Ecological Damage and Restoration
for the BP *Deepwater Horizon* Gulf of Mexico Oil Spill:
Lessons Learned from the *Exxon Valdez* Experience

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United States Senate

Environment and Public Works Committee

Subcommittee on Water and Wildlife

"Assessing Natural Resource Damages Resulting from the BP Deepwater Horizon Disaster"

July 27, 2010

Thank you inviting me to testify with regard to assessing the impact of the *Deep Horizon* oil spill in the Gulf of Mexico. I was Chief Scientist for the *Exxon Valdez* Oil Spill Trustee Council from 1990 to 2001 during the Damage Assessment and Restoration programs. Those of us who participated in these programs learned much from this experience, and I hope we can pass this on to those who are dealing with the current spill. While every oil spill varies with the circumstances, large damaging spills share enough characteristics to be notable, especially in the human response. My colleague Stan Senner is providing testimony on the procedural and administrative lessons in Alaska, and I will emphasize scientific lessons learned. Some of our testimony relies on a document that we assembled with the assistance of Dr. Charles Peterson of the University of North Carolina, Dr. Dennis Heineman of the Ocean Conservancy, and Dr. Jeff Short of Oceana. (see attachment A).

Following the *Exxon Valdez* oil spill in 1989 a large number of studies were initiated to determine the damage from the spill, many of which lasted several years or more. Then in 1991 a settlement was reached with the Exxon Corporation for damage to public resources. The settlement initiated the Restoration Program with annual payments from the Exxon Corporation of $90 million a year for 10 years. A final Restoration Plan was approved by the trustee council in 1994. Some damage assessment was carried forward into the restoration phase and it became apparent that there was an unanticipated lack of recovery of injured species and lingering damage. This unanticipated damage resulted in a claim by the State and Federal governments for further compensation in 2006 under a reopener clause in the original settlement agreement. That claim has not been resolved.

In the course of assessing the impact of the *Exxon Valdez* spill we were able to evolve our approach to achieve a relatively efficient and effective scientific program in damage assessment and especially in restoration. It took some time to achieve this, and because the present spill is so much larger and involves so many more agencies and interests, it

will be an immediate challenge to make the scientific work comprehensive and integrated.

It is critically important that we do all we can to ensure that the pre- and post-impact status of the Gulf ecosystems, including contaminant characterizations, is being assessed and documented as rigorously as possible in at least the most biologically productive and sensitive parts of the Gulf coast. These areas include the estuaries and especially the marshes and wetlands behind the barrier islands along the coast, which are the breeding and nursery grounds of myriad aquatic, intertidal, and avian species. Given the widespread and intensive application of chemical dispersants, the very large amounts of oil on the ocean's surface, and the presence of large quantities of subsurface oil, it also is critical to be sampling oceanic surface, deepwater and bottom communities as well.

Here are ten lessons learned or suggestions; some of these may be obvious and others not.

1. **Value of an ecosystem-based approach.** Because many state and federal government natural resource agencies are organized and operated based on individual species, it is not easy to implement ecosystem-based approaches. Organizing spill studies around individual species or groups of species at the expense of a broader ecosystem-based view--e.g., studying impacts on seabirds and their recovery independent of the ecological conditions that sustain them (food supply, habitat quality, etc.)--make it hard to achieve an overall assessment of the health of the Gulf ecosystem. Ultimately, however, the health of the ecosystem, more so than the individual pieces, should be the yardstick by which we judge the success of a large-scale restoration program.

   Several years after the Alaskan spill, when affected populations were not meeting recovery objectives, we launched a series of ecosystem-based studies of fish, birds and mammals that cast a much larger net in Prince William Sound, taking into account food supply, reproduction, disease, and predators, as well as any lingering oil exposure. These studies were very effective in achieving a better understanding of the individual species for which management agencies were responsible, and also gave us insight into the trajectory of an ecosystem that is so important to the people of Alaska. In addition, these multi-disciplinary and multi-institutional studies helped breakdown artificial barriers that inevitably grow as a result of dividing up the responsibility for the ecosystem, when no such divisions exist in nature. We actually allocated seed money to groups of government, academic and private industry scientists to plan these ecosystem-based studies, which then went through several rounds of peer review by outside independent scientists. The end result was more tightly integrated and comprehensive studies across institutional lines.

2. **Value of a complete assessment of damage**. It is important not to end a damage assessment too soon, as subtle and indirect effects may not emerge for a while and we must understand the entirety of the damage to know when the ecosystem has been made whole. For example, detailed laboratory experiments carried out on pink salmon years after the Alaska spill showed that damage could

be done to developing embryos and expressed later in poor survival of adults as the result of exposure to oil in the low parts per billion range, as opposed to parts per million. These findings support a view that there can be damaging effects from a spill long after the visible oil is gone.

3. **How studies now will help in the future.** Beyond knowing the full impact of a large spill, a rigorous and robust scientific program pays long-term dividends in advancing our knowledge of ecosystems so that we may more intelligently manage marine activities in the future. For example, pink salmon management in Prince William Sound was advanced greatly by the detailed studies during the damage assessment and restoration work following the *Exxon Valdez* spill. Support from the restoration program enabled the mass marking of hatchery reared pink salmon in Prince William Sound, making it possible to distinguish them from and better protect wild stocks. While no one wants ecological disasters, it is important not to miss the opportunity to gain knowledge that will enable better future management.

4. **Value of historical data.** Take advantage of those organisms and habitats that have the best timelines of data and research prior to the spill as possible indicators of pre-spill conditions. Such information can permit application of the rigorous and potentially powerful statistical assessment approach, the Before-After-Control-Impact design (known as BACI). For example, finding damage to the harbor seal population in Prince William Sound was enabled by good aerial survey data leading up to the spill, and these surveys were continued for years afterwards. Funding implementation of an Ocean Observing System in the Gulf of Mexico, as well as in other parts of the country, would represent real progress establishing environmental baselines that will support evaluation of future threats and long-term restoration from this spill.

5. **Documenting the physical properties and detailed chemical composition of the oil**. Detailed chemical analyses of oil from the reservoir tapped by the *Deepwater Horizon* are crucial to anticipating the behavior and biological effects of the oil, as well as for confirming the provenance of oil collected from impacted environments. These tests and analyses should be conducted on oil samples collected before and after contact with seawater. Physical tests on oil collected prior to seawater contact should include measurements of viscosity, compressibility and density as functions of temperature and pressure. Chemical composition analyses should include measurements of normal alkanes, beginning with methane through at least tetracontane (n-C_{40}), aromatic hydrocarbons from benzene through 6-ring polycyclic aromatic hydrocarbons (PAH), including alkylated homologues bearing up to four alkyl carbon atoms, and alicyclic biomarkers analyzed by gas-chromatography/mass spectrometry at m/z 191, 217 and 218. These measurements also should be done on samples at various states of weathering to document how composition changes. The chemical similarity of oil spilled from the *Deepwater Horizon* and other sources of South Louisiana crude oil, as well as from the presence of numerous natural and human-derived sources of petroleum in the Gulf, make it important to chemically differentiate

spilled oil in various states of weathering and other sources of petroleum present in samples of water sediment and tissues collected.

6. **The power to detect change.** The obvious bears stating: longer time series and more frequent sampling will enhance statistical power to detect change. Monitoring programs need to be designed to distinguish oil-spill responses from unrelated spatial and temporal variation in the ecosystems that are affected. Many wildlife census techniques are surprisingly only able to detect changes when they are greater than about 50%, but the chances of detecting change are much better with longer time-series and more frequent sampling. In Alaska the Exxon corporation scientists claimed that as long as the census data for a species fell within the statistical bounds of historical data then that species could be considered recovered. So frequent and long-term sampling will be useful for better understanding both damage and recovery.

7. **Planning now for a smaller long-term program in the future.** Greater efficiency in the future can be obtained by coordinating offshore chemical and biological sampling with onshore efforts, so that when the wide scope of initial studies is eventually scaled back, it will be easier to consolidate the effort and retain maximum logistical efficiency. Stated another way, all other considerations being equal, co-locate as many different chemical/biological studies as possible at the same stations. This approach is essential to integration of studies that must be done to provide the ecosystem-based approach, which is the only means of inferring broader indirect effects of the spill. The models routinely used to estimate natural resource impacts of oil spills by matching oil concentrations, transport, chemical transportation, and fate to spatial distribution of biological resources only address short-term acute impacts of separate species, thereby seriously underestimating ecosystem impacts of the spill. Our initial studies of the intertidal damage from the *Exxon Valdez* in Alaska were largely uncoordinated with subtidal assessments, so that it became impossible to achieve a maximally integrated and less expensive program in later years. In fact, the initial intertidal studies documenting extensive damage were so elaborate that conducting valid follow up studies to assess recovery in later years would have cost many millions of dollars. Hence, the Exxon Valdez Oil Spill Trustee Council had other priorities and chose not to conduct those follow up studies.

8. **Available ships**. The lack of oceanographic sampling platforms, e.g. ships, though not a big problem in Alaska, appears to be one in the Gulf of Mexico. I have colleagues who wish to revisit stations in Gulf of Mexico that were sampled in years before the spill, but are unable to find a sampling platform. There is apparently a bottleneck for research into the effects of the spill due to the limited amount of ship time and space available.

9. **How many were killed?** Typically, only a small proportion of the marine birds, mammals and turtles that are killed by a spill are ever recovered at sea or ashore. Given that a number of factors, such as oil type, wind patterns, distance from shore, scavenging rates, and taxon-specific buoyancy of carcasses affect the recovery rate, it is necessary to rigorously design and implement carcass recovery

efforts and experiments to estimate loss rates and enable accurate estimates of the total numbers of wildlife mortalities.

10. **How toxic is the oil?** It will be important to initiate laboratory studies of oil and dispersant toxicity in large aquaria simulating natural ecosystems to augment the field assessment studies. These toxicity studies should involve collection of freshly released *Deepwater Horizon* oil as well as oil at various stages of aging and weathering in the testing. Experiments should run tests of oil alone and, very critically, oil combined with dispersants. The tests should not end with the typical short-term 3-5 day acute toxicity tests, but should include treatments to assess chronic impacts of longer-term (months) exposures, perhaps pulsed so as to replicate the continuing delivery of *Deepwater Horizon* oil into the Gulf. There are virtually no available data on toxicity of oil to deepwater species and to the degree possible much more testing should be done. It is possible that this approach may yield more information on the consequences of the spill to the broader Gulf of Mexico ecosystem as other approaches, especially its deep pelagic fauna, as it is notoriously difficult to establish pollution effects to mobile pelagic organisms from field census data.

In conclusion there are valuable lessons to be learned from the *Exxon Valdez* oil spill experience that will help refine the damage assessment and restoration activities in the Gulf of Mexico. Application of these lessons would make the large sums of money spent under these programs more efficient and effective in determining what happened, satisfying the American Public and helping to make the Gulf Mexico whole.

Attachment A

Assessing Natural Resource Damages from the BP *Deepwater Horizon* Gulf of Mexico Oil Spill: Lessons Learned from the *Exxon Valdez* Experience
May 24, 2010

It is critically important that we do all we can to ensure that the pre- and post-impact status of ecosystems, including contaminant levels, are documented as rigorously as possible in at least those parts of the Gulf coast that are most sensitive, most biologically productive, and most important for wildlife and habitat conservation. These areas include the estuaries and especially the marshes and wetlands behind the barrier islands along the coast, which are the breeding and nursery grounds of myriad aquatic, intertidal, and avian species. Given the widespread and intensive application of chemical dispersants and uncertain fate of oil from a deepwater source, however, it also is critical to be sampling pelagic and benthic communities as well.

We have not had the opportunity to review or be briefed on the full suite of damage assessment and monitoring activities in the Gulf, but each of us (see below) is a veteran of the damage assessment and restoration science programs in Prince William Sound and the northern Gulf of Alaska following the *Exxon Valdez* oil spill (EVOS). Based on our collective experience, we offer the following recommendations with respect to the current situation in the Gulf of Mexico. This is not a comprehensive list of suggestions; some of these items may be obvious and others may not be. Any or all of us would be pleased to discuss these ideas further. Our contact information is below (at bottom).

Organizational

1. Put in place a strong coordinating scientific body, including at least a core group of external peer reviewers who remain in place on an extended basis, thus providing continuity in perspectives. Such a structure will help ensure coordination and cull unnecessary or marginal studies (which often are previously unfunded projects that agencies have wanted to carry out for a long time) that come out of the woodwork in times of crisis. Coordination needs involve meeting the challenge of forging an ecosystem-based natural resource injury assessment that acknowledges the interconnectedness among resources and creates explicit linkages among injury assessment studies. An effort should be made to include experts who have experience with comparable oil spills, such as the IXTOC I or other spills in subtropical waters.
2. Transparency is essential. The public will want to know what is being studied and what is being learned. While some of those details may be sensitive, it is crucial to share whatever can be appropriately shared about impacts. This will allay unnecessary fears and concerns about secrecy. The Unified Command/response organization already has provided a web page to coordinate and share news. Something similar is one tool that would help with communication about the scientific effort to the public and with coordination among researchers.

3. Institute integrated ecosystem-based studies on what are anticipated to be the hardest hit areas as a means to coordinate and merge—both conceptually and operationally—what otherwise could be disparate efforts of various federal, state and local agencies, as well as universities and private companies, across the Gulf of Mexico. Integrated studies will produce the best and most useful science, as well as be most efficient from an organizational standpoint. Only by constructing an ecosystem context for the injury assessment studies can indirect effects of the spill be inferred and evaluated, such as consequences of impacts on competitors, prey, and predators that can include trophic cascades.

Scientific

1. Put integrative water quality samplers, such as semi-permeable membrane devices (SPMDs), in key habitats and make use of bivalves, such as oysters, with existing histories of PAH analyses. It is critical to establish chemical baselines that will enhance the capacity to infer impacts of the spill wherever damage is most likely to occur. Suspension feeders, such as oysters, are very efficient at accumulating particulate matter, including oil microdroplets that may result from natural or artificial dispersion of oil into the water column.
2. Deployment of SPMDs, preferably spiked with performance reference compounds (i.e., selected perdeuterated PAH), permits time-integrated detection of background non-polar organic contaminant concentrations at the parts per trillion level. While it will take perhaps a week or two to procure and deploy SPMDs (commercially available from Environmental Sampling Technologies [St. Joseph, MO]), their deployment now and retrieval after another two weeks will give an unparalleled indication of background contamination levels. The ability of contaminants extracted from SPMDs deployed prior to impacts from the *Deepwater Horizon* accident to elicit CYP1A responses in standardized test organisms, such as rainbow trout, is an especially powerful approach for evaluating the effects of potentially confounding background contaminants.
3. It is likely that the sea surface microlayer fauna will be greatly affected, so sampling it (control and impact) may provide measures of damage, especially to floating fish eggs and larval stages of fish and crustaceans. We missed this in EVOS.
4. Take advantage of those organisms and habitats that have the best baselines and timelines of data and research prior to the spill as possible indicators of pre-spill conditions. Such information can permit application of the rigorous and potentially powerful statistical assessment approach, the Before-After-Control-Impact design (known as BACI).
5. Documenting the physical properties and chemical composition of the oil from the reservoir tapped by the *Deepwater Horizon* is crucial to anticipating the behavior and biological effects of the oil, as well as for confirming the provenance of oil collected from impacted environments. These tests and analyses should be conducted on oil samples collected before and after contact with seawater. Physical tests on oil collected prior to seawater contact should include measurements of viscosity, compressibility and density as functions of temperature and pressure. Chemical composition analyses should include measurements of normal alkanes, beginning with methane through at least

tetracontane (n-C_{40}), aromatic hydrocarbons from benzene through 6-ring polycyclic aromatic hydrocarbons (PAH), including alkylated homologues bearing up to four alkyl carbon atoms, and alicyclic biomarkers analyzed by gas-chromatography/mass spectrometry at m/z 191, 217 and 218. These measurements also should be done on samples at various states of weathering to document how composition changes.

6. The most useful pre-impact information on baseline levels of exposure to organic toxicants includes documentation of basal levels of the liver enzyme cytochrome P4501A1 (CYP1A), which requires excision of liver tissue and immediate storage in liquid nitrogen. This enzyme is induced in response to exposure to many of the toxic components in crude oil and is one of the most sensitive indicators of exposure available. Other environmental contaminants also can induce CYP1A (e.g., PCBs), so documenting pre-impact levels will be extremely valuable for detecting induction of oil contaminants in fish habitat. For fish, the most useful species would be one that is easily collected, abundant and widely distributed along the coastal estuaries, but don't forget the pelagic environment, especially given the widespread use of dispersants, which is presumably dispersing oil widely in the water column. In the case of EVOS, some of the best documented lingering effects were found in harlequin ducks, a diving species that feeds largely off benthic mollusks that were associated with oil-contaminated sediments.
7. Pre-impact samples of benthic infauna on Gulf beaches, tidal flats, and salt marshes are very important. These invertebrates in sedimentary habitats are largely sessile, thus showing clearly any spatially explicit oiling impact, and serve as prey for many bottom-feeding fishes, shorebirds, ducks, and crustaceans, such as the commercially important blue crab. The statistically most powerful design for sampling impacts to shoreline communities involves pairing oiled and control sites, where pairing is done to ensure environmental similarity in all physical, chemical, and sedimentary conditions prior to the spill. Such paired designs, using replicate pairs of oiled and control sites, can minimize confounding due to differences in the pre-existing environment.
8. Identify any ongoing biological sampling efforts (e.g., National Status and Trends Mussel Watch, bird surveys, etc.), and especially those for species at risk and of special concern, and then maintain and enhance the sampling effort in the context of creating a sampling design that permits a rigorous assessment of spill impacts.
9. The obvious bears stating: longer time series and more frequent sampling will enhance statistical power to detect change. Monitoring programs need to be designed to distinguish oil-spill responses from unrelated spatial and temporal variation in the ecosystems that are affected.
10. Coordinate offshore chemical and biological sampling with onshore efforts, so that when the wide scope of initial studies is eventually scaled back, you will be able to collapse the effort and retain maximum logistical efficiency. Stated another way, all other considerations being equal, co-locate as many different chemical/biological studies as possible at the same stations. This approach is essential to integration of studies that must be done to provide the ecosystem-based approach, which is the only means of inferring broader indirect effects of the spill. The routine models used to estimate natural resource impacts of oil

spills by matching oil concentrations, transport, chemical transportation, and fate to spatial distribution of biological resources only address short-term acute impacts of separate species, thereby seriously underestimating ecosystem impacts of the spill.

11. Make sure QA/QC procedures are in place. It is perhaps best to adopt those of the NOAA NRDA group rather than inventing new ones.
12. Typically, only a small proportion of the marine birds, mammals and turtles that are killed by a spill are ever recovered at sea or ashore. Given that a number of factors, such as oil type, wind patterns, distance from shore, scavenging rates, and taxon-specific buoyancy of carcasses affect the recovery rate, it is necessary to rigorously design and implement carcass recovery efforts and experiments to estimate loss rates and enable accurate estimates of the total numbers of wildlife mortalities.
13. Given evidence of subsurface oil in the deeper waters of the Gulf of Mexico, much more attention should be focused on the size and trajectory of the submerged oil plume, its impacts to deepwater benthic communities, and the associated deepwater use of chemical dispersants. The impacts of the *North Cape* oil spill at Point Judith, Rhode Island, should be examined to help design impact assessment studies for the *Deepwater Horizon* spill because this spill occurred during windy and wavy conditions that mixed and dispersed the oil throughout the water column, resulting in substantial mortality of lobsters and crabs from the sea floor. Some crustaceans are highly sensitive to oil and other toxicants, making the blue crab and shrimps of the Gulf coast important targets of impact studies.
14. Initiate laboratory studies of toxicity in mesocosms that can best reproduce natural field conditions to augment the field assessment studies. These toxicity studies should involve collection of freshly released *Deepwater Horizon* oil and also deploy oil at various stages of aging and weathering in the testing. Experiments should run tests of oil alone and, very critically, oil combined with dispersants. The tests should not end with the typical short-term 3-5 day acute toxicity tests, but should include treatments to assess chronic impacts of longer-term (months) exposures, perhaps pulsed so as to replicate the continuing delivery of *Deepwater Horizon* oil into the Gulf.

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