A spatio-temporal gap analysis of cetacean survey effort in the U.S. Mid- and South Atlantic

by
Meghan Rickard

Dr. Andrew Read, Advisor
May 2015

Masters project submitted in partial fulfillment of the requirements
for the Master of Environmental Management degree in
the Nicholas School of the Environment of Duke University
2015

Executive Summary

In January 2015, the Bureau of Ocean Energy Management (BOEM) released the 2017-2022 Draft Proposed Program for oil and gas leasing on the outer continental shelf, which includes a large area of the Atlantic. The release of this proposal was preceded by a final Environmental Impact Statement in February 2014 and a July 2014 Record of Decision to consider permit applications for seismic surveys in the Mid- and South Atlantic planning areas. These planning areas are the focus for the geological and geophysical activities (G&G), which, combined, stretch from Delaware to central Florida and include 855,000 square kilometers of sea floor. The renewed interest in oil and gas exploration in the U.S. Atlantic and steady pace of recent decision making is significant because the Atlantic has been off limits to oil and gas since 1982. The species and habitats in these areas are essentially naïve to the potential effects of seismic exploration and there is substantial concern within the scientific community about the environmental impacts of seismic surveys. In particular, cetaceans depend on sound in all aspects of their lives, from communication to navigation, and some species are known to be vulnerable to the effects of seismic surveys. Thirty-four species of cetaceans (i.e., whales, dolphins, and porpoises) are found in these areas alone, six of which are endangered.

To protect cetaceans from negative impacts of seismic exploration and to make the best management decisions possible, we need to know where they are and when they're there. Systematic line-transect surveys are typically used to provide this information, which is especially important at smaller spatial scales, such as the Mid- and South Atlantic planning areas that likely exhibit seasonal or inter-annual variability in species occurrence. The objectives of my project, therefore, were to identify gaps in space and time of cetacean survey effort and to inform BOEM of the needs for additional survey effort.

Methods

Cetacean survey effort tracklines, previously aggregated and standardized, were my primary dataset. The dataset included 40 surveys from 1992 to 2014. The survey tracklines were provided by the National Oceanic and Atmospheric Administration (NOAA), from the Southeast and Northeast Fisheries Science Centers, and the University of North Carolina – Wilmington. Surveys took place in 17 of the 23 years from two platforms, aerial (30 surveys) and shipboard (10 surveys).

I used ArcMap 10.2 to create 25 km^2 grid cells, which I then used to depict spatial survey coverage in the Mid- and South Atlantic planning areas. When the dataset was corrected for total effort, the tracklines were intersected with the grid cells and spatially joined on the trackline length sum. I repeated this process for each season (Winter=December, January, February; Spring=March, April, May; Summer=June, July, August; Fall=September, October, November). To estimate how total linear survey effort changed with increasing distance from shore, I used a 250 meter bathymetric contour (representing the shelf-break) and the U.S. Exclusive Economic Zone (EEZ) (200 miles offshore) to further divide the planning areas.

Results

Effort has not been consistent through the years. Seasonally, summer contained the highest number of surveys and winter had the most linear survey effort. Fall had the fewest surveys and least total linear effort. Spatially, hot spots of survey coverage are evident in two potential Navy Undersea Warfare Training Range (USWTR) areas in Onslow Bay, NC and Jacksonville, FL. Significantly less survey effort occurred between the shelf break and the EEZ, and little to no survey effort occurred outside the EEZ. Seasonal spatial gaps were also clear, particularly during the fall.

Based on the results, I make two primary recommendations:

1. Future surveys should be conducted during the fall in all areas;
2. Pelagic areas, especially areas outside of the EEZ, should be a priority for future survey effort

Overall, as distance from shore increases, less survey effort occurs and less is known about the occurrence of cetacean species. Considering that oil and gas exploration and development has moved father offshore into deeper water in recent years, and that the proposed Atlantic lease sale includes areas outside the EEZ, increased attention needs to be focused in the pelagic areas, particularly during the fall. Understanding spatial and temporal trends in cetacean use of the Mid- and South Atlantic planning areas is critical to making informed management decisions regarding seismic exploration.

Acknowledgements

This project would not have been possible without the assistance of many people. I would like to thank my advisor, Dr. Andy Read, for his continued guidance and support throughout this project. I am especially grateful to Jason Roberts for graciously answering all of my questions and allowing me to build my project around all of his hard work. Thank you to Drs. Pat Halpin and Doug Nowacek for their encouragement and help developing the project.

Table of Contents

Introduction

As human use of the ocean has increased and diversified, so has the level of sound present in the ocean (CBD 2012). Sound levels have risen steadily over the past 60 years, doubling every decade (NRC 2003). Elevated noise levels are driven by increased human activities, including shipping, construction (dredging, pile driving), sonar, offshore energy (wind turbines, oil and gas extraction), and seismic exploration (CBD 2012). Despite its far-reaching and pervasive nature, noise is not managed in the same manner as other pollutants at a national or international level (Agardy et al. 2007). Nevertheless, there is a growing concern within the scientific community about increasing levels of noise in the ocean and the biological effects of this pollutant. Fish, sea turtles, and cetaceans are all negatively impacted by anthropogenic noise (CBD 2012).

In 2010, the Obama administration set its sights on the Atlantic for prospective oil and gas extraction when Congress directed the Bureau of Ocean Energy Management (BOEM), the federal agency responsible for conducting evaluation, planning, and leasing of offshore energy in the U.S., to prepare an environmental impact statement. President Obama also proposed a lease sale off the coast of Virginia for the 2012 to 2017 offshore energy program but withdrew this proposal after the Deepwater Horizon disaster in the Gulf of Mexico. In March 2012, BOEM published their draft programmatic environmental impact statement (PEIS) for geological and geophysical (G&G) activities, primarily seismic exploration, for the years 2013 through 2020 (BOEM 2012). The process progressed rapidly as the National Oceanographic and Atmospheric Administration (NOAA) issued a Biological Opinion required under the Endangered Species Act (ESA) Section 7 finding that the proposed activities are not likely to jeopardize endangered species (NMFS 2013). The final PEIS, published in February 2014, estimated that 138,000 injuries would occur to marine mammals as a result of G&G activities, ranging from temporary hearing changes to death, and a further 13.5 million disturbances, including changes to behavior like feeding, mating, and communicating (BOEM 2014a). BOEM released the Record of Decision (ROD) in July 2014, which adopted the mitigation strategies proposed in the PEIS (BOEM 2014b). BOEM is now considering permit applications for geological and geophysical activities; ten have been submitted so far and could begin operating as soon as this year (2015). Most recently, in January 2015 BOEM released its next five year program plan which includes a large lease area in the Atlantic (BOEM 2015).

The renewed interest in oil and gas in the Atlantic and steady pace of decision making is significant because the Atlantic has been off limits to oil and gas exploration since 1982, so the species and habitats in these areas are essentially naïve to the effects of seismic exploration. The Mid- and South Atlantic planning areas are the focus for G&G activities (see Appendix A). The combined areas stretch from Delaware to central Florida and include 855,000 square kilometers of sea floor. Thirty-four species of cetaceans (i.e., whales, dolphins, and porpoises) are found in these areas, six of which are endangered, including the blue (*Balaenoptera musculus*), fin (*Balaenoptera physalus*), sei (*Balaenoptera borealis*), humpback (*Megaptera novaeangliae*), sperm (*Physeter microcephalus*), and North Atlantic right whales (*Eubalaena glacialis*).

The North Atlantic right whale population is currently estimated at around 450 individuals and its habitat ranges along the entire Atlantic coast. Right whales migrate between southern calving areas off the coasts of Georgia and Florida to feeding areas in the Gulf of Maine. Little is known about the exact migratory corridor along the coast but suitable habitat for migration has been found to extend farther offshore than originally thought (Schick et al. 2009). Biologically Important Areas (BIAs) for cetaceans within U.S. waters have also been identified for the East Coast (LaBrecque et al. 2015), including the North Atlantic right whale migratory corridor and southeast calving areas, which overlap with the Mid- and South Atlantic planning areas. The North Atlantic right whale is only one example of a species that could be impacted by the introduction of seismic exploration in the Atlantic.

During seismic surveys, air gun blasts occur every 10 to 20 seconds, 24 hours per day, seven days per week, for weeks to months at a time (Nieukirk et al. 2004). Air guns direct sound into the seafloor, and the sound is reflected back to a towed hydrophone array and processed to identify potential oil and gas reservoirs (NRC 2003). Seismic surveys are operated by towing an air gun behind a ship with an array of hydrophones several kilometers long to record the returned signal. Air guns typically produce low frequency, high energy sound which travels easily through water and can be heard thousands of miles away. Baleen whale vocalization and hearing range directly overlaps with the sounds produced by seismic surveys (Southall et al. 2007). Nieukirk et al. (2004) found that airguns from vessels more than 3000 kilometers away off the coasts of Canada, Africa, and Brazil, masked baleen whale calls recorded on the Mid-Atlantic Ridge.

Cetaceans use sound in every aspect of the lives, from foraging to mating, and any decrease in their ability to rely on the use of sound is potentially detrimental to their individual fitness and overall population health (Richardson et al. 1995). Impacts of noise on cetaceans are generally categorized as behavioral, acoustic, or physiological (Nowacek et al. 2007). Of most concern are temporary or permanent hearing shifts, abandonment of habitat, disruption in migration, feeding, and mating patterns, and masking of biologically important sounds. Indirect effects are also possible, such as diminished availability of prey and increased susceptibility to other hazards like predation and vessel collision (Simmonds et al. 2004).

The goal of this paper is not to summarize the effects of seismic surveys on cetaceans, but there are many examples from decades of studies (see Richardson et al. 1995, Gordon et al. 2004, Nowacek et al. 2007, Weilgart 2007, CBD 2012 for reviews). Clark and Gagnon (2006) found that fin and humpback whales stopped vocalizing across large areas, on the scale of 10,000 square nautical miles, during seismic surveys. Bowhead whales change their diving behavior and respiration rates when exposed to the sound of air guns (Robertson et al. 2013). Stone and Tasker (2006) establish that small odontocetes like harbor porpoises and common dolphins move out of the immediate area during seismic surveys and large baleen whales turn away from the sound source and increase their distance. Seismic surveys have also been a concern in the strandings of beaked whales (Malakoff 2002; NRC 2003). Taken together, therefore, these responses are variable and short term-responses may not represent the long-term population-level impacts (Weilgart 2007).

To protect cetaceans from potential negative impacts of seismic exploration and to make the best management decisions possible, we need to know where they are and when they're there. Line-transect surveys are typically used to provide this information, and to inform risk assessment models and the development of mitigation measures. It is especially important to generate data on species occurrence at smaller spatial scales like the planning areas that likely exhibit patterns of seasonal or inter-annual variability. Thus, the objectives of my project were to identify spatial and temporal gaps in cetacean survey effort in the Mid- and South Atlantic planning areas and to help prioritize new surveys to fill those gaps.

Methods

Data

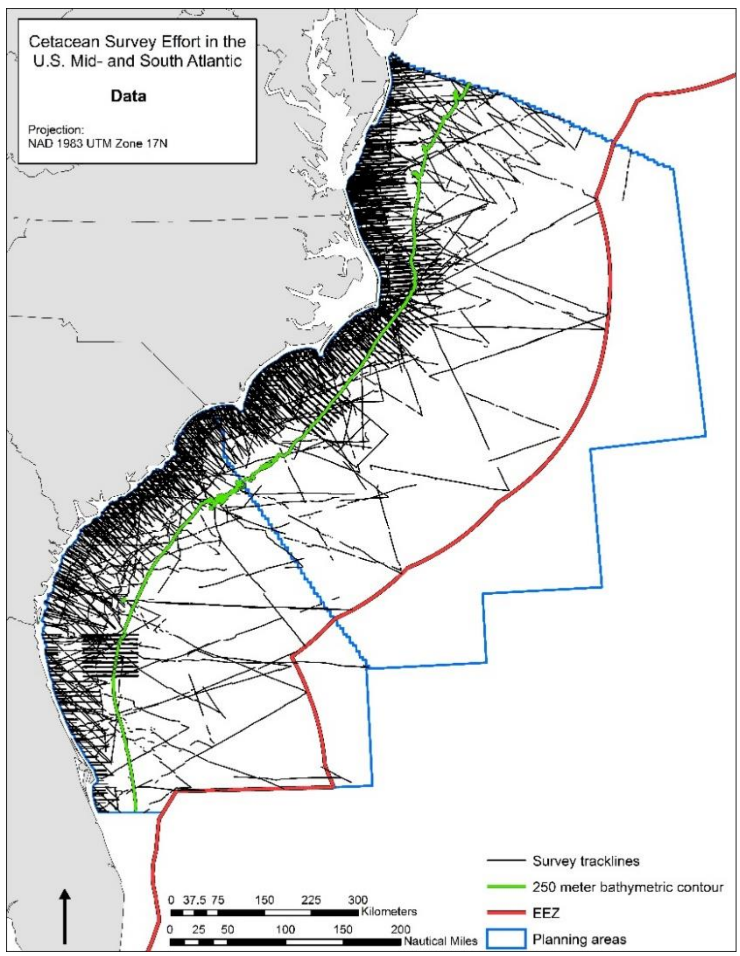
The primary dataset used in my analysis was cetacean survey effort tracklines, sourced from Roberts et al. 2015. The dataset contained 40 surveys from 1992 to 2014 provided by NOAA, from the Southeast and Northeast Fisheries Science Centers (SEFSC, NEFSC), and the University of North Carolina – Wilmington (UNCW). Surveys took place in 16 of the 23 years from two platform types, aerial (30 surveys) and shipboard (10 surveys). The timeframes of the surveys varied; eleven surveys spanned multiple years. Nine surveys had tracklines primarily within the North Atlantic planning area and only included the tail end of the survey track in the Mid-Atlantic planning area. Ten surveys had tracklines completely within the Mid- and South Atlantic planning areas.

All other reference data was downloaded from the internet. The BOEM Atlantic planning areas and 2017-2022 Draft Program Plan Atlantic lease and buffer were downloaded from BOEM's website (http://www.boem.gov/Oil-and-Gas-Energy-Program/Mapping-and-Data/Atlantic.aspx; http://www.boem.gov/2017-2022-Map-Layer-Files/). The U.S. Atlantic bathymetry data was downloaded from Data.gov (https://catalog.data.gov/dataset/egloria-cnt-u-s-atlantic-east-coast-bathymetry-contours). The U.S. Exclusive Economic Zone (EEZ) was downloaded from the U.S. Geological Survey (http://coastalmap.marine.usgs.gov/GISdata/basemaps/boundaries/eez/NOAA/useez_noaa.htm).

Eleven of the surveys were one-sided (ex: surveyname_left, surveyname_right) and were therefore listed twice in the dataset. These surveys counted for half the effort of a regular (two-sided) survey because the observers operated independent of each other. To correct for such variation in effort, total trackline length of one-sided surveys was divided in half. This correction resulted in the total trackline length of the survey when both sides were added together. Because the observers were independent, the total trackline length for each side was not always the same, but most was within 100 kilometers. With corrected survey effort, the total linear trackline length for cetacean survey effort was 336,370 kilometers.

Analysis

I used ArcMap 10.2 (ESRI 2014) for all analyses. I projected the tracklines in NAD 1983 UTM Zone 17N to calculate the length in linear units. The tracklines were then clipped to the planning areas boundary (Map 1). I constructed 25 square kilometer grid cells using the Fishnet tool to evaluate spatial coverage of the tracklines within the planning areas. I chose this size



Map 1. Cetacean survey effort tracklines dataset clipped to Mid- and South Atlantic planning area boundaries with 250m bathymetric contour and U.S. Exclusive Economic Zone (EEZ).

based on BOEM's standard outer continental shelf lease block size (http://www.boem.gov/Oil-and-Gas-Energy-Program/Mapping-and-Data/Atlantic.aspx#GISTABLE). I clipped grid cells were also clipped to the planning areas boundary. I intersected the tracklines with the grid cells and added a new field to the attribute table of the intersected tracklines called LENGTH. I calculated the geometry in kilometers and selected for the surveys that were one-sided. The LENGTH field of the selected surveys was divided by 2 to correct for effort. The grid cells and tracklines were then spatially joined on the LENGTH field sum when the grid cells contained the tracklines. The output was the total length of linear survey effort in each grid cell. I also split the full dataset into seasons by selecting for month (Winter=December, January, February; Spring=March, April, May; Summer=June, July, August; Fall=September, October, November) and the same set of steps was completed for each season.

To determine how the total linear survey effort varied with distance from shore (inner limit to shelf break, shelf break to EEZ, EEZ to outer limit), I merged the planning areas into one polygon. I then selected for the 250-m depth contour from the bathymetry shapefile. The Feature to Polygon tool failed to cut the polygon at the 250 meter contour because the 250 meter contour line was not solid and did not cross over the planning areas boundary on the southern end, so I traced over the contour line using the Cut Polygons tool in the Editor Toolbar. When the planning areas polygon was successfully cut, I clipped the original tracklines shapefile to the new polygons, added a new LENGTH field, calculated field geometry in kilometers, and corrected for survey effort before taking the sum statistic. I exported summary statistics were exported and compiled them in Microsoft Excel to produce graphs and tables of spatial and temporal survey coverage.

Results

Temporal Gaps

Effort has not been consistent throughout the years, and there was no survey effort during 7 of the 23 years (1993, 1994, 1996, 1997, 2000, 2003, 2006) (Figure 1). The highest number of surveys occurred in 1995 (seven), followed by five surveys in both 2010 and 2012. A recent decrease in survey coverage is due to the fact that some recent surveys are not yet available. There were no shipboard surveys after 2005.

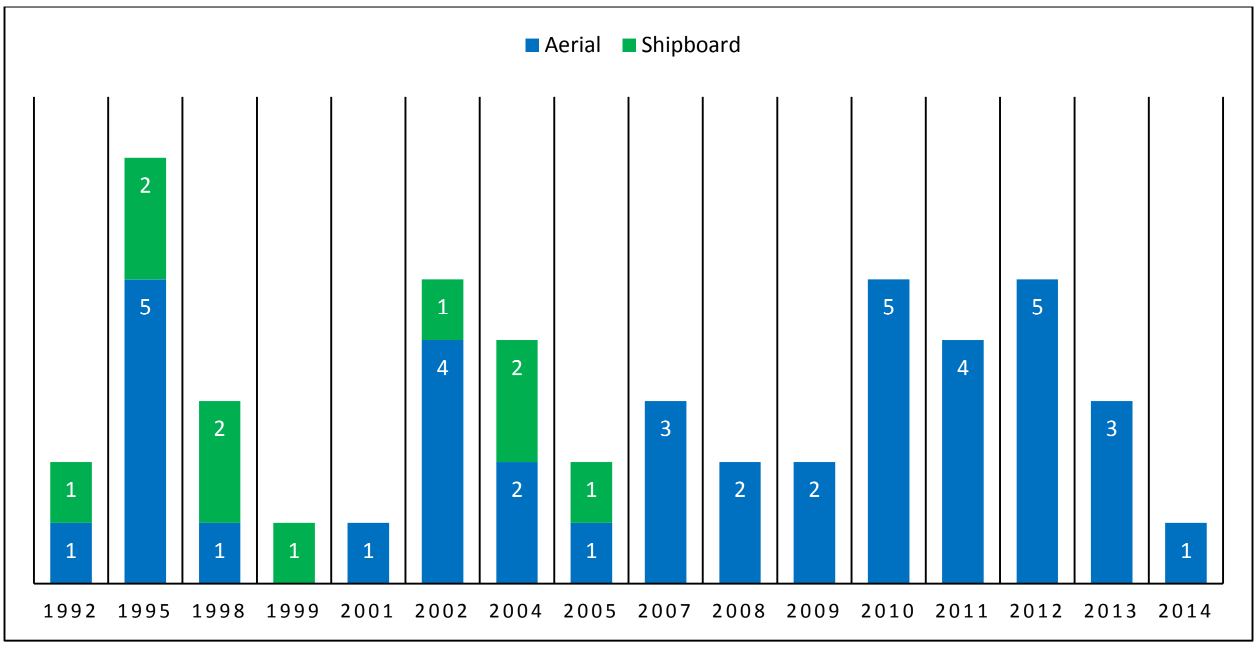


Figure 1. Number of surveys per year. Values include any survey for which tracklines occurred in that year.

On a seasonal time scale, the highest number of surveys occurred in the summer and the most linear survey effort occurred in the winter (Figure 2). Only 16 surveys occurred exclusively within one season, 15 in the summer and 1 in the winter. The fewest surveys and the least amount of total linear survey effort occurred in the fall.

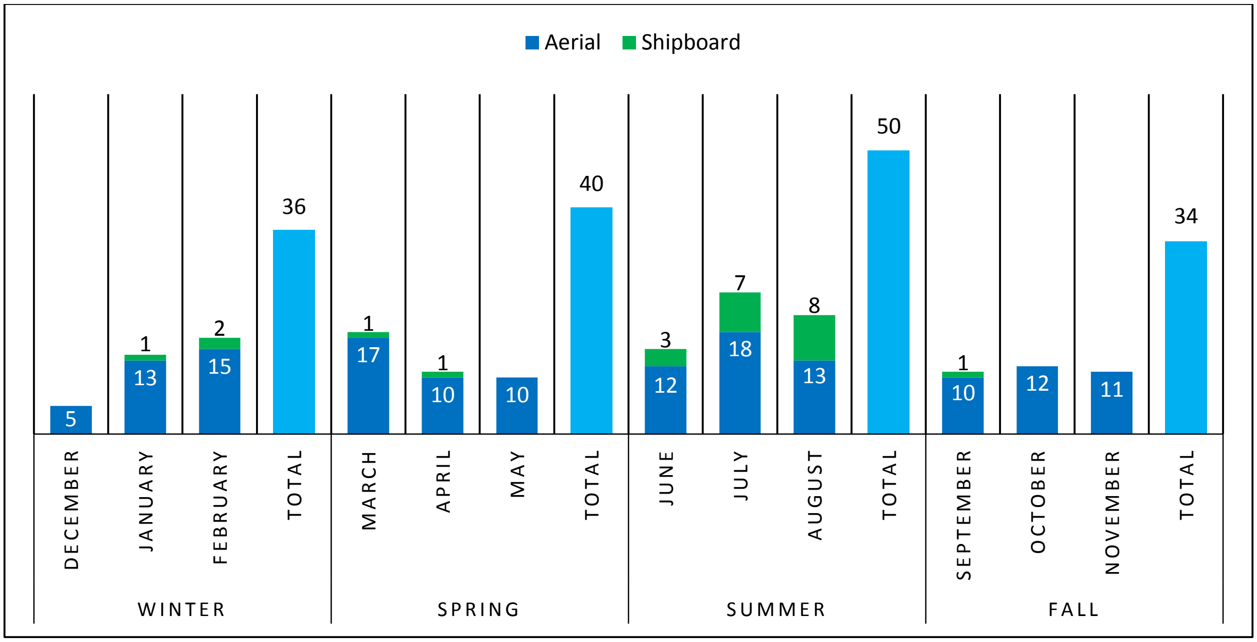


Figure 2. Number of surveys per season.

As noted above, not all surveys contained tracklines occurring in just one month, season, or year. The values in Figure 2 are based on any survey containing tracklines present in that month, so surveys were counted more than once, and up to three times, in one season.

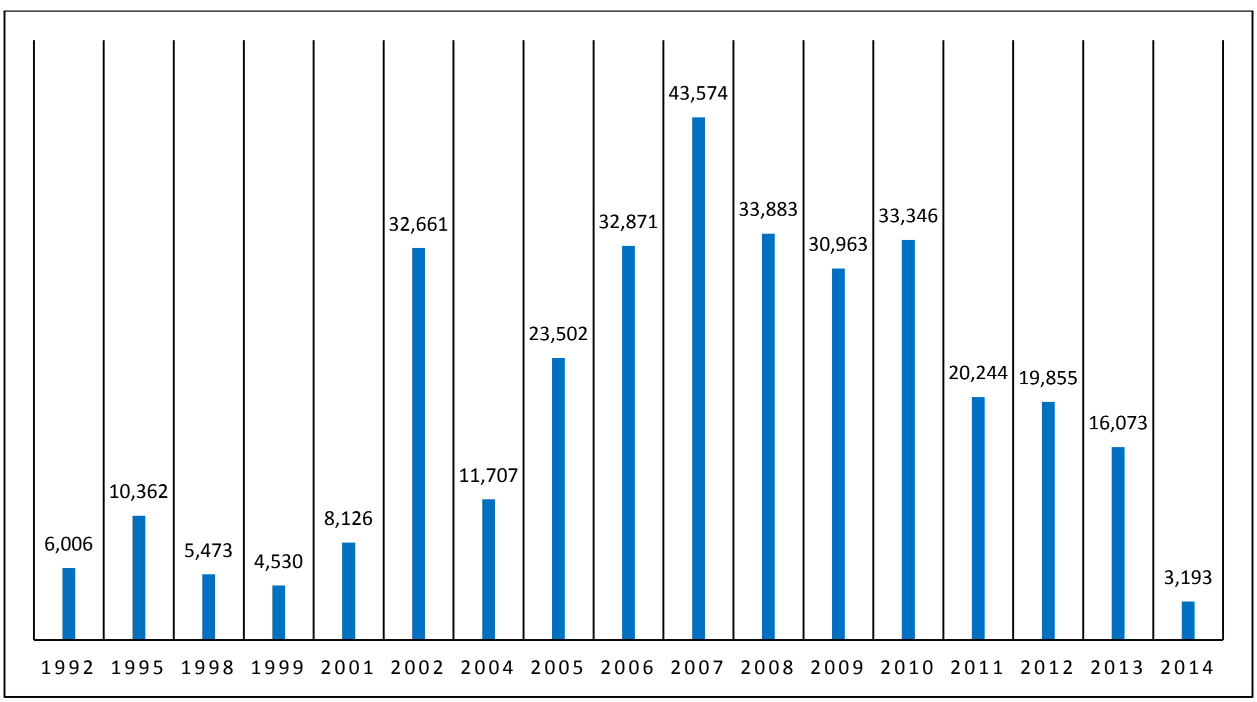


Figure 3. Total linear survey effort (kilometers) per year.

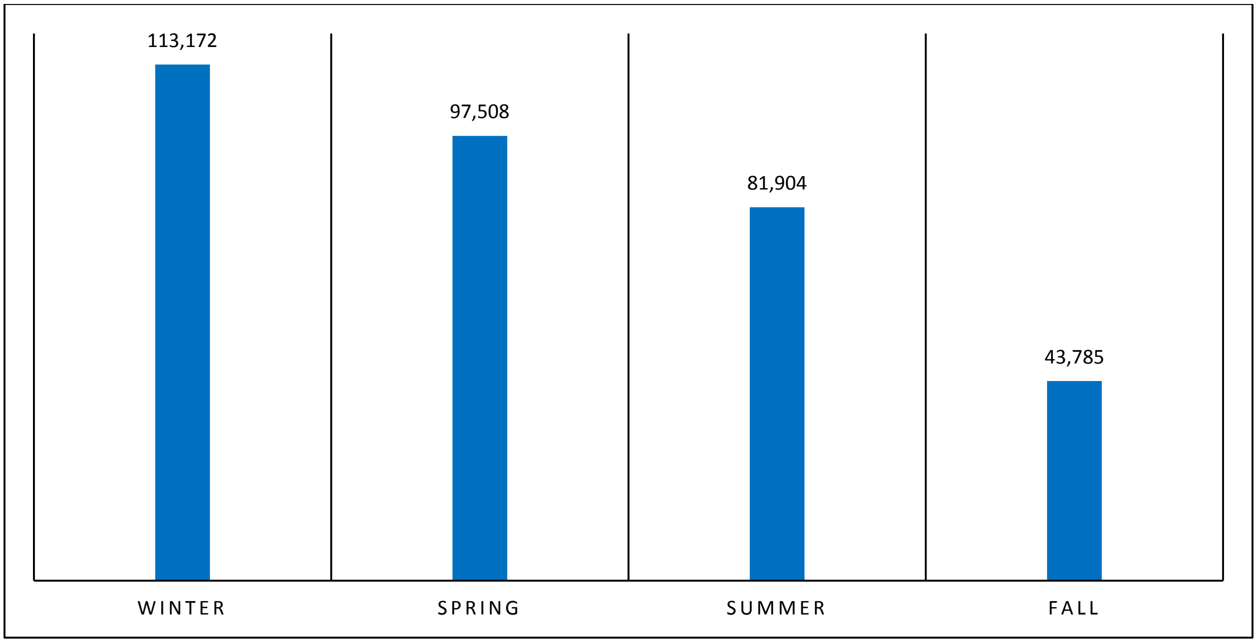


Figure 4. Total linear survey effort (kilometers) by season (Winter=December, January, February; Spring=March, April, May; Summer=June, July, August; Fall=September, October, November).

A comparison between the number of surveys and total linear survey effort highlights the fact that a higher number of surveys does not necessarily correspond to increased survey effort (Figures 3 and 4).

Spatial Gaps

Results for all tracklines were mapped to show the total linear survey effort per cell (Map 2). Overall, 39% of the cells have not been surveyed (with varying spatial representation because not all cells are full size). Hot spots of survey coverage include two potential Navy Undersea Warfare Training Ranges (USWTR) in Onslow Bay, NC and Jacksonville, FL, which have been the targets of dedicated survey effort. There has also been concentrated survey effort off the coast of North Carolina, as well as South Carolina and Virginia, all of which is almost completely contained within BOEM's 50 mile buffer, included to minimize multiple use conflicts, for the

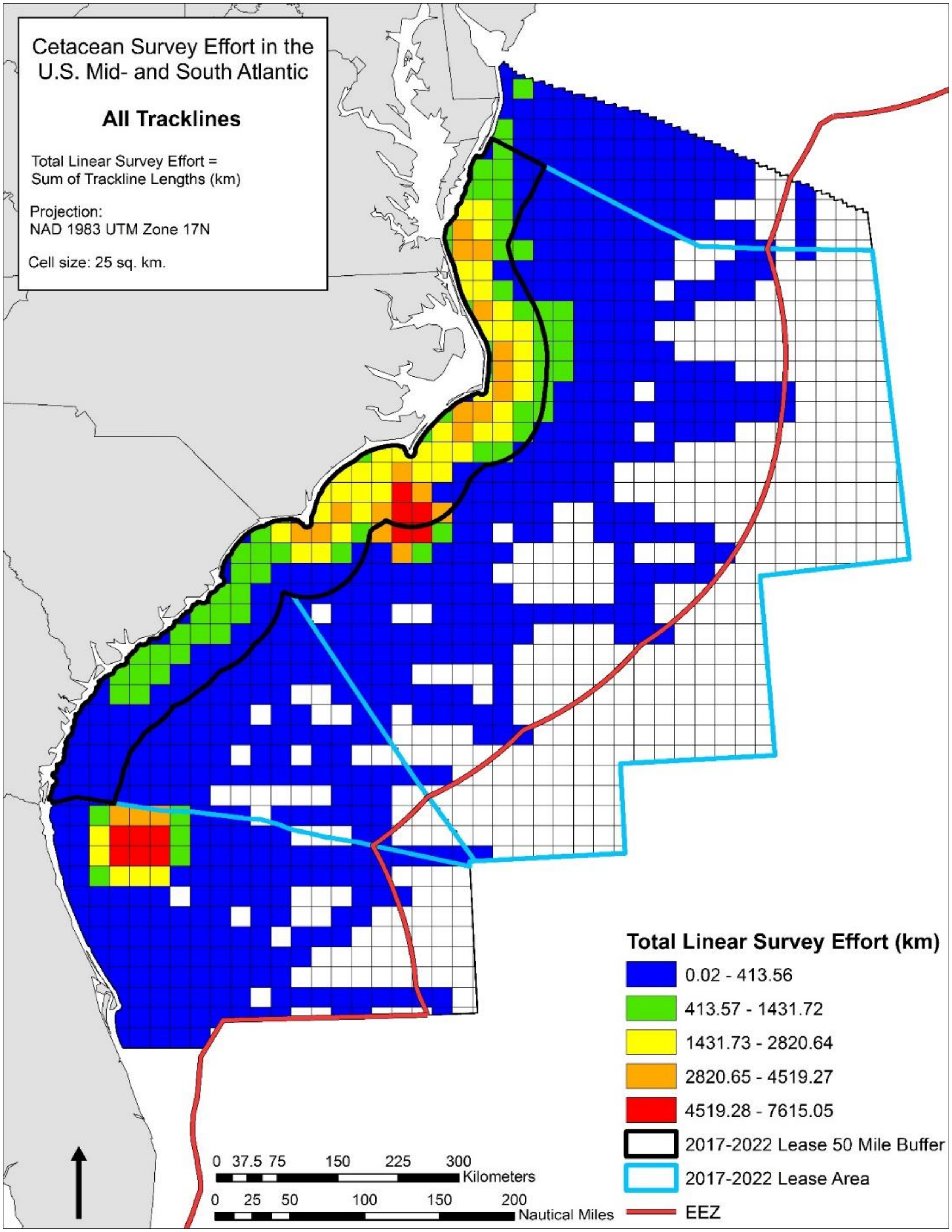
2017-2022 Draft Program Plan’s Atlantic lease. Both the proposed lease area and the G&G area of interest extend to the outer boundaries, while the coverage of survey effort does not. The EEZ appears to be a limit for spatial survey effort.

On a seasonal basis, spatial gaps in survey effort become readily apparent (Map 3). There is a lack in spatial coverage during the fall, compared to more widespread coverage of survey effort during the summer. All seasons retain the hot spots of survey coverage in the USWTR areas, with the exception of Onslow Bay which is less prominent in the winter and spring. Summer is the only season in which survey effort regularly extends out to the EEZ, while the majority of survey effort remains closer to shore during the spring, fall, and winter.

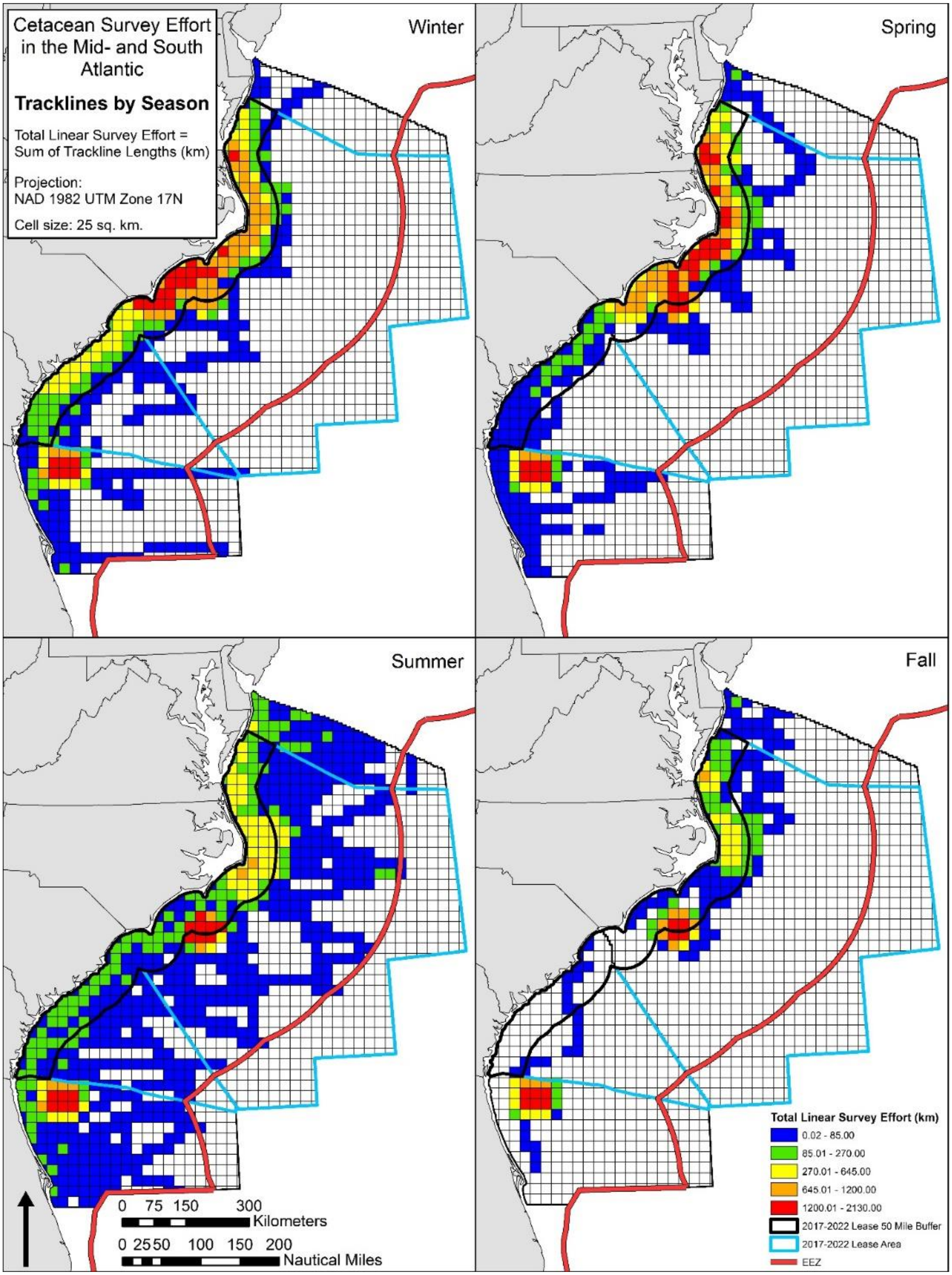
Table 1. Total linear survey effort as distance from shore increases; shoreward boundary of planning areas to shelf break (approximated by 250m depth contour), shelf break to Exclusive Economic Zone (EEZ), EEZ to offshore boundary of planning areas.

Area	Total Linear Survey Effort (km)
Inner limit to shelf break	263,078.98
Shelf break to EEZ	73,025.42
EEZ to outer limit	255.72

Table 1 shows the results of the analysis of the planning areas as distance from shore increases. More than half of all linear survey effort occurred from three miles offshore (the inner limit of the planning areas) to the shelf break. Outside the EEZ, very little survey effort has occurred. These values reflect the results of the analysis in Maps 2 and 3.



Map 2. Total linear cetacean survey effort (kilometers) per 25 sq. km. cell in the Mid- and South Atlantic planning areas.



Map 3. Total linear cetacean survey effort (kilometers) per 25 sq. km. cell by season. Winter=December, January, February; Spring=March, April, May; Summer=May, June, July; Fall=September, October, November.

Discussion and Recommendations

The only areas within the planning area boundaries in which cetacean spatial and temporal distributions are known with a reasonable degree of confidence are the two USWTR areas. The coast of North Carolina has received a significant amount of attention from the scientific community to better assess cetacean occurrence, which accounts for some of the concentration of survey effort. Overall, there is little survey effort as distance from shore increases.

In summary, the largest temporal gap is during the fall months and the largest spatial gap is pelagic areas, especially outside the EEZ. To fill spatial and temporal survey effort gaps, I make two recommendations for future surveys:

1. Fall months should be emphasized; and
2. Pelagic areas, especially outside the EEZ, should be a priority

As oil and gas exploration and development moves farther offshore into deeper water, improved knowledge of cetaceans in space and time in those areas outside the EEZ is crucial. Additionally, the lease sale for the 2017-2022 program extends to the outer limits of the planning areas to include the areas outside the EEZ. As seen in the Atlantic Pending Surveys map (Appendix B), the seismic surveys proposed in the submitted permit applications cover the whole extent of the planning areas, with significant overlap around the outside boundaries, including the outer limit. The implications of the introduction of these activities cannot be fully assessed until areas outside the EEZ have received a reasonable amount of survey coverage.

Given the spatial and temporal gaps of survey effort described here, I make another recommendation related to the ecology of deep-diving cetacean species. Since seismic survey effects are known to be particularly harmful for deep diving species that are typically associated with deeper waters past the shelf-break, like beaked whales and sperm whales, survey effort should also focus on these species in future surveys. Furthermore, despite the extensive survey coverage of nearshore waters, there remains known species gaps. For example, stranding data informs us that pygmy and dwarf sperm whales are common in the U.S. Atlantic yet they are very rarely seen during surveys (Read et al. 2014). Beaked whales are vulnerable to noise but identification at the species level during surveys is difficult, which results in lumping and vague conclusions about their distribution (Schick et al. 2011). These cryptic species need more concentrated survey coverage to narrow estimates of population and distribution.

Some of the drivers of these spatial and temporal gaps in survey coverage are weather and funding constraints. If the primary cause for lack of survey effort from year to year and during all seasons is funding, then a concerted effort from the government is needed to prioritize cetacean research surveys in monetary appropriation to meet the needs described here. Geographic biases also occur due to highly utilized areas or a particular interest in an area or a species (Kot et al. 2010). This is evident in the high degree of survey effort in the USWTRs.

Furthermore, all survey platforms should be utilized including aerial, shipboard, as well as passive acoustic monitoring (PAM) (Kot et al. 2010). The lack of shipboard surveys after 2005 represents a missed opportunity for survey effort. Kot et al. (2010) found that using two or more survey platforms provided more representative data than only one. The use of PAM is less invasive and allows long-term datasets to be recorded over a large area (Nieukirk et al. 2004). By supplementing aerial and shipboard surveys with PAM, missed observations and cryptic species can be accounted for to the best of our ability.

Other studies of survey effort coverage have been conducted but on a global scale (Kaschner et al. 2012). The recommendations presented here are important because they provide a closer look at survey effort coverage on a smaller spatial scale (i.e., the Mid- and South Atlantic planning areas) and for one particular order of species (cetaceans). Schick et al. (2011) recognized the need for more marine mammal data, especially south of Cape Hatteras, in all areas and seasons. Kot et al. (2010) found that observations of marine mammals were highest in the summer and records showed the highest densities of effort close to shore with decreasing amounts moving offshore, supporting the findings of this analysis.

Lastly, the most straightforward method of seismic survey mitigation is to prevent overlap with cetaceans in space and time (Weir and Dolman 2007). Spatio-temporal restrictions on human activities, like seismic exploration, are seen as one of the most effective ways to balance protection of species and the need for those activities (Agardy et al. 2007). This is especially important given the number and severity of effects of anthropogenic sound on cetaceans. Understanding spatial and temporal trends in cetacean use of the Mid- and South Atlantic planning areas is critical to making informed management decisions regarding seismic exploration.

Limitations and Future Directions

As previously mentioned, not all surveys were included in my dataset. For example, the Atlantic Marine Assessment Program for Protected Species (AMAPPS) surveys, a joint effort between BOEM and NOAA, were conducted from 2010 to 2014 and the report from these surveys is due to be released in June 2015. The inclusion of these surveys will expand spatial and/or temporal coverage of survey effort.

The primary limitation of this analysis is the issue of detectability. Detectability is summarized by the value of Effective Strip Width (ESW), or how far away an observer can detect an animal based on platform and species. Aerial surveys, for example, have a smaller ESW and are more likely to miss deep diving species. Shipboard surveys can cover a larger area, and large whale species are easier to detect than small dolphins or porpoises. The map results take all surveys in the dataset into account, regardless of platform and target species, which only gives a relative comparison of survey effort in the planning areas. One kilometer of survey effort from a ship will cover a different amount of area compared to one kilometer of survey effort from a plane, especially if targeting different species.

Stronger results could be produced if ESW values were applied as a buffer around tracklines based on platform and target species. The buffer would represent the total area surveyed and the percent of each grid cell surveyed could be calculated for a measurement of absolute coverage. Another future direction is to quantify a linear amount of survey effort that is needed in order for any given area to be considered completely surveyed. This could be done by using the results of the surveys and following the increase in effort within a cell until all species that could be seen were observed. This would be useful because there is currently no published standard for a minimum amount of survey effort that should be reached before management decisions can be made.

References

BOEM Gulf of Mexico OCS Region (2012). Atlantic OCS Proposed Geological and Geophysical Activities Mid-Atlantic and South Atlantic Planning Areas Draft Programmatic Environmental Impact Statement, Volume I: Chapters 1-8. March 2012. 550p. http://www.boem.gov/BOEM-Newsroom/Library/Publications/2012/BOEM-2012-005-vol1-pdf.aspx

BOEM Gulf of Mexico OCS Region (2014a). Atlantic OCS Proposed Geological and Geophysical Activities Mid-Atlantic and South Atlantic Planning Areas Final Programmatic Environmental Impact Statement, Volume I: Chapters 1-8, Figures, Tables, and Keyword Index. February 2014. 788p. http://www.boem.gov/BOEM-2014-001-v1/

BOEM (2014b). Record of Decision Atlantic OCS Proposed Geological and Geophysical Activities Mid-Atlantic and South Atlantic Planning Areas, Final Programmatic Environmental Impact Statement (PEIS). 11 July 2014. 12p. www.boem.gov/Record-of-Decision-Atlantic-G-G/

BOEM (2015). 2017-2022 Outer Continental Shelf Oil and Gas Leasing Draft Proposed Program. 299 p. www.boem.gov/Five-Year-Program-2017-2022/

Clark, C. W., & Gagnon, G. C. (2006). Considering the temporal and spatial scales of noise exposures from seismic surveys on baleen whales. *IWC/SC/58 E*, *9*.

Convention on Biological Diversity (CBD) (2012). Scientific synthesis on the impacts of underwater noise on marine and coastal biodiversity and habitats. United Nations Environment Programme, Convention on Biological Diversity, Subsidiary Body on Scientific, Technical and Technological Advice. Sixteenth meeting, Montreal, 30 April-5 May 2012. 93p.

ESRI 2014. ArcGIS Desktop: Release 10.2 Redlands, CA: Environmental Systems Research Institute.

Kaschner, K., Quick, N. J., Jewell, R., Williams, R., & Harris, C. M. (2012). Global coverage of cetacean line-transect surveys: status quo, data gaps and future challenges. *PloS one*, *7*(9), e44075.

LaBrecque, E., Curtice, C., Harrison, J., Van Parijs, S. M., & Halpin, P. N. (2015). 2. Biologically Important Areas for Cetaceans Within US Waters–East Coast Region. *Aquatic Mammals*, *41*(1), 17-29.

Malakoff, D. (2002). Suit ties whale deaths to research cruise. Science, 298, 722–723.

National Marine Fisheries Service (NMFS) (2013). Endangered Species Act Section 7 Consultation Biological Opinion. Programmatic Geological and Geophysical Activities in the

Mid- and South Atlantic Planning Areas from 2013 to 2020. 19 July 2013. 370 p. www.boem.gov/Final-Biological-Opinion-19-July-2013/

National Research Council (2003). *Ocean noise and marine mammals*. Ocean Studies Board. National Academies Press.

Nieukirk, S. L., Stafford, K. M., Mellinger, D. K., Dziak, R. P., & Fox, C. G. (2004). Low-frequency whale and seismic airgun sounds recorded in the mid-Atlantic Ocean. *The Journal of the Acoustical Society of America*, *115*(4), 1832-1843.

Nowacek, D. P., Thorne, L. H., Johnston, D. W., & Tyack, P. L. (2007). Responses of cetaceans to anthropogenic noise. *Mammal Review*, *37*(2), 81-115.

Richardson, W. J., Greene Jr, C. R., Malme, C. I., & Thomson, D. H. (2013). *Marine mammals and noise*. Academic press.

Roberts, J.J., Best, B.D., Mannocci, L., Halpin, P.N., Palka, D.L., Garrison, L.P., Mullin, K.D., Cole, T.V.N., McLellan, W.M. (2015). Habitat-based cetacean density models for the Northwest Atlantic and Northern Gulf of Mexico. Manuscript in preparation.

Robertson, F. C., Koski, W. R., Thomas, T. A., Richardson, W. J., Würsig, B., & Trites, A. W. (2013). Seismic operations have variable effects on dive-cycle behavior of bowhead whales in the Beaufort Sea. *Endangered Species Research*, *21*, 143-160.

Schick, R. S., Halpin, P. N., Read, A. J., Slay, C. K., Kraus, S. D., Mate, B. R., Baumgartner, M.F., Roberts, J.J., Best, B.D., Good, C.P., Loarie, S.R. & Clark, J. S. (2009). Striking the right balance in right whale conservation. *Canadian Journal of Fisheries and Aquatic Sciences*, *66*(9), 1399-1403.

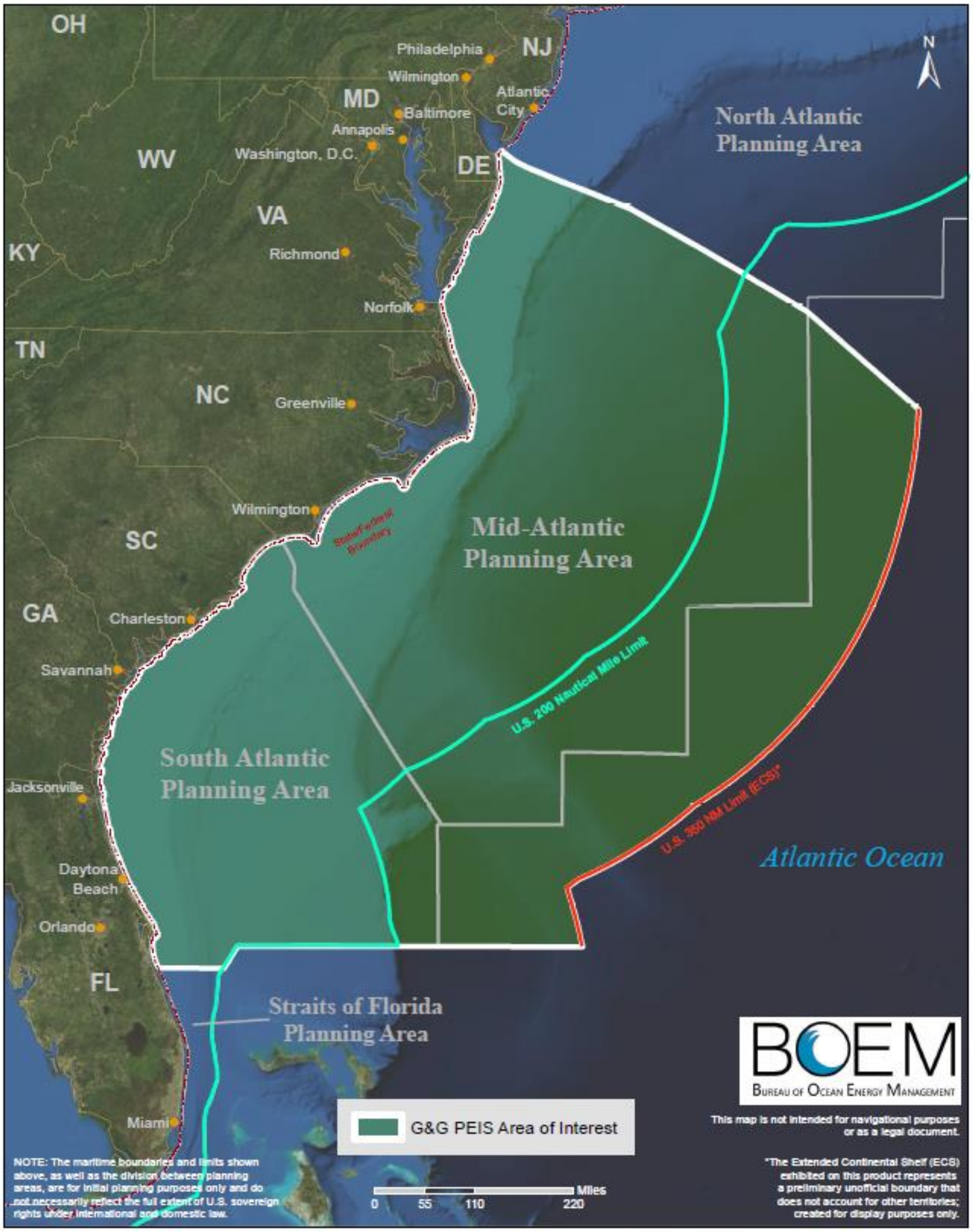
Schick, R. S., Halpin, P. N., Read, A. J., Urban, D. L., Best, B. D., Good, C. P., Roberts, J.J., LaBrecque, E.A., Dunn, C., Garrison, L.P., Hyrenbacj, K.D., McLellan, W.A., Pabst, D.A. & Stevick, P. (2011). Community structure in pelagic marine mammals at large spatial scales. *Marine Ecology Progress Series*, *434*, 165-181.

Simmonds, M., Dolman, S., & Weilgart, L. (2004). Oceans of noise: A WDCS science report. *Whale and Dolphin Conservation Society*.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene, C. R., Kastak, D., Ketten, D.R., Miller, J.H., Nachtigall, P.E., Richardson, W.J., Thomas, J.A. & Tyack, P. L. (2007). Marine mammal noise exposure criteria: Initial scientific recommendations. *Aquatic mammals*, *33*(4), 411-509.

Stone, C. J., & Tasker, M. L. (2006). The effects of seismic airguns on cetaceans in UK waters. *Journal of Cetacean Research and Management*, *8*(3), 255.

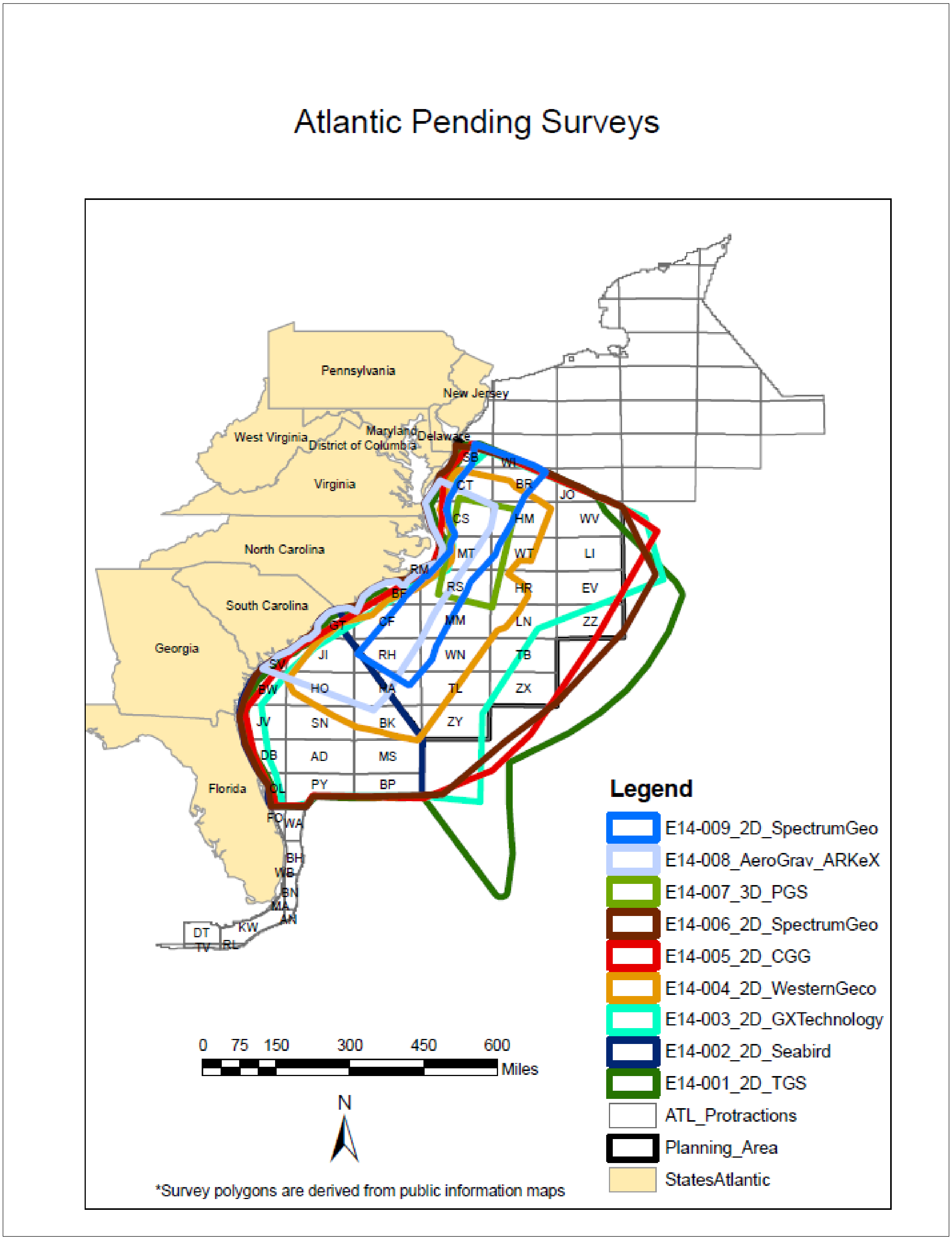
Appendix A. Bureau of Ocean Energy Management Atlantic Geological and Geophysical Activities Area of Interest



Atlantic OCS G&G Programmatic EIS
Area of Interest

http://www.boem.gov/Atlantic-G-G-PEIS/

Appendix B. Bureau of Ocean Energy Management Atlantic Pending Seismic Surveys



http://www.boem.gov/Atlantic-G-and-G-Permitting/