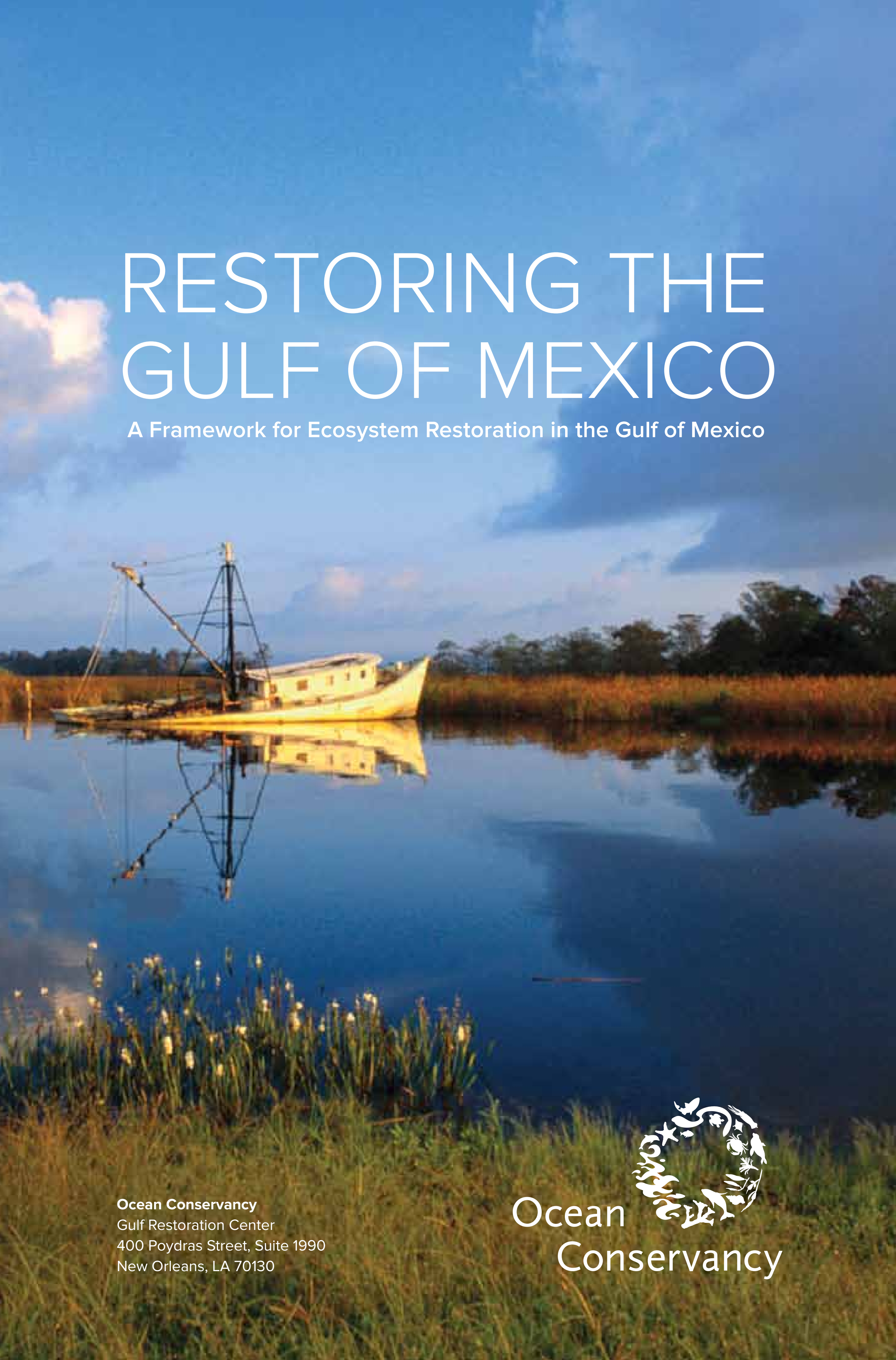
RESTORING THE GULF OF MEXICO

A Framework for Ecosystem Restoration in the Gulf of Mexico



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If we act with wisdom and courage, we have the opportunity to chart a new future.

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The human and environmental tragedy of the BP Deepwater Horizon explosion and Macondo oil well blowout focused the world's attention on the Gulf of Mexico ecosystem and the human communities that depend upon it. During the months that followed the blowout, I witnessed the tragedy firsthand: flying over the affected area, examining barrier islands from small boats, walking along oil-soaked wetlands and beaches and even diving into the oil slick to document the unfolding crisis. I also spent a great deal of time with the people whose lives and livelihoods are intricately connected to the Gulf and whose resources and communities were severely harmed by the discharge of oil.

The Gulf is an extraordinary ecosystem; and its resources and people deserve to be made whole through a comprehensive, long-term restoration effort. Despite many decades of degradation—from oil spills to water pollution to wetlands damage to overfishing—the Gulf ecosystem remains uniquely valuable, not only to the Gulf Coast states, but also to the entire United States.

My view on the need for restoration is shared by experts who have gathered and analyzed the evidence. Experts such as the members of the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling have unanimously recommended a well-funded, long-term restoration program. A healthy Gulf ecosystem is crucial to the economies, cultures and ways of life in Gulf Coast communities. Secretary of the Navy Ray Mabus, former governor of Mississippi, observed: "As the Gulf ecosystem is rebuilt, economic activity will rise, jobs will be created and the region's health will improve."

The Restoration Framework provides both the background and a blueprint for the Gulf ecosystem rebuilding effort. The immediate need is to have effective damage assessment and restoration planning under the Natural Resource Damage Assessment (NRDA) now being conducted by the state and federal NRDA trustees. Beyond NRDA restoration, however, President Barack Obama has made a commitment to restore the Gulf, not only from harm caused by discharged oil, but also from long-term degradation. Consequently, the NRDA restoration plan should contain the essential set of steps to achieve lasting health for the ecosystem, economy and communities of the Gulf. And it will lay crucial groundwork upon which the Gulf Coast Ecosystem Restoration Task Force, and any subsequent version of that task force established by Congress, should build as it charts a restoration course to address ecosystem degradation beyond the scope of the NRDA effort.

In the following pages, the Restoration Framework demonstrates that three broad restoration targets are essential: coastal environments, offshore marine resources and human communities. Integrated, balanced sets of projects are crucial because the Gulf's coast, blue water and people are so closely interrelated. That is, no matter how well-intentioned any individual project may be, a piece-meal approach will simply not be effective in producing the best outcome. Instead, a science-based, integrated package of restoration projects offers the greatest likelihood of achieving sustainable ecological, economic and community benefits. And based upon my many conversations in the affected communities, I am convinced that local perspectives, businesses and workers are invaluable for achieving the best restoration outcomes. Finally, a long-term scientific monitoring and research program is essential to take the pulse of the Gulf, evaluate the effectiveness of restoration projects and make course corrections if necessary. The Restoration Framework captures the critical elements needed to guide the NRDA trustees in their task. A comprehensive, long-term restoration program can help turn a disaster into a healthy ocean future for the Gulf and its people.

The Gulf oil blowout has caused enormous suffering and yet, if we act with wisdom and courage, we have the opportunity to chart a new future for the Gulf. The Restoration Framework can help transform the catastrophe and leave a legacy of hope for the people and the environment of the Gulf Coast.

PHILIPPE **COUSTEAU**
Co-founder and President
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ACKNOWLEDGEMENTS

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The Gulf of Mexico region has benefited enormously from Ocean Conservancy’s relationships with partners so deeply committed to improving ocean health. We especially offer thanks to the Walton Family Foundation for its long-standing support in the region, as well as its recent grant to help restore the Gulf in the wake of the BP oil disaster. In addition, we acknowledge and thank the following donors for their generous contributions toward these efforts: Beneficia Foundation, The Bernice Barbour Foundation, Thomas and Patience Chamberlin, Code Blue Charitable Foundation, Hollomon-Price Foundation, Johnson Ohana Charitable Foundation, Heidi Nitze, Oak Foundation, Panaphil Foundation, Sidney Stern Memorial Trust, Triad Foundation and Weiler Foundation.

Ocean Conservancy is grateful for the inspiration and contributions to this document from citizens, commercial and recreational fishermen, natural resource agencies, local nongovernmental organizations, and the seafood, charter for-hire and hospitality industries from around the Gulf. The Restoration Framework strives to reflect and amplify the environmental restoration priorities and strategies important to regional stakeholders, particularly members of coastal communities whose livelihoods, traditions and futures depend on a fully restored, healthy Gulf.

Finally, the entire Ocean Conservancy staff has shaped and participated in this organization’s response to the BP oil disaster. Many Ocean Conservancy staff members—especially the Gulf Restoration Program and the Communications, Development and Government Relations departments—assisted in the development, review and production of this document.

The Gulf of Mexico is a large, productive, warm-water marine ecosystem that provides extraordinary services not only to Gulf Coast communities but also to the nation.

The BP Deepwater Horizon oil disaster severely impacted portions of the ecosystem along with the region's economies and communities. That damage, however, occurred against a backdrop of decades-long challenges ranging from the loss and degradation of wetlands and barrier islands along the coast to formation of "dead zones" in the northern Gulf to overfishing and lost fisheries productivity. The BP oil disaster triggered a national call to action to go beyond the impacts of the blowout and address the long-term degradation the region has suffered. As the nation carries out its commitment to restore the Gulf ecosystem to a healthy condition, restoration must address both short- and long-term damage in three key areas: coastal environments, blue-water resources and coastal communities.

Two primary vehicles exist for restoring the Gulf ecosystem and the resilience of its coastal communities. The first is the Natural Resource Damage Assessment (NRDA) restoration planning process, required by the Oil Pollution Act (OPA) of 1990, which directly addresses damage from BP's hydrocarbon discharges and associated response activities. The second is the development of an ecosystem restoration strategy by the Gulf Coast Ecosystem Restoration Task Force, created via Executive Order, which addresses long-term, system-wide degradation. Restoration activities carried out as part of NRDA should reflect an integrated, ecosystem-based approach that complements and fits with the broader restoration effort. Legislative proposals now before Congress would dedicate substantial percentages of the penalties paid by the responsible parties under the Clean Water Act (CWA) for discharge of oil into the Gulf of Mexico to fund broader ecosystem restoration and support scientific research and monitoring. These proposals would also establish a Gulf Coast Ecosystem Restoration Council to develop and implement a comprehensive restoration plan based on the Task Force strategy.

In light of past oil spill restoration experiences in the United States, the scope and scale of the BP disaster and the Gulf's history of environmental degradation, successful restoration will likely require decades. Given the critical need to restore the Gulf for the benefit of its communities and the long-term timeframe for achieving restoration goals, it is essential that an effective restoration program be established now that can guide the region to successful outcomes through the years and decades ahead.

An effective Gulf ecosystem restoration program—addressing not only immediate injuries from BP oil but also long-term environmental degradation—must begin with a clearly articulated vision that includes an understanding of how the ecosystem functions, its status and the sources of stress. Among the key elements to be understood are ecosystem functions and dynamics as well as distribution of and relationships among biota and habitats from the coast to the deep ocean basin.

With that foundation established, it is possible to chart a course that leads to a healthy Gulf—one that is resilient, biologically diverse, productive and capable of providing goods (e.g., seafood) and services (e.g., fishing) to communities on a sustainable basis. A successful restoration vision must have clear benchmarks. Otherwise, restoration end points will be uncertain, and it will be difficult to measure progress and determine whether goals are achieved. It is essential to develop clear performance indicators and to monitor and evaluate them rigorously over the long term. Consequently, a commitment of financial resources is needed for scientists, decision-makers and the public to monitor the Gulf's vital signs, identify and analyze emerging patterns or problems and track recovery of habitats and species.

In order to be fully effective, restoration decisions—whether made under the NRDA or a broader ecosystem restoration program established by Congress—must adhere to clearly defined principles and criteria. Because the stakes are so high and billions of dollars are potentially involved, it is critical that the people responsible for allocating those funds start with and adhere to a strong foundation of operating principles. These principles should include: sound management and public transparency and accountability; stable, predictable and coordinated funding for restoration projects and monitoring; specific, measurable, feasible objectives for all projects; consistent use of peer review by independent experts; coordination and integration of projects within a comprehensive ecosystem restoration plan; integration of science—including monitoring and research—throughout the program; and use of adaptive management to adjust projects and program directions based on new information. Finally, project selection should be guided by specific, objective criteria consistent with these core principles.

The interlinked nature of the Gulf's coastal and marine resources, combined with the fact that environmental stressors are associated with both land- and ocean-based activities, make an ecologically and geographically balanced restoration approach essential. In addition, restoration should take account of the economic and cultural roles played by the Gulf ecosystem and should enable Gulf residents to benefit not only from long-term gains in sustainable ecosystem services, but also from near-term employment, workforce development and formation of intellectual capital for a restoration economy.

Toward these goals, and based on a review of ecosystem processes and stressors, the Restoration Framework makes the following recommendations for priority restoration strategies within the three key areas of coastal environments, ocean resources and coastal communities:

1 Restore, Protect and Maintain the Coast, with Emphasis on Wetlands

- Reconnect rivers with estuaries and wetlands by restoring influxes of fresh water and sediment;
- Reestablish wetland vegetation and fish and waterfowl habitats in obsolete canals by backfilling with dredged material from spoil banks or using other sources of material compatible with site characteristics; and
- Protect wetlands from incompatible development, and restore or enhance ecologically beneficial freshwater flows that promote natural recovery.

2 Restore, Protect and Maintain Coastal and Marine Habitats of Significance

- Promote natural sediment recruitment and exchanges;
- Maintain or enhance natural vegetation, reduce foot and vehicular traffic and create adequate buffers from development;
- Protect and enhance bird and sea turtle nesting sites and associated habitats;
- Reestablish or maintain existing oyster reefs and sea grasses for fisheries and other ecosystem services; and
- Protect corals from incompatible human activities.

3 Gulf of Mexico Ecosystem Research and Monitoring (GEM) Program for Adaptive Management

- Create a permanently funded Gulf of Mexico Ecosystem Research and Monitoring (GEM) Program for Adaptive Management.

4 Reduce the Northern Gulf Hypoxic Zone ("Dead Zone")

- Shrink the "dead zone" area by reducing nutrient loads into the Gulf of Mexico.

It is possible to chart a course that leads to a healthy Gulf—one that is resilient, biologically diverse, productive and capable of providing goods (e.g., seafood) and services (e.g., fishing) to communities on a sustainable basis.

5 Protect, Restore and Maintain Wildlife Populations

- Gather basic information on the status, biology and ecology of marine mammals, sea turtles and coastal and marine birds in the Gulf;
- Implement existing recovery and management plans for threatened and endangered species and species of special conservation or management concern; and
- Evaluate threats to wildlife, such as marine debris, vessel strikes and artificial lighting on offshore platforms, and work to reduce threats, especially if deemed to be significant at the population level.

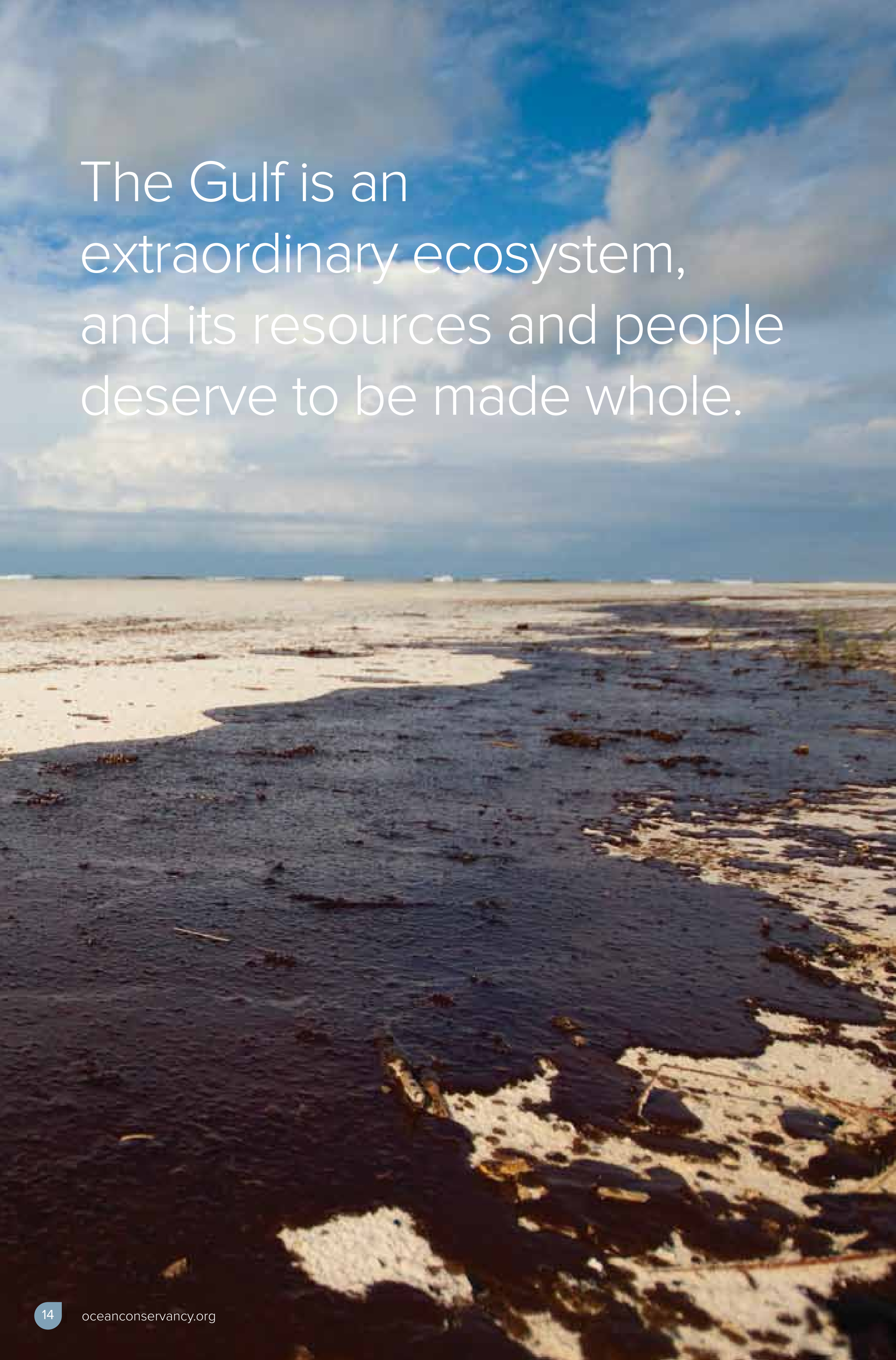
6 Sustain Globally Competitive Gulf Fisheries

- Improve fishing opportunities and increase economic benefits through investments in fisheries science and monitoring; and
- Invest in gear technology and fleet performance initiatives that increase environmental and economic benefits.

7 Promote Community Recovery and Resiliency

- Restore, expand or enhance public-use areas and amenities;
- Enable the fishing industry to modernize and become more competitive through gear conversions, investments in product quality and improved marketing;
- Promote recovery and long-term health of subsistence and minority fishing communities; and
- Engage local businesses and train and employ a local Gulf workforce in the implementation of restoration projects.

The recommendations highlighted here and described more fully in the main body of the Restoration Framework provide a blueprint that will help policy-makers and the public craft lasting restoration solutions that correct both injury caused by the BP blowout and long-term degradation. The result can be a shared, sustainable and healthy future for the fish, wildlife and people of the Gulf.



The Gulf is an extraordinary ecosystem, and its resources and people deserve to be made whole.

Introduction: Purpose, Context and Decision-making

On April 20, 2010, BP's Deepwater Horizon exploded, killing 11 oil-industry workers and discharging an estimated 4.9 million barrels of oil and 500,000 tons of gaseous hydrocarbons into the northern Gulf of Mexico (Fig. 1.1.).

1.1. PURPOSE OF THE RESTORATION FRAMEWORK

The discharged oil and gas and the massive use of chemical dispersants and other response and cleanup measures polluted water, air, seafloor and shorelines; killed a variety of coastal and marine wildlife; and caused enormous economic disruption and emotional stress for the people who live, work and recreate on the Gulf Coast. The BP Deepwater Horizon oil disaster (BP oil disaster) triggered a massive and immediate response effort to contain and clean up the oil. This disaster also violated various federal and state laws, some of which will result in fines and penalties or restoration costs, potentially running into the billions of dollars, from BP and other responsible parties.

The BP oil disaster prompted a commitment by President Barack Obama to go beyond this disaster to "restore the unique beauty and bounty of the region" by addressing long-standing ecosystem challenges in the Gulf of Mexico more broadly. President Obama recognized that the BP oil discharge is just the latest blow to a region that has suffered from decades of environmental degradation. Given the economic and cultural importance of the Gulf to the nation and the inextricable link between the health of the Gulf's environment and the health of the economy, it is essential that the President's commitment is upheld and a long-term restoration plan implemented to address injuries from the BP oil disaster and from ongoing degradation of the ecosystem. Ultimately, the goal of restoration must be to advance the long-term health and resiliency of the Gulf's ecosystem, including the people and communities who depend on this national treasure.

Ocean Conservancy's Restoration Framework is a tool for decision-makers and the public to facilitate effective restoration planning and implementation, based in part on lessons learned from the *Exxon Valdez* oil spill and other restoration initiatives. The Restoration Framework presents key elements necessary for this development, including an overview of the Gulf of Mexico ecosystem, sources of environmental stress, principles for effective restoration and approaches to restoration. It also brings together a wide array of contextual information and offers recommendations on restoration strategies.

Specifically, our aim is to:

- inform and thereby facilitate public participation in restoration processes and programs; and
- provide input and guidance for those who will make decisions about the allocation of funds available for environmental restoration, whether in response to damage caused by the BP oil disaster or by decades of environmental degradation in the Gulf ecosystem.

With the public attention brought to the Gulf from the BP oil disaster and high-level commitments to restore this important ecosystem and the communities that depend on it, we hope the Restoration Framework can play a pivotal role in facilitating a successful restoration outcome.

Figure 1.1. On April 20, 2010, the Deepwater Horizon mobile drilling rig exploded and sank, claiming the lives of 11 workers and triggering the largest, unintentional marine oil spill in history.

1.2. POLICY AND LEGAL CONTEXT

The March 1989 *Exxon Valdez* oil spill prompted passage of the Oil Pollution Act (OPA) of 1990, landmark federal legislation that strengthened and clarified liability and procedures for oil disaster response, natural resource damage assessment and restoration. Before OPA, injuries to natural resources caused by oil and hazardous substance spills were addressed through a patchwork of spill-related laws, such as the Clean Water Act of 1972 (CWA), Deepwater Port Act of 1974, Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act of 1986. OPA and its associated regulations for conducting natural resource damage assessments supersede some of these preexisting statutes (e.g., CERCLA) with regard to oil spills. Although OPA has become the primary statute of relevance to oil discharges, other statutes such as CWA still apply. The National Environmental Policy Act (NEPA), described in more detail below, is another relevant statute especially important for the restoration phase. NEPA requires federal agencies to identify and disclose publicly the environmental impacts of restoration actions that they propose. It also requires federal agencies to seek and consider public input regarding the selection of preferred restoration actions.

1.2.1. NATURAL RESOURCE DAMAGE ASSESSMENT (NRDA)

In accordance with OPA, federal and state governments initiated a formal NRDA following the Deepwater Horizon oil disaster. At present, the NRDA is carried out on behalf of the public under the supervision of trustees of publicly-owned natural resources from federal and Gulf state governments, with the cooperation of BP. Federal and state trustees are collectively called the Deepwater Horizon Oil Spill Trustee Council (Trustee Council).

The purposes of the NRDA are to:

- document that natural resources, such as air, water, marshes, fishes and wildlife, were exposed to and injured by the discharge of oil and gas in the Deepwater Horizon oil disaster;
- document the scope and significance of the exposure and injury;
- develop a restoration plan; and
- present a claim for compensation by the responsible parties for the cost of restoring the natural resources injured by the disaster and for the reduced or lost services (human uses) they provide.

Funds recovered through the NRDA must be used to restore injured natural resources and reduced or lost services and cannot be used for any other purpose. Funds obtained through the NRDA may not be used to compensate businesses or individuals for lost income or other forms of private damages suffered as a result of the oil disaster. These losses may be recovered through the Gulf Coast Claims Fund or private claims against BP and other responsible parties.

The regulations guiding the NRDA provide that trustees may undertake emergency restoration, if needed, to prevent further harm to injured natural resources. Responsible parties also can voluntarily enter into agreements with trustees to conduct early restoration before a final settlement is reached. In fact, an April 2011 agreement among BP, the federal government and the five Gulf states provides $1 billion for early restoration and enables such efforts to begin.

1.2.2. OIL DISCHARGE FINES UNDER THE CLEAN WATER ACT (CWA)

The federal government and several Gulf state governments are now pursuing civil and criminal penalties against BP and other responsible parties. Under the CWA, it is unlawful to discharge oil into navigable waterways along shorelines or in coastal waters. Penalties assessed under the CWA start at $1,100 per barrel of oil discharged and may go as high as $4,300 per barrel if gross negligence is established. Under existing laws, any penalties obtained under the CWA are deposited in the Oil Spill Liability Trust Fund (OSLTF) and can be used to pay for or reimburse oil pollution removal costs and related expenses. The money also can be used to pay for the costs incurred by trustees in carrying out their duties to assess natural resource damages, and for developing and implementing plans for the restoration, rehabilitation, replacement or acquisition of the equivalent of damaged natural resources. The amount available from the OSLTF for NRDA-related expenditures is capped at $500 million; and the real aim of the OSLTF is to support future oil disaster response efforts, especially when responsible parties cannot be identified. Hence, under current law, the OSLTF is not a practical source of funds for large-scale ecosystem restoration in the Gulf. Congressional action is required to direct CWA penalties to support large-scale restoration of the Gulf ecosystem or economy.

In July 2011, the Resources and Ecosystems Sustainability, Tourist Opportunities, and Revived Economies of the Gulf Coast States (RESTORE) Act of 2011 was reintroduced in the Senate and, if passed, would deposit 80 percent of the CWA penalties into a Gulf fund for environmental restoration, including research and science, and possibly for other purposes, such as infrastructure.

1.2.3. NATIONAL ENVIRONMENTAL POLICY ACT (NEPA)

Passed by Congress in 1969, NEPA is the country's bedrock environmental statute; it imposes a "due diligence" requirement on federal agencies to analyze the environmental impacts of proposed federal actions. NEPA also requires public disclosure of assessed impacts and an opportunity for public comment on proposed actions.

In the case of publicly-owned natural resources, particularly ocean or coastal marine resources, the federal government typically takes the lead in developing, implementing and coordinating restoration actions on behalf of the public. Federal involvement in restoration planning and implementation is therefore subject to NEPA and its implementing regulations. For example, federal agency actions may require preparation of an environmental assessment or a more rigorous environmental impact statement. The latter is triggered when federal actions are expected to have significant environmental effects.

The National Oceanic and Atmospheric Administration's (NOAA) Restoration Office, a division of the National Marine Fisheries Service (NMFS), is coordinating development of a programmatic environmental impact statement (PEIS) in conjunction with the other state and federal trustees in an effort to streamline federal NEPA compliance for restoration activities related to the BP oil disaster. The PEIS is appropriate because the complex nature and large scale of the disaster may necessitate major restoration actions over a wide area involving multiple publicly-owned natural resources. The PEIS is the umbrella document that state and federal government trustee agencies will use to analyze a range of restoration alternatives, select preferred alternatives and guide development of an eventual NRDA restoration plan. When the draft PEIS for the BP oil disaster and related restoration plan is publicly released in late 2011 or early 2012, it will trigger a public comment period.

1.2.4. OTHER POTENTIAL SOURCES OF FINANCIAL RESOURCES

A number of other federal and state statutes may lead to the assessment of fines from BP and other responsible parties. For example, under the federal Migratory Bird Treaty Act (MBTA), it is unlawful to take or kill any migratory bird, including any part, nest or egg of any of more than 1,000 protected species. Individuals or corporations who violate the MBTA or its regulations are guilty of a misdemeanor and can be fined up to $15,000 per count. Bird deaths resulting from exposure to oil, other contamination or collateral injury may trigger fines under the MBTA.

The federal Marine Mammal Protection Act (MMPA) provides for civil penalties up to $11,000 per incident for harming or killing a marine mammal. In addition, several species of wildlife are listed as threatened or endangered in the Gulf of Mexico; so the federal Endangered Species Act (ESA) may come into play. Unlike the civil penalties that can be invoked under the MMPA, however, ESA penalties may be more difficult to link to responsible parties because the legal standard is different than either the MMPA or MBTA.

There also may be recovery of financial resources under state laws. For example, in May 2010, the state of Louisiana filed a lawsuit against BP in state court for the death of and injuries to Louisiana's aquatic life and wildlife. In its complaint, the state alleges that BP violated a state law prohibiting the killing or taking of fish, wild birds, mammals and other wildlife and aquatic life in violation of Title 56 of Louisiana Revised Statutes. The case has been removed to a federal district court in New Orleans where about 300 other lawsuits generated by the oil disaster have been consolidated.

Oil Pollution Act NRDA Framework

Figure 1.2. Designated trustee agencies determine the extent and significance of oil disaster injuries by conducting a Natural Resource Damage Assessment, which consists of three phases (pre-assessment, restoration planning and restoration implementation). BP Deepwater Horizon trustees have received a down payment of $1 billion toward early restoration funding.

Typically, fines or penalties assessed under these laws can be deposited in accounts that are dictated by individual laws. For example, some of the fines obtained under the MBTA in connection with the April 2003 Buzzards Bay fuel oil spill were deposited in the North American Wetlands Conservation Fund. It is possible that such funds may be directed to projects in the Gulf region, but they will not be directly available for the restoration of injured natural resources or broader ecosystem restoration. In the case of the *Exxon Valdez* oil spill and the subsequent settlements among Exxon and the state and federal governments, a portion of the criminal fines assessed against Exxon was forgiven. Exxon then paid additional sums to the state and federal governments (separately) as "criminal restitution," with the requirement that those funds be used exclusively for restoration in the area affected by the oil disaster.

1.3. ORGANIZATION, DECISION-MAKING AND PUBLIC PARTICIPATION

At present, there are two main venues for making decisions about restoration activities related to the BP oil disaster in the Gulf of Mexico: the federal-state Deepwater Horizon Oil Spill NRDA Trustee Council and the Gulf Coast Ecosystem Restoration Task Force, which was established by an executive order issued by President Obama.

In one form or another, these regional bodies or processes will be at the center of decisions about restoration in the Gulf, though state-specific restoration planning processes will be influential.

1.3.1. NRDA TRUSTEE COUNCIL

The NRDA is a legal process under OPA, whereby federal and state natural resource trustees represent the public interest to ensure that natural resources injured in an oil spill are restored. Trustees are charged with making the environment and public whole for injuries to natural resources and services resulting from an incident involving a discharge or substantial threat of a discharge of oil. Making the environment and public whole includes both restoring injured resources to the condition they would have been in but for the spill and compensating for the temporal loss of natural resources and the ecosystem services they provide, from the time of injury until the time they are fully restored.

Each of the five Gulf states (Florida, Alabama, Mississippi, Louisiana and Texas), and the federal government, through NOAA and the Department of the Interior, has named one or more trustees for purposes of the Deepwater Horizon NRDA. Collectively, the trustees are organized and govern themselves through a Trustee Council.

On October 1, 2010, the Department of the Interior, on behalf of the trustees, published notice in the Federal Register that the governments would conduct an NRDA. This was followed by public notice (by NOAA) on February 17, 2011, that the Trustee Council was initiating "restoration scoping," and a PEIS would be prepared on a Gulf Spill Restoration Plan.

In the NRDA, the Trustee Council is responsible for addressing natural resource injuries or impaired or lost natural resource services related to the BP oil disaster (Fig. 1.2.). By law, the public has several opportunities to participate in the development and implementation of a restoration plan. In addition to restoration scoping (now past), the public will be able to comment on the draft programmatic environmental statement, suggest and comment on restoration strategies and projects throughout the process and comment on a draft restoration plan. The trustees maintain an online administrative record, available for public examination, at *http://www.doi.gov/deepwaterhorizon/adminrecord/index.cfm*. Key NRDA documents are or should be available there.

A damage assessment can be prolonged and complex, and typically can take three or more years to finalize. The duration of the Deepwater Horizon NRDA is unknown, but for a spill of this size it could potentially be even longer.

If a settlement resolves NRDA claims more quickly, the Trustee Council presumably will move promptly to complete and then implement a restoration plan. Typically, restoration funds obtained through the NRDA would be jointly held by federal and state governments and administered by the Trustee Council, as described above. It is possible, however, that the specific terms of a settlement agreement would establish other procedures, though such procedures would still need to be consistent with NRDA regulations. A Memorandum of Agreement guides relationships on the Trustee Council among the federal government and five Gulf states. It can be viewed as part of the online administrative record cited above.

Regulations guiding the NRDA provide for early restoration, which can be undertaken before completion of the NRDA process or a settlement. In the case of the BP Deepwater Horizon oil disaster, the federal and state governments and BP negotiated a $1 billion Early Restoration Framework Agreement (Deepwater Horizon Oil Spill Trustees, 2011). Under this agreement, each of the five Gulf states, plus NOAA and United States Department of the Interior, is to receive $100 million to implement early restoration activities. The remaining $300 million will be used for projects selected by the federal trustees (NOAA and Department of the Interior) from proposals submitted by the state trustees.

Early restoration projects must be funded and implemented in compliance with NRDA regulations, but detailed procedures are not laid out. In the case of the Deepwater Horizon Trustee Council, a majority of trustees must approve all early restoration projects. Those projects approved by the Trustee Council will then be negotiated with BP for inclusion in an early restoration plan. All draft early restoration plans will be made available for public comment. Based on the current timeline, the trustees anticipate putting out a draft early restoration plan in the fall of 2011. Environmental benefits from early restoration will be quantified using the "best available science," and credit will be given to BP in the form of natural resource damage "offsets."

1.3.2. GULF COAST ECOSYSTEM RESTORATION TASK FORCE

In June 2010, President Obama assigned Secretary of the Navy Ray Mabus the responsibility to craft a plan of federal support for the long-term economic and environmental restoration of the Gulf Coast region. In September, Secretary Mabus delivered his report, *America's Gulf Coast: A Long-Term Recovery Plan After the Deepwater Horizon Oil Spill*, to the President (Mabus, 2010) (Fig. 1.3.). One of Secretary Mabus's central recommendations was the creation of a Gulf Coast Ecosystem Restoration Task Force (hereafter, "Task Force"), which the President accomplished by executive order on October 5, 2010 (The White House, 2010).

Unlike the NRDA process, which is limited to consideration of injuries to natural resources (and reduced or lost services) as a direct result of the BP oil disaster, the Task Force has the broader mission of restoring the Gulf of Mexico ecosystem from decades of environmental degradation—in other words, making the ecosystem better than it was before the BP hydrocarbon discharge. According to the executive order (The White House, 2010):

> To effectively address the damage caused by the BP Deepwater Horizon Oil Spill, address the long-standing ecological decline and begin moving toward a more resilient Gulf Coast ecosystem, ecosystem restoration is needed.

President Obama established the Task Force to coordinate intergovernmental responsibilities, planning and exchange of information so as to better implement Gulf Coast ecosystem restoration and to facilitate appropriate accountability and support throughout the restoration process. Task Force members include senior representatives from the federal Departments of Defense, Justice, Interior, Agriculture, Commerce and Transportation; the Environmental Protection Agency; Office of Management and Budget; Council on Environmental Quality; Office of Science and Technology Policy and Domestic Policy Council and representatives from the five Gulf states. Lisa Jackson, Administrator of the Environmental Protection Agency, is chair of the Task Force, and Executive Director John Hankinson is responsible for day-to-day activities.

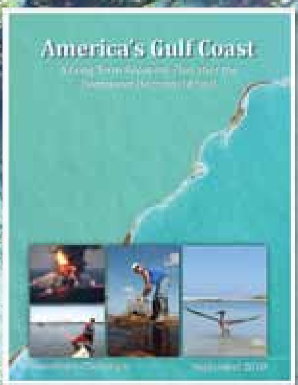


Figure 1.3. Secretary of the Navy Ray Mabus prepared this report at the request of President Barack Obama. Released in September 2010, the "Mabus Plan" was the first to lay out a road map for environmental and economic recovery in the Gulf of Mexico following the BP disaster and decades of environmental neglect.

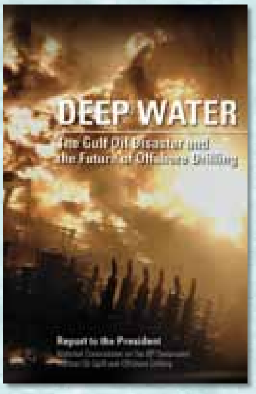


Figure 1.4. The Commission's report, released in January 2011, discusses the root causes and environmental, economic, and social impacts of the BP oil disaster. The report recommends ways to prevent and mitigate future oil disasters and the policies needed to restore the environment after the disaster.

The Task Force has established a website, *www.epa.gov/gulfcoasttaskforce/*, which provides information about Gulf restoration and invites public comments.

The Task Force is specifically charged with preparing a Gulf Coast Ecosystem Restoration Strategy that includes goals for ecosystem restoration and development of a set of performance indicators to track progress and coordination of intergovernmental restoration efforts guided by shared priorities. Because there are many existing plans that pertain to restoration activities in the Gulf, the Task Force will emphasize strategy and coordination among existing agencies and interests.

The Task Force is also required to engage local stakeholders, communities, the public and other officials throughout the Gulf Coast region to ensure that they have an opportunity to share their needs and viewpoints in order to inform the work of the Task Force, including the development of the strategy. The Task Force is developing mechanisms for public engagement, and its meetings to date have included opportunities for public comment.

Since the members and missions of the Task Force and the Trustee Council overlap, it is essential that there is tight coordination between them. The restoration program to be administered by the Trustee Council can be viewed as a subset of the broader array of actions to be guided and coordinated by the Task Force, although the Task Force has no authority or direct role in decisions made by the Trustee Council.

1.3.3. NATIONAL COMMISSION ON THE BP DEEPWATER HORIZON OIL SPILL AND OFFSHORE DRILLING

While there is much to be resolved about when and how Gulf restoration activities will proceed, and with what financial resources, the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling (hereafter, "Commission"), established by the President in May 2010, has provided important guidance and recommendations on the path forward (Graham et al., 2010) (Fig. 1.4.).

The Commission highlights the need for a "long-term restoration effort that is well funded, scientifically grounded and responsive to regional needs and public input." Among the Commission's specific recommendations related to ecosystem restoration are the following:

- Congress should dedicate 80 percent of the CWA penalties to long-term restoration of the Gulf of Mexico; and
- Congress and federal and state agencies should build the organizational, financial, scientific and public outreach capacities needed to put the restoration effort on a strong footing.

In reaching the first recommendation, the Commission notes that "without a reliable source of long-term funding, it will be impossible to achieve restoration in the Gulf." However, in order for funding to be most efficiently directed at long-term restoration, the Commission also observes that there is need for a decision-making body with "authority to set binding priorities and criteria for project funding." The Task Force may meet this objective, but it "lacks some features necessary to effectively direct long-term restoration efforts in the Gulf—most importantly, the ability to set binding goals and priorities." The Commission recommends that Congress "establish a joint state-federal Gulf Coast Ecosystem Restoration Council," and the Council "should implement a restoration strategy for the region that is compatible with existing state restoration goals" and "set short- and long-term goals with binding criteria for selecting projects for funding."

1.4. WHAT HAPPENS NEXT?

Successful restoration of the Gulf of Mexico ecosystem from the effects of the BP oil disaster and decades of environmental degradation will require an enormous amount of money, as well as a high degree of coordination and extraordinary commitments—political and financial—from federal and state governments, industry, the public and a whole array of stakeholders.

The $1 billion provided by BP under the NRDA for early restoration should be only a down payment on what is required, but it will enable some restoration work to begin. How the Trustee Council and states make decisions in regard to early restoration is important because this process will influence the trustees' decision-making throughout the life of the restoration program. To that end, a transparent process is needed, with full public participation and scientific peer review, consistent with the principles outlined in Chapter 2.

Beyond early restoration funds, if the NRDA process is pursued through the full administrative claims process and ultimately ends up in court, many years could pass before funds are available for restoration of natural resources and lost or reduced services. The same is true for possible penalties under the CWA or other environmental statutes. In July 2011, Congress took a significant step toward redirecting CWA fines to the Gulf for environmental restoration with the reintroduction of the RESTORE Act in the United States Senate. The legislation would allocate 80 percent of the total CWA fines to restoration, of which states would receive 35 percent, a Gulf Council would receive 60 percent and a research and science program would receive 5 percent. It is unclear whether or when Congress will pass the legislation allocating funds for restoration and recovery in the Gulf region.

As with the agreement for early restoration, in all likelihood federal and state governments will negotiate a settlement with BP and other responsible parties to address the governments' claims and provide financial resources so that a full program of restoration and recovery can move forward. In the case of the *Exxon Valdez* oil spill, the federal government and state of Alaska settled their claims against Exxon Corporation about two years after the tanker ran aground.

Regardless of when and how legal and financial claims ultimately are resolved, this Restoration Framework is prepared with the hope and under the assumption that the necessary commitments, coordination and financial resources will be adequate to support ecosystem restoration in the Gulf of Mexico.

Establishing a Platform for Success: Mission, Principles & Project Criteria

The Trustee Council, Task Force and individual agencies can help ensure that restoration is successful by providing a solid platform for planning and implementation of restoration activities.

2.1. DEFINING A MISSION

Critical elements of this architecture include articulating a compelling mission statement, meaningful restoration principles and clear criteria for selecting specific restoration projects. Having these elements in place will position decision-makers for success and increase public confidence in the restoration planning process.

The first order of business should be to devise a mission statement to express what decision-makers hope to accomplish and guide subsequent planning and actions. The mission statement also conveys critical information to the public to set proper expectations and facilitate engagement. The following is an example of a mission statement, based in part on the reports by Secretary Mabus and the Commission (Mabus, 2010; Graham et al., 2011):

> Restore and enhance the health, resilience and biodiversity of the Gulf of Mexico ecosystem and assist communities in recovering from the harm caused by the BP Deepwater Horizon disaster through a comprehensive, science-based restoration initiative and improved management and conservation of fish, wildlife and their habitats.

The reality is that restoration from harm caused by oil is a marathon, not a sprint. It may take several years to resolve questions about the nature and scope of injury to natural resources caused by the BP oil disaster, determine the full costs and the availability of and limitations on restoration funding and establish the administrative structures and processes by which to allocate restoration funds and to evaluate progress. Based in part on the experience following the *Exxon Valdez* oil spill and a review of other restoration initiatives, we recommend the following principles for effective restoration and criteria for selection of restoration projects. These guidelines apply to recovery from the BP oil disaster and from decades of environmental degradation and should be valuable regardless of the specific entities responsible for allocation of restoration funds.

2.2. PRINCIPLES FOR EFFECTIVE RESTORATION

The principles below are intended to guide development of restoration decision-making structures, processes and plans; to measure their sufficiency; and to enhance their accountability.

2.2.1. SOUND MANAGEMENT

- Efficient, transparent, responsive management that is accountable to the public;
- Active, full participation by relevant federal entities and all Gulf states, individually and collectively, over time;
- A formal and recognized process that engages the public, including broad representation from the region's communities and stakeholders;
- Commitment by federal and state partners to incorporate local and traditional knowledge in management decisions;
- Coordination between the restoration planning phase of the NRDA conducted in response to the BP oil disaster and the broader restoration planning functions of the Gulf Coast Ecosystem Restoration Task Force; and
- A comprehensive, science-based, ecosystem-focused restoration strategy—resting on a clear vision for a healthy Gulf ecosystem—supplemented by annual work plans, progress reports and periodic requests for project proposals.

2.2.2. STABLE AND COORDINATED FUNDING

- Coordination of projects supported by funds allocated from various revenue sources (to ensure that projects are consistent, complementary and not duplicative);
- Predictable funding streams, consistent from year to year, and sustained over the long term;
- Funding levels commensurate with the magnitude of restoration goals;
- Endowment established to support permanently the research and monitoring needed to assess the health of the Gulf, evaluate the efficacy of restoration measures and facilitate adaptive management;
- Funds provided by the parties responsible for the oil disaster under OPA, CWA and other sources, such as MBTA and ESA; and
- Additional funds contributed by the private sector for matching or leveraging restoration funds provided by state and federal governments.

2.2.3. PRUDENT PROJECT SELECTION

- Established criteria clearly linking projects to specific, measurable, feasible objectives (see Section 2.3.);
- Projects subject to independent scientific peer review in selection and evaluation processes;
- Projects coordinated and integrated within the framework of a comprehensive ecosystem restoration strategy; and
- Reevaluation of restoration priorities and activities as information on the extent and significance of injury to natural resources is obtained from the NRDA as well as other scientific sources.

Figure 2.1. Wetlands, sea grasses and fish are examples of coastal and marine natural resources important to the Gulf ecosystem and economy, and in need of restoration attention.

2.2.4. STEWARDSHIP

- Restoration and enhancement efforts address the whole Gulf ecosystem from coastal to blue-water environments (Fig. 2.1.);
- Habitat protection and enhancement efforts support long-term resiliency and sustainability for coastal communities; and
- Rehabilitation focuses on degraded natural resources and ecosystem services that provide sustainable economic opportunities and human uses.

2.2.5. SENTINEL SYSTEM FOR THE FUTURE

- Monitoring and management systems in place to identify and address lingering injury from BP oil, evaluate effectiveness of restoration projects and make necessary adjustments based on performance in achieving goals; and
- Permanent “take the pulse of the Gulf” science program to track ecosystem health, identify emerging problems and facilitate solutions (Fig. 2.2.).

2.3. CRITERIA FOR SELECTING AND FUNDING RESTORATION PROJECTS

As restoration moves from planning to implementation, there will be myriad proposals for projects on which to spend restoration funds. The ultimate success of these projects—which must be measured by the health and resilience of the ecosystem—rests on selection, implementation and evaluation of a series of integrated projects, consistent with a Gulf-wide plan and rigorous application of criteria, to ensure that only the best and most appropriate projects are funded. The restoration program that emerges should take a comprehensive, integrated ecosystem approach and strive for results that are greater than the sum of the individual projects. The criteria described below can be applied at the strategic level as well as at the level of individual projects.

The following criteria, based in part on those developed and tested by the *Exxon Valdez* Oil Spill Trustee Council (1994), are recommended to guide project selection for Gulf restoration:

- Priority will be given to restoration projects that facilitate recovery of injured natural resources and lost services by addressing systemic problems facing the ecosystem, including historical degradation;
- Priority will be given to restoration of natural resources and ecosystem services that have economic, cultural and subsistence value to people living and working along the Gulf Coast;
- Extra consideration should be given to projects that increase the resilience of socially vulnerable communities;
- Priority will be given to projects that benefit multiple species or resources;
- Restoration activities should have clear, measurable and achievable end points;
- Possible harmful effects on nontarget resources and services should be considered when evaluating proposed restoration activities;
- Competitive, innovative, collaborative and cost-effective proposals for restoration projects will be encouraged;
- Projects that are scalable may be funded in part, provided that the funded component stands alone in terms of its benefits, even if the rest of the project is not funded;
- Project sponsors demonstrate due diligence that includes scientific, technical, economic and social evaluation of design, design alternatives and implementation of the effort; and
- Priority will be given to restoration projects that include plans integrating workforce development and job creation benefiting people who live and work in the area, including disadvantaged and underemployed populations.

Figure 2.2. The productivity and health of the Gulf of Mexico ecosystem are influenced by oceanographic currents, river inflows and human activities along the coast and in the ocean.

2.4. SUPPORTING REGIONAL ECONOMIC RECOVERY THROUGH RESTORATION

Successful restoration will require participation by the public and private sectors. Implementation of restoration projects and research and monitoring programs will create significant economic opportunities for the region. It is critical that knowledgeable and experienced businesses, organizations and residents are selected for implementation of restoration projects and activities through a competitive bidding process. In the implementation of restoration projects, preference should be given to qualified, regionally-based entities to create jobs locally and pump money back into the local economy. (Chapter 6 discusses strategies for facilitating economic renewal along the Gulf Coast.)

The Gulf Ecosystem: A Profile and Vision for a National Treasure

In order to be effective, a program to restore the Gulf ecosystem must rest on a thorough assessment of the status of the ecosystem, taking into account the effects of the BP oil disaster and long-term environmental degradation, as well as a vision for what comprises a healthy and resilient Gulf of Mexico.

Without understanding how the ecosystem functions, its status and its sources of stress, it will be challenging at best to design a restoration program with measurable objectives, either in response to the effects of the BP oil disaster or systemic degradation. In the absence of such information, restoration end points are unclear, making it difficult for policy-makers, resource managers and the public to measure progress and recognize when goals are achieved.

This chapter gives a technical overview of ecosystem functions, biota and habitats from the Gulf Coast to the deep ocean basin, and highlights major sources of stress originating on land or at sea. Combined with Chapter 4, "BP Deepwater Horizon Oil Disaster Impacts," it provides a foundation for restoration planning.

3.1. DESCRIPTION OF THE GULF OF MEXICO ECOSYSTEM

The Gulf of Mexico—a productive, warm-water, large marine ecosystem—is the ninth largest body of water in the world and supports an amazing variety of warm temperate and tropical marine species. The Gulf ecosystem is also heavily used by people. For example, it accounts for about 30 percent of U.S. commercial fishery landings and 44 percent of U.S. recreational catch, 12 percent of U.S. domestic oil production and 25 percent of domestic natural gas production.

It is not surprising that the northern Gulf ecosystem has been greatly altered by human activities, including nutrient loading and disrupted patterns of sediment deposition from the Mississippi River and Atchafalaya River, heavy fishing pressure and intense oil and gas activities. Global climate change will likely cause further widespread modification of this ecosystem. The following description of the ecosystem is organized into two broad sections. First, Section 3.1. provides an overview of the ecosystem and how it functions. Section 3.2. describes the same ecosystem with respect to its different habitats and identifies sources of environmental stress, which are summarized at the end of the chapter. Section 3.3. highlights the sources of environmental stress and the resulting symptoms these stressors trigger in the ecosystem. Section 3.4. addresses the future health of the Gulf of Mexico by discussing the importance of a vision for the Gulf and the elements needed to realize that vision.

3.1.1. PHYSIOGRAPHY

The Gulf of Mexico is a semi-enclosed, warm temperate to tropical, Mediterranean-type sea, about 1.5 million square kilometers (0.58 million mi^2) in area, that communicates with the Caribbean Sea north and south of the Island of Cuba. It is bordered by the United States to the north and Mexico to the west and south. The Gulf has a broad continental shelf off the west coast of Florida, most of Texas and Louisiana and the Yucatan Peninsula (Fig. 3.1.). Its abyssal plain (an area deeper than 3,000 meters [9,843 ft]), whose axis lies in a southwest to northeast direction, has a maximum depth of about 4,000 meters (13,123 ft) in its western sector and accounts for about 20 percent of the area of the Gulf. The shallow habitats are more ecologically productive, occurring in water depths of less than 20 meters (66 ft) and account for 38 percent of the Gulf area. Sediments derived from continental erosion (terrigenous sediments) dominate much of the seafloor in the northern and western Gulf, while biogenic carbonate sediments (from living processes) dominate the seafloor in the eastern portion of the Gulf off western Florida, Veracruz and the Yucatan Peninsula. Barrier islands fringe much of the United States Gulf Coast, and warm-water coral reefs occur in southern Florida, off Texas and off the Yucatan Peninsula. The varying climate, geology and freshwater inputs interact to create habitats that range from beaches, marshes, shallow estuaries and lagoons and productive continental shelves to rocky reefs, banks, deepwater seeps, coral reefs, extensive deepwater soft bottoms and open-water pelagic areas. Much of the Gulf's outer continental shelf is populated by a series of drowned reefs and islands with hard substrates that may be of particular importance in maintaining certain fish populations.

3.1.2. OCEANOGRAPHY

The oceanography of the Gulf of Mexico is greatly influenced by semi-permanent weather patterns in the western Atlantic Ocean, namely the existence of the Bermuda High, for much of the year, but also by the dry, cooler, continental air that flows in winter from the north. An area of high pressure in the western Atlantic results in a predominant southeasterly flow of air into the Gulf.

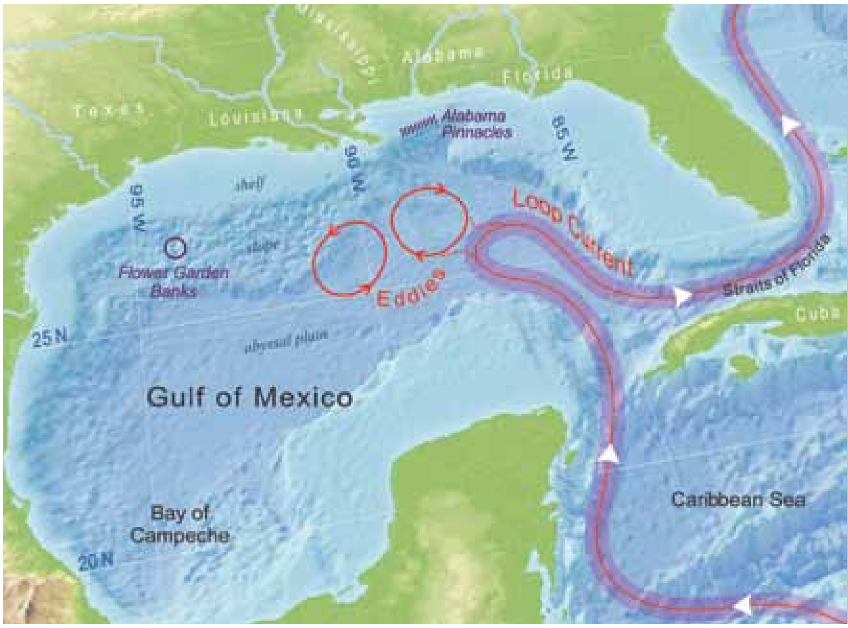


Figure 3.1. The Gulf of Mexico has a complex seafloor topography, including a relatively shallow continental shelf that grades into a deep abyssal plain, or basin, at its center. River inputs, currents and eddies are significant defining characteristics of the Gulf ecosystem.

Figure 3.2. Surrounded by a fertile deltaic plain, the Mississippi River empties on average 16.8 million cubic meters of water per second into the Gulf and 450 million metric tons of sediment. Historically, the river spilled its banks during floods, spreading sediment that contributed to the Delta's growth.

The main water circulation features in the Gulf consist of:

- a large clockwise movement—the Loop Current, the dominant feature of the eastern Gulf—which enters through the Yucatan Straits and exits between the southern tip of Florida and Cuba; and
- large eddies with either warm (anticyclonic) or cold (cyclonic) cores that dominate the central and western Gulf.

The eddies shed from the Loop Current in the eastern Gulf and move to the west along the continental shelf edge, eventually shoaling and degrading in the northwest Gulf (Sturges & Leben, 2000). Eddies tend to be found in cyclonic and anticyclonic pairs (Fig. 3.1.). Their interactions with each other and the shelf edge as they move westward have important consequences for local biological production due to associated upwelling and downwelling and their roles in onshore and offshore transport of nutrients and organisms. Water masses with different temperature and salinity properties meet at fronts on the shelf. Shelf fronts occur along the northern Gulf, from northern Mexico through Florida, as well as along the northern portions of the Yucatan Peninsula. The shelf fronts can be important aggregation areas for plankton, nekton and marine pelagic predators that are otherwise widespread. Water circulation on the shelf is quite variable and controlled mainly by local wind fields.

More than 150 rivers supply fresh water to the Gulf. The Mississippi River is the largest river system in North America and supplies well over half of the annual total volume of more than 10^{12} cubic meters of fresh water entering the Gulf. The Mississippi River also carries large quantities of nutrients and pollutants from about half the area of the contiguous United States, including the farm belt (Fig. 3.2.).

The plume of the Mississippi River, entering either from the Atchafalaya River or the so-called "bird's-foot" delta of the Mississippi River, is a major influence on the oceanography of the central Gulf and the productivity of its shelf. Its plume flows as less-dense water overriding saltier, deeper offshore water.

The coastal northern Gulf climate is quite variable seasonally: rapid warming with heavy runoff from land in the spring; quiescent hot summers with occasional wind events; rapid cooling in the late summer and fall with the potential for major tropical anticyclones; and moderate winters with occasional cold-air outbreaks from the north. Water temperatures are about 13 to 15 degrees C (55-59 degrees F) in the coldest months and about 29 to 31 degrees C (84-88 degrees F) in the warmest months, varying with the year and location. Annual mean sea surface temperature fluctuates between 26 and 27 degrees C (79-81 degrees F) (Heileman & Rabalais, 2009). Long-term climate change is already affecting the Gulf. For example, in Mobile Bay the onset of the spring phytoplankton bloom is now about two weeks earlier than it was in 1947 (M. Graham, personal communication, 2010), which is consistent with a warming climate.

3.1.3. PRODUCTIVITY

The Gulf as a whole is a moderately high primary productivity basin (250-300 g C/m^2-yr) compared to other portions of the world's oceans. There are two main gradients in biological productivity in the Gulf: productivity is highest on the continental shelf, decreasing generally offshore and decreasing with depth. These gradients reflect the supporting primary productivity from photosynthesis that is highest in shallow water close to land where nutrients are plentiful and in well-lit surface waters above the "compensation depth" (above which

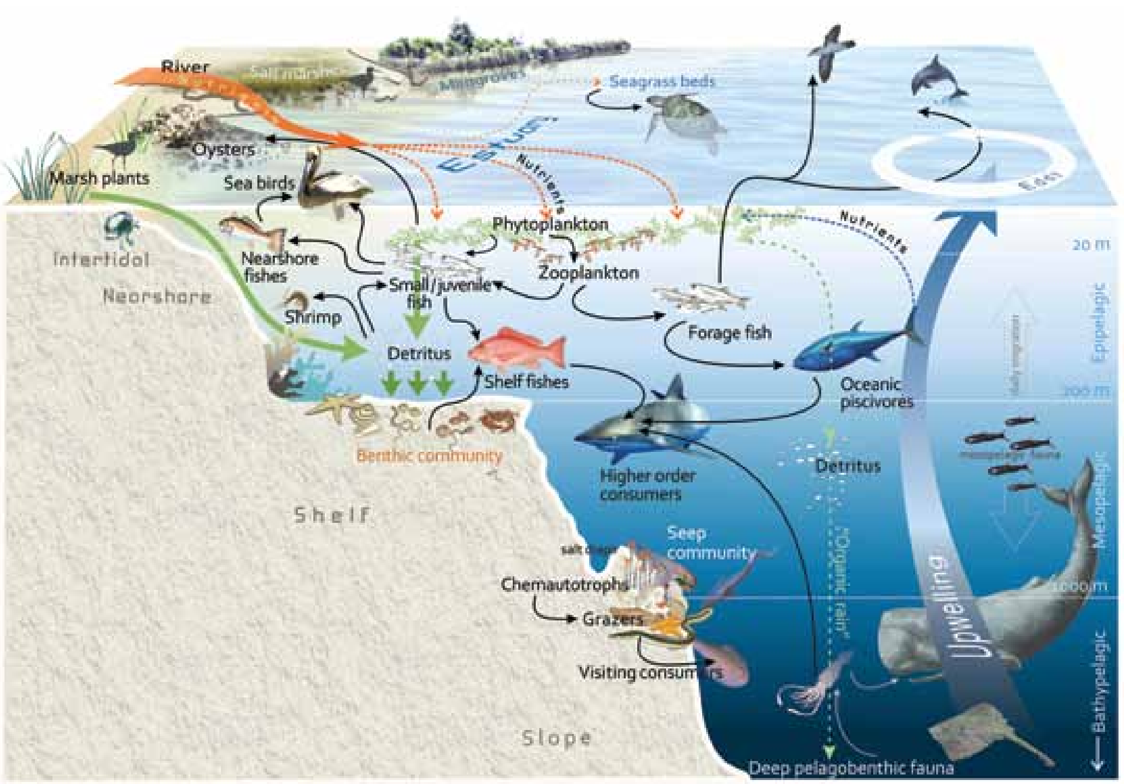


Figure 3.3. A depiction of the ecosystem in the northern Gulf of Mexico, showing major habitats, animal groups and food web relationships.

the organic matter produced by photosynthesis is greater than that consumed by respiration).

In the Gulf, biomass of living organisms decreases rapidly with depth, both in the water column and with depth of the sea bottom, in concert with proximity to primary production. These gradients in production and in the supply of organic matter are the most important controlling factors for the abundance of marine life in the Gulf (Fig. 3.3.).

3.1.4. BIODIVERSITY

Besides productivity, biodiversity—or the variety of life in a place—is one of the other important attributes of ecosystems. Biodiversity reflects the different functions or niches in an ecosystem and the species that are present to carry out those functions or fill those niches. Ecosystems are optimized by natural selection on the species level to use energy wherever and whenever it is available. Different organisms inhabit various parts of the ecosystem (niches) and play different roles in the operation of ecosystems through production, consumption and recycling of materials under a host of different circumstances. The warm, subtropical waters of the Gulf harbor a larger diversity of organisms than in colder, temperate water to the north, but not as high as can be found in the tropics. Recently, the Harte Research Institute at Texas A&M University-Corpus Christi undertook a survey of marine biodiversity in the Gulf (Felder & Kamp, 2009) (Fig. 3.4.). Out of a total of 224,787 described marine species in the world, the authors estimated that 15,419 of them are found in the Gulf. This compares to 26, 927 in Europe, 6,150 in Hawaii and 10,836 in South Africa. These numbers are the best available at present and should not be considered final.

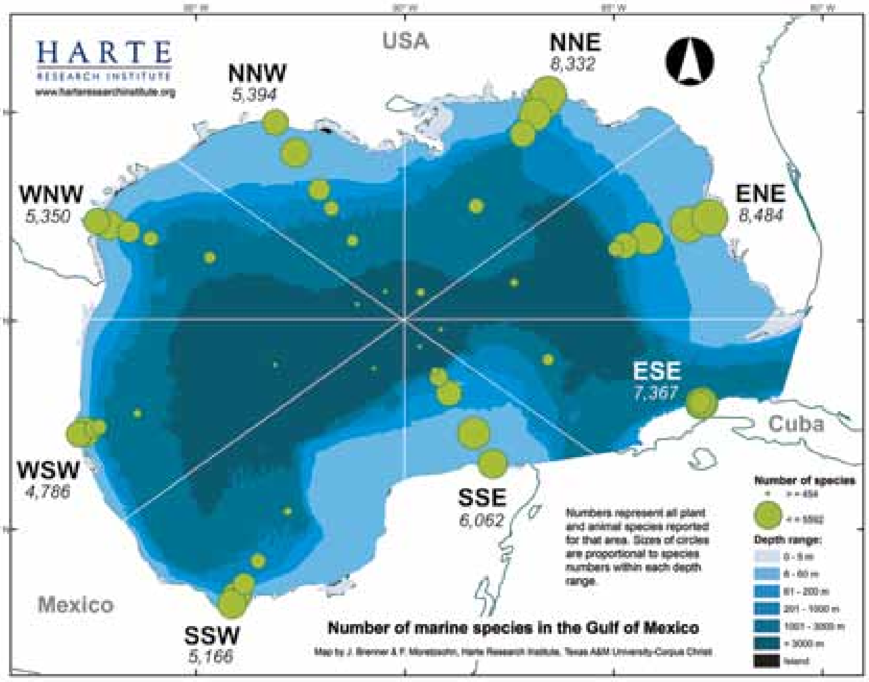


Figure 3.4. The Gulf of Mexico has a high diversity of marine species, with a gradient of increasing diversity from the open ocean to more productive, nearshore waters.

3.2. HABITATS

This section describes the main habitats of the northern Gulf by their physical characteristics and biological productivity, as well as several representative species from various trophic levels. These species are a small fraction of the thousands that live in the Gulf; they were chosen because of their importance to ecosystem functions or to people.

Figure 3.5. Areas of high relief on the Gulf seafloor, such as salt diapirs, or domes, are home to a diversity of marine life.

3.2.1. OFFSHELF

The central Gulf of Mexico has 6,000 square kilometers (2,317 mi^2) of deep water and is not well studied. There are some notable exceptions, including the extensive geological and geochemical data gathered during petroleum exploration, which reveal the unique chemosynthetic communities of deepwater petroleum seeps, methane hydrates and brine pools.

The continental slope and deep ocean basin in the Gulf of Mexico each accounts for about 20 percent of the area of the Gulf. The largest slope environments are located off northeastern Mexico, Texas and Louisiana, and are composed mainly of muddy sediments derived from continental erosion. Underlying salt deposits provide some topographic complexity, affecting oceanography from local to mesoscale (Fig. 3.5.), and are associated with the Flower Garden Banks off Texas and Louisiana and the Pinnacles off Mississippi and Alabama. Deepwater currents tend to be guided by bottom topography. The shelf is relatively narrow off the mouth of the Mississippi River, from which the sediment outflow continues downslope through the Mississippi Trough and Canyon, which bisects the continental slope close to its narrowest point.

Pelagic—The relatively narrow continental shelf off the Mississippi River brings open-water pelagic habitats relatively close to land. Cyclonic and anticyclonic eddy pairs migrating along the shelf break entrain the plume of the Mississippi River and transport it offshore, producing a nutrient-rich, open-water pelagic habitat and attracting nekton and top-level predators, such as sperm whales, relatively close to shore (Davis et al., 2002). Cyclonic eddies associated with slight elevations of the sea surface generally have higher levels of nutrients and chlorophyll associated with them and a shallower depth for the deep chlorophyll maximum. Cyclonic eddies also have higher biomass of zooplankton (Davis et al., 2002) than anticyclonic eddies. The former are areas of upwelling and are colder than the surrounding areas, while anticyclonic eddies are warmer than surrounding waters.

Like other oceans and seas, the offshelf habitat in the northern Gulf of Mexico has a highly diverse epipelagic zone from 0 to 200 meters (656 ft) below the surface; a mesopelagic zone from 200 to 1,000 meters (656-3,280 ft), including a layer of organisms that migrate vertically to the surface every night and return at dawn; and a bathypelagic zone greater than 1,000 meters (3,280 ft), where no sunlight penetrates. Ecosystem biomass drops off rapidly below 200 meters (656 ft), the lower boundary of the mixed layer. The mixed layer is the uppermost province of the pelagic zone. In the Gulf, the mesopelagic deep-scattering layer—named for the acoustic reflectivity of its organisms—is located between 450 and 550 meters (1,476-1,804 ft) during the day. These organisms avoid daytime surface predators and rise at night to feed on the abundant planktonic communities (Kaltenberg et al., 2007) near the sea surface. Prominent organisms in the deep-scattering layers include copepods, ctenophores, salps, tunicates, worms, shrimp, squid and myctophid (lantern) fish (Fig. 3.6.). These vertically migrating layers support a variety of predatory fishes, night-foraging seabirds and marine mammals. The deep-scattering layers are part of the mesopelagic fauna (200 meters down to a depth of 1,000 meters [656-3,280 ft]).

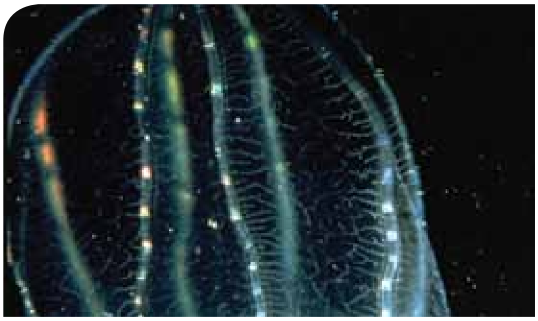


Figure 3.6. The deep waters of the Gulf and the seafloor are home to various animals, such as the comb jelly.

The fauna of the bathypelagic zone is not well-known or characterized. Large bathypelagic organisms collected in trawls and seen from submersibles include bristlemouth fish, decapod shrimp, squid, dragonfish and gulpers (Burghart et al., 2010). The bathypelagic micronekton include a high proportion of species that brood their eggs, while the shallower mesopelagic zone has many fewer brooders (Burghart et al., 2007).

The very deep sea contains a rich variety of single-celled organisms that include bacteria and archaea. Some of these single-celled organisms fix dissolved inorganic carbon, and others metabolize dissolved organic carbon. Dissolved organic matter is a huge reservoir of carbon, as much as 200 times greater than living biomass in the ocean. Dissolved organic matter exists in a reversible equilibrium with microscopic gels that provide a habitat for bathypelagic protists (single-celled organisms) (Verdugo & Santschi, 2010). In addition, dissolved inorganic carbon fixation rates (supported by chemoautotrophy) that rival those of heterotrophic microbes have recently been shown in the bathypelagic zone of the deep Atlantic (Reinthaller et al., 2010); these are likely to play the same role in the deep Gulf. Among the archaea are methane-oxidizing species that are abundant near sources of this gas, such as natural petroleum seeps. This genetically diverse community of prokaryotes is fed on by heterotrophic nanoflagellates and ciliates to form complex interactions at the base of the mesopelagic and bathypelagic food webs, the well-known microbial loop (Nagata et al., 2010).

Back at the surface of the open Gulf, two species of the brown seaweed sargassum form large floating rafts in the late spring and summer (Fig. 3.7.). These rafts of sargassum are an important surface habitat for a variety of creatures (Rooker et al., 2006), some of which are found only in this habitat. Common fishes found here include sargassumfish, sargassum pipefish, planehead filefish and sargassum triggerfish. Common invertebrates include crustaceans, nudibranchs, hydrozoans and bryozoans. Sargassum is also a good habitat for juvenile fishes and sea turtles. The floating rafts of sargassum are particularly common in the northwest Gulf (Gower & King, 2008) in spring and then move eastward and are injected into the Atlantic Ocean starting in July. In some summers, total sargassum biomass may be as much as 6 million tons in the Gulf. In the open waters of the Gulf, sargassum may contribute as much as 60 percent of the primary production in the upper meter of water (Carpenter & Cox, 1974; Pérès, 1982). Sargassum is also often washed ashore in the Gulf, adding nutrients to coastal habitats and providing feeding opportunities for shorebirds and other wildlife as it decays.

Among the more prominent megafauna of the offshore pelagic zone are swordfish, white and blue marlin, wahoo, blue runner, yellowfin and bluefin tuna, seabirds, whale sharks and a variety of cetaceans.

Atlantic bluefin tuna, an iconic top predator, is one of the largest and fastest fishes in the world; and it once supported an extremely lucrative fishery (Safina, 1997). Bluefin tuna have a remarkable set of adaptations allowing them to live a demanding, highly mobile life in the open ocean (Fig. 3.8.). A high rate of metabolism, endothermy and unique molecular adaptations underlie a remarkable physiology for sustained, high-speed swimming. Recent tagging studies have shown mixing of the eastern and western stocks in the central North Atlantic Ocean. The open pelagic portion of the Gulf of Mexico contains one of the two known spawning grounds for this species (Rooker et al., 2007). Based on tagging and genetic data, it has been suggested that the Gulf stock is different from the stock that spawns in the Mediterranean Sea; but there is no consensus on this view.

Based on larval distribution, the greatest spawning activity of bluefin tuna occurs in association with the shelf break in the northern Gulf. The frontal systems on the shelf have the greatest concentrations of larvae. Bluefin tuna in the Gulf reach sexual maturity at 8 years, and the average age of females in the spawning grounds is 11 years. Peak spawning occurs from mid-to-late May (Brothers et al., 1983). Tuna are batch spawners—i.e., each female spawns more than once per season—and large tunas can spawn 30-60 million eggs annually (Baglin, 1982). The eggs hatch in just a few days in the warm water of the Gulf, and peak abundances are found in April, May and June.

Figure 3.8. Atlantic bluefin tuna, migrating thousands of miles and diving to depths of 1006 meters (3,300 ft), spawn in the northern Gulf of Mexico between January and June.

Figure 3.9. Bottlenose dolphins inhabit harbors, bays and offshore waters of the Gulf of Mexico. They feed on a variety of prey and hunt for food using a highly developed sense of hearing, or echolocation.

Figure 3.7. Sargassum is a type of seaweed that serves as floating habitat for many species, including the sargassumfish (*Histrio histrio*) and triggerfish in the open ocean. Large mats of sargassum form where tides meet in what are called convergence zones. Trash and surface oil also collect here, impacting sargassum and its marine inhabitants.

Bluefin tuna forage mainly in the upper mixed layers of the ocean, feeding on cephalopods, fishes and crustaceans. Bluefin tuna appear to feed at a trophic level higher than other tunas. While mainly pelagic foragers, as much as 20 percent of the bluefin tuna diet in shallow areas is comprised of benthic organisms.

Among the prominent seabirds in the offshelf and slope areas of the Gulf are jaegers, Audubon's shearwaters, band-rumped storm petrels and sooty terns (Davis et al., 2000). There is much seasonal variability due to migration patterns of some of these species. Many seabirds are associated with areas of higher phytoplankton and zooplankton biomass within cyclonic eddies and in shear zones between eddies.

The masked booby is an open-ocean seabird in the gannet family found in the Gulf of Mexico. It is the largest of the boobies, with a wingspan up to 150 centimeters (59 in) and weighing up to 1.5 kilograms (3.3 lb). It breeds on tropical islands in the southern Gulf and the Caribbean (Tunnel & Chapman, 1988); otherwise, it spends its entire life at sea. Masked boobies feed on pelagic fishes and squid, particularly on flying fish. They plunge-dive from heights up to 30 meters (98 ft) to catch their prey. Aggregations of masked boobies are often found near schools of dolphin or tuna, which are both top-level predators also attracted to schools of pelagic fishes.

Twenty-eight species of whales and dolphins reportedly occur in the Gulf (Davis et al., 2002). Several species of dolphins are sighted commonly from aerial and shipboard surveys. These include: bottlenose (Fig. 3.9.), spinner, Atlantic spotted, pantropical spotted, Risso's, striped and Clymene, as well as melon-headed and short-finned pilot whales. Many whales and dolphins concentrate over the continental slope where there are convergences between eddies and, presumably, where their planktonic and micronekton foods are concentrated. The offshelf transport of nutrient-rich water by shelf-edge eddies is a key process in supplying a productive trophic base and determining a high quality cetacean habitat. Other dolphins and whales tend to be found along the shelf break, not preferentially associated with cyclonic eddies and confluences.

A resident population of sperm whales in the Gulf congregates within 100 kilometers (62 mi) of the Mississippi River mouth (Davis et al., 2002), mainly associated with elevated chlorophyll concentrations (O'Hern & Biggs, 2009). Sperm whales feed mainly on mesopelagic and bathypelagic squid. The average diving depth of sperm whales in the Gulf is 644 meters (2,113 ft), and acoustic recordings during the dives are consistent with the use of long-range biosonar to locate patches of prey (Watwood et al., 2006). Recent genetic evidence suggests that females in the Gulf population breed exclusively there, and males move between Gulf populations and those in the Mediterranean Sea, Western North Atlantic and North Sea (Englehaupt et al., 2009).

Continental Slope and Abyss Benthos—Cold-seep chemosynthetic communities associated with oil and gas seepage and brine seepage stand out as areas of unusual biological activity on the otherwise mostly homogeneous deep-sea muddy bottoms of the continental slope (Fig. 3.10.). Brine seeps occur over salt-core diapirs (intrusions of ancient brine into the surface layers of the ocean sediment) and are scattered over the shelf break and continental slope of the northern Gulf. Cold-seep communities are mainly decoupled in their energy supply from overlying photosynthetic communities near the ocean surface and depend on high-energy, chemically-reduced sources (H_2S and methane) for their metabolic energy and carbon (Childress et al., 1986; Fisher et al., 1987).

The dominant organisms in these slope communities are either mussels or vestimentiferan worms. At one site, chemosynthetic-dependent mussels live at the edge of these hypersaline, methane-rich pools at a depth of 650 meters (2,133 ft) on the continental slope (MacDonald et al., 1990). Cold seeps and brine seeps support epibenthic fauna and mussels and vestimentiferan worms that provide structure and habitat for associations of diverse benthic animals in an environment generally lacking much in the way of habitat diversity (Berquist et al., 2003). Similar communities involving chemosynthetic bacterial mats in petroleum seeps are apparently common on the upper continental shelf of the Gulf (Sassen et al., 1993). An estimated 400,000 barrels of oil seep naturally into the Gulf of Mexico every year (National Research Council, 2003).

Hard-bottom habitat is also scattered along the continental slope and consists of authigenic carbonate deposits. These deposits are formed in situ by the combined metabolic activity of sulfate-reducing and methane-oxidizing bacteria in areas of natural gas seepage during or after sediment deposition.

These elevated, carbonate-based substrates allow large sessile (fixed) animals to settle and grow, including ahermatypic (non reef-building) hard corals, gorgonians, sponges, hydroids and anemones. These hard-bottom communities appear to be the end point of a succession of animals that colonize petroleum seepages. The hard corals, gorgonians and anemones do not depend for nutrition on the chemosynthetic processes in the seeps that supported the original colonizers, such as tube worms and mussels (Continental Shelf Associates International, Inc., 2007), but instead feed on the rain of organic matter from the surface.

Away from seepage areas, the majority of the continental slope consists of soft sediments and has a diverse benthic and pelagobenthic fauna.

Animals living here obtain food from the rain of organic matter from the waters above, or from utilizing the organic material coming downslope from the continental shelf and, in particular, from the Mississippi River. The numbers and biomass of bacteria, meiofauna and the infauna sampled by grabs and cores, as well as the macrofauna sampled by dredge, all decrease with depth as the rain of material from the photic (light) zone is metabolized and sinks into the deep sea. Benthic community oxygen consumption decreases from values of 30 millimoles $O_2 m^{-2} day^{-1}$ at the top of the slope near the shelf break to one millimole $O_2 m^{-2} day^{-1}$ at 3,000 meters (9,843 ft) depth (Rowe & Kennicut, 2002). An unusual feature of the northern Gulf continental slope communities is that the meiofauna (0.063-0.5 mm) has a higher biomass than the macrofauna (>0.5 mm). An extensive trawl survey of the macrofauna on the continental slope east and west of the Mississippi Canyon found 126 species of deepwater fishes and 432 species of invertebrates in 46 bottom trawls between depths of 200 and 3,000 meters (656 and 9,843 ft). Shrimp, crabs, sea pens and sea cucumbers were some of the prominent invertebrates comprising the trawl catches and appearing in deep-sea photographs. Skates, rays, batfish, rattail fish, hakes, cod-like fish and gapers were some of the more common fishes encountered (Galloway et al., 2001).

Large predators are apparently quite abundant on the continental slope and perhaps throughout the abyssal region (Carney, 1994; P. Montagna, personal communication, 2010). Benthic feeding fishes appear to be very active in the Gulf, and some highly mobile species, such as rattails and eels, derive most of their nutrition from chemosynthetic communities. Others use production from such brine and methane seeps, as well as from photosynthesis in surface waters (MacAvoy et al., 2002).

The continental slope environment of the northern Gulf is perhaps more heavily polluted than comparable areas in other parts of the United States, likely due to the disposal of wastes from the thousands of wells drilled in the northern Gulf

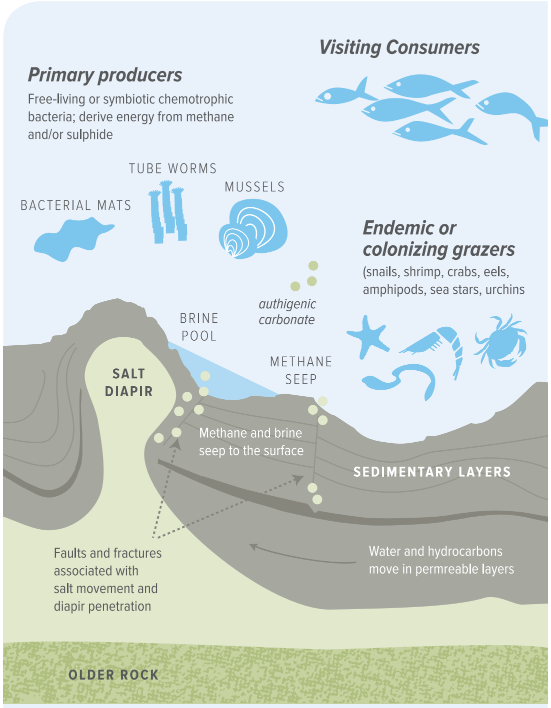


Figure 3.10. A diagram of a cold-seep community on the continental slope associated with petroleum seepage from a salt diapir, or salt dome, showing fauna that utilize seepage and accompanying geochemical fluids.

and the deposition of contaminated sediments from the Mississippi River. A wide-ranging survey was recently conducted in the northern Gulf from west Florida to mid-Texas, and enrichment of polynuclear aromatic hydrocarbons (PAHs) in concentrations up to about one part per million were found at several sites. The elements Ba, Ni, Pb, Cd, As, Cu and Mn were variously enriched from 2- to 10-fold over background levels (Wade et al., 2008).

3.2.2. CONTINENTAL SHELF

The broad shelf through most of the northern Gulf of Mexico is rich in marine life, which is supported by plentiful nutrients, warm temperatures and high primary productivity from plankton and submerged aquatic vegetation. In addition, an influx of plant material from land (washed into the Gulf by rivers, runoff and tides) supplements the large number of detritus feeders.

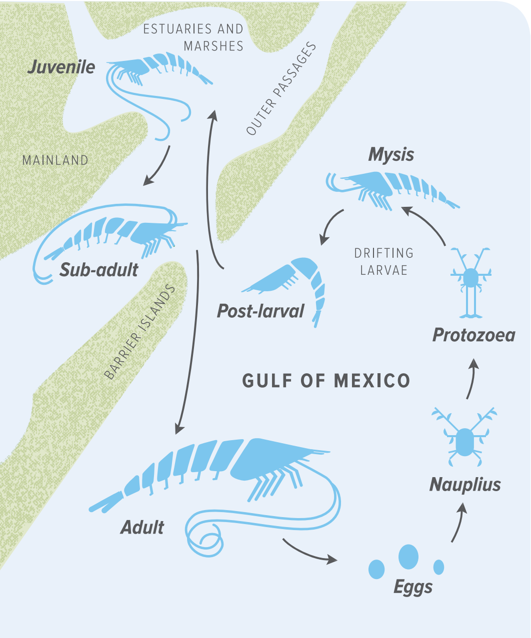


Figure 3.11. A diagram of the life cycle of brown shrimp in the northern Gulf of Mexico, showing the location of the life stages.

Pelagic—Most of the biological production in the central northern Gulf pelagic zone occurs on the shelf. The peak spring flows of the Mississippi River carrying the necessary influx of nutrients are followed by water stratification and an annual phytoplankton bloom as the days lengthen in April and May. The spring phytoplankton bloom is followed by a zooplankton bloom, mainly in June. Copepods are a particularly important component of the zooplankton for passing energy and biomass to higher trophic levels. Other common zooplankton include protozoans, chaetognaths, polychaete worms and euphausiid crustaceans. These species spend their whole lives as plankton; but some, mostly larval forms of larger animals, such as fishes, corals, gastropods, polychaetes, echinoderms and crabs, are only temporarily in the planktonic stage.

Demersal fishes and shrimp are mainly tied to estuaries for at least part of their life cycles in the northwestern Gulf, with relatively low diversity over muddy bottoms and seasonal migrations often evident. In the eastern Gulf, however, rock and reef-related species are more important, diversity is greater and there are more species unique to this portion of the Gulf (Darnell, 1990).

As in other temperate and subtropical marine environments, the sexually mature adults of many commercially important species move out of estuaries and spawn on the shelf. The life cycles of such species as brown shrimp and blue crab illustrate the link between offshore spawning areas and inshore estuarine rearing habitats (Fig. 3.11.). After the adults have spawned, the newly hatched post-larval shrimp move to the bottom of the shelf and ride the northward-flowing bottom currents, generated from the passage of cold fronts in the spring, into the mouths of the estuaries (Rogers et al., 1993). Opportunistic post-larval blue crabs ride from the shelf environment to the mouths of estuaries on similar currents, depending on favorable winds, summertime flood tides with minimal amplitude and occasionally nocturnal tidal regimes (Morgan et al., 1996). Larvae of pink shrimp that spawn in the Dry Tortugas have behavioral adaptations to find cross-shelf tidal currents that transport them 100 kilometers (62 mi) into the mouths of Florida estuaries (Criales et al., 2007).

Common forage fishes in shelf habitats include menhaden, anchovies, sardines and mackerel. Menhaden are among the most abundant forage fishes in the Gulf and support the second largest fishery in the United States—about 639,000 metric tons (1,408,753,855 lb) per year. Menhaden are caught mainly in a reduction fishery; the fish are processed into fish oil and meal used in animal feed. Menhaden are filter-feeding planktivores as adults

Figure 3.12. Kemp's ridley, a federally endangered sea turtle, nests almost exclusively on beaches in southern Texas and northern Mexico. While primary foraging grounds are in the northern Gulf, these turtles are known to migrate up the United States Atlantic seaboard.

and live just 3 to 4 years. Adults spawn offshore in winter, and young menhaden arrive later in the year in coastal estuaries where they mature. In addition to being an important part of the commercial fisheries in the Gulf, they form an important trophic step from plankton to higher-level predators, such as large fishes, seabirds and marine mammals.

Red snapper, a valued species in recreational and commercial fisheries across the northern Gulf shelf, occupies the next trophic level above the forage fishes; they feed on small fishes, crustaceans and other benthic invertebrates. This species is found in greatest abundance at depths of 15 to 90 meters (49-295 ft) but also occurs in shallower inshore waters, most often in cooler months. Red snapper become sexually mature before they reach 30 centimeters (12 in) in length, and adult females are batch spawners, spawning frequently between late May and early October.

Sea turtles are a prominent part of the Gulf shelf vertebrate fauna. There are five species in the Gulf of Mexico: green, leatherback, Kemp's ridley (Fig. 3.12.), loggerhead and hawksbill. The most commonly encountered species are loggerheads, followed by leatherbacks and Kemp's ridleys. All five are federally listed as threatened or endangered species, and Kemp's ridleys are the most endangered of the group.

Kemp's ridleys are the smallest of the five species of sea turtles occurring in the Gulf, with adults weighing an average of 45 kilograms (99 lb). About 7,000 Kemp's ridleys are in the Gulf. This species feeds mainly on the continental shelf across the northern Gulf. They are omnivorous, feeding mostly on crabs but also on other crustaceans, jellyfish, sea urchins and algae (National Park Service, n.d.). Adults mate offshore and females come ashore as many as three times in spring and summer to lay eggs. For the females, these nesting events may only occur every 1 to 3 years (i.e., not necessarily annually). The only known nesting beaches for Kemp's ridleys are in the Gulf of Mexico, mainly Playa de Rancho Nuevo, Tamaulipas, Mexico, but also on beaches in south Texas. They are caught inadvertently in commercial trawl fisheries for shrimp and occasionally at public fishing piers by recreational anglers (Rudloe & Rudloe, 2005). As with other sea turtles in the Gulf, Kemp's ridleys are cold sensitive and can be stunned by unusually cold winter temperatures and killed during prolonged winter cold in shallow waters (Foley et al., 2007). Prior to the BP oil disaster, sea turtles appeared to be recovering in large part due to the use of turtle excluder devices in shrimp trawls and nesting beach protection.

Figure 3.13. First discovered by fishermen in the late 1800s, the Flower Garden Banks are elevated seafloor features home to a breathtaking array of marine life. Today, much of the area is within a national marine sanctuary.

Figure 3.14. Sea grasses, flowering plants that grow and reproduce in the nearshore marine environment, are important nursery areas for finfish and shellfish.

The Gulf of Mexico shelf seabird fauna comprises a mixture of temperate and tropical species, with many more northerly forms wintering in the Gulf. Most of the seabirds in the Gulf feed on forage fishes, but some take other prey. Black skimmers, for example, also feed on small shrimp. The northern gannet is a large, prominent, fish-eating sea bird in the Gulf shelf environment. Northern gannets, like the related pelicans, are plunge-diving seabirds. This species nests on the North Atlantic Coast (e.g., Maritime Provinces in Canada), and the young birds migrate south, initially swimming and then flying during their first winter migration. Many young gannets spend their first three years at sea, including in the Gulf, foraging on small shoaling fish. Adults are very efficient flyers, often gliding up to 30 meters (98 ft) above the ocean while searching for fishes, or at other times just above the tops of waves, taking advantage of the updrafts of air from the surface of the ocean (USFWS, 2010).

Benthos—Continental shelf benthic communities reflect substrates and available oxygen, with much of the shelf west of the Mississippi River under the influence of seasonal hypoxia from organic nutrient enrichment. However, there are also sandy shoals that are elevated off the otherwise muddy bottoms, and they contain a diverse array of infauna. The predominant infaunal groups of the continental shelves are polychaete worms and amphipod crustaceans (Dubois et al., 2009).

On the edge of the continental shelf directly south of the Texas-Louisiana border is a unique feature, the Flower Garden Banks (Fig. 3.13.). These banks have been well studied because they occur in an area of active oil and gas production. The banks consist of coral reef structures that have grown up on salt diapirs, relatively common features in the Gulf, but nowhere as diverse and untouched as the Flower Gardens. The banks have living corals from a depth of about 15 to 45 meters (49-148 ft), comprising mainly the genera *Monastrea*, *Diploria* and *Porites*.

Figure 3.15. Salt marshes are transitional areas between land and water, occurring along the intertidal shore of estuaries in the Gulf. The productivity of salt marshes is very high and is critical to the marine food web.

The carbonate sediments of the banks are also due to numerous calcareous algae that thrive in the warm, clear water over the Flower Garden Banks. There is greater than 50 percent cover of corals here, the highest in the Western Hemisphere. They provide habitat for 175 species of tropical reef fishes and numerous species of invertebrates, including sea fans and whips, sponges, anemones and crinoids. At the base of these diaper-supported structures, high-density, gas-saturated brine seeps into pools in the ocean bottom.

3.2.3. BAYS, ESTUARIES AND BEACHES

There are numerous bays, lagoons and estuaries in the Gulf—40 are listed in the Gulfbase website for the Texas, Louisiana, Mississippi, Alabama and Florida coasts (Moretzsohn et al., 2011). The habitats within these areas are defined by salinity, tide and, especially, predominant vegetation types.

The Gulf of Mexico has a very small tidal range (a maximum of about 0.45 meters [1.5 ft]), but because of the often very gradual increase in landward elevations, large areas of some habitats (e.g., marshes), are exposed during low tide. Many of the bays and lagoons in Florida and Texas, and to a lesser extent Mississippi, have beds of sea grass, whereas the bays and estuaries of Louisiana, Mississippi and Alabama have more extensive marshes. The Big Bend area of Florida has very extensive sea grass beds.

There are about 1 million hectares (2.5 million ac) of sea grass beds in the Gulf. Sea grass beds—also categorized as submerged aquatic vegetation (SAV)—can be composed of seven sea grass species as well as other species of vascular plants rooted in the sediments (Fig. 3.14.). Three of the most common varieties of sea grasses are turtle grass, shoalgrass and manatee grass. Sea grass beds are important for stabilizing the bottom, as habitat for a variety of invertebrates and fishes and for dampening the effects of wave action and storm surge. Blades shed from sea grasses break down into detritus, an important source of organic matter in shallow water ecosystems. Sea grasses provide shelter from predatory fishes and contain a diversity of invertebrates and fishes. Sea grass meadows are also a valuable wintertime feeding habitat for ducks. For example, 78 percent of the North American population of redhead ducks over-winters in the vast sea grass meadows of the Laguna Madre of Texas and Tamaulipas.

Salt marshes are very extensive in the north central Gulf, defining much of the shoreline features and habitat (Fig. 3.15.). At the water's edge, the predominant emergent aquatic vegetation is smooth cordgrass, which thrives in salinities of about 16 parts per thousand (ppt). As cordgrass and other vegetation die back or are shed, they break down into detritus, which is an important source of food for invertebrates and some small fishes. Macrophytes and filamentous algae also appear to be major sources of primary production for macrofauna living in marshes (Winemiller et al., 2007). Shrimp and blue crab are associated with marsh and wetland vegetation and are found in highest abundances close to the edge of marsh vegetation. Juvenile brown shrimp, white shrimp and blue crab were found in highest abundances within one meter of the vegetative edge of marshes in the northwest Gulf (Minello & Rozas, 2002), showing the importance of marsh vegetation not only for sediment stabilization, but also as a structured habitat for commercially important estuarine invertebrates. This study estimated that degradation of marshes resulting in greater than 70 percent open water is likely to lead to decreases in these crustaceans.

Figure 3.16. The Gulf of Mexico supports the only remaining significant wild oyster harvest in the world. Oyster reefs are natural breakwaters that buffer the coast from storms and provide essential habitat for many marine species, including those sought by anglers.

The Gulf of Mexico is a national treasure; and with a clear and compelling vision, adequate funding and political will, the Gulf Coast and waters can be fully restored.

Figure 3.17. Brown pelicans live in warm coastal marine and estuarine environments and inhabit protected islands, waterfronts and marinas. The species was removed from the United States endangered species list in 2009, but the states of Louisiana and Mississippi list the brown pelican as endangered and in Texas it is listed as threatened.

In slightly less saline and inland areas of estuaries are brackish marshes—the habitat for marsh hay cordgrass and widgeon grass. Approximately 20 species of SAV were identified in a survey of the northern Gulf; *Rupia maritima* or widgeon grass, a brackish water plant, was the most commonly encountered species (Merino et al., 2009). Here, open water is less extensive, with ponds and channels predominating. Brackish marsh is a very important habitat for young stages of crab, shrimp and fishes. The brackish marshes grade further inland into intermediate marsh areas. The intermediate marsh has even more restricted open water of lower salinity, in the range of 3 ppt. Here, reeds and rushes are important components of the vegetation and serve as an important habitat for young stages of estuarine and marine organisms.

In contrast to the trophic structure of estuaries elsewhere in the United States (e.g., San Francisco Bay and Chesapeake Bay), the benthic communities of northern Gulf of Mexico estuaries and bays are dominated by detritivores, such as certain clams and polychaetes, which may account for as much as 90 percent of the biomass of these communities (Gaston et al., 1997). Suspension feeders appear to be a relatively minor component of the benthic fauna in contrast to other estuaries.

Oyster reefs are another major biological structure important in Gulf estuaries (Fig. 3.16.). They provide a habitat for a variety of animals and play an important structural role in stabilizing estuaries in the face of storm-caused erosion. These reefs are very sensitive to changes in salinity and long-term changes in freshwater supply. Saltwater incursions have had marked effects on the location of oyster reefs in estuaries (Berquist et al., 2006).

As with invertebrates, there is a great deal of overlap in forage fishes found in bays and estuaries as well as on the shelf. Menhaden, mullet and anchovies are abundant in bays among the many smaller species of fishes that live there. Spot and Gulf killifish are also important permanent inhabitants of shallow water marshes and estuaries in the Gulf.

Red drum are in the next trophic level up from the forage fishes and are a prominent sport fish across the northern Gulf, feeding on small fishes, crustaceans and mollusks. They are a long-lived species, up to 37 years, and can weigh up to 27 kilograms (60 lb) in the Gulf (TPWD, 2010). They spawn inshore in the fall and winter. At first, the young fish live in very shallow water but can spend more time offshore as they mature. Adult red drum, however, are often found in very shallow water and even in fresh water many miles from the ocean.

The brown pelican is ubiquitous in the shallow bays and estuaries of the northern Gulf (Fig. 3.17.). It is one of the largest birds on the Gulf Coast, weighing up to 5 kilograms (11 lb) and having a wingspan of up to 2.5 meters (8 ft). Brown pelicans are plunge divers, feeding almost exclusively on fishes in the marine environment. They nest in colonies on coastal islands and raise their young in clutches of about 3 chicks, which they tend for up to 9 months.

The West Indian manatee is a seasonal inhabitant of shallow coastal environments in the northern Gulf of Mexico (Pabody et al., 2009) and is commonly also seen in freshwater rivers. Listed as an endangered species, it is most commonly found in Florida, being limited to warm-water habitats due to the lack of body insulation. Manatees are herbivores, and they feed on large quantities of a variety of aquatic vegetation, such as sea grass. They may live as long as 60 years and may be up to 4 meters (13 ft) in length. They mature sexually by about 4 years and generally have one calf at a time. An adult female can expect to have a calf every 2 to 5 years.

Humans have greatly altered the coastal estuaries and bays of the Gulf of Mexico. In a comparative study of two estuaries in the shallow northeast Gulf—one relatively unaltered and one that had been subjected to greater human influence—Livingston (1984) reported differences in species composition between the two. The altered estuary had greatly reduced sea grass beds; and the fish fauna had shifted to species that were primarily plankton feeders, whereas there had been a greater diversity of feeding types previously. A 16-year study of Perdido Bay estuary on the Alabama-Florida border indicated that anthropogenic nutrient loading has resulted in plankton blooms and loss of benthic infaunal invertebrates in the system. Long-term climatological cycles also may have played a role in these changes (Livingston, 2007).

In contrast to the muddy sediments that predominate in coastal Louisiana, Mississippi and to some extent, Mobile Bay in Alabama, the shorelines of Alabama, Texas and Florida have mainly sandy beaches. These sandy beaches, many of them on barrier islands facing the open Gulf, have distinct groups of animals, including clams, amphipods, mole crabs, polychaetes and small fishes (Kindinger, 1981; Rocha, 1995). Diversity of fauna in these sediments seems to increase with decreasing grain size.

3.3. PAST OR PRESENT SOURCES OF ENVIRONMENTAL STRESS

The BP oil disaster, which occurred more than 40 miles (64 km) off the coast of Louisiana and discharged oil from nearly a mile beneath the surface, is only the latest and most dramatic example of human activities that have profoundly affected this large marine ecosystem. Even before the BP blowout, decades of environmental degradation had taken a toll on Gulf coastal and marine habitats and species. Today, the Gulf is stressed by human activities in or along the Gulf itself and even hundreds of miles inland. The range of environmental stressors and resulting symptoms (Fig. 3.18.) underscores the scope of the restoration challenge and the degree of commitment and funding needed from decision-makers to reverse the trajectory of an ecosystem in peril.

3.4. ENVISIONING A HEALTHY GULF

The expanding human population of the last several hundred years has taken an increasingly heavy toll on the Gulf ecosystem. Extraction of natural resources and modification of the ecosystem continue in the absence of solid evidence of what the limits might be. In other words, when will a threshold be crossed such that the ecosystem fundamentally shifts into a degraded condition that can no longer meet human needs or those of the indigenous fauna and flora?

Recognizing that one cannot turn back the clock to the conditions that prevailed prior to human settlement, what constitutes a sustainable and healthy ecosystem in the Gulf of Mexico? Gulf residents, and others with knowledge of and a stake in this national treasure, will want to resolve this question by defining a shared vision for a healthy and productive Gulf (Fig. 3.19.). This vision is necessary to guide restoration priorities, serve as a reference point for evaluating progress toward a future desired state (e.g., restoration goals) and adapt restoration strategies to achieve better performance in the years ahead. Citizens should have an opportunity to bring this vision into focus as restoration programs take shape and are implemented.

For purposes of this Framework, a healthy Gulf is one that has substantially recovered from decades of environmental degradation and shows fewer signs of stress from the human activities described in Figure 3.18. A healthy Gulf is resilient, biologically diverse, productive and capable of providing goods (e.g., seafood) and services (e.g., fishing) on a sustainable basis. It is a region where disappearing coastal habitats are stable or increasing, depleted fish populations are rebuilt and fisheries restored, former low-oxygen “dead zones” support marine life and productive fisheries and little known or presently undiscovered seafloor communities are fully documented and managed for conservation. In essence, this picture of the Gulf means that restoration strategies, such as those discussed in Chapter 6, are working; and key indicators of Gulf ecosystem health, like those species and habitats profiled in Appendix II, are trending upward.

Gulf residents, stakeholders and resource managers will need to know whether and how quickly restoration efforts are moving the region toward an ecologically healthier Gulf. Decision-makers must be able to evaluate the performance of restoration measures, understand whether these measures are improving ecosystem health and, based on this information, adjust restoration approaches as needed. Quantitative restoration metrics will also need to be developed so that any changes in environmental quality resulting from restoration activities are documented. Such metrics were developed for the Chesapeake Bay and Everglades restoration initiatives to ensure accountability and maximize restoration success.

It is essential that clear performance indicators are developed as part of any and all restoration activities in the Gulf of Mexico. The Harte Research Institute is developing a "report card" to track the status and health of the Gulf ecosystem, and The Nature Conservancy has worked with the Harte Research Institute, Ocean Conservancy and other organizations to begin to develop a series of restoration "metrics." Both of these exercises should be helpful for the Trustee Council and Task Force as they develop and implement restoration plans for the Gulf.

Just as important as identifying performance indicators is a commitment to monitor and rigorously evaluate performance and make adjustments (i.e., adaptive management) in restoration activities. Monitoring and evaluating performance requires that there be a program in place and resources provided for scientists to "take the pulse of the Gulf"—to monitor its vital signs, identify and study emerging patterns or problems and track recovery of habitats and species.

At some point in the future—perhaps one or two decades from now—an appropriate nonpartisan body, such as the General Accountability Office or the National Research Council, may be asked to evaluate ecosystem restoration in the Gulf of Mexico. What was attempted and what was accomplished in the restoration programs? Were the billions of dollars spent in a way that brought tangible, positive and lasting results? What will be the legacy of ecosystem restoration in the Gulf? Gulf residents, and indeed the nation, must act now to define a bold vision for restoration, taking into account their values and aspirations, as well as the needs of the ecosystem, and then work to turn that vision into a reality.

FIGURE 3.18.

Present sources and symptoms of environmental stress in the Gulf of Mexico

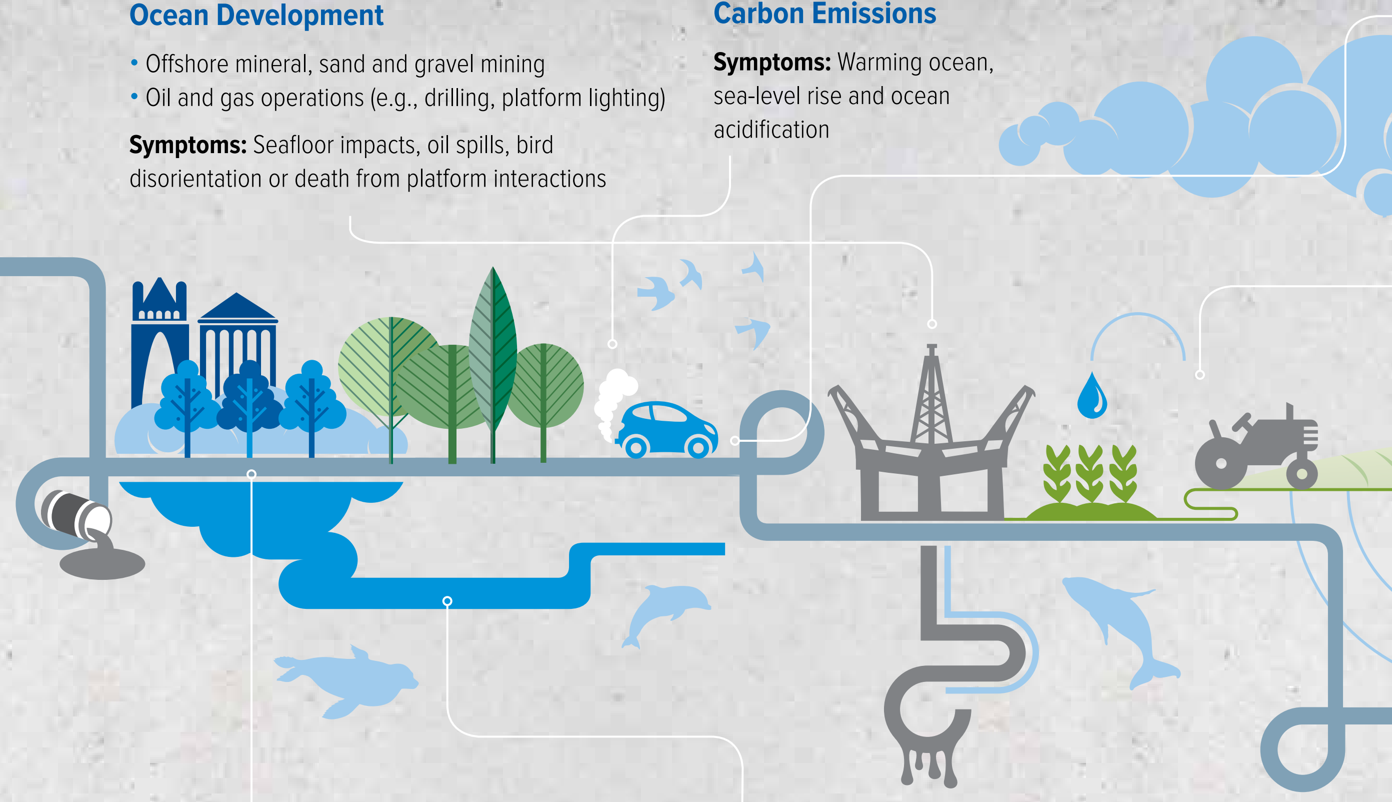
Ocean Development

- Offshore mineral, sand and gravel mining
- Oil and gas operations (e.g., drilling, platform lighting)

Symptoms: Seafloor impacts, oil spills, bird disorientation or death from platform interactions

Carbon Emissions

Symptoms: Warming ocean, sea-level rise and ocean acidification



Coastal Development

- Residential and urban construction
- Petrochemical extraction & processing
- Channel modification (e.g., dredging)
- Shoreline hardening (e.g., seawalls)
- Beach nourishment

Symptoms: Habitat loss, seafloor impacts, water quality impacts, sinking land, air quality impacts, bird/sea turtle nesting habitat impacts, fisheries impacts, seafood safety concerns

Altered Freshwater Flows

- Water control structures (e.g., impoundments, dams, dikes, levees)
- Canal construction
- Water withdrawals
- Too little, too much sediment

Symptoms: Habitat loss, changes in estuarine tidal forces and salinity balance, shifts in fisheries distribution

FIGURE 3.18.

Nonpoint Source Pollution

- Agricultural nutrient runoff
- Urban runoff pollution such as animal waste, hydrocarbons (e.g., grease, oil), sediment and metals

Symptoms: Nutrient enrichment, harmful algal blooms, low dissolved oxygen “dead zones”, loss of marine habitat, beach and shellfish bed closures

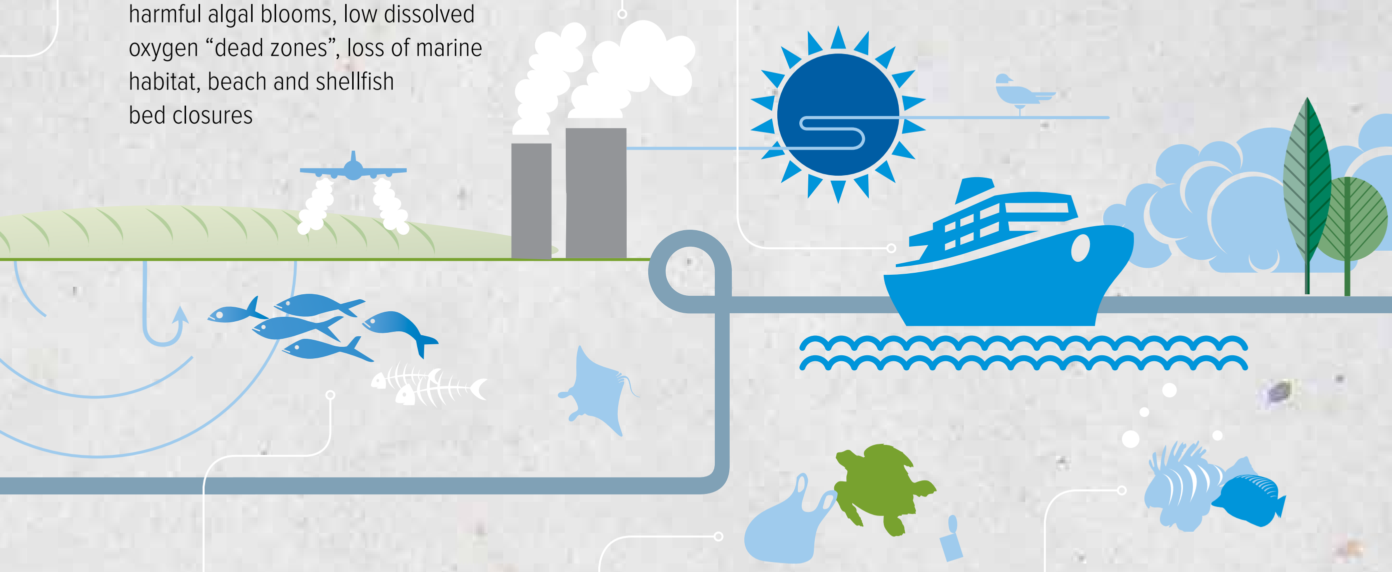
Boating

Symptoms: Habitat damage (e.g., propeller injury, wildlife interactions), water quality impacts

Point Source Pollution

- Industrial (e.g., water intakes, discharges)
- Municipal (e.g., sewage)

Symptoms: Water quality impacts, seafood safety concerns



Fishing

Symptoms: Population depletion (overfishing), gear interactions with bottom habitat and wildlife (e.g., bycatch), seafloor impacts

Marine Debris

Symptoms: Wildlife injury or death

Exotic, Invasive Species

- Aquarium releases (e.g., lion fish)
- Ballast releases

Symptoms: Displacement of native species, disrupted ecological relationships

Source: Adapted largely from the Gulf of Mexico Fishery Management Council, Final Environmental Impact Statement for the Generic Essential Fish Habitat Amendment of the Gulf of Mexico (2004).

BP Deepwater Horizon Oil Disaster Impacts

The breach in BP's subsea Macondo well released more than 776 million liters (about 205 million gal) of oil and 500,000 tons of gaseous hydrocarbons over a three-month period before the well was permanently sealed (Fig. 4.1.).

4.1. BACKGROUND

In addition, BP or government response agencies used an unprecedented amount of chemical dispersants totaling 6.8 million liters (1.8 million gal), of which 58 percent was applied to surface oil slicks. (Corexit 9500 was the primary formulation used to break up BP oil.)

The known distribution of surface and subsurface oil overlapped with the peak spawning of important marine species, including bluefin tuna and red snapper. Floating mats of sargassum algae found in offshore convergence zones and known to attract many fish, bird and other wildlife species would have been exposed to surface oil accumulating in the same areas. For birds and sea turtles, the disaster occurred during migration, nesting or over-wintering seasons, depending on the species; and some marine mammals, such as bottlenose dolphins, would have been pregnant or accompanied by young during the time when oil was in and on the water. Hence, shorebirds, wading birds, seabirds, marine mammals and sea turtles are among the animals killed by the oil in open water or in oiled coastal habitats. A total of 1,695 kilometers (1,053 mi) of the northern Gulf Coast was oiled, including a swath of coastal marsh 732 kilometers (455 mi) long and from 5 to 20 meters (16-65 ft) wide. Coastal wetlands, barrier islands, beaches and mud bottoms were exposed to oil, as were marine habitats, such as sea grass, sand and mud bottoms, and deepwater corals. The oil disaster also affected human activities dependent on natural resources (ecosystem services), including commercial and recreational fishing, other forms of recreation and subsistence uses (Fig. 4.2.).

The effects of the oil and related response activities on public natural resources and their related human uses remain the focus of intense study through the NRDA and other independent or non-NRDA research initiatives. The large geographical area and offshore, deepwater origin of the oil discharge, combined with the wide array of habitats and species exposed to oil and the unprecedented use of chemical dispersants (both at depth and on the surface), will complicate efforts to document and attribute natural resource injuries to the oil or response efforts. For example, while the use of dispersants may have prevented oil slicks from reaching and contaminating sensitive and fertile coastal habitats, dispersants used at depth could have disproportionately exposed aquatic life inhabiting deeper waters to acute toxic effects. The chronic impacts of chemical dispersants used in these quantities are also largely unknown. For these reasons, long-term monitoring of key species and ecosystem functions is critical to detect lingering or subtle injuries and guide the selection of appropriate restoration measures.

4.1.1. INJURY TO BIOLOGICAL RESOURCES

In general, natural resource injuries from exposure to oil or due to associated response efforts fall into three basic categories:

Mortality. Immediate or delayed death following exposure to oil or response activities, or reductions in critical food sources resulting from the spill or other causes;

Sublethal Effects. Injuries affecting the health and physical condition of organisms (including eggs and larvae) that do not result in the direct or immediate death of juvenile or adult organisms. However, injuries that initially appear sublethal ultimately may be fatal. Some sublethal effects, such as compromised growth, reproduction or immune system function, may result in impacts at a population level; and

Habitat Degradation. Alteration or contamination of the physical or chemical components of the habitat, which diminish the capacity of the habitat to support fauna and flora, or which continue to expose wildlife to oil or other contaminants.

NRDA regulations define injury as “an observable or measurable adverse change in a natural resource or impairment of a natural resource service.” The most serious injuries result in measurable population declines, and the effects may persist for more than one generation. For example, direct mortality from the oil may significantly reduce the number of breeding-age members of a species’ population, and it may take years to recover from that loss of breeders and reduced productivity. Sublethal injuries may impair reproductive ability or reduce survival in a large portion of a population exposed to oil.

4.1.2. GOVERNMENT REPORTS OF ACUTE MORTALITY TO WILDLIFE

The most visible impacts of an event like the BP oil disaster are often oiled wildlife. Table 4.1. presents a summary of birds, sea turtles and marine mammals recovered, dead or alive, on shorelines and in the water in the spill area. Wildlife collected in the field are initially evaluated for obvious signs of external oiling or injury, and then may be subject to additional analysis or necropsy to help determine the exact cause of death or injury. While the numbers presented in Table 4.1. do not necessarily reflect a determination of cause of death, they

Figure 4.1. An oil slick stretching for hundreds of miles could be seen from space in the weeks following the oil discharge.

Figure 4.2. Charter for-hire and subsistence fishermen who depend on the Gulf for a living could not access fishing grounds during the BP oil disaster due to mandatory fishing closures.

Estimating Seabird Deaths Attributed to the *Exxon Valdez* Oil Spill (Alaska)

Scientists estimated that between 100,000 and 645,000 seabirds comprising 91 species were killed from exposure to oil released by the tanker *Exxon Valdez* that ran aground in Prince William Sound, Alaska, on March 24, 1989. The best estimate of the total actual number of seabird mortalities was 250,000 (Piatt & Anderson, 1996). About 30,000 carcasses were recovered in the months following the oil spill; but due to sinking, scavenging, winds and currents, the retrieved carcasses represented only a fraction of the actual death toll. As part of the damage assessment process, scientists used a combination of carcass drift-recovery experiments, models and a mortality multiplier to estimate the number of seabirds actually killed by *Exxon Valdez* oil.

provide some basis for gauging the disaster's impacts on these animal groups. Moreover, the actual number of wildlife mortalities associated with the BP oil disaster will be higher, possibly much higher, than the number of documented wildlife mortalities because recovered carcasses typically represent a small portion of the total number of animals that died from oil-related injuries. Scientists will derive estimates of the total number of animal deaths based on an extrapolation of documented deaths.

More than 7,250 birds representing about 100 species have been recovered, dead or alive, from the BP oil impact area. The highest bird mortalities documented so far are among marine and coastal birds, such as various gull and tern species, northern gannets, brown pelicans and black skimmers. Oiled shoreline and marsh habitats also put rails, herons and other wading birds and shorebirds at risk. Of the 613 sea turtles recovered dead to date, Kemp's ridleys account for 481 (79 percent) of the total. The majority of marine mammal strandings reported are for bottlenose dolphins. Other cetaceans recovered dead are spinner dolphins, an unidentified pygmy or dwarf sperm whale, a melon-headed whale, a sperm whale and one unidentified cetacean. Relatively few of the recovered sea turtle and cetacean carcasses showed visible signs of oiling, though this does not necessarily mean that there was not exposure to oil (e.g., external oil may no longer have been visible on the recovered carcass or oil may have been ingested or inhaled).

Appendix II describes a series of coastal and marine fishes, wildlife, invertebrate species and habitats that were or may have been affected by BP oil. Taken as a group, the status of these coastal and marine species and habitats can serve as indicators of injury and recovery from BP oil as well as the overall health of the Gulf ecosystem.
As more information about impacts to these species and habitats becomes available, the accounts will be updated and posted at *http://www.oceanconservancy.org/keystonespecies*.

Table 4.1. Status of Wildlife Recovered from the BP Deepwater Horizon Oil Impact Area

WILDLIFE CATEGORY	VISIBLY OILED		NOT VISIBLY OILED		UNKNOWN OILING		TOTAL
	ALIVE	DEAD	ALIVE	DEAD	ALIVE	DEAD	
BIRDS*	1,062 (541)*	2,121	0	3,387	958 (602)*	873	7,258
SEA TURTLES	456	18	80	517	–	78	1,149
MARINE MAMMALS**	2	10	11	130	–	17	170
	1,520 (541)*	2,149	91	4,034	958 (602)*	968	8,577

Sources: Deepwater Horizon Bird Impact Data from the DOI ERDC NRDA Database (May 12, 2011), Deepwater Horizon Response Consolidated Fish and Wildlife Collection Report (April 17, 2011).
* – The number in parentheses is the number of birds that were collected alive and then died. This number is subtracted from the total to avoid double-counting birds.
** – All but one animal recovered are cetaceans (dolphins and whales).

Appendix II has descriptions of a series of coastal and marine fishes, wildlife, invertebrate species and habitats that were or may have been affected by BP oil. Taken as a group, the status of these coastal and marine species and habitats can serve as indicators of injury and recovery from BP oil as well as the overall health of the Gulf ecosystem. As more information about impacts to these species and habitats becomes available, the accounts will be updated and posted at http://www.oceanconservancy.org/keystonespecies.

Table 4.2. Summary of Studies on Fate and Impacts of BP Oil and Response

category	number of studies	category	number of studies
OIL AND GAS FATE	76	BENTHIC	9
FISH*	36	DEEP SEA	9
COASTAL WETLAND	32	DISPERSANT FATE	5
PLANKTON	23	HYPOXIA	5
INVERTEBRATES	21	SEA TURTLES	5
MARINE MAMMALS	17	SEA GRASSES	5
MICROBIOLOGY	14	STORM IMPACTS	5
BIRDS	13	FOOD WEBS	5
CORALS	12	OCEANOGRAPHY	4
WATER COLUMN	12	OFFSHORE SEAWEED	3
PLANTS	10	SHARKS	3
BEACHES	9	TERRAPIN	1

TOTAL: **333 STUDIES**

* This category does not include sharks.
Sources: NOAA Coastal Data Development Center (2011, June). *Deepwater Horizon Research and Monitoring*, National Science Foundation. (2011, February), NOAA Gulf Spill Restoration (2011, June) and news media reports.

4.1.3. INJURY TO HABITATS

Coastal and marine habitats were also harmed by oil or the activities implemented to contain or remove it during disaster response efforts. The following habitats are either those that the trustees had identified as impacted (based on pre-assessment studies) or are now the focus of assessments to determine the extent and significance of injury: salt marshes (Fig. 4.3.), submerged aquatic vegetation (sea grasses), sandy beaches, mangroves, waters of the Gulf of Mexico and adjoining states, deepwater communities, nearshore benthos/sediments, oyster reefs and corals. Sea grasses and oyster reefs are examples of marine habitats affected by disaster response vessels or activities. Response boats scarred sea grass beds during boom placement and retrieval, and oyster beds were apparently killed by low salinity levels resulting from the large pulses of outflowing fresh water released into estuaries to repel incoming oil.

4.1.4. STUDIES ON OIL IMPACTS

More than 300 studies of various kinds and by many institutions have been conducted or are underway in the Gulf to understand whether, to what extent and how natural resources were injured by BP oil or related response activities (Table 4.2.). Of these 300 studies, 57 are NRDA studies for which study plans have been posted at *http://www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data/*. Additional NRDA studies are underway but not disclosed to the public because they may be used to build a legal case against BP and other responsible parties for damages to publicly-owned natural resources or lost uses of those resources.

The National Science Foundation (NSF) awarded more than 150 rapid response grants to researchers to study the environmental impacts of oil released from BP's damaged wellhead, and brief summaries of NSF-funded projects are available at *http://www.nsf.gov/awardsearch/*. Other researchers have been funded by or through various universities and Sea Grant programs.

Results from studies on the biological or ecological impacts of the BP oil disaster may not be published or otherwise made available to the public for some time. However, scientists are reporting anomalous events or abnormalities in their species or habitats of interest that could be a consequence of direct or indirect exposure to oil, chemical dispersants or some combination. For example, researchers at Tulane University and the University of Southern Mississippi (USM) collected thousands of blue crab larvae with an unusual orange substance trapped underneath their carapaces (Perry, 2011; Taylor, 2011). Preliminary analysis of the samples at USM identified petroleum and the dispersant Corexit in the droplets, and research is continuing to determine the origins of the droplets.

Figure 4.3. Salt marshes and beaches were among the types of coastal habitats oiled during the BP oil disaster. In Louisiana, oil coated hundreds of miles of salt marshes. Around the northern Gulf, beaches and beach uses were closed to the public while cleanup operations were under way.

The Dauphin Island Sea Lab has documented lower than average phytoplankton biomass off the coast of Alabama in a year that was predicted to have high summertime biomass, signaling a potential shift in the nearshore carbon budget and food web (Graham, 2011). Louisiana State University has examined red snapper with lesions and enlarged and discolored livers—signs that are consistent with a weakened immune system caused by exposure to a toxin (Blair, 2011; J. Cowan, personal communication, 2011). Researchers at the University of West Florida in Pensacola also have reported finding fishes with fin rot and lesions (Staats, 2011). Researchers from the University of South Florida have collected deformed foraminifera, microscopic organisms at the base of the Gulf food web (Staats, 2011). Researchers from a NOAA 2010 expedition reported damaged or dead coral approximately 11 kilometers (7 mi) from the Macondo wellhead and are conducting research to determine the source of these impacts (Rudolf, 2010; NOAA, 2010).

Beyond abnormalities that possibly can be attributed to oil exposure, it will be necessary to understand whether any of these problems results in sublethal, chronic or delayed effects for species at the population level. Detecting changes in fish and crab populations may be delayed at least until the larval class of 2010 reaches maturity. In some species, such as blue crabs, the impacts may be seen in 3 to 5 years. But in long-lived species, such as bluefin tuna or sea turtles, it could take a decade or more before effects (or lack thereof) are documented.

Studying Impacts on an Iconic Species: Red Snapper *Lutjanus campechanus* (Gulf-Wide)

Red snapper are distributed throughout the Gulf and are dependent on the Gulf ecosystem for their entire life history. Red snapper are bottom-dwelling fish, so it is highly likely that they came in contact with oil along the Gulf seafloor. Furthermore, red snapper larvae and eggs are present at the water's surface and throughout the water column where they may have been directly exposed to oil and dispersants (NOAA Fisheries Service, 2010). Exposure to oil can cause death or sublethal effects in eggs and larvae, which may affect the long-term reproductive success of the red snapper stock (Rice et al., 2007; Incardona et al., 2005). Red snapper with severe fin rot, lesions, discolored livers and other abnormalities have been found throughout the Gulf during the 2011 red snapper fishing season (Pittman, 2011). Independent research is underway to study the causes, distribution, frequency and background occurrence of these fish infections. Some researchers believe the symptoms are secondary infections due to compromised immune systems. Continued research and long-term monitoring are needed to understand fully the impact of the BP oil disaster on red snapper.

Compensating the Public for Lost Access: The Case of the *M/V Westchester* (Louisiana)

Past Gulf oil spills provide insight into how to make the angling public whole following the loss of recreational fishing opportunities caused by the BP oil disaster. In November 2000, the *M/V Westchester* ran aground, discharging 2.1 million liters (550,000 gal) of crude oil into the lower Mississippi River, temporarily restricting fishing and hunting access to the Delta National Wildlife Refuge and the Pass-a-Loutre State Wildlife Management Area. To measure the cost in dollars for the loss of hunting and angling access and present a claim to the responsible party, the trustees quantified normal levels of recreational activities and the economic value of those activities to hunters and anglers. The trustees relied on the Louisiana Marine Recreational Fishing Statistics Survey to estimate the number of anglers that normally visited the area and interviewed refuge and management area resource managers to estimate the average number of hunting trips. They estimated that the reductions in angler and hunter days as a result of the oil spill were 655 and 805, respectively. The trustees then reviewed the literature to determine that the amount consumers were willing to pay for their recreational trips ranged from $38.41 to $62.30 per hunting trip, and $40.17 to $109.88 per angling trip. The total combined economic losses for hunting and recreational uses ranged from $57,193 to $122,060. Based on these figures, funds were collected from the responsible party as compensation for losses in recreational services and were used to build boat docks and other recreational amenities near the impact area.

4.2. LOST OR REDUCED NATURAL RESOURCE SERVICES (HUMAN USES)

The physical and biological functions of natural resources provide a wide array of services to people. Barrier islands and marshes buffer coastal communities from storms. Fish populations support commercial, recreational and subsistence fisheries. Natural areas and marine wildlife provide ecosystem services that support a thriving tourism industry by drawing visitors far and wide. Another kind of service is "passive use," such as the pleasure a person derives from knowing that whales and other wildlife are present and living in the ocean.

The BP oil disaster affected services, such as recreational use of beaches and marine waters, tourism and fisheries, when government agencies restricted public access during oil cleanup operations or closed waters to fishing due to seafood safety concerns. However, it remains to be seen whether the physical or biological functions of any natural resources have been compromised by the BP oil disaster in ways that actually reduce their services or uses to people. In general, ecosystem services may be defined as reduced or lost if any of the following applies:

- Reduced physical or biological functions performed by the natural resources that support services;
- Reduced aesthetic and intrinsic values or other indirect uses provided by natural resources;
- Reduced access to natural resources resulting from government restrictions intended to protect public health and safety; or
- Reduced desire of people to use a natural resource or area.

The disaster immediately affected the public's use of natural resources when governments imposed rules restricting the public's access to natural resources or when perceived injury to or contamination of natural resources, such as beaches or seafood, eroded public confidence in the integrity of those resources. At a minimum, the disaster affected the following human uses of natural resources because of reduced access: commercial fishing, for-hire recreational fishing, private recreational fishing, subsistence or cultural traditions, shoreline recreation and tourism.

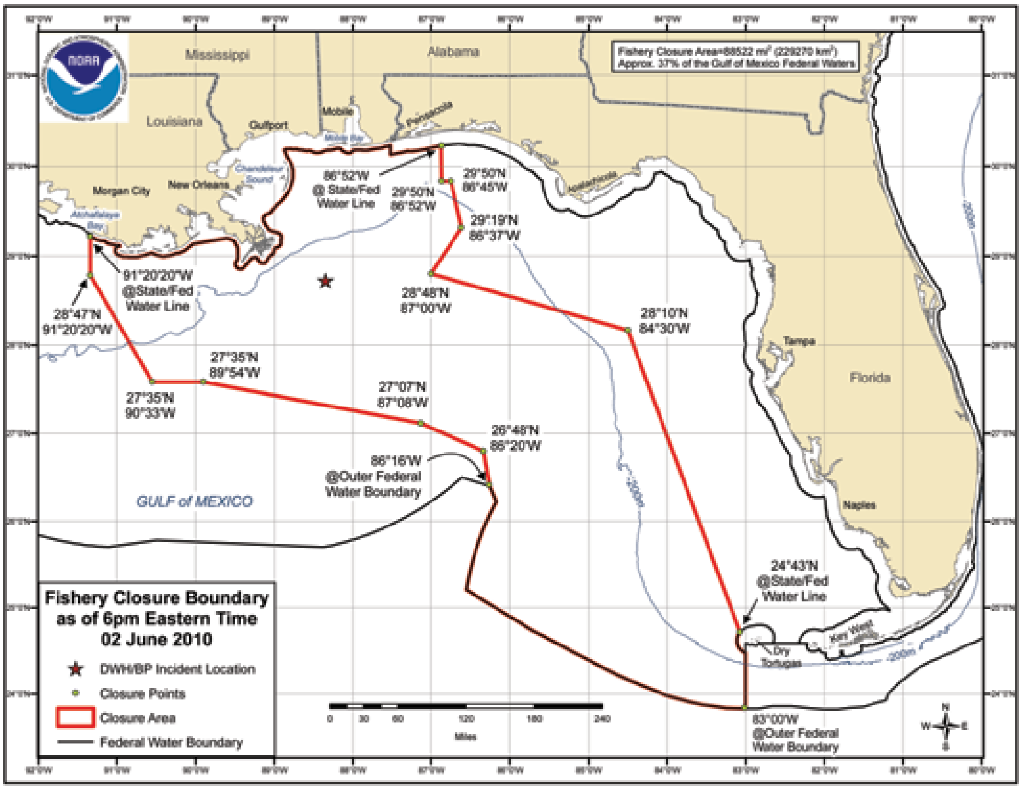


Figure 4.4. More than one-third of federal waters in the Gulf were closed to recreational and commercial fishing during the BP oil disaster.

4.2.1. LOST OR REDUCED SERVICES FOLLOWING THE BP OIL DISASTER

An example of the public's reduced use of fishery and ocean resources was the federal fishery closure that covered 229,214 square kilometers (88,500 mi^2) (37 percent) of federal waters in the northern and eastern Gulf during the summer of 2010. The closure had a measurable impact on the angling public's ability to access offshore waters (Fig. 4.4.). For example, during May-August 2010, the number of anglers that took for-hire fishing trips in Alabama, West Florida, Louisiana and Mississippi decreased 80, 33, 60 and 98 percent, respectively, compared to the 10-year average in each of those states. Members of the public who do not own boats gain access to offshore waters via for-hire charter boats. Similarly, the number of trips anglers took in their own or rented boats declined between 13 and 23 percent over the 10-year average in those states, with the exception of western Florida, where displaced anglers redirected their fishing effort (unpublished data from the Marine Recreational Fishery Statistics Survey Program provided by the Gulf States Marine Fisheries Commission to Ocean Conservancy, 2011). State fishing grounds in Alabama, Louisiana, Mississippi and West Florida also were closed for different durations, affecting commercial, recreational and subsistence fishermen.

Economic and polling data suggest that the public's negative opinion of Gulf natural resources, such as beaches and seafood, increased following the BP disaster, hurting the tourism and seafood industries. During the summer of 2010, state agencies issued swimming or health advisories and closed beaches (e.g., Pensacola, FL, and Grand Isle, LA). Hotel cancellations increased from Louisiana to Florida, and demand for Gulf seafood declined dramatically as a result of the BP oil disaster. The Gulf seafood brand had still not recovered a year later (Greater New Orleans, Inc., 2011). Subsistence use of natural resources was also affected. For example, anecdotal information indicates that members of at least one Native American tribe, the Houma Nation, reduced their catch of seafood, opting instead for store-bought products.

4.2.2. VALUING LOST OR REDUCED SERVICES

The NRDA will determine the dollar value of lost services resulting from injury to publicly-owned natural resources caused by the BP oil disaster and the amount necessary to compensate the public for those economic losses. (The loss of personal or real property, profits or earning capacity are not natural resource damages and are therefore not addressed under NRDA.) Trustees use various methods to estimate the public's lost use or access to natural resources. One of these is provided by economic valuation methodology, whereby people's willingness to pay for certain ecosystem services is estimated using surveys or data on payments that they make for gaining access to a resource. For an example, see the sidebar on the *M/V Westchester* oil spill on p. 56. Economic valuation methods can also be used to calculate the cost of restoring damaged resources with a technique that estimates the amount of "replacement" habitat needed to restore lost ecosystem services. This technique is also used to calculate the additional habitat needed to compensate people for the loss in ecosystem services they experience while the habitat is restored to pre-damage levels.

4.2.3. PASSIVE USES

Many of the services that ecosystems provide are related to their active use. For example, people use natural resources as sources of food, shelter and recreation. Another important source of ecosystem benefits, however, is related to their "passive" or "nonuse" value. People feel satisfaction from knowing that ecosystems they care about exist and thrive, even if they do not actively benefit from ecosystem services. One way this value is expressed is through the payments that many people make to help protect natural resources they may never have the opportunity to observe directly, such as marine mammals. After the *Exxon Valdez* oil spill, a study revealed that the "passive" or "nonuse" value of the natural resources that were harmed by the spill was $2.8 billion.

Restoration Approaches and Themes

This chapter assumes that restoration efforts will likely proceed on at least two tracks—one track would follow NRDA regulations adopted under OPA.

As described below, an NRDA-based restoration program must be linked to natural resources injured as a result of the BP Deepwater Horizon oil disaster. The second track, recommended in Secretary Mabus's September 2010 report to President Obama, is likely to address more broadly environmental degradation and recovery of the Gulf of Mexico ecosystem. This track would need to be supported with non-NRDA funds, such as CWA fines or appropriated funding, and would be guided by some kind of standing, region-wide council, perhaps along the lines of the present Gulf Coast Ecosystem Restoration Task Force.

These two tracks are related and to some degree overlapping—and should be closely coordinated—but nonetheless are distinct and will operate with different legal constraints. There also may be different or additional processes that cannot be anticipated now, especially if restoration funds are directly allocated among individual Gulf states without a link to or role for a regional restoration council.

5.1. NRDA-BASED RESTORATION

Two elements are key to defining what NRDA-based restoration activities will look like (see 15 Code of Federal Regulations [C.F.R.] 990.30). First, there must be a link to injury:

> **Restoration** means any action (or alternative), or combination of actions (or alternatives), to restore, rehabilitate, replace or acquire the equivalent of injured natural resources and services.

And, second, the goal of NRDA-based restoration is to restore that which was injured to its "baseline" condition:

> **Baseline** means the condition of the natural resources and services that would have existed had the incident not occurred. Baseline data may be estimated using historical data, reference data, control data or data on incremental changes (e.g., number of dead animals), alone or in combination, as appropriate.

Redfish Bay Sea Grass Protection (Texas)

The Texas Parks and Wildlife Department (TPWD) established new management measures in 2006 to protect ecologically important sea grass beds from motorboat propeller (prop) scarring in the Redfish Bay State Scientific Area (RBSSA) in southeast Texas. The RBSSA is a part of both the Aransas and Corpus Christi bay ecosystems and has about 12,500 hectares (32,000 ac) of prime fishing habitat, including 5,666 hectares(14,000 ac) of submerged sea grass beds. It hosts the northernmost extent of the sea grass species, turtle grass, in Texas. Prior to implementing the program, TPWD biologists did an extensive survey of the area and found significant prop scarring. Other human-caused disturbances include dredge and fill and nutrient loading.

Input from anglers, fishing guides, conservation organizations and others was gathered to identify the best ways to protect shallow-water sea grasses and develop the new measures. Resource managers wanted to maximize boater access while also protecting habitat. No-prop zones were originally proposed but rejected in favor of the area-wide prohibition on the uprooting of sea grasses with an outboard motor. The management measures do not close any portion of Redfish Bay to any type of watercraft.

Initially, special preferred access lanes (PALs) were created where inflicting damage would not be punishable. Even though TPWD staff have observed that boater use of PALs is lower than planned, prop damage to sea grass beds outside PALs has decreased 45 percent since the prohibition on scarring went into effect. Due in large part to area boaters changing their practices and demonstrating stewardship toward the resource, propscarring is less of a problem and sea grass beds are recovering in Redfish Bay.

5.1.1. PRIMARY AND COMPENSATORY RESTORATION

Under NRDA regulations, there are two types of restoration activities: primary and compensatory. Primary restoration is intended to speed the recovery of injured natural resources, while compensatory restoration is intended to pay back the public for services that were lost during the period of recovery (i.e., the time from the date of injury until the natural resource has returned to baseline). In general, primary restoration focuses directly on an injured natural resource and is often "on-site" (i.e., at the place where the injury occurred).

An example of on-site primary restoration would be to replant sea grasses if exposure to oil or perhaps response activities (e.g., boat propellers) had killed or damaged a sea grass bed. This action would be undertaken if the trustees found that it would take an unacceptably long time for that sea grass bed to recover on its own. Primary restoration does not have to occur on-site, however. For example, if endangered Kemp's ridley turtles were killed due to exposure to oil, it may be productive to increase the level of protection on the beaches where this species lays eggs (thus enhancing survival of young turtles), even if those beaches are not near the locations where the actual turtle mortality occurred.

One of the realities of restoration in the offshore marine environment is that it may not be possible to identify primary restoration activities that are feasible for many, if not most, individual injured resources. For injured marine habitats and species with offshore, sometimes pelagic, distributions or for marine ecosystem services like fisheries, opportunities for physical restoration in a literal sense are limited. In some cases—for example, wild-caught species—it may be possible and necessary to adjust management practices in order to facilitate recovery. In the case of the *North Cape* oil disaster off Rhode Island, for instance, the trustees decided to restore injured lobster populations by reducing the catch of designated female lobsters—an approach that increased local egg production and recruitment. The responsible party worked with the trustees and paid local fishermen to clip the tails of 1.24 million female lobsters up to 97 kilometers (60 mi) offshore (Fig. 5.1.). The practice of clipping protected lobsters alerted fishermen to release animals with notched tails, giving released lobsters another opportunity to spawn. After molting, the lobsters would lose the notch in their tails and could once again be legally retained by fishermen (DeAngelis et al., 2010).

While primary restoration focuses on speeding the recovery of injured resources, compensatory restoration focuses on paying back the public for the value of the services to people that were lost or reduced. For example, if recreational access to a public beach decreased because of the presence of oil or response activities, then NRDA regulations provide for compensation of the public during the time it takes for such uses to return to pre-spill levels. One way of doing this is to acquire "equivalent resources." In this case, for example, one approach is to acquire and provide access to additional beaches where the public may recreate.

Ultimately, the NRDA trustees will assemble a combination of technically feasible primary or compensatory activities that will comprise the restoration plan. The goal of these projects—as a package—is to make the environment and public whole. The projects in the restoration plan must be proportionate in scale and cost to the natural resource injury and the value of lost or reduced services. In other words, there cannot be a wide disparity between the quantified injuries and value of lost services compared to the scale and cost of what is proposed as restoration.

Figure 5.1. Clipping female lobster tails meant these animals could not be legally caught until they had reproduced and molted, allowing the population to recover from mortalities associated with the *North Cape* oil disaster (Rhode Island).

Fishing Gear Conversion Program a Win-Win (Gulf-Wide)

Opportunities exist to transform the Gulf of Mexico shrimp fishery for a more sustainable and profitable future. Together, members of the shrimp industry, Texas Sea Grant, Ocean Conservancy and Sustainable Fisheries Partnership have launched the Gulf of Mexico Shrimp Fishery Improvement Roundtable to implement innovative and practical measures to improve the fishery. Shrimp fishing gear innovations are available that greatly reduce bycatch, improve shrimp quality, reduce fuel consumption and are likely to have less impact on the ocean floor. Already, technological improvements have been developed that reduce bycatch well beyond minimum government standards and reduce fuel consumption by up to 39 percent. This improvement in fuel consumption will significantly reduce the carbon footprint of the fishery and provide much needed relief to fishermen struggling with the volatile cost of fuel.

5.2. ECOSYSTEM RESTORATION

In general, ecosystem restoration is directed at systemic problems—such as insufficient sediment to maintain coastal wetlands and barrier islands or excessive nutrients polluting the water and causing large seasonal dead zones—that compromise major ecosystem functions. See Figure 3.18. for a more complete list of environmental stressors on the Gulf of Mexico ecosystem. In his report to the President, Secretary Mabus noted:

> The need to recover from the direct impacts of the oil disaster should serve as the impetus to jump-start a broader effort to restore and protect the Gulf Coast's ecosystems.

Accordingly, Secretary Mabus recommended that Congress dedicate a significant portion of CWA penalties to restoration and recovery in the Gulf region. Several months later, the National Oil Spill Commission issued a similar recommendation in its report and called on Congress to direct 80 percent of CWA fines toward implementation of a region-wide Gulf restoration strategy. Both Secretary Mabus and the Commission also called on Congress to establish a standing restoration council to take the place of the existing Gulf Coast Ecosystem Restoration Task Force, which was established by executive order.

The structure, operations and formal scope of a restoration council as recommended by Secretary Mabus and the Commission have not been defined. However, if Congress acts to redirect CWA penalties to Gulf restoration and establishes a restoration council along the lines of the existing Task Force, the council will not be subject to the more restrictive NRDA regulations for project selection. Hence, this body would most likely be in the best position to plan more broadly and support restoration of the Gulf ecosystem from decades of environmental degradation.

Several bills have been introduced in Congress to address funding and organizational issues related to Gulf restoration. Perhaps most significantly, on July 21, 2011, Senators Landrieu and Shelby and a bipartisan coalition of seven other Gulf senators, introduced the RESTORE Act of 2011, which would direct 80 percent of the CWA fines into a Gulf Coast Restoration Trust Fund. The RESTORE Act (S. 1400) has successfully moved through

Committee in the Senate and a largely similar bill, HR 3096, has been introduced in the U.S. House of Representatives. Status updates on Gulf restoration legislation pending in Congress are available at *www.oceanconservancy.org*.

5.3. THE ROLE OF SCIENCE IN RESTORATION

Science should be an integral part of every phase of restoration in the Gulf of Mexico, whether in the context of the NRDA program led by the Trustee Council or a broader ecosystem restoration effort led by the Task Force or some other entity. Indeed, the executive order establishing the Task Force (The White House, 2010) makes clear that it must address science in restoration by identifying "monitoring, research and scientific assessments needed to support decision-making for ecosystem restoration efforts and evaluate existing monitoring programs and gaps in current data collection."

The National Commission also recognized that "planning and program design for any comprehensive Gulf restoration effort will have to be based on sound science." Chapter 7 of the Commission's report included the following description of what is required (Graham et al., 2011):

> A successful, Gulf-wide scientific process would likewise be structured to allow meaningful and timely input by scientists into the decision-making process. Ideally, it would provide a science program with the resources to evaluate individual projects for consistency with a comprehensive plan; to research long-term restoration issues; and to develop and apply performance measures and indicators of long-term restoration that allow decision-makers to adjust the plan based on new science or changed circumstances. Particularly with respect to long-term research issues, the diverse resources and expertise of the federal government should be brought to bear (p. 212).

A key element in a science-based restoration program is independent peer review by experts who do not have conflicts of interest. The *Exxon Valdez* Oil Spill Trustee Council established a scientific peer review panel and process under the guidance of a chief scientist who was not affiliated with any of the government agencies represented on the Trustee Council or associated with the entities seeking restoration funds from the Trustee Council. His role was to manage the peer review process and provide independent advice to the executive director of the Trustee Council

and to the Trustee Council itself. The *Exxon Valdez* Trustee Council called on the chief scientist and the peer review panel to review objectively all project proposals for technical merit and for consistency with the overall restoration plan and goals. The same peer reviewers also examined project reports and provided opinions on whether project and restoration goals were on track. Although there may be differences in the nature and scale of the work undertaken in Alaska following the *Exxon Valdez* oil spill and what can be anticipated in the Gulf of Mexico, the principle of integrating independent scientific review into making decisions about and evaluating restoration activities should still apply.

As noted in the recommendation from the Commission, there is need "to develop and apply performance measures and indicators of long-term restoration that allow decision-makers to adjust the plan based on new science or changed circumstances." (See Section 3.4., Envisioning a Healthy Gulf). Toward that objective, Section 6.3. recommends the establishment of a permanent, endowed Gulf of Mexico Ecosystem Research and Monitoring (GEM) Program for Adaptive Management (Fig. 5.2.). This program would be a key mechanism to ensure that there would be a steady flow of carefully targeted monitoring and research data with which to plan, evaluate and adjust restoration activities in the Gulf.

5.4. RESTORATION THEMES

Making the best use of funds provided through the NRDA, CWA fines or other sources for ecosystem restoration in the Gulf will depend on planning and careful setting of priorities for what could be a very significant—but nonetheless limited—amount of funding. The challenge and opportunity are to leverage and allocate these funds to achieve maximum benefit for the ecosystem as a whole, while satisfying any legal requirements, such as returning injured natural resources to their pre-spill condition in the case of NRDA funds. In the end, restoration must not only result in benefits to individual species, habitats or services but must collectively contribute to a healthier, more resilient Gulf ecosystem.

The Gulf's natural bounty, economy and quality of life are inseparable; so restoring the Gulf is as much an environmental necessity as an economic and cultural one. Full restoration of the Gulf means that the coastal and marine resources critical to the economic productivity, social fabric and resiliency of coastal communities are abundant, in good ecological condition and well managed. Successful restoration of the Gulf ecosystem will make both the environment and the people whole again. The following overarching themes should be used as the basis for planning, funding and implementing restoration: coastal environments, marine resources and coastal communities.

5.4.1. COASTAL ENVIRONMENTS

The Gulf's coastal resources, ranging from fertile wetlands and productive estuaries to iconic species like the brown pelican, provide numerous ecosystem services and benefits. The wetlands and barrier islands help buffer the coast from violent storms, protecting people and property. Oyster reefs and sea grasses are natural breakwaters and fish refuges, combating erosion and supporting fisheries from Texas to Florida. An estimated 95 percent of the Gulf's commercial fishes and many popular recreational species spend a portion of their lives in estuaries. Great numbers of migratory birds and waterfowl attract birdwatchers and hunters to the Gulf Coast. The beaches of the Gulf draw visitors from near and far.

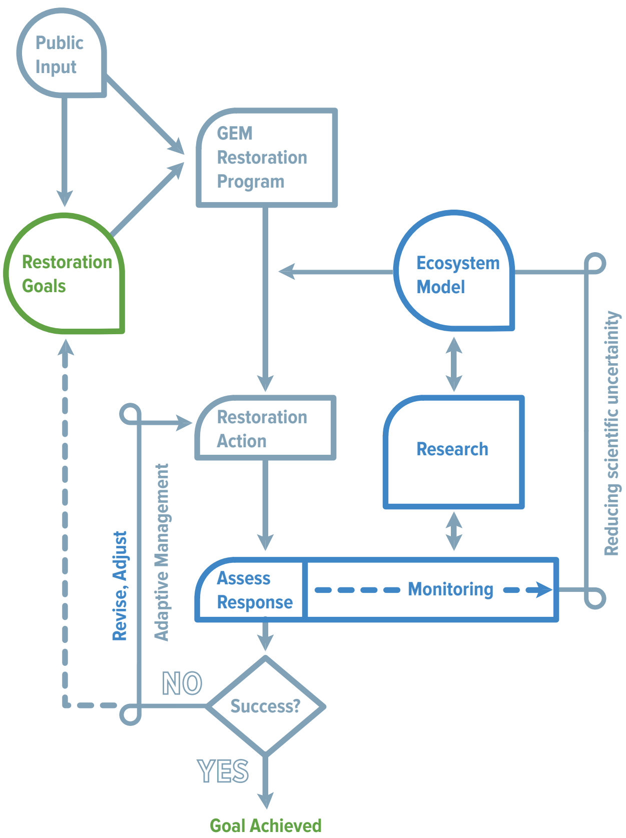
Decades of heavy usage, now exacerbated by the effects of the BP oil disaster, have taken their toll on these natural treasures. The loss of wetlands may have been accelerated by the oil's effects, particularly on the Mississippi River Delta, while the recovery of precarious sea turtle or bird populations exposed to oil could be in jeopardy or even reversed. Restoring the coast and coastal habitats will require a systemic, strategic or site-specific approach, depending on the resource in question and scale of restoration. Depleted wetlands and barrier islands need the natural process of freshwater flows reestablished to deliver land-building sediment. On a smaller scale, for example, sea turtle and bird populations can be enhanced through protecting or improving important nesting habitats at specific sites.

5.4.2. MARINE RESOURCES

Gulf marine habitats include those found nearshore and those offshore in the open or deep ocean where much remains to be learned about the diversity and role of marine organisms in the ecosystem. From underwater sea grasses that provide critical nursery habitat for many valuable marine species, such as gag grouper, to the beauty of coral reefs that sustain diving businesses, nearshore marine habitats (outside the barrier islands) are immensely important to fisheries, recreation and tourism. Offshore habitats are equally important to the ecosystem and economy. Floating mats of sargassum provide shelter or food for young sea turtles, finfish and shellfish, as well as for seabirds. The water column itself is an incubator for floating eggs and larvae spawned by finfish, shrimp or crabs. As finfish mature, they may take refuge near deeper water, hard-bottom formations or, as is the case for adult brown shrimp, in the muddy, soft-bottom seafloor. Gulf deep-sea habitats harbor soft and stony corals, some as old as 2,300 years, and communities of tube worms, mussels and other creatures concentrating around seafloor vents, or cold seeps.

The Gulf's marine resources are no more immune to the environmental degradation of the past several decades than are coastal resources and may be at even greater risk from the BP oil disaster. The dead zone (area of low oxygen) that forms off Louisiana and Texas every summer reduces the available habitat for valuable fishery species like brown shrimp, and it kills less-mobile marine organisms. Chronic overfishing in the Gulf has depleted populations of several species of finfish. Sargassum, deepwater corals, hard-bottom reefs, soft-bottom habitats, shrimp, finfish, seabirds and marine mammals (Fig. 5.3.) are among the marine resources that the BP oil disaster did or could impact. Natural recovery of marine resources through improved management, coupled with intensive, long-term monitoring and research, should be the most practical approach. Other resources may require more direct interventions, such as reducing land-based pollutants (e.g., nutrients) and marine pollutants (e.g., small, human-caused chronic releases of oil), and improving the management of fishery resources and offshore habitats.

Figure 5.2. An endowed Gulf of Mexico Ecosystem Research and Monitoring (GEM) Program for Adaptive Management would seek to broaden knowledge of factors driving Gulf health, support applied fisheries research and adaptive management and provide essential feedback on the effectiveness of restoration activities.



5.4.3. COASTAL COMMUNITIES

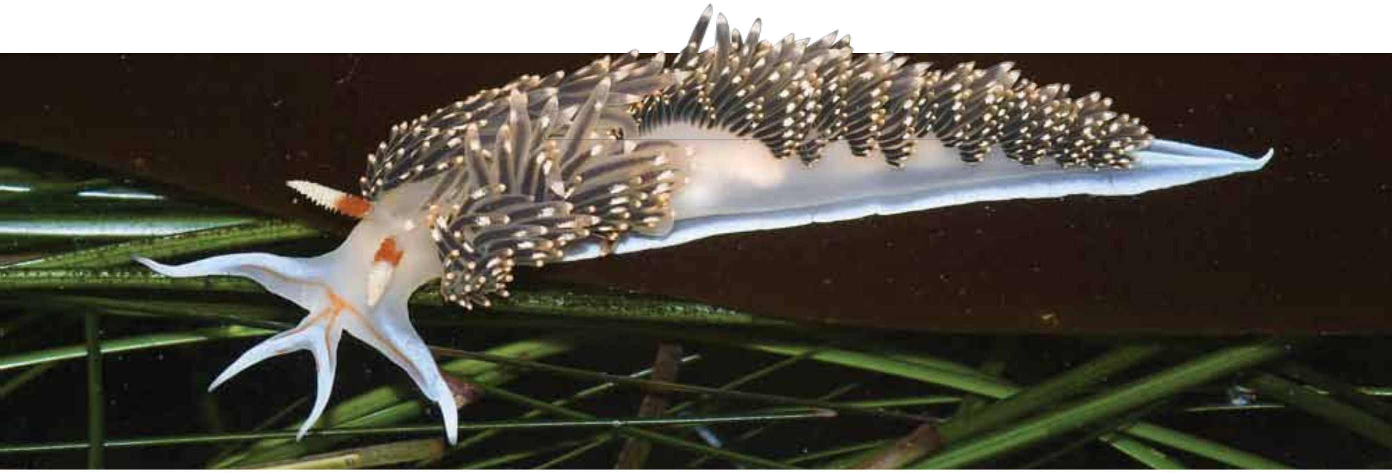
The five U.S. Gulf Coast states account for the world's seventh largest economy, producing a gross domestic product of over $2.3 trillion each year. More than 20 million people live in the region today, and the population is expected to increase by 10 percent by 2015. More than 5 million people visit Gulf beaches each year, and millions more enjoy the Gulf's wetlands and ocean waters each year to swim, hunt or fish. Tourism and recreation generate $9 billion in wages and support more than 600,000 jobs. Recreational fisheries in the Gulf of Mexico generate about $12 billion in economic activity and the seafood industry another $10.5 billion (Fig. 5.4.). Nearly 40 percent of all seafood produced in the contiguous 48 states is landed in the Gulf, where a thriving seafood industry supports approximately 213,000 jobs. The oil, gas and shipping industries employ tens of thousands of additional people in the region. More than 356,000 Native Americans are members of tribes in Gulf states, and many have historical or cultural connections to coastal areas.

The breadth and value of goods and services the Gulf produces for the nation and its numerous economic benefits to local communities belies the environmental challenges the region and its people face. When crises like Hurricane Katrina and the BP oil disaster occur, the region's lack of resilience is exposed and communities experience extreme hardship. The BP oil disaster affected local communities on multiple levels: businesses in the fishing, seafood, lodging and retail industries were impacted due to consumer loss of confidence; subsistence users avoided Gulf seafood; families were destabilized by job loss; and residents and cleanup workers were concerned about their health. Even before the BP oil disaster, many coastal residents saw their natural environment change in ways that put their security, livelihoods and futures at risk. The key to the recovery and resiliency of local communities is restoring and maintaining the natural resources and related ecosystem services that, for example, will reverse coastal erosion, keep ocean waters clean and oxygenated and sustain fish and wildlife populations for the benefit of residents, tourists, hunters, private anglers and commercial fishermen.

Figure 5.3. Sperm whales, which can live up to 70 years, are federally listed endangered species in the United States.

Figure 5.4. Higher freshwater discharges and lower salinities have been associated with higher blue crab recruitment and commercial fisheries productivity in places like Louisiana.

Recommended Restoration Strategies



The Gulf's coastal and marine habitats and fish and wildlife resources are interconnected, such that the health of one habitat type or species affects the productivity of others in the ecosystem.

The interlinked nature of coastal and marine resources, combined with the fact that environmental stressors are associated with both land- and ocean-based activities (see Chapter 3), underscores the importance of an ecologically and geographically balanced approach to restoration.

The roles played by marine and coastal environments in the biology of Gulf species at different life history stages highlight the need for restoration strategies that address the entire ecosystem. For example, most finfish species caught offshore in commercial and recreational fisheries need nursery habitat supplied by coastal wetlands and waters as young fish. In another example, adult brown and white shrimp inhabiting the deeper waters of the continental shelf produce offspring that drift into estuaries as larvae. Here, the maturing shrimp consume large amounts of detritus, help filter estuarine waters and provide food for fishes and wading birds.

The marine environment is also influenced by what takes place on the coast and further inland, and vice versa. For instance, the impacts of agricultural practices on land extend deep into Gulf waters where nutrient-laden Mississippi River water contributes to the formation of a large seasonal dead zone. The BP oil disaster originated more than 64 kilometers (40 mi) offshore, but oil exposure affected bird species that breed as far away as Canada; they were exposed while migrating through the Gulf (Fig. 6.1.).

In selecting restoration strategies, decision-makers should address systemic environmental stressors and support the recovery of coastal communities with strong ties to those resources. Faced with a finite amount of funding and a long list of restoration projects, decision-makers must make meaningful and strategic investments. Toward that end, this chapter recommends priority restoration strategies that address each of the three themes—coastal environments, marine

The coastal zone is where terrestrial, freshwater and marine environments converge and create a gradient in ecological niches that support numerous species.

Gulf of Mexico: Ecological Pathway for Species Exposed to BP Oil or Dispersants

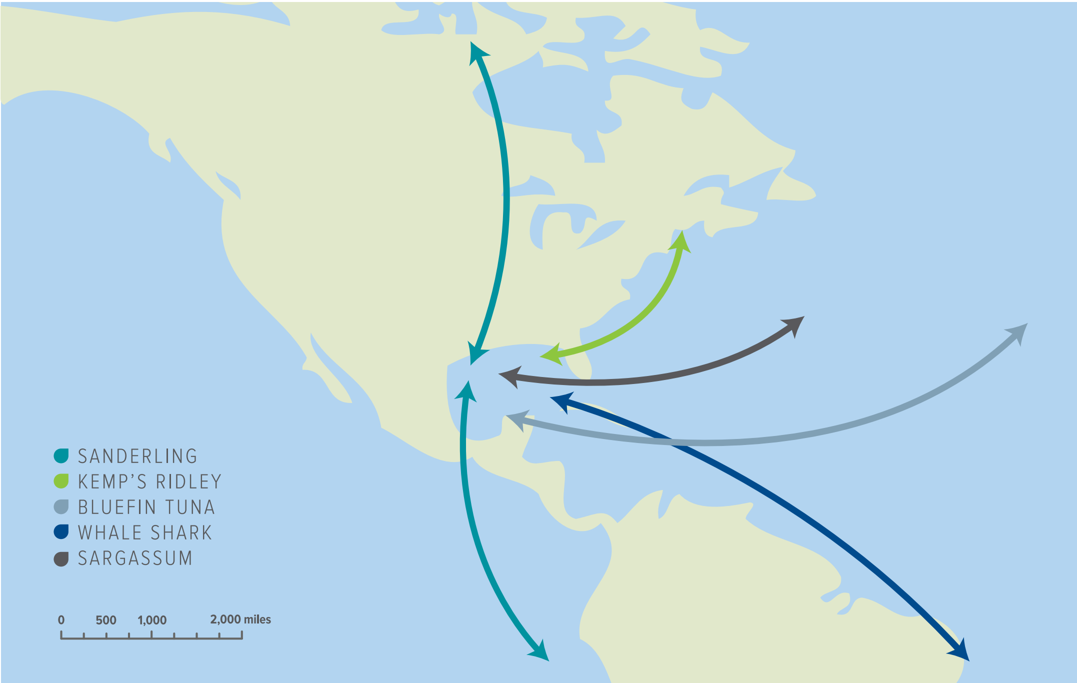


Figure 6.1. The Gulf is an important link in the ecological chain for many species that utilize Gulf beaches, barrier islands and waters on their way to nesting or foraging habitats thousands of miles away.

Figure 6.2. This spring 2011 image shows that large amounts of sediment in the Mississippi River empty into the Gulf via the leveed main river channel, bypassing much of the Delta. Historically, before levees, the river provided sediment via side channels, or distributaries, and periodic flooding.

resources and coastal communities—described in Chapter 5. Each recommendation is accompanied by a brief description of the challenges or needs facing a particular resource or community. These strategies are relevant both to injuries and lost or reduced services resulting from the BP Deepwater Horizon oil disaster and to degradation of the Gulf ecosystem more broadly.

Restoration strategies and projects should be periodically evaluated and modified based on performance, new data or shifts in the types, distribution or severity of environmental stressors. Monitoring and modifications are particularly needed with respect to the BP Deepwater Horizon NRDA. As new information about natural resource injuries becomes available from NRDA studies, trustee agencies should adapt their restoration strategies accordingly.

6.1. RESTORE, PROTECT AND MAINTAIN THE COAST, WITH EMPHASIS ON WETLANDS

As described in Chapter 3, the Gulf's coastal habitats comprise a remarkably productive part of the Gulf ecosystem. The coastal zone is where terrestrial, fresh water and marine environments converge and create a gradient in ecological niches that supports numerous species. The coast's wetlands and barrier islands together provide many ecosystem services, such as nursery or nesting habitats for fish and wildlife species, nutrient absorption, pollutant filtration, erosion attenuation and storm buffering. Restoring the coast, and particularly its wetlands, would: 1) increase the sustainability of coastal ecosystems; 2) support a diversity of habitats important to fish and wildlife as well as related industries and livelihoods; 3) strengthen the resiliency of coastal communities susceptible to storms and sea level rise; and 4) reduce the risk to private property and economic infrastructure such as ports, oil and gas pipelines and refineries.

The Delta-Wide Crevasses Project (Louisiana)

The Delta-Wide Crevasses project is designed to aid the formation of freshwater and intermediate marsh in shallow, open-water areas through the construction and maintenance of new and existing crevasses (see below) in the Mississippi River Delta south of Venice, Louisiana. The project, covering an area of 2,108 hectares (5,210 ac), is jointly sponsored by the Louisiana Department of Natural Resources and the NMFS. At the time of project initiation, 15 percent of the area was marsh and 85 percent was open water. The project area is in the Pass-a-Loutre Wildlife Management Area and Delta National Wildlife Refuge.

A crevasse is a break in a levee that allows the river to deposit sediments into adjacent shallow bays. Artificial crevasse construction is an attempt to mimic the natural crevasse formation process that was responsible for building more than 80 percent of the active Mississippi River Delta. Rock-armored levees constructed along the Mississippi River have prevented most of the regular flooding that historically created crevasses.

The first series of crevasses was completed in 1999; the second was completed in 2004. In total, 17 new crevasses have been created, and five existing ones have been restored, leading to significant new acreage on the Mississippi Delta (Fig. 6.3.).

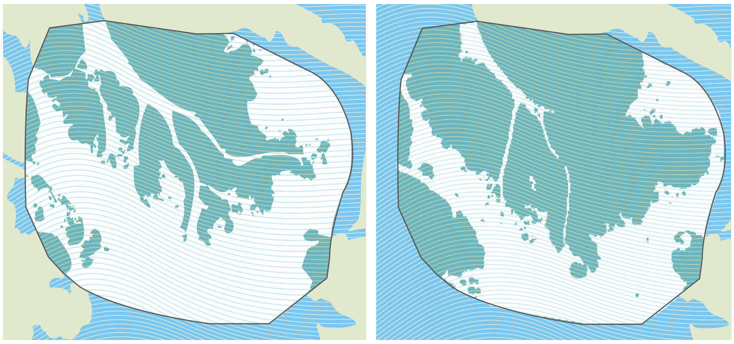
Gulf wetlands are in a state of constant, natural flux due to the dynamic nature of the Gulf and its river systems, particularly the Mississippi and Atchafalaya rivers. For example, when the lower Mississippi changes course, which it has done about every 1,000 years, water and sediment shift from one delta to another, creating disparities in sedimentation. Historically, the river would top its banks, creating either a uniform sheet of water over the landscape, or several more concentrated flows called splays, both of which redistributed sediment from the channel to the broader delta (Viosca, 1927). The role of wetlands in ecosystem function and fisheries productivity cannot be overstated; for example, researchers have found that shrimp yields are directly related to marsh acreage in Louisiana's estuaries (Turner, 1977). Unfortunately, Gulf wetlands are in an accelerated state of decline because of an expanding human footprint and the disruption of key hydrological processes.

6.1.1. MISSISSIPPI RIVER DELTA

Since the 1930s, when large-scale reengineering of the lower Mississippi River expanded, coastal Louisiana has lost 4,856 square kilometers (1.2 million ac) of land (CPRA, 2007). A system of levees and dikes built along the Mississippi River during the last century interrupted the natural cycle of flooding and sediment deposition (Templet & Meyer-Arendt, 1988). These structures prevent marsh-forming sediment loads from reaching surrounding wetlands. Sediment now largely bypasses once-connected side channels (distributaries), as it is transported to the continental shelf via a plume at the mouth of the Mississippi River (Fig. 6.2.). Consequently, wetlands are receding and barrier islands are increasingly isolated from the Mississippi Delta. Marsh loss is also attributed to dams, channelization of levees and other flood control structures upstream that prevent sediments from moving downstream, depriving coastal wetlands of essential growing medium.

Converting marsh habitat to open water (canals) for navigation and for access to oil and gas fields has exacerbated the deteriorating condition of coastal wetlands (Steyer et al., 2008). Thousands

Delta Wide Crevasses Coastal Wetlands Planning, Protection and Restoration Act



Class	2001 Crevasse Splay Acres	2007 Crevasse Splay Acres
WATER	179	124
LAND	116	171
TOTAL	295	295

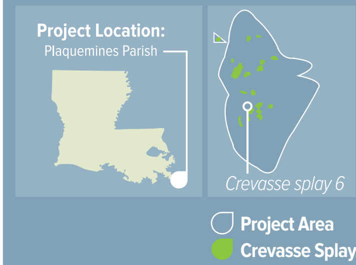


Figure 6.3. Marsh expansion resulting from water diversions, such as crevasses on the Delta, can be seen from a time-series satellite image.

Source: U.S. Department of the Interior; U.S. Geological Survey; National Wetlands Research Center; Lafayette, Louisiana; and Louisiana Coastal Protection and Restoration Authority, New Orleans Field Office.

of miles of canals excavated primarily for oil and gas pipelines and access have increased saltwater intrusion, killed freshwater wetlands and increased fragmentation and associated erosion (Ko & Day, 2004). Canals intended to facilitate oil and gas extraction and transport have increased the amount of open water, leaving energy infrastructure more exposed and vulnerable to storms. Spoil banks created with the dredge of excavated canals are higher than the surrounding marsh, altering the natural exchange of water, sediment and organisms within the estuary (Reed & Wilson, 2004). The physical side effects associated with the removal of hydrocarbons are also a contributing factor. Scientists have determined that land sinks faster in oil and gas fields where the extraction of hydrocarbons from subsurface pockets creates down-faulting or subsidence (Ko & Day, 2004).

In its Comprehensive Master Plan for a Sustainable Coast, the State of Louisiana indicates that reconnecting the river with estuaries and wetlands is a priority for restoring ecosystem health and coastal resiliency, and that reengineering the lower Mississippi River to reestablish sediment flows is one of the long-term solutions (CPRA, 2007). River diversions and crevasses are examples of structures that have reconnected Mississippi River water with the Delta, benefiting estuary health by lowering salinity or increasing marsh habitat.

Another promising restoration strategy is reestablishing marsh habitat in canals originally dredged to access oil and gas wells. In locations where oil and gas wells are no longer producing and have been abandoned, the connecting canals dredged for energy development have become obsolete. These canals can be restored to some degree by using the dredged material originally deposited as spoil banks to backfill the open water and grow new marsh vegetation. Backfilling canals is a relatively cost-effective, low maintenance approach to wetlands restoration (Turner et al., 1994). Because dredged material available in spoil banks that have settled is generally insufficient to completely backfill canals, it may be desirable and feasible in some instances to augment this material with additional sediment brought in from elsewhere.

The science underlying coastal restoration is complicated, and some proposals in Louisiana's Master Plan may be controversial with respect to their long-term efficacy at restoring wetlands and possible impacts on communities. For example, redirecting fresh water into estuaries will lower salinities and, if not properly timed, could impact local fishermen—both positively and negatively—by redistributing fisheries for sea life such as oysters, shrimp and blue crabs. Nonetheless, in some form, investing in the restoration of coastal wetlands, particularly in the Mississippi Delta, is widely accepted as a primary and necessary strategy to help restore resilience in the Gulf ecosystem.

Recommendation: *Reconnect rivers with estuaries and wetlands by restoring influxes of fresh water and sediment.*

The Comprehensive Master Plan for a Sustainable Coast, first developed in 2007 and now under revision, should remain the primary planning tool for rebuilding wetlands in the Mississippi River Delta. A revised Master Plan should be subject to independent scientific peer review and public consideration before its scheduled completion in 2012. Specific projects and combinations of projects stemming from the Master Plan should also be considered within the context of broader regional restoration efforts initiated as a result of the BP oil disaster.

Figure 6.4. Menhaden, a valuable fish species, spends part of its life in estuaries where lower salinity levels and abundant food sources aid survival.

Recommendation: *Reestablish wetland vegetation and fish and waterfowl habitats in obsolete canals by backfilling with dredged material from spoil banks or using other sources of material compatible with site characteristics.*

State and federal agencies should return canals no longer used by the oil and gas industry to natural marsh habitat, concentrating on backfilling canals in areas where marsh is more intact and less degraded (Baustian & Turner, 2006). The following factors have been shown to influence the success of backfilling and should be considered in planning future projects: canal depth, soil type, canal dimensions, locale, dredge operator skill and permitting conditions (Turner et al., 1994).

6.1.2. COASTAL WETLANDS AND ESTUARIES OUTSIDE THE MISSISSIPPI RIVER DELTA

The loss of coastal wetlands, such as marsh and mangrove habitats, is not unique to the Mississippi River Delta. From the 1950s until the 1990s, the Texas coast experienced an 8 to 9 percent decrease in estuarine vegetation, largely attributed to subsidence caused by past oil and gas extraction and more recently to urban, residential and infrastructural development (Moulton et al., 1997; TPWD, 2005). Similarly, salt marsh along Florida's Gulf Coast has been lost to residential and commercial development or ecologically altered due to impoundments (Montague & Wiegert, 1990). Florida's tidally dependent mangroves, the most abundant anywhere in the Gulf, are in poor condition and declining due to similar stressors (FWC, 2005). While protection of remaining intact wetlands from development is an important restoration strategy, reestablishing key natural processes will facilitate recovery of coastal wetlands. For example, freshwater hydrology is one of the most altered natural processes Gulf-wide that needs attention if the health and productivity of estuaries and estuarine-driven fisheries are to be restored.

Structural engineering projects designed to meet human needs have disrupted habitat-sustaining freshwater inflows into estuaries elsewhere across the Gulf of Mexico. Dams, levees and dikes, as well as the demand for water for human consumption and agriculture, have altered the seasonal timing, rates and locations of freshwater inflows into estuaries, with far-reaching impacts on wetlands, open-water habitats and fishery species from Texas to Florida (Turek et al., 1987). Unrestricted freshwater inflows carry ecologically beneficial sediment into estuaries, providing a growing substrate for marsh vegetation and replenishing beaches and barrier islands that lose sand to erosion. Freshwater inflows also help temper salinity levels, repel saltwater-tolerant predators (e.g., oyster drill), flush contaminants from estuaries and create a nursery habitat for numerous crustaceans and finfish (More, 1969; Caffey & Schexnayder, 2002; Browder, 1985; Buzan et al., 2009; Longley, 1994) (Fig. 6.4.).

Recommendation: *Protect wetlands from incompatible development, and restore or enhance ecologically beneficial freshwater flows that promote natural recovery.*

Protection of remaining high-value wetlands, defined as those in stable ecological condition or better, through acquisition of land or conservation easements from willing landowners, should be a primary restoration strategy. Restoring wetlands by planting should be pursued only if the underlying hydrologic processes and patterns are sufficient to sustain the growth and survival of plantings.

Figure 6.5. Jetties are designed to reduce erosion, but in some cases, have the opposite effect by disrupting the natural movement of sand, leading to surpluses or deficits of sand along a beach.

Increasing freshwater inflows into the Gulf can have a positive impact on the health of estuaries and productivity of estuarine-dependent fisheries. Innovative approaches, such as water banking, should be pursued to maximize in-stream flows. In Texas, for example, existing legislation makes possible the acquisition of water rights, which can be a critical tool in maintaining and restoring freshwater inflows to tidal river estuaries. In states where water laws restrict voluntary, market-based water transactions, agencies should pursue mandatory limits on water withdrawals from rivers and creeks at critical times of the year. The percent-of-flow approach, for example, would limit the amount of water that could be withdrawn to a percentage of stream flow at the time of withdrawal. This system is currently employed in parts of southwest Florida such as the lower Alafia and lower Peace rivers. By adopting the percent-of-flow method, water resource managers can minimize impacts of water withdrawals on estuarine resources during sensitive, low-inflow periods while allowing landowners to increase water withdrawals on a gradual basis as inflows increase (Flannery et al., 2002).

Dune Walkovers: A Big Step for Dune Restoration (Florida)

Following the Tampa Bay oil disaster in 1993, the NRDA found that oil disaster response activities had resulted in significant harm to area beaches. A total of 21 kilometers (13 mi) of oiled sand was impacted. Fort De Soto Park, the staging area for response activities near St. Petersburg, was especially heavily impacted. As a result, the natural resource trustees determined that construction of dune walkovers at Fort Desoto would help restore the beach's ecology and recreational uses, both harmed by the oil disaster. In addition, Fort De Soto Park had been an area of high pedestrian traffic, which also degraded dune habitat.

Dune walkovers are artificial pathways that channel foot traffic away from scattered footpaths. This facilitates natural accumulation of sand in undisturbed areas, allowing dune vegetation to stabilize, hold sand and combat erosion. Dune walkovers can last 20 years if constructed using durable, ultraviolet-radiation-resistant, recycled materials. The Fort De Soto dune walkover projects, implemented by Pinellas County government at a cost of $144,000, resulted in the restoration of 2 acres of dunes.

6.2. RESTORE, PROTECT AND MAINTAIN COASTAL AND MARINE HABITATS OF SIGNIFICANCE

Coastal and marine habitats of great economic significance, ecological sensitivity or rarity should be priorities for restoration and protection. Barrier islands, beaches, oyster reefs and sea grass beds provide a range of ecosystem services for people and wildlife by: 1) buffering shorelines and coastal communities from storms, 2) providing nesting habitats for species federally listed as threatened or endangered, such as sea turtles and shorebirds, and 3) providing nursery habitats for commercially and recreationally important finfish. In addition, the rarity of corals in the northern Gulf, combined with their fragility and longevity, highlight the need to protect concentrations of these unique organisms.

6.2.1. BARRIER ISLANDS, BEACHES AND DUNES

The strip of land comprising barrier islands, beaches and dunes is where land meets sea and both terrestrial and marine species coexist. Geological, climatic and coastal processes (e.g., tides, waves, hurricanes, sea level changes) have always made the shoreline a very dynamic environment, but human activities have exacerbated the rate of natural change. Habitat loss, fragmentation or simplification, excessive predation, altered ecology and erosion are the most serious threats to the function and condition of barrier islands, beaches and dunes. In particular, erosion is a systemic and long-term problem along the Gulf shoreline, which is receding as much as 3 meters (10 ft) per year in some places. The combined effects of manufactured structures, such as hardened shorelines, and other factors, such as sea-level rise and storm damage, compound the problem of erosion, which threatens native species and hurts local communities by reducing both resiliency to storms and public use of these areas.

Artificial shoreline structures like jetties, seawalls and impoundments designed to stabilize shoreline and reduce erosion have had unintended negative effects. These structures alter the interaction of currents and waves along the coast, redistributing large quantities of sand and sediment that create surpluses in some areas and deficits in others (Komar, 1998; Morton, 2004). For example, jetties have been known to redistribute sand offshore (Fig. 6.5.), creating shallow water and dangerous conditions for boaters. Seawalls deflect wave energy downward and result in the erosion of intertidal beach habitat. Mechanical beach supplementation may be appropriate on an emergency or interim basis but is not a sustainable, long-term restoration strategy. Dredging disturbs the seafloor, and the deposition of material can harm the environment in a variety of ways, such as disturbing intertidal plant and animal communities (e.g., sea turtle or shorebird nesting and feeding habitats), exposing people or wildlife to contaminants found in the dredged materials, impairing water quality and discoloring the white sand beaches that define the image of many Gulf shores (Peterson & Bishop, 2005; Peterson et al., 2006). Dunes—important reservoirs of sand that help replenish beaches during storms—have also been degraded by coastal development, erosion and the loss of native vegetation.

Recommendation: *Promote natural sediment recruitment and exchanges.*

Natural resource agencies considering nearshore engineering projects to stabilize shorelines and rebuild erosion-prone barrier islands and beaches should choose methods that support, not alter, natural processes. For example, they should replace manufactured structures or features known to disrupt the natural flow of sediments (e.g., jetties and bulkheads) with more sustainable alternatives, such as vegetative cover (sea grasses and submerged aquatic cover), nonstructural stabilization (coir logs and organic matting), shoreline revetment (oyster shell and coarse limestone) or natural offshore breakwaters (oyster reefs).

Fishing Line Cleanup at Rookery Islands (Florida)

The NRDA, following the Tampa Bay oil disaster of 1993, documented harm to nesting birds, such as brown pelicans and double-crested cormorants. Under NRDA rules, the trustees needed to select a restoration activity that was linked to and would benefit these injured species. They selected a cleanup of discarded monofilament fishing line, a well-documented cause of bird deaths in Tampa Bay. Removing monofilament reduces potential bird entanglement and death, thereby aiding recovery of bird populations impacted by the oil disaster.

Local conservation groups, including Save Our Seabirds, the Tampa Chapter of the National Audubon Society and Tampa Baywatch, received funds to implement two cleanup efforts, which were completed in 2000 and 2002 in Boca Ciega Bay. Volunteers and staff from these nonprofit groups and NOAA removed discarded monofilament from mangrove branches in wetland bird habitat. The monofilament was placed in a clear tube for use as an educational display. During the course of the cleanup, injured birds were taken to rehabilitation centers.

Monofilament, a non-biodegradable material that can remain in the marine environment for many years, is also responsible for devastating impacts to other marine species. Public education programs to prevent this hazard are designed to encourage anglers to dispose of used fishing line properly and replace their line often, so it is less likely to break and become lost in the water.

Little Bay Finfish and Shellfish Nursery Habitat Restoration (Alabama)

Following Hurricane Katrina, the Alabama Department of Conservation and Natural Resources-State Lands Division (SLD) received NOAA Fisheries Emergency Disaster Relief Program (EDRP) funds to conduct finfish and shellfish nursery habitat restoration. The SLD targeted the majority of these funds toward a large-scale restoration project at Little Bay in south Mobile County. The Little Bay Restoration Project site is located just west of the mouth of Bayou La Batre on the north shore of Mississippi Sound in Mobile County, Alabama.

This area has experienced significant long-term erosion, on the order of 1.5 to 3 meters (5-10 ft) per year. The objective of the project was to halt or slow this erosion and to restore the shoreline to its 1950 alignment, including sealing a breach in the peninsula that creates Little Bay. The project design included the placement of approximately 1,585 meters (5,200 ft) of permeable segmented breakwaters, the dredging and placement of approximately 99,392 cubic meters (130,000 yd^3) of sandy sediments and the planting of approximately 100,000 plugs of native vegetation to restore 14 hectares (34 ac) of salt marsh. Approximately 610 meters (2,000 ft) of bagged oyster shells were placed on the Little Bay side of the project.

Caution should be used when considering mechanical barrier island or beach replenishment methods, such as dredging or pumping sand from offshore or ship channels, and should always be designed to meet the biological needs of shoreline-dependent species. These methods are appropriate only on a limited basis when dredge materials have been tested for contaminants, match the composition of natural beach sands without excess shell debris or unnatural materials and do not pose a health risk to wildlife and people.

Recommendation: *Maintain or enhance natural vegetation, reduce foot and vehicular traffic and create adequate buffers from development.*

Protecting and restoring sand dunes, especially at inlets where bird-nesting habitats are critical yet limited, should be part of a sustainable strategy to renourish beaches. The best course of action is planting native vegetation on dunes to recruit and retain sand needed to support healthy dune habitats and to provide local beaches with natural, stored sources of sand. Directing access to boardwalks and keeping people out of sensitive areas will help maintain natural vegetative cover and reduce erosion.

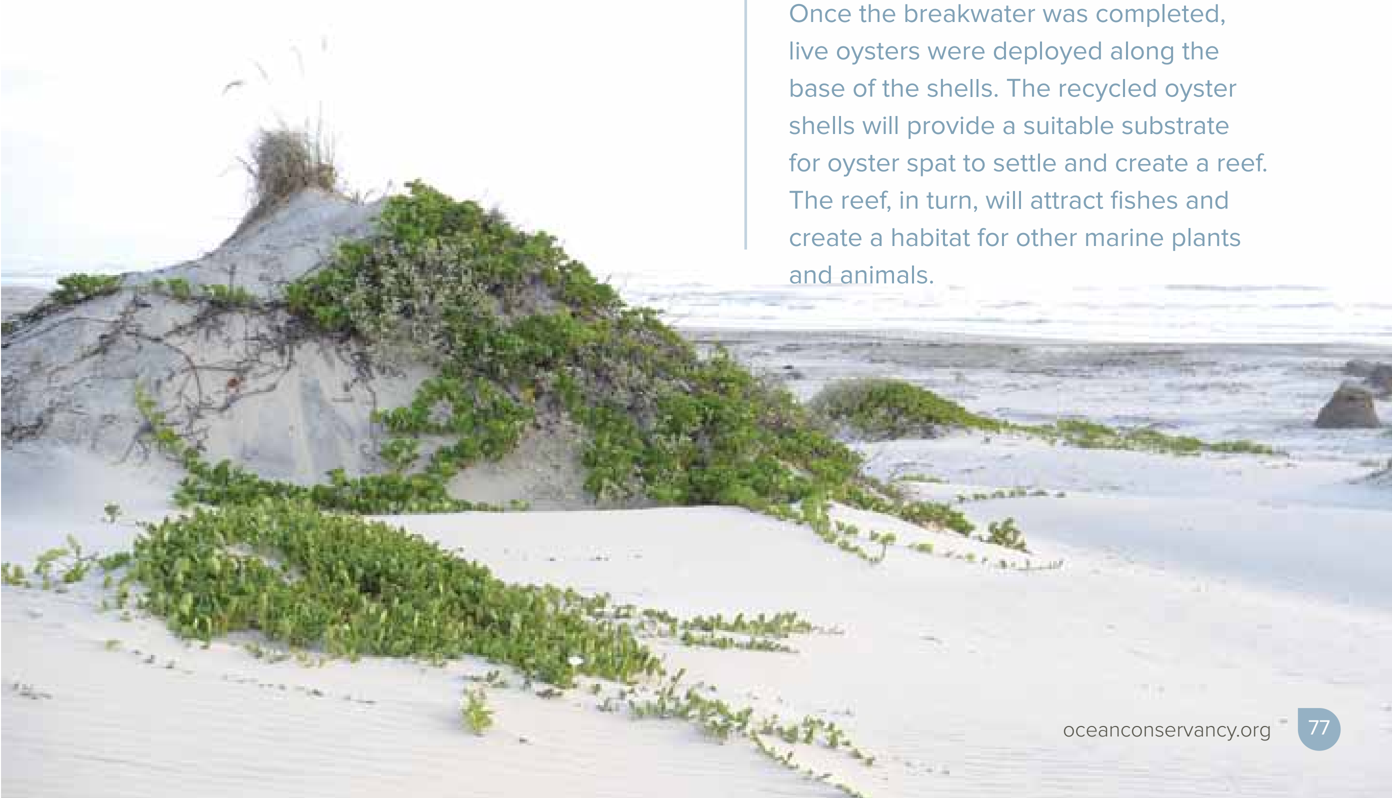
6.2.2. NESTING HABITATS

Many visitors come to the Gulf Coast to view the region’s diverse and abundant wildlife. Whether on- or offshore, visitors can see numerous resident or migratory bird species and one or more of the five sea turtle species that breed or feed in the Gulf. All five turtle species and two species of birds are listed under the Federal ESA. Relative to the entire Gulf Coast, a disproportionate number of beach-nesting bird species breed along the northern Gulf Coast, utilizing beaches, flats, dunes, bars, barrier islands and similar nearshore habitats. Coastal development, beach nourishment projects, artificial lighting, domestic or feral animals and vehicular traffic are among the most serious threats to shoreline nesting birds, sea turtles and their habitats. Protection of nesting sites from incompatible human activities is critical to the health of bird and sea turtle populations (Fig. 6.6.) and to maintain natural resources that support a thriving tourism industry.

Recommendation: *Protect and enhance bird and sea turtle nesting sites and associated habitats.*

Remaining tracts of undeveloped coastal and shoreline areas identified as high quality and high priority nesting habitats should be acquired and managed for natural values and compatible public uses, such as recreation, fishing and wildlife viewing. Such coastal properties can be protected through fee-simple acquisitions, permanent conservation easements or use of landowner incentives. Human activities in developed areas adjacent to important nesting habitats should be minimized, especially during sensitive seasons. For example, reduce or replace harmful artificial lighting; implement best management practices for beach nourishment projects; restrict vehicular or foot traffic in sensitive areas; reduce domestic or feral animal predation; and eliminate marine debris that endangers birds, turtles and other fish and wildlife.

Figure 6.6. Beaches and dunes are essential to the biology of sea turtles and birds by providing egg-laying habitat. Protecting or enhancing beach nesting habitat is a restoration priority in the Gulf.



Deer Island Restoration Project (Mississippi)

The Deer Island restoration project is a $14.5 million project led by the Mississippi Department of Marine Resources and the U.S. Army Corps of Engineers, Mobile District. This Mississippi Coastal Improvement Program project is part of an ongoing effort to restore Deer Island to its size prior to Hurricane Katrina. Dredge material is being used to add 81 hectares (200 ac) to the now 162 hectare (400 ac), state-owned island, which has suffered from erosion and has been battered by several hurricanes, including Katrina in 2005. The habitats restored with the dredge material include tidal marsh, beach, dune and coastal forest.

As another component of this large project, a breakwater was installed to protect about 244 meters (800 ft) of shoreline on the northeast corner of Deer Island. The breakwater was created using bags of recycled oyster shells stacked and staked along the shoreline. Once the breakwater was completed, live oysters were deployed along the base of the shells. The recycled oyster shells will provide a suitable substrate for oyster spat to settle and create a reef. The reef, in turn, will attract fishes and create a habitat for other marine plants and animals.

Mobile Bay Oyster Gardening Program (Alabama)

The Mobile Bay Oyster Gardening Program, established in 2001, was modeled on the successful Chesapeake Bay Oyster Gardening Program. The program uses volunteers (oyster gardeners) along the shores of Mobile Bay to grow oysters in protected gardens. The gardens are stocked with live spat collected in the wild or spawned in a hatchery.

Each oyster gardener grows oysters in up to four gardens from late June to November. During this time, the juvenile oysters grow from a few millimeters to several centimeters. The gardens are suspended from the oyster gardener's wharf, so they remain off the bottom and away from pilings, increasing water flow to the oysters. On average, each volunteer grows 250 oysters per garden. Oyster gardeners tend their gardens each week by washing away any fouling and removing predators. In mid-November, program personnel return to each oyster gardening site, collect the oysters and stock them on reefs in Mobile Bay. The reefs are carefully selected to be outside normally harvested areas. The protection and maintenance the oyster gardeners give their oysters allow the oysters to attain a larger size more rapidly than they would in the wild. This larger size will improve the survival rate, increasing the probability of restoration success. To date, the Mobile Bay Oyster Gardening Program has placed more than 400,000 oysters on reefs around Mobile Bay. Continued monitoring of these reefs has proven the program to be a success.

6.2.3. OYSTER REEFS AND SEA GRASS BEDS

Oyster reefs and sea grasses are two highly productive, but threatened, nearshore habitats in the Gulf. The Gulf of Mexico supports the only remaining significant wild oyster harvest in the world and has some of the best of the few remaining reefs in the world (Beck et al., 2011). The oyster industry, particularly in Louisiana, was recovering from Hurricane Katrina when the BP Deepwater Horizon oil disaster resulted in renewed hardship.

Oysters improve water quality by removing pollutants and stabilize erosion-prone shoreline habitats by absorbing and redistributing wave energy. Oysters support a valuable fishery in the Gulf of Mexico, generating about $60 million per year in oyster landings—more than 50 percent of the value of all oyster landings nationwide. About 70 percent of all oyster landings by weight in the U.S. come from the Gulf of Mexico (NOAA, 2011). Oyster reefs support other fisheries by providing habitat and fishing opportunities. One study indicated that 23 percent of the annual total marine-angling days in Louisiana were spent over oyster reefs (Haby et al., 2009). The conservation or construction of oyster reefs can also result in the creation of jobs. For example, a recent project in Florida to restore 1,112 hectares (2,500 ac) of oyster reefs created about 100 jobs (Martin County, Oyster Reef Restoration Project, 2011).

Reduced river inflows into bays and estuaries across the Gulf have increased salinity and exposed oysters to predators and diseases that would otherwise be inhibited by freshwater. Large pulses of fresh water also can kill oysters, as was the case during the BP oil disaster when water from the Mississippi River was diverted into Barataria Bay to repel oil from sensitive marsh habitats. Pollution, hypoxia and over-harvesting are additional threats to oyster reefs.

Sea grasses generate an estimated annual value of up to $4,600 per acre by supporting critical life history needs of many commercially important offshore marine species, including finfish and shellfish (Indian River Lagoon National Estuary Program, 2008). Sea grasses buffer the coast

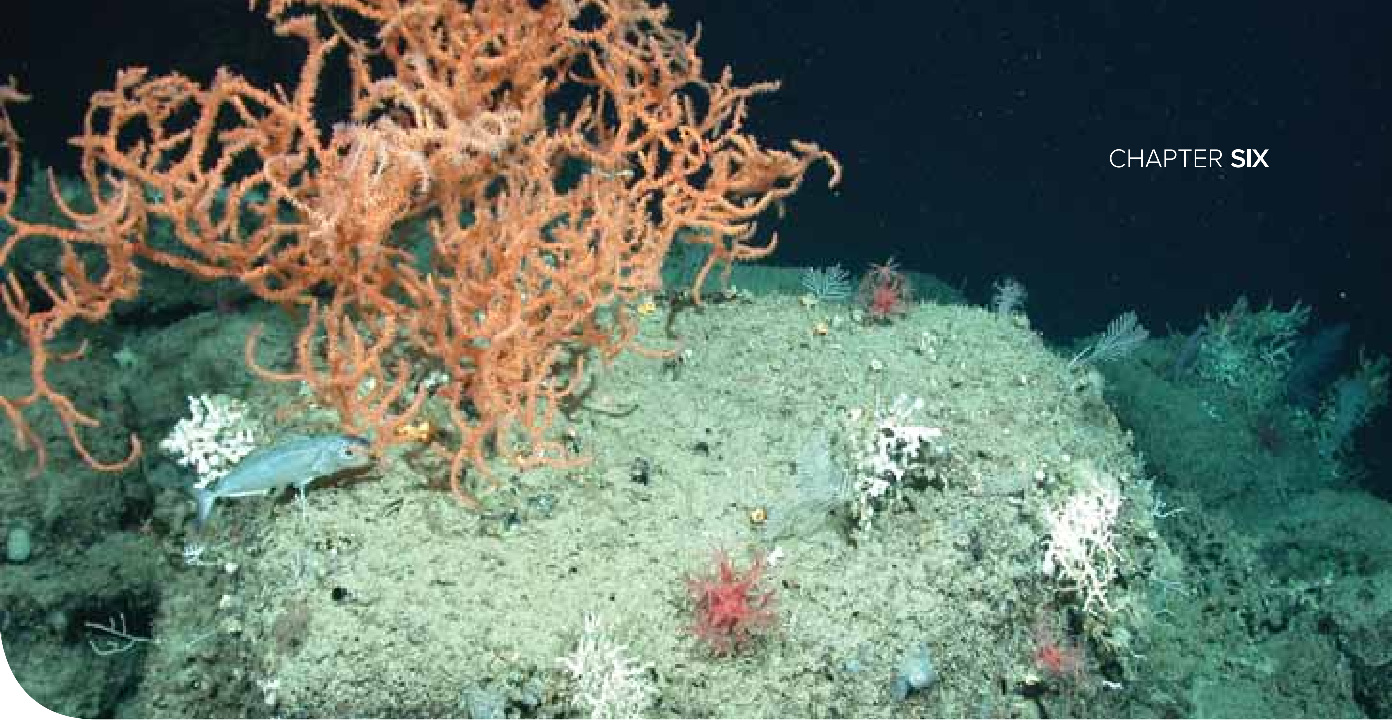


Figure 6.7. Deepwater corals, found at depths of about 50 to 2000 meters (160-6,560 ft) around the Gulf of Mexico, are fragile, slow-growing organisms that can live 1,000 years.

from erosion forces and nourish offshore habitats through organic matter transfers. Birds, sea turtles, bottlenose dolphins and manatees congregate in sea grass beds to feed on the vegetation itself or on the organisms drawn to this underwater habitat.

Sea grasses and other submerged aquatic vegetation have experienced Gulf-wide declines, ranging from 20 to 100 percent, depending on the estuary. The largest contiguous sea grass beds are in Florida and Texas, but remnants exist near the Chandeleur Islands, Mississippi Sound and on the Alabama coast. The most significant threats to sea grasses are reduced water quality and clarity caused by nutrient-fed algal blooms or sedimentation and boat propeller damage to rhizomes.

Recommendation: *Reestablish or maintain existing oyster reefs and sea grasses for fisheries and other ecosystem services.*

Expansion and restoration of publicly-owned oyster reefs would help the oyster industry recover and provide benefits to other user groups (e.g., anglers) and the ecosystem more broadly. Specifically, reefs should be reestablished and designated as either production reefs or primarily for ecosystem services. The two reef types should be designed to work synergistically, though they may need to be separated to avoid conflicts among users. Oyster reefs serve as natural breakwaters, provide essential fish habitats and create angling opportunities, but production reefs would be available to industry for harvest and as a source of seed oysters for transplantation to private leases. In rebuilding or reestablishing oyster reefs, natural resource agencies, contractors or other project managers should give preference to local oystermen and other fishermen in order to optimize the use of existing knowledge and infrastructure while creating local jobs. For sea grass restoration, natural resource agencies should pursue a combination of the following steps: replanting, management actions such as designated boat corridors (designed in consultation with industry and local users), nonpoint source pollution controls and public education (e.g., increased signage) to reduce interactions between boaters and sea grass beds.

6.2.4. CORALS

Gulf of Mexico corals, ranging from the deep, cold-water coral communities of the continental slope to the mesophotic ("twilight zone") corals on the shelf and the warm-water reefs in the shallow coastal zone, are a priority for conservation (Fig. 6.7.). Coral ecosystems are hotspots of biodiversity, attracting many organisms and providing feeding, spawning and nursery habitats for fish species, including those of commercial or recreational importance (NOAA, 2010a; *Acropora* Biological Review Team, 2005). Up to 170 fish species have been documented from hard-bottom habitats along the West Florida Shelf and Slope (Brooke & Schroeder, 2007). Many deep-sea corals are slow growing, long-lived and fragile; consequently, physical injury to corals could be long-lasting or

Alaska Ecosystem Research Endowment is a Model for the Gulf of Mexico (Gulf-Wide)

Research funded in part through the North Pacific Research Board (NPRB), which was established and endowed by Congress, benefited two separate fisheries off the coast of Alaska in the Bering Sea that had been in conflict due to overlapping distributions of target species. Bottom trawling for flatfish and cod in areas of high crab densities, particularly snow, Tanner and red king crabs, had resulted in significant bycatch and mortality of these crab species, which are of high commercial value. Surveys conducted with the help of NPRB funding estimated crab mortality caused by bottom trawling and produced estimates of mortality associated with the different bottom trawl gear parts. Most importantly, researchers showed that increasing the clearance between trawl gear and the seafloor allowed more crabs to escape unharmed, reducing the number of crab deaths significantly while still catching flatfish and cod. Bycatch of nontarget fishery species is also a challenge in the Gulf of Mexico, where additional investments in science and research could lead to management solutions.

even irreversible. In many cases, growth rates, life histories and ecology are unknown (NOAA, 2008). Shallow, warm-water coral reefs in the U.S. portion of the Gulf of Mexico are generally limited to southern Florida where roughly 6,000 coral reefs are found between Key Biscayne and Dry Tortugas (Florida Department of Environmental Protection, 2011; Rohmann & Monaco, 2005).

Unsustainable fishing practices are a significant threat to Gulf corals. Overfishing has resulted in decreased biodiversity and shifts in the ecosystem structure of shallow-water and mid-water coral reefs where top predators are increasingly absent. Furthermore, interactions with some types of fishing gear—such as bottom trawls, traps or pots and bottom longlines—can pose a problem for both deepwater and shallow-water coral reefs due to mechanical damage.

Non-fishing threats to corals in the Gulf include climate change, invasive species, diseases, pollution from coastal development and vessel groundings and anchoring. Coral bleaching and ocean acidification—both associated with climate change—damage or kill corals.

Oil and gas activities in the Gulf of Mexico can be a significant threat to corals, especially as the industry moves into new areas. Poorly sited oil and gas development activities, including platform and pipeline placement, can directly damage corals. Exposure to oil can be lethal to corals and can also inhibit key biological functions, such as photosynthesis (in shallow species), growth or reproduction. In fall of 2010, researchers observed damaged or dying corals 11 kilometers (7 mi) from BP's ruptured Macondo wellhead (NOAA, 2010b; Cordes, 2011). While these observations need further evaluation, they highlight the vulnerability of deep-sea corals to oil discharge from energy drilling activities in the Gulf. Known natural occurrences of deepwater corals are within several hundred meters of oil platforms, and some platforms are suspected to have populations of deepwater corals attached to them. Expanded buffer zones and possibly other mitigation measures are needed to ensure that expanded oil and gas exploration and extraction do not mechanically impact live corals or their substrates.

Mining of methane hydrate, a potential new energy source, could become a substantially greater threat if this practice moves from the experimental phase to the production phase (Brooke & Schroeder, 2007). The main threat from mining is mechanical disturbance of the seafloor. On a large scale, extraction activities could undermine the carbonate substrate that supports coral community development. An indirect impact of physical disturbance would be sediment resuspension and the release of pollutants from the seafloor, which would diminish water quality in deeper Gulf waters and could suffocate coral and sponge colonies (S. Brooke, personal communication, 2011).

Recommendation: *Protect corals from incompatible human activities.*

Protecting coral communities from incompatible human uses, such as oil and gas development, mining and harmful fishing practices, will help maintain the ecosystem services and essential fish habitats they provide. Specifically, the following actions should be taken: review the adequacy of and possibly increase spatial buffers between deep-sea corals and oil and gas development activities regulated by the Bureau of Ocean Energy Management and Bureau of Safety and Environmental Enforcement; ensure that the Gulf of Mexico ensure that the Gulf of Mexico Fishery Management Council's fishery management plans and protected area designations are based on the latest information on coral distribution and that fisheries' interactions with corals are addressed; and expand coral reef monitoring and research programs.

6.3. GULF OF MEXICO ECOSYSTEM RESEARCH AND MONITORING (GEM) PROGRAM FOR ADAPTIVE MANAGEMENT

Restoration of the Gulf ecosystem must be informed, supported and evaluated by science; and it is critical that a robust, long-term science program be in place from the outset (Bjorndal et al., 2011). Such a program should take advantage of the work on BP oil-related impacts carried out under the NRDA and by independent researchers, and should be designed to detect lingering or sublethal injuries that extend over many years. More broadly, a restoration science program should provide information to support the design and selection of ecosystem restoration projects, evaluate the effectiveness of those projects and the overall program and facilitate adaptive management going forward.

Even in the absence of events like the BP oil disaster, the Gulf of Mexico ecosystem is in perpetual flux. Natural changes in oceanographic conditions, combined with chronic impacts from past and present human activities on land or at sea, affect habitat quantity and quality as well as the abundance and distribution of marine life. Understanding change in the Gulf ecosystem—whether from natural or anthropogenic causes—requires long-term science and is essential to lasting restoration, management and conservation.

Following the *Exxon Valdez* oil spill in Alaska, the *Exxon Valdez* Oil Spill Trustee Council made an early decision to make a major investment of restoration funds in science, both to facilitate restoration of related injuries and to guide management and conservation efforts in the future. That investment in science continues more than 20 years after the oil disaster. Also in Alaska, the North Pacific Research Board was established by Congress and endowed as a source of competitive grants to support applied research that contributes to management and conservation of marine resources. Research funded by the North Pacific Research Board has improved scientists' ability to forecast ecosystem changes, answered important questions about fish-habitat relationships and led to more-informed resource management decisions.

Drawing in part on the Alaska experience, members of the scientific and conservation communities have proposed versions of a permanent, endowed Gulf of Mexico Ecosystem Research and Monitoring (GEM) Program for Adaptive Management to supplement and extend beyond the restoration science carried out in connection with NRDA, GRI and Task Force programs in the Gulf. An expanded, ongoing Ocean Observing System in the Gulf of Mexico should be included in and supported by the GEM program so that ocean scientists can detect changes in the marine ecosystem and forecast the impacts of those changes on ecosystem productivity and fishery resources.

Recommendation: *Create a permanently funded Gulf of Mexico Ecosystem Research and Monitoring (GEM) Program for Adaptive Management.*

Congress should segregate funds into a separate account within the U.S. Treasury and dedicate the revenue stream from the earnings, after adjusting for inflation, for support of ecosystem monitoring and research projects. Grants should be awarded on a competitive basis to academic institutions, marine research consortia, government agencies and other appropriate entities, with emphasis on an integrated series of scientific research and monitoring projects over a long time horizon. In order to provide an adequate level of continuing support, Congress should designate more than $1 billion of the CWA penalties for the separate GEM account. A grants decision-making board should be established and operated by a regional entity, such as the Gulf of Mexico Alliance, under the fiscal and administrative authority of the U.S. Department of Commerce. Members of the board should include stakeholders from the Gulf region as well as representatives of key federal and state agencies and academic institutions.

6.4. REDUCE THE NORTHERN GULF "DEAD ZONE"

The "dead zone" is an area of low oxygen that forms every summer in the northern Gulf of Mexico off the coasts of Louisiana and Texas. It is characterized by hypoxia, a condition in which dissolved oxygen levels drop to 2 mg/l or lower and create detrimental conditions for organisms that require oxygen.

US Gulf Waters Hypoxic Locations

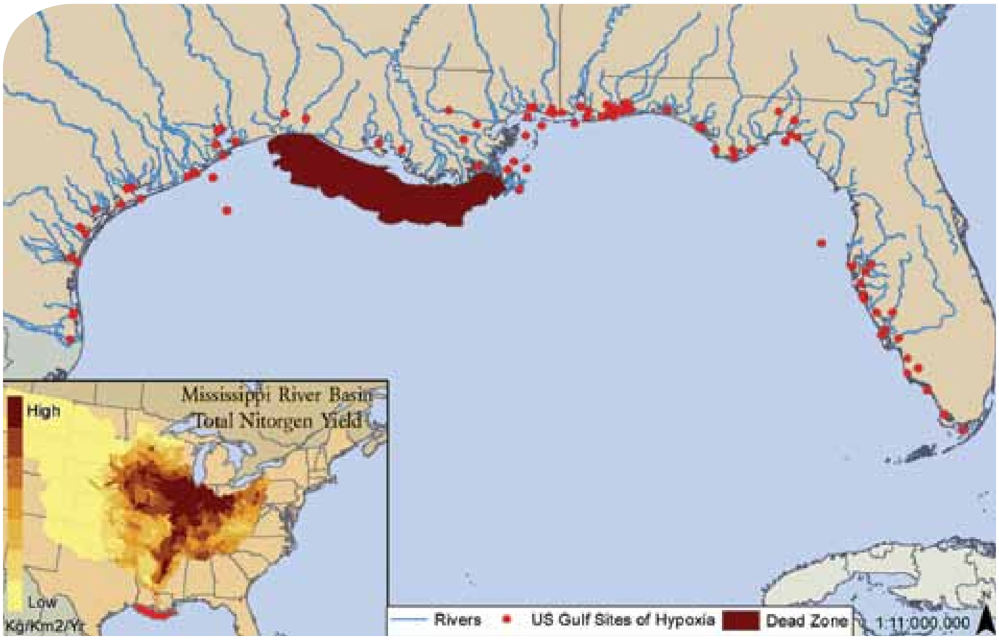


Figure 6.8. An excess of nutrients entering rivers as runoff, combined with stratification of ocean waters during summer, creates areas of low oxygen ("dead zones") inhospitable to marine life.

The average size of the dead zone from 2006 to 2010 was 17,300 square kilometers (6,680 mi^2); and in 2011, it measured 17,520 square kilometers (6,765 mi^2), which is larger than the state of Connecticut (Rabalais, 2010; Rabalais, 2011). The primary cause of the dead zone is nutrient pollution that contains excess nitrogen and phosphorus and originates in the Mississippi River Basin. When the nutrient-loaded runoff is coupled with stratification of the water column in spring and summer, it triggers a series of ecological events that ultimately result in a layer of oxygen-depleted water trapped in the lower 5 to 30 meters (16-98 ft) of the water column. While the northern Gulf dead zone receives the most visibility, dozens of dead zone 'pockets' documented around the Gulf also merit attention (Committee on Environment and Natural Resources, 2010).

The majority of the nutrients delivered to the Gulf—78 percent of the nitrogen and 66 percent of the phosphorus—come from nonpoint sources (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2008). Of the 31 states contributing runoff to the Mississippi River Basin, nine states, making up only one-third of the area, contribute more than 75 percent of the nitrogen and phosphorus to the Gulf: Illinois, Iowa, Indiana, Missouri, Arkansas, Kentucky, Tennessee, Ohio and Mississippi (listed in order of highest contribution) (U.S. Department of the Interior, 2008). Hypoxia's negative impacts on marine resources may include long-term, ecological shifts in food webs and species diversity. Atlantic croakers exposed to periods of hypoxia in the northern Gulf were recently reported to have reduced reproductive function, shifts in sex ratio and abnormal ovarian development in some females (Thomas & Rahman, 2011). Researchers have estimated that the dead zone reduces the habitat area available for brown shrimp by up to 25 percent (Craig et al., 2005). This could result in the displacement or loss of fishery resources, a decrease in fishing opportunity or suboptimal yields for fishermen. In its 2008 Gulf Hypoxia Action Plan, the Mississippi River/Gulf of Mexico Watershed Nutrient Task Force established the goal of reducing the size of the hypoxic zone to approximately 5,000 square kilometers (1931 mi^2) by 2015.

For-Hire Industry Group's Sustainable Fisheries Business Model (Gulf-Wide)

The newly formed Charter Fisherman's Alliance (CFA) is a growing association of like-minded small business owners who operate charter-fishing businesses. Their fundamental goal is to achieve sustainability and accountability for Gulf of Mexico fisheries, while maximizing access for the millions of recreational anglers who rely on charter boats to access the fishery. They plan to achieve this through outreach, education and proactive engagement in management and political processes. By working within the framework of the Magnuson-Stevens Fishery Conservation and Management Act, the CFA will promote innovative fishery management and restoration plans that, in turn, promote the growth of the fishery, improve data collection and science and increase the accountability of the for-hire fishery. The CFA believes that good fisheries management and healthy, resilient Gulf ecosystems go hand-in-hand with profitable businesses and strong coastal economies.

Recommendation: *Shrink the "dead zone" area by reducing nutrient loads into the Gulf of Mexico.*

States in the Mississippi River Basin and relevant federal agencies (e.g., USDA and EPA) should redouble their commitment to implement nutrient reduction strategies that reduce the size of the dead zone to 5,000 square kilometers (1,931 mi^2) (Mississippi River/Gulf of Mexico Watershed Nutrient Task Force, 2008). Agencies should increase or shift the amount of targeted assistance to priority counties in the upper or lower Mississippi River Basins or in relevant Gulf state basins that contribute to smaller pockets of hypoxia Gulf-wide (Fig. 6.8.). This assistance should be used for voluntary actions to implement better nutrient management strategies. One existing exemplary program is the Mississippi River Basin Healthy Watersheds Initiative, which works with farmers to maintain agricultural productivity while avoiding, controlling and trapping nutrient runoff. It is essential that scientific monitoring be a component of these programs in order to quantify their impacts on local and Gulf nutrient loads and hypoxia. Agencies also should consider taking a stronger regulatory approach, such as establishing numerical water quality standards for nitrogen and phosphorus in states throughout the Mississippi River drainage basin, the mouth of the Mississippi River and the northern Gulf of Mexico (Committee on the Mississippi River and the Clean Water Act, National Research Council, 2008). Finally, agencies should aim to increase the interception and sequestration of excess nutrients by restoring, creating or enhancing natural and treatment wetlands through programs such as the farmable wetlands program.

6.5. RESTORE, PROTECT AND MAINTAIN WILDLIFE POPULATIONS

Among the rich fauna of the Gulf of Mexico ecosystem are five species of sea turtles, more than 150 species of coastal and marine birds and at least 22 species of marine mammals. All five of the sea turtles, two of the birds and two of the marine mammals—sperm whale and West Indian manatee—are listed under the federal ESA. Among the marine mammals, all of which are protected by the MMPA, are Bryde's whale, Cuvier's beaked whale, rough-toothed dolphin, Clymene dolphin, pygmy killer whale and melon-headed whale. Most people have never heard of these species or many of the other marine mammals found in the Gulf, and it is no surprise that for the majority of these species there are insufficient data to determine stock structure, abundance, distribution, trends, health status or vital rates, such as survival and reproduction.

More information is needed from NRDA studies and other research in the Gulf about impacts of the BP oil disaster on the Gulf's sea turtles, marine mammals and coastal and marine birds. Beyond impacts from that event, however, all have suffered to one degree or another from population declines and the systemic degradation of the Gulf ecosystem. The presence of at least nine species federally listed as threatened or endangered and many other species of conservation concern in the Gulf suggests that the conservation needs of marine vertebrates in this region should be a higher priority. In many cases, migrating sea birds, marine mammals, and sea turtles that forage, stopover or nest in the U.S. portion of the Gulf also spend part of their life cycles in other countries, some thousands of miles away, where threats to their survival also need attention (Fig. 6.1.).

One common need, especially for marine mammals but also for turtles and birds, is to gather more scientific information, ranging from data on abundance and distribution to better understanding of the ecological and environmental factors influencing and limiting their populations (e.g., Bjorndal et al., 2011). Obtaining this information would require coordinated and cooperative efforts

Fishing Association Links Best Practices with New Markets (Gulf-Wide)

The Gulf of Mexico Reef Fish Shareholders' Alliance (Alliance) represents approximately 40 percent of the $8 million red snapper fishery and is committed to supporting sustainability in the Gulf of Mexico. The Alliance has been a leader in the Gulf by developing a platform for the sustainability of reef fish and fishing businesses.

The Alliance is a model of how to move "red-listed" fishes—fish that consumers should avoid unless the fisheries improve—into recovery, ensuring the sustainability of Gulf fisheries. By unifying members of the industry through a commitment to sustainability, the Alliance has gained support from distributors, restaurants and consumers-at-large whose patronage of responsible fisheries is clearly an important factor in recovery. The Alliance's multifaceted sustainability plan identifies the following objectives: fishery-wide adoption of quotas for individual fishermen, sustainability certification, traceability, safety testing, consumer research and marketing.

In March 2011, the Alliance introduced Gulf Wild™ branded seafood from the Gulf of Mexico. This innovative program was developed collaboratively with the support of the Environmental Defense Fund, Sustainable Fisheries Partnership, New England Aquarium, Gulf of Maine Research Institute, Ocean Conservancy and other marketing and seafood industry professionals. It provides consumers with trackability of their seafood back to the vessels and additional seafood testing to ensure safety and authenticity of the product. The conservation covenants adopted by the Alliance fishermen, along with the Gulf Wild™ brand, will further secure a healthier Gulf of Mexico.

at the state, federal and international levels. Although scientific information in and of itself does not restore a species, a basic understanding of the status, biology and ecology of wildlife is the foundation on which restoration, management and conservation actions rest. The GEM program described in Section 6.3. is a possible source of funding for some of the needed surveys, research and monitoring; but fundamentally, these needs must be addressed and supported by the federal and state agencies that have management and trust responsibilities for wildlife.

Beyond gathering scientific information about marine mammals, sea turtles and birds in the Gulf, restoration efforts directed at sea turtles, marine mammals and coastal and marine birds can take many forms. Section 6.2.2., Nesting Habitats, outlines the need and opportunity to protect beaches, barrier islands and other habitats where birds and sea turtles nest. The following recommendations are offered as a representative sample of the strategies and actions that should be considered when addressing restoration needs for wildlife in the Gulf.

Recommendation: *Gather basic information on the status, biology and ecology of marine mammals, sea turtles and coastal and marine birds in the Gulf.*

Marine wildlife agencies throughout the Gulf should obtain essential biological and ecological information lacking for many wildlife species so that informed and coordinated conservation actions can be taken to protect or restore vulnerable, rare or threatened populations on at least an ecosystem (Gulf-wide) scale. Officials should obtain baseline data needed to determine stock structure, abundance, distribution, trends, health status and vital rates, such as survival and reproduction, which are currently insufficient for the majority of marine mammal species inhabiting the Gulf (Marine Mammal Commission, 2011). Principal recommendations developed by an expert panel for improving sea turtle population assessments should be implemented in the Gulf (National Research Council, 2010). For offshore marine avifauna, formal, long-term population and fishery bycatch surveys are lacking in the Gulf and should be a higher priority for researchers (C. Haney personal communication, 2011). Finally, officials should leverage existing multi-national research initiatives, such as the Gulf of Mexico Large Marine Ecosystem Project, or state-federal-private partnerships, such as the Gulf Coast Joint Venture, to collect data for use in developing management measures across jurisdictions.

Recommendation: *Implement existing recovery and management plans for threatened and endangered species and species of special conservation or management concern*

State and federal agencies should facilitate implementation of existing plans developed to help the recovery, management or conservation of marine wildlife that utilize Gulf waters or the Gulf Coast. For example, recovery plans already developed for threatened or endangered cetaceans (e.g., sperm whale), birds (e.g., piping plover) or sea turtles (e.g., Kemp's ridley) contain population recovery or management goals and threat-abatement strategies that officials should follow to rebuild or maintain sustainable population levels (NMFS, 2010; USFWS, 2003; USFWS & NMFS, 1992). For wildlife species of conservation or management concern, officials should ensure that populations remain at or above sustainable levels and coordinate across state, federal or international borders to achieve population-specific conservation goals.

Recommendation: *Evaluate threats to wildlife, such as marine debris, vessel strikes and artificial lighting on offshore platforms, and work to reduce threats, especially if deemed to be significant at the population level.*

Resource management agencies should collaborate across borders to assess and address human activities that threaten wildlife. Agencies should implement strategies to reduce threats to all wildlife, focusing initially and urgently on endangered or threatened marine mammals, sea turtles and coastal and marine birds. Officials should leverage existing government or non-governmental programs and collaborate with industry and the public to implement proven or practical mitigation or restoration strategies. For example, known marine debris hotspots should be a guide for developing strategies that reduce debris at the source or from pathways to the ocean. As another example, officials should strive to reduce bird collisions with Gulf oil and gas platforms by identifying and using bird-friendly artificial lighting that shows promising results in the North Sea (Russell, 2005; Poot et al., 2008).

6.6. SUSTAIN GLOBALLY COMPETITIVE GULF FISHERIES

Across the Gulf, commercial and recreational fishing industries are cultural and economic pillars. The Gulf generates annually more than $27 billion in economic activity through these industries while providing significant recreational opportunities for residents and visitors alike. Nearly 40 percent of the seafood landed in the contiguous U.S. comes from this region alone. Unfortunately, past unsustainable management and fishing practices have taken a toll on the region's fish populations, impacting not only the environment but also the economic health of coastal communities. Successfully restoring and sustainably managing fish populations will improve their resiliency and help them persevere in the face of natural or human-caused disasters (Gulf of Mexico Fishery Management Council, 2004). Moreover, the productivity and value of some key Gulf fisheries could be substantially higher when depleted fish populations are restored. Figure 6.9. illustrates how a rebuilt Gulf red snapper population can support a sustainable catch more than twice the 2010 allowable catch level.

Beyond their regional importance, healthy fisheries in the Gulf would help the commercial fishing industry compete more effectively in the global marketplace where buyers and consumers are increasingly interested in sustainably caught seafood of high quality. This trend presents opportunities for Gulf fisheries to help meet the demand for sustainable seafood through actions such as formal certification by the Marine Stewardship Council. Interest in sustainability is not limited to the commercial seafood industry, however. Gulf of Mexico charter-for-hire businesses are also taking steps to ensure that their sector is sustainably managed and provides recreational opportunities to residents and visitors.

6.6.1. NECESSARY INVESTMENTS IN SCIENCE, DATA COLLECTION AND MONITORING

Gaps in fisheries observation, monitoring, data collection and reporting represent a long-standing challenge to securing and maintaining sustainable fisheries in the Gulf of Mexico. Of the 42 managed reef fish species in the Gulf, roughly 75 percent of those species lack sufficient information for fishery managers to determine if the population is being caught at an unsustainable rate (i.e., overfished in a formal population assessment). Increasing both the number and frequency of fish population

assessments are needed to optimize science-based catch levels in order to end and prevent overfishing, provide adequate rebuilding plans and support long-term, sustainable management of valuable Gulf fisheries.

Restoration commitments that improve existing fisheries monitoring, data collection and reporting provide the means to increase fish populations, expand sustainable ecosystem services and improve direct economic benefits to Gulf communities and businesses. Regional fishery scientists and managers have repeatedly emphasized the importance of improving the accuracy, reliability and timeliness of collecting and reporting at-sea fisheries data for management decisions and assessments of fish population health. More robust, accurate and timely information on catch, discards, bycatch and status of fish populations would reduce uncertainty inherent in management decisions and enable managers to be more precise and effective in maintaining healthy fisheries and the fishing opportunities they support. For example, when commercial reef fish long-line vessels needed to reduce their interactions with protected sea turtles, NMFS closed an area of the Gulf to all long-line fishing where interactions were known to occur. If fishery managers had more complete data on the actual number of sea turtle-and-vessel interactions documented by onboard video observation technology, the closure might have been smaller or avoided entirely. Instead, managers were forced to rely on less-precise bycatch estimates, and the margin of error necessarily led to more conservative fishery closure decisions.

Significant advancements in technology and improved survey methods provide an opportunity to address these long-standing issues. Investments in fishery monitoring techniques, such as electronic fishing logbooks and video monitoring—two priorities identified in the Gulf Council's five-year research plan—and more frequent private angler catch and effort surveys, can play valuable roles in supplementing investments in traditional fishery observation programs. These innovations can provide a cost-effective means of producing more

timely records of what fishermen catch and discard. For example, video cameras used in the Pacific hake fishery to monitor compliance with the rule that all catch (target and nontarget species) be retained for dockside sorting of bycatch species has decreased discarding at a much lower cost than traditional human observers and has resulted in more efficient at-sea catch handling (Alaska Fisheries Science Center, 2008). In the recreational fishery, electronic logbooks on for-hire vessels, more frequent private angler field surveys, timely processing of logbook and angler survey data and other advancements in data collection would provide more timely information for management and improve catch estimates. These improvements would help the private angler and for-hire fisheries maximize fishing opportunities while helping to ensure that catch levels are sustainable.

A GEM-type program, as described in Section 6.3., is a possible source of funding to support pilot projects examining the performance of novel fisheries data collection methods and technologies. Operations or data processing costs associated with full implementation and use of new and improved fisheries data collection tools should be part of the cost of doing business and would therefore be the responsibility of fishery managers and the fishing industry.

Investing in fisheries restoration can also improve the sustainability and economic viability of Gulf fishing businesses. Investments in fishing gear that reduce the catch of nontarget marine life can improve both fuel efficiency and product quality. Additionally, practices that optimize fishing performance can aid the industry in transitioning to sustainable fisheries and lasting success.

Recommendation: *Improve fishing opportunities and increase economic benefits through investments in fisheries science and monitoring.*

State and federal fishery agencies can help facilitate fishery recovery and sustainability in the Gulf by seeking improvements in science, data collection and monitoring. The following types of restoration actions should be undertaken as part of this strategy:

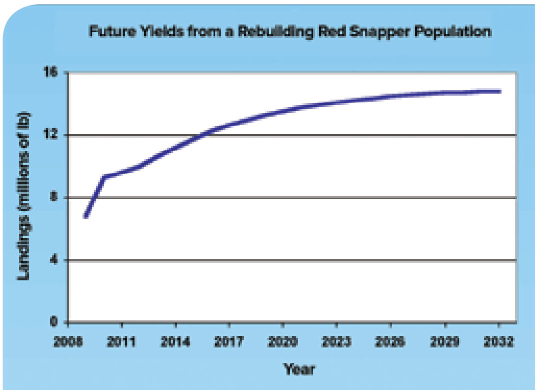


Figure 6.9. A fully rebuilt Gulf of Mexico red snapper population can support a sustainable catch more than twice the 2010 allowable catch level.

Source: National Marine Fisheries Service. 2009. Stock assessment of red snapper in the Gulf of Mexico–SEDAR update assessment, Report of the update assessment working group. Miami, FL. August 24-28, 2009.

- Facilitate in-season reporting and monitoring of fishing quotas by implementing more effective and timely at-sea data collection tools for commercial fishing and for-hire recreational vessels;
- Improve the at-sea documentation of discarded fishes through video monitoring or expanded observer coverage;
- Increase managers' ability to monitor in-season recreational quotas through more timely monitoring of fisheries in order to optimize management and prevent quota overruns; and
- Expand fishery-independent surveys and fishery population assessments to monitor the health of the region's fish populations.

6.6.2. INVESTMENTS IN INNOVATIVE FISHING GEAR AND PRACTICES

Fishery restoration investments have another facet as well. Best management practices and innovations in fishing gear can improve the sustainability and economic viability of Gulf fisheries. Investments in fishing gear can reduce catch of nontarget marine life, increase fuel efficiency (Fig. 6.10.) and improve product quality. In addition, adoption of best practices that optimize fishing performance can aid the Gulf fishing industry in transitioning

to sustainable fisheries and positioning itself for success. These technological and capacity innovations would help fishermen improve their environmental and economic performance in use of Gulf fishery resources in order to meet demand for sustainable products (Fig. 6.11.).

Recommendation: *Invest in gear technology and fleet performance initiatives that increase environmental and economic benefits.*

The following types of restoration actions should be undertaken as part of this strategy:

- Reduce bycatch and vessel-operating expenses while helping fishermen remain competitive by implementing or expanding gear conversion and technology transfer programs for the shrimp and reef fish fishing fleets; and
- Optimize fleet-wide fishing efforts and profitability by adopting market-based management approaches and enabling fishermen to exit the fishery through well-designed voluntary vessel or permit buyouts where overcapacity is an issue.

6.7. PROMOTE COMMUNITY RECOVERY AND RESILIENCY

Restoration of the Gulf ecosystem must address the needs of people who live and work in the region. The Gulf's coastal and marine habitats are rich with natural resources that support local residents' livelihoods, cultures and ways of life. Chronic environmental degradation of these natural resources, exacerbated by impacts from the BP oil disaster, compromises their economic value and environmental services to local residents, businesses and communities. In addition to economic mainstays, such as oil and gas extraction, shipping and tourism, the restoration and sustainable management of fish, wetlands, beaches, ocean habitats and wildlife are essential to the region's economic recovery, long-term prosperity and cultural identity.

Figure 6.11. *(left)* Bycatch reduction devices could mean less unwanted catch of non-target species, fewer crushed shrimp, faster sorting and expanded markets for shrimp product sourced sustainably.

Figure 6.10. Shrimp fishermen using steel cambered trawl doors combined with hydrodynamic nets experience significant fuel savings, less wear on engines and lower maintenance costs.

Some of the key coastal- and marine-based pillars of the regional economy—tourism, recreation, commercial and recreational fishing and seafood processing—cannot recover and prosper without restoring the underlying ecosystem services and natural resources that support them. Similarly, coastal communities with mixed subsistence economies—reliant on seafood and other biological resources not only for cash income but also for direct, noncommercial support of families, particularly in the Mississippi River Delta—are exceptionally at risk due to persistent land loss, natural disasters and, most recently, impacts from the BP oil disaster. In addition to communities with mixed subsistence economies, low income, minority, immigrant and other socially vulnerable communities generally face greater difficulties in recovering from events such as the BP oil disaster.

Recovery of industries and communities is directly related to sustained investments in environmental restoration that promote natural resource replenishment, ecosystem health and coastal resistance to erosion, subsidence and sea-level rise (Wamsley et al., 2009; Templet & Meyer-Arendt, 1988). Well-designed projects to restore natural resources and uses of resources will make the greatest restoration contribution if they utilize local businesses that train and employ local labor. In that way, projects not only restore ecosystem services, they also provide direct economic benefits to affected communities.

Protected Areas of the U.S. Gulf of Coast & Waters

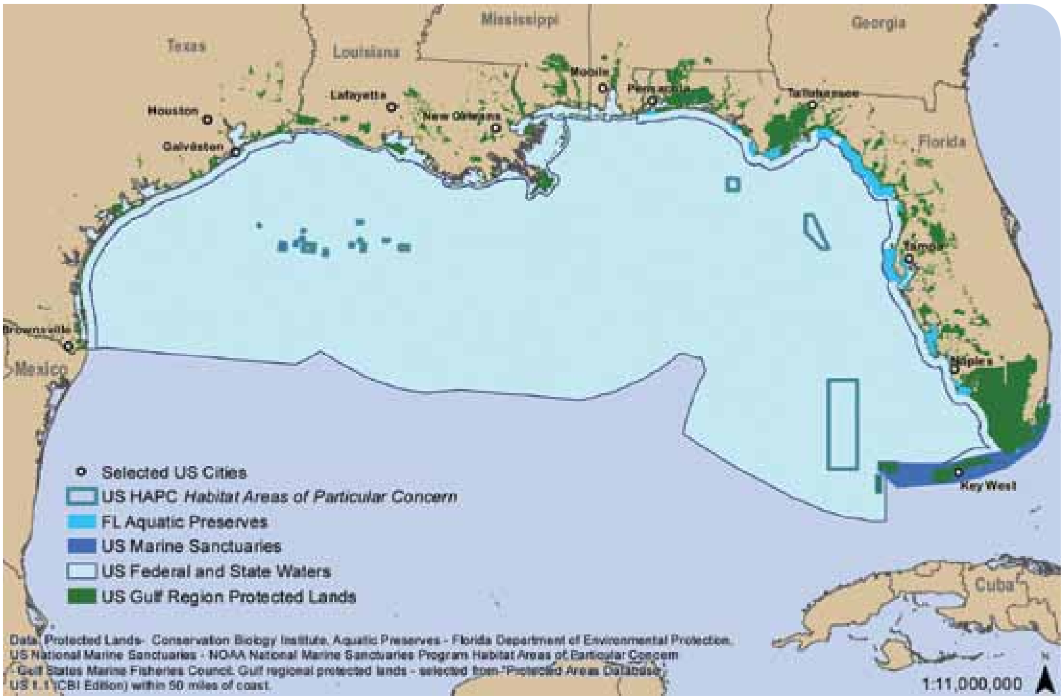


Figure 6.12. Natural areas managed for conservation around the Gulf attract tourists and residents alike who participate in wildlife watching, fishing, hunting or other forms of recreation that support local economies.

More broadly, environmental restoration could help revitalize coastal communities by creating new jobs and business opportunities in sustainable industries. A restoration economy is driven by the reality that natural resources and the services they provide are truly economic assets. A specialized workforce and technological advances in water management, improved fishing gear, green building, sustainable and safe energy development, disaster mitigation and oil spill preparedness and response should be part of this restoration economy.

6.7.1. TOURISM, RECREATION AND RECREATIONAL FISHING

The Gulf's inviting beaches, abundant wildlife, natural areas, locally-caught seafood and cobalt-blue offshore waters are defining characteristics that draw visitors. Overall, the Gulf region's tourism and recreation industry supports more than 620,000 jobs that yield more than $9 billion in wages paid each year (Gulf of Mexico Alliance, 2008). The annual value of the region's tourism industry is $35 billion (Yoskowitz, 2009), which represents 19 percent of the tourism industry nationwide. Restoring the coastal landscape and marine resources will improve the region's ability to deliver quality recreational opportunities and help build the Gulf's reputation as a top ecotourism and recreation hub.

Gulf beaches draw more than 21 million visitors per year. Wildlife watchers in the Gulf states (including eastern Florida) spend nearly $7 billion on trip-related expenses each year, while hunters and anglers spend approximately $16 billion (U.S. Department of the Interior & U.S. Department of Commerce, 2006). Out of an estimated 12.5 million hunters in the U.S., 2.3 million (18 percent) do some hunting in the Gulf states. The Gulf accounts for 28 percent of total recreational fishing trips in the U.S. According to a NOAA fisheries-economics study (2008), the $998 million in direct expenditures by recreational anglers generated more than $12 billion in sales and supported more than 113,000 jobs throughout the Gulf region. State and federally-managed coastal and marine nature preserves, such as Sabine and Breton national wildlife refuges, Gulf Island National Seashore and the Florida Keys National Marine Sanctuary, receive more than 7.5 million visitors annually. Across the Gulf, there are more than 150 state and federal natural resource areas, which are located in coastal counties and parishes. These areas include some of the nation's oldest refuges and preserves, created in the 1930s to protect and enhance migratory bird habitats (Fig. 6.12.).

Recommendation: *Restore, expand or enhance public-use areas and amenities.*

Recognizing that natural resources and amenities drive a multibillion-dollar tourism industry throughout the Gulf, and that their associated ecosystem services or human uses were impacted by the BP oil disaster, governments at the local, state and federal level should implement the following steps:

- Maintain or enhance the ecological integrity of state and federally-managed natural areas (e.g., parks, wildlife preserves, refuges and management areas), and expand or make them more accessible to enhance recreational opportunities and experiences;
- Improve infrastructure along beaches to enhance user accessibility and experiences as well as to protect sensitive plant communities and nesting habitats (e.g., boardwalks, dune walkovers and interpretive signage); and
- Create public fishing infrastructure, piers, boat launches, marinas and fish-cleaning stations that promote mixed natural resource uses in a sustainable manner.

6.7.2. COMMERCIAL FISHING AND SEAFOOD

Commercial fishing is a key industry that shapes not only the economy but also the way of life in the region. The total annual dockside value of fishery products at ports throughout the Gulf is more than $600 million, generating more than $10 billion in sales and supporting more than 213,000 jobs. In terms of dockside value, Louisiana led the region in 2009, followed by Texas, Florida (Gulf region), Alabama and Mississippi.

It is critical to the success of the commercial fishing industry that the health of the Gulf ecosystem is managed for biological diversity, productivity and resiliency so it can continue to supply much of the nation's domestic seafood. Following the *Exxon Valdez* oil spill, Alaska's seafood industry made

significant efforts to regain lost market share and promote Alaska seafood. In global markets, farmed salmon made headway after the *Exxon Valdez* oil spill, effectively undercutting Alaska's wild salmon. The Alaska Seafood Marketing Institute helped improve product quality and later embraced Marine Stewardship Council certification as part of a strategy to recover lost market share. The Gulf fishery could benefit from a similar initiative as Gulf shrimpers, for example, face a parallel problem from a glut of cheap imports.

Recommendation: *Enable the fishing industry to modernize and become more competitive through gear conversions, investments in product quality and improved marketing.*

Fishery managers, the Gulf Congressional delegation and the seafood industry can help fishermen make this transition by implementing or supporting the following measures:

- Promote fishing gear upgrades and best practices that reduce bycatch and fuel costs, and make fishermen more competitive by improving the quality of the catch;
- Invest in new monitoring, traceability and reporting tools to promote better data management and increase consumer confidence in seafood integrity and sustainability;
- Position Gulf seafood for regaining or expanding market share through a coordinated effort to promote Gulf seafood; and
- Invest in product quality technologies, systems and best handling practices.

6.7.3. SUBSISTENCE AND MINORITY FISHING COMMUNITIES

Thousands of families along the Gulf Coast make their livings from fishing, oyster harvesting and shrimp trawling. These families are Native American, African American, Caucasian, Cajun, Vietnamese, Cambodian, Lao, Croatian and Mexican, among others. The continuing economic and environmental damage from the BP oil disaster has affected all of these groups and comes on the heels of other injuries inflicted by natural and human-created causes, such as Hurricane Katrina and ongoing wetlands loss. As one example, the Houma Nation, with 17,000 members, many of whom are dependent on subsistence fishing,

experienced hardship following the BP oil disaster because of fishery closures and lost confidence in seafood safety. Alaska Native communities experienced similar impacts following the *Exxon Valdez* oil spill.

It is important to accelerate the recovery of subsistence and minority fishing communities by increasing the availability and quality of natural resources that sustain them, and by increasing their communities' confidence in resources they consume. Modernizing fishing gear could reduce operating costs, increase fishing safety and help limit impacts on sensitive habitats important to fish species. Employment of local residents in restoration activities (discussed in Section 6.7.), as well as use of local and traditional knowledge in designing those projects, are also essential for recovery of these communities. Providing new economic opportunities in restoration will enhance and diversify their economic base.

Recommendation: *Promote recovery and long-term health of subsistence and minority fishing communities.*

State legislatures and agencies, as well as Congress and federal agencies, could promote the recovery of these communities by taking the following actions:

- Modernize fishing gear to reduce operating costs, increase fishing safety and help limit the impact on sensitive habitats and species important to local fisheries;
- Fund and implement fishing gear conversion packages to minimize environmental impacts;
- Implement a long-term seafood safety monitoring program in subsistence fishing communities, and train local workers to conduct testing;
- Restore fishing, crab and oyster grounds in areas with high concentrations of subsistence users; and
- Provide natural flood protection to reduce disaster risk to socially vulnerable communities.

6.7.4. RESTORATION WORKFORCE, INDUSTRIES AND INNOVATION

Coastal communities, including those with socially vulnerable residents, could benefit if worthy projects are implemented with preference given for local businesses and workers to carry out restoration projects. Development of skills and intellectual capital through training and participation in implementation of Gulf restoration projects will provide the foundation for a restoration economy serving long-term needs in the Gulf and other places (Gordon et al., 2011).

Recommendation: *Engage local businesses and train and employ a local Gulf workforce in the implementation of projects.*

- Utilize existing training funds, including National Emergency Grant funds, to provide skills training and job placement for underemployed fishermen and disadvantaged local workers in restoration projects;
- Give incentives in restoration projects through procurement rules for contractors to develop plans and partnerships for training and hiring local underemployed fishermen and disadvantaged workers;
- Use procurement rules to give preferences to businesses headquartered or primarily located along the Gulf Coast, including set-asides based on federal benchmarks for small and disadvantaged businesses;
- Invest in public-private partnerships for training and placing local workers in ecosystem restoration projects, including development of industry certifications for restoration-related occupations targeting underemployed and disadvantaged workers;
- Develop partnerships between industry and community-based organizations and fishing associations to identify and place workers in restoration projects; and
- Invest in public-private Centers of Excellence to commercialize innovations in water management and ecosystem restoration, including technology transfer programs, incubators, seed funds and entrepreneurial training.

6.8. IMPLEMENTING RESTORATION: THE PATH TO A HEALTHIER GULF AND REGIONAL RECOVERY

The Gulf of Mexico is a national treasure, yet the region faces enormous economic, social and environmental challenges. Given the importance of the Gulf and its natural resources to the U.S., the nation should step forward, invest in the region and help it secure an economically prosperous and sustainable future through restoration and enhancement of its natural resources. For example, the Gulf Coast is retreating in many places due to human activities and natural factors. The nation should invest in and implement sustainable, creative solutions to arrest and reverse land loss in the Mississippi River Delta if local communities are to survive and thrive. The same is true across the Gulf, whether in Alabama, Florida, Louisiana, Mississippi or Texas: the Gulf Coast is poised for renewal through strategic and significant investments in coastal and marine restoration.

The region's economic renewal is directly related to the success of ecological restoration and the long-term health of coastal and marine resources so critical to the prosperity of coastal communities. One of the greatest opportunities for a sustainable and sustained economic recovery that is in keeping with the region's marine-based economy and way of life is its working waterfronts. The Gulf's working waterfronts have a history and legacy that must be revitalized, not only to support traditional industries—shipping, shipbuilding, fishing and seafood processing—but also to accommodate new marine enterprises and infrastructure that enhance public access and ecosystem resiliency.

The restoration strategies discussed in this chapter are a guide for decision-makers seeking how best to spend limited dollars on specific projects with collective impacts that will put the region back on the path to ecological health and economic renewal. Now the challenge is to ensure that the financial resources for restoration are directed toward high-value projects based on the principles and criteria described in Chapter 2. The American people, on whose behalf state and federal agencies are undertaking restoration, are ultimately the clients of restoration. As such, the public—particularly local communities dependent on the resources or services the Gulf provides—is entitled to a transparent and participatory process that reflects their vision and values for a fully restored, healthy Gulf of Mexico.

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Key Species and Habitat Profiles

The species and habitats described below were selected to represent the biological diversity from the Gulf of Mexico. As information becomes available, Ocean Conservancy will track the status of these resources with respect to impacts of the BP oil disaster and use them as indicators of impact on and recovery of the Gulf of Mexico ecosystem. Beyond the effects of the BP oil disaster, the status of these species and habitats also generally reflects the quality and condition of the Gulf of Mexico ecosystem.

BIRDS

Black Skimmer *(Rynchops niger niger)*

LIFE HISTORY AND DISTRIBUTION

Black skimmer males are slightly larger than females, weighing 369 grams (13 oz) compared to 272 grams (9.6 oz). On average, black skimmers are 46 centimeters (18 in) in length. The lower mandibles (bottom part of the bill) is longer than the upper mandible. As black skimmers fly, they skim the water with their lower mandible to catch small fish. Once the lower mandible touches a fish, the upper mandible snaps down instantly; this foraging style distinguishes them from other birds. Black skimmers are social birds. They nest in colonies and often with other species, such as laughing gulls or gull-billed terns. These colonies are located on beaches, gravel or shell bars, dredge deposition islands, salt marshes, and sometimes rooftops. They construct simple surface scrapes as their nests, and females lay between 2 and 5 eggs. Black skimmers breed along both the Pacific and Atlantic coasts of the U.S. On the Atlantic, their summer breeding range is from Massachusetts and Long Island south to the coast of Florida, and extends into the Gulf Coast and Mexico. During the winter, they can be found as far north as North Carolina and extend into southern Mexico. Black skimmers are found year-round along the Gulf of Mexico in Texas, Louisiana, Mississippi, Alabama and Florida. Skimmers consume small fishes and small crustaceans.

THREATS FROM OIL

As oil and tar balls wash onto islands and marshes, black skimmers are susceptible to oil exposure. Oil exposure on breeding and roosting areas would mean displacement and potential oil contamination of black skimmers. Oiled feathers can cause matting and loss of feather integrity, which can cause death or delayed negative impacts on health. Black skimmers also can be exposed to oil while feeding, if their beaks are fouled with oil or they directly ingest oil as they skim the sea surface for food. The impacts of eating oil-contaminated fish by hatchling and adult black skimmers are not fully understood. Cleanup efforts can disturb black skimmers by interrupting breeding and nesting activities, which could lower reproductive success.

BP OIL IMPACTS

As of May 12, 2011, the USFWS has recorded 55 black skimmers (51 dead) with visible oiling and another 193 dead black skimmers with either no visible oiling or the presence of oil unknown.

The specific impacts of the BP oil disaster on black skimmers will remain unknown until the NRDA and independent research results are released.

BIRDS

Brown Pelican *(Pelecanus occidentalis)*

LIFE HISTORY AND DISTRIBUTION

Adult brown pelicans grow to 1.4 meters (54 in) in length and weigh 3.6 to 4.5 kilograms (8-10 lb) with a wingspan of up to 2.3 meters (7.5 ft). Brown pelicans are the only pelicans that are plunge divers, plunging into the water to catch fish. The peak of their egg laying is March through May in most of their nesting area in the U.S., which extends from South Carolina to Florida in the east, into southern California in the west and along Alabama, Louisiana, Mississippi and Texas in the Gulf. Conservation efforts, such as reintroduction programs and managed nesting islands, have helped reestablish brown pelican populations in some areas of the U.S. The species was removed from the federal endangered species list in 2009, but the states of Louisiana and Mississippi still classify their populations as endangered, and Texas lists its population as threatened. Brown pelicans use the Gulf states for breeding and wintering and are found in warm coastal marine and estuarine environments, which range from protected islands to waterfronts and marinas. Pelicans are primarily fish-eaters and consume 4 pounds of fish a day.

THREATS FROM OIL

Oil contamination on breeding and roosting areas can mean displacement and oil contamination of pelicans. Since they are plunge divers, pelicans can encounter oil from surface slicks. Incubating birds that become oiled can transfer oil from breast feathers to eggs, which can reduce hatching success.

BP OIL IMPACTS

As of May 12, 2011, the USFWS has recorded 339 brown pelicans (152 dead) with visible oiling and another 425 dead brown pelicans with either no visible oil or the presence of oil unknown. The USFWS has also counted 187 live brown pelicans with visible oiling and 149 with unknown oiling, which may have been rehabilitated and released.

The specific impacts of the BP oil disaster on brown pelicans will remain unknown until the NRDA and independent research results are released.

Clapper Rail *(Rallus longirostris)*

LIFE HISTORY AND DISTRIBUTION

Clapper rails have flattened bodies, enabling them to slip between the reeds and tall marsh grasses. They are 36 to 41 centimeters (14-16 in) long and weigh approximately 272 grams (9.6 oz). Male clapper rails are territorial throughout the year and are especially aggressive during the breeding season. During the summer, clapper rails inhabit salt and brackish marshes containing open water. In the winter, clapper rails may rely on denser vegetation, elevated parts of the marsh or more mature plants. They are nocturnal, making them difficult to observe; they seldom fly and are good swimmers. Clapper rails have a wide distribution. They can be found along North America's Atlantic and Gulf coasts, ranging from New Jersey south to the Gulf of Mexico and islands in the western Caribbean. On the West Coast, distribution is patchy from San Francisco Bay to Baja California. Clapper rails are omnivores and locate their prey by sight and perhaps by smell. Their diet consists mostly of crustaceans, such as crabs, shrimp, clams and mussels. They also consume small fish, insects, seeds, birds' eggs and slugs.

THREATS FROM OIL

Clapper rails may encounter oil on the water surface or on marsh vegetation, and oiled plumage can result in death or reduced survival. Rails may consume oiled prey or experience problems if the presence of oil reduces the density of their prey. If oil penetrates deep into marsh vegetation and sediments, rails may continually be re-exposed to oil as long as it is present in the marsh.

BP OIL IMPACTS

As of May 12, 2011, the USFWS has recorded 29 clapper rails (27 dead) with visible oiling and another 84 dead clapper rails with either no visible oil or the presence of oil unknown.

The specific impacts of the BP oil disaster on clapper rails will remain unknown until the NRDA and independent research results are released.

BIRDS

Common Loon *(Gavia immer)*

LIFE HISTORY AND DISTRIBUTION

A characteristic feature of the common loon is its bright red eyes. To be efficient swimmers and deep divers, their large, powerful webbed feet are placed far back on their bodies. Unlike most birds, which have hollow, light bones, loons have solid bones. Typically, an adult weighs between 3.6 and 5.5 kilograms (8-12 lb) and has a wingspan of up to 1.5 meters (58 in). Since their bodies are heavy compared to their wing size, loons require a 31- to 183-meter (100-600 ft) runway to take off from water. Loons are waterbirds and typically come to shore only to mate and incubate eggs. During the spring, usually in April or early May, loons return to the northern forested lakes and rivers to breed. In the winter, loons can range up to 100 kilometers (62 mi) offshore across the continental shelf, but they are commonly found along inland coastal waters, such as bays, channels, coves and inlets. Common loons spend a portion of their winter in the Gulf of Mexico. Their diet consists of fish, mollusks, amphibians and insects.

THREATS FROM OIL

Loons are highly vulnerable to encountering oil in nearshore surface waters. As divers, loons also can encounter oil at different water depths. When faced with oil slicks, they dive rather than fly, which increases the risk of being oiled. Common loons could experience loss or contamination of their food sources due to oil and dispersants. Cleanup efforts could displace the loons from their preferred habitats.

BP OIL IMPACTS

As of May 12, 2011, the USFWS has recorded 39 common loons (33 dead) with visible oiling and another 28 dead common loons with either no visible oil or the presence of oil unknown.

The specific impacts of the BP oil disaster on common loons will remain unknown until the NRDA and independent research results are released.

Least Tern *(Sternula antillarum)*

LIFE HISTORY AND DISTRIBUTION

Least terns are 13 to 20 centimeters (8-9 in) in length and weigh approximately 28 grams (1 oz). Their wingspan is about 51 centimeters (20 in). Least terns prefer to nest on sand and gravel beaches. They also nest on riverine sandbars, mudflats and sometimes gravel rooftops. They forage in shallow-water habitats, which include bays, lagoons, estuaries, river and creek mouths, tidal marshes and ponds. On the Atlantic Coast they breed from Maine to Argentina. They also nest in the Great Lakes region in Michigan, Minnesota, Wisconsin and Ohio, and in the Missouri River drainage. During the winter, terns can be found in the Gulf of Mexico and Central America to Peru and Brazil. To capture food, a tern hovers from 1 to 10 meters (3-32 ft) over the water and plunges through the surface to capture its prey. A least tern's diet consists mainly of small fishes as well as crustaceans and insects.

THREATS FROM OIL

Because least terns depend on beaches for nesting habitat, they and their eggs are at risk of being oiled. While foraging in shallow-area habitats, least terns can consume oil directly or through eating oil- and dispersant-tainted prey. Any loss of prey species from oil or dispersant exposure may limit available food sources for terns. During cleanup efforts, human disturbance can cause terns to abandon their nests, which might result in a smaller offspring year class.

BP OIL IMPACTS

As of May 12, 2011, the USFWS has recorded 49 least terns (46 dead) with visible oiling and another 55 dead least terns with either no visible oil or the presence of oil unknown.

The specific impacts of the BP oil disaster on least terns will remain unknown until the NRDA and independent research results are released.

BIRDS

Northern Gannet *(Morus bassanus)*

LIFE HISTORY AND DISTRIBUTION

Northern gannets are large seabirds with an average total length of 1 meter (39 in) and a wingspan of up to 2 meters (70 in). These birds can descend into plunge dives from 10 to 40 meters (33-130 ft) in the air. They can dive as deep as 22 meters (72 ft) in the water, using their feet and wings to propel forward to catch fish. Gannets live most of their lives at sea, coming to land only to breed. During the breeding season, northern gannets form loud, dense colonies, where breeding adults are thought to form lifelong monogamous pairs. These colonies tend to be on remote and inaccessible coastal cliffs, stacks, steep slopes and islands. During the first 3 years of their lives, northern gannets typically remain at sea year-round. These juveniles will return to breeding areas, where they will spend several years in colonies as nonbreeders. At 5 to 6 years of age, they reach maturity and obtain a nest site in preparation for breeding. In the U.S., the overall winter range for northern gannets at sea extends from the continental shelf in New England to south along the Atlantic Coast to Florida, and west along the coast of Texas to the northeastern part of Mexico. They consume squid and a variety of schooling fishes.

THREATS FROM OIL

Since northern gannets spend a majority of their time at sea and dive deep into the ocean in pursuit of fishes, they are at risk of exposure to oil and dispersants at and below the surface. Subadult gannets remain in the Gulf longer than do mature adults, which migrate north to breed in March and April. As a result, subadult gannets would be especially vulnerable due to their prolonged stay in contaminated waters.

BP OIL IMPACTS

Northern gannets are among the birds most clearly impacted by the BP oil disaster. The first documented oiled bird was a young northern gannet rescued off the coast of Louisiana. As of May 12, 2011, the USFWS has recorded 297 northern gannets (225 dead) with visible oiling and an additional 129 dead northern gannets with either no visible oil or the presence of oil unknown.

An ornithologist at Memorial University of Newfoundland used recent research with satellite tags to suggest that thousands of northern gannets are at risk since they migrate to the Gulf annually.

The specific impacts of the BP oil disaster on northern gannets will remain unknown until the NRDA andindependent research results are released.

Royal Tern *(Sterna maxima maxima)*

LIFE HISTORY AND DISTRIBUTION

Royal terns have an average length of 0.5 meter (18 in), a wingspan of about 1.2 meters (4 ft), and weigh approximately 0.5 kilogram (1 lb). Adults possess long orange bills and full black caps that form spiky crests at the backs of their heads. As the nesting season progresses, their foreheads become whiter and remain so through the nonbreeding season. From April to July, royal terns breed in large colonies on barrier islands and other isolated locations near the coast. Royal terns typically lay one egg per year. They can form dense nesting colonies, numbering in the thousands. Year-round, royal terns are associated with warm marine waters and tend to forage close inshore. They use the Gulf region for both breeding and wintering grounds. As plunge divers, they forage over shallow inshore salt water, which is 10 to 20 meters (33-65 ft) deep. Their main diet consists of fishes and shrimp.

THREATS FROM OIL

By plunging into the water to capture their meals, royal terns can encounter oil at or below the ocean surface and in the water column. Oiled royal terns that are incubating may transfer oil to their eggs or young. Royals terns may eat tainted fishes or regurgitate them to feed their chicks, but the consequences are largely unknown.

BP OIL IMPACTS

As of May 12, 2011, the USFWS has recorded 149 royal terns (116 dead) with visible oiling and an additional 123 dead royal terns with either no visible oil or the presence of oil unknown.

The specific impacts of the BP oil disaster on royal terns will remain unknown until the NRDA and independent research results are released.

CRUSTACEANS

Blue Crab *(Callinectes sapidus)*

LIFE HISTORY AND DISTRIBUTION

The blue crab is a type of crustacean with 5 pairs of legs, the fifth pair being oar-like swimming legs. The shell is drawn out into a large spine. The blue crab's brownish-green carapace (shell) is approximately 18 centimeters (7 in) wide from point to point, and 10 centimeters (4 in) long. The blue crab supports one of the largest commercial and recreational fisheries in the Gulf. In 2008, 2.1 million kilograms (46.6 million lb) of blue crab were caught in the Gulf of Mexico and sold dockside for $40.2 million. Blue crabs are keystone species that play a critical role in the ecosystem as both prey and predator. Blue crabs, at all life stages, are important food sources for a variety of animals. Mating typically happens in brackish water from February to November. Spawning usually occurs during the spring and summer. As the eggs develop and are ready to be released, females migrate offshore in search of saltier water and offshore currents. Blue crabs are bottom dwellers in every type of habitat and thought to be widely distributed in Gulf estuaries. Blue crabs are opportunistic feeders, meaning they consume what is readily available.

THREATS FROM OIL

Blue crab adults and larvae could be exposed to oil and dispersants on the sea surface, in the water column and on the sea floor. These impacts may be lethal or sublethal. Direct contact with oil and dispersants would most likely be lethal to larval crabs. Also, if oil contamination reduces the fertility of adult female crabs, the number of future spawns would be reduced. Consuming contaminated phytoplankton and other food sources is another risk of oil exposure. Marine invertebrates can accumulate polycyclic aromatic hydrocarbons (PAHs) for years. Long-term effects of PAHs in crabs can lead to behavioral changes in feeding and affect reproduction. This can have ecological food-web consequences.

BP OIL IMPACTS

Thousands of blue crab megalopae (second stage in crab larval development) with unusual orange droplets trapped under their carapaces were collected in the Gulf following the BP oil disaster. The occurrence of these droplets is apparently unprecedented. Scientists at the University of Southern Mississippi have done a preliminary analysis that indicated the presence of petroleum and Corexit dispersant in the orange droplets. Research is being conducted to determine the source of the orange droplets and the impacts of this substance on the developing larvae.

The specific impacts of the BP oil disaster on blue crabs will remain unknown until the NRDA and independent research results are released.

CRUSTACEANS

Brown/White Shrimp *(Farfantepenaeus aztecus/Litopenaeus setiferus)*

LIFE HISTORY AND DISTRIBUTION

Brown shrimp have reddish-brown shells and dark green and red tail-fan appendages. They typically grow to 23 centimeters (9 in) in length. White shrimp reach up to 25 centimeters (10 in) in length, and their shell color ranges from white to greenish-gray. Brown and white shrimp have similar life cycles. They both reproduce in the offshore waters of the Gulf, usually in waters deeper than 14 meters (45 ft). Brown shrimp are most abundantly caught in May, June and July. White shrimp are most abundantly caught in August, September and October. Post-larval brown and white shrimp are carried inshore by currents and then use vegetated habitats, such as sea grasses, algae, marshes and mangroves for feeding and growing to maturity. Brown shrimp are most abundant in the northern and northwestern Gulf off Louisiana, Texas and east coast of Mexico. White shrimp are most abundant in areas with extensive estuarine marshes and in the Mississippi River Delta of Louisiana. The Gulf is the largest regional shrimp producer in the U.S. For 2008, the dockside value for shrimp from the Gulf states was about $366 million. Both brown and white shrimp are omnivorous scavengers. They are also important prey for many species.

THREATS FROM OIL

Brown and white shrimp have a high probability of being exposed to oil in the water column and are experiencing shrinking habitat due to the loss of coastal wetlands throughout the Gulf. It is possible that bottom trawling may chronically resuspend oil if it occurs in areas with oiled sediments. Shrimp are able to metabolize PAHs, but their metabolites could cause sublethal effects. Shrimp are an important food source for many species, so impacts on shrimp populations have the potential to impact animals that consume them.

BP OIL IMPACTS

Portions of the Gulf federal and state fishing waters were closed to shrimp fishing during the 2010 season. This had a negative economic impact on the fisheries, and recovery of the fishery may be slow due to persistent consumer perceptions about the safety of Gulf seafood. The total economic and ecological impacts to brown and white shrimp are unknown.

The specific impacts of the BP oil disaster on brown and white shrimp will remain unknown until the NRDA and independent research results are released.

Royal Red Shrimp *(Hymenopenaeus robustus* or *Pleoticus robustus)*

LIFE HISTORY AND DISTRIBUTION

Adult royal red shrimp are sexually dimorphic. Females reach a total length of about 20 centimeters (8 in) and males a total length of approximately 15 centimeters (6 in). They reach maturity at about 3 years and have a maximum lifespan of about 5 years. Royal red shrimp are found in areas with blue and black mixtures of sand, silt, mud and a gritty white calcareous mud. They are found in habitats where sediment is being carried offshore, such as where major rivers empty into the sea. More specifically, they can be found near the Dry Tortugas, which contain white calcareous mud and the blue and black silt of the Mississippi River Delta. These shrimp have been observed among deep-sea corals. The range of royal red shrimp is estimated to be along the continental shelf between 80 and 730 meters (590-2,395 ft), while most shrimp are found between depths of 250 and 475 meters (820-1,558 ft). Royal reds are distributed throughout the Gulf and along the Atlantic coast from Cape Cod, Massachusetts, to French Guiana in South America. More specifically, within the Gulf, royal red shrimp are found off Florida and in the northeastern Gulf.

THREATS FROM OIL

Royal red shrimp inhabit a large geographic area and occupy deep-sea habitats. They may be exposed to oil and dispersants in the water column or on the seafloor. Lack of information on the biology and populations status of this shrimp species complicates understanding possible oil impacts.

BP OIL IMPACTS

On November 20, 2010, a fishermen caught royal red shrimp that were contaminated with semisolid tar balls. In response, NOAA closed 10,912 km^2 (4,213 miles)federal waters off the coast of Louisiana to royal red shrimp fishing. Samples of royal red shrimp, along with other shrimp species and reef and pelagic finfish from specific areas, underwent sensory and chemical testing in December 2010 and January 2011, and were determined to be safe for human consumption.

The specific impacts of the BP oil disaster on royal red shrimp will remain unknown until the NRDA and independent research results are released.

FISHES

Bluefin Tuna *(Thunnus thynnus)*

LIFE HISTORY AND DISTRIBUTION

Atlantic bluefin tuna can grow to 3 meters (10 ft) in length and weigh more than 635 kilograms (1,400 lb). They are highly migratory and can be found at depths of 488 to 1006 meters (1,600-3,300 ft). In the Gulf, western Atlantic bluefin tuna mature at 8 years of age. Spawning occurs in surface waters. A long-lived species, bluefin tuna can reach lifespans of 40 years. They have a wide geographic distribution: In the western Atlantic, bluefin are found from the Gulf of Mexico to Newfoundland. In the eastern Atlantic, they are found from the Canary Islands to south of Iceland and throughout the Mediterranean. Bluefin tuna can be found in the Gulf from January to June, and spawning peaks in April and May. Although bluefin are distributed throughout the Gulf, there are two spawning hotspots. One is in the northwestern Gulf; the other is in the northeastern Gulf, which overlaps with the area oiled by the BP oil disaster. Both hotspots are along the slope where the shallow continental shelf depth changes rapidly to the deep sea. Bluefin tuna are opportunistic feeders, commonly consuming fishes, squid and crustaceans.

THREATS FROM OIL

After hatching, larvae search for food close to the surface and have a high likelihood of contact with oil. Low levels of exposure to oil would likely be fatal for the larvae. This means the oil spill could severely reduce an entire year class of the population. The impact of the spill might be a tipping point in creating a non-recoverable population. The oil spill might cause stress and induce behavior changes that reduce spawning frequencies or reproductive success.

BP OIL IMPACTS

In the spring of 2009, Tag-A-Giant researchers tracked an Atlantic bluefin tuna in the Gulf. The data indicate that part of their spawning habitat overlapped with oil from the BP oil disaster. The timing of the spill coincided with the peak spawning time for bluefin tuna.

Using the European Space Agency's and NASA's satellite data that documents the extent of surface oiling and simulated bluefin spawning habitats and larval development, researchers estimate that exposure to oil reduced the number of juvenile bluefin tuna in the 2010 year class by more than 20 percent.

The specific impacts of the BP oil disaster on bluefin tuna will remain unknown until the NRDA and independent research results are released.

Bull Shark *(Carcharhinus leucas)*

LIFE HISTORY AND DISTRIBUTION

Bull sharks have robust bodies and blunt, rounded snouts. Coloration is typically pale to dark gray on the dorsal side, fading to white on the underside. Generally, females are larger than males, averaging 2.5 meters (7.8 ft) and weighing about 129 kilograms (285 lb). Males grow to an average length of 2.2 meters (7.3 ft) long and weigh 95 kilograms (209 lb). Bull sharks inhabit the continental shelf waters to a depth of about 150 meters (492 ft), but prefer to live in shallow coastal waters less than 30 meters (100 ft) deep. They are commonly found in estuarine and fresh water, such as lagoons, bays and river mouths. Bull sharks are common in state waters in the northern Gulf, especially near the mouth of the Mississippi River. They have a large nursery area in coastal and inland waters of Louisiana. Bull sharks are apex predators—animals that reside at the top of their food chain and have no natural predators. A significant decrease in or loss of their population could affect the entire food web. Bull sharks consume fishes, stingrays, juvenile sharks, turtles, birds, dolphins, terrestrial mammals, shrimp, crabs and squid.

THREATS FROM OIL

As an apex predator, bull sharks could consume oil-tainted prey, such as oiled birds, which could have sublethal impacts on their health. Since some of their important nursery habitat is in areas of Louisiana that were oiled, pups and juvenile sharks could be exposed to oil, and females could be forced to bear young in suboptimal habitats.

BP OIL IMPACTS

There were anecdotal reports that bull sharks were found closer to shore than normal when the BP oil was released into the Gulf.

The specific impacts of the BP oil disaster on bull sharks will remain unknown until the NRDA and independent research results are released.

FISHES

Gulf Menhaden *(Brevoortia patronus)*

LIFE HISTORY AND DISTRIBUTION

Adult Gulf menhaden are 13 to 20 centimeters (5-8 in) in length. They are fast-swimming fish with modified gill structures to enhance feeding efficiency. As juveniles and adults, Gulf menhaden are omnivorous filter feeders that consume phytoplankton and organic detritus. In the spring, menhaden larvae between 3 and 5 weeks old enter estuaries, nearshore rivers, bays and other nearshore habitats to mature. Optimal nursery habitats for larval and juvenile Gulf menhaden are estuaries with extensive marsh (greater than 405 hectares [1,000 acres]). Juvenile Gulf menhaden spend their first summer in nearshore waters and migrate offshore in late fall to spawn. From December to February, they are caught in the northern Gulf between 4 and 48 fathoms west and east of the Mississippi River Delta. Gulf menhaden form large, dense schools, usually comprised of individuals of similar size and age class, near the surface. The majority of Gulf menhaden landings occur in Louisiana and Mississippi with a smaller quantity from Texas and Alabama waters. In 2008, approximately 420 million kilograms (927.5 million lb) of Gulf menhaden were landed in the U.S. and valued at about $64.4 million.

THREATS FROM OIL

Early life stages, such as eggs, post-larval and juvenile menhaden, are vulnerable and may be killed outright if they come into direct contact with oil. Menhaden also may be affected if oil results in reductions of the plankton on which they feed.

Experience with Pacific herring following the *Exxon Valdez* oil spill may be relevant to menhaden. In Alaska, it was documented that oil killed embryos in eggs or caused abnormalities in young of the Pacific herring. The lingering effects of the spill likely contributed to the collapse of the herring population in Prince William Sound four years after that spill.

BP OIL IMPACTS

The distribution of menhaden in the nearshore and coastal waters of the Gulf make them vulnerable to impacts from BP oil. The specific impacts of the BP oil disaster on menhaden will remain unknown until the NRDA and independent research results are released.

Red Drum *(Sciaenops ocellatus)*

LIFE HISTORY AND DISTRIBUTION

Red drum, a popular game fish, derive their name from their reddish hue and the drum-like sound produced by males through vibrating a muscle in their swim bladders during spawning. The lifespan of red drum is 20 to 30 years, and they can reach a maximum length of 1.5 meters (5 ft) and weigh 45 kilograms (100 lb). The spawning season occurs from mid-August to mid-October in Gulf waters near the mouths of estuaries and inlets. Larvae find food and shelter in sea grass and brackish marshes. As they mature, red drum move to the Gulf and will generally remain in this area. Young red drum feed on small crabs, shrimp and marine worms. As they grow older, they feed on larger crabs, shrimp and small fishes. They are generally bottom feeders but will feed in the water column when the opportunity arises.

THREATS FROM OIL

Red drum eggs and larvae can become contaminated with oil through direct contact, absorption of oil dissolved in water or consumption of tainted food. Juveniles might become contaminated in estuaries, while adults can encounter oil in deep waters in the Gulf.

BP OIL IMPACTS

The specific impacts of the BP oil disaster on red drum will remain unknown until the NRDA and independent research results are released.

FISHES

Red Snapper *(Lutjanus campechanus)*

LIFE HISTORY AND DISTRIBUTION

Red snapper are pinkish red in color with light-colored or white undersides. They can reach a maximum length of 1 meter (39 in) and weigh up to 23 kilograms (50 lb). Spawning occurs from May through October, peaking July through September. Spawning grounds are in shelf-edge environments of moderate to high structural relief. New red snapper recruits search for benthic habitats, including open habitats (e.g., muddy or sandy flats) and structured habitats (e.g., rock outcroppings), from late June until September. As adults, they are bottom dwellers and usually reside near natural and artificial structured habitats (e.g., ledges, caves, artificial reefs, oil rigs and the like) in the deep waters of the continental shelf. It is thought that red snapper exhibit site fidelity, but recent evidence suggests that red snapper in the eastern Gulf might display lower site fidelity than previously estimated. Red snapper are found from North Carolina to the Florida Keys and throughout the Gulf of Mexico. As adults, they consume prey found near the ocean floor, such as crab, shrimp, squid, octopus and small fishes. Currently, Gulf red snapper are classified as overfished, with the size of the population well below what scientists consider healthy.

THREATS FROM OIL

Since red snapper are bottom-dwelling fish, they can be exposed to oil in the water column or on the seafloor. There is the potential for lethal exposure or extended, sublethal effects in adult and immature fish.

Red snapper eggs and larvae are particularly susceptible to oil at or just below the surface. The eggs are buoyant, floating on the water surface for 20-27 hours after fertilization and before hatching. The developing larvae can occur anywhere from surface waters to several hundred feet below the surface.

BP OIL IMPACTS

In April 2011, some red snapper caught in the oil spill area had severe fin rot (particularly on their anal fins), dark lesions on their skin, discoloration or striped skin and enlarged livers, gallbladders or bile ducts. Researchers have hypothesized that these fish have secondary bacterial and parasitic infections due to a compromised immune system. This reduced immune system might result from chronic exposure to a toxin, which could have stemmed from the BP oil disaster. Research continues to track the locations and frequency of fishes with these abnormalities, and to determine what causes them.

The specific impacts of the BP oil disaster on red snapper will remain unknown until the NRDA and independent research results are released.

Whale Shark *(Rhincodon typus)*

LIFE HISTORY AND DISTRIBUTION

Whale sharks, the world's largest fish, can grow to 14 meters (45 ft) in length. They use a suction filter-feeding method, drawing water into their mouths at high velocities. The surface portions of their bodies are grey, blue or brown with white spots between vertical and horizontal stripes, which gives the whale shark a unique checkerboard color pattern. Researchers think that female whale sharks reach sexual maturity at 25 to 30 years of age and have found that they are ovoviviparous, bearing live young with a litter size of over 300 pups. These sharks prefer warm waters with surface temperatures between 21 and 30 degrees Celsius (70-86 degrees F) and with high primary productivity, meaning abundant amounts of plankton. They are primarily surface swimmers, but can also be found in deep waters far from land. They seasonally enter shallow water areas near estuaries and river mouths, which may be feeding or breeding and birthing grounds. Whale sharks are distributed throughout the Gulf of Mexico, with the highest concentrations off the Louisiana Mississippi River Delta. They consume a variety of planktonic prey, such as small crustaceans, fishes and occasionally tuna and squid.

THREATS FROM OIL

Because whale sharks are surface swimmers and feed on plankton and small pelagic fish, they can ingest oil and dispersants. Oil can clog their gills, which results in the inability to extract oxygen from the water. Whale sharks reach sexual maturity at a late age, produce a small number of young and grow slowly, so their rate of recovery would be slow.

BP OIL IMPACTS

The BP Deepwater Horizon disaster released oil into an area designated as essential fish habitat for whale sharks, increasing their chances of oil exposure. Whale sharks were spotted swimming in oiled water. It is not known if they are able to detect oil and dispersants, but their presence in oiled areas indicates that they cannot.

The specific impacts of the BP oil disaster on whale sharks will remain unknown until the NRDA and independent research results are released.

MARINE MAMMALS

Bottlenose Dolphin *(Tursiops truncatus)*

LIFE HISTORY AND DISTRIBUTION

Bottlenose dolphins range from 2 to 4 meters (6-12.5 ft) in length, with males being larger than females. Adults weigh between 136 and 635 kilograms (300-1,400 lb) and are long-lived animals with a lifespan of about 50 years. Bottlenose dolphins are mammals, meaning they are endothermic, give birth to live young and produce milk to nourish their offspring. On average, mature females give birth every 3 to 6 years. Bottlenose dolphins usually travel in groups of 2 to 15 individuals. Offshore, bottlenose dolphins often travel in groups of several hundred individuals. These dolphins live around the world in tropical and temperate ocean waters in both inshore habitats, such as harbors and bays, and offshore habitats, such as the deep waters of the inner continental slope. In the Gulf, bottlenose dolphins can be found from coastal waters to the continental slope. They have well-developed hearing and locate and capture food by echolocation. They feed on a variety of prey items, such as fishes, squid and crustaceans, including shrimp.

THREATS FROM OIL

Bottlenose dolphins can be exposed to oil in the water column or as they swim to the surface to breathe air. Their blowholes can become clogged with oil, leading to suffocation. Severe oil exposure can result in death. There also are concerns about the impacts of oil exposure on pregnant dolphins, which could cause miscarriages or otherwise harm fetuses. Previous oil spills show that bottlenose dolphins do not know how to avoid and leave extensive oil-covered areas. Dolphins also can eat contaminated prey, with unknown effects.

BP OIL IMPACTS

According to NOAA, from February 2010 to July 3, 2011, 445 stranded dolphins were found along the Gulf Coast. As of April 7, 2011, 15 of the dolphins had oil on their bodies, and eight of these had oil specifically linked to the BP oil disaster. From January to July 2011, there have been 222 dead dolphins, 85 of them premature, neonatal or stillborn calves. It is important to note that the 445 dolphins were reported as part of an ongoing unusual mortality event, which started prior to the disaster. However, the stranding that occurred after the oil release needs to be fully evaluated to determine the cause of death. In addition, despite the presence of BP oil on the dolphins, researchers need to determine whether the oil was the cause of death or a contributing factor.

The specific impacts of the BP oil disaster on bottlenose dolphins will remain unknown until the NRDA and independent research results are released.

Bryde's Whale *(Balaenoptera edeni)*

LIFE HISTORY AND DISTRIBUTION

Bryde's whales have 250 to 350 baleen plates—fibrous hair-like plates that are about 0.4 meter (16.5 in) long and are used to filter food—on each side of their mouth. Bryde's whales grow to about 12 to 17 meters (40-55 ft) in length and weigh approximately 40,823 kilograms (90,000 lb). Their heads are about 25 percent of their bodies' lengths. Typically, females breed every second year. Bryde's whales usually dive for about 5 to 15 minutes. They are found worldwide in tropical, subtropical and warm temperate waters from 16 to 22 degrees Celsius (61-72 degrees F). The 2009 best population estimate for Bryde's whales in the northern Gulf of Mexico was 15. This small population of Bryde's whales lives in the shelf-break region in the northeastern Gulf and consumes pelagic fishes, such as mackerel, herring, mullet and anchovies. They also feed on cephalopods and pelagic crustaceans, such as krill. Typically, Bryde's whales rely more heavily on fishes than crustaceans. Their feeding methods include skimming the surface, lunging and creating bubble nets.

THREATS FROM OIL

Bryde's whales can swim and resurface in water containing oil. They rely on prey that can become contaminated with oil. Oil in the water column can foul their baleen, potentially compromising the whale's ability to feed.

BP OIL IMPACTS

The specific impacts of the BP oil disaster on the Bryde's whale will remain unknown until the NRDA and independent research results are released.

MARINE MAMMALS

Sperm Whale *(Physeter macrocephalus)*

LIFE HISTORY AND DISTRIBUTION

Adult male sperm whales can grow to 16 meters (52 ft) in length and weigh as much as 40,823 kilograms (45 tons). Adult females grow to approximately 11 meters (36 ft) and weigh 13,608 kilograms (15 tons). Sperm whales have a large, blunt heads with small, underslung jaws. These whales, federally listed as endangered, can dive for longer than an hour. Sperm whales may live as long as 70 years and have low recruitment rates. They can be found in nearly all marine waters deeper than 1,000 meters (3,280 ft) that are not covered with ice, with the exception of the Black Sea and Red Sea. Adult males typically occupy higher latitudes and will migrate toward lower latitudes occasionally to breed. Females and juveniles generally remain in tropical, subtropical and temperate regions. In the northern Gulf, sperm whales are present in all seasons. They are especially common near the Mississippi Canyon. In 2009, the best estimated sperm whale population for the northern Gulf was 1,665. Since they spend a majority of their time in deep waters, sperm whales forage mainly on or near the ocean bottom, consuming giant and colossal squids.

THREATS FROM OIL

Sperm whales risk being exposed to oil and dispersants when they forage on or near the ocean floor and dive from the sea surface through the water column. The effects of oil on sperm whales depend on the nature of the oil and the type and duration of exposure. The noise and disturbance associated with oil spill response activities, such as vessel traffic, can be equally harmful.

BP OIL IMPACTS

At least 2 dead sperm whales have been reported from April 30, 2010 to April 17, 2011 in the area defined as the designated spill area.

The specific impacts of the BP oil disaster on sperm whales will remain unknown until the NRDA and independent research results are released.

West Indian Manatee *(Trichechus manatus)*

LIFE HISTORY AND DISTRIBUTION

The West Indian manatee, federally listed as an endangered species, has a large, seal-shaped body with paired flippers and a round, paddle-shaped tail. An average adult is about 2.7 meters (9 ft) long and weighs 454 kilograms (1,000 lb). While calving peaks in the spring, calves may be born at any time of the year. Manatees are mammals found in marine, estuarine and freshwater environments within tropical and subtropical regions. They prefer habitats where fresh water is periodically available to reduce osmotic stress and slow-moving, shallow waterways provide access to the coast where consumable vegetation can be found. In waters colder than 20 degrees Celsius (68 degrees F), manatees are more susceptible to cold stress and cold-induced mortality. Manatees migrate seasonally to adapt to changing water temperatures. When water temperatures rise during the summer (April to September), most manatees travel extensively along the Gulf Coast as far west as Texas and into rivers and canals. They often use secluded canals, creeks and lagoons near the mouths of coastal rivers for feeding, resting, mating and calving. Manatees are herbivores that feed opportunistically on a wide variety of plants, especially sea grass.

THREATS FROM OIL

As oil moves near shore, manatees may swim through oil on or below the surface of the water. Oil can contaminate and damage sea grass beds and other vegetation that manatees eat. Sea grass beds also may be injured during response activities by boat propellers, as was the case in the Deepwater Horizon oil disaster response effort.

BP OIL IMPACTS

Manatees are widely distributed along the Gulf Coast during the summer and were observed in oil- impacted areas.

The specific impacts of the BP oil disaster on manatees will remain unknown until the NRDA and independent research results are released.

MOLLUSKS

Eastern Oyster *(Crassostrea virginica)*

LIFE HISTORY AND DISTRIBUTION

Eastern oyster reefs provide refuge and foraging habitats for many juvenile and adult finfish and invertebrates, such as crabs and shrimp. Eastern oysters are also important filter feeders, improving water quality by reducing the amount of suspended material and associated contaminants in the waterways. This improved water quality enhances the growth of sea grasses and other vegetation. Eastern oysters are protandric, meaning they first mature as males and then usually change to females later in life. There are a number of factors that determine the sex of an oyster, such as the sex and proximity of nearby oysters and environmental and nutritional stresses. During a spawning season, a single female can release 10 to 100 million eggs. The duration of the spawning season varies, depending on water temperature, salinity and physiochemical interactions. Spawning is seasonal and typically occurs in the summer. Within hours of eggs being fertilized, eastern oyster larvae develop shells and begin to move on their own. After developing through several free-swimming larval stages, an oyster larva seeks an appropriate substrate on which to attach itself. Once the larva locates a suitable substrate, it undergoes metamorphosis during which morphological changes enable the oyster to become permanently attached to the substrate.

Eastern oyster reefs are located in intertidal environments, such as shallow saltwater bays, lagoons and estuaries. Their range extends from the Gulf of St. Lawrence in Canada through the Gulf to the Bay of Campeche, Mexico, and to the West Indies. In the Gulf, oysters occur mostly at depths of 0 to 4 meters (0-12 ft). In 18 to 24 months, oysters reach harvest size, 7.6 centimeters (3 in) in length. The favorable environmental conditions in the Gulf enable oysters to grow throughout the year. The Gulf region provides two-thirds of the nation's commercial Eastern oysters. In 2008, oystermen from the five Gulf states took 9.4 million kilograms (20.7 million lb) of oysters and sold them dockside for $60 million.

THREATS FROM OIL

Oysters can be smothered and killed by oil. Eastern oysters are indicators of the health of estuarine habitats and can be used to monitor the presence of PAHs, heavy metals and persistent pesticides in the water.

BP OIL IMPACTS

As a precautionary measure during the BP disaster, Louisiana and Alabama temporarily closed portions of their oyster fishing areas. In addition, oysters in Louisiana were damaged from the influx of fresh water created by the opening of freshwater diversions in order to move oil away from the Gulf's shores. The long-term impacts on oyster beds are unknown, but the economic impacts of oyster mortalities and closed fishing areas are being felt by Gulf oyster fishermen. NRDA research by NOAA and state agencies, as well by independent researchers, is under way to monitor and determine the impacts to Gulf oyster beds.

TURTLES

Kemp's Ridley Sea Turtle *(Lepidochelys kempii)*

LIFE HISTORY AND DISTRIBUTION

The Kemp's ridley sea turtle is federally listed as an endangered species. From May to July, large numbers of female Kemp's ridleys come ashore in a synchronous nesting event called an *arribada*, a Spanish term for "arrival." Many Kemp's ridleys congregate to nest on a specific beach near Rancho Nuevo, Mexico, and a smaller cohort of turtles nest on Padre Island National Seashore in Texas. Waves of females come ashore in the spring and summer to lay clutches of approximately 100 eggs in burrows that they dig on the beach. Each female will participate in a nesting season once every 1 to 3 years, coming ashore one to three times in that season. During the first 2 years of life, Kemp's ridleys depend on sargassum for foraging, protection and rest. In contrast, adult Kemp's ridleys primarily live in the ocean's neritic zone, which is an area that spans from shallow depths at the low tide mark to 198 meters (650 ft) at the edge of the continental shelf. Kemp's ridleys inhabit areas throughout the Gulf of Mexico and U.S. Atlantic seaboard, ranging from Florida to New England. A significant proportion of the adult male Kemp's ridley population may reside in the vicinity of nesting beaches year-round in the Gulf. Outside of the nesting areas in Mexico and Texas, the major habitats for Kemp's ridleys are the near- and inshore waters of the northern Gulf, especially Louisiana waters. These turtles are often found in salt-marsh habitats. As adults, their diet consists mainly of swimming crabs but may also include fishes, jellyfish, mollusks and some algae.

THREATS FROM OIL

Due to their presence in the Gulf at all life stages, the Kemp's ridley's potential exposure to oil and dispersants within the water column is high. Potential impacts include mortality, sublethal stress and chronic impairment, including potential deleterious effects on reproduction and recruitment. Floating mats of sargassum can easily become contaminated with and retain oil. These mats provide critical habitat for juveniles, which would be exposed to oil at a sensitive early life stage. Juvenile and adult Kemp's ridleys are also at risk of exposure from potentially ingesting oil and dispersant-contaminated sargassum and crabs.

BP OIL IMPACTS

Scientists found scores of dead juvenile Kemp's ridleys floating among oil-fouled debris in the deep ocean. From April 30, 2010 to February 15, 2011, 481 dead Kemp's ridleys were recovered in the Gulf. Five nests were relocated from the Gulf to the Atlantic Ocean to prevent hatchling exposure to oil and dispersants. At Padre Island National Seashore, scientists are collecting blood from nesting females and testing embryos for evidence of exposure to hydrocarbons. Currently, there are 115 Kemp's ridley sea turtle nests on Padre Island National Seashore.

As of July 18, 2011, 199 Kemp's ridley turtle nests, a record number, were found along the Texas coast. This number is up from the 139 nests in 2010 and from the 197 nests in 2009. In July 2011, the upper Texas coast set a record as well, with 22 nests found from the Matagorda Peninsula to Sabine Pass. Most were found on Galveston Island, which also set a record with 15 nests. However, near Rancho Nuevo in Mexico, scientists counted between 18,000 and 20,000 nests this year. This number is up from the 13,000 nests from 2010, but still below the 22,000 nests recorded in 2009. Although the increase in nests along the Texas coast is a good sign, the effects of the BP oil disaster could take years to surface.

The specific impacts of the BP oil disaster on Kemp's ridleys will remain unknown until the NRDA and independent research results are released.

HABITATS

Deepwater Corals

LIFE HISTORY AND DISTRIBUTION

Deepwater corals have slow growth rates and are found at depths of 49 to 1,999 meters (160-6,560 ft). Little is known about their feeding mechanisms or the timing and methods of their reproduction. Instead of containing zooxanthellae—symbiotic algae that provide food through photosynthesis for tropical, shallow-water corals—the polyps of deepwater corals appear to be suspension feeders that capture organic detritus and plankton from the strong, deep-sea currents. They vary from small, solitary colonies to large, branching, tree-like structures, and are typically found along rocky ledges or in narrow regions where currents are strong, such as seamounts, ridges, pinnacles and mounds. Deepwater corals provide critical habitat and reproductive grounds for commercially important species. Deepwater corals encircle the Gulf of Mexico, with known locations including the South Texas Banks, the Mississippi and Alabama Pinnacles, Pulley Ridge off Florida and some spots off Cuba and Mexico.

THREATS FROM OIL

Little to no research has been done on oil impacts to deep-sea corals, but concerns would include smothering by oil and toxic effects of oil and dispersants in the water column.

BP OIL IMPACTS

About 11 kilometers (7 mi) southwest of the Macondo wellhead, scientists discovered a brown substance covering *Callogorgia americana*, a type of gorgonian soft coral, in an area measuring 15 to 40 square meters (50–130 sq. ft). The gorgonians were dead or dying, with large areas missing tissue or had tissue falling off the skeleton. In an area about 400 meters (~.25 mi) away, a colony of *Madrepora* species, a type of hard coral, was partially covered with a similar brown substance and producing abundant mucous. Laboratory analysis of the corals and sediments will determine if the brown substance is associated with BP oil.

The specific impacts of the BP oil disaster on deepwater corals will remain unknown until the NRDA and independent research results are released.

HABITATS

Marine Soft Sediments

LIFE HISTORY AND DISTRIBUTION

Marine soft sediments generally consist of sand, silt, clay or mud. Soft sediments are inhabited by a variety of organisms. Diatoms reside on the sediment surface in intertidal and subtidal zones. In tropical and temperate areas, sea grasses are rooted in soft sediment. Soft sediments are complex habitats, where physical and biological elements, ranging from sunlight intensity to sediment mixing by invertebrates, interact to change the sediment composition. Annelid worms create tube structures within the substrate, and organisms, such as sea pens, project above the surface, altering the water flow, and as a result, the sediment structure. Benthic organisms living within the soft sediment feed on microscopic algae and organic detritus falling onto the sediment surface. The physical composition of marine soft sediments varies tremendously, depending on the area. For example, deep-sea sediments are primarily composed of silica-based materials, such as dead diatoms and other microscopic organisms; beach sediments tend to be sandy; and estuaries have sediments that tend to be muddy. The continental shelf sediments can be anywhere on the spectrum, depending on water currents and nearby landmasses. Marine soft sediments cover most of the seabed, also known as the ocean floor. In the Gulf of Mexico, away from areas of seepage, the majority of the continental slope is soft sediment and has a diverse benthic and pelagobenthic fauna.

THREATS FROM OIL

The concentrations of oil in sediment that are toxic to benthic organisms are not well characterized in the deep Gulf of Mexico.

After the 1979 Ixtoc 1 oil disaster in the Bay of Campeche in Mexican waters of the Gulf, it was estimated that as much as 25 percent of the released oil sank and was unaccounted for after that. Three months after the blowout, however, NOAA researchers documented concentrations of oil in benthic sediments as high as 10,000 parts per million near the well. Such concentrations are likely toxic to a variety of benthic organisms. Unfortunately, there was little done in the way of long-term studies following the Ixtoc 1 disaster, so nothing is known about the persistence of biological effects.

BP OIL IMPACTS

As is evident by the oiled sand and tar balls that continue to wash up, some oil remains on the shallow seafloor close to Gulf coastlines, and it may remain there for some time. However, the status of the deep seafloor environment is difficult to assess, and researchers have contrasting interpretations of whether there is oil on the seafloor.

A scientist at Louisiana State University believes that most of the oil remains dispersed as tiny particles in the water column. A microbial expert at the Lawrence Berkeley National Laboratory found only 6 percent of 1,440 core samples from 120 different sites in the Gulf had any level of contamination. In contrast, a researcher from the University of Georgia made early reports that the seafloor in the vicinity of the Macondo well was covered in a brown material, and suggested that the substance was probably linked to the BP oil disaster. Soft sediment samples still need to be tested to confirm the presence of BP oil.

The specific impacts of the BP oil disaster on marine soft sediments will remain unknown until the NRDA and independent research results are released.

HABITATS

Salt Marshes

LIFE HISTORY AND DISTRIBUTION

Salt marshes are transitional areas between land and water, occurring along the intertidal shores of estuaries and sounds. They are also characterized by low-energy coasts. The marsh's substrate is composed of mud and peat—decomposing plant material that is often several feet thick. Because salt marshes are submerged by tides and contain decomposing plant matter, the peat can have low oxygen levels. The salinity, temperature, oxygen levels and frequency and extent of flooding of the marsh controls the types of plants and animals found in that habitat. Salt marshes first form when a seed or raft of a smooth cordgrass (*Spartina alterniflora*) arrives, and then spreads vegetatively through rhizomes (horizontal stems). Over time, the *Spartina* becomes dense and collects sediment and peat, causing the habitat to become more terrestrial and enabling plants that are less tolerant of salt to invade. Overall, salt marshes have high productivity and low species diversity.

Generally, marshes are divided into two areas: low marsh and high marsh. The low marsh, located along the seaward edge of the salt marsh, is generally flooded at high tide and exposed during low tide. The predominant plant in the low marsh area is *Spartina*, which is very tolerant of daily flooding and sun exposure. Although few animals consume *Spartina*, it is an important habitat for many animals and plants that live on it and in the marsh's substrate, which is well protected by its roots. The decayed form of *Spartina* provides nourishment for many species. As tidal water advances into the marsh and then retreats, it carries in nutrients that stimulate plant growth and redistributes plant detritus throughout the estuary, which feeds fishes and other organisms. The high marsh area is generally flooded only during storms and unusually high tides, but its soil is mostly saturated.

Young fishes forage for food on the mud bottom of the marsh and on plants. Another salt-marsh resident, the fiddler crab (*Uca rapax*), aids in *Spartina* growth by burrowing and aerating the sediment. Fiddler crabs consume algae, bacteria, fungus and detritus, and are also a food source for a number of animals. Mysid shrimp (*Americamysis bahia*) are small, shrimp-like crustaceans found primarily in the Gulf of Mexico and the eastern coast of Florida. Mysid shrimp act as indicators of marsh recovery because they die at much lower levels of hydrocarbon contamination than do other organisms. Salt marshes occur worldwide, particularly in middle to high latitudes. More specifically, they can be found along the Atlantic and Gulf of Mexico coasts, ranging between 25 degrees and 42 degrees N latitude. Salt marshes are found along many north Florida estuaries, and the entire coast of Louisiana is occupied by extensive salt marshes.

THREATS FROM OIL

Marshes are located in areas of low wave action, meaning oil will not easily be broken up and dispersed by waves. Oil buried in the anoxic mud of marshes will not degrade. Hence, oil may persist in marsh habitats for a long time. Marsh plants can be smothered by oil, but the plants may sprout again from their roots. If oil has penetrated deeply into marshes, and especially into the underlying peat and sediments, it can be reintroduced into the environment with the tides or during storms. In turn, the fishes and wildlife that live in the marsh can be exposed to oil on a repeated or chronic basis.

In places where marsh vegetation is damaged by contact with oil or by response activities, there may be increased erosion.

BP OIL IMPACTS

Gulf-wide, approximately 747 kilometers (464 mi) of salt marsh experienced some level of oiling. In Louisiana alone, about 702 kilometers (436 mi) of salt marsh were oiled, and roughly 132 kilometers (82 mi) of those were heavily oiled. The total area and impact to salt marshes will be better understood as ongoing research and NRDA results are released.

HABITATS

Sargassum

LIFE HISTORY AND DISTRIBUTION

Sargassum, a type of brown seaweed, floats in surface waters in island-like masses. It undergoes vegetative reproduction, a type of asexual reproduction, in which new plants grow from vegetative parts. Sargassum has low nitrogen and phosphorus requirements and exhibits optimal growth in water with temperatures of 24 to 30 degrees Celsius (75-86 degrees F) and salinity of 36 ppt. Researchers hypothesize that the seaweed starts growing each year between March and June in the northwest Gulf of Mexico and dies about a year later in the Atlantic, in an area of the Sargasso Sea northeast of the Bahamas. Sargassum acts as an important nursery habitat for many species, increasing early life survival. Sargassum offers larval and juvenile fishes and juvenile sea turtles protection from predators. Some commercially important fishes found suspended in sargassum include larval and juvenile yellowfin tuna, wahoo, marlin, gray triggerfish and amberjacks. As this seaweed washes up to Gulf beaches, the organisms living in the sargassum provide food for shorebirds and gulls.

THREATS FROM OIL

The same winds and currents that move the oil at the water's surface also move sargassum, an important floating habitat. Sargassum is very vulnerable to oiling. Aquatic species that depend on sargassum might have a reduced survival rate as a result of oil exposure. The greatest impacts are likely on the organisms that depend on sargassum as a nursery habitat in their early life stages.

BP OIL IMPACTS

Pelagic algal mats were in direct contact with oil and dispersants, and were probably burned during response efforts. The effects of oil exposure on the algal mats and the animals that depend on them will be better understood when the NRDA and independent research results are released. Long-term data on this ecosystem is limited, and this habitat is free-floating, which makes quantifying impacts difficult.

Sea Grass

LIFE HISTORY AND DISTRIBUTION

Sea grasses are flowering plants that grow and reproduce in the marine environment. Similar to terrestrial plants, they possess leaves, roots, flowers and seeds, and use photosynthesis as their source of energy. To reproduce underwater, sea grasses produce filamentous pollen grains that are transported by water currents. Sea grasses often occur in areas with low to moderate current velocities. Light availability, water clarity, water temperature, salinity, sediment composition, nutrient levels, wave energy and tidal range affect the growth of sea grass. Many of the bays and lagoons in Florida and Texas and, to a lesser extent, Mississippi, have beds of sea grass. Sea grass beds provide food, shelter or protection from predators for waterfowl, fishes and invertebrates. They also act as nursery areas for juvenile fish and invertebrates, which are often of commercial and recreational importance. Beds of sea grass act as buffers against storm surges and helps improve water quality by stabilizing sediments with their roots. Sea grasses are primary producers—organisms with the capacity to produce organic compounds from inorganic material, supporting the base of the food web.

THREATS FROM OIL

As oil comes ashore, it can adhere to sea grass, smothering the plant. Unless the underlying sediments are heavily oiled, sea grasses have the capacity to grow new leaves. Based on the observations of three specific sea grass species in the northwestern part of the Persian Gulf, researchers concluded that the studied sea grasses did not experience acute or long-term degradation from the Gulf War oil disaster, which released an estimated 0.5 to 8.0 million barrels of oil. This highlights the possible resilience of sea grasses, though the organisms that depend on the sea grass blades and use sea grass beds as nurseries are susceptible to the impacts of the oil.

BP OIL IMPACTS

Boom placement by oil response vessels along shorelines and across smaller bays and estuaries in Louisiana, Mississippi, Alabama and Florida resulted in damage to sensitive, shallow sea grass habitats. Boat bottoms and propellers scarred sea grass beds and removed sediment. NOAA has identified sea grass beds as a priority for early restoration. Currently, teams are surveying the extent of the damage to sea grass beds and forming restoration plans.

The specific impacts of the BP oil disaster on sea grass beds will remain unknown until the NRDA and independent research results are released.

HABITATS

Shallow-Water Corals

LIFE HISTORY AND DISTRIBUTION

Corals have no specialized organs or sensory systems. They obtain oxygen and expel waste through their thin living tissue. Most shallow-water corals have evolved to form a special symbiotic relationship with zooxanthellae, algae which supply corals with glucose, glycerol and amino acids through photosynthesis. These products allow corals to form skeletons, grow and reproduce, which they can do either sexually or asexually. Most corals reproduce during annual spawning events that are triggered by seawater temperature changes, the lunar cycle and time of day. Fragments of colonies broken by wave action or buds produced by individual polyps may re-cement and survive independently on the reef. Shallow-water coral reefs grow best in warm water between temperatures of 24 and 27 degrees Celsius (70-85 degrees F). Reef-building corals prefer clear, shallow water, where sunlight can penetrate to reach the coral's zooxanthellae. These reef-building corals are typically found in waters shallower than 70 meters (230 ft). They are most prolific in depths between 18 and 27 meters (60-88 ft), in tropical and subtropical waters. In the Gulf, the Florida Keys National Marine Sanctuary and the Flower Garden Banks National Marine Sanctuary both contain shallow-water corals. There are other shallow-water corals distributed elsewhere in the Gulf.

THREATS FROM OIL

The impacts of oil spills on coral reefs are difficult to predict since each spill presents a unique set of physical, chemical and biological conditions. The composition of the oil that comes in contact with the coral will determine the extent of the damage. Corals can come in direct contact with oil, be exposed to an oil-water mixture below the water surface or encounter weathered, sediment-associated oil, which could potentially smother them.

BP OIL IMPACTS

The specific impacts of the BP oil disaster on shallow-water corals will remain unknown until the NRDA and independent research results are released.

Acronyms

CFA	Charter Fisherman's Alliance
CWA	Clean Water Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CPRA	Coastal Protection and Restoration Authority
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FWC	Florida Fish and Wildlife Conservation Commission
GOMA	Gulf of Mexico Alliance
GEM	Gulf of Mexico Ecosystem Research and Monitoring Program for Adaptive Management
GRI	Gulf of Mexico Research Initiative
MMPA	Marine Mammal Protection Act
MBTA	Migratory Bird Treaty Act
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NSF	National Science Foundation
NRDA	Natural Resource Damage Assessment
SLD	Natural Resources-State Lands Division
NPRB	North Pacific Research Board
NPS	National Parks Service
OPA	Oil Pollution Act
OSLTF	Oil Spill Liability Trust Fund
ppt	parts per thousand
PAHs	polycyclic aromatic hydrocarbons
PEIS	programmatic environmental impact statement
RBSSA	Redfish Bay State Scientific Area
RESTORE	Resources and Ecosystem Sustainability, Tourist Opportunities and Revived Economies of the Gulf Coast States Act of 2011
PALs	preferred access lanes
SAV	submerged aquatic vegetation
SEFSC	Southeast Fisheries Science Center
TPWD	Texas Parks and Wildlife Department
USCG	United States Coast Guard
USGS	United States Geological Survey
USM	University of Southern Mississippi
USFWS	U.S. Fish and Wildlife Service

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OCEAN CONSERVANCY

For 40 years, Ocean Conservancy has brought scientists and citizens together to find solutions for a healthy ocean. We examine threats to the ocean and propose sound, practical policies that protect the ocean and its inhabitants as well as our own lives. We recognize that leadership means cooperation—among governments, businesses, scientists, policymakers, conservation organizations and citizen advocates.

www.oceanconservancy.org.

GULF RESTORATION AND FISHERIES PROGRAM

Ocean Conservancy's Gulf Restoration and Fisheries program is focused on the restoration of the Gulf of Mexico ecosystem. Ocean Conservancy has been addressing key threats facing the Gulf for more than two decades. Key accomplishments include successfully promoting the use of fishing gear that reduces incidental taking of Kemp's ridley sea turtles—which are federally listed as endangered—transforming regional fishery management systems to focus on science-based management plans that end overfishing and restore depleted fish populations and launching the largest global volunteer event of its kind—the International Coastal Cleanup. We are now combining our regional expertise with a seasoned team of *Exxon Valdez* oil spill experts to ensure the effective restoration and enhancement of the Gulf ecosystem and its dependent communities.

Cover: (Corbis images) Ocean Conservancy chose the cover image of a storm-damaged shrimp boat as a symbol of the myriad challenges that everyone who cares about the Gulf must address. This boat is also a symbol of hope. Just as Gulf coast communities have always come together after hurricanes to rebuild, Ocean Conservancy believes that by working together the people of the Gulf—and the nation–can restore this ecosystem to its rightful place as a national treasure and source of bounty for generations to come.

Ocean Conservancy