Gulf of Mexico Ecosystem Science Assessment and Needs

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A product of the Gulf Coast Ecosystem Restoration Task Force Science Coordination Team

April 2012

Suggested citation:
Walker, Shelby, Dausman, Alyssa, and Lavoie, Dawn, eds., 2012, Gulf of Mexico Ecosystem Science Assessment and Needs—A Product of the Gulf Coast Ecosystem Restoration Task Force Science Coordination Team, 72 p.

Executive Summary

The Gulf Coast Ecosystem Restoration Task Force (GCERTF) was established by Executive Order 13554 as a result of recommendations from "America's Gulf Coast: A Long-term Recovery Plan after the Deepwater Horizon Oil Spill" by Secretary of the Navy Ray Mabus (Mabus Report). The GCERTF consists of members from 11 Federal agencies and representatives from each State bordering the Gulf of Mexico. The GCERTF was charged to develop a holistic, long-term, science-based Regional Ecosystem Restoration Strategy for the Gulf of Mexico. Federal and State agencies staffed the GCERTF with experts in fields such as policy, budgeting, and science to help develop the Strategy. The Strategy was built on existing authorities and resources and represents enhanced collaboration and a recognition of the shared responsibility among Federal and State governments to restore the Gulf Coast ecosystem. In this time of severe fiscal constraints, Task Force member agencies and States are committed to establishing shared priorities and working together to achieve them.

As part of this effort, three staffers, one National Oceanic and Atmospheric Administration (NOAA) scientist and two U.S. Geological Survey (USGS) scientists, created and led a Science Coordination Team (SCT) to guide scientific input into the development of the Gulf of Mexico Regional Ecosystem Restoration Strategy.

The SCT leads from the GCERTF coordinated more than 70 scientists from the Federal and State Task Force member agencies to participate in development of a restoration-oriented science document focused on the entire Gulf of Mexico, from inland watersheds to the deep blue waters. The SCT leads and scientists were organized into six different working groups based on expanded goals from the Mabus Report:

1. Coastal habitats are healthy and resilient.
2. Living coastal and marine resources are healthy, diverse, and sustainable.
3. Coastal communities are adaptive and resilient.
4. Storm buffers are sustainable.
5. Inland habitats and watersheds are managed to help support healthy and sustainable Gulf of Mexico ecosystems.
6. Offshore environments are healthy and well managed.

Each working group was charged with defining their specific goal, describing the current conditions related to that goal (for example, the status of coastal habitats in the Gulf of Mexico), providing high-level activities needed to further define and achieve the goal, with associated outcome-based performance indicators, and identifying the scientific gaps in understanding to accomplish the goal and implement the recommended activities. The overall scientific assessment reveals that the Gulf of Mexico ecosystem continues to suffer from extensive degradation, and action is necessary to develop a healthy, resilient, and sustainable Gulf of Mexico ecosystem.

The six groups also were tasked with outlining the necessary monitoring, modeling, and research needs to aid in achieving the goals. Recognizing that (1) the scientific needs (monitoring, modeling, and research) overlap among many of the goals, and (2) an overarching scientific framework could be developed to implement the necessary science in support of the Strategy, a seventh group was created with several members from each of the original six working groups. This seventh group compiled all of the cross-cutting monitoring, modeling, and research needs previously identified by the individual groups. These scientific requirements are found in Chapter 5 of this document.

The seventh group also has developed a Science Plan, outlined in Chapter 6. The Science Plan provides the basic science infrastructure to support the overall Gulf restoration program and Strategy. The Science Plan allows for the development of an iterative and flexible approach to adaptive management and decision-making related to restoration projects based on sound science that includes monitoring, modeling, and research. Taken in its entirety, this document helps to articulate the current state of the system and the critical science needs to support effective restoration of the Gulf of Mexico resources that have been trending towards decline for decades.

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A product of the Gulf Coast Ecosystem Restoration Task Force Science Coordination Team

Edited by Dr. Shelby Walker[a], Dr. Alyssa Dausman[b], Dr. Dawn Lavoie[b]

1 Introduction

The Gulf Coast Ecosystem Restoration Task Force (GCERTF) was established by Executive Order 13554 as a result of recommendations from "America's Gulf Coast: A Long Term Recovery Plan after the Deepwater Horizon Oil Spill" by the Secretary of the Navy, Ray Mabus (Mabus Report)[1]. The GCERTF consists of members from 11 Federal agencies and representatives from each State bordering the Gulf of Mexico. Federal and State agencies staffed the GCERTF with experts in fields such as policy, budgeting, and science to help develop the Gulf of Mexico Regional Restoration Strategy (Strategy). The Strategy was built on existing authorities and resources and represents enhanced collaboration and a recognition of the shared responsibility among Federal and State governments to restore the Gulf Coast ecosystem. In this time of severe fiscal constraints, Task Force member agencies and states are committed to establishing shared priorities and working together to achieve them.

The Science Coordination Team (SCT) for the GCERTF was developed to guide scientific input in the development of the Strategy. The intent of the Strategy was to articulate the long-standing issues facing the Gulf of Mexico ecosystem and to identify recommendations to help address these issues. Fundamental to the success of the Strategy is ensuring that it has a robust and defensible scientific foundation. The GCERTF was tasked with producing the Strategy within 1 year of the signing of the Executive Order that created the GCERTF. Given this accelerated timeline, the activities of the SCT and those of the Strategy development occurred in parallel, with draft products from the SCT helping to inform the Strategy development over the compressed timeframe. The Strategy development worked through an iterative process to identify and develop the issues, goals, and objectives of the Strategy, starting initially from the following principles initially identified in the Mabus Report.[2]

Principle 1. Coastal wetland and barrier shoreline habitats are healthy and resilient.
Principle 2. Fisheries are healthy, diverse, and sustainable.
Principle 3. Coastal communities are adaptive and resilient.
Principle 4. A more sustainable storm buffer exists.
Principle 5. Inland habitats, watersheds, and offshore waters are healthy and well managed.

As part of the Strategy development, the GCERTF synthesized and applied these principles in defining four goals that capture the restoration needs of the Gulf: Restore and Conserve Habitat; Restore Water Quality; Replenish and Protect Living Coastal and Marine Resources; and Enhance Community Resilience. Because the SCT work was occurring concurrently with the Strategy development, the SCT continued to use the Mabus initial five (then six, noted below) principles (now termed "goals") as the guiding construct for their work. Elements within each of these goals can be used by the GCERTF to continue to refine their activities moving forward with implementation. The SCT work included identifying current conditions in the Gulf of Mexico as they relate to these goals and specifying activities, actions, and performance indicators needed to address these goals with respect to current conditions and gaps in knowledge. The SCT recognized that the challenges facing the Gulf of Mexico ecosystem are numerous and determined that addressing these six goals would serve to inform the Strategy and its four goals and associated objectives, as well as future efforts in the Gulf that may not be directly addressed by the Strategy. The activities outlined in this document are intended as recommendations, not commitments on the part of the GCERTF, and are not intended to replace any specific actions recommended by the GCERTF in implementation, but instead, help provide the foundation to ensure that the GCERTF actions are scientifically robust.

The goals highlighted within this document are oriented around the many components of the ecosystem, including the human component. Given the interconnected nature of the Gulf ecosystem, issues that relate to one goal (for example, coastal habitats are healthy and resilient) often have direct bearing on other goals (for example, living coastal and marine resources are healthy, diverse, and sustainable) and as such, are discussed in multiple areas. Additionally, as a document articulating the science intended to support the Strategy, many of the activities and actions described herein enable the knowledge and understanding required to make and implement informed decisions, in addition to articulating discrete restoration efforts that can be used by the GCERTF or other entities involved in restoration in future planning. The SCT recognized that both discrete actions and the science underpinning them need to be advanced to ensure effective restoration efforts.

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[a] National Oceanic and Atmospheric Administration, Science Coordination Team Lead.

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In addition to describing the current state of the Gulf of Mexico ecosystem and necessary actions to help address it, the SCT determined a need to define an overarching science framework or program that would help advance the activities defined here. This program would help ensure that focused and ecosystem-wide science would be available to provide the foundation for successful development, implementation, and adaptive management of projects, and maintain a broader, integrated and holistic perspective of the entire ecosystem.

Process

The first SCT meeting, held in January 2011, had 27 participants. From that meeting, five Science Working Groups (SWGs) were developed. More than 70 scientists from 10 Federal agencies and 5 State governments participated on the SCT and in the five SWGs (Table 1). The SWGs were tasked with the following deliverables at that time:

- Define the principles (now termed "goals") in terms that can be understood by a diverse audience and are measurable.
- Describe the current conditions (that is, baseline) and key issues underlying these goals.
- Identify three to five activities and supporting actions (that is, *not* site-specific projects) that should be implemented to achieve the goals; use existing reports and information as resources.
- Identify specific and measurable outcome-based (preferably *not* output) performance indicators (for example, ecosystem function versus acres restored). Identify and address specific gaps in current understanding to accomplish and support the goals and implement the scientific activities.

Table 1. States and Federal agencies participating on the Science Coordination Team and Science Working Groups.

States
Alabama
Florida
Louisiana
Mississippi
Texas
Federal Agencies
Bureau of Ocean Energy Management (BOEM)
National Aeronautics and Space Administration (NASA)
National Oceanic and Atmospheric Administration (NOAA)
National Park Service (NPS)
The White House Office of Science and Technology (OSTP)
U.S. Army Corps of Engineers (USACE)
U.S. Department of Agriculture (USDA)
U.S. Environmental Protection Agency (EPA)
U.S. Fish and Wildlife Service (FWS)
U.S. Geological Survey (USGS)

Additional meetings were held with full SCT membership present on March 1, 2011, and then with only the SWG leads on March 2, 2011. The purposes of these meetings were to help refine and expand the above deliverables. Additional tasks were assigned to the SWGs to help refine the input, including:

- Refine the high-level activities previously identified.
- Identify specific monitoring needs for measuring progress towards the goals.
- Identify recurring issues shared by some of the goals, such as sediment input, freshwater input, climate change, etc.

As discussions among the teams progressed, the SCT decided to separate the team focusing on Inland Habitats, Watershed, and Offshore Waters into one team focusing on Inland Habitats and Watersheds and a second team focusing on Offshore Environments. The rationale behind this separation was that the two regions are distinct, with differing stressors and problems. The discussion highlighted the need to maintain coordination between the two resultant teams, given the connection of input from the watershed (that is, nutrients, sediments, and contaminants) and the watershed's affects on offshore waters (that is, "dead zone" formation). The final goal teams are:

Group 1. Coastal habitats are healthy and resilient.
Group 2. Living coastal and marine resources are healthy, diverse, and sustainable.
Group 3. Coastal communities are adaptive and resilient.
Group 4. Storm buffers are sustainable.
Group 5. Inland habitats and watersheds are managed to help support healthy and sustainable Gulf of Mexico ecosystems.
Group 6. Offshore environments are healthy and well managed.

In addition to these groups, a separate subgroup was established to examine the science framework necessary to support an effective adaptive management capacity. This subgroup evaluated the research, modeling, monitoring, and decision support needs (information and tools for resource managers and decision-makers) and integration required to inform planning and evaluation of restoration efforts. Many of the recommendations from goal teams were used to inform the subgroup examining the science framework to support adaptive management.

This document is a compilation of those deliverables from the SCT and SWGs. **Note:** The compilation is an evolving document and will be continually improved and refined based on discussion with the broader Gulf of Mexico stakeholder community. It has benefitted tremendously from the substantial input from the SCT, SWGs, and a suite of external reviewers (groups and individuals not involved in the generation of this document) who are well-versed in the challenges facing the Gulf of Mexico and who provided candid and constructive comments on the scope, content, and format of this document.

2 Goals

2.1 Coastal Habitats Are Healthy and Resilient

Coastal wetlands, estuaries, and barrier shoreline habitats (for example, barrier islands, mainland beaches, natural levees, ridges, chenieres, and other shoreline habitats) are intrinsic to the health, resiliency, and sustainability of the Gulf of Mexico and to the ecosystem services upon which humans rely. The goals are to promote a sustainable and resilient ecosystem supported by wetlands, estuaries, and barrier shorelines that achieve and maintain a dynamic and productive synergy of ecologic, economic, and social capacities that can adapt to and recover from harmful change. Healthy ecosystems should be able to adapt to meet the needs of future generations with a minimal reliance on human intervention.

Wetland habitats support wildlife and fisheries, help maintain water quality, and protect shores from storm surge and wave action.[3,4,5] The Gulf of Mexico is home to a major percentage of the U.S. coastal wetlands; Louisiana alone represents nearly 40% of the wetlands in the continental U.S.[6] Rapid loss of Gulf of Mexico habitats is occurring from population growth and development, sea-level rise, subsidence, and storm events. In addition, past alterations to regions such as the Everglades and the Mississippi River delta have considerably changed these ecosystems. Numerous engineering projects have resulted in altered hydrology and reduced availability of sediments to replenish deltaic wetlands. Dredging to establish canals and pipelines to support the oil and gas industry has further compromised the integrity of these ecosystems.

Estuaries are among the most productive systems on earth; more than 95% of the commercially fished species and many recreationally fished species from the Gulf of Mexico depend on estuaries during some part of their life cycle. The diminished quality of Gulf estuaries is amply evidenced by reduced water clarity and quality, loss of seagrass meadow acreage, fish consumption advisories, and harmful algal blooms resulting in beach and shellfish bed closures. Another service that estuaries provide is carbon sequestration.[7]

The barrier islands, beaches, and mainland shorelines along the Gulf Coast are naturally dynamic and are influenced by storms and sea-level rise. Many shorelines are naturally ephemeral and often move from under/around static, human-built structures. Barrier island habitats also are affected by human development and engineering projects that reduce deposition of sediments and increase the potential for erosion.

Subgoal 1: Develop a better understanding of the key ecosystem factors that make coastal habitats resistant in the face of various stressors that are affecting them.

Subgoal 2: Quantify the important relations among sediments, nutrients, and salinity or freshwater flow as they relate to optimal distribution and function of coastal habitats.

Subgoal 3: Determine thresholds or tipping points that can be monitored to trigger management action and develop restoration strategies to maintain and restore vital coastal habitats.

Subgoal 4: Focus planning and projects on restoration to resilient and sustainable habitat conditions, as opposed to historical or past benchmarks.

2.2 Living Coastal and Marine Resources Are Healthy, Diverse, and Sustainable

Healthy Gulf of Mexico living marine resources (algae, corals, oysters and mussels, crabs, shrimp, fish, turtles, seasbirds, and marine mammals, among other organisms) are important because of their inherent value to the ecosystem as well as to the region's economy (commercial and recreational values). Many of these species can be used as indicators of overall ecosystem health because they are sensitive to biological, chemical, and physical conditions of the ecosystem and may reflect environmental changes through population abundance and other variables. Maintaining living coastal and marine resources that are healthy today, and that are also resilient and sustainable into the future, is an ambitious goal considering the multiple ecosystem stressors that affect these resources. Humans have changed Gulf ecosystems through a variety of activities directly affecting living resources, such as fisheries harvests, and indirectly through loss of habitat and degraded water quality; therefore, unless human activities are modified, the health of the Gulf living coastal and marine resources will likely continue to decline.

Living coastal and marine resources today are at abundances below those the ecosystem supported historically; they are now sustainable only through extensive fishery management actions and conservation measures. As the habitats that these resources need for survival continue to be altered, degraded, and lost, management of the living marine resources alone will likely not prevent future declines. The level of ecosystem services that the Gulf of Mexico has provided cannot be sustained at the current levels, leaving little buffer against stresses (for example, substantial freshwater input into estuaries from rivers due to extreme flooding events can impact oysters, which are sensitive to salinity levels in water).

With sufficient data, economic and ecosystem service effects of natural and human-influenced (anthropogenic) disasters can be estimated, but current deficiencies in resources and habitat data limit our ability to adequately estimate changes from short- and long-term stressors. An important tool for improving our understanding of the ecosystem is modeling, which, in turn, can support critically-needed planning. However, monitoring data are essential for building such models. Well-developed models can be used in planning efforts to seek efficient methods for protecting habitats in conjunction with harvesting or maintaining living marine resources and ensuring that stocks continue for generations to come.

Subgoal 1: Reduce the negative stressors that affect the current value and future sustainability of Gulf of Mexico living marine resources.

Subgoal 2: Estimate the economic effects on living marine resources and their habitats through ecosystem service analysis to assess changes from short- and long-term stressors.

Subgoal 3: Develop and implement validated ecosystem models of the physical and biological factors in the Gulf of Mexico to understand the effects of factors that may be controlled (such as the amount of sediment that is being released into the Gulf) or are beyond our control (such as sea-level rise and ocean acidification).

Subgoal 4: Increase protection and improvements in the management of the Gulf ecosystem and watersheds to avoid and reverse declines in the availability of quality habitat, the ecosystem, and the resources the ecosystem supports.

2.3 Coastal Communities Are Adaptive and Resilient

Resilient Gulf Coast communities have the capacity to adapt to changes, including those associated with short- and long-term environmental hazards, both natural and human. Communities need to be adaptive and resilient to a host of risks and changes, including the following events:

- Natural disasters, such as hurricanes and other storms, and long-term hazards, such as coastal erosion and relative sea-level rise;
- Human-influenced disasters, such as oil spills; and
- Societal and economic challenges, such as downturns in specific industries reliant on ecosystem services and risks to infrastructure supporting Gulf communities (for example, potable water) and industries (for example, transportation routes).

Because the Gulf Coast is diverse environmentally, economically, and culturally, the needs and interests of coastal communities may vary, and the most effective solutions are based on local conditions.

Subgoal 1: Conduct research to fully assess the relations between ecological systems and communities, and use the research to identify management practices that sustain ecological functions and ecosystem services, as well as enhance ecological and community resilience.

Subgoal 2: Identify commonalities and differences in community needs and current conditions across the Gulf Coast to ensure that local community-driven efforts are developed to promote community resilience and cohesion.

Subgoal 3: Provide coastal communities with the ability to plan for and achieve community growth while minimizing current and future risks.

Subgoal 4: Increase awareness and understanding of ecosystems for Gulf Coast leaders and residents as to how land change, anthropogenic modifications, and natural and manmade hazards can affect ecosystem function and resilience.

Subgoal 5: Organize human networks at the community and regional levels to understand, prepare for, and recover from the risks inherent in living on this coast.

Subgoal 6: Equip coastal community leaders with the skills to communicate risk to managers at all administrative levels and to the community at large.

Subgoal 7: Consolidate community support tools and information into accessible formats that encourage local communities to evaluate multiple scenarios when making decisions that affect community resiliency.

Subgoal 8: Establish community buy-in for all programs and projects related to the Gulf Coast Ecosystem Restoration effort.

2.4 Storm Buffers Are Sustainable

The overall intent of this goal is to provide sustainable natural and man-made storm buffers for the Gulf Coast with limited unintended consequences (such as negative effects on adjacent areas or other components of the ecosystem), recognizing that not every coastal community may receive or benefit from effective storm buffers. Accordingly, the focus is on specific activities that would accomplish the following:

- Identify areas particularly vulnerable to storms and inundation in order to allow prioritization of projects and actions to reduce future impacts;
- Develop an understanding of natural processes, such as sediment transport, which would improve the sustainability of natural buffers in those environmental settings where such processes were historically present;
- Develop tools that accurately assess and identify strategies in constructing or restoring effective built and natural buffers to reduce risks to storm surge; and
- Develop and evaluate tools and provide guidance that could assist Federal agencies, States, and local governments in their efforts to provide sustainable and cost-effective protection against storms and rising sea levels.

Subgoal 1: Develop a better understanding of critical landscape features (i.e., geomorphic, biological, physiochemical, engineered) to reduce storm risk for communities across the Gulf.

Subgoal 2: Develop a better understanding of engineering tools used in storm risk assessment such as storm surge models and coastal erosion models.

Subgoal 3: Assist in the prompt sharing of latest relevant natural and social science to Federal, State, and local agencies to reduce risk to people and property.

2.5 Inland Habitats and Watersheds Are Managed to Help Support Healthy and Sustainable Gulf of Mexico Ecosystems

Healthy inland habitats and watersheds are critical to a sustainable Gulf of Mexico. For example, the Mississippi River watershed encompasses 31 states and approximately 1.85 million square miles (4.76 million km^2).[8] Human management of this river catchment system controls the delivery of nutrients, pollutants, freshwater, and sediments into the Gulf of Mexico. Land-use practices within the watershed also affect the habitats that are vital corridors of wildlife migrations. Downstream from the watershed, these land-use effects establish the conditions of brackish waters and estuaries that are important nursery areas for fisheries. The ultimate goal of a healthy, sustainable Gulf of Mexico cannot be achieved without paying attention to how management decisions of the watershed are integrated with downstream ecosystems.

Subgoal 1: Characterize the quality and quantity of freshwater entering the Gulf of Mexico.

Subgoal 2: Understand how and where inland land uses are affecting the Gulf of Mexico. Prioritize where restoration or remediation should occur.

Subgoal 3: Understand and prioritize appropriate restoration and conservation actions.

Subgoal 4: Working with storm buffers (see above), develop a sediment budget (for example, sources, sediment transport pathways, and sinks) for the Gulf of Mexico. Balance competing interests and prioritize actions.

2.6 Offshore Environments Are Healthy and Well Managed

Offshore environments require protection and management to ensure the continued ecological viability and sustainable use of their rich resources, such as seafood and oil and gas. Within the Gulf of Mexico, offshore environments encompass a variety of ecosystems, including mesophotic coral reefs, cold-water coral mounds, gas hydrates, chemosynthetic cold-seeps, and water column and soft bottom communities, as well as submerged canyons that create a diverse group of biological niches for biodiversity and ecological functions. These environments are healthy and resilient when they can sustain the ecosystem services upon which humans rely. For example, commercial and recreational fisheries harvest and oil and gas extraction are both important ecosystem services.

To determine if these sensitive ecosystems should be managed, and if so, to manage them well, they must first be defined. Characterizing these environments includes accurately mapping their locations; inventorying their biological diversity (species richness) and determining population sizes; locating areas of high primary productivity; understanding the reproductive cycles, habitat needs, and life spans of organisms; and determining connectivity for keystone species and indicators. Mapping and inventorying these resources and monitoring identified performance indicators provide an accurate baseline against which to monitor for changes as restoration actions are enacted. Using the research and performance indicators to provide a more clear understanding of these environments enables sound management decisions related to resource utilization (that is, determining sustainability of fisheries, balancing energy needs with the effects of drilling for oil and gas).

It is also important to document and highlight the many linkages between deepwater and nearshore habitats. These habitats are connected by biology, chemistry, and physical oceanography. For example, cold-water coral mounds depend on surface productivity for the rain of organic matter on which they feed, and that productivity is stimulated by the transport of nutrients from other regions to the Gulf of Mexico region by ocean currents. However, when studying and modeling offshore systems, there is typically discontinuity between offshore modeling approaches and those that characterize the nearshore environment. Efforts to monitor, assess, and model the offshore environment should also address the connectivity of the offshore and the nearshore/estuarine/inland systems.

Subgoal 1: Develop a comprehensive long-term monitoring program that builds upon current measurements of key indicator parameters (hydrodynamics, water quality/chemistry, air quality, meteorology).

Subgoal 2: Develop a smart system to monitor and integrate offshore indicators and thresholds that provide information to resource managers on events related to the health and status of the offshore ecosystems (for example, hypoxia, fish and wildlife kills, phytoplankton blooms, anomalous physical parameters, shelf-impinging Loop Current eddies, etc.).

Subgoal 3: Integrate existing high-resolution Gulf of Mexico ocean modeling and forecast capabilities into an operational ecosystem model capable of supporting real-time offshore incident response.

Subgoal 4: Develop a comprehensive consortium for marine scientists and oceanographers working in the Gulf of Mexico to develop data standards and data management tools, prioritize research and monitoring needs, and foster collaboration among academia, nonprofit, State, and Federal scientists.

Subgoal 5: Establish long-term monitoring of deep-sea seeps, chemosynthetic ecosystems, and cold-water coral ecosystems to improve understanding of the vulnerability of these ecosystems.

3 Current Conditions

3.1 Coastal Habitats Are Healthy and Resilient

This section addresses the current state of important Gulf Coast habitats by habitat type, and by State. The Gulf Coast is influenced by a diverse array of geomorphic and anthropogenic processes that shape differently the habitats we observe, from the large deltaic environments associated with the Mississippi River to small patches of seagrass meadow. For example, natural processes may generate and sustain barrier islands in one area differently than processes building barrier islands in another region. Human activities, particularly those reducing sediment distribution and altering hydrology, affect wetland habitats to varying degrees depending on the region, with Louisiana wetlands being more affected than wetlands in other States. Because of the different processes shaping Gulf habitats, coastal habitat types are not uniformly distributed. For example, some States may have seagrass meadows whereas others do not, making direct comparisons between States more complex. Understanding current conditions as they relate to the diversity and status of Gulf habitats provides a foundation for determining actions needed to restore these habitats.

3.1.1 Coastal Wetlands

Wetlands (marine, estuarine, and freshwater) in the coastal watersheds of the Gulf are vast. As of 2004, these wetlands occupied an areal extent of 19,071,000 acres (77,180 km^2); 415,570 acres (1,682 km^2) were lost during the period 1998 to 2004. As a result of the four hurricanes since 2005, Katrina, Rita, Ike, and Gustav, an additional loss of 209,790 acres (849 km^2) of wetlands has occurred.[9] Estimates of Gulf-wide wetland acreage and losses since 1998—as measured in 2004—for selected wetland categories are provided below:[10,c]

In 2004, the Gulf Coast had 19,071,000 acres of wetlands. More than 415,000 acres were lost during 1998–2004.

- Marine intertidal (common description: nearshore): 28,950 acres total (117 km^2), with 1,890 acres lost [7.65 km^2] since 1998;
- Estuarine emergent (common description: salt marsh): 2,384,880 acres total (9,651 km^2), with 44,090 acres lost [178 km^2] since 1998;
- Estuarine shrub (common description: mangroves or other estuarine shrubs): 677,800 acres total (2,743 km^2), with 1,340 acres lost [5.42 km^2] since 1998;
- Freshwater emergent (common description: inland marshes): 2,730,050 acres total (11,048 km^2), with 49,670 acres lost [201 km^2] since 1998; and
- Freshwater shrub (common description: shrub wetlands): 1,581,930 acres total (6,401 km^2), with 218,760 acres lost [885 km^2] since 1998.

Salt marshes are the dominant coastal community habitat type from Florida's Apalachicola Bay south to Tampa Bay. Florida's salt marshes have suffered less than 10% areal loss overall, but some urban coastal areas have faced more severe losses.[11] Almost 21% (4,984 acres [20.2 km^2]) of the emergent tidal wetlands in Tampa Bay were lost between 1950 and 1990, with salt marshes and salt barrens suffering disproportionately greater losses (37.0 and 35.3%, respectively), with dredge and fill activities being the primary cause. In contrast, between 1995 and 2007, the areal extent of emergent tidal wetlands has actually increased by 433 acres (1.75 km^2) or about 2.2%.[12] Another saltwater habitat, mangroves, has also suffered losses over the years, but to a lesser extent. In 12 counties in South Florida, mangroves have decreased from 170,691 acres (690.8 km^2) during 1988–1990 to 168,411 acres (681.5 km^2) during 2006–2008, which is an overall loss of 1.4%.[13] Recent estimates of mangrove loss for Tampa Bay are approximately 5% (1950s–2007).[14] Along the west coast of Florida, mangrove and salt marsh habitats have also suffered loss; for example, in Collier County (Naples), habitat loss is 8,421 acres or approximately 7% (pre-development to 2004).[15,16]

As of 2002, **Alabama** had 271,000 acres (1,097 km^2) of wetlands in its two coastal counties. An additional 400,000 acres (1,619 km^2) of coastal streams and estuarine waters are encompassed within the Mobile Bay complex. Freshwater marshes in all of coastal Alabama declined by approximately 69% from 1955 to 1979. More than 6,177 acres (25 km^2) were lost during that time.[17]

From the 1950s to the 1990s, coastal marshes in **Mississippi** declined from an estimated 67,000 acres (271 km^2) to 58,000 acres (235 km^2), which amounts to approximately 13% of the total marsh area. This marsh loss is attributed to urbanization and development (40%), as well as to conversion to open water (26%).[18]

Louisiana has approximately 30% of the total coastal marsh in the United States—and accounts for 90% of coastal marsh loss—in the lower 48 states.[19] This loss—which totals 1,205,120 acres [4,877 km^2] from 1932 to 2010—is primarily due to human activities, such as the construction of levees and dams, the installation and dredging of canals for oil and gas exploration, the creation of channels for navigation, and subsidence due to fluid withdrawals).[20,21,22] Most recently, the four hurricanes in 2005–2008 increased these losses (see above).

In 1992, the extent of the **Texas** coastal wetlands was estimated at 3,894,753 acres (15,760 km^2), with about 85.3% palustrine, 14.5% estuarine, and 0.1% marine wetlands. Overall, coastal Texas wetlands sustained an estimated net loss of 210,590 acres during 1955–1992.[23] More recently in Galveston Bay, five wetland classes [estuarine (emergent and scrub) and palustrine (emergent, forested, and scrub)] decreased in the five counties that surround the Bay from 972,780 acres in 1996 to 946,988 acres in 2005.[24]

[c] The following list does not provide all wetland categories and losses in the Gulf of Mexico, only selected categories. A complete list of wetland categories and losses can be found in the reference provided. The complete list sums to 19,071,000 acres (77,180 km^2) total in the Gulf of Mexico, with 415,570 acres (1,682 km^2) lost during the period 1998 to 2004.

3.1.2 Estuaries and Coastal Beaches

Gulf Coast estuaries are among the most productive of natural systems. The estuaries support considerable seafood production, including finfish, shrimp, crabs, and oysters. A number of Gulf Coast estuaries show indications of impaired uses. The percentage of Gulf estuaries impaired for either aquatic-life use, human use, or both is 41% (impaired aquatic-life use, 27%; impaired human use, 6%; and estuaries listed as impaired for both human and aquatic-life use, 8%). Thirty-nine percent of Gulf estuaries are currently threatened (in fair condition). Approximately 20% of Gulf estuaries are considered unimpaired.[25]

3.1.2.1 Water Quality

The most widespread and major impairments in tidal streams and estuaries in **Florida**, like most Gulf States, are from mercury (measured as accumulation in fish tissue), fecal bacteria, and depressed levels of dissolved oxygen.[26] Microbial pollution is a major cause of water-quality impairment in shellfish harvesting areas and recreational beaches around the Gulf of Mexico.

Alabama's estuaries—including Mobile Bay, the fourth largest U.S. estuary—received a fair ranking for water quality in EPA's 2008 National Coastal Condition Report.[27] As of 2004, detectable concentrations[d] of polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDT), and mercury were most common in fish tissue from the Mobile Delta, while concentrations of cadmium were detected in the lower Mobile Bay associated with Penaeid shrimp at levels almost six times higher than in non-Penaeid shrimp samples.[28]

Mississippi has approximately 758 square miles (1,963 km^2) of coastal waters, including large estuaries, smaller bays and tidal rivers, creeks, and bayous. Of these waters, 97% fully support aquatic life as determined by dissolved oxygen content, temperature, and pH. As of 2010, Mississippi had 14 water bodies, including the Gulf of Mexico, under fish consumption advisories for mercury. The advisories are for the larger predator species, including king mackerel in the Gulf.[29] Between 2004 and 2008, 79 advisories were issued for Mississippi beaches due to high bacteria levels.[30]

In 2010, approximately 50% of **Louisiana's** bays and estuaries were in good condition, 50% were impaired, and 0% were threatened. Common causes of impairment included bacteria, mercury in fish tissue, and depressed dissolved oxygen concentrations.[31] With respect to specific designated uses, Louisiana's water quality has shown incremental improvements since 2002 for fish and wildlife propagation (good condition in 2002, 62.8%; in 2010, 64%).[32,33] During the 2010 swimming season, 55% of beach days were affected by notification actions while the percentage was 53% in 2009 and 66% in 2008. In 2009 and 2010, Louisiana conducted sanitary surveys to investigate possible sources of contamination, though none could be identified.[34,35]

In **Texas**, substantial impairments in tidal streams and estuaries include (1) dioxin and PCBs in fish tissue, primarily in the Galveston Bay complex,[36] and (2) pathogenic bacteria in streams in Houston and estuaries in the upper- and midcoastal regions.[37] Depressed levels of dissolved oxygen and mercury contamination of fish tissues are reported for Texas coastal water bodies.[38] In 2010, Texas issued 207 advisories for high bacteria levels on beaches compared to 152 advisories in 2009.[39,40]

3.1.2.2 Sediment Quality

Poor sediment quality ratings are usually due to high concentrations of metals (cadmium, mercury, lead, and zinc) or organic chemicals (polycyclic aromatic hydrocarbons, or PAHs) with known toxic effects on benthic biota. The Gulf Coast region in general is rated poor for sediment toxicity. Poor ratings for 13% of the areas were based on sediment toxicity, and 45% of the areas were rated poor based on benthic community condition.[41] However, in specific regions, sediment contaminants were less frequently observed. The sediments of **Alabama** (Mobile), **Mississippi**, and many of the **Florida** estuaries, such as Apalachicola, Pensacola, Sarasota and Tampa Bays, and Charlotte Harbor, were rated as fair.[42]

The State of **Florida** has developed an atlas—the 1994 Florida Coastal Sediment Contaminants Atlas—of estuarine sediment contamination, based on data from approximately 700 sites.[43] PAHs were detected in about 70% of the samples tested for organic chemicals; polychlorinated biphenyls (e.g., PCBs) were detected in 55% of the samples tested, and chlorinated pesticides (e.g., DDT, dieldrin) were detected in 28% of the samples tested. No indication was provided regarding biological impact or levels of concern.[44] In a 1991 assessment, Florida had several sites (in Tampa Bay and Apalachicola Bay) with PCBs and DDT at some of the highest levels observed in the survey.[e,45]

Median sediment quality guideline values for chemical contaminants were not exceeded in sediments from Lake Pontchartrain in **Louisiana** or from the Mississippi Sound reaches in Louisiana. However, lower threshold values were exceeded for arsenic, cadmium, and nickel at several stations.[46]

[d] "Selected target species were then analyzed for contaminants including metals and organic compounds (PAHs, PCBs, and pesticides). These compounds, once consumed can accumulate in the body over time. Predation on contaminated fish will result in contamination of the higher trophic levels resulting in bioaccumulation. This bioaccumulation can be cause for concern among human populations consuming fish. Analyses for contamination were done using the whole body of the fish. Neither EPA nor FDA guidance criteria exist for whole body contaminants, therefore no comparison to consumption advisories can be made with these results. Contaminants are listed based on their presence or absence. It should be noted that if a contaminant is present it is not necessarily in a concentration that would pose a risk; it is only in a concentration above the minimum detection limit." *http://adem.alabama.gov/programs/coastal/coastalforms/FinalNCANEPReport06.pdf*

[e] Specific concentrations were highlighted as being 10X higher than the next highest and therefore were excluded from the mean determination for the area.

Texas sediments have been studied in several regions. Those associated with the upper Laguna Madre showed evidence of benthic community stress and moderate sediment contamination, but major flooding in the region may have affected results. The Texas Commission on Environmental Quality found that most sites in the Coastal Bend Bays region meet requirements for good condition, while EPA guidelines ranked 10 of 50 sites as having degraded benthic communities. Five sites in Galveston Bay showed evidence of contaminant-induced degradation, whereas 15 sites did not.[47] Restrictions on produced water discharges into coastal estuaries and dredged material disposal practices that minimize reintroduction of contaminants have been suggested to possibly decrease levels of sediment contamination.[48]

3.1.2.3 Freshwater Inflow

Historically, freshwater inflows from rivers, streams, and local runoff help maintain the salinity gradients, nutrient loadings, and sediment inputs that (in combination) produce an ecologically sound and healthy estuary. More recently, the Mississippi River and its freshwater discharge strongly influence physical, chemical, and biological processes in the Gulf of Mexico, with major effects on Gulf water quality, including contributing to the largest zone of oxygen-depleted coastal waters in the United States.[49]

While the extent and range of freshwater inflows are not explicitly known, methods for determining the quantity and quality of freshwater inflows needed to maintain coastal margins in, for example, Texas, have been developed based on hydrodynamic modeling and flow analysis.[50] While freshwater inflow is required for many healthy estuaries, it should be noted that freshwater often carries unhealthy levels of constituents such as excess fertilizer, which can cause hypoxia. In the case of the Mississippi River system, especially, freshwater carries too little beneficial sediment to the needed locations. Groundwater connectivity and flow are also important for ensuring adequate freshwater inflow and even more so in drought conditions.

The **Florida Department of Environmental Protection** has developed plans for determining Minimum Flows and Levels (MFL) for water bodies. The State of Florida has conducted short-term monitoring programs to develop baseline data that can be used to establish MFLs needed to maintain water-quality conditions (salinity, nutrient, and sediment levels) that promote healthy estuarine ecosystems.

Estuaries on the upper **Texas** coast into **Louisiana—**and those on the northwest **Florida** coast**—**are subject to major effects from freshwater inflow, but all the Gulf States and their estuaries, particularly their oyster fisheries, seagrass meadows, and salt–brackish marshes, are affected by variations in freshwater inflow and associated water-quality conditions.[51]

3.1.3 Oyster and Coral Reefs

Living reefs are rich natural resources that provide many ecosystem services. Because of their need to attach to firm substrates in their adult form, oysters (most commonly the Eastern Oyster *Crassostrea virginica*) build up large reefs over time, with one generation after another selecting these firm ocean bottoms and the remains of previous generations near the coast. Living oyster reefs support themselves by taking in nutrients and oxygen from waters flowing over them. Complex, established oyster reefs provide habitat for the larval, juvenile, and adult forms of marine species of invertebrates and vertebrates. Complex oyster reefs in the shallow nearshore area attenuate wave action, helping to conserve nearshore habitats. Oyster reefs have high economic value because they are a prized food source for humans, in addition to being eaten by marine animals, so these reefs are often in demand for harvest. Oyster reefs can be adversely affected by overharvesting and changes in freshwater inflow, sedimentation, and tropical storms. A recent assessment of oyster reefs globally determined that Gulf of Mexico oyster reefs were largely in fair condition (categories are good, fair, poor, and functionally extinct). Globally, the overall condition of native oyster reefs in most of the 144 bays in 40 ecoregions that were evaluated was poor.[52]

In **Florida**, although there is often a lack of empirical evidence to demonstrate a pattern of decline for oyster resources, fisheries managers and researchers have recognized a slow but steady decline in the condition of oyster reef habitat in most Gulf Coast estuaries. Fluctuations occur in fisheries' dependent and independent data over relatively short periods, although these data are not always adequate to make science-based decisions about the condition of oyster reef habitat. Notwithstanding these indicators, the declining condition and areal extent of oyster reef habitat has been recognized based on more subjective observations of the conditions of reefs or their absence. More recently, resource managers have compared maps of oyster reefs through time, and have found that existing oyster habitat is being lost with little growth of new natural reefs.[53] Restoration projects designed to improve and enhance depleted oyster reefs have been successful in maintaining some commercially viable oyster reef habitat in several estuarine systems; however, more extensive oyster reef restoration should be required to slow the continuing loss of oyster reefs on Florida's Gulf Coast.[54,55]

More than 3,000 acres (12.1 km^2) of oyster reefs are in **Alabama's** waters. Historically, oysters have been found throughout coastal waters of Alabama; however, substantial concentrations of oysters are now more limited in areas of Mobile Bay and the Mississippi Sound. Alabama oyster populations are under constant threat from ecosystem stressors such as tropical storms,[56] repeated periods of drought, sedimentation, and other associated anthropogenic effects. Freshwater inputs into Mobile Bay and Alabama's coastal waters have been reduced due to upstream water-use demands for industrial, agricultural, and human needs, which have increased dramatically over the last 10 years. The enhanced drought conditions in Alabama and surrounding States have caused higher numbers of predatory oyster drills (*Urosalpinx cinerea*) to inhabit coastal oyster reefs.[57] These conditions and recent disasters have resulted in a 90% reduction of the oyster population on most of Alabama's reefs in just a few years.[58]

In **Mississippi**, the oyster resources have suffered from several sequential disasters, from Hurricane Katrina[59] and other storms, to droughts, to floods, to extended periods of high water temperatures, to low dissolved oxygen events, and the Deepwater Horizon oil spill. Oyster restoration efforts, developed in response to Hurricane Katrina, have been delayed, or otherwise set back by many of these more recent events. Currently, the reefs are at their lowest levels since Hurricane Katrina.

Because of its large amount of shallow estuarine habitat, **Louisiana** bays and territorial waters have historically held high numbers of oysters, as manifest in the large volume of oyster landings from the State.[60] Water quality (salinity and food availability) and areas of "hard bottom" are two critical environmental parameters controlling the abundance of oysters in an area. Hard substrate often may be supplied by individuals who hold a lease to cultivate oysters in Louisiana State waters. Oyster stock is thought to be at sustainable levels, although in the last several years, a series of hurricanes, high freshwater discharge events, and anthropogenic effects have affected oyster abundance in Louisiana waters.

In **Texas**, the oysters and the reefs that support them are under serious stress. These multiple stressors include hurricanes, hydrologic alterations due to enlargements of navigation channels, oyster disease (Dermo), pollution, predators, and heavy commercial harvest pressure. One report (2002) notes that the distribution and areal extent of oyster reefs in Galveston Bay have changed significantly since the 1950s. One study indicated a significant increase in the areal extent of the reefs (which could also be attributable to changing methodologies), but that this increase has not replaced the large amounts of shell that were removed by historical dredging.[61] In addition, it is estimated that sedimentation from Hurricane Ike in 2008 buried 60% of oyster reef habitat in the Galveston Bay system.[62] Prior to the storm, Galveston Bay had been home to about 70% of Texas' oyster landings.[63]

Coral reefs consist of living organisms, so, like oyster reefs, they are living shorelines. Coral reefs provide the same complex habitat benefits to other organisms as do oyster reefs, and they also are economically valuable as ecotourism destinations. However, Gulf of Mexico coral reefs are threatened by pollution and physical disturbance resulting from human work and recreational activities.

Shallow-water coral reef ecosystems of southern **Florida** encompass an estimated 30,800 km^2 and extend from the Dry Tortugas in the Florida Keys as far north as Tarpon Springs on the Gulf of Mexico coast and St. Lucie Inlet on the Atlantic Ocean coast.[64] These reefs are affected by a variety of stressors, including elevated surface-water temperatures (causing coral bleaching events), tropical storms (causing physical damage and scouring), coastal development and runoff (affecting water quality), coral disease, and aquatic invasive species. Monitoring results have shown an overall decline in hard coral cover of 44% at quantitatively surveyed stations, likely due to a combination of factors, such as those noted above.[65]

The banks of the northwestern Gulf (for example, Flower Garden Banks) are among the shallower-water coral areas in the best condition in the U.S. western Atlantic. Pulley Ridge is a series of drowned barrier islands on the southwest Florida Shelf, which are the deepest known light-dependent coral reefs in the United States. While many people are familiar with shallow warm-water reefs, the Gulf also has deep, cool-water reefs that are important in providing habitat for a complex food web that includes fishery species. There are also other deeper coral (for example, Viosca Knoll Lophelia deepwater coral reefs or southwest Florida slope Lithoherms) that are unique to the Gulf.[66] Coral reefs are threatened by pollution and physical disturbance resulting from the work and recreational activities of humans.

3.1.4 Seagrass and Submerged Aquatic Vegetation

Seagrass and submerged aquatic vegetation (SAV) habitats support recreational and commercial fisheries while also providing storm protection in estuaries and shallow coastal waters of the Gulf.[67,68] They also baffle the movement of water allowing for the settlement of suspended sediments and a subsequent increase in water clarity. However, human activities have negatively affected seagrass and SAV; these habitats are particularly susceptible to impacts from dredging and filling, due to direct deposition of fill material and increased turbidity impacting light penetration.[69]

Florida's seagrass resources decreased by 30–40% in several locations from the 1940s and 1950s until the early 1980s, primarily because of anthropogenic activity.[70] While seagrass acreage is still below historical levels in some locations, some other areas are showing increased seagrass acreage. For example, an 11% increase in seagrass was measured in Tampa Bay during 2008–2010, which leaves 5,103 acres left to restore to meet the Tampa Bay National Estuary Program goal of restoration of 38,000 acres.[71] Florida State waters and the adjacent Federal waters include the two largest contiguous seagrass beds in the continental United States: the Florida Keys and the Florida Big Bend regions (55% statewide SAV area). The remaining seagrass area, 381,200 acres (1,543 km^2), is distributed in estuaries and lagoons throughout the State. The total seagrass area in both State and Federal waters is more than 3 million acres (12,140 km^2).

Alabama has stands of seagrasses in Mobile Bay and its delta, Perdido Bay, and in parts of the Mississippi Sound. Overall acreage in 2002 was 44.5% of the acreage in 1940, including 691 fewer acres (2.8 km^2) along the western shore of Mobile Bay, with most of the difference south of Dog River, and 268 fewer acres (1.1 km^2) in the Mississippi Sound. In

Baldwin County, overall acreage in 2002 was 11.7% of the acreage in 1955.[72] More recently, more than 1,300 acres (5.3 km^2) were lost between 2002 and 2009, primarily due to substantially less SAV in the Delta and Mobile Bay in 2009.[73]

Historically, **Mississippi's** barrier islands, including the northern shorelines of Ship, Horn, and Petit Bois Islands, as well as Cat and Round Islands, supported populations of shoal grass, Engelmann's seagrass, manatee grass, and turtle grass; however, wide-ranging changes have occurred during the last 70 years. Declines in seagrass meadow acreage often corresponded with the decline in barrier island land area. During 1969–2002, the Mississippi Sound lost 85.7% of its seagrass coverage (11,120 acres [45.0 km^2] of its formerly 12,973-acre [52.5 km^2] coverage).[74]

Fresh and oligohaline SAV can be found throughout **Louisiana's** coastal zone marshes and estuaries, and are mostly dominated by *Ruppia maritima* (widgeon grass) and *Vallisneria americana* (wild celery).[75] Louisiana marine seagrass beds are limited to shoals west of the Chandeleur Islands (11,149 acres [45.1 km^2]) and Lake Pontchartrain. These beds no longer exist around the Timbalier Islands and Isles Dernieres, which represents a loss of 705 acres (2.85 km^2).[76]

In 1994, **Texas** had approximately 235,660 acres (954 km^2) of seagrasses on its coastline. The vast majority is in Laguna Madre, including Baffin Bay, and these meadows have lost 10–20% of their seagrass coverage since 1965. In the Corpus Christi and Redfish Bay areas, total seagrass acreage was fairly stable over a 40-year time frame. On the central coast, there has been a 10% increase in total area of vegetated bottom in the Matagorda Bay system between the 1970s and 1987.[77] On the upper coast, in the Galveston Bay system, the area of SAV decreased from 2,500 to 5,000 estimated acres (10.1 km^2–20.2 km^2) in the 1950s to just 700 acres (2.83 km^2) in 1993, for a decline of 70–86%.[78]

3.1.5 Harmful Algal Blooms

Massive blooms of the harmful algae, *Karenia brevis*, occur along the west **Florida** coast almost every year and last from 3 to 4 months. This algal species produces neurotoxic shellfish poisoning and human respiratory irritation. Harmful algal blooms (HABs) and associated toxins also cause fish kills and marine mammal mortality; the blooms can result in seafood safety consumption advisories and beach advisories and closures. These episodic blooms cause an economic loss of \$18–\$24 million per event.[79] Ciguatera poisoning, as a result of a non-bloom-forming dinoflagellate, occurs in the summer in **Florida**, Puerto Rico, and also in the Virgin Islands, where it is estimated that 50% of human adults have been poisoned at least once.[80,81]

Blooms occur more sporadically in **Texas** and throughout the Gulf of Mexico. Regions of south Texas around Laguna Madre have continuous brown tides caused by the chrysophyte *Aureococcus*, resulting in an annual loss of several million dollars due to effects on tourism and recreational fisheries.[82] Recent evidence suggests that HAB events have increased during the past 30 years, and that blooms may be altered by climate change and coastal pollution.[83]

3.1.6 Barrier Islands and Mainland Beaches

Much of **Florida's** Gulf Coast shoreline is eroding, although erosion rates are comparatively low, generally on the order of 1–2 feet per year (ft/yr) (0.30–0.61 m/yr), because of repeated artificial beach nourishment and persistently low wave heights. Hotspots of erosion around tidal inlets[84] and erosion rates on the order of 10 ft/yr (3.05 m/yr) on portions of St. Joseph Peninsula have been observed. More than 485 miles, or approximately 59% of the State's beaches, are eroding. At present, about 387 of the State's 825 miles of sandy beaches have experienced "critical erosion," which is a level of erosion that threatens substantial development, recreational, cultural, or environmental interests. Florida uses beach nourishment as a preferred way to add sand to a system that has been starved by altered inlets because it provides a substantial level of storm protection for upland properties and is the least detrimental to the coastal system, though the full ecological effect of beach nourishment is not known.[85]

Alabama has two extensive coastal peninsulas: Fort Morgan at the mouth of Mobile Bay and Perdido Key at the mouth of Perdido Bay. Additionally, Alabama has multiple coastal islands, with Dauphin Island being the largest. In Alabama, coastal land loss is caused primarily by beach and bluff erosion. Rates of land loss between 1958 and 1996 averaged 15.1 acres/yr (656,599 feet squared per year [ft^2/yr] or 0.06 km^2/yr), and between 1996 and 2006, land loss averaged 31.9 acres/yr (1,388,544 ft^2/yr or 0.13 km^2/yr), with the recent rate of loss largely due to the formation of a breach approximately 2 km wide, removing a 98.8 acres (4,305,564-ft^2 or 0.4-km^2) segment of the barrier during Hurricane Katrina.[86]

In **Mississippi**, rather than retreating rapidly landward, the barrier islands migrated laterally from east to west, through persistent longshore sand transport driven by waves. The establishment of navigational channels within the island passes has disrupted natural sediment transport systems resulting in loss of sand to the system. From 1840 to 2007, Horn Island decreased by 19%, Cat Island decreased by 40%, Petit Bois Island decreased by 52%, and Ship Island decreased by 60% in land area.[87] Horn Island dunes, once reaching 20–30 ft (6.10–9.14 m) in height, were severely affected by Hurricane Katrina, with washovers, breaches, loss of substantial elevation, and, in some cases, obliteration.

The greatest rates of erosion are found along the barrier islands and intervening mainland beaches of central and eastern **Louisiana**. For example, the Chandeleur Islands in Breton Sound have exhibited large changes in erosion rates. Historic erosion rates of approximately 27 ft/yr (8.23 m/yr) have increased within the past decade to more than 125 ft/yr (31.8 m/yr), predominantly due to storm activities. Additionally, more than 66% (85.1 acres [0.34 km^2]) of the land area of the Chandeleur Islands remaining in 2004 was removed by Hurricanes Katrina and Rita in 2005. In contrast, only

18% of that land mass was lost between 1850 and 1920, a 70-year period.[88] Restoration efforts on other Louisiana barrier islands (Terrebonne and Barataria Bay) have shown beneficial results.

Texas has 367 miles (591 km) of Gulf and approximately 3,300 miles (5,310 km) of bay–estuary–lagoon shorelines. The long-term mean shoreline change rate loss is 2.3 ft/yr (0.70 m/yr). Dune formations vary across Texas with well-developed repeating foredune ridges up to 40 ft (12.2 m) in height around Nueces, vegetated and relatively stable dunes on Mustang and North Padre Island, and migrating dunes that are bare of vegetation and highly susceptible to wind erosion in the arid environment on the lower coast.[89] Many foredunes have been destroyed by hurricanes, including those around Galveston and beach ridges along the McFaddin National Wildlife Refuge.[90,91] Shoreline development and high erosion rates have inhibited dune recovery.[92]

All barrier islands and mainland beaches are subject to the additional effects of relative sea-level rise, which increases rates of erosion. Relative sea-level rise could also, in part, worsen the impacts of tropical storms on barrier islands and beaches in the future.

While many areas are undergoing loss, areas of accretion, where the shoreline has moved seaward, were also observed in **Texas**, **Louisiana**, and **Florida**. Some of these areas occur on the lee side of man-made structures perpendicular to the beach (for example, groins on open beaches or jetties at tidal inlets).

3.2 Living Coastal and Marine Resources Are Healthy, Diverse, and Sustainable[f]

3.2.1 Management Plans

Currently, seven Federal fishery management plans[93] address the following living marine resources in the Gulf of Mexico: coastal migratory pelagic species, red drum, reef fish, shrimp, spiny lobster, stone crab, and coral and coral reefs. All of these plans except red drum include multiple species (50 finfish species, 11 crustaceans, and more than 315 other invertebrates including corals).

In addition to the seven Federal fishery management plans, other management plans exist relating to the following living marine resources:

- highly migratory species (NOAA, NMFS, and the Office of Sustainable Fisheries[94]);
- offshore aquaculture practices (the Gulf of Mexico Fishery Management Council's [Gulf Council] Offshore Aquaculture Plan [applies only to Federal waters]);
- ten State fishery management plans (for example, menhaden) (see Appendix, Section C.2.1 for citations of these management plans); and
- eight Federal Endangered Species Act (ESA) recovery plans (five sea turtles, Florida manatee, smalltooth sawfish, and Gulf sturgeon).

See the References and Resources sections for a complete listing of all the plans.

Various management authorities (Gulf of Mexico Fishery Management Council, Gulf States Marine Fisheries Commission, State and Federal fish and wildlife agencies) would benefit from improved coordination, and developing and implementing comprehensive regulations and protocols to benefit living marine resources.

The Gulf of Mexico also is home to seven endangered and two threatened vertebrate species under ESA. Loggerhead sea turtles are listed as threatened throughout their range, including in the Gulf of Mexico;[95] green, hawksbill, Kemp's ridley, and leatherback sea turtles are all endangered. Smalltooth sawfish are listed as endangered, and the Gulf sturgeon is listed as threatened. Endangered marine mammals include the sperm whale and the Florida manatee; 20 more species of marine mammals routinely inhabit the Gulf and are protected under the U.S. Marine Mammal Protection Act (MMPA). In addition to the other coral species mentioned, two threatened *Acropora* coral species (elkhorn and staghorn) reside in the Gulf of Mexico.

3.2.2 Stressors

Given the dependence of living coastal and marine resources on coastal habitats, continued loss or degradation with no intervention to reverse the trend has resulted in declining fish populations which can result in food web disruptions that threaten ecosystem diversity and stability. Stocks will likely no longer be sustainable, which in turn will adversely affect coastal communities and the coastal economy. The following stressors must be addressed to ensure sustainability of fishery stocks and a healthy, diverse ecosystem.

3.2.2.1 Habitat

Coastal wetlands and estuaries are some of the most productive ecosystems on earth, but are disappearing at a high rate.

As noted previously, coastal wetlands and estuaries are some of the most productive ecosystems on earth. The mix of environments in these nearshore coastal waters (for example, tidal and subtidal zones, as well as fresh, brackish, and marine waters) supports highly diverse and dynamic communities.[96,97] It has been estimated that nearly all commercial fish landed in the Gulf of Mexico, particularly the northern Gulf, are estuarine dependent at some point in their life cycle.[98] Unfortunately, these coastal and estuarine habitats are being lost at a high rate; for example, from 1998 to 2004, freshwater coastal wetland loss

[f] The living coastal and marine resource team was originally focused on the topic of fisheries (per the original Mabus goal). The team expanded the goal to include the broader diversity of living coastal and marine resources in the aquatic environment; however, birds and terrestrial animals were not explicitly included in this assessment.

in the Gulf of Mexico was six times higher than freshwater coastal wetland loss along the Atlantic and 25% higher than for all other wetland types.[99] An example of the impact of habitat loss is the striped bass population, whose levels are low along the Mississippi coast, and whose coastal populations in Louisiana have been declining. Striped bass have been extirpated from Alabama waters. Habitat loss resulting from changes in freshwater flow has been implicated as the likely cause for low/declining populations of striped bass.[100]

Coastal habitat loss is a direct result of subsidence, sea-level rise, loss of sediment, inundation, and alterations in salinity regimes. Other stressors also contribute to habitat degradation and loss, including:

- Invasive species (for example, lionfish, orange cup coral, Asian tiger shrimp, green mussel, giant salvinia, and several species of tilapia);[g]
- Marine debris;
- Physical habitat destruction/alteration;
- Changes to water temperatures;
- Climate change and ocean acidification;
- Poor fisheries management practices; and
- Emergency response actions.

Less is known about the role that continental shelf habitats play in fisheries health and production, especially with regards to nutrient dynamics, food web connectivity, topography, and permanence and functionality of reef and hard bottom habitats. Also, little is known about the effects from the Deepwater Horizon incident in 2010, although there will likely be ecosystem effects throughout the food web, and possibly direct effects on some commercial and recreational fisheries and on endangered or threatened species.[101,102] Hundreds of sea turtle nests were effectively relocated to prevent them from being oiled due to the Deepwater Horizon oil spill. Unfortunately, sea turtles were oiled as a result of the spill.[103] Gulf sturgeon are dependent on clean, free-flowing riverine environments for spawning.[104] Poor water quality, altered freshwater flow, and sediment loading could interfere with sturgeon reproduction. Additionally, numerous non-listed species (for example, oysters, clams) are affected by acute (for example, oil spills) and chronic (for example, excess sediment loading) stressors. Toxins could be introduced into the food chain by exposed bottom dwellers (for example, blue crab, polychaetes, and mantis shrimp) because they are the base of the food chain for many larger fish species. Continued studies on the potential effects from the Deepwater Horizon incident are necessary to more accurately assess the condition of the ecosystem. The extent of these effects may not be known for several years or, in some cases, decades.

We must develop a strategic coastal and marine restoration plan that supports essential habitats for all living marine sources from birth through all stages of life.

Some existing regulations focusing on living coastal and marine resources highlight the connected nature of healthy habitat and robust species. For example, Essential Fish Habitat (EFH), as defined by the Magnuson-Stevens Act (MSA), includes all types of aquatic habitat—wetlands, coral reefs, seagrasses, rivers—where fish spawn, breed, feed, or grow to maturity. Specifically, the MSA defines EFH as: "*...those waters and substrate necessary to fish for spawning, breeding, feeding, or growth to maturity*."[105]

Additionally, the ESA also identifies and provides protection for certain habitats, known as critical habitat. Critical habitat is defined as "*the specific areas within the geographical area occupied by the species, at the time it is listed, on which are found those physical or biological features (I) essential to the conservation of the species and (II) which may require special management considerations or protection; and specific areas outside the geographical area occupied by the species at the time it is listed that are determined by the Secretary to be essential for the conservation of the species*."[106]

3.2.2.2 Competing Resource Use

Competition among multiple fisheries in the same area(s) is expanding. Conflicts abound among all users (recreational, commercial, and industrial). Additionally, the potential is great for loss of important fishing grounds because of such industrial uses as shipping lanes, oil and gas development, alternative energy forms (for example, wind turbines), and marine aquaculture facilities.[h]

3.2.2.3 Bycatch in Inshore, Nearshore, and Offshore Waters

Many key species and benthic habitats may be substantially affected through bycatch[107] and fishing gear impacts. In general, bycatch examples include turtles and other non-target species captured in trawling operations and throwbacks from recreational fisheries, and the highest bycatch ratios are bottom trawl and bottom longline fisheries. Relatively high bycatch ratios are estimated for Gulf of Mexico shrimp trawl fisheries, although the shrimp trawling effort in the Gulf of Mexico has declined substantially in recent years. Atlantic croaker and turtles (loggerhead, Kemp's ridley, and leatherback) are major bycatch-caught species in the Gulf of Mexico shrimp trawl fishery.[108] Trawling operations have also been documented to damage benthic ecosystems.[109]

[g] Note: Invasive species can degrade habitat (e.g., zebra mussel [*http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=5*]), but also provide a direct threat to native species through consumption or out-competition (e.g., lionfish [*http://nas.er.usgs.gov/queries/FactSheet.aspx?SpeciesID=963*])

[h] Note: The Gulf Council's Offshore Aquaculture Plan (*http://www.gulfcouncil.org/fishery_management_plans/aquaculture_management.php*) requires that consideration be given to important commercial and recreational fishing grounds during the siting phase.

The commercial reef fish fishery in the Gulf of Mexico is another important Southeast Region fishery. Several hundred participating vessels target valuable red snapper (*Lutjanus campechanus*) and other reef fish species. Regulations have been implemented requiring that sea turtle release gear be onboard reef fish–permitted vessels when fishing to facilitate the safe release of any sea turtles or smalltooth sawfish caught. In addition, vessels with commercial and for-hire reef fish vessel permits are required to possess specific documents providing instructions on the safe release of sea turtles or smalltooth sawfish incidentally caught with hook-and-line gear.[110]

Other examples of species affected by bycatch in inshore, nearshore, and offshore waters include:

- Endangered and threatened species;
- Marine mammals and marine birds;
- Reef fish;
- Benthic invertebrates;
- Billfish;
- Bluefin tuna;
- Blue crab;
- Atlantic croaker;
- Sharks; and
- Flatfish.

3.2.2.4 Overfishing

Managed species are assessed to determine whether a population has been overfished (currently in a depleted state) or if it is undergoing overfishing (fisheries practices). Of the Federally managed finfish species that have been assessed, four stocks are considered to be overfished (in a depleted state) (gag grouper, gray triggerfish, greater amberjack, and red snapper) with three stocks undergoing overfishing (current fishing practices) (gag grouper, gray triggerfish, and greater amberjack). Overfishing is also occurring in various State-managed fisheries, including striped bass.

In addition to those species formally defined as having been overfished or undergoing overfishing, there is concern that overfishing could be substantially affecting a large number of non-assessed species. For example, gag grouper, grey triggerfish, greater amberjack, red snapper, and dusky shark have all been documented to have been overfished or are undergoing overfishing.[111] Additional species are known to have been overfished or are undergoing overfishing, including species within the following groups:

- Migratory pelagics;
- Flatfish;
- Reef fish (for example, red snapper, vermilion snapper); and
- Bottom fish (for example, grouper, goliath grouper).

3.3 Coastal Communities Are Adaptive and Resilient

3.3.1 Risk Assessment

Gulf coastal communities are at risk from acute events (for example, hurricanes, oil spills) and chronic conditions (for example, land loss, sea-level rise). The Deepwater Horizon oil spill and hurricanes in 2004, 2005, and 2008 exposed the vulnerability of and effects on communities on many levels.

> ***It is incumbent upon us to improve comprehensive economic and land-use planning, as well as to increase implementation abilities at the local level. Communities need tools to understand ecosystem-related health risks and to make better decisions in their planning efforts.***

Excessive storm winds damage the coastal community infrastructure, create public safety issues, and increase insurance costs and risks for people and businesses. Mississippi River floods, such as those in 1922, 1927, and 2011 can ruin crops for an entire growing season, which results in negative effects on the regional economy. In addition, these floods can displace people either temporarily or permanently. High water can also reduce or stop Mississippi River navigation traffic, which can result in economic losses of up to $295 million per day.[112]

Coastal communities face major risk from inundation during storms, but accessing accurate and understandable information about potential solutions for reducing this risk is a key challenge.[113] An example of this issue is public use and understanding of the digital Flood Insurance Rate Maps (DFIRMs).[114] Some map systems are not user friendly for the general public. In other cases, databases to interpret vulnerability and risk and the actual DFIRMS may not be up to date. Another example is FEMA's Hazus methodology,[115] which is useful for estimating potential physical damage to residential and commercial buildings, schools, critical facilities, and infrastructure, but it is a challenge to keep the underlying data current with limited funding to track and map new development.

Gulf Coast communities have access to a community self-assessment tool called the Coastal Resilience Index (CRI). The CRI was developed by the NOAA Coastal Storms Program, the Mississippi–Alabama Sea Grant Consortium, the Louisiana Sea Grant College Program, and the Gulf of Mexico Alliance Coastal Community Resilience Team. The CRI provides information on the ability of a community (or communities) to reach and maintain acceptable levels of functioning after a disaster, as well as information on the potential damage from sea-level rise. NOAA developed the Critical Facilities Tool to accompany a CRI; this tool is now publicly available Gulf-wide.[116] The intent of this tool is to provide an initial assessment of a community's critical facilities and road miles within the FEMA 1% annual chance flood zone. This tool can be used to search by state and county/parish to get a quick "snapshot" of critical facilities, such as roads, airports, communication towers, schools, power stations, medical care facilities, etc. The usefulness of this tool, however, is dependent on the accuracy of the underlying databases, which in this case, is the critical facilities database.

3.3.2 Understanding the Risks

Many of the risks that face Gulf Coast communities are connected to natural dynamic coastal processes. Residents who have never before lived in vulnerable coastal areas may not be aware of the potential risks. Some of the public may understand current risks, but may not understand how to interpret future risks or what proactive actions could be implemented. The National Flood Insurance Program's (NFIP) Community Rating System (CRS) is a voluntary incentive program that recognizes and encourages community floodplain management activities that exceed the minimum NFIP requirements.[117] For flooding risks, no attempt has been made to separate the effects of specific CRS activities, improved building codes and enforcement, infrastructure projects, and the location of wetland alterations within watersheds. This knowledge could improve understanding of the effects of physical development on flood outcomes.[118] Additionally, broadening the awareness (and importance) of floodplain maps, such as DFIRMs, to the general public could reduce risk.[119]

Louisiana has several ongoing, focused efforts that address the understanding of risk. LSU Sea Grant staff and LSU Cooperative Extension agents work with parishes and municipalities to inform them about risk from storms and sea-level rise. The Governor's Office of Homeland Security & Emergency Preparedness funds efforts to educate communities about several risk reduction programs, including the CRS program. The Office of Coastal Protection and Restoration is currently revising Louisiana's ecosystem restoration and hurricane protection master plan that establishes risk reduction targets for coastal communities. These targets will likely be pursued through a combination of structural and non-structural restoration and protection measures.

NOAA's Coastal Storms Program, the NOAA Coastal Services Center, the Gulf of Mexico Sea Grant programs, and stakeholders are working with local leaders around the Gulf coast on issues surrounding land-use redevelopment and the effects on community hazard resilience. The work includes understanding the available tools to assess and identify land development and the relationship to the susceptibility of communities to hazards. There is also training provided on how to use the tools. Information on the tools and work being conducted by various organizations, as well as expert points of contact are also provided as part of the program.[120] For example, funds from the NOAA Coastal Storm Program and Mississippi Coastal Zone Management support the Southern Mississippi Planning and Development District in educating Mississippi coastal communities about the CRS. The Mississippi communities are also supported in applying to improve their rating.

3.3.3 Understanding the Importance and Function of Natural Coastal Systems

Communities, including public real estate developers, planners, and policy makers, may lack understanding of the importance and function of natural coastal systems, such as dunes and wetlands. As population and developmental pressure increase in coastal regions, these natural coastal buffers are disappearing. The function of natural resources is slow to recover and often may not be restored due to major land-use alterations (for example, construction of impermeable surfaces).[i]

Louisiana's Comprehensive Master Plan for a Sustainable Coast states that "…wiser land-use practices must govern the way we live in this dynamic landscape if we are to create safe communities that thrive over the long-term."[121] Part of

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[i] **Statutory and Regulatory Limitations of the State of Texas.** Texas is the only Gulf State that has a mixed authority with Dillon's Rule for counties and smaller cities with populations of 5,000 or less and home rule for larger cities. (See Texas Const. Art. 11, § 4). With the exception of Cameron County in Texas, coastal counties have not been specifically granted land-use planning authority by the State constitution or legislative statute. Cities and counties along the coast with public beaches bordering on the Gulf of Mexico must adhere to two State statutes—the Texas Open Beaches Act (OBA) (Tex. Nat. Res. Code § 61.001-61.025) and the Dune Protection Act (DPA) (Tex. Nat. Res. Code, §§ 63.001, *et seq*). The Texas OBA protects the public's rights of access to and use of public beaches. The Texas OBA prohibits any person to create, erect, or construct an obstruction, barrier, or restraint generally within 1,000 feet landward of mean high tide that will interfere with the public's right to free and unrestricted access to public beaches. The Texas DPA ensures the protection of dunes and dune vegetation from adverse effects resulting directly or indirectly from construction activities. The Texas DPA requires the commissioner's court of any county with public beaches bordering on the Gulf of Mexico to establish a dune protection line along the Gulf shoreline up to 1,000 feet landward of mean high tide. The county may allow the governing body of a municipality to assume this responsibility within its corporate limits and extraterritorial jurisdiction. The Texas General Land Office (GLO) Beach/Dune Rules (31 Tex. Admin. Code § 15.1, et al.) are the implementing regulations for the OBA and the DPA. The Beach/Dune Rules require local governments to adopt beach access and dune protection programs and to integrate them into a single Beach Access and Dune Protection Plan consisting of procedural and substantive requirements for permitting beachfront construction and management of the beach/dune system within their jurisdiction. The Beach Access and Dune Protection Plans must be certified by the GLO as being consistent with the OBA and DPA.

Texas counties have floodplain management authority only within floodplains. However, counties are limited in their ability to restrict inappropriate development outside the floodplain that may negatively affect the floodplain. Municipalities in Texas have the authority to establish residential, commercial, and industrial zones in a way that could provide better opportunities for municipalities to become more resilient (See Texas Const. Art. 11, § 5).

Texas Municipalities can enforce floodplain regulations within the floodplain, as well as further restrict inappropriate development outside the floodplain. County land use in Texas is an issue that continues to draw concerns from county officials about their limited ability to prevent some of the negative effects of development and lack of ability to control growth. Much of the State's residential growth is occurring outside city limits in areas where counties do not have the power to enact the same development standards that cities do, resulting in haphazard development. In the other Gulf States that have the statutory ability to institute land-use planning and implement ordinances, these efforts may be limited by available resources (i.e., funding, staff, and time).

this challenge is identifying, describing, and quantifying how humans benefit from a variety of products and services provided by the environment. These ecosystem services are contributions from the environment that support, sustain, and enrich human life. Ecosystem services are generally divided into four categories: *supportive* (for example, nutrient cycling), *regulating* (for example, disturbance regulation), *provisioning* (for example, food and water), and *cultural services* (for example, recreation).[122]

3.3.4 Living and Working on the Gulf Coast

Many people who live on or near the coast also work on the coast. Their livelihoods are tied to a coastal activity or resource, whether commercial, recreational, or subsistence fishing, navigation, oil and gas exploration and production, fabrication (ships, oil, and gas), hunting, eco- or heritage tourism, etc. Some people might work in another industry or location, but many hold jobs that cannot be easily transferred to areas outside the coast. Additionally, many coastal jobs stem from each region's culture where both local employment and strong cultural connections increase the resilience of a community.

Another factor is affluence. While affluence generally provides greater access to resources, there are other means of increasing resilience. One example is the Vietnamese community of New Orleans East, where strong community organizational, social, and economic ties enabled them to recover more quickly from Hurricane Katrina than other communities. Working together, they assisted each other by rebuilding homes and businesses, while not waiting for outside assistance. However, the Deepwater Horizon oil spill and aftermath is adversely affecting this community, which is dependent on Gulf fisheries for subsistence and economic growth.

3.3.5 Relocation Assessment and Planning before Disasters

The risks faced by some areas are so great that relocation is often the only way to ensure safety and sustainability. Relocation, however, presents major challenges for individuals and whole communities.

Financial feasibility, preservation of culture and heritage, and selection of new locations that are resilient, sustainable, and economically viable are all part of the relocation challenge. Unfortunately, many of the coastal areas projected as suitable for relocation have become increasingly vulnerable to storm surge, storm wind impacts, land loss, subsidence, and sea-level rise. Often, moving far enough inland to remove these vulnerabilities does not fully mitigate risk. Additionally, relocation inland may remove access to traditional employment based on the economic resources of the coast. In **Mississippi**, the Turkey Creek community declined optional buyouts due to their strong historic ties to the region. However, the community was able to convince planners to provide ring levee storm protection. In other areas of coastal Mississippi, home owners were willing and voluntarily participated in the Mississippi Coastal Improvement Plan (MsCIP) buyout program, lowering the need for upgraded storm protection. In **Texas**, the City of Galveston, Galveston County, and the General Land Office are also actively involved in a buy-out program funded by FEMA Hazard Mitigation Grant Program funds for Hurricane Ike and by State appropriations.

Some communities, such as the United Houma Nation,[123] have recognized coastal hazards and are adopting and improving plans for evacuating, mitigating risk to infrastructure and housing, and maintaining their economy while preserving their way of life. Improved local planning, including planning for redevelopment in advance of disasters, and providing relocation aid in the short term after a disaster are needed in many coastal communities.

3.3.6 Long-Term Recovery and Redevelopment Planning after Disasters

Some communities have developed recovery plans to help them rebuild in the aftermath of natural disasters. At the local level in **Texas**, some communities have prepared recovery plans. In response to the 2008 Hurricane Ike, the Galveston City Council initiated the recovery planning process by appointing a Galveston Community Recovery Committee. The committee was charged with developing a vision, goals, and projects that would move Galveston along the road to full recovery from Ike's devastation.[124] In a related effort, Galveston County prepared the Bolivar Blueprint in 2010 to address hurricane recovery on the Bolivar Peninsula.[125]

In southern **Louisiana**, six parishes combined efforts to produce a Comprehensive Economic Development Strategy in 2010.[126] However, this level of planning has not been implemented throughout the Gulf. Following Hurricanes Katrina and Rita in 2005, Louisiana initiated the "Louisiana Speaks" regional planning effort coast wide. During this planning, the public was engaged to make decisions based upon a handful of scenarios related to urban planning, ecological restoration, and natural disaster effects.

3.3.7 Perception of Seafood Safety

The Deepwater Horizon oil spill has caused many people across the Nation to believe that Gulf seafood is not safe to eat, creating a substantial economic problem for Gulf communities. Part III of *A Study of the Economic Impact of the Deepwater Horizon Oil Spill*, released in March 2011, focused on public perception, including effects on the seafood industry and market.[127] Telephone interviews conducted in key national media markets across the United States found that "restaurant customers were generally positive toward **Louisiana** Seafood after 2006 (73.3% held favorable opinions)." After the oil spill, 50% held unfavorable opinions. This perception is creating hardship and disruption in some communities dependent on fishing for subsistence. Similar perceptions occur after major (Category 3 or higher) hurricanes in the Gulf of Mexico, thus indicating a repeating problem with seafood safety perception.

Federal agencies (FDA and NOAA) and groups from Gulf of Mexico States release up-to-date information on seafood safety, but these efforts have not changed general public opinion. Florida Sea Grant has a Web page addressing issues on seafood safety relative to the Deepwater Horizon oil spill.[128] Consumption safety and analytical methodologies are addressed on the Web page for general public review. Florida Department of Environmental Protection (DEP) has information on seafood safety and testing, including data on levels of polycyclic aromatic hydrocarbons (PAHs), in Gulf of Mexico fish. This information includes a summary of passing or failing tests, which makes the data easier to understand. The Florida Department of Agriculture and Consumer Services plans to continue sampling and analyzing fish during the next 3 years to assure the safety of Florida's seafood. The **Mississippi–Alabama** Sea Grant Consortium Web site links to Florida and Texas seafood safety sites and has additional information on seafood safety workshops and training for commercial fishermen on safety or seafood harvests in the Gulf of Mexico.[129] The **Alabama** Deptartment of Public Health and the Dauphin Island Sea Lab have a variety of materials on their Web sites that address seafood safety issues.[130,131]

Information on seafood safety[130] is provided on the Gulf of Mexico Regional Sea Grant Web page (*http://gulfseagrant.tamu.edu/oilspill/index.htm*). The Web page explains how PAHs affect human health and how analyses are performed, and contains frequently asked questions to better inform the public. The Gulf Seafood Marketing Coalition, a council that represents industry, state agencies, and seafood marketing groups, is working to expand the market share of seafood from the Gulf in the wake of the Deepwater Horizon oil spill. Sea Grant sits on the Gulf Seafood Marketing Coalition advisory board. Also, the Louisiana Seafood Marketing Board and groups like the Alabama Gulf Fisheries Marketing and Promotion Board contribute to assessing and informing the public on seafood safety.

Addressing the negative seafood safety perception presents research, testing, and outreach needs; science is needed to verify that the seafood is safe (or consumption limitations), and marketing is needed to effectively inform and change perceptions about Gulf seafood safety.

3.3.8 Other Stressors

Erosion, subsidence, and sea-level rise are affecting and stressing many coastal environments and communities. **Florida** produced a plan to address climate change, "Florida's Resilient Coasts: A State Policy Framework for Adaptation to Climate Change," noting that Florida is on the front line for climate change and sea-level rise effects.[132] **Mississippi** recently completed a Sea-Level Rise Action Plan for Coastal Mississippi.[133] The U.S. Army Corps of Engineers addresses saltwater intrusion, erosion effects, and land change in the MsCIP Environmental Impact Statement,[134] and in the **Louisiana** Coastal Area Final Near-Term Study Report.[135]

In **Louisiana**, up to 80% of the citrus crop was found to be saltwater-stressed due to saltwater intrusion from sea-level rise.[136] A recent Entergy Corporation study concluded that "Economic losses will increase by 50–65 percent in the 2030 timeframe driven by economic growth and subsidence, as well as the impacts of climate change."[137]

"Confronting Climate Change in the Gulf Coast Region" is a comprehensive report released by the Union of Concerned Scientists and the Ecological Society of America and was written by leading university and government scientists in the Gulf States. This report examines the potential effects of climate change upon the various ecosystems of this diverse and rich Gulf region. The authors highlight that global sea-level rise will likely have a disproportionate effect along the Gulf Coast shoreline because of its flat topography, regional land subsidence, extensive shoreline development, and vulnerability to major storms. Other impacts, including changes in precipitation patterns, have considerable uncertainty, but effects on the Gulf will likely be driven not only by regional changes, but also those occurring far upstream, given the extent of the Gulf watersheds.[138]

3.4 Storm Buffers Are Sustainable

3.4.1 Storm Surge Evaluations

The threat to coastal communities from storm surge and waves continues to increase as coastal populations increase. The threat is exacerbated by increases in the severity and frequency of storms, increases in relative sea-level rise, and in some locations, the erosion of protected wetlands and shorelines.

> ***Small differences in elevation of less than 1 foot can greatly affect habitat type, land area, and flooding potential.***

Levees, barrier islands, dunes, wetlands, and other storm buffering features may reduce storm surge risk, but they also can cause a build-up of storm surge by obstructing the movement of water driven by hurricane-force winds. Barrier islands alter the movement of water toward the coast, providing blocking action by forcing the water to move through gaps between islands, an effect that is lessened once the storm surge overtops an island.[139] The enhanced roughness of wetlands can slow the advance of storm surge, causing a small local increase in storm surge seaward of the wetland and reducing the surge landward of the wetland or slowing its arrival time slightly.[140,141] Each of these processes might tend to retard the storm surge propagation in one area, but in the process of slowing storm surge advance, the movement of water might be slightly redirected toward another location causing a local storm surge increase elsewhere. Natural and man-made protection and buffering features like wetlands and barrier islands do not decrease the mass of water driven into the region by the hurricane winds (mass is conserved); however, they do change the momentum and redistribute the storm surge. Therefore, engineered changes in one part of a natural coastal system can create unintended consequences elsewhere in the system. The potential for these unintended consequences must be considered in evaluating storm buffering options.

Such an evaluation can be made through application of high-resolution modeling tools to evaluate and assess the effects of surge and waves at a local level. A wide variety of potential storms must be considered in order to adequately identify areas subject to substantial surge risk and to identify areas where storm buffers are most critical.

Although regional tools and tools based only on elevation estimates provide some information, major risks can be overlooked by not performing fine-scale local assessments and modeling. After Hurricanes Katrina and Rita in 2005, efforts were undertaken to assess the coasts of **Mississippi** and **Louisiana** for susceptibility to storm surge flooding with a coupled surge and wave modeling system. The modeling system was applied to hindcast Hurricane Katrina for the Interagency Performance Evaluation Task Force (IPET) study.[142] The entire coasts of Mississippi and Louisiana were modeled with a suite of more than 500 storms to quantify the surge and wave hazard, the influence of coastal features, and the effectiveness of certain coastal risk reduction features as part of the MsCIP, the Louisiana Coastal Protection and Restoration study (LACPR), and FEMA flood mapping studies. Model grids were created that incorporated the best possible topographic and bathymetric information and included fine resolution where necessary to appropriately resolve the physical system. Currently, Louisiana's Master Plan is re-evaluating storm surge, as it affects and is affected by restoration and protection projects.

The USACE and others have continued to develop the modeling system, which consists of multiple hurricane wind and pressure field models, the offshore wave model WAM, the storm surge model ADCIRC, and nearshore wave-prediction model STWAVE. The ADCIRC and STWAVE models are tightly coupled, and all models can be set up through a graphical user interface. Work also has been conducted to tightly couple ADCIRC with the UnSWAN wave model.[j] Present development work is focused on incorporating morphology change during storms.

Coupled surge and wave modeling methodologies, similar to those described for Mississippi and Louisiana, are being employed for the entire **Texas** coast as part of a FEMA flood mapping study. Although FEMA flood maps exist, the most modern storm surge methodologies have not been currently applied to **Alabama** coastal areas.

The Gulf Coast region of **Florida** has storm surge assessments that, for many areas, are more than 20 years old. These assessments use a variety of storm surge risk and operational forecast models and techniques that provide surge elevation differences between areas for the same risk level of the storm. Additionally, the different tools/models lead to different answers within the region. The storm surge assessments have been used for many different purposes such as Flood Insurance Agency flood insurance risk assessment, Coastal Construction Control Line risk assessment, Department of Transportation road and bridge work, and Civil Defense evacuation plans. None of the programs have attempted to update the assessments as of the present time frame.

3.4.2 Shallow-Water Bathymetry and Low Land-Elevation Coverage

A proper understanding of the relations of land elevation to water height is paramount to the planning and success of coastal restoration and management. Given the microtidal range and expanse of intertidal wetlands along the Gulf of Mexico coastline, small differences of less than 1 foot in elevation can result in great differences in habitat type, land area, and flooding potential. Moreover, the coastal landscape is highly dynamic, particularly in **Louisiana**, where the land is sinking or subsiding at rates greater than 2 cm/yr[143] and subject to acute scour and overwash from recurring hurricanes.

Planning efforts to protect coastal communities and restore wetlands and barrier islands require accurate, high-resolution elevation data, which currently does not exist in any reliable or complete dataset or map coverage.

- The USGS maintains the National Elevation Dataset, which provides a reliable data source for upland elevations above the 5-foot (1.52-m) contour and coastal interface.
- NOAA maintains seafloor bathymetry maps and models below the 2-m contour with only sparse, targeted, and generally dated hydrographic surveys of nearshore and inland bays.
- Some Gulf States have State-specific programs assessing bathymetry and elevation. For example, the Northwest Florida Water Management District has light detection and ranging (LiDAR) data and digital elevation models (DEMs) for all of the watersheds in the panhandle of Florida. Also, the Florida Emergency Operations Center collects LiDAR data for all of the coastal counties of Florida.

The coastal margin at the land–sea interface presents many technological and logistical challenges for collecting and monitoring absolute elevation and change (accretion, subsidence) of intertidal habitats, and thus accounts for the lack of reliable and wide-area data and models. The National Estuarine Research Reserve System (NERRS) around the Gulf maintains, at various levels, sediment elevation tables (SET) that measure changes in height of salt marsh sediments.

The lack of elevation controls and map sets for the coastal zone is further complicated by the lack of shallow-water bathymetry data of the nearshore, by limited surface elevation surveys of wetland marshes and coastal forests, and by the different datums used to reference land elevations and water levels.

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[j] The UnSWAN model is the Simulated Waves Nearshore model converted to unstructured meshes.

3.4.3 Variable Subsidence, Relative Sea-Level Rise, and Coastal Erosion Rates

Relative sea-level rise in geologically stable areas such as Pensacola, **Florida**, has been shown to be about 2 mm/yr,[144] but the analysis of tide records from a gauge near Venice, **Louisiana**, shows relative sea-level rise rates in excess of 25 mm/yr.[145] Additionally, there are many locations where the rates of subsidence, therefore relative sea-level rise (which includes both subsidence and eustatic sea-level rise), are unknown. Equally as important is that no clear policy or guidance has been accepted across agencies—or even within the region—on how to address projected relative sea-level rise rates within the planning process for new projects. This lack of guidance presents several substantial challenges:

- Determining the best estimate of uncertainty associated with future sea-level rise rates;
- Determining how to build projects that are designed to “withstand” future increases in relative sea-level rise;
- Identifying the required persistence or duration of projects in light of relative sea-level rise (standard is a 50-year planning horizon); and
- Determining appropriate project maintenance costs.

3.4.4 Sand and Sediment Availability for Restoration

Substantial information on the current conditions of sediment resources in the Gulf of Mexico is available in the 2009 report, “Technical Framework for the Gulf Regional Sediment Management Master Plan,” developed by the Habitat Conservation and Restoration Priority Issue Team of the Gulf of Mexico Alliance.[146] The current conditions can be summarized from the report as follows.

Florida’s beach and dune system acts as the first line of defense against storms. The Florida DEP maintains an online database for identifying suitable sand sources. The database includes comprehensive information about offshore sediment and geological features; it also supports the design and construction of beach restoration and nourishment projects. To date, more than 300 km of beaches have been replenished through the Florida DEP program.

The **Mississippi–Alabama** shelf is bounded to the west by the Mississippi River delta and to the east by the Desoto Submarine Canyon. This portion of the Gulf of Mexico has been described as a slowly subsiding, passive continental margin; major episodes of deposition and erosion occur in response to sea-level oscillations. Sediment dynamics are influenced by fluvial processes, both historical and present day, and by the reworking of barrier island materials by currents.

Although natural beach exists in parts of **Alabama**, natural beach along most of the **Mississippi** shoreline is replaced by salt marshes and man-made beaches. Information on materials potentially available for storm buffers can be accessed through the USGS St. Petersburg Coastal and Marine Science Center in Florida, which houses data for five major geophysical surveys and a collection of sediment-core description sheets collected from Federal waters off Mississippi and Alabama.

Sediment resources in **Louisiana** are dominated by current sediment loads and historic paleodeposits from the Mississippi River delta. The Framework report (noted above) suggests that, in this geological setting, large volumes of sand (for beaches and dunes) and mixed sediment (for marshes) required for barrier island restoration can mainly be obtained from offshore sources. However, access to some of the “dredgeable” sand is limited by subsea infrastructures placed by the oil and gas industries, as well as by environmental and cultural concerns about dredging and variability of deposits in the shoals. Renewable sediment sources are also being investigated in the Mississippi River by the State of Louisiana.

A **Louisiana** Sand Management Plan (LASMP) is being developed by the Louisiana Office of Coastal Protection and Restoration. This plan will form an integral part of a Regional Sediment Management Plan for Louisiana. Another potential source of sediment for restoration and development of storm buffers in Louisiana is sediment carried by the Mississippi River itself. However, the only long-term suspended sediment information for the Mississippi River is derived from data developed using samples taken at Tarbert’s Landing, Louisiana, more than 300 river miles (556 km) upstream from the confluence of the river with the Gulf of Mexico.

A limited study is currently underway to characterize the suspended sediment budget for the lower river to determine the amount and particle size of suspended sediment available in the river for future restoration efforts. The suspended sediment load of the river has decreased since historical times.[147] Preliminary results of this study have identified areas where sediments are stored in the river channel and patterns of loss of water and sediments under varying flow conditions. Other studies indicate that a considerable amount of material is stored annually in the channel of the river, and a substantial amount of the flow of water and sediment exits the river before reaching the Bird’s Foot Delta at the mouth of the river.[148]

The upper, inner shelf **Texas** coast is more mud-dominated than the lower coast environment; limited sand is available onshore and offshore. Sandy sediments are needed for coastal projects, which has led to the implementation of new sediment management practices, the use of stockpiled dredged materials along the Gulf Intracoastal Waterway, and the identification of sediments trapped in coastal engineering structures. Recent interest has developed regarding the sand resources that may be available in the submersed paleochannels associated with the Sabine, Trinity, Brazos, Colorado, and Rio Grande Rivers. In general, the trend in fluvial–deltaic wetlands along the Texas coast is one in which vegetated wetlands are being replaced by water and barren flats. Sediment is needed to help these subsiding/eroding marsh systems keep pace with relative sea-level rise.

3.5 Inland Habitats and Watersheds Are Managed to Help Support Healthy and Sustainable Gulf of Mexico Ecosystems

The Gulf of Mexico is under stress, sometimes extreme, due to anthropogenic (human influenced) alterations to natural hydrology and water quality, as well as by natural processes, throughout the watersheds. In the upper Mississippi River watershed, sediment is trapped in reservoirs behind dams, and much overland flow via runoff does not deliver sediment to the rivers due to flood-control infrastructure. Moreover, urban and agricultural development decreases sediment yield of rivers. Additionally, this development negatively affects water quality through contaminated stormwater, fertilizer, pesticide, industrial, and wastewater runoff.

In the lower Mississippi River reaches, sediment, freshwater, and nutrients/pollutants bypass wetlands and are discharged offshore due to flood control and navigation management. The discharges result in several negative effects.

- Natural coastal wetlands are rapidly converting to open water.
- Freshwater habitats are experiencing more saline conditions.
- Water quality is documented as being severely impaired in several locations in all Gulf States (see Section 3.1). For example, excess nutrient input from the Mississippi River watershed, combined with seasonal stratification, has yielded a recurring "dead zone" in the northern Gulf of Mexico. In 2011, the dead zone was estimated to be 17,520 km^2.[149]

In the regions outside the Mississippi River system, upstream water use, containment, and management lead to decreased (or increased) freshwater downstream, causing unbalanced salinity regimes in coastal wetlands and estuaries; essentially, the timing and quantity of water can lead to excessive fresh or saline water in estuaries or at the wrong time of year. The altered hydrologic regime also has led to the increased instance of nutrients/pollutants in water bodies throughout the watershed and increased/decreased sedimentation. An unbalanced hydrologic regime can negatively affect habitats for SAVs, oysters, or juvenile fish. Excessive nutrient levels can negatively affect coastal wetlands, seagrasses, and fisheries, and can contribute to increasing occurrences of harmful algal blooms and hypoxic conditions, resulting in damages to Gulf waters and its marine animals. Many systems within the Gulf would benefit from watershed restoration. These include, but are not limited to, the following.

- In **Florida**, watershed restoration should focus on the Suwannee, Peace/Myakka, and Kissimmee/Lake Okeechobee/Caloosahatchee Complexes for water quality and the Apalachicola/Chattahoochee/Flint for water quantity.
- In **Alabama**, focus should be on the Mobile Bay, Mobile and Alabama Rivers, Wolf Bay, Weeks Bay, Fish River, Magnolia River, Perdido Bay, Perdido River, Escatawpa River, and Mississippi Coastal (including Mississippi Sound) watersheds.
- In **Mississippi**, the following are priority watersheds: Yazoo River, Pearl River, Mississippi Sound, Back Bay Biloxi, and Bay of St. Louis/Wolf River/Jordan River for water quality. Pascagoula River/Leaf River are priorities for water quality and quantity.
- In **Louisiana**, the Mississippi River system (including the Atchafalaya) is the priority watershed. Water quality and quantity issues also are in the Chenier Plain and river basins terminating in the Lake Pontchartrain basin.
- In **Texas**, to maintain natural salinities and nutrient and sediment delivery and to ensure healthy nearshore and offshore ecosystems, restoration should focus on the following watersheds: Galveston Bay (Trinity and San Jacinto Rivers) and San Antonio Bay for water quantity. Corpus Christi/Nueces Bay, Matagorda system, (Colorado/Lavaca/Brazos/Guadalupe Rivers), Laguna Madre (Upper and Lower), and Aransas/Copano Bays are priorities for water quantity and quality. The Rio Grande River and Sabine Lake are border water bodies that also require restoration activities.

3.6 Offshore Environments Are Healthy and Well Managed

Restoration, protection, and management of the Gulf of Mexico region have traditionally focused on parts of the offshore near the coastal environment at the land–water interface where citizens work, live, and enjoy recreational activities. Unfortunately, the majority of the offshore marine environment is out of sight and therefore out of mind to most citizens until an extreme event—such as a devastating hurricane or a catastrophic environmental disaster like the Deepwater Horizon oil spill—brings this inextricable relationship between the coastal environs and the offshore into distinct focus.

The structure and function of the Gulf of Mexico's Large Marine Ecosystem (LME), including its offshore resources and unique habitats (for example, nationally important commercial and recreational fisheries, open-ocean pelagic communities, highly migratory species, threatened and endangered species, live bottom and pinnacles, deepwater corals, and deepwater benthic communities) are not well understood. By extension, the understanding of stressors on the offshore LME and the strategies, which could reduce or reverse the threats to ecosystem resiliency and sustainability, are less developed for many Gulf coastal areas—albeit of equal importance. Due to the interconnectivity of nearshore and offshore ecosystems, improving the breadth of knowledge about how the offshore LME functions also will improve what is known about how nearshore ecosystems function.

One of the most visible signs of the watershed/water-quality issues in the Gulf of Mexico is the “Dead Zone” or the “Hypoxic Zone” off the coasts of Louisiana, Texas, and Mississippi that forms every summer and is a result of excess nutrients from rivers discharging into the Gulf. Hypoxia means low oxygen and is primarily a problem in estuaries and coastal waters. The abundance of nutrients, eutrophication, promotes algal growth. As dead algae decompose, oxygen is consumed in the process, resulting in low levels of oxygen in the water. Hypoxia can cause fish to leave the area and can cause stress or death to bottom dwelling organisms that cannot move out of the hypoxic zone. Other conditions include the episodic release of pollutants from industry in the region, the most notable of which is the Deepwater Horizon oil spill, which has short- and long-term effects that have yet to be determined. The microbial community in the offshore water column may have been a major factor contributing to the degradation of dispersed oil from that event.[150,151]

Additional key factors affecting the health of the offshore environment include energy exploitation, marine traffic, accidental introductions of nonnative species, climate change, ocean acidification, damage resulting from severe weather, nonpoint source pollution, harmful algal blooms, and freshwater management programs and the subsequent changes in freshwater input.

4 Activities, Actions, and Performance Indicators

This section highlights key activities, actions, and performance indicators to help achieve the goals discussed in Section 2 of this report. These include restoration actions as well as the science required to support restoration. These activities and actions are intended to build off of existing efforts, where available, and capitalize on the foundation of information that exists for Gulf restoration. These activities are intended to support (not supplant) the activities outlined in the GCERTF Restoration Strategy and to provide a solid scientific foundation for projects and efforts that move ahead as part of the Strategy and as part of future restoration efforts. As part of advancing restoration and associated science activities, the investigations and assessments conducted or underway in the Gulf (by Federal and State agencies, academia, and Non-Governmental Organizations [NGOs]) should be more readily shared and synthesized so as to allow for more time and resources to be allocated toward restoration projects where there are known fixes. The activities outlined below are recommendations only, and it is recognized that specific future investments will be based on continued planning by the GCERTF. The performance indicators below have been included as suggestions on how to measure progress in restoration, with the acknowledgement that specific investments for implementation of the GCERTF Restoration Strategy will be decided by the GCERTF.

4.1 Coastal Habitats Are Healthy and Resilient

4.1.1 Activity 1

Coastal communities and resource managers may more effectively plan future restoration activities through improved understanding of how historic changes in land use, shoreline position, bathymetry, and topography have changed coastal habitat distribution and function. In addition, the effects of variations in loadings of water, sediment, nutrients, and other pollutants from past events can provide data for future activities. By identifying locations or situations where habitats have been comparatively resistant to stressors, and conversely, identifying areas where habitats have demonstrated particular susceptibility to stressors, scientists and managers can develop effective means for assessing and quantifying resilience for different types of coastal habitats. This information can serve to inform more focused efforts targeting specific habitat types.

Activity 1

Improve resilience and ensure the long-term viability of Gulf ecosystems and the habitats that the Gulf supports, including coastal wetlands, seagrass meadows, and barrier shorelines.

4.1.1.1 Key Actions

- Identify and inventory historic changes in land use, habitat distribution, shoreline position, bathymetry and topography, loadings of water, sediment, nutrients, and pollutants as they co-occur with relevant stressors; identify specific locations or situations where habitats have been comparatively resistant to stressors (for example, assessing similar habitats with differing responses to stressors).
- Determine the relations among Gulf habitats, their processes and functions, and the quality of ecosystem services that are currently being provided.
- Identify key factors or measures of ecosystem resilience for coastal wetland, seagrass, and barrier shoreline habitats.
- Determine the amount of water, sediment, and nutrients needed to support sustainable coastal habitats.
  - Determine water and nutrient budgets that consider groundwater, riverine, and marine sources.
  - Determine sediment budgets that (*see also* Storm Buffers are Sustainable, Activity 2 [Section 4.4.2 of this report]):
    - quantify natural and modified sediment gains and losses,
    - identify excess sediments that may be used for restoration efforts, and
    - consider sediment quality.
- Examine currently used or proposed indicators of resiliency, and identify potential new determinants of ecosystem resilience including indices. Develop a methodology for assessing and quantifying resilience for different types of coastal habitats, such as salt marshes, barrier islands, and seagrass meadows.
- Use field and laboratory studies to test factors, indicators, and protocols for their ability to determine habitat susceptibility or resilience to stressors.
- Develop models to predict ecosystem resilience under different stressor paradigms, including the following:
  - climate change and sea-level rise,
  - subsidence,
  - river discharge and associated sediment, nutrient, and pollutant loading, and
  - storm intensity and frequency, associated wave action, and rainfall.
- Develop decision-support tools that are sufficiently robust to predict the amount of water, sediment, and nutrients needed to support sustainable coastal habitats,
  - considering surface waters, groundwater, and marine sources;

- ◦ considering sea-level rise scenarios identified by the Intergovernmental Panel on Climate Change (IPCC) and supported by the best regional technical understanding in the Gulf;
  - ◦ considering storm intensity, frequency, and associated wave action and rainfall; and
  - ◦ accounting for river discharge and sediment, nutrient, and pollutant loading.
- Using the information developed on habitat–stressor relations and model output, identify and evaluate restoration and protection options for their ability to ensure long-term health of coastal habitats, including considerations of the following areas:
  - ◦ interactions between habitat types,
  - ◦ criteria for selecting restoration options,
  - ◦ measures to validate restoration effectiveness,
  - ◦ habitats for threatened and endangered species changes in fisheries productivity and sustainability of cultural resources, and
  - ◦ sustainability of water and sediment quality.

4.1.1.2 Performance Indicators

- An increase in the number of coastal habitats assessed for ecosystem services and evaluated for effects from stressors.
- Species diversity increases in previously affected habitats.
- A regional monitoring plan and a data management interface are in place.
- A suite of methods and tools are available to allow managers to predict ecosystem responses to potential stressors:
  - ◦ climate and sea-level rise;
  - ◦ subsidence;
  - ◦ storm intensity and frequency and associated rainfall and wave action;
  - ◦ river discharge and associated sediment, pollutant, and nutrient loading; and
  - ◦ increased coastal development.
- Available decision-support tools include models that allow prediction of ecosystem responses and the associated uncertainty of the predictions. The models are tested with experimental, natural, historical, and hypothetical disturbance events.
- Areal extent of diminished habitats increases for habitats such as coastal wetlands, seagrass/submerged aquatic vegetation, shellfish beds, and barrier islands.
- Net increases are evident in the level of ecosystem services provided by affected wetlands and barrier island/barrier shoreline habitats.

4.1.2 Activity 2

Activity 2

Ensure long-term vitality of Gulf Coast estuaries

4.1.2.1 Key Actions

- Determine current sediment loads, freshwater flow, and nutrient and pollutant loads in rivers/tributaries and Gulf receiving waters.
- Examine the effects of upstream hydrologic modification and varying freshwater flow on estuarine health.
- Determine the relation among sediment loading and water clarity and optimal distribution and function of estuarine habitats (based on the natural processes of environmental settings of the Gulf).
- Develop volumetric controls for runoff based on future development and urbanization and recommend their implementation to promote improved hydrology in affected coastal watersheds.
- Use assessment tools and management actions, including those focused on land use, to restore the distribution and function of healthy estuarine habitats.
- Building on existing efforts, develop and implement watershed-wide nutrient and contaminant reduction strategies, where necessary, in source waters and flow through estuarine habitats and buffers.
  - ◦ Decrease nutrient and chemical discharge from point sources, where necessary, including publicly owned treatment works and industry;
  - ◦ Decrease the amount and type of fertilizer runoff in industrial and nonindustrial use; and
  - ◦ Decrease the amount of nonpoint source runoff of nutrients and pollution from coastal development.

4.1.2.2 Performance Indicators

- Extent and distribution of shellfish beds in lagoon and bay environments are increased.
- Acreage and frequency of shellfish closures are reduced.
- Distribution and function of other important estuarine habitats are known and optimized.
- Status of important biotic populations/communities improves.
- Percentage of estuarine waters with impaired water and sediment quality is reduced.
- Natural salinity gradients are achieved and maintained.
- Nutrient and contaminant inputs to Gulf waters decrease to levels that sustain healthy habitats and species.
- Percentage of beaches with impaired water quality is reduced.
- Extent and duration of hypoxic events in Gulf estuaries and in Gulf waters decrease.
- Frequency, extent, and duration of harmful algal blooms in Gulf waters are reduced.

4.1.3 Activity 3

4.1.3.1 Key Actions

Activity 3

Restore the functionality and sustainability of coastal wetlands.

- Assess baseline wetland condition and evaluate the stressors most associated with poor wetland conditions across the Gulf of Mexico. Evaluate how changes in wetland condition trend over time.
- Develop a comprehensive coastal wetland monitoring program for the Gulf that includes monitoring elements such as sediment elevation tables, relative wetland elevation, land-to-water ratios, and optimal metrics for assessing resilient wetland conditions (similar to the Coastwide Reference Monitoring System [CRMS][152] in Louisiana).
- Quantify and delineate the hydrologic regimes of watersheds supporting coastal bottomlands, swamps, and marshes. Determine the current sediment load, freshwater flow, and nutrient/pollutant load in rivers/tributaries as they relate to the current condition and extent of wetlands.
- Determine the relations among varying scales of river diversion and the ecological function and resilience of emergent wetlands.
- Assess marshes and swamps that have been restored by diverting rivers and determine the degree to which function, distribution, and resilience have been restored.
- Examine the function and resilience of emergent wetlands that have been restored by sediment augmentation over time, evaluated against existing, nonaffected similar-type habitats. Determine the degree to which function, distribution, and resilience have been restored as a result of sediment augmentation and/or beneficial use of dredged material.
- Examine the success and ecological performance of mitigation bank efforts as well as cost effectiveness.
- Measure the structure, rates, and processes that reflect wetland ecosystem condition and the ecosystem services they provide.
- Identify tipping points that indicate the need for management actions. Develop management strategies that can be employed to increase or decrease sediment/nutrient loadings to ensure optimal distribution, function, and long-term vitality of wetlands.
- Implement restoration efforts that reintroduce natural flow regimes into coastal wetlands.
- Reintroduce the Mississippi River into the delta plain via land-building diversions in a way that mimics the natural delta cycle.
- Strategically use dedicated dredging materials for wetland creation and wetland protection efforts.
- Increase acquisition of upland habitat acreage to allow for inland migration of coastal wetland complexes.

4.1.3.2 Performance Indicators

- Overall net increase in wetland ecological condition as measured by structural indicators of wetland condition.
- Wetland vertical accretion rates maintain pace of subsidence/sea-level rise.
- Land-loss rate decreases.
- Areal extent of essential habitat for native species increases (on public and private lands).
- Sediment delivery and deposition rate is optimized to enhance land development and accretion.
- Hydrologic stressors (for example, discharge, velocity, depth/duration/frequency of flooding) are minimized.
- Nutrient and pollutant inputs into wetlands are reduced to, or are maintained at, levels that support healthy habitats.
- Acres of coastal bottomlands, swamps and marshes tracts, and coastal upland habitats are increased and protected via acquisition and other conservation activities.

4.1.4 Activity 4

4.1.4.1 Key Actions

Activity 4

Ensure sustainability of barrier islands, mainland beaches, and other shoreline habitats.

- Identify structural and functional characteristics of shoreline habitats that are critical to the various types of shoreline habitats, the functions and structures of these characteristics, and the particular characteristics that make these habitats more or less vulnerable to stressors, such as the following:
  - High wave action,
  - Sea-level rise, and
  - Frequent storm activity.
- Evaluate methods for reducing shoreline erosion, increasing accretion, and protecting shoreline habitats.
- Establish a network of sites and a consistent set of parameters to monitor shoreline habitat characteristics and vulnerability.
- Use natural shoreline protection measures, such as vegetative plantings and oyster reef/living shoreline restoration, to protect vulnerable or degraded shoreline habitats.

- Develop sand and sediment delivery projects that enhance barrier islands, mainland beaches, and other shoreline habitats by using direct placement and natural sediment transport processes.
- Consider artificial shoreline protection measures where restoration to natural conditions is not sustainable, feasible, or desirable.

4.1.4.2 Performance Indicators

- Number of shoreline habitats that are assessed for ecosystem function and services.
- A network of sites and a consistent set of parameters are defined and implemented to monitor and maintain shoreline habitat viability.
- Area of shoreline habitats is enhanced by restoration projects.
- Erosion rates on barrier islands, barrier shorelines, and mainland beaches are reduced.
- Erosion of marsh shorelines along coastal waters and bays is reduced.
- Historical loss of barrier island/barrier shoreline habitat is reduced as result of restoration activities.
- Volumes and configurations of barrier islands are maintained at levels that are sustainable with minimal continuing intervention.

4.2 Living Coastal and Marine Resources Are Healthy, Diverse, and Sustainable

4.2.1 Activity 1

4.2.1.1 Key Actions

Activity 1

Protect and restore important habitats for living marine resources. These habitats include estuaries, wetlands, coral reefs, sargassum mats, and deepwater habitats.

- Improve and maintain the current baseline of current habitat conditions/status.
- Develop a long-term habitat monitoring program to determine the success of restoration projects and associated living marine resources that is capable of interfacing with living marine resource data.
- Establish ecosystem health indicators to monitor ecosystem conditions, including sentinel sites and sentinel species. Sentinel sites/species are plants, animals, and specific geographic locations (for example, Flower Garden Banks) that can be tracked over time to help alert researchers, decision-makers, and the public to current or potential trends and their effects on the ecosystem.
- Establish a prioritization process for selecting habitat protection and restoration projects.
- Develop conceptual model(s) of the Gulf of Mexico estuarine, coastal, and offshore ecosystem(s) that identify sentinel species for various functional guilds. Establish an interagency decision-making group or structure to facilitate expedited resolution of sometimes disparate and overlapping multiagency jurisdictions, authorities, and/or programs central to complex protection and restoration actions, as follows:
    - Ensure that the regulatory actions taken pursuant to the ESA, MMPA, the Magnuson–Stevens Fishery Conservation and Management Act (Gulf of Mexico Fishery Management Council; essential fish habitat), Fish and Wildlife Conservation Act, Migratory Bird Treaty Act, the Natural Resource Damage Assessment process, Coastal Zone Management Act, and the Clean Water Act are coordinated in a manner to support protection/restoration actions.
- Ensure that critical upland habitats, as well as habitats in the estuarine, nearshore (for example, oyster habitat), and deepwater environments, are protected and restored to provide ecosystem services and habitat forming processes necessary to support landscape-scale protection, restoration, and adaptation to changing climatic conditions/sea-level rise.

4.2.1.2 Performance Indicators

- Increased ecosystem productivity of coastal, estuarine, and offshore habitats as measured by abundance of appropriate indicator species (for example, sentinel species).
- Increased number of ecological models developed for functional guilds.
- Increased distribution and abundance of habitats that support healthy populations of living coastal and marine resources.
- Reduction or reversal of degradation patterns of coastal, estuarine, and offshore habitats throughout the Gulf of Mexico (for example, coral, oyster reefs).
- Improved or maintained water quality/chemistry (offshore and inshore) to support habitat and living coastal and marine resource populations.
- Increased seasonal species diversity, richness, abundance, and distribution.
- Increased number of objectives in current fishery management plans and achievement of threatened/endangered species recovery plans.

4.2.2 Activity 2

4.2.2.1 Key Actions

> **Activity 2**
>
> ***Develop a strategic coastal and marine spatial plan that is consistent with and supportive of essential habitats for all life history stages of living marine resources.***

- Develop the necessary data layers to identify current uses, by sector (for example, oil and gas, fishing, recreational use), of Gulf of Mexico (State and Federal) waters.
- Engage in marine spatial planning across all sectors.
- Describe the life history patterns of living marine resources on a spatial and temporal basis.
- Ensure that data for key biotic (for example, life history patterns, fish passage) and abiotic factors (for example, bathymetry, hydrology, sediment flow, salinity, patterns of sea-level rise) are acquired for the foundation of a coastal and marine spatial plan.
- Integrate consideration of ecosystem services into the development of coastal and marine spatial plans.

4.2.2.2 Performance Indicators

- Standardized high-quality digital data and information are available for the Gulf of Mexico for planning purposes.
- Adverse effects and demands on Gulf of Mexico living resources are reduced due to coastal and marine spatial plan development and implementation.

4.2.3 Activity 3

4.2.3.1 Key Actions

> **Activity 3**
>
> ***Enhance and improve existing long-term monitoring programs and develop additional programs as necessary to facilitate adaptive management of living marine resources in the Gulf of Mexico.***

- Identify data gaps for all life stages of key species and prioritize data collection efforts. Develop plans/programs to fill data gaps.
- Standardize, coordinate and increase data acquisition and sharing.
- Develop ecosystem models to explore relations between and among management actions and responses of living marine resources.
- Form an interactive group of researchers, management agencies, conservation organizations, and resource users to adaptively manage living marine resources by assessing and modifying management actions as indicated by monitoring data.
- Expand physical monitoring networks to include biological and ecosystem metrics.

4.2.3.2 Performance Indicators

- Existing monitoring programs are coordinated among Federal and State agencies to identify data gaps, collect necessary data, and coordinate research needs.
- Temporal and spatial monitoring of sentinel sites and species throughout the Gulf of Mexico are improved and coordinated.

4.3 Coastal Communities Are Adaptive and Resilient

4.3.1 Activity 1

> **Activity 1**
>
> ***Establish and enhance capacity-building program(s) for local governments.***

By improving coastal decision-makers' understanding of how community resiliency and ecosystem resiliency are fundamentally linked, the decision-makers can be more fully informed of the benefits of its actions (or consequences of the lack thereof) in *readily understandable* terms.

To accomplish this activity, local training opportunities and workshops on how to prepare grant proposals should be developed to help build coordinated and integrated coastal regional planning committees. These committees will then possess an improved ability to make more informed decisions regarding better protection and restoration of ecosystem services and valued ecosystem components.

These capacity-building programs can support community and ecosystem resilience by bringing together local planners, emergency managers, floodplain managers, and/or building code officials (and others where appropriate). They can be taught about the natural and beneficial use of their coastal ecosystems (wetlands/floodplains), how they support resilient communities, and the local officials' roles in protecting/restoring them.

Increased capacity for local communities and officials to make better informed decisions in building community and ecosystem resiliency can be achieved through a series of workshops for local officials. Given the varying regulatory frameworks and coastal landscapes, workshops should be tailored to meet each State's specific needs. Successful completion of the program, which would be based on knowledge gained, a commitment to improving ecosystem resilience, and possibly demonstrating that commitment (through outreach activities), would result in storm-prepared certification. Certified communities would be eligible for grant funding for planning and projects that support ecosystem and community resilience.

4.3.1.1 Key Actions

- Work with States to understand the needs of local governments in regard to addressing ecosystem needs.
  - What is existing capacity (that is, resources, programs, knowledge, political will, etc.)?
  - What are the barriers to ecosystem resilience (restoration) activities?
- Design State-specific workshops that help local officials understand the relation between ecosystem resilience and community resilience in their State and how they can improve community resilience by addressing ecosystem needs in county (parish) and local government activities.
- Design and implement certification programs for planners.
- Design and implement grant programs.

4.3.1.2 Performance Indicators

- Increased number of State-specific workshops conducted.
- Establishment of certification program.
- Number/percentage of (participating) communities that have incorporated knowledge gained from the workshops into their local plans (generic—any type of plan) increases.
- Number/percentage of (participating) communities that have incorporated knowledge gained from the workshops into their ordinances (regulatory incorporation) increases.
- Number/percentage of (participating) communities that have implemented other projects related to the workshops increases.
- Percentage of local officials (Gulf wide) who understand the benefits of ecosystem resilience (requires baseline study) increases.
- Percentage of population in (participating) communities that understand the benefits of ecosystem resilience (requires baseline study) increases.
- Number/percentage of (participating) communities that have established and adopted regional partnerships for broad-based coastal decisions increases.

4.3.2 Activity 2

Activity 2

Enhance, expand, and enable locally driven solutions.

Planning is critical to the ability of coastal communities to prevent, adapt, and rebound from disasters, negative economic and social/cultural changes, and chronic long-term ecological stressors. At the local level, some communities have prepared recovery plans, but others have not. Identifying the strongest indicators of resilience and examining how communities have used these resources to maximize resilience is an integral part of community planning.

Addressing options and resources for local- and community-initiated relocation planning, hazard mitigation planning, or post-disaster redevelopment planning is essential. The diversity of culture and ecological conditions across the Gulf Coast necessitates local solutions for resilience. Local communities understand the challenges they face better than anyone, but often lack the resources to meet these challenges. Federal and State agencies are suited to create long-term solutions, but may not understand the challenges of a particular population. Guided by the Whole Community concept, involvement of a wider range of players from the private and nonprofit sectors, including nongovernmental organizations and the general public, in conjunction with the participation of Federal, State, (Tribal) and local government partners, will foster better coordination and working relationships. Local and regional networks can act as the bridge to connect government agencies and individual communities. This may be the key to increasing trust between the government and the populations it strives to serve. Local and regional networks across the Gulf can also ensure that the goals and objectives related to resilience, restoration, and recovery programs meet the needs of local populations in a manner that does not discriminate based on race, color, national origin (including limited-English proficiency), religion, and disability.

4.3.2.1 Key Actions

- Improve capacity for comprehensive, economic, and land-use planning, as well as increasing implementation at the local level.
- Provide tools for communities to better understand ecosystem-related health risks and make better decisions.
- Connect networks across the coast to help communities share infrastructure, ideas, and human capital across a region.

4.3.2.2 Performance Indicators

- Community networking capacity is tracked.
- Improved understanding of ecosystem-related health risks.
- Increased implementation of comprehensive planning at local levels.

4.3.3 Activity 3

Activity 3

Enhance communication of risk information to promote resilience to coastal hazards.

Actions can be taken at the individual, community, and local government levels to substantially reduce vulnerability and enhance individual and community resilience to coastal hazards. Sometimes, however, such actions are not taken. While acknowledging that financial, political, and physical constraints may limit action, lack of understanding of risk and of ways to reduce vulnerability is a major barrier. Effective communication of risk to all community members and identifying ways to reduce risk are critical to fostering resilience to coastal hazards across the Gulf region.

A risk communication initiative aimed at identifying appropriate local resilience actions and then fostering resilience actions/behaviors in the Gulf should be based on social science research. As an example, the fields of risk communication and community-based social marketing could contribute to identifying successful actions, messages, and delivery methods.

At the most basic level, there is a need to communicate with coastal residents and decision-makers about what puts them at risk and what they can do to reduce their risk. Understanding current awareness, perceptions, beliefs, and behaviors, as well as the constraints and incentives to pursue resilience behaviors, should be part of building a successful communication initiative. Key elements of a successful comprehensive restoration effort are (1) developing effective avenues of communicating among all interest groups that identify risk, (2) presenting potential actions that all interested parties should implement to increase their resilience and adaptive capacity to change, and (3) providing sound, *understandable* science information that facilitates their choices toward a more resilient condition.

The messenger plays a key role in risk communication. Development of a multipronged communication delivery system would minimize the chance of excluding segments of the community. Messengers could include representatives from local government, faith-based organizations, community groups, nonprofits, businesses, and individual community members.

4.3.3.1 Key Actions

- Identify existing sources of risk and how the risk information is delivered.
- Identify community stakeholders.
- Develop and implement effective communication delivery systems to which stakeholders are receptive.
- Tailor communication strategies to individual stakeholder groups.
- Design outreach workshops for stakeholder groups demonstrating how the communication delivery systems can be used to enhance their decision-making process.
- Use adaptive management techniques to periodically gauge the effectiveness of the delivery systems and re-evaluate and revise, as needed.

4.3.3.2 Performance Indicators

- Number/percentage of stakeholders accessing communication sources increases.
- Number/percentage of stakeholders referencing risk information sources in planning documents increases.
- Number/percentage of stakeholders citing risk information sources as instrumental in decision-making (requires study/workshop) increases.

4.3.4 Activity 4

Activity 4

Identify and support critical research initiatives supporting community resilience.

Along the Gulf, community resilience is tied to ecological resilience. Coastal areas in the United States have been, and are predicted to continue, seeing substantial changes to their ecosystems.

The Gulf Coast is currently experiencing numerous changes, such as a decline of wetlands, rising coastal waters, and effects from energy development, as well as adverse weather effects on coastal ecosystems and associated human communities.

The interconnected nature of the Gulf's coastal populations and ecosystems necessitates an integrated approach to properly maintain and restore this area. However, the drivers of change to these systems are not adequately understood.

Historically, management programs that were implemented without an understanding of the interdependence of these systems often produced unintended consequences on resource-dependent individuals and communities residing in the coastal zone. Affecting behavioral change across a community requires that the community's values, beliefs, and knowledge of the issue be reflected in any proposed effort. Increasing adoption of resilience practices across a large region such as the Gulf Coast requires a thorough assessment of the area's networks. To enhance its resilience, a community should adopt recommended practices to promote this capacity.

4.3.4.1 Key Actions

- Identify the barriers to adoption of resilience practices.
- Determine target populations' current awareness of resilience issues.
- Determine how information is communicated to a community.

4.3.4.2 Performance Indicators

- Development in high-risk areas across all economic levels is tracked.

- Population levels, economic income, and diversity of employment categories to pre- and post-affected levels are compared.
- Number of communities participating in regional planning efforts is tracked.
- Number of community and regional resilience plans is tracked.

4.4 Storm Buffers Are Sustainable

4.4.1 Activity 1

Activity 1

Provide uniform storm surge and wave evaluations for the entirety of the Gulf Coast and use evaluations to identify high-risk areas and features that may diminish the storm buffering character of the coastline.

Since the storms in 2005–2007, substantial time and resources have been spent refining storm surge and wave modeling techniques, improving statistical reliability and running multistorm scenarios to better understand storm surge and wave risks in Texas, Louisiana, and Mississippi. However, equivalent efforts have not occurred for much of the coasts of Alabama and Florida. In order to accurately compare risk across the Gulf of Mexico region and help identify priority areas where investments should be made in storm buffers, either similar methodologies should be employed across the Gulf Coast, or the methods should be tested and compared to ensure that their outputs are comparable. One way to accomplish this is to establish analytical testbeds and a process by which multiple modeling methodologies are compared and assessed.

One critical factor that drives model accuracy is the existence and rapid availability of a high-quality digital elevation model for the entire Gulf Coast region. Although several State and Federal agencies fund periodic surveys and updates of bathymetry and topography, no entity is charged with collecting, compiling, updating, and providing quality assurance of bathymetric data and then making the information readily available for the entire Gulf Coast. Although many agencies have geospatial data responsibilities for the Gulf Coast area, none of them are charged with this responsibility.

Additionally, the accuracy of storm surge and wave models is dependent upon good information and field data collection. The measurement of surge and waves during the storms is critical, and the understanding of the resilience of wetlands and resistance to erosion and the roughness coefficients of various vegetation types are important model input parameters.

4.4.1.1 Key Actions

- Inventory and evaluate models for storm surge, waves, and coastal erosion to determine the most appropriate and best ones for use in developing risk assessment of storm surge and wave impacts. Conduct benchmark testing to assess models via blind testing and analytical testbeds where data are available. An example of an effort that has initiated this process can be found at *http://testbed.sura.org/*.
- Accelerate efforts to develop, update, and maintain a uniform and high-quality digital elevation model for the Gulf of Mexico.
- Use best available technology to run storm surge and wave models for the entire Gulf Coast. Include model(s) runs that factor in potential relative sea-level rise scenarios.
- Plan, design, and construct (enhance where existing) an appropriate network to monitor storm surge, waves, and coastal erosion for the calibration of models used in developing risk assessment of storm surge and wave impacts. This network should have the capacity to monitor a full suite of meteorological parameters, tidal stage, and an appropriate suite of water-quality parameters during storm events. This would include a coastwide reference modeling system similar to the CRMS[153] already available for the Louisiana Gulf Coast region.
- Enhance existing nearshore riverine and estuarine monitoring networks to withstand a category 4 storm.
- Refine the risk or vulnerability indices developed for the general public, using the modeling output (developed from the previous three items in this list), to enhance the local understanding of risk from surge and waves, and to prioritize at-risk populations.

4.4.1.2 Performance Indicators

- Increase in percentage of the Gulf Coast that has been assessed using the uniform technique.
- Increase in percentage of the Gulf Coast with online maps of surge and wave risk available to the general public.

4.4.2 Activity 2

Activity 2

Develop/update Gulf-wide sediment budget (for example, sources, sediment transport pathways, and final depositional sites) to document sediment movement around the Gulf.

Although too much fine-grained sediment is considered to be a pollutant in some parts of the Gulf of Mexico, in other parts, sediment is, unfortunately, not present in sufficient amounts to accomplish restoration goals. Also, sand is not always available in preferable locations, and the transport of sediment from one location to another is energy intensive and costly. One way to work with these issues is to develop a regional sediment management plan for the Gulf of Mexico.

A framework for this idea has been developed by the Gulf of Mexico Alliance, but minimal funding has been available to support the concept. In the northern Gulf, much work is needed to identify sediment resources from the rivers and streams entering the Gulf of Mexico and then to determine the relations between fluvial sediment budgets and coastal sediment budgets.

Accurate elevation information, as already described, is not only critical for storm surge and wave estimates, but is also essential for understanding the volume of sediments available, the pattern of sediment movement, and the volume of the sediments required to accomplish coastal restoration. For example, Blum and Roberts (2009) postulated that 13 billion cubic meters of sediment is necessary to sustain coastal Louisiana in its present configuration.[154] This estimate, as well as any other local or regional estimate of volume of sediment required for a restoration effort, is completely dependent upon accurate bathymetry. Furthermore, accurate elevation information is critical to measuring the rate of subsidence, which again allows us to estimate whether there is adequate material to restore a storm buffer feature over time and whether or not that feature will remain above the water surface for the intended project life span. As noted previously, efforts to develop, update, and maintain a digital elevation model should also be pursued.

4.4.2.1 Key Actions

- Increase sediment-use efficiency and effectiveness in restoration projects by building on and implementing the Regional Sediment Management framework proposed by the Gulf of Mexico Alliance.

4.4.2.2 Performance Indicators

- Increase in the percentage of Gulf watersheds with quantitative sediment budgets.

4.4.3 Activity 3

> **Activity 3**
>
> ***Focusing on high-risk populations identified in Activity 1, identify general actions that could/should be taken that would help to provide sustainable reductions in storm surge risk. Convey that information to States and local communities.***

Throughout the past several decades, useful information on best management practices for local institutions about such things as stormwater runoff and nonpoint source pollution has been compiled into manuals and distributed to local governments and individuals. A similar idea could be employed by convening a technical writing committee and producing a manual of storm buffer options that should be considered by local entities and could potentially be constructed by local governments. Topics that could be covered in this manual include nonstructural solutions, design of resilient infrastructure, maintenance guidelines for structural components, use of vegetative buffers, and barrier island maintenance and design for maximum storm surge attenuation.

4.4.3.1 Key Actions

- Further identify actions that could be taken by local communities.
- Develop a guide of “Storm Surge Best Management Practices” that could be made available to local municipalities and county and parish governments.

4.4.3.2 Performance Indicators

- Progress on or completion of manual; completion of scheduled updates and revisions.
- Number of locally designed and built storm buffer projects that are implemented using information provided in the aforementioned manual or documents.

4.5 Inland Habitats and Watersheds Are Managed to Help Support Healthy and Sustainable Gulf of Mexico Ecosystems

4.5.1 Activity 1

> **Activity 1**
>
> ***Reduce nutrient/pollutant inputs in upper watersheds to prevent their delivery to the coastal wetlands and Gulf of Mexico.***

4.5.1.1 Key Actions

- Increase implementation of best management practices and native buffers, such as wetland and riparian, in watersheds.
- Develop and implement watershed-wide nutrient and contaminant reduction strategies.
- Document water-quality improvements resulting from implementation of best management practices.

4.5.1.2 Performance Indicators

- Overall increase in ecological condition of waters as measured by key indicators across the Gulf of Mexico basin and in the Gulf of Mexico.
- Decrease in area, frequency, and intensity of hypoxic events.
- Nutrient/contaminant inputs into wetland and Gulf decrease to, or are maintained at, healthy levels.
- Increase in percentage of land area within watersheds with effective best management practices in place.
- Increase in health of fish and wildlife that have been exposed to harmful materials or conditions.

4.5.2 Activity 2

4.5.2.1 Key Actions

Activity 2

Evaluate inland land-use practices, and modify them as necessary.

- Evaluate upstream reservoir and dam management practices that affect delivery of freshwater and sediments to deltaic and estuarine systems.
- Evaluate effectiveness of agricultural, residential, industrial, and commercial best management practices.
- Determine how inland land use affects the Gulf of Mexico and what actions are needed to address deleterious effects.
- Improve coordination among regulatory agencies in the watersheds, particularly of the Mississippi River, which could contribute to improved water quality and where improvements would be helpful.

4.5.2.2 Performance Indicators

- Increase in the areal extent of essential habitat for native species in both public and private ownership.
- Increase areal extent of sustainable land use (development, agriculture, etc.).
- Increase in fish and wildlife and vegetative species populations: abundance, distribution, diversity, and productivity.

4.5.3 Activity 3

4.5.3.1 Key Actions

Activity 3

Develop a comprehensive long-term monitoring program that measures system parameters (from watershed to Gulf).

- Integrate existing Federal, State, local, and other monitoring systems into the comprehensive long-term monitoring program and identify gaps.
- Provide near real-time information for an adaptive management program.
- Provide important baseline data for quantifying the effects of major events in the future (floods, spills, hurricanes, fire, etc.), and long-term information on trends in key system parameters from across the Gulf of Mexico basin and in Gulf of Mexico waters. Evaluate how changes in these conditions in streams, rivers, lakes, wetlands, and coastal waters trend over time.
- Facilitate and inform the energy, transportation, fishing, and recreation industries by providing real-time measures of the status of the systems and conditions throughout basins and watersheds.
- Develop a data management plan, building on existing resources, to facilitate data sharing between agencies, academia, and the public.

4.5.3.2 Performance Indicators

- Increased percentage of water inflow with accurate sediment and nutrient loading measurements.
- Inclusion of an adaptive management framework, with a long-term monitoring program, in all restoration plans resulting from the GCERTF.
- Establishment and use of a centralized data management structure for Gulf restoration by Federal, State, and local partners.

4.5.4 Activity 4

4.5.4.1 Key Actions

Activity 4

Reduce water-quantity conflicts (human and habitat) (see also Coastal Habitats, High-Level Activities for additional recommendations addressing water quantity).

- Determine the current and historical/natural/balanced hydrologic regime for Gulf of Mexico watersheds and establish hydrologic restoration goals for project implementation.
- Evaluate the ecological and societal effects of the altered water-quantity regime.
- Develop hydrologic alternatives to the current altered state.
- Develop and expand water conservation practices to minimize conflicts among water users such as municipal, wildlife, fisheries, agricultural, etc.

4.5.4.2 Performance Indicators

- Stream and river discharge and flood duration, frequency, and elevation increase or decrease and are managed appropriately.
- Areal extent of land inundated during flood events increases or decreases, as appropriate.
- Hydrologic regimes of watersheds are quantified and delineated in order to support management and improve our understanding of watershed hydrology.
- Natural salinity dynamics are maintained.

4.6 Offshore Environments Are Healthy and Well Managed

4.6.1 Activity 1

Activity 1

Enhance and expand an observing system focused on key indicators related to a resilient offshore water column and benthic habitats.

The framework of a regional monitoring system is already in place; the Gulf of Mexico Coastal Ocean Observing System (GCOOS) is part of a larger, integrated ocean observing system (*http://gcoos.tamu.edu/*). This system has a series of monitoring buoys, but needs to be expanded to better cover certain areas and to provide an overall assessment of offshore environments; benthic landers[155] should be included so that the monitoring includes the sensitive seafloor ecosystems, as well as the water column above them. This system can integrate satellite remote sensing data with on-the-ground/water sampling data and provide some of the primary data necessary for ecosystem models.

4.6.1.1 Key Actions

- Integrate additional existing observing systems into the GCOOS network.
- Expand to "observatory" concept, for example, ecosystem indicators.
- Develop and implement a Gulf-wide program to map and characterize seafloor habitat.

4.6.1.2 Performance Indicators

- Increased resolution/coverage of GCOOS stations.
- Location of benthic communities (hard and soft bottom) is mapped and quality (extent and character) improves. Offshore hydrodynamics (wave and current characteristics) are measured and monitored to support management.
- Offshore meteorology is measured and monitored to support management.
- Nutrient/contaminant inputs in the Gulf decrease to healthy levels.

4.6.2 Activity 2

Activity 2

Reduce effects of hypoxia by improving detection, tracking, and forecasting ability.

Leverage ongoing activities and goals of the Mississippi River/Gulf of Mexico Watershed Nutrient (Hypoxia) Task Force to serve as indicators of hypoxia effects on offshore waters. Supplement Hypoxia Task Force observations where needed to examine other areas of hypoxia within the Gulf.

4.6.2.1 Key Actions

- Map nutrient and contaminant sources and assess levels and effects.
- Map hypoxia, harmful algal blooms, and other stressors and assess effects across the Gulf of Mexico.
- Relate the extent and duration of hypoxia and harmful algal blooms to economic and other effects on fisheries and other natural resources and services (in coordination with Inland Habitats and Watersheds and Living Coastal and Marine Resources).

4.6.2.2 Performance Indicators

- Percentage of the Gulf of Mexico that is mapped for nutrient and contaminant sources increases over time.
- Percentage of the Gulf of Mexico that is mapped for hypoxia, HABs, and other stressors increases over time.

4.6.3 Activity 3

Activity 3

Analyze offshore indicators to support coastal and marine spatial planning and habitat conservation.

Analyze offshore indicators to support coastal and marine spatial planning and decisions regarding protected areas and sanctuaries within the Gulf.

4.6.3.1 Key Actions

- Map human activities by sector (for example, fishing, oil and gas, transportation, etc.) and assess trends.
- Map currents and pelagic and benthic habitats; map protected areas, sensitive habitats, and biodiversity hotspots and identify gaps in protection.
- Identify gaps in knowledge and assessment to conduct ecosystem management and take actions to fill those gaps.

4.6.3.2 Performance Indicators

- Assessments of effects on corals (coral bleaching events, extreme temperature fluctuations, and ocean acidification) increase.
- Assessments of the microbial community increase.
- Quality of benthic habitats (hard and soft bottom) and water column communities increases/improves.
- Offshore fisheries species populations (abundance, distribution, diversity, and productivity) increase.

4.6.4 Activity 4

4.6.4.1 Key Actions

Activity 4

Assess current operational and research modeling efforts within the Gulf and support offshore ecosystem protection and preservation efforts.

- Develop a modeling strategy for the Gulf of Mexico ecosystem with appropriate parameters that span site-specific to regional scales.
- Identify existing watershed (surface water), groundwater, estuarine, offshore, erosion, and habitat models across the Gulf.
- Use models to modify or adjust restoration and protection actions, and to provide analysis and guidelines to the efficiency of different restoration strategies/projects (such as re-establishment of freshwater flow, nutrient loads, suspended sediment deposition, storm buffers, and barrier island restorations) under an adaptive management framework.

4.6.4.2 Performance Indicators

- Increased communication and data sharing between agencies and academia.
- Comprehensive data management plan executed to support modeling and monitoring efforts.

5 Cross-Cutting Monitoring, Modeling, and Research Priorities

The goals highlighted in this document and within the GCERTF Strategy are oriented around the many components of the ecosystem, including the human component. Given the interconnected nature of the Gulf ecosystem, issues that relate to one goal (e.g., coastal habitats), often have direct bearing on other goals (e.g., living marine resources). The scientific activities highlighted here—monitoring, modeling, and research—overlap among many of the goals and will provide the knowledge and understanding needed to make and implement informed decisions. Please note that this section correlates to Appendix C in the GCERTF Strategy.

5.1 Cross-Cutting Priorities

A long-term Gulf of Mexico monitoring program will support a variety of restoration and protection project alternatives and provide the data foundation to make accurate predictions to protect human life and restore the ecosystem. Such a program should be used to determine baseline conditions for inland watersheds and estuarine, coastal, and offshore waters, to measure change and project effectiveness, and to support adaptive management decisions for Gulf restoration. A Gulf of Mexico modeling network should also be developed that increases certainty in forecasts and estimates of ecosystem services at a variety of stages along the restoration continuum for decision-makers and the public.

Further, research and basic discovery are needed to improve understanding of the ecosystems that exist in the Gulf and how they can be sustained when the Gulf is undergoing extreme adverse conditions, including human and natural disasters, such as oil spills or hurricanes, and climate change. Focused research on human impacts, solutions, and risk is needed, as well as information about the economic impacts to humans and ecosystem services. There should be a strong reliance on basic research on such subjects as ecosystem loss, adaptability, variability, and resiliency in all forms.

These activities will promote learning and help guide the planning, implementation, and evaluation of the restoration and protection efforts articulated in the goals of this Strategy, as well as future restoration efforts in the Gulf. As the monitoring, modeling, and research priorities identified below are implemented, shared learning among all stakeholders should occur over multiple iterations of the adaptive management process. Science is critical in the development of the projects, but equally critical is the determination of scientific and cost effectiveness of restoration projects and to not repeat mistakes or ineffective efforts. The priorities outlined here highlight preliminary needs supporting Gulf ecosystem restoration. Addressing these needs should include an assessment of the existing capacity (monitoring assets and data streams, model inventories, and research results) and investments to build upon this capacity.

5.2 Monitoring Priorities

Performance indicators are used to determine system-wide and project-level monitoring. Monitoring also is conducted to address decision-critical uncertainties and to parameterize models needed to assess performance. The data needed to support monitoring and modeling should be prioritized to ensure the most important needs are addressed. The following were identified as high priorities:

5.2.1 Monitoring Programs

- Collect information about existing watershed, basin-wide, estuarine, coastal, offshore, and habitat monitoring programs across the Gulf (e.g., Gulf Coast Ocean Observing System, Coastwide Reference Monitoring System) and identify gaps that should be filled to better support adaptive management.
- Recommend ways to integrate these programs and fill gaps to establish a comprehensive network that can provide the information necessary for managers operating at different scales (from local to national) to make informed decisions, adapt their actions as needed, and assure effective stewardship of Gulf ecosystem resources. Identify gaps in the monitoring programs that need to be filled to support adaptive management.
- Use a hypothesis-based approach for assessment of system performance.
- Foster data comparability, consistency, and standardization across programs, projects, and habitats.
- Improve data dissemination and visualization tools to provide information to resource managers.

5.2.2 Monitoring Variables

- Collect high-resolution topographic, bathymetric, geodetic, and tidal data to develop and maintain (with frequent updates over time) high-quality digital elevation models for the Gulf of Mexico that reflect and quantify changes to a dynamic (that is, constantly changing) land and seafloor.
- Collect water, sediment, pollution, and nutrient loading data from a comprehensive network of inland stream stations and gauges, lake stations, and wetland stations, as well as nearshore/offshore ocean observing stations that also record wave, current, and sediment transport characteristics.
- Monitor networking capacity (for example, workshops, training, engagement of local planners) of Gulf Coast communities, as well as environmental awareness and environmental attitudes of its citizens.
- Specific data acquisition needs are presented below the following table. Many of these variables can serve multiple goals and would be considered high priority; however, each restoration project should be assessed to determine if it incorporates the monitoring elements required to determine project efficacy.

	Habitats (coastal)	Habitats (inland) and water-sheds	Living coastal and marine resources and offshore environments	Coastal communities (including storm buffers)
PHYSICAL				
Sediment, nutrient, pollutant loads, and freshwater flow rates	X	X	X	X
Land:water ratios	X	X	X	X
Topography/bathymetry	X	X	X	X
Shoreline position and form and dimensions of beaches and dunes and barrier islands	X		X	X
Erosion and accretion rates	X			X
Seafloor change	X	X		
Hydrology (water-surface elevation, current velocity, wave characteristics, salinity, temperature)	X	X	X	X
Meteorology	X		X	
Air quality		X	X	
Marsh elevation (accretion, subsidence, sediment elevation table)	X		X	X
Relative sea-level rise rates (subsidence and global sea-level rise)	X	X	X	X
Geodetic vertical datum	X	X		X
BIOLOGICAL				
Invasive species	X	X	X	
Fisheries composition/abundance/diversity/productivity/tissue contaminants	X		X	
Fisheries landings			X	X
Wildlife, avian, and living marine resources abundance/diversity and distribution (including sentinel species)	X	X	X	
Plant community composition/abundance/diversity/productivity	X	X	X	
Benthic macroinvertebrates or key benthic assemblages	X	X	X	
Phytoplankton, harmful algae species occurrence, toxin production	X	X	X	
Zooplankton	X	X	X	
Pathogens	X	X	X	
Microbial ecology		X	X	
CHEMICAL				
Water quality (nutrients, ammonia, silica, turbidity, total suspended solids, water clarity, contaminants [e.g., PAHs, PCBs], metals, dissolved oxygen, salinity, temperature, depth, conductivity, secchi depth, PAR, pH, chlorophyll *a*, carbon)	X	X	X	
Coastal, nearshore and offshore seafloor sediment characteristics (sediment composition, bulk density, organic matter, total carbon (C), total nitrogen (N), phosphorous (P), grain size, total organic carbon (TOC), sediment toxicity)	X	X	X	
HABITAT				
Habitat classification (including classification of impaired habitats)	X	X	X	
Aerial extent of essential habitat	X	X	X	
Aerial extent of sustainable land use		X		
SOCIOECONOMIC				
Socioeconomic data on habitat and living marine resources			X	X
Social and community capacity for emergency preparedness				X
Population and development in high-risk or hazardous areas				X
Community networking capacity				X
Environmental awareness and attitudes, as well as barriers to adopting resilience practices				X

5.3 Modeling Priorities

Models can be used to modify or adjust restoration and protection actions, and to provide analysis and guidelines to the efficacy of different restoration strategies/projects (such as re-establishment or modification of freshwater flow, nutrient loads, suspended sediment deposition, storm buffers, barrier island restorations). Modeling is used to understand system processes, make predictions related to different management/restoration scenarios/projects, and guide monitoring. Modeling can also be utilized to address future uncertainties, like the effects of relative sea-level rise. As with the use of adaptive management overall, model assumptions and uncertainties should be clearly articulated to ensure that planning and decisions are fully informed. The six Science Working Groups (SWG) and the GCERTF identified the following as high priorities.

5.3.1 Modeling Programs

- Document existing watershed (surface water), groundwater, estuarine, offshore, erosion, and habitat models across the Gulf and encourage collaboration among users of the models.
- Use models to modify or adjust restoration and protection actions, and to provide analysis and guidelines on the efficiency of different restoration strategies/projects (such as re-establishment of freshwater flow, nutrient loads, suspended sediment deposition, storm buffers, and barrier island restorations) in an adaptive management framework.
- Promote fully coupled surface-water–groundwater models linked to watershed, coastal, biological, ecological, and offshore models to support adaptive management strategies and evaluate the effects of restoration projects on the ecosystem over time.

5.3.2 Modeling Input

A comprehensive monitoring network with organized data management and quality assurance/control can provide the necessary input for models. The models also can be used to guide data collection and monitoring programs by evaluating the reduction in predictive uncertainty by the inclusion/exclusion of existing data and proposed monitoring sites (that is, the “worth” of the data).

5.3.3 Modeling Needs

- Predictions and adaptive management
    - Employ ecosystem modeling to support planning and explore relations between management actions and resource response (SWG 2).
    - Develop models and other decision-support tools to predict the amount of water, sediment, and nutrients needed by coastal habitats to support wetland and marine organisms (SWG 1):
        - Under realistic sea-level rise scenarios,
        - Including riverine and marine sources, and
        - Incorporating water-quality data and hydrologic flow data.
    - Develop models to predict ecosystem resilience under different stressor paradigms, including SWG:
        - Climate change and sea-level rise,
        - Subsidence,
        - Storm intensity and frequency, associated wave action, and rainfall, and
        - River discharge and associated sediment, nutrient, and pollutant loading.
    - Test models with experimental, natural, and hypothetical disturbance events (SWG 1).
    - Identify and address critical model limitations and uncertainties including compounding uncertainties when linking with one or more models and/or into future years (SWG 1).
    - Develop uniform methodologies for including relative sea-level rise considerations into modeling and project planning for sustainable storm buffers including wetland accretion (SWG 4).
    - Improve models for predicting coastal response to relative sea-level rise and storm effects (SWGs 1, 4, 6).
- Physical and biological models (SWG 2).
    - Develop storm surge, wave, and coastal erosion models that can be used in developing risk assessment of hurricane, storm surge, and wave effects (SWG 4).
        - Couple storm surge and wave modeling (SWG 4) for hindcasting (used for Katrina) with flood modeling for risk assessment.
            - » Develop coherent and robust model for entire Gulf (all States).
            - » Topographic data.
            - » Bathymetric data (or lack of bathymetry and low land elevation data).
            - » Offshore wave model WAM.
            - » Storm surge model ADCIRC.
            - » Nearshore wave model STWAVE or UnSWAN.
    - Develop and enhance hurricane wind and pressure field models (SWG 4).

- ◦ Evaluate sustainability of storm buffers and barrier islands as habitats using coastal erosion and morphologic evolution models (SWGs 1, 4):
- ◦ Focus global climate models to address Gulf of Mexico needs (SWG 4).
- ◦ Develop models to understand the hydrologic regime of targeted watersheds of the Gulf of Mexico. Develop surface-water–groundwater integrated models of coastal systems with transport included (SWG 5).
- ◦ Model impacts of hydrologic restoration and protection (for example, diversions, levee realignments) on diversity and/or production of living resources (for example, vegetation, fish, and shellfish) (SWGs 1, 2).
- ◦ Model impacts of habitat loss (for example, marsh degradation) on diversity and/or production of living resources (for example, vegetation, fish, shellfish) (SWGs 1, 2).

5.4 Research Priorities

The influences of ecosystem variability, gaps in knowledge, and inadequate understanding of complex ecosystem functions and responses cause uncertainty that can greatly influence risk in management actions. Ecosystem research to support management decision-making can be helpful in reducing this risk. The six Science Working Groups and the GCERTF identified the following as high priorities.

5.4.1 Research Programs

Testing underlying assumptions of ecosystem behavior is an integral component of supporting research. Numerous hypotheses have been identified from previous studies conducted across the Gulf Coast; however, results should be focused on clearly meeting the Strategy needs. Supporting research should be directed at reducing scientific uncertainty to improve confidence in modeling and monitoring tools and ultimately management actions. Additionally, a key weakness that basic research must help address is simply discovering what ecosystems exist in the Gulf that are or may be impacted. It is essential that monitoring, modeling and research development activities are integrated from the initial stages of restoration and protection planning in order to support adaptive management decision-making.

5.4.2 Research Needs

Specific research needs that underpin restoration goals are described in the following table. Addressing these needs would serve to support broader ecosystem-wide restoration efforts. Additional effort should be directed to addressing questions that inform discrete restoration projects.

Resilience	• Develop a shared vision of ecosystem resilience. • Identify key determinants of resilience for estuarine, coastal wetland, forested ridges, and barrier shoreline habitats. • Examine the relation between ecological and human community resilience. • Examine how land change, sediment types, anthropogenic modifications, and flood and storm damage risks can affect ecosystem resilience.
Natural Processes	• Develop an understanding of coastal and marine natural processes, such as sediment transport, currents, and shoreline retreat, and the spatial variability of future sea-level rise. • Quantify (spatially and temporally) relative sea-level rise (including subsidence) rates. • Determine the relation between shallow stratigraphy and natural processes. • Quantify Gulf of Mexico sediment budget. • Quantify the amount of sediment and nutrients that bypass wetlands and are discharged offshore. • Identify those nutrient levels that are excessive and lead to negative impacts in coastal wetlands, seagrasses, and fisheries, and contribute to harmful algal blooms and hypoxic conditions. • Establish the key relations between nutrients, sediment, and salinity as they relate to water clarity, optimal ecological function, and optimal distribution of habitats and species. • Provide a more comprehensive understanding of life histories of affected living marine resources, food web dynamics, and essential habitat conditions. • Investigate surge/wave/vegetation interactions and the influence on geomorphologic evolution of landforms. • Identify agricultural practices that utilize less fertilizer, water, and pesticides and preserve topsoil.
Risk	• Develop a better understanding of critical landscape and geologic features (i.e., geomorphic, geologic, biological, physiochemical, engineered) to reduce storm risk. • Develop a better understanding of engineering tools utilized in storm risk assessment such as storm surge models and coastal erosion models. • Improve understanding of the impact of physical development on flood outcomes. • Understand vulnerability of communities to storm surge, land loss, subsidence, and sea-level rise. • Refine risk or vulnerability indices. • Examine approaches to communicate to coastal residents and decision-makers what puts them at risk and what they can do to reduce risk, and identify constraints and incentives to pursue resilient behaviors. • Identify features that make shoreline habitats more or less vulnerable to stressors such as sea-level rise, high wave energy, storm surge, coastal erosion, and sediment loss. • Establish the relation between ecosystem restoration and community storm risk reduction. • Identify the cultural, economic, and social impacts of relocation of people out of risky coastal areas.
Ecosystem Services	• Determine processes and functions supported by Gulf Coast habitats and the degree to which optimal function and provision of priority ecosystem services is presently occurring. • Measure rates and processes that reflect wetland ecosystem condition and the ecosystem services they provide, and consider functional equivalence. • Determine assessed value of fishing, recreation and ecosystem services that are provided to the community. • Determine the relation between nutrient loading and ecological function, along with the potential for: ◦ Development of hypoxia and associated impacts on the benthos, ◦ Development of harmful algal blooms, ◦ Loss of seagrass meadow acreage, ◦ Change in fisheries productivity, and ◦ Change in soil composition.
Assessment	• Identify measures and criteria to validate restoration effectiveness and thresholds that that trigger management actions. • Identify tipping points that indicate the need for management actions to ensure functionality and sustainability. • Develop ecological indicators for ecosystem structure and function. • Identify research-based criteria for meeting water quality standards. • Identify most efficient paths for various community types to improve resilience.
Restoration and Hydrologic Modification	• Examine impacts of upstream hydrologic modification and varying freshwater flow on estuarine vitality. • Identify optimal water timing, quality, and quantity to support sustainable ecosystem habitats. • Determine relation between varying scales of river diversion and ecological function and resilience of wetlands. • Examine function and resilience of emergent wetlands and barrier shorelines that have been restored by sediment augmentation. • Examine how upstream reservoir and dam management practices impact delivery of sediment and freshwater to coastal ecosystems. • Identify storm buffering consequences of common coastal engineering projects. • Identify the optimal size of natural buffers for water filtration. • Examine ecological function and resilience of other habitat restoration efforts such as oyster reefs, coral reefs, vegetative plantings, and submerged aquatic vegetation.
Climate	• Develop uniform methodologies for including relative sea-level rise considerations into modeling and project planning. • Develop uniform methodologies for including climate change-induced variations in precipitation, evapotranspiration, and changes in storm intensity and frequency into future planning decisions.

6 Science Plan

6.1 Introduction

The GCERTF has developed a plan to restore and manage the resources of the Gulf Coast and to enhance the resiliency of Gulf Coast communities. To accomplish these tasks, a formal and effective process for using all available and appropriate scientific and technological resources to attain ecosystem protection and restoration goals is recommended and is documented in this Science Plan. The scope of the Science Plan includes all data acquisition, monitoring and assessments, model and decision-support tool development, and assimilation of associated scientific products to support future implementation of the GCERTF Strategy. This Science Plan reaffirms the need for close and continuing coordination between scientists and State and Federal coastal resource managers in jointly addressing the critical ecosystem needs of the Gulf Coast.

6.1.2 Background

Gulf Coast natural resource managers have long recognized the magnitude of degradation of Gulf ecosystems and have undertaken substantial efforts to address this problem. Advocacy groups have been formed for protecting and restoring Gulf ecosystems. Federal and State statutes have been enacted that authorize and finance coastal wetland restoration efforts on a large scale. In spite of these efforts and with only a few success stories on which to build, such as the Coastal Wetlands Planning, Protection and Restoration Act and the Mississippi Coastal Improvement Plan, wetland losses and deterioration of coastal waters have continued. People are experiencing threats to their livelihoods as shorelines retreat and marshland disappears. Fisheries are over-used and water quality degrades; communities become vulnerable to the effects of coastal degradation. Public and private sectors are seeking rapid actions to protect the Gulf. Wetland protection and restoration are being developed and implemented at an unprecedented large scale, often integrating physical and biological elements. Now, more than ever, sound science is needed to support systems-level, integrated coastal protection and restoration strategies to support local, State, and regional planning as well as to enable adaptive restoration and management of Gulf ecosystems. Robust monitoring is needed to evaluate project effectiveness and to provide future directions. A major component of implementing the GCERTF science vision is incorporating advanced science and technology into projects and research for Gulf restoration while also considering future uncertainties such as climate change. This Science Plan provides a systematic framework for identifying science issues and for improving coordination of scientific activities among Federal, State, local, non-governmental, and academic efforts. The Science Plan should be reviewed and updated periodically to reflect advances in science and technologies.

6.1.3 Objectives of the Science Plan

It is the intent of this Science Plan to provide the basic science infrastructure to support the overall Gulf restoration program, allowing for the development of an iterative and flexible approach to adaptive management and decision-making.

Specifically, the **objectives of the Science Plan** are to:

- Provide a ***framework for decision-making***, requiring issues to be clearly and technically defined.
- Provide long-term, continuous ***scientific data, analysis, interpretation, and recommendations*** that are critical to the design, construction, operation, and monitoring of restoration projects.
- Develop ***enabling tools, methodologies, and protocols*** for system-level restoration planning and assessment.
- ***Resolve uncertainties*** about the system that limit restoration planning.
- ***Assess the immediate and long-term effectiveness*** of restoration actions in meeting program goals.

To do this, it is recommended that **specific activities of the Science Plan** should include the following:

- ***Review and assess goals and objectives*** of the GCERTF Strategy to make sure they can be achieved and sufficiently measured.
- ***Identify science needs*** that support achievement of those goals and objectives.
- Establish long-term continuous ***monitoring networks*** needed to meet the identified scientific needs of the Strategy.
- Establish and maintain ***an independent science and technology advisory and review board***.
- Establish ***modeling and scientific research*** needed to meet the identified scientific needs of the Strategy.
- Establish performance measures and ***monitor and evaluate the performance*** of program elements in achieving their stated goals.
- ***Assess and report on the progress*** of the science program through periodic reporting and technical workshops, including but not limited to:
    - A biennial report on all projects. Each project summarized in a two-page tabular format.
    - An annual reporting meeting where all investigators funded by the GCERTF report on the questions they are addressing and progress to date.
    - A full report on all projects on a 5-year cycle. Reports would be in scientific literature format and potentially could be submitted for publication.
- Coordinate with the National Academy of Sciences (minimum of a 5-year cycle) on ***external review of the science program and its efficacy*** in supporting the adaptive management of Strategy restoration efforts.

There is growing recognition that restoration and protection efforts simply will not succeed without a good scientific foundation. This foundation should include: (1) recognition by the implementing body that scientific understanding is critical to successful restoration and protection programs; (2) placement of the science and technology program in the organizational structure where it can be used as a primary component of decision-making; (3) delivering relevant science information to managers in a timely and useful manner; and (4) continued monitoring of projects to measure success and to support adaptive management. The GCERTF implementation approach must be based on using the best information, and this Science Plan demonstrates how these challenges will be addressed using an adaptive management framework as implementation of the GCERTF Strategy moves forward.

6.2 Adaptive Management

6.2.1 Background

Adaptive management prescribes a management process wherein actions can be changed in relation to their efficacy for restoring or maintaining an ecological system in a specified desired state or ecological potential.[156] It is a science-based approach to ecosystem management where predicted outcomes can have a high level of uncertainty. A key component of adaptive management is a feedback mechanism based on characterizing current system conditions and responses to management actions supplemented with an understanding of the system dynamics. These are discerned through rigorous monitoring, modeling, and research combined into integrative assessments and synthesis. This information helps decision-makers to sequentially improve management actions so that future system conditions can be achieved that are more consistent with program goals and objectives than past actions.

Adaptive management allows the development of an iterative and flexible approach to management and decision-making with the following benefits:

- Emphasizes that management actions can be viewed as experimental manipulations of the ecosystem. Results of manipulations can be monitored and studied.
- The resulting data can be used to influence future management decisions.[157]
- Examination of historical trends assists in current adjustments.
- Scientists and managers collaboratively design plans for managing complex and incompletely understood ecological systems.[158]
- Alternative management actions can be assessed using rigorous experimental design and decision analysis.
- Possible outcomes of management alternatives and the values of each outcome can be compared to management goals and objectives over time.
- Uncertainty can be analyzed and exploited to identify key gaps in information and understanding.

Adaptive management may be passive, wherein management actions are modified in response to monitored changes in observed system behavior or condition. Not all projects lend themselves to this type of adaptive management; certain management actions cannot be manipulated after construction, for example. Active adaptive management involves changing management actions or operations in order to test hypotheses. So while the goal of passive adaptive management is to improve existing management approaches, the goal of active adaptive management is to learn by experimentation in order to determine the best management strategy. Adaptive management programs, whether using passive or active approaches, are incorporated into most of the large restoration and protection programs nationwide, and they all have similar elements that are described below. These elements are intended to be implemented in an iterative fashion, and not necessarily linearly.

6.2.2 Adaptive Management Elements

Goals and Objectives. Clearly focused and quantitative goals and objectives are central to adaptive management and are the most important part of the planning process.[159] Restoration and protection planning (Figure 6.1) will face three major challenges (posed as critical questions below) that must be addressed by stakeholders, managers, and scientists in identifying the goals and objectives that will ensure creation of communities and ecosystems that are sustainable and exhibit resilience.

- What are the gaps in data and scientific understanding that preclude or limit restoration and protection planning?
- How can priorities for resource features (for example, habitat and associated biota) in time and/or space be assigned and resolved to determine a consensus on the future desired ecosystem?
- What combinations of active and passive management are required to reduce ecological maintenance costs, support desirable populations of fish and wildlife, and provide ecosystem goods and services in a sustainable manner?

Well-defined goals and specific, measurable, attainable, relevant, timebound (SMART) objectives will be used to guide the development of conceptual models.

Conceptual Models. Conceptual models are qualitative or quantitative diagrams or narratives that will be used to identify stressors, working hypotheses, and key uncertainties by depicting general pathways by which large-scale drivers affect ecosystem attributes that are important to people. The conceptual models allow linkages between human actions in the restoration effort and ecosystem response and guide the identification of performance measures. The models can provide a framework for targeting monitoring variables and tracking the status of human and system responses. Conceptual models are revised over time when new monitoring, modeling, and research findings are incorporated. This allows monitoring

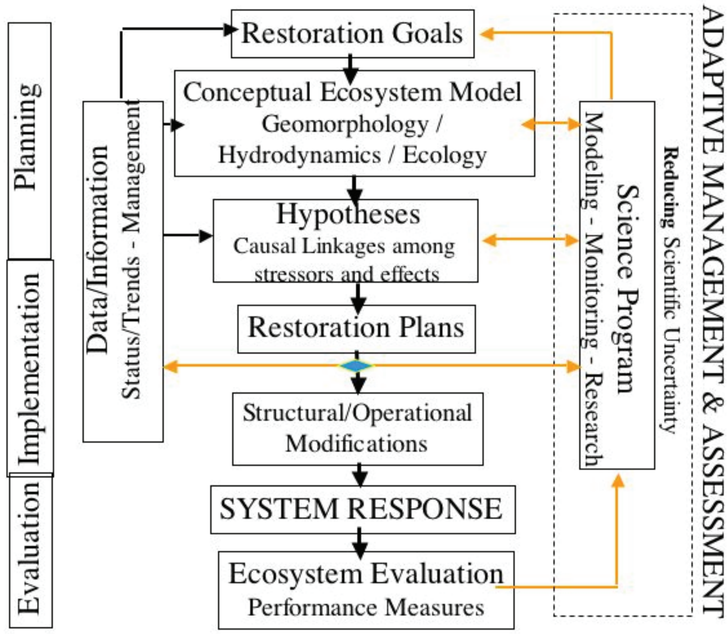

Figure 6.1 Science plan approach proposed for developing comprehensive ecosystem restoration and protection plans for the GCERTF (adapted from the Comprehensive Everglades Restoration Plan and used by the Louisiana Coastal Area Study).

strategies to be improved, data gaps to be identified, and critical uncertainties to be addressed, enhancing the ability of decision-support tools to produce successful restoration and protection projects.

Performance Measures. Performance measures will be derived through the conceptual modeling process. Performance measures are defined as standards or indicators used to evaluate the outcome of management actions. Three groups of indicators will be used to assess performance following Maddox et al. (1999)[160]: (1) assessment indicators for tracking of ecosystem attributes to expected values (targets); (2) predictive indicators for warning of ecosystem stress; and (3) diagnostic indicators for the interpretation of ecosystem change.

The performance measures must:

1. Be measurable and understandable to the public,
2. Have outcomes or targets specified for the desired Gulf condition,
3. Be sensitive to ecosystem change as a result of GCERTF decisions and project implementation, and
4. Verify restoration and protection effectiveness and answer hypotheses.

Uncertainties. A key to adaptive management is the identification of uncertainties. These uncertainties could be related to the variable responses of restoration and protection projects to management actions, the most appropriate engineering design for a restoration action, or the nature and magnitude of effects on stakeholder interests. Regardless of whether our uncertainties are the result of lack of knowledge or understanding of events and processes, inherent natural variability, or our failure to understand how our decisions will influence outcomes, they need to be clearly identified. Once identified, uncertainties will be listed to describe what is known and not known regarding the proposed restoration and protection actions. Those uncertainties that limit restoration and protection decision-making effectiveness should be a focus of the adaptive management scientific process.

Research. Research to support implementation of the GCERTF Strategy should focus initially on testing critical hypotheses and uncertainties identified from the conceptual modeling process. Numerous other hypotheses have been identified from previous studies conducted across the Gulf Coast; however, results should be focused on clearly meeting GCERTF Strategy needs. Supporting research should be directed at reducing scientific uncertainty to improve confidence in modeling and monitoring tools and, ultimately, management actions. Additionally, a key weakness that basic research must help address is simply discovering which ecosystems exist in the Gulf that are or may be affected.

The GCERTF should develop and implement a comprehensive strategy for identifying and integrating existing research and models to support Gulf ecosystem protection and restoration. The research strategy would be developed by an Interagency Research Advisory Group and incorporate those priorities identified by the GCERTF Science Coordination Team, those previously identified by Gulf States and Federal partners, as well as the Gulf of Mexico Research Plan[161] that match up with the goals and priority actions identified in the GCERTF Strategy. This will include expansion and enhancement of predictive, simulation, and risk assessment models and ecological forecasting capabilities. Additionally, ecosystem research needs to be continued at a high level in order to identify the "unknown" unknowns about anthropogenic effects and to better understand underlying ecological and other processes that may limit or complicate the ability of a resource or habitat to respond in the desired way (that is, to be restored).

Monitoring. Continuous, long-term, accurate monitoring is paramount in this endeavor because it provides critical feedback between decision-making and system response relative to adaptive management goals and objectives. Monitoring characterizes actual system response to management actions, whereas models forecast probable futures. Monitoring will be hypothesis driven such that assessments will be robust enough to detect change and identify unanticipated responses. Feedback from long-term monitoring provides the "adaptive" feature that is the basis of adaptive management and can be used to judge project effectiveness.

The GCERTF should develop and implement a comprehensive strategy for identifying and integrating existing monitoring networks and developing a strategic monitoring plan to support Gulf ecosystem protection and restoration. The spatial extent and complexity of Gulf ecosystems necessitate establishment of a standing Interagency Monitoring Advisory Group composed of representatives from Federal and State monitoring agencies and external partners to develop a clear monitoring strategy with appropriate parameters that span site-specific to regional scales. This monitoring strategy would minimize duplication of effort and maximize coverage, integration, reliability, and timeliness of data acquisition through partnerships, shared resources, and shared opportunities.

The types of data collected during monitoring should support program management decision-making; therefore, monitoring plans, programs, and policies will be updated according to protection and restoration priorities. Monitoring will be used as a metric for calibration, reporting, and measuring the effectiveness of the restoration and protection efforts.

Modeling. A model is a tool that can be used to guide management decisions related to restoration actions. Models can be separated into two broad categories—conceptual (as discussed earlier) and operational models. Mathematical models are types of operational models that can be used as key management tools that:

- Provide quantitative assessments of ecological risks posed by the diverse and disparately-scaled environmental stressors regulating Gulf Coast ecosystems
- Assist scientists and managers in developing restoration and protection approaches and management plans for adaptive management in the broader context of sustainability.
- Estimate outcomes of management decisions, including likelihood and degree of effectiveness as well as risk of failure.
- Help scientists and managers in the design of effective monitoring plans needed to support adaptive management and to evaluate sustainability.

Models will be used to develop concepts, educate, simulate processes, test hypotheses, forecast future conditions, conduct planning, assess the results of management actions, and identify additional information and research needs. When sufficient data exist, the introduction of a modeling component to a restoration and protection program can help forecast the trajectories of success. Adaptive management relies extensively on the use of models to articulate understanding and forecast the effects of alternative management actions. Development of interactive, spatially explicit models that allow the evaluation of simulated results of proposed management alternatives are therefore strongly recommended.[162] When data are insufficient to support robust models, more scientific research and/or data collection is necessary to allow for model construction and validation.

The limitations of models are often not properly communicated to the managers that intend to use them to assess restoration actions. Thorough uncertainty analysis must be conducted early in model development to determine if the model is capable of providing a reliable prediction based on a question posed by management. This needs to be communicated to managers before restoration decisions are made based on model results. If the predictive capability of the model is poor for a specific project or restoration action, then a series of tests on the model can determine what additional data need to be collected to reduce that predictive uncertainty.

With a restoration target as big as the Gulf of Mexico, there are going to be many different types of models developed to understand the system. These include, but are not limited to, ecosystem, land change, habitat, surface water, groundwater, ocean circulation, storm surge and wave, variable-density flow and transport, contaminant and nutrient loading and distribution, coastal erosion, and socio-economic effects. We have already seen this approach established in Louisiana for the ongoing effort to establish project prioritization as part of the effort to revise the State's coastal master plan. Many of these models will be complicated because the Gulf of Mexico is an ecosystem with great variability. Likewise, some models will be simpler and more appropriate for local-scale analyses. The important point is that the best approach is to establish a "toolbox" where multiple models, spanning short- to long-run times, coarse to fine resolution, and stand-alone and integrated capabilities, can be used interdependently depending on the modeling need. Regardless, there needs to be a concerted effort to ensure that the models are held to high standards and are evaluated properly, as well as to ensure transparency in the model development. As a result, an Interagency Modeling Advisory Group, similar to the Interagency Monitoring Advisory Group, should be developed.

Assessment. Project assessments use the monitoring, modeling, and research outputs to analyze the responses of the system to GCERTF Strategy implementation. The project and program assessments will be quantitative and technically defensible. Assessments will involve the evaluation of differences among monitoring and modeling outputs, specific target values or ranges of performance measures, and/or the degree of ecological functioning restored.

Data Management. Management of data collected prior to implementation of the GCERTF Strategy as well as data collected during implementation of the strategy is critical to ensure establishment of “institutional memory” within the GCERTF. This institutional memory is an important part of the science foundation stated in Section 1. The data should be available in a form accessible to all sponsors and, with limited but necessary controls, available to the public, in a computing environment that allows analysis and synthesis.

The GCERTF should develop and implement a comprehensive strategy for identifying and integrating relevant datasets to support Gulf ecosystem protection and restoration. A successful strategy will be driven by (1) identification and development of mechanisms for managing integrated and synthesized data and information; (2) development and implementation of a long-term, integrated observing system from the coastal region to the deepest offshore regions of the Gulf of Mexico; and (3) data products and information services—including the assembly and development of the existing long-term data records, for example, regional climate data along with current observations. The integration of monitoring, modeling, and research datasets and findings into desktop applications such as the USGS EverVIEW system, where resource managers have access to data manipulation and modeling and visualization tools, will improve the decision-making process.

The data management challenges for the GCERTF are not just about increased data volume; the data infrastructure must provide ease of discovery, assimilation, and integration of observations; provide data stewardship and Web-accessible archives; and provide data transparency among the GCERTF partners and the public. These strategies/capabilities are currently non-existent or underdeveloped in the Gulf of Mexico.

Policies. The GCERTF should establish a clear and consistent data management, monitoring, modeling, and research policy as part of their overarching restoration plan and include specific guidelines, such as:

- **Applicability**
  - Datasets generated will support and improve the restoration and protection plan.
  - Monitoring and research will address project and program-level goals and objectives, gaps in our understanding, and data needs to support models and other decision-support tools.
  - Models will forecast the trajectories of restoration and protection efforts and guide improvements in the monitoring program and the restoration plan.
- **Public Release**
  - Monitoring, modeling, and research datasets generated will be releasable to the public upon completion and review.
  - Models will be developed from open-source, publicly available codes.
- **Coordination**
  - Monitoring and research at project and system levels will build upon existing monitoring initiatives, networks and capacities, and research institutions and cooperatives.
  - Facilitated discussions among partner agencies will address expansion of monitoring to close recognized gaps as well as reductions in redundant monitoring efforts.
  - Modeling efforts across the Gulf will be identified to ensure that models used are “state of the science.”
- **Standardization**
  - Development and implementation of standardized protocols and methodologies will be promoted to better integrate data across various scales and geographic regions.
- **Provider**
  - Recognized and experienced monitoring, modeling, and research entities (Federal, State, academic, NGO, industry) will be used.
- **Data Access**
  - Data, models, and research findings will be provided digitally to a regional and/or national archive and made Web accessible.
- **Data Format**
  - Data will be provided in digital and community-recognized formats, for example, ASCII, netCDF, ESRI shapefile, etc.
- **Quality Assurance/Quality Control (QA/QC)**
  - All data will follow published QA/QC standards before release to the public or use by managers, and all reports and manuscripts will undergo peer review.
  - Specific modeling codes will be benchmarked and published to ensure that the physics of the ecosystem are accurately represented. All models will be peer reviewed by an expert panel before release to the public or use by managers. Availability of robust data to make model runs meaningful will be ensured.
- **Metadata**
  - Appropriate geospatial metadata will be available and provided with the data.

- **Data Validation**
  - Data will be validated and/or compared to a standard reference.
- **Archived**
  - Monitoring data will be archived according to standards determined by the Interagency Monitoring Advisory Group.
  - Models will be archived according to standards determined by the Interagency Modeling Advisory Group.
  - Research findings will be archived according to standards determined by the Interagency Research Advisory Group.
- **Model Calibration**
  - Models will be calibrated according to standards determined by the Interagency Modeling Advisory Group using the most advanced programs and technology available. Models will be validated and verified with data that are collected and managed as part of the restoration effort with appropriate QA/QC.
- **Transparency**
  - Monitoring and assessment, modeling, and research findings will be compiled, synthesized, and communicated in a manner so that they will be available to the scientific, management, and policy communities, decision-makers, stakeholders, and the general public.

The monitoring, modeling, research, and data management policies established will provide initial guidance that will be updated according to protection and restoration priorities and needs.

6.3 Science Program Structure

The science program structure to support implementation of the GCERTF strategy will rely upon careful integration of existing science consortiums, programs, and institutions within Gulf States and across the region, such as the Gulf of Mexico Alliance, Comprehensive Everglades Restoration Program, Gulf of Mexico Sea Grant College Programs, and National Estuarine Research Reserves in the Gulf, to name a few. The program structure proposed herein provides a means to incorporate multiple disciplines, promote close communication between scientists and practitioners, ensure an intense level of independent technical review, and focus on developing analytical tools responsive to all stakeholders and sponsor needs. Implementation of the Science Plan will be sufficiently flexible to identify and incorporate new technologies into the research approach as those technologies are developed.

Implementation of the Science Program can be accomplished through an integrated, interdisciplinary, and well-funded interagency effort led by a Science Board. The Science Board would leverage funding where possible, appropriate funds to support the goals and objectives of the Strategy, and coordinate with and use existing science capacities in the Gulf of Mexico to fill critical data and information gaps while minimizing new processes and procedures. The Science Board would fund new science needs not otherwise accounted for in order to achieve the objectives described in this document. A clearly defined hierarchy will be established that follows well-defined lines of responsibility and accountability. The Science Board would have direct upward reporting and management responsibility to Program Management and will be part of the governance structure that will be identified by the GCERTF in the Strategy document. The Science Board also would coordinate implementation of the Science Plan with an Advisory Board, which would serve in an independent, scientific advisory capacity to the Science Board, as well as to the GCERTF.

The Science Board would assemble all the necessary science working groups and teams required to provide a mechanism for sharing information, exchanging ideas, identifying concerns, and creating solutions in the context of adaptive management for sustainability of Gulf Coast ecosystems. The Science Board would use existing groups, institutions, and agencies wherever possible to fill these needs. The Science Board would be responsible for ensuring that all aspects of the Science Program are integrated, for avoiding potential duplication of scientific studies, and for ensuring that an annual science plan with integrated monitoring, modeling, and research is established and a comprehensive conceptual model is maintained. The Science Board would ensure that stakeholders, the public, and project implementers are aware of the most up-to-date understanding of the system. The Science Board would ensure that information flows from the science program to tool users and stakeholders, complementing a broader Strategy communication initiative. The Science Board would work within the governance structure of the GCERTF to ensure that the feedback process is undertaken, reviewed, and modified as necessary during the course of implementing the GCERTF strategy.

The Science Program would provide specific decision-making support tools that can help identify, develop, and analyze management options. Some teams/groups that could help support the Science Board in its mission to ensure that GCERTF planning and implementation are based upon the best-available scientific information are:

1. Environmental Benefits Assessment Team,
2. Modeling and Assessment Group,
3. Monitoring and Data Acquisition Group,
4. Research and Uncertainty Assessment Group, and
5. Data Management Team.

An Advisory Board would provide national perspective and oversight to the Science Board. The Advisory Board would review the major scientific thrust of the Science Plan, monitor the peer review process to ensure that adequate quality assurance and control and "state of the science" technology are incorporated into the Science Plan, and provide feedback on execution of the Science Plan and the Restoration Plan itself. It would provide evaluation and interpretation of scientific issues to Federal, State, and NGO leadership. The Advisory Board's primary responsibility would be to ensure that sound science and scientifically based findings are properly incorporated into the GCERTF implementation strategy and decision-making process. It would also ensure consistency with national science policies and provide recommendations to the GCERTF.

6.4 Making Adaptive Management Work

The structures and processes that need to be developed for the GCERTF provide the important elements of an adaptive management program. However, really making adaptive management work means that all participants involved in the GCERTF restoration and protection efforts must acknowledge that implementation is a learning process and adaptation must occur. Recognizing that structures will develop and change over time, the specific program elements proposed here are designed to promote learning and adaptation from the start, rather than making adaptive management a concept added on to existing restoration and protection planning. The GCERTF implementation strategy will provide an opportunity for participants to begin adaptive management in the early stages of program planning.

6.4.1 The Need to Promote Learning in the Gulf Coast

The revision of models as data are collected and research is conducted represents a learning process and is the feedback that corrects restoration and protection implementation and helps direct future planning efforts. Such learning requires that future planning establish these revisions in specific processes and structures to ensure a robust scientific foundation for program management.

Synthesis of monitoring data. A key role of the Science Plan is to produce periodic synthesis documents that summarize monitoring data and use the data to verify existing models. Modeling synthesis documents can focus future monitoring, or targeted research, on areas of greatest variability or restoration risk. Identification and coordination of efforts already ongoing within the States will be the starting point for this activity. For instance, the Louisiana Office of Coastal Protection & Restoration already generates annual monitoring reports for many of the protection and restoration projects in the State, and has created a Systems Assessment group within its Louisiana Applied Coastal Engineering & Science Division to begin generating status reports on a larger, hydrologic-basin scale.

Evaluation of experimental manipulations. The enhanced values of scientifically designed and adequately monitored, small- and large-scale experimental manipulations/restoration projects are derived from the inferences that can be drawn from their results. For example, it should be possible after a period of diversion operation at a certain discharge regime to not only know how vegetation composition and distribution at the receiving area changed, but what the likely results would be if the duration or timing of the operational regime were modified in the future. Additionally, innovative and untested actions should be considered not just as important learning opportunities, but perhaps as the only learning opportunities that exist; therefore, they should be supported with strong scientific designs and monitoring programs.

Progress report/Report card. One developing form of reporting on ecosystem management performance is the environmental progress report or report card.[163] An environmental progress report or report card presents summary status information on ecosystem endpoints, and it communicates progress of management in improving ecosystem condition. It should communicate the status of the system in terms of endpoints and reflect trends over time to judge progress in an easy-to-understand format for the public. Some common elements of environmental performance reporting are seen in the report cards on ecosystem management by State and Federal agencies in the Everglades, Chesapeake Bay, and San Francisco Bay. An environmental progress report or report card will be an important tool for reporting to the public on Gulf of Mexico restoration efforts.

Science symposia. To promote dissemination of current findings, discussion of new ideas, and cross-disciplinary interaction, the Science Plan will regularly convene a Science Symposium providing a common forum for presentation of results and progress in protection and restoration science. Several regionally-specific examples exist that could be used as models for a Gulf-specific forum, such as the Greater Everglades Ecosystem Restoration conference, the Louisiana State of the Coast conference, Bays and Bayous Symposium, and the Northern Gulf Institute's annual science meeting.

The Annual Science Report and Plan. The Science Board/Consortium will annually prepare a Science Report to summarize progress, identify challenges and unmet needs, and provide accountability for the funds expended on Science Plan activities. Emerging from the Science Report will be an accompanying annual Science Plan, which will articulate the activities of the program in the next year as part of a multi-year vision for GCERTF science needs. Annual science reporting efforts, such as the annual South Florida Environmental Report, might be used as templates for this type of communication.

6.4.2 Adaptation—Closing the Adaptive Management Loop

Learning and adaptation are the elements of an adaptive management process that close the feedback loop and begin the iterative process over again. In this phase of the process, information (in the form of monitoring data), the results of experimental manipulations, and the results of predictive models are combined to yield either confirmations of existing knowledge, or new descriptions of system status and explanations of the factors that control the system. While much of this takes place within the scientific community, vital information needs to be learned by all of the stakeholders. The use of that knowledge to halt or constrain negative behavior, or to improve or expand positive behavior, is adaptation. During multiple iterations of the adaptive process, new understanding of how the system operates may even result in the reformulation of goals and objectives.

Disciplined adaptation within a program that addresses the desires of many different stakeholders can be a challenging process to implement and control. While the acquisition of some information, such as from a controlled experiment or a monitoring program, can be planned, other information arrives unexpectedly. For example, the opportunity to acquire knowledge about the response of the delta-building process to periodic, large-scale perturbations cannot be predicted.

Adaptive management of any large ecosystem requires the ability to change on a regular, predictable schedule as well as in rapid response to unpredicted events. Given what is known about year-to-year variability of riverine and meteorological drivers, it seems realistic to consider establishing a regular system status review on a time schedule of 5 to 10 years, similar to the schedule that has been adopted for Chesapeake Bay synthesis reports. However, a rapid response decision-making mechanism should be considered as a vital element of a future adaptive management process.

Finally, GCERTF stakeholders must remember the importance and the need to take a science-based long-term conservation approach to changing those goals from one adaptive interval to another. If stated well, a long-term ecosystem goal should not be subject to fads or political whim. The restoration and protection of desirable conditions for many of the ecosystem elements of the Gulf Coast is likely to require decades rather than years. Success will require unwavering commitment as well as vision.

Appendix A. Definitions and Acronyms

A.1 Coastal Habitats Are Healthy and Resilient

Coastal wetlands are transitional areas between terrestrial and coastal ocean systems, exchange freshwater and saltwater, are influenced by tides, and exist in shallow water environments. Gulf of Mexico wetlands include freshwater to saltwater marshes, forested wetlands, mangroves, and shrub swamp habitats. Healthy wetlands are critical to the life cycles of fish, shellfish, migratory birds, and other wildlife. Fully functional wetlands improve surface-water quality by filtering residential, agricultural, and industrial waters, recycling nutrients, and buffering coastal areas against storm surge and wave damage. Wetlands have the potential to mitigate the effects of sea-level rise. They also tend to be dynamic features that may be altered by changes in sediment transport, storms, and other natural processes.

Estuaries are mixing zones of freshwater and saltwater and are enclosed or semi-enclosed bodies of water that receive freshwater and sediments from rivers and tidal influx from coastal oceans. Estuaries include riparian areas, upstream waters influenced by tides, and headwater tidal streams. Healthy estuaries provide important feeding, spawning, and nursery habitats for a wide variety of fish, shellfish, birds, wildlife, and plant species. Some estuaries include submerged aquatic vegetation (SAV) communities that stabilize shorelines from erosion, reduce nonpoint-source loadings, improve water clarity, and provide wildlife habitat. Fully functional Gulf Coast estuaries provide favored recreational areas for humans and living environments for diverse wildlife species, and produce significant seafood resources, which include finfish, oysters, crabs, clams, and shrimp.

Barrier islands are narrow ridges of sand parallel to and seaward of the mainland coast. They occur in chains with tidal inlets between the barriers. Primary islands typically have a Gulf front, a wave-built beach followed by a foredune wind-built ridge, and then a habitat of marsh. Barrier islands may include maritime forest habitat. Functional barrier islands maintain essential salinity gradients in the back-bay estuaries and provide protection from storm surge and wave action for mainland shores and wetlands.[164] Barrier islands also provide important habitats, for example, foraging shorebirds and nesting sea turtles. Barrier islands also have a dynamic geomorphology and are changing over time, sometimes quickly (from tropical storms or hurricanes) or slowly (from gradual changes in river discharge and sediment loads, as well as wave action).

Mainland beaches occur on the Gulf front with landward foredune ridges or dunes. Functional mainland beaches provide protection from storm surge and wave action for mainland shores and wetlands.[165] Mainland beaches provide habitats that are crucial to the continuing health and well-being of wildlife, including dune-dwelling beach mice and nesting least terns.

Natural levees, ridges, cheniers, and other shoreline habitats are additional natural features across the Gulf Coast. These sometimes linear features are higher in elevation than the adjacent coastal wetlands. Natural levees of the Mississippi River and their distributaries trend perpendicularly toward the coast, while cheniers run parallel to the coast. Functional shoreline habitats provide important wildlife sanctuaries and feeding grounds (including stopover habitats for migratory songbirds), reduce storm surge, and help to serve as barriers between the Gulf and the estuaries by moderating water regimes within estuaries.

A.2 Living Coastal and Marine Resources Are Healthy, Diverse, and Sustainable

Living coastal and marine resources include finfish, shellfish, marine mammals, sea turtles, and other economically or ecologically important species. Commercial and recreational fisheries, as well as threatened and endangered species are included in this definition.

Healthy and diverse refers to an ecosystem that exhibits naturally occurring species at all trophic levels and an abundance of quality habitat.

Sustainable refers to the concept that all species, whether or not they are commercially and recreationally important species, are managed in a manner to ensure that they can naturally persist over time, and can maintain the ability to deliver products and services (for example, ecosystem services such as commercial harvest and recreational opportunities) that society can use and that are necessary for ecosystem function. For example, for commercial and recreational fisheries, sustainable means that fisheries are not overharvested or overfished, that targeted species are capable of supporting population levels suitable for harvest (that is, the resource can be used), and that ecological requirements are met.

Ecosystem Services: Ecological processes or functions which have value to individuals or society. (McCarthy, J.J., Osvaldo, F.C., Leary, N.A., Dokken, D.J., and White, K.S., eds., 2001, Climate change 2001—Impacts, adaptation and vulnerability: Cambridge, Cambridge University Press.)

A.3 Coastal Communities Are Adaptive and Resilient

Coastal: From the “Coastal Zone Management Act” (CZMA) Definitions—All five Gulf of Mexico States follow the CZMA definitions and boundaries. However, the specific definitions of each State’s coastal zone as they apply to conservation and restoration planning vary by State.

- **Texas** establishes its seaward boundary into the Gulf of Mexico at the limit of State title and ownership, which is 10.36 miles (16.7 km) from the Gulf shoreline. In addition to inland tidal influence set 100 yards (91.4 m) inland of the mean high-tide line along tidal river and stream segments, Texas has an inland boundary based on the coastal facility designation line, adopted under the Oil Spill Prevention and Response Act of 1991. The inland boundary also includes wetlands lying within 1 mile (1.61 km) inland of the mean high-tide line of the tidal river and stream segments.

- The **Louisiana** coastal zone varies from 16 to 32 miles (25.7 to 51.5 km) inland from the Gulf of Mexico, as defined by an act of the State Legislature. Specific restoration plans for coastal Louisiana, such as the joint State–USACE *Louisiana Coastal Area Ecosystem Restoration Study*, may consider a planning area larger than the current legislatively-defined coastal zone, to include areas that may be subject to surge and areas that directly influence or are influenced by coastal processes. The use of highways I-10 to I-12 works as a very general rough boundary, mainly because that boundary has been used in the past for emergency preparedness and by insurance companies. Louisiana is evaluating an update to the coastal definition and plans to present the update to the legislature.
- The **Mississippi** coastal zone includes the three counties adjacent to the coast.
- The **Alabama** coastal zone extends inland to the continuous 10-foot (3.05 m) elevation contour in Baldwin and Mobile Counties.
- The **Florida** coastal zone encompasses the entire State, but has a second tier that applies to the coastal counties and their municipalities.

Community refers to a cohesive, interacting, human, social group generally composed of multiple households whose members reside in a specific locality and share a common government. Communities also often have a common cultural, historical, and occupational heritage, but may also be organized around other social, cultural, or economic themes. Communities tend to self-identify and perceive themselves as distinct from the larger society in which they exist. Individuals may identify with more than one community (based on scale, residence, occupation, or place of employment).

Adaptive is the ability to adjust or modify to suit changing conditions, environments, or circumstances.

Resilience is the capacity of human and natural/physical systems to adapt to and recover from change. Community resilience can be further defined as the ability to exist and thrive in a dynamic environment. Resilient communities may adjust living and working habitats and routine activities in order to recover from change and to return to a state of sustainable functionality. Resiliency is also the ability of human and natural or physical systems to withstand the effects of singular or multiple changes.

Sustainable refers to a state of the wetlands, waters, and barrier shorelines that achieves and maintains a dynamic and productive synergy of ecologic, economic, and social capacities that are resilient, adaptive, and able to transform or change to meet the needs of future human generations with a minimal reliance on human intervention.

A.4 Storm Buffers Are Sustainable

A **storm buffer** is a man-made or natural feature that has the potential of reducing storm surge or waves.

A **sustainable storm buffer** is a feature that can act or be adapted to reduce storm surge and waves under changing conditions. The feature "works with" natural conditions, or is itself a natural feature, over broad regional and long time scales.

A.5 Inland Habitats and Watersheds Are Managed to Help Support Healthy and Sustainable Gulf of Mexico Ecosystems

Watersheds and their inland **habitats** include all major river systems, their drainage basins, deltas, estuaries, and associated habitats within each watershed. Inland habitats encompass a land perspective, and watersheds encompass a water perspective. For this definition as it relates to the Gulf of Mexico, the inland habitats are defined geographically by the watershed extent.

Healthy refers to an ecosystem that performs and sustains its natural function. A healthy ecosystem should include the following: essential habitat; minimal alterations to natural hydrology and sediment load in watersheds; passage of clean water downstream; natural levels of sediment and nutrients delivered to floodplains and delta plains; sediment budgets that are in balance to support accretion where needed to maintain habitat; a diverse assemblage of species; land and water free of anthropogenic contaminants; industry and anthropogenic activity that is in balance with the natural system; geomorphic processes responsible for maintaining landscape and ecosystem integrity operating at levels necessary for sustainability (for example, the delta cycle–delta building versus land loss); and maintained wildlife corridors.

Well-managed and sustainable inland habitats and watersheds are managed in a comprehensive, system-wide approach with the goal of long-term sustainability. Monitoring programs and availability of adaptive management tools (in-place decision-making processes and funding) are a priority. Well-managed systems have enforcement mechanisms in place and can support multiple uses that do not conflict with ecosystem function through well-thought-out and equitable planning, compliance assistance, and regulatory capacity. Partnerships between resource user groups and managers are used to plan development, mitigate conflicts, and monitor the health and dynamics of the system.

A.6 Offshore Environments Are Healthy and Well Managed

Offshore waters include everything seaward of the Gulf shoreline and seaward of the surf zone.[166,167] (Overlap with Coastal Habitat occurs in the shoreface zone where coastal systems transition to the inner shelf.) Some coastal areas have barrier islands; in those locations, offshore is defined as seaward of the barrier island shoreline.

Healthy refers to a healthy ecosystem composed of offshore waters that meet water-quality standards, adapt to altered governing parameters (for example, climate change, ocean acidification, increased storm frequency and strength), contain a diverse assemblage of species, are free of anthropogenic contaminants, and have human activity in balance with natural systems.

Well-managed: Well-managed offshore waters require that a comprehensive, system-wide approach is implemented with goals of long-term sustainability. Monitoring programs and the availability of adaptive management tools (in-place decision-making processes and funding) are a priority. Well-managed offshore waters support multiple uses with well-considered and equitable planning, and have regulatory and enforcement mechanisms in place to prevent and reverse degradation.

Offshore benthic environments in the Gulf of Mexico include:

- **Mesophotic coral ecosystems** are light-dependent (that is, photosynthetic) coral communities, as well as associated communities of algal, sponge, invertebrate, and fish species that are present in the deepest half of the photic zone (30-m to 150-m depth) in tropical and subtropical regions.[168] These communities may serve as refugia for some species because they are buffered from thermal stress, nutrient and pollutant runoff, and storm-induced wave damage due to their depth.[169]
- **Cold-water coral ecosystems** are light-independent coral communities, as well as associated communities of sponge, invertebrate, and fish species that are present below the euphotic zone. Also known as “deep-sea coral ecosystems,” these biomes include soft and hard corals and provide critical three-dimensional habitat in the deep ocean. The communities typically occur in areas of hard bottom, strong currents, and high surface productivity, which are necessary to sustain the nutritional needs of the nonphotosynthetic corals.[170]
- **Gas hydrates** are crystalline solids consisting of gas molecules, usually methane, surrounded by water molecules. They are stable at water depths greater than 300 m and are a potential energy resource.[171]
- **Chemosynthetic cold-seeps** are light-independent communities characterized by tubeworms and/or mussels that have bacterial symbionts capable of feeding on compounds (methane, hydrogen sulfide) that seep from the seafloor.[172] While the fauna are somewhat similar to chemosynthetic communities found near hydrothermal vents, Gulf of Mexico seeps do not expel heated fluids.[173]
- **Soft bottom communities** are composed of a variety of burrowing invertebrates, including many types of worms and crustaceans. This type of habitat characterizes much of the Gulf of Mexico.

A.7 Acronyms

BICM	Barrier Island Comprehensive Monitoring
BOEM	Bureau of Ocean Energy Management
CCMP	Comprehensive Conservation Management Plan
CRI	Coastal Resilience Index
CRS	Community Rating System
CZMA	Coastal Zone Management Act
DEM	Digital Elevation Model
DEP	Department of Environmental Protection (Florida)
DDT	Dichlorodiphenyltrichloroethane
DFIRMs	Digital Flood Insurance Rate Maps
DPA	Dune Protection Act
EFH	Essential Fish Habitat
ESA	Endangered Species Act
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FWS	U.S. Fish and Wildlife Service
GCERTF	Gulf Coast Ecosystem Restoration Task Force
GCOOS	Gulf of Mexico Coastal Ocean Observing System
GLO	General Land Office (Texas)
GoM	Gulf of Mexico
HAB	Harmful algal bloom
IOOS	Integrated Ocean Observing System
IPCC	Intergovernmental Panel on Climate Change
IPET	Interagency Performance Evaluation Task Force
LACPR	Louisiana Coastal Protection and Restoration study
LASMP	Louisiana Sand Management Plan
LCA	Louisiana Coastal Area
LiDAR	Light detection and ranging
LME	Large Marine Ecosystem
MFL	Minimum Flows and Levels
MMPA	U.S. Marine Mammal Protection Act
MSA	Magnuson-Stevens Act
NERRS	National Estuarine Research Reserves
NFIP	National Flood Insurance Program
NASA	National Aeronautics and Space Administration
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
OBA	Open Beaches Act (Texas)
OSTP	The White House Office of Science and Technology
PAH	Polycyclic aromatic hydrocarbon
PCB	Polychlorinated biphenyl
SAV	Submerged aquatic vegetation
SCT	Science Coordination Team
SET	Sediment elevation tables
SIMM	Seagrass Integrated Mapping and Monitoring project
SWGs	Science Working Groups
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey

A.8 Units of Measurement

mi	miles
mi^2	square miles
mm	millimeters
m	meters
km	kilometers
km^2	square kilometers
ft	feet
mm/yr	millimeters/year
cm/yr	centimeters/year
m/yr	meters per year
km/yr	kilometers/year
km^2/yr	square kilometers/year
ft/yr	feet per year
ft^2/yr	square feet/year

Appendix B. Goal-Specific Gaps in Understanding

This section presents gaps in the current understanding of the Gulf ecosystem that need to be addressed to restore the Gulf Coast to a healthy, resilient state. Addressing these gaps would also help meet the goals established by the GCERTF to resolve the adverse conditions in the Gulf of Mexico caused by natural and anthropogenic (such as the Deepwater Horizon oil spill) events.

B.1 Coastal Habitats Are Healthy and Resilient

To identify the key determinants of resilience to ensure the long-term viability of Gulf ecosystems and the habitats that the Gulf supports, including wetlands, estuaries, and barrier shorelines:

- Depict the Gulf region and its habitats with a map that illustrates the detailed physical characteristics, including elevation, shoreline position, bathymetry, and surface-water characteristics.
- Inventory and classify all coastal habitat types and their historical and current distribution, and the processes/functions/services that they perform.
- Estimate the amount of water, sediment, and nutrients needed to support coastal habitats under natural and modified restoration scenarios.
- Obtain data on historical changes in land use, habitat distribution, and sediment/nutrient/pollutant loads as they vary with relevant stressors.
- Identify the sources of excess sediment and amounts potentially available for restoration activities.
- Define and compile ecological indices (for example, hydrologic, quality of vegetation, water quality, etc.) or other tools that can be used to assess current condition as it relates to optimal state.
- Compile restoration options and procedures for evaluating their ability to ensure the long-term viability of coastal habitats, which includes the following considerations:
    - Measures and criteria to validate degree of restoration effectiveness from various completed projects;
    - Ecological thresholds (for example, “tipping points”) that should trigger appropriate, adaptive management actions;
    - Habitats for threatened and endangered species;
    - Changes in fisheries productivity;
    - Sustainability of cultural resources; and
    - Potential for introducing species and proliferating those species.
- Obtain knowledge of the potential effects of hydrologic modification, including considerations of sediment loading and freshwater flow on estuarine vitality.

To ensure the long-term vitality of Gulf Coast estuaries:

- Develop an understanding of the relations among nutrient and pollutant loading, ecological function, and resilience of estuaries that inform the following:
    - Development of hypoxia and associated effects on the benthos;
    - Development of harmful algal blooms;
    - Loss of seagrass acreage;
    - Change in fisheries productivity;
    - Impairment of shellfish harvesting areas and resulting fish consumption advisories; and
    - Impairment of water quality on beaches leading to beach advisories.

To restore functionality and sustainability of coastal wetlands:

- Determine functional rates and processes that reflect wetland ecosystem condition, functional equivalence, and the services they provide.
- Define the relation between varying scales of river diversion and the ecological function and resilience of emerging wetlands.
- Identify the levels of freshwater flow, nutrient/pollutant loading, and suspended sediment necessary to ensure long-term wetland function.

To ensure sustainability of barrier islands, mainland beaches, and other shoreline habitats:

- Determine the characteristics of various shoreline habitats considered critical to protecting their function and structure or predicting their vulnerability to stressors, such as:
    - Sea-level rise;
    - Limited sediment budget;
    - High wave action; and
    - Frequent storm activity/storm surge.
- Evaluate potential methods for reducing erosion, increasing accretion, and protecting shoreline habitats, including:
    - Artificial shoreline protection;
    - Natural restoration; and
    - Living shorelines and reefs.
- Determine the relation between varying scales of seafloor disruptions (for example, dredging shipping channels, presence of pipelines) and the ecological function and resilience of barrier islands and sandy beaches.
- Establish a monitoring program that periodically updates the state of sandy beaches and barrier islands that can be used to identify and warn of impending large-scale losses of habitat.

B.2 Living Coastal and Marine Resources Are Healthy, Diverse, and Sustainable

- Biological data
  - Obtain species data to accurately assess status and trends. Current level of uncertainty for species assessments is high, making it difficult to ascribe quantifiable environmental and anthropogenic effects on Gulf species.
  - Use appropriate abundance data that are relevant to species and regional life history stages to conduct stock assessments.
  - Develop up-to-date life history models that are based on newer data to model effects of current ecosystem drivers on species.
  - Document migratory patterns of living marine resources.
  - Document essential fish habitat/critical habitat for all life stages.
  - Assess risk from contaminants and the potential for bioaccumulation.
  - Assess potential risk of biological diseases, for example Vibrio, that affect seafood safety.
- Socioeconomic Data
  - Obtain socioeconomic data across the Gulf.
  - Identify the human dimensions of the fishery across the Gulf.
  - Assess the value of fishing, recreation, and ecosystem services to the community.

B.3 Coastal Communities Are Adaptive and Resilient

- Understand issues and impediments to fair housing (including relocation of those with lower incomes) and what the cultural, economic, and social effects may be in developing a resiliency plan.
- Need to determine if participation in the NFIP CRS program affects local planning and development.
- Obtain dependable flood data for accurately determining the true flood loss history of a community. Flood loss data are based on flood claims from policy holders for losses greater than $1,000. Repetitive structure losses are identified only on structures that have had two or more claims above $1,000 in a 10-year period.
- Need to assess how land use and land change influence community resilience.
- Determine the relation between ecological resilience and community resilience.
- Assess the effect of community relocation on community resilience, including:
  - How much ownership should the community have in relocation?
  - What incentives, if any, should be provided to keep the community together during this process?
  - Can a community be relocated without changing its cultural identity and resource utilization?
- Identify the most effective social models for resilience for the various cultural and ecological groups, as well as for the Gulf Coast as a whole.
- Investigate whether “traditional ecological knowledge” can increase community resilience.
- Identify if community’s trust in government is an important component to community resilience.
  - Does the importance of trust on resilience vary by region, cultural heritage, or resource usage, etc.?
  - How do we effectively improve the perception of the trustworthiness of the government?
  - How can local media be incorporated in this communication process?
  - How can community outreach be effectively utilized to directly involve more community members and local neighborhood organizations with the government?
- Improve understanding of how environmental or risk awareness can increase resilience.
- Increase awareness of and address misconceptions about climate change and sea-level rise, including projections and potential effects, and how these scientific phenomena will affect them in the long and short term.

B.4 Storm Buffers Are Sustainable

- Improve understanding of surge, wave, and vegetation interactions and the geomorphologic evolution of landforms to better refine high-level storm surge and wave modeling capability.
- Improve understanding of the storm buffering consequences of common coastal engineering projects.
- Establish sediment budgets (for example, Mississippi River sediment load).
- Improve information on sediment transport and availability throughout the Gulf. This effort should include the shallow geology, which affects the performance of structures, may be a source of usable sediment, and helps define the regional geomorphology.
- Improve shallow-water bathymetry and low-land elevation information to build a high-resolution digital elevation model and measure subsidence.

- Develop uniform methodologies for including relative sea-level rise considerations into modeling and project planning for sustainable storm buffers, including wetland accretion.
- Develop methodologies to focus global climate change models to specifically address Gulf Coast planning needs.

B.5 Inland Habitats and Watersheds Are Managed to Help Support Healthy and Sustainable Gulf of Mexico Ecosystems

- Develop a model to understand the hydrologic regime of targeted watersheds of the Gulf of Mexico.
- Develop comprehensive, user-friendly, easily accessible data management network.
- Establish an information-rich decision framework, for example, a Coastal and Marine Spatial Planning tool (see Offshore Environments are Healthy and Well Managed below in Section B.6).
- Improve mapping, monitoring, and assessment (see Offshore Environments are Healthy and Well Managed below in Section B.6).
- Establish natural and engineered (for example river diversions) sediment delivery capabilities for building new land, based on scientific assessments.
- Establish research-based, not presumptive, criteria for meeting water-quality standards.
- Identify and improve best long-term management practices for inland watershed management.
- Obtain hydrologic analyses of sustainable water timing, quality, and quantity.
- Identify wetland parameters that increase pollutant uptake.
- Identify optimal size of natural buffers for water filtration.

B.6 Offshore Environments Are Healthy and Well Managed

- Develop a comprehensive, user-friendly, easily accessible data management network.
- Establish an information-rich decision framework, for example, Coastal and Marine Spatial Planning tool, incorporating the following:
    - Articulation of what restoration means;
    - Identification of the spatial extent of the ecosystem and valued components;
    - Identification of dominant or prevailing stressors;
    - Identification of which valued ecosystem components are at greatest risk from stressors; and
    - Linkages of management actions and protection strategies with threat reductions and an ecosystem component.
- Improve mapping, monitoring, and assessment, especially in the offshore environment:
    - Develop ecological indicators for ecosystem structure and function; use these to inform additional data and assessment needs.
    - Use indicators to conduct more comprehensive monitoring of physical, chemical, and biological factors that may better inform management decisions. Examples may include:
        - Comprehensive baseline system assessments;
        - Habitat mapping with geomorphology, community structure, and distribution;
        - Expansion of aerial imagery and remotely sensed data coverage and analysis;
        - Increased regularity of quantitative, cross-trophic level surveys to improve estimates of abundance, community structure, reproductive status, contaminant loadings, etc., and improve understanding of food web connectivity;
        - Increased understanding of the connectivity among the inshore, nearshore, and offshore resources and environments;
        - Enhanced Integrated Ocean Observing System (IOOS)/GCOOS and related infrastructure; and
        - Frequent and targeted assessments of marine, coastal, and terrestrial threatened and endangered species for improved management recommendations.
- Develop maps and collect information on hydrography, background and distribution of contaminants data, and ocean currents, including:
    - Recent shallow water bathymetry;
    - Offshore and coastal hydrographic data;
    - Data collection regarding the health of organisms across trophic levels and life-history strategies; and water-quality analysis related to oil spills on a long-term basis in a subtropical climate.

Appendix C. Resources

C.1 Coastal Habitats Are Healthy and Resilient

C.1.1 Alabama: Related Alabama Coastal Resources

Dauphin Island Sea Lab
http://www.disl.org/research.html

Mississippi–Alabama Sea Grant/Gulf of Mexico Research Plan, Deepwater Horizon Oil Spill Information
http://www.masgc.org/gmrp/dwh.htm

Auburn University Marine Extension and Research Center
http://www.aces.edu/dept/fisheries/aumerc/

Mobile Bay National Estuary Program
http://www.mobilebaynep.com/

Alabama Department of Environmental Management (ADEM)

> National Coastal Assessment, Alabama, 2000–2004
> *http://adem.alabama.gov/programs/coastal/coastalforms/FinalNCANEPReport06.pdf*
>
> ADEM Coastal Programs
> *http://www.adem.state.al.us/programs/coastal/default.cnt*
>
> ADEM/ADPH Coastal Alabama Beach Monitoring Program
> *http://adem.alabama.gov/programs/coastal/beachMonitoring.cnt*
>
> Alabama's 2010 §303(d) List of Impaired Streams for Alabama—Fact Sheet
> *http://adem.alabama.gov/programs/water/wquality/2010AL303dFactSheet.pdf*
>
> Alabama's Water Quality Assessment and Listing Methodology, January 2010
> *http://www.adem.state.al.us/programs/water/wquality/2010WAM.pdf*
>
> Alabama Department of Conservation and Natural Resources (ADCNR), State Lands Division
> *http://www.outdooralabama.com/public-lands/*

U.S. Coast Guard: Environmental Sensitivity Index Maps—Sector Mobile
http://ocean.floridamarine.org/ACP/mobacp/ESI_MAPS/AL_ESI_MAPS/INDEX.pdf

C.1.2 Florida: Related Florida Coastal Resources

DEP's Florida Wetland Information Center developed a framework for a State-wide ecological restoration program for wetlands and their associated uplands using ecosystem management and ecological principles. The Center has been developed to aid local governments and community organizations with their restoration efforts by providing online tools and research materials needed for the implementation and management of restoration projects.
http://www.dep.state.fl.us/water/wetlands/fwric/guidance.htm

Details of the Comprehensive Everglades Restoration Plan:
http://www.evergladesplan.org/about/rest_plan_pt_01.aspx

Charlotte Harbor Comprehensive Conservation and Management Plan (CCMP):
http://www.chnep.org/CCMP/CCMP.htm

Tampa Bay CCMP:
http://water.epa.gov/type/oceb/nep/tampabay.cfm

Sarasota Bay CCMP:
http://water.epa.gov/type/oceb/nep/upload/2004_02_26_ccmp_tampabay.pdf

Impaired waters:
http://www.dep.state.fl.us/water/watersheds/assessment/303drule.htm

Draft plan for development of a Statewide total maximum daily load for mercury:
http://www.dep.state.fl.us/water/tmdl/merctmdl.htm

Reference sites freshwater inflow:

- Northwest Florida Water Management District—Minimum Flows and Levels
  http://www.nwfwmd.state.fl.us/rmd/mfl/mfl.htm
- South Florida Water Management District—Minimum Flows and Levels
  http://www.sfwmd.gov/portal/page/portal/xweb%20protecting%20and%20restoring/minimum%20flows%20and%20levels%20(everglades)
- Southwest Florida Water Management District—Documents and Publications
  http://www.swfwmd.state.fl.us/documents/
- St. Johns River Water Management District—Minimum Flows and Levels
  http://www.sjrwmd.com/minimumflowsandlevels/index.html
- Suwannee River Water Management District—Minimum Flows and Levels
  http://www.srwmd.state.fl.us/index.aspx?NID=55

To protect and manage seagrass resources in Florida, an official, State-sponsored program led by Paul Carlson with the Fish and Wildlife Research Institute was established. The Seagrass Integrated Mapping and Monitoring (SIMM) project aims to produce an annual report documenting seagrass cover and species composition changes at monitoring stations located throughout the State as well as a comprehensive report every 6 years, combining site-intensive monitoring data and trends with Statewide seagrass cover estimates and maps showing seagrass gains and losses. A Northern Gulf of Mexico Report for the period 1940 to 2002 and a Statewide status report are available at:
http://pubs.usgs.gov/sir/2006/5287/pdf/CoverandContents.pdf
http://myfwc.com/media/659303/FinalSHRSReport062510.pdf

Critical Erosion Report 2010:
http://www.dep.state.fl.us/beaches/publications/pdf/CritEroRpt7-11.pdf

For 100-year storm elevations, post-storm reports, shoreline rate change reports, and other historical monitoring reports:
http://www.dep.state.fl.us/beaches/publications/tech-rpt.htm

Inlet Management Plans: DOH Beach Sampling Results
http://esetappsdoh.doh.state.fl.us/irm00beachwater/default.aspx

C.1.3 Louisiana: List of Resources for Current Conditions in Louisiana

Coastal Wetlands Planning, Protection and Restoration Act Program
http://lacoast.gov/new/default.aspx

Louisiana Coastal Area (LCA) Ecosystem Restoration Program
http://www.lca.gov/

Louisiana Coastal Protection and Restoration Authority
http://coastal.louisiana.gov/

Louisiana Department of Environmental Quality
http://www.deq.louisiana.gov/portal/

Louisiana Department of Natural Resources
http://dnr.louisiana.gov/

Louisiana Department of Wildlife and Fisheries
http://www.wlf.louisiana.gov/

C.1.4 Texas: List of Resources for Current Conditions on Texas Coast

Impaired waters, including 303(d) list and maps:
http://www.tceq.state.tx.us/compliance/monitoring/water/quality/data/wqm/swqm_data.html

Water-quality conditions at Gulf and bay beaches:
http://texasbeachwatch.com/

Erosion rates for Gulf and bay shorelines:
http://www.beg.utexas.edu/coastal/imsindexNew.php

Status and trends of coastal wetlands by region:
http://www.glo.texas.gov/what-we-do/caring-for-the-coast/environmental-protection/protecting-wetlands/status-and-trends-reports.html

Status and trends of coastal wetlands:
http://www.texaswetlands.org/

Exotic and invasive species:
http://www.tpwd.state.tx.us/huntwild/wild/species/exotic/

Seagrass locations:
http://gis-apps.tpwd.state.tx.us/website/Seagrass/viewer.htm

Oyster reefs—Galveston Bay system:
http://galvbaydata.org/Habitat/OysterReefs/tabid/836/Default.aspx

Oyster reefs—northern Gulf:
http://www.nature.org/wherewework/northamerica/Gulfofmexico/preserves/art16835.html

Harmful algal blooms:
http://www.tpwd.state.tx.us/landwater/water/environconcerns/hab/

Freshwater inflows and estuaries:
http://www.tpwd.state.tx.us/landwater/water/conservation/freshwater_inflow/

Dunes:
http://www.glo.texas.gov/what-we-do/caring-for-the-coast/_publications/DuneManual.pdf

Environmental Sensitivity Index:
http://koordinates.com/layer/793-texas-environmental-sensitivity-index-shoreline/

Environmental indicators report—Corpus Christi Bay system:
http://www.cbbep.org/publications/publications.html

State of Galveston Bay system:
http://gbic.tamug.edu/sobs/symposium.html

C.1.5 Additional Mapping Links and Resources

NOAA Coastal Services Center:
http://www.csc.noaa.gov/data/

Gulf of Mexico Coastal Ocean Observing System (GCOOS):
http://gcoos.rsmas.miami.edu/

NOAA Physical Oceanographic Real-Time System (PORTS):
http://tidesandcurrents.noaa.gov/ports.html

Northern Gulf Institute:
http://www.northernGulfinstitute.org/home/ngi.php

Region IV Coastal Analysis and Mapping:
The Federal Emergency Management Agency (FEMA) has compiled the list of resources at the following Web page in support of the coastal engineering analysis and remapping effort in the southeastern States:
http://www.southeastcoastalmaps.com/resources/resources.php

C.2 Living Coastal and Marine Resources Are Healthy, Diverse, and Sustainable

C.2.1 Gulf of Mexico Fishery Management Council Fishery Management Plans

http://www.gulfcouncil.org/fishery_management_plans/reef_fish_management.php

http://www.gulfcouncil.org/fishery_management_plans/shrimp_management.php

http://www.gulfcouncil.org/fishery_management_plans/spiny_lobster_management.php

http://www.gulfcouncil.org/fishery_management_plans/stone_crab_management.php *http://www.gulfcouncil.org/fishery_management_plans/coral_management.php*

http://www.gulfcouncil.org/fishery_management_plans/migratory_pelagics_management.php

http://www.gulfcouncil.org/fishery_management_plans/red_drum_management.php

http://www.gulfcouncil.org/fishery_management_plans/aquaculture_management.php

C.2.2 Gulf States Marine Fisheries Commission Plans

Berrigan, M., Candies, T., Cirino, J., Dugas, R., Dyer, C., Gray, J., Herrington, T., Keithly, W., Leard, R., Nelson, J.R., and Van Hoose, M., March 1991, The oyster fishery of the Gulf of Mexico, United States—A regional management plan: Ocean Springs, MS, Gulf States Marine Fisheries Commission. *http://www.gsmfc.org/publications/GSMFC Number 024.pdf*

Etzold, D.J., and Christmas, J.Y., November 1977, A comprehensive summary of the shrimp fishery of the Gulf of Mexico, United States—A regional management plan: Ocean Springs, MS, Gulf Coast Research Laboratory. *http://www.gsmfc.org/publications/Technical Report Series No. 2 Part 2.PDF*

Frug, D., March 2006, The striped bass fishery of the Gulf Mexico, United States—A regional management plan: Ocean Springs, MS, Gulf States Marine Fisheries Commission. *http://www.gsmfc.org/publications/GSMFC Number 137.pdf*

Guillory, V., Perry, H., and VanderKooy, S., eds., October 2001, The blue crab fishery of the Gulf of Mexico, United States—A regional management plan: Ocean Springs, MS, Gulf States Marine Fisheries Commission. *http://www.gsmfc.org/publications/GSMFC Number 096.pdf*

Leard, R.L., Mahmoudi, B., Blanchet, H., Lazauski, H., Spiller, K., Buchanan, M., Dyer, C., and Keithly, W., December 1995, The striped mullet fishery of the Gulf of Mexico, United States—A regional management plan: Ocean Springs, MS, Gulf States Marine Fisheries Commission. *http://www.gsmfc.org/publications/GSMFC Number 033.pdf*

Leard, R., Matheson, R., Meador, K., Keithly, W., Luquet, C., Van Hoose, M., Dyer, C., Gordon, S., Robertson, J., Horn, D., and Scheffler, R., May 1993, The black drum fishery of the Gulf of Mexico, United States—A regional management plan: Ocean Springs, MS, Gulf States Marine Fisheries Commission. *http://www.gsmfc.org/publications/GSMFC Number 028.pdf*

Lukens, R.R., ed., May 1989, Spanish mackerel fishery management plan—Gulf of Mexico: Ocean Springs, MS, Gulf States Marine Fisheries Commission. *http://www.gsmfc.org/publications/GSMFC Number 019.pdf*

VanderKooy, S., ed., March 2001, The spotted seatrout fishery of the Gulf of Mexico, United States—A regional management plan: Ocean Springs, MS, Gulf States Marine Fisheries Commission. *http://www.gsmfc.org/publications/GSMFC Number 087.pdf*

VanderKooy, S.J., ed., October 2000, The flounder fishery of the Gulf of Mexico, United States—A regional management plan: Ocean Springs, MS, Gulf States Marine Fisheries Commission. *http://www.gsmfc.org/publications/GSMFC Number 083.pdf*

VanderKooy, S.J., and Smith, J.W., eds., March 2002 (revised), The menhaden fishery of the Gulf of Mexico, United States—A regional management plan: Ocean Springs, MS, Gulf States Marine Fisheries Commission. *http://www.gsmfc.org/publications/GSMFC Number 099.pdf*

C.2.2.1 Endangered Species Recovery Plans

http://www.nmfs.noaa.gov/pr/pdfs/recovery/turtle_green_atlantic.pdf

http://www.nmfs.noaa.gov/pr/pdfs/recovery/turtle_hawksbill_atlantic.pdf

http://www.nmfs.noaa.gov/pr/pdfs/recovery/turtle_kempsridley.pdf

http://www.nmfs.noaa.gov/pr/pdfs/recovery/turtle_kempsridley_draft2.pdf

http://www.nmfs.noaa.gov/pr/pdfs/recovery/turtle_leatherback_atlantic.pdf

http://www.nmfs.noaa.gov/pr/pdfs/recovery/turtle_loggerhead_atlantic.pdf

http://www.nmfs.noaa.gov/pr/pdfs/recovery/sturgeon_gulf.pdf

http://www.nmfs.noaa.gov/pr/pdfs/recovery/smalltoothsawfish.pdf

http://www.fws.gov/northflorida/Manatee/Documents/Recovery%20Plan/Manatee%20Recovery%20Plan.pdf

C.3 Coastal Communities Are Adaptive and Resilient

Coastal Resiliency Index: A Community Self-Assessment *http://www.seagrant.noaa.gov/focus/documents/HRCC/resiliency_index_7-15-08.pdf*

Climate Community of Practice in the Gulf of Mexico *http://masgc.org/climate/cop/index.html*

C.4 Storm Buffers Are Sustainable

New Orleans District Corps of Engineers, 2009, Risk Depth Maps with Pumping
http://www.mvn.usace.army.mil/hps2/hps_risk_depth_map.asp

C.5 Inland Habitats and Watersheds Are Managed to Help Support Healthy and Sustainable Gulf of Mexico Ecosystems and Offshore Environments are Healthy and Well Managed

http://water.epa.gov/type/watersheds/whatis.cfm

http://www.nrcs.usda.gov/programs/mrbi/mrbi_overview.html

http://www.nrcs.usda.gov/programs/mrbi/mrbi_watersheds_maps_and_list_page.html

http://www.usda.gov/wps/portal/usda/usdahome?contentidonly=true&contentid=2009/11/0586.xml

C.5.1 Hypoxia

Gulf of Mexico Hypoxia Monitoring Implementation Plan

Gulf Hypoxia Monitoring Stakeholder Committee Membership

Gulf Hypoxia Monitoring Stakeholder Committee Background Information

Hypoxia White Paper

C.5.1.1 Alabama

Oyster Reef Restoration in Bon Secour Bay, Alabama
http://www.aces.edu/dept/fisheries/aumerc/research/oyster-restoration.php

C.5.1.2 Florida

Florida Fish and Wildlife Commission Preliminary 2005 Research Cruise
http://myfwc.com/research/

Short-term Effects of a Low Dissolved Oxygen Event on Estuarine Fish Assemblages Following the Passage of Hurricane Charley
http://www.springerlink.com/content/x22334h36j087p2q/

Exploring Temporal and Spatial Variability in Nekton Community Structure in the Northern Gulf of Mexico: Unraveling the Potential Influence of Hypoxia
http://research.myfwc.com/engine/download_redirection_process.asp?file=06switzer_5337.pdf&objid=51065&dltype=publication

C.5.1.3 Louisiana

Hypoxia in the Gulf of Mexico: Research Activities of the Louisiana Universities Marine Consortium
http://www.gulfhypoxia.net/

C.5.1.4 Mississippi

Mississippi Coastal Zone Management Program Section 309 Assessment and Strategy
http://www.masgc.org/gmrp/plans/MSDMR.pdf

C.5.1.5 Texas

Hypoxia modeling in Corpus Christi Bay using a Hydrologic Information System
http://www.crwr.utexas.edu/gis/gishydro08/WaterQuality/Hypoxia_model.htm

WATERS Test Bed Site—Corpus Christi Bay
http://www.watersnet.org/wtbs/wtbs05/index.html

C.5.1.6 Federal Hypoxia Links

Scientific Assessment of Hypoxia in U.S. Coastal Waters

Committee on Environment and Natural Resources. 2010. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC.
http://www.whitehouse.gov/sites/default/files/microsites/ostp/hypoxia-report.pdf

The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (*http://www.epa.gov/msbasin*)

The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force consists of 5 Federal agencies, 10 State agencies, and Federally recognized tribes

- Moving Forward on Gulf Hypoxia
  http://water.epa.gov/type/watersheds/named/msbasin/upload/Hypoxia-Task-Force-FY10-Annual-Report_508.pdf
- FY 2011 Operating Plan: A Compilation of Actions to Implement the *Gulf Hypoxia Action Plan 2008*
  http://water.epa.gov/type/watersheds/named/msbasin/upload/Hypoxia-Task-Force-FY11-Operating-Plan_508.pdf

National Oceanic and Atmospheric Administration (NOAA) (*http://www.noaa.gov/*)

- Gulf of Mexico Hypoxia Watch
  http://www.ncddc.noaa.gov/hypoxia/
  Hypoxia Watch uses near-real-time shipboard measurements of bottom dissolved oxygen to create data and map products that show anoxic and hypoxic conditions in the western and north-central Gulf of Mexico.

- National Centers for Coastal Ocean Science: Gulf of Mexico Hypoxia Assessment
http://oceanservice.noaa.gov/products/pubs_hypox.html
The goals of the hypoxia science assessment are to document the state of knowledge of the extent, characteristics, causes, and effects (ecological and economic) of hypoxia in the northern Gulf of Mexico.
- Center for Sponsored Coastal Ocean Research: Gulf of Mexico Ecosystems and Hypoxia Assessment (NGOMEX)
http://www.cop.noaa.gov/stressors/pollution/current/gomex-factsheet.aspx
To address the issue of hypoxia in the Gulf of Mexico, the National Centers for Coastal Ocean Science, Center for Sponsored Coastal Ocean Research, is supporting multiyear, interdisciplinary research projects to develop a fundamental understanding of the northern Gulf of Mexico ecosystem. The focus is on the causes and effects of the hypoxic zone and the prediction of its future extent and effects.
- Dead Zone Data Visualization
http://www.nnvl.noaa.gov/MediaDetail.php?MediaID=84&MediaTypeID=2
A product of the NOAA Environmental Visualization Laboratory, this data visualization discusses the causes of hypoxia in the Gulf of Mexico. Run-time is 3:50.
- Harmful Algal Bloom and Hypoxia Research and Control Act Fact Sheet
http://oceanservice.noaa.gov/redtide/pdfs/habhrca_fact_sheet.pdf
Produced by NOAA's National Ocean Service.
- Ecosystem Description: Hypoxia in the Gulf of Mexico
http://oceanservice.noaa.gov/products/pubs_hypox.html
An overview of hypoxia in the Gulf of Mexico for NOAA's Coastal Services Center.
- Diving Deeper: Dead Zone Podcast
http://oceanservice.noaa.gov/podcast/supp_july09.html#deadzone
Learn about dead zones in this interview with Dr. Rob Magnien from the Center for Sponsored Coastal Ocean Research. (11:42 minutes; July 1, 2009).

<u>Environmental Protection Agency (EPA)</u>

- Hypoxia in the Northern Gulf of Mexico: Scientific Assessment of Causes and Options for Mitigation
http://yosemite.epa.gov/sab/sabproduct.nsf/02ad90b136fc21ef85256eba00436459/6f6464d3d773a6ce85257081003b0efe%21OpenDocument
At the request the Office of Water, the EPA Science Advisory Board evaluated the state-of-the-science regarding the Gulf of Mexico hypoxic zone and prepared an updated science assessment.

<u>U.S. Geological Survey (USGS)</u>

- USGS Hypoxia in the Gulf of Mexico Studies
http://toxics.usgs.gov/hypoxia/
The USGS provides scientific information to support management actions intended to reduce excess nutrients in the Mississippi River Basin and hypoxia in the Gulf of Mexico.
- Hypoxia in the Gulf of Mexico: Publications and Online Reports
http://co.water.usgs.gov/hypoxia/html/newpubs.html
The USGS Toxics Program maintains a complete bibliography of publications produced by USGS researchers.
- Mississippi River Basin/Gulf of Mexico Watershed Nutrient (Hypoxia) Task Force
http://toxics.usgs.gov/hypoxia/task_force.html
The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force was established in the fall of 1997 as part of the government's plan to address hypoxia in the Gulf of Mexico.

Appendix D. Science Coordination Team Sub-Working Group Membership

Membership by Groups

1. Coastal habitats are healthy and resilient
EPA Lead
Jan Kurtz (EPA)
Edmund Russo (USACE)
Mark Ford (NPS)
Louise Hose (NPS)
Randy Shaneyfelt (AL)
Abby Sallenger (USGS)
Greg Steyer (USGS)
James Harris (FWS)
Tom Calnan (TX)
Jim Pahl (LA)
Becky Prado (FL)
Michael C. Trusclair (USDA)
Kimberly Clements (NOAA)
Geoff Scott (NOAA)
Callie Hall (NASA)
Craig Peterson (NASA)

2. Living coastal and marine resources are healthy, diverse, and sustainable
NOAA lead
Becky Allee (NOAA)
Henry Folmar (MS)
Cathy Tortorici (NOAA)
Luiz Barbieri (FL)
Steve Geiger (FL)
Edmund Russo (USACE)
Glenn Thomas (LA)
Heather Finley (LA)
Rebecca Hensley (TX)
Howard Jelks (USGS)
Matthew Andersen (USGS)
Bruce Spiering (NASA)
Joe Jewel (MS)
Debbie Devore (FWS)
Callie Hal (NASA)
Gary Fitzhugh (NOAA)

3. Coastal communities are adaptive and resilient
NPS lead
Mark Ford (NPS)
Susan Rees (USACE)
Heidi Stiller (NOAA)
Jim Weatherford (TX)
Michele Deshotels (LA)
Rosalyn Kilcollins (FL)
Adam Baumgart-Getz (USGS)
Ann Foster (USGS)
Joe Fritz (USDA)
Christa Rabenold (NOAA)
Bill Graham (NASA)
Ted Mason (NASA)
Tina Shumate (MS)

4. Storm buffers are sustainable
USACE lead
Barb Kleiss (USACE)
Louise Hose (NPS)
Mark Ford (NPS)
Michele Deshotels (LA)
Jim Weatherford (TX)
Todd Walton (FL)
Richard Hartman (NOAA)
David Green (NOAA alternate)
Ty Wamsley (USACE)
Jack Kindinger (USGS)
Phil Turnipseed (USGS)
Craig Peterson (NASA)
Ted Mason (NASA)

5. Inland habitats and watersheds are managed to help support healthy and sustainable Gulf of Mexico ecosystems
FL FWC & USDA lead
Pete Heard (USDA)
Philip Barbour (USDA)
Amber Whittle (FL)
Lynn Sisk (AL)
Henry Folmar (MS)
Troy Pierce (EPA)
Randy Shaneyfelt (AL)
Dugan Sabins (LA)
Dan Kroes (USGS)
Jerry W. Cain (MS)
Bruce Spiering (NASA)
Bill Graham (NASA)
Rebecca Hensley (TX)
Chris Kelble (NOAA)
Laurie Rounds (NOAA)

6. Offshore environments are healthy and well managed
BOEM and NOAA lead
Mike Miner (BOEM)
Rost Parsons (NOAA)
Dugan Sabins (LA)
Amanda Demopoulos (USGS)
Jeffrey N. Cross (NPS)
Jim Nance (NOAA)
Jan Kurtz (EPA)
John Quinlan (NOAA)
James Tolan (TX)
Amber Whittle (FL)

7. Research, Monitoring, Modeling to Support Adaptive Management
USGS lead
Greg Steyer (USGS)
Barb Kleiss (USACE)
Rick Raynie (LA)
Russ Beard (NOAA)
Mike Miner (BOEM)
Jan Kurtz (EPA)
Amber Whittle (FL)
Lynn Sisk (AL)
Troy Pierce (EPA)
Amanda Demopoulos (USGS)
Debbie Devore (FWS)
John Quinlan (NOAA)

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