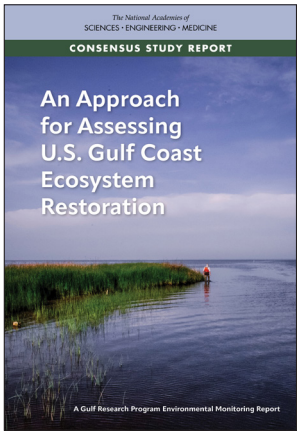
Consensus Study Report
HIGHLIGHTS
March 2022

An Approach for Assessing U.S. Gulf Coast Ecosystem Restoration



The Gulf of Mexico (GoM) has a combination of ecological richness, economic value, and physical location that makes it unique among America's seas. Its habitats and ecosystems include oyster reefs, salt marshes, seagrass beds, mangrove forests, estuaries, barrier islands, coral reefs, and sandy beaches, as well as the water column and bottom habitats of the Gulf itself. In the 21st century, these valuable ecosystems have been under substantial pressure from coastal development, pollution, overfishing, agriculture, and other human activities, and are under increasing stress from climate change.

The Deepwater Horizon (DWH) platform explosion and resulting oil spill in April 2010 significantly impacted Gulf ecosystems – and the funds from DWH legal settlements have led to the largest ecological restoration investment in history. Now, nearly a decade into these restoration efforts, it is time to assess the impacts of these activities and to lay a foundation for restoration efforts that will continue beyond the allocation of DWH funds.

Initiated by the Gulf Research Program (GRP) at the National Academies of Sciences, Engineering, and Medicine, this report discusses long-term environmental trends along the U.S. Gulf of Mexico coast with a particular focus on the various steps for assessing the cumulative effects of restoration activities. The report also evaluates the relevant existing resources, including available data, for informing decision making.

ASSESSING THE CUMULATIVE EFFECTS OF RESTORATION: CURRENT AND EMERGING APPROACHES

The cumulative effects of restoration refer to the collective additive (equal to the sum of their individual effects), synergistic (greater than the sum of their individual effects), and antagonistic (less than the sum of their individual effects) effects of all restoration activities that occur within a setting defined by common or connected characteristics of hydrology, geomorphology, ecology, ecological function, and/or biodiversity. Assessment of the cumulative effects of restoration may occur at various geographic landscape scales such as a marsh, bay, estuary, watershed, or the even the Gulf Coast itself. The scale of assessment may also be defined by other specifics such as ecosystem processes, political boundaries, or type of restoration method.

Measurable changes as a result of restoration actions are often confounded by the effects of multiple interacting stressors, including long-term environmental trends such as sea level rise or changes in ocean temperature. Approaches that can be used to consider and address restoration efforts within the context of multiple stressors include:

- **Analyzing Antagonism and Synergism in Restoration Efforts.** Like cumulative effects of restoration, the effects of multiple stressors can be additive, synergistic, or antagonistic; they may also be either beneficial or detrimental relative to program goals and objectives. Exploring how to make use of ecological synergies and avoid antagonistic interactions could improve benefits and efficacy of multi-project restoration efforts.
- **Developing Conceptual Models and Hypotheses.** Conceptual models graphically represent the interactions among drivers, pressures, and stressors;

restoration actions; and ecosystem responses. They are crucial for determining restoration project priorities and assessing future projections.

- **Employing Multiple Lines of Evidence.** Evaluating the effects of a restoration effort often involves an individual body of water or watershed, which by its nature cannot be replicated, preventing assignment of cause-and-effect via standard methods of statistical analysis alone. An evidence-based evaluation methodology that utilizes multiple lines of evidence and causal criteria can be very useful and include approaches such as modeling, uncertainty analysis, meta-analysis, and literature reviews.

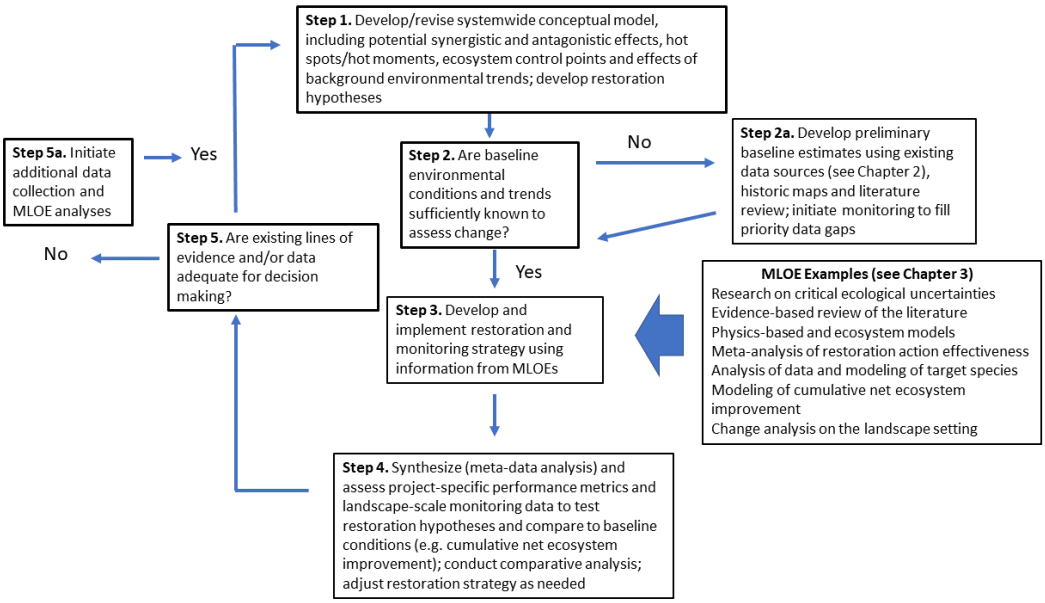


Figure 1. A flow chart approach for environmental restoration to assess cumulative effects of multiple restoration projects, using multiple lines of evidence (MLOE) and an iterative adaptive management approach.

Because environmental background trends are exhibiting higher variability over time, restoration practices that have been successful in the past may no longer be adequate to compensate for the effects of anticipated changes in these trends. Program-level adaptive management techniques can provide restoration program managers with the ability to revisit and update large-scale restoration strategies, based on periodic review of monitoring data and progress towards programmatic goals. Figure 1 illustrates ways that program-level adaptive management efforts can incorporate various approaches, including those mentioned above as well as others, for assessing cumulative effects for better outcomes.

In addition to these methods, other approaches that are important for assessing cumulative effects, especially at larger scales such as Gulf-wide, include:

- **Conducting Data Synthesis**. Synthesis efforts are needed to determine how much the many individual restoration efforts, collectively, have resulted in measurably improved coastal and estuarine ecosystems across the GoM region. In addition, such analyses provide a mechanism for adjusting efforts to produce better restoration outcomes. The synthesis framework makes it possible to address difficult and exceedingly complex environmental questions and provide answers that lead to increased understanding of coastal and estuarine system dynamics and, ultimately, better management decisions.
- **Employing Emerging Technologies.** Recent advancements in data-driven techniques such as artificial intelligence (AI), machine learning, deep learning, cloud, and edge computing are expected to fundamentally transform many domains of human endeavor, including post-restoration monitoring. Traditional remote sensing, combined with new sensing technologies and AI-driven techniques, can generate high-quality long-term monitoring data across terrestrial and coastal ecosystems.

BARRIERS TO EVALUATING CUMULATIVE EFFECTS

Adequate scientific evidence needed to evaluate cumulative effects of restoration on a regional scale in the Gulf of Mexico is currently not available and, to date, no entity has been tasked to develop and implement a strategy for assessing cumulative effects of environmental restoration efforts. Environmental benefits associated with multiple restoration projects have been observed within some Gulf of Mexico estuaries and watersheds, although not at larger scales. Without a focused effort and strategy, rigorous synthesis of the effects of multiple restoration projects at a regional or Gulf-wide scale cannot easily be conducted.

Because environmental changes can influence the success or failure of restoration efforts and can hinder the ability to detect potential cumulative effects of multiple restoration efforts, a thorough understanding of long-term environmental trends is essential for decision-makers and restoration practitioners. There are significant spatial and temporal gaps in monitoring Gulf of Mexico-wide environmental indicators and data collection and dissemination efforts limit development of this important and valuable capability. Specifically:

- Long-term environmental trends across the Gulf Coast states are monitored by a patchwork of agencies, non-profits, and industries for a variety of reasons (e.g., regulatory, environmental tracking, per-

formance evaluation). Study designs, data collection methods, analyses and data availability vary and are often not comparable, making synthesis very difficult.

- One-time Gulf-wide monitoring studies are useful, but without periodic updates, do not generate enough information to determine long-term background trends needed for cumulative effects assessments.
- Key metrics to assess landscape-scale changes and support adaptive management include those necessary to estimate environmental trends associated with climate change; freshwater, nutrient and sediment loading to coastal waters; land use/land cover; ambient water quality; status and trends of fish species, marine mammals, turtles, and birds; and primary and secondary production. Enhanced efforts and standardization of methods are especially needed for ambient water quality; tide gage data and subsidence measurements; estimating the extent and effects of ocean and coastal acidification; tracking, targeting needed research, and managing the effects of tropicalization on fishery species, other species, and habitats; and estimating the ecological functioning of restored habitats.

Recommendation A: Enhanced, consistent, and sustained long-term monitoring, analysis, synthesis, and reporting of environmental trends and indicators are urgently needed to enable the detection and tracking of cumulative effects of multiple restoration projects. Monitoring efforts should focus on those supporting the assessment of cumulative effects at estuarine, regional, and larger scales. The DWH funding entities should immediately evaluate methods, identify funding mechanisms, and charge an entity to lead efforts to coordinate and enhance long-term priority monitoring efforts and promote consistent data collection, analysis, synthesis, and reporting between programs; support periodic assessments of collected data; assess the use of advanced techniques; and ensure data availability, with the goal of implementing these changes within 3-5 years.

INCORPORATING WHAT HAS BEEN LEARNED

The Gulf Coast environmental restoration community (federal agencies, states, non-governmental organizations, and local public and private entities) has an opportunity to incorporate what has been learned from past and ongoing ecosystem restoration to inform future projects and programs supported by the remaining DWH funds. However, unless data and information from existing projects are made accessible and identification of information needed to assess cumulative effects of restoration efforts is undertaken more expeditiously, opportunities to improve the likelihood of success in the remaining projects will be greatly reduced or even permanently lost. Although it may be too early to fully assess cumulative effects of DWH-funded restoration efforts due to lag times between implementation and detection of effects, applying 'lessons learned' from existing restoration efforts can help mitigate future risks of failure and ensure that DWH funds are invested wisely to increase the likelihood of meaningful and long-term Gulf of Mexico recovery and resilience.

Recommendation B: Restoration funding entities should adopt guidance to ensure that, as soon as they are available, all data, reports, and other project-specific information are deposited into freely accessible repositories that follow FAIR (Findable, Accessible, Interoperable, Reusable) principles. The DWH funding entities should identify and allocate resources to ensure that these data repositories remain functional throughout the life of each program, and additional support (as needed) should be sought to maintain data access in the future.

Recommendation C: The DWH funding entities should expedite the issuance of guidance for adaptive management and cumulative effects assessment at the programmatic scale for DWH-funded large-scale and multiple restoration efforts. Guidance should include consistency in monitoring criteria that facilitate cumulative effects assessments.

Recommendation D: The DWH funding entities should immediately initiate a synthesis of available information from DWH-funded projects to assess characteristics of successful and unsuccessful restoration efforts. Results should be utilized in designing and implementing effective large-scale restoration projects within geographic areas of concern, and/or adjusting restoration approaches and techniques with the remaining funds from the DWH settlement.

INCORPORATING SYNERGISTIC AND ANTAGONISTIC EFFECTS

Natural and anthropogenic drivers create multiple ecosystem pressures and stressors that act on restoration efforts over broad spatial scales, ranging from individual projects to entire ecosystems. The cumulative impacts of these pressures and stressors are often complex, resulting in synergistic and antagonistic effects of ecological significance. However, synergistic and antagonistic effects of large-scale restoration efforts in the Gulf of Mexico have not been assessed to date, and results from a limited number of assessments are mixed.

Recommendation E: DWH funding entities should evaluate mechanisms that support cross-state and

Gulf-wide collaboration among researchers, resource managers, and practitioners, with an objective to design and implement restoration efforts that allow assessment of antagonistic and synergistic effects.

BUILDING A FRAMEWORK FOR ASSESSING CUMULATIVE EFFECTS

The use of multiple lines of evidence to develop a framework to help assess cumulative effects for large-scale restoration efforts in the Gulf of Mexico has been proposed and, in some cases, applied. Assessment of cumulative effects of large-scale restoration is a recent research area and work on applying this research to restoration implementation is needed.

Opportunities exist now to prepare for the assessment of cumulative effects and restoration success from existing regional or large-scale restoration efforts in the Gulf of Mexico. These include:

- Applying methods to assess functional equivalency between restored and natural sites;
- Assessing the degree of environmental stress from natural and anthropogenic sources;
- Applying a multiple lines of evidence approach to assess cumulative effects at the estuary or watershed scale in preparation for Gulf-wide efforts;
- Undertaking comparative analysis of estuaries or watersheds across the Gulf of Mexico to develop a greater understanding of similarities and differences among these systems; and
- Evaluating expected benefits of a restoration effort as compared to a future condition without the effort.

These opportunities will involve consideration of changing environmental trends and a commitment to monitor, analyze, synthesize, and report results.

Recommendation F: To take advantage of the unprecedented opportunity to assess cumulative effects and inform restoration efforts ongoing and planned in the Gulf of Mexico, DWH funding entities should evaluate and implement mechanisms necessary to address priority research needs and support efforts to prepare for the assessment of cumulative effects within the next 3-5 years. Mechanisms could include providing explicit responsibility to and support for existing Gulf-wide entities; development of an independent, regional, multidisciplinary, multiagency team; or a distribution of effort between existing entities.

Recommendation G: As additional monitoring data and scientific evidence become available, DWH program managers should continue to collaboratively develop and implement an adaptive management strategy for the Gulf of Mexico restoration effort, including the development of ecosystem conceptual models. Evaluation of priority issues should use the best available tools and methods, focus on progress of cumulative effects assessments and restoration objectives, and identify necessary changes to restoration approaches if needed. Mechanisms to continue these efforts beyond the eventual sunset of DWH restoration programs should be identified and implemented.

THE COMMITTEE ON LONG TERM ENVIRONMENTAL TRENDS IN THE GULF OF MEXICO

Holly Greening (Chair), CoastWise Partners; **Walter R. Boynton**, Chesapeake Biological Laboratory, University of Maryland; **Heida L. Diefenderfer**, Coastal Sciences Division, Pacific Northwest National Laboratory; **Albert A. George II**, South Carolina Aquarium; **Kenneth L. Heck, Jr.**, Dauphin Island Sea Lab and University of South Alabama; **Barbara A. Kleiss**, Department of River-Coastal Science and Engineering, Tulane University; **Catherine L. Kling**, Dyson School of Applied Economics and Management, Cornell University; **Bethany A. Carl Kraft**, Volkert, Inc.; **Lary D. McKinney**, Harte Research Institute for Gulf of Mexico Studies, Texas A&M University; and **Deepak R. Mishra**, Department of Geography, University of Georgia. Staff of the National Academies of Sciences, Engineering, and Medicine: **Deborah Glickson** (Study Director); **Laura Windecker** (Study Director); **Megan May** (Associate Program Officer); and **Thelma Cox** (Program Coordinator).

For More Information . . . This Consensus Study Report Highlights was prepared by the National Academies of Sciences, Engineering, and Medicine based on the Consensus Study Report An Approach for Assessing U.S. Gulf Coast Ecosystem Restoration (2022). The study was sponsored by The Gulf Research Program. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project. Copies of the Consensus Study Report are available from the National Academies Press, (800) 624-6242; http://www.nap.edu or via the Gulf Research Program web page athttps://www.nationalacademies.org/gulf/gulf-research-program

Division on Earth and Life Studies

The National Academies of
SCIENCES • ENGINEERING • MEDICINE