An integrated modeling approach to predict the expansion of invasive Zebra mussels at Northern Latitudes

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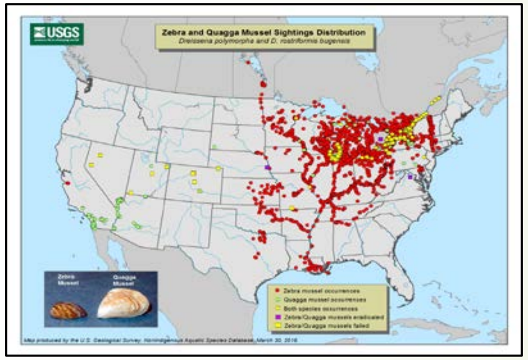
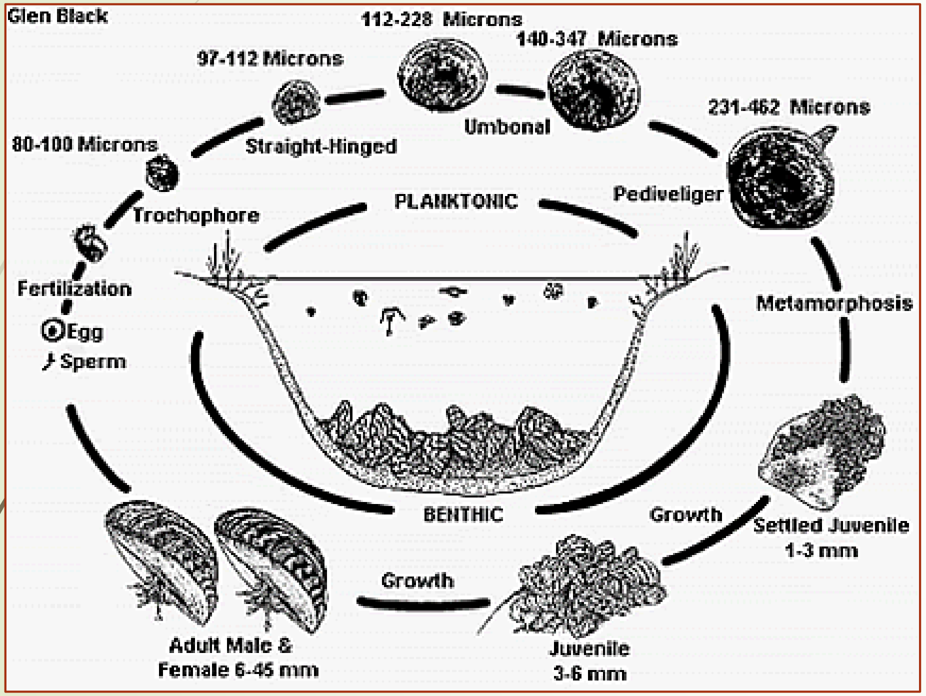
Introduction/Background

- Zebra Mussels
  - Highly invasive aquatic species
  - Reduces local diversity
  - Caused >$300M in damage and prevention
  - Spread mechanisms are complex and poorly understood



Zebra mussel (*Driessena polymorpha*): distribution and life history



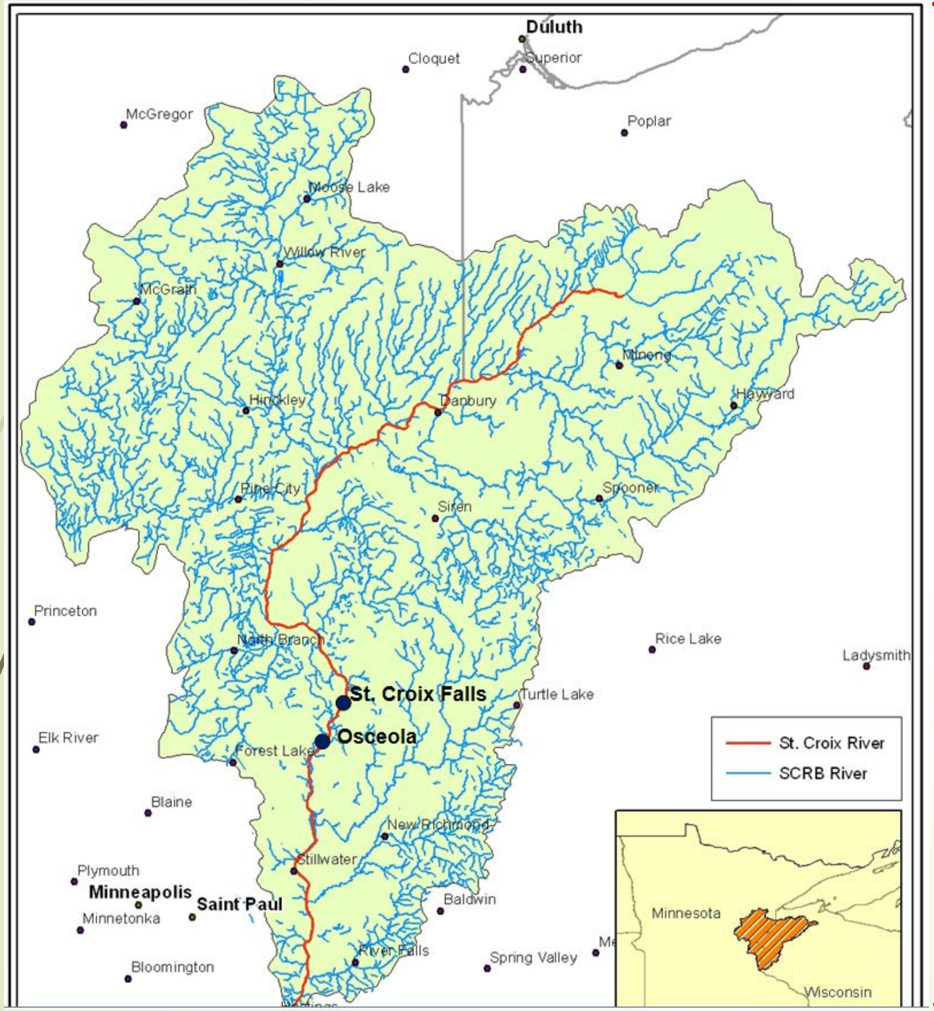
from U.S. Fish and Wildlife line art collection
http://www.fws.gov/midwest/mussel/images/zebra_mussel_%20life_cycle.html
accessed 14 September 2012

- Complex life history
  - Planktonic larval form
  - Benthic juvenile and adult form
- Habitat requirement studies
  - Regional or coarse national
  - Focused on lentic environments
  - Little known about responses to turbulent lotic environments
- Inter-basin and upstream spread primarily facilitated by humans

- Zebra mussels can survive for a long time out of water
- In fact, adult zebra mussels can survive out of water for several days or weeks if the temperature is low and humidity is high

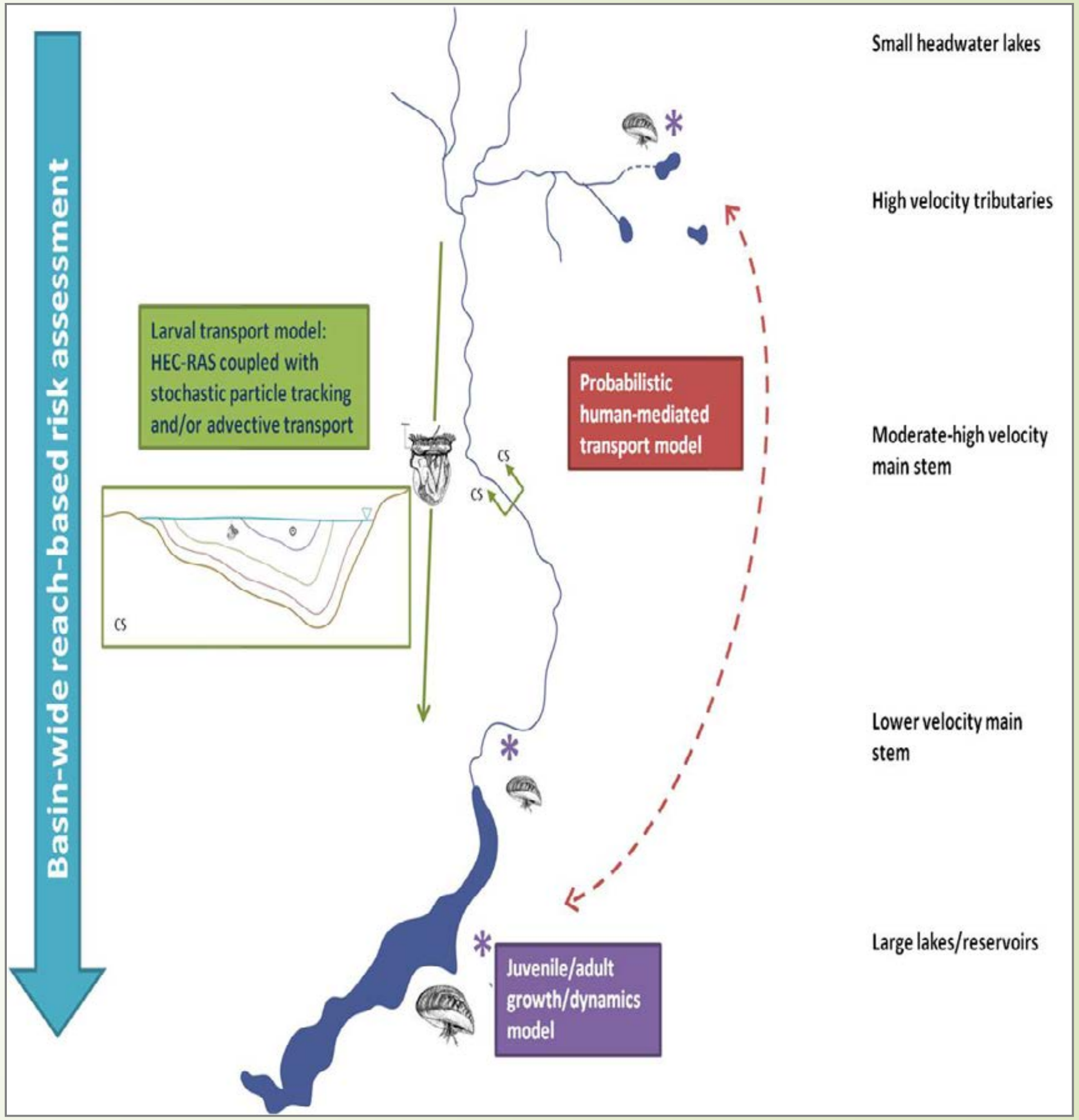
- Recommended quarantine times when drying out a boat:
  - January - 51 Days
  - February - 32 Days
  - March - 21 Days
  - April - 13 Days
  - May - 8 Days
  - June - 5 Days
  - July - 5 Days
  - August - 5 Days
  - September - 5 Days
  - October - 13 Days
  - November - 21 Days
  - December - 51 Days

Case Study: St. Croix River Watershed

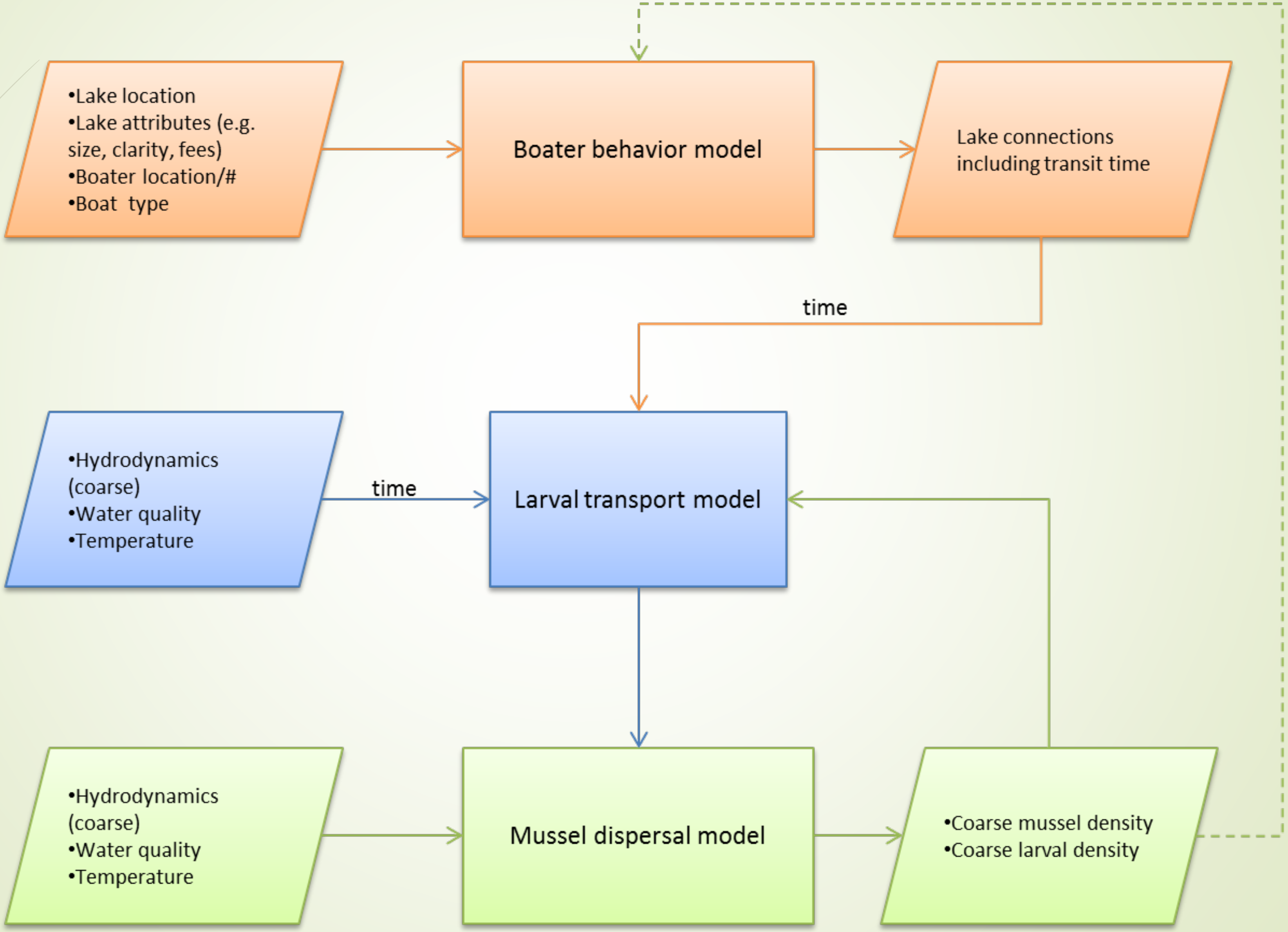


Objectives

- Develop integrated model that can project potential risks of zebra mussel invasion
- Develop conceptual framework for modelling approach
- Identify any data gaps
- Develop model components
  - Ecological
  - Physical
  - Anthropogenic
- Develop risk assessment for zebra mussel dispersal



Conceptual Model



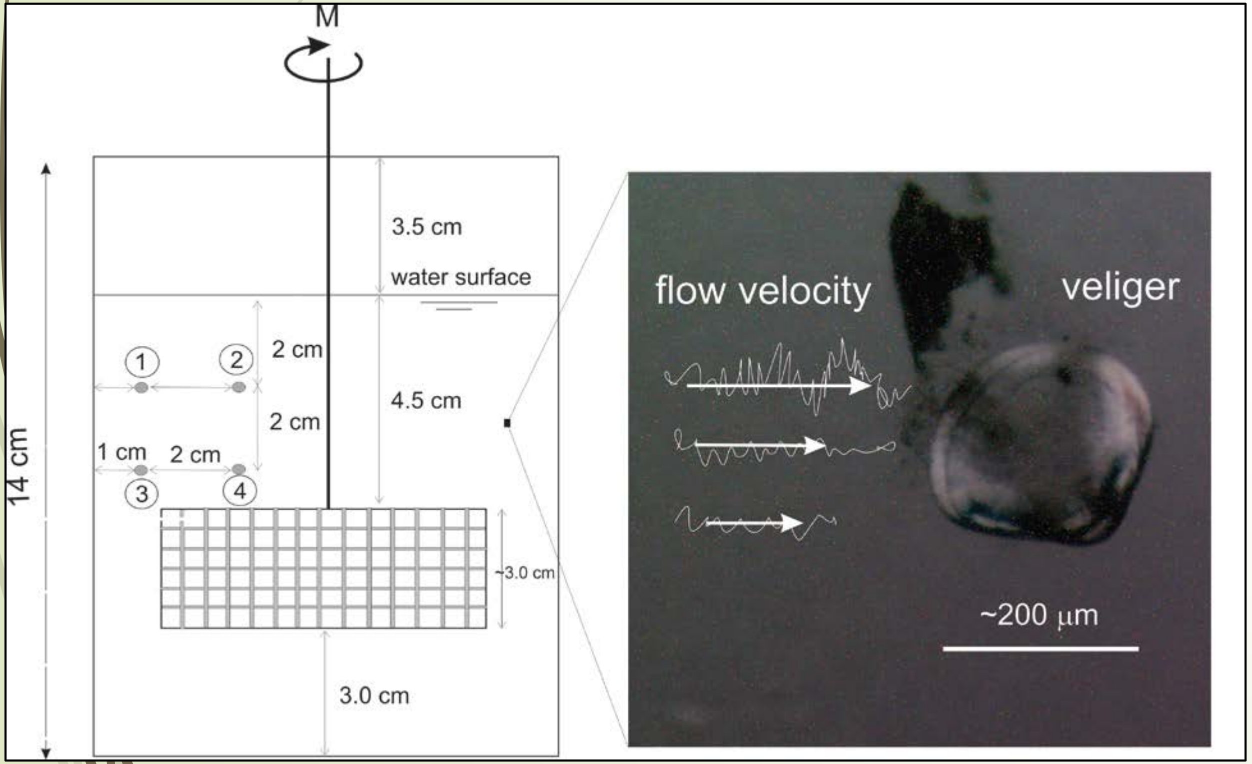
Approach

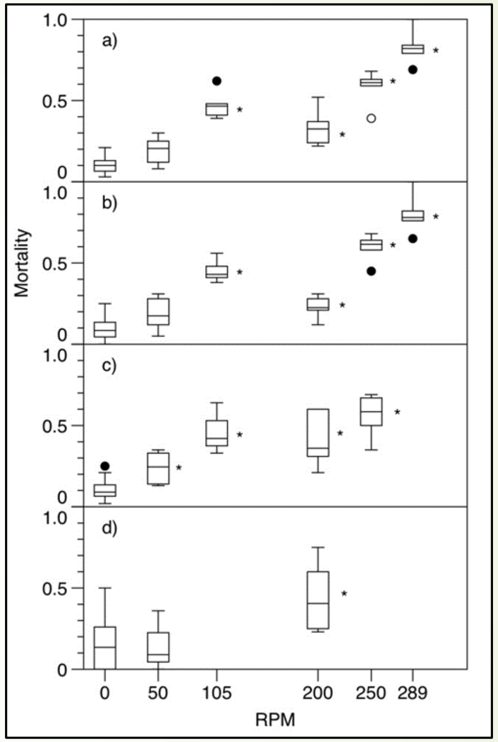
Data gap

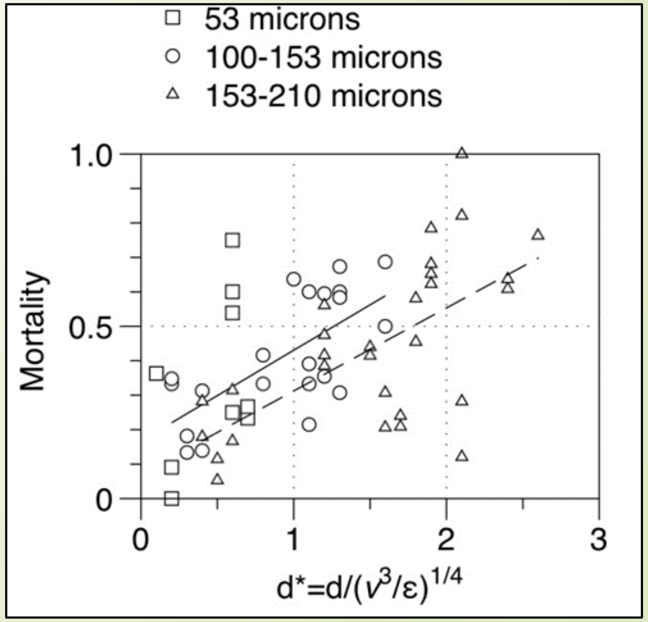
- Larval dispersal is critical for ecological spread, but poorly understood. Current hypotheses indicate that turbulence might dictate which reaches are accessible to larvae

- Collaborating with St. Anthony Falls lab at the U. Minnesota in collaboration with St. Paul District (determining turbulence affects on Z. mussel larva)
  - Preliminary results indicate that turbulence can impact larval survival, however, quantifying the exact influence is proving difficult

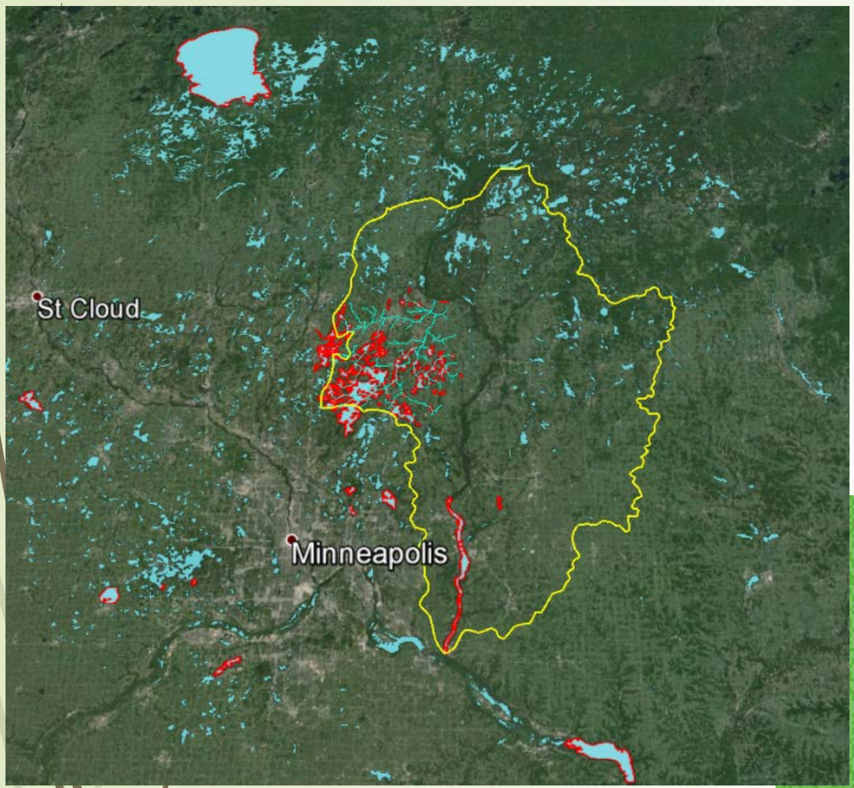
Turbulence Experiment



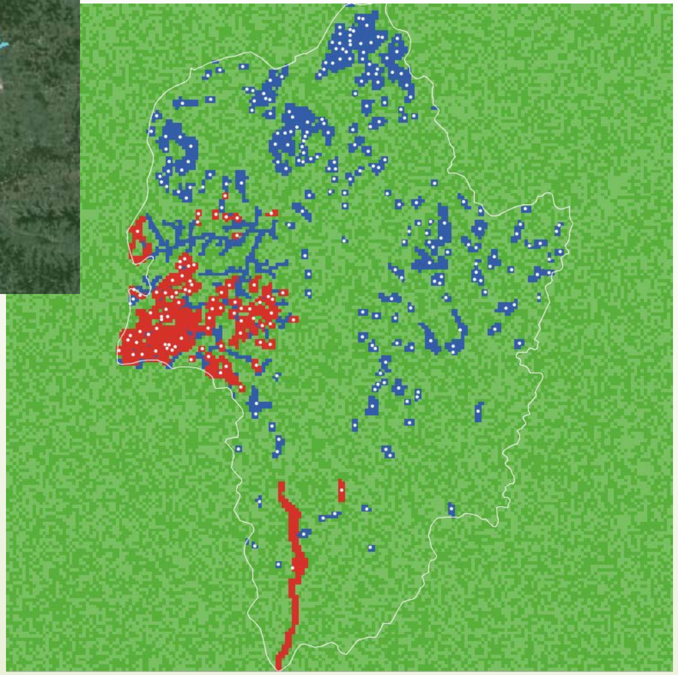




Integrated Modeling Approach



St. Croix River Watershed



Hydro-Boater-Zebra mussel model

Hydro Model

- SWAT model of St. Croix watershed (courtesy of St. Croix Watershed Research Station)

Boater Model

- Calculate attractiveness of each waterbody to boaters
- Simulate boater movement
- Determine if boaters introduce Zebra mussels

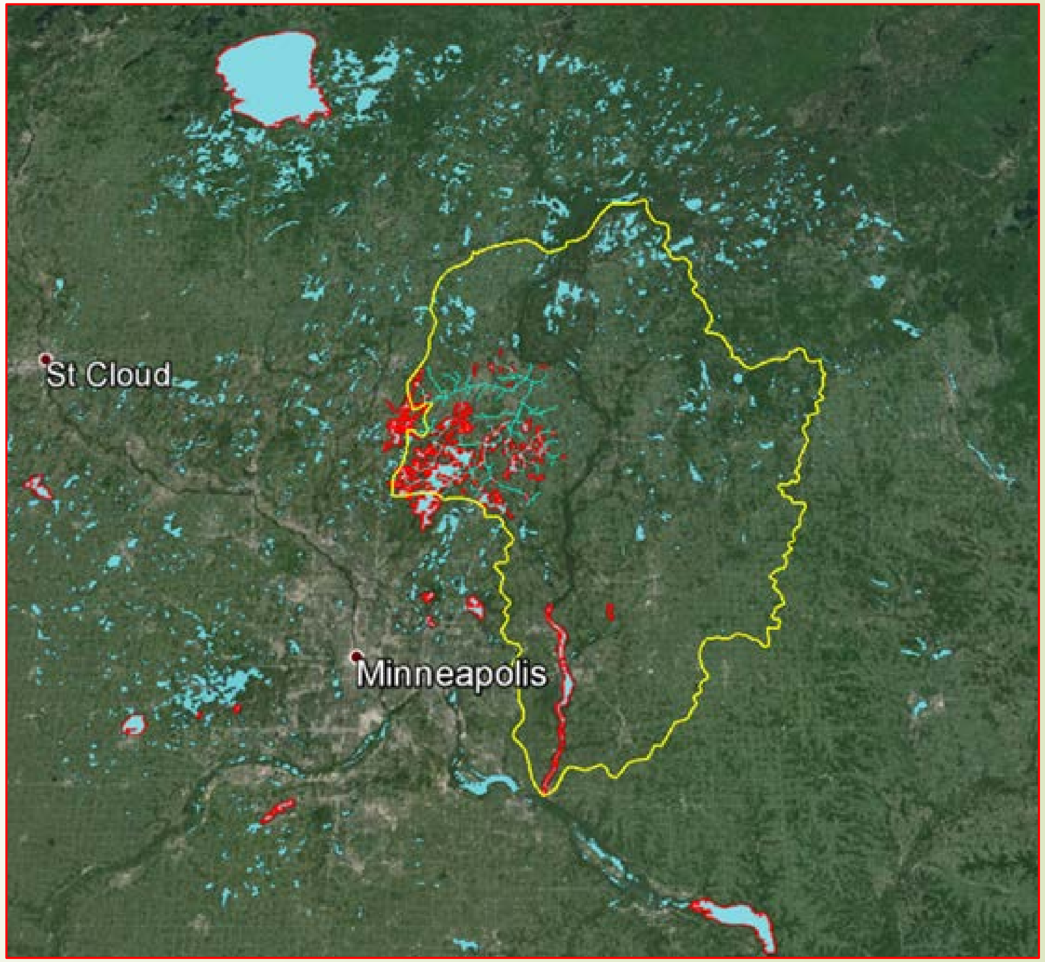
Zebra Mussel Model

- Calculate if Zebra mussels can survive in new habitat
- Simulate population dynamics
- Determine if veligers disperse among waterbodies

Approach: Hydro Model

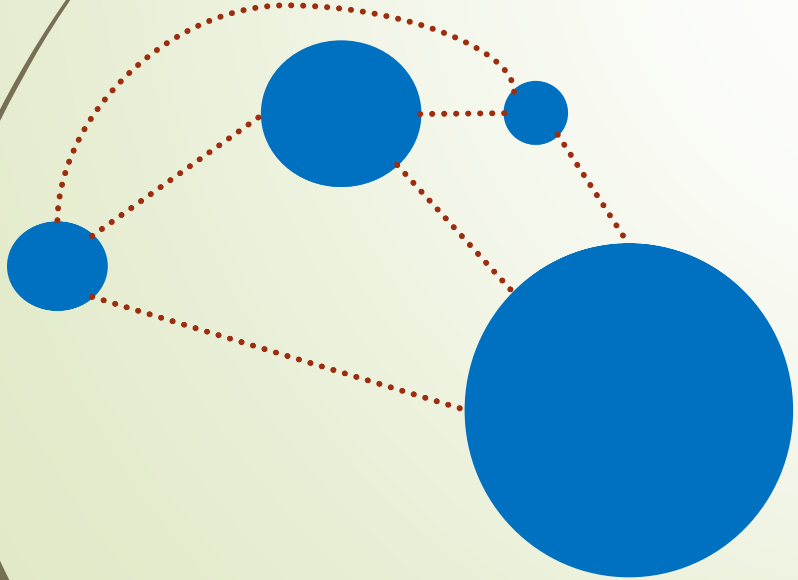
Physical environment

- SWAT model of St. Croix watershed (courtesy of St. Croix Watershed Research Station)
  - Models flow and hydrodynamics in watershed
  - Used velocities to determine turbulence values to larval survival
  - Provides connectivity from lake-to-lake



Approach: Boater Behavior

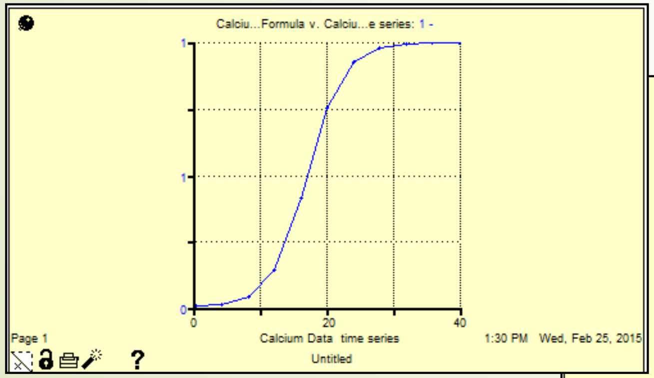
- Boats are thought to be major driver in Zebra mussel dispersal
- Developed **Constrained Gravity Model** to determine the probability that a boater at one location goes to any other location
  - $T_{ij} = A_i Z_i W_j c_{ij}^{-\alpha}$
    - $c_{ij}^{-\alpha}$: Calculates distance between centroid of each water body, and every other water body
    - W_j: Factors that attract boaters
    - A_i: Ensures all boats arrive somewhere
    - Z_i: Probability that boat leaving infested waters carry Zebra mussels

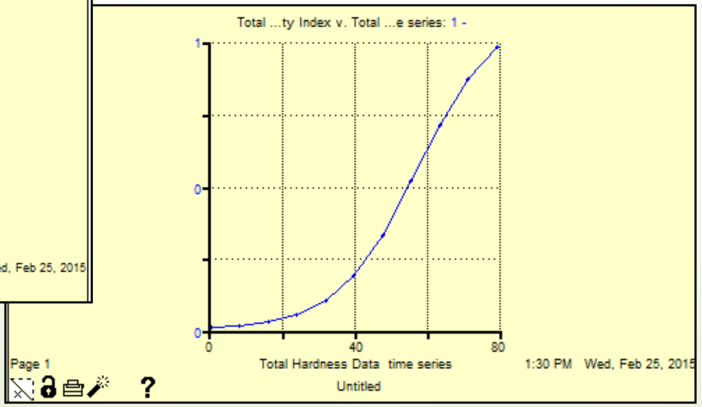


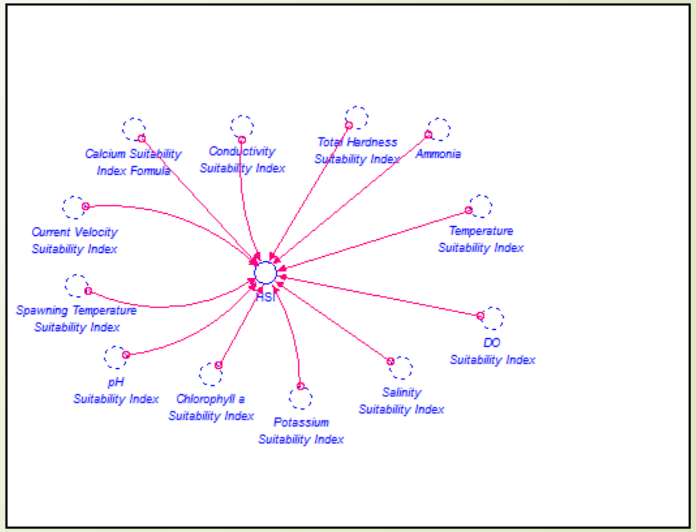
Approach: Habitat

Ecological environment

- 12 parameter habitat suitability model (Bartell et al., USACE report)
  - **Ammonia**, calcium, hardness, conductivity, **DO**, chlorophyll a, salinity, potassium, **velocity**, **temperature**, **spawning temp**, pH
  - $HSI = \left(\prod_{i=1}^{5} ZSI_i\right)^{1/5}$



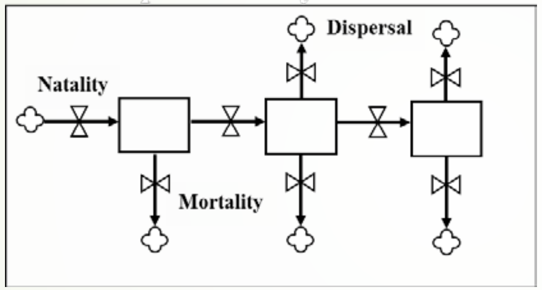




Zebra Mussels Dynamics

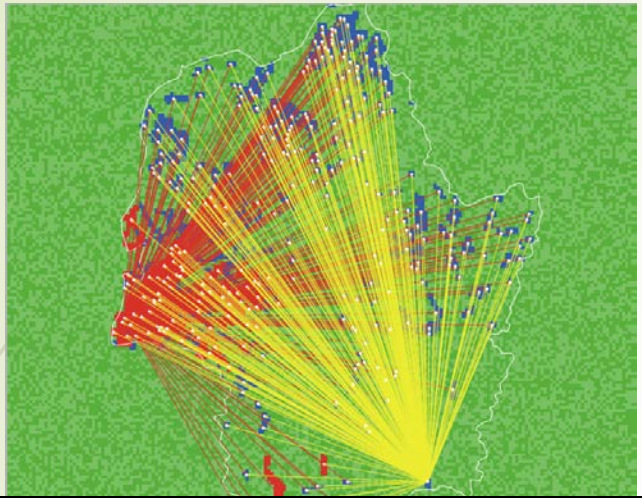
Zebra Mussel Model

- Simulate population dynamics
  - Stage-based population dynamics model
    - Larvae
    - Juveniles
    - Adults



  - Stage-specific survival rates based on environmental parameters
  - Probability of dispersal to other water bodies, or attachment to boats increases the longer Zebra mussels are present in a given water body

Integrated model



- Input SWAT, GIS, and Environmental, and Zebra Mussel data into Netlogo framework
  - Extensions: GIS, Matrix, R, Table, Array
- Boats are agents that can carry zebra mussels from one lake to another
- Simulate seasonal boater movement patterns across watershed to determine which lakes are most likely to become infected

Model Results

- Zebra Mussel dispersal will be difficult to contain at Northern Latitudes
- Gravity model needs further refinement: size and distance are not enough
- Limiting factors aren't that limiting.
- Turbulence results have not been incorporated into model. Hopefully, they will provide more tractable management strategies.

Acknowledgments

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Questions?