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Quantifying Acoustic Impacts on Marine Species: Methods and Analytical Approach for Activities at the MCAS Cherry Point Range Complex

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PREFACE

This report was funded by United States Marine Corps, U.S. Marine Corps Air Station Cherry Point Range Complex in support of modeling for determining the acoustic impacts to endangered and protected marine mammals.

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14. ABSTRACT. The United States Department of the Navy is required to assess impacts of anthropogenic sound in the water on protected marine species in compliance with applicable laws and regulations. This report applies to the U.S. Marine Corps Air Station Cherry Point (MCAS Cherry Point) Environmental Impact Statement and describes the methods and analytical approach to quantifying the number of potential effects to marine species as a result of training activities occurring at MCAS Cherry Point. Stock breakouts are also discussed to present a comprehensive overview of the methods to quantify acoustic impacts on marine mammals. The Navy Acoustics Effect Model (NAEMO) serves as the primary data entry point for activity information and as a repository for modeling output and estimated effects. The Navy used specific information about environmental conditions, best available marine species data, and projected activities within MCAS Cherry Point as inputs into NAEMO.

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List of Abbreviations and Acronyms

Acronym	Definition
7 YEAR	Number of Times an Event Happens in Seven Years
AFTT	Atlantic Fleet Training and Testing
ANNUAL	Number of Times an Event Happens in One Year
BT-9	Brandt Island
BT-11	Piney Island
CAL	Caliber
CASS	Comprehensive Acoustic Simulation System
CFR	Code of Federal Regulations
DOPAA	Description of Proposed Actions and Alternatives
EC	Electrical and Computer
EIMS	Electronic Information Management System

List of Abbreviations and Acronyms (Cont'd)

Acronym	Definition
EIS	Environmental Impact Statement
GI	Gastrointestinal
GRAB	Gaussian Ray Bundle
HOOCOW	Hours of Operation and Counts of Weapons
HYCOM	Hybrid Acoustic Coordinate Ocean Model
LOA	Letter of Authorization
MCAS	Marine Corps Air Station
MEM	Military Expended Material
MSMT	Marine Species Modeling Team
NAEMO	Navy Acoustic Effects Model
NEW	Net Explosive Weight
NMFS	National Marine Fisheries Service
NMS	Northern Migratory Stock
NMSDD	Navy Marine Species Density Database
NNCES	Northern North Carolina Estuarine Stock
NUWC	Naval Undersea Warfare Center
OAML	Ocean and Atmospheric Master Library
PTS	Permanent Threshold Shift
RMS	Root-Mean-Square
SEL	Sound Exposure Level
SMS	Southern Migratory Stock
SNCES	Southern North Carolina Estuarine Stock
SPL	Sound Pressure Level
TTS	Temporary Threshold Shift
U.S.	United States
USMC	U.S. Marine Corps
UTM	Universal Transverse Mercator

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1 INTRODUCTION

The United States Marine Corps (USMC) contracted the Naval Undersea Warfare Center (NUWC) Division Newport Marine Species Modeling Team (MSMT) to conduct a collection of quantitative impulsive effects analyses required for a seven-year authorization request from 2021–2028 for exercises within the Marine Corps Air Station (MCAS) Cherry Point Range Complex. The purpose was to determine the level of behavioral disturbances and physiological effects for individual marine mammals and sea turtles resulting from a series of surface detonations taking place within Pamlico Sound. Surface detonations are expected as the result of testing and training activities occurring at two targets (Brandt Island (BT-9) and Piney Island (BT-11) Bombing Range) inside of Pamlico Sound that involves deployment of various types of ordnance within the range. There were individual evaluations for each ordnance deployment, taking into account the Net Explosive Weight (NEW), number of ordnance expended, and environmental parameters at the geographic location of the target. Summaries of the cumulative predicted exposures for each species from all activities occurring within one-year and seven-year periods are provided.

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2 MODELING APPROACH

Impulsive effects modeling was conducted using the Navy Acoustic Effects Model (NAEMO), the Navy's standard model for collating, analyzing, and reporting potential effects of Navy at sea training and testing activities on marine mammals and sea turtles. The scenario definition(s) describe the inputs to NAEMO, including acoustic/impulsive sources used, duration, and platform type, speed and depth for each activity. Locations and annual occurrences of each scenario are also recorded.

Source characteristics are integrated with environmental data (bathymetry, sound speed, bottom characterization, and wind speed) to calculate the three-dimensional sound field for each source with either the Comprehensive Acoustic System Simulation/Gaussian Ray Bundle (CASS/GRAB) or the Navy's Standard Parabolic Equation sound propagation codes. Marine species density information is then processed to develop a series of distribution files for each species present in the study area. Each distribution file varies the abundance and placement of the animals based on uncertainty defined in the density and published group size. The scenario details, three-dimensional sound field data, and marine species distributions are then combined in NAEMO to build virtual three-dimensional representations of each event and environment. This information is then processed by NAEMO to determine the number of marine species exposed in each scenario.

The NAEMO simulation process is run multiple times for each season to provide an average of potential effects on marine species. Each iteration reads in the species dive data and introduces variations to the marine species distributions in addition to the initial position and direction of each platform and ordnance within the designated area. Navy marine species impulsive effects criteria and thresholds are then applied in the NAEMO Post-Processor to quantify the number of marine mammals and sea turtle effects. Results from each iteration are averaged to provide the number of marine species effects for a given period. A complete description of the NAEMO model and modeling approach used for this analysis can be found in the Navy's Phase III Quantitative Analysis Technical Report (Blackstock et al. 2017).

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3 DATA INPUTS

Individual scenarios for each of the sources identified in Table 4-1 were developed. A scenario will include multiple sorties that are likely to operate within the same day. These scenarios include the counts and clusters of ordnance deployed during the various activities that take place within Pamlico Sound on an annual basis. Counts refer to the numbers of ordnance deployed relatively far apart in time, typically more than a few minutes, while clusters describe ordnances deployed in quick succession, generally within a few minutes. For modeling purposes, counts are modeled as independent sources spaced out in time but clusters are modeled as a group of sources detonating at the same time. Scenarios can have both counts and clusters defined to simulate multiple group deployments of ordnance (i.e., multiple gun bursts). The modeled source depth is also defined in the scenario. All sources proposed for use in Pamlico Sound, identified in Table 4-1, have been determined by USMC personnel to detonate at or near the surface. For NAEMO modeling purposes, all ordnance analyzed are assumed to detonate at 0.1 meters below the surface.

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4 Source Characteristics

The ordnances analyzed include a variety of air-to-surface missiles, rockets, bombs, and gunfire expended on the Pamlico Sound targets. For modeling purposes, each ordnance was assigned to a specific impulsive bin and corresponding NEW based on the Navy's Phase III comprehensive environmental compliance and sustainment process. Only sources with a NEW greater than 0.1 lb were considered for modeling while all other ordnances were classified as de minimis or inert; thus, not requiring acoustic analysis.

Table 4-1 System Source Characteristics for Modeled Sources

Source	*Impulsive Bin*	*Net Explosive Weight (Modeled)*	*Net Explosive Weight (Exact)*
Large Arms Rounds–Live–30 mm	E1	0.25 lb	0.1019 lb
Large Arms Rounds–Live–40 mm	E1	0.25 lb	0.1199 lb
2.75-inch Rockets	E3	2.5 lb	2.5 lb
5-inch Rockets	E6	20 lb	15 lb

Standard NAEMO analysis characterizes a source's NEW based on its bin parameters, but results are available for both the modeled NEW and exact NEW, per request of the USMC. Both sets of parameters used in the NAEMO analysis are shown in Table 4-1 and non-modeled ordnances are detailed in Table 4-2.

Table 4-2 Non-Modeled Sources

Ordnance Type	*Reason for Not Being Modeled**
Small Arms Rounds Excluding .50 CAL	De minimis
.50 CAL	De minimis
Large Arms Rounds–Inert	Inert
Rockets–Inert	Inert
Bombs and Grenades–Inert	Inert
Pyrotechnics	Inert
*De minimis sources have a NEW less than 0.1 lb.	

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5 AREAS OF OPERATION

The proposed USMC activities are scheduled to take place within the MCAS Cherry Point Range Complex, outlined in Figure 5-1. This range encompasses most of Pamlico Sound and the two targets within it, Brandt Island Target (BT-9) and Piney Island Target (BT-11), illustrated in Figure 5-2.

Each scenario was modeled at BT-9, using both the impulsive bin NEW and the exact NEW of the source. All sources used at BT-11 are inert and not modeled for impulsive effects; though the military expended material (MEM) was considered (Section 9.2).

The USMC provided one-year and seven-year proposals for the expected munitions expenditures that would be used in the training activities within Pamlico Sound from 2021–2028. Based on these data and additional information given about the nature of specific activities, scenarios were created for each ordnance to reflect a realistic daily occurrence of each activity. Each scenario represents a single-day event and has a unique combination of platform counts, ordnance counts, and cluster sizes. For any scenarios where activity-specific information was unavailable, comparable scenarios from the Atlantic Fleet Training and Test (AFTT) study area database (Department of the Navy, 2018) were consulted in order to determine the appropriate values for the counts and clusters. The platform count, cluster size, and counts per day defining the quantities of a representative single day event for each ordnance are outlined in Table 5-1.

Table 5-1 Source Counts and Modeling Locations for Modeled Sources Only

Ordnance Type	*Platform Count*	*Source Cluster*	*Daily Source Count*	*Modeled Areas*
Large Arms Rounds–Live–30 mm	6	25	10	BT-9
Large Arms Rounds – Live–40 mm	6	5	50	BT-9
2.75-inch Rockets	3	1	14	BT-9
5-inch Rockets	3	1	14	BT-9

Alternative numbers were established for each event to project the proposed amount of ordnance expenditures anticipated over a one-year and seven-year timeframe given impulsive effects from a single-day event. These values (Section 9.3) were calculated by dividing the annual and seven-year ordnance number totals, listed in Table 5-2, by the amount of expenditure used for an individual event, defined by the multiplication of the number of platforms, cluster and count.

The inert events, taking place in both BT-9 and BT-11, were created to fulfill the proposed amount of annual and seven-year inert expenditures and similar to the comparable live activity but do not necessarily match them exactly. For the ordnances involved in both air-to-surface and surface-to-surface trainings, the overall munitions expenditure was broken down into separate scenarios by percentages derived from data provided in the 2014–2019 letter of authorization (LOA). The combined expenditures of applicable ordnances with both air-to-surface and surface-to-surface involvement add up to the overall number of the expenditure provided.

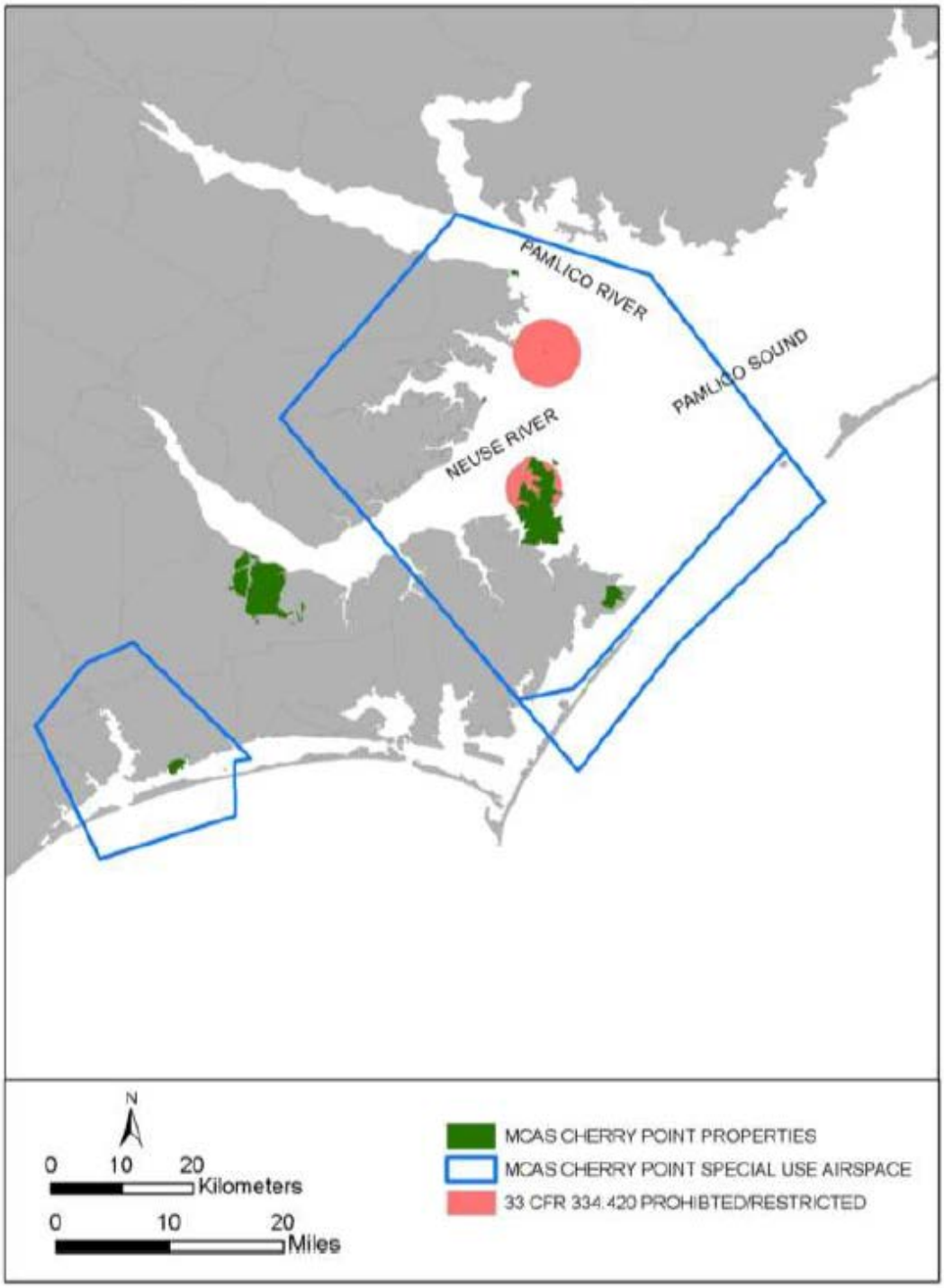

Figure 5-1 MCAS Cherry Point Range Complex

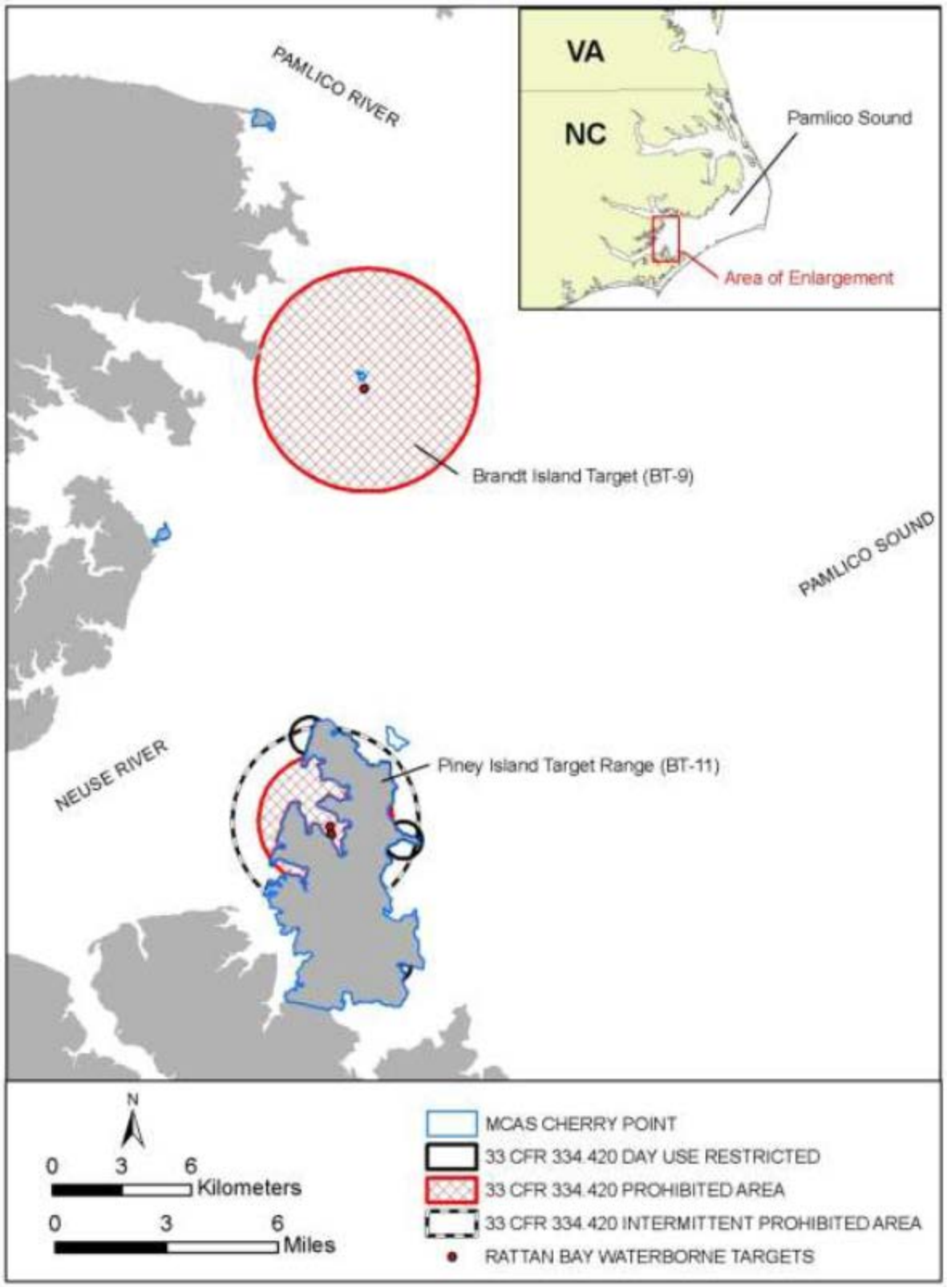

Figure 5-2 Pamlico Sound Modeling Areas and Testing Targets

Table 5-2 Hours of Operation and Counts of Weapons (HOOCOW)

Location	*Proposed Annual*	*LOA 2021-2028*
Bombing Exercise Air-to-Surface (Inert)	**6,000**	**42,000**
BT-11 Model box	4,500	31,500
BT-9 Model box	1,500	10,500
GUNEX .50 Cal Air-to-Surface (Inert)	**884,029**	**6,188,207**
BT-11 Model box	416,358	2,914,507
BT-9 Model box	467,671	3,273,700
GUNEX .50 Cal Surface-to-Surface (Inert)	**109,486**	**766,398**
BT-11 Model box	8,642	60,493
BT-9 Model box	100,844	705,905
GUNEX 30mm BT-9	**3,432**	**24,024**
BT-9 Model box	3,432	24,024
GUNEX 40mm BT-9	**10,420**	**72,940**
BT-9 Model box	10,420	72,940
GUNEX Large Arm Rounds Surface-to-Surface (Inert)	**360,739**	**2,525,173**
BT-11 Model box	240,334	1,682,338
BT-9 Model box	120,405	842,835
GUNEX Small Arms Rounds Air-to-Surface (Inert)	**1,656,960**	**11,598,720**
BT-11 Model box	1,224,583	8,572,081
B-T9 Model box	432,377	3,026,639
GUNEX Small Arms Rounds Surface-to-Surface (Inert)	**118,650**	**830,550**
BT-11 Model box	25,417	177,919
BT-9 Model box	93,233	652,631
Rocket Exercise 2.75-in. BT-9	**220**	**1,540**
BT-9 Model box	220	1,540
Rocket Exercise 5-in. BT-9	**68**	**476**
BT-9 Model box	68	476
Rocket Exercise Air-to-Surface (Inert)	**7,094**	**49,658**
BT-11 Model box	6,250	43,750
BT-9 Model box	844	5,908
Pyrotechnics Expenditures	**11,412**	**79,884**
BT-11 Model box	8,912	62,384
BT-9 Model box	2,500	17,500
Grand Total	**3,168,510**	**22,179,570**

6 ENVIRONMENTAL DATA

The Ocean and Atmospheric Master Library (OAML) and Hybrid Coordinate Ocean Model (HYCOM) databases were utilized for the NAEMO analyses. The Naval Oceanographic Operations Command maintains the OAML and provides a baseline set of Navy standard core models, databases, and algorithms. OAML databases include bathymetric data, bottom sediment properties, and wind speed data required for conducting underwater sound propagation analyses. HYCOM is a hybrid coordinate ocean model run by the National Oceanic and Atmospheric Administration and provided the salinity and temperature data.

Data for four environmental characteristics (bathymetry, sound speed profile, sediment type, and wind speed) were obtained or derived for January (winter), April (spring), July (summer), and October (fall). Bathymetry data was obtained from the Digital Bathymetric Database Variable-Resolution. Salinity and temperature data from the HYCOM database were used to derive sound speed profiles. The wind speed was extracted from the Surface Marine Gridded Climatology database.

The databases used for each environmental parameter are shown in Table 6-1. More detail of the environmental data used in the NAEMO model can be found in the Navy's Phase III Quantitative Analysis Technical Report (Blackstock et al. 2017).

Table 6-1 Oceanographic and Atmospheric Master Library Environmental Databases

Parameter	***Database***
Bathymetry	Digital Bathymetric Database Variable-Resolution Version 6.2 (Level 0)
Sound Speed Profile	HYCOM Version 2.2
Wind Speed	Surface Marine Gridded Climatology Version 2.0
Geo-Acoustic Parameters	Re-Packed Bottom Sediment Type Version 2.0 (includes High-Frequency Environmental Acoustics Version 1.0)
	Low-Frequency Bottom Loss Version 11.1*
	High-Frequency Bottom Loss Version 2.2*
*Low-frequency and high-frequency bottom loss databases are used to capture the variability of bottom sediment to absorb or reflect energy from high-frequency and low-frequency sound sources.	

Sound propagation is calculated at representative points throughout each modeling area using CASS/GRAB. During a simulation, each source in the scenario is randomly placed within the modeling area and within 0.5 nm of each other. It is assumed that sound propagation at each source follows the same propagation as the closest propagation point.

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7 MARINE SPECIES DENSITY AND DISTRIBUTION DATA

The MCAS Cherry Point Range Complex encompasses the Pamlico Sound training areas, BT-9 and BT-11 ranges. Known species present in these locations are bottlenose dolphins (*Tursiops truncatus)*, Hardshell turtles (*Hardshell turtle)*, Kemp's ridley turtles (*Lepidochelys kempii)*, leatherback turtles (*Dermochelys coriacea),* and loggerhead turtles (*Caretta caretta*) (Table 7-1). Virtual animals, known as animats, of these species were distributed in NAEMO based on available density data obtained from the AFTT Study Area of the Navy Marine Species Density Database (NMSDD) (Department of the Navy, 2018).

AFTT density layers for the turtle species covered the boundaries of the required modeling area while the available bottlenose dolphin data did not extend past the barrier islands into Pamlico Sound. To compensate for this, the bottlenose dolphin densities from the AFTT database were supplemented with information obtained by Read et al. (2003) that established a year-round value of 0.183/km^2 within Pamlico Sound, see Section 7.1 for further details.

Table 7-1 Marine Species That Occur Within Pamlico Sound

Common Name	***Scientific Name***
Bottlenose dolphin–northern migratory stock (NMS)	*Tursiops truncatus*
Bottlenose dolphin–southern migratory stock (SMS)	*Tursiops truncatus*
Bottlenose dolphin–northern North Carolina estuarine system stock (NNCES)	*Tursiops truncatus*
Bottlenose dolphin–southern North Carolina estuarine system stock(SNCES)	*Tursiops truncatus*
Hardshell turtle	*Hardshell turtle*
Kemp's ridley turtle	*Lepidochelys kempii*
Leatherback turtle	*Dermochelys coriacea*
Loggerhead turtle	*Caretta caretta*

Density information is provided in more detail in Sections 7.1 and 7.2 for individual species that reside within Pamlico Sound, grouped under odontocetes and turtles. Though there is no evidence that additional species consistently venture inside of Pamlico Sound, the remaining species that reside within the AFTT Study Area (Table 7-2) were modeled in the unlikely event that impulsive sound escaped into the offshore water outside of Pamlico Sound. AFTT density layers were again used, though these species are only present along the offshore areas outside of Pamlico Sound.

The finest temporal resolution for the NMSDD data for the Pamlico Sound Study Area is seasonal. The four seasons are defined as:

- Winter: December–February
- Spring: March–May
- Summer: June–August
- Fall: September–November

However, density data are rarely available at this temporal resolution. For each area and season, the Navy's goal is to identify the best available density estimate, and thus, different data sources may be

relied upon. To select marine species density estimates, the Navy established a data hierarchy based on available data (Department of the Navy 2017).

For most marine megafauna, abundance is estimated using line-transect surveys or mark-recapture studies (Barlow 2010; Barlow and Forney 2007; Calambokidis et al. 2008). These methods usually produce a single value for density that is an averaged estimate across large geographical areas, commonly referred to as a "uniform" density estimate. In some cases, the survey area is broken up into several strata and density estimates are derived for each stratum (a "stratified" density estimate). More recently, a method called spatial habitat modeling has been developed to estimate cetacean densities that address some of these shortcomings (Barlow et al. 2009; Becker et al. 2012; Becker et al. 2010; Becker et al. 2016; Becker et al. 2014; Ferguson et al. 2006; Forney et al. 2015; Forney et al. 2012; Redfern et al. 2006). Note that spatial habitat models are also referred to as "species distribution models" or "habitat-based density models." These models vary and make predictions at the scale of underlying environmental covariates.

Table 7-2 AFTT Species Outside of Pamlico Sound

Species Name	***Scientific Name***
Atlantic spotted dolphin	*Stenella frontalis*
Atlantic white sided dolphin	*Lagenorhynchus acutus*
Beaked whale	*Ziphiidae*
Bearded seal	*Erignathus barbatus*
Blue whale	*Balaenoptera musculus*
Bryde's whale	*Balaenoptera edeni*
Clymene dolphin	*Stenella clymene*
False killer whale	*Pseudorca crassidens*
Fin whale	*Balaenoptera physalus*
Fraser's dolphin	*Lagenodelphis hosei*
Harbor porpoise	*Phocoena phocoena*
Harp seal	*Pagophilus groenlandicus*
Hooded seal	*Cystophora cristata*
Humpback seal	*Megaptera novaeangliae*
Killer whale	*Orcinus orca*
Kogia whale	*Kogia spp*
Melon headed whale	*Peponocephala electra*
Minke whale	*Balaenoptera acutorostrata*
North Atlantic right whale	*Eubalaena glacialis*
Northern bottlenose whale	*Hyperoodon ampullatus*
Pantropical spotted dolphin	*Stenella attenuata*

Table 7-2 AFTT Species Outside of Pamlico Sound (Cont'd)

Species Name	*Scientific Name*
Pilot whale	*Globicephala spp*
Pygmy killer whale	*Feresa attenuata*
Ringed seal	*Pusa hispida*
Risso's dolphin	*Grampus griseus*
Rough toothed dolphin	*Steno bredanensis*
Seals	*Phocidae*
Sei whale	*Balaenoptera borealis*
Short beaked common dolphin	*Delphinus delphis*
Sperm whale	*Physeter macrocephalus*
Spinner dolphin	*Stenella longirostris*
Striped dolphin	*Stenella coeruleoalba*
West Indian manatee	*Trichechus manatus*
White beaked dolphin	*Lagenorhynchus albirostris*

7.1 Odontocetes

7.1.1 Bottlenose Dolphin, *Tursiops truncatus*

The only odontocete species that actively resides in Pamlico Sound is the bottlenose dolphin. A density of 0.183 for all bottlenose dolphins per square kilometer was used year-round for the Pamlico Sound modeling analyses. This number derives from *Abundance of Bottlenose Dolphins in the Bays, Sounds, and Estuaries of North Carolina* (Read et al., 2003) and corresponds to the value used in the USMC's request for 2014–2019 authorization. Though the aerial survey study from Goodman et al. (2007) reports a higher density value for some seasons, the data from Read et al. was used because it utilizes a mark-recapture photographic survey, more conservative and applicable than an aerial survey. This rationale also falls in line with the USMC's most recent request (2014–2019) for authorization.

There are four stocks of bottlenose dolphin present within Pamlico Sound: NMS, SMS, NNCES, and SNCES. Though there are no available density estimates for each specific stock, abundance approximations from NOAA provided population sizes for the four stocks in consideration. The NMS and SMS stocks have data available from 2017 while the most recent surveys for the NNCES and SNCES are from 2013 and 2006, respectively (Hayes et al., 2018). The abundance estimates for each stock in coastal and estuarine water of the U.S. East Coast used in the modeling analyses are outlined in Table 7-3.

Table 7-3 Bottlenose Dolphin Stock Abundances

NMS	6,639
SMS	3,751
NNCES	823
SNCES	188
Total	11,401

These abundance numbers do not reflect the abundance within Pamlico Sound. They were only used to calculate the percentages used to generate the stock breakout of the bottlenose dolphin distributions within Pamlico Sound. Density was assumed uniform across the sound, illustrated in Figure 7-1 on the following page. Stock proportions were applied to the overall bottlenose dolphin distributions, based on 0.183 animals per square kilometer (Read et al., 2003), by using the percentage of a stock's abundance in relation to the cumulative population of all four stocks. Breakouts occurred on a monthly basis and an entire stock's proportion was reduced to zero if the NOAA stock assessment clearly indicated an absence from Pamlico Sound in that month. Refer to the NOAA stock assessments for further information about stock movement (Hayes et al., 2018). For any month where a stock(s) was absent, the remaining present stock's proportions were adjusted accordingly. The monthly proportions are outlined in Table 7-4.

Table 7-4 Monthly Stock Breakout Percentages for Bottlenose Dolphin

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
NMS	88.97%	88.97%	88.97%	59.21%	59.21%	58.23%	0.00%	0.00%	58.23%	58.23%	59.21%	59.21%
SMS	0.00%	0.00%	0.00%	33.45%	33.45%	32.90%	78.77%	78.77%	32.90%	32.90%	33.45%	33.45%
NNCES	11.03%	11.03%	11.03%	7.34%	7.34%	7.22%	17.28%	17.28%	7.22%	7.22%	7.34%	7.34%
SNCES	0.00%	0.00%	0.00%	0.00%	0.00%	1.65%	3.95%	3.95%	1.65%	1.65%	0.00%	0.00%

Updated species distributions were created based on these percentages and modeled for impulsive effects from the proposed trainings within Pamlico Sound. Results are provided for individual stocks instead of the species as a whole, though the combined effects from all four stocks does represent the overall bottlenose dolphin effects.

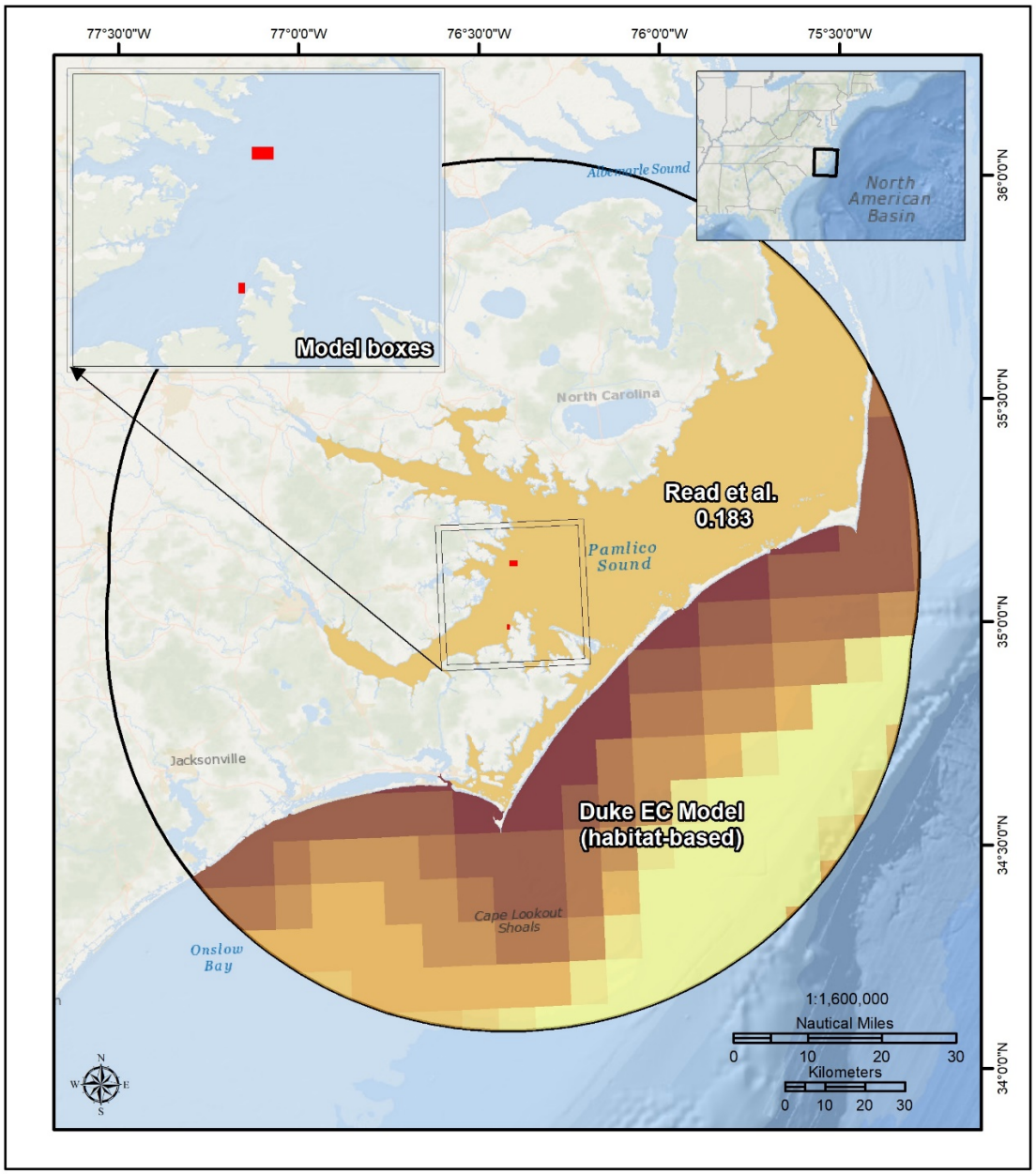

Figure 7-1 Bottlenose Dolphin Year-Round Density in Pamlico Sound

7.2 AFTT Species Outside of Pamlico Sound

Modeling for the remaining species within the AFTT study area (Table 7-2) resulted in zero exposures. As this modeling was only performed to ensure that no harmful sound escaped Pamlico Sound, density layers and results are not included for these species in this report. Refer to the Atlantic Fleet Training and Testing Final Environmental Impact Statement/Overseas Environmental Impact Statement for further information about species' density and characteristics.

7.3 Turtles

The four turtle species in consideration (hardshell, Kemp's ridley, leatherback, and loggerhead) all reside within Pamlico year-round, though there is seasonal variation for each. Density information from the Atlantic Fleet Training and Testing Final Environmental Impact Statement/Overseas Environmental Impact Statement was used for all modeling presented in this report. The following sections contain density plots for the modeled turtle species in the study area.

7.3.1 Hardshell turtle, *Hardshell turtle*

Figures 7-2 and 7-3 refer to the hardshell turtle densities in Pamlico Sound for fall/winter/spring and summer, respectively.

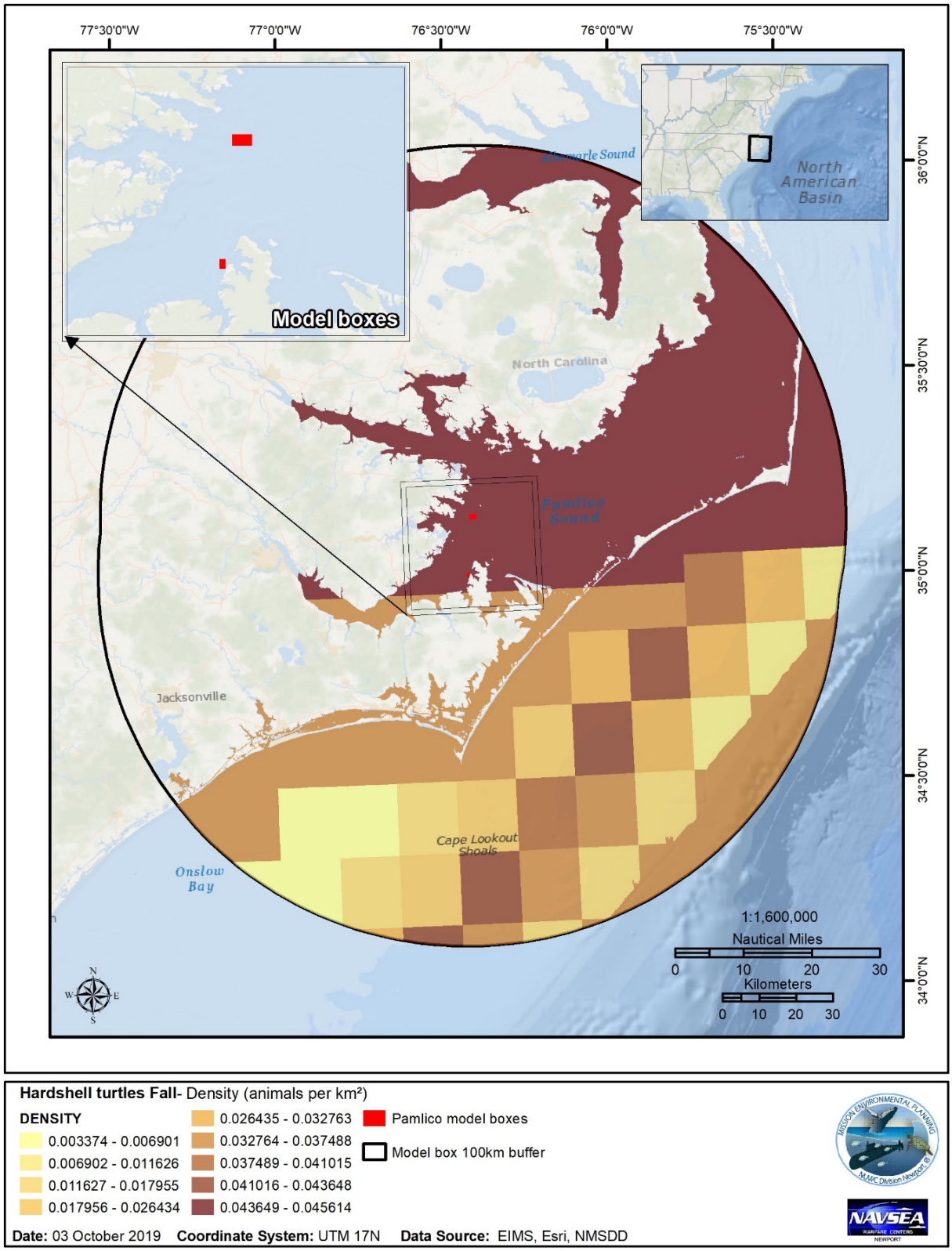

Figure 7-2 Hardshell Turtle Fall/Winter/Spring Density in Pamlico Sound

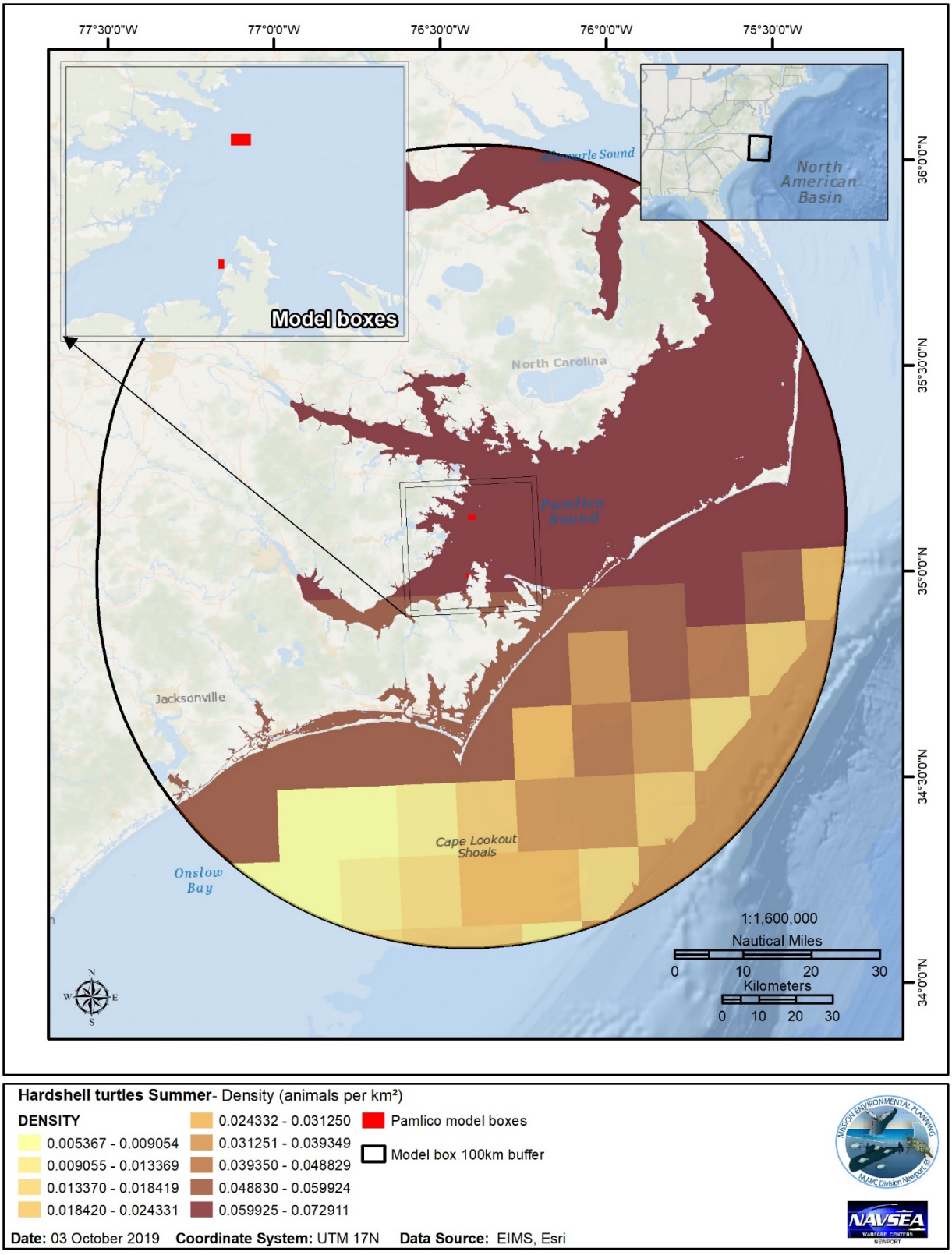

Figure 7-3 Hardshell Turtle Summer Density in Pamlico Sound

7.3.2 Kemp's Ridley Turtle, *Lepidochelys kempii*

Figures 7-4 and 7-5 refer to the Kemp's ridley turtle densities in Pamlico Sound for summer/fall/winter and spring, respectively.

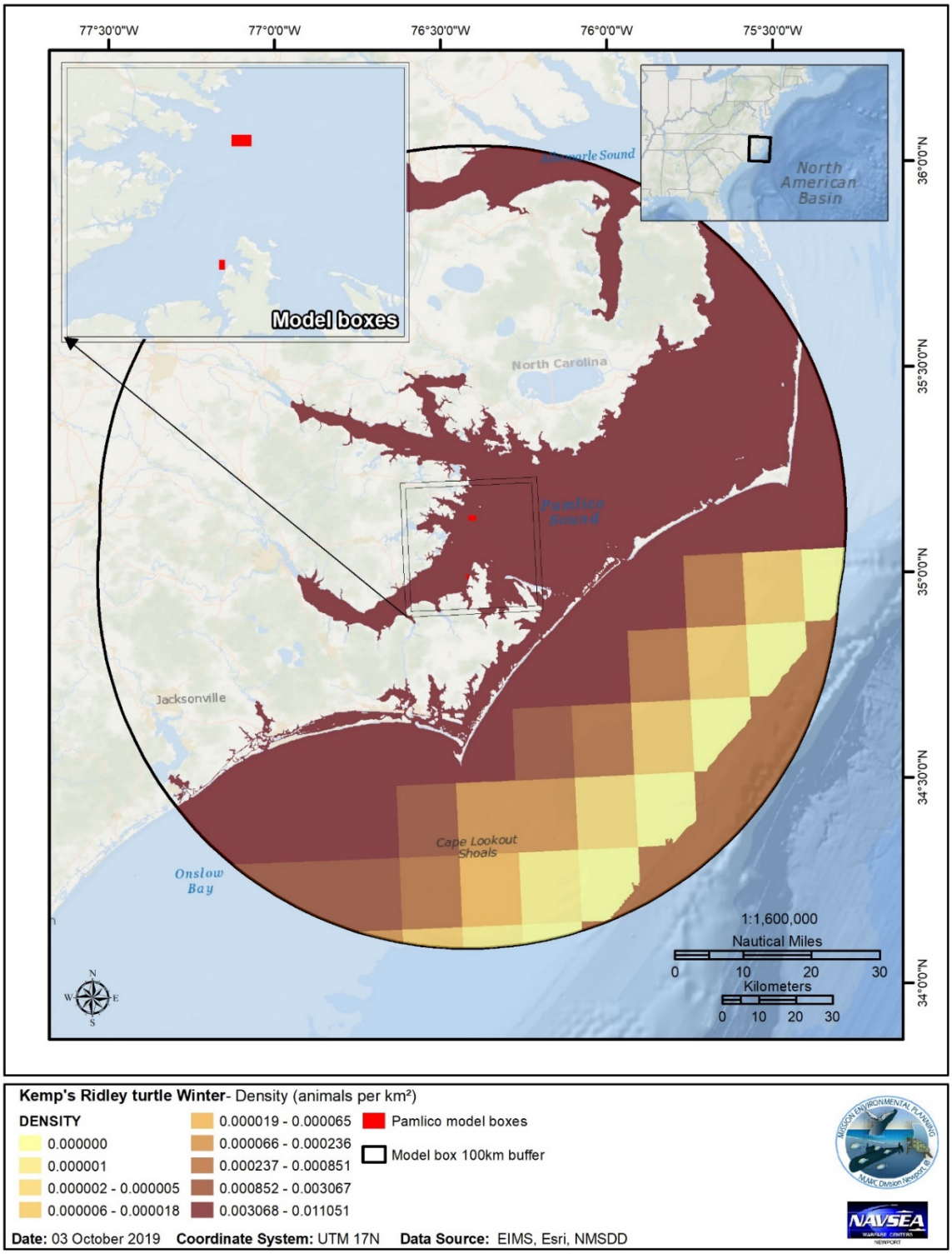

Figure 7-4 Kemp's Ridley Turtle Summer/Fall/Winter Density in Pamlico Sound

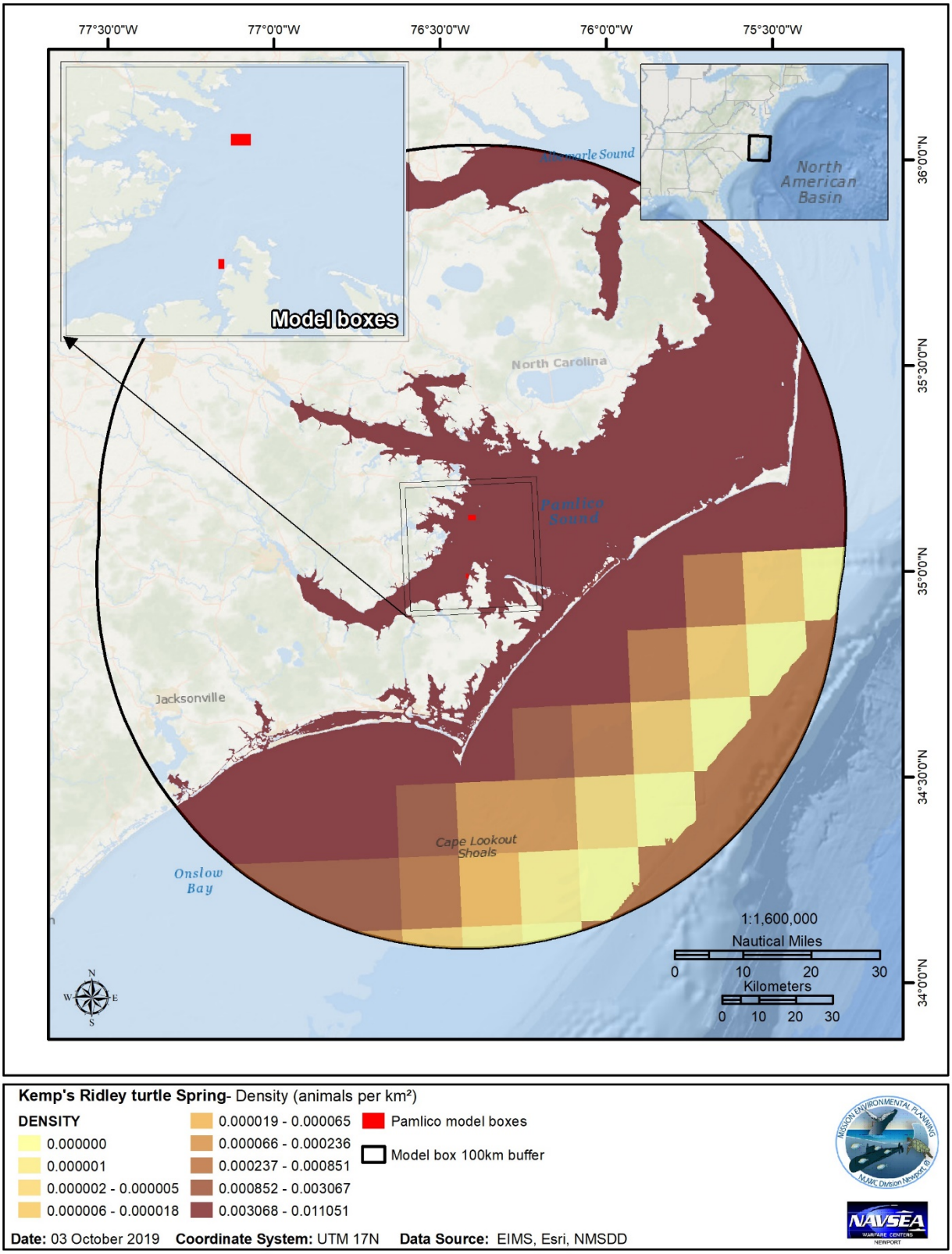

Figure 7-5 Kemp's Ridley Turtle Spring Density in Pamlico Sound

7.3.3 Leatherback Turtle, *Dermochelys coriacea*

Figures 7-6, 7-7 and 7-8 refer to the leatherback turtle densities in Pamlico Sound for summer, winter, and spring, respectively.

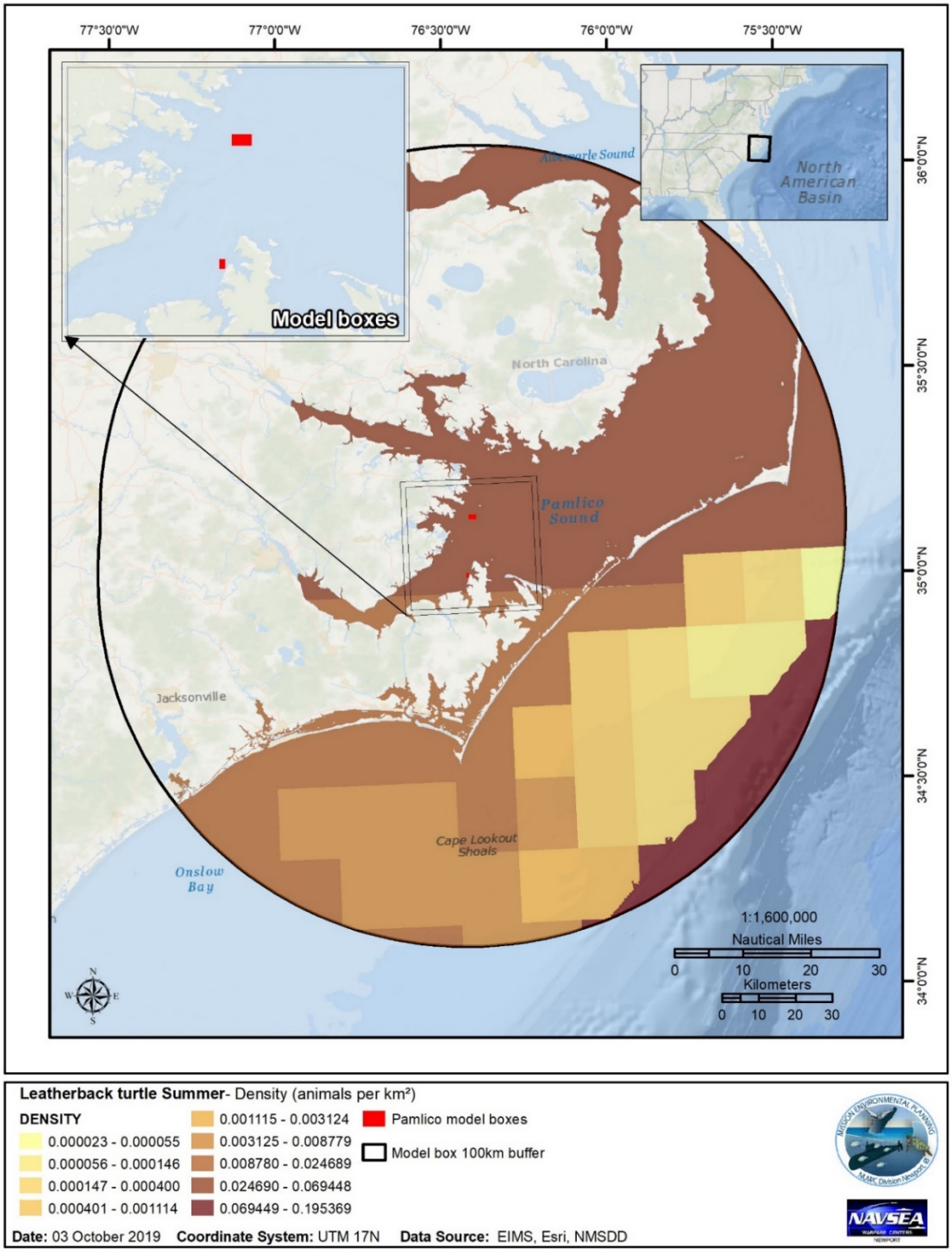

Figure 7-6 Leatherback Turtle Summer Density in Pamlico Sound

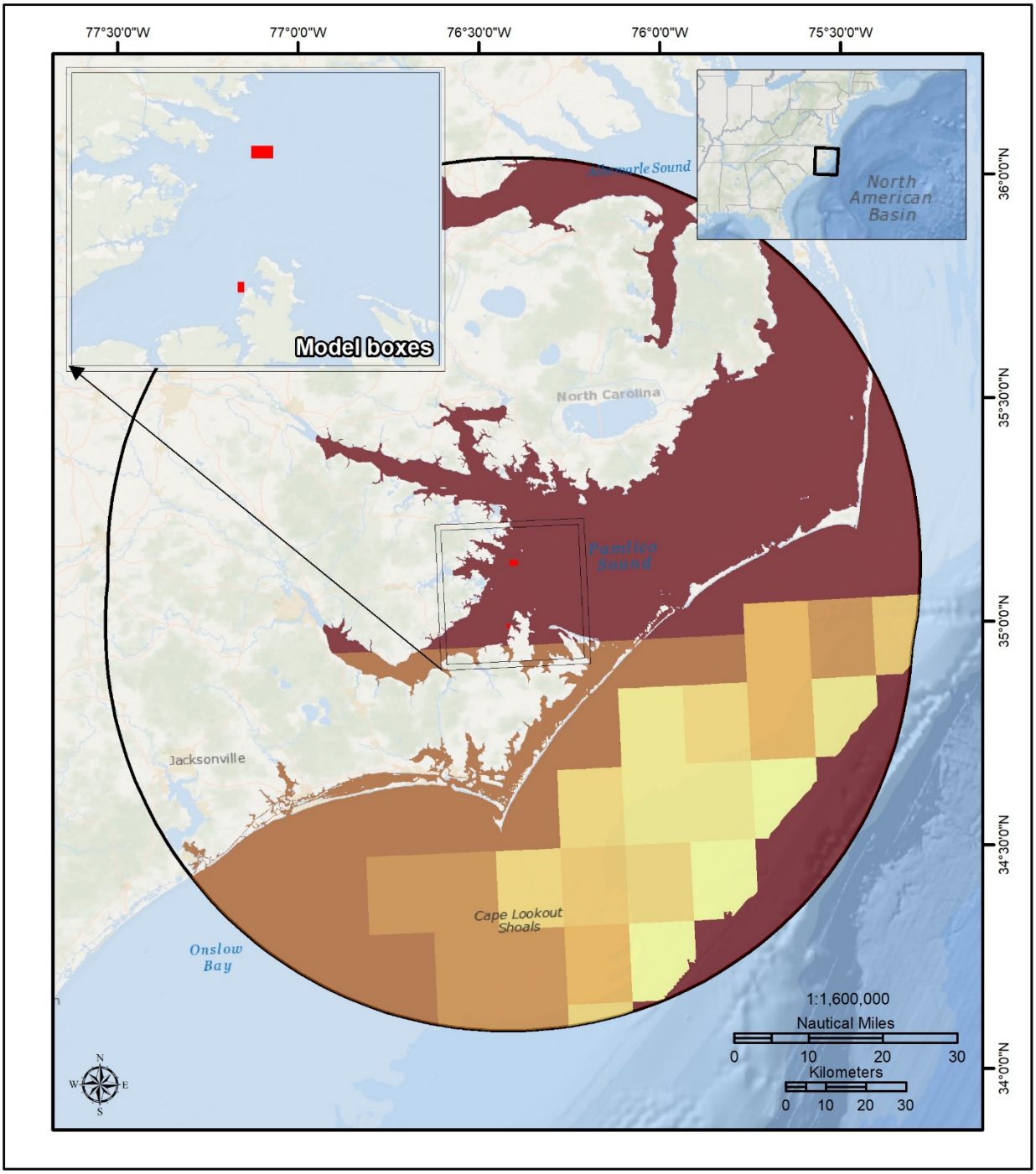

Figure 7-7 Leatherback Turtle Winter Density in Pamlico Sound

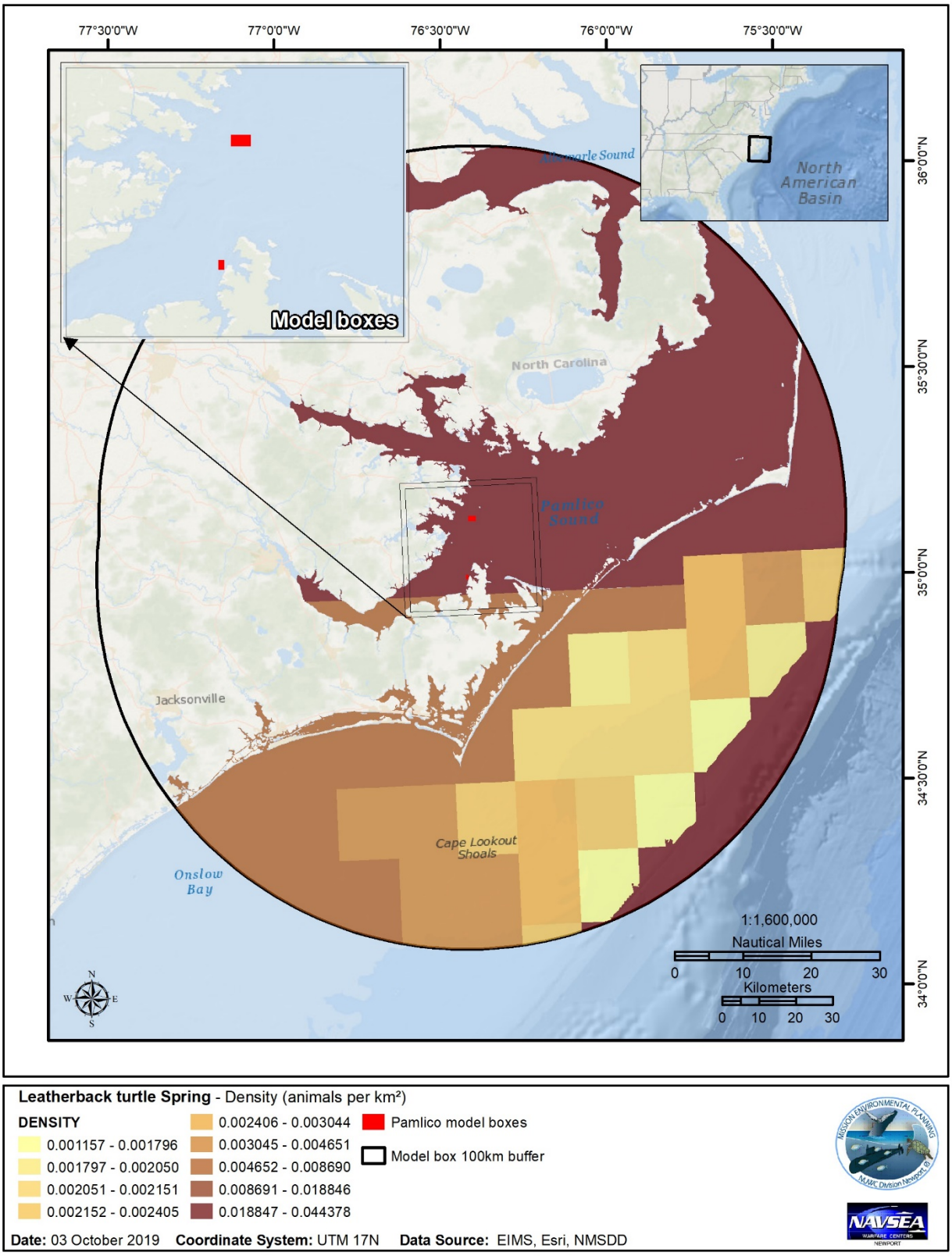

Figure 7-8 Leatherback Turtle Spring/Fall Density in Pamlico Sound

7.3.4 Loggerhead turtle, *Caretta caretta*

Figures 7-9, 7-10 and 7-11 refer to the loggerhead turtle densities in Pamlico Sound for summer, fall, and winter/spring, respectively.

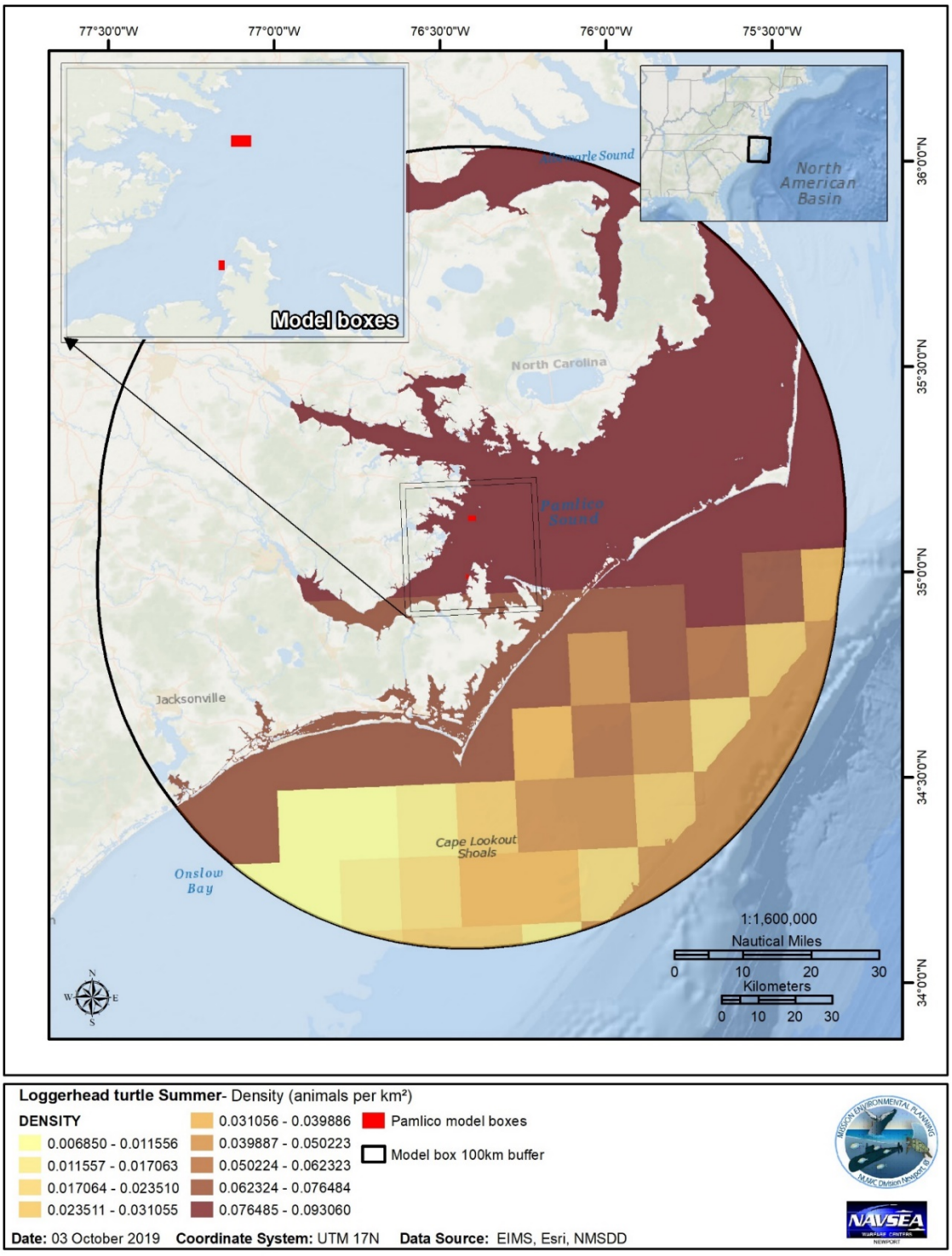

Figure 7-9 Loggerhead Turtle Summer Density in Pamlico Sound

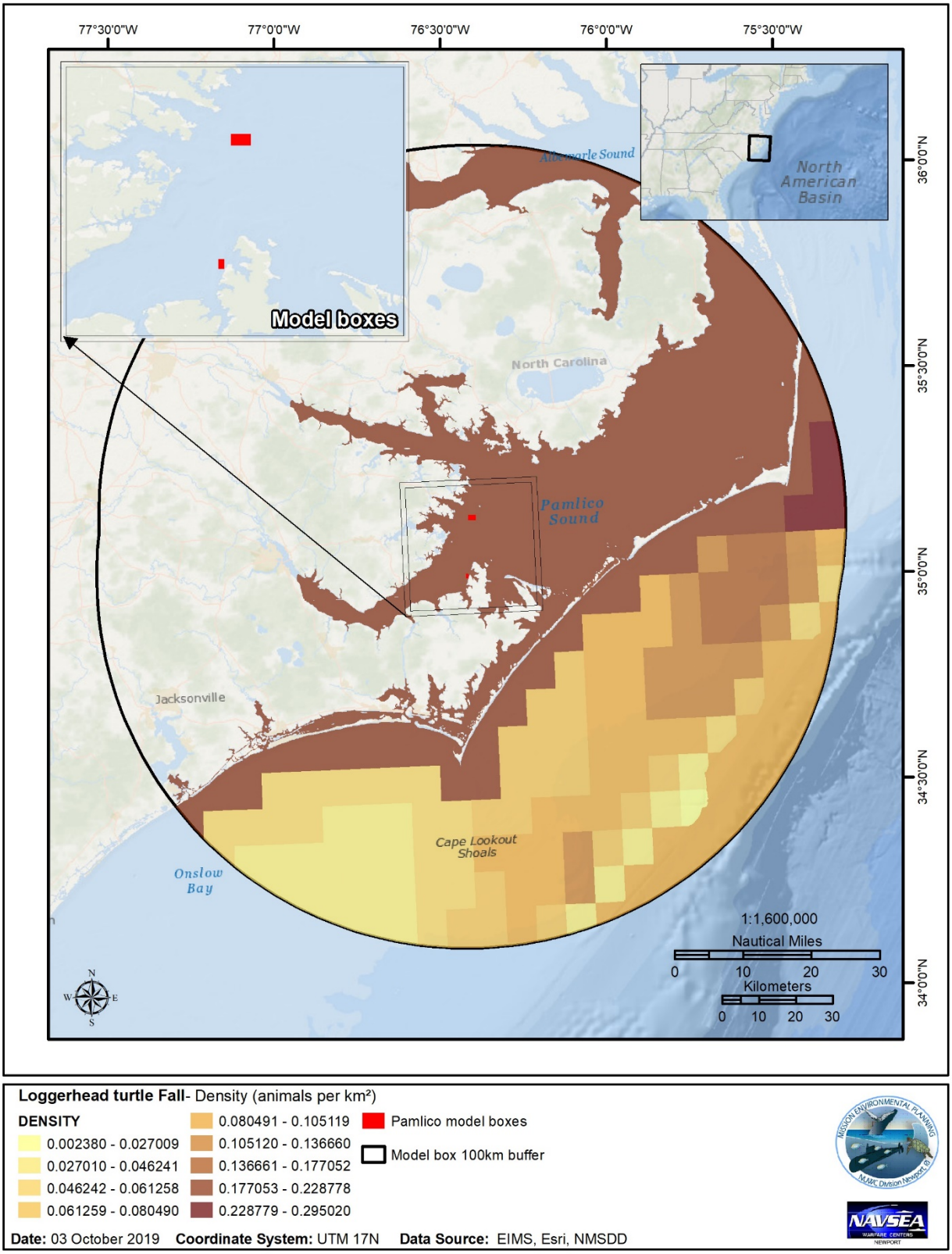

Figure 7-10 Loggerhead Turtle Fall Density in Pamlico Sound

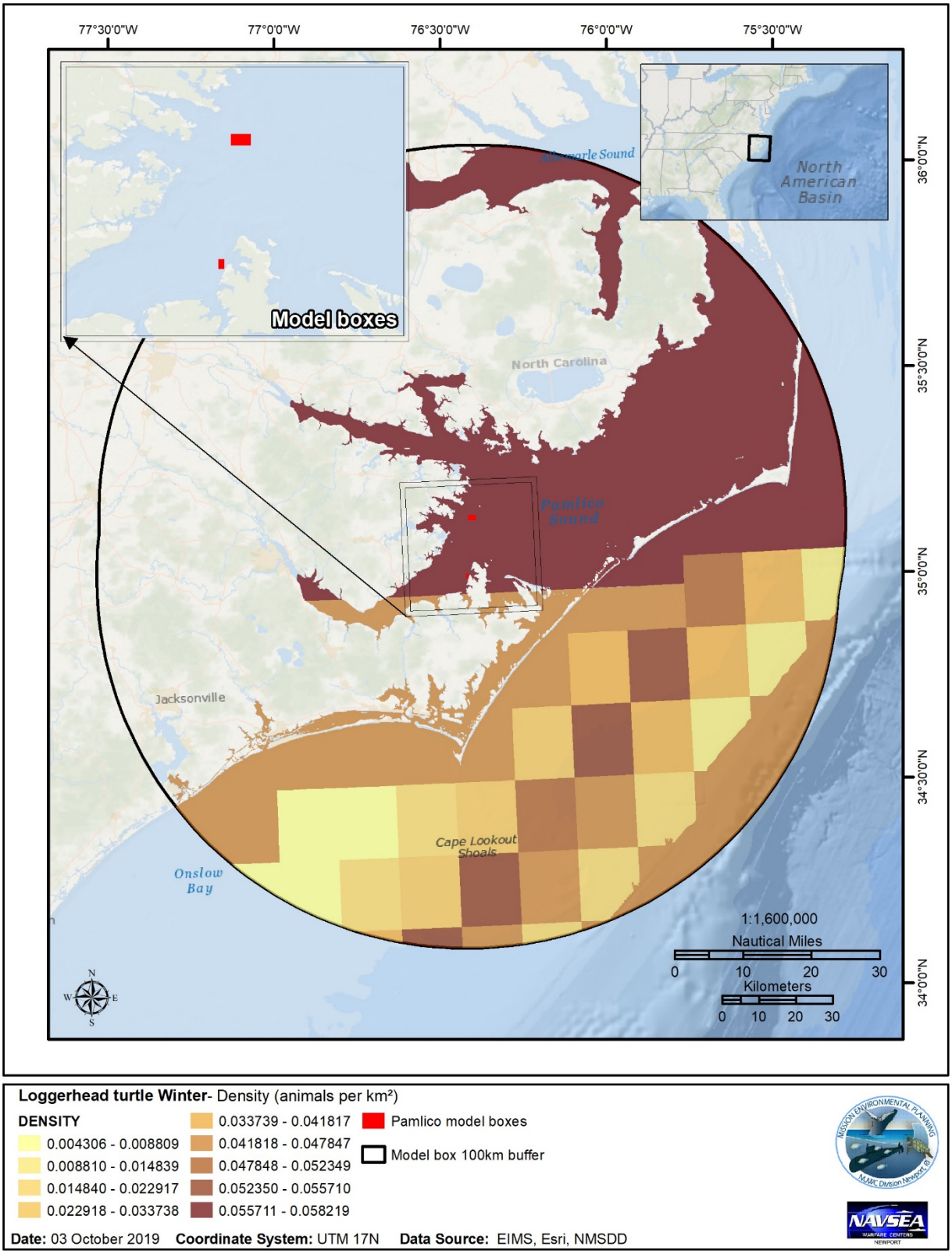

Figure 7-11 Loggerhead Turtle Winter/Spring Density in Pamlico Sound

8 Marine Mammal Criteria and Thresholds

The Navy's Phase III marine mammal criteria and threshold (Department of the Navy 2017) data was utilized for this analysis. The criteria provide specific threshold levels for acoustic and impulsive sources that can be used to determine potential auditory effects (Permanent Threshold Shift (PTS)/Temporary Threshold Shift (TTS)), behavioral responses to underwater anthropogenic sound, and non-auditory physiological impacts.

All received impulse, Sound Exposure Level (SEL), and Sound Pressure Levels (SPLs) are recorded for each mammal or turtle in the defined area that received an SPL level of at least 100 dB. These values are then compared against all thresholds defined in Table 8-1 to calculate exposure numbers.

Table 8-1 Effects, Criteria, and Thresholds for Impulsive Sources

Group	*Species*	*Behavioral Criteria*	*Physiological Criteria*		
			Onset TTS	*Onset PTS*	*Onset Gastrointestinal (GI) Tract Injury SPL 50%*
Low-Frequency Cetaceans	All mysticetes	163 dB SEL	168 dB SEL 213 dB SPL	183 dB SEL 219 dB SPL	243 dB re 1 µPa peak
Mid-Frequency Cetaceans	Most delphinids, beaked whales, medium and large toothed whales	165 dB SEL	170 dB SEL 224 dB SPL	185 dB SEL 230 dB SPL	243 dB re 1 µPa peak
High-Frequency Cetaceans	Porpoises, River dolphins, *Cephalorynchus* spp., *Kogia* spp.	135 dB SEL	140 dB SEL 196 dB SPL	155 dB SEL 202 dB SPL	243 dB re 1 µPa peak
Otariidae/Odobenidae (in water)	California sea lion, Guadalupe fur seal, Northern fur seal	183 dB SEL	188 dB SEL 226 dB SPL	203 dB SEL 232 dB SPL	243 dB re 1 µPa peak
Phocinae (in water)	Harbor seal	165 dB SEL	170 dB SEL 212 dB SPL	185 dB SEL 218 dB SPL	243 dB re 1 µPa peak
Monochinae (in water)	Northern elephant seal	165 dB SEL	170 dB SEL 212 dB SPL	185 dB SEL 218 dB SPL	243 dB re 1 µPa peak
Turtles	All turtles	175 dB root-mean-square (RMS)	189 dB SEL 226 dB SPL	204 dB SEL 232 dB SPL	243 dB re 1 µPa peak

Mortality and slight lung injury thresholds are calculated using the mass and depth of the mammal. An adult mass and a calf mass are defined for each species based on data from *Criteria and Thresholds for U.S. Navy Acoustic and Explosive Impacts to Marine Mammals and Sea Turtles* (2017c). Mortality (50% risk of extensive lung injury):

$$Mortality\ Impulse\ Threshold = 144M^{1/3}(1 + \frac{D}{10.1})^{1/6}\ Pa - s\ .$$

Injury (50% risk of slight lung injury):

$$Slight\ Lung\ Injury\ Impulse\ Threshold = 65.8M^{1/3}(1 + \frac{D}{10.1})^{1/6}\ Pa - s\ ,$$

where *D* is depth (meters) and *M* is mass (kg).

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9 Modeling Results

9.1 Acoustic Effects

Cumulative modeling results for each species are presented in the tables 9-1 through 9-4. Results represent an average effect based on the one hundred and twenty simulations conducted for each scenario. Modeling was performed on adults and calves independently and the results were averaged assuming a standard ratio of 70 percent adults to 30 percent juveniles.

Results from NAEMO analyses using both the impulsive bin NEW and the exact source NEW, are provided. Tables 9-1 and 9-3 detail the effects based on the event multipliers defined for Annual while tables 9-2 and 9-4 provide the effects based on the event multipliers defined for seven Year. Because multiple simulations are run and results are averaged, fractional takes can be predicted. Effect predictions of 0.5 or higher are rounded to one to determine the number of takes resulting from these activities.

Table 9-1 Potential Marine Species Exposures for Annual (Impulsive Bin NEW)

Species	*Sum of Behavioral*	*Sum of TTS*	*Sum of PTS*	*Sum of GI Tract Injury*	*Sum of Slight Lung Injury*	*Sum of Mortality*
Bottlenose dolphin northern migratory	38.68	15.19	1.234	0.059	0.0091	0.0039
Bottlenose dolphin NNCES	6.738	3.703	0.063	0	0	0
Bottlenose dolphin SMS	25.856	10.394	0.45	0.071	0	0
Bottlenose dolphin SNCES	0.816	0.7	0.058	0	0	0
Hardshell turtles	381.411	0.13	0.274	0.013	0	0
Kemps Ridley turtle	29.743	0	0	0	0	0
Leatherback turtle	132.088	0	0	0	0	0
Loggerhead turtle	839.71	0.143	0.077	0	0	0
Grand Total	**1455.02**	**30.26**	**2.156**	**0.143**	**0.0091**	**0.0039**

Table 9-2 Potential Marine Species Exposures for Seven Year (Impulsive Bin NEW)

Species	*Sum of Behavioral*	*Sum of TTS*	*Sum of PTS*	*Sum of GI Tract Injury*	*Sum of Slight Lung Injury*	*Sum of Mortality*
Bottlenose dolphin northern migratory	270.769	106.335	8.635	0.416	0.0658	0.0282
Bottlenose dolphin NNCES	47.152	25.935	0.439	0	0	0
Bottlenose dolphin SMS	180.982	72.765	3.148	0.499	0	0
Bottlenose dolphin SNCES	5.711	4.899	0.405	0	0	0
Hardshell turtles	2669.87	0.915	1.916	0.094	0	0
Kemps Ridley turtle	208.194	0	0	0	0	0
Leatherback turtle	924.627	0	0	0	0	0
Loggerhead turtle	5877.977	0.999	0.538	0	0	0
Grand Total	**10185.22**	**211.848**	**15.081**	**1.009**	**0.0658**	**0.0282**

Table 9-3 Potential Marine Species Exposures for Annual (Exact NEW)

Species	*Sum of Behavioral*	*Sum of TTS*	*Sum of PTS*	*Sum of GI Tract Injury*	*Sum of Slight Lung Injury*	*Sum of Mortality*
Bottlenose dolphin NMS	27.594	8.435	1.022	0.04	0.0091	0.0039
Bottlenose dolphin NNCES	5.203	1.964	0.044	0	0	0
Bottlenose dolphin SMS	19.821	4.98	0.392	0.071	0	0
Bottlenose dolphin SNCES	0.617	0.634	0	0	0	0
Hardshell turtles	345.527	0.059	0.287	0	0	0
Kemps Ridley turtle	26.835	0	0	0	0	0
Leatherback turtle	116.854	0	0	0	0	0
Loggerhead turtle	760.503	0.129	0.135	0	0	0
Grand Total	**1302.954**	**16.201**	**1.88**	**0.111**	**0.0091**	**0.0039**

Table 9-4 Potential Marine Species Exposures for Seven Year (Exact NEW)

Species	*Sum of Behavioral*	*Sum of TTS*	*Sum of PTS*	*Sum of GI Tract Injury*	*Sum of Slight Lung Injury*	*Sum of Mortality*
Bottlenose dolphin NMS	193.145	59.044	7.156	0.283	0.0658	0.0282
Bottlenose dolphin NNCES	36.42	13.76	0.306	0	0	0
Bottlenose dolphin SMS	138.737	34.872	2.746	0.499	0	0
Bottlenose dolphin SNCES	4.321	4.443	0	0	0	0
Hardshell turtles	2418.692	0.416	2.01	0	0	0
Kemps Ridley turtle	187.848	0	0	0	0	0
Leatherback turtle	817.96	0	0	0	0	0
Loggerhead turtle	5323.52	0.904	0.943	0	0	0
Grand Total	**9120.643**	**113.439**	**13.161**	**0.782**	**0.0658**	**0.0282**

9.2 Military Expended Materials

Table 9-5 shows the number of each type of MEM that is associated with each alternative of activity for one-year and seven-year timeframes.

Table 9-5 Military Expended Materials for Each Alternative

Ordnance Type	*Annual MEM*	*7 Year MEM*
Bombing Exercise Air-to-Surface (Inert)	**6,000**	**42,000**
Bomb (Non-explosive)	**6,000**	**42,000**
BT-11 Model box	4,500	31,500
BT-9 Model box	1,500	10,500
GUNEX .50 Cal Air-to-Surface (Inert)	**1,768,058**	**12,376,414**

Table 9-5 Military Expended Materials for Each Alternative (Cont'd)

Ordnance Type	*Annual MEM*	*7 Year MEM*
Small Caliber Projectile (Non-Explosive)	**884,029**	**6,188,207**
BT-11 Model box	416,358	2,914,507
BT-9 Model box	467,671	3,273,700
Small Caliber Projectile casings	**884,029**	**6,188,207**
BT-11 Model box	416,358	2,914,507
BT-9 Model box	467,671	3,273,700
GUNEX .50 Cal Surface-to-Surface (Inert)	**218,972**	**1,532,796**
Small Caliber Projectile (Non-Explosive)	**109,486**	**766,398**
BT-11 Model box	8,642	60,493
BT-9 Model box	100,844	705,905
Small Caliber Projectile casings	**109,486**	**766,398**
BT-11 Model box	8,642	60,493
BT-9 Model box	100,844	705,905
GUNEX 30mm BT-9	**6,864**	**48,048**
Medium Caliber Projectile (Explosive)—Fragments	**3,432**	**24,024**
BT-9 Model box	3,432	24,024
Medium Caliber Projectile casings	**3,432**	**24,024**
BT-9 Model box	3,432	24,024
GUNEX 40mm BT-9	**10,420**	**72,940**
Grenade (Explosive)—Fragments	**10,420**	**72,940**
BT-9 Model box	10,420	72,940
GUNEX Large Arm Rounds Surface-to-Surface (Inert)	**721,478**	**5,050,346**
Large Caliber Projectile (Non-Explosive)	**360,739**	**2,525,173**
BT-11 Model box	240,334	1,682,338
BT-9 Model box	120,405	842,835
Large Caliber Projectile casings	**360,739**	**2,525,173**
BT-11 Model box	240,334	1,682,338
BT-9 Model box	120,405	842,835
GUNEX Small Arms Rounds Air-to-Surface (Inert)	**3,313,920**	**23,197,440**
Small Caliber Projectile (Non-Explosive)	**1,656,960**	**11,598,720**
BT-11 Model box	1,224,583	8,572,081
BT-9 Model box	432,377	3,026,639
Small Caliber Projectile casings	**1,656,960**	**11,598,720**
BT-11 Model box	1,224,583	8,572,081
BT-9 Model box	432,377	3,026,639
GUNEX Small Arms Rounds Surface-to-Surface (Inert)	**237,300**	**1,661,100**
Small Caliber Projectile (Non-Explosive)	**118,650**	**830,550**
BT-11 Model box	25,417	177,919

Table 9-5 Military Expended Materials for Each Alternative (Cont'd)

Ordnance Type	*Annual MEM*	*7 Year MEM*
BT9 Model box	93,233	652,631
Small Caliber Projectile casings	**118,650**	**830,550**
BT-11 Model box	25,417	177,919
BT-9 Model box	93,233	652,631
Pyrotechnics Expenditures	**45,648**	**319,536**
Compression pad or plastic piston	**11,412**	**79,884**
BT-11 Model box	8,912	62,384
BT-9 Model box	2,500	17,500
Endcap-Chaff and Flare	**11,412**	**79,884**
BT-11 Model box	8,912	62,384
BT-9 Model box	2,500	17,500
Flare	**11,412**	**79,884**
BT-11 Model box	8,912	62,384
BT-9 Model box	2,500	17,500
Flare O-ring	**11,412**	**79,884**
BT-11 Model box	8,912	62,384
BT-9 Model box	2,500	17,500
Rocket Exercise 2.75 in. BT-9	**220**	**1,540**
Rocket (Explosive)—Fragments	**220**	**1,540**
BT-9 Model box	220	1,540
Rocket Exercise 5 in. BT-9	**68**	**476**
Rocket (Explosive)—Fragments	**68**	**476**
BT-9 Model box	68	476
Rocket Exercise Air-to-Surface (Inert)	**7,094**	**49,658**
Rocket (Non-Explosive)	**7,094**	**49,658**
BT-11 Model box	6,250	43,750
BT-9 Model box	844	5,908
Grand Total	**6,336,042**	**44,352,294**

9.3 Description of Proposed Actions and Alternatives (DOPAA)

The number of times each event occurs within one year and seven years at both Pamlico Sound target areas are shown in Table 9-6. Each source was modeled in a separate event. The number of events was selected to provide the correct annual and seven year ordnance values. The fractions are a byproduct of defining all events based on a mean number of ordnance when in reality there are ranges in numbers.

Table 9-6 Number of Events that Take Place within One Year for Each Alternative

Location	*Annual*	*7 Year*
Bombing Exercise Air-to-Surface (Inert)	**83.333**	**583.333**
BT-11 Model box	62.500	437.500
BT-9 Model box	20.833	145.833
GUNEX .50 Cal Air-to-Surface (Inert)	**147.338**	**1031.368**
BT-11 Model box	69.393	485.751
BT-9 Model box	77.945	545.617
GUNEX .50 Cal Surface-to-Surface (Inert)	**18.248**	**127.733**
BT-11 Model box	1.440	10.082
BT-9 Model box	16.807	117.651
GUNEX 30mm BT-9	**2.288**	**16.016**
BT-9 Model box	2.288	16.016
GUNEX 40mm BT-9	**6.947**	**48.627**
BT-9 Model box	6.947	48.627
GUNEX Large Arm Rounds Surface-to-Surface (Inert)	**120.246**	**841.724**
BT-11 Model box	80.111	560.779
BT-9 Model box	40.135	280.945
GUNEX Small Arms Rounds Air-to-Surface (Inert)	**92.053**	**644.373**
BT-11 Model box	68.032	476.227
BT-9 Model box	24.021	168.147
GUNEX Small Arms Rounds Surface-to-Surface (Inert)	**13.183**	**92.283**
BT-11 Model box	2.824	19.769
BT-9 Model box	10.359	72.515
Pyrotechnics Expenditures	**114.120**	**798.840**
BT-11 Model box	89.120	623.840
BT-9 Model box	25.000	175.000
Rocket Exercise 2.75 in. BT-9	**5.238**	**36.667**
BT-9 Model box	5.238	36.667
Rocket Exercise 5 in. BT-9	**1.619**	**11.333**
BT-9 Model box	1.619	11.333
Rocket Exercise Air-to-Surface (Inert)	**84.452**	**591.167**
BT-11 Model box	74.405	520.833
BT-9 Model box	10.048	70.333

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