Habitat Suitability and Distribution Modeling as Components of Integrated Risk Assessments

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USGS science for a changing world

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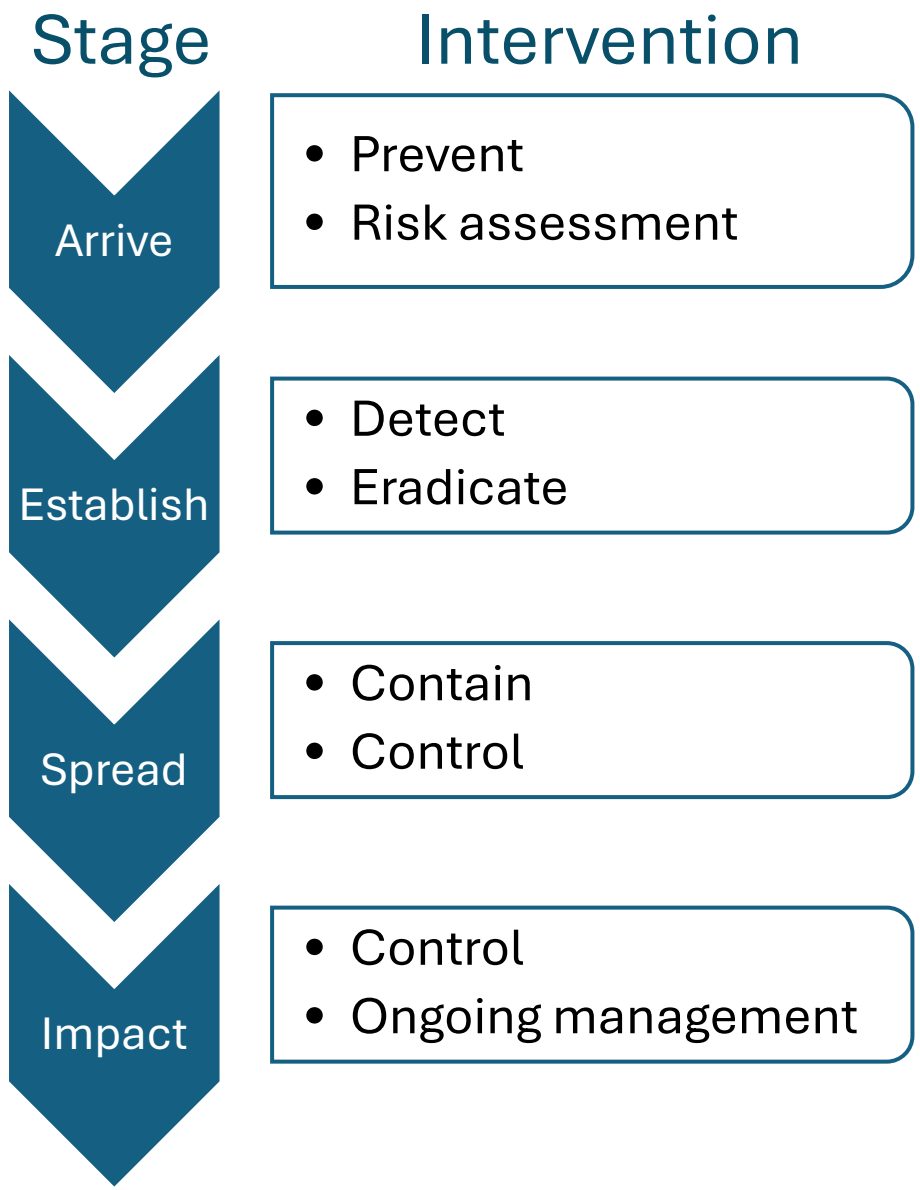
Environmental habitat and distribution modeling

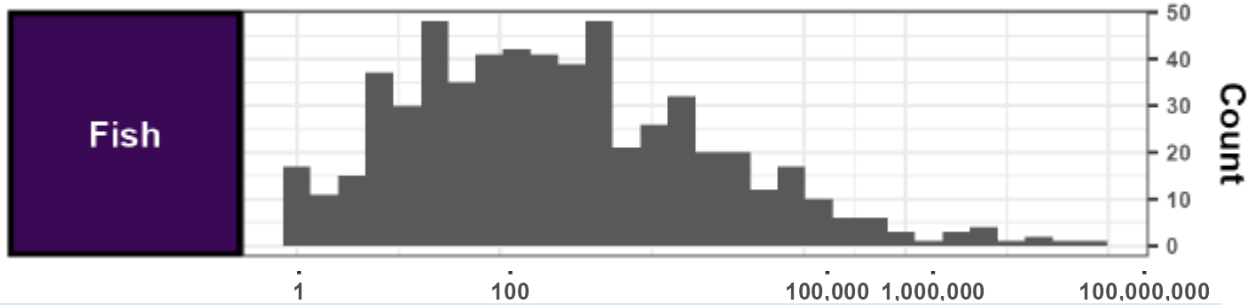
- Often the first step in risk assessments
- Assesses risk of establishment
- In comprehensive assessment also need components
  - Impact
  - Spread
  - Feasibility to intervene



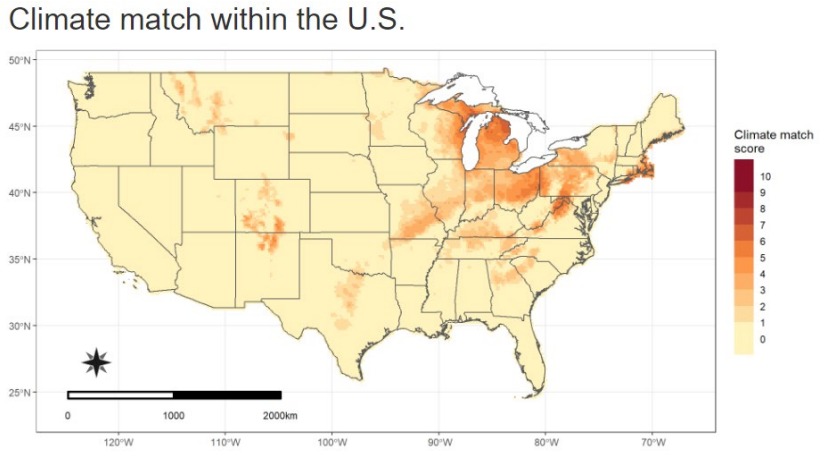
Impact – Horizon scans

- Negative, benign, or beneficial (Schlaepfer et al. 2011 *Con Bio*)
- Horizon Scans
  - National Horizon Scan
  - Southwest Regional Horizon Scan
    - Focal pathway
    - Boat hitchhiking

Arrive - Propagule pressure from import



Establish- 840 species (395 fish)



Impact – Expert evaluation (24 experts)

Invasion history
Human health or economic
Ecological

Daniel et al. Biological Conservation. *Accepted*

Spread

Credits: California Division of Boating and Waterways

- Many aquatic invasive species spread via the recreational boater pathway
- Zebra mussels aided by byssal apparatus and planktonic larval stage
- Free-swimming larvae carried in ballast water, and boat hulls
- Desiccation tolerance ~ 5 days

Objectives: Zebra mussel risk assessment

1) Establishment: Evaluate habitat suitability of water bodies in Texas and eastern New Mexico

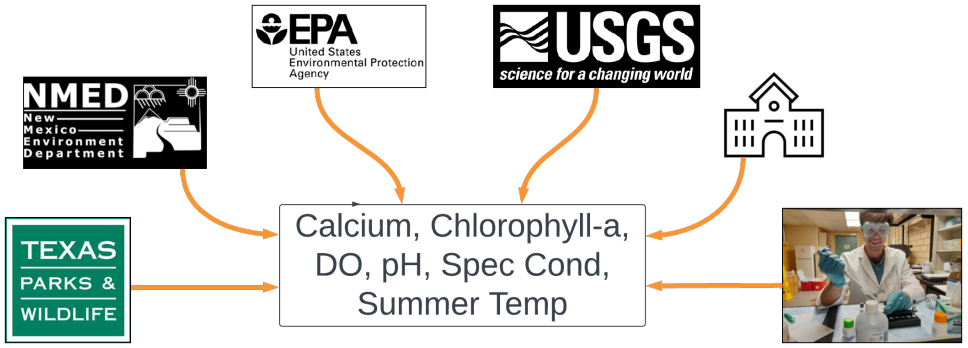
2) Spread: Determine the contribution of each lake to overall lake network connectivity

3) Prioritization: Combine both elements and identify critical lakes to zebra mussel invasion

Study area

Co-authors: D. Creamer, R. Patino, M. McGarrity

Establishment: Habitat Suitability Index

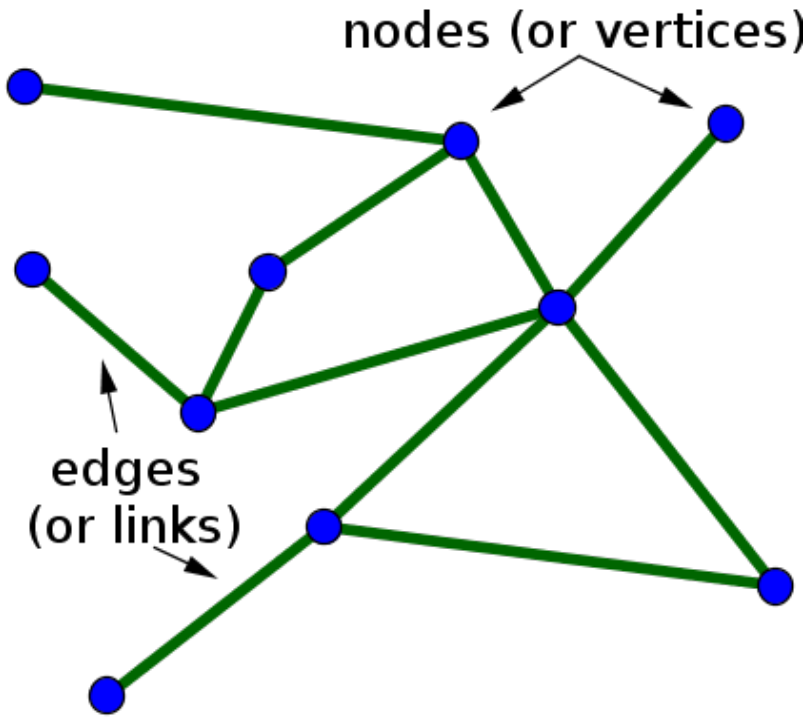


Parameter	Unsuitable (0)	Low Suitability (.33)	Moderately Suitable (.66)	Highly Suitable (1.0)
Calcium (mg Ca/L)	< 8	8-15	15-30	> 30
Chlorophyll-a (µg/L)	< 2.0 or > 25	2.0-2.5 or 20-25	8-20	2.5-8
Dissolved Oxygen (mg/L)	< 3	3-7	7-8	> 8
pH	< 7.0 or > 9.5	7.0-7.8 or 9.0-9.5	7.8-8.2 or 8.8-9.0	8.2-8.8
Specific Conductance (µs/cm)	< 30	30-60	60-110	> 110
Summer Water Temperature (C)	< 10 or > 32	26-32	10-20	20-26

Credits: Adapted from Mackie and Claudi (2010)

Spread: Lake Connectivity

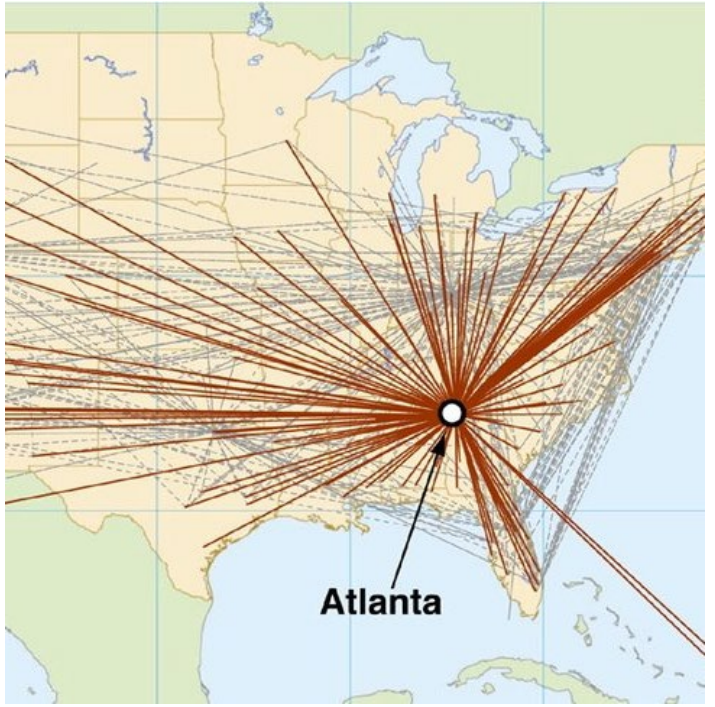
- Network analysis to represent flow of organisms between locations of topological importance
  - Nodes are lakes
  - Edges are roadways
- Maximum edge distance 363 km
  - Lakes within this distance of each other are connected
- Three centrality measurements to describe connectivity
  - Degree score, betweenness score, and cutpoints

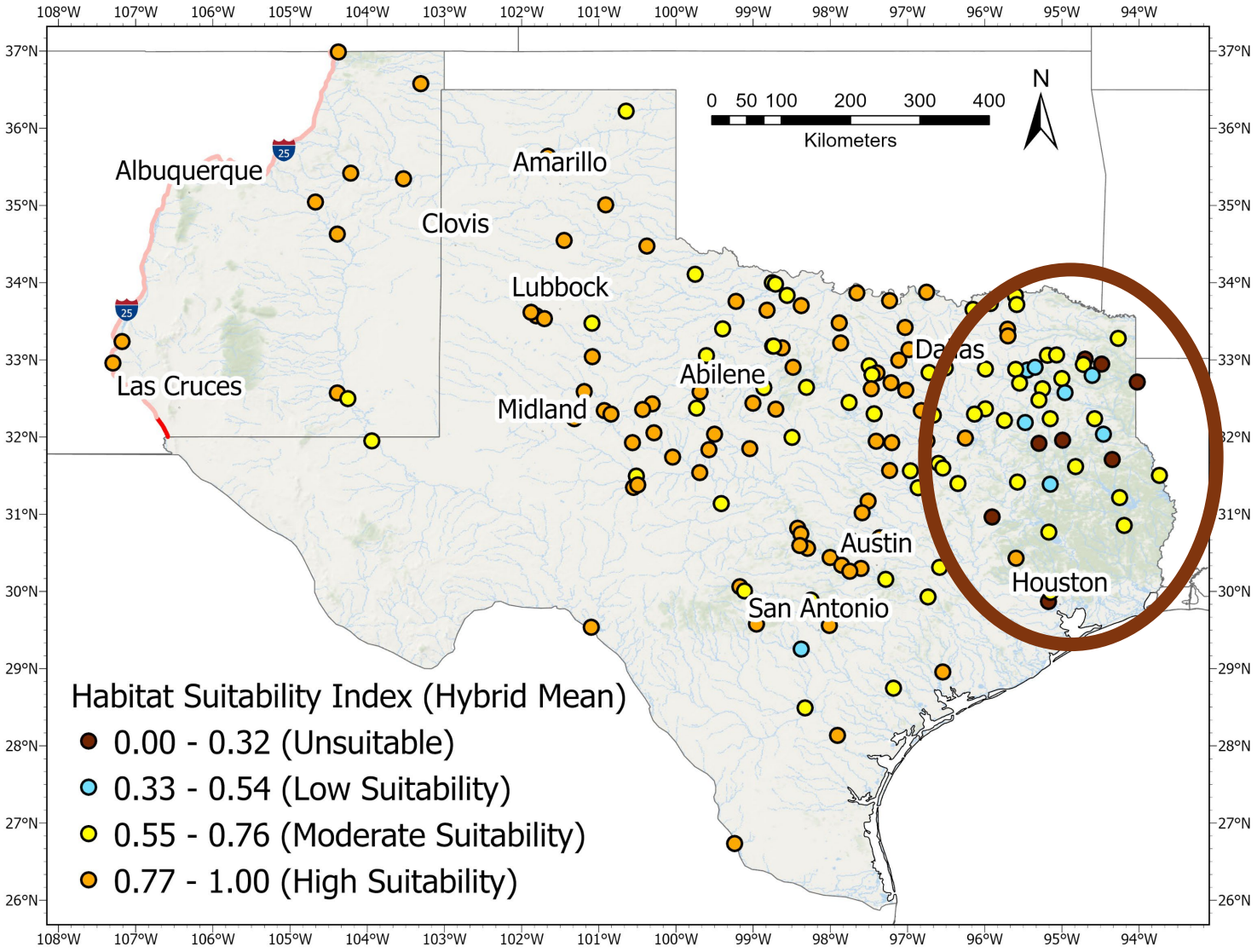


Credits: ©DQ Nykamp, *Math Insight*

Hubs, stepping stones, and cut points

- Degree score is the number of connections to other lakes -> **hub**
  - A highly connected lake is more likely to be invaded and become a hub for further spread
- Betweenness is the frequency a lake is located on the shortest path between two lakes -> **stepping stone**
  - A disproportionate amount of flow within the system will go through these lakes
- Cutpoint is when removal of the lake causes a continuous network to break into isolated parts

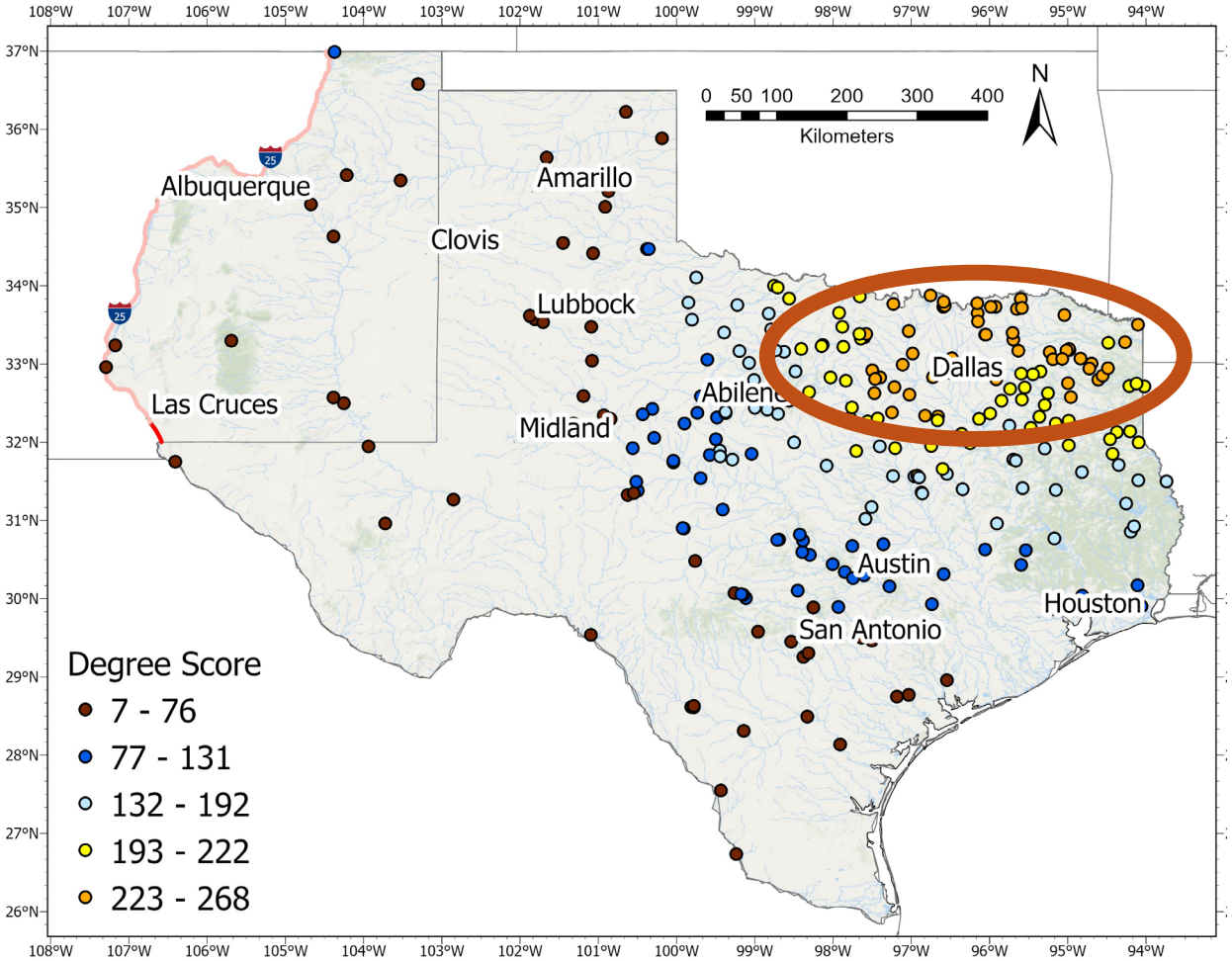




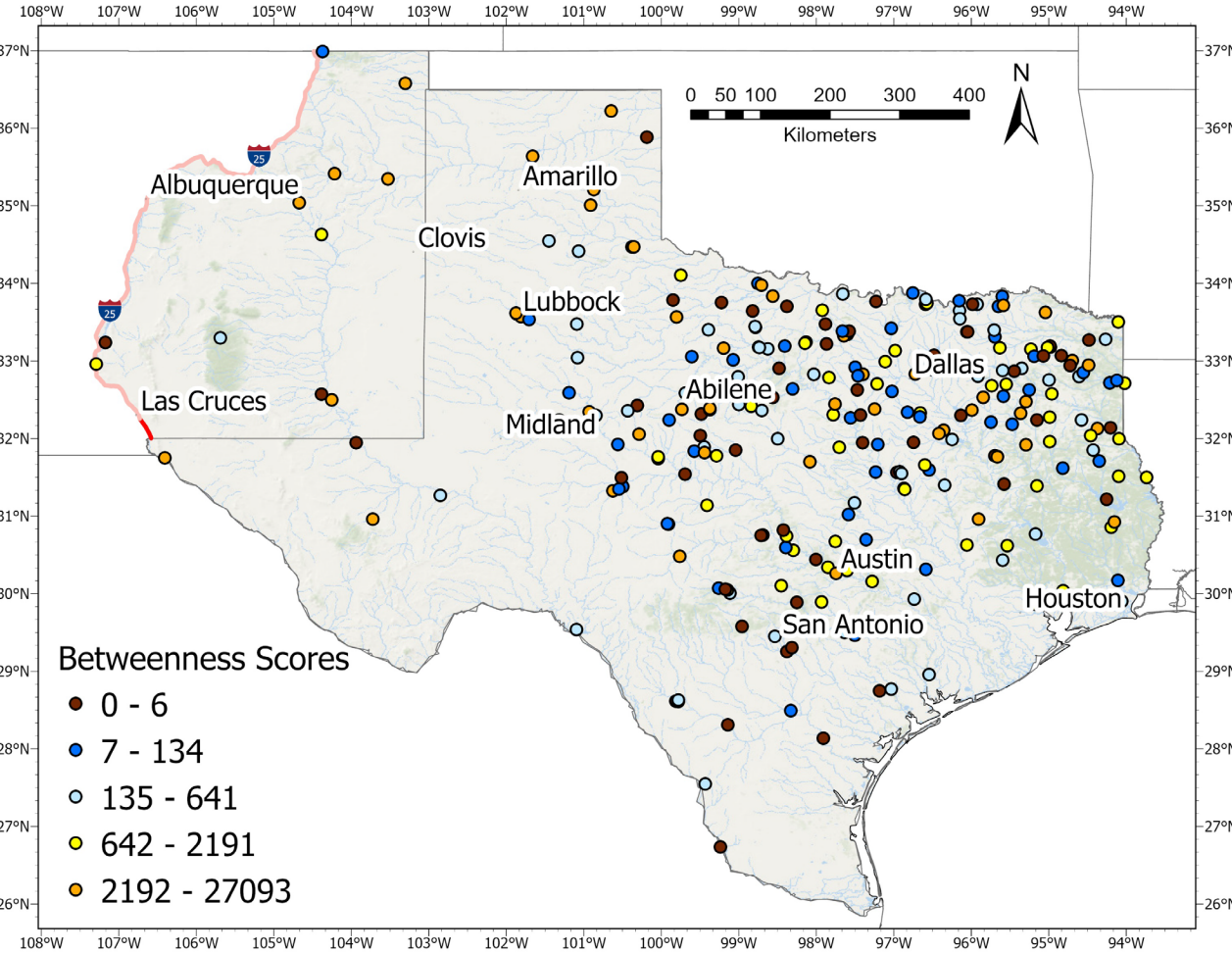
Habitat Suitability Results

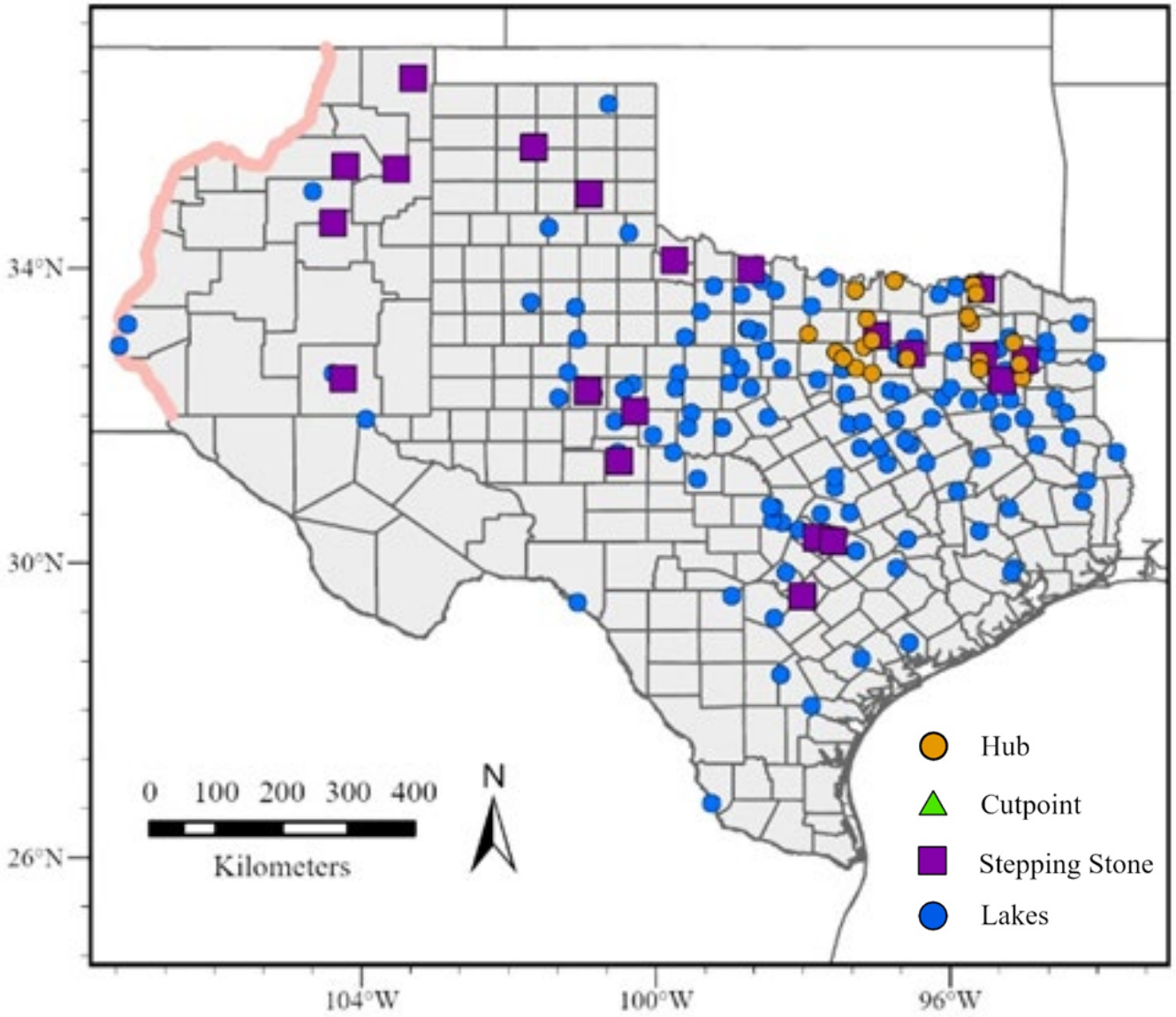
Results: Network Analysis

Hubs



Stepping stones





Critical lakes

- Habitat and centrality measures not correlated
- Moderately or highly suitable habitat HSI > 0.33
- Hubs: Top 20% Degree Score
- Stepping stones: Top 20% Betweenness Score

Model validation

- Infestation status and
  - habitat suitability index ($r = 0.32$, $p < 0.001$)
  - network centrality scores ($r = -0.15$, $p = 0.34$)
- Water samples from 20 lakes for eDNA predicted by network and another model
  - No new detections

Discussion

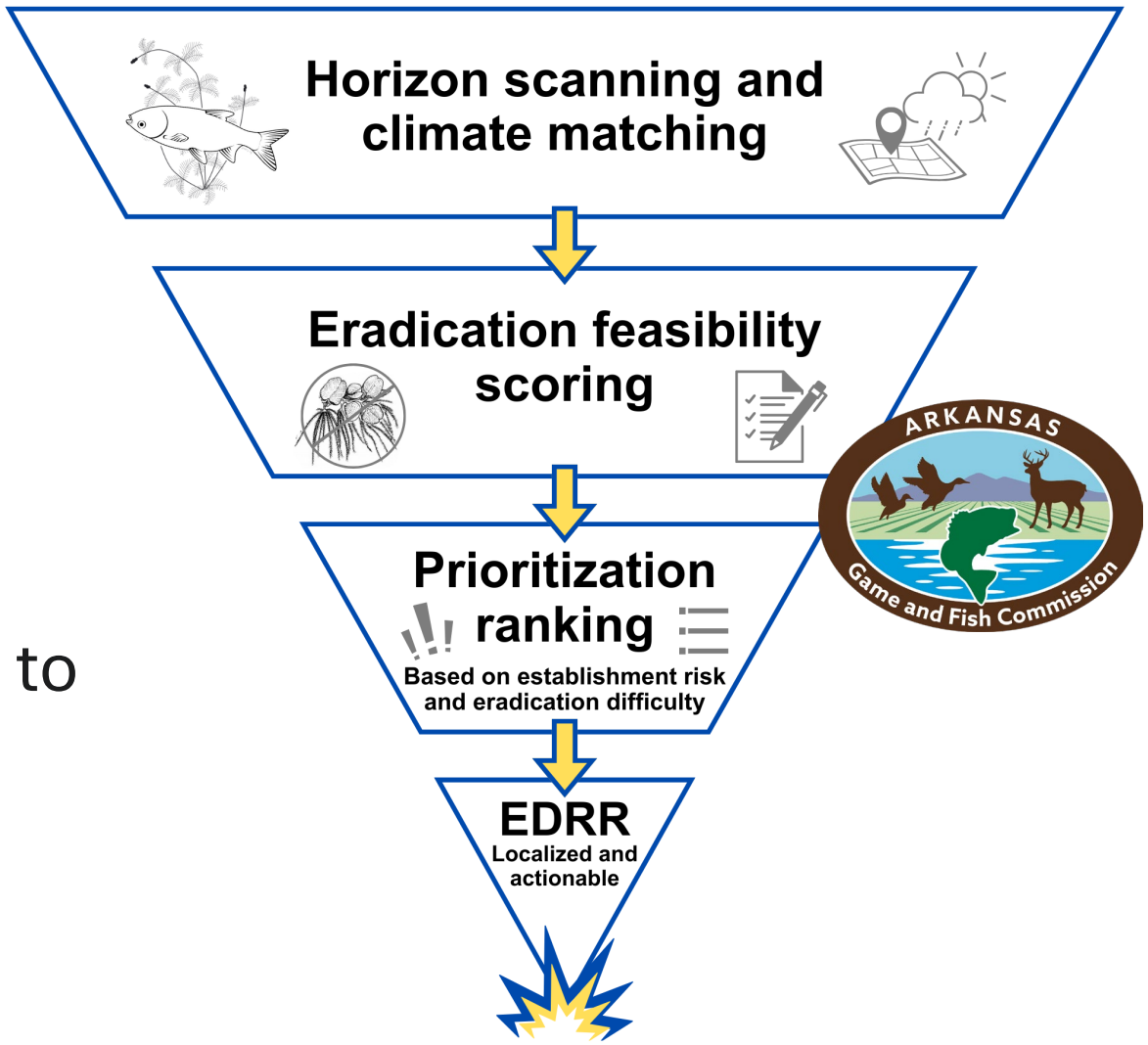
- Study area lake habitat is broadly suitable in western Texas
  - Rarity of aquatic habitats will slow down dispersal?
- Highly connected network
    - Multiple pathways of dispersal and stepping stones
- No correlation between centrality metrics and infestation status
  - Others have found correlation (Kao et al. 2021 *Biological Invasions*)
- Habitat suitability good indicator of establishment BUT
  - Other criteria necessary to help prioritize limited resources

Feasibility to intervene

- Invasive species management is driven by practicality as well as by the ecology of a species (Osunkoya et al. 2019 *J Env Mgmt*)
- Eradication feasibility- the realistic ability of managers to eradicate a species within predetermined spatial boundaries
- Giant salvinia as model species
  - Cost-efficient treatments are available to eradicate small populations
  - Ecological cost of no management intervention is high
  - Incipient invasion across the southeastern United States

Objectives

- Establishment: estimate distribution probability under current and future climates
- Intervention: score waterbodies according to difficulty of eradicating
- Prioritization: combine both elements to rank waterbodies

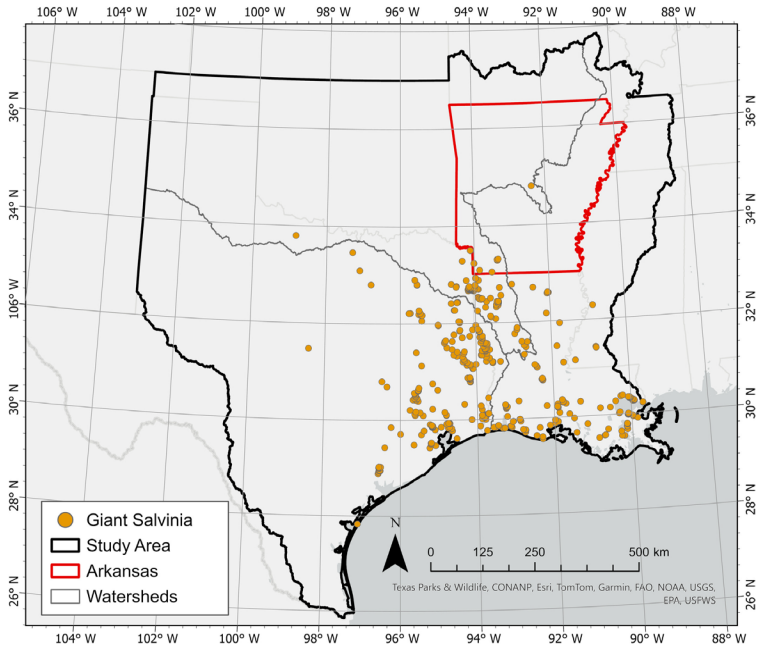


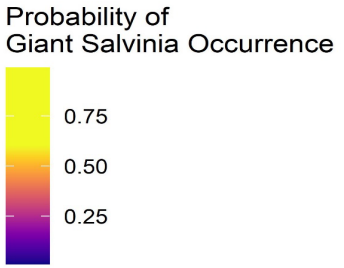
Roberts et al. 2024 *Ecological Solutions and Evidence*

Establishment Risk

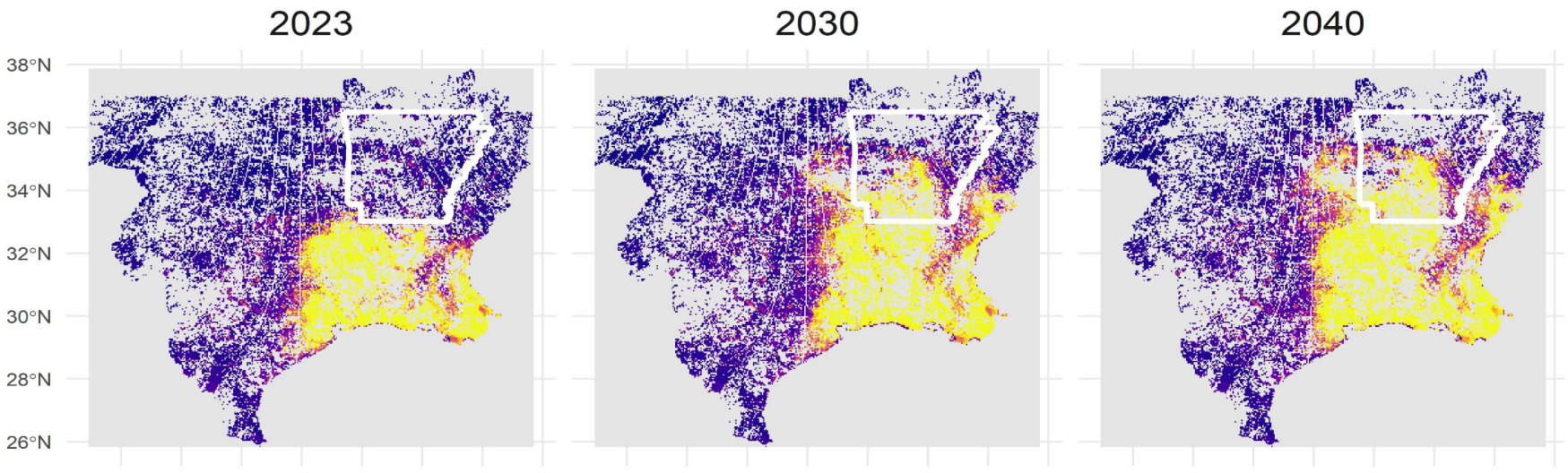
- Inputs
  - WQ
  - Anthropogenic
  - Climate
  - Occurrence data
- Output
  - Probability of occurrence
  - Future RCP 8.5 (business as usual) to year 2090

Current occurrences





Future predictions

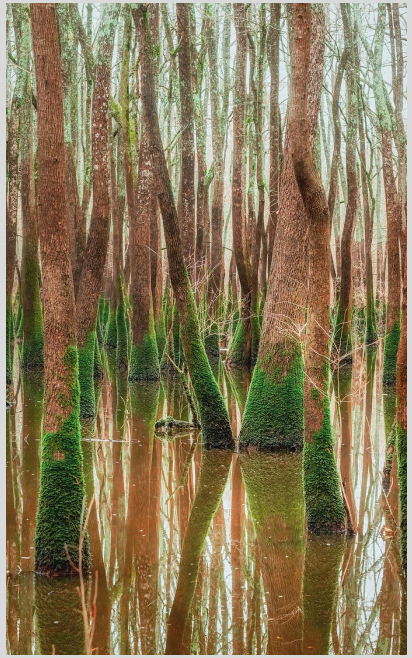


Eradication difficulty

- Waterbody size
- Habitat complexity
  - Woody wetland and herbaceous wetland
- Ownership
  - Private/public
- Most difficult
  - Larger water bodies
  - High habitat complexity
  - Private land ownership

Waterbody size

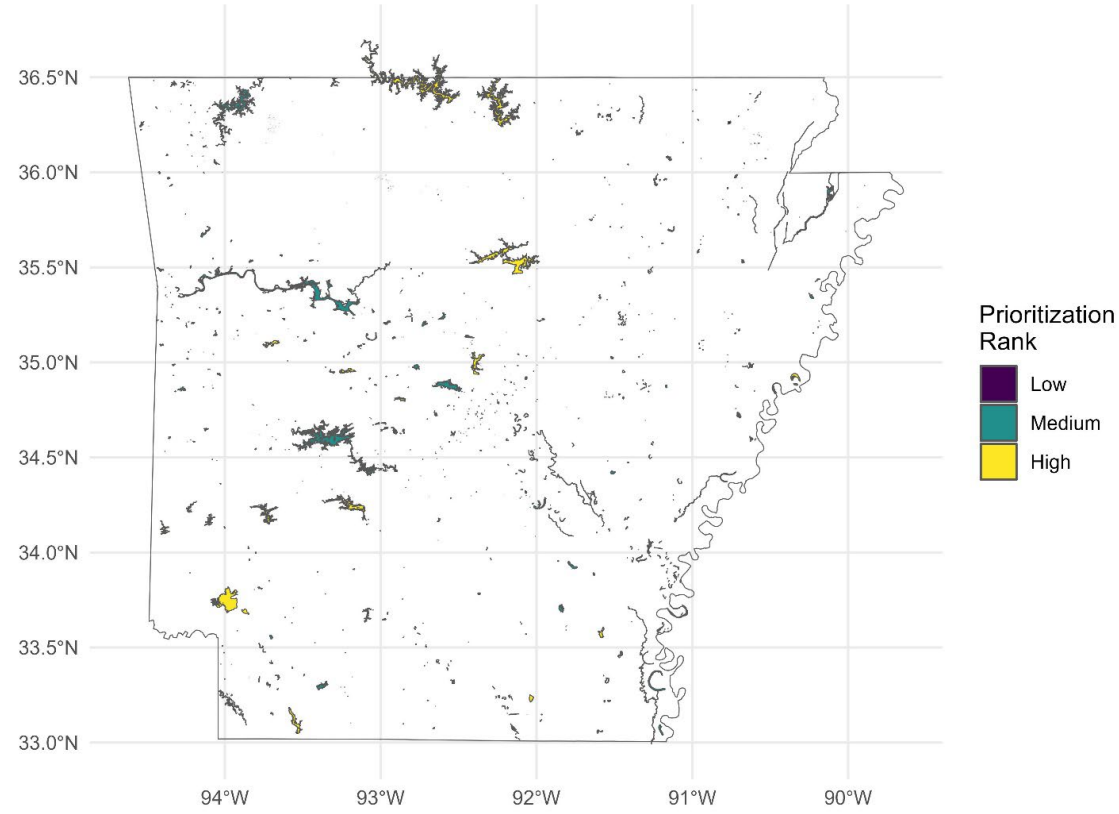
Habitat complexity

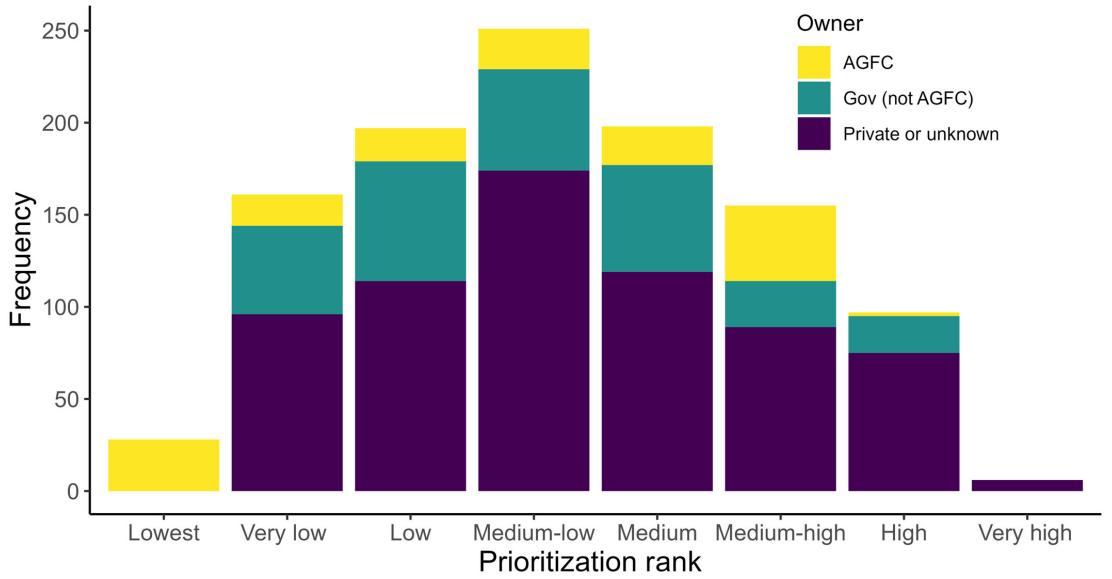


Ownership

Prioritization

- Establishment risk and eradication feasibility not correlated
- Eradication feasibility heavily depends on landownership
- Co-production of establishment and eradication criteria
- Climate change moving target





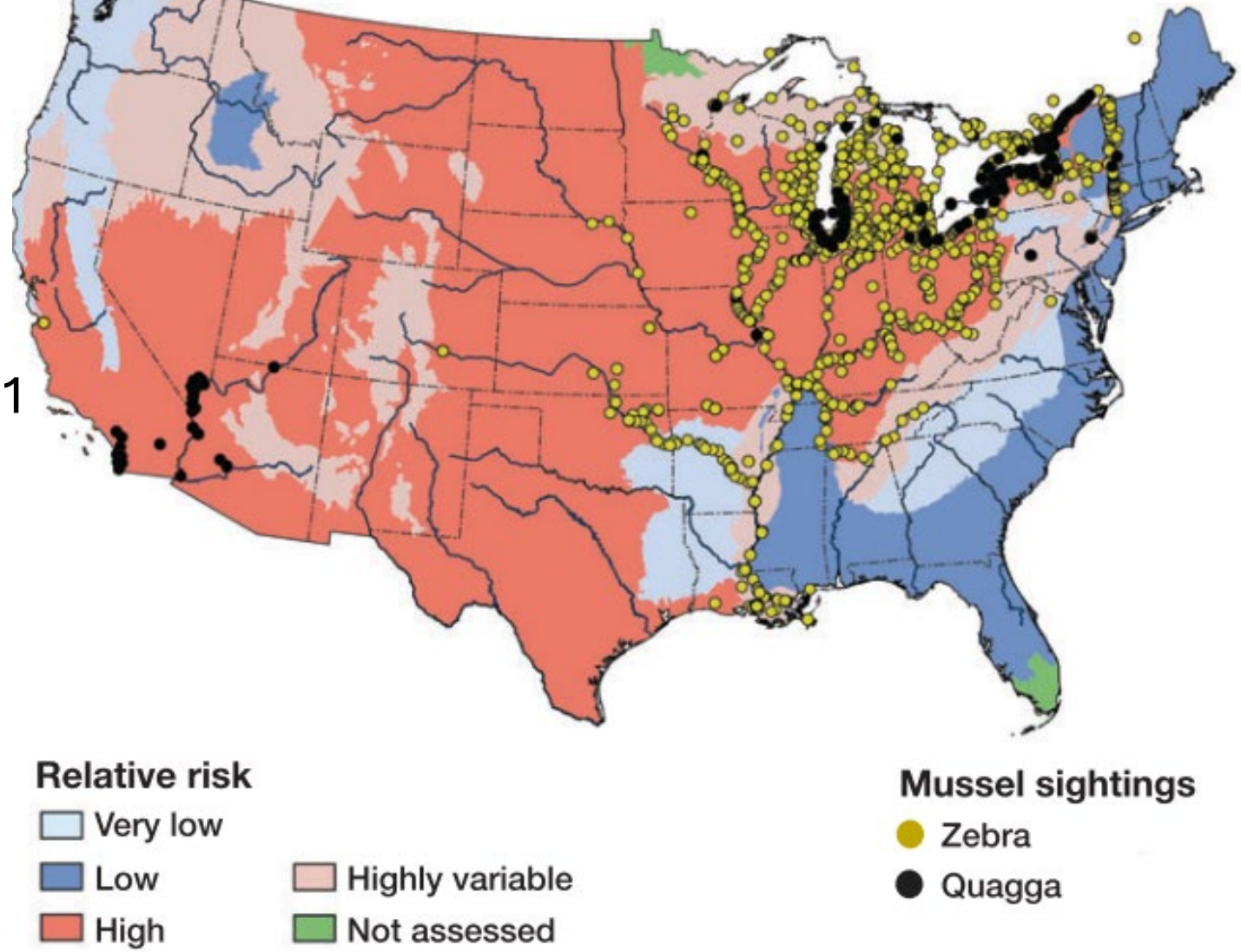
Why shouldn’t we rely on habitat suitability modeling?

- Low transferability of SDM, especially for AIS (Liu et al. 2020 *Eco Letters*)
- Correlative models underestimate potential for species establishment by
  - not accounting for adaptation
  - Using broadly available but not proximally causal predictor variables
- Species are relatively rare at start of invasion process
- Ignores other stages of invasion
  - Need to consider spread, impact, or management interventions to create actionable prioritizations

Best information available

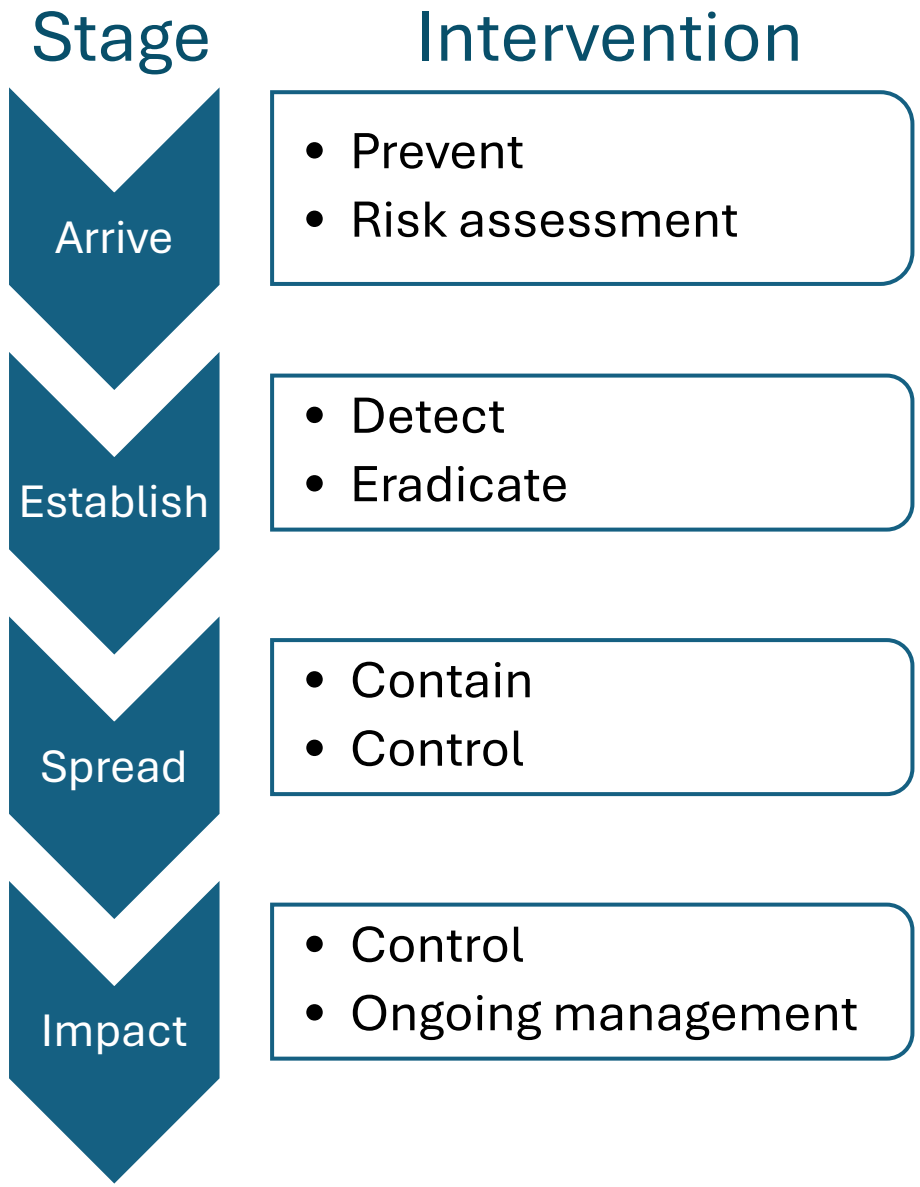
- If tied to underlying processes can be more accurate
- Improvement to zebra mussel occurrence predictions
  - Boat ramps (Rodriguez-Rey 2021 *Biological Invasions*)
  - Calcium (Whittier et al. 2008 *Frontiers in Ecology and the Environment*)

Calcium-based risk assessment by Whittier et al.



Conclusions

- Recognize there will always be unaccounted aspects of establishment, spread, and intervention feasibility in risk assessments
- Critical to measure success and continually reassess any decision support tool



Future directions in AIS research

- Comparing invasive species dispersal models
  - Validation and improving applicability
- Hotspot analysis and evaluation of eDNA to detect coastal invasive species and SGCN in Red River
  - Improving estimation and detection of rare species
- Trade-offs of native and non-native species with flow-alteration in Pecos River
  - Incorporating nonstationarity under environmental change in ecosystem dynamics

Thank you!

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