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NOAA RESTORE Act Science Program - Science Plan

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I. Executive Summary

To be developed after initial EOB and RSPAWG review.

II. Background

2.1. Purpose

In 2012, the U.S. Congress passed (Pub.L. 112-141) the "Resources and Ecosystem Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States Act" (RESTORE Act). The RESTORE Act transfers 80% of all administrative and civil penalties paid by responsible parties in connection with the *Deepwater Horizon* incident to a Gulf Coast Restoration Trust Fund. The RESTORE Act also establishes several programs, funded by the Trust Fund, to aid in the ecological and economic recovery of the Gulf Coast states. Under Section 1604 of the RESTORE Act, the National Oceanic and Atmospheric Administration (NOAA) was directed to establish a Gulf Coast Ecosystem Restoration Science, Observation, Monitoring, and Technology Program (NOAA RESTORE Act Science Program). This program is to be funded by 2.5% of the Gulf Coast Ecosystem Restoration Trust Fund plus 25% of the Trust Fund accrued interest.

The purpose of the NOAA RESTORE Act Science Program is to achieve an integrative, holistic understanding of the Gulf of Mexico ecosystem, as well as to support (to the maximum extent practicable) restoration efforts and the long-term sustainability of the ecosystem, including its fish stocks, habitats, fishing industries, coastal communities and their economies.

The Program's emphasis is on conducting and synthesizing science, observations, and monitoring to provide useful information that improves understanding and management of the Gulf of Mexico ecosystem, enhances restoration projects, and supports sustainable fisheries.   NOAA's administration of the RESTORE Act Science Program will focus on areas where NOAA has unique capacity and potential for leading significant research with lasting benefits to promote the health of this ecosystem.

This Science Plan lays out the initial path forward for the Program. Given that the amount of funds to be made available have yet to be defined, NOAA envisions that its science investments will evolve over time, adapting to changing information and knowledge. This Plan will be refined based on new knowledge and greater understanding of the full scope of the Program, pending any additional resolutions under the Clean Water Act as a result of the Deepwater Horizon event. The content of this Plan highlights the initial areas of investment for the Program, the process by which those areas were determined, and the anticipated sequencing of investments. Additionally, it provides information on how the Program will be implemented and the partners with which the Program will leverage future opportunities.

The RESTORE Act Science Program represents an opportunity and capacity to help integrate the diverse science efforts across the Gulf into something that will advance overall understanding of the Gulf of Mexico as an integrated ecosystem.

2.2. Introduction

2.2.1 Vision, Mission, Outcomes, and Focus Areas

NOAA's vision for the RESTORE Act Science Program is for long-term sustainability of the Gulf of Mexico ecosystem and the communities that depend on it. The mission of the Program, as directed in the RESTORE Act, is to initiate and sustain an integrative, holistic understanding of the Gulf of Mexico ecosystem and support, to the maximum extent practicable, restoration efforts and the long-term sustainability of the ecosystem, including its fish stocks, fishing industries, habitat, and wildlife through ecosystem research, observation, monitoring, and technology development.

Desired outcomes of the NOAA RESTORE Act Science Program are:

- The Gulf of Mexico Ecosystem is understood in an integrative, holistic manner;
- Restoration activities are guided by this ecosystem understanding;
- Management of the Gulf of Mexico ecosystem is guided by this ecosystem understanding; and
- Long-term sustainability of the Gulf of Mexico ecosystem is achieved, supporting the communities and economies that depend on this ecosystem.

Numerous documents have been developed in recent years that identify science needs in the Gulf of Mexico. Many of these documents were produced with extensive stakeholder input and in consultation with resource managers throughout the Gulf States. In developing the goal for this program, these documents were referenced to ensure high priority and recurring needs were captured. Section 1604 of the RESTORE Act, the section that created the RESTORE Act Science Program, states that funds should be expended for marine and estuarine research; marine and estuarine ecosystem monitoring and ocean observation; data collection and stock assessments; pilot programs for fisheries independent data and reduction of exploitation of spawning aggregations; and cooperative research. The goal was constructed to be responsive to this language and consistent with science needs identified previously for the region. The NOAA RESTORE Act Science Program will enable the collection and dissemination of scientific information to better inform decision making related to the following goal:

Support the science necessary for better understanding and management of the Gulf of Mexico ecosystem, specifically:

- *healthy, diverse, sustainable, and resilient estuarine, coastal and marine habitats*
- *healthy, diverse, sustainable, and resilient coastal and marine resources, including fisheries*
- *resilient and adaptive coastal communities.*

Research categories are broadly articulated in the RESTORE Act. In order to ensure this research program addresses known regional priorities and expends funding judiciously, four focus areas (i.e., types of science) have been identified to guide investment. Focusing the activities supported by this program will help ensure that the research, observations, science, and technology are coordinated, complement existing and future science efforts and address, in an integrated and holistic manner, the critical knowledge needed for Gulf of Mexico ecosystem restoration and management. These focus areas were developed to consider the ecosystem as a whole and help describe the elements essential for understanding and sustaining a healthy Gulf ecosystem in the future. The focus areas do not define specific science needs, but rather encompass a suite of approaches of scientific study which, when taken together, will meet the desired outcome of improved holistic understanding of the Gulf of Mexico ecosystem. The focus areas are:

1. *Ecosystem structure, functioning and connectivity* through integrative field and laboratory studies; for example:
    a. Support research and analysis to understand interconnections between the ecosystem, its living resources, and the human element to inform the ecosystem perspective and support ecosystem

management;

   b. Provide contextual information to support fisheries and wildlife sciences and restoration planning and implementation;

   c. Develop ecosystem-based scenario forecast and integrated assessment models to inform goal-setting and evaluate effectiveness of management and restoration strategies, including climate-related and other drivers of change.

2. *Holistic approaches to observing and monitoring* with advanced and innovative technologies to monitor fisheries, Federal trust species, and other natural resources, and data integration tools focused on the observing needs in the Gulf of Mexico; for example, support development of:

   a. Observation and monitoring efforts to identify, map, and assess habitats, including poorly known deep-water habitats, including relevant physical and biochemical parameters;

   b. Observation assets to monitor resources, including fisheries and protected species, and to enhance and improve fishery and wildlife management in the Gulf.

3. *Integrated analysis and synthesis of existing and new data* to advance the state of ecological knowledge through the search for patterns and principles; for example:

   a. Organize, synthesize and present ecological information in a manner useful to researchers and resource managers;

   b. Support meta-analyses, data mining, policy research, development and application of science-based measures of ecosystem integrity, productivity, resiliency, recovery, and restoration.

4. *Periodic state of health assessments,* incorporating environmental, socio-economic, and human well-being benefits and elements; for example:

   a. Support iterative gap analysis to identify priority needs to support broader ecosystem understanding;

   b. Support development of ecological and socio-economic indicators, including those specifically related to fisheries in both state and federal waters, as well as Federal trust species such as migratory birds, threatened and endangered species, and marine mammals, to inform regular assessment activities and evaluate success of restoration projects and management activities.

Each of these elements - vision, mission, outcomes, and focus areas - will drive the priorities and specific areas of investment outlined in this Science Plan.

2.2.2 Engagement Summary

To be successful, the NOAA RESTORE Act Science Program must harness the expertise of the research community working in the Gulf of Mexico and link it to the region’s pressing science needs. An engagement process that connects researchers, resource managers, and resource users and allows their collective knowledge to inform the direction of the Program is required. NOAA, working with our U.S. Fish and Wildlife Service partner, has and will continue to actively engage stakeholder including representatives from the Gulf States Marine Fisheries Commission, Gulf of Mexico Fishery Management Council, universities, Federal agencies, and non-governmental organizations. These interactions shaped the Program’s science plan framework and, subsequently, this science plan and the science priorities included within it.

Because this science plan grew out of the Program’s science plan framework, this plan has been strengthened by the input gathered and assimilated during the construction of the framework. That input was received through a series of virtual engagement sessions hosted by the program in August and September of 2013, from an engagement session held in conjunction with the Gulf of Mexico Alliance All-hands Meeting in June 2013, and from input sent directly to the Program. Specific to this science plan, feedback from a series of presentations on the Program offered at conferences and workshops throughout the beginning of 2014 and input from an engagement session at the Gulf of Mexico Oil Spill and Ecosystem Science Conference in January 2014 has shaped the development of the plan. With the release of this draft version of the science plan, a formal comment period combined with additional virtual engagement sessions focused on gathering specific input on the plan will provide stakeholders with an opportunity to respond to the specifics of the plan and offer constructive suggestions on how to make it responsive to the research and management needs of the Gulf of Mexico.

In general, the engagement approach the Program has and will continue to take seeks to raise awareness of the Program and solicit input through several different avenues. In addition to one-on-one meetings and seminars with stakeholders, the Program seeks to have a presence at ocean and coastal science and resource management conferences and workshops within the Gulf of Mexico region and nationally. At these conferences and workshops, the Program presents Program updates and when possible hosts structured engagement sessions. The Program has held virtual engagement sessions in the past and will continue to use this forum in the future as well. The Program maintains a website (http://restoreactscienceprogram.noaa.gov/) where the latest information on the program is available and stakeholders can sign up to receive alerts and announcements about the program. Finally, stakeholders can always submit input to the program at noaarestorescience@noaa.gov.

One of the goals of this engagement process is to ensure that activities supported by the NOAA RESTORE Act Science Program complement the research and monitoring activities supported by other organizations in the Gulf of Mexico region including the Centers of Excellence established by the RESTORE Act, the Gulf Coast Ecosystem Restoration Council, and Gulf States. In addition, the Program is engaging with other research programs stemming from the Deepwater Horizon oil spill such as the Gulf Research Program at the National Academy of Science, the Gulf of Mexico Research Initiative, and the National Fish and Wildlife Foundation's Gulf Environmental Benefit Fund. NOAA is also actively engaging and coordinating with governmental and non-governmental research programs active in the region prior to the Deepwater Horizon oil spill.

2.2.3 Priorities Development

Long-term priorities for implementation of the Program were drawn from prior science and research needs assessments for the Gulf of Mexico and from input the Program received while engaging with stakeholders. In establishing these long-term science priorities, NOAA reviewed the numerous science and research needs assessments documented for the Gulf of Mexico over the past several years and conducted over 100 meetings seeking input from stakeholders including representatives from the Gulf States Marine Fisheries Commission, Gulf of Mexico Fishery Management Council, universities, federal agencies, and non-governmental organizations. We looked for commonality among assessments and stakeholder input to identify priorities then cross-checked what we assembled through additional engagement with resource managers, researchers and public review.

When considering which priorities should be included for the long-term implementation of this Program, several points were considered:

- What are the management and restoration science needs?
- How will the research priority support management science needs?
- How will the research priority help achieve the Program's stated goals?
- Is the priority duplicative with other science programs in the Gulf of Mexico?
- Will the priority fill knowledge gaps in the scientific knowledge about the Gulf of Mexico, leading to a more holistic understanding of the ecosystem?
- Is the priority within the scope of this Program?

Initially, the most important point to consider was the support for science needs of the management community.

Providing the science necessary for resource managers to make sound management decisions is foundational to this Program realizing its mission: ‘to achieve an integrative, holistic understanding of the Gulf of Mexico ecosystem and support, to the maximum extent practicable, restoration efforts and the long-term sustainability of the ecosystem, including its fish stocks, habitats, wildlife, and fishing industries.’ Without ensuring that the long-term priorities of this Program support the necessary science for sound management, holistic understanding and long-term sustainability of the ecosystem cannot be actualized. In addition to providing the science necessary to improve management and restoration decisions of today, the research carried out through this program will contribute to a more comprehensive understanding and better management of the ecosystem in the future.

2.2.4 Succession of Priorities

Initial phases of NOAA’s RESTORE science program will emphasize short-term priorities:

- Comprehensive inventory and assessment (i.e., strengths/weaknesses) of ongoing ecosystem modeling efforts (conceptual and quantitative);
- Identification of currently available health/condition indicators of Gulf of Mexico ecosystem components, including humans, followed by comparative analysis of strengths and weaknesses and design/testing of additional indicators; and
- Assessment of monitoring and observation needs and development of recommendations to build off existing assets to establish a Gulf wide monitoring and observation network.

The inventory and gap analysis of ecosystem models, indicators and monitoring efforts the sustainability and health of the Gulf of Mexico ecosystem will be undertaken first. With this initial effort underway, program emphasis will shift toward developing the integrated monitoring/observations, modeling, and end-to-end analytical basis to support management decisions. Efforts will then increase on activities supporting the long-term research priorities, building on the gap analysis, and growing science basis in areas that have the greatest probability of influencing management and restoration decisions in the context of evolving understanding of socioeconomic impacts. Additional detail on phased efforts planned is provided for each research priority.

III. Research Priorities

Ten long-term research priorities have been identified through the process described above. For each priority in this section the discussion includes the management needs that drive the priority, an initial list of key activities, and anticipated outputs and outcomes. The priorities are grouped under the most relevant focus area; however, many priorities support more than one focus area.

Focus Area 1: Ecosystem structure, functioning and connectivity through integrative field and laboratory studies.

Priority 1.1 - Forecasting, analysis and modeling of climate change and weather effects on the sustainability and resiliency of Gulf ecosystems.

In the Gulf, tens of billions of dollars will be spent to construct restoration projects over the next two decades. Key needs of trustee state and federal agencies include determining the types of information that should be incorporated into the design of large-scale restoration projects proposed for the Gulf to ensure long-term project sustainability in the face of anticipated climate-driven changes and extreme weather. The impacts of climate change (e.g., sea level rise, salinity changes, landscape changes, temperature increases) or extreme events such as hurricanes have not yet been routinely incorporated into restoration planning, owing to limited availability of scientific predictive guidance directly applicable to the design and adaptive management of restoration projects.

Furthermore, little is known about how project sponsors should develop and implement strategies for monitoring and observing projects to effectively assess the impacts of climate change and extreme events on specific types of restoration projects and overall on restoration programs across the large-scale ecosystem. Despite existing, robust observation and monitoring activities in the Gulf focused on water levels, land subsidence, habitat change, and salinity among others, little is known about the parameters and instrumentation necessary to measure climate change and extreme events as it relates to Gulf restoration projects.

Management needs:

a) Knowledge of how to best incorporate scientific understanding of the anticipated impacts of climate change and extreme events on the performance of restoration projects in the Gulf of Mexico.

b) Knowledge of methods and instrumentation necessary to measure the impacts of climate change and extreme events on restoration projects, and dedicated adaptive management that include adequate monitoring infrastructure to assess progress and inform decision-making.

c) A better understanding of how to develop an observation and monitoring strategy will be important for trustee agencies to develop adaptive management plans for projects and programs as climate change and extreme events alter physical and biological conditions.

Key Activities:

1. Determine the existing state of the science about general impacts of climate change and extreme events on restoration projects, and what aspects are applicable to the Gulf.
2. Determine the observation and monitoring requirements for effective assessment of climate change and extreme event impacts on various types of restoration projects common for the Gulf.
3. Investigate how climate and climate change (i.e. changes in ocean acidity, temperature, precipitation patterns, sea level rise, etc.) shapes the structure and function of the ecosystem and the connection between its living resources and communities.

4. Conduct research to forecast direct and indirect effects of climate change on indicator, particularly significant, or susceptible species.
5. Analyze, model and predict the effects of major environmental events in the future, both natural and human driven (floods, spills, hurricanes, fire, etc.).
6. Downscaling of global and regional climate models and projections to provide guidance for local and regional predictions.
7. Develop and apply dynamically coupled Earth System (atmospheric, hydrodynamic, oceans) and ecological models to forecast the impacts of sea level rise and storm inundation.
8. Incorporate climate-related effects and thresholds into ecosystem modeling platforms.
9. Integrate downscaled climate models with existing and improved hydrologic modeling platforms focused on forecasting freshwater and sediment delivery to coastal systems.
10. Assess the ability of key coastal habitats (e.g., marshes, barrier islands) in SLR and climate adaption to inform and guide restoration priorities.

Sequence:

Literature survey and annotated bibliography of existing state of science world-wide and existing observation and monitoring systems in the Gulf is the first step. This is followed by an assessment of how the science is transferable to the Gulf. The last step is a Gulf–specific observation, monitoring, and modeling implementation plan for assessing climate change and extreme events impacts on restoration projects.

Outputs:

- A literature survey of published and unpublished work on climate change and extreme events as they may impact coastal ecosystem restoration projects.
- An annotated bibliography based on the literature survey.
- For work outside the Gulf (both US and internationally) an assessment of applicability and transferability to Gulf restoration needs.
- Recommendations for a Gulf implementation strategy for monitoring and observations of restoration projects to better detect the impacts of climate change and extreme events.
- Guidance tools for predicting impacts of climate change and high-impact weather on restoration activities.

Outcomes:

- Gulf of Mexico trustee agencies and project sponsors understand the potential impacts of climate change and extreme events on various types of restoration projects.
- Observation and monitoring practices in the Gulf of Mexico include instrumentation and methods to effectively measure impacts of climate change and extreme events.
- Restoration projects in Gulf of Mexico are adaptively managed and effectively sustained in the face of these impacts.

Priority 1.2 - Construct accurate, actionable and accessible ecosystem models for the Gulf of Mexico.

Modeling is an important tool for developing a holistic understanding of the Gulf of Mexico ecosystem. A robust and rigorous modeling approach grounded in observations and an experimentally derived understanding of the components and processes in the ecosystem can elucidate connections between these components and processes. Such an approach can also identify gaps in our understanding to be targeted for future observational and experimental work. A modeling approach can be particularly useful in simulating an observational network and making informed decisions about where to place new observational assets. Once a model or a suite of models are robust enough, they can be used to inform management decisions and, in the best-case scenario, accurately predict the changes that will result from a given management action and/or change in environmental conditions.

To arrive at this end goal of model development, a forum or venue for bringing ecosystem model developers and users together would be helpful. Testbeds, such as those developed by NOAA (www.testbeds.noaa.gov), often for meteorological applications, have been used to transition new capabilities from research to application, bringing together scientists from the research and development communities with operational end-users like forecasters and decision-makers with the purpose of testing whether advanced capabilities are reliable and useful for the forecasting and decision-making communities.

In addition to improvements in models focused on specific processes (e.g., hypoxia) or areas of the Gulf of Mexico ecosystem (e.g., oyster recruitment in a specific estuary), an initiative to regionally integrate these models is also needed to develop a more comprehensive understanding of how the entire Gulf of Mexico ecosystem functions. These more comprehensive system-wide models would aid the management community when it comes to making decisions about species with broad ranges or complex and disperse life cycles and begin to consider and account for the full geographic extent of decisions.

Management needs:

a) Models which can quantify and model sources, fate, and transport of abiotic and biotic components within the ecosystem.

b) Regional integration of models to produce a more comprehensive understanding of how the entire Gulf of Mexico ecosystem functions.

c) A forum or venue for ecosystem modelers and resource managers to evaluate and refine ecosystem models.

d) Data dissemination tools that translate model output into actionable information on a timeframe consistent with management needs.

Key Activities:

1. Expand and refine existing monitoring and observation systems to track nutrient pollution to the Gulf and its ecosystem impacts (e.g. hypoxia, harmful algal blooms), in support of scenario forecast models aimed at informing nutrient reduction management strategies.

2. Synthesize new and existing data and advancements in understanding and ecosystem processes to improve ecosystem modeling, especially for the prediction of ecosystem change, in the Gulf of Mexico.

3. Incorporate in a holistic fashion the multiple pathways by which nutrient and other pollutants impacts the Gulf of Mexico ecosystem including humans.

4. Model and predict the effects of major environmental events, both natural and human driven (e.g., floods, spills, hurricanes, and fire).

5. Model resource stability and sustainability and include interactions between and among fisheries, habitat, threatened and endangered species, ecosystem processes, and stressors to assist with making ecosystem-based management decisions.

6. Modeling connectivity patterns for management of a Marine Protected Area Network in the Gulf of Mexico.

7. Use objective modeling techniques, including observing system simulation experiments, to evaluate

optimal deployment of ecosystem monitoring and observing assets.

Sequence:

Initially, the focus should be on improving the robustness of existing models and linking the growth of observational networks and experimental work to the gaps in observations and understanding identified by models. The next phase will be supporting the development of data dissemination tools, which make model output accessible to the management community. At the same time, connections between model developers and the management community will need to be developed and fostered to realize the end-goal of models which inform management decisions. Eventually, it will be necessary to begin to combine individual models or support the development of system-wide models that seek to map out the connections between all the components and processes in the Gulf of Mexico ecosystem.

Outputs:

- A suite of ecosystem models which elucidate the connections between components and processes in the Gulf of Mexico LME.
- A suite of ecosystem models which have the capacity to accurately predict changes in the Gulf of Mexico ecosystem in response to environmental change and management action.
- Modeling tools which translate ecosystem model outputs into actionable information in a timeframe consistent with management needs.
- An ecosystem modeling testbed or similar forum/venue where ecosystem modelers and resource managers can test and evaluate models.
- A single or multiple system-wide models for the Gulf of Mexico ecosystem which incorporate individual models targeting different components and processes in areas of the Gulf of Mexico ecosystem.

Outcomes:

- Gulf of Mexico resource managers and researchers understand and can model the connections between different components and processes in the Gulf of Mexico LME.
- Gulf of Mexico resource managers have tools or a forum where modeling results are presented in a useable format and in a suitable timeframe to inform management decisions.
- Resource management practices and policies in the Gulf of Mexico LME consider and incorporate ecosystem modeling.
- Ecosystem models underpin adaptive management and integrated ecosystem assessment in the Gulf of Mexico LME.
- A community of ecosystem modelers aware of each other’s work and interested in integrating their models to develop more comprehensive system-wide models for the Gulf of Mexico LME.

Priority 1.3 - Quantify sediment, nutrients, and water flow as they relate to the connection and function of coastal habitats and understand the relationship between these flows.

The water, suspended sediments and nutrients transported from watersheds to the coastal zone by rivers is critical to many natural processes that create and nourish habitats and living resources. Human activities have greatly altered these transport processes, however. Along the Gulf of Mexico, most of the rivers carry elevated levels of nutrients and sediments which fuel algal blooms, result in hypoxia, block light to underwater grasses and smother critical habitats. The magnitude and timing of freshwater inputs determine where certain organisms, e.g. oysters, can grow and reproduce. Much of the sediment transported by the Mississippi River that used to nourish coastal marshes is now captured upstream by the many dams in the river, and the levees along the lower river block remaining suspended sediments from reaching the marshes where they can help raise elevations to keep pace with subsidence and rising sea levels. The combination of freshwater inputs that cause density stratification, and nutrients which fuel massive algal blooms each Spring, results in the largest hypoxic zone in North America.

Management of Gulf ecosystem impacts from altered flows, excessive nutrients and increased/ reduced suspended sediments has been fragmentary and often ineffective, leading to continued degradation of habitats. Impacts include direct threats to people (e.g. vulnerability to storm surges) and threats to the living resources and habitats which sustain the economic vitality of this region. Many believe that we are nearing “tipping point” levels of degradation in some of the Gulf’s habitats and living resources, beyond which the ecosystem could suffer catastrophic impacts that would be extremely difficult, if not impossible, to reverse.

Traditional management of freshwater flows, nutrients and suspended sediments treats these constituents and their impacts as isolated and disconnected entities, and can lead to unintended consequences as byproducts of these strategies. For example, nutrient load reduction is the sole focus of efforts to reduce the northern Gulf’s large hypoxic zone. Similarly, sediment is the primary focus of efforts to divert Mississippi River waters to adjacent marshes. Since these diverted waters now contain high concentrations of nutrients, unintended consequences to the marshes are appearing such as less robust and resilient marsh grass growth. Furthermore, the re-establishment of freshwater flows in some areas is dramatically altering habitats and abundance of economically important resources.

Management needs:

a) Holistic ecosystem approaches to the management of freshwater flows, nutrients and suspended sediments.

b) Comprehensive ecosystem goals for restoration and accompanying management approaches that consider the range of benefits and consequences of alternative management scenarios.

c) Tools to forecast outcomes with the confidence sufficient to drive the large expenditures needed to reach restoration goals.

Key Activities:

1. Holistic understanding of the relationship between nutrients, sediments, and freshwater inputs and their effects on ecosystem structure and function under a range of scales of variability, both natural and anthropogenic.

2. Determination of the sources, sinks, and transport pathways between watershed, coastal and deep water environments to develop sediment, nutrient, and carbon budgets for the Gulf ecosystem.

3. Determination of cause and effect relationships between sediment, nutrient loading and freshwater inputs, and the distribution and sustainability of estuarine habitats and associated ecosystem services.

4. Identify sources of contamination in the Gulf of Mexico, understand the presence and flow of contaminants in the Gulf food web, and develop recommendations to reduce exposure (to human health risks).

5. Determination of societally-supported quantitative ecosystem restoration goals

6. Characterize the quality, quantity and variability of freshwater, sediments, nutrients and contaminants entering the Gulf of Mexico including current and historical loads in rivers/tributaries and Gulf receiving waters.

7. Quantify and delineate the historical and current hydrologic regimes of watersheds supporting key coastal habitats (e.g., bottomlands, swamps, marshes, sea grasses) and potential changes under various future scenarios.

8. Determination of the scale and scope of monitoring and observation systems necessary to quantitatively track changes in freshwater, sediment and nutrient delivery into the Gulf and to support the modeling/forecasting needed to proactively inform management strategies.
9. Develop the capacity to examine the effects of upstream (e.g., reservoir and dam management) and coastal hydrologic modifications (e.g., diversions) have on the delivery of freshwater, nutrients, and sediments to coastal ecosystem structure and function.
10. Develop the capacity to determine extant and optimal levels of sediment, nutrients, and water delivery to support sustainable coastal ecosystems and associated habitat and living resources within the context of management driven goal setting.

Sequence:

Synthesis, evaluation and refinement of management needs and goals to direct efforts toward the highest priority and tractable needs is a critical first step under this priority followed by identification of science, observational, and model development needs and gaps necessary to achieve these key management needs. Once these needs and gaps have been identified, deployment of holistic, integrated and multi-disciplinary research programs to fill the needs would be initiated. Next, establishment and testing of needed long-term observational efforts to support model development and management driven goal setting would begin. Finally, transition of developed modeling tools and observational data/platforms into long-term operational frameworks to sustain long-term adaptive management applications would be pursued.

Outputs:

- Operational ecosystem-based scenario forecast models and tools to inform management goal-setting for establishing and revising BMPs for nutrient, sediment, and freshwater loads most effective for Gulf ecosystem conservation and restoration.
- Synthesis document on current and historical loads and trends of freshwater, nutrient, and sediment in rivers and tributaries of estuarine and coastal waters of the Gulf.
- Synthesis document on the nutrient and sediment sources to estuarine and coastal waters, including the relative role of watershed versus offshore based sources, and how these inputs vary with climatic and hydrologic factors.
- Synthesis document on the multiple ecosystem impacts of altered freshwater flows, nutrient concentrations and sediment delivery.
- Document that articulates societally supported and science-based quantitative ecosystem restoration goals.
- Synthesis document on management, information, and science needs to support scenario forecast model development that will support the management actions to reach quantitative restoration goals.
- Recommendations for operational monitoring and observation programs with sufficient detection and analytical capabilities to adequately support data acquisition and process studies needed for scenario forecast model development.

Outcomes:

- The scientific basis and compelling societal benefits to drive holistic ecosystem approach to management with respect to sediment, nutrient, and water flows and their impact on coastal ecosystems.
- Ecosystem structure and function is maintained at desired levels and highly resilient to changes in nutrient, sediment and water discharge under expected natural and anthropogenic scenarios.

- Adaptive management of the Gulf ecosystem and associated habitats and living resources positioned to move from reactive to proactive mode based on available, reliable, and sustainable management toolset capabilities for comprehensive synthesis, observations and modeling of impacts of sediment, nutrient and water flows.

Priority 1.4 - Provide a more comprehensive understanding of life histories of living marine resources, food web dynamics, and habitat utilization (e.g., connecting habitats, ontogeny, and food webs) as guidance for living marine resources management.

The connections between the ecosystem, living marine resources, and humans can be understood by the flow of fixed carbon. Quantifying and understanding the flow of fixed carbon between habitats will identify and measure the connections between habitats, resources, and communities. Quantifying the rates of primary production, secondary production, and decomposition in Gulf of Mexico habitats will provide a fuller understanding of the accumulation of biomass and the sequestration of carbon.

The ecological interplay within and among species such as resource and mate competition, predator-prey, habitat utilization, larval dispersal, juvenile refugia, disease transmission, and parasite-host interactions are fundamental to understanding community and ecosystem functioning. Increasing our understanding of habitat utilization patterns and species movement patterns such as developing large-scale tagging programs for sea turtles, seabirds and marine mammals or understanding the larval movements and early life history development processes of singularly important fish and invertebrates species in the Gulf of Mexico will significantly inform management and restoration options. Further understanding of the processes that drive ecosystems will be obtained by clarifying trophic interactions through techniques such as stable isotope and fatty acid analyses in combination with diet studies conducted at the finest taxonomic resolution possible.

The population demographics and movement patterns of living marine resources between habitats at various life stages is an important determinant of ecosystem health in the Gulf of Mexico. Quantifying and understanding these variables and the relationship between habitats, resources, and communities is necessary to achieve a holistic ecosystem-based understanding of resource management and protection. This understanding will be enhanced by developing and utilizing a comprehensive habitat and living marine resource database that integrates biogeochemical and oceanographic data.

Fishery Management Councils and Commissions and certain States and Federal agencies would benefit from spatially explicit, fishery-independent habitat surveys, fishery-integrated ecosystem assessments that include habitat-specific vital rates, fishery surveys in and out of existing ranges, research to determine impacts of fishery and other human activities on habitats essential for sustaining living marine resources, and more efficient, less destructive, and less wasteful fishing gear. Additionally, foundational studies that compile existing data, demonstrate known changes in status and population dynamics, and explicitly identify data gaps are needed.

The quantity and quality of freshwater flowing into the Gulf of Mexico is significantly influencing the coastal and marine habitats and living marine resources in the Gulf. Upstream agricultural, residential, industrial, and commercial water management practices are intertwined with best management practices of upstream reservoirs and dams. Understanding the connection between upstream land use practices, hydrologic modifications and variability in downstream freshwater flows are needed to address this issue.

Development, pollutants, including oil and dispersants, nutrient enrichment, ocean acidity, invasive species, sea level rise, hurricanes, floods, and other chronic, acute, lethal, and sublethal stressors can significantly impact the ability of natural systems and species to maintain cohesion and sustainable populations. These and other stressors shape the structure and function of ecosystems and the connection between and among the living resources and the biotic and abiotic communities within which they live. Understanding these connections onshore, on the water surface, in deep water, and between the surface and various water depths below and how the resiliency of each area is impacted by the various stressors is vital to developing effective management schemes.

Management Needs:

a) Inventory, review of applicability and utility, and gap analysis of management actions that have been or could be applied to enhance the health and sustainability of Gulf of Mexico living marine resources.

b) Better understanding of the factors controlling primary production and the sources, fate, and transport of fixed carbon throughout the Gulf of Mexico ecosystem.

c) Better understanding of food web dynamics, larval movements, and ecological interactions within and among species and habitats is needed to comprehensively manage living marine resources.

d) Better understanding of fish, invertebrate, and wildlife populations in the Gulf of Mexico and how these populations interact with each other and habitats to create a healthy marine ecosystem.

e) Guidance and decision-support tools for effective ecosystem-based fisheries management.

f) Better understanding of how and where upstream land uses are affecting coastal and marine habitats and living marine resources of the Gulf of Mexico.

g) Better understanding of the factors that contribute to and disrupt ecosystem, community, and population resiliency to prioritize habitats and species for conservation and targeted management actions.

Key Activities:

1. Understand the factors that influence the creation and movement of carbon through the Gulf Ecosystem.
2. Develop the tools for understanding how the various trophic levels in the Gulf interact to create a sustainable and resilient ecosystem.
3. Understand the relationship between marine and coastal protected areas and the health of fish and wildlife populations.
4. Increase understanding of the role of habitats in supporting healthy marine ecosystems and populations of indicator fish, invertebrates, and wildlife.
5. Develop guidance approaches and decision-support tools for effective ecosystem-based fisheries management.
6. Expand and refine existing fishery population assessments to include habitat-specific vital rates.

Sequence:

The inventory and gap analysis of ecosystem indicators influencing the sustainability and health of living marine resources in the Gulf of Mexico should be undertaken first. Beyond that initial focus, all other recommended research efforts can occur simultaneously and priority should be afforded to those efforts that have the greatest probability of influencing management and restoration decisions that have the greatest immediacy due to economic, social, or political factors.

Outputs:

- An inventory and gap analysis of Gulf ecosystem indicators that support sustainable living marine resource.
- Analysis of factors controlling primary production and fixed carbon movement in the Gulf.
- Data and analysis of food web dynamics, larval movements, and ecological interactions within and among species and habitats.

- Data and analysis of interspecific interactions among Gulf fish, invertebrate, and wildlife populations and their habitats that determine marine ecosystem health.
- Guidance and decision-support tools useful for managers engaged in ecosystem-based fisheries management.
- Data and analysis describing how and where upstream land use practices and water discharges affect Gulf habitats and living marine resources.
- Data and analysis of the factors that influence ecosystem, community, and population resiliency.

Outcomes:

- Increased knowledge of data gaps and supportable conclusions to help guide future scientific investigations.
- Increased ability to understand how primary production and carbon flow influences productivity of Gulf living marine resources.
- Increased ability to understand how management actions influencing primary production and carbon flow one area may impact another.
- Increased ability to manage and protect those populations and habitats that are crucial to a healthy Gulf ecosystem.
- Increased understanding of how and where changes in upstream water management actions might benefit or harm Gulf living marine resources.
- Increased ability to predict how habitat utilization and the movement of species within the Gulf will inform habitat conservation and support restoration.
- Increased ability to determine how and to what degree natural and human-based stressors will impact the resiliency of habitats, populations, communities, and ecosystems within the Gulf.

Focus Area 2: Holistic approaches to observing and monitoring and cross-cutting across priorities.

Priority 2.1 - Develop and implement advanced engineering, tagging and biological technologies to improve monitoring.

Managers need to have a better understanding of the status of stocks in the Gulf of Mexico. The over reliance on fishery-dependent data, the large number of moderate to small stocks, the complication of managing international trans-boundary stocks and the habitat diversity that requires gear innovations within industry and survey fleet requires new approaches to collecting data. The development of innovative tools can decrease the costs of observations, mapping and monitoring. More effective quantification of discards will allow managers to fully realize the value of target fisheries without impacting non-target, overfished or protected species. Investments in innovative fishery monitoring techniques, such as electronic fishing logbooks and video monitoring can provide a cost-effective means of producing more information.

Information on genetic characteristics of stocks as well as the migrations of stocks can best be understood by applying state-of-the-art tagging and genetic methodologies. Several investigators suggest that lack of information about movements and stock structure limits our ability to manage trans-boundary stocks and to effectively implement marine spatial planning. In addition, tagging programs which will improve accuracy of fisheries stock assessment by developing improved estimates of natural and fishing mortality rates are needed (GMFMC 2008). Experts consistently identify scientific or technological investments and management actions as top restoration priorities (Ocean Conservancy and the Gulf of Mexico University Research Collaborative, 2012). Development of a large-scale fish genetic and smart tagging program will allow more accurate estimates of population status and assist in examining population connectivity among Gulf fishes to better understand species-specific resiliency. (Ocean Conservancy and the Gulf of Mexico University Research Collaborative, 2012)

Comprehensive characterization of microbial communities is now possible through molecular- and image-based sensor technologies such as the Environmental Sampling Processor (ESP) and flow cytobot, respectively. For example, these technologies have been deployed on buoys and used for real-time detection of harmful algal blooms and their toxins. Deployment of autonomous vehicles (e.g. gliders) increases the spatial and temporal breadth of monitoring capabilities, and can be outfitted with sensors to capture physical, chemical, and biological properties targeting all ecosystem trophic levels.

Management needs:

a) Improved, quantity and quality of information for assessments of fish protected species stocks in the Gulf.

b) Improved information to understand the connectivity between various portions of the ecosystem.

c) More effectively quantify discards and reduce bycatch of a variety of species during fishing activities.

Key Activities:

1. Develop a large-scale tagging program (conventional dart tags, PIT tags, telemetry, and genetic tagging methods) to better quantify fishing mortality rates, movements, and improve estimates of natural mortality.
2. Develop and implement advanced technologies (e.g. autonomous vehicles, acoustic, genetic, optical and tagging technologies) to improve ecosystem structure and function, including assessment of LMR resources.
3. Provide new/improved/best available turtle excluder devices (TEDs) and TED training and installation to shrimp fishermen in state and federal waters.
4. Develop a large-scale innovative tagging program for finfish, sea turtles, seabirds and marine mammals to contribute to baseline information on their abundance, movement patterns, somatic growth, mortality and reproductive vital rates.

Sequence:

Conduct an assessment of the state of the art in innovative technologies that can be used in the Gulf. This assessment will determine the potential gains in efficiency and improvements in data collections that can be expected. High value tools then will be implemented on a pilot scale to evaluate the functionality and value. Finally an implementation plan for full-scale deployment for highly rated tools will be developed.

Outputs:

- Synthesis document on the benefits and potential pitfalls of tagging methodology, including recommendations for application to Gulf ecosystem conservation and restoration needs.
- Synthesis document on evaluation (including cost-benefit) of advanced technologies (including tagging, TEDs, ESPs, flow cytobots, etc.) for enhancing existing monitoring programs targeting ecosystem (including LMR) assessments.
- Implementation plan for application of advanced technologies for improved assessment of LMRs.
- Ratings to define the utility of a variety of advanced technologies.
- More complete data on the actual number of sea turtle-and-vessel interactions documented by onboard

video observation technology.

Outcomes:

- Gulf of Mexico resource managers are provided more precise data that allows less precautionary implementation of fishery management measures.
- International trans-boundary stocks are managed more effectively.
- Gulf of Mexico resource managers are able to consider an expanded data source when making conservation decisions.
- Improved bycatch information.
- Improved stock structure and movement information.
- More comprehensive spatial and temporal monitoring in support of adaptive management of ecosystem restoration activities.
- Expanded and more efficient data collections to support scenario forecast models to inform ecosystem management.

Priority 2.2 - Coordinate and integrate existing Gulf monitoring to develop a network of LMR monitoring systems including fisheries dependent and independent data collection.

Establishment of baseline conditions for watersheds and estuarine, coastal, and offshore waters will provide reference points from which to measure ecosystem change and management effectiveness (e.g., efficacy of protected resource recovery plans or habitat restoration methods). Ultimately, a comprehensive network using the most innovative capabilities will result in long-term improvements to the quality and availability of spatially explicit data strengthening resource assessments, indicator development, and ecosystem models, improving their utility as decision-support tools in the Gulf of Mexico.

Stock assessment, ecosystem, and habitat suitability models are examples of decision support tools that can assist regional resource managers in planning, designing, and implementing a successful management process. These models are most effective when they are built and validated with comprehensive data sets from rigorous integrated monitoring efforts. To achieve holistic ecosystem-based protection and restoration in the Gulf of Mexico, decision support tools must be developed with high quality data from throughout the Gulf. Data comparability, consistency, and standardization across program, projects, and habitats are crucial, as are improved tools for data dissemination, visualization, and application by resource managers.

Managers require a spatially and temporally comprehensive multi-media monitoring network to determine the condition of important ecosystem components, including the population structure of managed fisheries, wildlife, and protected resources. In addition, the climatological, biogeochemical, physical oceanographic, and other habitat features are critical to fully understand the health and demographics of these living resources. In the context of Gulf protection and restoration, a comprehensive observations and monitoring network will provide the data foundation necessary to support the development and selection of management and restoration project alternatives.

Information must be made available for managers operating at different geographic scales to make informed decisions and modify their actions as needed to effectively manage ecosystem resources across the Gulf. Adaptive management is a management process wherein actions are modified in relation to their efficacy for restoring or maintaining an ecological system in a desired state or ecological potential (Holling and Gunderson 2002). A key component of adaptive management is a feedback mechanism based on characterizing current ecosystem conditions and measured responses to management actions supplemented with an understanding of the system dynamics and baseline condition. This information is obtained through rigorous monitoring, modeling, and research combined into integrative assessments and synthesis (Walker, et al. 2012).

Management needs:

a) Assessment and tracking of ecosystem status and trends.

b) Data to build and maintain robust decision-support tools for adaptive, ecosystem-based management (protection and restoration).

Key Activities:

1. Coordinate and integrate existing Gulf monitoring to develop fisheries independent monitoring systems for fisheries species.
2. Coordinate and integrate existing recreational and commercial fishery dependent sampling programs.
3. Fund research and development for reducing wildlife impacts resulting from fisheries interactions (e.g., boat strikes, bycatch and depredation).
4. Inventory, coordinate and integrate existing Gulf observations and monitoring efforts to develop a monitoring network including characterization of physical and biogeochemical properties, food web trophic dynamics, habitat, wildlife and fisheries data collection.
5. Expand and refine existing monitoring and observation systems to support hydrodynamic, biogeochemical, and ecological models that assess and predict the effects of natural and anthropogenic stressors on ecosystem stability and sustainability.
6. In key areas where fisheries sustainability is threatened, develop monitoring programs to support adaptive management based on ecosystem response (including fisheries and human dimensions).

Sequence:

The initial step is to conduct an inventory and suitability/applicability analyses of existing Gulf of Mexico observations and monitoring programs and their associated data. Key regions will be identified that have elevated need for adaptive management for fisheries sustainability. Next data gaps will be identified (e.g., spatial, temporal, gear, methods, protocols). Finally, a coordination, integration, governance, and implementation strategy will be developed to use existing monitoring programs to build the framework for a comprehensive habitat and living resource monitoring network, including monitoring support for indicators and models that are used to adaptively manage fisheries responses to ecosystem stressors. This strategy will include a resource needs assessment to identify specific requirements for implementation. Identified data gaps and/or deficiencies will be addressed in the implementation strategy. Implementation will be dependent on identification of an appropriate governance body and available resources.

Outputs:

- Comprehensive inventory of existing Gulf of Mexico observations and monitoring programs.
- Suitability/applicability analysis of each program for inclusion into a Gulf-wide network of programs.
- Gap analysis to identify missing information (e.g., spatial, temporal, life history, habitat, gear types).
- Network governance structure and implementation strategy for the Gulf of Mexico Observations and Monitoring Network.
- Incorporation of monitoring programs into adaptive management implementation plans in selected regions.
- Integrated Gulf of Mexico Observations and Monitoring Network and associated integrated data base structure.

Outcomes:

- Gulf of Mexico resource managers understand the availability and utility of existing observations and monitoring programs and their data.

- Gulf of Mexico resource managers, modelers and researchers have access to a functioning observations and monitoring network; and access to the collected data and associated visualization tools.
- The Gulf of Mexico Monitoring Network supports improved ecosystem modeling and adaptive management.

<u>Focus Area 3. Integrated synthesis and analysis of new and existing data to advance the state of ecological knowledge through the search for patterns and principles</u>

Priority 3.1 - Create an integrative, unified, and easily accessible data framework that tabulates, synthesizes and provides opportunity for analysis of new and existing social and environmental data in order to develop long-term trend information.

The ability to conduct truly integrative and synthetic analysis of the Gulf ecosystem depends in large measure upon ready access to the wealth of data that has been, and continues to be collected throughout the Gulf region, including not only physical and biogeochemical measurements, but also data from the social and human-health sciences. Traditionally, data collection in the Gulf has been accomplished through a number of largely uncoordinated Federal, State, and academic efforts, including Federal and regional IOOS activities, Federal and State fisheries monitoring, and numerous academic projects. In many cases, the data resulting from these efforts remains unavailable outside the institutions that collect it, so that its full value remains unexploited by the relevant research and management communities (cf. Sempier et al, 2009). According to the Gulf of Mexico Alliance Governor's Action Plan II, "...currently there is no information system that allows easy access to information and data for scientists conducting region-wide comparative studies; nor is there a convenient way for managers and policy makers to tap into the knowledge gained from this research." Virtually every summary of Gulf research and restoration needs contains some reference to this problem.

The requirement for data *comparability* presents special challenges, over and above the more mechanical aspects of Web-based data integration and presentation. The Gulf data record has been built up over many decades through numerous "purpose-built" sampling programs designed and carried out for different reasons. As a result, the data record for any given measured parameter has been generated using a range of sampling, analytical, and reporting protocols. Assembling these varied datasets into a coherent whole that allows truly long-term and/or regional trend analysis requires a careful and dedicated effort by scientists.

Management needs:

a) A data system that "...fosters data comparability, consistency, standardization across programs, projects, and habitats" (Walker et al., 2012) with an emphasis on reuse of existing data.
b) Improved data dissemination and visualization tools to provide information to resource managers.
c) A compilation and synthesis of biological *and* socioeconomic data.

Key Activities:

1. Assess current capabilities for managing integrated and synthesized data and information.
2. Create and maintain long-term, quality controlled Ecosystem Data Records (EDRs) that highlight historical trends and anomalies in important ecosystem parameters, including the human dimension.
3. Implement agreed-upon standards for data documentation, non-proprietary data formats, and transport protocols.

Sequence:

The initial phase will consist of consolidating information about existing regional-scale data-management programs, of which there are a number (including GCOOS, GULF OF MEXICOA, GAME, GRIDc, and internal NOAA efforts). Gaps in data coverage (spatial, temporal, topical) will need to be developed and prioritized. The assembly of Ecosystem Data Records, including QA/QC, normalization and reconciliation, and conversion will be a continuous and resource-intensive process.

Outputs:

- Quality-controlled, consistently formatted, spatially and temporally continuous records of key ecosystem parameters.
- A system of linked, federated data resources that is searchable through a common interface.

Outcomes:

Researchers and managers have easy access to a spatially and temporally extensive body of quality-assured ecosystem data that enables a more synthetic, holistic understanding of the Gulf ecosystem.

Priority 3.2 - Collect information and develop decision support tools needed to implement, monitor and adaptively manage habitat including coastal and marine protected areas.

Gulf of Mexico habitats, from wetlands and barrier islands to the deep ocean, are affected by numerous and diverse processes, including sea level rise, nutrient overloading, extreme weather events, and extraction of living marine and energy-related resources. Evaluating the effects of these processes on habitat and ecosystem function will require timely access to data showing the location, type, and baseline and current condition of Gulf of Mexico habitats in order to more efficiently formulate and execute conservation, restoration and response plans (Ocean Conservancy and the Gulf of Mexico University Research Collaborative, 2012, Petersen et al. 2011, Walker et al., 2012). Development of tools used to assist in data collection and analysis should enable resource managers to identify habitat type, structure and function; protect habitat from degradation; assess the progress of restoration measures; and monitor habitat health and resiliency under pressure from long-term and episodic stressors (Petersen et al. 2011, Walker et al., 2012).

Management needs:

a) A baseline assessment of habitat location, extent, and condition using existing information that can then be used to direct and prioritize the acquisition of new data and product development.

b) Modeling tools to help researchers identify the ecosystem components that contribute to resiliency and the environmental and anthropogenic stressors that negatively affect them.

c) Monitoring tools to develop ecosystem health indicators that allow managers to identify baseline conditions and compare habitat health across a variety of sites in order to prioritize and synergize action.

d) Planning tools to inform the design and implementation of commercial and recreational infrastructure and resource use to ensure critical habitats are protected and the resources that they support are sustainable.

Key Activities:

1. Complete mapping and characterization of coastal and marine (including deep-ocean) habitats using remote sensing and full suite of hydrographic methodologies (e.g, high resolution bathymetry and backscatter).
2. Compile full habitat inventory to be used for habitat-specific vital rates and to help develop more accurate spatial sampling and mapping protocols (e.g. habitat-stratified monitoring designs) to improve habitat identification and monitoring strategies.

3. Collect information needed to implement and monitor marine resource management efforts.
4. Conduct biogeographic assessments to site, design, implement, and evaluate marine protected areas.

Sequence:

An initial step is to inventory existing data collections to identify gaps and determine data accuracy and resolution, engaging stakeholders as necessary to determine needs and priorities.

Existing data should be updated to current format and classification standards to facilitate spatial and temporal comparisons and trends analyses. In parallel with these actions, work to develop and implement management tools can be pursued, including development of a suite of habitat modeling, monitoring and planning tools that inform scalable monitoring and management plans with measurable objectives.

Output:

- Comprehensive inventory of Gulf of Mexico habitats, ensuring that current formats and classification standards have been applied.
- Listing of prioritized areas for data collection.
- High-resolution maps identifying critical habitats "of great economic significance, ecological sensitivity or rarity" (Ocean Conservancy and the Gulf of Mexico University Research Collaborative, 2012).
- Analytical tools able to assess and rank habitat health; identify and predict impacts from stressors; and provide spatial analyses to support marine resource management and marine protection actions.

Outcomes:

- Gulf of Mexico habitats are protected and managed using methods that promote sustainable and resilient ecosystem[s].
- The state of health of Gulf of Mexico habitats is accurately assessed and easily compared to the state of reference sites.
- Gulf of Mexico resource managers can identify healthy vs. at-risk habitats and make informed protection and conservation decisions based on a strong foundation of scientific knowledge.
- Gulf of Mexico resource managers are able to easily monitor the progress of restoration and recovery programs with increased accuracy.
- Faster, more precise responses to future incidents that are potentially threatening to critical habitats.

Focus Area 4: Periodic state of health assessments, incorporating environmental, socioeconomic, and human well-being benefits and elements

Priority 4.1 - Develop a better understanding of ecosystem services and other determinants of resilience for coupled social and ecological systems.

Ecosystem Services, the contributions that ecosystems provide that support, sustain, and enrich human life, have been long recognized by scientists and communities, though perhaps the term 'ecosystem service' was not used. In a 2005 publication by the National Academy of Sciences (NAS), it was noted that 'Despite growing recognition of the importance … they are often taken for granted and overlooked in environmental decision-making.' This disregard for ecosystem services was reiterated by Santos and Yoskowitz (2012) with the release of a website specifically designed for distribution and sharing of information on ecosystem services, 'Although ecosystem services are critical to human well-being, cases in which they have been applied to real policies and decisions are rare. For society to make informed decisions about a sustainable use of the environment, a link from the quantification of ES to society's needs is necessary.' It is well documented that the structural and functional characteristics of ecosystems is what brings about the services (Anton et al. 2011) that humans have come to depend on for food and water (provisioning services), regulation of disturbances (regulating services), habitat for wildlife (supporting services), and aesthetics (cultural services). However, incorporation of ecosystem services into ecosystem management policy remains inadequate.

Managers need to have a better understanding of the ecosystem services provided by the Gulf of Mexico ecosystem. Managers need a foundational understanding of what services are provided by the Gulf of Mexico LME. The *Millennium Ecosystem Assessment: Research Needs* (Carpenter et al. 2006) identified numerous needs to improve management of ecosystems. Among these, the following are particularly relevant for the Gulf of Mexico:

(iv) systematic information on stocks, flows, and economic values of many ecosystem services (e.g., freshwater fisheries, natural hazard regulation, groundwater, and pollination);

(v) knowledge of trends in human reliance on ecosystem services, particularly services without market values (e.g., domestic fuel wood and fodder);

(vi) systematic local and regional assessments of the value of ecosystem services; and (vii) connections between data on human systems and ecosystems.

Managers need methodology for assessing the quality of ecosystem services, assigning values to those services, and documenting how interactions with humans can impact those services.

Once ecosystem services have been identified, and methodology for assessing quality has been established, there still lies the issue of how managers go about integrating consideration of ecosystem services into the decision-making process. Over the past decade or so, many researchers have attempted to tackle this obstacle by developing 'frameworks' that would guide integration of these services into decision-making. In 2013 Yoskowitz et al. released a proposed framework that was developed based on existing work and their own application using expertise gained about ecosystem services in the Gulf of Mexico. While this framework has been released, the process needs to be disseminated and tested and other processes may need to be developed as well.

Management needs:

a) Knowledge of the ecosystem services provided in the Gulf of Mexico.

b) Methodology to assess quality of and assign values to ecosystem services;

c) Process for integrating ecosystem services into the management decision-making process.

Key Activities:

1. Determine how the connections among Gulf habitats influence the quality of ecosystem services currently provided.
2. Analyze socioeconomic and cultural linkages with ecological processes in the Gulf of Mexico.
3. Develop approaches and tools for assigning values to ecosystem services in the Gulf of Mexico.

Sequence:

Baseline data establishing the connections between Gulf of Mexico habitats and their respective ecosystem services must be collected prior any analysis to assess quality of those services. Similarly, a foundational understanding of what ecosystem services exist must be established before socioeconomic and cultural linkages can be determined. Once a solid baseline is ascertained, further analyses can be performed to determine status and valuation tools can be developed for use by resource managers.

Outputs:

- Comprehensive inventory of Gulf of Mexico habitats and the ecosystem services each provides.
- Quality assessment of Gulf of Mexico habitats.
- Rating system to define the quality of ecosystem services.
- Report on the socioeconomic and cultural linkages with ecological processes in the Gulf of Mexico.
- Tools for assigning values to ecosystem services in the Gulf of Mexico.

Outcomes:

- Gulf of Mexico resource managers understand the linkages between habitats and ecosystem services.
- Environmental management policies in the Gulf of Mexico LME include consideration of ecosystem services.
- Gulf of Mexico resource managers are able to consider ecosystem services when making conservation decisions.

Priority 4.2 - Identify or develop state of health indicators for the Gulf of Mexico ecosystem, including the socio-economic component.

As resource managers make the move away from single-species management toward a more holistic, integrated approach to management, there has been much discussion surrounding the indicators that would be necessary to measure and monitor the state of health at an ecosystem level. It is becoming increasingly more acknowledged that managers must not only focus on the environmental elements and associated indicators, but socioeconomic and human well-being as well (Kelble et al. 2013). This priority area centers around the concept of identifying indicators that will serve as valid proxies for the environmental, socioeconomic, and human well-being elements of the ecosystem and allow for periodic assessments of the state of health.

In the 2009 Sea Grant publication, *Gulf of Mexico Research Plan* (Sempier et al. 2009) one of the research priorities identified was the need to 'Determine the correct variables to use as indicators of ecosystem health, identify the optimal methods to measure the indicators, and design better-defined indices with more indicators to evaluate the status of ecosystems'. This priority was ranked as one of the top five needs (Sempier et al. 2009). Before routine State of Health assessments for the Gulf of Mexico can be contemplated, a standard set of ecosystem indicators must be established. This standard must determine the minimal set of indicators and the confidence associated with those indicators to truly reflect the health of the ecosystem. Once a standard set of indicators has been established, there must be agreement on how those indicators will be measured. The sampling protocol, frequency, and spatial distribution of these indicators must be defined in the methodology. Without standardized methodology, managers will not be able to rely on ecosystem indicators for long-term status and trends assessments for which management decisions will be based upon.

Ecosystem indicators must reliably reflect not only the ecosystem state of health but must also serve as suitable proxies for human well-being. The *Gulf of Mexico Research Plan* (Sempier et al. 2009) identified research topics associated specifically with ecosystem indicators and effective management, accurate, timely and synoptic assessments, and the link to human uses of the ecosystem in three of the top ten priorities. Ecosystem indicators can be an effective tool for the management decision-making process if they are corrected vetted, represent the factors of the environment that are most suitable for assessing ecosystem health, and provide a valid proxy to establish a linkage to human well-being.

Management needs:

a) Standard set of ecosystem indicators to reflect ecosystem health.
b) Methodology to measure ecosystem indicators.
c) Ability to use ecosystem indicators to link ecosystem health to human-well-being and base

management decisions on those indicators.

Key Activities:

1. Analyze ecosystem indicators to support coastal and marine resources and decisions regarding conservation areas.
2. Understand optimal threshold numbers for indicator and particularly important species.
3. Coordinate and integrate existing Gulf monitoring efforts to track sentinel species and sites.

Sequence:

An initial inventory of what indicators (both ecosystem and human well-being) are currently in use must be completed before an assessment of the utility of those indicators can be performed. Once a comprehensive inventory is available, the indicators can be evaluated to determine how well they represent the ecosystem health and human well-being. From this evaluation, a standardized set of indicators can be selected for application and guidance documentation developed that provides protocols to follow for collecting data on the indicators and the process for incorporating results into management decisions.

Outputs:

- Comprehensive inventory of ecosystem and human well-being indicators currently in use in the Gulf of Mexico.
- Analysis of utility of ecosystem indicators to affectively represent the state of ecosystem health.
- Analysis of utility of human well-being indicators to affectively represent the state of human community health.
- Standardized set of ecosystem indicators for use in State of Health assessments.
- Guidance manual defining protocol for use of indicators (both ecological and human well-being), including (minimally) best methodology, spatial distribution, and frequency.
- Guidance for managers to incorporate data from indicators into the decision-making process.

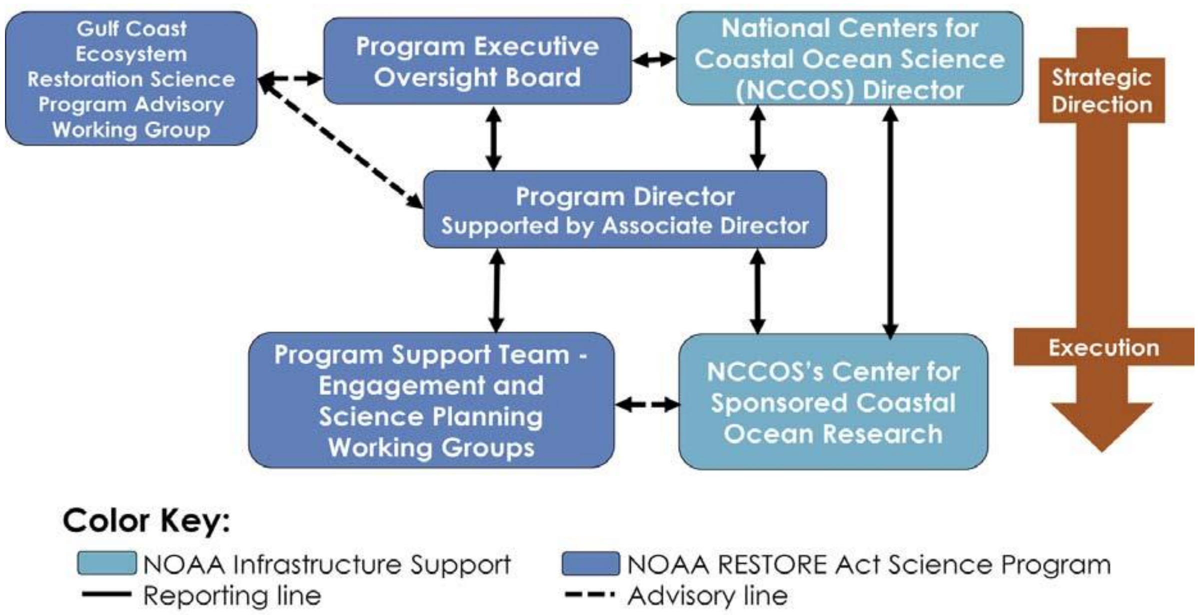
Outcomes:

- Resource managers routinely consider ecosystem indicators in the decision-making process.
- Coastal communities are knowledgeable about State of Health reports and able to use reports to improve their community’s ecosystem health and human well-being.

IV. Program Structure and Administration

The NOAA RESTORE Act Science Program is the responsibility of NOAA in collaboration with the U.S. Fish and Wildlife Service (USFWS). Within NOAA, the National Ocean Service has responsibility for program planning and implementation, under the supervision of an Executive Oversight Board composed of senior executives representing all NOAA Line Offices and the USFWS. The Program will be a peer-reviewed competition, using Federal Funding Opportunities and other mechanisms, issued on a regular basis, to request proposals from eligible groups and independent mail and panel reviewers to evaluate proposals. The processes for announcing, awarding and overseeing research investments comport with all applicable federal, DOC and NOAA regulations and guidance for federal assistance. For the RESTORE Act Science Program, additional requirements will be included to comply with the legislation and any applicable Treasury regulations.

4.1. Program Management



NOAA RESTORE Act Science Program Leadership and Support Team: Led by the RESTORE Act Science Program Director and Associate Director, the Support Team has responsibility to develop short and long term goals and priorities for the NOAA RESTORE Act Science Program, in consultation with partners and stakeholders, and for program implementation. The team has representation from the USFWS and from across NOAA. The Program Director and Associate Director lead planning, execution, and review of the science, engagement, and program management and serves as primary point of accountability and authority for execution of Program. The NCCOS Director provides supervisory leadership and oversight and administrative support to Gulf-Based Program Director in carrying out program strategies and actions. The Science Support team is responsible for the science planning, coordination, and engagement; provides communication of stakeholders goals/priorities; maintains needed transparency between federal, state, academic and non-governmental organizations (NGO) relations; and facilitates outreach and engagement.

Internal oversight: The Program Executive Oversight Board oversees development and implementation of the program, providing strategic and programmatic guidance to the Program Support Team and approval of the Science and Engagement Plans developed by the Support Team. will provide oversight to NOAA's National Ocean Service (NOS), which has been designated by NOAA as the executing body of the Program, in the administration of the funds available under the program, and will collaborate with the Restore Act Council, science advisory bodies that may be established pursuant to the Act, and other entities as deemed appropriate by NOAA or the Department of Commerce.

External guidance: The Gulf Coast Ecosystem Restoration Science Program Advisory Working Group (RSPAWG), established under NOAA's Science Advisory Board, will provide independent guidance and review of the program. The RSPAWG will focus on the broad research, monitoring, and management components of the NOAA RESTORE Act Science Program, advising NOAA's Science Advisory Board on capabilities and conditions of the program. The RSPAWG will also provide a mechanism for formal coordination among the multiple organizations conducting restoration and ecosystem science in the Gulf of Mexico (including RESTORE-related science, as required by Section 1604). In addition to the RSPAWG, the Program will periodically conduct an independent, external review of the program to assess its effectiveness. While still in the concept stage, it is envisioned that such an independent review would be conducted on a regular basis, such as initially after the first three years of the NOAA RESTORE Act Science Program and then every 4-5 years.

Consultation and Coordination: Pub. L. 112-141 Section 1604(b)(1) of the RESTORE Act specifies that NOAA shall consult with the Director of the USFWS, and coordinate (Section 1604(f)) with "other existing Federal and State science and technology programs in the States of Alabama, Florida, Louisiana, Mississippi, and Texas, as well as between the Centers of Excellence." Section 1604(b)(4) of the Act also requires that NOAA consult with the GMFMC and GSMFC "in carrying out the program". Although such a provision is not included in the guidance to the Centers of Excellence under Section 1605, or in the criminal settlement agreements, such as those funding the science programs for the National Academy of Sciences, these and other groups also have acknowledged the need for coordination.

During implementation of the NOAA RESTORE Act Science Program, NOAA will work to ensure that the program is addressing Gulf of Mexico ecosystem priorities and that the work addressed is well-coordinated with other science activities in the region. NOAA already works with most of these partners and stakeholders in various capacities and looks forward to continuing the dialog as related to this program. NOAA is currently in discussions with the groups who have or will be receiving funds as a result of the Deepwater Horizon event supporting restoration and science. These discussions serve as fora to discuss priorities and help reduce duplication of effort.

4.2. Program Parameters

Eligible Activities

As stated in Section 1604 of the Act, funds may be expended for, with respect to the Gulf of Mexico:

- Marine and estuarine research;
- Marine and estuarine ecosystem monitoring and ocean observation;
- Data collection and stock assessments;
- Pilot programs for fishery independent data and reduction of exploitation of spawning aggregations;
- Cooperative research.

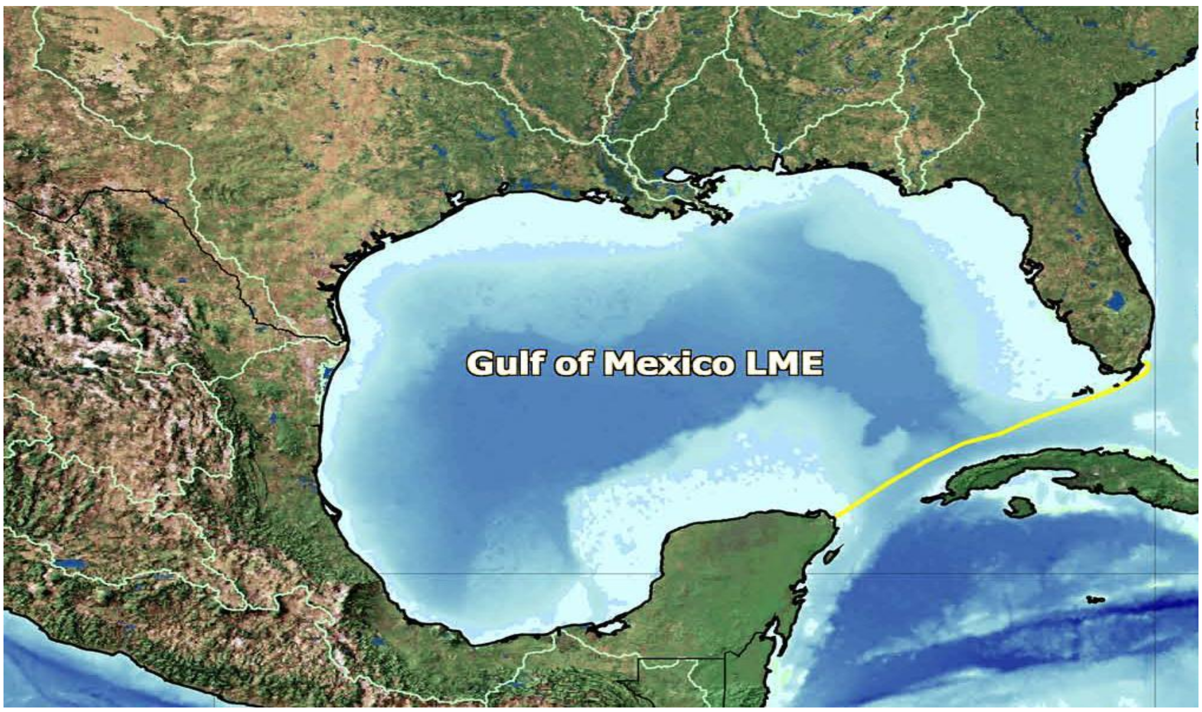
The Act also instructs NOAA as follows:

Species included - The research, monitoring, assessment, and programs eligible for amounts made available under the program shall include all marine, estuarine, aquaculture, and fish species in State and Federal waters of the Gulf of Mexico.

Research Priorities – In distributing funding under this subsection, priority shall be given to integrated, long-term projects that 1) build on, or are coordinated with, related research activities; and 2) address current or anticipated marine ecosystem, fishery, or wildlife information needs.

Geographic scope

The Gulf of Mexico ecosystem, to which the NOAA RESTORE Act Science Program applies, is not defined in the RESTORE Act. In contrast, the Gulf Coast Region was defined by the Act and is applicable to the other elements under the RESTORE Act. For the purposes of this program, the Gulf of Mexico is defined as the Gulf of Mexico Large Marine Ecosystem (LME), with an emphasis on marine and estuarine environments. In general, LMEs are natural regions of ocean space encompassing coastal waters from river basins and estuaries to the seaward boundary of continental shelves and the outer margins of coastal currents. They are relatively large regions of 200,000 km^2 or greater, with natural boundaries based on four ecological criteria: bathymetry, hydrography, productivity, and trophically related populations. The Gulf of Mexico LME includes waters that extend beyond the U.S. State and Federal waters (i.e., international waters). The Program will support research conducted in the Gulf of Mexico LME or on processes which impact the Gulf of Mexico LME in a direct, significant, and quantifiable way.



Program Duration

Recognizing that resolution of all administrative and civil penalties may be protracted, initial investments from the NOAA RESTORE Act Science Program (using penalties generated by the Transocean settlement) will be expended over a period of 7-10 years. However, the program is envisioned to have an operating timeline of approximately 20 years (assuming allocation to the NOAA RESTORE Act Science Program from the Trust Fund can be managed separately from other components of the Trust Fund). This timeline assumes a future resolution of civil penalties as a result of on-going litigation.

Project Duration

In keeping with the research priorities identified in the Act, priority shall be given to integrated, long-term projects. "Integrated" projects are defined as cross-disciplinary and may link observations/monitoring, modeling, and field/laboratory research. "Long-term" projects are defined as greater than three (3) years in duration, and will receive priority except in those instances where short-term awards may be required to support program execution or initial short-term investments.

Eligibility for Funding Opportunities

- Eligible applicants are institutions of higher education, other non-profits, state, local, Indian Tribal Governments, commercial organizations, and US Territories that possess the statutory authority to accept funding for this type of research.
- Federal agencies that possess the statutory authority to accept funding for this type of research may

apply.

- The NOAA RESTORE Act Science Program Funding Opportunities will not be used to hire and fund the salaries of any permanent Federal employees, but may fund travel, equipment, supplies, and contractual personnel costs associated with the proposed work.
- Foreign researchers may apply as sub-awards through an eligible US entity.
- Principal investigators(PIs) are not required to be employed by an eligible entity that is based in one of the five Gulf of Mexico States (Florida, Alabama, Mississippi, Louisiana, Texas); however, PIs that are not from Gulf of Mexico-based eligible entities are encouraged to collaborate with partners from a Gulf of Mexico-based eligible entity.

Funding Restrictions

The Act stipulates activities that are not eligible under this program. The funds provided may not be used:

- for any existing or planned research led by NOAA, unless agreed to in writing by the grant recipient;
- to implement existing regulations or initiate new regulations promulgated or proposed by the NOAA; or
- to develop or approve a new limited access privilege program for any fishery under the jurisdiction of the South Atlantic, Mid-Atlantic, New England, or Gulf of Mexico Fishery Management Councils.

With respect to the first bullet, If the research being proposed:

- is substantially part of work that is currently tracked in a NOAA Line Office Annual Operating Plans (AOPs), any grant or other funding mechanism documentation, or other budgetary or program management documents (using appropriated funds); or,
- is substantially part of work that has been proposed in a NOAA budget formulation program change summary (regardless of success) or other budget formulation documents at the NOAA Line Office level since July 2012 (using appropriated funds); or,
- is substantially duplicative of efforts *implemented* by NOAA, i.e., conducted by NOAA federal scientists or contract scientists on behalf of NOAA (using appropriated funds),

then the research being proposed is not eligible for funding under the RESTORE Act Science Program. Final determination of the eligibility of the proposed research will be made by the Program.

Scientific Integrity

To ensure scientific integrity, the NOAA RESTORE Act Science Program will comply with the NOAA Administrative Order (NAO) on Scientific Integrity (NAO 202-735D). Independent reviews will be performed by scientific peers, not affiliated with institutions that propose projects, to avoid conflicts of interest in the selection of funded research, and in compliance with the NOAA Policy on Conflicts of Interest for Peer Review.

The Program will apply the rigorous, competitive, peer-review process established by NOAA's Center for Sponsored Coastal Ocean Research (CSCOR) to select research projects. This review process is extensive and well-documented to make it as transparent as possible to applicants. In most instances, the Program will utilize both mail reviews, to provide comments on individual proposals, and panel reviews, to look at the suite of proposals. The requirement for quality science will be carried through the entire project from concept to final products by including peer-review at all critical levels, seeking the advice of external experts, and initiating regular reviews of the programs.

Funding Mechanisms

The NOAA RESTORE Act Science Program will likely rely most heavily on grants and/or cooperative agreements as the funding mechanism. However, the program will allow for a mix of funding approaches that provide the flexibility needed to do the work required and involve appropriate institutions.

Partnerships

Recognizing the inherent complexity of the Gulf of Mexico ecosystem and the diversity of disciplines and expertise that will be required to advance current understanding and support long-term sustainability of the ecosystem, preference will be given to collaborative efforts.

Data and Information Sharing

Eligible applicants awarded funding under the NOAA Restore Act Science Program will be required to comply with NOAA Administrative Order 212-15 and the guidance provided in the Procedural Directives. Environmental data and information collected and/or created under an awarded grant/cooperative agreement will be made visible, accessible and independently understandable to users in a prescribed manner, i.e., near real time where appropriate and within two years after the data are collected or created, the data will have undergone quality assurance/quality control using community-accepted standards, protocols etc., free of charge or at minimal cost that is no more than the cost of distribution to the user, except where limited by law, regulation, policy or by security requirements.

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VI. Appendices

Appendix I. Overview of existing/anticipated Gulf programs

Several other groups have or are anticipated to receive funding as a result of the Deepwater Horizon oil spill. NOAA believes it is imperative that all recipients of settlement funds derived from the spill money coordinate science activities to maximize the benefit to the environment and people of the Gulf of Mexico. These recipients include, but are not limited to:

- The National Fish and Wildlife Foundation (NFWF) received $2.5 billion from the Transocean and BP settlements with the U.S. Department of Justice. These funds are specifically focused on ecosystem restoration, including barrier island construction, in the Gulf States. Half of the funds are specifically dedicated to barrier island and river diversion projects in Louisiana.
- The National Academy of Sciences (NAS) received $500 million from the Transocean (January 2013) and BP (November 2012) settlements with the U.S. Department of Justice, and these funds are to be used for human health and environmental protection, including oil spill prevention and response, in the Gulf over a 30-year period.
- The North American Wetlands Conservation Fund (NAWCF) received $100 million from the BP criminal settlement (November 2012) to be used for wetlands restoration, conservation, and projects benefitting migratory birds.
- Gulf of Mexico Research Initiative (GULF OF MEXICORI) is receiving $500 million from BP over 10 years to fund an independent research program designed to study the impact of the oil spill and its associated response on the environment and public health in the Gulf of Mexico.
- The Deepwater Horizon Natural Resources Damage Assessment (conducted under OPA 90) Board of Trustees are mandated to restore, rehabilitate, replace, or acquire the equivalent of the injured natural resources with the goal of restoring injured resources and services to baseline (pre-spill) conditions, and to compensate the public for interim losses that occur during the time it takes those resources to recover.

Appendix II. List of Acronyms and Abbreviations

AOP – Annual Operating Plan

BMP – Best Management Practice

CSCOR – Center for Sponsored Coastal Ocean Research

DOC – Department of Commerce

EDR – Ecosystem Data Record

ESP – Environmental Sample Processor

GAME – Geospatial Assessment of Marine Ecosystems

GCOOS – Gulf of Mexico Coastal Ocean Observing System

GMFMC – Gulf of Mexico Fishery Management Council

GULF OF MEXICOA – Gulf of Mexico Alliance

GRIDc – Gulf of Mexico Research Initiative and Data Center

GSMFC – Gulf States Marine Fisheries Commission

IOOS – Integrated Ocean Observing System

LME – Large Marine Ecosystem

LMR – Living Marine Resource

NAO – NOAA Administrative Order

NAS – National Academy of Sciences

NOAA – National Oceanic and Atmospheric Administration

NOS – National Ocean Service

OA/OC – Quality Assurance/Quality Control

PI – Principal Investigator

RESTORE Act – Resources and Ecosystems Sustainability, Tourist Opportunity, and Revived Economies of the Gulf States Act of 2012

RSPAWG – RESTORE Science Program Advisory Working Group

TED – Turtle Excluder Device

USFWS – U.S. Fish and Wildlife Service