Incorporating Human Behavior into Ecological Models of Invasive Species

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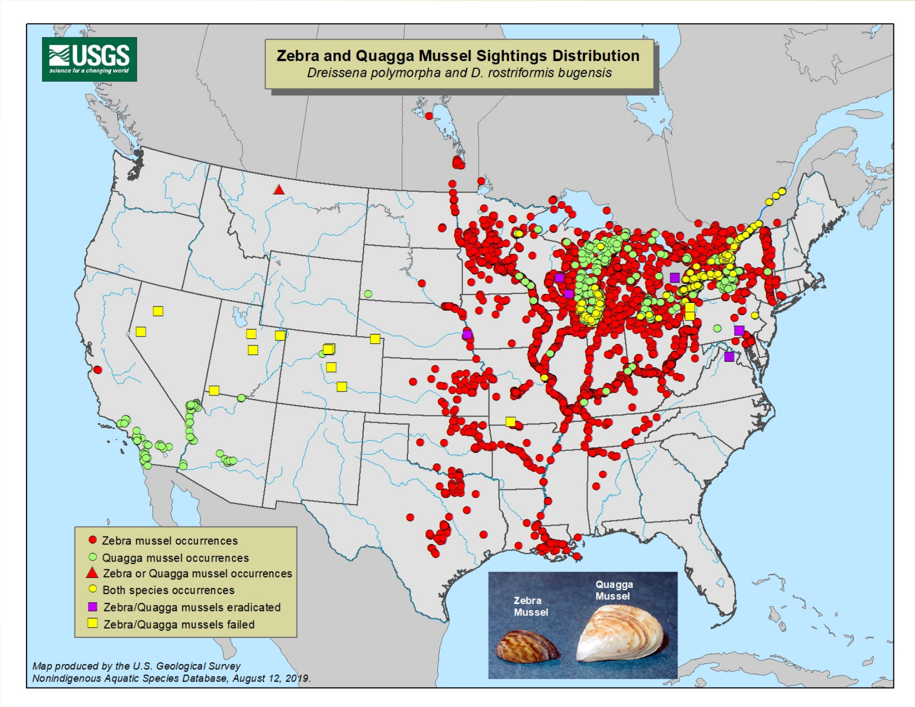
Outline

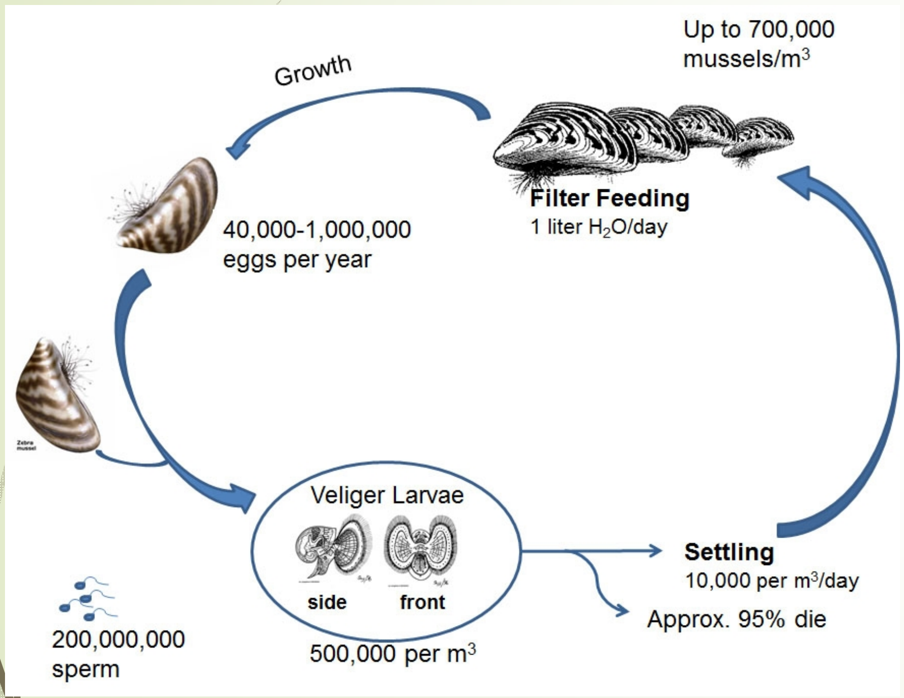
- History of Dreissenid Mussels
- Damage done by Dreissenid Mussels
- Bureau of Reclamation Dreissenid Mussel Model
- Texas Mussel Model
- Lessons Learned
- Acknowledgements
- Questions

Background

- Dreissenid Mussels
  - First introduced from Europe in 1986
  - Highly invasive aquatic species
    - Reduces local diversity
    - Caused approximately $1 Billion in damage and prevention last year

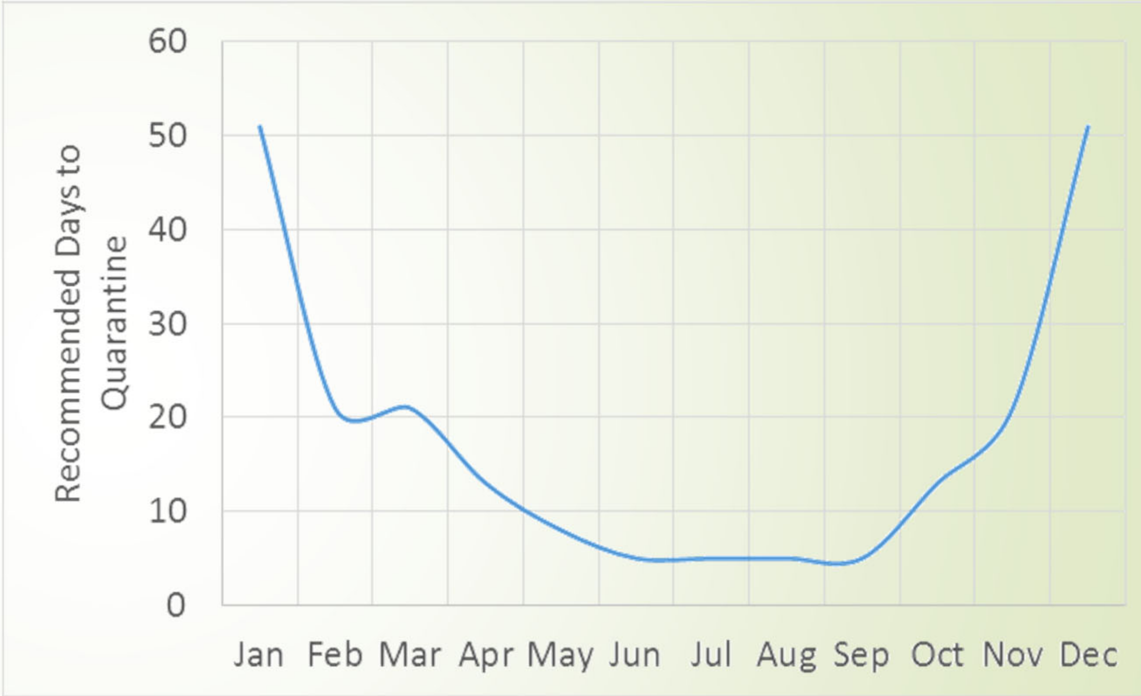


Dreissenid mussel life history and distribution

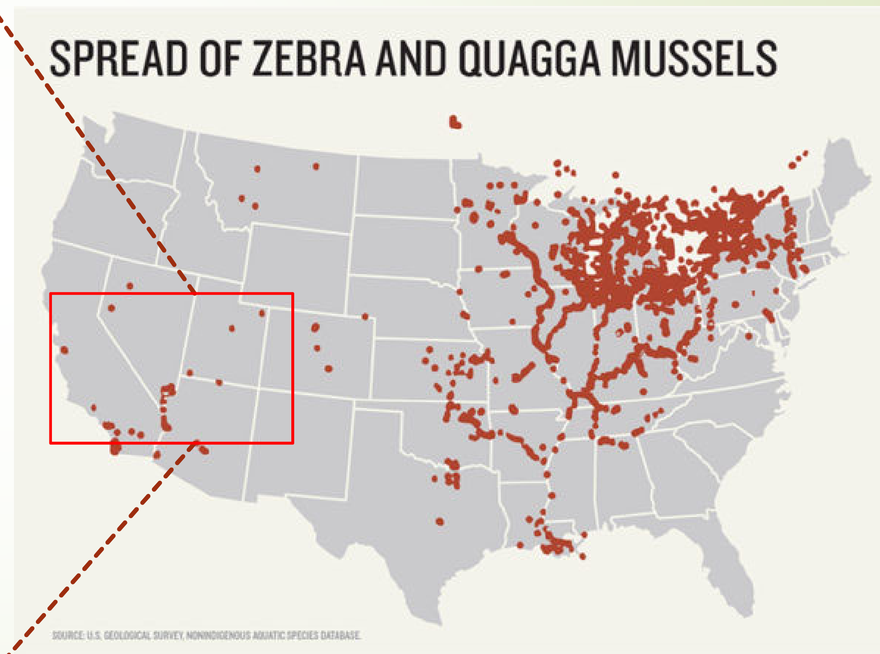


- Complex life history
  - Planktonic larval form
  - Benthic juvenile and adult form
- Habitat requirement studies
  - Focused on lentic environments
  - Little known about responses to turbulent lotic environments
- Inter-basin and upstream spread primarily facilitated by humans

- Adult mussels can survive out of water for several days or weeks if the temperature is low and humidity is high

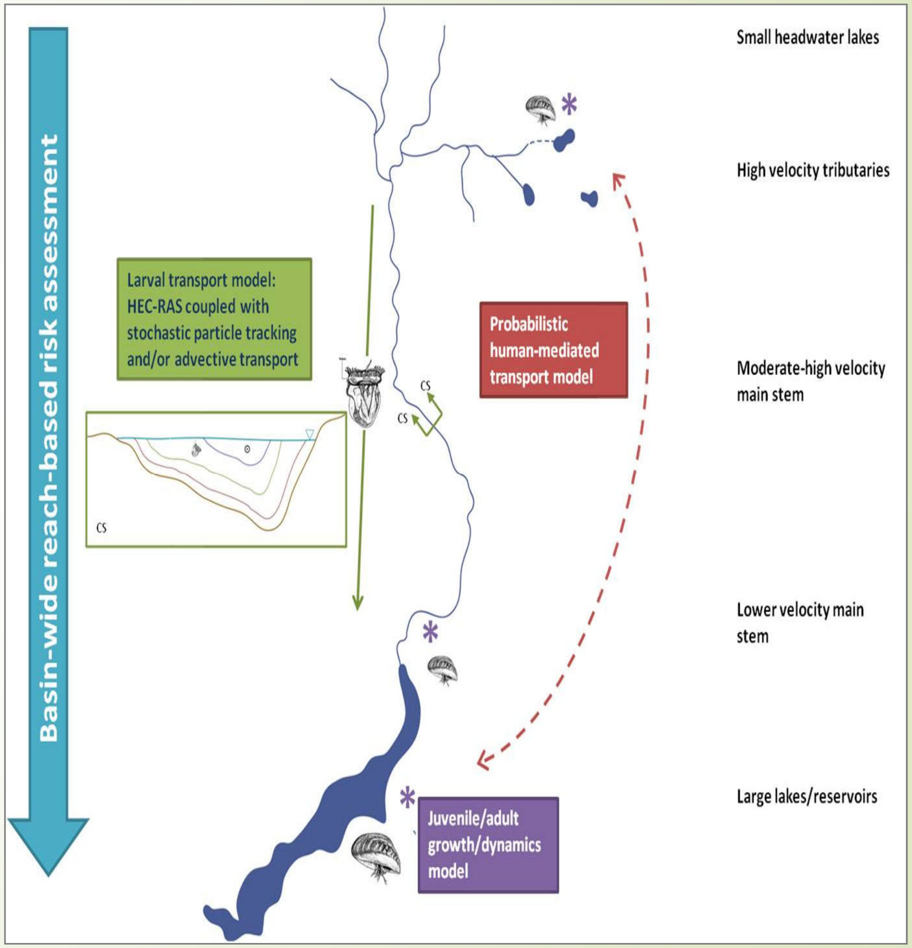


Dreissenid Mussel Modeling
Nine USBR Reservoirs in four regions



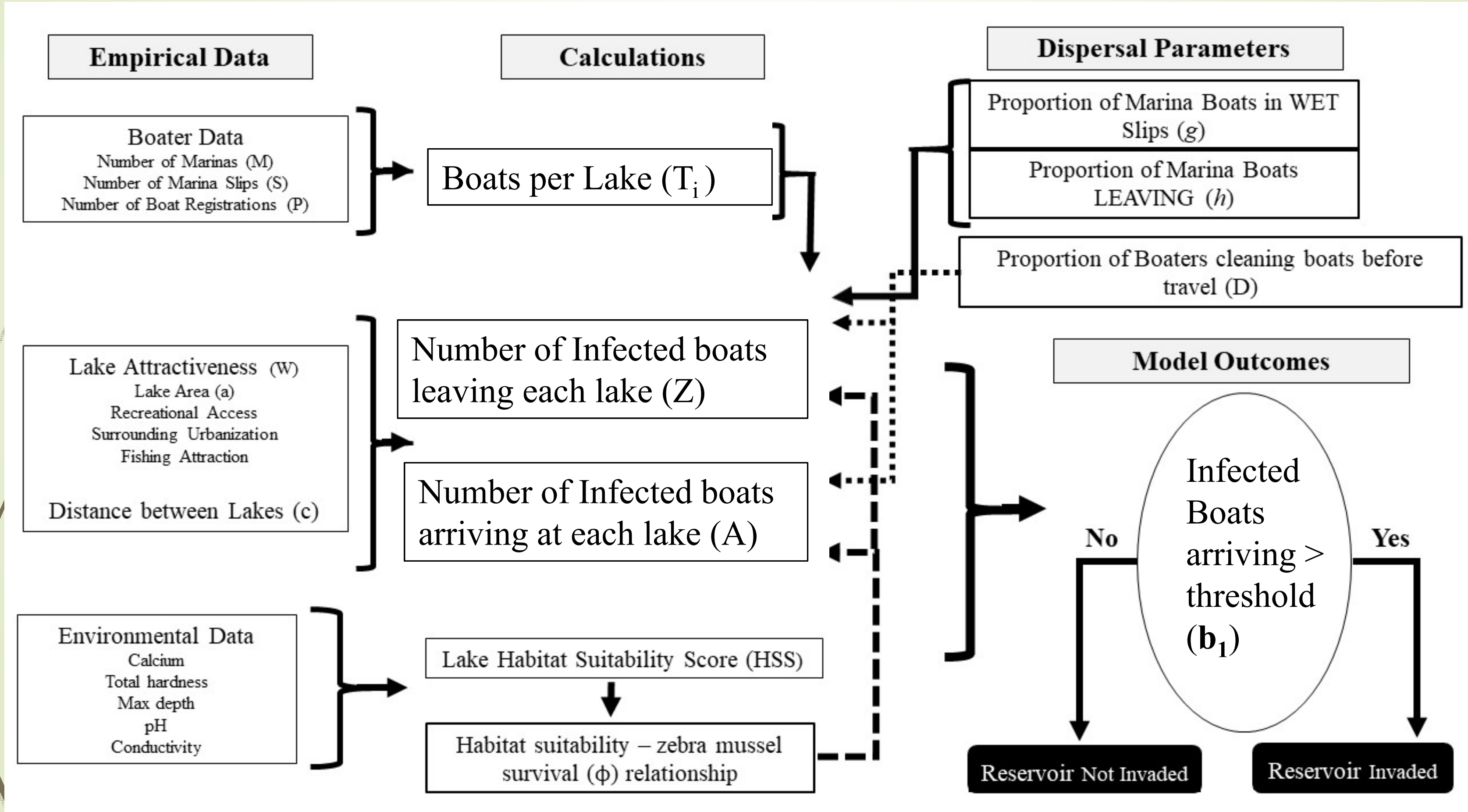
Objectives

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

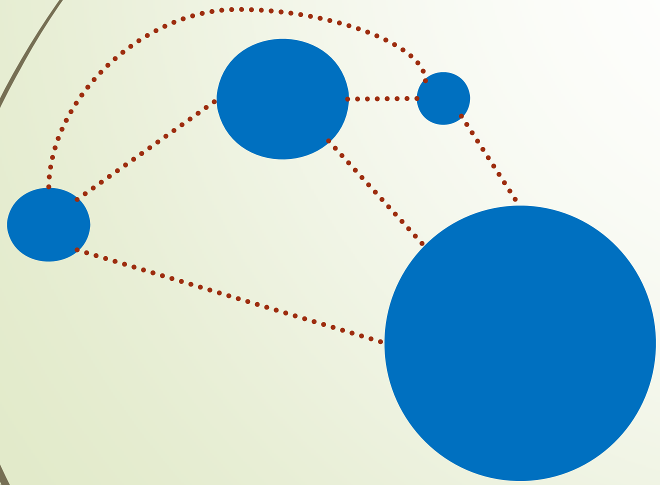


Dreissenid Mussel Modeling

Model Components and Database Development

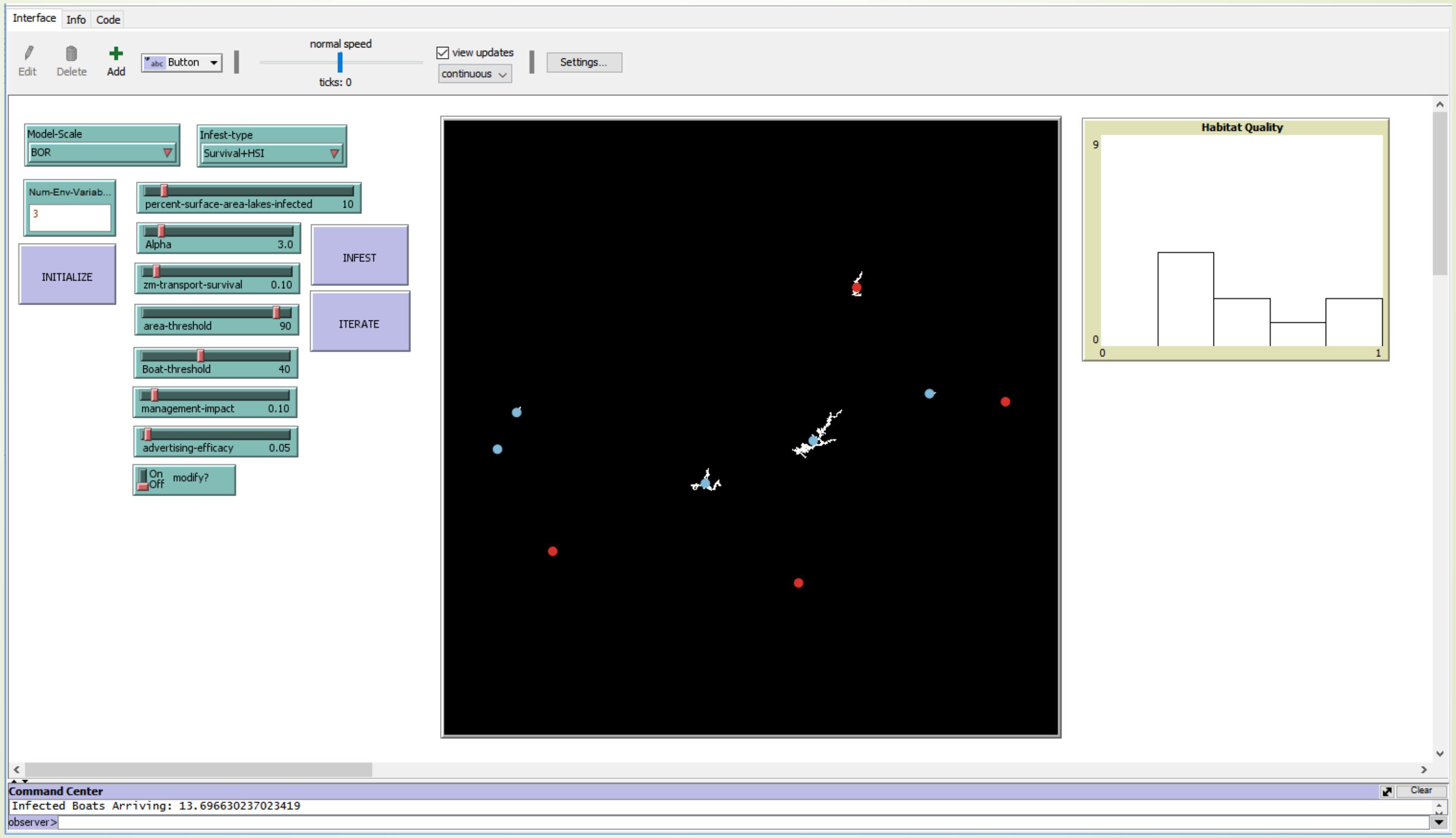


Approach: Boater Behavior

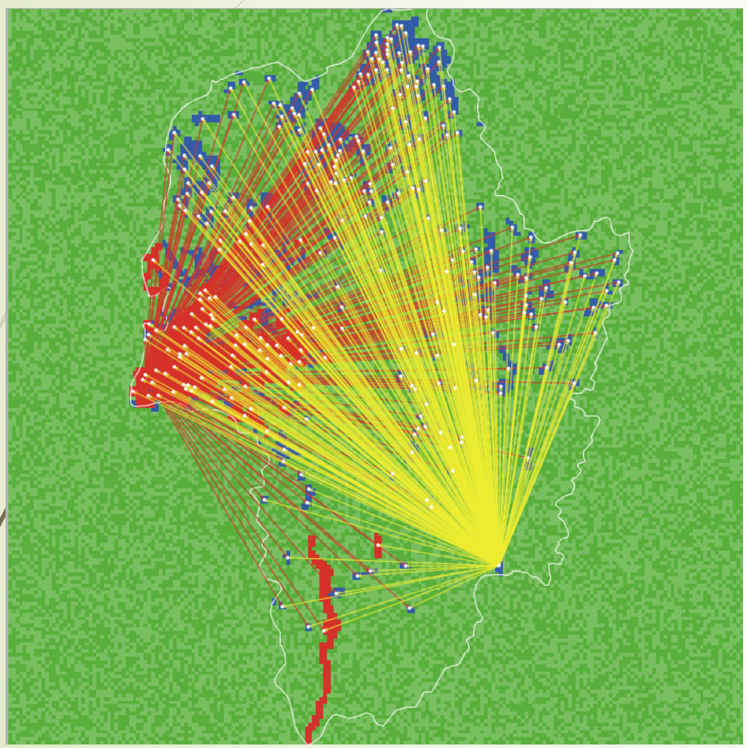


- Boats are thought to be major driver in Zebra and Quagga mussel dispersal
- Developed **Constrained Gravity Model** to determine the probability that a boater at one location goes to any other location
  - $\boldsymbol{T_{ij} = A_i Z_i W_j c_{ij}^{-\alpha}}$
    - $c_{ij}^{-\alpha}$: Calculates distance 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: number of boats leaving infested waters carrying mussels

Dreissenid Mussel Modeling USACE/USBR Model



Integrated model

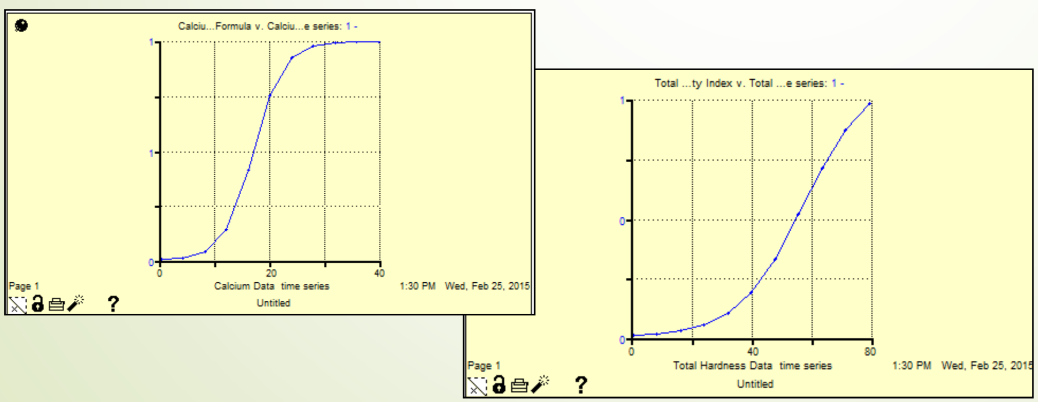


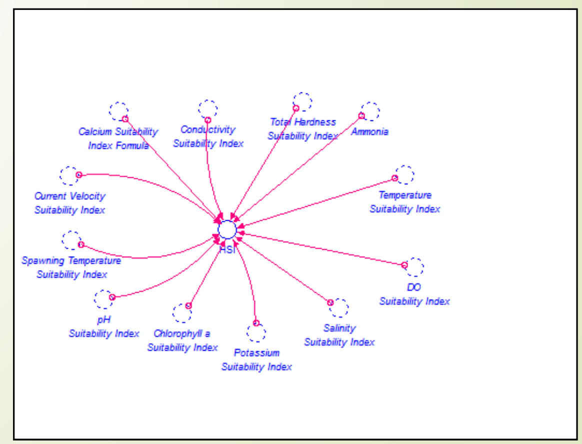
- Import GIS, and Environmental, and Dreissenid Mussel data into Netlogo framework
- Simulate seasonal boater movement patterns across watershed to determine which lakes are most likely to become infected

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
  - $HSI = \left(\prod_{i=1}^{4} SI_i\right)^{1/4}$





Dreissenid Mussels Dynamics

Dreissenid Mussel Model

- Probability of successful colonization in new water bodies depends on habitat quality

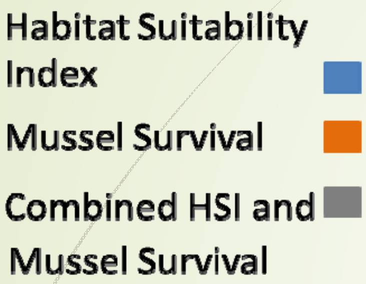
Parameter	Distribution Potential: Low-to-no	Moderate	High
Calcium	<15 mg/l	15-25 mg/l	>25 mg/l
pH	<7.3 or >9.0	7.3-7.5 or 8.7-9.0	7.5-8.7
Mean Summer Temperature	–	0-15° C	16-31° C
Maximum Temperature	<10° or >31° C	10-31° C	10-31° C
Dissolved Oxygen	<4 mg/l	4-8 mg/l	>8 mg/l
Salinity	>10 mg/l	5-10 mg/l	<5 mg/l

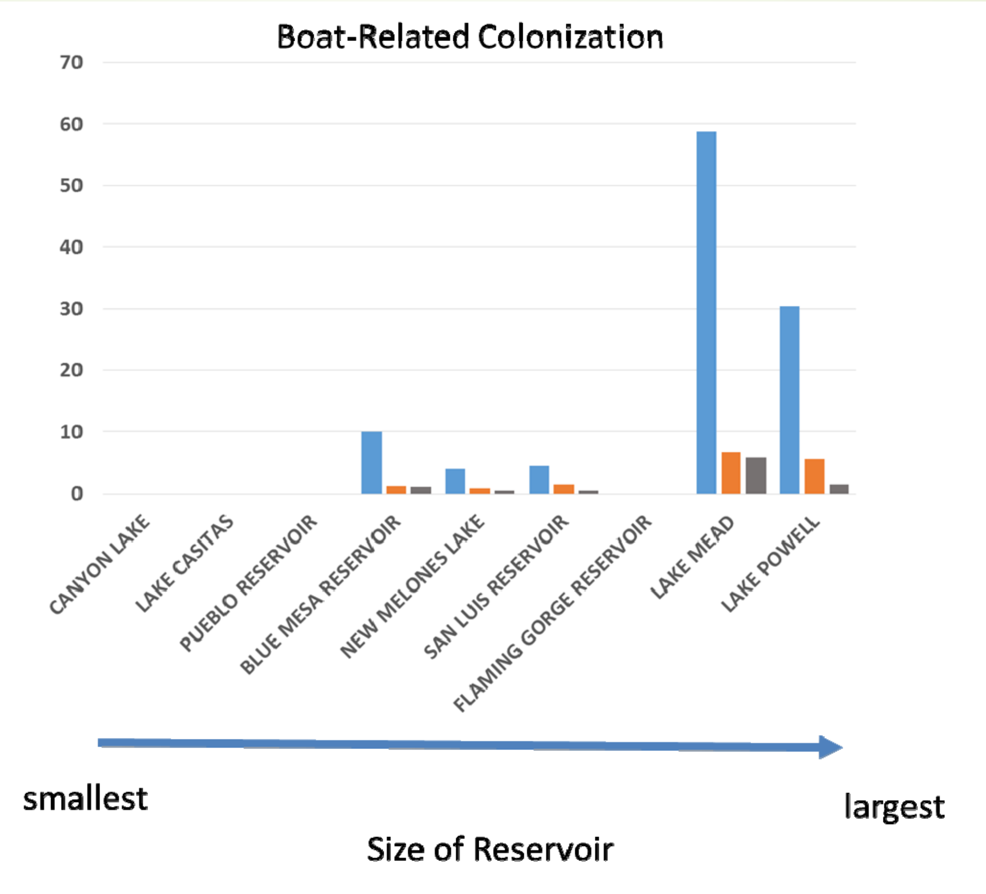
Quagga Mussel Environmental Requirements from California Study

Zebra Mussel Environmental Requirements (Baker et al. 1993a)

Parameter	Adult Survival	Adult Growth (possible)	Adult Growth (optimal)	Larval Growth (possible)	Larval Growth (optimal)
Temperature	0-33° C	6-30(?)° C	?	12-24° C	17-18° C
Salinity	0-12 mg/l	0-0.6 mg/l	?	0-? mg/l	?
pH	7.0-?	7.5-?	?	7.4-9.4	8.4-8.5
Calcium	?	?	34.5-76 mg/l	≥ 12 mg/l	40-? mg/l

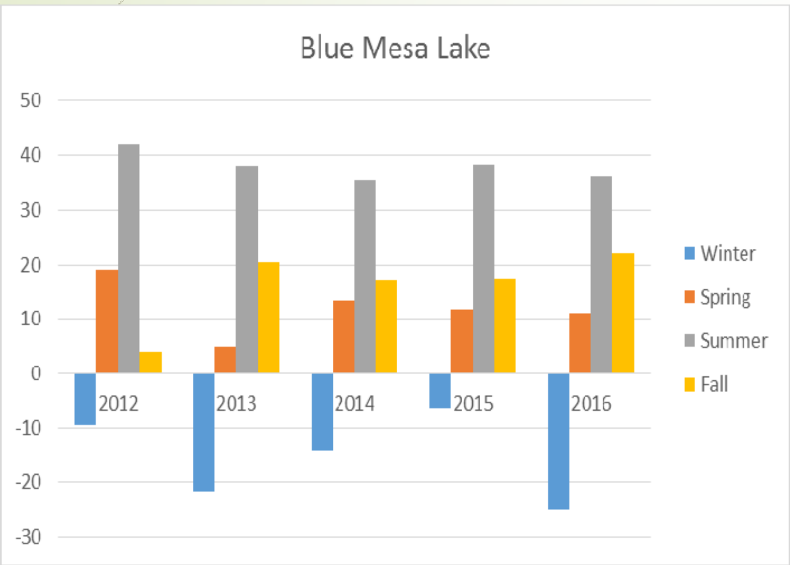
Initial Model Results for Lakes in Western US (9 reservoirs)

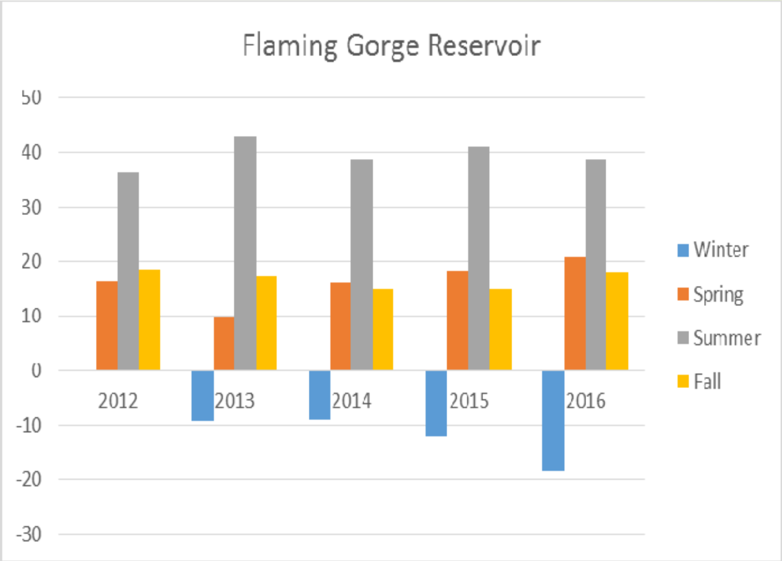




Environmental data

seasonal differences



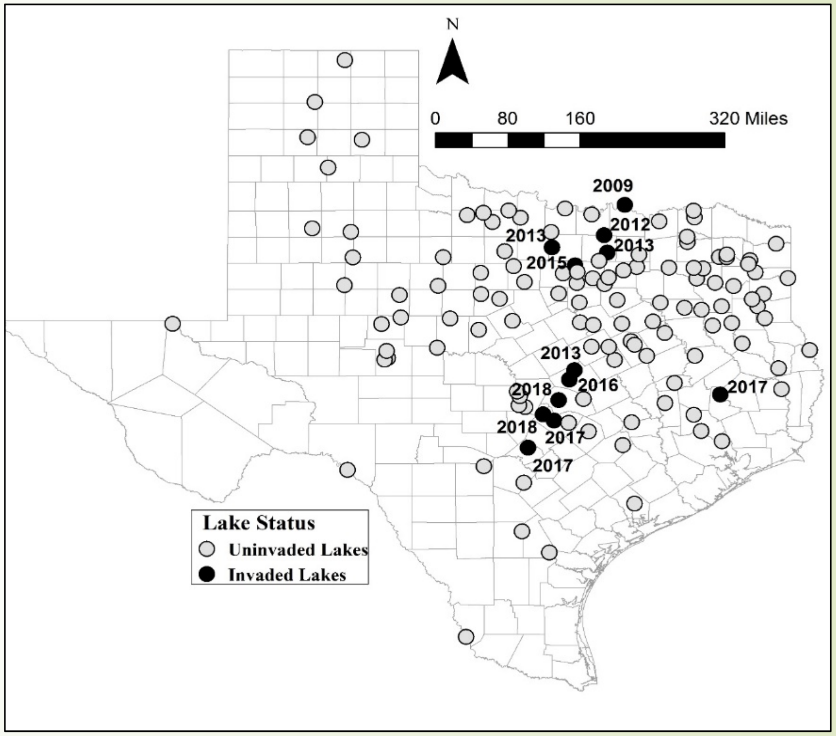


Initial Model – Lessons Learned

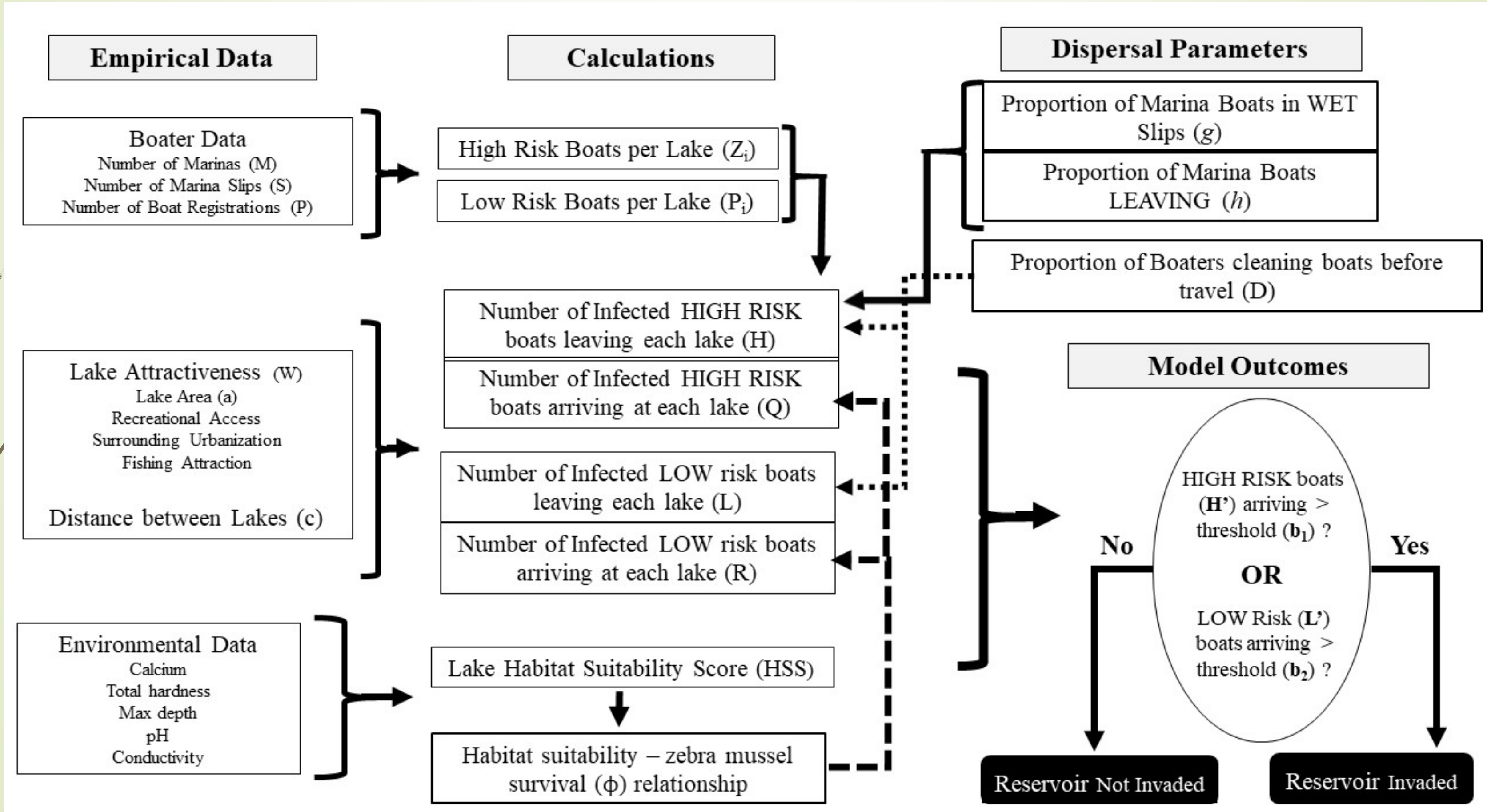
- Watershed complexity is hard to capture with 9 reservoirs: need to include more waterbodies of different sizes
- Gravity model needs further refinement: size and distance are not enough

Texas Zebra Mussel Model

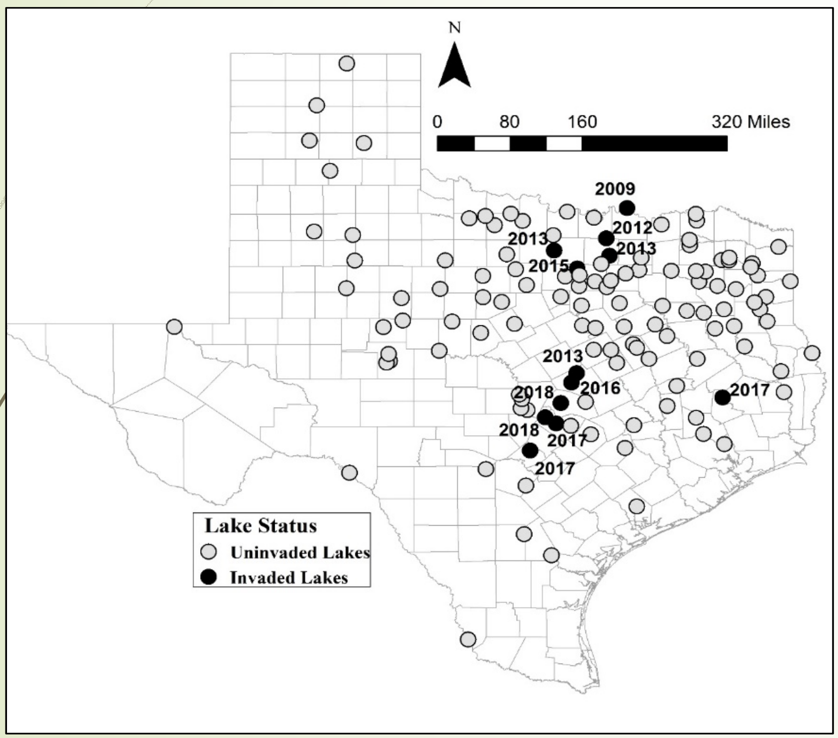
- Since 2009, more than 20 lakes across five river basins have been invaded.
- A constrained gravity model was developed to incorporate habitat suitability, risk of different boater types, and lake attractiveness.



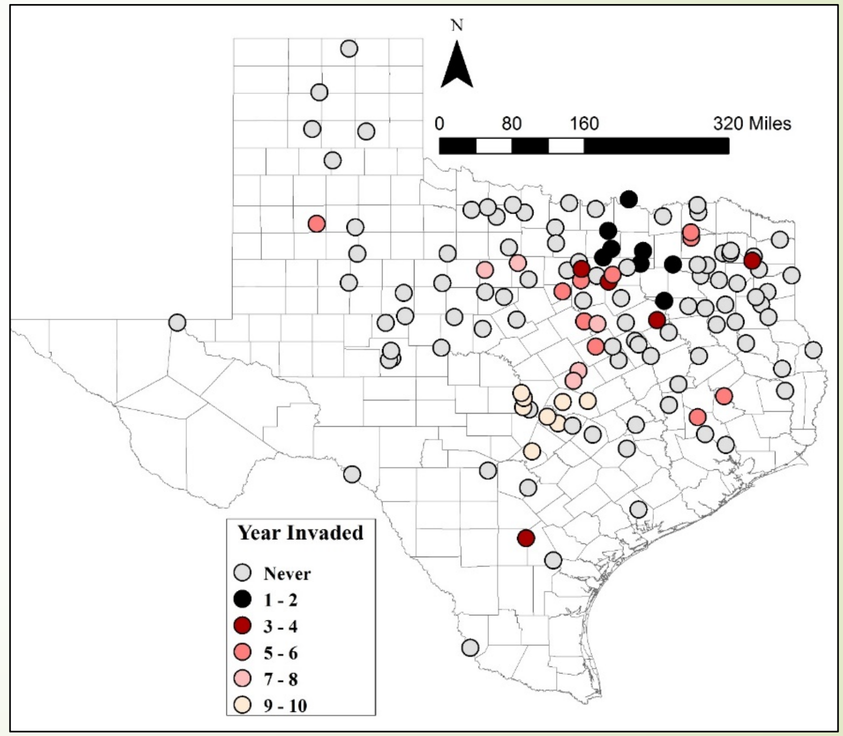
Dreissenid Mussel Modeling
Model Components and Database Development



TX Model

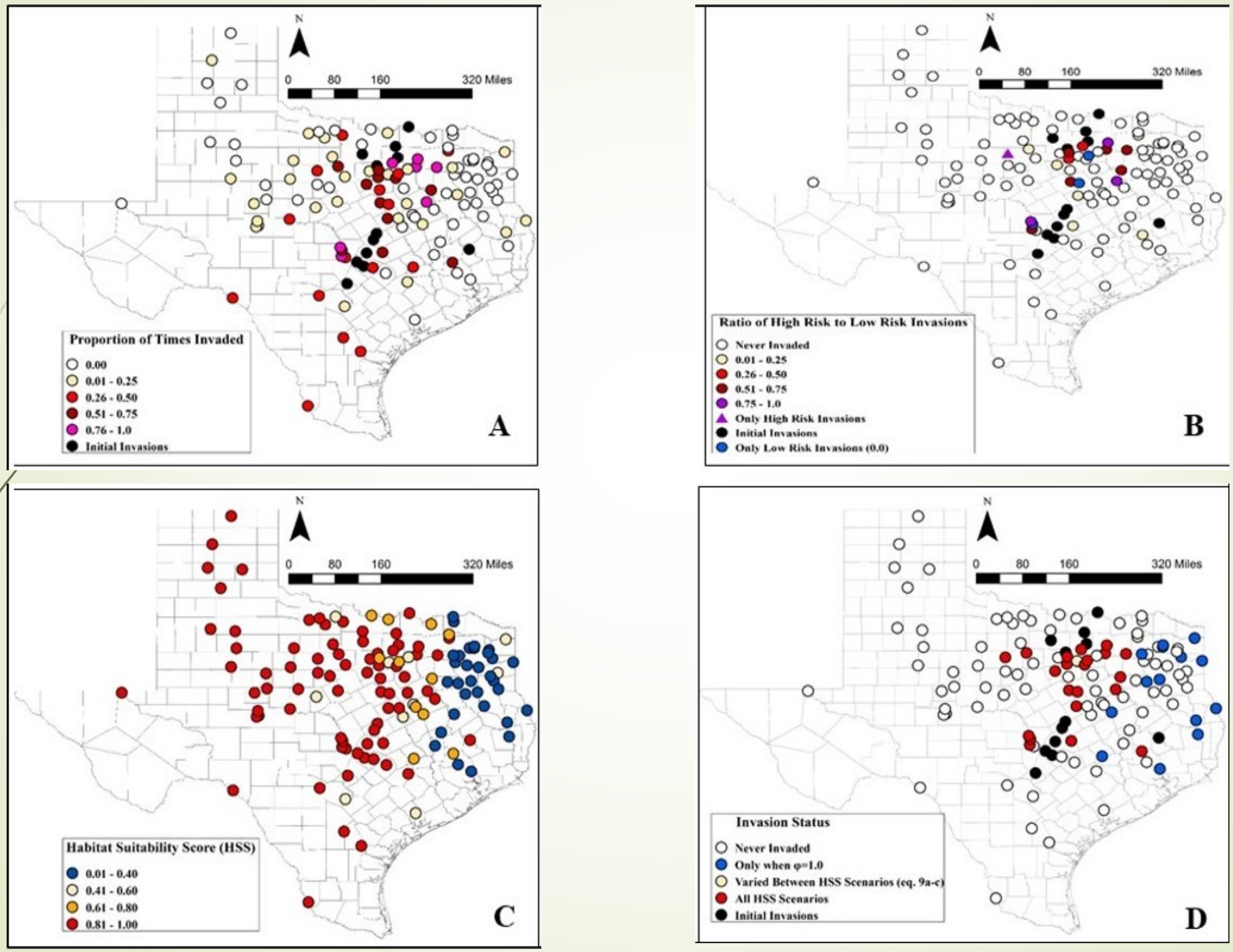


N
0
80
160
320 Miles
2009
2012
2013
2013
2015
2013
2016
2018
2018
2017
2017
2017
Lake Status
Uninvaded Lakes
Invaded Lakes

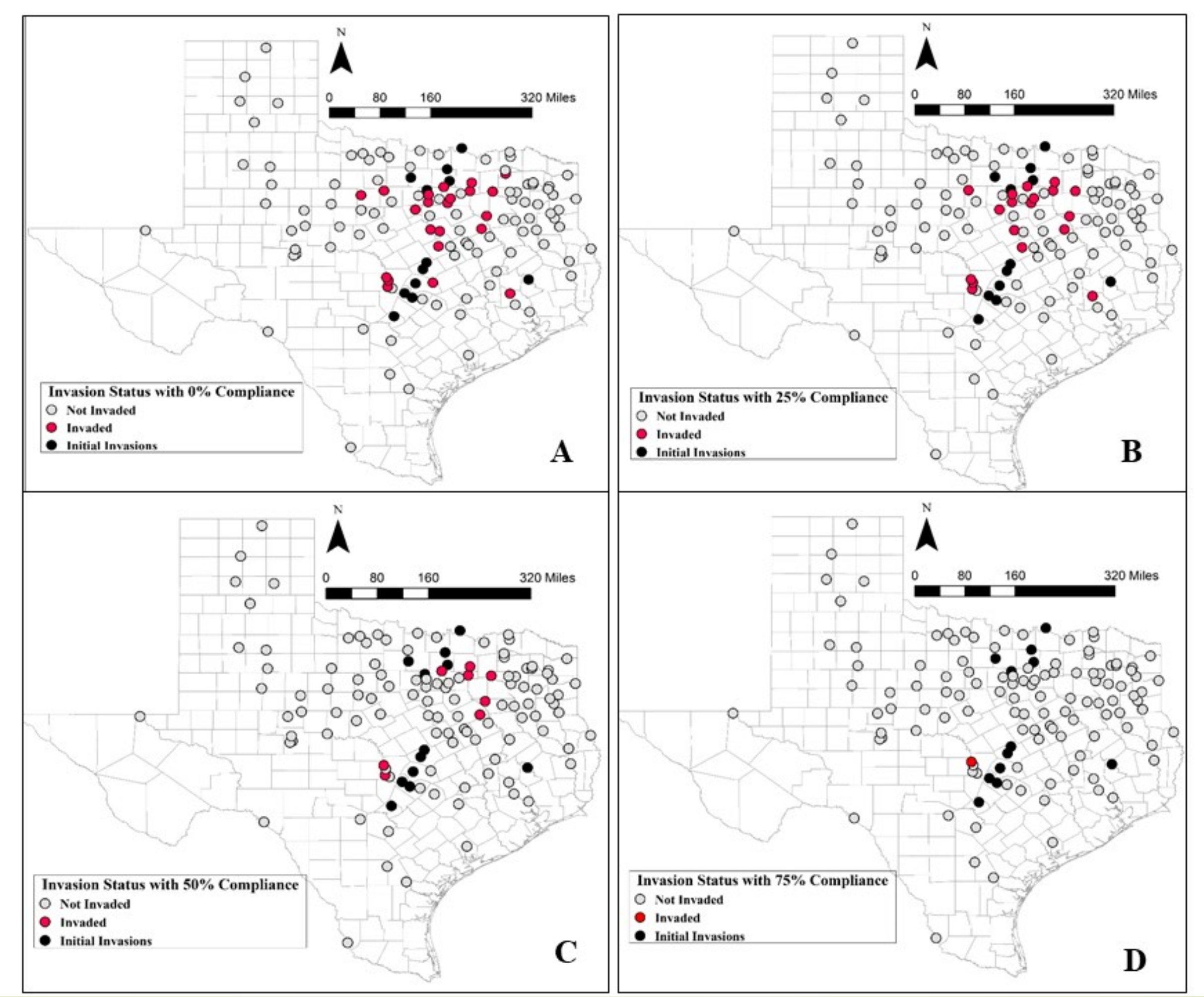


N
0
80
160
320 Miles
Year Invaded
Never
1 - 2
3 - 4
5 - 6
7 - 8
9 - 10

Results of Texas Model

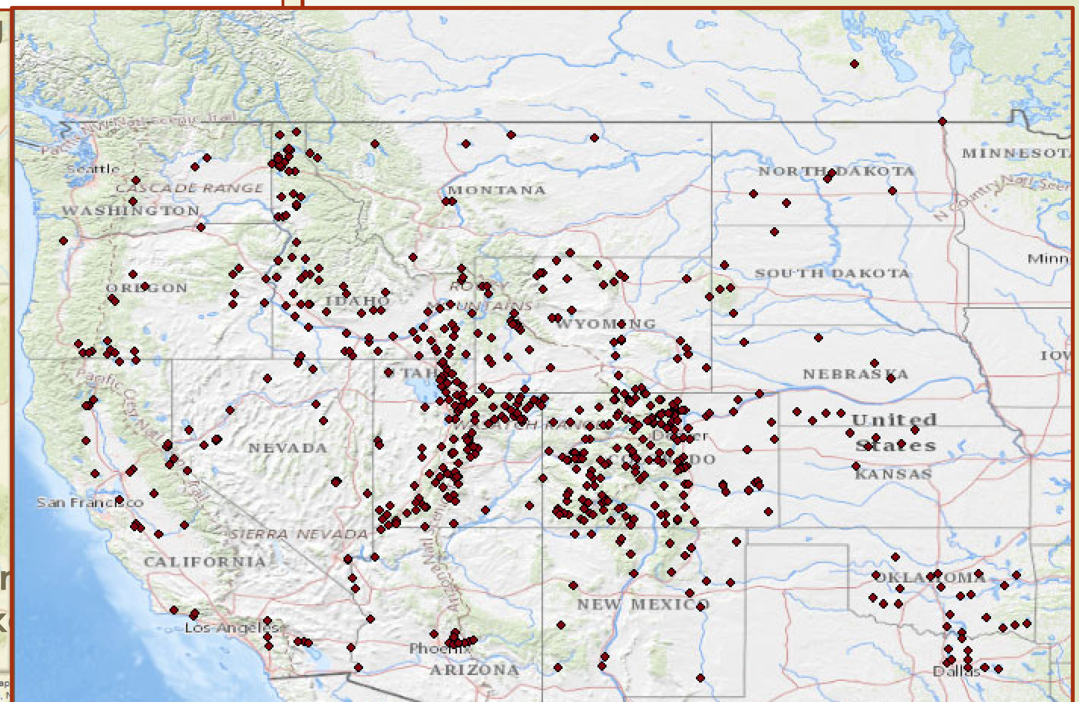


Importance of Management



Initially: Focused on a system of nine USBR Reservoirs in four regions:

- Mid Pacific Region
- Upper Colorado Region
- Great Plains Region
- Lower Colorado Region



Currently: Adding up to 600 additional water bodies that have been sampled for Dreissenid mussel presence

Model Updates

- Improve the way we quantify waterbody attractiveness
- Incorporate code that describes aesthetics

Take Home Messages

- Dreissenid mussel invasion = **Big problem**
  - Large ecological and economical consequences
  - Large geographic range from invasion
- Collaboration is crucial for understanding the invasion spread
- Incorporate a large number of different sized waterbodies to understand the spread
- Quantifying aesthetics of a region is important
- Management is dependent upon coordinated compliance
- Coordination is more critical when management crosses state lines

Acknowledgements

- Integrated Ecological Modeling team from the Engineer Research and Development Center
- The U.S Bureau of Reclamation
- Aquatic Nuisance Species Research Program, ERDC
- Texas Park and Wildlife

Questions?