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REPORT IN BRIEF

An Ecosystem Services Approach to Assessing the Impacts of the *Deepwater Horizon* Oil Spill in the Gulf of Mexico

As the Gulf of Mexico recovers from the Deepwater Horizon oil spill, natural resource managers face the challenge of fully understanding the impacts of the spill and setting priorities for restoration work. The full value of losses resulting from the spill cannot be captured, however, without consideration of changes in ecosystem services--the benefits delivered to society through natural processes. In the short term, natural attenuation appeared to be one of the more effective remediation approaches both in the deep sea and in wetlands. Still, the long-term impacts cannot yet be determined.

The largest marine oil spill in U.S. history, the *Deepwater Horizon* explosion released nearly 5 million barrels* of crude oil over a period of three months. Since the oil spill, there have been numerous studies by the academic research community, the private sector, and the federal government aimed at understanding the environmental impacts on the Gulf of Mexico. However, environmental impacts tell only part of the story. The people who live and work around the Gulf of Mexico (20 million people in the United States alone) depend on services offered by the ecosystem for their well-being and livelihood. For example, the wetlands of the Gulf region protect the coast from storm surges; the region's fisheries account for approximately 25 percent of the seafood harvested in the contiguous United States; and the Gulf supports an energy sector that produces about 30 percent of the nation's oil and nearly 20 percent of its natural gas. Disruptions in the ecosystem caused by the oil spill could impair these services, leading to economic and social impacts that may not be apparent from an assessment of environmental damage alone.

An interim report from this committee found that evaluating changes to ecosystem services would help capture and value the full breadth of impacts to the ecosystem and the public. This report expands on that finding, discussing the benefits and challenges associated with using an ecosystem services approach, describing potential impacts of response technologies, exploring the role of resilience, and offering suggestions for areas of future research.

The Ecosystem Services Approach

Currently, state and federal natural resource agencies use the Natural Resource Damage Assessment (NRDA) process to assess ecosystem damage. The NRDA process assesses injuries and losses to natural resources in ecological terms (e.g. number of acres damaged or number of fish killed), which can be translated to restoration activities (e.g. acres restored or fish stocks replaced).

However, for a deep spill of the magnitude of *Deepwater Horizon*, it can be difficult to assess injury to the ecosystem based on injuries to individual resources. As oil rises from the depths and ocean currents move oil from place to place, the impacts of the spill spread throughout the ecosystem. Furthermore, impacts to the

Box 1. Ecosystem Services — Benefits People Obtain from Ecosystems

Ecosystem services are the benefits provided by ecosystems that support, enrich, and sustain human life. These benefits are commonly classified into four categories (provided below, with examples).

Provisioning
food, animal feed, fuel, fiber

Regulating
climate regulation, flood control, water purification

Cultural
recreation, spirituality, and aesthetics

Supporting
nutrient cycling, primary production, soil formation

* According to McNutt et al. (2012), BP's containment efforts captured approximately 800,000 barrels of oil before it reached the marine environment, making the total amount of oil to enter the water column closer to 4.2 million barrels.

community cannot be defined without a better understanding of the social and economic consequences of the effects of the spill on ecosystems.

An ecosystem services approach provides a more holistic view of the overall range of damages and informs options for restoration. This approach requires an understanding of three factors:

- ***Environmental impact***—What are the impacts of disturbances on the structure and basic functioning of ecosystems?
- ***Ecological production function***—How do changes in the structure and function of ecosystems affect the potential provisioning of ecosystem services?
- ***Valuation***—How do changes in the provisioning of ecosystem services affect human well being, and how can the value of these changes be estimated in monetary terms?

Challenges in Using the Ecosystem Services Approach

Conceptually, an ecosystem services approach has many advantages, but its application in real world situations brings a number of challenges.

Establishing Pre-spill Baselines

To judge the extent of damage caused by the spill, scientists need to understand the state of the ecosystem before the *Deepwater Horizon* disaster occurred. Depending on the ecosystem service being addressed, there are substantial differences in the amount and quality of data available. Furthermore, many ecosystems are rapidly changing and were already degraded even before the spill, making pre-spill baselines more difficult to establish.

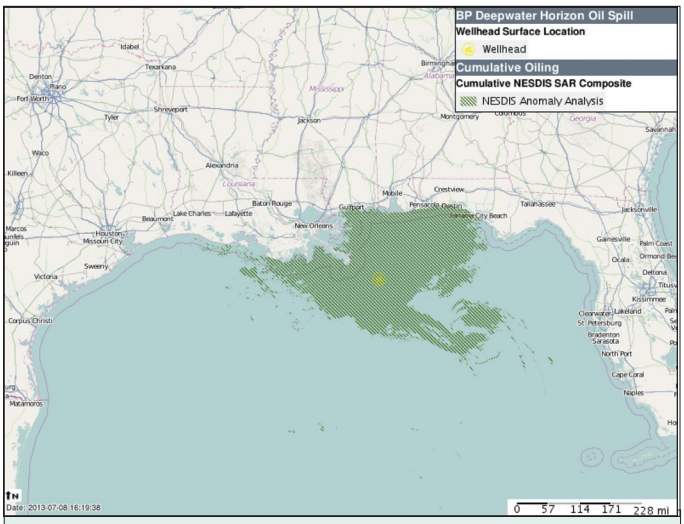

Figure 1. The cumulative spatial extent of the *Deepwater Horizon* oil spill at the surface of the water in the Northern Gulf of Mexico (*green shading*), and the location of the Macondo wellhead (*yellow shading*).

Source: NOAA

Box 2. Applying the Ecosystem Services Approach

The report's authoring committee developed case studies that illustrate the challenges of using the ecosystem service approach to assess the impacts of the spill, and demonstrate the range of existing knowledge and available information. The case studies highlight the four primary types of ecosystem services, and illustrate how the value of some services is more readily measured than others. The coastal wetlands case study illustrates a well-studied ecosystem service; the deep Gulf of Mexico case study provides an example of a much less understood ecosystem service.

Relating Ecosystem Changes to Benefits to Humans

Some ecosystem services can be translated to a monetary value relatively easily—for example, the role of coastal wetlands in reducing the intensity of storms can be valued by calculating the cost of repairing storm damage that would have been incurred without protection from wetlands. However, work has only just started to determine the value of other, less-studied ecosystem services.

Understanding Complex Ecosystems

Difficulty also comes from the lack of comprehensive ecosystem models to evaluate the full impact of events such as the *Deepwater Horizon* oil spill. These models would allow greater understanding of how the elements of the ecosystem interact and produce services of value to humans.

Response Efforts

Due to the magnitude of the *Deepwater Horizon* oil spill and the potential for oil to reach shore, a huge response effort took place with the primary objective of reducing the amount of oil reaching the fragile and ecologically important wetlands and coastal areas of the North Gulf. These efforts, which included the skimming and burning of oil, chemical treatments to disperse oil, and the construction of booms to prevent oil from making landfall—decreased the volume of oil that came ashore. However, several of these technologies were used in ways or at scales never before attempted. For example, the volume of dispersants applied during this spill triggered considerable public concern. While much more research is needed to fully understand the impacts of the oil and dispersants in the water column and on marine life, there is a growing consensus that the dispersants were effective in breaking up the oil, making it more available for biodegradation by marine microbes and reducing the amount of oil on the sea surface and the corresponding risks. As for the oil that reached coastal areas, response and clean up efforts were comparatively less effective and more expensive.

Box 3. Two Case Studies for Implementing the Ecosystem Services Approach

The Coastal Wetlands – Regulating Service

The vegetation of coastal wetlands provides frictional resistance that slows storm winds, reduces wave height, and protects the coast against storm surges. Among the many impacts of oil damage to wetlands is the reduction in the regulating ecosystem service of storm protection.

Environmental Impact: Numerous studies indicate that perennial marsh vegetation can recover quickly from contact with oil, with little or no long-term impairment. However, where the oil smothers plant root systems, vegetation dies and the loss of root systems causes the erosion of sediment, converting once productive marshland to open water. The full acreage of wetland lost due to the spill has not been established.

Ecological Production Function: Storm mitigation can be shown to be directly related to the total area of wetlands. Thus change in total wetland area is a direct and practical measurement of change in ecosystem services in Gulf Coast wetlands.

Valuation: The storm protection afforded by coastal wetlands can be valued in monetary terms by estimating the cost of storm damage that would be incurred in the absence of coastal marshes. To calculate this, information on the economic value of the land that lies in the storm path is needed, because damage to cities would be more costly than damage to rural areas. Data are also needed on the condition of wetlands, because fragmented marsh is not as effective at reducing storm surge.

Figure 2. Scientists take samples on oiled marshland. *Credit: NOAA*

The Deep Gulf of Mexico– Supporting Service

The deep sea, defined in this report as depths of 200 meters and greater, is the largest yet least well understood element of the Gulf of Mexico ecosystem. Based on current understanding, the deep Gulf of Mexico primarily provides supporting services by recycling nutrients depleted during photosynthetic activity in the ocean's sunlit surface waters. This stable source of nutrients provides greater resilience to the whole ecosystem.

The *Deepwater Horizon* spill gave scientists the opportunity to learn more about the regulatory service of pollution attenuation, which was well documented for shallow marine environments but previously unknown for the deep-sea water column. Scientists discovered that deep dwelling oil-degrading bacteria digested a significant amount of oil from the Macondo well.

Environmental Impact: The environmental impacts of the oil spill on the deep Gulf of Mexico are being investigated as part of the NRDA process, which has not yet been completed. A small number of peer reviewed studies are available, and indicate that the primary impacts are reductions in the amount of dissolved oxygen and nitrogen in the deep sea, a result of the microbial degradation of oil. The oil has had toxic effects on deepwater corals and other deep sea species.

Ecological Production Function: The deep Gulf of Mexico is so vast and sampling so sparse that gaps in knowledge make it difficult to apply an ecosystem service approach in a quantitative way. More research is needed to develop an ecological production function for the services the system provides.

Valuation: The pollution attenuation service afforded by the deep Gulf of Mexico could be valued in monetary terms by estimating the cost of equivalent human-engineered oil removal methods. However, with current understanding, scientists are challenged to estimate how much oil would be attenuated by deep sea microbes, or which human-engineered methods could best replicate this service.

Incorporating more science into the remediation process would help scientists employ the most effective response technologies and determine the endpoint of the response effort. A better understanding how the response effort affected the environment will not be possible until damage assessment data and the results of long-term monitoring studies become available.

Looking Forward

The funding that will be available through criminal and civil settlements offers an unprecedented opportunity for research to establish a better baseline understanding of the Gulf of Mexico ecosystem and further develop an ecosystem services approach to damage assessment for large spills. The committee identified research needs that will help implement an ecosystem services approach in the Gulf of Mexico.

Build a Data Infrastructure System

There is a critical need for an overarching infrastructure for organizing and integrating the wealth of data that has been and will be collected in the Gulf of Mexico. This infrastructure will be needed to support comprehensive ecosystem models that can be used to evaluate the impacts and linkages between ecosystem services.

Develop More Comprehensive Models of the Gulf of Mexico Ecosystem

In the long-term, more comprehensive models that can relate the drivers of change to the structure and function of the ecosystem are needed. Such a system would incorporate all the relevant processes—including biological, physical, social, and economic—to describe the dynamics of each ecosystem service in the Gulf of Mexico.

In the shorter term, models of subcomponents of the ecosystem can help establish the value of ecosystem services for a distinct resource use, location, habitat, and user community.

Incorporate Social and Economic Factors into Ecosystem Research

Although a substantial body of data exists to support a better understanding of ecosystem structure and function within the Gulf of Mexico, data regarding socio-economic and human dependencies lags far behind. Collecting and synthesizing data on economic and human factors and including them in the appropriate models will help capture the full range of ecosystem impacts.

How to Define and Build a More Resilient Gulf of Mexico Ecosystem

Resilience—the capacity of a system to respond to disturbances—is an important component of ecosystem management because it helps sustain a continuing flow of valuable ecosystem services. Building resilience to unpredictable events such as large oil spills will require decisions that strengthen ecosystems (for example, by maintaining biodiversity) and incorporate adaptive management (the continuous integration of new data and information into management plans).

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** Resigned from the committee April 2011*

The National Academies appointed the above committee of experts to address the specific task requested by the National Oceanic and Atmospheric Administration. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.

EXPERT CONSENSUS REPORT

For more information, contact the Ocean Studies Board at (202) 334-2714 or visit http://dels.nas.edu/osb. Copies of *An Ecosystem Services Approach to Assessing the Impacts of the* Deepwater Horizon *Oil Spill in the Gulf of Mexico* may be purchased from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; or downloaded free at www.nap.edu.