# UPPER MISSISSIPPI RIVER RESTORATION (UMRR)

# SCIENCE IN SUPPORT OF RESTORATION AND MONITORING

# FY 2017 SCOPES OF WORK



These Scopes of Work (SOWs) describe science support tasks for the US Army Corps of Engineers' Upper Mississippi River Restoration (UMRR) (formerly Environmental Management Program), authorized by Congress in the 1986 Water Resources Development Act, and as amended, to be performed by the USGS-Upper Midwest Environmental Sciences Center (UMESC) in La Crosse, Wisconsin; the five UMRS basin states of WI, MN, MO, IA, and IL; and the Corps of Engineers

## Extrinsic and Intrinsic Control of Water Clarity in Pool 8 of the Upper Mississippi River

**Previous LTRM project:**

This study was inspired by comments from reviewer comments on a manuscript addressing alternative stable states in Pool 8 (Giblin 2017). The reviewer specifically asked about whether the authors could quantify the role of extrinsic forcing on TSS in pool 8, as it had been assumed that this was minimal. This question was beyond the scope of the previous study, but is an important one that we propose to pursue here.

**Principal Investigator:**


**Deanne Drake**
Wisconsin Department of Natural Resources
Phone: (608) 781-6363
Email: ddrake@usgs.gov


**Collaborators:**


**Alicia Weeks, John Kalas, and James Fischer**
Wisconsin Department of Natural Resources
Phone: (608) 781-6378
Email: aweeks@usgs.gov, jkalas@usgs.gov, JamesR.Fischer@wisconsin.gov

**Jeff Houser and KathiJo Jankowski**
USGS
Phone: (608) 781-6262 and (608)781-6242
Email: jhouser@usgs.gov and kjankowski@usgs.gov


**Introduction:**

Theoretical understanding of ecological state transitions in freshwater is based primarily on studies of shallow lakes (e.g. Scheffer et al. 1993, Groffman et al. 2006), with many well-known examples of lakes transitioning between clear-water, macrophyte-dominated conditions and a turbid-water, phytoplankton-dominated conditions. Rivers are primarily driven by extrinsic, physical controls and few or no clear examples of biologically mediated state transitions exist for rivers. Two of the most obvious recent changes in the upper impounded reach of the UMR, however, have been increased water clarity and increased prevalence of aquatic vegetation over the last ~25 years, which may fit within lake-based theories of biological control. Because the UMR is a relatively in-tact floodplain system with extensive, lake-like backwaters and impounded areas, it conceivably functions like a lake, at least in some respects. Water clarity in such a system is regulated by a complex set feedbacks among biological and physical processes, but is thought to center on aquatic vegetation (Scheffer et al. 1993). Our institutional understanding of changes in the UMR is that improved light conditions allowed aquatic vegetation to expand, initiated a positive feedback where increased vegetation contributed to further improvement in water clarity, and led to other changes in the ecosystem. Mechanistic evidence for this, however, is difficult to establish because many changes in potential drivers occurred over approximately the same period.

Three central principles underlying ecological states transitions are that: 1) Each of the alternative states is reinforced (maintained) by the biological components of the ecosystem – i.e. intrinsic features of and feedbacks prevent intermediate states and frequent transitions between states. 2) Within each state the ecosystem exhibits relative stability and resistance to perturbations. 3) Due to this stability and intrinsically mediated hysteresis, transitions between states are non-linear and tend to occur at discrete threshold values of drivers or as the result of a strong perturbation such as a storm or species introduction. We propose to use existing LTRM data to determine whether these three conditions for state transitions have been met in Pool 8.

**Relevance:**

This work will contribute to theoretical understanding of state transitions in floodplain rivers, but it is also relevant to the current LTRM programmatic emphasis on resilience (Bouska et al. in review). We will determine whether water clarity in Pool 8 is strongly controlled by watershed processes (e.g., runoff) or responds more strongly to in-system, biological control (e.g. aquatic vegetation abundance). It should also allow a cursory exploration into mechanisms that may be responsible for the increase in water clarity in Pool 8 over the last 25 years, and may serve as a springboard for a more thorough analysis of this.

We will use the LTRM data to examine whether the three principles about state transitions described above apply to the changes in water clarity observed in Pool 8 over the last 25 years. These can be viewed as fundamental questions about the ecology and resilience of the UMR. Unlike other rivers, does the UMR system "act" like a lake with strong internal biological and physical feedbacks, or is it a river-like, linear system that is physically defined by inputs from the catchment? Here we propose to produce a manuscript for peer review, organized around using LTRM water quality and vegetation data to:

1) Quantify extrinsic and intrinsic influence on TSS within Pool 8 of the UMR.

   If changes in water clarity are externally driven, within-pool TSS concentrations over the 25-year period of record should reflect TSS concentrations in water entering the pool. I.e. the $\Delta$TSS in input water = $\Delta$TSS in backwaters and the impounded area. Alternatively, if TSS within the pool is regulated by internal processes, in-pool TSS over the 25-year record will not mirror input TSS. I.e. $\Delta$TSS in input water $\neq$ $\Delta$TSS in water in backwaters, impounded areas and outflow water.

2) Determine whether the relative abundances of phytoplankton and macrophytes shift according to theoretical expectations based on lakes. I.e. do chlorophyll a concentrations decrease at the time aquatic vegetation increases?

3) Examine the TSS time series for evidence of non-linear change (thresholds) and periods of relative stability.

Preliminary analyses have been undertaken and suggest that this study will yield both support for and against the idea of intrinsic control of river water clarity and threshold-type changes. This can be discussed in the context of the UMR which has characteristics of both rivers and lakes, and will comprise a novel contribution to the literature of understanding of ecological state transitions in freshwater ecosystems. It will also improve our institutional understanding of what influences water clarity and aid management in targeting the most responsive aspects of the ecosystem. Quantification or description of the capacity of the ecosystem to recover from perturbations is a direct assessment of relative stability (principle 3 above) and is a key element in understanding resilience in the UMR.

The authors made a decision to focus on Pool 8 in this manuscript. The study is analytically complex and is a considerable undertaking in terms of time required. Our primary objective was to addresses a fundamental question in aquatic ecology in detail, and it was decided that an in-depth treatment of Pool 8 and the questions surrounding state change was preferable to a lighter treatment of multiple study areas. We envision an expansion of the analyses to other pools in subsequent work.

**Methods:**

The following methods are under development and describe starting points for the analyses.

1) We will use regression analyses to compare concentrations of total suspended solids (TSS) in the following over the 25-year LTRM data history:

*Inputs* **–** Lock and dam 7 (LD7) and the associated French Island and Lake Onalaska spillways are the major inputs to Pool 8; approximately 96% of the output volume at LD8 comes through LD7 and its associated spillways. Main channel input samples have been collected at a location approximately 2 km downstream of LD7 (Figure 1), and at both spillways. Tributaries potentially affecting in-pool TSS are the Root River (median = 2.35% of Lock and Dam 8 discharge), La Crosse River (median 1.05% of LD8 discharge), and Coon Creek (median 0.26% of LD8 discharge). We assume that groundwater is not a major input or output for Pool 8.

*In-pool areas* **-** impounded and connected backwater strata (Figure 1) were used to quantify change over time. These areas are connected to the main channel, but have much lower water velocity and are much shallower than the main channel.

*Outputs* **-** LD8 and the Reno spillway comprise outputs. The LD8 fixed-site sampling location was changed in 2005 from the main channel ~ 1 km upstream of the dam, to a location at the dam itself.

2) We will compare chlorophyll a concentrations to our best estimate of vegetation biomass (i.e., sum of the 6 rake scores at a site) over time to assess whether changes over time conform to expectations.

3) We will test a series of regression models to determine whether there is evidence for discrete thresholds and periods of relative stability within the TSS time series.

**Milestones and products:**

| Tracking number | Products | | Staff | | Milestones |
|---|---|---|---|---|---|
| 2018EX1 | Draft manuscript: Extrinsic vs Intrinsic Control of Water Clarity in the UMR | | Drake, Weeks. Kalas, Fischer, Houser and Jankowski | | 30 March 2018 |

**References:**


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Groffman, P.M., Baron, J.S., Blett, T. et al. 2006. Ecological Thresholds: The Key to Successful Environmental Management or an Important Concept with No Practical Application? Ecosystems 9: 1. doi:10.1007/s10021-003-0142-z

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# Developing methods of estimating submersed aquatic vegetation biomass in the Upper Mississippi River to expand capabilities within the UMRR program and improve the utility of the long-term vegetation data

**Principal Investigator:**
Deanne Drake
Wisconsin Department of Natural Resources
Phone: (608) 781-6363
email: ddrake@usgs.gov

**Collaborators:**
Eric Lund
Minnesota Department of Natural Resources (MNDNR)
Phone: (651) 345-3331 ext. 223
Email: eric.lund@state.mn.us

Erin Adams
Wildlife Biologist
Upper Mississippi River National Wildlife & Fish Refuge - La Crosse District
N5727 County Road Z Onalaska, WI 54650
Office: 608-779-2387
Cell: 608-780-7301
Email: erin_adams@fws.gov

**Framing of this work within the LTRM and previous studies:** LTRM base vegetation monitoring was designed to efficiently provide basic, critical information regarding the distribution of aquatic vegetation in large areas if the UMRS. The large spatial extent of the sampling meant that the data collected were restricted to presence-absence plus a general index of abundance, rake score. While this provides critical information at a large (pool) scale, there are limitations to the data produced as previous studies have noted. Of particular relevance here, vegetation biomass cannot be estimated from LTRM rake score data with confidence (e.g. Kenow et al. 2007, Yin and Kreiling 2011, Deppa 2016, Drake et al. 2017). Here we propose to investigate a new approach to better estimate vegetation biomass during annual LTRM sampling. The new estimation will be based on field measurement of the weight of submersed vegetation caught on the rake at a subset of stratified-random LTRM sites. The primary objective of this work is to reduce current limitations and improve our understanding of the vegetation data currently collected with a modest amount of additional work (<20 hours of field time per year at each LTRM field station). The new estimation does not rely on rake scores, although rake scores will be recorded as usual and relationships could potentially emerge in the future.

Specifically, we propose to take three initial steps toward developing and evaluating methods for plant biomass estimation:

1) Expand an existing data set relating raked biomass to total plot (actual) biomass. This will be done in collaboration with the USFWS who are collecting plot total biomass data in a Lake Onalaska project. Data collected here will be pooled with those collected in 2016 by Drake et al. during the LTRM *P. crispus* study to provide a broader base for inference.

2) Investigate relationships between plant morphotype and biomass caught on the rake to determine whether multiple, distinguishable relationships exist (e.g. determine whether raking collects a larger proportion of branched species than unbranched species), and

3) Collect raked SAV fresh weight data at a subset of LTRM vegetation sampling sites in Pools 4 and 8 to permit exploratory data analysis and to quantify the time requirement of this approach.

We note that this study does not include any detailed modelling of potential rake score versus biomass relationships, but will provide data with which this could potentially be attempted. We also note that it is unlikely that the results of this work could be used to reconstruct historical biomass based on LTRM data, and this is not a goal of the study.

This work builds on several previous studies which have noted limitations in our ability to estimate biomass of aquatic vegetation using LTRM rake score data. I.e. the only available biomass proxy (rake score) is not well correlated with harvested biomass (Kenow et al. 2007, Yin and Kreiling 2011, Deppa 2016, Drake et al. 2017). For example, median biomass of *Vallisneria americana* (wildcelery) was not strongly associated with a plant density (rake) score greater than 1 (Deppa 2016, Figure 1), and the biomass of plots yielding plant density (rake) scores from 1-5 overlap considerably. Drake et al. 2017 found that rake scores of 1 encompassed between <1 g and 560 g fresh weight of aquatic vegetation caught on the rake (examples in Figure 2).

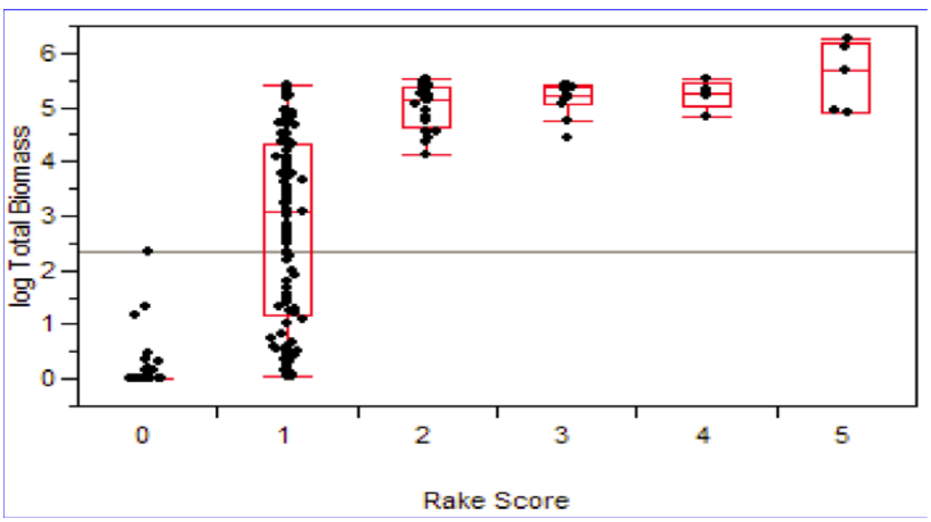


Figure 1. Wildcelery biomass vs LTRM rake score. Reproduced from Deppa 2016.

**A** **B** **C**

Figure 2. Examples of raked fresh biomass weighing A. <1 g, B. 197 g, and C. 353 g, all of which receive a rake score of 1. The maximum recorded rake fresh weight with a score of 1 was 560 g (Drake et al 2017). Biomass is strongly dependent on plant length and degree of branching, but rake score is relatively insensitive to these.

Instead of using rake scores to estimate actual biomass, we propose to use the **weight** of vegetation caught on the rake to estimate actual biomass. Drake et al. (2017) identified a strong relationship between the weight of SAV in plots (actual biomass) and the weight of vegetation in rake samples (raked biomass) based on data collected in 2016 during a study of *P. crispus* (Figure 3). While that study focused on areas dominated by *P. crispus*, approximately one third of the data were collected in reference areas dominated by native species. Thus the relationship may be broadly applicable, may vary to some degree depending on SAV species or morphotype, or may not hold under further scrutiny. The aquatic vegetation survey data that we propose to collect here (n = 40) will include sites dominated by *V. americana* will augment the 2016 *P. crispus* dataset (n = 90) and will allow us to determine 1) whether the rake biomass-plot biomass relationship extends beyond the 2016 *P. crispus* study and 2) whether different relationships exist for other SAV species or morphotypes in the UMR system.

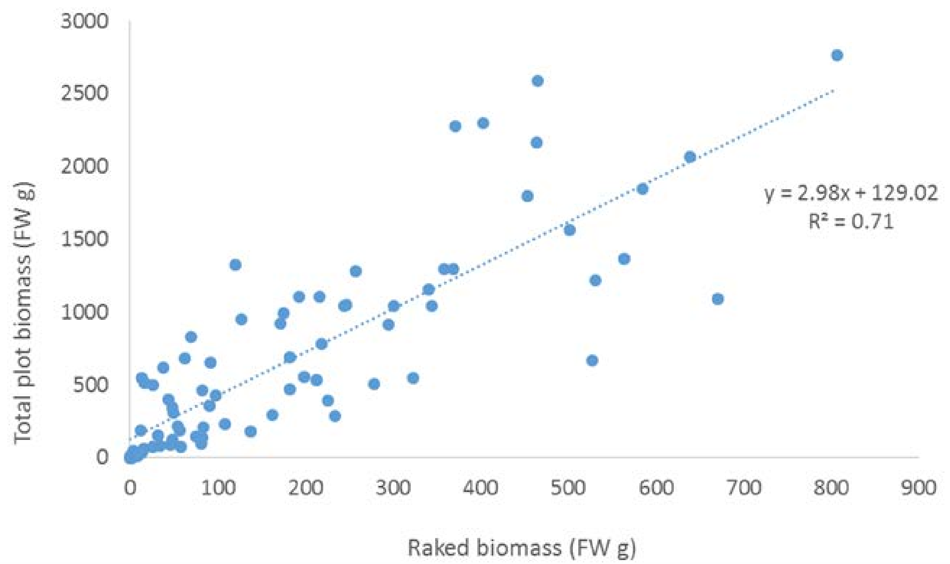


Figure 3. Rake and snorkel-harvested plot biomass relationship for individual rakes (not full sites). Data were collected in 2016 in Lake Onalaska and Pool 8 (Drake et al. 2017). This figure includes both *P. crispus*-dominated sites and native species-dominated sites.

Biomass estimation methods need to be practical in the field setting (i.e. doable in terms of time and effort) and must be minimally subject to bias and individual interpretation as a large number of employees participate in surveys over time. We believe that recording the weights of vegetation brought up on rakes at a subset of sites annually may meet these criteria. Thus, the overarching goal of the work proposed here is to develop a straightforward, repeatable and efficient method for estimating biomass per unit area in LTRM vegetation data collection.

**Relevance of research to UMRR**:

The relevance of this work is described above, but to summarize, biomass estimation would be an important step forward in understanding and quantifying functional value and effects of aquatic vegetation. It would allow us to supplement current presence/absence measures (percent frequency occurrence) with quantification of SAV-based processes such as fish habitat provision, oxygen production, phosphorus sequestration and release, and changes to water clarity. These are fundamental drivers of ecosystem health and resilience and are of central importance to the UMRR program and management. Aquatic vegetation biomass mediates biogeochemistry, habitat, and hydraulics in the UMRS, identified as essential ecosystem characteristics in the UMRS Ecosystem Restoration Objectives report (USACE 2011). While this study does not focus on HREPs, the ability to estimate biomass would improve our ability to assess the effectiveness of these projects in terms of plant-based ecosystem functions and support of river food webs. For example, PFO within 400 m of Phase III islands was high prior to and did not change with construction of the islands (Drake and Gray, in preparation). The biomass of aquatic plants, however, may have remained the same or may have increased considerably with island construction – this is unknown. The ability to make some inference around biomass would provide a much stronger argument for potential agents of change and improve our mechanistic understanding of ecosystem change. This ability would also bring the UMRR program in line with some other nationally significant large-scale ecosystem studies in terms of biogeochemical inferences (e.g. the role of seagrasses in Puget Sound food webs and provision of ecosystem services is based on biomass estimations, Guerry et. al 2011).

**Methods 1) Collect total plot biomass and rake information in collaboration with the USFWS**.

We will conduct LTRM surveys with added biomass measurements in conjunction with USFWS wildcelery monitoring in August, 2017. This work focuses on wildcelery, which is recognized as a critical food source supporting significant populations of migrating waterfowl, especially canvasback ducks (*Aythya vallisneria*) in the UMR Flyway. Understanding patterns in wildcelery abundance, its capacity to provide a food resource, and the potential drivers and feedbacks affecting production of this species are all biomass-based analyses that directly inform waterfowl management. The USFWS has documented wildcelery abundance in Lake Onalaska since 1978 using a destructive harvest approach in which divers collect and count whole plants from approximately 140, 1 $m^2$ quadrats per year.

USFWS surveys are conducted in one day during the first week of August each year. Established *V. americana* transects and plots will be visited, and Wisconsin and Minnesota DNR (depending on availability) and USFWS boats and crews will work simultaneously. Divers will guide the rake used for LTRM aquatic vegetation surveys to the top of the harvested quadrat, and rakes will be pulled through the quadrat. This rake subplot (R) will be treated as one of 6 sub-plots measured using LTRM methods, and a standard LTRM survey (Yin et al. 2000) will be conducted. The vegetation caught on the rake in each subplot will be separated into individual species. The fresh weight of each species-fraction will be recorded. The diver-harvested portion will also be sorted and weighed. The raked and diver-harvested samples will then be re-combined and quantified using the standard USFWS survey procedure. If time is limited samples will be returned to the laboratory for sorting and weighing. Data produced at each site will therefor include 1) LTRM standard site data 2) Biomass of *V. americana* and all other species in the plot, and 3) biomass of *V. americana* and all other species on the rake.

**Methods 2) Collect fresh weights of SAV on rakes during regular LTRM surveys at a subset of 42 sample points in each of Pools 4 and 8.**

We will 1) determine the time requirement for collecting systematic SAV fresh weight data, allowing an assessment of the costs involved in adopting this approach, and 2) explore biomass estimation. The differing morphology of aquatic vegetation will likely manifest as distinct rake score vs. fresh-weight relationships for species, but to simplify and control time requirements, submersed plant species will be separated into 4 morphologically similar groups: 1) long, skinny morphology comprising mostly or all wildcelery and water stargrass, 2) tangled, bushy morphology comprising mostly or all coontail and Canadian water weed, 3) masses of fine stems comprising mostly or all narrow-leaf pondweeds plus all other species, and 4) filamentous algae.

Forty-two of the 450 2017 LTRM vegetation study sites have been selected from each of Pools 4 and 8 for inclusion in this study, i.e. every tenth site number (e.g. sites 1, 11, 21, 31, etc. to point 421 – excluding sites in the isolated backwater stratum). At these sites, after standard LTRM surveys are completed, the aquatic vegetation on each rake pull will be retained and sorted into the 4 components described above. If the site is unvegetated, samples will be collected and weighed at the next vegetated site within the same stratum that is encountered during the course of typical LTRM sampling (i.e. based on proximity). Plant samples will be drained of water, weighed, and recorded in the field or, if samples are difficult to separate or weather conditions are unfavorable, the raked samples will be returned to the field station for separation and weighing. Ten, ~100 g fresh weight specimens of each morphotype will be retained, dried and submitted for elemental analysis (WI DNR only). The time spent required for sorting and weighing plants will be recorded.

**Quantitative Methods**

Data collected during this study will be used to assess the “doability” and time requirements of the methods, and to determine where efficiencies can be gained (e.g. can the weights of vegetation at sites dominated by algae be determined for whole, unsorted samples?). Data analyses will include, for the snorkel surveys, production of simple regressions to quantify relationships between plot biomass and raked biomass by species and by morphotype. These relationships will allow estimation of actual biomass per $m^{-2}$ from rake weights (e.g. Figure 3) and allow us to determine whether plants can be grouped by morphotype or if finer divisions are necessary. We will examine errors associated with biomass estimates, and evaluate using unaltered weight of vegetation collected on rakes to represent “minimum biomass”. For the raked weight data collected during LTRM sampling, we will produce distributions of raked weights by category and stratum, calculate means with confidence intervals, and, if possible, conduct a power analysis to estimate a required sample size. Elemental concentration data from both this study and the 2016 *P. crispus* project will be used to estimate nutrient standing stocks. These data could also be used to inform further analyses including rake score relationships to biomass (perhaps using composited data rather than individual rake data), spatial patterns or stratum-related patterns in biomass, and studies of the potential influence of filamentous algae on nutrient cycling.

**Milestones and products:**

| Tracking number | Products | Staff | Milestones |
|---|---|---|---|
| 2018BIO1 | Completion of USFWS collaborative field work, data entry, laboratory work and LTRM additional field data collection | Drake, Holman, Lund | 30 August 2017 |
| 2018BIO2 | Draft LTRM Completion Report: Estimating biomass of submersed aquatic vegetation in the UMR | Drake, Lund, Holman | 30 March 2018 |
| 2018BIO3 | Final LTRM Completion report: Estimating biomass of submersed aquatic vegetation in the UMR | Drake, Lund | 30 October 2018 |

**Literature cited**


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## Plankton Community Dynamics in Lake Pepin – the role crustacean zooplankton

**Previous LTRM project:**

This work is the last piece of an ongoing project and expands on the previous project 'Analysis of Lake Pepin Rotifers' (2015D15). The crustacean zooplankton data generated from the current proposal would be combined with the rotifer data and used in the analysis of the 'Plankton Community Dynamics in Lake Pepin' (2015LPP2) project. The crustacean data would provide a complete plankton data set for analysis with the objective of gaining further insight into the spatial and temporal dynamics of plankton communities and the role of crustacean zooplankton on the Upper Mississippi River (UMR).

**Name of Principal Investigator:**

Rob Burdis
Minnesota Department of Natural Resources
1801 South Oak St.
Lake City, MN 55041
651-345-3331 x224
robert.burdis@state.mn.us

**Collaborators:**

Jodie Hirsch
Minnesota Department of Natural Resources
500 Lafayette Rd
St Paul, MN 55155-4025
651-259-5105
jodie.Hirsch@dnr.state.mn.us
Jodie will provide in-kind training for identification and methods as needed. She is the MN DNR's expert zooplankton biologist and has done most of the sample enumeration for past Lake Pepin zooplankton samples.

Chris Dawald
Minnesota Department of Natural Resources
1801 South Oak St.
Lake City, MN 55041
christopher.dawald@state.mn.us
Chris is a Natural Resource Specialist for the Lake City LTRM Field Station and completed the identification and enumeration of rotifers for the 'Analysis of Lake Pepin Rotifers' (2015D15) project. Chris would learn crustacean zooplankton identification and enumeration for this project.

**Introduction/Background:**

The Lake City Field Station has three years of Lake Pepin phytoplankton samples enumerated with the purpose to characterize and examine phytoplankton dynamics on the UMR. The current proposal to enumerate crustacean zooplankton from Lake Pepin is the last portion of an ongoing project that would give us a complete plankton data set (i.e., phytoplankton, rotifers, & crustacean zooplankton) for a three year period and allow us to better analyze plankton dynamics. Incorporating crustacean zooplankton data in the analysis will allow us to test for important relationships between the different plankton trophic levels. While the primary focus of the 'Plankton Community Dynamics in Lake Pepin' project will be on phytoplankton, having crustacean zooplankton data available for analysis is important because they can exert 'top down' controls on the phytoplankton community through grazing. Similarly, the availability of a quality phytoplankton community can have a 'bottom up' effect on the zooplankton community by providing a food source or lack thereof.

**Relevance of research to UMRR**:

The objective of the current proposal is to expand the ongoing work to understand the complete plankton community necessary for analysis of the 'Plankton Community Dynamics in Lake Pepin' project (2015LPP2) by adding crustacean zooplankton data to the already existing rotifer and phytoplankton data sets. The 'Plankton Community Dynamics in Lake Pepin' analysis is intended to gain further insight into the spatial and temporal dynamics of plankton communities and the variables driving them on the UMR. As primary producers, phytoplankton are directly affected by physical and chemical factors and can grow in abundance to the extent that they can significantly impair recreational use of the resource. Eutrophication is a fundamental concern in the management of all water bodies and limnologists have demonstrated the strong relationship between nutrient loading and phytoplankton biomass. For example, cyanobacteria (blue-green algae) in particular are strongly linked to eutrophic conditions and are an environmental hazard due to toxins contained within their cells. A comprehensive assessment of the plankton community in Lake Pepin will lead to an understanding of the fundamental drivers of ecosystem health and resilience such as water velocity and residence time.

While the current proposal and projects are specific to Lake Pepin, insight into plankton dynamics and the mechanisms driving them may be applicable to other reaches of the UMR. In addition, insight gained from this work can be used to help guide future strategies for plankton analysis in the LTRM element, including what to do with the immense archive of phytoplankton samples that have been collected by the LTRM field stations since 1993 as part of the routine water quality sampling effort.

Lastly, the complete plankton community dataset can provide critical information prior to an anticipated invasion by invasive carp. Two invasive carp in particular, *Hypophthalmichthys molitrix* (silver carp) and *H. nobilis* (bighead carp) are known to feed primarily on plankton. To date, *H. nobilis* has been found in Lake Pepin on only three occasions, while *H. molitrix* has yet to be recorded (pers. com. Schlesser and Dieterman, 2017). As plankton serve a critical role at the bottom of the food chain, having a complete dataset both pre and post invasion will provide a unique opportunity to understand the ecosystem response to the invasion.

**Specific research framework citation:**

A STRATEGIC PLAN FOR THE UPPER MISSISSIPPI RIVER RESTORATION PROGRAM 2015 – 2025

<u>Objective 2.1 Strategy 2</u>: 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
<u>Objective 2.2 Strategy 1</u>: Conduct focused research and analyses to gain critical, management-relevant information about the Upper Mississippi River ecosystem's process, function, structure, and composition as well as the dynamics and interactions among system components

**Methods**:

Specifically designed zooplankton counting software will be made available to the Lake City field station by the MN DNR. The software paired with a high quality digital microscope available from MN NDR

Fisheries Research will provided us with state of the art zooplankton enumeration and measuring capabilities. This effort would identify and measure three summers (2012-2014) of fixed site crustacean zooplankton samples (approximately 132 samples) for use in the 'Plankton Community Dynamics in Lake Pepin' project (2015LPP2). Data would be paired with existing rotifer (2015D15) and phytoplankton (2015LPP2) data to examine relationships between plankton trophic levels providing a more complete understanding plankton dynamics on the UMR.

**Special needs/considerations, if any:**

All of the equipment, software, training and set up for this project would be provided in-kind by the MN DNR.

**Products and Milestones:**

| Tracking number | Products | Staff | Milestones |
|---|---|---|---|
| 2018PLK1 | Three year (2012-2014) data set of Lake Pepin crustacean zooplankton data. Crustacean zooplankton samples collected at four fixed sites in Lake Pepin will be processed to obtain species composition and biomass estimates | Burdis | 30 March 2018 |
| 2018PLK2 | Analysis: Data would be paired with existing rotifer (2015D15) and phytoplankton (2015LPP2) | Burdis | 31 December 2018 |

| FY18 Equipment Refreshment | | | |
|---|---|---|---|
| | | | |
| **Field Station** | **Equipment** | **Estimated cost** | **Component** |
| Lake City | Hach FH950 Velocity Meter | $ 5,100 | Fish |
| La Crosse | Groban 7 KW Honda Generator 13HP GX390 | $ 5,000 | Fish |
| La Crosse | Evinrude 130 HP 20" ETEC (net boat) | $ 9,000 | Fish |
| La Crosse | Garmin GPS Map76 | $ 500 | veg |
| La Crosse | Gibson 12 cu. Ft. | $ 850 | wq |
| La Crosse | Minisonde | $ 5,000 | wq |
| Bellevue | Generator | $ 5,000 | Fish |
| Bellevue | Hach FH950 Velocity Meter | $ 5,100 | Fish |
| Bellevue | Hach FH950 Velocity Meter | $ 5,100 | wq |
| Big Rivers | Stereo Microscope | $ 2,500 | Fish |
| Big Rivers | Marine radio / cell phone | $ 500 | Fish |
| Big Rivers | Garmin 537s | $ 1,500 | wq |
| Big Rivers | Hach, Flow Meter | $ 5,000 | wq |
| Big Rivers | Marine radio / cell phone | $ 500 | wq |
| | | | |
| | **Subtotal** | **$50,650** | |
| | | | |
| Great Rivers | 130 HP Evinrude outboard motor | $ 2,000 | fish |
| Great Rivers | Getac M220-4B1P ruggedized laptop computer | $ 5,000 | fish |
| Great Rivers | Garmin GPSMap 168 sounder | $ 1,500 | fish |
| Great Rivers | Cole Parmer Air cadet pump | $ 700 | wq |
| IRBS | electronic scale | $ 1,200 | fish |
| IRBS | Generator | $ 5,000 | fish |
| IRBS | Velocity or turbidimeter | $5,500 | fish |
| IRBS | Hydrolab Minisonde | $ 6,000 | wq |
| IRBS | Peristaltic pump | $ 2,000 | wq |
| | **Subtotal** | **$38,900** | |
| | **Indirect (15%)** | $ 5,835 | |
| | **Total IL** | **$44,735** | |
| | | | |
| | **State total** | $ 95,385 | |
| | **with UMESC 3.00%** | **$ 98,247** | |

# Smallmouth Buffalo population demographics of the Upper Mississippi River Basin

**Previous LTRM project:**

This is a new project for the UMRR and LTRM: however, it does build on, and will incorporate, data collected by a previous effort of the Big Rivers and Wetlands Field Station. The effort undertaken by the Big Rivers and Wetlands Field Station was not funded by UMRR. A draft of the results of this project is attached.

This project also will work in conjunction with an LTRM effort to collect Smallmouth Buffalo during the 2017 field season. All the LTRM component specialists (with the exception of Pool 8 due to low catch rates) are currently collecting Smallmouth Buffalo, and the goals of that project are identical to goals outlined in this proposal. Structures collected through this work were to be under base, archived, and processed as time and funding allow, and requested funding would allow for processing (otolith removal, mounting, sectioning, aging) during the winter of 2017-18.

**Name of Principal Investigator:**

Levi Solomon soloml@illinois.edu and Kris Maxson kmaxs87@illinois.edu; Illinois Natural History Survey, Illinois River Biological Station

**Collaborators (Who else is involved in completing the project):**

LTRM fish component specialists will assist by collecting fishes:

Steve DeLain steve.delain@state.mn.us
Andy Bartels abartels@USGS.gov
Mel Bowler Melvin.bowler@dnr.iowa.gov
Eric Ratcliff eratcliff@illinois.edu
Eric Gittinger egitting@illinois.edu
John West John.West@mdc.mo.gov
Jason DeBoer jadboer@illinois.edu
Andrya Whitten awhitten@illinois.edu

Seth Love salove@illinois.edu and Quinton Phelps Quinton.Phelps@mdc.mo.gov will provide assistance with processing of samples, data from the Open River reach, and assistance with data analysis

Brian Ickes bickes@usgs.gov and Andy Casper afcasper@illinois.edu will provide assistance with data analysis and writing any/all reports/publications.

**Introduction/Background:**

Smallmouth buffalo are one of few abundant, system-wide, commercially valuable fish species on the Upper Mississippi River System (UMRS) and support a partner managed, multistate, commercial industry throughout the UMRS. However, little is known about Smallmouth Buffalo life history and much of the published literature is 50+ years old and often not from a large river environment. Additionally, outside of the work done on the Open River, no data of Smallmouth Buffalo population demographics exists from anywhere on the UMRS. Thus, the goal of this project is to provide basic population demographics (age structure, growth rates, mortality) about Smallmouth Buffalo on the LTRM trend pools of the UMRS. Using this data, we can better understand the response of a fish species, in this case Smallmouth Buffalo, to potential disturbance or restoration. In addition, increasing our knowledge of population demographics could lead to a better understanding of the resiliency of Smallmouth Buffalo and potentially other benthic species. For example, if Smallmouth Buffalo age structure and growth rates are similar among all LTRM study reaches, it would show that they are potentially very resilient to higher levels of disturbance (invasive species, lack of connectivity, etc.) and commercial fishing that is present in the lower three study reaches and lacking in the upper three study reaches. If age structure and growth rates differ significantly we can begin to identify potentially factors driving observed differences. This can complement the existing community structure and fisheries population data that LTRM currently collects by incorporating addition parameters (recruitment patterns) while providing baseline data throughout the UMRS in advance of further natural and anthropogenic disturbances.

Other species of fish are abundant, system-wide, or commercially valuable and include Common Carp, Channel Catfish, Freshwater Drum, however, none of those species match the Smallmouth Buffalo in value per pound and numerical abundance throughout the entire UMRS. We chose Smallmouth Buffalo in part due to the Big Rivers and Wetlands Field Station's recent efforts to study basic population demographics of Common Carp and Freshwater Drum from all LTRM study reaches. In addition, as collection of fishes was originally proposed under base to, and agreed upon by, all field station fish component specialists, we opted for a single species approach as additional resources may have been needed to expand to include Channel Catfish or any other species.

**Relevance of research to UMRR**:

This project builds on work previously done by Seth Love and Quinton Phelps to document population demographics of Smallmouth Buffalo on the Open River Reach using fish collected in 2014. One of the goals of Love and Phelps was to acquire current baseline data on Smallmouth Buffalo population demographics for the Open River Reach. This project would add data from all other trend pools to produce a system-wide assessment of the current status of Smallmouth Buffalo on the UMRS. However, due to low catch rates of Smallmouth Buffalo through LTRM methods on Pool 8, we are omitting Pool 8 from data collection.

Specifically, the information collected through this study would

- enhance our understanding of an important species system wide
- provide more information for the Commercial Fish Indicator
- Inform the next Status and Trends Report as well as the Annual Report to Congress.
- Support the UMRR partnering agencies by leveraging UMRR data to management strategies and regulations
- supports the UMRR by developing a better understanding of the ecology of the UMRS and its resources.

In addition, this would allow for comparison among age structure between the upper river reaches (where HREP's with high river connectivity are common) and lower river reaches and the Illinois River (where HREP's with high river connectivity are less common). It would also allow for comparisons among differing degrees of disturbances (invasive species, altered hydrograph, etc.) between upper and lower reaches of the UMRS.

**Methods**:

LTRM fish component specialists are currently collecting Smallmouth Buffalo during routine monitoring on LTRM trend pools (with the exception of Pool 8) and freezing them upon returning from the river. Fishes will then be picked up by Illinois River Biological Station (IRBS) staff and processed at a later date. Processing will include recording of individual fish's capture data (date, location, gear, length, weight, and collector), removal of the otoliths, and archiving otoliths in coin envelopes. After otoliths are allowed to dry, they will be mounted in epoxy, sectioned using a low speed saw, mounted to a microscope slide and digitally photographed. Digital photographs will be used to estimate the age of individual fish and measure annuli to calculate growth rates. Methods will follow those developed by Love and Phelps.

**Products and Milestones:**

| Tracking number | Products | Staff | Milestones |
|---|---|---|---|
| 2018SMBF1 | Collection of smallmouth buffalo for otoliths | Field Stations Fish Component Staff | 31 October 2017 |
| 2018SMBF2 | Transfer of fish to IRBS | Solomon, Maxson | 30 November 2017 |
| 2018SMBF3 | Processing of otoliths | Solomon, Maxson | 30 May 2018 |
| 2018SMBF4 | Analysis: Mixed modeling approach to separate growth responses into both AGE and YEAR effects | Ickes, Solomon, Maxson | 30 June 2018 |
| 2018SBMF5 | Draft analysis methods and results write-up | Ickes | 30 September 2018 |
| 2018SBMF6 | Draft LTRM Completion Report | Solomon, Maxson, et al. | 30 May 2019 |

## UMRR LTRM Water Quality (WQ) laboratory modernization

The UMRR LTRM Water Quality (WQ) laboratory has been an essential component of the UMRR Program since the early 1990s. At that time, analyses in the WQ lab were limited to total suspended solids and sediment particle size. Other water sample analysis was contracted out to Eau Galle Laboratory. In 1993, the decision was made to expand the capability of the UMRR LTRM laboratory so LTRM water samples could be analyzed in-house. The main reason for the move was to decrease cost to the LTRM element. Doing so significantly increased the analytical capacity of the laboratory to include analyses of nitrogen, phosphorous, chlorophyll, etc. The number of samples analyzed each year increased from a few thousand to the more than 60,000 samples analyzed currently. What did not expand during this time period was the footprint of the WQ laboratory itself. In fact, the footprint of the laboratory decreased when the USGS Environmental Management Technical Center, which formerly housed the UMRR LTRM WQ laboratory, moved to the USGS Upper Midwest Environmental Sciences Center in 2004. The room into which the WQ laboratory moved was not designed specifically for the UMRR LTRM laboratory. Also, there has been no modernization of casework, fume hoods, etc. during this time frame (2004 until today). The current WQ laboratory does not functionally meet the needs of the laboratory analysts, the working environment is far from ideal.

The state of the laboratory is outdated and obsolete by today's industry standards. The current design of the UMRR LTRM WQ lab does not allow efficient use of space for current work nor does it allow the UMRR the flexibility of increasing capabilities as UMRR Program needs expand. For example, new capabilities could include carbon and sediment nutrient analysis. The proposed modernization will expand the UMRR LTRM WQ footprint from a combination of small, disjointed rooms totaling 1,075 square feet to a more open concept of 1,575 square feet and bring the area up to industry standards by creating a safe, efficient, and collaborative work environment. Modernization also will improve energy efficiency and airflow management, incorporate new technologies, and remodel laboratory space built in the 1970s. Other benefits of remodeling laboratory space include making the space more open to improve work flow, facilitate better communication among lab members and integration of procedures. In addition, remodeling would provide additional counter space for upgraded instruments and more room for storage of lab materials and samples.

Having a dedicated UMRR LTRM Lab allows the UMRR Program to keep costs low compared industrial labs. (For example, the range for UMRR LTRM WQ Lab cost per samples is $7-$20 while industrial lab costs run $20-$60.) The proposed modernization will allow the UMRR LTRM WQ laboratory to maintain its high standards of running analyses efficiently and giving researchers accurate data in a timely manner.

USGS UMESC will cost-share an additional $250K for this project.

| Tracking number | Products | Staff | Milestones |
|---|---|---|---|
| 2018LM1 | Contract design work | Goede, Yuan, Sauer | 30 September 2018 |
| 2018LM2 | Purchase of walk-in refrigerator/freezer | Yuan | 30 September 2018 |
| 2018LM3 | Construction complete | Goede, Yuan, Sauer | 30 September 2020[1] |

[1]Tentative date

# Landscape Pattern Research and Application on the Upper Mississippi River System (2018-2021)

**Previous LTRM Projects:**
*2008-2009: Landscape ecology indicators applied to the Upper Mississippi River System*
*2010-2012: Development of landscape pattern indices for the Upper Mississippi River System*
*2013-2015: Landscape pattern research and application on the Upper Mississippi River System*
*2016-2018: Landscape pattern research and application on the Upper Mississippi River System*

**Name of Principal Investigators:**
Nathan R. De Jager, USGS, 608-781-6232, ndejager@usgs.gov
Molly Van Appledorn, USGS, 608-781-6323, mvanappledorn@usgs.gov
Jason Rohweder, USGS, 608-781-6228, jrohweder@usgs.gov

**Collaborators:**

UMESC LTRM Branch staff, field station staff, HREP managers

**Introduction/Background:**

The U.S. Army Corps of Engineers Upper Mississippi River Restoration Program's landscape patterns research framework (De Jager 2011) described research activities that would lead to the development of a suite of quantitative measures that can be used to: 1) track status and trends of landscape patterns that affect various ecological processes (e.g., community succession and nutrient cycling), 2) identify areas for restoration on a systemic basis, and 3) develop a better understanding of the ecological consequences of modifications to landscape patterns in the contexts of ecosystem restoration and environmental change.

The first objective of the research framework was to develop measures of landscape structure to capture general aspects of ecosystem function, for the purpose of identifying areas for ecosystem restoration and to track status and trends at the UMRS system scale. Research into four types of landscape patterns was proposed and has been conducted: 1) patterns of floodplain inundation (De Jager et al. 2012), 2) patterns of land cover composition (De Jager et al. 2011), 3) patterns of floodplain habitat connectivity (De Jager and Rohweder 2011a), and 4) patterns of aquatic area richness (De Jager and Rohweder 2011b). In addition, a landscape indicators web browser was developed to provide resource managers and the public a way to view the maps and metrics developed during the above studies.

The second objective of the research framework was to link the measures of landscape structure developed through the first objective with local-scale ecological properties and processes. The purpose of the second objective was to better understand the ecological consequences of changes to landscape patterns due to restoration efforts and/or environmental change. Research into four types of ecological properties/processes was proposed and has been conducted: 1) floodplain community composition and succession (De Jager et al. 2012, 2013), 2) floodplain soil nutrient dynamics (De Jager et al. 2015), 3) aquatic community composition (De Jager and Houser 2016), and 4) patterns of aquatic nutrient concentrations (De Jager and Houser 2012).

Below, we use two case studies to outline how measures developed via the first objective can be used to define general and broad-scale management actions while analyses conducted to address the second objective can be used to identify specific hydrogeomorphic conditions that ought to promote specific ecological outcomes via restoration actions.

*Case Study #1: Aquatic areas, nutrient concentrations, and fish communities*

One of the primary goals of the UMRR is to restore and rehabilitate aquatic areas. By calculating the diversity of aquatic areas, De Jager and Rohweder (2011b) show where the landscape mosaic of the UMRS contains diverse assemblages of aquatic areas and where efforts could be taken to improve aquatic area diversity by strategically placing new restoration projects. While this information is important for program managers and regional decision makers, it provides little information to local project planners and managers as to what physical characteristics a given project could contain to support different ecological properties and processes. For this reason, studies conducted by De Jager and Houser (2012 and 2016) show how the concentrations of limiting nutrients (nitrogen and phosphorous) and fish communities vary across contrasting aquatic areas and gradients of hydrological connectivity. In particular, large shifts in nutrient concentrations and fish communities occur at water flow velocities near 0.1 m/sec. This critical threshold could be used to identify hydro-geomorphic patterns that could be created via management actions to ultimately change ecological patterns and processes.

*Case Study #2: Flood Inundation, Vegetation Communities, and Soils*

An increasingly important goal of the UMRS management community is to restore floodplain forest cover (Guyon et al. 2012). By calculating measures of floodplain forest cover, De Jager and Rohweder (2011a) show where and how restoration efforts could reduce forest fragmentation and enhance forest connectivity across the UMRS. As was the case in the above example, such analyses can be used to pinpoint areas where restoration efforts could have relatively large impacts on forest area and connectivity. However, it is unclear how management agencies can best restore forest cover, given the altered hydrological regime of the UMRS, increasing abundances of invasive species, and large herbivore populations that are sometimes 5X their historical densities. For this reason, De Jager et al. (2012, 2013, 2015) show how invasion by exotic species, herbivory by white-tailed deer and flood inundation patterns impact soil nutrient availability and forest succession. In particular, flood inundation durations lasting longer than 60 days per growing season appear to limit establishment of less flood tolerant species. A lack of regeneration in such areas can lead to successful invasion of sites by an invasive grass (*Phalaris arundinacea*) to alter the long-term resilience of floodplain forests. This information is currently being incorporated into restoration projects to identify water level management strategies and/or floodplain elevations that ought to support floodplain forests, as well as develop strategies to suppress invasive species and promote forest regeneration.

The above case studies demonstrate how a multi-scale approach can be used to bridge gaps between regional and local-scale decision making processes regarding aquatic and floodplain areas. However, changing future environmental conditions (i.e., changes in temperature, flow regime, species invasions, etc…) make it difficult to determine the degree to which relationships developed in the past can be used to generate expectations about the effects of restoration projects in the future. For this reason the landscape patterns research framework identified the development of spatially explicit simulation modelling as a research priority.

**FY18-21 Project Objectives**

In conjunction with the Habitat Needs Assessment-II, new datasets have been developed to characterize landscape-scale hydrogeomorphic patterns in both aquatic and floodplain areas. In addition, efforts are being made to develop methods to simulate alternative flood inundation scenarios and associated changes in vegetation succession. For FY 2018-2021, we will utilize these new datasets to generate broad-scale measures that characterize important aspects of hydrogeomorphology. In addition, we will utilize other data collected by LTRM or other agencies along the UMRS to better understand how hydrogeomorphic patterns influence local ecosystem properties and processes. Finally, we will further develop spatially explicit simulation modeling approaches to forecast changes to patterns of flood inundation and forest succession.

**Specific Project Activities:**

1. Continue and complete flood inundation modelling work
    a. Facilitate the long-term curation of the inundation modelling framework by creating an accessible platform for it.
    b. Continue empirical examination of model outputs with additional field data collection and analyses (in collaboration with LTRM field stations).
    c. Provide technical assistance on the proper use of model outputs.
    d. Assist partner agencies on development of additional uses for the model in HREP project planning.
2. Integrate flood inundation model outputs with vegetation data to better understand how multiple aspects of flood regime shape vegetation communities and dynamics.
    a. Identify opportunities to apply a better understanding flood-vegetation interactions at the HREP scale.
3. Examine inundation model outputs for spatial and temporal trends in different aspects of flood regime.
4. Evaluate alternative scenarios of floodplain management and environmental change on patterns of forest succession in the UMRS
5. Evaluate alternative scenarios of floodplain management and environmental change on patterns of nutrient and carbon cycling in the UMRS

**Staff time requirements:**

Funding to support Nathan De Jager (Principal Investigator for landscape ecology within the UMRR program) at 100% per year for FY2019-2021 will be used to design studies, conduct GIS and other data analyses, write reports and publications, and provide technical assistance to the UMRR partnership in the area of landscape ecology. Funding to support Molly Van Appledorn (developer of the system-wide flood inundation model for HNA-II) at 100% per year will be used to support modelling efforts, design studies, conduct GIS and other data analyses, write reports and publications, and provide technical assistance to UMRR partnership in the area of ecohydrology. Jason Rohweder (GIS modeler) at 30% per year will be used to conduct various GIS analysis and develop new modelling tools for use by N.R. De Jager, M. Van Appledorn, and others within the UMRR partnership.

**Expected milestones and products:**

Manuscripts and other products will be developed based on the proposed work. The specific form and number of manuscripts will be coordinated through the UMRR annual scope of work process. In addition to manuscripts, research findings will be presented at various UMRS forums each year, as well as national scientific conferences.  Annual status reports will be provided each year.

**Literature Cited:**

De Jager, N.R. and Rohweder, J.J. 2011a. Spatial scaling of core and dominant forest cover in the Upper Mississippi and Illinois River floodplains, USA. Landscape Ecology 26: 697-708.

De Jager, N.R. and Rohweder, 2011b. Spatial Patterns of aquatic habitat richness in the Upper Mississippi River floodplain, USA. Ecological Indicators 13:275-283.

De Jager, N.R, Rohweder, J.J., and J.C. Nelson. 2011. Past and predicted future changes in the land cover of the Upper Mississippi River floodplain, USA. River Research and Applications. 10.1002/rra.1615.

De Jager, N.R. Thomsen, M.T., Yin, Y. 2012. Threshold effects of flood duration on the vegetation and soils of the Upper Mississippi River floodplain, USA. Forest Ecology and Management 270:135-146.

De Jager, N.R. and Houser, J.N. 2012. Variation in water mediated connectivity influences patch distributions of total nitrogen (TN), total phosphorous (TP) and TN:TP ratios in the Upper Mississippi River, USA. Freshwater Science 31: 1254-1272.

De Jager, N.R., Cogger, B.J., and Thomsen, M.T. 2013. Interactive effects of flooding and deer browsing on floodplain forest recruitment. Forest Ecology and Management 303:11-19.

De Jager, N.R., Swanson, W., Strauss, E.A., Thomsen, M., Yin, Y. 2015. Flood pulse effects on nitrification in a floodplain forest impacted by herbivory, invasion, and restoration. Wetlands Ecology and Management 23(3).

De Jager, N.R., and Houser, J.N. 2016. Patchiness in a large floodplain river: associations among hydrology, nutrients, and fish communities. River Research and Applications 32: 1915-1926.

Guyon, L., Deutsch, C., Lundh, J., Urich, R. 2012. Upper Mississippi River Systemic Forest Stewardship Plan. U.S. Army Corps of Engineers. 124 pp.

# Operationalizing Ecosystem Resilience Concepts in the Upper Mississippi River System (2019-2021)

## INTRODUCTION

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

The goal of the UMRS system description was to simplify a complex system to identify the fundamental characteristics of the system. In doing so, we reviewed the relevant historical context that has shaped the current state of the UMRS, recognized valued uses of and services provided by the UMRS, and identified key ecological resources that are needed to support those valued uses and services. Further, we identified the major controlling variables that are known to influence key ecological resources. Because the resilience assessment is intended to inform restoration decisions and a system description is considered the foundation for a resilience assessment, we engaged UMRR partner agencies throughout the development process, thereby gaining broad acceptance of the completed system description. A manuscript has been written, reviewed by the UMRR partnership and is currently accepted for publication pending minor revisions.

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

Table 1. The following indicators of general resilience were developed for the Upper Mississippi River System.

| General Resilience Principle | UMRS Resilience Metric |
|---|---|
| Maintain diversity and redundancy | Aquatic area diversity |
| | Floodplain inundation diversity |
| | Fish functional diversity and redundancy |
| | Aquatic vegetation diversity |
| | Floodplain vegetation diversity |
| Manage connectivity | Longitudinal aquatic connectivity |
| | Lateral connectivity |
| Manage slow variables and feedbacks | Water surface elevation fluctuations |
| | Nutrient loads |
| | Sediment loads |
| | Invasive species |

The second evaluation of the assessing the system element focuses on specified resilience. Initial work on this will be done in FY2018 with current funding, and will first focus on understanding trends in controlling variables for which data is available. Evaluation of controlling variable trends provides information on the range of conditions the system has experienced over monitored time periods and the direction the system is moving, and could be incorporated into the third status and trends of the UMRS. The specified resilience assessment will summarize our current state of understanding of the resilience of key ecological resources to changes in controlling variables, depicted in the system description conceptual models, and develop a framework for evaluating management-relevant relationships for potential thresholds of concern. Given the numerous major resources and controlling variables identified in the system description conceptual models, we plan to identify and evaluate relationships with greatest priority (and data) and focus on one analysis to complete during the remaining funded time. For example, if we were interested in the resilience of aquatic vegetation, we would evaluate its response in relation to the various controlling variables known to influence its distribution and response (Figure 1).

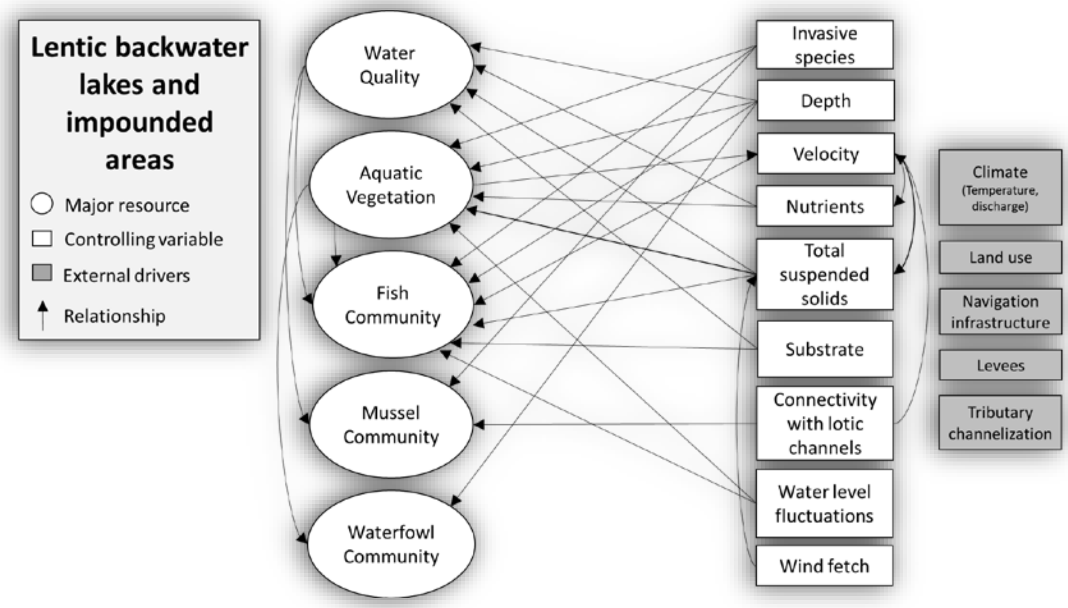


Figure 1. The lentic backwater lakes and impounded areas conceptual model lays out known relationships between major ecological resources and controlling variables.

**Next Steps: Improving our understanding of the specified and general resilience of the UMRS and their implications for river restoration and management**

The next increment for Operationalizing Ecosystem Resilience Concepts (FY19-FY21) is to extend the objectives of the current resilience assessment to include 1) continued efforts to understand specified resilience, 2) empirical investigations (based on LTRM data) to better understand the associations between general resilience metrics and the condition and persistence of major resources identified in the system description conceptual models , 3) conceptual development of the connections between HREP actions and specified and general resilience, and 4) a synthesis of the above to provide understanding of how the resilience assessment could inform and improve the management of the UMRS. We expand on the latter three objectives below, which fit into the third element of the assessment focused on adaptive governance and management (Figure 2).

While indicators of general resilience have been developed by applying principles of general resilience to how we understand the UMRS to function, empirical tests of the associations between such indicators and measures of ecosystem health such as those collected by LTRM are nearly absent in the resilience literature. Furthermore, our understanding of the associations between these resilience metrics and riverine biota could be substantially improved using LTRM data. Such empirical tests of the associations between these broad metrics and measures of ecosystem health derived from the LTRM data would improve our understanding of what these indicators, and changes therein, mean for the biota of the UMRS. Given the spatial and temporal extent of the LTRM data, there are a variety of approaches available for quantitatively assessing the implications of the general resilience indicators for the stability or persistence of major resources (e.g., vegetation and fish) over time. Evaluation of general resilience indicators would be an important contribution to the scientific literature and improve our understanding of how to best use these indicators in making restoration and management decisions.

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

The final objective we will pursue is a synthesis of all the resilience assessment elements in the form of a programmatic report, a scientific manuscript, and a summary pamphlet for communicating with non-technical audiences. In these synthesis documents, we would document and describe how our approach has improved the understanding of how the UMRS functions and our ability to manage for resilience within the UMRR program. Further, we would identify remaining work that would improve our ability to manage for resilience and constraints that limit our ability to manage for aspects of resilience.

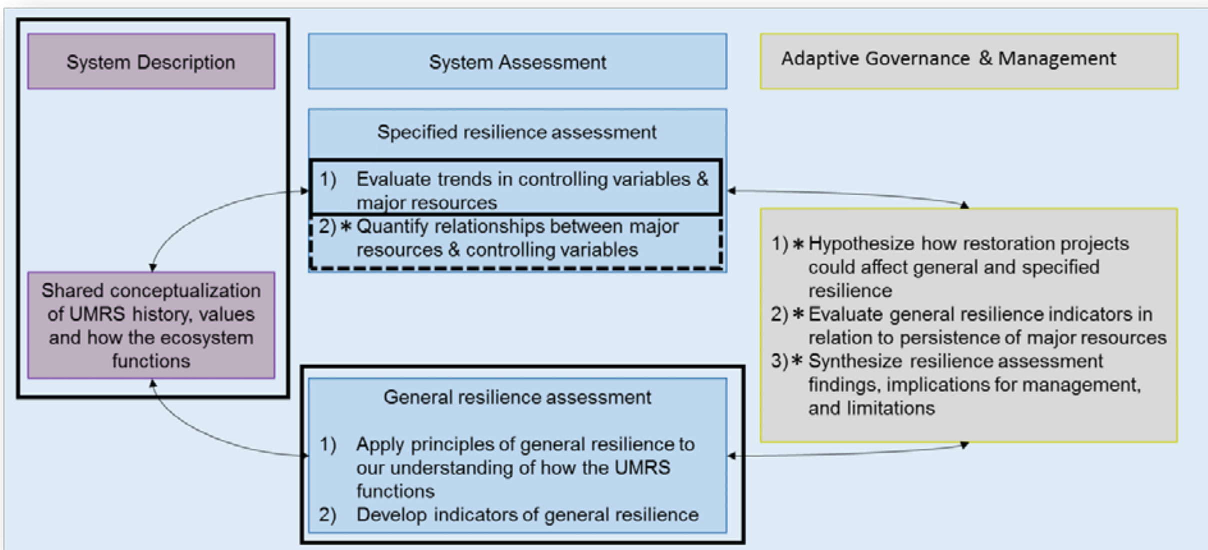


Figure 2. A schematic of the three elements of the UMRS Resilience Assessment and the major objectives of each element (adapted from O'Connell et al. 2015). Black boxes enclose items to be completed (solid) or partially completed (dashed) with current funding. Asterisks indicate work to be completed with additional funding.

**OBJECTIVES**

The objectives of this project are are as follows:

1) Quantify additional relationships between controlling variables and major resources (derived from our resilience assessment conceptual models) where thresholds of potential concern are thought to occur and scale-relevant data are available. Examples of possible analyses include:

    a) How do connectivity with the main channel, water quality, and substrate influence lentic mussel communities?
    b) How does the availability and quality of spawning, nursery, foraging, and refugia opportunities shape the lotic fish communities?
    c) How do inundation patterns influence floodplain forest community types, demographics, and diversity?
2) Evaluate coping capacity of floodplain reaches in relation to general resilience indicators
    a) Test indicators of general resilience by assessing the persistence of major resources across the four floodplain reaches using UMRR-LTRM data
        i) What differences in native fish communities are associated with contrasts in aquatic area diversity, longitudinal connectivity, lateral connectivity, and non-native species?
        ii) What differences in aquatic vegetation communities are associated with aquatic area diversity, water surface elevation fluctuations, total suspended solids, and nutrient loads?
3) Conceptualize and assess potential effects of HREPs on general resilience indicators and controlling variables, particularly those with thresholds of known or potential concern
    a) Develop testable hypotheses regarding how individual HREPs influence controlling variable(s) and general resilience indicators
    b) How do current management actions affect the resilience of the UMRS?
    c) Is there potential to improve current management actions, or develop new management actions, as a result of considering the river's resilience?
4) Synthesize how understanding derived from the resilience assessment could inform and improve the management of the UMRS

**STAFF REQUIREMENTS**

This proposed work will be the primary responsibility of a river ecologist (Kristen Bouska, USGS-UMESC) collaborating with scientists at the U.S. Geological Survey, Upper Midwest Environmental Sciences Center (UMESC), the UMRR Resilience Working Group, and scientists and managers throughout the UMRR partnership. In addition, Jeff Houser (USGS-UMESC) will contribute 15% of his time (in-kind) to provide overall project leadership and coordination with the larger partnership.

**WORKPLAN AND DELIVERABLES**

Manuscripts and other products will be developed based on the proposed work. The specific form and number of manuscripts and other products will be coordinated through the UMRR annual scope of work process. The project PIs (Bouska and Houser) will work with the Resilience Working Group (membership is appended) to develop the annual Scope of Work. We will begin by evaluating management-relevant relationships between major resources and the factors that most likely affect their resilience, and testing resilience indicators developed in the first phase of the resilience assessment. We will quantify these aspects of resilience to the extent possible with existing UMRR LTRM data. Finally, we will examine theoretical and empirical descriptions of the effects management actions (i.e., HREPs) have on the resilience of the UMRS. This will be done via coordination with scientists and managers across the UMRR partnership who assist in designing and monitoring HREPs.

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.

UMRR Resilience Working Group members

| Name | Affiliation | Email |
|---|---|---|
| Kristen Bouska | USGS UMESC | kbouska@usgs.gov |
| Dave Bierman | Iowa DNR | dave.bierman@dnr.iowa.gov |
| Andy Casper | INHS; LTRM Havana FS | afcasper@illinois.edu |
| Mark Cornish | USACE | mark.a.cornish@usace.army.mil |
| Nate De Jager | USGS UMESC | ndejager@usgs.gov |
| Shawn Giblin | Wisconsin DNR | Shawn.Giblin@Wisconsin.gov |
| Jon Hendrickson | USACE | Jon.S.Hendrickson@usace.army.mil |
| Jeff Houser | USGS UMESC | jhouser@usgs.gov |
| Dave Herzog | Missouri DOC | David.herzog@mdc.mo.gov |
| Marvin Hubbell | USACE | Marvin.E.Hubbell@usace.army.mil |
| Kirsten Mickelsen | UMRBA | kmickelsen@umrba.org |
| Nate Richards | USACE | Nathan.S.Richards@usace.army.mil |
| Stephen Winter | USFWS | stephen_winter@fws.gov |
| | | |
| **Former members** | | |
| Melinda Knutson (retired) | USFWS | |
| Nate Richards (reassigned) | USACE | |
| Ken Barr (retired) | USACE | |

# 4-Band Aerial Camera Acquisition, Integration, and Testing for 2020 Land Cover/Land Use Mission

**Previous LTRM project:**
This project lays the groundwork for the collection of aerial imagery that will be used in the creation of the next iteration of systemic land cover/land use (LCU) data for the Upper Mississippi River System (UMRS). Systemic aerial imagery has been acquired, and vegetation datasets derived from that imagery, by the Upper Mississippi River Restoration (UMRR) Program's Long Term Resource Monitoring (LTRM) element on a decadal basis beginning in 1989 and follow-up imagery missions in 2000 and 2010/2011.

**Name of Principal Investigators:**
Jennifer Dieck, DOI-USGS, 608-781-6382, jdieck@usgs.gov
Larry Robinson, DOI-USGS, 608-781-6354, lrobinson@usgs.gov

**Collaborators (Who else is involved in completing the project):**
Brian Lubinski, DOI-USFWS, Biologist/Pilot, brian_lubinski@fws.gov
Brian is a USFWS Migratory Bird Surveys Pilot and flew the systemic aerial imagery mission of 2010/2011. He will provide acquisition oversight and Project Aviation Safety Plans for this project.

Janis Ruhser, DOI-USGS, Biologist, jruhser@usgs.gov
Janis is the primary image processing expert at UMESC and will process, georeference, and mosaic all imagery collected for the integration and testing of the 4-band camera system

**Introduction/Background:** Please address all of these questions:

This scope seeks to answer 1) how much time is required and what are the best image collection parameters to acquire, process, and orthomosaic 4-band images, and 2) what image resolutions are best suited for vegetation interpretation using the new 80-megapixel FWS camera system and the LTRM's 31-Class Generalized Vegetation Classification System?

Based on digital image acquisition testing in 2009, 8"/pixel for the UMRS floodplain north of Lock & Dam 13 and 16"/pixel for the UMRS to the south and the Illinois River represented the best compromise for vegetation mapping that could be completed and distributed within four years. This project will determine if those resolutions are still appropriate or should be changed given the new camera system's more sensitive sensor and larger size.

The UMRR LTRM element's mission is "to 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."

A larger, more sensitive 4-band camera system will collect better imagery in 2020 in far less time than it took to complete the 2010/2011 aerial imagery missions and this proposal will quantify those improvements.

Sample imagery collected in 2019 will identify one or more HREPs above and below Lock and Dam 13 for testing. If the USACOE has preferred sites, they will be targeted for testing purposes.

**Relevance of research to UMRR**:

A Phase One 80-megapixel 4-band dual camera (co-registered to a 60-megapixel achromatic camera and merged in flight by software) will provide higher quality imagery than previous mapping efforts for the next iteration of UMRS LCU by producing stereo imagery that can be viewed and interpreted in either color infrared (CIR) or true color (red/green/blue, or RGB). At the same resolution as 2010/2011 imagery, the Phase One's larger footprint would require approximately one third less time to collect the entire UMRS compared to the smaller 39-megapixel footprint camera used in 2010/2011.

Since the 39-megapixel camera used for the 2010/2011 imagery was a 3-band solution that collected CIR imagery only, the 4-band camera represents a substantial upgrade by having the ability to display the imagery in either CIR or natural color (or RGB). [The CIR imagery is better suited at displaying subtle differences in chlorophyll content necessary to identify plants to the genus level using the 31-Class Generalized Vegetation Classification System. However, RGB imagery is more 'user-friendly' and a better format for producing background aerial mosaics that provide a more intuitive landscape context for the CIR-derived vegetation data to overlay.] In addition, this 4-band camera technology offers a substantial improvement in pixel size reduction (so that more pixels fit on the same physical size sensor), pixel light sensitivity, faster shutter speeds (reducing pixel smear), and image noise reduction. Lastly, newer, faster electronics in this camera system allow for faster recycle times resulting in the plane being able to fly faster which reduces operational costs.

Advanced preparation for the 2020 LCU will ensure that image acquisition parameters are established well in advance of 2020. We will conduct tests that evaluate the best light sensitivity settings (ISO) and shutter speed combinations to use. Images are collected in a RAW format and must be converted to TIFF for classification and orthorectification. This conversion process includes determining which image processing settings produce results that are both tonally accurate and properly color-balanced. Distributed image processing using HTCondor (or its equivalent) will also be evaluated for processing programs that support it to determine if more computer processing power can further reduce production time. Settings that consistently deliver the best image quality and fastest processing times will be noted in the final report and used for the 2020 systemic collection.

Knowing how riverine habitats change over-time is essential for UMRR partners and river managers. For example, floodplain forests and emergent vegetation are important components of large river ecosystems. Floodplain forests provide habitat for a broad range of plants and animals, play an essential role in maintaining the biological diversity of the UMRS, reduce soil erosion, and improve water quality by trapping sediment and sequestering plant nutrients. Emergent plants are important part of the transition zone between terrestrial and open water and indicate a healthy hydrologic regime in floodplain rivers. They provide important food and habitat for fish and wildlife, help prevent erosion, and our indicators of the extent of critical marsh habitat.

This works addresses Goal 2; Objective 2.1 in UMRR's Strategic Plan for the Upper Mississippi River Restoration Program, 2015-2025.

**Methods**:

A Phase One iXU-RS 160 Achromatic 60-megapixel camera) and mounting plate (Figure 1, used for co-registration with the iXU-R 180 RGB camera) will be purchased in FY2018 and integrated into the USFWS's existing remote sensing platform. This integration of hardware and software in FY2018 will have several components:

- Testing of various camera settings, such as shutter speed and ISO on image quality at time of collection
- Testing the effects of various image processing settings such as tone, contrast, white balancing, and color balancing on final image appearance
- Evaluating the potential use of distributed processing for image conversion and mosaicking

In FY2019, sample 4-band imagery will be collected at 6-12"/pixel for pools above Lock and Dam 13 and 12-20"/pixel for the rest of the UMRS and evaluated by UMESC image interpreters to determine optimum resolution for the 2020 UMRS imagery acquisition. Once consensus is reached, a flight plan will be developed and ready for use in the summer of 2020. All funds received from the USACOE to assist in the achromatic camera acquisition, integration, and testing will be returned as in-kind flight time once the acquisition of 2020 aerial imagery begins.


*Figure 1. The 4-band Phase One RGB and Achromatic camera system with base plate* and image samples.

Special needs/considerations, if any:

Other remote sensing enhancements, such as adding a high-definition thermal infrared camera and/or a newer inertial measurement unit are also being considered to further improve the Service's remote sensing capabilities, all of which will directly benefit its federal partners in resource monitoring.

With the faster electronic of this camera, a $1,000/hour mission flown at 150 knots will clearly cost less than one flown at 120 knots back in 2010/2011. As a result, aerial imagery missions with this upgraded system will produce a less expensive and better quality end product. Funding by the USACOE toward the purchase of this camera will be credited the same amount in flight time hours for the 2020 systemic mission.

It should also be noted that while this effort is a collaboration between FWS and the USACOE, it will continue to pay dividends for other federal agencies charged with managing our nation's resources while ensuring that decades of remote sensing expertise remains viable. Its purchase, integration, and testing will substantially benefit the LTRM's LCU efforts when the 2020 systemic acquisition occurs and this work is best considered above and beyond the typical LTRM funding for LCU maintenance and GIS support.

**Milestones and products:**

| Tracking number | Products | Staff | Milestones |
|---|---|---|---|
| 2018CAM1 | Collection of test 4-band imagery, evaluation of image quality and image processing using HT Condor distributed processing software. | Robinson | Summer 2018 |
| 2018CAM2 | Collection and evaluation of sample floodplain at various resolutions above and below Lock and Dam 13 (where the Upper Mississippi River transitions from a floodplain composed complex aquatic vegetation above to a more channelized system that is largely agrarian in nature below). | Robinson | Summer 2019 |
| 2018CAM3 | Draft LTRM Completion report detailing integration and testing procedures and recommendations of optimal image resolution for the 2020 systemic imagery collection. | Robinson | Fall 2019 |
| 2018CAM4 | Final LTRM Completion report with sample images detailing integration and testing procedures and recommendations of optimal image resolution and final flight plan for the 2020 systemic imagery collection. | Robinson | Winter 2019 |