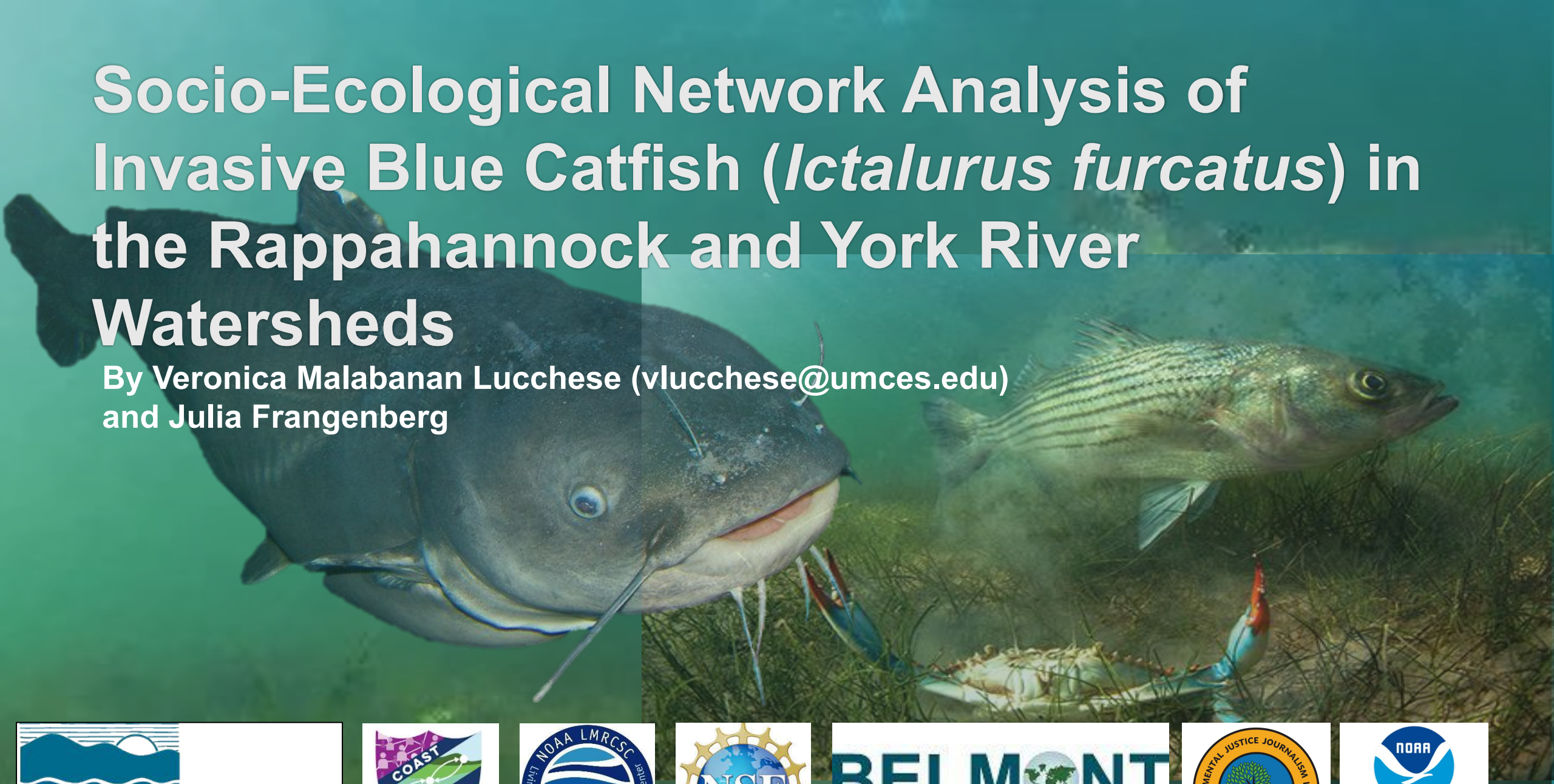
Socio-Ecological Network Analysis of Invasive Blue Catfish (*Ictalurus furcatus*) in the Rappahannock and York River Watersheds

By Veronica Malabanan Lucchese (vlucchese@umces.edu) and Julia Frangenberg



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Comparison of the York and Rappahannock watersheds can reveal local versus broader fisheries trends.

Similarities

- Prolific Blue Catfish Population
- Sport Fishing Destination
- Important Fisheries Habitat
- Rich Indigenous History that Endures Today

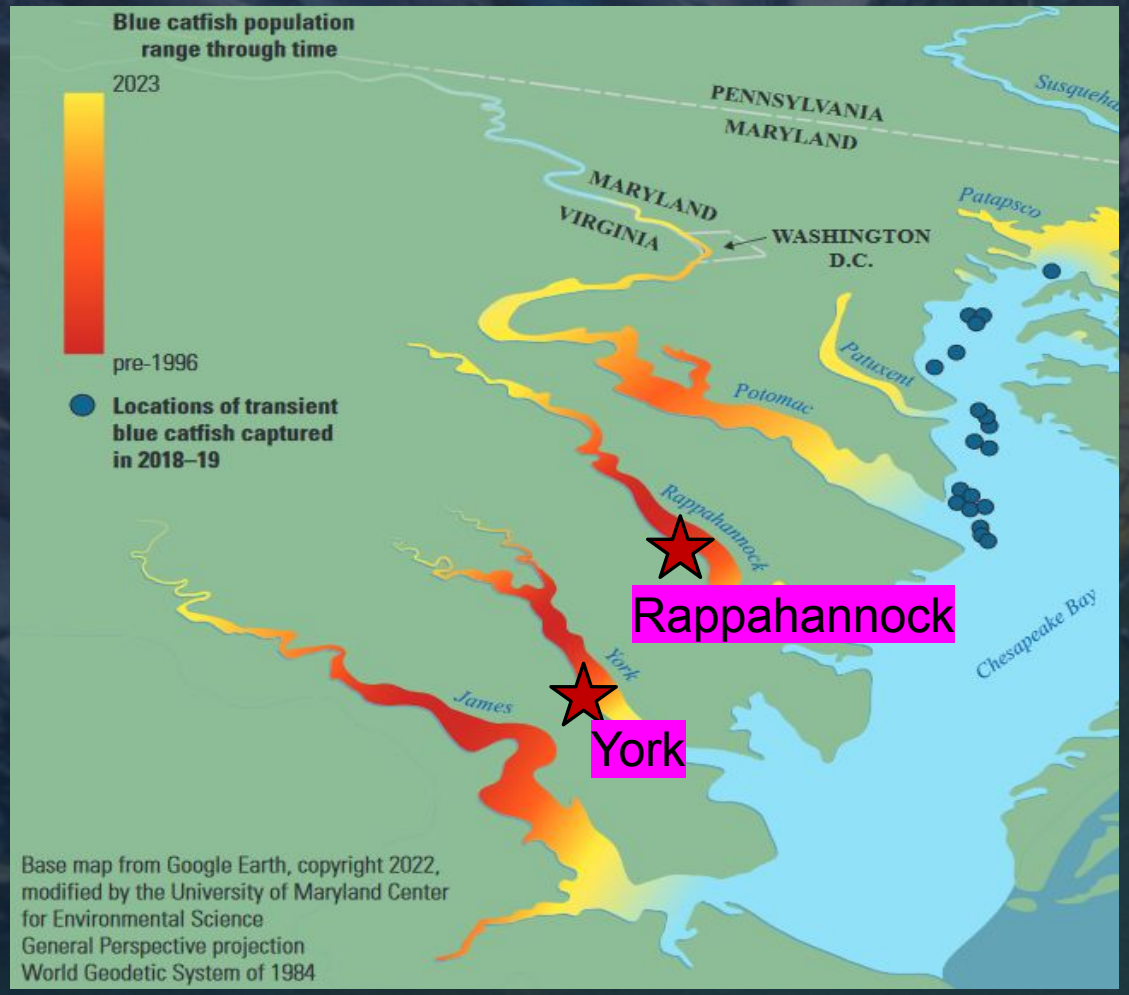
Differences

York

- Larger area and population
- More Urbanization
- NOAA Habitat Blueprint Region

Rappahannock

- Smaller area and population
- Data Center Alley

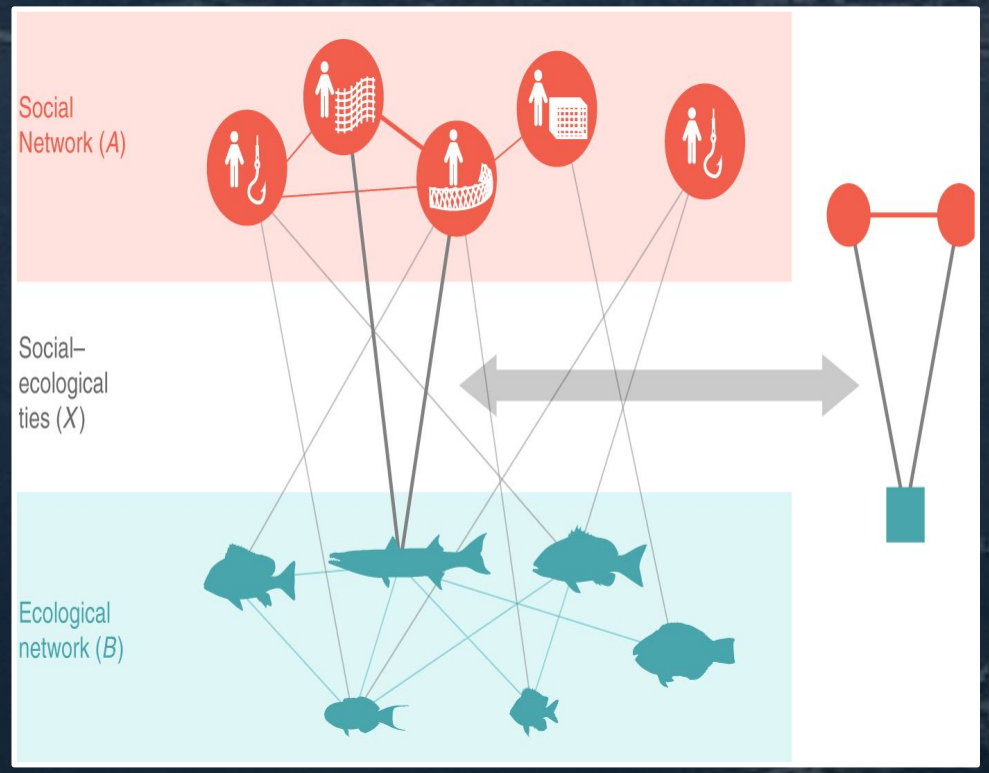


(Felver, 2017; Liu & Fisher, 2020; Chesapeake Bay Program, 2020; Robertson et al., 2024; Buchanan, 2025)

Socio-Ecological Network Analysis uses diverse data to help evaluate and manage fishery connections.

(Folke, 2006; Barnes et al., 2017; Berkes, 2017; Sayles et al., 2022)

Network Analysis uses centrality measures to quantify actors or species relationships



Degree Centrality

Measures the importance of a node by the number of its direct connections.

Betweeness Centrality

Measures the number of shortest paths between nodes. Identifies bridges or flows of information.

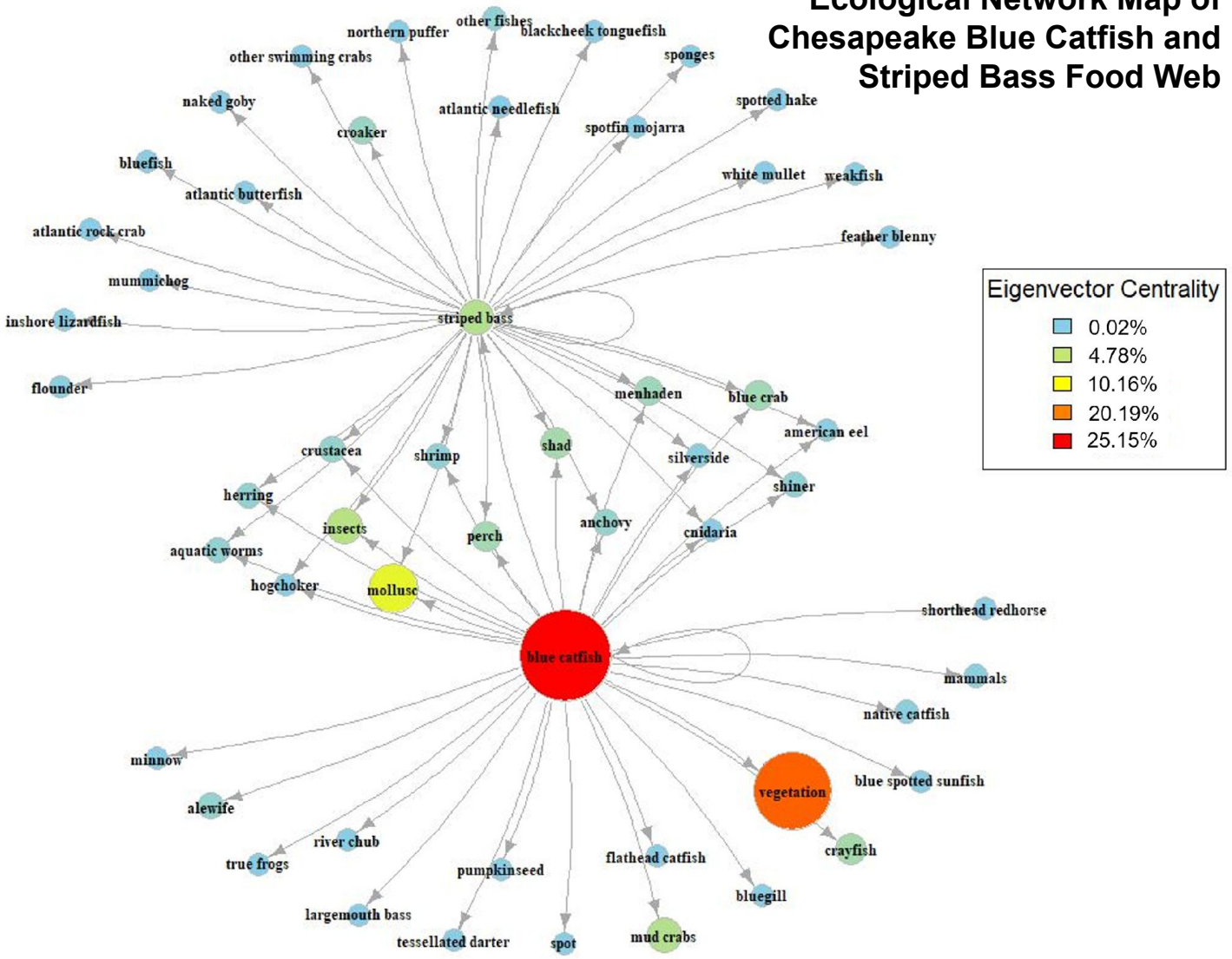
Eigenvector Centrality

Measures a node's connection to other highly connected nodes. Indicates influence.

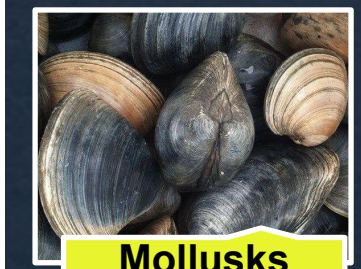
(Lizardo; Newman, 2018; Wolitzky, 2022; Lee, 2025)

Invasive Blue Catfish are more influential in Chesapeake Striped Bass habitat.

Ecological Network Map of Chesapeake Blue Catfish and Striped Bass Food Web

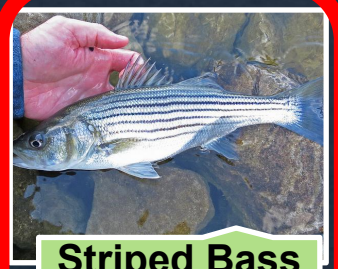


Most Influential Shared Prey Species

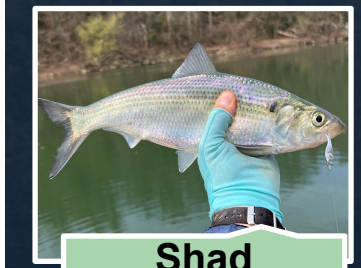


Mollusks (10.2%)

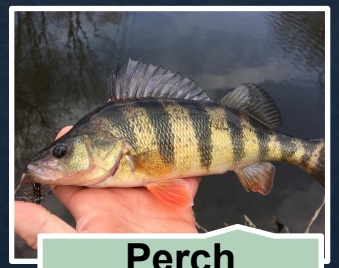
Insects (5.1%)



Striped Bass (4.8%)



Shad (3.3%)



Perch (3%)

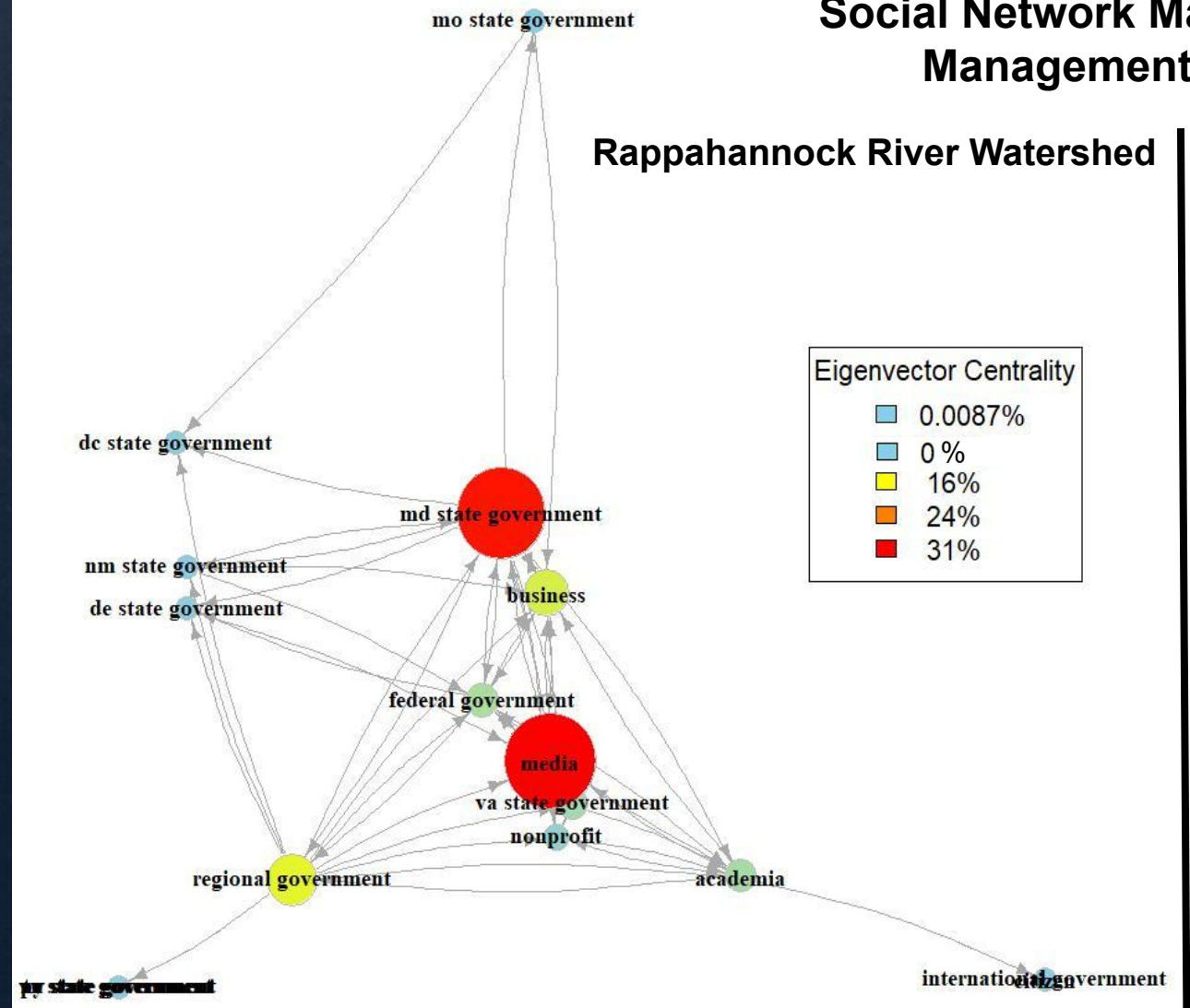
Blue Crab (2.8%)

Menhaden (2.3%)

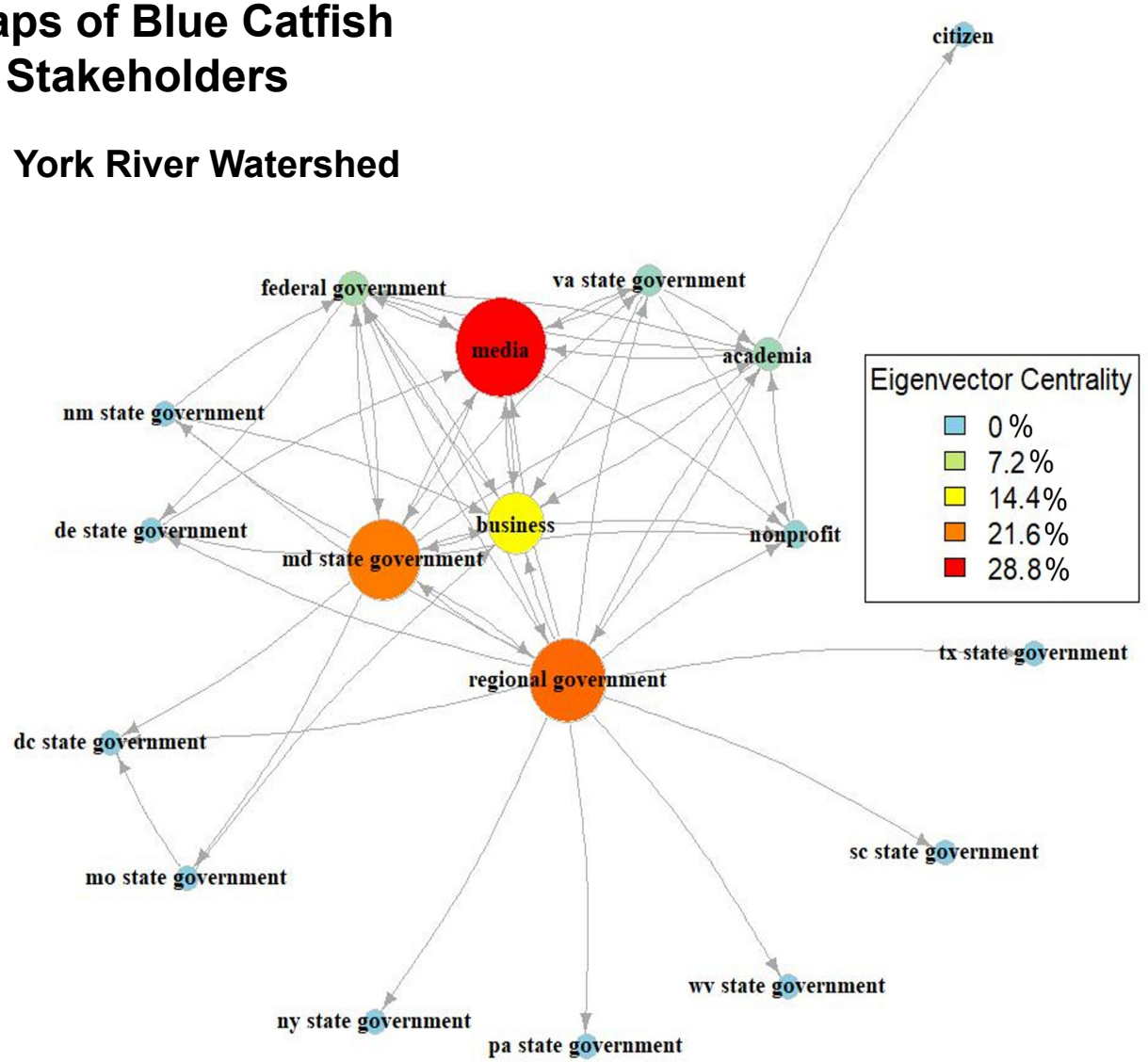
Management influence is centered around a select group of nodes.

Social Network Maps of Blue Catfish Management Stakeholders

Rappahannock River Watershed



York River Watershed



Media is a key for communicating with blue catfish stakeholders in both watersheds

Most Influential

Media

- LinkedIn, YouTube, Facebook, and X (Twitter)
- Most influential across both river watersheds

Maryland (MD) State Government

- MD Department of Natural Resources
- More influential in the Rappahannock

Regional Government

- Chesapeake Bay Program
- More influential in the York

Least Influential

Citizen

- Academia the sole connector for both watersheds
  - Virginia Institute of Marine Science
  - College of William and Mary

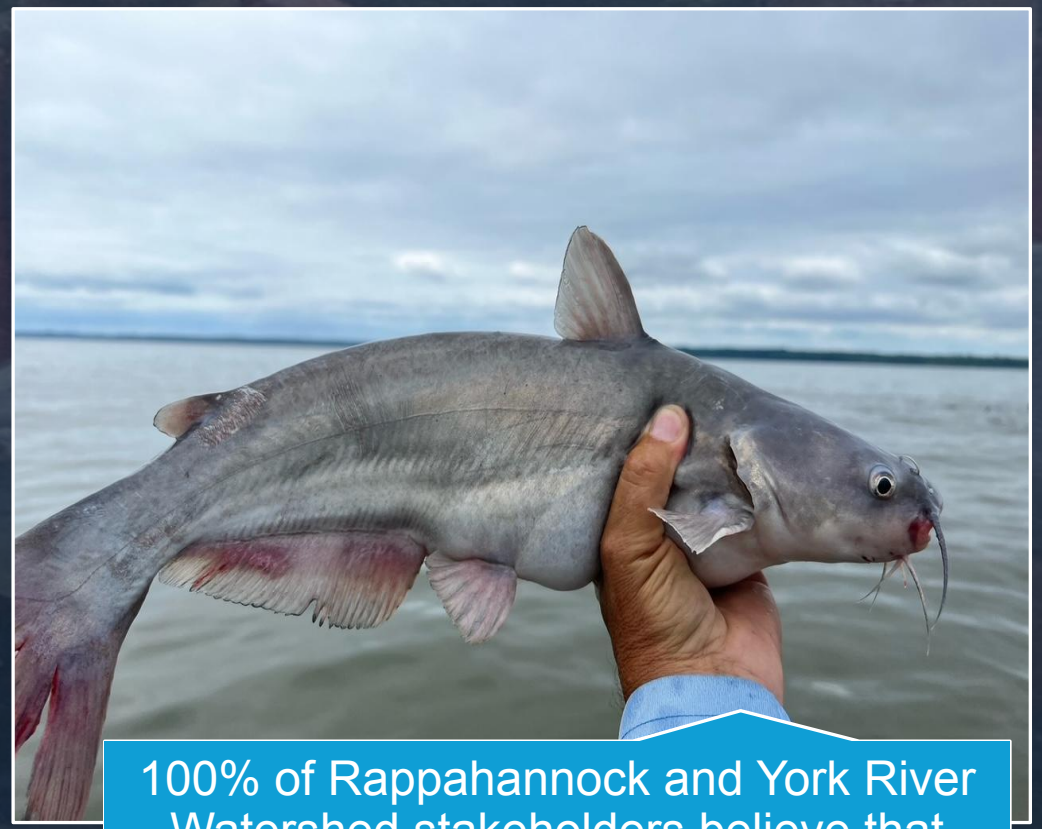
Nonprofit

- Media, Maryland State Government, Regional Government, Academia, and Virginia State Government are connectors for both

Virginia (VA) State Government

- VA Department of Wildlife Resources and VA Department of Health
- More influential in the Rappahannock than the York

Survey results show that fisheries health is unanimously important, but addressing the blue catfish issue is not



100% of Rappahannock and York River Watershed stakeholders believe that healthy fisheries are important for Chesapeake Bay communities and the environment

"Invasive fish species, like blue catfish, are a problem for our Chesapeake Bay and should be dealt with or removed."

Strongly Agree – Agree

- 73% Rappahannock
- 72% York

Strongly Disagree – Moderately Disagree

- 27% Rappahannock
- 28% York

Socio-Ecological Network Analysis can help address interdependent blue catfish challenges

Ecological Network Analysis

- Blue catfish significantly influence the native food web

→ **Native fisheries impacts should be included in management studies**

- Striped Bass
- Blue Crab
- Molluscs

Social Network Analysis (Maps and Metrics)

- Few influential and bridging actors
- Lack of representation from key actors

→ **This type of management evaluations can help target future initiatives**

- Identify pathways to specific stakeholders
- Assess engagement and messaging efficacy

Social Network Analysis (Sentiment Analysis)

- Healthy fisheries is a priority
- Majority see blue catfish as an issue
  - Business less likely

→ **Qualitative data informs management of stakeholder priorities**

- Aid in stakeholder engagement and support
- Inform responsive and pre-emptive decisions

Socio-Ecological Network Analysis's versatile design fuels responsive, ecosystem-specific recommendations

Replicating ecological network analysis for other keystone species

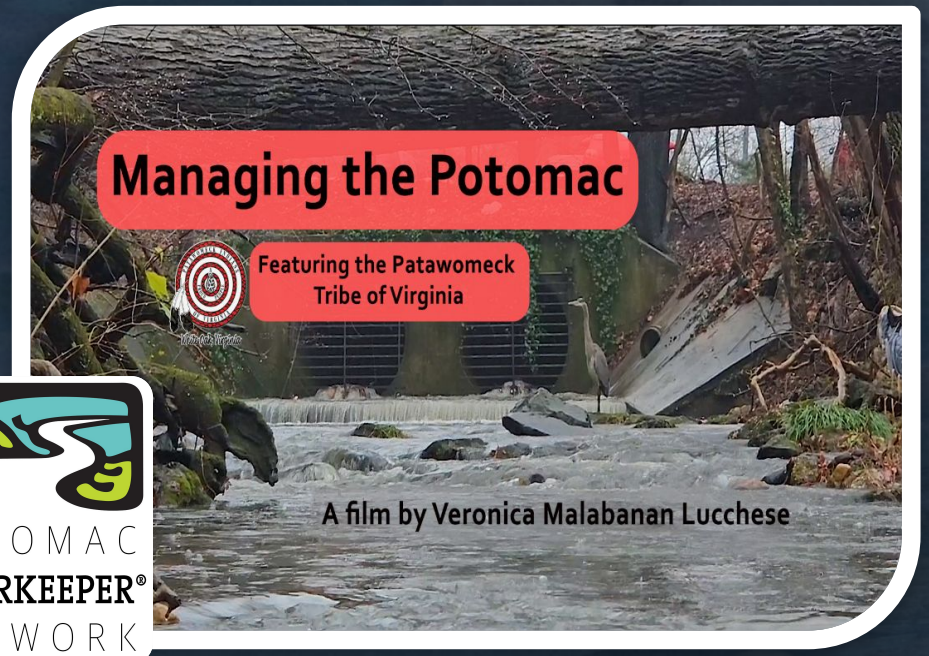
- Blue crab

Replicate social network analysis for…

- Other species (striped bass and blue crab)
- Watersheds (Patapsco)
- Facebook data

Exponential random graph models (ERGM) for modeled baselines to comparisons

Using media and film to make study more accessible



POTOMAC RIVERKEEPER® NETWORK

Managing the Potomac: Featuring the Patawomeck Tribe of Virginia on YouTube | https://tinyurl.com/PotomacSNA

Acknowledgements

Thank you to…

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Additional acknowledgments: Dr. Eric Schott, Dr. Madeline Brown, Dr. Jacob Cram, Donzell Brown, Christien Martin, and Adriana Schulman

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Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration.

Unlocking Connections: Using Social Science to Meet Chesapeake Fishery Needs

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and Julia Frangenberg

(Visit https://tinyurl.com/rapp-york-sena or scan QR code for YouTube links and References)

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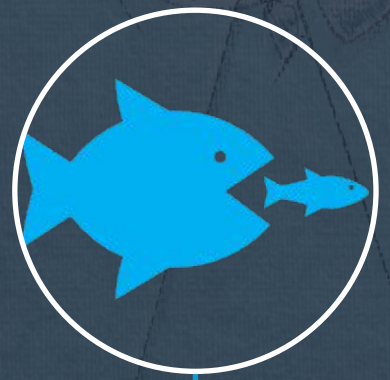


Diet-based ecological network analysis is an efficient tool study species interaction.

Gut Content Analysis Data from Literature Review

- Focused on blue catfish and striped bass in the Bay
- Peer-reviewed and government-funded literature
- 7–8 publications for each predator for balanced representation

Data Cleaning and Standardization

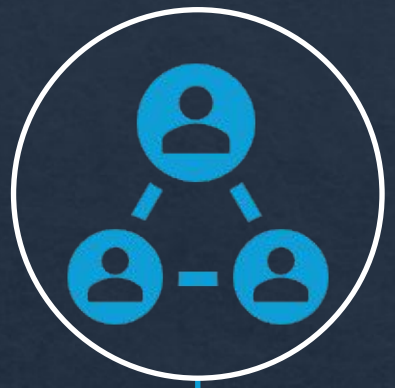
- Two-column predator–prey dataset in Microsoft Excel
- RStudio to convert all characters to lowercase and removal of extraneous characters
  - *tidyr* package

Network Map/Metrics for Blue Catfish and Striped Bass Food Web

- RStudio for analysis
  - *igraph, tidyverse*, and *dplyr* packages
- Food Web Network Map
- Centrality Statistics

(Sander et al, 2017; Costa & Angelini, 2020; Meyer et al., 2020)

Web-based social network analysis is a practical method to evaluate management relationships



Hyperlink Relationships Data from Google Web-Scraping

RStudio to mine and compile links from Google searches

httr, jsonlite, and *rvest* packages

Search Terms: blue catfish + [Rappahannock/York] river management

Mined to 3rd search depth

- (1) Links from initial query page
- (2) Hyperlinks off the 1st link page
- (3) Hyperlinks off the hyperlinked page

Data Cleaning and Standardization

RStudio to convert all characters to lowercase and removal of extraneous characters

- *tidyr* package

Recategorize

- Links to owner names
- Names to actor groups (i.e. NOAA to federal government)

Removal of self-linking relationships

Network Maps/Metrics of Management Connections

RStudio for analysis

- *igraph, tidyverse*, and *dplyr* packages

Stakeholder Network Maps for the York and Rappahannock

Centrality Statistics for the York and Rappahannock

(Kreakie et al., 2016; Newman, 2018; Sayles et al., 2022)

Surveys help gather quantitative and qualitative stakeholder data for social network analysis

Stakeholder Survey Data

Data Cleaning and Standardization

Sentiment Analysis

Qualtrics survey
- May 19 to September 30, 2025

Stakeholder knowledge, perceptions, and relationships related to invasive blue catfish in the Bay.

Virtual and in-person dissemination
- $50 Visa Gift Card Incentive

RStudio to convert all characters to lowercase and removal of extraneous characters
- *tidyr* package

Aggregated zip code responses by watershed

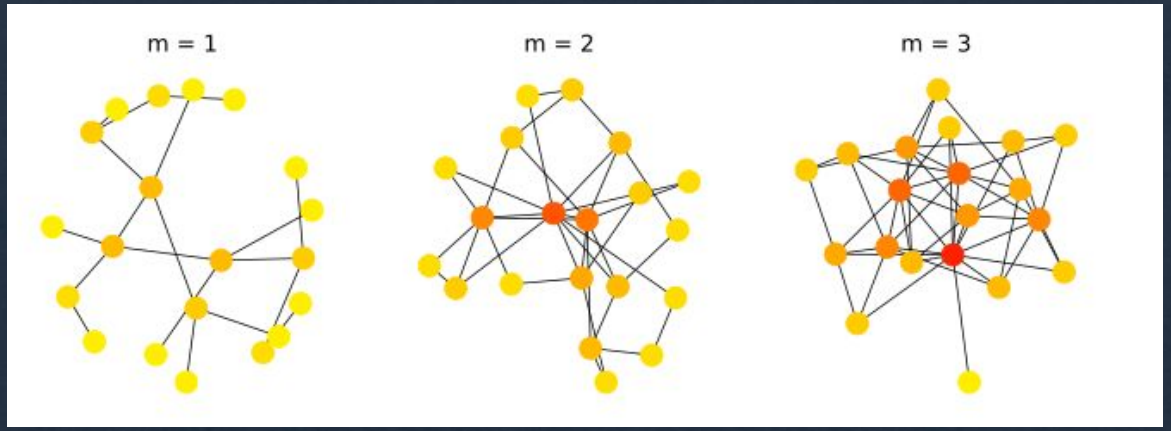
Keep only responses within Rappahannock and York River Watersheds

Separated responses by stakeholder group in Microsoft Excel

Rate of agreement (Likert scale) calculated
- Fisheries importance
- Blue catfish perceptions

This study was approved by the University of Maryland, College Park Institutional Review Board (IRB) (IRB number: 2325019-2)

Exponential Random Graph Models (ERGMs) can establish baselines for future studies.



Exponential Random Graph Models (ERGMs)

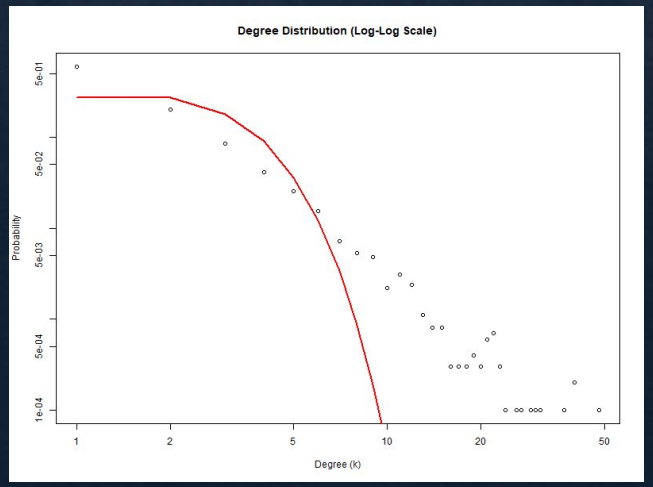
- Creating baseline networks using real-world parameters (24, 27, 34, 40-42).
  Identifying structures influenced by chance versus those shaped by dependencies.
- igraph package in R Studio (43).

Barabási-Albert (BA) Model and Hubs

- Identifying influential hubs: "rich-get-richer" principle (27, 44).
- Generating at 100 BA models for robust comparisons (45).

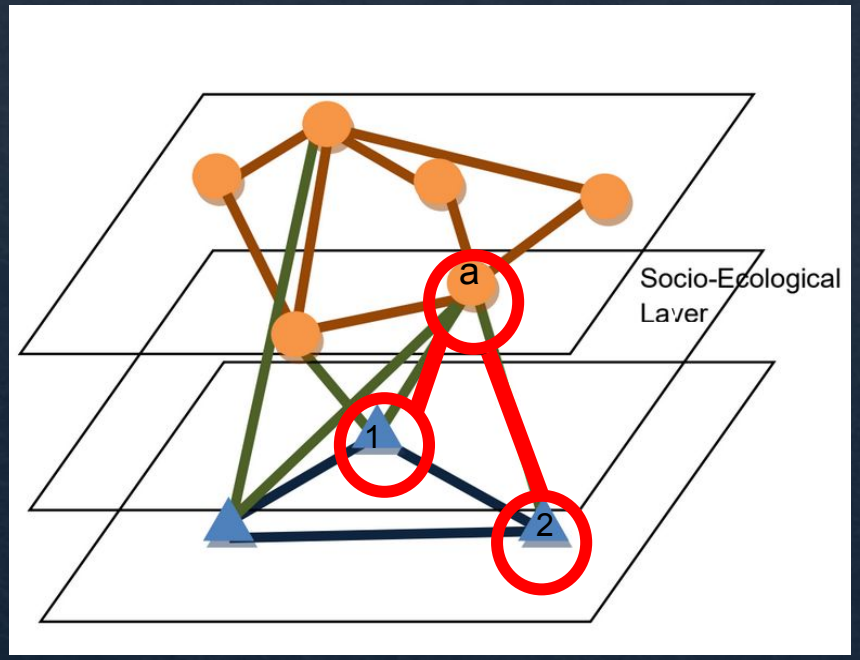
Modularity: Community Detection

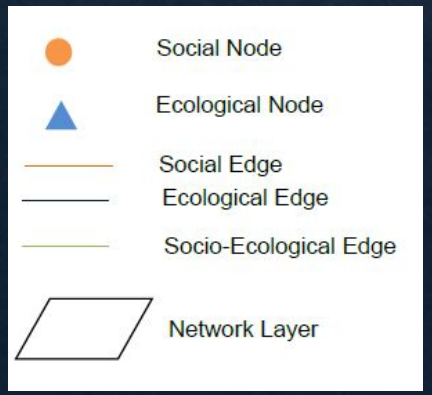
- Network tendencies to form smaller subgroups (46).
- Comparing modularity between real-world and BA models (27, 41, 42, and 46).



(24) Bodin et al., 2014; (27) Newman, 2018; (34) Munguia-Vega et al., 2022; (40) Barnes et al., 2017; (41) Martin et al., 2017; (42) Packer et al., 2020; (43) Csárdi et al., 2025; (44) Taylor & Suthers, 2021; (45) Weissman, 2020; (46) Bodin et al., 2006

Analyzing multi-level, socio-ecological systems can reveal their network dynamics.





No single network structure suits all invasive species management (23).

Tributary-specific research (15)

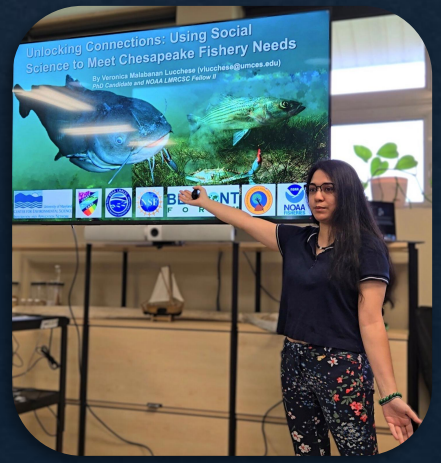
Transdisciplinary approach helps with participant diversity and authority diffusion (24-26).

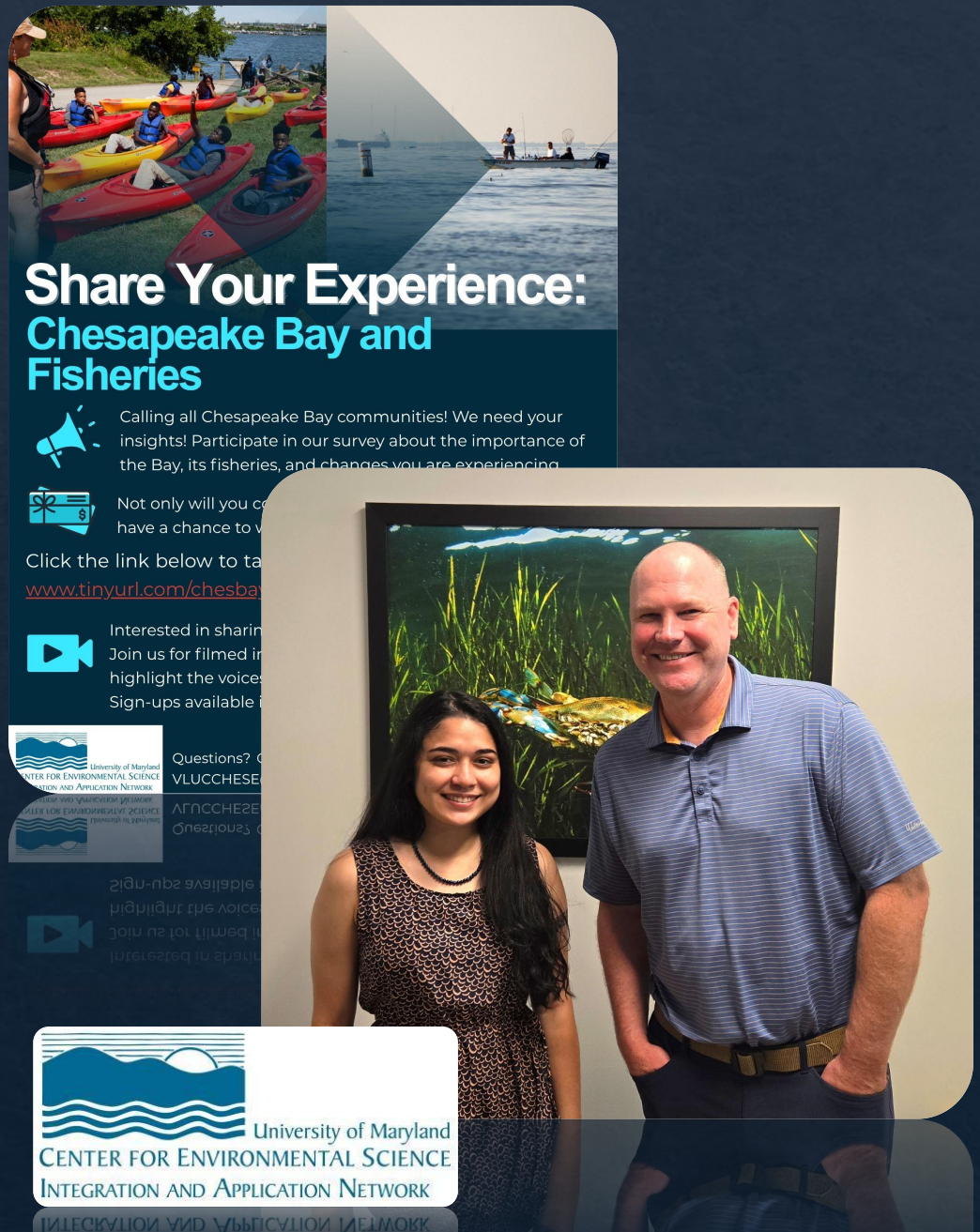
Mixed-method approach to track diversity, equity, and inclusion (DEI) (25, 27).

Literature reviews
Surveys/Interviews
Graph theory

(15) CBP, 2020 (a); (23) Barnes et al., 2017; (24) Bodin et al., 2014; (25) Bodin et al., 2020; (26) Ashlander et al., 2022; (27) Newman, 2018

Gathering answers from a diversity of stakeholders requires both virtual and face-to-face outreach





PhD Candidate and NOAA-LMRCSC Fellow II

Environmental Science and Programs Manager for the Environmental Justice Journalism Initiative (EJJI)

NOAA Chesapeake Bay Office and Invasive Catfish Workgroup

Strengthen my relationships with blue catfish and related fisheries managers

Before Graduation

CERF 2025, Complete survey, ethnographic film, and publish 1-2 papers

Graduation: December 2026

Post-graduation plans: International post-doctoral researcher and lecturer