Multispecies movement and use of various habitats in the Mississippi Sound with an emphasis on future oyster reef construction

Austin Draper[1]

Michael J. Andres[2], Mark S. Peterson[2], and Wei Wu[2]

[1]ERDC Environmental Laboratory Coastal Ecology Team

[2]The University of Southern Mississippi, Ocean Springs, MS 39564

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Habitat restoration

- Restoration seeks to restore specific habitats, functions, or species
- Multispecies influence

Oyster decline

- Oyster global abundance has decreased
- Recent decline within the MS Sound
- Oysters have numerous positive effects
- Reef construction has become common
- Influence on transient visitors is poorly understood

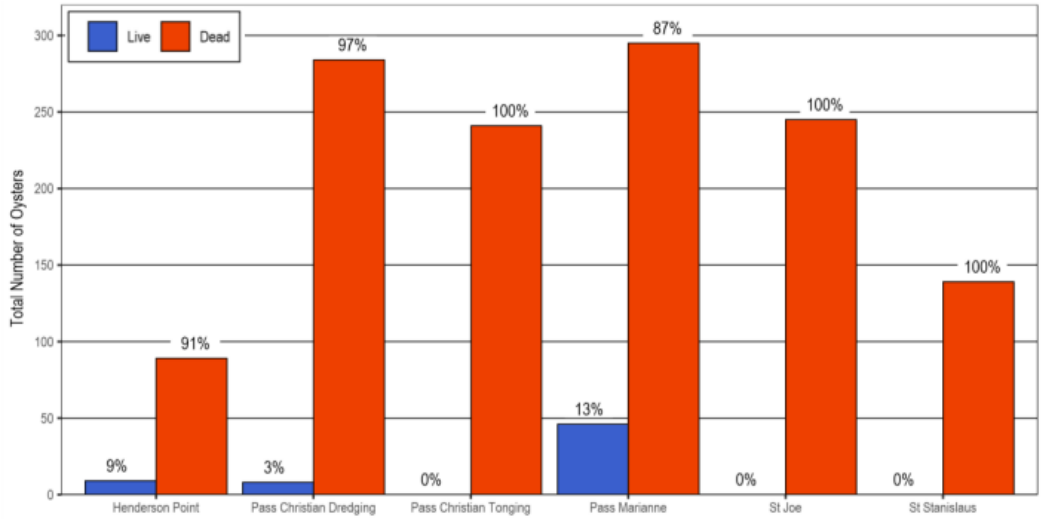


Figure 1. Numbers of live and dead oysters collected on Mississippi harvest reefs for the week of June 10, 2019. Blue bars represent number of live oysters collected, and red bars represent dead oysters. Percentages represent reef-specific mortality estimate [(total number dead / total number collected) x 100]. *Source*: MDMR

26 August 2020

Translator Disclaimer

Mass Mortality of the Eastern Oyster *Crassostrea virginica* in the Western Mississippi Sound Following Unprecedented Mississippi River Flooding in 2019

James H. Gledhill, Ann Fairly Barnett, Marc Slattery, Kristine L. Willett, Gregory L. Easson, Stephanie Showalter Otts, Deborah J. Gochfeld

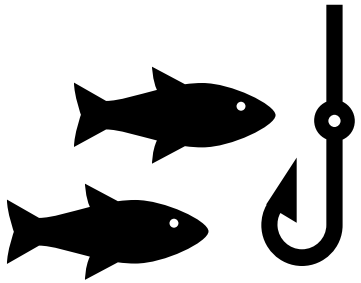
Transient fish

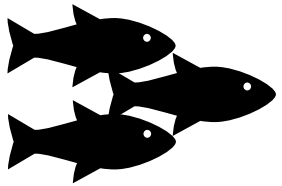
- Transient fish – “Species that only occasionally use oyster reefs or reef adjacent habitat”
- Central issue is attraction vs production
- Does reef provide benefit?

Attraction vs production

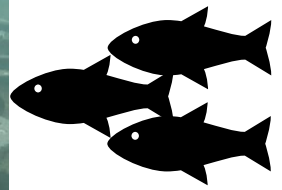
Figure credit: Jade M. Carver at Louisiana State University

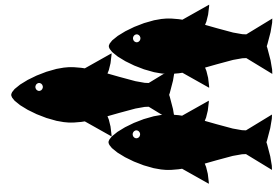
Attraction





Production



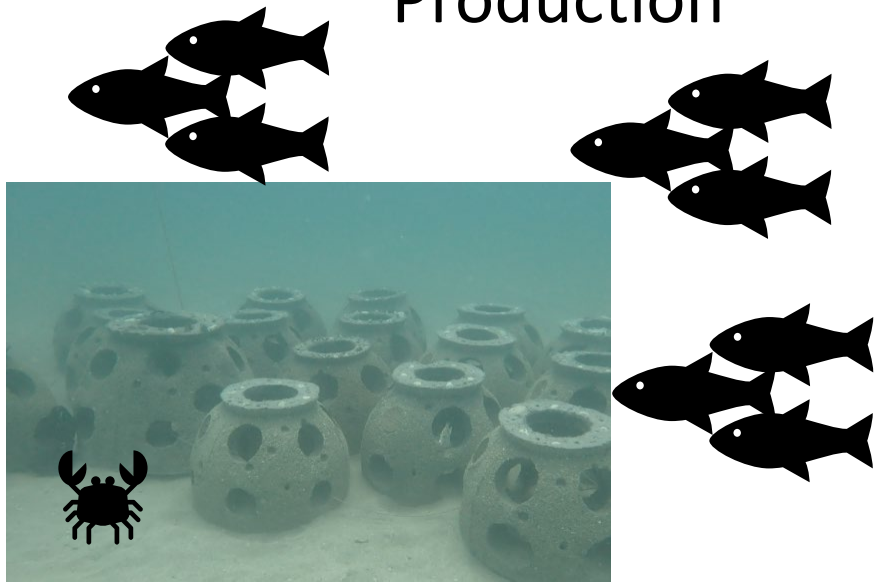


Attraction vs production

Figure credit: Jade M. Carver at Louisiana State University

Attraction

Production

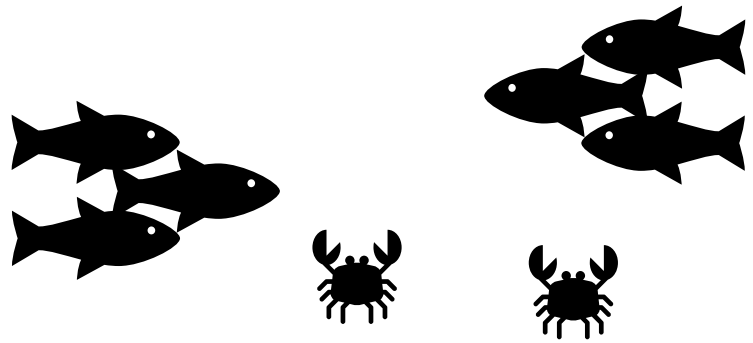


Attraction vs production: baseline data

Before construction:

1. Movements
2. Resource preferences

Must assess for multiple species



Chapter objectives:

- **Ch. 1: describe emigration patterns of a threatened anadromous fish species to nearshore and alongshore habitats**
  - Provide data on possible influence on a protected species
- **Ch. 2: describe movements of multiple species in a coastal bay sub-system**
  - Insight into movements in an area primed for restoration
- **Ch. 3: model transient fish use associated with infauna and sediment metrics**
  - Fill data gaps on pre-restoration preferences for habitat, infauna, and sediment

Chapter 1: Fall emigration patterns of Pascagoula River Gulf Sturgeon, *Acipenser oxyrinchus desotoi*

Manuscript in prep. to Bulletin of Marine Science

Austin Draper[1], Wei Wu[1], Elizabeth Greenheck[1], Michael J. Andres[1], Mark S. Peterson[1], Paul O. Grammer[2], Dylan Kiene[3], Sean P. Powers[3], and Jennifer L. Green[4]

[1]Division of Coastal Sciences and [2]Center for Fisheries Research and Development, School of Ocean Science and Engineering, The University of Southern Mississippi, Ocean Springs, MS 39564.

[3]Department of Marine Sciences, University of South Alabama, 5871 USA Drive North, Mobile, Alabama 36688.

[4]Mississippi Department of Marine Resources, Department of Marine Fisheries, Finfish Bureau, 1141 Bayview Ave, Biloxi MS 39530

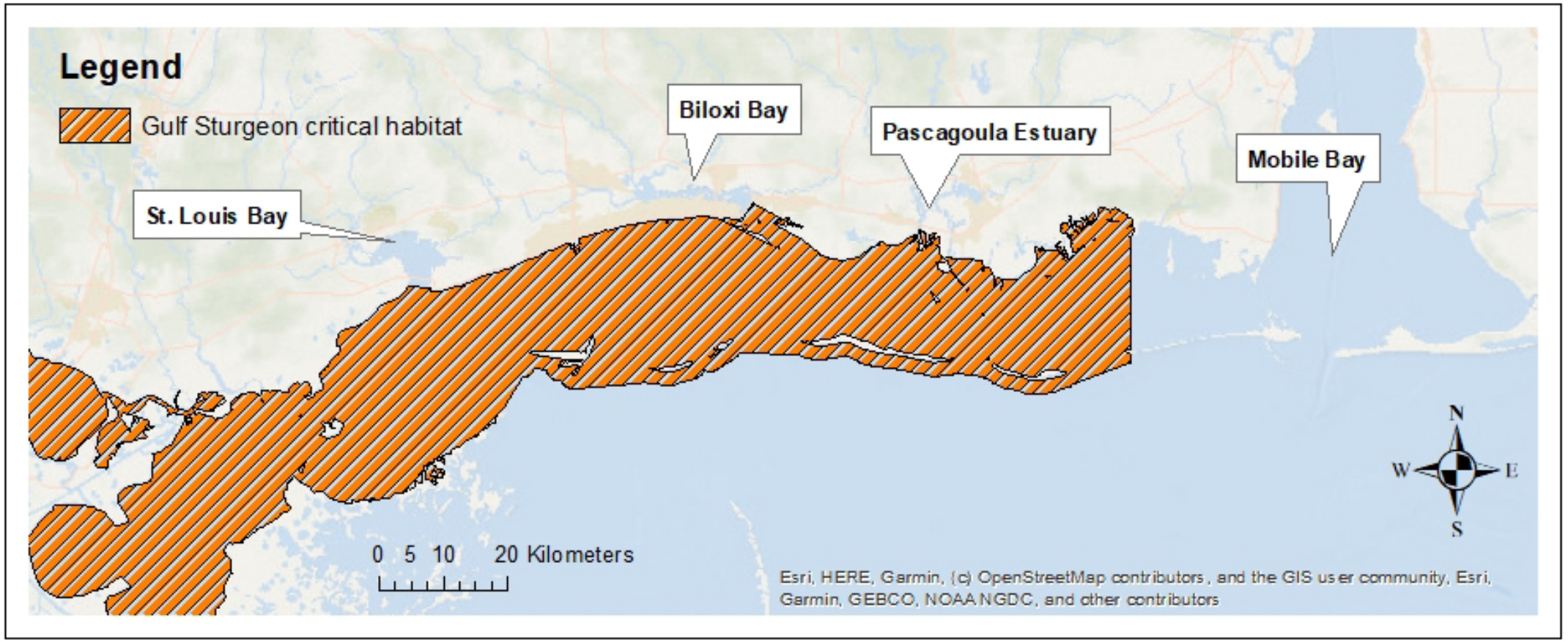
THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Introduction

- Gulf Sturgeon are a threatened anadromous species in the northern Gulf of Mexico
- Undergo yearly river emigration to overwinter foraging grounds
- Research has defined overwinter foraging habitat is estuaries for juveniles and marine/barrier islands for subadults/adults
- Subadults and adults may use alongshore, and nearshore more than previously thought

Importance

- Analysis of alongshore and nearshore movements are required
- Alongshore = along mainland
- Nearshore = between mainland and barrier islands

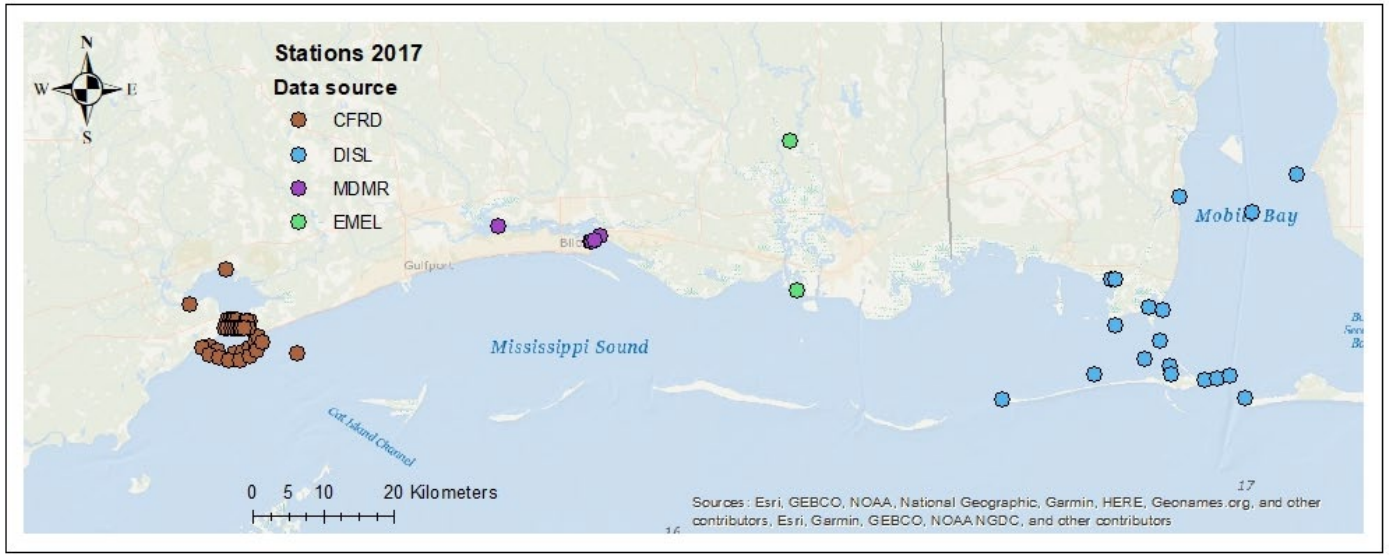


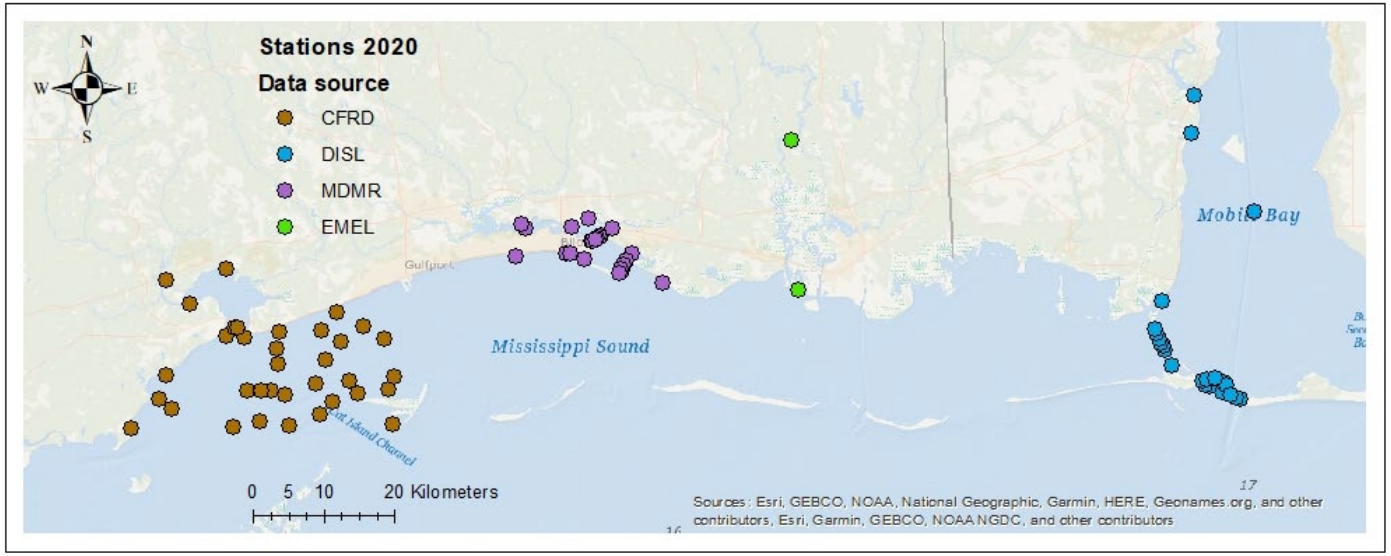
Objective

- Provide detail on emigration patterns into alongshore and nearshore environments
- Specifically:

1. Fish emigrating east vs west of Pascagoula River
2. Factors influencing travel rate
3. Factors influencing timing of emigration

Methods





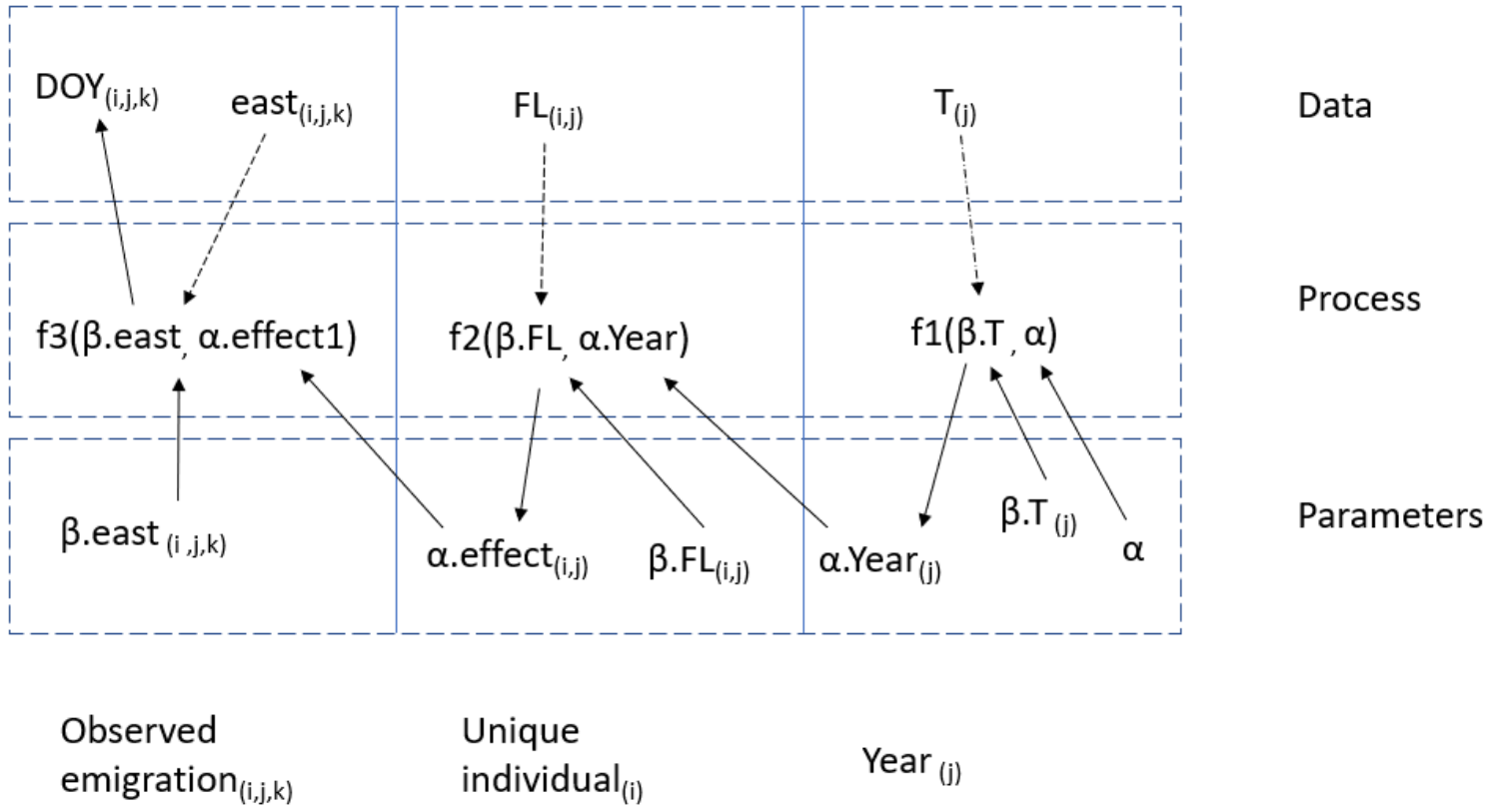
- Telemetry data from 2017-2021
- Tags (InnovaSea V7-V16)
- VR2W receivers (InnovaSea)
- First detection outside of river mouth considered “emigration”
- Number of fish moving east vs west was multiplied by weighting factor

Eg: weight = 1 – [# of receivers east or west/total # of receivers]

- Rate = distance between/time between (meters/hr)
- Emigration timing was day of year (DOY) of last detection

Models

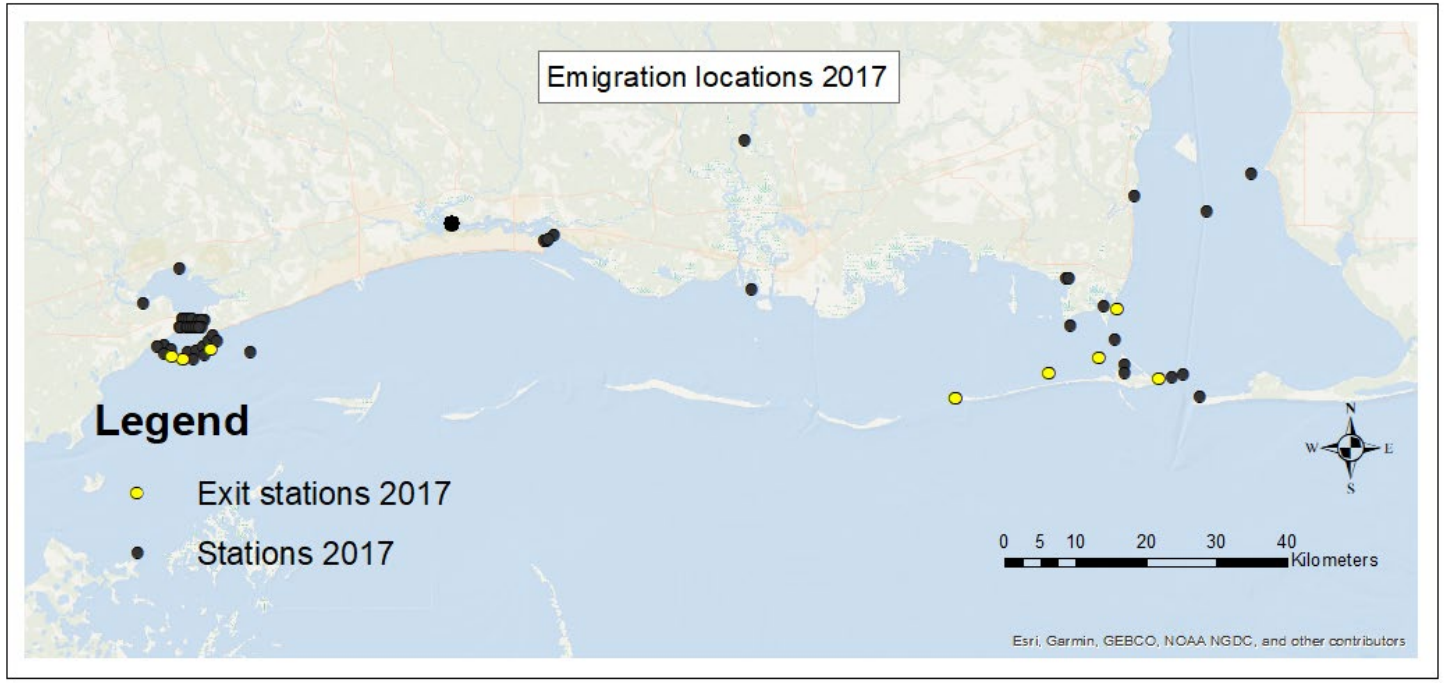
- Bayesian multi-level regression to understand DOY and travel rate
- Direction (east)
- Fork length (FL)
- Temp. slope (T)
- MCMC 50k iterations
- Trace plots and DIC

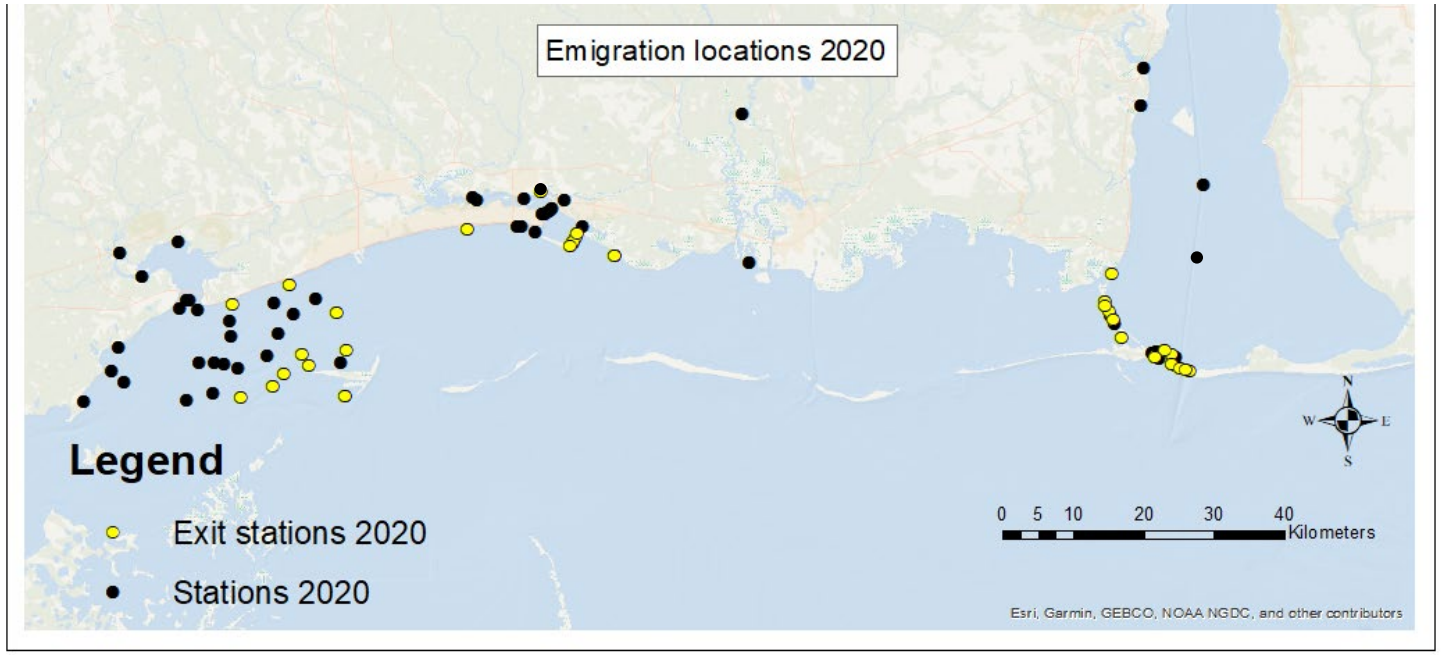


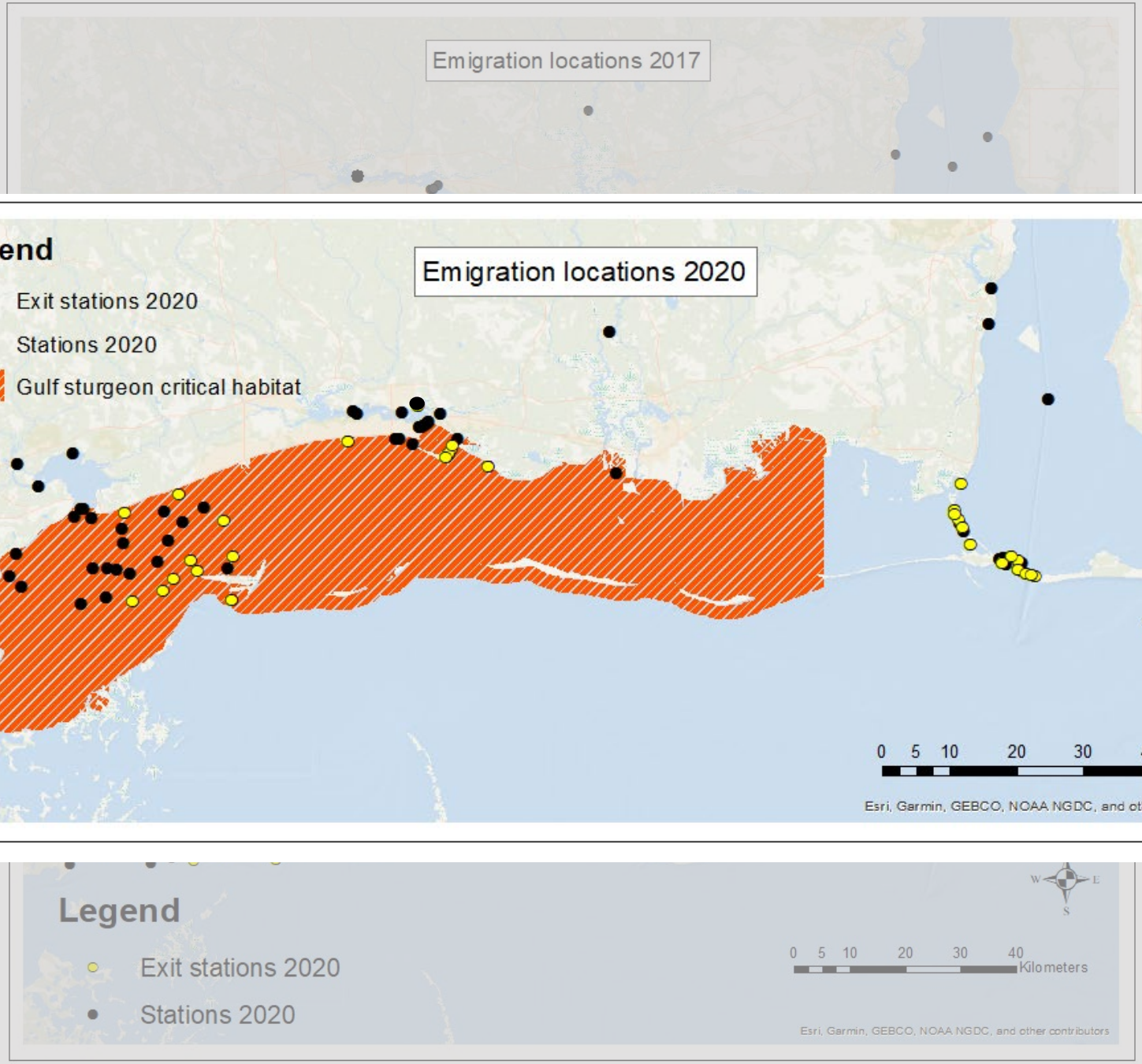
Results

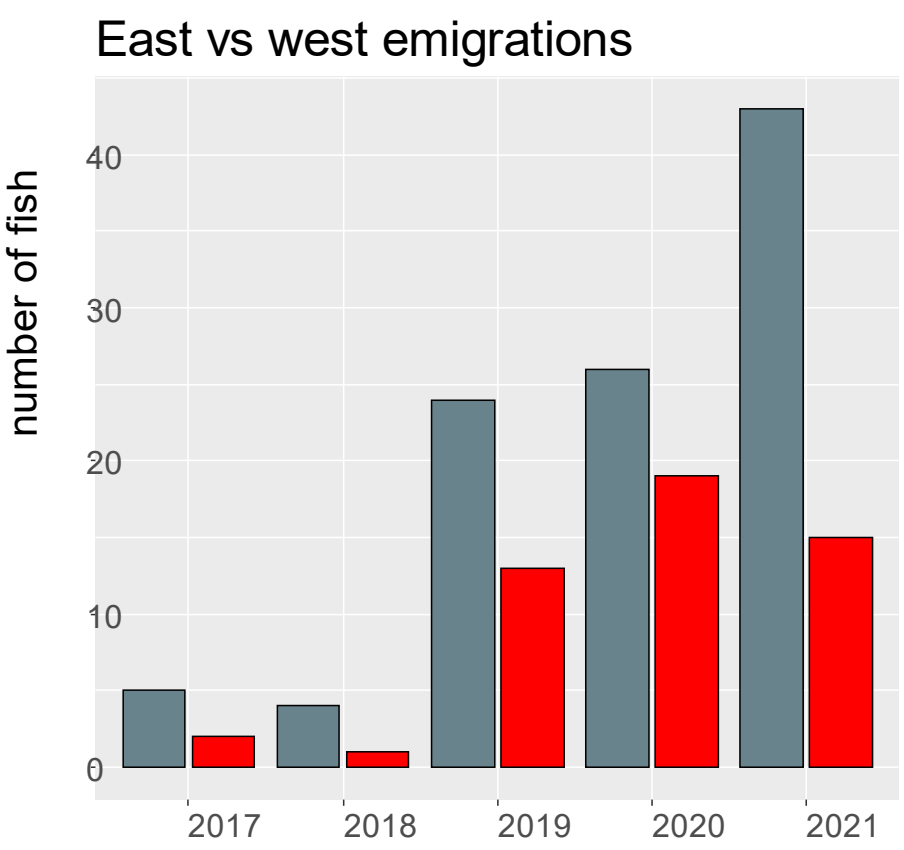
- 153 emigration events
- Adults and subadults primary size class (>890 mm FL)

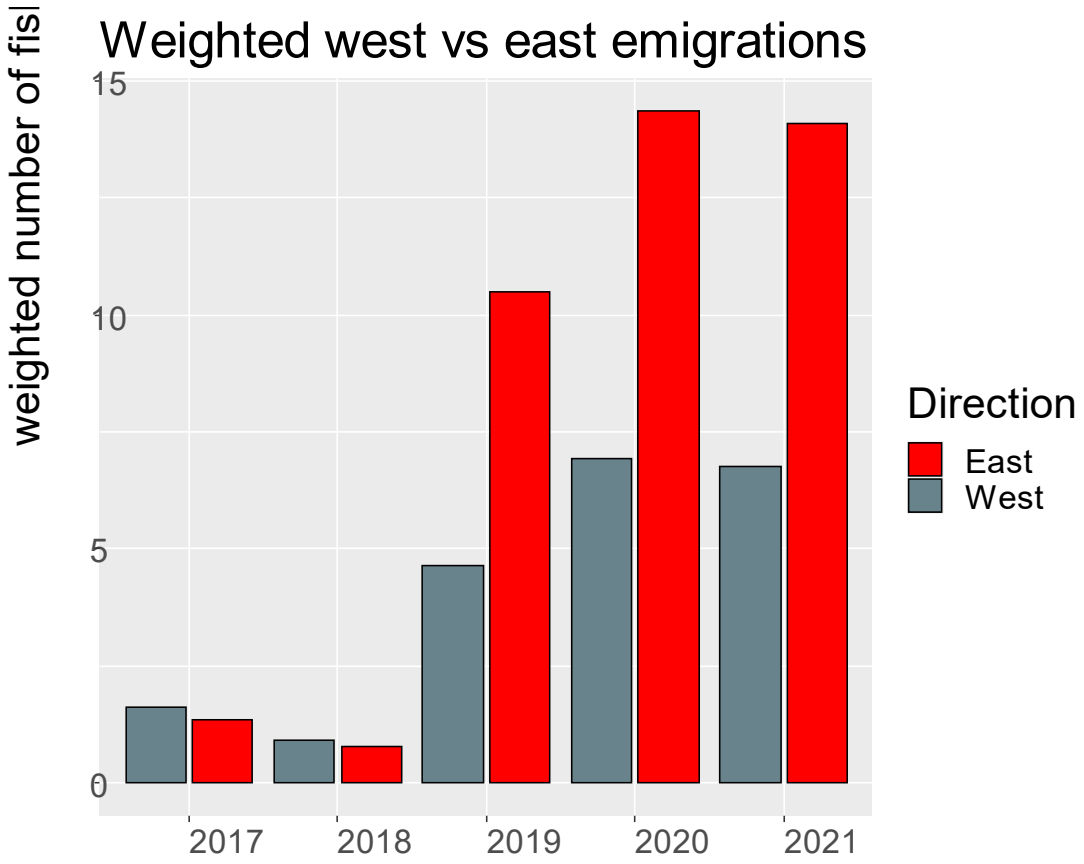
Emigration year	No. emigrating juveniles	No. emigrating sub-adults	No. emigrating adults
2017	0	2	5
2018	0	5	0
2019	0	10	27
2020	1	15	29
2021	0	13	46


Emigration locations 2017
Legend
Exit stations 2017
Stations 2017
N
W
E
S
0 5 10 20 30 40
Kilometers
Esri, Garmin, GEBCO, NOAA NGDC, and other contributors


Emigration locations 2020
Legend
Exit stations 2020
Stations 2020
N
W
E
S
0 5 10 20 30 40
Kilometers
Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

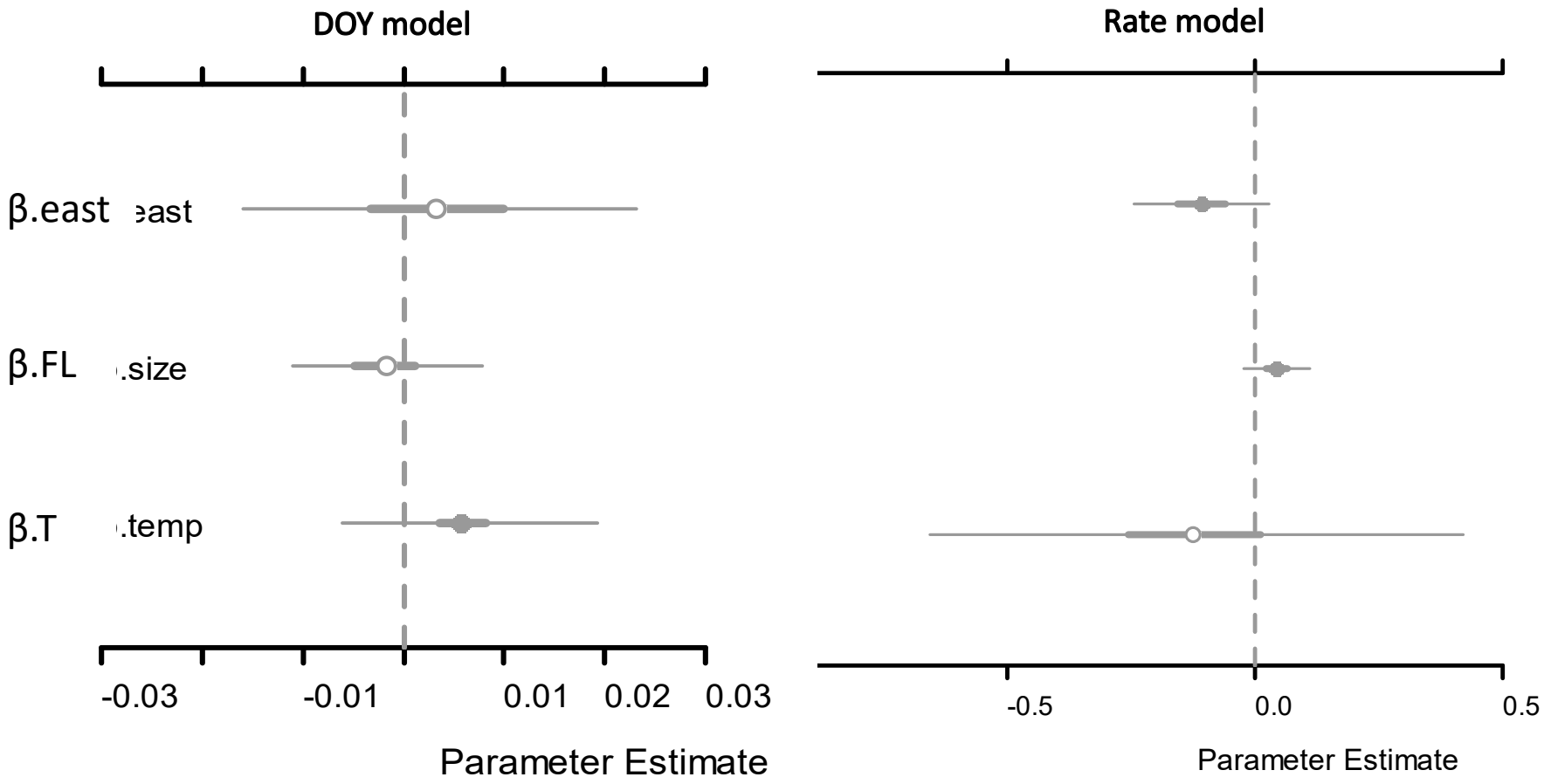

Emigration locations 2017
Legend
Exit stations 2020
Stations 2020
0 5 10 20 30 40
Kilometers
Esri, Garmin, GEBCO, NOAA NGDC, and other contributors
Emigration locations 2020
Legend
Exit stations 2020
Gulf sturgeon critical habitat
Stations 2020
N
W
E
S
0 5 10 20 30 40
Kilometers
Esri, Garmin, GEBCO, NOAA NGDC, and other contributors


East vs west emigrations
number of fish
40
30
20
10
0
2017
2018
2019
2020
2021


Weighted west vs east emigrations
weighted number of fish
15
10
5
0
2017
2018
2019
2020
2021
Direction
East
West

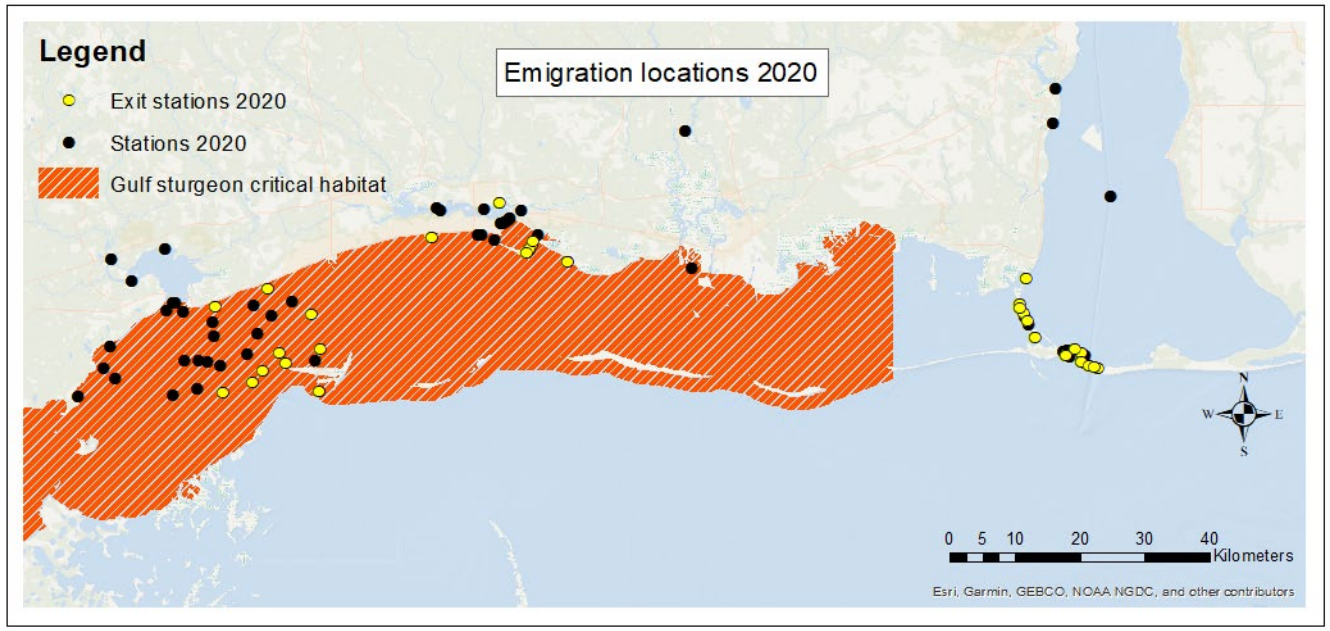

Legend
N
W
E
S

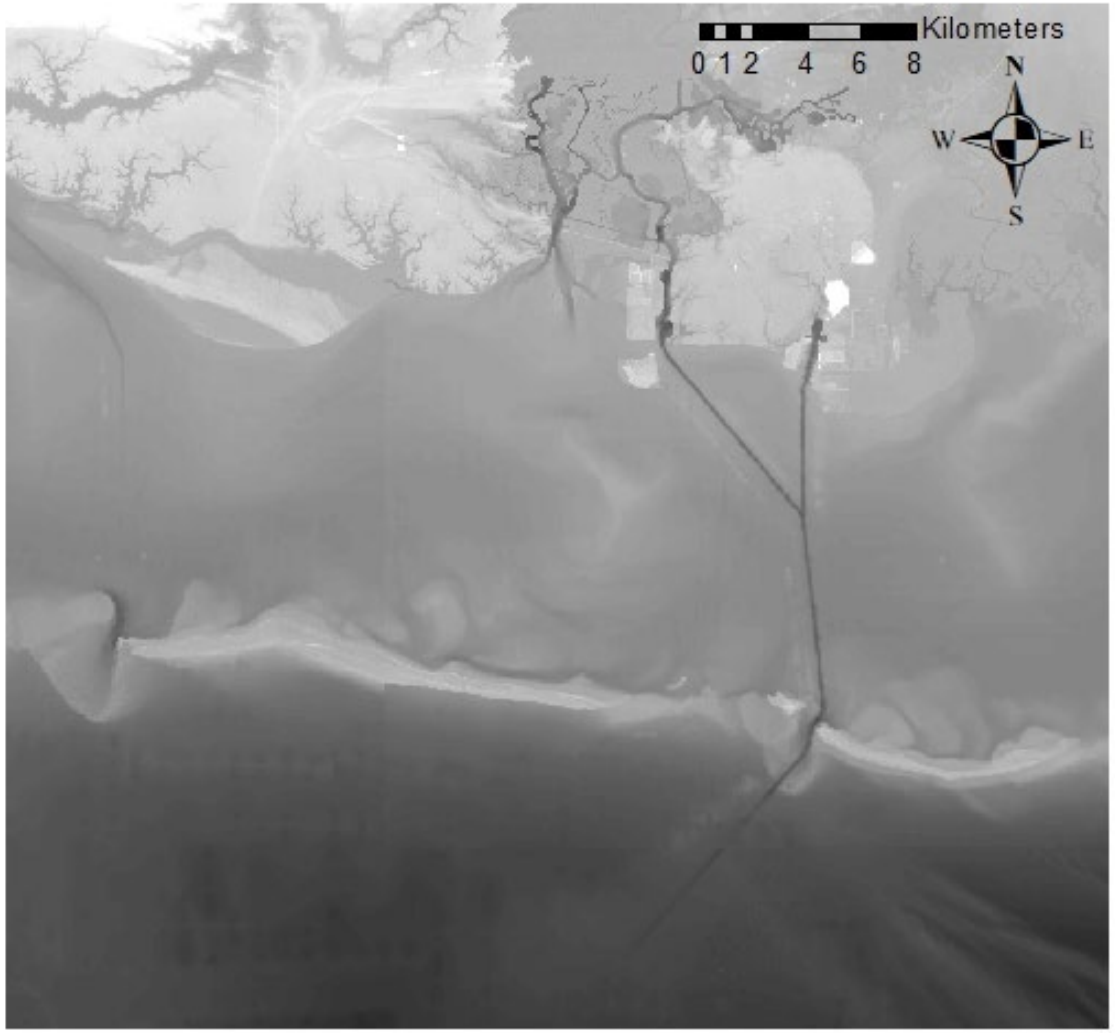
Results: emigration DOY and rate models



Discussion

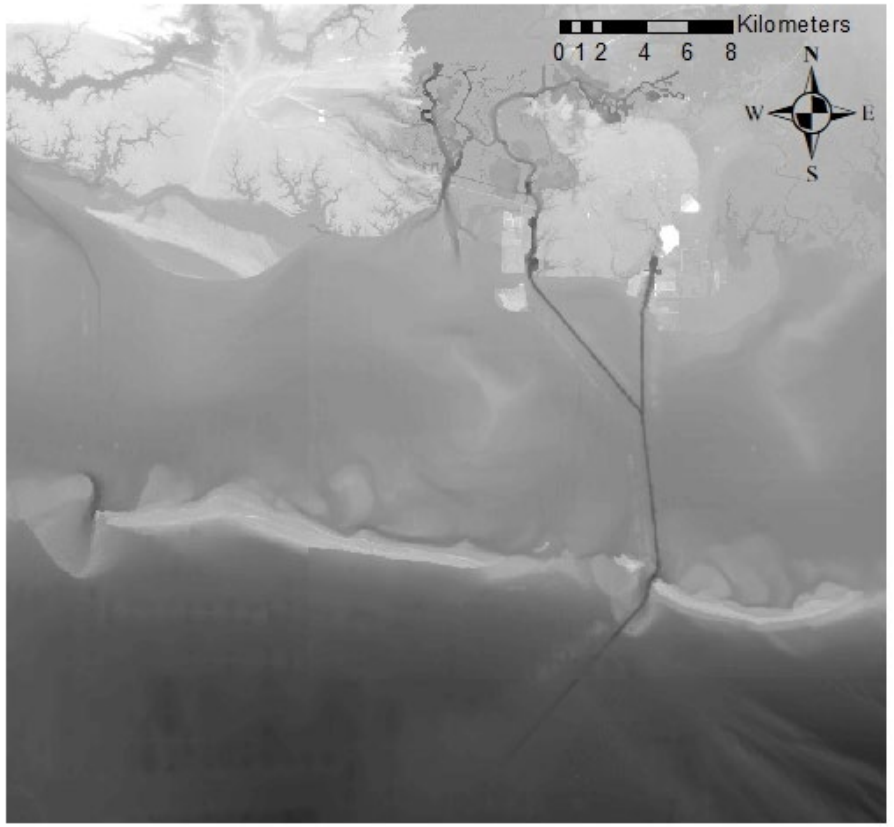
- Nearshore and alongshore habitats
- Few juveniles emigrating
- Travel rate was slower east
- Temperature affects emigrations





Three interactions between Gulf sturgeon and oyster restoration

- GS are using alongshore and nearshore
- Ship channels may influence emigration
- Slower emigrations may increase importance of estuary



Chapter objectives:

- **Ch. 1: describe emigration patterns of a threatened anadromous fish species to nearshore and alongshore habitats**
  - Provide data on possible influence on a protected species
- **Ch. 2: describe movements of multiple species in a coastal bay sub-system**
  - Insight into movements in an area primed for restoration
- **Ch. 3: model transient fish use associated with infauna and sediment metrics**
  - Fill data gaps on pre-restoration preferences for habitat, infauna, and sediment

Chapter 2: Seasonal changes in space use for three trophically-distinct fish species in a coastal bay system

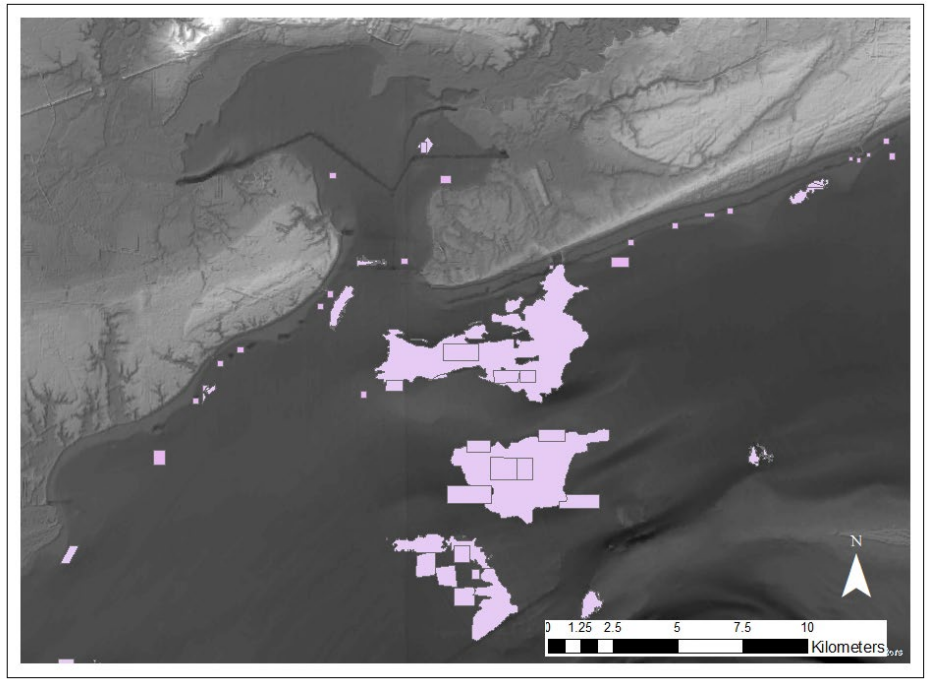
Manuscript in prep. for Environmental Biology of Fishes

Austin Draper, Paul O. Grammer, Mark S. Peterson, and Michael J. Andres, Jill M. Hendon

The University of Southern Mississippi, Ocean Springs, MS 39564

Introduction

- The Mississippi Sound is a highly productive estuarine system
- Anthropogenic impacts
- Restoration and protection is ongoing



26 August 2020

Translator Disclaimer

Mass Mortality of the Eastern Oyster *Crassostrea virginica* in the Western Mississippi Sound Following Unprecedented Mississippi River Flooding in 2019

James H. Gledhill, Ann Fairly Barnett, Marc Slattery, Kristine L. Willett, Gregory L. Easson, Stephanie Showalter Otts, Deborah J. Gochfeld

Importance

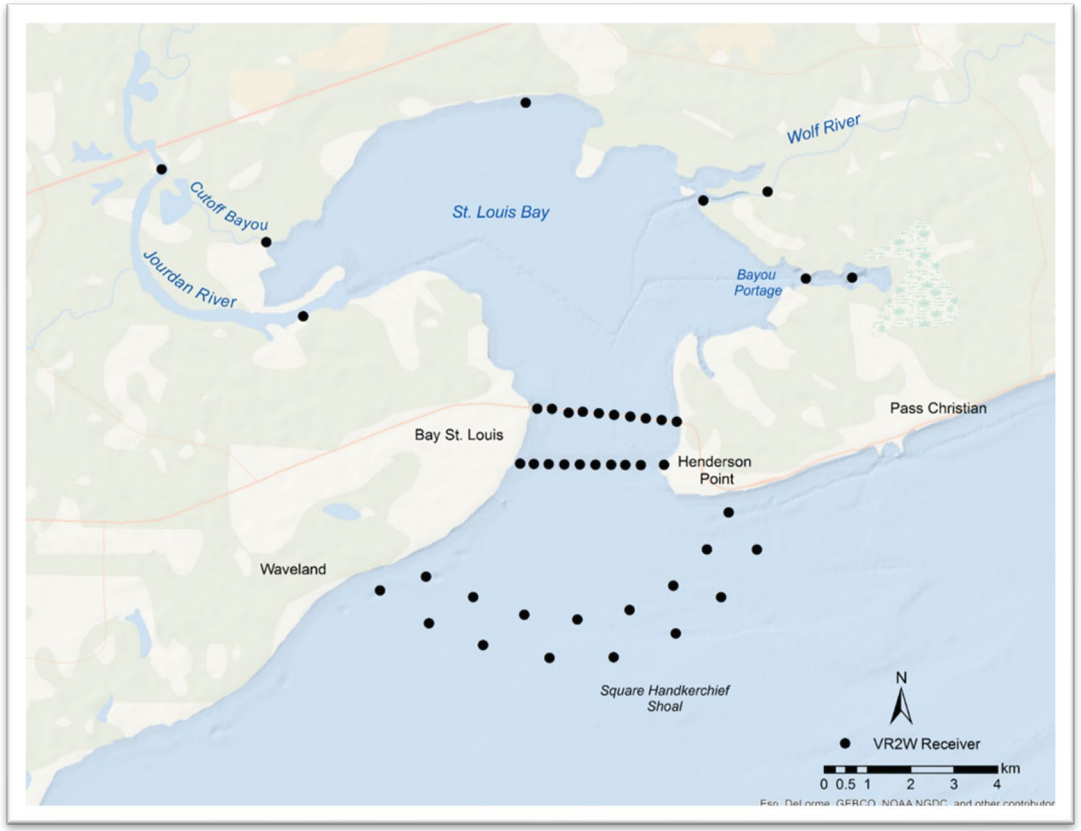
- Increasing environmental change
- Very little is known about transient movements

Objective:

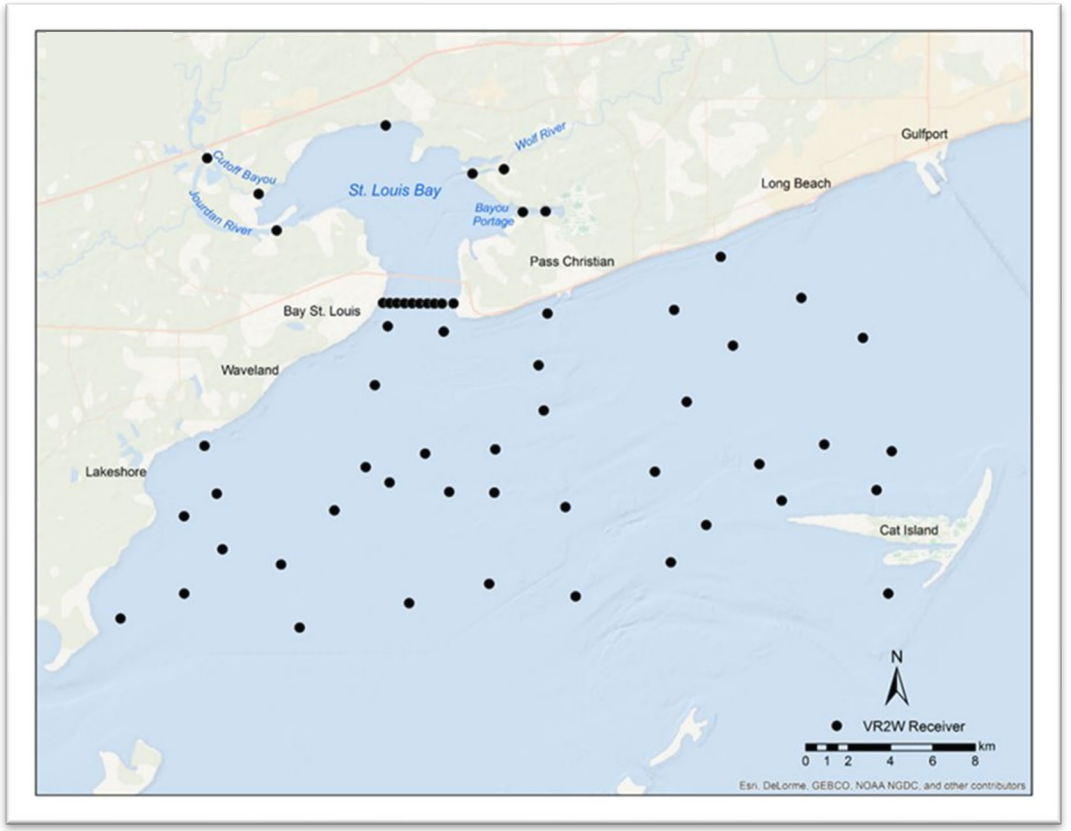
- Describe seasonal movements of three different fish species with unique foraging

Study site

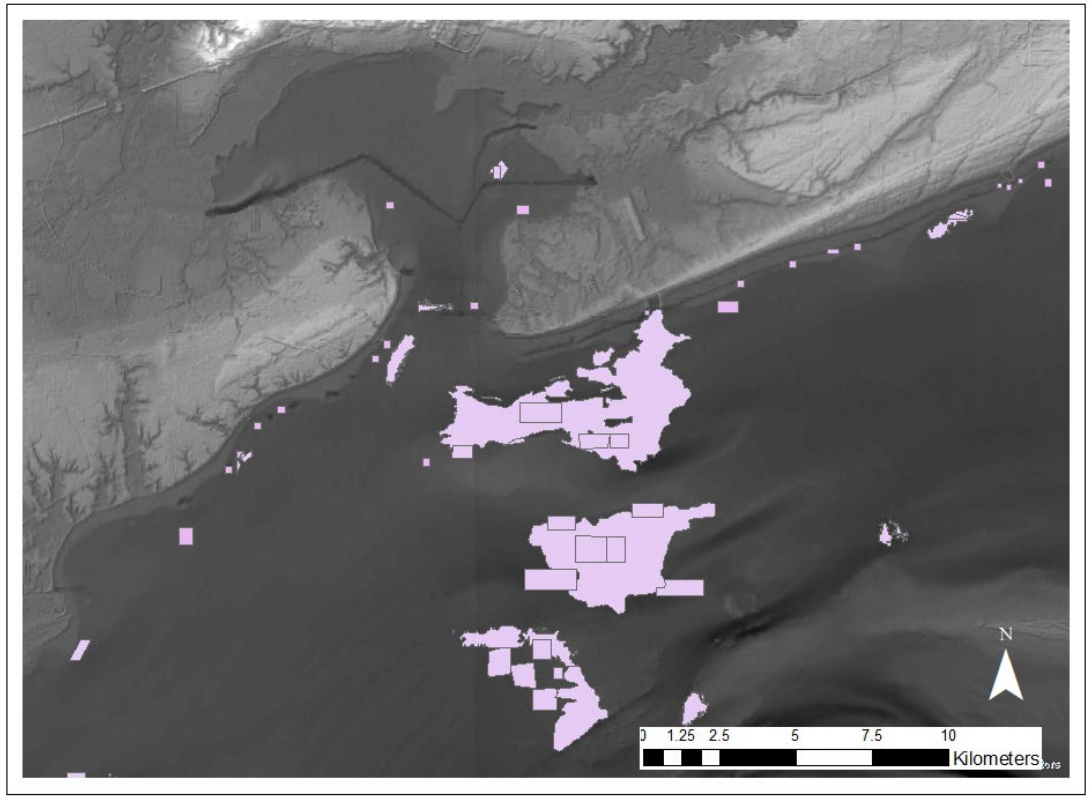
2017-2018

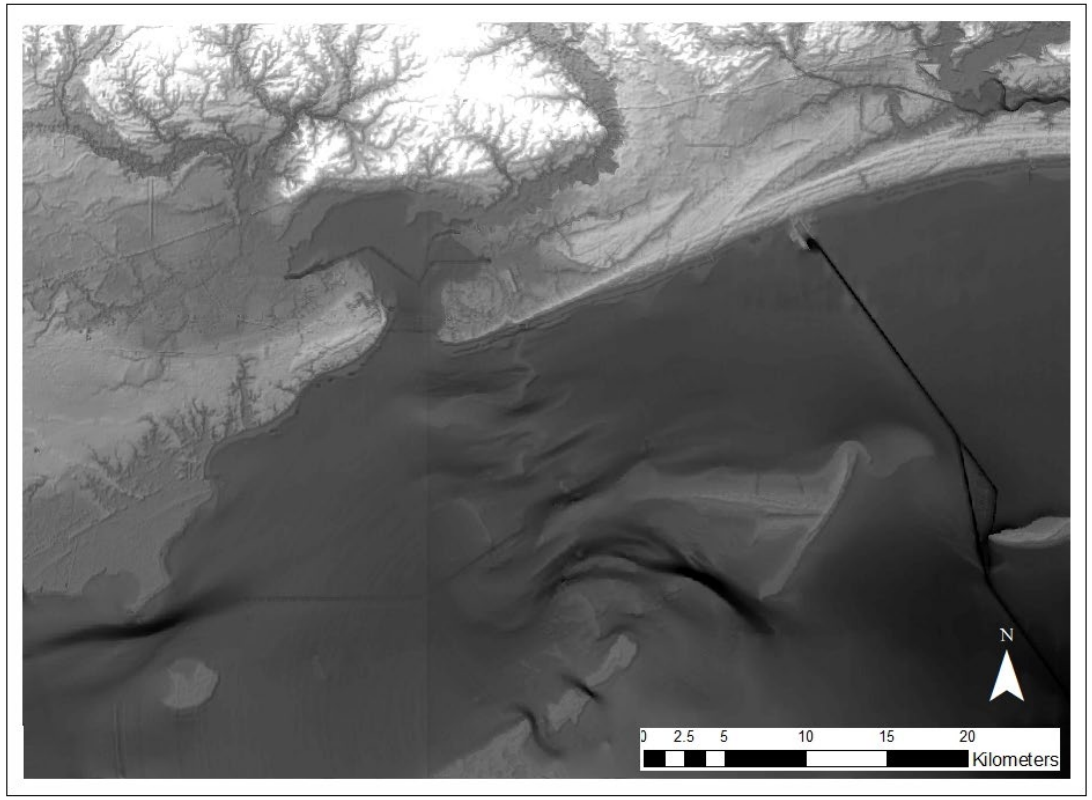


2019-2020



Study site



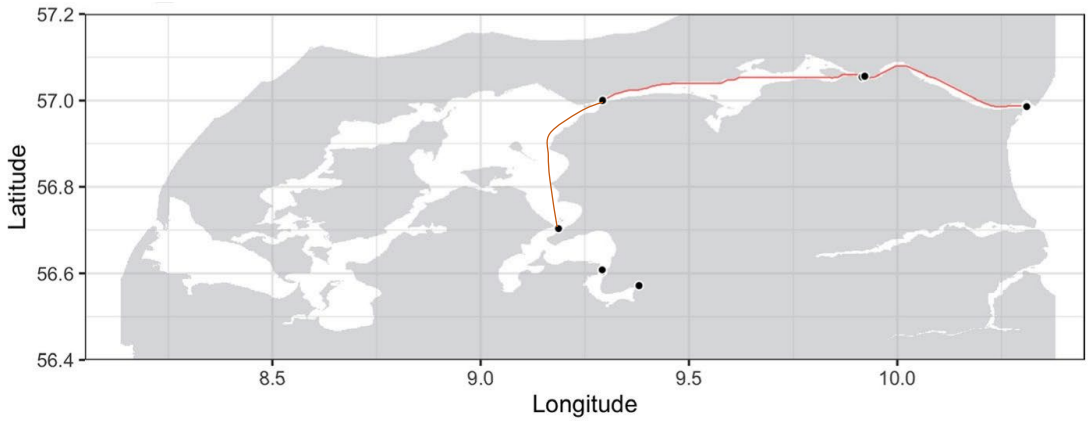


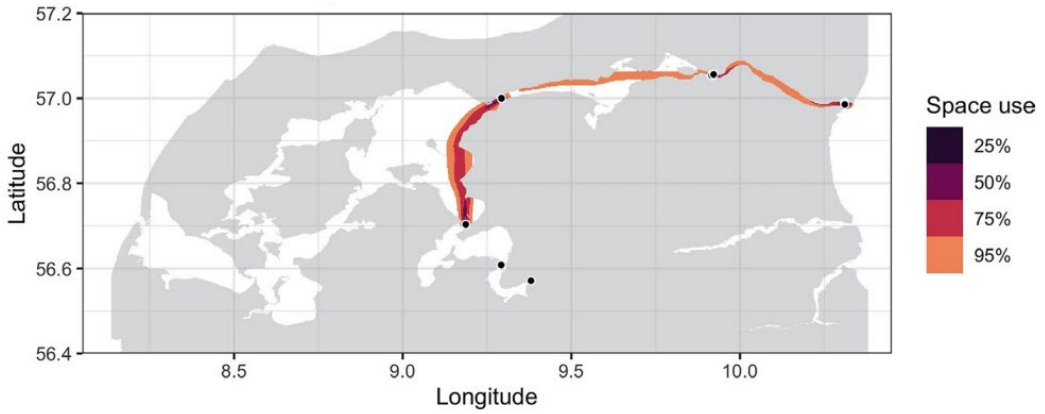
Methods: acoustic telemetry

- Implanted acoustic transmitters and tracked using fixed-receiver acoustic telemetry (InnovaSea) within and around St. Louis Bay, MS from 2017-2020
- 20 Bull Sharks (BS) — average 76.2 cm FL (48.3 – 98.0 cm)
- 36 Red Drum (RD) — average 62.6 cm TL (42.0 – 75.6 cm)
- 75 Gulf Sturgeon (GS) — average 113.6 cm TL (40 – 190 cm)

Methods: models

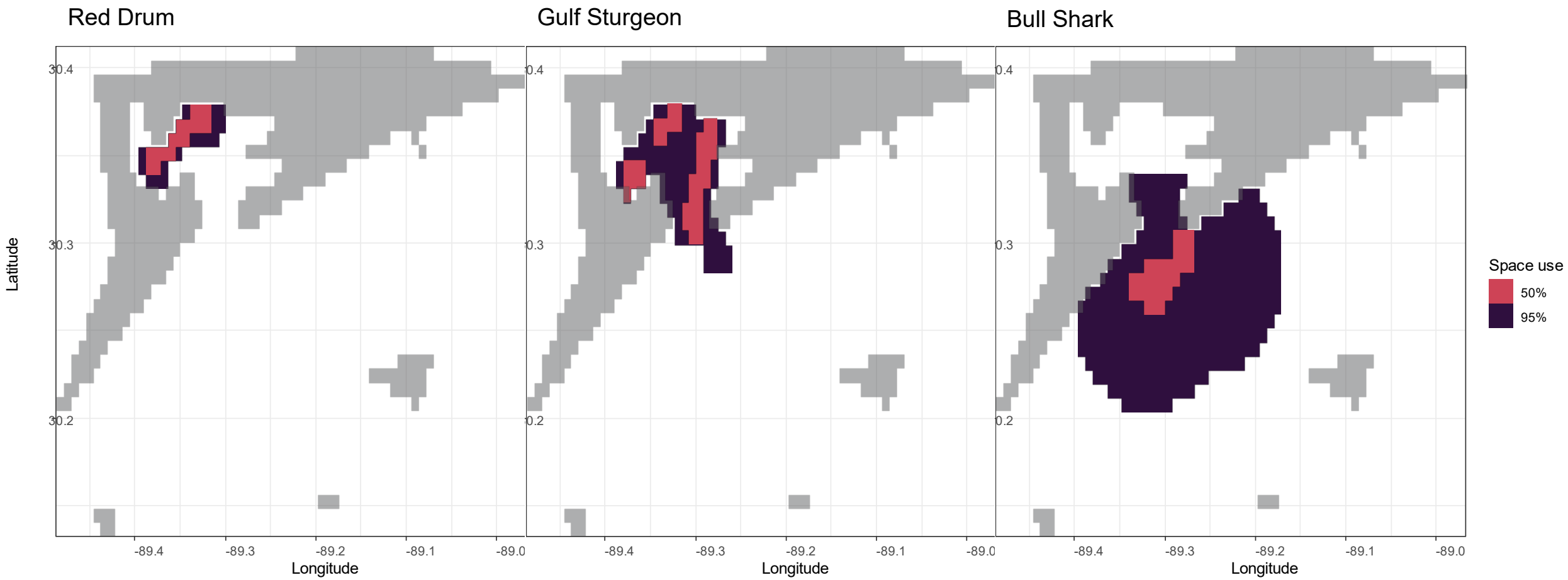
- R package (RSP—Refined Shortest Paths) - movements of animals tracked with acoustic transmitters in environments constrained by landmasses
- Dynamic Brownian Bridge Movement Model used to calculate utilization distributions (UD)



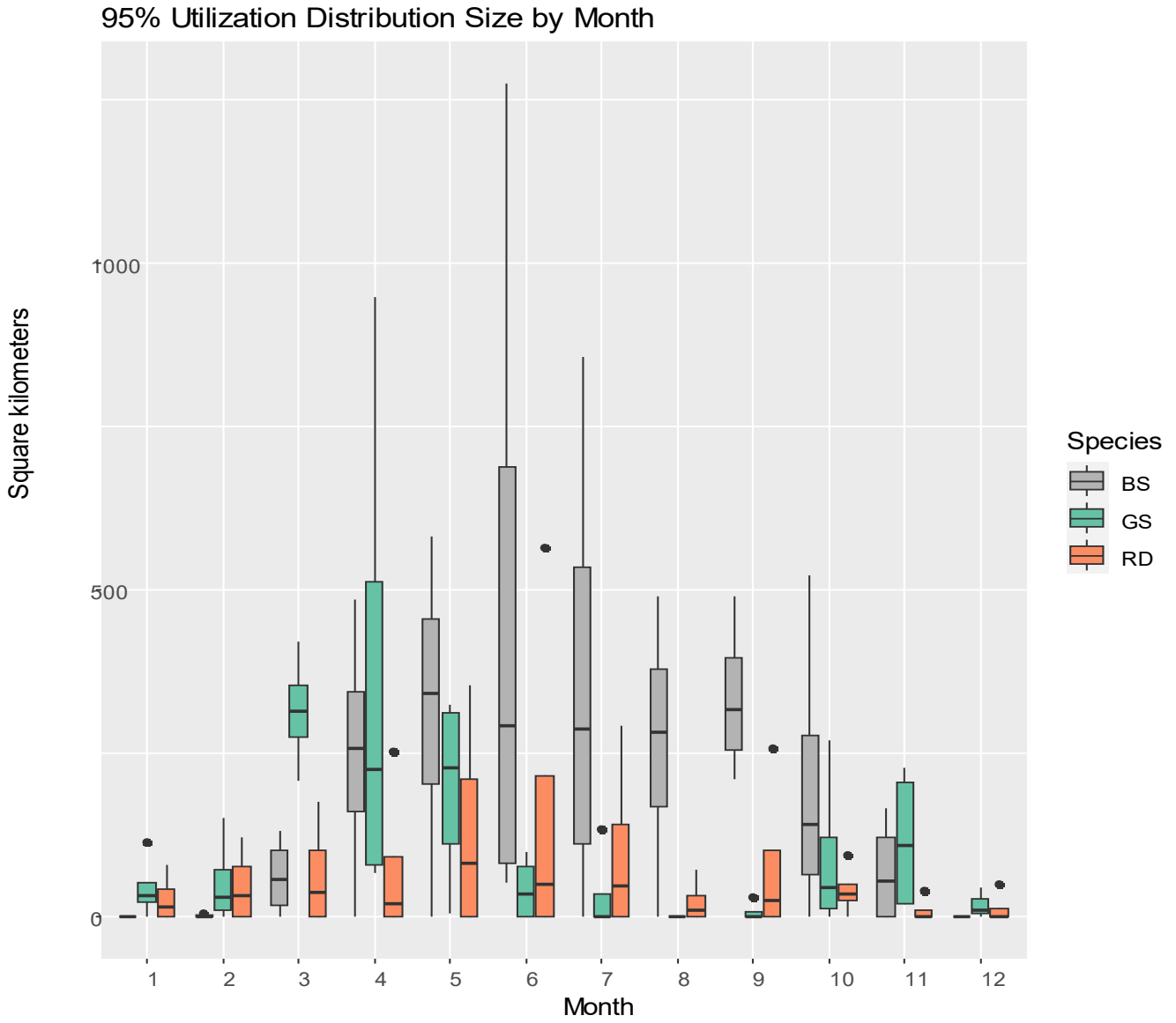


Niella Y, Flávio H, Smoothey AF, et al. Refined Shortest Paths (RSP): Incorporation of topography in space use estimation from node-based telemetry data. Methods Ecol Evol. 2020;11:1733–1742.

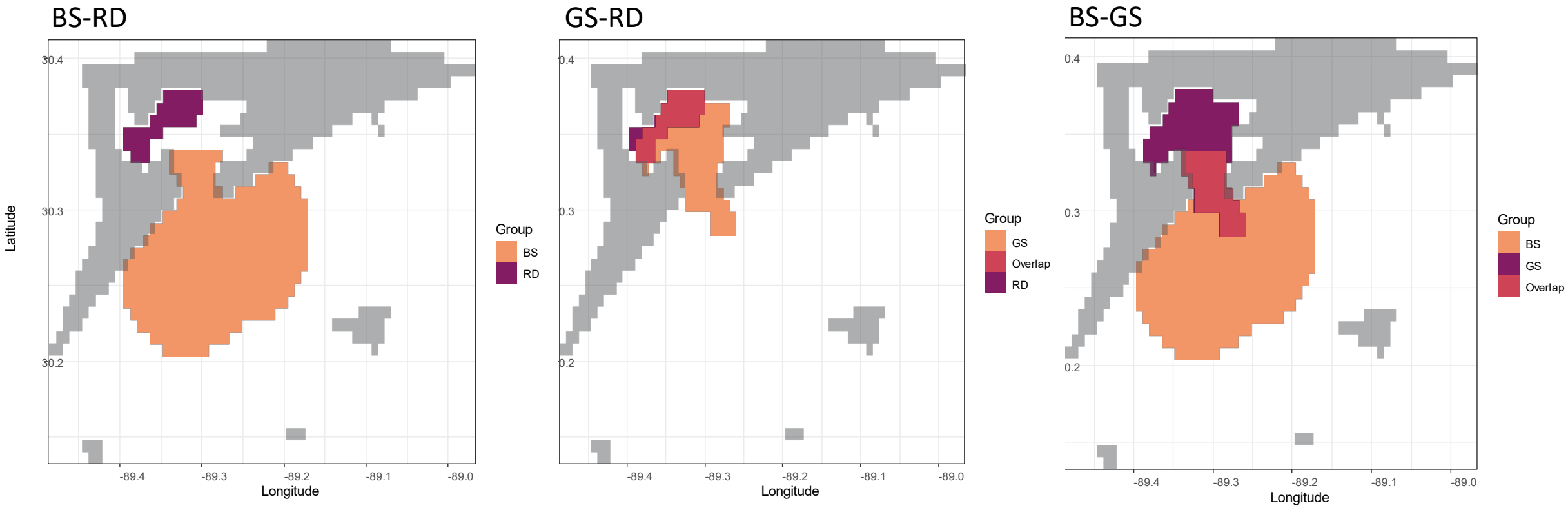
Results: April 2018



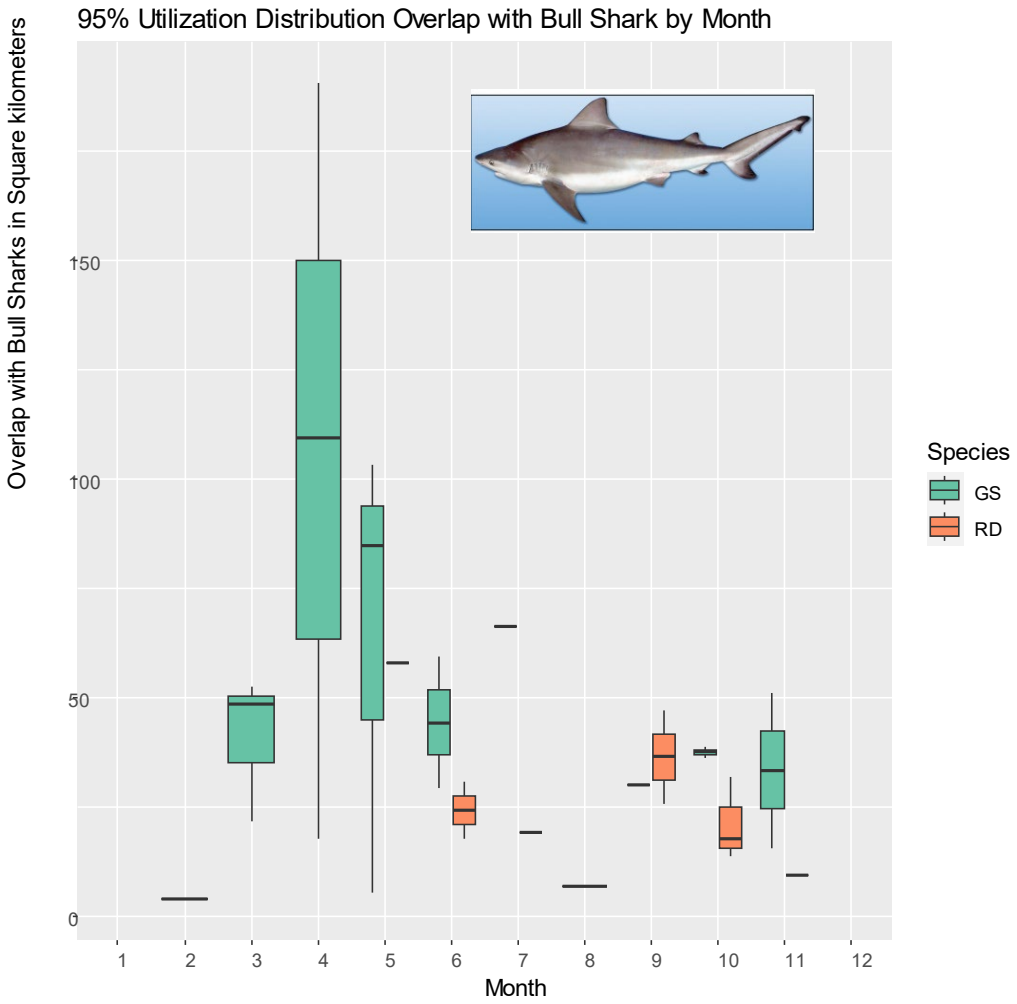
Results: Space use size

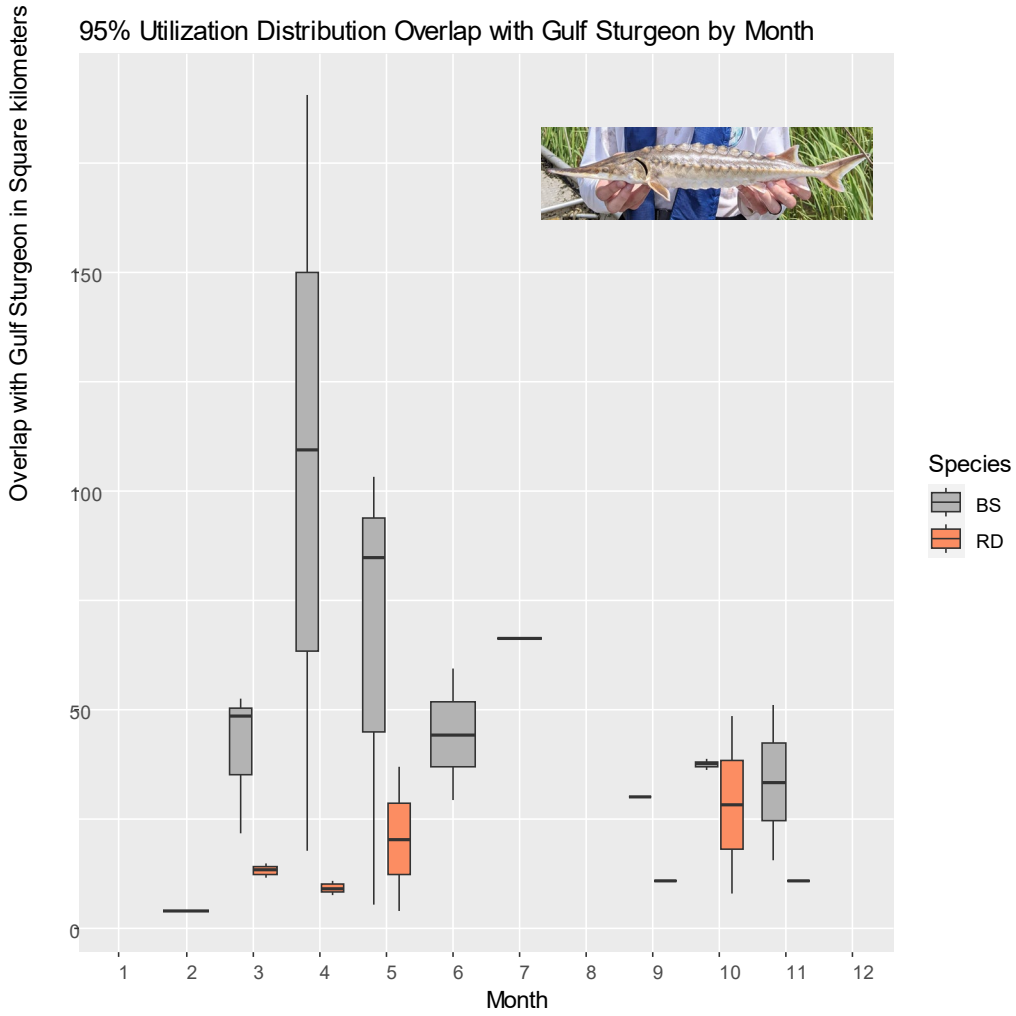


Results: 95% overlaps



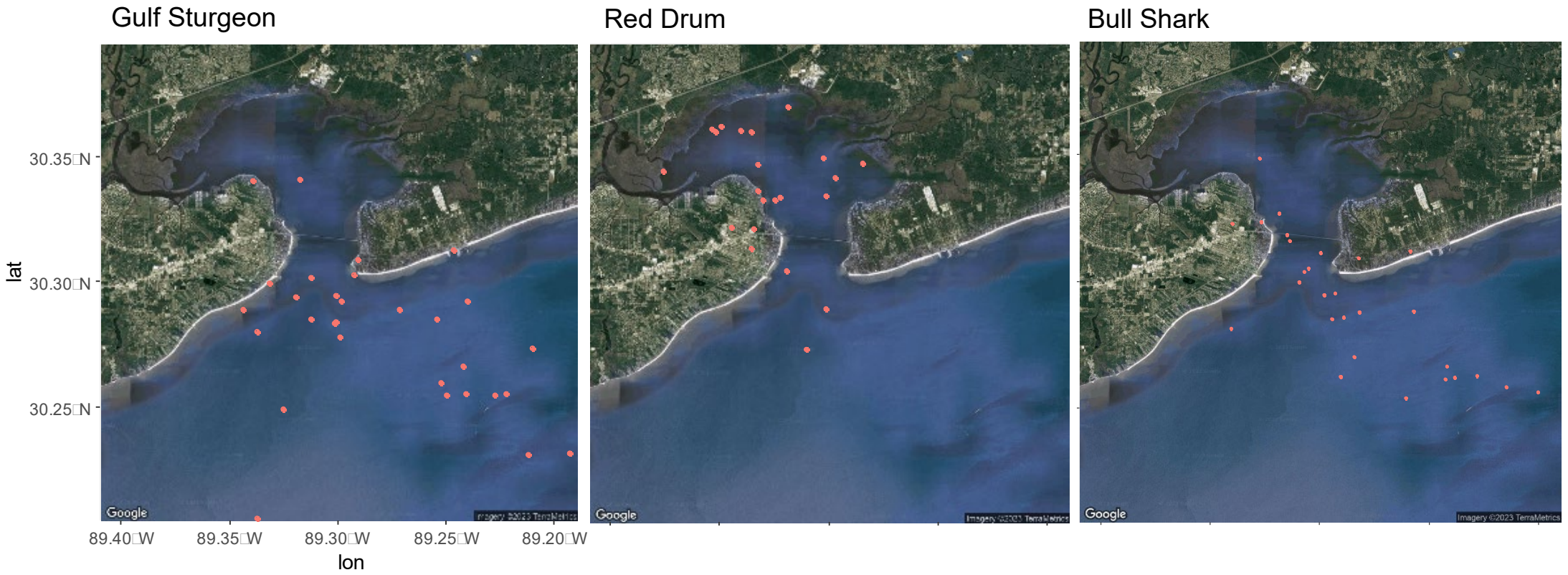
Results: 95% overlaps





Utilization distribution centroid models

- Centroid of 95% UD (dependent)
- Jourdan, Wolf, and Pearl river monthly metrics (independent)




Kiln
Diamondhead
Gulfport
Long Beach
St Louis Bay
Pass
Christian
Bay St Louis
Waveland

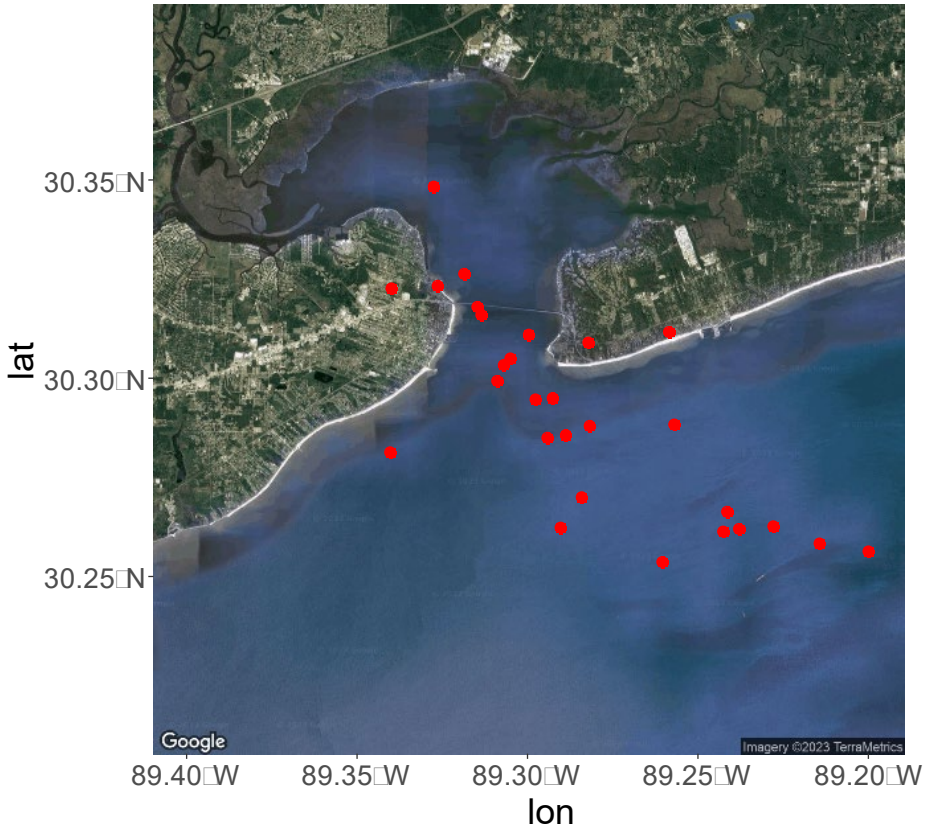
Bull Shark model

- Significant model ($p < 0.05$; $R^2 = 0.28$)
- Pearl river conductivity significant

Interpretation:

- Increased cond. = movement north

```
Coefficients:
                 Estimate Std. Error  t value Pr(>|t|)
(Intercept)     3.029e+01  1.482e-02 2043.631  < 2e-16 ***
pearl_avg_gage -1.399e-02  1.095e-02   -1.278  0.21249
pearl_avg_cond  2.580e-06  8.064e-07    3.199  0.00361 **
```



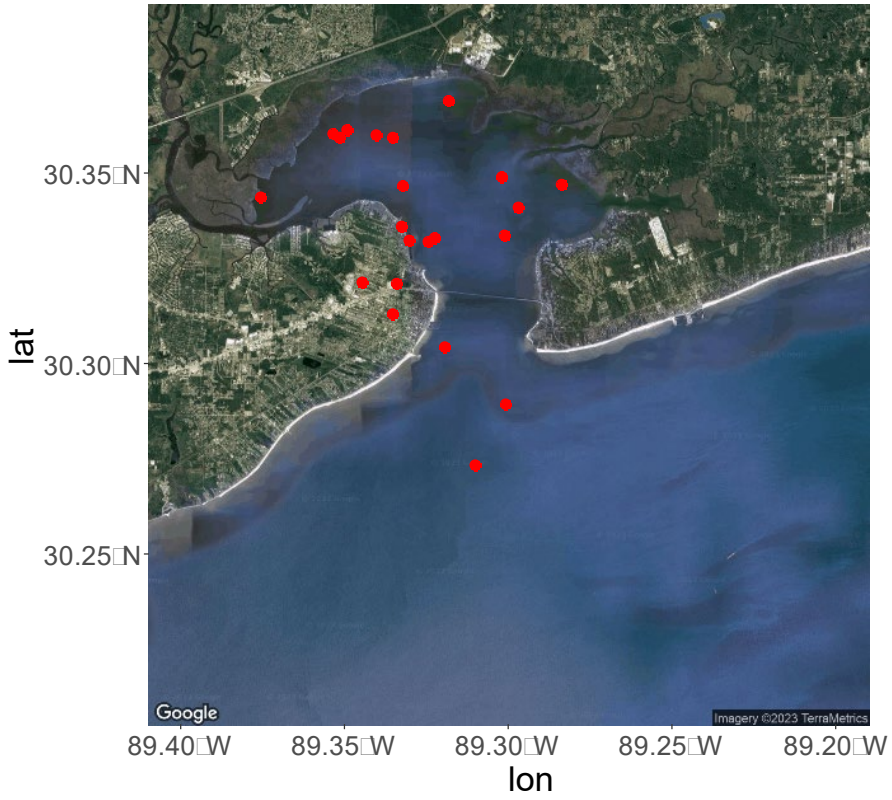
Red Drum model

- Significant model ($p < 0.05$; $R^2 = 0.46$)
- Jourdan River avg. gage significant

Interpretation:

- High discharge in bay = movement south

```
Coefficients:
                Estimate Std. Error  t value Pr(>|t|)
(Intercept)    30.355416   0.016656 1822.546  < 2e-16 ***
wolf_avg_gage   0.012685   0.007123    1.781 0.090144 .
jord_avg_gage  -0.046278   0.011475   -4.033 0.000652 ***
```



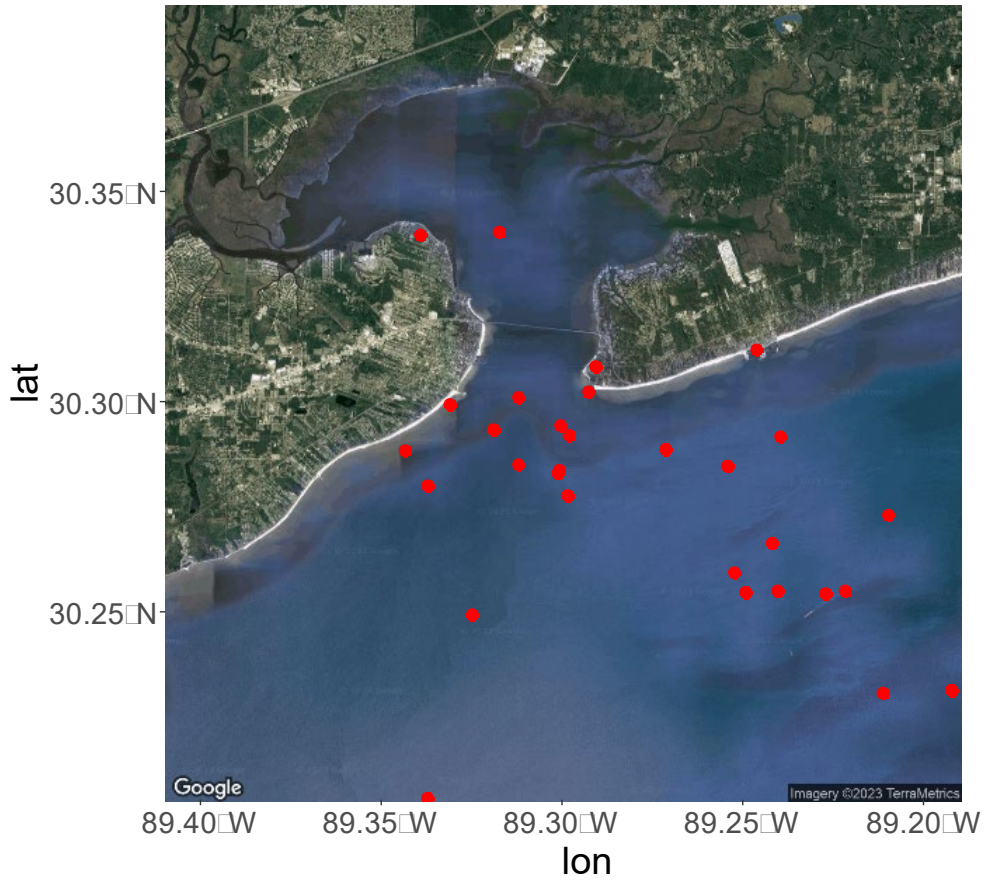
Gulf Sturgeon model

- Significant model ($p < 0.05$; $R^2 = 0.26$)
- Pearl gage and conductivity significant

Interpretation:

- High discharge in sound = movement south
- High cond. in sound = movement north

```
Coefficients:
                Estimate Std. Error  t value Pr(>|t|)
(Intercept)    3.029e+01  1.248e-02 2426.563   <2e-16 ***
pearl_avg_gage -2.335e-02  9.171e-03   -2.546   0.0165 *
pearl_avg_cond  2.814e-06  1.053e-06    2.672   0.0122 *
```

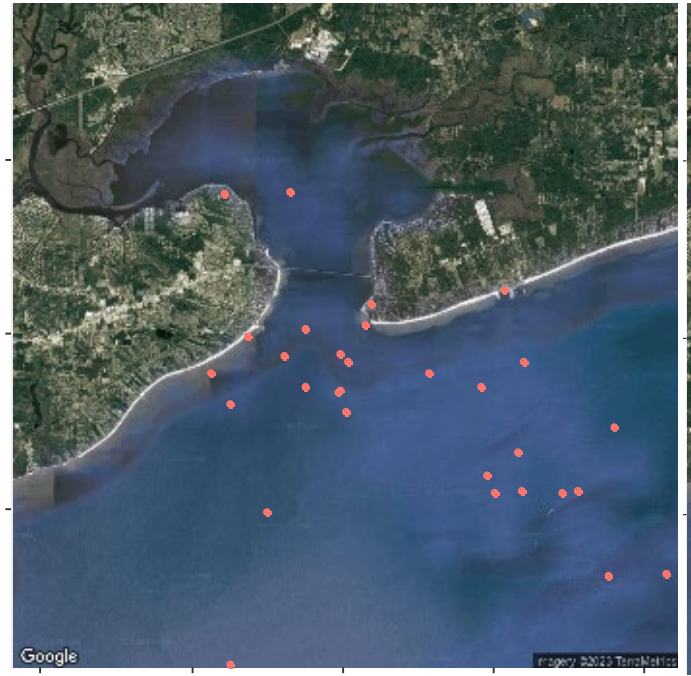


Discussion

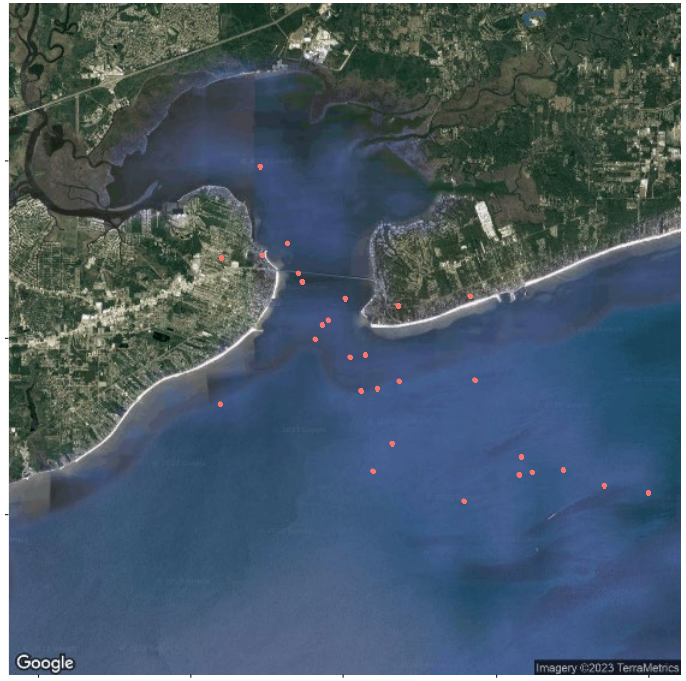
- GS/BS controlled by variables outside the sub-system, RD controlled from within
- GS/BS use the most space, RD more confined
- Large overlaps for GS and BS, seasonal with RD

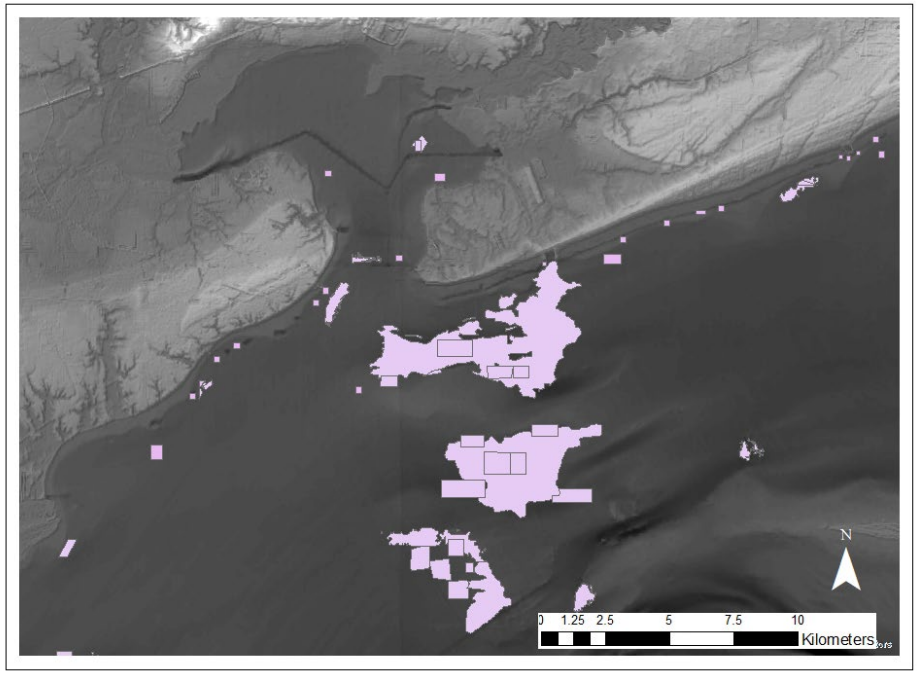
Red Drum

Gulf Sturgeon



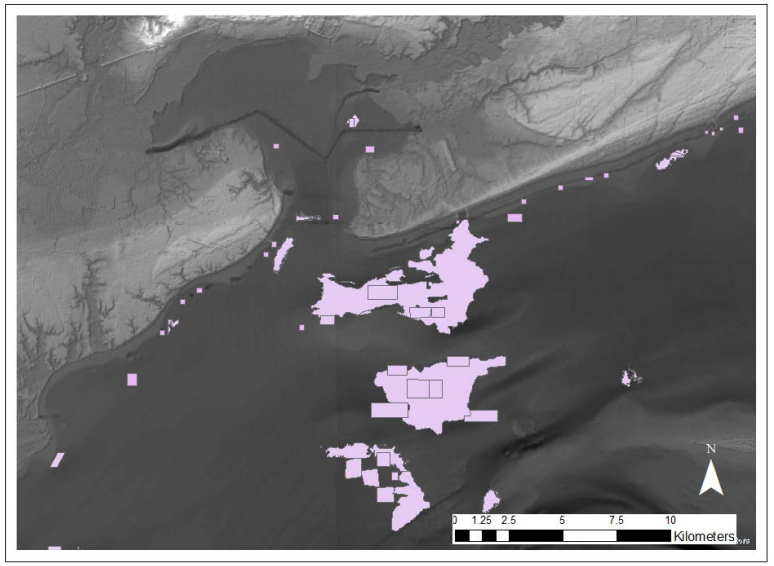
Bull Shark

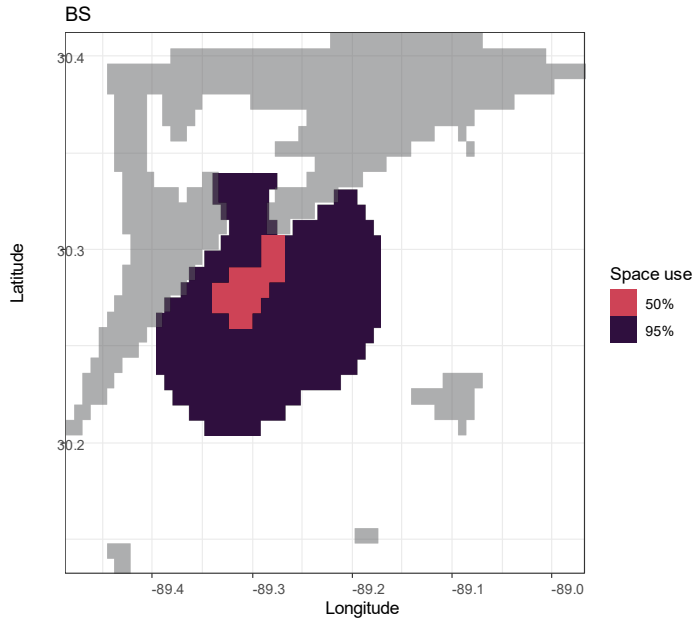




Conclusion

- RD may benefit most from within-bay restoration
- BS/GS may benefit from restoration within and outside the bay
- Overlap primarily occurred around bay mouth (restoration can have large influence here)
- Freshwater intrusion events may limit BS/GS movement into subsystem
- Many considerations for restoration in this area
- These findings can inform management decisions so that restoration can maximize benefit across species





Chapter objectives:

- **Ch. 1: describe emigrations patterns of a threatened anadromous fish species to nearshore and alongshore habitats**

- Insight into possible influence on a protected species

- **Ch. 2: describe movements of multiple species in a coastal bay sub-system**

- Insight into movements in an area primed for restoration

- **Ch. 3: model transient fish use associated with infauna and sediment metrics**

- Clarify specific pre-restoration preferences for habitat, infauna, and sediment

Chapter 3: Multispecies use of northern Gulf of Mexico estuaries prior to oyster reef restoration

Manuscript in prep. for Gulf and Caribbean Research

Austin Draper[1], Michael J. Andres[1], Katherine Wright[2], Mark S. Peterson[1] Wei Wu[1]

[1]Division of Coastal Sciences, School of Ocean Science and Engineering, The University of Southern Mississippi, Ocean Springs, MS 39564.

[2]Department of Biological Sciences, Nicholls State University, 906 East 1st Street, 112 Beauregard Hall, Thibodaux, Louisiana 70310, USA

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

GCRL ESTUARINE AND MOVEMENT ECOLOGY LAB- THE UNIVERSITY OF SOUTHERN MISSISSIPPI

Introduction

- Oyster reef creation is planned in two locations within MS Sound
- Few restoration projects include pre- and post-restoration monitoring of resource availability (infauna), sediment change, and multispecies use

Mississippi looking at ways to boost oyster production

Published: Aug. 9, 2016 at 7:59 PM CDT

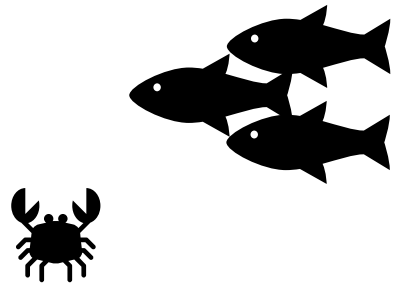
The Mississippi Department of Marine Resources is considering multiple sites for off-bottom oyster aquaculture in order to reach the goal of producing 1 million sacks a year by 2025.

Objective

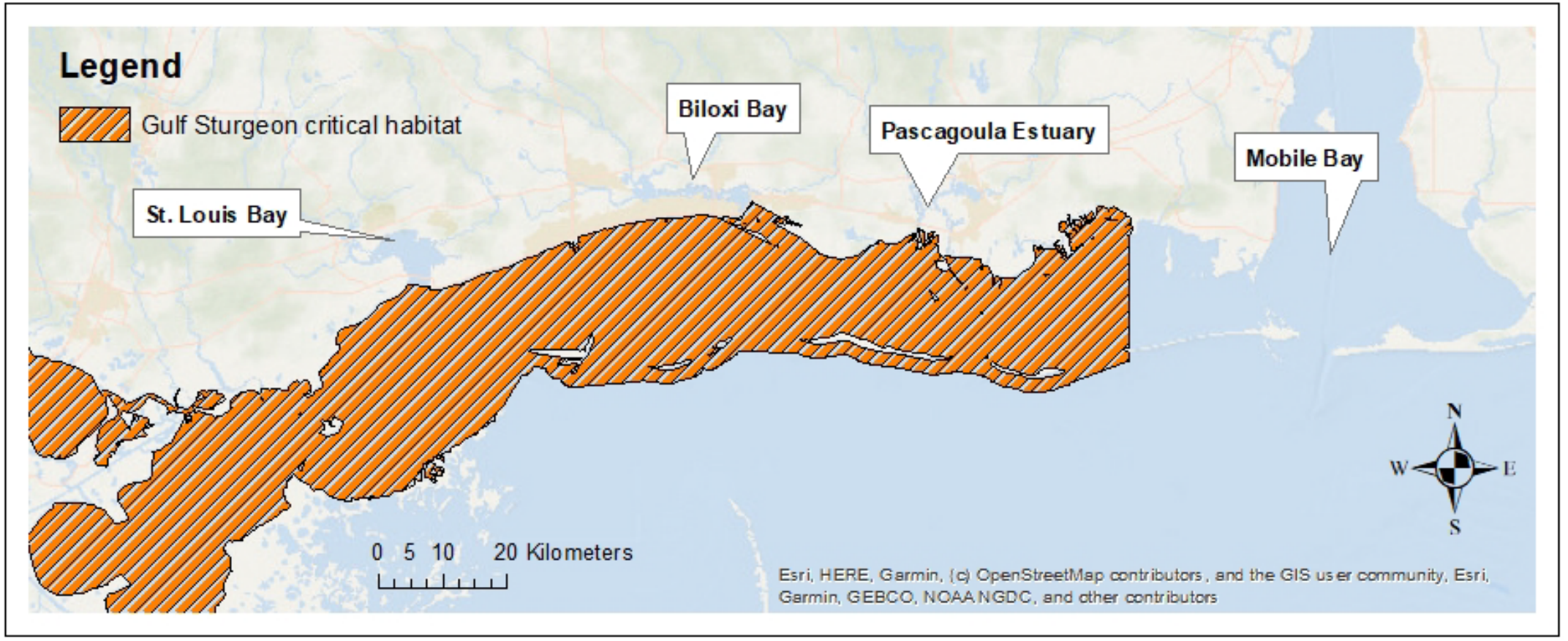
Describe pre-construction baseline information so post-construction influences can be understood

Specifically:

1. Fish use of pre-construction habitats prior to restoration
2. Model effect of infauna and sediment characteristics on fish use



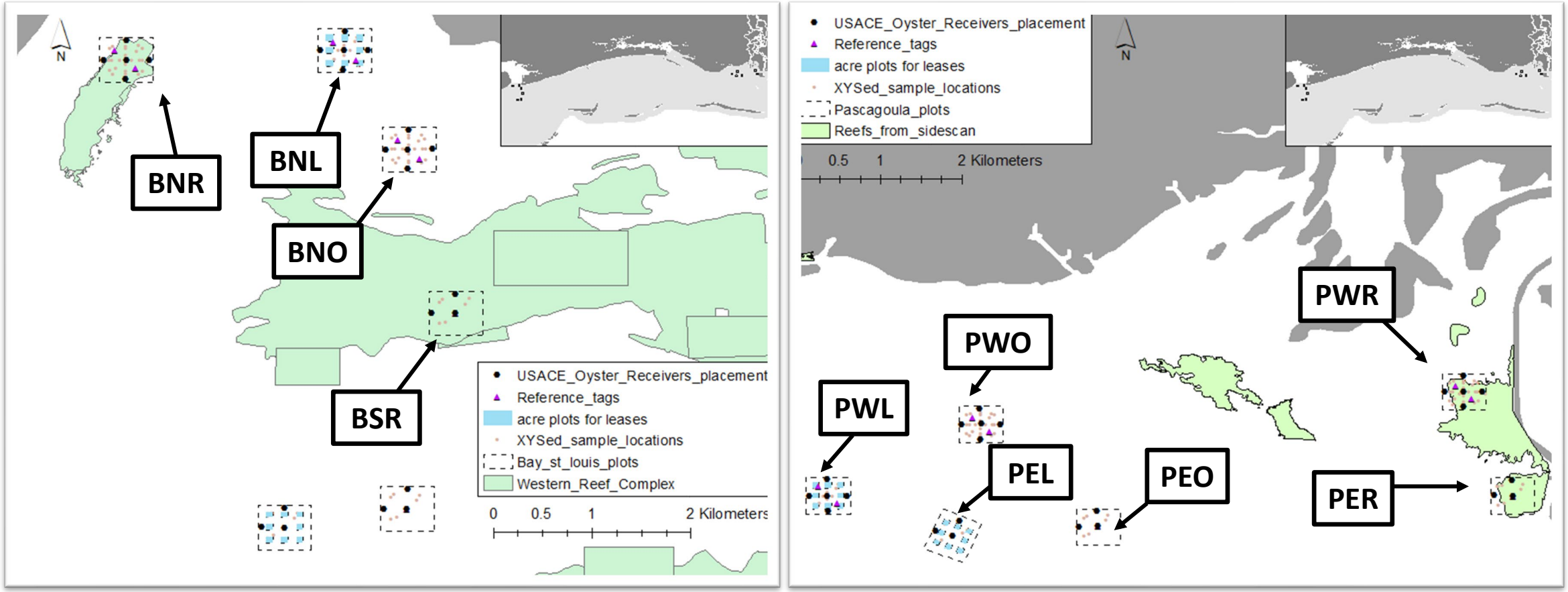
Study sites


Legend
Gulf Sturgeon critical habitat
Biloxi Bay
Pascagoula Estuary
Mobile Bay
St. Louis Bay
N
W
E
S
0 5 10 20 Kilometers
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community, Esri, Garmin, GEBCO, NOAA NGDC, and other contributors

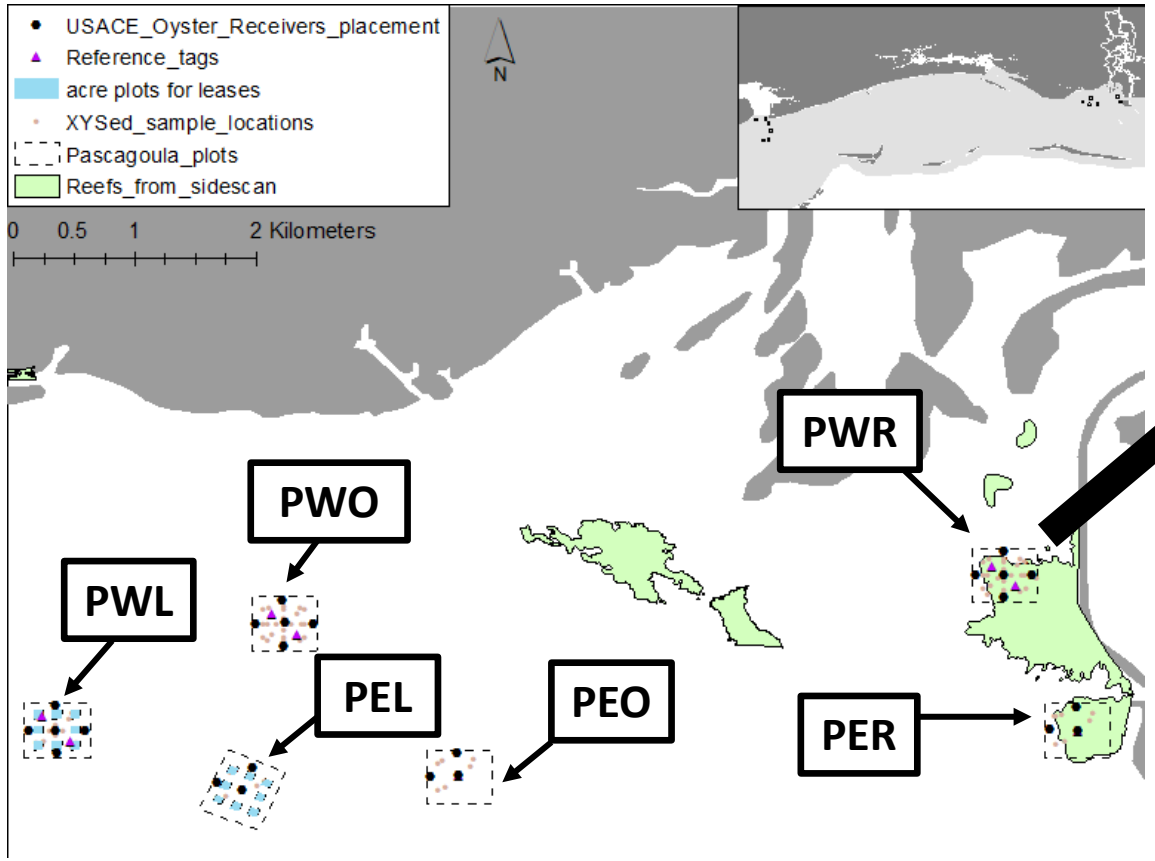
Methods

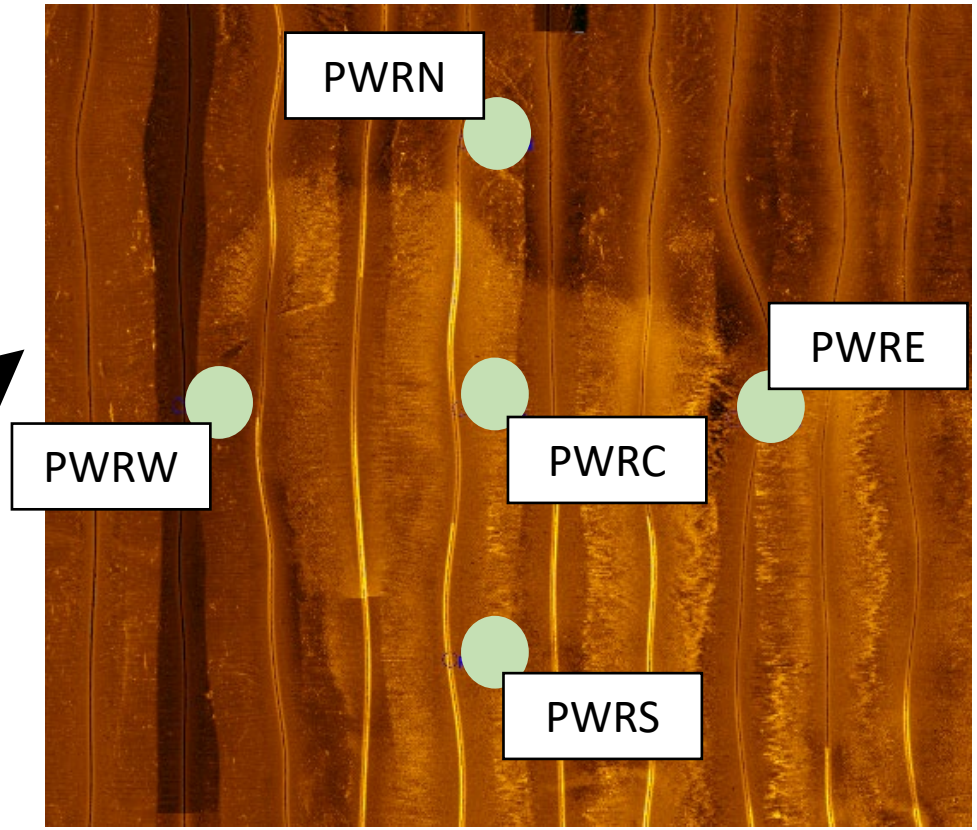
- Deployed receivers on natural oyster reef, open bottom, and pre-reef construction bottom
- Internal acoustic tags (Innovasea V7-V16) in 3 species
- VR2W receivers (Innovasea)
- Infauna/sediment samples (Petite Ponar; triplicate) in 200m radius of receivers

Methods


BNR
BNL
BNO
BSR
USACE_Oyster_Receivers_placement
Reference_tags
acre plots for leases
XYSed_sample_locations
Bay_st_louis_plots
Western_Reef_Complex
0 0.5 1 2 Kilometers
N
USACE_Oyster_Receivers_placement
Reference_tags
acre plots for leases
XYSed_sample_locations
Pascagoula_plots
Reefs_from_sidescan
0.5 1 2 Kilometers
N
PWR
PWO
PWL
PEL
PEO
PER

Methods

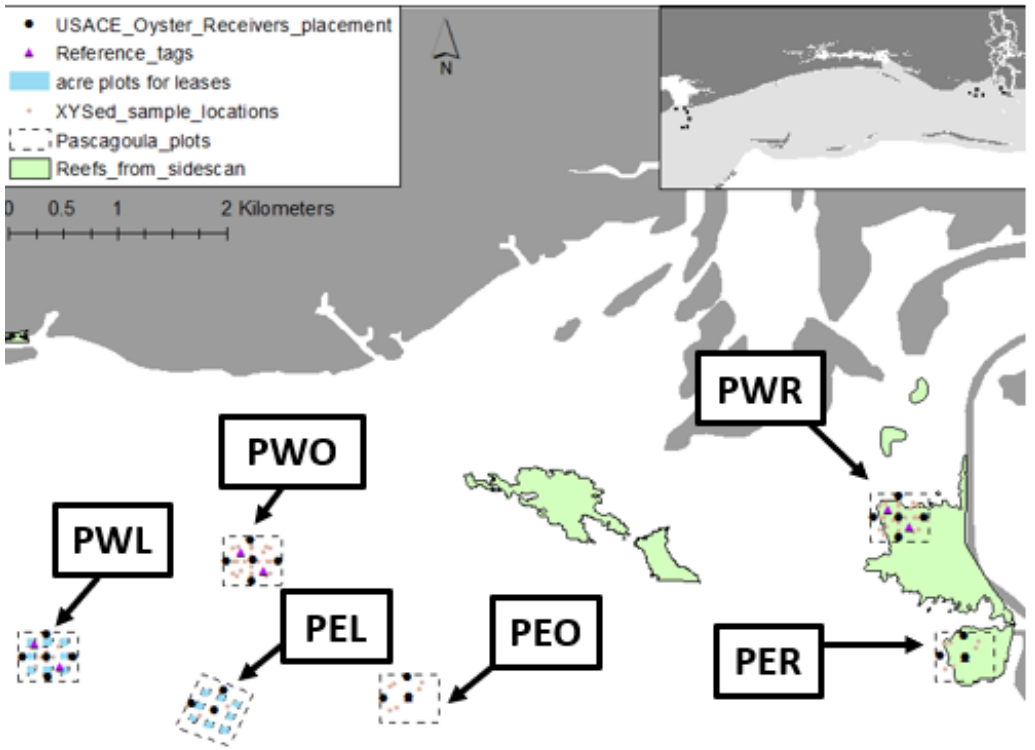

USACE_Oyster_Receivers_placement
Reference_tags
acre plots for leases
XYSed_sample_locations
Pascagoula_plots
Reefs_from_sidescan
N
0 0.5 1 2 Kilometers
PWR
PWO
PWL
PEL
PEO
PER


PWRN
PWRE
PWRW
PWRC
PWRS

Model structure

```
count ~ (1|Site) + abundance + percent.sand + percent.carbon
```

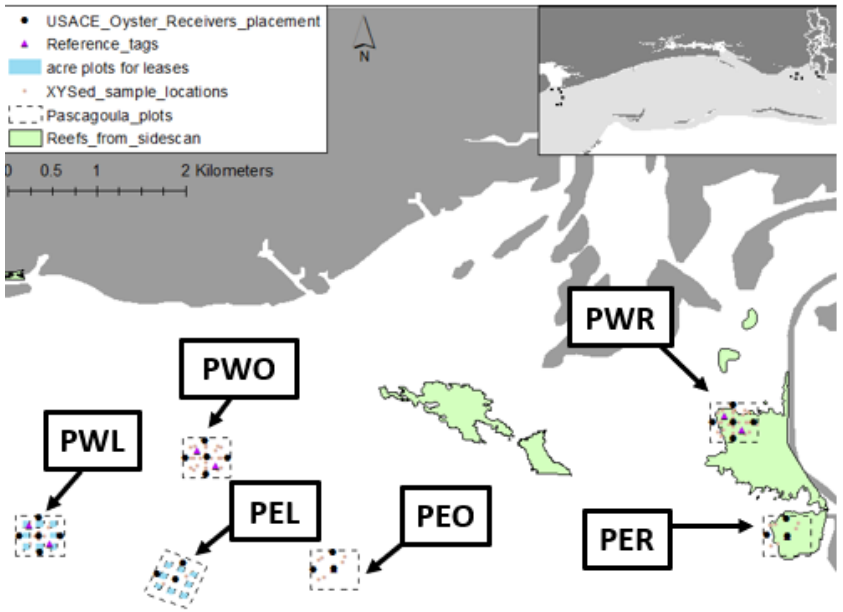
- Generalized linear mixed-effects model (GLMM)
- Count – # of detections at a station (response variable)
- Site – Site that detections occurred (used as random intercept)
- Infauna/sediment predictor variables checked for multicollinearity via VIF
- Models chosen based on BIC



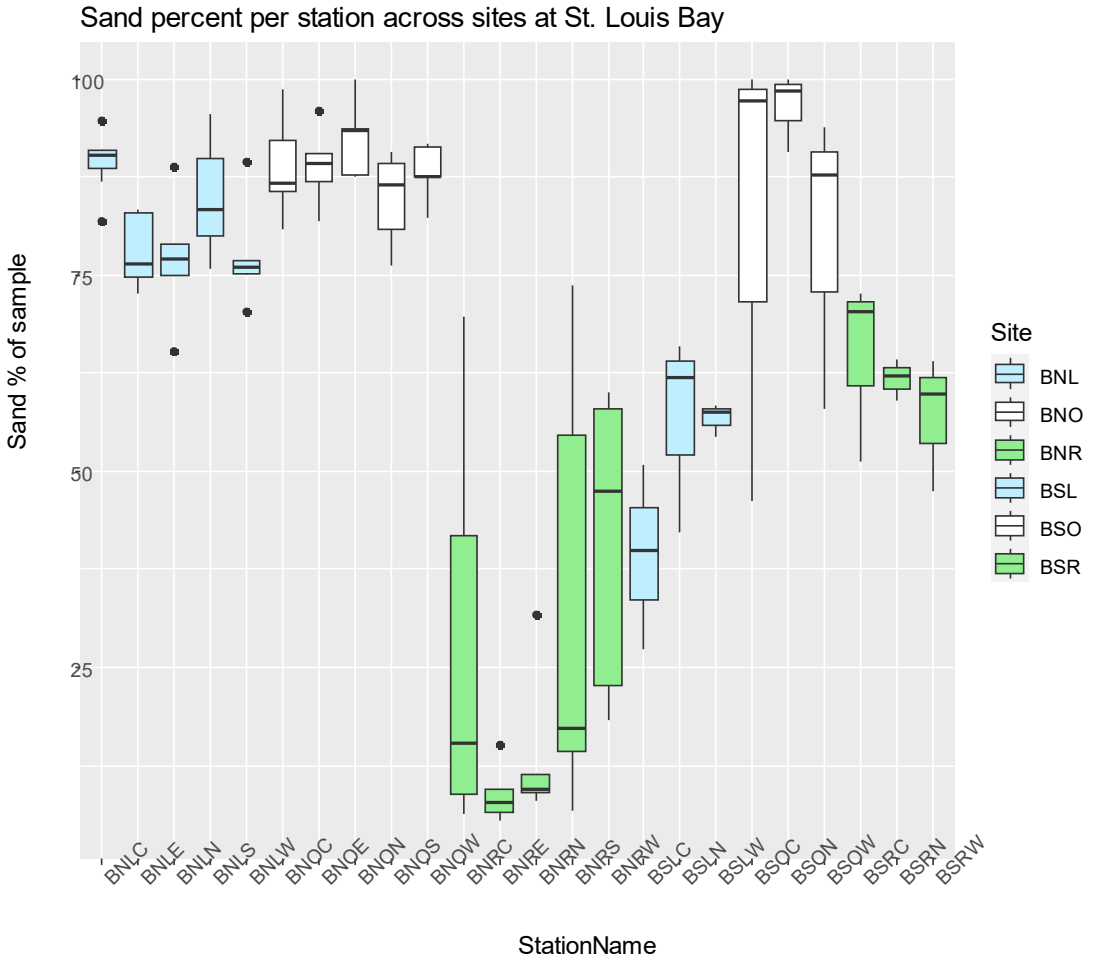
Model variables

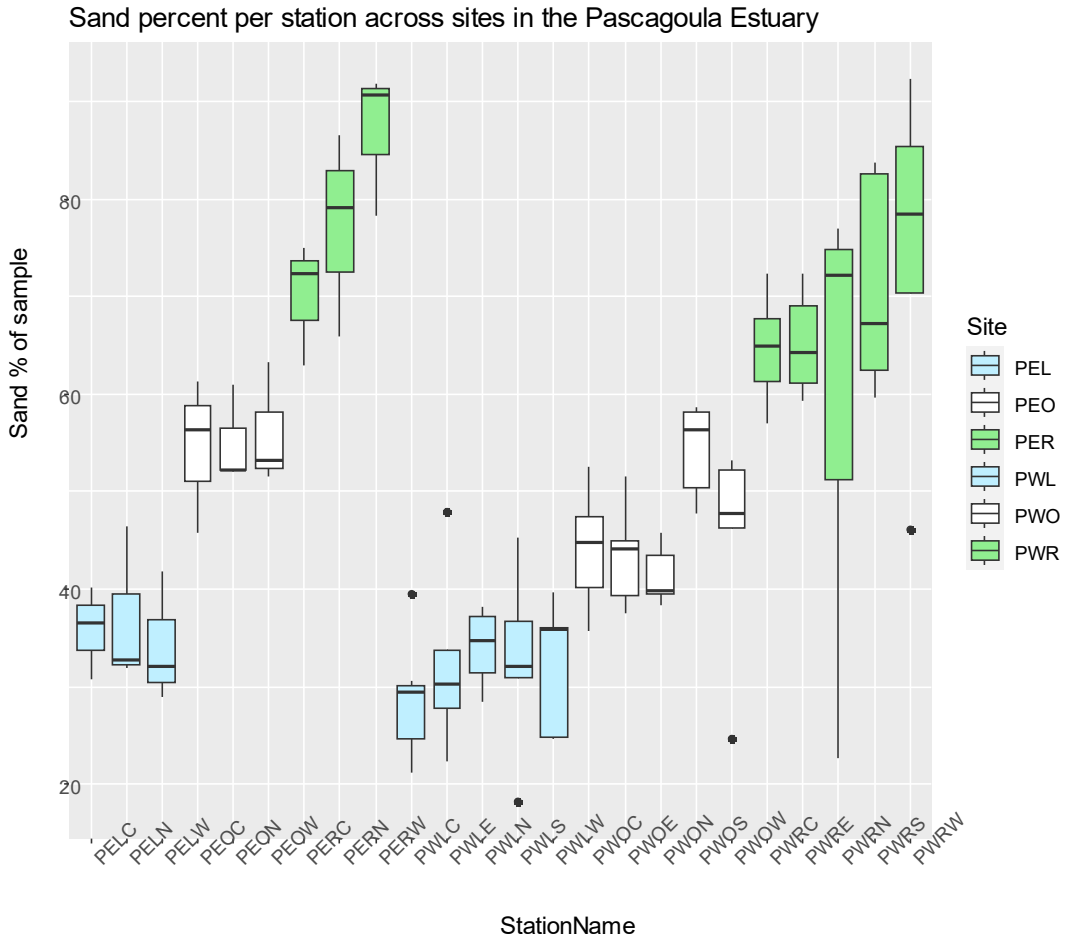
```
count ~ (1|Site) + abundance + percent.sand + percent.carbon
```

- Abundance – number of organisms per sample
- Richness – number of species per station
- %C – % Organic carbon per sample
- %N –% Total nitrogen per sample
- Simpson index – diversity which considers evenness



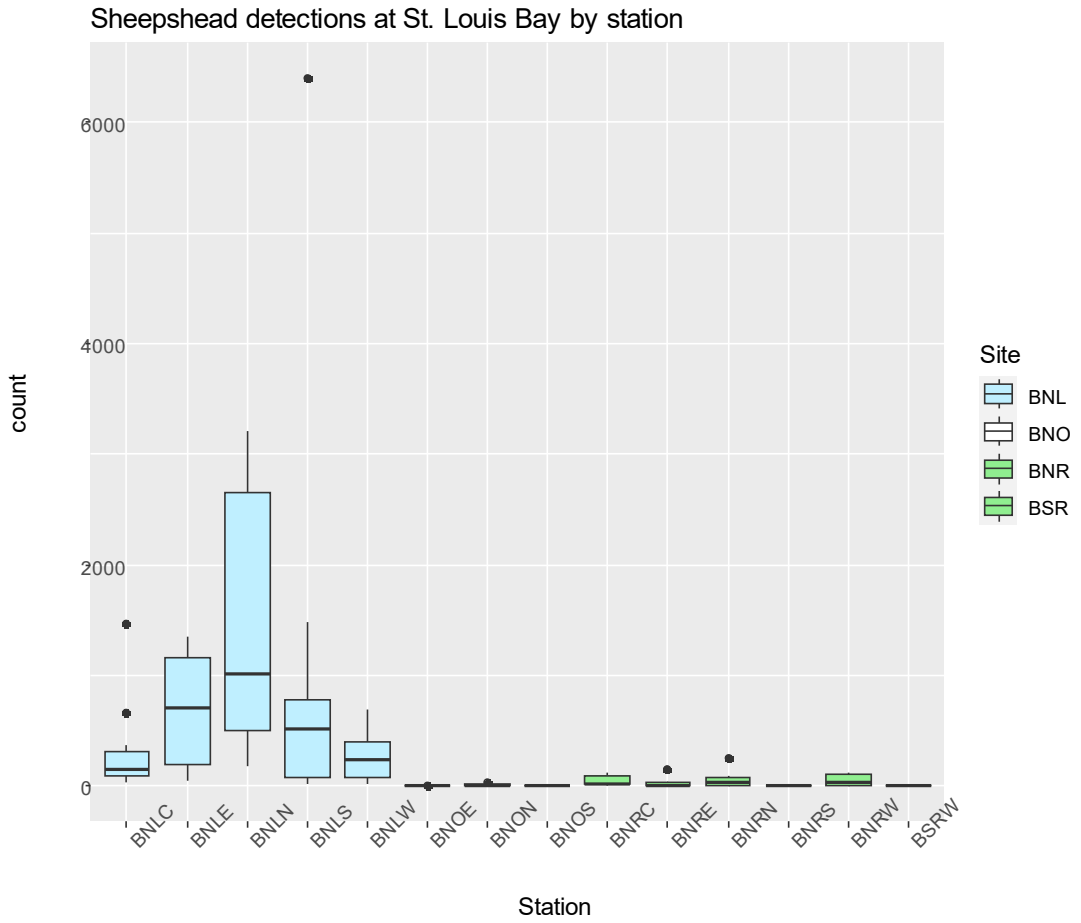
Results: % Sand per station



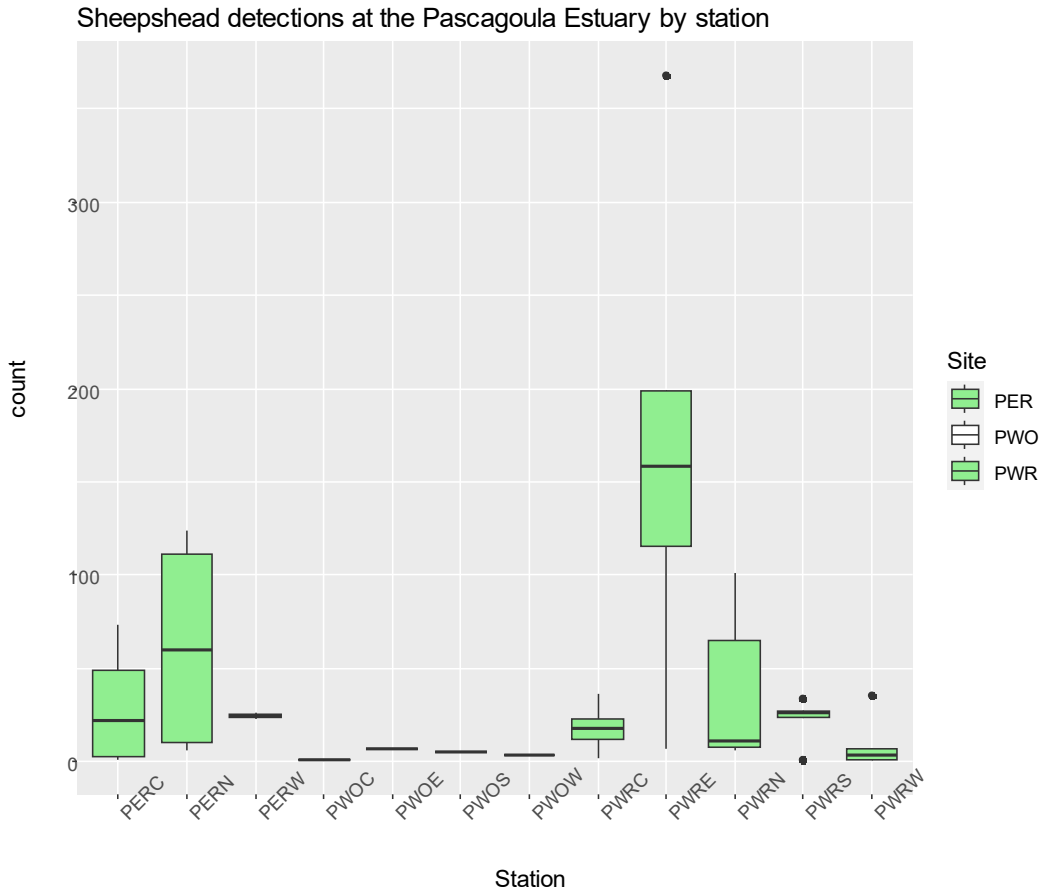


Sheepshead (n = 19)

St. Louis Bay

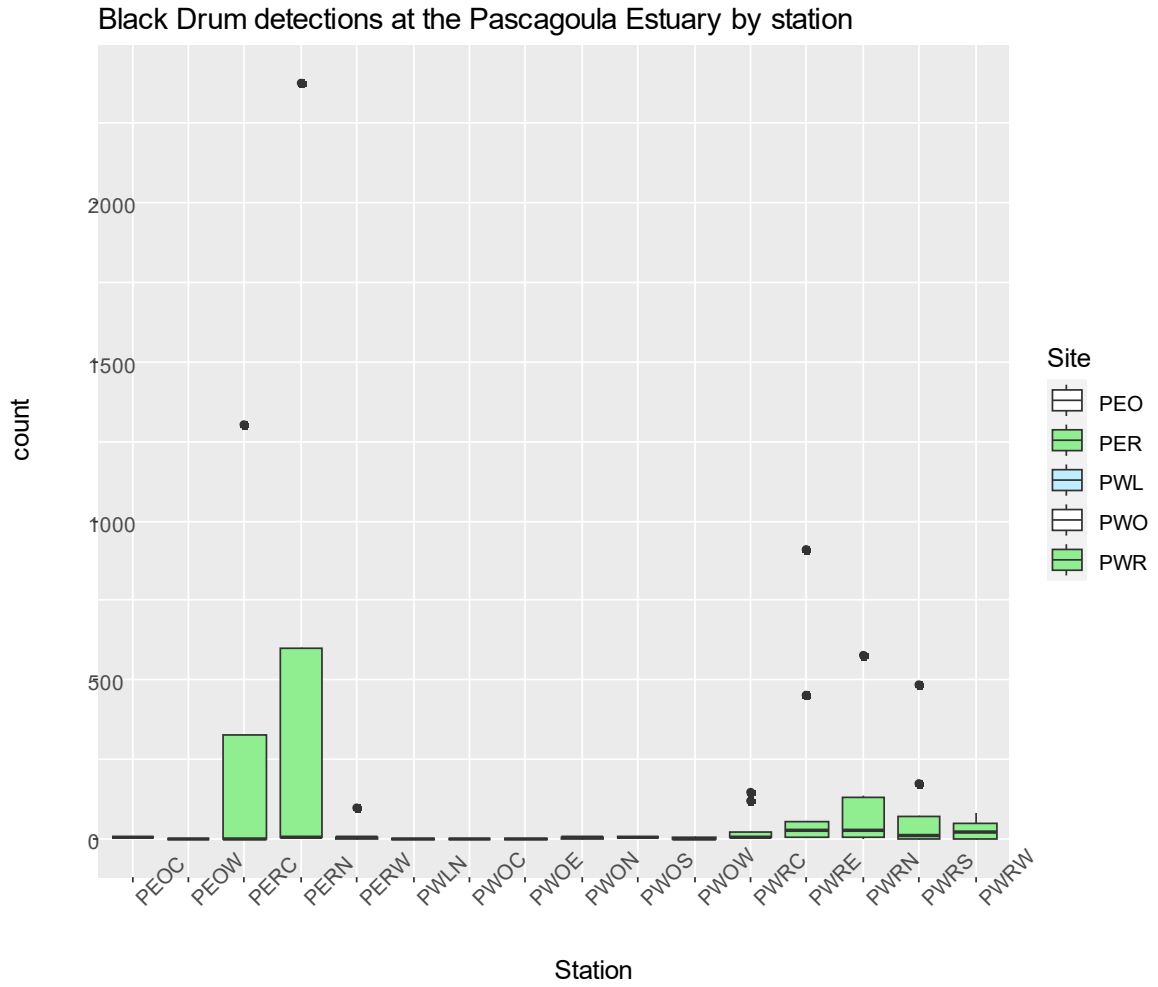


Pascagoula River Estuary



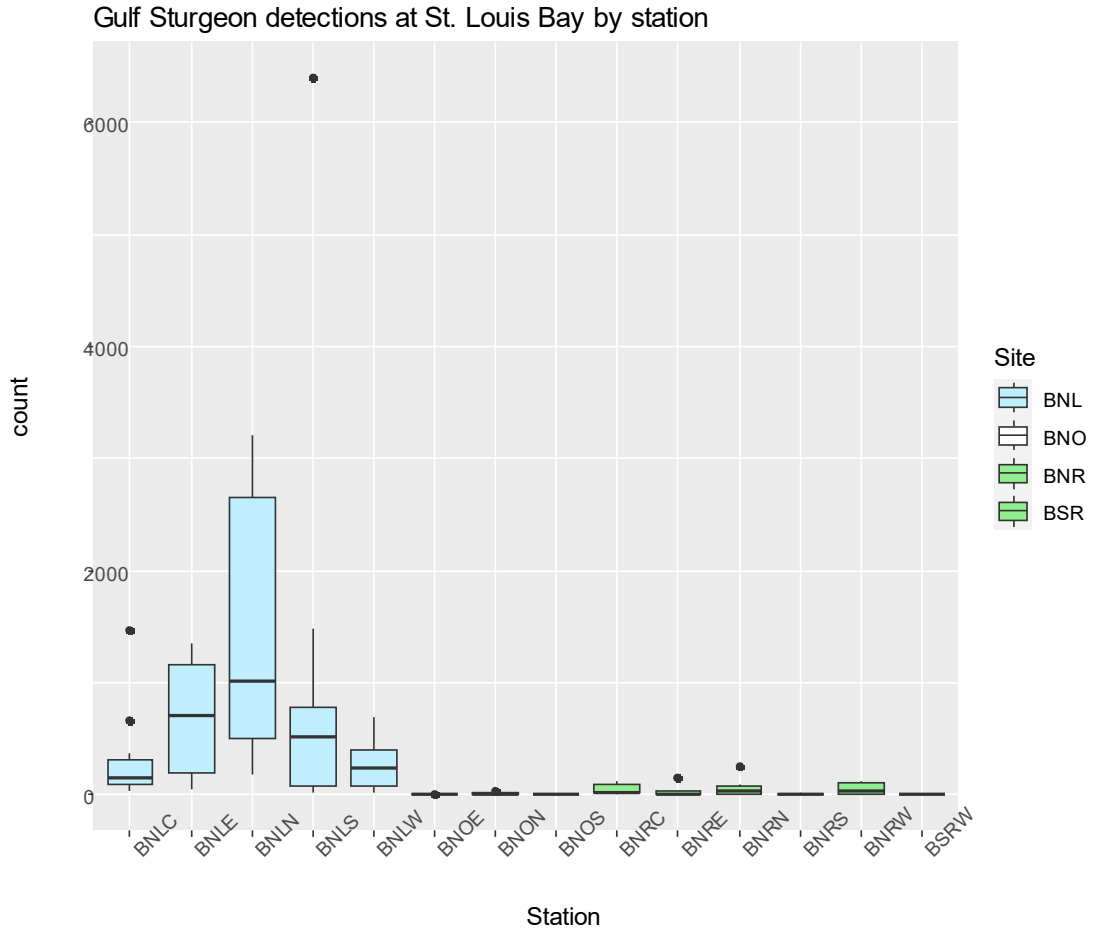
Black Drum (n = 9)

Pascagoula River Estuary

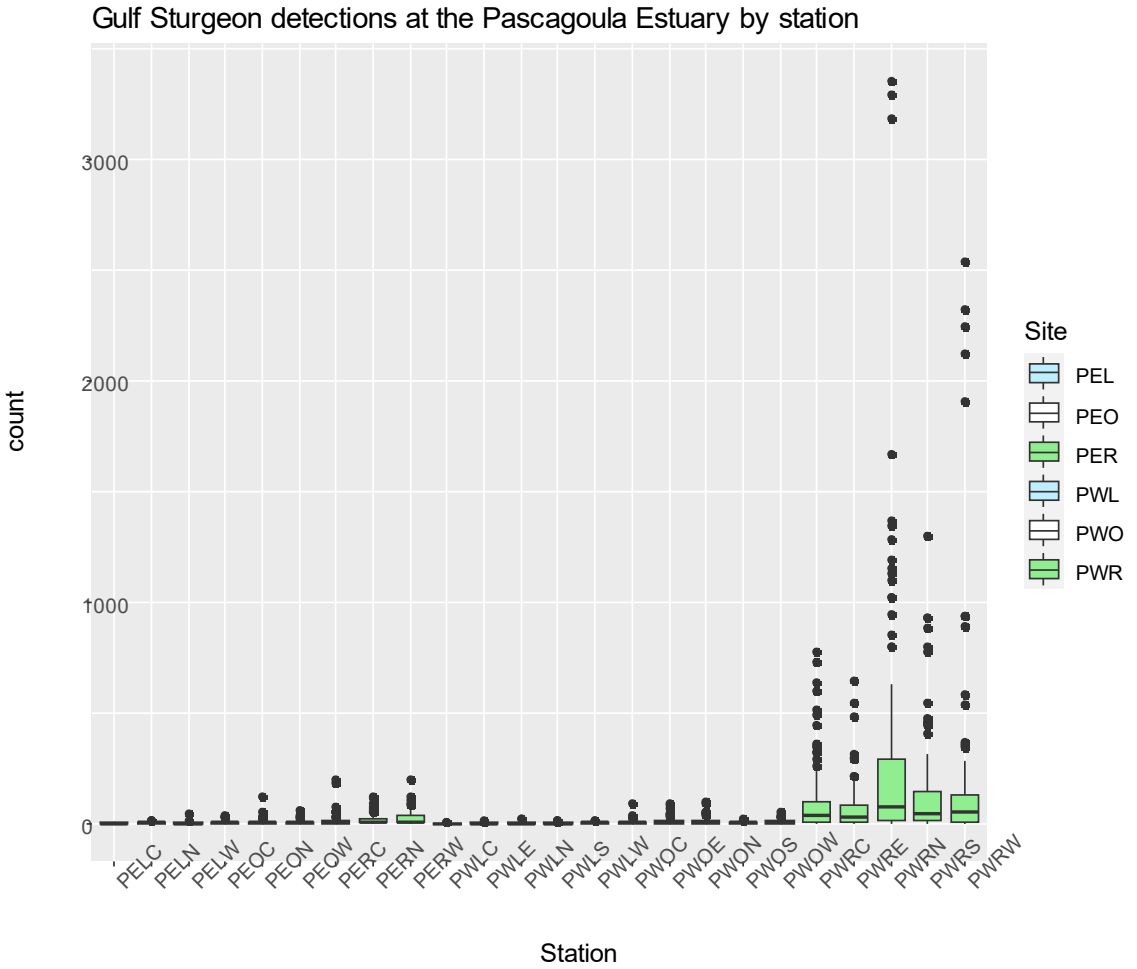


Gulf Sturgeon (n = 171)

St. Louis Bay



Pascagoula River Estuary



Sheepshead (SH) model

- % Carbon has positive effect
- Simpson has positive effect

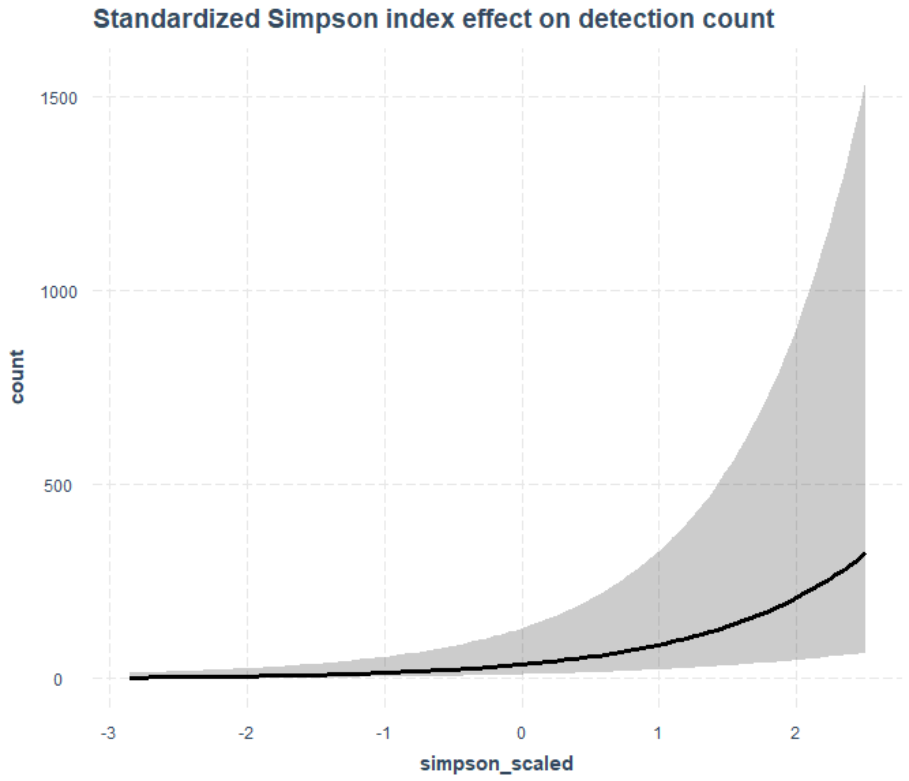
Interpretation:

- Preferred high diversity and high organic matter content
- Living reef locations

```
count ~ (1|Site) +
```

FIXED EFFECTS:

	exp(Est.)	S.E.	z val.	p
(Intercept)	[illegible]	[illegible]	[illegible]	[illegible]
avg.perc.carb_scaled	2.508	0.364	2.526	0.012
simpson_scaled	2.382	0.175	4.958	0.000



Black Drum (BD) model

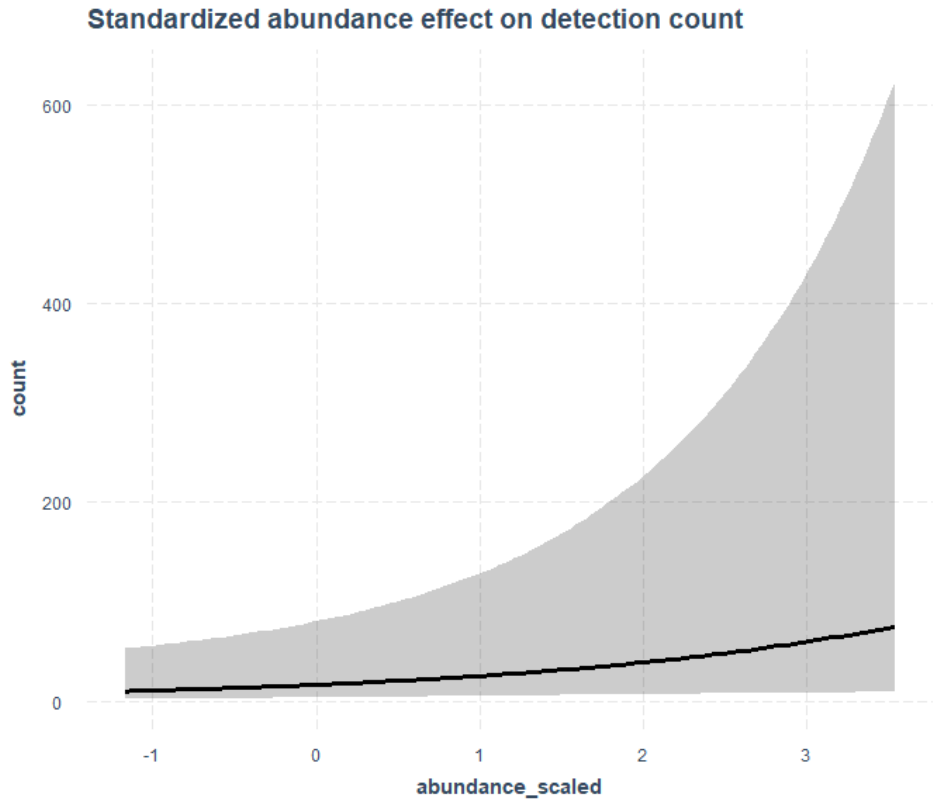
- Abundance has positive effect

Interpretation:

- Sites with large quantities of food

FIXED EFFECTS:

	exp(Est.)	S.E.	z val.	p
(Intercept)	16.557	0.791	5.346	0.000
abundance_scaled	1.533	0.206	2.079	0.038



Gulf Sturgeon (GS) model

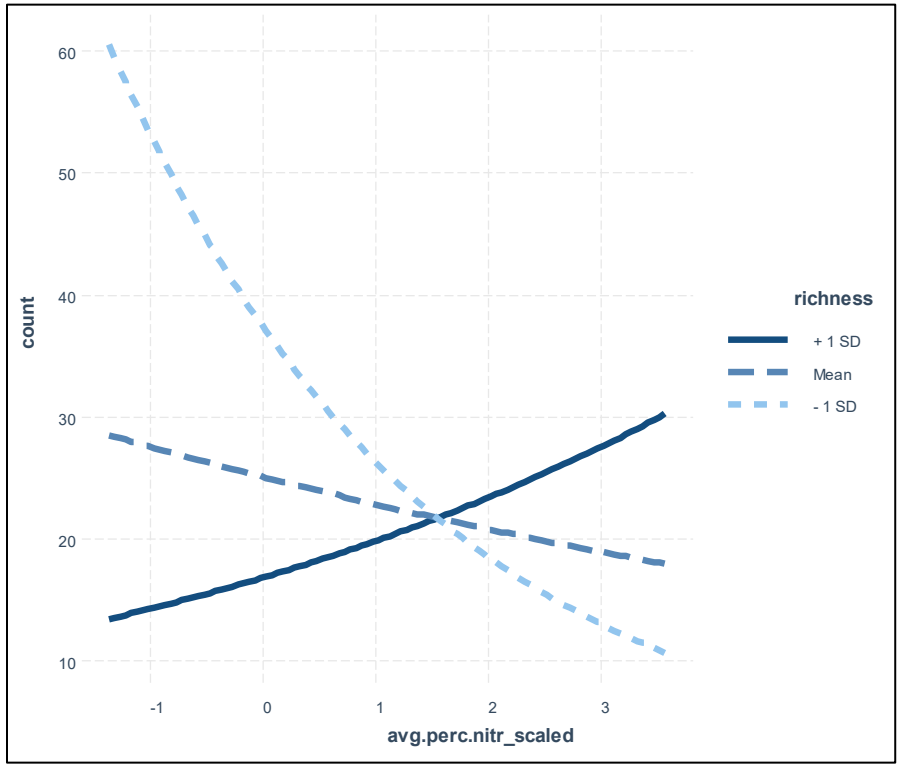
- Interaction between %N and richness

Interpretation:

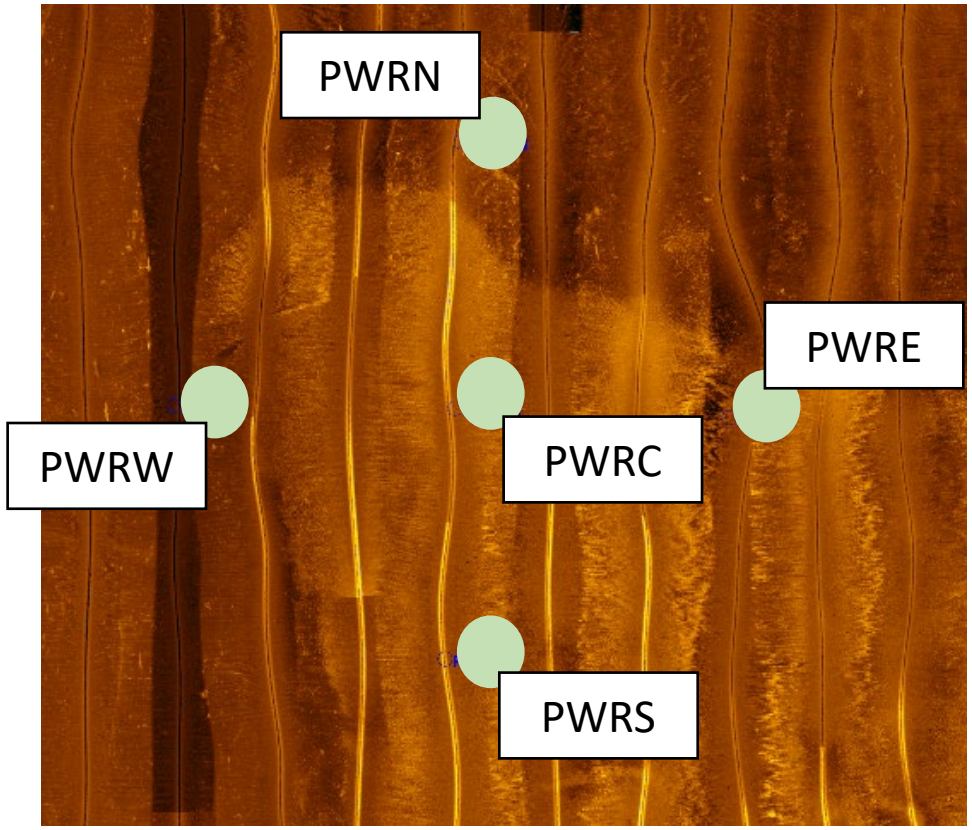
- Represents foraging in different spatial contexts

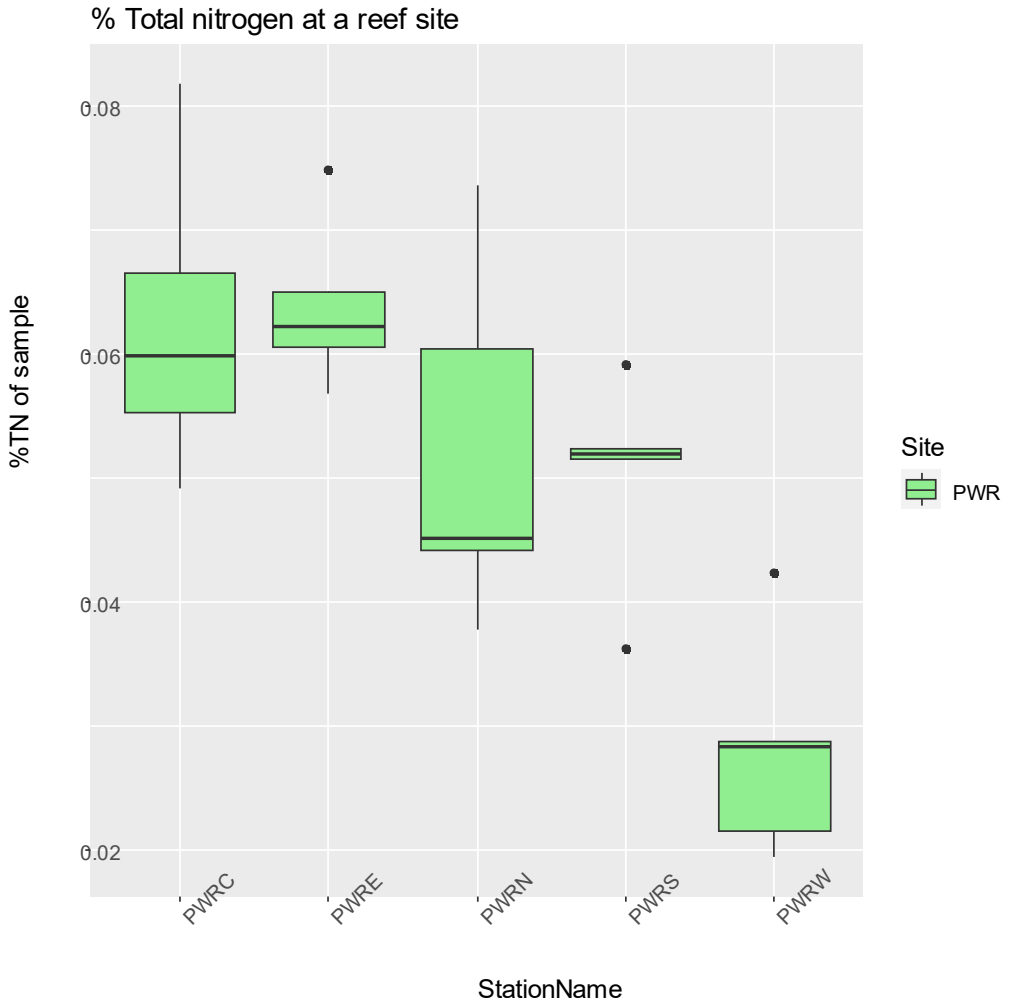
FIXED EFFECTS:

	exp(Est.)	S.E.	z val.	p
(Intercept)	88.232	0.450	9.965	0.000
avg.perc.nitr_scaled	0.404	0.123	-7.392	0.000
richness	0.932	0.009	-7.716	0.000
avg.perc.nitr_scaled:richness	1.047	0.010	4.441	0.000

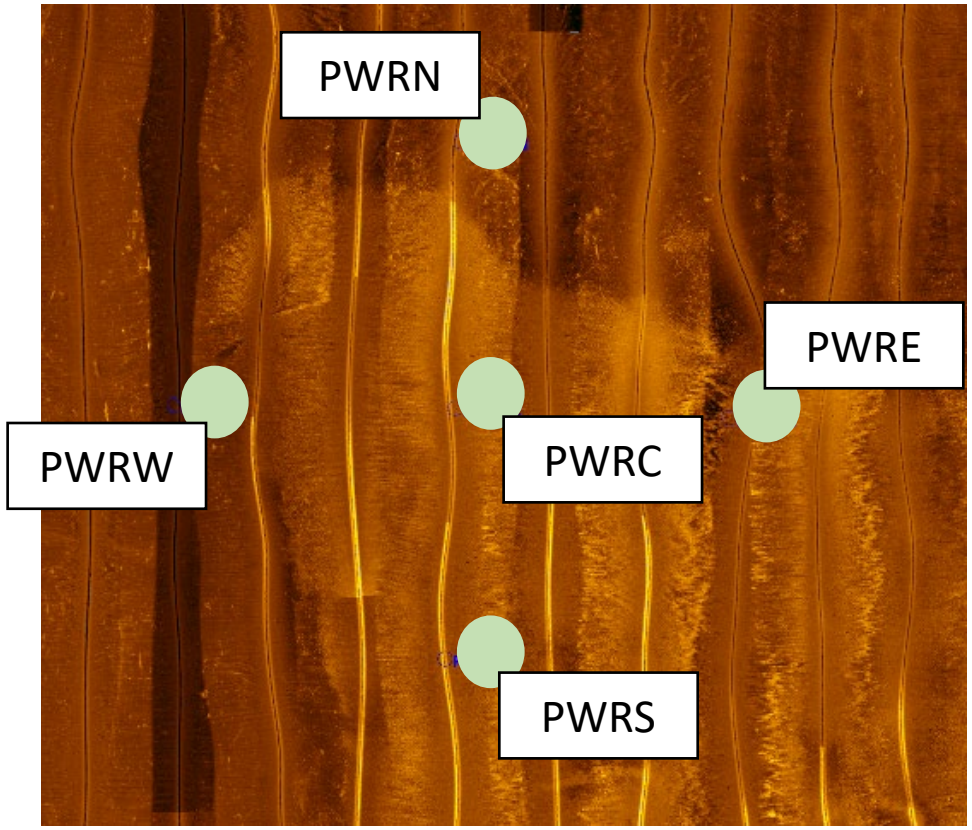


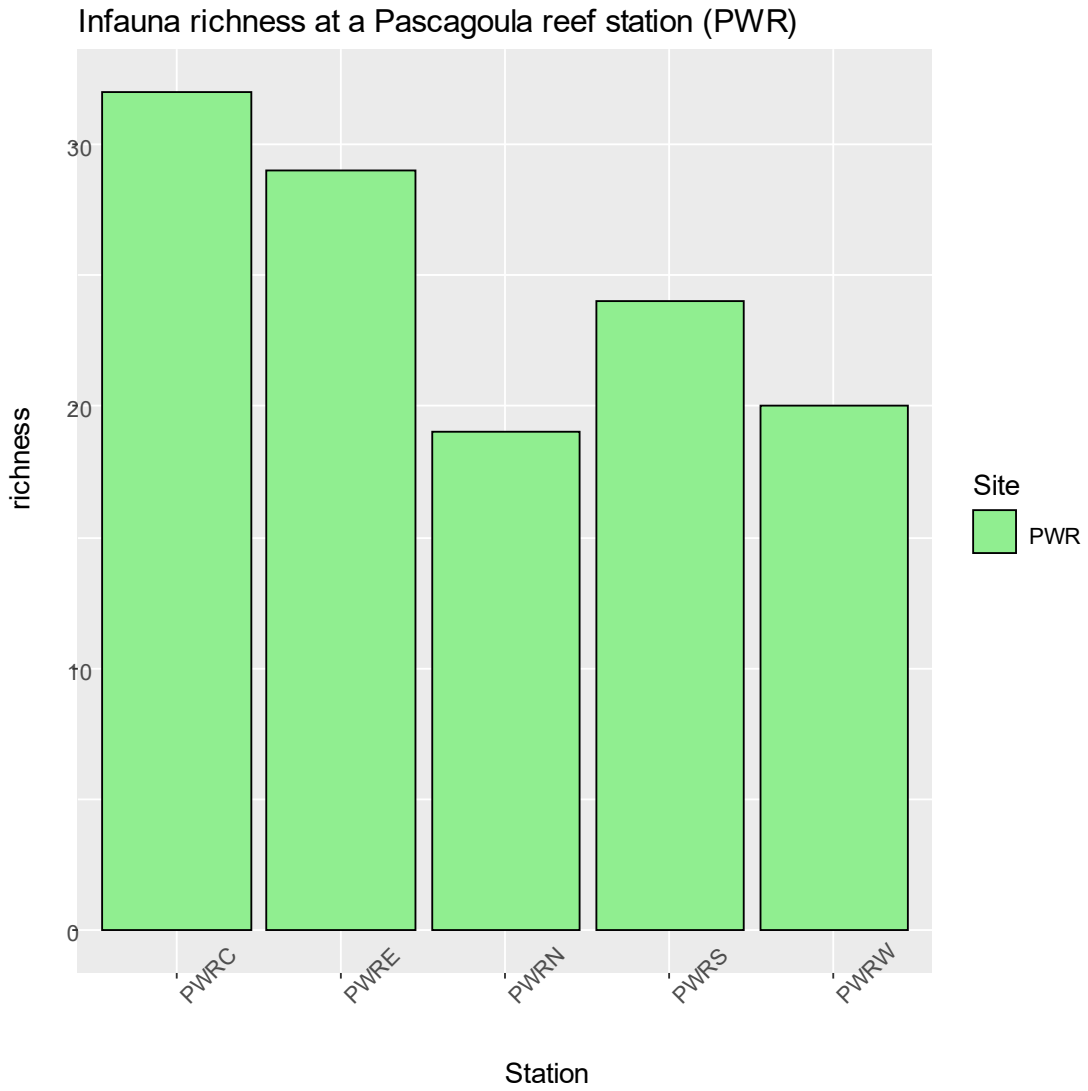
GS model interpretation



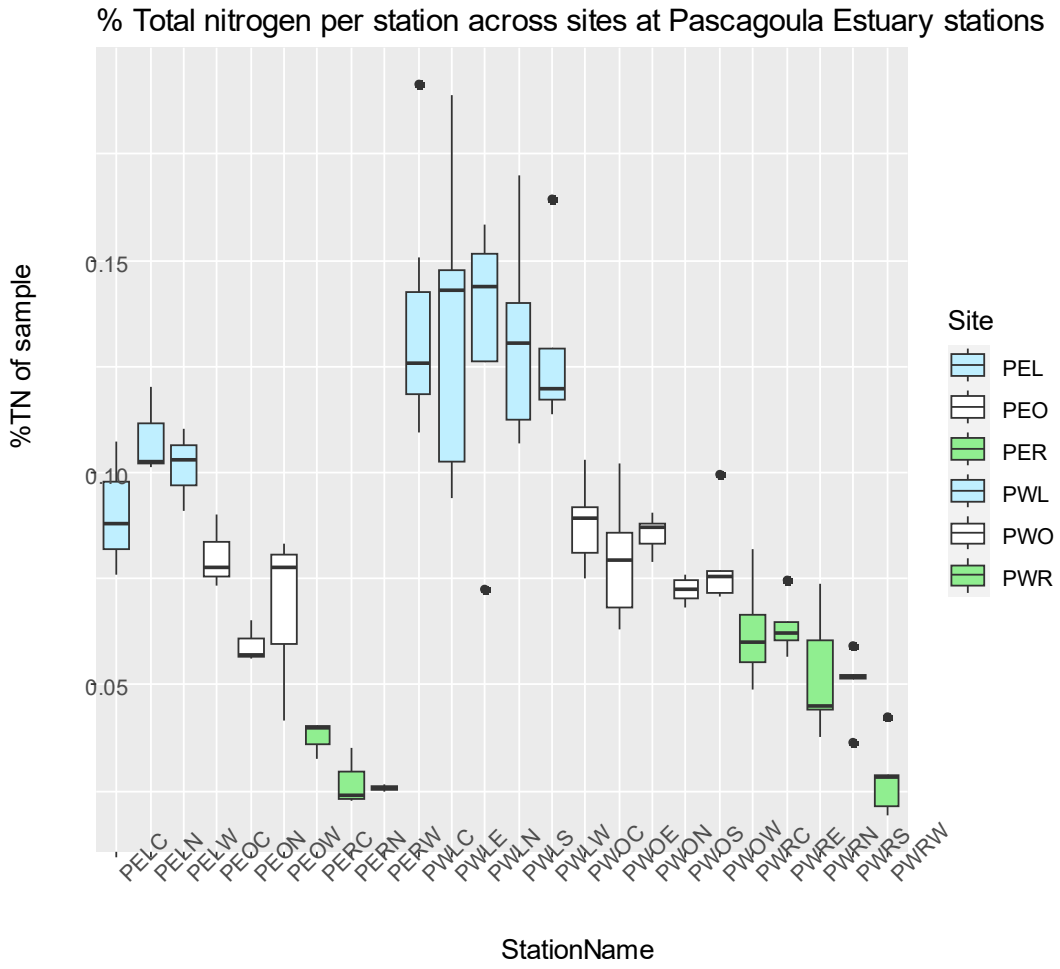


GS model interpretation



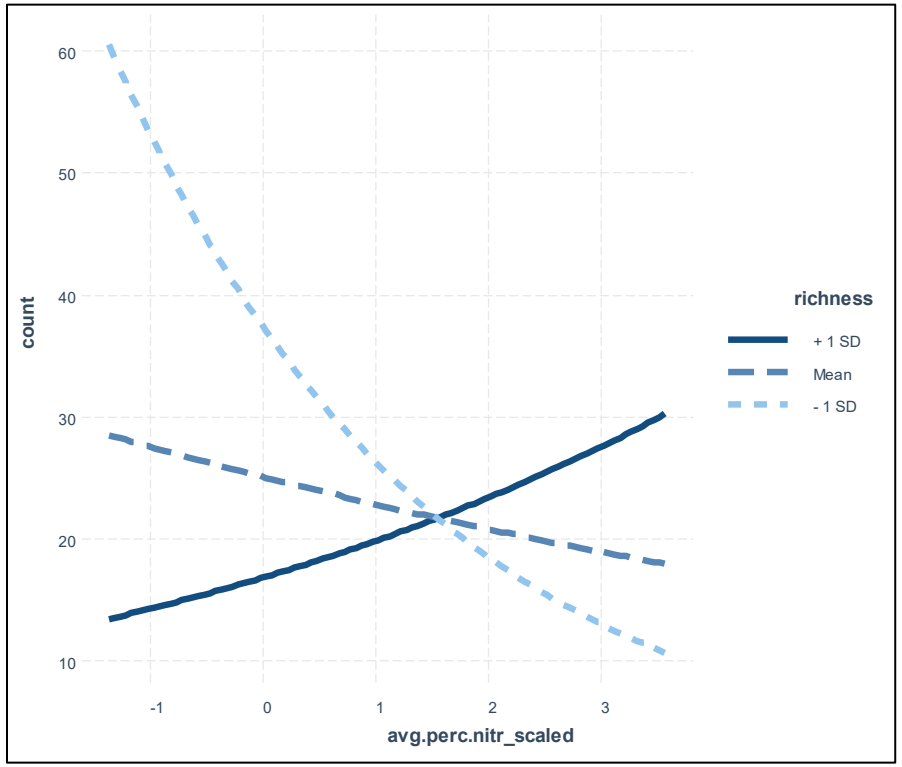


Gulf Sturgeon (GS) model



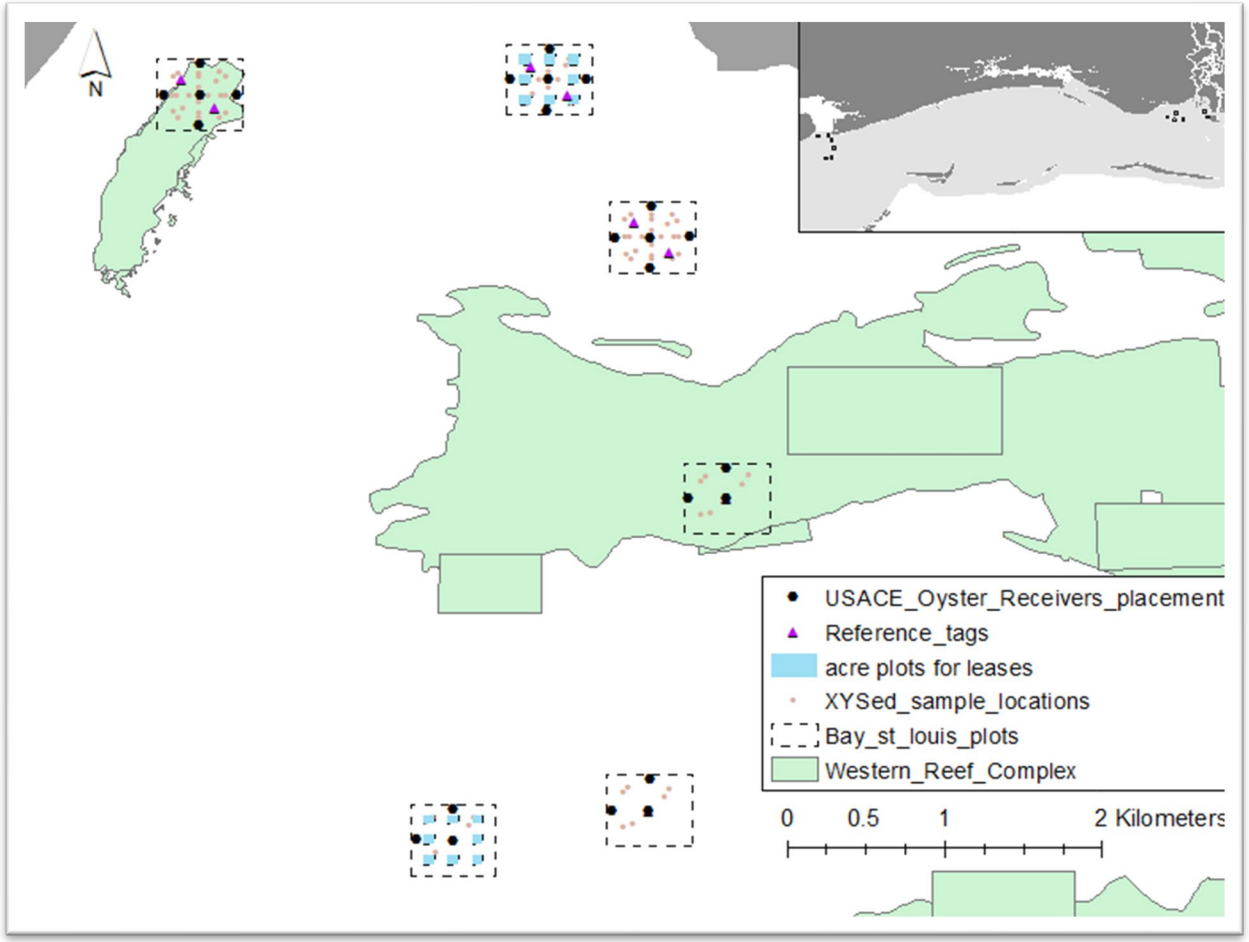
FIXED EFFECTS:

	exp(Est.)	S.E.	z val.	p
(Intercept)	88.232	0.450	9.965	0.000
avg.perc.nitr_scaled	0.404	0.123	-7.392	0.000
richness	0.932	0.009	-7.716	0.000
avg.perc.nitr_scaled:richness	1.047	0.010	4.441	0.000



Conclusion

- Spatial context matters
- Sandy habitats
- Benefit may depend on sub-habitats made available
- Halo effect for GS
- Organic matter and diversity for SHP
- Abundance for BDM
- Equipped to look at post-restoration



Thesis objective and summaries

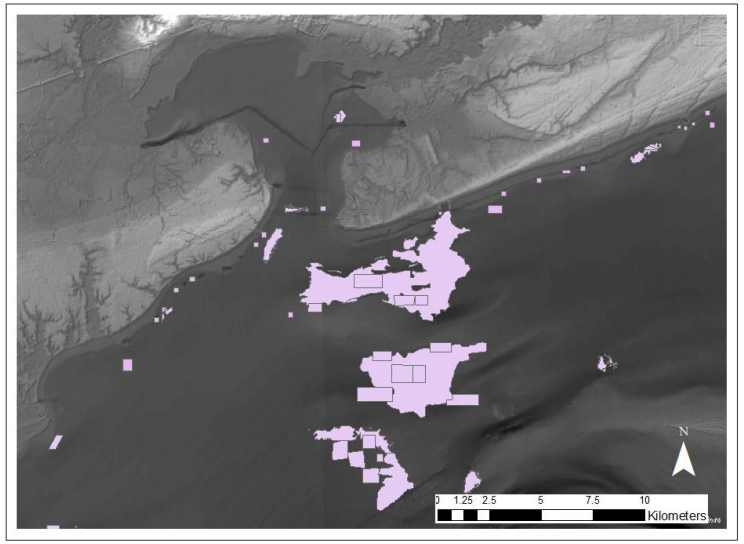
- **Ch. 1: describe emigrations patterns of a threatened anadromous fish species to nearshore and alongshore habitats**
  - Emigrations are occurring to habitats where reef construction will occur
- **Ch. 2: describe movements of multiple species in a coastal bay sub-system**
  - Transient fish use bay mouths frequently and are controlled by freshwater
- **Ch. 3: model transient fish use associated with infauna and sediment metrics**
  - Fish habitat preferences are hierarchical

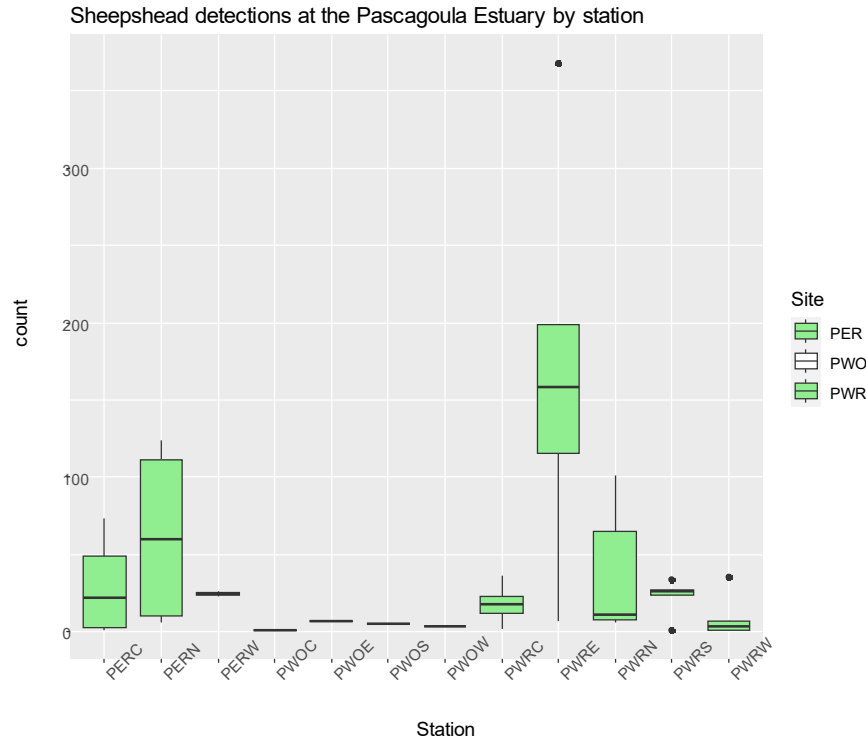
Considerations

- Coastal estuarine areas are highly complex
- transient fish occupy areas where oyster restoration will occur
- Influence of reefs depends on landscape setting

Local considerations:

- Natural functions of reefs must be sustained
- Transient fish considerations modify decisions
- Impacts of reef may change over time
- Long term monitoring likely required



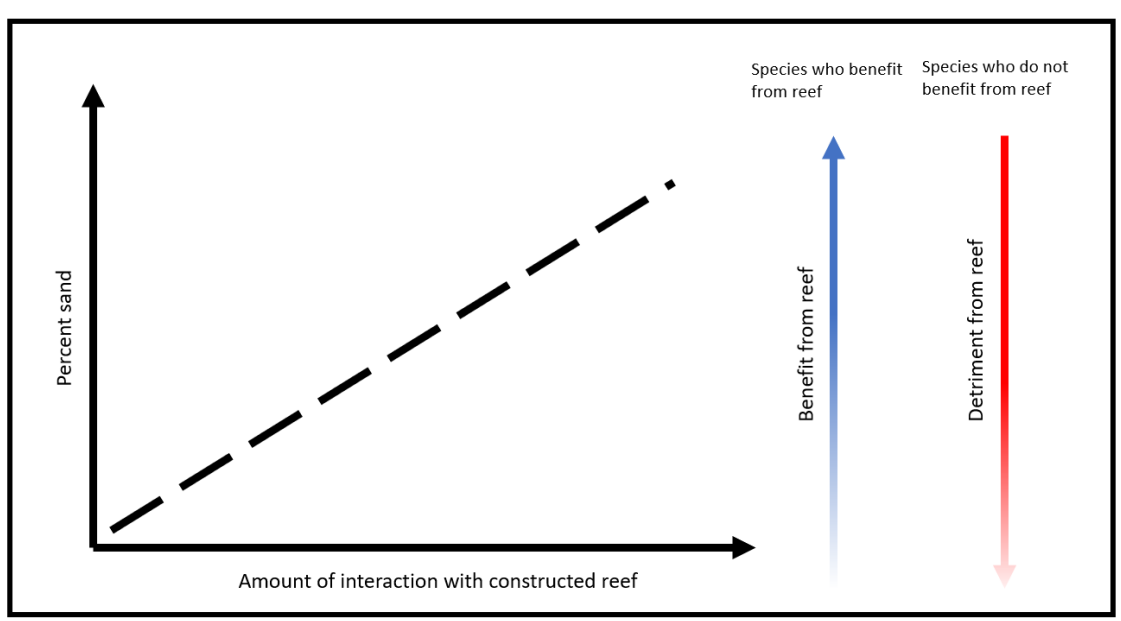


Conclusion

- Highlights potential interaction between transient fish and oyster restoration
- Transient fish have high economic value and must be considered
- Understanding impacts is difficult
- Future research can use this baseline information

Acknowledgements

- Committee
- Significant data contributions: CFRD, DISL, MDMR
- Ch 1:
  - Grammer, E. Haffey, E. Greenheck, K. Price, G. Schumacher, B. Lynch, A. Cohuo, K. Yeager, K. Schindler, A. Yarnall, S. Whitehead
  - IACUC protocol #: 17101205
- Ch.2:
  - Tagging: Christopher Lapniewski, Justin Lewis, Jennifer Green
  - Center for Fisheries Research and Development: Jill Hendon, Jim Franks, Jeremy Higgs
- Ch.3:
  - Field: P. Grammer, K. Wright, E. Haffey, K. Price, G. Schumacher, B. Lynch, P. Vick, J. Green, F. Bechard, D. Bailey, B. McCoy, L. McCoy , M. Frank, S. Rider, M.J.A's 2018-2019, 2021 Marine Ichthyology classes
  - CFRD: J. Hendon, J. Higgs, J. Franks, C. Lapniewski
  - US Army Corps: T. Slack, B. Lewis
  - DISL: T. Nelson
  - IACUC protocol #: 17101205



1.Figure of the hypothesized influence of reef construction on transient fish in relation to sand content.

The Y-axis represents the amount of sand within the sediments, the x-axis is the amount of interaction a transient fish would have with a constructed reef, and the slope represents the increase of transient fish interaction and percent sand. On the right, the blue line represents the benefit that can be gained from constructed reefs which increases with sand. The red line represents the negative effects a constructed reef may have which decreases with sand.

Site specific considerations

- Hierarchy exists for site selections
- Reefs must be constructed in viable locations for oysters
- Transient fish used bay mouths and sandy reefs directly adjacent to freshwater inflow

Temporal considerations

- During early construction periods, reefs may initially act as disturbance to transient fish
- Knowing presence and timing of transient fish use can help control when construction occurs (especially important for threatened species)
- Reef colonization may impact fish over time
- Species such as BDM who prefer abundant prey of any kind benefit
- GS maybe not initially
- Long time monitoring likely required