Upper Mississippi River Restoration Program

Science in Support of Restoration and Management
FY17 SOW

Enhancing Restoration and Advancing Knowledge of the Upper Mississippi River

Addressing the FY2015–2025 UMRR Strategic Plan
6 March 2017

Addendum

Developing and Applying Indicators of Ecosystem Resilience to the UMRS

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.

Most management agencies are interested in quantifying the resilience of ecosystems because it can help them identify locations, scales, and degrees of management intervention needed to maintain healthy, productive ecosystems, or to shift ecosystems to more desirable states. In some cases, managers might be interested in reducing the resilience of an undesirable state (e.g., the turbid, unvegetated state above), whereas in other cases, managers might be interested in maintaining or increasing the resilience of a desirable state (e.g., the clear-water, vegetation state above).

Although there exists a substantial theoretical and conceptual literature on ecological resilience and how it could inform ecosystem management, applied examples are less common. Very little work has been done to develop indicators of ecosystem resilience for large rivers. Nevertheless, many of these concepts are clearly relevant to the Upper Mississippi River System (UMRS) and the U.S. Army Corps of Engineers' Upper Mississippi River Restoration (UMRR) Program. For example, the UMRS has experienced changes that have been associated with reduced resilience and shifts to undesirable states in other ecosystems. Examples of such changes include accumulation of nutrients and sediments, redirection of water flows, altered flow regimes and water elevations, changes in flood frequency and floodplain connectivity, and proliferation of non-native species. How have these changes influenced the health and resilience of the UMRS?

The UMRS also exhibits characteristics that likely contribute to its resilience and which may be augmented by various management actions. The longitudinal orientation of the river provides a diversity of climatic and environmental conditions, which might maintain the resilience of, for example, fish communities in the face of interannual variability and long term changes in climate and other ecological drivers. Some portions of the UMRS maintain extensive lateral connections and hydrogeomorphic diversity across the floodplain, which allow fish species to persist through substantial seasonal and interannual fluctuations by seeking suitable habitat in various locations. How do these hydrogeomorphic characteristics and the diversity of fish, vegetation, invertebrates, and other biota they contribute to the health and resilience of the UMRS?

It is likely that management actions could alter some of the features typically attributed to resilience. For example, if connections among contrasting aquatic areas substantially contribute to the resilience of the UMRS, then how and where could managers modify hydrological connectivity (e.g., dredging, altering channel-backwater connections, island construction) to improve the resilience of desired states or reduce the resilience of undesired states?

OBJECTIVES (*Note: Objective 3 (bold text below) will be the emphasis during FY2017*)

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 the conceptual model to guide:**
   a) **Development of indices of resilience for the UMRS using data from the UMRR-LTRM.**
   b) **Description of the current resilience of multiple reaches of the UMRS.**
   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?**
4) Evaluate the potential effects of HREPs on resilience of the UMRS
   a) Conceptually: Expand conceptual model to specifically consider what aspects of resilience may be affected by HREPS.
   b) Empirically: Use LTRM data and additional data collected at selected HREPS to evaluate actual effects observed in the field.
5) Consider how understanding derived from addressing the above objectives could inform and improve management of the UMRS.
   a) How do current management actions affect the resilience of the UMRS?
   b) Is there potential to improve current management actions, or develop new management actions, as a result of considering the river's resilience?
6) Suggest ways in which ecological experiments or natural variation can be used to test our understanding of resilience within the UMRS, and consider the potential for managing resilience through HREPs.

WORKPLAN AND DELIVERABLES

We have identified the Major Resources and Controlling Variables of the UMRS in the conceptual models described in a draft manuscript:

Bouska, K.B., J.N. Houser, and N. De Jager. Developing a shared understanding of the Upper Mississippi River: the foundation of a resilience assessment.

A draft of this manuscript was distributed for review in FY 2016. In FY 2017 a revised version of this manuscript will be submitted for publication.

The next phase of the project will use UMRR-LTRM data to quantify select relationships from those conceptual 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 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.

Expected Time Line:

Activity	Fiscal year
Revise and submit the following manuscript for publication: Bouska, K.B., J.N. Houser, and N.R. De Jager. Developing a shared understanding of the Upper Mississippi River: the foundation of a resilience assessment.	FY2017
Use LTRM data to quantify and understand select relationships within the conceptual models presented in the above manuscript	FY17-18
Apply indices of resilience to UMRS using LTRM data, and evaluate factors affecting resilience within UMRS.	FY1717-18
Draft manuscript on the General Resilience of the UMRS	FY 17??
Consider how resilience concepts can inform and improve management of the UMRS, and ways to test resulting predictions.	FY17-18
Communicate results to partnership, and write reports and manuscripts	FY17-18

Tracking number	Products	Staff	Milestones
2016R1	Updates provided at <u>each</u> quarterly UMRR CC meeting and A team meeting	Bouska, Houser	Various
	Submit following manuscript for publication: Bouska, K.B., J.N. Houser, and N. De Jager. Developing a shared understanding of the Upper Mississippi River: the foundation of a resilience assessment.	Bouska, Houser, De Jager	30 May 2017
	Draft General Resilience of the UMRS manuscript to RWG for review	Bouska, Houser	15 September 2017

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

Background:

This scope of work outlines a series of projects and related output maps, models, and written reports designed to produce information useful in diagnosing habitat conditions for the Upper Mississippi River System (UMRS) for 1989, 2010 and projected future conditions. This work is part of a broader effort to develop a Habitat Needs Assessment for the UMRS. For a more complete description of the entire project, see the Habitat Needs Assessment Project Management Plan. Briefly, the assessment will consist of two primary activities, decided upon during a project steering committee meeting on 7/19-7/20/2016: 1) data analysis and modelling work that will lead to a system-wide habitat inventory for the river and floodplain, and 2) identification of habitat needs based on the habitat inventory and existing Upper Mississippi River Restoration (UMRR) Program objectives (Figure 1). The system-wide habitat inventory will incorporate conceptual models and measures of ecosystem resilience developed during an ongoing UMRR Resilience Assessment along with data and models developed by LTRM since a previous HNA conducted in 2000. The linkages among existing program documents, the Resilience Assessment and the Habitat Needs Assessment are conceptualized in Figure 1.

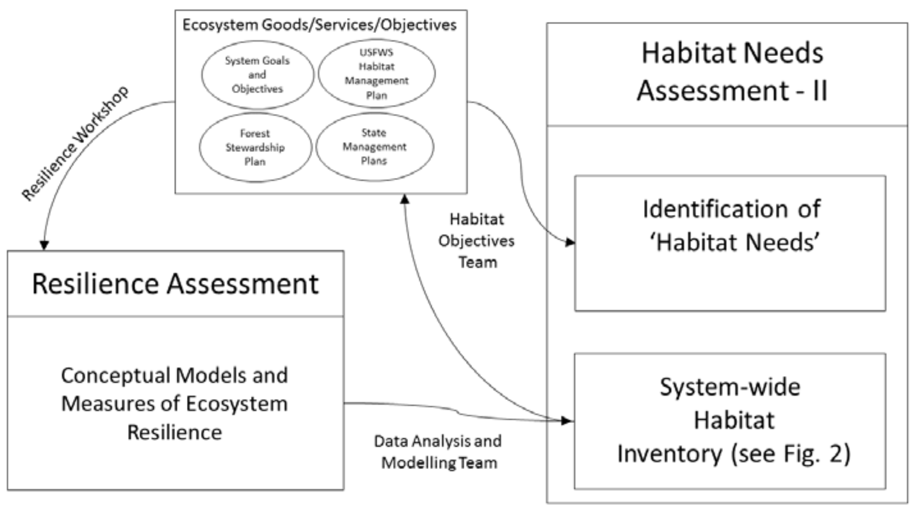


Figure 1. Connections among Upper Mississippi River Restoration (UMRR) Program planning documents, the UMRR Resilience Assessment, and the UMRR Habitat Needs Assessment II.

The remainder of this document outlines a series of general activities to be conducted by the Data Analysis and Modelling Team to produce information products related to the system-wide habitat inventory (Fig. 2). It does not address activities or personnel involved with the identification of habitat needs, or any query tools needed to extract information from datasets developed during the HNA-II process. The primary activities that are discussed here include: 1) developing ecologically meaningful habitat maps for aquatic and floodplain portions of the Upper Mississippi River System, 2) modelling projected future habitat distributions under alternative management and/or climate scenarios, and 3) developing a geodatabase that will be delivered to the Habitat Objectives Team to aid in the identification of existing and projected future habitat needs.

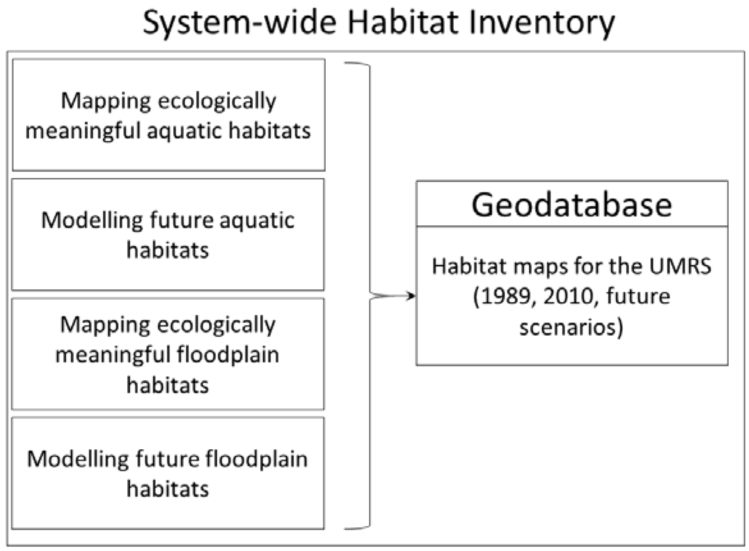


Figure 2. The system-wide habitat inventory will consist of efforts focused on developing ecologically meaningful habitat maps for aquatic and floodplain areas, as well as modelling projected future changes in the abundance and distribution of various habitat types. This information will be entered into a relational database that the Habitat Objectives Team (See Fig. 1) can use to identify habitat needs.

Aquatic Habitats (Allison Anderson, PI):

Maps of general aquatic habitats for the entire UMRS will be completed for the years 1989 and 2010. These two time periods were selected because: 1) data already exist for 1989, 2) only minor changes in habitat conditions are expected from 1989 to 2000 (the only other possible time period), and 3) strong differences in habitat conditions are expected between 1989 and 2010 given recent restoration actions and changing environmental conditions. These maps will consist of an ecologically meaningful classification that incorporates information regarding depth, connectivity, and associated relationships to limnological conditions and species distributions. Aquatic habitats will be defined by examining associations between species and measures of geomorphology, biogeochemistry, and hydraulics. Major activities will consist of delineating primary aquatic features, adding information regarding depth and connectivity, conducting data analyses to determine the ecological meaning of each habitat class, and drafting a written report summarizing the methods and results. These data will form the primary basis for measuring the current abundance and distribution of major UMRS aquatic habitats and their relationship to species distribution patterns.

Products and Milestones

Tracking number	Products	Staff	Milestones
2017AH1	Develop general classification for 2010 and refit 1989-- Key Pools completed	Janis Rusher	30 January 2017
2017AH2	Develop general classification for 2010 and refit 1989-- Rest of system	Janis Rusher	30 July 2017
2017AH3	Develop enhanced lentic areas--Add Connectivity and depth of side channels, structured MCB to aquatic areas for Key Pools	Jim Rogala	30 January 2017

2017AH4	Develop enhanced lentic areas--Add Connectivity and depth of side channels, structured MCB to aquatic areas for rest of system	Jim Rogala	30 August 2017
2017AH5	Develop enhanced lotic areas--Add Connectivity and depth of side channels, structured MCB to aquatic areas for Key Pools	Jason Rohweder	30 January 2017
2017AH6	Develop enhanced lotic areas--Add Connectivity and depth of side channels, structured MCB to aquatic areas for rest of system	Jason Rohweder	30 August 2017
2017AH7	Conduct ecological assessment of enhanced aquatic areas--conduct analyses in Key Pools	Allison Anderson, Kristen Bouska, Jeff Houser, Alicia Weeks	30 March 2017
2017AH8	Conduct ecological assessment of enhanced aquatic areas--complete draft report	Allison Anderson, Kristen Bouska, Jeff Houser, Alicia Weeks	30 September 2017
2017AH9	Apply ecological relationships to entire system and incorporate into geodatabase	Tim Fox	30 September 2017

Modelling future aquatic habitats (James T. Rogala, PI):

Sedimentation in aquatic areas was identified by both the Resilience Assessment and many Steering Committee members as one of the primary drivers of the long-term distribution of aquatic habitats and the overall resilience of the river system. This effort will develop a modelling framework to address potential changes in future aquatic habitats due to variable rates of sedimentation in lentic areas. The framework will incorporate some of the known drivers derived from past studies to address spatial patterns. The framework may include sedimentation resulting from alluvial fan formation. The product from the modelling effort will consist of summary tables of changes by Navigation Pool or sub-pool sections. This summary will estimate potential future shifts in the abundance of general aquatic habitat classes based on changes in depth and connectivity.

Products and Milestones

Tracking number	Products	Staff	Milestones
2017FAH1	Develop Model in Key Pools	Jim Rogala	30 March 2017
2017FAH2	Apply Model to entire system	Jim Rogala	30 August 2017
2017FAH3	Draft report	Jim Rogala	30 September 2017

Floodplain Habitats (Molly Van Appledorn, PI):

Similar to aquatic habitat classification efforts, a floodplain habitat classification will be developed for the UMRS for current conditions. Maps will comprise an ecologically meaningful classification that incorporates information regarding floodplain inundation patterns, soil type, climate, and floodplain vegetation. The major activities of this project will consist of developing flood inundation models for the entire river system, conducting data analyses to identify areas suitable for various soil types and plant species, and drafting a written report summarizing the methods and results. These data will form the primary basis for measuring the current abundance and distribution of major floodplain habitats and associated species distributions.

Products and Milestones

Tracking number	Products	Staff	Milestones
2017FH1	Develop water surface profiles and flood inundation models for the UMRS	Molly Van Appledorn	30 January 2017
2017FH2	Refine/update levee and lidar data for isolated areas	Jason Rohweder	28 February 2017
2017FH3	Analyze floodplain vegetation and forestry data	Molly Van Appledorn, Nate De Jager	30 April 2017
2017FH4	Draft report	Molly Van Appledorn, Nate De Jager	30 September 2017
2017FH5	Apply ecological relationships to entire system and incorporate into Geodatabase	Tim Fox	30 September 2017

Modelling future floodplain habitats (Nathan R. De Jager, PI):

One of the stated limitations of the first Habitat Needs Assessment conducted in 2000 was the need for a more robust method of forecasting changes to floodplain forest communities. This project will therefore develop a floodplain vegetation succession model to make future projections, under different management and/or environmental scenarios. The model will incorporate alternative scenarios of primary disturbances known to influence floodplain forests (e.g., timber harvest, herbivory, invasion by invasive species, and changes to river flows) to forecast potential changes to forest composition and major floodplain habitats.

Products and Milestones

Tracking number	Products	Staff	Milestones
2017FFH1	Format/develop input datasets	Jason Rohweder	30 March, 2017
2017FFH2	Develop flood inundation model extension	TBA	30 March, 2017
2017FFH3	Conduct modelling and write draft report	Nate De Jager	30 September 2017

Geodatabase (Timothy J. Fox, PI):

All mapping products identified above will be incorporated into a single relational database that links species occurrences, geomorphic features, biogeochemical attributes, and hydraulics to the different aquatic and floodplain habitats. This database will allow other GIS analysts to access the data and further develop analytical capabilities to extract measures of habitat amount and distribution at specific spatial and temporal scales. It should be noted that no ability to query the data for specific measures will be provided as it is envisioned that the Habitat Objectives Team will determine the extent to which they will need to query the database. This data base will constitute the extent of technology and data transfer for the project.

Products and Milestones

Tracking number	Products	Staff	Milestones
2017GEO1	Develop Geodatabase/compile all lookup tables and data layers	Tim Fox	30 September 2017

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)

<u>Objectives</u>

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

2017L1: Presentation(s): One or more presentations will be given at conferences and workshops regarding the general concept and ongoing progress of the Habitat Needs Assessment. For more specific work items and products see the HNA SOW.

2017L2: Data/Map Set: Reed Canarygrass abundance and distribution in the UMR (Pools 3-13) and areas at risk of invasion.

In 2016L4 we have developed methods to model and map the distribution of reed canarygrass in the UMRS. In this project, we will extend these methods to other pools in the Upper Impounded Reach (Pools 3-13) and provide distribution maps to Partners. Funding to support Jason Rohweder and Erin Hoy is being provided by the Audubon Society. This project addresses objective 2.1 of the landscape patterns research framework, floodplain community composition and succession.

Products and Milestones

Tracking number	Products	Staff	Milestones
2017L1	Presentations: Habitat Needs Assessment for the UMR (and related conf. calls and such)	De Jager	30 September 2017

2017L2	Data/Map Set: Reed canarygrass abundance and distribution in the UMR (Pools 3-13) and areas at risk of invasion	De Jager, Rohweder, Hoy (UMESC)	30 September 2017
	On-Going		
2016L3	Draft Manuscript: Review of Landscape Ecology on the UMR	De Jager (UMESC)	30 September 2017
2016L4	Draft Manuscript: Reed canarygrass abundance and distribution in the UMR.	Miller & Thomson (UW-L), De Jager Hoy and Rohweder (UMESC)	30 September 2017
	Intended for distribution		
Manuscript: De Jager, N.R., Rohweder, J.J. In Review. Changes in aquatic vegetation and floodplain land cover in the Upper Mississippi River System (1989-2000-2010). (2016L1)			
Manuscript: Swanson, W., De Jager, N.R., Strauss, E.A., Thomsen, M. In Review. Effects of flood inundation and invasion by *Phalaris arundinacea* on nitrogen cycling in an Upper Mississippi River floodplain forest. (2016L2)			
Manuscript: De Jager, N.R., Swanson, W., Hernandez, D.L., Reich, J., Erickson, R., Strauss, E.A. Effects of flood inundation, invasion by *Phalaris arundinacea*, and nitrogen deposition on extracellular enzyme activity in an Upper Mississippi River floodplain forest. (2015L5)			
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)			
Manuscript: Weeks, A.M., De Jager, N.R., Haro, R.J., Sandland, G.J. In Review. Spatial and temporal relationships between the invasive snail Bithynia tentaculata and submersed aquatic vegetation in Pool 8 of the UMR. (2016L6)			
Manuscript: Scown, M. W., Thoms, M. C. and De Jager, N. R. In Review. The effects of survey technique and vegetation type on measuring floodplain topography from DEMs. Earth Surface Processes and Landforms. (2015L8)			

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

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

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.

This study will look at winter and summer water quality conditions pre and post-construction to determine the current extent and increase of winter habitat suitable for limnophilic fishes and any negative effects on summer water quality. Monitoring would include spatial in-situ sampling along with continuous temperature and dissolved oxygen measurement during both summer and winter.

This effort will provide insights on habitat response to a modification of flow into a backwater lake and meets several goals and objectives of the UMRR Strategic Plan for 2015 -2025 including: Obj. 1.2, Strategy 2; Obj. 2.1, Strategy 2; Obj. 2.2, Strategy 1, 2, 5.

Products and Milestones

Tracking number	Products	Staff	Milestones
2017PL1	Collection of pre-construction winter water quality data	Burdis, Moore, DeLain, Lund	February 2017
2017PL2	Collection of pre-construction summer water quality data	Burdis, Moore, DeLain, Lund	August 2017
2017PL3	Collection of post-construction winter water quality data	Burdis, Moore, DeLain, Lund	February 2018 – 2019(?) Dependent on construction date
2017PL4	Collection of post-construction summer water quality data	Burdis, Moore, DeLain, Lund	August 2018 – 2019(?) Dependent on construction date
2017PL5	Summary report: Tabular and graphical summary of water quality data	Burdis, Moore	December 2018 - 2019 (?) Dependent on construction date

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.

Pool 12 Overwintering HREP Adaptive Management Fisheries Response Monitoring – pre-project fisheries population monitoring

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.

Introduction/Background: The Iowa DNR has been studying centrarchid overwintering habits and habitat requirements in the Upper Mississippi River for over 30 years. This work has identified the physical conditions necessary for overwintering and ecological responses to fisheries habitat restoration in HREPs such as Brown's Lake (Pool 13) and Mud and Sunfish Lakes (Pool 11). All of these projects considered fish movement into individual backwaters and habitat suitability in response to restoration. Centrarchid overwintering issues have long been important to river managers because much backwater habitat has been greatly altered or reduced by sedimentation since the 1930s. Centrarchids are also a key component of the sport fishery in the Upper Mississippi River, and public interest in the population dynamics of these species is high.

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.

Relevance of research to UMRR: The Pool 12 Overwintering HREP is being designed and implemented using active adaptive management principles to assess fisheries benefits beyond individual backwaters, whereas prior HREP monitoring considered centrarchid condition and behavior within specific backwaters. This work ultimately aims to answer long-standing questions related to the spacing of fish overwintering HREP projects, and this is an ideal case to attempt this assessment for the reasons mentioned in the Introduction.

The Iowa DNR has been collecting pre-project data in these backwater lakes since 2006. We will have several years of pre-HREP project and post-HREP project fisheries data that will inform the adaptive management process that many UMRR partners are interested in as the UMRR evolves. The pre- and post-dredging fisheries monitoring of this HREP will inform other river managers who are working on topics such as standardized HREP monitoring protocols (USACE and USGS), bluegill overwintering models (USACE), and research frameworks associated with aquatic overwintering issues in the Upper Mississippi River Basin (USGS). This work falls within the USACE's priority research areas for FY17.

Methods: Pre-project (pre-dredging) data has been collected in Pool 12 since 2006. In FY17 we will collect another annual increment of pre-project fisheries data (pool-wide electrofishing and backwater lake-specific fyke netting). We will continue with these sampling efforts in the rehabilitated and control lakes throughout the construction period. We will attempt to collect as many years of post-project data as we have of pre-project data from each backwater lake so we can compare "before and after" centrarchid condition, population dynamics, and mortality to assess if there is a positive response in the fishery in the rehabilitated backwaters.

Continued post-project fisheries monitoring will also show if centrarchid populations will be enhanced throughout the entirety of Pool 12, or just in the rehabilitated lakes. We also have pool-wide and backwater fisheries monitoring conducted annually in neighboring Pool 13 as part of standard UMRR LTRM fisheries component monitoring. Thus, Pool 13 will also serve as a control to determine if the fisheries response is specific to the rehabilitated areas in Pool 12, or if centrarchid population dynamics remain similar to those we observe in Pool 13 during the same period of time.

"Treatment" (rehabilitated) Lakes	"Control" Lakes
Sunfish (RM 564)	Wise (RM 561.5)
Kehough (RM 567.5)	Fishtrap (RM 566)
Tippy (RM 571.5)	Green's (RM 572.5)
Stone (RM 572)	Frentress (RM 576)

Products and Milestones

Tracking number	Products	Staff	Milestones
2017P13a	Collect annual increment of pool-wide electrofishing data	Bierman and Bowler	1 November 2016
2017P13b	Collect annual increment of fyke netting data from backwater lakes	Bierman and Bowler	15 November 2016
2017P13c	Perform otolith extraction from bluegills for aging	Bierman and Bowler	1 December 2016
2017P13d	Age determination of bluegills collected in Fall 2014	Bierman and Bowler	1 February 2017
2017P13e	In-house project databases updated	Bierman and Bowler	31 March 2017
2017P13f	Summary report compiled and made available to program partners	Bierman and Bowler	30 September 2017

Pool 12 Overwintering HREP Adaptive Management Fisheries Response Monitoring – Pre-project Biological Response Monitoring; Crappie Telemetry – Kehough Lake

Introduction/Background:
See previous section
Relevance of research to UMRR:
See previous section

Methods: This project was initially attempted during FY 2016. However there was an unusual and extended high-water period from late December through most of January that resulted in the loss of all tagged crappie. The study will be attempted again in FY2017 as described here. This proposal will provide a year of pre-project centrarchid telemetry in Kehough Lake. Methods used in the FY2015 radio tracking study will be repeated; please note that these are covered in the previous section.

In this study, transmittters will be implanted in 50 white and/or black crappie in one overwintering backwater in Pool 12: Kehough Lake. Kehough Lake will be rehabilitated in Phase III of the Pool 12 Overwintering HREP. Transmitters will be implanted after water temperatures have fallen below 10^{o}C. Fish will be tracked intensively for a period of one year and every fish will be located once every two weeks. By stratifying the year into two-week segments and locating every fish within each two-week period, issues of autocorrelation of animal locations will be avoided (Otis and White 1999, Fieberg 2007). For each crappie location, position will be recorded with a GPS unit and dissolved oxygen, temperature, depth, secchi, and flow will be measured. This design will potentially yield 50 locations per two-week sample period (1,300 annually).

The 80% UD utilization contour for each backwater will again be quantified and graphed, using Kernel methods in the Home Range Extension (HRE) for ArcView (Rogers and Carr 2002). We will also again explore how landscape features such as the main channel, position in the pool or side channel complex, or proximity to other overwintering backwaters affects the UD.

Timeline: Late October 2016 through 30 September 2017, with transmitter activation in Nov 2016.

Milestones and products:

Tracking number	Products	Staff	Milestones
2017AM1	Capture fish and affix radio tags to white crappies in study lakes	Bierman, Hansen, Bowler, Theiling	November 2016
2017AM2	Location of tagged fish and update in-house project database	Bierman, Hansen, Bowler, Theiling	Ongoing through FY17
2017AM3	Complete tracking portion of study	Bierman, Hansen, Bowler, Theiling	30 September 2017
2017AM4	Summary report: Analysis of tracking data and quantification of 80% UDs for Stone, Tippy, and Green lakes	Bierman, Hansen, Bowler, Theiling	30 September 2017
2017AM5	Summary report: Analysis of tracking data and quantification of 80% UDs for Kehough lake	Bierman, Hansen, Bowler, Theiling	30 September 2018

References

Fieberg, J. 2007. Kernel density estimators of home range: smoothing and the autocorrelation red herring. Ecology 88:1059-1066.

Otis, D. L., and G.C. White. 1999. Autocorrelation of location estimates and the analysis of radio tracking data. Journal of Wildlife Management 63:1039-1044.

Rogers, A.R., and A.P. Carr. 2002. HRE: The home range extension for ArcView user manual. Centre for Northern Forest Ecosystem Research, Ontario Ministry of Natural Resources. 27pp.

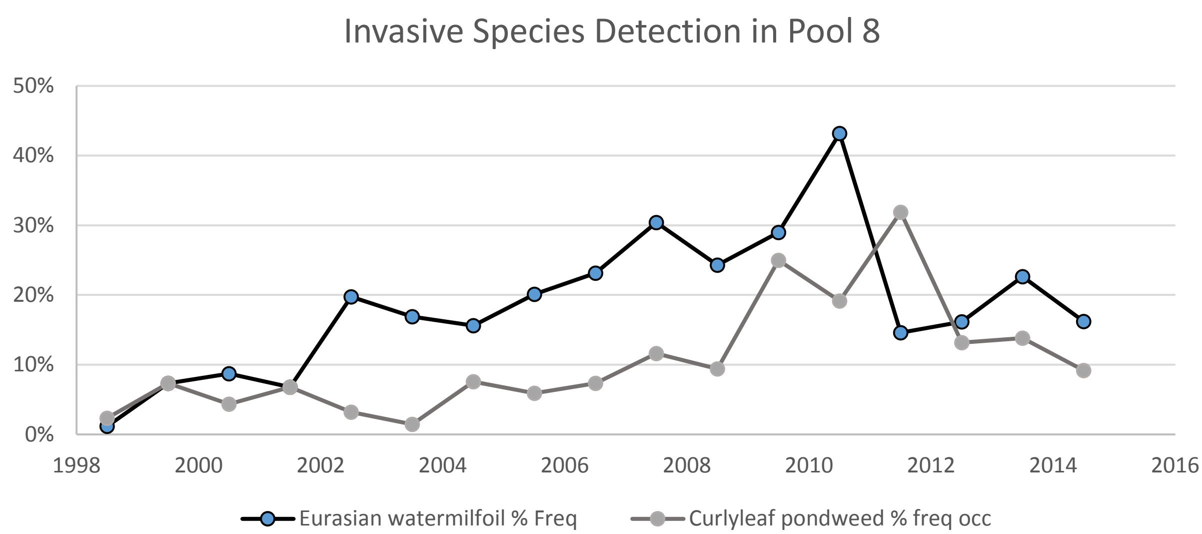
Understanding biological shifts in the UMR due to invasion by *Potamogeton crispus*

Description of Work

Invasive *Potamogeton crispus* (curlyleaf pondweed) has an unusual phenology with mid-summer senescence, fall germination, and possible winter photosynthesis. Here we examine its contribution to nutrient cycling and winter dissolved oxygen in Pool 8 of the UMR. We will quantify biomass, nutrient standing stocks growing season and senescence, and phytoplankton abundance associated with *P. crispus* beds. Seasonal logger data will be used to track winter dissolved oxygen concentrations associated with *P. crispus* beds and reference sites.

Aquatic invasive species (AIS) are a primary threat to aquatic ecosystem health. In addition to displacing native species, AIS can modify environments. In 17 years of annual vegetation monitoring, invasive *P. crispus* has been detected at 2-31% of sites in Pool 8 of the UMR (Figure 1) – its distribution is patchy with high densities noted in several backwater areas. The methods used by the LTRM, however, likely underestimate the prevalence of *P. crispus* due to its unusual phenology. Most growth and reproduction (formation of vegetative buds) occurs by mid-June, and senescence generally occurs by mid-July (Nichols and Shaw, 1986). LTRM surveys are conducted between mid-June and mid-August to target the predicted maximum biomass of aquatic vegetation generally, but miss the *P. crispus* maximum. The potentially large biomass of invasive *P. crispus* in combination with its temporally offset growth and senescence, plus its capacity for winter photosynthesis make it of particular interest in UMR ecosystem health. We propose to quantify the following biological shifts in the UMR ecosystem associated with *P. crispus*:

- **Earlier C, N and P fixation and release via decay** (mass balance calculations)
- **Increased primary production by phytoplankton** - a result of mid-summer senescence and nutrient release (reference site comparison)
- **Increased dissolved O_2 in winter - a** result of winter photosynthesis (reference site comparison)



We will determine whether senesce of *P. crispus* is linked to increased abundance of phytoplankton, which may also link to mid-summer metaphyton blooms (Sullivan and Giblin 2012). Similar nutrient-mediated links have been described in other systems – for example, an increase in phytoplankton biomass was seen in response to senescence and decay of invasive *Myriophyllum spicatum* in Lake Monroe, Indiana (most likely a result of P release; Landers, 1982).

Turions of *P. crispus* sprout in autumn and overwinter under the ice. Observations in Pool 8 and elsewhere (e.g. Nichols and Shaw 1986) suggests that *P. crispus* is photosynthetically active even under low light conditions created by thick ice and snow cover, and the species may contribute to winter periods of oxygen supersaturation and fish kills. This study includes a comparison of dissolved O_2 dynamics in macrophyte beds dominated by *P. crispus* and native plants.

Understanding patterns in stream nutrient spiraling at a national scale, as developed by LINX 1 project (Peterson et al. 2001) was a major step forward in stream ecology. The role of periphyton and macrophytes in nutrient cycling of small, headwater streams was a component of this work. The timing and relative amounts of nutrient sequestration by *P. crispus* (and of native plants) in a large river are of particular interest in this context.

<u>Methods</u>

Answering the questions posed here will require us to 1) produce estimates of *P. crispus* biomass and nutrient standing stocks during maximum and senescence phases, 2) quantify phytoplankton chlorophyll a concentrations in *P. crispus* beds and reference sites, and 3) track diurnal patterns of DO in *P. crispus* beds and reference sites during winter.

Site selection: Thirty sites were established: ten within *P. crispus* beds in the Stoddard area, ten within *P. crispus* beds in the Lake Onalaska area, and ten reference sites in upper Pool 8 matched for depth and other physical conditions, where native *Potamogeton* species have been detected in previous LTRM surveys.

Sampling methods:

i. Measure per-rake and per-quadrat biomass (including belowground) in May of 2016, during the normal July-August LTRM survey period, and in October when P. crispus is actively growing. Standard rake data will be collected at each site, and a standard water quality data and samples will be collected at a subset of sites.
ii. Develop a quantitative relationship between standard LTRM summer survey data and peak biomass of P. crispus, if possible, for application at the pool scale and over time.
iii. Measure plant N & P content in P. crispus for estimation of seasonal nutrient standing stocks in roots, stem, and reproductive structures (turions).
iv. Estimate nutrient contributions to the water column through senescence of P. crispus.
v. Deploy data loggers for temp/cond/DO measurements will be deployed:
    - December 2015 (approximate time of 2014 fish kills)
    - June 2016 (maximum biomass)
    - August 2016 (senesced)
    - October 2016 (new growth)

Destructive harvest to determine biomass will be conducted during approximately ten-day periods in May 2016, during the regular LTRM sampling season (mid-June to mid-August), and in October 2016.

Standard LTRM survey data will be collected following established protocols (Yin et al. 2000) during every site visit, with the addition of total plant biomass collection in 1 of the 6 rake sub-sites for each site. Whole plants, including roots, of all species within the raked area (approximately 1.5 m x 0.35 m) will be collected by a snorkeler. Biomass samples will be stored in burlap bags, on ice, and in coolers and will be returned to the laboratory for processing within 24 hours. Wet and dry mass of each species and each tissue type (belowground, aboveground, turions) will be determined. *P. crispus* samples will be composited by tissue type, homogenized by grinding, and ~40- g subsamples will be submitted to AgSource Laboratory (Bonduel) for CNP analyses. Dry samples of all species and tissue type will be stored for at least 1 year for possible future analyses and comparison.

Time frame and logistic considerations for the work

FY 2017 Phytoplankton analyses pending (contracted). Data compilation, quantitative analyses, and manuscript development for a report and submission to peer-reviewed journal. Identification of further work such as relation to O2 supersaturation/fish kills or N tracer studies comparing N dynamics in a native and invasive *Potamogeton*.

Report 1 June 2017
Manuscript for peer review 15 December 2017.

Milestones and products:

Tracking number	Products	Staff	Milestones
2016PC2	Draft Report: Understanding biological shifts in the UMR due to invasion by *Potamogeton crispus*	Drake, Giblin, Nissen, Kalas	1 June 2017

References

Sullivan, J.F. and S.M. Giblin. 2012. Growth, Tissue Composition and Stoichiometry of Duckweed Grown in Low Nutrient Backwaters of the Upper Mississippi River

Landers, D.H. 1982: Effects of naturally senescing aquatic macrophytes on nutrient chemistry and chlorophyll a of surrounding waters. Limnology and Oceanography 27(3), 428–39

Nichols, S.A. and B.H. Shaw. 1986. Ecological life histories of the three aquatic nuisance plants, *Myriophyllum spicatum*, *Potamogeton crispus*, and *Elodea canadensis*. Hydrobiologia 131: 3-21

Peterson, B.J., W.M. Wollheim, P.J. Mulholland, and 12 other authors. 2001. Control of Nitrogen Export from Watersheds by Headwater Streams. Science: 292 (5514), 86-90

Yin, Y., J.S. Winkelman, and H.A. Langrher. 2000. Long Term Resource Monitoring program procedure: aquatic vegetation monitoring. U.G. Geological Survey, LTRMP 95-P002-7, La Crosse, Wisconsin

Assessing recent rates of sedimentation in the backwaters of Pools 4, 8, and 13 to support river restoration and the Habitat Needs Assessment.

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. The results of the 1997 – 2001 study found relatively low rates of backwater sedimentation compared to most other studies. This finding could be because many of the other studies measured rates in areas of known sediment accumulation, whereas Rogala et al. distributed transects in a stratified random design to assess pool-wide sedimentation rates. Alternatively, the study period for the Rogala et al. work included an extremely high discharge year (2001) during which the scouring that occurred may have reduced net rates of sedimentation during the 5 year period included in that study. The study proposed here will use comparisons of bed elevations in 2016/17 to those observed in the 1997 – 2001 study to assess net sedimentation rates since 2001. This longer (i.e., > 15-yr) period of change will likely substantially improve our estimates of current rates of backwater sedimentation.

Introduction/Background:

The fate of backwaters in the UMRS is a concern of river resource managers, as these backwaters are critical for biota associated with lentic habitats. Loss of water depth due to sedimentation is a primary concern. Backwater depth has been identified as controlling variables in the conceptual models produced as part of the ongoing UMRR resilience assessment (Bouska et al. in prep) and is a fundamental component of the second Habitat Needs Assessment (HNA II). Understanding the rate at which those depths are changing due to sedimentation will improve the projections of future conditions made as part of HNA II. Many backwater restoration projects contain a component to remove sediment that has accumulated since the backwaters were created (or expanded) by lock and dam construction. Ongoing sedimentation will further threaten backwater habitat, therefore information on backwater sedimentation is critical for making informed decisions on habitat rehabilitation needs (e.g., Gaugush and Wilcox 2002).

Relevance of research to UMRR:

This project should improve our understanding of backwater sedimentation rates by resurveying LTRM transects previously surveyed annually from 1997 to 2002. The annual surveys provided much insight into associations between sedimentation and the predictor variables of discharge and bed elevation. Given the high annual variability in rates determined from that study, and the short period of study (four annual change increments), sedimentation over longer time periods (e.g., decadal scale) is difficult to predict. The longer 15-yr period of change that we will assess should substantially improve our overall estimates of recent rates of sedimentation in backwaters of the Upper Impounded Reach of the UMR. Information derived from this project will substantially inform projections of future system conditions produced as part of HNA II, and will be useful in broader assessments of restoration needs.

The study transects are distributed across a range of backwater size and hydraulic connectivity and include a full range of water depths. This provides the opportunity to assess associations between those characteristics and sedimentation rates. A better understanding of the types of backwater areas where degradation through high rates of sedimentation are likely can improve selection and planning of restoration projects such as dredging that maintain or enhance existing deep backwater habitat. The information can also be used to estimate project longevity by applying sedimentation rates to project areas.

The proposed work address UMRR Strategic Plan (2015-2025) Objective 2.1 – Assess and detect changes in, the fundamental health and resilience of the Upper Mississippi River ecosystem by continuing to monitor and evaluate its key ecological components of aquatic vegetation, bathymetry, fish, land use/land cover, and water quality. Specifically Strategy 2 within that Objective: Conduct scientific analysis, research, and modeling using UMRR's long term data, and any necessary supplemental data, to gain knowledge about the Upper Mississippi River ecosystem status and trends and process, function, structure, and composition

Methods:

This study will use the same sampling design and survey methodology used in the 1997-2002 study (Rogala et al. 2003). A summary of those methods is provided here:

Randomly selected locations were used to establish transects across backwaters in Pools 4, 8, and 13. A stratified design based on backwater lake size and connectivity was used to select 25 transects in each pool. Two transects were selected in each of the 6 largest backwater lakes in each pool, and 13 transects split across low and high connectivity backwater lakes.

The measurement of bed elevation along established transects is split into over-ice and open-water surveys. The measurements through the ice are performed wherever possible (i.e., aquatic and ice not froze to bottom) and open-water surveys performed at the nearshore locations. Pre-determined distances from an endpoint are used to locate survey locations along transects. Water depth is measured during over-ice surveys, and the depth converted to a bottom elevation relative to an established temporary vertical benchmark by using a level. Bed elevation is measured by leveling for open-water surveys.

Rates of sedimentation at each survey location will determined by the simple difference between bed elevations of the 2002 and the resurvey. Mean rates for various areas of interest (e.g., pool, aquatic/terrestrial, specific subareas) will be estimated using designed-based statistics. Correlation between sedimentation rates and bed elevation will be determined with mixed models similar to those used in the 1997-2002 study.

Transects will be relocated and reestablished as needed and open-water nearshore surveys will be completed the fall of 2016. Over- ice surveys will be completed in the winter of 2016-17.

Milestones and products:

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

Literature Cited:

Bouska, K.L., J.N. Houser, and N. R. De Jager. In prep. Developing a shared understanding of the Upper Mississippi River: the foundation of a resilience assessment.

Gaugush, R. F., and D. B. Wilcox. 2002. Recommended investigations of sediment transport and deposition for predicting future configurations of Upper Mississippi River System channels and floodplain. U.S. Geological Survey, Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin, September 2002. LTRMP 2002- P001. 5 pp. + Appendix. (NTIS PB2003-101509)

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

Developing and applying trajectory analysis methods for UMRR Status and Trends indicators – Year 2

Introduction/Background:
In 2015, a proposal was funded titled "Developing and applying trajectory analysis methods for UMRR Status and Trends indicators" (Ickes and Minchin 2015). The project sought to determine whether functional fish assemblages (habitat, feeding, and reproductive guild assemblages) were on discernibly non-random trajectories over a 22-year period of time within and among each of the six UMRR LTRM study reaches. Results, presented in a summary letter in 2015, clearly demonstrated functional shifts in UMRS fish assemblages for all functional guild classes and UMRR LTRM study reaches with the sole exception of reproductive and habitat guilds in the Open River Reach of the Mississippi River.

Results from 2015 clearly demonstrated fundamental functional attributes of UMRS fish assemblages are changing over time in a directional way. Our initial null hypothesis was that trends over time in functionally-defined fish assemblages would be of a random nature. However, this hypothesis was rejected for the vast majority of functional groups and study reaches examined. The directionality of the shifts over time suggest some form of forcing mechanism, that itself is non-random, is likely driving these directional shifts. This forcing agent may be intrinsic to the fish communities themselves, or extrinsic factors that are directly affecting functional fish community responses throughout the UMRS. Intrinsic forces may include (a) effects of non-native fish species on native fishes; (b) changes in trophic and food web structure; and (c) changes in functional interactions within the fish community itself (i.e., predator-prey dynamics), perhaps mediated by changes in exploitation or disease. Extrinsic forces may include (a) effects of habitat rehabilitation; (b) habitat impairment; or (c) changes in river dynamics (i.e., flood and drought cycles; nutrient eutrophication; primary production pathways).

This work contributes to a body of knowledge that seeks to develop methods and indicators for Status and Trends Assessments within the UMRS basin. The method is capable of assessing whether communities are heading in an acceptable direction, even if they have not yet attained their desired composition. Our initial work has demonstrated that Trajectory Analysis as a method is sufficiently sensitive and adequate to detect trends in fish community functional responses across 1200 miles of river. Second, we seek to further study the proximate drivers of the observed trajectories to identify the intrinsic and extrinsic forces driving observed directional shifts in functional community attributes. Identifying the forces driving observed trajectories may suggest new management approaches that can influence fish communities throughout the UMRS. Finally, we seek to determine the fundamental nature of the trajectory responses themselves, indicative of possible regime shifts, with implication for ecological resilience assessments just beginning within the basin. Resilience theory provides three sets of mechanisms that give rise to regime shifts observable in ecological responses: (1) linear; (2) nonlinear; and (3) hysteretic responses. Further work is needed to identify which of the three mechanisms is driving observed trajectory shifts in fundamental functional attributes of UMRS fish assemblages.

Methods:
Fish community indicators will be developed and analyzed using Trajectory Analysis. Annual data for each multivariate fish indicator developed from each of six long term study reaches on the UMRS, will be analyzed for significant trends over time, and differences in the status and trends of each indicator will be evaluated among the six study reaches, representing 1200 river miles. For those functional groups and study reaches with demonstrably non-random trajectories over time, additional analysis and

modeling will seek to infer (1) the mechanistic form of the trajectory response (linear, nonlinear, hysteresis); and (2) the environmental covariates seemingly driving these observed trajectory responses.

Products and Milestones

Tracking number	Products	Staff	Milestones
2015B17	Draft Manuscript: Fish Trajectory Analysis	Ickes, Minchin	28 February 2017
2016B17	Draft Manuscript: Developing and applying trajectory analysis methods for UMRR Status and Trends indicators – Year 2	Ickes, Minchin	28 February 2017

References

Ickes, B.B. and P. Minchin. 2015. Developing and applying trajectory analysis methods for UMRS Status and Trends indicators. Summary Letter issued to the U.S. Army Corps of Engineers, Rock Island District and a product of the Upper Mississippi River Restoration program. 9 pp.

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.

Product Description

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 2017
	Intended for distribution		
Draft manuscript: Inferring decreases in among- backwater heterogeneity in large rivers using among-backwater variation in limnological variables (2010E1)			

Additional Aquatic Vegetation, Fisheries, and Water Quality Research

Tracking number	Products	Staff	Milestones
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 2017
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 June 2018
2016A6a	Draft manuscript: Aquatic Plant Response to Large-Scale Island Construction in the Upper Mississippi River.	Drake and Gray	31 January 2017
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?	Yin	28 February 2017
Fisheries			
2006B6	Draft manuscript: Spatial structure and temporal variation of fish communities in the Upper Mississippi River. (Dependent on 2008B9 acceptance into journal)	Chick	TBD
2016B14	Draft completion report: Exploring Years with Low Total Catch of Fishes in Pool 26	Gittinger, Ratcliff, Lubinski, Chick	30 Sept 2016
Water Quality			
2015D15	Analysis of Lake Pepin rotifers; data from 2012-2014	Burdis	30 June 2017
2015D16	Draft manuscript: Trends in water quality and biota in segments of Pool 4, above and below Lake Pepin	Burdis	31 Dec 2016
Intended for Distribution			
Manuscript: Benefits of Collaboration among Long Term Fish Monitoring Programs in Large Rivers (Fisheries Journal) Counihan, Ickes, Casper, Sauer 2016B12			
Manuscript: An Assessment of Long Term Changes in Fish Communities within Large Rivers of the United States (Environmental Monitoring journal) Counihan, Ickes, Casper, Sauer 2016B13			
Manuscript: Relationship between the temporal and spatial distribution, abundance, and composition of zooplankton taxa and hydrological and limnological variables in Lake Pepin (Reformatting for submission to River Research and Applications) Burdis 2016D17			

USACE UMRR LTRM Technical Support

This paper describes the roles of the U.S. Army Corps of Engineers district UMRR LTRM Technical Representatives, which are supported with LTRM funds to help facilitate the two directional communications between each home district and the Regional Program. These individuals shall serve as a point of contact with each district for LTRM data and information, and the use of LTRM data in the identification, formulation, and evaluation of HREPs.

This SOW captures an anticipated level of effort to accomplish the tasks herein, which is reflected in the funding allocated. This SOW represents approximately 190 hours for each representative (n=3) in fiscal year 2016; no change from FY2015.

[NOTE: In years when the annual appropriation is less than the amount needed to fully fund Base Monitoring (such as FY13 and FY16), the amount available for the Corps' LTRM Technical Representatives could be reduced proportionately and the SOW could be adjusted accordingly. This option may be exercised for FY17]

MAJOR DUTIES

1. Technical Support to Regional LTRM Manager

Estimated Level of Effort (~40 hours)
For all Document Review – Each document review should be coordinated throughout home district as appropriate, all comments received should be consolidated, and transmitted to the LTRM Project Manager (copy furnish the other 2 district LTRM Representatives). A minimum of 2 weeks of review and comment preparation time should be provided, if possible.

a. Annual SOW (translation of the 2015-2025 UMRR Strategic & Operational Plan annually for Base Monitoring and Science in Support of Restoration & Management SOWs) – participate in conference calls as needed (1-2/yr)
b. Other reports - varies, as needed, and could include research frameworks, research proposals, Resilience indicator project
c. Regular monthly conference calls with the UMRR Regional Program Manager, LTRM Project Manager, 3 HREP coordinators, 3 LTRM Technical Representatives, and others as needed (~12/yr)

2. Represent UMRR LTRM and home district at all regular A-Team Meetings

Estimated Level of Effort (~40 hours)
Work under this heading includes two directional communications – regional coordination, bringing information back to the districts, and bringing local knowledge, issues, or questions to the A-Team. The level of effort hours will vary with length of meeting, meeting location, and level of prep/follow up.

a. Conference calls – 2/year
b. Meetings – ~2/year
c. Support A-Team activities as appropriate

3. Serve as UMRR LTRM data and resource contact for district PDTs (HREP-LTRM Integration)

Estimated Level of Effort (~80 hours)
Generally, each district's LTRM Technical Representative serves as a proactive resource, promoting the use and/or application of LTRM data (including research, models, etc) in their home district, primarily for project planning and monitoring. Knowledge of the available datasets (online and others), models, graphical browsers, etc, and personnel at UMESC and the field station(s) is critical for this task.

4. Other Meeting Attendance (if funding and time allow)

Supported Level of Effort (~30 hours)
Work under this heading includes dissemination of information from meeting and conference attendance to district personnel, PDT's, as appropriate. Discretion in choosing meetings is strongly recommended since the **funding level does not support attendance at all of these listed below**.

a. MRRC–Held in conjunction with April A-Team meeting
b. UMRCC –annual and/or technical session meetings
c. FWWG, FWIC or RRAT (tech) for meetings in home district

COMMUNICATION
Each UMRR LTRM Technical Representative will participated in regular UMRR Program conference calls and provide updates of their significant UMRR and UMRR-related activities to the UMRR LTRM Management Team. If any significant activities are reported to their Commander, the UMRR management will be made aware.

POC for the UMRR LTRM Technical Representatives is the UMRR LTRM Project Manager, Karen Hagerty.

Products and Milestones

Tracking number	Products	Staff	Milestones
2017COE1	Quarterly update submitted to the LTRM Management Team	McCain, Theiling, Potter	31 December 2016
2017COE2	Quarterly update submitted to the LTRM Management Team	McCain, Theiling, Potter	30 March 2017
2017COE3	Quarterly update submitted to the LTRM Management Team	McCain, Theiling, Potter	30 June 2017
2017COE4	Quarterly update submitted to the LTRM Management Team	McCain, Theiling, Potter	30 September 2017

UMRR LTRM Team Meeting

To foster communication between USACE, USGS-UMESC and state field station staff, a joint meeting of all staff will be held in FY2017. 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 TBD.

Products and Milestones

Tracking number	Products	Staff	Milestone
2017FM1	Meeting date coordination	All LTRM Staff	16 January 2017
2017FM2	Agenda development	All LTRM Staff, led by UMESC	10 February 2017
2017FM3	Meeting logistics	Sauer	On-Going
20157M4	Meeting participation	All LTRM Staff	TBD

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.

UMRR Science in Support of Restoration and Management – Remaining Tasks from FY2014 and FY2015

Tracking number	Milestone	Original Target Date	Modified Target Date	Date Completed	Comments	Lead
Seamless Elevation Data						
2015LB9	Lidar (Tier 2) processing for Pool 1, 2, and Lockport	31-Dec-15		31-Dec-16	no cost acquisition of new LiDAR	Dieck, Hanson
2015LB10	Seamless Elevation processing for Pool 2 and 19	31-Dec-15		31-Dec-16	resolved data quality issues (Pool 19)	Dieck, Hanson
Development of Mussel Vital Rates						
2014MVR1	Brief summary report	30-Sep-15		30-Sep-15	completed, in UMESC review	Newton, Zigler, Davis
2014MVR2	Progress update	30-Sep-16		30-Sep-16		Newton, Zigler, Davis
2014MVR3	Completion report on a vital rates of native mussels at West Newton Chute, UMRS	30-Sep-17				Newton, Zigler, Davis
Effects of Nutrient Concentrations on Zoo- and Phytoplankton						
2014NC1	Counting of phytoplankton samples	13-Mar-15		2-Mar-15		Giblin, Campbell, Houser, Manier
2014NC2	Database completed and analysis completed	13-Mar-16	13-Mar-17		Working With UWL staff. Analysis will have to be conducted after academic year.	Giblin, Campbell, Houser, Manier
2014NC3	Full manuscript completed	13-Mar-18				Giblin, Campbell, Houser, Manier
Ecological Shifts Turbid to Clear States						
2014ES1	Literature review and initial analyses competed	13-Mar-15		15-Nov-14		Giblin, Ickes, Langrehr, Bartels
2014ES2	Refined analyses and draft manuscrpt prepared	13-Mar-16		4-Jan-16	reconciling journal review comments	Giblin, Ickes, Langrehr, Bartels
2014ES3	Manuscipt submitted for publication	13-Mar-17				Giblin, Ickes, Langrehr, Bartels
Asian Carps Recruitment Sources (#2)						
2014CRS1	Summary letter	31-Jan-15		16-Jan-15		Phelps, Mccain
2014CRS2	Manuscript	31-Mar-16	30-Aug-16	30-Aug-16	in review at Aquatic Invasions	Phelps, Mccain
Effects of Asian Carps on Native Piscivore Diets (#3)						
2014NPD1	Summary letter	31-Jan-15		16-Jan-15		Phelps, Mccain
2014NPD2	Manuscript	31-Mar-16	30-Oct-16	17-Nov-16	submitted to Environmental Biology of Fishes	Phelps, Mccain
Early Life History of Invasive Carps (#4)						
2014CLH1	Summary letter	31-Jan-15		16-Jan-15		Phelps, Mccain
2014CLH2	Manuscript	31-Mar-16		1-Jan-16	in press	Phelps, Mccain
Fish Indicators of Ecosystem Health						
2015FI1	Preliminary set of species identified for the different assemblages by study reach submitted to A-Team as status update and for review	30-Aug-15	10-Feb-16	16-Feb-16	Post doc hiring delay resulted in project delayed	Anderson, Casper, McCain
2015FI2	Draft recommendation for the best attainable or target for each assemblage by study reach submitted to A-Team for Review	1-Oct-15	10-Feb-16	16-Feb-16	For presentation at 2016 UMRR Science Mtg in La Crosse briefing	Anderson, Casper, McCain
2015FI3	Initial draft Project Report submitted to A-Team for review	1-Dec-15	15-Mar-16	30-Mar-16	Incorporate feedback from 2016 UMRR Science Mtg presentation into La Crosse A-team briefing	Anderson, Casper, McCain
2015FI4	Final draft Project Report submitted to A-Team for review and endorsement at JANUARY meeting	1-Mar-16	15-Dec-16	16-Dec-16	all requested changes were made	Anderson, Casper, McCain
2015FI5	Final draft Project Report submitted to UMRR CC for endorsement at FEBRUARY meeting	15-Jul-16	15-Jan-17	15-Jan-17	on schedule	Anderson, Casper, McCain
2015FI6	Final Report	1-Jun-16	28-Feb-17			Anderson, Casper, McCain
Plankton community dynamics in Lake Pepin						
2015LPP1	Phytoplankton processing; species composition, biovolume	30-Dec-15		22-Oct-15		Burdis
2015LPP2	draft manuscript: Plankton community dynamics in Lake Pepin	30-Sep-16	30-Mar-18		delayed due to field station staffing shortages and will also include data	Burdis
Estimating trends in UMRR fish and vegetation levels using state-space models						
2015SST1	Draft completion report: Evaluation of trend estimation methods for LTRM fish and vegetation indices	30-Sep-15	15-Dec-15	29-Jan-16	Project delayed by computing challenges.	Gray
2015SST2	Final completion report: Evaluation of trend estimation methods for LTRM fish and vegetation indices	31-Dec-15	15-Mar-16	27-Mar-16		Gray
2015SST3	Provide trend estimates for fish and vegetation web browser pages	30-Sep-16	31-Dec-16	27-Dec-16		Gray, Schlifer
Predictive Aquative Cover Type Model - Phase 2						
2015AQ1	Develop 2-D hydraulic model of upper Pool 4	30-Sep-15		30-Sep-15		Libbey (MVP H&H)
2015AQ2	Apply model to Pool 4 and resolve discrepancies	31-Dec-15	31-Mar-16	31-Mar-16		Yin, Rogala
2015AQ3	Detailed summary of work for Phases I & II	31-Dec-15	3-Jun-17		Resolving model discrepancy took longer than anticipated. Needs extension of summary deadline	Yin, Rogala, Ingvalson

FY17 SOW Addendum

Estimating backwater sedimentation resulting from alluvial fan formation

Introduction/Background:

The need for information on sedimentation in the Upper Mississippi River System (UMRS) was established early in the planning for a monitoring/research component in what is now the Upper Mississippi River Restoration (UMRR) Program. Workshops held in 1994 and 2000 recommended a wide range of general investigations that might further inform resource managers on sediment transport and deposition of sediments in the UMRS (Gaugush and Wilcox 1994; Gaugush and Wilcox 2002). Several of the recommended investigations focused on better understanding rates of accumulation of sediment in backwaters, a known concern among most resource managers.

Sediment deposition in backwaters derives from two primary mechanisms: 1) deposition of fine sediment as it precipitates out from the water column and 2) deposition of near-bed coarse sediments delivered from adjacent channels. Some studies investigating fine sediment deposition have been done in the past, and at least some estimates of rates exist. In contrast, relatively little is known about the areas where sands are accumulating, or the rates at which they are accumulating.

Coarse sediment deposition in backwaters is often in the form of delta-like deposits (i.e., alluvial fans) where channels enter backwaters. Other depositional areas can be found as side channels enter into impounded areas in the lower portions of pools in the upper reaches. Sand deposits provide valuable habitat diversity, but at the expense of deeper water habitats. The accumulation of sand is a longer-term deposition, whereas fine sediment deposits can be removed during future high flow events. Given the potential for altering backwaters in a long-term manner, a better understanding of alluvial fan formation is needed when considering future conditions of the UMRS.

Relevance of research to UMRR:

The objective of this pilot study is to develop automated methods to determine the frequency and rate of alluvial fan formation in backwaters over a 20-yr period. These methods can then be applied more systemically in backwaters of the UMRS. This information complements ongoing backwater sedimentation studies by looking at one type of sediment accumulation that has been found to be significant in some backwaters. For example, during the North/Sturgeon HREP planning, several large alluvial fans were identified as features that have changed habitat substantially. A better understanding of the frequency and rate of alluvial fan formation provides the opportunity to assess whether these changes are desired, and if not desired, assess the types of habitat projects that might address the issue.

The proposed work address UMRR Strategic Plan (2015-2025) Objective 2.1 – Assess and detect changes in the fundamental health and resilience of the Upper Mississippi River ecosystem by continuing to monitor and evaluate its key ecological components of aquatic vegetation, bathymetry, fish, land use/land cover, and water quality. Specifically, Strategy 2 within that Objective: Conduct scientific analysis, research, and modeling using UMRR's long term data, and any necessary supplemental data, to gain knowledge about the Upper Mississippi River ecosystem status and trends and process, function, structure, and composition.

Methods:

In most cases, alluvial fan formation results in either very shallow water or a transition to terrestrial. This attribute provides an opportunity to evaluate, at least in a coarse manner, the changes by using remote sensing. Aerial photography can provide changes in land cover types that reflect changes from deep to shallow, and from aquatic to terrestrial. The UMRR has developed systemic land cover GIS data at a decadal scale (i.e., 1989, 2000, 2010), thus providing the opportunity to map alluvial fan frequency and magnitude for the UMRS.

This proposed pilot study will investigate the effectiveness of comparing the series of UMRR land cover datasets. The study will consider potential issues with spatial rectification, differences in mapping methodology, water level on the day of photography, and variation in land cover that may be a result of other variables. Rectification errors will not be corrected, but rather addressed with buffers. These buffers will assure that changes observed are not a product of spatial rectification errors. Differences in mapping methods among the three datasets will be addressed by using the best cross-linked attribute, and then further investigate the changes found using other attributes as found to be effective. Water level issues are lesser of an issue than is often believed because the photography is capturing vegetation types that reflect longer periods of water level conditions. Problems are only likely to occur if water levels were very high on the day of photography such that the vegetation types were completely overtopped and not visible in the photographs. The variations in land cover from year to year in response to conditions other than bed elevation may be an issue. However, those types of change would be uniform across backwaters as opposed to the unique morphometry of alluvial fans. Algorithms will be developed to distinguish alluvial fans from other changes that might be present.

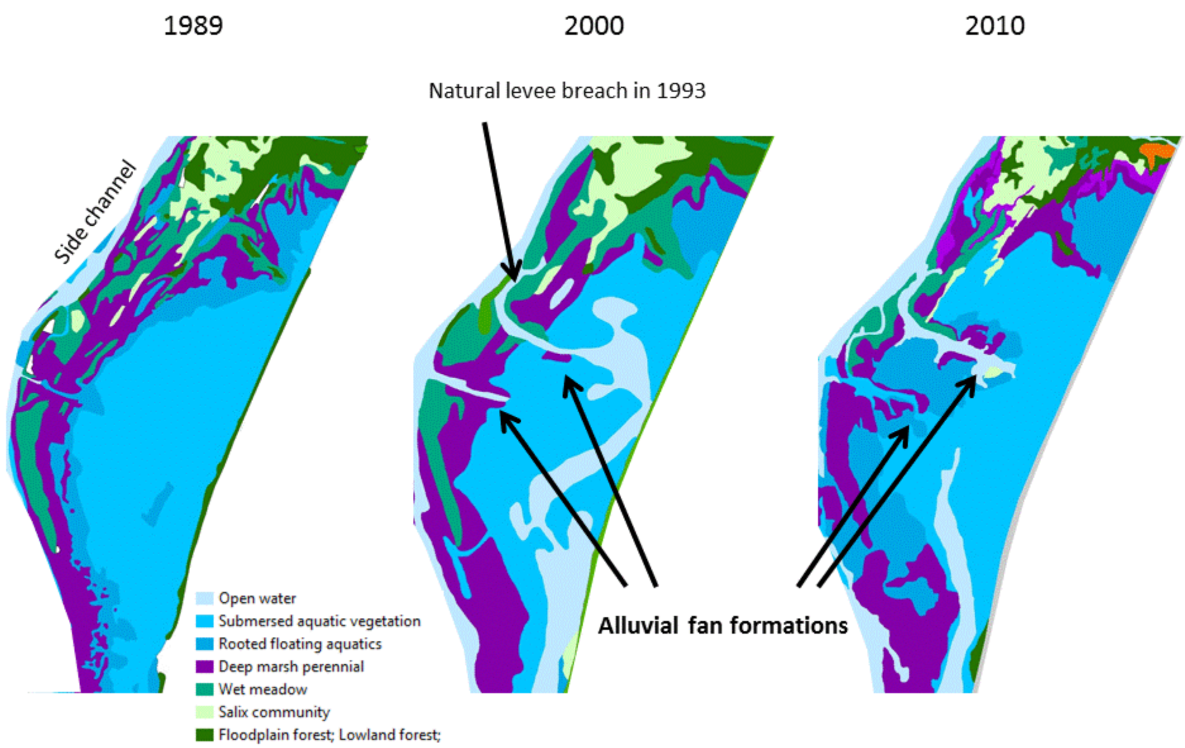
The pilot will be conducted in the upper three LTRM study reaches (Pools 4, 8, and 13). Maps of land cover changes that potentially reflect alluvial fan formation will be produced for three time periods: 1989-2000, 2000-2010, and 1989-2010. The potential for erosion of fans will be looked for in the 2000-2010 period. The land cover changes mapped will include the more certain changes from aquatic types to terrestrial types (e.g., submergents to grass), but also include potential changes depicted by deeper aquatic types changing to shallow aquatic types (e.g., submergents to emergent). See the figure for an example of how a known alluvial fan formation is reflected in land cover type changes.

The maps will be analyzed to determine the frequency and magnitude of features indicating alluvial fan formation. Individual alluvial fans will be enumerated within each pool to determine frequency. If warranted, more elaborate frequency determinations may be performed on attributes of interest. For example, frequency within sections of a pool or by size of fan may be done if the data allows (i.e., enough fans are found to justify that analysis). Magnitude measures of these features will include overall size in pool (e.g., area, % of backwater area lost to fans) and size statistics (e.g., mean, maximum). We may also be able to look at magnitude for each of the two periods (1989-2000; 2000-2010). We will not measure vertical accumulation on these fans.

Products and Milestones

Tracking number	Products	Staff	Milestones
2017SED1	Land cover GIS datasets identifying areas of potential alluvial fan formation	Rogala, Hansen, Nelson	30 Sept 2017
2017SED2	Draft contract report summarizing findings and providing recommendations for expanding the project system-wide	Rogala, Hansen, Nelson	31 Dec 2017
2017SED3	Final Report	Rogala, Hansen, Nelson	30 June 2018

Example of alluvial fan formation in a Pool 8 backwater



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

Previous LTRM project:
This project advances our understanding of fish habitat requirements, thus building upon numerous previous projects. System-wide analyses of fish community structure have provided evidence that broad-scale differences in water clarity, water temperature, velocity and vegetation across LTRM reaches are associated with fish community structure (Chick et al. 2005; Chick et al. 2006). Similarly, reach-based analyses have identified important factors influencing fish community structure (Barko et al. 2005). Further, criteria representing seasonal overwintering habitat requirements of important game species have been identified (Palesh and Anderson 1990; Bodensteiner and Lewis 1992; Knights et al. 1995; Johnson et al. 1998; Bartels et al. 2008).

Recently, multi-reach species distribution models (AHAG 2.0) were developed from the LTRM fisheries data to provide estimates of probability of occurrence in relation to environmental variables for a limited number of individual species (Ickes et al. 2014). The effort described below is similar in that we will evaluate species' responses across environmental gradients. However, the use of species archetype models differs from previous work by modeling multiple species simultaneously, then statistically clustering species based on their responses across environmental gradients. Following suggestions from the authors of AHAG 2.0, our models will be developed at the reach/pool scale. This methodology expands upon previous work by not only estimating species-specific responses to environmental variables, but also allowing inferences to be made regarding 1) seasonal controlling variables that structure both the broader fish community; 2) seasonal habitat requirements of groups of species; and 3) tradeoffs of management actions for numerous s

Introduction/Background:

<u>What's the issue or question?</u>

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). The use of archetype models allows us to evaluate abundance and distribution responses to environmental gradients across species, allowing inference of community-wide habitat requirements. By generating clusters ("archetypes") by period, we can evaluate whether seasonal habitat associations align with hypotheses formulated based on our understanding of life history guilds. Further, if habitat associations do align with life history guilds, we can gain an understanding of life history attributes of poorly understood and possibly rarer species by borrowing information from similarly clustered, but well understood and more common species. Finally, by developing archetype models separately for study reaches, we can evaluate the variation in species-level responses and the diversity in fish community responses across reaches.

What do we already know about it?

Development of the UMRS fish life history database (O'Hara et al. 2007) allows us to group many of the common species into guilds from which we can infer broad habitat requirements. For example, in the spring and early summer, pelagophilic spawners require sufficient velocities to transport eggs long distances while phytophilic spawners require submerged vegetation and little to no velocity. Species-specific field investigations have provided further refinement of criteria that represent overwintering requirements (Bodensteiner and Lewis 1992; Knights et al. 1995; Johnson et al. 1998; Bartels et al. 2008). Additionally, regional single species distribution models have provided an understanding of important environmental covariates that influence distributions for a subset of the fish community; however, the authors suggested that reach/pool-scale models would be required to capture response curves for a larger suite of species (Ickes et al. 2014). The proposed work follows the aforementioned recommendation and combines it with a multi-species modeling approach to improve our understanding of habitat associations across the diverse fish community within the UMRS.

Why is it important?

Among the UMRS ecosystem restoration objectives is managing for a diverse and abundant native fish community (U.S. Army Corps of Engineers 2009). Critical to achieving this objective is characterizing the habitat requirements across the fish community.

Relevance of research to UMRR:

Objective(s) or hypothesis: The objectives of this work are to develop multi-species models from existing LTRM fisheries data to 1) identify the dominant responses to environmental gradients within the fish community of each study reach; 2) infer habitat requirements based on environmental responses and our current understanding of life history strategies; and 3) summarize response (archetype) diversity by reach. We hypothesize that seasonal species archetypes, driven by velocity and depth gradients, will relate to life history (e.g., spawning, foraging, overwintering) requirements. We also hypothesize that reaches with greater geomorphic and hydrologic complexity (i.e., habitat) will support a broader diversity of responses.

Relevance (demonstrate scientific and/or management value): Advancing our understanding of habitat associations of the broader fish community allows us to better define habitat needs within a reach and across the system. Further, the clustering of different species within archetypes based on their response to environmental gradients can provide an understanding of habitat requirements of poorly-understood species by making inferences based on similarly clustered, but well-understood species. By focusing on covariates that are commonly manipulated by restoration practices, implications of habitat restoration practices can be evaluated. Collectively, this information can provide managers the ability to more broadly estimate impacts and benefits of restoration projects on the fish community.

How the project enhances on-going work: Response (archetype) diversity can be used within the ongoing Resilience Assessment as an indicator of general resilience. From a habitat requirements perspective, this work complements on-going efforts within the Habitat Needs Assessment II.

How this work relates to needs of UMRR and river managers: The limited fundamental life-history information available on large-river fishes is considered to be a significant obstacle to managing riverine fish communities (Galat and Zweimuller 2001). This approach uses new techniques to gain insight into habitat associations across the fish assemblage and in doing so meets the guiding principles of the UMRR 2015-25 strategic plan (USACE 2015) by developing analyses that can be used to identify reach-scale habitat needs, habitat projects, and inform trade-off evaluations of habitat restoration projects (Objective 1.1). Additionally, changes in geomorphic and hydrologic complexity have impacts on species assemblages; understanding the gradients that fish are responding to can aid in understanding mechanisms of assemblage change across the system (Objective 2.2). Further, seasonal consideration of habitat associations allows for evaluation of life history-specific requirements. For example, fall (period 3) sampling may provide unique habitat associations to infer overwintering requirements, complementing existing research framework efforts (Ickes 2005). Finally, the proposed work supports the broad goal of restoring and maintaining the diverse native fish fauna by improving our understanding of habitat requirements (UMRCC 2010).

Methods:
We will evaluate species responses to environmental gradients within sampling periods using models that capitalize on similarity of responses among species. For example, our data might suggest responses to flow and temperature by bluegill and black crappie are similar relative to those by emerald shiner and bigmouth shiner.
These multivariate models, termed ‘species archetype models,’ are treated as improvements over fitting multiple single-species models for two reasons. First, fitting multiple single-species models may be impractical from a logistics perspective, and may also yield results that may be difficult to interpret in a multi-species context. By contrast, the multivariate species archetype models (SAMs) provide summaries across species (even while offering species-specific estimates). Second, the multivariate models acknowledge the reality that species responses to environmental covariates may be correlated; capitalizing on this correlation by using a multivariate model improves conclusions, and particularly so for rare species (by grouping them with prevalent species having statistically similar responses; Hui et al. 2013).

SAMs also offer improvements over algorithmic site-based approaches such as multidimensional scaling often used by ecologists. The former may be more appealing to science-based agencies than the latter because SAMs attempt to approximate (“model”) the processes that yielded the data, and because not attempting to approximate those processes may lead to incorrect conclusions (Warton et al. 2012). Note that each archetypal response in a SAM represents a group of species that responds to environmental gradients in a statistically similar way. Communities observed at a site may be viewed as being comprised of multiple overlapping species distributions and, hence, archetypes, that, in turn, generate a unique assemblage at that one location (Dunstan 2013). SAMs have been used to evaluate fish species and fish species archetype associations with environmental gradients using count and biomass data (Dunstan et al. 2013). More about SAMs may be found in Dunstan et al. (2013) and Hui et al. (2013).

We will use LTRM fish data from day electrofishing in 2015 from all strata in Pool 8 and the Open River reach. We will model both species detection/nondetection data as well as species counts. Multi-species responses will be modeled as functions water temperature, velocity, turbidity and depth. The potential for stratum effects, after adjusting for all covariates will be evaluated; if present, those effects will be addressed by including stratum effects. We will follow an elaboration of the SAM model described by Dunstan et al. (2013) that allows for period-specific archetypes to vary by sampling period

Milestones and products:

Tracking number	Products	Staff	Milestones
2017FA1	Draft report on period-specific inferences on environmental gradients and species-environment associations by period	Bouska, Gray	15 Feb 2018
2017FA2	Final Report	Bouska, Gray	15 Sept 2018

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Investigation of metabolism, nutrient processing, and fish community in floodplain water bodies of the Middle Mississippi River

Introduction/Background:

Floodplains are a vital component of large river ecosystems. Floodplains provide refuge areas for sensitive and juvenile aquatic organisms during flood events and increase ecosystem diversity by providing variable habitats (Ward et al 1999). As the floodplain undergoes cycles of connectivity nutrient processing and sediment capture occurs, removing potential pollutants from the system (Noe and Hupp 2009, Kroes et al 2015). Distribution of water bodies across the floodplain results in a suite of backwaters, channels, and lakes with different connectivity regimes. River control structures have disconnected the Middle Mississippi River (MMR) from over 80% of its historic floodplain. In many areas this has resulted in a narrow floodplain with limited connectivity to floodplain water bodies. Personal observation does suggest that a connectivity regime exists even within the restricted floodplain. However, very little is known about how these water bodies function independently and as part of the greater Mississippi River system. This information is needed by managers in order to effectively restore limited functional processes (i.e. HREP) or manage floodplain habitats. We propose to pilot an investigation of a subset of MMR floodplain water bodies. We will assess fish and invertebrate community and functional groups. These data will allow us to assess differences in communities between water bodies and based on time since connectivity to the river. While LTRM fish sampling will not occur concurrently to all of our sampling these data will result in a fish community database that will allow us to make comparisons of community structure between floodplain water bodies and the river. Net ecosystem metabolism (NEP) in each water body during the study period will be used to estimate floodplain contributions of primary productivity to the river system. We will further associate NEP with continuous nitrogen dynamics in one location in order to estimate the influence of connectivity on nutrient removal from the system.

Relevance of research to UMRR:

We propose to examine floodplain water body function across a gradient of connectivity to the main river. This pilot study will explore fish and aquatic invertebrate community structure, nutrient depletion, and ecosystem metabolism in off-channel areas that span a gradient of connectivity. We hypothesize that decreasing connectivity to the main river will result in more unique fish assemblages and more lentic water quality conditions. Further, we expect nitrogen concentrations to decrease as water bodies become disconnected from flood waters or the main channel and as primary productivity in the water column increases (Sobotka and Phelps 2016).

Other data sources suggest that these backwater habitats function very differently. For example data collected from a backwater (the Blew Hole) in the Open River reach of the Middle Mississippi River (MMR) suggests a different fish community is using this off-channel habitat (including species of interest to the public e.g. Centrarchids) however the size of this backwater has decreased by 50% since 1993 due to sedimentation. Additionally, no water quality data has been collected at this location. Another larger backwater was created during the record-breaking flood 2015. This provides us with an excellent opportunity to collect data as that backwater community is established.

The Army Corps of Engineer Research and Development Center (ERDC; Vicksburg, MS) is currently working with partners in the Lower Mississippi River floodplain to understand the relationship between river-floodplain connectivity (spatiality and temporally) and biota (fish, invertebrates, and allochthonous/ autochthonous contributions to the riverine ecosystem). Our methods are designed to complement portions of that study.

1. Scientific Framework for Landscape Patterns research on the Upper Mississippi and Illinois River Floodplains

Objective 1: Developing structural measures of landscape pattern

1.4. Patterns of aquatic area richness

- This study would provide ground-truthing for measures of limited habitat heterogeneity (e.g. do existing floodplain lakes in the MMR function differently from secondary channels based on fish community or water quality).

Objective 2: Examining the ecological consequences of landscape patterns

2.2 Floodplain soil nutrient dynamics

- This study would provide estimates of relative nitrogen processing rates as well as over-all nitrogen capture in backwater, side-channel, and lake water bodies.

2.3 Aquatic community composition

- This study would result in fish community data across a gradient of floodplain water bodies and allow preliminary assessment of the relationship between fish community and structural heterogeneity in the floodplain.

2. Indicators of ecosystem health for the Upper Mississippi River system

4.7.6 Species Richness [Community Structure]

- This study would sample the fish community associated with water bodies that can become disconnected from the main river. The floodplain may be a source of rare species to the main river.

5.4.1 Backwater fishes assemblage

- While the Open River Reach lacks backwater habitat similar to that found in the pooled river there are habitats that may be used by a backwater fish assemblage which are not sampled by LTRM. These include floodplain water bodies minimally or infrequently connected to the main river. This study would sample the fish community associated with these water bodies. The floodplain may be a source of these species to the main river.

3. UMRR Strategic plan 2015 – 2025

Goal 2: Advance knowledge for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem

Objective 2.1: Assess, and detect changes in, the fundamental health and resilience of the Upper Mississippi River ecosystem by continuing to monitor and evaluate its key ecological components of aquatic vegetation, bathymetry, fish, land use/ land cover, and water quality.

Strategy 2, Strategy 4

- The gradient of floodplain habitat is a critical component of large river ecosystems however the LTRM is not designed to sample these habitats. This study will allow researchers to better understand the floodplain as a refuge habitat for sensitive or juvenile fishes and how nutrient cycling processes are influenced by flooding. An understanding of connectivity between the floodplain and the MMR main river is important in assessing the resiliency of the system.

Objective 2.2: Provide critical insights and understanding regarding a range of key ecological questions through a combination of monitoring, additional research, and modeling in order to inform and improve management and restoration of the Upper Mississippi River ecosystem.

Strategy 1, Strategy 4

- This study will provide information critical to understanding how connectivity influences fish community and physio-chemical processes. Managers need this information to better design restoration projects to meet their goals (e.g. restoration efforts aimed at reducing nutrient transport during flooding).

Methods:

1. Quantify connectivity of floodplain water bodies to the main channel (Oliver et al 2016).
   a. Using topobathy GIS layers we will identify connection cut-off points between the main channel and selected water bodies. These cut-offs will be used in conjunction with elevation data from the nearest river gage to assess frequency of connectivity.
   b. Pilot water bodies with frequent (permanent or near permanent), intermediate (connected < 100 dpy), and rare (connected < every 5 years) connectivity regimes will be selected for initial study.
   c. Timing of connection will be monitored during the study period.
2. Collect fish and invertebrate community data from selected floodplain water bodies.
   a. A minimum of 5 seine hauls and 5 electrofishing runs will be done during each sampling event.
   b. Effort will be standardized across gears.
      i. Fish (Seining and electrofishing).
      ii. Invertebrates (Chip basket, benthic sled, Ponar TBD).
   c. Sampling will occur once a month between March and August 2017. Sampling will also occur before and after large flood events.
3. Water quality metrics will be collected monthly or bi-monthly between March and August 2017.
   a. Sampling will occur in conjunction with regularly scheduled LTRM fixed site sampling.
   b. TSS and VSS samples will be analyzed at the MDC Big Rivers and Wetlands laboratory using UMESC procedures.
   c. Total nitrogen and dissolved inorganic nitrogen samples will be analyzed at the UMESC laboratory.
   d. Oxygen and temperature profiles will be collected to quantify stratification.
4. Continuous dissolved oxygen and temperature data will be collected from each water body. Light extinction data will be collected during each sampling effort. Continuously collected nitrogen data will be collected at a single site to assess the relationship between metabolism and nitrogen capture.
   a. These data will be used to model ecosystem metabolism at each site (Sobotka and Phelps 2016).
5. Results of fish community surveys and water quality metrics will be compared using non-metric multivariate methods to identify differences among water bodies. Floodplain data will be compared to LTRM water quality and fish component data to evaluate differences between the main channel and floodplain habitats. Nutrient and metabolism data will be correlated to assess nutrient capture and depletion rates.

6. This is a one year study. If findings are promising we propose to increase sampling across additional water bodies and river reaches.

Milestones and products:

Tracking number	Products	Staff	Milestones
2017MMF1	Fish and water quality databases completed	Sobotka	30 August 2017
2017MMF2	Draft report completed - will detail differences between the floodplain habitats and the main channel and associations between fish community and water quality attributes with connectivity of the water body to floodwaters or the main channel	Sobotka	30 December 2017
2017MMF3	Final Report	Sobotka	30 June 2018

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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.

Temperature dynamics in fluvial systems respond to a diverse array of drivers (Caissie 2006). The natural geomorphic template of a river establishes the basic processes that influence spatial and temporal patterns in temperature, such as elevation, river width, water residence time, light availability, and groundwater input. For instance, although we generally expect that average river temperature will increase with stream order, recent work has shown that longitudinal thermal regimes can vary across rivers depending on catchment geomorphology (Fullterton et al. 2015) or dominant water sources (i.e., snow, rain, or groundwater; Lisi et al. 2013). In addition, depending on floodplain morphology and river flow, complicated thermal patterns can develop laterally across river floodplains and backwater habitats that are important for several life stages of river biota (Figure 1; e.g., Tonolla et al. 2010). In many cases, however, river thermal regimes have been altered by anthropogenic activities such as dams or channelization, thermal inputs from industrial sources, or the removal of riparian forest cover. Therefore, 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.

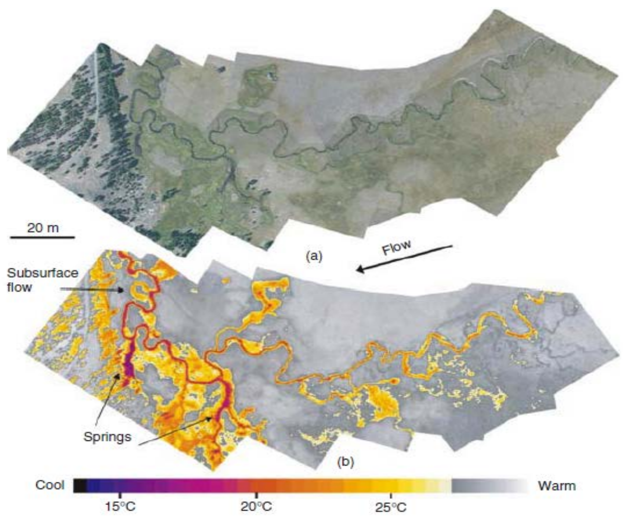

Figure 1. Thermal image of the upper Middle Fork John Day River (Oregon, USA) showing complex temperature patterns across the floodplain, location of groundwater springs, and occurrence of subsurface flow (image from Handcock et al. 2012).

Recent work has shown that the Mississippi River is one of the most thermally polluted rivers globally (Raptis et al. 2016) and that like many other rivers and streams across the US (Kaushal et al. 2010), the Upper Mississippi may be warming over time (LTRM, unpublished data; Figure 2). This has important implications for all aspects of river functioning and management including the availability of thermally suitable habitat for fish, rates of biogeochemical processes that control nutrient availability, and can even have implications for human health through increasing the frequency and extent of blooms of toxic cyanobacteria (Paerl and Paul 2012).

The LTRM element of the UMRR program has an extensive dataset on river temperatures from the last 25 years (Figure 2). The current dataset includes fairly high temporal resolution temperature data from fixed sites (~every 2 weeks for 25 years) and high spatial resolution temperature data from SRS episodes (point measurements across multiple strata 4x per year). While these data provide a number of pieces of important information (e.g., estimation of annual and long-term trends, understanding patterns in temperature across strata), they are limited in providing some key information. For example, the spatial resolution of current data do not allow us to quantitatively map the availability of thermal habitats across the river. This is turn limits how well we can assess the influence of habitat restoration projects on thermal dimensions of habitat quality. Furthermore, the temporal scale of our current dataset limits our ability to assess how temperature responds to shorter term drivers (storm events/high flow events) that affect the thermal environment at shorter time scales (hours, days, weeks) and inform our understanding of how the river will respond to shifting precipitation patterns and warmer temperatures.

Therefore, we propose a pilot study to evaluate the spatial and temporal dynamics of temperature in the UMR. We will use a combination of airborne thermal infrared remote sensing (TIR) and an array of in-situ temperature loggers to map surface temperature across habitats and seasons in Pool 8 the UMR. TIR has been used widely in riverine habitats for diverse applications such as mapping groundwater inflows (Figure 1; Loheide and Gorelick 2006), coldwater refugia (Torgersen et al. 2001, Hancock et al. 2012), thermal pollution (Raptis et al. 2016), and mapping river-floodplain connectivity (Tonolla et al. 2010). As far as we know, however, TIR has not been used to map spatial patterns in temperature in a river as large and complex as the UMR. These data can be turned into a “river thermal-scape” GIS layer which can be directly linked with existing spatial layers for the river such as bathymetry, vegetation, and land cover data to inform our understanding of spatial patterns and habitat availability.

Thus, these data will fill important gaps in our understanding of temperature dynamics of the river, including how the physical dimensions of the river influence thermal regimes, how thermal habitat is distributed across the landscape and how river temperatures respond to change at short time scales. Specifically we will ask the following questions:

1. How does temperature vary spatially across the diverse habitat types of Pool 8?
2. Do temporal patterns differ across habitats (e.g., rate of warming in the spring, cooling in the fall)? What controls these differences among and within habitat types?
3. How does connectivity among habitats (e.g., backwater & main channel) influence spatial and temporal patterns in temperature?

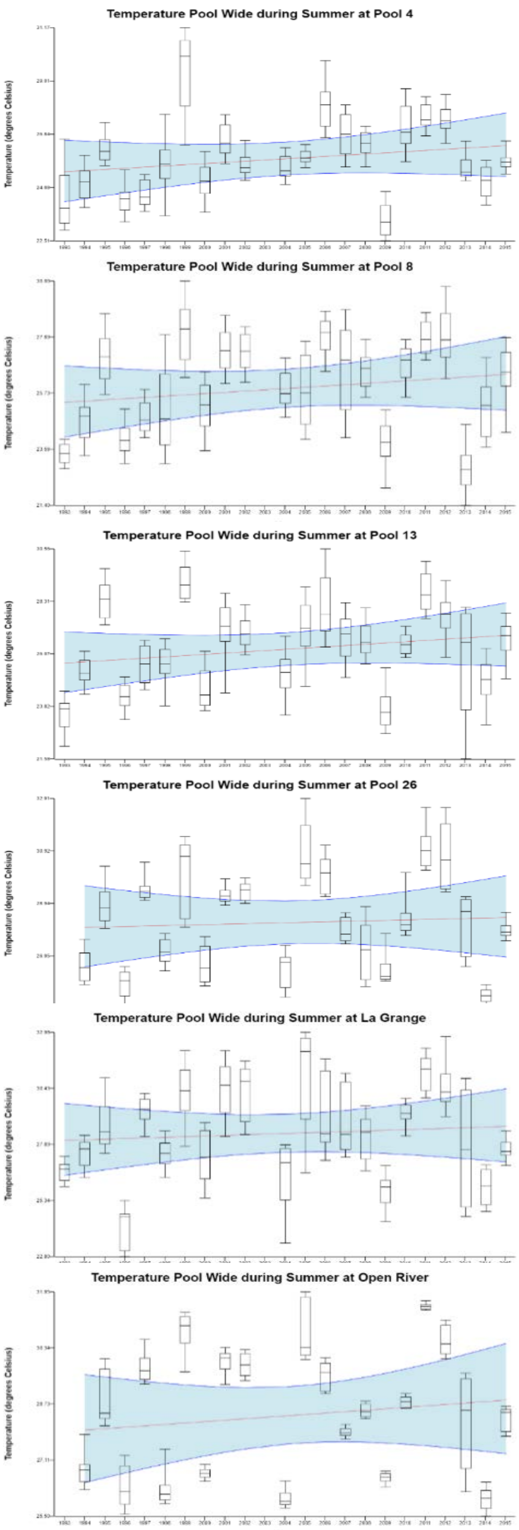

Figure 2. Median temperatures in all UMR Study pools from 1993-2015. (Data & figures generated from LTRM Graphical Water Quality Database Browser).

Methods:

We will collect airborne thermal and natural color imagery and deploy continuous temperature loggers during the Spring and Summer SRS sampling events in Pool 8 of the UMR. Synchronizing our imagery collection with SRS sampling events will allow us to spatially map water quality data onto both thermal and visible imagery at two contrasting river stages. The visible imagery will provide context for thermal signatures. This is being proposed as a Pool 8 specific project because there are several issues to consider and methods to develop (discussed below) before applying airborne thermal imagery to generate reliable temperature data across broader portions of the UMR.

<u>Airborne Imagery</u>:

To collect imagery, we will use a cooled, mid-wave infrared (3.0-5.0 microns) FLIR SC8343 camera and a Phase One iXU-R 180 digital aerial camera. The SC8343 is a high-definition fixed camera with a 1,280 x 720 pixel sensor. A 25mm lens will be used at an altitude of 915 meters, generating 14-bit thermal imagery at 0.5 meters per pixel. The Phase One iXU-R is an 80-megapixel camera that uses a 10,328 x 7,760 pixel visible light sensor. The iXU-R 180 will use a 70mm lens and collect imagery at a resolution of 0.07 meters per pixel (~3" per pixel).

Both cameras are installed in the U.S. Fish and Wildlife Service (FWS) Migratory Bird Program's (MBP) Partenavia P68 Observer aircraft and tightly integrated into the plane's position and orientation system. This allows the camera to record an image event with precise latitude, longitude, altitude, roll, pitch, and heading for every exposure collected and the gyro-stabilized mount ensures that all imagery is nearly perfectly vertical and isolated from engine vibration. Geographic information system (GIS) and image processing software can use this information to mosaic hundreds or thousands of single images into seamless and GIS-ready orthorectified mosaics.

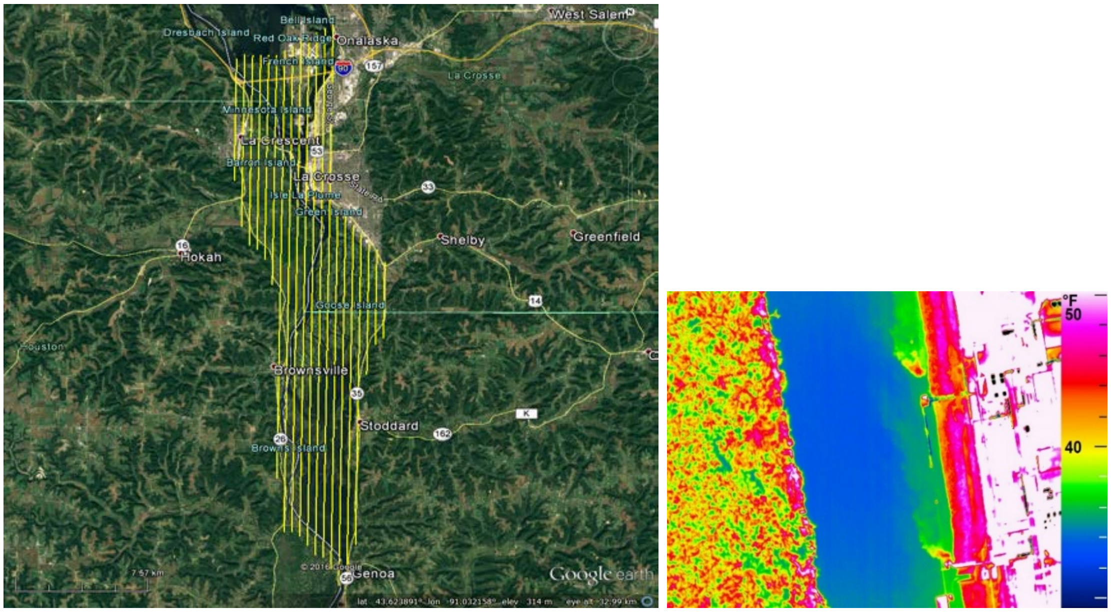

Figure 3. The thermal infrared flight plan for Pool 8 of the Upper Mississippi River will take approximately three hours to collect 20 lines of imagery at a resolution of 0.5 meters per pixel. Inset image shows a power plant outflow into the Mississippi near Clinton, IA (image: Larry Robinson).

The SC8343 thermal camera uses a mid-wave sensor which records both reflected and emitted energy. For this reason, we will collect all imagery in the morning when the river's surface is typically calmer and the sun is lower on the horizon, reducing the potential for sun glare and surface turbulence. Thus, the water surface temperatures should be more reflective of actual temperatures than later in the day when the sun and wind will have a greater effect on the accuracy of image data. The flight plan, shown above in Figure 3, will take approximately three hours to collect 20 lines of imagery, thereby minimizing the potential for temperature change over time.

We will post-process the positional information documented for each image using Applanix POSPac MMS to remove errors in the GPS signal and determine sensor attitude (omega, phi, kappa) recorded by Partenavia's gyro-stabilized camera mount. Each frame can then be referenced to the earth's surface using Inpho's OrthoMaster, and mosaicked into a single image with ERDAS Imagine MosaicPro. **The final products will be a 14-bit TIFF-format thermal mosaic that contains surface temperature readings and a natural color mosaic collected simultaneously.**

<u>Temperature Loggers</u>:

In order to ground-truth imagery information and to generate more fine-scale temporal temperature data, we will install continuous temperature loggers at surface depth (0.2m) at 15 fixed sites in pool 8 (Hobo Water Temp Pro v2, Onset Corp, Onset, MA) prior to the initial flight in April 2017. These loggers will remain deployed at least for one year. In addition, the UMR is a deep enough river that there is potential for vertical temperature stratification in several locations which may limit the utility of surface temperature data. This pilot study will allow us to test and account for how widespread and influential its effect may be.

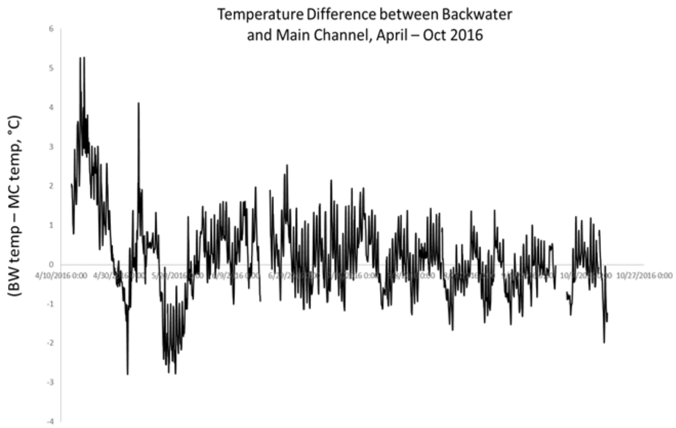

Figure 4. Differences in daily temperatures as measured by Main channel and Stoddard GREON buoys from April – October 2016. (J. Houser, unpublished data).

Therefore, we will deploy temperature loggers at depth at a subset of fixed sites to evaluate the occurrence of vertical stratification. To assess how widespread this is across Pool 8, we will use the approach of other authors that have applied Reynolds numbers (Torgersen et al. 2001) which combine temperature and velocity data to assess the potential for thermal stratification of water. Furthermore, LTRM data suggest that stratification typically occurs at velocities under 0.1 m/s, thus we can use historic profiles to assess the spatial distribution of stratification as well (Soballe and Fischer 2004).

Expected Products/Outcomes

This project will generate high spatial-resolution temperature layer for Pool 8 in TIFF image and Esri GRID formats and high temporal-resolution temperature data at fixed sites in Pool 8 as raw data and as an Esri shapefile. These data will allow us to link spatial temperature patterns to other existing spatial data including depth, flow, land cover and vegetation as well as spatially-referenced water quality data obtained during the two SRS sampling events. By doing two overflights, we will be able to assess the influence of river stage on the temperature distribution of Pool 8. Furthermore, high resolution temporal data distributed across the pool will provide information on how and why temperature may vary differently among habitats and help to identify important drivers (Figure 4).

Relevance and future applications for the UMRR

There are several other potential applications for these types of data that would apply to Goal 2 of the UMRR Strategic Plan (USACE 2015): "Advance knowledge for restoring and maintaining a healthier and more resilient Upper Mississippi River ecosystem". Specifically, this project fits within Objective 2.2 to "Conduct focused research and analyses to gain critical, management-relevant information about the UMR ecosystem's process, function, structure and composition as well as the dynamics and interactions among system components". For example, these data could enhance understanding of connectivity among habitats, assist with mapping the spatial extent of the impact of HREPs on thermal habitat, provide maps of potentially suitable fish habitat during key periods of the year (larval fish production/nursery habitat in spring; thermal habitat availability in the fall at the time of staging for over-wintering; availability of summertime thermal refugia for cool water species), and potentially link temperature spatially with harmful cyanobacterial blooms. This project would allow to explore the utility of thermal imagery for these type of applications in the UMR.

Milestones and products:

Tracking number	Products	Staff	Milestones
2017TL1	Draft report on feasibility and utility of surface water temperature map	Jankowski, Robinson, Ruhser	30 December 2017
2017TL2	Final report and data distribution	Jankowski, Robinson, Ruhser	30 March 2018

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Evaluation of a System-Wide Floodplain Inundation Model for Ecological Applications

Introduction/Background

Inundation dynamics are considered to be a key driver of floodplain ecosystem structure and function. In the Upper Mississippi River System (UMRS), floodplain inundation is believed to affect such diverse ecological processes such as sedimentation dynamics (Knox 2001, Benedetti 2003), biogeochemical cycling (De Jager et al. 2015), population dynamics of native and nonnative fishes (Chick et al. 2005), and forest succession (De Jager et al. 2013). Because of the numerous linkages between flooding dynamics and ecological processes, characterizing inundation is an essential step towards informing management decisions and understanding the structure and function of the UMRS floodplain ecosystem. Only recently, however, have we begun to systematically quantify inundation dynamics for the purposes of informing HREP design, ongoing management activities, and scientific studies.

We are developing a spatially-explicit floodplain inundation model for the UMRS as part of the Habitat Needs Assessment II (Figure 1). At its most basic level, the model relates gauge-derived river stage to specific locations on the floodplain surface to determine at what river stage that location is expected to be hydrologically connected to the river. Based on this relationship, the river stage hydrograph is distributed across the floodplain and can be used to extract information that is ecologically relevant for the ecosystem dynamic or property of interest. For example, it is possible to map areas experiencing inundation deeper than 10 cm and longer than 30 days in order to understand forest regeneration patterns, as such inundation attributes may cause young tree seedling mortality. Because organisms interact with flood events in complex and species-specific ways (Merritt et al. 2010), the flexibility in defining and extracting custom inundation attributes that this modeling framework affords makes it widely applicable across management and research objectives of the UMRR.

Spatially-explicit characterizations of flooding are powerful tools for decision-making as they provide users with an understanding of the physical context in which management actions must take place. According to the Habitat Needs Assessment II objectives, the UMRS inundation model will be used to 1) systematically describe inundation dynamics currently experienced on the floodplain and semi-aquatic areas, 2) establish linkages between vegetation patterns and flooding, and 3) explore potential impacts on floodplain forests under varying hydrologic and management scenarios. There is additional interest from the broader community of scientists and practitioners to use the model to inform other research and management activities including tree planting and forest management practices under the Systemic Forest Stewardship Plan, HREP island design and placement, water level management, and to evaluate nutrient reduction potential by floodplains over broad spatial extents. Given the wide range of potential applications, it is important to thoroughly evaluate the model's performance in order to avoid potential model misuse or misinterpretation. The research aims to validate this system-wide inundation model by comparing model results to empirical data on inundation patterns across the entire UMRS.

Objectives, Study Area and Methods:

The overall goal of this study is to evaluate the performance of the UMRS inundation model using empirical evidence of floodplain inundation. Such information is useful in understanding spatial distributions of model error and its potential sources, which ultimately can inform at what spatio-temporal scales the model is most appropriate. Model evaluation also aids end-users in understanding the approach's strengths and weaknesses to avoid misuse or misinterpretation of model results.

The UMRS inundation model establishes a relationship between expected inundation at a given location on the floodplain surface and a gauge-derived river stage, and uses this relationship as a foundation to quantify user-defined flooding attributes. For this reason, the proposed evaluation effort focuses on documenting the flooding extent-stage relationship in the field and comparing these patterns to model predictions.

The study will address two guiding questions:

1) How does the spatial extent of inundation vary in the field across a range of flow conditions?
2) Does the UMRS inundation model capture a reasonable level of reality?

Although the UMRS inundation model applies to the entire upper river system (Upper Mississippi River Pool 3 downstream to Cairo, MO, and the Illinois River basin), it is impractical to evaluate the model over the entire model domain with empirical data. Therefore, this study will take place in six study reaches of the UMRS (Pools 4, 8, 13, 26, Open River Reach, and the La Grange Pool of the Illinois River) in order to provide insight into the model's ability to capture inundation dynamics in reaches of contrasting hydrology, geomorphology, and water level management practices.

Question 1: How does spatial extent of inundation vary in the field across a range of flow conditions?

The spatial extent of floodplain inundation will be sampled in each study reach using a two-part strategy that couples a spatially-extensive, temporally-limited sampling approach with a spatially-limited, temporally-extensive sampling approach. Together, the paired approaches will provide an understanding of the variability of inundation extent at multiple spatial and temporal scales.

A) Spatially-extensive, temporally-limited sampling:

The goal of this sampling approach is to document the extent of floodplain inundation across a spatially-broad sample of water edges but for a limited range of flow conditions. The sampling will occur in every study reach for two time periods of contrasting river stage: one week of high and one week of moderate river stages. The exact timing of week-long sampling is dependent on field station resource and personnel availability as well as river flow conditions, but will likely occur prior to the peak LTRM field season (high flows) and a week during or after the peak field season (moderate flows). Documentation of flooding extent during low flow conditions is less desirable due to the objectives of the UMRS inundation model as well as the existing information on flood extent from aerial photography previously captured during low river stages.

We will use a spatially-balanced sampling design following the Generalized Random Tessellation Stratified Survey Design (GRTS) framework of Stevens and Olsen (1999) to document the extent of floodplain inundation by surface water. The GRTS sampling design was developed for aquatic resource monitoring programs and has several characteristics that are well suited for this study: it generates a representative population of sample points over broad spatial areas, it avoids sample bias from linear features (such as floodplains), and it is statistically-valid for estimating sample variance across space (Stevens and Olsen 1999).

The GRTS framework will be used to generate a sample of points located on the floodplain surface and near the water's edge at low-flow conditions. Field teams will visit these points, travel to the edge of water nearest to the designated sampling location, and document the geographic coordinates of the water's edge using a GPS unit (Figure 2). Because the UMRS inundation model makes predictions of inundation due to surface water connectivity only, mapping of isolated depressions or ponding will not be necessary.

Field teams will be provided with coordinates of sampling locations ranked in order of sampling priority. Sampling will proceed for a week with the goal to inventory as many points sequentially from the list as safely possible. Ideally, the same set of points would be visited for both sampling periods even though it is likely that the edge of water nearest to the sampling points would vary.

The end result of this field effort is a spatially-balanced inventory of geo-referenced points with an established relationship between inundation extent and river-stage. Alone, this is a valuable dataset with which to test the UMRS inundation model hypotheses over broad scales. These data are even more valuable when coupled with finer-resolution empirical measures of inundation extent detailed below.

B) Spatially-limited, temporally-extensive sampling:

The goal of this sampling effort is to document inundation extent at a limited number of sites across the range of flow conditions experienced during the 2017 growing season, essentially mapping the entry of water onto and recession from the floodplain surface across time. To achieve this goal, Thermochron iButton temperature data-loggers (model DS1921G) will be used to document inundation through time, a method that has successfully detected the extent and duration of flooding for the purposes of inundation model evaluation (Van Appledorn et al., in review) and general hydrologic characterizations of wetlands and floodplains in other river basins (Helfield et al., 2007; Anderson et al., 2015).

The iButton loggers will be deployed in each study reach ahead of the spring flood pulse (approximately late March to early April) and retrieved after the main field season is completed (late August). Prior to deployment, iButtons will be waterproofed and programmed to record ambient temperatures every 12 hours, allowing approximately 5 months of continuous data collection. A subset of iButtons will be deployed as control units to record air and river temperatures; control units will aid in determining whether an iButton was submerged and for how long through a comparative analysis (Figure 3). It is possible that iButtons will fill their memory capacity before they can be retrieved, but the loggers may be programmed so that no data will be overwritten or erased.

In each study reach, iButtons will be deployed at three sites with the objective of maximizing observations across gradients of relative elevation and flow-path distance to the navigation channel (both calculated in the geospatial processing steps of UMRS inundation model development; see Figure 1A-B). These are the physical gradients that are expected to strongly influence model results, and allow for comparisons of model variability across multiple spatial scales. The three sites will be chosen from the GRTS-generated list of sampling point locations from Part A above with the goal of spanning the length of each study reach. iButton loggers will be deployed in three parallel transects that extend orthogonally to the water's edge with each transect comprising 5 loggers (Figure 2). The spatial density of deployment along the transects will be informed by examining relative elevation maps; steeper slopes may necessitate more dense sampling than shallower slopes. Final determination of iButton deployment locations will be made in collaboration with field station staff and UMESC statisticians.

This sampling effort will produce detailed records of inundation through space and time at a total of 45 locations throughout the study reaches, allowing for a greater understanding of local variation in flooding within the broader context of reach-wide inundation patterns. The sampling effort will also allow for a direct comparison of UMRS inundation model predictions of flooding duration because the model may be used to simulate daily time steps of water levels during the time of iButton deployment.

Question 2: Does the UMRS inundation model capture a reasonable level of reality?
Results from the field sampling effort will be compared to model hypotheses in several ways to generate estimates of overall model error under high flow and moderate flow conditions (Part A above), as well as error for timing and location of local floodplain inundation (Part B above). In each comparison, the UMRS inundation model will be used to predict inundation for the time period of empirical data collection. To understand the model's performance predicting patterns of reach-wide inundation (Part A), the distance between predicted water edge and field-measured water edge will be quantified. Values will be summarized across each reach, but also examined in space to evaluate possible patterns of model error associated with factors such as tributary inputs, poor representation of land surfaces by LiDAR products, longitudinal patterns of water surface curvature, etc. We will compare predicted inundation extents as well as durations at the location of each iButton logger to understand the model's ability to capture local variability. Model error may be evaluated across all loggers at every deployment site (3 sites per reach, 15 loggers per site) and examined at finer scales to explore potential sources of discrepancies between empirical and modeled inundation dynamics. Results of error analyses will be interpreted within an ecological context in order to draw conclusions about the model's ability to capture ecologically-relevant patterns of inundation.

Outcomes:
This study supports the development of a robust, system-wide floodplain inundation model for use in UMRS management and research applications. We will produce two complementary empirical datasets that document the extent of inundation for multiple river stages in 6 study reaches of the UMRS, and use these datasets to evaluate the performance of the UMRS floodplain inundation model across contrasting geomorphologic and hydrologic contexts. We will quantify spatial distributions of model error and evaluate its potential sources, assess at what spatio-temporal scales the model is most appropriate, and communicate these results to end-users in a final report to avoid misuse or misinterpretation of model predictions.

Products and Milestones

Tracking number	Products	Staff	Milestones
2017FH6	Site selection and field protocol finalization	Van Appledorn, Moore, Fischer, Bierman, Chick, Herzog, and Casper	March 31, 2017
2017FH7	Preparation and deployment of temperature loggers	Van Appledorn, Moore, Fischer, Bierman, Chick, Herzog, and Casper	April 30, 2017
2017FH8	Conduct spatially-extensive field sampling effort during high river stage	Van Appledorn, Moore, Fischer, Bierman, Chick, Herzog, and Casper	June 30, 2017
2017FH9	Conduct spatially-extensive field sampling effort during moderate to moderately-low river stages	Van Appledorn, Moore, Fischer, Bierman, Chick, Herzog, and Casper	31 August, 2017

2017FH10	Retrieve temperature loggers	Van Appledorn, Moore, Fischer, Bierman, Chick, Herzog, and Casper	30 September 2017
2017FH11	Post-processing and analysis of logger data and water-edge mapping	Van Appledorn	31 October 2017
2017FH12	A written summary of validation results will be submitted as a supplement to the Habitat Needs Assessment II that identifies potential sources of UMRS inundation model error, discusses the validity of the model's assumptions, and provides guidance on appropriate model use.	Van Appledorn	31 December 2017

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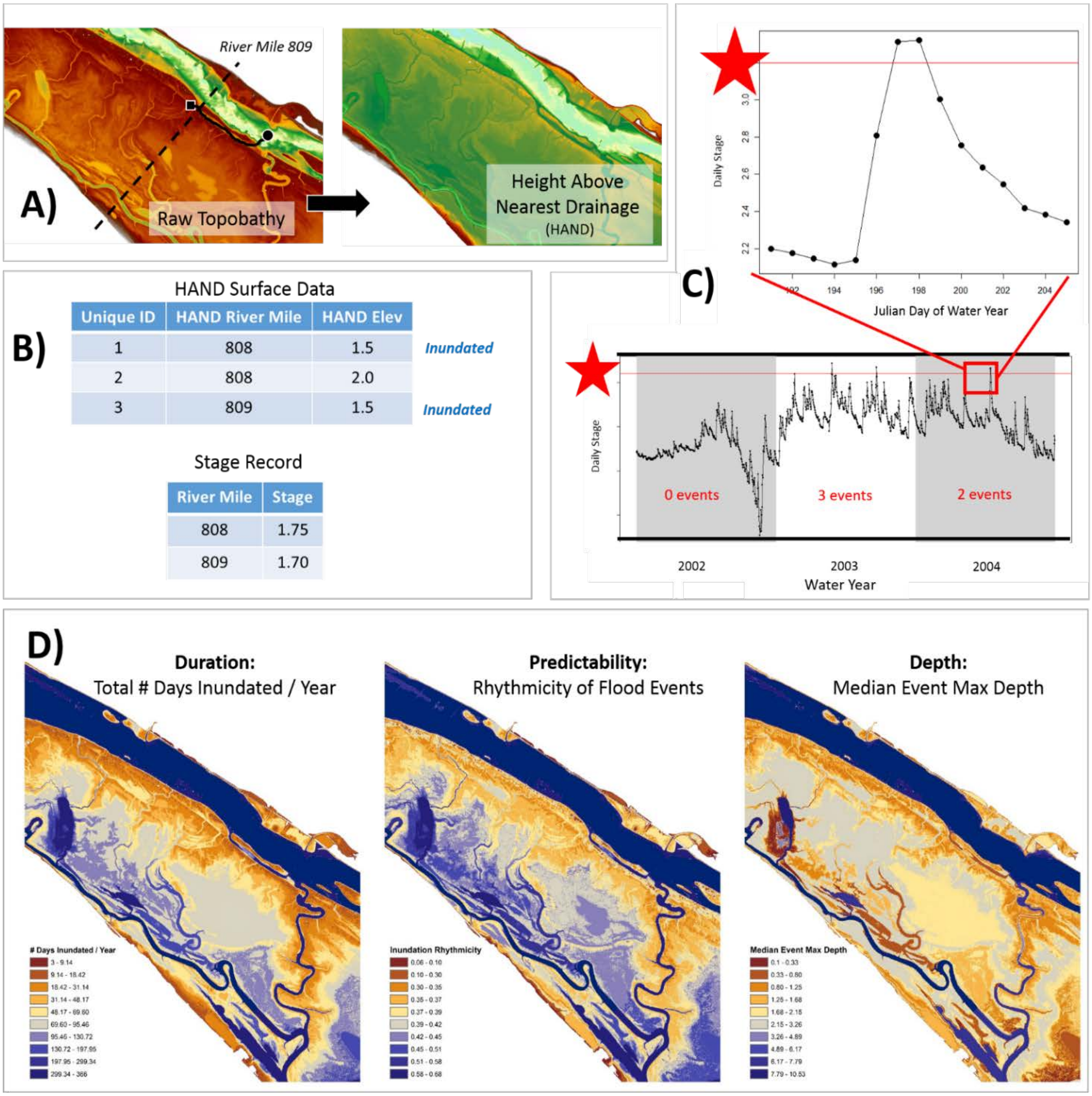
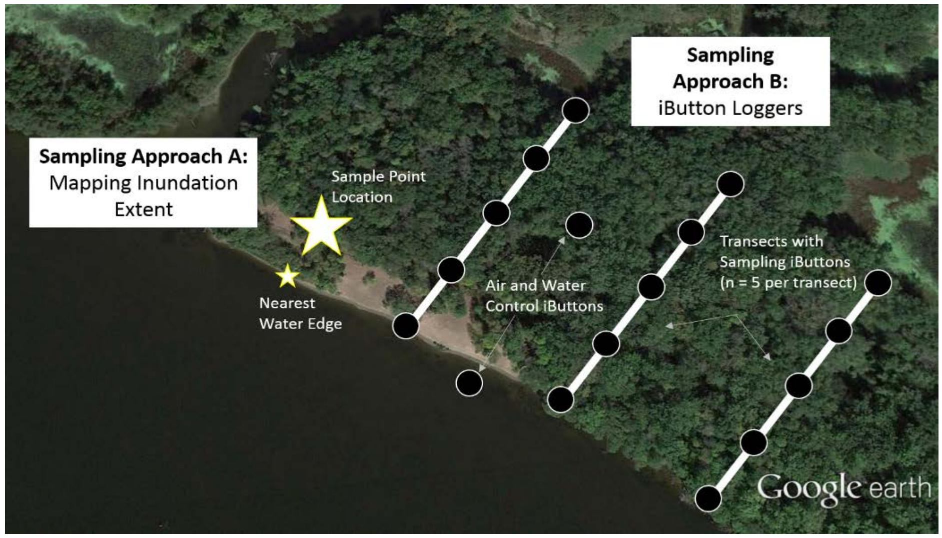


Figure 1. The UMRS inundation model uses a modified “bathtub” modeling approach to map summary statistics of dynamic inundation patterns. First, a Height Above Nearest Drainage (HAND) map is computed for the floodplain surface (A). HAND is a de-trended, hydrologically-enforced relative elevation surface in which values represent the elevation difference between any given point in the landscape (black square) and the elevation of the entry point to the navigation channel (black circle) into which it flows (flow path as solid line). Next, inundation is modeled at the point in which a given cell’s relative elevation is exceeded by the stage of the navigation channel into which that cell flows (B). Knowing this relationship, inundation may be modeled dynamically over any period of record by referencing the stage hydrograph of the navigation channel (C) and summarizing attributes of inundation events defined by the relative elevation at which a cell is expected to become inundated (star and red line). A number of metrics may be computed and expressed spatially, including metrics describing the duration, predictability, and depth distributions of inundation events (D).

Figure 2. Study design schematic for one site. In Approach A, the edge of water nearest to a sampling point location is recorded using a GPS. In Approach B, inundation dynamics are inferred using data continuously collected over a 5-month period from iButton temperature loggers deployed along transects (3 per site, 5 loggers per transect) and control loggers.



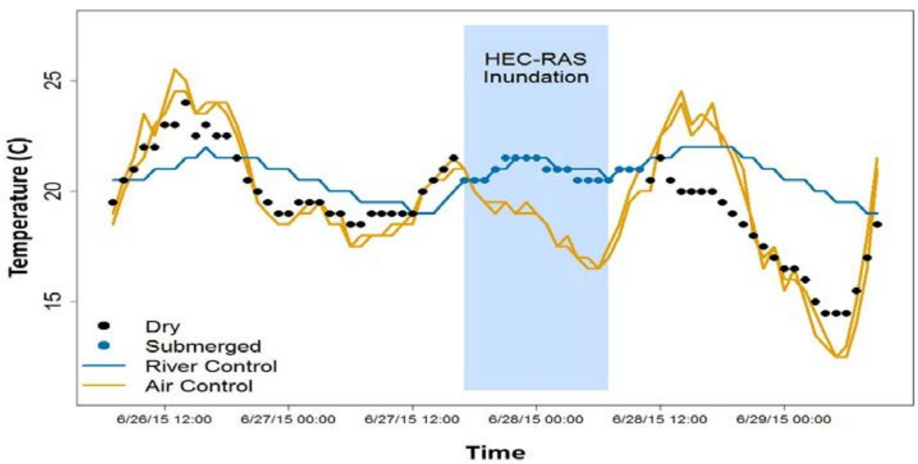


Figure 3. Example of temperature analysis for determining iButton submergence (from Van Appledorn et al., *in revision*). Observations of hourly temperatures from a test iButton (dots) are compared to temperatures recorded by control iButtons deployed in the air and under the river’s water surface (lines). Observations tracking with air control data are defined as dry, while points tracking with river control data are defined as submerged. Here, these comparisons were used to evaluate a 2-dimensional HEC-RAS hydraulic model.