

PROJECT INFORMATION

Project Director's Name*	Bryan Piazza
Organization*	The Nature Conservancy
Project Title*	OysterFlows: Using science and data visualization to evaluate freshwater impacts to oysters in the Gulf
Reporting Period*	May 1, 2020 - April 30, 2023

Note to Grantees: In sections 1 to 5, we ask you to highlight your accomplishments (including outputs and outcomes) through this grant award. These sections of the final grant report will be made available to the public.

1. GOALS AND ACCOMPLISHMENTS

1.1 Please restate the goals and objectives of your project.*

The overall goal of this project is to deliver a science-based decision support tool that allows you to consider how upstream water use and management decisions and climate change are likely to affect both naturally-occurring and restored oyster reefs along the Gulf coast. Specifically, we propose to expand and improve the first-generation OysterFlows app by 1) Identifying additional GOM basins for tool development using a desktop analysis approach that considers need and opportunity, oyster extent and condition, previous and future investments in oyster restoration, flow model availability, and likely climate-change impacts; 2) Updating the OysterFlows framework by adding the ability to incorporate downscaled climate models, future water use, and coastal hydrodynamic modeling results; and 3) Expanding the improved OysterFlows app to at least three additional basins (as prioritized in objective 1).

1.2 Describe the accomplishments of your project. You should include both the anticipated accomplishments that you outlined in your project proposal as well as any *unanticipated* accomplishments that have since occurred. Describe any activities you have conducted, programmatic progress made, or project benchmarks and milestones met.*

We held a project kick-off meeting (Zoom) on October 8, 2020.

Objective 1: Identifying and prioritizing areas of the Gulf of Mexico for OysterFlows app development in partnership with a Technical Advisory Committee

Task 1.1 Desktop Analysis to Prioritize Basins/Bays for OysterFlows App expansion

This task was completed on March 18, 2021.

Task 1.2 Technical review of selection methods and priority Basins/Bays and formation of the Technical Advisory Committee. The project team worked together on the selection methods, so final review of basin selection methods (above) was done upon selection of new basins. Outreach began to stakeholders in the Calcasieu and Sabine Basins in February, 2021 and in the Pearl, Wolf, and Jourdan basins in the third week of March 2021, and a stakeholder review board was assembled in Mississippi during the final week of March. The project team met with stakeholders in Calcasieu/Sabine basins on

April 15, 2021. The first Technical Advisory Group meeting was held on December 6, 2021. Meeting participants: 1) reviewed project goals and timelines; reviewed Technical Advisory Committee roles and responsibilities; and 3) reviewed the statistical methods and data inputs, results for each basin, decision points for final models, and potential to evaluate management scenarios through the models. The TAG includes members from Louisiana State University, Louisiana Sea Grant, Texas Parks and Wildlife, The Nature Conservancy (TX and LA), Mississippi Department of Marine Resources, and Mississippi State University.

The next TAG meeting was held in summer 2022 (August) to review model/analysis results and provide input on the OysterFlows tool.

The Sabine/Calcasieu Basins End User Group (stakeholder advisory committee) met on December 7, 2021 and the Mississippi Sound Basin End User Group met on December 8, 2021. The purpose of the meetings was to: 1) review project goals and timelines; 2) review end user group roles and responsibilities; and 3) provide feedback and suggestions on management scenarios and tool application. They also provided potential management scenarios to be evaluated in the region, connections to other work, and others that were missing from our current list. During these meetings we also began to discuss the preferred objectives for the application interface, as an introduction to interface design.

This topic was visited again more intensively during the next round of EUG meetings, which took place in summer 2022 (August).

The Calcasieu/Sabine EUG has members from Louisiana Department of Wildlife and Fisheries, Cameron Parish Port, Harbor & Terminal District, Louisiana Sea Grant, Tommy's Seafood, Texas Parks and Wildlife Department, Community Foundation Southwest Louisiana, National Weather Service, and TNC Texas.

The Mississippi Sound EUG has members from Healthy Gulf, Mississippi Commercial Fisheries United, Mississippi Department of Marine Resources, Mississippi State University, The Nature Conservancy (MS), Crystal Seas Oysters, Pearl River Basin Keeper
Mississippi Department of Environmental Quality, Mississippi Alabama Sea Grant, and Mississippi Wildlife Federation.

Task 1.2. New basin selection was completed on March 17, 2021, and those basins were reviewed and finalized on March 18, 2021 in a project team meeting. Mississippi Sound was chosen as it contains the Pearl, Wolf and Jourdan river basins and its oysters are affected by openings of the Bonnet Carre floodway during Mississippi River floods. We also chose the Pascagoula basin as a "reference" basin, as it is a healthy river/bay system.

Objective 2: Update the OysterFlows framework by adding the ability to incorporate downscaled climate models and coastal hydrodynamic modeling results

Task 2.1 Update OysterFlows Data for Existing Basins

The data collection and formatting has been completed for the existing basins. Data collection included additional observed parameters that may be explored under Task 2.3 when models for all selected basins are revisited/created. Data collection for the updated OysterFlows Application covered five regions: Calcasieu, Sabine, Pearl (Lake Borgne), Pascagoula Bay, and Bay St. Louis. Available data were obtained from open-source websites (the Coastwide Reference Monitoring System, Texas Water Development Board, and United States Geological Society), which provided information on: Water Temperature (°C), Ambient Temperature (°C), Specific Conductance (uS/cm), Salinity (ppt), Gage height (ft), and Precipitation (cm). Also included in the data exploration were variables representing recent releases from Bonnet Carre (for the Pearl watershed). Additionally, wind speed and direction data were collected from the National Centers for Environmental Information website. Finally, WaterFALL™ (<https://waterfall.rti.org/>) modeled flows were included to examine the relationships between streamflow and receiving waters in their contributing watersheds.

Gathered data were preprocessed by (1) converting into standard units (2) transforming all data to a consistent timestep (e.g. daily), and (3) handling of missing values. Data exploration was performed by looking at the relationship between the target (salinity) and additional variables available in close proximity to the site being modeled. Exploration revealed that the natural logarithm of the modeled streamflow tended to be the strongest predictor of salinity at each site modeled, although auxiliary variables were beneficial at improving model fit.

Task 2.2 Obtain Data for New Basins and Climate Projections

This task is complete. In addition to data collected under Task 2.1, WaterFALL streamflow models were developed for four new watersheds: the Wolf, Jourdan, Biloxi, and Tchoutacabouffa Rivers. For each new watershed, daily gridded precipitation and temperature time series were acquired from the PRISM climate group. Streamflow models were calibrated at two USGS stream gages, with parameters distributed regionally to ungauged portions of the basins. Baseline hydrologic models are complete for the four new watersheds, plus the five previously-modeled watersheds. For modeling future climate, downscaled CMIP5 temperature and precipitation projections have been acquired in each watershed. Climate change impacts are being modeled by re-simulating historic conditions with a set of seasonal “adjustment factors” that proportionately scale magnitude of rainfall events and directly increase temperature values. These factors are derived from a method for modeling future climate conditions in the Louisiana 2017 and upcoming 2023 Coastal Resource Master Plan.

Task 2.3 Model Runs and Statistical Analysis. This task is complete. Final model runs, incorporating the final climate projections (Task 2.2) and the statistical analysis (detailed below) are expected were completed in spring 2022.

Statistical analysis: Using R statistical software, various models were tested in their suitability to predict salinity given available data at the target sites. A variety of linear regression models, polynomial regression models, and autoregressive models were explored. The exploration confirmed that a linear regression model of salinity versus downstream flow, where the flow variable was first log-transformed, provided a capable and parsimonious fit.

Performance metrics from this Linear-Log model show that the residuals exhibit a symmetrical distribution centered near zero, which is desirable. Low standard errors as well as very small $\Pr(>|t|)$ coefficients, confirmed the suitability of the chosen predictor variables for each model. K-fold cross-validation was applied to ensure a thorough analysis independent of training vs validation data. The use of k-fold cross-validation techniques prevents the model from overfitting or selection bias, by using different portions of the data to train and test on subsequent iterations. With this train-test split (or “folding”) process, the order of the values is preserved, which is necessary for temporally dependent datasets (i.e., data cannot be randomly shuffled). The timeseries is split at different points along the timeseries, a process which is repeated k times (here $k=5$). Draft functions in R include an “flow-reduce” argument, which allow users to see how predictions (aggregated by month) may change compared to observed an optimal salinity ranges for oyster health.

Objective 3: Develop the Next-Generation OysterFlows App for Five River Basins, including the Sabine and Calcasieu River Basins

Task 3.1 Developing the Improved OysterFlows User Interface in Partnership with Both Upstream and Coastal End-

Users.

This task has been started. In summer 2022 (August), we began talking with the EUGs about desired objectives for the tool and design parameters. We also began the back-end design by using completed modeling to develop the data products and workflow process and document that will determine how datasets, look-up tables, and web services will be used and integrated to facilitate the front-end (user interface) capability of the app (i.e., the buttons, etc. pushed by the user). The TAG and EUGs also provided information on what type of management scenarios/desired functionality they desired at meetings in summer 2022. During these meetings it was apparent that the stakeholders really want more of an educational tool than a management tool. This is explained in a later question and highlighted in the new scope of work for our new agreement (see below).

We met with the developers to provide the overview of modeling output style and potential "knobs" that can be turned (e.g., see <https://tnc.box.com/s/7r056zlyi63aqi05pbuunithl9vmuj3>) in spring 2022 ahead of the stakeholder meetings. We also met with developers after the meeting in summer 2022 to discuss the desires of the stakeholders and different options for conveying information in the tool.

Task 3.2 Training and Beta-testing

This task has not been started.

Task 3.3 OysterFlows App launch

This task has not been started.

Note that we submitted our NCE request late and, after discussions with NAS GRP staff, are entering into a new 6-month agreement (in-lieu of a NCE) to finish Task 3.1, 3.2, 3.3. Therefore, we have not reported on those tasks. Also note that all data and information products from the entire project (this grant and new grant) will be submitted at the end of the new grant. This is because those data and information products will change with final model runs and the inclusion of files for coding and launching the webapp. Discussion of the design of those tasks is included in this report.

2. Outputs

Before the form is completed, you may click "Save & Continue Editing" at the bottom of the page at any time to save your work or "Next" to move onto the next page of this form.

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** denotes required fields*

2. OUTPUTS

Outputs are tangible or measurable deliverables, products, data, or publications produced during the project period.

2.1. Please indicate the number of students (K-12, undergraduate, or graduate), postdoctoral scholars, citizen scientists, or other trainees involved in the project. *

Please enter 0 if none were involved.

K-12 students	0
Undergraduate students	0
Graduate students	0
Postdoctoral scholars	0
Citizen Scientists	0
Other Trainees	0

2.2. Has your project generated any data and/or information products? *

Generation of data includes transformations of existing data sets and generation of data from existing resources (e.g., maps and images). Information products include publications, models, software, code, curricula, and digital resources.

(Check all that apply.)

Responses Selected:

None

2.3. Briefly describe how you fulfilled the approved Data Management Plan and, if applicable, any changes from the approved plan. *

As stated above, we are moving into a new 6-month agreement. Because one of our tasks in this grant is to re-run the model one last time (updated through WY2022), it will change the data products that we would submit to close out this grant (current data management plan). Therefore, all of the data and information management tasks for this grant and the new grant will be uploaded at the end of the new grant. To do this, I added an additional task, called Data and Information Management, to the new work plan and will upload all data and information from both grants (as now the app data and information products are transferred to the new grant) in the last month on the new 6-month timeline.

2.4. Aside from data and information products, what other tangible or measurable deliverables or products (e.g., workshops, trainings, and outreach events) were produced during the project period? *

Upon completion of this form, you may upload supplemental material that represent the tangible or measurable deliverables or products to complement this narrative report.

We held online workshops for stakeholders - both the Technical Advisory Groups (TAG) and the End User Group (EUG) for both the Sabine/Calcasieu and Mississippi Sound areas.

5. Project Outcomes

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5. PROJECT OUTCOMES

Outcomes refer to the **impact(s), consequence(s), result(s), or effect(s)** that occur from carrying out the activities or outputs of the project. Outcomes may be environmental, behavioral, health-related, or programmatic. Example outcomes include, but are not limited to: increased learning, knowledge, skills, and motivation; policy changes; actions taken by a group as a result of information generated by your project.

5.1. Please describe the outcomes achieved during your project and how they were assessed. For this question, we are interested in learning about the immediate short-term outcomes that have already occurred during or as a result of your project. Do not include long-term outcomes you foresee your work contributing to beyond the end of the project. *

Because we haven't created the web app tool yet, I will highlight some noteworthy outcomes from our modeling and analysis tasks. We brought together a variety of researchers from other universities (e.g. University of Southern Mississippi, Louisiana State University) and agencies (Louisiana Coastal Protection and Restoration Authority, USGS Cooperative Fish and Wildlife Research Unit) to share ideas, information, and data to make our project even better than we scoped it. For example, we wanted to make our climate projections comparable to those used for Louisiana's coastal restoration program. So we partnered with a modeler from Louisiana CPRA to improve the CMIP5 projections with downscaled data used by CPRA. We also partnered with researcher from LSU and USGS to use new estimates of oyster mortality at different salinity gage readings. These are the first of their kind data, and we have partly incorporated them into our analysis. These partnerships will go on after this project, as we learn how to make better water management information available.

Brought together a variety of researchers from other grants and universities that were brought together USM, LSU, Coop Unit to share information and data.

5.2. We're interested in hearing not just the results of your project but what are their implications for or contributions to:

- offshore energy system safety,
- environmental protection and stewardship, and/or
- health and community resilience

Please describe what you consider to be the most remarkable accomplishment or finding of your project. What can others learn from your accomplishment and finding? How do you see it fitting in with your greater field of study or community of practice? *

We confirmed our hypothesis that we could use modeled hydrologic estimates to predict oyster health in the estuaries of Louisiana and Mississippi. Also, we confirmed that climate change will impact those relationships and the distribution of oysters and the success of oyster reef restoration in the future.

We determined that the best thing to put forward was not a tool to manipulate hydrology, but rather an educational tool. We learned that the level of education is not high enough, and the real value in this modeling is to provide information to show people the effects of climate and water use on oysters.

6. Communication

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Note to Grantees: In Section 6, we seek input from you to help us evaluate the Gulf Research Program's funding strategy. This section will not be made available to the public.

6. Information to Inform GRP Evaluations

6.1. Sharing the difficulties you encountered helps us learn from your experience. Describe any challenges you encountered in your project and how you addressed or overcame them. Challenges are inherent to conducting any complex project. These may include (but are not limited to): unexpected staffing changes, changes in the community you are working in, appearance of a new technology or dataset in the field you are working in, challenges accessing a field site, policy or regulatory changes that affect the issue you are addressing, low recruitment rates, delays in setting up services, or other problems in implementing and conducting your project. *

The first and biggest challenge was the Covid 19 pandemic. This project kicked off right in the beginning of the Covid pandemic, and as I have stated in my 12-month and 24-month reports, Covid affected our team in a number of ways, leading to a six month delay in starting the project. We have faced multiple timing and schedule challenges during year 1. For example, all project team members (TNC and RTI contractor) were working from home during the first year of this project. Many of us have small children and have faced varied and often changing levels of virtual and homeschooling responsibilities throughout the reporting period. Next, Covid-19 created multiple delays in finishing other projects, which needed to be completed and delivered by project team members before work on this project could begin. This backup phenomenon especially influenced one of the co-PIs and her ability to start and complete Objective 1, Task 1.1 of this project. Finally, TNC was forced into an organization-wide budget reduction due to anticipated effects of Covid-19 on the US economy. This budget reduction resulted in widespread hour reductions, mandatory leave use, and temporary furloughs necessary to retain as many TNC staff members as possible through the economic recession. These budget reduction actions affected four members of project team, further influencing our ability to get this project moving according to the original schedule. That delay carried through the entire project period.

Next, we found the stakeholder engagement to be different than we expected, and it was challenging to elicit what they wanted in a tool. Specifically, we thought they'd want more than they did. We thought that they would want a management tool that they could use to actually assess flows against oyster habitats. However, this is not what they wanted. They actually want educational tools to show the impacts of changes in river flows and river management on oyster populations and oyster harvest zones.

Finally, during the final months of the project, we found new information (data, publications, etc.) that pointed to new, actual thresholds of oyster mortality linked to salinity regimes. This information bolsters the Chatry-Dugas curve and is more relevant with respect to climate impacts already manifesting themselves in our estuaries. This new information is terrific, but it arrived too late for us to really use it fully. We did as much as we could with the new information, but we think these new data sources would have made the modeling more robust.

6.2. We like to hear about what you learned from your work and how you feel it affects future work or the work of others. Think back on your project strategies, methods, and activities, what worked and what did not? Is there anything you would do differently in the future? If so, tell us what and why. *

First, we learned about new data that quantified actual mortality rates of oysters subjected to pulses of high and low saline water. These data did not exist prior to the beginning of this project, and they enhanced our modeling to the extent that we could incorporate them into the analysis. We only learned of these data during the Restore America's Estuaries 2022 conference, very near the end of the project period. Therefore, we were not able to use them to the extent that we wanted to, because of time. However, we were able to use them to some extent, and they made our estimates better.

Second, we learned of and applied the climate data downscaling method that the Louisiana Coastal Protection and Restoration Authority uses for the Louisiana Coastal Master Plan. Therefore, we were able to build off the climate assessments used in the Louisiana Coastal Master Plan and also get the projected future Mississippi River flows data used in the master plan. making our future freshwater inflow estimates usable for regionwide coastal planning.

Third, we learned that the stakeholders were not where we thought they'd be in terms of their knowledge and desire for how they would use the tool. Through our Technical Advisory Group meetings and End User Group meetings, we found out that stakeholders didn't really want a tool where users could control flows. Rather, they were more interested in an approach that educated about the effects of climate change and provided illustration of the differences in where oysters could thrive currently and with climate change. Because of that input, we changed the scope of what the tool will do, as we develop it during the next phase of this project (new 6-month agreement). This type of learning was a desired effect of the outreach objective, so we are happy that we were able to do more extensive outreach remotely, due to Covid. The video format was conducive to this discussion, because we were able to provide documents, etc. up on the screen and engage more people simultaneously.

6.3. What are the next steps for this work, either for you and your project team or other researchers? Has this project led to other opportunities to work in this area? *

We needed another 6 months to complete the full project, due to delays caused by the Covid-19 pandemic. The PI did not file the no-cost extension materials early enough, so NAS, GRP agreed to do another agreement for 6-months to develop and publish the OysterFlows web app. We hope that our analysis and this work will be used to cite oyster reef restoration projects in coastal Louisiana and Mississippi, and we would like to extend this work to other US Gulf Coast estuaries.

6.4. Have you developed new collaborations or partnerships (formal or informal) as a result of this work? If yes, please describe the new collaborations or partnerships. *

Yes, we have developed a collaboration with Dr. Megan LaPeyre's lab (USGS Cooperative Fish and Wildlife Research Unit, LSU to integrate the new data on oyster mortality into the modeling. Currently, Megan's estimates are made with static salinity observations at the closest salinity monitoring station. By integrating her data into the model, we can expand the range of the relationships to areas that are currently unmonitored.

We have also developed a partnership with the Louisiana Coastal Protection and Restoration Authority, where we worked together on the climate methodology so that our analysis is comparable to the other modeling analyses done for the Louisiana Coastal Master Plan.

6.5. What, if any, positive changes in policy or practice do you foresee as a result of your work? *

We hope that this work and our next 6-month grant will produce information that will benefit oyster restoration in Louisiana and Mississippi. We'd like to expand this work to more estuaries along the Gulf Coast.

6.6. If you could make one recommendation to the Gulf Research Program for how best to build on the work you conducted in this project, what would it be? *

It would be beneficial to expand this work to all major rivers in the Gulf with oyster resources. That way this analysis could be integrated into NOAA's gulfwide oyster planning, NRDA/RESTORE planning, etc., as well as other conservation and restoration efforts (e.g., restoration led by The Nature Conservancy).

7. Communication and Dissemination

Before the form is completed, you may click "Save & Continue Editing" at the bottom of the page at any time to save your work or "Next" to move onto the next page of this form.

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Note to Grantees: In Section 7, we ask you to help us communicate the importance, progress, and accomplishments of your work. Information provided in this section will be used by the Gulf Research Program to highlight its funded projects in print and electronic informational and promotional materials. The intended audience for the information provided in this section is different and should be thought of as a general audience. When you return to the dashboard, you may upload images that represent and illustrate the work of your project.

7.1. Please describe the most exciting or surprising thing you have learned while working on this project in a way that is understandable by a general audience. *

We learned (during Restore America's Estuaries, 2022) that there are brand new data that quantify the effects of both low and high salinity events on oyster health and mortality. These data were not available when we started the project and only became available a few months prior to the end of the grant. We were able to work with the scientist that had those data (Dr. Megan LaPeyre) to incorporate some of those data into the modeling, and that incorporation made the relationships between flow and oyster health stronger.

7.2. Do you have any stories that capture the impact of this project? (optional)

If so, please share one or two. Examples of what we are interested in include stories of people/communities that the project has helped; lives that have changed; work that led to policy change, such as legislation or regulation; and research breakthroughs.

Because we will be finishing the OysterFlows tool in a new agreement, we don't have any stories yet.

7.3. Have any communications, outreach, or dissemination activities occurred in relation to your project?*

Please describe:

- Any press releases issued (other than that issued by the National Academies of Sciences, Engineering, and Medicine) about the project.
- Any media coverage or news stories about the project.
- Any social media accounts, websites, listservs, or other communication vehicles used to communicate information about this project. Please include relevant web addresses if available.

There were two stories written about the project. One is for the TNC website, and the other was for [NOLA.com](http://www.nola.com).

Websites below.

<https://www.nature.org/en-us/about-us/where-we-work/priority-landscapes/gulf-of-mexico/stories-in-the-gulf-of-mexico/oysterflows/>

https://www.nola.com/news/environment/new-tool-to-help-manage-gulf-of-mexico-oysters-on-the-way-thanks-to-a/article_ad9bb508-28ed-11eb-96b6-ef5f2e687f83.html