MARINE MAMMAL COMMISSION

28 December 2012

Christopher Doley
Habitat Restoration Division
Office of Habitat Conservation
National Marine Fisheries Service
1315 East-West Highway
Silver Spring, MD 20910-3225

Dear Mr. Doley:

The National Oceanic and Atmospheric Administration (NOAA) has a key role on the Deepwater Horizon Natural Resource Damage Assessment Trustee Council, which is charged with assessing injuries to natural resources resulting from the Deepwater Horizon oil spill and with developing a restoration plan to address those injuries, including injuries to marine mammals and their habitats. The Marine Mammal Protection Act established the Marine Mammal Commission to oversee and advise federal officials regarding activities that may adversely affect marine mammals and the ecosystems upon which they depend. In that capacity, the Commission offers the following recommendations and rationale to assist the Council in restoration planning for the Gulf.

RECOMMENDATIONS

The Marine Mammal Commission recommends that NOAA work with the other co-Trustees to include in the restoration plan—

- specific projects that will assess, over the long term (20 years or more), injuries to marine mammals and recovery from injuries resulting from the Deepwater Horizon oil spill and associated response activities; recommended projects include—
  - marine mammal stock assessment surveys;
  - enhancement of the Gulf marine mammal stranding program;
  - live capture/release health assessments;
  - contaminants analyses;
  - assessment of the physiological effects of oil and chemical dispersants on marine mammals and model species;
  - environmental studies (including prey studies);
- activities to ensure long-term monitoring, assessment, and recovery of all of the marine mammal stocks found in inshore, coastal, and offshore ecosystems throughout the northern Gulf; and
- projects to minimize other risk factors that may impede recovery of Gulf marine mammals; recommended projects include—
  - establishing or expanding fishery observer coverage;
  - minimizing incidental takes in fisheries and indirect effects of fishing on important prey species;
  - monitoring sound levels;
  - minimizing effects of sound;

- reducing other environmental impacts.

The Marine Mammal Commission further recommends that NOAA work with the other co-Trustees to—

- ensure that restoration projects include long-term monitoring to determine whether the projects are achieving their goals and injured resources are indeed being restored;
- develop a science-based, multidisciplinary project selection process that is open to all appropriate researchers and encourages data sharing; and
- manage restoration projects using an adaptive management approach that informs and guides management of Gulf resources over the long term.

RATIONALE

The Oil Pollution Act of 1990 requires that federal, state, and tribal Natural Resource Trustees conduct a Natural Resource Damage Assessment to evaluate the degree and extent of injuries resulting from an oil discharge event. Evaluating injuries includes compiling information on environmental conditions pre- and post-spill to determine the short- and long-term environmental effects of the spill and response activities. The Trustees use that information to identify appropriate restoration activities—i.e., activities that will bring natural resources back to pre-spill conditions—and compensate the public for interim losses.

Restoration planning is based on the assumption that we know not only what injuries occurred from a spill, but also the pre-spill conditions to which the ecosystem must be restored. However, for the Deepwater Horizon oil spill, we lack the necessary baseline information on the status and ecology of most Gulf marine mammal populations. We also lack a sufficient understanding of the potential effects of oil spills and response activities on marine mammals living in different habitats. The following summarizes available information on pre-spill baseline conditions, potential injurious effects based on past research and oil spill events, and effects that may have occurred from the Deepwater Horizon oil spill. Based on that information, the Commission has identified a number of restoration projects to (1) assess long-term injuries resulting from the oil spill and response activities, and promote recovery from those injuries, and (2) address other risk factors for the Gulf's marine mammal stocks.

Baseline information on Gulf of Mexico marine mammal stocks

Twenty-one cetacean and one sirenian species reside in or regularly visit the inshore, coastal, and offshore waters of the Gulf of Mexico (Waring et al. 2010). They comprise 57 stocks, 37 of which are bottlenose dolphin stocks. Existing information on the status and life history of marine mammal stocks in the Gulf falls well short of that needed to assess their pre-spill status and vulnerability to various risk factors, including oil spills (Table 1). Most pre-spill studies focused on specific activities and specific species (e.g., responses of sperm whales to seismic surveys). Despite the fact that the Gulf is highly industrialized and has been the site of multiple marine mammal unusual mortality events over the past 20 years, few studies have been directed toward developing the baseline information needed to assess the vulnerability of marine mammals to oil and gas development, oil spills, and other risk factors.

Under ideal conditions, scientists would be able to respond to a spill by tracking the oil and its dispersion, characterizing the interactions between the oil and marine mammals, documenting the resulting physical and physiological effects, and judging their significance to the animals' reproduction, foraging, survival, and movements (e.g. whether they abandoned or lost access to important habitat). This reductionist or mechanistic approach could provide a robust understanding of the means by which a spill affects marine mammals, but it requires detailed knowledge of the affected species under pre-spill conditions. However, a reductionist approach is rarely possible and scientists often must resort to a more general approach by comparing the endpoint of whatever mechanism(s) might be behind the impacts (i.e. pre- and post-spill status (abundance and trends)) of a population and inferring effects based on the observed changes. In the Deepwater Horizon spill, even a general approach has not been possible because of the lack of baseline (pre-spill) information on population status.

Indeed, extensive data collection efforts by NOAA and the Fish and Wildlife Service for the pre-assessment phase of the natural resource damage assessment began immediately after the spill. Those data are useful to a degree, such as for characterizing marine mammal movements and behavior before, during, and after oil and chemical dispersants reached key coastal and deepwater habitats (and thus providing a partial basis for estimating the effects of the spill and response activities on marine mammals), but do not provide information about natural variability in movements and behavior over time that would be provided by proper baseline studies.

Potential effects of the oil spill and response activities on marine mammals

Given the gaps in information related to the Deepwater Horizon spill, one option is to infer possible effects based on information from other regions and contexts. Current understanding of the effects on marine mammals of exposure to oil is based primarily on information from (1) observations made of marine mammals during other oil spills (Geraci and St. Aubin 1990, Loughlin et al. 1994, Smultea and Würsig 1995, Bickham et al. 1998, Bodkin et al. 2002, Boehm et al. 2007, and Matkin et al. 2008), (2) a small number of controlled exposure studies using captive marine mammals (Geraci et al. 1983, Smith et al. 1983, St. Aubin et al. 1985), (3) simulation and in vitro studies (Braithwaite et al. 1983, Godard et al. 2004), and (4) observations of the effects of accidental and controlled oil exposure on species other than marine mammals (Bickham et al. 1998, Mazet et al. 2001, Golet et al. 2002, Mohr et al. 2007, Esler et al. 2010).

That information provides ample evidence that exposure to oil can harm marine mammals. Inhalation of specific volatile organics from some types of oil can cause respiratory irritation, inflammation, or emphysema. Similarly, ingestion of oil can cause gastrointestinal inflammation, ulcers, bleeding, diarrhea, or maldigestion. Certain inhaled and ingested chemicals in oil also can damage organs such as the liver, kidney, adrenal glands, spleen or brain; cause anemia, cancer, congenital defects, and immune system suppression; or lead to reproductive failure. Chemical contact can cause skin and eye irritation and inflammation; burns to mucous membranes in the mouth and nares; or increased susceptibility to infection. Oil mixtures also can physically foul the baleen of mysticete whales, which they use for filtering food.[1]

[1] The Bryde's whale is the only mysticete whale occurring regularly in the Gulf. North Atlantic right whales are sighted rarely in the Gulf and fin whales have stranded there occasionally, but are not regular inhabitants.

Response activities to contain and remove spilled oil also can injure marine mammals. Increased vessel and air traffic can disrupt foraging, habitat use, daily or migratory movements, and other behavior (e.g., breathing and resting) (Nowacek et al. 2001, Constantine et al. 2004, Williams et al. 2006, Stensland and Berggren 2007, Lusseau et al. 2009). Increased vessel traffic also adds to the risk of vessel strikes (Laist et al. 2001, Fish and Wildlife Service 2001, Bechdel et al. 2009), although no strikes were reported during the prolonged Deepwater Horizon spill and response phase. Noise from seismic surveys (such as those used to detect potential leaks around the wellhead in the present case) or other response-related activities may cause disturbance or displacement, hearing loss (temporary or possibly permanent), or other physical injury to marine mammals (McCauley et al. 2000, National Research Council 2003). Responders to the Deepwater Horizon spill used large quantities of dispersants at the surface (e.g., Corexit 9527, Corexit 9500A) and at the wellhead (Corexit 9500A) (Kujawinski et al. 2011, www.restorethegulf.gov) even though the long-term effects of Corexit and other dispersants on marine mammals are largely unknown (National Research Council 2005). Responders also used booms and skimmers to contain and collect surface oil and in-situ burning to remove it. These activities could have affected marine mammals through direct interaction (entrapment) and/or through displacement from habitat. Burning reduces the overall amount of oil in the water but leaves behind a residue of uncertain composition and toxicity (Benner et al. 1990, Wang et al. 1999). It also puts additional chemicals into the air, posing inhalation risks.

Oil spills also may affect marine mammals indirectly by altering the marine ecosystem and key features of their habitat (Paine et al. 1996, Golet et al. 2002, Peterson et al. 1996, National Research Council 2002). Such alterations could include reductions in prey or seagrass biomass (the latter for manatees), shifts in prey or seagrass distribution, or contamination of prey or seagrass. The oil from the *Exxon Valdez* spill that accumulated in sediments continues to contaminate nearshore environments in southeast Alaska, and this contamination appears to have impeded the recovery of sea otters in the region (Bodkin et al. 2002). How long that effect will persist is uncertain (Page et al. 2002, Rice et al. 2003, Neff et al. 2006, Boehm et al. 2007). Predictions that spilled oil that had accumulated in coastal and offshore bottom sediments in the Gulf would be released during hurricanes and storms were realized after Hurricane Isaac hit the Louisiana coast in September 2012 (www.huffingtonpost.com/2012/09/06/gulf-oil-spill-hurricane-isaac_n_1861657.html). Thus, strong storms are likely to result in intermittent, recurring effects on the marine ecosystem from the release of oil from sediments for a considerable time into the future (Machlis and McNutt 2010). Further research is needed to characterize physical and biogeochemical degradation rates of this oil in the Gulf of Mexico to evaluate the potential persistence of such long-lasting effects.

Preliminary assessment of marine mammals affected by the oil spill

The scope and significance of injuries to Gulf marine mammals as a result of the Deepwater Horizon oil spill have yet to be fully determined by the Trustees. However, any assessment of oil spill-related injuries to marine mammals should consider the following—

- 155 bottlenose dolphins, two sperm whales, two *Kogia* spp. (dwarf and pygmy sperm whales), two melon-headed whales, and six spinner dolphins stranded in the northern Gulf during the response phase of the spill (30 April 2010 through 17 April 2011), representing significantly more stranded animals than the mean number reported from this region in the same months during 2002-2009 (www.nmfs.noaa.gov/pr/health/oilspill/);
- some of those strandings may have been part of what has been deemed an unusual mortality event, involving a significantly higher than average number of deaths of bottlenose dolphins

and other cetaceans (Figure 1, (www.nmfs.noaa.gov/pr/health/mmume/cetacean_ gulfofmexico2010.htm) in the Gulf after early 2010 which could have had a significant effect on the resilience and survival of affected stocks;

- health assessments of coastal bottlenose dolphins in Barataria Bay, Louisiana, an area heavily affected by the spill, indicated high rates of poor health and suppressed metabolic and immune function (www.gulfspillrestoration.noaa.gov/2012/03/study-shows-some-gulf-dolphins-severely-ill/); and
- movements of sperm whales with home ranges near the spill site indicate that although whales remained in the area after the oil spill, they avoided the most heavily surface-oiled areas (www.gulfspillrestoration.noaa.gov/wp-content/uploads/2012/05/2011_10_12_ MAMMAL _Sperm_Whale_Tagging_LA-signature_Redacted3.pdf).

Information collected and analyses conducted to date are not sufficient to allow unambiguous conclusions about the spill and response actions as contributing factors. Therefore, the Commission believes that the Trustees should be taking a precautionary approach by assuming that the spill and response efforts likely contributed to the injury of the above-mentioned Gulf marine mammal species. It also is likely that other species and stocks of marine mammals that occur in the same habitats were injured but their injuries were not detected (Williams et al. 2011).

Restoration priority 1: Assessing long-term injuries resulting from the oil spill and response activities and promoting recovery from those injuries

A comprehensive assessment of marine mammal injuries resulting from the spill could take many years—longer than the timeframe available for consideration during the initial stage of restoration planning. Wildlife studies have revealed chronic, delayed, and indirect effects of the *Exxon Valdez* spill that lasted longer and were more severe than expected or assumed (Peterson et al. 2003). Exposure to oil from that spill was still impeding recovery of certain sea otter and killer whale populations 15 years later (Ballachey et al. 2007, Matkin et al. 2008). The Deepwater Horizon oil spill differs in some important respects from the *Exxon Valdez* spill, but long-term effects are a significant concern for Gulf marine mammals because of the vastly greater amount of oil spilled, the greater quantity of dispersants applied at the surface and wellhead, the similarly low recovery rates of spilled oil, uncertainty regarding the eventual disposition of both oil and dispersants, and uncertainty regarding the sub-lethal effects of the spill and spill response on marine mammals and on ecosystem elements important to marine mammals.

Although past studies and injury assessments have fallen short in many respects, much could be learned from careful assessment of current and future conditions and changes. Ensuring the effectiveness of restoration efforts for marine mammals and other natural resources requires a science-based, hypothesis-driven approach that integrates all available and pertinent information collected before, during, and after the spill and builds on and expands our current understanding of expected effects. Without a strong scientific follow-up to this spill, restoration efforts may be misguided, shortsighted, ineffective, or even harmful.

To ensure that restoration is guided by sufficient information, the Commission—with input from staff at NOAA and other federal agencies—prepared the enclosed report entitled "Assessing the Long-term Effects of the BP Deepwater Horizon Oil Spill on Marine Mammals in the Gulf of Mexico: A Statement of Research Needs." The report was intended to guide assessment of the spill's

long-term effects on marine mammal populations, to guide mitigation and restoration efforts, and to help track the changes in the Gulf ecosystem, including those resulting from recovery and restoration. In it, the Commission summarized potential effects of oil exposure and response activities on marine mammals and identified areas of study that should be given high priority in an assessment of long-term effects. Such areas of study include the following.

- Evaluating the effect of exposure to oil or dispersant-related contaminants on physiological functions (immune, reproductive, and other vital systems): This involves assessing the health status, contaminant loads, and markers of contaminant exposure of stranded or live-captured animals; conducting necropsies of dead animals; assessing reproductive rates and indicators of reproductive failure (e.g., aborted fetuses, malformed offspring), controlled exposure experiments on model species (e.g., mink); and genomic analyses;
- Assessing oil- and/or response-related changes in the ecosystem that reduce prey availability: This involves evaluating the body condition of live and stranded animals, looking for changes in diet as determined by observations of foraging behavior and stomach/intestinal content and tissue analyses (e.g., fatty acids, stable isotope studies), and prey surveys to assess biomass and changes therein over space and time;
- Evaluating how oil and/or response activities may have led to ecosystem changes (e.g., harmful algal blooms, hypoxia or anoxia) that are harmful to marine mammals: This involves observations of stranded animals and stranding patterns; analyses of fluids, tissues, and prey of marine mammals for evidence of toxins; and monitoring of harmful algal blooms and hypoxic/anoxic zones; and
- Determining the extent to which exposure to oil and/or response activities leads to a deterioration in status of marine mammal populations involving individual fitness, population vital rates (survival and reproduction), population abundance and trends, and habitat use patterns: This involves observations of mortality rates and evidence of reproductive failure, and aerial, vessel, shoreline, and acoustic surveys to assess relative or absolute changes in the number and distribution of animals, especially mother/calf pairs.

For the most part, the Trustees have incorporated these priorities into the various workplans developed to assess spill-related injuries to marine mammals and other natural resources in the Gulf. However, an ongoing assessment of marine mammal injuries should be included in the Trustee's restoration plan to account for and address long-term injuries. As the Trustees develop a better understanding of the effects of the oil spill on marine mammals, they can adapt restoration projects to target marine mammal species and habitats that are most at risk. An adaptive approach that builds on information obtained from continued injury assessment is a critical component of effective restoration planning. As noted by the National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling in its 2011 *Deep Water* report, "A sophisticated understanding of the full range of impacts from a large-scale oil spill is critical to effective recovery and restoration efforts" (Oil Spill Commission 2011).

For these reasons, the Marine Mammal Commission recommends that NOAA work with the other co-Trustees to include in the restoration plan specific projects that will assess, over the long term (20 years or more), injuries to marine mammals and recovery from injuries resulting from the Deepwater Horizon oil spill and associated response activities. The plan should include a combination of projects targeted at studying both direct biological effects on individuals (such as exposure to oil, disturbance, displacement from preferred habitats, injury, or other physiological

effects) as well as indirect effects on the ecosystem as a whole (such as a decrease or displacement of key prey species or an increased vulnerability to harmful algal blooms or hypoxia/anoxia). Where studies of individual animals are not feasible, studies to track population-level changes in abundance or vital rates over time may help in assessing chronic effects resulting from the oil spill or associated response activities. Attributing changes in vital rates or population abundance to exposure likely will require a "weight of evidence" approach based on a range of studies focused on individuals, populations, and the ecosystem.

Projects that should be included in an ongoing assessment of injuries to marine mammals and their habitats resulting from the Deepwater Horizon oil spill and associated response activities include—

- Marine mammal stock assessment surveys: Surveys to assess the abundance and distribution of marine mammal stocks are necessary to provide the baseline against which changes in the status of a stock can be measured. Stock assessments require a basic understanding of stock structure, as stocks comprise the basic units of conservation within a species. The inadequacy of information on stock structure for many Gulf species, particularly coastal, bay, and estuarine bottlenose dolphins, is a significant impediment to current stock assessment efforts. Stock assessment methods differ depending on the stocks being assessed, but typically involve either a combination of vessel and aerial surveys or mark-recapture methods using photo-identification or genetic sampling. Stock assessment surveys should be conducted at least every other year for each stock, and should cover all portions of a stock's range and all seasons of the year.
- Enhancement of the Gulf marine mammal stranding program: Marine mammal stranding programs provide information on the presence of marine mammal species and stocks, movement patterns, reproduction, age structure, health, toxin exposure, and sources of mortality. Stranding programs in the Gulf played a key role during the oil spill by monitoring coastal areas for stranded animals, collecting tissues for various types of analyses, and caring for live-stranded animals and moving them to facilities that could provide the necessary care. However, those programs operate primarily on a volunteer basis, often with limited or inconsistent institutional support. Existing support is not sufficient to sustain those programs and the kind of effort needed to assess the long-term effects of the spill. Particular focus should be on building capacity for stranding programs throughout the northern Gulf, including investments in training, equipment, supplies, data management, sample analyses, and rehabilitation facilities. Support should be provided to bring in experienced researchers and veterinarians from other regions to train local responders and to ensure that information collected from stranded animals is integrated with other assessment studies and contributes to a better understanding of the long-term effects of the oil spill and other human activities on Gulf marine mammals.
- Live capture/release health assessments: The health of individual animals can be an important indicator of the adverse effects of risk factors, including exposure to oil, dispersants, and response activities. Coupled with information collected from dead stranded animals, in-depth assessments of live stranded or captured animals have provided important information on marine mammal health, disease, and causes of mortality. Live capture/release is a proactive means to evaluate risk factors and assess health conditions within populations, and it has been used in studies of coastal and estuarine bottlenose dolphin populations in the

Gulf and elsewhere. Health assessments typically require collaboration among researchers from federal agencies, private institutions, aquaria, and not-for-profit organizations.

- Contaminants analyses: Determining whether marine mammals have been exposed to oil, dispersants, or other spill-related contaminants is important for estimating injuries from spills and response activities. Data on contaminant exposure also are important to investigation of the ongoing unusual mortality event in the northern Gulf—an event involving several hundred bottlenose dolphins to date. However, many of the samples collected from marine mammals during and after the Deepwater Horizon oil spill have yet to be analyzed for contaminants, including polycyclic aromatic hydrocarbons and dispersants. Research is needed to determine the types of samples that are the best indicators of exposure. Such research will require the development of reliable, standardized methods for determining and quantifying exposure levels. Development of such methods should be a priority, followed by contaminant analyses of the available tissues. If some types of contaminants cannot be reliably detected in marine mammal tissues (e.g., due to rapid elimination or other processes), then NOAA should give high priority to development of alternative methods for determining exposure.
- Assessment of the physiological effects of oil and chemical dispersants on marine mammals and model species: Additional research is needed to better understand how marine mammals respond physiologically to oil and chemical dispersants. Controlled exposure experiments using captive marine mammals as test subjects are the best option from a scientific perspective. The use of non-marine mammal model species (such as mink) may be logistically more feasible, but such approaches require the assumption that marine mammals will respond similarly, which may not be the case. Simulations and in-vitro studies offer alternative approaches to studying physiological effects and, for ethical reasons, may be preferred for certain types of studies.
- Environmental studies (including prey studies): Large-scale changes in community structure or prey abundance caused by the oil spill and response efforts can affect the carrying capacity and distribution of marine mammal populations. Quantifying those effects will require an integrated, multi-disciplinary approach. Tracking the movement and disposition of oil and dispersants throughout the water column relative to the distribution of marine mammals and their prey species in the ecosystem seems essential for characterizing the ecological effects of oil, dispersants, and other response activities.

Because the species and stocks vulnerable to—and likely affected by—the spill are found in a range of inshore, coastal, and offshore ecosystems, the Marine Mammal Commission recommends that NOAA work with the other co-Trustees to include in the restoration plan activities to ensure long-term monitoring, assessment, and recovery of all of the marine mammal stocks found in inshore, coastal, and offshore ecosystems throughout the northern Gulf.

Restoration priority 2: Addressing other risk factors for the Gulf's marine mammal stocks

In all likelihood, the oil spill is having effects on marine mammals in addition to those cumulative impacts from other human activities that are affecting marine mammal populations. Returning marine mammal stocks to a healthy state will thus not only require addressing the effects of the oil spill, but also the other risk factors from human activities in the Gulf of Mexico. Seismic surveys used to locate oil and gas reserves or monitor their depletion generate high energy, low frequency sounds that can cause permanent or temporary hearing damage in marine mammals

(Gordon et al. 2004), cause them to change their behavior, and cause them to change their habitat use patterns. Commercial fishing gear used in the Gulf can entangle and drown marine mammals (Garrison 2007). Dolphins frequently ingest and become entangled in recreational fishing gear (monofilament fishing lines and hooks), which generally leads to death (Powell and Wells 2011, Wells et al. 1998, Wells et al. 2008). Commercial and recreational vessel traffic and commercial tour operations directed at marine wildlife can disturb or displace marine mammals (Bejder et al. 2006, Nowacek et al. 2001). Commercial shipping also introduces a large amount of low-frequency sound energy into the Gulf (Snyder 2007). Military activities also can generate significant sound that can be injurious to certain marine mammals (Jepson et al. 2003). Agricultural runoff can cause excess nutrients to enter the Gulf. These nutrients lead to blooms of algae that die and degrade, depleting the oxygen in the water and creating hypoxic zones that cannot sustain marine life (Craig et al. 2001). Other blooms result in the production of toxic substances that effectively poison invertebrates, fish, and marine mammals (Magaña et al. 2003, Twiner et al. 2011). Table 2 provides a more complete list of natural and human-caused risk factors to marine mammals in the Gulf. Addressing the risk factors will help build resilience in Gulf marine mammal populations and accelerate recovery from the harmful effects of the spill.

To minimize other risk factors that may impede recovery of Gulf marine mammals, the Marine Mammal Commission recommends that NOAA work with the other co-Trustees to include in the restoration plan the following projects—

- Establishing or expanding fisheries observer coverage: An expansion of current observer coverage is necessary to quantify and minimize incidental takes of marine mammals in Gulf commercial and recreational fisheries, including the menhaden purse seine, shrimp trawl, shark gillnet, pelagic longline, reef fish, and charter boat/headboat fisheries;
- Minimizing incidental takes in fisheries and indirect effects of fishing on important prey species: Conduct additional research and testing of alternative fishing gear, time-area restrictions on fishing activities, and other measures to reduce incidental takes of marine mammals in Gulf commercial and recreational fisheries and also the indirect effects of fishing on important prey species of marine mammals;
- Monitoring sound levels: Establish a monitoring program to assess sound levels and sound-related effects on marine mammals from a variety of human activities, including commercial shipping, oil and gas development (including seismic studies), and military operations and training;
- Minimizing effects of sound: Develop measures to minimize the direct, indirect, and cumulative effects of human-caused sound on marine mammals and their prey species; and
- Reducing other environmental impacts: Implement measures to reduce the occurrence and extent of hypoxic and anoxic zones and harmful algal blooms.

The Marine Mammal Commission further recommends that NOAA work with the other co-Trustees to ensure that restoration projects include long-term monitoring to determine whether the projects are achieving their goals and injured resources are indeed being restored. Long-term monitoring will provide critical information on the effectiveness of various projects and will help focus restoration efforts on activities that are having the greatest benefit. Monitoring also will help identify projects that might be having adverse impacts on targeted or other natural resources, and assist in minimizing those adverse impacts. Information on the effectiveness of restoration efforts is

critical not just for ensuring the best use of restoration resources in the Gulf, but also to help guide restoration planning efforts for other, future oil spill events.

Selection of assessment and restoration projects

A comprehensive and effective injury assessment and restoration plan should outline not only the types of projects that will be needed, but also specify the standards and criteria those projects must meet to be considered for funding. At a minimum, assessment projects should have clear goals and objectives, include scientifically robust data collection and analysis procedures, and require timely publication of results in peer-reviewed literature. The Trustees also must ensure that the selection of assessment and restoration projects is an independent, science-based, review process. Selection of projects should be based on scientific merit, appropriateness, and cost-effectiveness. Awards should not necessarily be limited to researchers based in the Gulf region. This is especially critical for marine mammal projects for which scientific expertise and capacity exist largely outside the Gulf region. Researchers should be encouraged to work across disciplines and to make assessment and monitoring data available in raw form after a certain period of time to other interested researchers and to the public. Finally, restoration projects should be designed such that outcomes inform and guide adaptive management of Gulf resources over the long term. To those ends, the Marine Mammal Commission recommends that NOAA work with the other co-Trustees to develop a science-based, multidisciplinary project selection process that is open to all appropriate researchers and encourages data sharing. These restoration projects should be managed using an adaptive management approach that informs and guides management of Gulf resources over the long term.

The Commission hopes NOAA finds the Commission's report and the recommendations provided here to be helpful as the agency works with the other co-Trustees for the Deepwater Horizon oil spill on developing a restoration plan for Gulf natural resources. Please feel free to share the Commission's recommendations and comments with the other co-Trustees.

Sincerely,

Michael L. Gosliner for

Timothy J. Ragen, Ph.D.
Executive Director

Enclosure: Assessing the Long-term Effects of the BP Deepwater Horizon Oil Spill on Marine Mammals in the Gulf of Mexico: A Statement of Research Needs (Marine Mammal Commission, August 2011).

cc: Helen Golde, Acting Director, National Marine Fisheries Service Office of Protected Resources
Dr. Roy Crabtree, Regional Administrator, National Marine Fisheries Service Southeast Regional Office
Dr. Bonnie Ponwith, Director, National Marine Fisheries Service Southeast Fisheries Science Center
David Westerholm, Director, NOAA Office of Response and Restoration

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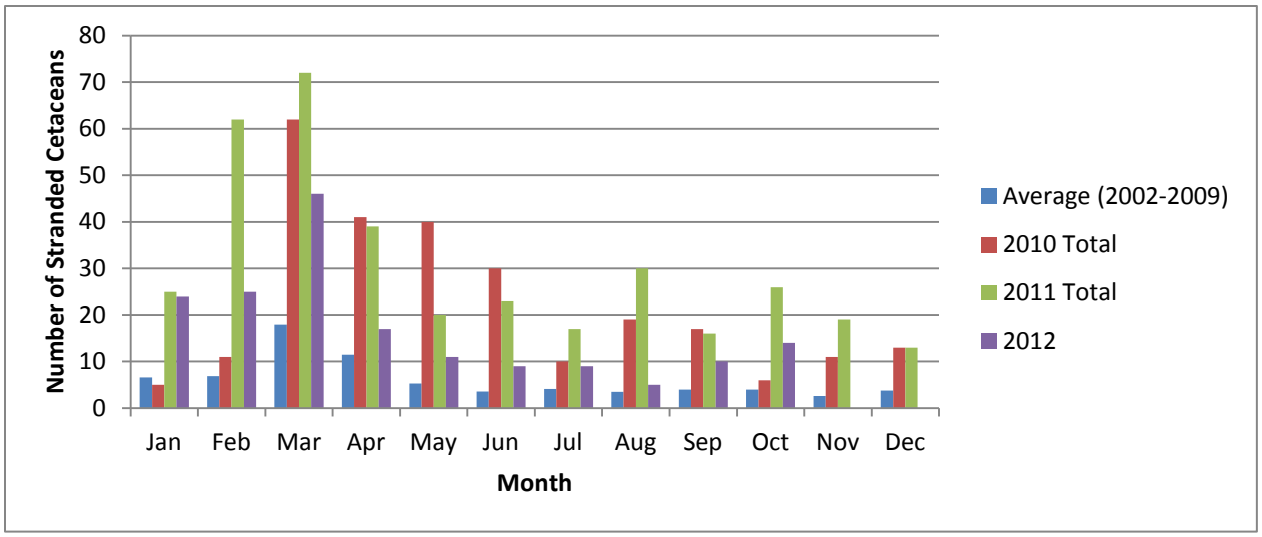

Figure 1. Cetaceans (dolphins and whales) stranded in the northern Gulf of Mexico from Franklin County, Florida, to the Texas/Louisiana border, by month (Source: NOAA, www.nmfs.noaa.gov/pr/health/mmume/cetacean_gulfofmexico2010.htm)

Table 1. Baseline information for marine mammal species in the Gulf of Mexico. The population information is from Waring et al. (2010) and the information regarding prey species is from Jefferson et al. (2008). For all stocks, the information is not sufficient to meet the requirements of the Marine Mammal Protection Act. CV=coefficient of variation, N_{best}=best estimate of abundance, N_{min}=minimum estimate of abundance, PBR=potential biological removal level, E=endangered under the Endangered Species Act, S=strategic under the Marine Mammal Protection Act). *As identified in Waring et al. (2010), although many sources of mortality and serious injury also may be applicable to other species.

Species/stock (E=endangered, S=strategic)	Abundance – N_{best} (CV) N_{min} PBR	Distribution and movement patterns	Stock structure	Social structure	Vital rates	Health status	Prey species	Total human-caused mortality/ serious injury	Possible sources of human-caused mortality/ serious injury*
Sperm whale (*Physeter macrocephalus*) (E/S)	N_{best} = 1,665 (CV = 0.20) N_{min} = 1,409 PBR = 2.8	Oceanic throughout the Gulf	Gulf stock distinct from other Atlantic Ocean stocks	Highly social, with adult females and juveniles of both sexes occurring together in mixed groups	Unknown	Unknown	Primarily deepwater cephalopods and fishes	Unknown	Oil and gas operations (seismic surveys), pollution
Sperm whale (*Physeter macrocephalus*) (E/S) Puerto Rico and US Virgin Islands stock	Unknown, PBR undetermined	Continental slope and oceanic waters surrounding Puerto Rico and the U.S. Virgin Islands	Limited information to distinguish from other Atlantic Ocean or Gulf stocks	Highly social, with adult females and juveniles of both sexes occurring together in mixed groups	Unknown	Unknown	Primarily deepwater cephalopods and fishes	Unknown	Coastal pollution, ship strikes
Bryde's whale (*Balaenoptera edeni*) (S)	N_{best} = 15 (CV = 1.98) N_{min} = 5 PBR = 0.1	Primarily along the shelf break (200 m) in the northeastern Gulf	Unknown	Generally found as singles or pairs, no calves observed	Unknown	Unknown	Small schooling fishes	Unknown	Ship strikes, other sources unknown
Cuvier's beaked whale (*Ziphius cavirostris*)	N_{best} = 65 (CV = 0.67) N_{min} = 39 PBR = 0.4	Oceanic throughout the Gulf	Unknown	Very cryptic, usually in groups of less than 5	Unknown	Unknown	Primarily squids, also deepwater fishes and crustaceans	Unknown	Unknown, possible military activities (sonar) in Atlantic Ocean

Species/stock (E=endangered, S=strategic)	Abundance – N_{best} (CV) N_{min} PBR	Distribution and movement patterns	Stock structure	Social structure	Vital rates	Health status	Prey species	Total human-caused mortality/ serious injury	Possible sources of human-caused mortality/ serious injury*
Blainville's beaked whale (*Mesoplodon densirostris*)	N_{best} = 57 (CV = 1.40) N_{min} = 24 (Estimate for all *Mesoplodon* sp.) PBR = 0.2	Oceanic throughout the Gulf	Unknown	Very cryptic, usually in groups of less than 5	Unknown	Unknown	Primarily squids, also deepwater fishes	Unknown	Unknown, possible military activities (SONAR) in Atlantic Ocean
Gervais' beaked whale (*Mesoplodon europaeus*)	N_{best} = 57 (CV = 1.40) N_{min} = 24 (Estimate for all *Mesoplodon* sp.) PBR = 0.2	Oceanic throughout the Gulf	Unknown	Very cryptic, usually in groups of less than 5	Unknown	Unknown	Primarily squids, also deepwater fishes	Unknown	Unknown, possible military activities (sonar) in Atlantic Ocean and fisheries interactions
Bottlenose dolphin (*Tursiops truncatus*) continental shelf stock	Unknown, survey data more than 8 years old, PBR undetermined	Waters from 20 to 200 m throughout the Gulf	Uncertain but complex, stock is a mixture of genetically distinct coastal and offshore ecotypes	Highly social	Unknown	Unknown	Generalist, preference for sciaenids, scombrids, and mugilids, with squids more important in deeper waters	Unknown	Fisheries interactions, gunshot wounds, vessel strikes, oil rig removals, marine debris entanglement and ingestion
Bottlenose dolphin (*Tursiops truncatus*) eastern coastal stock	N_{best} = 7,702 (CV = 0.19) N_{min} = 6,551 PBR = 66	Mainland shore to waters 20 m deep east of 84° W	Uncertain but complex, coastal stocks divided for management purposes based on dissimilar habitat characteristics	Highly social	Unknown	Limited health assessment data from Sarasota Bay	Generalist, preference for sciaenids, scombrids, and mugilids, with squids more important in deeper waters	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, dredging, harmful algal blooms, disease, gunshot wounds, mutilations, vessel strikes, oil rig removals, marine debris entanglement and ingestion

Species/stock (E=endangered, S=strategic)	Abundance – N_{best} (CV) N_{min} PBR	Distribution and movement patterns	Stock structure	Social structure	Vital rates	Health status	Prey species	Total human-caused mortality/ serious injury	Possible sources of human-caused mortality/ serious injury*
Bottlenose dolphin (*Tursiops truncatus*) northern coastal stock	N_{best} = 2,473 (CV = 0.25) N_{min} = 2,004 PBR = 20	Mainland shore to waters 20 m deep from the Mississippi River Delta east to 84°W	Coastal stocks divided for management purposes based on dissimilar habitat characteristics	Highly social	Unknown	Limited health assessment data from St. Joseph Bay	Generalist, preference for sciaenids, scombrids, and mugilids, with squids more important in deeper waters	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, dredging, red tide, disease, gunshot wounds, mutilations, vessel strikes, oil rig removals, marine debris entanglement and ingestion
Bottlenose dolphin (*Tursiops truncatus*) western coastal stock (S)	Unknown, survey data more than 8 years old, PBR undetermined	Mainland shore to waters 20 m deep west of the Mississippi River Delta	Uncertain but complex, coastal stocks divided for management purposes based on dissimilar habitat characteristics	Highly social	Unknown	Unknown	Generalist, preference for sciaenids, scombrids, and mugilids, with squids more important in deeper waters	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, dredging, red tide, disease, gunshot wounds, mutilations, vessel strikes, oil rig removals, marine debris entanglement and ingestion
Bottlenose dolphin (*Tursiops truncatus*) oceanic stock	N_{best} = 3,708 (CV = 0.42) N_{min} = 2,641 PBR = 26	Upper continental slope (200-1000 m) throughout the Gulf	Uncertain but assumed complex	Offshore morphotype, groups as big as 200 but typically around 20	Unknown	Unknown	Generalist, preference for sciaenids, scombrids, and mugilids, with squids more important in deeper waters	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, disease, gunshot wounds, mutilations, vessel strikes, oil rig removals, marine debris entanglement and ingestion

Species/stock (E=endangered, S=strategic)	**Abundance – N_{best} (CV) N_{min} PBR**	**Distribution and movement patterns**	**Stock structure**	**Social structure**	**Vital rates**	**Health status**	**Prey species**	**Total human-caused mortality/ serious injury**	**Possible sources of human-caused mortality/ serious injury***
Bottlenose dolphin (*Tursiops truncatus*) St. Joseph Bay stock (S)	N_{best} = 81 (CV = 0.14) N_{min} = 72 PBR=0.7	St. Joseph Bay	Stocks provisionally based on discrete communities, supported by genetics data	Community-based, some individuals exhibit extreme philopatry	Some data regarding individual reproduc-tive rates, stock-wide rates unknown	Limited health assessment data	Preference for sciaenids, scombrids, and mugilids	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, ecotourism, red tide, marine debris entanglement and ingestion
Bottlenose dolphin (*Tursiops truncatus*) St. Vincent Sound/ Appalachicola Bay/ St. George Sound stock (S)	N_{best} = 537 (CV = 0.09) N_{min} = 498PBR = 5	St. Vincent Sound/ Appalachicola Bay/ St. George Sound	Stocks provisionally based on discrete communities, supported by genetics data	Community-based, some individuals exhibit extreme philopatry	Some data regarding individual reproduc-tive rates, stock-wide rates unknown	Unknown	Preference for sciaenids, scombrids, and mugilids	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, ecotourism, red tide, marine debris entanglement and ingestion
Bottlenose dolphin (*Tursiops truncatus*) Barataria Bay stock (S)	N_{best} = 138 (CV = 0.08) N_{min} = 129 PBR = 1.3	Barataria Bay	Stocks provisionally based on discrete communities, supported by genetics data	Community-based, some individuals exhibit extreme philopatry	Some data regarding individual reproduc-tive rates, stock-wide rates unknown	Unknown	Preference for sciaenids, scombrids, and mugilids	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, ecotourism, red tide, marine debris entanglement and ingestion
Bottlenose dolphin (*Tursiops truncatus*) 29 remaining bay, sound, and estuarine stocks (S)	Unknown, survey data more than 8 years old, PBR undetermined for remaining 30 stocks	Bays, sounds, and estuaries throughout the Gulf	Stocks provisionally based on discrete communities, supported by genetics data	Community-based, some individuals exhibit extreme philopatry	Some data regarding individual reproduc-tive rates, stock-wide rates unknown	Unknown	Preference for sciaenids, scombrids, and mugilids	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, ecotourism, red tide, marine debris entanglement and ingestion

Species/stock (E=endangered, S=strategic)	Abundance – N_{best} (CV) N_{min} PBR	Distribution and movement patterns	Stock structure	Social structure	Vital rates	Health status	Prey species	Total human-caused mortality/ serious injury	Possible sources of human-caused mortality/ serious injury*
Atlantic spotted dolphin (*Stenella frontalis*)	Unknown, survey data more than 8 years old, PBR undetermined	Continental shelf throughout the Gulf, generally in waters 20-200 m	Unknown, separate from Atlantic stock for management purposes, supported by genetics data	Typical group sizes are less than 50, associate with smaller groups of bottlenose dolphins in some cases	Unknown	Unknown	Small epi- and mesopelagic fishes and squids, and benthic invertebrates	Unknown	Fisheries interactions, dredging, red tides
Pantropical spotted dolphin (*Stenella attenuata*)	N_{best} = 34,067 (CV = 0.18) N_{min} = 29,311 PBR = 293	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Typical groups are less than 100 dolphin but as many as 650 dolphins in a group have been observed	Unknown	Unknown	Small epi- and mesopelagic fishes, squids and crustaceans	Unknown	Unknown
Striped dolphin (*Stenella coeruleoalba*)	N_{best} = 3,325 (CV = 0.48) N_{min} = 2,266 PBR = 23	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Typical groups consist of about 50 dolphins	Unknown	Unknown	Small epi- and mesopelagic fishes and squids	Unknown	Vessel strike
Spinner dolphin (*Stenella longirostris*)	N_{best} = 1,989 (CV = 0.48) N_{min} = 1,356 PBR = 14	Continental slope (200-2000 m), primarily in the eastern Gulf	Unknown, separate from Atlantic stock for management purposes	Occur in very large cohesive groups of up to 800 dolphins	Unknown	Unknown	Small epi- and mesopelagic fishes and squids	Unknown	Fisheries interactions
Rough-toothed dolphin (*Steno bredanensis*)	Unknown, survey data more than 8 years old, PBR undetermined	Oceanic throughout the Gulf and, less commonly, the continental shelf	Unknown, separate from Atlantic stock for management purposes	Typically in groups of less than 25 dolphins, associated with Sargassum in many cases	Unknown	Limited info from rehab animals	Fish, including larger species (mahi mahi) and squids	Unknown	Unknown

Species/stock (E=endangered, S=strategic)	Abundance – N_{best} (CV) N_{min} PBR	Distribution and movement patterns	Stock structure	Social structure	Vital rates	Health status	Prey species	Total human-caused mortality/ serious injury	Possible sources of human-caused mortality/ serious injury*
Clymene dolphin (*Stenella clymene*)	N_{best} = 6,575 (CV = 0.36) N_{min} = 4,901 PBR = 49	Oceanic throughout the Gulf but more common west of the Mississippi River	Unknown, separate from Atlantic stock for management purposes	Occur in large groups of up to 300 dolphins	Unknown	Unknown	Little known, small epi – and mesopelagic fishes and squids	Unknown	Unknown
Fraser's dolphin (*Lagenodelphis hosei*)	Unknown (no recent sightings) PBR undetermined	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Extremely rare, associated with melon-headed whales in some cases	Unknown	Unknown	Small midwater fishes, squids, and crustaceans	Unknown	Unknown
Killer whale (*Orcinus orca*)	N_{best} = 49 (CV = 0,77) N_{min} = 28 PBR = 0.3	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Groups typically of 6-10 whales. Photo-identification indicates wide ranging but with some habitat fidelity	Unknown	Unknown	Gulf prey largely unknown, one instance of predation on pantropical spotted dolphins	Unknown	Unknown
False killer whale (*Pseudorca crassidens*)	N_{best} = 777 (CV = 0.56) N_{min} = 501 PBR = 5	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Occur in cohesive groups that average 25 whales	Unknown	Unknown	Fish including larger species (dolphin fish) and squids	Unknown	Fisheries interaction
Pygmy killer whale (*Feresa attenuata*)	N_{best} = 323 (CV = 0.60) N_{min} = 203 PBR = 2	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Little known, occur in groups of less than 20 whales	Unknown	Unknown	Fishes and squids	Unknown	Unknown

Species/stock (E=endangered, S=strategic)	Abundance – N_{best} (CV) N_{min} PBR	Distribution and movement patterns	Stock structure	Social structure	Vital rates	Health status	Prey species	Total human-caused mortality/ serious injury	Possible sources of human-caused mortality/ serious injury*
Dwarf sperm whale (*Kogia sima*)	N_{best} = 453 (CV = 0.35) N_{min} = 340 (Estimate for all *Kogia* spp.) PBR = 3.4	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Very cryptic, usually in groups of less than 5	Unknown	Unknown	Primarily deepwater cephalopods	Unknown, minimum estimates from stranding data	Fisheries interactions, ingestion of marine debris
Pygmy sperm whale (*Kogia breviceps*)	N_{best} = 453 (CV = 0.35) N_{min} = 340 (Estimate for all *Kogia* spp.) PBR = 3.4	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Very cryptic, usually in groups of less than 5	Unknown	Limited data from captive animals	Primarily deepwater cephalopods	Unknown, minimum estimates from stranding data	Fisheries interactions, ingestion of marine debris
Melon-headed whale (*Peponocephala electra*)	N_{best} = 2,283 (CV = 0.76) N_{min} = 1,293 PBR = 13	Oceanic throughout the Gulf but more common west of the Mississippi River	Unknown, separate from Atlantic stock for management purposes	Occur in large cohesive groups of up to 275 whales	Unknown	Unknown	Small fishes and squids	Unknown, minimum estimates from stranding data	Unknown
Risso's dolphin (*Grampus griseus*)	N_{best} = 1,589 (CV = 0.27) N_{min} = 1,271 PBR = 13	Shelf break area and oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Multiple groups of 5-10 dolphins typically occur over large areas	Unknown	Limited data from captive animals	Crustaceans, squids, and other cephalopods	Unknown, minimum estimates from stranding data	Fisheries interactions, red tide
Pilot whale, short finned (*Globicephala macrorhyncus*)	N_{best} = 716 (CV = 0.34) N_{min} = 542 PBR = 5.4	Oceanic throughout the Gulf but more common west of the Mississippi River	Unknown, separate from Atlantic stock for management purposes	Highly social, in groups of 20 or more	Unknown	Unknown	Primarily squids but also fishes	Unknown, minimum estimates from stranding data	Fisheries interactions

Species/stock (E=endangered, S=strategic)	**Abundance – N_{best} (CV) N_{min} PBR**	**Distribution and movement patterns**	**Stock structure**	**Social structure**	**Vital rates**	**Health status**	**Prey species**	**Total human-caused mortality/ serious injury**	**Possible sources of human-caused mortality/ serious injury***
West Indian Manatee (*Trichechus manatus*) (E/S)	N_{min} (via aerial surveys) = 5,067 (2,779 on east coast of Florida, 2,288 on west coast of Florida) PBR = 12	In freshwater, brackish and marine environments along the Gulf, from Florida to Louisiana	Florida manatees considered a single stock, but separated into management units	Disperse in the warmer months to feed, breed and socialize, aggregate in warm-water refuges during colder times of year, calves typically stay with their mothers for 2 years	Rmax= 6.2%	Limited studies provide data on contamin-ants, hormone levels, and nutrition	Herbivores, feed on an extensive range of aquatic vegetation	Minimum estimates from stranding data	Vessel strikes, cold water exposure, red tides, drowning in water control structures, fisheries interactions, marine debris entanglement and ingestion

Table 2. Anthropogenic and natural risk factors in the Gulf of Mexico and potential consequences to marine mammals.

Activities	Specific risk factor	Potential consequences
Oil and gas development	Oil spills and leaks	Direct exposure: skin irritation/inflammation, necrosis, respiratory effects, organ damage Indirect: shifts in or loss of prey, habitat degradation
	Noise (seismic surveys, construction and decommissioning of platforms, and general operations)	Physical trauma, permanent or temporary hearing loss, avoidance of preferred habitat
	Vessel operations	Vessel collisions (injury/mortality), avoidance of preferred habitat
	Production waste (drill fluids and cuttings, produced water, deck drainage, municipal wastes, and debris)	Organ damage and impaired immune system function from heavy metal contamination, habitat degradation (decreased water quality), loss of prey
Commercial and recreational fishing	Fishing with nets, lines, pots/traps	Entanglement in and ingestion of fishing gear
	Fishing for prey species	Depletion of prey species, habitat alteration
	Vessel operations	Vessel collisions (injury/mortality), avoidance of preferred habitat
Shipping and vessel traffic	Noise, vessel operations	Vessel collisions (injury/mortality), avoidance of preferred habitat
Military activities	Vessel operations	Vessel collisions (injury/mortality), avoidance of preferred habitat
	Noise (SONAR training and testing, explosives)	Acoustic and non-acoustic physical trauma, avoidance of preferred habitat, mortality in severe cases
Agriculture	Runoff of land-based pollutants (resulting in harmful algal blooms, anoxic or hypoxic "dead" zones)	Direct: injury/mortality Indirect: habitat degradation, shifts in or loss of prey species
Coastal development	Noise from pile driving for marina and bridge/causeway construction	Acoustic trauma (at short range), acoustic disturbance, avoidance of preferred habitat
	Dredging	Loss of sea grass beds, habitat degradation
	Loss of coastal wetlands and other coastal habitats	Loss of prey habitat, habitat degradation
Renewable energy	Pile driving for anchoring wind and wave turbines	Acoustic trauma (at short range), acoustic disturbance, avoidance of preferred habitat
	Turbine operations	Physical trauma, electromagnetic disturbance, avoidance of preferred habitat
Greenhouse gas emissions	Ocean acidification	Shifts in or loss of prey species
	Warming seas	Habitat degradation, shifts in or loss of prey
	Increased storm activity and increased severity of storms	Shifts in prey, avoidance of preferred habitat
	Sea level rise, leading to coastal habitat loss	Loss of prey habitat, habitat degradation
Natural events	Seepage of oil	Direct: organ damage Indirect: habitat degradation
	Harmful algal blooms (e.g., red tide)	Injury/mortality, shifts in prey
	Predation	Injury/mortality
	Large-scale ecosystem fluctuations	Shifts in or loss of prey
	Hurricanes	Shifts in prey, avoidance of preferred habitat, displacement of animals, habitat degradation or destruction
	Water temperature anomalies	Shifts in prey, avoidance of preferred habitat, cold stress

Assessing the Long-term Effects of the BP Deepwater Horizon Oil Spill on Marine Mammals in the Gulf of Mexico: A Statement of Research Needs

Prepared by the Marine Mammal Commission
with input from the National Marine Fisheries Service,
National Ocean Service, Fish and Wildlife Service, and
Bureau of Ocean Energy Management, Regulation and Enforcement

Marine Mammal Commission
4340 East-West Highway, Room 700
Bethesda, Maryland 20814

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Front cover: Bottlenose dolphins swimming in oil during the Deepwater Horizon oil spill incident. (Photograph: A. Brandon/Associated Press)

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Executive summary

The April 2010 explosion of BP's Deepwater Horizon offshore drilling unit in the Gulf of Mexico resulted in an oil spill with significant ecological, social, and economic consequences. Achieving a full understanding of the spill's effects likely will require years of assessment because some effects may continue or worsen, whereas others may not yet have been realized or become apparent. In addition, spill effects may be confounded by the effects of other risk factors such as climate change, fisheries, commercial shipping, military activities, and coastal development.

Oil spills can affect marine mammals through direct contact, inhalation, or ingestion of oil; injury and disturbance from response activities; and long-term ecological changes. Questions about the potential effects of oil spills and the response activities on marine mammals—partially informed by past studies—guided much of the monitoring effort immediately after the Deepwater Horizon spill. Similar questions provide a framework for assessing the spill's long-term effects.

The Marine Mammal Commission, with input from related federal agencies, drafted this statement of research needs to guide assessment of the spill's long-term effects, to guide mitigation and restoration efforts for Gulf marine mammal populations, and to help track the changes in the Gulf ecosystem, including recovery and restoration.[1] It also should help guide assessment of effects on marine mammals from future spills in the Gulf and elsewhere.

The statement outlines legal mandates for assessing the spill's overall effects, potential effects on marine mammals, assessment efforts to date, priorities for future efforts, and the general need to improve assessment strategies on Gulf of Mexico marine mammals. All such efforts should be a high priority during or immediately after a spill. However, the likelihood of detecting certain impacts decreases with time and the utility and value of certain types of research declines accordingly. At this time, the Commission gives higher priority to assessment of long-term effects, including (1) assessing the health status of stranded or live-captured animals; (2) assessing oil spill-related changes in the ecosystem leading to a potential reduction in prey availability; (3) evaluating other ecosystem changes that are harmful to marine mammals and that may have been exacerbated by the spill (e.g., harmful algal blooms, hypoxia or anoxia); and (4) determining the extent to which exposure to oil and/or response activities leads to a reduction in status involving individual fitness, population vital rates (survival and reproduction), and population abundance and trends.

Implementation of the needed research will require resources beyond those currently available, as well as improved infrastructure (e.g., research vessels, aircraft, and laboratories), more trained personnel, better sampling methods, and refined analytical tools to detect and assess the effects of exposure to oil. Coordination of research activities is critical to focus on the most important topics, achieve collaboration to the greatest degree possible, develop a weight-of-evidence approach for detecting effects, and avoid unnecessary duplication of effort. Collaboration and partnerships among the involved federal, state, and local agencies, industry, non-governmental organizations, research institutions and organizations, and the public also should help maximize the benefits of limited resources and minimize the effects of research activities on marine mammals.

[1] The views contained in this statement are those of the Marine Mammal Commission and do not necessarily reflect the views of the natural resource Trustees designated under the Oil Pollution Act to assess natural resource injuries associated with the Deepwater Horizon spill and to develop and implement a plan to restore injured resources under their trusteeship.

Perhaps as much as anything, the spill and the national response to it provided a sharp reminder of how much remains to be learned about status of marine mammals in the Gulf. Such information is necessary to support management strategies that are science-based and sufficient to maintain the health and stability of the Gulf of Mexico marine ecosystem.

Introduction

In April 2010 BP's offshore drilling unit Deepwater Horizon exploded, burned, and sank in the Gulf of Mexico, 52 miles southeast of Venice, Louisiana (Figure 1). Eleven of the 126 workers on the rig were killed and, over the following 86 days, an estimated 4.9 million barrels (206 million gallons) of oil were spilled into the Gulf (National Oceanic and Atmospheric Administration 2010). This was the largest accidental oil spill ever reported. The response also was massive, involving 13 federal agencies; multiple agencies from the five Gulf states; numerous local agencies; non-governmental organizations; oil companies and contractors; academia; and thousands of local residents, volunteers, and expert consultants.

In addition to the loss of life, the spill's effects have been significant ecologically, socially, and economically. Furthermore, some effects may continue or worsen and others may not yet have been realized or become apparent. To make matters more complex, any assessments of spill effects will be confounded by the effects of other risk factors such as climate change, fisheries, commercial shipping, military activities, and coastal development. For all these reasons, efforts to understand the spill's effects will require careful assessment of long-term effects.

Figure 1. Fire boat response crews battle the blazing remnants of the offshore oil rig Deepwater Horizon April 21, 2010. Multiple Coast Guard helicopters, planes and cutters responded to rescue the Deepwater Horizon's 126 person crew. (Photograph: U.S. Coast Guard)

Marine mammals may be affected by (1) the oil, its metabolites, or dispersants through direct contact, ingestion or inhalation; (2) injury and disturbance from response activities; and (3) short and long-term ecological changes resulting from the spill and response efforts. Relative to many forms of marine life, some marine mammals are more readily observed and studied. They also are long-lived and feed at high trophic levels, and likely will integrate ecosystem effects of the spill and response activities over many years. For those reasons, they may serve as useful indicators of at least some aspects of the health of the Gulf ecosystem following the spill.

Purpose

The Marine Mammal Commission has drafted this statement of research needs with input from the respective staffs of the National Oceanic and Atmospheric Administration's National Marine Fisheries Service and National Ocean Service, the Fish and Wildlife Service, and the Bureau of Ocean Energy Management, Regulation and Enforcement (formerly the Minerals Management Service)—the primary agencies responsible for the conservation of marine mammals and for regulation of offshore oil and gas activities. The recommendations and conclusions of this statement, however, are solely those of the Commission.

The Commission developed this statement to help guide (1) assessment of the long-term effects of the Deepwater Horizon oil spill and associated risk factors on marine mammals, (2) mitigation and restoration efforts for Gulf marine mammal populations, and (3) monitoring of changes in the Gulf ecosystem, including recovery and restoration.[2] The statement also should help guide assessment of effects on marine mammals from future spills in the Gulf and elsewhere.

Statutory authorities pertaining to assessment of spill effects on marine mammals

The Oil Pollution Act of 1990 provides for federal, state, and tribal Natural Resource Trustees[3] to conduct a Natural Resource Damage Assessment following an oil spill. The assessment consists of collecting and analyzing information to evaluate the nature and extent of injuries resulting from an incident. Trustees then determine the restoration[4] actions needed to bring injured natural resources and services back to baseline conditions and make the environment and public whole for interim losses (15 C.F.R. § 990.30). Natural resources include wildlife, such as marine mammals, sea turtles, seabirds, fishes, and invertebrates (e.g., corals, shrimps), and their habitat. Services include the functions of and benefits derived from those natural resources, such as those that support tourism, fishing, boating, marine products, and transportation. The Responsible Parties (i.e., those responsible for damages resulting from the incident) pay the costs of natural resource damages (including the costs of assessing such damage) and compensate the public for lost services derived from those natural resources. To assess damages and plan restoration, the Trustees must compare the best available baseline[5] information on conditions before the spill against information collected during and after the spill.

The Marine Mammal Protection Act of 1972 seeks to prevent marine mammal species and population stocks[6] from diminishing, as a result of human activities, beyond the point at which they cease to be significant functioning elements of their marine ecosystems. For any particular species or stock, the Act defines that point as the lower limit of its optimum sustainable population, which is defined as the population's maximum net productivity level. Determining whether a species or stock has fallen below that level requires information on population stock structure and abundance. The Act includes a general moratorium on the take[7] of marine mammals, subject to certain exceptions. Title IV of the Act—the Marine Mammal Health and Stranding Response Program—is aimed specifically at assessing the health status and trends of marine mammal populations.

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[2] The damage assessment and restoration process under the Oil Pollution Act operates independently of the Marine Mammal Commission.

[3] Natural Resource Trustees are those officials of federal and state governments, Indian tribes, and foreign governments designated under authority of 33 U.S.C. 2706(b) of the Oil Pollution Act for the Deepwater Horizon incident. They include representatives of the five affected coastal states (Florida, Alabama, Mississippi, Louisiana, and Texas), the Department of Commerce (National Oceanic and Atmospheric Administration), the Department of the Interior (Fish and Wildlife Service, National Park Service, Bureau of Land Management, and Bureau of Indian Affairs), and the Department of Defense.

[4] Any action (or alternative), or combination of actions (or alternatives), to restore, rehabilitate, replace, or acquire the equivalent of injured natural resources and services (15 C.F.R. § 990.30).

[5] The term "baseline" is used here to mean the conditions of natural resources and services that would have existed had the incident not occurred (15 C.F.R. § 990.30). Therefore, baseline conditions do not necessarily imply that those conditions were pristine.

[6] The Marine Mammal Protection Act defines a population stock to mean "a group of marine mammals of the same species or smaller taxa in a common spatial arrangement, that interbreed when mature."

[7] The Marine Mammal Protection Act defines a "take" to mean "to harass, hunt, capture, or kill, or attempt to harass, hunt, capture, or kill any marine mammal."

The Endangered Species Act of 1973 provides for the conservation of threatened and endangered plants and animals and the habitats critical to their survival. All federal agencies are required to use their authorities in furtherance of the purposes of this act by carrying out programs for the conservation of endangered species and threatened species. The Act also requires federal agencies, in consultation with the Fish and Wildlife Service and/or the National Marine Fisheries Service (depending on the species involved), to ensure that actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of designated critical habitat of such species. With certain exceptions, the Act prohibits any action that takes[8] listed species of endangered or threatened fish or wildlife, including marine mammals.

The National Environmental Policy Act of 1969 establishes a national policy and goals for the protection, maintenance, and enhancement of the environment and a process that federal agencies must use to achieve those goals. The Act requires that federal agencies consider the environmental impacts of their proposed actions before acting. It also emphasizes public involvement in government actions affecting the environment by requiring assessment and disclosure of the risks of proposed major federal actions.

Marine mammals in the Gulf of Mexico

Twenty-one cetacean species and one sirenian reside in or regularly visit the Gulf of Mexico (Waring et al. 2010; Table 1). They comprise 58 stocks, 37 of which are bottlenose dolphin stocks. The National Marine Fisheries Service has management responsibility for the cetacean species and the Fish and Wildlife Service has responsibility for the Florida subspecies of the West Indian manatee.

Table 1. Marine mammal stocks in the Gulf of Mexico.

Sperm whale*	Bryde's whale	Killer whale
Cuvier's beaked whale	Atlantic spotted dolphin	False killer whale
Blainville's beaked whale	Pantropical spotted dolphin	Pygmy killer whale
Gervais' beaked whale	Striped dolphin	Dwarf sperm whale
Bottlenose dolphin (oceanic)	Spinner dolphin	Pygmy sperm whale
Bottlenose dolphin (continental shelf)	Rough-toothed dolphin	Melon-headed whale
Bottlenose dolphin (coastal – 3 stocks)	Clymene dolphin	Risso's dolphin
Bottlenose dolphin (bay, sound, estuary –32 putative stocks)	Fraser's dolphin	Pilot whale, short-finned
West Indian manatee*		

*Listed as endangered under the Endangered Species Act

Existing information on the status of each stock (Appendix A) falls well short of that required under the Marine Mammal Protection Act and needed to assess their pre-spill status and vulnerability to various risk factors. The necessary information includes stock structure, distribution,

[8] The Endangered Species Act defines "take" to mean "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct."

abundance, movement patterns, age structure, reproductive rates, survival rates, and health (nutritional status, immune function, and exposure to contaminants, biotoxins, and infections).

The lack of research infrastructure (especially logistic support) is a significant impediment to surveys and other assessment studies. Most studies conducted to date have focused on specific topics (e.g., response of sperm whales to seismic surveys). Few studies have been directed toward understanding the cumulative effects of multiple risk factors, despite the fact that the Gulf is relatively industrialized and multiple marine mammal unusual mortality events have occurred there over the past 20 years. Appendix B lists anthropogenic and natural risk factors present in the Gulf and their potential effects on marine mammals.

Potential effects of the Deepwater Horizon oil spill on marine mammals

All marine mammal stocks in the Gulf may have been, or may still be, affected by the Deepwater Horizon spill. All effects are initially manifested at the individual level, and must lower the individual's probability of survival or reproduction to affect the population. The effects may be direct (e.g., contact with oil or dispersants, interactions with response activities) or indirect (e.g., degradation of habitat, reduced availability of prey).

The null hypothesis (H_0) is that the spill did not have, is not having, and will continue to not have significant effects on marine mammals. The major alternative hypotheses are as follows:

H_1 - Spilled oil causes injury, lesions, disease, or death through—
- H_{1a} - external contact
- H_{1b} - internal contact

H_2 - Exposure to oil- or dispersant-related contaminants causes physiological dysfunction of—
- H_{2a} - the immune system
- H_{2b} - the reproductive system
- H_{2c} - other vital systems

H_3 - Exposure to response activities causes injury via—
- H_{3a} - vessel strikes
- H_{3b} - interactions with booms or other response equipment
- H_{3c} - noise introduced into the marine environment

H_4 - Exposure to oil and/or response activities disturbs or disrupts significant biological behaviors, including—
- H_{4a} - foraging
- H_{4b} - reproduction
- H_{4c} - resting

H_5 - Exposure to oil and/or response activities leads to displacement from primary habitat

H_6 - Exposure to oil and/or response activities leads to disruption of social organization

H_7 - Oil and/or response-related changes in the ecosystem reduce prey or seagrass availability through—

H_{7a} - prey displacement
H_{7b} - reduction in biomass of prey or seagrass

H_8 - Oil and/or response activities lead to other ecosystem changes harmful to marine mammals via—
H_{8a} - hypoxia or anoxia
H_{8b} - harmful algal blooms

H_9 - Exposure to oil and/or response activities leads to reduction in status involving—
H_{9a} - individual fitness
H_{9b} - population vital rates (reproduction and survival rates)
H_{9c} - population abundance and trends

Under each of these alternative hypotheses, the full nature and extent of any effects will depend on a variety of factors, such as the—

- chemical constituents of the oil and dispersants, which change over time as oil and dispersants degrade and are metabolized
- dose of exposure (amount and duration)
- route of exposure (e.g., inhalation, ingestion, external contact, transplacental)
- type and trophic level of prey or seagrass consumed and their contaminant levels
- marine mammal species involved, and
- physical characteristics of individually affected animals (e.g., age, sex, reproductive and health status).

Current understanding of the potential effects of oil on marine mammals is based primarily on information from (1) observed effects of other oil spills on marine mammals (see reviews by Geraci and St. Aubin 1990 and Loughlin et al. 1994; also see Smultea and Würsig 1995, Bickham et al. 1998, Bodkin et al. 2002, Boehm et al. 2007, and Matkin et al. 2008), (2) a small number of controlled exposure studies using captive marine mammals (Geraci et al. 1983, Smith et al. 1983, St. Aubin et al. 1985), (3) simulations and *in vitro* studies (Braithwaite et al. 1983, Godard et al. 2004), and (4) observed effects of accidental and controlled oil exposure on non-marine mammal species (Bickham et al. 1998, Mazet et al. 2001, Golet et al. 2002, Mohr et al. 2007, Esler et al. 2010). The results to date are informative, but do not provide a sufficient basis for predicting, with full confidence, the severity of either short- or long-term effects of the Deepwater Horizon spill on marine mammals. However, they provide ample evidence that exposure to oil can harm marine mammals. For example, inhalation of specific volatile organics from some types of oil can cause respiratory irritation, inflammation, or emphysema. Similarly, ingestion of oil may cause gastrointestinal inflammation, ulcers, bleeding, diarrhea, or maldigestion. Certain inhaled and ingested chemicals in oil also may damage organs such as the liver, kidney, adrenal glands, spleen or brain; cause anemia, cancer, congenital defects, and immune system suppression; or lead to reproductive failure. Chemical contact may cause skin and eye irritation; inflammation; burns to mucous membranes, mouth and nares; or increased susceptibility to infection. Oil mixtures can physically foul the baleen of mysticete whales, which is used for filtering food.[9]

[9] The Bryde's whale is the only mysticete whale occurring regularly in the Gulf. North Atlantic right whales are sighted rarely in the Gulf and fin whales have stranded there occasionally, but are not regular inhabitants.

Response activities to contain and remove spilled oil also may affect marine mammals in the Gulf. Increased vessel and air traffic may disrupt foraging, habitat use, daily or migratory movements, and behavior (e.g., breathing and resting patterns) (Nowacek et al. 2001, Constantine et al. 2004, Williams et al. 2006, Stensland and Berggren 2007, Lusseau et al. 2009). Increased vessel traffic also increases the risk of vessel strikes (Laist et al. 2001, Fish and Wildlife Service 2001, Bechdel et al. 2009), although none were reported during the prolonged spill and response phase. Noise from seismic surveys (such as those used to detect potential leaks around the wellhead) or other response-related activities may cause disturbance or displacement, hearing loss (temporary or possibly permanent), or other physical injury to marine mammals (McCauley et al. 2000, National Research Council 2003). Responders used large quantities of dispersants at the surface (e.g., Corexit 9527, Corexit 9500A) and at the wellhead (Corexit 9500A) (Joint Information Center 2011; Kujawinski et al. 2011). Being listed on the National Contingency Plan product schedule maintained by the Environmental Protection Agency, the Regional Response Team had pre-approved the use of Corexit prior to the spill. The Environmental Protection Agency was consulted and concurred on decisions related to the volume of dispersants used in response to the spill, and conducted additional toxicity testing during the spill. These tests are helping to fill gaps in existing knowledge, as the long-term effects of Corexit and other dispersants on marine mammals are largely unknown (National Research Council 2005). Responders also used booms (Figure 2) and skimmers to contain and collect surface oil and *in-situ* burning to remove it, and these activities also may affect marine mammals both through direct interaction and displacement from habitat. Burning reduces the overall amount of oil in the water, but also leaves behind a residue of uncertain composition and toxicity (Benner et al. 1990, Wang et al. 1999) and puts additional chemicals into the air, posing inhalation risks.

Figure 2. Bottlenose dolphin surfacing near oil spill boom, Grand Isle, Louisiana. (Photograph: S. Rosedahl/Flickr)

Oil spills also may affect marine mammals indirectly by altering the marine ecosystem and the key features of their habitat (Paine et al. 1996, Golet et al. 2002, Peterson et al. 1996, National Research Council 2002). Such effects could include reductions in prey or seagrass biomass, shifts in prey or seagrass distribution, or contamination of prey or seagrass. Oil from the *Exxon Valdez* spill accumulated in sediments, continues to contaminate nearshore environments, and appears to have impeded recovery of sea otters (Bodkin et al. 2002). How long that effect will persist is uncertain (Page et al. 2002, Rice et al. 2003, Neff et al. 2006, Boehm 2007). In the Gulf, spilled oil that has accumulated in coastal and offshore bottom sediments could be re-released during hurricanes and storms, resulting in intermittent, recurring effects on the marine ecosystem (Machlis and McNutt 2010). Further research is needed to characterize physical and biogeochemical degradation rates in the Gulf of Mexico to evaluate the likelihood of such long-lasting impacts.

Assessment activities to date

Responding to stranded marine wildlife exposed to oil was a high priority during the days immediately following the Deepwater Horizon oil spill. Under the Unified Command[10], the National Oceanic and Atmospheric Administration and the Fish and Wildlife Service worked with the Oiled Wildlife Care Network to coordinate the Gulf marine mammal stranding network, revise the marine mammal response guidelines developed by Johnson and Ziccardi (2006) to address Gulf species, train stranding responders regarding hazardous materials and chain-of-custody protocols, and distribute sampling supplies. Wildlife Operations under the Unified Command also initiated aerial surveys of the affected area to search for injured or dead marine mammals and other wildlife. The Unified Command for the oil spill response established a wildlife hotline for reporting oiled, injured, distressed, or dead marine mammals, sea turtles, and birds. Reports from the hotline and information from response vessels and aerial survey teams helped guide emergency response efforts. At the same time, the National Oceanic and Atmospheric Administration, the Fish and Wildlife Service, and other natural resource Trustees began assessing and quantifying exposure and injury to marine mammals and other wildlife as part of the Natural Resource Damage Assessment process.

Figure 3. Bottlenose dolphin observed with oil on dorsal fin, Mississippi Sound, Mississippi. (Photograph: B. Crone/National Oceanographic and Atmospheric Administration)

Response efforts were determined by the nature and tractability of the concern or question to be addressed and availability of infrastructure and other assessment resources. The National Oceanic and Atmospheric Administration and the Fish and Wildlife Service expanded aerial surveys to track movements of selected marine mammal stocks, document their direct exposure to oil (Figure 3), and describe their physical and/or behavioral reactions if and when they came into contact with oil. They enlisted academic researchers to deploy passive acoustic monitoring buoys near the Deepwater Horizon wellhead to detect the presence of vocalizing marine mammals. They responded to stranding reports, collecting and arranging for the analysis of blood, tissue, and other samples from stranded animals. They also placed observers on a limited number of response vessels to assess the immediate and obvious effects of skimming and burning operations. Although the initial data collection efforts are not a substitute for pre-spill baseline data for most Gulf marine mammal stocks, they were instrumental in determining movement patterns and behavioral responses of marine mammals immediately before, during, and after oil and chemical dispersants reached key coastal and deepwater habitats. For that reason, the data collected will provide a critical reference for analyses of spill and response effects.

In May 2010 the federal and state Trustees for the Deepwater Horizon oil spill Natural Resource Damage Assessment established a Technical Working Group for Marine Mammals and

[10] The organizational structure for wildlife response during an oil spill is outlined in Johnson and Ziccardi (2006).

Sea Turtles.[11] The working group is composed of scientists and other representatives from federal and state Trustee agencies and contracted consultants and academics, and works in cooperation with the Responsible Parties. Since its establishment, the group has developed and evaluated work plans for identifying and quantifying injuries to marine mammals and sea turtles. Initial plans focused on short-term assessment, including (1) documenting exposure of marine mammals and sea turtles in oiled areas and exposure of particular species and habitats, (2) assessing the effects of response activities, (3) gathering and analyzing baseline information as possible, and (4) filling other data gaps. Natural Resource Damage Assessment projects already conducted or currently being conducted by the Marine Mammal and Sea Turtle Technical Working Group include—

- photo-identification and biopsy sampling of bottlenose dolphin populations at selected estuarine sites (Barataria Bay, Louisiana; Chandeleur Sound, Louisiana; Mississippi Sound, Mississippi; and St. Joseph Bay, Florida)
- large-vessel pelagic research cruises to—
  - visually assess and photo-document marine mammal contact with oil and occurrence of marine mammals in oiled areas
  - deploy satellite tags and collect biopsy samples from Bryde's whales, sperm whales, and other marine mammals in offshore waters
  - collect habitat information including surface hydrographic data, temperature profiles, salinity, dissolved oxygen, and acoustic echo-sounder backscatter information to characterize water column productivity and prey resources, and
  - deploy low and mid-frequency passive acoustic monitoring buoys
- aerial surveys to estimate abundance and assess distribution of Florida manatees in oil-affected areas, document locations of manatees in distress, and inform rescue efforts
- live capture-release studies of bottlenose dolphins in Barataria Bay, Louisiana, and Sarasota Bay, Florida, to assess sub-lethal and chronic health impacts,
- genetic analyses of biopsy and stranding samples for species identification, sex determination, and/or stock structure,
- manatee tracking data analysis, and
- prey and seagrass sampling.

At present, the approved work plans do not include assessment of contaminant effects on marine mammals. The Commission considers this to be an important topic to be investigated.

In October 2010 the Trustees confirmed damage and injury to natural resources and issued a notice of intent to begin planning restoration activities.[12] Planning and implementation of restoration activities likely will take several years and require integration and analysis of multiple types of information (Figure 4). These include measures and comparisons of the ecological, biological, geophysical, chemical, and oceanographic conditions in the Gulf, both pre- and post-spill, and/or modeling of conditions where pre- and/or post-spill information is not available (e.g., French-McCay 2004). Restoration activities that may benefit marine mammals include not only clean-up of the spilled oil, but also (1) basic assessment of the marine mammal stocks in the Gulf, and (2)

[11] The Marine Mammal and Sea Turtle Technical Working Group is one of many technical working groups established by the Trustees under the Natural Resource Damage Assessment process to conduct damage assessments. For a brief description of all technical working groups and associated work plans, see http://www.gulfspillrestoration.noaa.gov/.
[12] 75 Fed. Reg. 60800, 1 October 2010.

reduction of other human-related risk factors in the Gulf, such as noise from seismic surveys, vessel traffic, SONAR (SOund Navigation And Ranging) and military activities; fishery interactions; disturbance from tourism and illegal feeding; harmful algal blooms and anoxic zones.

Determining the respective roles of human-related risk factors and their interactions with the spill is a substantial but important challenge. In 2010, prior to the spill, unusually high numbers of bottlenose dolphins began to strand in the northern Gulf.[13] When the spill began, the National Oceanic and Atmospheric Administration already was initiating consultation with the Working Group for Marine Mammal Unusual Mortality Events to determine whether an unusual mortality event should be declared (in accordance with section 404 of the Marine Mammal Protection Act). The spill delayed the consultation until the National Oceanic and Atmospheric Administration could reanalyze the data on marine mammal mortalities along the northern Gulf before, during, and after the oil spill. Consultation with the Working Group was reinitiated in October and, in December, the National Oceanic and Atmospheric Administration declared the deaths to constitute an unusual

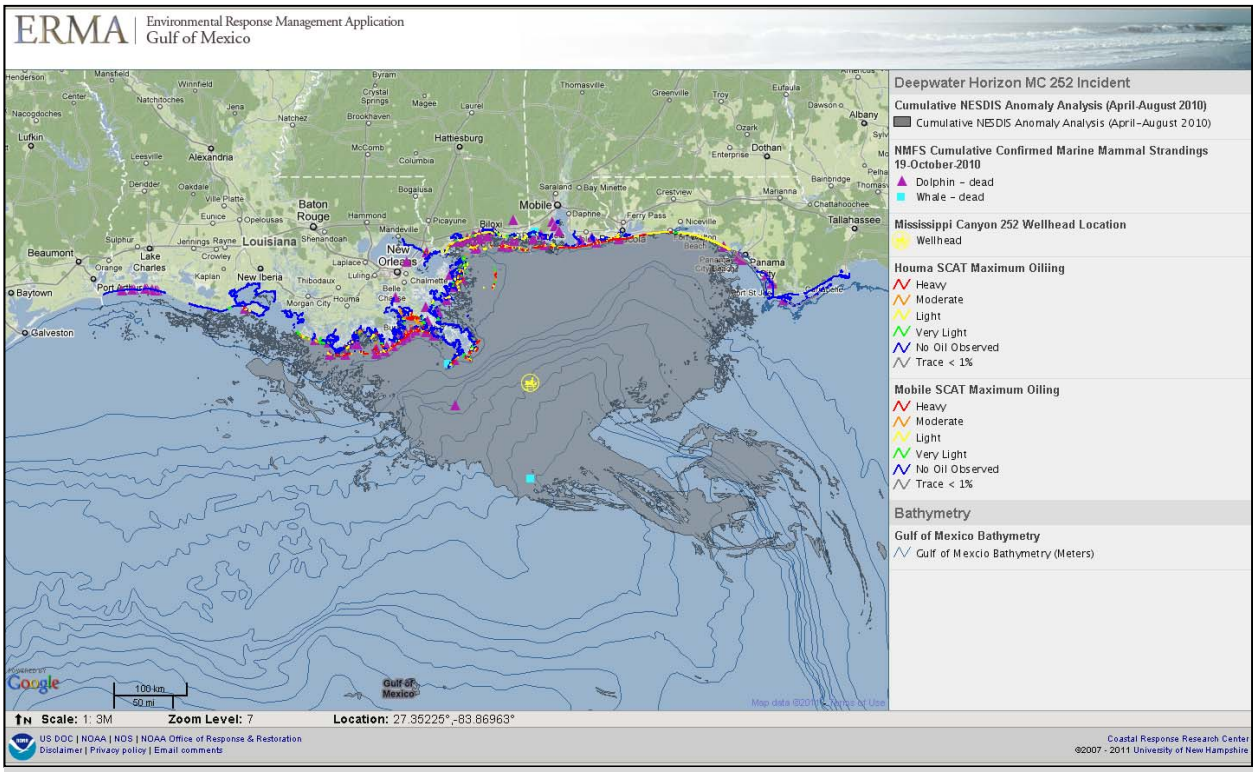


Figure 4. Map of cumulative marine mammal strandings in the Gulf as of 19 October 2010 and maximum shoreline oiling observations using data from shoreline cleanup and assessment of August 2010. Other types of data related to the spill and assessment activities also can be mapped and analyzed using the Environmental Response Management Application. (Map: National Oceanic and Atmospheric Administration Office of Response and Restoration)

[13] http://www.nmfs.noaa.gov/pr/health/mmume/cetacean_gulfofmexico2010.htm

mortality event. To the extent practicable, the National Oceanic and Atmospheric Administration and the Working Group are coordinating the investigation of these mortalities (pre- and post-oil spill) with ongoing Natural Resource Damage Assessment activities where the data needs of these two processes coincide.

Assessing the spill's long-term effects on Gulf marine mammals

Exposure to oil from the *Exxon Valdez* oil spill had a long-term effect on marine mammals, 15 years or more after the spill (Matkin et al. 2008; Ballachey et al. 2007). Although the spills differ in some important respects, long-term effects are a reasonable concern for Gulf marine mammals because of the amount of oil spilled, the quantity of dispersants applied both at the surface and at the wellhead, the low recovery rates of spilled oil, uncertainty regarding the eventual disposition of both oil and dispersants (Crone and Tolstoy 2010; National Oceanic and Atmospheric Administration 2010; Nihous 2011), and uncertainty regarding the effects of the spill and response on features of the ecosystem important to marine mammals. In the *Exxon Valdez* case, long-term wildlife studies have revealed chronic, delayed, and indirect effects that were longer and more severe than previously expected or assumed (Peterson et al. 2003).

The null and alternative hypotheses listed above provide a foundation for assessing the long-term effects of the Deepwater Horizon oil spill on Gulf marine mammals. Evaluating each of the alternative hypotheses requires a variety of research approaches that are suitably adapted to the physical conditions in the Gulf, its marine mammal species (some of which are more difficult to assess than others), and the nature of the spilled oil and response activities. The opportunity to assess some acute effects may have passed but, in those cases, retrospective analyses could provide insights into actual effects or provide useful guidance for responding more effectively to future events. For those hypotheses that still can be tested with ongoing or new studies, especially regarding longer term or indirect effects, a variety of research tools and/or approaches are available (see Boyd et al. 2010, Perrin et al. 2009, and additional references in Appendix C for descriptions of standard research methods).

The alternative hypotheses are inter-related. Studies to characterize direct and indirect effects are particularly useful because they help describe how the effects occur. Where those studies are not possible, it still may be feasible to study survival and reproductive rates, which integrate and reflect the total influence of direct and indirect effects. However, vital rates vary by year, geography, age, and sex (Baker et al. 2010) and also may be difficult to assess for some species. When those rates cannot be determined, it still may be possible to assess population abundance and trends, which reflect the total influence of survival and reproduction for closed populations (i.e., with no migration in or out of the population) and the added influence of emigration and immigration for open populations. The Commission believes that attributing changes in vital rates or population abundance to exposure likely may require a "weight of evidence" approach based on a wide range of studies focused on individuals, populations, and the ecosystem generally.

The hypotheses, potential research tools for evaluating them, the associated benefits, and the relative priority that the Commission gives to each hypothesis are described in Table 2, and illustrated in Figure 5. The Commission considers all of the hypotheses to be a high priority during or immediately after a spill. However, because certain effects are less likely with time, the value of research into those effects declines accordingly.

In the past, researchers have had limited and inconsistent access to infrastructure (e.g., research vessels, analytical laboratories), personnel, and funding. Although there are considerable funds available through the Natural Resource Damage Assessment process, it is not clear yet whether these funds will be available for studies of long-term effects or for filling important data gaps existing before the spill. In addition, funding through annual appropriations is not likely to improve significantly in the coming years. However, funding for studies of long-term effects may be available from non-governmental sources such as the Gulf of Mexico Research Initiative, which has been funded by BP.

Assessment efforts likely will focus on a subset of the Gulf's marine mammal species that are considered to be at particularly high risk or more easily studied. For example, sperm whales have been more intensively studied than other deepwater cetaceans in the Gulf because of their endangered status and the overlap of their habitat with deepwater oil and gas operations (Jochens et al. 2008). As a result, studies focusing on sperm whales and their movements and foraging patterns are likely to continue. Coastal species such as bottlenose dolphins are less well studied but potentially more accessible to researchers. Bryde's whales are the only baleen whales in the Gulf and they also have been a focus of post-spill assessment because of their small population size. Without additional infrastructure to support research on long-term effects, studies of most other Gulf species will be limited and opportunistic. Therefore, estimating potential impacts of the oil spill on those other marine mammal species may depend heavily on modeling and inference based on the more studied species.

Absent additional resources, inadequate research methods also will constrain the assessment of long-term effects. Among other things, researchers need better sampling methods to detect and assess the effects of exposure to oil. For example, studies of ringed seals, fish, and other species suggest that certain samples (e.g., bile, urine, blood, and feces) are the best indicators of exposure to polycyclic aromatic hydrocarbons (Englehardt 1978, Balk et al. 2011). Such samples are difficult to obtain from live marine mammals. Instead, researchers studying contaminants in marine mammals have used skin and blubber biopsies from live-stranded or free-ranging animals (Marsili et al. 2001, Aguilar and Borrell 2004, Wilson et al. 2007, Godard-Codding et al. 2011) or liver and other tissues from dead animals (Holsbeek et al. 1999, Kannan and Perrotta 2008). These other tissues may be more easily obtained but are not as revealing as the preferred samples.

Finally, as noted above, research on the long-term effects of the spill will be confounded by the effects of other anthropogenic activities and natural perturbations in the Gulf. Such factors may include seismic surveys for oil and gas reserves, routine oil and gas operations, commercial and recreational fisheries, shipping and military activities, tourism, hypoxia and anoxia, harmful algal blooms, hurricanes, natural oil seeps, and climate disruption (Appendix B). Research will also be confounded by changes in the physical and biogeochemical properties of Deepwater Horizon oil over time as the result of natural weathering and degradation. Assessing these confounding factors, and distinguishing their effects on marine mammals from the long-term effects of the oil spill, will be a considerable challenge, particularly given the limited resources available for research.

Future research strategies and capacity

The extent to which we can learn more about the spill's effects on marine mammals, as well as the effects of other human-related factors, will depend largely on our ability to improve research

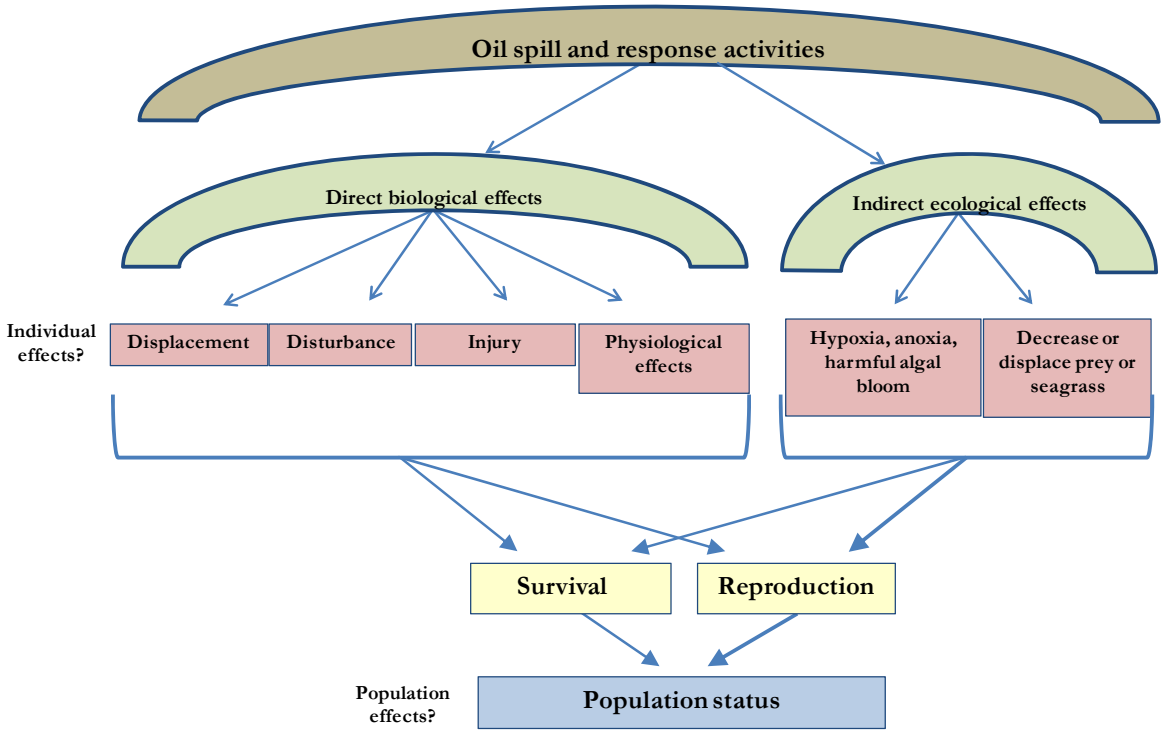


Figure 5. Conceptual framework for assessing the effects of the Deepwater Horizon oil spill on marine mammals in the Gulf of Mexico. The spill and response activities may result in direct biological effects or indirect ecological effects on individuals. To be biologically significant at the population level, those effects must reduce either survival or reproduction, or both. Research strategies focused on individual effects seek information on the means by which the spill and response activities affect marine mammals, whereas research aimed at the population level seeks information aimed at determining their conservation significance over the long-term. A "weight of evidence" approach may be necessary to link effects observed at the individual level to long-term population-level effects on survival and reproduction.

strategies and capacity in the Gulf. The Deepwater Horizon oil spill provided a sobering indicator of the shortcomings of our current research and management approach for marine mammals in the Gulf of Mexico. Those shortcomings can be grouped under five key topics, as follows.

Stock assessment: Stock structure is the most fundamental assessment information because it provides the basis for defining units of conservation. The lack of information on stock structure for multiple species, particularly coastal, bay, and estuarine bottlenose dolphin populations, is a significant impediment to further stock assessment efforts. Other shortcomings pertaining to the movement patterns and abundance and trends of stocks near the spill also undermine assessment of spill effects. Stock assessment information also is necessary to provide the baseline against which changes in the status of a stock can be measured. The Southeast Fisheries Science Center of the National Marine Fisheries Service is responsible for assessing the stocks of marine mammals in the Gulf, and the Department of the Interior is responsible for assessing stocks of manatees in the Gulf of Mexico. Improving their capacity to complete these assessments in the future should be a high priority.

Table 2. Hypotheses to assess the long-term effects of the Deepwater Horizon oil spill on Gulf marine mammals, potential research approaches, benefits, and relative priorities for long-term research. The Commission considers all of the hypotheses to be a high priority during or immediately after a spill. However, the likelihood of seeing certain effects decreases with time and the value of research into those effects declines accordingly.

Hypothesis	Research approaches	Why important	Short/ long-term priority
H_1 - Spilled oil causes injury, lesions, disease, or death through— H_{1a} - external contact H_{1b} - internal contact	Examinations of stranded live animals, necropsies of dead stranded animals, observations of living or dead animals at sea	Marine mammal contact with high concentrations of oil was a major concern immediately after the spill, but that concern declined as the oil was removed from the ecosystem by response activities or natural processes	High/Low
H_2 - Exposure to oil- or dispersant-related contaminants causes physiological dysfunction of— H_{2a} - the immune system H_{2b} - the reproductive system H_{2c} - other vital systems	Assessment of health status and contaminant loads of stranded or live-captured animals, necropsies of dead animals, assessment of reproductive rates, observations of reproductive failure (e.g., aborted fetuses, malformed offspring), controlled exposure experiments, genomics	Marine mammals may concentrate contaminants through bioaccumulation if they ingest oil during foraging or ingest oil-contaminated prey. Existing evidence suggests that the immune and reproductive systems are particularly vulnerable to contaminants. The elevated number of premature, stillborn, or neonatal bottlenose dolphins over the past two years raises questions about exposure to oil as a possible contributing factor.	High/High
H_3 - Exposure to response activities causes injury via— H_{3a} - vessel strikes H_{3b} - interactions with booms or other response equipment H_{3c} - noise introduced into the marine environment	Observations or records of vessel operators or onboard observers, examination of stranded animals for evidence of vessel-related wounds, assessment of hearing organs/tissues or other organs of dead stranded animals	Response activities are a serious concern immediately following a spill, but such activities have decreased to a low level or have been discontinued throughout the northern Gulf.	High/Low
H_4 - Exposure to oil and/or response activities disturbs or disrupts significant biological behaviors, including— H_{4a} - foraging H_{4b} - reproduction H_{4c} - resting	Foraging studies using various types of instrumentation (e.g., location, depth, dive characteristics), observations of feeding behavior, analysis of stomach/intestinal contents, observations of mother-calf pairs and their daily movement patterns	Changes in significant biological behaviors were most likely during and immediately after the spill and over the duration of response activities. However, spill and response activities that may disrupt behavior are largely over.	High/Low

Hypothesis	Research approaches	Why important	Short/ long-term priority
H_5 - Exposure to oil and/or response activities leads to displacement from primary habitat	Movement and habitat studies using telemetry, shoreline, vessel-based, or aerial observations, passive acoustics to detect presence	Spilled oil and response activities (e.g., vessels, noise) may have temporarily or permanently displaced marine mammals from their primary habitat, thereby reducing their survival and/or reproduction and, thus, population status.	High/ Medium
H_6 - Exposure to oil and/or response activities leads to disruption of social organization	Observations of pod size during various activities (e.g., feeding, resting), frequency of mother-calf pairs and duration of their bond	Social organization likely would be most easily disrupted during the spill and response activities, which are largely over.	High/Low
H_7 - Oil and/or response-related changes in the ecosystem reduce prey or seagrass availability— H_{7a} - prey displacement H_{7b} - reduction in biomass of prey or seagrass	Observations of condition of stranded animals, changes in diet as determined by observations of foraging behavior, stomach/intestinal content analyses, prey and seagrass surveys to assess biomass and changes therein over time and space (i.e., cooperation with agencies involved in fisheries assessment)	The spill or response activities could lead to long-term changes in marine mammal condition if they have bio-accumulated large concentrations of contaminants or if the spill and response activities lead to a decrease or displacement of prey biomass.	High/High
H_8 - Oil and/or response activities lead to other ecosystem changes harmful to marine mammals via— H_{8a} - hypoxia or anoxia H_{8b} - harmful algal blooms	Observations of stranded animals, analysis of tissues for evidence of toxins, monitoring of harmful algal blooms and hypoxic/anoxic zones	The elevated numbers of marine mammals stranding in the northern Gulf pre- and post-spill raise concerns about Gulf environmental conditions. The 2010-2011 unusual mortality event began before the spill, but it is possible that the spill has exacerbated the mortality event.	High/High
H_9 - Exposure to oil and/or response activities leads to reduction in status involving— H_{9a} - individual fitness H_{9b} - population vital rates (reproduction and survival rates) H_{9c} - population abundance and trends	Observations of increased number of dead animals, observations of evidence of reproductive failure (e.g., fetuses, malformed offspring), absolute or relative decrease in numbers of mother/calf pairs, aerial, vessel, or shoreline surveys	Individual fitness and population survival and reproduction rates are relatively difficult to measure, although reproduction rates can be evaluated by looking at the absolute and relative frequencies of mother-calf pairs over time. Repeated surveys of abundance over time provide the most general indication of spill and response effects, although counts generally do not provide insights into the nature of any observed changes. Nonetheless, trends in abundance are the most basic and important indicators of possible spill and response effects.	High/High

Stranding program: Over the past several decades, stranded marine mammals have become a major source of information used to manage marine mammal stocks in U.S. waters. Stranding networks have been developing in virtually all U.S. coastal areas, but they are less well developed in certain areas, including the Gulf. If improved, such networks provide an opportunity to collect information on species/stocks present, movement patterns, reproduction, age structure, health, and sources of mortality. In the Gulf, stranding networks played a key role during the spill by monitoring coastal areas for stranded animals, collecting tissues for various types of analyses, and caring for live-stranded animals and moving them to facilities that could provide the necessary care. The Gulf's stranding networks must be further developed and supported to assist with the tracking of the long-term effects of the oil spill.

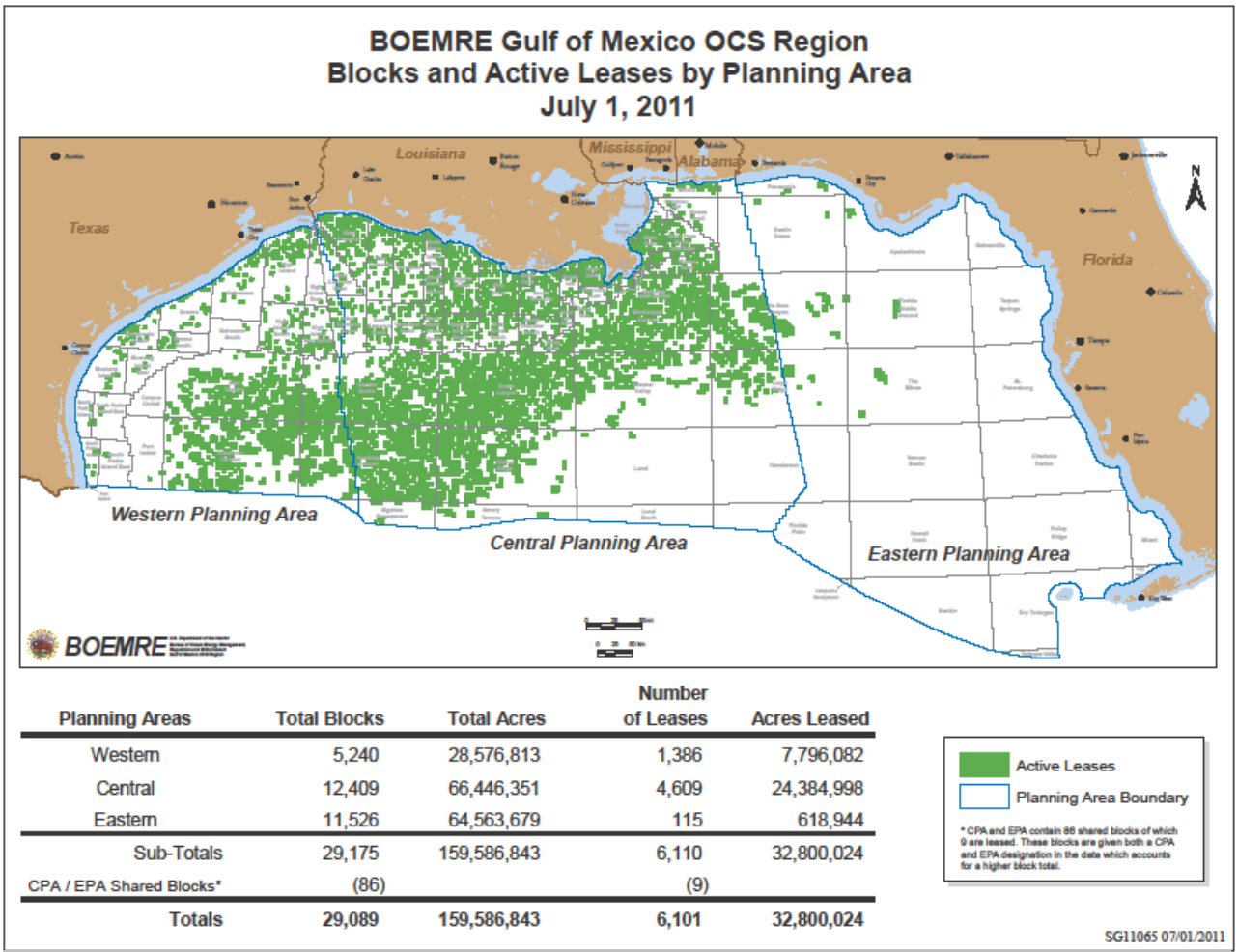
Health assessments: The health of individual animals can be an important indicator of adverse effects from natural or anthropogenic risk factors in the ocean or coastal environment, including exposure to oil, dispersants, and response activities. Coupled with information from dead stranded animals, in-depth assessments of live stranded or captured animals have provided important information on marine mammal health, disease, and causes of mortality (Figure 6)—all information needed to promote effective conservation efforts (Hall et al. 2010). Live capture/release studies in particular are a proactive means for evaluating risk factors in living bottlenose dolphin populations (Wells et al. 2004). National Oceanic and Atmospheric Administration and Fish and Wildlife Service scientists are working collaboratively with researchers from other federal agencies, private institutions, aquaria, and not-for-profit organizations to conduct health assessments in areas affected by the spill and control areas. The assessments will help determine the effect of exposure to oil and identify other risk factors, including those that may have contributed to the unusually high number of dolphin deaths in 2010 and 2011. Two assessment projects have been funded to date under the Natural Resource Damage Assessment process; longer term funding sources are needed but have yet to be identified.

Figure 6. Researchers conducting health assessment of wild bottlenose dolphins in Georgia. (Photograph T. Speakman/National Oceanic and Atmospheric Administration)

Environmental studies: The northern Gulf is a dynamic and heavily industrialized area. In addition to extensive oil and gas operations (Figure 7), the Gulf is the site of extensive commercial shipping, commercial and recreational fishing, military activities, recreational activities, coastal development, and freshwater and nutrient/contaminant input from the Mississippi and Atchafalaya River Basin watersheds. The adverse effects of all of these activities are manifested in a number of ways, including the occurrence of extensive hypoxic and anoxic zones and harmful algal blooms. Large-scale changes in community structure or prey abundance caused by the oil spill or other anthropogenic or natural disturbances can affect the carrying capacity or distribution of marine mammal populations. Evaluating the adverse effects of these many factors, managing the activities

that cause them, and mitigating their impacts on the Gulf ecosystem, including marine mammals and their prey, will require a major commitment. In addition, environmental studies should include research on marine mammal/prey dynamics. Efforts to understand the oil spill's long-term effects on marine mammals likely will fall far short of their objective if research and management capacity in the Gulf are not enhanced. Assessing the relative roles of various threats to the Gulf's marine mammals will be a challenge, as illustrated by the difficulty of evaluating any potential influence of the spill on the recent bottlenose dolphin mortality events in the northern Gulf.

Cumulative effects: Finally, the status of the Gulf's marine mammal populations will vary not as a function on any single risk factor, but rather as a function of all of them, including the interactions between those factors. At the least, marine mammal research and management should be capable of identifying the marine mammal stocks in the Gulf and assessing their relative abundances and trends to determine if, when, and where they are being exposed to cumulative effects that hinder their potential to grow and recover. The current state of science in the Gulf is not sufficient to support even the most basic of statements about the status of most Gulf marine mammal stocks. Although the Commission supports efforts to characterize the full long-term effects of the oil spill on the Gulf's marine mammals, those efforts will have to be integrated with efforts to obtain information on the effects of other important risk factors.



Planning Areas	Total Blocks	Total Acres	Number of Leases	Acres Leased
Western	5,240	28,576,813	1,386	7,796,082
Central	12,409	66,446,351	4,609	24,384,998
Eastern	11,526	64,563,679	115	618,944
Sub-Totals	29,175	159,586,843	6,110	32,800,024
CPA / EPA Shared Blocks*	(86)		(9)	
Totals	**29,089**	**159,586,843**	**6,101**	**32,800,024**

Figure 7. Map of Gulf of Mexico Outer Continental Shelf active oil and gas leases as of 1 July 2011. (Map: Bureau of Ocean Energy Management, Regulation and Enforcement)

Federal agency missions and responsibilities in the Gulf

The Marine Mammal Commission drafted this statement of research needs with substantial input from staff of the National Marine Fisheries Service, National Ocean Service, Fish and Wildlife Service, and Bureau of Ocean Energy Management, Regulation and Enforcement (formerly the Minerals Management Service). Other federal agencies with substantial research programs and/or management responsibilities in the Gulf include the U.S. Geological Survey, the Office of Naval Research, the Chief of Naval Operations Environmental Readiness Division (N45), the U.S. Coast Guard, and the National Science Foundation.

Marine Mammal Commission: The Marine Mammal Commission is an independent agency of the U.S. Government, established under Title II of the Marine Mammal Protection Act to provide independent oversight of the marine mammal conservation policies and programs being carried out by federal regulatory agencies. With regard to the spill, the Commission's primary role is oversight of the other federal agencies responsible for response, assessment, and restoration. The Commission believes that it can play a useful role by convening interagency working groups where response, assessment, and restoration could benefit from coordination. The Commission also administers a small annual grant program that supports projects aimed at meeting the conservation and protection goals of the Marine Mammal Protection Act. In addition, the Commission has initiated an annual survey of federally funded research on marine mammals to determine the nature of research conducted or supported by each agency. Information from the survey will be used to assess ways to enhance and target specific marine mammal research and conservation activities.

National Oceanic and Atmospheric Administration: The National Oceanic and Atmospheric Administration's mission is to understand and predict changes in climate, weather, oceans, and coasts, to share that knowledge and information with others, and to conserve and manage coastal and marine ecosystems and resources to meet the Nation's economic, social, and environmental needs. As part of this mission, the National Oceanic and Atmospheric Administration sustains and manages ocean and coastal resources and evaluates the status of, and threats to, protected marine species, including whales, dolphins, and seals and sea lions (excluding walrus). Within the National Oceanic and Atmospheric Administration, the National Marine Fisheries Service and the National Ocean Service assume important responsibilities for protecting marine resources.

The National Marine Fisheries Service is responsible for protecting and conserving many of the Nation's living marine resources, including fish stocks, marine mammals, and endangered species and their habitats. The Service administers its research and management responsibilities through its headquarters in Silver Spring, Maryland, six regional offices, six science centers, and numerous labs and satellite offices throughout the country. The Service works in close association with academic institutions, communities, non-profit organizations, states, tribes, and other federal agencies. The Service's Southeast Fisheries Science Center and Southeast Regional Office conduct and coordinate research and management of the Gulf of Mexico and South Atlantic Ocean. The Southeast Fisheries Science Center is responsible for scientific research on living marine resources that occupy marine and estuarine habits of the continental southeastern United States, from Texas to North Carolina as well as Puerto Rico and the U.S. Virgin Islands. The Southeast Regional Office administers provisions of the Marine Mammal Protection Act and Endangered Species Act and, along with the Southeast Fisheries Science Center, coordinates and manages the activities of the regional stranding network. The Service's Office of Protected Resources works to conserve, protect, and recover marine mammals and endangered species and is responsible for overall administration and

coordination of the Marine Mammal Health and Stranding Response Program. That program (1) oversees responses to stranded marine mammals along the U.S. coast, (2) assesses trends in marine mammal health, (3) correlates those trends with environmental data, and (4) maintains effective responses to unusual mortality events.

The National Ocean Service promotes safe marine navigation, assesses the health of coastal and marine resources, responds to natural and human-induced threats, and conserves the coastal ocean environment. The National Ocean Service's Office of Response and Restoration provides comprehensive solutions to environmental hazards caused by oil, chemicals, and marine debris. In addition, the National Oceanic and Atmospheric Administration Damage Assessment, Remediation, and Restoration Program coordinates and guides natural resource damage assessments by working with remedial agencies, Natural Resource Trustees, and responsible parties to protect and restore National Oceanic and Atmospheric Administration trust resources injured by releases of hazardous substances and oil. In addition, the Service's Center for Human Health Risk investigates how the marine environment affects people's health and socio-economic well-being. The Center's Oceans and Human Health Initiative is focused on new methods, approaches, and tools for evaluating how marine organisms respond to pollution, global climate change, coastal development and other human-related risk factors, and how best to identify and characterize chemical and microbial threats to marine ecosystems and human health. The Center's Chemical Contaminants research group explores ways to identify and measure contaminants of concern in the marine environment.

Fish and Wildlife Service: The Fish and Wildlife Service is a federal agency within the Department of the Interior. Its mission is to conserve, protect, and enhance fish, wildlife, plants, and their habitats for the continuing benefit of the American people. As the principal federal partner responsible for administering the Endangered Species Act, the Fish and Wildlife Service has the lead in recovering and conserving most endangered species, including the Florida population of the West Indian manatee. It works cooperatively with the U.S. Geological Survey and state and local Trustees in the Gulf to conduct the Natural Resource Damage Assessment. It is guided in this work by the Department of the Interior's Natural Resource Damage Assessment and Restoration Deepwater Horizon Case Management Office.

Bureau of Ocean Energy Management, Regulation and Enforcement: The Bureau (formerly the Minerals Management Service) also is within the Department of the Interior. It is the federal agency responsible for overseeing the development of energy and mineral resources on the Outer Continental Shelf. In accordance with the Outer Continental Shelf Lands Act, operations on the Outer Continental Shelf must preserve, protect, and develop oil and natural gas resources in a manner that is consistent with the need to make such resources available to meet the Nation's energy needs as rapidly as possible; to balance orderly energy resource development with protection of human, marine, and coastal environments; to ensure the public a fair and equitable return on the resources of the Outer Continental Shelf; and to preserve and maintain free enterprise.

Section 20 of the Outer Continental Shelf Lands Act authorizes the Bureau's Environmental Studies Program and establishes three general goals for the program:

- to establish the information needed for assessment and management of environmental impacts on the human, marine, and coastal environments of the Outer Continental Shelf and the potentially affected coastal areas

- to predict impacts on the marine biota that may result from chronic, low level pollution or large spills associated with oil and gas production, from drilling fluids and cuttings discharges, pipeline emplacement, or onshore facilities
- to monitor human, marine, and coastal environments to provide time series and data trend information for identification of significant changes in the quality and productivity of these environments, and to identify the causes of these changes.

The research priorities of the Environmental Studies Program are determined by mission relevance, technical feasibility, scientific merit, timing, applicability, and affordability. In the Gulf, research on protected species has been driven by information gaps and recommendations for research either as part of the "terms and conditions" or the "conservation recommendations" of Endangered Species Act Section 7 consultations. Recent and upcoming programmatic consultations that may result in new studies include geological and geophysical activities and explosive removals of platforms.

Current and ongoing studies in the Gulf that may affect or have implications for marine mammals include seismic survey mitigation measures and an analysis of marine mammal observer reports, a sperm whale acoustic prey study (SWAPS), and a workshop on the status and applications for acoustic monitoring of marine mammals. New studies for 2011 include the effects of oil and gas exploration on sperm whales in the eastern Gulf and estuarine bottlenose dolphins. The Deepwater Horizon oil spill likely also will prompt new environmental studies to assess the impacts and long-term recovery of marine mammals in the Gulf.

Research permits and coordination

The Endangered Species Act and the Marine Mammal Protection Act require permits or other authorizations for all research, assessment, and enhancement activities that may take threatened or endangered marine mammals (in the case of the Endangered Species Act) or non-listed marine mammals. These activities include scientific research, the import or export of marine mammal parts, photography, rehabilitation, public display, capture from the wild, or other activities that may intentionally or incidentally affect marine mammals. Permits are issued by the National Marine Fisheries Service for cetaceans and most pinnipeds and by the Fish and Wildlife Service for manatees, polar bears, walruses, and sea otters. Permits typically take 6-9 months to process for non-listed marine mammals and 12 months for listed marine mammals; Letters of Confirmation for taking by harassment typically can be processed in about 4 months. Permits to access public lands and collect samples in marine areas managed by the National Park Service or other agencies also may be required and should be pursued concurrent to permits issued by the National Marine Fisheries Service and the Fish and Wildlife Service. As part of the permitting process, the Services evaluate the proposed research to determine if it is unnecessarily duplicative of ongoing research. To avoid unnecessary disturbance of animals, permit holders are required, to the maximum extent possible, to coordinate their activities. Permit applicants also may be required to comply with the provisions of the Animal Welfare Act.

Many researchers involved in assessment of the spill's impact on marine mammals are not affiliated with federal agencies. The Marine Mammal Commission appreciates their work and encourages their continued participation in this effort. Many of them already have permits for work in the Gulf or on species potentially affected by the spill. However, coordination of research

activities is critical to focus on the most important research topics, collaborate whenever possible, and avoid unnecessary duplication of research. Such collaboration should help maximize the benefits of limited resources and minimize unnecessary research-related effects on marine mammals. The Marine Mammal Commission has encouraged the Permits Office of the National Marine Fisheries Service to facilitate research on the Gulf's marine mammals by coordinating scientists already holding research permits and helping to guide future research.

During the summer of 2010, the National Marine Fisheries Service, working with the Fish and Wildlife Service, posted a notice on MARMAM (an online mailing list pertaining to marine mammal issues) about research and response activities in the Gulf. In addition, the Service wrote all researchers holding permits or letters of confirmation to encourage research coordination during and after the spill response.

The success of long-term research efforts will depend on collaboration by the involved federal, state, and local agencies, industry, non-governmental organizations, research institutions and organizations, and the public. Among other things, the participants in such research should meet annually to summarize their results and adapt their future research plans as needed.

Additional resources

Several websites have been established to provide information to the public regarding the Deepwater Horizon oil spill, including response, assessment, research, and restoration activities. A partial list of websites in included in Appendix D.

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Appendix A. Baseline information for marine mammal species in the Gulf of Mexico. The population information is from Waring et al. (2010) and the information regarding prey species is from Jefferson et al. (2008). For all stocks, the information is not sufficient to meet the requirements of the Marine Mammal Protection Act. CV=coefficient of variation; N_{best}=best estimate of abundance; N_{min}=minimum estimate of abundance; PBR=potential biological removal level; E=endangered under the Endangered Species Act; S=strategic under the Marine Mammal Protection Act). *As identified in Waring et al. 2010, although many sources of mortality and serious injury also may be applicable to other species.

Species/stock (E=endangered, S=strategic)	**Abundance – N_{best} (CV) N_{min} PBR**	**Distribution and movement patterns**	**Stock structure**	**Social structure**	**Vital rates**	**Health status**	**Prey species**	**Total human-caused mortality/ serious injury**	**Possible sources of human-caused mortality/ serious injury***
Sperm whale (*Physeter macrocephalus*) (E/S)	N_{best} = 1,665 (CV = 0.20) N_{min} = 1,409 PBR = 2.8	Oceanic throughout the Gulf	Gulf stock distinct from other Atlantic Ocean stocks	Highly social, with adult females and juveniles of both sexes occurring together in mixed groups	Unknown	Unknown	Primarily deepwater cephalopods and fishes	Unknown	Oil and gas operations (seismic surveys), pollution
Sperm whale (*Physeter macrocephalus*) (E/S) Puerto Rico and US Virgin Islands stock	Unknown, PBR undetermined	Continental slope and oceanic waters surrounding Puerto Rico and the U.S. Virgin Islands	Limited information to distinguish from other Atlantic Ocean or Gulf stocks	Highly social, with adult females and juveniles of both sexes occurring together in mixed groups	Unknown	Unknown	Primarily deepwater cephalopods and fishes	Unknown	Coastal pollution, ship strikes
Bryde's whale (*Balaenoptera edeni*) (S)	N_{best} = 15 (CV = 1.98) N_{min} = 5 PBR = 0.1	Primarily along the shelf break (200 m) in the northeastern Gulf	Unknown	Generally found as singles or pairs, no calves observed	Unknown	Unknown	Small schooling fishes	Unknown	Ship strikes, other sources unknown
Cuvier's beaked whale (*Ziphius cavirostris*)	N_{best} = 65 (CV = 0.67) N_{min} = 39 PBR = 0.4	Oceanic throughout the Gulf	Unknown	Very cryptic, usually in groups of less than 5	Unknown	Unknown	Primarily squids, also deepwater fishes and crustaceans	Unknown	Unknown, possible military activities (sonar) in Atlantic Ocean
Blainville's beaked whale (*Mesoplodon densirostris*)	N_{best} = 57 (CV = 1.40) N_{min} = 24 (Estimate for all *Mesoplodon* sp.)	Oceanic throughout the Gulf	Unknown	Very cryptic, usually in groups of less than 5	Unknown	Unknown	Primarily squids, also deepwater fishes	Unknown	Unknown, possible military activities (SONAR) in Atlantic Ocean

Species/stock (E=endangered, S=strategic)	Abundance – N_{best} (CV) N_{min} PBR	Distribution and movement patterns	Stock structure	Social structure	Vital rates	Health status	Prey species	Total human-caused mortality/ serious injury	Possible sources of human-caused mortality/ serious injury*
	PBR = 0.2								
Gervais' beaked whale (*Mesoplodon europaeus*)	N_{best} = 57 (CV = 1.40) N_{min} = 24 (Estimate for all *Mesoplodon* sp.) PBR = 0.2	Oceanic throughout the Gulf	Unknown	Very cryptic, usually in groups of less than 5	Unknown	Unknown	Primarily squids, also deepwater fishes	Unknown	Unknown, possible military activities (sonar) in Atlantic Ocean and fisheries interactions
Bottlenose dolphin (*Tursiops truncatus*) continental shelf stock	Unknown, survey data more than 8 years old, PBR undetermined	Waters from 20 to 200 m throughout the Gulf	Uncertain but complex, stock is a mixture of genetically distinct coastal and offshore ecotypes	Highly social	Unknown	Unknown	Generalist, preference for sciaenids, scombrids, and mugilids, with squids more important in deeper waters	Unknown	Fisheries interactions, gunshot wounds, vessel strikes, oil rig removals, marine debris entanglement and ingestion
Bottlenose dolphin (*Tursiops truncatus*) eastern coastal stock	N_{best} = 7,702 (CV = 0.19) N_{min} = 6,551 PBR = 66	Mainland shore to waters 20 m deep east of 84° W	Uncertain but complex, coastal stocks divided for management purposes based on dissimilar habitat characteristics	Highly social	Unknown	Limited health assessment data from Sarasota Bay	Generalist, preference for sciaenids, scombrids, and mugilids, with squids more important in deeper waters	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, dredging, harmful algal blooms, disease, gunshot wounds, mutilations, vessel strikes, oil rig removals, marine debris entanglement and ingestion

Species/stock (E=endangered, S=strategic)	Abundance – N_{best} (CV) N_{min} PBR	Distribution and movement patterns	Stock structure	Social structure	Vital rates	Health status	Prey species	Total human-caused mortality/ serious injury	Possible sources of human-caused mortality/ serious injury*
Bottlenose dolphin (*Tursiops truncatus*) northern coastal stock	N_{best} = 2,473 (CV = 0.25) N_{min} = 2,004 PBR = 20	Mainland shore to waters 20 m deep from the Mississippi River Delta east to 84°W	Coastal stocks divided for management purposes based on dissimilar habitat characteristics	Highly social	Unknown	Limited health assessment data from St. Joseph Bay	Generalist, preference for sciaenids, scombrids, and mugilids, with squids more important in deeper waters	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, dredging, red tide, disease, gunshot wounds, mutilations, vessel strikes, oil rig removals, marine debris entanglement and ingestion
Bottlenose dolphin (*Tursiops truncatus*) western coastal stock (S)	Unknown, survey data more than 8 years old, PBR undetermined	Mainland shore to waters 20 m deep west of the Mississippi River Delta	Uncertain but complex, coastal stocks divided for management purposes based on dissimilar habitat characteristics	Highly social	Unknown	Unknown	Generalist, preference for sciaenids, scombrids, and mugilids, with squids more important in deeper waters	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, dredging, red tide, disease, gunshot wounds, mutilations, vessel strikes, oil rig removals, marine debris entanglement and ingestion
Bottlenose dolphin (*Tursiops truncatus*) oceanic stock	N_{best} = 3,708 (CV = 0.42) N_{min} = 2,641 PBR = 26	Upper continental slope (200-1000 m) throughout the Gulf	Uncertain but assumed complex	Offshore morphotype; groups as big as 200 but typically around 20	Unknown	Unknown	Generalist, preference for sciaenids, scombrids, and mugilids, with squids more important in deeper waters	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, disease, gunshot wounds, mutilations, vessel strikes, oil rig removals, marine debris entanglement and ingestion
Bottlenose dolphin (*Tursiops truncatus*) St. Joseph Bay stock (S)	N_{best} = 81 (CV = 0.14) N_{min} = 72 PBR=0.7	St. Joseph Bay	Stocks provisionally based on discrete communities,	Community-based, some individuals exhibit extreme philopatry	Some data regarding individual reproduc-tive rates,	Limited health assessment data	Preference for sciaenids, scombrids, and mugilids	Unknown, minimum estimates from stranding data not	Fisheries interactions, ecotourism, red tide, marine debris entanglement and

Species/stock (E=endangered, S=strategic)	Abundance – N_{best} (CV) N_{min} PBR	Distribution and movement patterns	Stock structure	Social structure	Vital rates	Health status	Prey species	Total human-caused mortality/ serious injury	Possible sources of human-caused mortality/ serious injury*
			supported by genetics data		stock-wide rates unknown			distinguished by stock	ingestion
Bottlenose dolphin (*Tursiops truncatus*) St. Vincent Sound/ Appalachicola Bay/ St. George Sound stock (S)	N_{best} = 537 (CV = 0.09) N_{min} = 498PBR = 5	St. Vincent Sound/ Appalachicola Bay/ St. George Sound	Stocks provisionally based on discrete communities, supported by genetics data	Community-based, some individuals exhibit extreme philopatry	Some data regarding individual reproduc-tive rates, stock-wide rates unknown	Unknown	Preference for sciaenids, scombrids, and mugilids	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, ecotourism, red tide, marine debris entanglement and ingestion
Bottlenose dolphin (*Tursiops truncatus*) Barataria Bay stock (S)	N_{best} = 138 (CV = 0.08) N_{min} = 129 PBR = 1.3	Barataria Bay	Stocks provisionally based on discrete communities, supported by genetics data	Community-based, some individuals exhibit extreme philopatry	Some data regarding individual reproduc-tive rates, stock-wide rates unknown	Unknown	Preference for sciaenids, scombrids, and mugilids	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, ecotourism, red tide, marine debris entanglement and ingestion
Bottlenose dolphin (*Tursiops truncatus*) 29 remaining bay, sound, and estuarine stocks (S)	Unknown, survey data more than 8 years old, PBR undetermined for remaining 30 stocks	Bays, sounds, and estuaries throughout the Gulf	Stocks provisionally based on discrete communities, supported by genetics data	Community-based, some individuals exhibit extreme philopatry	Some data regarding individual reproduc-tive rates, stock-wide rates unknown	Unknown	Preference for sciaenids, scombrids, and mugilids	Unknown, minimum estimates from stranding data not distinguished by stock	Fisheries interactions, ecotourism, red tide, marine debris entanglement and ingestion
Atlantic spotted dolphin (*Stenella frontalis*)	Unknown, survey data more than 8 years old, PBR undetermined	Continental shelf throughout the Gulf, generally in waters 20-200 m	Unknown, separate from Atlantic stock for management purposes, supported by genetics data	Typical group sizes are less than 50; associate with smaller groups of bottlenose dolphins in some cases	Unknown	Unknown	Small epi- and mesopelagic fishes and squids, and benthic invertebrates	Unknown	Fisheries interactions, dredging, red tides

Species/stock (E=endangered, S=strategic)	Abundance – N_{best} (CV) N_{min} PBR	Distribution and movement patterns	Stock structure	Social structure	Vital rates	Health status	Prey species	Total human-caused mortality/ serious injury	Possible sources of human-caused mortality/ serious injury*
Pantropical spotted dolphin (*Stenella attenuata*)	N_{best} = 34,067 (CV = 0.18) N_{min} = 29,311 PBR = 293	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Typical groups are less than 100 dolphin but as many as 650 dolphins in a group have been observed	Unknown	Unknown	Small epi- and mesopelagic fishes, squids and crustaceans	Unknown	Unknown
Striped dolphin (*Stenella coeruleoalba*)	N_{best} = 3,325 (CV = 0.48) N_{min} = 2,266 PBR = 23	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Typical groups consist of about 50 dolphins	Unknown	Unknown	Small epi- and mesopelagic fishes and squids	Unknown	Vessel strike
Spinner dolphin (*Stenella longirostris*)	N_{best} = 1,989 (CV = 0.48) N_{min} = 1,356 PBR = 14	Continental slope (200-2000 m), primarily in the eastern Gulf	Unknown, separate from Atlantic stock for management purposes	Occur in very large cohesive groups of up to 800 dolphins	Unknown	Unknown	Small epi- and mesopelagic fishes and squids	Unknown	Fisheries interactions
Rough-toothed dolphin (*Steno bredanensis*)	Unknown, survey data more than 8 years old, PBR undetermined	Oceanic throughout the Gulf and, less commonly, the continental shelf	Unknown, separate from Atlantic stock for management purposes	Typically in groups of less than 25 dolphins; associated with Sargassum in many cases	Unknown	Limited info from rehab animals	Fish, including larger species (mahi mahi) and squids	Unknown	Unknown
Clymene dolphin (*Stenella clymene*)	N_{best} = 6,575 (CV = 0.36) N_{min} = 4,901 PBR = 49	Oceanic throughout the Gulf but more common west of the Mississippi River	Unknown, separate from Atlantic stock for management purposes	Occur in large groups of up to 300 dolphins	Unknown	Unknown	Little known, small epi – and mesopelagic fishes and squids	Unknown	Unknown

Species/stock (E=endangered, S=strategic)	Abundance – N_{best} (CV) N_{min} PBR	Distribution and movement patterns	Stock structure	Social structure	Vital rates	Health status	Prey species	Total human-caused mortality/ serious injury	Possible sources of human-caused mortality/ serious injury*
Fraser's dolphin (*Lagenodelphis hosei*)	Unknown (no recent sightings) PBR undetermined	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Extremely rare; associated with melon-headed whales in some cases	Unknown	Unknown	Small midwater fishes, squids, and crustaceans	Unknown	Unknown
Killer whale (*Orcinus orca*)	N_{best} = 49 (CV = 0,77) N_{min} = 28 PBR = 0.3	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Groups typically of 6-10 whales. Photo-identification indicates wide ranging but with some habitat fidelity.	Unknown	Unknown	Gulf prey largely unknown, one instance of predation on pantropical spotted dolphins	Unknown	Unknown
False killer whale (*Pseudorca crassidens*)	N_{best} = 777 (CV = 0.56) N_{min} = 501 PBR = 5	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Occur in cohesive groups that average 25 whales	Unknown	Unknown	Fish including larger species (mahi mahi) and squids, known to attach small and large cetaceans	Unknown	Fisheries interaction
Pygmy killer whale (*Feresa attenuata*)	N_{best} = 323 (CV = 0.60) N_{min} = 203 PBR = 2	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Little known; occur in groups of less than 20 whales	Unknown	Unknown	Fishes and squids, known to attack small cetaceans	Unknown	Unknown
Dwarf sperm whale (*Kogia sima*)	N_{best} = 453 (CV = 0.35) N_{min} = 340 (Estimate for all *Kogia* spp.) PBR = 3.4	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Very cryptic, usually in groups of less than 5	Unknown	Unknown	Primarily deepwater cephalopods	Unknown, minimum estimates from stranding data	Fisheries interactions, ingestion of marine debris
Pygmy sperm whale (*Kogia breviceps*)	N_{best} = 453 (CV = 0.35) N_{min} = 340	Oceanic throughout the Gulf	Unknown, separate from Atlantic stock	Very cryptic, usually in groups of less than 5	Unknown	Limited data from captive	Primarily deepwater cephalopods	Unknown, minimum estimates from	Fisheries interactions, ingestion of

Species/stock (E=endangered, S=strategic)	Abundance – N_{best} (CV) N_{min} PBR	Distribution and movement patterns	Stock structure	Social structure	Vital rates	Health status	Prey species	Total human-caused mortality/ serious injury	Possible sources of human-caused mortality/ serious injury*
	(Estimate for all *Kogia* spp.) PBR = 3.4		for management purposes			animals		stranding data	marine debris
Melon-headed whale (*Peponocephala electra*)	N_{best} = 2,283 (CV = 0.76) N_{min} = 1,293 PBR = 13	Oceanic throughout the Gulf but more common west of the Mississippi River	Unknown, separate from Atlantic stock for management purposes	Occur in large cohesive groups of up to 275 whales	Unknown	Unknown	Small fishes and squids	Unknown, minimum estimates from stranding data	Unknown
Risso's dolphin (*Grampus griseus*)	N_{best} = 1,589 (CV = 0.27) N_{min} = 1,271 PBR = 13	Shelf break area and oceanic throughout the Gulf	Unknown, separate from Atlantic stock for management purposes	Multiple groups of 5-10 dolphins typically occur over large areas	Unknown	Limited data from captive animals	Crustaceans, squids, and other cephalopods	Unknown, minimum estimates from stranding data	Fisheries interactions, red tide
Pilot whale, short finned (*Globicephala macrorhyncus*)	N_{best} = 716 (CV = 0.34) N_{min} = 542 PBR = 5.4	Oceanic throughout the Gulf but more common west of the Mississippi River	Unknown, separate from Atlantic stock for management purposes	Highly social; in groups of 20 or more	Unknown	Unknown	Primarily squids but also fishes	Unknown, minimum estimates from stranding data	Fisheries interactions
West Indian Manatee (*Trichechus manatus*) (E/S)	N_{min} (via aerial surveys) = 5,067 (2,779 on east coast of Florida, 2,288 on west coast of Florida) PBR = 12	In freshwater, brackish and marine environments along the Gulf, from Florida to Louisiana	Florida manatees considered a single stock, but separated into management units	Disperse in the warmer months to feed, breed and socialize; aggregate to warm-water refuges during colder times of year; calves typically stay with a cow for 2 years	Rmax= 6.2%	Limited studies provide data on contamin-ants, hormone levels, and nutrition	Herbivores; feed on an extensive range of aquatic vegetation	Minimum estimates from stranding data	Vessel strikes, cold water exposure, red tides, drowning in water control structures, fisheries interactions, marine debris entanglement and ingestion

Appendix B. Anthropogenic and natural risk factors in the Gulf of Mexico

Activities	Specific risk factor	Potential consequences
Oil and gas development	Oil spills and leaks	Direct exposure: skin irritation/inflammation, necrosis, respiratory effects, organ damage Indirect: shifts in or loss of prey, habitat degradation
	Noise (seismic surveys, construction and decommissioning of oil platforms, and general operations)	Physical trauma, avoidance of preferred habitat
	Vessel operations	Vessel collisions (injury/mortality), avoidance of preferred habitat
	Production waste (drill fluids and cuttings, produced water, deck drainage, municipal wastes, and debris)	Organ damage and impaired immune system function from heavy metal contamination, habitat degradation (decreased water quality), loss of prey
Commercial and recreational fishing	Fishing with nets, lines, pots/traps	Entanglement in and ingestion of fishing gear
	Fishing for prey species	Depletion of prey species, habitat alteration
	Vessel operations	Vessel collisions (injury/mortality), avoidance of preferred habitat
Shipping and vessel traffic	Noise, vessel operations	Vessel collisions (injury/mortality), avoidance of preferred habitat
Military activities	Vessel operations	Vessel collisions (injury/mortality), avoidance of preferred habitat
	Noise (SONAR training and testing, explosives)	Acoustic and non-acoustic physical trauma, avoidance of preferred habitat, mortality in severe cases
Agriculture	Runoff of land-based pollutants (resulting in harmful algal blooms, anoxic or hypoxic "dead" zones)	Direct: injury/mortality Indirect: habitat degradation, shifts in or loss of prey species
Coastal development	Noise from pile driving for marina and bridge/causeway construction	Acoustic trauma (at short range), acoustic disturbance, avoidance of preferred habitat
	Dredging	Loss of sea grass beds, habitat degradation
	Loss of coastal wetlands and other coastal habitats	Loss of prey habitat, habitat degradation
Renewable energy	Pile driving for anchoring wind and wave turbines	Acoustic trauma (at short range), acoustic disturbance, avoidance of preferred habitat
	Turbine operations	Physical trauma, electromagnetic disturbance, avoidance of preferred habitat
Greenhouse gas emissions	Ocean acidification	Shifts in or loss of prey species
	Warming seas	Habitat degradation, shifts in or loss of prey
	Increased storm activity and increased severity of storms	Shifts in prey, avoidance of preferred habitat
	Sea level rise, leading to coastal habitat loss	Loss of prey habitat, habitat degradation
Natural events	Seepage of oil	Direct: organ damage Indirect: habitat degradation
	Harmful algal blooms (red tide)	Injury/mortality, shifts in prey
	Predation	Injury/mortality
	Large-scale ecosystem fluctuations	Shifts in or loss of prey

Activities	Specific risk factor	Potential consequences
	Hurricanes	Shifts in prey, avoidance of preferred habitat, displacement of animals, habitat degradation or destruction
	Water temperature anomalies	Shifts in prey, avoidance of preferred habitat, cold stress

Appendix C. References describing data collection and analysis methods

The following references provide detailed descriptions of data collection and analytical methods used to assess the potential effects of the Deepwater Horizon oil spill on marine mammals in the Gulf of Mexico. References include Gulf-specific studies where available.

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Appendix D. Online resources for the Deepwater Horizon oil spill

A number of websites have been established to provide information to the public regarding the Deepwater Horizon oil spill. The following is a select list. (All sites last accessed 3 August 2011.)

U.S. Government website on Deepwater Horizon oil spill response and restoration activities: http://www.restorethegulf.gov

National Oceanic and Atmospheric Administration Office of Response and Restoration website on Deepwater Horizon oil spill response: http://response.restoration.noaa.gov/deepwaterhorizon

National Oceanic and Atmospheric Administration Damage Assessment, Remediation, and Restoration Program's Gulf Spill Restoration website (including Natural Resource Damage Assessment workplans): http://www.gulfspillrestoration.noaa.gov

National Marine Fisheries Service Office of Protected Resources Gulf of Mexico oil spill website: http://www.nmfs.noaa.gov/pr/health/oilspill.htm

U.S. Fish and Wildlife Service website on Deepwater Horizon oil spill response: http://www.fws.gov/home/dhoilspill/index.html

Environmental Protection Agency Response to the BP Oil Spill in the Gulf of Mexico website: http://www.epa.gov/BPSpill/

Oiled Wildlife Care Network Blog (includes archived postings regarding Deepwater Horizon wildlife response activities): http://owcnblog.wordpress.com

Bureau of Ocean Energy Management, Regulation and Enforcement BP/Deepwater Horizon oil spill library and reading room: http://www.boemre.gov/deepwaterreadingroom

Marine Mammal Commission Deepwater Horizon oil spill website: http://www.mmc.gov/oil_spill/welcome.shtml

National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling website and report: http://www.oilspillcommission.gov

U.S. Coast Guard/Bureau of Ocean Energy Management, Regulation and Enforcement Joint Investigation Team website and report: http://www.deepwaterinvestigation.com

Gulf of Mexico Research Initiative (BP funded research on effects of the Deepwater Horizon oil spill and related topics): http://www.gulfresearchinitiative.org

Gulf of Mexico Sea Grant Programs Deepwater Horizon Oil Spill Research and Monitoring Activities Database: http://gulfseagrant.tamu.edu/oilspill/database.htm


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