Environment and Natural Resources Trust Fund

Revised Research Addendum

Project Manager Name: Jessica Kozarek

Project Manager Email address: jkozarek@umn.edu

Project Title: Conserving Minnesota's native mussel legacy: Quantifying habitat interactions

Project number: ID # 004-A

Abstract

Freshwater mussel abundance and distribution are inherently linked with their habitat through sediment transport processes in moving waters (i.e. sedimentation, bed stability, and suspended sediment). This project seeks to quantify the complex interactions between mussels and their habitat using a combination of field data collection in the Minnesota River Basin (MRB) and the St. Croix River and controlled laboratory experiments in the Outdoor StreamLab (OSL) and flumes at St. Anthony Falls Laboratory (SAFL). We will revisit sites previously surveyed by MN DNR across a gradient of changing environmental conditions to examine the feasibility of resampling mussel sites to detect changes in mussel populations as a result of changing environmental conditions. Field work will also provide critical information to define parameters used in laboratory experiments. A subset of mussels will be measured in the field for indicators of physiological stress. Experiments will focus on mussel response to suspended sediment and bed instability. The experimental phase is critical to enable measurements that are difficult, dangerous, or impossible to collect at high flow rates in the field and to control potential confounding variables in mussel response such as pesticides, etc. that may be present in field sites. Information on mussel response to sediment processes is critical to Minnesota's ability to 1) maintain ecosystem services provided by mussels (e.g. improved water clarity and river bed stability), 2) use long term mussel monitoring as an indicator for changes in water quality, 3) to evaluate the suitability of potential mussel reintroduction sites, and 4) to define specific habitat criteria for restoration planning (e.g. pinpoint areas where bank stabilization and decreased sediment load will have the greatest impact on retaining or reintroducing mussels to their historic range). A third component of this project, public engagement, will be integrated with field data collection and laboratory experiments through public presentations, an exhibit at the MN State Fair, and social media.

Background

Native freshwater mussels are among the most imperiled animals in the U.S. (Wilcove and Master, 2005), and are important to many river ecosystems. They are threatened by a number of factors, chief among them: habitat destruction and alteration from land use change and pollution (Williams et al., 1993; Strayer et al., 2004), climate change and invasive species (Gallardo and Aldridge, 2013). The impact of loss of species is unknown but could be substantial given mussels' key role in aquatic ecosystems. Mussels affect ecosystem function by altering algal populations directly through filter-feeding (Strayer et al., 1994, 1999; Vaughn et al., 2004) and nutrient cycling (Vaughn and Hakenkamp, 2001; Spooner et al., 2013). The presence of mussels influences riverbed habitat. Mussels act as "ecosystem engineers" (Jones

et al. 1994, 1997; Moore, 2006) by providing large, hard substrate, and burrowing behavior that mixes and aerates the substrate (Gutiérrez et al., 2003). Mussels may also help stabilize sediment. Zimmerman and de Szalay (2007) showed that the presence of mussels increased shear strength and sediment compression, although not sediment erosion under high flow events. They concluded that the presence of mussels and their roles as “ecosystem engineers” (Gutiérrez et al. 2003) impact benthic communities in significant ways (Hakenkamp et al., 2001; Vaughn et al. 2004).

Brim Box and Mossa (1999) discuss the impact of sedimentation on freshwater mussels and conclude that while sediment regimes are often cited as potential causes of mussel populations, there exists much uncertainty in these associations, mainly because of the complexity of collecting appropriate field data for both mussels and sediment. This paper highlights the need for quantitative work to determine the mechanisms through which sedimentation affects freshwater mussels. The impacts of sedimentation can be broken down into suspended sediment impacts and substrate stability impacts. Few studies have directly assessed the impacts of suspended sediment (TSS) on freshwater mussels (e.g. Aldridge et al. 1987; Landis et al., 2013). In addition, there has been interest in the relationship between substrate stability and mussels in stream systems. Allen and Vaughn (2010) reviewed various studies that examined the relationship between sediment stability (as related to shear stress) and conducted studies that showed mussel density was related to measures of substrate stability at high flows. As Allen and Vaughn (2011) point out, earlier studies either measured shear stress in the field under low flows or used simulation modeling to predict shear stress at a variety of discharge levels. To our knowledge there have been no laboratory studies to directly measure shear stress impacts on mussels, although Allen and Vaughn (2011) showed that presence of mussels could influence the gravel erosion in artificial streams.

The Minnesota River Basin (MRB) was historically home to a diverse assemblage of freshwater mussels with 37 species known to have occurred in this watershed (Bright et al., 1990). Of these 46% have been extirpated since 1908 (Bright et al., 1990). Bright et al. (1990) list low oxygen levels, low water levels, predation, siltation and unstable substrates as likely contributors to the decline of mussels in the MRB. The St. Croix watershed, in contrast to the MRB, has maintained a dense and diverse mussel population. This is likely due to the maintenance of intact high quality ecosystems, especially in the upper parts of the watershed (after logging). Recent data provided by the MN DNR (Bernard Sietmann, pers. comm.) show that the relative density of mussels in the St. Croix watershed (a National Wild and Scenic River), on average, is 4.5 times that of the MRB and the relative richness is 3.5 times higher. Based on their studies, the DNR found 39 species in the St. Croix watershed and only 23 species in the MRB.

While the exact causes of the decline in mussel species in the MRB are not known, changes to sediment processes are often listed as likely culprits. The Minnesota River Basin (MRB) has experienced significant long term and recent environmental change. Over 78% of the basin, historically a mix of wetlands and prairies, is now cultivated for row crop agriculture (Musser et al., 2009). Recent increases in corn prices have led to additional land use changes. By 2008, 80,000 acres in the MRB had been taken out of conservation reserve programs (Musser et al., 2009; USDA CEAP) in response to ethanol demand (USDA-NASS, online statistic database, http://quickstats.nass.usda.gov/). To convert the landscape to highly productive agriculture, ditches and extensive subsurface tile drainage networks have been developed to accelerate water removal from the land (Musser et al., 2009). Although the Minnesota River and its larger tributaries, where the bulk of freshwater mussels are typically found, have not been modified directly (except for a few dam removals), the accelerated upstream drainage, coupled with increases in precipitation, has resulted in a significant increase in discharge (Karl et al. 1996;

Novotny & Stefan, 2007; Johnson et al., 2009; Schottler et al., 2013). Likely due to the higher discharge, large tributaries in the MRB have widened 10 – 40% over the past 70 years (Schottler et al., 2013), and leading to a shift in mobilized sediment sources within the MRB (Schottler et al., 2013, Belmont et al., 2011). In the Le Sueur River basin, 70% of the mobile sediment from 2000-2010 originated from near channel sources such as bank, bluffs and channel incision (Belmont et al., 2011), and not upland sources such as agricultural field run-off. Despite contributing only 25% of the flow to Lake Pepin, the MRB is responsible for more than 74% of the sediment load to Lake Pepin, and the sediment accumulation rate in Lake Pepin has increased tenfold over the past 150 years (Engstrom et al., 2009; Kelley and Nater, 2000). These recent increases in discharge and sediment mobilization can lead to higher suspended sediment concentrations, lower bed stability or both.

In summary, mussel diversity has greatly diminished in the MRB over the years of increased agricultural activity and alteration of the landscape. These landscape alterations in conjunction with increased precipitation have led to increased discharge and sediment loads in the MRB. While there are likely other contributing factors driving the decline of mussel diversity in agricultural landscapes, such as increased oxygen demand, pesticides, etc., our project will focus on the dynamics between water flow, sediment load and bed stability (relationship between shear stress and bed material erodibility) and mussel response. We will link field measurements, with flow and water quality measurements of the conditions mussels are experiencing in the MRB and St. Croix to experiments designed to determine in a controlled environment the effect of increased suspended sediment and bed instability on adult mussels. The linkage of field work and experiments will enable us to investigate the influence of sediment processes on mussel well-being.

Hypothesis

Our primary hypothesis is that mussel well-being as measured by population characteristics (distribution, density, and diversity), stress, and feeding and movement, is affected by altered habitat conditions, specifically high levels of suspended sediment, increased flow, and unstable bed sediment. To examine this hypothesis, the following sub-hypothesis will be examined:

H1: Mussel communities are more dense, diverse and stable in areas of low suspended solids and stable substrates when controlled for other water quality stressors

H2: Mussel assemblages will respond to recent (decadal) environmental change. This change will be measureable in re-sampling previous survey sites.

H3: Mussels found in areas of high total suspended solids and unstable sediments are more physiologically stressed than mussels from other areas. The degree of stress is likely to vary among species.

H4: Mussels subjected to varying levels of sediment stability in a laboratory setting will show a range of physiological responses, similar to those hypothesized to be found in field collected populations. These responses will vary among species.

To test these hypotheses, we will use a combination of field data collection and laboratory experiments. The goals of each projected activity are laid out below.

Goals of Project Activities (Activity 3 is non-research related):

Activity 1. Strategic Resampling of Survey Sites: Quantifying Environmental Conditions

1a. Spatial data collection

Goal: Compile information on past surveys of mussel species distribution and density, and existing monitoring data on water quality and discharge.

1b. Resampling plan

Goal: Based on spatial data collected, identify key watersheds across mussel species distribution and density, water quality (TSS), and discharge in MRB and St. Croix watershed. Omit sites that have high levels of pesticides or other contaminants.

1c. Field data collection

Goals: Identify changes between previous surveys and current conditions by resampling a subset of Statewide Mussel Survey sites. Test H1 and H2 by collecting detailed information about the current state of mussel assemblages and environmental conditions at field sites to understand the current relationship between mussel assemblages and environmental conditions. Constrain laboratory experiments using measured and monitored environmental conditions.

Activity 2: Quantifying Mussel Response to Changes in Environmental Conditions

2a. Background levels of mussel stress

Goal: Test H3 by measuring physiological stress of mussels at sampling sites.

2b. Physiological and behavioral response of mussels to suspended sediment

Goal: Test H3 and H4 by measuring physiological stress of mussels in a laboratory setting with controlled levels of suspended sediment and flow.

2c. Physical reaction of mussels to bed stability

Goal: Test H3 and H4 by measuring mussel behavioral response to changes in bed stability.

Activity 3: Engaging the MN Public in Native Mussel Conservation (non-scientific)

3a. MN state fair exhibit

Goal: Reach 20,000+ people per day at the MN State Fair historic DNR building with a native mussel display led by student researchers.

3b. Students as teachers

Goal: Directly reach 50+ people in place-oriented groups and others indirectly through word of mouth. Students serve as teachers by giving 3 public talks.

3c. Measures of reach, engagement and conversations

Goal: Quantify the impact of engagement activities through measures of engagement and virality, the sharing and discussion of posted information in Social Media (measure incoming links and visits to blog posts, Twitter mentions, etc.)

Methodology

This interdisciplinary project combines the expertise of the research team in hydrology and hydraulics, geomorphology, and mussel biology to address the question of how mussels respond to changes in flow and sediment regimes. Limited field work (Activity 1c) will be combined with existing environmental data (Activity 1a and 1b) to examine the population response to changing environmental conditions and to constrain laboratory experiments (Activity 2b and 2c). Background levels of mussel stress will be documented (Activity 2a). Because field work is limited to two seasons and 9 sites, due to the expected variability in mussel response to

a range of potential stressors, controlled laboratory experiments will be used to provide information on the response of mussels to changes in flow and sediment characteristics (a likely cause of mussel decline in MN). In this way we can 1) document how mussel populations are changing in watersheds with large changes in flow and sediment loading (if this change is measurable), and 2) directly measure mussel response to flow and sediment processes in a controlled environment. The following section lays out methodology for each activity. This project is set up to first gather existing information, then visit selected sites to gather information to constrain laboratory experiments and document changes in mussel populations, and finally to test mussel response to sediment related stressors (e.g. increased suspended sediment, or bed instability) in controlled laboratory experiments.

Activity 1. Strategic Resampling of Survey Sites: Quantifying Environmental Conditions

1a. Spatial Data Collection

Data collection will focus on two watersheds, the Minnesota River Basin (MRB), and the St. Croix watershed (Figure 1). Mussel species diversity in the MRB has declined compared to historic levels while the St. Croix serves as a refuge for state and federally endangered mussel populations and thus acts as a reference location. Mussel species distribution, flow characteristics and water quality will be compared for sub-watersheds within each basin and between basins. Mussel species distribution, density, and habitat data will be gathered from the Minnesota Department of Natural Resources (MN DNR) statewide surveys. Stream flow and water quality monitoring data will be compiled from available sources including Minnesota Pollution Control Agency (MPCA), United States Geological Survey (USGS), and other potential sources including the Minnesota Department of Agriculture (MDA), and local watershed or soil and water conservation districts.

Data sources:

MPCA water quality data:

http://www.pca.state.mn.us/index.php/water/water-monitoring-and reporting/water-quality-and-pollutants/water-quality-data.html

MN DNR Statewide Mussel Survey:

http://www.dnr.state.mn.us/nhnrp/mussel_survey/index.html

DNR/MPCA Cooperative Stream Gaging

http://www.dnr.state.mn.us/waters/csg/index.html

USGS Stream Gaging and Water Quality

http://waterdata.usgs.gov/mn/nwis/current/?type=flow

http://waterdata.usgs.gov/mn/nwis/current/?type=quality&group%20Key=basin%20cd

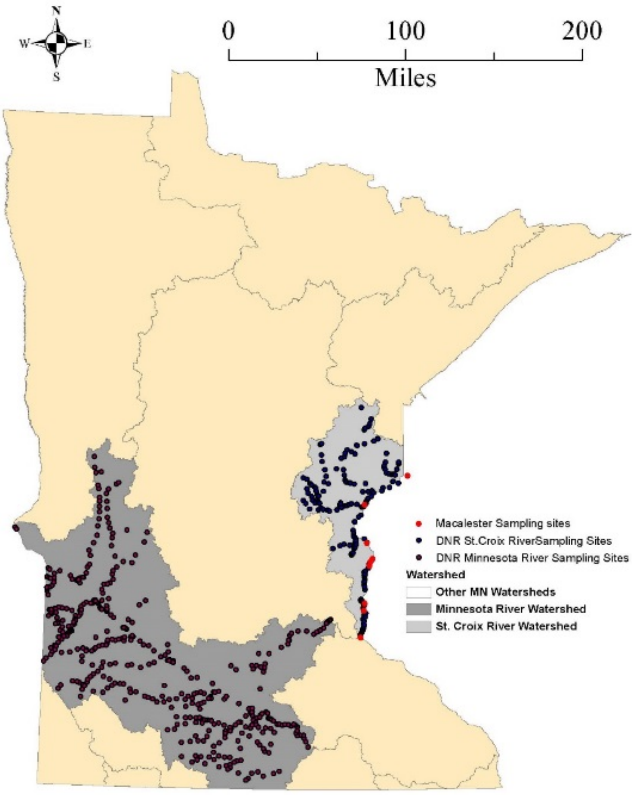


Figure 1. Map of MN DNR Statewide Mussel Survey sampling sites in the Minnesota River Basin (MRB) and St. Croix watershed. Red dots indicate previous Macalester sampling sites.

1b. Resampling Plan

Data collected from Activity 1a will be examined to quantify the range of suspended sediment (TSS), discharge, substrate conditions, and mussel densities and diversity in the MRB and potential reference sites in the St. Croix basin. From these data we will choose at least 9 sites in the MRB that encompasses the range of annual TSS output, relative mussel density and mussel species richness found in MRB. These sites will be selected to represent a gradient of high, moderate, and low impact of recent environmental alternations. We will also choose at least 3 sites from the St. Croix to serve as “reference” sites. We will consult with the MN DNR about the appropriateness of our sampling sites.

1c. Field Data Collection

Field data collection will be split into two parts: 1) data collection to quantify changes in mussel populations compared to the MN DNR statewide mussel survey, and 2) data collection to constrain experimental variables. For the first part, we will conduct mussel surveys (timed qualitative sampling) following DNR protocols for the same amount of time as the original sampling by DNR (the number of individuals collecting multiplied by the amount of time spent collecting is the total collection time). We will have 3-4 people survey the site by splitting the team up, with 2 heading upstream and 1 or 2 downstream from our point of entry. The sampling method will be snorkeling, wading, SCUBA, or a combination of these depending on the water depth as specified in the MN DNR protocol. Per MN DNR protocol, we will emphasize searching a large area and a variety of habitats to find mussel aggregations and a diversity of species. The area covered will depend on conditions and mussel abundance. The MN DNR often covered > 200 m in both directions from the point of entry although the amount of area covered varied between sites.

Secondly, we will conduct more detailed field studies at the same sites. Our goal is to both understand the current relationship between mussel diversity/community dynamics and bed conditions, and to provide information to constrain laboratory experiments. At locations where we measure mussel species richness and relative density we will measure near bed water velocity (with a SonTek® Argonaut ADV), and calculate low flow shear stress at each site (e.g., Dittrich and Schmedtje, 2006; Lamouroux et al., 1992; Howard and Cuffey, 2006; Dietrich and Whiting, 2013). We will also collect sediment within the mussel 'zone' at the substrate surface and excavate to collect sediment that represents past conditions. We will return these samples to the laboratory where we will measure grain size distribution by sieving. Because we will not be able to collect high flow data on shear stress, we will use grain size information and stream flow data, to coarsely model shear stresses and sediment transport (BAGS; Pitlick et al. 2009), under the full range of flow conditions. We will also measure sediment organic matter (as loss on ignition). These measurements will provide information about substrate conditions and stability, and mussel community diversity and density and will help inform experimental parameters in Activity 2.

Activity 2: Quantifying Mussel Response to Changes in Environmental Conditions

2a. Background levels of mussel stress

We will quantify the background physiological condition of mussels in the MRB and St. Croix River based on the methods of a number of studies have used tissue glycogen to assess physiological stress in unionids (Satyaparameshwar, 2006; Baker and Hornbach, 2008; Gangloff et al., 2008; McGoldrick et al., 2009; Sousa et al., 2011. We will choose two species, likely *Actinonaias ligamentina* and *Amblema plicata* (pending MN DNR approval). *Actinonaias ligamentina* is more sensitive to adverse environmental conditions than *Amblema plicata* (Baker and Hornbach, 2008; Spooner and Vaughn, 2008). Distribution data from the MN DNR shows these two species are distributed throughout the MRB and St. Croix. We will collect foot tissue samples which will be analyzed using methods from Naimo et al. (1998) and Naimo and Monroe (1999) so as to not remove mussel specimens from the MRB or sacrifice mussels. Our final selection of mussel species will be dependent on the following criteria: 1) availability in both MRB and St. Croix, 2) reproductive status, 3) MN DNR approval, 4) lab appropriateness, 5) potential stress response based on previous studies, 6) sexual dimorphism. We will also measure the shell lengths of mussels and count external shell annuli (an indicator of life span or stress cycles). We expect to collect up to 800 samples to overcome the natural variability in glycogen levels. Despite this variability, glycogen remains a common indicator of mussel health. In addition, we will collect information on mussel shell length and annuli. The relationship between shell length and annuli will be used as a metric to describe growth rates. While it will not be possible to differentiate between rest lines and annual growth rings without sacrificing mussels, more annuli per length of shell generally indicates stress (either less growth per year, or more rest lines due to stress). This activity will provide crucial background information on the spatial variability of mussel physiological condition in the MRB and St. Croix.

2b. Physiological response of mussels to suspended sediment

Laboratory experiments will investigate mussels' response to elevated levels of suspended sediment and flow (Table 1), expanding previous research (Payne et al. 1999) to levels encountered in the MRB. These experiments will be conducted in a laboratory flume at St. Anthony Falls Laboratory (SAFL) at the University of Minnesota. Real-time mussel response will be recorded using gape sensors to measure the degree to which shells are open, and the amount of time open they are or closed compared to background levels. Gape sensors have been used with bivalves to create biological early warning systems (de Zwart et al. 1995), but also to evaluate the response of mussels to episodic stressors such as brief changes in water

velocity and turbulence (Miller et al. 1999), or estimate filtration rates (Lorenz et al. 2013). These systems take advantage of bivalves' typical response to disturbance, which is to close their shells. Typically, bivalves gape to allow water to circulate for feeding, respiration, and waste removal.

We will measure gape using modified gape sensors made from a Hall effect sensor and small disk magnets installed near the tip of at least 15 individual mussel shells (specific mussel species will be determined in consultation with MN DNR and following results from Activity 1). This system has been used by a number of researchers to investigate gape movements in bivalves (e.g. Lorenz et al. 2013; Robson et al. 2009). At the end of experiments 1, 3, and 5, other physiological measurements will be collected from mussels (e.g. glycogen) to directly compare to field measurements.

The selection of TSS levels, flow levels and mussel species requires careful consideration. For this reason, we set up Activity 1 to provide the information needed to select appropriate variables. TSS and flow are not independent variables as higher flows increase shear stress, increasing sediment suspension, etc., so the selection of normal and elevated flows and TSS levels will be based on an analysis of data collected in Activity 1a. Mussel selection will be based on similar criteria to those listed in Activity 2a. Densities will be selected to represent typical field densities (on the order of 2-4 animals/m^2). Food levels will be monitored and supplemented as necessary. During this time we will measure basic water quality parameters (e.g., temperature, pH, hardness, chlorophyll concentration, etc). The length of experiments will be selected to represent the timing of exposure to elevated TSS levels in the field.

Table 1. Proposed experimental matrix of suspended sediment levels and flow rates. Values will be selected based on Activity 1 data collection and field work.

TSS levels	**Flow rates**
Control (background)	Normal
TSS1	Elevated1
TSS2	Elevated2
TSS3	-
TSS4	-
TSS5	-

2c. Physical reaction of mussels to bed stability

The physical reaction of mussels to bed stability will be measured in a unique outdoor field-scale experimental stream at SAFL at the University of Minnesota (Figure 2; Table 2). This facility allows high-resolution, field-scale experiments to occur in a realistic mobile-bed meandering channel and associated floodplain under precise input controls of both flood hydrograph and sediment supply. Constructed in 2008, this tool is a significant advance in river science (Wilcock et al. 2008) allowing for the controlled study of feedbacks between physical, chemical, and biological processes that are difficult or impossible to scale. Previous OSL research includes quantifying relationships between macroinvertebrate grazing, periphyton growth and current velocity (Merten et al. 2010), feedbacks between vegetation and sand bar stability (Rominger et al. 2010), and interactions between channel and subsurface processes (Nowinski et al. 2011; 2012). Sediment fed into the stream at the inlet is captured at the downstream end, quantified, and recirculated for later feed.

All measurements in the OSL are referenced using a reflectorless total station (Sokkia 30RK) into the local OSL coordinate system to allow comparisons between experiments and over years. A high-resolution data acquisition (DAQ) carriage designed for outdoor use in the OSL enables the precise positioning of instrumentation within a 3 m by 1.5 m area of the channel. The DAQ carriage can be outfitted with attached sonar (Panametrics C304), ultrasonic transducer (Massa M300), and laser displacement sensor (Keyence LKG) to measure bed and water surface. Both subaerial and subaqueous topography are collected and meshed together to produce channel and stream bank topography and water surface elevations. This cart can be moved and scanned Repeat observations of sediment surface topography are used to estimate bedload transport in dunes.

Control of flow and sediment feed in this experimental channel allows researchers to directly manipulate bed stability. Mussel response will be documented using a combination of behavioral (gape, movement, burial) and physiological measurements (comparable to background measurements from the MRB). Bed stability will be quantified by 1) repeat sonar scans, 2) direct measurements of bedload with a mini-Helley-Smith sampler, 3) by mass balance of sediment fed at the inlet and captured at the downstream end. Bed shear stress will be quantified using an acoustic Doppler velocimeter (ADV). Mussel movement will be documented using sonar scans, notes, photography, and by attaching visible floating coded string to individual mussels. All experiments will be conducted during the late spring to early fall (primarily in the summer months) when temperatures are above 10^{o}C (usually April – October).

The selection of flow rates, rate of change, duration of elevated flows, and mussel species requires careful consideration. For this reason, we set up Activity 1 to provide the information needed to select appropriate variables. Mussel selection will be based on similar criteria to those listed in Activity 2a. Densities will be selected to represent typical field densities (on the order of 2-4 animals/m^2). This facility utilizes water from the Mississippi River, so food supplements are unlikely, but the current conditions will be tested and addition food added if necessary. During this time we will measure basic water quality parameters (e.g., temperature, pH, hardness, chlorophyll concentration, etc). The length of experiments will be selected to represent the duration of flood events recorded in Activity 1a.

Figure 2. Location of test mussel bed in SAFL's Outdoor StreamLab.

Table 2. Proposed experimental matrix for bed stability experiments. Values will be selected based on Activity 1 data collection and field work.

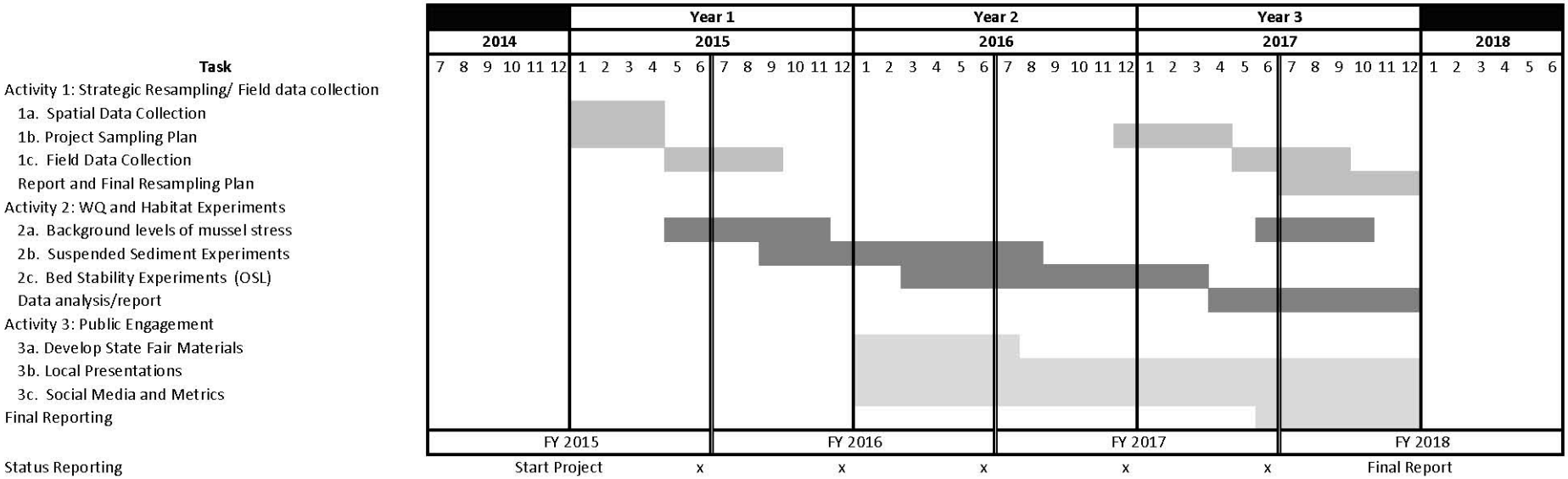
Flow rate	Rate of change	Duration
Low	No change	Minutes
Normal	Slow	Hours
Elevated1	Moderate	Day
Elevated2	Fast	-

Results and Deliverables

We will present the results from our project through a number of deliverables. Scientific results from Activities 1 and 2 will be submitted for publication in peer-reviewed journals as well as presented in local (e.g., St. Croix River Research Rendezvous) and national (e.g., Society of Freshwater Science, Freshwater Mollusk Conservation Society) meetings of natural resource professionals. We will also meet with biologists in charge of Minnesota mussel conservation efforts (i.e., Mike Davis and Bernard Sietman, MN DNR) to discuss our results and offer ideas to improve mussel community resampling methodology to detect changes in native mussel populations due to changes in environmental conditions. We are also excited to present the results from our project to Minnesota public through an extension of the MN DNR's popular Historical DNR Building at the State Fair (Activity 3). Project results and general information about mussels and the importance of water and habitat quality will be shared by researchers and students through public presentations, and social media (Activity 3). A comprehensive report of results and analysis from this project will be submitted to the LCCMR by December 2017.

Timetable

This project is dependent on three full summer seasons for field data collection and Outdoor StreamLab experiments. Three years of work are planned beginning over four fiscal years. The project will initiate in January 2015 and the final report is scheduled to be completed in December 2017.



Budget

2014 Detailed Project Budget

Project Title: Conserving Minnesota's native mussel legacy: Quantifying habitat interactions

IV. TOTAL ENRTF REQUEST BUDGET 3 years

BUDGET ITEM	AMOUNT
Personnel:	
Research Associate: Jessica Kozarek (33.6% benefits, 25% time yrs. 1-3)	$ 61,942
Professor: Miki Hondzo (33.6% benefits, 3.8% time yr 2)	$ 8,651
Instrumentation Specialist: (33.6% benefits, 2% time yrs. 1-3)	$ 13,400
Technician (36.8% fringe, 1.7% time yrs. 1-3)	$ 4,228
Post-doc: Amy Hansen (20.4% benefits, 10.5% hrs yrs, 1-3)	$ 16,746
Undergraduate research assistants (7.4% benefits, 25% time yrs. 1,3, 70% yr 2)	$ 24,784
River Life Coordinator: Patrick Nunnally (33.6% benefits, 2% time yrs 1-3)	$ 5,661
Info Tech Professional: Joanne Richardson (36.8% benefits, 6% time yrs 1-3)	$ 13,453
Contracts:	
Macalester College (Activity 1: Field data collection): Dan Hornbach (Professor), Kelly MacGregor (Associate Professor), Mark Hove (Research Associate), Undergraduate students Cost includes: Personnel (70%), Travel to field sites (10%), Supplies - SCUBA and field equipment maintenance (5%), Misc. travel (maintenance, student presentations, etc.) (1%), and cost of assays (14%)	$ 177,051
Equipment/Tools/Supplies:	
Activity 2 flume experiments: supplies including gape sensors, laboratory equipment for measuring suspended sediment, and Outdoor StreamLab equipment (velocity, bed elevation)	$ 13,875
Activity 3: Materials for film/video and handouts	$ 3,434
Travel:	
in-state (3, 2-day trips for 1 researcher, yrs 1 and 3, 400 mi at $0.565, $77 lodging, $46 meals)	$ 1,975
Additional Budget Items:	
Mussel physiological stress measurement ($30/mussel)	$ 4,800
TOTAL ENVIRONMENT AND NATURAL RESOURCES TRUST FUND $ REQUEST =	$ 350,000

V. OTHER FUNDS

SOURCE OF FUNDS	AMOUNT	Status
Funding History:		
ENRTF through LCCMR, D. Hornbach and M. Hove (Macalester): Freshwater Mussel Resources in the St. Croix River. 7/1999-6/2001	$ 58,000	
National Park Service, M. Hove and D. Hornbach (Macalester) Community analysis of the mussel population downstream of the St. Croix Falls hydropower dam. 2000-2002.	$ 40,900	
National Park Service, M. Hove and D. Hornbach (University of Minnesota) Mussel communities in the St. Croix National Scenic Riverway community population monitoring and distribution surveys. 2000-2005.	$ 56,266	
National Park Service, K. MacGregor and D. Hornbach (Macalester): Monitoring Sediment Dynamics in the St. Croix River and the Impact on Federally Endangered Mussels. 4/2008-12/2010	$ 148,824	

Credentials

(Attached at end)

Dissemination and Use

Through the collaboration with the River Life program at the University of Minnesota, we seek to engage the public in water quality issues, broadly, and freshwater mussel conservation, specifically. River Life is a program of the Institute for Advanced Study at the University of Minnesota that works to build communities of knowledge and practice that develop new understandings of systems of people, land, and water together. They work through student programs (training of the next generation), develop collaborative cross-disciplinary research agendas (science to humanities) and develop digital (social media) and face-to-face programs. Efforts will be monitored with metrics designed to measure reach, engagement, and conversations.

Macalester College will assist with engaging Minnesota public in mussel conservation through a variety of activities. Macalester College researchers and students will assist with data collection and analysis for Activities 1 and 2. Researchers and students will present the results from our project to Minnesota public through an extension of the MN DNR's popular Historical DNR Building at the State Fair (Activity 3). We will help develop interpretation for the indoor fish aquaria and present project results, as well as general information about mussels and the importance of water and habitat quality, to DNR building visitors.

We will present scientific results at local and national meetings attended by the public and natural resource professionals and project findings will be submitted for publication in peer-reviewed journals. Results will be shared directly through conversations with MN DNR and others working with freshwater mussels in Minnesota.

References

Aldridge, D. W., B. S. Payne, and A. C. Miller. 1987. The effects of intermittent exposure to suspended solids and turbulence on 3 species of freshwater mussels. Environmental Pollution 45:17–28.

Allen, D.C. and C.C. Vaughn. 2010. Complex hydraulic and substrate variables limit freshwater mussel species richness and abundance. Journal of the North American Benthological Society 29: 383–394.

Allen, D.C. and C.C. Vaughn. 2011. Density-dependent biodiversity effects on physical habitat modification by freshwater bivalves. Ecology 92: 1013–1019

Baker, S.M. and D.J. Hornbach. 2008. Zebra mussels (*Dreissena polymorpha*) attached to native mussels (Unionidae) or inanimate substrates: Comparison of physiological rates and biochemical composition. American Midland Naturalist 160:20-28.

Barry S. Payne , Andrew C. Miller & Lawrence R. Shaffer (1999) Physiological Resilience of Freshwater Mussels to Turbulence and Suspended Solids, Journal of Freshwater Ecology,14:2, 265-276, DOI: 10.1080/02705060.1999.96636.

Belmont P., Gran K.B., Schottler S.P., Wilcock P.R., Day S.S., Jennings C., et al. (2011) Large shift in source of fine sediment in the upper Mississippi river. Environmental science & technology 45, 8804–10.

Bright, R. C., C. Gatenby, D. Olson and E. Plummer. 1990. A survey of the mussels of the Minnesota River,1989. University of Minnesota Bell Museum of Natural History, St. Paul. 189 p.

Brim Box, J. B., AND J. Mossa. 1999. Sediment, land use, and freshwater mussels: prospects and problems. Journal of the North American Benthological Society 18:99–117.
de Zwart, D., K.J.M. Kramer, and H. A. Jenner. 1995. Practical experiences with the biological early warning system "Mosselmonitor", Environmental Toxicology and Water Quality 10: 237-247.
Dietrich, W. E. and Whiting, P. (2013) Boundary Shear Stress and Sediment Transport in River Meanders of Sand and Gravel, in River Meandering (eds S. Ikeda and G. Parker), American Geophysical Union, Washington, D. C.
Dittrich, A. and Schmedtje, U. (1995), Indicating shear stress with FST-hemispheres - effects of stream-bottom topography and water depth. Freshwater Biology, 34: 107–121.
Engstrom D.R., Almendinger J.E. & Wolin J.A. (2009) Historical changes in sediment and phosphorus loading to the upper Mississippi River: mass-balance reconstructions from the sediments of Lake Pepin. Journal of Paleolimnology 41, 563–588.
Gallardo, B., D. C. Aldridge. 2013. Evaluating the combined threat of climate change and biological invasions on endangered species. Biological Conservation 160: 225–233.
Gangloff, M.M., K.K. Lenertz and J.W. Feminella. 2008. Parasitic mite and trematode abundance are associated with reduced reproductive output and physiological condition of freshwater mussels. Hydrobiologia. 610: 25-31.
Guttiérrez, J. L., C. G. Jones, D. L. Strayer and O. O. Iribarne. 2003. Mollusks as ecosystems engineers: the role of shell production in aquatic habitats. Oikos 101:79-90.
Hakenkamp, C. C., S. G. Ribblett, M. A. Palmer, C. M. Swan, J. W. Reid and M. R. Goodison. 2001. The impact of an introduced bivalve (*Corbicula fluminea*) on the benthos of a sandy stream. Freshwater Biology 46: 491–501.
Howard JK and Cuffey KM. 2006. The functional role of native freshwater mussels in the fluvial benthic environment. Freshwater Biology 51:460-74.
Johnson H.O., Gupta S.C., Vecchia A. V & Zvomuya F. (2009) Assessment of Water Quality Trends in the Minnesota River using Non-Parametric and Parametric Methods. Journal of environmental quality 38, 1018–1030.
Jones, C. G., J. H. Lawton and M. Schachak. 1994. Organisms as ecosystem engineers. Oikos 69:373–386.
Jones, C. G., J. H. Lawton and M. Schachak. 1997. Positive and negative effects of organisms as ecosystem engineers. Ecology 78:1946–1957.
Karl T.R., Knight R.W., Easterling D.R. & Quayle R.G. (1996) Indices of climate change for the United States. Bulletin of the American Meteorological Society 77, 279 – 292.
Kelley D.. & Nater E.. (2000) Source apportionment of lake bed sediments to watersheds in an Upper Mississippi basin using a chemical mass balance method. Catena 41, 277–292.
Lamouroux, N., B. Statzner, U. Fuchs, F. Kohmann, *and* U. Schmedtje *(*1992*),* An unconventional approach to modeling spatial and temporal variability of local shear stress in stream segments, Water Resour. Res., 28*:* 3251–3258*.*
Landis, A.M.G , W. R. Haag , and J. A. Stoeckel. 2013. High suspended solids as a factor in reproductive failure of a freshwater mussel. Freshwater Science, 32:70-81.
Lorenz, S., F. Gabel , N. Dobra, and M. T. Pusch. 2013. Modelling the effects of recreational boating on self-purification activity provided by bivalve mollusks in a lowland river. Freshwater Science 32(1):82-93.
McGoldrick, D.J., J.L. Metcalfe-Smith, M.T. Arts, D.W. Schloesser, T.J. Newton, G.L. Newton, E.M. Monroe, J. Biberhofer, and K. Johnson. 2009. Characteristics of a refuge for native freshwater mussels (Bivalvia: Unionidae) in Lake St. Clair. Journal of Great Lakes Research. 35: 137-146.
Merten, E. C., W. D. Hintz, A. F. Lightbody, and T. Wellnitz. 2010. Macroinvertebrate grazers, current velocity, and bedload transport rate influence periphytic accrual in a field-scale experimental stream. Hydrobiologia 652(1):179–184.

Miller, A. C., B. S. Payne, and L. R. Shaffer. 1999. A Shell Gape Monitor to Study Effects of Physical Disturbance on Freshwater Mussels, Journal of Freshwater Ecology 14(2):241-247.
Moore, J. W. 2006. Animal ecosystem engineers in streams. BioScience 56:237–246.
Musser, K., S. Kudelka, R. Moore. 2009. Minnesota River Trends. Water Resources Center, Minnesota State University, Mankato, MN.
Naimo, T.J. and E.M. Monroe. 1999. Variation in glycogen concentrations within mantle and foot tissue in *Amblema plicata plicata*: Implications for tissue biopsy sampling. American Malacological Bulletin, 15: 51 - 56
Naimo, T.J., E. D. Damschen, R. G. Rada and E. M. Monroe. 1998. Nonlethal Evaluation of the Physiological Health of Unionid Mussels: Methods for Biopsy and Glycogen Analysis. Journal of the North American Benthological Society, 17: 121-128.
Novotny E. V. & Stefan H.G. (2007) Stream flow in Minnesota: Indicator of climate change. Journal of Hydrology 334, 319–333.
Nowinski, J. D., M. B. Cardenas, and A. F. Lightbody. 2011. Evolution of hydraulic conductivity in the floodplain of a meandering river due to hyporheic transport of fine materials. Geophysical Research Letters 38(1).
Nowinski, J. D., M. B. Cardenas, A. F. Lightbody, T. E. Swanson, and A. H. Sawyer. 2012. Hydraulic and thermal response of groundwater-surface water exchange to flooding in an experimental aquifer. Journal of Hydrology 472-473:184–192.
Payne B. S., A. C. Miller, and L. R. Shaffer. 1999. Physiological Resilience of Freshwater Mussels to Turbulence and Suspended Solids, Journal of Freshwater Ecology. 14(2): 265-276.
Pitlick, J., Y. Cui, P. Wilcock. 2009. Manual for computing bed load transport using BAGS (Bedload Assessment for Gravel-bed Streams) Software. Gen. Tech. Rep. RMRS-GTR-223. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 45 p.
Robson, A., R. Wilson, C. G. de Leaniz. 2007. Mussels flexing their muscles: a new method for quantifying bivalve behavior. Marine Biology 151:1195–1204
Rominger, J. T., A. F. Lightbody, and H.M. Nepf. 2010. Effects of added vegetation on sand bar stability and stream hydrodynamics. Journal of Hydraulic Engineering 136(12):994–1002.
Satyaparameshwar, K.,T.R. Reddy and N.V. Kumar. 2006. Study of carbohydrate metabolism in selected tissues of freshwater mussel, *Lamellidens marginalis* under copper sulphate toxicity. Journal of Environmental Biology 27: 39-41.
Schottler S.P., Ulrich J., Belmont P., Moore R., Lauer J.W., Engstrom D.R., et al. (2013) Twentieth century agricultural drainage creates more erosive rivers.
Sousa, R, F. Pilotto, D.C. Aldridge. 2011.Fouling of European freshwater bivalves (Unionidae) by the invasive zebra mussel (*Dreissena polymorpha*). Freshwater Biology 56: 867-876.
Spooner, D. E. and C. C. Vaughn, 2008. A trait-based approach to species' roles in stream ecosystems: climate change, community structure and material cycling. Oecologia 158: 307–317.
Spooner, D.E., P.C. Frost, H. Hillebrand, M.T. Arts, O. Puckrin and M.A. Xenopoulos. 2013. Nutrient loading associated with agriculture land use dampens the importance of consumer-mediated niche construction. Ecology Letters 16 : 1115-1125
Strayer, D.L, D. C. Hunter, L. C. Smith and C. K. Borg. 1994. Distribution, abundance, and roles of freshwater clams (Bivalvia, Unionidae) in the freshwater tidal Hudson River. Freshwater Biology 31:239–248.
Strayer, D.L, N. F. Caraco, J. J. Cole, S. Findlay and M. L. Pace. 1999. Transformation of freshwater ecosystems by bivalves: a case study of zebra mussels in the Hudson River. BioScience 49:18–27.

Strayer, D.L., J. A. Downing, W. R. Haag T. L. Kling, J. B. Layzer, T. J. Newton, and S. J. Nichols. 2004. Changing perspectives on pearly mussels, North America's most imperiled animals. BioScience 54:429–439.

Vaughn, C.C. and C. C. Hakenkamp. 2001. The functional role of burrowing bivalves in freshwater ecosystems. Freshwater Biology 46:1431–1446.

Vaughn, C.C., K. B. Gido and D. E. Spooner. 2004. Ecosystem processes performed by unionid mussels in stream mesocosms: species roles and effects of abundance. Hydrobiologia 527:35–47.

Wilcock, P. R., C. H. Orr, and J. D. Marr. 2008. The need for full-scale experiments in river science. Eos, Transactions American Geophysical Union 89(1):6–6.

Wilcove, D. S., and L. L. Master. 2005. How many endangered species are there in the United States? Frontiers in Ecology and the Environment 3:414–420.

Williams, J. D., M. L. Warren, Jr., K. S. Cummings, J. L. Harris, and R. J. Neves. 1993. Conservation status of freshwater mussels of the United States and Canada. Fisheries 18:6–22.

Zimmerman, G. F. and F. A. de Szalay. 2007. Influence of unionid mussels (Mollusca: Unionidae) on sediment stability: an artificial stream study. Fundamental and Applied Limnology *(*Archiv für Hydrobiologie)168:299–306.

Jessica Lindberg Kozarek
St. Anthony Falls Laboratory
University of Minnesota, 2 3rd Ave. SE, Minneapolis, MN 55414
Telephone: (612)624-4679; Email: jkozarek@umn.edu

EDUCATION

Ph.D. Biological Systems Engineering, Virginia Tech, May 2011
Dissertation: Channel Morphology and Riparian Vegetation Influences on Aquatic Habitat.
Advisor: Dr. W. Cully Hession

M.S. Biological Systems Engineering, Virginia Tech, May 2006
Thesis: Development and Comparison of 17beta-Estradiol Sorption Isotherms for Three Agriculturally Productive Soils from Different Physiographic Regions in Virginia.
Advisor: Dr. Mary Leigh Wolfe

B.S. Chemical Engineering, The Pennsylvania State University, May 2002
Minor: Environmental Engineering

PROFESSIONAL EXPERIENCE

2010-present: **Ecogeomorphology and Stream Restoration Research Associate**, National Center for Earth Surface Dynamics, St. Anthony Falls Laboratory, University of Minnesota
Conduct experiments on the physical, chemical, and biological interactions between a channel and its floodplain; Mentor undergraduate and graduate research assistants; Teach *Hydrologic Design* (Spring 2011); Develop research plan and acquire funding for the Outdoor StreamLab (OSL).

2005-2010: **Graduate Assistant**, Biological Systems Engineering, Virginia Tech
Evaluated in-stream habitat using field methods, high-resolution digital topography, and multi-dimensional hydraulic modeling; Analyzed the influence of riparian vegetation on geomorphology and stream temperature; Assisted with stream restoration pre-construction monitoring and installation; Aided stream and wetland field and laboratory projects.

2008-2009: **Instructor and Graduate Assistant,** Agricultural Technology, Virginia Tech
Taught *Computer Applications in Agriculture* (Fall 2008) weekly lectures and laboratory sessions for freshmen level computer course; Conducted recruiting, open houses, and alumni surveys in support of the AT program.

2003-2005: **Graduate Assistant**, Biological Systems Engineering/Dairy Science/Civil Engineering, Virginia Tech
Developed isotherm parameters describing the sorption of natural steroid estrogens to agricultural soils; Supervised study to collect and analyze dairy manure composition; Analyzed composition of liquid dairy manure in different stages of treatment using standard methods and gas chromatography.

2001: **Green Engineering Intern, US EPA**, Environmental Careers Organization, Boston, MA
Edited *Green Engineering* (Allen and Shonnard, 2001) textbook and solutions manual; Assisted with GE workshops with academia and industry.

PEER-REVIEWED PUBLICATIONS

Khostonejad, K., J.L. Kozarek and F. Sotiropoulos (in revision) Simulation-based approach for stream restoration structure design: model development and validation. Journal of Hydraulic Engineering.

Guentzel, K.S., M.J. Sadowsky, M. Hondzo, B.D. Badgley, J. C. Finlay, J.L. Kozarek (in revision) Measurement and modeling of denitrification in sand-bed streams of varying land use. Journal of Environmental Quality.

Plott, J.R., Diplas, P. Kozarek, J.L., Dancey, C.L. Hill, C., Sotiropoulos, F. (2013) A generalized log law formulation for a wide range of boundary roughness typically encountered in natural streams. Journal of Geophysical Research: Earth Surface. 118: 1419-1431.

Resop, J.P., Kozarek, J.L., Hession, W.C. (2012) Terrestrial laser scanning for delineating in-stream boulders and quantifying habitat complexity measures. Photogrammetric Engineering and Remote Sensing. 78(4): 363-371.

Kozarek, J.L., Hession W.C., Dolloff, C.A., Diplas, P. (2010) Hydraulic complexity metrics for evaluating in-stream brook trout (*Salvelinus fontinalis*) habitat. Journal of Hydraulic Engineering. 136(12): 1067-1076.

Kozarek, J.L., Wolfe M.L., Love, N.G., Knowlton K.F. (2008) Sorption of estrogens to agricultural soil from Virginia, USA. Transactions of the ASABE. 51(5): 1591-1597.

SELECT CONFERENCE PRESENTATIONS (*presenter)

Kozarek, J.L.* 2011. In-stream Structures in the OSL: Implications for Stream Restoration. Upper Midwest Stream Restoration Symposium, February 27-March 2, 2011, Oconomowoc, WI.

Kozarek, J.L.* and F. Sotiropoulos. 2011. Outdoor StreamLab (OSL): Full-Scale Outdoor Experiments to Strengthen Stream Restoration Science**.** River Restoration Northwest, February 1-3, 2011, Stevenson, WA.

Kozarek, J.L.*, J.R. Plott, P. Diplas, F. Sotiropoulos, A.F. Lightbody. 2010. Scour and deposition patterns in complex flow around stream restoration structures in a meandering stream channel (Poster). AGU Fall Meeting, December 13-17, San Francisco, CA.

Resop, J.P., **J.L. Kozarek***, W.C.Hession (2010) Terrestrial Laser Scanning for Quantifying Habitat and Hydraulic Complexity Measures: A Comparison with Traditional Surveying Techniques (Poster). AGU Fall Meeting, December 13-17, San Francisco, CA.

Kozarek, J.L.* and W.C. Hession. 2010. Relative Influence of Bank Vegetation on Stream Temperature in Urban and Non-urban Watersheds (Poster). Minnesota Water Resources Conference. October 18-19, 2011. St. Paul, MN.

Kozarek, J.L.*, W.C. Hession, C.A. Dolloff. 2007. Hydraulic Complexity Metrics and Brook Trout Habitat Preferences. International Symposium on Ecohydraulics, February 18-23, 2007. Christchurch, NZ.

WORKSHOP PRESENTATIONS

Kozarek, J.L. 2010. Outdoor Streamlab (OSL): Opportunities for research on ecohydrology and nutrient cycling. National Center for Earth Surface Dynamics Summer Institute, August 23, 2010. St. Anthony Falls Laboratory, Minneapolis, MN.

Kozarek, J.L.* and W.C. Hession. 2007. Linking fluvial morphology and aquatic ecosystems. Professional workshop: Introduction to Fluvial Geomorphology, VA/WVA Water Resources Conference, Blacksburg, VA.

HONORS/AWARDS

- American Society of Agricultural and Biological Engineers (ASABE) M.S. Graduate Student Research Awards, 1st place, 2006
- Paul E. Torgersen Graduate Student Research Excellence Awards, M.S. poster competition, 2nd place, 2006
- Alpha Epsilon (Biological Systems Engineering Honorary), 2004

EDUCATION AND OUTREACH ACTIVITIES

Mentored 28 undergraduate student researchers at St. Anthony Falls Laboratory (2010-2013) including 10 students identified through North Star STEM Alliance (The Minnesota Louis Stokes Alliance for Minority Participation and 3 students identified as underrepresented in STEM through the National Center for Earth Surface Dynamics NSF REU program.

Heitkamp, B., J.L. Kozarek. Water and Sediment: Exploring the Work of Rivers, Earth Science Teacher Workshop (~ 20 middle school teachers). Developed materials for a flume exercise and co-taught a full-day workshop through the University of Minnesota STEM Education Center. October 10, 2013.

Presenter and organizer of half-day hands-on exercises for the Summer Institute for Earth Surface Dynamics (~40 PhD, post-doc, and early career scientists) in the Outdoor StreamLab. 2010: Opportunities for research on ecohydrology and nutrient cycling. 2013: Experiments in the Outdoor StreamLab. National Center for Earth Surface Dynamics, St. Anthony Falls Laboratory, Minneapolis, MN.

Day, S., J.L. Kozarek, and B. Heitkamp. Wicked River: Is the river truly wicked? Why do floods and other disasters happen? Presentation and hands-on river table demonstration as part of the Art, Science, History, and Adventure aboard the Jonathan Padelford Riverboat Afloat on the Mississippi River. August 1, 2012.

Co-organizer and technical committee for the 2010 -2014 Upper Midwest Stream Restoration Symposium (UMSRS), work with UMSRS coordinator, B. Heitkamp, and the technical committee on the technical program and logistics of the UMSRS meeting. This symposium serves as a mode for dissemination of stream restoration related research as well as providing the opportunity for feedback from practitioners and future collaborators into current stream restoration research needs.

DANIEL J. HORNBACH

ADDRESS: Department of Environmental Studies
Macalester College
1600 Grand Ave.
St. Paul, MN 55105

TELEPHONE: Office - (651) 696-6101
Fax - (651) 696-6443

E-MAIL: Hornbach@Macalester.edu

EDUCATION: Ph.D.: Miami University, Oxford, Ohio. 1980. Major Zoology.
M.S.: University of Dayton, Dayton, Ohio. 1976. Major: Biology.
B.S.: University of Dayton, Dayton, Ohio. 1974. Major: Biology.

ACADEMIC EXPERIENCE:

- Faculty member, Department of Biology, Macalester College. Assistant Professor: September 1984 -August 1987; Associate Professor: September 1987 - August 1993; Full Professor: September 1993 - December 1997; DeWitt Wallace Professor: January 1998 – PRESENT
- Associate Editor, American Midland Naturalist. September 1995-2001.
- Assistant Professor, Department of Biology, University of Virginia. September 1980 - May 1984.

SELECTED GRANTS (HORNBACH AS PI OR CO-PI):

- Legislative Commission on MN Resources (1999-2001) - $58,000
- National Park Service (2000-2002) - $40,900
- National Park Service (2001-2004) - $60,000
- National Park Service (2004-2007) - $214,000
- National Park Service (2008-2010) - $149,100
- National Park Service (2009-2011) - $50,000
- National Park Service (2009-2010) - $55,535
- National Park Service (2010-2011) - $24,300
- National Park Service (2012) - $18,600

SELECTED PUBLICATIONS – REFERRED PAPERS

Hornbach, D.J., J.G. March*, T. Deneka*, N.H. Troelstrup and J.A. Perry. 1996. Factors influencing the distribution and abundance of the endangered winged mapleleaf mussel, *Quadrula fragosa* in the St. Croix River, Minnesota and Wisconsin. American Midland Naturalist 136: 278-286.

Hornbach, D.J. and T. Deneka. 1996. A comparison of a qualitative and a quantitative collection method for examining freshwater mussel assemblages. Journal of North American Benthological Society 15: 587-596.

Baker, S. and D.J. Hornbach. 1997. Acute physiological effects of zebra mussel (*Dreissena polymorpha*) infestation on two unionid mussels, *Actinonaias ligamentina* and *Amblema plicata*. Canadian Journal of Fisheries and Aquatic Sciences 54: 512-597.

Tyrrell*, M. And D.J. Hornbach. 1998. Selective predation by muskrats on freshwater mussels in 2 Minnesota rivers. Journal of North American Benthological Society 17: 301-310.

Baker, S. and D.J. Hornbach. 2000. Physiological status and biochemical composition of a natural population of unionid mussels (*Amblema plicata*) infested by zebra mussels (*Dreissena polymorpha*). American Midland Naturalist 143: 443-452.

Baker, S. and D.J. Hornbach. 2001. Seasonal metabolism and biochemical composition of two unionid mussels, *Actinonaias ligamentia and Amblema plicata*. Journal of Molluscan Studies 67: 407-416.

Cope, W.G., M.C. Hove, D.L. Waller, D.J. Hornbach, M.R. Bartsch, L.A. Cunningham*, H.L. Dunn and A.R. Kapuscinski. 2003. Evaluation of relocation of unionid mussels to *in situ* refugia. Journal of Molluscan Studies 69: 27-34.

Baker, S.M. and D.J. Hornbach. 2008. Zebra mussels (*Dreissena polymorpha*) attached to native mussels (Unionidae) or inanimate substrates: Comparison of physiological rates and biochemical composition. American Midland Naturalist 160:20-28.

Hornbach, D.J., M.C. Hove, B. Dickinson*, K. MacGregor and J.R. Medland. 2010. Estimating population size and habitat associations of two federally endangered mussels in the St. Croix River, Minnesota and Wisconsin, USA. Aquatic Conservation: Marine and Freshwater Ecosystems 20: 250-260.

Szumowski*, S.C., S.L. Boyer, D.J. Hornbach and M.C. Hove. 2012. Genetic diversity of two common freshwater mussel species, *Lampsilis cardium* and *Quadrula pustulosa* (Bivalvia, Unionidae), in a large federally protected waterway (St. Croix River, Minnesota/Wisconsin, U.S.A.). American Malacological Bulletin 30: 1-14.

Sansom. B.J.*, D.J. Hornbach, M.C. Hove, and J.S. Kilgore. 2013. Effects of flow restoration on mussel growth in a Wild and Scenic River North American River. Aquatic Biosystems 9: 6 (11 pages).

Hornbach, D.J. M.C. Hove, H. Liu, F.R. Schenck, D. Rubin and B.J. Sansom. 2013. The influence of two differently sized dams on mussel assemblages and growth. Hydrobiologia *in press.*

Kelly Revenaugh MacGregor
Associate Professor, Macalester College

Macalester College
Geology Department
1600 Grand Avenue
Saint Paul, MN 55015
Phone: (651) 696-6441
Email: macgregor@macalester.edu

Education

Mendenhall Postdoctoral Fellowship	Geology	US Geological Survey, Menlo Park	2002-2003
Ph.D.	Earth Sciences	University of California, Santa Cruz	1996-2002
Post-baccalaureate	Chemistry	Baruch College	1995-1996
Post-baccalaureate	Physics	Hunter College	1995-1996
B.A.	Geology	Williams College	1989-1993

Academic Employment

6/2011-present	Macalester College, St. Paul, Minnesota, Department of Geology	Department Chair
2010-present	Macalester College, St. Paul, Minnesota, Department of Geology	Associate Professor
2003-2010	Macalester College, St. Paul, Minnesota, Department of Geology	Assistant Professor
Spring 2001	Earth Sciences Department, UC Santa Cruz	Instructor
1996-2002	Earth Sciences Department, UC Santa Cruz	Graduate Fellow/ Teaching Assistant

Relevant Published Scholarly Work *undergraduate authors, graduate student authors

Sanders, J.W., Cuffey, K.M., **MacGregor, K.R.,** Collins, B. (2013). The sediment budget of an alpine cirque. *GSA Bulletin*, January/February 2013, v. 125, no. 1-2, p. 229-248. doi:10.1130/B30688.1.

MacGregor, K.R., Riihimaki, C.A., Myrbo, A., Shapley, M.D., Jankowski, K. (2011). Geomorphic and climatic change over the past 12,900 years at Swiftcurrent Lake, Glacier National Park, Montana. *Quaternary Research, 75(1),* doi:10.1016/j.yqres.2010.08.005.

Hornbach, D.J., Hove, M.C., Dickinson, B.D., **MacGregor, K.R.**, Medland, J.R. (2010) Estimating population size and habitat associations of two federally endangered mussels in the St. Croix River, Minnesota and Wisconsin. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **20**:250-260. DOI: 10.1002/aqc.1081.

MacGregor, K.R., Anderson, R.S., Anderson, S.P., and Waddington, E.D., (2000). Numerical simulations of glacial-valley longitudinal profile evolution. *Geology*, v. 28, No. 11, p. 1031-1034.

Loeb, C., Hornbach, D., **MacGregor, K.M.,** Hove, M. (in preparation). Using Geographic Information Systems (GIS) to map bathymetric changes in the St. Croix River 1968-2008. *Water Resources Research*

Relevant invited presentations

2013 Featured guest at 'The Beaker and Brush Discussion', Amsterdam Bar, St. Paul. Sponsored by the Science Museum of Minnesota and the Minnesota Museum of American Art, January 8, 2013

2012 'Assembling Minnesota: A Geologic History of the North Star State", July 7-14, Camp Unistar, MN

2010 'Modern-day and historical sediment transport in the St. Croix River, MN/WI: preliminary analysis and implications for native mussel populations'. Presentation to the American Institute for Professional Geologists, Minnesota chapter, Roseville, MN, May 6, 2010

2009 'Teaching 5-12th grade students about glaciers and climate', Presentation and workshop at the annual meeting of the Minnesota Earth Science Teachers Association, St. Cloud, MN, February 2009

2008 'Sediment Transport in the St. Croix River', Minnesota Geological Survey, Minneapolis, MN, Spring 2008

2004 'A Tale of Two Rivers', St. Anthony Falls Laboratory/NCED, University of Minnesota, Minneapolis, MN

2003 'Preliminary Tales of Historical Sediment and Water Transport in the Columbia River Basin: Dam It!', United States Geological Survey, Santa Cruz, CA

Relevant Presentations at National Conferences **undergraduate, graduate student authors*

Jackson, K.J., **MacGregor, K.R**., Hornbach, D.J. (2010). Bed Sediment Grain Size Distribution and Flow Dynamics of Indianhead Reservoir, St. Croix River, MN/WI. Abstract EP31A-0732 presented at 2010 Fall Meeting, AGU, San Francisco, California, 13-17 December.

Hornbach, D.J., Hove, M.C., **MacGregor, K.R.,** Colehour, A. (2010). Temperature Refugia for Mussels in Rivers? Burrow Deeper. North American Benthological Society Meeting, May 2010.

Hornbach, D.J., Hove, M.C., **MacGregor, K.R.** (2009) Mussel density at Interstate Park, St. Croix River, MN and WI: A new equilibrium? International Symposium of the Freshwater Mollusk Conservation Society, Baltimore, MD, April 19-24, 2009.

Hornbach, D.J., Loeb, C., Hove, M.C., **MacGregor, K.R.** (2009) Using GIS to assess dam impact on river bathymetry, St. Croix River, MN/WI. North American Benthological Society Meeting, May 2009.

MacGregor, K.M., Hornbach, D., Hove, M., Loeb, C., Ritz, L., Major, R., (2008), Sediment Transport in the St. Croix River, MN/WI Above and Below the St. Croix Falls Dam, *Eos Trans. AGU*, 89(53), Fall Meet. Suppl., Abstract H53C-1069. December 2008, American Geophysical Union Meeting, San Francisco, CA.

Hornbach, D.J., Hove, M.C., **MacGregor, K.R.** (2007). Can freshwater mussel density be predicted by complex hydraulic parameters? North American Benthological Society Meeting, May 2007.

Kushner, E., **MacGregor, K.,** Hornbach, D. (2006). Analysis of sediment transport data and calculation of historical sediment load, St. Croix River, MN/WI. GSA Abstracts with Programs, Vol. 38, No. 7, Paper 143-34. October 2006, Geological Society of America meeting, Philadelphia, PA.

Hornbach, D.J., Hove, M.C., **MacGregor, K.R**. (2006). Using hydraulic parameters to predict mussel density: a preliminary study. North American Benthological Society meeting, Abstract 735.

MacGregor, K., and Hornbach, D. (2005). Preliminary analysis of bed and suspended sediment transport in a protected watershed, and the effect on native mussel populations. *Eos Trans. AGU, 86(18),* Joint Assembly Supplement, Abstract NB33G-07. May 2005, American Geophysical Union Meeting, New Orleans, LA.

MacGregor, K.R., Gelfenbaum, G., Rubin, D. (2003) Preliminary analysis of water discharge and suspended sediment data from the Columbia River Basin: shifting rating curves and diminishing sediment loads. *Eos, Transactions*, v. 84, No. 46, H52A-1162. December 2003, American Geophysical Union Mtg, San Francisco, CA.

Grants Received

2013 Keck Foundation/NSF proposal: Geomorphic and paleoenvironmental research in Glacier National Park. **Award: $46,000**

2010 Keck Foundation/NSF proposal: Geomorphic and paleoenvironmental research in Glacier National Park. **Award: $40,000**

2008 National Science Foundation, co-PI on Ordway Center proposal *A Strategic Development Plan for Macalester College's Katherine Ordway Natural History Study Area* **Award: $24,575**

2007 National Park Service, co-PI with Dan Hornbach (Macalester): *Monitoring Sediment Dynamics in the St. Croix River and the Impact on Federally Endangered Mussels*. **Award: $148,824**. 4/2008-12/2010

2007 Supporting member on a proposal to the Mellon Foundation for the Three Rivers Center: Curricular and Research Innovation in Environmental Studies at Macalester College. **Award: $300,000**.

2005 National Science Foundation, Geology and Paleontology, co-PI with Kurt Cuffey, UC Berkeley. *Collaborative Research: Ice and Rock Processes in Cirques*. **Award: $190,000** ($70,000 to Macalester) 9/2005-10/2008

Mark Curtis Hove

University of Minnesota, Department of Fisheries, Wildlife and Conservation Biology
1980 Folwell Avenue, St. Paul, Minnesota 55108
work: (651) 472-3182 home: (651) 644-0762 e-mail: Mark_Hove@umn.edu

Education

University of Minnesota	B.S. Fisheries and Biochemistry	1981-1987
Virginia Polytechnic Institute and State University (VPI&SU)	M.S. Fisheries Science	1987-1990

Work Experience

Research Associate, University of Minnesota, (Dr. Francesca Cuthbert, supervisor) Compose grant proposals, mentor students, conduct research projects, analyze data, and compose reports and publications. 2010-present.

Research Biologist, Macalester College, (Dr. Daniel J. Hornbach, supervisor) Compose grant proposals, mentor students, maintain research projects, analyze data, and compose reports on mussel conservation research topics. 1999-present.

Research Fellow, University of Minnesota, (Dr. Anne R. Kapuscinski, supervisor) Composed grant proposals, mentored students, conducted research projects, analyzed data, and composed reports on aquaculture, aquatic bioassessment, and mussel conservation research topics. 1990-2010.

Select Grants Awarded

Determination of host fish requirements of select rare upper Mississippi River mussel species. 2012. Grantor – Minnesota Department of Natural Resources, St. Paul, Minnesota. Funds granted - $15,000 to Mark Hove, University of Minnesota.

St. Croix Scenic Riverway mussel conservation. 2011. Grantor – National Park Service, Omaha, Nebraska. Funds granted - $7,133 to Mark Hove and Dan Hornbach, Macalester College.

Determination of host fish requirements of select rare upper Mississippi River mussel species. 2011. Grantor – Minnesota Department of Natural Resources, St. Paul, Minnesota. Funds granted - $15,000 to Mark Hove, University of Minnesota.

Federally endangered winged mapleleaf conservation on the St. Croix Scenic Riverway. 2010. Grantor – National Park Service, Omaha, Nebraska. Funds granted - $24,292 to Mark Hove and Dan Hornbach, Macalester College.

Converting hydropower dam operation to run-of-the-river: the effect on endangered mussels and their habitat. 2009-2011. Grantor – National Park Service, Omaha, Nebraska. Funds granted - $49,952 to Kelly MacGregor, Dan Hornbach and Mark Hove, Macalester College.

Life history requirements of rare mussels. 2008-2009. Grantor – Minnesota Department of Natural Resources and US Fish and Wildlife Service, St. Paul, Minnesota. Funds granted - $20,000 to Mark Hove, University of Minnesota.

Habitat requirements of the winged mapleleaf mussel – potential habitat degradation and decline in the St. Croix River. 2005-2007. Grantor – National Park Service, Omaha, Nebraska. Funds granted - $213,991 to Dan Hornbach and Mark Hove, Macalester College.

Peer-reviewed publications

Hornbach, D. J., M. C. Hove, H. Liu, F. R. Schenck, D. Rubin, and B. J. Sansom. 2013. The influence of two differently sized dams on mussel assemblages and growth. Hydrobiologia *In press*.

Sansom, B. J., D. J. Hornbach, M. C. Hove, and J. S. Kilgore. 2013. Effects of flow restoration on mussel growth in a Wild and Scenic North American River. Aquatic biosystems 9(6): 1-11.

Bloodsworth, K. H., B. R. Bosman, B. E. Sietman, and M. C. Hove. 2013. Host fishes and conservation status of *Alasmidonta marginata* (Bivalvia: Unionidae) in Minnesota. Northeastern Naturalist 20(1): 49-68.

Hove, M. C., M. T. Steingraeber, T. J. Newton, D. J. Heath, C. L. Nelson, J. A. Bury, J. E. Kurth, M. R. Bartsch, W. S. Thorpe, M. R. McGill, and D. J. Hornbach. 2012. Early life history of the winged mapleleaf mussel (*Quadrula fragosa*). American Malacological Bulletin 30(1): 47-57.

Fritts, A. K., B. E. Sietman, M. C. Hove, N. E. Rudh, J. M. Davis, D. J. Heath. 2012. Early life history and conservation status of the monkeyface, *Theliderma metanevra* (Mollusca: Bivalvia) in Minnesota and Wisconsin. Walkerana 15(2): 99-112.

Sietman, B. E., J. M. Davis and M. C. Hove. 2012. Mantle display and glochidia release behaviors of five quadruline freshwater mussel species (Bivalvia: Unionidae). American Malacological Bulletin 30(1): 39-46.

Szumowski, S. C., S. L. Boyer, D. J. Hornbach, and M. C. Hove. 2012. Genetic diversity of two common freshwater mussel species, *Lampsilis cardium* and *Quadrula pustulosa* (Bivalvia: Unionidae), in a large federally protected waterway (St. Croix River, Minnesota/Wisconsin, U.S.A.). American Malacological Bulletin 30(1): 59-72.

Hove, M. C., B. E. Sietman, J. E. Bakelaar, J. A. Bury, D. J. Heath, V. E. Pepi, J. E. Kurth, J. M. Davis, D. J. Hornbach, and A. R. Kapuscinski. 2011. Early life history and distribution of pistolgrip (*Tritogonia verrucosa* (Rafinesque, 1820)) in Minnesota and Wisconsin. American Midland Naturalist 165(2): 338-354.

Boyer, S. L., A. A. Howe, N. W. Juergens, and M. C. Hove. 2011. A DNA-barcoding approach to identifying juvenile freshwater mussels (Bivalvia:Unionidae) recovered from naturally infested fishes. Journal of the North American Benthological Society 30(1): 182-194.

Hornbach, D. J., M. C. Hove, B. D. Dickinson, K. R. MacGregor and J. R. Medland. 2010. Estimating population size and habitat associations of two federally endangered mussels in the St. Croix River, Minnesota and Wisconsin, USA. Aquatic Conservation: marine and freshwater ecosystems 20: 250-260.

Hornbach, D. J., V. J. Kurth, and M. C. Hove. 2010. Variation in freshwater mussel shell sculpture and shape along a river gradient. American Midland Naturalist 164: 22-36.