Good morning, Mr. Chairman, and thank you for this opportunity to testify. I am a scientist with 20 years of training and experience on the use of sound by marine animals and the effects of sound on life in the ocean, and I am a Distinguished Professor in the Nicholas School of the Environment and the Pratt School of Engineering at Duke University. I have devoted a significant part of my career to research and investigation regarding the effects of noise on ocean life, particularly marine mammals. I have authored many papers specifically on the effects and mitigation of human-caused ocean noise on animals, including papers with coauthors from government, industry and NGOs (e.g., Nowacek et al., 2013). Furthermore, and specific to the topic of today's hearing, I have served for more than 10 years on a panel of independent scientists, convened by the International Union for the Conservation of Nature (IUCN), focused on minimizing the risks of offshore oil/gas development (including seismic surveys) on Western Gray Whales.

The ability to hear and to perceive sound is of the utmost importance for ocean animals. Many ocean animals, particularly marine mammals such as whales, rely for their very existence on their ability to use sound. For these animals, sound is central to their ability to find food, to locate other animals, to avoid predators, to reproduce, and thus to survive. Many species of fishes also rely on sound for carrying out vital life functions such as territory defense, mate attraction and mediating spawning aggregations. We also know that sea turtles are able to hear low frequency sounds, though we know less about they utilize sound in their every day lives.

Given the transcendent importance of sound and hearing to many ocean life forms, noise that is out of the ordinary – that is louder than the normal background levels of sound – can disrupt the normal behavior of ocean animals. The best available science confirms this point. For example, a recently published paper reviews more than 20 years of peer-reviewed studies demonstrating that wildlife, including a range of marine mammals, are adversely affected by human-produced noise (Shannon et al., 2015). The studies reviewed document that adverse effects can include displacing animals, changing whale foraging patterns, predator-avoidance, feeding behavior, and silencing whales or otherwise causing them to alter their vocal behavior. Of utmost importance in the conclusion of this review is that the noise can and does '**impact individual fitness** (i.e., the basis of population level effects) **and the structure of ecological communities'**.

In light of the proven adverse effects of human-generated noise in the ocean, it is important to recognize the power of seismic airguns to disrupt and harm marine life. Seismic airguns generate the most intense sounds that humans put in the ocean short of explosives. Firing a standard airgun array deployed behind a seismic survey vessel generates approximately 250-260 dB of sound, and while it is difficult to draw exact equivalents in air, these levels approximate the epicenter of a grenade blast and would easily cause the rupture of the human eardrum. Moreover, due to the efficiency with which sound travels underwater—many times more efficient than in air—the sound of seismic air guns can be heard greater than 2500 miles from the source under some propagation conditions (Figure 1 and Nieukirk et al., 2012). It is therefore possible that a seismic survey operating off Georgia or the southern Carolinas, for example, will be detectable and possibly disrupt marine life and degrade the marine environment off the state of Florida.

The seismic testing permits currently under consideration by the U.S. Bureau of Ocean Energy Management would allow the continuous overlapping firing of seismic airguns along a broad range of the east coast from the New Jersey/ Delaware border to central Florida (Figure 2). Each survey would discharge its airguns approximately every 10 or 12 seconds, and would operate 24 hours per day. If these permits are granted, ocean animals located in that wide area of the Atlantic Ocean would be exposed to noise levels that are likely to cause impacts and to disrupt essential behavior patterns.

I will now provide a more detailed discussion of the effects (documented and potential) of seismic airguns, along with suggestions for ways to avoid or mitigate those effects.

Seismic airguns have been demonstrated to disrupt behavior of marine species over substantial distances. Several studies produced over the last three years (see Blackwell et al., 2013; 2015; Castellote et al., 2012; Cerchio et al., 2014; Di Iorio & Clark, 2010), including after the BOEM FEIS was released, demonstrate that seismic airguns affect vital behaviors of baleen whales—across a variety of biological contexts (migration, breeding, feeding)—over very large scales (e.g., > 100 miles). Baleen whales are the giants of the ocean, using low frequency sound to communicate and explore their environment, the same sound frequencies produced by seismic air guns; many baleen whales are listed as endangered. Notably, the endangered North Atlantic right whale, whose migratory path and calving grounds lie within the proposed seismic exploration area, are among the most vulnerable, with fewer than 500 individuals remaining. Other studies have documented significant foraging loss in toothed whales and porpoises exposed to even moderate received levels of seismic airgun noise (Miller et al., 2009; Pirotta et al., 2014). A number of studies have reported substantial horizontal and vertical displacement of some commercial fish species around seismic airgun surveys, resulting in loss of fisheries catch over large areas of ocean (Engas et al., 1996; Lokkeborg et al., 2010; Slotte et al., 2004). Studies of other predominantly low-frequency noise sources have reported decrements in anti-predator response and foraging success in a variety of fish and marine invertebrates (Holles et al., 2013; Purser & Radford, 2011; Voellmy et al., 2014).

These studies implicate a wide range of marine taxa, from whales to invertebrates; affect behaviors that are essential to survival and reproduction; and operate, in some cases, at scales of marine populations. Population level consequences are calculated and modeled using these exact behaviors (e.g., reproductive success), therefore if we are documenting that such behavior is compromised by a disturbance, then the disturbances are having some affect on the population.

The potential impacts of seismic surveys, as with other anthropogenic noise sources, are typically assessed as individual activities (e.g., a single survey) using relatively simple methods based entirely on expected sound exposure levels and decades-old guidelines (HESS Team 1999). Impact is assessed based on the number of animals estimated to receive a sound level high enough to possibly cause harm. It is clear that while sound exposure levels are important over very short spatial and temporal scales for individual animals, recent documentation of the areas ensonified by seismic signals indicate that a broader paradigm of assessment is required (Guerra et al., 2011; Nieukirk et al., 2012), specifically because the natural, ambient noise levels in areas surrounding seismic surveys can be elevated by an order of magnitude or more even between the sound pulses produced by the array (Figure 3).

For example, with regard to quantifying potential impacts of discrete activities on marine mammals, the impact threshold used by BOEM in its Environmental Impact Statement for the Atlantic and by NOAA in its forthcoming environmental review—a threshold that lies at the core of their analysis—is overly simple, artificially rigid, and hopelessly outdated. It proceeds on the demonstrably false assumption that animals do not respond to impulsive noise at levels below 160 dB_{RMS}, and respond with 100% probability at higher levels, such that no impacts are presumed beyond 9 or 10 kilometers from the seismic source. This 160 dB "threshold" originated from a single report more than 15 years ago, based largely on studies conducted in the 1980s (HESS, 1999), but since then very considerable evidence has accumulated indicating that behavioral impacts (e.g., interruption of feeding, avoidance of the area) from pulsed sources can and do occur well below that threshold (Blackwell et al., 2013). For example, migrating bowhead whales showed acoustic responses when pulses were only just detectable, and they continued to respond as the levels increased, including showing behavioral responses at ~120 dB (Blackwell et al., 2015; Richardson, Miller, & Greene, 1999). In sperm whales, exposure to seismic surveys has been associated with a substantial decline in buzz rate [buzzes are part of the whale's echolocation system and they occur when they are attempting to capture something], a proxy for prey-capture attempts, at received levels of 135-147 dB_{RMS} (P. J. O. Miller et al., 2009). Research in the Arctic has shown that very few beluga whales occurred within 12 miles of a full-scale seismic survey, but that there was an unexpectedly high density of beluga whales 12 to 20 miles from such surveys (Miller et al. 2005). Based on site-specific propagation conditions, this suggests animals were displaced over quite large areas at distances for which the received level was < 130 dB_{RMS}. A probabilistic risk function with a 50% midpoint at 140 dB_{RMS} that accounts, even qualitatively, for contextual issues likely affecting response probability (e.g., whether the animal is feeding or traveling), comes much closer to reflecting the existing scientific data than the 160 dB_{RMS} step-function that has been used (Southall et al., 2007). If such a function were used, it is likely that the agencies' quantitative estimate of marine mammal impacts from Atlantic seismic surveys would very substantially exceed the already large number calculated in BOEM's current impact assessment.

Additional impacts of noise come in the form of masking and stress. "Masking," the term used to describe a situation when the perception of one sound is affected by the presence of another, can occur at received levels that are just above the ambient noise level. The effects of masking on marine mammals have been largely ignored but should be integrated into impact assessments. This is important for seismic signals for two primary reasons. First, as distance from the source increases, the acoustic energy in the pulses, originally compacted into the impulse, becomes increasingly spread in time, such that it can fill the gap between the original pulses (Guerra et al., 2011; Nieukirk et al., 2012). Secondly, in the area nearer to the survey, the energy from one pulse reverberates and raises the ambient noise significantly for most of the time between pulses (Figures 1&3). For species whose hearing thresholds are close to the natural background levels (Clark & Ellison, 2004; Clark et al., 2009), any measureable change in the background noise floor from anthropogenic sources can potentially lead to masking. Seismic surveys have been demonstrated to mask frequencies used by whales and many species of fish at hundreds and thousands of miles from the source (Nieukirk et al., 2004, 2012). Recently derived exposure metrics and methods to quantify loss of communication space are available to analyze such impacts (Clark et al., 2009; Hatch, et al., 2012). Noise from human activities also results in elevated levels of stress hormones in many vertebrates (Wikelski & Cooke, 2006), and such connections between noise levels and stress hormones have been measured in marine mammals, specifically North Atlantic right whales (Rolland et al., 2012). Prolonged elevated levels of stress hormones cause deleterious effects to vertebrate systems, including compromising reproductive capabilities (McEwen, 2000).

Unfortunately, BOEM has not properly analyzed these serious, long-range effects.

That these surveys affect animals is undeniable, and our ability to incorporate these documented short-term effects into population level impact assessments is also growing (Christiansen et al., 2015; King et al., 2015).

Having established that impacts occur, it is prudent to move to a discussion about what can be done to reduce and indeed minimize those impacts if seismic surveys are to take place. To this end, I offer the following thoughts, which represent a logical, feasible and thorough set of recommendations that can be adopted by the responsible agencies (i.e., BOEM and NMFS):

1. Revise the programmatic EIS prepared by BOEM for the Atlantic G&G program
    a. There is a fundamental mismatch between the impact analysis and mitigation measures in BOEM's EIS and the spatial/ temporal reality of the environmental problem that the proposed high-energy seismic program represents.
    b. The analysis of cumulative impacts and the potential ramifications for populations of marine animals in the Atlantic is inadequate. The EIS, to its credit, acknowledges the seriousness of these chronic, cumulative effects (EIS at 3-51 to 3-52), but does not address the problem in its analysis or mitigation.

The following recommendations would apply if, after a revised analysis, BOEM decides to let seismic airgun permitting proceed.

2. Minimize the energy being introduced into the water. The EIS, in failing to analyze the problem at the appropriate scale (instead deferring such considerations to the project-specific stage), did not engage in the creative thinking that is imperative here.
    a. Scale the area(s) open to seismic surveys according to the lease areas included in the final Proposed Lease Plan, with seismic airgun surveys permitted to operate only in those areas and areas immediately adjacent (e.g., 5 nm from the potential lease boundary). Based on the draft plan, this would mean no surveys allowed within roughly 50 miles of the coast, north of Virginia, or south of Georgia
    b. Require or strongly incentivize the use of noise-quieting technologies to reduce the amount of acoustic energy produced by seismic surveys
    c. Enact market-based mechanisms to minimize the redundancy of surveys, e.g., multi-client surveys, which are common internationally (e.g., Norway).
3. Protect important and vulnerable species and habitats
    a. Establish seasonal closures for right whales at a biologically meaningful scale. As noted above, several studies produced over the last two years (see Blackwell

et al., 2013; 2015; Castellote et al., 2012; Cerchio et al., 2014; Di Iorio & Clark, 2010), including before and after the BOEM FEIS was released, demonstrate that seismic airguns affect vital behaviors of baleen whales—across a variety of biological contexts (migration, breeding, feeding)—over very large ranges (e.g., > 100 miles). Given the distances over which behavioral impacts, masking, etc., are likely to occur, the time-area closures for right whales set forth in the EIS do not sufficiently mitigate harm to their target species.

   b. Recently developed animal density and distribution models (Figure 4) identify an area off Cape Hatteras (know as 'The Point") as having the greatest marine mammal biodiversity of any area off the entire east coast of the United States; as BOEM recognizes, the area is also of high importance to fish, seabirds, and sea turtles. Yet this area falls within the survey area of all nine seismic applications that BOEM has received (though, notably, largely outside the potential lease area). The Point area, and possibly others (e.g., mid-Atlantic canyons and the Charleston Bump) represent significant areas of biodiversity and should be removed from consideration for seismic airgun surveys as well as future oil/gas development.

4. Establish a comprehensive marine animal monitoring program. The EIS provides only for mitigation monitoring, i.e., the monitoring of a small "safety zone" radius around each survey vessel, which is wholly inadequate as a means of detecting larger-scale and cumulative impacts on marine life. A comprehensive monitoring program should be enacted immediately. The program must have: i) a strong research component, including primary research on offshore species density, habitat use and diversity; and ii) a broad-scale monitoring component beyond near-array mitigation monitoring; and iii) required industry participation in the program, e.g., by submitting environmental data to the program and support analyses of those data to improve mitigation efforts. To be effective, the program must be multi-year and multi-institutional, making effective use of existing data and expertise. It does <u>in no way</u> substitute for the mitigation measures described above, but can inform mitigation and management over the long term (Nowacek et al., 2013). An integrated approach requires increasing both the breadth and depth of baseline data on the trends and health of marine animal populations, as well as including comprehensive analyses of aggregate sound exposures, potentially interacting effects, and the cumulative effects from multiple noise sources. These analyses need to be conducted on appropriate temporal and spatial scales.

Thank you again, Mr. Chairman, for this opportunity to appear before the Committee. I would be glad to respond to your questions.

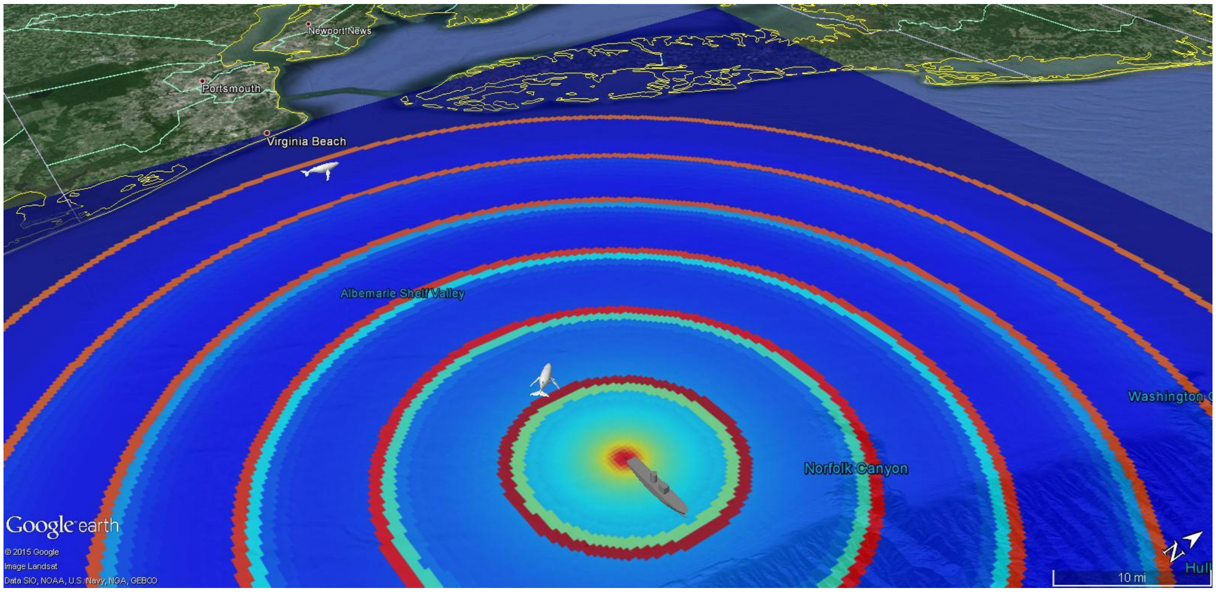

Figure 1. The sound field 60 seconds after the initial seismic survey pulse produced by the vessel near the Norfolk Canyon off the coast of Virginia. Pulses are produced every 10 seconds, a normal interval for seismic surveys. The close whale is 10 nm from the source, the distant one near Virginia Beach is ~50 nm from the source. The propagation conditions will affect the amount of energy reaching a given point, but these modeling tools are available and the pictured scenario is quite plausible. The levels experienced by the close whale are almost continuously at or above levels known to impact baleen whales, and the distant whale experiences these levels for the ~10 seconds around the time of the pulse. The dark red color maps to approximately 175 dB, the light green to 125 dB, and the light blue to 100 dB.

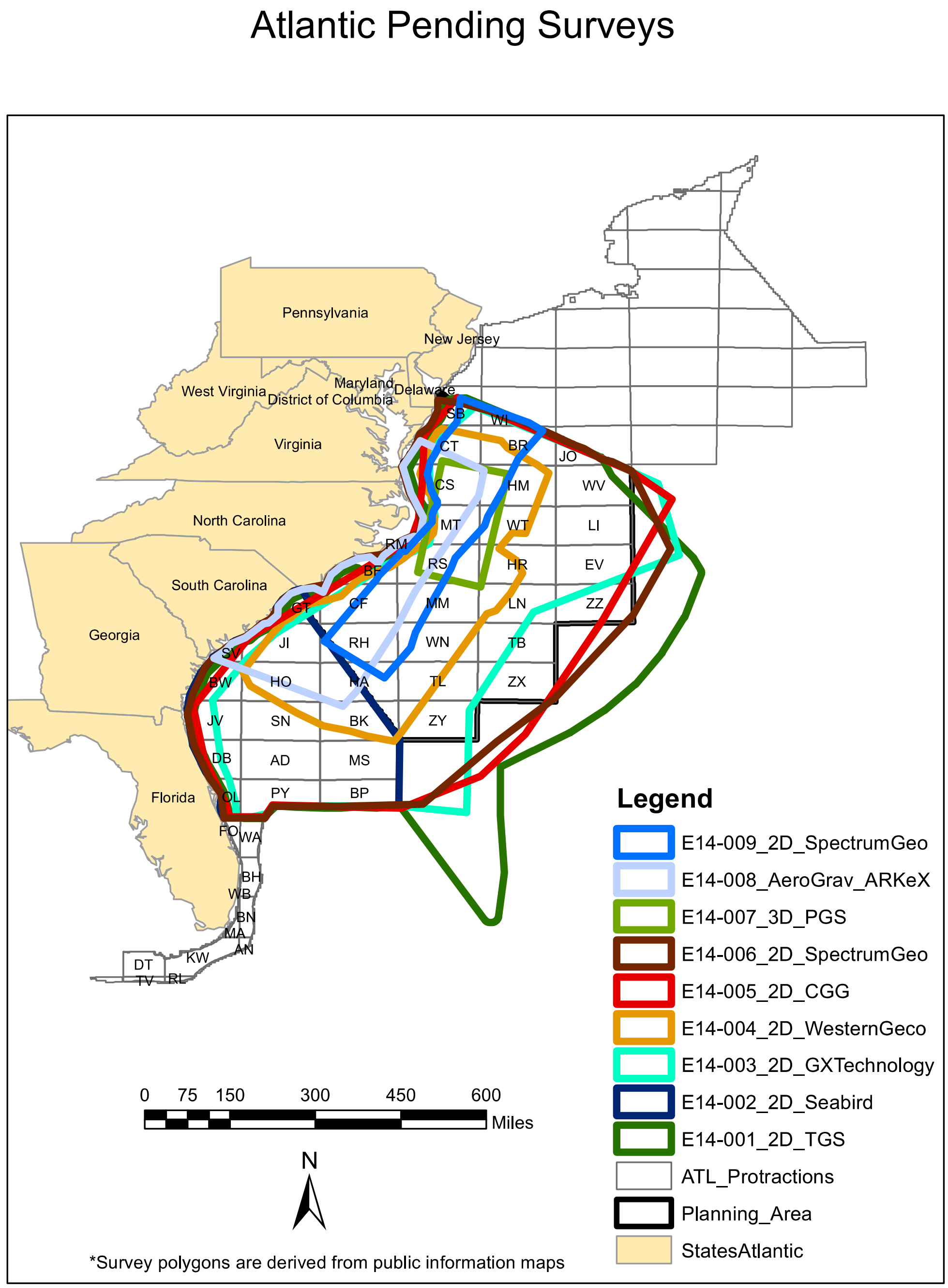

Figure 2. Permits under consideration at BOEM for geological and geophysical surveys in the Atlantic. The overlapping survey areas represent significant concern with respect to unnecessary and harmful repeated exposure to seismic surveys.

Slide 4: Noise levels 7.5 sec after the impulse at 30-100km range.

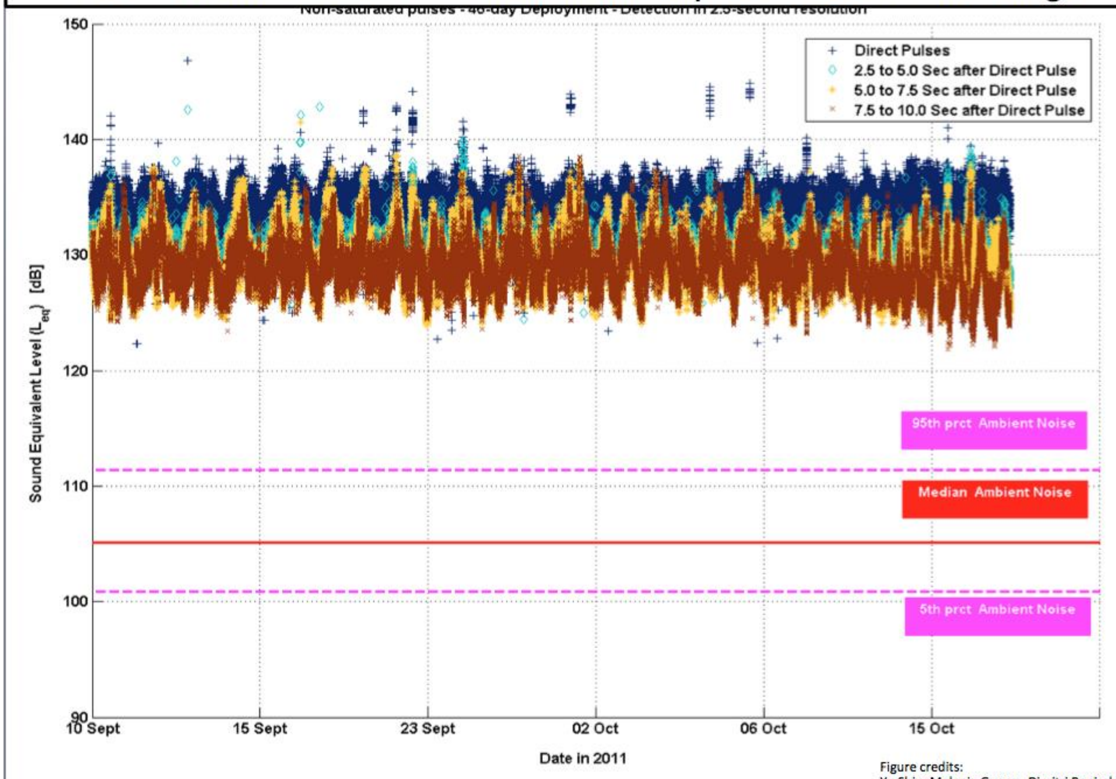

Figure credits:
Yu Shiu, Melania Guerra, Dimitri Ponirakis
Peter Dugan, Marian Popescu, Chris Clark.

Figure 3. Noise levels at the time of, 2.5-5, 5-7.5 and 7.5-10 seconds after a seismic survey pulse. Note the significantly elevated noise levels even many seconds after the pulse. Ambient noise levels are shown with red and pink lines. It is important to remember that every increase of 10 dB represents an order of magnitude increase in sound intensity; so even between pulses the ambient noise is elevated by 1-2 orders of magnitude. This result is corroborated by published studies (Guerra et al., 2011).

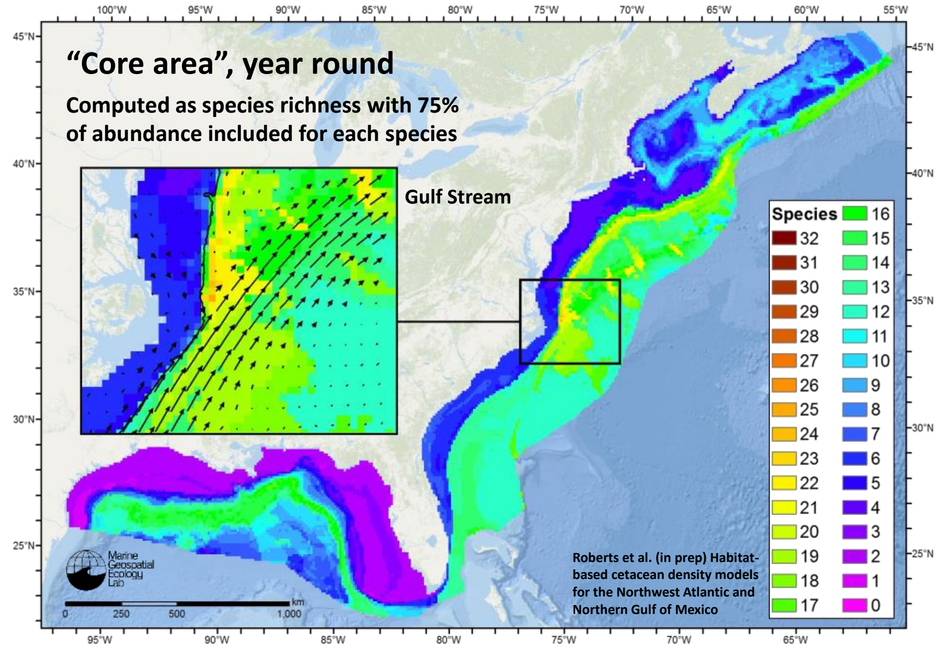

Figure 4. The Hatteras Point area (inset) located ~35 miles offshore of the NC coast. The species richness (colormap) shows this to be a critical area for cetaceans. The use and importance of this area for many species of fishes, sea turtles and seabirds is also well established.

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