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Managing Marine Mammal Issues: Corporate Policy, Stakeholder Engagement, Applied Research, and Training

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Abstract

Offshore development requires management of potential impacts of industry sounds on marine mammals. From a business perspective, industry representatives should realize that stakeholders and the regulatory community often assume, *a priori*, that industry sounds will impact whales, seals, and other marine mammals. The onus is on industry to demonstrate that potential impacts—including behavioral impacts—can be mitigated to an acceptable level. Furthermore, acceptable levels of mitigation must be demonstrated against a backdrop of confusion caused in part by a poor understanding of industry sounds and underwater sound propagation, incomplete knowledge of marine mammal hearing ability, and limited data on the ability of sound to injure or change the behavior of marine mammals. This paper describes BP's strategy for managing this issue. The key elements of this strategy include:

- A flexible corporate approach through adherence to environmental performance requirements, which guide operations globally but allow the flexibility needed to consider regionally or locally important issues, such as differences in species, sound sources, business requirements, and other factors.
- Constructive engagement with stakeholders who might influence business outcomes.
- Support of applied research that might yield results with either regional or global business ramifications.
- Establishment of a training program to better prepare the BP work force involved with marine mammal issues.

While this approach may not be well suited for every oil and gas company, it is clear that all companies need to articulate, at least internally, a strategy that recognizes the issue of marine mammals and underwater sound in a business context. Ignoring the issue, or hoping that it will not impact operations, is to run an unacceptable risk of delayed or inefficient projects and expensive lost opportunities.

Introduction

Environmental economist Len Shabman, when asked about the most significant development in the environmental movement over the past 30 years, responded with a description of what he calls "the rebuttable presumption":

> Years ago environmental improvements had to be justified starting from the current condition of the environment. The burden was on the proponents of an improved environment… [But now the] rebuttable presumption on a wetland is that you will avoid filling it. The rebuttable presumption on a natural resource damage assessment case is that you are going to put it back like it was. That's the starting point of the argument. It is not "How does it look today and can we justify making it better?" The starting point is some ideal. The starting point is "How should it look?" (Streever 2007).

Shabman's concept of the rebuttable presumption is as true for the issue of the effects of industrial sound on marine mammals as it is for other environmental issues. For better or worse, the onus of proof has shifted from environmental proponents to industry proponents. To preserve the privilege of finding and developing offshore oil and gas, industry must demonstrate that underwater sounds created during seismic exploration, development, production, and abandonment do not create unacceptable risks for whales, seals, and other marine mammals.

Issues surrounding marine mammals and sound are technically complex, highly emotive, and poorly understood. A reasonable understanding of the issues requires knowledge of oil industry operations, underwater acoustics, physiology, behavioral ecology, the positions of advocacy organizations, and rapidly evolving environmental laws and policies. Research is needed to close a number of important knowledge gaps and develop approaches to mitigation. For example, sounds associated with marine exploration and production activities are not well characterized within the frequency ranges relevant

to marine mammals, and technologies intended to decrease underwater sounds from industry activities are in their infancy. Useful biological research is difficult because the animals in question are hard to find, can only be seen when on the surface, can only be heard if they are calling, cannot generally be kept in captivity, and often respond to sounds in different ways.

The technical literature consists of thousands of journal articles, four reviews by the National Research Council of the National Academy of Sciences in the United States (National Research Council 1994, 2000, 2003, 2005), and at least one important book (Richardson et al. 1995). Despite a number of valuable studies and a growing body of useful results, McCauley and Cato (2003) pointed out that the literature on marine mammals and sound is dominated by anecdotal information, reviews of the primary literature, reviews of reviews, and uninformed comment. This state of affairs underscores the fact that gathering new data is time consuming, costly, and often unsuccessful. It also points out that the issue is not new—in fact, the potential for industry sounds to impact marine mammals has been recognized since at least the early 1970s (see, for example, Payne and Webb 1971). Also, for the oil and gas business, caution is essential in interpreting "facts" because of the presence of a large number of "reviews of reviews" and papers that rely on uninformed comment. Apparently knowledgeable people, including those working on behalf of industry and those working for environmental advocacy organizations, may present "facts" that are not supported by data.

Efforts to inform and influence emerging legislation must deal not only with information that is riddled with knowledge gaps, but also with strong emotional assumptions and the specter of highly restrictive regulations and litigation. While no marine mammal deaths have been unequivocally attributed to industry sounds, the industry has very little data to refute the rebuttable presumption of potential harm.

In practical terms relevant to the industry, regulatory approaches may include complete closure of some areas, seasonal restrictions on operations, or limiting operations to daylight hours with visibility suitable for spotting marine mammals. In addition, professional marine mammal observers may be required for some activities, and passive acoustic monitoring techniques may be needed to detect marine mammals by their calls (Weir and Dolman 2007). In both cases, specialized personnel and additional equipment must be deployed. Marine mammal concerns also may delay projects and lead to requirements for long-term research and monitoring. Facility placement and pipeline routing may be dictated by potential marine mammal impacts. Lastly, litigation and stakeholder concerns can hurt profitability, relationships with lenders, and corporate reputations. It is sometimes said that potential impacts from sound on marine mammals could ultimately threaten industry's license to operate, effectively ending offshore oil and gas operations in important regions around the globe.

Industry's total investment in the appropriate management of marine mammal issues is unknown, but consists of both direct and opportunity costs. Direct costs include investments in marine mammal observers for mitigation, support of marine mammal research, and occasionally costs associated with changes in project plans required to reduce the risk of harming marine mammals. Opportunity costs include costs of avoiding protected areas. Although costs to the industry are unknown and biological knowledge gaps and ecopolitical complexities introduce frustrating uncertainties, the issue of marine mammals and sound generates a business risk that the oil and gas industry should recognize and manage.

Background

Marine mammals include dolphins, porpoises, whales, seals, walruses, manatees, dugongs, sea otters, and polar bears. To date, most issues related to underwater sounds generated by the oil and gas industry have focused on potential impacts to dolphins, porpoises, whales, and seals.

Some basic information should be understood by anyone interested in the interactions between underwater sounds and marine mammals and the business risk posed by this issue. This information can be divided into four categories: underwater sound, marine mammal hearing, direct harm from underwater sound, and behavioral responses to underwater sound.

Underwater Sound

Rapidly changing pressure—that is, mechanical energy that cycles as a wave—in air and water is perceived as sound, which can be characterized by its frequency, usually measured in hertz (Hz), and its amplitude, or "loudness," usually reported in decibels (dB). One often-confusing aspect of sound measurements reported in decibel units is related to the "reference pressure". In air, dB are generally reported in reference to 20 µPa (i.e., microPascals), while in water dB are generally reported in reference to 1 µPa. Ideally, the reference pressure should be incorporated as part of the units; for example, underwater sounds should normally be reported in units of dB re 1 µPa. Because in-air and underwater sounds are usually reported in different units, they cannot be compared directly. It is also important to understand that a 3 dB increase in amplitude (regardless of the reference pressure) constitutes a doubling of sound intensity. For example, a 113 dB re 1 µPa sound has twice the intensity of a 110 dB re 1 µPa sound.

Although frequency and amplitude are often the only sound characteristics reported in technical documents, other characteristics of sound may be important for marine mammals. *Impulsive sounds*, such as those that might arise from explosives, airguns, or impact pile drivers, seem to have different effects than *continuous sounds*, such as the sounds generated by propellers, drilling, and operating facilities. For impulsive sounds, the *duty cycle*, or the time between pulses, can be an important consideration. Other characteristics, such as *rise time*, or the time it takes for a sound to reach its peak amplitude, can be a factor in assessing potential impacts.

As distance from the source increases, amplitude generally decreases and frequency content generally changes, with higher frequencies diminishing over shorter distances than lower frequencies. With this in mind, it is important to understand

if reported sounds are *received levels* (sound received at a particular location some distance from the source) or *source levels* (sound received at a theoretical point in space 1 m from the source). Because many sources are large structures or a group of separate sound sources—such as the hull of a ship or an airgun array towed behind a seismic vessel (Fig. 1)—source levels are typically extrapolated based on sound received at various distances from the source. Thus, high source levels reported for large sources (sometimes called *distributed sources*) such as ships or airgun arrays may not actually exist in the environment. While source levels sometimes offer a convenient means of comparing one source to another, they are not meaningful for understanding potential impacts to marine mammals. Instead, impact assessment should focus on received levels, or those that actually reach a marine mammal.

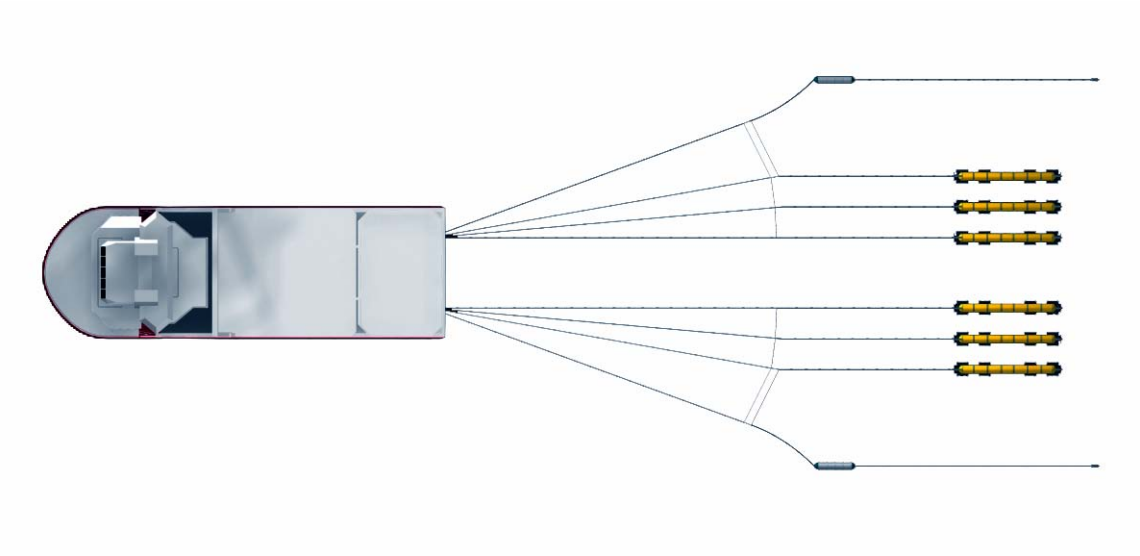

Fig. 1—Seismic vessel with airgun array. To compute underwater sound source levels from distributed sources, such as air gun arrays or ship hulls, sound levels are measured at several locations some distance from the source and extrapolated back to a single theoretical point. On typical offshore seismic shoots, sound emanates from machinery noise passing through the hull of the ship, propeller noise, multiple air guns, and even strumming noise caused by cables passing through the water, but source levels based on field measurements assume that all of these sounds come from a single theoretical point near the center of the air gun array.

Estimates of received sound levels at various distances from a source are highly dependent on water depth, surface conditions, bottom conditions, water temperature, water column stratification, natural ambient sound levels, and other factors. In some circumstances, such as in the presence of unexpected “ducts” that conduct sound in a relatively narrow corridor, estimates can be grossly inaccurate. As such, field data are needed to supplement models of sound propagation and attenuation. Even when field measurements are available, data should be interpreted with caution because of the absence of standard approaches to measuring underwater sound and the even more difficult task of estimating the sounds at a biological receptor, such as a whale’s ear.

Marine Mammal Hearing

The hearing sensitivity and frequency range of animals, including marine mammals, can be investigated using behavioral techniques and physiological measurements. Either technique can be used to generate an audiogram, which plots hearing sensitivity across a range of frequencies (Fig. 2). While the techniques in theory should be consistent with one another, limited evidence suggests that this is not always the case. In addition, field observations of marine mammal behavior, laboratory examination of ear anatomy (specifically, the structure of the cochlea), and recordings of vocalizations can yield insights on hearing.

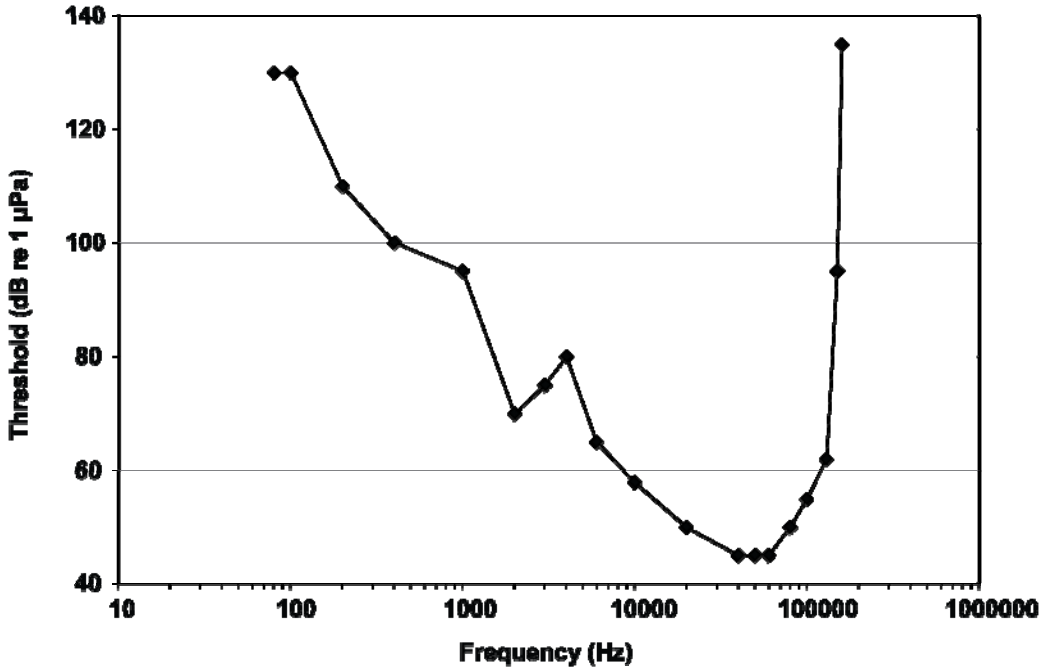

Fig. 2—An audiogram for a bottlenose dolphin, plotting the animal's ability to hear across a range of frequencies (adapted from Johnson 1967).

Limited available data suggest that marine mammals can be divided into four groups based on their hearing ranges (Table 1) (Southall et al. in press). Each group and each species also have "zones of best hearing," but these zones are well documented for only a small number of species.

Table 1—Hearing Ranges of Marine Mammals

Category	Frequency Range	Species
High-frequency cetaceans	200 Hz–180 kHz	18 species and subspecies of porpoises, river dolphins, and other relatively small toothed whales
Mid-frequency cetaceans	150 Hz–160k Hz	32 species of dolphins and most of the large-toothed whales, such as killer whales, beluga, and narwhals
Low-frequency cetaceans	7 Hz–22 kHz	The baleen (filter-feeding) whales
Pinnipeds (underwater)	75 Hz–75 kHz	Seals, sea lions, and walruses

Direct Harm from Underwater Sound

Direct harm to marine mammals from industry sounds is often difficult to document, but several types of damage are possible (Richardson et al. 1995). Extremely loud received levels of sound can damage tissues. Very sudden, extremely high changes in pressure levels sometimes associated with loud sounds, such as those from explosives, airguns, and impact pile drivers, can cause severe trauma at close distances. Sounds of the appropriate amplitude and frequency can lead to resonance and subsequent bleeding in some tissues at greater distances (Dalecki 1998), although this has not been shown to occur under field conditions. In theory, sound also can induce gases dissolved in blood and tissues to form bubbles, similar to the bends experienced by divers (Fernandez et al. 2005). However, perhaps in part because basic industry mitigation practices and avoidance behaviors of many marine mammals limit exposure to extremely loud sounds, prevailing opinion increasingly suggests that the risk of direct damage to tissues other than those associated with hearing is low.

Sounds at levels below those likely to damage most tissues can cause both permanent and temporary hearing damage, or *threshold shift* (Richardson 1995; Nachtigall et al. 2004; Finneran et al. 2005). Threshold shift changes the shape of an animal's audiogram, limiting its ability to hear certain frequencies. Changes in hearing ability can be extremely important to

marine mammals that rely on sound to find prey, avoid predators, navigate, and communicate with other animals. Currently active research is investigating the relationship between repeated exposure to impulsive sounds (including sounds generated by industry activities) and temporary threshold shift. Recovery times following temporary threshold shift are also being investigated. Although it is usually assumed that sounds louder than those required to induce temporary threshold shift can induce a permanent shift, very little is known about permanent threshold shift in marine mammals.

Behavioral Responses to Underwater Sound

Despite the possibility of direct harm from sound—mainly in the form of hearing damage—environmental concerns are increasingly focused on sound-induced behavioral changes that may include altered diving behavior, movement away from a feeding area, alterations of migration routes, and disruption of breeding or nursing (Richardson et al. 1995; Richardson et al. 1999; Southall et al. in press) (Fig. 3). Some of these behavioral impacts could cause physical harm. For example, altered diving behavior can conceivably lead to decompression sickness in some species (Fernandez et al. 2005). However, it is often difficult to establish correlations between underwater sounds and behavioral responses, in part because marine mammals are difficult to observe in their natural environment and in part because different animals of the same species—and even individuals under slightly different circumstances—respond differently to similar sounds. For example, some whales might actively avoid seismic vessels, others may swim toward them, and still others might not appear to react at all.

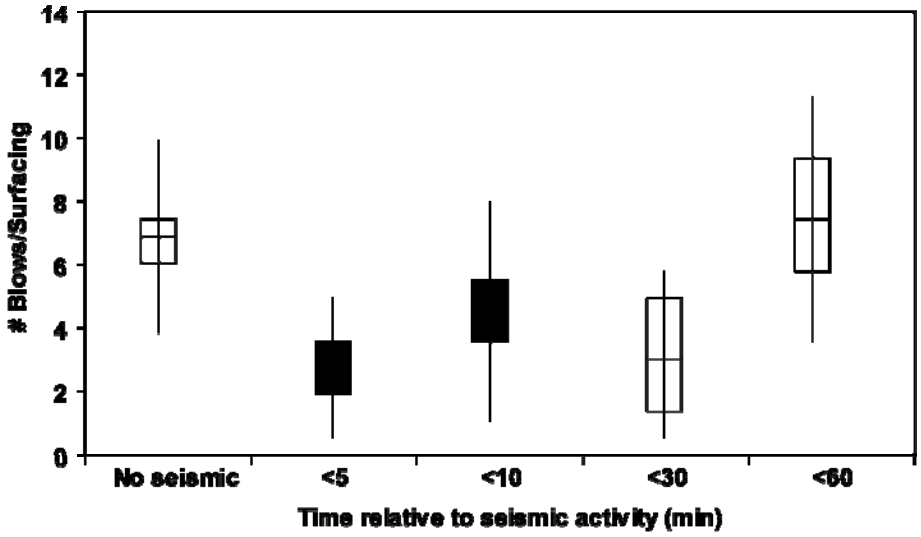

Fig. 3—Some marine mammals seem to respond to industry sounds, including airgun sounds (adapted from Richardson and Malme 1993). Here, bowhead whales appear to change their breathing pattern when exposed to airgun sounds. (Bars represent the 95% confidence interval and vertical lines represent ±1 standard deviation.)

A Strategy to Address Risks Posed by Marine Mammals

Recognizing the complexities of marine mammal issues and their potential to impact the oil and gas industry, BP uses a multifaceted strategy to mitigate business risk. This strategy involves:

- A *flexible corporate approach* through adherence to environmental performance requirements, which guide operations globally but allow the flexibility needed to consider regionally or locally important issues, such as differences in species, sound sources, business requirements, and other factors.
- *Constructive engagement with stakeholders* who might influence business outcomes.
- Support of *applied research* that might yield results with either regional or global business ramifications.
- Establishment of a *training* program to better prepare the BP work force involved with marine mammal issues.

A Flexible Corporate Approach

Although shareholders and other stakeholders expect major energy companies to behave consistently around the globe, different regions often require different approaches to marine mammal management for at least four reasons:

- Marine mammals and their habitats differ from region to region,
- Bathymetric and oceanographic conditions dramatically affect sound propagation,
- Industry activities generate various sounds and offer different opportunities for mitigation, and

- Regional and local social and political climates often define issues of greatest importance.

Bearing in mind both the need for global consistency and the need for regional and even project-specific flexibility, BP developed a global approach, called an *environmental performance requirement* (EPR), for marine mammals in 2005. All new major projects must incorporate the EPR, and all existing and new operations must consider it and incorporate its requirements where practicable. In addition, as a minimum, all projects must obey applicable laws relevant to marine mammal management.

During project planning, the EPR requires a screening process based on environmental sensitivities. If marine mammals face potential impacts, a formal environmental assessment is required. Using existing data, environmental assessments can identify species present, group these species based on their audiograms, identify and characterize potential sound sources, consider sound propagation, consider possible behavioral responses to sounds, and cross-reference all of this information to determine which, if any, species are most likely to be impacted and to describe the magnitude of potential impacts. For example, an environmental assessment undertaken for a BP project in Angola identified 19 marine mammal species that could be present and listed vessel sounds, drilling sounds, and piling sounds as potentially important. A matrix was developed in which the hearing bandwidth for each species was compared with the bandwidth of sound sources. Where hearing and sounds overlapped, further assessment described potential impacts and mitigation opportunities.

When environmental assessments identify potential impacts, project planners should consider mitigation measures ranging from measures to detect and avoid marine mammals to application of sound attenuation technologies (Weir and Dolman 2007; Spence 2007). If significant knowledge gaps weaken environmental assessments, planners should consider precautionary mitigation and voluntary engagement in relevant applied research.

The BP marine mammal EPR also provides specific guidance for some activities. For example, all BP seismic exploration projects must apply the UK Joint Nature Conservation Committee (JNCC) Guidelines or their equivalent (http://www.scar.org/information/JNCC_Seismic_survey_guidelines.pdf). For projects other than seismic exploration with the potential to impact marine mammals, operators must monitor a zone with a 500-m radius or a zone in which impulsive sounds exceed 180 dB re 1 µPA. If marine mammals are present within the zone during the 30 minutes before scheduled start of activities, work cannot commence. If a marine mammal swims into this zone after work has commenced, shutdown should be considered based on assessment of risks by trained observers. If visibility makes observation of this zone impossible or challenging, passive acoustic monitoring or other detection techniques should be considered.

As new information becomes available, the EPR will be updated. For example, because new information suggests that the 180 dB re 1 µPA guideline may be too conservative (Southall et al. in press), this guideline may be changed soon.

Constructive Engagement with Stakeholders

Stakeholder engagement is a necessary part of the business process in the highly emotive world of marine mammal conservation, underpinned by a complex landscape of cooperating and competing advocacy organizations and regulators. While stakeholders may not have direct authority, they can influence regulatory decisions and relationships with funding partners, shareholders, and the public. Also, insights provided through stakeholder engagement can improve projects.

BP's Northstar project in Alaska provides an example of successful stakeholder engagement (Fig. 4). Initial discussions with stakeholders, including representatives from nearby Inupiat communities, identified significant concerns about the potential for sounds associated with an offshore production facility to influence the behavior of bowhead whales. A collaborative approach to study design and implementation was undertaken by individuals often perceived to have irreconcilable differences, including academic, government, and industry scientists and representatives of Alaska's Inupiat community.

Frequent stakeholder communications and formal meetings twice each year have led to a study that has contributed to our understanding of bowhead responses to relatively low-level continuous sounds. After four years, an external Science Advisory Committee consisting of university and government acousticians, statisticians, and biologists was convened to review the study at the request of stakeholders. The Science Advisory Committee agreed that whales responded to Northstar sounds, but encouraged further analyses (now ongoing) and suggested that data collection efforts should be reduced while analyses were completed (North Slope Borough Scientific Advisory Committee 2005). Recently, many of the stakeholders, working directly with BP, published a short paper identifying a number of important points that contributed to the success of the collaborative process:

- Appreciation of traditional (Native) knowledge,
- Commitment to long-term work,
- Articulation of scientific questions that captured general concerns,
- Open communication among participants,
- Commitment to high statistical power, and
- Limited personnel turnover.

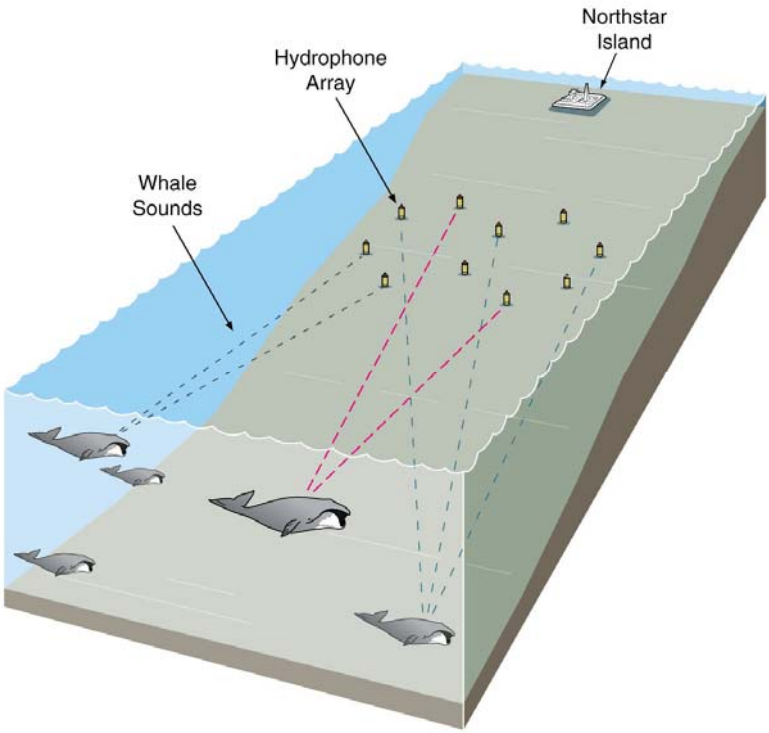

Fig. 4—BP's bowhead whale study at Northstar, in the Alaskan Beaufort Sea, uses directional hydrophones to compare the locations of calling whales during periods when Northstar is generating different levels of sound to answer the broad question, "Are the calling whales farther offshore when Northstar sounds are stronger?"

The Value of Applied Research

While applied research can provide insights needed to assess and mitigate potential impacts, identification of the most appropriate research questions is sometimes challenging. One approach is to identify questions that are not receiving adequate attention from others and that are specific to industry needs, such as research that will lead to better methods of detecting marine mammals at night or in low visibility and research that can reduce sound levels associated with industry activities. Another approach involves contributing to studies of broad interest to the marine mammal research community.

Some research questions have universal application, while others are more regional or even situational. An understanding of airgun sound characteristics across a reasonably wide frequency bandwidth is important to anyone exploring for oil and gas offshore. Conversely, studying behavioral responses of a particular species of marine mammal exposed to a particular sound source, such as driving sheet pile through gravel, may not be very important for operations where the species being studied is not present or where sheet pile is not driven through gravel. While most studies have at least some value to industry and to the scientific community, the value will vary depending on operational needs and study time scales.

Whenever possible, industry should focus on questions of universal interest that have the potential to improve business practices within a reasonably short time. For example, characterization of certain sound sources at BP's Northstar facility, such as the hovercraft used to transfer crews back and forth to the island (Blackwell and Greene 2005), may be useful to others considering ways to reduce underwater sounds associated with routine vessel traffic. This will not, however, be possible in all cases. For example, the study leading to improved understanding of bowhead whale responses to production sounds from the Northstar facility will not be very useful to Gulf of Mexico operators concerned about potential impacts to sperm whales from seismic exploration.

For several years, a number of companies have tried to work together on marine mammal and sound research. Currently, the Sound and Marine Life Joint Industry Programme managed by the International Oil and Gas Producers Association is undertaking a multi-year research effort (http://www.soundandmarinelife.org/). By agreement, the Joint Industry Programme's projects are intended to be of interest globally. Examples include improvements in technologies intended to detect whales, broad understanding of behavioral reactions in response to airguns based on analyses of data compiled from dozens of seismic operations around the world, compilation of sound characterization data from many oil and gas industry activities, and improved understanding of hearing through direct testing, anatomical studies, and modeling. In addition, many of the programme's member companies independently support regionally important studies, such as range surveys of the sousa dolphin in New Guinea, ecological studies of the western gray whale in Russia, and population studies of the beluga whale in Alaska.

Training the Work Force to Address Marine Mammal Issues

An awareness of marine mammal and sound issues in the oil and gas industry exists because of media coverage and concerns raised by stakeholders and regulatory agencies in some areas. However, this broad awareness has not yet been translated into broad expertise. It would be fair to say that most of the industry's work force, including geophysicists whose operations are likely to be affected by the issue and environmental professionals tasked with compliance and permitting, need to develop skills and competencies to deal with stakeholder concerns, to understand relevant environmental assessments, and to recognize or design effective and efficient mitigation measures. Most of the industry work force likely to be confronted with marine mammal issues needs little more than basic familiarization training. BP's training for nonspecialists uses slides, video clips, sound recordings, and open discussion to cover topics such as marine mammal diversity, marine mammal hearing, industry sounds, legal requirements, environmental assessments, use of marine mammal observers, use of passive acoustic monitoring systems, ramp-up and shutdown requirements for seismic operations, emerging technologies that may allow improved detection of marine mammals, and applied research. Although the training covers a number of topics, it is intended only to provide familiarization and as such can be delivered in four or five hours, making it reasonably accessible to those requiring this level of understanding. Employees likely to be more deeply engaged in marine mammal issues can take more intensive courses from commercial vendors.

While there is some possibility that specialized marine mammalogists may eventually be employed by some companies, the diverse needs of most companies suggest that the industry will continue to rely on scientific generalists with varying levels of expertise on marine mammal issues. To maximize the collective value of knowledge possessed by generalists, virtual networks of company experts can be established and web-based tools can be created to provide information and assist with tasks such as environmental assessments. BP is developing web-based guidance linked to the company's Marine Mammal and Sound Environmental Performance Requirement. The guidance includes a glossary, a table of marine mammals occurring in different regions where BP operates, a summary of hearing abilities for marine mammals, and a table of known sound signatures. When required, specialists with in-depth expertise can be contracted on a program- or issue-specific basis.

Addressing the Rebuttable Presumption

In a sense, the marine mammal and sound issue can be summed up as a poorly understood issue with many technical and political nuances that can dramatically affect offshore operations. On the one hand, there is very little evidence to support concerns about the potential for sounds associated with offshore oil and gas industry activities to impact marine mammals, especially when assessed in comparison with the well-known and often lethal impacts from activities such as commercial fishing, which kills more than an estimated 1,500 marine mammals every day as bycatch (Read et al. 2006). On the other hand, it is not possible to prove an absence of impacts, and limited evidence suggests that behavioral responses to sound could have consequences for some species of marine mammals under some circumstances. Based on currently available knowledge, reasonable people can reasonably disagree about the importance of potential impacts to marine mammals.

Nevertheless, Shabman's principle of the rebuttable presumption applies. The onus is on industry to demonstrate that potential impacts can be mitigated to an acceptable level. Whether or not individuals involved with projects believe that risks to marine mammals justify concerns over potential impacts, industry representatives have a responsibility to manage business risks arising from these concerns. The approach adopted by BP emphasizes a regionally flexible set of operational requirements, the need to engage with stakeholders, the value of applied research, and development of a competent workforce. While this approach may not be well suited for every oil and gas company, it is clear that all companies need to articulate, at least internally, a strategy that recognizes the issue of marine mammals and underwater sound in a business context. Ignoring the issue, or hoping that it will not impact operations, is to run an unacceptable risk of delayed or inefficient projects and expensive lost opportunities.

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