DISPERSANT USE IN THE **ARCTIC ENVIRONMENT**

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Things You **Should Know**

- Eight countries have territory in the Arctic.
- Depending on the time of year or location of a spill, responding to spills in the Arctic can present unique challenges requiring appropriate equipment, knowledge, and experience.
- The presence of ice and cold temperatures can greatly reduce the spreading and weathering of spilled oil.
- Biodegradation occurs in all marine environments, including ice-covered waters.
- Scientists have been studying the effects of dispersants on the marine environment for over 30 years, and are still actively engaged in dispersant research, development, and innovation in all temperatures, including the Arctic.
- Dispersants can be used effectively in cold temperatures, in the presence of ice, even in brackish waters.
- Dispersant formulations today are more efficient and safer to use in the environment than materials used in early response efforts.
- Dispersant use in Arctic environments and heavy ice is an appropriate response countermeasure if application requirements are met.
- In open drift ice conditions, waves may be strong enough for chemical dispersion of oil; in dense ice, propellers from a vessel can be used to generate turbulence and result in effective dispersion.

Overview

Dispersants are products used in oil spill response to enhance natural microbial degradation, a naturally occurring process where microorganisms remove oil from the environment. All environments contain naturally occurring microbes that feed on and break down crude oil. Dispersants aid the microbial degradation by forming tiny oil droplets, typically less than the size of a period on this page (<100 microns), making them more available for microbial degradation. Wind, current, wave action, or other forms of turbulence help both this process and the rapid dilution of the dispersed oil. The increased surface area of these very small oil droplets in relation to their volume makes the oil much easier for the petroleum-degrading microorganisms to consume.

Dispersants can be used under a wide variety of conditions since they are generally not subject to the same operational and sea state limitations as the other two main response tools — mechanical recovery and burning in place (also known as in-situ burning). While mechanical recovery may be the best option for small, near-shore spills, which are by far the majority, it has only recovered a small fraction of large offshore spills in the past and requires calm sea state conditions that are not needed for dispersant application. When used appropriately, dispersants have low environmental and human health risk and contain ingredients that are used safely in a variety of consumer products, such as skin creams, cosmetics, and mouthwash (Fingas et al., 1991; 1995).

This fact sheet summarizes the oil spill response and dispersant use requirements for releases in Arctic environments, including regulatory requirements.

Fact Sheet Series

Introduction

The Arctic is thought to hold the world's largest remaining untapped gas reserves and some of its largest undeveloped oil reserves with a significant proportion of these reserves existing in offshore coastal habitats in the Arctic's shallow and biologically productive shelf seas. Oil and gas exploration efforts in the Arctic continue to undergo increased public scrutiny because the potential for oil spills, whether from blowouts, pipeline leaks, or shipping accidents, poses a risk to arctic ecosystems. One of the major public concerns is whether an effective oil spill response can be carried out in the Arctic.

The Arctic is characterized by a short productive season, low temperatures, and periods of limited sunlight. As a result, it may take an extended time for Arctic regions to recover completely from the habitat disruption of any kind. Responding to an oil spill presents challenges in general, but Arctic conditions require additional considerations to protect the people and the environment.

Geopolitical Ownership of the Arctic

In 1982, the United Nations treaty known as the "Law of the Sea" Convention, was passed and granted exclusive economic rights to any natural resource that is present on or beneath the sea floor out to a distance of 200 nautical miles (230 miles; 371 kilometers) beyond their natural shorelines. Based on the terms and conditions of the Law of the Sea Convention, significant undersea portions of the Arctic belong to Canada, the United States, Russia, Norway, and Denmark. They can also extend their claim up to 350 miles from shore for any area that is proven to be a part of their continental shelf. This additional resource inclusion adds Iceland, Sweden, and Finland claiming ownership. All of these nations have gained significant oil and natural gas resources as a result of this treaty. However, the United States has yet to sign the treaty due to concerns regarding American economic and security interests.

Arctic Considerations

The following are some of the main factors associated with potential difficulties of working in the Arctic (King, 2012):

- Remoteness and Lack of Infrastructure: there are few existing pipelines to transport oil and gas, few deep-water ports and limited transportation in and out of the area; extreme weather conditions and the presence of ice make transport difficult for much of the year.

FIGURE 1. Geopolitical boundaries within the Arctic Circle. Source: http://www.arctic.gov

- **Low Temperatures:** the extreme winter conditions of the Arctic require that equipment and personal protection be specially designed to withstand frigid temperatures.
- **Harsh Environment:** the range of extremes, e.g., from frozen ground and permafrost to marshy Arctic tundra and the presence of snow and ice, can inhibit activities.
- **Presence of Ice:** dynamic icepack conditions can hinder transport of personnel, equipment, and oil for extended periods.
- **Biological Resources:** the main Arctic resources of concern are (Johnsen et al., 2010):
  - the large number of migratory birds from around the globe that breed and live seasonally in the area, inhabiting both off shore and on shore areas.
  - a variety of mammals that inhabit the regional ocean waters and near shore and shoreline areas, including a number of protected species.
  - fish such as salmon, cod, and pollock that thrive in Arctic and sub-Arctic waters, supporting valuable commercial and subsistence fisheries.

Responding to Spills in the Arctic

Oil spill response is demanding under most circumstances and Arctic conditions can impose additional environmental and logistical challenges. The three primary options for oil spill response are mechanical recovery, in situ-burning, and the use of dispersants. Any final decision to utilize a particular response strategy depends on the spill conditions at the time, relative risks to response personnel and the environment, and a Net Environmental Benefit Analysis (NEBA) of all aspects of the strategy (see **Fact Sheet #6: Assessing Dispersant Use Trade-offs** for a discussion of NEBA).

As in all spill responses, monitoring and observation are crucial in providing real-time information on the size of a surface slick and direction that it may be moving. Such close scrutiny allows responders to modify the response to the changing situation and to use the best tools at all times.

Effects of Arctic Conditions on Spilled Oil

Perhaps the most significant challenge posed by an Arctic spill is dealing with the presence of ice since it may make it more difficult to find a spill, reach it, and safely deploy equipment and personnel. Refer to **Fact Sheet #3 — Fate of Oil and Weathering** for more information on the processes that affect oil on the water's surface.

Processes that need to be considered for oil slicks, and how Arctic conditions influence them, include:[1]

- **Oil spreading:** Cold temperatures tend to slow the rate of spreading. Any oil spilled on an ice surface may be completely contained as a thick pool if the ice has natural contours that act to contain it. As a result, slicks on ice tend to be thicker and less extensive than slicks on open water. Additionally, snow may absorb spilled oil, further reducing its spread.
- **Oil movement:** In many Arctic areas, water currents under the ice are not strong enough to carry spilled oil very far. Surface roughness under the ice will serve to slow oil movement and oil will generally remain in the area where the spill occurred. However, if the ice begins drifting, the oil will drift with it.
- **Evaporation:** Oil spilled in sub-freezing temperatures evaporates more slowly than oil in warmer temperatures. Oil under snow will evaporate even more slowly. Oil under or trapped in ice is not expected to evaporate to any significant extent. Less evaporation means that oil remains suitable for dispersion or burning for longer periods of time.
- **Emulsification and natural dispersion:** Ice environments can reduce mixing action from waves, thus reducing the rate or likelihood of emulsification or natural dispersion.
- **Biodegradation:** Studies have shown that natural biodegradation of oil under Arctic conditions and in the deep ocean continues at a significant rate (McFarlin, 2011; Hazen, 2010; Zhenmei, 2011).
- **Oil under new sea ice:** During extreme cold, oil spilled under new or growing sea ice can be encased in ice within hours to days as the ice grows downward and thickens. However, oil spilled under ice in late spring in the Arctic, or after mid-spring in the sub-Arctic, may not be encased by growing ice since ice no longer continues to grow in warming conditions.

  If oil has been frozen in growing ice, it will remain trapped until the spring thaw, when the daily air temperatures stay above freezing. This will then allow the oil to move to the surface through cracks in the melting ice. Once the oil reaches the ice surface, it may remain in patches on the melting ice.
- **Oil under old sea ice:** Oil spilled under multi-year ice will remain in place as it would under first-year ice, however, older ice appears to trap more oil than first-year ice. This can result in very thick individual pools of oil beneath the surface. Oil spilled under old ice may also rise to the surface through cracks, but this is likely to be much later in the melt season than with new first-year ice.
- **Oil during spring thaw conditions:** When an ice sheet breaks up, oil remaining in melt pools on the surface will likely drain onto the water in the form of a very thin rainbow-colored sheen trailing from the drifting and melting ice. Thick oils that have gelled in the cold could enter the water as thicker, non-spreading mats or droplets. Once exposed to mixing action from waves, fluid oil may naturally disperse or form thicker emulsions, depending on the properties of the oil.

[1] The information provided in this section was obtained from Potter et al.'s "**Spill Response in the Arctic Offshore**" (2012).

Dispersant Use in Arctic Habitats

In general, dispersants are affected by the arctic environment in the following manner:[2]

- **Cold temperatures:** Dispersants are effective when applied at freezing and near-freezing temperatures. If the spilled oil remains liquid, dispersants are likely to be effective if wave action is present or mixing energy is provided in another manner, e.g., propeller wash. If oil can be dispersed, cold temperatures may actually increase the window of opportunity for dispersant use by slowing the weathering process due to evaporation.
- **In ice:** In waters partially covered with ice, waves are greatly reduced, slowing the rate of weathering of the oil. Since weathered oil is more difficult to disperse, the presence of ice can increase the dispersant effectiveness. In areas with less than 70 – 90 % ice cover, decreases in wave energy do not limit the effectiveness of dispersants. In denser ice floe accumulations, however, a response vessel's bow thrusters or propellers may be needed to provide the mixing energy needed for dispersion to occur.
- **Salinity:** Most dispersants are effective in water with a salinity between 25 and 40 parts per thousand (PPT) (e.g., saltwater). The effectiveness of most dispersants declines when salinities are higher or lower than this range, althought dispersants for fresh water use have been developed.
- **Toxicity:** Modern dispersants are composed of low toxicity, biodegradable chemicals, and ingredients found in many household products. The toxicicity effects from dispersed oil are from the oil itself and not the dispersants (EPA, 2010). Dispersants do not increase the toxicity of the oil. Dispersants themselves are of low toxicity to marine life and are less toxic than the oil that is dispersed; concentrations start low and are rapidly diluted. However, dispersed oil can cause temporary impacts to sensitive marine species, but these are limited to the immediate spill vicinity and for a short period of time. See **Fact Sheet #4 — Toxicity and Dispersants** for more information.
- **Biodegradation:** Dispersed oil readily biodegrades in the marine environment at temperatures approaching those expected in Arctic waters (McFarlin, 2010). Naturally occurring oil-degrading microbes begin to grow on dispersed oil droplets within hours to days. Compared to biodegradation rates at room temperature, i.e., at 21°C (70°F), those experienced under Arctic water conditions, ca 0° – 5°C (32-41°F), are only slightly reduced.[3]

Regulatory Requirements

Although arctic conditions pose significant challenges, dispersants are still a viable option. This is especially true when mechanical recovery using such tools as boom and skimmers cannot be used successfully in heavily iced areas. Decision-makers must evaluate the trade-offs and challenges associated with the use of dispersants and make science-based decisions on the likely effects of dispersed oil on the resources and the arctic habitats. A Net Environmental Benefit Analysis (NEBA) should be employed to address the issues associated with oil remaining on the surface or dispersed into the water column.

Regulatory Considerations in the US

Given the challenges of mechanically recovering oil in offshore and coastal environments before it spreads over a much larger area, decisions need to be made about how to best manage floating oil using a combination of response options for the incident-specific conditions. This is particularly true when oil is spilled in an ice environment. A decision to use dispersants involves evaluating the potential trade-offs: decreasing the expected risks to wildlife on the water surface and shoreline habitats while increasing the potential risk to organisms in the water column. It is possible that the use of dispersants may be the only viable response option.

There are several federal and state requirements for protecting the natural resources during an oil spill response, including the waters of the US Arctic.[4] Whenever federal agencies authorize, fund, or carry out actions that may adversely modify or destroy critical habitats, they must consult the federal natural resource trustee agencies to ensure that any effects to protected species and resources from the spill response are documented and

[2] The information provided in this section was obtained from Potter et al.'s "**Spill Response in the Arctic Offshore**" (2012).

[3] For reference, a 5°C (41°F) temperature exists at a 5,000 ft (1,500 m) depth in the Gulf of Mexico and around the world.

[4] During an oil spill event which may affect listed species and/or critical habitat, emergency consultations under the ESA are implemented for oil spill response actions. The FOSC coordinates the consultation requirements specified in the ESA regulations, 50 CFR 402.05, with the pollution response responsibilities outlined in the NCP, 40 CFR 300.

addressed. The regulations that must be addressed in a spill response include:

- The **National Historic Preservation Act** (NHPA) — impacts to cultural and archaeological resources.
- The **Alaska Historic Preservation Act** — including subsistence activities or the resources upon which they depend.
- The **Endangered Species Act** (ESA)/**Essential Fish Habitat** (EFH) and the critical habitat components of each.

Each is summarized below.

National Historic Preservation Act (NHPA)

During an oil spill, there is the potential for the oil as well as the necessary cleanup measures to potentially affect historic properties and archaeological sites. The National Historic Preservation Act (NHPA) requires federal agencies to consider potential impacts of projects they carry out, assist, or permit on historic properties. Historic properties or historic resources are defined as "*any prehistoric or historic district, site, building, structure, or object included in, or eligible for inclusion in, the National Register [of Historic Places], including artifacts, records, and material remains related to such a property or resource.*" Historic properties need not be formally listed in the National Register to receive consideration under Section 106. It only needs to meet the criteria for listing in the National Register.

Section 106 of the NHPA seeks to accommodate historic preservation concerns with the needs of an emergency spill response through consultation; however, immediate rescue and salvage operations conducted to preserve life or property are exempt from the provisions of Section 106. For spill responses in US waters of the Arctic, the Federal On Scene Coordinator (FOSC) is responsible for ensuring that historic properties are appropriately considered in the planning for and during emergency response actions. This includes the operational use of all response tools.

Alaska Historic Preservation Act

Under the *Alaska Statutes, 41.35.020 — Title to Historic, Prehistoric, and Archaeological Resources*, historic, prehistoric, and archeological resources situated on land owned or on state-owned or controlled land, including tideland and submerged land, require protection and documentation to any and all actions that will potentially affect them, including an oil spill response.

The Act defines "historic, prehistoric, and archeological resources" as deposits, structures, ruins, sites, buildings, graves, artifacts, fossils, or other objects of antiquity which provide information pertaining to the historic or prehistoric culture of people in the state as well as to the natural history of the state. The Act is designed to preserve and protect these resources from loss, desecration, and destruction so that the scientific, historic, and cultural heritage embodied in these resources may pass undiminished to future generations.

The Endangered Species Act (ESA)

The ESA requires all federal agencies to carry out programs for the conservation of threatened and endangered plants and animals and the habitats in which they are found.[5] There are approximately 2,000 species listed under the ESA as endangered or threatened; 17 are residents of Alaska. The U.S. Fish & Wildlife Service (USFWS) maintains a worldwide list of endangered species (USFWS, 2013) and the National Oceanic and Atmospheric Administration (NOAA) Fisheries Office of Protected Resources (OPR) manages mostly marine and anadromous species (NOAA Fisheries, 2013), while the USFWS manages the remainder of the listed species, mostly terrestrial and freshwater species.

FOSCs are required to coordinate with natural resource trustees and efforts must be made to ensure the protection of endangered species and their critical habitats (USFWS and NFMS, 1998; USCG et al., 2001).[6] Endangered species protection should be addressed during planning stages as well as actual responses. In each of the environments covered here, there are different lists of endangered species and protection methods will vary greatly. FOSCs need to consult with the federal Resource Trustees to consider the likely effects and impacts from the various response countermeasures on the trust resources and their critical habitats.

5 The Endangered Species Act of 1973 (ESA), as amended, 16 U.S.C. §1531 et seq., provides a means to protect threatened and endangered species and the ecosystems upon which they depend. The ESA requires that federal agencies insure that the actions they authorize, fund, or carry out do not jeopardize listed species or adversely modify their designated critical habitat. Regulations for conducting Section 7 consultation are set forth in 50 CFR Part 402.

6 The EPA/USCG and the Department of the Interior (DOI) U.S. Fish & Wildlife Service (Service) and the NOAA National Marine Fisheries Service (NMFS) and National Ocean Service signed an Interagency Memorandum of Agreement (MOA) stipulating emergency consultation procedures for oil spill response under the Endangered Species Act (ESA). A copy of this MOA can be obtained from http://www.uscg.mil/npfc/docs/PDFs/urg/App/ESA_MOA_AppA_04.pdf.

For the use of dispersants, existing application requirements in the US are determined by the Regional Response Teams (RRTs) that limit their application and use to waters typically 3 miles from shore and in waters deeper than 10 meters (refer to **Fact Sheet #5 — Dispersant Use Approvals in the United States**). The Trustees may provide recommendations for how to minimize or avoid adverse effects to listed species during the emergency response. Such recommendations are strictly advisory and are to be implemented at the discretion of the emergency response personnel (USCG et al., 2001).

Essential Fish Habitat (EFH)

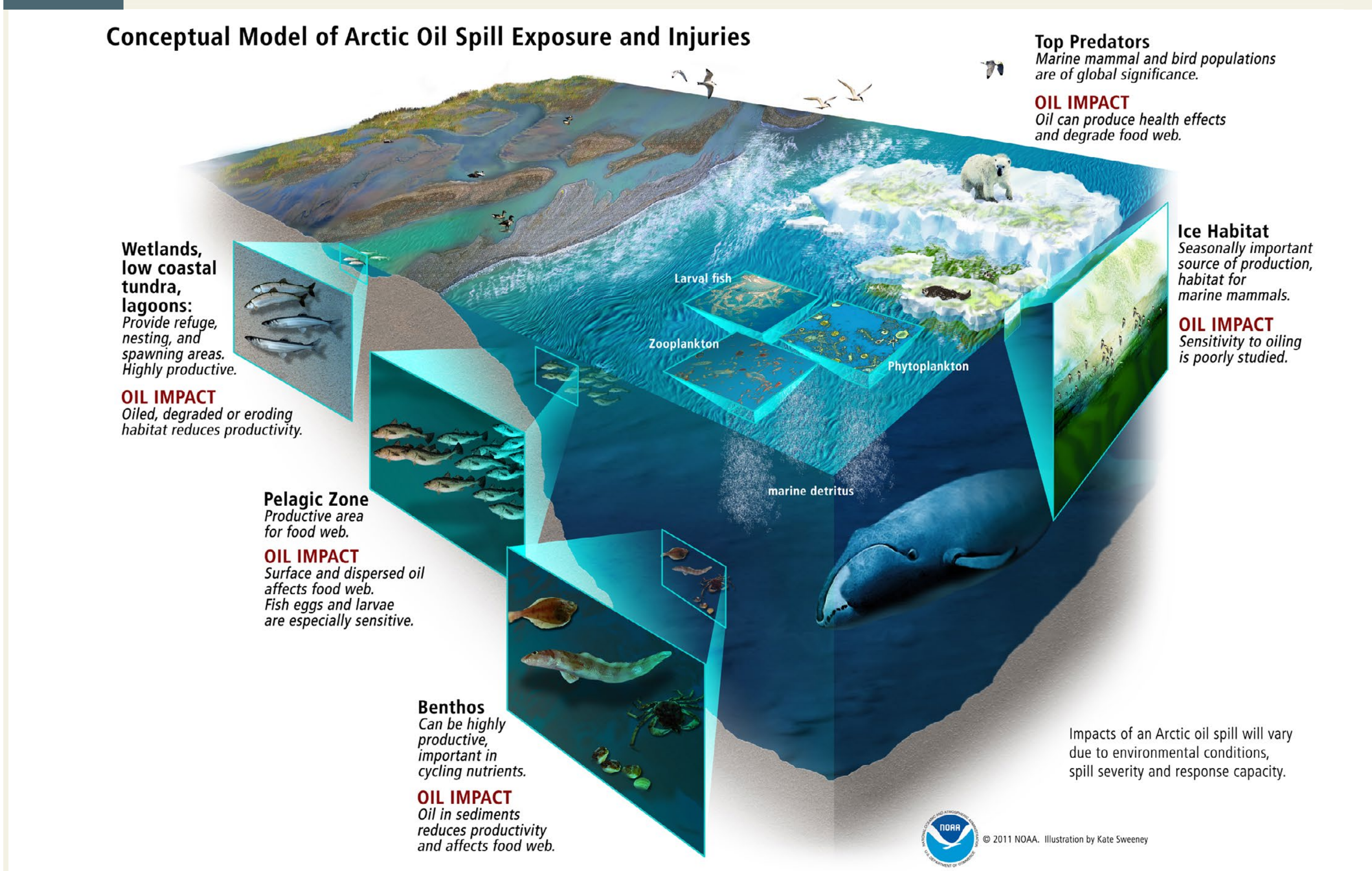
NOAA Fisheries works with the regional fishery management councils to identify the essential habitat for every life stage of the federally managed species under the Magnuson-Stevens Act (NOAA Fisheries, 2012). Using the best available scientific information, EFH and habitat areas of particular concern (HAPCs)[7] have been described for approximately 1,100 managed species to date. NOAA Fisheries has identified coastal wetlands, corals, rivers, and fish passages as being critical habitats [8] or HAPC for their protected species.

Figure 2 provides NOAA's conceptual model to summarize the potential oil spill response exposure and injury to resources in Arctic US waters. NOAA used this model to determine the likely effects an oil spill will have on the environment (including natural resources that people use). For more information on the potential impact to the resources that utilize the critical habitats refer to **Fact Sheet #6 — Assessing Dispersant Use Trade-offs**.

[7] HAPCs are considered high priority areas for conservation, management, or research because they are rare, sensitive, stressed by development, or important to ecosystem function.

[8] Critical habitat is designated for the survival and recovery of species listed as threatened or endangered under the ESA.

FIGURE 2. Conceptual model of Arctic oil spill exposure and injury. Source: NOAA/Kate Sweeney, 2011



References

36 CFR Part 800 — **Protection of Historic Properties.** Available online from: http://www.achp.gov/nhpa.html.

Budzik, P. 2009. **Arctic Oil and Natural Gas Potential.** U.S. Energy Information Administration Office of Integrated Analysis and Forecasting Oil and Gas Division. October 2009.

Fingas, M. F., D. A. Kyle, N. D. Laroche, B. G. Fieldhouse, G. Sergy, and R. G. Stoodley. 1995. "**The Effectiveness of Spill Treating Agents**." The Use of Chemicals in Oil Spill Response, ASTM STP1252, P. Lane, ed. ASTM, Philadelphia, Pennsylvania.

Fingas, M. F., R. G. Stoodley, N. Stone, R. Hollins, and I. Bier. 1991. **Testing the Effectiveness of Spill-Treating Agents: Laboratory Test Development and Initial Results.** In: Proc. 1991 International Oil Spill Conference. API. Washington, DC.

Hazen, T.C., E.A. Dubinsky, T.Z. DeSantis, G.L. Andersen, Y.M. Oiceno, N. Singh, J.K hansson, A. Probst, S.E. Borglin, J.L. Fortney, W.T. Stringfellow, M. Bill, M.S. Conrad, L.M. Tom, K.L. Chavarria, T.R. Alusi, R. Lamendella, D.C. Joyner, C. Spier, J. Baelum, M. Auer, M.L. Zemla, R. Chakroborty, E.L. Sonnenthal, R.D. Haeseleer, H-Y.N. Holman, Sl Osman, Z. Lu, J.D. Van Nostrand, Y. Deng, J. Zhou, and O.U. Mason. 2010 **Deep-sea oil plume enriches indigenous oil-degrading bacteria.** In: Science Express, August 24, 2010 DOI: 10.1126/science. 1195979.

Johnsen, K.I., B. Alfthan, L. Hislop, J.F. Skaalvik (Eds.). 2010. **Protecting Arctic Biodiversity**. United Nations Environment Programme, GRID-Arendal. 100 pages. Available online from: www.unep.org.

King, H. 2012. **Oil and Natural Gas Resources of the Arctic** — Geology.com webpage: Available from: http://geology.com/articles/arctic-oil-and-gas/.

McFarlin, K.M., R.A. Perkins, W.W. Gardiner and J.D. Word, 2011 **Evaluating the biodegradability and effects of dispersed oil using Arctic test species and conditions: Phase 2 activities**. In Proceedings of the 34th Arctic and Marine Oilspill Program (AMOP) Technical Seminar on Envrionmental Contamination and Repsone, Calgary, Alberta, Environment Canada, Ottawa, Ontario, Canada.

National Oceanic and Atmospheric Administration (NOAA) Fisheries. 2013. **Office of Protected Resources: Species Information** webpage. Last updated on January 10, 2013. Available online from: http://www.nmfs.noaa.gov/pr/species/index.htm.

Potter, S. I. Buist, K. Trudel, D. Dickins, and E. Owens. 2012. **Spill Response in the Arctic Offshore**. Prepared for the American Petroleum Institute and the Joint Industry Programme on Oil Spill Recovery in Ice. 157 pages. Available online at: http://www.api.org/environment-health-and-safety/clean-water/oil-spill-prevention-and-response/spill-response-in-arctic-offshore.aspx.

U.S. Coast Guard (USCG), U.S. Environmental Protection Agency, Department of Interior (DOI), U.S Fish & Wildlife Service (USFWS), National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) and National Ocean Service (NOS). 2001. **Inter-agency Memorandum of Agreement Regarding Oil Spill Planning and Response Activities Under the Federal Water Pollution control Act's National Oil and Hazardous Substances pollution Contingency Plan and the Endangered Species Act**. Available online from: http://www.uscg.mil/npfc/docs/PDFs/urg/App/ESA_MOA_AppA_04.pdf.

U.S. Fish & Wildlife Service (USFWS). 2013. **Endangered Species Program: Find Endangered Species** webpage. Last updated on February 21, 2013. Available from: http://www.fws.gov/endangered/.

U.S. Fish & Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS). 1998. Endangered Species Consultation Handbook: Procedures for Conducting Consultation and Conference Activities under Section 7 of the Endangered Species Act. 315 pages. Available online from: http://www.fws.gov/endangered/esa.../esa_section7_handbook.pdf.

Zhenmei Lu, Ye Deng, Joy D Van Nostrand, Zhili He2, James Voordeckers, Aifen Zhou, Yong-Jin Lee, Olivia U Mason, Eric A Dubinsky, Krystle L Chavarria, Lauren M Tom, Julian L Fortney, Regina Lamendella, Janet K Jansson, Patrik D'haeseleer, Terry C Hazen and Jizhong Zhou, 2011. **Microbial gene functions enriched in the Deepwater Horizon deep-sea oil plume.** In: The ISME Journal (2012) 6, 451–460; doi:10.1038/ismej.2011.91; published online 4 August 2011.