Mississippi Based RESTORE Act Center of Excellence 2020–2023 Research Summary

PROGRAM OVERVIEW

The Mississippi Based RESTORE Act Center of Excellence (MBRACE) is Mississippi's Center of Excellence under the RESTORE Act's Center of Excellence Research Grants Program. MBRACE is a consortium of Mississippi's four main research universities [Jackson State University (JSU), Mississippi State University (MSU), The University of Mississippi (UM), and The University of Southern Mississippi (USM)], with USM serving as the lead institution. The mission of MBRACE is to seek sound comprehensive science- and technology-based understanding of the chronic and acute stressors, both anthropogenic and natural, 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.

RESEARCH PRIORITIES

To help guide the State of Mississippi in efficiently addressing its ecological- and economic-based coastal improvement and restoration priorities, MBRACE invited proposals that addressed critical research gaps in the north-central Gulf of Mexico in two topic areas: (1) Water Quality, and (2) Oyster Reefs and their Sustainability. MBRACE specifically sought projects that increased the understanding of:

- Seasonal trends, variability, and atypical conditions in water quality that can be used to establish baseline conditions along Mississippi's coastline.
- Dynamics of freshwater inflow (e.g. timing, duration, quality) and associated sedimentation, urban runoff, altered salinity regimes, and effects on estuarine and coastal systems, including but not limited to nutrient loading, bacterial loading, harmful algal blooms, and hypoxia.
- Oyster biology, ecology, and production, including, but not limited to, larval transport, settlement, growth, abundance, and survival, and
- Parameters and locations for optimal cultch deployment and oyster seed deployment to enhance oyster production and reef sustainability.

FUNDED PROJECTS

In Fall 2017, MBRACE funded its first projects through the Core Research Program. Four projects were funded at $625,000 each to examine how ecological conditions relevant to oysters

vary over time and between newly restored oyster reefs and adjacent unrestored oyster reefs in Mississippi Sound, Mississippi. In 2020, MBRACE funded the second round of the Core Research Program and together the four projects received an additional $1.4 million to continue research and monitoring efforts as well as the addition of new project components. Additionally, in 2020 MBRACE established the Competitive Grants Program and awarded three projects funded at approximately $450,000 each. These projects focused on dynamics of freshwater inflow on coastal water quality as well as oyster biology, ecology, and production.

MBRACE Funded Projects, 2020-2023

Research Project Title	Investigators	Funding Program	Award Amount
Sustainability and restoration of oyster reef habitat in Mississippi Sound: a larval transport and recruitment approach	Jerry Wiggert (Lead; The University of Southern Mississippi), Mustafa Kemal Cambazoglu, Scott P. Milroy, Chet F. Rakocinski	Core Research Program	$411,354
Oyster Gape Measurement	Kamal Ali (Lead; Jackson State University), Ali Abu-El Humos, Huiru Shih	Core Research Program	$206,732
Abiotic and biotic influences on current and historic distributions of oyster reefs	Greg Easson (Lead; University of Mississippi), Marc Slattery, Allison Woolsey	Core Research Program	$377,388
Water quality and benthic habitat observations for enhanced understanding and sustainable management of oyster reefs in Mississippi Sound	Adam Skarke (Lead; Mississippi State University, Anna Linhoss, Robert Moorhead, Padmanava Dash, Prem Parajuli	Core Research Program	388,184
Impacts of water quality on oyster development to inform oyster reef restoration and sustainability on the Mississippi Gulf Coast	Deborah Gochfeld (Lead; University of Mississippi), Kristine Willett, Stephanie Showalter Otts	Competitive Grants Program	$442,942

The distribution of submarine groundwater discharge and its effect on coastal water quality in Mississippi	Adam Skarke (Lead; Mississippi State University), Alan Shiller (University of Southern Mississippi), Kristina Mojica, Natasha Dimova (University of Alabama)	Competitive Grants Program	$450,052
Optical observation of oyster larvae (O3L)	Xiaodong Zhang (Lead; The University of Southern Mississippi), Eric Powell	Competitive Grants Program	$449,907

PROGRAM HIGHLIGHTS

During the 2020–2023 period, the MBRACE Directorate:

- Gave 4 presentations about the MBRACE program at regional and national conferences
- Participated in 3 Mississippi Department of Environmental Quality Restoration Summit outreach events
- Hosted 3 MBRACE All-Hands Meetings
- Awarded 4 undergraduate internships under the MBRACE *Deepwater Horizon* Memorial Internship Program
- Applied for and was selected as a host office for the National Academies of Science Gulf Research Program Science Policy Fellowship and was matched with a fellow in the first year as a host office

RESEARCH HIGHLIGHTS

Through the seven projects funded by MBRACE in 2020–2023 :

- 32 graduate students were supported
- 5 postdoctoral researchers were supported
- 21 undergraduate students were supported
- 9 student dissertations/theses were supported
- 48 presentations were given at professional conferences
- 10 journal articles were accepted for publication, with 16 submitted or in preparation at the time of project closeout

Key research findings and takeaways:

Water Quality

- The 2019 Bonnet Carré Spillway opening had significant effects on the Mississippi Sound, particularly the western portion. It takes Mississippi River water approximately 8 days to reach the sound after the Spillway opens and it causes a significant decrease in salinity. This introduction of freshwater into the Sound decimated the oyster populations in Mississippi.
- Soil and Water Assessment Tool (SWAT) watershed models developed for the Wolf and Jourdan Rivers demonstrated the influence of these rivers on water quality in western Mississippi Sound. These models have the ability to quantify suspended particulate matter, turbidity, colored dissolved organic matter, chlorophyll *a*, phycocyanin, total alkalinity, pCO_2, and salinity.
- Submarine groundwater discharge (SGD) is present in Mississippi Sound, especially along the beaches and moreso in the western Sound that the eastern Sound. SGD can dominate nutrient inputs to the Sound during drier months when river flow is low. SGD is an important, but poorly constrained, hydrologic process that affects coastal water quality by transporting environmental stressors, such as nutrients, contaminants, and pathogens, into the ocean. SGD may directly contribute to degradation of water quality through eutrophication, harmful algal blooms, and ultimately hypoxia.

Oyster Reefs and their Sustainability

- Early recruitment of oyster larvae is extremely limited in Mississippi waters due tomultiple stressors including, but not limited to, decreased salinity from freshwater inputs, hypoxia, inadequate food supply, harmful algal blooms, and low pH. These stressors have negative impacts on oysters on all early life stages but newly settled spat are most vulnerable.
- Salinity has a significant effect on oyster growth and survival. Low salinity decreases oyster spat settlement and growth rate of juveniles. Oyster larvae are unable to survive when salinity is below 10.
- In addition to salinity, food supply for oyster larvae also limits recruitment and survival. Successful larval recruitment requires a relatively protein-rich diet that might be provided by small-sized particles, including picoplankton, bacteria, and/or viruses.
- Habitat suitability assessments found that relay locations in Biloxi Bay are viable sources of oyster larvae for Mississippi reefs. Additionally, other potential sources include Louisiana,and potentially Alabama, state waters.
- A system to measure oyster gaping continuously was developed which can be used as an indicator of environmental health as well as the health of the oysters. This system allows for real-time monitoring of the reef's health. Knowledge of when oyster spawning is taking place in real time allows for action to be taken to maximize settlement.

Key management implications:

Water Quality

- Effect of Bonnet Carré Spillway openings
    - Satellite imagery used to investigate the effect of Bonnet Carré Spillway openings on water quality is freely available and the analysis routines developed are in the Google Earth Engine. Therefore, many analyses can be performed without the need for expensive software or purchasing high resolution imagery.
    - A drop in water specific conductivity observed during years when the Bonnet Carré Spillway was closed appears to not occur nearshore, suggesting that the best chance for sustainable oyster reefs is closer to Henderson Point.
- SWAT watershed models
    - SWAT watershed modeling creates capacity to better understand and predict the dynamics of freshwater inflow from the Wolf and Jourdan Rivers into the Mississippi Sound, including alteration of temperature, DO, and salinity regimes as well as water quality parameters such as nutrient loading.
    - 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.
    - The greatest effect in reducing total suspended solids and phosphorus loading includes:
        - Ponds
        - Wetlands
        - Ponds + Wetlands + Streamside Management Zone (30m)
- Submarine groundwater discharge
    - Maps of submarine groundwater discharge (SGD) “hotspots” can inform the evaluation of the suitability of seafloor locations as benthic habitat for oysters and optimize restoration actions like oyster cultch deployment.
    - Data mining of locations/times of fish kills and beach closures in association with wind, water level, and radon may provide insight into causative mechanisms.
    - Monitoring stations for radon, temperature, salinity, dissolved oxygen, water levels, and wind speed/direction could help establish causal linkages between potential SGD forcing functions and impacts.
    - Study of beach SGD sources could provide insight into what contamination control measures would be cost-effective. Such studies could include isotopic tracers of nutrient sources, water source tracers, and anthropogenic indicators such as enteric bacteria, rare earths, and other contaminants of emerging concern (e.g., pesticides, pharmaceuticals, microplastics).
    - Oxygen isotopes and Re could provide a tracer set indicative of terrestrial water sources to the Sound, including local rivers, Mississippi River, and SGD.
    - SGD flux observations can serve as boundary conditions for hydrodynamic models and an explanatory variable for habitat suitability modeling.

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Oyster Reefs and their Sustainability

- Oyster biology, ecology, and production
    - Researchers developed a system to measure oyster gaping continuously which can be used as an indicator of environmental health as well as the health of oysters.
    - In the presence of flood-associated stressors, managers and decision-makers should anticipate:
        - Reduced growth of veliger larvae which could result in longer times in the water column, increasing their susceptibility to stressors and predators
        - Reduced settlement success with reduced recruitment to the benthos
        - Reduced survival and growth of new recruits (spat) that would reduce their recruitment to the local oyster population
        - Reduced survival and growth of juvenile oysters would reduce their survival to adulthood and potentially delay sexual maturity
    - Oyster larvae feed on naturally occurring organic material in the water column; the quality of this food source is critical in minimizing time to metamorphosis (growth and development rate) and success at metamorphosis.
- Parameters and locations to enhance oyster production and reef sustainability
    - Researchers developed a daily modeling system that natural resource managers can use to guide decisions on restoration as well as emergency management.
    - Development of a oyster gaping sensor system allows for real-time monitoring of the reef's health and allows for timely intervention when possible.
        - Knowledge of when oyster spawning is taking place in real time allows for action to be taken to maximize settlement.
    - Decision-makers should take into account early life stages of oysters during the planning and implementation of restoration projects. Larval survival and recruitment are critical to achieving the State's restoration goals.
        - Management thresholds should be developed to guide decision-making concerning when and where to place oyster seed or spat-on-shell on reefs.
        - Hatchery larval production for remote setting and seed aquaculture is an important restoration activity that may be able to boost oyster populations in years of poor recruitment due to flooding events.
        - Establishing a network of continuous monitoring stations to provide real-time data at priority oyster reef locations is needed to inform oyster reef management.
    - As optical data can be collected relatively easily and processed in near real-time, the optical data-driven larval metamorphosis model can be used as a very cost-effective and efficient tool for searching locations that provide high quality food supply for oyster larval recruitment.

PUBLICATIONS RESULTING FROM MBRACE-FUNDED RESEARCH

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2. Bhattarai S, Parajuli PB, Filip To SD. 2023. Comparison of flood frequency at different climatic scenarios in coastal forested watersheds. Climate 11(2). https://doi.org/10.3390/cli11020041.
3. Bhattarai S, Parajuli PB. 2023. Best management practices affect water quality in coastal watersheds. Sustainability 15. https://doi.org/10.3390/su15054045.
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5. Pruett JL, Pandelides AF, Willett KL, Gochfeld DG. 2021. Effects of flood-associated stressors on growth and survival of early life stage oysters (*Crassostrea virginica*). Journal of Experimental Marine Biology and Ecology 544:151615. https://doi.org/10.1016/j.jembe.2021.151615.
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7. Pruett JL, Showalter Otts S, Willett KL, Gochfeld DJ. 2022. Accounting for the entire oyster life cycle in restoration efforts: a brief for policy makers. University of Mississippi. National Sea Grant Law Center Publication NSGLC-22-06-03. http://nsglc.olemiss.edu/projects/oysterreefrestoration/index.html.
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