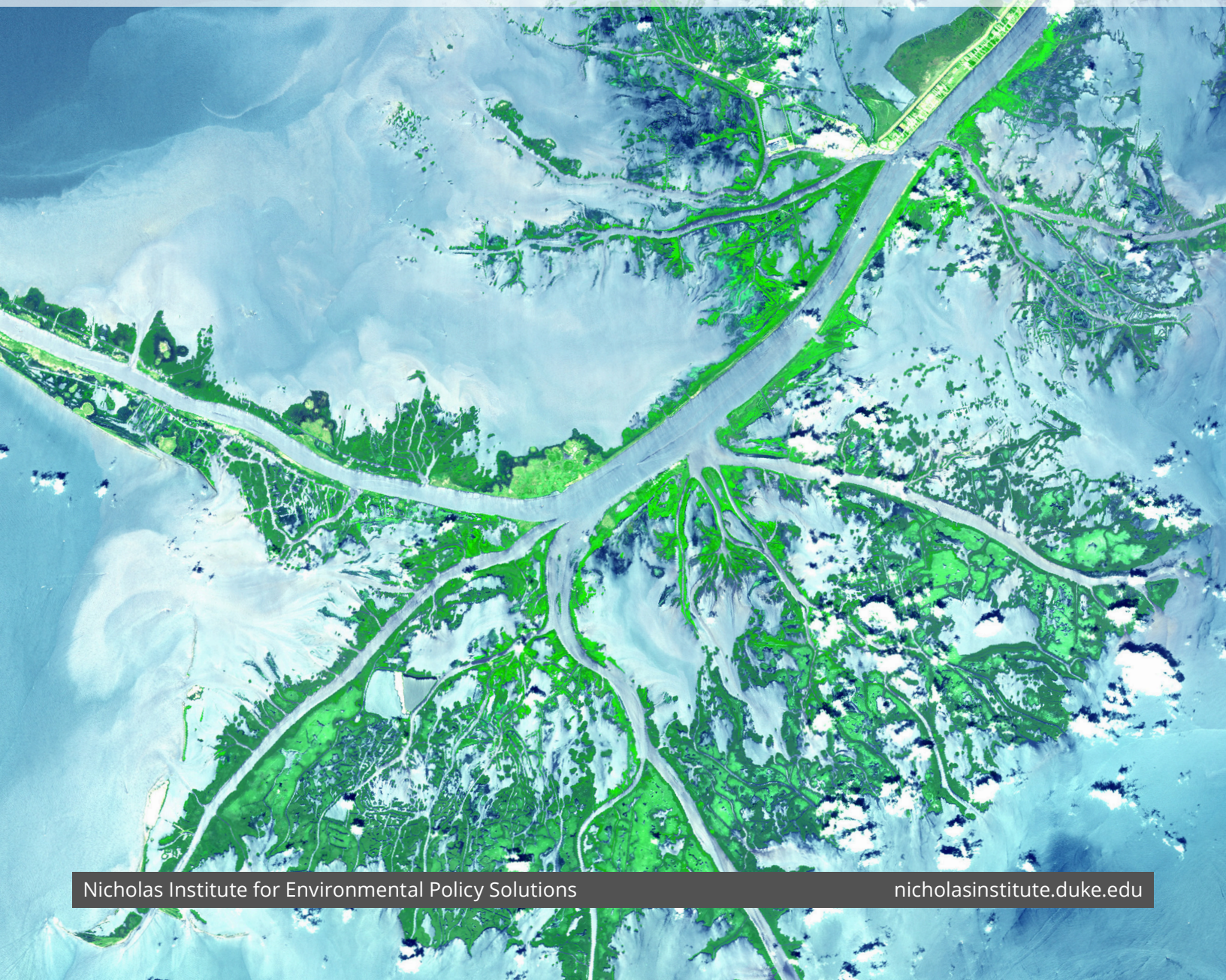
Duke
NICHOLAS INSTITUTE
FOR ENVIRONMENTAL POLICY SOLUTIONS

Gulf of Mexico Ecosystem Service Logic Models and Socio-Economic Indicators (GEMS)

GEMS PHASE II REPORT: COASTAL RESTORATION

Lydia Olander, Christine Shepard, Heather Tallis, David Yoskowitz, Kara Coffey, Chris Hale, Rachel Karasik, Sara Mason, and Katie Warnell



Nicholas Institute for Environmental Policy Solutions nicholasinstitute.duke.edu

Gulf of Mexico Ecosystem Service Logic Models and Socio-Economic Indicators (GEMS)

GEMS PHASE II REPORT: COASTAL RESTORATION

CONTENTS

BRIDGE COLLABORATIVE

The Nature Conservancy

TEXAS A&M UNIVERSITY CORPUS CHRISTI | HARTE RESEARCH INSTITUTE FOR GULF OF MEXICO STUDIES

Duke NICHOLAS INSTITUTE

National Ecosystem Services PARTNERSHIP

INTRODUCTION

Project Background

Billions of dollars will be spent on large-scale restoration of Gulf ecosystems over the coming decades, but there is currently no shared platform to guide assessment and reporting of restoration progress and effectiveness for the broad set of environmental, social, and economic goals shared by the many institutions working in the Gulf. The diversity of these goals—including habitat restoration, water quality improvement, marine resource protection, community resilience, and economic revitalization—means that a variety of metrics are needed to fully evaluate the effectiveness of coastal projects funded with restoration dollars. A set of common models and metrics relevant across projects, programs, and locations can facilitate effective project planning and evaluation.

Duke University's Nicholas Institute for Environmental Policy Solutions, The Harte Research Institute, and The Nature Conservancy, with support from the National Academies' Gulf Research Program, are leading a project to advance standardized metrics of restoration success by developing ecosystem service logic models (ESLMs) with stakeholders from the five Gulf states, relevant federal agencies, and technical experts. ESLMs trace the effects of restoration strategies as they influence ecological and social systems to create outcomes that are important to people. The use of logic models is recommended by the National Academies of Science as a best practice for monitoring plan design; these models can provide a practical and transferable approach for measuring success at different scales.

Numerous strategies for coastal restoration exist, and there are many places along the Gulf coast where restoration can be implemented. ESLMs are a great

tool to compare across restoration strategies and locations to match likely restoration outcomes with stakeholder goals. In addition, evidence that accompanies these models can be used to clarify uncertainties that need to be considered and to identify critical research gaps.

This project is a case study of the Bridge Collaborative, a global coalition of scientists, practitioners, and organizations rapidly moving beyond business as usual to create a more equitable and sustainable world. It will be used to test Bridge guidance on logic models and evidence evaluation as tools to advance cross-sector impact.

Project Phases

The GEMS project was conducted in two phases. Phase I focused on understanding the various types of oyster reef restoration occurring in the Gulf and how those projects contribute to social and economic well-being. Phase II builds on the approach developed in Phase I and applies it to a broad spectrum of coastal projects receiving restoration dollars—including other habitat restoration, hydrological reconnection, recreational enhancement, and water quality improvement projects—currently being used or planned across the five U.S. states along the Gulf of Mexico. An advisory council with representatives from state and federal governments, funders, and critical partners provided insight on the selection of restoration approaches that were included. Both phases involved engagement of restoration experts and practitioners, conversations with a broad suite of stakeholders, and in-person workshops at local and regional scales.

PHASE II PROCESS

Phase II Summary

In Phase II of the GEMS project we identified metrics available to monitor the social and economic outcomes of a wide variety of coastal projects funded in the Gulf. To do this, we built ecosystem service logic models (ESLMs) illustrating how these projects' impacts cascade through the biophysical system to result in social and economic outcomes. ESLMs were built through an iterative process including literature review and expert consultation. We then hosted in-person and virtual workshops to brainstorm and select feasible metrics for measuring relevant social and economic outcomes included in the Phase II ESLMs.

Project Types Considered for the GEMS Project Phase II

For Phase II of the GEMS project we expanded our focus to assess socioeconomic metrics for 16 coastal project types, including habitat restoration, recreational enhancement, and water quality improvement projects (Table 1). Not all these project types fall into the category of "restoration" in the strictest sense (e.g., installing baffle boxes for outflow treatment), however, all projects considered for Phase II are being funded by restoration dollars in the Gulf.

Table 1. Project types included in GEMS Phase II

Project Categories	Project Types (all projects are linked to a page with more info)	Description of Project and Techniques Used in the Gulf
Habitat restoration	Salt marsh restoration	Constructing dikes to isolate an area and pumping in sediment, planting new native vegetation, or creating river diversions. These interventions typically create conditions for native salt marsh vegetation to reestablish. Planting new vegetation kickstarts this process and provides a layer of redundancy when paired with one of the other restoration actions.
	Sea grass restoration	Transplanting seagrass into restoration sites (very common), seeding seagrass (less common, newer technique), and modifying sediment to facilitate seagrass growth (usually used in combination with transplanting or seeding). Many projects are done to mitigate seagrass loss due to development, as required by the Clean Water Act. Some projects attempt to benefit seagrass by addressing water quality issues.
	Mangrove restoration	Techniques primarily consist of restoring site conditions to those that are conducive to mangrove growth and waiting for mangrove propagules to colonize the site. Activities include hydrological restoration (to restore proper tidal flow, freshwater inputs, and salinity levels) and restoring sediment elevation. In some areas mangrove site creation, rather than restoration, is being performed.
	Living shoreline installation	Living shorelines are combinations of vegetation planted along a shoreline and a structure to help hold the vegetation in place. In the Gulf, the structural component of the living shoreline is usually a breakwater and can be made of a variety of materials, including bagged oyster shell, granite, eco-concrete, and reef balls or blocks.
	Beach and dune restoration	Beach restoration aims to replace sand that erodes from a beach. It is usually completed by dredging offshore sand and adding it onto the beach. Dune restoration also aims to offset sand erosion but may also include increasing dune size and resilience. There are three major types of dune stabilization techniques: importing dredged sand from offshore to build up the dune, planting grasses or other plants to secure the sand, and installing fencing along the dune on both the seaward and landward sides of the dune.
	Restoring hydrologic connectivity	Restoring hydrologic connectivity means "restoring or mimicking natural connections that have been broken or disrupted by infrastructure such as roads and levees."[1] This often involves removing barriers to flow (e.g., old flood control structures) or installing structures like culverts to enable water to flow under or around an existing barrier. These projects are often proposed with the goal of benefiting declining marsh or seagrass habitats, with the added benefit of fish passage and habitat creation.

1. As defined by the RESTORE Council: https://restorethegulf.gov/sites/default/files/Restore%20Hydrology%20FS%20042619.pdf.

Project Categories	Project Types (all projects are linked to a page with more info)	Description of Project and Techniques Used in the Gulf
Recreational enhancement	Boat ramp installation/ repair	Typically boat ramp projects entail either repairing existing boat ramps or constructing new boat ramps and are meant to increase access to public waterways, offshore areas, and inaccessible campgrounds.
	Fishing pier installation/ repair	There are several different ways to construct or restore/enhance the central body of the pier (e.g., different materials used), however, central to all pier construction is the installation of load-bearing piles in the benthos to anchor the main body of the pier. Successful projects improve accessibility to the waterfront, facilitating increased coastal-based anthropogenic activity in the areas around the pier.
	Trail and boardwalk installation/ repair	Specific techniques for trail and boardwalk projects are generally site specific and can vary in installation processes and materials used. Trails are generally installed on raised ground, while boardwalk installation is required for access over wet or marshy areas and therefore consist of raised platforms, requiring the installation of footings into the substrate.
Water quality infrastructure improvement: Wastewater management	Sewage system improvements	Sewage system improvements include two specific techniques: converting basic septic systems to either centralized sewer systems or advanced septic systems, and repairing existing sewage system components.
	Wastewater treatment plant upgrades	Wastewater treatment plants (WWTPs) are centralized systems meant to remove toxins, pathogens, organic material, and more from sewage and wastewater. Remaining water after the treatment process is known as grey water and could potentially be used for services such as crop irrigation, industrial cooling processes, and in some cases drinking water.
	Treatment wetlands installation	Treatment wetlands are engineered systems designed to replicate the structure and services provided by wetlands to perform tertiary wastewater treatment, particularly phosphorus and waterborne pathogen removal, and nitrogen transformation and removal. Treatment wetlands are often used to support traditional municipal and industrial wastewater treatment but can also be used for treatment of stormwater, aquaculture, and mine drainage.

Project Categories	Project Types (all projects are linked to a page with more info)	Description of Project and Techniques Used in the Gulf
Water quality infrastructure improvement: Stormwater management	Gray infrastructure repairs/ improvements	Gray infrastructure for stormwater management refers to a network of water retention and purification infrastructure (such as pipes, ditches, swales, culverts, and retention ponds) meant to slow the flow of stormwater during rain events to prevent flooding and reduce the amount of pollutants entering waterways. Restoration projects for gray infrastructure typically do not focus on the entire system, but rather on enhancing, repairing, removing, or installing new infrastructure in ways that will optimize the efficiency of the system.
	Green infrastructure installation	Green infrastructure for stormwater management includes a variety of methods designed to slow or retain precipitation where it falls, rather than collecting precipitation and directing it to a centralized pond or treatment system. Green infrastructure components usually complement the existing gray infrastructure stormwater system. It is common for multiple types of green infrastructure to be used in combination.
	Outflow treatment installation	Baffle boxes are infrastructure components typically found near the end of the stormwater management system, positioned at outfalls or in types of stormwater management infrastructure. Stormwater runoff enters through the boxes which capture sediment and pollutants in the storage zones.
	Agricultural best management practices	Best management practices for agriculture include a suite of management techniques intended to reduce nutrients and other pollution types from agricultural lands reaching waterways: cover crops, conservation tillage, riparian buffers, livestock exclusion from streams, and improved fertilizer management. Constructed wetlands can remove pollutants from agricultural runoff.

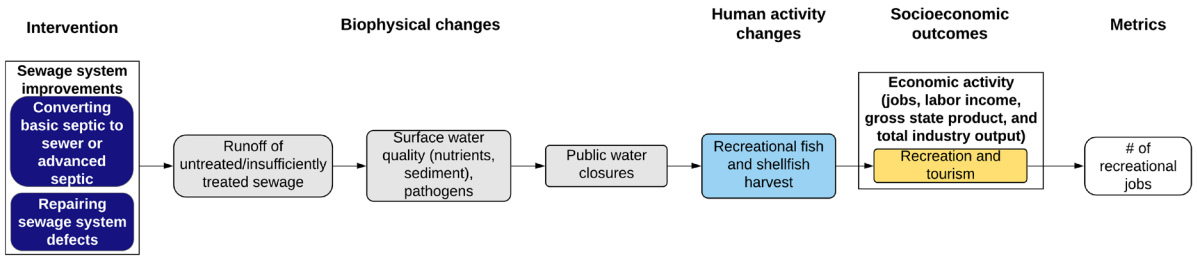
Ecosystem Service Logic Models

For every project type shown in Table 1, we created an ESLM that illustrates how the project's impacts cascade through the biophysical system to result in social and economic outcomes. Models were developed through literature review and expert consultation and were adapted based on expert, practitioner, and stakeholder input gathered at in-person and virtual workshops.

These ESLMs are housed in an online database. Users can examine static versions of the models created by the GEMS project team or link to an editable version of each model that can be adapted to a user's specific project site. Models can identify outcomes for use in proposals, to help with project/program justification, or to develop a monitoring plan. Exploring the model database by outcome is also possible: a user can determine what project types are most likely to result in outcomes of interest which will aid in selecting restoration approaches.

ESLMs show the cascade of changes that restoration (dark blue box) causes in the biophysical and ecological systems (gray boxes), which then lead to changes in human activities (light blue boxes), and socioeconomic outcomes (yellow boxes). Many of the biophysical and ecological changes (gray boxes) are critically important outcomes for projects and programs, but we assume they are already being measured and tracked.

Figure 1. Example simplified ESLM



Social and Economic Outcomes

New metrics were created based on the social and economic outcomes identified in the Phase II ESLMs (Table 2). Outcomes that also appeared in the oyster reef restoration models developed in Phase I are not included in this list, because metrics for those outcomes have already been identified. These repeated outcomes—such as shoreline protection from erosion, economic activity from commercial fish harvest, economic activity from restoration spending, economic activity from recreational fishing, and cultural values—and their associated metrics can be found in our Phase I report and in the GEMS online tool. For the outcomes that did not overlap with Phase I, we developed draft social and economic metrics for each outcome based on a literature review (Appendix B) and expert outreach. These draft metrics were then used as prompts during the workshops described in the next section.

Strong/weak links: In addition, we indicate whether an outcome has a strong or weak link to a particular project type based on expert input. If, through our evidence and expert assessment, we determined that a particular outcome was likely to have a detectable, significant change based on a particular project activity, then we categorized it as a strong link. This change might be significant only through the additive effects of multiple similar projects. A weak link between a particular restoration action and outcome indicates indicates that a change in that outcome is likely to be small and less likely to be detectable. These strong/weak categorizations can be reviewed for each project type in the GEMS online model database.

Table 2. Relevant social and economic outcomes identified from the Phase II ESLMs

Outcome category	Specific outcome
Human health	Mosquito-borne disease
	Seafood-associated disease
	Skin and respiratory effects related to toxin exposure
	Waterborne disease
	Food security for communities
	Mental health & psychological well-being
	Drownings/injuries at beaches
Water costs	Cost of freshwater
	Cost of drinking water treatment
	Cost of wastewater treatment
Infrastructure costs	Cost to local property owner
	Gray stormwater infrastructure improvement cost
	Maintenance costs
Economic activity	Economic activity from recreation and tourism activity
	Economic impacts of health-related fishery closures
	Economic impacts of health-related recreational closures
	Economic activity from local businesses
Property costs	Property damage from flooding
	Property value
Disruption	Social disruption from flooding or project construction

Workshops

Phase II workshops focused on the water quality improvement projects. Given how different these projects are from oyster reef restoration (covered in Phase I), they led to a wide range of new social and economic outcomes. There is also a non-overlapping group of experts and practitioners that work on water quality issues and water quality infrastructure.

Regional Workshop

The project team designed and facilitated an in-person workshop on March 3 and 4, 2020 hosted in Houston, Texas. Experts from across the Gulf region were invited to 1) share feedback on the restoration techniques included for water quality improvement projects, 2) give input on logic models, 3) clarify social and economic outcomes, and 3) brainstorm lists of possible metrics. Participant expertise included public health researchers, water quality researchers, restoration practitioners, environmental justice advocates, social scientists, economists, natural resource managers, and more. For a list of participants, please refer to Appendix A.

Through a series of presentations, the project team introduced the project goals and each of the draft water quality improvement logic models, and then facilitated full group discussions while notetakers captured all feedback from participants. The project team presented examples that demonstrated how socioeconomic outcomes can be linked to the restoration, and what types of metrics might be considered to evaluate those outcomes. The full group then broke out into several small groups, and facilitators asked participants in each group to suggest metrics. Participants were also asked if they were aware of existing data sets that could be used by project and program managers. Groups then considered the feasibility of implementation of the metrics into existing or new projects or programs, and if the proposed metric was able to reflect the impact of water quality restoration—what we call the attribution. All breakout group feedback was documented by the project team. After the workshop, the feedback was combined into a metrics database for further refinement.

Metrics Refinement Workshops

The project team organized a series of virtual workshops to assess the metrics suggested during the regional workshop. This effort differed from the regional workshop in that participants were asked to compare the draft metrics list against the SMARTs criteria with a particular focus on feasibility, as well as prioritize a select set of recommended metrics. Practitioners and experts that had Gulf state-level, local-level, or subject matter expertise were invited to join one of two themed

Resilience

One of the goals of coastal projects and programs in the Gulf is to build coastal and community resilience. Resilience refers to the ability to "bounce back" or recover after some kind of emergency or hazardous event. These events can include hurricanes and other coastal storms, sea level rise, and flooding. A community can be resilient in many ways, including economically, socially, or structurally. We found that facets of resilience overlap with many of the other outcomes linked to restoration we address in this project. We highlight those outcomes that our expert advisors believe represent some facet of coastal community resilience in our online tool using the letter "R." These resilience-relevant outcomes do not fully capture all the aspects of community resilience; we aim only to indicate which of our outcomes (and their associated metrics) might be used to examine certain aspects of resilience.

workshops (see full participant list in Appendix A). Participants joined either the "Health" or the "Economics and Cost" workshop series using the Webex virtual conference platform. Project team members captured all feedback from the online discussions and documented metric preferences.

Expert Consultations

The additional habitat restoration and recreational enhancement projects covered in Phase II only introduced a few new outcomes beyond those considered for the oyster reef restoration. These outcomes were: drownings/injury, maintenance costs, boat accidents, property damage from flooding, and dredging. For each of these outcomes we identified relevant experts who could help us think about what metrics (if any) were feasible to track these outcomes and then asked each expert for recommendations of others to consult. For each outcome, we consulted with at least two experts.

Social and Economic Metrics

Phase II Metrics

Using the processes of expert elicitation through workshops and one-on-one consultation described above, we refined a list of feasible social and economic metrics that could be used to monitor outcomes identified for our Phase II project types. These metrics are intended to be easily accessible and usable for practitioners, researchers, and funders. The selected metrics are organized by scale and tier and are available in Appendix C and a searchable online database.

Scale and Tier

Scale refers to the scope of the data collection. Project-scale metrics could feasibly be measured and reported by individual projects. Program-scale metrics are for cumulative, regional scale results and often need to be measured or modeled for a suite of projects by a third party. Program-scale measures can also be developed by aggregating project scale data.

Tier refers to the ease of data collection; tier 1 metrics are relatively low-effort and easy to measure, while tier 2 metrics would require additional effort and expertise for data collection and/or analysis. R&D metrics do not have fully established methods for measurement or required data needed to track them are not readily available.

Core Metrics

From the full list of socioeconomic metrics, we identified core metrics for both project and program scales (Tables 3 & 4). Core metrics are identified to provide a short list that can be used across projects to allow for consistency, comparison, and rolling up results. For metrics to be considered core, they need to be common across project types. Core metrics are metrics that are strongly linked to at least half of the project types in at least one of the four GEMS project categories (habitat restoration, oyster reef restoration, recreational enhancement, and water quality improvement).

Table 3. Project scale core GEMS metrics

Outcome	Metric	Habitat restoration (7 project types)	Oyster restoration (6 project types)	Recreational enhancement (3 project types)	Water quality improvement (7 project types)
Core metrics common across all categories and project types					
Economic activity: Restoration/intervention	Number of restoration jobs supported by project	7	6	3	7
	Restoration expenditures by project	7	6	3	7
Core metrics common across all project categories					
Economic activity: Recreation and tourism	Change in recreational activity expenditures associated with project site visitation	5	3	2	4
Human health: Mental health & psychological well-being	Change in cognitive function	5	3	3	4
	Change in subjective well-being	5	3	3	4
Additional core metrics for specific project categories					
Cultural values: Knowledge	Education-related knowledge: Number of people with additional knowledge of habitat effects and other project outcomes	6	3	2	3
	Awareness: Number of people with additional knowledge of habitat effects and other project outcomes based on project site	6	3	2	3
Cultural values: Other	Project identified cultural value	5	6	3	2
Economic activity: Recreation and tourism	Number of jobs supported through recreational fishing at project site	5	3	2	2
	Change in recreational fishing expenditures associated with project site visitation	5	3	2	2
Human health: Food security for communities	Proportion of surveyed harvesters who say that food caught/harvested at the site is important for feeding their household	4	4	3	1
Property protection	Amount of property adjacent to shoreline with reduced erosion after project	5	3	0	0
Property value	Change in property value across affected properties	3	0	3	3

Note. Numbers in the right-hand columns are the number of project types within each category to which the metric is strongly linked. Colored right-hand columns indicate that the metric is strongly linked to at least half of the project types within the category and is considered a core metric for that project category.

Table 4. Program scale core GEMS metrics

Outcome	Metric	Habitat restoration (7 project types)	Oyster restoration (6 project types)	Recreational enhancement (3 project types)	Water quality improvement (7 project types)
Common across all project types and categories					
Economic activity: Restoration/intervention	Change in economic activity from restoration spending	7	6	3	7
Additional metrics for specific project categories					
Cultural values: Knowledge	Awareness: Number of people with additional knowledge of habitat effects and other project outcomes on broader scale.	6	3	2	3
Cultural values: Other	Program-identified cultural value	5	6	3	2
Economic activity: Recreation and tourism	Change in economic activity from recreational fishing	5	3	2	2
Economic activity: Finfish/shellfish harvest	Change in economic activity from project-associated commercial fish harvest	4	3	0	2

Note. Numbers in the right-hand columns are the number of project types within each category to which the metric is strongly linked. Colored right-hand columns indicate that the metric is strongly linked to at least half of the project types within the category and is considered a core metric for that project category.

Measurement Protocols

In order to make GEMS metrics actionable, where possible we are in the process of developing measurement protocols for each tier 1 and 2 project-scale metric. These protocols are under development but will be linked in the metrics database. Protocols include descriptions of and links to measurement procedures used in other studies that may be a template for the development of measurement protocols for a user's program or project.

Equity

Where applicable, for each project-scale protocol we have included methods for assessing the access and distribution of restoration project outcomes. This type of assessment is necessary for identifying inequities in delivery of project outcomes. For the GEMS project, equity refers to the distribution of resources, support, empowerment, or other benefits in such a way that individuals or groups that are most in need receive the necessary support for attaining and maintaining well-being. Equity also includes the distribution of costs in such a way that there is not an unnecessary or disproportionate burden placed on any group, especially marginalized populations.

Additional methods around equity will help practitioners answer the following questions:

(1) Are the services provided by the intervention available to all and will they continue to be accessible?

(2) How are benefits distributed across vulnerable communities and underrepresented groups?

Program-Scale Protocols

Program-scale metrics will require larger, Gulf-wide efforts to collect and analyze data. We describe the types of protocols and analyses that will need to be developed here, but have not yet created specific measurement protocols for program-scale metrics.

PRODUCTS

The GEMS project has resulted in multiple products:

Website

The GEMS website (nicholasinstitute.duke.edu/project/gems) hosts information about the project, as well as all our products. The website is the central location where users of this information can find databases to search for our ESLMs and relevant metrics.

Phase I Report

The summary of GEMS work on oyster reef restoration can be found in a separate report that documents methods and findings of Phase I.

Other Products

The GEMS project is continuing to create and release products—check our products page for new resources.

NEXT STEPS

Implementing a standardized socioeconomic monitoring system to track project outcomes over time across the Gulf of Mexico will take additional steps after the GEMS project is completed in mid-2021. To make this system operational we propose follow up work that would move this effort forward.

(1) Pilot monitoring project-scale protocols. We have selected metrics that were deemed applicable and feasible by experts, however, they will remain untested at the end of our project. We suggest that our metrics and their associated protocols are tested on upcoming projects funded in the Gulf to determine whether they are appropriate or whether they need to be adapted and updated. It might also be possible to do some retroactive monitoring for some existing projects if the measurement protocol allows. Piloting relevant GEMS metrics will not only allow on-the-ground testing of our work

but will also facilitate the full development of more detailedmetrics protocols that can be shared with others.

(2) **Develop a Gulf-wide program scale monitoring system to assess cumulative effects.** The same data and underlying analytics are needed to understand the social and economic implications for coastal communities of an oil spill, a hurricane, a new large-scale diversion, or the cumulative impacts of coastal restoration projects. These data need to be collected and analyzed regularly, every 3–5 years, to be useful for decision makers. State and federal agencies, restoration funders, resource managers, community organizations, and nongovernmental organizations would all like to understand better how they can manage coastal resources to build community resilience and support the coastal (blue) economy. The GEMS project has outlined what these program-scale monitoring efforts might look like and what data they would need. We propose a future effort that would:

   (a) Develop credible and feasible methodologies for collecting the necessary data and conducting the underlying analysis for understanding social and economic responses to changes such as disasters or restoration projects of coastal communities at a regional scale.

   (b) Test these methodologies.

   (c) Convene a working group of key federal and state agencies and funders (e.g., SeaGrant, GRP, NFWF) to develop a plan for how to institutionalize this data collection and analysis process.

APPENDIX A. WORKSHOP PARTICIPANTS

Regional Workshop Participants

Becky Allee, GOMA/NOAA

Patrick Barnes, Barnes, Ferland and Associates (BFA) Environmental Consulting

Brie Bernik, RESTORE Council

Xiang Bi, University of Florida

Ronald Bond, University of California, Davis (Atwill Water & Foodborne Disease Lab)

Christa Court, University of Florida

Mike Donahue, AECOM

Brian Harper, US Army Corps of Engineers, Regional Planning and Environmental Center

Jennifer Harper, FL DEP

Al Hindrichs, LA DEQ

Paul Hindsley, Eckerd College

Devyani Kar, Coalition To Restore Coastal Louisiana; Environmental Defense Fund

Lisa Krimsky, University of Florida

Danny Patterson, Gulf States Health Policy Center

Jeff Pinsky, US Army Corps of Engineers, Regional Planning and Environmental Center

George Ramseur, Mississippi Department of Marine Resources

Lisa Smith, EPA's National Health and Environmental Effects Research Laboratory

Edward Trapido, LSU School of Public Health

Metrics Refinement Workshop Participants

Health Workshop Participants

Joie Acosta, RAND

Ashley Bennis, Texas Sea Grant

Jill Csekitz, Texas Commission on Environmental Quality and Gulf of Mexico Alliance Water Resources Team

Kathryn Keating, Louisiana State University Department of Sociology

Missy Partyka, Mississippi-Alabama Sea Grant

Paul Sandifer, College of Charleston

Helena Solo-Gabriele, University of Miami

Edward Trapido, Louisiana State University School of Public Health

Mike Wetz, Harte Research Institute for Gulf of Mexico Studies

Economic and Cost Workshop Participants

Jeff Adkins, National Oceanic and Atmospheric Administration

Mindy Burton, National Oceanic and Atmospheric Administration

David Cochran, University of Southern Mississippi

Peter Edwards, The Pew Charitable Trust

Scott Hemmerling, The Water Institute of the Gulf

Paul Hindsley, Eckerd College

Mike Jepson, National Oceanic and Atmospheric Administration National Marine Fisheries Service

Jim Lee, Texas A&M University – Corpus Christi

Walter Peacock, Texas Sea Grant

Amanda Torres, City of Rockport

Pete Wiley, National Oceanic and Atmospheric Administration Office for Coastal Management

APPENDIX B. REFERENCES USED TO CREATE DRAFT METRICS LISTS

Abt Associates. 2015. Developing Socioeconomic Metrics to Measure DOI Hurricane Sandy Project and Program Outcomes. Prepareed for National Fish and Wildlife Foundation. https://www.doi.gov/sites/doi.gov/files/uploads/Socio_Economic_Metrics_Final_Report_11DEC2015_0.pdf.

Ahn, J., H. Moon, J. Shin, and J. Ryu. 2020. "Social Benefits of Improving Water Infrastructure in South Korea: Upgrading Sewage Treatment Plants." *Environmental Science and Pollution Research* 27: 11202–11212.

Baldera, A., D.A. Hanson, and B. Kraft, B. 2018. "Selecting Indicators To Monitor Outcomes across Projects and Multiple Restoration Programs in the Gulf of Mexico." *Ecological Indicators* 89: 559–571.

Black, K., and E. McBean. 2018. "Drinking Water Supply Systems: Decreasing Advisories and Improving Treatment through Real-Time Water Quality Monitoring." *Journal of Water Supply: Research and Technology—AQUA* 67(4): 317–331.

Gangavarapu, B.S., M. Najafi, and O. Salem. 2003. "Quantitative Analysis and Comparison of Traffic Disruption Using Open-Cut and Trenchless Methods of Pipe Installation." In *New Pipeline Technologies, Security, and Safety*, edited by Mohammad Najafi, 1714–1724. Proceedings of the ASCE International Conference on Pipeline Engineering and Construction, held in Baltimore, Maryland, July 13–16, 2003.

Haller, L., G. Hutton, and J. Bartram. 2007. "Global Cost-Benefit Analysis of Water Supply and Sanitation Interventions." *Journal of Water and Health* 5(4): 481–502.

Khader, A.I., D.E. Rosenberg, and M. McKee. 2013. "A Decision Tree Model to Estimate the Value of Information Provided by a Groundwater Quality Monitoring Network." *Hydrology and Earth System Sciences* 17: 1797.

Kikwasi, G. 2012. "Causes and Effects of Delays and Disruptions in Construction Projects in Tanzania." In *Australasian Journal of Construction Economics and Building-Conference Series* (Vol. 1, No. 2, pp. 52–59).

Leggett, C.G., and N.E. Bockstael. 2000. "Evidence of the Effects of Water Quality on Residential Land Prices." *Journal of Environmental Economics and Management* 39(2): 121–144.

Dillard, M.K., T.L. Goedeke, S. Lovelace, and A. Orthmeyer. 2013. Monitoring Well-being and Changing Environmental Conditions in Coastal Communities: Development of an Assessment Method. NOAA Technical Memorandum NOS NCCOS 174. Silver Spring, MD. 176 pp.

Mason, S., and L. Olander. 2018. Ecosystem Services Conceptual Model Application: Testing General Model Adaptability. National Ecosystem Services Partnership Conceptual Model Series No. 4. Durham, NC: Duke University, Nicholas Institute for Environmental Policy Solutions. https://nicholasinstitute.duke.edu/sites/default/files/publications/escm_application_testing_general_model_adaptability_web.pdf.

Matthews, J.C., E.N. Allouche, and R.I. Sterling. 2015. "Social Cost Impact Assessment of Pipeline Infrastructure Projects." *Environmental Impact Assessment Review* 50: 196–202.

NOAA Recreational Fishing Data. https://www.fisheries.noaa.gov/topic/recreational-fishing-data.

Pennino, M.J., J.E. Compton, and S.G. Leibowitz, S.G. 2017. "Trends in Drinking Water Nitrate Violations across the United States." *Environmental Science & Technology* 51(22): 13450–13460.

Phaneuf, D.J., V.K. Smith, R.B. Palmquist, and J.C. Pope. 2008. "Integrating Property Value and Local Recreation Models to Value Ecosystem Services in Urban Watersheds." *Land Economics* 84(3): 361–381.

Pindyck, R.S. 2019. "The Social Cost of Carbon Revisited." *Journal of Environmental Economics and Management* 94: 140–160.

Price, J.I., P.R. Lloyd-Smith, D.P. Dupont, and W.L. Adamowicz. 2019. "Floods and Water Service Disruptions: Eliciting Willingness-to-Pay for Public Utility Pricing and Infrastructure Decisions." *Water Economics and Policy* 5(02): 1850021.

Rentfrow, P.J., C. Mellander, and R. Florida. 2009. "Happy States of America: A State-Level Analysis of Psychological, Economic, and Social Well-Being." *Journal of Research in Personality* 43(6): 1073–1082.

Samonte, G., P. Edwards, J. Royster, V. Ramenzoni, and S. Morlock. 2017. Socioeconomic Benefits of Habitat Restoration. NOAA Tech. Memo. NMFS-OHC-1, 66 p.

Tardieu, L., S. Roussel, J.D. Thompson, D. Labarraque, and J.M. Salles. 2015. "Combining Direct and Indirect Impacts to Assess Ecosystem Service Loss Due to Infrastructure Construction." *Journal of Environmental Management* 152: 145–157.

Vantarakis, A., S. Paparrodopoulos, P. Kokkinos, G. Vantarakis, K. Fragou, and I. Detorakis. 2016. "Impact on the Quality of Life When Living Close to a Municipal Wastewater Treatment Plant." *Journal of Environmental and Public Health* 2: 1–8.

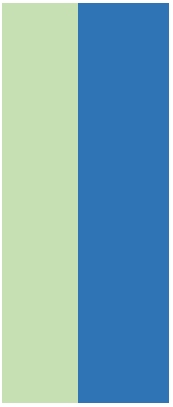
Vedachalam, S., A.J. Mandelia, and E.A. Heath. 2019. "The Impact of Source Water Quality on the Cost of Nitrate Treatment." *AWWA Water Science* 1(1): e1011.

Zimmerman, R. 2001. "Social Implications of Infrastructure Network Interactions." *Journal of Urban Technology* 8(3): 97–119.

APPENDIX C: FULL METRICS LIST

Colored right-hand columns indicate that the metric is strongly linked to at least half of the project types within the category and is considered a core metric for that project category. Additional details about the metrics, including protocols for tier 1 and tier 2 project-scale metrics, are available on the GEMS website.

Outcome	Metric Title	Definition	Tier	Scale	Core metric by project category			
					HR	ORR	RE	WQ
CULTURAL VALUES								
Knowledge	Education-related knowledge: Number of people with additional knowledge of habitat effects and other project outcomes	The number of people with additional knowledge of, change in behavior, or change in attitude towards habitat effects and other project outcomes due to project-associated educational outreach, assessed using project-scale methodologies such as surveys, interviews, or focus groups.	2	Project				
	Awareness: Number of people with additional knowledge of habitat effects and other project outcomes on broader scale	The number of people with additional awareness of habitat effects and other project outcomes, or change in perception of the project, due to living or working in proximity to the project, assessed using program-scale methodologies such as surveys, interviews, or focus groups.	2	Program				
	Awareness: Number of people with additional knowledge of habitat effects and other project outcomes based on project site	The number of people with additional awareness of habitat effects and other project outcomes, or change in perception of the project, due to proximity to the project, assessed using project-scale methodologies such as surveys, interviews, or focus groups.	2	Project				
Other	Project identified cultural value	Identification and evaluation of cultural ecosystem services (CES), which vary by community, for monitoring. Where possible, project team can develop framework for pre- and post-restoration monitoring of CES.	2	Project				
	Program identified cultural value	Identification and evaluation of cultural ecosystem services (CES), which vary by community, for monitoring. Where possible, program team can develop framework for pre- and post-restoration monitoring of CES.	2	Program				

Outcome	Metric Title	Definition	Tier	Scale	Core metric by project category			
					HR	ORR	RE	WQ
ECONOMIC ACTIVITY								
Agriculture	Change in crop or livestock revenue	The change in reported annual revenue from crop or livestock yield from farms participating in agricultural BMPs. Reported annually and pre- and post-project implementation.	1	Project				
	Number of aquaculture jobs supported by project	The number of jobs directly supported by an oyster aquaculture project during operation (jobs supported through design and construction would be included in the "restoration jobs" metric below) reported as full-time employee equivalents every year.	1	Project				
Finfish/Shellfish harvest	Change in economic activity from project associated commercial fish harvest	Jobs, labor income, gross state product, and total industry output modeled annually based on NOAA commercial harvest data and state data (e.g., Florida commercial fisheries) for relevant species. Change in economic activity from commercial fish harvest could be due to changes in target populations or areas closed to harvest due to water quality issues. Reporting harvest and revenue (intermediate outputs for calculating this metric) may also be useful to give a full picture on how commercial harvest patterns have changed in response to the project.	2	Program				
	Change in economic activity from project associated commercial aquaculture harvest	Jobs, labor income, gross state product, and total industry output modeled annually based commercial harvest data and state data (e.g., USDA Census of Aquaculture) for relevant species.	2	Program				
Local businesses	Change in local business revenue from project disruption	The change in reported revenue from local businesses whose normal operations are temporarily or permanently impacted by disruption from project construction. Reported pre- and post-project construction.	2	Project				

Outcome	Metric Title	Definition	Tier	Scale	Core metric by project category			
					HR	ORR	RE	WQ
Recreation and tourism	Change in recreational activity expenditures associated with project site visitation	Estimate of total recreational activity expenditures due to the project compared to baseline of recreational activity expenditures in surrounding area, calculated as the number of recreational trips to the project site (estimated from random sampling counts as part of structured monitoring).	2	Project				
	Number of jobs supported through recreational fishing at project site	The number of direct, indirect, and induced jobs associated with recreational fishers visiting the restored reef, based on fishing expenditures determined through a survey of recreational fishing anglers conducted by the restoration project.	2	Project				
Recreation and tourism	Change in recreational fishing expenditures associated with project site visitation	Estimate of total recreational fishing expenditures due to the project compared to baseline of recreational fishing expenditures in surrounding area, calculated as the number of recreational fishing trips to the project site (estimated from random sampling counts as part of structured monitoring) multiplied by the average trip expenditure (from NOAA FEUS 2018 Report).	2	Project				
	Change in economic activity from recreational fishing	Jobs, labor income, gross state product, and total industry output modeled annually at a county to regional level. Angler surveys will account for the difference in activity associated with a restoration project, which would then be used as input into the economic impact analysis (see Texas Half Moon Reef example [PDF]).	2	Program				

Outcome	Metric Title	Definition	Tier	Scale	Core metric by project category			
					HR	ORR	RE	WQ
Restoration/Intervention	Number of restoration jobs supported by project	The number of jobs directly supported by the restoration project, including but not limited to project design, construction, project site maintenance, education, and monitoring, reported every year.	1	Project				
	Total restoration expenditures by project	The total amount of money spent on the restoration project as reported in the project budget every year.	1	Project				
	Change in economic activity from restoration spending	Jobs, labor income, gross state product, and total industry output would be modeled based on project expenditures.	2	Program				
Health related closure: Recreation and tourism	Change in recreation and tourism associated economic activity associated with a closure period	Change in economic activity from recreation and tourism in area with repeated or long-term closures. This can be measured with a location-specific scenario analysis or survey instrument.	3	Program				
HUMAN HEALTH								
Drownings and other injuries	Change in number of drownings/spinal injuries/ rescue incidents (per # of visitors to the site)	Number of injuries and drownings after project implementation, measured through surveys of beach patrol or reviewing available incident reporting data.	3	Project				
Food security for communities	Proportion of surveyed harvesters who say that food caught/harvested at the site is important for feeding their household	Estimate of proportion of surveyed harvesters who say that food harvested at project site is important for feeding their household and if that has changed since the installation of the project at site.	2	Project				
	Proportion of protein or nutrition from food harvested at restoration site	Relative measure of contribution of subsistence harvest from areas with restoration projects (e.g., seafood, birds, mushrooms) to household nutrition, measured by adding questions to existing national nutrition surveys.	3	Program				

Outcome	Metric Title	Definition	Tier	Scale	Core metric by project category			
					HR	ORR	RE	WQ
Mental health and psychological well-being	Change in cognitive function	Change in performance on simple recall or other cognitive function tests pre- and post-recreation activity or time at project site.	2	Project				
	Change in subjective well-being	Change in self-reported state of well-being. Survey of visitors pre- and post-time at project site.	2	Project				
Mosquito-borne illness	Change in number of reported cases of mosquito-borne illness in counties near the project site	Change in number of reported cases of mosquito-borne illness in counties near the project site, measured through available CDC, hospital, and clinic data and ground truthed with survey instruments. Such measurements have not yet taken place and are in the R&D Phase.	3	Project				
Public safety (related to evacuations)	Change in number of days evacuation routes are closed	Change in the number of times that an evacuation route adjacent to the project site is inaccessible due to flooding, based on a simple count of closures.	1	Project				
Respiratory disease	Change in number of reported cases of respiratory illness in counties near the project site	Change in number of reported cases of respiratory disease in counties near the project site, measured through available CDC, hospital, and clinic data and ground truthed with survey instruments. Such measurements have not yet taken place and are in the R&D Phase.	3	Project				
Seafood-associated disease	Change in number of reported cases of seafood associated disease in counties near the project site	Change in number of reported cases of seafood associated disease in counties near the project site, measured through available CDC, hospital, and clinic data and ground truthed with survey instruments. Such measurements have not yet taken place and are in the R&D Phase.	3	Project				
Skin and respiratory effects of toxin exposure	Change in number of reported cases of skin and respiratory affects in counties near the project site	Change in number of reported cases of toxin-exposure related skin and respiratory effects in counties near the project site, measured through available CDC, hospital, and clinic data and ground. truthed with survey instruments. Such measurements have not yet taken place and are in the R&D Phase.	3	Project				

Outcome	Metric Title	Definition	Tier	Scale	Core metric by project category			
					HR	ORR	RE	WQ
Waterborne disease	Change in number of reported cases of waterborne diseases in counties near the project site	Change in number of reported cases of waterborne disease in counties near the project site, measured through available CDC, hospital, and clinic data and ground truthed with survey instruments. Such measurements have not yet taken place and are in the R&D Phase.	3	Project				
PROPERTY PROTECTION & VALUE								
Property protection (erosion)	Number of properties or length of infrastructure adjacent to shoreline with reduced erosion after project	Total amount of public infrastructure or private property (measured in number and type of properties, or length of road) that experiences decreased adjacent erosion rates due to the restoration project reported every year.	2	Project				
Property protection (flooding)	Modeled avoided flood damage and/or number of people with reduced flood frequency or depth	Change in coastal or inland flood damages and/or number of people experiencing reduced flood depths or frequencies based on models that compare flood scenarios with and without the project	2	Project				
	Change in property damage (per value of property) caused by flooding with the project in place (as opposed to without)	Change in number and value of coastal or inland flood related claims payouts within the county or census tract of the project.	2	Project				
Property value	Change in property value across affected properties.	Changes to property values based on proximity to project site, using a hedonic pricing method.	2	Project				
GREENHOUSE GAS EMISSIONS								
Social cost of greenhouse gas emissions	Change in economic costs resulting from carbon emissions	Changes in economic costs resulting from carbon emissions associated with the project, measured using the social cost of carbon (a measure of the economic harm from greenhouse gas emissions emitted per ton of carbon equivalent). The current central estimate of the social cost of carbon is over $50 per ton in 2021 dollars.	1	Project				

Outcome	Metric Title	Definition	Tier	Scale	Core metric by project category			
					HR	ORR	RE	WQ
SOCIAL DISRUPTION								
Social disruption due to project or flooding	Change in number of critical facilities (roads, hospitals, schools) affected by stormwater flooding (with frequency and duration of closures if possible)	Total number of critical facilities or businesses that experienced flooding, temporary or permanent closure, or had reduced hours around project site, as measured by survey.	2	Project				
	Number of days of disrupted services due to project	Total number of days of disruption, annually, due to project construction of maintenance, as reported by project.	1	Project				
WATER SYSTEM COSTS								
Cost to property owner	Total sewer conversion costs for homeowners	Costs to homeowners of the septic to sewer conversion, measured in average cost per homeowner and total cost for all homeowners associated with the project (from project documentation).	1	Project				
	New sewer conversion costs for homeowners	Net costs to homeowners for the septic to sewer conversion, incorporating average upfront cost per homeowner, average annual savings on septic maintenance, and annual water bill cost (need to use survey).	2	Project				
Drinking water treatment costs	Change in drinking water treatment cost (at facility)	Change of water treatment costs since project implementation, shared by utility, and change of measured water quality near project site.	2	Project				

Outcome	Metric Title	Definition	Tier	Scale	Core metric by project category			
					HR	ORR	RE	WQ
Freshwater cost	Change in homeowner cost of fresh water for irrigation	Change of irrigation costs outlined in home-owner utility bills since project implementation in places that use and track reclaimed water, and change of measured water quality near project site.	2	Project				
	Change in municipal water costs	Change in municipal water expenditures based on the municipality's use of reclaimed water, as monitored by the municipality.	3	Project				
Gray stormwater infrastructure improvement costs	Change in cost of storm-water treatment facility upgrades or maintenance due to addition of green infrastructure	Reported frequency of stormwater treatment facility upgrades, measured through survey of stormwater treatment facilities.	3	Program				
Wastewater treatment Costs	Episodic storm related costs (Change in incidence of (or total fines paid by treatment plants for) wastewater discharge violations reported annually)	Change in incidence of and total fines paid by wastewater utilities due to wastewater discharge violations, from utility data, based on utility's willingness to share data.	3	Project				
	Change in wastewater treatment cost (at facility)	Change in wastewater treatment cost, from utility data, based on utility's willingness to share data.	3	Project				

Author Affiliations

Lydia Olander, Nicholas Institute for Environmental Policy Solutions

Christine Shepard, The Nature Conservancy

Heather Tallis, The Bridge Collaborative

David Yoskowitz, Harte Research Institute for Gulf of Mexico Studies, Texas A&M University Corpus Christi

Kara Coffey, Harte Research Institute for Gulf of Mexico Studies, Texas A&M University Corpus Christi

Christine Hale, Harte Research Institute for Gulf of Mexico Studies, Texas A&M University Corpus Christi

Rachel Karasik, Nicholas Institute for Environmental Policy Solutions

Sara Mason, Nicholas Institute for Environmental Policy Solutions

Katie Warnell, Nicholas Institute for Environmental Policy Solutions

Citation

Olander, L., C. Shepard, H. Tallis, C. Shepard, D. Yoskowitz, K. Coffey, et al. 2021. GEMS Phase II Report: Coastal Restoration. NI R 21-05. Durham, NC: Duke University

Acknowledgements

This project has benefited from the input of many experts, practitioners, and stakeholders in the Gulf of Mexico. This work is supported by the Gulf Research Program of the National Academy of Sciences, Engineering, and Medicine under award number 2000008884. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Gulf Research Program or the National Academies of Sciences, Engineering, and Medicine.

Published by the Nicholas Institute for Environmental Policy Solutions in 2021. All Rights Reserved.

Publication Number: NI R 21-05

Cover Image: USGS/Unsplash

Nicholas Institute for Environmental Policy Solutions

The Nicholas Institute for Environmental Policy Solutions at Duke University is a nonpartisan institute founded in 2005 to help decision makers in government, the private sector, and the nonprofit community address critical environmental challenges. The Nicholas Institute responds to the demand for high-quality and timely data and acts as an "honest broker" in policy debates by convening and fostering open, ongoing dialogue between stakeholders on all sides of the issues and providing policy-relevant analysis based on academic research. The Nicholas Institute's leadership and staff leverage the broad expertise of Duke University as well as public and private partners worldwide. Since its inception, the Nicholas Institute has earned a distinguished reputation for its innovative approach to developing multilateral, nonpartisan, and economically viable solutions to pressing environmental challenges.

Contact

Nicholas Institute
Duke University
P.O. Box 90335
Durham, NC 27708

1201 Pennsylvania
Avenue NW
Suite 500
Washington, DC 20004

919.613.8709
nicholasinstitute@duke.edu