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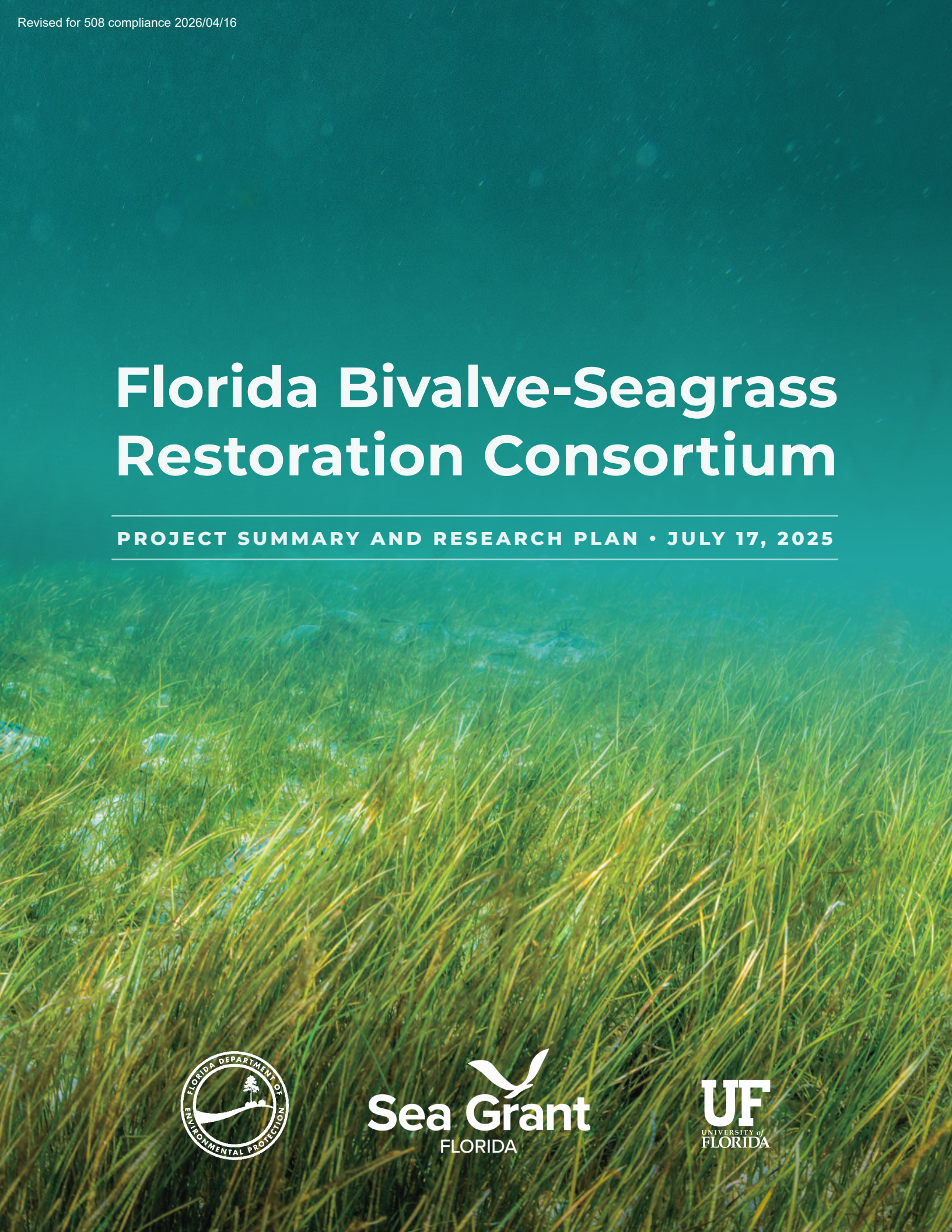
Florida Bivalve-Seagrass Restoration Consortium

PROJECT SUMMARY AND RESEARCH PLAN • JULY 17, 2025



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Florida Bivalve-Seagrass Restoration Consortium

PROJECT SUMMARY AND RESEARCH PLAN • JULY 17, 2025

Executive Summary

Florida's coastal and estuarine ecosystems have been negatively affected by nutrient pollution, driven largely by human activities. Excess nutrients have resulted in algal blooms and loss of important habitats, including seagrass beds. In response, seagrass restoration strategies have been developed and implemented but remain impacted by poor water quality. To combat this challenge, there is increasing interest in co-restoration of seagrass and native bivalve species, which would improve those stocks and (potentially) further improve local water quality. Bivalve restoration is increasingly being implemented in seagrass-dominated areas; however, standardized, science-based methods and best practices for bivalve-seagrass co-restoration in Florida do not exist for current restoration projects. Yet, such information is critical for the collective improvement and optimization of projects statewide

To address this gap, the Florida Department of Environmental Protection and Florida Sea Grant partnered to establish the Florida Bivalve-Seagrass Restoration Consortium, comprising scientists, practitioners, stakeholders, and resource managers. The first goal of the Consortium was to identify research priorities, objectives, and experimental goals that should be met to better inform bivalve-seagrass co-restoration. This document provides an overview of the Consortium's consensus recommendations as of Spring 2025, and will guide a forthcoming Request for Proposals for projects that align with these recommendations.

Based on consensus among Consortium members, the initial focus of this effort will be to evaluate the effects of incorporating hard clams (*Mercenaria* spp.) into estuarine restoration initiatives, and better quantify their role in facilitating seagrass restoration efforts. This experimental approach aims to limit the initial scope of work to activities that are achievable based on available time and funding. An additional goal of the Consortium is to document and elevate additional needs that fall outside the scope of this initial effort, but are important for advancing bivalve-seagrass restoration (e.g., needs to evaluate other bivalve species and longer-term recruitment studies).

This research plan provides an overview of the proposed experimental approach. It will be supplemented by a methods addendum that provides greater technical detail regarding experimental design for the coordinated network experiment. The technical addendum will also include the methods for site selection, project implementation, and monitoring of the parameters and/or parameter categories identified in this document.

The results generated from this effort will be used to develop associated best practices for bivalve-seagrass restoration in Florida, and will culminate in the development of a guide to inform and enhance existing and future restoration efforts.

Background

Florida is experiencing unprecedented negative impacts to its coastal and estuarine ecosystems, primarily due to nutrient pollution from urban and agricultural sources, which is driven by continued human population growth and increased development (Finkl et al., 2005; Nagy et al., 2012; Freeman et al., 2019; Lirman et al., 2019). Elevated nutrient levels can cause increases in density (blooms) of microalgae that reduce water clarity and quality. Perhaps one of the most notable impacts is increased frequency and severity of harmful algal blooms (HABs), which can result in widespread mortality of coastal invertebrates, fishes, and marine mammals (Heil & Muni-Morgan, 2021). When high densities of algae shade seagrasses for extended periods, these ecosystems become impaired and may eventually collapse (Okey et al., 2004; Burkholder et al., 2007). Seagrasses are foundation taxa, providing numerous ecological functions and ecosystem services throughout Florida's estuaries. Thus, the loss of seagrass habitat can have significant environmental and economic impacts.

The widespread problem of declining estuarine health has created increased demand for ecosystem restoration projects. Given the importance of seagrasses to Florida's estuarine ecosystems, seagrass restoration is an important tool that can contribute to the recovery and maintenance of estuarine health and resilience. Academic and agency researchers, resource managers, industry practitioners and environmental non-governmental organizations (NGOs)/nonprofits have initiated seagrass restoration projects around the state where they have been degraded or completely lost. Many of these efforts are increasingly incorporating bivalve shellfish as a nature-based strategy to enhance water quality, stabilize sediments, and improve restoration outcomes. Restoring multiple species together can enhance success of one or more target species through facilitation or other positive interactions (Halpern et al., 2007; Silliman et al., 2024), and this approach has been successful in some aquatic environments (e.g., McAfee et al., 2021). There is evidence to suggest that seagrass restoration and recovery may be enhanced by filter-feeding bivalves (Gagnon et al., 2020; Donaher et al., 2021). For example, studies have shown that bivalves can benefit seagrasses by reducing turbidity and enriching nutrients, among other positive effects (although these effects are dependent on the species used, location, and other factors; Gagnon et al., 2020). Additionally, the presence of bivalves has been linked to increased resilience to repeated disturbances in seagrass beds (Donaher et al., 2021). In turn, seagrasses can positively affect bivalves by providing shelter and stabilizing sediments, among other possible benefits (Gagnon et al., 2020). While there is some evidence to suggest that restoration of seagrass in conjunction with filter-feeding bivalves would have a range of benefits for both taxa, there is also evidence that introducing infaunal bivalves such as clams can negatively impact seagrasses under some circumstances (Donaher et al., 2021). Restoration efforts should therefore be conducted after initial assessments of the seagrass condition and causes of disturbance to address location-specific problems.

> "There is evidence to suggest that seagrass restoration and recovery may be **enhanced by filter-feeding bivalves.**"

Large-scale improvements in reducing or eliminating land-based sources of pollution, including improved stormwater and wastewater management practices, are required to fully address large-scale water quality issues in Florida's estuaries. However, given the ability of bivalves to improve water quality locally through biological filtration (e.g., reducing turbidity and potentially HABs by filtering out excess sediments and microalgae), several projects are underway throughout Florida to increase native bivalve abundance. Examples of ongoing and upcoming funded initiatives are described below.

- **A Billion Clams for Charlotte Harbor** is an initiative led by clam farmers to restore native clams (*Mercenaria* spp.) to Charlotte Harbor estuary with the goal of reducing red tide via natural filter feeding (WINK News, 2021). The initiative was funded via appropriations from the State of Florida in 2022 ($1 million) and 2024 ($1.5 million).

UF/IFAS Photo by Cristina Carriz

Clams being distributed for a clam buyback and shellfish restoration project in the Indian River Lagoon.

- **All Clams on Deck**, administered by the Gulf Shellfish Institute, aims to restore clams (*Mercenaria* spp.) in Southwest Florida estuaries with the goal of removing excess nutrients to benefit the ecosystem (Gulf Shellfish Institute, n.d.). In 2022, this initiative was supported by a $2.5 million State of Florida appropriation, a $2.5 million federal appropriation, and a $500,000 award from the Manatee County Board of County Commissioners. Manatee County has also supported oyster restoration in the Manatee River using state-appropriated and federal RESTORE Act (pot three) funds.
- The **Indian River Lagoon Billion Clam Initiative** aims to restore clam populations to improve local water quality through filtration (Indian River Lagoon Clam Restoration Project, n.d.); academic partners include the University of Florida's Whitney Laboratory for Marine Bioscience and the Florida Oceanographic Society. The Florida Fish and Wildlife Conservation Commission awarded $2.2 million to support this initiative in 2022, and the Coastal Conservation Associated has also provided substantial financial support for this effort, including a $100,000 donation in 2023.
- Sarasota Bay Watch has been engaged in ongoing **clam restoration** activities since 2015, and was awarded the first Florida Department of Agriculture and Consumer Services shellfish restoration lease in 2023. Their activities have included partnering with community volunteers to deploy clams (*Mercenaria* spp.) throughout Sarasota Bay at semi-annual events, with the goal of boosting clam populations and increasing associated water filtration (Solutions to Avoid Red Tide, 2019). Their efforts have supported local clam farmers, as clams used in restoration are purchased from local farmers, creating a market for larger clams that may grow beyond market size during periodic shellfishery closures (e.g., due to red tides or hurricanes). Sarasota Bay Watch also hosts an annual fundraising event that generates thousands of dollars in donations, which support the purchase of clams for restoration in Sarasota Bay.
- **Oyster Revitalization in the Choctawhatchee Bay**, an initiative led by a partnership between the Choctawhatchee Basin Alliance, the Choctawhatchee Bay Estuary Program, and Walton County, received $500,000 of state-appropriated funds in 2022 to support oyster restoration in Choctawhatchee Bay with the goal improving water quality and increasing recreational fish habitat.

Enhancing bivalve populations has the potential to enhance seagrass restoration, recovery, and recruitment success. Additionally, because bivalves are often sourced from commercial aquaculture farmers for restoration, this strategy has the potential to economically support farmers by providing an alternative source of revenue (i.e., from restoration practitioners purchasing seed or adult bivalves, including those at sizes not suitable for the foodservice industry; Florida Sea Grant, 2021). Because of the ecological and economic potential of integrating bivalves into seagrass restoration, millions of dollars in funding have been allocated by federal, state, and local government entities, as well as nonprofit organizations, in recent years to support such efforts in Florida estuaries.

> “A coordinated approach to assessing **the efficacy of bivalve-seagrass restoration** will aid in streamlining procedures to better identify trends and compare outcomes across systems within Florida.”

In light of this substantial investment, particularly from the State of Florida, its agencies, and multiple nonprofit organizations, there exists a significant need to scientifically determine the efficacy of such projects and determine the best approaches for future work. Although there is some evidence to illustrate positive effects of the inclusion of clams in seagrass restoration efforts (e.g., Zhang et al., 2021), other evidence suggests that while the effects of bivalve-seagrass co-restoration may be beneficial under some circumstances, these results may not extend to all species, locations, or methodologies (e.g., Gagnon et al., 2020). Further, there are no standardized metrics to evaluate bivalve-seagrass restoration efficacy or recommendations for best practices to maximize restoration success. Thus, there is a clear need for scientific evaluation of bivalve-seagrass restoration specifically in Florida estuaries, which can serve as a foundation for the development of science-based guidance that standardizes and optimizes approaches, provides mechanisms to evaluate success, and maximizes potential for success.

The Florida Legislature provided funding to support science that will ultimately guide future restoration efforts. Thus, the opportunity exists to understand and address data gaps regarding the ecological relationships between bivalves and seagrasses, including the extent to which (if at all), restoration generates mutual benefit (e.g., Fales et al., 2020; Donaher et al., 2021). A coordinated approach to assessing the efficacy of bivalve-seagrass restoration will aid in streamlining procedures to better identify trends and compare outcomes across systems within Florida. The results of this approach, including well-defined experimental procedures and evaluation methods, will guide the development of best practices for co-restoration of bivalves and seagrasses, which will benefit restoration practitioners and optimize the success of future efforts. Several examples of best practices for other systems and species exist (e.g., The National Academies of Sciences, Engineering, and Medicine, 2017; Fitzsimons et al., 2019; Gamble et al., 2021), and these can provide a basis for a Florida-specific approach.

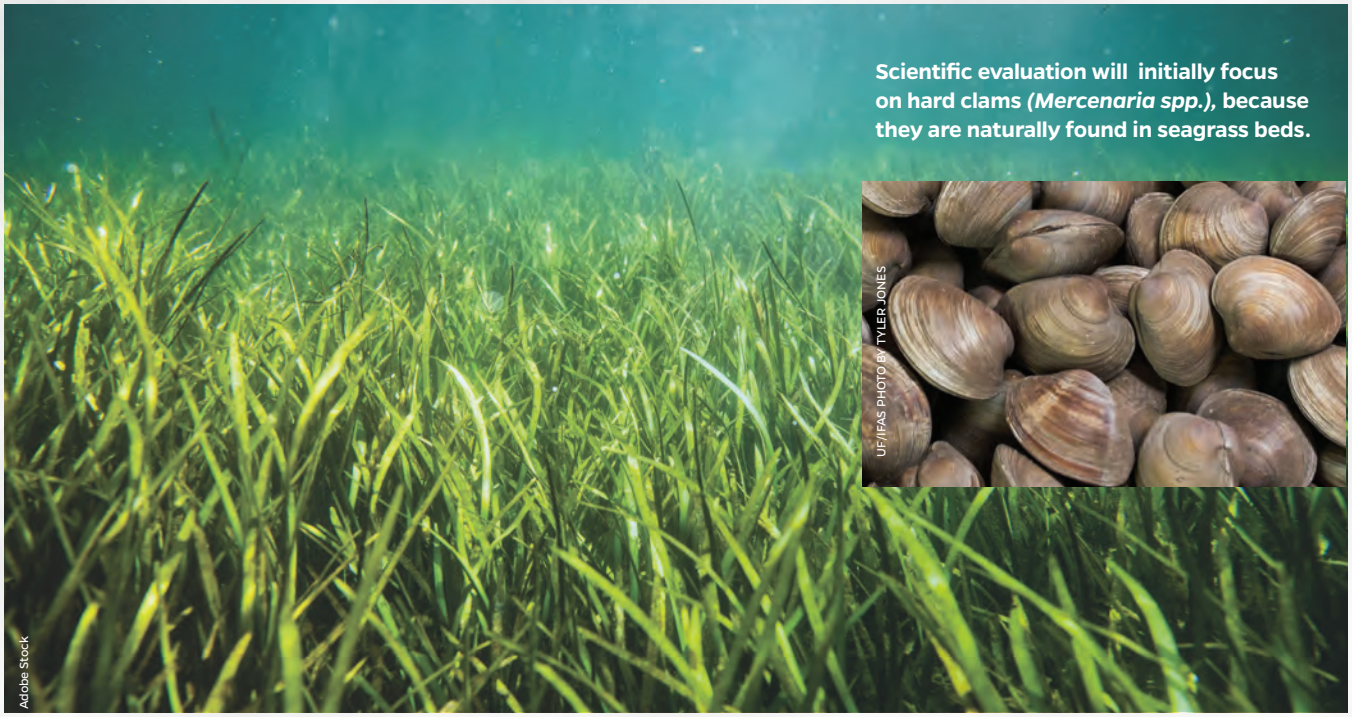
Need

The traditional approach to distributing funding to address a given issue is to define the programmatic needs of the state and issue a request for proposals to which various entities or teams respond in order to address portions of the stated needs. This approach, while commonly employed, has inherent drawbacks in that there is intensive effort required to prioritize respondents’ proposals and often all the needs of the state are not collectively met by respondents. Further, multiple uncoordinated investigations can lead to conflicting results and a need for additional work to make definitive conclusions. **In this plan, we propose to accomplish scientific investigations in a unified way that provides answers to fundamental questions of bivalve restoration efficacy, critical ecological relationships between bivalves and seagrasses, and methodologies to optimize future work.**

Purpose and Project Description

With support from the Florida Department of Environmental Protection, Florida Sea Grant—through its statewide network of locally based Extension Agents and associated research faculty—developed a consortium-based approach to accomplish the required scientific investigations in a unified manner. This newly established Florida Bivalve-Seagrass Restoration Consortium includes experts from universities, non-governmental organizations, and state agencies, who have provided guidance on critical science needs pertaining to bivalve-seagrass restoration. A subgroup of Consortium members volunteered to comprise a "Core Development Team," which created a web-based survey designed to aid in documenting research objectives that had arisen during previous discussions among Consortium members. In April 2025, the survey was sent to the full ~100-member Consortium, comprising scientists, practitioners, stakeholders, and resource managers, to determine highest priority research needs. Roughly one quarter of Consortium members responded to the survey, and responses generally aligned with feedback received during formal and informal discussions among members regarding research priorities. Responses are provided in the Appendix, and the following sections of this document summarize the priority research areas and experimental approaches that should be pursued based on the Consortium's recommendations.

The Consortium's goal is ultimately to answer the questions of bivalve-seagrass restoration efficacy, critical ecological relationships between bivalves and seagrasses, and methodologies to optimize future co-restoration projects in Florida. Although scientific evaluation of these questions is of interest for all Florida bivalve species, we anticipate that the initial focus of these studies will be hard clams (*Mercenaria* spp.), because these species are naturally found in seagrass beds (Heck et al., 2002) and are easily sourced for restoration via aquaculture (with appropriate consideration of genetic impacts). To accomplish this goal, respondents to a forthcoming Request for Proposals will collect the same metrics in different systems under unified guidance throughout the project (see Experimental Approach section of this plan).



Scientific evaluation will initially focus on hard clams *(Mercenaria spp.)*, because they are naturally found in seagrass beds.

Identification of Priority Research Areas

The *Florida Bivalve-Seagrass Restoration Research Plan* aims to establish a standardized approach for implementing and evaluating restoration efforts that integrate seagrasses and bivalves. This plan will provide a science-based guide for experimental design, data collection, and evaluation to inform and maximize the success of future co-restoration activities.

PRIORITY QUESTIONS

The Core Development Team identified five priority research questions based on the survey results. These research priorities are similar to those identified during previous working groups (Gulf Shellfish Institute, 2021; Simpson et al., 2022; Florida Sea Grant, 2023). Survey results suggested multiple types of shellfish, including clams, oysters, scallop species; however, **the Core Development Team recommends initially focusing on clams due to (1) the number of high-priority questions (five in total), (2) time horizon of the project (less than three years), and (3) available funding**, in addition to the factors outlined in the need section above. It is also worth noting that there are multiple ongoing efforts to inform oyster restoration activities (e.g., NOAA Restoration Center, 2022; Florida Oyster Recovery and Science Working Group), but there are currently no best practices available regarding clams and seagrass. Although clams are recommended as the initial focal species for this effort, project proposals that incorporate other bivalve species will be considered if they address the priority research questions and objectives outlined below.

The priority research questions identified were:

1. How do bivalves (including characteristics such as size, genetic diversity, etc.) affect seagrass and vice versa?
2. What is the optimal bivalve density for improving water clarity and nutrient dynamics?
3. How do bivalve-seagrass interactions influence water clarity, denitrification, and other ecosystem services?
4. Can co-restoration of bivalves and seagrasses improve the efficiency, resilience, and scalability of aquatic ecosystem restoration?
5. What is restoration success and what environmental conditions support successful co- restoration projects?

OBJECTIVES

1. Quantify interactions and feedback between clams and seagrasses affecting the growth and survival of both taxa, as well as nutrient cycling.
2. Evaluate the delivery of ecosystem services by clams and seagrasses such as filtration, denitrification, and sediment stabilization.
3. Identify background sediment and water quality conditions that support clam-seagrass co- restoration.
4. Standardize co-restoration monitoring methods and share data across a network of resource managers and practitioners.
5. Inform scalable co-restoration strategies through regular communication and directed input from Consortium partners.

Experimental Approach

The primary strategy identified by the Florida Bivalve-Seagrass Restoration Consortium to address the priority research questions and objectives outlined above is a **coordinated network experiment** that uses the same experimental approach in as many estuaries as possible across Florida. The experiment will involve as many collaborators as possible, and experimental methods will be developed based on ongoing feedback and coproduction of experimental designs by the Consortium and collaborators.

The exact design of the experiment will be determined by the Consortium, but at minimum should include seagrass-only plots/treatments, seagrass-bivalve plots/treatments, and bivalve-only plots/treatments. The research sites should:

a. Include but not be limited to the following five regions: Tampa Bay, Sarasota Bay, Charlotte Harbor, Indian River Lagoon, and Suwannee Sound[1];
b. Be placed in areas that are suitable for restoration and where permitting is achievable within the time horizon of this project (i.e., research results must be available to the Consortium by March 30, 2027); and

[1] These regions were identified by the Consortium for several reasons. Tampa Bay, Sarasota Bay, Charlotte Harbor, and Indian River Lagoon are part of the U.S. Environmental Protection Agency's National Estuary Program, and thus have active regulatory frameworks in place regarding nutrient management and seagrass habitats. These areas are also all currently undergoing clam restoration activities with dedicated funding that was received with the goal of benefitting water quality, seagrass habitats, and aquaculture practitioners; thus, new work spurred by the Consortium effort can build upon these existing projects. Suwannee Sound was chosen as a relatively "pristine" region that already supports large, naturally healthy bivalve populations and seagrass habitats and could potentially serve as a useful comparison to more disturbed/modified regions where restoration activities are centered.

c. Allow for the ability to compare clam-seagrass interactions in a restored area to those in an unrestored (control) areas.

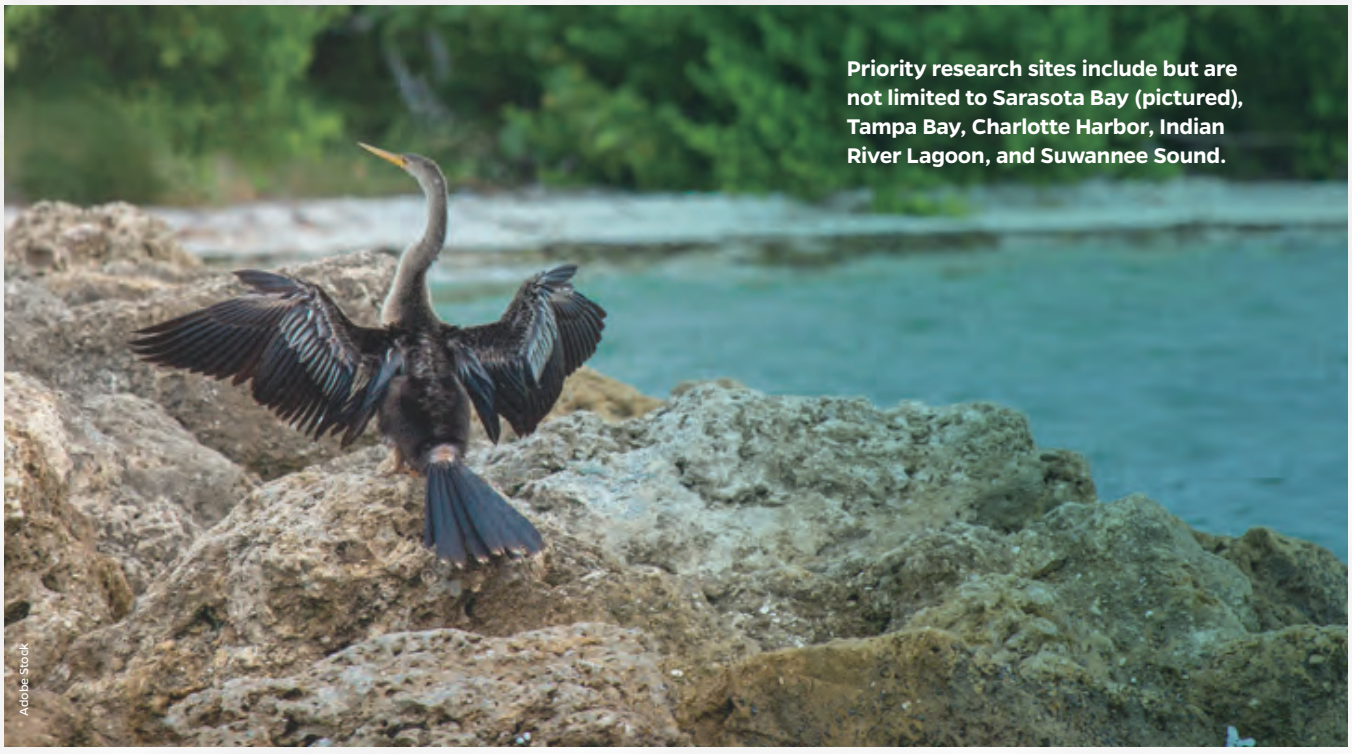
To allow for comparability of data across regions, the same metrics will be collected across projects in the coordinated network experiment to evaluate (1) suitability and site characteristics and (2) bivalve-seagrass interactions. The portfolio of metrics measured during the experiment is designed to support the development of robust, repeatable, and feasible protocols to be used widely when implementing co-restoration projects. The Core Development Team identified the following standardized metrics that all coordinated network experiment participants should monitor during the experiment:

1. Suitability and site characterization:
   - a. **Sediments:** Grain size, bulk density, organic matter, and porewater nutrients, porewater sulfides
   - b. **Waters:** Turbidity, nutrients, salinity, temperature, dissolved oxygen, chlorophyll, and variability within each of these metrics
   - c. **Hydrodynamics:** Water flow, residence time, and particle movement
2. Clam-seagrass interactions:
   - a. **Seagrass indicators:** Percent cover, shoot density, species composition, canopy height
   - b. **Clam indicators:** survival, size/growth, condition index, recruitment (e.g., veliger number, juvenile settlement)
   - c. **Nutrient flux:** Benthic fluxes of measured oxygen; ammonium; nitrate; sulfides; and phosphate exchanges across the sediment water-interface; and
   - c. **Density surveys:** Bivalve and seagrass densities (separately and together) both within and outside of restoration sites

Detailed, written guidance on experimental design and methodologies for collecting each of these metrics will be developed in consultation with coordinated network experiment PIs to ensure all collaborators follow the same procedures.

The Core Development Team also anticipates the development of a **numerical model** to determine the impacts of clams at specific densities on water quality in various locations. To parameterize and test these models, field measurements—ideally taken from sites within the coordinated network experiment—are expected to be conducted in various environments. These include measurement of the following two functions:

- Water filtration by clams via lab and in situ rate measurements
- Denitrification via core incubations to measure net N_2 production



Adobe Stock

Priority research sites include but are not limited to Sarasota Bay (pictured), Tampa Bay, Charlotte Harbor, Indian River Lagoon, and Suwannee Sound.

There is also a need for additional studies and experimental approaches that complement the coordinated network experiment. For example, the Consortium recognized a need to develop new monitoring approaches that better evaluate different aspects of bivalve-seagrass restoration success. For example, genetic approaches to evaluating whether restored clams are creating reproductive, self-sustaining populations should be developed and expanded. While the scope and timeline of this project precludes a complete evaluation of long-term reproductive success of restored clams, methods should continue to be refined, and data collected as part of the coordinated network experiment, particularly genetic data on clams introduced to restoration sites, could support future analyses of this nature.

Although the experimental approach outlined here has been developed by the Consortium to address the priority research questions and objectives related to bivalve-seagrass co-restoration, studies that fall outside the scope of this experimental approach will also be considered if they address the priority research questions and objectives in this plan.

Outputs and Engagement

To track results generated from the experimental approaches outlined above, the Consortium will establish and update a shared database platform to upload and access protocols and results. Additionally, the Consortium will contribute to a database of relevant literature regarding the current state of the science regarding bivalve-seagrass restoration and feedbacks between shellfish and seagrass to inform experimental design and the development of best practices for bivalve-seagrass restoration. Further, Consortium members will analyze data to evaluate trends and compare their findings to existing studies to develop best available guidance and best practices for restoration. This will culminate in the development of a written Florida Bivalve-Seagrass Restoration Guide, developed in consultation with Consortium members.

Florida Sea Grant will ensure that the Consortium fully engages with each other and broader constituencies, including the interested public, primarily through its network of extension agents and specialists. In addition to continuing to organize quarterly Consortium meetings, additional workshops and meetings will be scheduled as needed to share results with stakeholders and revise questions/priorities. Ongoing engagement with the Consortium and stakeholders will also aid in the ongoing identification of new experts who should be engaged in the Consortium.

Research Funding

Up to $3.6 million is available to conduct this work. A Request for Proposals will be used to secure bids and identify project teams that can address the priorities outlined in this document. The Core Development Team and the Consortium will need to come to consensus on the identification of the research objectives that can be reasonably addressed within the available budget and funding timeframe (project end date is October 15, 2027).

Funded projects will be responsible for the establishment of research plots and implementation of data collection protocols that adhere to this research plan, including consideration of permitting and costs of closing out the activities under this project (e.g., clean up and removal of data collection equipment).

University of Florida's Whitney Laboratory for Marine Bioscience works to restore local oyster reef habitats.

University of Florida

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Appendix

The following appendix provides results of a web-based survey administered to members of the Florida Bivalve-Seagrass Restoration Consortium (n ≈ 98). The survey was distributed to Consortium members via email on April 4, 2025 and responses were collected through April 9, 2025. A total of 27 people responded to the survey, although each respondent did not necessarily answer every question (the number of respondents is indicated for each question presented below).

Figure A1. Map of existing/planned restoration areas identified by survey respondents.

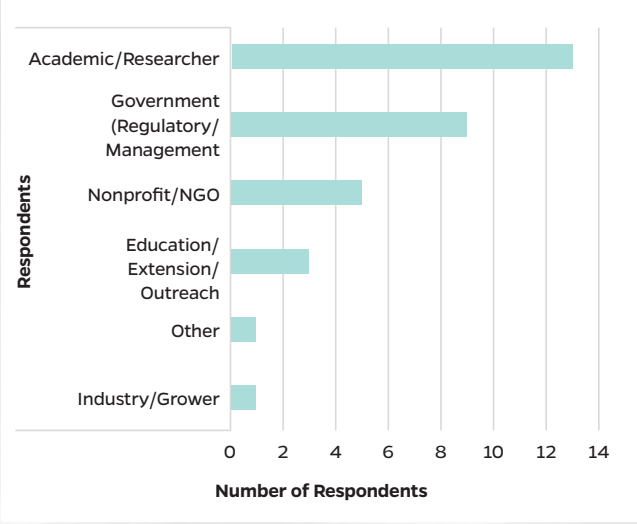

Figure A2. Affiliation categories indicated by survey respondents (n = 26). Respondents were able to choose more than one affiliation category.

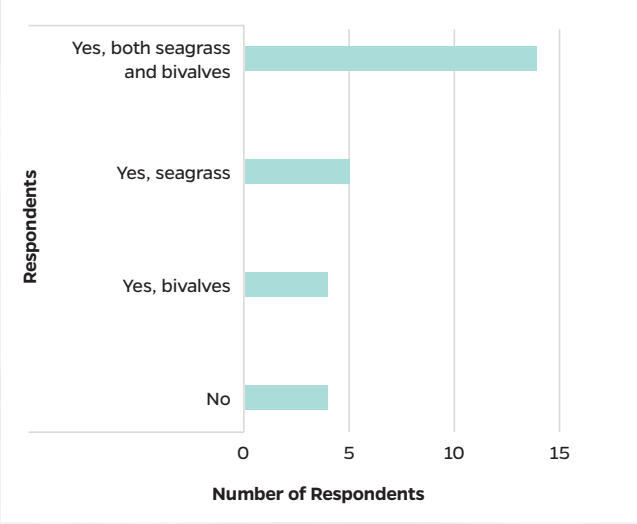

Figure A3. Responses (n = 27) to the question "Are you currently conducting any relevant research or restoration with bivalves or seagrass?"

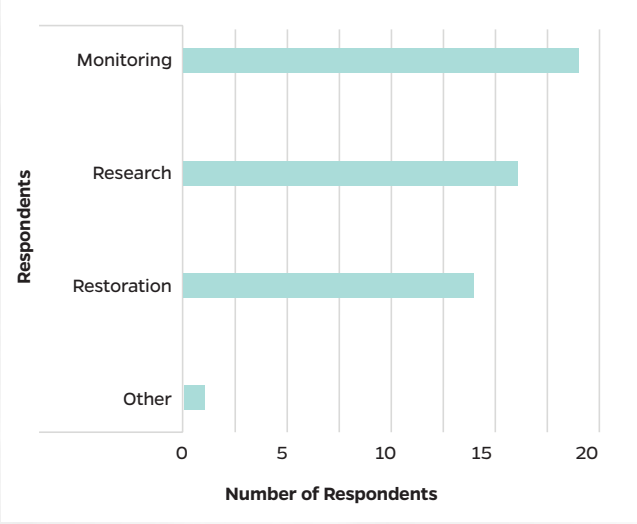

Figure A4. The type of work respondents (n=23) reported being engaged in pertaining to seagrass and/ or bivalve restoration.

Respondents were asked to rank key research questions identified during previous workshops and discussions from most important (1) to least important (5).

Table A1. The average ranking respondents (n = 27) assigned to research questions pertaining to clam and seagrass interactions.

Ranking	Question
1	What are the background sediment and water quality conditions that: Indicate seagrasses could survive if planted? Indicate clams would add value to the restoration (e.g., water residence time, hydrodynamic stress, sediment nutrients)?
2	Do clam-seagrass interactions improve restoration efficiency? (e.g., via biofiltration, nutrient availability)
3	What is the density of clams needed to improve water quality and clarity, and how does this relationship vary in dense seagrass vs. sparse seagrass?
4	What is the natural density of clams in seagrass meadows vs. unvegetated areas?
5	How do clam-mediated nutrient additions (feces, pseudofeces) influence seagrass reproductive output and growth?

Table A2. The average ranking respondents (n = 27) assigned to research questions pertaining to ecosystem services of bivalves.

Ranking	Question
1	How will water filtration, denitrification and bio-deposition rates vary across different environments (e.g., IRL) and with site-specific stressors?
2	What are the in situ rates of beneficial services from clams, such as denitrification, biodeposition, and water filtration per capita/per biomass?
3	How do bivalves offset factors such as ammonium regeneration and increased oxygen demand?
4	What is the genetic structure of wild clam (or other bivalve) populations and what changes have they undergone?

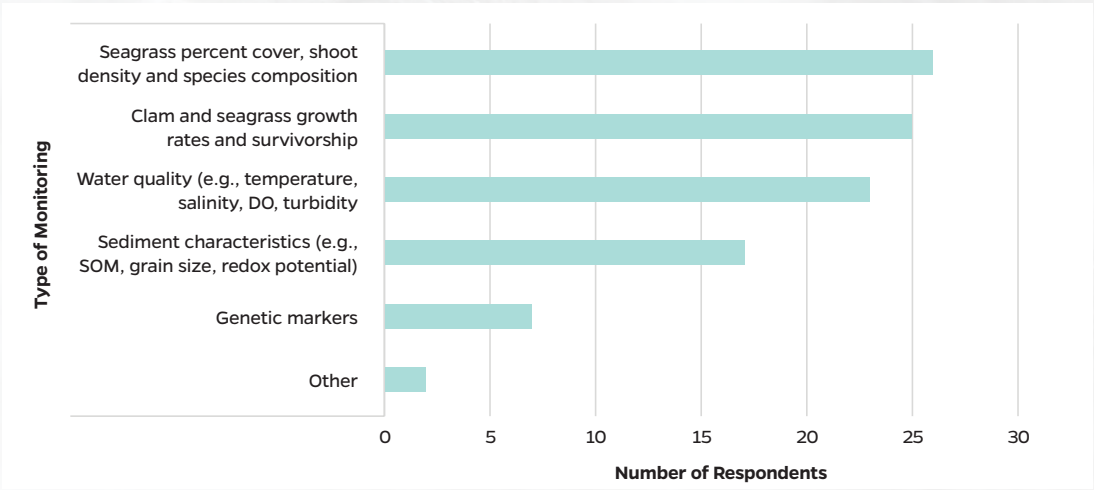

Figure A5. Standardized methods that respondents indicated should be used to monitor bivalve and seagrass restoration success. Respondents were able to choose more than one monitoring method.

Acknowledgements

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