Expanding and Evaluating the Biological Content of the Marine Cadastre Ocean Reporting Tool

by

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Executive Summary

The MarineCadastre.gov website, a collaboration between The National Oceanic and Atmospheric Administration (NOAA) and Bureau of Ocean Energy Management (BOEM), provides a platform through which marine planners can access a variety of spatial data. To expand the services offered by MarineCadastre.gov and improve communication of complex spatial data, the NOAA Office for Coastal Management and BOEM are developing the Marine Cadastre Ocean Reporting Tool (ORT).

The ORT is designed to summarize spatial information for user-selected areas of interest in the Atlantic Ocean, spanning from Virginia to Florida. The prototype of the tool categorizes information in 5 main sections: (1) General Information, (2) Energy and Minerals, (3) Natural Resources and Conservation, (4) Transportation and Infrastructure, and (5) Economics and Commerce. The Natural Resources and Conservation content currently identifies overlapping areas between the report polygon and important habitats for migratory and endangered species, as well as locations of artificial reefs, Coastal Barrier Resource Areas, and legally protected areas. While limited information is presented for the endangered North Atlantic right whale, the tool currently lacks information on additional marine mammal species and marine birds.

Given the federal protection granted to all marine mammals by the United States Marine Mammal Protection Act of 1972 and the vulnerability of marine mammal and marine bird populations to offshore development, the spatial and temporal distributions of marine mammal and marine bird species are important to consider in marine spatial planning. The primary objective of this report is to present infographic designs for inclusion in the ORT that summarize the abundance and seasonal variation of marine mammals and marine bird species. A two-step approach was used to create infographic designs that align with the needs of ocean stakeholders: (1) zonal summaries of predicted marine mammal and marine bird abundance were created using geospatial analysis techniques, and (2) the infographic designs were evaluated by potential tool users and modified accordingly.

The infographic designs were constructed using predictive density models, which estimate the number of animals per square kilometer. The marine mammal density models were developed by the Duke University Marine Geospatial Ecology Lab, while the marine bird density

models were designed by the NOAA National Centers for Coastal Ocean Science (NCCOS). Summaries of Marine-Life Data Analysis Team products synthesizing marine mammal or marine bird abundance and species richness for ecologically relevant species groupings were also included within infographic designs. The methods presented in the report detail the spatial analysis techniques associated with each infographic.

A snowball sampling method was used to engage stakeholders and collect insight from potential tool users about the effectiveness of the infographic designs. Professionals from federal and state agencies, as well as non-profit organizations, with expertise in marine mammals or marine birds were asked to evaluate the initial designs through semi-structured interviews. Resulting themes in interview responses were used to inform revisions to the original infographic designs.

This report presents recommendations for four marine mammal and three marine bird infographic designs that summarize annual, seasonal, or monthly abundance and species richness for groupings of species or individual species. If these proposed infographics are integrated with the ORT, they will help inform a variety of marine spatial planning activities, such as offshore wind development, and conservation efforts. While scientists may use the ORT to explore available data, managers and planners may use the infographic content presented to guide the location and timing of various ocean uses. Furthermore, lawyers from environmental non-profits may use the ORT as a research tool for public comment letters or petitions promoting marine species conservation. Continued engagement with users of the tool following release of the ORT to the public will help identify further applications and future enhancements.

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Introduction

Through Executive Order No. 13547 (2010), President Obama established the National Ocean Policy (NOP), designed to coordinate stewardship of ocean, coastal, and Great Lakes ecosystems. The NOP created the National Ocean Council, tasked with producing an implementation plan and supporting the development of regional coastal and marine spatial plans (NOC, 2013). The marine spatial planning process informs management decisions and policy development through intensive data collection, analysis, and mapping (Shucksmith and Kelly, 2014). Of the nine United States regional planning areas recognized by the NOP, currently the Northeast, Mid-Atlantic, and Pacific Islands have opted to establish formal regional planning bodies (NOAA, 2017). Although regional planning bodies do not possess independent legal authority, they are intended to increase communication and coordinate planning processes between states, tribes, and Regional Fishery Management Councils (NOC, 2013).

The National Ocean Council certified the first regional ocean plans in December 2016 (NSOE, 2016). The Northeast and Mid-Atlantic regional planning bodies developed the Northeast Ocean Plan and the Mid-Atlantic Ocean Action Plan respectively through intensive public and scientific input processes (Nicholson et al., 2016; LaBelle et al., 2016). Gathering stakeholder input ensures relevant information is being presented in a format that can be easily understood and applied by ocean planners (Shucksmith and Kelly, 2014). Both the Northeast and Mid-Atlantic regions have established extensive data portals where individuals can explore ocean resources and human use information (NROC, 2017, http://www.northeastoceandata.org/; MARCO, 2017, http://midatlanticocean.org/data-portal/).

In addition to regional ocean data portals, MarineCadastre.gov serves as a critical platform through which marine planners can access spatial information. Established through a partnership between the U.S. Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) Office for Coastal Management and the U.S. Department of the Interior's Bureau of Ocean Energy Management (BOEM), MarineCadastre.gov was originally designed to support renewable energy exploration and development on the U.S. Outer Continental Shelf (MarineCadastre.gov, 2017). The portal has expanded to now host over 200 datasets, spanning biological, physical, economic, and regulatory themes covering all United States marine planning regions (MarineCadastre.gov, 2017). To streamline the data exploration process for ocean stakeholders, MarineCadastre.gov also hosts spatial tools, such as the National Viewer web-mapping platform (MarineCadastre.gov, 2017).

To assist coastal and marine planners with more localized management activities, the Marine Cadastre team is developing the online Ocean Reporting Tool as an extension to the MarineCadastre.gov portal. This web-based tool is designed to provide high-level summary statistics and interpretative analysis for portions of the Atlantic Ocean spanning from northern Virginia to southern Florida (SOW, 2015). Thus, the current prototype covers the entire Southeast Regional Planning Area and the southernmost extent of the Mid-Atlantic Regional Planning Area (NOAA, 2017). By synthesizing marine geospatial information into a format that can be easily applied by ocean planners, the tool will aid marine spatial planning efforts by summarizing complex data on ecological patterns, locations of coastal and ocean resources, and economic benefits associated with ocean uses. Given the wide range of data integrated within the tool, the intended tool audience includes federal and state government agencies, non-profit organizations, and legislative aids.

The existing tool prototype presents limited information on marine mammals and does not include data related to seabirds. Given that all marine mammals are federally protected under the Marine Mammals Protection Act of 1972 (MMC & NMFS, 2007), the abundance and distribution of marine mammals is an important consideration for offshore planning efforts. Furthermore, the abundance and distribution of seabirds is becoming increasingly relevant information for marine planners as active commercial leases for offshore wind energy development are approved (Gilman et al., 2016). The purpose of this project is to propose methods for integrating currently available marine mammal and seabird predictive density models into the Ocean Reporting Tool to support marine spatial planning efforts. The main research questions are:

(1) What content from currently available modeled marine mammal and marine bird data will be useful to ocean stakeholders?
(2) How can this information be conveyed in a meaningful manner to ocean stakeholders?
(3) How could this information be applied by one or more user groups in a management or policy setting?

To address these research questions, I used geospatial analysis techniques to produce draft infographic designs summarizing the spatial and temporal distributions, as well as predicted abundance, of marine mammals and seabirds. I then shared my draft infographic designs with professionals in the non-profit, state government, and federal government sectors to identify aspects of the designs that could be improved to better align with the needs of various ocean stakeholders.

The following report first provides detailed information on the current prototype of the Ocean Reporting Tool and the data sets used in the infographic designs. I then present the spatial analysis methods I used to generate the infographic designs and describe my stakeholder engagement approach. By synthesizing feedback provided by professionals in my results, I present evidence to support modifications to the initial designs. Finally, I discuss the associated limitations with the designs, infer how various ocean stakeholders could apply the information presented, and provide recommendations for future development of the biological content of the Ocean Reporting Tool.

The Marine Cadastre Ocean Reporting Tool

The current prototype of the Marine Cadastre Ocean Reporting Tool (ORT) allows the user to generate a summary report by selecting from a list of known areas or drawing a custom area (Appendix A, Image 1). The list of known areas for which reports have been pre-generated include “Special Interest Areas” and “Other Areas by State”. Given that the current prototype is focused on the southeastern United States, the five states included are: (1) Virginia, (2) North Carolina, (3) South Carolina, (4) Georgia, and (5) Florida (Appendix A, Image 2). For each state, the user may select federal waters (3 to 50 nautical miles), state waters (shoreline to 3 nautical miles), or waters by coastal county. For the state of Florida, the federal waters are further divided into north and south regions. Under the “Special Interest Areas” list, the user may select from National Estuarine Research Reserves or Wind Planning Areas. Currently pre-generated reports exist for six National Estuarine Research Reserves, representing all five states listed in the tool. Eight offshore Wind Planning Areas are listed and associated with the states of North Carolina, South Carolina, and Georgia.

To create a custom report, the user may draw a polygon in the Atlantic Ocean along the southeastern United States. The size of the custom area is restricted by requiring the user to zoom to a minimum scale before drawing a polygon. Once the polygon is submitted to the tool, an anticipated wait time will appear, which is generally two minutes.

Each report presented by the tool includes five tabs: (1) General Information, (2) Energy and Minerals, (3) Natural Resources and Conservation, (4) Transportation and Infrastructure, and (5) Economics and Commerce (Appendix A, Image 3). The General Information tab displays facts regarding fundamental geographic, social, and regulatory information. For example, the South Carolina Grand Strand Wind Planning Area report indicates the geographic area spans 2,540.625 km^2 of federal waters, and 12 federal statues, such as the Endangered Species Act, apply in this area.

The Energy and Minerals tab includes information on both renewable and fossil fuel energy sources. Offshore wind energy, wave power, tidal power, and ocean current power resource potential are reported, as well as oil and gas resource potential. Regarding minerals, surficial sediment classification, location of sediment resources, marine mineral leases, beach nourishment projects, and ocean disposal sites are presented. However, beach nourishment project information has not yet been compiled for Virginia.

The Transportation/Infrastructure and Economics/Commerce tabs highlight information related to marine transportation and the ocean economy by state. AIS Vessel Traffic, shipping lanes, and nearby principle port locations are included under Transportation and Infrastructure. Ocean job contributions to state gross domestic product, as well as contributions by industry and fishing economic value are summarized under the Economics and Commerce tab. For example, the South Carolina Grand Strand Wind Planning Area report indicates that over 3 billion dollars in goods and services and 70,000 jobs are provided by South Carolina’s ocean industries.

The Natural Resources and Conservation tab presents information on important habitats for migratory and endangered species, as well as deep sea coral. Furthermore, the location of artificial reefs, Coastal Barrier Resource Areas, and protected areas, such as National Wildlife Refuges, are included. Information specifically for the North Atlantic right whale, one of the most highly endangered marine mammals, is also displayed on the Natural Resources and Conservation and Transportation/Infrastructure tabs. This includes the percent of a report area intersecting right whale calving critical habitat, as well as overlap with right whale vessel speed restricted areas. Apart from North Atlantic right whales, no other data regarding marine mammals currently exists in the tool. Furthermore, no information on marine birds is presented. Thus as highlighted in the previously stated research questions, the primary objective of this project is to develop stakeholder-informed infographic designs of complex modeled marine mammals and seabirds data for integration into the ORT.

Marine-life Data Analysis Team Modeled Data

(1) Marine Mammals

To address the need for information on seasonal distributions and habitats of marine mammals, the Duke University Marine Geospatial Ecology Lab used 23 years (1992-2014) of aerial and shipboard line-transect cetacean surveys coupled with environmental variables to predict cetacean (i.e. whales, dolphins, and porpoises) abundance through density surface modeling (Roberts et al., 2016). This modeling approach combines distance sampling techniques and multivariate regression models (Roberts et al., 2016). Distance sampling methods estimate the abundance of cetaceans within large geographic areas, while multivariate regressions determine environmental correlates with cetacean distribution, such as a sea surface temperature (Roberts et al., 2016). Habitat-based density models were produced for 26 cetacean species and 3 multi-species guilds in the U.S. Atlantic and Gulf of Mexico at a 10 km cell resolution (Roberts et al., 2016). Species guilds, such as beaked whales, were created when sightings data was insufficient and no distinction could be made between the spatiotemporal distributions of multiple species (Roberts et al., 2016). Of the 29 species and species guilds modeled, sufficient sightings data was available for 11 cetacean species to be modeled at monthly intervals, while the remaining models occur at an annual temporal resolution (Roberts et al., 2016).

To provide synthesized information across multiple cetacean species, the Marine-Life Data Analysis Team (MDAT) produced summary products for sub-sets of species (Curtice et al., 2016). MDAT is a collaboration between the Duke University Marine Geospatial Ecology Lab, the Northeast Regional Ocean Council, the NOAA National Centers for Coastal Ocean Science, the NOAA Northeast Fisheries Science Center, and Loyola University, Chicago (Curtice et al., 2016). Cetacean species were grouped for the summary products based on ecological characteristics, Endangered Species Act listing, and sensitivity to low, medium or high frequency sounds (Curtice et al., 2016). Sound sensitivity is of particular interest due to oceanic noise pollution associated with seismic activity, vessel traffic, and Sound Navigation and Ranging (sonar) (Curtice et al., 2016). Of the modeled cetacean species, 6 were classified as sensitive to low frequency sounds, 24 were classified as sensitive to mid frequency sounds, and 3 were classified as sensitive to high frequency sounds (Table 1, Curtice et al., 2016). These sensitivities include both direct sensitivity to sound and sensitivity to the masking of important communications or ecological cues when noise pollution occurs in these ranges (Southall et al. 2007). Note the total of sound sensitive species is greater than 29 (the total number of species and species guilds modeled) because species within guilds were classified individually.

Table 1: Cetacean species classified by sound sensitivity. Table from pg. 44 of the MDAT Technical Report (Curtice et al., 2016).

Marine Mammal Sound Sensitivity			
Low frequency 7 Hz to 22 kHz	Mid frequency 150 Hz to 160 kHz		High frequency 200 Hz to 180 kHz
Blue whale	Atlantic spotted dolphin	Northern bottlenose whale	Dwarf sperm whale
Bryde's whale	Atlantic white-sided dolphin	Pantropical spotted dolphin	Harbor porpoise
Fin whale	Blainville's beaked whale	Risso's dolphin	Pygmy sperm whale
Humpback whale	Bottlenose dolphin	Rough-toothed dolphin	
North Atlantic right whale	Clymene dolphin	Short-beaked common dolphin	
Sei whale	Cuvier's beaked whale	Short-finned pilot whale	
	False killer whale	Sowerby's beaked whale	
	Fraser's dolphin	Sperm whale	
	Gervais' beaked whale	Spinner dolphin	
	Killer whale	Striped dolphin	
	Long-finned pilot whale	True's beaked whale	
	Melon-headed whale	White-beaked dolphin	

Six cetacean species are listed under the Endangered Species Act (Table 2, Curtice et al., 2016). All species modeled were also divided into four ecological groupings: (1) Baleen Whales, (2) Sperm and Beaked Whales, (3) Small Delphinoids, and (4) Large Delphinoids (Curtice et al., 2016).

Table 2: Cetacean species listed under the Endangered Species Act. Table from pg. 39 of the MDAT Technical Report (Curtice et al., 2016).

ESA listed
Blue whale
Fin whale
Humpback whale
North Atlantic right whale
Sei whale
Sperm whale

MDAT derived total abundance summary products by adding values for each 100 km^2 cell across all individual species abundance layers for the given summary product grouping. For example, for the low frequency sound sensitivity stressor group, the individual density models of the Blue whale, Bryde's whale, Fin whale, Humpback whale, North Atlantic right whale, and Sei whale were added to calculate the total predicted abundance of all 6 species within each 100 km^2 cell. Similarly for species richness, multiple species layers were added on a cell by cell basis after first converting the individual density models to presence/absence layers. To determine whether the species was present within a given cell, all cell values included within 95% of the total predicted abundance for the species were converted to a 1, denoting presence, while the bottom 5% of total predicted abundance values were marked as 0, indicating absence. By adding multiple presence/absence layers, the total for each cell indicates the number of species present, or species richness. For all 29 cetacean species and species guilds modeled, as well as the subsets of these species, total abundance and species richness summary products are available for viewing on the Northeast Ocean Data portal, and available for download from the OBIS-SEAMAP site. (Curtice et al., 2016)

(2) Seabirds

The NOAA National Centers for Coastal Ocean Science (NCCOS) developed preliminary models and maps predicting long-term average marine bird relative occurrence and relative abundance for Phase 1 of a project funded by BOEM (Kinlan et al., 2016). The primary goal of the collaborative project is to assist marine spatial planning efforts by developing maps depicting the distribution of marine bird species along the waters of the U.S. Atlantic Outer Continental Shelf (OCS) (Kinlan et al., 2016). The predictive maps and models were developed for 40 marine bird species at 2 km cell resolution based on environmental predictor variables and visual sighting survey data spanning from 1978 to 2014, which can be accessed through the "Compendium of Avian Occurrence Information for the Continental Shelf Waters along the Atlantic Coast of the U.S." database (Kinlan et al., 2016).

The occurrence and abundance models are considered to produce relative values rather than absolute values, as predicted by the marine mammal models, because of data limitations and the absence of a measure of detectability and availability bias within the modeling approach (Curtice et al., 2016). The marine bird occurrence probability model results indicate the long-term average relative occurrence probability per visual survey transect segment (Kinlan et al., 2016). Likewise, the marine bird abundance models represent the long-term average relative abundance of individuals per transect segment (Kinlan et al., 2016). Thus, the abundance models and resulting maps display where species are likely to be more or less abundant (Kinlan et al., 2016). Where sufficient survey data was available, the NCCOS team developed species relative occurrence probability and abundance models by season (Kinlan et al., 2016). Based on transitions in environmental conditions along the Atlantic OCS, the seasons were defined as September – November (fall), December – February (winter), March – May (spring) and June-August (summer) (Kinlan et al., 2016).

To assist BOEM in estimating the potential ecological impacts of offshore wind energy projects, Normandeau Associates developed sensitivity rankings to describe the vulnerability of marine bird species to collision and displacement (Willmott et al., 2013). The sensitivity of marine bird species to colliding with offshore wind turbines was defined by annual occurrence, breeding, and feeding time in the Atlantic OCS, nocturnal and diurnal flight activity, percent time observed flying at the height of the turbine rotor swept zone, and macro avoidance of wind turbines (Willmott et al., 2013). Macro avoidance is defined as the behavior of marine birds to avoid offshore wind facilities completely (Willmott et al., 2013). Displacement in the context of marine birds refers to relocation of foraging grounds during the construction and operation of an offshore wind facility, which could have potential fitness consequences (Willmott et al., 2013). The parameters used to define species displacement sensitivity included disturbance reactions to ships and helicopters, the range of habitats used by the species, and annual occurrence, breeding, and feeding time in the Atlantic OCS (Willmott et al., 2013).

Using the higher collision and displacement sensitivity rankings produced by Normandeau Associates, MDAT created stressor sensitivity-based products encompassing 29 higher collision sensitivity marine bird species and 15 higher displacement sensitivity marine bird species (Table 3, Curtice et al., 2016). Currently available summary products include relative abundance and species richness, defined as the relative number of individuals or species respectively per 4 km^2. All avian predictive abundance models were normalized by the respective mean prior to inclusion in the summary products (Curtice et al., 2016). Other synthetic product groupings include spatial (i.e. nearshore vs. offshore/pelagic), ecological (i.e. feeding strategies), and species of conservation concern (Curtice et al., 2016). Avian species have been grouped by conservation priority by the Atlantic Marine Bird Conservation Cooperative (AMBCC) (Curtice et al., 2016). Furthermore, the North American Bird Conservation Initiative provides a listing of priority species in Bird Conservation Region 30 (BCR30) spanning from Virginia to Maine (ACJV, 2014). The only marine bird species of the 40 modeled that is listed under the Endangered Species Act is the Roseate Tern (USFWS, 2011). All summary products are available for viewing on the Northeast Ocean Data portal, and accessible to download via the OBIS-SEAMAP site.

Table 3: Species listed as having high sensitivity to collision with wind turbines and habitat displacement (Willmott et al., 2013). Table from pg. 43 of the MDAT Technical (Curtice et al., 2016).

Avian		
Higher collision sensitivity		Higher displacement sensitivity
Arctic tern	Laughing gull	Arctic tern
Atlantic puffin	Leach's storm petrel	Atlantic puffin
Audubon's shearwater*	Long-tailed duck	Black guillemot*
Black guillemot*	Manx shearwater	Black scoter
Black scoter	Northern fulmar	Common eider*
Black-legged kittiwake	Northern gannet	Common loon
Common eider*	Pomarine jaeger	Common murre
Common loon	Razorbill	Common tern
Common murre	Red phalarope	Great black-backed gull
Common tern	Red-necked phalarope	Long-tailed duck
Cory's shearwater	Red-throated loon	Manx shearwater
Double-crested cormorant	Roseate tern	Northern gannet
Great black-backed gull	Sooty shearwater	Razorbill
Great shearwater	Surf scoter	Red-throated loon
Herring gull	White-winged scoter	Roseate tern
Horned grebe	Wilson's storm petrel	Surf scoter
		White-winged scoter

Methods

Marine Mammal Initial Infographic Designs

Given the diverse products produced by MDAT that are available for cetaceans, I selected summary layers for the initial designs that are currently available for download on the MarineCadastre.gov Data Registry (MarineCadastre.gov, 2017). These include abundance and species richness summaries for all cetacean species and sound sensitivity (high, medium, and low) groupings (Table 4).

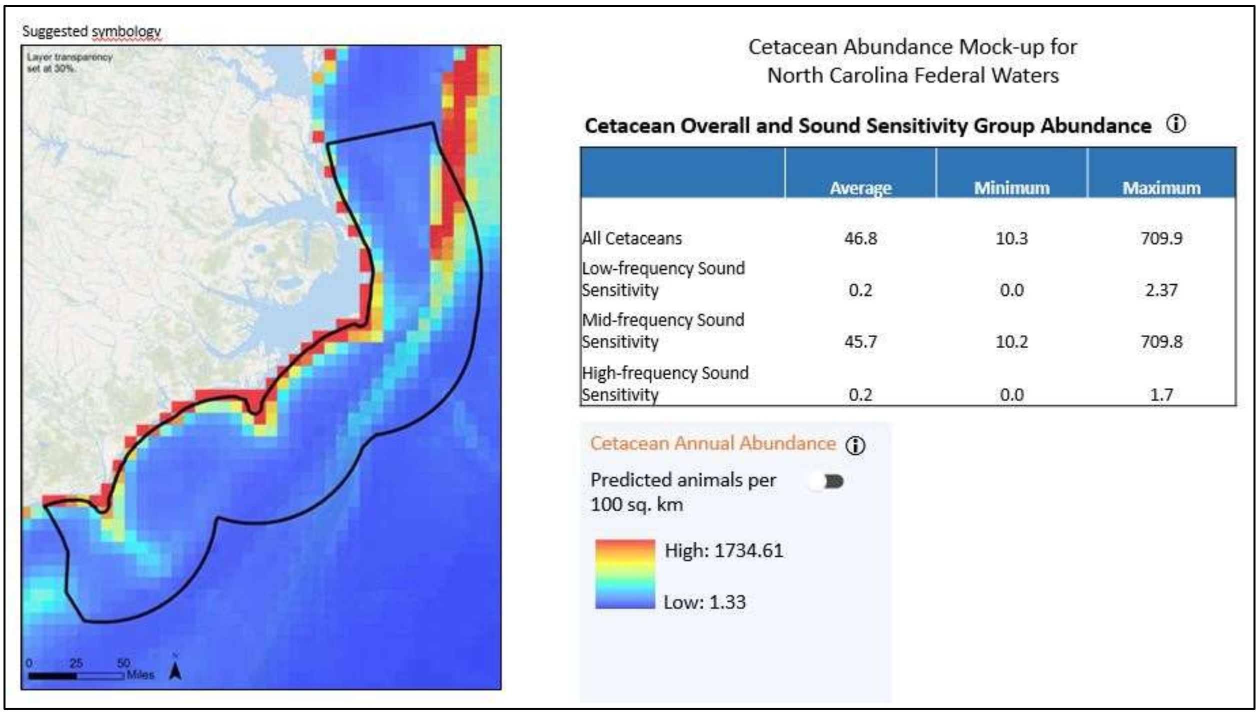
Table 4: Monthly cetacean predictive density models and summary products selected for initial infographic designs. Note all monthly models can be accessed via a link on the MarineCadastre.gov Data Registry. In addition, models are being periodically updated as new data becomes available.

Categories	Datasets
Monthly Cetacean Predictive Density Models	Atlantic white-sided dolphin
	Bottlenose dolphin
	Fin whale
	Harbor porpoise
	Humpback whale
	Minke whale
	North Atlantic right whale
	Risso's dolphin
	Sei whale
	Short-beaked common dolphin
	Sperm whale
Summary Cetacean Products	All Cetaceans Abundance
	All Cetaceans Species Richness
	Sound Sensitivity Group Abundance
	Sound Sensitivity Group Species Richness

(1) Abundance Summary Product Infographic

For the "All Cetaceans" and sound sensitivity grouping abundance layers, I calculated the average, minimum, and maximum predicted abundance values per 100 km^2 in federal waters offshore North Carolina (Image 1). I selected this report area for the draft display because federal waters are among the largest areas included in the ORT current list of known areas. Given the coarse 10 km cell resolution of the cetacean modeled products, the data is better suited for large polygon areas located offshore. The average, minimum, and maximum values were calculated by running the "Zonal Statistics as Table" tool in Python (Appendix C). I designated the zone as a raster version of the North Carolina Federal Waters polygon, projected to match the WGS 1984 projection of the cetacean summary products (Appendix C). To ensure the raster version of North Carolina Federal Waters aligns with the cetacean summary abundance raster, I specified the output file cell size as equivalent to the summary abundance raster cell size in the environment settings (Appendix C). The resulting average output for "All Cetaceans", for example indicates on average, approximately of 46.8 cetaceans are predicted to be present annually within 100 km^2 in federal waters offshore North Carolina (Image 1).

Image 1:



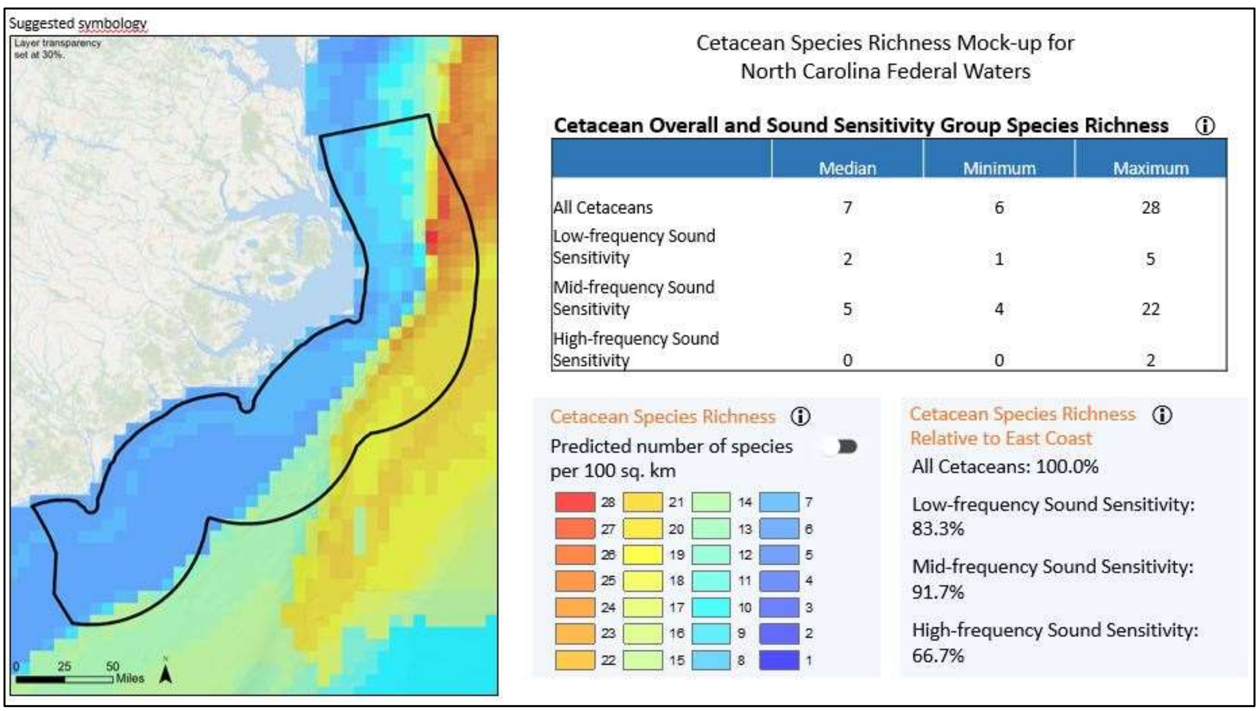
	Average	Minimum	Maximum
All Cetaceans	46.8	10.3	709.9
Low-frequency Sound Sensitivity	0.2	0.0	2.37
Mid-frequency Sound Sensitivity	45.7	10.2	709.8
High-frequency Sound Sensitivity	0.2	0.0	1.7

(2) Species Richness Summary Product Infographic

Similarly, for "All Cetaceans" and sound sensitivity groupings of species richness, I reported the median, minimum, and maximum predicted species richness values per 100 km^2 in North Carolina Federal Waters. I selected median rather than average for the measure of center because the values of species richness are represented as integers. I also applied the "Zonal Statistics as Table" tool to produce summary statistics for the raster version of the North

Carolina Federal Waters polygon. The resulting median for "All Cetaceans", for example, indicates there are a minimum of 6 cetacean species present within 100 km^2 in North Carolina Federal Waters (Image 2). For the species richness infographic design, I also calculated the percent of species located within North Carolina Federal Waters relative to the number of species modeled. For example, given there are 6 species classified as low-frequency sound sensitive (Table 1), and a maximum of 5 of these species are located within 100 km^2 in North Carolina Federal Waters, there are 5 of 6, 83.3%, low-frequency species along the east coast predicted to be located in North Carolina Federal Waters (Appendix B, Image 2). It is important to note a limitation of this approach with the species richness data. The maximum value presented for 100 km^2 may not reflect the true maximum of species observed in federal waters offshore North Carolina because two cells with a species count of 5 may not represent the same 5 species.

Image 2:



	Median	Minimum	Maximum
All Cetaceans	7	6	28
Low-frequency Sound Sensitivity	2	1	5
Mid-frequency Sound Sensitivity	5	4	22
High-frequency Sound Sensitivity	0	0	2

(3) Species Presence by Month Infographic

To provide summary information at a finer temporal resolution, I explored the monthly models available for 11 cetacean species (Table 4). I presented the 11 species in a tabular format, so the user could determine species presence by month within a given planning area (Image 3). To calculate monthly presence for each species, I first converted the density layers to presence/absence layers following a method similar to the MDAT protocol for species richness determination (Curtice et al., 2016). Using NumPy functions in Python, I totaled all of the values in the monthly raster for a given species (Appendix D). I assigned a 0 to cells with values in the bottom 5% of total abundance, and a 1 to cells with values in the remaining 95% of total abundance (Appendix D). A value of 1 denoted species presence in a cell, and 0 indicated species absence. I then imported the presence/absence files to a new Python script, where I created a loop that applied the "Zonal Statistics as Table" tool to each file to calculate the sum of the cells within the South Carolina Grand Strand Wind Planning Area (Appendix E). The resulting sums were stored in a geodatabase table and divided by the number of cells present in the wind planning area (Appendix E). Thus, a percent of the wind planning area occupied by each species was produced at monthly intervals, with presence in the wind planning area defined by a value greater than 0%.

On the far right column of the species monthly presence design, I also included the International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species classification to provide an estimate of the species global status. The IUCN Red List provides the conservation status of species on a global scale, as well as taxonomic and distributional information (IUCN, 2017). Species considered threatened with a higher risk of global extinction are designated as Vulnerable, Endangered, or Critically Endangered, while species with a low risk of extinction are listed as Least Concern (IUCN, 2017). Of the 11 cetacean species modeled at monthly intervals, the Fin whale, North Atlantic right whale, and Sei whale are listed as Endangered, the Sperm whale is listed as Vulnerable, and the remaining 7 species are listed as Least Concern (Image 3).

Image 3:

Cetacean Species Present by Month for South Carolina Grand Strand Wind Planning Area

Species	Months Present	IUCN Listing
Atlantic white-sided dolphin	None	Least concern
Bottlenose dolphin	Jan, Feb, Mar, Apr, May, Jun, Jul, Aug, Sep, Oct, Nov, Dec	Least concern
Fin whale	None	Endangered
Harbour porpoise	None	Least concern
Humpack whale	Jan, Feb, Mar, Dec	Least concern
Minke whale	None	Least concern
North Atlantic right whale	Jan, Feb, Mar, Apr, Nov, Dec	Endangered
Risso's dolphin	None	Least concern
Sei Whale	Mar	Endangered
Short-beaked common dolphin	None	Least concern
Sperm Whale	None	Vulnerable*

(4) North Atlantic right whale Infographic

Given major conservation concerns surrounding the North Atlantic right whale in the southeastern region of U.S. Atlantic waters, I selected the monthly North Atlantic right whale density models to summarize as an independent infographic. To test an alternative approach, I summarized monthly abundance of North Atlantic right whales within the South Carolina Grand Strand Wind Planning Area as the percent of the area within the wind planning polygon containing above average abundance (Image 4). The average value was equivalent to the mean cell value presented in the statistics section under the "Symbology" tab of Raster Properties in ArcMap. For each monthly density raster, I used the "Con" function in "Raster Calculator" to reclassify cells with a value above average abundance as a 1 and anything below average abundance as a 0. I then used the "Zonal Statistics as Table" tool to sum the values of the cells within the South Carolina Grand Strand Wind Planning Area zone. Given the raster layers only contained values of 1 or 0, the sum represented the number of cells scoring above average abundance within the wind planning area. I then calculated the area with above average abundance using the following formula:

(Number of Cells above Average/Number of Cells within Planning Area)*100

I organized the results for each month into a table (Image 4). In addition, I produced summaries for the months of January and July to compare the abundance of North Atlantic right whales predicted to be present within the wind planning area relative to the East Coast (Image 4). I selected January and July to represent changes in the distribution of North Atlantic right whales between winter and summer seasons. I calculated percentages using the following formula:

(Sum of abundance in the planning area/Sum of all abundance for the raster layer)*100

I determined the sum of abundance values in the wind planning area from the sum statistic in the "Zonal Statistics as Table" tool, while I calculated the sum of all values in the raster layer using Python NumPy. The percent can be interpreted as follows: for the South Carolina Grand Strand Wind Planning Area, 0.39% of the total abundance of North Atlantic right whales along the East Coast are predicted to be present during the month of January (Image 4).

Image 4:

North Atlantic right whale above average abundance for South Carolina Grand Strand Wind Planning Area

Month	% Area with Above Average Abundance
January	67.80%
February	71.43%
March	100.00%
April	92.86%
May	0.00%
June	0.00%
July	0.00%
August	0.00%
September	0.00%
October	0.00%
November	64.29%
December	57.14%

North Atlantic right whale abundance relative to east coast

January: 0.39%

July: 0.00%

Seabird Initial Infographic Designs

As with the cetacean summary products, I selected a subset of the MDAT avian summary products based on the layers that are currently available for download on the MarineCadastre.gov Data Registry. These include "All Avian" total relative abundance and species richness, as well as the relative abundance and species richness of the avian higher collision and higher displacement stressor sensitivity groups (Table 5).

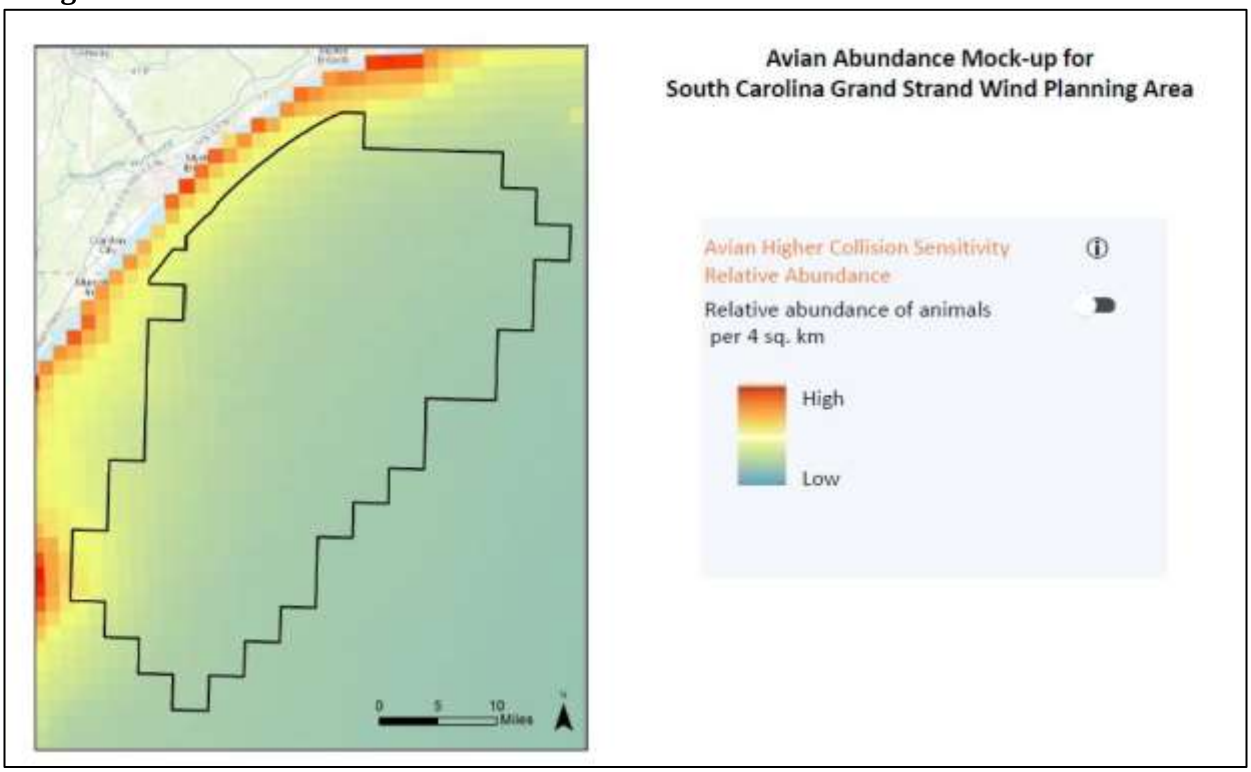
Table 5: Seasonal avian predictive abundance models and annual summary products selected for initial infographic designs. Note seasonal models are available for download via a link on the MarineCadastre.gov site.

Categories	Datasets
Seasonal Avian Models (AMBC High Conservation Priority)	Atlantic Puffin
	Audubon's Shearwater
	Black-capped Petrel
	Common Loon
	Least Tern
	Long-tailed Duck
	Northern Gannet
	Razorbill
	Red-necked Phalarope
	Red-throated Loon
	Roseate Tern
	White-winged Scoter
Summary Avian Products	All Avian Abundance
	All Avian Species Richness
	Higher Collision Sensitivity Abundance
	Higher Collision Sensitivity Richness
	Higher Displacement Sensitivity Richness
	Higher Displacement Sensitivity Richness

1) Abundance Summary Product Infographic

Given that the seabird density layers indicate relative abundance, rather than absolute abundance as provided by the cetacean models, the zonal statistics approach is not appropriate for summarizing abundance because the numeric cell values must be interpreted on a qualitative scale of low to high. By visually inspecting the layers for all seabirds, higher collision, and higher displacement abundance, the user can identify areas of highest relative abundance in relation to an area of interest. For the first infographic design, I demonstrated this approach by overlaying the avian higher collision sensitivity relative abundance layer with the South Carolina Grand Strand Wind Planning Area (Image 5). The areas of highest relative seabird abundance tend to occur outside the boundaries of the wind planning area (Image 5).

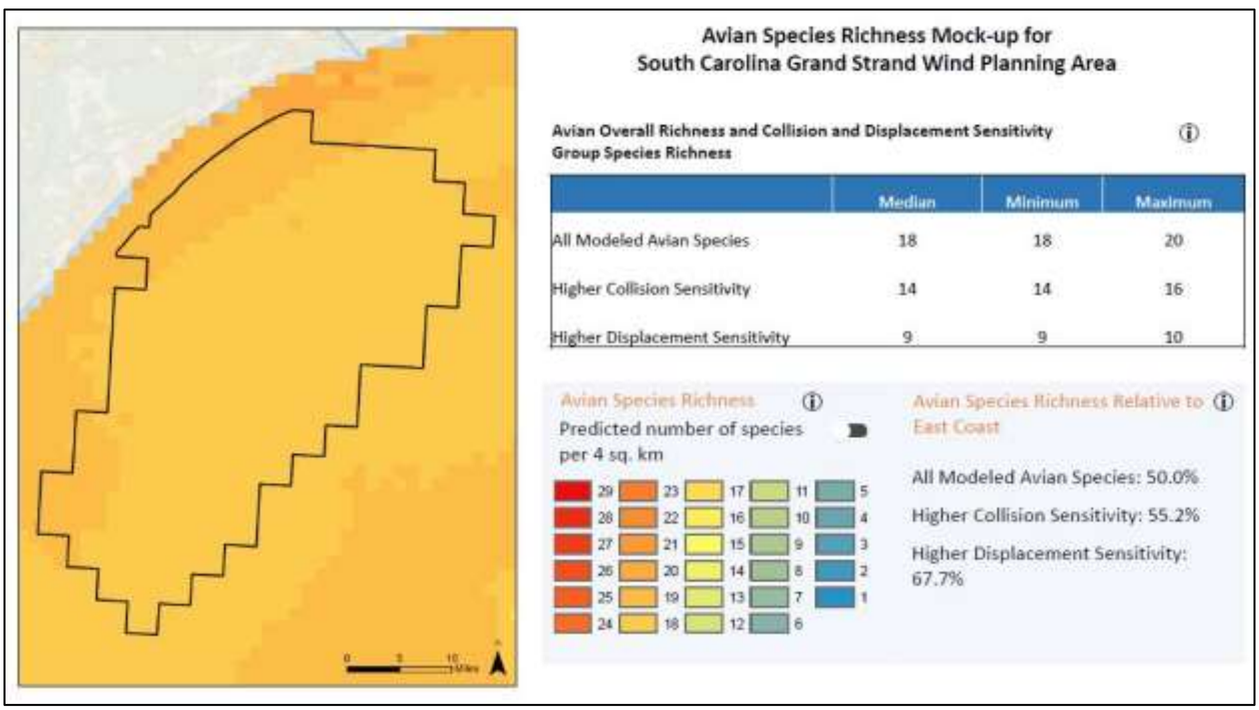
Image 5:



(2) Species Richness Summary Product Infographic

For the species richness avian summary products, the zonal statistics methodology is applicable because the count of species can be summarized meaningfully as median, minimum, and maximum values. To produce these summary statistics, I selected the South Carolina Grand Strand Wind Planning Area as the zone of interest because the higher collision and higher displacement sensitivity summaries are likely of greatest relevance with regard to proposed offshore wind planning areas. The resulting summary for the higher collision sensitivity species richness layer, for example, indicates there are a maximum of 16 seabird species with a higher risk of colliding with wind turbines present per 4 km^2 in the South Carolina Grand Strand Wind Planning Area (Image 6). Furthermore, I calculated the percent of species located within the wind planning area relative to the number of species modeled (Image 6). Given there are 29 modeled species classified as higher collision sensitive, and a maximum of 16 of these species are located within the wind planning area, there are 16 of 29, or 55.2%, of higher collision sensitivity species along the east coast located in the wind planning area (Image 6). As with the cetacean designs, a limitation of this approach is the maximum value presented for 4 km^2 may not reflect the true maximum of species observed in the wind planning area because two cells with a species count of 16 may not represent the same 16 species.

Image 6:



(3) Species Presence by Season Infographic

Although the individual avian species models are not available at monthly time intervals as for the cetaceans, the seasonal models provide a finer temporal resolution. To highlight species of conservation concern, I displayed the 12 AMBCC High Conservation Priority species for which seasonal models were available in a tabular format (Table 5). Using the same calculations to determine presence and absence from the cetacean abundance layers, I created a Python script that converted relative abundance values within the bottom 5% of the total abundance to 0 (absent) and the remaining 95% of values to 1 (present). In a separate Python script, I created a loop that calculated the sum of values within the South Carolina Grand Strand Wind Planning using the “Zonal Statistics as Table” tool. I converted the sum for each species and season to percent of the wind area occupied and stored the values in a geodatabase table. For any value greater than 0%, the species was marked as present in the wind planning area for the respective season. Because of survey sighting data limitations, models are not available each season for 6 of the 12 AMBCC High Conservation Priority species (Table 6).

Table 6: AMBCC High Conservation Priority species lacking predictive abundance models for all four seasons.

Avian Species	Seasonal Models Available
Least tern	Summer
Long-tailed Duck	Fall, Winter, Spring
Red-necked Phalarope	Fall, Summer
Red-throated Loon	Fall, Winter, Spring
Roseate Tern	Fall, Spring, Summer
White-winged Scoter	Fall, Winter, Spring

In the infographic design, I placed an asterisk next to the season listings for each species lacking all four seasonal models so that a distinction can be established between absence of the species and lack of data (Image 7).

Image 7:

Avian Species of AMBCC High Conservation Priority Present by Season for South Carolina Grand Strand Wind Planning Area

Species	Seasons Present	Spatial Distribution
Atlantic Puffin	None	Offshore/Pelagic
Audubon's Shearwater	None	Offshore/Pelagic
Black-capped Petrel	None	Offshore/Pelagic
Common Loon	Fall, Winter, Spring	Nearshore
Least Tern	Summer*	Nearshore
Long-tailed Duck	Winter, Spring*	Nearshore
Northern Gannet	Fall, Winter, Spring, Summer	
Razorbill	None	Offshore/Pelagic
Red-necked Phalarope	Fall, Summer*	Offshore/Pelagic
Red-throated Loon	Fall, Winter, Spring*	Nearshore
Roseate Tern	Fall*	Nearshore
White-winged Scoter	None	Nearshore

In the far right column of the seabird seasonal presence design, I specified whether each species is classified as having a nearshore or offshore/pelagic spatial distribution (Image 7). I included this information to estimate the relative locations of these species because there is no option currently to display the individual density raster layers in the infographic. The spatial classifications reported were retrieved from the MDAT technical report, which grouped species spatially for the summary products (Curtice et al., 2016). No spatial classification was provided for the Northern Gannet in the MDAT technical report (Curtice et al., 2016).

Stakeholder Engagement

To evaluate my initial marine mammal and seabird designs in the context of marine spatial planning, I developed a stakeholder engagement plan in collaboration with Adam Bode, the NOAA Office for Coastal Management Regional Geospatial Coordinator for the Southeast and Caribbean. Adam began gathering input from environmental federal and state agencies, as well as non-profit organizations, during the conceptual phases of the ORT development. Although legislative aids and industry professionals may also be potential users of the ORT, NOAA did not contact these sectors during initial outreach efforts because they wanted to prioritize stakeholders with whom they have previously collaborated until a more advanced prototype of the tool was produced. Once the ORT beta prototype was released, Adam collected additional feedback from those initially interviewed and began expanding engagement efforts to a larger pool of potential tool users. During discussions with potential tool users, Adam provided a demonstration of the ORT and recorded comments related to four main topic areas: (1) usability, (2) information requirements, (3) special interest areas, and (4) uses for the tool.

Following a similar format, I organized meetings with potential tool users to gather feedback on both the current prototype of the tool, and more specifically critiques of my initial marine mammal and seabird infographic designs. After receiving Duke University IRB approval (no. D0859), I began recruiting participants for semi-structured interviews via email. To account for differences in perspectives based on sector, I focused my outreach efforts on three primary user groups: (1) environmental non-profit organizations, (2) state agencies, and (3) federal agencies. Although respondent geographic locations varied along the East coast, all participants were involved with projects in the portion of the Atlantic Ocean covered by the ORT. With the exception of one in-person meeting, all interviews were conducted by conference call or Skype due to diverse locations of participants. The number of respondents on each call ranged from one to three individuals. All interviews were audio-recorded after receiving consent from participants.

To begin each interview, I asked participants to describe the primary responsibilities associated with their respective job titles and to highlight any projects they are currently involved with along the U.S. southeastern coastline. Via WebEx or Skype screen-sharing, I provided a demonstration of the tool by generating a report for a known area (i.e. North Carolina Federal Waters) and briefly displaying the summary statistics of each of the five content areas. Questions 1-5 in the interview guide served as a resource to direct the conversation if needed; however, many respondents addressed these questions through their comments without directly being prompted (Appendix G). To address Questions 6-9, I presented either the marine mammals or seabird infographic designs in a PowerPoint presentation, depending on the respondent's professional focus (Appendix G). Given the semi-structured interview approach, I asked follow-up questions to expand upon the respondent's specific comments that are not provided on the interview guide. After the participants had reviewed all marine mammals or seabird infographic designs, I asked them to rank the importance of each design on a scale from 1 to 5, with 1 indicating Unimportant and 5 indicating Very Important. Following the interviews, I transcribed all responses from audio-recordings and coded responses for common suggestions to improve each design.

After my initial interview, I asked respondents to provide recommendations for others in their field who may be interested in learning more about the ORT and my respective marine mammal and seabird infographics. Thus, I relied on a "snowball" sampling method where interview respondents provide referrals to other individuals within their social networks. Overall, 20 respondents were interviewed from 11 organizations. Grouped by sector, the organizations were composed of 5 environmental non-profits, 3 state agencies, 1 federal cooperative, and 2 federal agencies.

Results

Marine Mammal Infographic Designs Content Evaluation

Based on feedback received from professionals of four environmental non-profit organizations, one federal conservation cooperative, and two federal agencies, I altered the draft marine mammal infographic designs to accommodate the needs of ocean stakeholders. Although I also shared the designs with a state agency, the respondents did not feel they were qualified to provide detailed feedback, stating, "We do not have expertise in that. We also don't have jurisdiction over cetaceans at the state level." Thus, state agencies were not one of the target stakeholder groups for gathering feedback specifically on the cetacean designs. When comparing the scores respondents provided for infographic importance on a scale of 1 to 5, with 5 being very important, the North Atlantic right whale infographic designs had the lowest overall average rating amongst non-profits and second-lowest amongst federal agencies (Figure 1). However, this ranking does not reflect the overall goal of the infographic design, but rather how the information is currently conveyed. For example, regarding the initial North Atlantic right whale designs, one respondent from a non-profit organization stated "The format isn't helpful, but the purpose of it is a 5." All respondents agreed that presenting data specifically for the North Atlantic right whale is valuable because of the major conservation concerns associated with the endangered species.

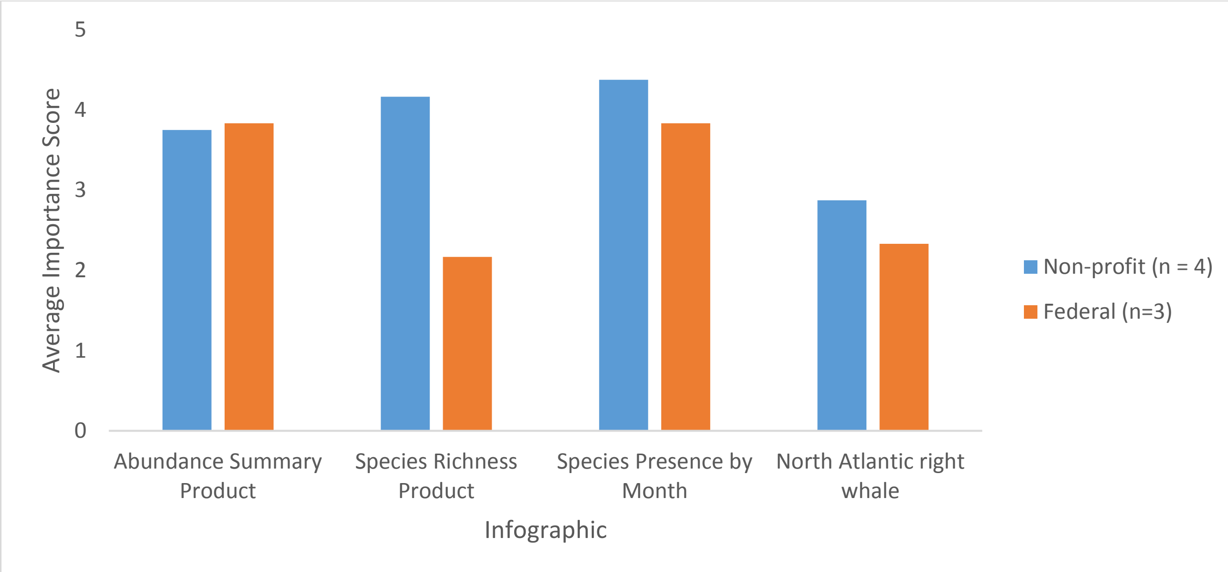


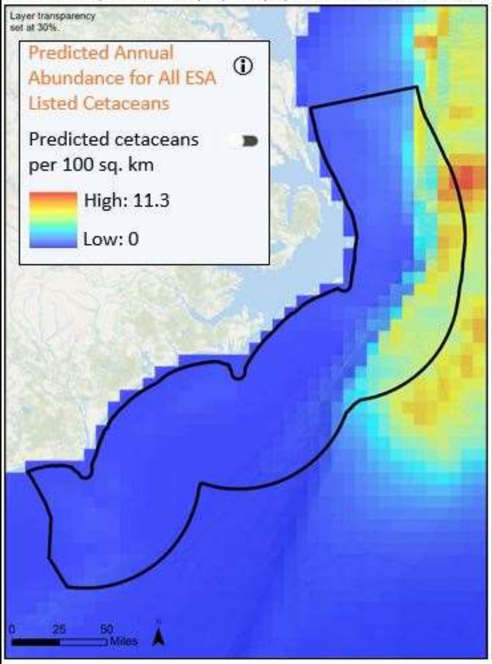
Figure 1: Responses per marine mammal infographic by professional sector to the question: "On a scale of 1 to 5, with 1 being Unimportant and 5 being Very Important, how would you rank the importance of this design?" The value equivalent to n indicates the number of organizations or agencies represented.

(1) Abundance Summary Product Infographic

While respondents indicated estimates of abundance are useful, the "All Cetaceans" category was not of particular interest because it encompasses a large range of species with no indication of the species composition. For example, a respondent from a federal agency stated, "This is dominated by bottlenose dolphins. If I was someone new coming into this, I wouldn't know necessarily by looking at this that all of that red on the shoreline is probably bottlenose dolphins." Furthermore, a respondent from an environmental non-profit stated, "'All Cetaceans' is a pretty broad swath, covering endangered and non-endangered species. Everything is protected by the MMPA, but they are going to be protected on a stock by stock basis." Another respondent from a separate environmental non-profit said, "The priority would be the whales on the east coast that are endangered or threatened under the ESA." Based on this common interest among respondents for species status information, I removed the "All Cetaceans" category from the draft infographic design, and included a zonal statistics summary for the "All ESA Listed" MDAT summary abundance layer (Image 8).

Image 8:

All ESA Listed Species Summary Layer Displayed for North Carolina Federal Waters



Predicted Annual Abundance of Marine Mammals

Cetaceans, referring to an order of marine mammals that includes dolphins, porpoises, and whales, are highly-mobile species of global conservation concern. The Marine-Life Data Analysis Team has developed summary products for groupings of cetacean species based on ecological characteristics, Endangered Species Act listing, and sensitivity to low, medium or high frequency sounds.

The summary values presented in the following table indicate the predicted number of cetaceans occurring annually within a 100 sq. km grid cell of the report polygon. For example, annual cetacean abundance models predict an average of 45 individuals sensitive to mid-frequency sounds are present within a 100 sq. km grid cell in the Federal waters off the coast of North Carolina.

For more information on habitat-based cetacean density models and associated summary groupings:
http://seamap.env.duke.edu/models/Duke-EC-GOM-2015/
http://seamap.env.duke.edu/models/mdat/

Showing the minimum, average, and maximum values per 100 sq. km within the report area.

	Minimum	Average	Maximum
All ESA Listed	0.02	0.49	3.53
Low-frequency Sound Sensitivity (7 Hz to 22kHz)	0.02	0.20	2.37
Mid-frequency Sound Sensitivity (150 Hz to 160 kHz)	10.28	45.72	709.79
High-frequency Sound Sensitivity (200 Hz to 180 kHz)	0.00	0.17	1.70

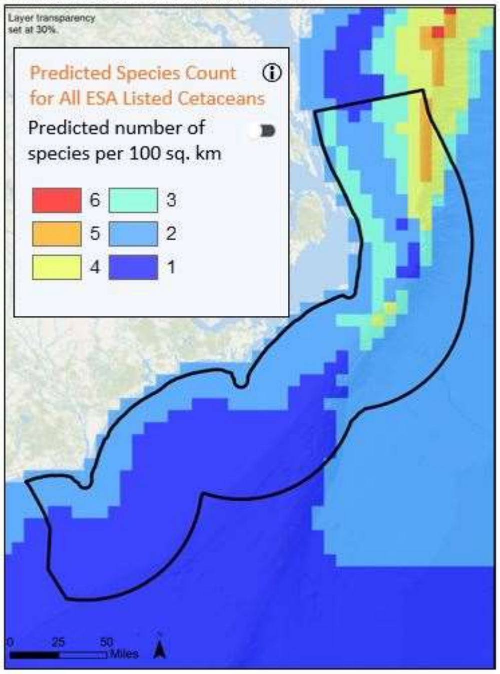
The summary statistics were generally understood by respondents and considered helpful. One respondent from an environmental advocacy organization stated, “I think it’s good you have the maximum value because it provides some arguing room so to speak.” This comment was made in reference to the observation that the average does not highlight the variation of abundance, particularly for report areas as large as federal waters. Respondents also indicated having the layer displayed on the map is useful for understanding spatial variation.

(2) Species Richness Summary Product Infographic

Similarly to the abundance infographic feedback, respondents indicated interest in species richness summaries for groupings of ESA-listed species. Therefore, I also replaced the “All Cetaceans” category with the “All ESA Listed” MDAT species richness layer (Image 9).

Image 9:

All ESA Listed Species Summary Layer Displayed



Predicted Count of Marine Mammal Species

Species richness is a measure of the total number of species present. The Marine-Life Data Analysis Team developed species richness summary products from the marine mammal predictive abundance models.

The summary values presented in the following table indicate the predicted number of cetacean species occurring within a 100 sq. km grid cell of the report polygon. For example, annual cetacean abundance models predict a maximum of 5 cetacean species listed under the Endangered Species Act (ESA) are present within a 100 sq. km grid cell in the Federal waters off the coast of North Carolina.

Showing the minimum, median, and maximum values reported per 100 sq. km within the report area.

	Minimum	Median	Maximum
All ESA Listed	1	2	5
Low-frequency Sound Sensitivity (7 Hz to 22kHz)	1	2	5
Mid-frequency Sound Sensitivity (150 Hz to 160 kHz)	4	5	22
High-frequency Sound Sensitivity (200 Hz to 180 kHz)	0	0	2

Several respondents asked if a summary of what species are encompassed by the value presented would be available. Although the current species richness layer does not include the associated species, I created a demonstration of this option using ArcMap Model Builder and the “Sample” tool. I presented the specific species list in the infographic as if the user could hover over a value to view the species list (Appendix B, Image 1). Options to hover and view values currently exist for several infographic designs on the ORT prototype.

A respondent from a federal agency also highlighted that the original percentages presented in the “Cetacean Species Relative to East Coast” are contradictory because if the “All Cetaceans” category is 100%, then subsequently all sub-groupings should be as well. This discrepancy is the result of percentages being calculated from maximum values reflecting a 100 km^2 rather than the entire report area. As a future consideration, I added an additional table column for the maximum species value for the entire report area (Appendix B, Image 1). This information is obtained by viewing the output of the “Sample” tool run with the species presence/absence layers. I then used the report area maximum to re-calculate the percent of modeled species in the report area. Thus, the percent of totaled modeled species can only be accurately calculated if a maximum count of species for the report area is determined.

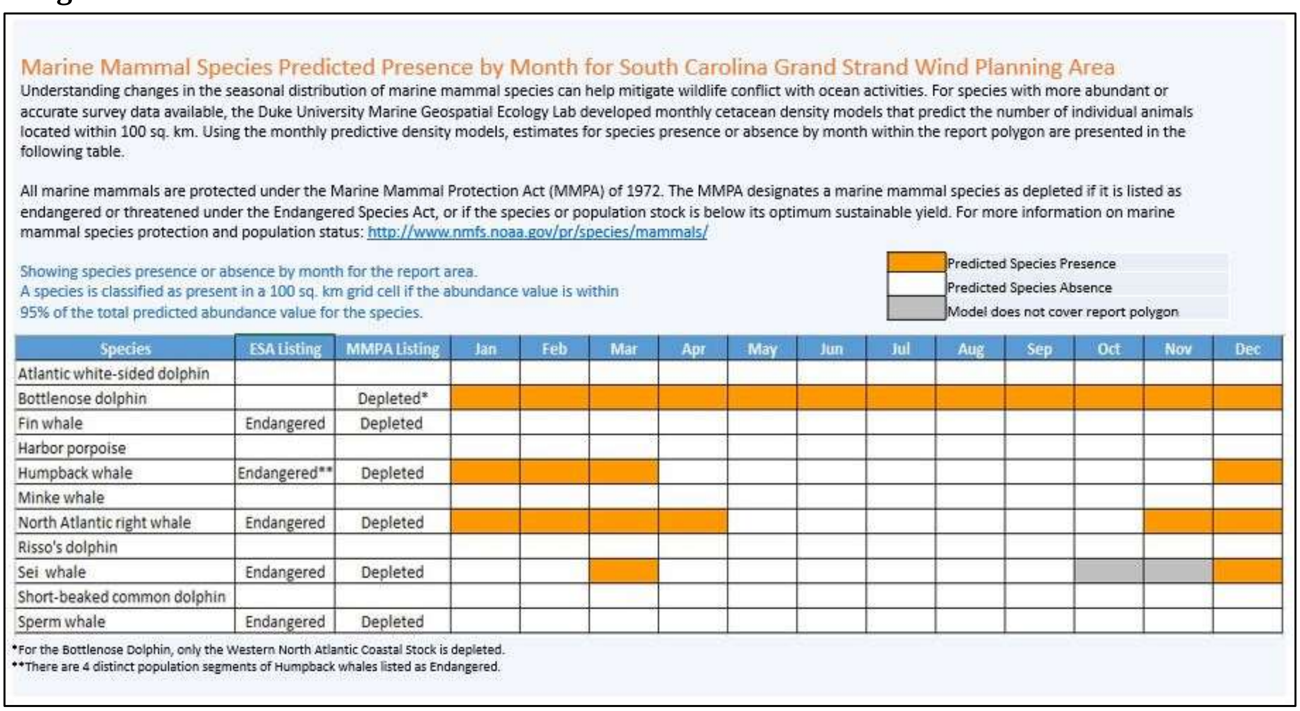
(3) Species Presence by Month Infographic

Many respondents were pleased to see summaries of monthly presence by species because of the finer temporal scale than the annual summary products. Despite their frequent use in international settings, the IUCN listings were identified as having minimal relevance to United States policy. One respondent from a conservation non-profit stated,

> "Other than biologists, and perhaps government bureaucrats, I don't know anybody who would have any idea what the IUCN listing meant. And certainly from a legal standpoint, in compliance with mitigation or anything like that, it means nothing."

Furthermore, a respondent from an environmental non-profit organization stated, "You have the IUCN listings, because I'm a U.S. lawyer, I care more about the domestic legal status. The ESA would be helpful, but the MMPA status would be as well." To accommodate the common request for ESA and MMPA status information and address the diverse range of potential ORT users, I replaced the IUCN column with ESA and MMPA listing information (Image 10). To address stakeholder concerns of distinguishing between species absence and a lack of modeled data, I converted the table to a shaded box diagram, using orange to indicate species presence, white species absence, and gray no modeled data available for the study area (Image 10).

Image 10:



Marine Mammal Species Predicted Presence by Month for South Carolina Grand Strand Wind Planning Area

Understanding changes in the seasonal distribution of marine mammal species can help mitigate wildlife conflict with ocean activities. For species with more abundant or accurate survey data available, the Duke University Marine Geospatial Ecology Lab developed monthly cetacean density models that predict the number of individual animals located within 100 sq. km. Using the monthly predictive density models, estimates for species presence or absence by month within the report polygon are presented in the following table.

All marine mammals are protected under the Marine Mammal Protection Act (MMPA) of 1972. The MMPA designates a marine mammal species as depleted if it is listed as endangered or threatened under the Endangered Species Act, or if the species or population stock is below its optimum sustainable yield. For more information on marine mammal species protection and population status: http://www.nmfs.noaa.gov/pr/species/mammals/

Showing species presence or absence by month for the report area.
A species is classified as present in a 100 sq. km grid cell if the abundance value is within 95% of the total predicted abundance value for the species.

Predicted Species Presence
Predicted Species Absence
Model does not cover report polygon

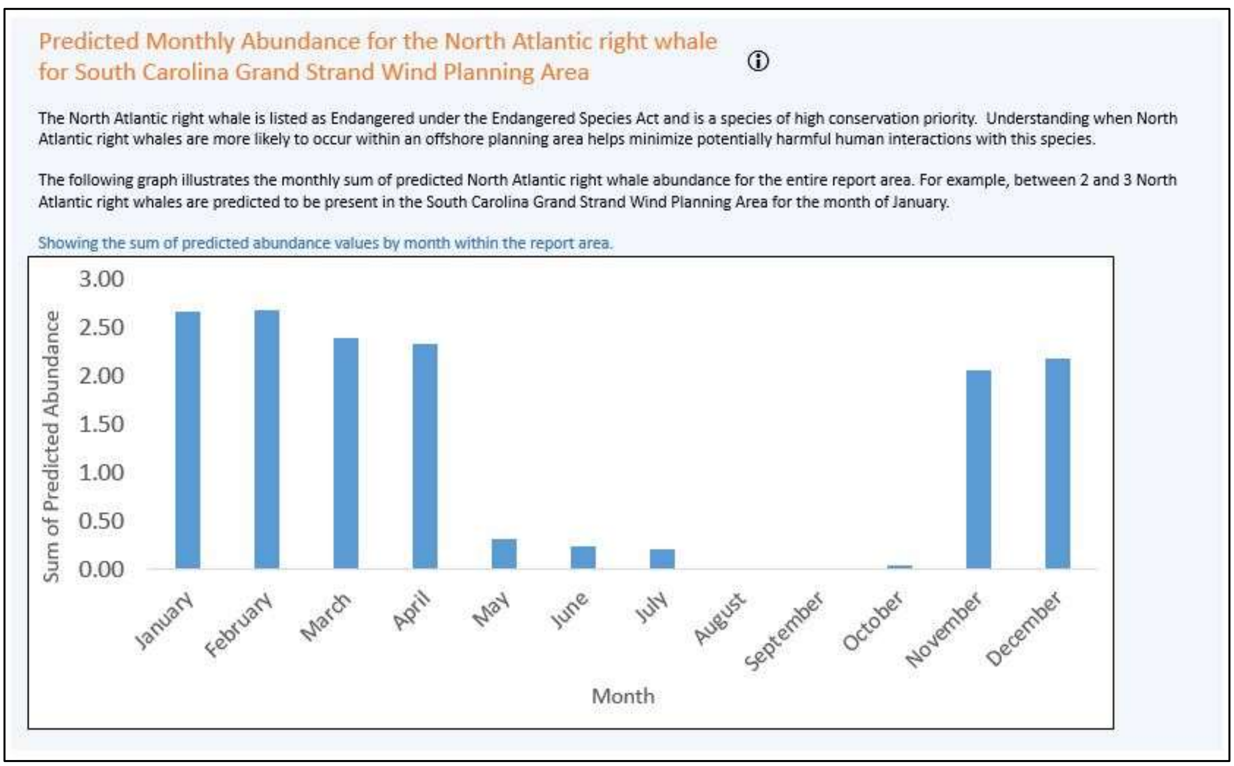
Species	ESA Listing	MMPA Listing	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Atlantic white-sided dolphin														
Bottlenose dolphin		Depleted*												
Fin whale	Endangered	Depleted												
Harbor porpoise														
Humpback whale	Endangered**	Depleted												
Minke whale														
North Atlantic right whale	Endangered	Depleted												
Risso's dolphin														
Sei whale	Endangered	Depleted												
Short-beaked common dolphin														
Sperm whale	Endangered	Depleted												

*For the Bottlenose Dolphin, only the Western North Atlantic Coastal Stock is depleted.
**There are 4 distinct population segments of Humpback whales listed as Endangered.

(4) North Atlantic right whale Infographic

Although all respondents identified the North Atlantic right whale as a species of top conservation concern in the southeast region, the presentations of percent above average and percent abundance relative to the east coast were confusing to many respondents. One scientist from a conservation non-profit stated, "The idea I had in my head was for the South Carolina Grand Strand Wind Planning Area, 67% was the probability that North Atlantic right whales would be in that area in January." Furthermore, a lawyer from a conservation non-profit indicated the percent above average information could easily be misinterpreted as the percent of the total number of individuals for the species located within the planning area. For example, a tool user could quickly look at the table and assume 100% implies every North Atlantic right whale is located in the South Carolina Grand Strand Wind Planning Area in March. To minimize the risk of misunderstanding the data summaries, I replaced the monthly percent above average abundance values with total abundance estimates (Image 11).

Image 11:



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Respondents also suggested a visual component would be more useful than a tabular format. For example, a federal scientist stated, "I would say, the way people may get it, is if you did one of those graphs…that shows January through December and gives you a little chart of density over time." A bar chart of predicted North Atlantic right whale abundance by month is presented in the revised infographic design (Image 11). I calculated the total predicted abundance estimate for each month using the sum function of the Zonal Statistics as Table tool. Respondents from federal agencies also expressed interest in observing monthly abundance charts for ESA-listed baleen whales and bottlenose dolphins, specifically for offshore wind planning areas.

Seabird Infographic Designs Content Evaluation

I modified the draft seabird infographic designs to incorporate feedback provided by respondents from one non-profit organization, state agencies in Virginia and North Carolina, a federal government agency, and the same federal conservation cooperative referenced in the marine mammals infographic designs results. The species richness design had the lowest overall Likert importance score. The respondent from the federal cooperative rated this design particularly low, stating "Richness is just always a complicated and often not useful measure." However, a respondent from a state agency expressed a differing opinion, giving richness the highest ranking of 5. Thus comments regarding the relative importance of species richness showed greater variation than comments for the abundance and seasonal designs (Figure 2).

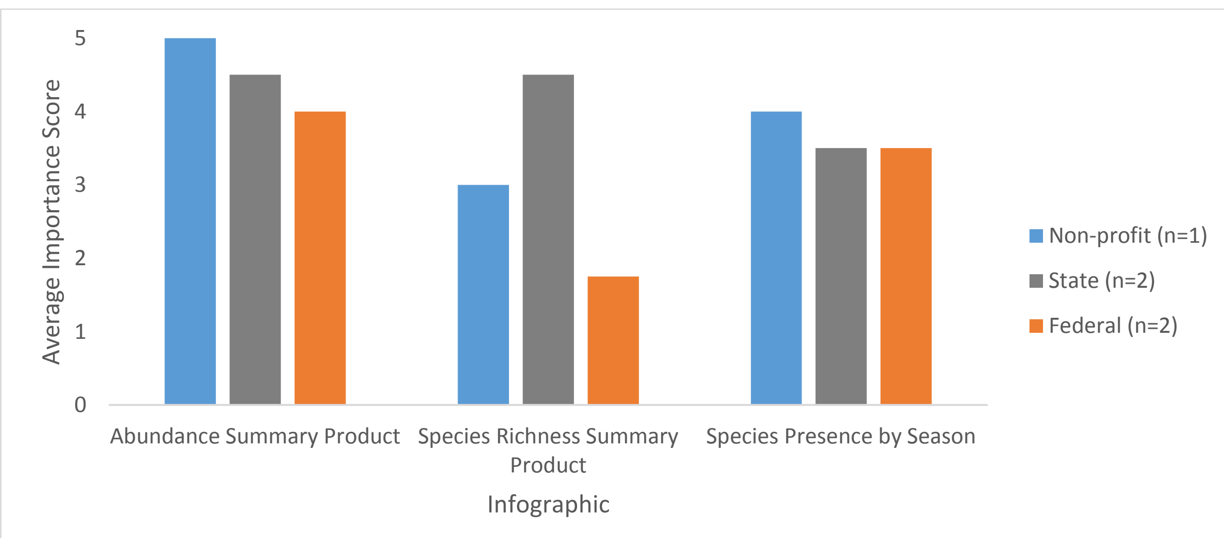


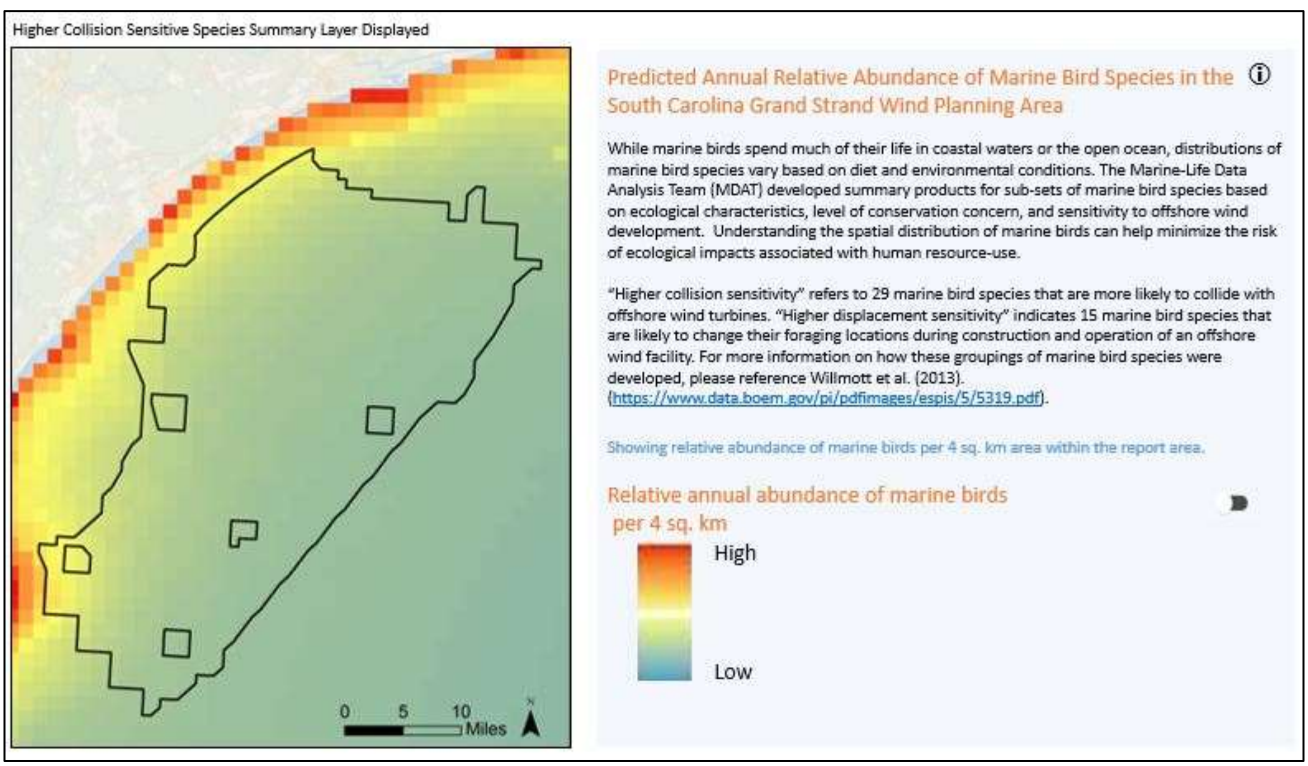
Figure 2: Responses per seabird infographic by professional sector to the question: "On a scale of 1 to 5, with 1 being Unimportant and 5 being Very Important, how would you rank the importance of this design?" The value of n indicates the number of organizations or agencies represented.

Respondents overall indicated the three infographic designs complimented one another. For example, a respondent from a non-profit group stated, “I think they are all good. I think you want to take the data in them together…they feed off of one another. I think if you took one away that would really hurt what you could use it for.”

(1) Abundance Summary Product

Although summary statistics could not be presented for the seabird abundance layers due to the relative nature of the models, respondents indicated overlaying the higher collision sensitivity and higher displacement sensitivity abundance layers with a polygon report area, particularly a wind planning area, is helpful (Image 12). A common question regarding the design was for an explanation of the criteria used to develop the higher collision sensitivity layer. I included a brief summary of the definition of “higher collision sensitivity” and “higher displacement sensitivity” in the infographic design to clarify the terminology. Furthermore, respondents also expressed interest in viewing the report that determined the sensitivity classifications; thus a link to the Willmott et al. (2013) study is included in the revised infographic.

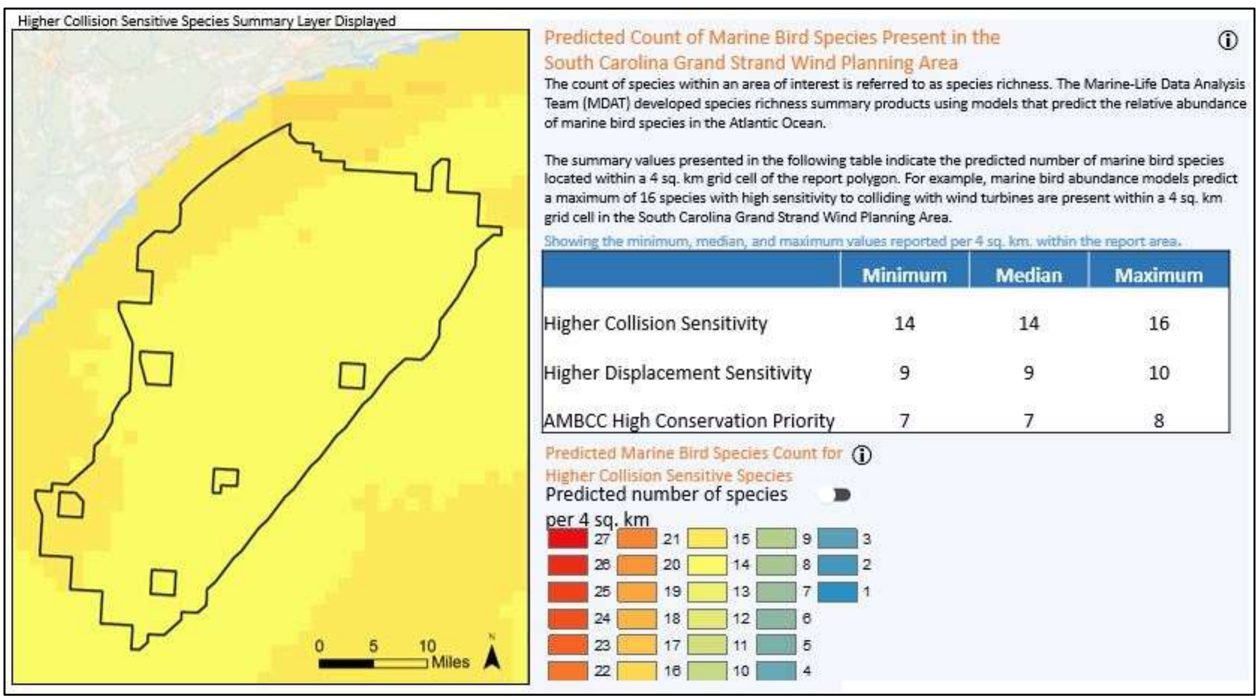
Image 12:



(2) Species Richness Summary Product Infographic

In parallel to comments regarding the marine mammal designs, respondents indicated the "All Avian" layer was very broad and specific sub-groupings would better address their interests. For example, a federal scientist suggested narrowing the grouping by "certain priority species, or kind of highly visible or ones that are going to be real problems." Thus, I replaced the zonal statistics summary for the "All Avian" category with the Atlantic Marine Bird Conservation Cooperative (AMBCC) High Conservation Priority summary layer (Image 13).

Image 13:



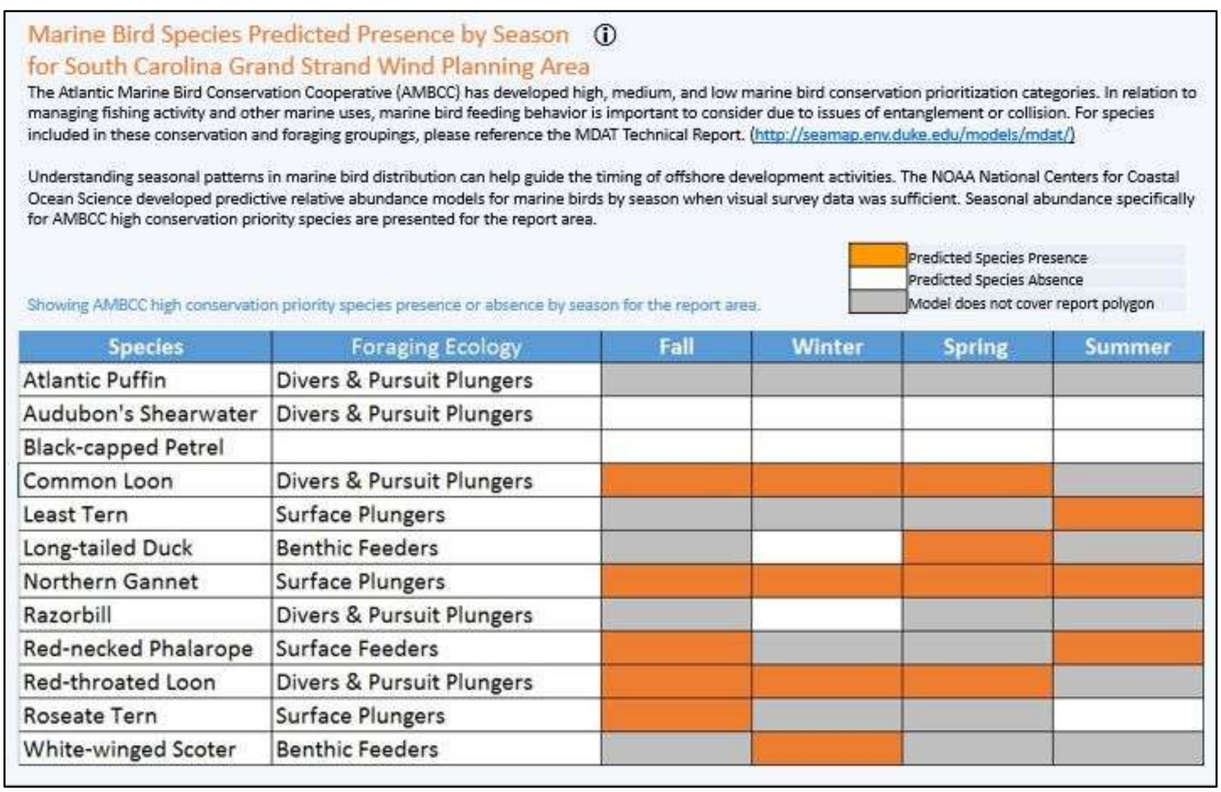
	Minimum	Median	Maximum
Higher Collision Sensitivity	14	14	16
Higher Displacement Sensitivity	9	9	10
AMBCC High Conservation Priority	7	7	8

Interview participants also requested to view the specific species included in the species count. For example, a respondent from a state agency said "Even though this is helpful, it wouldn't be as helpful as knowing which species are present…That would be good if you could click on that and it would show you which species they are talking about." I created a demonstration of how the specific species list could appear with the percentages adjusted for richness of the entire report area (Appendix B, Image 2). An ArcMap model builder workflow is presented in Appendix F to illustrate the corresponding methods using the "Sample" tool.

(3) Species Presence by Season Infographic

Given that several comments regarding seasonality arose during discussions of the summary product seabird infographics, respondents were pleased to see a seasonal presence table. A common critique was that the spatial distribution column (offshore/nearshore) may not be very relevant given this summary is produced for a known area. For example, a federal scientist commented, “The wind planning area is small enough, and you are not going to be able to know where that line is between nearshore and offshore or pelagic.” When asked what additional species attributes would be more useful, a respondent from a state agency indicated, “what these species would feed on, whether they are diving or near surface or what they are dependent on.” Based on similar interest in feeding behavior from other respondents, I replaced the spatial distribution column with foraging ecology information, collected from guilds in the MDAT Technical Report (Curtice et al., 2016). As with the marine mammal designs, I also transitioned from a list of seasons to shaded boxes to provide a clearer distinction between absence and lack of modeled data (Image 14). As a respondent from a non-profit stated, “Part of it is just understanding there is a limitation to what you can know about these birds at this time.”

Image 14:



Marine Bird Species Predicted Presence by Season
for South Carolina Grand Strand Wind Planning Area

The Atlantic Marine Bird Conservation Cooperative (AMBCC) has developed high, medium, and low marine bird conservation prioritization categories. In relation to managing fishing activity and other marine uses, marine bird feeding behavior is important to consider due to issues of entanglement or collision. For species included in these conservation and foraging groupings, please reference the MDAT Technical Report. (http://seamap.env.duke.edu/models/mdat/)

Understanding seasonal patterns in marine bird distribution can help guide the timing of offshore development activities. The NOAA National Centers for Coastal Ocean Science developed predictive relative abundance models for marine birds by season when visual survey data was sufficient. Seasonal abundance specifically for AMBCC high conservation priority species are presented for the report area.

Predicted Species Presence
Predicted Species Absence
Model does not cover report polygon

Showing AMBCC high conservation priority species presence or absence by season for the report area.

Species	Foraging Ecology	Fall	Winter	Spring	Summer
Atlantic Puffin	Divers & Pursuit Plungers				
Audubon's Shearwater	Divers & Pursuit Plungers				
Black-capped Petrel					
Common Loon	Divers & Pursuit Plungers				
Least Tern	Surface Plungers				
Long-tailed Duck	Benthic Feeders				
Northern Gannet	Surface Plungers				
Razorbill	Divers & Pursuit Plungers				
Red-necked Phalarope	Surface Feeders				
Red-throated Loon	Divers & Pursuit Plungers				
Roseate Tern	Surface Plungers				
White-winged Scoter	Benthic Feeders				

Several interview participants highlighted the importance of oceanographic factors in determining seasonal seabird distribution. One respondent from a state agency explained, "There are annual changes in the Gulf Stream, sea surface temperature, and forage fish availability. So all of those impact location of these birds within a given year or season." Although incorporating a map of oceanographic parameters into the ORT may be difficult due to the dynamic nature of the data, links to websites, such as the NOAA Office of Satellite and Product Operations (http://www.ospo.noaa.gov/Products/ocean/index.html) and HYCOM (https://hycom.org/), could be included in the descriptive text for the seasonal seabirds infographic to emphasize this connection and assist users in accessing this information.

Respondent Identified Applications

Given the diversity of professions covered by respondents, including scientists, managers, lawyers, and advocates, user identified applications for the marine mammals and seabird data were influenced by personal experiences. A respondent from a non-profit organization stated, "My way of advocacy is to think of what can go wrong, and then how do I argue against that or bolster what I need." Advocacy and legal professionals tended to assume the role of industry when critiquing the infographic designs. A lawyer from a conservation non-profit explained:

> "So the perception of a lack of data, or a lack or sightings being a lack of habitat use, I guess from an industry standpoint is always our biggest concern. So that people will look at a map and say, 'Well there are no sightings there, so obviously this is a safe place to go. It's fine to put a wind farm here, it's fine to go fishing here, it's fine to put a shipping lane here. There is all this data around it but nothing here.' It's saying the absence of data is not data on absence."

In addition to predicting how industry professionals would respond to the cetacean infographics, this excerpt also highlights a common concern amongst respondents of distinguishing species absence from a lack of surveying effort. Respondents explained dealing with limited data and uncertainty within planning processes is challenging. In the case of offshore wind planning, a respondent from a state agency stated:

> “Not only do you have to consider the footprint of the wind farm project out there, you also have to consider the infrastructure required to bring the power onshore, and then also the vessels and stuff that construct and maintain. And you are crossing into these travel corridors for marine mammals and sea turtles, especially if you go farther and farther offshore, which is better for seabirds…So it gets complicated really fast.”

Despite these complexities, respondents indicated the infographic designs would provide meaningful input for management and policy. A lawyer from an environmental non-profit highlighted the importance of summarizing information on endangered species specifically for wind planning areas:

> “As far as cetaceans go, the right whale stuff is kind of the big one we are always paying attention to in the southeast…Right whale abundance in a wind planning area, that’s the type of thing I think all sorts of people would find incredibly helpful. The wind sighting process is still so new for everyone. Everyone’s trying to figure out how to address those issues.”

In addition to predicting North Atlantic right whale abundance in a wind planning area, respondents emphasized the importance of having information available at seasonal temporal resolutions for seabirds and monthly temporal resolutions for marine mammals. Interview participants explained presence and abundance estimates by month or season would be helpful for identifying windows of offshore construction or establishing seasonal closures and restrictions for fisheries and shipping traffic. A respondent from a federal agency stated:

> “We just wrapped up yesterday a 3-day workshop talking about certain aspects of the wind regulatory process. And one thing we talked about a little bit was the idea of windows for different elements of the overall site assessment and construction and operations.”

From a spatial analysis perspective, providing this information in a summary report could reduce data collection time for various stakeholders. A federal scientist stated in reference to the seasonal avian presence table:

> "I mean this is really helpful. There are multiple ways you could go into it, but if you just wanted to get this for the wind planning energy area, that would take a long time of turning layers on and off."

Beyond the seasonal information, a respondent from a state agency indicated the summary information presented for seabirds, as well as additional information in the broader tool, could be applied when developing responses to permit inquiries. Regarding the overall tool, a federal environmental specialist stated:

> "I think it would be useful for exploring in planning. A high level review for what might be in a particular area. I mean it could even be used for a reference for some review with NEPA documents or things like that. If we want to refer to that as where we got some of our information that could be helpful too."

A federal scientist also mentioned the summary information would be useful from not only a conservation perspective, but a public relations viewpoint as well:

> "If I'm a wind energy group, I don't just care about the conservation community, I care about the public. So, if you are mowing down a whole bunch of species that are low conservation priority, well that's still going to make a lot of people not happy."

Legal and advocacy respondents from non-profit organizations also mentioned the marine mammal and seabird infographics, as well as other content, such as vessel traffic and beach nourishment information presented in the overall tool, could be useful for commenting on an Environmental Impacts Statement, creating a petition for protected areas, or developing exhibits for hearings. The following quote from a wildlife conservation advocate summarizes a broad benefit of the tool:

> "It's so encouraging for me that there is more information presented in a readily accessible format because it creates a more informed dialogue…I try to do fact based advocacy as much as I can, so I really appreciate things like this that promise to provide more facts in a readily digestible format to inform the debate."

Discussion

Technical Limitations and Considerations

Regarding the proposed marine mammal and marine bird infographic designs, it is important to highlight potential challenges of integrating the methodology with the ORT framework. The workflow presented in Appendix F for determining the list of species associated with each richness value could be applied to the pre-defined reports; however, this approach requires manual review of the final "Sample" tool table to compare combinations of species, making it incompatible with the custom "Draw Area" function of the ORT. The most streamlined approach would involve the creation of a new layer or index table that lists the species present for each 100 km^2 cell area for the entire extent of the summary species richness layer; thus, the index table could be queried for any custom report area. Given the design of such a layer or table will be time intensive, the current summary of minimum, median, and maximum values per 100 km^2 produced by the Zonal Statistics as Table tool is a more feasible option than calculating maximum richness for the report area.

In contrast to the average or median approach, the final infographic design for the North Atlantic right whale utilizes the Zonal Statistics sum function, which represents a total for the entire polygon area. An abundance bar chart could be produced for any of the 11 cetacean species for which monthly models are available. However, 12 separate abundance layers are used to construct this infographic, totaling 132 abundance layers for all 11 species. Given conservation concerns for the North Atlantic right whale, this species is of top priority for displaying a monthly abundance graphic. If capacity exists within the ORT to include bar charts for additional cetacean species, interview respondents indicated interest in including other ESA-listed species or bottlenose dolphins.

Although interview respondents generally supported expanding the marine mammals and marine bird data in the ORT, there were concerns regarding limitations of the data presented. Given the infographic designs are based on density models for marine mammals and seabird species, all abundance values and temporal species presence measures are predicted and thus have associated uncertainty. Measures of modeling error are not indicated within the infographic designs for simplicity; however, links to the data sources and reports provided in the proposed infographic designs would allow the tool user to access existing products estimating statistical confidence for the marine mammals and avian density models. Standard error and coefficient of variation (CV) raster layers are available for each predictive density cetacean model via the OBIS-SEAMAP site (2016). Standard error indicates the accuracy of the estimated abundance through comparison to the actual abundance, considering survey effort and statistical influence of environmental predictor variables (Curtice et al., 2016). Furthermore, the CV represents a ratio of standard error to predicted density, where a value greater than 1 corresponds with high uncertainty (Curtice et al., 2016). For example, the CV tends to be higher in areas (i.e. farther offshore) and seasons (i.e. winter) of low survey effort (MarineCadastre.gov, 2016). Confidence intervals (90%) and CV raster layers have also been created for the seabird density models by the NCCOS modeling team using a bootstrapping resampling procedure and can be accessed via the project site (NCCOS, 2017). ORT users can reference these uncertainty products to determine the level of model confidence within their report area.

In addition to model limitations associated with survey effort, the extent and resolution of the cetacean and marine bird predictive density models pose a challenge for integration with the ORT. The coarse resolution (10 km) of the marine mammal predictive density models results in a mismatch between the polygon boundaries of a report area and raster cells. While larger polygons, such as offshore federal waters by state, still contain a robust number of raster cells, some smaller pre-defined report areas are not compatible with the cell resolution. For example, when applying the ArcMap Zonal Statistics tool on the North Atlantic right whale January density layer, only one cell exists in the resulting raster output for the South Carolina Charleston and Winyah Wind Planning Areas; thus, any summary statistics produced would be misleading because they only reflect a single cell.

To address report area constraints, a summary could be produced only if a threshold for a minimum count of cells is surpassed. If a count of five cells were selected as the threshold, only the South Carolina Grand Strand, the North Carolina Kitty Hawk, and the North Carolina Wilmington East Wind Planning Areas would be suitable for generating cetacean infographics for offshore wind planning. A cell-count or area threshold could also be applied to restrict summary calculations for custom drawn report areas. Furthermore, it may be helpful to report the area covered by the summary (i.e. five cells = 500 km^2) so the viewer is aware the statistics do not reflect the exact area covered by the polygon. It is also important to note the National

Estuarine Research Reserve polygons are located too closely to shore to overlap with the marine mammal and seabird density layers. Further, the state waters and waters offshore by county polygons are not sufficiently large for calculating cetacean density summaries. Given the finer resolution (2 km) of the marine bird density models, the issues of raster and report area polygon alignment are less extreme than for marine mammals.

Potential Stakeholder Applications

The ORT appeals to a wide variety of stakeholders and has an extensive range of applications. Given similarities in comments by profession, job title (i.e. scientist or lawyer) provides a useful predictor of ORT applications in addition to sector (non-profit or government) (Table 7). Based on my discussions with professionals of federal and state agencies, as well as non-profit organizations, the draft summary statistics presented may have greater application potential for less technically trained users. For example, the information presented, such as seasonal marine bird presence within a wind planning area, could be cited by a National Environmental Policy Act (NEPA) analyst in an environmental assessment document, or by a non-profit group writing a public comment letter; however, scientists who specialize in seabirds will already be familiar with the migratory patterns of various species. Both federal and non-profit scientists indicated the proposed infographic designs and overall tool would be useful for exploratory analysis and directing them to relevant data layers. The metadata tab and links to data sources will likely provide a valuable service for marine scientists and GIS specialists, who would likely need to download the data layers in order to obtain the level of detail needed for their analysis.

Applications of the infographic material are also dependent upon the level of detail. Individual species abundance information may be more useful for regulatory purposes, while information for groupings of species may be more appropriate for project scoping-efforts. For example, designating a seasonal closure or restrictions on offshore development may require information on the migratory patterns of a single species of conservation concern. On the other hand, annual abundance for groups of species could help identify biologically rich areas offshore activities should avoid in general.

Table 7: Matrix of potential ORT applications. Please note that this is not an exhaustive list of applications, but provides a generalized summary based on stakeholder input. A blank box indicates no interview respondents represented the category.

	Scientist	**Lawyer**	**Manager/Policy Analyst**
Non-profit	• Exploratory analysis	• Public comment letters • Petitions • Exhibitions for public hearings	---
Federal and State Government	• Identification of relevant data sources	---	• Review of NEPA documents • Planning location/timing of offshore activities

In addition to the non-profit and government stakeholder groups interviewed, industry professionals represent another potential target audience of the ORT that were not included in this analysis. For example, offshore wind energy companies could use the tool to determine if endangered or threatened species are located within the wind planning area, as well as seasonal windows of construction. This information could aid them in preparing site assessments and identifying environmental impacts. Furthermore, federal fishery management councils and state-level marine fishery commissions could use information presented in the tool to guide the location and timing of temporary fishery closures. Continued ORT outreach efforts could explore the perspectives of industry and fishery stakeholders.

To further accommodate the information needs of various tool users, a future consideration for tool functionality is to allow users to select multiple pre-defined report areas for comparison. Several stakeholders expressed an interest in comparing multiple report areas to define relative importance of summary values presented. For example, higher collision sensitive bird species richness could be compared across wind planning areas to determine if a new proposed planning area has relatively higher or lower species richness. Comparisons between similar report areas could also be presented as an infographic, rather than altering the overall tool functionality to display multiple reports at once. Continued stakeholder input following public release of the ORT on the MarineCadastre.gov site will provide valuable insight to applications of the tool and suggestions for enhanced functionality.

Conclusions and Recommendations

The extensive spatial data summaries presented in the current version of the Marine Cadastre Ocean Reporting Tool appeal to a variety of ocean stakeholders, including scientists, managers, policy analysts, and lawyers within government and non-profit sectors. Although the current natural resources and conservation related information is of interest to potential tool users, including additional marine mammal and seabird data will increase the utility of the tool. Providing summaries of the predicted abundance, species richness, and seasonal or monthly presence of marine mammals and marine bird species within areas of interest will support offshore planning activities, such as the siting and construction of offshore wind farms. However, it is important to recognize the marine mammal and seabird density models incorporated in the infographic designs are predictive, and therefore have associated limitations and uncertainty. As new predictive models are released that include more recent visual survey data, our understanding of the spatial distribution of marine mammals and seabirds will continue to improve.

In addition to the marine mammals and seabirds predictive density models and associated summary products included in this report, other existing sources of marine mammals and seabird data may be considered for inclusion in the ORT. NOAA's Biologically Important Areas for cetacean species and Audubon Important Bird Areas identify other locations of conservation significance that could be incorporated as infographics. Furthermore, the MDAT release of diversity and core abundance area summary products for marine mammals and seabirds could be included in future versions of the ORT. The proposed infographics presented in this report illustrate a select grouping of many possible methods for communicating complex modeled data to marine planners and conservationists and are intended to encourage discussion of data communication approaches in support of marine spatial planning efforts.

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Appendices

Appendix A: Marine Cadastre Ocean Reporting Tool Preview

Image 1: Main splash page

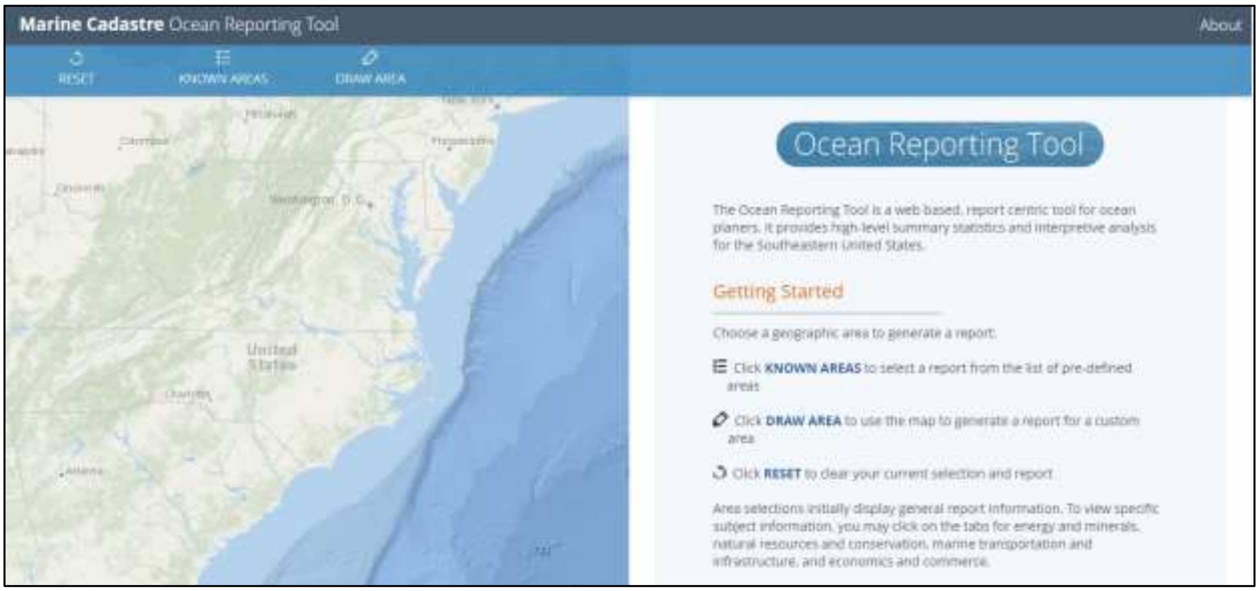


Image 2: Option to generate a report from a pre-defined area

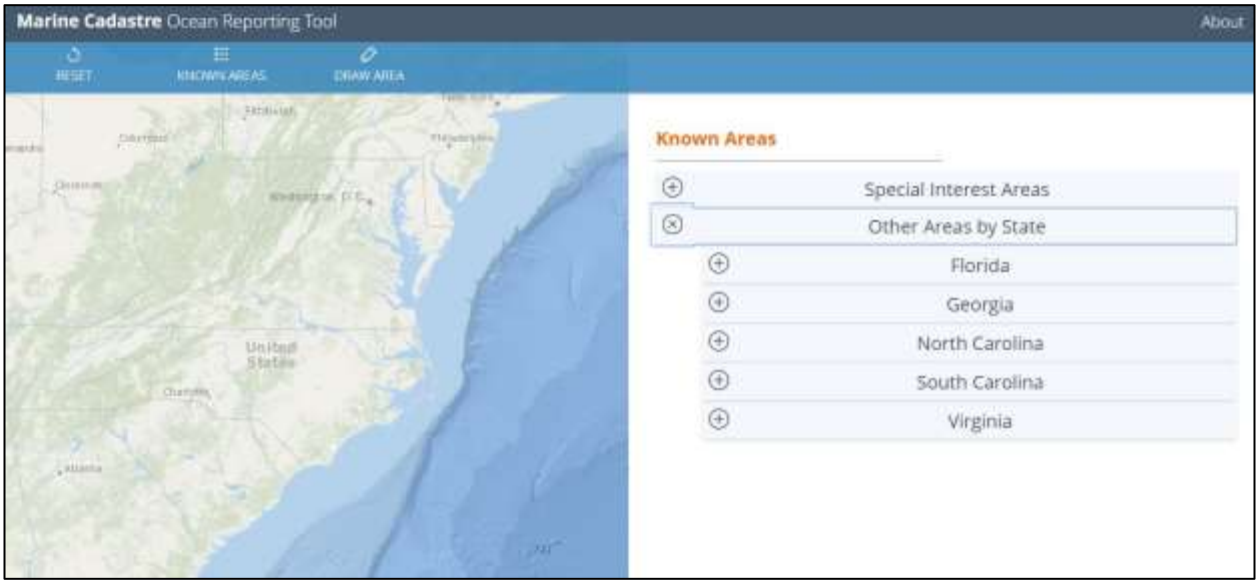
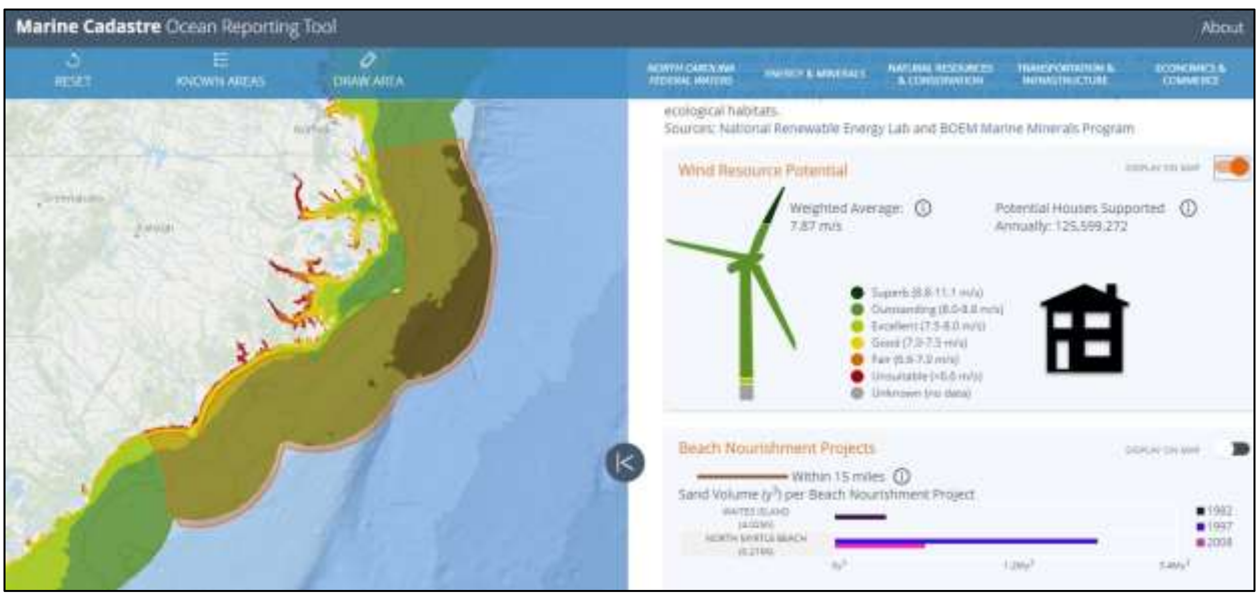


Image 3: Sample report for North Carolina Federal Waters



Appendix B: Future Considerations for Species Richness Summary

Image 1: Marine mammal species richness design with maximum richness calculated for the entire report area.

Future Consideration for Zonal Statistics Approach for Species Richness

Predicted Count of Marine Mammal Species for Federal Waters Offshore North Carolina

	Minimum	Median	Maximum	Maximum for Entire Report Area
All ESA Listed	1	2	5	6
Low-frequency Sound Sensitivity (7 Hz to 22 kHz)	1	2	5	6
Mid-frequency Sound Sensitivity (150 Hz to 160 kHz)	4	5	22	24
High-frequency Sound Sensitivity (200 Hz to 280 kHz)	0	0	2	3

Dwarf sperm whale
Harbor porpoise
Pygmy sperm whale

Predicted Number of Species Present Relative to Total Species in Group

All ESA Listed:
100.00%

Low-frequency Sound Sensitivity: 100.00%

Mid-frequency Sound Sensitivity: 100.00%

High-frequency Sound Sensitivity: 100.00%

Image 2: Seabird species richness design with maximum richness calculated for the entire report area.

Future Consideration for Zonal Statistics Approach for Species Richness

Predicted Count of Marine Bird Species Present for South Carolina Grand Strand Wind Planning Area

	Minimum	Median	Maximum	Maximum for Entire Report Area
Higher Collision Sensitivity	14	14	16	16
Higher Displacement Sensitivity	9	9	10	10
AMBCC High Conservation Priority	7	7	8	8

Common loon
Least tern
Long-tailed Duck
Northern Gannet
Red-necked phalarope
Red-throated loon
Roseate tern
White-winged scoter

Predicted Number of Species Present Relative to Total Species in Group

Higher Collision Sensitivity:
55.2%

Higher Displacement Sensitivity:
66.7%

AMBCC High Conservation Priority:
72.7%

Appendix C: Python Code to Produce Zonal Statistics Output from Summary Products

```
# Zonal Statistics Calculations for Predicted Abundance/Species Richness for All ESA listed and Sound Sensitivity
#Marine Mammal Groups Infographic
# Script created by Ashley Gordon
# April 2017
# Purpose of script: Calculate zonal statistics minimum, average, and maximum using marine mammal summary
#products

#Load necessary packages
import arcpy, os, sys, csv
arcpy.CheckOutExtension("Spatial")
from arcpy.sa import*

#Set relative paths
scriptDir = os.path.dirname(sys.argv[0])
rootDir = os.path.dirname(scriptDir)
dataDir = os.path.join(rootDir, "Data")
scratchDir = os.path.join(rootDir, "Scratch")

#Set initial environment settings
arcpy.env.workspace = scratchDir
arcpy.env.overwriteOutput = True
arcpy.env.snapRaster = dataDir + "\Abundance_Summary_Products\mammal_abundance_All_ESA_listed_
absolute.tif"
arcpy.env.cellSize = dataDir + "\Abundance_Summary_Products\mammal_abundance_All_ESA_listed_absolute.tif"

#Allow user to select polygon of interest for analysis
#User selects polygon from a list of known areas
polygon_name = sys.argv[1]

#To run as stand alone script, uncomment the following line
#polygon_name = 'North Carolina Federal Waters'

#OR user draws their own area
Custom_Report_Area = sys.argv[2]

#Set general parameters for Zonal Statistics as Table Tool, specifying the drawn area as the zone if the user does
#not select a known area
if polygon_name == '#':
  custom = arcpy.FeatureSet(Custom_Report_Area)
  custom_area = dataDir + '\custom_report_area.shp'
  custom_areap = scratchDir + '\custom_report_area_p.shp
  #Convert the custom area to a polygon shapefile
  arcpy.FeatureToPolygon_management(custom, custom_area, "", "ATTRIBUTES", "")
  #Select raster layer to define coordinate system
  coor_system = dataDir +"\Abundance_Summary_Products\mammal_abundance_All_ESA_listed_absolute.tif"
  out_coordinate_system = arcpy.Describe(coor_system).spatialReference
 #Project shapefile to match output coordinate system of the raster (WGS 1984)
  arcpy.Project_management(custom_area, custom_areap, out_coordinate_system    areaRaster = scratchDir +
 "\custom_area.img"
  arcpy.PolygonToRaster_conversion(custom_areap,"OBJECTID", areaRaster) #Convert the polgyon to a raster for
  zonal statistics analsyis
```

```
#Set the new projected raster zone equal to the zone for zonal statistics
    Zone = areaRaster
    zoneField = "Value"

#Select polygon as specified from the drop down list if user does select a known polygon area
else:
    #Specify path to the geodatabase containing the list of known areas
     known_areas = dataDir + "\ORT_KnownAreas.gdb\ORT_REPORTS_Simplified"
     selected_area = dataDir + "\ORT_KnownAreas.gdb\selected_area"
     expression = '"AOI_NAME"= \'%s\'' %polygon_name
   #Run select tool to create polygon of interest
    arcpy.Select_analysis(known_areas, selected_area,expression)
   #Project selected area to match raster projection
    selected_areap = scratchDir + "\selected_areap.shp"
    coor_system = dataDir +"\Abundance_Summary_Products\mammal_abundance_All_ESA_listed_absolute.tif"
    out_coordinate_system = arcpy.Describe(coor_system).spatialReference
    transform_method = "WGS_1984_(ITRF00)_To_NAD_1983"
    arcpy.Project_management(selected_area, selected_areap, out_coordinate_system, transform_method)
    areaRaster = scratchDir + "\selected_area.img"
   #Convert the polygon to a raster for zonal statistics analysis
    arcpy.PolygonToRaster_conversion(selected_areap,"OBJECTID", areaRaster)
    Zone = areaRaster #Set the new projected raster zone equal to the zone for zonal statistics
    zoneField = "Value

#Allow tool user to specify zonal statistics analysis on marine mammals abundance or species richness summary
#products
products = sys.argv[3]
#To run as stand-alone script, uncomment next line
#products = "Species_Richness_Summary_Products"

if products == 'Abundance_Summary_Products':
     calculation = "MIN_MAX_MEAN"
     column = "Mean"
     label = "abundance"
else:
     calculation ="ALL"
     column = "Median"
     label= "richness"

#Create final output table to store all zonal statistics sums in the scratch folder
out_path = scratchDir
out_name = sys.argv[4]

#To run as stand-alone script, uncomment next line
#out_name = "ZonalStats_Marine_Mammals_Summmary.dbf"
arcpy.CreateTable_management(out_path, out_name)

#Create output table fields for abundance or species richness summary products
arcpy.AddField_management(scratchDir + "\\" + out_name, "Product", "TEXT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "Min", "FLOAT")
#Label column as mean for abundance products
arcpy.AddField_management(scratchDir + "\\" + out_name, column, "FLOAT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "Max", "FLOAT")
arcpy.DeleteField_management(scratchDir + "\\" + out_name, "Field1")
```

```
#Run Zonal Statistics as Table Tool for each summary raster product in the abundance or species richness folder

arcpy.env.workspace = (dataDir + "\\"+ products)
summary_table = out_path + '\\' + out_name
sums = {}
#List all abundance or species richness summary product rasters
rasterList = arcpy.ListRasters()
for raster in rasterList:
     inValueRaster = raster
    #Save Zonal Stats tables in memory
     table = ZonalStatisticsAsTable(Zone, zoneField, inValueRaster, "in_memory", "DATA", calculation)
     if products == 'Abundance_Summary_Products':
         new_name = raster[:-13]  #Remove absolute.tif from the file name
    else:
         new_name = raster[:-4]  #Remove .tif from the file name
    #Insert a cursor to pull value from min, average, and max column in Zonal Statistics Table
        cur = arcpy.UpdateCursor(table)
    for row in cur:
      min = row.getValue('MIN')
      avg = row.getValue(column)  #avg = row.getValue('MEAN')
      max = row.getValue('MAX')
      sums[new_name + "MIN"] = min
      sums[new_name + column] = avg
      sums[new_name + "MAX"] = max
del cur

 #Add values for each layer to the final output table
endList = ('mammal_%s_All_ESA_listed' %label, 'mammal_%s_Sound_sensitivity_Low_freq' %label,
'mammal_%s_Sound_sensitivity_Mid_freq' %label, 'mammal_%s_Sound_sensitivity_High_freq'%label)

for end in endList:
     layer = end.replace("_", " ")
    #Create a new Insert cursor to add values to the blank summary output tabl
    with arcpy.da.InsertCursor(summary_table, ("Product", "Min", column, "Max")) as cursor:
         cursor.insertRow((layer, sums[end + "MIN"], sums[end + column], sums[end + "MAX"]))
```

Appendix D: Python Code to Produce Presence/Absence Files

```
#Marine Mammals Presence/Absence Script
#Script created by Ashley Gordon
#April 2017
#Purpose of tool: Calculate presence/absence layers for monthly marine mammals abundance models based on a
#threshold of percent abundance

#Load necessary packages including NumPy
import sys, os, arcpy
import numpy as np
from arcpy.sa import *
arcpy.CheckOutExtension("Spatial")

#Set relative path names
scriptDir = os.path.dirname(sys.argv[0])
```

```
rootDir = os.path.dirname(scriptDir)
dataDir = os.path.join(rootDir, "Data")
scratchDir = os.path.join(rootDir, "Scratch")
arcpy.env.overwriteOutput = True

#Specify the percent cutoff for presence/absence layers (i.e. cells with values in the bottom 5% of the total
#abundance will be marked as absent)
percent = 0.05

#Allow the user to specify if they would like to create presence/absence files for one or multiple species
species = sys.argv[1]

#To test as stand alone script, uncomment following line
#species = ('Bottlenose_dolphin;Humpback_whale;North_Atlantic_right_whale')

speciesList = species.split(';')

#Create an empty list that will be populated with species folder names selected by the tool user

folderList = []

#Add species folder paths selected by the user to folderList

for species in speciesList:
     species.strip('')
     folderList.append(dataDir + '\\Monthly_Models\\' + species)

#Loop through every file in each folder and convert the abundance rasters to presence/absence rasters
for folder in folderList:
     arcpy.env.workspace = folder
    #Create list of raster names
    spList = arcpy.ListRasters()
    for sp in spList:
       #Convert the raster to numpy array
       myRaster = arcpy.Raster(sp)
       Sp_month= arcpy.RasterToNumPyArray(myRaster)
       #Remove any No Data values, retain values only greater than 0
       Sp_nz = Sp_month[(Sp_month > 0)]
       #Calculate the sum of all values in the raster
       Sp_sum = np.sum(Sp_nz)
       #Calculate the percent absence threshold
       Threshold = Sp_sum * float(percent)
       #Sort the array from least to greatest
       Sp_sort = np.sort(Sp_nz)
       #Cumulatively sum the array
      Sp_csum = np.cumsum(Sp_sort)
       #Only retain values in the array that are below the percent threshold
      Sp_absence = Sp_csum[(Sp_csum < Threshold)]
      #Determine the number of rows in the array
      num_rows = len(Sp_absence)
      #Identify the abundance value corresponding to the threshold in the sorted array
      abundance = Sp_sort[num_rows]
```

```
    #Identify the maximum value in the sorted array
    maxx = np.max(Sp_sort)
    #Adjust for rounding truncation
    max = maxx+1
    #Reclassify original raster so any values below threshold are reclassified as absent (0) and above threshold
    #present (1)
    arcpy.env.mask = myRaster
    #When running from tool in ArcMap, box of 0's appearing in Atlantic Ocean, source of error undetermined
    myRemapRange = RemapRange([[0, abundance, 0], [abundance, max, 1]])
    outReclass = Reclassify(myRaster, "VALUE", myRemapRange, "NODATA")
    #Specify output name and save
    outRaster =  folder +"\PresenceAbsence\\" + sp[:-14]+".img"
    outReclass.save(outRaster)
```

Appendix E: Python Code to Product Zonal Statistics for Presence by Month

```
# Zonal Statistics Approach for Marine Mammals Presence by Month Infographic
# Script created by Ashley Gordon
# April 2017
# Purpose of tool: Generate an output table that lists the percent area within a polygon occuppied each month by
marine mammal species
# For any value greater than 0%, the species is marked as present in the infographic table

#Load necessary packages
import arcpy, os, sys, csv
arcpy.CheckOutExtension("Spatial")
from arcpy.sa import*

#Set relative paths
scriptDir = os.path.dirname(sys.argv[0])
rootDir = os.path.dirname(scriptDir)
dataDir = os.path.join(rootDir, "Data")
scratchDir = os.path.join(rootDir, "Scratch")

#Set initial environment settings
arcpy.env.workspace = scratchDir
arcpy.env.overwriteOutput = True
arcpy.env.snapRaster = dataDir +
"\Monthly_Models\Bottlenose_dolphin\EC_Bottlenose_dolphin_month01_abundance.img"
arcpy.env.cellSize = dataDir +
"\Monthly_Models\Bottlenose_dolphin\EC_Bottlenose_dolphin_month01_abundance.img"

#Create final output table to store all zonal statistics sums in the scratch folder
out_name = sys.argv[4]

#Uncomment line below to run as stand-alone script
#out_name = "Monthly_Marine_Mammals.dbf"
```

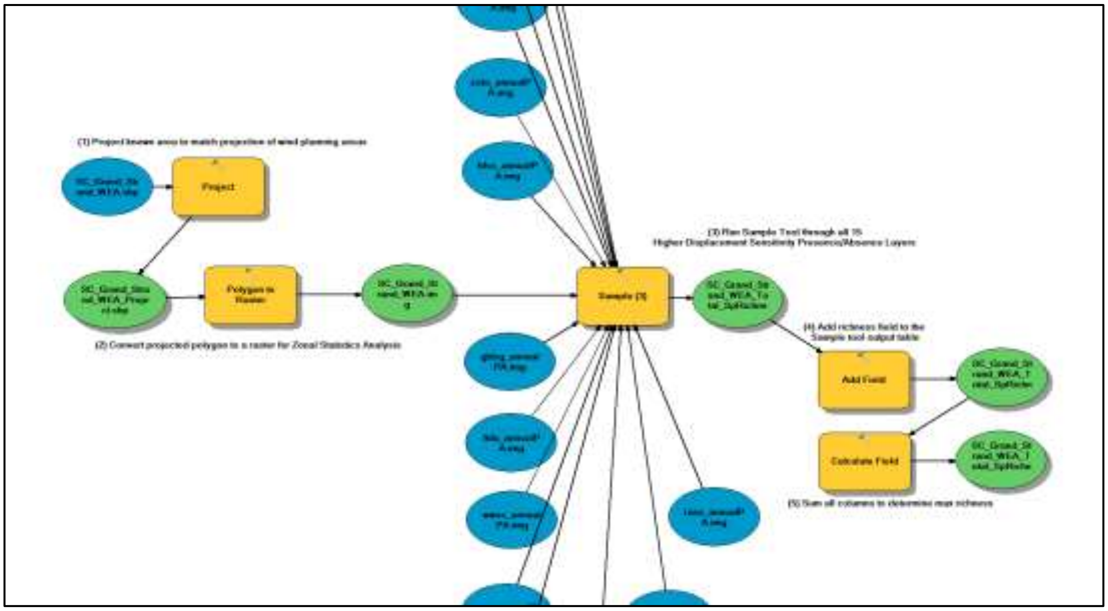
```
arcpy.CreateTable_management(scratchDir, out_name)
#Add speices, IUCN listing, and month fields
arcpy.AddField_management(scratchDir + "\\" + out_name, "Species", "TEXT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "Jan", "FLOAT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "Feb", "FLOAT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "Mar", "FLOAT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "Apr", "FLOAT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "May", "FLOAT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "Jun", "FLOAT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "Jul", "FLOAT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "Aug", "FLOAT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "Sep", "FLOAT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "Oct", "FLOAT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "Nov", "FLOAT")
arcpy.AddField_management(scratchDir + "\\" + out_name, "Dec", "FLOAT")
arcpy.DeleteField_management(scratchDir + "\\" + out_name, "Field1")

#Allow user to select polygon of interest for analysis OR draw their own
#User selects polygon from a list of known areas

polygon_name = sys.argv[1]

#To run as stand alone script, uncomment the following line
#polygon_name = 'South Carolina Grand Strand Wind Planning Area'

#OR user draws their own area

Custom_Report_Area = sys.argv[2]

#Set general parameters for Zonal Statistics as Table Tool, specifying the drawn area as the zone if the user does
not select a known area

if polygon_name == '#':
    custom = arcpy.FeatureSet(Custom_Report_Area)
    custom_area = dataDir + '\custom_report_area.shp'
    custom_areap = scratchDir + '\custom_report_area_p.shp'
   #Convert the custom area to a polygon shapefile
    arcpy.FeatureToPolygon_management(custom, custom_area, "", "ATTRIBUTES", "")
    coor_system = dataDir  +"\Monthly_Models\Bottlenose_dolphin\
    EC_Bottlenose_dolphin_month01_abundance.img"
  #Select raster layer to define coordinate system
    out_coordinate_system = arcpy.Describe(coor_system).spatialReference
  #Project shapefile to match output coordinate system of the raster (WGS 1984)
   arcpy.Project_management(custom_area, custom_areap, out_coordinate_system)
   areaRaster = scratchDir + "\custom_area.img"
  #Convert the polgyon to a raster for zonal statistics analsyis
   arcpy.PolygonToRaster_conversion(custom_areap,"OBJECTID", areaRaster)
   Zone = areaRaster #Set the new projected raster zone equal to the zone for zonal statistics
   zoneField = "Value"
```

```
#Select polygon as specificed from the drop down list if user does select a known polygon area
else:
   #Specify path to the geodatabase containing the list of known areas
    known_areas = dataDir + "\ORT_KnownAreas.gdb\ORT_REPORTS_Simplified"
    selected_area = dataDir + "\ORT_KnownAreas.gdb\selected_area"
    expression = '"AOI_NAME"= \'%s\'' %polygon_name
    #Run select tool to create polygon of interest
    arcpy.Select_analysis(known_areas, selected_area,expression)
    #Project selected area to match raster projection
    selected_areap = scratchDir + "\selected_areap.shp"
    coor_system = dataDir +"\Monthly_Models\Bottlenose_dolphin\
    EC_Bottlenose_dolphin_month01_abundance.img"
    out_coordinate_system = arcpy.Describe(coor_system).spatialReference
    transform_method = "WGS_1984_(ITRF00)_To_NAD_1983"
    arcpy.Project_management(selected_area, selected_areap, out_coordinate_system, transform_method)
    areaRaster = scratchDir + "\selected_area.img"
   #Convert the polygon to a raster for zonal statistics analysis


   arcpy.PolygonToRaster_conversion(selected_areap,"OBJECTID", areaRaster)
   Zone = areaRaster #Set the new projected raster zone equal to the zone for zonal statistics
   zoneField = "Value"

#User selects species to include in table

species = sys.argv[3]

#To test as stand alone script, uncomment following line
#species = ('Atlantic_white_sided_dolphin;Humpback_whale;North_Atlantic_right_whale')

speciesList = species.split(';')

#Create an emtpy list that will be populated with species folder names selected by the tool user

folderList = []

#Add species folder paths selected by the user to folderList
for species in speciesList:
   species.strip('')
   folderList.append(dataDir + '\\Monthly_Models\\' + species + '\\PresenceAbsence\\')

#Create empty dictionary to store Zonal Statistics output
sums = {}
#Loop through every file in each folder and calculate the percent of the selected area occupied by each species per
#month
for folder in folderList:
   arcpy.env.workspace = folder
   summary_table = scratchDir + '\\' + out_name
   rasterList = arcpy.ListRasters() #List all monthly presence/absence rasters for the species
   for raster in rasterList:
        inValueRaster = raster
        #Save Zonal Stats tables in memory
```

```
        table = ZonalStatisticsAsTable(Zone, zoneField, inValueRaster, "in_memory", "DATA", "SUM")
        name = raster[:-4]     #Remove .img from the file name
        new_name = name[3:]           #Remove EC_ from name
        #Insert a cursor to pull value from Sum and Count Column in Zonal Statistics Table
        cur = arcpy.UpdateCursor(table)
        for row in cur:
        #Convert sum of cells to percent of total area of the polygon
        percent = (row.getValue('SUM')/row.getValue('COUNT'))*100
        sums[new_name] = round(percent,2)
        del cur

#Add values for each species as a new row to the final table

for species in speciesList:
   #Create a new Insert cursor to add values to the blank summary output table
    #Note that no data is available for months 10 and 11 below the Northeast for the Sei whale; indicate no data
    #with -9999
    if species == 'Sei_whale':

      with arcpy.da.InsertCursor(summary_table, ("Species", "Jan", "Feb", "Mar", "Apr", "May", "Jun", "Jul", "Aug", 
"Sep", "Oct", "Nov", "Dec")) as cursor:
           cursor.insertRow(("Sei whale", sums[species + "_month01"], sums[species + "_month02"], sums[species + 
"_month03"], sums[species + "_month04"], sums[species + "_month05"], sums[species + "_month06"], 
sums[species+"_month07"], sums[species+"_month08"], sums[species+"_month09"], -9999, -9999, sums[species 
+"_month12"]))

   else:
      with arcpy.da.InsertCursor(summary_table, ("Species","Jan", "Feb", "Mar", "Apr", "May", "Jun", "Jul", "Aug", 
"Sep", "Oct", "Nov", "Dec")) as cursor:
           cursor.insertRow((species, sums[species + "_month01"], sums[species+ "_month02"], sums[species+ 
"_month03"], sums[species + "_month04"], sums[species + "_month05"], sums[species + "_month06"], 
sums[species +"_month07"], sums[species +"_month08"], sums[species +"_month09"], 
sums[species+"_month10"], sums[species +"_month11"], sums[species+"_month12"]))
```

Appendix F: Species Richness ArcMap Model

Workflow can be adapted for different known areas and presence/absence files for seabirds or marine mammals. Example shown is for the annual presence/absence models of higher displacement sensitive seabird species within the SC Grand Strand Wind Planning Area.



Appendix G: Interview Guide

1. What are your primary responsibilities as [job title] with [agency or organization]?
2. Are there specific offshore geographic areas ("known areas") that you are currently using or anticipate needing information on in the next 12 to 18 months?
3. Do you see yourself or staff using this tool and if so, how? Please indicate any specific management scenarios.
4. What additional functionality would you like to see included in the tool?
5. Are there other priority data sets that should be considered for inclusion?
6. What information from this [cetacean or seabird] data list would you consider a priority?
7. What aspects of the [specific infographic] do you like? Dislike?
8. Please rate each infographic in importance on a scale from 1-5:
    1. Unimportant
    2. Of little importance
    3. Moderately important
    4. Important
    5. Very important
9. Recommendations for others to talk to?