Natural Resource Damage Assessment
April 2012
Status Update
for the *Deepwater Horizon* Oil Spill

April 2012
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Executive Summary

On April 20, 2010, an explosion and fire on the mobile offshore drilling unit *Deepwater Horizon*, which was being used to drill a well for BP in the Macondo prospect (Mississippi Canyon 252 – MC252), killed 11 men and injured 17 others. The rig sank and left the well spewing tens of thousands of barrels of oil per day into the Gulf of Mexico. It is estimated that 5 million barrels (210 million gallons) of oil were released from the Macondo wellhead. Of that, approximately 4.1 million barrels (172 million gallons) of oil were released directly into the Gulf of Mexico over nearly three months.[1]

Under the Oil Pollution Act of 1990 (OPA),[2] those responsible for an oil spill are financially responsible for a variety of costs, including spill cleanup costs, increased costs of public services related to the spill, property damage related to the spill, compensation for public and private economic losses, and restoration of injured natural resources. While the U.S. Coast Guard is directing federal efforts to clean up the *Deepwater Horizon* oil spill, state and federal natural resource trustees are responsible for leading efforts to assess impacts to natural resources and to restore those injured resources to the condition they would have been in had the spill not occurred.

The Natural Resource Damage Assessment (NRDA) regulations,[3] under OPA, designate federal, state and tribal natural resource trustees[4] to conduct NRDAs on behalf of the public. Ultimately, the trustees have a mandate to restore, rehabilitate, replace or acquire the equivalent of the damaged natural resources.[5] To meet this mandate, the trustees seek to restore injured resources and services to baseline[6] (the condition they would have been in had the spill not occurred) and to compensate the public for interim losses (the losses that occur during the time it takes the resources to recover to baseline).

The *Deepwater Horizon* NRDA, given its geographic size, three-dimensional nature and ecological complexity, may continue for years. State and federal trustees are working together to determine how the oil spill affected the Gulf of Mexico's natural resources and the human use of those natural resources. With potential natural resource injury spanning five states and their waters, as well as federal waters, this is the largest damage assessment ever undertaken.

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[1] Oil Budget Team. Oil Budget Calculator Technical Documentation. November 2010. http://www.restorethegulf.gov/sites/default/files/documents/pdf/OilBudgetCalc_Full_HQ-Print_111110.pdf. While the official oil budget estimate is that 4.9 million barrels of oil were released from the well, approximately 820,000 barrels were siphoned directly from the wellhead into a holding tank on the surface, resulting in approximately 4.1 million barrels being released into the environment.

[2] 33 U.S.C. § 2701 *et seq*.

[3] 15 C.F.R. § 990 *et seq.*

[4] *Trustees* (or *natural resource trustees*) means those officials of the federal and state governments, of Indian tribes, and of foreign governments designated under 33 U.S.C. § 2706(b) of OPA. 15 C.F.R. § 990.30. *See also* 40 C.F.R. §§ 300.600-615.

[5] 33 U.S.C. § 2706 (d)(1).

[6] *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. 15 C.F.R. § 990.30.

The natural resource trustees for this case include the National Oceanic and Atmospheric Administration (NOAA) and the Department of the Interior (DOI) from the federal government[7] and designated agencies within each of the five affected Gulf states: Florida,[8] Alabama,[9] Mississippi,[10] Louisiana,[11] and Texas[12] (see Figure 2). Immediately after the oil spill started, trustee scientists trained in emergency response to marine pollution mobilized and began collecting environmental information to quantify baseline conditions and potential impacts. In accordance with the OPA regulations, all potential responsible parties were invited to participate in the *Deepwater Horizon* NRDA.[13] BP is the only responsible party participating in the cooperative NRDA process.

The goal of this status update is to compile an overview of the potential impacts to the Gulf of Mexico ecosystem caused by the *Deepwater Horizon* oil spill. This document focuses on presenting an approach that begins with quantifying impacts with either a specific resource (e.g., birds) or habitat (e.g., nearshore marsh). As individual impacts to these interconnected resources are assessed, the results will provide the information and framework required to evaluate how they produce adverse impacts throughout the larger Gulf of Mexico ecosystem. Figure 8 illustrates this concept. For the human use portion of the NRDA, the interconnected resource/habitat categories are related either to direct lost use or to the intrinsic value[14] associated with a resource/habitat category.

This document outlines the trustees' past and near-term future activities to assess the injury to the Gulf of Mexico ecosystem and the lost human use of those resources caused by the oil spill and associated response actions, such as dispersant application, in situ burning, booming, and oil and debris removal. To that end, this status update provides a snapshot of assessment activities. It is important to bear in mind that the *Deepwater Horizon* NRDA is an ongoing and dynamic process. Even at the time of publication, NRDA teams are in the field collecting new samples and conducting laboratory analysis, which will help shape our future efforts. This report also describes the trustees' processes for developing and implementing restoration plans and projects.

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[7]The Department of Defense (DOD) also is a trustee of natural resources associated with DOD-managed land on the Gulf Coast, which is included in the ongoing NRDA, but DOD is not a signatory of the Framework for Early Restoration Addressing Injuries Resulting from the Deepwater Horizon Oil Spill (an agreement among the trustees and BP to allocate $1 billion in early restoration funds) or a participant in the Phase 1 Early Restoration Plan.

[8]Florida: Department of Environmental Protection; Fish and Wildlife Conservation Commission

[9]Alabama: Department of Conservation and Natural Resources; Geological Survey of Alabama

[10]Mississippi: Department of Environmental Quality

[11]Louisiana: Coastal Protection and Restoration Authority; Department of Environmental Quality; Department of Wildlife and Fisheries; Department of Natural Resources; Oil Spill Coordinator's Office

[12]Texas: Texas Commission on Environmental Quality; Texas General Land Office; Texas Parks and Wildlife Department

[13]Potentially responsible parties identified thus far are listed in the Trustees' Notice of Intent to Conduct Restoration Planning (see Section I.3, Timeline) as BP Exploration and Production Inc., Transocean Holding Inc., Triton Asset Leasing GmbH, Transocean Offshore Deepwater Drilling Inc., Transocean Deepwater Inc., Anadarko Petroleum, Anadarko E&P Company LP and MOEX Offshore 2007 LLC. 75 Fed. Reg. 60800 (Oct. 1 2010) http://www.federalregister.gov/articles/2010/10/01/2010-24706/discharge-of-oil-from-deepwater-horizonmacondo-well-gulf-of-mexico-intent-to-conduct-restoration#h-3.

[14] *Intrinsic value* means the inherent worth of a resource or habitat.

I. Introduction

1. Background

On April 20, 2010, an explosion and fire on the mobile offshore drilling unit *Deepwater Horizon*, which was being used to drill a well for BP in the Macondo prospect (Mississippi Canyon 252 – MC252), killed 11 men and injured 17 others. The rig sank and left the well spewing tens of thousands of barrels of oil per day into the Gulf of Mexico. It is estimated that 5 million barrels (210 million gallons) of oil were released from the Macondo wellhead. Of that, approximately 4.1 million barrels (172 million gallons) of oil were released directly into the Gulf of Mexico over nearly three months.[15] Under the Oil Pollution Act of 1990 (OPA),[16] those responsible for an oil spill are financially responsible for a variety of costs, including spill cleanup costs, increased costs of public services related to the spill, property damage related to the spill, compensation for public and private economic losses, and restoration of injured natural resources. While the U.S. Coast Guard is directing federal efforts to contain and clean up the *Deepwater Horizon* oil spill, state and federal natural resource trustees are responsible for leading efforts to assess impacts to natural resources and to restore those injured resources back to baseline (the condition they would have been in had the spill not occurred).

In what was the largest and most prolonged offshore oil spill in U.S. history, oil and dispersants impacted all aspects of the coastal and oceanic ecosystems. These impacts ranged from the deep ocean floor, through the oceanic water column, to the highly productive coastal habitats and estuaries along the northern Gulf of Mexico. These ecosystems are critical to the health of countless recreationally and commercially important species as well as the many threatened and endangered species in the Gulf of Mexico and along the coastal areas of Texas, Louisiana, Mississippi, Alabama and Florida. In addition to their ecological and commercial importance, these marine and coastal species and habitats also provide abundant recreational opportunities and use for the public.

OPA holds the polluter (responsible party(ies)) financially liable for oil removal costs, as well as damages incurred because of an oil spill.[17] The latter includes injuries to:

1. natural resources,
2. real or personal property,
3. subsistence use of natural resources,
4. government revenues,
5. business profits or earning capacity, and
6. increased costs of public services.

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[15]Oil Budget Team. Oil Budget Calculator Technical Documentation. November 2010. http://www.restorethegulf.gov/sites/default/files/documents/pdf/OilBudgetCalc_Full_HQ-Print_111110.pdf. While the official oil budget estimate is that 4.9 million barrels of oil were release from the well, approximately 820,000 barrels were siphoned directly from the wellhead into a holding tank on the surface, resulting in approximately 4.1 million barrels being released into the environment.

[16]33 U.S.C. § 2701 *et seq*.

[17]33 U.S.C. § 2702.

Property damages and increased public service costs are recoverable by a state or local government and would include claims such as the costs associated with using a police force for spill-related activities or damage to a state facility. Government revenues are recoverable by federal, state or local governments and would include claims such as the loss of revenue from a toll road closed due to an oil spill or a decrease in revenues from fishing licenses. These claims can be submitted directly to the responsible party(ies) for consideration. Damages for injuries to real or personal property, subsistence use of natural resources and business profits or earning capacity also are recoverable by individuals or businesses directly from the responsible party(ies). Private party (non-governmental) claims arising out of the *Deepwater Horizon* oil spill can be reviewed and resolved directly by a Supervised Claim Program currently administered under the direction of the United States District Court for the Eastern District of Louisiana. Alternatively, both private and governmental parties can make a claim directly to the Oil Spill Liability Trust Fund administered by the U.S. Coast Guard's (USCG) National Pollution Fund Center.[18]

Natural resources damages are recoverable only by state, federal, tribal or foreign natural resource trustees (defined below). The trustees, who are working together in a Trustee Council, will implement restoration plans intended to restore, rehabilitate, replace or acquire the equivalent of the damaged natural resources to compensate the public for the loss of those natural resources and the services those resources provide.

This document deals solely with the natural resource damages and the path to restoration of injured resources. The process for such natural resource damage assessment and restoration is described below.

2. Legal Basis

The Natural Resource Damage Assessment (NRDA) regulations[19] under OPA designate federal, state and tribal natural resource trustees[20] to conduct NRDAs on behalf of the public. Ultimately, the trustees are mandated to restore, rehabilitate, replace or acquire the equivalent of the damaged natural resources.[21] To meet this mandate, the trustees seek to restore injured resources and services to baseline[22] (the condition those resources would have been in had the spill not occurred) and to compensate the public for interim losses (the losses that occur during the time it takes the natural resources to recover to baseline).

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[18] For more information on the U.S. Coast Guard National Pollution Fund Center refer to: www.uscg.mil/npfc/About_NPFC/osltf.asp. *See also* 26 U.S.C. § 9509 (creation of the Oil Spill Liability Trust Fund) and 33 C.F.R. Part 136 (National Pollution Fund Center Claims Procedures). For more information about the Gulf Coast Claims Facility Transition Process and the Court Supervised Claim Program for the BP Oil Spill, refer to http://gulfcoastclaimsfacility.com.

[19] 15 C.F.R. § Part 990.

[20] *Trustees* (or *natural resource trustees*) means those officials of the federal and state governments, of Indian tribes and of foreign governments designated under 33 U.S.C. § 2706(b) of OPA. 15 C.F.R. § 990.30.

[21] 33 U.S.C. § 2706 (d)(1). *See also* 40 C.F.R. §§ 300.600-615.

[22] *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. 15 C.F.R. § 990.30.

Over the course of the NRDA process, the trustees assess the nature and extent of the injuries to natural resources due to the release of the oil and associated response actions. The trustees also develop a restoration plan(s), seek compensation from the responsible party(ies),[23] oversee and/or implement the restoration plan(s), and conduct/oversee monitoring to ensure successful restoration. Liability for natural resource damages includes the cost of conducting the damage assessment and implementing appropriate restoration actions. Under OPA NRDA regulations,[24] the trustees are required to invite the responsible parties to participate in the NRDA.

Why Cooperative Assessment?

Under the OPA, the trustees are encouraged to pursue cooperative damage assessments with the responsible party(ies) after an oil spill. The OPA regulations require the trustees to invite the responsible party(ies) to participate, to the extent possible, in the damage assessment process. There are several reasons why this type of assessment is beneficial to the trustees and, ultimately, the public.

The alternative to cooperative assessments is assessments conducted in parallel by the trustees and the responsible party(ies). In those cases, each side typically develops a separate damage assessment that is ultimately presented to and ruled on by the courts, either through a trial or settlement. This approach can increase the cost of the assessment and may pave the way for dueling data sets and lengthy disputes about which is correct.

The cooperative assessment is intended to save time and money. By inviting the responsible party(ies) to participate in the process from the beginning, the trustees and responsible party(ies) can have a continuous dialogue and concerns can be raised as early as during the development of sampling protocols. This can prevent major disagreements at the end of the process when little can be done to change the sampling regimes or data collection. The trustees and the responsible party(ies) are free to (and in this case are) conduct independent or non-cooperative studies when agreement cannot be reached.

Since its inception in the mid-1990s, cooperative assessments have facilitated settlement, improved the rigor of damage assessments and expedited the restoration of the public's injured natural resources.

[23] In the case of an offshore facility (other than a pipeline or a deepwater port licensed under the Deepwater Port Act of 1974 (33 U.S.C. § 1501 *et seq*.)), the responsible party is the lessee or permittee of the area in which the facility is located or the holder of a right of use and easement granted under applicable state law or the Outer Continental Shelf Lands Act (43 U.S.C. §§ 1301–1356) for the area in which the facility is located (if the holder is a different person than the lessee or permittee), except a federal agency, state, municipality, commission or political subdivision of a state, or any interstate body, that as owner transfers possession and right to use the property to another person by lease, assignment or permit. 15 C.F.R. § 990.30.

[24] 15 C.F.R. § 990.14(c)

NRDA researchers collect sediment samples during a 2010 assessment operation in Louisiana.

Through the collection and analysis of information, the trustees may demonstrate that injuries to natural resources[25] resulted from the oil spill (or actions conducted in response to the spill). The trustees undertake this effort by demonstrating that the released oil or associated response action had a pathway to a particular species or habitat, that the habitat or species was exposed to the released oil or impacted by the response action, that the level of oil exposure or impact from the response action was enough to cause an injury,[26] and finally, that the injured habitat and species or lost services can be restored, rehabilitated and replaced or that the equivalent of the injured natural resources and services can be acquired.

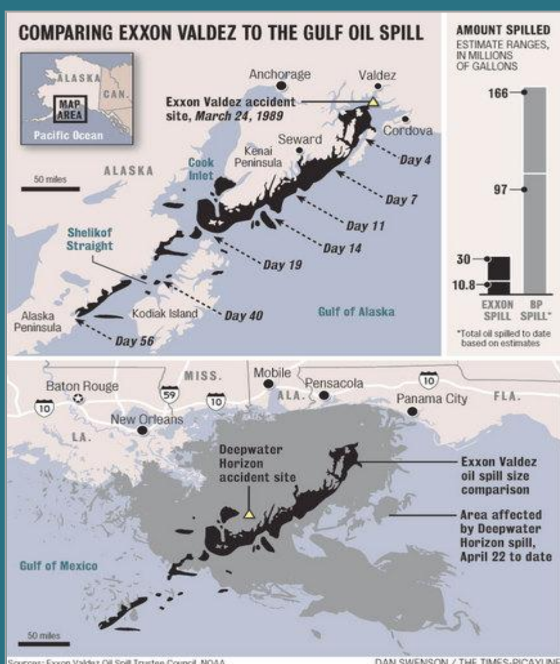
[25] *Natural resources* means land, fish, wildlife, biota, air, water, ground water drinking water supplies, and other such resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the United States (including resources of the Exclusive Economic Zone), any state or local government or Indian tribe, or any foreign government, as defined in section 1001(20) of OPA. 33 C.F.R. § 990.30.

[26] *Injury* means an observable or measurable adverse change in a natural resource or impairment of a natural resource service. Injury may occur directly or indirectly to a natural resource and/or service. Injury incorporates the terms ‘‘destruction,’’ ‘‘loss,’’ and ‘‘loss of use’’ as provided in OPA. 15 C.F.R. § 990.30.

Exxon Valdez vs. *Deepwater Horizon*

There is a natural tendency to look back to another major American oil spill, the *Exxon Valdez*, and make comparisons about injury, process and timelines. When doing so, it is important to understand that these are extremely different incidents with respect to both environmental and regulatory conditions.

The *Exxon Valdez* oil spill occurred instantaneously on the surface of a relatively small water basin during very cold weather. Nineteen days after the oil spill, most of the 11 million gallons (262,000 barrels) of oil had made landfall. Within two months (56 days), the entire known volume of oil had reached the rocky shores of Prince William Sound. The Alaska and federal trustees pursued a damage assessment without the involvement of the responsible party, Exxon, and did so under the authority of the Clean Water Act.



By contrast, the *Deepwater Horizon* oil spill occurred over approximately three months from the depths of a large basin of water with very warm surface and atmospheric conditions. During the incident, the end was never predictable. Due to the location of the spill, oil did not immediately wash ashore. For the trustees, this was an extended period for data collection. More than 100 days from the start of the spill, the approximate spatial extent of the initial coastal shoreline oiling was able to be determined, though re-oiling continues to occur along the coast. The spatial extent of the oil at the sea floor is still unknown.

The five Gulf state trustees along with the federal trustees are pursuing a largely cooperative assessment (i.e., working with a responsible party, BP) under the Oil Pollution Act, which was enacted by Congress in direct response to the *Exxon Valdez* oil spill.

Illustration published June 22, 2010; Updated August 5, 2010
Note 1: The two images represent surface area covered with oil or sheen obtained from aerial photography. The extent of sub-surface migration of oil within and beyond the surface area imagery is unknown.
Note 2: The current estimated *Deepwater Horizon* oil spill volume is about 5 million barrels (210 million gallons). Approximately 4.1 million barrels were released into the Gulf of Mexico and roughly 820,000 barrels were siphoned from the wellhead into response vessels.

Under the NRDA regulations, the process for demonstrating a causal relationship between the released oil and adverse effects on the environment is carried out through three steps, as illustrated in Figure 1.

1. Pre-assessment: Trustees determine whether injury to public trust resources[27] has occurred or is likely to occur. Activities to determine the extent and severity of injury include collecting time-sensitive data and reviewing scientific literature about the released substance and its impact on trust resources. Mathematical models may be used to help predict the fate and effects of the oil spill on trust resources. If resources are injured or likely injured, trustees proceed to the next step.

2. Restoration Planning (Including Injury Assessment): In this stage, trustees quantify injuries and identify possible restoration projects. Economic and scientific studies are employed to quantitatively assess the injuries to natural resources and services that those resources provide. Studies are also used as a basis for developing a restoration plan that outlines alternative approaches for speeding the recovery of injured resources and services and compensating for their loss or impairment from the time of injury to recovery. Trustees evaluate the proposed restoration alternatives based on factors identified in the OPA NRDA regulations and draft and seek public comment on a restoration plan. The restoration plan identifies alternatives considered, discusses their evaluation and proposes projects intended to compensate for the injuries. Examples of restoration include enhancing beach and marsh shoreline, creating oyster reefs and other shellfish habitat, improving recreational opportunities and conducting species recovery programs. From the responsible parties, the trustees recover the costs of conducting the assessment and restoration planning – a process in which the responsible party(ies) may choose to work cooperatively with the trustees.

3. Restoration Implementation: The final step is to implement restoration and monitor its effectiveness. The trustees seek funding from the responsible party(ies) to implement the restoration, unless restoration is implemented by the responsible party(ies), subject to trustee oversight. If the responsible party(ies) does not agree to fund the restoration, the trustees may bring suit or submit a claim for damages to the Oil Spill Liability Trust Fund. The United States may seek to recover from the responsible parties any compensation paid by the fund.

[27] Public trust resources are natural resources held in trust by government for use by the public.

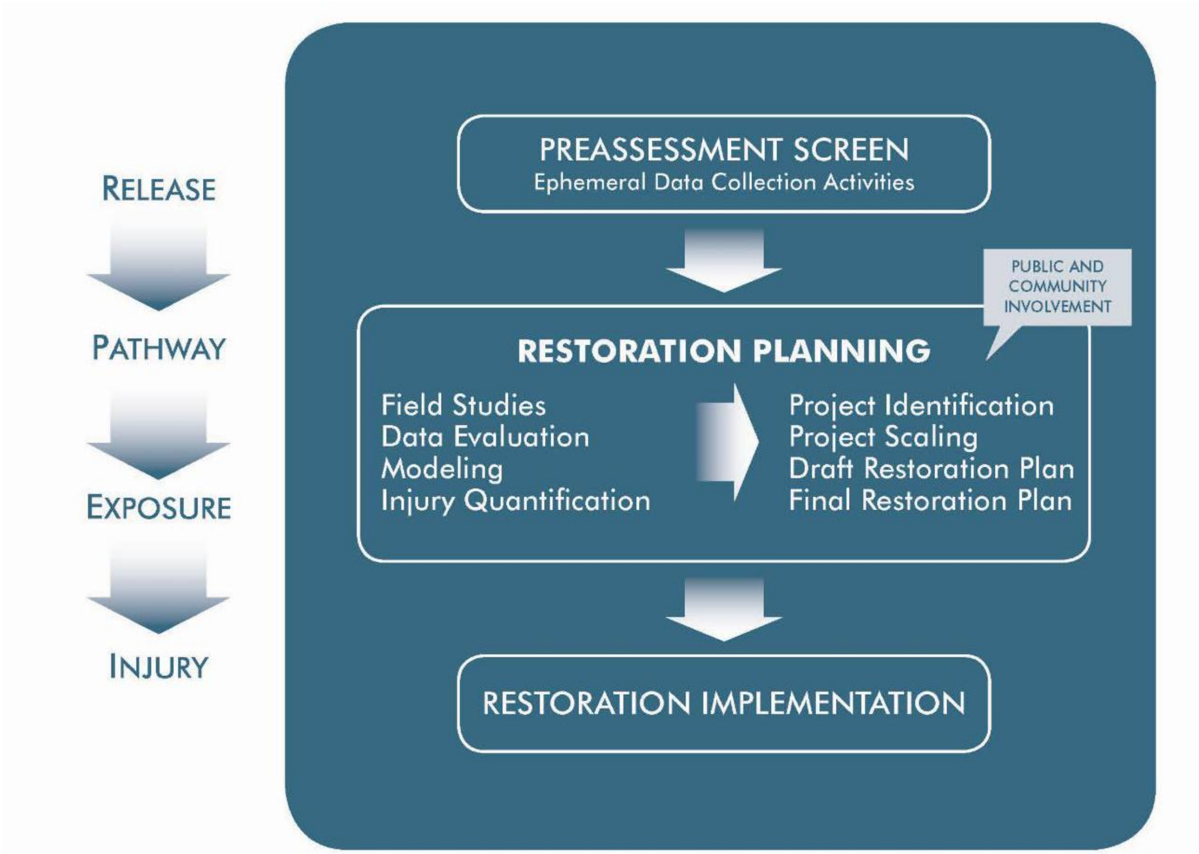


Figure 1. Illustration of the Damage Assessment Process. If the trustees can establish a pathway for contaminants or response activities (*e.g.*, oil, dispersants or stranded boom on tidal marshes) to encounter a certain resource or the potential for injury, they will move on to restoration planning. The Restoration Planning Phase includes injury assessment and scoping for appropriate restoration projects— soliciting public input. Once the injury is quantified and the appropriate amount and types of restoration are identified, a final restoration plan(s) is implemented and monitored for success. Emergency and early restoration actions can occur prior to injury quantification and implementation of a final restoration plan(s).

3. NRDA Approach and Timeline

NRDA Approach

The *Deepwater Horizon* NRDA, given its geographic size, three-dimensional nature and ecological complexity, may continue for years. State and federal trustees are working together to determine how the oil spill affected the Gulf of Mexico's natural resources, ecosystems and the associated human uses. With potential natural resource injury spanning five states and their waters, as well as federal waters, this is the largest damage assessment ever undertaken.

Trustee scientists, trained in emergency response to marine pollution, mobilized immediately after being notified that the spill was occurring and began collecting environmental information to quantify potential impacts. In accordance with the OPA regulations, all potentially responsible parties were invited to participate in the *Deepwater Horizon* NRDA.[28] BP is the only responsible party participating in the cooperative NRDA process.

***Deepwater Horizon* NRDA Trustees**

Federal Trustee Agencies

Department of the Interior
- U.S. Fish and Wildlife Service
- Bureau of Land Management
- National Park Service

Department of Commerce
- National Oceanic and Atmospheric Administration

State Trustee Agencies

Florida
- Department of Environmental Protection
- Fish and Wildlife Conservation Commission

Alabama
- Department of Conservation and Natural Resources
- Geological Survey of Alabama

Mississippi
- Department of Environmental Quality

Louisiana
- Coastal Protection and Restoration Authority
- Oil Spill Coordinator's Office
- Department of Environmental Quality
- Department of Wildlife and Fisheries
- Department of Natural Resources

Texas
- Commission on Environmental Quality
- General Land Office
- Parks and Wildlife Department

Figure 2. Natural resource trustee agencies participating in the *Deepwater Horizon* NRDA Trustee Council. Participating are two federal agencies, including three Department of the Interior bureaus, and 13 state agencies from the five affected states. While the OPA NRDA regulations designate trusteeship to affected federal Indian tribes, no federally recognized Indian tribes have asserted trusteeship for natural resources injured by the *Deepwater Horizon* oil spill.

The *Deepwater Horizon* NRDA focuses on assessing the injuries to the ecosystem resources and habitats from the deep ocean to the coastlines of the five Gulf states (Figure 3). Information

[28]Potentially responsible parties identified thus far are listed in the Notice of Intent to Conduct Restoration Planning (see Section I.3, Timeline) as BP Exploration and Production Inc., Transocean Holding Inc., Triton Asset Leasing GmbH, Transocean Offshore Deepwater Drilling Inc., Transocean Deepwater Inc., Anadarko Petroleum, Anadarko E&P Company LP and MOEX Offshore 2007 LLC. 75 Fed. Reg. 60800 (Oct. 1 2010) http://www.federalregister.gov/articles/2010/10/01/2010-24706/discharge-of-oil-from-deepwater-horizonmacondo-well-gulf-of-mexico-intent-to-conduct-restoration#h-3.

continues to be collected to assess potential impacts to fish, shellfish, terrestrial and marine mammals, turtles, birds, and other sensitive resources as well as their habitats, including wetlands, beaches, mudflats, bottom sediments, corals and the water column. Lost human uses of these resources and habitats such as recreational fishing, boating, hunting and beach activities also are being assessed. Technical teams consisting of scientists from academic institutions and state and federal agencies, working in coordination with BP, have been conducting numerous surveys and collecting samples for multiple resources and habitats since the oil spill began.

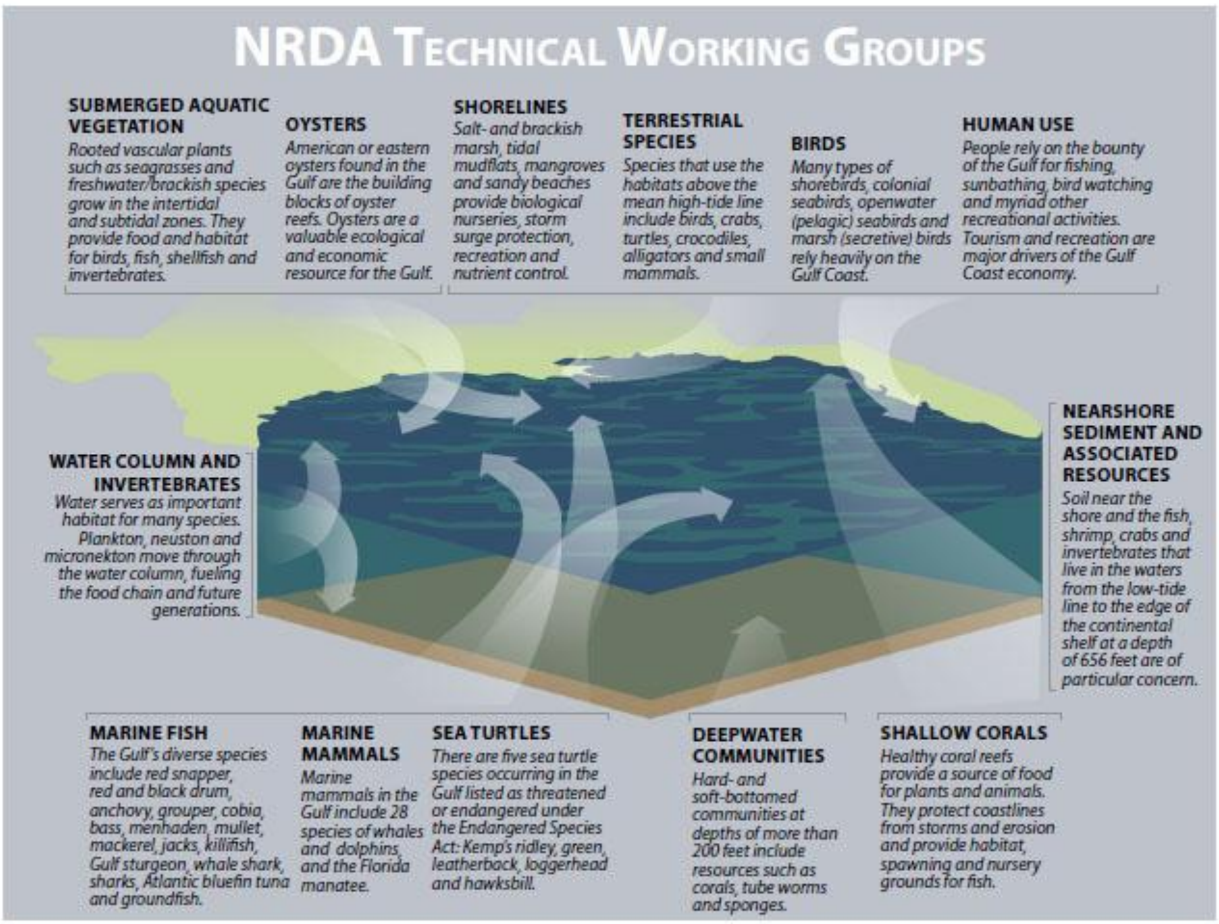


Figure 3. The *Deepwater Horizon* oil spill presents a vast and complex three-dimensional threat to organisms, habitats and ecosystems of the northern Gulf of Mexico. Each resource listed above is evaluated by a team of experts known as a Technical Working Group.

In the days and weeks after the Macondo well began spewing oil into the Gulf of Mexico 5,000 feet below the ocean surface, two discrete pathways for potential impacts to water column organisms and habitats became apparent. At the wellhead, natural and chemical dispersion (through the injection of 771,000 gallons of dispersants at the source) created smaller oil particles that became sequestered at depth and moved with the deep sea currents. More visibly, the ocean's surface became blanketed with oil that moved toward shore with the wind and tides. Some of this surface oil also was chemically dispersed through aerial application of more than 1 million gallons of dispersants (see Figure 4 for an illustration of potential pathways).

At depth, the oil and dispersant mixed with the surrounding water. Through a rapid scientific response, researchers working as part of the NRDA, the response effort and the academic community were able to locate, track and measure the concentrations of a deep sea "plume." Scientists have found evidence of hydrocarbons believed to be from the Macondo release in the vicinity of the wellhead, to the north and northeast, and to the southwest. These findings have been replicated by several non-NRDA research expeditions. Most scientists agree that the dominant direction of the deep plume was to the southwest, carried by slow moving currents (about 1 knot) through a deep sea canyon at a depth of approximately 3,700 feet.

In addition, the failure of the Top Kill response action, which attempted to plug the well by pumping heavy drilling mud into the wellhead, resulted in the deposition of drilling mud on the ocean floor that may contribute to the overall injury. The oil, dispersants and drilling mud threaten the **deepwater communities** that thrive in a low-energy environment characterized by high pressure, near-freezing temperatures and constant darkness. The soft sediments and sporadic coral outcroppings at this depth are home to tube worms, bacteria, jellyfish, fish and corals that have adapted to this environment. Some of these coral colonies and tube worms can live for hundreds of years.[29] Sperm whales will dive to these depths to feed on squid, skate, fish and sharks.[30] In an unprecedented effort, the trustees are currently working to quantify the nature and magnitude of the injury to this unique and sensitive deep sea ecosystem using approaches that incorporate the use of remotely operated vehicles, autonomous underwater vehicles, and water and sediment sampling.

Much of the oil rose through the **water column** to the surface, taking about five hours to complete the journey. As it rose, some oil dissolved in the water column. The rest of the oil continued to spread out over a wider area and drift with the currents as it moved upward. Both the oil and the dissolved hydrocarbons encountered plankton, jellyfish, fish and many other marine organisms along the way. BP applied more than 1 million gallons of dispersants[31] to portions of the surface oil as a response action to break apart the oil particles, facilitate biodegradation of the oil and decrease shoreline impact. This action dispersed these particles into the shallow water layer (0-30 feet) immediately beneath the ocean's surface. The shallow water layer is a critical area in the oceanic ecosystem where almost all of the primary productivity occurs and where **planktonic organisms** (including larvae of many important marine species) congregate, forming the foundation of the marine food chain. Fish, sea turtles and marine mammals feed on these organisms and likely consumed oil-contaminated prey.

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[29]Bergquist DC, FM Williams, and CR Fisher. 2000. Longevity record for deep-sea invertebrate. Nature 403: 499-500.; CSA International, Inc. 2007. Characterization of northern Gulf of Mexico deepwater hard bottom communities with emphasis on Lophelia coral. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2007-044. 169 pp. + app.
[30]NOAA National Marine Fisheries Service. Sperm Whales *(Physeter macrocephalus).* http://www.nmfs.noaa.gov/pr/species/mammals/cetaceans/spermwhale.htm.
[31]Approximately 1.84 million gallons of total dispersant have been applied—1.07 million on the surface and 771,000 sub-sea. Deepwater Horizon Incident Joint Information Center. 2010. The Ongoing Administration-Wide Response to the Deepwater BP Oil Spill. http://www.restorethegulf.gov/release/2010/08/06/ongoing-administration-wide-response-deepwater-bp-oil-spill.

The surface oil also directly impacted **birds, fish, marine mammals and sea turtles**. Aerial photographs documented pods of dolphin swimming through large slicks of surface oil. Sperm whales and whale sharks were observed in the oil-impacted area during the oil spill. Sea turtles and birds were retrieved from the slick. Juvenile sea turtles and fish also were exposed at the surface to oiled ***Sargassum***, a highly productive, floating marine ecosystem comprised of seaweed and other organic materials that these and other marine species use for food and shelter. Some of the *Sargassum* moved toward shore with currents in long windrows along with the surface oil.

After several weeks at sea, the oil drifted into the commercially vital and ecologically productive nearshore habitats of the northern Gulf of Mexico. The shallow waters of the northern Gulf of Mexico support a variety of commercial fisheries (brown and white shrimp, crab, mackerel, red snapper, etc.), and millions of acres of **submerged aquatic vegetation**, essential habitat for juvenile fish and shellfish. **Oyster reefs**, a complex estuarine habitat that supports an important commercial seafood industry, were exposed to the incoming oil slick through sediments and the water column. **Shallow water coral reefs** along the Florida coast and off of Texas potentially were threatened as well.

The oil eventually made landfall across the **shorelines** of Texas, Louisiana, Mississippi, Alabama and Florida. It most severely affected the edges of saltwater and brackish marshes where oil was stranded for long periods. Sand beaches, barrier islands, tidal mud flats and mangrove stands also were oiled. Sediments closest to heavily oiled shorelines appear to have been more heavily oiled than those farther offshore, threatening the productive marsh edge estuarine zone. Once on marsh shorelines, the oil impacted not only marine organisms for which these habitats are essential nurseries but also posed a threat to **terrestrial wildlife**, marsh and shore birds. Animals that feed along shorelines and on estuarine fish and shellfish risked dermal contact and ingestion of oil.

The NRDA also is designed to measure the **lost human use** of these natural resources and habitats. From the beginning of the spill, recreational use of the Gulf of Mexico's natural resources and habitats has been compromised. Such losses included disruptions in recreational boating and fishing, beach activities, and bird watching. They include the loss of human use as a result of actual and perceived negative impacts to the Gulf region.

Collectively, the pathway and potential exposures described here make it likely that the oil released as a result of the *Deepwater Horizon* oil spill exposed and impacted almost all parts of the northern Gulf of Mexico marine ecosystem—from the deep sea through the water column to the shores. Figure 5 provides an illustration of this likely impact—identifying and briefly describing how some of the ecosystems comprising the Gulf of Mexico marine ecosystem may have been affected.

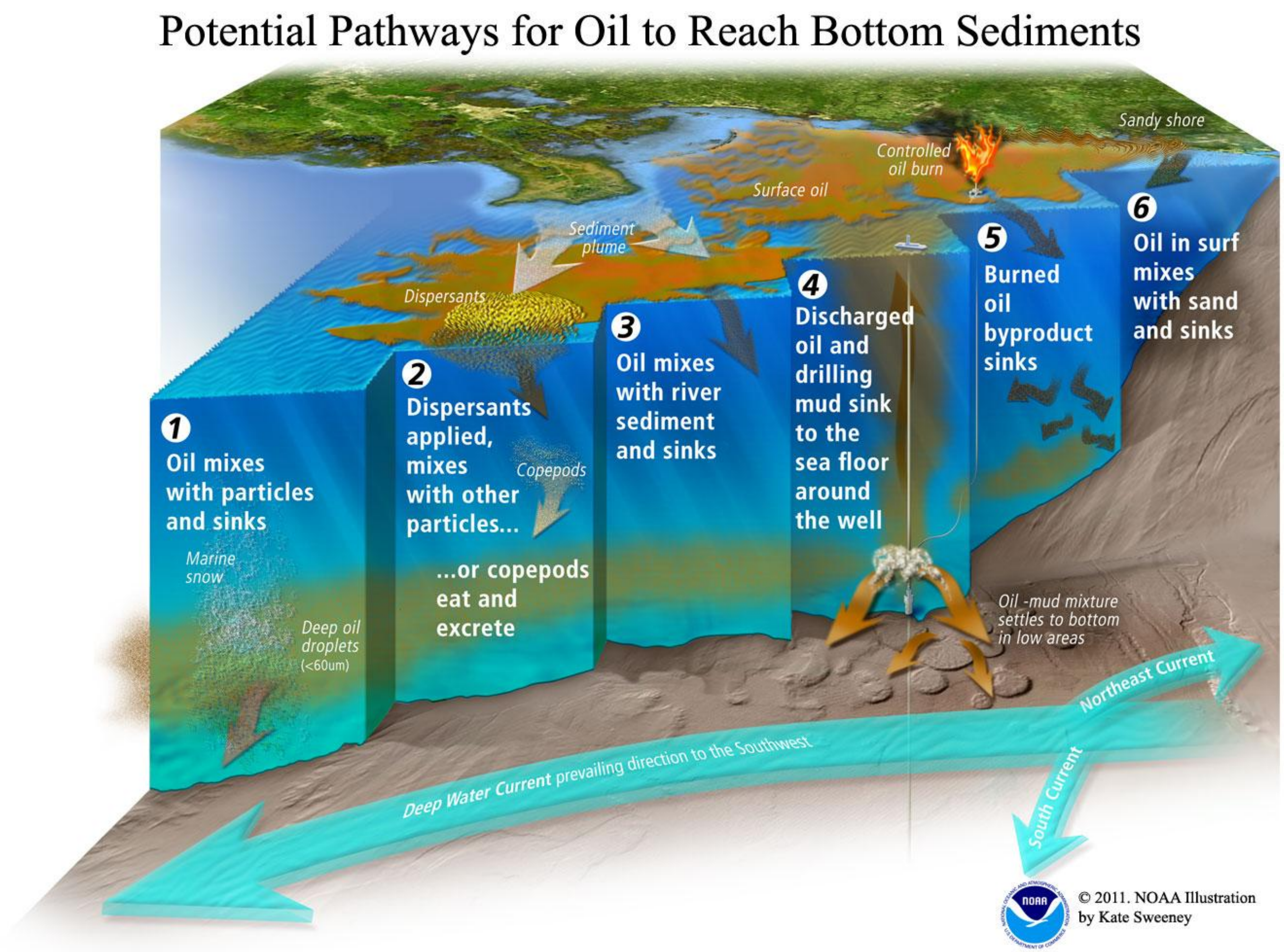

Figure 4. Potential pathways by which oil released from the Macondo well moved through the marine and coastal ecosystems and reached the bottom sediments.[32]

[32] *Deepwater Horizon* Unified Area Command. 2010. Summary report for sub-sea and sub-surface oil and dispersant detection: Sampling and monitoring. Operational Science Advisory Team. December 17, 2010

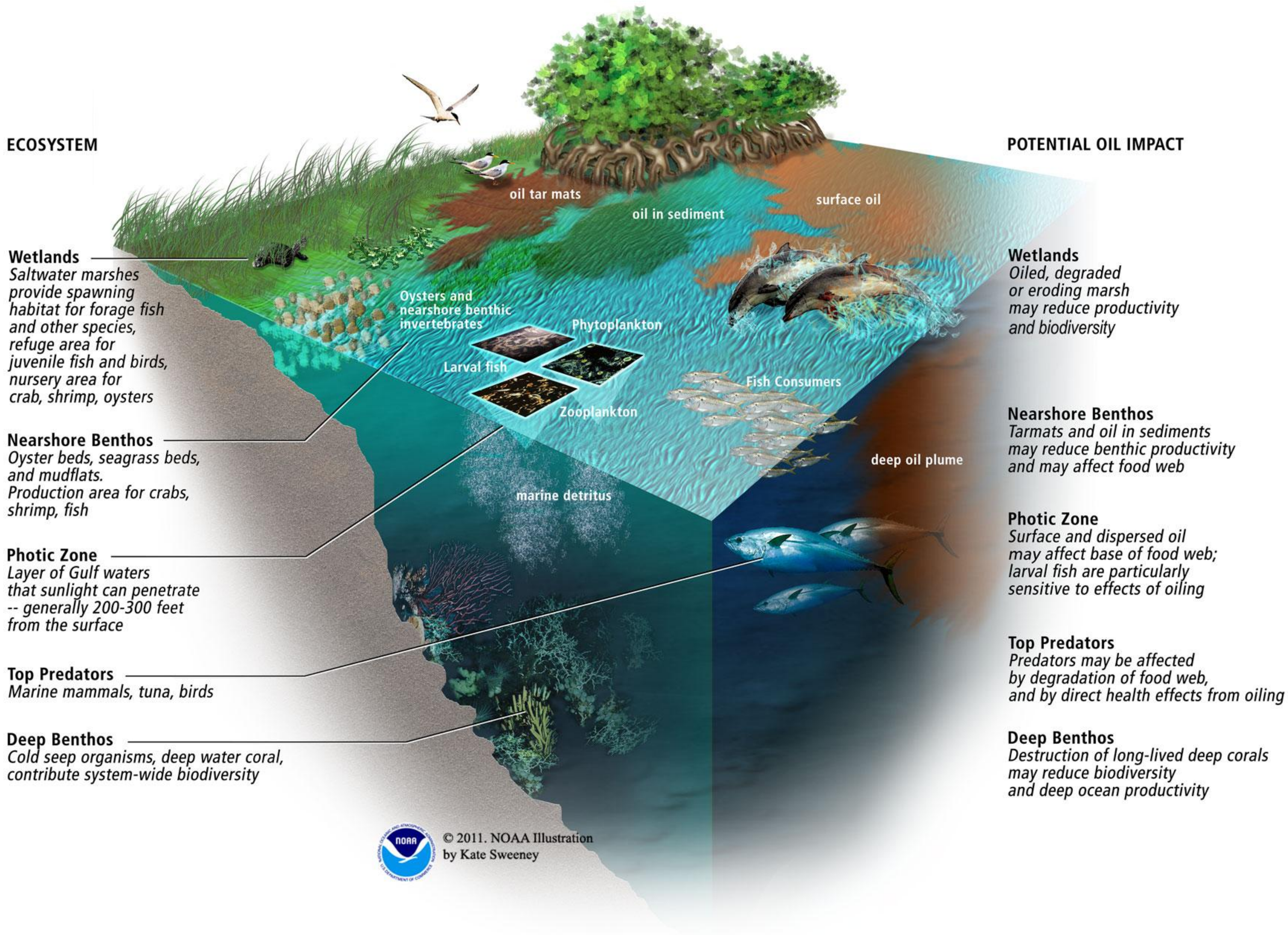

Figure 5. Preliminary conceptual model for selected natural resource exposure and injuries within the Gulf of Mexico marine ecosystem.

Timeline

From the Gulf of Mexico's deep sea sediments to its coastal marshes, damage assessment teams have worked to assess the pathways and exposures and quantify the effects of the released oil and associated response actions for the restoration planning outlined under the NRDA process. Beginning in the earliest days of the disaster, BP and the trustees agreed to conduct cooperative assessments when possible (see Cooperative Assessment inset, page 9).

Throughout the summer of 2010, observations and sample collections by the trustees demonstrated sufficient evidence of the potential for injuries to natural resources. Based on this information, the trustees filed a Notice of Intent to Conduct Restoration Planning in the *Federal Register* on September 29, 2010. This legal document signaled a shift from the Pre-assessment Phase to the Restoration Planning Phase of the NRDA. In that phase the trustees are to "identify and document impacts to the Gulf of Mexico's natural resources and the public's loss of use and enjoyment of these resources as the first stage under the regulations for developing a restoration strategy."[33]

Since the spill occurred, Shoreline Cleanup and Assessment Technique (SCAT) field teams have surveyed more than 4,300 linear miles of shoreline and documented approximately 1,100 linear miles of oiling.[34] They are reporting that approximately 220 miles of shoreline were heavily oiled and 140 miles moderately oiled. Due to shoreline cleanup operations, natural degradation and remobilization of oil in the coastal areas, the mileage of heavily to moderately oiled shoreline impact has changed and decreased. The remaining miles of shoreline received some degree of oiling, consisting of light oiling and/or tarballs, which continue to wash ashore.

Field teams also are responding to the spill by collecting potentially injured and dead wildlife. Damage assessment and response teams to date have collected 8,567 live and dead birds, of which 1,423 were rehabilitated and released. To date, teams also have collected 536 live sea turtles, 456 of which were visibly oiled. Eighty-eight percent (469) of these turtles were later released. In addition, 613 dead turtles were collected. Trustees working as part of the *Deepwater Horizon* oil spill response translocated 274 turtle nests from northern Gulf of Mexico beaches to the Atlantic coast of Florida during summer 2010. A total of 14,796 hatchings were released into the Atlantic to avoid potential exposure to *Deepwater Horizon* oil. Teams also have collected 171 marine mammals to date, of which 153 were dead.

In early 2011, the NOAA Protected Resources Division declared an Unusual Mortality Event (UME) for cetaceans (marine mammals including whales, dolphins and porpoises) in the northern Gulf of Mexico from February 2010 through the present.[35] Under the Marine Mammal Protection Act of 1991, a UME is defined as "a stranding that is unexpected, involves a

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[33]Notice of Intent to Conduct Restoration Planning (pursuant to 15 C.F.R. § 990.44) Discharge of Oil from the Deepwater Horizon Mobile Offshore Drilling Unit and the Subsea Macondo Well into the Gulf of Mexico, April 20, 2010.

[34]Marsh, 501.4 miles; Beach, 553.6 miles; Other, 92.7 miles.

[35]NOAA National Marine Fisheries Service. Marine Mammal Unusual Mortality Events. http://www.nmfs.noaa.gov/pr/health/mmume/ and http://www.nmfs.noaa.gov/pr/health/mmume/cetacean_gulfofmexico2010.htm

significant die-off of any marine mammal population and demands immediate response." The impetus for the declaration was the sharp increase in the discovery of premature, stillborn or neonatal (newborn) bottlenose dolphin strandings in the region. In 2011, there were 356 strandings (compared to a historical average of 74). Many of these animals had visible oil on their bodies. To the extent possible, necropsies are being used to evaluate the role that oil and/or response activities played in their deaths.

In addition, a large number of samples of various types (water, sediment, biological tissue) have been collected for oil and dispersant-related chemical analysis. As of January 2012, almost 50,000 total contaminant chemistry samples have been collected. To date, laboratories have completed more than 23,000 total analyses, of which almost 18,000 have been validated by third parties.

Once they have undergone a comprehensive quality control check, all data obtained through the cooperative process is publicly available at www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data/.

The trustees will continue to assess the Gulf of Mexico's resources and habitats for significant adverse impacts that can be linked to the oil spill. Because some adverse impacts (i.e., decrease in juvenile fish populations) may not be immediately apparent, the trustees must carefully consider each resource when deciding how to proceed.

4. Restoration Plan

Restoration activities are intended to restore or replace habitats, species and services to their baseline condition (primary restoration) and to compensate the public for interim losses from the time natural resources are injured until they are restored or replaced to achieve baseline conditions (compensatory restoration). To meet these goals, the restoration activities need to produce benefits that are related, or have a nexus, to natural resources injured and associated service losses resulting from the oil spill, associated response or clean-up activities.

Restoration Terms Defined

Restoration: Any action that restores, rehabilitates, replaces or acquires the equivalent of the injured natural resources.

Primary Restoration: Any action that replaces or restores injured natural resources and services to their baseline condition.

Compensatory restoration: Any action that replaces or restores the natural resource injuries and services lost from the date of injury until recovery to baseline conditions occurs.

Emergency Restoration

Emergency restoration includes actions that are taken by the trustees during the spill response to prevent or reduce continuing natural resource impacts and prevent potential, irreversible loss of natural resources.

The trustees collectively are implementing three emergency restoration[36] projects as part of the *Deepwater Horizon* oil spill addressing submerged aquatic vegetation, waterfowl and sea turtles. The submerged aquatic vegetation project is being completed to prevent additional injury by restoring submerged aquatic vegetation beds harmed by propeller scarring and other response vessel impacts. The shorebird habitat enhancement project provided alternative wetland habitat in Mississippi for waterfowl and shorebirds that might otherwise winter in oil-affected habitats. The sea turtle project was completed to improve the nesting and hatching success of endangered sea turtles on the Texas coast, including Padre Island National Seashore. Some trustees also implemented additional response and emergency restoration actions independent of the other trustees and BP.

Early Restoration

Early Restoration is the implementation of projects prior to the final quantification of injury. On April 21, 2011, the trustees announced the "Framework for Early Restoration Addressing Injuries Resulting from the Deepwater Horizon Oil Spill," in which BP agreed to fund $1 billion in Early Restoration projects.[37] Under the agreement, DOI, NOAA and the five spill-affected Gulf states (Florida, Alabama, Mississippi, Louisiana and Texas) each will receive $100 million to implement projects. The remaining $300 million will be allocated by NOAA and DOI for projects proposed by state trustees. All projects must meet the requirements of the April 2011 agreement and be approved by BP and the Trustee Council, which is comprised of the *Deepwater Horizon* natural resource trustees. A 60-day public comment period on the Draft Phase I Early Restoration Plan/Environmental Assessment (DERP/EA) ran from December 14, 2011, to February 14, 2012. Locations of the proposed Phase I projects appear in Figure 6. Visit www.gulfspillrestoration.noaa.gov to view the Phase I Early Restoration Plan/Environmental Assessment and view additional details on Phase I projects.

[36]Under the damage assessment regulations, the trustees are authorized to conduct emergency restoration actions before the damage assessment process is complete. The following criteria must be met for the trustees to implement these actions: *(1) The action is likely to minimize continuing or prevent additional injury; (2) The action is feasible; (3) The costs of the action are not unreasonable; (4) The trustees must provide notice to identified responsible parties and, to the extent time permits, invite their participation; and (5) The trustees must provide notice to the public of the justification for, nature and extent of, and results of emergency restoration actions within a reasonable time frame of taking such actions.*

37NRDA trustees announce $1 billion agreement to fund early Gulf Coast restoration projects. http://www.noaanews.noaa.gov/stories2011/20110421_nrdarestoration.html.

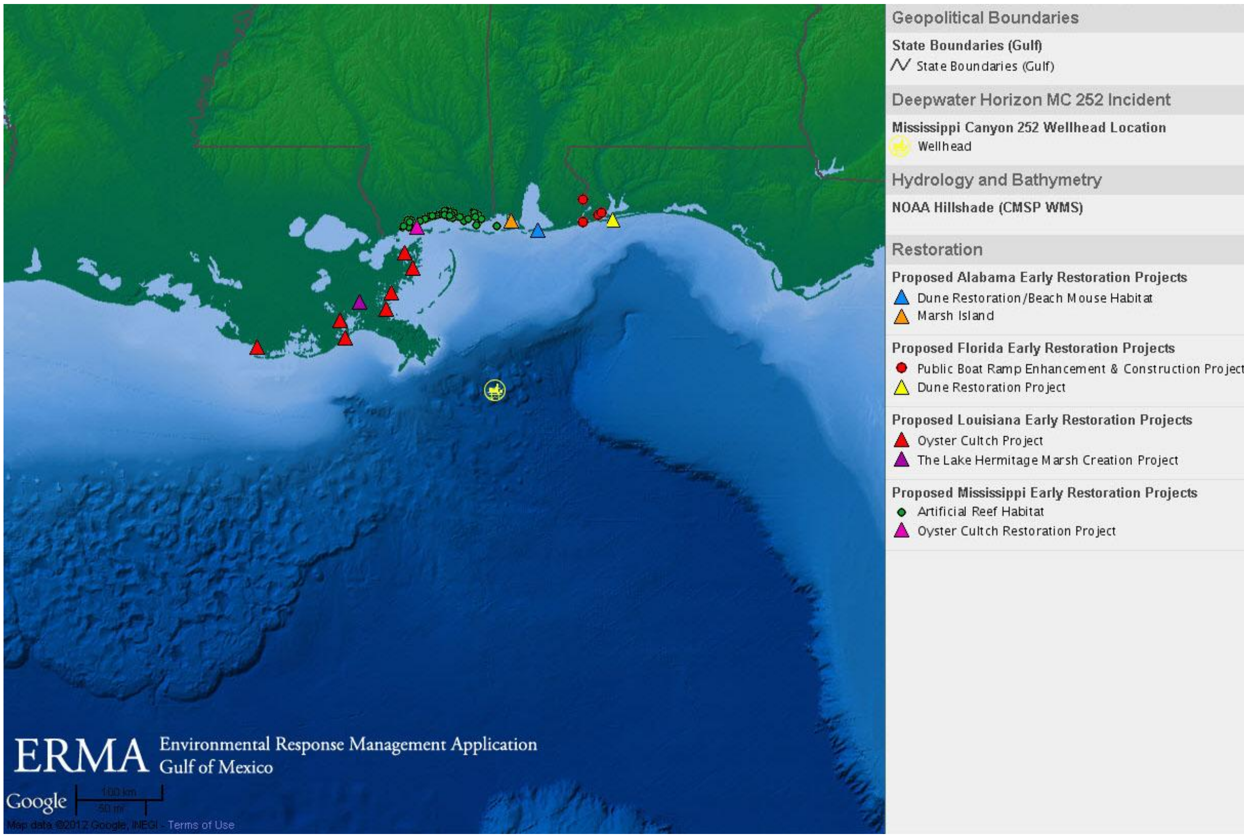

Figure 6. This map shows the locations of the proposed projects included in the Draft Phase I Early Restoration Plan.

Gulf Spill Restoration Planning Programmatic Environmental Impact Statement

The trustees are preparing a Draft Programmatic Environmental Impact Statement (DPEIS) to address environmental impacts from and to facilitate the selection of primary (return to baseline conditions) and compensatory (compensating the public for interim loss of resources and services) restoration alternatives.

Public input from scoping conducted as part of that process, and similar exercises conducted by individual trustees, also will be considered in the development of early restoration plans (see Section I.4). The DPEIS will assist the trustees in making informed decisions regarding the selection and implementation of a range of restoration types that could be used to compensate the public and the environment for the loss of natural resources and services from the *Deepwater Horizon* oil spill. The Notice of Intent to Begin Restoration Scoping and Prepare a Programmatic Environmental Impact Statement was published in the *Federal Register* on February 17, 2011.[38] Throughout the spring and summer of 2011, the trustees held public meetings in various locations throughout the spill-affected Gulf states and in Washington, D.C.

[38] 76 Fed. Reg. 9327 (Feb. 17 2011).

Through the process to date, the public was provided opportunities to submit suggestions on types of restoration projects that could adequately restore the affected resources. Public involvement occurs by providing input at public meetings or by submitting comments or projects online or by mail. All comments and submitted projects will be reviewed by the trustees in developing a restoration plan or plans for the *Deepwater Horizon* oil spill.

II. About this report

This report provides a brief overview of the approaches used by the *Deepwater Horizon* natural resource trustees in their initial efforts to assess the spatial and temporal extent and severity of exposure of natural resources and habitats to oil, dispersants and response actions. In order to claim that a resource has been injured as a result of the oil spill, the trustees must establish that 1) a pathway exists for oil or activities related to the oil spill response to make contact with the resource, 2) resources were exposed to oil or response actions, and 3) an injury to the resource resulted from the exposure. As a result, these initial efforts to assess exposure of natural resources and habitats to oil, dispersants and response actions are tailored to addressing these three components. Trustees remain committed to a long-term assessment of the Gulf, recognizing that the *Deepwater Horizon* oil spill will affect the region's natural resources for years to come.

To set the stage for what can be a bewildering amount of information, Figure 7 provides a context and basis for the various resources and habitats within the northern Gulf of Mexico marine ecosystem that were potentially exposed and injured by *Deepwater Horizon* oil, dispersed oil, drilling muds and/or actions taken during the response. The terms used in Figure 7 are further discussed in the inset that follows, Oceanic Biological and Light Zone Terminology.

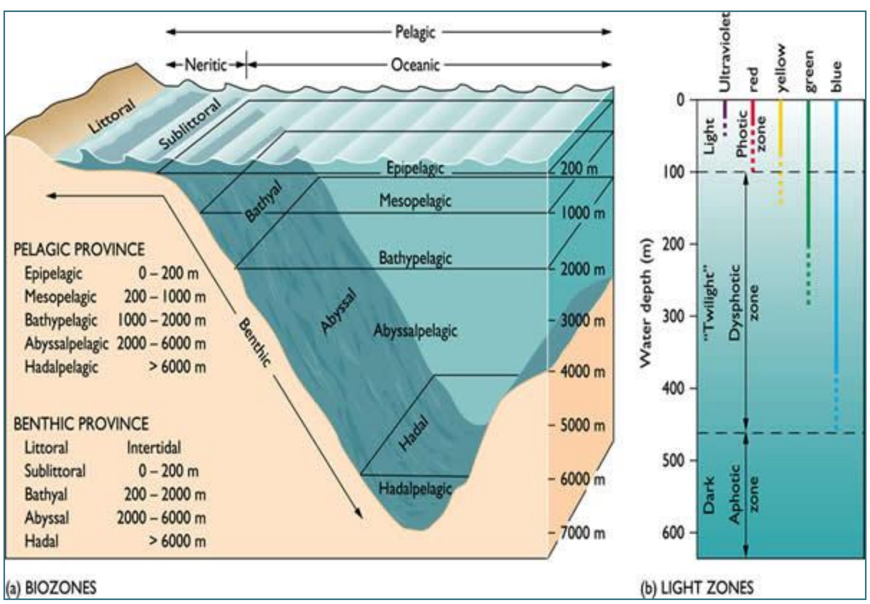

Figure 7. This figure shows the various pelagic and benthic provinces of the ocean (left) and its vertical light zones (right). The terminology used in this figure is described in the adjacent guide to Oceanic Biological and Light Zone Terminology.[39]

[39] Image source: MarineBio.org. http://marinebio.org/oceans/light-and-color.asp

Oceanic Biological and Light Zone Terminology:

Pelagic Zones:

Pelagic refers to all ocean waters. Pelagic waters are divided into two horizontal zones: the neritic zone and the oceanic zone.

- Horizontal Terminology (see Fig. 7)

The **neritic zone** refers to coastal waters from the low tide line to the edge of the continental shelf, a bathymetric depth of 200 meters (656 feet).

The **oceanic zone** extends from a bathymetric depth of 200 meters (656 feet) and beyond, which can include waters thousands of meters deep. This zone is further divided into five zones: epipelagic, mesopelagic, bathypelagic, abyssalpelagic and hadalpelagic.

- Depth Terminology (see Fig. 7)

Epipelagic refers to pelagic waters from 0 to 200 meters in depth where there is enough light for photosynthesis. This zone is well-oxygenated and has stable salinities and temperature. Nearly all primary production in the ocean occurs here. Consequently, plants and animals are largely concentrated in this zone.

Mesopelagic refers to oceanic waters from 200 to 1,000 meters in depth. Although some light penetrates this second layer, it is insufficient for photosynthesis. At about 500 meters the water also becomes depleted of oxygen. Some organisms living in the mesopelagic zone will rise to the epipelagic zone at night in order to feed.

Bathypelagic refers to oceanic waters from 1,000 to 2,000 meters in depth. This layer is characterized by total darkness, near-freezing temperatures and high pressure. There is no longer any plant life at this depth. The Macondo wellhead is located in this zone.

Abyssalpelagic refers to oceanic water from 2,000 to 6,000 meters in depth. There is no established pathway of *Deepwater Horizon* oil to this ocean depth. The deepest reported depth in the Gulf of Mexico is 4,384 meters.[40]

Hadalpelagic refers to oceanic water deeper than 6,000 meters. The Gulf of Mexico is not known to have a hadalpelagic zone.

Benthic Zones:

Benthic refers to the benthos, or sediment, and its associated flora and fauna. This zone is further divided into five vertical zones: the littoral, sublittoral, bathyl, abyssal and hadal zones.

The **littoral** zone is the coastal region of the neritic zone extending from the highest tide line to the lowest tide line, an area also referred to as the intertidal zone. This area is characterized by high energy and sediment transport, both shoreward and alongshore.

The **sublittoral** zone is the region of the neritic zone extending from the lowest tide to the edge of the continental shelf, a bathymetric depth of 200 meters (656 feet).

The **bathyal** zone is the benthic region of the oceanic zone located in water depths of 200 to 2,000 meters. This benthic zone corresponds to benthos in the epipelagic and mesopelagic oceanic zone. The Macondo wellhead is located in this benthic zone.

The **abyssal** zone is the benthic region of the oceanic zone located in water depths of 2,000 to 6,000 meters. This benthic zone corresponds to benthos in the abyssalpelagic oceanic zone.

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[40]GulfBase.org. General Facts about the Gulf of Mexico. http://www.gulfbase.org/facts.php.

The **hadal** zone is the benthic region of the oceanic zone located in water depths greater than 6,000 meters. This benthic zone corresponds to benthos in the abyssalpelagic oceanic zone. The Gulf of Mexico is not known to have a hadal benthic zone.

Light Zones:

The **photic zone**, or light zone, refers to surface waters where there is sufficient light penetration to support photosynthesis. The depth can vary based on turbidity but generally extends to about 100 meters. Approximately 90% of sea life lives in the photic zone.

The **dysphotic zone**, or twilight zone, refers to pelagic waters where some light penetrates into the water column — but not enough to support photosynthesis. The maximum depth of this zone varies but is approximately 450 to 600 meters.

The **aphotic zone**, or dark zone, refers to pelagic waters where all light ceases to penetrate into the water column and resident organisms must rely on bioluminescence and chemosynthesis to live. The Macondo wellhead is located in this light zone.

Information used in this report is derived from response activities, the NRDA and independent scientific studies. The trustees currently are in the middle of the damage assessment, and therefore this report focuses on describing the approaches used, their rationale and the sampling performed to date. It should be understood that as the assessment continues and as results are received, additional or new approaches and sampling may be required.

For resources/habitats where exposure to *Deepwater Horizon* oil and/or adverse response actions has been established, additional studies are being conducted to quantify the injury. Section III describes the current activities of the ongoing injury assessment. This overview is presented in such a way as to conceptually follow the oil from the release point, 5,000 feet below the surface of the ocean and approximately 50 miles offshore, across the continental shelf to the shorelines of Texas, Louisiana, Mississippi, Alabama and Florida. Following this format, each resource or habitat category will be discussed in the following manner:

- Description of the resource in the Gulf of Mexico that may be impacted by the *Deepwater Horizon* oil spill,
- Description of the threat that the *Deepwater Horizon* oil spill poses to the resources,
- Description of the assessment plan by which the trustees are evaluating injury to and/or loss of the resource,
- Description of the next steps in assessing injury to the resource, and
- Description of the relevant work plans for each resource discussed.

While this presentation format detracts from the integrated nature of the Gulf of Mexico ecosystem, it provides a logical format by which important elements of the ecosystem can be discussed. As individual impacts to these interconnected resources/habitats are assessed, the results will provide the information and framework required to evaluate how they produce adverse impacts throughout the larger Gulf of Mexico ecosystem.

As NRDA work plans and data become public, they have been and will continue to be posted on www.gulfspillrestoration.noaa.gov and http://losco-dwh.com. Data that are made public also are available on www.geoplatform.gov/gulfresponse/. The Administrative Record for the NRDA is available at http://www.doi.gov/deepwaterhorizon/adminrecord/index.cfm.

III. Injury Assessment Categories

The Gulf of Mexico is a complex productive ecosystem. Many ecosystem components were exposed to oil for a prolonged period. In order to manage the evaluation of the complex suite of effects from the spill, ecosystem components are being evaluated by category. This section provides a general description of the approach taken by the trustees for the assessment of natural resources in the Gulf of Mexico by resource/habitat categories (Figure 8). As described earlier (Section I.3), these resource/habitat categories were chosen based on an evaluation of the oil's post-release pathways. When integrated, effects observed in the resource/habitat categories chosen for exposure and injury quantification in the Restoration Planning Phase will illustrate the broader health of the Gulf of Mexico ecosystem.

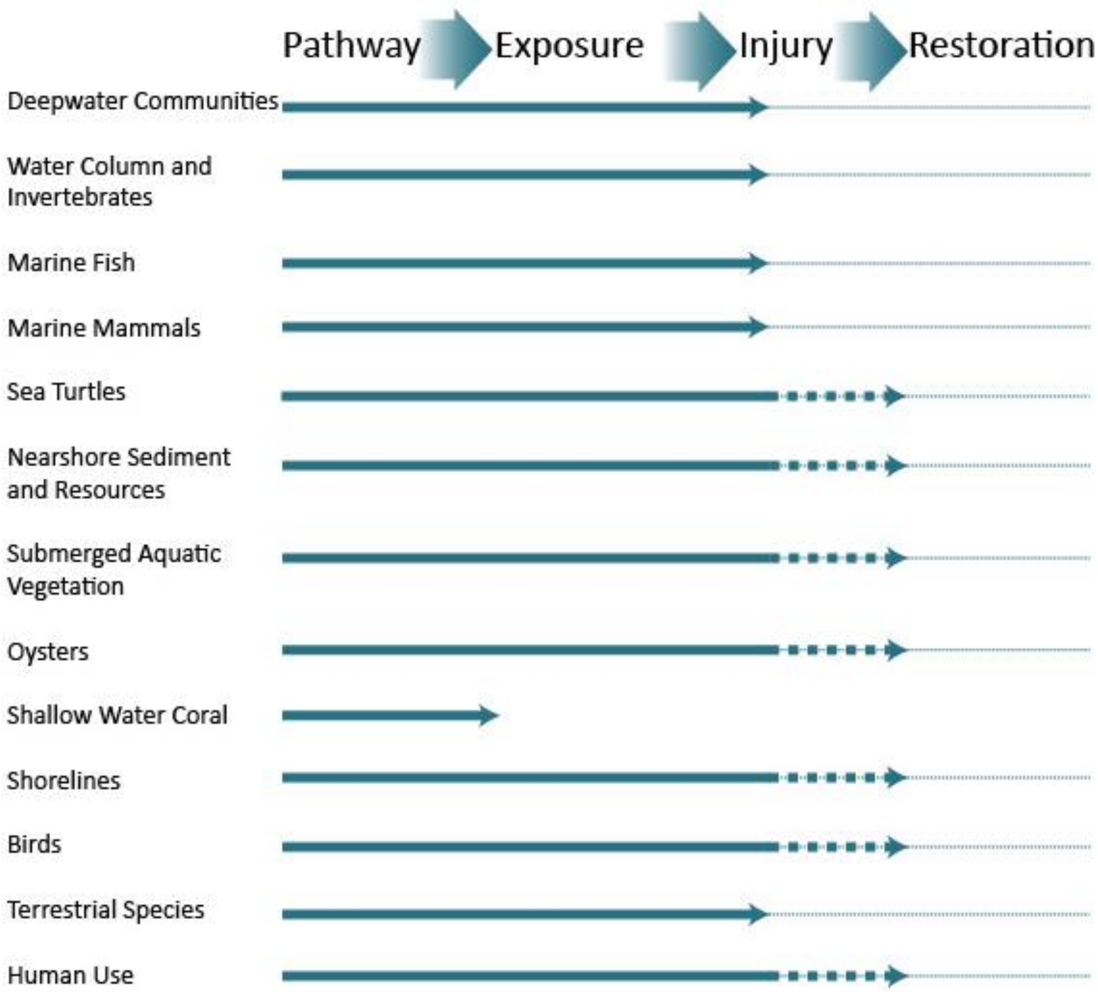

Figure 8. In each resource category, the trustees are working to determine whether an injury occurred, and, if so, to quantify the amount of injury. The trustees are beginning to implement restoration projects for several resource types to which injury is known or reasonably inferred to have occurred.

Each of these resource categories has ecological links to one or more other resource categories. Consequently, the trustees are coordinating closely across resource categories to determine the environmental impacts to the northern Gulf of Mexico coastal and marine ecosystem and to develop an appropriate restoration strategy for restoring the ecosystem.

The goal of this section of the report is to present an overview of the potential impacts to the Gulf of Mexico ecosystem and to summarize the assessment approaches the trustees are using to determine potential exposure and injury. It is important to note that this report presents only a snapshot of the assessment work as of early 2012, and that assessment work plans are often adapted as interim results become available. Because each resource/habitat is interconnected with one or more of the others, adverse impacts to one resource/habitat are likely to reverberate throughout the larger Gulf of Mexico ecosystem. For the human use component, the interconnected resource/habitat categories are related due to direct lost use or intrinsic value.

In addition to the ecological resource categories listed in Figure 8, several supporting work groups are in place to provide technical, logistical and scientific support to each resource category. In particular, the trustees have support groups of experts in place for chemistry and toxicity information and testing, for aerial surveys and observations, and for data management. These support groups are working with each Technical Working Group as needed to assist in evaluating oil exposure and potential damages as a result of the spill, including response activities. This process includes the development of oil index maps that track the cumulative distribution of oil over time and space. The chemistry and toxicity groups are available to provide information on the chemical concentration of samples, toxicity of those concentrations on particular biota, and existing and relevant chemical and toxicological research to help inform the injury assessment process. The aerial survey team has been and is available to map coastlines, count birds and mammals, or observe general oil conditions. Finally, the data management team has been working to collect, record and assimilate the thousands of environmental samples, analytical and observational records.

1. Toxicity

Assessment Plan

A researcher from the University of California at Santa Barbara checks a water sample for air bubbles on board the NOAA Ship Pisces *during a September 2010 NRDA mission.*

The primary goal of the toxicity investigations is to evaluate toxicological responses of representative Gulf of Mexico aquatic animals to discharged oil and dispersants. The results from this work will be integrated with the other appropriate resource/habitat results. For example, toxicity results for fish may be integrated into the hydrodynamic modeling results and the fish distribution results to determine the distribution and magnitude of the biological fish injury. Similarly, toxicity results for shrimp or oysters may be integrated with information relating to the resource's exposure to quantify the magnitude and distribution of injury to those resources. To date, toxicity testing has been conducted or is planning to be conducted on the list of species provided in Table 1.

Table 1. List of Species on which toxicity testing has been conducted or is planned as part of the evaluation of the toxicological responses of representative Gulf of Mexico aquatic animals to discharged oil and dispersants related to the *Deepwater Horizon* oil spill.

Inland silverside	*Menidia beryllina*
Sheepshead minnow	*Cyprinodon variegates*
Red drum	*Scianenops ocellatus*
Southern flounder	*Paralichthys lethostigmata*
Speckled sea trout	*Cynoscion nebulosus*
Goggle eye	*Selar crumenophthalmus*
Cobia	*Rachycentron canadum*
Mahi-mahi	*Coryphaena hippurus*
Bluefin tuna	*Thunnus orientalis*
Yellowfin tuna	*Thunnus albacares*
Grass shrimp	*Palaemonetes pugio*
Blue crab	*Callinectes sapidus*
Eastern oyster	*Crassostrea virginica*
Fiddler crab	*Uca minax*

Assessment

To assess the effects of *Deepwater Horizon* oil, several tests are being and will be conducted using Gulf of Mexico fish and invertebrate species. Currently, 15 principal investigators are implementing tests in nine research laboratories to complete toxicity investigations for the NRDA. Pathways investigated include water accommodated fractions (WAFs) of oil, exposure to oil droplets, exposure to oiled sediment, and ingestion of contaminated prey/food and various oil plus dispersant combinations. The types of oil used for laboratory tests are intended to represent the same oil types to which resources likely were exposed to over the duration of the oil spill. Likewise, exposure scenarios used for laboratory test exposures are intended to represent the breadth of ways individual species are thought to have been exposed to oil as a result of the spill. Endpoints evaluated during these tests include survival, growth, reproductive metrics, development, tissue damage (histology), gene expression, immunological impacts and behavior. The majority of tests are focused on the impacts to sensitive early life stages (e.g., embryo and larvae) or on adults during their reproductive cycles. The schedule of toxicity testing coincides with the reproductive season(s) for each test species.

2. Deepwater Benthic Communities

A colony of coral with dying and dead sections (on left), apparently living tissue (top right) and bare skeleton with sickly looking brittle star on the base has been documented near the Deepwater Horizon *well head.*

Resource

The deepwater benthic communities category encompasses resources living deeper than about 200 feet, including mobile megafauna (large mobile organisms such as crabs) and hardground and soft-bottom associated communities. Hardground communities include deepwater and mesophotic (light-dependent) coral communities (both hard and soft corals), fish, sediment-dwelling and mobile invertebrates, and chemosynthetic tubeworms and mussels. Mesophotic coral communities occur in the deepest part of the photic zone, meaning they can exist at depths with low levels of light. For mesophotic coral communities, energy is obtained via photosynthesis and input of surface-derived food sources such as settling plankton. In the deeper waters of the aphotic zone, distinct coral communities also exist where light penetration is insufficient to sustain photosynthesis. These communities obtain food from the steady rain of detritus from photosynthetically active surface waters above. In contrast, tube worms and mussel beds in deep aphotic waters obtain energy from a symbiotic relationship with chemosynthetic bacteria, which utilize chemicals emanating from the sea floor to produce energy. In other words, these chemosynthetic communities derive their energy and biomass from sources other than sunlight. Deep sea fish are discussed in Section III.4, Marine Fish.

Many of the deepwater hardground communities in this area of the northern Gulf of Mexico have only been identified within the past couple of decades,[41] and our understanding of the complex ecosystems they support is based on limited knowledge. Within the northern Gulf of Mexico, hardgrounds (and the communities they support) are uncommon relative to other community types, but their biodiversity and complexity are significant.[42, 43, 44, 45] Geochemical conditions and microbial activity conducive to the precipitation of carbonate hardgrounds are required for their creation.[46] Hydrocarbon inputs also are required to sustain seep-based tubeworm communities. [47,48,49] Once the hardground is created, however, other factors, such as currents, are more important for the establishment of coral communities. As a result, both chemosynthetic and hardground coral communities are distributed in scattered patches across vast plains of soft-bottom and unoccupied shell-hash seafloor.

The more ubiquitous soft sediment (containing primarily silts and clays in varying proportions) residing between hardground communities provides habitat for a different variety of benthic organisms. These soft-bottom communities are characterized by less conspicuous species such as polychaete worms, small crustaceans and bacteria that burrow in the sediment for food and shelter. These communities consist of multiple size classes of organisms ranging from larger animals that live on the surface of the bottom sediments (i.e., epibenthic macrofauna such as deep sea crabs and sea cucumbers), to macrofauna, to microscopic benthic invertebrates (meiofauna) that burrow and dwell within the sediment itself. While deepwater soft-bottom communities are often diverse (containing many different species), average species *density* (the number of individuals in a given area) is relatively low, mostly due to patchy food sources.[50]

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[41]CSA International, Inc. 2007. Characterization of northern Gulf of Mexico deepwater hard bottom communities with emphasis on *Lophelia* coral. U.S. Department of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2007-044. 169 pp. + app.

[42]Fisher C R., H Roberts, EE Cordes, and B Bernard. 2007. Cold seeps and associated communities of the Gulf of Mexico. Oceanography 20(4): 68 –79.

[43]MacDonald IR and CR Fisher. 1996. Life without light. National Geographic Oct:313-323.

[44]Bergquist DC, T Ward, EE Cordes, T McNelis, R Kosoff, S Hourdez, R Carney, and CR Fisher. 2003. Community structure of vestimentiferan-generated habitat islands from upper Louisiana slope cold seeps. Journal of Experimental Marine Biology and Ecology 289: 197-222.

[45]Cordes, EE, M McGinley, E Podowski, EL Becker, S Lessard-Pilon, ST Viada and CR Fisher. 2008. Coral communities of the deep Gulf of Mexico. Deep Sea Research I 55: 777-787.

[46]Roberts, HH, CR Fisher, B Bernard, JM Brooks, M Bright, RS Carney, EE Cordes, S Hourdez, JL Hunt, Jr., SB Joye, IR MacDonald, C Morrison, K Nelson, V Samarkin, W Shedd, E Becker, M Bernier, G Boland, M Bowles, L Goehring, M Kupehik, S Lessard-Pilon, H Niemann, C Petersen, J Potter, and G Telesnicki. 2007. ALVIN Explores the Deep Northern Gulf of Mexico Slope. Eos, Transactions, American Geophysical Union 88: 341-342.

[47]Cordes, EE, DC Bergquist, K Shea, and CR Fisher. 2003. High hydrogen sulfide demand of long-lived vestimentiferan tube worm aggregations modifies the chemical environment at deep-sea hydrocarbon seeps. Ecology Letters 6: 212-219.

[48]Becker, EL, SA Macko, RW Lee and CR Fisher. 2011. Stable isotopes provide new insights into vestimentiferan physiological ecology at Gulf of Mexico cold seeps. Naturwissenshcaften. 98: 169-174.

[49]Cordes, EE, EL Becker, and CR Fisher. 2010. Temporal shift in nutrient input to cold-seep food webs revealed by stable-isotope signatures of associated communities. Limnology and Oceanography 55: 2537-2548.

[50]Grassle, JF. 1991. Deep sea benthic biodiversity. BioScience 41(7): 464-469.

Threat

Impacts of oil spills to deepwater communities are difficult to predict because each spill presents a unique set of physical, chemical and biological conditions. Some primary modes of exposure for deepwater communities in oil spills include:

- Direct exposure to dispersed oil (*e.g.*, physical smothering) where bottom discharges stay at the ocean bottom;
- Direct exposure to dispersed and non-dispersed oil (*e.g.*, physical smothering) where oil sinks down from higher depths of the ocean;
- Direct exposure to dispersed and non-dispersed oil dissolved in sea water and/or partitioned onto sediment particles; and
- Indirect exposure to dispersed and non-dispersed oil through the food web (*e.g.*, uptake of oiled plankton, detritus, prey, etc.).

Other possible impacts from the presence of dispersed and non-dispersed oil being considered include effects of response actions, oxygen depletion in bottom waters due to bacterial metabolism of oil and/or dispersants, and light deprivation under surface oil.

Assessment Plan

The trustees have focused on the following activities:

- Mapping the spatial distribution of oil/dispersant and drilling mud from the *Deepwater Horizon* release;
- Mapping soft- and hard-bottom habitats along the continental shelf and sea floor;
- Assessing the potential for toxicity, physical fouling, etc. for any habitats exposed to oil or dispersant or indirect adverse effects associated with their releases; and
- Assessing changes in community composition, survival and reproduction attributable to exposure to oil, dispersant, drilling mud or indirect effects of the spill.

To date, these activities have been implemented through a series of cruises using remotely operated vehicles (ROVs), autonomous underwater vehicles (AUVs) and other ship-based research tools. Trustees have collected and may continue to collect sediment and tissue samples to characterize exposure and to document adverse effects that may have been caused by the *Deepwater Horizon* oil spill. Figure 9 depicts a number of the sites where the trustees are focusing deepwater community assessment activities. Additional specific efforts are described in greater detail below.

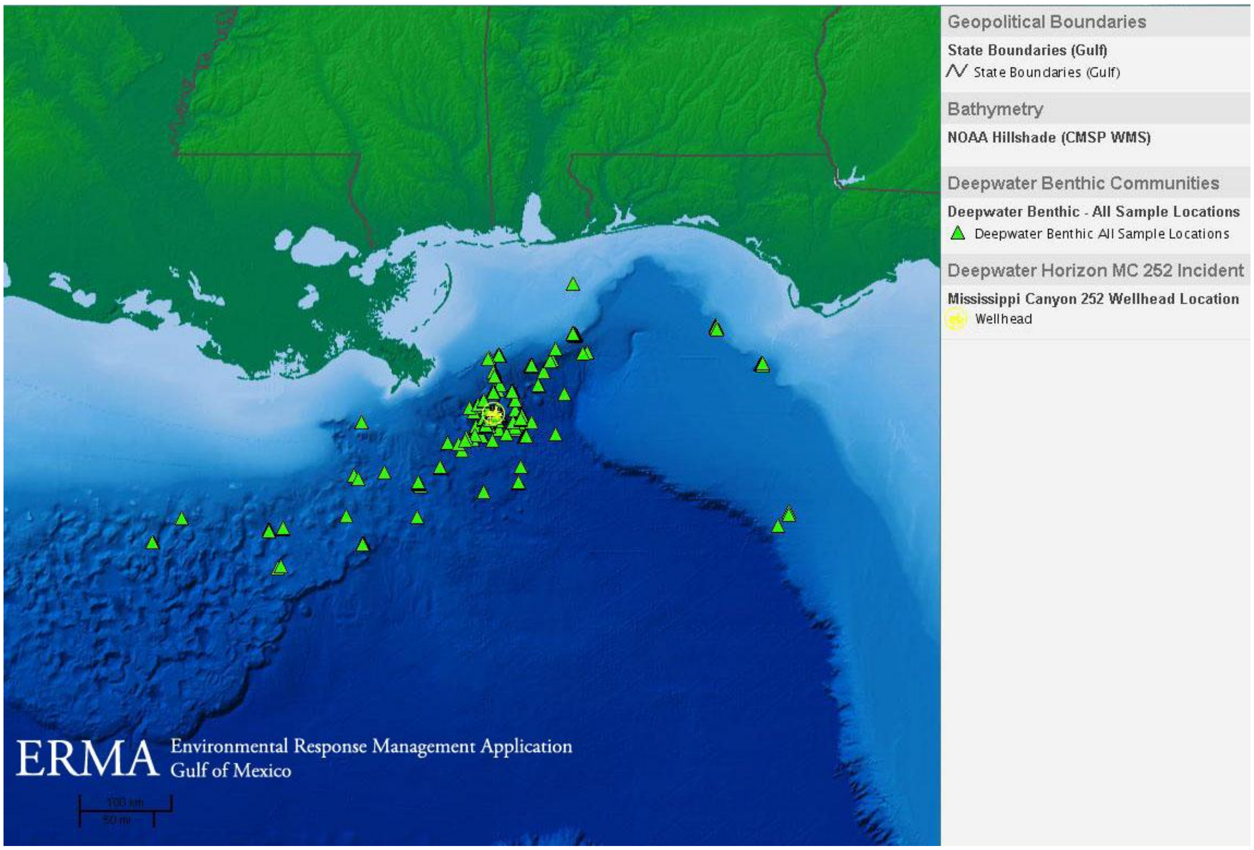

Figure 9. This map illustrates the locations in the western and eastern Gulf of Mexico where the trustees are focusing their deepwater community assessment.

Baseline Data

To accurately assess injury to natural resources in the deepwater benthic zone of the Gulf of Mexico relative to baseline, the trustees are employing historical data about the condition of natural resources. When historical data are unavailable, the trustees will compare potentially affected resources to similar resources in unaffected ("reference") locations.

The extent of historical data available for use in the assessment varies by resource and also by the assessment approach being used. Assessment activities for deepwater corals rely on the use of photographic and video imaging techniques. In the case of deep sea hardground coral communities, very little historical image data are available. In many cases, the location and composition of hardground coral communities was unknown prior to the oil spill, and assessment activities have focused on identifying the locations of these communities and the species that constitute them. Figure 10 depicts known locations of deepwater coral communities in the northern Gulf of Mexico and where samples have been collected to date. In the case of mesophotic reefs (light-dependent coral reefs that exist at a depth of between 130-500 feet below the surface), historical video data are available and may be used to assess oil spill impacts relative to baseline. In the case of the soft-bottom infaunal and epifaunal communities,[51]

[51]Soft-bottom infaunal communities exist within the soft-bottom sediments. Soft-bottom epifaunal communities exist on top of the soft-bottom sediments.

assessment activities are focusing on community metrics in relation to sediment concentrations of spill-related contaminants and other sediment parameters.

For resources for which limited historical data are available, reference locations are used. Reference locations are selected to ensure that the resources are the same or similar but shown (through analytical chemical and modeling techniques) to be outside of the influence of the oil spill. In some cases, resource studies evaluate exposure to *Deepwater Horizon* oil (or other contaminants such as dispersants or any indirect adverse effects of the oil spill) and resource conditions along gradients in these two parameters. In such cases, statistical techniques can be employed to tease out correlations between the oil spill contaminants (and adverse indirect effects) and resource condition.

Assessment

Deepwater Corals

A diver works with coral as part of a restoration project.

There are approximately 150 to 200 potential hard-bottom sites within 15 miles of the wellhead, not all of which support seep or coral communities. A major component of assessment efforts to date has included survey work to confirm the presence of deepwater coral communities at these locations. Potential impacts to corals and associated organisms are being and will continue to be assessed at known or newly identified communities, using photographic and video documentation. This image documentation is being collected for analysis by experts in deepwater community ecology for enumeration of species abundance and documentation of any visual evidence of adverse effects on the biologic communities. In addition to these techniques, other tools being used include rotary, time-series sediment traps to assess potential exposure and analytical techniques to age and genetically identify coral and associated biota. Finally, tissues and nearby sediments are being collected and analyzed for exposure to hydrocarbons and other spill-related contaminants.

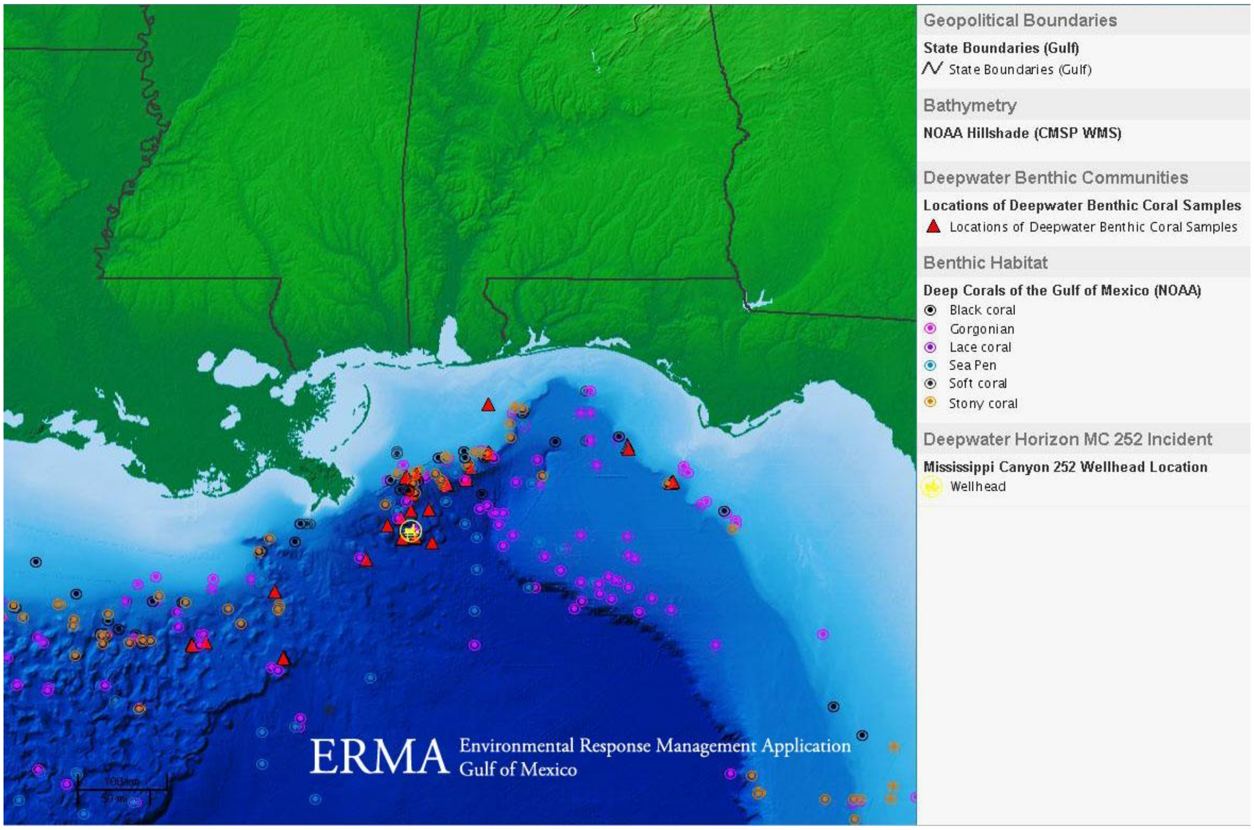

Figure 10. This map illustrates the locations of trustee deepwater coral samples and known locations of deepwater corals in the northern Gulf of Mexico.

Thus far, visual observations suggest that two hard-bottom coral communities have been impacted by the oil spill, one located 7 miles to the southwest of the wellhead[52], and another located 3 miles to the southeast of the wellhead. It has been shown that the diffused plume of oil and dispersants moved in all directions immediately around the wellhead and at greater distances to the southwest of the wellhead, establishing the potential exposure pathway (see Figure 11). Hydrocarbons present in sediments and tissues collected at the site to the southwest also have been identified as emanating from the oil spill, thus establishing the exposure of natural resources at this location. Hydrocarbon fingerprinting at this and the other adversely affected site is ongoing, but at both locations many corals have been identified as dead or dying. The full extent of injury is still being assessed.

[52] White HK, PY Hsing, W Cho, TM Shank, EE Cordes, AM Quattrini, RK Nelson, R Camilli, AWJ Demopoulo, CR German, JM Brooks, HH Roberts, W Shedd, CM Reddy and CR Fisher. 2012. Impact of the Deepwater Horizon oil spill on a deep-water coral community in the Gulf of Mexico. Proceedings of the National Academy of Sciences of the United States. Published ahead of print March 27, 2012.

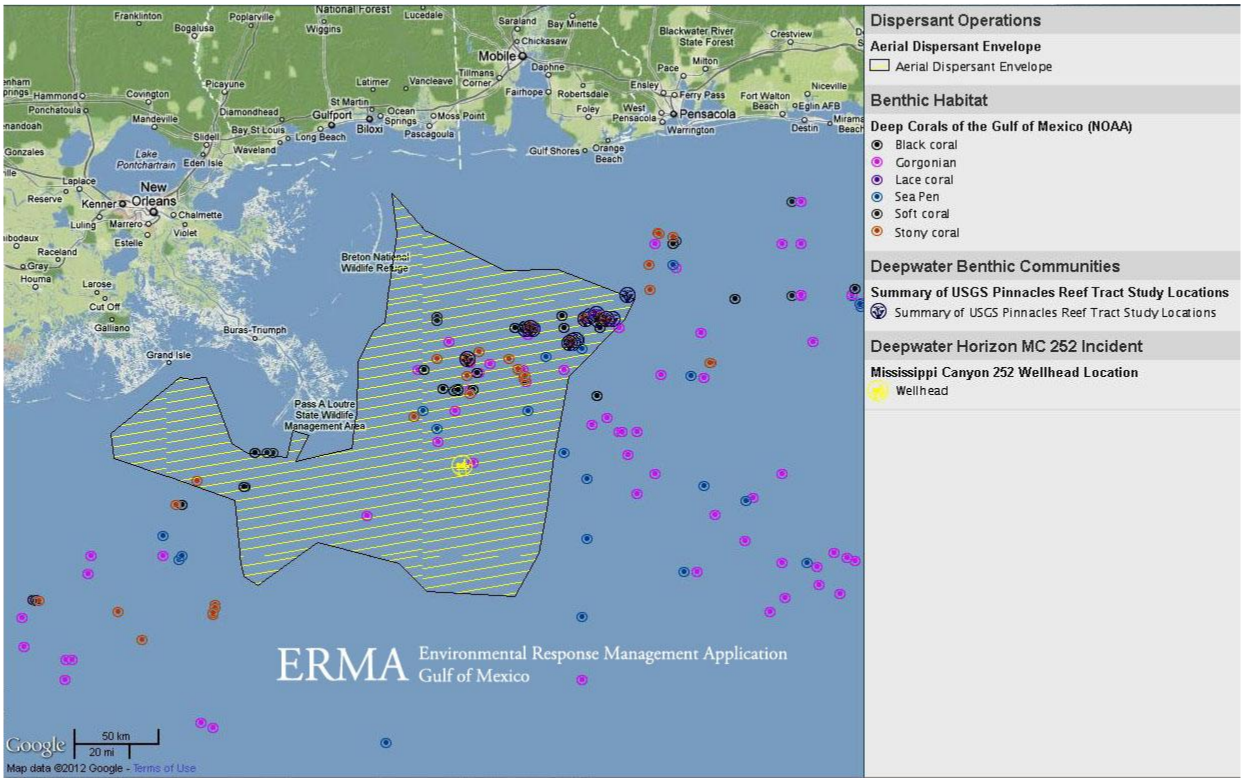

Figure 11. This map illustrates the location of known deepwater corals in the Gulf of Mexico in relation to the *Deepwater Horizon* wellhead and area in which aerial dispersants were applied.

Soft-Bottom Habitats

For soft-bottom habitats, visual documentation and sediment coring are being used to determine the level and spatial extent of oiling and to assess the potential adverse effects on benthic communities caused by *Deepwater Horizon* dispersed oil and/or drilling mud. In addition, deepwater red crabs have been targeted for exposure and injury assessment. Given the vast area of soft-bottom sediments in the northern Gulf of Mexico and the logistical complexities associated with conducting a physical sweep of the whole area, knowledge gained from selected locations (see Figure 12) likely will be used to model the full extent of oiling on the deepwater sediments. Knowledge of pre- and post-oil spill community composition and hydrocarbon exposure in these habitats will inform the injury assessment.

Mesophotic Coral Reefs

Data from semi-permeable membrane devices (SPMDs) suggest that Alabama Alps, one mesophotic reef area, may have been exposed to petroleum hydrocarbons. But to date, the trustees have not established a pathway for subsurface oil or dispersants to directly, adversely impact coral reefs in the mesophotic zone. The focus of the assessment also has been on determining if the release of oil and dispersant or the presence of the surface slick may have indirectly, adversely impacted resident fish populations. Preliminary evidence from cruises targeting these reefs has indicated that populations of resident planktivorous (plankton-eating) fish are significantly decreased. By evaluating more closely historical pre-release video taken at these reefs, trustees aim to confirm this finding and, if confirmed, determine if the decrease is the result of the oil spill or other factors. Potential adverse impacts to mesophotic reef corals also have been observed and analysis of collected video and photographic imagery is ongoing. Mesophotic reef sampling locations are depicted in Figure 12.

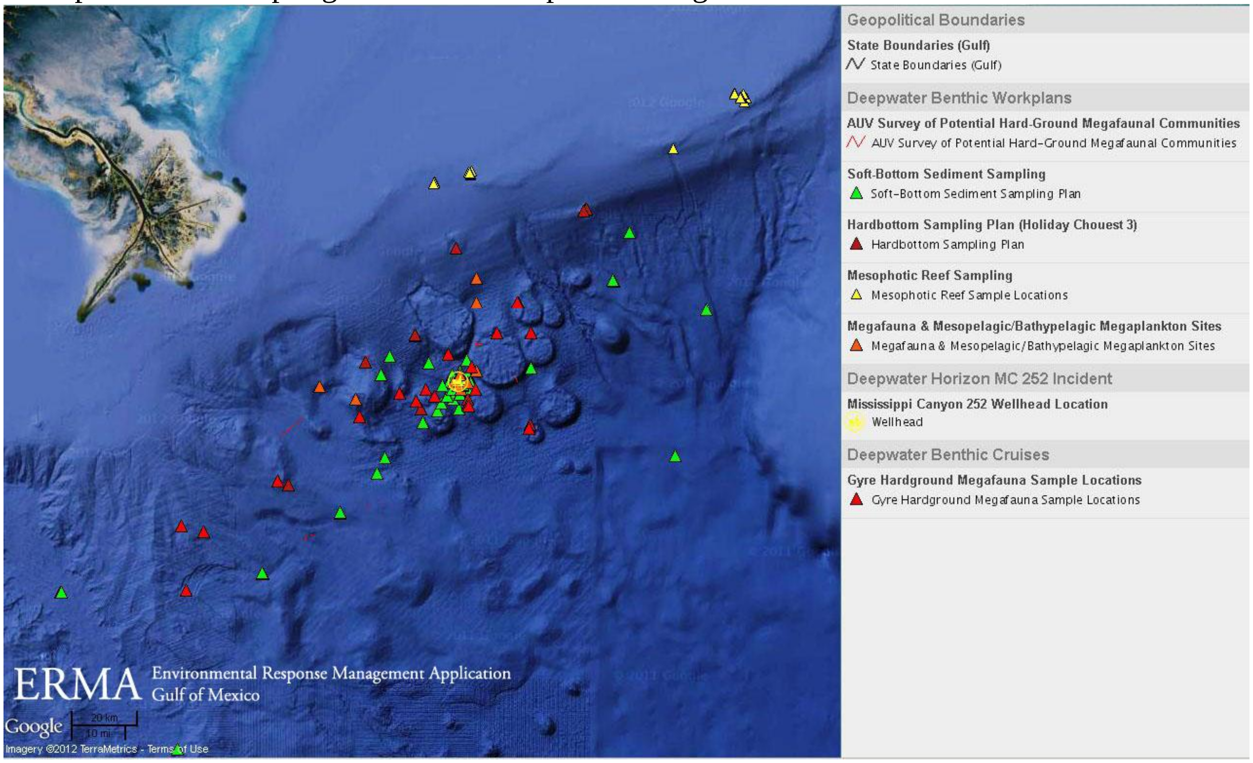

Figure 12. This map illustrates the locations of NRDA samples collected to assess damage to mesophotic reefs and hard- and soft-bottom habitats.

Next Steps

Currently no additional damage assessment field work in these three deepwater habitat types is scheduled. Assessment efforts are currently focused on analyzing and interpreting data that have been collected to date. Based on the results of these efforts, however, additional field work or habitat monitoring may be warranted.

Relevant Work Plans

Relevant work plans can be found by visiting www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data.

3. Water Column and Invertebrates

Resource

The waters of the Gulf of Mexico serve as an important and diverse habitat for many species of fish, birds, mammals, turtles, shellfish and other invertebrates. The oceanic ecosystems can be broadly categorized as follows:

- Neuston – organisms that are associated with the surface of the water including many plankton, bacteria, *Sargassum* and some fish (especially larval fish);
- Plankton – organisms that float or drift with the water (examples include bacteria, microscopic plants and animals, jellyfish, early life stages of species such as fish and crab, etc.);
- Nekton – organisms that swim in the water (examples include fish, mammals, turtles, etc.); and
- Benthos – organisms that inhabit the bottom of the ocean (examples include seagrass, crustaceans, mollusks, corals, polychaetes, oysters, etc.).

The resources of primary interest for assessment in this category are the water itself and planktonic organisms, including the neuston, nekton and micronekton (<2 cm)[53]. Many of these organisms migrate vertically through the water column to feed in surface waters at night. Marine fish are being assessed through similar work plans and methods but are discussed in Marine Fish, Section III.4. Marine mammals and sea turtles are also being assessed individually and are discussed in Section III.5 and Section III.6 respectively.

Threat

Oil in and on the surface of marine waters has the potential to affect the health of a wide variety of important aquatic resources and habitats. The mixture of oil and gas released from the broken wellhead mixed with ocean water and undoubtedly came into contact with various organisms characterized as plankton, micronekton and neuston as it passed through and settled at the surface of the water column. Water column organisms that came into contact with oil risked exposure through ingestion, inhalation and dermal contact.

Researchers label water sample bottles during lab analysis.

[53] Micronekton are actively swimming organisms ranging in size between plankton (<2 cm), which drift with the currents, and larger nekton (>10 cm), which have the ability to swim freely without being overly affected by currents.

Researchers gather water samples from a rosette that measures CTD (conductivity, temperature, depth).

There are two discrete pathways for potential impacts to water column organisms and habitats. At the wellhead, natural dispersion and chemical dispersion (through the injection of dispersant at the source) created smaller oil particles that became sequestered in the deep ocean and moved through the depths carried by deep sea currents. Larger droplets of oil with sufficient buoyancy moved upwards through the 5,000-foot water column toward the surface. Oil that did not dissolve (i.e., partition into the water) during the ascent formed slicks on the surface of the ocean that were carried by wind and currents.

At depth, through chemical and natural dispersion, oil remained suspended and highly diluted in the water column as deep as 4,200 feet.[54] This highly dispersed oil mixture became susceptible to biodegradation and diffusion in a low-energy environment characterized by high pressure, near-freezing temperatures and constant darkness. As the oil and dispersant mixed with the surrounding water, some of it appears to have adhered to marine snow[55] and was deposited as a surficial flocculent[56] layer on the deep sediments and hardgrounds. The plume of small oil droplets remaining in the bottom waters was moved away from the wellhead in various directions by slow moving currents. Information examined to date suggests that a substantial amount of the oil droplet plume moved to the southwest of the wellhead through a deep sea canyon at an average depth of approximately 3,700 feet. As the plume moved away from the wellhead, results reported by multiple cruises conducted independently of the NRDA process demonstrated that the processes of diffusion, mixing and biodegradation acted to decrease the concentrations of hydrocarbons measured in these waters.

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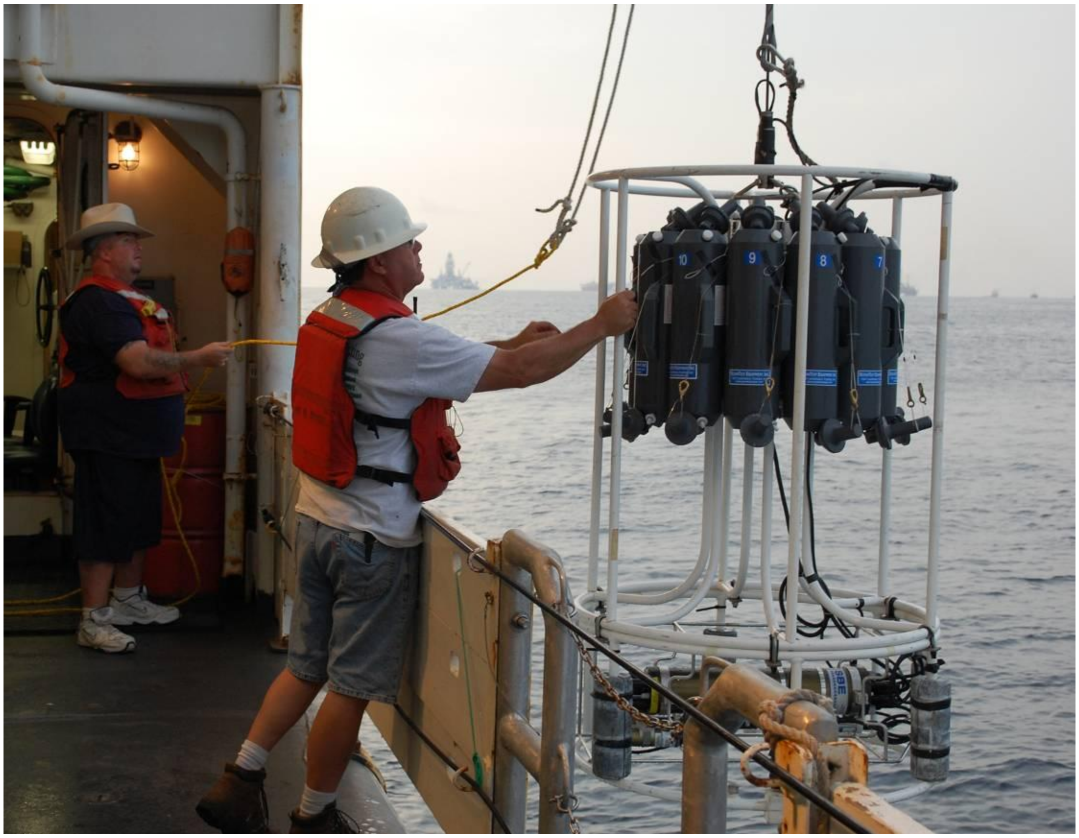
[54]Camilli, R, CM Reddy, DR Yoeger, BAS Van Mooy, MV Jakuba, JC Kinsey, CP McIntyre, SP Sylva, and JV Maloney. 2010. Tracking hydrocarbon plume transport and biodegradation at *Deepwater Horizon*. Science 330(6001): 201–204; Hazen, TC, EA Dubinsky, TZ DeSantis, GL Andersen, YM Piceno, N Singh, JK Jansson, A Probst, SE Borglin, JL Fortney, WT Stringfellow, M Bill, ME Conrad, LM Tom, KL Chavarria, TR Alusi, R Lamendella, DC Joyner, C Spier, J Baelum, M Auer, ML Zemla, R Chakraborty, EL Sonnenthal, P D'haeseleer, HN Holman, S Osman, Z Lu, JD Van Nostrand, Y Deng, J Zhou, and OU Mason. 2010. Deep-sea oil plume enriches indigenous oil-degrading bacteria. Science 330(6001): 208–211; Valentine D, JD Kessler, MC Redmond, SD Mendes, MB Heintz, C Farwell, L Hu, FS Kinnaman, S Yvon-Lewis, M Du, EW Chan, FG Tigreros, and CJ Villanueva. 2010. Propane respiration jump-starts microbial response to a deep oil spill. Science 330(6001): 204–208; *Deepwater Horizon* Unified Area Command. 2010. Summary report for sub-sea and sub-surface oil and dispersant detection: Sampling and monitoring. Operational Science Advisory Team. December 17, 2010.

[55]A continuous shower of mostly organic detritus falling from the upper layers of the water column. http://oceanservice.noaa.gov/facts/marinesnow.html

[56]A non-consolidated layer of biogenic, detrital material relatively rich in organic matter that can represent an important food-web component for invertebrates and fish.



Researchers prepare to deploy an array of sensors to evaluate conditions in the water column.

The oil not remaining in the deep ocean rose through the water column on a journey to the surface. As it rose, some of the hydrocarbons dissolved into the water. The oil that did not dissolve created a large and sometimes patchy surface slick that drifted with the currents. The hydrocarbons that reached the surface and did not evaporate weathered and emulsified into a reddish-brown mousse that created a dark blanket of oil on the surface of the ocean. Oil did not just remain on the surface. Dispersants applied at the surface to break apart the oil particles and facilitate biodegradation dispersed these particles into the shallow water layer (0- 30 feet). Microscopic photosynthetic organisms, which live in the photic zone and depend on the sun's light for survival, were potentially impacted both by direct exposure to the toxic hydrocarbons present in the oil and by the loss of energy for photosynthesis. These planktonic organisms are the foundation of the marine food chain. Fish, sea turtles and marine mammals all feed on these organisms and are also susceptible to ingestion and inhalation of, or dermal contact with, oil.

In addition to the large volume of oil in the water column, 1.84 million gallons of dispersants also were applied as part of the effort to decrease the environmental impacts of the oil: 1.07 million gallons on the surface and 771,000 gallons at the wellhead.[57] Dispersants used during response operations at the surface and at the wellhead were designed to break down oil into

[57] Deepwater Horizon Incident Joint Information Center. 2010. The ongoing Administration-wide response to the Deepwater BP Oil Spill. http://www.restorethegulf.gov/release/2010/08/06/ongoing-administration-wide-response-deepwater-bp-oil-spill.

smaller particles that mix into the water, enhance biodegradation, and reduce heavy surface water and shoreline oiling. As noted above, the application of dispersants may also pose a threat to aquatic organisms.

The depth and duration of the Macondo well blowout caused an unprecedented omni-dimensional threat, both from the oil and from the dispersant used to combat it. Trustees have been studying the fate and transport of the oil, taking into account the application of dispersants at the surface and by subsurface injections.

Assessment Plan

The goals of the water column assessment plan are:

- To document the release, pathway, exposure and injury using field measurements; and
- To quantify the level of water column injury using a combination of field sampling and models.

For this resource category, the trustees have collected sufficient chemical, physical and biological field-based evidence to demonstrate pathways. Three-dimensional hydrodynamic modeling is being used to evaluate the transport of oil and dissolved constituents. After calibrating the model with field data in an iterative process, the model will better define the potential pathways and assist the trustees in the selection of future physical and biological sampling locations. Ultimately, the model will incorporate the oil fate and transport with biological species distributions to quantify injury based on known toxicity ranges for representative species.

Baseline Data

As a major component of the water column assessment plan, the trustees are studying the temporal and spatial distribution and densities of ichthyoplankton (fish eggs and larvae), other zooplankton (tiny drifting organisms, such as rotifers, copepods, krill, dinoflagellates and other protozoans) and some phytoplankton (free-floating algae, protists and cyanobacteria). The NOAA Fisheries' Southeast Area Monitoring and Assessment Program (SEAMAP) has sampled plankton in the epipelagic water column throughout the Gulf of Mexico for the past 25 years.[58] These data provide an important component for the trustees to assess the nature and variability of the baseline conditions. The overall NRDA plankton sampling plan takes advantage of this historical data set and plans for continuation of SEAMAP and extension of the program into locations that are only sporadically sampled by SEAMAP. Additionally, the NRDA investigation collects samples in deeper water, down to about 5,000 feet, to document the biological community in this area of the Gulf of Mexico.

[58]As noted above, the NRDA process is charged with assessing the injuries to natural resources resulting from the oil spill, including actions taken during the response. Thus, the trustees have an obligation to understand the baseline conditions – or pre-spill conditions. In the *Deepwater Horizon* oil spill, the trustees are fortunate to have access to long-time series information regarding fishing stocks, turtles and marine mammal abundances, ichthyoplankton abundance and distributions, and shoreline sediment and nearshore benthic contaminant concentrations. These data are available through the ongoing efforts of several different long-term NOAA efforts, including the National Status & Trends program, SEAMAP, annual stock assessments, etc.

Assessment

Physical and Chemical

To document and quantify potential injury based on the concentration and duration of exposure to oil, the trustees are documenting the fate and transport of oil (including dispersed and burned fractions) through numerous water quality transect and sentinel station surveys to inform submerged oil plume modeling and sediment sampling locations across different habitats. Specifically, trustees have collected data to document physical and chemical water conditions and free-oil droplet concentrations at multiple depths. Analyses of both dissolved (*e.g.*, monoaromatic [such as benzene and alkylbenzenes] and lower molecular weight polycyclic aromatic hydrocarbons [such as naphthalenes]) and separate phase hydrocarbon distributions and concentrations in samples have been and continue to be conducted to help understand and model the structure, fate, weathering, transport and toxicity of the oil. Figure 13 depicts the types and locations of water column samples taken for these analyses.

An Integrated Ocean Observing System glider is used to locate and track oil at various levels in the water column as well as on the water surface.

Trustees also are monitoring currents throughout the water column in the vicinity of the wellhead via acoustic Doppler current profilers (ADCPs) to improve water sampling location selections and to refine data inputs into models. Conductivity, temperature and depth (CTD) measurement probes collect data to characterize the physical properties of the water column. Combined, these data allow for a better characterization of the physical aspects of the surface mixed layer and the interfaces (i.e., pycnoclines) that separate discrete water masses found within the water column. In addition, throughout the water column, dissolved oxygen data have been collected to help assess the effect of microbial degradation of the oil on deepwater oxygen conditions as well as for tracking the fate of the oil. Fluorescence data were extensively collected during and immediately following the release. These data also are being evaluated to look for oil that was suspended and/or dissolved in the water column. Data on suspended sediments, chlorophyll concentrations and other physical measurements also are being collected.

Biological

The existing data that describe plankton distributions in potentially affected areas in the deepwater offshore are less extensive than data available for the shelf areas. First, the composition and density of plankton in the vicinity of the *Deepwater Horizon* oil spill and the subsequent areas of impact have not been previously quantified in detail, especially in the deepwater areas surrounding the release site. Second, vertically stratified sampling in the upper water column is sparse. Other data gaps include the under-representation of fish, squid, soft-bodied organisms and marine snow in net-based surveys.

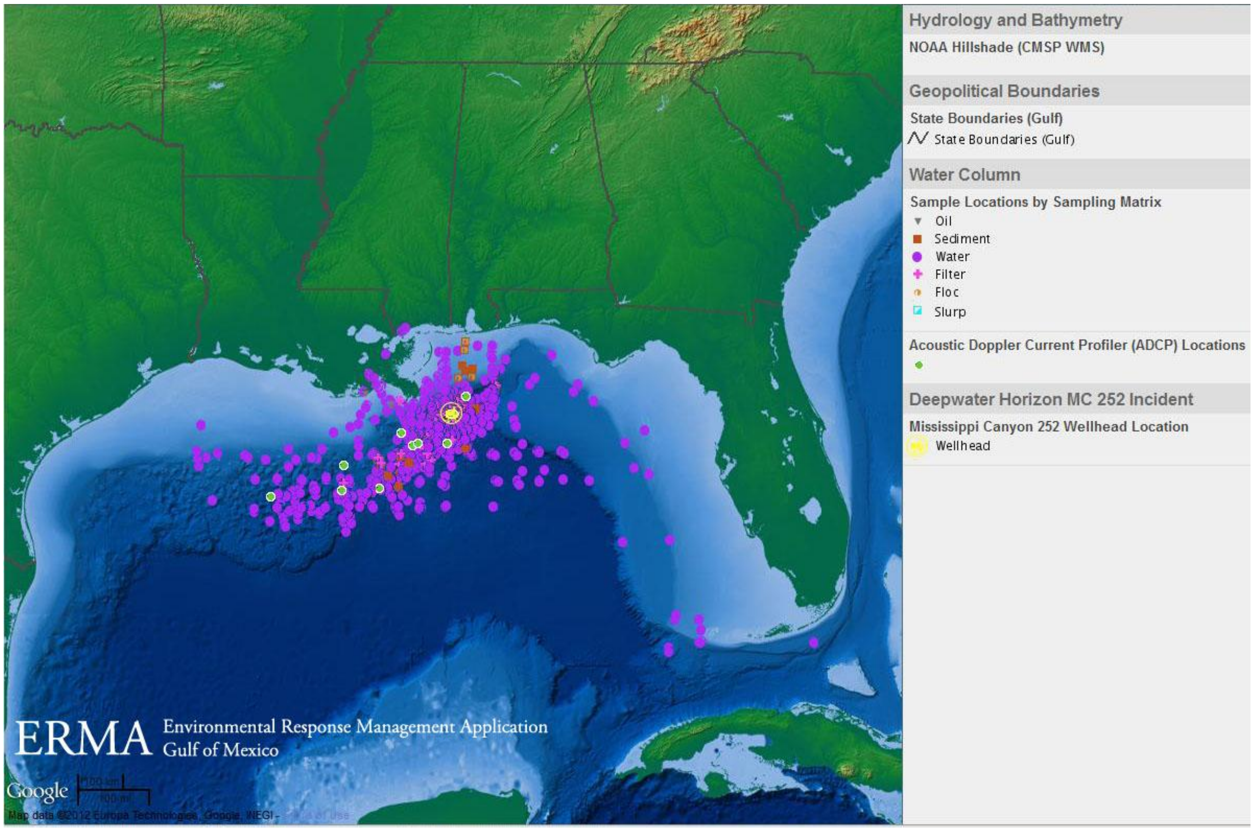


Figure 13. This map illustrates the many types and locations of water column data the trustees have collected in the Gulf of Mexico.

A series of cruises that began in fall 2010 and ran through summer 2011 (aboard the research ships *Walton Smith*, *Pisces*, *McArthur II*, *Nick Skansi*, *Meg Skansi*, *Bunny Bordelon*, *HOS Davis* and *Oceanus*) targeted many of these data gaps by conducting seasonal sampling with multiple gear types across a broad area of the shelf, shelf break and offshore waters beyond the shelf break (see Figure 14). The gear included bongo nets[59] and neuston nets to capture plankton in the upper portion of the water column. Depth-stratified sampling from the surface down to about 5,000 feet was conducted using the 1 meter [about 3 feet] and 10 meter [about 30 feet] Multiple Opening/Closing Net and Environmental Sensing System (MOCNESS). In addition to being depth stratified, the larger of the MOCNESS nets captures somewhat larger, more mobile plankton, ichthyoplankton, small fish and invertebrates. The trustees used towed imaging systems such as the digital autonomous video plankton recorder (DAVPR), second generation video plankton recorder (VPR-II), the Holocam (holographic camera images), shadowed imaged particle profiling and evaluation recorder (SIPPER), and in situ ichthyoplankton imaging system (ISIIS) to target broad areas and sample soft-bodied organisms and marine snow that are under-represented by net sampling. Finally, acoustic systems were used to look at the plankton and

[59]For a description of plankton nets refer to: http://www.whoi.edu/page.do?cid=11254&pid=8415&tid=282http://www.whoi.edu/page.do?cid=11254&pid=8415&tid=282.

nekton. These imaging and acoustic systems also provide additional data between the stations at which net sampling occurred. Combined, these data, collected across multiple gear types, will be examined in the context of modeling and remote sensing data to look for changes in the planktonic community related to the oil spill.

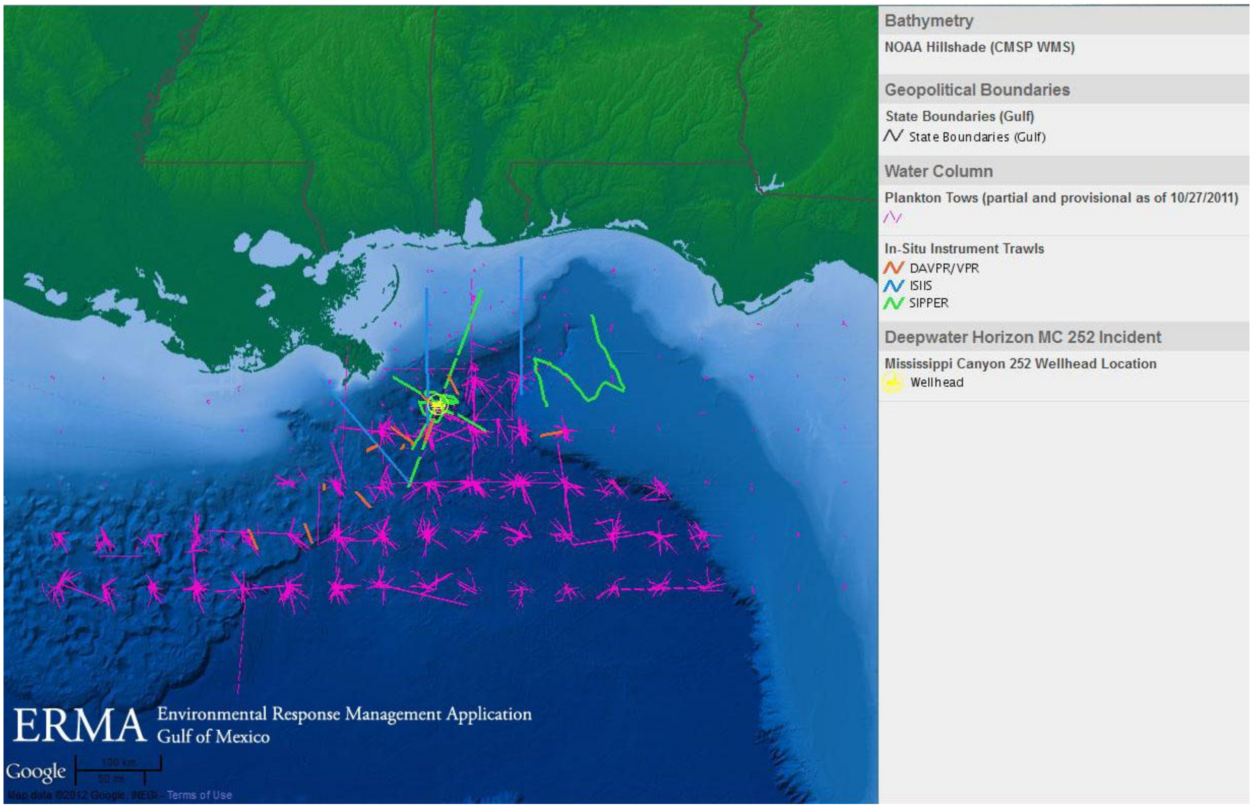


Figure 14. This map illustrates biological and in-situ trawls conducted by NRDA researchers in support of water column assessment work.

Next Steps

Water sampling information near natural seeps and abandoned wells is part of the baseline work being conducted to estimate the contribution of these sources to hydrocarbon concentrations in the water column compared to the contributions resulting from the oil spill. As previously mentioned in Section III.1, toxicity testing is under way using a variety of organisms endemic to the Gulf of Mexico. This testing will look at toxicity from oil and dispersants as well as any synergistic toxicity associated with increased toxicity caused by exposure to sunlight (phototoxicity).

Once all field and lab work is complete, a comprehensive analysis of all available data will be conducted to determine the extent of injury to the water column. These data will be used to inform the hydrodynamic and biological modeling effort that will support the assessment.

Relevant Work Plans

Relevant work plans can be found by visiting www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data.

4. Marine Fish

Bluefin tuna are a Gulf species prized by commercial and recreational fishermen alike.

Resource

The highly productive coastal estuaries and shorelines of Texas, Louisiana, Mississippi, Alabama and Florida support a tremendous and diverse fishery resource. These marine resources in turn feed higher trophic levels[60] including birds, marine mammals, sea turtles and terrestrial wildlife. They also comprise one of the most productive sea food industries in the world**.** The Gulf of Mexico region provides 33% of the nation's seafood.[61] In 2008, commercial fishermen in the Gulf of Mexico harvested 1.27 billion pounds of finfish and shellfish that earned $659 million in total landings revenue.[62] The Gulf of Mexico accounted for more than 44% of all U.S. marine recreational fishing catch in 2009 (by pounds).[63] In addition, 3.2 million recreational fishermen took at least one fishing trip in the Gulf of Mexico region, totaling 24 million individual fishing trips in 2008.[64, 65] Marine fish are both ecologically and economically important in the Gulf of Mexico. Therefore, the impacts to marine fish as a result of oil and dispersant exposure have implications for other resource categories and human use.

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[60]The *trophic level* of an organism is the position it occupies in a food web.

[61]National Marine Fisheries Service, National Oceanic and Atmospheric Administration. 2010. Annual commercial landings statistics. Years queried: 2007-2009. http://www.st.nmfs.noaa.gov/st1/commercial/landings/annual_landings.html (as cited in Mabus, R. 2010. America's Gulf Coast: A long term recovery plan after the Deepwater Horizon oil spill. http://www.epa.gov/indian/pdf/mabus-report.pdf).

[62]NOAA. 2010. Fish Stocks in the Gulf of Mexico Fact Sheet. http://sero.nmfs.noaa.gov/sf/deepwater_horizon/Fish_economics_FACT_SHEET.pdf.

[63]NOAA National Ocean Service. 2011. The Gulf of Mexico at a Glance: A Second Glance. U.S. Department of Commerce, Washington, D.C. http://stateofthecoast.noaa.gov/gulfreport.html.

[64]NOAA. 2010. Fish Stocks in the Gulf of Mexico Fact Sheet. http://sero.nmfs.noaa.gov/sf/deepwater_horizon/Fish_economics_FACT_SHEET.pdf.

[65]The information presented in this section has implications for several aspects of the NRDA as well as other OPA claims. For example, the commercial fishery information illustrates the significance of commercial fishing and suggests that commercial fishing claims may be significant under OPA for this spill. Similarly, the recreational fishing statistics point to possible claims from the recreational fishing industry. They are presented here to illustrate the fact that in the context of the Gulf of Mexico ecosystem, fisheries are important, not solely for their commercial uses, but as a valuable component of the marine ecosystem.

Because the entire food chain may have been affected by oil and dispersant exposure, the trustees are studying fish in several trophic levels. Therefore, the toxicity testing being conducted or planning to be conducted on fish focus on species that represent different trophic levels. For example, the inland silverside primarily feeds on zooplankton, speckled sea trout feeds on shrimp and small fish, and mahi mahi is an apex predator, meaning it is near the top of the food chain with few predators.

Federal officials assess how a sample is processed aboard the Research Vessel Caretta *and chain of custody protocol is followed when handling specimens associated with the oil spill.*

In addition to fish and food web dynamics, the Gulf sturgeon is also a focus of the marine fish assessment. Gulf sturgeon are listed as threatened under the Endangered Species Act. [66,67] Their habitat includes the bays and estuaries of Florida, Alabama, Mississippi and Louisiana as well as freshwater rivers from the Suwannee River, Florida, to the Mississippi River. Based on possible exposure scenarios related to oil movement in these coastal waters, the Gulf sturgeon is being assessed for potential injury.

The marine fish assessment is intertwined with studies of water column and invertebrates, Section III.3; the nearshore sediment and associated resources, Section III.7; submerged aquatic vegetation assessment, Section III.9; shoreline (marsh/estuarine habitat, in particular), Section III.11; and oysters, Section III.8.

Threat

Fish are exposed to dissolved oil and dispersants and oil droplets through a variety of pathways, including direct dermal contact (*e.g.*, swimming through oil and dispersants or waters with elevated dissolved hydrocarbon concentrations and other constituents), ingestion (*e.g.*, via food base) and inhalation (*e.g.*, elevated dissolved contaminant concentrations in water passing over the gills). Fish that have recently ingested contaminated prey may themselves be a source of contamination for their predators. Further, certain petroleum metabolites can be toxic to fish, and the fish can experience stress, reproductive failure and other sublethal effects while metabolizing hydrocarbons.

Studies have suggested that sublethal hydrocarbon exposure on fish can lead to the development of lesions.[68] Eggs and larvae of many fish species are highly sensitive to oil exposure, resulting in decreased spawning success and abnormal larval development.[69] Other potential direct effects that may occur as a result of exposure to hydrocarbons include reduced growth, enlarged livers, changes in heart and respiration rates, fin erosion, and reproductive impairment. Recent results from studies looking at potential synergetic effects of dispersants in oil exposure have suggested that the dispersants make it easier to move hydrocarbons across membranes – and thus may enhance exposure.[70,71] Fish also may be indirectly impacted through degradation of supporting habitat or food base.

[66]NOAA National Marine Fisheries Service. Endangered and Threatened Species and Critical Habitats under the Jurisdiction of the NOAA Fisheries Service: Gulf of Mexico. April 6, 2011. http://sero.nmfs.noaa.gov/pr/endangered%20species/specieslist/PDF2010/Gulf%20of%20Mexico.pdf

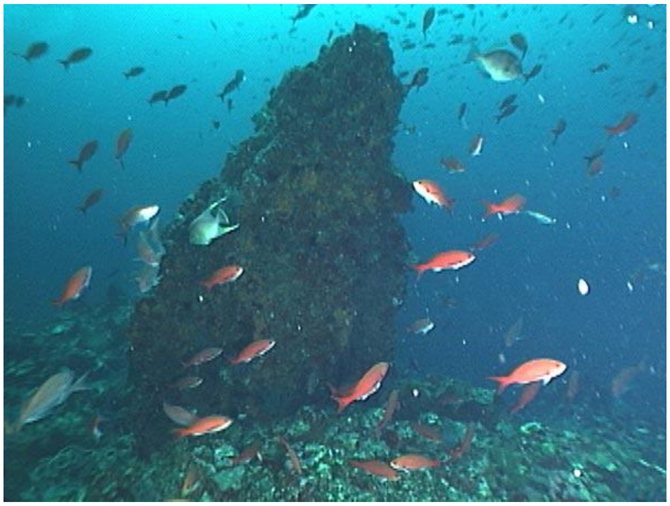
[67]For a summary of the Endangered Species Act of 1973 please refer to: http://www.fws.gov/laws/lawsdigest/esact.html.

[68]Myers, MS, LL Johnson, and TK Collier. 2003. Establishing the causal relationship between polycyclic aromatic hydrocarbon (PAH) exposure and hepatic neoplasms and neoplasia-related liver lesions in English sole (*Pleuronectes vetulus*). Human and Ecological Risk Assessment 9: 67–94.

[69]Incardona, J, TK Collier, NL Scholz. 2011. Oil spills and fish health: exposing the heart of the matter. Journal of Exposure Science and Environmental Epidemiology. 21: 3-4.

[70] Wolfe MF, JA Schlosser, GLB Schwartz, S Singaram, EE Mielbrecht, RS Tjeerdema, and ML Sowby. 1997. Influence of dispersants on the bioavailability and trophic transfer of petroleum hydrocarbons to primary levels of a marine food chain. Aquatic Toxicology 42(3): 211-227.

[71] Wolfe MF, JA Schlosser, GLB Schwartz, S Singaram, EE Mielbrecht, RS Tjeerdema, and ML Sowby. 2001. Influence of dispersants on the bioavailability and trophic transfer of petroleum hydrocarbons to larval topsmelt (*Antherinops affinis*). Aquatic Toxicology 52(1):49-60.



Creole fish, amberjack and several other species school around a basalt spire at Alderdice Bank, Texas.

The *Deepwater Horizon* oil spill occurred across a very large area of the Gulf of Mexico, potentially impacting estuarine, nearshore and offshore fish. The oil spill occurred during the peak spawning period for some species and also may have adversely affected juveniles and eggs in the prolific nurseries of the Gulf Coast estuaries and in the open ocean.

Many fish species can metabolize toxic hydrocarbons, which reduces the risk of human exposure to contaminants through seafood and the bioaccumulation of contaminants in the food web. There is ample scientific evidence, however, that hydrocarbon exposure can result in negative effects (both lethal and sublethal) on fish health and on fisheries populations.[72] Fish also can be affected by consumption of contaminated prey and, in turn, can affect upper level predators if they have only recently been exposed to toxic hydrocarbons.

Gulf sturgeon are anadromous fish, inhabiting the fresh waters of coastal rivers from Louisiana to Florida during the warmer months and the Gulf of Mexico and its estuaries and bays in the cooler months. While they can live for about 60 years, the more common lifespan is 20-25 years. Sturgeons reach sexual maturity at around age 8. In 1991, the species was listed as a threatened species under the Endangered Species Act (ESA) (56 FR 49653).

Gulf sturgeon are bottom feeders and eat primarily macroinvertebrates, including brachiopods, mollusks, worms and crustaceans. All foraging occurs in brackish or marine waters of the Gulf of Mexico and its estuaries; sturgeon do not forage in riverine habitat. Given their home range and foraging behavior, Gulf sturgeon may have been exposed and adversely affected by the oil spill.

Assessment Plan

The goals of the fisheries and shellfish assessment plan are:

- To document pathway, exposure and injury using field measurements and sampling; and
- To quantify the level of fish injury using field data, toxicity literature, laboratory toxicity analyses and modeling.

The trustees have been conducting a series of studies designed to characterize the extent and duration of oiling conditions in the Gulf since the *Deepwater Horizon* oil spill and to determine

[72] Di Giuilo, R.T. and D.E. Hinton. 2008. The toxicology of fishes. Taylor & Francis.

abundances and distribution of fisheries, including eggs and larvae, in the areas potentially affected. These studies have been conducted in coastal zones (estuarine and nearshore) and in deepwater. Invertebrate prey also have been tested for polycyclic aromatic hydrocarbon (PAH) contamination. An extensive toxicity testing protocol has been developed to determine the toxicity of oil and dispersants on a variety of important species potentially exposed to the spill.

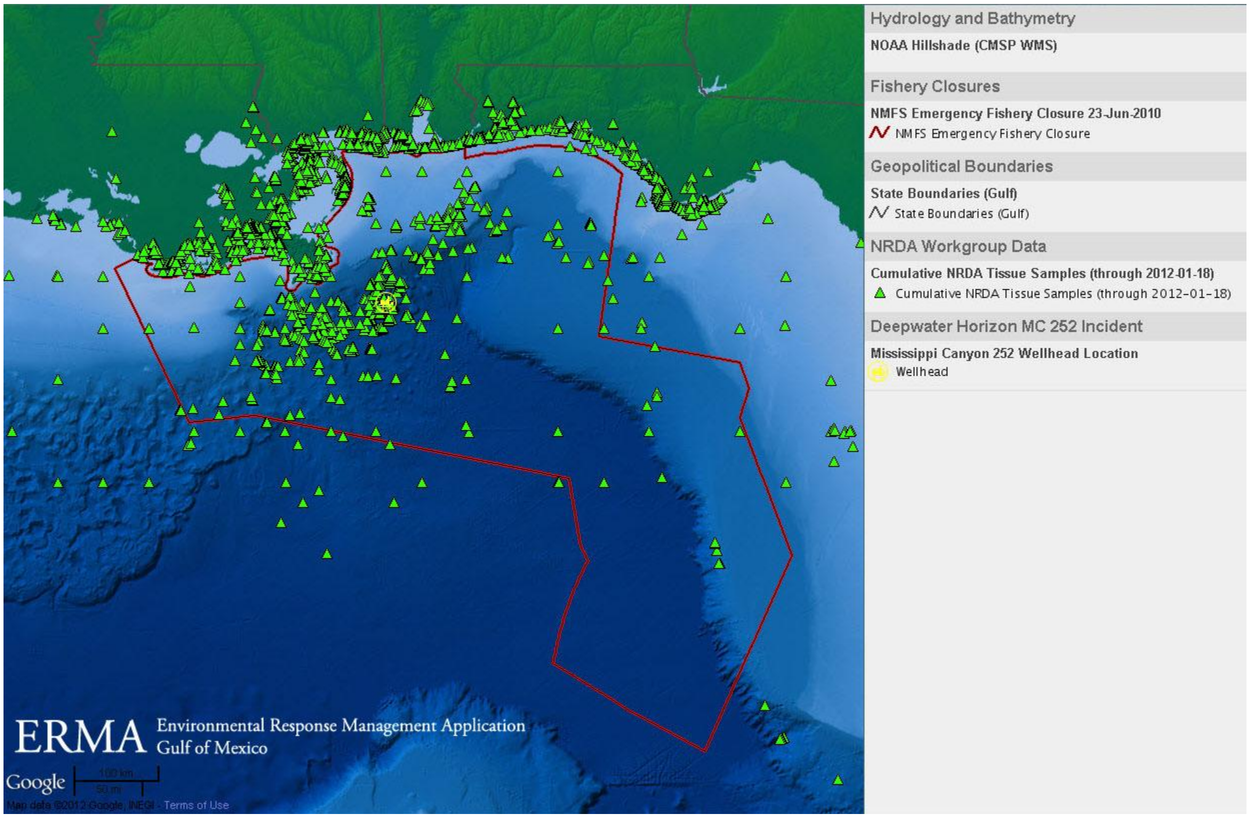


Figure 15. This map illustrates the midsummer 2010 federal fishery closure and the locations of the trustee tissue samples through early 2012.

Baseline Data

Trustees will use pre-impact data for fish abundance in the Gulf of Mexico waters near the oil spill to establish baseline. Such data will include historical information on density, diversity and distribution of ichthyoplankton and fisheries stocks in the northern Gulf of Mexico.

Assessment

Deep Ocean Fish

Offshore sampling cruises have been characterizing conditions throughout the water column since summer 2010. Sampling of fish, fish larvae and fish eggs, in addition to plankton (see Section III.3, Water Column and Invertebrates) also has been conducted. Mid-water trawls provide data on the composition, distribution and densities of juvenile and adult fish and larger invertebrates in the offshore. These cruises targeted deepwater communities (mesopelagic and bathypelagic, i.e., between about 2,300 feet and 4,600 feet) that often migrate vertically through the water column on a daily basis. Data collection, which occurs seasonally, began in winter 2010 and continued through 2011. No additional plankton trawls are planned as of now.

The smaller nets that have been used to target early life stages of fish do not readily capture small pelagic fish. To determine abundance and distribution of such fish, the trustees completed a survey that combines acoustic sampling and a larger, near-surface trawl net with aerial observations to gather information.

Sargassum and Associated Communities

Sargassum in the Gulf of Mexico consists generally of two species, *Sargassum natans* and *Sargassum fluitans*. The pelagic brown algae are an oasis in the open ocean that supports an assemblage of marine fish, invertebrates and other marine life. In spring 2011, the trustees began a multi-pronged assessment to understand potential injuries to *Sargassum* habitat and communities. First, they conducted a series of aerial surveys and vessel-based assessments of *Sargassum* and *Sargassum* communities. Second, the trustees conducted an analysis of remote sensing data to determine the general location and spatial extent of the *Sargassum* in the Gulf of Mexico over time. Third, based on the results from the first and second parts of the study, lab studies may be used to establish effects on *Sargassum* from oil and dispersant exposure.

Nearshore Cetacean and Sea Turtle Prey

The trustees are collecting tissue samples from fish and invertebrates to investigate potential exposure to prey species and potentially higher trophic levels that consume them. This sampling is occurring in Louisiana and includes liver and bile analysis for PAH metabolites, as well as whole body samples that could be tested for PAHs.

Toxicity Testing

Toxicity testing, primarily of embryolarval stages of a wide variety of fish species endemic to the Gulf of Mexico, will help to assess toxicity due to exposure to oil and dispersant mixtures.

Gulf Sturgeon

The objectives of the Gulf sturgeon plan are three-fold and address exposure and injury through:

- Comparison of the pre-oil spill condition of adult sturgeon to post-oil spill condition, focusing on adults that migrated into the Gulf of Mexico after the oil spill;
- Documentation of winter habitat use in the Gulf of Mexico relative to exposed or impacted areas; and
- Comparison of blood chemistry and health condition of adults when they return to inland rivers.

The trustees are using existing programs initiated by NOAA and the U.S. Fish and Wildlife Service (USFWS) recovery efforts that have historically tagged Gulf sturgeon and monitored their movement in and around impacted areas. To date, the trustees have added 135 receivers in coastal areas from Louisiana to Florida.

Trustees will analyze blood samples for potential indication of exposure to toxic oil compounds, DNA fragmentation and reproductive disruptions.

Blue Crab Megalope

The trustees are examining the impact of oil on early life history stages of blue crabs through monitoring and/or analysis of blue crab megalopae (final larval stage) and egg-bearing females from the natural environment, and through culture of blue crabs using egg-bearing females taken from oil-impacted barrier island beaches and a control beach. Phase I involves the collection of megalopae and egg-bearing female tissues and the storage of both for subsequent examination and analysis. Phase II involves the laboratory sorting, identification, and photo-documentation of megalopae collected in settlement samples in 2010 and 2011. Phase III involves chemical analysis of the samples to determine the composition of oily droplets which were found under the carapaces of blue crab megalopae from impacted areas, and may provide for the culture of blue crabs in the laboratory.

Next Steps

Laboratory analysis of the thousands of samples collected over the course of this assessment has not yet been completed. Once gathered, all field and laboratory data will be analyzed using models, remote sensing information, literature, historical data and professional judgment to determine the extent and nature of exposure to *Deepwater Horizon* oil and dispersant constituents and any impacts on marine resources.

Relevant Work Plans

Relevant work plans can be found by visiting www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data.

5. Marine Mammals

Resource

Marine mammals that reside in or are regular visitors to the Gulf of Mexico include 21 species of cetacean (whales and dolphins) and one sirenian (manatee). All are protected under the Marine Mammal Protection Act. Additionally, six whales (sperm (*Physeter macrocephalus*), sei (*Balaenoptera borealis*), finback (*Balaenoptera physalus*), blue (*Balaenoptera musculus*), humpback (*Megaptera novaeangliae*) and North Atlantic right whales (*Eubalaena glacialis*)) and the Florida manatee (*Trichechus manatus*) are listed as endangered under the Endangered Species Act.

Cetacean species found in the Gulf of Mexico (common and scientific)	
Sperm whale*	*Physeter macrocephalus*
Bryde's whale	*Balaenoptera edeni*
Cuvier's beaked whale	*Ziphius cavirostris*
Blainville's beaked whale	*Mesoplodon densirostris*
Gervais' beaked whale	*Mesoplodon europaeus*
Common bottlenose dolphin	*Tursiops truncatus*
Atlantic spotted dolphin	*Stenella frontalis*
Pantropical spotted dolphin	*Stenella attenuata*
Striped dolphin	*Stenella coeruleoalba*
Spinner dolphin	*Stenella longirostris*
Rough-toothed dolphin	*Steno bredanensis*
Clymene dolphin	*Stenella clymene*
Fraser's dolphin	*Lagenodelphis hosei*
Killer whale	*Orcinus orca*
False killer whale	*Pseudorca crassidens*
Pygmy killer whale	*Feresa attenuata*
Short-finned pilot whale	*Globicephala macrorhynchus*
Pygmy sperm whale	*Kogia breviceps*
Melon-headed whale	*Peponocephala electra*
Risso's dolphin	*Grampus griseus*
Dwarf sperm whale	*Kogia sima*
*** Indicates species listed under ESA Source: MMC 2008 Annual Report to Congress http://mmc.gov/reports/annual/pdf/2008annualreport.pdf**	

Threat

Whales, dolphins and manatees can be exposed to chemicals in oil or dispersants in several ways:

- Internal exposure by consuming oil or contaminated prey or inhaling volatile oil and dispersant-related compounds,
- External exposure, by swimming in oil or dispersants and having oil or dispersants directly on the skin and body, and
- Maternal transfer of contaminants to embryos.

In addition to chemical exposure, response activities, such as collecting and burning oil at sea, skimmer operations, boom deployment, berm construction and boat traffic could directly injure marine mammals or cause behavioral changes.

Assessment Plan

The goals of the marine mammal assessment plans are:

- To document the pathway, exposure and injury using field measurements and observations and
- To quantify the level of injury using field sampling, population observations, laboratory analysis and existing toxicity literature.

Baseline Data

The trustees will use existing marine mammal surveys from the NOAA Southeast Fisheries Science Center conducted in summer 2009 and early 2010 to inform baseline. The Science Center also has a decade of distribution data for Bryde's whales. Information from the U.S. Geological Survey (USGS) Southeast Ecological Research Center will contribute to evaluating baseline for manatees.

Assessment

This dolphin carcass was recovered on Grand Isle Beach, Louisiana, in January 2012.

Study plans are being implemented to assess indirect and direct exposure and impacts to whales, dolphins and manatees. The trustees have divided the northern Gulf of Mexico assessment area in four different study groups:

(1) the open ocean (oceanic zone) targeting primarily sperm whale, Bryde's whale, striped dolphin and Risso's dolphin;
(2) coastal bottlenose dolphins;
(3) estuarine bottlenose dolphins; and
(4) manatees (which live in rivers, estuaries and canals).

For potential exposure and impacts to oceanic marine mammals, the trustees conducted research cruises to document distribution, exposure, population demographics, habitat and presence of deep oceanic prey such as squid. This was done through boat and aerial surveys, passive acoustic monitoring over time, satellite tagging, tissue sampling, prey trawling and echosounder surveys. Tissue samples may be analyzed for oil-related contaminants and genetics. Habitat information has been collected to characterize water column productivity.

For the assessment of coastal bottlenose dolphins, aerial surveys have been performed since the spill to document changes in distribution and abundance during and after the spill.

For estuarine dolphins, the trustees are conducting studies to detect changes in fecundity, survival, distribution and abundance. Boat-based surveys collect photo documentation data for comparison to baseline abundance and site fidelity, prevalence of calves and identification of individuals to track for survival analysis.

Dolphin health assessments on live animals also are being conducted in a contaminated area (Barataria Bay) and an area not exposed to the oil (Sarasota Bay). This includes internal and external examinations and sampling of blood, skin/blubber and urine for contaminants and health parameters. Dolphins will be evaluated for anemia, organ damage, immune suppression, endocrine disruption, nutritional changes and chronic stress.

Preliminary findings indicate that bottlenose dolphins in Barataria Bay, which received heavy and prolonged exposure to oil, are showing signs of severe ill health including low body weight, anemia, low blood sugar and/or symptoms of liver and lung disease. Nearly half of the 32 dolphins examined also have abnormally low levels of the hormones that help with stress response, metabolism and immune function. Satellite and very high frequency (VHF)[73] tags have been put on dolphins in Barataria Bay to track movements, range and preferred habitats

Veterinarians collect samples from a dolphin in Barataria Bay, Louisiana, during August 2011 health assessments.

In early 2011, NOAA declared an Unusual Mortality Event (UME) for cetaceans (whales and dolphins) in the northern Gulf of Mexico from February 2010 through the present.[74] Under the Marine Mammal Protection Act of 1991, a UME is defined as "a stranding that is unexpected, involves a significant die-off of any marine mammal population and demands immediate response." The impetus for the declaration was the sharp increase in the discovery of premature, stillborn or neonatal bottlenose dolphin strandings in the region beginning in February 2010. From February through April 2010, 114 cetacean strandings were documented; in the six months between May and the beginning of November 2010, 122 cetaceans were documented as stranded or reported dead in the offshore. Since then, the stranding rate has continued to be well above historical averages. In 2011, there were 356 strandings (compared to a historical average of 74). Locations of marine mammal strandings are depicted in Figure 16. Of specific concern is the increase in the number of premature, stillborn or neonatal stranded bottlenose dolphins documented in February and March 2011. In February

[73]Very high frequency is between 30-300 MHz.
[74]NOAA National Marine Fisheries Service. Marine Mammal Unusual Mortality Events. http://www.nmfs.noaa.gov/pr/health/mmume/ and http://www.nmfs.noaa.gov/pr/health/mmume/cetacean_gulfofmexico2010.htm

2011, stranding was documented for 34 neonatal bottlenose dolphins compared with only one documented neonatal stranding in 2010 (and an average of two documented neonatal strandings for the years 2002-2007). Whenever possible, the trustees are conducting necropsies on dead animals. They also are analyzing samples to evaluate the role that oil and/or response activities may have played in the deaths. The trustees are coordinating their activities, where possible, with the investigation being conducted by the UME Working Group into the cause of these dolphin deaths, including any linkages to *brucella* infections that have been reported in stranded animals.

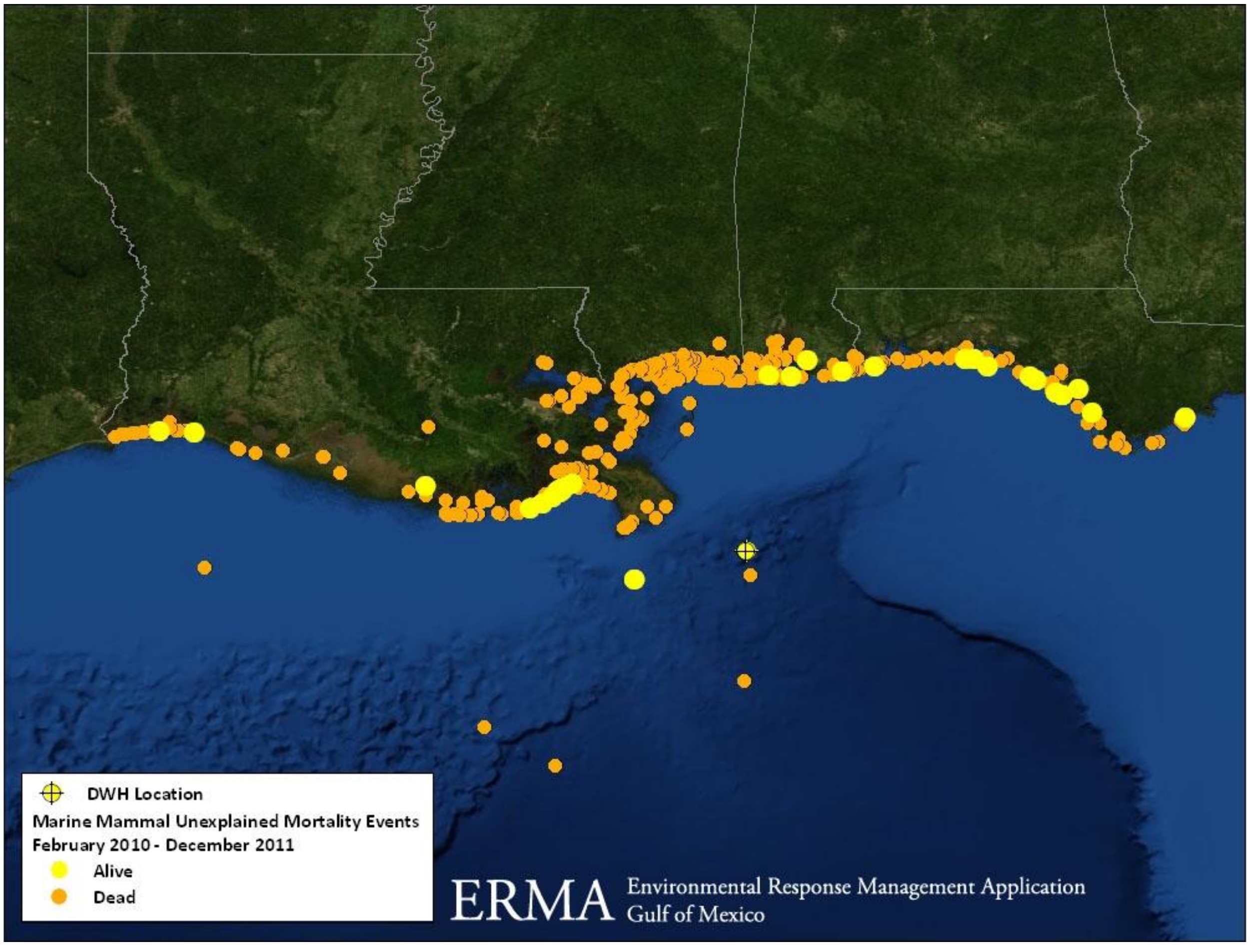


Figure 16. This map illustrates marine mammal strandings in the Gulf of Mexico from early 2010 through the end of 2011.

The Florida manatee inhabits the coastal waters, estuaries and freshwater river systems of Florida. Manatees could be most susceptible to contaminant exposure if oil enters estuaries, river mouths and intracoastal waters inshore of barrier islands, particularly where there are seagrass beds upon which manatee forage. During the warm season (spring to fall), manatees disperse throughout Florida waters and some migrate to neighboring states including Alabama, Mississippi and Louisiana, with some individuals having traveled as far west as the middle Texas coast. They spend the vast majority of their time in very shallow waters close to shore.

Aerial surveys were conducted to estimate abundance and assess distribution of Florida manatees in areas affected by and adjacent to the *Deepwater Horizon* oil spill (before, during and after impact). Surveys also were conducted over impacted areas to document locations of marine mammals in fouled areas; to document locations of fouled, distressed or dead animals; and to inform manatee rescue efforts.

Scientists from the USGS are investigating the movement of 19 manatees throughout the region using telemetry. This information is being used to produce habitat use and travel-corridor maps for Apalachicola Bay, Wakulla and other Florida Panhandle areas. Maps will show how the manatees use habitat features to rest and feed at low speeds and how they use travel corridors at higher speeds. Maps of manatee-use patterns generated by telemetry will be compared with those of the Florida Fish and Wildlife Conservation Commission's aerial survey distribution data. Movement patterns also will be compared with distribution of submerged aquatic vegetation and information on shoreline oiling.

Next Steps

Aerial surveys were conducted seasonally from April 2011 through April 2012 to cover broad-scale synoptic surveys of the continental shelf and shelf break from Brownsville, Texas, to Dry Tortugas, Florida. The purpose was to collect information on distribution, abundance, species identification and exposure of marine mammals.

Marine mammal prey sampling began in September 2011 to assess potential exposure through contaminated prey in the estuarine/coastal environment. The prey samples, including those taken in 2010 and 2011, will undergo chemical analysis for oil and dispersant related compounds.

A targeted assessment of sublethal and chronic health impacts on coastal and estuarine bottlenose dolphins in Barataria Bay and a reference site (Sarasota Bay, FL) was conducted in 2011. Sublethal endpoints include anemia, organ damage, immune suppression, endocrine disruption, nutritionals and chronic stress. Satellite and VHF tags are being used in Barataria Bay to track movements, range and preferred habitats, and follow up field work is being planned for the spring 2012 for the animals that were studied, including a number of pregnant females Results will be compared to existing health surveys conducted at Sarasota, St. Joseph and Beaufort, North Carolina.

Relevant Work Plans

Relevant work plans can be found by visiting www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data.

6. Sea Turtles

Resource

There are five sea turtle species living in the Gulf of Mexico listed as threatened or endangered under the Endangered Species Act: Kemp's ridley (*Lepidochelys kempii*), green (*Chelonia mydas*), leatherback (*Dermochelys coriacea*), loggerhead (*Caretta caretta*) and hawksbill (*Eretmochelys imbricata*).[75] The western Gulf of Mexico is the primary place in the world where the Kemp's ridley sea turtle nests.

Threat

Sea turtles can be exposed to chemicals in oil or dispersants in several ways:

- Internal exposure by consuming oil or contaminated prey or inhaling volatile oil and dispersant-related compounds,

- External exposure to sea turtles or eggs from oiled nesting beaches,
- External exposure by swimming in oil or dispersants and having oil or dispersants directly on the skin and body, and
- Maternal transfer of contaminants to embryos and eggs.

A veterinarian prepares to clean a severely oiled Kemp's ridley turtle.

In addition to chemical exposure, response activities, such as collecting and burning oil at sea, skimmer operations, boom deployment, berm construction, increased light at night on or near nesting beaches, equipment use and storage as a result of beach cleanup operations and boat traffic could directly injure sea turtles, block access to turtle nesting beaches and/or cause behavioral changes.

Assessment Plan

The goals of the sea turtle assessment plans are:

- To document the pathway, exposure and injury using field measurements and observations and
- To quantify the level of injury using field sampling, population observations, laboratory analysis and existing toxicity literature.

[75] For more information on sea turtles refer to: http://www.nmfs.noaa.gov/pr/species/turtles/.

Baseline Data

Information on Kemp's ridley nesting success and habitat utilization collected by National Park Service Padre Island National Seashore, home to a successful nesting colony of Kemp's ridley, will provide baseline for sea turtles. Sea turtle nesting surveys have been routinely conducted on ~368 km of Florida Panhandle beaches (Escambia County through Franklin County) since 1989 and on 75 km of Alabama beaches (Mobile and Baldwin counties) since 2003. These surveys are conducted with consistent levels of effort that allow year to year comparisons.

Assessment

Trustees are assessing exposure to all sea turtles but specifically those observed to be most affected: loggerhead and Kemp's ridley sea turtles. The trustees have divided the northern Gulf of Mexico assessment area into three geographic ecological zones:

(1) nesting beaches,
(2) coastal waters (neritic zone) where juveniles and adults live and feed, and
(3) open ocean waters where post-hatchlings, juveniles and adults live and feed, especially in and around floating *Sargassum*.

Given the potential routes of exposure and threats described above, the trustees are conducting a series of studies designed to better understand and quantify the presence and distribution of these sea turtles in the northern Gulf of Mexico and the level of contaminant exposure they may have experienced.

For the neritic turtles, aerial surveys and satellite telemetry have been and are being conducted to document abundance and spatial distributions. Samples from dead, stranded animals are collected in an attempt to determine potential exposure to oil-related contaminants. Figure 17 shows locations where trustees have located stranded sea turtles.

A wildlife biologist from Georgia's Department of Natural Resources surveys oiled Sargassum in the Gulf of Mexico.

For oceanic turtles, an important component of the sea turtle assessment is the assessment of *Sargassum* habitat. *Sargassum* is highly productive marine seaweed that floats at the surface of the ocean and provides the framework for a large, floating oceanic ecosystem. This habitat or mini-ecosystem provides an environment for a distinctive and specialized group of marine animals and plants, many of which are not found elsewhere. The habitat is important to juvenile fish and turtles, which seek food and shelter in *Sargassum*. It, like the surface oil, tends to aggregate in oceanic convergence zones created by the wind and currents.

Throughout the summer and into the early fall 2010, large swaths of *Sargassum* were observed as being oiled. As a result, the *Sargassum* habitat acted as a focal point for the exposure of oil to many types of sea life, including sea turtles, which are susceptible to dermal contact, inhalation and ingestion of oil. Oiled *Sargassum* can sink — resulting in a loss of habitat —which also contributes to the injury.

As presented in Section III.4, *Sargassum* is a vital open water habitat for sea turtles, particularly juveniles. During the oil spill, sea turtle rescue efforts documented 574 turtles in this habitat, 464 of them visibly oiled. Also, the floating mat provides shelter and attracts a diverse array of marine organisms. The trustees are examining the density and diet of sea turtles in this geographic zone via boat surveys. To this end (impact on prey abundance), they also are looking at fish and invertebrate density, abundance, diversity and contaminant concentration in and around *Sargassum* habitats that may have been impacted by the oil spill.

To determine the direct impacts of oil to sea turtle health and reproductive output, the trustees have conducted and continue to conduct studies assessing the physical condition of the nesting female loggerhead and Kemp's ridley sea turtles, as well as inter-nesting movements, blood chemistry, egg and hatchling toxicity, and hatching and emergence success.

Trustees working as part of the spill response translocated 274 nests from northern Gulf of Mexico beaches to the Atlantic coast of Florida during summer 2010. A total of 14,796 hatchlings were released into the Atlantic to avoid potential exposure to *Deepwater Horizon* oil. Trustees also have collected more than 500 turtle eggs for chemical and toxicological analysis. To document changes in the abundance, distribution and movement of female sea turtles, the trustees have collected satellite tag data on 28 sea turtles, which could indicate potential impacts resulting from the oil spill. Additionally, trustees are collecting and analyzing beach sand for chemical, toxicological and physiologically relevant levels of oil and constituents along nesting beaches in the Gulf of Mexico.

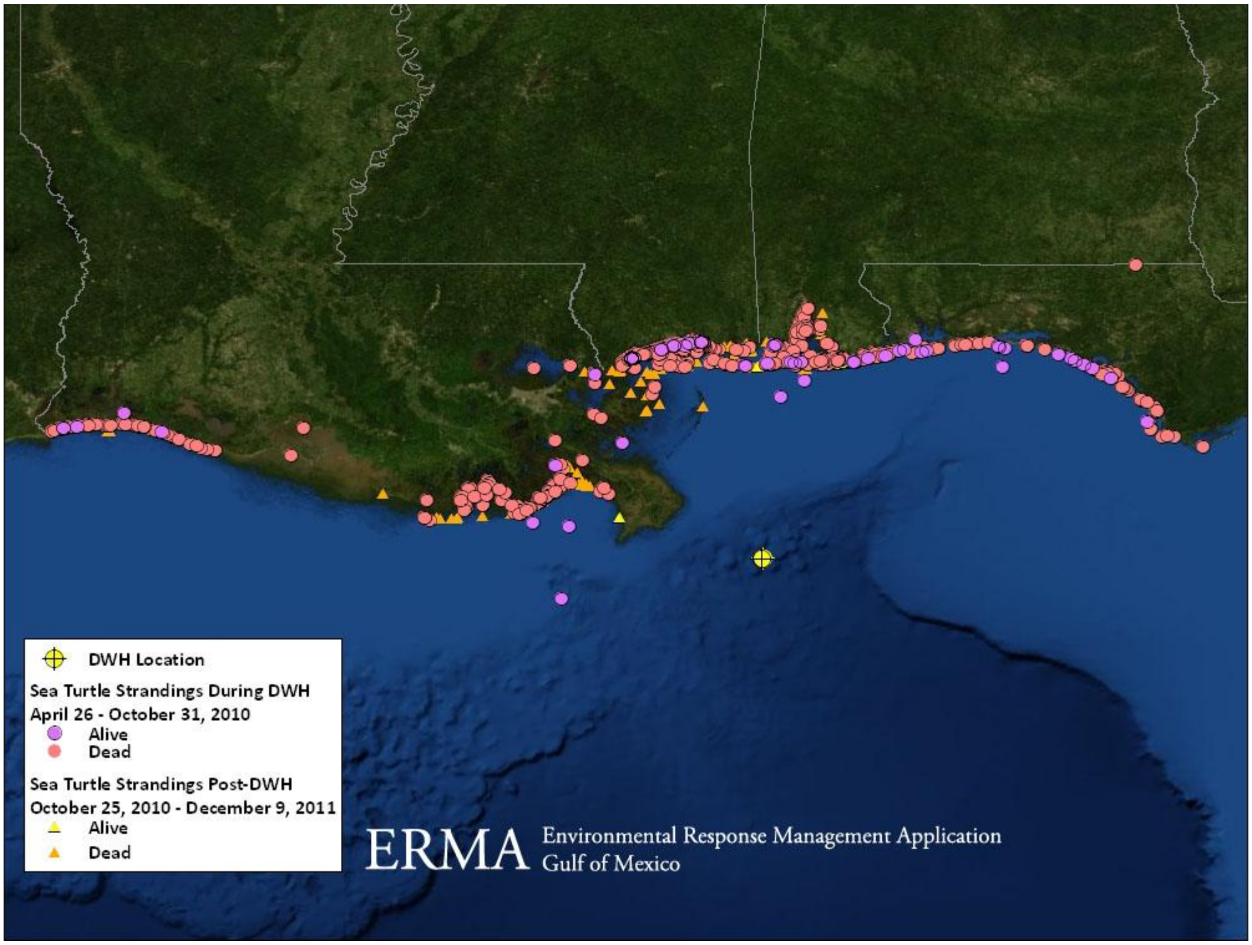


Figure 17. This map illustrates the locations in which trustee researchers have located stranded sea turtles in the Gulf of Mexico from the start of the spill through late 2011.

Next Steps

Aerial surveys were conducted seasonally from April 2011 through April 2012 to cover broad-scale synoptic surveys of the continental shelf and shelf break from Brownsville, Texas, to Dry Tortugas, Florida. The purpose was to collect information on distribution, abundance, species identification and exposure of sea turtles.

Sea turtle prey sampling began in September 2011 to assess potential exposure through contaminated prey in the estuarine/coastal environment. The prey samples, including those taken in 2010 and 2011, will undergo chemical analysis for oil and dispersant-related compounds.

During the response, hematology and blood chemistry data were collected for 350 live sea turtles. The trustees plan to do a full analysis and interpretation of the results to assess the health impacts and mortality risk for these animals.

Several sea turtle studies concluded in 2011. These include *Sargassum* studies related to sea turtle abundance and prey availability, necropsy analysis of sea turtles and netting surveys west of the Mississippi River Delta.

Turtle nests were relocated as part of the oil spill response.

For Kemp's ridley and loggerhead sea turtles, the trustees are continuing a multi-year field study to assess potential exposure and effects on nesting females, their nests and eggs. The study will include tagging females for post- and inter-nesting distribution information and chemical and toxicological analysis of embryo mortalities and hatchling tissue. The trustees will also assess the role the response actions may have had on nesting and hatchling success (e.g., beach cleaning and nest translocations).

Relevant Work Plans

Relevant work plans can be found by visiting www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data.

7. Nearshore Sediment and Associated Resources

This section focuses on nearshore sediment and associated biological resources, including fish, shrimp, crabs and other invertebrates. For the most part, these resources occupy the sub-littoral and neritic zones of the ocean. Some biological resource groups found in the nearshore environment are being assessed individually either because of the distinct footprint and assessment methods (*e.g.*, oysters, submerged aquatic vegetation) or because the resource can be found in and beyond the nearshore environment (*e.g.*, sea turtles). Hence, separate discussions for damage assessment of oysters can be found in Section III.8; submerged aquatic vegetation in Section III.9; and sea turtles in Section III.6. Deepwater sediments are discussed in Section III.2.

Resource

The sub-littoral benthic sediments of the Gulf of Mexico serve as an important and diverse habitat for many species. Crabs, shrimp, fish, birds and terrestrial wildlife feed on the rich populations of organisms living on and in the nearshore sediments, such as worms and bacteria that feed on organic material in the sediments. As such, these resources are a vital and integral part of the Gulf of Mexico ecosystem.

This sediment-based ecosystem notably includes the major shrimp species in the Gulf of Mexico, including white, pink and brown shrimp. The Gulf region landings of shrimp are the nation's largest with 73% of the national total.[76]

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[76] NOAA National Marine Fisheries Service. 2009. Fisheries of the United States- 2008. http://www.st.nmfs.noaa.gov/st1/fus/fus08/index.html

There are three key commercial species of crabs in the Gulf of Mexico region that are supported by sediment-based ecosystems: blue crab, Gulf stone crab and stone crab. Blue crabs are the most economically valuable crab species for the region. Louisiana landings provide approximately 26% of the nation's blue crabs.[77] In 2008, the combined economic value of the blue crab catch for the five Gulf Coast states was approximately $39.6 million.[78] Shrimp and crab species are located in coastal areas at certain phases of their lifecycles but have offshore components to their lifecycles as well. For organizational purposes, they will be considered under this "nearshore sediment" resource category.

Threat

As discussed earlier, oil and dispersants reaching the nearshore environment were transported on the surface of the water column by wind and currents. Several pathways for surface oil to reach nearshore sediments are depicted in Figure 4. For oil to become incorporated into the bottom sediment, oil particles that are buoyant must either weather to a dense asphaltic material that can then sink to the bottom or absorb to or adhere to a heavier particle and sink.

Oil droplets may sink as a result of being absorbed onto either marine detritus (non-living particulate organic material) or inorganic sediment (*e.g.*, sediment particulate introduced to the Gulf from the Mississippi River). These same particles can be consumed by organisms and eliminated in excretions (i.e., fecal pellets) that sink. Finally, oil that was deposited on shore mixed with sediment and washed back out with the tide, eventually settling to the bottom, can result in exposure.

This submerged oil creates a hazard to the wide variety of organisms that live in the nearshore environment, including grasses, benthic fish, crabs and other invertebrates. Many of these animals forage in the sediments for food and are susceptible to oil through dermal contact and intake by respiration and direct ingestion. Shrimp and crab species could be impacted from the oil spill due to direct mortality of adults or post larvae or due to sublethal impacts such as reduced reproductive success.

Assessment Plan

The goals of the sediment assessment plan are:

- To characterize the extent and distribution of nearshore sediment oiling,
- To model exposure of organisms in the water column and benthos to hydrocarbons in the nearshore sediments, and
- To evaluate and quantify injury to nearshore benthic organisms.

Baseline Data

In order to interpret sediment contaminant data collected during this assessment, the trustees have identified multiple sources of pre-spill contaminant data in nearshore sediments in the

[77] NOAA National Marine Fisheries Service. 2010. Fish Stocks in the Gulf of Mexico Fact Sheet. http://sero.nmfs.noaa.gov/sf/deepwater_horizon/Fish_economics_FACT_SHEET.pdf.
[78] NOAA National Marine Fisheries Service. 2010. Fish Stocks in the Gulf of Mexico Fact Sheet. http://sero.nmfs.noaa.gov/sf/deepwater_horizon/Fish_economics_FACT_SHEET.pdf.

northern Gulf of Mexico and are compiling these data. The data are from academic sources, state and federal agencies and independent research.

Further, the trustees will execute a number of formal literature reviews to gather information on benthic habitats and communities associated with marsh edges and sand shorelines, as well as contaminant levels in sediments across the affected area before the spill and in areas that were not oiled. The data will further allow us to interpret conditions in the affected habitats and communities to quantify injury.

A number of baseline data sets collected specifically for the *Deepwater Horizon* oil spill also will be used to put the current studies in perspective. These include shoreline and submerged oil data collected during the response as well as the targeted coastal data collected by the trustees prior to the oil making landfall. These baseline data are being used to plan the current assessments and may prove effective in establishing more accurate injury timelines.

Assessment

Trustees conducted an initial reconnaissance of shallow sub-littoral habitats in the nearshore water column within approximately 0.6 mile (1 km) from the shoreline, targeting areas where submerged oil was observed during the response or was expected to be found based on shoreline oiling observations. Transects were conducted using weighted snares, which are made of an oil adherent material, towed on the bottom behind a boat. The presence or absence of submerged oil was assessed based on information obtained from the towed snares and through the use of sentinel stations (snares anchored to the bottom and suspended in the water column using an anchored line). Field teams observe the snares visually or with ultra-violet light in order to determine if a snare encountered oil. In total, 2,892 chain drags and sentinel deployments were executed for this effort. When oil was detected, sediment samples were collected and analyzed for physical properties, oil contamination and other parameters.

Using the results from the 2010 sampling efforts and the shoreline oiling data, the trustees developed a statistically robust stratified sampling plan. The plan included sediment and biota sample collection. Collection and analysis are a coordinated effort between this resource assessment, the shoreline assessments (Section III.11) and the nearshore prey assessment (Section III.12). They are unified by a joint site selection plan. The 2011 sampling effort focused on the sub-littoral zone within specific distances from shore. The trustees also used existing literature to assess the density, abundance, biomass and key species associated with various nearshore communities. Together, and working closely with the fish and water column assessment efforts, these studies will elucidate the level of oil exposure sustained by nearshore communities.

Statistical sampling of benthic sediments may be followed by a targeted sediment sampling addendum. This work would address sites of specific concern for the trustees that were not addressed by the initial assessment because of its random design.

Next Steps

Data from these studies continue to be produced from the laboratories. As they are produced, they are being analyzed and compiled. Once sufficient data are available, the trustees will collate and interpret the results to inform future assessment work and evaluate injury.

Relevant Work Plans

Relevant work plans can be found by visiting www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data.

8. Oysters

Resource

Mussel Watch scientists bring up a trawl of oysters for testing.

The eastern oyster (*Crassostrea virginica*) is an integral component of coastal ecosystems and local economies along the Gulf of Mexico. Biogenic reefs formed by the aggregation of this species provide numerous ecological benefits to estuarine systems and a valuable fishery resource. The Gulf region leads the nation in oyster production, with some 67% of the total harvest in 2008.[79] In 2008, the economic value of the commercial landings in the Gulf Coast states was more than $60 million.[80]

Threat

Oysters can be exposed to oil and dispersants through dermal contact, feeding and respiration in all life stages and through filtration (feeding) for adult life stages. Direct impacts on eggs and larval survival, or changes in the ecosystem that support the oyster (*e.g.*, reduced water quality) due to oil impacts, also constitute modes of exposure. Adult oysters may experience reduced growth and reproductive impairment when exposed to oil.

Oysters also were exposed in all life stages to changes in water quality (*e.g.*, pH and salinity) resulting from actions undertaken in response to the spill. Exposure to water quality changes has both direct and indirect impacts on adult oysters as well as on eggs and larval survival. Exposure to water quality changes can also adversely impact the health of oyster habitat and the ecosystem that supports oysters.

Oysters spawned during the oil spill. Once these animals spawn, early larval stages move with the currents near the surface of the water and are unable to actively avoid potential injury from

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79 NOAA. 2010. Fish Stocks in the Gulf of Mexico Fact Sheet. http://sero.nmfs.noaa.gov/sf/deepwater_horizon/Fish_economics_FACT_SHEET.pdf.

80 NOAA. 2010. Fish Stocks in the Gulf of Mexico Fact Sheet. http://sero.nmfs.noaa.gov/sf/deepwater_horizon/Fish_economics_FACT_SHEET.pdf.

exposure to oil, dispersants and other response activities. At its largest aerial extent, the oil slick covered a significant portion of the Gulf of Mexico's estuarine-dependent species' spawning grounds.

Assessment Plan

The goals of the oyster assessment plan are:

- To document the pathway, exposure and injury using field measurements and observations.
- To use a combination of biological, chemical and toxicological measures to evaluate injury.

Baseline Data

There are several sources of baseline data available to assist in the oyster injury assessment. Data from the Mussel Watch Program[81] is useful in determining baseline levels of polycyclic aromatic hydrocarbons (PAH) in oyster tissues. Oyster tissues have been collected for a number of years and provide a long history of PAH levels in oysters. Additional sources of baseline data are available from preexisting sampling programs conducted by the states to assess oyster resources. These data characterize natural variability in oyster abundance, population structure, mortality, oyster settlement, etc.

Assessment

Trustees are assessing impacts to oysters at more than 150 sites from Louisiana to Florida. For historical comparison, approximately half of the selected sites have existing data sets from studies conducted by states prior to the spill. Approximately 5,000 oysters were collected for contaminant, disease and gonad analysis as part of the injury assessment in 2010 and early 2011. More than 4,500 additional oysters were collected later in 2011 for these same metrics (see Figure 18 for details). More than 2,000 water samples were collected for larval counts, and 350 quadrats[82] were used to collect information on live and dead oyster density and biomass by size at the historical sites in 2010. In 2011, oyster dredges were used to collect samples for relative abundance and biomass as well as disease and gonad condition analysis. Approximately 600 quadrats were collected in 2011 to gather information on the same metrics from 2010.
The trustees collected more than 2,000 settlement plates to measure oyster recruitment from fall 2010 through fall 2011, with approximately half being enumerated. Lastly, the trustees have generated more than 2,500 samples for sediment analyses (grain size and chemistry) from samples collected at approximately 1,000 point locations over three sampling events.

Due to the opening of the Morganza and Bonnet Carre spillways in 2011, some areas were influenced by low salinities. To account for this, trustees collected dredge samples both before the spillways were opened and following the return to more normal salinities in areas expected to be affected by the spillway openings.

[81] See http://ccma.nos.noaa.gov/stressors/pollution/nsandt/
[82] A quadrat is a square made of metal, wood or plastic that is used to delineate an area for sampling.

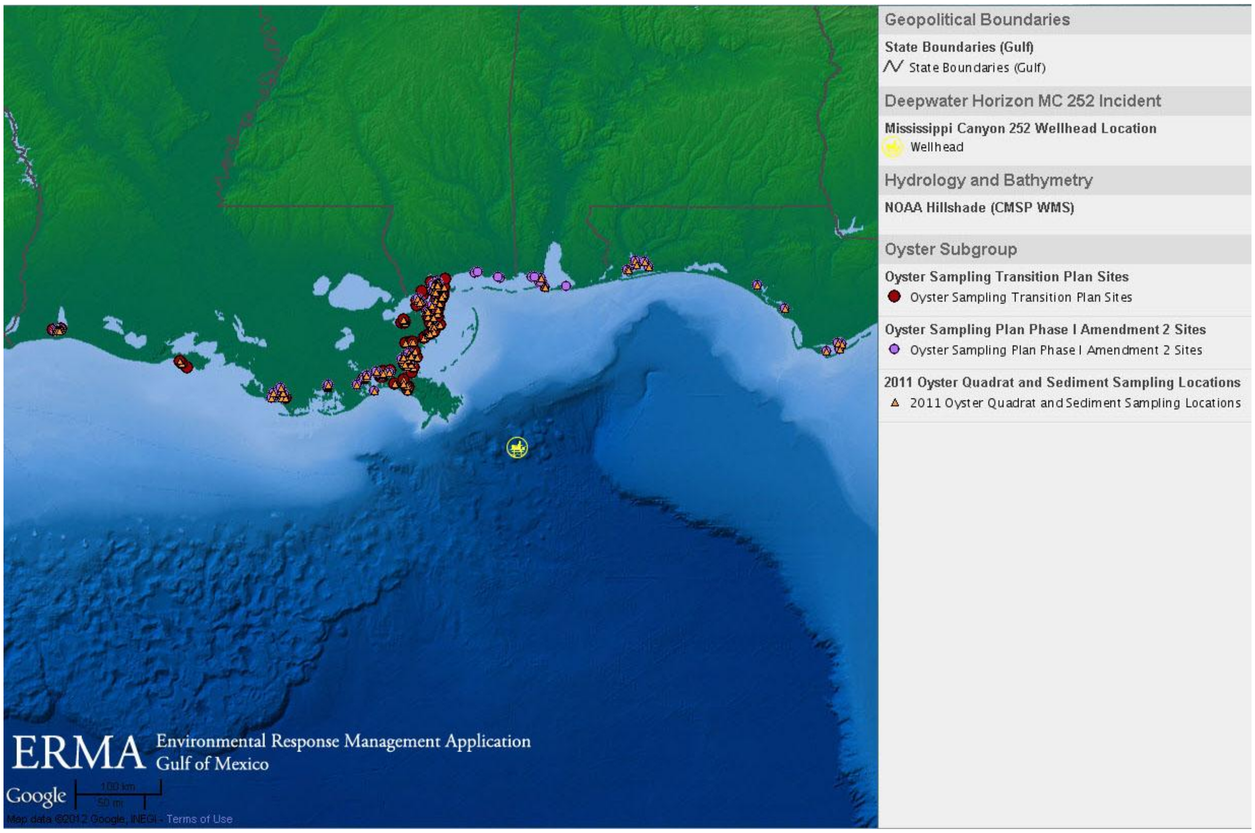

Figure 18. This map illustrates the sites in which NRDA teams have collected samples related to assessing the health of oysters potentially affected by the *Deepwater Horizon* spill.

Next Steps

The trustees are in the process of compiling and analyzing data collected to date. Future plans include continued sampling at historically sampled sites and random sites at known reefs to monitor recovery. A study of intertidal oysters also is being conducted. Information about oyster abundance and biomass as well as tissue sampling will be sought. Trustees will continue to evaluate response actions, including the opening of freshwater diversions, which may have had a negative impact on oysters.

All post-spill data will be compared to pre-spill data to evaluate impacts from the spill. Trustees also are evaluating additional steps to map oyster resources in the impacted area in order to understand the spatial extent of oyster injury. This additional mapping will be conducted after the results from the fall 2011 sampling are evaluated to help guide where the mapping should occur.

Relevant Work Plans

Relevant work plans can be found by visiting www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data.

9. Submerged Aquatic Vegetation

Response vessels' propellers left multiple scars like this one in underwater grass beds when attempting toboom off shallow areas to prevent oil from reaching shorelines.

Resource

Submerged aquatic vegetation (SAV) refers to a group of rooted vascular plants that grows up to the water surface but not above it. Some SAV species, such as various seagrasses, grow in marine water, and other species occur in fresh and brackish habitats of the Gulf of Mexico. SAV is an important habitat in the aquatic ecosystem because it provides food and habitat for fish, shellfish, crustaceans and other invertebrates, which enhances the productivity of these habitats. It also is an important foraging habitat for resident and migrating birds. It serves as nursery habitat for many species, produces oxygen in the water column as part of the photosynthetic process, protects shorelines from erosion and enhances water quality by filtering water and removing excess nutrients. In the Gulf of Mexico, there are more than 3 million acres of SAV that provide these services.[83]

Threat

SAV can be exposed to oil by direct contact (i.e., smothering) and by uptake by rhizomes through contaminated sediments. Exposure also can take place via uptake of hydrocarbons through plant membranes. In addition, seeds may be affected by contact with oil contained within sediments. Dispersants can cause injury to aquatic vegetation by breaking down the thin waxy cuticle of the plant, allowing greater penetration of oil fractions into seagrass leaves, thereby increasing phytotoxicity.[84] In addition, this physical damage to the cuticle could cause a reduction in growth due to the increased physiological stress on the plant. Finally, actions such dragging anchors through SAV beds commonly occur during oil spill responses and result in physical scarring of the SAV bed. The physical scarring of SAV beds is a problem because it causes damage to the SAV, loss of SAV biomass, increased sediment re-suspension and in severe cases increased erosion. These impacts can result in further degradation of the SAV beds and make them more susceptible to other disturbances (i.e., hurricanes).[85]

[83]Handley L, D Altsman, and R DeMay, Eds. 2007. Seagrass status and trends in the northern Gulf of Mexico: 1940-2002. U.S. Geological Survey Scientific Investigations Report 2006-5287 and Environmental Protection Agency Gulf of Mexico Program, Virginia, 267pp.

[84]Yamada, M, H Takada, K Toyoda, AYoshida, A Shibata, H Nomura, M Wada, M Nishimura, K Okamoto, and K Ohwada. 2003. Study on the fate of petroleum-derived polycyclic aromatic hydrocarbons (PAHs) and the effect of chemical dispersant using an enclosed ecosystem, mesocosm. Marine Pollution Bulletin 47: 105-113.

[85]South Florida Natural Resources Center and National Park Service. 2008. Patterns of propeller scarring of seagrass in Florida Bay. Resource Evaluation Report SFNRC Technical Series 2008:1, 39pp.; Gulf of Mexico Program. 2004. Seagrass habitat in the northern Gulf of Mexico: Degradation, conservation, and restoration of a valuable resource. U.S. Geological Survey Report 855-R-04-001, 28 pp.

Assessment Plan

The primary goals of the SAV assessment plan are:

- To document pathway, exposure and injury using field measurements; and
- To quantify the degree of SAV community injury using field sampling and existing toxicity literature.

Baseline Data

Federal, state and local resource management agencies and non-governmental organizations conduct SAV mapping and monitoring on a routine (regular or semi-regular) basis within areas of the Gulf of Mexico potentially impacted by the *Deepwater Horizon* oil spill. Examples of such organizations include the Dauphin Island Sea Lab, Florida Fish and Wildlife Conservation Commission, Grand Bay National Estuarine Research Reserve, Gulf Coast Research Laboratory, Mobile Bay National Estuary Program, USGS, Florida Department of Environmental Protection, the National Park Service and NOAA. These programs provide recent and historic data collected over multiple years and seasons that may be useful in documenting baseline conditions of at-risk and oiled SAV resources. Sampling designs, field methods and assessment measures may differ across programs due to varying conditions among regions and water bodies and dissimilar organizational objectives. However, most existing monitoring programs share common elements and possess significant overlap with the NRDA measures.

To the maximum extent possible, data from existing SAV monitoring programs will be used to characterize baseline conditions of SAV resources potentially affected by the *Deepwater Horizon* oil spill.

Assessment

To assess injury to the Gulf of Mexico SAV, the trustees have implemented a phased approach. First, NOAA oil trajectories were used to identify 19 sites that were potentially threatened by oil, spanning an area from the Chandeleur Islands, Louisiana, to the Florida Keys. Before the oil reached the nearshore environment, the trustees collected baseline data at these sites. Sediment, vegetation and invertebrates were collected for chemical analysis. The SAV sites were further evaluated for general conditions including fish abundance and composition, vegetation (rhizome and shoot counts), and invertebrate composition and biomass. Photographs and aerial imagery also documented baseline conditions (general health, coverage and density).

Using updated data and information from the response effort, the trustees identified 14 of the 19 sites as primary sites for sampling based on potential oil exposure. The other five sites were considered of secondary importance based on exposure risk. Of the 14 primary sites, nine were chosen as priority sites. In addition to the sentinels referenced in Section III.7, Nearshore Sediment and Associated Resources, the trustees deployed 131 sentinels (adsorbent pads used to detect the presence or absence of oil) and 85 stationary polyethylene membrane devices (PEMDs)[86]. Both types of devices were employed to detect oil floating through the water column

[86]For additional information on PEMDs refer to: Carls MG, LG Holland, JW Short, RA, Heintz, SD Rice. 2004. Monitoring polynuclear aromatic hydrocarbons in aqueous environments with passive low-density polyethylene

within SAV beds. The trustees collected further sediment, plant and invertebrate tissue samples from priority sites for chemical analysis.

The lined seahorse is one of many marine mammals that use seagrass as its habitat.

Oil was detected at five of the nine priority sites: Big Lagoon in Florida, Perdido Bay (which borders Florida and Alabama), Petit Bois and Horn Islands in Mississippi, and the Chandeleur Islands in Louisiana. A fresh/brackish water site in Pass a Loutre, Louisiana, later was added to assess an important feeding ground for waterfowl. Samples were collected in the priority areas in fall 2010. Analysis results confirm that multiple stations on the central and southern portions of the Chandeleur Islands were exposed to *Deepwater Horizon* oil. Seagrasses, solvent rinses of the seagrasses, sediments, invertebrates and detritus were all documented to have concentrations of the oil. In order to evaluate seasonal changes to the health of the oiled SAV beds, further sampling was conducted for the Chandeleur Islands.

The phased approach to documenting exposure and injury included photographs, samples, observations and GIS mapping. As of mid-March 2011, trustees had collected 951 observation records and 921 chemistry samples from 19 field sites. Going forward, the trustees will continue to watch for mortality of vegetation and associated fauna and other degradation effects of the *Deepwater Horizon* oil spill.

Next Steps

The trustees will collect additional sediment, plant tissue samples and observational data to confirm any continued exposure at the Chandeleur Islands. Additional field efforts are tentatively planned for fall 2012 to record the general condition of the SAV beds, collect fish abundance and composition information, examine vegetation (rhizome and shoot counts), and collect invertebrate cores for species numbers and biomass. These data will be compared to pre- and post-oiling surveys and historical data. Additionally, aerial imagery collected over time will be analyzed for changes in acreage or percent cover of the beds at each site.

Relevant Work Plans

Relevant work plans can be found by visiting www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data.

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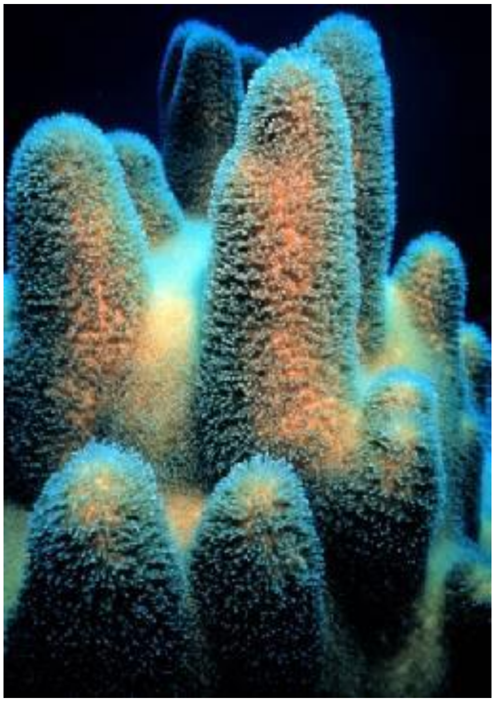
membrane devices. Environmental Toxicology and Chemistry 23(6): 1416-1424.
http://www.crrc.unh.edu/toxicity_summit/carls_et_al_2004d_pemd.pdf

10. Shallow Water Coral Reefs



Studies of shallow water coral reefs have not documented evidence of exposure to oil, dispersants or disruptive response activities.

Note: Deepwater coral is addressed in Section III.2, Deepwater Benthic Communities

Resource

Isolated communities of shallow water corals occur in many areas of the continental slope in the Gulf of Mexico. Emergent rock substrate often supports "live bottom" communities consisting of sponges, hydroids, corals, and sea whips that can attract dense fish populations[87] These communities, while common and widespread, are not adequately mapped to permit a detailed assessment. As a result, impacts to these communities will be evaluated in concert with the nearshore sediment and associated resources assessment and the mesophotic reef component of the deepwater benthic communities assessment.

The most extensive coral reefs in the Gulf of Mexico occur off Texas and Florida. Healthy coral reefs are among the most biologically diverse and economically valuable ecosystems on earth, providing vital ecosystem services. Coral ecosystems are a source of food for millions of plants and animals; protect coastlines from storms and erosion; provide habitat, spawning and nursery grounds for economically important fish species; and provide jobs and income to local economies from fishing, recreation and tourism.

Due to the extensive distribution of oil and dispersant from the *Deepwater Horizon* oil spill, the trustees were concerned about injury to shallow water corals from Texas to Florida. This notably includes the Florida Reef Tract, which extends approximately 530 km (318 miles) from Martin County on the Atlantic coast to the Dry Tortugas, west of Key West in the Gulf of Mexico.

Threat

Impacts of oil spills to coral reefs can vary based upon physical, chemical and biological conditions. How corals are exposed to oil and the compositions of the oil at the time of impact bears directly on how serious the impact will be. Some primary modes of exposure for coral reefs in oil spills include:

- Direct oil contact is possible when surface oil is deposited on intertidal corals that live near the surface of the water and become exposed with the tides;

[87] Thompson, M.J., W. W. Schroeder, N.W. Phillips, B.D. Graham. 1999. Ecology of Live Bottom Habitats of the Northeastern Gulf of Mexico: A Community Profile. United States Geological Survey. USGS/BRD/CR--1 999-0001. OCS Study MMS 99-0004

- Rough seas and light soluble oil can combine to mix the oil into the water below the surface where it can impact corals. Corals are exposed to less oil beneath the water surface, but the lighter oil components that mix easily are often the most toxic;
- Subsurface oiling can occur when heavy oils weather or mix with sediment material. This increases the density of the oil to the point where it may sink, potentially smothering corals;
- Oil contact through the food web (oil in plankton, detritus, prey, etc.) is also a potential route of exposure to corals; and
- Other indirect exposures from oil spills may include effects of oxygen depleted water due to microbial metabolism of oil and/or dispersants and toxic algal blooms resulting from the oil spill.

Assessment Plan

The goals of the shallow water coral assessment plan are:

- To document baseline condition of the shallow water corals along the Florida Reef Tract, Florida Middle Grounds, East and West Flower Garden, Stetson, Sonnier Banks and corals mixed with SAV beds in south Florida and
- To continue to monitor all sites for evidence of exposure.

Baseline Data

Several coral reef monitoring programs have existed for years, and those efforts help form the foundation of current work to document the pre-impact condition of the corals. The baseline data was gathered by various groups conducting regularly scheduled, long-term coral reef monitoring in the Florida Keys and Flower Gardens.

Assessment

To document the potential routes of exposure and effects, the trustees conducted a series of studies designed to get a better understanding of the potential exposure of oil to shallow water corals and to quantify potential loss of corals, loss of other coral community components and loss of ecological services provided by these communities. These studies have included continuous monitoring of previously surveyed sites, including photos, video, deployment of semi-permeable membrane devices (passive samplers to monitor water quality), and sediment and tissue collection. Taken together, this suite of data and observations is designed to identify and evaluate exposure to the *Deepwater Horizon* oil or the response activities and any adverse effects resulting from such exposure. Hundreds of tissue, water, oil and sediment samples have been collected in and around shallow water coral habitat.

To date, the trustees have conducted dozens of sampling trips to shallow water coral reefs with the exception of the Florida Middle Grounds and corals mixed with SAV beds in south Florida and have documented no evidence of exposure to *Deepwater Horizon* oil, dispersants or disruptive response activities. The evaluation of pathways and exposure of nearshore live bottom coral communities and mesophotic reefs continues.

Next Steps

Given that a pathway for exposure has not yet been strongly established for shallow water coral reefs, the trustees will not pursue further field work for a damage assessment at this time. Should information arise in the future that indicates that the assessment of shallow water corals could be benefited by additional field work; the trustees will revisit the injury assessment strategy for this resource. Assessment activities for shallow water live bottom communities and mesophotic reefs will continue as part of the nearshore and deepwater benthic community assessment, respectively.

Relevant Work Plans

Relevant work plans can be found by visiting www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data.

11. Shorelines

Resource

The northern Gulf of Mexico has a variety of shoreline habitat types that are important to wildlife, fish, shellfish and humans. This habitat includes herbaceous coastal wetlands, mangrove habitat, sand beaches and mudflats.

Waves of oil and tarballs washed up on Grand Isle, Louisiana.

Shorelines provide a variety of ecological services, including biological nurseries, storm surge protection, recreational enjoyment, nutrient control, etc. Unfortunately, coastal areas across the northern Gulf of Mexico have been losing land at a very high rate over the last 50 years due to a variety of factors including subsidence, rising sea level, resource management decisions, adverse impacts from oil and other industries, and storms. The majority of this land loss is occurring in the wetlands of southeastern Louisiana.

More than half of the coastal wetlands within the lower 48 states are located in the northern Gulf of Mexico region; Louisiana alone has approximately 40% of the total. These productive shorelines support marine biological productivity levels that are among the highest in coastal waters throughout the contiguous United States and are part of the ecological continuity that exists between the land and the open ocean. Estuaries, where freshwater and saltwater mix, provide many crucial ecological functions. These coastal environments provide critical habitat and shelter for numerous species of fish, shellfish, birds and mammals. This provision of habitat combined with the high primary productivity of coastal marsh vegetation creates an ideal nursery ground rich in food that fuels high rates of growth in numerous species of finfish and shellfish, thereby illustrating the important link between wetland marsh productivity and the resulting fisheries productivity. Wetlands also provide the important functions of storm surge protection and water quality improvement.

Black mangrove (*Avicennia germinans*), a highly productive coastal habitat, occurs throughout the northern Gulf of Mexico and is important for maintaining shoreline protection and stabilization. The Louisiana coast is the northern extent of its range. It is an essential feeding and nursery habitat for juvenile fish.

Beaches are vital both ecologically and economically. Ecologically, beaches are an important element of shoreline stabilization that helps protect against erosion. They also provide habitat for numerous invertebrates that helps maintain shoreline health through sediment drainage and facilitating nutrient transport as well as providing food source for numerous shoreline and migratory birds. Finally, beaches also provide critical ecological habitat for nesting sea turtles and shorebirds. In addition to the ecological importance of beaches, the sand beaches of the northern Gulf Coast are important recreational destinations and tourist attractions that support local economies.

Marshy shorelines in Louisiana's Barataria Bay Basin were heavily oiled by the Deepwater Horizon *oil spill.*

Vast areas of mudflat can be found throughout the Mississippi River Delta and estuarine bays of Louisiana, Mississippi and Alabama. Mudflats are important habitat for invertebrates and other organisms. Like other intertidal habitats, mudflats play an important role in nutrient cycling and dissipating wave energy. Mudflats can be very productive, typically having benthic macroalgae and microalgae in the upper sediment layers. This primary productivity is linked to higher trophic levels, including resident and migratory birds that forage for invertebrates in the sediments, such as polychaetes, mollusks and crustaceans.

Oyster and shallow water coral reef habitats are being assessed as individual resource categories in Sections III.8 and III.10, respectively. Sea turtles are also assessed as an individual resource category in Section III.6.

Threat

The impact of oil on a shoreline can be influenced by a variety of factors, including the type of shoreline habitat, the amount and freshness of the oil washing ashore, the depth it penetrates horizontally along the surface and vertically into the sediment, and the length of time it remains.

In wetland and mangrove habitat, oil can stress and potentially stunt the growth of or kill the vegetation and associated organisms. Without the plant roots to hold the soil together, the marsh is at risk of accelerated erosion from waves and storms. Weathered oil deposited on sediment and vegetation can be re-suspended through bioturbation (i.e., burrowing activity), wave action and storm events. Oil can seep into the sediment, be bioturbated downward into the sediments and/or be buried through deposition of new sediment. Neutrally buoyant emulsified oil can remain suspended in nearshore environments, resulting in re-exposure of shorelines and nearshore resources.

On beaches, organisms are impacted from oil by both physical smothering and toxicity. Invertebrates that live in the sand can be exposed, impacted and re-impacted by oil as submerged oil from offshore is washed ashore. Oiled wrack, made up of seaweed and other organic materials that come ashore, also poses a significant threat to beaches. Whether the wrack is oiled or removed, foraging seabirds are impacted through the contamination or loss of a biologically productive habitat where their prey (insects and small organisms) seek shelter.

In addition to impacts from oiling, shoreline habitat can be threatened by response actions. Booms used to prevent oil from reaching the shoreline can become stranded in wetlands. Techniques used to remove oiled vegetation or sediment and liquid oil in wetlands may result in physical disturbance and loss of organisms. In addition, beaches can be impacted by actions such as sand removal, sand sifting, and use of heavy machinery and vehicles that also can result in physical disturbance and loss of organisms.

In mudflats, the diverse array of burrowing species risk being smothered by oil mats that come to rest on top of the sediments. As with wetland sediments, oil can also seep into the mudflat sediment and be bioturbated downward, thus compounding the threat to organisms that live there.

Assessment Plan

The goal of the shoreline assessment plan is:

- To collect and evaluate ephemeral and other data that will assist in evaluating impacts to shoreline resources and habitat from *Deepwater Horizon* oil and response actions taken as a result of the spill.

Baseline Data

Sediment, water and tissue samples collected across the five Gulf states prior to the oil reaching shore provide a baseline against which to measure impacts. Reference sites have also been selected for comparison.

Assessment

In order to address unique characteristics of various shoreline habitats, they were divided into several components including herbaceous marshes, mangroves, beaches and mudflats. The assessment includes evaluation of the severity, spatial extent and duration of shoreline oiling across marsh and mangrove using aerial and ground surveys. Aerial surveys were used to examine the coastline and help direct ground surveys. Ground surveys, photographs and measurements of oil in sediment and on vegetation have been recorded at more than 2,700 sites. Biological measures documenting exposure based on changes in primary productivity, food web support and habitat area will be coupled with toxicity threshold information to assist in evaluating injury to shoreline resources and habitat. In addition, chemical analysis for sediment will be used to determine oil concentrations that will assist in injury assessment.

Since the spill occurred, Shoreline Cleanup and Assessment Technique (SCAT) field teams have surveyed more than 4,300 linear miles of shoreline and documented approximately 1,100 linear miles of oiling.[88] They are reporting that approximately 220 miles of shoreline were heavily oiled and 140 miles moderately oiled. Due to shoreline cleanup operations, natural degradation and remobilization of oil in the coastal areas, the mileage of heavily to moderately oiled shoreline impact has changed and decreased. The remaining miles of shoreline received some degree of oiling, consisting of light oiling and/or tarballs, which continue to wash ashore. This information will be combined with observations on depth penetration of shoreline oil to determine the acreage of total shoreline oiled by degree of oiling for each shoreline type.

Marsh and Mangrove

A NRDA team surveys Louisiana marsh in fall 2010.

Assessment for marsh and mangrove habitat includes biological measurements to evaluate the extent and degree of oiling, aerial and other remote sensing photography to evaluate oiled vegetation, and soil and vegetation samples for analysis of a number of biological factors. This information will be used to assess vegetative health and productivity. In addition, biological measurements have been collected to evaluate potential effects of oil on coastal marsh fiddler crabs and periwinkle snails, both indicator species for marsh health.

Fall 2010 field sampling along the Louisiana shoreline is complete. The trustees revisited impacted and reference sites throughout 2011 to monitor changes and continue collecting environmental information. The spring and fall 2011 field sampling have been completed. The fall 2011 field sampling included biological measurements of fiddler crabs and periwinkle snails in heavily oiled areas in Louisiana.

The scope of data collection expanded to Mississippi and Alabama during 2011. Additional areas in Louisiana were also established to monitor effects of marsh cleanup in significantly oiled areas in northern Barataria Bay. These studies are being coordinated with the nearshore sediment and fish assessment teams to assess the littoral (intertidal) and sublittoral (subtidal) marsh edge and sand shore environments. An exposure study of Florida marshes to tar balls and other types of weathered oil is complete. Potential effects due to response activities such as the use of boom or cleanup of select heavily oiled wetland areas will also be evaluated.

[88] Marsh, 501.4 miles; Beach, 553.6 miles; Other, 92.7 miles.

Mudflat

The assessment of mudflats will use existing information and data collected by other resource assessment work to inform injury including Nearshore Sediment and Associated Resources (Section III.7).

Sand Beach

The trustees are using data regarding the degree of beach oiling that was collected during the response and is still being collected to inform this assessment. Along with the oiling impacts, the trustees are also including in their injury assessment the response activities and methods used to clean the beaches and remove oiled sand, organic material and debris.

Next Steps

The trustees completed field sampling through 2011. Trustees plan to revisit impacted and reference marsh, mangrove and crab/snail sites in fall 2012. Trustees also expect to collect additional remote sensing and elevation survey data in early 2012. Evaluation of existing data is ongoing. Subsequent monitoring may occur on an annual basis in the future.

The assessment of adverse impacts from response efforts in the sand beach will continue. These efforts will be coordinated with the sea turtle (Section III.6) and bird (Section III.12) assessment activities.

The trustees will continue working on a comprehensive oiling map that will combine response and NRDA shoreline oiling information. This map will be used in concert with assessment information to provide a more comprehensive picture of the extent of oiling and associated injury.

The trustees will continue assessment of beach and mudflat through existing information and data. This work will be closely coordinated with the nesting turtle assessment.

Relevant Work Plans

Relevant work plans can be found by visiting www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data.

12. Birds

Resource

A U.S. Fish and Wildlife Service biologist carries an oiled pelican from a nesting area in Barataria Bay, Louisiana, to a waiting boat.

The Gulf of Mexico provides nesting and wintering habitat for a diverse and abundant assemblage of birds. These assemblages shift seasonally with migrations. The northern Gulf Coast is important to a variety of birds that nest on beaches, flats, dunes, bars, barrier islands and other nearshore habitats. Breeding species of regional importance include American oystercatcher, snowy plover and Wilson's plover. The Breton National Wildlife Refuge off the Louisiana coast supports one of the world's largest colonies of sandwich terns. The northern Gulf Coast also supports nearly half of the southeastern population of brown pelican. The U.S. Fish and Wildlife Service (USFWS) removed the Eastern brown pelican from the list of endangered and threatened species in Alabama, Florida and points northward along the Atlantic coast of the United States in 1985 (50 FR 4938). In November 2009, USFWS removed brown pelican from the list entirely. As part of the requirements of delisting due to recovery, USFWS must implement a monitoring program in cooperation with the states for a minimum of five years. In the Gulf of Mexico, post-delisting monitoring of brown pelican populations is continuing.

Gulf Coast marshes are important to many secretive marsh birds, which are species that live in dense marsh vegetation so they are difficult to spot. These species include black rail, clapper rail, king rail, Virginia rail, sora, least bittern and American bittern.

The Gulf of Mexico is critically important wintering habitat for a variety of migratory birds. The eastern boundary of the Mississippi Flyway runs through the peninsula of southern Ontario to western Lake Erie, then southwest across Ohio and Indiana to the Mississippi River, where it closely follows the river to the Gulf of Mexico. This route is used by numerous species of waterfowl, shorebirds and passerines. The majority of North American land birds seeking winter homes in the tropics via the Mississippi Flyway take a shortcut across the Gulf of Mexico.

The Gulf Coast also supports protected bird species. Of particular importance is the piping plover, which is federally listed under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1544, 87 Stat. 884). The Gulf of Mexico is one of the piping plover's key wintering areas. At least 70 percent of all piping plovers winter on the shores of the Gulf of Mexico.[89]

[89] NRDA Work Plan for determining injury to the Piping Plover (*Charadrius melodus*) from the DWH (MC252) Oil Spill Bird Study #7.

The northern Gulf of Mexico also provides resources to many pelagic (ocean dwelling) birds. The most commonly observed pelagic species using these waters during the summer include band-rumped storm petrel and bridled tern. The Audubon's shearwater and band-rumped storm petrel are the highest priority species for conservation attention in the Gulf of Mexico.

Threat

Birds are likely to be exposed to chemicals in oil or dispersants in a number of ways:

- External exposure directly to skin and feathers caused by resting on the water's surface and diving beneath the water's surface, and utilizing oiled beaches and marshes;
- Internal exposure as the animals preen and try to clean their feathers;
- Internal exposure as they as they feed in contaminated water and adjacent beaches and vegetated areas, or inhale volatile oil-related compounds;
- Maternal transfer of contaminants to embryos and eggs.

An oiled brown pelican is cleaned at a wildlife rehabilitation center in Plaquemines Parish, Louisiana.

Oiled birds can lose the ability to fly, dive for food or float on the water, which can lead to drowning. Oil interferes with the water repellency of feathers and can lead to hypothermia. In addition, birds may ingest or inhale oil while cleaning (preening) their feathers, by consuming contaminated vegetation or prey, or by incidental ingestion of contaminated sediment. This can either kill the bird or lead to long-term physiological, metabolic, developmental, and behavioral effects which ultimately lead to reduced survival and reproduction. Exposure also can reduce the hatching of eggs and survival of hatchlings. Therefore, avian injury can be identified through acute mortality, productivity loss, decrease in reproductive success, sublethal effects and loss of prey resources.

Seabirds, colonial waterbirds, coastal marsh birds, shorebirds and a variety of other birds occurring in coastal areas may be susceptible to oiling impacts. Several work plans have been developed to concurrently evaluate oil exposure and potential oil spill-related injuries to these different avian guilds (groups of species using similar resources in similar ways). Some of these efforts, such as the beach bird and aerial bird studies, provide data on a wide range of bird species. Other studies focus on oiling impacts to particular groups of birds, such as secretive marsh birds, colonial waterbirds, and piping plover. Additional studies focusing on a variety of avian endpoints related to oiling exposure are currently in development.

Assessment Plan

The goal of the bird assessment plans are:

- to document the pathway, exposure and injury using field measurements and observations and
- to quantify the level of injury using field sampling, observations, laboratory analysis, existing literature and modeling.

Two models will be used along with other lines of evidence to evaluate avian injury. The models include:

- the beached bird model based on carcass deposition on beaches and marshes and
- the live oiled bird model based on three parameters: the number of birds in the area, the percent of birds oiled and the mortality rate of oiled birds.

The trustees understand that not all birds exposed to and injured by *Deepwater Horizon* oil will be located, collected and counted. The above models help quantify injury more accurately while accounting for differences in searcher efficiency, bird carcass drift, carcass persistence and sublethal effects of oil exposure.

Baseline Data

Given the diversity of birds in the northern Gulf of Mexico, the trustees have collaborated with regional and national experts to develop a series of injury work plans designed to collect the best available science. Certain studies evaluated injury to a wide range of birds while others focused on specific avian guilds. In general, documentation and modeling of bird injury consists primarily of assessing acute lethal and non-lethal effects. Each work plan is designed to gather data that ultimately will be used to assess injury. As part of individual work plans, or as additional activities, trustees have also been conducting a series of aerial surveys over open water, along potentially affected shorelines and by photographic census of breeding bird colonies. These surveys will help identify avian distribution and abundance in the area prior to the oil spill, during the height of the spill and after the well was capped.

A total of 8,567 live and dead birds were collected in the northern Gulf of Mexico as part of wildlife response and NRDA operations. Of the live birds, 1,423 were rehabilitated and released. These birds represent more than 100 species collected in all five Gulf Coast states. Locations of recovered live and dead birds are depicted in Figure 19. Visit www.doi.gov/deepwaterhorizon for more detail on wildlife collection reports.

Assessment

Aerial Bird Surveys

Aerial surveys were conducted to document the densities and abundance of waterbirds and seabirds in areas potentially affected by the oil spill. Data acquired in the surveys will support the Beach Bird Model and other avian injury studies. Surveys include offshore (pelagic) transects, shoreline surveys, marsh transects, and breeding colony surveys. Surveys used a combination of visual observation, photography, and videography. Surveys extended from Corpus Christi, Texas to the Florida Keys, and extended up to 100 km offshore. Select bird nesting colonies were also photographed to document nesting bird numbers and densities.

Beached Bird Surveys

The trustees are estimating the rate of spill-related carcass deposition on sand beaches and marshes. For sand shoreline, designated transects from south Texas to Florida Keys and southeastern Florida were surveyed at regular intervals from May through September 2010 to identify and recover bird carcasses. This study provides a direct measure of background and oil spill-related avian mortality as part of the beached bird model. Bird recovery data generated as part of the oil spill response wildlife operations will be used to support a modified version of the beached bird model to estimate mortality in marshes. Three studies to refine mortality estimates and reduce uncertainty were also conducted, including searcher efficiency, beach carcass persistence and carcass drift:

> Bird Detection/Searcher Efficiency Study
> The objective of this study is to evaluate the efficiency of crews searching for beached bird carcasses associated with the *Deepwater Horizon* oil spill. Bird carcasses salvaged outside the oil spill area were placed on selected beaches that were being surveyed to determine the proportion of carcasses found. Beach survey teams were not informed which of their beaches were treated. The searcher efficiency study for sand beaches was conducted cooperatively in fall 2010. The marsh study was completed in the fall 2011.
>
> Carcass Persistence Study
> The objective of this study is to evaluate the length of time that bird carcasses persist on beaches and in marshes along the Gulf Coast before being removed by predators or the Gulf of Mexico's tidal influences. The beach carcass persistence study was completed in the summer 2011. The marsh study was completed in the fall 2011.
>
> Carcass Drift Study
> The objective of this study is to evaluate the drift and duration of bird carcasses in the Gulf of Mexico. Bird carcasses and floating dummies were deposited in coastal areas and offshore and tracked using radio telemetry to determine if and when carcasses were deposited on the beach. The study was completed in August 2011.

Secretive Marsh Birds

Injury to secretive marsh birds is being assessed using a combination of surveys to evaluate relative densities, oiling rates and comparison of mortality rates in oil-impacted areas and non-impacted reference areas. Density estimates were derived using secretive marsh bird callback surveys, fiddler crab density estimates (a principal clapper rail food) and helicopter surveys. Oiling rate estimates were obtained by the capture and examination of marsh birds using visible and ultraviolet light. Mortality rate estimates of two representative species (clapper rails and seaside sparrows) in oiled and un-oiled habitats were estimated using radio telemetry techniques.

Colonial Waterbirds
Injury to colonial nesting birds is being assessed using a combination of surveys to evaluate abundance within in the northern Gulf of Mexico, estimating the proportion of birds that are visibly oiled and comparing survival rates of oiled and un-oiled adult birds. Colonial waterbird abundance estimates were derived from aerial surveys. Oiling proportion estimates were obtained by surface observation of colonies and roosting sites in the northern Gulf of Mexico. Survival rate estimates of oiled and un-oiled adult birds from three representative species (great egret, brown pelican and black skimmer) were derived using radio and satellite telemetry techniques.

Breeding Shorebird Study
Injury to nesting shorebirds is being assessed by surveying breeding pairs of American oystercatchers and plover species throughout the spill's area of potential impact. These data will estimate the proportion of adult birds that were oiled and note disturbance related to oil spill response activities. Surveys of breeding shorebirds in Alabama, Mississippi and Louisiana have been conducted.

Non-breeding Shorebirds
Injury to shorebirds wintering in the northern Gulf of Mexico is being assessed using a combination of surveys to evaluate abundance, estimating the proportion of birds that are visibly oiled and comparing survival rates of oiled and un-oiled adult birds. Shorebird abundance estimates were derived from aerial surveys. Oiling proportion estimates were obtained by surface observation of foraging and roosting sites from Texas to Florida. Survival rate estimates of oiled and un-oiled adult birds from one representative species (American oystercatcher) were derived using radio telemetry techniques.

Pelagic Birds
Injury to pelagic seabirds is being assessed by placing trained bird observers on ships to evaluate offshore seabird diversity and abundance of seabirds and assess the incidence and degree of external oiling. Aerial surveys were also used to estimate seabird densities and abundance.

Piping Plover
Injury to piping plovers is being assessed by estimating the number of piping plovers in oiled and reference areas during the winter, documenting the frequency and degree of oiling, and evaluating over-winter survival of plovers in these areas via color band marking and re-sighting activities. The trustees also evaluated the return of marked plovers to the nesting areas in summer 2011.

Raptors
The trustees evaluated potential spill-related mortality in two piscivorous raptors species: bald eagle and osprey. Studies include a rapid assessment of oiling effects and response activities on osprey reproduction in 2010, an assessment of bald eagle and osprey nests and reproductive productivity in 2011 and documentation of the presence of oiled nesting material in osprey nests.

Waterfowl

Injury to waterfowl is being assessed by estimating abundance and distribution within oil impacted marshes, open water habitats and along beaches, and documenting dead and live oiled wintering waterfowl via boat surveys within aquatic habitats and open waters; and walking beach surveys. Target birds include diving ducks, dabbling ducks and geese with a special focus on resident mottled ducks known to over-winter within the oil spill area. In addition, this assessment evaluated oiling impacts of submerged aquatic vegetation (habitat which provides principal dietary items for a number of waterfowl species) as well as searcher efficiency of field survey crews attempting to locate waterfowl carcasses in marsh habitats.

Wintering Openwater Waterbirds

Injury to birds over-wintering in coastal openwater habitats within the spill area were assessed by estimating target species (common loons, American white pelicans, and northern gannets) abundance and distribution derived from aerial surveys and documenting oiling occurrence and extent derived from beach- and boat-based surveys.

Colonial Waterbird Photo Census and Analysis of Oiling and Survival Data

Colony photographs from 2010 and 2011 are being analyzed and compared (before-after/control-impact analysis) to document potential differences in select bird nesting colonies.

Blood Physiology Assessment

Polycyclic aromatic hydrocarbons found in crude oil have been associated with a variety of adverse effects in birds, including oxidative damage to red blood cells and other physiological effects. Such effects may compromise a variety of vital functions in birds, such as the ability to fly, swim, forage, migrate, and reproduce. This assessment activity evaluates physiological effects in birds to determine if hemolytic anemia and other physiological effects are key diagnostic features in birds oiled by the *Deepwater Horizon* oil spill.

Next Steps

The trustees are in the process of summarizing and analyzing data collected to date and continue to develop both the Beached Bird Model and the Live Oiled Bird Model as integral components of the bird injury assessment. Trustees are also developing a comprehensive literature review evaluating chemical, toxicological and physiologically relevant levels of oil exposure to a multitude of avian species. Evaluation of response actions that may have had a negative impact on birds is ongoing and being closely coordinated with shoreline (Section III.11) assessment activities. Additionally, the Trustees plan to conduct a series of avian toxicity studies to evaluate the effects of *Deepwater Horizon* oil, dispersants and their related compounds on various representative avian species. Collectively, these studies will assist in the interpretation of information generated from NRDA avian pre-assessment studies conducted throughout oil-impacted areas in the northern Gulf region.

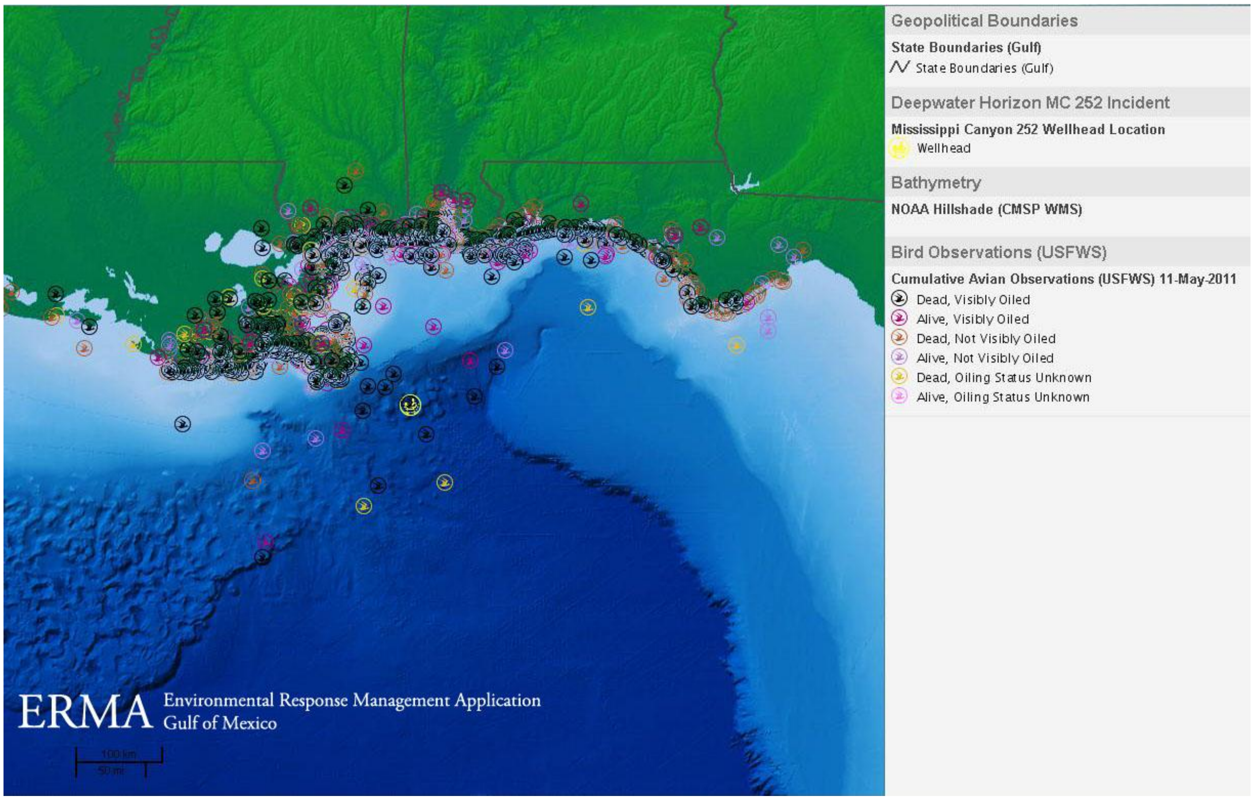


Figure 19. This map depicts the number of recovered birds, live and dead.

Relevant Work Plans

Relevant work plans can be found by visiting www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data.

13. Terrestrial Species

Resource

There are several important types of habitat that can extend above the mean high tide line, including marshes, mudflats, mangrove stands and sand beaches. Terrestrial species that use these habitats include birds, crabs, turtles, alligators, small mammals, and other aquatic and terrestrial species.

In particular, many species listed as endangered, threatened or as a species of concern under federal or state laws live within these habitats. The coastal dunes of Alabama and Florida are habitat for seven subspecies of beach mice, and six of these beach mice are listed as endangered or threatened under state and federal law. Diamondback terrapins also use these habitats and are of particular concern because their populations are sensitive to small decreases in adult and juvenile survival rates. Due to their long lives, slow growth, slow development to sexual maturity and low reproductive rates, any decrease in survival rates can have long-term and negative consequences. Additionally, they are the only terrestrial animals that live, forage and reproduce entirely in the water and sediment of coastal marsh areas.

Threat

Alligators, such as this pair in the Noxubee National Wildlife Refuge, Mississippi, are among the species that use the habitats above the mean high tide line.

Terrestrial species are potentially injured by the spill along with their terrestrial and aquatic habitats. When oil reaches land, it can severely impact coastal habitats including marshes, mudflats, mangrove stands and beaches. The organisms that use these habitats are at risk from direct fouling by the oil, as well as exposure via consumption of prey that has been contaminated by the oil spill. In particular, diamondback terrapins are susceptible to adverse effects from the spill because they inhabit brackish water, spending most of their lives at the aquatic-terrestrial boundary in estuaries. Otter and mink may also forage and shelter in contaminated estuarine environments. Many habitats used by these species likely were negatively impacted by response activities such as shoreline cleanup efforts, placement of boom and siting of land-based staging areas. Trustees are continuing to evaluate potential impacts to diamondback terrapins, alligators, otter and mink.

Assessment Plan

The goal of the beach mice assessment plan is:

- To document disturbance to or destruction of the sand dune habitat of endangered and candidate beach mice species in Alabama and Florida due to activities related to spill response.

Baseline Data

Federal, state and local resource management agencies and non-governmental organizations conduct monitoring of terrestrial wildlife resources within areas of the Gulf of Mexico potentially impacted by the *Deepwater Horizon* oil spill. These efforts provide recent and historic data collected over multiple years and seasons that may be useful in documenting baseline conditions of at-risk resources.

Assessment

The data collected and knowledge gained through the Shorelines (Section III.11) and Nearshore Sediment and Associated Resources (Section III.7) assessments are being used to inform the terrestrial species injury assessment.

The trustees contemplated impacts to beach mice, otter, mink, terrapins, alligator and coastal dunes. Since the spill began, the trustees have been documenting observations of oiled habitats and oiled terrestrial wildlife. Trustees have also been examining other specific impacts for listed species, including beach mice and terrapins.

Beach Mice

The Alabama beach mouse is an endangered species that lives in the coastal dunes of Alabama and Florida.

The coastal dunes of Alabama and Florida provide habitat for seven subspecies of beach mice. Five of the beach mice subspecies (Alabama, Perdido Key, Choctawhatchee, St. Andrew and Anastasia Island) are listed as federally endangered, and one subspecies, the southeastern beach mouse, is listed as federally threatened. The remaining subspecies, the Santa Rosa beach mouse, is a federal species of concern and is a candidate species for future listing. Injury to beach mice is being assessed by documenting disturbance or destruction of sand dune habitat that occurred as a result of oil spill response activities. Habitats that are currently or potentially occupied by beach mice are being evaluated. High-resolution aerial imagery, information from land managers and responders, and ground surveys are being used to document the occurrence, extent and severity of disturbance or diminishment to beach mice habitat.

Terrapins

Louisiana has collected terrapin eggs in potentially impacted areas, which will be analyzed for the presence of contaminants.

Next Steps

Quantifying injury to resources due to spill response actions is an important step in the damage assessment for terrestrial species, and the trustees are currently working to identify and compile information on activities associated with the oil spill response. Examples include number and location of cleaning crews, completed shoreline treatment recommendation forms, and quantity of oiled debris removed the shoreline. This information will be used to evaluate not only potential injuries to terrestrial wildlife, aquatic life and their supporting habitats, but also to evaluate other natural resource categories.

Relevant Work Plans

Relevant work plans can be found by visiting www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data.

14. Human Use

Resource

Lost human use of natural resources, such as recreational fishing, are evaluated as part of the NRDA process.

Humans, like wildlife, rely on the natural resources of the Gulf of Mexico. Outdoor recreationists make more than 150 million trips per year to the Gulf of Mexico.[90] From fishing to sunbathing to bird watching and countless other recreational activities, people depend on Gulf Coast waters and nearshore environments for valuable recreational, cultural and ecological resources and services. Tourism and recreation are large contributors to the Gulf of Mexico economy. There are more than 640,000 jobs yielding more than $10 billion in tourism and recreation wages paid each year in the Gulf Coast region.[91] In 2009, 2.8 million recreational fishermen from the four Gulf of Mexico states participating in the Marine Recreational Fisheries Survey (Florida, Alabama, Mississippi and Louisiana) took at least one fishing trip in the Gulf of Mexico region. When recreational fishermen visiting from outside these four states are included, approximately 23 million individual fishing trips occurred in the Gulf of Mexico.[92] The Gulf region leads the nation in oyster production, with some 67 percent of the total harvest in 2008.[93]

Threat

Just the threat of oil exposure can cause beaches and fisheries to be closed to protect the environment and public health. Enjoyment of activities such as boating, fishing, hunting, swimming, sunbathing and wildlife viewing may be diminished, not only by the presence of oil but also by the threat of oil and by response activities. Under OPA a compensable injury has occurred when the public's access to the enjoyment of their natural resources is denied or restricted in some way due to an oil spill.

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[90]U.S. Department of Agriculture. National Survey of Recreation and the Environment, 1999-2007. http://www.srs.fs.usda.gov/trends/Nsre/NSRECert.html.
[91]Bureau of Labor Statistics. 2006. Employment and Wages Data Files
[92]NOAA National Marine Fisheries Service. 2010. Fisheries of the United States 2009. http://www.st.nmfs.noaa.gov/st1/fus/fus09/index.html.
[93]NOAA National Marine Fisheries Service. 2010. Fish Stocks in the Gulf of Mexico Fact Sheet. http://sero.nmfs.noaa.gov/sf/deepwater_horizon/Fish_economics_FACT_SHEET.pdf.

Assessment Plan

The goal of the human use assessment is:

- To quantify lost use of and diminished values for natural resources affected by the oil spill.

The lost human use assessment for the *Deepwater Horizon* oil spill is not a cooperative assessment. While some data are being collected cooperatively (e.g., counts of beach visitation from aerial overflights), the trustees and BP are analyzing the collected datasets individually. Each party will use its data to arrive at separate conclusions about the value of the lost use injury. Therefore, the data being collected by both sides are not being made public at this time because it may eventually be used in litigation if the two parties cannot reach agreement. Nonetheless, the lost human use of natural resources and services due to the *Deepwater Horizon* oil spill has been well publicized, and a large-scale, comprehensive assessment to determine the scale of those losses is on-going.

Baseline Data

Several sources exist for baseline and historical data on human uses of natural resources and services in the Gulf of Mexico. Monthly data for recreational fishing trips on private boats, on charter/party boats and from shore are available for publically accessible sites along the Gulf Coast from 1981 to the present.[94] Data are available for the number of fishing, hunting and wildlife viewing trips in the United States by state and include trips by Gulf Coast state residents and non-residents.[95] Monthly visitation estimates to national parks located along the Gulf Coast are also available for the period January 2000 (earlier for some parks) to the present.[96] Monthly visitation estimates for certain state parks also are available.[97] Information about recreation trips to coastal areas in the contiguous United States is available from 1999 to 2007 and includes the destination of trips and activities undertaken.[98]

Assessment

The trustees are employing a variety of efforts for estimating the diminished use and lost value from the *Deepwater Horizon* oil spill including surveys of recreational activities and values, investigations of possible approaches for estimating lost total value and initiation of those approaches, and background studies on economic activity related to marine recreation and total

[94]NOAA National Marine Fisheries Service. 2011. Recreational Fisheries Statistics Queries. National Marine Fisheries Service, Fisheries Statistics Division. www.st.nmfs.noaa.gov/st1/recreational/queries/index.html.

[95]U.S. Fish and Wildlife Service and U.S. Census Bureau. 2006. 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation. www.census.gov/prod/2008pubs/fhw06-nat.pdf.

[96]Data is available for DeSoto National Memorial (FL), Dry Tortugas National Park (FL), Everglades National Park (FL), Gulf Islands National Seashore (MS; FL) and Jean Lafitte National Historic Park and Preserve (LA). National Park Service. 2011. NPS Stats. www.nature.nps.gov/stats/index.cfm.

[97]State of Louisiana. 2011. Louisiana Office of State Parks. www.crt.state.la.us/parks/; Mississippi Department of Wildlife, Fisheries and Parks, 2011. http://home.mdwfp.com/; Florida Department of Environmental Protection, Recreation and Parks, 2011. http://www.dep.state.fl.us/parks/.

[98]USDA Forest Service. 2011. National Survey on Recreation and the Environment. Available: www.srs.fs.usda.gov/trends/Nsre/nsre2.html.

value. For direct/recreational use losses, the focus will be on three sectors: boating and boat-based fishing, shoreline fishing and general shoreline use. The impacts of the spill on consumer prices for seafood will also be evaluated. The total impact due to direct oiling, threat of oiling and response activities will be taken into account.

The estimation of lost value involves four general information-collection efforts: determination of direct use/recreational use under spill-impacted conditions, determination of baseline recreational use, assessment of the value of lost and diminished recreation trips and assessment of the lost total value (both direct/recreational and passive use). Onsite counts and surveys to assess levels of direct use/recreational use continue to be conducted at shoreline use and boating locations along the Gulf Coast. Aerial overflights are also ongoing to quantify the number of visitors engaging in direct shoreline use along the Gulf Coast. Surveys have been conducted to characterize spill impacts to residents of the Gulf states as well as nationally. An additional survey collected information about the spill impacts to boaters not included in the onsite sampling.

At this time, it is anticipated that the direct/recreational use onsite and aerial overflight sampling described above, which started shortly following the spill, will continue until it is determined that direct/recreational use in the Gulf of Mexico has returned to baseline levels. The second effort, determination of baseline direct/recreational use, involves review of existing data sets and comparison of historical information on direct/recreational use with the information collected in the onsite counts, surveys and overflights. Once it is determined that the use of the resources has returned to baseline, the recreational/direct use trips from the baseline time period can be compared with the recreational/direct use trips from a matching time period under spill-impacted conditions to determine the number of lost recreational trips resulting from the spill. The third effort involves assessing the value of recreational trips lost, as well as the diminution in the value of trips that are taken in other than baseline conditions. This work will be the continuation of the recreation assessment that is already under way and the development of appropriate strategies for assessing baseline use and valuing lost recreation. The total value assessment activities also are the continuation of the ongoing total value assessment.

Next Steps

Trustees plan to continue collecting data on impacts to human use activities involving the Gulf of Mexico's natural resources and conducting valuation studies to understand the value users place on these natural resources. Trustees also plan to incorporate results of the biological injury assessments detailed above into the lost human use assessment.

Relevant Work Plans

Relevant work plans can be found by visiting www.gulfspillrestoration.noaa.gov/oil-spill/gulf-spill-data.

IV. Conclusion

The *Deepwater Horizon* oil spill Natural Resource Damage Assessment is by far the largest ever conducted. Given its geographic size, three-dimensional nature and ecological complexity, the assessment likely will continue for years. The state and federal trustees will continue to work together to determine how the oil spill affected the Gulf of Mexico's natural resources and the human use of those natural resources.

The goal of the injury assessment is to create a holistic view of the effects from the discharged oil to the Gulf of Mexico ecosystem. Immediately following the start of the spill, the trustees evaluated the resources at risk in the affected area and developed injury assessment hypotheses and conceptual models to guide field investigations. Trustees then developed work plans to document the pathway and exposure of discharged oil to resources and services that may have been affected. Finally, the trustees designed and implemented studies to evaluate the severity and extent of injuries to resources and services from discharged oil and to evaluate alternative hypotheses for potential injuries. As of March 1, 2012, the trustees have completed or are participating in more than 100 NRDA investigations spanning every major resource category. The work plans that direct these efforts and the bulk of the associated verified data have been and will continue to be made available to the public at www.gulfspillrestoration.noaa.gov/gulf-spill-data. Most of these work plans provide detailed technical methods, implementation information and estimates of study costs.

Many ongoing and proposed activities in 2012 involve the collection and analysis of field data needed to confirm the presence of natural resource injury or inform estimates of the magnitude of injury and associated reductions in services. Models and literature-based methods also are used in selected investigations. The scale and cost of trustee investigations has been considered carefully. The trustees' ongoing effort to fully assess the impacts of the oil spill to the Gulf of Mexico ecosystem balances the need for cost-effective assessment with the unprecedented geographic scale and complexity of this spill.

V. Appendix

Photo Credits

1. *NRDA researchers collect sediment samples during a 2010 assessment operation in Louisiana. Credit: NOAA.*
2. *A researcher from the University of California at Santa Barbara, checks a water sample for air bubbles on board the NOAA Ship* Pisces *during a September 2010 NRDA mission. Credit: NOAA*
3. *A colony of coral with dying and dead sections (on left), apparently living tissue (top right) and bare skeleton with sickly looking brittle star on the base has been documented near the* Deepwater Horizon *well head. Credit: Lophelia II 2010 Expedition, NOAA-OER/BOEMRE.*
4. *A diver works with coral as part of a restoration project. Credit: NOAA.*
5. *Researchers label water sample bottles during lab analysis. Credit: NOAA*
6. *Researchers gather water samples from a CTD (conductivity, temperature, depth) rosette. Credit: NOAA.*
7. *Researchers prepare to deploy an array of sensors to evaluate conditions in the water column. Credit: NOAA*
8. *An Integrated Ocean Observing System glider is used to locate and track oil at various levels in the water column as well as on the water surface. Credit: NOAA*
9. *Bluefin tuna are a Gulf species prized by commercial and recreational fishermen alike. Credit: NOAA*
10. *Federal officials assess how a sample is processed aboard the Research Vessel* Caretta *and chain of custody protocol is followed when handling specimens associated with the oil spill. Credit: NOAA*
11. *Creole fish, amberjack and several other species school around a basalt spire at Alderdice Bank, Texas. Credit: NOAA, FGBNMS and SSE/NGS*
12. *This dolphin carcass was recovered on Grand Isle Beach, Louisiana, in January 2012. Credit: NOAA*
13. *Veterinarians collect samples from a dolphin in Barataria Bay, Louisiana, during August 2011 health assessments. Credit: NOAA*
14. *A veterinarian prepares to clean a severely oiled Kemp's ridley turtle. Credit: NOAA and Georgia Department of Natural Resources*
15. *A wildlife biologist from Georgia's Department of Natural Resources surveys oiled Sargassum in the Gulf of Mexico. Credit: Georgia Department of Natural Resources*
16. *Turtle nests were relocated as part of the oil spill response. Credit: USFWS*
17. *Mussel Watch scientists bring up a trawl of oysters for testing. Credit: NOAA*
18. *Response vessels' propellers left multiple scars like this one in underwater grass beds when attempting to boom off shallow areas to prevent oil from reaching shorelines. Credit: Harold Hudson, Florida Keys National Marine Sanctuary*
19. *The lined seahorse is one of many marine mammals that use seagrass as its habitat. Credit: SEFSC Pascagoula Laboratory; Collection of Brandi Noble, NOAA/NMFS/SEFSC*

20. *Studies of shallow water coral reefs have documented no evidence of exposure to oil, dispersants or disruptive response activities. Credit: NOAA*
21. *Waves of oil and tarballs washed up along the beaches of Grand Isle, Louisiana. Credit: NOAA*
22. *Marshy shorelines in Louisiana's Barataria Bay Basin were heavily oiled by the* Deepwater Horizon *oil spill. Credit: NOAA*
23. *A NRDA team surveys Louisiana marsh in fall 2010. Credit: NOAA*
24. *A U.S. Fish and Wildlife Service biologist carries an oiled pelican from a nesting area in Barataria Bay, Louisiana, to a waiting boat. Credit: Coast Guard Photo by Petty Officer 2nd Class John D. Miller.*
25. *An oiled brown pelican is cleaned at a wildlife rehabilitation center in Plaquemines Parish, Louisiana. Credit: Greg Thompson, USFWS*
26. *Alligators, such as this pair in the Noxubee National Wildlife Refuge, Mississippi, are among the species that use the habitats above the mean high tide line. Credit: USFWS Roger Smith.*
27. *The Alabama beach mouse is an endangered species that lives in the coastal dunes of Alabama and Florida. Credit: USFWS*
28. *Lost human use of natural resources, such as recreational fishing, are evaluated as part of the NRDA process. Credit: Brett Prettyman*