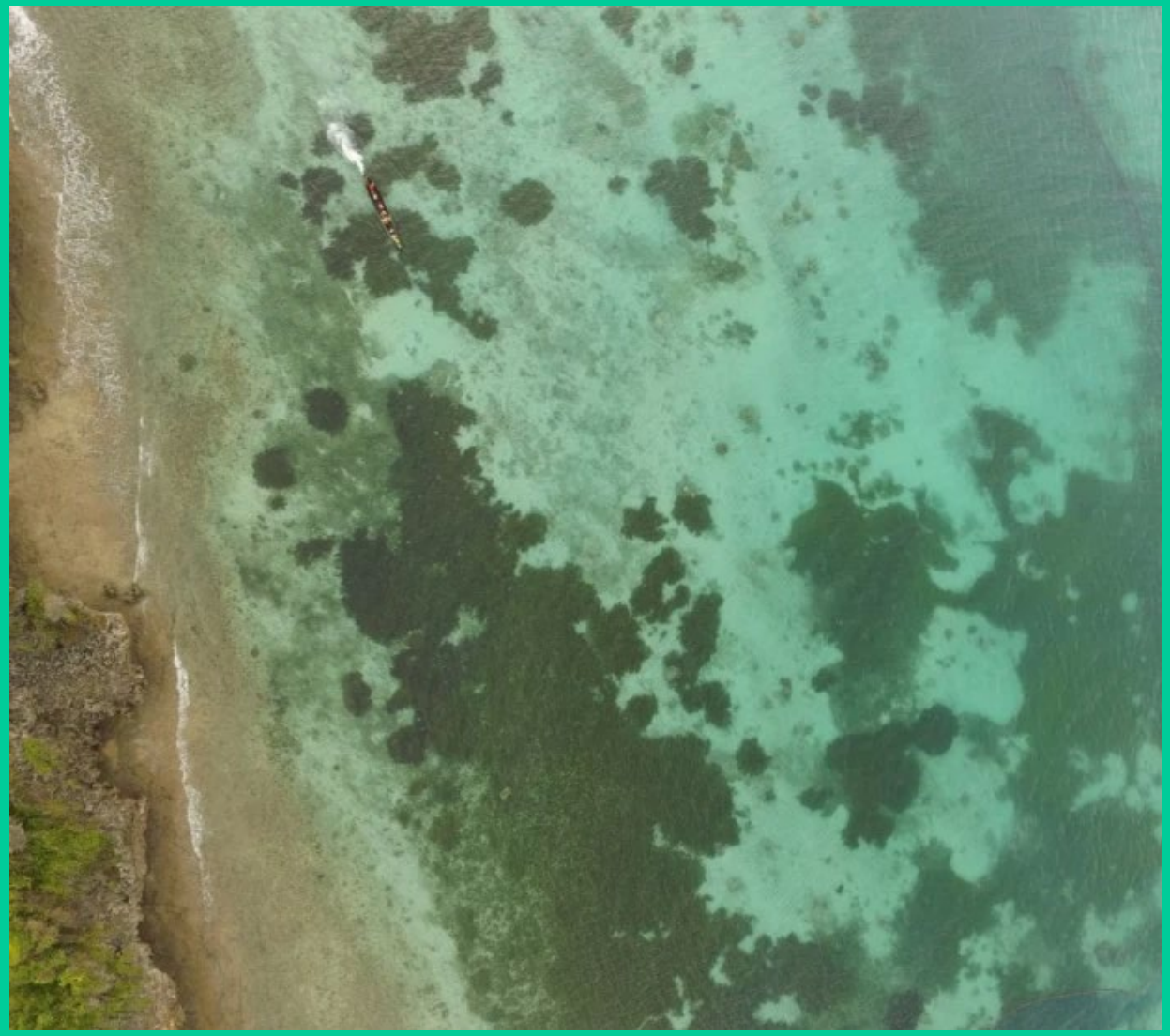
Seagrass Seascape Responses To Water Quality Across Spatial Scales In Biscayne Bay

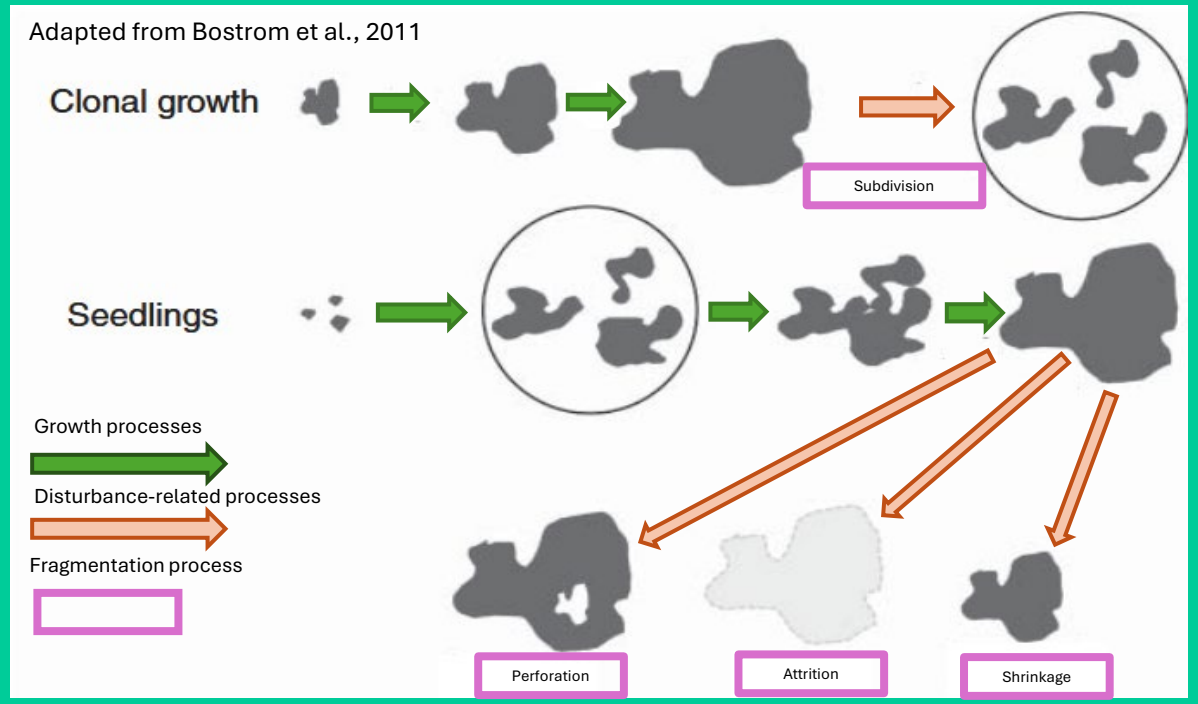
Marianna Coppola, W. Ryan James, Jonathan R. Rodemann, Jennifer S. Rehage, Rolando O. Santos

Florida International University,

Rationale

Seagrass Meadows Are Dynamic Across Space and Time





Structural Heterogeneity

Biodiversity

Ecosystem Functions

MacArthur and Wilson 1967; Lundholm 2009; Tamme et al, 2010

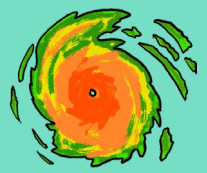
Rationale

Seagrass Meadows Are Dynamic Across Space and Time

Environmental Variability

Spatial:	**Temporal:**
Temperature	Diurnal cycles
Humidity	Seasonality
Nutrients	Tidal cycles
Topography	Climate change over geological eras

Disturbances



Natural

Anthropogenic

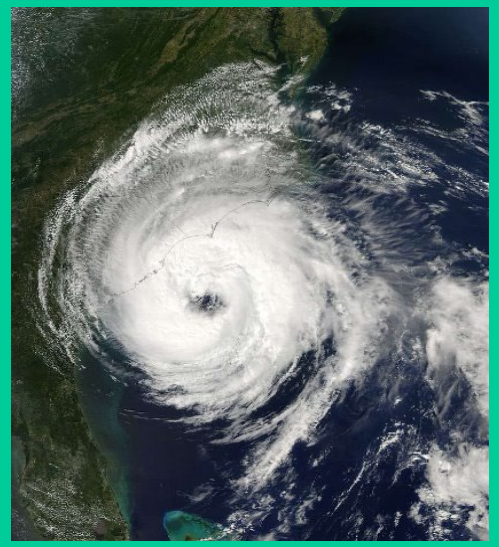
MacArthur and Wilson 1967; Lundholm 2009; Tamme et al, 2010

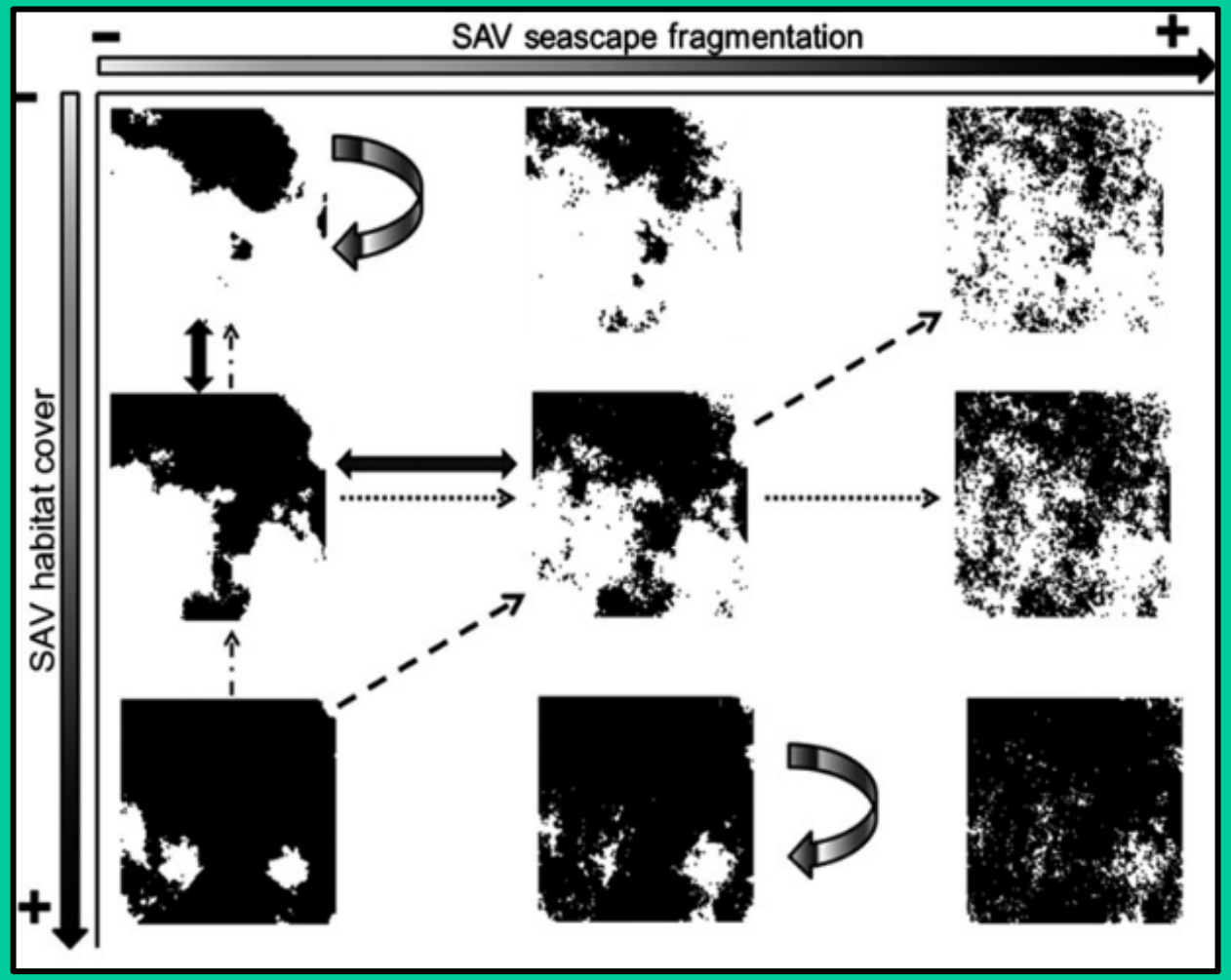
Anthropogenic Disturbance Impacts Seagrass Beds

Urban development

Declining water quality

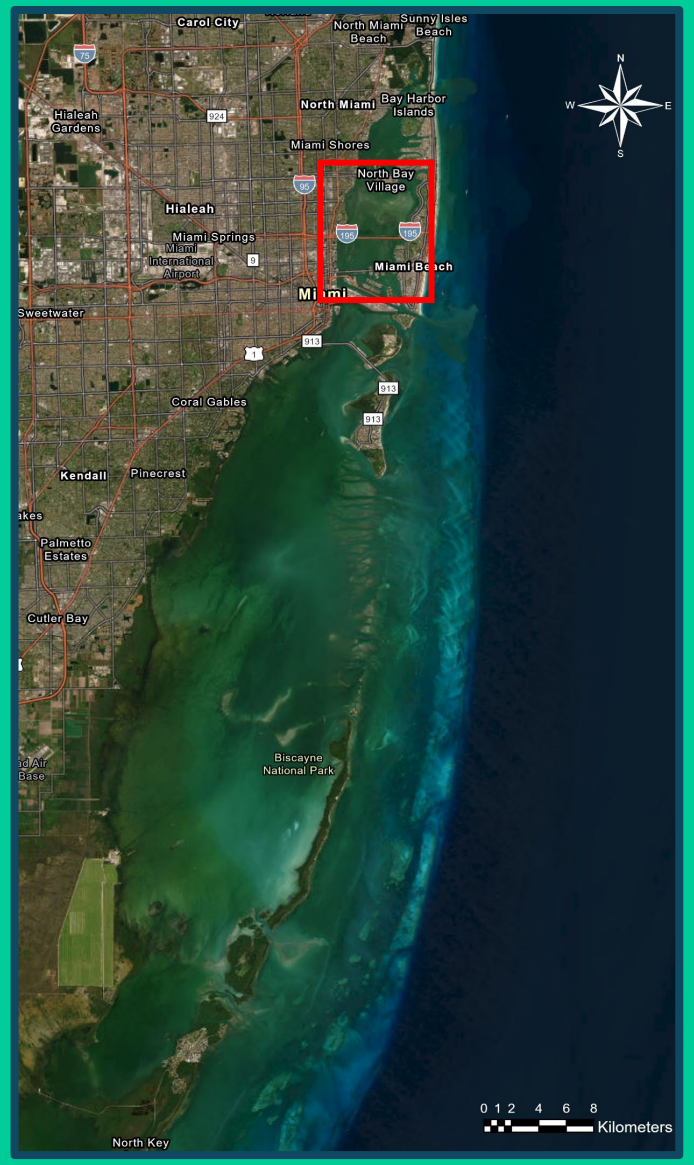
Climate change





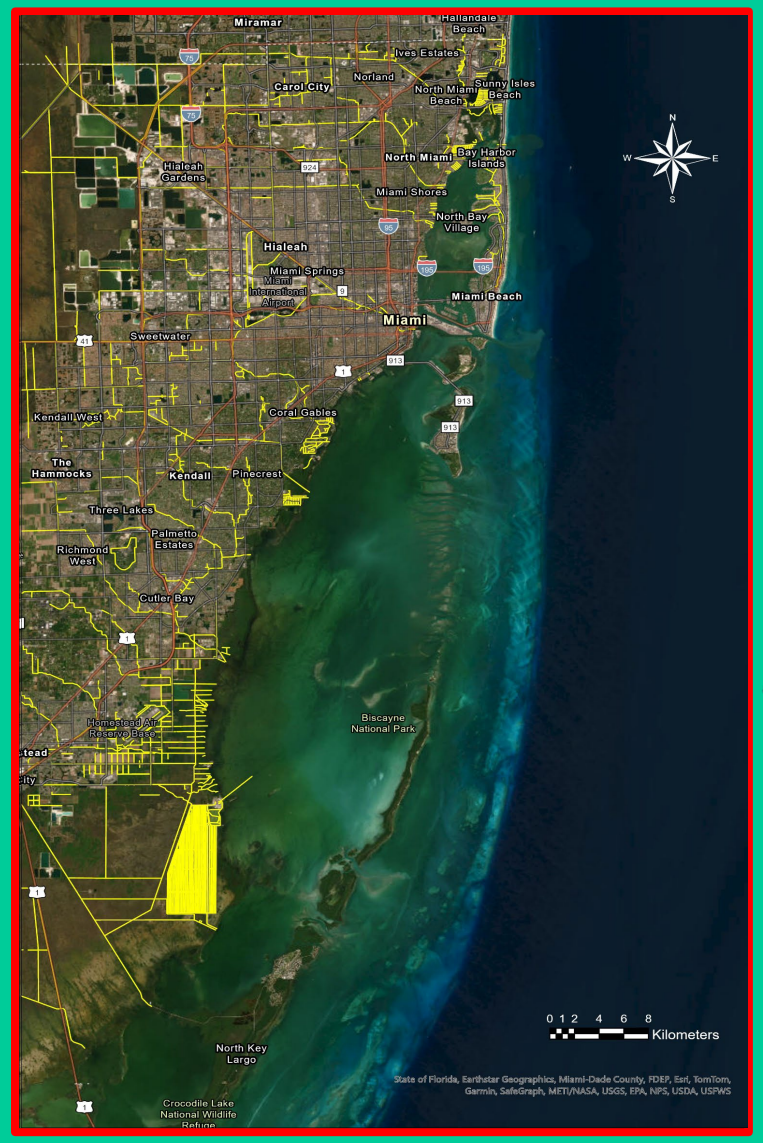
Rationale

Seagrass die-off in Biscayne Bay



Rationale

Water quality influences seagrass habitat loss and fragmentation



Alterations in salinity and nutrient regimes

Santos et al., 2011

Research Question

How does water quality influence habitat fragmentation and loss in seagrass meadows?

How can we answer? 

1. Submerged Aquatic Vegetation (SAV) Habitat Maps

2. Measure Spatial Patterns

3. Model SAV-water quality relationships

Methods: Remote Sensing

Where is the seagrass: Seascape mapping

- **10-meter pixel size**
- **Suitable for long term mapping**
- **Freely available data**

SATELLITE DATA + ***IN SITU* DATA**

Random Forest

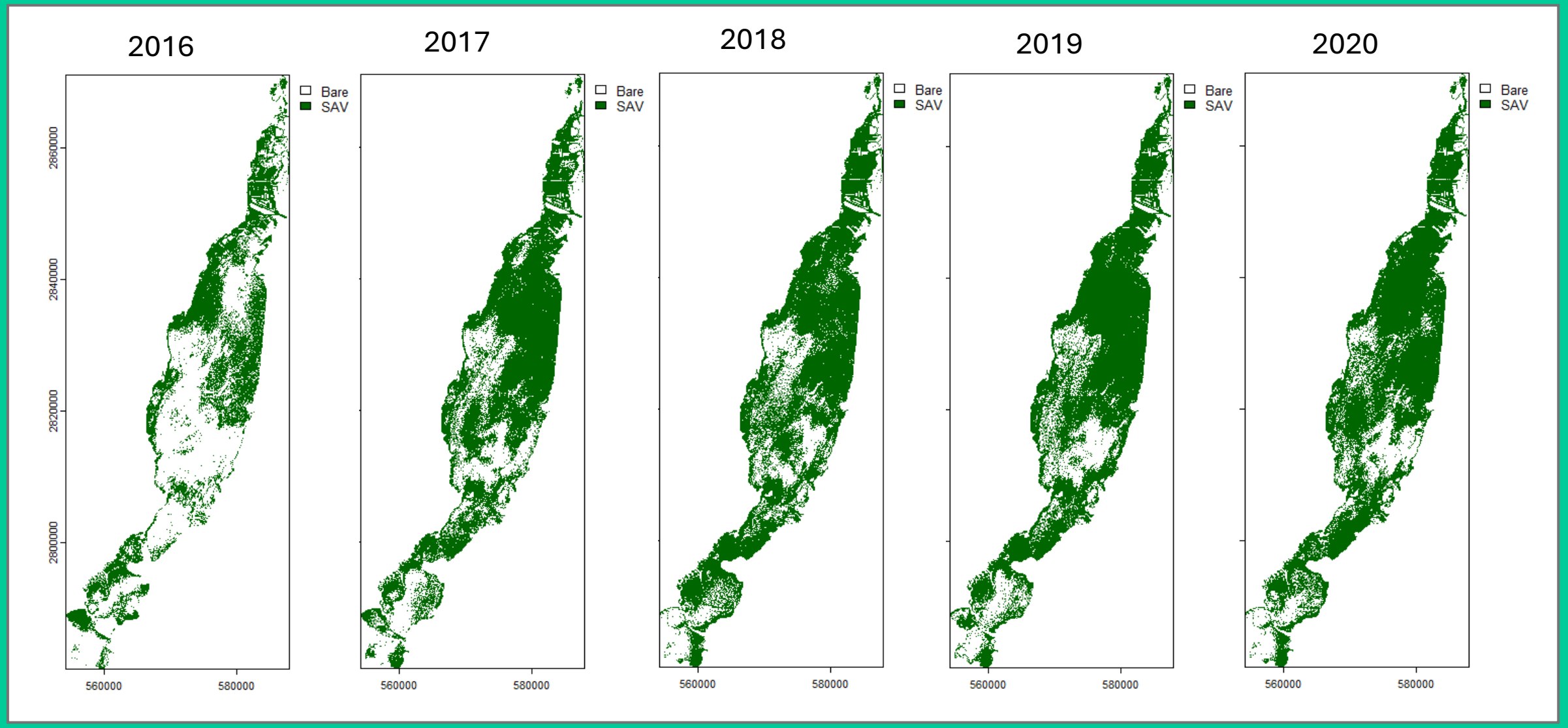
CLASSIFICATION MODELS

SEASCAPE MAPS

MEASURE SPATIAL PATTERNS

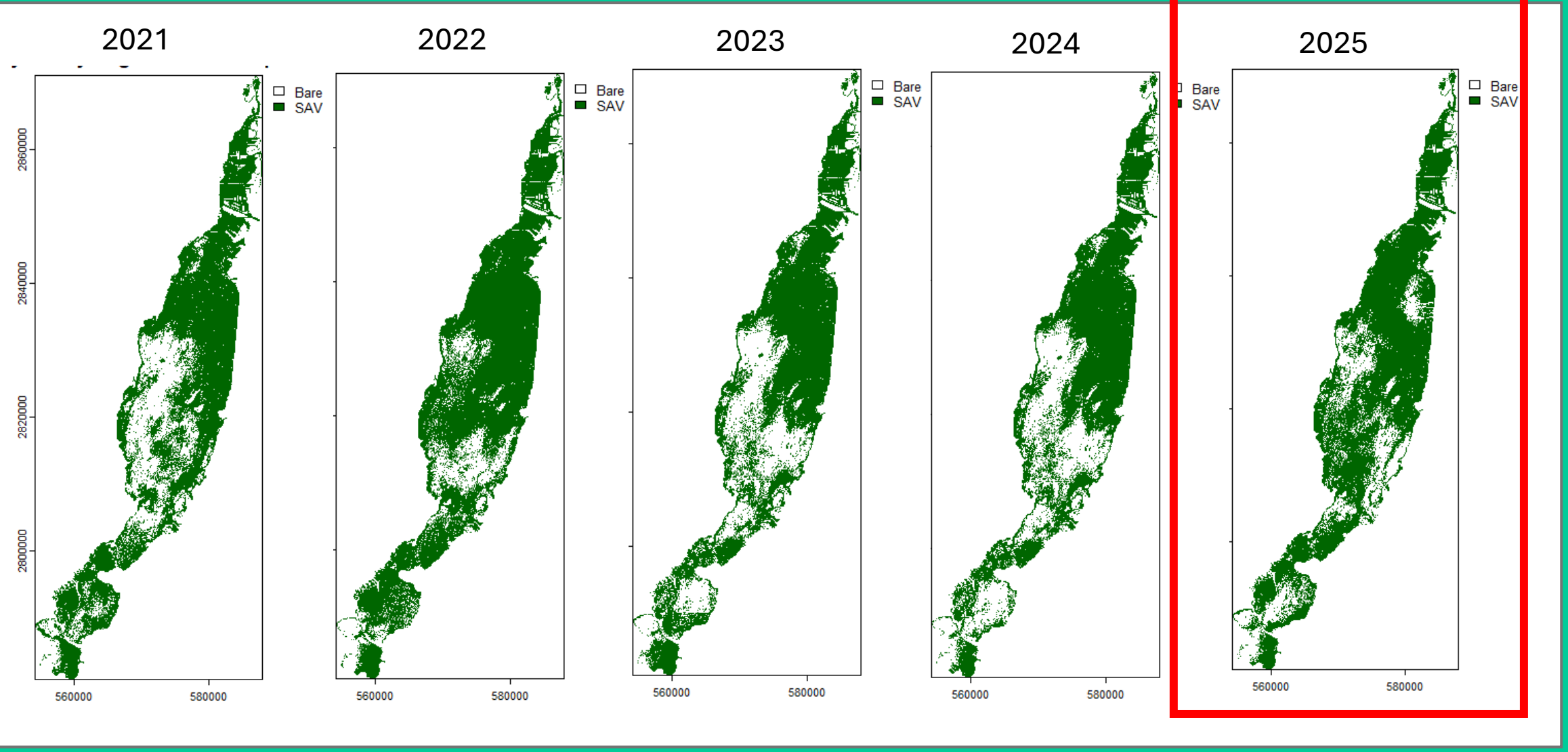
Preliminary results

SAV Seascape Maps



Preliminary results

SAV Seascape Maps



Methods: Measure Spatial Patterns

Spatial Patterns Metrics

1. Percent of SAV = $\dfrac{\text{SAV area}}{\text{Tot Area}}$

2. Patch Density = $\dfrac{\text{\# of patches}}{\text{Tot Area}}$

3. Edge Density = $\dfrac{\text{Tot edge length}}{\text{Tot Area}}$

4. Fragmentation Index = $\dfrac{4\sqrt{PD * LD * AWMPAR}}{\text{Gyrate\_MN}}$

Santos et al., 2016

100-meter radius

500-meter radius

700-meter radius

Effects Of Water Quality On SAV Structure

Generalized Linear Mixed Models

Response:

Spatial Pattern Metrics

- Percent of Landscape (PLAND)
- Patch Density (PD)
- Edge Density (ED)
- Fragmentation Index (FRAG)

Predictors:

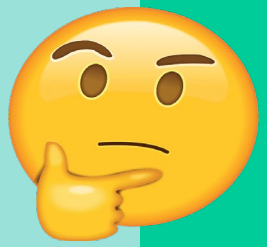
Water Quality 2021-2025

1. Salinity (avg) ppt
2. Salinity (st. dv.) ppt
3. Total Nitrogen (avg) mg/l
4. Total Phosphorous (avg) mg/l
5. Turbidity (avg) NTU

$$\text{Spatial Pattern Metric}_{100m} \sim WQ_1 + WQ_2 + \ldots + WQ_5$$

$$\text{Spatial Pattern Metric}_{500m} \sim WQ_1 + WQ_2 + \ldots + WQ_5$$

$$\text{Spatial Pattern Metric}_{700m} \sim WQ_1 + WQ_2 + \ldots + WQ_5$$



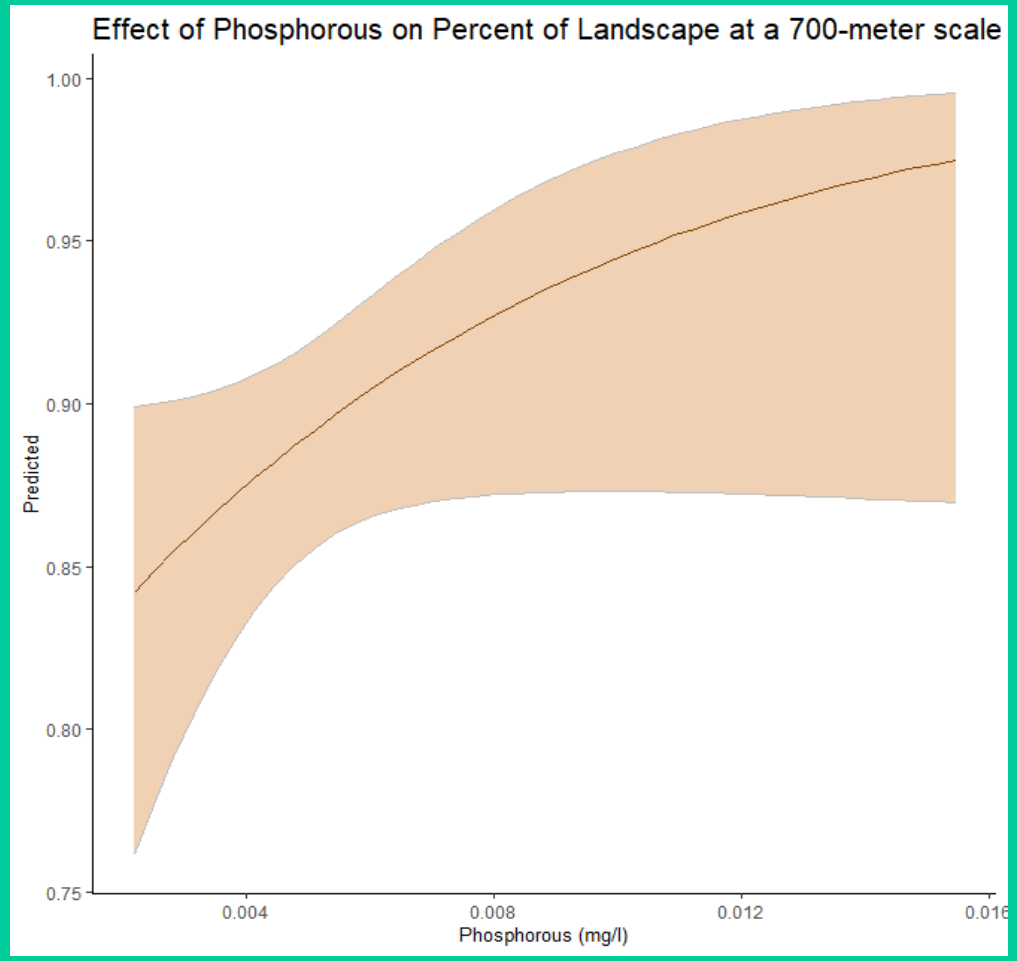
Results

Effects of water quality on Percent of Landscape (PLAND)

$PLAND_{700m}$ ~ Total Phosphorous

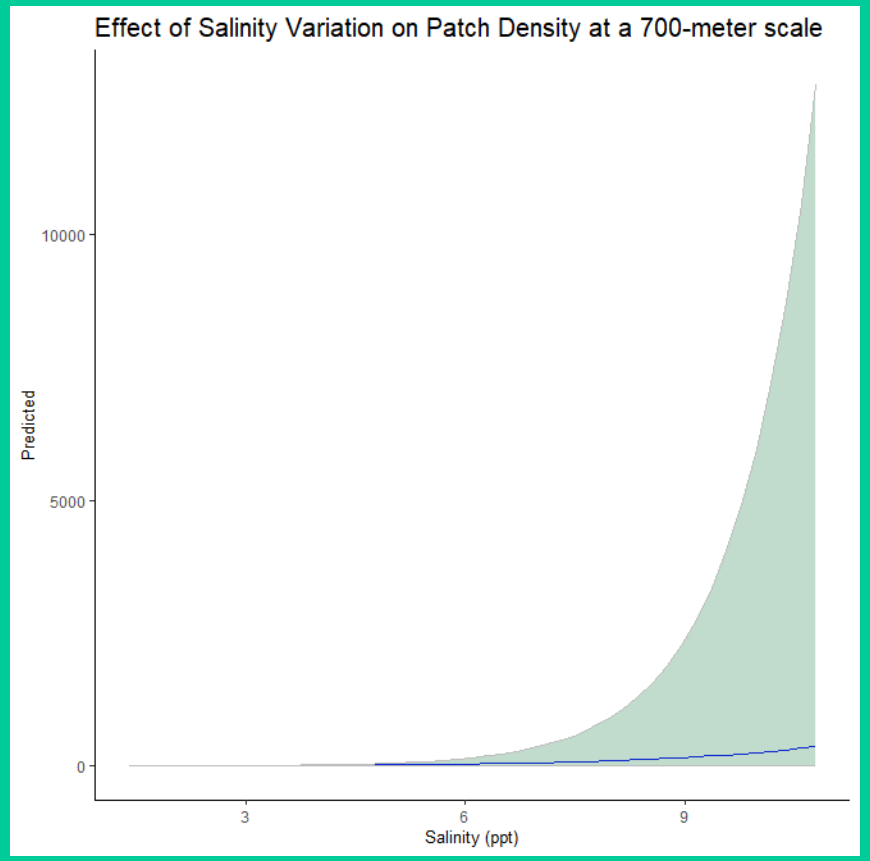
SAV ~ 95 %

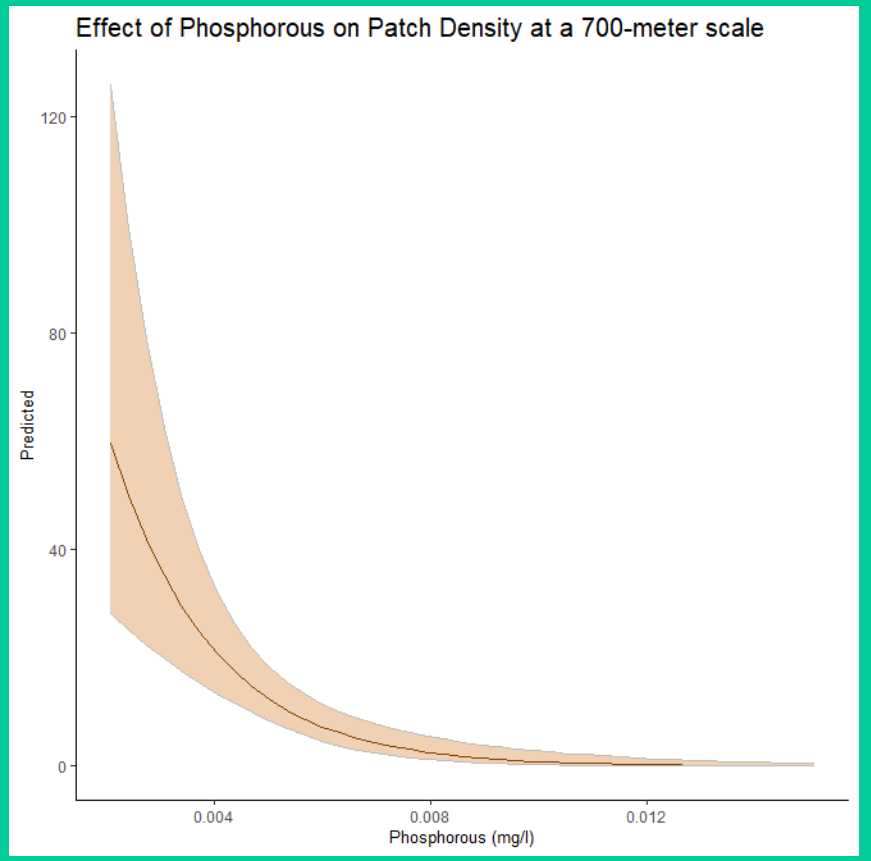
SAV ~ 75 %



Effects of water quality on Patch Density

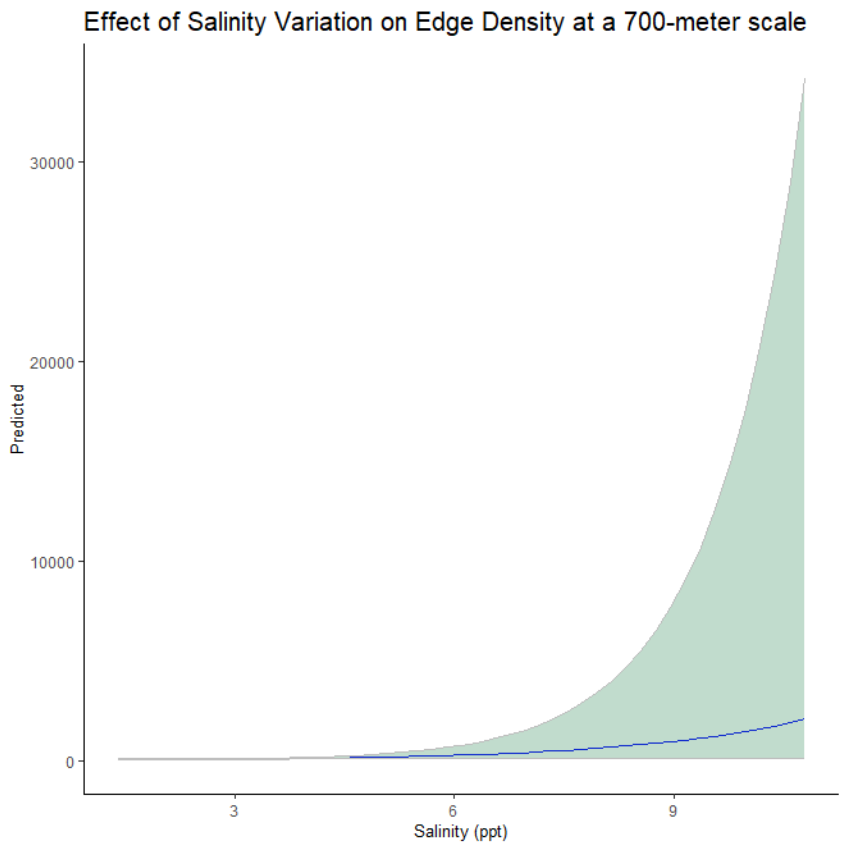
PD_{700m} ~ Salinity_sd + Total Phosphorous

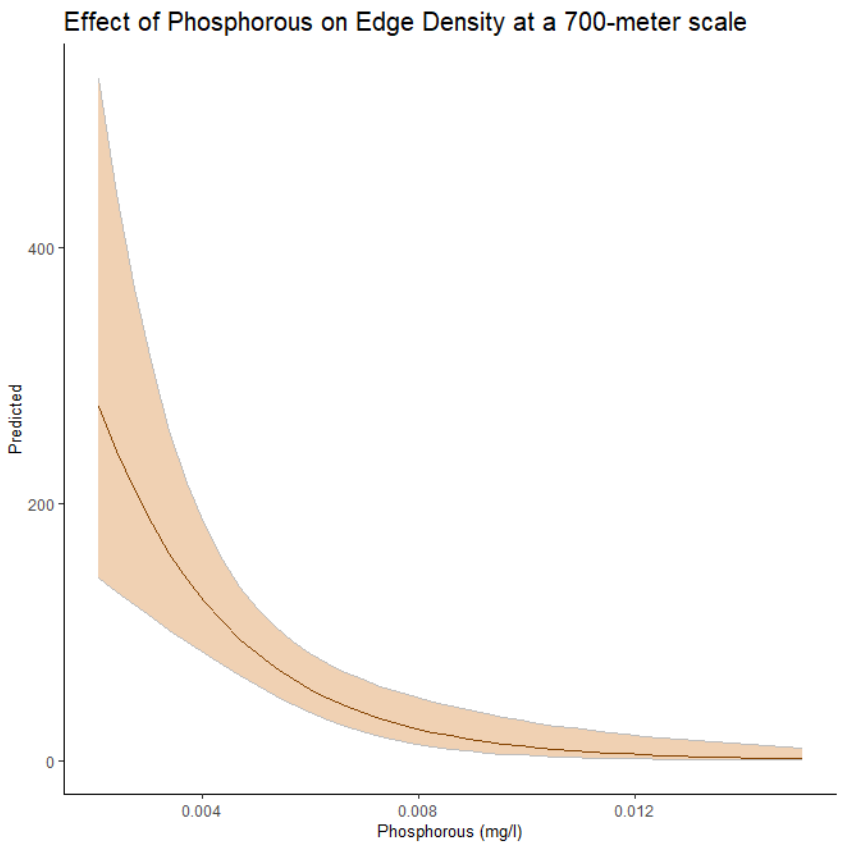




Effects of water quality on Edge Density

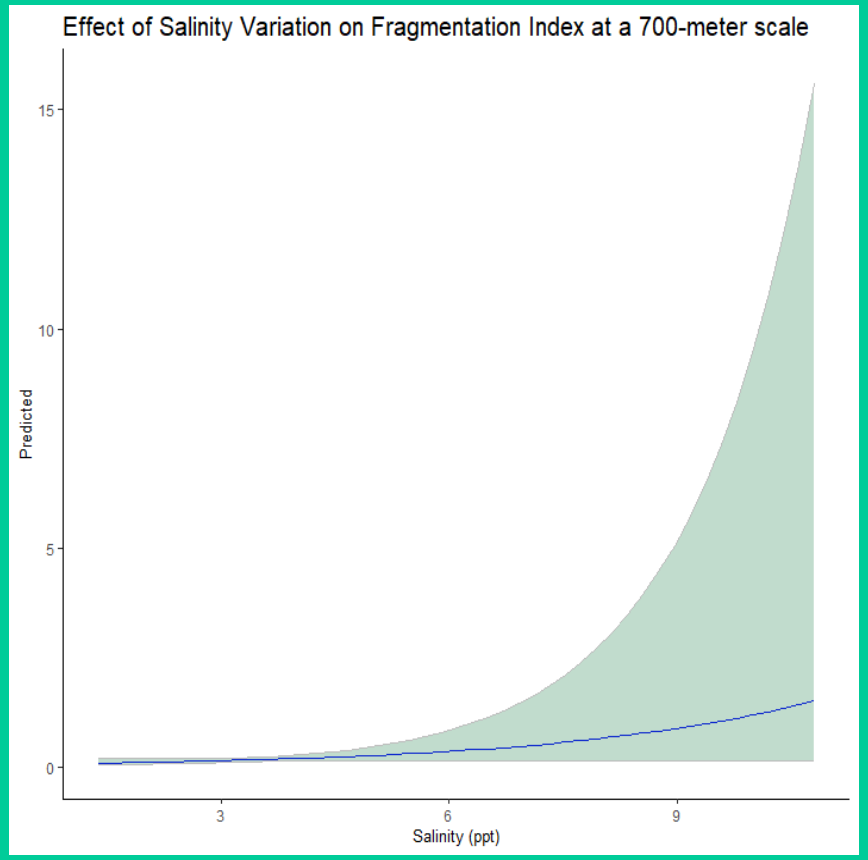
$ED_{700m} \sim Salinity\_sd + Total\ Phosphorous$

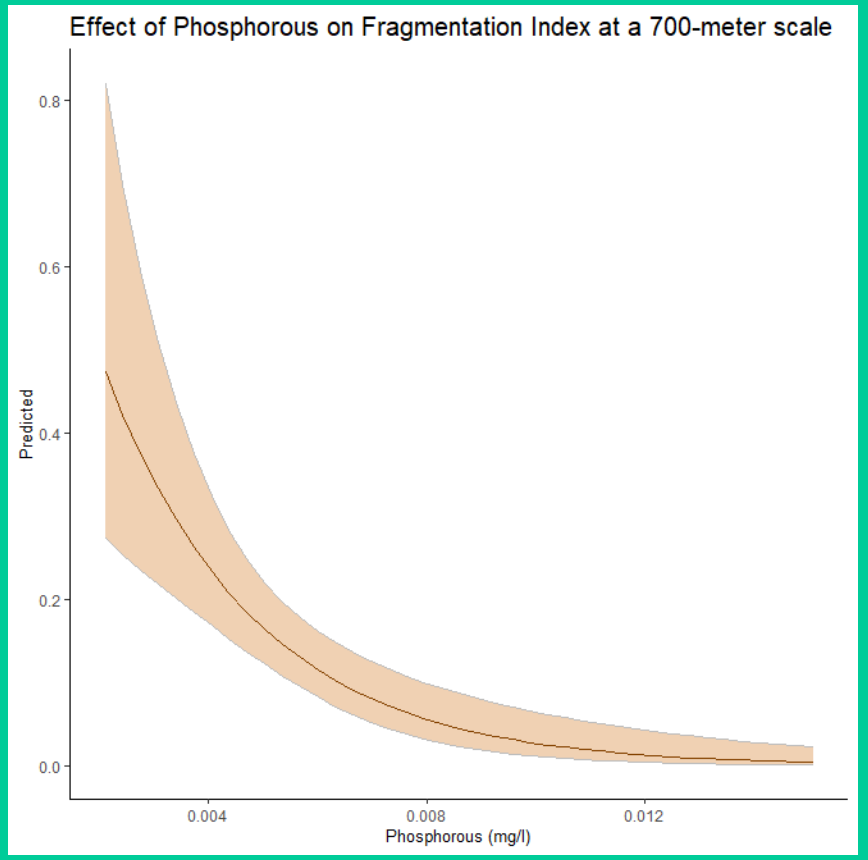




Effects of water quality on Fragmentation

$FRAG_{700m}$ ~ Salinity_sd + Total Phosphorous





Conclusion

Salinity variation and total phosphorous affect seagrass structure consistently across scales

Salinity Variability

\+ Patch Density

\+ Edge Density

\+ Fragmentation Index

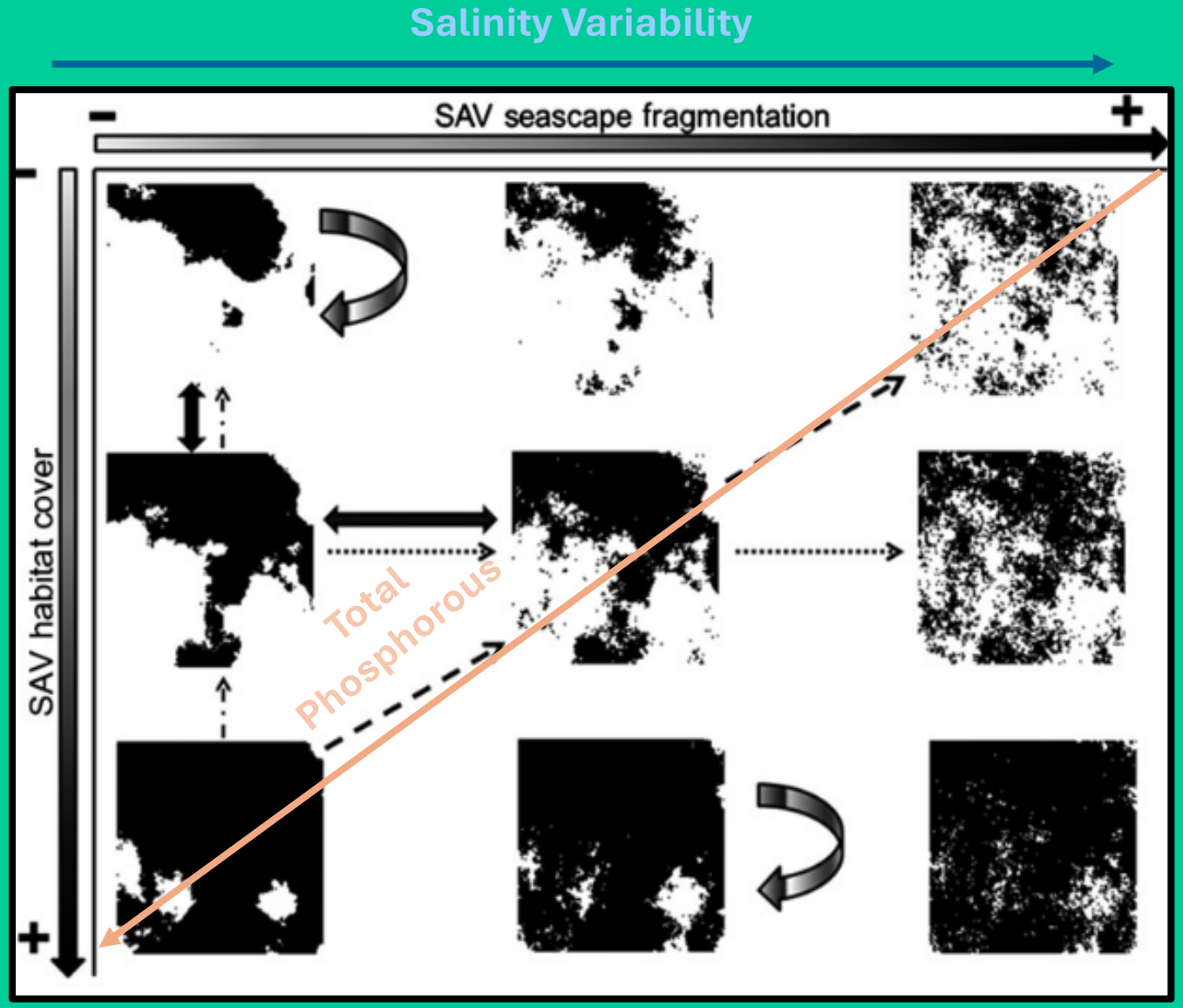
Mean total phosphorous

\+ Percent of SAV

\- Patch Density

\- Edge Density

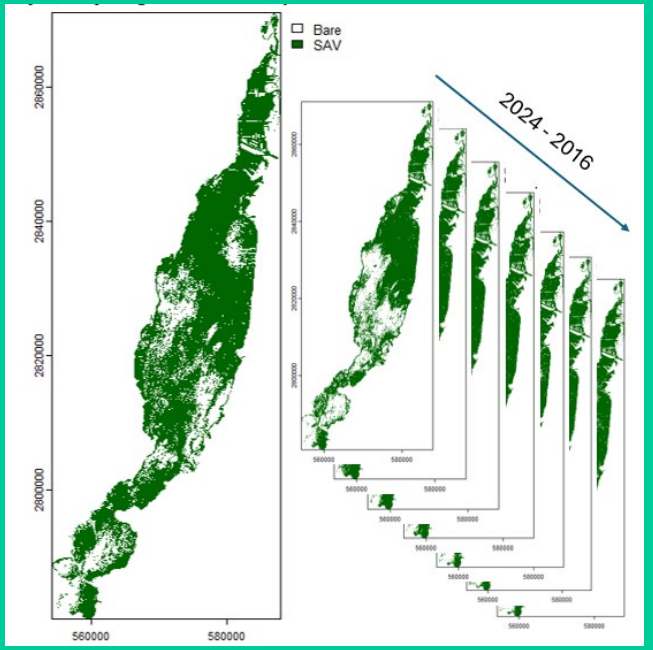
\- Fragmentation Index



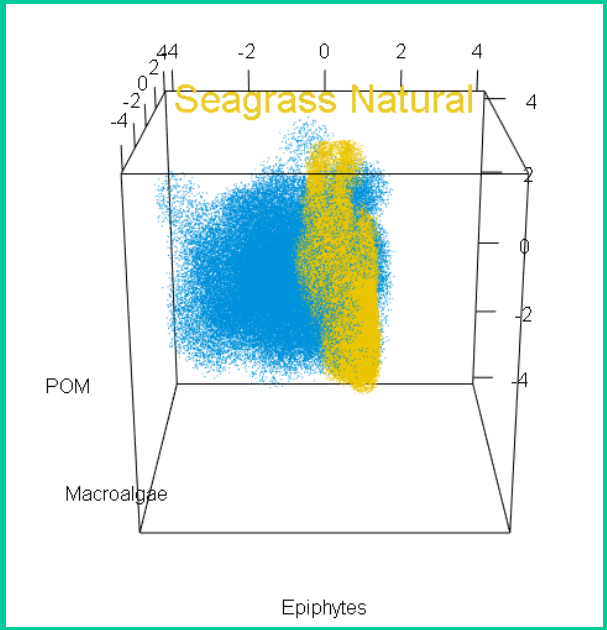
Next Steps

Further Understand Seascape Dynamics Across Water Quality Conditions

1. Model SAV structure as a function of water quality across time



2. Discriminate between seagrass- and algal-dominated habitat classes



3. Apply multivariate analytical tools to simultaneously account for spatial characteristics

Acknowledgements

Major Advisors

- Rolando Santos-Corujo
- Jennifer S. Rehage

Santos Seascape Ecology Lab

- Nicolas Rivas
- Valentina Bautista
- Gina Badlowski
- Hannah-Marie Lamle
- Christine Nation
- Sofia Garcia
- W. Ryan James
- Jonathan Rodemann
- Justin Lesser

Rehage Lab

Thanks to all the folks who helped with fieldwork!

FIU SEL Lab

FIU Institute of Environment, Florida International University

Miami-Dade County

United States Environmental Protection Agency

Fulbright Italy

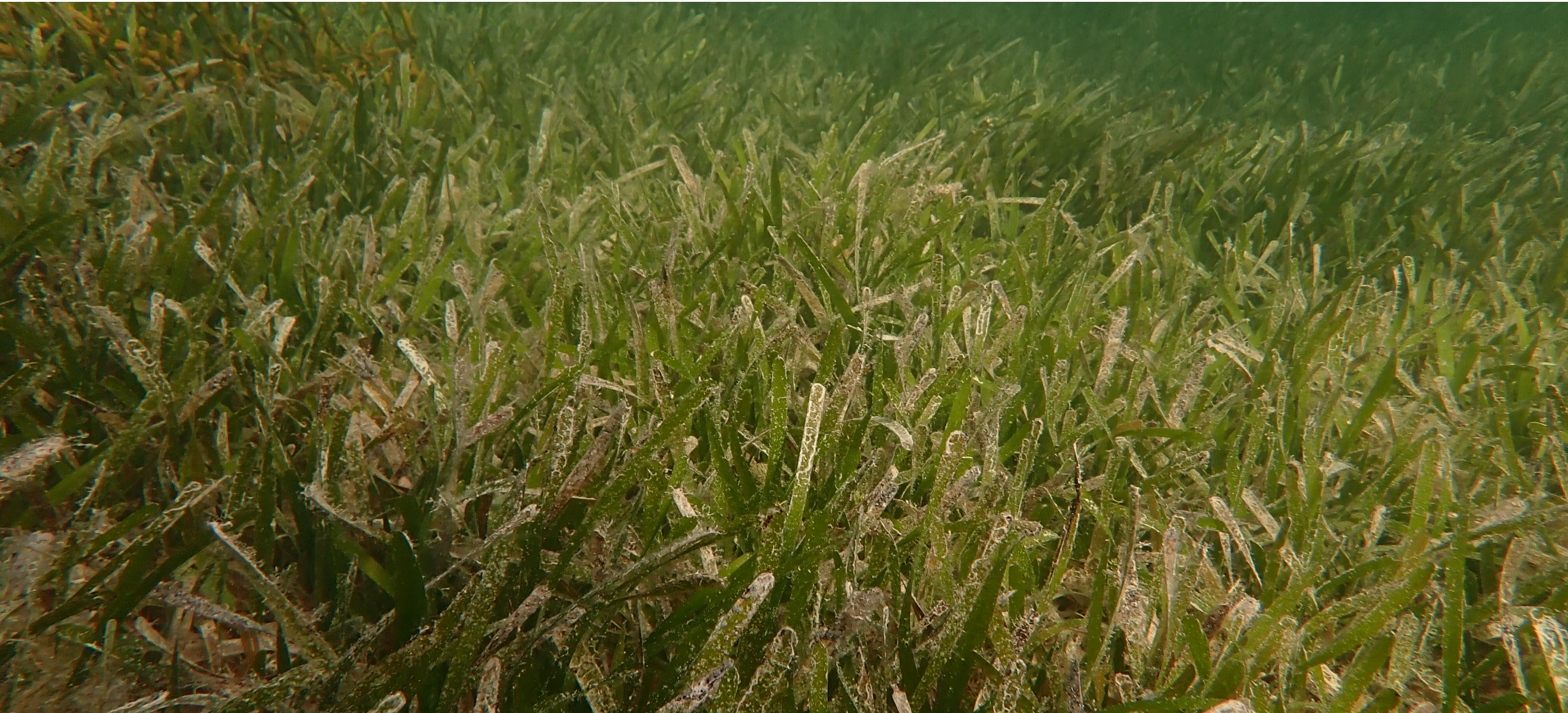
asprs The Imaging & Geospatial Information Society, Florida International University

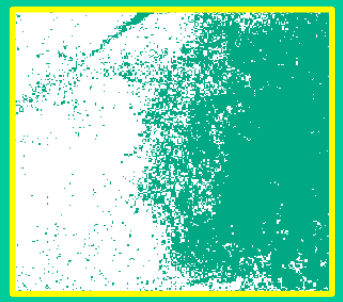
NOAA National Oceanic and Atmospheric Administration, U.S. Department of Commerce

FIU Center for Aquatic Chemistry and Environment

NSF Center of Research Excellence in Science and Technology

TIME FOR QUESTIONS!





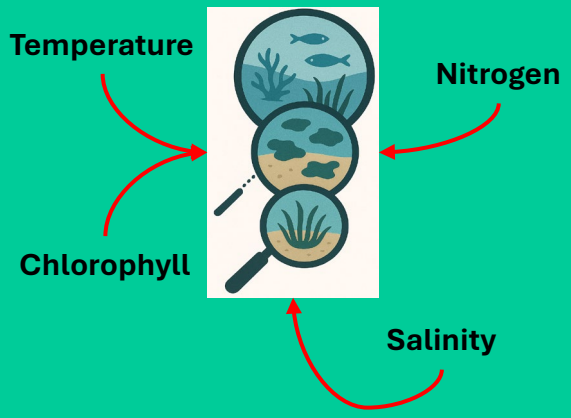
Proposal Outline

Introduction

- Landscape Heterogeneity
- Seagrass seascape ecology
- The problem of scale

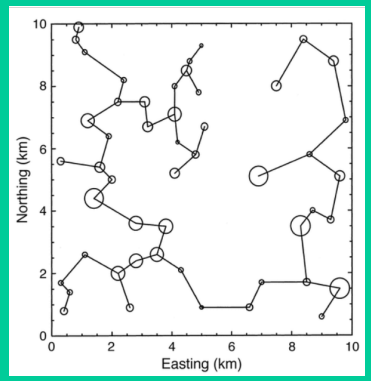
Ch 1: Seagrass structure across scales

Ch 2: Effects of Water Quality Across Hierarchical Levels

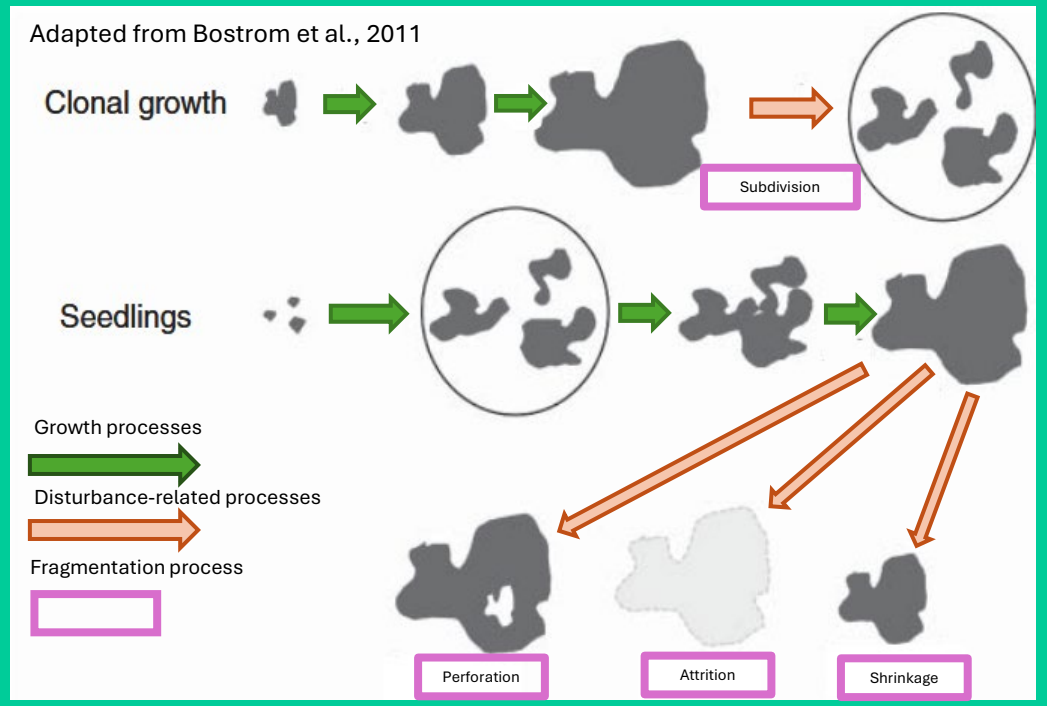


Ch 3: Seascape patterns influence fish habitat selection

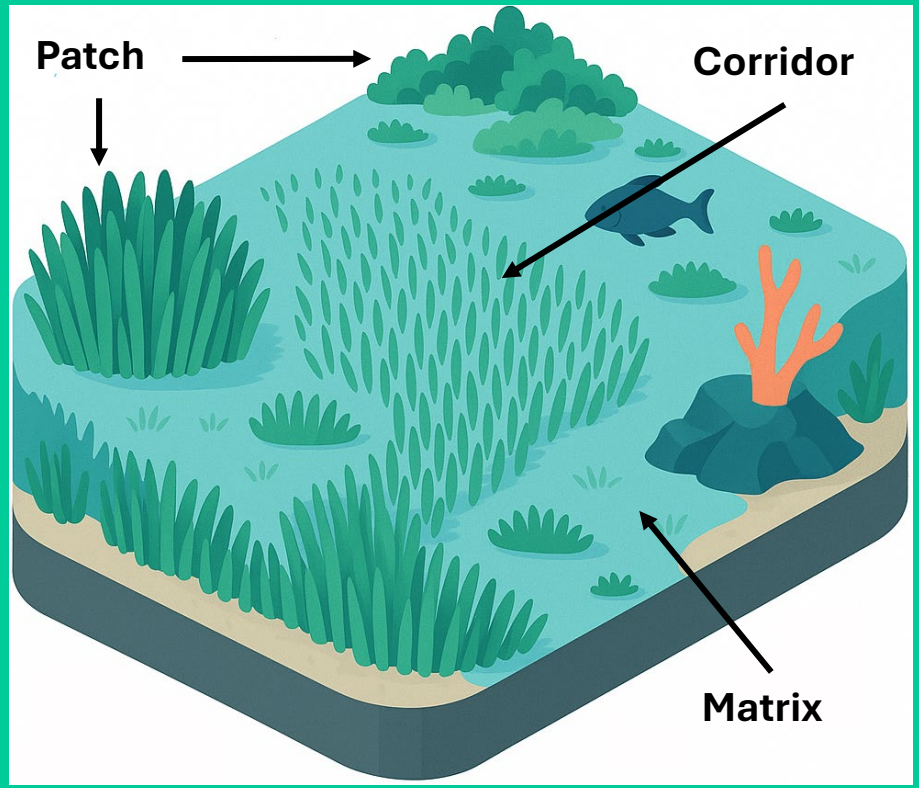
Ch 4: Effects of Seascape Structural Connectivity and Reef Fish Communities



Seascape Ecology: Seagrass Dynamics Across Spatial Scales



Seascape ecology provides a spatially explicit framework to study seagrass dynamics across spatial scales



Bostrom et al., 2011, Santos et al., 2016, Pittman 2017

Ecosystems Are Heterogeneous Across Space

Biological diversity

Ecosystem functions

MacArthur and Wilson 1967; Lundholm 2009; Tamme et al, 2010

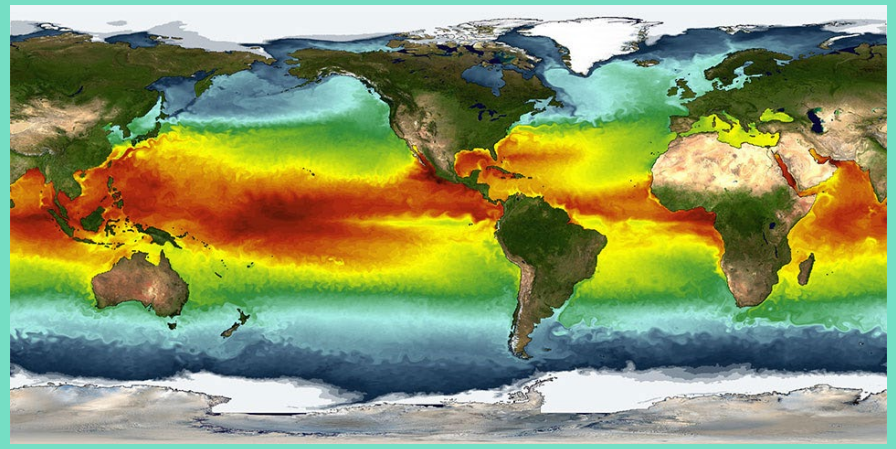
Spatial heterogeneity

Environmental Variability

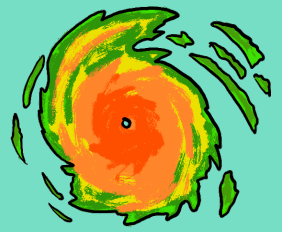
Spatial:

Environmental gradients of
- Temperature
- Humidity
- Nutrients
- Topography

Temporal:
- Diurnal cycles
- Seasonality
- Tidal cycles
- Climate change over geological eras



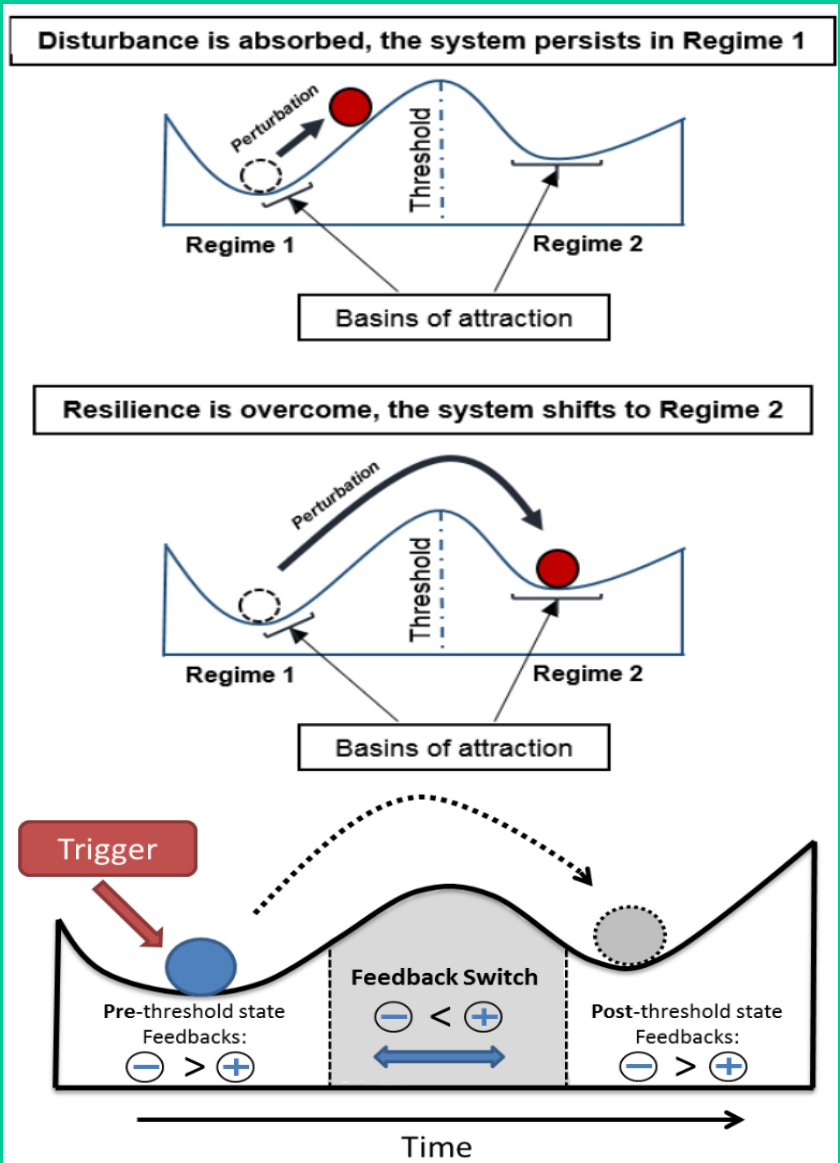
Disturbances

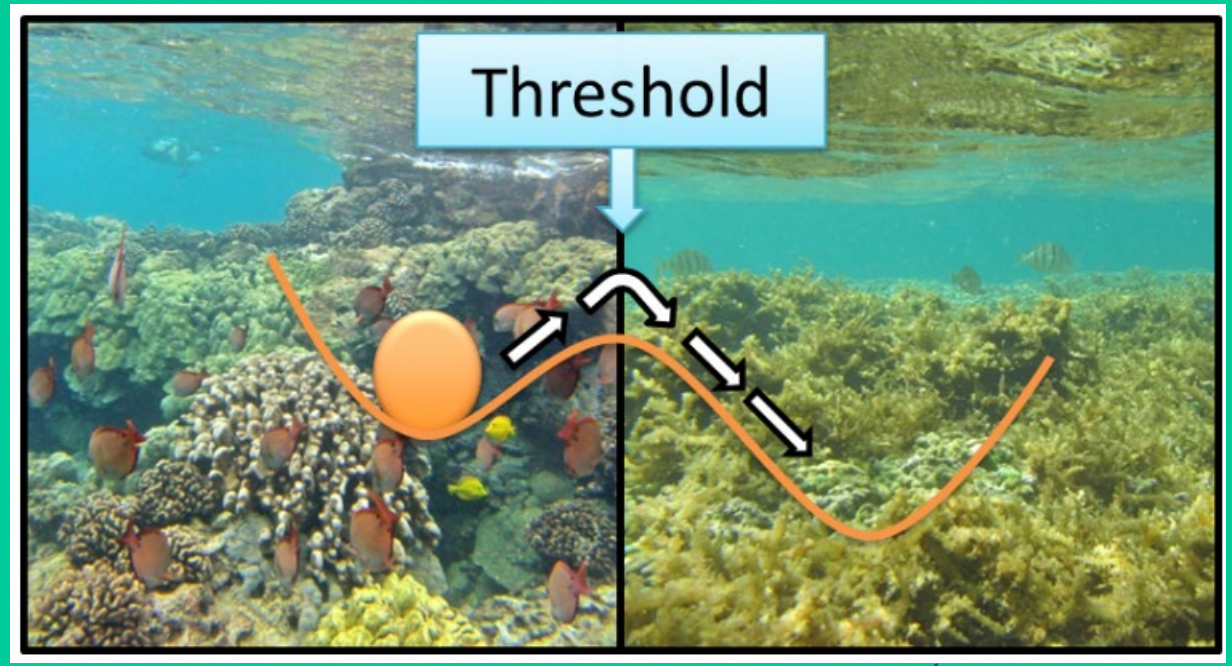


- Storms
- Fires
- Pests

- Urban development
- Sea level rise

Anthropogenic disturbance impacts seagrass beds





Desired state:
- Rich biodiversity
- Crucial ecosystem functions

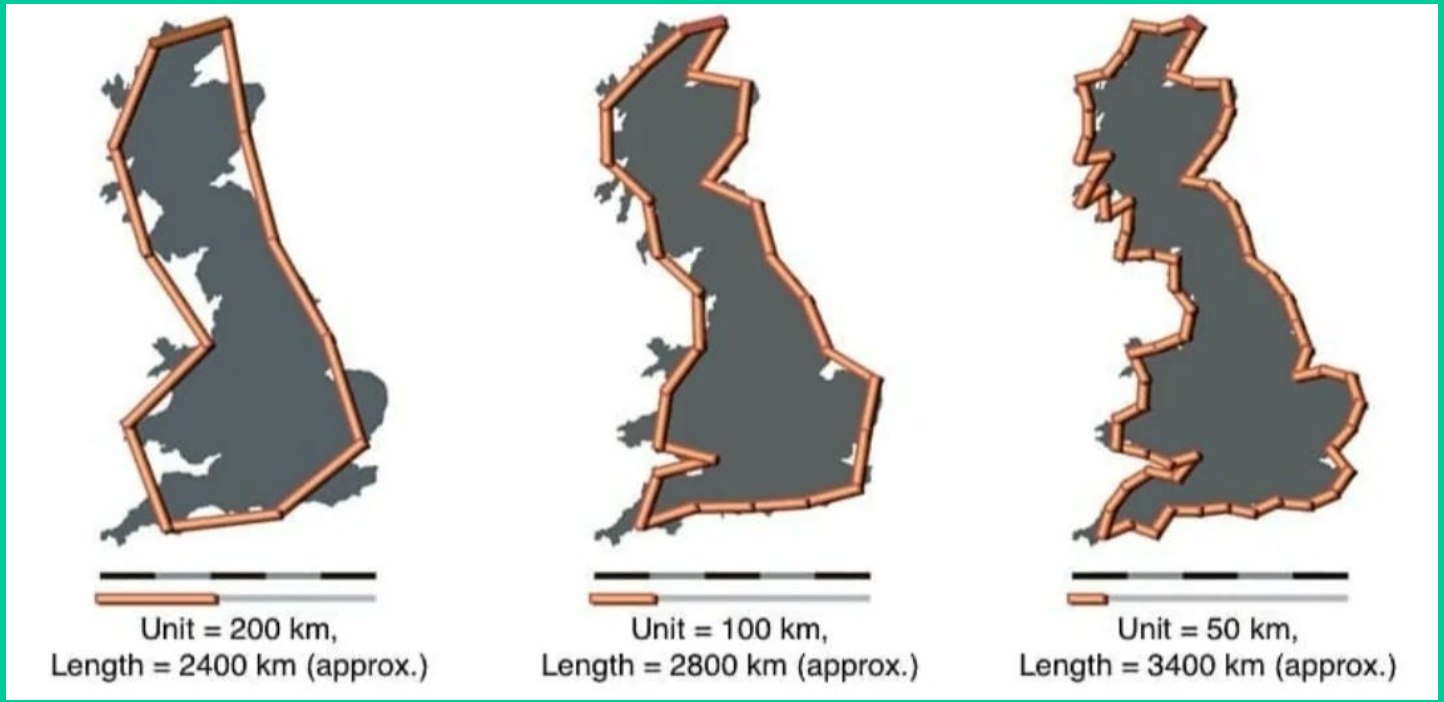
Undesired state:
- Low biodiversity
- No ecosystem functions

Introduction – The Problem Of Scale In Seascape Structure

Scale is the spatial measure of a phenomenon

The coastline paradox: how long is the coast of Britain?

Wedding et al., 2011; Lecours et al., 2015

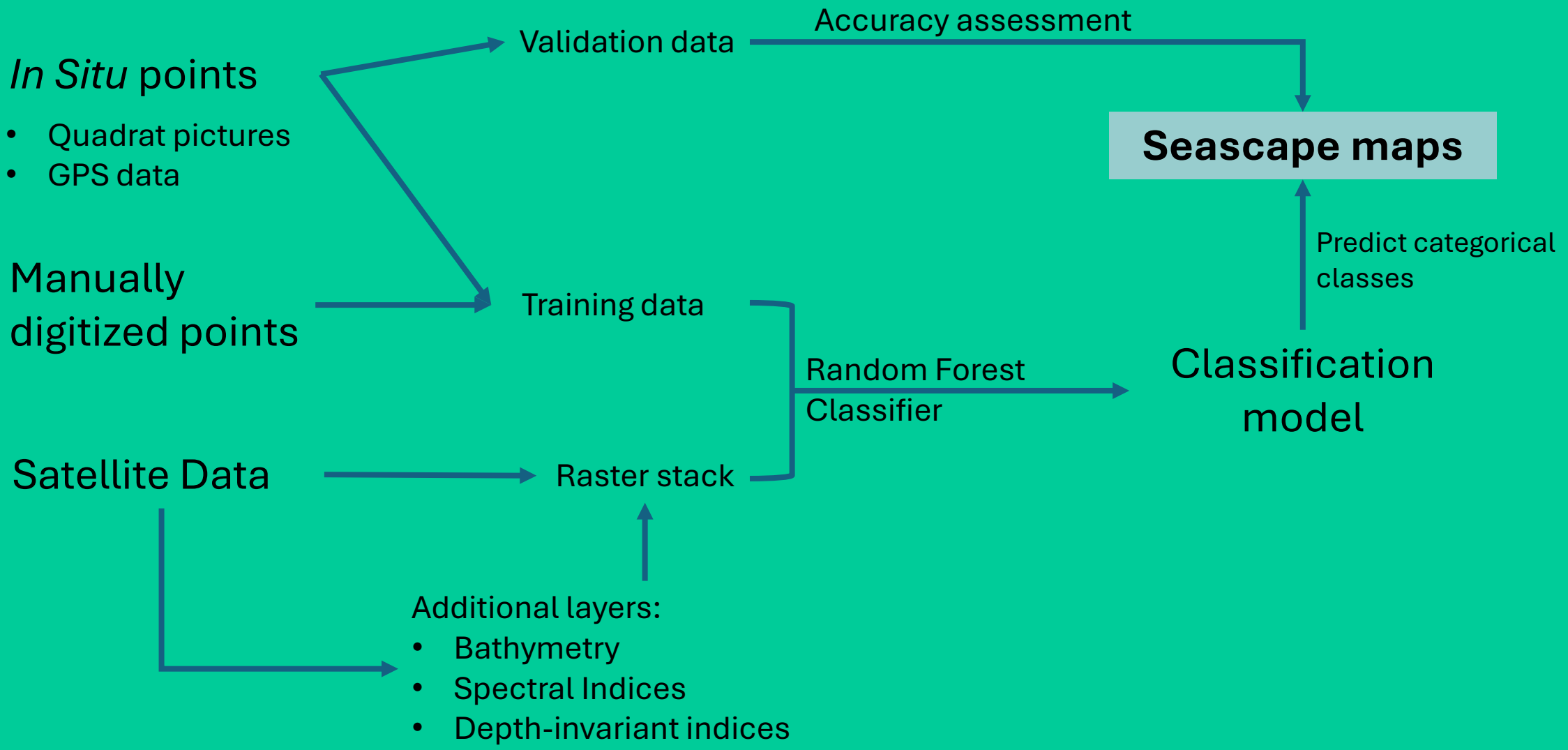


Multi-scale Seascape Studies

- Well-established in landscape ecology
- Growing body of literature in seascape ecology
- Need for spatial pattern analysis across scales

Scale is the lens to understand the relationship between patterns and processes

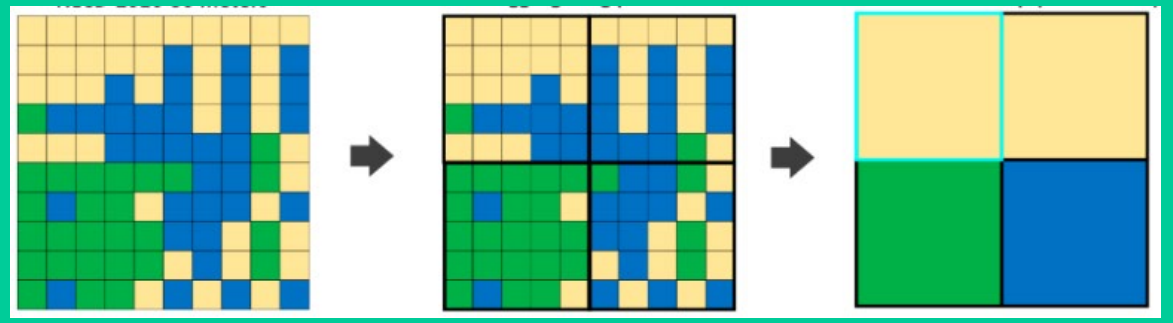
Mapping Workflow



Scale In Categorical Habitat Maps

GRAIN

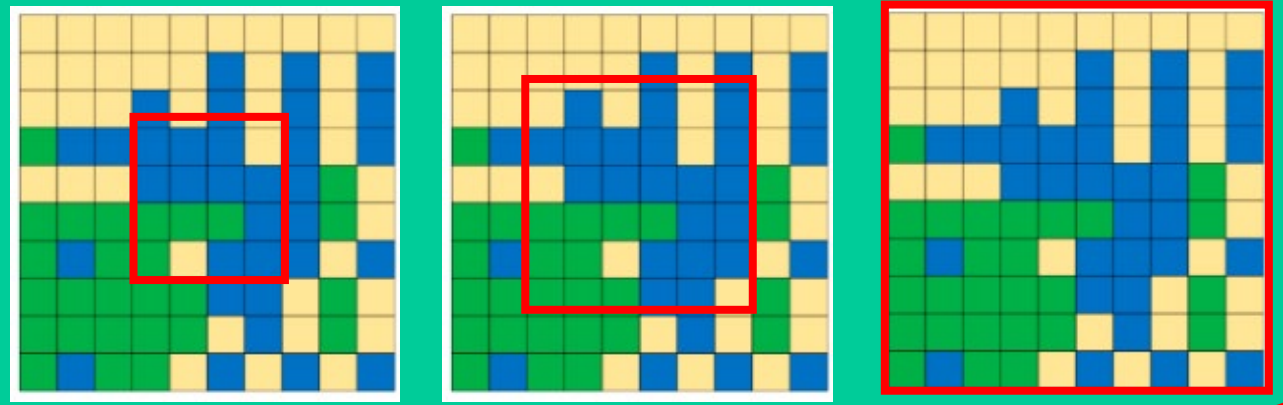
Pixels can be aggregated at different spatial scales



100-meter radius
700-meter radius
2000-meter radius

EXTENT

Extent of measurements can be increased or reduced

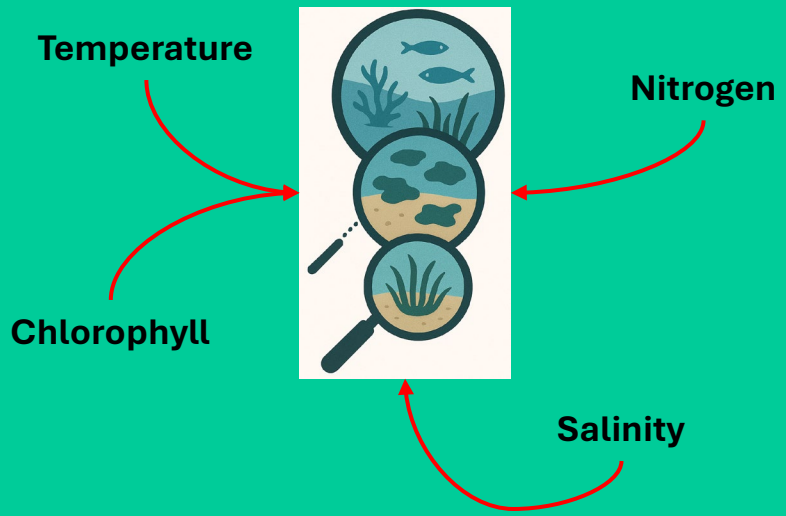


Adapted from Gu and Congalton 2020

Scale is the lens to link ecological patterns and processes

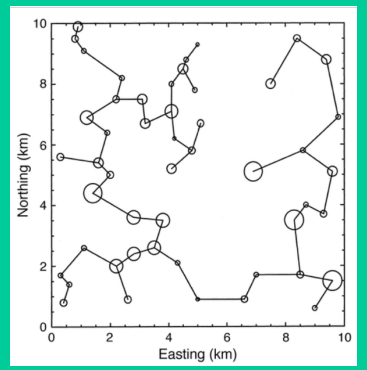
Ch 1: Seagrass structure across scales

Ch 2: Effects of Water Quality Across Hierarchical Levels



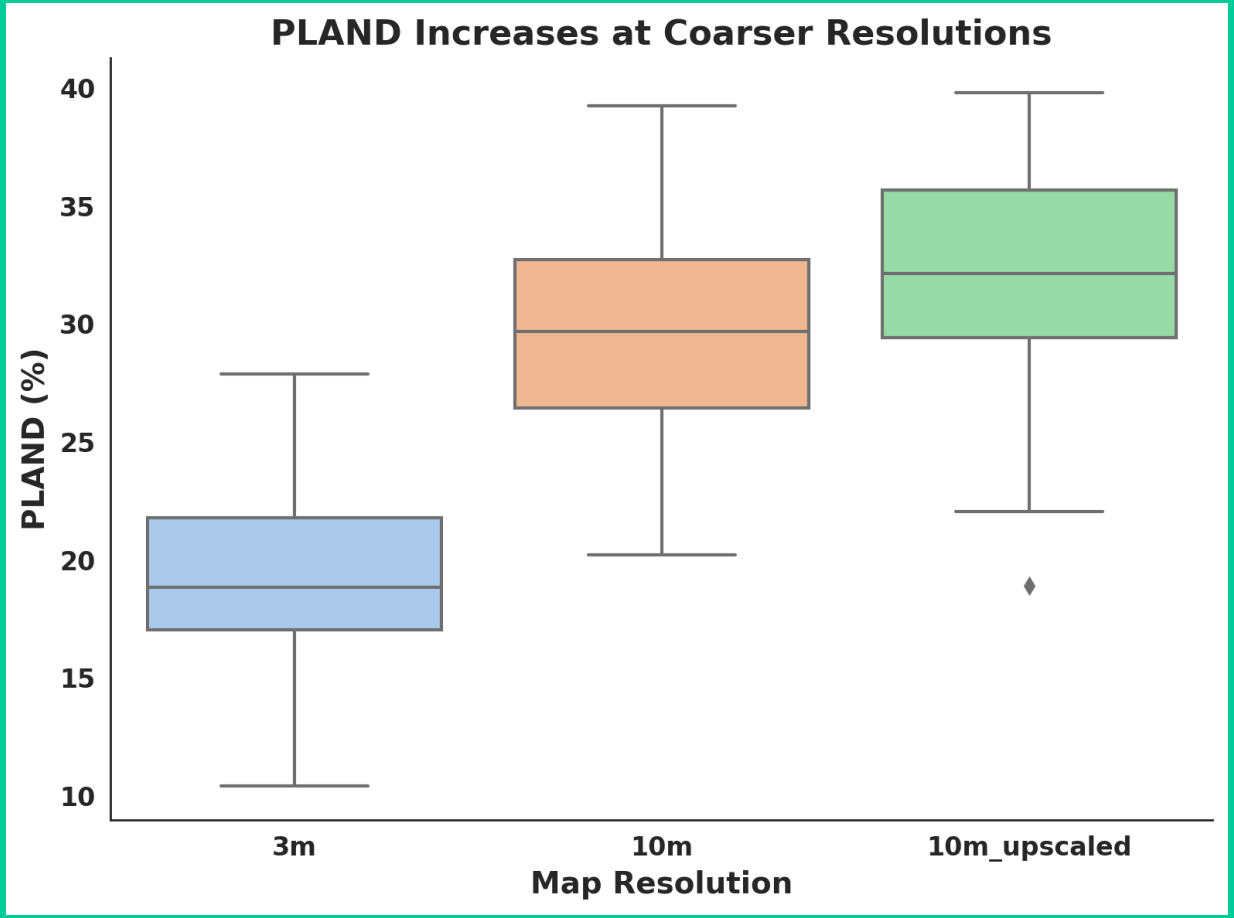
Ch 3: Seascape patterns influence fish habitat selection

Ch 4: Reef Fish Responses to Seascape Connectivity



Spatial Patterns Across Grain

H1a) SPMs measure at coarser grain resolution overestimate seagrass cover and underestimate the number of patches and shape complexity compared to finer grain



Example of expected results for PLAND = Proportion of seagrass in the landscape

Measuring Spatial Patterns

SPM metrics from time series maps
(**configuration**)

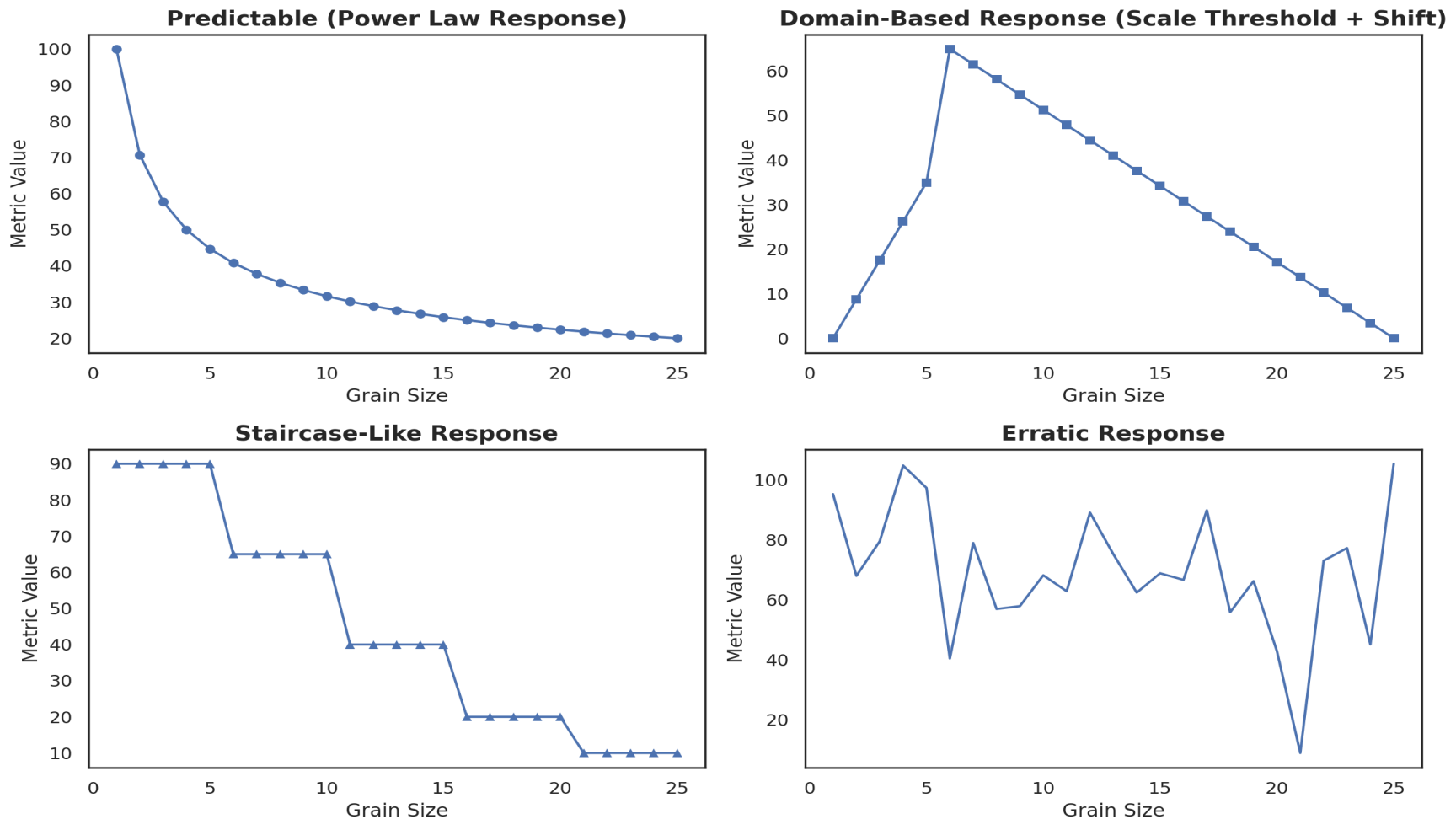
1. Percent of Seagrass in the Landscape
2. Patch Density
3. Edge Density
4. Fragmentation Index

Water quality data from Miami-Dade Department of Environmental Resource Management (DERM)
(**disturbance regime**)

Temperature
Salinity
Nitrogen
Phosphorous
PH
Conductivity

Spatial Patterns Across Extents

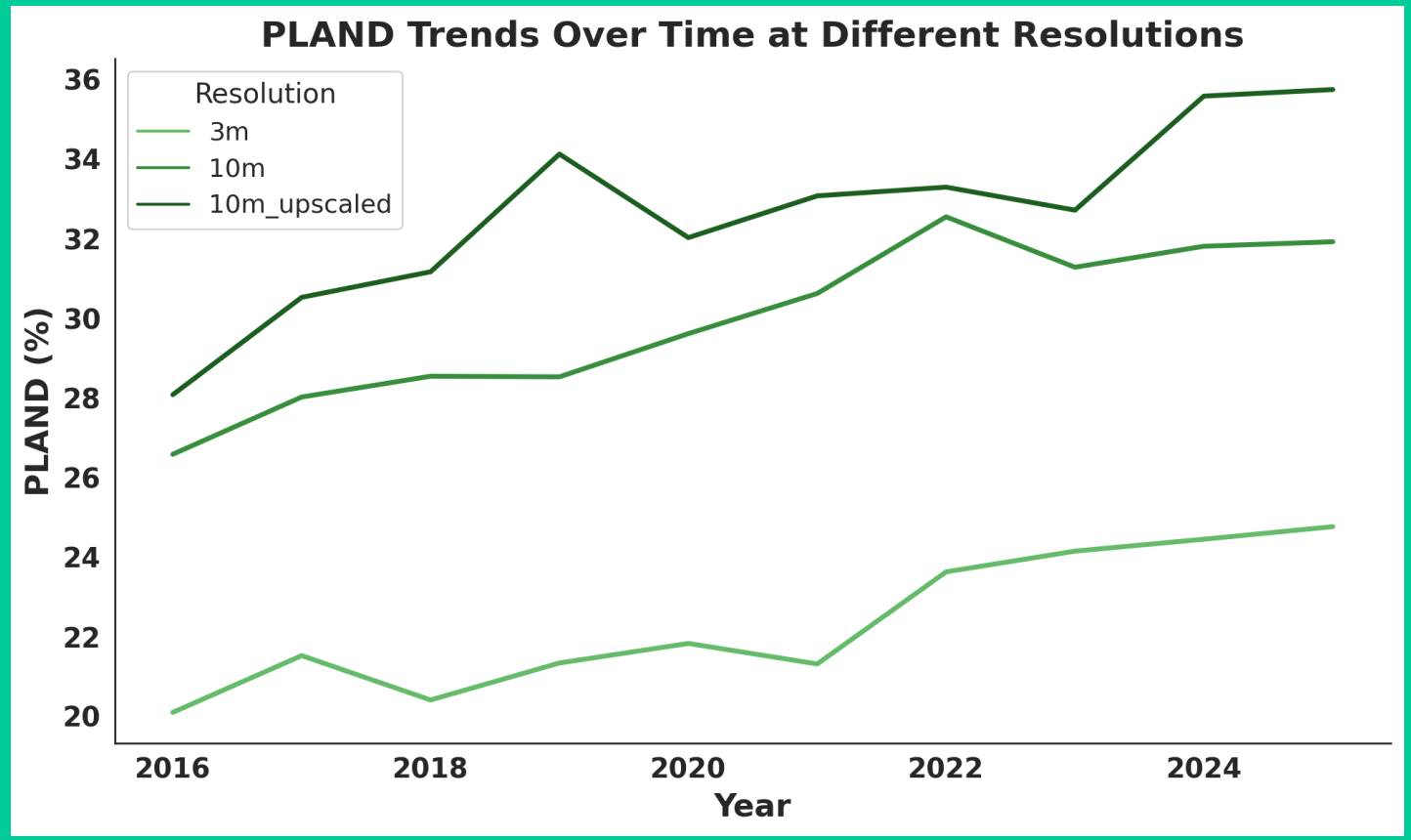
H1b) SPMs will display 4 types of scaling responses



Wu et al., 2004, Alhamad et al., 2011

Spatial Patterns Temporal Trends

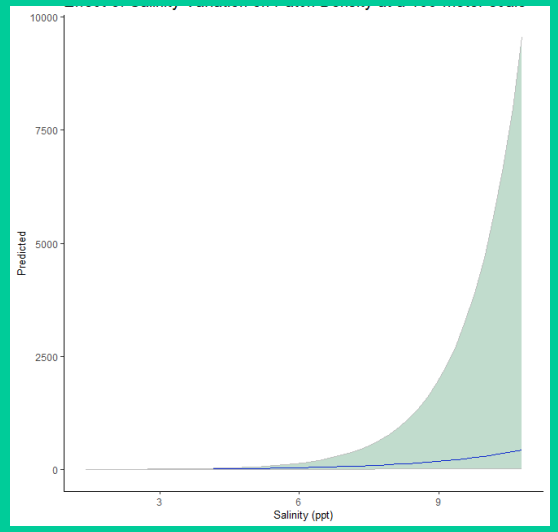
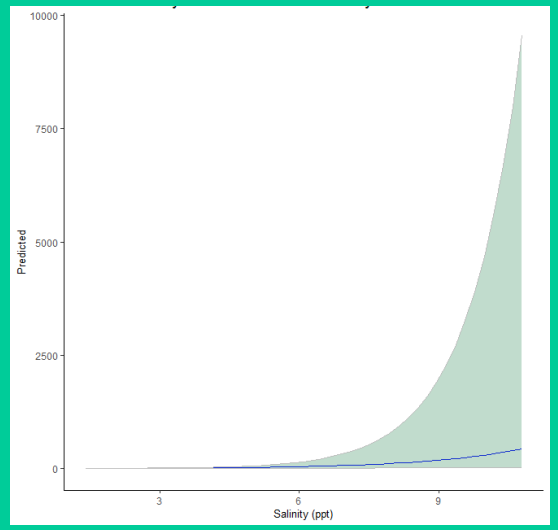
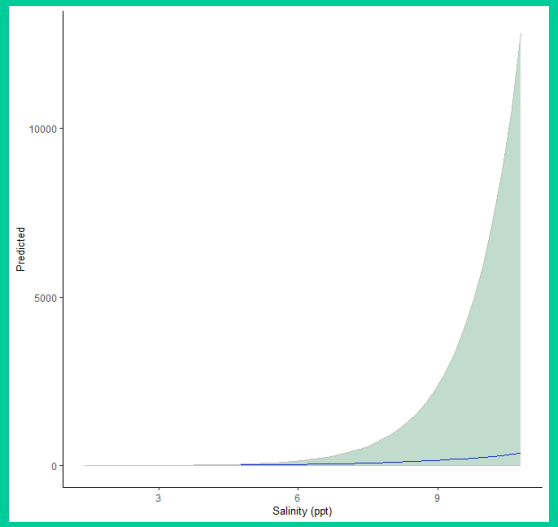
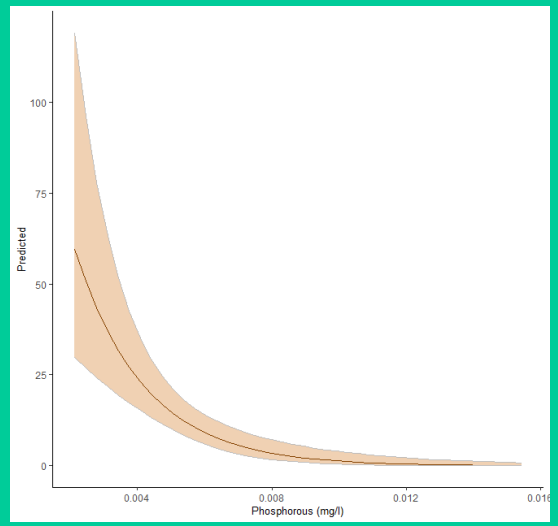
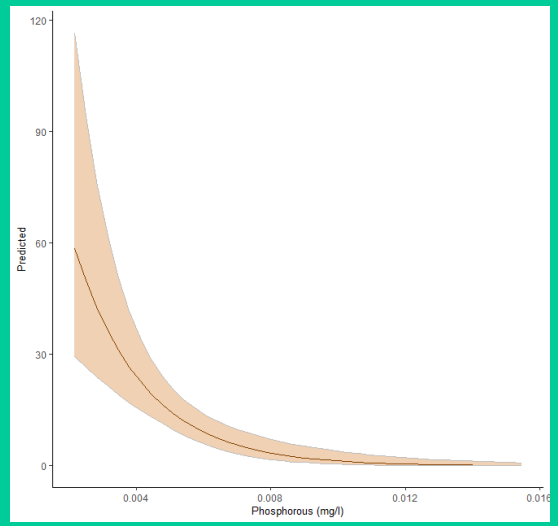
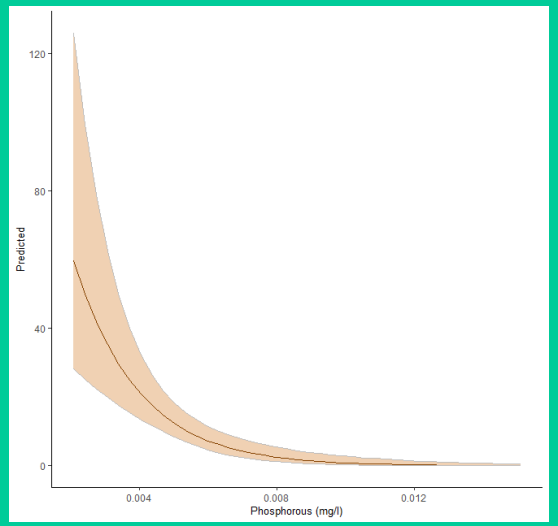
H1c) SPMs with a predictable scaling behavior will show consistent temporal trends across scales



Example of expected results for PLAND = Proportion of seagrass in the landscape

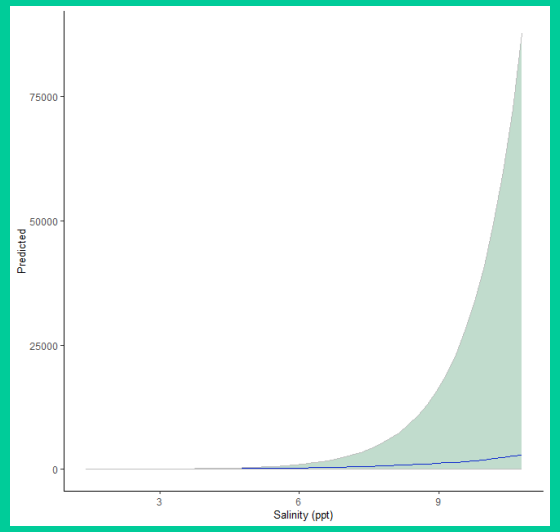
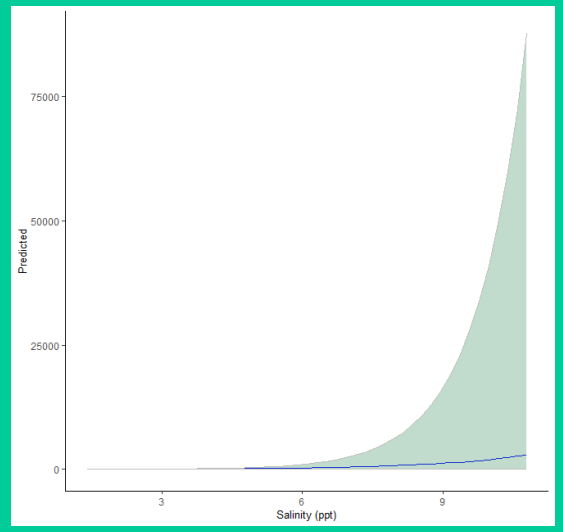
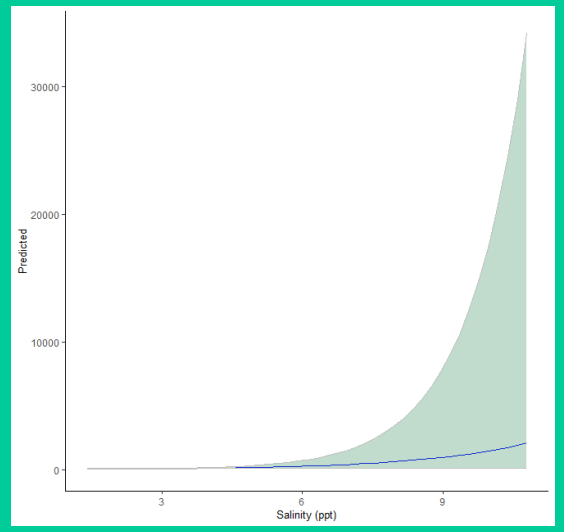
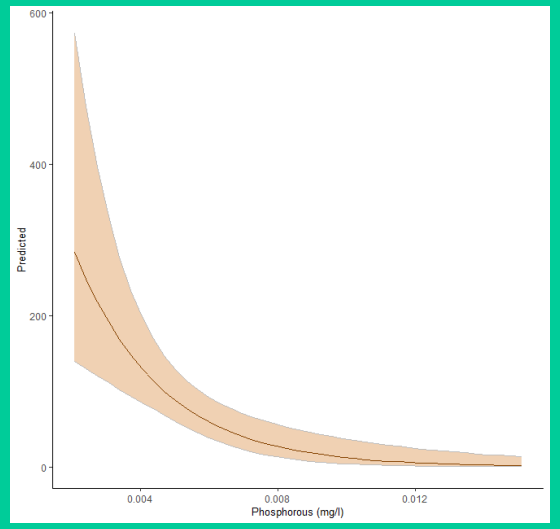
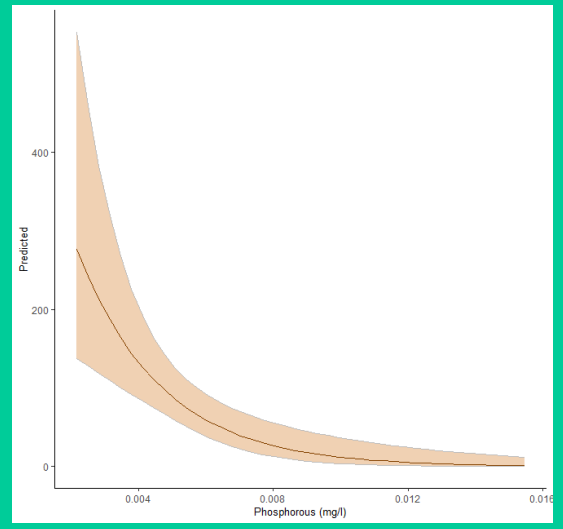
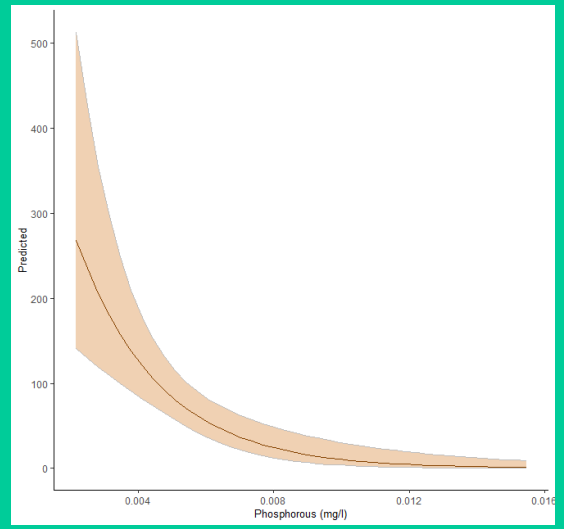
Results

Effects of water quality on Patch Density

	100-meter radius	500-meter radius	700-meter radius
Salinity Variation			
Phosphorous			

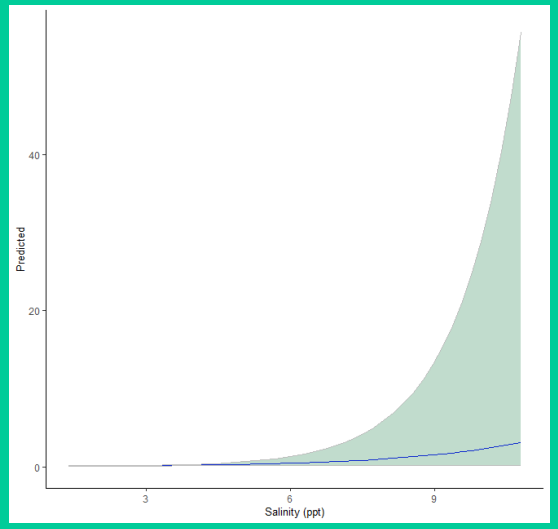
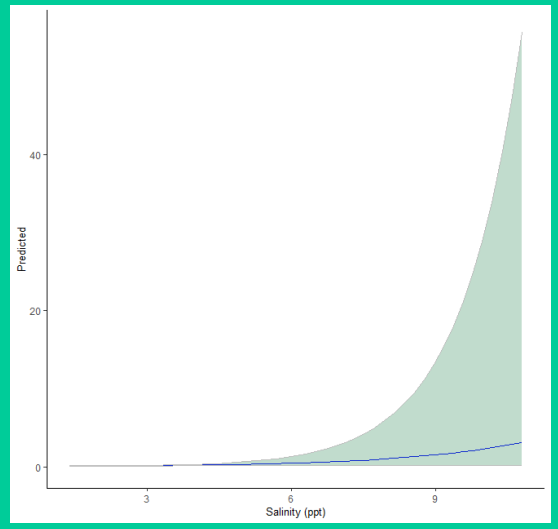
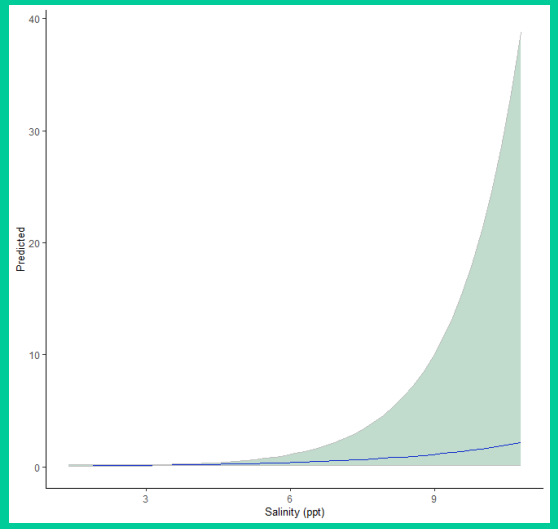
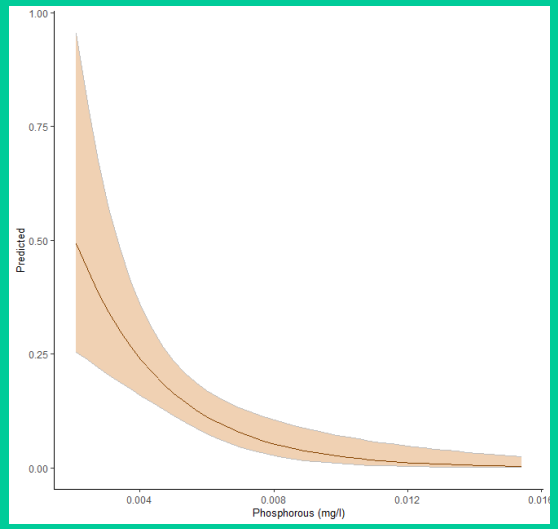
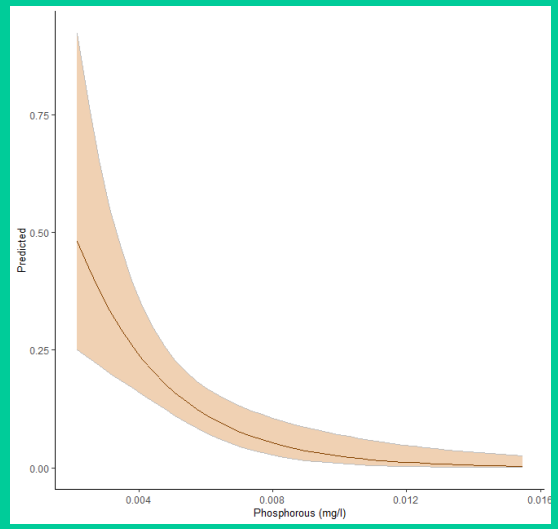
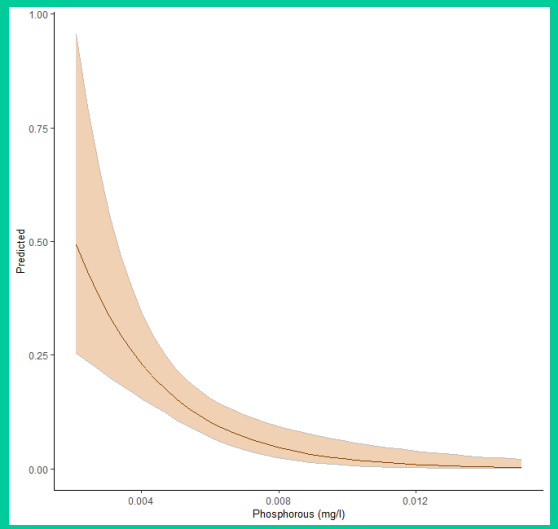
Results

Effects of water quality on Edge Density

	100-meter radius	500-meter radius	700-meter radius
Salinity Variation			
Phosphorous			

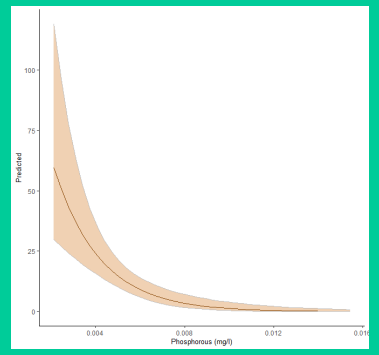
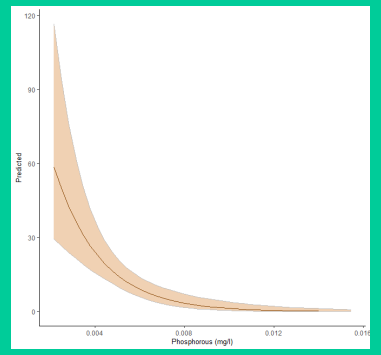
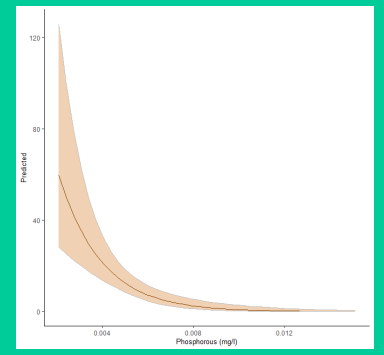
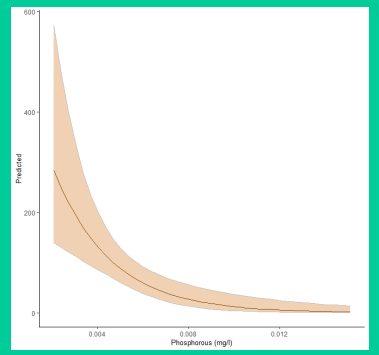
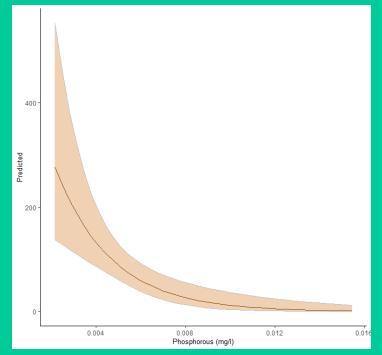
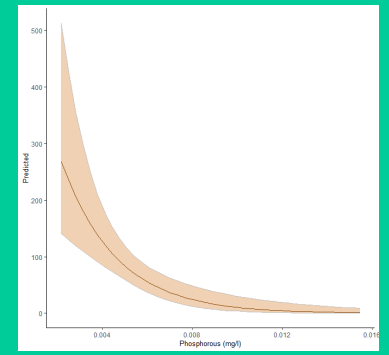
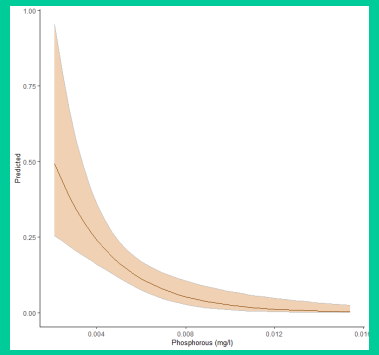
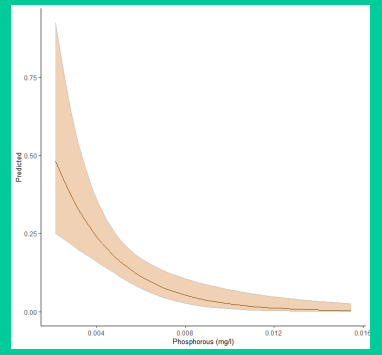
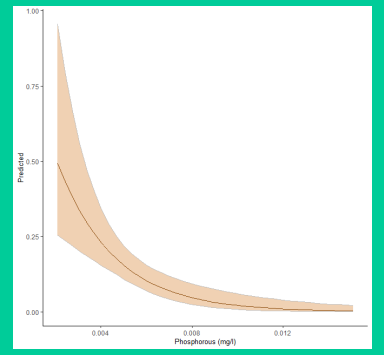
Results

Effects of water quality on Fragmentation

	100-meter radius	500-meter radius	700-meter radius
Salinity Variation			
Phosphorous			

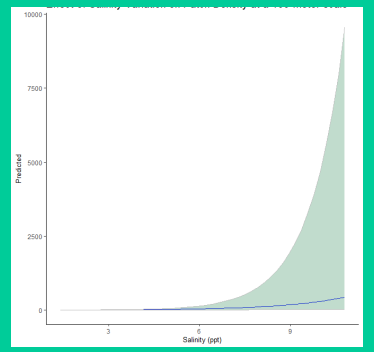
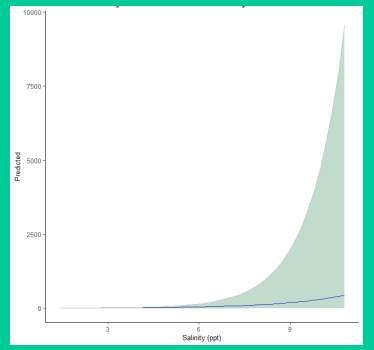
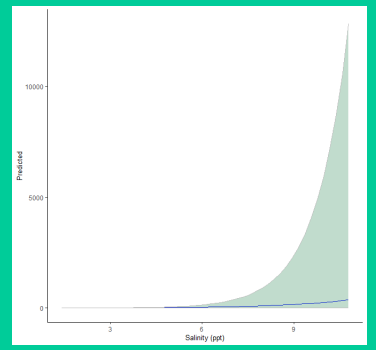
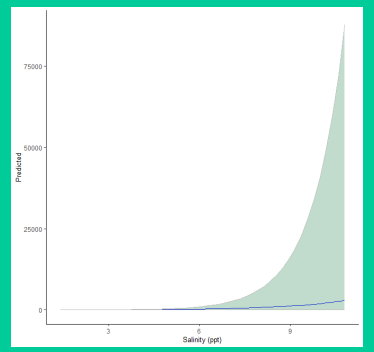
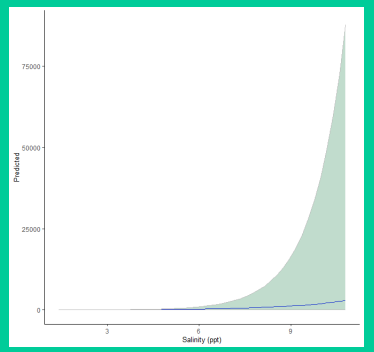
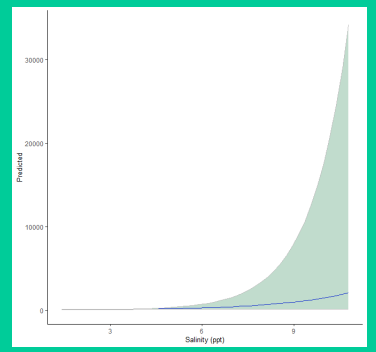
Results

Effects of Mean Total Phosphorous

	100-meter radius	500-meter radius	700-meter radius
Patch Density			
Edge Density			
Fragmentation Index			

Results

Effects of Variation in Salinity

	100-meter radius	500-meter radius	700-meter radius
Patch Density			
Edge Density			
Fragmentation Index