TITLE: Alteration of Nutrient Cycling and Food Web Structure by Profundal Quagga Mussels in Lake Michigan

PRINCIPAL INVESTIGATORS:

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OBJECTIVES:

The overarching objective of this project is to quantify the altered flux of carbon and phosphorus through the profundal quagga mussel community, and to determine the effect of these mussel-mediated fluxes on ecosystem-scale nutrient dynamics and energy flow. To accomplish this objective, we will examine the key processes governing dreissenid-altered phosphorus cycling, with controlled field and laboratory experiments. These measurements and the parameterizations developed from these measurements are then synthesized into numerical 1-D and 3-D models of this impacted cycling, effectively linking the various activities into an applied, transferrable result.

Objective 1: To quantify and parameterize the recycling and transformation of phosphorus by dreissenids in Lake Michigan, as a function of location (nearshore vs. offshore) and hydrodynamics.

Objective 2: To quantify and parameterize the in-situ mussel seston grazing rate in Lake Michigan.

Objective 3: To quantify and parameterize near-bed hydrodynamics as they pertain to mussel water column filtration, as a function of season, location, and basic known physical processes (e.g. internal waves, storms, etc.).

Objective 4: To model dreissenid-influenced phosphorus transport, uptake, and transformation in Lake Michigan with 1-D and 3-D approaches that utilize/test existing and newly developed (from objectives above) parameterizations of relevant biogeochemical and hydrodynamic processes.

METHODOLOGY: The project utilizes a combination of field measurements, laboratory experiments, and numerical modeling to accomplish the above objectives. The field measurements will be focused on two primary sites, both a nearshore (10m depth) and an offshore (55m depth) location (near Milwaukee, WI). These sites are chosen to be representative of the dreissenid-influenced nearshore and offshore zones of the Great Lakes, with the offshore site being located in the hypolimnium for the majority of the thermally-stratified period. The field measurements will span one complete year, meaning that they resolve all seasons, including the winter/spring well-mixed period. Field measurements will be a combination of fixed moorings and monthly “episodic” sampling. The fixed moorings will measure full water-column velocities and temperatures, to continuously characterize hydrodynamic and thermal stratification at the sites; this continuous data can then be used to extrapolate results from the episodic sampling throughout the year. Importantly, at the deep water site, a high-resolution, downward-looking current and turbulence profiler will also be deployed, to resolve the mussel-influenced bottom boundary layer characteristics to within several cm of the lake bed.

Monthly episodic sampling will also be carried out at the field sites (weather-permitting through the winter). This will involve the measurement of in-situ mussel grazing rates and phosphorus excretion/egestion, as well as the collection of feces and pseudofeces for later analysis. Soluble reactive phosphorus profiles will also be collected, using a novel syringe collection technique. Additionally, Dr. Liao’s UnderWater Micro Particle Image Velocimetry (UWMPIV) system will be deployed during episodic cruises. This instrument provides direct measurements of near-bed particle and dissolved fluxes, allowing for the estimation of the mussel seston grazing rate and measurement of near-bed gradients comprising the concentration boundary layer. For the physical characterization during these cruises, microstructure measurements will be made with Purdue’s Self-Contained Autonomous Microstructure Profiler (SCAMP), from which the vertical distribution of the turbulent diffusivity – a key parameter determining the true filtration capacity of dreissenids – will be obtained. Finally, laboratory experiments target the quantification of the long-term fate of phosphorus in dreissenid feces and pseudo-feces, with month-long incubations of quagga mussels.

In terms of linking the above technical work to the stated project objectives, the numerical modeling objective (#4) attempts to synthesize these measurements into parameterizations that can be then used as model components for various processes. Initially, we will produce a 1-D water column mixing model of seston that will account for water column turbulence, settling, resuspension, and, of course, dreissenid uptake and transformation. This 1-D model is forced with the observed water column properties and is not meant to simulate the complex nutrient dynamics of the entire Lake Michigan. Rather, it provides an effective test bed where process-specific parameterizations can be implemented and process interactions can be examined. The ultimate goal, of course, is a fully 3-D model of dreissenid-impacted nutrient dynamics in Lake Michigan; while this is beyond the scope of what can be accomplished here, 3-D hydrodynamic simulations using Purdue’s Lake Michigan hydrodynamic model will be performed for the study year in order to generalize the study results to other locations, examine the impact of lateral variability and advection, and to attempt to calculate the true mussel filtration extent by including a dreissenid sink term in the model.

RATIONALE: Invasive zebra and quagga mussels appear to have profoundly altered Great Lakes food webs and nutrient cycles. Recent declines in the abundance of plankton, Diporeia, and planktivorous fish coincide with increased quagga mussel abundance. Additionally, altered nutrient cycles have promoted the growth of benthic algae. However, the exact mechanisms responsible for these changes, and the role of dreissenids, remain poorly defined. This lack of understanding impedes our ability to define optimal nutrient loading and fish stocking goals, and to predict the long-term response of the lake. Especially important is the development of robust parameterizations that can quantify dreissenid grazing and nutrient cycling under various hydrodynamic conditions throughout the year. This project attempts to address several key processes in dreissenid nutrient cycling that are still not well understood, including grazing of phytoplankton, excretion of dissolved phosphorus, and the long-term fate of biodeposits. The focus is primarily on the mid-depth, hypolimnetic region, which appears to be a sink for water column carbon and nutrients, but for which there are virtually no direct, in situ measurements of dreissenid-mediated carbon and phosphorus cycling. A critical requirement is the measurement of hydrodynamic processes, which directly affect the transport of seston to benthic dreissenids, and their capacity to influence plankton abundance and nutrient concentrations throughout the water column. Such measurements will allow for the revision of Lake Michigan biogeochemical models, which currently do not account for dreissenid grazing and nutrient recycling.