The Gerry E. Studds Stellwagen Bank National Marine Sanctuary as a regional case study for integrating protected species and protected area management tools to study and mitigate impacts of anthropogenic noise sources on marine mammals.

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ABSTRACT

Energy development in US federal waters is big business, and has become an important ingredient in the United States' (US) ocean policy mix. Despite the limited offshore geographic area for which leasing is currently authorized, the amount of oil and gas production from the Outer Continental Shelf (OCS) is significant. In its recently released final report, the US Commission on Ocean Policy recommended that the Minerals Management Service should conduct long-term environmental research and monitoring to better understand cumulative, low-level, and chronic impacts of OCS oil and gas activities on the marine environment (US Commission on Ocean Policy, 2004). In this paper we present the Gerry E. Studds Stellwagen Bank National Marine Sanctuary (SBNMS) as a case study in which we are assessing regulatory needs surrounding seismic surveying and other anthropogenic sound sources on two fronts: developing policy and gathering scientific information. Here, we examine the status of current US policy used to regulate anthropogenic sound within US National Marine Sanctuaries and ask a series of questions regarding the application of the US Marine Mammal Protection Act. We examine the relationship between current management tools focused on marine mammal species and marine protected areas, and highlight the role that spatially and temporally explicit regulatory models could play in integrating these tools. SBNMS is introduced as an urbanized marine environment, a feeding site for numerous protected marine mammal species and a pending site for increased use of seismic surveying technologies associated with energy inventories and liquid natural gas terminal development in the Gulf of Maine. A collaborative effort to monitor SBNMS's acoustic environment throughout the year using an array of autonomous recording units is described, and the utilities of these acoustic data for characterizing whale demographics, whale locations relative to ship traffic and whale-watching vessels and the Sanctuary's annual "noise budget" are detailed. Finally, the experimental set-up for a preliminary study of the acoustic signatures generated by two commonly-used but poorly-characterized seismic surveying technologies (boomers and mini-sparkers) is introduced to generate discussion by members of the International Whaling Commission's Scientific Committee (IWC's SC) who are participating in a pre-meeting to "Review the Potential Impacts of Seismic Surveys on Cetaceans". Although this paper discusses US policy at some length, it does so not to imply that the US approach warrants this forum's particular attention, but instead to provide the IWC's SC with reference points for discussing how to design and/or prioritize future scientific research efforts to best address common domestic and international regulatory questions surrounding the potential impacts of seismic surveys on cetaceans.

KEYWORDS: SANCTUARIES, NOISE, MONITORING, SURVEY-ACOUSTIC

INTRODUCTION

The US Outer Continental Shelf (OCS), as managed by the US Department of the Interior's Mineral Management Service (MMS), consists of all submerged land extending from three nautical miles into the Atlantic Ocean, the Pacific Ocean, the Arctic Ocean and the Gulf of Mexico (excluding the coastal waters off Texas and western Florida) to the 200 nautical mile limit of the US Exclusive Economic Zone (EEZ) (Outer Continental Shelf Lands Act, 1953). Through Congressional moratoria and Presidential action, about 610 million acres of the more than 1.7 billion acres (~36%) of OCS have been designated off limits to oil and gas leasing through 2012, confining most of the federal OCS leasing program to the central and western Gulf of Mexico (95% of current offshore production), a small portion of the eastern Gulf of Mexico, existing offshore California leases, and areas off Alaska (US Commission on Ocean Policy, 2004).

Currently, all new oil development is prohibited within the thirteen designated US National Marine Sanctuaries. US National Marine Sanctuaries encompass about 734 thousand acres (representing 0.1% of the total area under oil/gas leasing moratoria and 0.04% of total OCS acreage) and are managed by the US Department of Commerce's National Oceanic and Atmospheric Administration (NOAA). All but one of the Sanctuaries has regulations expressly prohibiting or restricting oil and gas exploration or development. In addition, President

Clinton's 1998 executive memorandum to the Secretary of the Interior extended a prohibition on the granting of new oil and gas leases in all National Marine Sanctuaries until June 30, 2012 (Presidential Executive Memorandum 1111, 1998). Despite these regulatory and executive actions, the issue of oil development in National Marine Sanctuaries is by no means settled. Clinton's memorandum can be rescinded by a succeeding president, and Congress can pass legislation to allow oil exploration throughout the entire OCS, including National Marine Sanctuaries (Chandler and Gillelan, 2005). Thus far, such legislation has not passed both the House and the Senate due to heavy opposition by members of Congress from coastal states.

On August 8th, 2005, the 109th Congress of the United States passed the Energy Policy Act of 2005. In response to increasing problems matching national demand for oil and natural gas with international supply, the Act's intent was to establish a comprehensive, long-range US energy policy by providing tax incentives and loan guarantees for energy production of various types. The Act also directs the Secretary of the Interior to inventory and analyze oil and natural gas resources beneath all of the waters of the OCS using "any available technology, except drilling, but including 3-D seismic technology to obtain accurate resource estimates" (Energy Policy Act, 2005). Not only does the Energy Policy Act's inventory include areas currently under drilling moratoria, it requires the MMS to "identify and explain how legislative, regulatory, and administrative programs or processes restrict or impede the development of identified resources and the extent that they affect domestic supply, such as moratoria, lease terms and conditions, operational stipulations and requirements, approval delays by the Federal Government and coastal States, and local zoning restrictions for onshore processing facilities and pipeline landings" (ibid). Clearly, data from this inventory will be useful for state and federal governments interested in revisiting offshore drilling moratoria in the future. However, it has yet to be determined whether the use of seismic exploration systems in US marine protected areas such as National Marine Sanctuaries directly conflicts with US protected area legislation, such as the National Marine Sanctuary Act (National Marine Sanctuaries Act, 1992).

In addition to potential conflicts surrounding *where* seismic surveying for oil and gas resources is conducted, there are also potential conflicts arising from *the sounds* produced by surveying systems. Although researchers and industries have mapped the seafloor using sidescan sonar, multibeam bathymetry and high-resolution seismic-reflection profiling for decades, very little is known about the acoustic properties of the pulses actively generated by these systems (especially in the horizontal dimension) and/or their possible impacts on marine mammals and other marine life . Thus, the Energy Policy Act's mandate to increase seismic exploration in the OCS may also present conflicts with US protected species legislation, including the Endangered Species Act (Endangered Species Act, 1973) and the Marine Mammal Protection Act (Marine Mammal Protection Act, 1972). In its 2003 report, the US National Research Council's (NRC's) "Committee on the Potential Impacts of Ambient Noise in the Ocean on Marine Mammals" concluded that concern surrounding anthropogenic sound and marine mammals was warranted, given the endangered status of many marine mammals, the identified importance of sound in the lives of marine mammals, the potential for harm from excessive noise and the paucity of data with regards to the amount of sound introduced into the oceans by human activity and its potential impact on marine mammals (National Research Council of the National Academies, 2003). The NRC also emphasized that it was important to conduct additional research on the topic before conclusions could be drawn. On the international level, the International Whaling Commission (IWC) Scientific Committee's (SC's) Working Group on Environmental Concerns came to similar conclusions when it convened a Mini-Symposium on Anthropogenic Noise in 2004 (International Whaling Commission, 2004).

In this paper, we describe the current framework for regulating the potential impacts of sound from seismic surveying in the US's OCS. Our discussion is divided between protected species and protected area-directed approaches, and we highlight the absence of more integrative, ecosystem-based regulatory options. Finally, we present research in progress at the Gerry E. Studds Stellwagen Bank National Marine Sanctuary that can be used as a case study for addressing gaps in both the regulatory framework and the scientific knowledge surrounding the potential impacts of anthropogenic sound sources, including poorly-characterized seismic technologies, on marine ecosystems. Although this paper discusses US policy at some length, it does so not to imply that the US approach warrants the IWC SC's particular attention, but instead to provide members with reference points for discussing how to design and/or prioritize future scientific research efforts to best address domestic and international regulatory questions surrounding the potential impacts of seismic surveys on cetaceans.

MARINE PROTECTED SPECIES LEGISLATION, NOISE AND SEISMIC SURVEYING

Currently, protected species statutes are the most prominent management tools utilized by the US government to regulate impacts *specific to marine mammals* due to anthropogenic sound sources in the marine environment. Since 1973, marine mammal species that frequent US waters and are threatened or in danger of extinction have been listed and protected under the US Endangered Species Act (ESA) (Endangered Species Act, 1973). In addition, since 1972, all marine mammal populations in US waters, regardless of their status, have been

protected by the US Marine Mammal Protection Act (MMPA) (Marine Mammal Protection Act, 1972). The MMPA was initially passed primarily to regulate the incidental deaths of marine mammals in commercial fisheries. However, in 1981 the Act was amended to take into consideration other anthropogenic activities leading to the incidental deaths or harassment of small numbers of marine mammals. The Small Take Program, implemented by NOAA Fisheries' Protected Resources Division to permit these activities, was first utilized by the oil and gas industries to regulate the impacts of noise associated with mineral exploration on marine mammals; specifically, the impacts of airgun array signals on Arctic species (Richardson *et. al.*, 1995). In 1994, amendments to the MMPA expanded the Small Take Program to include the Incidental Harassment Authorization and General Authorization permitting programs. In addition, the 1994 amendments to the MMPA statutorily defined harassment to assist NOAA in regulating disturbance associated with anthropogenic activities, such as noise. Finally, in 2003 the US Congress passed a new provision under the MMPA redefining harassment in the context of military readiness activities (National Defense Authorization Act, 2003).

The authorization of the MMPA expired in 1999. In June, 2005, the Administration/NOAA transmitted a proposed bill to reauthorize the MMPA to Congress (National Oceanic and Atmospheric Administration, 2005a). This bill suggests revisions to the definition of harassment under the MMPA. The proposed language would consider only acts with "significant" potential to injure marine mammals to be level A harassment, and only acts that disrupt natural behavioural patterns "to a point where such behavioural patterns are abandoned or significantly altered" or are "directed toward a specific individual, group or stock of marine mammals" to be level B harassment (ibid). In clarifying its rationale for these revisions, the Administration states that "the proposed definition would improve the enforceability of the prohibition without compromising conservation measures" (National Oceanic and Atmospheric Administration, 2005b). Some marine mammal researchers agree that the definition of harassment should be revised in order to streamline the permitting process for scientific research, including the impacts of underwater sound on marine life (Scientific Research Caucus of the Advisory Committee on Acoustic Impacts on Marine Mammals, 2006). In a recent statement, they recommend that "Congress should amend the Marine Mammal Protection Act to revise the definition of harassment to cover only activities that meaningfully disrupt behaviours that are significant to the survival and reproduction of marine mammals (ibid). Current reauthorization packages on Capitol Hill (both bills introduced in the 108th and 109th Congresses, and drafts circulated for discussion) include a variety of options to readdress the balance of sound producers (e.g., industry, defense and scientific research) and marine mammal protective interests under the MMPA's harassment definition. Hearings to address reauthorization issues in the 109th Congress are expected in early fall 2006.

Debates surrounding the regulation of anthropogenic sound are particularly difficult to resolve for sources, such as the active sources used in seismic surveys, whose potential impacts on marine mammals are either beginning or continuing to undergo scientific scrutiny. Under the ESA, NOAA must require other federal agencies to consult with them regarding activities that jeopardize the continued existence or result in the destruction or adverse modification of critical habitat (Endangered Species Act, 1973). Although the current language of the MMPA was clearly written with the precautionary principle in mind, under the MMPA statute proponents retain the right to decide whether consultation with NOAA is necessary for activities with the potential to result in take and/or harassment (Marine Mammal Protection Act, 1972). The question often faced by NOAA in attempting to meet its mandates under these statutes is: should the agency regulate sound sources whose impacts on marine mammals have not been comprehensively documented, and if not, at what point in the process of scientific study, peer review and publication should NOAA determine that there is evidence to support regulation? Further questions include: should scientists engaged in research that is attempting to quantify the impacts of various sound sources on marine mammals be regulated differently then other sound producers? Would collaborative efforts currently underway between academic scientists, resource managers, industry and defense agencies continue to be funded if the burden to prove harassment was shifted towards regulators and away from sound producers? If not, is it appropriate to support the current definition of harassment to keep stakeholders financially engaged in gathering additional information, especially given that additional information may be used to regulate those funding the research?

To further parameterize these questions as they relate to the active sources used in seismic surveying, under what temporal/spatial conditions should regulation for these technologies be considered? Under the Energy Policy Act's mandate, we identify two general categories of geographic areas where seismic surveying activity is expected to increase: 1) areas where oil and gas resources are known to be rich and where exploration and/or extraction have historically been allowed, and 2) areas where oil and gas resources may or may not be rich, but where exploration and extraction have historically been prohibited (including many marine protected areas). If the potential impacts of seismic surveying continue to be addressed solely for marine mammal and ESA-listed species, and thus solely via protected-species legislation, we can identify two general types of regulatory concerns affiliated with the same two general categories of geographic areas described above: 1) areas where increasing sound associated with increasing levels of seismic surveying may exceed chronic intensity thresholds

within frequency ranges utilized by permanent or seasonally resident protected or endangered species, or 2) areas where permanent or seasonally resident marine mammal populations may now be exposed for the first time or with more predictable regularity to seismic survey sounds that are within the animals' range of acoustic sensitivity. Thus, for the first category of areas (those where exploration and extraction has historically been allowed) NOAA may need to consider permitting under the MMPA and/or consultation under the ESA for seismic technologies that have historically been used at lower levels without regulation, while for the second category of areas (those where surveying has for the most part been prohibited) NOAA may need to consider permitting and/or consultation for seismic technologies that have thus far been used elsewhere without regulation. In addition, concerns surrounding possible cumulative impacts for both protected and/or ESA-listed species and other acoustically-sensitive marine species such as fish, sharks and turtles exposed to increasing seismic activity may warrant NOAA's focus, but are difficult and/or impossible to address species-specifically. The first step in addressing regulatory questions such as these in a more ecologically-holistic, ecosystem-based context, is to integrate the current US species-specific management tools, such as the ESA and MMPA, with the current US area-specific management tools, such as the Executive Order on Marine Protected Areas (Presidential Executive Order 13158, 2000) and the National Marine Sanctuaries Act.

MARINE PROTECTED AREA LEGISLATION, NOISE AND SEISMIC SURVEYING

In the same year in which it passed the MMPA, Congress passed the Marine Protection, Research, and Sanctuaries Act of 1972. This Act created the Marine Sanctuaries Program to "preserve or restore marine areas for their conservation, recreational, ecological and aesthetic values" (Marine Protection, Research and Sanctuaries Act, 1972). However, during floor debate prior to its passage, members of the US House of Representatives' Merchant Marine and Fisheries Committee[1] were adamant that the Act was not purely a preservation statute, and that multiple uses of Sanctuary waters were expected (Chandler and Gillelan, 2004). Thus, since its' inception, the Marine Sanctuaries Program has sought to balance protective interests in areas of the marine environment deemed of value to the nation, with extractive interests in areas of the marine environment valued by commercial fishing, recreational fishing and other recreational uses, oil and gas exploration and extraction, Naval defense, coastal safety operations, marine transport, and scientific research. The Marine Sanctuaries Program is managed from within NOAA's National Ocean Service; thus, the US Secretary of Commerce manages Sanctuaries as well as many of the extractive user groups identified above.

Over the past thirty-four years, the Sanctuaries Act has been substantively amended six times, changing it from a two page law to an over thirty page law in an attempt to resolve questions regarding its authority to prevent conflicting uses. In 1992, comprehensive amendments to the Act lead it to be renamed The National Marine Sanctuaries Act (National Marine Sanctuaries Act, 1992). The amendments to the NMSA in 2000 imposed a moratorium on the number of Sanctuaries; capping the program at the thirteen designated/approved Sanctuaries that currently exist. The authorization of the NMSA expired in 2005. Reauthorization packages that include provisions to lift the moratorium on additional Sanctuary designations have been drafted and/or introduced in the 108th and 109th Congresses. However, controversies, primarily surrounding the prohibition or regulation of fishing permits and oil and gas leases in current and future Sanctuaries remain unresolved by the US government.

The NMSA provides several tools for protecting designated National Marine Sanctuaries. Most generally, "The Secretary may undertake or authorize all necessary actions to prevent or minimize the destruction or loss of, or injury to, Sanctuary resources, or to minimize the imminent risk of such destruction, loss, or injury" (National Marine Sanctuaries Act, 1992; section 312b). Additionally, if the Secretary finds a *federal* action is likely to destroy, cause the loss of, or injure a Sanctuary resource, the National Marine Sanctuary Program is required to recommend reasonable and prudent alternatives that will protect Sanctuary resources if implemented by the agency in taking the action (National Marine Sanctuaries Act, 1992; section 304d). Finally, the NMSA allows the Secretary of Commerce to issue regulations for each Sanctuary designated and the system as a whole that, among other things, specify the types of activities that can and cannot occur within the Sanctuary (National Marine Sanctuaries Act, 1992; section 308). While each Sanctuary has its own unique set of regulations, there are some regulatory prohibitions that are typical for many sanctuaries: discharging material or other matter into the Sanctuary, disturbance of, construction on, or alteration of the seabed, disturbance of cultural resources, and exploring for[2], developing, or producing oil, gas, or minerals (often with grandfather clauses for pre-existing operations). In addition, some sanctuaries prohibit other activities, such as the disturbance of marine mammals, seabirds, and sea turtles, operation of aircraft in certain zones, use of personal watercraft, mineral mining and anchoring of vessels (National Marine Sanctuaries Act, 1992; Section 306).

[1] US House of Representatives' jurisdiction over National Marine Sanctuaries' legislation is now under the Resources Committee.
[2] However, see discussion of Energy Policy Act (2005) Inventory Provision, which mandates all exploratory activities except drilling.

Clearly, meeting the NMSA's mandates to "prevent or minimize" and/or to "identify and mitigate" activities that are likely to destroy, cause the loss of, or injure Sanctuary resources requires striking delicate and dynamic balances between the competing interests of multiple constituencies as well as multiple federal agencies. Models that allow levels of regulation to vary both geographically and seasonally to reflect spatial and temporal variations in marine animal life histories provide more options for regulators and policy-makers weighing economic, national security and conservation goals. In addition, for regulatory models to adequately protect marine ecosystems, they must reflect the often complex relationships among species occupying multiple tropic levels. For example, ecosystem-based regulation may need to account for tradeoffs among multiple species-specific calculations of risk of depletion or adverse affects and/or address cumulative risks from multiple anthropogenic activities. As part of its "New Priorities for the 21st Century—NOAA's Strategy Plan", the agency has recently identified one of its four mission goals as "protect, restore, and manage the use of coastal and ocean resources through an ecosystem approach to management" (National Oceanic and Atmospheric Administration, 2005c).

According to the US Commission on Ocean Policy, ecosystem-based management "looks at all the links among living and non-living resources, rather than considering single issues in isolation…considers human activities, their benefits, and their potential impacts within the context of the broader biological and physical environment… focuses on the multiple activities occurring within specific areas that are defined by ecosystem, rather than political, boundaries" (US Commission on Ocean Policy, 2004). This approach is entirely consistent with the policies and purposes of the NMSA, which provides authority "for comprehensive and coordinated conservation and management of these marine areas, and activities affecting them, in a manner which complements existing regulatory authorities…" (National Marine Sanctuaries Act, 1992; section 301b). As is clearly identified in this mandate, the application of ecosystem-based management within Sanctuaries involves intensive collaboration with other regional agencies charged with managing components of the ecosystem both within and beyond Sanctuary boundaries. Sanctuaries are not ecosystems unto and of themselves, but rather represent portions of ecosystems with clear geographic boundaries within which environmental stressors caused by humans and natural events can be examined, monitored, evaluated, and managed (Gerry E. Studds Stellwagen Bank National Marine Sanctuary Ecosystem-Based Working Group, 2004).

NOAA has determined that to effectively manage Sanctuary resources, scientists must first adequately characterize what these resources are and the threats they face. For this reason, NOAA has made the development of "site characterizations" for each Sanctuary a strategic planning priority (National Oceanic and Atmospheric Administration, 2006a). Efforts to characterize threats to US National Marine Sanctuary resources closely parallel such efforts in US National Parks. In 1997, the National Parks Overflights Act identified natural sound in US National Parks as a resource and a value to be appreciated, concurrent with all other natural values that are specified in laws, regulations, executive orders, and policies (National Parks Overflights Act, 1997; section 3a). The National Park Service's Natural Sound Program seeks to balance the multiple use mandates of National Parks (mandates similar to those for National Marine Sanctuaries), by measuring and monitoring "both individual types of sound sources and their cumulative effects…[to determine] what levels and types of noise are appropriate or acceptable for different management areas throughout a park" (Natural Sound Program, 2006). With very similar goals in mind for marine areas of concern, the NRC's 2003 report *Ocean Noise and Marine Mammals* recommended the establishment of "noise budgets", defined as the sum of the relative contributions made by identified sound sources to the total sound field (National Research Council of the National Academies, 2003). The report further recommended that "noise budget" determinations for various parts of the ocean should include representations of seasonal and spatial/temporal differences. Finally, the NRC specifically identified the need to define the sound contribution of different vessel types within the major category of shipping. While the report's focus was global, many of its insights and recommendations can be used at the Sanctuary level to provide a local understanding of the issue. Insights achieved at the local level can then be used to inform the larger issue at national and international levels.

GERRY E. STUDDS STELLWAGEN BANK NATIONAL MARINE SANCTUARY: A CASE STUDY

The Acoustic State of the Sanctuary

The Gerry E. Studds Stellwagen Bank National Marine Sanctuary (SBNMS) has become a hub of research focused on evaluating the potential impacts of noise on marine mammals both due to its mandate under the National Marine Sanctuary Act (NMSA), and due to the fragility of its species and habitats. The Sanctuary is an "urban" marine Sanctuary located in close proximity to a large population density coastal zone, encompassing 842-square-miles of open water and the seafloor below at the mouth of Massachusetts Bay off the northeastern coast of the US (see Figure 1). As shown in Figure 1, the International Maritime Organization (IMO)-approved Traffic Separation Scheme for the Port of Boston runs directly through the Sanctuary in an east-west pattern,

routing the daily transits of container ships, tankers carrying oil and liquefied natural gas and cruise lines. The Boston Harbour Outfall Tunnel discharges ~300 million gallons of treated effluent per day twelve miles west of the Sanctuary's western border. In addition, a Massachusetts Bay Disposal Site (MBDS) just outside the Sanctuary's northwestern border has been used since the 1940's. Finally, in 2000, a fiber optic cable was laid across the northern edge of the Sanctuary under a federal permit.

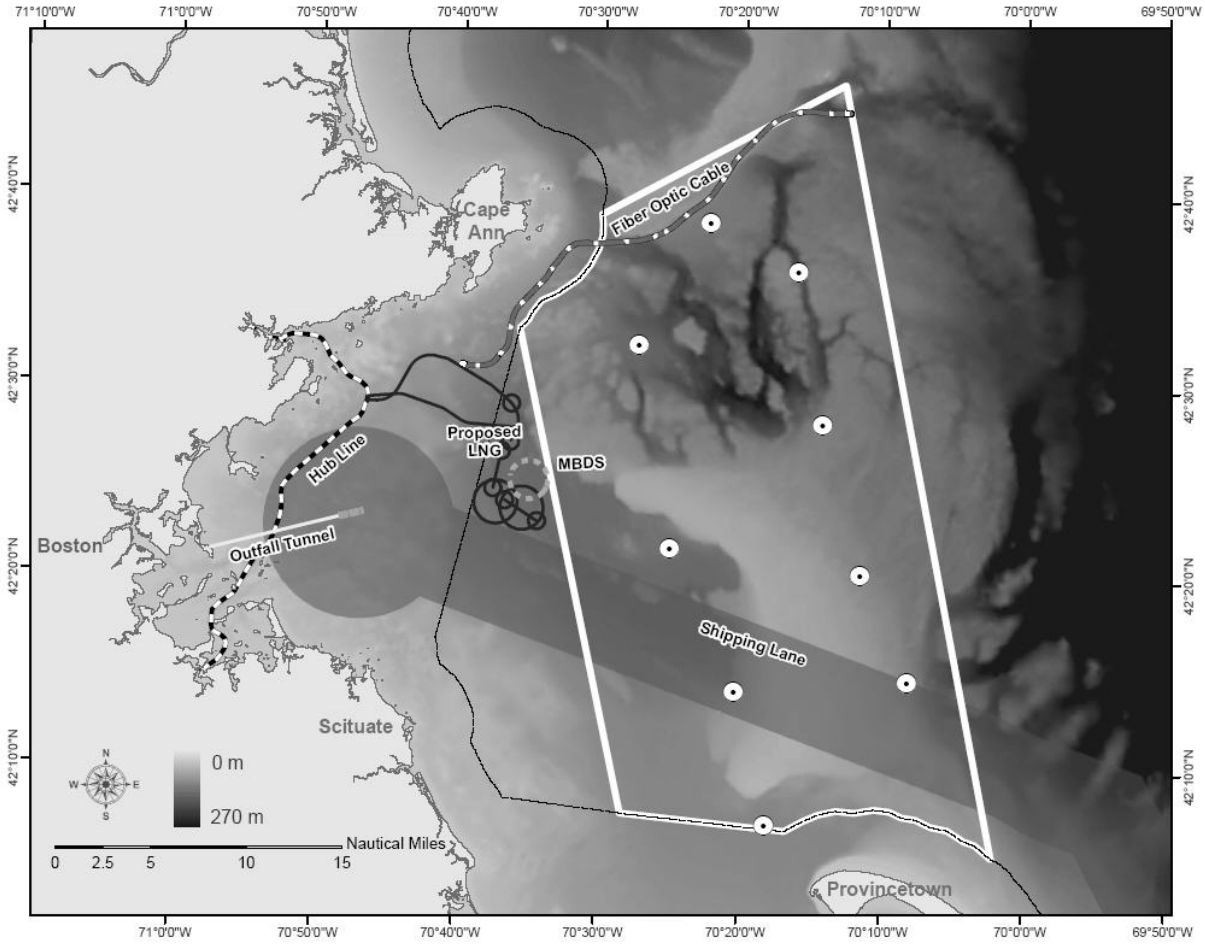

Figure 1. Bathymetry of Massachusetts Bay, 3-mile boundary line between state and federal waters, boundary lines for SBNMS, dots showing locations of nine autonomous recording units (ARU's) deployed within SBNMS, and existing and proposed locations of several commercial activities directly adjacent to or within SBNMS and referred to in text.

The central feature of the Sanctuary, Stellwagen Bank, is an underwater plateau of sand and gravel created by glacial processes at the end of the last great ice age during the Pleistocene epoch. As waters in deeper Stellwagen basin and the Gulf of Maine encounter the bank's rising elevation, upwelling currents occur. As a result, Stellwagen is home to some of the oldest and highest capacity commercial fisheries in the world, with approximately 440 commercial vessels fishing in the Sanctuary every year using mobile and fixed gear throughout the water column and on the bottom. On a regional scale, the Sanctuary is a part of the Gulf of Maine ecosystem, which is an important feeding ground for endangered marine mammals such as North Atlantic right whales, humpback whales and finback whales. In addition, several mammal species that are not currently listed as endangered or threatened are resident in the Sanctuary, including North Atlantic minke and pilot whales, Atlantic white-sided dolphins, harbour porpoises, and harbour and grey seals. Approximately one million whale watch passengers visit Sanctuaries each year, utilizing fourteen to sixteen whale watch boats from coastal ports, each of which makes one to three visits a day in season.

Concerns regarding vessel traffic, physical disturbance, pollution and noise ultimately defeated industry and MMS proposals to mine sand and gravel deposits in the Sanctuary in the late 1980s and early 1990s (Chandler and Gillelan, 2004). Currently, however, several proposals to build liquefied natural gas (LNG) terminals in Massachusetts Bay and/or coastal Massachusetts are under consideration by state and federal agencies. Two companies have proposed LNG locations on the northwestern border of SBNMS between the current Massachusetts Bay Disposal Site (MBDS) and the current Traffic Separation Scheme (see Figure 1). These

regional proposals are part of a larger effort by the US to address domestic energy demands by importing larger volumes of LNG. The importation of natural gas and the construction and operation of LNG terminals are governed by the Natural Gas Act (Natural Gas Act, 1938) and the Deepwater Port Act (Deepwater Ports Act, 1974). As lead agencies for the licensing of LNG terminals, the Federal Energy Regulatory Commission, the US Coast Guard, and the Maritime Administration are required to coordinate their activities and consult with other Federal agencies who have either jurisdictional authority over resources, including living marine resources, within the affected area or who have expertise in a particular matter related to the proposed activity (Maritime Transportation Security Act, 2002).

In 2005, in partial fulfilment of its role as a consulting agency, NOAA drafted a list of recommended best practices for LNG terminals (National Oceanic and Atmospheric Administration, 2006b). It this draft, NOAA recommended that lead agencies "select sites for LNG terminals and associated pipeline networks to avoid/minimize both construction and operation impacts on ESA critical habitat (e.g., right whale critical habitat), EFH, estuarine passes, fishing areas, designated recreational zones, National Estuarine Research Reserves, National Marine Sanctuaries, and other specially designated zones" (ibid). In addition, NOAA recommended a variety of steps to prevent or minimize the impacts of activities surrounding LNG terminal construction and operation that could impact marine life, including cooling water discharge, physical alterations and pollution related to construction and/or accidents, addition of infrastructure both above and below water, vessel traffic and docking associated concerns, and noise associated with seismic surveying of sites, pile driving during site construction, increased vessel traffic etc. (ibid). As the marine environment presents no physical boundary between selected sites and adjacent marine areas, characterizing the "acoustic footprint", both spatially and temporally, of sources associated with nearby LNG terminals, oil and gas drilling etc. is essential if we are to accurately characterize the impacts these type of developments will have on the Sanctuary's acoustic environment.

Passive Acoustic Monitoring in the Sanctuary

To begin characterizing the acoustic environment and health of SBNMS, a collaborative group of academic researchers and NOAA managers has installed an array of nine autonomous recording units (ARUs) to monitor underwater sounds between 0 and 1000Hz throughout Sanctuary waters for one calendar year (see Figure 1). ARU data will be used to compare Sanctuary sound levels with (1) baleen whale audiogram models to estimate the potential for hearing loss (for example, see Erbe, 2002) and (2) the sounds produced by baleen whales in the Sanctuary to determine the potential for masking. To calculate the "noise budget" (National Research Council of the National Academies, 2003) of SBNMS, the contributions and frequency characteristics of noise from biological, meteorological, and anthropogenic sources will be identified (Curtis *et al.*, 1999). Modelling will determine, for a specific location and its acoustic environment, the range at which a sound of a given frequency could be received from that location and how that range would change daily, seasonally, and yearly, as a result of changes in the acoustic environment (Frankel *et al.*, 2002).

ARU data will be used to localize vocalizing whales (identified by the species-specific characteristics of their vocalizations) and calculate distributions and acoustic densities for different species in Sanctuary waters throughout the year. These data will aid the Sanctuary's ongoing monitoring of whale densities relative to the current Traffic Separation Scheme. Due to their critically endangered status, locating vocalizing right whales within the Sanctuary will remain a priority for ARU data analysis.

The same data can be analyzed to determine the number of vessels traversing the acoustic monitoring area, the acoustic characteristics of a vessel at its closest point of approach (CPA) to an ARU, and the received characteristics of the vessel as a function of such factors as distance, bathymetry, and water temperature. SBNMS is ideally situated to generate methodologies to merge data from acoustic monitoring devices with vessel reporting data to identify the contributions made by various vessel classes to noise within a clearly-defined and well-studied area of the ocean. Data from single ARUs will be converted into spectrographic displays (i.e., acoustic scenes) that can be modified to visualize the acoustic scene over a user-selected range of time scales, for example, years, seasons, months or days. These same data can be statistically analyzed to calculate acoustic budgets at each ARU site. Data from all nine ARUs will be integrated using data interpolation techniques to create a spatial composite of the sound field throughout SBNMS. By this procedure, the estimated sound field for some window of time (e.g., 1 minute) for some specified frequency band (e.g., 50 – 150Hz) can be represented by a colour scale (e.g., from red, a high sound level, to blue, a low sound level) and a sequence of such fields can then be animated as a "sound movie", showing changes in the spatial distribution of sound levels over time.

Such "sound-field movies" will be generated for frequency bands that contain the sounds of commercial vessels as well as vocally-active baleen whale species (e.g., 15-25 Hz for fin whales, 80-400 Hz for right whales, 200-800Hz for humpback whales). Acoustic data will be used to identify times and orientations relative to the ARUs

for acoustic sources within SBNMS. Data from a vessel's CPA to an ARU will be examined for more detailed acoustic characteristics, such maximum received level (used to estimate source levels), total ensonified area (horizontal spatial extent within isopleths of interest), and duration (temporal extent) for any impulsive sources, will be recorded for sources' identified within frequency bands of interest. Parallel analysis efforts will determine the relative contribution of vocalizing whales to sound fields at specific frequencies. This contribution can be subtracted from total received level estimates, with the remainder representing ambient noise minus whale activity.

Sources identified from ARU data will then be linked to vessel data from the Universal Shipborne Automatic Identification System (AIS). The AIS is a vessel reporting and collision avoidance technology that reports a vessel's ID, speed, and geographic location as often as every two seconds. The system allows tracking and identification of vessels not covered by radio or radar. The US Coast Guard implements IMO regulations regarding the AIS within the US EEZ, and currently requires AIS carriage on most self-propelled vessels greater than 65 feet and over 300 gross tons, with additional requirements for tows and passenger vessels (Maritime Transportation Security Act, 2002; Federal Register, 2003). Within and in the vicinity of SBNMS, this requirement mainly captures large tanker and cargo vessels, large passenger vessels, towing vessels, and other international vessel types. Transponders aboard vessels transiting a range of 50 to 150 nautical miles from the AIS receiver station at SBNMS's headquarters in Scituate Harbor (see Figure 1) continuously report vessel identities, locations and speeds. This coverage includes SBNMS, Cape Cod Bay, and ocean areas east of Cape Cod and Cape Ann. Both time and spectrographic features for ARU-identified sources will be used to screen AIS records. Additionally, portable GPS units will be used to log the spatial movements of commercial whale watching vessels within the Sanctuary. These data will be merged with the ARU data to characterize the noise contribution made by this vessel class. Once acoustic sources are matched to AIS data points, individual vessel tracks can be displayed simultaneously with "sound movies". Identifying the relative importance of sources that contribute to the sound field within SBNMS will help the Sanctuary focus future research efforts and assess regulatory needs where necessary.

Preliminary characterization of seismic surveying equipment signatures

SBNMS's passive acoustic monitoring program has presented a unique and timely opportunity to acoustically fingerprint two of the mid-frequency, shallow-penetrating seismic reflection systems most likely to be used in association with pending LNG site exploration and national energy inventory initiatives. Small, mid- and high-frequency, shallow-penetrating seismic reflections systems have been largely ignored by previous research. These systems (e.g., boomers, sparkers, CHIRPs, bubble pulsers, and subbottom profilers) are commonly used for geologic research, benthic habitat mapping, mineral resource identification, and pre-construction/post-construction site assessment and monitoring in estuarine and continental shelf environments. In late September, 2006, Gontz *et al*. (2006) will examine the acoustic signatures of 1) a high-resolution, shallow-penetrating, surface towed, boomer seismic system (operating with peak frequencies around 500-2000Hz) and 2) a high-resolution, shallow-penetrating, near-surface towed, mini sparker seismic system (operating with peak frequencies around 150-1700Hz) using several ARUs. Two ARUs will be selected; one over hard substrate and one over soft substrate. Since the ARU's used to monitor year-round are sampling at 2000Hz, two additional ARUs sampling higher frequencies (10,000Hz) will be deployed at the sites of experimentation to capture the full spectrum of the seismic systems' signatures. Each system will be towed over the four ARUs during a 6h window on a single day. Marine mammal observation data collected before the experiment will be used to inform choice of location within SBNMS, and a detailed marine mammal mitigation protocol developed in consultation with NOAA Fisheries' Office of Protected Resources will be implemented during the experiment to prevent potential impacts on resident species.

Geophysical data will be post-processed to create optimal imagery for publication to show the relationship of distance and the spectral analysis. Acoustic data from the day of the experiment will be visualized and browsed manually to isolate the acoustic signatures of the towing vessel and/or the seismic systems. Statistical measurements including the median and bandwidth (frequency spread), duration (time spread), and received levels of the signals will be computed. Acoustic data from the ARUs not used in experimentation will also be browsed. If the signatures of the towing vessel and/or the seismic systems are detected on multiple ARUs, acoustic data will be integrated using data interpolation techniques to create a spatial composite of the sound field over the time period of the experiment. Boomer and sparker signatures will be compared to (1) baleen whale audiogram models to estimate the potential for hearing loss (for example, see Erbe, 2002) and (2) the sounds produced by baleen whales in the Sanctuary to determine the potential for masking. Additionally, the influence of substrate on the acoustical spectrum of these technologies will be examined. The results of this project will be made available to NOAA Fisheries' Acoustics Program and Office of Protect Resources to assist the agency in its continuing assessments of permitting and environmental compliance mandates under the ESA, MMPA and the National Environmental Policy Act. In addition, these results will aid SBNMS and National

Marine Sanctuary Program managers in fulfilling their mandates to both characterize the impacts of human activities on Sanctuary resources and, where necessary, prevent or mitigate adverse affects.

CONCLUSIONS

At the end of 2002, energy development in federal waters accounted for more than 30% of US oil production and 25% of US natural gas production (US Commission on Ocean Policy, 2004). Energy experts estimate that some 60% of the oil and 41% of the natural gas still to be discovered in the US will come from offshore areas (Minerals Management Service, 2006). As federal and state governments continue to debate whether or not to open state and federal waters to new oil and gas leases, a comprehensive inventory of the nation's energy resources (recently mandated by the Energy Policy Act, 2005) will assist policy makers in evaluating the costs and/or benefits of their decisions. Unfortunately, very little information is currently available regarding the possible costs affiliated with increased use of the seismic surveying technologies that will be used to implement such an inventory, including possible adverse affects due to sound. Although discussions surrounding both documented and speculated impacts of anthropogenic sound sources on species within the US EEZ have focused on marine mammals protected under the MMPA and/or listed under the ESA, species-specific regulation can, in some cases, lead to both scientifically and economically unjustifiable emphasis on particular species, while ignoring other marine species for whom impacts may be as or more severe. In addition, given the complex nature of marine ecosystems, retaining populations as "functional elements of the ecosystem" (Marine Mammal Protection Act, 1972) and/or promoting their "continued existence" (Endangered Species Act, 1973) may depend largely on the health of their physical habitats or the populations of prey they depend on for food, rather than mitigation of more direct threats.

NOAA has recognized the importance of addressing both coastal and ocean research as well as management using more holistic, ecosystem-based methods to allow regulators to incorporate multi-species dynamics, spatially and temporally-explicit models, and cumulative impacts from multiple anthropogenic activities. The thirteen areas currently designated as US National Marine Sanctuaries, while not representing entire ecosystems, represent another important tool in NOAA's regulatory toolbox for monitoring and managing the impacts of anthropogenic activities in a spatially discrete context. In addition, the NMSA directs the Secretary of Commerce to "undertake or authorize all necessary actions to prevent or minimize the destruction or loss of, or injury to, Sanctuary resources, or to minimize the imminent risk of such destruction, loss, or injury" (National Marine Sanctuaries Act, 1992; section 312b). This directive closely parallels the Secretary of Interior's responsibilities under the National Park Service Organic Act's (National Park Service Organic Act, 1916), highlighting rich opportunities for interagency collaboration in developing management guidelines for anthropogenic sound sources within US National Marine Sanctuaries and US National Parks. That said, it remains to be seen whether the scope of the US's current regulatory toolbox for marine protected species and marine protected areas is adequate for addressing the impacts of human activities on marine ecosystems as wholes, rather than the sums of their parts.

Matching the appropriate regulatory balance with statutory language is particularly difficult when scientific knowledge is either rapidly evolving or absent. The acoustic signatures of several of the seismic surveying systems most commonly utilized in shallow offshore habitats contain energy in frequency bands that overlap the sounds produced by protected marine mammal species as well as commercially and ecologically valuable fish species. The use of passive acoustic monitoring systems, such as the one that has been deployed within the Gerry E. Studds Stellwagen Bank National Marine Sanctuary, to characterize the contribution from various sound sources relative to the total sound field provides a critical backdrop for evaluating the potential impacts that increased use of seismic surveying systems within or near marine protected areas might have on permanently and/or seasonally resident species. Comprehensive characterization of sources must include estimates of their temporal and spatial extents within multiple frequency ranges if such information is to be useful to NOAA in supporting the agency's efforts to prioritize limited funding. Finally, utilizing passive acoustic monitoring to comprehensively characterize multiple biotic and abiotic source types over long periods of time will highlight the utility of acoustic data for understanding the marine environment, and support NOAA's efforts to incorporate acoustic sensors within US and global ocean observation systems. As passive acoustic monitoring initiatives are increasingly included within existing and proposed programs designed to monitor and/or mitigate the potential impacts of anthropogenic sound sources throughout the world's oceans, SBNMS represents a test-bed for the efficacy of our current scientific tools for collecting, analyzing and applying these data to regulatory questions of interest.

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