will achieve the stated objectives. Provide sufficient detail so that the likelihood of achieving each of the objectives can be fully evaluated. Include a description of study area(s). If you are uncertain of the validity of your statistical approach, review by Brian Gray is recommended prior to submission.

a. Zooplankton samples will be collected at a subset of WQ Stratified Random Sampling (SRS) sties. This will provide broad spatial and seasonal coverage. Samples will be collected at full sites where CHL-S and PHYTO samples are collected.
  i. 5 sites per stratum (MC, SC, and BW) per SRS episode.
  ii. Additional sites will be randomly selected from full site list.
b. Known volume, depth integrated samples will be filtered through 80 μm mesh and the concentrated sample rinsed into the sample bottle. 3 sub-samples will be collected at each site and combined for the final sample.
c. Concentrated samples will be fixed in ethyl alcohol and sent to UMESC in sample coolers and sent on to Big Rivers and Wetlands Field Station with return cooler shipment.
d. 60 mL subset of LTRM standard phytoplankton sample will be analyzed with the same procedures to evaluate the applicability of using those samples for zooplankton collection.
e. A minimum of 200 individuals will be identified from each sample (if possible). Samples with large numbers of individuals will be subsampled. Samples will be adjusted to a known volume, mixed, and a subsample collected with a Hensen-Stemple pipette. All individuals in each subsample will be enumerated until the total number counted exceeds 200.
f. Zooplankton will be identified to the lowest practicable taxonomic levels: such that estimates of abundance, and community structure can be calculated.
g. Biomass will be calculated using lengths from a subsample of individuals and published length-mass regressions (Dumont et al. 1975, Culver et al. 1985).
h. Community data sets will be compared between pools and between habitats within pools using the mvabund package in R.
i. Multivariable regression will be used to determine how functional groups of zooplankton (e.g. rotifers or copepods) respond to environmental metrics (e.g. temperature, suspended solids).

Timeline:
Project begins 2019 Spring SRS or as early as possible given funding distribution. Sample collection ends winter SRS 2020 (Feb 2020) and draft report completed Dec 2020.

Products and Milestones

Tracking number	Products	Staff	Milestones
2019zoo1	Progress report	Sobotka and Fulgoni	30 Dec. 2019
2019zoo2	Draft LTRM Completion report on utility of zooplankton community monitoring for HREP assessment	Sobotka and Fulgoni	30 Dec. 2020
2019zoo3	Final LTRM Completion report on utility of zooplankton community monitoring for HREP assessment	Sobotka and Fulgoni	30 June 2021
2019zoo4	Draft LTRM Completion report on detailing differences between pools and habitats. Report will also investigate the potential	Sobotka and Fulgoni	30 Dec. 2020
2019zoo5	Final LTRM Completion report on detailing differences between pools and habitats. Report will also investigate the potential	Sobotka and Fulgoni	30 June 2021

Citations

BURDIS, R. M., AND J. K. HIRSCH. 2017. Crustacean zooplankton dynamics in a natural riverine lake, Upper Mississippi River. Journal of Freshwater Ecology 32:240–258.

CULVER, D. A., M. M. BOUCHERLE, D. J. BEAN, AND J. W. FLETCHER. 1985. Biomass of Freshwater Crustacean Zooplankton from Length–Weight Regressions. Canadian Journal of Fisheries and Aquatic Sciences 42:1380–1390.

DEBOER, J. A., A. M. ANDERSON, AND A. F. CASPER. 2018. Multi-trophic response to invasive silver carp (Hypophthalmichthys molitrix) in a large floodplain river. Freshwater Biology 63:597–611.

DEVRIES, D. R., R. A. STEIN, AND M. T. BREMIGAN. 1998. Prey Selection by Larval Fishes as Influenced by Available Zooplankton and Gape Limitation. Transactions of the American Fisheries Society 127:1040–1050.

DUMONT, H. J., I. VAN DE VELDE, AND S. DUMONT. 1975. The dry weight estimate of biomass in a selection of Cladocera, Copepoda and Rotifera from the plankton, periphyton and benthos of continental waters. Oecologia 19:75–97.

HURST, T. P. 2007. Causes and consequences of winter mortality in fishes. Journal of Fish Biology 71:315–345.

JEPPESEN, E., M. SØNDERGAARD, J. P. JENSEN, K. E. HAVENS, O. ANNEVILLE, L. CARVALHO, M. F. COVENEY, R. DENEKE, M. T. DOKULIL, B. FOY, D. GERDEAUX, S. E. HAMPTON, S. HILT, K. KANGUR, J. KÖHLER, E. H. H. R. LAMMENS, T. L. LAURIDSEN, M. MANCA, M. R. MIRACLE, B. MOSS, P. NÕGES, G. PERSSON, G. PHILLIPS, R. PORTIELJE, S. ROMO, C. L. SCHELSKE, D. STRAILE, I. TATRAI, E. WILLÉN, AND M. WINDER. 2005. Lake responses to reduced nutrient loading – an analysis of contemporary long-term data from 35 case studies. Freshwater Biology 50:1747–1771.

NUNN, A. D., L. H. TEWSON, AND I. G. COWX. 2012. The foraging ecology of larval and juvenile fishes. Reviews in Fish Biology and Fisheries 22:377–408.

PENDLETON, R. M., C. SCHWINGHAMER, L. E. SOLOMON, AND A. F. CASPER. 2017. Competition among river planktivores: are native planktivores still fewer and skinnier in response to the Silver Carp invasion? Environmental Biology of Fishes 100:1213–1222.

SAMPSON, S. J., J. H. CHICK, AND M. A. PEGG. 2009. Diet overlap among two Asian carp and three native fishes in backwater lakes on the Illinois and Mississippi rivers. Biological Invasions 11:483–496.

SASS, G. G., C. HINZ, A. C. ERICKSON, N. N. MCCLELLAND, M. A. MCCLELLAND, AND J. M. EPIFANIO. 2014. Invasive bighead and silver carp effects on zooplankton communities in the Illinois River, Illinois, USA. Journal of Great Lakes Research 40:911–921.

SOMMER, U., R. ADRIAN, L. DE SENERPONT DOMIS, J. J. ELSER, U. GAEDKE, B. IBELINGS, E. JEPPESEN, M. LÜRLING, J. C. MOLINERO, W. M. MOOIJ, E. VAN DONK, AND M. WINDER. 2012. Beyond the Plankton Ecology Group (PEG) Model: Mechanisms Driving Plankton Succession. Annual Review of Ecology, Evolution, and Systematics 43:429–448.

WAHL, D. H., J. GOODRICH, M. A. NANNINI, J. M. DETTMERS, AND D. A. SOLUK. 2008. Exploring riverine zooplankton in three habitats of the Illinois River ecosystem: Where do they come from? Limnology and Oceanography 53:2583–2593.

WETZEL, R. G. 2001. Limnology: Lake and River EcosystemsThird. Academic Press, San Diego.

Reforesting UMRS forest canopy openings occupied by invasive species

Previous LTRM project:

This project builds upon a previous non-LTRM study entitled "Japanese hops control and management," implemented by the USACE and the National Great Rivers Research and Education Center (NGRREC), and awarded through a cooperative agreement issued by the Great Rivers Cooperative Ecosystem Studies Unit (CESU) and ERDC. This new proposed study represents a second phase of a project focused on identifying cost effective methods for: 1) eradicating and controlling invasive species in UMRS floodplains; and 2) reforesting areas that have been heavily colonized by invasive species. The previous study identified effective herbicide treatments for treating Japanese hops in the field, and documented the role of periodic flooding in redistributing Japanese seeds and providing a mechanism for it to recolonize treated sites. Results also indicated that traditional tree planting methods using bare root seedlings and containerized saplings were likely to fail without additional intensive maintenance requirements. Study findings are documented in a final report. This study will also complement a current gap study that is being funded by the UMRR Science in Support of Restoration and Management program by assessing reforestation techniques that could be utilized to close gaps.

Name of Principal Investigators:

Dr. Lyle Guyon, Terrestrial Ecologist, National Great Rivers Research & Education Center, One Confluence Way, East Alton, IL 62024; 618-468-2870; lguyon@lc.edu. Specific roles: project planning, implementation and oversight of monitoring activities, data analysis and report writing.

Robert Cosgriff, Lead Forester, USACE St. Louis District, 301 Riverlands Way, West Alton, MO 63386; 636.899.0074; robert.j.cosgriff@usace.army.mil. Specific roles: site selection, project planning and coordination, implementation and oversight of tree plantings and maintenance regimes.

Collaborators:

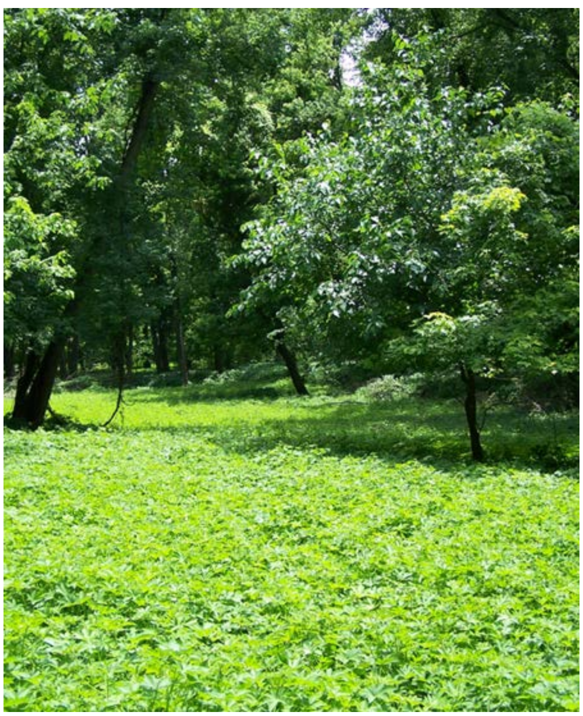
Ben Vandermyde, Lead Forester, USACE Rock Island District, PO Box 534, Pleasant Valley, IA 52767; 309.794.4522, ben.j.vandermyde@usace.army.mil. Specific roles: site selection, project planning, implementation and oversight of tree plantings and maintenance regimes.

Andy Meier, Forester, USACE St. Paul District; 651.290.5899; andrew.r.meier@usace.army.mil. Specific roles: site selection, project planning, implementation and oversight of tree plantings and maintenance regimes.

Introduction/Background:

Invasive species are increasing in abundance and dominance within the UMRS and have the ability to completely dominate and maintain a site in an invasive disclimax community. Within the UMRS, invasive species are dominating natural canopy gaps and preventing natural reforestation from occurring. This creates significant issues for natural resource managers trying to promote healthy forest communities and forest species and structural diversity. This project evaluates the effectiveness of artificial reforestation to quickly close canopy gaps and reduce the impact of invasive species commonly occurring throughout the UMRS.

Forest communities of the Upper Mississippi River System (UMRS) are highly productive, provide valuable habitat for many species of birds and wildlife, improve water quality, control erosion, and contribute to local and regional economies (Yin et al. 1997; Romano 2010; Guyon et al. 2012; Urich et al. 2002; Johnson and Hagerty 2008). These important communities have seen a significant decline in acreage, diversity and health since pre-settlement due to harvests, conversion to agriculture and altered hydrology (Yin et al. 1997). The declining trend has continued as community composition has shifted to a single dominant species and a lack of natural regeneration is occurring (Urich et al. 2002, Johnson and Hagerty 2008, Guyon et al. 2012, Guyon and Battaglia 2018). Invasive species are a significant contributor to the decline in forest community health and diversity by impacting natural forest regeneration (Urich et al. 2002, Guyon et al. 2012).



Reed canarygrass (*Phalaris arundinacea*), Japanese hops (*Humulus japonicus*) and Johnsongrass (*Sorghum halepense*) are invasive species that are causing significant natural regeneration issues on the UMRS (Adams et al. 2011, Guyon et al. 2012). These species are increasing in dominance and distribution across the UMRS. Reed canarygrass and Johnsongrass establish in dense, sod-forming monocultures that preclude other species. Mowing and herbicides are commonly used to control these species. However, complete eradication of the plant from a restoration or reforestation site rarely occurs and the site quickly becomes dominated by the two species following treatments. Both species are not shade tolerant (Maurer and Zedler 2002). Japanese hops (*Humulus japonicus*) is an invasive annual or weakly perennial vine species that has been spreading throughout the UMRS over the past 10-15 years and is found in all three USACE Districts on the UMRS. It readily establishes in forest canopy gaps and other open areas in riverine and riparian habitats, forms dense monocultures that inhibit the survival and growth of native species, and is particularly effective in suppressing tree and shrub regeneration. Analysis of forest inventory data from Mississippi River Pools 24, 25 and 26 suggest that 15-20% of the floodplain forest has Japanese hops existing in the understory, mostly in small gaps. Japanese hops exhibits a growth pattern typical of trailing vine species, and can generally climb to a height of about 15 feet. When it forms dense stands it can overtop and quickly outcompete native vegetation. It has a high light requirement, and observations indicate that it rapidly colonizes edge areas and canopy gaps in forested floodplain settings where it can exploit full available sunlight. As a highly shade intolerant species, it cannot survive beneath a closed forest canopy.

Canopy gaps are a natural occurrence in floodplain forests, and are created as trees succumb to disturbance events (e.g., flooding and wind) or senescence. Forests of the UMRS are dominated by species such as silver maple (*Acer saccharinum*) and eastern cottonwood (*Populus deltoides*) that are reaching the end of their life cycle in many areas and can create large canopy gaps when they die. The 1993 flood event created significant canopy gaps where between 30-70% mortality occurred in mature trees in lower UMRS pools (Yin et al. 1997; Cosgriff et al. 2007). Continued mortality has occurred due to more recent flooding and increased wind-throw from weakened canopy structure. An additional disturbance event that is just starting to impact UMRS forests is Emerald Ash Borer (EAB). Both Rock Island and St Paul Districts have sites with EAB. EAB causes 100% mortality in all species of ash. Green ash (*Fraxinus pennsylvanica*) is the second most dominant tree species within USACE St. Louis District Rivers Project Office floodplain forests and represents 20% of the total tree population. As green ash succumbs to EAB, additional canopy gaps will be created providing further opportunity for invasive species such as reed canarygrass, Johnsongrass and Japanese hops to become even more widespread.

Under natural forest successional dynamics, disturbance events would create canopy gaps of varying size and distribution. Species recruitment into the canopy gaps would be tied to inundation potential, gap size, soil texture, proximity to parent trees, herbivory, and seedling competition for light and nutrients. Initially, native lighter seeded species (*Populus deltoides*, *Salix nigra*, *Platanus occidentalis*) would occupy the gaps first. The life history of these species includes producing numerous small seeds that are readily distributed by wind and water. These species are also typically fast growing, closing forest gaps over the course of a few years and reducing competition with other forest species. There is the potential to use native, fast growing tree species to close existing forest gaps and reduce the impact of invasive species (Kim et al. 2006, Adams et al. 2011). Kim et al. was able to reduce reed canarygrass by 56-68% the second year after planting willow cuttings in Washington wetlands. Planted cuttings were 3 foot in length and between 0.5 and 1 inch in diameter and planted on a 2, 3 and 4 foot spacing. However, we believe that this cutting size and planting density would not be effective in gaps where Japanese hops is prevalent on the UMRS. Following a 2017 Japanese hops field trial using eastern cottonwood cuttings (7 foot in length), it was determined that the densest

planting (4 foot spacing) provided Japanese hops with an added advantage as it created a trellis between cuttings and quickly overtook the treatment site. Additionally, we determined that trees less than an inch in diameter were easily pulled over by Japanese hops. We believe that cuttings greater than an inch in diameter planted on a 4x8 foot or greater spacing will provide the best treatment to control invasive species on the UMRS.

This project will evaluate the effectiveness of black willow cuttings and eastern cottonwood and sycamore container stock in shading out invasive species on four sites within the UMRS. Two planting densities will be evaluated for black willow cuttings, 4x8 and 8x8 foot spacing. Container stock will be planted on a 16x16 foot spacing. Black willow easily establishes from cuttings, whereas 3 gallon container stock will provide plants with excellent root reserves for rapid growth within the first growing season. Additionally, half of each planting treatment will receive mowing and herbicide application on invasive species to evaluate the effect of standard management practices. We believe that fast growing trees, planted at the right density, will shade out invasive species. We are looking for a management approach that will require as few resources as possible and minimal need for future treatments to reduce invasive species vigor until the trees can become established. This is an important consideration as much of the UMRS floodplain forest resource is on islands and other difficult to access areas.

Relevance of research to UMRR:

Control and management of invasive species is necessary to prevent further degradation and maintain the health and sustainability of terrestrial floodplain habitat in the UMRS. These forest communities have declined in abundance, diversity and health since settlement. Current forest community health is declining because over-mature trees are reaching the end of their life cycle, there is an increase in the frequency and duration of flood disturbance events and EAB will have a catastrophic impact on the UMRS ash populations. There is the added potential for the establishment of invasive species with active management and the creation of reforestation sites, timber stand improvements and timber harvests. The overarching goal of this specific project is to identify effective reforestation methods, with and without traditional tree planting maintenance practices (e.g., herbicides, mowing), for use as a cultural treatment in the control and management of invasive species populations in UMRS floodplain forest habitats.

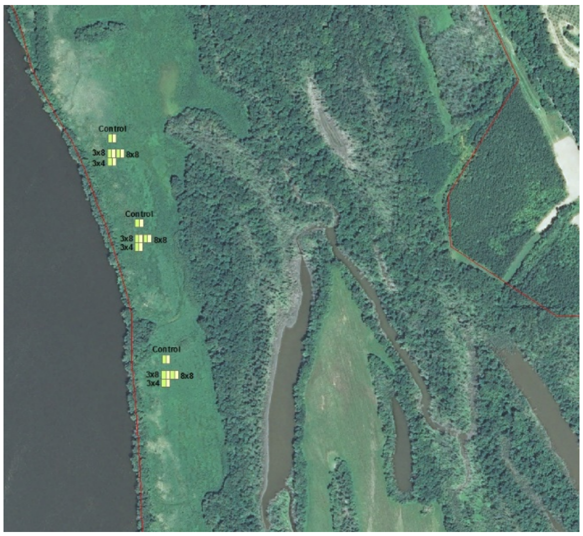
Specifically, this study will address the following questions:

1) Can artificial reforestation be used as a technique to close canopy gaps and reduce the abundance of invasive species such as reed canarygrass, Johnsongrass, and Japanese hops?
2) What is the most cost-effective planting density to achieve expedient canopy closure with minimal maintenance requirements?
3) Can successful reforestation be attained without the use of standard management maintenance techniques (mowing, herbicide application, etc…)?
4) Can early successional species be used to replace green ash following the establishment and spread of emerald ash borer throughout the UMRS floodplain?

This project will inform river restoration and management by determining planting densities and maintenance regimens necessary to control invasive species and rapidly establish floodplain forest canopy cover in impacted areas. It addresses sections vi and viii of 2018 Focal Area 4.2, Understand and Quantify Floodplain Vegetation Dynamics, by investigating the impacts of active forest management practices on invasive species and forest regeneration.

Methods:

The project will occur at four different study sites and have three replicates per location. Each study site is under a slightly different resource management regime but is significantly impacted by invasive species. Reds Landing in Pool 25 is an active 110 acre reforestation site that was first planted in 2013. This site had significant reed canarygrass and minimal Japanese hops present until a flooding event in 2014 brought in seed. Currently the site has a dense population of Japanese hops that is affecting survivorship and growth of tree seedlings and is replacing reed canarygrass as the dominant understory plant. The Timber Ridge Site is a 35 acre wetland restoration and reforestation site located along lower Piasa Creek, a tributary of the Mississippi River in Pool 26. This site has dense populations of Japanese hops, reed canarygrass and Johnsongrass. The third study site is located in Rock Island District near Bellevue, IA, adjacent to the confluence of the Maquoketa and Mississippi Rivers. This site has had a dense population of reed canarygrass that has recently been replaced with Japanese hops. The fourth study site is located in St. Paul District near Guttenberg, Iowa. This site has a dense population of reed canary grass. All four sites are exhibiting the typical lack of natural regeneration due to the prevalence of invasive species.



Within each replicate, there will be there will be four 1/10th acre study plots containing three planting densities and one control treatment. The study will have a split plot design where half of each treatment (1/20th acre) will receive maintenance and the other half will not. Due to the remote location of many Japanese hops populations, annual maintenance following planting will not be feasible in many areas, and this will hopefully allow us to identify a threshold for planting density that effectively eliminates the need for maintenance. In the study plots, we will compare survivorship and growth of large black willow cuttings planted at two different densities (4x8 ft and 8x8 ft) and 3 gallon eastern cottonwood and American sycamore (*Platanus occidentalis*) trees planted at one density (16x16 ft). Long term survivorship of trees is contingent on their ability to grow taller than competing herbaceous vegetation, and large cuttings should provide a size and growth advantage. Cuttings will be a minimum of seven feet in length and planted to a depth of approximately three feet using a hydro-spade, which utilizes high-pressure water to hydro-drill a planting hole for large diameter cuttings. Annual maintenance activities will include three mowing treatments, one pre-emergent herbicide (sulfometuron) application and one post-emergent herbicide (glyphosate) application. Each treatment block will be mowed around it to reduce the potential for lateral growth of Japanese hops into the plots.

Invasive species, other naturally occurring ground-layer vegetation, and planted trees within each study plot will be monitored twice a year over the course of the study. Initial sampling will occur prior to the first mowing each year to get a baseline assessment of invasive species and vegetation coverage at the sites. 100% of the trees planted in each treatment will also be measured at this time to determine over-wintering and flood survivorship. An additional monitoring effort will occur 2-4 weeks after the second maintenance treatment to determine seasonal invasive species and herbaceous plant production, coverage, and frequency of occurrence. 100% of the trees planted at each treatment will be measured again at this time to determine survivorship and seasonal growth rates.

Quantifiable data will be collected from ten 0.25 m^2 quadrats randomly located within each 1/20th acre split plot. Coverage of invasive species in each quadrat will be measured on a percent scale. Additional herbaceous layer vegetation will be recorded by species and percent cover. Subsequent to on-site measurements conducted during the second seasonal monitoring effort, aboveground invasive species biomass will be collected from three randomly selected quadrats in each split plot and brought back to NGRREC's laboratory to determine oven-dry weight. The dbh (diameter at breast height) and height of all planted trees at each study site will be recorded by species. Any naturally occurring tree regeneration greater than 1.37 m (4.5 ft) in height in the quadrats will also be tallied and recorded by species and size class (dbh and height).

Data analysis will follow a split plot experimental design testing for the effects of planting density and maintenance on several quantifiable measures of vegetation response including invasive species coverage and biomass, total vegetation species richness, diversity and coverage, and survivorship and growth of planted trees.

Special needs/considerations:
None

Timeline:
The proposed period of performance is April 1, 2019 – March 31, 2021.

Products and Milestones

Tracking number	Products	Staff	Milestones
2019ref1	Progress report	Guyon and Cosgriff	30 Dec. 2019
2019ref2	Progress report	Guyon and Cosgriff	30 Dec. 2020
2019ref3	Draft LTRM Completion report	Guyon and Cosgriff	31 March 2021
2019ref4	Final LTRM Completion report	Guyon and Cosgriff	30 Dec. 2021

References:

Adams, C., Kauth, P., and Sorenson, J. 2011. Assessing competition between reed canary grass (*Phalaris arundinacea*) and swamp white oak (*Quercus bicolor*). Ecological Restoration 29(4), 332-338.

Cosgriff, R.J., Nelson, J.C., Yin, Y., 2007. Floodplain forest response to large-scale flood disturbance. Transactions of the Illinois State Academy of Science 100 (1), 47-70.

Guyon, L. and Battaglia, L. 2018. Ecological characteristics of floodplain forest reference sites in the Upper Mississippi River System. Forest Ecology and Management 427 (1), 208-216.

Guyon, L., Deutsch, C., Lundh, J., Urich, R., 2012. Upper Mississippi River Systemic Forest Stewardship Plan. United States Army Corps of Engineers.

Johnson, B.L., Hagerty, K. H. (Eds.), 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. 102 pp + Appendixes A–B.

Kim, D., Ewing, K, Giblin, D. 2006. Controlling *Phalaris arundinacea* (reed canarygrass) with live willow stakes: A density-dependent response. Ecological Engineering 27, 219-227.

Maurer, G. and Zedler, J. 2002. Differential invasion of a wetland grass explained by tests of nutrients and light availability on establishment and clonal growth. Oecologia 131, 279-288.

Romano, S. P., 2010. Our current understanding of the Upper Mississippi River System floodplain forest. Hydrobiologia 640(1), 115-124.

Urich, R., Swenson, G., Nelson, E., 2002. Upper Mississippi and Illinois River Floodplain Forests: Desired Future and Recommended Actions. Upper Mississippi River Conservation Committee. Rock Island, IL.

Yin, Y., Nelson, J.C., Lubinski, K.S., 1997. Bottomland hardwood forests along the Upper Mississippi River. Natural Areas Journal 17(2), 164-173.

Combining genetics, otolith microchemistry, and vital rate estimation to inform restoration and management of fish populations in the UMRS

Previous and ongoing LTRM projects:
In FY2018, UMRR funded a project titled *Investigating vital rate drivers of UMRS fishes to support management and restoration*. That ongoing project examines several vital rate functions of a suite of fishes that represent a spectrum of ecological survival strategies. A microchemistry component was also funded as part of the vital rate project, to provide information on natal origins of the specimens collected. This ancillary proposal would assess the role of genetic distinctiveness, at the scale of the LTRM study reaches, on the growth, recruitment, and mortality rates quantified in the previous proposal. The natal origins and genetic distinctiveness of fish populations may have great influence on vital rate functions, and these are foundational in the understanding of any differences observed in the vital rates themselves. Our research will therefore facilitate improved understanding of the mechanisms behind observed changes in fish populations, which is emphasized in focal area 5.2. Additionally, the genetic samples that will be used in the proposed research have already been collected as part of the project funded in FY2018; this substantial previous effort will significantly reduce the budget of our proposed research because we do not need to allocate funds for sample collection.

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The following individuals will oversee project components, conduct data analyses, and write manuscripts:
Genetics – Wes Larson (Assistant Unit Leader, USGS Coop Unit, UW-SP, wes.larson@uwsp.edu) and postdoctoral researcher.

Introduction/Background:
Most organisms exhibit substantial intraspecific diversity that can include variation in traits such as growth, age-at-maturity, reproductive phenology, and homing fidelity (Hooper et al. 2005). This within species diversity stabilizes ecosystem processes and promotes food web and fisheries sustainability (i.e. portfolio effect, Schindler et al. 2010). It is therefore extremely important to develop management strategies that preserve diverse portfolios of intraspecific diversity (DuFour et al. 2015, Schindler et al. 2015). The first step in developing management strategies that accomplish this goal is deciding which components of the portfolio should be managed separately. Genetic data have been most frequently used for this purpose because they provide important information on evolutionary history as well as historic and contemporary connectivity (Funk et al.

2012). However, much greater accuracy and resolution of management units can be achieved when multiple data sources are combined. For example, discrete management units for Pacific salmon are defined using genetic, demographic, and ecological data (Waples 1991). The overarching goal of our proposal is to combine genetic data collected here with data from the previously funded project *"Investigating vital rate drivers of UMRS fishes to support management and restoration"* to provide a robust body of research that will allow managers to confidently define management units and prioritize habitats for restoration.

Genetic data provide an excellent tool to define management units because they allow researchers to determine how life-history diversity influences population connectivity and demography. For example, species that are migratory or are able to move large distances have an increased ability to exchange genes between populations, and may therefore exhibit reduced genetic population structure across broad spatial scales (Bohonak 1999). In contrast, species that have limited dispersal tend may have more genetically distinct populations. Additionally, genetic data facilitate investigation of the impacts of habitat fragmentation on connectivity. Specifically, reduced connectivity of habitat patches due to fragmentation can alter the exchange rates between populations and lead to population differentiation in species that may not have historically displayed these patterns.

While using genetic data to define discrete management units for well-studied species, such as Pacific salmon, is relatively feasible, this task is much more difficult in systems such as the UMRS, where many more species exist, and less research funding is generally available. Additionally, we have almost no knowledge of population genetic structure in the UMRS because little genetic data has been previously collected (but see Bessert and Ortí 2008). For these reasons, we have decided to analyze representative species encompassing a broad suite of life-histories to ensure that our findings will be broadly applicable. Specifically, we will analyze genetic data from the following six species collected at the six LTRM field stations: emerald shiner, bullhead minnow, channel catfish, freshwater drum, bluegill, and gizzard shad. These species range from relatively sedentary (e.g. bluegill) to highly vagile (e.g. channel migratory) and display a variety of reproductive strategies and population dynamics. We expect a spectrum of genetic isolation to occur across our study species in the UMRS. For example, we expect that nest building lentic fishes, such as centrarchids, will display higher levels of genetic differentiation among LTRM reaches than pelagic spawning lotic fishes, such as freshwater drum (e.g.(Stepien et al. 2007). We also expect that fragmentation within the riverine landscape through physical barriers or reduced connectivity of habitat patches has altered the exchange rates between populations and lead to population differentiation.

Once genetic structure is determined, these data can be paired with vital rates to determine how rates correspond to genetic stock boundaries and paired with microchemistry data to investigate patterns of connectivity across multiple timescales. Including this diverse array of species and data types will allow us to define conservation units based on life-history strategies that can be applied to other species. In other words, examining this broad array of species will allow us to make important inferences about species not included in the project and possibly define conservation units for these other species without having to obtain additional data. The primary objectives of our project are to 1) determine the genetic population structure and diversity of six UMRS fishes, 2) determine if different genetic stocks of the same species exhibit differences in vital rates or natal origins as inferred from otolith microchemistry, and 3) define management units based on life-history strategies that can be used to inform conservation and restoration efforts.

Relevance of research to UMRR:
Our proposed research addresses Focal Area 3 (Interactions and associations of hydrogeomorphology with biota and water quality) and Focal Area 5 (Vital rates of biotic communities) of the 2018 Focal Areas for UMRR Science in Support of Management. Specifically, our proposal most directly addresses Focal Area 3 subarea 2 and focal area 5 subarea 2. We outline how our proposal directly addresses these focal areas below.

The primary objectives of subarea 3.2 are to (1) determine if functional diversity in UMRS fish communities is related to habitat diversity and (2) determine the spatial patterns of life history diversity in the UMRS and how this relates to past and present environmental conditions. The primary objective of subarea 5.2 is to better understand the mechanisms behind observed changes in fish populations and the implications of these changes for UMRS management. We believe our project can address the following three questions that are related to these focal areas: (1) How does habitat diversity shape population diversity?, (2) How has population diversity changed over time?, and (3) How can we use information on population diversity to inform management?

Our project will investigate genetic structure and diversity of six species sampled across a broad range of habitats in the UMRS. Using these data, we will be able to understand how different habitat characteristics shape population genetic characteristics within and among species. For example, it is possible that more lentic species, such as bluegill, will display higher genetic diversity in reaches with a predominance of impounded habitats compared to riverine habitats, indicating that bluegill populations in lentic habitats are genetically healthier and more robust. Lotic species, on the other hand, may exhibit an opposite pattern. This information will be valuable for prioritizing habitats for conservation. In other words, genetic data will facilitate identification of genetically robust populations that are currently healthy as well as genetically weak populations that may require management intervention to persist. Knowledge of spatial genetic structure will also allow managers to better scale management interventions towards specific management goals. For example, if populations are structured at relatively fine scales (e.g., Navigation Pool), assessment and restoration of important habitats for those species will be best examined at a similar spatial scale. This will allow managers to restore spawning, nursery, overwintering, and feeding habitats at relevant spatial scales to ensure that management actions result in desired outcomes.

Additionally, genetic data will allow us to investigate how changes to the UMRS environment over time have impacted different species and populations. The lock and dam system on the UMRS has clearly impacted connectivity among populations, but our knowledge of these impacts is based primarily on tagging data and is therefore relatively limited in scope. Genetic data, on the other hand, can elucidate population-wide effects of barriers to connectivity and help to determine how locks and dams have impacted certain species and populations. Many long-standing questions related to connectivity that are relevant to the management exist in the UMRS, and genetic analyses will allow the UMR community to re-examine these questions. For example, Lock and Dam 19 is known to be a barrier to fish movement, though not impenetrable. Through evaluating genetic structure of six species across the six LTRM field stations, we will better understand where intermixing between populations occurs across species with different life histories and be able to assess whether certain physical barriers influence population structure and diversity.

The genetic information collected in this project is highly complementary to the previously funded project "*Investigating vital rate drivers of UMRS fishes to support management and restoration"* and the combination of the data collected in both projects will be useful for addressing UMRR focal areas. Age, growth, recruitment and mortality data that is being collected as part of the currently funded study will provide information on spatial patterns of populations dynamics; this information can then be used to investigate possible mechanisms explaining the changes in fish abundance and community structure that have been observed in the UMRS. However, the ability to interpret vital rate data will be somewhat limited if no genetic data are available because genetic population structure and vital rates could be linked. For example, two sampling sites could differ in vital rates because of, differences in habitat conditions, differences in population structure, or a combination of both factors. If no differences in genetic population structure are found between sites, researchers can safely assume that the observed differences are likely due to environmental conditions. However, if population structure is found between sites, differences could be due to inherent genetic differences between populations. These separate scenarios have significant implications for management. Specifically, if population structure and vital rates are linked, then it may be unrealistic to expect a desired fish response (i.e. increased size structure of bass) to a habitat project in a given area, simply because that stock of fish is incapable of producing that response. For example, a perceived growth bottleneck may be the result of a genetically isolated population of fish that exhibits poor growth beyond a certain size (Miller et al. 2009).

Combining genetic results from this project with microchemistry data obtained from the previously funded project will also be vital for data interpretation and will lead to a more complete understanding of the spatial ecology of fishes in the UMRS that will be useful for constructing management units. Specifically, microchemistry provides data on where fish reside in their early life history whereas genetic analysis provides data on the spatial extent and rate that populations exchange migrants over evolutionary timescales (100s to 1000s of years). Often, the conclusions drawn from these two methods can differ because of the timescales they reflect. For example, Collins et al. (2013) used otolith microchemistry to infer that populations of a neotropical fish in Venezuela used separate breeding grounds, but these populations did not display any significant genetic structuring based on genetic analysis. This result highlights the importance of employing both otolith microchemistry and genetic analysis when investigating connectivity. It is likely that populations in the currently funded project will display differences in otolith microchemistry signatures. However, without genetic data, it will be impossible to determine whether those differences are the result of longstanding patterns of connectivity or simply habitat choice on short timescales.

The primary goal of this body of research (previously funded proposal and current proposal) is to provide information that managers can use to design conservation and restoration strategies that target appropriate scales. Our data will facilitate the creation of spatially explicit management units that are also tailored to specific life history strategies. This will allow managers to prioritize habitat preservation, restoration, and modification projects that achieve maximum positive impact while also reducing wasted effort. It is important to emphasize the fact that, to achieve this goal, data from all three sources (vital rates, otolith microchemistry, genetics) are necessary. Funds to obtain data on vital rates and otolith microchemistry have already been secured, and all genetic samples have been collected. We are requesting funds to complete the genetic analysis associated with this project to ensure that we are able to create a useful and comprehensive research product that will significantly improve management of the UMRS.

Methods:

Sample collection

Analysis of genetics, vital rates, and otolith microchemistry will be conducted on six species that were previously selected in the funded proposal "*Investigating vital rate drivers of UMRS fishes to support management and restoration."* These species were carefully chosen based on 1) life history strategy, 2) systemic and regional distribution, and 3) the ability of LTRM field stations to collect the majority of samples during regular LTRM field sampling (Table 1). Extensive sampling was conducted in summer and fall 2018 to collect data for the previously funded project and to collect genetic samples that could be paired with those data at a later date. This sampling occurred at pool 4 (Lake City, Minnesota, RKM 1210-1283), pool 8 (La Crosse, Wisconsin, RKM 1092-1131), pool 13 (Bellevue, Iowa, RKM 841-896), pool 26 (Alton, Illinois, RKM 325-389), La Grange Pool (Illinois River, RKM 129-254) and the open river (Cape Girardeau, Missouri, RKM 47-129). Target sample sizes for genetic analysis were 50 samples per species per LTRM site representing a total of 1,800 samples. LTRM field crews collected 1,841 genetic samples (Table 1), providing a robust sample for genetic analysis. We will randomly subsample the gizzard shad taken from Pool 26 from 108 to 67 to achieve our target sample size of 1,800.

Table 1. Species selected for estimation of vital rates, microchemistry and genetic analyses. The number of fin clips collected in FY18 from individual fish of each species are included for each LTRM study reach.

Species	**Life history strategy**	**Pool 4**	**Pool 8**	**Pool 13**	**Pool 26**	**Open River**	**La Grange**
Emerald shiner	Opportunistic	50	51	51	50	50	52
Bullhead minnow	Opportunistic	33	31	39	32	50	51
Channel catfish	Equilibrium	41	50	50	71	45	59
Freshwater drum	Periodic	50	50	50	50	50	53
Bluegill	Equilibrium	50	84	51	50	21	50
Gizzard shad	Periodic	50	50	53	108	50	65

Genetic analysis
Genetic analysis will be led by Dr. Wes Larson and primarily conducted by a postdoctoral researcher in the Larson Laboratory at UW-Stevens Point. The first step in genetic analysis is to genotype genetic markers across the genome, as these genetic markers each provide information of population history, demography, and genetic diversity. Genotyping for the proposed project will be conducted using a genomic technique termed restriction-site associated DNA (RAD) sequencing that will facilitate genotyping of thousands of genetic markers per species. RAD sequencing employs a restriction enzyme (in this case *SbfI*) to fragment the genome into thousands of small pieces, which are then sequenced on a high-throughput platform, such as the HiSeq4000 (Illumina, San Diego, CA). Single-nucleotide polymorphisms (SNPs) are then discovered and genotyped from the sequence data. RAD sequencing is currently the most commonly employed technique to genotype thousands of SNPs in non-model organisms and was a significant catalyst for the genomics revolution in these organisms (Andrews et al. 2016). Dr. Wes Larson has over half a dozen funded projects that utilize RAD and is considered a regional expert on this method.

RAD sequencing will be conducted using the "Best RAD" method described in Ali et al. (2016). After RAD data are obtained, we will use the program STACKS (Catchen et al. 2013) to identify and genotype SNPs from RAD data, and SNP filtering will be conducted using the methods outlined in Larson et al. (2014) to produce a final dataset of high-quality SNPs. SNP genotype data will be used in population genetic analyses to investigate population structure at neutral and adaptive markers, test for association between genetic and environmental data, and estimate various genetic diversity metrics. Patterns of population structure will be assessed for each dataset using statistical analyses such as analysis of molecular variance (Excoffier et al. 1992), Bayesian clustering analysis (Pritchard et al. 2000), discriminant analysis of principal components (Jombart and Ahmed 2011), and individual-based principal component analysis (PCoA). Three of these analyses are individual-based, facilitating detection of population admixture and potential straying. We will also calculate various estimates of genetic diversity, including observed and expected heterozygosity, allelic richness, and the proportion of polymorphic SNPs in each population. Finally, we will estimate effective population size (N_e), which will allow us to determine roughly how many breeding individuals contribute offspring to the next generation in each population.

The suite of genetic metrics that we obtain will provide important information about connectivity and genetic health of the populations and species included in the study. For example, comparing patterns of genetic structure will allow us to identify common barriers to migration, such as dams, that influence connectivity across multiple species. Additionally, this information will allow us to determine whether certain species respond differently to the same habitat feature. For example, certain habitat features may potentially impede movement of some fish but not others. Finally, estimates of genetic diversity obtained in this study will provide information about the genetic health of populations that may not be obvious based on traditional metrics. This information will allow us to determine whether certain populations may have undergone recent bottlenecks and may therefore be genetically compromised. These potentially compromised populations may be more vulnerable to future environmental changes as well as stressors such as disease outbreaks and extreme conditions.

Constructing management units
We will use data from genetic analyses, vital rate estimates, and otolith microchemistry to define spatially appropriate management units for six fish species that span a range of life history strategies. First, we will compare data from these three sources for all species separately to determine whether consistent patterns exist. For example, do we see consistent differences in vital rates, genetic structure, and microchemical signatures across similar spatial scales? Next, we will integrate data across multiple species to determine conserved trends and trends that are not shared. In this phase, we may observe that certain locks and dams or other habitat features appear to be barriers to connectivity for all species whereas other may only be barriers for a few species. Finally, we will synthesize all of this information and propose management units that are specifically tailored to various species and life-history types. These management units can then be used to improve the impact and efficiency of conservation and restoration projects.

Special needs/considerations, if any:

Timeline:
A timeline table is provided with project tasks and estimated dates of completion (Table 3). Data collection occurred during regular LTRM fish field sampling in 2018. Processing of samples will occur from late 2019 through 2020. Analysis and reporting will occur annually with the final report due in late 2021.

Table 2. A general timeline of all project components and tasks.

		2019			2020			2021		
	Task	Spr	Sum	Fall	Spr	Sum	Fall	Spr	Sum	Fall
Genetics	Laboratory analysis									
	Statistical analysis									
	Genetics Final Report/Manuscripts									

Products and Milestones

Tracking number	Products	Staff	Milestones
2019gen1	Progress report	Larson, Bartels, Bouska	30 Dec. 2019
2019gen2	Progress report	Larson, Bartels, Bouska	30 Dec 2020
2019gen3	Draft manuscript	Larson, Bartels, Bouska	30 Dec. 2021

Expected milestones and products:
Annual progress reports will be provided in the summer of each year. At the completion of this project, manuscripts will be prepared, published, and shared with the partnership. All manuscripts will be submitted no later than December 2021. Research products will come in the form of written documents, in addition to power point presentations at regional UMRS-related meetings.

Literature Cited

Ali, O. A., S. M. O'Rourke, S. J. Amish, M. H. Meek, G. Luikart, C. Jeffres, and M. R. Miller. 2016. RAD Capture (Rapture): Flexible and Efficient Sequence-Based Genotyping. Genetics **202**:389-+.

Andrews, K. R., J. M. Good, M. R. Miller, G. Luikart, and P. A. Hohenlohe. 2016. Harnessing the power of RADseq for ecological and evolutionary genomics. Nature Reviews Genetics **17**:81-92.

Bessert, M. L., and G. Ortí. 2008. Genetic effects of habitat fragmentation on blue sucker populations in the upper Missouri River (Cycleptus elongatus Lesueur, 1918). Conservation Genetics **9**:821-832.

Bohonak, A. J. 1999. Dispersal, gene flow, and population structure. Quarterly Review of Biology **74**:21-45.

Catchen, J., P. A. Hohenlohe, S. Bassham, A. Amores, and W. A. Cresko. 2013. Stacks: an analysis tool set for population genomics. Molecular Ecology **22**:3124-3140.

Collins, S. M., N. Bickford, P. B. McIntyre, A. Coulon, A. J. Ulseth, D. C. Taphorn, and A. S. Flecker. 2013. Population Structure of a Neotropical Migratory Fish: Contrasting Perspectives from Genetics and Otolith Microchemistry. Transactions of the American Fisheries Society **142**:1192-1201.

DuFour, M. R., C. J. May, E. F. Roseman, S. A. Ludsin, C. S. Vandergoot, J. J. Pritt, M. E. Fraker, J. J. Davis, J. T. Tyson, J. G. Miner, E. A. Marschall, and C. M. Mayer. 2015. Portfolio theory as a management tool to guide conservation and restoration of multi-stock fish populations. Ecosphere **6**.

Excoffier, L., P. E. Smouse, and J. M. Quattro. 1992. Analysis of molecular variance inferred from metric distances among DNA haplotypes: application to human mitochondrial DNA restriction data. Genetics **131**:479-491.

Funk, W. C., J. K. McKay, P. A. Hohenlohe, and F. W. Allendorf. 2012. Harnessing genomics for delineating conservation units. Trends in Ecology & Evolution **27**:489-496.

Hooper, D. U., F. S. Chapin, J. J. Ewel, A. Hector, P. Inchausti, S. Lavorel, J. H. Lawton, D. M. Lodge, M. Loreau, S. Naeem, B. Schmid, H. Setala, A. J. Symstad, J. Vandermeer, and D. A. Wardle. 2005. Effects of biodiversity on ecosystem functioning: A consensus of current knowledge. Ecological Monographs **75**:3-35.

Jombart, T., and I. Ahmed. 2011. adegenet 1.3-1: new tools for the analysis of genome-wide SNP data. Bioinformatics **27**:3070-3071.

Larson, W. A., L. W. Seeb, M. V. Everett, R. K. Waples, W. D. Templin, and J. E. Seeb. 2014. Genotyping by sequencing resolves shallow population structure to inform conservation of Chinook salmon (Oncorhynchus tshawytscha). Evolutionary Applications **7**:355-369.

Miller, L. M., S. W. Mero, and J. A. Younk. 2009. The Genetic Legacy of Stocking Muskellunge in a Northern Minnesota Lake. Transactions of the American Fisheries Society **138**:602-615.

Pritchard, J. K., M. Stephens, and P. Donnelly. 2000. Inference of population structure using multilocus genotype data. Genetics **155**:945-959.

Schindler, D. E., J. B. Armstrong, and T. E. Reed. 2015. The portfolio concept in ecology and evolution. Frontiers in Ecology and the Environment **13**:257-263.

Schindler, D. E., R. Hilborn, B. Chasco, C. P. Boatright, T. P. Quinn, L. A. Rogers, and M. S. Webster. 2010. Population diversity and the portfolio effect in an exploited species. Nature **465**:609-612.

Stepien, C. A., D. J. Murphy, and R. M. Strange. 2007. Broad- to fine-scale population genetic patterning in the smallmouth bass Micropterus dolomieu across the Laurentian Great Lakes and beyond: an interplay of behaviour and geography. Molecular Ecology **16**:1605-1624.

Waples, R. 1991. Pacific salmon, *Oncorhynchus* spp., and the definition of 'species' under the Endangered Species Act. *Mar. Fish. Rev.* 53, 11-22.

The Role of Large Wood in The Restoration of Habitat in the Upper Mississippi River System

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Introduction/Background:

Large wood has been recognized by biologists and river managers as an important tool in restoration. It provides a direct linkage between terrestrial and aquatic environments and plays a variety of significant geomorphic and ecological roles (Gregory et al. 2003, Wohl 2017). Large wood can change channel geometry and bedforms by affecting sediment storage and deposition patterns, influence local inundation and sediment dynamics on the floodplain via log jam formation, and affect water flow and biophysical processes in the hyporheic zone (Abbe and Montgomery 2003, Gurnell et al. 2002, Keller and Swanson 1979). Large wood also provides habitat for aquatic and terrestrial organisms, influences biogeochemical cycles, and serves as germination sites for plant propagules on the floodplain and on mobile floating log rafts (Collins et al. 2012, Lehtinen et al. 1997, Steel et al. 2003).

Large wood has been historically abundant in many streams and rivers but has often been systematically removed for hazard prevention or navigational purposes. The removal of large wood may have had cascading effects on riverine ecological communities by reducing the availability of important aquatic and terrestrial habitat structure, refugia from predators, and substrate for primary and secondary producers (USBR 2016). As a result, many restoration projects integrate woody structures to reestablish habitat and ecological processes in streams and rivers (Roni et al. 2015). The use of large wood in restoration efforts has generally focused on restoring local sport fish populations, but there are many other well documented, positive impacts on broader fish assemblages and other aquatic organisms (Lehitnen et al. 1997, Mott 2006, Coe et al. 2009, Entrekin et al. 2009).

Despite these important functions and habitat benefits, there has been very little research on large wood in great rivers, including the Upper Mississippi River System (UMRS), and even less on the use of large wood as restoration tools (Gregory et al. 2003). The few studies that have examined large wood in the UMRS have contributed some knowledge about basic eco-geomorphic patterns and relationships, but many critical gaps remain. Past studies in the UMRS have either focused on documenting the static spatial distribution of large wood along the main channel in association with shoreline cover types (Angradi et al. 2009, Angradi et al. 2010) or have examined its importance as a habitat attribute for predicting fish species occurrence (Ickes et al. 2014, Budd et al. in prep). However, there are far fewer studies that provide information on the dynamic nature of large wood in river systems or its broader ecological importance across habitats (USACE 2004, Angradi et al. 2009, USACE 2013). Specifically, organisms of management interest (e.g., waterfowl, turtles) and that are foundational to a healthy, resilient ecosystem (e.g., invertebrates, periphyton) can benefit from large wood (Lehitnen et al. 1997, Lindeman 1999, Angradi et al. 2009). Large wood in the UMRS has been shown to host very high abundances of caddis flies, for example, that are a rich food source for higher trophic levels (Haro, in prep).

The paucity of large wood research in the UMRS is problematic from both a basic science standpoint as well as a practical management standpoint. First, large wood may likely have an increasingly influential role in the UMRS as the result of changes in floodplain forests and altered hydrology. We expect increased movement of new wood into aquatic habitats as large stands of even-aged silver maple reach their longevity and green ash trees are killed by the invasive emerald ash borer. Increased channel bank erosion from more frequent and intense inundation events could also impact the sourcing of large wood in the river system and inputs from tributaries. It is therefore critical to understand the contribution of large wood to habitat creation as well as its role in supporting upper trophic levels so as to anticipate any management actions to respond to any potentially cascading effects of future environmental changes.

In addition, the Upper Mississippi River Restoration Program (UMRR) incorporates large wood in many of the restoration projects, yet very little is known whether these inclusions contribute to the stated goals of the project. There are two primary goals for the inclusion of large wood: 1) to provide habitat in the form of loafing structures for vertebrates such as turtles, eagles, and waterfowl, and 2) to aid in bank stabilization via rock-log structures and vanes (Figure 1; USACE 2013) with the assumption that the large wood also benefits wildlife and/or aquatic communities. Limited knowledge or monitoring regarding the fate and effectiveness of large wood with these different project goals is available. In addition, how the effect of placed wood varies in comparison to naturally occurring large wood or placed rock features, or when used across different environmental settings in the river, is largely unknown. Such information could inform future restoration projects by allowing managers to anticipate the effectiveness of incorporating large wood in settings with a given set of environmental conditions.

The primary goal of this project is to evaluate the ecological role of large wood in the UMRS, including existing wood structures included in HREPs and other bank stabilization projects and naturally occurring wood, so that river managers have a fuller understanding of the ecological implications of integrating wood into projects. We will achieve this by conducting field surveys of placed and naturally occurring large wood across project sites, measuring colonization rates of primary producers and invertebrates on experimentally placed wood pieces, and monitoring large wood for above-water use by vertebrates. We will address the following questions:

1. What is the fate and effectiveness of large wood features integrated into restoration projects in the UMRS?
2. What is the abundance of naturally-occurring large wood on restoration projects, and what factors influence this abundance?
3. How do environmental characteristics (e.g., flow velocity, depth) and tree species (green ash vs. silver maple) influence aquatic community assemblage and colonization rates on large wood?
4. What vertebrate animals use large wood on HREPs, and how does their use vary seasonally and spatially?

Relevance of Research to UMRR:

The proposed research will improve our understanding of the ecological role of large wood in the UMRS. Such information can inform future project selection and design by documenting relationships among large wood, aquatic organisms, and local habitat conditions. We anticipate this work will help inform methods of habitat restoration and management in the UMRS and other great rivers. This research addresses the follow themes and focal areas from the 2018 Science Meeting Focal Areas document: Theme 2, Focal Area 3, **Subarea 3.4**: associations between hydrogeomorphology and the quantity, distribution, and biophysical role of woody debris in the UMRS. Also, Theme 2, Focal Area 4, **Subarea 4.4**: understand effects of vegetation dynamics on wildlife use of the UMRS floodplain, will be addressed.

Methods:

This research project will include three complementary components: 1) a one-time survey of three types of wood structures used in restoration projects to understand the fate of large wood and associations with various environmental factors, 2) repeated surveys of large wood on island HREPS to understand natural wood recruitment in contrasting environmental settings, combined with an experiment to understand how new wood is colonized by primary (periphyton) and secondary (macroinvertebrates) producers that form the basis of the aquatic food web, and 3) a wildlife-use study focused on island HREPs using camera traps to understand vertebrate use. We describe these three components below.

Table 1. Locations of proposed sites in Pools 4, 5, 7, 8, and 9 of UMRS to be studied.

Project Name	Feature Name	Pool	Large Wood Structure Type	Year Constructed	Large Wood Primary Function	Aquatic Habitat Setting
Spring Lake Islands HREP	Deep Hole Island	5	Loafing Structure	2006	Wildlife Habitat	Contiguous Impounded Area
Spring Lake Islands HREP	Bulrush Island	5	Loafing Structure	2006	Wildlife Habitat	Contiguous Impounded Area
Spring Lake Islands HREP	Snipe Island	5	Loafing Structure	2006	Wildlife Habitat	Contiguous Impounded Area
Pool 8 Phase III Islands HREP	Horseshoe Island - West	8	Loafing Structure	2012	Wildlife Habitat	Contiguous Floodplain Shallow Aquatic Area
Pool 8 Phase III Islands HREP	Broken Bow Island	8	Loafing Structure	2012	Wildlife Habitat	Contiguous Floodplain Shallow Aquatic Area
Pool 8 Phase III Islands HREP	Snake Tongue Island	8	Loafing Structure	2012	Wildlife Habitat	Contiguous Floodplain Shallow Aquatic Area
Capoli Slough HREP	Island C-E-E1	9	Loafing Structure	2016	Wildlife Habitat	Contiguous Impounded Area + Main Navigation Channel
Capoli Slough HREP	Island G	9	Loafing Structure	2016	Wildlife Habitat	Contiguous Impounded Area + Main Navigation Channel
Harpers Slough HREP	HS Island	9	Loafing Structure	2016	Wildlife Habitat	Contiguous Impounded Area
Pool 8 Phase III Islands HREP	Upriver of Cant Hook Island	8	Rock-Log Structure	2013	Bank Stabilization	Contiguous Impounded Area + Main Navigation Channel
Rosebud Island Bank Stabilization	Rosebud Island	7	Rock-Log Structure	2003	Bank Stabilization	Contiguous Impounded Area
Red Wing Wildlife League Bank Stabilization	RWWL	4	Vane/Groin	2011	Bank Stabilization	Main Navigation Channel
Temporary Placement Sites	Teepeeola Island	4	Vane/Groin	2003	Bank Stabilization	Main Navigation Channel
Temporary Placement Sites	Crats Island	4	Vane/Groin	2003	Bank Stabilization	Main Navigation Channel

Component 1: Survey of Large Wood Features

For the survey, we have proposed sites located in Pools 4, 5, 7, 8, and 9 that include woody structures with the primary functions of either bank stabilization or as wildlife habitat. We propose to include nine HREP island sites that included wood as loafing structures as well as three sites that incorporated wood into rock vanes and two HREP sites that contain integrated rock-log structures for bank stabilization (Table 1, Figure 1). These sites were identified with assistance from Rock Island District USACE scientists, but final site selection will be done with input from additional agencies.

We will do a one-time survey of environmental characteristics, wood abundance, and macroinvertebrate and periphyton biomass on wood (and rock as applicable) at all sampling locations in Summer 2019 to assess the effects of large wood used in different types of projects (Table 1, Figure 1). On the nine HREP islands, we will sample two sites at each of the nine locations for a total of 18 unique sampling sites. Each sampling site will span 30 m of shoreline; we will select shoreline areas which contain large wood placed as part of the HREP design. To understand the effect of using wood across differing environmental settings, the two sampling sites will be located on island shorelines exposed to contrasting flow-velocity conditions – one exposed to relatively high-velocity flows and the other exposed to relatively low-velocity flows. At the RWWL, Teepeeola Island, and Crats Island sampling locations, we will sample three vanes with wood and three vanes

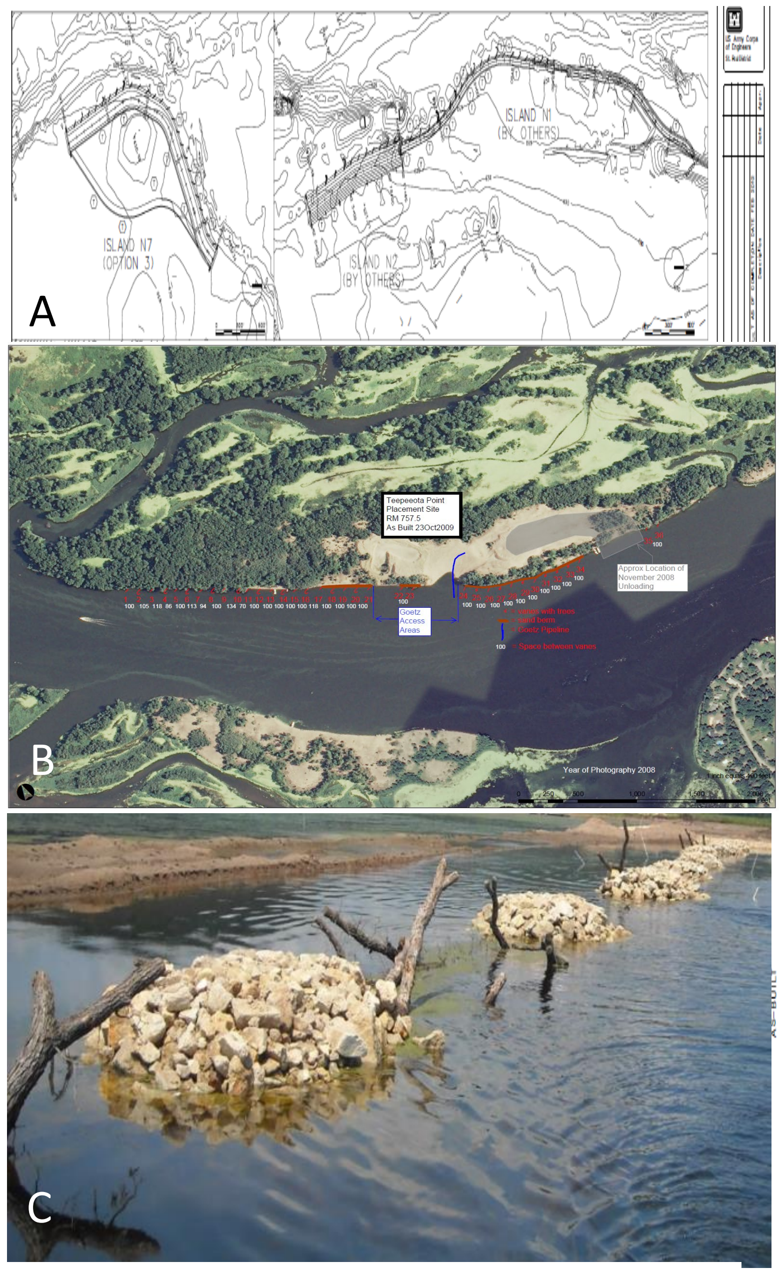

Figure 1. A) Diagram of placed wood features on Phase III Pool 8 Islands, indicated by a "T", B) Aerial photograph of vanes at Teepeeota Island, vanes with cross hatch contain wood, C) Rock-log structure in Pool 8.

without wood (except at Crats Island which only has two) for a total of 16 unique sampling sites. We will sample within a 5 m radius of each vane. At each of the two rock-log structure locations, we will select an area that includes three rock and three wood sites for a total of 12 unique sites. Site selection at sampling locations will occur in May-June 2019.

Below-water site characterization will include flow velocity, depth profiles, and substrate composition. We will use side-scan Lowrance sonar units mounted to the RSC boat to record river bed profiles and submerged large wood along each sample site. We will measure flow velocity up and downstream of structures. Above water, we will record the abundance, length, mean diameter, orientation in relation to river flow, structural complexity of large wood at the sample site, and proximity to other wood pieces following the recommendations of Wohl et al. (2010). We will compare the abundance and composition of macroinvertebrate communities and periphyton biomass on natural and engineered woody structures at each site as well as rocks at the vane/groin and rock-log structures. We will use macroinvertebrates and periphyton sampling methods for wood substrates in large rivers as detailed in Angradi et al. (2009) and Coe et al. (2006). Samples will be returned to the lab at UWL for macroinvertebrate processing, identification and chlorophyll analysis.

Environmental characteristics and structure type will be statistically evaluated for their ability to explain differences in large wood, macroinvertebrate and periphyton abundance across sites.

Component 2: Recruitment and Colonization of Large Wood on Island HREPs

For the recruitment and colonization study, we will focus on the nine HREP island sites. Access to these areas will be provided by the University of Wisconsin - La Crosse River Studies Center (RSC) Jon Boat or the LTRM boat stored at UMESC. We will obtain a Special Use Permit from US Fish & Wildlife Service (USFWS) prior to establishing sampling sites at these locations.

Figure 2. Experimental substrates similar to Hester-Dendy samplers will be constructed from wood slices. Six slices will be threaded directly onto extra-long eyebolts without intervening spacers, approximating an intact log as closely as possible.

At each of the nine HREP island sampling sites, we will establish a robust location marker to reference during repeated surveys to assess wood recruitment and loss in the form of a 10’ sign post in the area of highest elevation. We will record the compass angle and distance from the location marker to the shoreline, allowing us to re-sample approximately the same area at future dates. All above-water large wood present during the initial survey (described above) will be marked with aluminum forestry tags. Wood surveys following the same protocol as described above will be repeated in September 2019, January 2020, April 2020, and June 2020, to provide a first approximation of large wood dynamics within each site throughout the year. This will allow us to make an approximation of natural recruitment, storage, and transport of large wood across sites that could inform placement of wood in future projects (e.g., what are the hydrophysical characteristics of sites that receive more/less wood over time? What areas have high turnover of large wood?).

We will conduct a colonization experiment using modified Hester-Dendy samplers (Figure 2) to analyze community composition and colonization of large wood by primary (periphyton) and secondary (macroinvertebrates) producers. Samplers will be constructed using wood slices from two common tree species found in the UMRS. Green ash (*Fraxinus pennsylvanica*) will be used because of its current high mortality due to the invasion of the emerald ash borer, and silver maple (*Acer saccharinum*) will be used because of its abundance in floodplain forests. Each sampler will contain six slices from a single log approximately 15 cm in diameter; each slice will be 4 cm thick. By removing slices from the sampler, we will be able to conduct destructive sampling at multiple time points over the year (Figure 2).

We will obtain wood for sampler construction in collaboration with USACE foresters from La Crescent, MN. To facilitate sampling of periphyton, logs will be stripped of bark prior to sampler construction. Samplers will be suspended from buoys at a depth of approximately 0.75 m. Buoys will be tethered to existing logs deemed very unlikely to be mobilized, using wire cables and eyebolts. Two samplers (one of each tree species) will be placed in the higher- and lower-velocity sites on each of the nine islands, for a total of 36 samplers. Samplers will be installed in June 2019. Beginning in August 2019, the samplers will be examined every two months as conditions allow, over the course of one year. During each assessment a wood slice will be removed from each sampler and taken back to UWL for analysis. We will quantify macroinvertebrate species abundance, diversity, and biomass per wood slice by collecting, counting, identifying, drying and weighing all individuals present on the outside edge. We will evaluate periphyton biomass after removing macroinvertebrates by scraping material from two sections of known area on each piece onto a filter which will be frozen and stored for later chlorophyll analysis at UWL.

Component 3: Vertebrate Use of Large Wood

To evaluate wildlife (e.g., reptiles, birds, and mammals) use of large wood on HREP islands, we will seek a Special Use Permit from the USFWS to install field cameras at each of the nine HREP island sampling sites. Two field cameras will be secured with security boxes and cable locks to the sign post placed on each island and pointed toward the two sampling sites (angled downwards as need be with wooden shims). Cameras will be focused on a piece of large wood near the shoreline. We will sample three islands at a time, in rotation, using six Bushnell Trophy Cam HD Low Glow cameras.

In placing our cameras and reporting our camera trapping methods, we will follow the recommendations of Meek et al. (2014). Cameras will be deployed in each site for two-week periods every two months, as water levels allow, matching the sampling frequency for the macroinvertebrate and periphyton sampling. We will set cameras to take three still photographs when triggered by animal movement in the day or night, with a one-minute delay between triggers (8 GB SD cards can hold more than 7000 images). We will also set cameras to take three still photographs every 20 minutes throughout the day and night (about 3000 pictures per two-week period), to evaluate wood use by animals too small or slow (e.g., turtles) to trigger the camera motion sensor. At the time of camera installation, we will take field camera photographs of the site with the 30 m of the sampling area marked by a tape measure, and with meter sticks laid out perpendicular to the long axis of the piece of large wood in the center of the field of view. These images will allow us to estimate the length of shoreline within the field of view so we can estimate our sample area, and will aid in the determination of animal position relative to large wood when we evaluate images.

All images will be examined in lab, and those with the highest-quality animal image in them from each trigger event will be saved for analysis. For each saved image, we will record the species present, the number of individuals, and whether the animal is on, near (less than or equal to 1 m), or far (>1 m) from a piece of large wood. We will use these data to calculate animal occurrence per day and per meter of shoreline on or near vs. far from large wood, and across seasons, high- vs. low-velocity flow locations, and HREP sites.

Expected Outcomes

The data we collect will allow us to evaluate the overall fate and effectiveness of large wood features integrated into various types of habitat restoration projects in the UMRS. Our comparisons of macroinvertebrates and periphyton use of wood and rock will identify whether wood placement provides added habitat benefits for lower trophic level organisms, which could influence their use by fish for feeding. Our focused study on HREP islands is designed to provide insight as to how environmental characteristics influence the effect and use of large wood, such as flow velocity and geomorphic positioning, which river managers can use in decision-making about large wood placements in future projects. In addition, we will provide the seasonal documentation of vertebrate of wood loafing structures placed primarily for their benefit.

Products and Milestones

Tracking number	Products	Staff	Milestones
2019LW1	Progress Report	Thomsen, Jankowski	31 Dec. 2019
2019LW2	Draft LTRM Completion Report	Thomsen, Jankowski	31 Dec. 2020
2019LW3	Final LTRM Completion Report	Thomsen, Jankowski	30 April 2021

References:

Abbe, T.B. and Montgomery, D.R. 1996. Large woody debris jams, channel hydraulics and habitat formation in large rivers. River Research and Applications 12:201-221

Angradi, T.R., E.W. Schweiger, D.W. Bolgerian, P. Ismert, and T. Selle. 2004. Bank stabilization, riparian land use and the distribution of large woody debris in regulated reach of the upper Missouri River, North Dakota, USA. River Research and Applications 20:829-846.

Angradi, T.R., D.W. Bolgerian, T.M. Jicha, M.S. Pearson, D.L. Taylor, and B.H. Hill. 2009. Multispatial-scale variation in benthic and snag-surface macroinvertebrates assemblages in mid-continent great river (USA). Journal of the North American Benthological Society 28:122-141.

Angradi, T.R., D.L. Taylor, T.M. Jicha, D.W. Bolgrien, M.S. Pearson, and B.H. Hill. 2010. Littoral and shoreline wood in mid-continent great rivers (USA). River Research and Applications 26:261 – 278.

Budd, S., K. Gahm, B. Bennie, D. Burnham, R. Erickson, R. Haro, M. VanAppledorn, and K.J. Jankowski. Evaluating the impact of large wood on fish communities in the Upper Mississippi River, in prep.

Bureau of Reclamation and U.S. Army Engineer Research and Development Center (USBR and ERDC). 2016. National Large Wood Manual: Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure. 628 pages + Appendix.

Coe, H.J., P.M. Kiffney, and G.R. Pess. 2006. A comparison of methods to evaluate the response of periphyton and invertebrates to wood placement in large Pacific coastal rivers. Northwest Science 80 (4): 298-307.

Coe, H.J., P.M. Kiffney, G.R. Pess, K.K. Kloehn, and M.L. McHenry. 2009. Periphyton and invertebrate response to wood placement in large Pacific coastal rivers. River Research and Applications 25:1025:1035.

Collins, B.D., D.R. Montgomery, and K.L. Fetherston, T.B. Abbe. 2012. The floodplain large-wood cycle hypothesis: A mechanism for the physical and biotic structuring of temperate forested alluvial valleys in the North Pacific coastal ecoregion. Geomorphology. 139–140:460–470.

Entrekin, S.A., J.L. Tank, E.J. Rosi-Marshall, T.J. Hoellein, and G.A. Lamberti. 2009. Response of secondary production by macroinvertebrates to large wood addition in three Michigan Streams. Freshwater Biology 54: 1741-1758.

Gregory, S.V., M.A. Meleason, and D.J. Sobota. 2003. Modeling the Dynamics of Wood in Streams and Rivers. American Fisheries Society Symposium 37:315-335.

Gurnell, A.M., H. Piégay, F.J. Swanson, and S.V. Gregory. 2002. Large wood and fluvial processes. Freshwater Biology 47: 601-619.

Haro, R. J. Wood excavation by common net-spinning caddisflies in the upper Mississippi River. To be submitted to the Journal of Freshwater Biology.

Ickes, B.S., J.S. Sauer, N. Richards, M. Bowler, and B. Schlifer. 2014a. Spatially-explicit habitat models for 28 fishes from the Upper Mississippi River System (AHAG 2.0). A Program Report submitted to the U.S. Army Corps of Engineers' Upper Mississippi River Restoration-Environmental Management Program from the U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. January 2014. LTRMP Program Report 2014-P001. 26 pp. + Appendixes A–B.

Keller, E.A. and Swanson, F.J. 1979. Effects of large organic material on channel form and fluvial processes. Earth Surf. Process 4:361-380.

Lehtinen, R.G., N.D. Mundahl, and J.C. Madejczyk. 1997. Autumn use of woody snags by fishes in backwater and channel order habitats of a large river. Environmental Biology of Fishes 49:7-19.

Lindeman, P.V. 1999. Surveys of basking map turtles Graptemys spp. in three river drainages and the importance of deadwood abundance. Biological Conservation 88:33–42.

Meek P.D., G. Ballard, A. Claridge, R. Kays, K. Moseby, T. O'Brien, A. O'Connell, J. Sanderson, D.E. Swann, M. Tobler, S. Townsend. 2014. Recommended guiding principles for reporting on camera trapping research. Biodiversity and Conservation 23(9):2321–2343.

Mott, N. and Adams, M. 2006. Managing Woody Debris in River, Streams, and Floodplains. Stafford Wildlife Trust UK. George Street Press, Stafford – Wildlife Tryst Corporate Members.

Roni, P., T. Beechie, G. Pess, and K. Hanson. 2015. Wood placement in river restoration: fact, fiction, and future direction. Canadian Journal of Fisheries and Aquatic Sciences 72:466–478.

Steel, A.E., W.H. Richards, and K.A. Kelsey. 2003. Wood and wildlife: benefits of river wood to terrestrial and aquatic vertebrates. American Fisheries Society Symposium 37:235-247.

USACE. 2004. Final Report: Evaluation of Macroinvertebrate use of Woody Structure and Surrounding Substrate in the Open Portion of the Upper Mississippi River.

USACE. 2013. Upper Mississippi River 9-foot navigation channel biological opinion woody structure monitoring: 10 year status final report.

Wohl, E. 2013. Floodplains and wood. Earth-Science Reviews 123: 194 – 212.

Wohl, E. 2017. Bridging the gaps: An overview of wood across time and space in diverse rivers. Geomorphology 279:3–26.

Wohl, E., D.A. Cenderelli, K.A. Dwire, S.E. Ryan-Burkett, M.K. Young, and K.D. Fausch. 2010. Large in-stream wood studies: a call for common metrics. Earth Surface Processes and Landforms 35:618–625.

Illinois Water Way Aquatic Vegetation: Navigation Closure Study

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Introduction/Background:

The planned restrictions and closures of barge navigation on the Illinois waterway (IWW) in 2020 could potentially result in increased aquatic vegetation (AV) growth as a response to increased water clarity and decreased wave energy. The restrictions provide an opportunity to document potential AV response to reduced disturbance from barge navigation. Although the IWW historically supported abundant AV, it currently supports very little. Sass et al. (2017) determined that from downstream to upstream in the Illinois River, the percentage of sites supporting submersed AV were: Alton Reach (0%); La Grange Reach (9.4%); Peoria Reach (0%); Starved Rock Reach (2.8%); Marseilles Reach (8.1%); and Dresden Reach (82.6%). Existing monitoring for the presence and relative abundance (but not species) AV is minimal and includes LTRM water quality monitoring in the La Grange reach (RM 80-158) and by the LTEF in six pools between La Grange reach and Lockport (RM 325).

An AV response to reduced barge navigation would be ecologically significant and of basic interest in the UMRS. Specific details about a potential response (e.g. habitat characteristics and species) would also provide insights about the mechanisms limiting AV in the UMRS. Here we propose that the LTRM vegetation component, consisting of the MN, WI, and IA field station employees, dedicate approximately 1 week per year in 2019 (pre-closure), 2020 (during closure), and 2021 (post-closure) to conduct LTRM-type AV sampling in the IWW. Results of this work and additional AV data collected by LTEF and other associated studies will be summarized by LTRM field staff in an LTRM completion report.

The study would be designed to answer four main questions: 1) Does the prevalence of aquatic vegetation differ between the growing seasons prior to, during and after locks are closed to barge traffic, 2) if vegetation does become established during the same year of a lock closure, is it sustained during the following year when barge traffic returns to normal, 3) what are the species and habitat characteristics (depth, velocity, substrates) of the areas where vegetation establishes during one or more summers, and 4) do the results indicate that reductions in barge traffic facilitate establishment of aquatic vegetation?

Relevance of research to UMRR:

This study includes an assessment of the magnitude and frequency of waves, and potential alterations to the depth of light penetration associated with commercial and recreational boat traffic, as described in the water quality proposal from Janikowski and others. Briefly, we will deploy light intensity and pressure-based water depth data loggers at four stations along a transect that spans the navigation channel and impounded area in the lower starved rock pool during each week of vegetation sampling in 2019, 2020 and 2021.

Methods:

Study Area

The Starved Rock pool was selected for this study for several reasons. Land cover maps indicate that this pool supported submersed aquatic vegetation (SAV) at least as recently as 1989 (Figure 1) though more recent imagery (2010) indicate that SAV was limited to backwaters isolated away from the navigation channel. Other studies conducted in this pool within the most recent 15 years detected little aquatic vegetation (0 to 3% frequency of occurrence; Sass et. al. 2017, Cook and McClelland 2007, MACTEC 2006). Of note, the latter study included a census of AV beds >25m2 along the entire outer shoreline of this pool and only observed emergent plant beds (i.e. no SAV) and 4 total species. In addition, previous aquatic habitat suitability modeling efforts, conducted by LTRM staff and that were based on the predominant water clarity, turbidity and wind fetch, suggested that the Starved Rock Pool exhibited conditions favorable to SAV growth such that the relative scarcity of these species was likely attributed to other factors (i.e. herbivory or wave action from barges). Local biologist have also supported the potential for AV response to lock closures this pool (Aaron Yetter, pers com). Finally, at approximately 14 miles long, the relatively small Starved Rock Pool provides an opportunity to conduct an assessment of the annual occurrence of aquatic vegetation at multiple scales, including pool-wide, based on a sampling density comparable to traditional LTRM efforts on the UMR (i.e. 450 sites in each of the 3 approximately 44 mile long pools) and sample size proposed here.

Field Sampling

We estimate that three field crews (in three boats) can deploy and maintain water quality information loggers (see separate water quality proposal), survey approximately 150-200 sites per year using standard LTRM methods, and also potentially record observations or photographic records of shoreline vegetation in key areas. Sampling will be conducted during a similar timeframe each year, in August over approximately 1 week.

Site Selection

We propose to conduct stratified random sampling, whereby strata are based on 2010 aquatic areas and bathymetry maps (comparable to traditional LTRM delineations including that sampling is limited to areas less than 2.5 meters deep) and are modified to account for SAV distribution in 1989 land cover maps (Figure 1). More specifically, our proposed strata are: impounded, connected backwater, main channel and side channel areas outside of, and within 1989 SAV beds (i.e. IMP0, IMP1, BWC0, BWC1, SC0, MCB0 and MCB1). Sample size within each strata will be proportional to spatial extent, with a minimum of 20 sites in each of the 6 strata.

Timeline: This project includes collection of field data for three summer field seasons August 2019 – August 2021. A summary report and potential presentation of results at a regional conference or meeting will be produced by December, 2022.

Products and Milestones

Tracking number	Products	Staff	Milestones
2019SAV1	Field sampling - before lock closure	Lund, Drake, Bales, others	30-Aug-19
2019SAV2	Progress Report	Lund, Drake, Bales, others	30-Dec-19
2019SAV3*	Field sampling - during lock closure	Lund, Drake, Bales, others	30-Aug-20
2019SAV4*	Progress Report	Lund, Drake, Bales, others	30-Dec-20
2019SAV5*	Field sampling - after lock closure	Lund, Drake, Bales, others	30-Aug-21
2019SAV6*	Draft LTRM Completion	Lund, Drake, Bales	1-Apr-22
2019SAV7*	Final LTRM Completion	Lund, Drake, Bales	1-Dec-22

***Pending funding**

Citations:

Cook T.R., and M.A. McClelland. 2007. Submersed and Rooted Floating-leaved Aquatic Vegetation Abundances in the Dresden, Marseilles and Starved Rock Pools, Illinois River, 2005. Long Term Resource Monitoring element of the U.S. Army Corps of Engineers' Upper Mississippi River Restoration Program Completion Report 2005Glide3.

MACTEC Engineering and Consulting, Inc. 2006. Aquatic Vegetation Survey within the Dresden, Marseilles, and Starved Rock Pools of the Upper Illinois Waterway. Report prepared for the U.S. Army Corps of Engineers, Rock Island District. Contract DACW25-00-D-0005.

Sass G.G., Thad R. Cook T.R., Irons, K.S., McClelland, M.A., Michaels, N.N., and O'Hara, T.M. 2017. Experimental and comparative approaches to determine factors supporting or limiting submersed aquatic vegetation in the Illinois River and its backwaters. Long Term Resource Monitoring element of the U.S. Army Corps of Engineers' Upper Mississippi River Restoration Program Completion Report 2012E2.

Vonbank J.A., Hagy H.M.. and Casper, A.F. 2016. Energetic Carrying Capacity of Riverine and Connected Wetlands of the Upper Illinois River for Fall-Migrating Waterfowl. American Midland Naturalist 176:210-221.

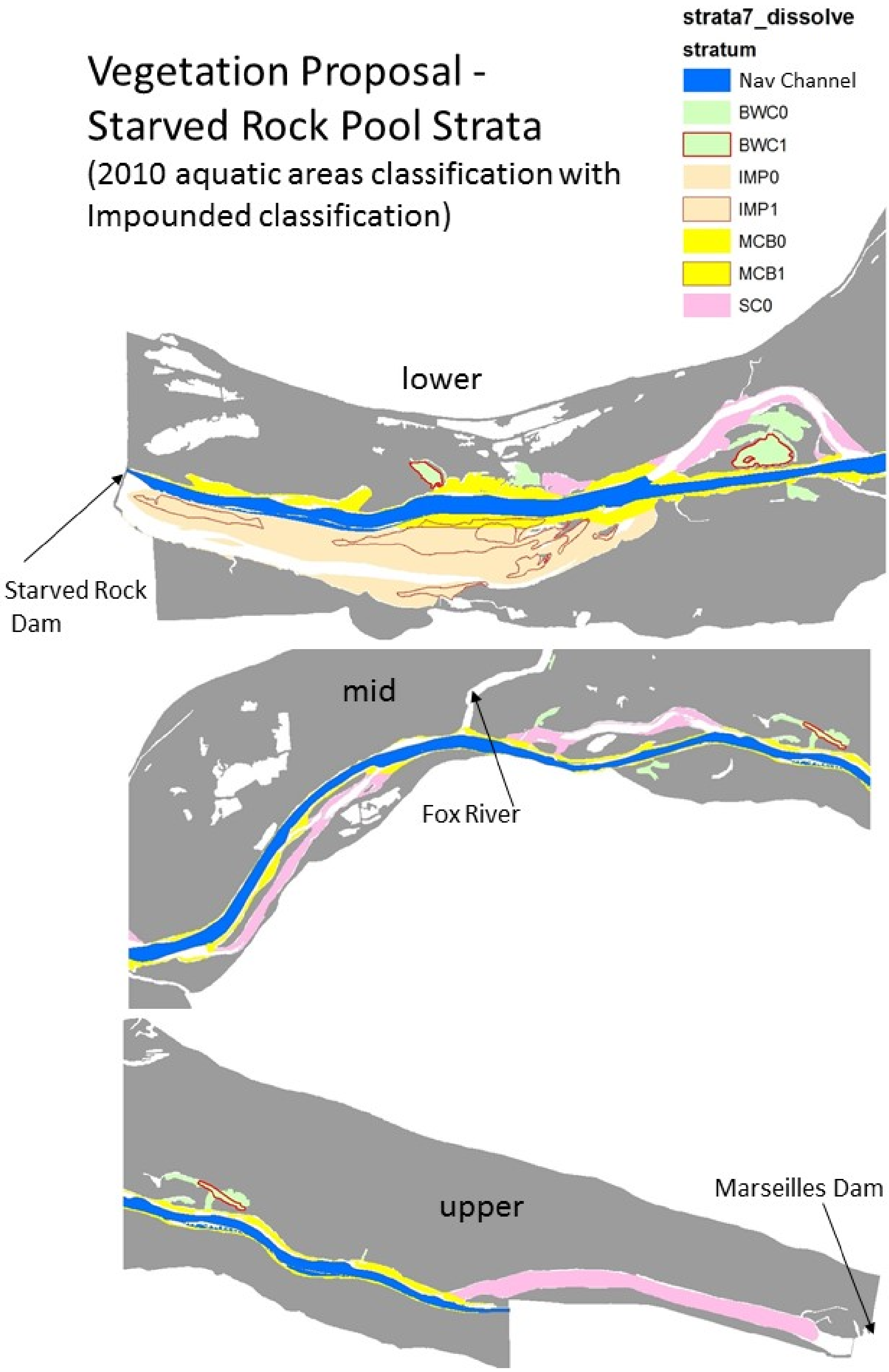

Figure 1. Starved Rock pool vegetation study strata: Contiguous Backwater (BWC), Impounded (IMP), Main Channel Border (MCB) and Side Channel (SC)

Pre- and Post-Maintenance Aerial Imagery for Illinois River's Alton through Brandon Lock and Dams, 2019-2020.

Previous LTRM project:
The U.S. Army Corps of Engineers' Upper Mississippi River Restoration (UMRR) Program Long Term Resource Monitoring (LTRM) element has collected aerial imagery of the Illinois River since 1989 for the Upper Mississippi River System (UMRS).

Name of Principal Investigators:
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Introduction/Background:
According to the Illinois Waterway (IWW) Project (https://www.mvr.usace.army.mil/Missions/Navigation/Navigation-Status/) and the Illinois Waterway Closure Plan (Attachment A), maintenance is required on the locks on the Illinois River. This maintenance will prepare the locks for both emergency situations and provide the ability to support major rehabilitation projects. Installation of bulkhead recesses to the locks is necessary to support dewatering as the emergency gates are no longer safe for dewatering. Currently, Brandon Rd, Dresden Island, Marseilles, and Starved Rock have emergency gates on the upper end and require bulkhead recesses. New miter gates are required at these same four IWW sites. Prior to the miter gates installation, the locks need to be dewatered using bulkheads, and replacement of the concrete sill and gate anchorage is required. Additionally, miter gate procurement requires approximately 2.5 years of lead time for fabrication from the time of contract award.

The Corps of Engineers' Rock Island District is planning an unprecedented closure on the Illinois Waterway in 2020. The Illinois Waterway, which provides a nine-foot channel connecting Lake Michigan with the Mississippi River, includes eight Lock and Dam sites which are overdue for significant repairs. The Corps is coordinating with the Navigation Industry and other partners (barge lines, shippers and business owners along on the waterway, and the Coast Guard) to coordinate the closures. To make the negative impact to commercial navigation as small as possible, the plan is to close 6 locks simultaneously. Since there is only one lock chamber at each site, if the lock is closed then no traffic can transit past that spot in the river. With traffic interrupted at one lock already, it makes sense to close multiple locks at the same time so the negative impacts aren't prolonged over the course of several years. A timeframe of July through October was chosen to enable efficient construction to take place after the highest probability of flooding, and before the harvest season gets into full swing.

The planned closures in 2020 include:

- *LaGrange Lock & Dam, Versailles.* Work will include dewatering the lock chamber to perform Major Rehabilitation and Major Maintenance. The antiquated and severely worn lock gate machinery will be replaced, and significant repairs will be made to the crumbling concrete and steel structures of the lock chamber. This work is anticipated to take up to 120 days to complete.
- *Peoria Lock & Dam, Creve Coeur.* This lock will be dewatered for approximately 60 days for inspections and maintenance of areas usually submerged.
- *Starved Rock & Dam, Ottawa, and the Marseilles Lock & Dam, Marseilles*. Work will include dewatering for the reconstruction of miter gate sills and anchorages so that new vertically framed Miter gates can be installed. The existing gates are original, and they do not meet current design and safety standards. This work is expected to take 90 to 120 days.
- *Dresden Island Lock & Dam, Morris, and Brandon Road Lock & Dam, Joliet.* Preparatory work will be done at these two sites, installing bulkhead slots in the existing emergency gate recesses so that the chambers can be dewatered to perform future work. There will be width restrictions for a couple of months while the slots themselves are under construction, and a shorter two-week closure at each of these sites to construct the bulkhead sill across the bottoms of the lock chambers.

In addition to the 2020 lock closures, the Marseilles and Starved Rock locks will be partially closed in June to September of 2019 and fully closed for 15 days in the month of August (see Attachment A).

Objectives:
The objective of this Scope of Work (SOW) is to document river and backwater conditions prior to the lock closures in the late-summer of 2019 as a baseline, and again in the late-summer of 2021 after the locks are reopened in using aerial imagery.

Relevance of research to UMRR:
It is expected that the lack of tow/barge traffic will reduce suspended sediment, improve water clarity, and increase the growth of aquatic vegetation along the main channel and in connected backwaters. Collecting aerial imagery at the end of the growing seasons in 2019, 2020 (as part of the planned systemic effort), and 2021 will help answer these questions:

- Will short-term complete closure (15 days) of the Marseilles and Starved Rock locks have any effect on floodplain vegetation in those pools in 2019?
- Will longer-term complete closure of the La Grange to Brandon locks – up to four months in 2020 – and lack of barge traffic have a restorative and persistent effect on the aquatic vegetation compared to previous years?

Methods:
The Upper Midwest Environmental Sciences Center (UMESC) will coordinate with the US Fish and Wildlife Service's (FWS) Migratory Bird Surveys Branch (MBSB) regional pilot to acquire 4-band aerial imagery of the selected study areas at approximately 0.4 meters/pixel (16 inches). This is the same resolution we anticipate collecting for the 2020 UMRS systemic aerial imagery project that will be used for generating land cover/land use maps. The flight plan requires 18 flight lines and 500 4-band stereo aerial images (60% overlap, 30% sidelap) using the 100-megapixel Phase One iXU-RS 1000 aerial camera and a 40mm lens (see Figure 1).

Figure 1. Lock and dam closure flight plan for the Alton Pool to Brandon Pool of the Illinois River. Note that only the main channel and adjacent backwater imagery will be collected.

FY2019:

1. Confirm study area boundaries and image acquisition windows.
2. Acquire 4-band aerial imagery at 0.4 meters/pixel (16 inches) of pre-closure conditions for Alton thru Brandon Pools in late-August/early-September of 2019.
3. Process and serve 4-band imagery to pool-based orthomosaics.
4. Write 2019 mission report and aerial mosaic metadata.

FY2021:

1. Acquire 4-band aerial imagery at 0.4 meters/pixel (16 inches) of post-closure conditions for Alton thru Brandon Pools in late-August/early-September of 2021.
2. Process 4-band imagery to pool-based orthomosaics.
3. Write 2021 mission report, aerial mosaic metadata.
4. Write internal report that graphically illustrates where change between 2019 and 2021, incorporating the 2020 systemic imagery for the same study area.

Products and Milestones

Tracking number	Products	Staff	Milestones
2019AER1	Acquire 4-band aerial imagery 2019	Lubinski, Robinson and Hop	late-August/early-September of 2019
2019AER2	Complete Orthomosaics and metadata 2019 Flight	Robinson and Hop	31-Dec-19
2019AER3	Progress Report	Robinson and Hop	30-Mar-20
2019AER4*	Acquire 4-band aerial imagery 2021	Lubinski, Robinson, and Hop	late-August/early-September of 2021
2019AER5*	Complete Orthomosaics and metadata 2021 FlightDraft LTRM Completion on aquatic vegetation change detection	Robinson and Hop	31-Dec-21
2019AER6*	Draft LTRM Completion on aquatic vegetation change detection	Robinson and Hop	30-Apr-21
2019AER7*	Final LTRM Completion on aquatic vegetation change detection	Robinson and Hop	30-Sep-21

***Pending funding**

2020 Aerial imagery covered under LTRM LCU Acquisition

Fish Community Response to the 2020 Illinois waterway Lock Closure.

Previous LTRM project:
This project builds on the LTRM fish and water quality components in the La Grange Reach. Methodology consistent with LTRM fish component and aspects of water quality component will be expanded to include most of the Illinois River waterway.

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Introduction/Background:

Commercial and recreational navigation are persistent and important uses of our navigable waterways (Lambert et al. 2010), but its ecological impact is difficult to assess and poorly understood. The Illinois River is an ecologically significant North American waterway. A series of lock closures is proposed in 2020 that could potentially reduce commercial and recreational traffic throughout the Illinois River. This creates a rare opportunity to evaluate ship-induced effects to our native biota.

Navigation can have detrimental effects to aquatic ecosystems at several hierarchical levels (Gabel et al. 2017). Mechanical wave depression and resulting energy from ship-induced waves can directly affect bank and channel morphology and contribute to resuspension of sediments (Rapaglia et al. 2011). Resulting increases in turbidity from sediment resuspension reduces primary productivity, macroinvertebrate abundance and diversity (Kefford et al. 2010), macrophyte growth and colonization, and composition and abundance of fish communities (Zajicek and Wolter 2018) using main channel border habitats. Ship-induced waves have had effects on all stages of fish ontogeny ranging from displacement and stranding, changes in species abundance and community composition, and lowered foraging efficiency contributing to reductions in growth and body condition. These effects were either a direct or indirect response to navigation frequency or boat-induced wave action. Abundance on rheophilic and lithophilic fish assemblages were notably affected by the duration and frequency of boat passage (Zajicek and Wolter 2018). Despite evidence of ship-induced fish effects, assessment of these impacts has not been evaluated on the Illinois River. A standardized approach building on the architecture of the LTRM framework will be necessary to comprehensively assess fish response to the 2020 lock closure on the Illinois waterway.

The exiting LTRM framework is a strong foundation to detect shifts in fish abundance and composition in the Illinois River, but it currently only collects data on the La Grange Reach. Although this is informative to assess lock closure impacts to the La Grange Reach, it is a compartmentalized response to a system-wide effect. To assess the effects of lock closure system-wide, expansion of LTRM methods accompanied by ship-induced related explanatory variables (i.e., vessel frequency, sediment resuspension, flow velocity, zooplankton abundance, water temperature, wave height) are needed. Existing infrastructure and sampling on the Illinois River can be standardized and leveraged to help meet this need. This includes existing main-channel border electrofishing by the IRBS's Long Term Survey and Assessment of Large River Fishes in Illinois (LTEF) from the Alton-Dresden Reach and a recent expansion to this effort in the Peoria Reach that also includes backwater and side-channel habitats, IRBS black carp hoop net sampling in the La Grange Reach, ILDNR Asian carp monitoring program electrofishing and minifyke netting in Lockport-Marseilles Reaches, INHS zooplankton and larval fish monitoring in Lockport-Alton Reaches and proposed macroinvertebrate abundance in the La Grange Reach. Therefore, a concentrated effort to fill existing gaps and coordinate data management is needed.

To meet this need and capitalize on this unprecedented opportunity, we propose the following research objectives:

1. Coordinate all existing fish monitoring efforts to collect fish abundance and community composition metrics and associated covariates to ensure standardization, data quality, and manage data to contribute to the understanding of lock closure assessment on fishes from 2019-2021.
2. Coordinate and conduct additional LTRM sampling on the Alton, Peoria, Starved Rock, and Marseilles pools to supplement existing data collection in these Reaches in 2019-2021. This would include incorporating partial to full LTRM fish component sampling (mainly electrofishing) through coordination with state, University, and UMRR partners on the Peoria, Starved Rock, and Marseilles, Reaches.
3. Monitor explanatory variables directly related to lock-closure (i.e., wave height, sediment resuspension, boating frequency) to isolate lock-closure specific responses from natural variation and additional indirect explanatory variables to account for comprehensive model explanation of variation (i.e., phytoplankton abundance, proposed macroinvertebrate

abundance, turbidity, total suspended solids (TSS), flow velocity, water temperature, vegetation cover).

4. Use fish otolith biochronology and body condition to determine effects of lock closure on growth and condition from non-transitory, short-lived species (e.g., emerald shiner, white bass, bluegill for biochronology and other commonly sampled fish species for body condition) (*Species can be collected to be consistent with those already being collected for vital rates*).
5. Increase collection of WQ and vegetation parameters (turbidity, TSS, percent cover of vegetation and percent density of vegetation) for fisheries crews operating throughout the Illinois River. This would include partnering agencies such as the IL DNR, FWS and USACE personnel focusing on Asian carp research and management. We would also add chlorophyll-a collection to LTRM fisheries crews at IRBS and process in house with a fluorometer.

Experimental design and research questions:

<u>Research question 1</u>: **Does lock closure directly (or indirectly) affect fish abundance based on strata (e.g., will abundance of fishes in main channel border habitats increase with a decrease in boat traffic?, Will young of year fishes abundance increase in main-channel border habitats in the absence of wave and flow perturbations?)?**

Response variables: Total fish abundance (and separately YOY fish abundance)

Potential explanatory variables: Time period, strata, year, reach, boating frequency, sediment resuspension, wave height, phytoplankton abundance, macroinvertebrate abundance, turbidity, flow velocity, water temperature, vegetation cover (Using auto-regressive techniques to account for spatial and temporal dependency of data and multilevel modeling to account for any nested data).

<u>Research question 2</u>: **Does the absence of boat traffic and resulting wave energy alter the distribution of abundances of particular feeding and habitat guilds among strata (Does abundance of rheophilic and lithophilic species increase as boating frequency decreases?)?**

Response variable: Abundance of feeding guilds or habitat assemblages (e.g., benthivore, rheophilic species, etc.)

Potential explanatory variables: Time period, strata, year, reach, boating frequency, sediment deposition, wave height, phytoplankton abundance, macroinvertebrate abundance, turbidity, flow velocity, water temperature, vegetation cover (Using auto-regressive techniques to account for spatial and temporal dependency of data and multilevel modeling to account for any nested data).

<u>Research question 3</u>: **Does reduction in boat traffic, resulting from lock closure, contribute to increased annual fish growth (less stress and more food availability) and body condition?**

Response variable: Otolith increment width (indicating yearly growth accounting for individual fish and temporal dependency of data) and body condition

Potential explanatory variables: Time period, strata, year, reach, boating frequency, sediment deposition, wave height, phytoplankton abundance, macroinvertebrate abundance, turbidity, flow velocity, water temperature, vegetation cover (Using auto-regressive techniques to account for spatial and temporal dependency of data and multilevel modeling to account for any nested data).

Research question 4: **Does reduction in boat traffic and associated wave action lead to an increase in water clarity? Will there be a decrease in turbidity or TSS or an increase in chlorophyll-a associated with the suspension of interpool barge traffic?**

Response variable: Secchi depth, turbidity, TSS, chlorophyll-1

Potential explanatory variables: Time period, strata, year, reach, boating frequency, sediment deposition, wave height, phytoplankton abundance, turbidity, flow velocity, water temperature, vegetation cover (Using auto-regressive techniques to account for spatial and temporal dependency of data and multilevel modeling to account for any nested data).

Additional research questions: **Macroinvertebrate abundance and zooplankton abundance (outlined in separate proposal) can also be used as response variables to ask question regarding lower trophic effects resulting from lock closure.**

Relevance of research to UMRR:

The proposed work would support multiple goals and objectives of the UMRR and partnering agencies including:

1. Upcoming lock and dam closures throughout the Illinois River. All Illinois waterway lock and dams (Brandon Road, Dresden Island, Marseilles, Starved Rock, Peoria, and La Grange) are scheduled to close for maintenance between July and October, 2020. This provides a unique opportunity to assess impacts of inter-pool barge traffic on riverine fishes including, but not limited to abundance, habitat use, body condition, and growth rates.
2. Habitat Rehabilitation and Enhancement Projects (HREP's). This project could provide a unique opportunity to gain insight into new restoration tools and HREP design that would benefit biotic communities that may be affected by vessel-induced disturbance.
3. Ongoing vital rates project (PI's: Bartels, Bouska, Phelps). This project builds on existing efforts of UMRR LTRM to study vital rates of selected species of fishes in the UMRS. That research, and this proposed research, addresses Focal Area 3 (Interactions and associations of hydrogeomorphology with biota and water quality) and Focal Area 5 (Vital rates of biotic communities) of the 2018 Focal Areas for UMRR Science in Support of Management. This proposed research could also be used to inform population dynamics and bioenergetics models (2.3.2 of Ickes 2018) within the Illinois River during the lock closure (2020), following lock closure (2021) and can be compared to results of data currently being collected (2018-2019).
4. Ongoing Resilience/HNA II efforts: Navigation infrastructure has been recognized as an "External Driver" of the UMRS by the ongoing Resilience efforts (Bouska, Houser, DeJager et al.) and the recently completed Habitat Needs Assessment II (McCain and Schmuecker 2018). However, the economic importance and systemic need for commercial navigation on the Illinois waterway have prevented the ability to conduct a navigation free assessment its potential to

affect aquatic communities. However, the impending lock closure gives the unique opportunity to see how aquatic communities respond in the absence of navigation-induced disturbance. Although channelization and dams would still remain in place (navigation infrastructure), the navigation within that framework would be stymied, thus allowing for an unprecedented assessment of a defined "driver" of the system.

Methods:

<u>Coordination of existing monitoring efforts</u>: Ensuring standardization and randomization of all existing data collection efforts from the Illinois River to minimize the amount of additional sampling needed to assess the effects of lock closure. IRBS coordinator will be responsible for coordinating effort, compiling and assimilating all data collected into a useable database, sharing that database with partnering agencies and researchers, and analyzing data from various agencies conducting monitoring on the Illinois River (Table 1). All current monitoring efforts will be adapted to LTRM standard protocols as applicable. Training for all non-LTRM field personnel will be conducted prior to sampling including lab and field-based demonstration. IRBS coordinator will also be responsible for presenting results and writing, or coordinating the writing, of all reports and publications about any effects of lock closure on the Illinois River.

Table 1. Existing agency efforts in the Illinois waterway (2019)

Agency program	Gear	Strata	Lockport	Brandon Rd	Dresden	Marseilles	Starved Rk	Peoria	LaGrange	Alton	Comments
IDNR - IL River team	EF	MCB			1	2	2	6	4	3	2-30 minute runs
IRBS - expanded LTEF	EF	MCB						30			
IRBS- LTEF	EF	SCB, BWS			4	7	4	18	2	18	
IDNR - Asian carp monitor	EF	MCB			8	8					
IDNR - Asian carp monitor	Mini-fyke	MCB			4	4					
IDNR - Asian carp monitor	Single unbaited hoop	MCB	4	4	4	4					
IRBS - Black carp monitori	Single Hoop	MCB							66		Unbaited
INHS (KBS,IRBS) - Zoop cr	Plankton tows	MCB				1	1	2	5	2	Per month
IRBS macroinvert (propos	Ponar	All							150		
FWS - Wilmington	EF	MCB			8	8					
NEW AC/FWS EFFORTS	**EF**					**7**	**26**				
NEW AC FWS EFFORTS	**Mini-fyke**		**10**	**10**	**16**	**16**	**20**	**24**			
NEW AC FWS EFFORTS	**Paired hoop**		**14**	**14**	**14**	**14**	**14**	**14**			
USACE - Chicago	EF	MCB	8	8							
IRBS - LTRM	EF	All							36		
IRBS - LTRM	Fyke	All							10		
IRBS - LTRM	Mini-fyke	All							24		
IRBS - LTRM	Paired hoop*	MCB							14		
Total	**EF**		**8**	**8**	**21**	**32**	**32**	**54**	**42**	**21**	
Total	**Hoop**		**18**	**18**	**18**	**18**	**14**	**14**	**80**	**0**	
Total	**Mini-fykes**		**10**	**10**	**20**	**20**	**20**	**24**	**24**	**0**	
Total	**Fyke**		**0**	**0**	**0**	**0**	**0**	**0**	**10**	**0**	
Total	**macroinvert**		**0**	**0**	**0**	**0**	**0**	**0**	**150**	**0**	
Total	**zoop**		**0**	**0**	**0**	**1**	**1**	**2**	**5**	**2**	

<u>To answer Research Questions 1 & 2:</u> In order to comprehensively assess system-wide effects of lock closure, we will be supplementing existing monitoring efforts (Table 1) by conducting a partial to full LTRM fish assessment on Alton, Peoria, Starved Rock, and Marseilles Reaches of the Illinois River in 2019, 2020, and 2021 encompassing pre-lock closure, lock closure, and post-lock closure assessment. The proposed IRBS coordinator and technicians will lead and help conduct field efforts as well as help coordinate other state and federal partners, in-house field station professionals, university personnel, and UMRR partners to assist with field sampling efforts. The largest reaches are La Grange and Peoria

(each 80 miles). La Grange Reach will already be covered as one of the existing UMRR RTAs and all electrofishing in Peoria Reach will be covered with LTEF and expanded LTEF monitoring. Starved Rock (16 miles) and Marseilles (24.5 miles) constitute only 40.5 miles collectively (only half of La Grange Reach by length). The majority of electrofishing and some netting is already being conducted in these pools, requiring a reduced effort in this area. However, existing methods used will need to be modified to include measuring all fishes collected and weighing fishes (in a minimum of Period 3). In addition, all ancillary data (temperature, dissolved oxygen, conductivity, secchi, velocity, percent cover of vegetation, density of vegetation) collected during standard LTRM sampling will also be collected by partnering agencies and personnel at every sampling site and used to populate our statistical models.

<u>To answer Research Question 3:</u> We will continue vital rates sampling currently underway (PI's: Bartels, Bouska, and Phelps) from 2018-2020 and extend sampling and collection for the La Grange Reach through 2022. This will allow fishes growing through the closure of 2020 to experience a full growing season prior to annuli formation in the winter of 2020/2021. Collection of those fishes in the LTRM field seasons of 2021 and 2022 will allow for measurement of the 2020 growth year and subsequent comparison against non-lock closure years (2018, 2019, 2021 and 2022) to determine growth response of fishes to lock closure. Collection methods will be identical to those currently being used by the LTRM fish component. Weights will also be taken from all fishes during a minimum of Period 3 to determine changes in relative weight during the closure.

<u>To answer Research Question 4:</u> We will expand collection of water quality parameters throughout the Illinois River to include turbidity, TSS, and secchi at all sites where fishes are sampled (see Table 1). TSS samples will be brought back to IRBS and processed according to modified LTRM protocols: modifications include weighing filters prior to use and again with suspended solids weight "in house" rather than at UMESC. While we recognize that this lacks the accuracy of full LTRM protocols, it will allow for comparisons from pre-, mid- and post lock closure to determine changes in TSS load of the Illinois River. In addition, we would initiate chlorophyll-a collection in the La Grange Reach by IRBS staff (samples must be filtered and frozen within 24 hours) and analyzed at UMESC (Kathi Jo Jankowski – see water clarity proposal for budget). The chlorophyll-a methodology will be conducted according to LTRM protocols for 2019-2021 to allow for pre-, mid-, and post closure comparisons of chlorophyll-a levels within the pool.

<u>Boat passage frequency:</u> Frequency of large vessel movement on every reach will be tracked and recoded using the Findship app for all reaches and any lockages through dams tracked through the US Army Corps of Engineers. Local barging companies (those that could still operate within a single navigational pool) may also be contacted to get additional information about intra-pool movements and associated wave action that they would generate.

<u>Macroinvertebrate sampling</u>: This is proposed benthic sampling (separate proposal) using LTRM macroinvertebrate protocols to estimate macroinvertebrate abundance as a stand alone response to barge frequency and sedimentation, and as a predictor of fish abundance.

<u>Sediment sampling</u>: Graduated sediment cup samplers (2 in. PVC) will be anchored throughout the LaGrange Reach (5 sampling stations dispersed throughout the pool) to measure sediment deposition. Sediment samplers will be checked bi-monthly, volume of suspended sediment recorded, baked and measured.

Wave height: Wave intensity and frequency will be measured using HOBO pressure sensitive loggers distributed throughout main channel borders (1 logger per 20 miles or 1 logger per pool in pools shorter than 20 miles).

Pool	Number of data loggers
Alton	4
La Grange	4
Peoria	4
Starved Rock	1
Marseilles	2

Zooplankton: Monthly zooplankton collection to estimate taxa-specific abundance will be conducted through cooperation with ongoing efforts by Illinois Natural History Field Station staff (Table 1).

Special needs/considerations, if any: To begin sampling and coordination, the release of funding by May 15, 2019 would be preferred.

Products and Milestones

Tracking number	Products	Staff	Milestones
2019FSH1	Field sampling - before lock closure	Lamer, Solomon, and others	30-Oct-19
2019FSH2	Progress Report	Lamer, Solomon, and others	30-Dec-19
2019FSH3*	Field sampling - during lock closure	Lamer, Solomon, and others	30-Oct-20
2019FSH4*	Progress Report	Lamer, Solomon, and others	30-Dec-20
2019FSH5*	Field sampling - after lock closure	Lamer, Solomon, and others	30-Oct-21
2019FSH6*	Draft LTRM Completion	Lamer, Solomon, and others	30-Dec-22
2019FSH7*	Final LTRM Completion	Lamer, Solomon, and others	1-Apr-22

***Pending funding**

References

Bouska, K. L., J. N. Houser, N. R. DeJager, and J. Hendrickson. 2018. Developing a shared understanding of the Upper Mississippi River: the foundation of an ecological resilience assessment. Ecology and Society 23 (2):6 https://doi.org/10.5751/ES-10014-230206

Gabel, F., S. Lorenz, and S. Stoll. 2017. Effects of ship-induced waves on aquatic ecosystems. Science of The Total Environment 601–602:926–939.

Ickes, B. S. 2018. A framework for research and applied management technical support in the Fish Component of the UMRR LTRM. U.S. aquatic over-wintering issues in the Upper Mississippi River Basin. U.S. Army Corps of Engineers' Upper Mississippi River Restoration Program Long Term Resource Monitoring element Completion Report. LTRM-2018B14

Kefford, B. J., L. Zalizniak, J. E. Dunlop, D. Nugegoda, and S. C. Choy. 2010. How are macroinvertebrates of slow flowing lotic systems directly affected by suspended and deposited sediments? Environmental Pollution 158(2):543–550.

Lambert, B. 2010. The economic role of inland water transport. Proceedings of the Institution of Civil Engineers - Civil Engineering 163(5):8–14.

McCain, K.N.S., and S. Schmuecker. 2018. Habitat Needs Assessment-II for the Upper Mississippi River Restoration Program: Linking Science to Management Perspective. U.S. Army Corps of Engineers, Rock Island District, Rock Island, IL

Rapaglia, J., L. Zaggia, K. Ricklefs, M. Gelinas, and H. Bokuniewicz. 2011. Characteristics of ships' depression waves and associated sediment resuspension in Venice Lagoon, Italy. Journal of Marine Systems 85(1–2):45–56.

Zajicek, P., and C. Wolter. 2019. The effects of recreational and commercial navigation on fish assemblages in large rivers. Science of The Total Environment 646:1304–1314.

Water Clarity and the IWW Lock Closure

Previous LTRM Project: NA

Principal Investigators:

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Collaborators:

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Deanne Drake, Vegetation Specialist-LTRM, Wisconsin Department of Natural Resources, La Crosse, WI, (608) 781-6363, Deanne.drake@wisconsin.gov; Assist with field work and deployment of sensors

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Water Quality Lab Technician/Student (s): to assist with data compilation, analysis and report writing in summers 2020-2021

Introduction/Background:

The closure of the IWW locks and dams during the summer of 2020 presents a unique opportunity to evaluate the effect of navigation traffic on several physical and biological aspects of the Illinois River. Reduced navigation traffic and the associated reduction in wave generation and prop-associated turbulence may affect water column sediment concentrations through reducing sediment resuspension and bankside erosion, which could result in temporary increases in water clarity. Water clarity is a fundamental variable that could drive changes in aquatic vegetation and fish communities through altering the light environment for photosynthesis, foraging, etc.

It is not clear to what extent water clarity may improve, however. Tow traffic causes changes in water flow through drawdown, displacement currents and backflow. These effects can increase sediment resuspension and bank erosion (Bhomik et al. 1981, Liou and Herbich 1976). Previous studies have shown that commercial traffic does indeed influence sediment resuspension and lateral movement and can impact water clarity adjacent to the channel (Environmental Science & Engineering 1981), but the effects can be highly variable depending on bed sediment characteristics, bottom profiles, river geometry, vessel size and speed, etc (Sparks et al. 1980, Bhomik et al. 1981, Smart et al. 1985). For example, a study of the effect of navigation and recreational boat traffic on sediment resuspension on Pool 9 of the UMR, found up to a 19% increase in TSS associated with vessel passage in the main channel and 22% increase in associated side channels and showed an increase in particle size associated with barge traffic (Smart et al. 1985). Bhomik et al (1981) found that increases in resuspension were greater along the channel border than in the center of the navigation channel, "supporting the hypothesis that traffic moves sediment laterally out of the navigation channel". The amount of resuspension found in these studies was variable, however, and depended primarily on bed sediment characteristics, bottom profiles, river geometry, and discharge. The duration of the sediment pulse associated with vessel passage was ephemeral and ranged from ~90 minutes for commercial vessels and ~30min for recreational vessels (Smart et al 1985, Bhomik et al. 1981). Johnson (1976) observed longer recovery times in the IL River than in the UMR. Interestingly, these authors also found that although commercial vessels impacted resuspension more than recreational boats in the main channel, recreational vessels had a substantial influence on sediment resuspension in backwater habitats.

The magnitude and duration of sediment resuspension from tow traffic depends on tow-induced current velocity in combination with ambient river velocity. Often once sediments are in suspension, they will remain in suspension because ambient river velocity is typically above settling velocity. The resulting ability to detect a change in water clarity is highly dependent on ambient suspended sediment concentrations, however (USACE 1980). Thus, previous studies have suggested that the major effects of river traffic on suspended sediments will be to eliminate periods of relatively low turbidity that might occur during low river flow.

Recreational boat traffic and barge movement within navigation pools will continue, but routine traffic within the main channel will be much reduced. Therefore, we anticipate that increases in water clarity will likely be most prevalent in shallow areas connected to the main channel (i.e., channel border, connected side channels, backwaters). Sediment resuspension is common or along shorelines that typically experience heavy wave action from barge traffic. We expect that the onset and duration of water clarity improvements will vary among navigation pools depending on river morphology, whether flows or sediment loads shift for other reasons such as precipitation events, tributary sediment loads, or gate operation during the closures.

We propose to focus on the following questions related to impacts on water clarity from the reduction in barge traffic in the summer of 2020: 1) Does reduced barge traffic alter wave action and sediment resuspension? 2) Does reduced traffic result in increased water clarity? Where? How much? To answer question 1, we will rely on information gathered by vegetation crews (see Lund et al. proposal). To answer question 2, we will consolidate and analyze water clarity data collected by LTRM, IL EPA, USGS and LTEF crews. We are not proposing additional data collection.

<u>Relevance of Research to UMRR</u>

The UMRS is considered both a "nationally significant ecosystem and commercial navigation system" (citation). This proposal directly touches on the dual role of the UMRS in assessing how changes in navigation traffic could affect water clarity, an important driver of other critical ecosystem functions such as fish community dynamics and growth, vegetation growth and primary productivity. Further, an understanding of the effects of reduced navigation traffic on water clarity at different temporal and spatial scales has the potential to inform the development of appropriately designed habitat restoration and enhancement projects.

Methods:

Question 1: Does reduced barge traffic alter wave action and sediment resuspension?

The effect of barge traffic on wave action and sediment resuspension is well established for the IL River by Bhomik (1981) and by studies in other sections of the UMRS (e.g., Smart et al 1985) and other large river systems (Gabel et al. 2017). Therefore, we propose only a smaller, targeted assessment at sites associated with vegetation sampling in Starved Rock Pool.

Vegetation crews will deploy continuous light and wave loggers along a transect spanning the navigation channel and one contiguous backwater at in the Starved Rock Pool for the duration of their vegetation sampling in 2019, 2020, and 2021 (2-3 days). Light meters will be suspended in the water column at the surface and at depth to calculate light extinction along the distance from the main channel to the shoreline and into a connected backwater. Pressure loggers will be placed near the shoreline at these transects to monitor wave action for the same time period. These data will give us a short-term assessment of the effect of passing barges on light and wave dynamics associated with vegetation survey sites.

Question 2. Does reduced barge traffic increase water clarity? Where? When? How much?

Effect of reduced barge traffic on water clarity at different temporal scales

We anticipate that if reduced navigation traffic influences water clarity, this likely would occur only during the period of lock closure and result in lower average and lower daily fluctuations in turbidity during that period. We will use two different datasets to assess whether this occurs.

1. Sub-daily time scale:

Marseilles and Brandon Road: We will use the turbidity and chlorophyll records collected every 15 minutes at the USGS gage stations in Marseilles and Brandon Road pools in combination with daily lock passage data to assess whether reduced traffic in 2020 affects daily averages and variation in water clarity as compared to other years (2019, 2021). Bhomik (1981) found that there were significant, but short duration spikes (< 90 minutes) in suspended solids associated with both barge and recreational boat passage, therefore, we anticipate that these would be most visible with higher resolution data available from these gages. We will choose additional years of data from the gage and barge traffic datasets that have similar water levels if 2019 and 2020 differ drastically from 2020.

2. Seasonal and inter-annual:

We will use all existing USGS turbidity gages on the IL River to establish whether there is a typical seasonal trend and whether the period of lock closure has an appreciable effect on turbidity values in channel border areas of pools closed to navigation traffic. This will occur in two ways: 1) At Marseilles and Brandon Road, we will use USGS gage information from 2020 to assess whether there is any change in the average or variation of turbidity during the period of lock closure relative to other points in the season that are open and to gages unaffected by the closures (Florence, IL). 2) We will compare intra-season variation in 2020 in Marseilles and Brandon Road to previous years with similar discharge to assess whether the reduction in navigation traffic resulted in changes in turbidity.

Spatial differences in how water clarity is impacted by reduced barge traffic

The effect of reductions in navigation traffic will likely play out differently across river reaches and aquatic areas. Variation in reach characteristics (average width, meanders, etc) can influence the degree to which barge traffic influences wave action and resulting sediment movement. In addition, based on data from previous work (Bhomik et al. 1981, Smart et al. 1975), the degree to which sediment pulses from passing barges move into connected backwaters and side channels depends on factors such as their connectivity and orientation to the main channel and the direction of the barge traffic. First, we will use turbidity datasets collected by LTEF teams, LTRM fish crews and LTRM vegetation crews to evaluate whether water clarity changes are more/less detectable among closed reaches. Second, we will use more spatially representative datasets from La Grange reach to assess whether there are notable differences among aquatic areas in the response of water clarity to lock closures.

1. Proposed LTEF/LTRM sampling: Turbidity samples are proposed to be collected as part of two other proposed efforts. First, fish teams will collect turbidity measurements as part of the proposed expanded LTRM surveys (Lamer and Sullivan, proposal). Second, vegetation crews will sample ~200 sites in Starved Rock pool during 2019, 2020 and 2021 and collect associated turbidity data (Lund et al, proposal).

2. La Grange reach: We will use secchi, turbidity, chlorophyll, TSS/VSS data from LTRM summer (Jul) and fall (Oct) SRS sampling in 2019, 2020 and 2021 to assess whether there are different spatial patterns during lock closure in 2020 than are typically observed during regular navigation. SRS sampling provides broader spatial information in locations where water clarity might increase during lock closures (e.g., backwaters, shallow areas) and will bracket the period of closure in that reach. If discharge is drastically different among these three, could use years with similar discharge in the LTRM database to year of barge traffic reduction to bracket expectations of normal TSS, chlorophyll, secchi, etc.

3. La Grange pool: Fixed site data will complement the SRS data by providing more detailed temporal information at several sites in the main channel, side channel and a backwater. We will use April-Oct data from LTRM fixed sites (secchi, turb, chl, and TSS/VSS) and EPA monitoring sites (TSS/VSS, chl, TOC). Fixed site dataset includes five tributaries as well which could be used to assess sediment loads from tributaries.

Table 1. Sources of water clarity information for the IL River from LTRM, LTEF, USGS, and IL EPA. MC = main channel, SC=side channel, BW=backwater, TRIB=tributary, Turb = laboratory measured turbidity, Chl = laboratory measured chlorophyll.

Pool	Agency	# of Sites	Parameters	Frequency	Locations
La Grange	LTRM	11	Secchi, TSS, VSS, Turb, Chl	4/closure; 10 from Apr-Oct	MC=4, SC=1, BW=1, TRIB=5
	LTRM	130	Secchi, TSS, VSS, Turb, Chl	July & Oct	MC=35, SC=20, BW=80
	EPA	1	TSS/VSS/Chl/TOC	Every 6 weeks	MC - Havana
Peoria	EPA	3	TSS/VSS/Chl/TOC	Every 6 weeks	MC - Lacon MC - Depue MC - Peoria
	LTRM - fish	20	Chl	Fish periods 2&3	MCB
Starved Rock	EPA	1	TSS/VSS/Chl/TOC	Every 6 weeks	MC - At Marseilles L&D
	LTRM	1	Light/wave height	1x per year by Veg team	Near Delbridge Island
	LTRM - fish	20	Chl	Fish periods 2&3	MCB
Marseilles	USGS	1	Turbidity, Chlorophyll	Daily	MC – Seneca - USGS 05543010
	LTRM-fish	20	Chl	Fish periods 2&3	MCB
Dresden					
Brandon Road	USGS	1	Turbidity, chlorophyll	Daily	MC – in Brandon Road lock chamber - USGS 05538020
Brandon Road	USGS	1	Turbidity, chlorophyll	Daily	MC – Brandon Road pool
Alton	USGS	1	Turbidity, chlorophyll	Daily	MC - Florence, IL
	LTRM-fish	20	Chl	Fish periods 2&3	MCB

Expected Outcomes

We expect that compiling data from these various spatial and temporal scales would capture an effect of reduced navigation on water clarity if it occurs. We will have fine-scale temporal data that will allow us to evaluate water clarity effects relative to barge traffic in "real-time" and broad-scale spatial data from LTRM and LTEF teams that will capture broader gradients across reaches and aquatic areas.

Products and Milestones

Tracking number	Products	Staff	Milestones
2019WC1	Field sampling - before lock closure	Jankowski (collaborating with Fish and SAV studies)	30-Oct-19
2019WC2	Progress Report	Jankowski (collaborating with Fish and SAV studies)	30-Dec-19
2019WC3*	Field sampling - during lock closure	Jankowski (collaborating with Fish and SAV studies)	30-Oct-20
2019WC4*	Progress Report	Jankowski (collaborating with Fish and SAV studies)	30-Dec-20
2019WC5*	Field sampling - after lock closure	Jankowski (collaborating with Fish and SAV studies)	30-Oct-21
2019WC6*	Draft LTRM Completion	Jankowski (collaborating with Fish and SAV studies)	1-Apr-22
2019WC7*	Final LTRM Completion	Jankowski (collaborating with Fish and SAV studies)	30-Jun-22

***Pending funding**

References

Bhomik, N.G., J.R. Adams, A.P. Bonini, C. Guo, D.J. Kisser, and M.A. Sexton. 1981. Resuspension and lateral movement of sediment by tow traffic on the Upper Mississippi and Illinois Rivers. Report of IL Institute of Natural Resources submitted to The Upper Mississippi River Basin Commission.

Environmental Science and Engineering. 1981. Navigation impact study, Illinois River, Pool 26, August 1980; Mississippi River, Pool 9, October 1980; Phase III, Task 9. Illinois Natural History Survey, Grafton, Illinois.

Gabel, F., S. Lorenz and S. Stoll. 2017. Effects of ship-induced waves on aquatic ecosystems. Science of the Total Environment. doi.org/10.1016/j.scitotenv.2017.05.206

Johnson, J. H. 1976. Effects of tow traffic on the resuspension of sediments and on dissolved oxygen concentrations in the Illinois and upper Mississippi Rivers under normal pool conditions. Technical Report Y-76-1, U.S. Army Engineer Waterways Experiment Station,
Environmental Effects Laboratory, Vicksburg, Mississippi, 181 pp.

Liou, Y. C., and J. B. Herbich. 1976. Sediment movement induced by ships in restricted waterways. Texas A & M University, TAMU-S6-76-209, COE Report No. 188, August.

Lund, E., D. Drake, and K. Bales. 2019. Illinois water way aquatic vegetation: Navigation closure study. Proposal submitted to the UMRR.

Smart, M., R. Rada, D. Nielson & T. Clafin, 1985. The effect of commercial and recreational traffic on the resuspension of sediment in navigation pool 9 of the upper Mississippi River. Hydrobiologia 126: 263–274.

Sparks, R. E., R. C. Thomas & D. J. Schaeffer, 1980. The effects of barge traffic on suspended sediments and turbidity in the Illinois River. U.S. Fish Wildl. Serv., Rock Island, 68 pp.

U.S. Army Corps of Engineers, Huntington District. 1980. Appendix J, vol. 1: Environmental and social impact analysis. Gallipolis Locks and Dam replacement, Ohio River, Phase I, Advanced engineering and design study, general design memorandum.

Notes from other proposals –