

Responding to Oil Spills in the U.S. Arctic Marine Environment

THE RISK OF A SERIOUS OIL SPILL IN THE ARCTIC is escalating due to potential increases in shipping traffic and oil and gas activities. To provide an effective response effort in challenging Arctic conditions—and minimize impacts on people and sensitive ecosystems—a full range of proven oil spill response technologies is needed. This report assesses the current state of science and engineering regarding oil spill response in Arctic waters and identifies key oil spill research priorities, critical data and monitoring needs, mitigation strategies, and important operational and logistical issues.

Mounting an effective oil spill response

is difficult in any environment, but oil spills in Arctic waters present an even greater challenge. In addition to extreme cold, rough seas, and darkness in winter months, Arctic oil spill responders must also contend with the region's remote location (Figure 1) and a lack of infrastructure, equipment, and trained personnel. Many aspects of the Arctic environment—including the presence of sea ice—can influence the behavior of spilled oil, yet most spill response technologies were designed for and tested in temperate regions.

The potential for an oil spill in the U.S. Arctic is growing. The warming climate is causing sea ice to retreat, opening up Arctic waters to increased activity from tankers using newly accessible shipping routes, fishing fleets following the northward migration of fish stocks, and cruise ships ferrying tourists interested in exploring the Arctic wilderness. At the same time, interest has grown in developing the Arctic's rich natural resources—there are an estimated 30 billion barrels of technically recoverable, undiscovered oil in the U.S. Arctic alone (see Figure 2 for exploration wells in federal waters and production wells in state waters).

This report evaluates the current state of science and engineering regarding oil spill response and



Figure 1. Left: Alaska and the continental United States, and surrounding countries and water bodies. Right: Alaska and U.S. Arctic waters, focused on the Bering Strait, Chukchi Sea, and Beaufort Sea. Map area corresponds to the red box in the map on the left.

environmental assessment of Arctic marine waters, with emphasis on U.S. waters in the Bering Strait and Chukchi and Beaufort Seas. The report identifies environmental conditions and monitoring priorities in the Arctic, recommends opportunities to advance oil spill research, identifies strategies to enhance infrastructure and logistics, and discusses mitigation, recovery, and restoration options.

UNDERSTANDING THE ARCTIC MARINE ENVIRONMENT

Understanding the Arctic environment is fundamental to oil spill response and recovery efforts. In addition to framing the environmental context of the region, information on physical processes—including ocean circulation, marine weather, and sea ice—can help responders predict where oil will spread and how weathering might change its properties.

Shoreline mapping and high-quality bathymetry provide context for the marine environment as well as important logistical information during response. From a biological perspective, understanding the Arctic food web helps identify key species for monitoring in the instance of an oil spill. Key areas for study include:

Ocean Processes and Characteristics

Ocean circulation, currents, and storm surges are important factors in supporting safe marine operations in the Arctic and for understanding the pathways and fate of spilled oil.

Marine Weather and Sea Ice Processes

Key weather parameters in the Beaufort and Chukchi region, including air and water temperature, winds, visibility, and hours of daylight, can impact oil spill response and marine and air operations. Factors such as ice thickness, concentration, and extent are critical to understanding how oil might behave in, on, and under the ice and to understanding operating limits for marine and air activities (see Figure 1).

Coastal Processes and Characteristics

High-quality bathymetry, nautical charting, and shoreline mapping data are needed for managing marine traffic and coordinating oil spill response. Regular updating will be necessary due to the rapid pace of coastal erosion.

Ecology and Community Structure

Knowledge of the current ecosystem structure is crucial to understanding how it may change over time or be impacted in the event of an oil spill. This data informs the identification of key species and areas of biological significance—for example, important foraging areas; places for spawning, nesting, or calving; or migration routes—that can then be used to prioritize research and monitoring.

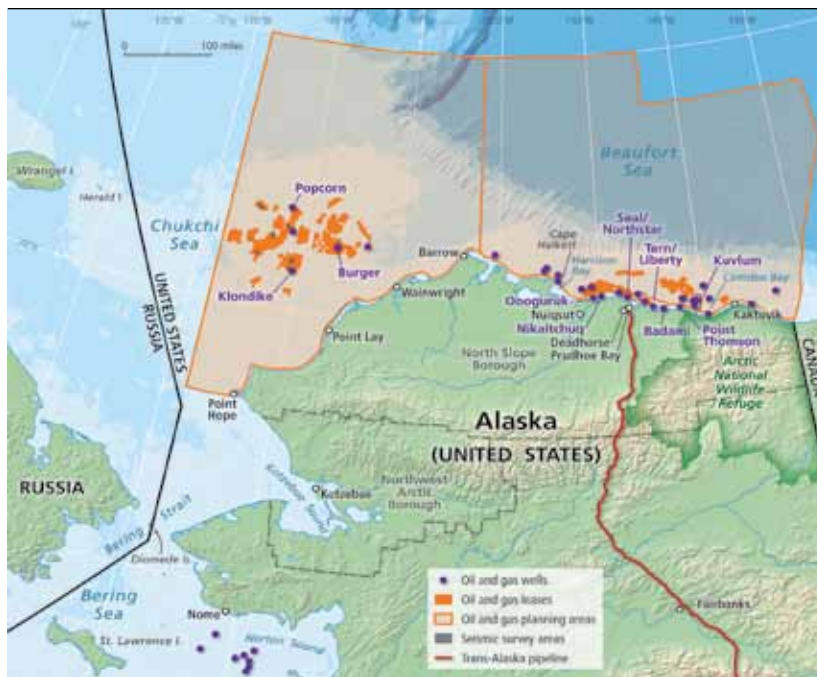


Figure 2. Oil and gas planning areas in the Chukchi and Beaufort Seas. Oil and gas lease areas are shown in orange, with seismic survey areas shown in grey. Selected oil and gas wells, some in Alaskan state waters and some in federal waters, are shown as purple dots.

Box I. Benchmark Data Needs

Baseline data are critical to assess changes over time. The Arctic environment is changing, due to seasonal and year-to-year variability, but also due to the impacts of climate change. That means historical data do not provide reliable baselines to assess current environmental or ecosystem states. Instead, benchmark data (reference points measured over time) would provide a more reliable monitoring approach to assess ecosystem status. Critical types of benchmark data for oil spill response in the Arctic include:

- Populations of fish, birds, and marine mammals and their distribution over space and time;
- The use of marine organisms, including fish, birds, and mammals for subsistence and for cultural reasons;
- Identification and monitoring of areas of biological significance (e.g., important foraging areas; places for spawning, nesting, or calving; or migration routes);
- Rates of change for key species (e.g., to the number of births and deaths or to life span);
- Sensitivity of key Arctic species to hydrocarbons;
- High-resolution coastal topography and shelf bathymetry to monitor rapidly eroding coastlines;
- Measurements of sea ice cover, thickness, and distribution.

Additional research and development needs include meteorological models to more accurately forecast the extent and thickness of sea ice and assimilation of traditional knowledge of sea state and ice behavior into forecasting models.

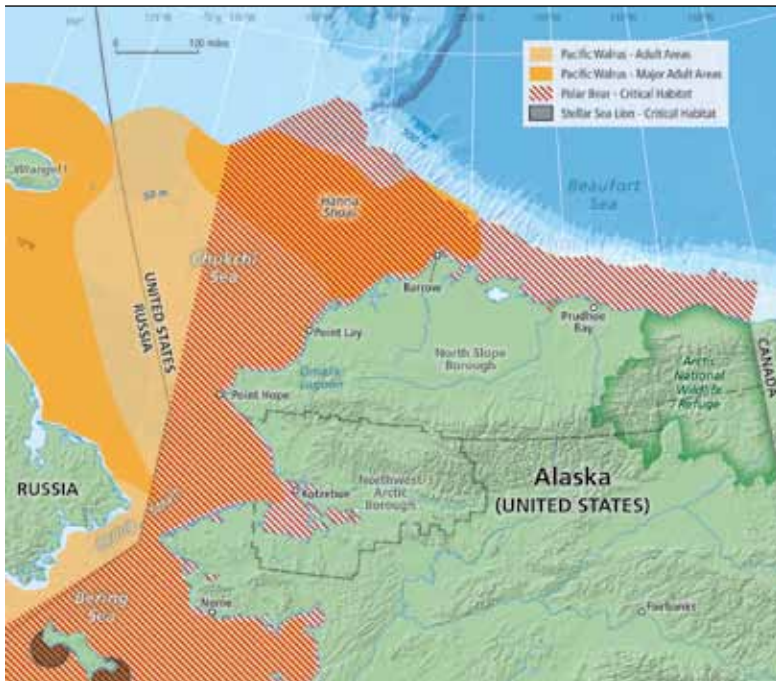


Figure 3. Gathering benchmark data on populations of Arctic fish, birds, and marine mammals is crucial to understanding how these populations might change in the event of an oil spill. This map shows the distribution of walrus, sea lions, and polar bears in U.S. Arctic waters. Data from the Arctic Environmental Response Management Application (ERMA), attributed to Audubon Alaska (Pacific walrus), NOAA (Stellar sea lion), and U.S. Fish and Wildlife Service (Polar bear).

An Observing Network is Needed to Support Oil Spill Response

Early warning is the key to rapid intervention in the event of an oil spill. Efforts are underway to monitor physical processes and ecosystem components in the Arctic—including, for example, community-based programs that collect information on ocean conditions or environmental parameters such as walrus populations, and data gathering projects organized by the Alaska Ocean Observing System and the Arctic Observing Network. However, each of these projects has different datasets, contributors, and potential or current users.

A community-based, multiuse observing network in the Arctic that provides a wide range of long-term, accessible benchmark information could bring these disparate data together in an integrated fashion to support oil spill response and other activities. Such a system could be a collaboration of federal, state, and tribal governments, non-governmental organizations, and maritime and oil and gas industries and could be organized by the Interagency Arctic Research Policy Committee (IARPC).

Understanding the Arctic Marine Environment

RECOMMENDATIONS

- High-resolution satellite and airborne imagery needs to be coupled with up-to-date high-resolution digital elevation models and updated regularly to capture the dynamic, rapidly changing U.S. Arctic coastline. Nearshore bathymetry and topography should be collected at a scale appropriate for accurate modeling of coastline vulnerability and storm surge sensitivity. Short- and long-term Arctic nautical charting and shoreline mapping that have been identified in NOAA and USGS plans should be adequately resourced, so that mapping efforts can be initiated, continued, and completed in timescales relevant to anticipated changes. To be effective, Arctic mapping priorities should continue to be developed in consultation with stakeholders and industry and should be implemented systematically rather than through surveys of opportunity.
- A real-time ice and meteorological forecasting system for the Arctic is needed to account for variations in sea ice coverage and thickness; it should include patterns of ice movement, ice type, sea state, ocean stratification and circulation, storm surge, and improved resolution in areas of increased risk. Such a system requires robust, sustainable, and effective acquisition of relevant observational data.

OIL SPILL RESPONSE RESEARCH

Laboratory experiments, field research, and practical experience gained from responding to past oil spills have built a strong body of knowledge on the properties of spilled oil and response techniques. However, much of this work has been done for temperate regions, and additional research is needed to make informed decisions about the most effective response strategies for Arctic spills. Processes that control oil behavior and weathering, in both open water and ice, are shown in Figure 5.

There is also a need to validate current and emerging oil spill response technologies in Arctic environmental conditions on operational scales. Carefully planned and controlled field releases of oil in the U.S. Arctic would improve the understanding of oil behavior in the Bering Strait and Beaufort and Chukchi Seas and allow for the evaluation of new response strategies specific to the region. Scientific field

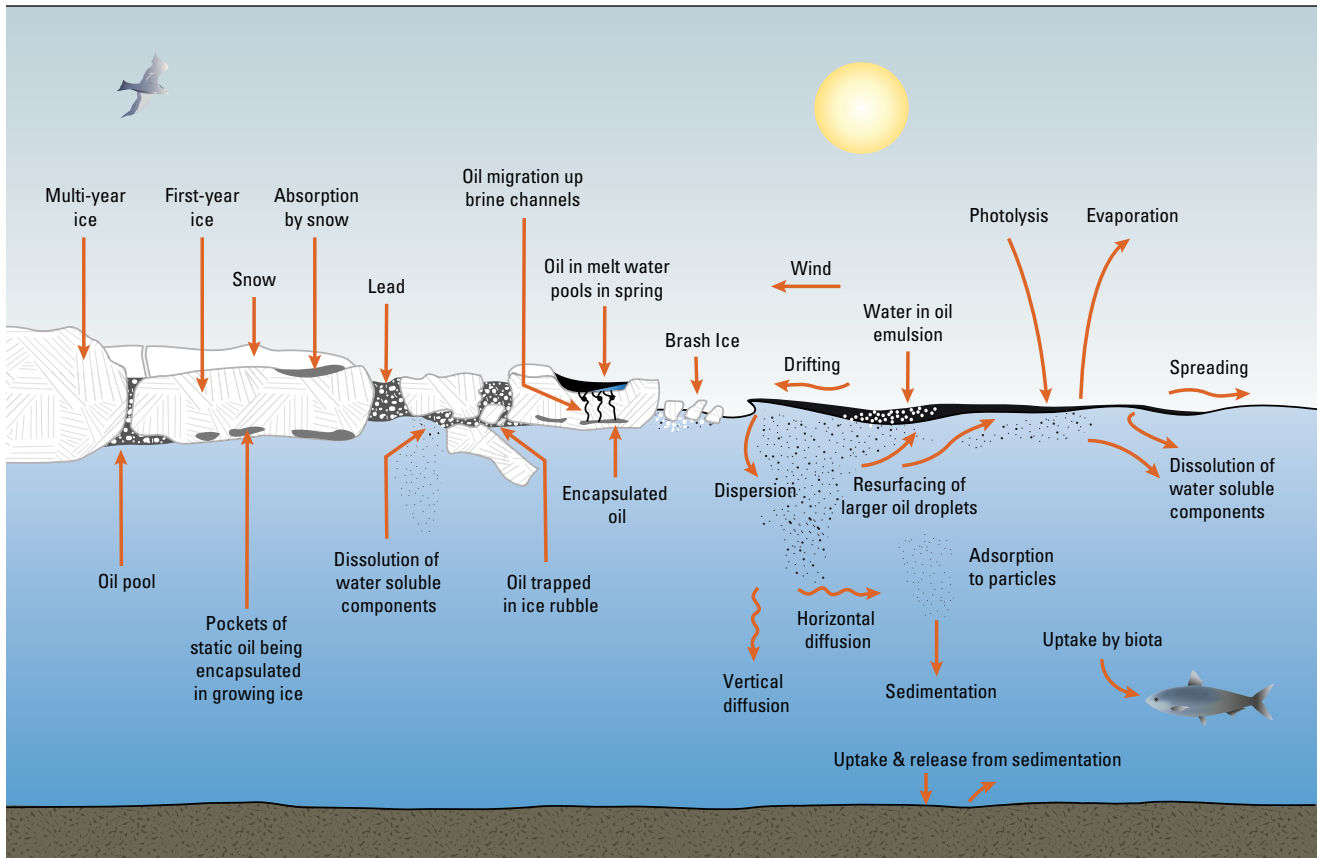


Figure 5. Environmental processes that affect oil behavior and weathering in open water and in ice. Modified from Daling et al., 1990, A. Allen.

releases that have been conducted elsewhere in the Arctic demonstrate that such studies can be carried out without measurable harm to the environment.

The Oil Spill Toolbox

Spill response options will vary depending on the oil type and volume, the location of the spill, and environmental conditions. Other considerations include the proximity of the spilled oil to sensitive marine ecosystems, populations of marine organisms, and culturally sensitive sites. The report reviews key oil spill countermeasures, which, together with the option of “no response,” make up the oil spill toolbox. Though much is known about oil behavior and response technologies in ice-covered environments, there are areas where additional research is needed to make informed decisions about the most effective response strategies for different Arctic situations.

Biodegradation and Dispersants

The degradation of oil by naturally occurring microbial communities (biodegradation) is an important process controlling the weathering and removal of oil in the sea. Chemical dispersants promote biodegradation by

breaking up oil droplets in the water column. There has been considerable debate over the effectiveness of chemical dispersants at low seawater temperatures, but recent studies show dispersants can be effective on non-emulsified oil at freezing temperatures if viscosity (resistance to flow) does not increase significantly.

Using subsea injection to apply dispersants directly to the blowout site could disperse oil at higher rates and with higher efficiency than aerial dispersant application. This technique can be employed even in darkness, extreme temperatures, strong winds, rough seas, or the presence of ice. However, more work needs to be done on the effectiveness, systems design, and short- and long-term impacts of subsea dispersant delivery.

Research and Development Needs

- Determining and verifying biodegradation rates for hydrocarbons in offshore environments
- Evaluating the toxicity of dispersants and dispersed oil on key Arctic marine species
- Improving methods for dispersant application for oil spills in ice

In Situ Burning

In situ burning—the controlled burning of oil at the site of the spill—can significantly reduce the amount of oil on the water and minimize the adverse effect of the oil on the environment. With relatively fresh oil that is wind-herded against an ice edge or collects in melt pools in the spring, in-situ burning can remove a majority of spilled oil. However, in open ocean conditions, oil can rapidly spread as thin slicks or films, becoming too thin to ignite.

Research and Development Needs

- Mapping the usefulness of chemical herders at different spatial scales, oil types, and weathered states and in conjunction with other methods such as in situ burning
- Improving ignition methods for in situ burning

Mechanical Containment and Recovery

Mechanical containment and recovery removes oil without adding chemicals to the water or creating burn residue. Small oil spills can be contained within some types of ice; however, large offshore spills can quickly spread to a thin sheen, which severely limits recovery. Oil slicks would need to be concentrated using equipment such as containment booms, vessels, and skimmers. The lack of approved disposal sites on land for contaminated water and oily waste, a lack of port facilities, and limited airlift capability make large-scale mechanical containment and recovery operations difficult in the Arctic.

Research and Development Needs

- Better knowledge of the limitations of mechanical recovery in both open water and ice

Detection, Monitoring, and Modeling

Knowing the location of spilled oil is critical to mounting an effective response. Over the past decade, several government and industry programs have evaluated rapidly developing remote sensing technologies for detection and tracking—for example, sonar, synthetic aperture radar, infrared, and ground-penetrating radar. In addition, the use of unmanned aerial vehicles and autonomous underwater vehicles to detect, track, and monitor oil has grown. However, aerial observers to map oiled areas and transmit critical information to response crews will continue to be needed.

Improvements in oil spill trajectory modeling will be needed to more accurately predict the movement of spilled oil. Promising advances in modeling better account for the incorporation of oil into brine

channels and freezing into ice, although under-ice roughness still requires further attention. Investment in detection and response strategies for oil on, within, and trapped under ice is needed for contingency planning. In addition, robust operational meteorological-ocean-ice and oil spill trajectory forecasting models for the U.S. Arctic would further improve oil spill response efforts.

Research and Development Needs

- Improving under-ice oil detection and response strategies
- Integrating remote sensing and observational techniques for detecting and tracking ice and oil

The Oil Spill Toolbox

RECOMMENDATIONS

- Pre-approval for the use of dispersants in Alaska should be based on sound science, including research on fates and effects of chemically dispersed oil in the Arctic environment, experiments using oils that are representative of those in the Arctic, toxicity tests of chemically dispersed oil at realistic concentrations and exposures, and the use of representative microbial and lower-trophic level benthic and pelagic Arctic species at appropriate temperatures and salinities.
- A comprehensive, collaborative, long-term Arctic oil spill research and development program needs to be established. The program should focus on understanding oil spill behavior in the Arctic marine environment, including the relationship between oil and sea ice formation, transport, and fate. It should include assessment of oil spill response technologies and logistics, improvements to forecasting models and associated data needs, and controlled field releases under realistic conditions for research purposes. Industry, academic, government, non-governmental, grassroots, and international efforts should be integrated into the program, with a focus on peer review and transparency. An interagency permit approval process that will enable researchers to plan and execute deliberate releases in U.S. waters is also needed.
- Priorities for oil spill research should leverage existing joint agreements and be addressed through a comprehensive, coordinated effort that links industry, government, academia, international and local experts, and non-governmental organizations. The Interagency Coordinating Committee on Oil Pollution Research, which is tasked to coordinate oil spill research and development among agencies and other partners, should lead the effort.

OPERATIONS, LOGISTICS, AND COORDINATION FOR AN ARCTIC OIL SPILL

The Oil Pollution Act of 1990 places the primary responsibility for mounting an effective oil spill response on the party who was responsible for the accident. However, federal, state, local, and tribal entities each have legal authorities to oversee, approve, and, if needed, supplement measures taken by the responsible party. A wide range of federal and state laws, as well as international treaties and agreements, weave a complicated web of duties, responsibilities, and authorities for all parties involved in a spill response.

The U.S. Coast Guard has a low level presence in the Arctic, especially during the winter. As a result, Coast Guard personnel, equipment, transportation, communication, navigation, and safety resources are not adequate for overseeing oil spill response in the Arctic. Furthermore, there is no comprehensive system for real-time vessel traffic monitoring or management in the Bering Strait or in the U.S. Arctic. This creates significant vulnerability for all Coast Guard missions, including oil spill response, and creates undue reliance on private industry and foreign national systems for monitoring. Significant gaps in coverage create numerous regional “blind spots,” where an early indication of elevated risks may not be apparent to officials ashore.

International Coordination

The U.S. has long engaged its regional neighbors in Arctic spill preparedness and has bilateral agreements with both Canada and Russia regarding oil spill response. Formal contingency planning and exercises with Canada have enabled both the U.S. and Canada to refine procedures and legal requirements for cross-border movement of technical experts and equipment in the event of an emergency. The resolution of anticipated response problems with Russia, including

communications between command centers, coordinated planning, trans-boundary movement of people and equipment, and identification of translators, needs to be accomplished in advance of an actual event.

Infrastructure

The lack of infrastructure and oil spill response equipment in the U.S. Arctic (Figure 6) is a significant liability in the event of a large oil spill. Building U.S. capabilities to support oil spill response will require significant investment in physical infrastructure and human capabilities, from communications and personnel to transportation systems and traffic monitoring. Prepositioning response equipment throughout the Arctic would provide more immediate access to oil spill countermeasures.

Training and Organization

Local communities possess knowledge of ice conditions, ocean currents, and marine life in areas that could be affected by oil spills, yet there have been only modest efforts to integrate local knowledge into formal incident command-based responses.

Flexible and scalable organization is important to develop an effective Arctic oil spill response. This can be achieved through drills, case studies, simulation, and organizational learning. To build system-wide capacity, sustained long-term training and continued resource investments are required. Inclusive and trustful communications, relationship-building, and decision-making; clear accountability; and on-going assessment and improvement are also needed.

STRATEGIES FOR RESPONSE AND MITIGATION

All pre-spill strategies emphasize oil spill prevention above everything else. In the event of an oil spill, however, strategies for decision-making and response are critical to keep oil away from the shore and to

Coast Guard Needs

RECOMMENDATIONS

- As oil and gas, shipping, and tourism activities increase, the U.S. Coast Guard will need an enhanced presence and performance capacity in the Arctic, including area-specific training, icebreaking capability, improved availability of vessels for responding to oil spills or other emergency situations, and aircraft and helicopter support facilities for the open water season and eventually year-round. Furthermore, Arctic assignments for trained and experienced personnel and tribal liaisons should be of longer duration, to take full advantage of their skills. Sustained funding will be required to increase the presence of the Coast Guard in the Arctic and to strengthen and expand their ongoing Arctic oil spill research programs.
- The U.S. Coast Guard should expedite its evaluation of traffic through the Bering Strait to determine if vessel traffic monitoring systems, including an internationally recognized traffic separation scheme, are warranted. If so, this should be coordinated with Russia. The Coast Guard should also consider obtaining broader satellite monitoring of Automatic Identification System (AIS) signals in the Arctic through government means or from private providers.



Figure 6. Lack of infrastructure and oil spill response equipment in the U.S. Arctic could present a significant liability in the event of a large oil spill. Arctic shipping routes, the Alaska Department of Environmental Conservation’s spill response equipment depots, and villages and towns with the capacity to land passenger jets in Alaska are shown.

minimize impacts on sensitive habitats, organisms, and people. No response method is completely effective or risk-free. Decision processes that evaluate options and strategies are critical to an effective response.

The Net Environmental Benefit Analysis (NEBA) process provides a framework to determine which oil spill countermeasures will be the most effective and will cause the least ecological damage, based on an analysis of environmental tradeoffs. NEBA incorporates prioritization criteria for the protection of sensitive and important ecosystem components that could be impacted by oiling, cleanup operations, or residual oil—for example, marine mammals, coastal habitats, fishes, or areas of cultural significance. An Arctic NEBA would also include information on the transport, fate, and potential effects of the spilled oil; knowledge of operational limits, advantages, and disadvantages of each oil spill response countermeasure for the natural resources at risk; and consideration of logistical constraints

Training and Organization

RECOMMENDATIONS

- The U.S. Coast Guard should expand its bilateral agreement with Russia to include Arctic spill scenarios, conduct periodic exercises to establish joint responses under Arctic conditions, and build on existing bilateral agreements with Russia and Canada to develop and exercise a joint contingency plan.
- Infrastructure to support oil spill response should be enhanced in the North Slope and Northwest Arctic Boroughs, with marine facilities for addressing response operations. The scope, scale, and location of infrastructure needs should be determined through structured decision processes, studies, and risk assessments.
- The U.S. Coast Guard and Alaska Department of Environmental Conservation should undertake the development of an oil spill training program for local entities to develop trained response teams in local villages. Industry should continue to participate in local training initiatives. Local officials and trained village response teams should be included in the coordinated decision-making and command process during a response event. Input from community experts should be actively solicited for inclusion in response planning and considered in conjunction with data derived from other sources. The Coast Guard should set this as an exercise objective in all government-led oil spill response exercises in the Arctic and should set the expectation that industry-led exercises will do the same.
- Relevant federal, state, and municipal organizations (such as the U.S. Coast Guard, National Oceanic and Atmospheric Administration, Bureau of Safety and Environmental Enforcement, Bureau of Ocean Energy Management, Alaska Department of Environmental Conservation, Alaska Department of Natural Resources, U.S. Fish and Wildlife Service, Alaska Fish and Game, North Slope Borough, and Northwest Arctic Borough), local experts, industry, and academia should undertake regularly scheduled oil spill exercises designed to test and evaluate the flexible and scalable organizational structures needed for highly reliable Arctic oil spill response.

and cleanup intensity. Due to the range of conditions typically encountered within an area affected by an oil spill, a combination of countermeasures, rather than a single response option, would be most likely to provide optimal protection for all environmental resources.

Controlling oil release and spread at the source of a spill, deterring animals from entering oiled areas, and capturing and rehabilitating oiled wildlife can help minimize the potential impact of oil spill response on wildlife, the broader ecosystem, and the food web. However, rehabilitation and release in the Arctic is complicated by remote locations, lack of response equipment, concerns over subsistence use of potentially oiled animals, and safety considerations when dealing with large animals like polar bears and walrus. Wildlife response plans will need to include key indicators of environmental health and prioritize response strategies. This includes a “no response” strategy, which may be preferable for some species.

Strategies for Response and Mitigation

RECOMMENDATIONS

- A decision process such as the Net Environmental Benefit Analysis should be used to select the response options that offer the greatest overall reduction of adverse environmental impacts. In the Arctic, areas of cultural and subsistence importance should be among the priority ecosystem components. In light of concerns regarding detrimental effects on ecosystems, further study should focus on the impact of oil spills on Arctic food webs and dynamics at different trophic levels. The process should involve regulators, resource managers, health authorities, technical specialists, scientific experts, and local experts.
- U.S. Fish and Wildlife Service, NOAA’s National Marine Fisheries Service, Alaska Fish and Game, co-management organizations, and local government and communities are the trustees for wildlife deterrence and rehabilitation. As appropriate, these agencies and groups should work together to explore and improve deterrent and rehabilitation methods for wildlife. Additional research and development for improved methods could benefit from the involvement of universities, non-governmental organizations, and others. Priorities should be set and regularly updated by the trustees for oil spill response based on the type of wildlife threatened, the season, other factors related to a spill, and updated research and methodology.

Locate additional information, including related reports, at <http://dels.nas.edu/osb>
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The National Academies appointed the above committee of experts to address the specific task requested by the U.S. Arctic Research Commission; American Petroleum Institute; U.S. Coast Guard; U.S. Department of the Interior, Bureau of Ocean Energy Management and Bureau of Safety and Environmental Enforcement; Marine Mammal Commission; National Oceanic and Atmospheric Administration; Oil Spill Recovery Institute; National Academy of Sciences. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee’s report.

For more information, contact the Ocean Science Board at (202) 334-2714 or visit <http://dels.nas.edu/osb>. Copies of *Responding to Oil Spills in the U.S. Arctic Marine Environment* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.

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