Supporting Scientific Discovery and Science-Based Guidance for Restoration and Management through the Mississippi Based RESTORE Act Center of Excellence (MBRACE)

Kelly Darnell

Director, MBRACE

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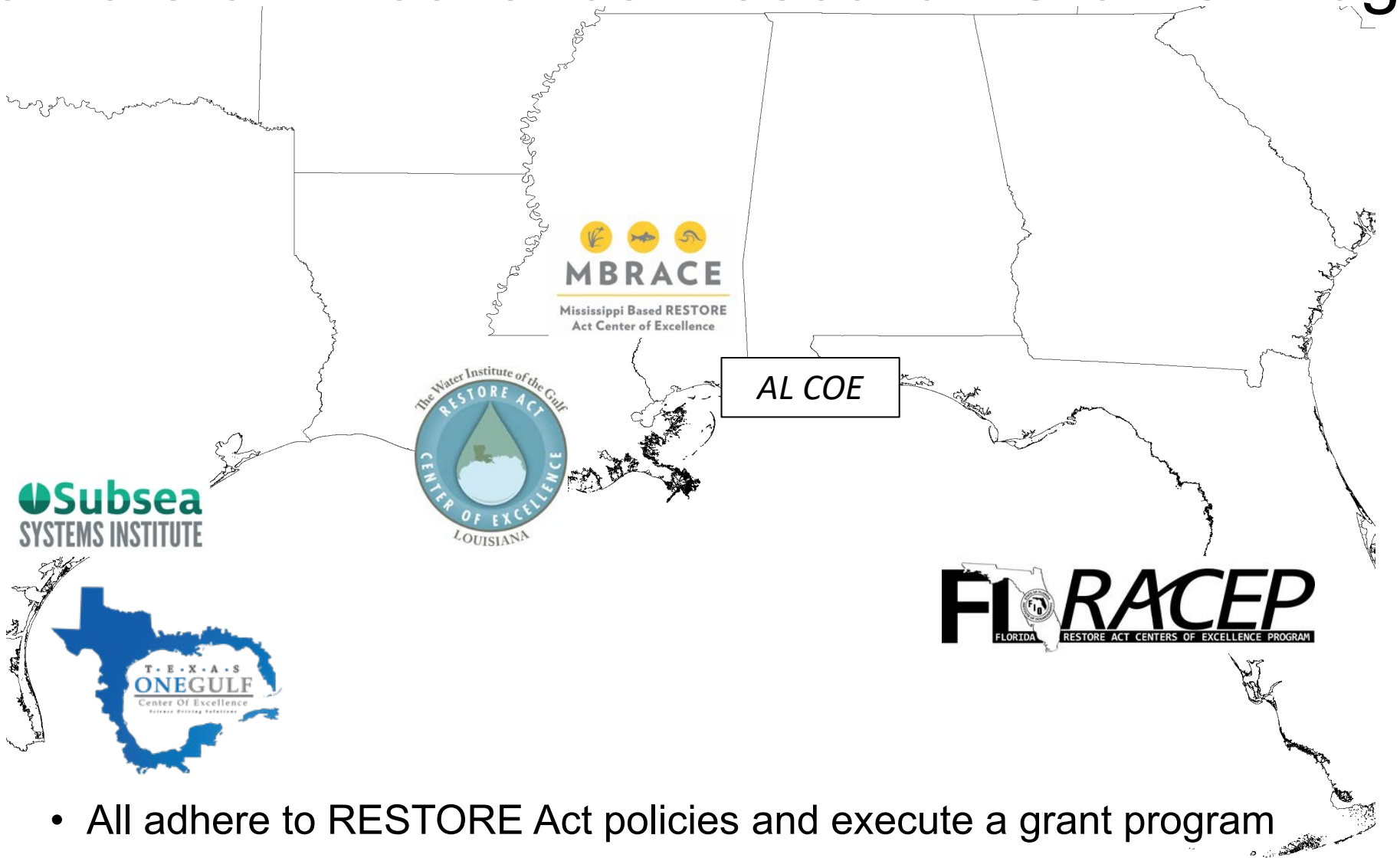
THE UNIVERSITY OF SOUTHERN MISSISSIPPI

MBRACE

Mississippi Based RESTORE Act Center of Excellence

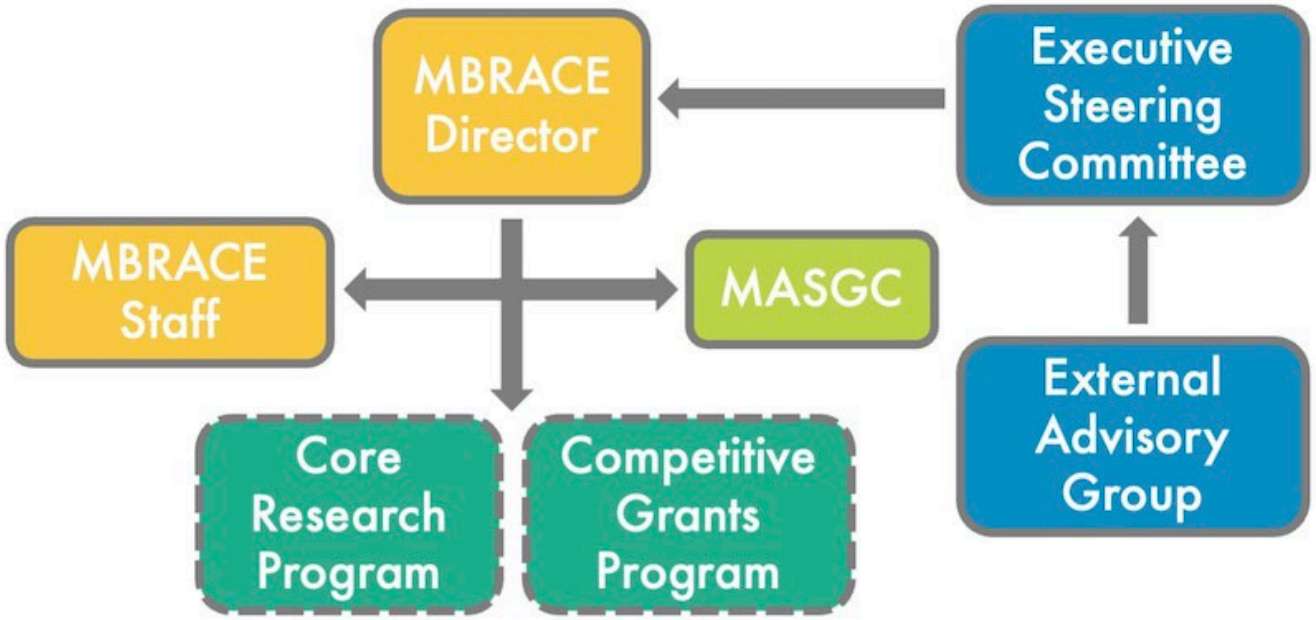
Centers of Excellence Research Grants Program



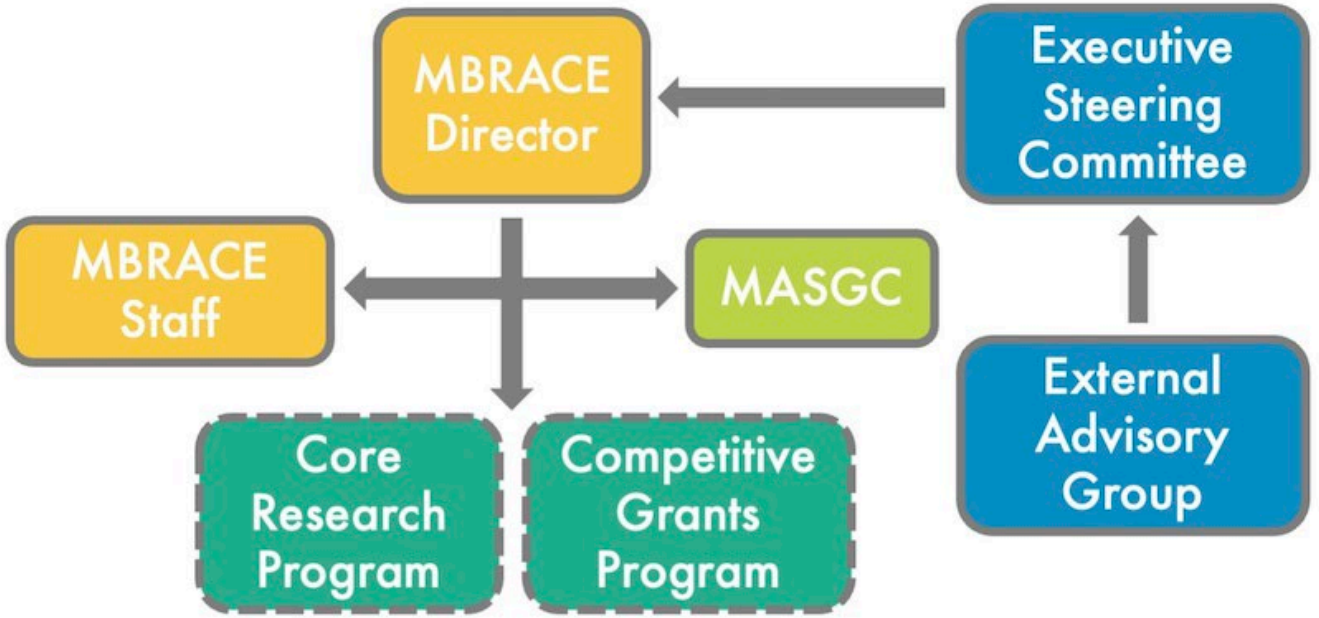
- All adhere to RESTORE Act policies and execute a grant program
- Each State receives $26M+ over 15 years
- Each Center is structured differently, has different scientific focus

- MBRACE is a consortium of Mississippi's four main research universities
- Designated by the State of Mississippi as the Center of Excellence in August 2016
- Mississippi Departmental of Environmental Quality is the state entity for MBRACE

Organizational Structure

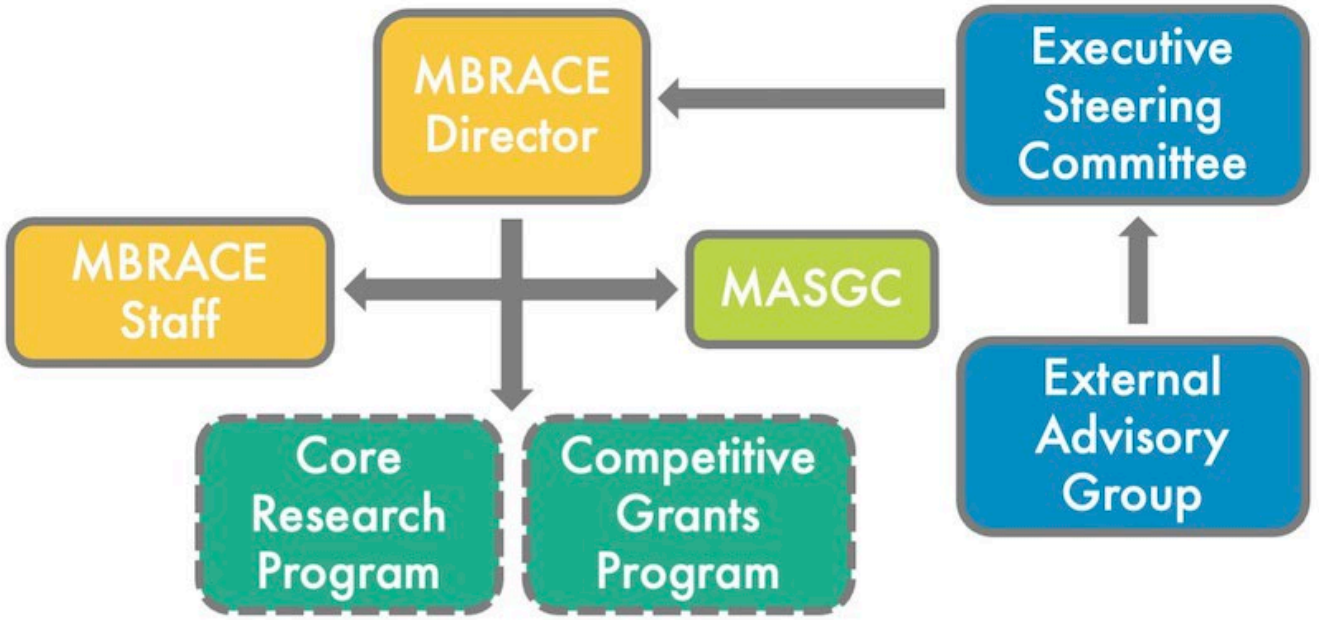


Organizational Structure



ESC: Works with the Directorate to ensure success of the program, reviews and approves the Science Plan and Requests for Proposals, and makes final funding decisions

Organizational Structure



Bill Benson, US EPA (retired)

Jane Caffrey, UWF

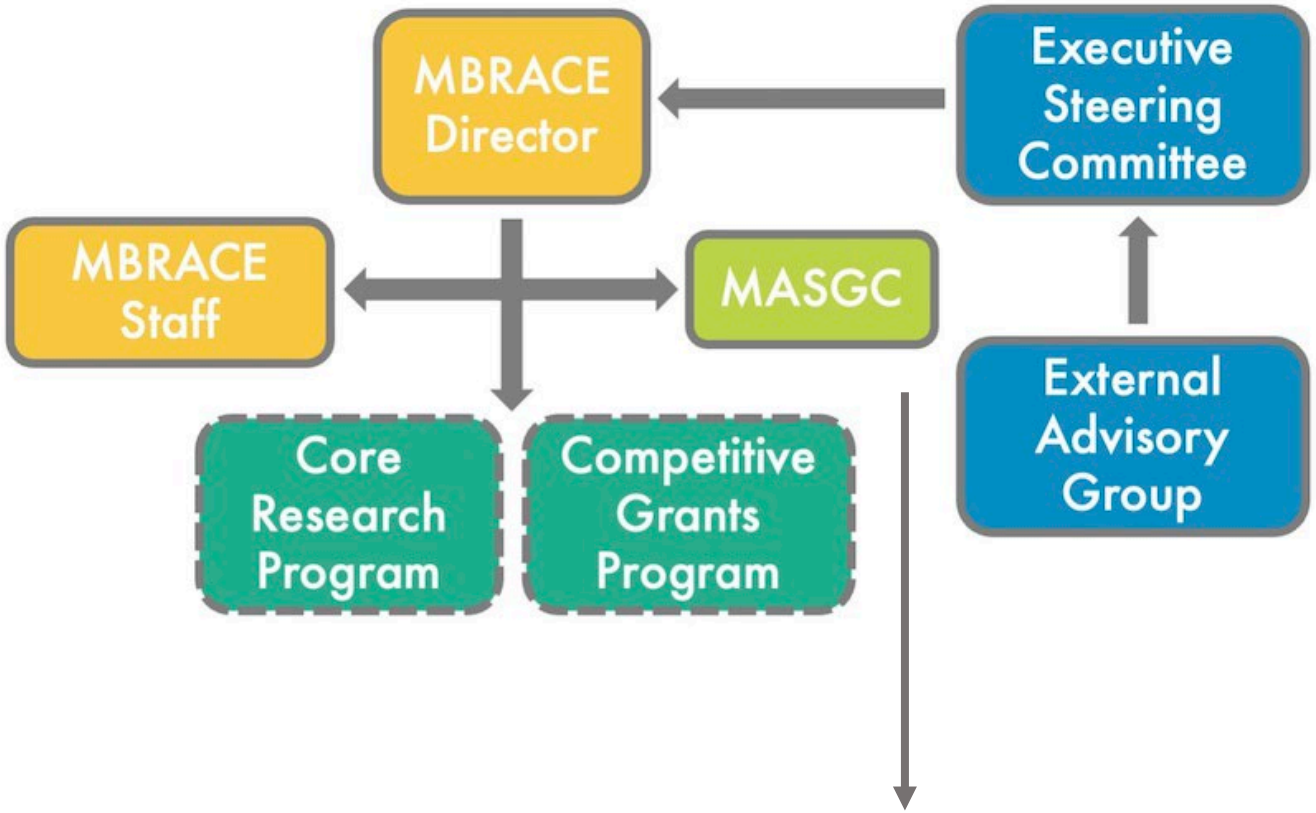
David Rudnick, NPS (retired)

Bill Fisher, EPA (retired)

Jennifer Pollack, TAMU-CC / HRI

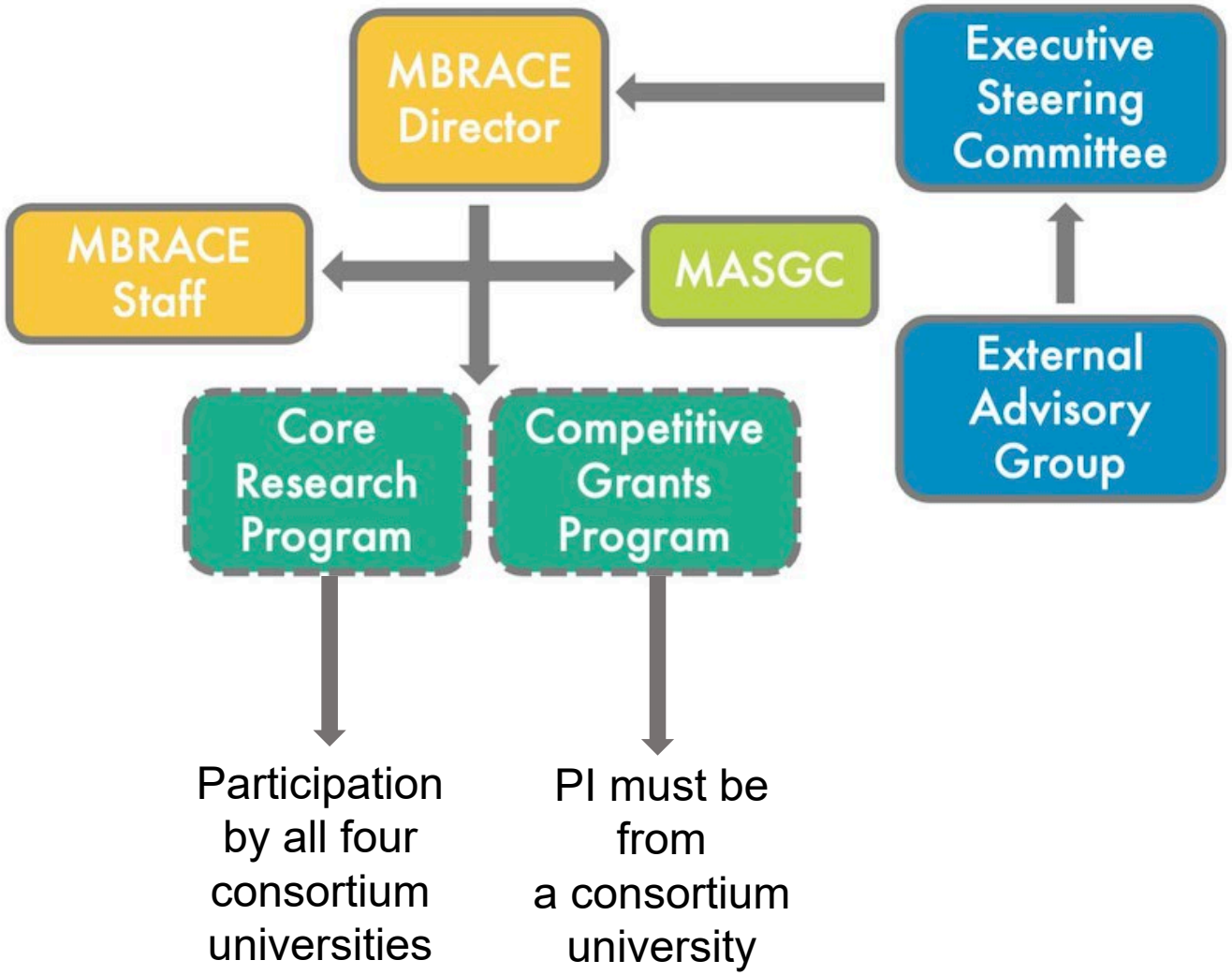
EAG: Technical and scientific experts in relevant fields, advise on long-term direction, conduct annual programmatic evaluations

Organizational Structure



Mississippi-Alabama Sea Grant Consortium: Coordinates proposal review process and assists with science communication

Organizational Structure



MBRACE Mission

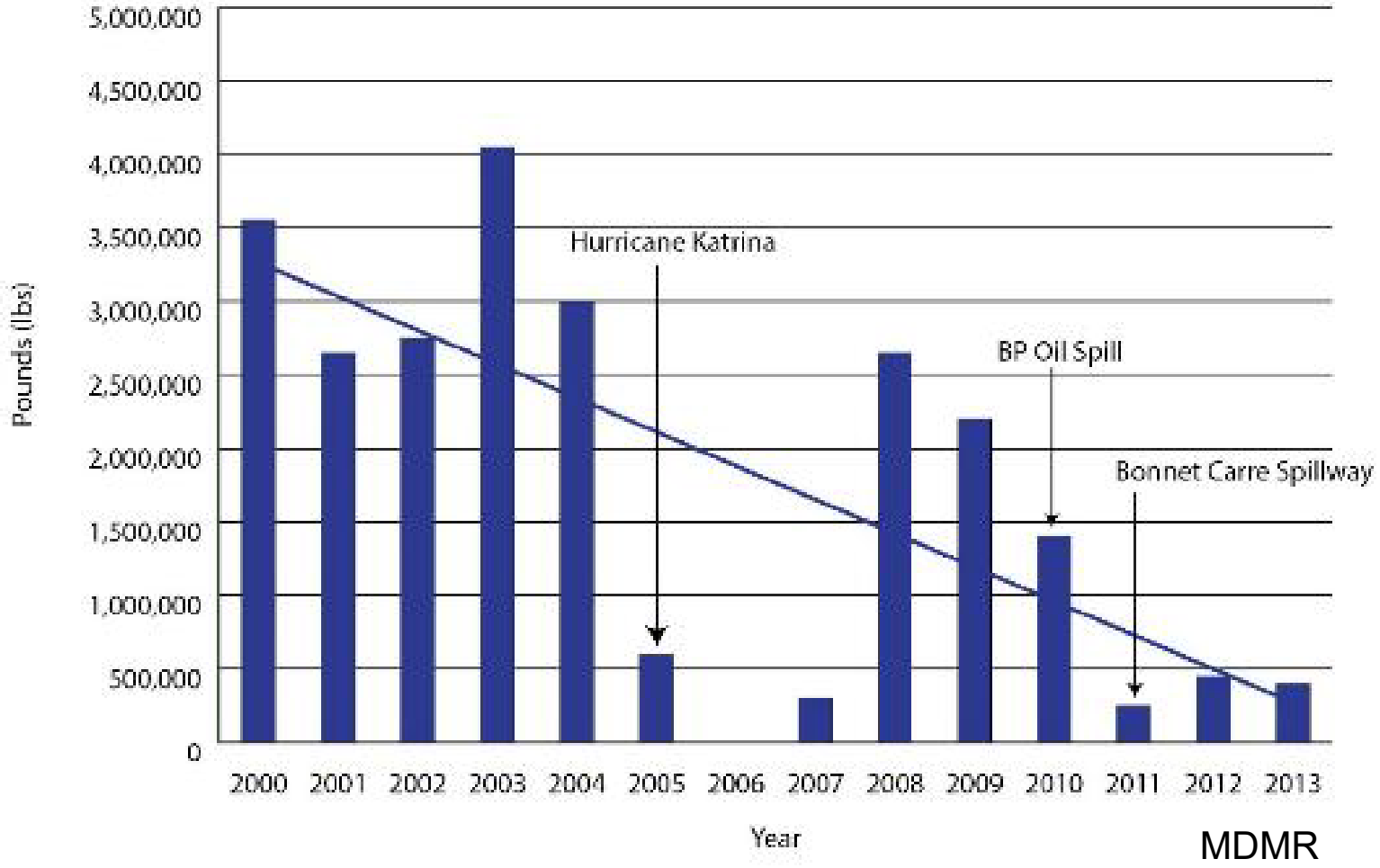
- Seek sound comprehensive science-and technology-based **understanding of the chronic and acute stressors on the dynamic and productive waters and ecosystems** of the northern Gulf of Mexico, and to **facilitate sustainable use of the Gulf's important resources**

- Serve as a **focal point for new, long-term research and socioeconomic initiatives** along the northern Gulf with relevance to **Mississippi's resources**

- Serve the people of Mississippi and the northern Gulf region with a scientifically based **understanding of ecosystem status and trends with special emphasis on improved forecasting abilities** to ensure sustainable coastal and ocean ecosystems of the Gulf

Oyster reef sustainability and water quality

Mississippi oyster landings over time

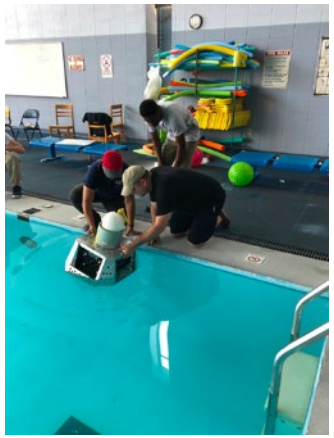


MDMR

- Responsive to State management needs
- >$7M to support research
- Focus on MS Sound

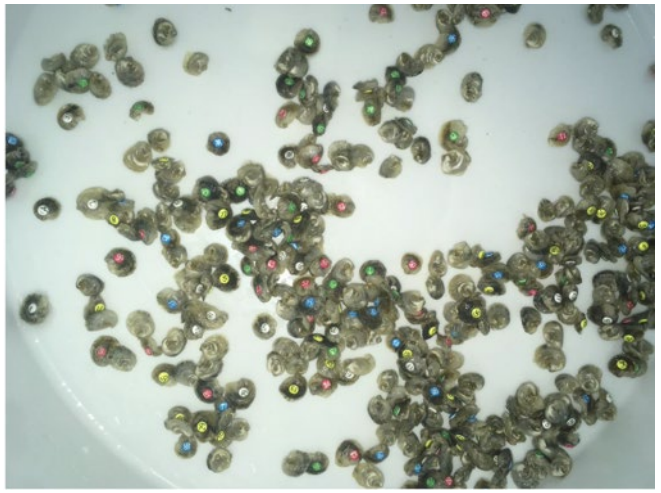
Core Research Program

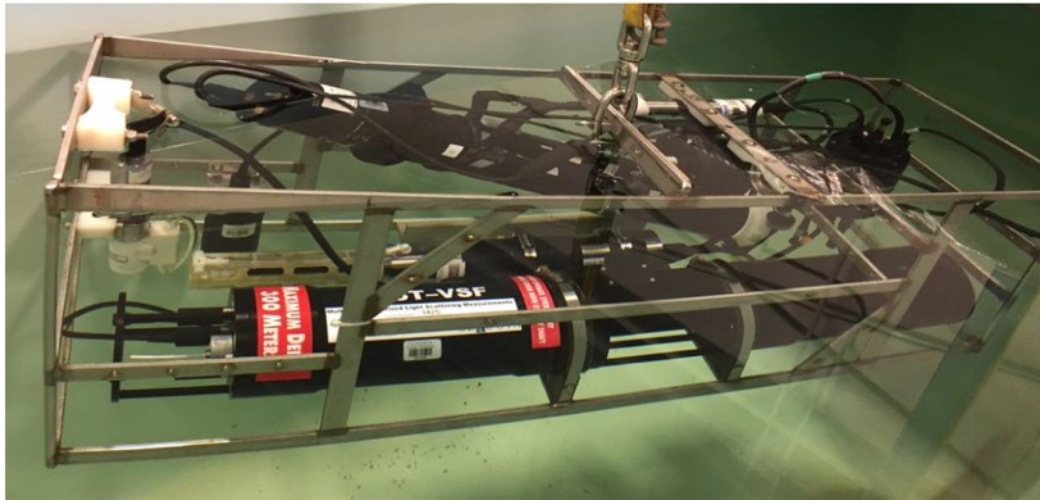
Four integrated projects that together focus on oyster reef sustainability and restoration, as well as the environmental factors that support healthy oyster reefs



- Focused on needs identified by State management agencies
  - Oyster biology, ecology, and response to stressors
  - Suitable locations for oyster restoration
- Field and lab studies, high tech remote sensing, monitoring, experiments, modelling
- Western MS Sound

Competitive Grants Program





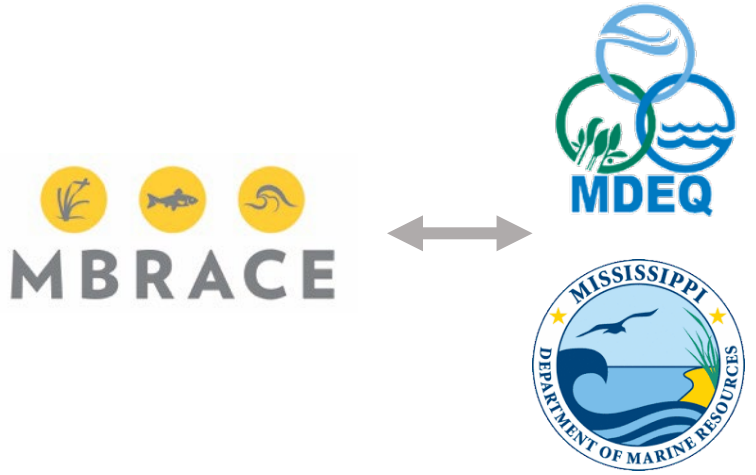
- Projects compliment Core Research Program

- Oyster response to stressors
- Influence of submarine groundwater discharge
- Oyster food availability and quality

Coordination and Collaboration

- Encourage collaboration across projects to facilitate integration and synthesis of data
  - Fund projects under same themes
  - Annual All Hands Meeting, research seminars
  - Sessions at scientific conferences
  - Historical perspective paper
  - Conceptual model

- Close partnership with MDMR and MDEQ to ensure projects address needs and to leverage resources



Impact of MBRACE-funded Research

55
Graduate Students Supported

81
Conference Presentations

30
Undergraduates Supported

15
Peer-Reviewed Publications

5
Dissertations/Theses Supported

65+
Datasets Available at GRIIDC

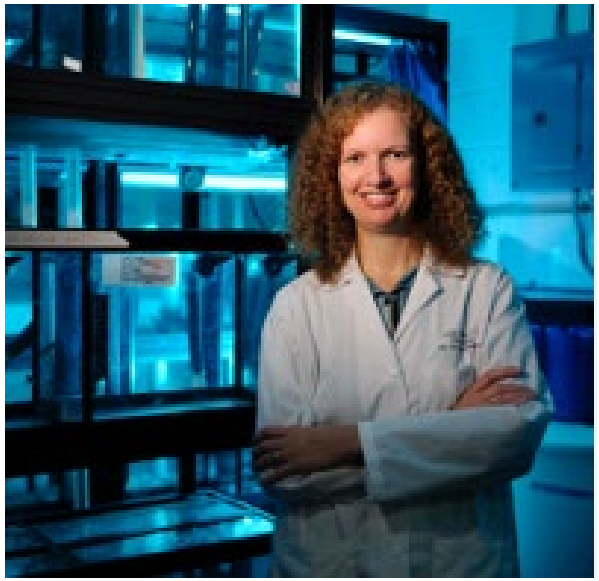
Visit mbrace.usm.edu
for more information

This project was paid for with federal funding from the Department of the Treasury under the Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act of 2012 (RESTORE Act). The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the Department of the Treasury.

Featured Speakers

Dr. Adam Skarke
Mississippi State University

Dr. Kristine Willett
University of Mississippi



MSU Core Research Program: Integrated River and Estuary Water Quality Monitoring and Modeling in the Northern Gulf of Mexico

PI Adam Skarke, MSU (July 2021- February 2023)
PI Anna Linhoss, MSU (January 2020-July 2021)
Co-PI Robert Moorhead, MSU
Co-PI Padmanava Dash, MSU
Co-PI Prem Parajuli, MSU

MISSISSIPPI STATE UNIVERSITY

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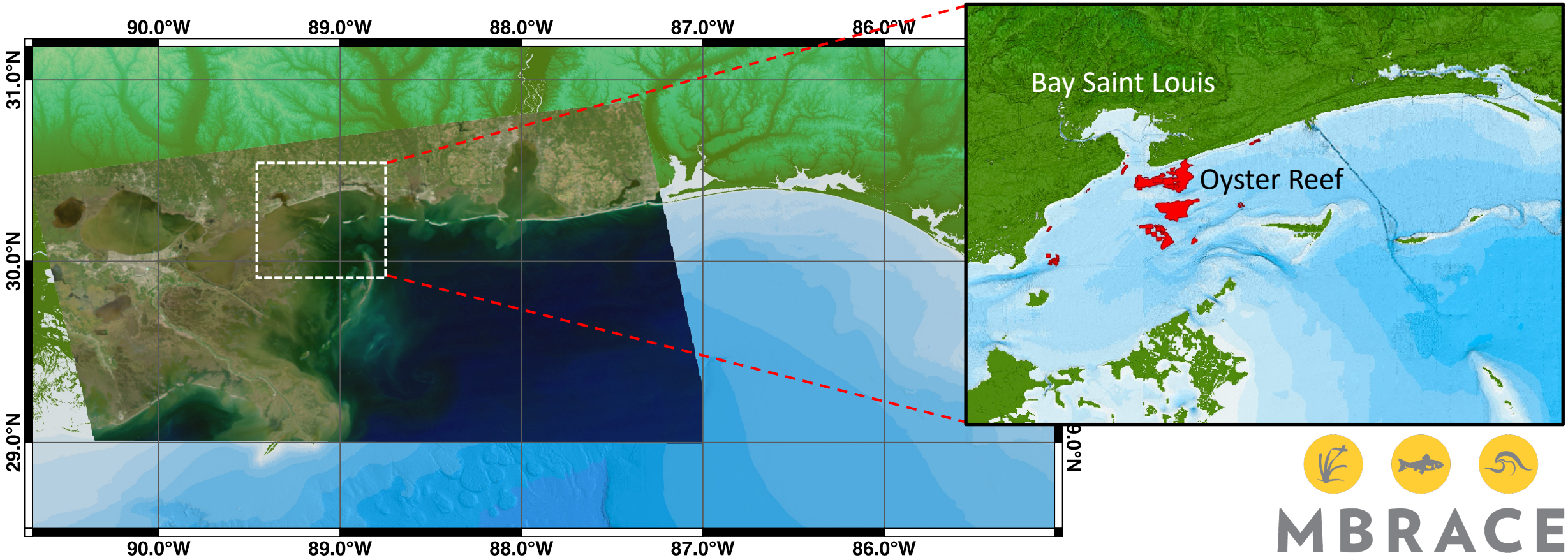
Project Motivation

Water quality is one of the most important factors affecting the ecological benefits and ecosystem services provided by a water body.

Water quality in coastal ecosystems can be particularly impacted by the dynamics of freshwater inflow due to the high amounts of organic matter, nutrients, pathogens, and sediments it introduces.



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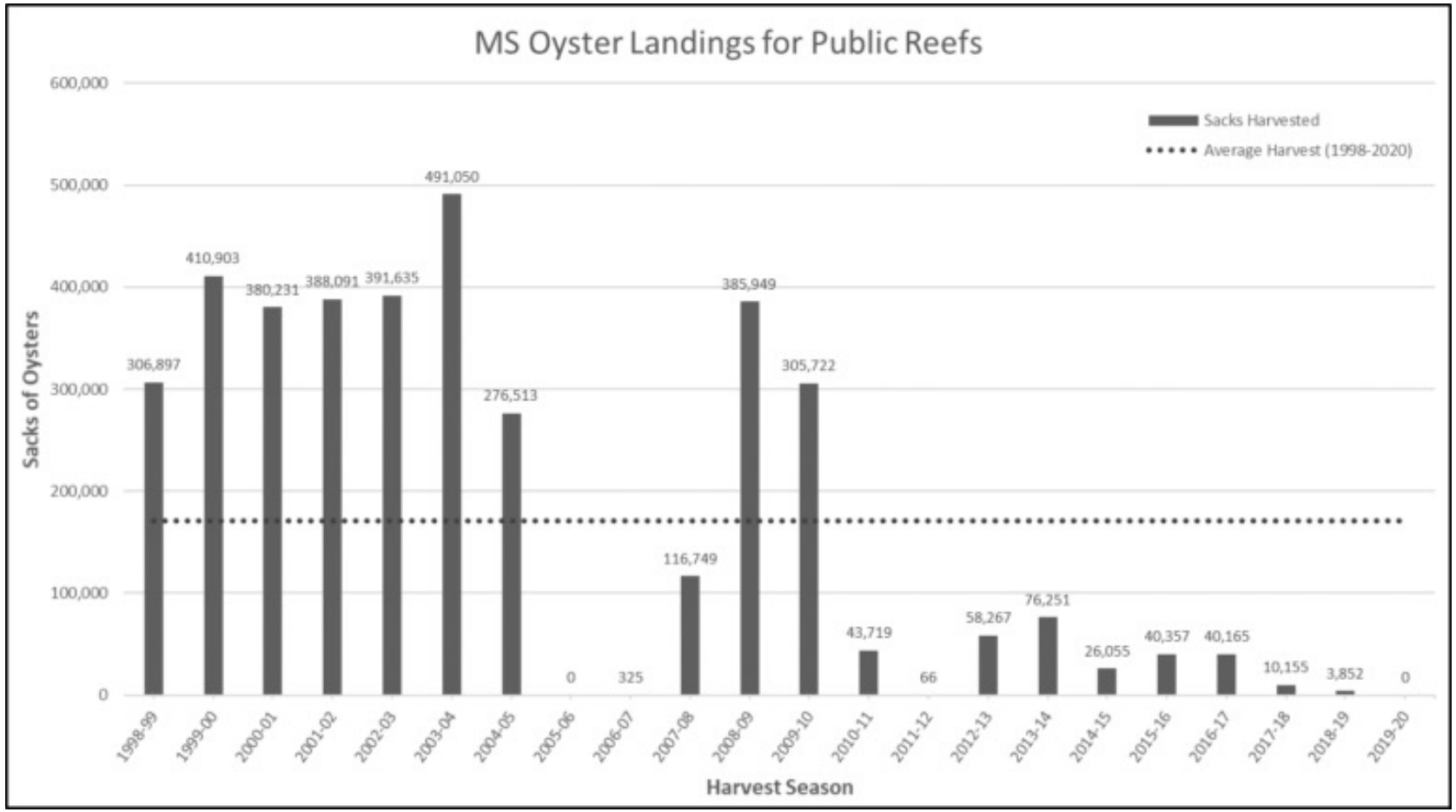
Project Motivation



In the Mississippi Sound, spatiotemporal variability in water quality associated with freshwater inflow can lead to altered salinity regimes, harmful algal blooms, and hypoxia which can imperil marine species, particularly oysters.

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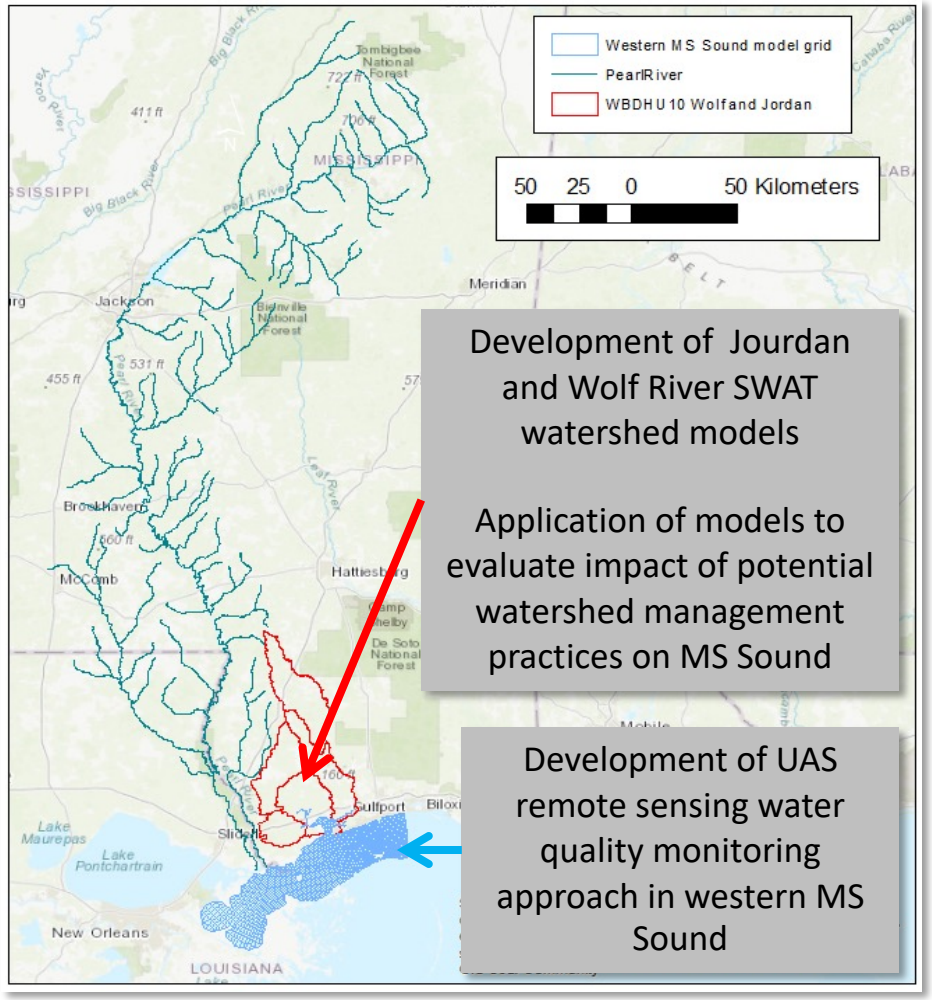
Project Goals and Objectives

Primary Goal: Development of watershed, riverine, and estuarine water quality models as well as remote sensing water quality monitoring approaches for the western Mississippi Sound.

Objectives:

- Develop of Soil and Water Assessment Tool (SWAT) models for Jourdan and Wolf Rivers.
- Evaluation of variation in total suspended solids and phosphorus yield to MS Sounds from Wolf and Jourdan Rivers resulting from implementation of different watershed best management practices.
- Development of unmanned aerial system (UAS) remote sensing algorithms for water quality monitoring in the western Mississippi Sound.



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Methods

Objectives:

- Develop of Soil and Water Assessment Tool (SWAT) models for Jourdan and Wolf Rivers.
- Calibration and validation of SWAT models with *in situ* hydrology and water quality data from Jourdan and Wolf Rivers.
- Evaluation of variation in total suspended solids and phosphorus yield to MS Sounds from Wolf and Jourdan Rivers resulting from implementation of different watershed best management practices

Methods:

- Tools: ArcGIS, SWAT (Arnold, J.G et. al., 1998), SWATCUP-Sufi2 (Abbaspour, 2013)
- Data:
  - USGS: Surface Elevation, Discharge, Water Quality Observed Data (TSS and Min P)
  - NOAA: Climate Data
  - USDA: Land Use Data

Objectives:

- Develop remote sensing algorithms for Unmanned Arial Systems imagery (UAS) so that the results can be used with satellite data to map the water quality and display the spatiotemporal distribution of a suite of water quality parameters..

Methods:

- **Manned Vessel**
  - CTD Profiles
  - Water Samples (3-depths)
  - Radiometer Data
- **Autonomous Surface Vessel**
  - Water Quality Observations
- **Unmanned Aerial Systems**
  - MicaSense RedEdge MX
    - Visible Light and Infrared Camera

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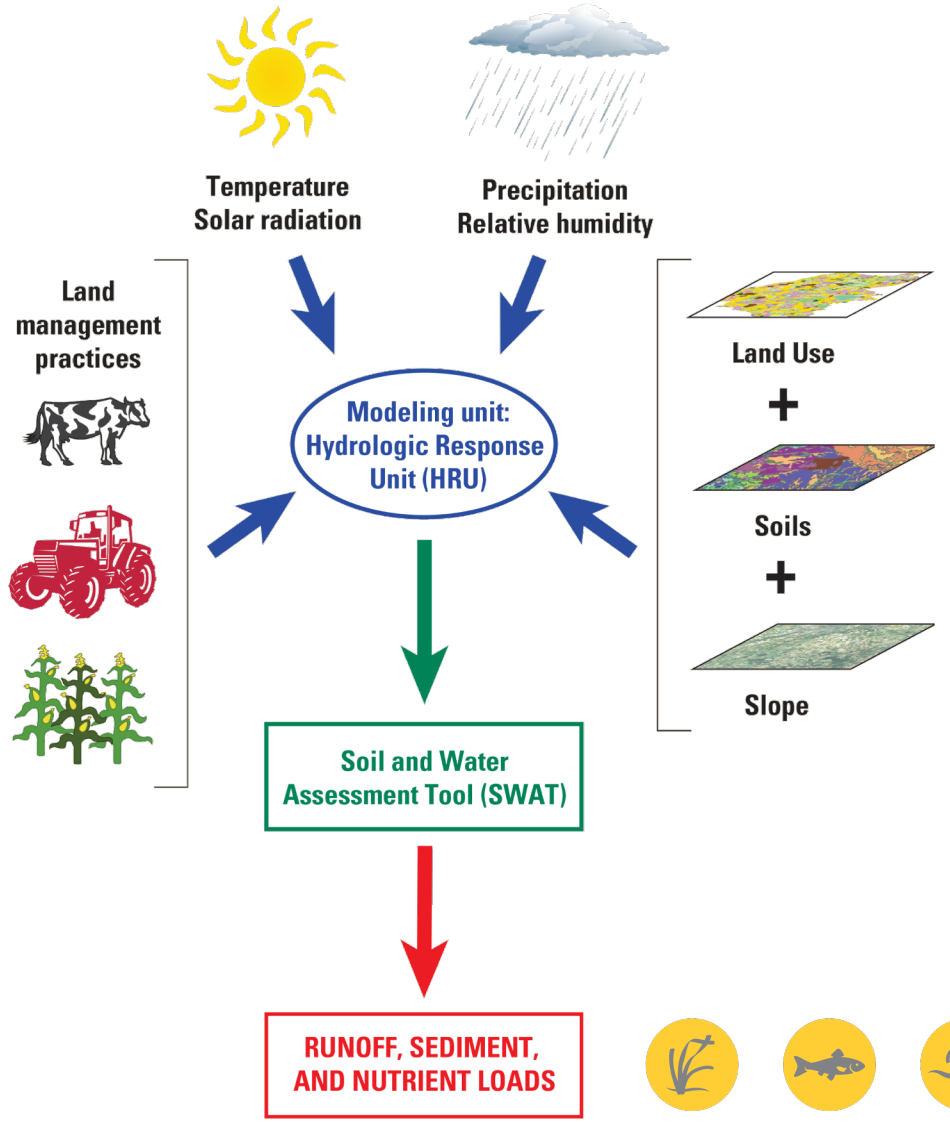
SWAT Model Development

Soil and Water Assessment Tool (SWAT) models were developed for the Wolf and Jourdan Rivers based on a robust set of observed environmental data parameters. (USDA-ARS).

The Soil & Water Assessment Tool is a small watershed to river basin-scale model used to simulate the quality and quantity of surface and ground water and predict the environmental impact of land use, land management practices, and climate change. SWAT is widely used in assessing soil erosion prevention and control, non-point source pollution control and regional management in watersheds.



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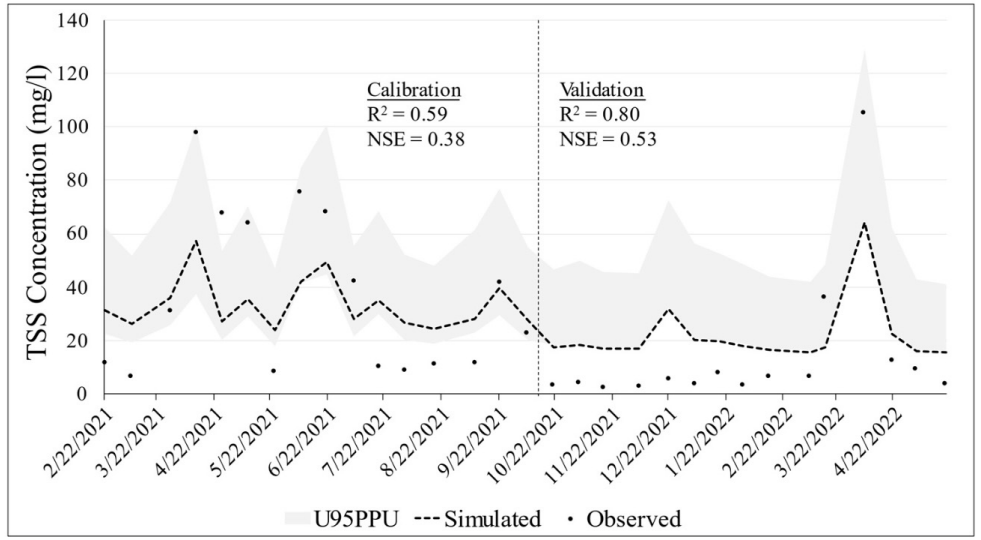
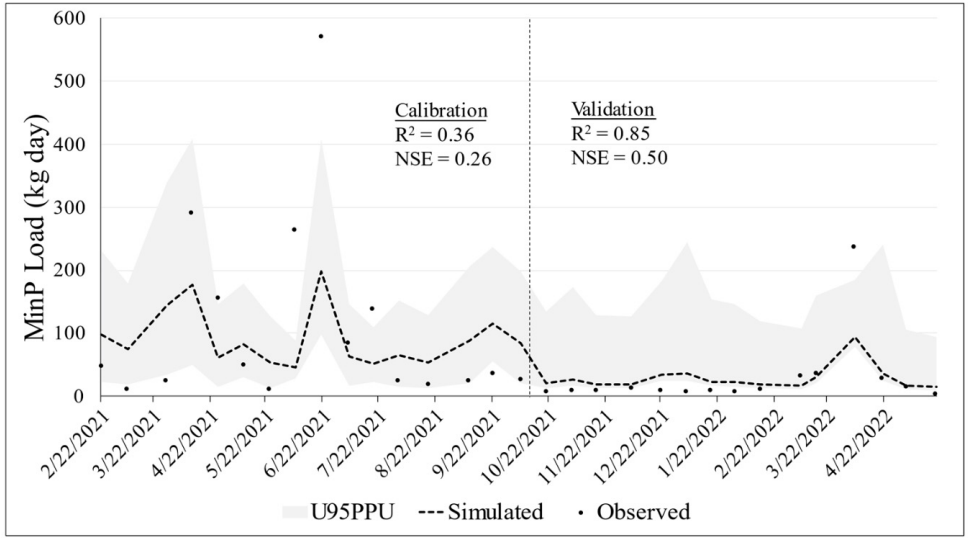
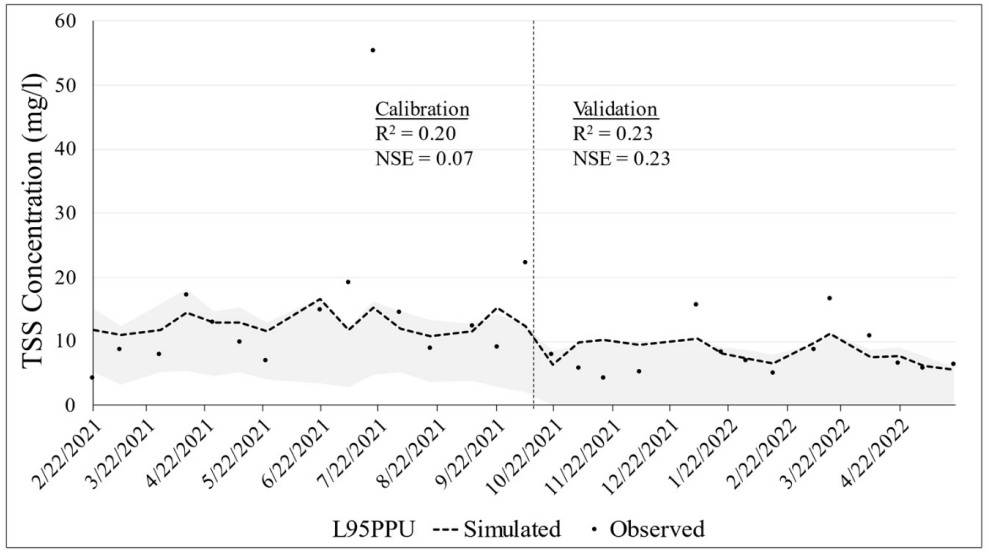
SWAT Model Validation



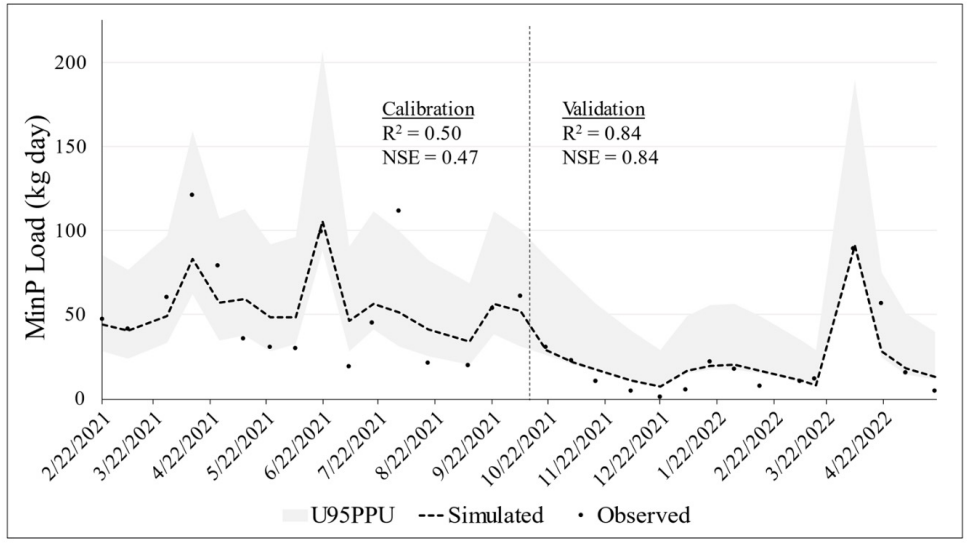
TSS Calibration and Validation of Wolf River Watershed



Phosphorus Calibration and Validation of Wolf River Watershed



TSS Calibration and Validation of Jourdan River Watershed



Phosphorus Calibration and Validation of Jourdan River Watershed

SWAT Model Validation

Parameter	Watershed	R^2	Nash–Sutcliff Efficiency Coeff. (NSE)
River Discharge (m^3/s)	Wolf	0.55	0.54
	Jourdan	0.34	0.34
Total Suspended Solids (TSS) Concentration (mg/l)	Wolf	0.80	0.53
	Jourdan	0.23	0.23
Phosphorus Loading (kg/day)	Wolf	0.85	0.50
	Jourdan	0.84	0.84

SWAT Evaluation of Watershed Management Practices for Mississippi Sound Water Quality

SWAT model used to assess the impact of three watershed scale structural best management practices on water quality entering MS Sound

- **Pond Creation**
- **Wetland Creation**
- **Streamside Management Zone Implementation**

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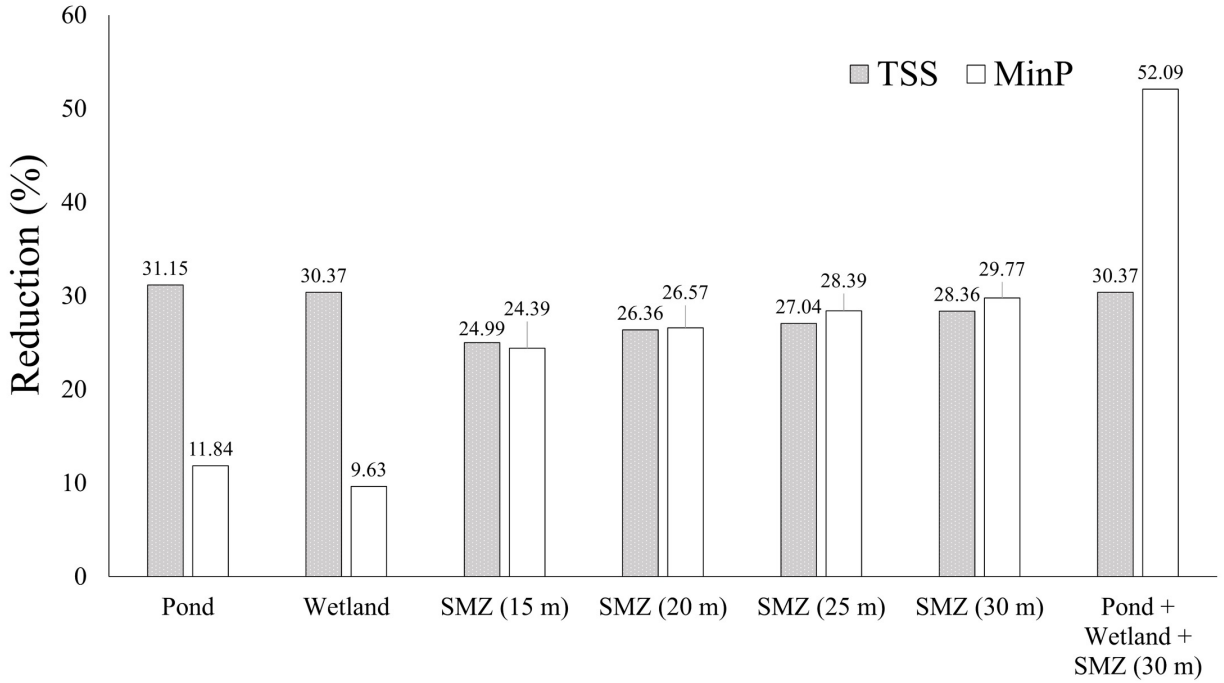
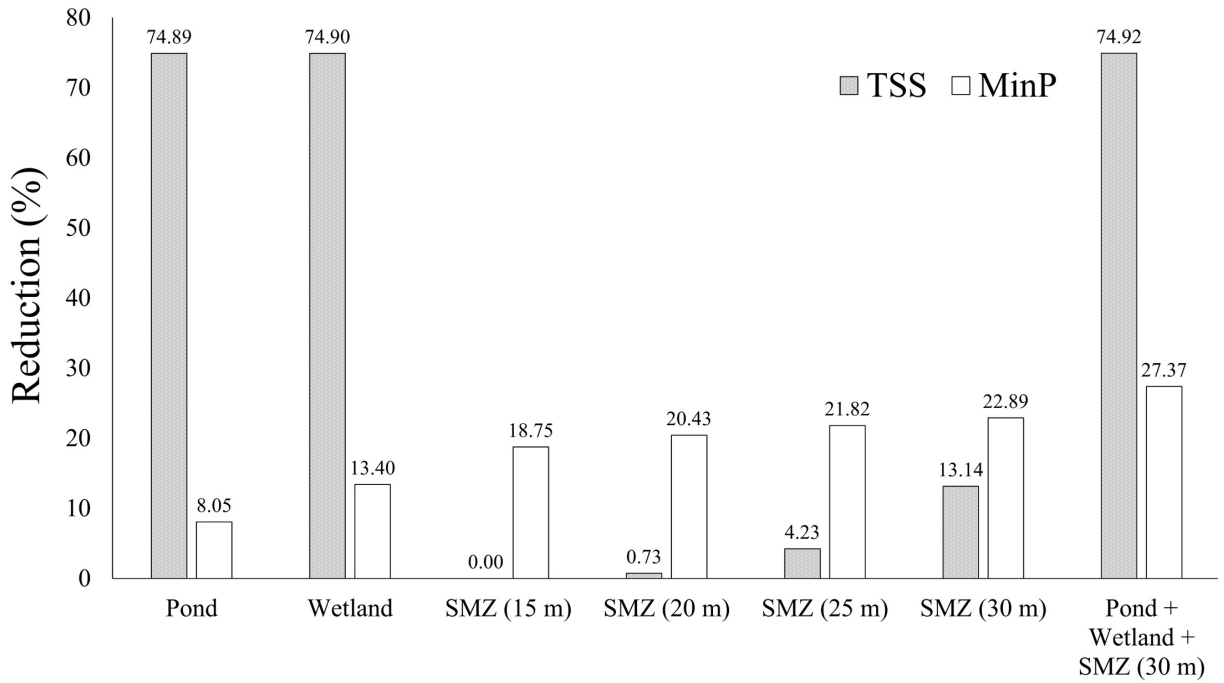
Evaluation of Watershed Management Practices



Effectiveness of Best Management Practices in Wolf River Watershed



Effectiveness of Best Management Practices in Jourdan River Watershed

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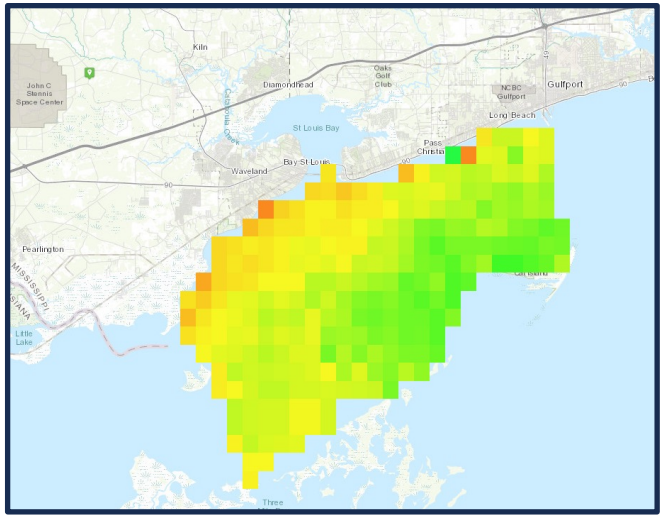
UAS Remote Sensing Water Quality Monitoring

Remote Sensing Algorithms Developed:

- Suspended Particulate Matter (SPM)
- Turbidity
- Chlorophyll a
- Colored Dissolved Organic Matter (CDOM)
- Phycocyanin
- Total Alkalinity (TA)
- Partial Pressure of CO_2(pCO_2)
- Salinity



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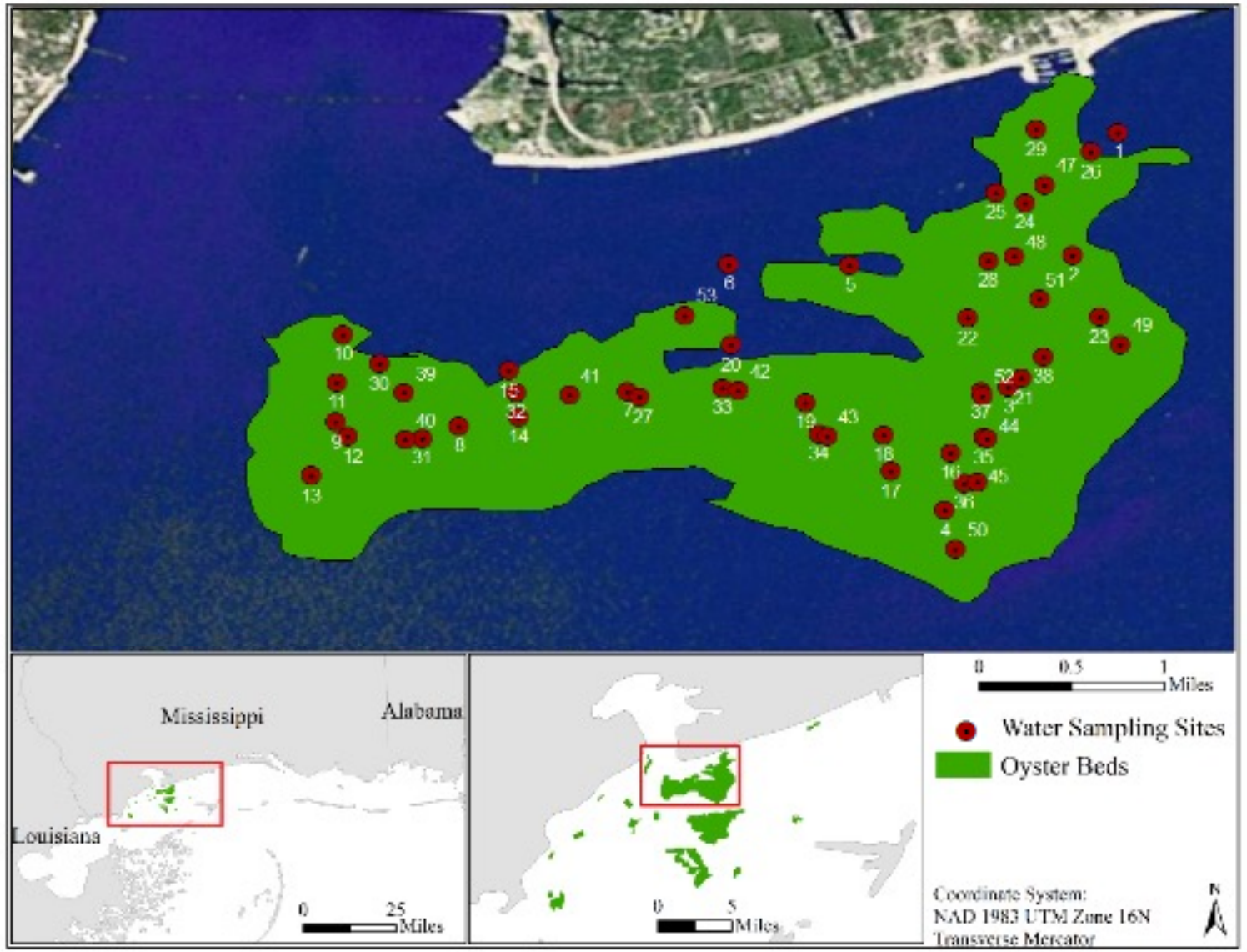
Remote Sensing Data Collection



Field Data Collection

- November 12, 2020 (12 sites)
- March 18, 2021 (1 site)
- June 2, 2021 (12 sites & ASV)
- July 26-29, 2021 (41 sites, ASV, & UAS)
- September 29, 2021 (ASV)
- April 1, 2022 (12 sites)
- September 12-16, 2022 (27 sites ASV & UAS)

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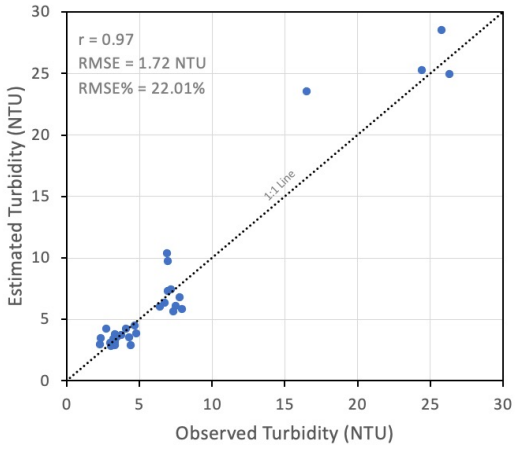
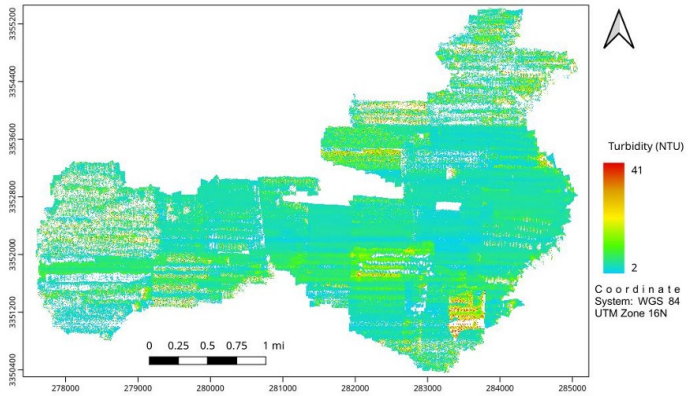
Remote Sensing Algorithm Development

Remote Sensing Algorithm for Turbidity

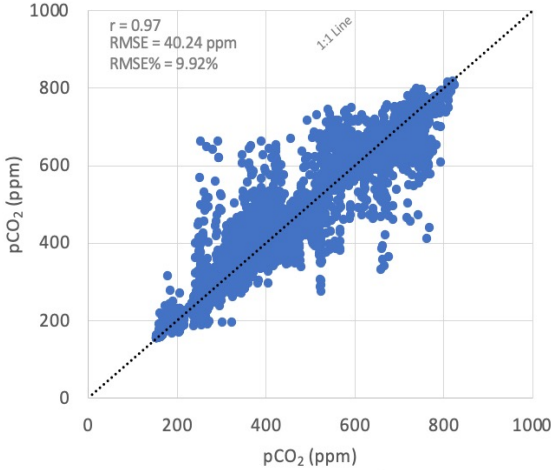


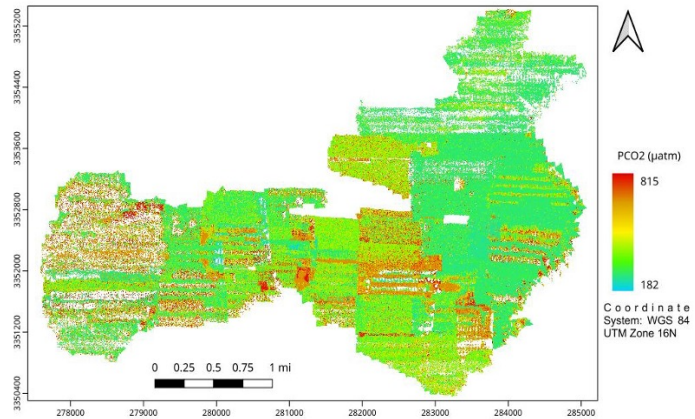


July 26-29, 2021

Algorithm validation using 25% of the dataset (n= 33)

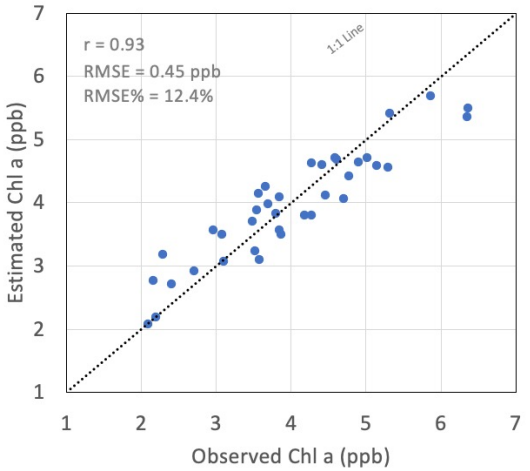
Remote Sensing Algorithm for pCO2

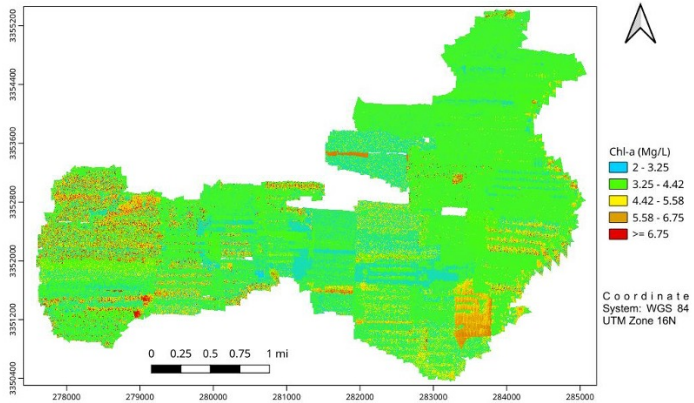




Algorithm validation using ~ 25% of the data collected (n = 9,954)

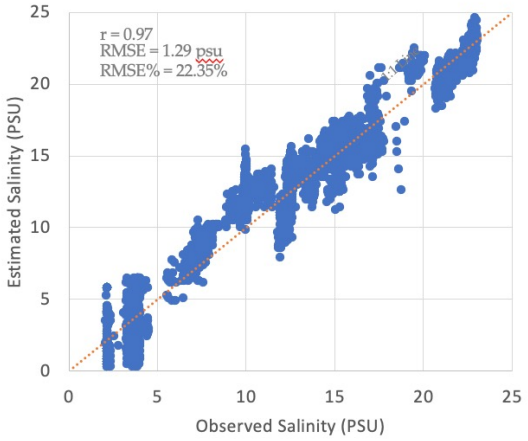
Remote Sensing Algorithm for Chlorophyll a

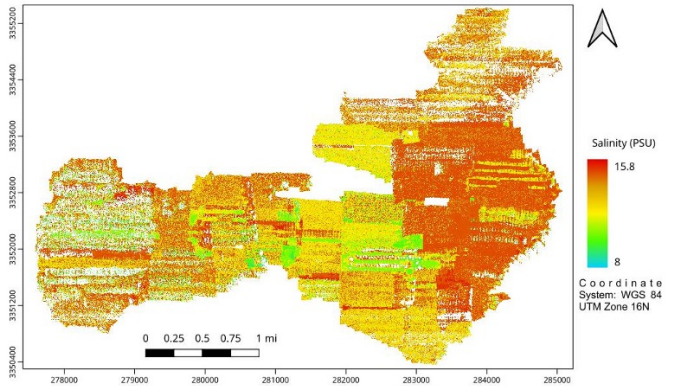




Algorithm validation using 25% of the dataset (n= 37)

Remote Sensing Algorithm for Salinity





Algorithm validation using ~ 25% of the data collected (n = 5,177)

Remote Sensing Algorithm Development

Remote Sensing Algorithm Predictive Capacity:

Water Quality Parameter	R^2	RMSE	RMSPE
Suspended Particulate Matter (SPM)	0.77	11.81 mg/L	25.1%
Turbidity	0.94	1.72 NTU	22.0%
Colored Dissolved Organic Matter (CDOM)	0.59	1.40 ppb	8.3%
Chlorophyll a	0.86	0.45 ppb	12.4%
Total Alkalinity	0.96	345 µmol kg^{-1}	10.0%
Partial Pressure of Carbon Dioxide (pCO2)	0.94	40.24 ppm	9.9%
Salinity	0.94	1.29 PSU	22.4%

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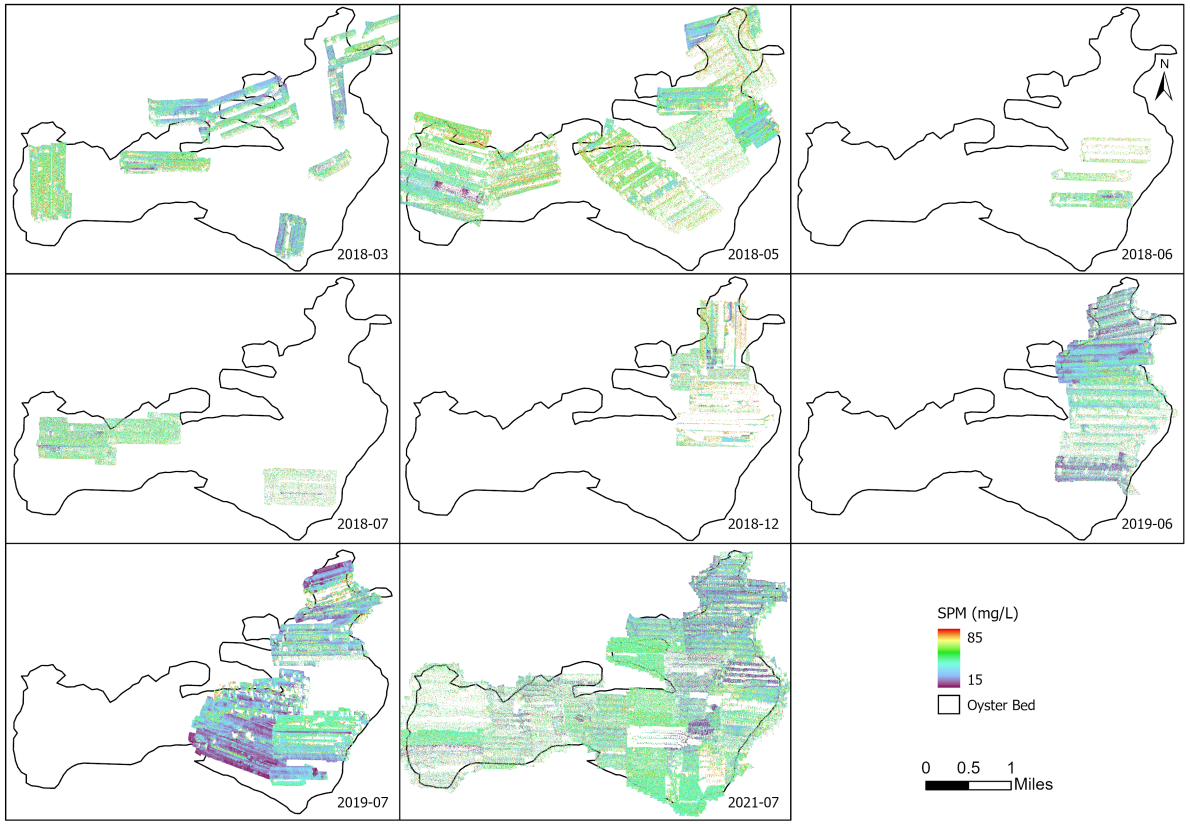
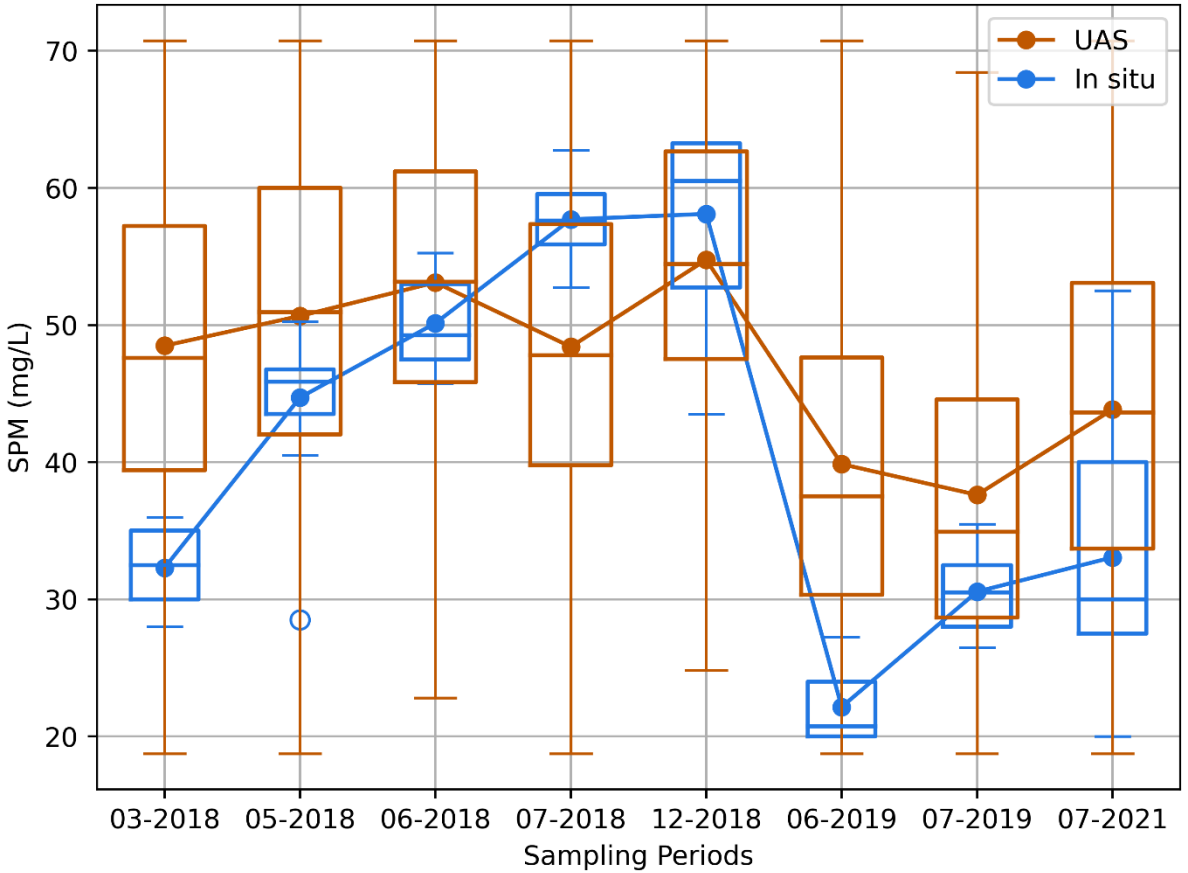
Water Quality Monitoring

Time Series of SPM Over Henderson Point Reef



SPM Trends Over Henderson Point Reef



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SWAT Modeling Key Results

- SWAT watershed models were developed for the Wolf and Jourdan Rivers.
- Resulting models demonstrate the influence of the Wolf and Jourdan Rivers on water quality in the western Mississippi Sound.
- Models evaluate the effectiveness of implementing best management practices in the Wolf and Jourdan River watersheds on reducing total suspended solids and phosphorus loading in waters entering the western Mississippi Sound.
- Greatest effect in reducing TSS and phosphorus loading:
  - Ponds
  - Wetlands
  - Ponds + Wetlands + Streamside Management Zone (30m)

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Water Quality Monitoring Key Results

- Field data was collected through 7 sampling trips from 105 sites
- ASV data was collected through 4 field campaigns from thousands of sites
- UAS data was collected through 2 week-long trips by 68 flights
- Remote sensing algorithms were developed that can quantifying suspended particulate matter, turbidity, CDOM, chlorophyll a, phycocyanin, total alkalinity, pCO2, and salinity in the western Mississippi Sound.
- Remote sensing algorithms yield time series of water quality parameters over oyster reefs.
- All the algorithms look promising with reasonably high R^2 and low RMSE

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How Results Can Inform Restoration/Management

- Results demonstrate which watershed management practices are most effective at reducing total suspended solid and phosphorus in Mississippi Sound waters.

- Scenarios of low flow from the Wolf and Jordan Rivers during summer months will be run to understand the resulting dissolved oxygen, temperature, and salinity in oyster reef areas and how these scenarios may affect oyster populations.

- SWAT watershed modeling creates capacity to better understand and predict the dynamics of freshwater inflow from the Wolf and Jordan Rivers into the Mississippi Sound including alteration of temperature, DO, and salinity regimes as well as water quality parameters including nutrient loading.

- Remote sensing results will indicate the spatiotemporal distribution of a suite of water quality parameters in WMS and causal mechanisms, which may inform management of water quality and oyster fisheries.

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Project Outputs

- **Theses & Dissertations:**
  - Shreeya Bhattarai, Mississippi State University Ph.D. Dissertation. 2023
- **Conference Presentations:**
  - Dash, P., Moorhead, R. J., Herman, J., Sankar, M. S., Moorhead, J., Beshah, W., Chesser, D., Lowe, W., Simmerman, J., and Turnage, G. 2021. Evaluation of Water Quality Data Collected using a Novel Autonomous Surface Vessel, Global Oceans 2021 Conference and Exposition, San Diego, CA, September 20-23, 2021.
  - Bhattarai Shreeya, and Prem B. Parajuli. 2022. Assessment of BMP practices on water quality of coastal watersheds in Mississippi. ASABE Annual International Virtual Meeting, July 17 to 20, 2022; Marriott Marquis Houston, Texas.
  - Bhattarai Shreeya, Prem B. Parajuli, and Filip To. 2022. Evaluation of terrestrial flow into coastal water by anticipating the sediment yield and nutrient loss. 2022 Mississippi Water Resources Conference, April 12-14, The Mills in Starkville, MS.
- **Peer-Reviewed Publications:**
  - Dash, P., Moorhead, R. J., Herman, J., Sankar, M. S., Moorhead, J., Beshah, W., Chesser, D., Lowe, W., Simmerman, J., and Turnage, G. 2021. Evaluation of Water Quality Data Collected using a Novel Autonomous Surface Vessel, Proceedings of Global Oceans 2021 Conference and Exposition, San Diego, CA, September 20-23, 2021.
  - Sankar, M.S., Dash, P., Lu, Y. et al. 2023. Seasonal changes of trace elements, nutrients, dissolved organic matter, and coastal acidification over the largest oyster reef in the Western Mississippi Sound, USA. Environ. Monit. Assess., 195, 175
  - Shreeya Bhattarai, Prem B. Parajuli, and S. D. Filip To. 2023. Comparison of flood frequency at different climatic scenarios in coastal forested watersheds. Climate.
  - Shreeya Bhattarai and Prem B. Parajuli. 2023. Water quality assessment with best management practices in coastal watersheds. Sustainability.

Acknowledgements

Mississippi Based RESTORE Act Center of Excellence
Mississippi State University Department of Geosciences
Northern Gulf Institute
Field Assistance: Jonathan Harris, Gray Turnage
Data Processing: Lee Hathcock
UAS Crew: David Young, Sean Meacham, Logan Renz, Cary Daniel McCraine, and Jessica Wolfe
ASV Crew: Jessica Wolfe & Daniel Chesser

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MISSISSIPPI STATE UNIVERSITY

NGI NORTHERN GULF INSTITUTE

MBRACE

Impacts of water quality on oyster development to inform oyster reef restoration and sustainability on the Mississippi Gulf Coast

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Mississippi Based RESTORE Act Center of Excellence

THE UNIVERSITY OF MISSISSIPPI
Environmental Toxicology

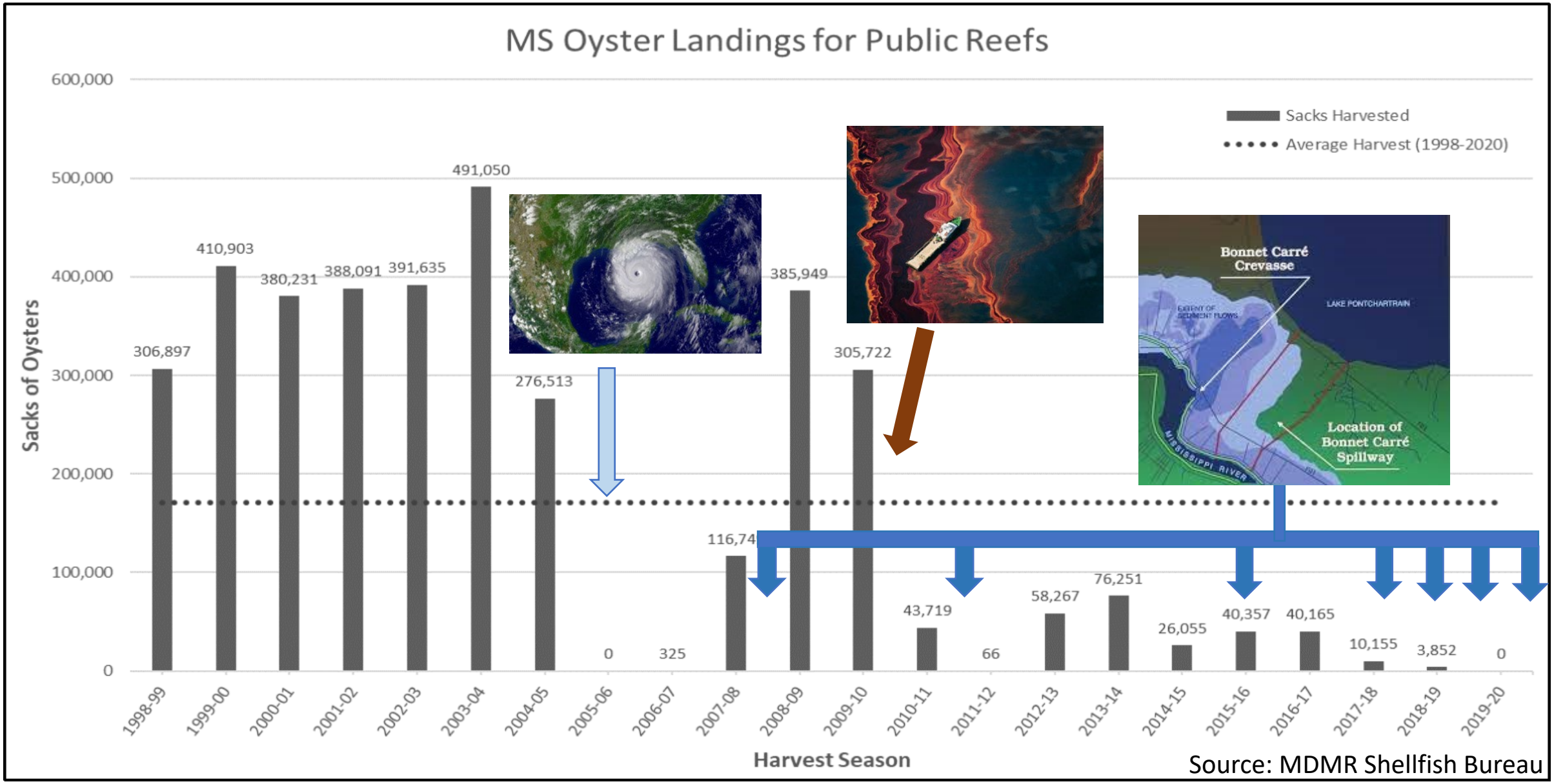
Sea Grant Law Center

What has Happened to Mississippi's Oysters?


Source: MS Dept. of Archives & History

Source: MSU Extension Center

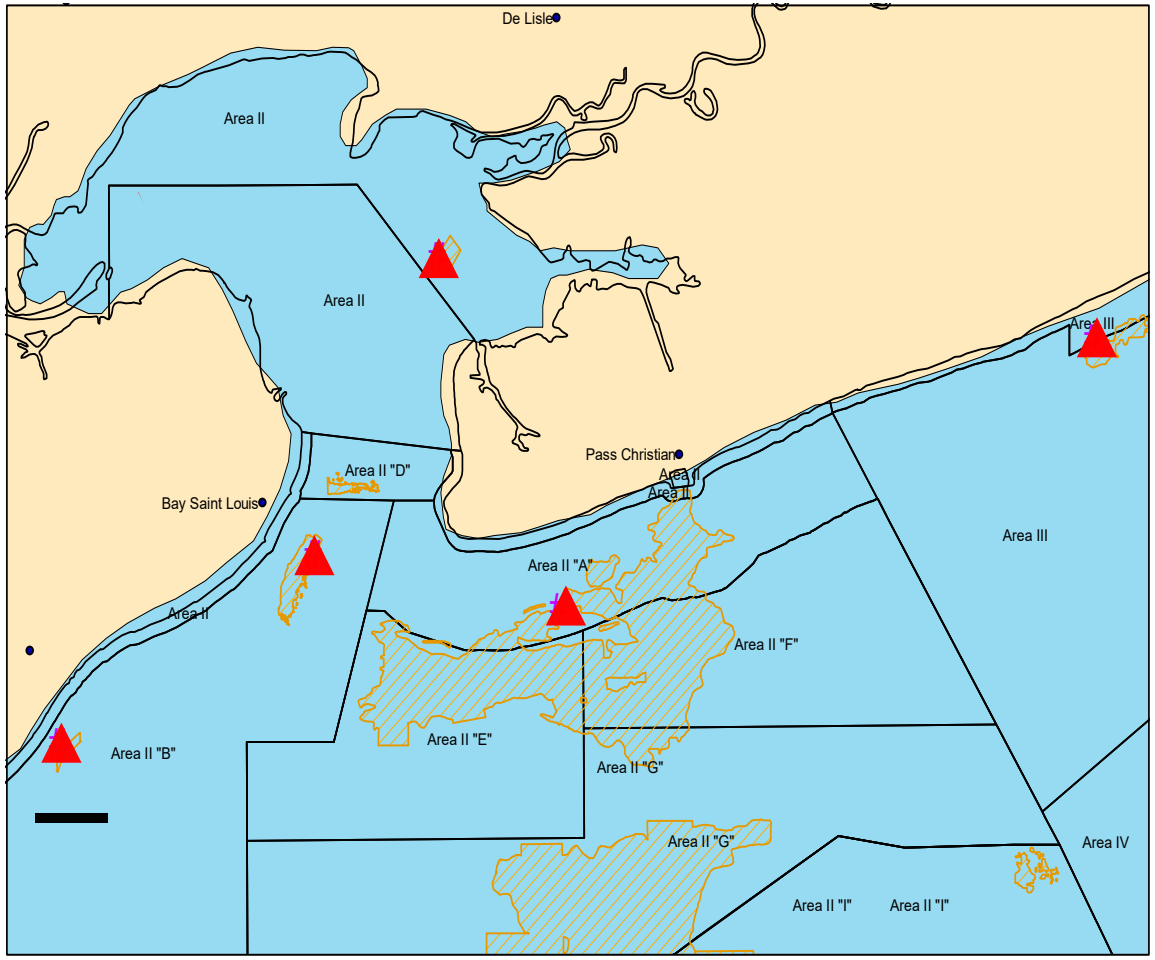
21st Century Declines in MS Oyster Populations



Source: MDMR Shellfish Bureau

No live oysters at any sites 2 months after BCS closure

2019 Environmental Toxicology Study Sites



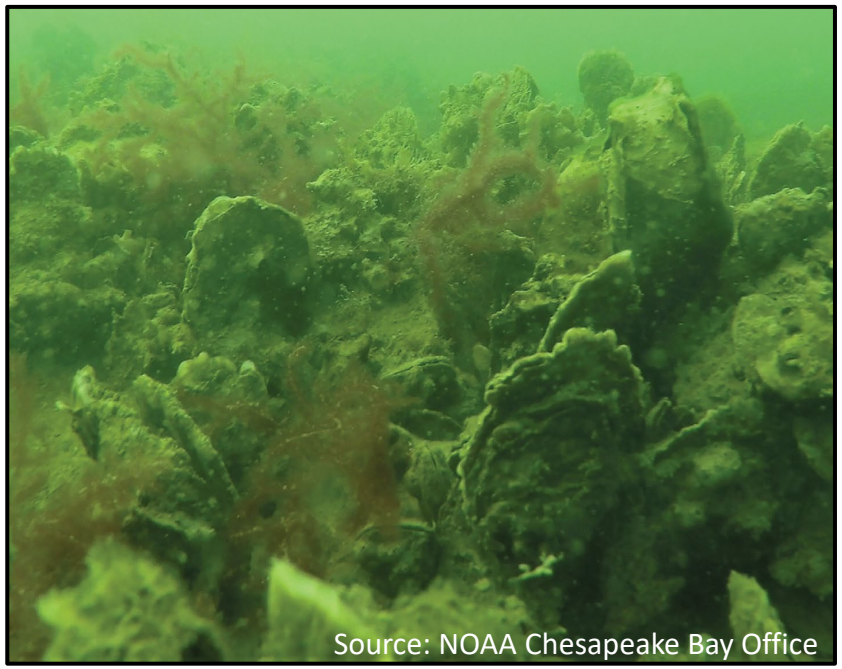
Journal of Shellfish Research, Vol. 39, No. 2, 235–244, 2020.

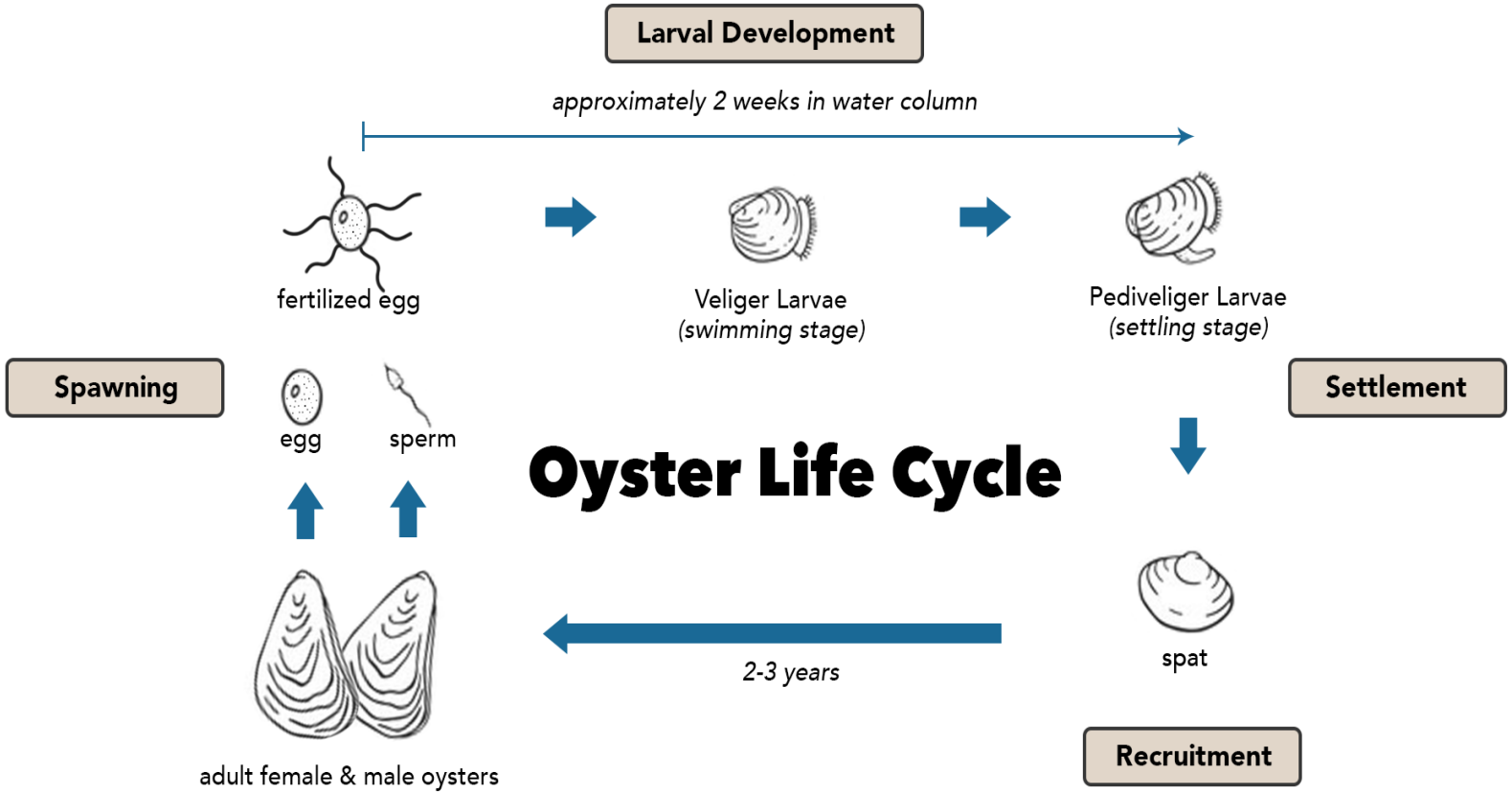
MASS MORTALITY OF THE EASTERN OYSTER *CRASSOSTREA VIRGINICA* IN THE WESTERN MISSISSIPPI SOUND FOLLOWING UNPRECEDENTED MISSISSIPPI RIVER FLOODING IN 2019

JAMES H. GLEDHILL,[1†] ANN FAIRLY BARNETT,[1†] MARC SLATTERY,[1] KRISTINE L. WILLETT,[1] GREGORY L. EASSON,[2] STEPHANIE SHOWALTER OTTS[3] AND DEBORAH J. GOCHFELD[1,4*]

Oyster reef restoration success depends on early life stages


Source: NOAA Gulf Spill Restoration


Source: NOAA Chesapeake Bay Office



= water quality stressor

Heavy rainfall

Increases stormwater runoff

Increases freshwater into estuaries

Increases nutrients

Algal Blooms

Die and decay

Increases CO_2/ Reduces pH

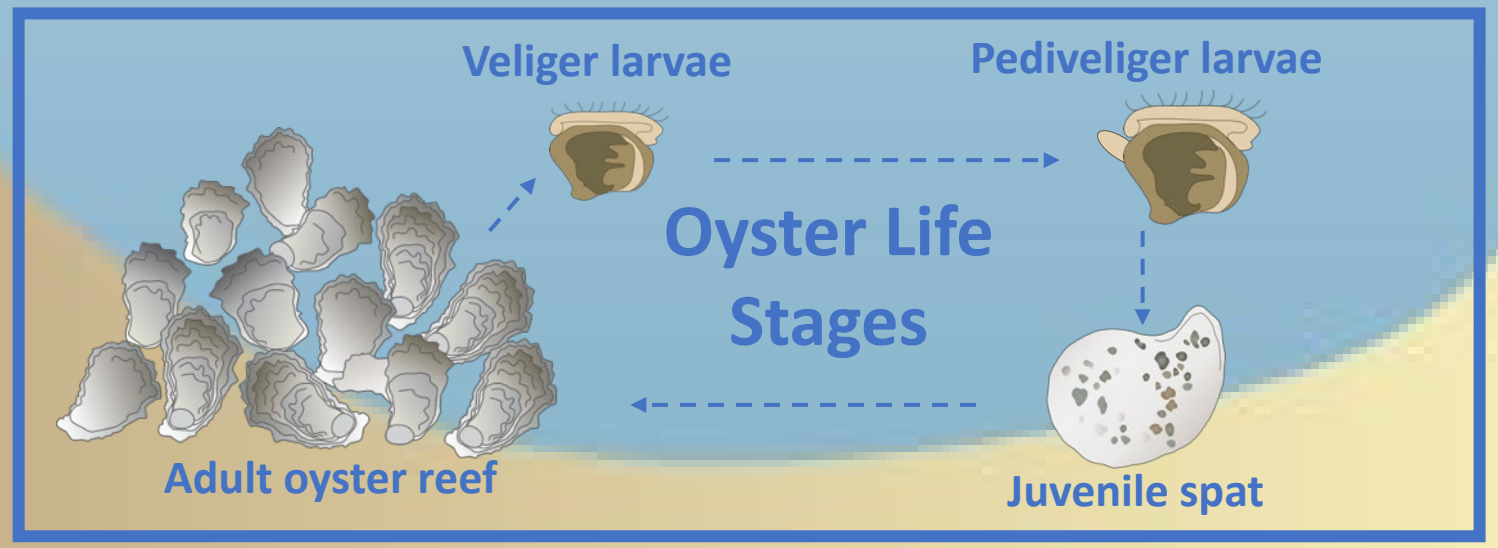
Decreases oxygen

Low Salinity

Coastal Acidification

Hypoxia

How do early oyster life stages respond to flood-associated stressors?



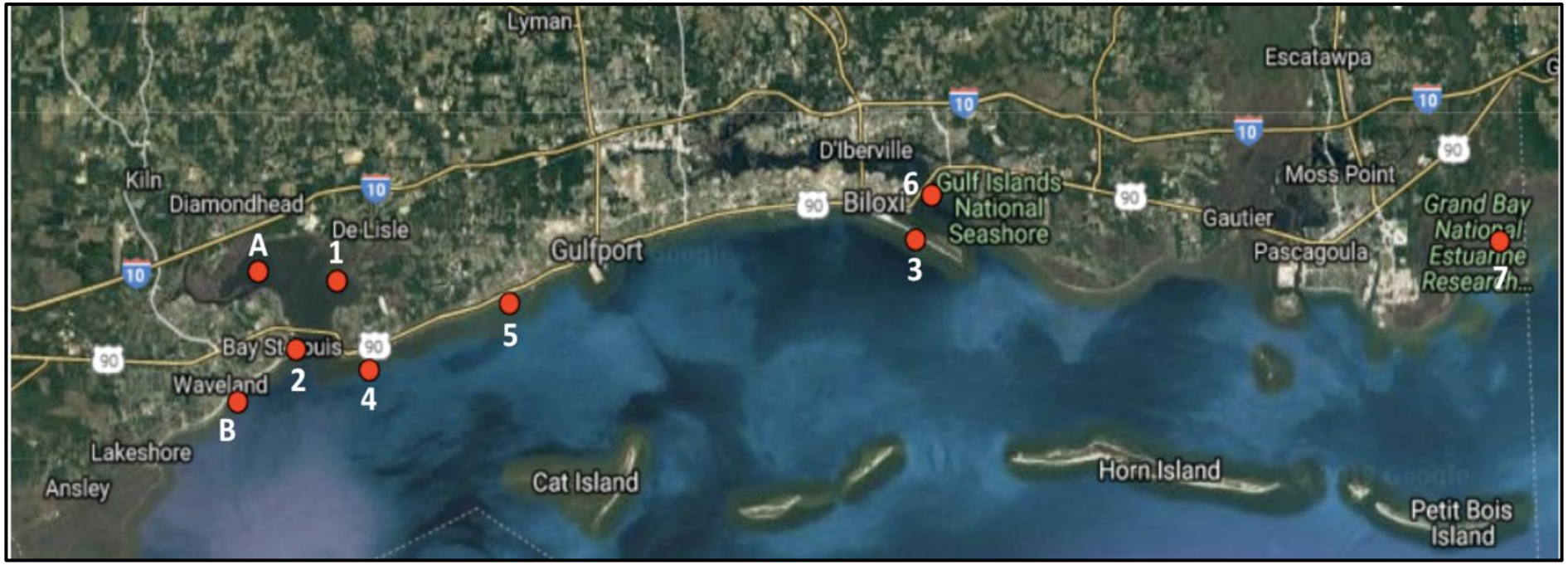
Images from the Integration and Application Network (ian.umces.edu/media-library)

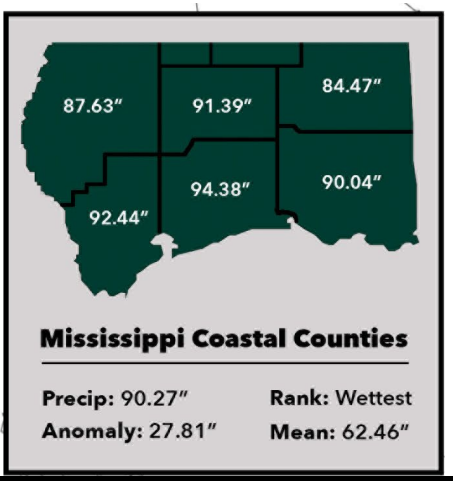
Project Goals and Objectives

Goal: Integrate field, laboratory and policy research on impacts of abiotic and biotic stressors on early life stages of oysters to inform sustainable oyster reef restoration efforts in MS coastal waters

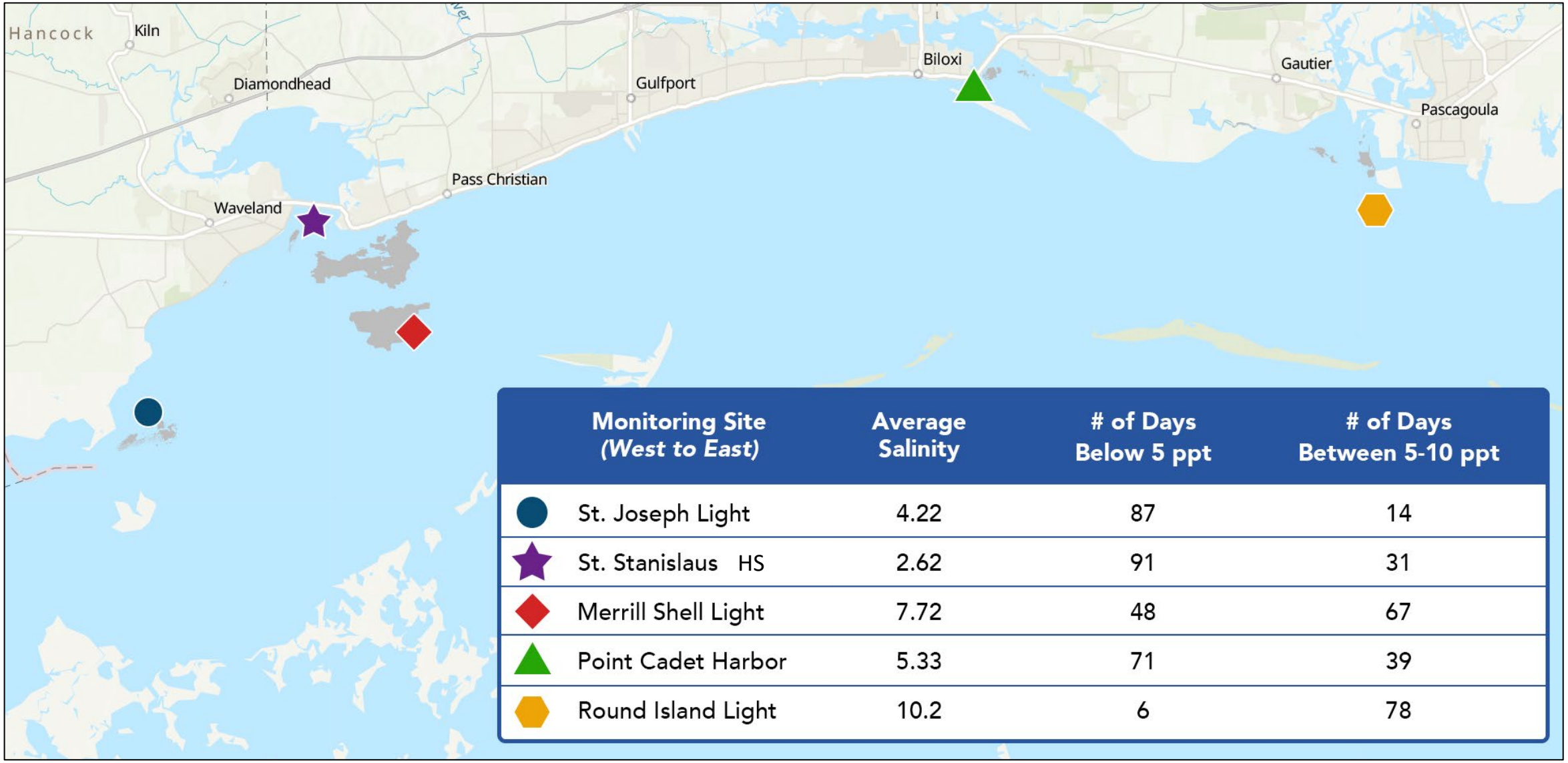
Objective 1:

- **Collect data on levels of water quality stressors across the MS Sound**





Salinity conditions near priority sites for oyster restoration in Mississippi (May-September 2021)



Monitoring Site (West to East)	Average Salinity	# of Days Below 5 ppt	# of Days Between 5-10 ppt
St. Joseph Light	4.22	87	14
St. Stanislaus HS	2.62	91	31
Merrill Shell Light	7.72	48	67
Point Cadet Harbor	5.33	71	39
Round Island Light	10.2	6	78

Project Objectives

Objectives 2 & 3:

- **Characterize effects of single and multiple stressors on early life stages of oysters in the lab**
- **Assess growth and survival of juvenile oysters deployed in the MS Sound**

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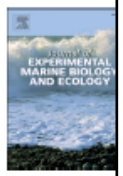

Effects of flood-associated stressors on growth and survival of early life stage oysters (*Crassostrea virginica*)

Jessica L. Pruett [a], Ann Fairly Pandelides [b], Kristine L. Willett [b], Deborah J. Gochfeld [a,b,*]

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ARTICLE

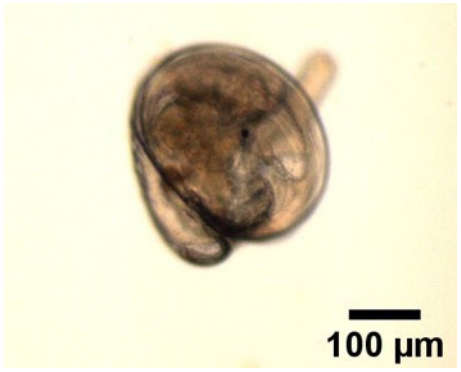
Coastal and Marine Ecology

Life-stage-dependent effects of multiple flood-associated stressors on a coastal foundational species

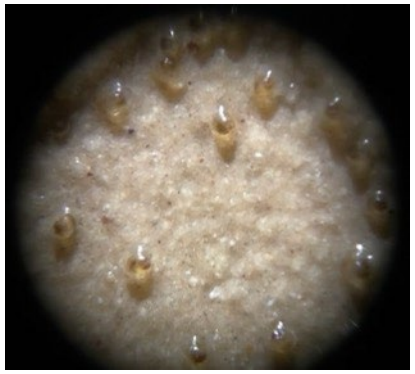
Jessica L. Pruett [1] | Ann Fairly Pandelides [2] | Jaycie Keylon [2] |
Kristine L. Willett [2] | Stephanie Showalter Otts [3] | Deborah J. Gochfeld [1,2]

How do early oyster life stages respond to flood-associated stressors?

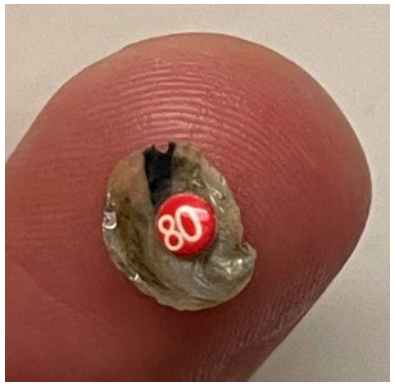
Veliger larvae
(48 hours old)



Pediveliger larvae
(14+ days old)



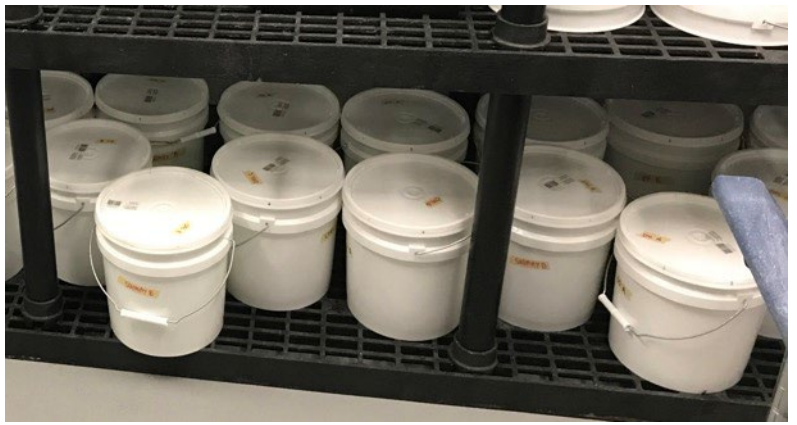
Post-settlement juvenile
(1-day post-set)



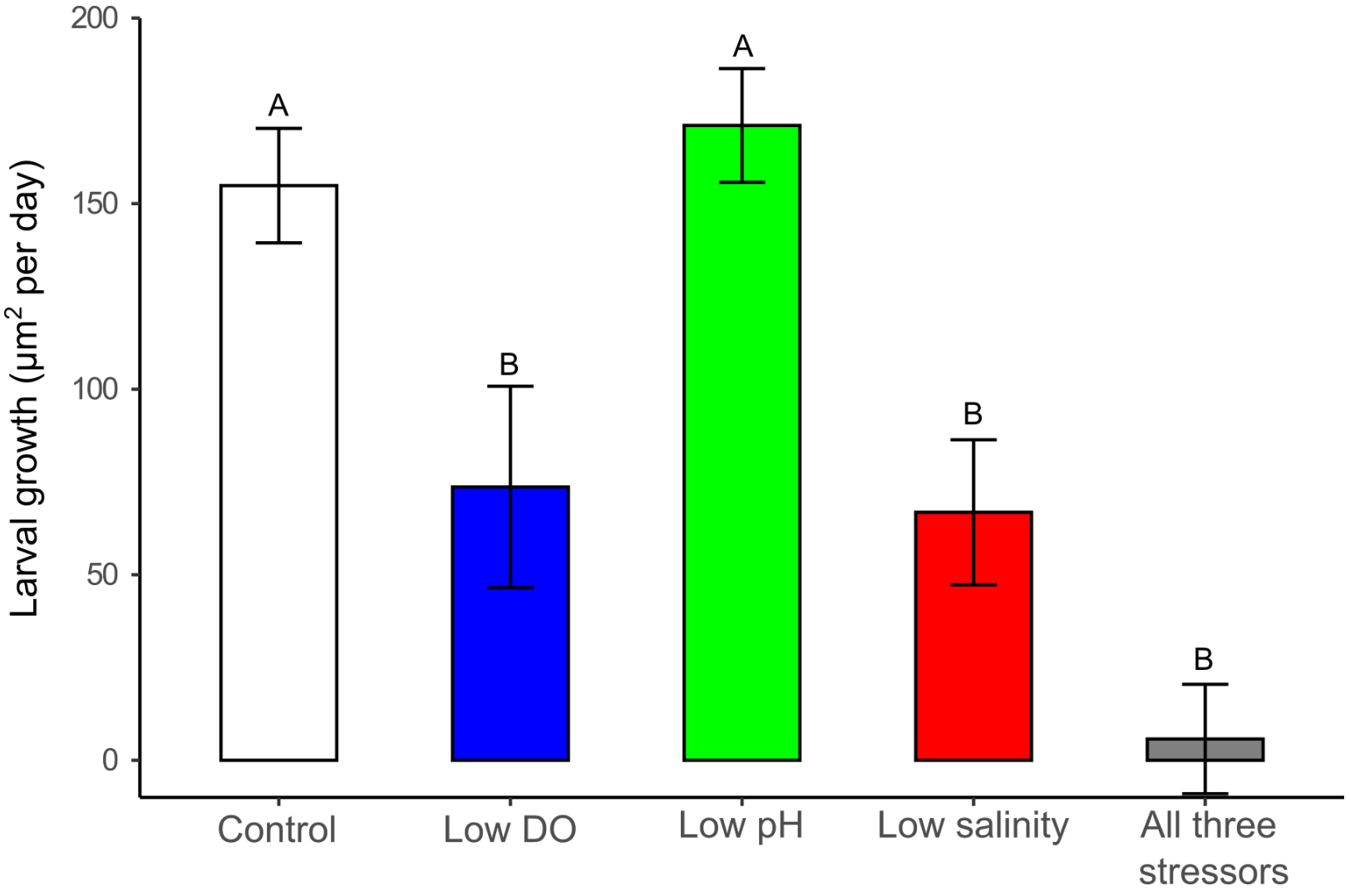
Early juvenile
(~4 weeks old)

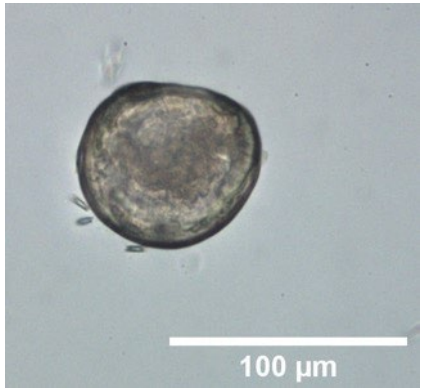
Stressor Treatments

- Low dissolved oxygen (< 2 mg/L O_2)
- Low pH (7.3-7.6)
- Low salinity (15 ppt → 6 ppt)
- Two-way combinations of stressors
- All three stressors



Reduced veliger growth in hypoxic and low salinity conditions



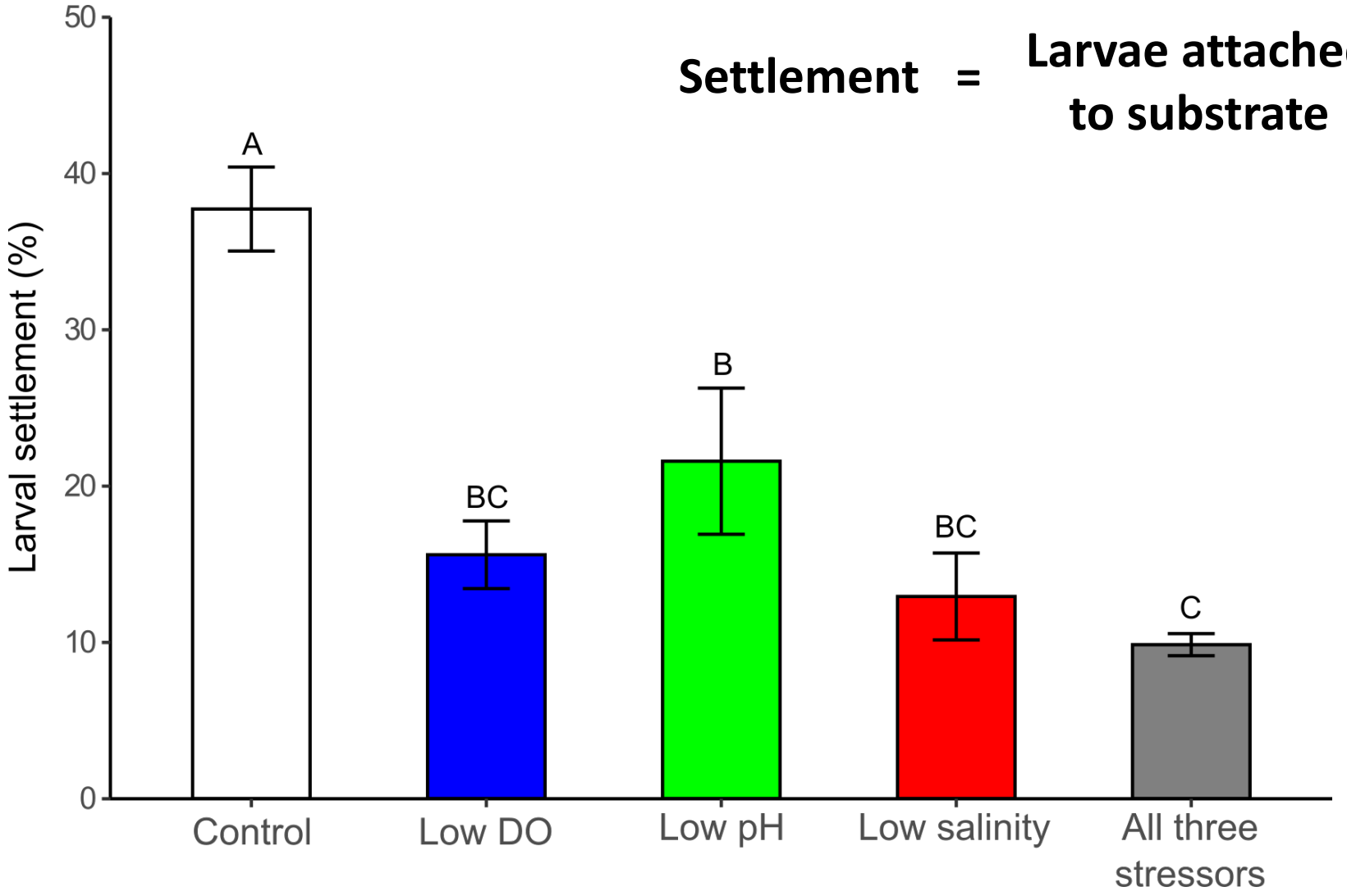


Control treatment

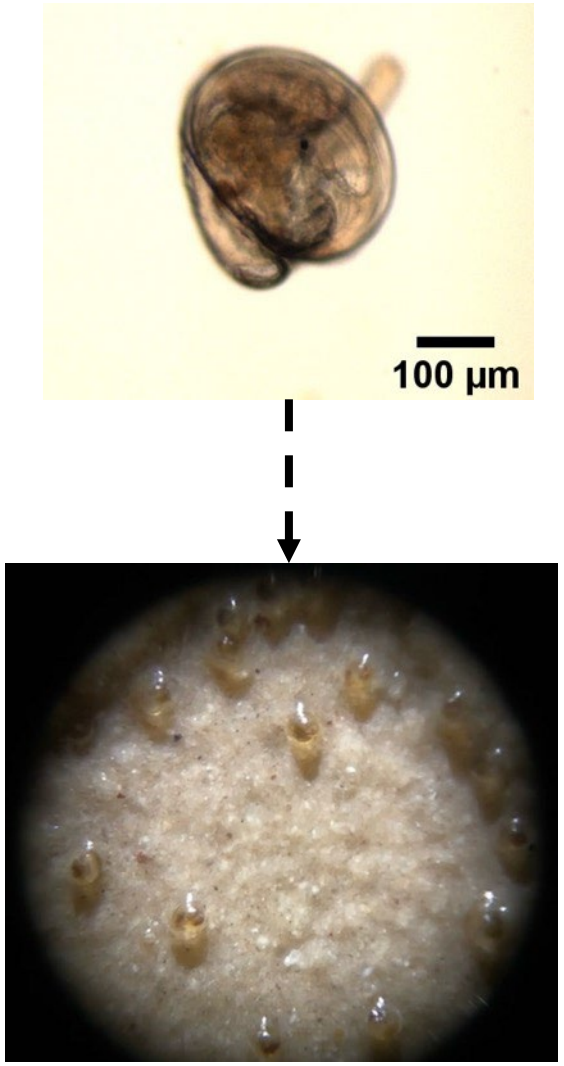
All stressors treatment

*Different letters denote means that are significantly different ($P < 0.05$)

Reduced settlement in flood-associated stressors

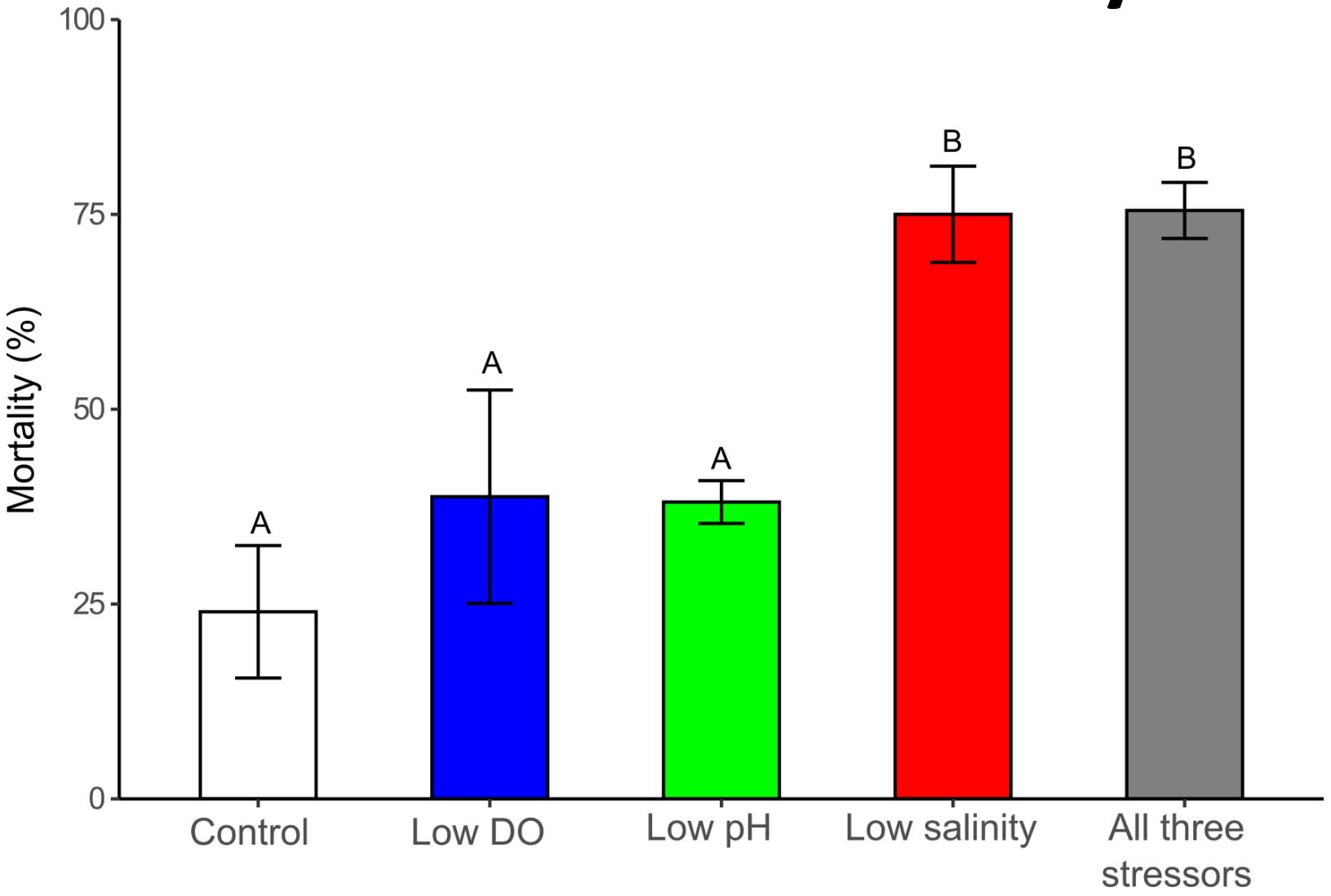


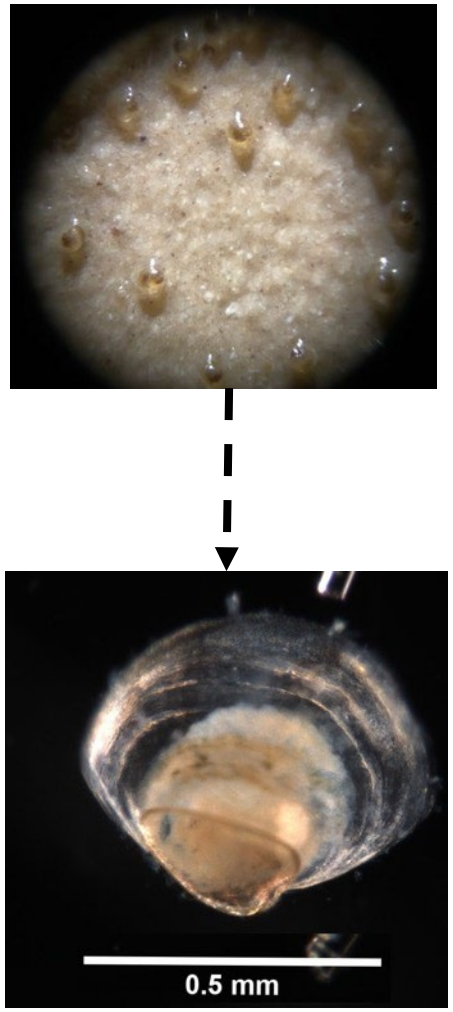
Settlement = Larvae attached to substrate



*Different letters denote means that are significantly different ($P < 0.05$)

Increased post-settlement mortality in lower salinity

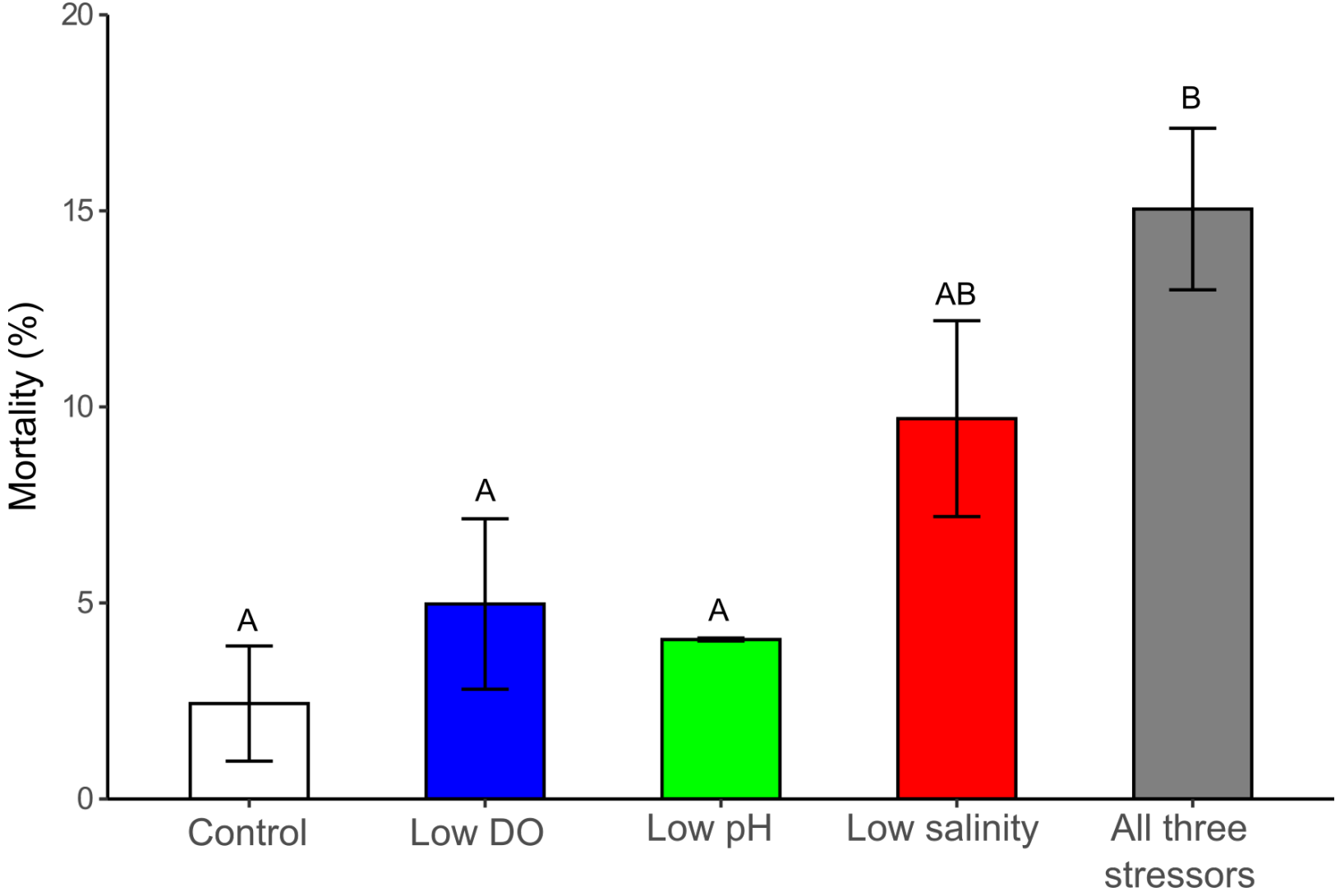




7-day old spat

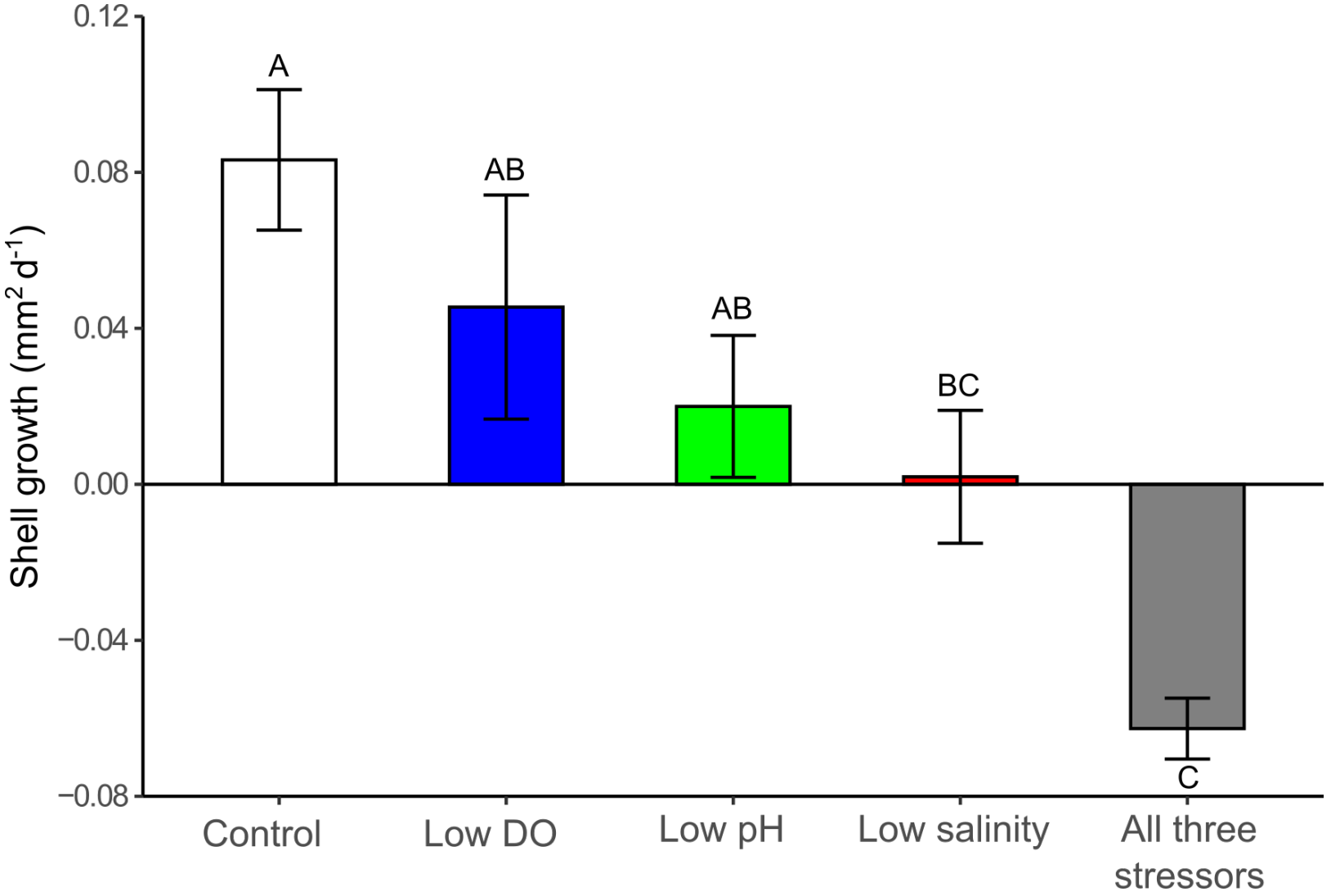
*Different letters denote means that are significantly different ($P < 0.05$)

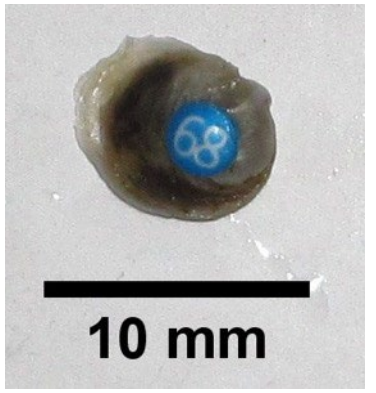
Increased juvenile mortality only in the presence of all three water quality stressors



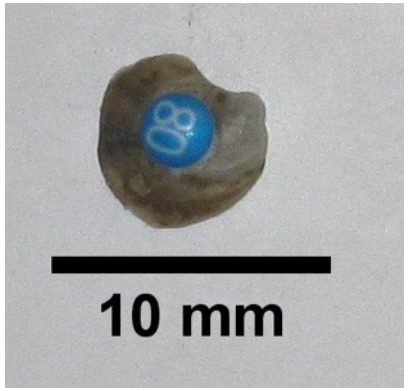
*Different letters denote means that are significantly different ($P < 0.05$)

Negative growth in the presence of all three stressors





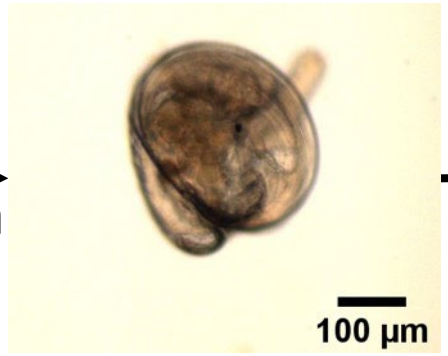
Control End



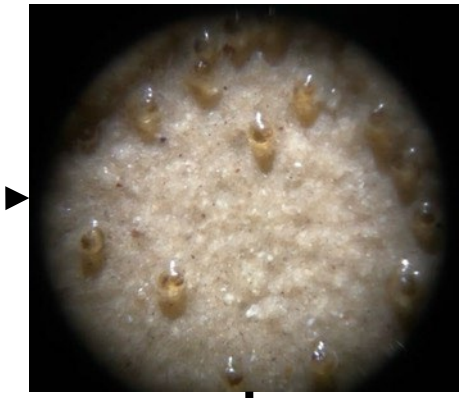
All Stressors End

*Different letters denote means that are significantly different ($P < 0.05$)

Longer time in water column



Reduced recruitment



Decreased survival

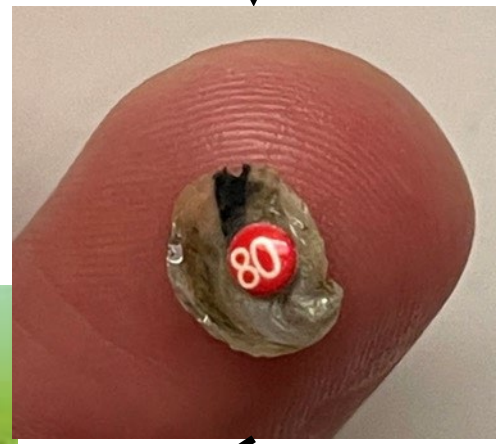
Reduced growth

Reduced settlement

Reduced recruitment

Flood-associated stressors

Adult spawning?



Reduced growth

Delayed sexual maturity/
Reduced resilience

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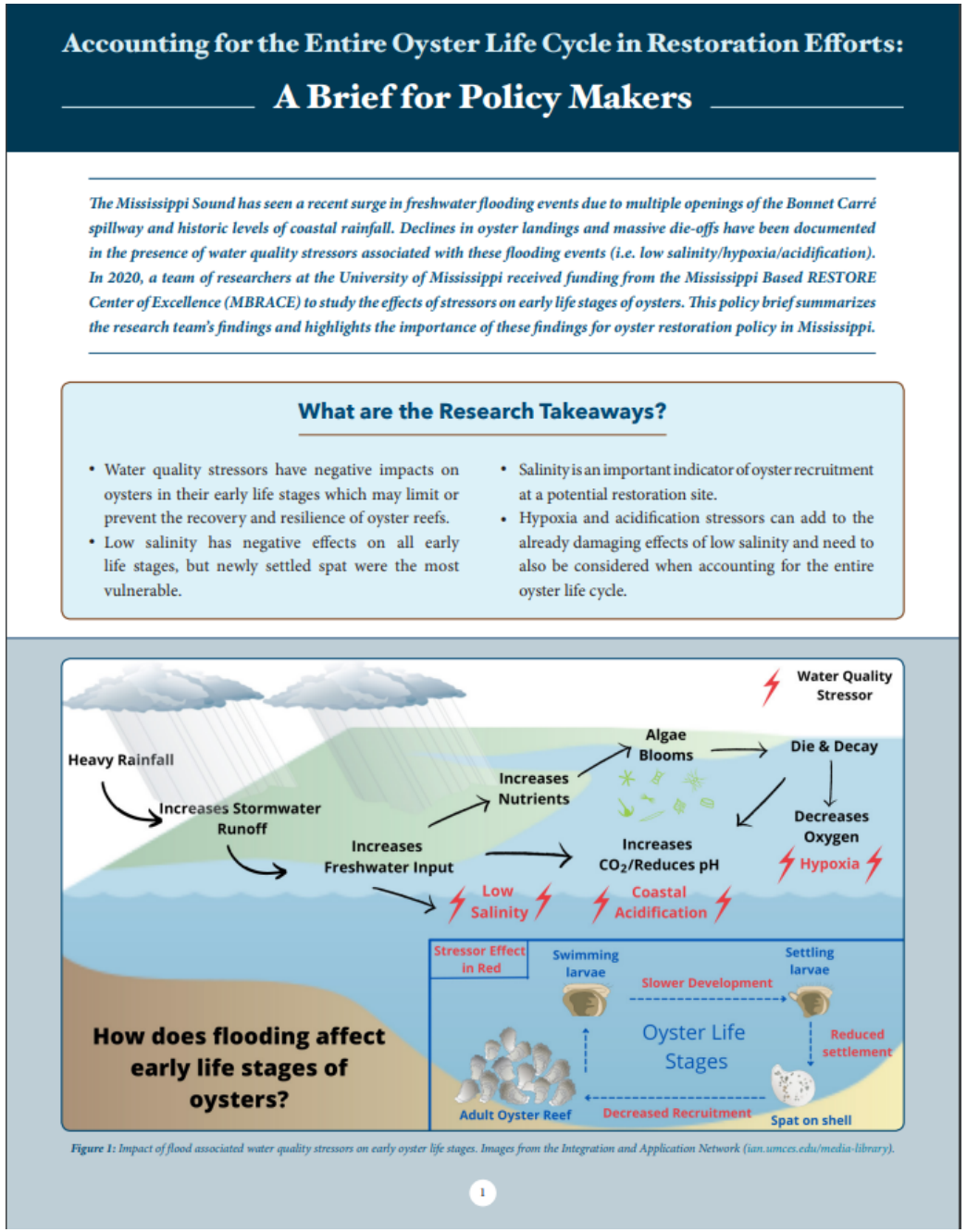


Accounting for the Entire Oyster Life Cycle in Restoration Efforts:

A Brief for Policy Makers

The Mississippi Sound has seen a recent surge in freshwater flooding events due to multiple openings of the Bonnet Carré spillway and historic levels of coastal rainfall. Declines in oyster landings and massive die-offs have been documented in the presence of water quality stressors associated with these flooding events (i.e. low salinity/hypoxia/acidification). In 2020, a team of researchers at the University of Mississippi received funding from the Mississippi Based RESTORE Center of Excellence (MBRACE) to study the effects of stressors on early life stages of oysters. This policy brief summarizes the research team's findings and highlights the importance of these findings for oyster restoration policy in Mississippi.

What are the Research Takeaways?

- Water quality stressors have negative impacts on oysters in their early life stages which may limit or prevent the recovery and resilience of oyster reefs.
- Low salinity has negative effects on all early life stages, but newly settled spat were the most vulnerable.
- Salinity is an important indicator of oyster recruitment at a potential restoration site.
- Hypoxia and acidification stressors can add to the already damaging effects of low salinity and need to also be considered when accounting for the entire oyster life cycle.

Figure 1: Impact of flood associated water quality stressors on early oyster life stages. Images from the Integration and Application Network (ian.umces.edu/media-library).

1

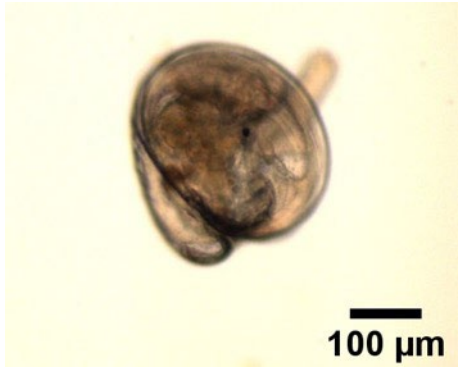
Objective 4.
Policy Brief

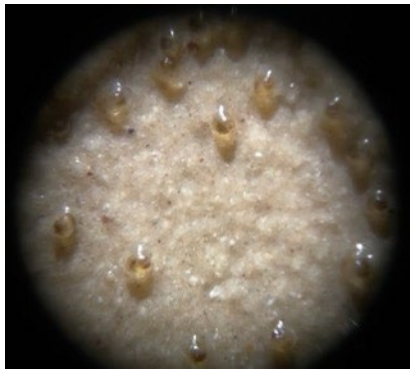
- Flood-associated stressors have negative impacts on early oyster life stages
- Salinity is an important indicator of oyster recruitment at a potential restoration site
- Hypoxia and acidification stressors can add to already damaging effects of low salinity

Project website: http://nsglc.olemiss.edu/projects/oysterreefrestoration/index.html

Next Steps

- Incorporation of early life stage tolerance thresholds into decision-making tools
- Enhancement of restoration aquaculture practices
- Leveraging existing environmental datasets to better understand the issues and challenges that affect oyster reef resilience
- Establishment of continuous monitoring stations at priority oyster reef locations throughout the Gulf of Mexico





= water quality stressor

Heavy rainfall

Increases stormwater runoff

Increases freshwater into estuaries

Increases nutrients

Algal Blooms

Die and decay

Increases CO_2/ Reduces pH

Decreases oxygen

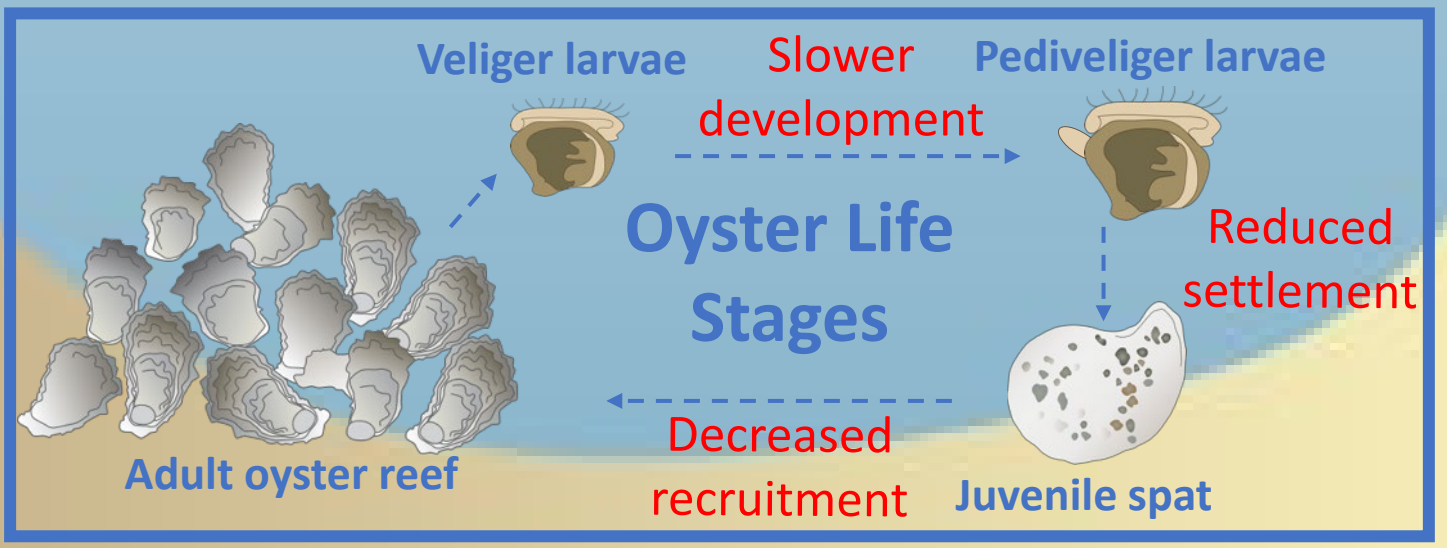
Low Salinity

Coastal Acidification

Hypoxia

Questions?

Project Webpage:
http://nsglc.olemiss.edu/projects/oysterreefrestoration/index.html



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  - Greg Easson, Marc Slattery, Luke Campbell, Allison Woolsey
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- Scott Rikard at Auburn University Shellfish Laboratory
- Megan Gima at Thad Cochran Marine Aquaculture Center

Thank You!

This project was paid for with federal funding from the U.S. Department of the Treasury, the Mississippi Department of Environmental Quality, and the Mississippi Based RESTORE Act Center of Excellence under the Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act of 2012 (RESTORE Act). The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of the Department of the Treasury, the Mississippi Department of Environmental Quality, or the Mississippi Based RESTORE Act Center of Excellence.