Stakeholder-Driven Modeling to Understand Oyster Population Sustainability

Project Location
Northeast Florida

Project Duration
September 2018 to July 2020

Project Leads
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Project Type
Catalyst – Targeted investment for advancing collaborative science

Products
- Oyster population model that has been built in the R programming language and made available on GitHub
- Spatially explicit estimates of oyster growth, mortality, and reproduction
- Recommendations for monitoring and restoration

Project Partners
- Guana Tolomato Matanzas National Estuarine Research Reserve
- Northeastern University
- Oregon State University

Project Webpage
nerrssciencecollaborative.org/project/White18

Overview

The Eastern oyster (*Crassostrea virginica*) is a foundational species in northeastern Florida estuaries. In addition to providing important ecosystem services, such as water filtration and shoreline protection, the oyster supports a valuable recreational and commercial fishery. However, scientists, managers, and oyster harvesters are concerned about the long-term viability of oyster populations. In the Guana Tolomato Matanzas (GTM) National Estuarine Research Reserve, water quality issues have caused some areas to close to harvesting, potentially intensifying harvesting pressure on remaining open areas. Other factors, such as predation, disease, and increased salinity, can also slow growth or kill oysters. This complicated situation led stakeholders and reserve staff to establish the GTM Oyster Water Quality Task Force and initiate new research efforts, such as this project.

By incorporating input from end users and leveraging recently collected field data and an existing oyster population model, this project catalyzed the application of current research to address questions identified by the task force. The project team conducted a modeling investigation to examine the influence of environmental factors on oysters and examine oyster population dynamics in different zones within the reserve. Modeling results identified areas with higher oyster reproduction, survival, and growth, which can be used to focus protection and restoration efforts in areas likely to have the most impact for bolstering local oyster populations.

Project Approach

Environmental conditions and oyster reef communities in the estuary vary significantly due to differences in freshwater inflow, tidal range, residence time, and harvest pressure. The project used a population dynamics model to assess the relative influence of different demographic factors on oyster population. The team adapted an existing size-structure projection model (Integral Projection Model) for oyster populations in Apalachicola Bay, Florida, using locally specific data on oyster growth, natural mortality, predation, and environmental data. Data were drawn from ongoing Guana Tolomato Matanzas Reserve oyster reef surveys, and new field data were collected as part of a National Science Foundation grant.

The project team then conducted a sensitivity analysis to estimate the relative impact of environmental factors and harvesting on reproduction and oyster reef growth in different regions of the estuary (Figure 1). Patterns of larval connectivity for oyster re-seeding in the estuary remain unknown, so the team estimated oysters' total lifetime reproductive output (eggs per recruit) to identify highly productive and resilient areas that would make good candidates for conservation or restoration.

Throughout the project, the team met regularly with end users and stakeholders who provided feedback on the development of the model and analysis of its results. At the close of the project, an end-user workshop trained Guana Tolomato Matanzas Reserve staff and Oyster Water Quality Task Force members on the model's use for future management applications.

Results

Modeling analyses revealed several trends in oyster population growth and mortality, which help answer the following key research questions:

How do oyster populations differ in growth, mortality, and sustainability within the estuary?
The project's findings showed that both oyster growth and mortality varied greatly by region within the reserve (Figure 2). In general, oysters grew to larger sizes and their survival and reproductive output (number of eggs per recruit) were higher in zones near the inlet (St. Augustine, Salt Run, and Butler). Oysters in the upstream reaches of the estuary were smaller (under the legal harvest size limit), had higher mortality, and lower reproductive output.

What is driving differences in oyster population sustainability?
The sensitivity analysis revealed an unexpected trend—areas with higher salinity showed higher growth—but further investigation is needed to tease out other potential factors that might be driving that trend. This study did not find any other clear relationships between abiotic factors and oyster mortality, but it's likely that food availability was a factor.

By comparing caged and uncaged oysters, the project team found that predation on the oysters was particularly high near the estuary inlet and during the early stages of the oyster's growth. Spatial differences in predators that target juvenile oysters, including mud crabs and crown conchs, may be driving the observed differences in oyster survival. Those predators seem to be least active in the St. Augustine area, which helps explain that area's particularly high reproductive output.

Where are good target locations for restoration?
These results can inform restoration by helping to locate high reproduction, high resilience areas of the reserve where restoration actions could have the most impact. Project analyses identified only four sites in the estuary where oysters are expected to typically survive to harvestable size: St. Augustine, Salt Run, Butler, and Matanzas River. Modeling of productivity (by estimating the eggs per oyster) found restoration or preservation activities in the St. Augustine and Salt Run zones have the greatest potential for success and positive impact.

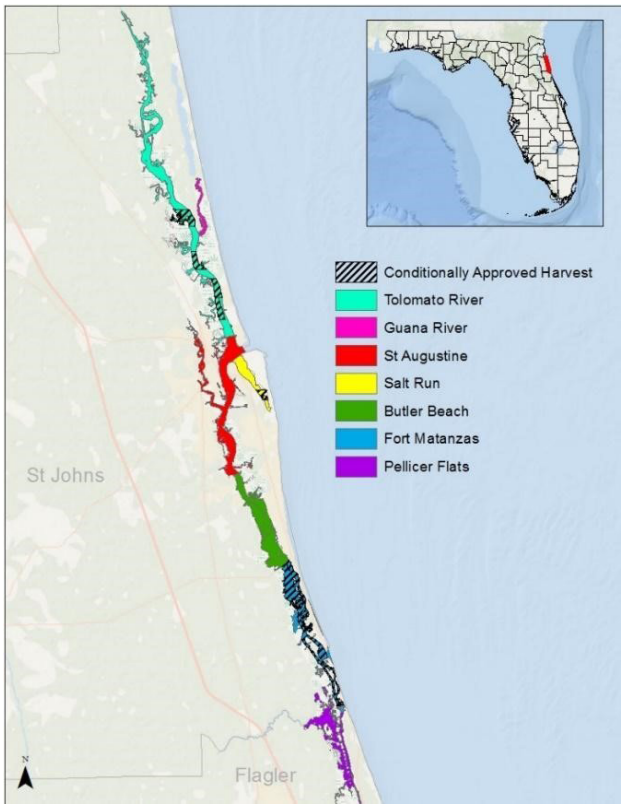

Figure 1. Map of oyster monitoring zones within Guana Tolomato Matanzas Reserve, Florida.

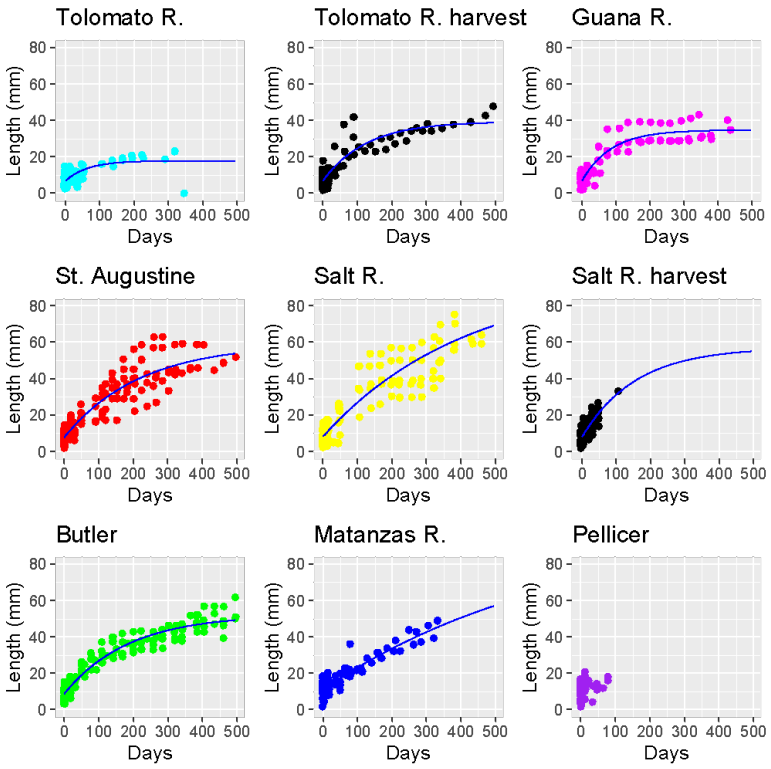

Figure 2. Growth of outplanted oysters in each zone over 500 days (beginning in July 2018). Each point represents the measurement of an experimental oyster at one sample date. Blue curves are fits of the nonlinear von Bertalanffy growth function. Colors correspond to zones in Figure 1.

Benefits

- Reserve staff improved their understanding of oyster population dynamics and gained a new modeling tool to support science-based decision-making for monitoring, restoration, education, and harvesting at the reserve.
- The project's finding of wide variation in growth and mortality across the estuary brought to light the need for more fine-scale spatial estimates of oyster populations to inform future planning. This is a departure from previous assumptions that a single estimate of oyster growth or mortality could be applied to an entire estuary or biogeographic region, and has implications for monitoring programs.
- Engagement with the project enhanced communication and collaboration with the Oyster Water Quality Task Force and coastal managers in northeast Florida. Project findings helped define areas for future research and helped catalyze a new research project on nutrient budgets and bivalves in the Guana River.

What's Next

- The project team continues to engage with reserve staff to use newly developed modeling tools to identify variables most important to monitor to assess long-term sustainability of oyster populations.
- Researchers will use the model to compare results from Guana Tolomato Matanzas and Apalachicola National Estuarine Research Reserves to describe variations between the two estuaries.
- New population genetics research is planned to provide more information on connectivity patterns and larval transport, which will allow for further spatial oyster management at the reserve.

Eastern oysters at Guana Tolomato Matanzas Reserve form beds in the intertidal areas. Healthy oyster populations provide many benefits, including supporting a fishery, preventing erosion and improving water quality. Photo credit: Nikki Dix

About the Science Collaborative

The National Estuarine Research Reserve System's Science Collaborative supports collaborative research that addresses coastal management problems important to the reserves. The Science Collaborative is managed by the University of Michigan's Water Center through a cooperative agreement with the National Oceanic and Atmospheric Administration (NOAA). Funding for the research reserves and this program comes from NOAA. Learn more at nerrssciencecollaborative.org or coast.noaa.gov/nerrs.