Project Name: Conducting habitat suitability measures to identify optimal oyster restoration locations along the Florida Gulf Coast

Contact Information:

Melanie Parker
727-502-4919
Melanie.Parker@MyFWC.com
Fish and Wildlife Conservation Commission
Fish and Wildlife Research Institute

Objective

The primary objective of the proposed project is to develop and implement a standardized approach to determining the habitat suitability of gulf coastal areas in Florida for future oyster (*Crassostrea virginica*) restoration efforts.

Rationale

Oysters are present along the entire length of the Gulf coast in Florida, but monitoring efforts focused on assessing population dynamics and environmental conditions have been sporadic or non-existent in many areas, especially those without a large commercial fishery. Without this background information, it is difficult to assess whether a particular location is truly in need of oyster restoration efforts or if the habitat is simply unsuitable for oysters. For this reason, it is imperative to develop a standardized, widely-applicable method for assessing oyster habitat suitability that can be employed before implementing costly restoration efforts.

Selection criteria for oyster restoration locations should include a suite of environmental variables. Salinity is likely the most important factor influencing the health and longevity of oysters, but the interaction of salinity and temperature is also important, especially in Florida where water temperatures can exceed 32 ^{o}C. Tolerable salinity ranges vary but generally fall somewhere between 10 and 30. When salinities fall below the tolerable range for more than a week or two, especially in the summer months when water temperature are high, oysters often experience acute stress and death. If salinities are consistently near the upper boundary or exceed the tolerable range, oyster are susceptible to increased disease and predation. Locations near creeks, canals or other sources of freshwater can offer refuge from high salinities but these quickly become uninhabitable if there is a storm event and large volumes of freshwater decrease salinities to below tolerable. Generally, oyster populations are most healthy and abundant in locations where salinities are dynamic and fluctuate regularly between 10 and 30. Other water quality parameters that are important to consider include dissolved oxygen concentration, pH, depth and turbidity.

Additional important environmental variables to consider at potential restoration sites are sediment composition, sedimentation rates and wave energy. When sedimentation rates are high at a selected site, oysters that settle on the restored substrate will likely be buried or unable to filter water efficiently if the substrate is not elevated sufficiently. High sedimentation rates can occur when strong currents scour soft sediments from one area and deposit them in another, or if soft sediments dominate the benthic composition of a potential restoration site. When sediment composition or sedimentation is a known factor, it can be mitigated by planting substrate materials in stages, allowing the first layer of substrate to settle before adding additional layers. This ensures the constructed reef remains elevated above the soft sediments. Restoration sites with high wave energy, or frequent large boat wakes, also increase the risk of high sediment loads, and in the worst cases shell movement, both of which can substantially decrease oyster survivorship (Wall et al 2005) and the effectiveness of a restoration effort.

When considering a restoration site, determining whether live oysters are present at, or near, the selected site is an important consideration. If there are low densities of live oysters or there is only a dead reef, this indicates that environmental conditions were likely suitable at some time in the past and developing a suitability profile will aid identifying those limiting factors that must be mitigated before restoration efforts are successful. If environmental conditions are found to be suitable, then it may be that there is not enough substrate available for larval settlement or there is inadequate larval oyster supply to the area. Measures of spat settlement rates can help determine if there is a larval source nearby, but timing is important as oyster reproduction is highly seasonal.

Historical data is often used to generate georeferenced Habitat Suitability Index (HSI) models that predict where oysters might be found in an estuary. Existing data sources detailing historical environmental conditions (datasondes, water quality monitoring programs, etc.) or oyster population distributions (e.g., Florida Department of Agriculture and Consumer Services (FDACS) survey data) can be of great use when developing HSI models for the selection of restoration sites. The variables incorporated into an HSI model vary among studies, but most commonly include salinity, bottom type or substrate, and water depth (Theuerkauf and Lipcius 2016). HSI models are most commonly developed by creating a suitability function for each variable. These functions are used to generate scores ranging from 0 to 1 for each value of a variable, with a value of 0 representing unsuitable conditions and a value of 1 representing optimal conditions. One limitation to HSI models is that the suitability functions are most commonly generated from suitable ranges as defined by the literature (Linhoss et al 2016), so they may not capture current climatic or biological conditions. A combination of historical data and recently collected field data could greatly improve the relevance of the suitability functions and therefore, the relevance of the resultant HSI model. The HSI model can be further strengthened by comparing and validating the results with independent oyster density measures from the field (Theuerkauf and Lipcius 2016).

Site Selection

In order to aid selection of sites for the proposed study, the Gulf coast of Florida was first grouped into four major regions based on geographic characteristics: Panhandle, North Peninsular, South Peninsular and Florida Bay (Figure 1). Secondarily, within each major region, those areas that have reported commercial oyster landings were considered – not because they support a commercial fishery, but because reported landings suggest that environmental conditions are suitable, or were once suitable, for oysters. Finally, the statewide oyster map layer compiled by the FWC – FWRI Oyster Integrated Mapping and Monitoring Program (OIMMP) (http://geodata.myfwc.com/datasets/oyster-beds-in-florida) was reviewed to assess the distribution of oysters at potential sites within a region.

The Panhandle region extends from the western boundary of the Florida Panhandle to Alligator Point in the easternmost Panhandle. Within this region, subtidal and intertidal oysters are found in several bays and estuaries including Pensacola Bay, Choctawhatchee Bay, St. Andrew Bay, St. Joseph Bay and the Apalachicola Bay system. Apalachicola Bay once contained the most productive oyster reefs in Florida, but oyster abundance and harvest rates declined sharply in 2012 due to a variety of environmental and anthropogenic factors. As a result, numerous efforts in recent years have focused on restoring oyster bars in Apalachicola Bay and increasing the resilience and sustainability of those areas that are commercially harvested. Pensacola Bay and St. Andrew Bay also support some commercial harvest, but those rates have also declined in recent years. Neither Choctawhatchee Bay nor St. Joseph Bay have large abundances of oysters and no commercial landings have been reported for either bay since 2011.

The North Peninsular region extends east from Alligator Point to just north of Tampa Bay and is comprised of rivers and creeks with open coastal discharges. Major rivers in this region include the Ochlockonee, St. Marks, Wacissa, Aucilla, Econfina, Steinhatchee, Suwannee, Wacasassa, Withalacoochee, Crystal, Homosassa, Chassahowitzka, Pithlachascotee and Anclote rivers. Each river has a mix of spring-fed and riverine flows, but the watersheds vary substantially in size. Due to the high output of the springs, most rivers maintain some flow even during dry periods, but localized rainfall can lead to large fluvial discharges. At the mouths of the rivers, there is generally a series of shallow intertidal fringing reefs and some discrete bars. Most of these are of little commercial value, with one exception occurring in the area from Suwannee Sound south through Cedar Key. In this area, commercial landings have more than doubled in recent years as oyster fishermen from the panhandle shifted harvest efforts to that area following the collapse of the oyster fishery in Apalachicola Bay. Ochlockonee and St. Marks also support some commercial harvest in the region.

The South Peninsular region is comprised of three relatively large embayments: Tampa Bay, Sarasota Bay and Charlotte Harbor. Rivers with large watersheds feed Tampa Bay (Hillsborough, Alafia, Little Manatee and Manatee) and Charlotte Harbor (Myakka, Peace and Caloosahatchee) and all three bays have many small urbanized creeks. Most of the rivers have modest flow and are prone to periods of drought and short (frontal) to long (seasonal) flood events. There are still extensive intertidal oysters, but the commercially viable subtidal reefs were depleted in the late 1800s and early 1900s by harvest for food and dredging for fill material. Harvest is minimal and many areas are classified as prohibited harvest areas by FDACS due to legacy pollution and fecal coliform risk. The Caloosahatchee River, located at the southern extent of the Charlotte Harbor area, has been highly altered through channelization and a direct connection to Lake Okeechobee. As a result, the Caloosahatchee estuary experiences altered patterns of freshwater quantity and quality, which in turn negatively affects the ecology and health of the local oyster populations.

The Florida Bay region, which is south of Sanibel Island, is comprised of a series of small embayments and coastal mangrove forests. Like the Caloosahatchee estuary, this region has also been negatively affected by urban development and channelization of waterways, resulting in dramatic alteration of natural water flow. Although oysters persist in this region as small intertidal bars, fringing patch reefs and mangrove-associated oysters, their distribution and abundance are likely limited by altered freshwater supply and seasonal hypersaline conditions. The Comprehensive Everglades Restoration Plan (CERP), which was enacted in 2000, aims to restore, preserve and protect the ecosystem by restoring more natural water flow patterns through South Florida, including the Florida Bay region and the Caloosahatchee River Estuary.

Methods

The proposed project will be conducted over a 4-year period and address four objectives: (1) data compilation, (2) mapping, (3) field monitoring and (4) a GIS-based HSI model. The data compilation component will be conducted during the first 6 months of the project. The mapping component will begin in year 1 and continue until all four sites are completed. Field monitoring will begin as soon as relevant data and information are compiled and continue for a minimum of two years. Development of a standardized approach, as well as a GIS-based habitat suitability model, for determining the suitability of coastal areas in Florida for future oyster restoration efforts will occur throughout the duration of the project.

Study Sites

In an effort to ensure methods are as widely applicable as possible, and to acquire more information on oyster populations throughout the Gulf coast of Florida, a minimum of one study site was selected from each of the Panhandle, North Peninsular and South Peninsular regions. The Florida Bay region has been excluded from the proposed study since it is already targeted by CERP efforts. In the Panhandle region, efforts will be focused in Pensacola Bay and St. Andrew Bay; Apalachicola Bay has been excluded since there are ongoing monitoring and restoration efforts already focused on that area. In the North Peninsular region, the Suwannee Sound through Cedar Key area has been selected as the study site and in the South Peninsular region, Charlotte Harbor will be the study site.

Data Compilation

Existing data from cooperating agencies will be compiled to analyze historical trends in environmental conditions and oyster population abundance and health in the four study sites.

Mapping

Initial surveys will be conducted by boat to determine general benthic composition (i.e., hard bottom vs. soft bottom) in the four study sites. Acoustic methods such as side-scan sonar will be used to characterize the benthic composition and the spatial location and extent of oysters at targeted locations in each of the four study sites (Grizzle et al 2017). If applicable, satellite or aerial imagery will be used to map intertidal reefs. Results from mapping efforts will be verified by grab sampling, diver surveys or visual observations. After the results are verified and finalized, the data will be used to develop a standard benthic classification scheme and determine substrate availability, or locations appropriate for placing substrate, for future restoration efforts.

Water Quality

Salinity, temperature, dissolved oxygen concentration, pH, depth, and turbidity will be measured monthly at multiple stations within each of the four study sites. In addition, continuous data loggers for recording salinity and temperature will be deployed at one location in each of the four study sites.

Sedimentation

Sedimentation rates will be assessed monthly by deploying replicate sediment traps at stations in each of the four study sites (Thomas et al 2007). Upon retrieval, contents will be rinsed into a container and filtered through pre-weighed 35 µm filters. The sediments and filters will be dried in a drying oven at 80°C for a minimum of 48 hours then dry weights recorded. Sedimentation rates will be calculated by dividing the total dry weight of the sediment sample by the number of days the sediment trap was deployed.

Wave Energy

Methods for measuring wave energy or relative water motion (Wall et al. 2005) will be investigated and then applied at appropriate stations in each of the four study sites.

Larval Supply

Larval supply will be assessed by measuring juvenile oyster recruitment rates. Three replicate spat monitoring arrays (spat = newly settled oyster) will be deployed at stations in each of the four study sites. Each of the arrays will be comprised of 12 axenic adult oyster shells (5-10 cm shell height) strung onto two separate lengths of galvanized wire (6 shells per wire). The shells will be oriented with their inner surface facing downward when suspended off the bottom. After a month-long deployment, the shell strings will be recovered, and juvenile recruitment will be estimated by discarding the top and bottom shells of each string and counting the number of settled spat on the underside of the remaining shells. Juvenile oyster recruitment rates will be calculated by dividing the raw number of spat per shell by the number of days the shell was deployed, then standardizing to a 28-day month (Parker et al 2013).

Oyster Density and Size Distribution

In the first year of the study, a one-time stratified random survey of oysters will be conducted in each of the four study sites. Survey locations will be selected from the statewide oyster map layer compiled by the FWC – FWRI OIMMP (http://geodata.myfwc.com/datasets/oyster-beds-in-florida). Specific sampling stations will be randomly selected from numbered grid squares overlying oyster habitat (Parker 2016). The total number of stations will be determined by reef acreage, but standardized sampling efforts will be applied in the each of the four study sites. Data will include classification of bottom substrate and, if hard substrate or live oysters are present, measures as described in the following paragraph.

During all years of the study, oyster density sampling will be conducted quarterly at stations with live oysters or with existing hard substrate habitat. At those stations, up to fifteen replicate quadrats will be randomly deployed and all oysters within each quadrat will be collected for determination of the total number of live oysters and dead oysters (Parker et al 2013). In addition, shell height (SH; maximum linear distance from the umbo to the ventral shell margin) measurements for all oysters 25 mm or larger will be recorded. A maximum of 25 SH measurements will be recorded for spat (oysters < 25 mm).

GIS-Based HSI Model

Suitability functions will be developed for environmental variables based on oyster habitat requirements described in the literature and observed in the field. The functions will be used to assign an HSI score ranging from 0 (unsuitable) to 1 (optimal) for each variable (Cake 1983, Soniat et al 2013, Theuerkauf and Lipcius 2016). HSI scores will then be used to create GIS layers for each environmental variable. Once the model is created, data collected during oyster density surveys will be used to verify the validity of the model (Theuerkauf and Lipcius 2016). Upon completion, HSI models will be made publicly available to aid future restoration efforts.

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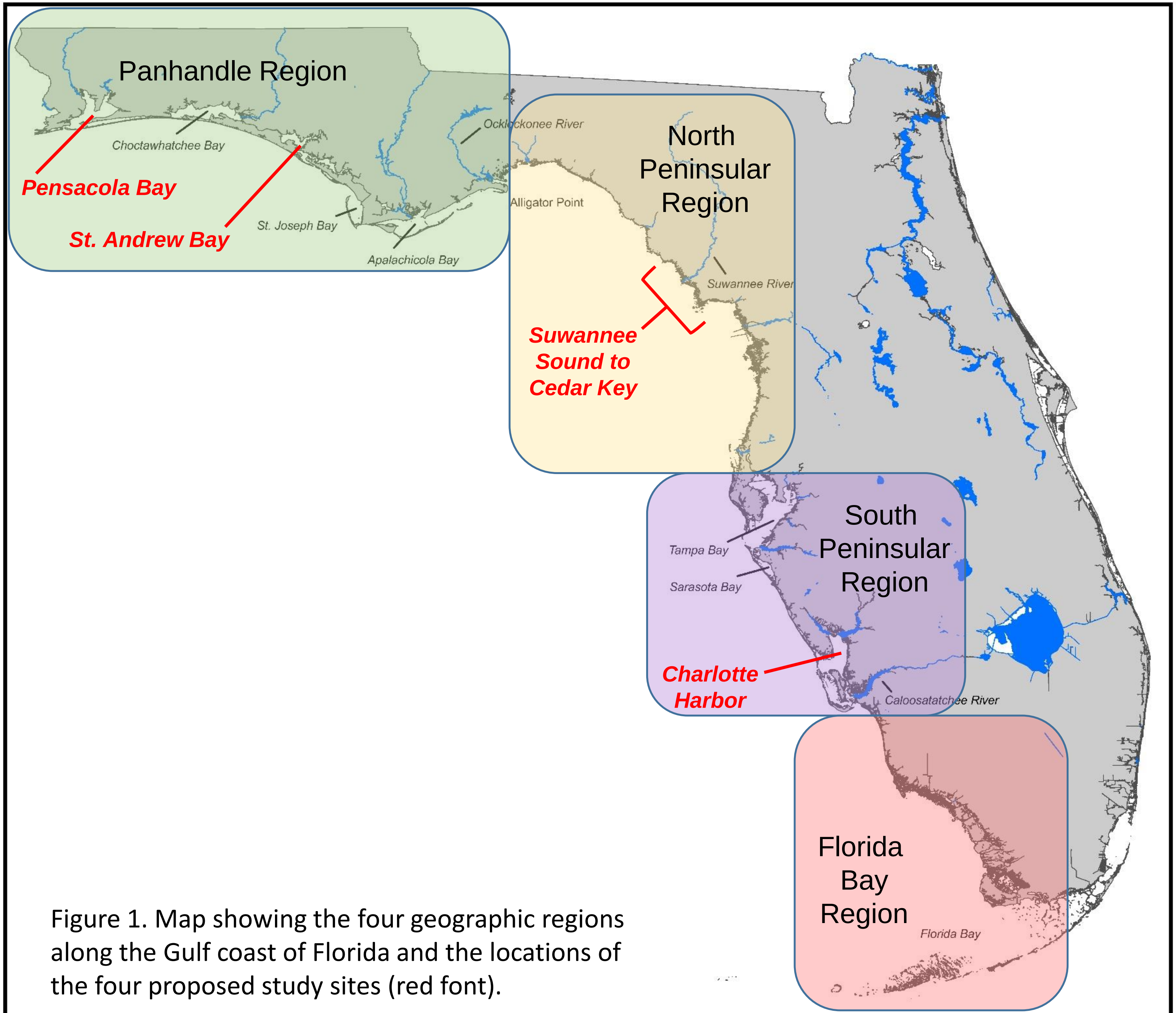

Figure 1. Map showing the four geographic regions along the Gulf coast of Florida and the locations of the four proposed study sites (red font).