Atlantic Fleet Training and Testing (AFTT)

2016 Marine Species Monitoring Annual Report



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Risso's dolphins (*Grampus griseus*). Photographed by Heather Foley, taken under National Marine Fisheries Service Scientific Permit No. 16185 (Duke University).

Matt Balazik (Virginia Commonwealth University) preparing to deploy the 0-m receiver on a loggerhead turtle (*Caretta caretta*) for the detection experiment. Photo courtesy of Virginia Aquarium, taken under National Marine Fisheries Service Scientific Permit No. 16134

Sperm whales (*Physeter macrocephalus*). Photo collected by the University of North Carolina Wilmington under NOAA Scientific Permit # 16473.

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ACRONYMS AND ABBREVIATIONS

AFAST	Atlantic Fleet Active Sonar Training
AFB	Air Force Base
AFTT	Atlantic Fleet Training and Testing
AIC	Akaike's information criterion
AMAPPS	Atlantic Marine Assessment Program for Protected Species
AMAR	Autonomous Multi-channel Acoustic Recorder
AMR	Adaptive Management Review
ARS	Acoustic Reference Source
AUTEC	Atlantic Undersea Test and Evaluation Center
BOEM	Bureau of Ocean Energy Management
BSE	bay, sound, and estuary
BSS	Beaufort sea state
CBBT	Chesapeake Bay Bridge-Tunnel
CI	confidence interval
cm	centimeter(s)
CNO	Chief of Naval Operations
COMPASS	Cetacean Observation and Marine Protected Animal Survey Software
CR	capture-recapture
CRC	Cascadia Research Collective
CREEM	Centre for Research into Ecological and Environmental Monitoring
CTD	conductivity, temperature, and depth
CV	coefficient of variation
dB	decibel(s)
dB re: 1 µPa	decibels referenced to 1 microPascal
DMON	digital acoustic monitoring
DMP	Data Management Plan
DOD	U.S. Department of Defense
DPM	detection-positive minutes
DTAG	digital acoustic tag
EAR	ecological acoustic recorder
EAR2	second generation EAR
EDT	Eastern Daylight Time
EEZ	Exclusive Economic Zone
EIMS	Environmental Information Management System
EPA	Environmental Protection Agency
ESA	Endangered Species Act
EWS	Early Warning System
FACSFAC	Fleet Area Control and Surveillance Facility
FS	Fort Story
FY	Fiscal Year
GIS	Geographic Information System
GOMEX	Gulf of Mexico
GPS	Global Positioning System
HARP	high-frequency acoustic recording package
HMM	hidden Markov model
hr	hour(s)
Hz	hertz
ICMP	Integrated Comprehensive Monitoring Program
ITS	Incidental Take Statement
JAX	Jacksonville (Florida)
JEB	Joint Expeditionary Base
JLOTS	Joint Logistics Over The Shore
kg	kilogram(s)
kHz	kilohertz
km	kilometer(s)
km^2	square kilometer(s)
LC	Little Creek
LFA	low-frequency active
LFDCS	low-frequency detection and classification system

LIMPET	Low-Impact Minimally Percutaneous External-electronics Transmitter
LMR	Living Marine Resources
LOA	Letter of Authorization
LTSA	long-term spectral averages
m	meter(s)
m/sec	meter(s)/second
M3R	Marine Mammal Monitoring on Navy Ranges
MABDC	Mid-Atlantic Bottlenose Dolphin Catalog
MAHWC	Mid-Atlantic Humpback Whale Photo-ID Catalog
MARU	Marine Autonomous Recording Unit
MFA	mid-frequency active
microMARS	miniature Marine Autonomous Recorder System
min	minute(s)
MINEX	Mine-neutralization Exercise
MMC	Marine Mammal Commission
MMPA	Marine Mammal Protection Act
MSM	Marine Species Monitoring
N45	Energy and Environmental Readiness Division
NAHWC	North Atlantic Humpback Whale Catalog
NAS	Naval Air Station
NAVFAC	Naval Facilities Engineering Command
NEFSC	Northeast Fisheries Science Center
NMFS	National Marine Fisheries Services
NMSDD	Navy Marine Species Density Database
NOAA	National Oceanic and Atmospheric Administration
NSN	Naval Station Norfolk
NSWC-PCD	Naval Surface Warfare Center, Panama City Division
OBIS-SEAMAP	Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations
ONR	Office of Naval Research
OPAREA	Operating Area
PAM	passive acoustic monitoring
PCAD	Population Consequences of Acoustic Disturbance
photo-ID	photo-identification
POP	persistent organic pollutant(s)
QC	quality control
RFA	relative foraging area(s)
RMS	Root Mean Squared
ROCCA	Real-time Odontocete Call Classification Algorithm
R/V	Research Vessel
SD	standard deviation
sec	second(s)
SEFSC	Southeast Fisheries Science Center
SNR	signal-to-noise ratio
SPL	sound pressure level
SPOT	Smart Position and Temperature
SSSM	switching state-space model
TPM	transition probability matrix
U.S.	United States
UNCW	University of North Carolina Wilmington
UNDET	underwater detonation
USWTR	Undersea Warfare Training Range
VACAPES	Virginia Capes
VAQF	Virginia Aquarium Foundation
VA WEA	Virginia Wind Energy Area
WMD	whistle and moan detector

SECTION 1 – INTRODUCTION

This report contains a summary of marine species monitoring activities funded by the United States (U.S.) Navy within the Atlantic Fleet Training and Testing (AFTT) Study Area during 2016. The U.S. Navy conducts marine mammal and sea turtle monitoring for compliance with the Letters of Authorization (NMFS 2013a, 2013b) and Biological Opinion (NMFS 2013c) issued under the Marine Mammal Protection Act of 1972 (MMPA) and the Endangered Species Act of 1973 (ESA) for training and testing in the AFTT Study Area. This report also reflects an evolution in the approach to monitoring reports for this area. Concurrent with Phase II of the U.S. Navy's Marine Species Monitoring (MSM) Program, the U.S. Navy and the National Marine Fisheries Service (NMFS) have agreed to assess compliance based on demonstrated progress towards addressing scientific objectives, rather than on specific monitoring requirements for each range complex from effort-based metrics. This report summarizes the progress, accomplishments, and results from projects currently conducted in the AFTT Study Area. Additional details on each project are available in individual technical reports linked directly from the corresponding sub-section of this report.

1.1 Background

The AFTT Study Area includes only the at-sea components of the range complexes and testing ranges in the western North Atlantic Ocean and encompasses the east coast of North America and the Gulf of Mexico (**Figure 1**). The Study Area covers approximately 2.6 million square nautical miles of ocean area, and includes designated U.S. Navy operating areas (OPAREAs) and special use airspace. The Study Area also includes several U.S. Navy testing ranges and range complexes, as well as Narragansett Bay, lower Chesapeake Bay, St. Andrew Bay, and pierside locations where sonar maintenance and testing occurs.

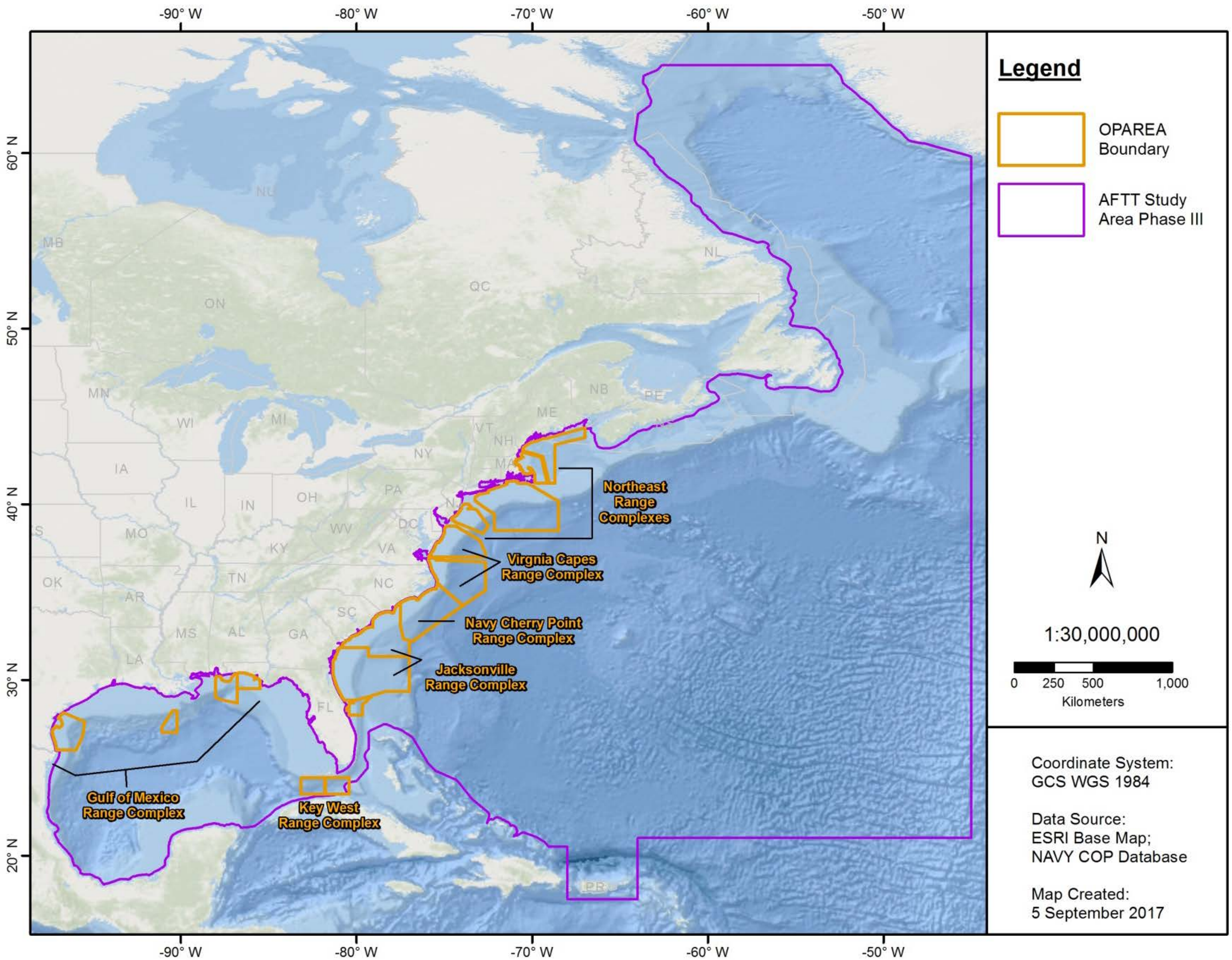

Figure 1. AFTT Study Area.

In order to issue an Incidental Take Statement (ITS) for an activity that has the potential to affect protected marine species, NMFS must set forth "requirements pertaining to the monitoring and reporting of such taking" (50 Code of Federal Regulations § 216.101(a)(5)(a)). A request for a Letter of Authorization (LOA) must include a plan to meet the necessary monitoring and reporting requirements, while increasing the understanding, and minimizing the disturbance, of marine mammal and sea turtle populations expected to be present. While the ESA does not have a specific monitoring requirement, the Biological Opinion issued in November 2013 by NMFS for the AFTT Study Area includes terms and conditions for continued monitoring in this region (NMFS 2013c).

The U.S. Navy previously submitted annual monitoring and mission activities reports for AFTT as well as for the Atlantic Fleet Active Sonar Training (AFAST) and the East Coast/Gulf of Mexico (GOMEX) Range Complexes to NMFS for 2009 through 2015 (DoN 2009, 2010a, 2010b, 2010c, 2010d, 2010e, 2011a, 2011b, 2011c, 2011d, 2012a, 2012b, 2012c, 2012d; 2013a, 2013b, 2014a, 2014b, 2014c, 2015a, 2015b, 2016a, 2016b).

The U.S. Navy has invested over $26 million (**Table 1**) in monitoring activities in the AFTT Study Area since 2009. Additional information on the program is available on the U.S. Navy's MSM program website (http://www.navymarinespeciesmonitoring.us). The website serves as an online portal for information on the background, history, and progress of the program, and it also provides access to reports, documentation, data, and updates on current monitoring projects and initiatives.

Table 1. Annual funding for the U.S. Navy's MSM program in the AFTT Study Area (formerly AFAST and East Coast/GOMEX Range Complexes) during FY09–FY16.

Fiscal Year (01 Oct–30 Sept)	Funding Amount
FY09	$1,555,000
FY10	$3,768,000
FY11	$2,749,000
FY12	$3,483,000
FY13	$3,775,000
FY14	$3,311,000
FY15	$3,700,000
FY16	$3,845,000
Total	**$26,186,000**

Key: FY = Fiscal Year

In addition to the Fleet-funded monitoring program, the Office of Naval Research (ONR) Marine Mammals and Biology Program and the Office of the Chief of Naval Operations (CNO) Energy and Environmental Readiness Division's (N45) Living Marine Resources (LMR) Program support coordinated Science & Technology and Research & Development focused on understanding the effects of sound on marine mammals, including physiological, behavioral, ecological, and population-level effects (DoN 2010f). These programs currently fund several significant ongoing projects relative to potential operational impacts to marine mammals within some U.S. Navy range complexes. Additional information on these programs and other ocean resource-oriented initiatives can be found at the U.S. Navy's Green Fleet – Energy, Environment, and Climate Change website.

1.2 Integrated Comprehensive Monitoring Program

The Integrated Comprehensive Monitoring Program (ICMP) provides the overarching framework for coordination of the U.S. Navy's marine species monitoring efforts (DoN 2010g) and serves as a planning tool to focus U.S. Navy monitoring priorities pursuant to ESA and MMPA requirements. The purpose of the ICMP is to coordinate monitoring efforts across all regions and to allocate the most appropriate level and type of monitoring effort for each range complex based on a set of standardized objectives, regional expertise, and resource availability. Although the ICMP does not identify specific monitoring or field projects, it provides a flexible, scalable, and adaptable framework for such projects using adaptive-management and strategic-planning processes that periodically assess progress and reevaluate objectives.

The ICMP is evaluated through the Adaptive Management Review (AMR) process to: (1) assess progress, (2) provide a matrix of goals and objectives for the following year, and (3) make recommendations for refinement and analysis of the monitoring and mitigation techniques. This process includes conducting an annual AMR meeting at which the U.S. Navy and NMFS jointly consider the prior-year goals, monitoring results, and related scientific advances to determine if monitoring plan modifications are warranted to more effectively address program goals. Modifications to the ICMP that result from AMR discussions are incorporated by an addendum or revision to the ICMP. As a planning tool, the ICMP will be routinely updated as the program evolves and progresses. The most significant addition in 2013/2014 was the development of the Strategic Planning Process (DoN 2013d), which serves to guide the investment of resources to most efficiently address ICMP objectives and intermediate scientific objectives developed through this process. More details on the Strategic Planning Process are provided in **Section 4**.

Under the ICMP, U.S. Navy-funded monitoring relating to the effects of U.S. Navy training and testing activities on protected marine species should be designed to accomplish one or more top-level goals as described in the current version of the ICMP (DoN 2010g):

(a) An increase in an understanding of the likely occurrence of marine mammals and/or ESA-listed marine species in the vicinity of the action (i.e., presence, abundance, distribution, and/or density of species).

(b) An increase in an understanding of the nature, scope, or context of the likely exposure of marine mammals and/or ESA-listed species to any of the potential stressors associated with the action (e.g., sound, explosive detonation, or expended materials), through better understanding of one or more of the following: (1) the nature of the action and its surrounding environment (e.g., sound-source characterization, propagation, and ambient noise levels); (2) the affected species (e.g., life history or dive patterns); (3) the likely co-occurrence of marine mammals and/or ESA-listed marine species with the action (in whole or part); and/or (4) the likely biological or behavioral context of exposure to the stressor for the marine mammal and/or ESA-listed marine species (e.g., age class of exposed animals or known pupping, calving, or feeding areas).

(c) An increase in our understanding of how individual marine mammals or ESA-listed marine animals respond (behaviorally or physiologically) to the specific stressors associated with the action (in specific contexts, where possible, e.g., at what distance or received level).

(d) An increase in our understanding of how anticipated individual responses, to individual stressors or anticipated combinations of stressors, may impact either: (1) the long-term fitness and survival of an individual; or (2) the population, species, or stock (e.g., through effects on annual rates of recruitment or survival).

(e) An increase in our understanding of the effectiveness of mitigation and monitoring measures, including increasing the probability of detecting marine mammals to better achieve the above goals (through improved technology or methods), both generally and more specifically within the safety zone (thus allowing for more effective implementation of the mitigation). Improved detection technology will be rigorously and scientifically validated prior to being proposed for mitigation, and should meet practicality considerations (engineering, logistic, and fiscal).

(f) A better understanding and record of the manner in which the authorized entity complies with the Incidental Take Authorization and Incidental Take Statement.

CNO-N45 is responsible for maintaining and updating the ICMP, as necessary, reflecting the results of regulatory agency rulemaking, AMRs, best available science, improved assessment methods, and more effective protective measures. This is done as part of the AMR process, in consultation with U.S. Navy technical experts, Fleet Commanders, and Echelon II Commands as appropriate.

1.3 Report Objectives

This report presents the progress, accomplishments, and results of marine species monitoring activities in the AFTT Study Area in 2016 and has two primary objectives:

1. Summarize findings from the U.S. Navy-funded marine mammal and sea turtle monitoring conducted in the AFTT Study Area during 2016, as well as analyses of monitoring data performed during this time period. Detailed technical reports for these efforts are referenced throughout this report and provided as supporting documents.
2. Continue the AMR process by providing an overview of monitoring initiatives, progress, and evolution of the ICMP and Strategic Planning Process for U.S. Navy marine species monitoring. These initiatives continue to shape the evolution of the U.S. Navy MSM program for 2017 and beyond to improve our understanding of the occurrence and distribution of marine mammals and sea turtles in the AFTT Study Area and their exposure and response to sonar and explosives training and testing activities.

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SECTION 2 – MARINE SPECIES MONITORING ACTIVITIES

2.1 Occurrence, Distribution, and Population Structure

In 2005, the U.S. Navy contracted with a consortium of researchers from Duke University, the University of North Carolina Wilmington (UNCW), the University of St. Andrews, and NMFS's Northeast Fisheries Science Center (NEFSC) to conduct a pilot study and subsequently develop a survey and monitoring plan. The plan included a recommended approach for data collection at the proposed site of the Undersea Warfare Training Range (USWTR) in Onslow Bay off the coast of North Carolina. The identified methods included surveys (aerial/shipboard, frequency, spatial extent, etc.), passive acoustic monitoring (PAM), photo-identification (photo-ID), and data analysis (e.g., standard line-transect, spatial modeling) appropriate to establish a fine-scale seasonal baseline of protected marine species distribution and abundance. As a result, a protected marine species monitoring program was initiated in June 2007 in Onslow Bay. Due to a re-evaluation of the proposed location for USWTR, the preferred location was changed to the Jacksonville Operating Area (JAX OPAREA). Therefore, a parallel monitoring program was initiated in January 2009 at the proposed USWTR site in the JAX OPAREA off the coast of Jacksonville, Florida. In addition to supporting the Jacksonville USWTR site monitoring, the program was also refined to support the monitoring requirements set forth in the Incidental Take Statements and Terms and Conditions for AFAST and the East Coast Range Complexes issued in 2009. In 2011, the program expanded beyond the previous Onslow Bay focus site to include a region of U.S. Navy training activity off the coast of Cape Hatteras to the north. This study area also serves to complement a pilot whale behavioral study initiated in that region at the same time. The overall approach to program design and methods has been consistent with the work that had been performed over the previous seven years, and work across the locations continues to evolve in response to the AMR process and changing priorities.

Although the initial intent of the Onslow Bay and JAX monitoring programs was to support development of the planned USWTR, the program evolved into established long-term study sites addressing intermediate scientific objectives within the ICMP framework for AFTT. The monitoring work at these sites provides a longitudinal baseline of data on marine species occurrence, distribution, abundance, and behavior in key U.S. Navy training areas and serves as a reference for addressing questions concerning exposure, response, and consequences.

In 2016, the longitudinal baseline study consisted of year-round multi-disciplinary monitoring through the use of aerial and vessel-based visual surveys, photo-ID, biopsy sampling, and PAM with high-frequency acoustic recording packages (HARPs). Monthly visual surveys were conducted year-round (weather permitting) using established tracklines and standard Distance-sampling techniques. A summary of accomplishments and basic results of these monitoring efforts for the reporting period is presented in the following subsections.

All previous annual reports on this component of the baseline monitoring program are available through the U.S. Navy's MSM program web portal (http://www.navymarinespeciesmonitoring.us/).

2.1.1 Visual Baseline Aerial Surveys

Visual aerial surveys were conducted at five study sites in the AFTT Study Area in 2016. All aerial surveys were flown along established tracklines using line-transect aerial survey designs and standard Distance-sampling protocols. During the current reporting period (January 2016–December 2016), surveys were conducted in both the offshore and nearshore waters of the Virginia Capes (VACAPES) OPAREA (**Sections 2.1.1.1 and 2.1.1.2,** respectively) and offshore waters of the Cherry Point and Jacksonville OPAREAs (**Sections 2.1.1.3 and 2.1.1.4**, respectively). Additionally, aerial surveys were conducted in Chesapeake Bay waters near Naval Air Station (NAS) Patuxent River (**Section 2.1.1.5**). Offshore aerial survey tracklines for the long-term Cherry Point/VACAPES OPAREAs (i.e., Norfolk Canyon and Cape Hatteras sites) and Jacksonville OPAREA are depicted in **Figures 2 through 4**, respectively.

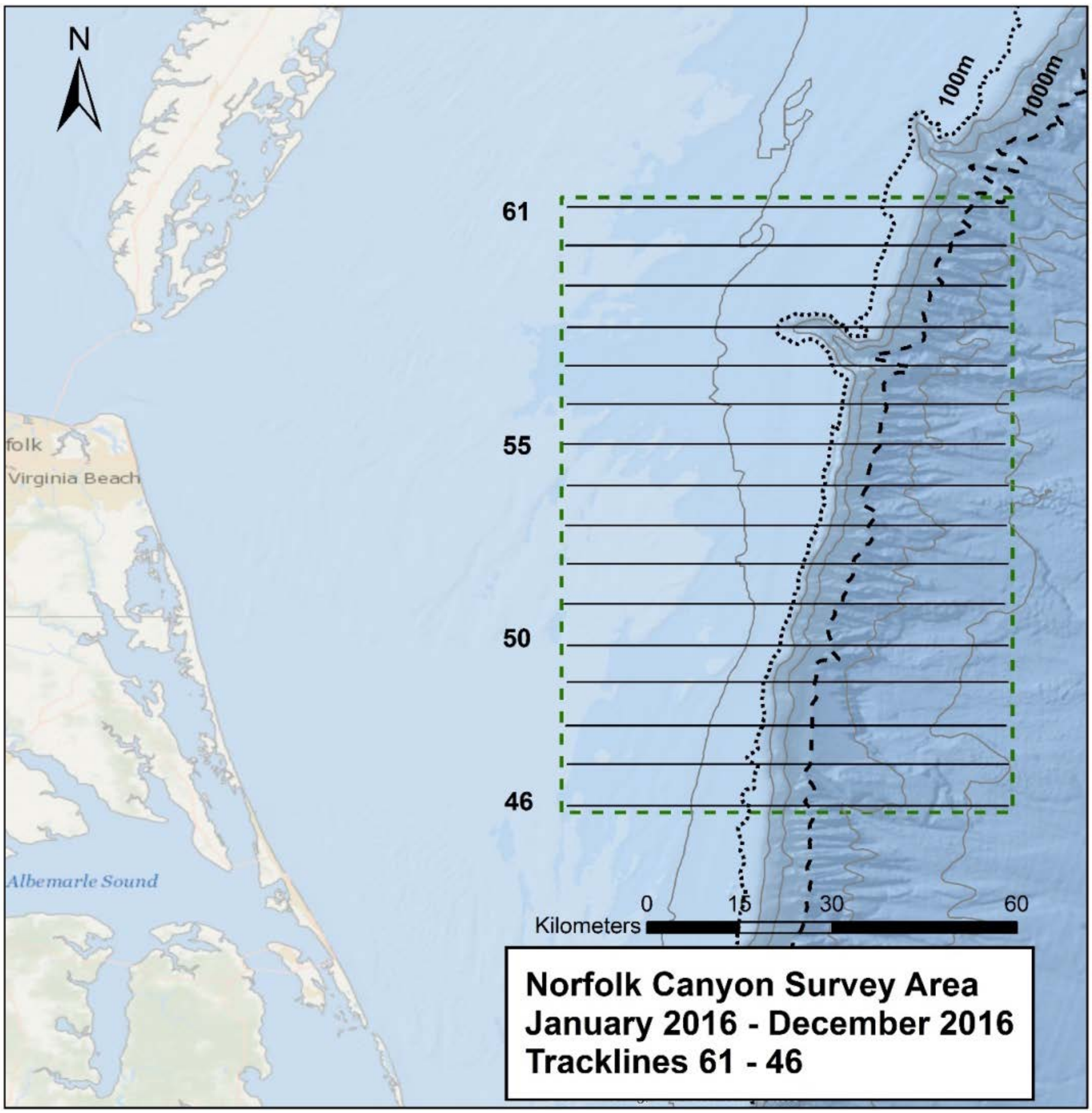


Figure 2. Norfolk Canyon survey area and aerial tracklines for 2016.

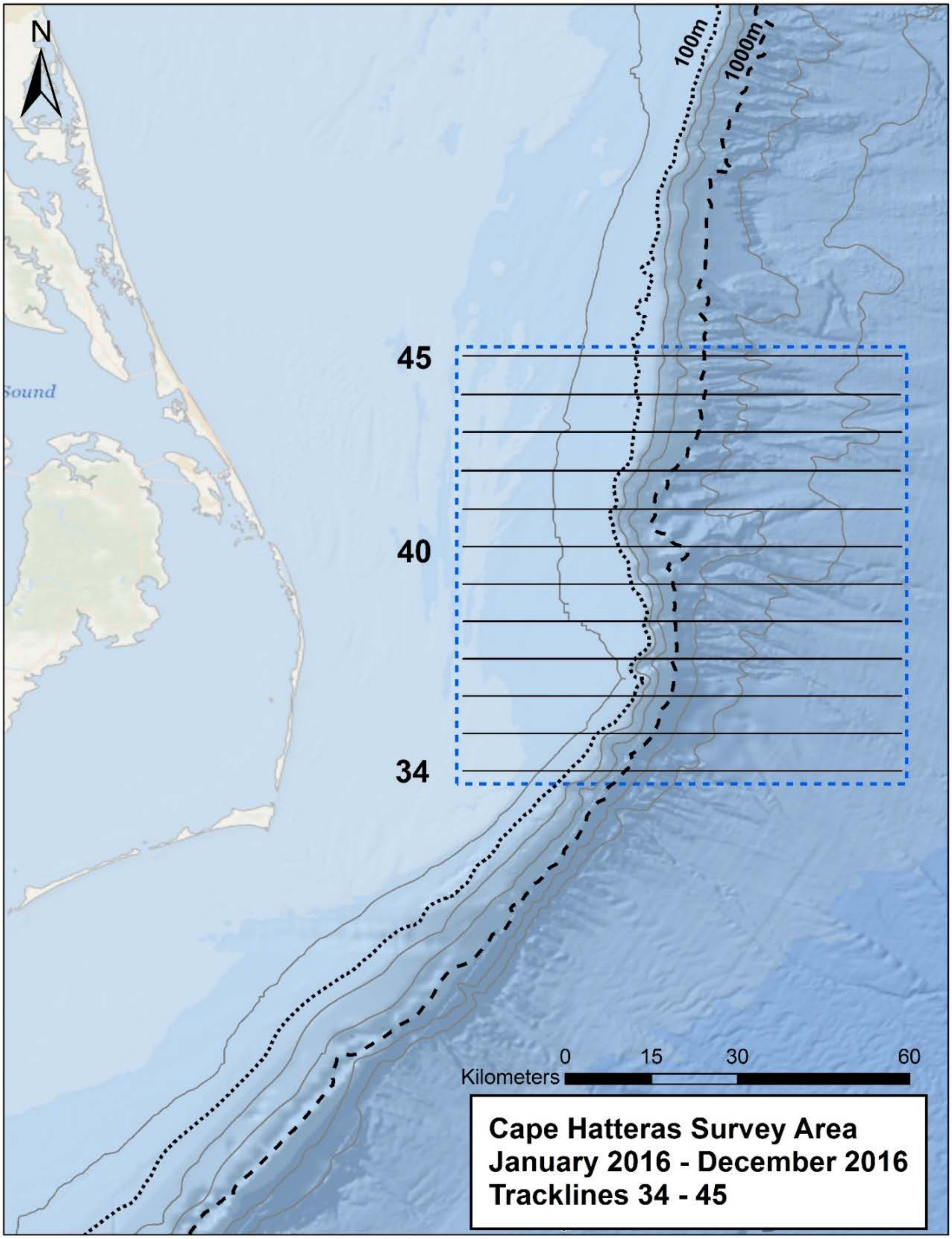


Figure 3. Cape Hatteras survey area and aerial tracklines for 2016.

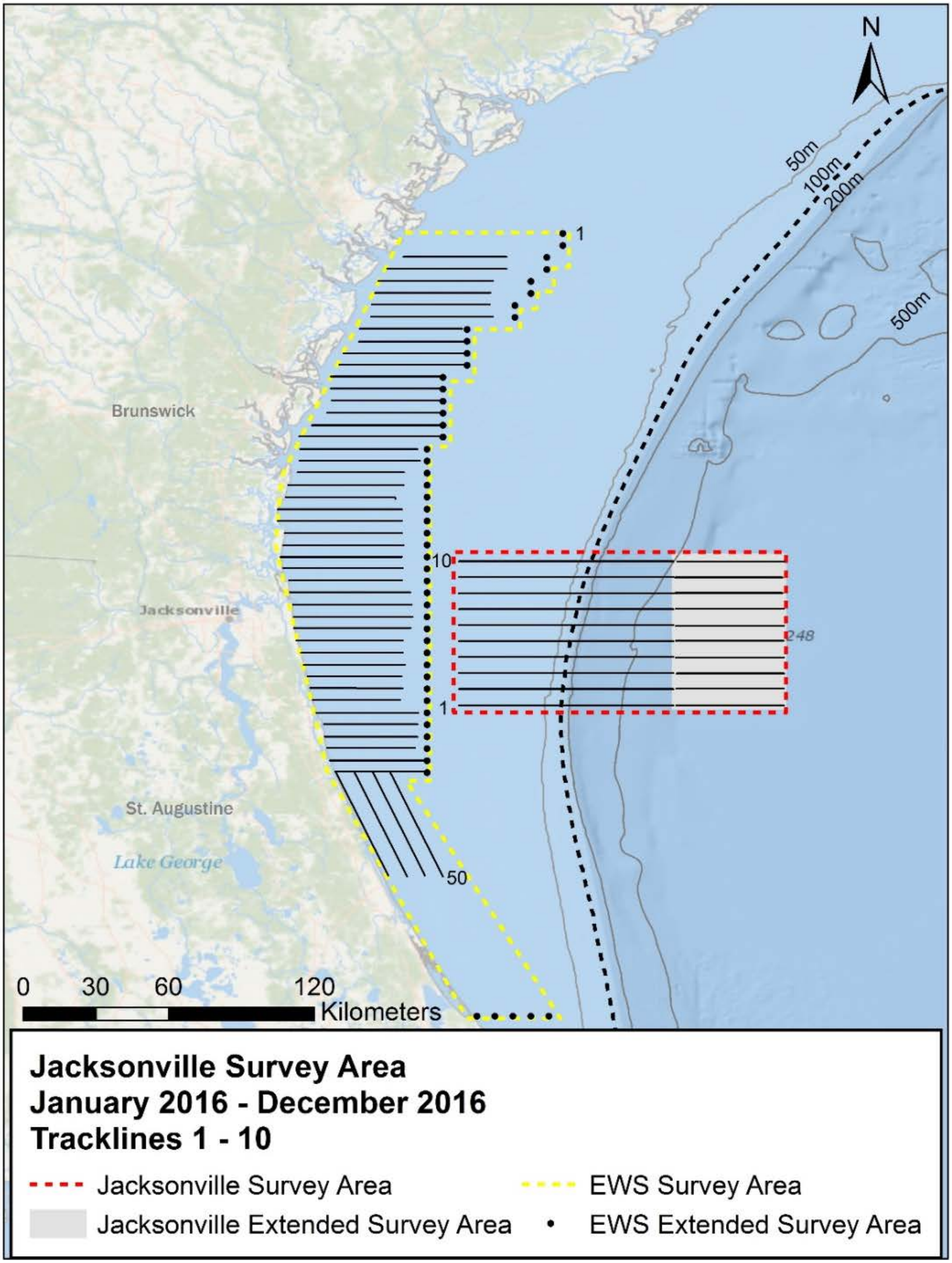


Figure 4. Jacksonville survey area and aerial tracklines for 2016.

2.1.1.1 Norfolk Canyon Study Area Offshore Aerial Surveys

Aerial survey efforts were initiated in the waters off Cape Hatteras, North Carolina, in May 2011 to assess the distribution and abundance of offshore cetacean species and sea turtles in this highly productive area. Beginning in 2015, the survey area was extended north following the shelf break to include the Norfolk Canyon region (**Figure 2**). In 2016, the Cape Hatteras survey area and the Norfolk Canyon survey areas were designated as unique entities. The Norfolk Canyon survey area is covered by 16 tracklines (#46–61) (**Figure 2**). This expansion resulted in a greater portion of the survey area falling within the airspace of the U.S. Navy's Fleet Area Control and Surveillance Facility (FACSFAC) in VACAPES. The Norfolk Canyon survey area overlaps the VACAPES OPAREA.

A total of 99 tracklines (7,089.25 kilometers [km]) over 18 days was covered in the Norfolk Canyon survey area (**Table 2**). Survey effort occurred in all 12 months. At least 2 survey days were achieved for 5 of the 12 months (February, May, July, August, and October). A full day of effort occurred in March and December. Partial effort was conducted in January, April, June, September, and November. Survey conditions during the 18 days ranged from Beaufort sea state (BSS) 1 to 6 with greater than 70 percent of effort in sea states of BSS 3 or lower. The majority of cetacean sightings (94.3 percent) occurred in BSS 3 or less. Cetacean sighting rates decreased as BSS increased, with 44.54 sightings/1,000 km surveyed in BSS 1, 33.04 sightings/1,000 km in BSS 2, 9.41 sightings/1,000 km in BSS 3, and 6.56 sightings/1,000 km in BSS 4. Sighting rates per month ranged from zero to 35.58/1,000 km. Sighting rate was highest in May, with 31 sightings recorded over 12 tracklines.

Table 2. Effort summary for aerial surveys conducted in the Norfolk Canyon survey area in 2016.

Month	Number of Survey Days	Tracklines Covered	Total km Flown	Total hr Underway*
January	1	4	290.50	2.4
February	2	8	586.90	4.7
March	1	6	418.55	5.6
April	1	4	283.95	3.3
May	2	12	864.80	10.6
June	1	4	291.95	2.4
July	2	17	1,183.7	14.1
August	3	16	1,157.30	12.6
September		4	294.45	2.5
October	2	12	847.25	9.5
November	1	4	289.40	3.3
December	1	8	580.50	6.4
Total	**18**	**99**	**7,089.25**	**77.4**

* Total hours (hr) underway reported as Hobbs hr = total engine time

A total of on-effort 122 sightings of 4,434 individual cetaceans representing 13 species was recorded (**Table 3, Figure 5**), including fin whale (*Balaenoptera physalus*; eight sightings of 11 individuals), humpback whale (*Megaptera novaeangliae*; two sightings of five individuals); minke whale (*Balaenoptera acutorostrata*; 1 sighting of 1 individual), bottlenose dolphin (*Tursiops truncatus*; 29 sightings of 701 individuals), short-finned pilot whale (*Globicephala macrorhynchus*; two sightings of 366 individuals), Cuvier's beaked whale (*Ziphius cavirostris*; one sighting of two individuals), Atlantic spotted dolphin (*Stenella frontalis*; 10 sightings of 298 individuals), unidentified beaked whales (*Mesoplodon* sp.; one sighting of three individuals), short-beaked common dolphin (*Delphinus delphis*; 21 sightings of 2,444 individuals), sperm whale (*Physeter macrocephalus*; six sightings of 11 individuals), Clymene dolphin (*Stenella clymene,* 1 sighting of 20 individuals), Risso's dolphin (*Grampus griseus*; eight sightings of 194 individuals), and striped dolphin (*Stenella coeruleoalba,* one sighting of 350 individuals).

Table 3. Sightings from aerial surveys conducted in the Norfolk Canyon survey area in 2016. On- and off-effort sightings are represented by #/# (on-/off-effort sightings).

Common Name	Scientific Name	Number of Sightings	Number of Individuals
Minke whale	*Balaenoptera acutorostrata*	1/0	1/0
Fin whale	*Balaenoptera physalus*	8/2	11/2
Humpback whale	*Megaptera novaeangliae*	2/3	5/5
Short-beaked common dolphin	*Delphinus delphis*	21/0	2,444/0
Risso's dolphin	*Grampus griseus*	8/0	194/0
Short-finned pilot whale	*Globicephala macrorhynchus*	26/8	366/92
Unidentified beaked whale	*Mesoplodon* sp.	1/1	3/4
Sperm whale	*Physeter macrocephalus*	6/0	11/0
Clymene dolphin	*Stenella clymene*	1/0	350/0
Striped dolphin	*Stenella coeruleoalba*	1/0	350/0
Atlantic spotted dolphin	*Stenella frontalis*	10/0	298/0
Bottlenose dolphin	*Tursiops truncatus*	29/2	701/78
Cuvier's beaked whale	*Ziphius cavirostris*	1/1	2/2
Unidentified delphinid		7/0	28/0
Loggerhead turtle	*Caretta caretta*	96/0	146/0
Leatherback turtle	*Dermochelys coriacea*	10/0	10/0
Unidentified shark		9/0	11/0
Manta ray	*Manta birostris*	18/0	21/0
Cownose ray	*Rhinoptera bonasus*	24/0	42,920/0
Ocean sunfish	*Mola mola*	28/0	33/0

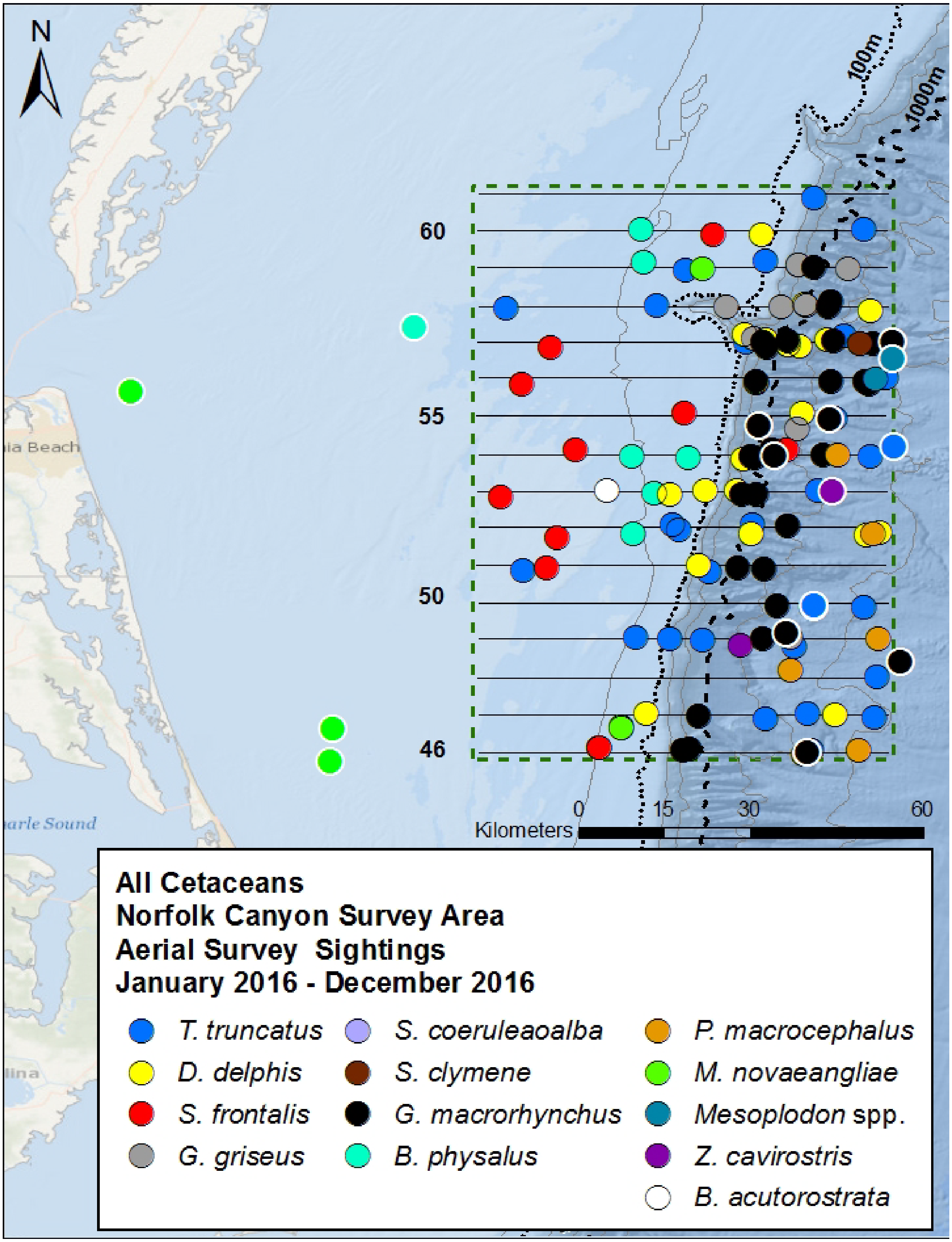


Figure 5. Cetacean sightings during aerial surveys in the Norfolk Canyon survey area in 2016. Off-effort sightings are identified by the white circles.

Fourteen off-effort sightings were recorded: fin whale (two sightings of two individuals), humpback whale (three sightings of five individuals), bottlenose dolphin (two sightings of 78 individuals) short-finned pilot whale (eight sightings of 93 individuals), Cuvier's beaked whale (one sighting of two individuals), unidentified beaked whales (one sighting of four individuals). A sighting was considered off-effort if it occurred while transiting to or from the survey area or during a cross-leg between tracklines. Any cetaceans that the survey team encountered while investigating a separate sighting cue were also labeled off-effort. If two species were seen associated with the same sighting cue both were considered to be on effort. The off-effort sightings are included in the tables and maps for each species but are excluded from any calculations.

There were 106 on-effort sightings of 156 individual sea turtles during the reporting period (**Table 3, Figure 6**). Loggerhead turtles (*Caretta caretta*) represented the majority (94 percent) of total sea turtles sighted. The vast majority of loggerhead turtle sightings were over the continental shelf inshore of the 100-meter (m) isobath. The only other sea turtle species identified in the Cape Hatteras and Norfolk Canyon survey areas was the leatherback turtle (*Dermochelys coriacea*; 6.4 percent of total sea turtles sighted). Leatherback turtles were observed in the northern portion of the Norfolk Canyon survey area, from the inshore waters to seaward of the 1,000-m isobath. Sighting rates were negatively correlated with BSS, with rates sharply declining at >BSS 2. Ninety percent of all sea turtle sightings occurred in the months of July and August.

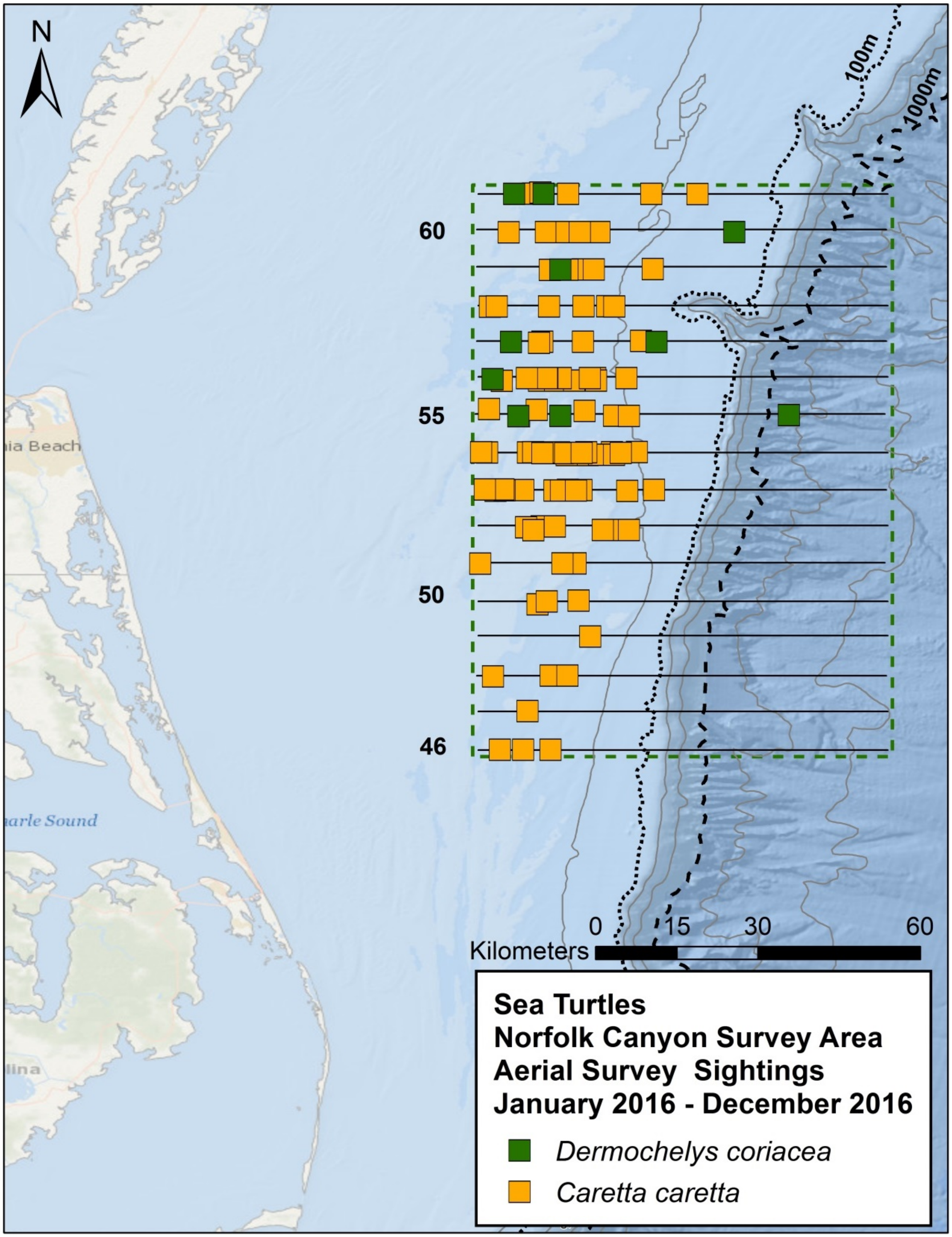


Figure 6. Sea turtle sightings during aerial surveys in the Norfolk Canyon survey area in 2016.

In addition to cetaceans and sea turtles, other pelagic marine vertebrates were observed (**Table 3, Figure 7**). Eleven sharks were recorded during the reporting period, largely inshore of the 1,000-m isobath. Seven of the 11 sharks could be identified as hammerhead sharks (*Sphyrna* sp.) based on head shape, but no sightings could be identified to species, therefore, they are combined here with unidentified sharks. Two species of rays were identified to species: manta rays (*Manta birostris; n*=21) and cownose rays (*Rhinoptera bonasus*; *n*=42,920). In addition, 33 ocean sunfish (*Mola mola*) were recorded, with the majority found inshore of the 100-m isobath.

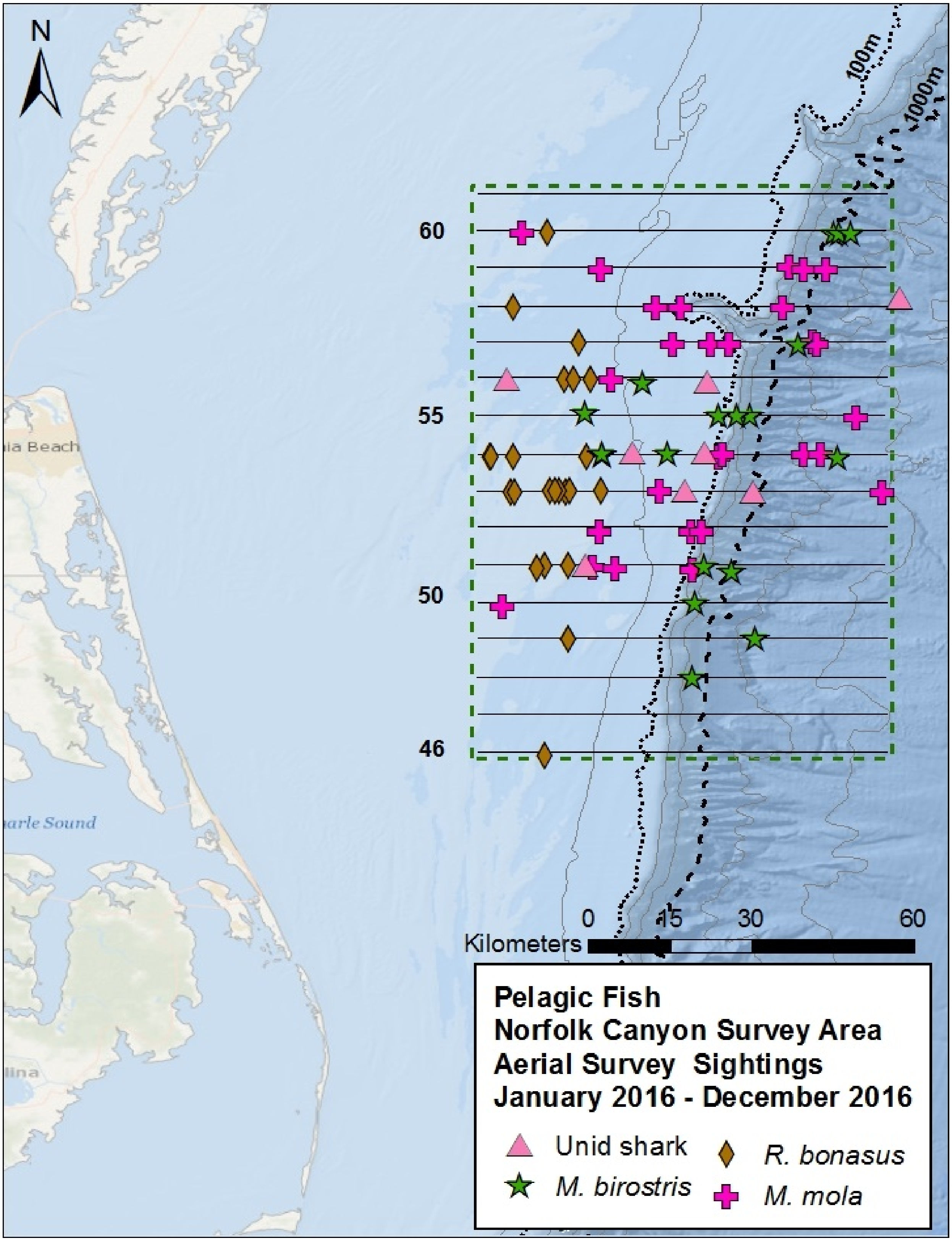


Figure 7. Pelagic fish sightings during aerial surveys in the Norfolk Canyon survey area in 2016.

For more information on this study, refer to the annual progress report for this project (McAlarney et al. 2017).

2.1.1.2 VACAPES Nearshore Aerial Surveys

The Virginia Aquarium & Marine Science Center Foundation, Inc. (VAQF) is tasked to conduct aerial surveys for the continental shelf region off the mouth of the Chesapeake Bay within the VACAPES OPAREA. The survey site includes an approximately 6,500-square kilometer (km^2) area off the coast of Virginia Beach. The current aerial surveys build upon previous survey efforts funded by Virginia Coastal Zone Management Program to document large whale occurrence in the vicinity of the Virginia Wind Energy Area (VA WEA) and contribute to regional mid-Atlantic ocean planning efforts. VAQF in collaboration with UNCW conducted line-transect aerial surveys from 2012 through 2016, although surveys were not flown every month or with consistent effort between years (Mallette et al. 2014, 2016). The U.S. Navy's MSM program funded the continuation of these surveys that began in early 2016.

A modified design for coordinated inshore (VAQF) and offshore (UNCW) aerial surveys was developed, based upon recommendations from the Centre for Research into Ecological and Environmental Modeling (CREEM) and discussions with UNCW and the U.S. Navy. CREEM advised periodic overlap of the survey areas between the offshore and coastal transect lines to calibrate for survey origin difference and to integrate data between sites. Eighteen survey days were planned, with two per month in November–April when large whale presence was thought to be highest in the area, and one per month in May–October. The plan was for one overlapping survey in each quarter or season, with the remainder non-overlapping. Two survey designs were established (**Figure 8**):

1. *Overlap*: the eastern ends of all transect lines overlapped 10 km with the western ends of the offshore lines (the white area in **Figure 8**), and
2. *No Overlap (truncated)*: transect lines did not overlap with the offshore transect lines (i.e., the eastern end of the coastal lines terminated at the longitude of the western end of the offshore lines).

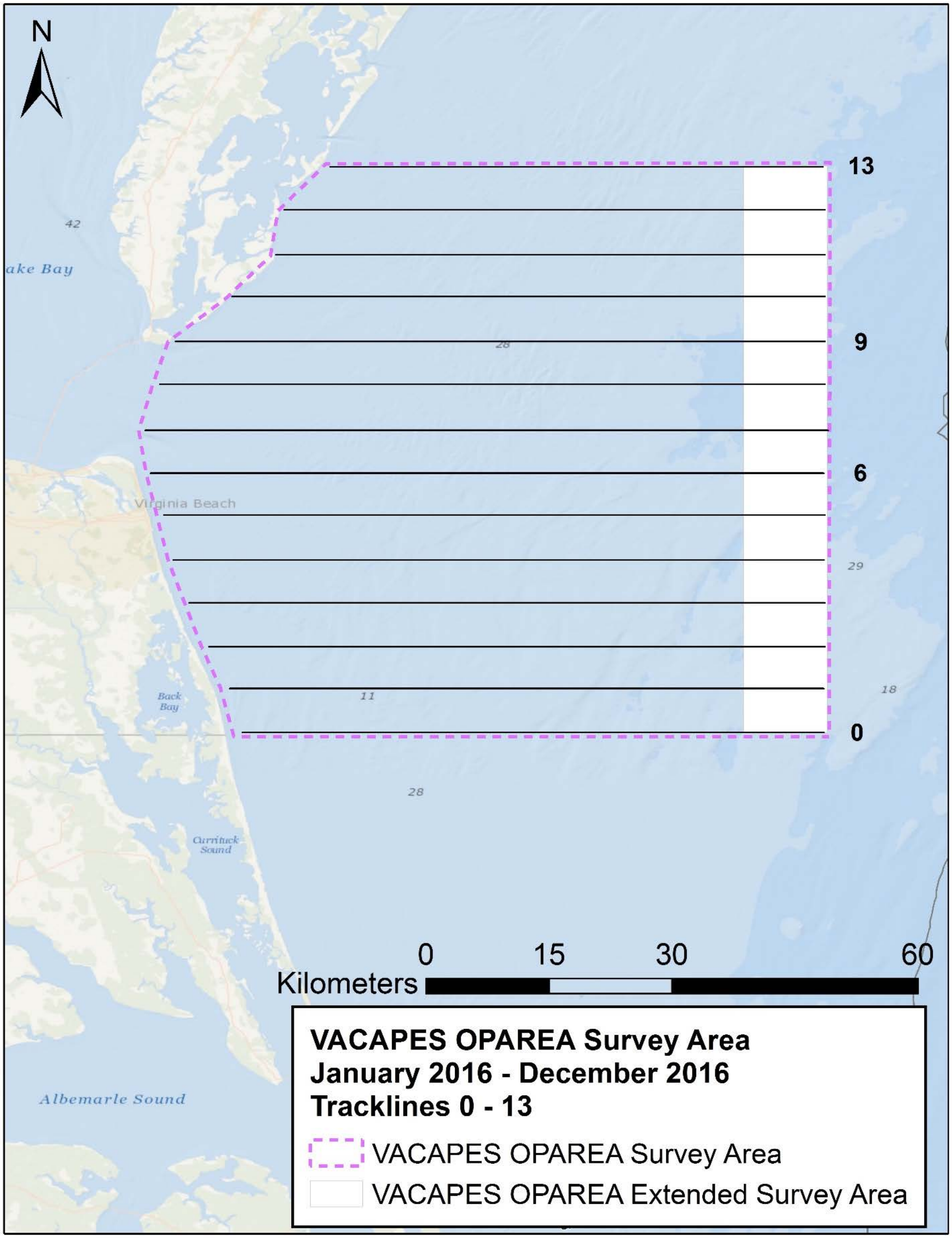


Figure 8. VACAPES nearshore survey area and aerial tracklines for 2016.

A total of 18 survey days were conducted covering 175.5 tracklines (11,923 km) in the VACAPES nearshore survey area in 2016 (**Table 4**). Survey effort occurred in each month of 2016. As previously mentioned, to achieve the allocated 18 survey days, two surveys per month were planned for November–April. One and a half to two survey days were achieved in five of the 12 months, with single days of effort occurring in May through November. The central portion of the survey area was given preference. Broader survey coverage was reduced in some cases to focus on supporting vessel surveys being conducted by HDR off the mouth of Chesapeake Bay, while at other times reduced survey coverage was due to operational airspace restrictions.

Table 4. Effort summary for aerial surveys conducted in the VACAPES nearshore survey area in 2016.

Month	Number of Survey Days	Tracklines Covered	Total km Flown	Total hr Underway*
January	2	12	780.11	5.5
February	2	24	1,530.80	10.6
March	2	20	1,516.10	13.6
April	2	20	1,289.40	9.9
May	1	8	574.95	5.0
June	1	11	748.20	6.0
July	1	14	881.60	7.1
August	1	14	894.10	6.5
September	1	12	688.60	5.2
October	1	10	740.20	5.6
November	1	6	460.80	3.0
December	3	26	1,818.30	14.8
Total	**18**	**175**	**11,923.16**	**92.8**

* Total hours (hr) underway reported as Hobbs hr = total engine time.

Conditions during the 18 survey days ranged from BSS 1 to BSS 4 with approximately 93 percent of effort in BSS 3 or lower. All cetacean sightings occurred in a BSS 3 or lower. Cetacean sighting rates decreased in sea states higher than BSS 2, with 8.97 sightings/1,000 km in BSS 1, 15.35 sightings/1,000 km in BSS 2, 4.18 sightings/1,000 km in BSS 3, and 0.00 sightings/1,000 km in BSS 4. Sighting rates per month ranged from 1.74/1,000 km to 31.00/1,000 km. Sighting rate was highest in March; with 47 sightings recorded over 1,515.1 km and 20 transect lines.

A total of 109 on-effort sightings of 1,848 individual cetaceans, representing six species, was recorded (**Table 5, Figure 9**), including fin whale (one sighting of two individuals), North Atlantic right whale (*Eubalaena glacialis,* two sightings of two individuals), humpback whale (two sightings of two individuals), short-beaked common dolphin (three sightings of 14 individuals), Atlantic spotted dolphin (two sightings of 155 individuals), and bottlenose dolphin (99 sightings of 1,673 individuals). Thirty-one off-effort sightings were recorded: humpback whale (five sightings of six individuals), unidentified balaenopterid (one sighting of one individual), Atlantic spotted dolphin (one sighting of 125 individuals), and bottlenose dolphin (24 sightings of 124 individuals). The off-effort sightings are included in the tables and maps for each species, but excluded from any calculations.

Table 5. Sightings from aerial surveys conducted in the VACAPES nearshore survey area in 2016. On- and off-effort sightings are represented by #/# (on-/off-effort sightings).

Common Name	Scientific Name	Number of Sightings	Number of Individuals
Fin whale	*Balaenoptera physalus*	1/0	2/0
North Atlantic right whale	*Eubalaena glacialis*	2/0	2/0
Humpback whale	*Megaptera novaeangliae*	2/5	2/6
Unidentified balaenopterid		0/1	0/1
Short-beaked common dolphin	*Delphinus delphis*	3/0	14/0
Atlantic spotted dolphin	*Stenella frontalis*	2/1	155/125
Bottlenose dolphin	*Tursiops truncatus*	99/24	1,673/124
Loggerhead turtle	*Caretta caretta*	282/4	313/4
Leatherback turtle	*Dermochelys coriacea*	10/2	11/2
Unidentified sea turtle		38/0	38/0
Unidentified shark		37/0	78/0
Manta ray	*Manta birostris*	2/0	2/0
Cownose ray	*Rhinoptera bonasus*	57/3	3,595/350
Ocean sunfish	*Mola mola*	3/0	3/0
Cobia	*Rachycentron canadum*	1/0	2/0

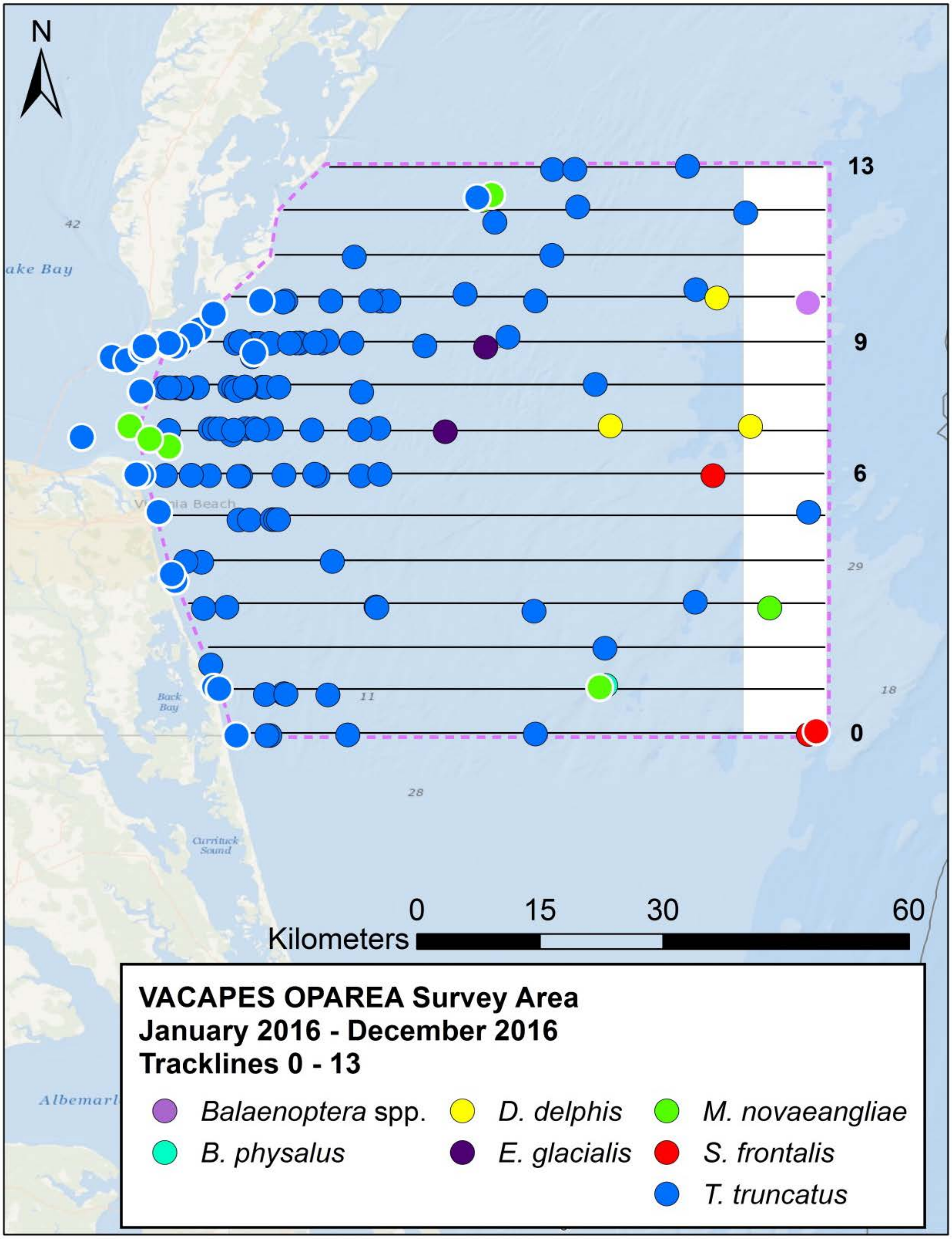


Figure 9. Cetacean sightings during aerial surveys conducted in the VACAPES nearshore survey area in 2016. Off-effort sightings are identified by the white circles.

There were 330 on-effort sightings of 362 individual sea turtles during the reporting period (**Table 5, Figure 10**). Loggerhead turtles represented the majority (86 percent) of total sea turtles sighted. The only other sea turtle species identified in VACAPES nearshore waters was the leatherback turtle (3 percent of total sea turtles sighted). Species identification for the remaining turtle sightings could not be established, and these were listed as "unidentified sea turtle." There were four off-effort sightings of loggerhead turtles (of four individuals) and two (of two individuals) of leatherback turtles. Sea turtles were detected during six of the 12 months surveyed, with the highest numbers of sightings in June. Sighting rates were negatively correlated with BSS, with rates sharply declining at > BSS 2.

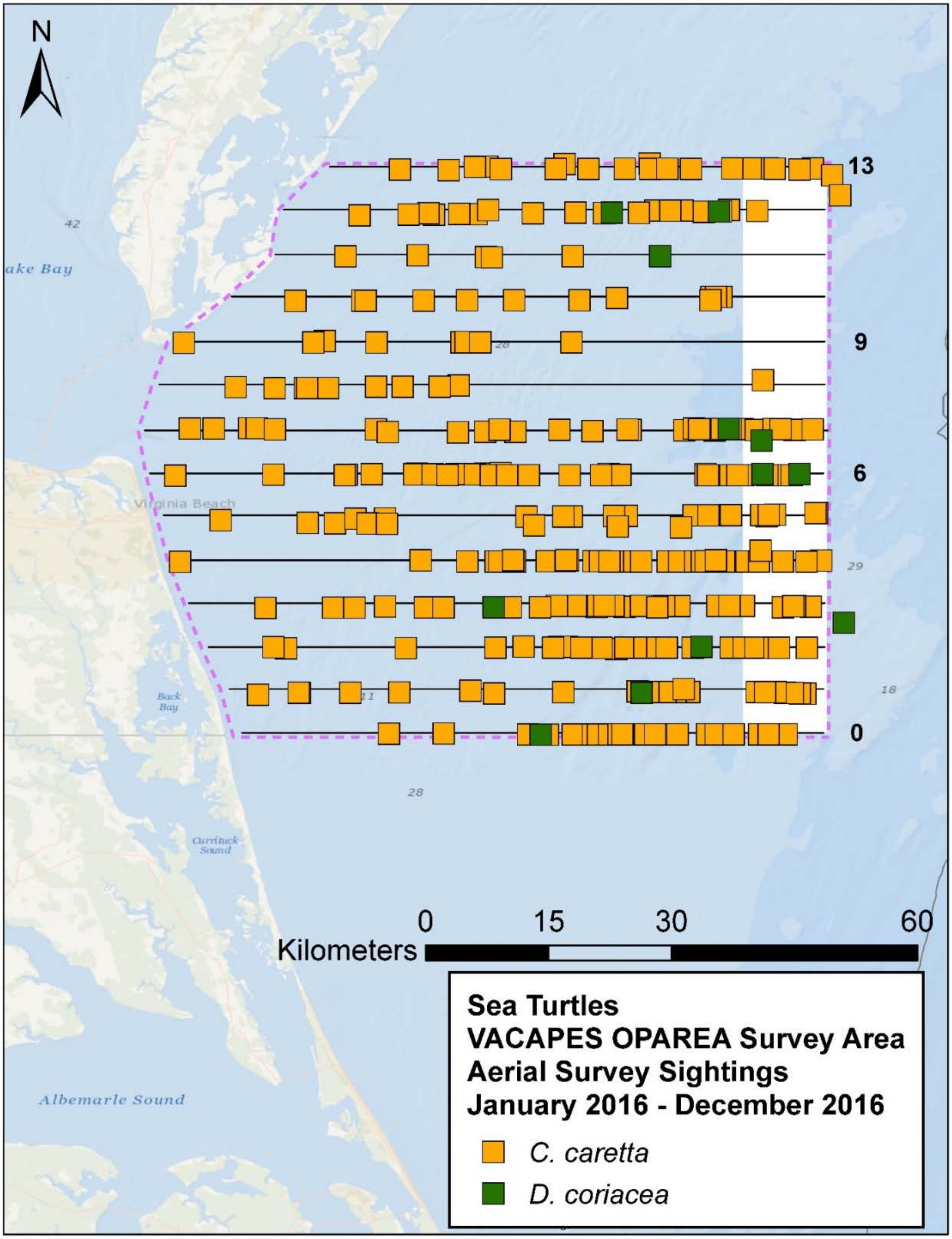


Figure 10. Sea turtle sightings during aerial surveys in the VACAPES nearshore survey area in 2016.

In addition to cetaceans and sea turtles, other pelagic marine vertebrates were observed (**Table 5**, **Figure 11**). Thirty-six sightings of unidentified sharks, totaling 78 individuals, were recorded during the reporting period. Seven of the 78 sharks recorded as unidentified could be identified as hammerhead sharks based on head shape, but since none of these sightings could be identified to species they were recorded as unidentified sharks. Two species of rays were identified, including two sightings of single manta rays and 57 sightings of cownose rays, totaling 3,525 individuals. In addition, three ocean sunfish were recorded. Two cobia (*Rachycentron canadum*) were observed underneath a loggerhead turtle. The survey team circled to identify the species of sea turtle and confirm the species of animals beneath the turtle. VAQF fisheries staff confirmed the fish species as cobia from the images collected during the sighting.

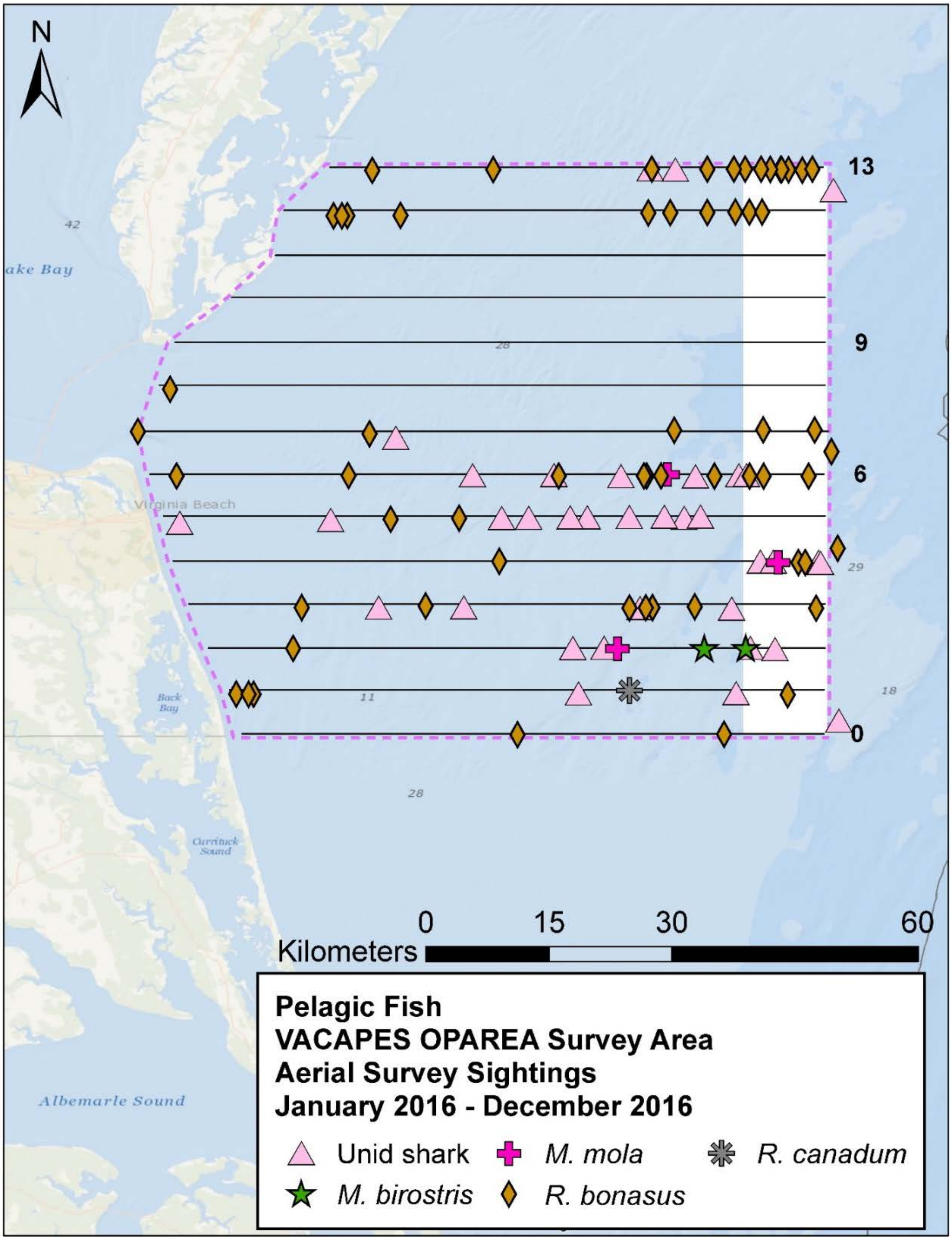


Figure 11. Pelagic fish sightings during aerial surveys in the VACAPES nearshore survey area in 2016.

For more information on this study, refer to the annual progress report for this project (Mallette et al. 2017).

2.1.1.3 Hatteras Study Area Offshore Aerial Surveys

Aerial survey efforts were initiated in the waters off Cape Hatteras, North Carolina, in May 2011 to assess the distribution and abundance of offshore cetacean species and sea turtles in this highly productive area. Fifteen days of survey effort covering 89 tracklines (6.140 km) were conducted in the Cape Hatteras survey area in 2016. Survey effort occurred in eight of 12 months (**Table 6**); directed effort at the Norfolk Canyon survey area and unfavorable weather precluded effort in January, February, April, and December. Two survey days were achieved for six of the eight months, with a single day of effort occurring in June and October.

Table 6. Effort summary for aerial surveys conducted in the Hatteras survey area in 2016.

Month	Number of Survey Days	Tracklines Covered	Total km Flown	Total hr Underway*
January	0	0	0	0
February	0	0	0	0
March	2	12	871.1	8.9
April	0	0	0	0
May	3	17	968.2	12.4
June	1	4	296.95	2.5
July	2	12	873.35	11.2
August	2	12	862.8	9.2
September	2	12	883.85	8.4
October	1	8	506.00	5.4
November	2	12	877.75	8.7
December	0	0	0	0
Total	**15**	**89**	**6,140.0**	**66.7**

* Total hours (hr) underway reported as Hobbs hr = total engine time

Conditions during the 15 survey days ranged from BSS 1 to BSS 6 with nearly 65 percent of effort in sea states of BSS 3 or lower. The majority of cetacean sightings (83 percent) also occurred in BSS 3 or less. Cetacean sighting rates decreased as BSS increased, with 53.12 sightings/1,000 km surveyed in BSS 1, 31.62 sightings/1,000 km in BSS 2, 20.89 sightings/1,000 km in BSS 3, 13.16 sightings/1,000 km in BSS 4, and 3.63 sightings/1,000 km in BSS 5. Sighting rates per month ranged from 3.37 to 30.99 sightings/ 1,000 km, with the highest sighting rate in May, when 17 tracklines were completed.

A total of 126 on-effort sightings of 7,696 individual cetaceans representing 13 species was recorded (**Table 7, Figure 12**), including fin whale (three sightings of three individuals), humpback whale (one sighting of one individual); short-beaked common dolphin (four sightings of 4,565 individuals), Risso's dolphin (two sightings of five individuals), short-finned pilot whale (31 sightings of 999 individuals), *Kogia* sp. (one sighting of seven individuals), Gervais' beaked whale (*Mesoplodon europaeus*; two sightings of 14 individuals), unidentified beaked whales (one sighting of two individuals), sperm whale (three sightings of four individuals), Clymene dolphin (two sightings of 385 individuals, Atlantic spotted dolphin (seven sightings of 376 individuals), bottlenose dolphin (58 sightings of 1,296 individuals), Cuvier's beaked whale (nine sightings of 18 individuals), and unidentified delphinid (two sightings of 21 individuals). Four off-effort sightings were recorded: humpback whale (one sighting of one individual), short-finned pilot whale (one sighting of 10 individuals), Risso's dolphin (one sighting of one individual), and Atlantic spotted dolphin (one sighting of 40 individuals). The off-effort sightings are included in the tables and maps for each species, but are excluded from any calculations.

Table 7. Sightings from aerial surveys conducted in the Cape Hatteras survey area in 2016. On- and off-effort sightings are represented by #/# (on-/off-effort sightings).

Common Name	Scientific Name	Number of Sightings	Number of Individuals
Fin whale	*Balaenoptera physalus*	3/0	3/0
Humpback whale	*Megaptera novaeangliae*	1/1	1/1
Short-beaked common dolphin	*Delphinus delphis*	4/0	4,565/0
Risso's dolphin	*Grampus griseus*	2/1	5/1
Short-finned pilot whale	*Globicephala macrorhynchus*	31/1	999/10
Pygmy/dwarf sperm whale	*Kogia* sp.	1/0	7/0
Gervais' beaked whale	*Mesoplodon europaeus*	2/0	14/0
Unidentified beaked whale	*Mesoplodon* sp.	1/0	2/0
Sperm whale	*Physeter macrocephalus*	3/0	4/0
Clymene dolphin	*Stenella clymene*	2/0	385/0
Atlantic spotted dolphin	*Stenella frontalis*	7/1	376/40
Bottlenose dolphin	*Tursiops truncatus*	58/0	1,296/0
Cuvier's beaked whale	*Ziphius cavirostris*	9/0	18/0
Unidentified delphinid		2/0	21/0
Loggerhead turtle	*Caretta caretta*	45/0	46/0
Leatherback turtle	*Dermochelys coriacea*	3/0	3/0
Unidentified sea turtle		1/0	1/0
Unidentified shark		14/	384/
Manta ray	*Manta birostris*	21/0	31/0
Cownose ray	*Rhinoptera bonasus*	1/0	900/0
Ocean sunfish	*Mola mola*	14/0	16/0

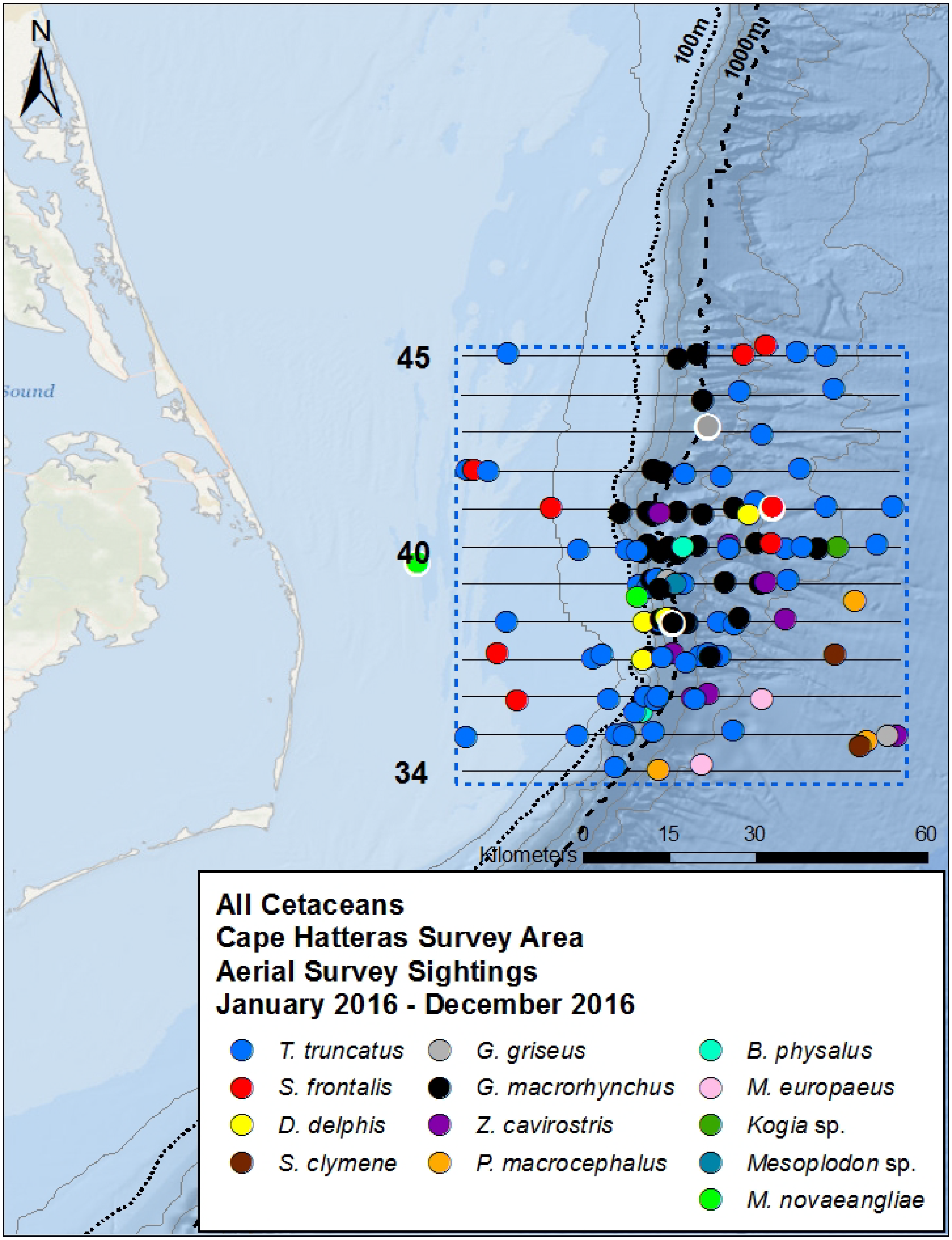


Figure 12. Cetacean sightings during aerial surveys in the Cape Hatteras survey area in 2016. Off-effort sightings are identified by the white circles.

There were 49 on-effort sightings of 50 individual sea turtles during the reporting period (**Table 7, Figure 13**). The highest number of sea turtles was in August. Loggerhead turtles represented the majority (92 percent) of total sea turtles sighted. The vast majority of loggerhead turtle sightings were over the continental shelf inshore of the 1,000-m isobath. The only other sea turtle species identified in the Cape Hatteras survey area was the leatherback turtle (6 percent of total sea turtles sighted). Leatherback turtles were observed in the northern portion of the Norfolk Canyon survey area, from the inshore waters to seaward of the 1,000-m isobath. Sighting rates were negatively correlated with BSS, with rates sharply declining at >BSS 2.

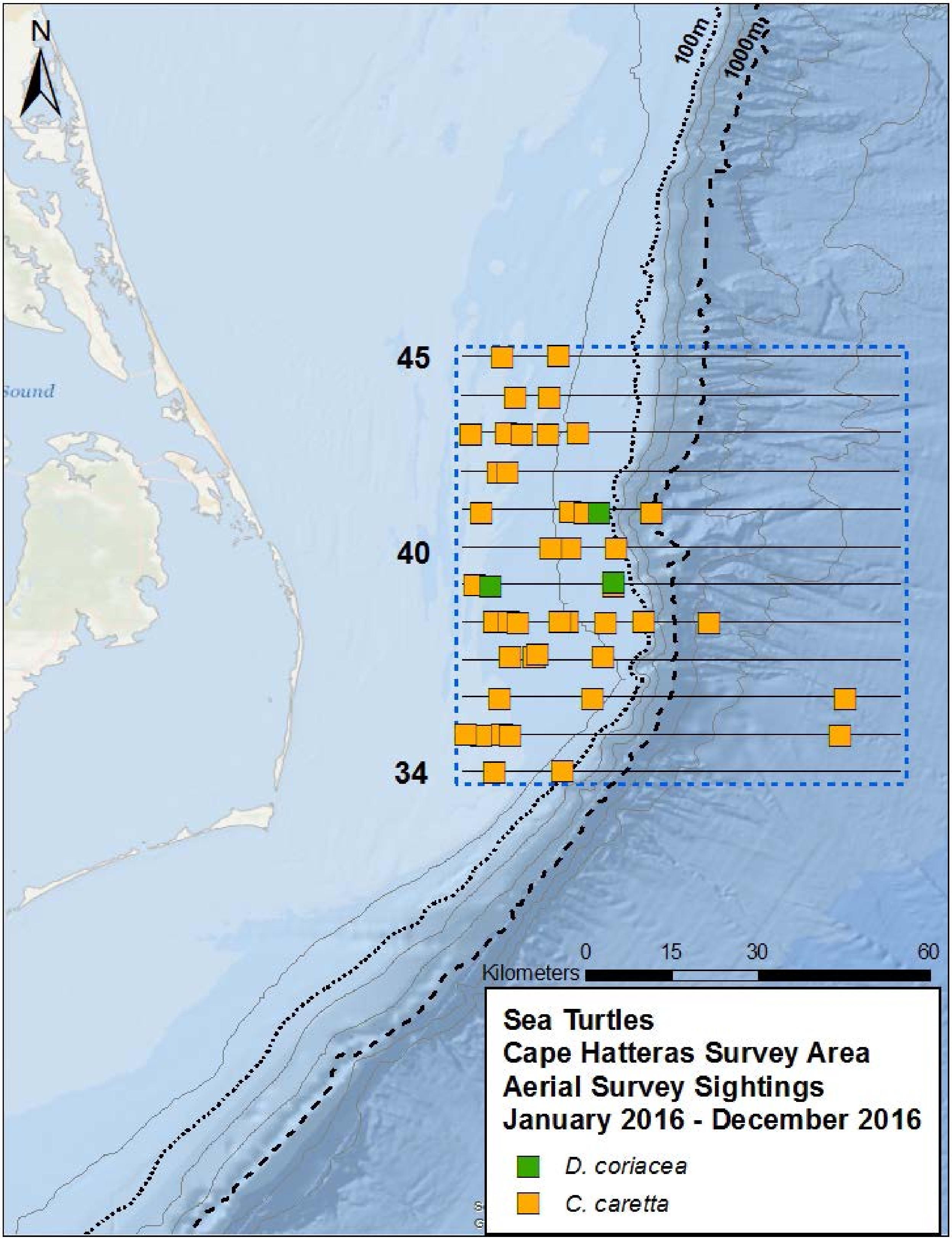


Figure 13. Sea turtle sightings during aerial surveys in the Cape Hatteras survey area in 2016.

In addition to cetaceans and sea turtles, other pelagic marine vertebrates were observed (**Table 7**, **Figure 14**). There were 14 sightings of sharks, for a total of 384 individuals, recorded during the reporting period, largely inshore of the 1,000-m isobath. Of the 384 sharks, 211 could be identified as hammerhead sharks based on head shape, but since none of these sightings could be identified to species they are combined here with unidentified sharks. Two species of rays were identified: manta rays (*n*=31) and cownose rays (*n*=900). In addition, 16 ocean sunfish were recorded.

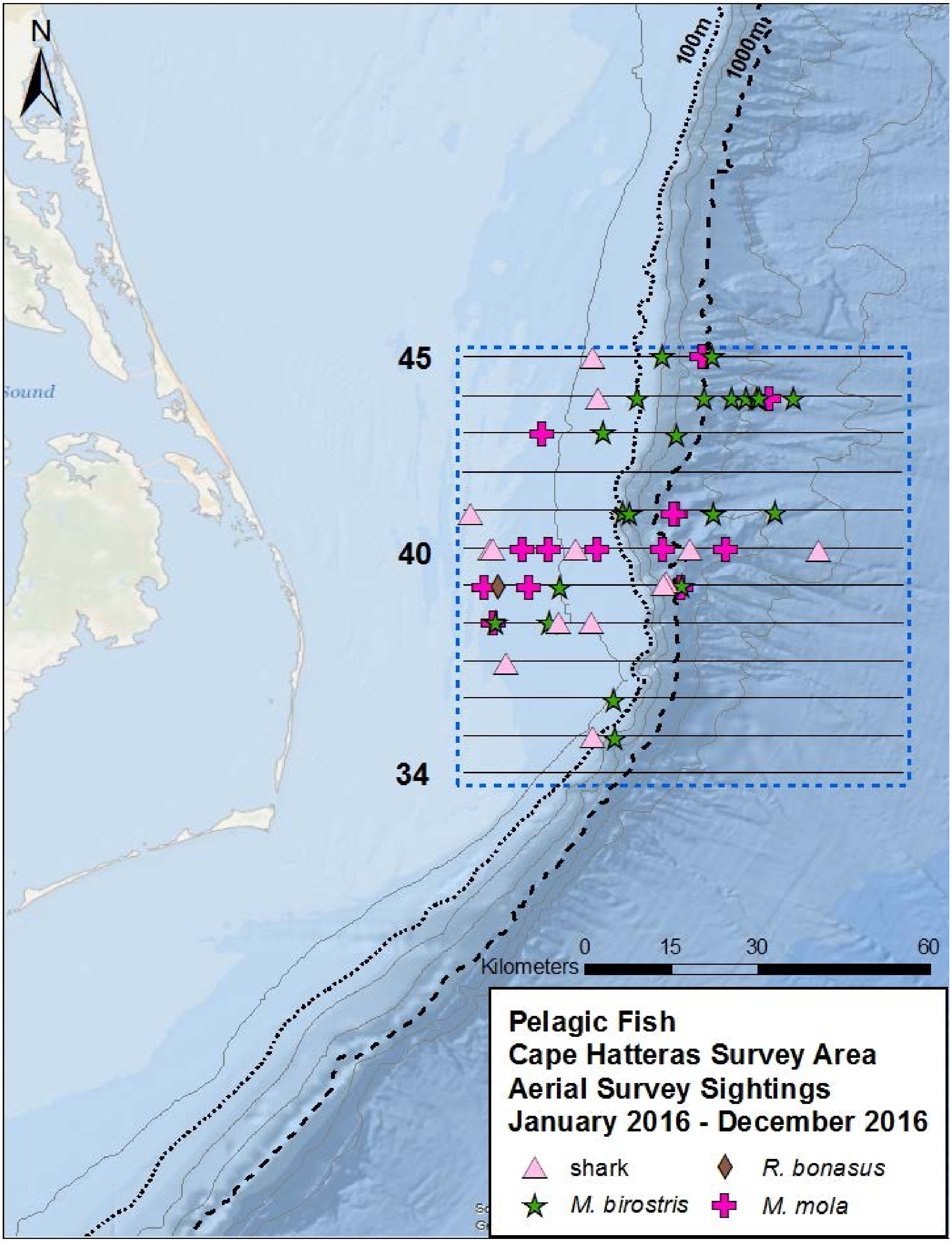


Figure 14. Pelagic fish sightings during aerial surveys in the Cape Hatteras survey area in 2016.

For more information on this study, refer to the annual progress report for this project (Cummings et al. 2017a).

2.1.1.4 Jacksonville Study Area Offshore Aerial Surveys

Aerial survey efforts were initiated in the Jacksonville OPAREA in 2011 to assess the distribution and abundance of offshore cetaceans in the region of the planned USWTR. The goal for 2016 was to conduct two days of survey effort each month between January and May. Effort was then shifted to participate in the U.S. Navy's Full Ship Shock Trials from May through October. Therefore, survey effort here only reflects that which was conducted during a five-month period from January through May 2016.

Researchers from UNCW conducted seven days of aerial survey effort covering 56 tracklines and approximately 4,112 km (**Table 8**) at the planned USWTR site within the Jacksonville OPAREA in 2016. Survey conditions ranged from BSS 0 to BSS 6, with the majority of the surveys flown in BSS 3 (39 percent).

Table 8. Effort summary for aerial surveys conducted in the JAX survey area, January 2016–May 2016.

Month	Number of Survey Days	Tracklines Covered	Total km Flown	Total hr Underway*
January	2	10	837.2	7.7
February	1	10	858.8	6.7
March	2	20	1,295.0	10.8
April	0	0	0	0
May	2	16	1,120.9	10.3
Total	**7**	**56**	**4,111.9**	**35.5**

* Total hours (hr) underway reported as Hobbs hr = total engine time

A total of 22 on-effort sightings of 287 cetaceans was recorded while on-effort in the JAX survey area (**Table 9, Figure 15**). Cetacean sighting rates dropped off dramatically at >BSS 2. Sighting rates dropped from 53.12/1,000 km to 13.16 sightings/1,000 km as BSS 1 increased to BSS 4. This year, despite the low amount of effort in BSS 5, three sightings were recorded. Four species of cetaceans were observed while on effort, including: bottlenose dolphin (15 sightings of 129 individuals), Atlantic spotted dolphin (four sightings of 99 individuals), rough-toothed dolphin (*Steno bredanensis*; one sighting of 50 individuals), and Risso's dolphin (one sighting of eight individuals). Identification to species could not be determined for one sighting of one delphinid. Four off-effort sightings were recorded: bottlenose dolphin (three sightings of 38 individuals) and short-finned pilot whale (one sighting of eight individuals).

Table 9. Sightings from aerial surveys conducted in the JAX survey area in 2016. On- and off-effort sightings are represented by #/# (on-/off-effort sightings).

Common Name	Scientific Name	Number of Sightings	Number of Individuals
Risso's dolphin	*Grampus griseus*	1/0	8/0
Short-finned pilot whale	*Globicephala macrorhynchus*	0/1	0/8
Rough-toothed dolphin	*Steno bredanensis*	1/0	50/0
Atlantic spotted dolphin	*Stenella frontalis*	4/0	99/0
Bottlenose dolphin	*Tursiops truncatus*	15/3	129/38
Unidentified delphinid		1/0	1/0
Loggerhead turtle	*Caretta caretta*	90/0	108/0
Leatherback turtle	*Dermochelys coriacea*	6/0	6/0
Unidentified turtle		2/0	2/0
Unidentified shark		11/0	12/0
Manta ray	*Manta birostris*	5/0	5/0
Unidentified ray		1/0	45/0
Ocean sunfish	*Mola mola*	6/0	6/0

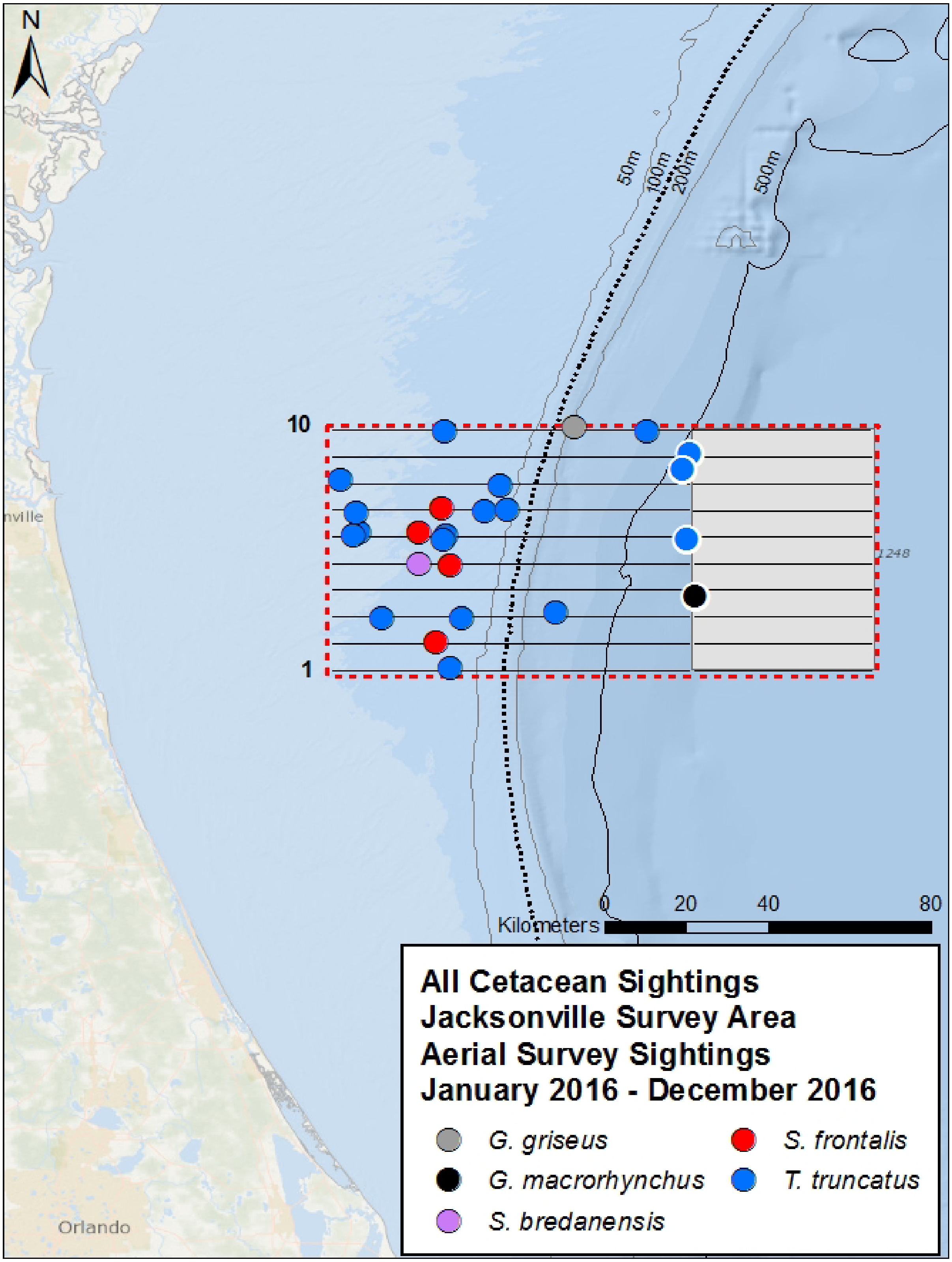


Figure 15. Cetacean sightings during aerial surveys in the JAX survey area in 2016. Off-effort sightings are identified by the white circles.

A total of 116 individual sea turtles were recorded during aerial surveys in the JAX survey area in 2016 (**Table 9**). Sighting rates were negatively correlated with BSS, with rates declining at higher sea states. Effort-corrected sea turtle sighting rates were higher in BSS 1 or BSS 2 than in BSS 3 or higher during this survey period. Sea turtles were observed every day of survey effort, with the highest sighting rates occurring in January. Observation rates ranged from a low of 3.09/1,000 km flown in March to a high of 51.36/1,000 km in January. Loggerhead turtles constituted the majority of sea turtles sighted (93 percent), followed by leatherback turtles (5 percent). Turtles labeled as unidentified (2 percent of sightings) were typically either of small size, submerged, or too far away for the observers to make an accurate identification to species. Loggerhead turtles were recorded predominantly in the shallower waters over the continental shelf, although a small number of individuals occurred beyond the continental shelf break (**Figure 16**). Leatherback turtles were recorded predominantly in the shallower waters over the continental shelf, inshore of the 100-m isobath, although one individual occurred beyond the continental shelf break (**Figure 16**).

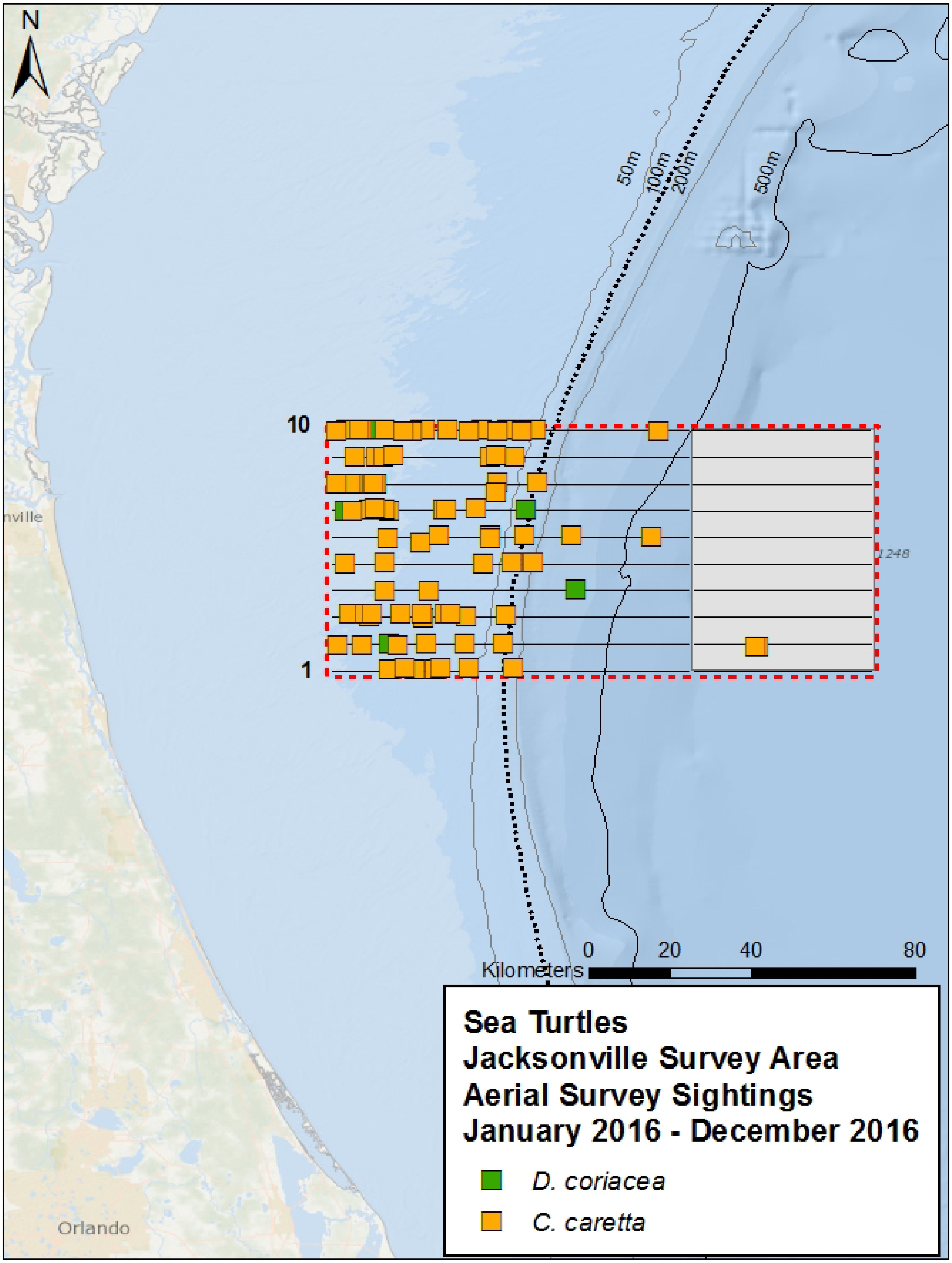


Figure 16. All sea turtle sightings during aerial surveys in the JAX survey area in 2016.

In addition to cetaceans and sea turtles, other pelagic marine vertebrates were observed, including sharks and rays (i.e., elasmobranch fishes) (**Table 9, Figure 17**)**.** Six ocean sunfish were sighted, with 83 percent of individuals sighted in January. Four of the ocean sunfish were seen in relatively shallow water near the western edge of the survey area; the other two were much farther offshore closer to the 500-m isobath. Five manta rays were sighted inshore of the 500-m isobath with all sightings (as well as a group of 45 unidentified rays) occurring in May. There were 11 sightings of sharks, totaling 12 animals. Four of the sharks could be identified as hammerhead sharks based on head shape, but since none of these sightings could be identified to species they were combined with the unidentified sharks. Sharks showed no discernable spatial or temporal trends in occurrence.

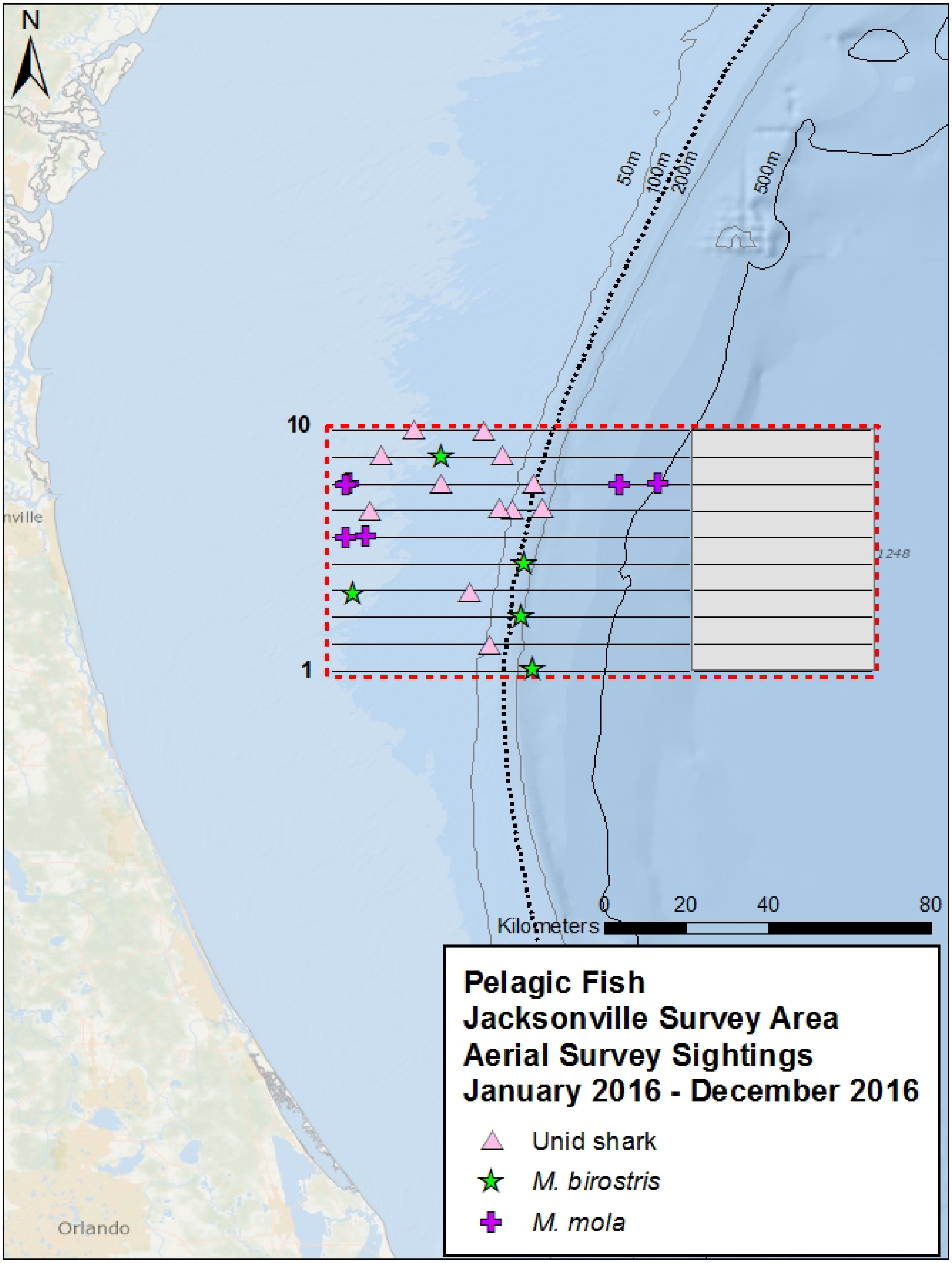


Figure 17. Pelagic fish sightings during aerial surveys in the JAX survey area in 2016.

For more information on this study, refer to the annual progress report for this project (Cummings et al. 2017b).

2.1.1.5 Chesapeake Bay (NAS Patuxent River) Aerial Surveys

Aerial surveys were initiated in April 2015 in the waters surrounding NAS Patuxent River in Chesapeake Bay to collect information and quantitative data on the seasonal occurrence, distribution, habitat use, and density of marine protected species to support planning and impact assessment analyses under NEPA, MMPA, and ESA. Researchers from UNCW conducted 10 days of monthly aerial survey effort in 2016 covering 5,834 km over the waters of the Chesapeake Bay and the mouth of the Potomac River, surrounding the NAS Patuxent River site (**Table 10, Figure 18**) in 2016. Survey conditions ranged from BSS 0 to BSS 5.

Table 10. Effort summary for aerial surveys conducted in the NAS Patuxent River survey area in 2016.

Month	Number of Survey Days	Tracklines Covered	Total km Flown	Total hr Underway*
January	1	18	586.50	5.5
February	1	18	582.10	5.6
March	1	18	584.05	5.2
April	1	18	583.10	5.2
May	1	18	574.90	6.3
June	1	18	589.70	5.2
July	1	18	580.35	6.2
August	1	18	584.70	5.8
September	0	0	0	0
October	1	18	588.78	5.6
November	1	18	580.00	5.3
December	0	0	0	0
Total	**10**	**180**	**5,834.18**	**55.9**

*Total hours (hr) underway reported as Hobbs hr = total engine time

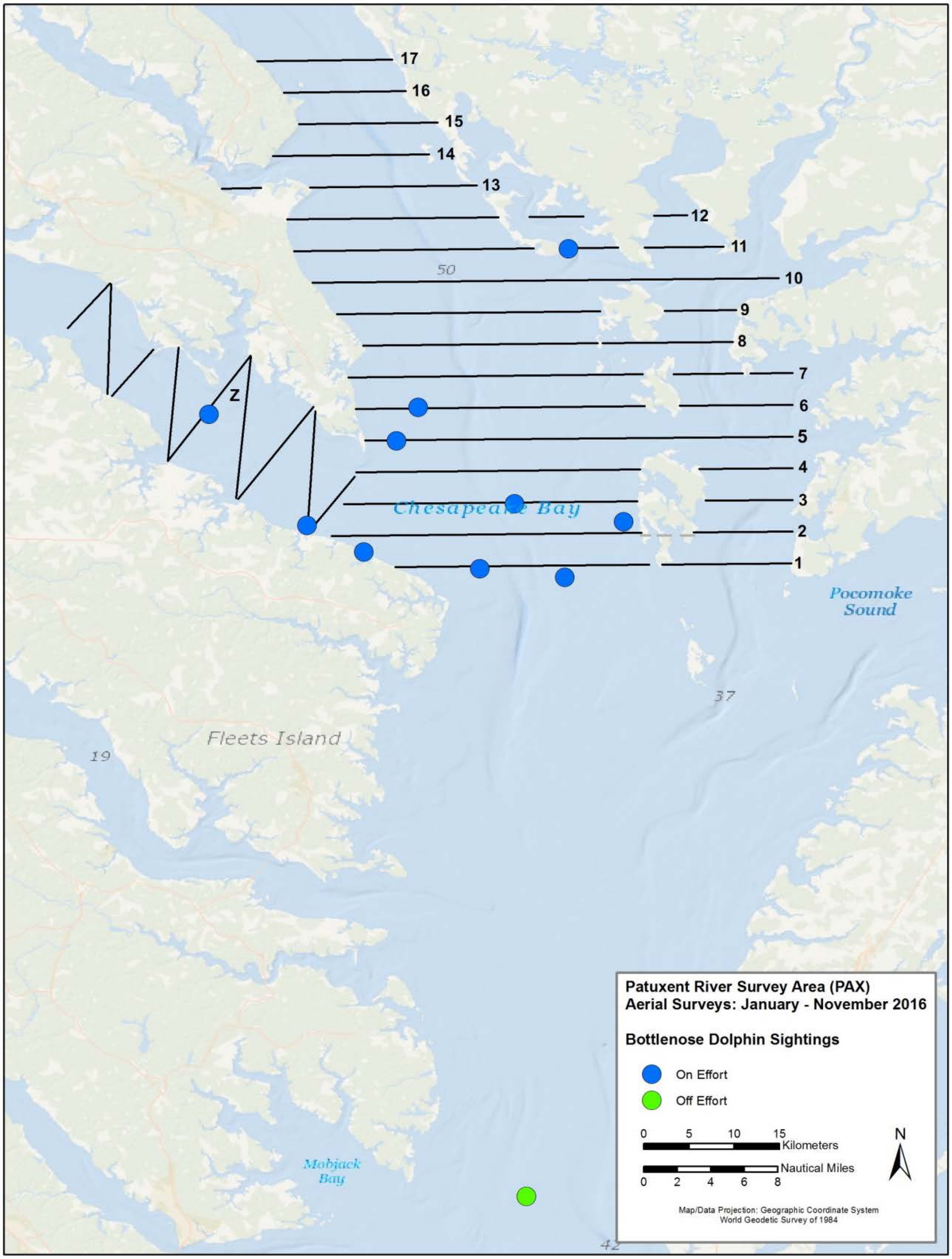


Figure 18. Bottlenose dolphin sightings from aerial surveys conducted in the Patuxent River survey area in 2016.

Between January and December 2016, 10 on-effort (*n*=301 individuals) and one off-effort (*n*=2 individuals) sightings of bottlenose dolphins were recorded (**Figure 18, Table 11**). All on- effort sightings occurred between May and August and were primarily concentrated in the southern portion of the survey area near the confluence of the Potomac River with Chesapeake Bay, with the exception of one sighting that occurred in the northeastern portion of the study area. One off-effort sighting of a pair of bottlenose dolphins occurred in April. These animals were observed in the center of the bay southeast of Mathews, Virginia, during the return transit to Norfolk.

Table 11. Sightings from aerial surveys conducted in the Patuxent River survey area in 2016. On- and off-effort sightings are represented by #/# (on-/off-effort sightings).

Common Name	Scientific Name	Number of Sightings	Number of Individuals
Bottlenose dolphin	*Tursiops truncatus*	10/1	301/2
Loggerhead turtle	*Caretta caretta*	11/0	11/0
Unidentified turtle		1/0	1/0
Cownose ray	*Rhinoptera bonasus*	26/0	909/0

There were 12 sightings of sea turtles recorded, the majority (*n*=11) were identified as loggerhead turtles, with one sighting classified as unidentified sea turtle. All sea turtle sightings occurred during the months of July and October in the Chesapeake Bay (**Figure 19**, **Table 11**).

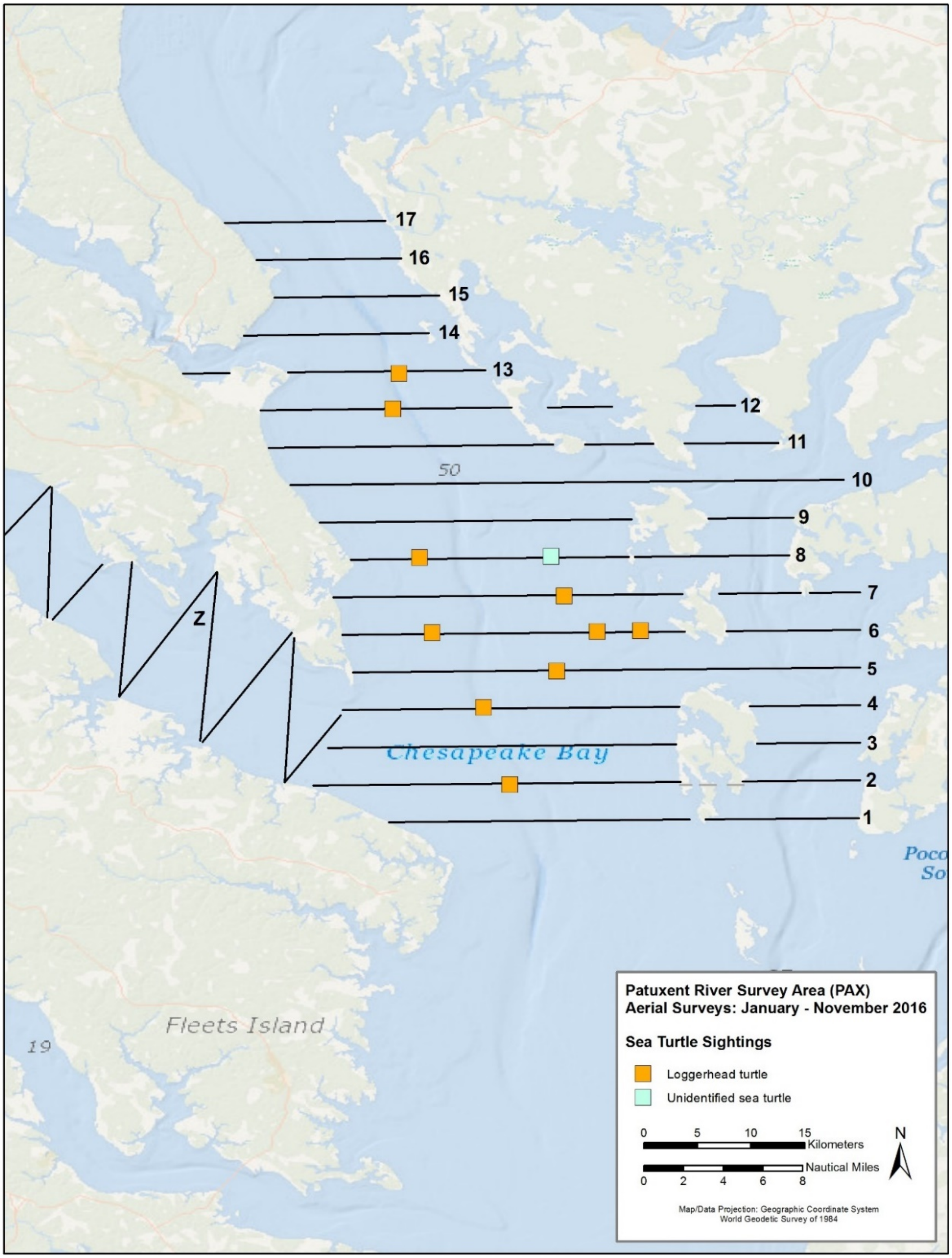


Figure 19. Sea turtle sightings from aerial surveys conducted in the Patuxent River survey area in 2016.

Cownose rays also were observed across the range of the survey area during May, July-August, and October 2016 (**Figure 20, Table 11**).

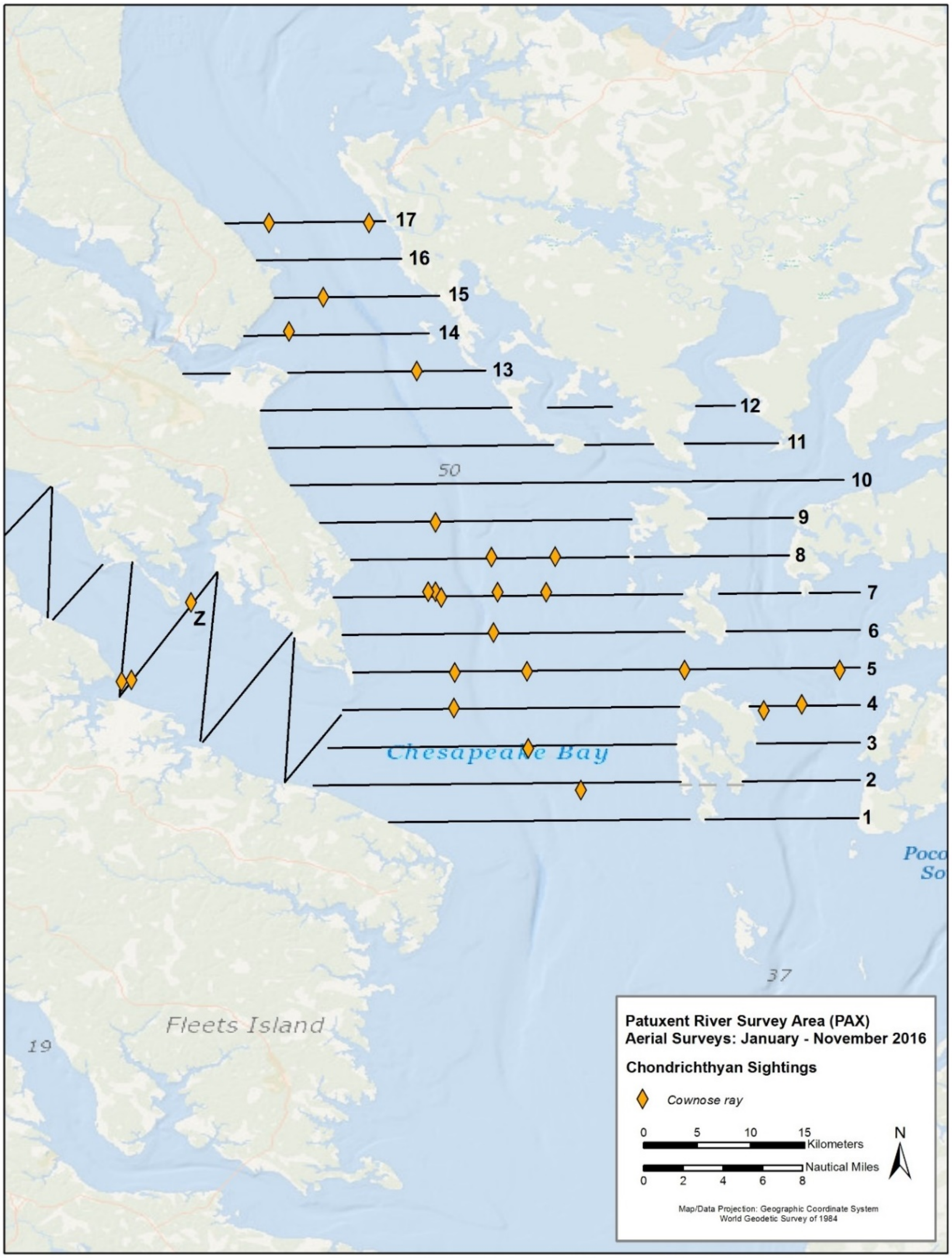


Figure 20. Cownose ray sightings from aerial surveys conducted in the Patuxent River survey area in 2016.

For more information on this study, refer to the annual progress report for this project (Richlen et al. 2017a).

2.1.2 Visual Baseline Vessel Surveys

Visual vessel surveys were conducted at multiple locations in the AFTT Study Area off the mid-Atlantic and southeastern United States during 2016. The long-term survey programs in the Cape Hatteras, Onslow Bay, and JAX OPAREAs were continued (**Sections 2.1.2.1 through 2.1.2.3**), as were the more recent efforts initated during 2014 off Virginia Beach, Virginia (**Section 2.1.2.4)** and in 2015 at both NAS Patuxent and Panama City, Florida (**Sections 2.1.2.5 and 2.1.2.6**, respectively).

2.1.2.1 Cape Hatteras Study Area Vessel Surveys

Fieldwork was conducted on 8 days between May 2016 and August 2016 aboard the Research Vessel (R/V) *Richard T. Barber* (**Table 12**, **Figure 21**) (Foley et al. 2017a). Fieldwork at Cape Hatteras in 2016 was dedicated to the Deep Divers and Satellite-Tagging projects (refer to **Section 2.2.1**, Foley et al. 2017b). Five days were dedicated to the Satellite-Tagging project and 3 days to the Deep Divers project (**Figure 21**). Fieldwork conducted during 2016 yielded 456.7 km and 57.3 hr of effort (**Table 12**) in BSS 0 to BSS 4. Survey effort was focused along the continental shelf break between Cape Hatteras and Norfolk Canyon.

Table 12. Effort summary for vessels surveys conducted in the Cape Hatteras study area, May –August 2016.

Month	Number of Survey Days	Total Survey Time (hr: min)	Time On Effort (hr:min)	Total km Surveyed
May	5	57:55	35:08	273.3
June	1	10:23	05:30	37.3
July	0	0	0	0
August	2	24:51	16:42	146.1
Total	**8**	**93:09**	**57:20**	**456.7**

Key: hr = hour(s); km = kilometer(s); min = minute(s)

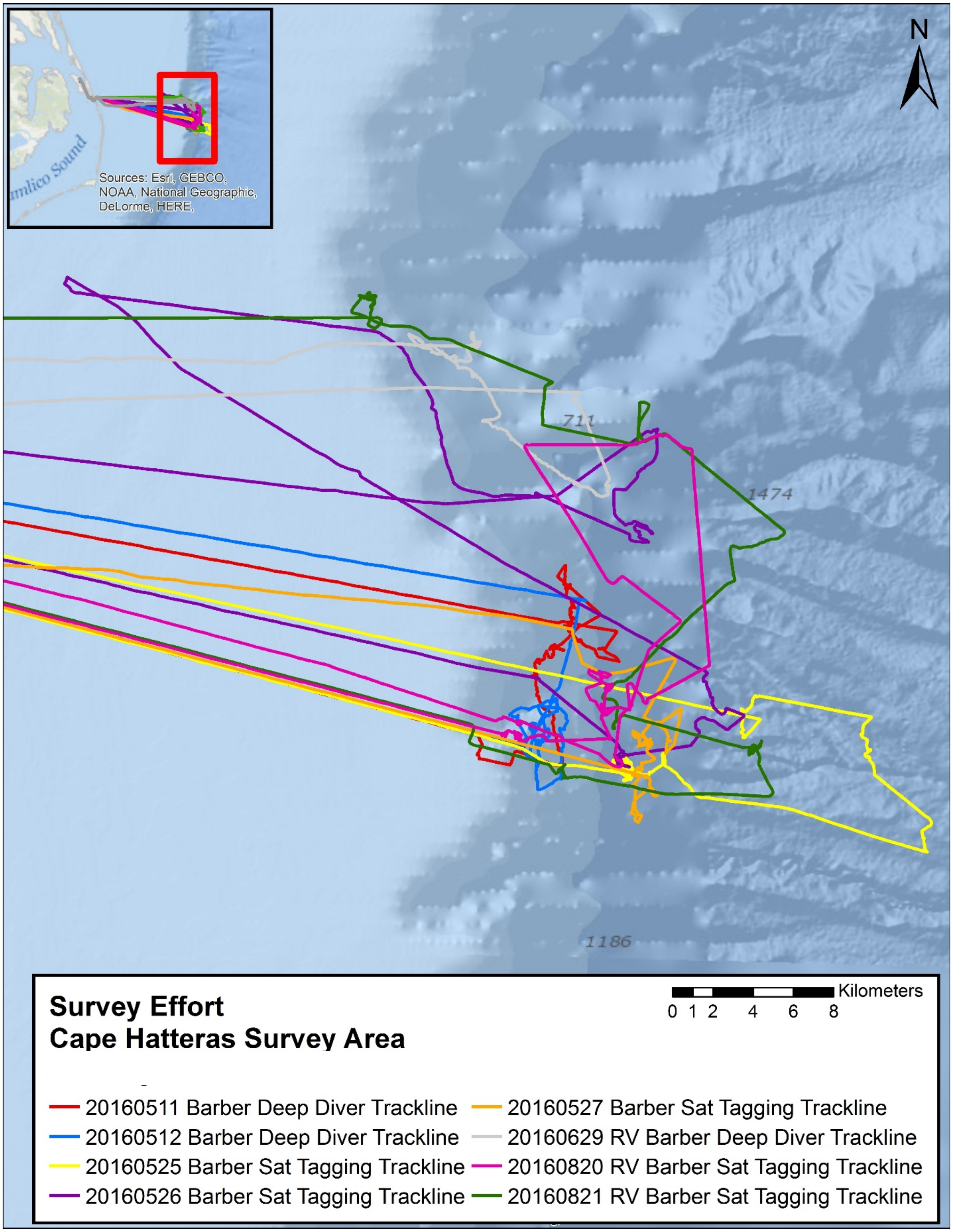


Figure 21. Survey effort on the R/V *Barber* in the Cape Hatteras study area, May–August 2016.

Seven species of cetaceans were encountered including 23 sightings of deep-diving odontocetes (**Figure 22**): short-finned pilot whale (*n*=16), Cuvier's beaked whale (*n*=6), and unidentified *Mesoplodon* sp. (*n*=1); as well as bottlenose dolphin (*n*=27); Risso's dolphin (*n*=2); short-beaked common dolphin (*n*=3); and Clymene dolphin (*n*=1). No sea turtles were encountered during vessel survey effort during 2016 in the Cape Hatteras study area (**Table 13**).

Table 13. Sightings from fieldwork conducted in the Cape Hatteras study area, May–August 2016. All sightings were made on effort.

Common Name	Scientific Name	Number of Sightings	Number of Individuals
Short-finned pilot whale	*Globicephala macrorynchus*	16	196
Cuvier's beaked whale	*Ziphius cavirostris*	6	29
Bottlenose dolphin	*Tursiops truncatus*	27	377
Risso's dolphin	*Grampus griseus*	2	175
Short-beaked common dolphin	*Delphinus delphis*	3	725
Clymene dolphin	*Stenella clymene*	1	250
Unidentified beaked whale	*Mesoplodon* sp.	1	1

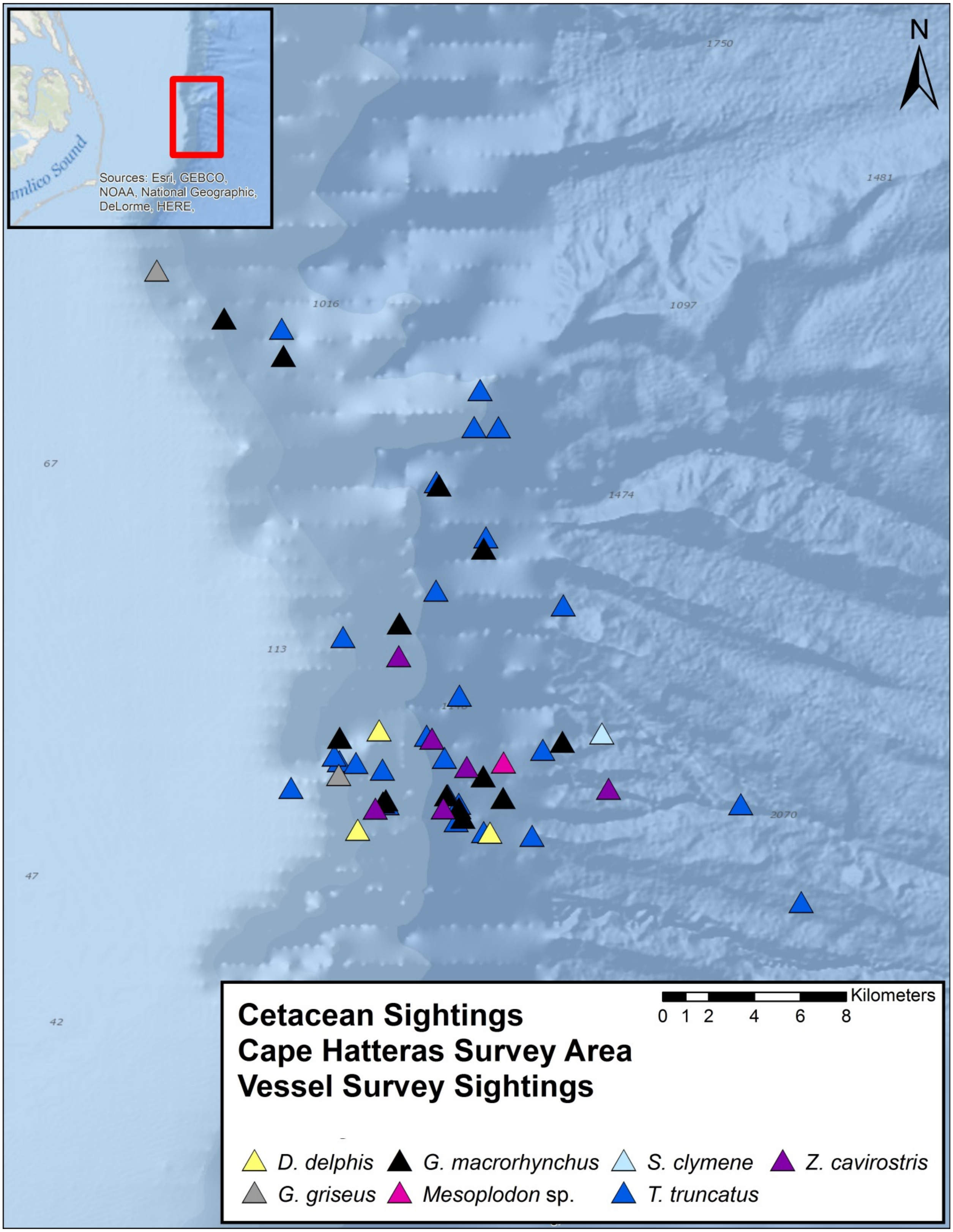


Figure 22. Locations of all cetacean sightings observed during vessel surveys in the Cape Hatteras study area, May–August 2016.

Eighteen tags were deployed during the reporting period. Observers deployed three digital acoustic tags (DTAGs) on short-finned pilot whales in the reporting period, while 15 satellite tags were placed on Cuvier's beaked whales (*n*=6), short-finned pilot whales (*n*=5), a bottlenose dolphin, a Risso's dolphin, a short-beaked common dolphin, and a Clymene dolphin during 2016 (see **Section 2.2.1** of this report for more information).

Observers obtained biopsy samples from four short-finned pilot whales from three groups (one sample on 12 and 26 May, and from the same group on 29 June) (**Figure 23**). Skin samples will be analyzed for sex determination. Voucher specimens of these samples have been archived with NMFS' Southeast Fisheries Science Center (SEFSC) in Lafayette, Louisiana.

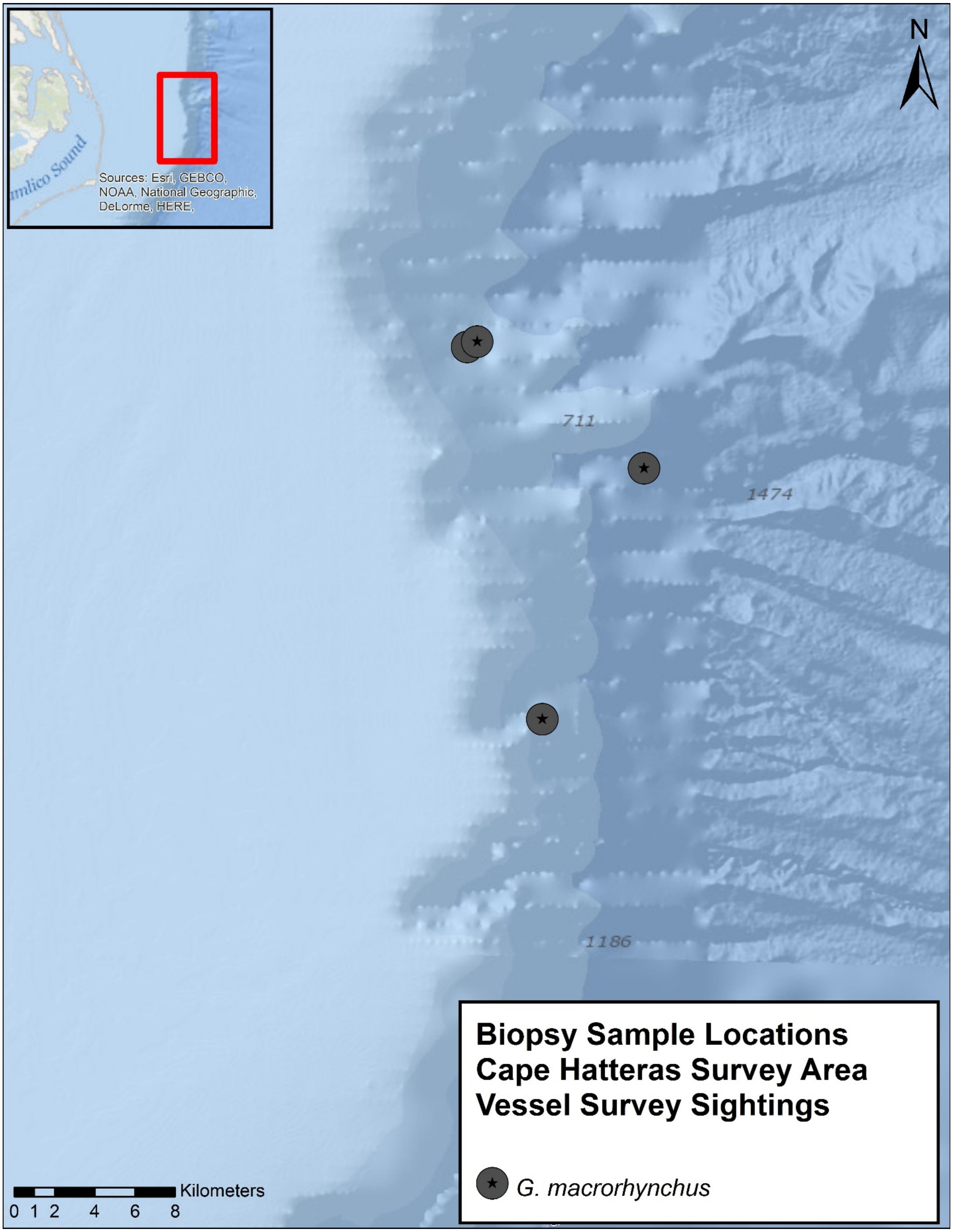


Figure 23. Distribution of biopsy sample locations collected during fieldwork in the Cape Hatteras study area, May–August 2016.

To date, photo-ID catalogs for 11 species are assembled, with 177 individuals resighted across all species (**Table 14**). Nearly 3,000 digital images were collected to confirm species identification and identify individual animals during fieldwork in 2016. Images of 414 newly identified animals were added to seven existing photo-ID catalogs: bottlenose dolphins, Atlantic spotted dolphins, short-finned pilot whales, sperm whales, Cuvier's beaked whales, short-beaked common dolphins, and Risso's dolphins. In 2015, a new photo-ID catalog was established for the Clymene dolphin observed in the Cape Hatteras study area.

Table 14. Comparison of photographs taken of animals in the Cape Hatteras study area in 2016 with existing photo-ID catalogs, showing matches made so far between this year's photos and the catalogs.

Common Name	Scientific Name	Photos Taken (2016)	Catalog Size to Date	Matches to Date
Fin whale	*Balaenoptera physalus*	0	1	0
Humpback whale	*Megaptera novaeangliae*	0	2	0
Short-beaked common dolphin	*Delphinus delphis*	116	30	1
Short-finned pilot whale	*Globicephala macrorhynchus*	1,498	718	160
Risso's dolphin	*Grampus griseus*	482	9	0
Pygmy/dwarf sperm whale	*Kogia* sp.	0	1	0
Sperm whale	*Physeter macrocephalus*	0	14	1
Clymene dolphin	*Stenella clymene*	148	3	0
Atlantic spotted dolphin	*Stenella frontalis*	0	24	0
Bottlenose dolphin	*Tursiops truncatus*	374	274	9
Cuvier's beaked whale	*Ziphius cavirostris*	360	50	6

Photo-analysis of the images taken in the Cape Hatteras survey area is ongoing. To date, nine bottlenose dolphins have been photographed on multiple occasions, spanning several years (**Table 15**). Ttr 1-001 was first photographed on 20 July 2009, resighted on 30 May 2011, and photographed for a third time on 27 June 2011. Ttr 6-018 and Ttr 9-013 were photographed together in both March 2012 and May 2013. Ttr 6-020 was observed in May 2011 and then again in October 2013. Ttr 7-031 and Ttr 7-038 were photographed on two separate occasions in 2011, and Ttr 7-058 was observed twice within 2013. Ttr 9-016 was initially photographed in 2011 and then again in June 2014. Ttr 9-027, first observed on 11 June 2014 (TtTag015), was observed a second time on 16 June 2014.

Table 15. Photo-ID matches of individual odontocete cetaceans, excluding short-finned pilot whales, in the Cape Hatteras study area.

ID[1]	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Ttr 1-001				X		X[y]					
Ttr 6-018^							X	X			
Ttr 6-020						X		X			
Ttr 7-031						X[y]					
Ttr 7-038						X[y]					
Ttr 7-058								X[y]			
Ttr 9-013^							X	X			
Ttr 9-016						X			X		
Ttr 9-027 (TtTag015)									X[m]		
Dde 7-002		X					X				
Pma-004								X[m]			
Zca-001r								X		X	
Zca-003r (ZcTag029)									X[m]		
Zca-005									X	X	
Zca-005r									X[y]		
Zca-006 (ZcTag040)									X	X	
Zca-008r (ZcTag047)									X		X

[1] Dde=*Delphinus delphis* (short-beaked common dolphin); Pma=*Physeter macrocephalus* (sperm whale); Sf=*Stenella frontalis* (Atlantic spotted dolphin; Ttr=*Tursiops truncatus* (bottlenose dolphin); Zca=*Ziphius cavirostris* (Cuvier's beaked whale)

[m] resighted within same month

[y] resighted within same year

^ observed together in multiple sightings

A single match of a short-beaked common dolphin off Cape Hatteras was made; Dde 7-002 was first photographed on 27 May 2007 and resighted nearly five years later on 15 March 2012 (**Table 15**).

A single sperm whale match has been made; Pma-004 was observed on 27 and 29 May 2013.

Six Cuvier's beaked whale matches have been made to date; two were made during this reporting period. Zca_003r was satellite tagged on 13 May 2014 (ZcTag029) and photographed again five days later. Zca_005r was photographed in May and October 2014. Zca_006 was photographed first on 26 May 2014 and was DTAGged at that time, although the tag was never recovered. On 14 June 2015, this individual was resighted and satellite tagged (ZcTag040). Zca_001r was photographed in a group of four animals on 05 October 2013 and was photographed again on 14 June 2015 in a group of five to seven whales. This individual represents our longest resight of a beaked whale, and also is an inter-seasonal match (**Table 15**). Zca_005 was sighted initially in May of 2014 and was resighted in June of 2015. Finally, Zca_008r was seen first in October of 2014 and was resighted and satellite tagged in May 2016 (ZcTag047).

None of the five short-finned pilot whales that were satellite tagged in 2016 were matched to the existing catalog. Six of the 19 short-finned pilot whales equipped with satellite tags in 2015 were either resighted or matched to the catalog. GmTag 122 was first seen in May 2012; it was satellite tagged on 16 May of 2015 and then sighted for a third time on 24 May 2015. Interestingly, Gma_2-011 (a female) was seen in the same three sightings as GmTag122 over the three-year span. GmTag127 was satellite tagged on 19 May 2015 and then resighted on both 24 and 25 May 2015. GmTag128 was sighted first on 01 June 2015 and was subsequently satellite-tagged on 16 June 2015. GmTag135 also was sighted initially in June of 2015 and was later instrumented with a satellite tag in October 2015. GmTag136 was DTAGged in May 2012, resighted for the first time in May 2015 and subsequently resighted and satellite tagged in October 2015. GmTag142 was first photographed in July 2010; it was seen again in July of 2013 and then satellite-tagged in October 2015. In addition, GmTag097, who was satellite tagged on 11 September 2014, was resighted on 24 May 2015.

The relatively high resight rate of short-finned pilot whales in the Cape Hatteras study area continued during 2016. To date, more than 22 percent (160 of 718) of the pilot whales in the catalog have been resighted, up from last reporting period when the resight rate of pilot whales was at 17 percent (61 of 367). Many individuals have been resighted on multiple occasions within the same year (57 of the 160 matches) and in different seasons; Gma_7-198, Gma_7-208 and Gma_7-211 were all sighted in May and October of 2015 and Gma_6-085 was sighted twice in May 2015 and on a third occasion in December 2015. In addition, nearly 65 percent of matches are resights between multiple years (103 of the 160 matches). Sixteen of the short-finned pilot whales in our catalog have been sighted on four or more occasions and one individual, Gma_9-027, has been photographed in six separate sightings between May 2008 and May 2015.

Cumulative

Total survey effort conducted since the beginning of the monitoring program, including all AFTT protected species monitoring and Deep Diver tagging effort for the Cape Hatteras study area, is reported in **Table 16**. The annual numbers of sightings by species for both cetaceans and sea turtles in the Cape Hatteras study area are presented in **Tables 17** and **18**, respectively. The number of biopsy samples collected to date in the Cape Hatteras study area is reported in **Table 19**. **Table 20** summarizes the catalog sizes and matches by species to date and numbers of images taken during the reporting period in the Cape Hatteras study area.

Table 16. Duration and distance surveyed since 2009 (Year 1) in the Cape Hatteras study area.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Total
Survey Hours	26	180	87	63	122	135	57	**670**
km Surveyed	296	1,097	1,049	879	922	991	457	**5,691**

Key: Year 1 (July 2009–December 2010), Year 2 (2011), Year 3 (2012), Year 4 (2013), Year 5 (2014), Year 6 (2015), and Year 7 (2016).

Table 17. Numbers of annual cetacean sightings since 2009 (Year 1) for each species observed from vessel surveys in the Cape Hatteras study area.

Species	Sightings						
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Balaenoptera physalus	0	0	1	2	0	0	0
Delphinus delphis	0	6	11	3	4	4	3
Globicephala macrorhynchus	9	33	52	35	26	53	16
Grampus griseus	1	2	2	0	1	2	2
Kogia sp.	0	0	0	0	0	1	0
Mesoplodon sp.	0	0	0	1	0	0	1
Physeter macrocephalus	0	1	4	3	2	4	1
Stenella clymene	0	0	0	0	0	0	1
Stenella frontalis	0	8	2	3	3	3	0
Stenella/Delphinus mix	0	1	0	0	0	0	0
Tursiops truncatus	23	27	54	38	14	47	32
Tursiops/Stenella mix	0	1	0	0	0	0	0
Ziphius cavirostris	0	3	1	2	16	13	7
Unidentified baleen whale	0	0	0	0	0	1	0
Unidentified beaked whale	0	0	0	4	3	1	0
Unidentified small whale	0	0	0	0	0	1	0
Unidentified delphinid	1	0	3	1	0	1	0
Total	**34**	**82**	**130**	**92**	**69**	**131**	**62**

Key: Year 1 (July 2009–December 2010), Year 2 (2011), Year 3 (2012), Year 4 (2013), Year 5 (2014), Year 6 (2015), and Year 7 (2016).

Table 18. Numbers of annual sea turtle sightings since 2009 (Year 1) for each species observed from vessel surveys in the Cape Hatteras study area.

Species	Sightings						
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Caretta caretta	2	0	2	7	0	2	0
Chelonia mydas	0	0	0	1	0	0	0
Dermochelys coriacea	0	0	0	0	0	4	0
Unidentified sea turtle	0	0	1	0	0	0	0
Total	**2**	**0**	**3**	**8**	**0**	**6**	**0**

Key: Year 1 (July 2009–December 2010), Year 2 (2011), Year 3 (2012), Year 4 (2013), Year 5 (2014), Year 6 (2015), and Year 7 (2016).

Table 19. Biopsy samples collected since 2011 (Year 2) in the Cape Hatteras study area.

Species	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Total
Balaenoptera physalus	0	0	3	0	0	0	**3**
Delphinus delphis	0	5	2	0	1	0	**8**
Globicephala macrorhynchus	4	33	10	5	14	4	**70**
Grampus griseus	0	0	2	0	0	0	**2**
Physeter macrocephalus	0	0	1	1	0	0	**2**
Stenella frontalis	6	0	2	2	2	0	**12**
Tursiops truncatus	14	10	13	2	1	0	**40**
Ziphius cavirostris	0	0	2	0	2	0	**4**

Key: Year 2 (2011), Year 3 (2012), Year 4 (2013), Year 5 (2014), Year 6 (2015), and Year 7 (2016).

Table 20. Summary of images collected during all vessel surveys in the Cape Hatteras study area, 2009–2016, with photo-ID catalog sizes and matches to date.

Species	2009-2016	
	Catalog Size	Matches
Balaenoptera physalus	1	0
Delphinus delphis	30	1
Globicephala macrorhynchus	718	160
Grampus griseus	9	0
Kogia sp.	1	0
Megaptera novaeangliae	2	0
Physeter macrocephalus	14	1
Stenella clymene	3	0
Stenella frontalis	24	0
Tursiops truncatus	274	9
Ziphius cavirostris	50	6

For more information on this study, refer to the annual progress report for this project (Foley et al. 2017a).

2.1.2.2 Onslow Bay Study Area Vessel Surveys

Vessel survey effort in Onslow Bay during 2016 consisted of two opportunistic survey days (13 and 14 September 2016) aboard the R/V *Barber*. Surveys in 2016 were focused on conducting a test attempting to deploy a digital acoustic tag (DTAG) on a small delphinid while simultaneously deploying a four-element distributed hydrophone array from the research vessel. This array enables the localization of vocalizations produced by delphinids. The ability to localize vocalizations to groups of animals, observed at the surface, would allow ascription of vocal events to surface behaviors. In addition, the array would provide species-specific voucher recordings for use in ongoing research in the classification of whistles and clicks. This type of adaptable array, used in conjunction with tagging studies, will help to better analyze and provide context to acoustic recordings obtained from tag data. While delphinids were observed on each survey, no DTAGs were deployed on either day. Fieldwork conducted during 2016 yielded 124.5 km and 6.9 hr of effort in BSS 2 to BSS 3. Only two sightings, both Atlantic spotted dolphin, were recorded.

Since the inception of the monitoring program in Onslow Bay in 2007, eight bottlenose dolphins and five Atlantic spotted dolphins have been resighted (**Table 21**, **Figure 24**), representing approximately 6 percent of the catalog for bottlenose dolphins (*n*=8 of 133) and 6 percent (*n*=5 of 86) for Atlantic spotted dolphins. Resightings of bottlenose dolphins and Atlantic spotted dolphins in Onslow Bay span up to six and 10 years, respectively. Two bottlenose dolphins (Ttr_7-015 and Ttr_8-009) were seen together in April of both 2009 and 2010. One bottlenose dolphin (Ttr_1-004) has been photographed now on three separate occasions: in October 2009, April 2010, and January 2012. Furthermore, one Atlantic spotted dolphin (Sfr_8-004) biopsied and photographed on 12 September 2011 was matched to an animal photographed on 28 June 2001 and on 24 June 2002 during surveys conducted in nearshore waters of Onslow Bay. An additional Atlantic spotted dolphin from the same 12 September 2011 group was matched to Sfr_9-023_MCB, photographed a month earlier on 19 August 2011 during surveys in the coastal waters off Marine Corps Base Camp Lejeune, North Carolina. Atlantic spotted dolphin Sfr_7-013 was first observed during an offshore AFTT Onslow Bay vessel survey on 12 September 2011 and was resighted on 25 July 2013 during an acoustic vessel survey in coastal waters of Camp Lejeune. Another Atlantic spotted dolphin (Sfr_2-003), observed on 12 September 2011, was resighted during 2016. These numerous resightings over multiple years and across seasons support the existence of considerable fine-scale population structure and some degree of residency for both bottlenose and Atlantic spotted dolphins in Onslow Bay. To date, no individuals of any other species have been resighted, although the numbers of sightings and catalog sizes for these species are very small. Images of the dorsal fins of stranded pelagic cetaceans in North Carolina are regularly compared with our photo-ID catalogs for Onslow Bay, but to date there have been no matches.

Table 21. Summary of photographs taken of animals in the Onslow Bay study area in 2016, along with photo-ID catalog sizes and total numbers of matches to date.

Species	Common Name	Images (2016)	Catalog Size	Matches
Globicephala macrorhynchus	Short-finned pilot whale	0	27	0
Grampus griseus	Risso's dolphin	0	22	0
Stenella frontalis	Atlantic spotted dolphin	22	86	5
Tursiops truncatus	Bottlenose dolphin	0	133	8
Steno bredanensis	Rough-toothed dolphin	0	12	0

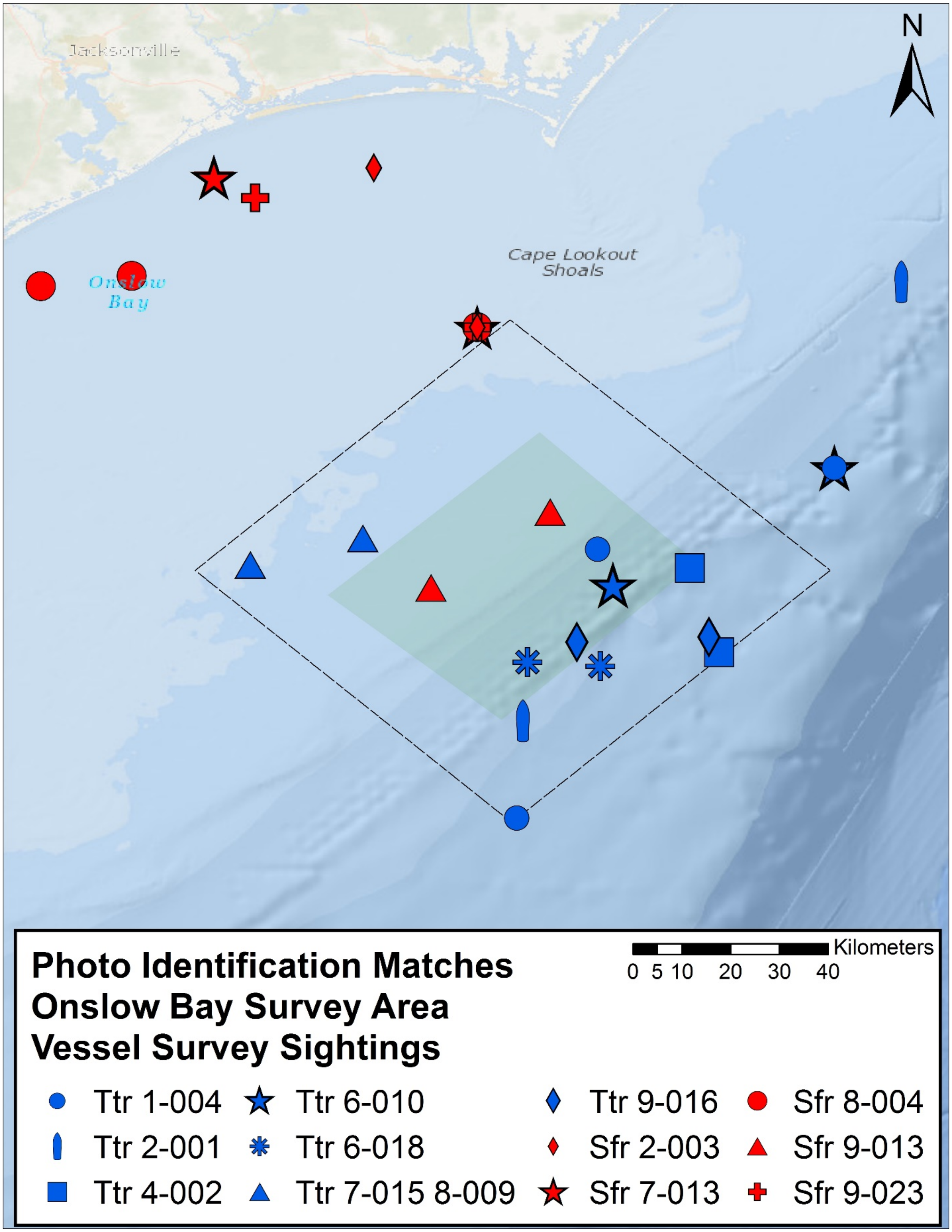


Figure 24. Locations of individual photo-matched dolphins to date within the Onslow Bay study area.

Cumulative

Total vessel survey effort conducted since the beginning of the monitoring program in the Onslow Bay study area is reported in **Table 22**. The annual numbers of sightings by species for both cetaceans and sea turtles in the Onslow Bay study area are presented in **Tables 23 and 24**, respectively. The numbers of biopsy samples collected to date in the Onslow Bay study area are reported in **Table 25**. **Table 26** summarizes the numbers of photo-ID images taken, catalog sizes, and matches by species to date in the Onslow Bay study area. Small vessel surveys in this area have since been discontinued.

Table 22. Duration and distance surveyed annually since 2007 (Year 1) in the Onslow Bay study area.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
Survey Hours	171	109	106	54	32	15	-	9	7	**503**
km Surveyed	2,334	1,742	1,556	754	497	186	-	122	125	**7,316**

Key: Year 1 (June 2007–June 2008); Year 2 (July 2008–June 2009), Year 3 (July 2009–June 2010), Year 4 (July 2010–December 2011), Year 5 (2012), Year 6 (2013), Year 7 (no survey effort during 2014), Year 8 (2015), and Year 9 (2016).

Table 23. Numbers of cetacean sightings annually since 2007 (Year 1) for each species in the Onslow Bay study area.

Species		Sightings							
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Globicephala macrorhynchus	1	0	2	0	0	1	-	0	0
Grampus griseus	3	0	3	0	1	0	-	0	0
Mesoplodon sp.	0	0	0	0	2	0	-	0	0
Stenella frontalis	6	17	17	9	1	0	-	2	2
Steno bredanensis	0	0	1	0	0	0	-	0	0
Tursiops truncatus	23	14	29	7	7	6	-	3	0
Unidentified delphinid	3	2	3	0	0	0	-	0	0
Unidentified small whale	0	0	0	0	1	0	-	0	0
Total	**36**	**33**	**55**	**16**	**12**	**7**	**-**	**5**	2

Key: Year 1 (June 2007–June 2008); Year 2 (July 2008–June 2009), Year 3 (July 2009–June 2010), Year 4 (July 2010–December 2011), Year 5 (2012), Year 6 (2013), Year 7 (no survey effort during 2014), Year 8 (2015), and Year 9 (2016).

Table 24. Numbers of sea turtle sightings annually since 2007 (Year 1) for each species in the Onslow Bay study area.

Species		Sightings							
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Caretta caretta	19	49	47	3	2	1	-	0	0
Dermochelys coriacea	0	0	2	0	0	0	-	0	0
Unidentified sea turtle	1	0	1	0	0	0	-	0	0
Total	**20**	**49**	**50**	**3**	**2**	**1**	**-**	**0**	**0**

Key: Year 1 (June 2007–June 2008); Year 2 (July 2008–June 2009), Year 3 (July 2009–June 2010), Year 4 (July 2010–December 2011), Year 5 (2012), Year 6 (2013), Year 7 (no survey effort during 2014), Year 8 (2015), and Year 9 (2016).

Table 25. Biopsy samples collected annually since 2010 (Year 4) in the Onslow Bay study area.

Species	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Total
Globicephala macrorhynchus	0	0	3	-	0	0	**3**
Grampus griseus	0	5	0	-	0	0	**5**
Stenella frontalis	2	2	0	-	0	0	**4**
Tursiops truncatus	0	8	7	-	0	0	**15**

Key: Year 4 (July 2010–December 2011), Year 5 (2012), Year 6 (2013), Year 7 (no survey effort during 2014), Year 8 (2015), and Year 9 (2016).

Table 26. Summary of images collected during all vessel surveys in the Onslow Bay study area, 2007–2016, with photo-ID catalog sizes and matches to date.

Species	2007-2016	
	Catalog Size	Matches
Globicephala macrorhynchus	27	0
Grampus griseus	22	0
Stenella frontalis	86	5
Steno bredanensis	12	0
Tursiops truncatus	133	8

For more information on this study, refer to the annual progress report for this project (Foley et al. 2017a).

2.1.2.3 Jacksonville Study Area Vessel Surveys

Vessel survey effort in the JAX study area during 2016 focused on questions of residency and population structure of odontocete cetaceans. During 2016, Duke researchers collaborated with the Naval Surface Warfare Center, Carderock Division in Potomac, Maryland, to utilize paid ship time aboard the R/V *Savannah*, based out of the Skidaway Institute of Oceanography in Savannah, Georgia, to conduct vessel surveys. This afforded researchers the opportunity to stay offshore overnight, allowing for more time on effort and sightings farther east than daily shore-based trips allow. The R/V *Exocetus* was deployed from the R/V *Savannah* in order to approach cetacean groups and obtain photo-ID images and biopsy samples. Additional surveys were conducted from the R/V *Richard T. Barber*, including two days of effort focused on deploying satellite tags (see Baird et al. 2017).

Fourteen days of vessel surveys were conducted in the JAX study area during February, April, June, July, August, and September 2016. Survey effort totaled 2,136 km, or 130.7 hr, of survey effort (**Table 27, Figure 25**). These surveys were conducted in BSS 0 to BSS 4 and covered the planned USWTR site and surrounding survey area, including shelf and oceanic waters.

Table 27. Effort summary for vessels surveys conducted in the JAX study area in 2016.

Month	Number of Survey Days	Total Survey Time (hr: min)	Time On Effort (hr:min)	Total km Surveyed
January	0	0	0	0
February	1	23.7	14:26	120.9
March	0	0	0	0
April	1	12:05	08:34	138.6
May	0	0	0	0
June	2	23:17	14:26	372.1
July	3	72:00	38:14	480
August	4	96:00	43:06	551
September	3	31:18	28:46	472.9
October	0	0	0	0
November	0	0	0	0
December	0	0	0	0
Total	**14**	**245:16**	**130:40**	**2,136**

Key: hr = hour(s); km = kilometer(s); min = minute(s).

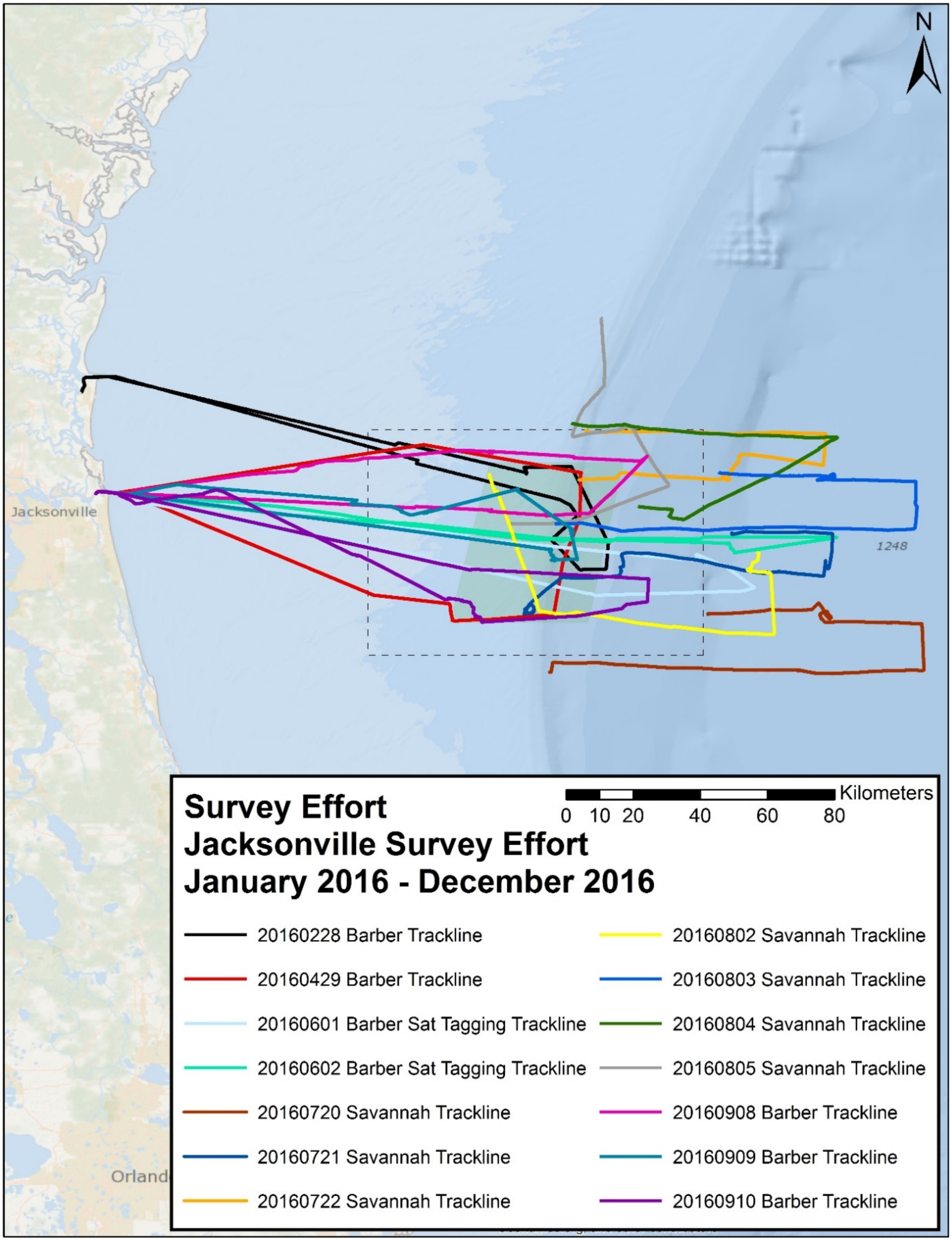


Figure 25. Survey effort during vessel surveys in the JAX study area in 2016.

Forty-two cetacean sightings of five species were recorded during these vessel surveys. As in previous years, bottlenose (*n*=18) and Atlantic spotted dolphins (*n*=10) were frequently observed, in addition to five sightings of short-finned pilot whales. Two sightings each of pantropical spotted dolphins (*Stenella attenuata*) and rough-toothed dolphins also were recorded, along with five sightings of unidentified delphinids (**Table 28**; **Figure 26**). As in previous years, bottlenose dolphins were encountered throughout the JAX study area, including deeper oceanic waters, whereas Atlantic spotted dolphins were restricted to the relatively shallow, continental shelf waters. Short-finned pilot whales and pantropical spotted dolphins were found exclusively in deeper oceanic waters. Rough-toothed dolphins were observed either at or inshore of the continental shelf break.

Table 28. Sightings from vessel surveys conducted in the JAX study area in 2016.

Common Name	Scientific Name	Number of Sightings	Number of Individuals
Short-finned pilot whale	*Globiecephala macrorynchus*	5	45
Pantropical spotted dolphin	*Stenella attenuata*	2	120
Atlantic spotted dolphin	*Stenella frontalis*	10	763
Rough-toothed dolphin	*Steno bredanensis*	2	66
Bottlenose dolphin	*Tursiops truncatus*	18	134
Unidentified delphinid		5	45
Leatherback turtle	*Dermochelys coriacea*	4	2
Loggerhead turtle	*Caretta caretta*	22	24

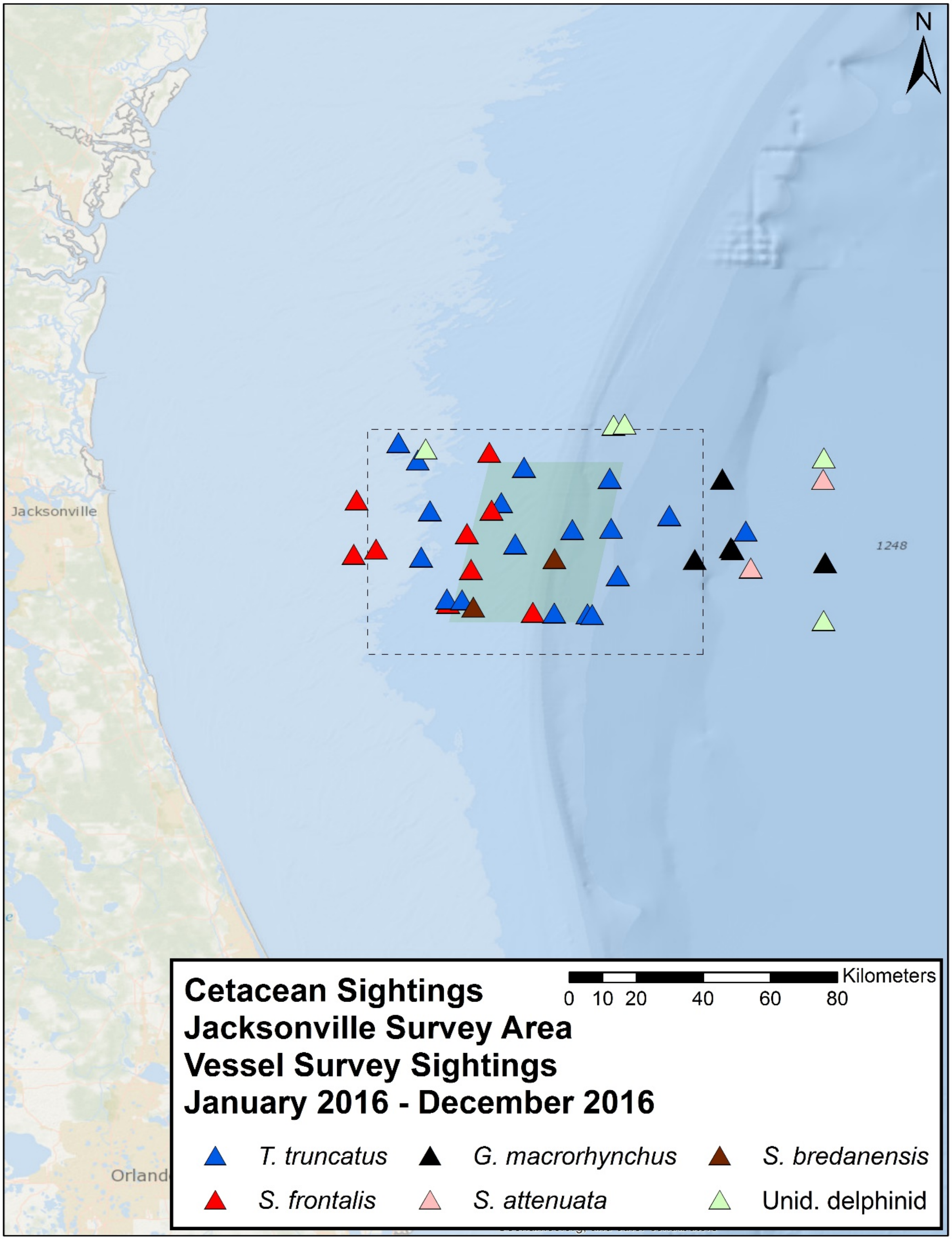


Figure 26. Cetacean sightings from vessel surveys conducted in the JAX study area in 2016.

Twenty-six sea turtles were recorded in the JAX study area during 2016. As in past years, the loggerhead turtle (*n*=22) was the most frequently recorded species, with a small number of sightings of leatherback turtles (*n*=4) (**Table 28**). The majority of all sea turtles were observed over the continental shelf (**Figure 27**).

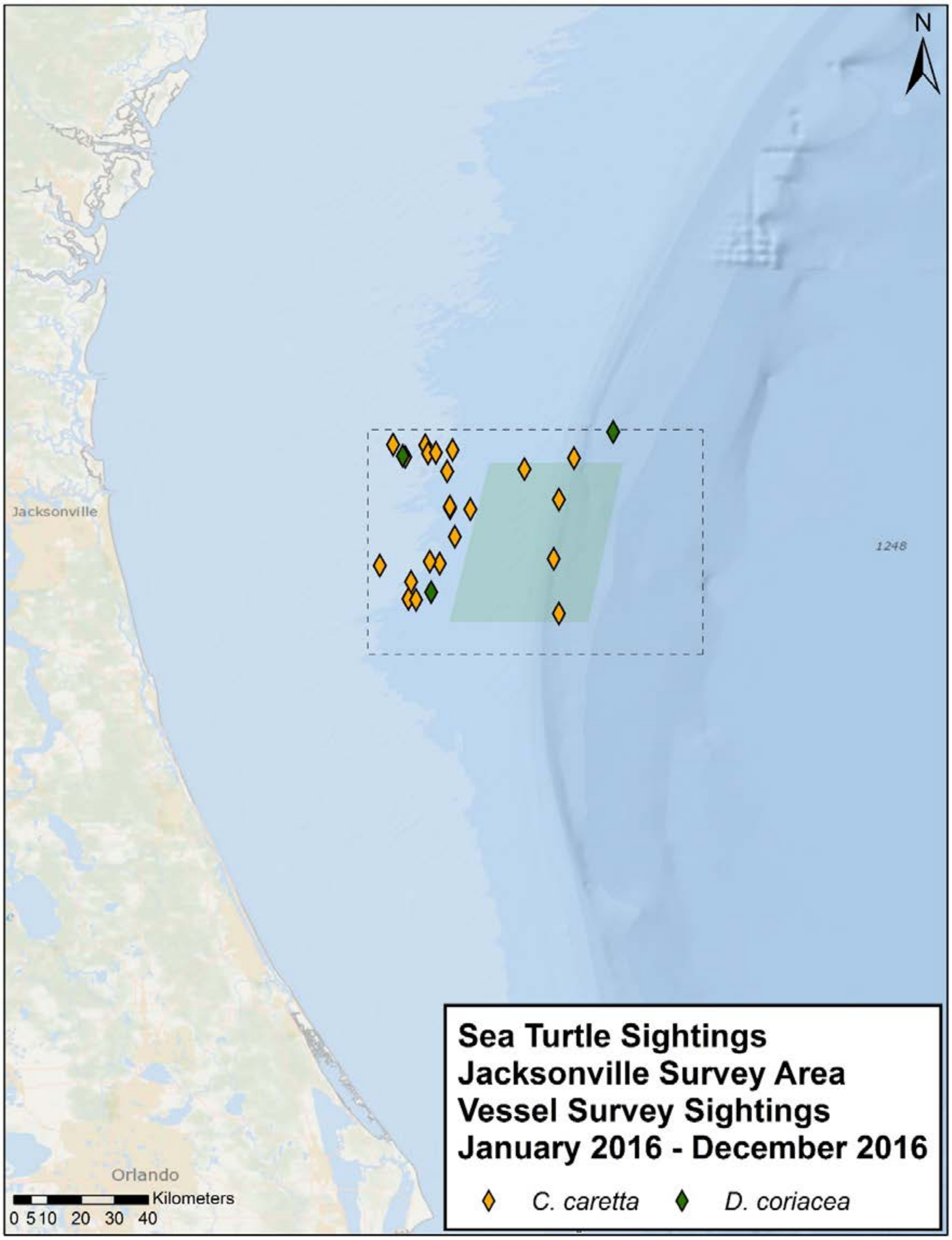


Figure 27. Sea turtle sightings from vessel surveys conducted in the JAX study area in 2016.

Four satellite tags were deployed on short-finned pilot whales and one on an Atlantic spotted dolphin in the JAX study area in June 2016 (see **Section 2.2.1** of this report for more information).

Twenty-four biopsy samples were collected from short-finned pilot whales (*n*=7), Atlantic spotted dolphins *(n*=7), bottlenose dolphins (*n*=5), rough-toothed dolphins (*n*=4), and pantropical spotted dolphins (*n*=1) (**Table 29, Figure 28**). Skin samples will be analyzed for sex determination. Voucher specimens of these samples have been archived with the NMFS' SEFSC in Lafayette, Louisiana.

Table 29. Biopsy samples collected from animals in the JAX study area in 2016.

Common Name	Scientific Name	No. Samples
Short-finned pilot whale	*Globicephala macrorhynchus*	7
Atlantic spotted dolphin	*Stenella frontalis*	7
Bottlenose dolphin	*Tursiops truncatus*	5
Rough-toothed dolphin	*Steno bredanensis*	4
Pantropical spotted dolphin	*Stenella attenuata*	1

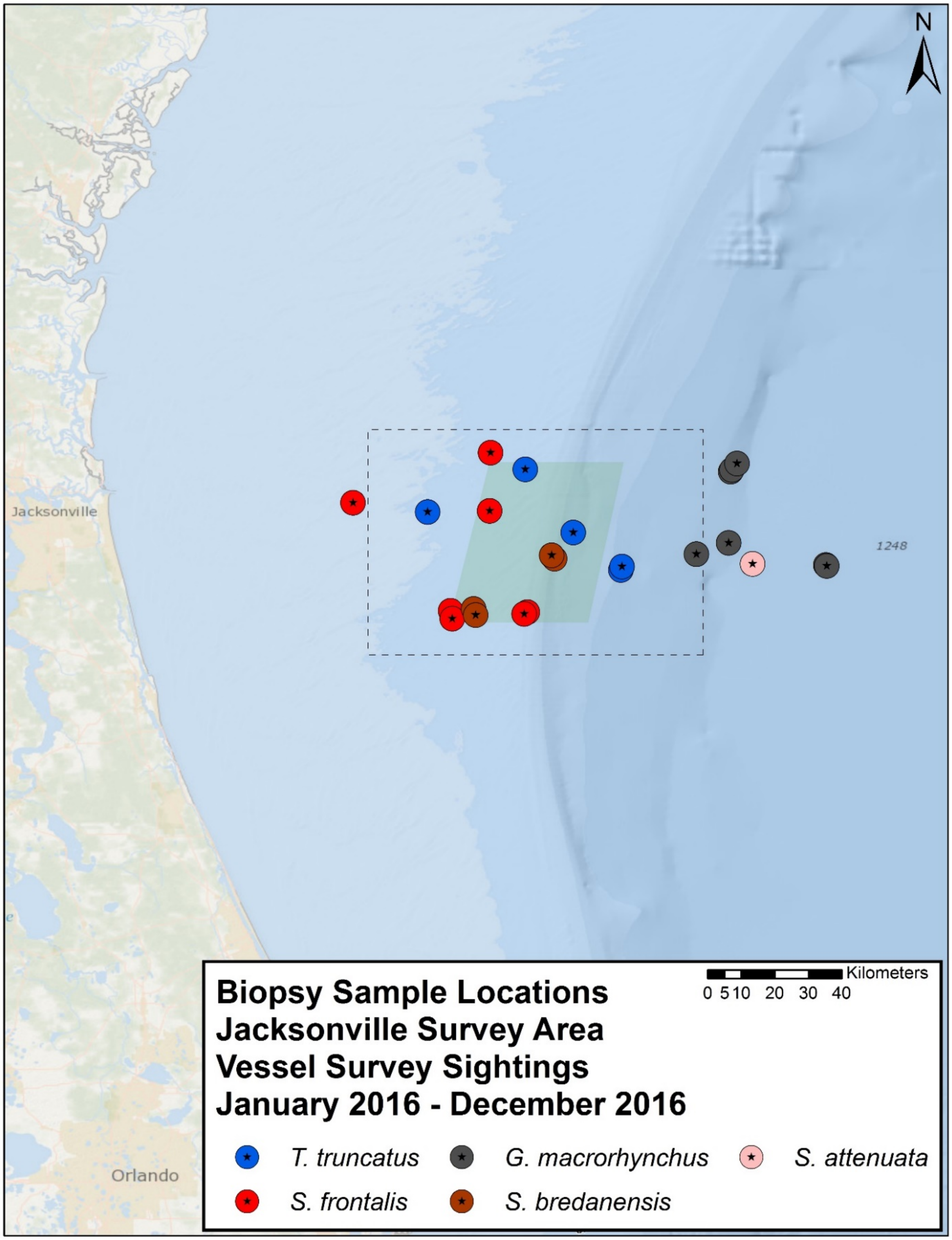


Figure 28. Locations of biopsy samples collected in the JAX study area in 2016.

Over 2,650 digital images were collected for species confirmation and individual identification during 2016, and 110 newly identified dolphins were cataloged (**Table 30**). Photo-ID catalogs for bottlenose and Atlantic spotted dolphins in the JAX study area currently consist of 114 and 154 individuals, respectively. Seventeen new identifications were added to the Jacksonville short-finned pilot whale photo catalog in 2016, for a catalog size of 29 individuals. A new catalog for rough-toothed dolphins in the JAX study area was made this year, consisting of 43 identifications. To date, three individual Atlantic spotted dolphins have been resighted within the JAX study area (**Figure 29**). Sfr 3-001 was observed first on 10 October 2010 and again on 19 March 2011; Sfr 8-005 was photographed during surveys on two consecutive days: 18 and 19 March 2011; Sfr 7-008, first cataloged in 2013, was resighted on 29 April 2016 (**Table 31**). In addition, two bottlenose dolphins were sighted together on 25 January 2012 and 18 July 2013 (**Table 31, Figure 29**). The Risso's dolphin photo-ID catalog consists of 36 individuals, but we have not identified any resightings. Eight individual rough-toothed dolphins have been resighted, as they were seen on consecutive days in September 2016 (**Table 31**).

Table 30. Summary of photo-ID images taken of animals in the JAX study area in 2016 with photo-ID catalog sizes and total number of matches across all years of effort.

Species	Common Name	Images 2016	Catalog Size	Matches
Globicephala macrorhynchus	Short-finned pilot whale	571	29	0
Grampus griseus	Risso's dolphin	0	36	0
Stenella frontalis	Atlantic spotted dolphin	696	154	3
Steno bredanensis	Rough-toothed dolphin	854	43	8
Tursiops truncatus	Bottlenose dolphin	384	114	2

Table 31. Photo-ID matches of bottlenose (Ttr), Atlantic spotted (Sfr), and rough-toothed (Sbr) dolphins observed in the JAX study area across years.

ID	Year							
	2009	2010	2011	2012	2013	2014	2015	2016
Ttr 2-004^				X	X			
Ttr 6-010^				X	X			
Sfr 3-001		X	X					
Sfr 7-008					X			X
Sfr 8-005			X[m]					
Sbr 1-001								X[m]
Sbr 1-002								X[m]
Sbr 6-001								X[m]
Sbr 6-002								X[m]
Sbr 7-001								X[m]
Sbr 7-002								X[m]
Sbr 7-003								X[m]
Sbr 7-004								X[m]

^ Observed together in multiple sightings
[m] Resighted within same month

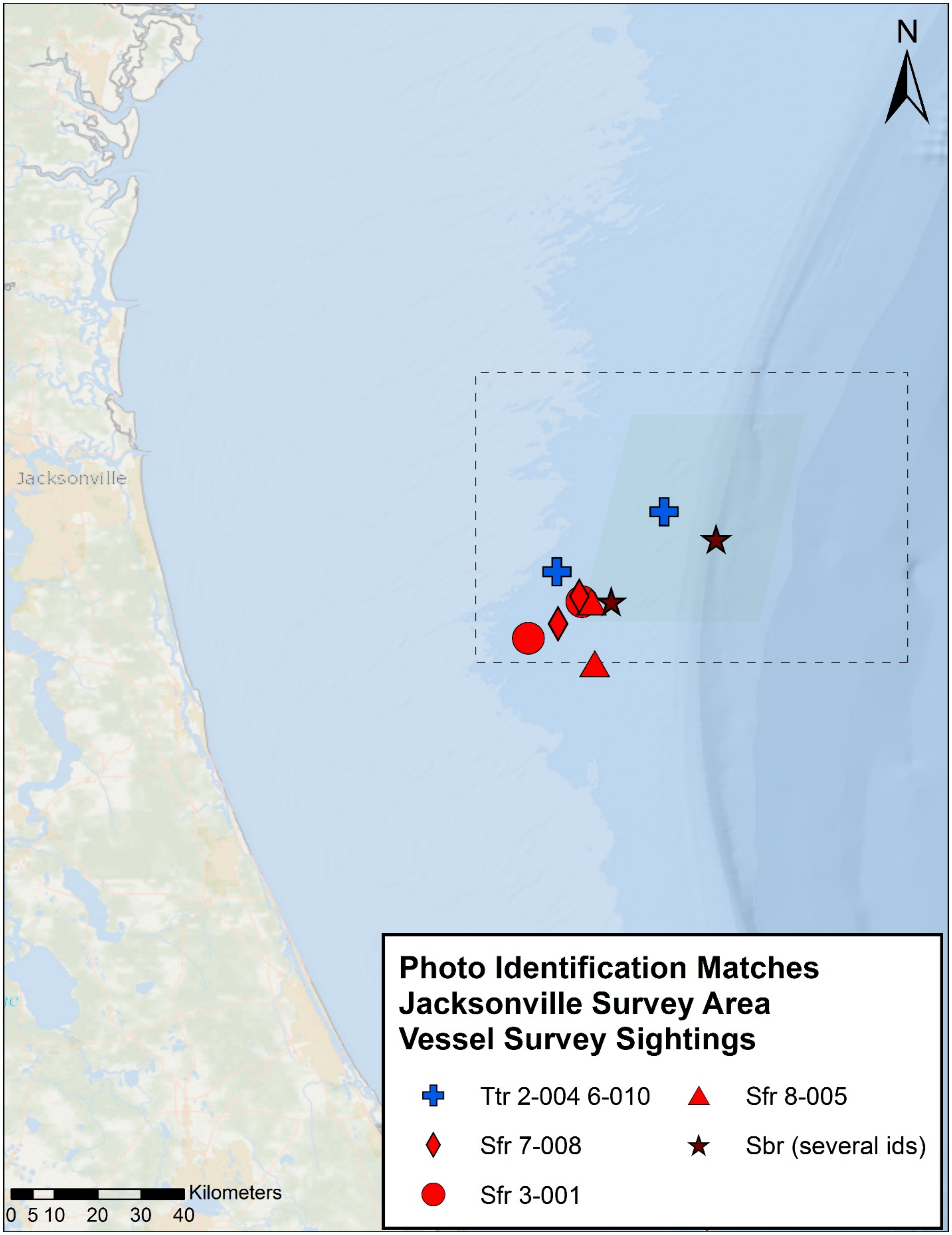


Figure 29. Locations of photo-matched dolphins within the JAX study area across all years.

The JAX short-finned pilot whale photo-ID catalog has been compared to both the Onslow Bay and Cape Hatteras short-finned pilot whale photo-ID catalogs, and no matches have been identified.

We also compared the short-finned pilot whale photo-ID catalogs from both the JAX and Onslow Bay study areas with catalogued individuals from The Bahamas, where the Bahamas Marine Mammal Research Organisation has been conducting surveys since 1991. More recently in The Bahamas, a U.S. Department of Defense's (DOD's) Strategic Environmental Research and Development Program project evaluating the behavioral ecology of deep-diving odontocetes of the area was conducted, and the short-finned pilot whale was one of the six target species.

Collectively, short-finned pilot whales have been observed on ten occasions in the Onslow Bay and Jacksonville study areas since surveys commenced in 2007. The Onslow Bay study area has a short-finned pilot whale photo-ID catalog of 27 individuals, while the JAX photo-ID catalog contains 29 individuals. To date, 12 short-finned pilot whales from these areas have been matched to The Bahamas photo-ID catalog: five were observed in the Onslow Bay study area and seven in the JAX study area (**Figure 30**). Five individuals were observed in the same group in both The Bahamas (02 June 2009) and Onslow Bay study area (18 August 2009), observed just over two months apart. Interestingly, all seven of the JAX matches were observed on the same day in the same group in both The Bahamas (17 September 2007) and in the JAX study area (26 September 2009). Additionally, three of these seven individuals observed in the JAX study area in 2009 were again observed in The Bahamas on 22 August 2015. We will continue to compare these catalogs for matches as photo-ID continues, as well as comparing the Cape Hatteras short-finned pilot whale photo-ID catalog to the Bahamas photo-ID catalog.

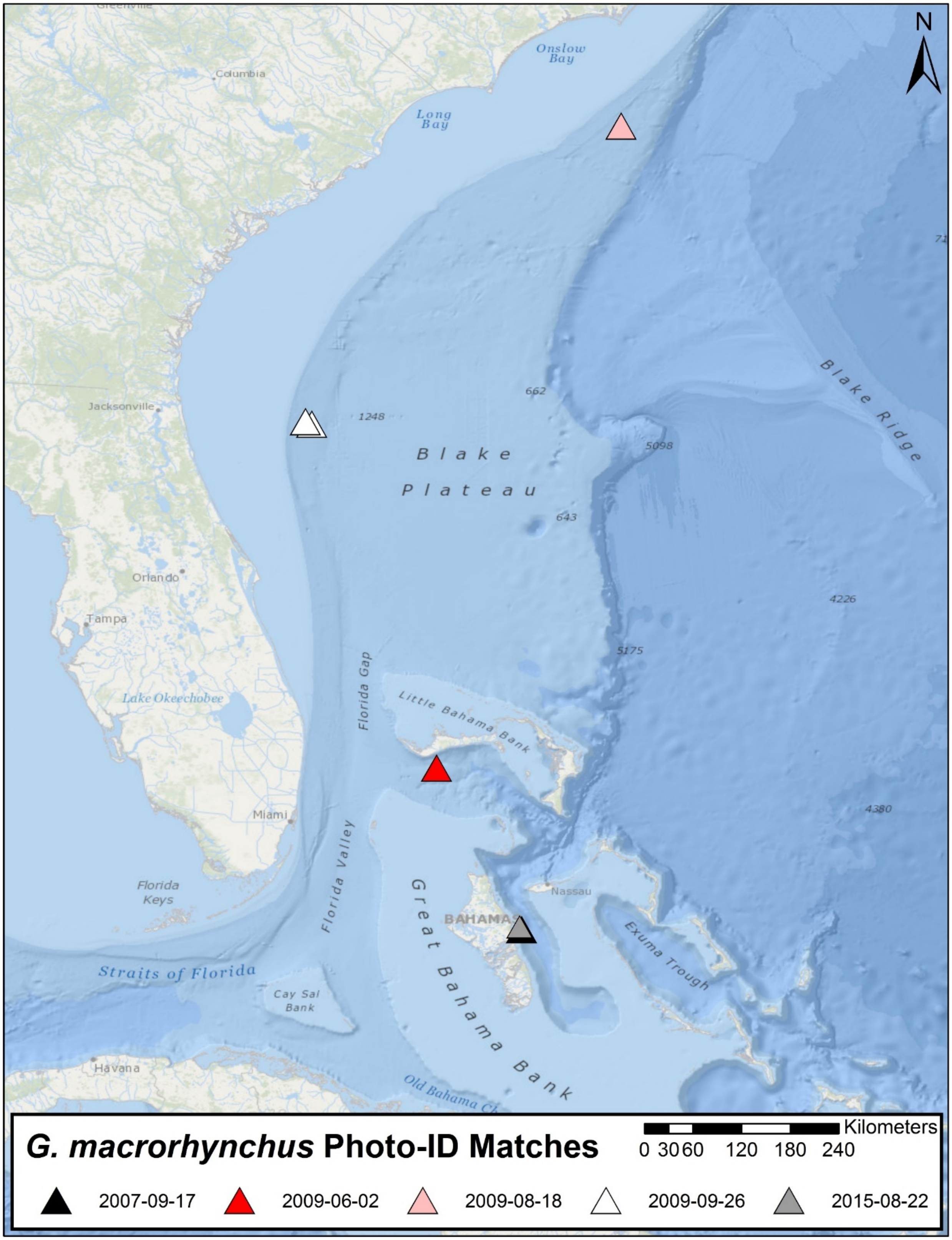


Figure 30. Locations of photo-matched short-finned pilot whales between the Onslow Bay, JAX, and Bahamas photo-ID catalogs.

Cumulative

Total survey effort conducted since the beginning of the monitoring program for the JAX study area is reported in **Table 32**. The annual numbers of sightings by species for both cetaceans and sea turtles in the JAX study area are presented in **Tables 33 and 34**, respectively. The numbers of biopsy samples collected to date in the JAX study area are reported in **Table 35. Table 36** summarizes the numbers of photo-ID images, catalog sizes, and matches by species to date.

Table 32. Duration and distance surveyed annually since 2009 (Year 1) in the JAX study area.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Total
Survey Hours	127	21	59	59	67	44	131	**508**
km Surveyed	2,074	346	937	1,022	1,227	858	2,136	**8,600**

Key: Year 1 (July 2009–December 2010), Year 2 (2011), Year 3 (2012), Year 4 (2013), Year 5 (2014), Year 6 (2015), and Year 7 (2016).

Table 33. Numbers of cetacean sightings annually since 2009 (Year 1) for each species in the JAX study area.

Species	Sightings						
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Eubalaena glacialis	0	0	0	0	1	0	0
Globicephala macrorhynchus	3	0	0	0	0	0	5
Grampus griseus	2	0	0	1	1	1	0
Stenella frontalis	35	6	14	9	20	10	10
Steno bredanensis	0	0	0	0	0	0	2
Tursiops truncatus	19	6	23	15	18	10	18
Tursiops/Stenella mix	0	0	0	0	1	0	0
Unidentified delphinid	13	0	4	3	4	0	5
Total	**72**	**12**	**41**	**28**	**45**	**21**	**42**

Key: Year 1 (July 2009–December 2010), Year 2 (2011), Year 3 (2012), Year 4 (2013), Year 5 (2014), Year 6 (2015), and Year 7 (2016).

Table 34. Numbers of sea turtle sightings annually since 2009 (Year 1) for each species in the JAX study area.

Species	Sightings						
	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
Caretta caretta	52	20	41	33	31	22	22
Dermochelys coriacea	8	3	4	1	3	2	4
Lepidochelys kempii	1	0	1	0	0	0	0
Unidentified turtle	8	3	3	1	0	0	0
Total	**69**	**26**	**49**	**35**	**34**	**24**	**26**

Key: Year 1 (July 2009–December 2010), Year 2 (2011), Year 3 (2012), Year 4 (2013), Year 5 (2014), Year 6 (2015), and Year 7 (2016).

Table 35. Biopsy samples collected annually since 2009 (Year 1) in the JAX study area.

Species	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Total
Globicephala macrorynchus	0	0	0	0	0	0	5	**5**
Grampus griseus	0	0	0	1	2	0	0	**3**
Stenella attenuata	0	0	0	0	0	0	1	**1**
Stenella frontalis	0	0	19	6	19	3	7	**54**
Steno bredanensis	0	0	0	0	0	0	4	**4**
Tursiops truncatus	0	0	12	5	10	5	5	**37**

Key: Year 1 (July 2009–December 2010), Year 2 (2011), Year 3 (2012), Year 4 (2013), Year 5 (2014), Year 6 (2015), and Year 7 (2016).

Table 36. Summary of images collected during all vessel surveys in the JAX study area 2009-2016, with photo-ID catalog sizes and matches to date.

Species	2009-2016	
	Catalog Size	Matches
Globicephala macrorhynchus	29	0
Grampus griseus	36	0
Stenella frontalis	154	3
Steno bredanensis	43	8
Tursiops truncatus	114	2

For more information on this study, refer to the annual progress report for this project (Foley et al. 2017a).

2.1.2.4 Virginia Beach and Naval Station Norfolk Vessel Surveys

From 2012 to 2015, HDR conducted vessel surveys and passive acoustic monitoring near Naval Station Norfolk (NSN) and Virginia Beach to assess the occurrence, distribution, and density of marine mammals. The primary goal of this project was to understand the seasonal occurrence and densities of bottlenose dolphins in the area so that the U.S. Navy can make more informed decisions on proposed training and testing activities and minimize potential impacts to marine mammals in this area. Vessel-based line-transect and photo-id survey field work for this project were completed in August 2015, and passive acoustic monitoring using both C-PODs and Ecological Acoustic Recorders (EARs) were completed in January 2016 and July 2016, respectively. This section includes a summary of the progress and updated results from 3 years of the study period for the line-transect, photo-ID, and C-POD work. Refer to **Section 2.3.2** of this report for presentation of the passive acoustic results from EAR deployments, which covered the entire 4-year study period.

The study area included waters around NSN, Joint Expeditionary Base Little Creek (JEB-LC), JEB Fort Story (JEB-FS), the Virginia Beach oceanfront, and the VACAPES Mine-neutralization Exercise (MINEX) W-50 training range (**Figure 31**). Two primary survey zones included COASTAL/INSHORE and OFFSHORE/MINEX zones. The INSHORE zone was a 310.4-km^2 strip extending from the shoreline to 3.7 km offshore. This zone included the Chesapeake Bay waters near NSN and waters off JEB-LC and JEB-FS and extended down the Atlantic coast towards the Virginia/North Carolina border. The MINEX zone encompassed Atlantic waters from 3.7 to 25.7 km from shore and included almost the entire VACAPES MINEX W-50a and W-50b training areas. Totals of 33 INSHORE and 28 MINEX line-transect surveys were conducted between August 2012 and August 2015. Total on-effort coverage included 3,634 km in the INSHORE zone and 2,916 km in the MINEX zone.

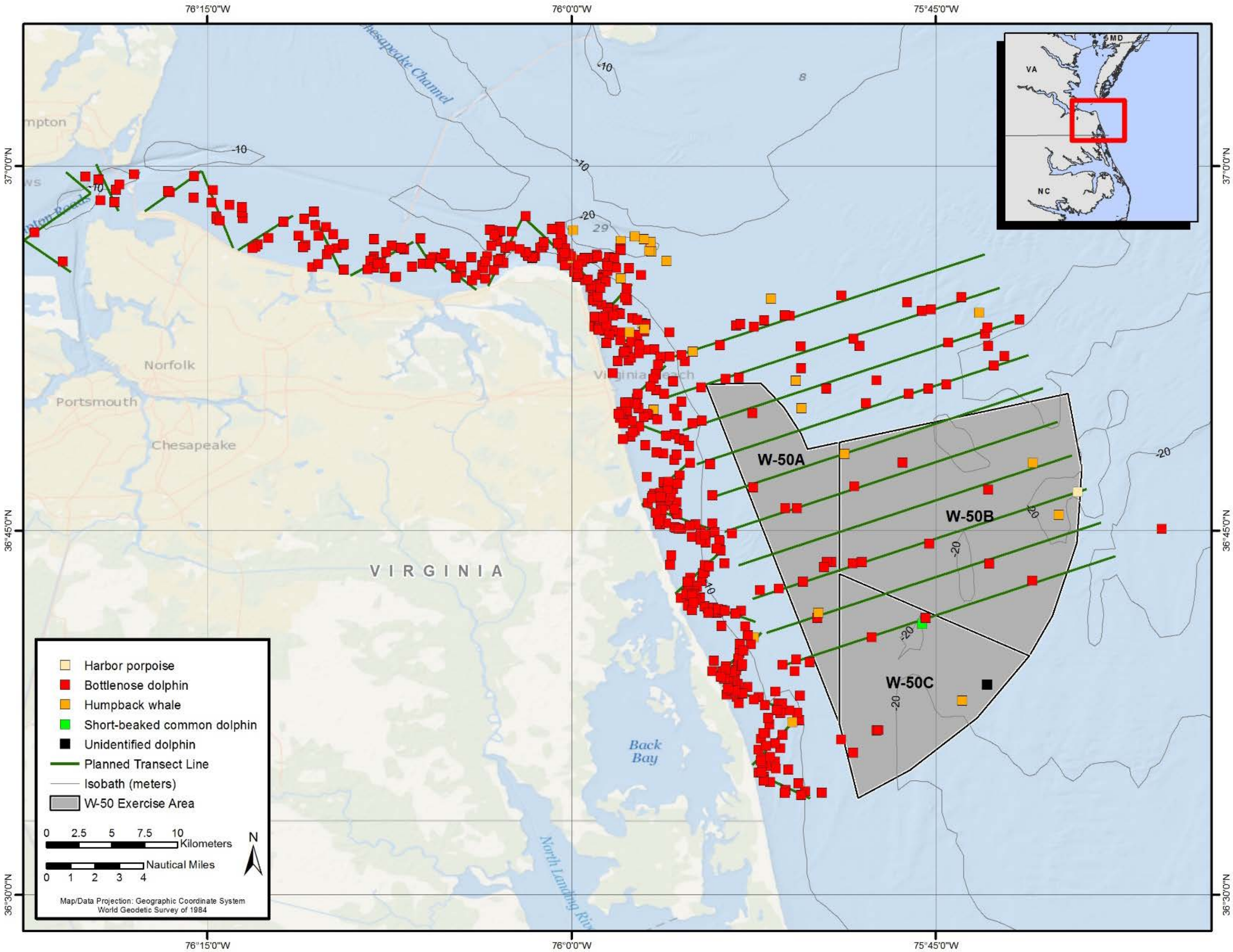


Figure 31. Marine mammal sightings during all line-transect vessel surveys near Naval Station Norfolk and Virginia Beach between August 2012 and August 2015.

A total of 546 marine mammal sightings and 111 sea turtle sightings were recorded during the line-transect surveys (**Table 37**; **Figures 31 and 32**). The majority (approximately 95 percent; *n*=517) of marine mammal sightings were of bottlenose dolphins. Humpback whale (*n*=26), harbor porpoise (*Phocoena phocoena*) (*n*=1), and short-beaked common dolphin (*n*=1) were also sighted (**Figure 31**). The one group of unidentified dolphins recorded was most likely short-beaked common dolphins; however, species identification could not be confirmed. Researchers sighted 91 marine mammal groups in the MINEX zone and 455 groups in the INSHORE zone (**Table 37**). Sea turtle sightings included loggerhead (*n*=71), leatherback (*n*=15), Kemp's ridley (*Lepidochelys kempii*) (*n*=1), unidentified (*n*=8), and unidentified hardshell (*n*=11) turtles (**Figure 32**). Researchers made 84 sea turtle sightings in the MINEX zone and 27 sea turtle sightings in the INSHORE zone (**Table 37**).

Table 37. Summary of marine mammal and sea turtle sightings near Naval Station Norfolk and Virginia Beach, August 2012–August 2015.

Zone	Season	No. Survey Days	Distance On-Effort (km)	No. Cetacean Sightings	No. Cetacean Individuals*	No. Sea Turtle Sightings	No. Sea Turtle Individuals*
INSHORE	Fall	9	1,022.9	227	2,550	9	9
INSHORE	Winter	8	794.3	30	318	0	0
INSHORE	Spring	9	1,020.8	65	710	0	0
INSHORE	Summer	7	796.3	133	2,198	18	18
INSHORE Total		***33***	***3,634.3***	***455***	***5,776***	***27***	***27***
MINEX	Fall	7	754.5	26	493	14	14
MINEX	Winter	6	600.3	9	25	0	0
MINEX	Spring	6	596.2	33	366	20	20
MINEX	Summer	9	965.0	23	291	50	50
MINEX Total		***28***	***2,916.0***	***91***	***1,175***	***84***	***84***
Total		**61**	**6,550.3**	**546**	**6,951**	**111**	**111**

*Total individuals = sum of best group size estimates.

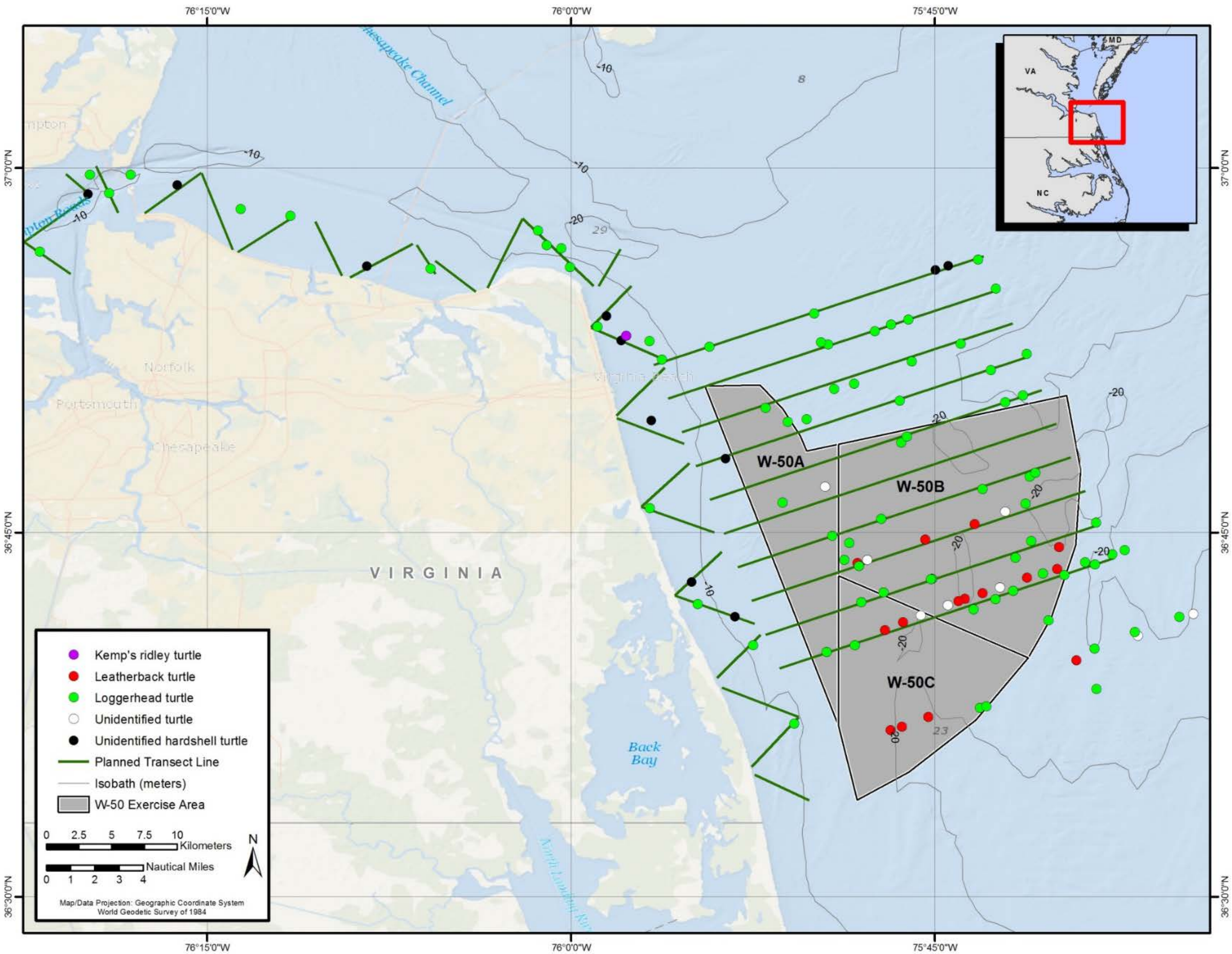


Figure 32. Sea turtle sightings during all line-transect vessel surveys in coastal waters around Naval Station Norfolk and Virginia Beach, Virginia, August 2012–August 2015.

Conventional Distance-sampling methods were used to generate density and abundance estimates from the line-transect survey data. Seasonal estimates were generated based on the following definitions: spring (March–May), summer (June–August), fall (September–November), and winter (December–February). Density and abundance estimates could only be generated for bottlenose dolphins, as the sample sizes for other species were too small to fit a detection function and produce reliable estimates of density and abundance.

Bottlenose dolphin density (individuals per km^2) and abundance (N) estimates were generated using 413 sightings and 3,535.3 km of effort in the INSHORE zone, and 77 sightings and 2,478.3 km of effort in the MINEX zone. All sightings and effort used in this analysis were recorded during acceptable sighting conditions (i.e., BSS 0 to BSS 3). Data were pooled to model the detection function and then stratified by season and zone. Bottlenose dolphin density varied both spatially and seasonally, with the highest densities estimated in the INSHORE zone during the fall and summer. Density and abundance estimates for this zone ranged from 3.88 individuals/km^2 (N=1,203; coefficient of variation [CV]=25%) in fall and 3.55 individuals/km^2 (N=1,101; CV=22%) in summer to 1.00 individuals/km^2 (N=311; CV=32%) in spring and 0.63 individuals/km^2 (N=195; CV=63%) in winter. Estimated densities and abundances for the MINEX zone were: 2.14 individuals/km^2 (N=1,277; CV=91%) in fall, 0.06 individuals/km^2 (N=37; CV=124%) in winter, 1.53 individuals/km^2 (N=913; CV=38%) in spring, and 1.39 individuals/km^2 (N=829; CV=69%) in summer. However, the fall and winter estimates are considered unreliable due to the extremely high CVs. Additional analyses using density-surface modeling techniques may provide more reliable and precise seasonal estimates for this zone. Additional density and abundance estimates were generated for specific areas and seasons within each zone and during different time periods (see Engelhaupt et al. 2016).

Photo-identification Effort

Twenty-seven photo-ID surveys were completed between August 2012 and August 2015 (**Figure 33**). A total of 193 bottlenose dolphin groups was sighted. Monthly surveys were not always possible due to poor weather conditions. An electronic photo-ID catalog was created using images of bottlenose dolphin dorsal fins collected from both the dedicated photo-ID and line-transect surveys to provide insight into stock structure. The cataloging effort is ongoing; the catalog currently contains 993 identified individuals and includes photos taken through July 2014 during both photo-ID and line-transect surveys. There is no sign of a plateau in the number of identified dolphins in the study area. Resight rates across surveys were low. Excluding same-day resights, there have been 155 matches of catalogued individuals, which include second resights of 28 individuals and third resights of three individuals. Most resights occurred within the same year (101 of 155), and all were recorded less than 23 km from the initial sighting. Dolphins sighted in Chesapeake Bay and along the Cape Henry region were not resighted along the Atlantic side of Virginia Beach in the southern portion of the study area. Additional survey effort and photo-ID analyses are required to discern sub-stock differentiation or any patterns in movements and site fidelity. Photos collected through July 2014 have been submitted for matching to NMFS' existing Mid-Atlantic Bottlenose Dolphin Catalog (MABDC; Urian et al. 1999). Based on data submitted to the MABDC, Urian et al. (2016) noted that the year-round effort from HDR (442 individual dolphins) was extremely useful for examining the potential mixing of the Northern Migratory and Northern North Carolina Estuarine System stocks in Chesapeake Bay and off Virginia Beach.

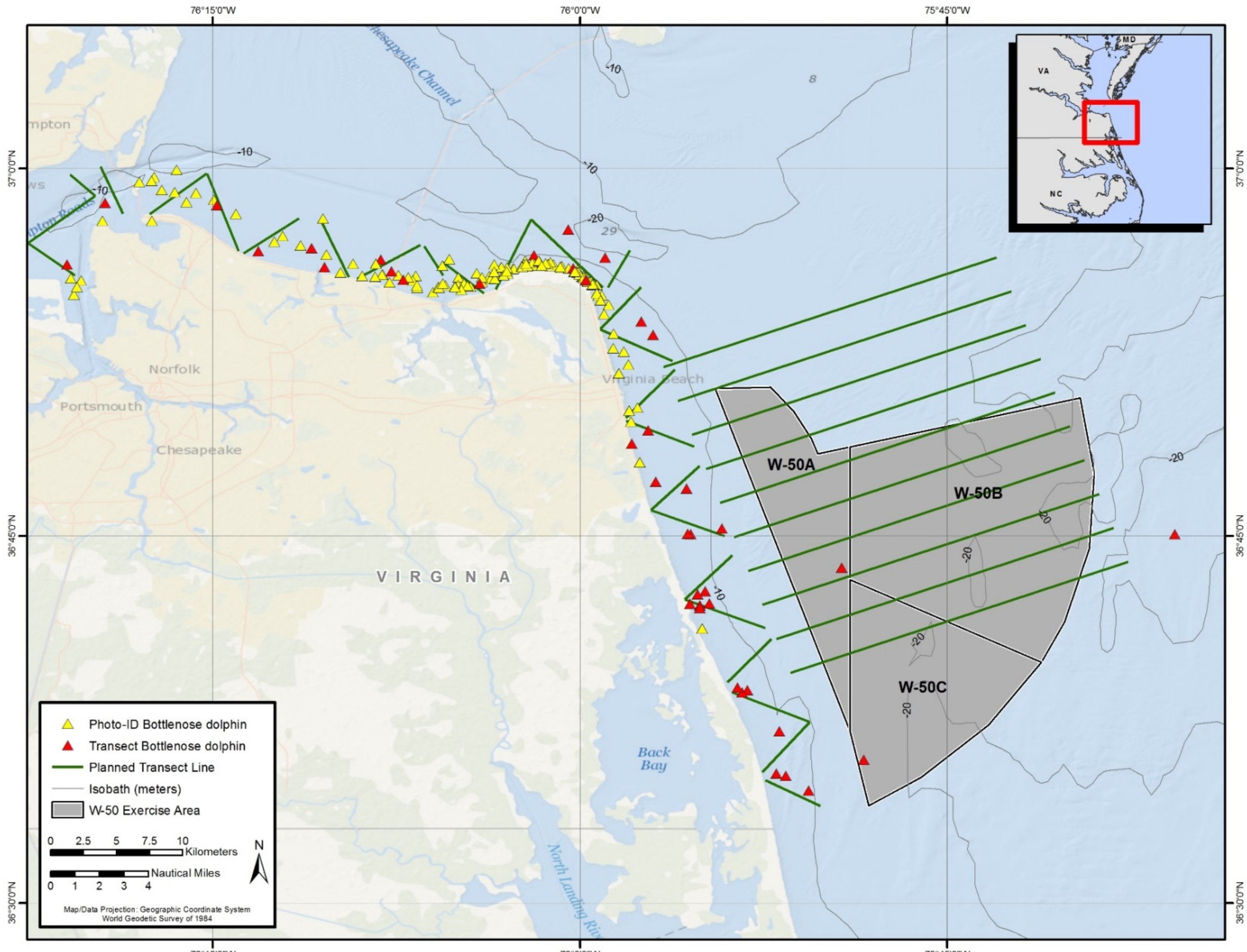


Figure 33. Group sighting locations in photo-ID catalog for bottlenose dolphins near Naval Station Norfolk and Virginia Beach, differentiating photos taken during photo-ID survey and line-transect surveys.

For more information on this study, refer to the final report for this project (Engelhaupt et al. 2016).

2.1.2.5 Chesapeake Bay (NAS Patuxent River) Vessel Surveys

As noted in **Section 2.1.1.5**, a study was initiated in 2015 to provide quantitative data and information on the seasonal occurrence, distribution, and density of marine mammals and sea turtles in Chesapeake Bay waters near NAS Patuxent. Information on the passive acoustic monitoring and aerial surveys associated with this study is found in **Sections 2.3.3 and 2.1.1.5**, respectively.

During each of the C-POD deployment/recovery trips, HDR researchers maintained a visual lookout for dolphins while underway. These surveys were non-systematic and opportunistically conducted to leverage vessel transit time for visual data collection. Time and weather permitting, efforts were made to obtain photographs to be used for photo-ID analysis. A recent collaboration was also established with researchers from Georgetown University (Potomac-Chesapeake Dolphin Project), who are also conducting bottlenose dolphin surveys in the Potomac River, and may result in combining efforts to establish a catalog of all photographed individuals in the NAS Patuxent River region. Photo-IDs can also be made available for comparisons with HDR's bottlenose dolphin photo-ID catalog from Norfolk and Virginia Beach, Virginia (Engelhaupt et al. 2016), which are also included as part of the MABDC, curated by Duke University.

During C-POD deployments in July of 2015 and 2016, four bottlenose dolphin sightings were made during C-POD refurbishment trips and extended survey effort north of the study site and into the Patuxent River (refer to **Figure 85** in **Section 2.3.3**). One sighting was made in July 2015, while three were in July 2016. Group size ranged from five to 70 individuals. Identification photos were collected during three of the four sightings for a total of 2,513 photos. Approximately half of the photographs have been sorted and prepared for cataloging. These data will be archived and available for future analysis and/or collaboration with researchers from Georgetown University and the MABDC.

For more information on this study, refer to the annual progress report for this project (Richlen et al. 2017a).

2.1.2.6 Panama City Vessel Surveys

Bottlenose dolphins inhabit the bay and coastal waters of the Florida Panhandle (reviewed in Waring et al. 2016). Currently, NMFS has delineated one Gulf coastal (Northern Coastal Stock) and seven bay, sound, and estuary (BSE) bottlenose dolphin stocks within the nearshore waters of the Florida Panhandle (Waring et al. 2016). Two of these BSE stocks, Choctawhatchee Bay and Apalachicola Bay, have been studied for one- to two-year periods using photo-ID surveys to estimate seasonal abundance and to provide insights into stock structure (Conn et al. 2011, Tyson et al. 2011, respectively). The St. Joseph Bay Stock, subject of the only long-term study of dolphins in the Florida Panhandle, has been studied since 2004 to understand seasonal abundance and distribution patterns (Balmer et al. 2013), assess dolphin health (Schwacke et al. 2010), and identify contaminant levels (Wilson et al. 2012, Balmer et al. 2015). Although these studies provided valuable information for BSE stock assessment in the Florida Panhandle, little is known about the distribution and movement patterns of dolphins that are part of the Northern Coastal Stock, with hypothesized stock boundaries extending from the Big Bend region of Florida (84°W longitude) to the Mississippi River Delta (Waring et al. 2016). During spring and fall, seasonal influxes of dolphins into the St. Joseph Bay region have been observed in which abundance increased two- to three-fold (Balmer et al. 2008). Additionally, extended movements of several individuals have been identified (St. Joseph Bay to Destin, Florida [approximately 100 km] and to

Mississippi Sound [approximately 300 km] [Balmer et al. 2016]), suggesting that the Northern Coastal Stock may seasonally co-occur with BSE stocks.

The Naval Surface Warfare Center, Panama City Division Testing Range (NSWC PCD) is located in the nearshore and offshore waters of the Florida Panhandle and Alabama, extending from the coast to over 220 km seaward, and inclusive of St. Andrew Bay, Florida. Limited data exist on the St. Andrew Bay Stock and adjacent Northern Coastal Stock. Blaylock and Hoggard (1994) conducted aerial line-transect surveys in the fall of 1992 and 1993 and estimated the abundance of the St. Andrew Bay Stock to be 124 (95% [confidence interval [CI]=59–259). Bouveroux et al. (2014) conducted photo-ID surveys in a limited portion of the St. Andrew Bay Stock's boundaries and estimated abundance ranging from 89 (95% CI=71–161) in March to May 2004 to 183 (95% CI=169–208) in June to July 2007. At present, there is no current abundance estimate encompassing the entire St. Andrew Bay Stock. Furthermore, it is unknown if the Northern Coastal Stock follows a similar pattern to what is observed in the St. Joseph Bay region, with seasonal influxes into St. Andrew Bay.

The goals of this study were to determine seasonal abundance, habitat use, and distribution patterns of bottlenose dolphins in St. Andrew Bay and adjacent coastal waters in the NSWC-PCD Testing Range using capture-recapture (CR) photo-ID survey methods. During fall in the St. Joseph Bay region, the observed two- to three-fold increase in abundance was attributed to Northern Coastal Stock dolphins entering St. Joseph Bay waters. St. Joseph Bay summer abundance was low, and animals sighted during this season were suggested to be representative of the BSE Stock. Thus, the seasons selected for initial surveying in St. Andrew Bay were summer (July 2015) and fall (October 2015) to determine abundance for the BSE Stock and provide insight into abundance and movements of Northern Coastal Stock dolphins. Additional photo-ID surveys were conducted in 2016 covering spring (April) and fall (October). Specific study objectives were as follows:

1. Identify which marine mammal species occur seasonally within St. Andrew Bay and nearby coastal waters (<3 km from shoreline);
2. Calculate seasonal resight rates for individual dolphins and develop a site-fidelity index for dolphins in this region to provide baseline data for future studies to assess long-term residence;
3. Determine distribution patterns for dolphins within and between St. Andrew Bay and coastal waters;
4. Estimate seasonal abundance across the two primary sessions (July and October 2015); and
5. Correlate dolphin presence with particular environmental parameters (e.g., water depth, water temperature, water salinity) and broad habitat types (e.g., shallow bay, channel, seagrass bed, surf zone, open water).

Analysis and Results from 2015 Surveys

For estuarine waters, contour transects (i.e., transects that follow a particular geographic feature) were followed either 500 m from the shoreline or along the 1-m depth contour. Contour transects in coastal waters were followed approximately 500 m and 3 km off the coastline (**Figure 34**). The total distance of all survey transects for the estuarine and coastal waters were 200 km and 52 km, respectively.

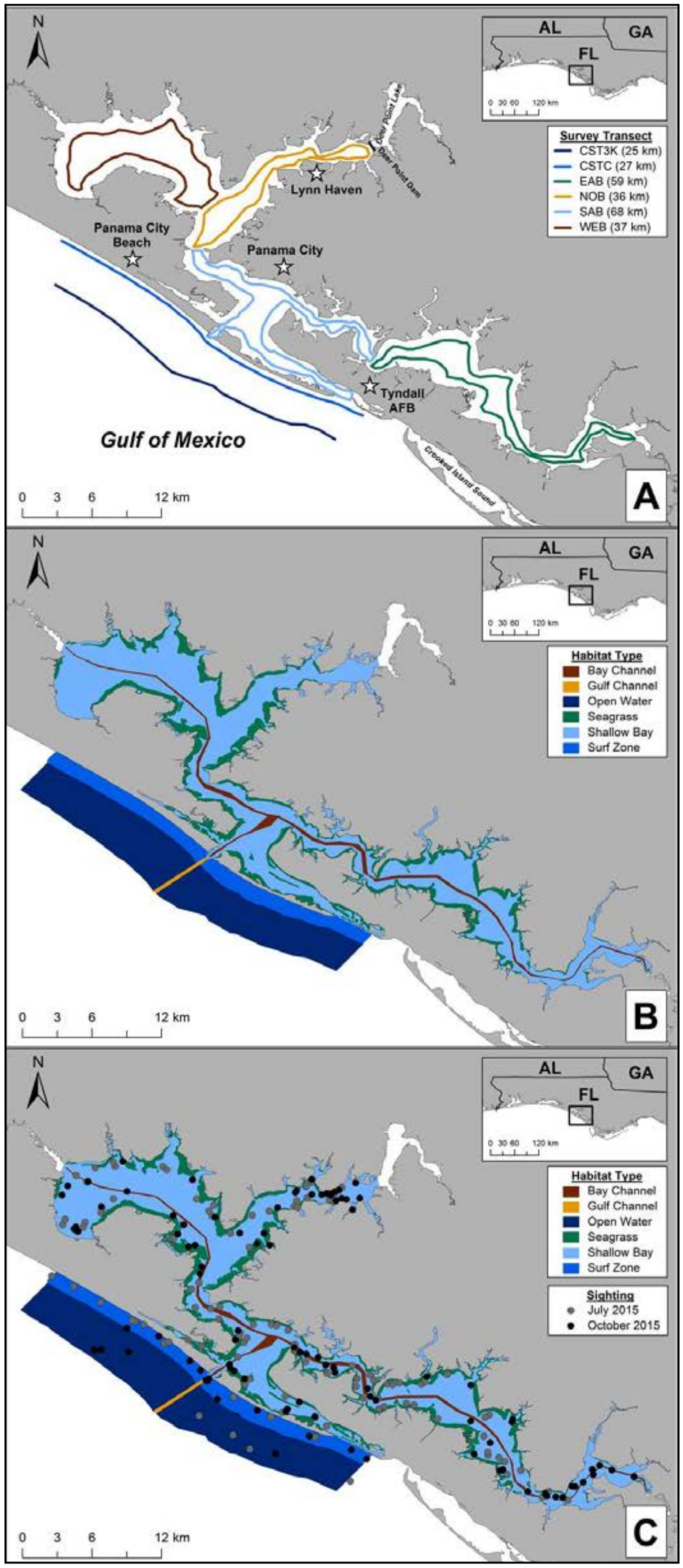


Figure 34. (A) St. Andrew Bay photo-ID study area with survey transects and survey distance (km) [Coastal 3 km offshore (CST3K), Coastal 0.5 km offshore (CSTC), East Bay (EAB), North Bay (NOB), St. Andrew Bay (SAB), and West Bay (WEB)], (B) habitat types, and (C) 2015 sighting distribution.

The survey vessel was a 6.3-m, center-console, rigid-hulled inflatable boat with twin 90-horsepower outboard engines. Survey speed was maintained at approximately 30 km/hr while searching for dolphins. At least three observers were on board each day, and each observer covered 60 degrees of the 180-degree sector forward of the vessel beam. During each survey, a sighting and associated sighting data (i.e., time, geographic location, total number of dolphins, group behavior(s), and various observational and environmental parameters [reviewed in Melancon et al. 2011] was recorded when any dolphin was encountered. A Canon EOS-1D X camera with a 100- to 400-millimeter telephoto lens (or comparable digital camera) was used to capture dorsal fin images of each individual in the group. Effort was made to photograph all dolphins within a sighting (full photo coverage) without regard to distinctiveness. Conditions that could preclude full coverage included: 1) prolonged adverse behavioral reactions by one or more dolphins in the group; 2) sighting duration greater than 45 min; and 3) adverse weather conditions.

All digital photographs were downloaded and sorted using protocols discussed in Speakman et al. (2010). A standardized approach was used to grade photograph quality and dorsal fin distinctiveness (Urian et al. 2014). Photographs and associated sighting data were entered into FinBase (Adams et al. 2006), a customized Microsoft Access (Microsoft Corporation, Redmond, Washington) database. Dorsal fin images were also incorporated into the Digital Analysis to Recognize Whale Images on a Network (DARWIN) program, which utilizes image-processing algorithms to identify dorsal fins that have the same or similar features (Roberts et al. 1999). The St. Andrew Bay project is the first to use DARWIN in conjunction with FinBase for dorsal fin matching, and the incorporation of both of these programs has formed the foundation of an enhanced and more efficient matching process that will be applied to other bottlenose dolphin photo-ID projects in the southeastern U.S.

Remote biopsy samples were collected using a Barnett Panzer V crossbow (Barnett Outdoors, LLC, Tarpon Springs, Florida). Sample collection and in-field processing have been described previously in Sinclair et al. (2015). Collected tissue was subsampled for five projects: genetics (skin), POPs (blubber), genomics (skin and blubber), stable isotopes (skin), and hormones (blubber).

Photo-ID survey effort was conducted in the St. Andrew Bay study area during 14–21 July, 27 July, and 12–18 October 2015 (additional scouting surveys and biopsy sampling effort were conducted on 13, 22–25, and 28–29 July and 19–23 October, which were not included in this survey summary). All bay and coastal transects were completed three times in each primary period, totaling six times across 2015. Cumulatively, 2,050 km were surveyed over 116 on-water hours (**Table 38**). A total of 162 sightings was recorded during 2015; 651 dolphins were observed, including 74 calves and three neonates (**Figure 34C**). Mean group size was 4.2 individuals; 95 percent of all dolphins sighted were photographed (*n*=616 of 651).

Table 38. Bottlenose dolphin photo-ID effort and results in the St. Andrew Bay study area, for each survey zone (bay and coastal), during July 2015, October 2015, and cumulatively (2015).

Zone	Total Hours	On-effort Hours	Total km	Survey km	Time in Contact (hr)	Total Sightings	Total Dolphins (FE)	Total Calves (PA)	Total Neonates (PA)	Mean Group Size (PA)	Dolphins Photographed	Proportion Photographed
July 2015												
Bay	48	27	848	659	14	66	213	22	1	3.4	205	0.96
Coastal	12	8	208	173	3	16	42	9	1	2.6	38	0.90
Total	**60**	**35**	**1,056**	**832**	**17**	**82**	**255**	**31**	**2**	**3.3**	**243**	**0.95**
October 2015												
Bay	43	25	763	575	14	64	328	32	1	5.3	314	0.96
Coastal	13	8	231	182	4	16	68	11	0	4.3	59	0.87
Total	**56**	**33**	**994**	**757**	**18**	**80**	**396**	**43**	**1**	**5.1**	**373**	**0.94**
2015												
Bay	91	52	1,611	1,234	28	130	541	54	2	4.4	519	0.96
Coastal	25	16	439	355	7	32	110	20	1	3.4	97	0.88
Total	**116**	**68**	**2,050**	**1,589**	**35**	**162**	**651**	**74**	**3**	**4.2**	**616**	**0.95**

Key: FE=field estimate; PA=photo analysis result.

During CR photo-ID surveys, 130 and 95 new, distinctive individuals were identified in July and October 2015, respectively (**Figure 35**). The numbers of new individual continued to increase with each sampling session, with no indication of reaching a plateau. Including photo-IDs collected during biopsy-sampling surveys), totals of 171 and 75 new, distinctive individuals were identified in July and October 2015, respectively (**Figure 35**). The number of distinctive individuals sighted in both July and October was 114. The St. Andrew Bay study area photo-ID catalog consists of 246 distinctive individuals.

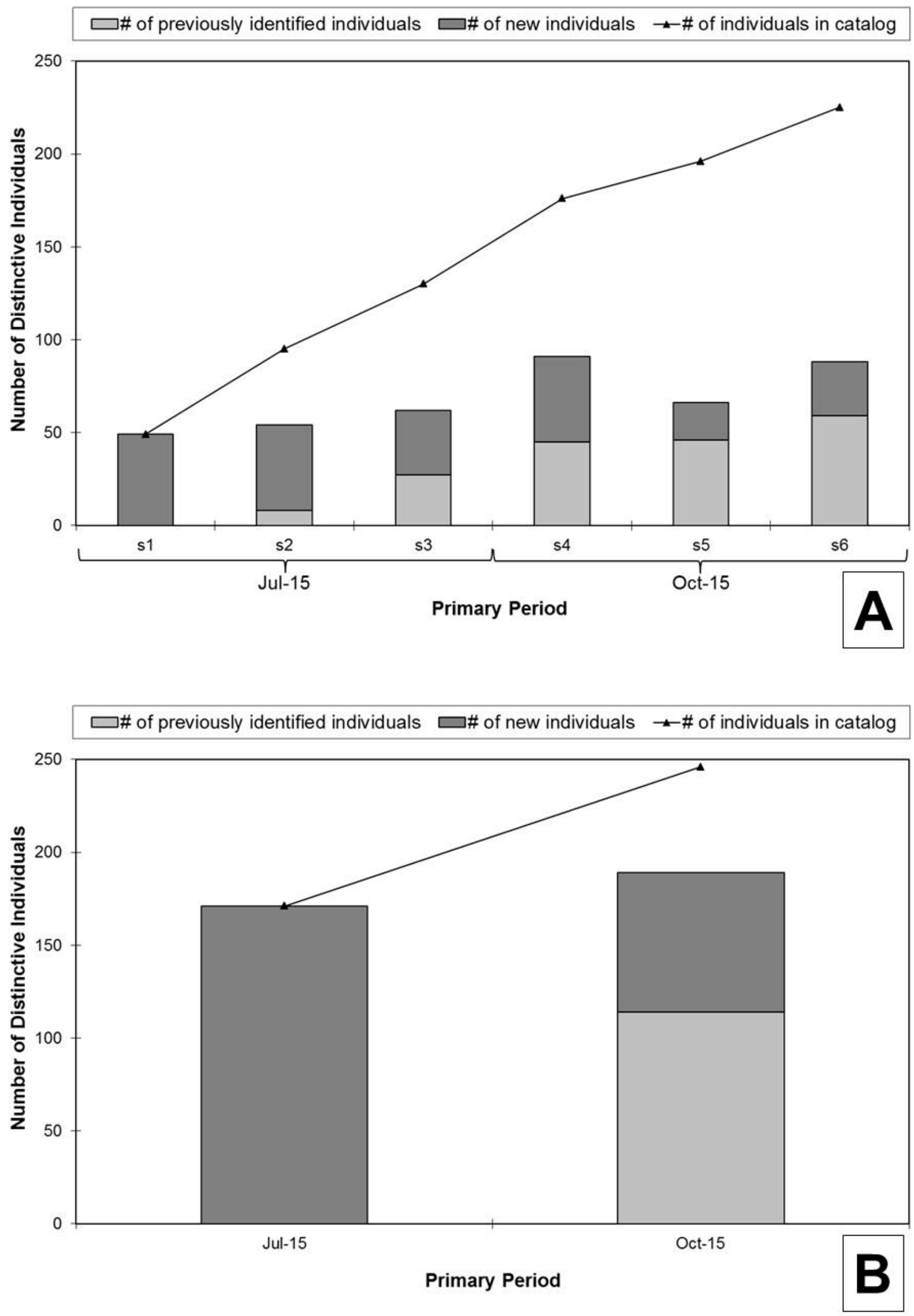


Figure 35. Number of distinctive individuals sighted and discovery curve for bottlenose dolphins in the St. Andrew Bay study area during (A) CR photo-ID survey secondary sessions and (B) all photo-ID effort (CR photo-ID and biopsy-sampling surveys) primary periods.

To identify movement patterns in the St. Andrew Bay region, the total numbers of distinctive animals sighted only in bay waters, only in coastal waters, and across both survey areas were determined for each survey period and across both survey areas (**Table 39**). In addition, all individuals in the St. Andrew Bay photo-ID catalog, across the 2015 fieldwork, were classified by their movement patterns (i.e., bay, coastal, or both). For the combined areas, a substantial majority of dolphins identified were seen only in bay waters, and dolphins occurring in both bay and coastal habitats only occurred in the central portion of St. Andrew Bay.

Table 39. Numbers of bottlenose dolphins identified only in St. Andrew Bay, only in coastal waters, or in both, in July 2015, October 2015, in both months, and over the full study.

Sampling Period	Area			Total
	Bay	Coastal	Both	
July 2015	141	28	2	171
October 2015	146	31	12	189
July & October 2015	101	5	8	114
Overall	182	49	15	246

To determine abundance, the 2015 St. Andrew Bay photo-ID dataset limits the selection of models to only closed population models. A variety of closed population models that relaxed one or more of the closed population assumptions were performed in programs MARK and CAPTURE (Rexstad and Burnham 1992; White et al. 1982). The most suitable model was determined by having (1) the lowest Akaike's information criterion (AIC) values (Burnham and Anderson 1992), and (2) model parameters thought to be most representative of dolphins along the northern Gulf coast of Florida (i.e., capture probabilities varying over time during and between survey periods).

Abundance estimates from the CR population models were derived from the numbers of distinctive animals sighted during each sample. The total population size (distinctive and non-distinctive individuals) for each sample was estimated as:

$$N_{total} = N_{distinct} / \Theta$$

where N_{total} = estimated total population size, $N_{distinct}$ = number of distinctive individuals, and Θ = estimated proportion of distinctive individuals in each sample (Wilson et al. 1999).

The closed population model M_o had the lowest AIC value and was the most appropriate fit for determining abundance in July and October 2015. Estimated abundance (and 95% CI) in the bay was 249 (200–337) in July and 314 (266–392) in October; in coastal waters the estimates were 189 (75–631) in July and 129 (79–270) in October. Total abundance for the entire study area was estimated at 399 (311–539) in July and 407 (346–499) in October. Based on overlapping confidence intervals, the differences between months were not significant.

To assess habitat use, all waters were classified into one of six habitat types: Bay Channel, Gulf Channel, Open Water, Seagrass, Shallow Bay, and Surf Zone (**Figure 34B**). Each habitat type was defined as a shapefile layer using ArcGIS 10.3 (ESRI, Redlands, California). Bay and Gulf Channel boundaries were determined using the locations of channel markers/buoys. Open Water habitat was defined as all Gulf waters between 1 and 4 km offshore. Seagrass habitat was defined by using the Florida Fish and Wildlife Research Institute Seagrass Habitat in Florida dataset (http://geodata.myfwc.com/datasets). Shallow Bay habitat was defined as all estuarine waters not Seagrass or Bay Channel habitats. Surf Zone habitat was defined as all Gulf waters from shoreline to approximately 1 km offshore. The area of each habitat type was calculated to determine total available dolphin habitat in the St. Andrew Bay study area. To identify fine-scale habitat preference, the relative density of dolphins per habitat area was calculated by dividing the total number of dolphins sighted in each habitat by the respective habitat area (km^2).

The majority of bay habitat in the St. Andrew Bay study area was classified as Shallow Bay (204.39 km^2), followed by Seagrass (41.97 km^2), and Bay Channel (29.22 km^2) (**Figure 36**). In coastal waters, Open Water comprised the majority of habitat (97.41 km^2), followed by Surf Zone (29.22 km^2), and Gulf Channel (1.06 km^2) (**Figure 36**). Overall, dolphin density in the St. Andrew Bay study area was highest in Channel (Bay and Gulf) and Seagrass habitat (**Figure 37**).

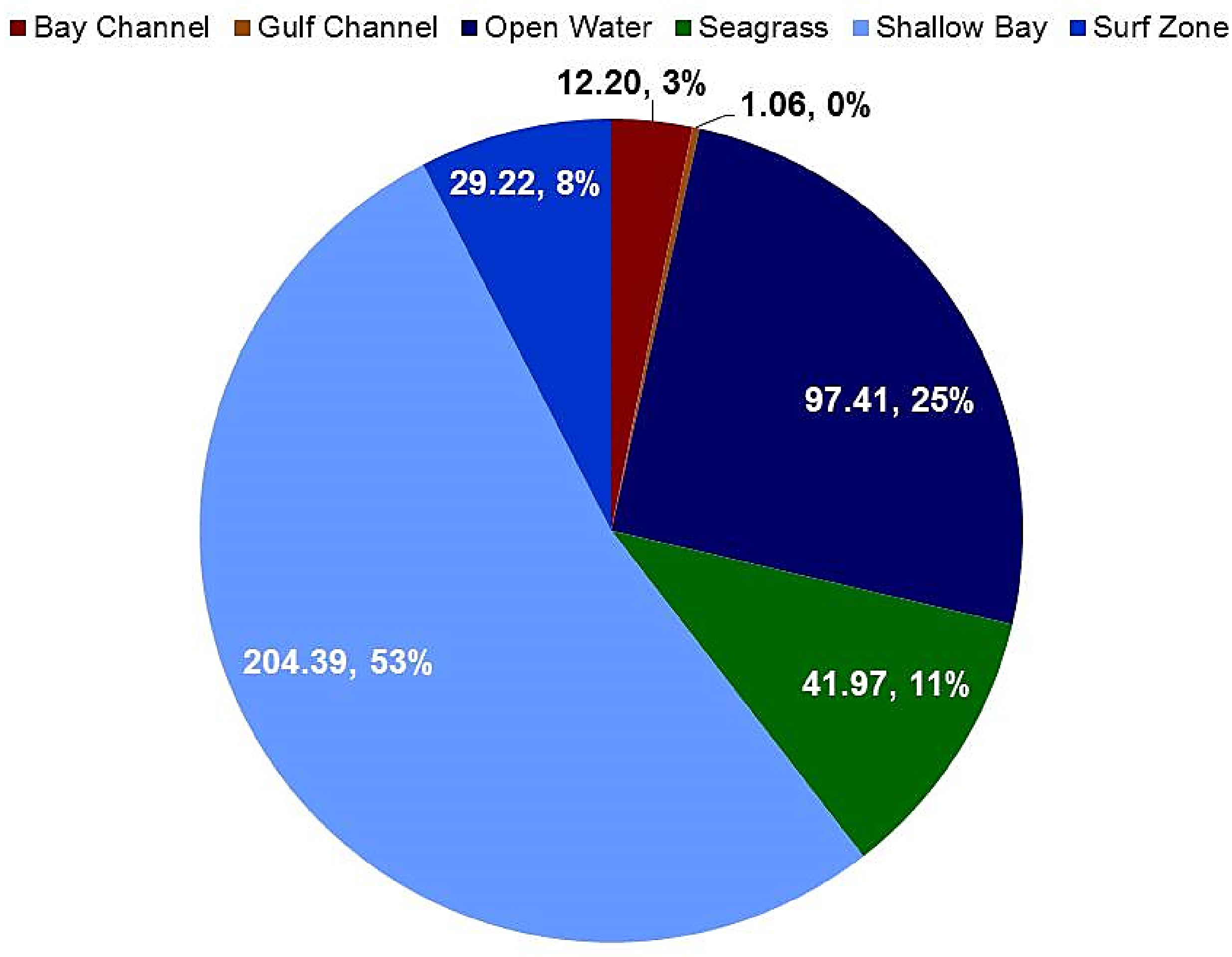


Figure 36. Total area (km^2) and percentage of available habitat in the St. Andrew Bay study area.

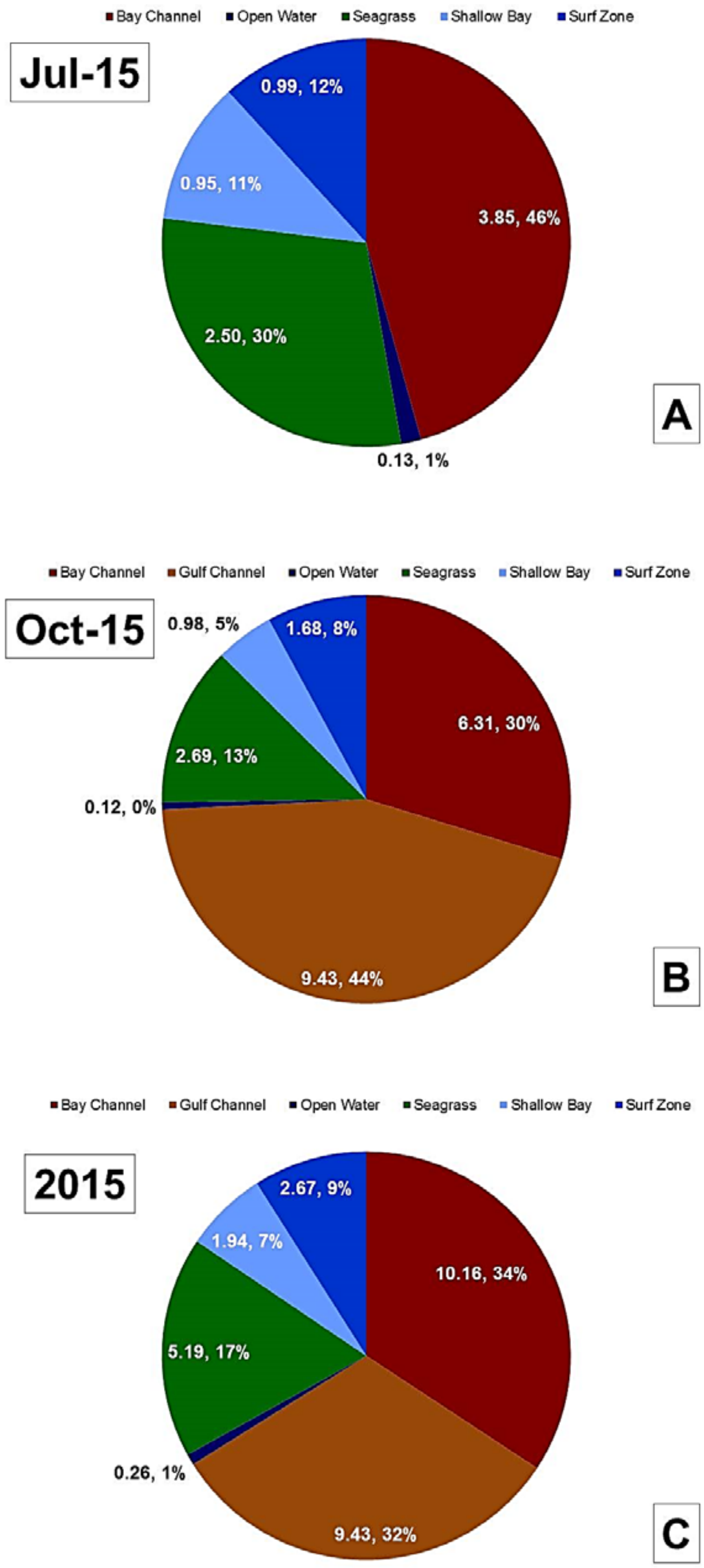


Figure 37. Density (total dolphins sighted/km^2) and percentage of dolphin habitat use in (A) July 2015, (B) October 2015, and (C) 2015 cumulatively in the St. Andrew Bay study area.

Prior to this fieldwork, little was known about the stock structure and contaminant levels of dolphins in the St. Andrew Bay region. In collaboration with SEFSC and the Northwest Fisheries Science Center, biopsy samples were collected to provide baseline data on genetics and persistent organic pollutants (POPs) in St. Andrew Bay dolphins.

Fifty-one (25 males, 26 females) remote biopsy samples were collected during 12 field days during the 2015 St. Andrew Bay fieldwork (34 in July and 17 in October) (**Figure 38**). POP analyses were conducted by the Northwest Fisheries Science Center on 39 samples (33 males; 16 females). POP class concentrations were all higher in males than females (**Figure 39**). For males and females, POP concentrations were highest in polychlorinated biphenyls, followed closely by dichlorodiphenyl-dichloroethanes, then chlordanes and polybrominated diphenyl ether. The lowest levels were shown in dieldrin, mirex, and hexachlorobenzene.

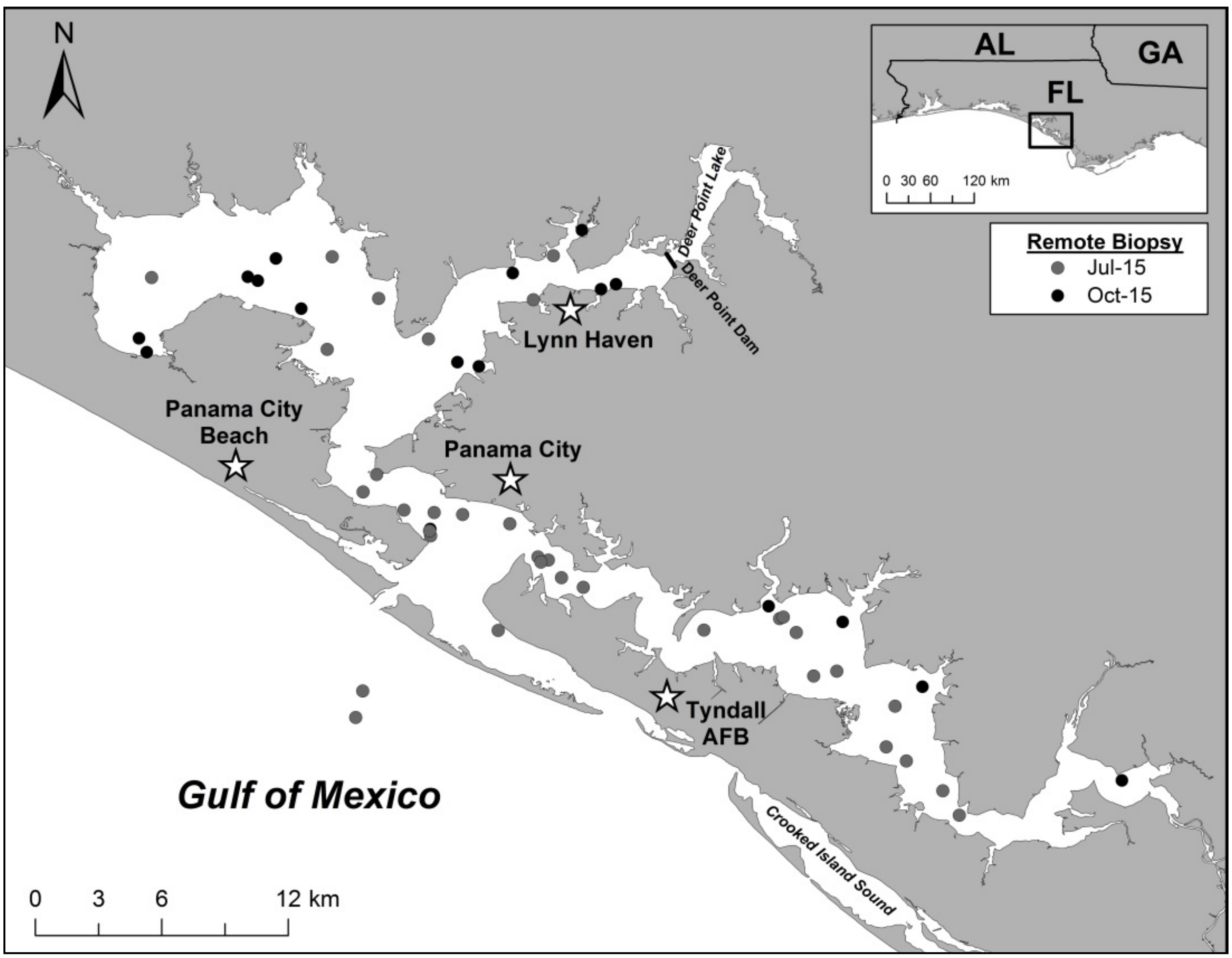


Figure 38. St. Andrew Bay study area remote biopsy sampling locations during 2015.

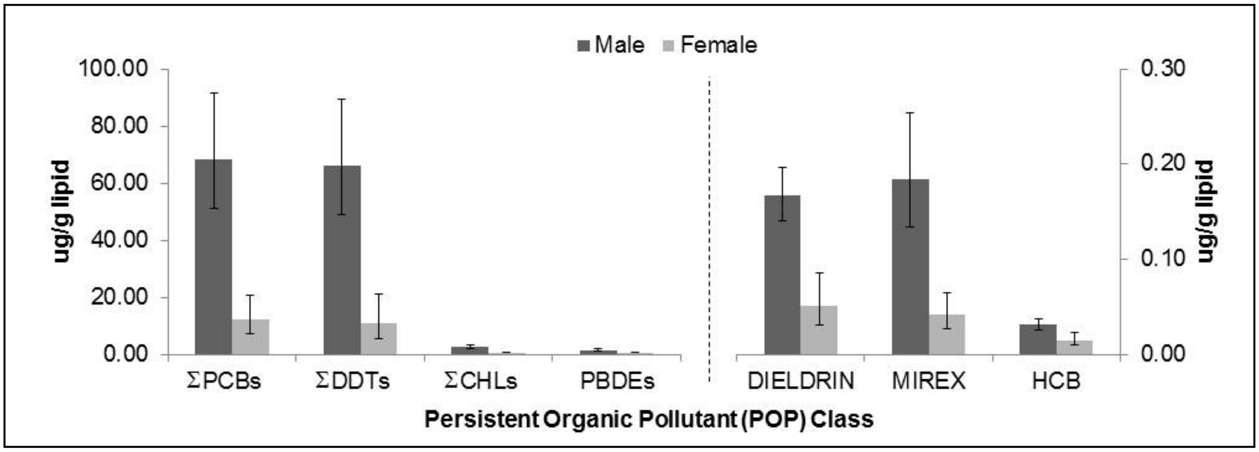


Figure 39. Concentrations (µg/g lipid; geometric mean, 95% CI) of seven classes of POPs measured in remote biopsy samples from bottlenose dolphins sampled in the St. Andrew Bay study area (*n*=23 males; *n*=16 females). PCBs=polychlorinated biphenyls; DDTs=dichlorodiphenyl-trichloroethanes; CHLs=chlordanes; PBDEs=polybrominated diphenyl ethers; and HCB=hexachlorobenzene.

The 2015 St. Andrew Bay field project was the first to provide a complete assessment of dolphin abundance, habitat use, and distribution patterns in this region. Based upon the small number of photo catalog individuals that were sighted in both bay and coastal waters (*n*=15 of 246; 6 percent) and the limited waterways into/out of the study area for potential immigration/emigration, the closed population models were likely appropriate for estimating BSE abundance. With the addition of the 2016 survey data, the robust population model may allow for the estimation of temporary immigration/emigration rates, which will provide additional insight on movements. Based upon extended movements of coastal dolphins in the northern Gulf of Mexico (Balmer et al. 2008, 2010, 2016), the closed population model assumptions of immigration/emigration were likely violated in the coastal and overall abundance estimates, as evidenced by the large confidence intervals.

The estimate abundance for St. Andrew Bay (249 in July; 314 in October) are generally comparable to other northern Gulf of Mexico BSE bottlenose dolphin stocks (Waring et al. 2016). A more comprehensive assessment of seasonal and year-round site fidelity will be possible with the inclusion of the 2016 photo-ID data. In addition, photo-ID catalogs from St. Andrew Bay (2004–2007) (Bouveroux et al. 2014) and adjacent St. Joseph Bay (2004–2013) (B. Balmer, personal communication; Balmer et al. 2008) are available in the Gulf of Mexico Dolphin Identification System, a tool to compare individual photo-ID catalogs across the northern Gulf of Mexico (Cush and Wells 2015). The results of both of those studies suggest long-term residency of dolphins in these BSE stocks, with some crossover of individuals between study areas. The current St. Andrew Bay photo-ID catalog is in the process of being added to the Gulf of Mexico Dolphin Identification System and subsequent searches may provide insight into long-term site fidelity of dolphins in the St. Andrew Bay study area and, conversely, movements across stock boundaries.

Gulf of Mexico BSE dolphins preferentially select for channel (Allen et al. 2001), spoil island (Smith et al. 2013), and seagrass (Barros and Wells 1998; Rossman et al. 2015) habitats. Dolphins in the St. Andrew Bay study area had similar habitat preferences, with dolphin density highest in Channel and Seagrass habitat types. Along the U.S. East Coast, Torres et al. (2005) observed that the majority of dolphins sighted along the coast were within 3 km of the shoreline, with a rapid decrease in numbers from 3 to

34 km offshore. The low density of dolphins in Open Water habitat may indicate a similar distribution of dolphins in the coastal waters of the St. Andrew Bay study area.

Summary of 2016 Surveys

The goal of the spring and fall 2016 surveys was to continue conducting photo-identification surveys to determine seasonal abundance, habitat use, and distribution patterns of bottlenose dolphins in St. Andrew Bay and adjacent coastal waters surrounding the NSWC-PCD. In addition, opportunistic remote biopsy samples from BSE and coastal dolphins were collected during the fall. The study area, transect lines, and survey design were identical to those used in 2015.

The spring 2016 fieldwork comprised nine field days and 952 km surveyed. A total of 73 sightings was recorded in which 462 dolphins (all bottlenose dolphins except for two Atlantic spotted dolphins sighted on CST3K transect), 27 calves, and 29 neonates were observed. A large influx of dolphins was observed in coastal waters, similar to observations of spring influxes into coastal waters of the adjacent St. Joseph Bay region, hypothesized to be members of the Northern Coastal Stock. Spring appears to be a seasonal reproductive peak with 2015 summer and fall surveys yielding only one to two neonates observed.

The fall 2016 fieldwork comprised 13 field days and 1,498 km surveyed. A total of 128 sightings were recorded in which 551 bottlenose dolphins, 69 calves, and no neonates were observed. In addition, four Atlantic spotted dolphins were sighted. The group of Atlantic spotted dolphins was the farthest southeast, and offshore sighting and they were subsequently resighted, less than 60 min later, northwest of their initial location while conducting surveys approximately 10 to 12 km offshore of the St. Andrew Bay coastline. A total of 17 remote biopsy samples were collected; BSE (n = 5) and CST (n = 12). Of the CST samples, 11 were collected from bottlenose dolphins and one was collected from an Atlantic spotted dolphin.

Data from the 2016 surveys is currently being analyzed. The four survey sessions across two years will provide a robust dataset for several manuscripts on topics including abundance, contaminant levels, distribution, habitat use, human interactions, and site fidelity. Based on the current project timeline, photo analysis will be completed by mid-2017 followed by drafts of manuscripts to coauthors by the end of 2017.

2.1.3 Pinniped Haulout Visual Surveys

Harbor seal (*Phoca vitulina concolor*) and gray seal (*Halichoerus grypus*) distribution along the U.S. Atlantic Coast appears to be expanding. Data from National Oceanic and Atmospheric Administration (NOAA) surveys have previously shown New Jersey as the southern extent for harbor and gray seals (NOAA 2015), with occasional sightings and strandings reported as far south as Florida and North Carolina for harbor and gray seals, respectively (Waring et al. 2016).

In 2014, the U.S. Navy initiated a study which aims to document seal presence at select haul-out locations in Narragansett Bay (Rhode Island) and lower Chesapeake Bay (Virginia) in order to acquire a better understanding of the seals' seasonal occurrence, habitat use, and haul-out patterns in these areas, which are important to U.S. Navy training and testing (e.g. JEB-LS, JEB-FS and NSN, NAS Oceana/Dam Neck Annex, and important nearshore range areas, and vessel transit routes). Identification and comparison of individual seals, using photo-ID, has provided valuable baseline information for the future assessment of relative abundance, seal movements, and site fidelity along the U.S. northeast and mid-Atlantic coasts.

A series of systematic shore-based counts of all seal species are being conducted at one haul-out location in Narragansett Bay (**Figure 40**) and four haul-out locations in lower Chesapeake Bay, on the Chesapeake Bay Bridge-Tunnel (CBBT) islands that span approximately 14 km from the first haul-out site (CBBT 1) to the fourth (CBBT 4) (**Figure 41**). The numbers of seals hauled-out and in the water were recorded during each count throughout the season. Photographs of seals also were collected between counts for CR analysis. Photographs of seals at the CBBT haul-out sites from 2010–2015 were obtained from a local angler and incorporated into the analysis where appropriate. Photographs are being used to develop local catalogs, and they will be compared to regional catalogs.

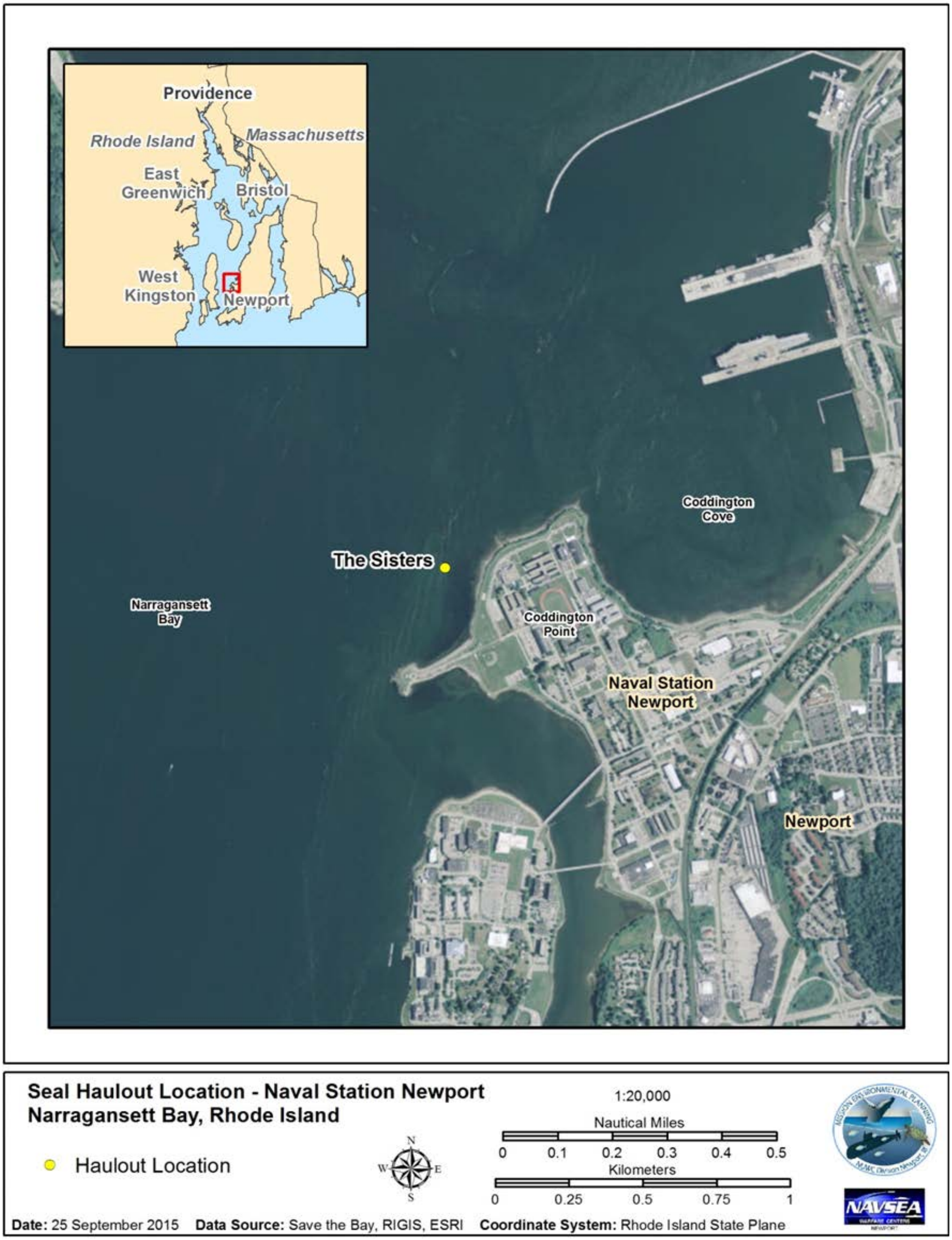


Figure 40. Location of the haul-out site in Narragansett Bay near Naval Station Newport.

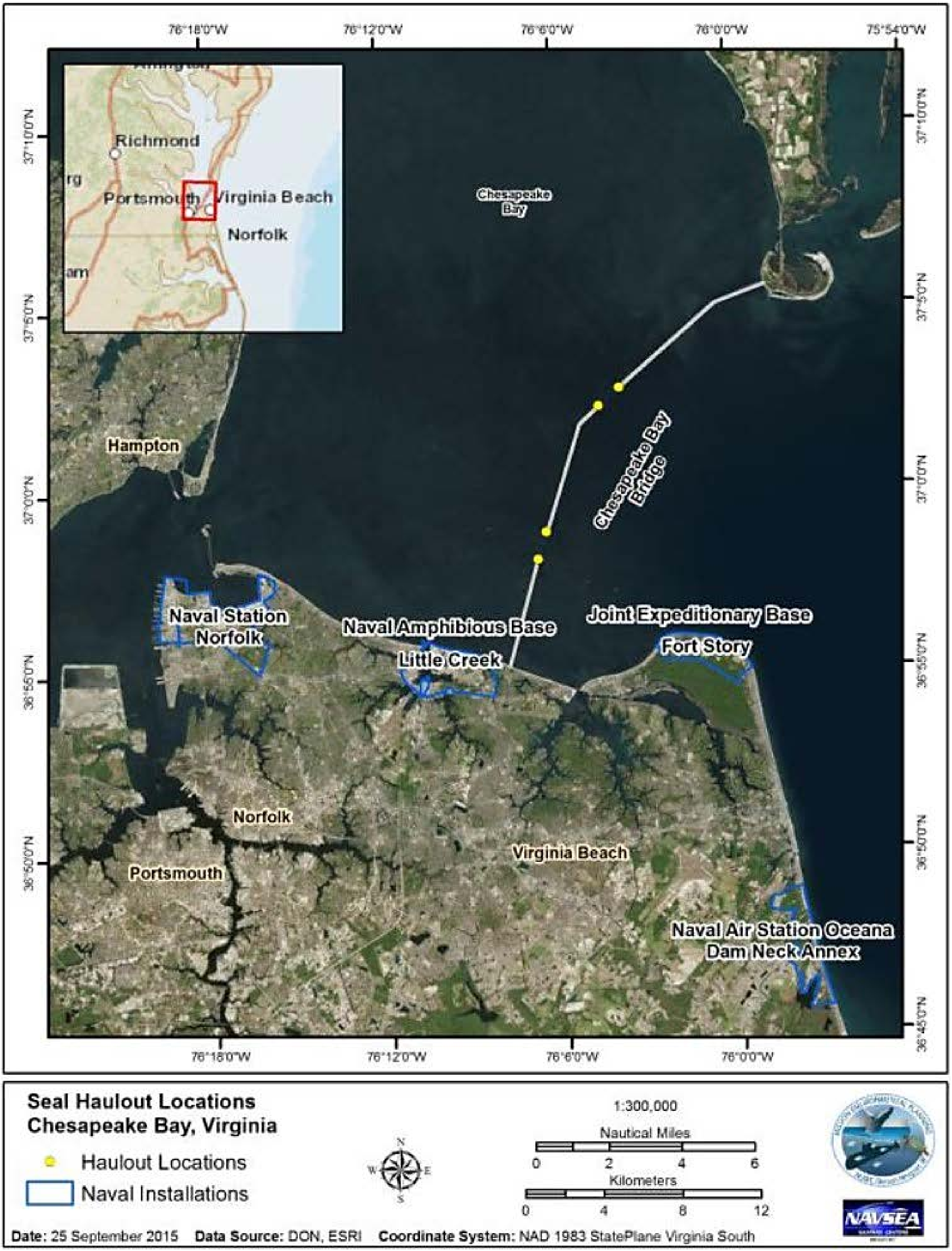


Figure 41. CBBT haul-out sites and their proximity to U.S. Navy training and testing areas in Virginia.

Chesapeake Bay Progress

For the first field season of the study, 13 survey days were completed from November 2014 to May 2015. A total of one gray seal and 112 harbor seals was sighted among the CBBT haul-out sites. Seals were observed on all survey days except one. Highest counts were recorded in February and March (though seal counts were not conducted in January, so this result may be biased). During the 2015–2016 field season, surveys were conducted from October 2015 to May 2016. A total of 184 harbor seals and 1 gray seal was sighted from December 2015 to April 2016. Seals were observed on 15 of the 21 (71.4 percent) survey days. Similar to the first field season, the highest counts were recorded in the months of February and March.

Photo-ID conducted via visual matching has shown that individuals have been resighted both within a season and across multiple seasons, indicating at least some degree of seasonal site fidelity. Of the 52 uniquely identified harbor seals, six (11.5 percent) were determined, to be present in the study area on more than one occasion. Identifiable resightings (or recaptures) for these six harbor seals spanned from five to 1,820 days (median=37 days). One individual was sighted on five separate surveys between December 2015 and March 2016.

Counts and photo-ID data collection have continued for the 2016–2017 field season. As of March 2017, 23 surveys have been conducted for the 2016–2017 field season. A total of 304 harbor seals has been sighted and no gray seals. Seals were observed on 18 of the 23 (78.3 percent) survey days. So far, the highest counts are in the months of January and February. More detail on the 2016–2017 field season will be provided in the 2016–2017 progress report.

Over three field seasons, the average number of harbor seals observed per survey has increased from 10 seals in 2014–2015, 13 seals in 2015–2016, to 15 seals in 2016–2017 (as of March 2017); with maximum counts for a single survey being 33, 39, and 40 respectively. Results indicate that harbor seals regularly occur in Virginia from November to May, with peak counts between January and March. Peak counts for the 2014–2015 and 2015–2016 field seasons seemed to coincide with some of the lowest recorded water temperatures, and as water temperatures rose above 55 degrees Fahrenheit, counts decreased.

A proof-of-concept tagging effort began during the 2016–2017 field season to investigate seal movement and habitat use near U.S. Navy training and testing areas in Virginia. Such information will better demonstrate the occurrence, migratory routes, and behavior of seals in this area, as well as provide a baseline for behavioral response studies in the future.

For more information on this study, refer to the 2015–2016 annual progress report for this project (Rees et al. 2016).

Narragansett Bay Progress

The initial pilot study was completed in May 2015. The haul-out site near Naval Station Newport was observed on 36 days during the 2014–2015 season. Harbor seals were observed on 24 of those days. The maximum number of seals hauled-out was 44 seals on 16 April 2015 and the average for the season was 15 seals. Additionally, a local non-profit organization, Save the Bay, provided seal sighting data from 1992–2013 that includes 112 locations throughout Rhode Island waters. That data was analyzed for historical and spatial patterns. During the 2015–2016 field season, seals were present from November 2015 until April 2016. Over 25 survey days, a total of 553 harbor seals was observed. Seals were observed on 23 of the 25 (92 percent) survey days. Similar to the 2014–2015 season, the highest counts were recorded in the months of February and March. The highest count on 17 March 2016 was 46 seals hauled out and three seals in the water. The average number of seals observed for the season was 22. The 2016–2017 field season began when three seals were sighted on 01 November 2016. During November–December 2016, 10 surveys were conducted and seals were observed on all 10 days, although only hauled-out during eight of the observation days. The total number of seals counted in those two months was 149. The maximum number of seals observed during was observation was 42 seals, and the average number of seals per observation was 14.

Preliminary photo-ID was conducted with WILD-ID analysis software (Bolger et al. 2012). The results confirm the presence of matches within the photo database, indicating some degree of site fidelity. This was confirmed with visual matching of photographs. Currently, the ExtractCompare software (Hiby 2015) package is being used to analyze the same photo database and compare the results. ExtractCompare may be able to better estimate populations, while also answering questions regarding site fidelity and preference. Counts, photo-ID, data collection, and analysis will continue for the 2016–2017 field season.

For more information on this study, refer to the 2015–2016 annual progress report for this project (Moll et al. 2016).

2.1.4 Mid-Atlantic Humpback Whale Catalog

Researchers from the Virginia Aquarium, more recently VAQF have been collecting sighting data and images for photo-ID of whales in the mid-Atlantic since 1989. VAQF curates the Mid-Atlantic Humpback Whale Photo-ID Catalog (MAHWC), an expanding collection of photos, which presently includes 282 unique whales. The objectives of these long-term efforts are to establish baseline data on humpback whale movement patterns, population demographics, site fidelity, and seasonal habitat use in the mid-Atlantic while supporting multi-decadal mark-recapture research in the broader western North Atlantic Ocean. These efforts can also serve to support assessment of human impacts (e.g., injuries from entanglement or watercraft), body condition, and behavior (e.g., foraging). Longitudinal mark-recapture data can also serve as a non-invasive mechanism to investigate and detect changes in patterns of humpback whale occurrence, inter-annual variation, and changes in distribution and phenology over time.

Survey effort and opportunistic sightings of humpback whales in the mid-Atlantic and southeastern U.S. have increased substantially in the past few years. To integrate data from a multitude of sources more effectively, both current and historic, a streamlined process for submissions, management, and access is necessary. In addition, simplifying and standardizing submissions from the mid-Atlantic to the broader regional and North Atlantic catalogs is essential to the efficiency of information exchange between regions. VAQF is currently developing a collaborative, integrative platform for the MAHWC that provides a broad-scale and high-quality scientific product that can elucidate questions to inform the U.S. Navy and other stakeholders of the identity, residency, site fidelity of, and habitat use by humpback whales in the mid-Atlantic and southeastern U.S. training areas. In development is a web-based interface to facilitate contributor access to the catalog. The development of the online platform for the MAHWC is currently in the first year of the proposed three-year project. The overarching goal of this project is to facilitate exchange of information among researchers who have been involved in humpback whale photo-ID efforts over the last 40 years in the North Atlantic.

During the current first phase of this project, VAQF has been working since June 2016 with key stakeholders to develop a data-sharing agreement, standardize photo matching and data submission protocols, and draft the web interface/database design modeled after that of the MABDC.

The MAHWC online catalog will be hosted on the Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP; Halpin et al. 2009) and is being modeled after the MABDC originally developed to assist NMFS in answering questions about the movement patterns and stock structure of coastal bottlenose dolphins. The coverage areas for both platforms are similar, as the MABDC serves as an online tool for bottlenose dolphin researchers from New Jersey to Florida.

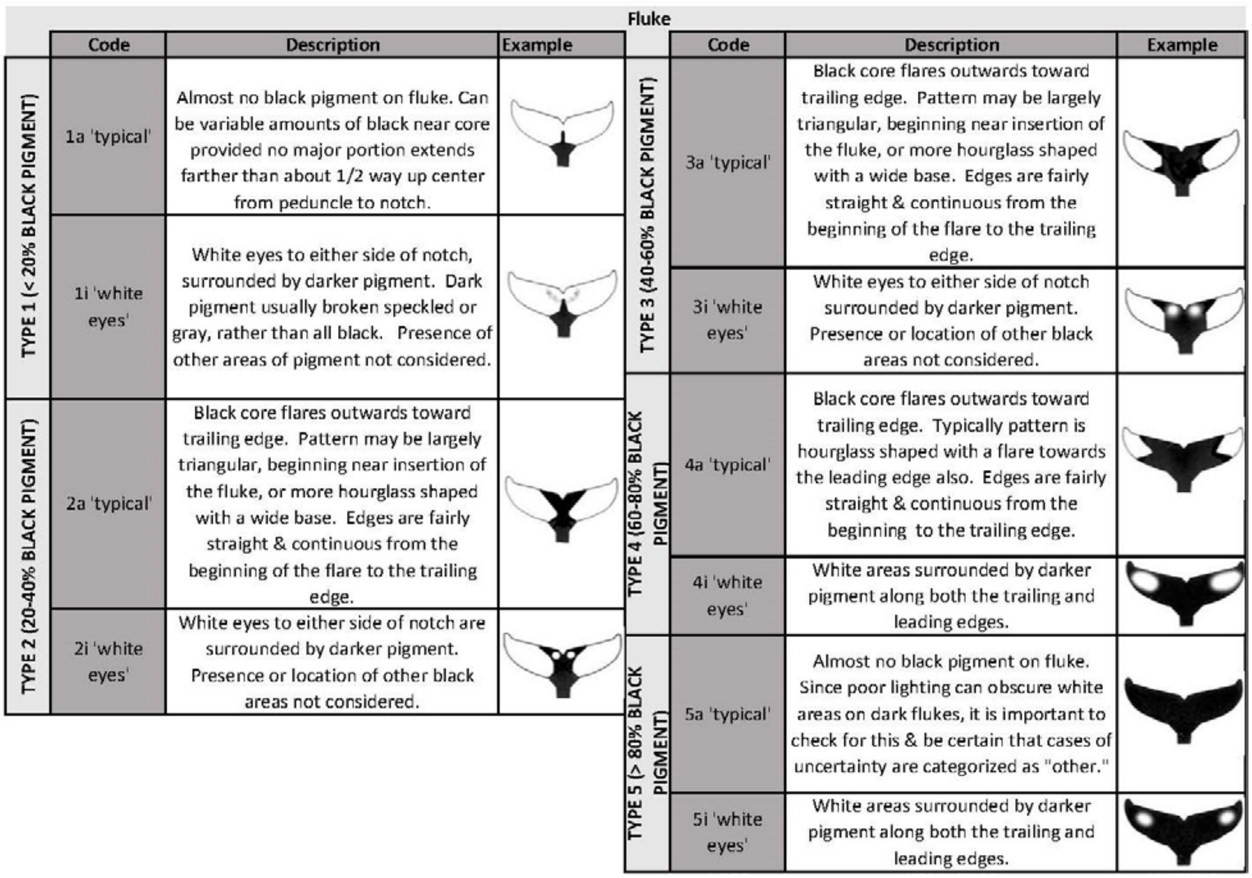
To provide quality assurance and to increase the efficiency of submissions to the MAHWC and among larger catalogs, standardized protocols for coding images and categorizing and matching individuals are being developed based upon existing examples and input from the core stakeholder group. Additionally, standardized data fields and database structure of the MAHWC are being designed to be compatible with the U.S. Navy's MSM program. Contributors will provide pertinent data to the MAHWC catalog via standard templates and following image- and data-accession protocols that contribute to the maintenance and quality of the database.

A broad data-sharing agreement is being developed in order to facilitate the exchange of sighting and individual life-history information among contributors rather than requesting permission for each individual match, as is often the case with other catalogs. A stakeholder workshop is tentatively scheduled for June 2017 in Virginia Beach, Virginia, upon completion of the preliminary online platform. A questionnaire has been developed for contributors and key collaborators to summarize the project background and scope of field data and to identify existing catalog features of the contributing institutions. Responses to the questionnaire will be summarized and pertinent components addressed in order to prioritize meeting objectives. The workshop agenda has been developed based upon priority items that require stakeholder input, including the image/data sharing agreement, standardized protocols, and database fields and structure. Demonstrations of the existing MABDC and the preliminary MAHWC will be presented and the group will explore available options to host the MAHWC. Currently, Duke's OBIS-SEAMAP hosts multiple other photo-ID catalogs (e.g., MABDC, Pacific Islands Photo-identification Network) and provides a user-friendly interface with tools for comparison of collections. Meeting outcomes will be summarized in a report and modifications to the database incorporated as agreed upon by the stakeholder group.

VAQF is working with the core collaborators and Duke University to develop a draft MAHWC data-sharing agreement. Fostering stakeholder consensus for data sharing and usage, although a time- and labor-intensive aspect of this project, is essential in order to resolve concerns and maintain and encourage support of contributors. A draft data-sharing agreement will be presented at or before the stakeholder workshop. One of the primary goals of the workshop will be to finalize a consensus data-sharing agreement among the primary collaborators.

All humpback whales in the current MAHWC catalog from 1989 through 2015 have been compared to the North Atlantic Humpback Whale Catalog (NAHWC), managed by Allied Whale (Bar Harbor, Maine). Images added in 2016 are at various stages of comparison with both the NAHWC and Gulf of Maine catalog, managed by the Center for Coastal Studies (Provincetown, Massachusetts). At the end of each season, the best images (including mid-Atlantic contributors) of all new whales added to the MAHWC are sent in batch to the Center for Coastal Studies and Allied Whale to be added to and compared with their catalogs.

Standardized protocols are being developed for the MAHWC based upon existing photo-ID catalogs. Unique feature codes used for categorizing and filtering (e.g., dorsal fin, fluke, peduncle knuckles, body scarring) for comparison among collections are being tailored to those whales in the MAHWC. Fluke code categories have been modified from those developed by the NAHWC. Flukes are initially classified by the grading of fully white (Type 1) to fully black (Type 5) coloring on the ventral surface. Within each Type, the most represented subcategories to be used in the catalog are being determined (e.g., typical, wide black trailing edge, white on trailing edge, white eyes). Examples of the subtypes "typical" and "white eyes" for each fluke Type are illustrated in **Figure 42**.



Fluke

Type	Code	Description	Example
TYPE 1 (< 20% BLACK PIGMENT)	1a 'typical'	Almost no black pigment on fluke. Can be variable amounts of black near core provided no major portion extends farther than about 1/2 way up center from peduncle to notch.	
	1i 'white eyes'	White eyes to either side of notch, surrounded by darker pigment. Dark pigment usually broken speckled or gray, rather than all black. Presence of other areas of pigment not considered.	
TYPE 2 (20-40% BLACK PIGMENT)	2a 'typical'	Black core flares outwards toward trailing edge. Pattern may be largely triangular, beginning near insertion of the fluke, or more hourglass shaped with a wide base. Edges are fairly straight & continuous from the beginning of the flare to the trailing edge.	
	2i 'white eyes'	White eyes to either side of notch are surrounded by darker pigment. Presence or location of other black areas not considered.	
TYPE 3 (40-60% BLACK PIGMENT)	3a 'typical'	Black core flares outwards toward trailing edge. Pattern may be largely triangular, beginning near insertion of the fluke, or more hourglass shaped with a wide base. Edges are fairly straight & continuous from the beginning of the flare to the trailing edge.	
	3i 'white eyes'	White eyes to either side of notch surrounded by darker pigment. Presence or location of other black areas not considered.	
TYPE 4 (60-80% BLACK PIGMENT)	4a 'typical'	Black core flares outwards toward trailing edge. Typically pattern is hourglass shaped with a flare towards the leading edge also. Edges are fairly straight & continuous from the beginning to the trailing edge.	
	4i 'white eyes'	White areas surrounded by darker pigment along both the trailing and leading edges.	
TYPE 5 (> 80% BLACK PIGMENT)	5a 'typical'	Almost no black pigment on fluke. Since poor lighting can obscure white areas on dark flukes, it is important to check for this & be certain that cases of uncertainty are categorized as "other."	
	5i 'white eyes'	White areas surrounded by darker pigment along both the trailing and leading edges.	

Figure 42. The five main fluke types, ranging from white (Type 1) to black (Type 5), with examples of the sub-categories "typical" and "white eyes" for each.

Dorsal fin, peduncle knuckle, and body scarring categories have been modified based upon those utilized by the Center for Coastal Studies. Catalogs from other species have also been reviewed for possible adaptation for the MAHWC. A protocol for systematically categorizing each identifying humpback whale image is in the process of being developed. This includes "Type" feature codes with text descriptions and will also include an example image or diagram for contributor reference when searching for matches. In order to maintain as much consistency as possible, one of the primary roles of the MAHWC curator will be to assign initial feature codes to images that are included in the catalog. These unique codes will permit more efficient filtering through the catalog. As technology advances and automated matching improves, software will continue to be evaluated that is compatible with the OBIS-SEAMAP platform for dorsal fin and fluke matching.

Future work includes coordination with Duke University to identify concerns or issues from the core collaborators and other contributors. Once technical development, testing, and de-bugging of the database are completed, the MAHWC web-based catalog will be launched for beta testing with Virginia images.

For more information on this study, refer to the annual progress report for this project (Mallette and Barco 2017).

2.2 Tagging Studies

During the reporting period, the U.S. Navy supported tagging studies of odontocetes (**Section 2.2.1**), baleen whales (**Sections 2.2.2 through 2.2.3**), and sea turtles (**Section 2.2.5**).

2.2.1 Tagging of Deep-Diving Odontocete Cetaceans—Hatteras and Jacksonville

Tagging activities were conducted off Cape Hatteras in 2016 building on work that began in 2014 to achieve a more robust picture of the medium-term movement patterns of these and other odontocete cetaceans. This constituted the third year of the Deep Divers project, which is focused on the distribution and ecology of several deep-diving odontocete species, including: beaked (Cuvier's beaked and *Mesoplodon* spp.), short-finned pilot, and sperm whales.

Researchers from Cascadia Research Collective (CRC) and Duke University tagged deep-diving odontocete cetaceans with satellite tags and DTAGs, respectively. Tagging of odontocete cetaceans by CRC complemented ongoing research by Duke University off Cape Hatteras by providing information on the movement and diving behavior of these species over the medium term (weeks to months) (Baird et al. 2017). Shorter-term dive data (i.e., hours to days) can be collected using DTAGs, and longer-term movement information (i.e., months to years) using photo-ID techniques (see **Section 2.1.2.1** of this report; Foley et al. (2017b). Attempts were made in the field to obtain digital images of all tagged animals to ensure that connections could be drawn between the photo-ID and satellite-tagging work. Photographic matches of tagged animals and their associates are presented in Foley et al. (2017a).

In a related project, five satellite tags were deployed on short-finned pilot whales (n=4) and an Atlantic spotted dolphin in the Jacksonville study area in June 2016.

2.2.1.1 Satellite-tagging

Cape Hatteras Study Area

During 2014 and 2015, remotely deployed Low-Impact Minimally Percutaneous External-electronics Transmitter (LIMPET) satellite tags were used to obtain movement data from nine Cuvier's beaked whales, 35 short-finned pilot whales, nine bottlenose dolphins, one sperm whale, and one short-beaked common dolphin, ranging over periods from 1.3 to 193.8 days (Baird et al. 2015, 2016).

CRC researchers deployed 15 satellite tags on six species in the Cape Hatteras study area in 2016: Cuvier's beaked whale (*n*=6), short-finned pilot whale (*n*=5), bottlenose dolphin (*n*=1), Risso's dolphin (*n*=1), short-beaked common dolphin (*n*=1), and Clymene dolphin (*n*=1) (**Table 40, Figure 43**). Five tags were equipped to record and transmit dive data (SPLASH10 tags) and were deployed on Cuvier's beaked whales. Nine other satellite tags were location-only Smart Position and Temperature (SPOT) tags, and one tag with a Fastloc® GPS receiver (SPLASH10-F) was deployed on a short-finned pilot whale. All tags had ceased transmitting by the end of 2016 (**Table 40**).

Table 40. Summary of satellite tag deployments in the Cape Hatteras study area in 2016.

Species[1]	Tag ID	Tag Type[2]	Deployment Date	Date of Last Transmission	Transmission Duration (days)	Deployment Latitude (°N)	Deployment Longitude (°W)
Dd	DdTag002	SPOT5	05/27/2016	06/08/2016	12	35.59	74.74
Gg	GgTag017	SPOT6	08/20/2016	09/07/2016	18	35.61	74.79
Gm	GmTag157	SPOT6	05/25/2016	10/04/2016	132	35.59	74.75
Gm	GmTag158	SPOT5	05/25/2016	10/23/2016	151	35.60	74.75
Gm	GmTag159	SPLASH10-F	05/26/2016	06/20/2016	25	35.62	74.71
Gm	GmTag160	SPOT6	05/26/2016	10/30/2016	157	35.70	74.74
Gm	GmTag161	SPOT6	05/27/2016	06/21/2016	25	35.60	74.74
Sc	ScTag001	SPOT6	05/25/2016	06/15/2016	21	35.61	74.69
Tt	TtTag029	SPOT6	05/25/2016	06/07/2016	14	35.60	74.64
Zc	ZcTag046	SPLASH10	05/25/2016	06/10/2016	16	35.59	74.75
Zc	ZcTag047	SPLASH10	05/25/2016	07/31/2016	67	35.60	74.75
Zc	ZcTag048	SPLASH10	05/27/2016	07/03/2016	37	35.59	74.74
Zc	ZcTag049	SPOT6	05/27/2016	08/28/2016	93	35.58	74.74
Zc	ZcTag050	SPLASH10	08/20/2016	09/20/2016	31	35.63	74.76
Zc	ZcTag051	SPLASH10	08/21/2016	09/01/2016	12	35.61	74.69

[1] Dd = *Delphinus delphis* (short-beaked common dolphin); Gg = *Grampus griseus* (Risso's dolphin) Gm = *Globicephala macrorhynchus* (short-finned pilot whale); Sc = *Stenella clymene* (Clymene dolphin); Tt = *Tursiops truncatus* (bottlenose dolphin); Zc = *Ziphius cavirostris* (Cuvier's beaked whale).

[2] SPLASH10 = location and dive data tag; SPLASH10-F = location and dive tag with Fastloc® GPS; SPOT5 and SPOT6 = Smart Position and Temperature (location only).

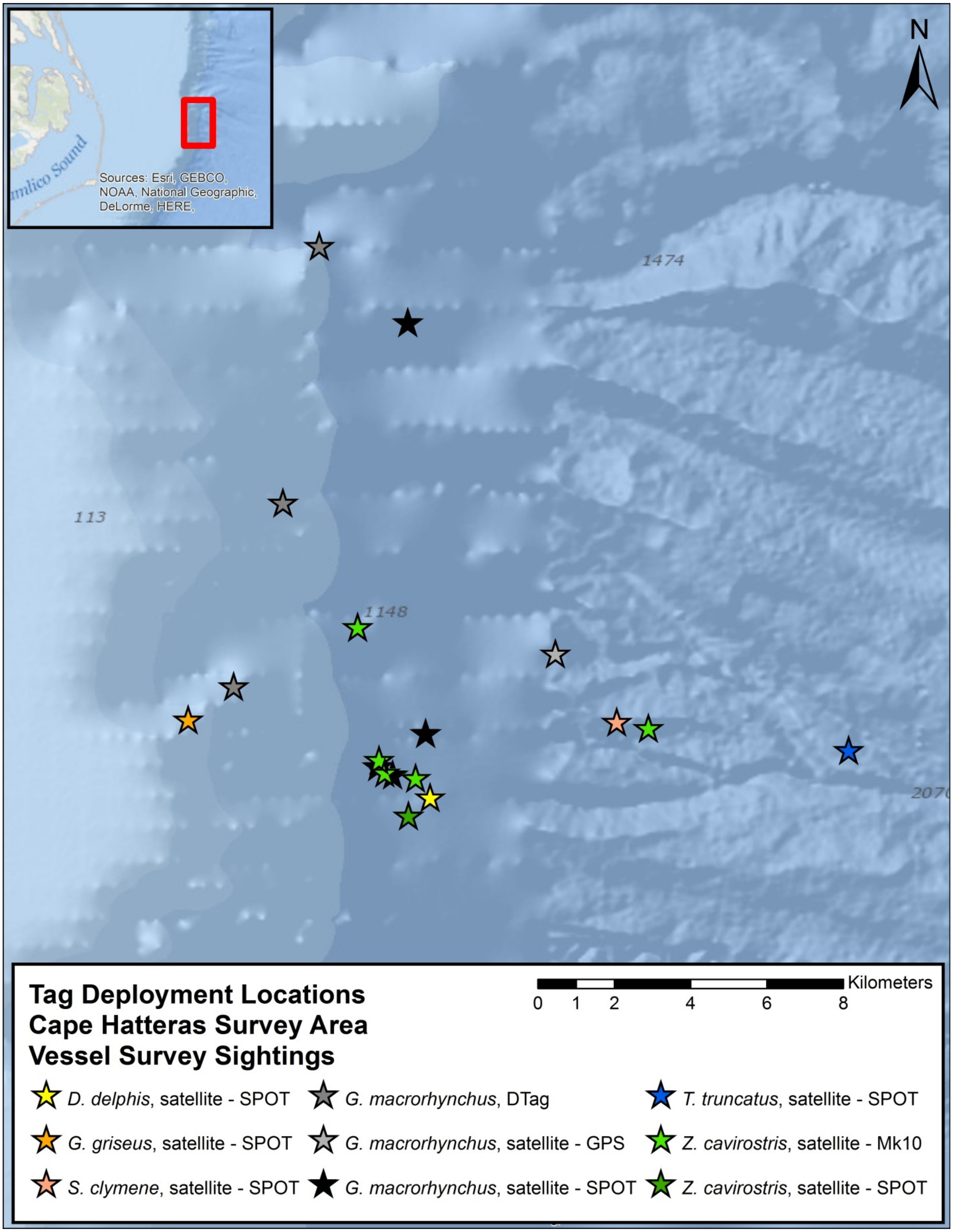


Figure 43. Locations of satellite tag deployments in the Cape Hatteras study area in 2016.

One location-only SPOT tag was deployed on a bottlenose dolphin, with an attachment duration of 13.1 days (**Table 40**). Cumulative distance moved was 1,016.4 km, yet the individual remained a mean distance from the tagging location was only 30.2 km, with a maximum distance of 79.1 km. Median depth determined from locations of the tagged individual was 1,837 m, with a maximum depth of 2,538 m. Location data combined with the nine bottlenose dolphins tagged in 2014 (Baird et al. 2015) and 2015 (Baird et al. 2016) indicate that movements are limited (**Figure 44**). A kernel density utilization distribution including all 10 individuals indicates that the core of the habitat used by the tagged bottlenose dolphins is on the continental slope off Cape Hatteras (**Figure 45**).

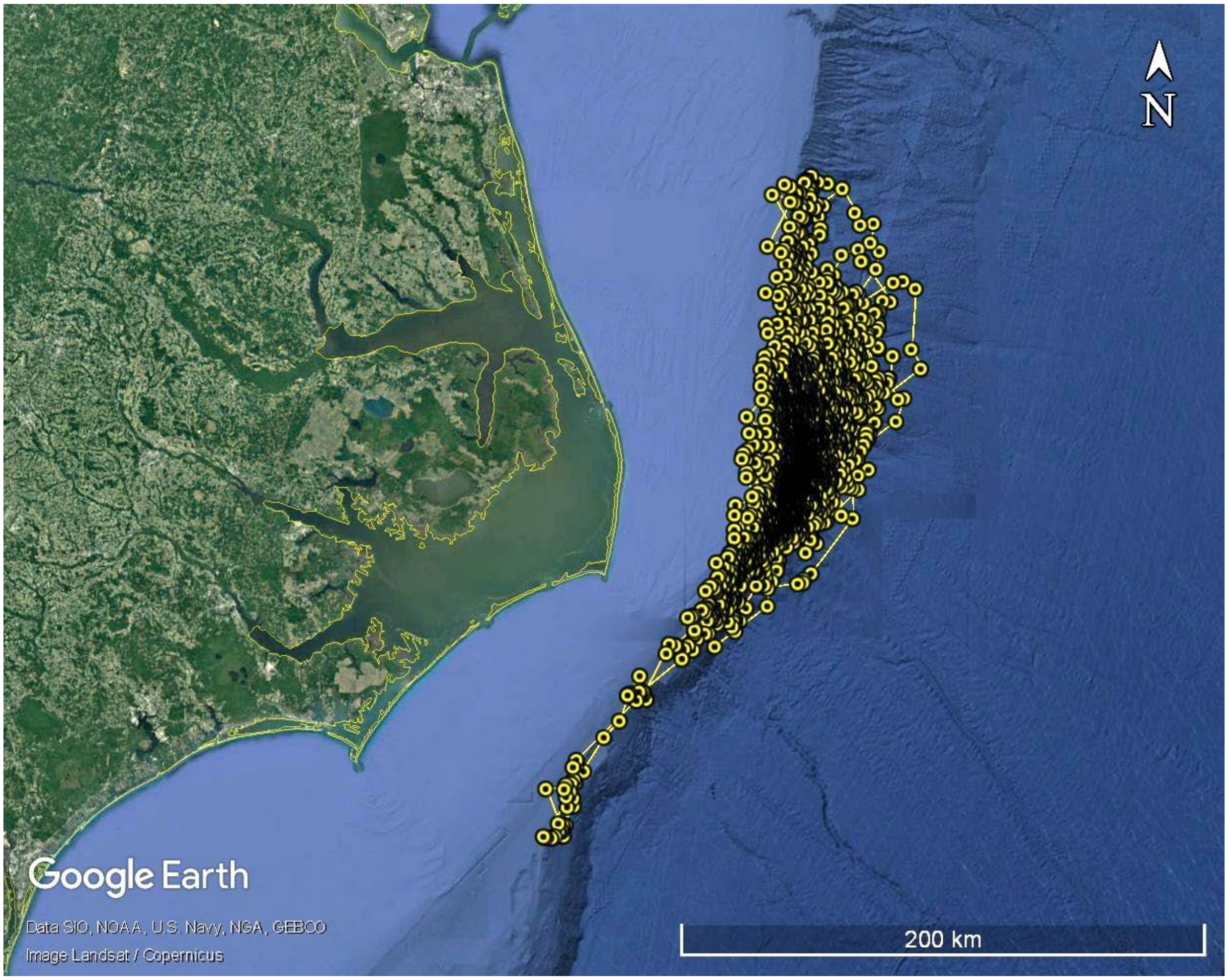


Figure 44. Filtered locations of all 10 satellite-tagged bottlenose dolphins off North Carolina in 2014 (*n*=5), 2015 (*n*=4), and 2016 (*n*=1).

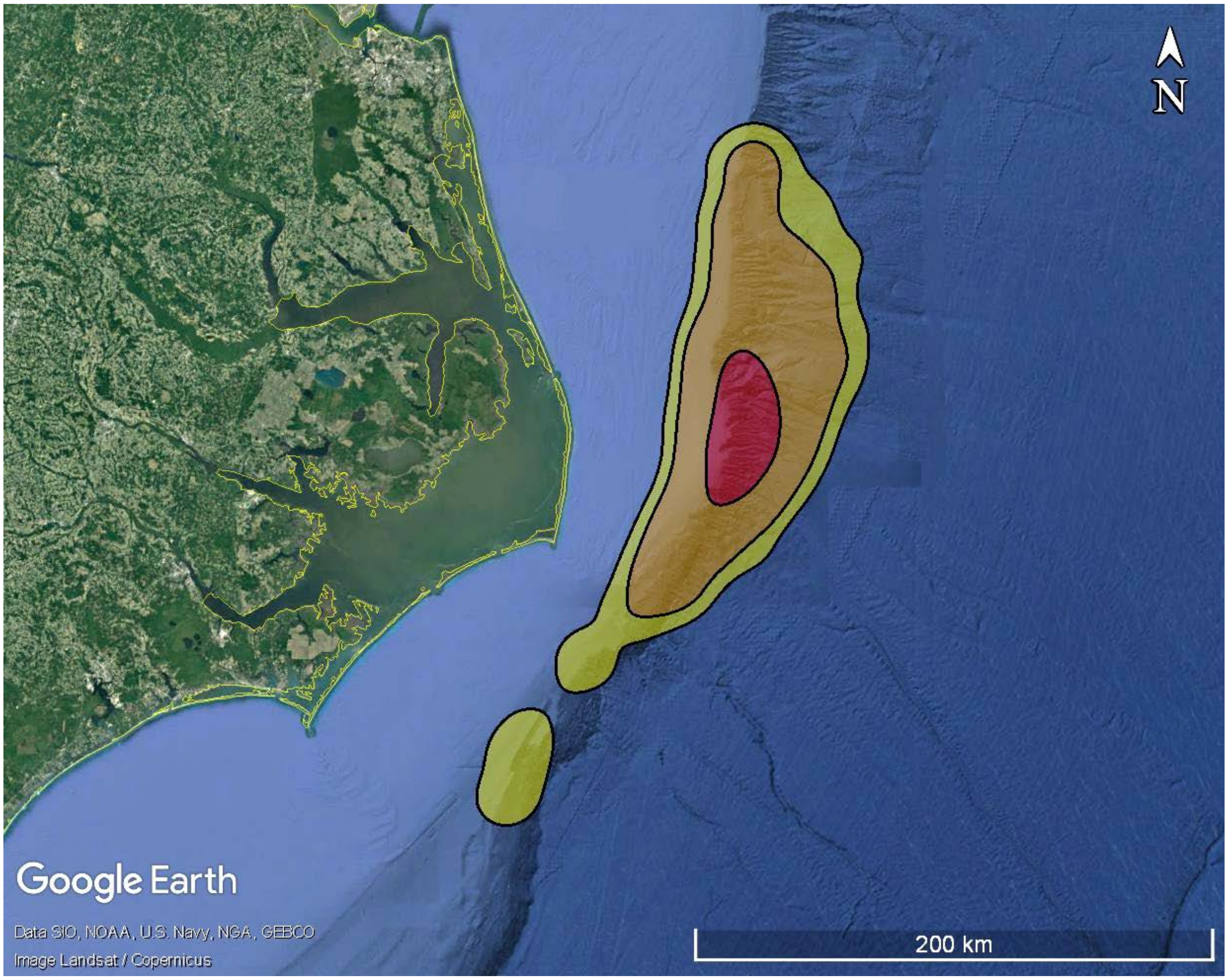


Figure 45. Probability density representation of 10 satellite-tagged bottlenose dolphins off North Carolina tagged between 2014 and 2016. The red area indicates the 50 percent density polygon (the "core range"), orange represents the 95 percent polygon, and yellow represents the 99 percent polygon.

A single location-only tag was deployed on a short-beaked common dolphin, and location data were obtained over an 11.34-day period. The cumulative distance moved by this individual was 678 km, yet the individual remained a median distance of 25.8 km from the tagging location, and had moved a maximum of 69.5 km from the tagging location when the tag stopped transmitting. The animal primarily remained over the shelf break and continental slope (**Figure 46**), often returning to near the area where it was tagged. Median depth determined from locations of the tagged individual was 573.2 m. Only a single short-beaked common dolphin had previously been tagged off Hatteras (in 2015) and showed considerably greater movements to the north (Baird et al. 2016).

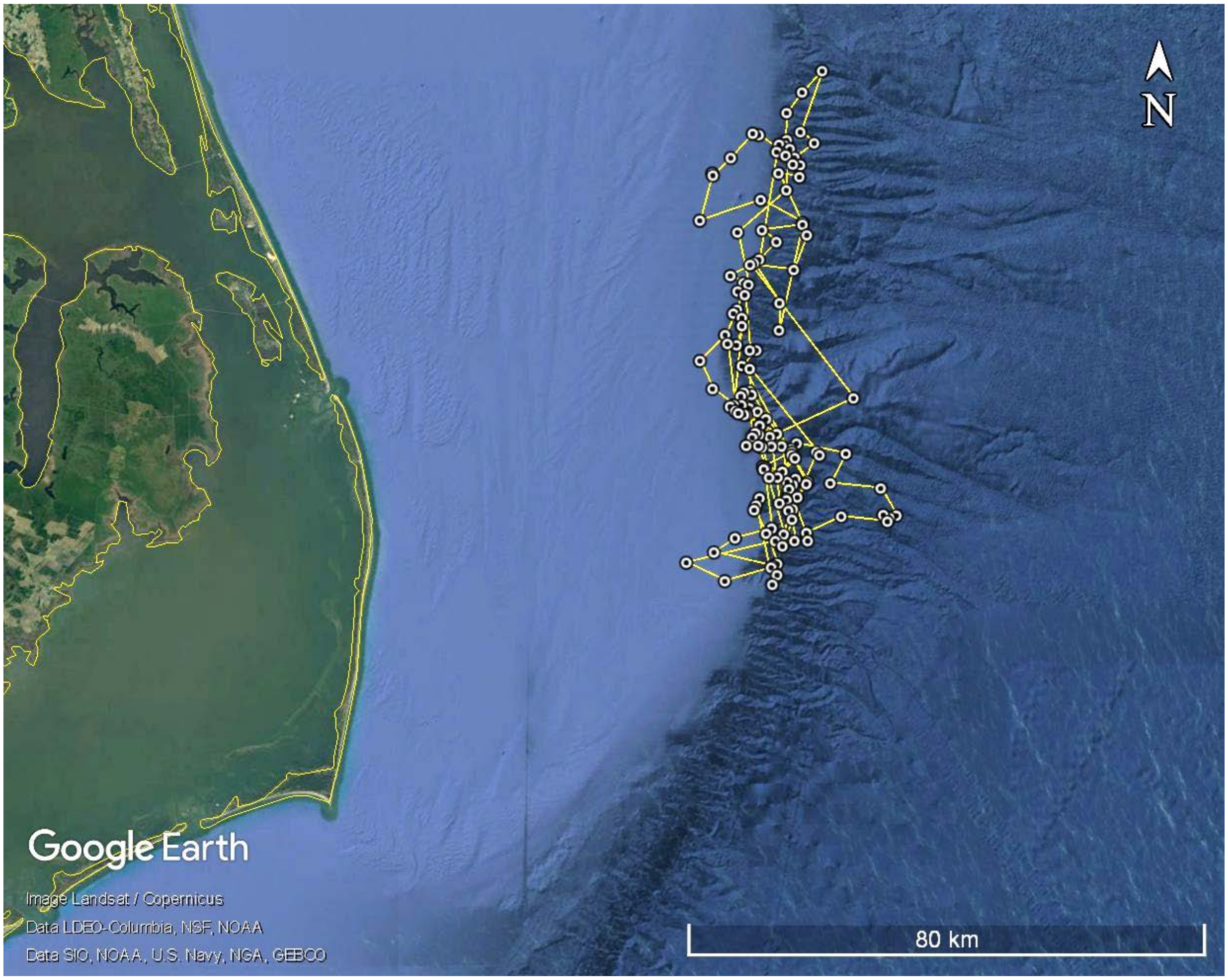


Figure 46. Filtered locations of a short-beaked common dolphin tagged off North Carolina in May 2016 over an 11-day period, with consecutive locations joined by a line.

One location-only tag was deployed on a Clymene dolphin, and location data were obtained over a 20.27-day period (**Table 41**). This is the first movement data available for this poorly known species. The cumulative distance moved by this individual was 1,684.5 km and the mean distance from the tagging location was 152.4 km, although it had moved a maximum of 268 km from the tagging location when the tag stopped transmitting. Despite being tagged on the continental slope, the individual primarily remained offshore of the slope (**Figure 47**), with a median depth of tagged animal locations of 2,689 m. During the time of the deployment, the animal moved away from and then returned to within 50 km of where it was tagged.

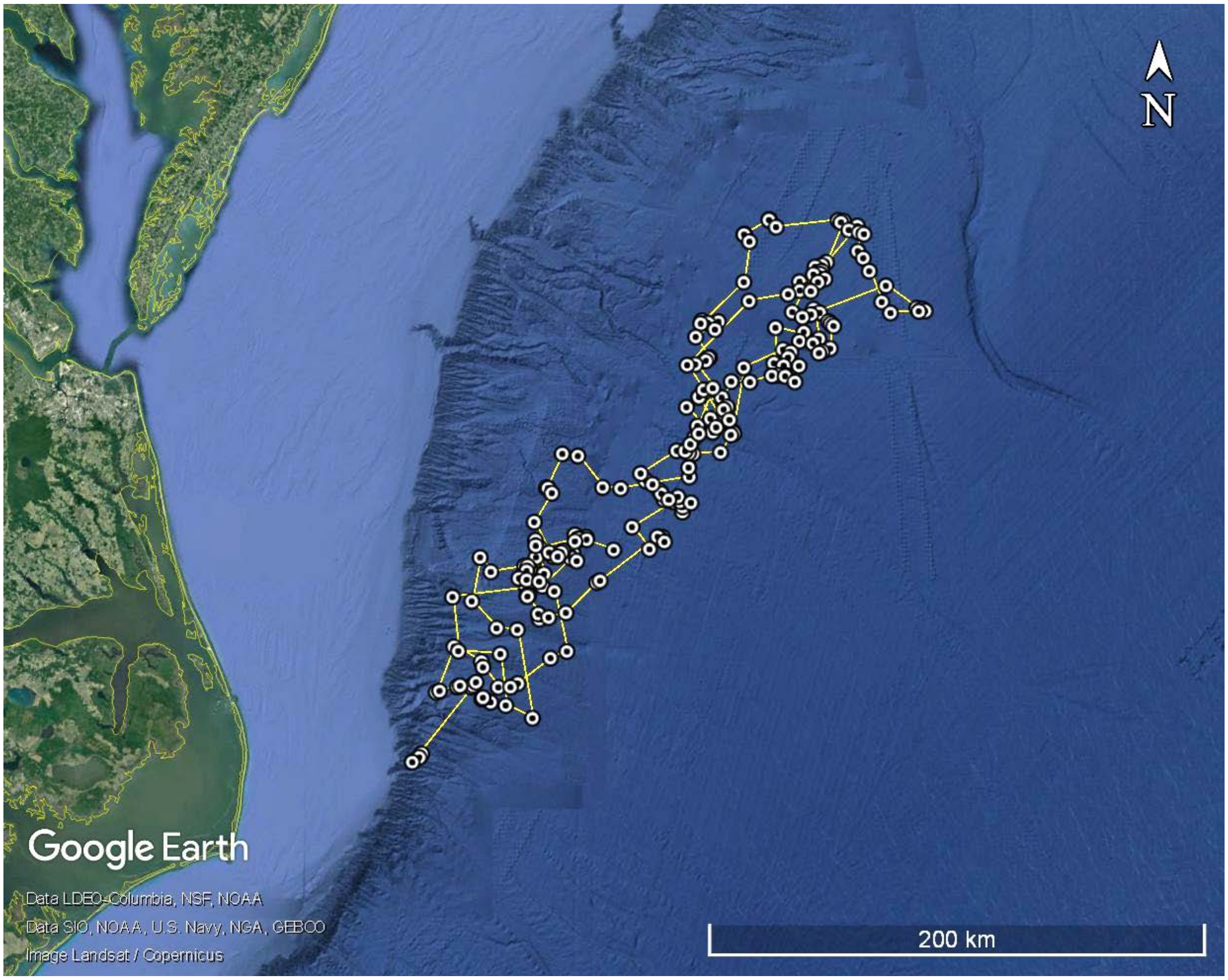


Figure 47. Filtered locations of a Clymene dolphin tagged off North Carolina in May 2016 over a 20-day period, with consecutive locations joined by a line.

Another location-only tag deployed on a Risso's dolphin transmitted location data over a 17.55-day period (**Table 41, Figure 48**). The cumulative distance moved by this individual was 1,453.8 km. While it remained a median distance of 170.6 km from the tagging location, around seven days post-tagging the animal moved directionally away from the general area to the south, and was 470 km from the tagging location when the tag stopped transmitting. The dolphin primarily remained over the continental slope (**Figure 48**), with a median depth of locations of 328 m.

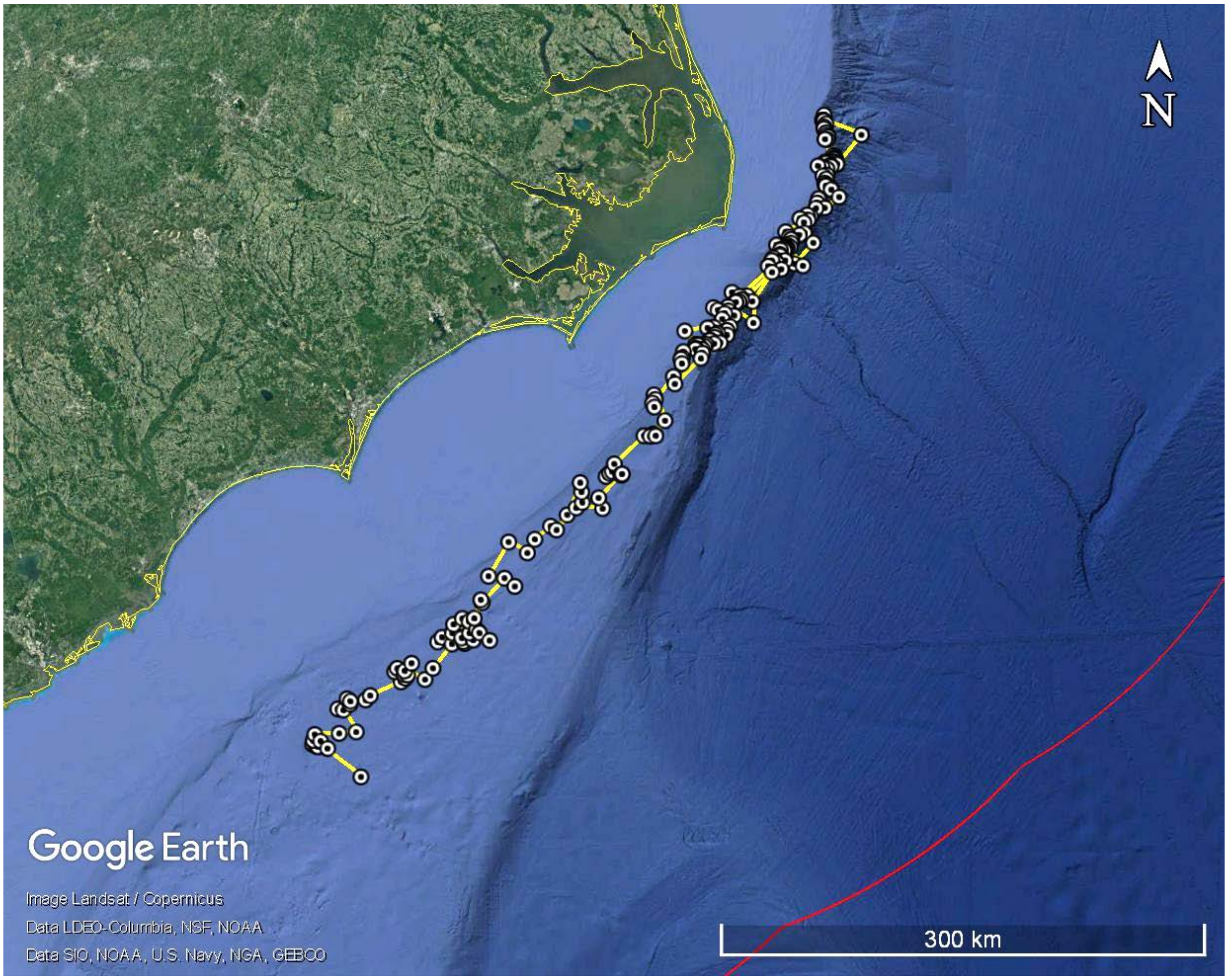


Figure 48. Filtered locations of a Risso's dolphin tagged off North Carolina in August 2016 over a 17.5-day period, with consecutive locations joined by a line. The outer boundary of the U.S. EEZ is shown with a red line.

Six satellite tags were deployed on Cuvier's beaked whales - one location-only tag and five location-depth tags (**Table 41**). Tags were deployed on two individuals in the same encounter on two different days, although assessment of distance between the two pairs of individuals during the period of tag overlap suggests that they did not act in concert throughout the duration of data transmission.

Movement patterns of the six individuals varied, with most remaining relatively close to the location where they were tagged. The individual (ZcTag051) tagged in the deepest water (1,774 m) in August left the area where it was tagged within two days and moved over 180 km away, while another animal tagged in May (ZcTag049) remained in the general area for over 80 days before eventually moving 120 km away. Most of the tagged individuals remained in relatively small areas on the continental slope near the tagging locations, with only occasional movements off the slope. The one individual that moved the farthest (ZcTag051) was the only individual primarily using waters off the continental slope. Four of the tagged Cuvier's beaked whales had three or more satellite-derived locations on the continental shelf (i.e., in <200 m depth). An assessment of location classes for ZcTag047, the individual with the largest number of locations on the shelf, indicates that these shallow locations are likely artifacts of poor location classes combined with the individuals' spending considerable time in close proximity to the shelf break. In general, the individuals tagged in 2016 had similar ranges to those tagged in previous years (**Figure 49**). While most of the tagged animals remained in or near the core area of the 2014 and 2015 tagged animals, staying near the continental slope off Cape Hatteras, two individuals did spend considerable time seaward of the slope, one moving over 140 km from the area where it was tagged within a few days of tagging. This may suggest the occasional occurrence of oceanic animals in the area of the apparently resident population. Results from individual photo-identification may help address longer-term site fidelity, for example whether either of those two individuals return in subsequent years. A probability-density distribution combining tag data obtained from 2014–2016 (**Table 41**) suggests that the core range for individuals tagged off Cape Hatteras is relatively small (**Figure 50**) and broadly overlaps with the core range of tagged bottlenose dolphins (**Figure 45**).

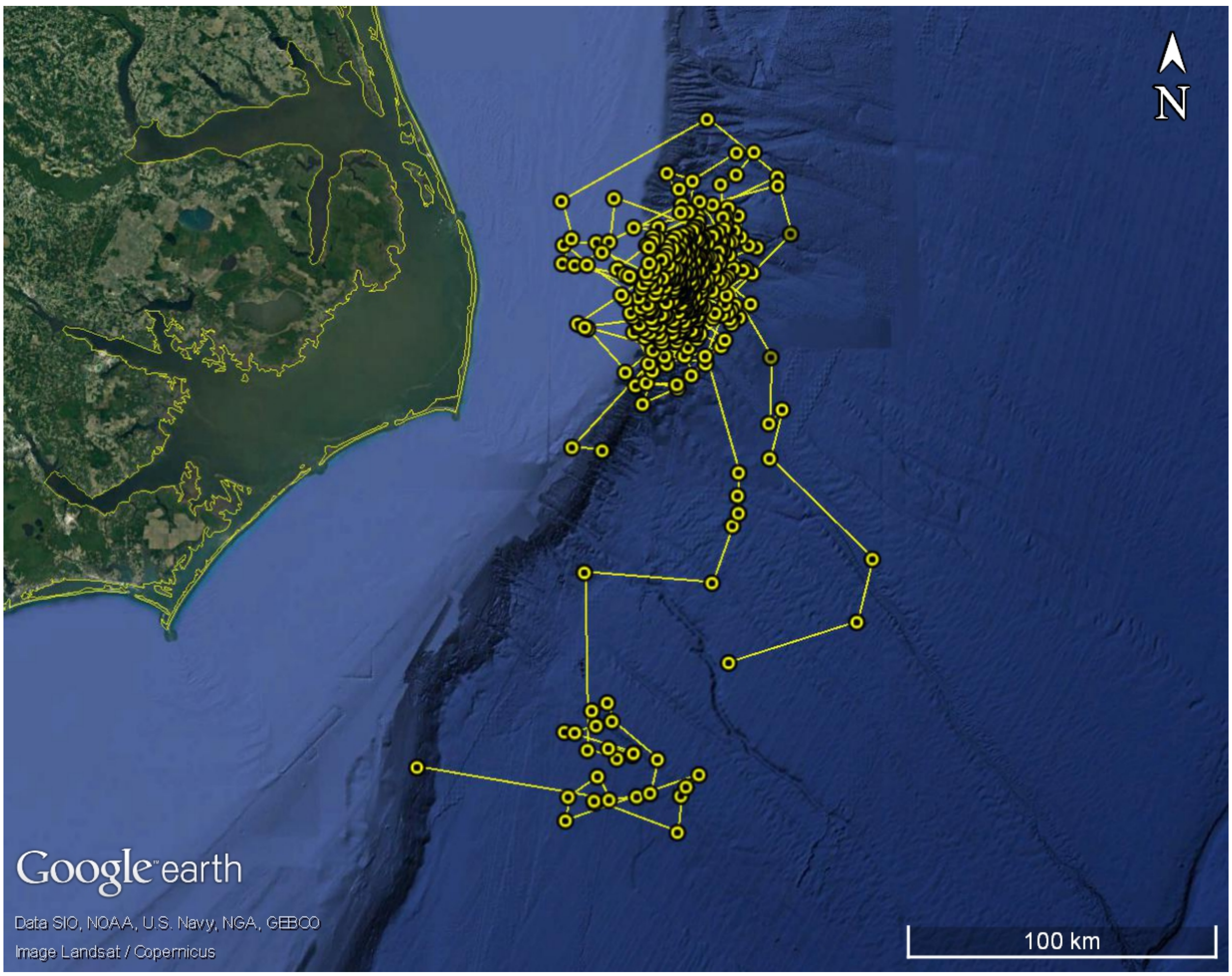


Figure 49. Filtered locations of Cuvier's beaked whales tagged off North Carolina in 2016, with consecutive locations joined by a line.

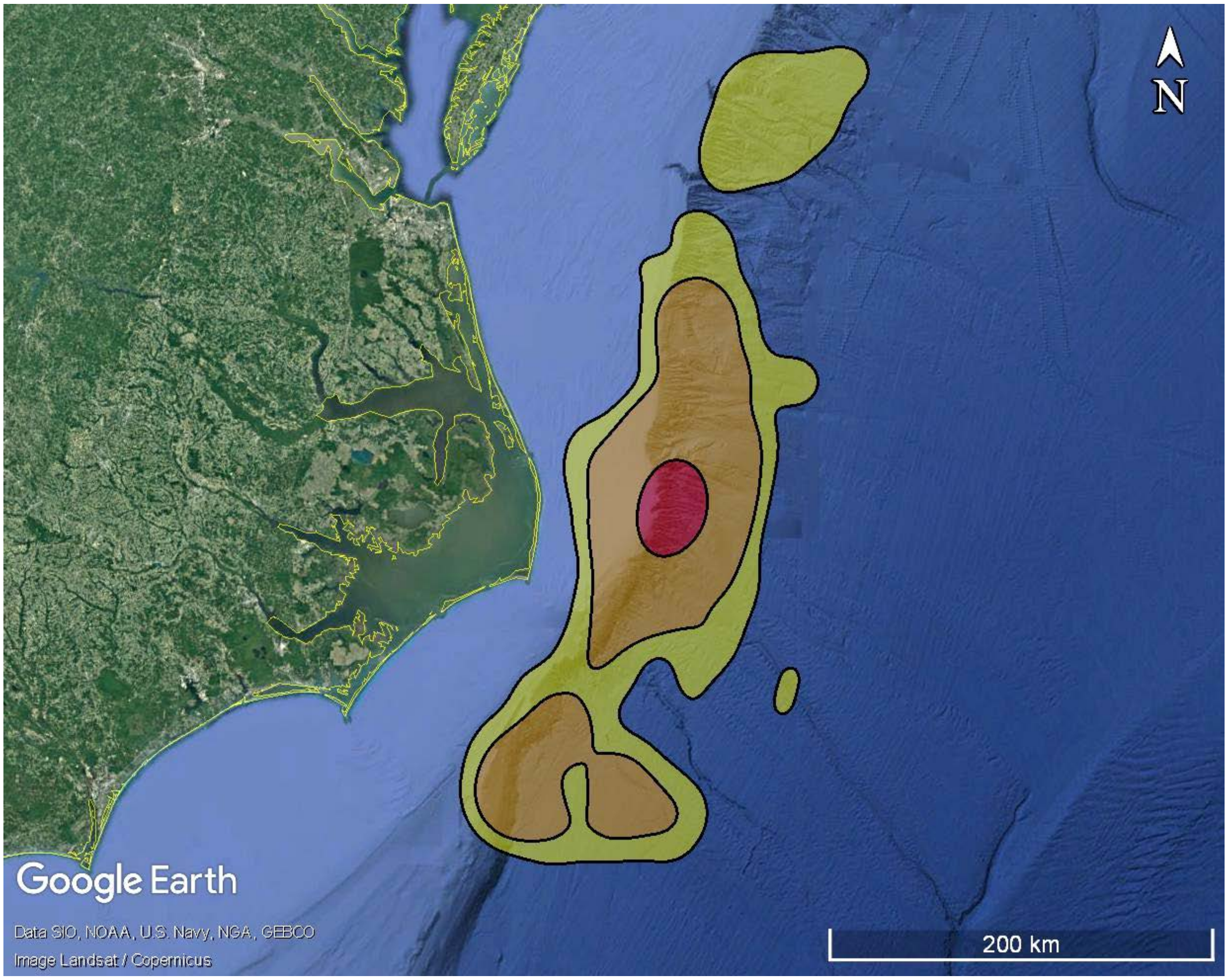


Figure 50. A probability density representation of Cuvier's beaked whale location data from 15 individuals tagged off North Carolina from 2014 to 2016. The red area indicates the 50 percent density polygon (the "core range"), orange represents the 95 percent polygon, and yellow represents the 99 percent polygon.

One of the location-depth tags (ZcTag047) had a pressure transducer failure shortly after deployment. While dive data were obtained from the tag that could be used for documenting dive durations, status messages from the tag indicated that dive depths were likely inaccurate. Dive data were obtained from the other four individuals tagged with location-depth tags, three of which remained primarily in slope waters and one of which spent its time seaward of the slope. Maximum dive depths and dive durations documented for the three individuals that primarily remained in slope waters ranged from 1,847 to 2,159 m and 68.7 to 152.5 min. Median depths at locations of these tagged individuals ranged from 1,009 to 1,340 m (maximum from 2,004 to 2,300 m), suggesting that many of the dives were likely to, or close to, the sea floor. A pseudotrack showing dive data relative to bottom depth is shown in **Figure 51**. The individual that spent almost all of its time seaward of the continental slope had one 78.5-min dive to 3,567.5 m. Assuming this was a V-shape dive, the ascent and descent rates would have averaged 1.32 meters/second (m/sec), within one standard deviation (SD) of the ascent/descent rates for other dives >1,000 m of this individual (mean=1.20 m/sec, SD=±0.28 m/sec). Bottom depths for locations of this individual shortly before (3,451 m) and shortly after (3,326 m) the deepest dive suggests that it is technically possible the dive depth was accurate, particularly given the uncertainty associated with Argos locations. However, while status reports from the tag showed no failure of the pressure transducer, the pressure transducer for the location-depth tags has been tested to 3,000 m on only a few occasions, thus this dive depth should be treated with caution.

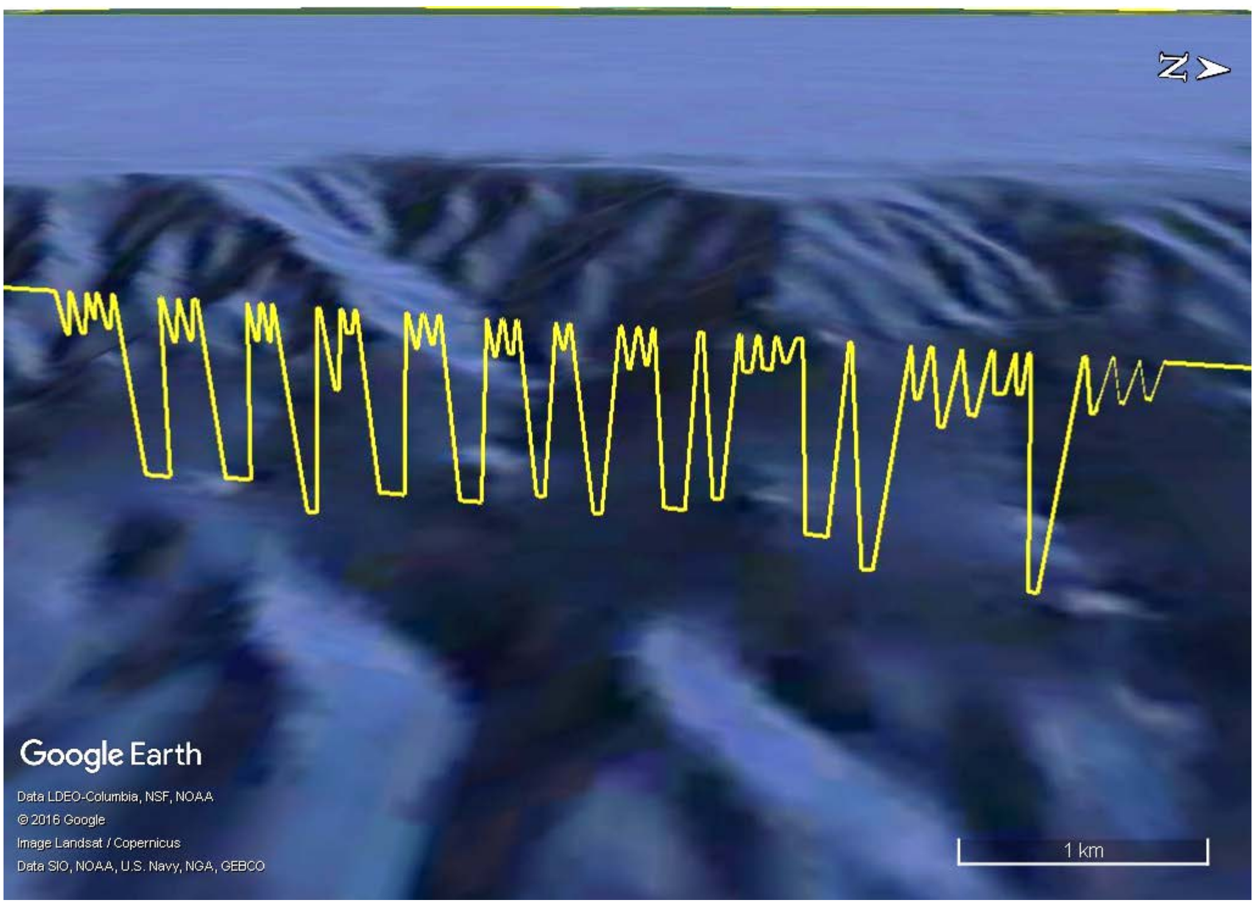


Figure 51. An example pseudotrack from Cuvier's beaked whale (ZcTag046) on the continental slope over a 17.5-hr period starting beginning 25 May 2016. The deep dives shown here range from 887 to 1,207 m in depth.

The dive-data records obtained from individuals in 2016, combined with the four individuals in 2015 and two individuals in 2014, will allow for a comparison of diving patterns of this species with data obtained elsewhere (i.e., Hawaii, California, Italy; Baird et al. 2006, 2008; Schorr et al. 2014; Tyack et al. 2006). One dive was recorded to 3,567.5 m (**Table 41**), deeper than any dive that has been previously recorded for Cuvier's beaked whales (Schorr et al. 2014; Baird et al. 2015, 2016), although as noted previously, this dive record should be treated with some caution.

Table 41. Summary of diving behavior data from location-depth tags.

Tag ID	# days behavior data	% of total record	# dives >50 m	Max dive depth (m)	Max dive duration (min)
ZcTag046	**4.05**	**40.6**	**196**	**1,847.7**	**68.7**
ZcTag048	**11.9**	**39.3**	**582**	**1,999.5**	**74.6**
ZcTag050	**1.6**	**6.6**	**59**	**2,159.5**	**152.5**
ZcTag051*	**5.9**	**63.2**	**147**	**3,567.5***	**78.5**

Key: % = percent; m = meter(s); min = minute(s); Zc = *Ziphius cavirostris* (Cuvier's beaked whale); *Pressure sensor on location-depth tags are rated to 2,000 m and have been tested to 3,000 m only a few times, thus this maximum dive depth should be treated with caution, as it is deeper than the known maximum dive depth for this species.

Five satellite tags were deployed on short-finned pilot whales from 25 to 27 May 2016. Four of these were location-only tags, and one was a prototype location-depth tag also obtaining Fastloc® GPS locations (**Table 41**). The attachment durations ranged from 24.3 to 156.7 days (median=131.8 days). The tags were deployed during five different encounters, and the distances between pairs of individuals suggested that all individuals generally acted independently.

Mean and maximum distances moved varied considerably among individuals, as did the typical depths used, suggesting considerable variability in movement patterns and habitat use among short-finned pilot whale groups off the U.S. Atlantic coast. Only one individual (GmTag159) spent the majority of its time seaward of slope waters, moving over 600 km from where it was tagged in less than 10 days, before returning back to the area it was tagged 10 days later. This tag recorded 727 Fastloc® GPS locations, in comparison to 206 Argos-derived locations. While the locations from the two positioning systems were generally similar, the track derived from the Argos-derived locations did deviate at times from the Fastloc® GPS track.

While the photo-ID work suggests that short-finned pilot whales display a high degree of site fidelity off Cape Hatteras, satellite tagging demonstrates that these animals cover a significant range up and down the continental slope, and occasionally into offshore waters. A map showing combined track and location data from all short-finned pilot whales tagged in 2014 (*n*=17), 2015 (*n*=19), and 2016 (*n*=5) is shown in **Figure 52**, with a probability-density representation shown in **Figure 53**. As with Cuvier's beaked whales and bottlenose dolphins, the core range centers off Cape Hatteras, although it extends north to offshore of Maryland. Unlike the other whales and dolphins, the 90 percent and 95 percent polygons for short-finned pilot whales extend much farther, along the continental slope all the way into Canadian waters, and out across the abyssal plain to the New England Seamount chain.

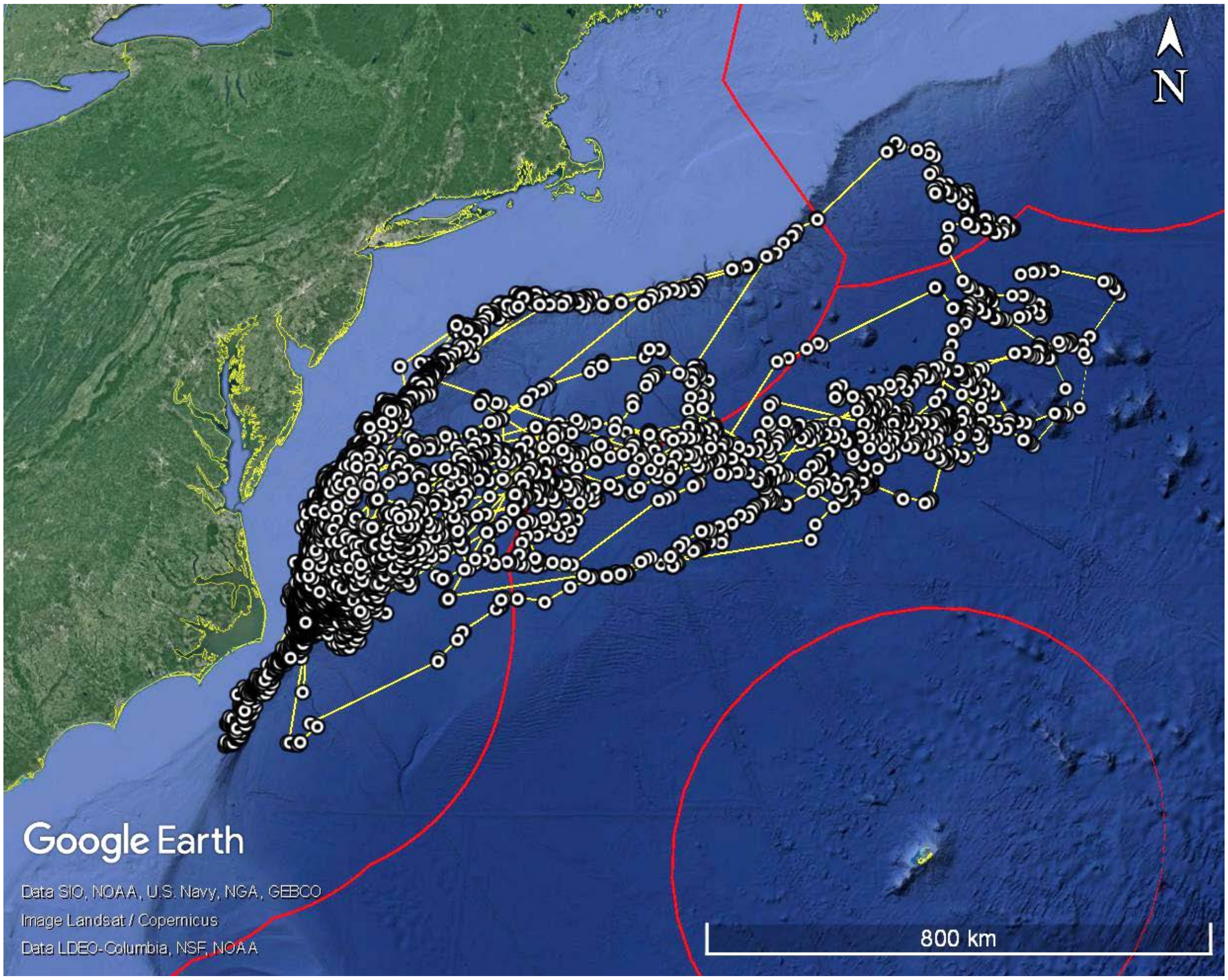


Figure 52. Filtered locations of all short-finned pilot whales tagged off North Carolina from 2014 (*n*=17), 2015 (*n*=19), and 2016 (*n*=5) (see Baird et al. 2015, 2016). EEZ boundaries are shown with red lines.

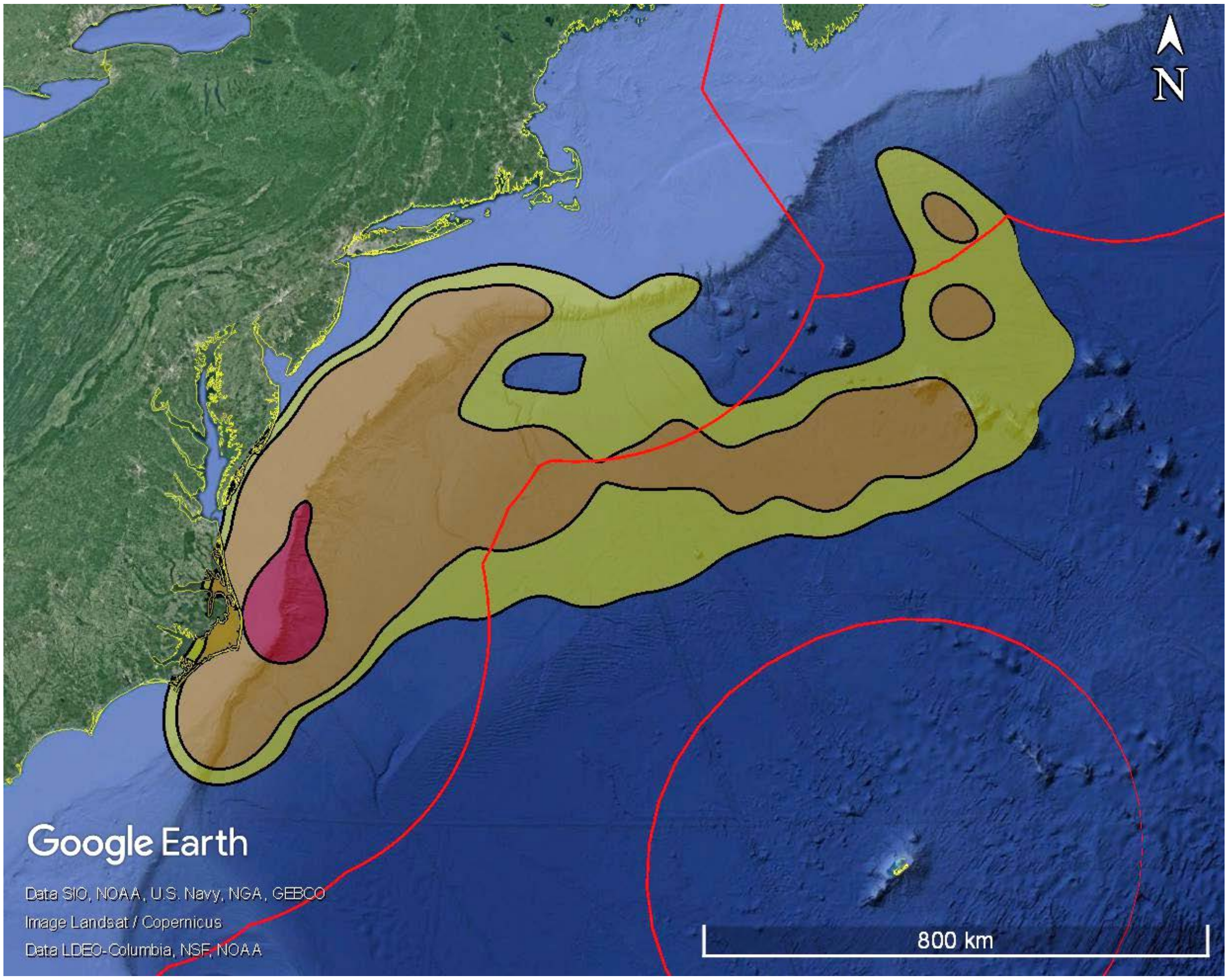


Figure 53. A probability-density representation of short-finned pilot whale location data from all individuals tagged off Hatteras in 2014 (*n*=17), 2015 (*n*=19), and 2016 (*n*=5). The red area indicates the 50 percent density polygon (the "core range"), orange represents the 95 percent polygon, and yellow represents the 99 percent polygon. EEZ boundaries are shown with red lines.

For more information on this study, refer to the annual progress report for this project (Baird et al. 2017).

Jacksonville Study Area

Four satellite tags were deployed on short-finned pilot whales and one on an Atlantic spotted dolphin in the Jacksonville study area in June 2016 (**Table 42**, **Figure 54**). For short-finned pilot whales, two tags were deployed on individuals within the same group on one day (one depth-transmitting and one location-only tag), and on the next day tags were deployed on individuals that were in different groups (also one depth-transmitting and one location-only tag). An analysis of the distances between the two individuals in each pair suggested that both pairs of tagged whales acted in concert. The mean distances apart between the individuals in the two pairs were 3.11 and 3.50 km, respectively, over the periods of tag overlap. Tags transmitted from 11.8 days (the Atlantic spotted dolphin) to 47.2 days (one of the short-finned pilot whales, **Table 42**). In general, the tagged individuals all remained relatively close to where they were tagged (**Table 43**), with the Atlantic spotted dolphin remaining in shelf waters (median depth=36 m, **Figure 55**), and the pilot whales remaining in waters over the slope (median depths ranging from 688 to 799 m, see **Table 43** and **Figures 56 through59**). Dive data were obtained from both of the depth-transmitting tags deployed on short-finned pilot whales, with data from 12.6 days (GmTag163) and 11.2 days (GmTag165).

Table 42. Satellite tag deployments on odontocete cetaceans in the Jacksonville study area in 2016.

Species[1]	Tag ID	Tag Type[2]	Deployment Date	Date of Last Transmission	Tag Duration (days)	Deployment Latitude (°N)	Deployment Longitude (°W)
Sf	SfTag001	SPOT	01-Jun-16	13-Jun-16	12	30.28289	80.43805
Gm	GmTag162	SPOT	01-Jun-16	12-Jul-16	40	30.22385	79.82004
Gm	GmTag163	Mk10	01-Jun-16	10-Jul-16	39	30.22762	79.81328
Gm	GmTag164	SPOT	02-Jun-16	19-Jul-16	47	30.24696	79.72234
Gm	GmTag165	Mk10	02-Jun-16	02-Jul-16	30	30.25456	79.72902

[1] Gm=*Globicephala macrorhynchus* (short-finned pilot whale); Sf=*Stenella frontalis* (Atlantic spotted dolphin)

[2] Mk10=location and dive data tag; SPOT=Smart Position and Temperature (location only) tag.

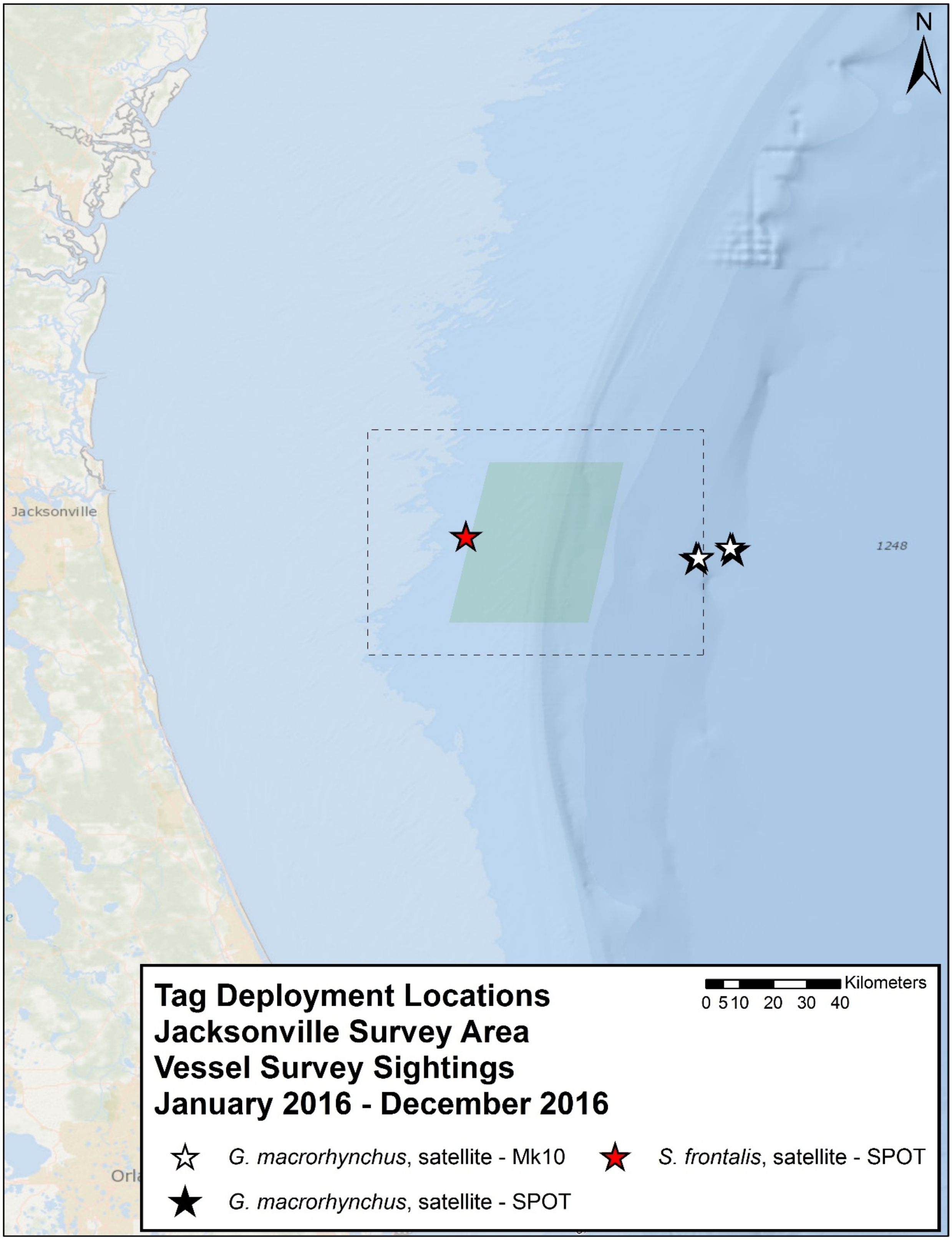


Figure 54. Locations of satellite tag deployments in the Jacksonville study area in 2016.

Table 43. Summary from analyses of satellite tag data from deployments in the Jacksonville study area in 2016.

Animal ID[1]	Tag Type[2]	Depth (m)		Distance from Shore (km)			Distance from 200-m Isobath (km)	
		Median	Max	Min	Median	Max	Median	Max
SfTag001	SPOT	36.2	44.8	68.5	85.4	96.3	40.3	52.8
GmTag162	SPOT	799.1	892.9	73.9	152.7	263.5	55.6	147.8
GmTag163	Mk10	796.4	890.0	93.0	154.6	266.1	51.5	147.6
GmTag164	SPOT	788.5	1,205.6	67.7	156.9	347.7	53.5	274.7
GmTag165	Mk10	688.3	897.5	68.2	164.2	306.8	39.7	190.2

[1] Gm=*Globicephala macrorhynchus* (short-finned pilot whale); Sf=*Stenella frontalis* (Atlantic spotted dolphin)

[2] Mk10=location and dive data tag; SPOT=Smart Position and Temperature (location only)

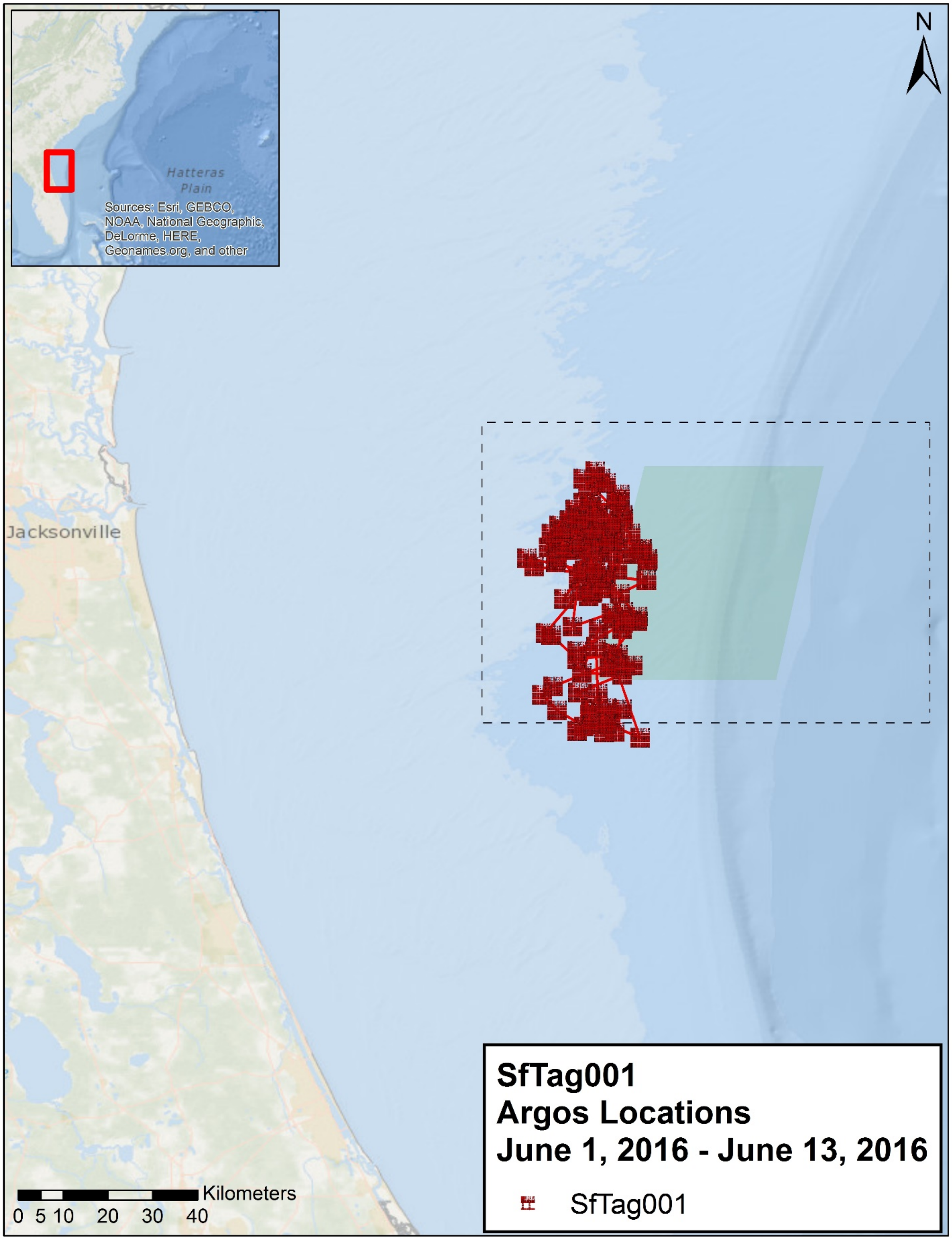


Figure 55. Filtered Argos locations of Atlantic spotted dolphin SfTag001 satellite tagged in the Jacksonville study area on 01 June 2016.

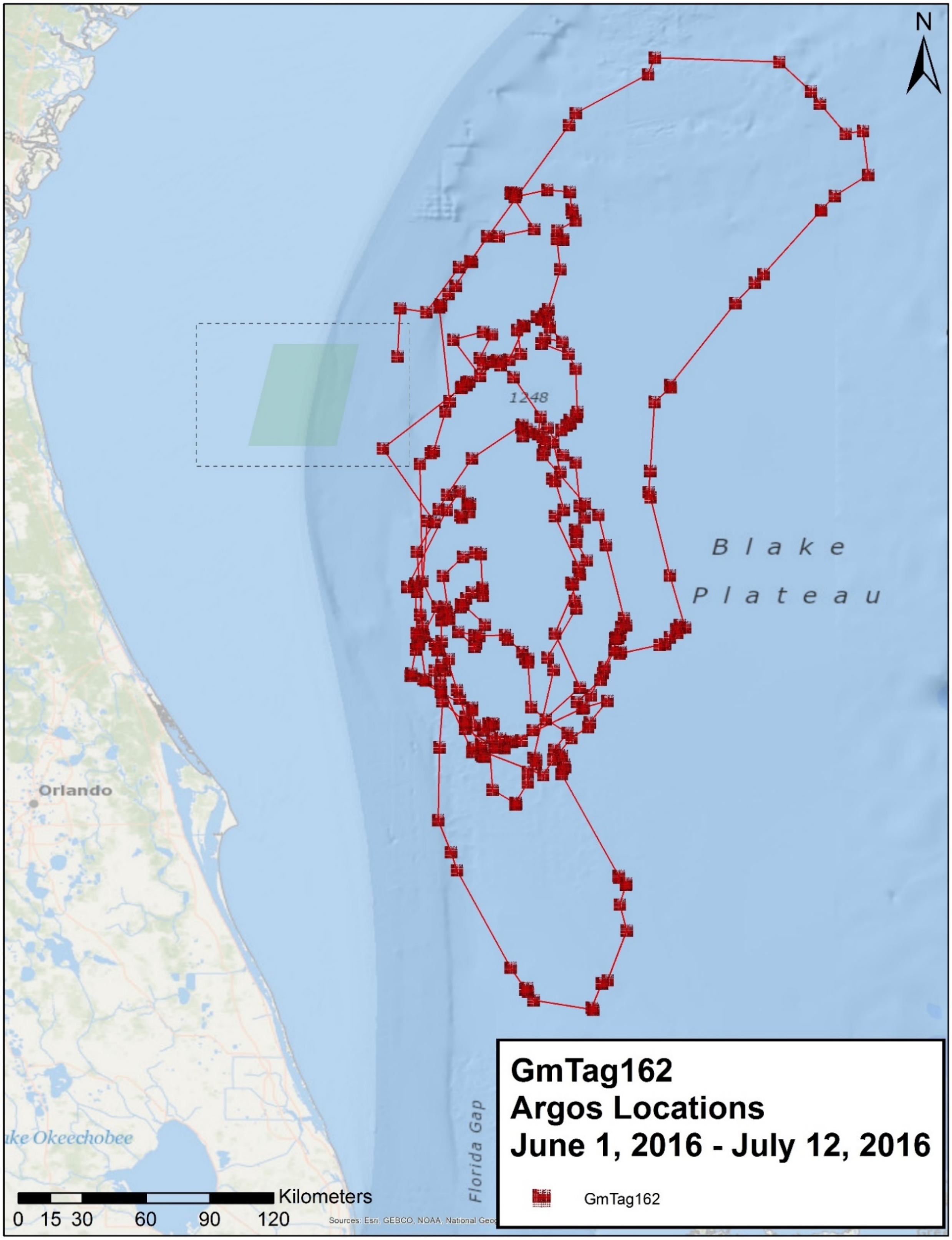


Figure 56. Filtered Argos locations of short-finned pilot whale GmTag162 satellite tagged in the Jacksonville study area on 01 June 2016.

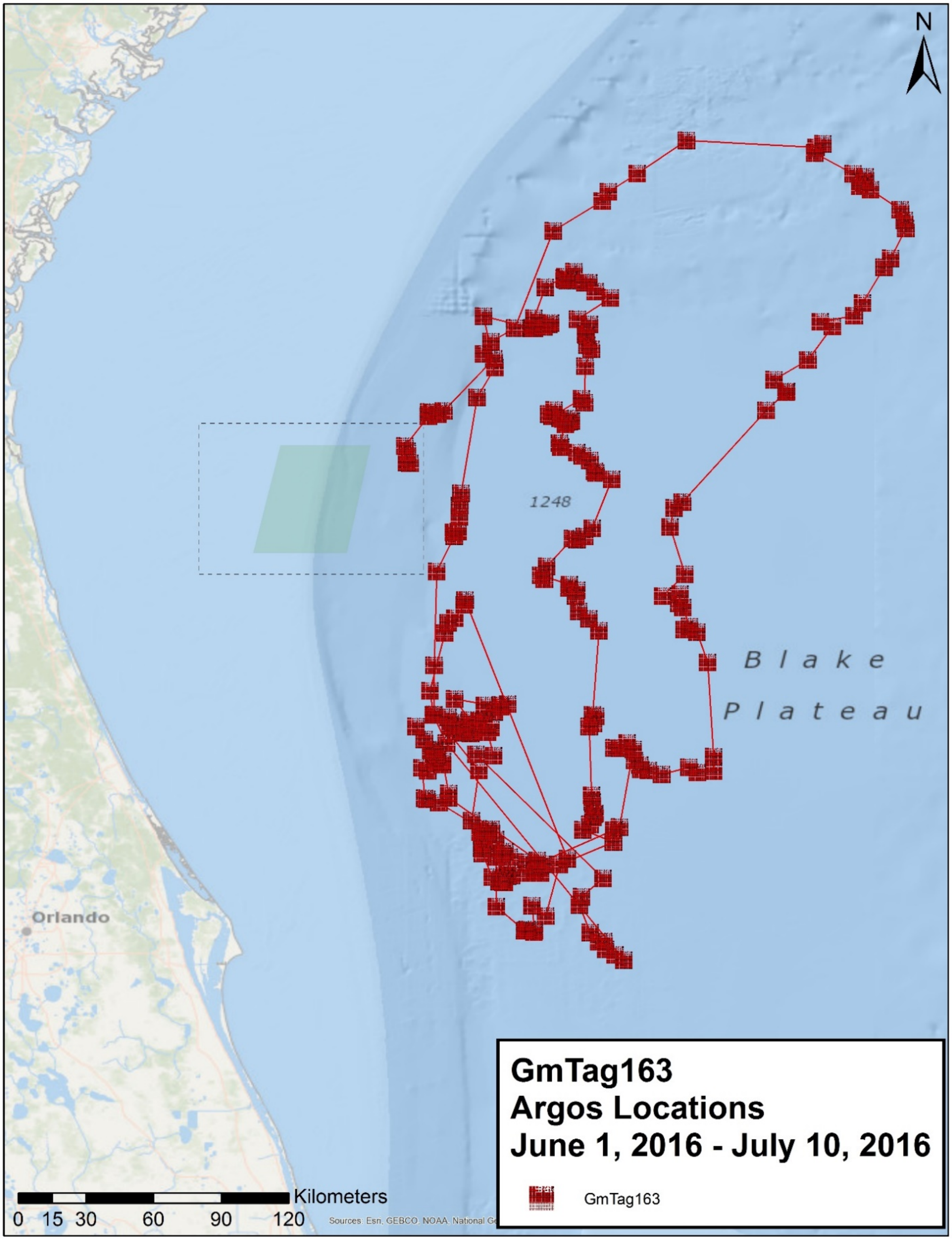


Figure 57. Filtered Argos locations of short-finned pilot whale GmTag163 satellite tagged in the Jacksonville study area on 01 June 2016.

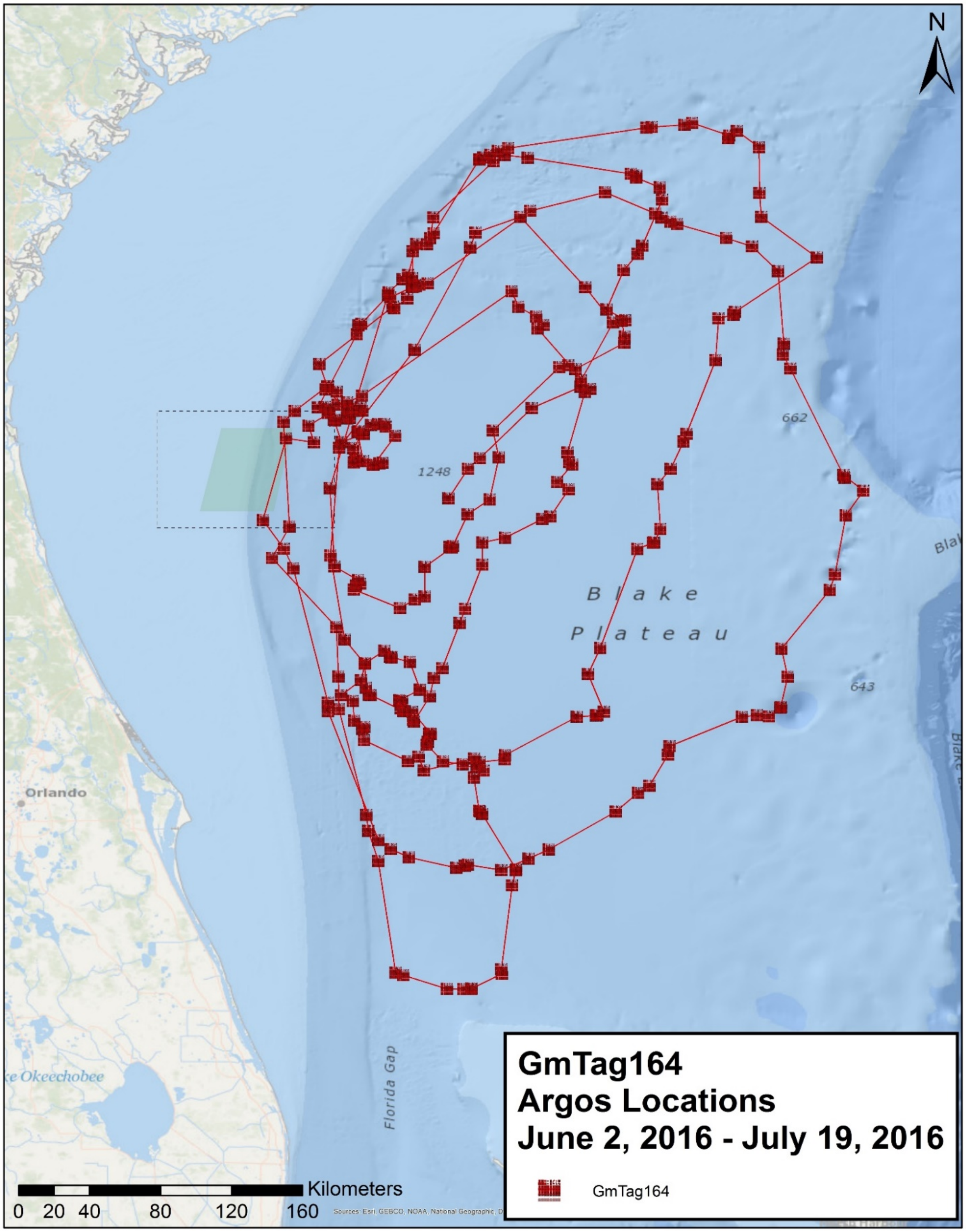


Figure 58. Filtered Argos locations of short-finned pilot whale GmTag164 satellite tagged in the Jacksonville study area on 02 June 2016.

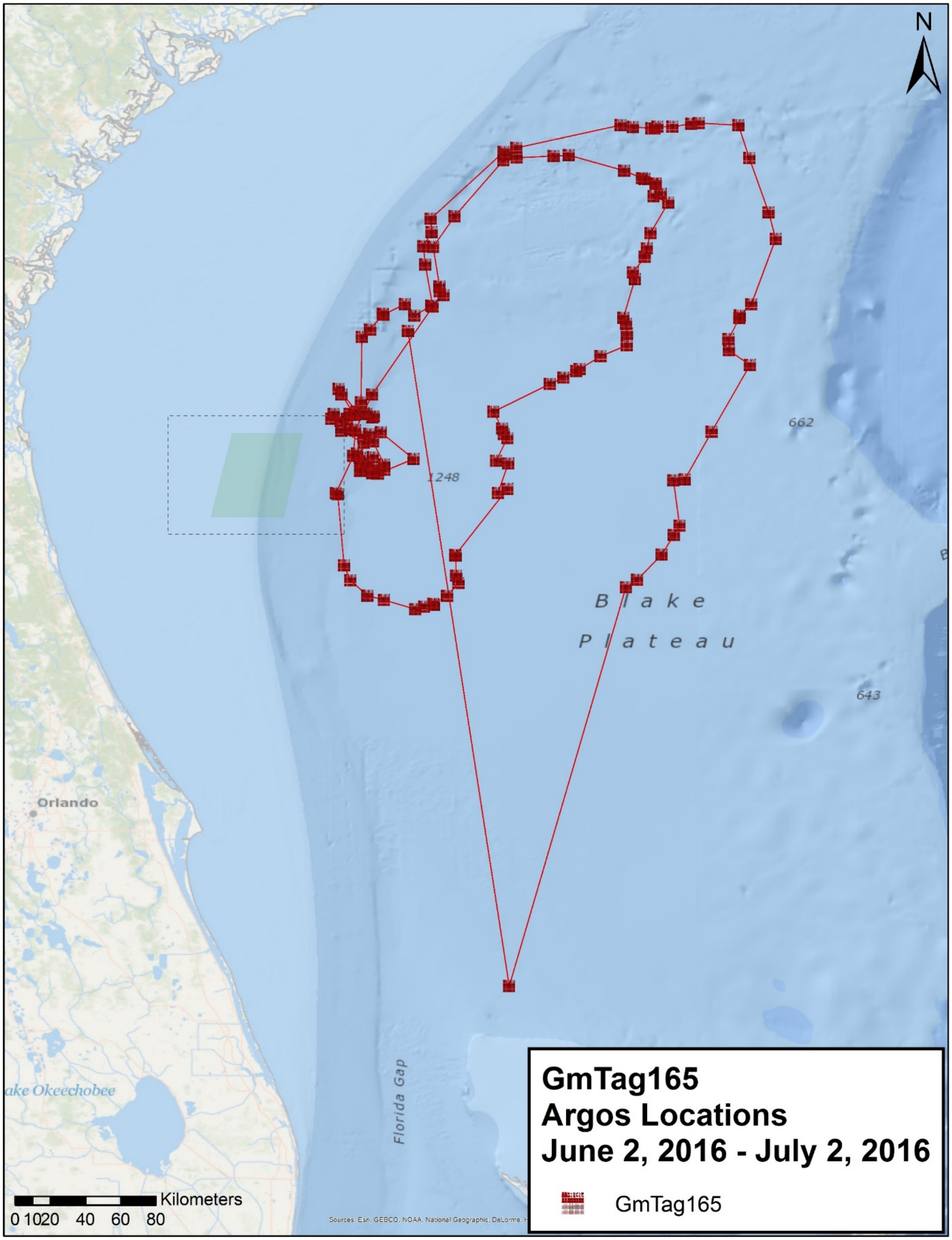


Figure 59. Filtered Argos locations of short-finned pilot whale GmTag165 satellite tagged in the Jacksonville study area on 02 June 2016

2.2.1.2 DTAGs

During 2016, Duke University deployed three DTAGs on short-finned pilot whales in the Cape Hatteras study area. Two of these DTAGs (Gm16_132a; Gm16_133a) were deployed during 11–12 May 2016. Behavioral focal follows were conducted prior to and during each tag deployment. The deployments lasted approximately 1.5 hr and 4 hr, respectively. To help understand vocal production in relation to observed behavior, a four-element distributed hydrophone array was deployed to record vocalizations in synchrony with the focal follows. This allowed researchers to accurately localize caller direction and link exact times of vocalizations with exact times of surface observations. A total of 5.25 hr of short-finned pilot whale vocalizations was recorded on the hydrophone array. Another DTAG was deployed on 29 June on a short-finned pilot whale (Gm16_181a). The focal individual was tracked during the tag's approximately 4-hr duration.

For more information on this study, refer to the annual progress report for this project (Foley et al. 2017b).

2.2.2 North Atlantic Right Whale Tagging

North Atlantic right whales migrate to coastal waters off Florida and Georgia during the winter months. The planned construction and operation of a USWTR off the Atlantic coast of Florida could result in interactions with right whales on their winter calving ground. Aerial- and vessel-based visual surveys as well as passive acoustic monitoring are currently being used to detect right whales in the coastal waters of Florida and Georgia, as well as in offshore areas near the planned USWTR.

Currently there are few data on the movement patterns of individuals, including movement rates (either north-south or east-west), dive depths, and dive durations. The vocalization rates of individual right whales on these wintering grounds also are poorly understood. A targeted tagging program is in progress to address these knowledge gaps, by collecting horizontal-movement, dive-profile, and vocal behavior from individual whales. These data are important to inform monitoring and mitigation techniques and to increase the U.S. Navy's understanding of the potential for disturbance to right whales as USWTR construction and training operations commence.

The field team includes members from Duke University and Syracuse University. Fieldwork has been conducted out of Fernandina Beach, Florida, during February 2014, February–March 2015, January–February 2016, and February 2017. In February 2014, weather conditions were suitable for tagging operations on 11 days, and right whales were located on nine of those days (Nowacek et al. 2015). DTAGs were successfully deployed on right whales on seven occasions. Individual whales showed variation in movement patterns along the coastline. Only one tag was successfully deployed on a single right whale during eight days of field effort in 2015 due to a very low number of animals being present on the winter grounds (Nowacek et al. 2016). Despite the lack of new data, additional work and analyses were undertaken focused on sound propagation modeling, creating and testing algorithms for detection and classification of right whale calls, and individual distinctiveness of right whale calls.

The focus of the 2016 research was to increase the sample size of tagged individuals. The third field season for this project took place during late January through February 2016. Weather conditions were suitable for tagging operations on 11 days during this time. There were 16 right whale sightings—two solitary individuals and 14 mother-calf pairs (**Table 44**). One identified whale—EGNO 3101—was seen on 25 January 2016 alone and resighted on 17 February 2016 with her calf. Three other mother/calf pairs were seen more than once—3405 and 3860 twice and 1281 four times; the 16 sightings represented only 10 identified individuals and nine calves. The nine calving females represent 69 percent of the 13 reported from the calving ground for the entire 2015—2016 season (NARWC 2016). During 2016, right whale sightings on their wintering grounds were significantly lower than historic levels, although on par with 2014.

Table 44. North Atlantic right whale sightings during January and February 2016.

Date	Latitude (°N)	Longitude (°W)	Group Size	Whale ID	Tag ID
25-Jan-16	30.69675	81.29469	1	3101	Eg16_025a
26-Jan-16	30.58681	81.22008	2	3115+calf	
30-Jan-16	30.54024	81.30135	2	3405+calf	Eg16_030a
31-Jan-16	30.90281	81.33092	2	1281+calf	Eg16_031a
01-Feb-16	30.6521	81.26485	2	3405+calf	
01-Feb-16	30.61079	81.11848	2	3860+calf	
01-Feb-16	30.73374	81.32282	2	1810+calf	Eg16_32a
17-Feb-16	30.64065	81.22863	2	3101+calf	Eg16_048a
17-Feb-16	30.65128	81.24881	2	1281+calf	Eg16_048b
20-Feb-16	30.30893	81.30338	2	3860+calf	
20-Feb-16	30.74928	81.21365	2	1281+calf	
20-Feb-16	30.88811	81.26799	2	3180+calf	
21-Feb-16	30.7986	81.32979	2	1281+calf	
22-Feb-16	30.65765	81.14512	2	1812+calf	
22-Feb-16	30.37812	81.14986	2	3317+calf	Eg16_053a
23-Feb-16	30.40043	81.35293	1	1968	

During 2016, a primary objective was to obtain longer duration tag attachments. Non-invasive suction cup DTAGs (anticipated tag duration 1 to 36 hr) include Fastloc® GPS technology, time-depth recorders, 3-D movement measurement, and acoustic recording capability. Seven tags were deployed on five different females; two females were tagged on two separate occasions (**Table 44**). EGNO 3101 was pregnant when first tagged on 25 January; she was tagged a second time on 17 February when she was resighted with a calf. EGNO 1281 was tagged twice, on 31 January and 17 February, and seen twice more after that; she was accompanied by a calf at all four sightings. Three other females with calves were tagged once. The seven deployments resulted in more than 37 hr of tag data. GPS-tracked individuals showed variable movement patterns, with individuals showing movement tracks on both north-south and east-west axes (**Figures 60 and 61**). Animals often covered up to 2 km/hr.

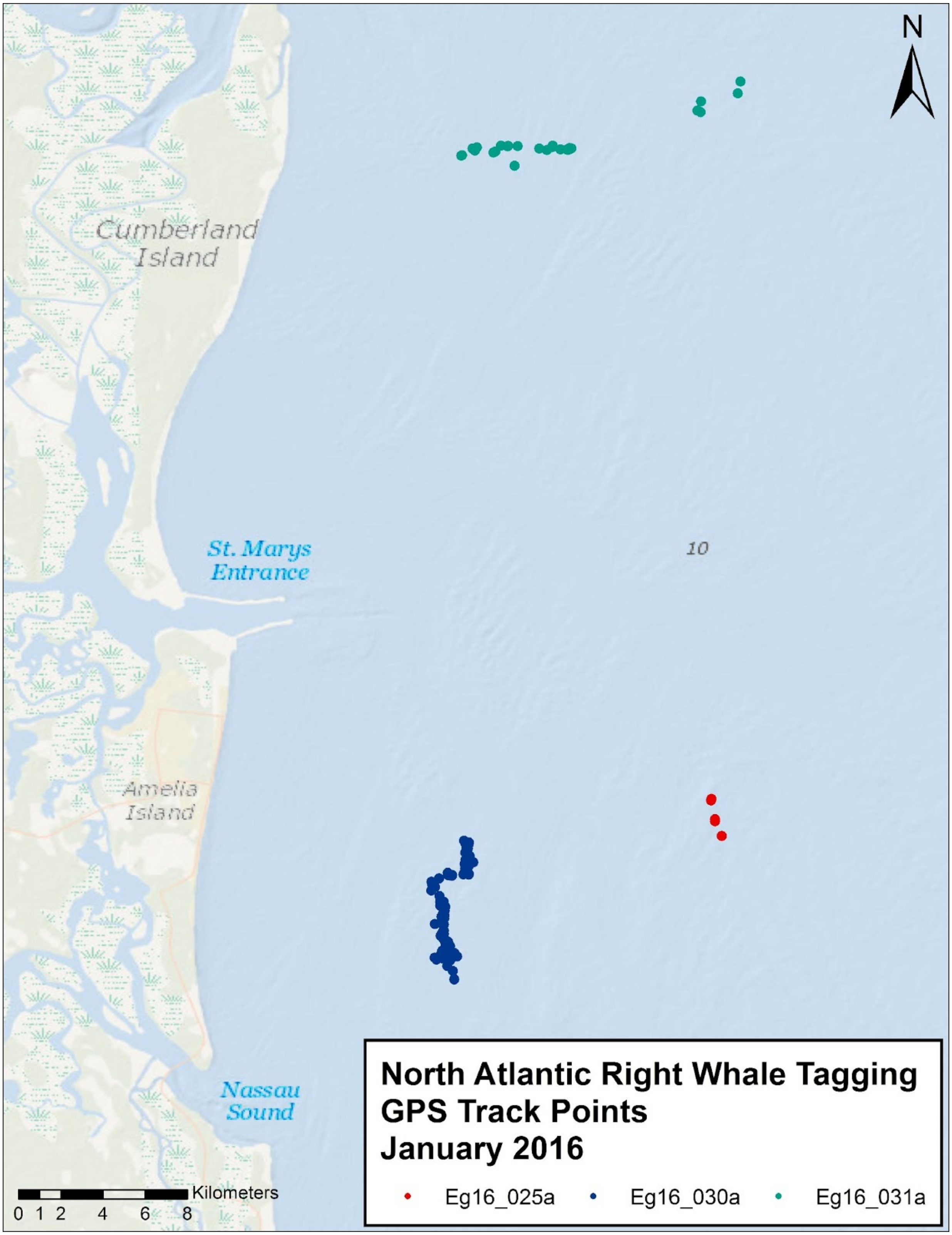


Figure 60. Surface positions for two tagged North Atlantic right whale mothers (EG16_030a—EGNO 3405, 30 January, and Eg16_031a—EGNO 1281, 31 January) and one pregnant female (Eg16_025a—EGNO 3101, 25 January) in January 2016.

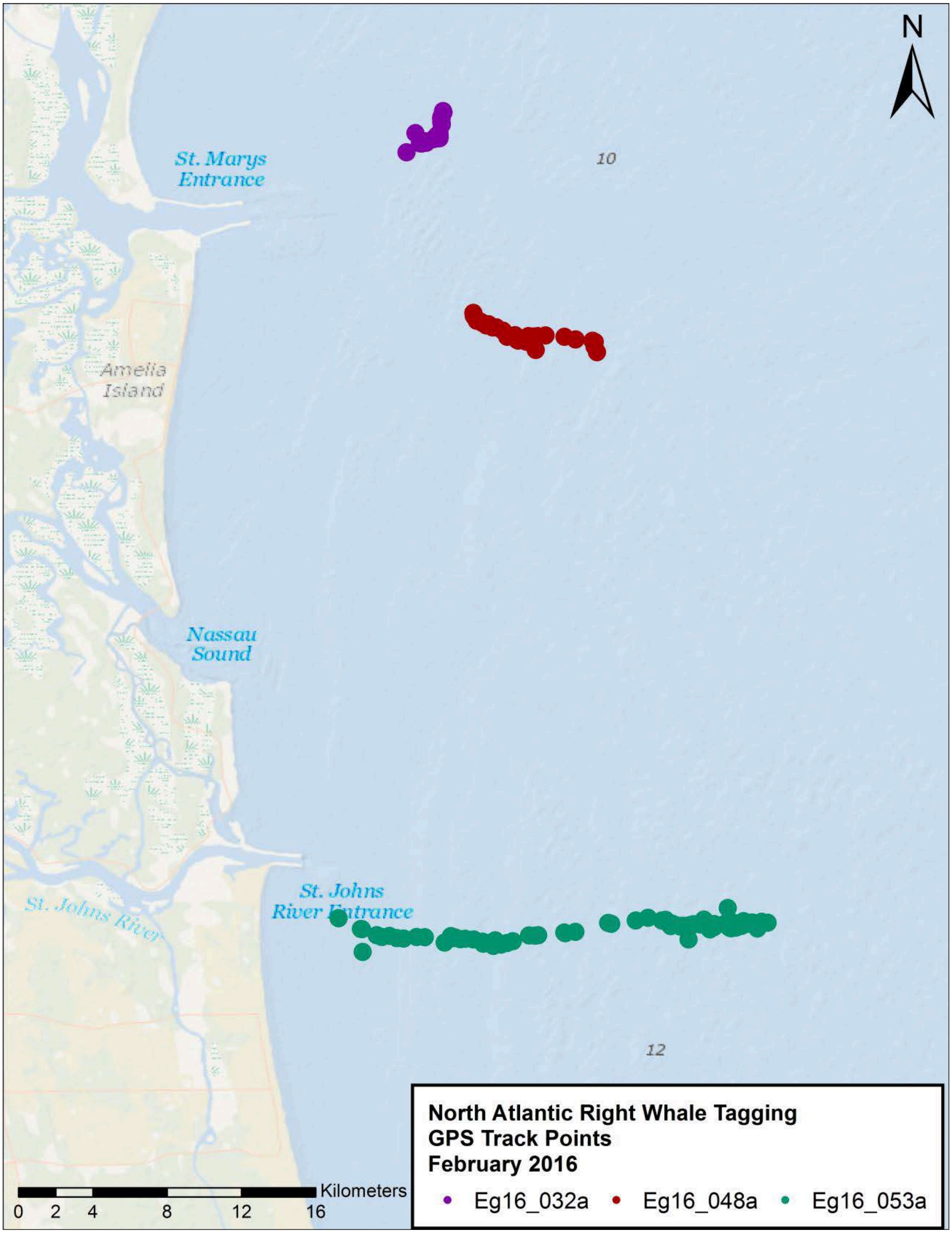


Figure 61. Surface positions for three tagged North Atlantic right whale mothers in February 2016 (Eg16_32a–EGNO 1810, 01 February; Eg16_048a—EGNO 1281, 17 February; Eg16_053a—EGNO 3317, 22 February).

Audio recordings from the DTAGs were reviewed visually and aurally in Raven Pro 1.5 (Cornell Bioacoustics Research Program, Ithaca, New York) for evidence of any right whale “up-calls.” Analysis from the 2016 season showed a clear pattern (**Table 45**). Among the six tags deployed on five different nursing mothers, only one right whale up-call was detected from 32 hr of tag data. The tag deployed on 25 January 2016 on EGNO 3101, before the birth of her calf, recorded 46 up-calls, for an average of 9.2 calls/hr and a peak rate of more than 10 calls/hr. When EGNO 3101 was tagged a second time on 17 February 2016, accompanied by a nursing calf, she was completely silent for the nearly 5-hr recording. Other sounds were successfully recorded by the DTAGs, such as noise from nearby ships and distant construction, as well as vocalizations from other cetacean species and from fish.

Table 45. Summary of acoustic tag data from calving female right whales in 2016.

Date	Tag ID	Whale ID (EGNO)	Acoustic Record Duration (hh:mm)	Status	Up-calls Detected (Including Calls from Other Whales)	Calls Per Hour of Tag Recording
25-Jan-16	Eg16_025a	3101	4:59	Pregnant	46	9.23
30-Jan-16	Eg16_030a	3405	4:44	Nursing	1	0.21
31-Jan-16	Eg16_031a	1281	6:26	Nursing	0	0
01-Feb-16	Eg16_032a	1810	1:44	Nursing	0	0
17-Feb-16	Eg16_048a	3101	4:56	Nursing	0	0
17-Feb-16	Eg16_048b	1281	2:49	Nursing	0	0
22-Feb-16	Eg16_053a	3317	11:47	Nursing	0	0

Unmanned aircraft system (UAS, “drone”) operations were successfully added to the field program in 2016. UAS data were collected during three days in February 2016. Aerial images were collected from several whales, which will aid in photogrammetry work. Additionally, photographs and a blow sample were collected from EGNO 1968, a whale that looked compromised (e.g., peeling and grayish skin) and had a piece of baleen that was clearly out of place protruding from the mouth. The photographs of this animal were submitted to the North Atlantic Right Whale Catalog (New England Aquarium) and the breath sample for ongoing analyses by Dr. Michael Moore at Woods Hole Oceanographic Institution.

Preliminary analyses of the acoustic, tracking, and dive data were completed for 2016, and further analyses of these data are being conducted under the supervision of Drs. Nowacek and Parks with students and technicians in their laboratories. A fourth year of fieldwork is currently underway in February 2017. The focus of the additional research will be to increase the sample size of tagged individuals, with an emphasis on single animals (not mother-calf pairs) when feasible.

For more information on this study, refer to the annual progress report for this project (Nowacek et al. 2017).

2.2.3 Mid-Atlantic Humpback Whale Monitoring

Since January 2015, HDR has been monitoring humpback whales to assess their occurrence, habitat use, and behavior in the mid-Atlantic region in order to establish baseline information about this species in U.S. Navy training and testing areas off Virginia. Information on the movements of individuals within this region has historically been very limited. Therefore, the baseline data obtained during this study are critical for assessing the potential for disturbance to humpback whales found in U.S. Navy training ranges and high-traffic areas in Chesapeake Bay and nearby coastal waters. Although humpback whales are the target of this study, data on other high-priority species of baleen whales are also collected when possible.

Three field seasons of dedicated humpback whale surveys have been conducted to date. During the initial field season (January–May 2015), vessel and aerial surveys were conducted in conjunction with photo-ID, focal-follow, and biopsy-sampling techniques to obtain baseline data on humpback whales in this region. Data from that field season also included humpback whale sightings recorded during concurrent bottlenose dolphin density surveys in December 2014 (Engelhaupt et al. 2015). The 2015/2016 field season (December 2015–May 2016) consisted of only nearshore vessel surveys to collect biopsy samples of humpback whales as well as photo-ID and focal-follow data from humpback whales and other high-priority baleen whale species, particularly in U.S. Navy training areas (e.g., W-50 MINEX zone) and shipping channels. Satellite-tagging methods were added during that field season to determine the movement patterns of humpback whales off Virginia Beach, specifically in areas of high shipping traffic and live-fire exercises. The 2016/2017 field season began in November 2016 and commenced during March 2017. Research efforts during this season include the use of nearshore vessel surveys to collect photo-ID data and biopsy samples and to deploy SPOT6 Argos-linked satellite tags. LIMPET-F Fastloc® GPS tags were also introduced to the project during the end of the season to test their functionality. Results from the 2016/2017 field season are summarized below.

Survey Effort

HDR has completed 29 nearshore vessel surveys for humpback whales between 01 November 2016 and 21 March 2017, covering 2,856 km of trackline (**Figure 62**).

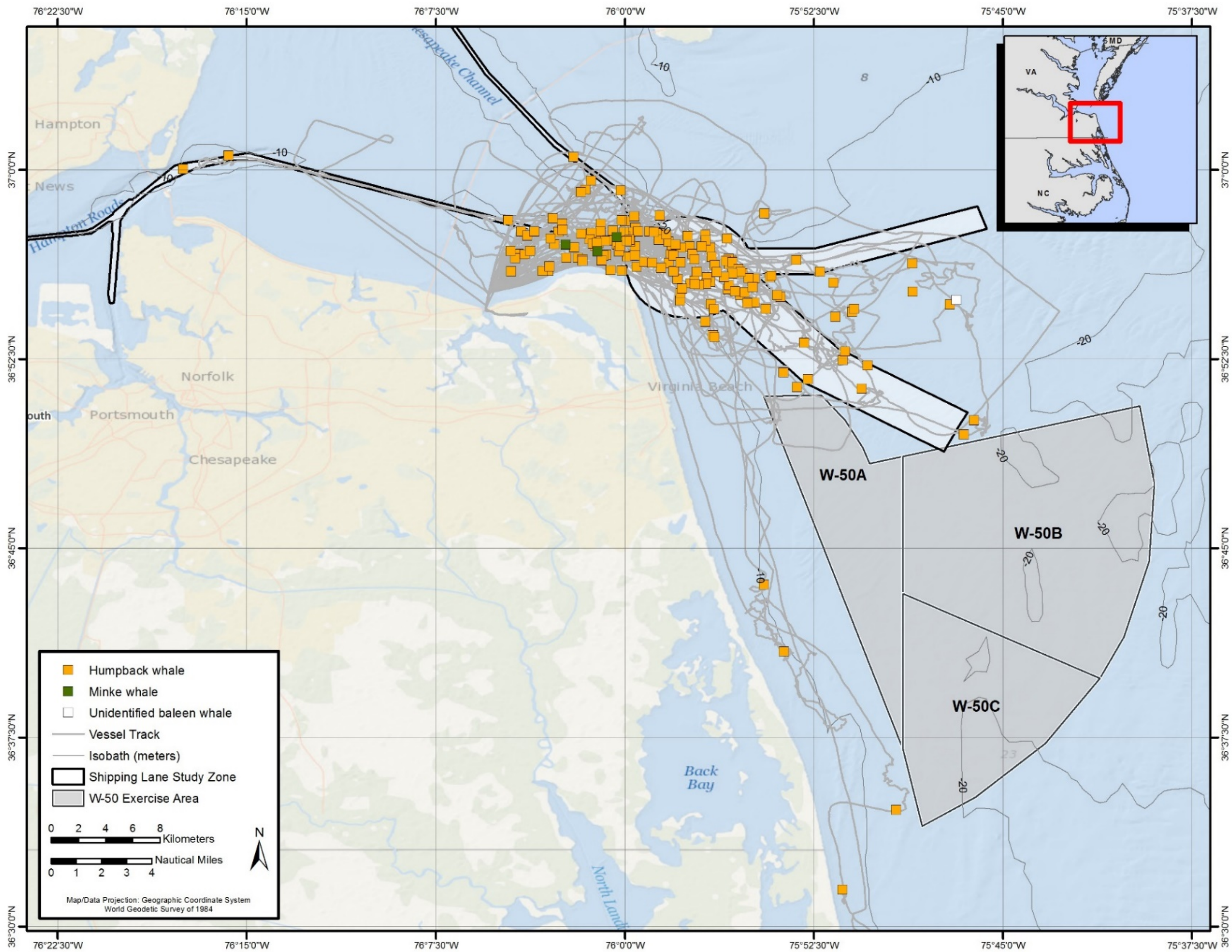


Figure 62. Nearshore survey tracks and locations of all humpback (*n*=168), minke (*n*=3), and unidentified baleen (*n*=1) whale sightings from 01 November 2016 through 21 March 2017.

Sightings

A total of 168 sightings of humpback whales was recorded during the 2016/2017 survey season (**Figure 62**). Additional baleen whale sightings included three sightings of individual minke whale sightings and one sighting of an unidentified large baleen whale. Eighty-seven (50.6 percent) of the 172 whale sightings were in the shipping lanes (all humpback whales), which is consistent with results from the previous two field seasons (Aschettino et al. 2016). Although no sightings were recorded in the W-50 MINEX zone, the lack of sightings in the W-50 MINEX zone is not surprising given the extremely small amount of effort in this area, mainly due to range closures.

Photo-identification

The 168 sightings of 248 total individual humpback whales equated to 59 unique humpback whales identified using dorsal fin and fluke images. Forty-five (76.3 percent) of those whales were categorized as juveniles based on their estimated size, while the remaining 14 (23.7 percent) were categorized as sub-adults or adults. Fifteen (25.4 percent) of the 59 individuals were re-sights to HDR's humpback whale photo-ID catalog; nine individuals were first seen during the 2014/2015 field season and six were first seen during the 2015/2016 field season. The remaining 44 whales were new individuals added to HDRs growing catalog, which, to date, has 107 unique humpback whales (not inclusive of humpback whale identifications from the Outer Continental Shelf Break Cetacean Study – see Engelhaupt et al. 2017). Forty-one of the 59 (69.5 percent) humpback whales were seen on more than one occasion during the 2016/2017 field season. When looking only at the first and last sighting date, and excluding same-day re-sightings, humpback whales were re-sighted between 1.9 and 75.0 days apart, with a mean re-sighting period of 32.9 days.

Biopsy Samples

Twenty-nine biopsy samples were collected from humpback whales during the 2016/2017 field season.

Twenty-nine humpback whale and two fin whale biopsy samples were processed at Duke University for stable isotope analysis. All humpback samples were collected during near shore surveys in the winter between the months of November and February and the two fin whale samples were collected during offshore surveys in April. The stable isotope signatures for the humpback whale and fin whale samples were comparable to those reported for other regions of the North Atlantic (Waples 2017). There was a significant difference in both δ^{13}C and δ^{15}N values between the humpback and fin whales in the study area. The humpback whales were slightly more depleted in δ^{13}C and had significantly higher δ^{15}N signatures than the fin whales (Waples 2017). The humpback whales had a mean δ^{15}N value of 14.6 (± 0.9) compared to the fin whales value of 10.5 (± 0.0). Given a difference in δ^{15}N values between the two species of 4.1 percent it is likely that the humpback whales are feeding at a higher trophic level than the fin whales in this area.

Genetic analyses identified 14 female and 15 male humpback whales sampled in the study area. There were no significant differences in δ^{13} values between male and female humpback whales, but females did have significantly lower δ^{15}N values than males. Findings suggest that the diets of the two sexes may differ in this area.

Once CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora) has issued an export permit, these samples will also be provided to the University of Groningen in The Netherlands for genetic analysis and integration into a larger North Atlantic humpback whale population study.

Tagging

Twenty-three SPOT-6 Argos-linked satellite tags and three LIMPET-F satellite tags were deployed. Tags transmitted between 2.7 and 43.9 days (mean=13.9 days). All tags deployed during the month of November were on animals classified as sub-adults. Tags deployed during the months of December through February (with the exception of one) were deployed on juveniles. All of the tagged whales recorded locations in the shipping lanes. In fact, 15 of the 20 (57.7 percent) of the tagged whales had Argos locations west of the CBBT (e.g., **Figure 63**), which is higher than the 22.2 percent of tagged whales tracked to this same area during the 2015/2016 field season (Aschettino et al. 2016). Tagged whales also utilized the primary nearshore study area, the W-50 MINEX zone, the continental shelf break, and offshore areas (e.g., **Figure 64**). Multiple tagged whales were recorded near NSN and JEB-LC. The farthest tracked whale (Whale HDRVAMn071 was last recorded approximately 122 km off Assateague, Virginia.

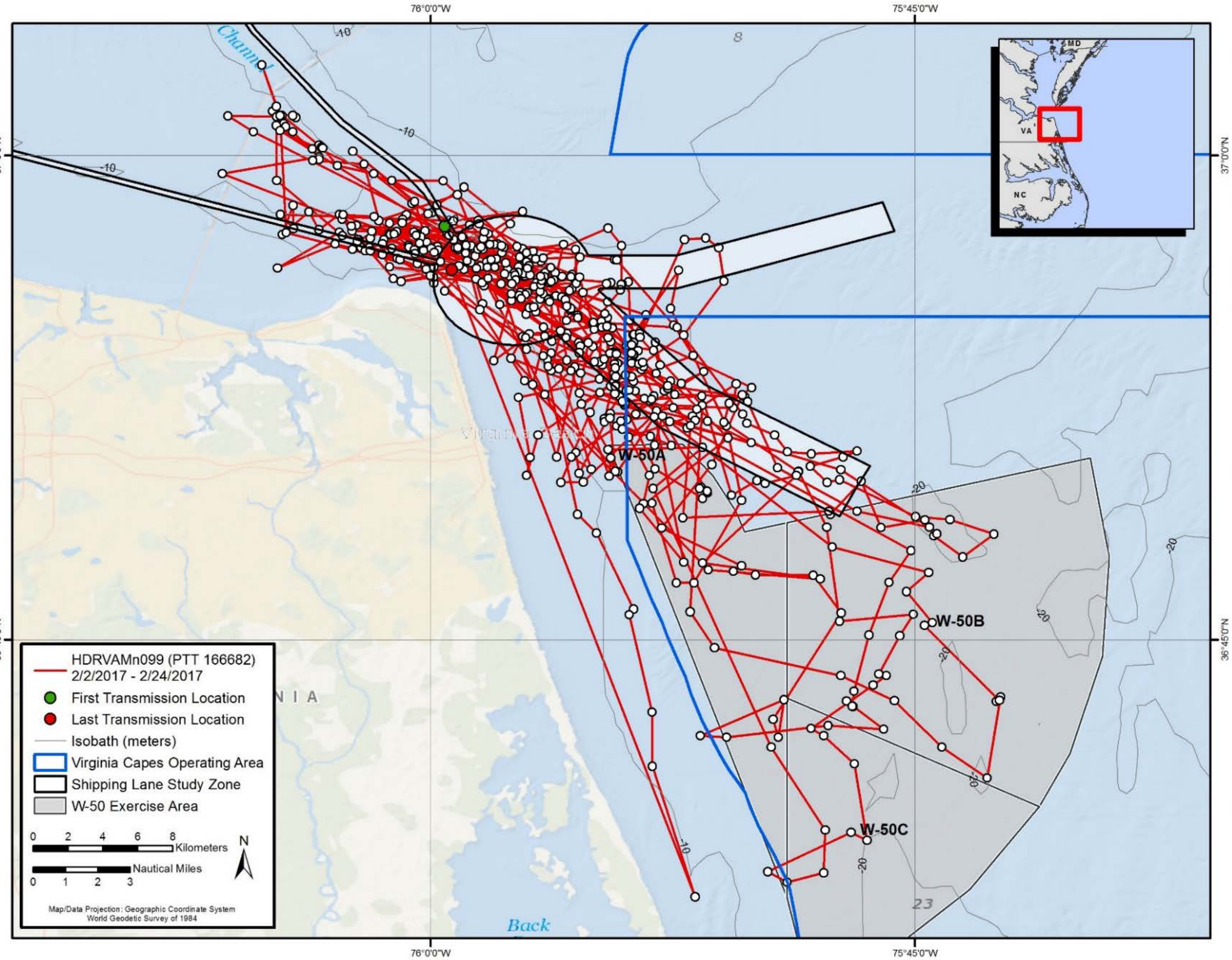


Figure 63. Filtered locations of tagged humpback whale HDRVAMn084 from 28 December 2016 through 24 February 2017 (over 21.9 days of tag-attachment duration), with consecutive locations joined by a line.

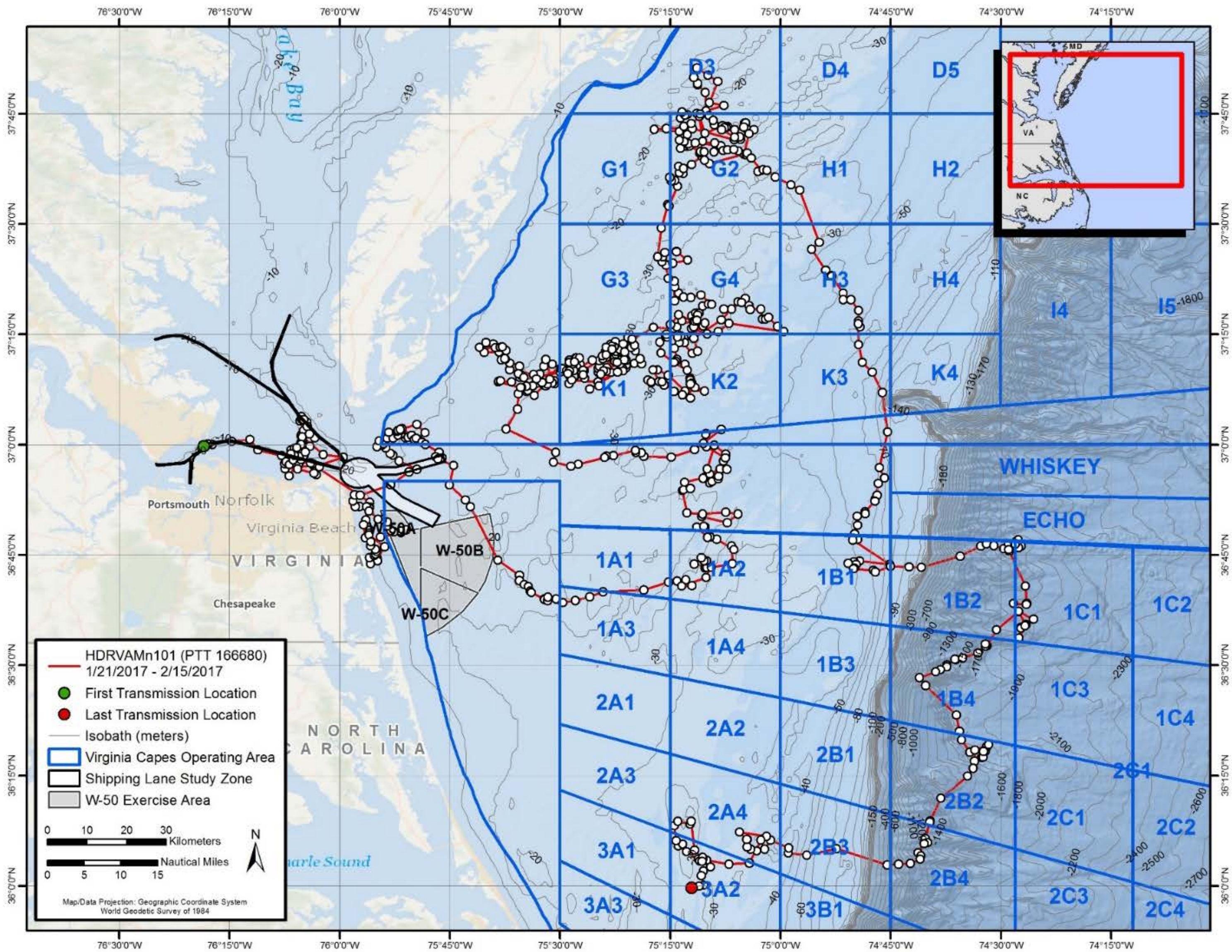


Figure 64. Filtered locations of tagged humpback whale HDRVAMn101 from 21 January through 15 February 2017, with consecutive locations joined by a line.

Data-analysis for this project is ongoing. Preliminary results indicate some site fidelity to the study area for individual humpback whales and a high level of occurrence within the shipping channels, which are important high-use areas for both the U.S. Navy and commercial traffic. A smaller number of animals are also spending time in or near the W-50 MINEX zone and the offshore VACAPES OPAREA where they are presumably within the hearing range of underwater detonation training exercises. Vessel interactions in the study area are still a concern for humpback whales. Approximately 8 percent of the individual humpback whales in the HDR catalog have scars or injuries indicative of propeller or vessel strikes. Four of the humpback whales added to the catalog during the 2016/2017 field season were later found dead, with three likely dead from large vessel interactions. In addition, most of the humpback whales seen during the three years of effort on this project and during previous studies appear to be juveniles that are spending more time in the study area than larger animals. Therefore, they may be may be at greater risk for injury (e.g., Swingle et al. 1993, Wiley et al. 1995, Aschettino et al. 2015, Aschettino et al. 2016). During the 2016/2017 field season, approximately 76 percent of the unique humpback whales identified were categorized as juveniles based on size estimates made in the field.

For more information on this study, refer to the annual progress report for this project (Aschettino et al. 2017).

2.2.4 VACAPES Outer Continental Shelf Cetacean Study

Since 2012, HDR has collaborated with the U.S. Navy to conduct marine mammal surveys near NSN, JEB-LC, JEB-FS, and NAS Oceana Dam Neck Annex and within the W-50 MINEX area (Engelhaupt et al. 2016). However, relatively limited survey effort has been conducted farther offshore in the VACAPES OPAREA, off the Virginia coast near the continental shelf break. Therefore, there are limited data and information on how offshore species, including beaked whales, endangered fin and sperm whales, and other large baleen whales utilize the deeper waters of this region.

Surveys for the VACAPES Outer Continental Shelf Cetacean Study began in April 2015 in association with the Mid-Atlantic Humpback Whale Monitoring project (Aschettino et al. 2016) and became a dedicated study beginning in 2016. The goal of this study was to determine the seasonal occurrence, movement patterns, site fidelity, behavior, and ecology of cetaceans in VACAPES waters. During the vessel surveys, researchers utilize a combination of techniques including focal follows, photo-ID, biopsy sampling, and satellite tagging.

Survey Effort

HDR has conducted 13 offshore vessel surveys between 12 April 2015 and 02 November 2016 covering 4,003 km of trackline (**Figure 65**). The study area is approximately 90 to 160 km off the Virginia coast, encompasses Norfolk and Washington Canyons, and ranges in depth from less than 100 m to over 2,000 m.

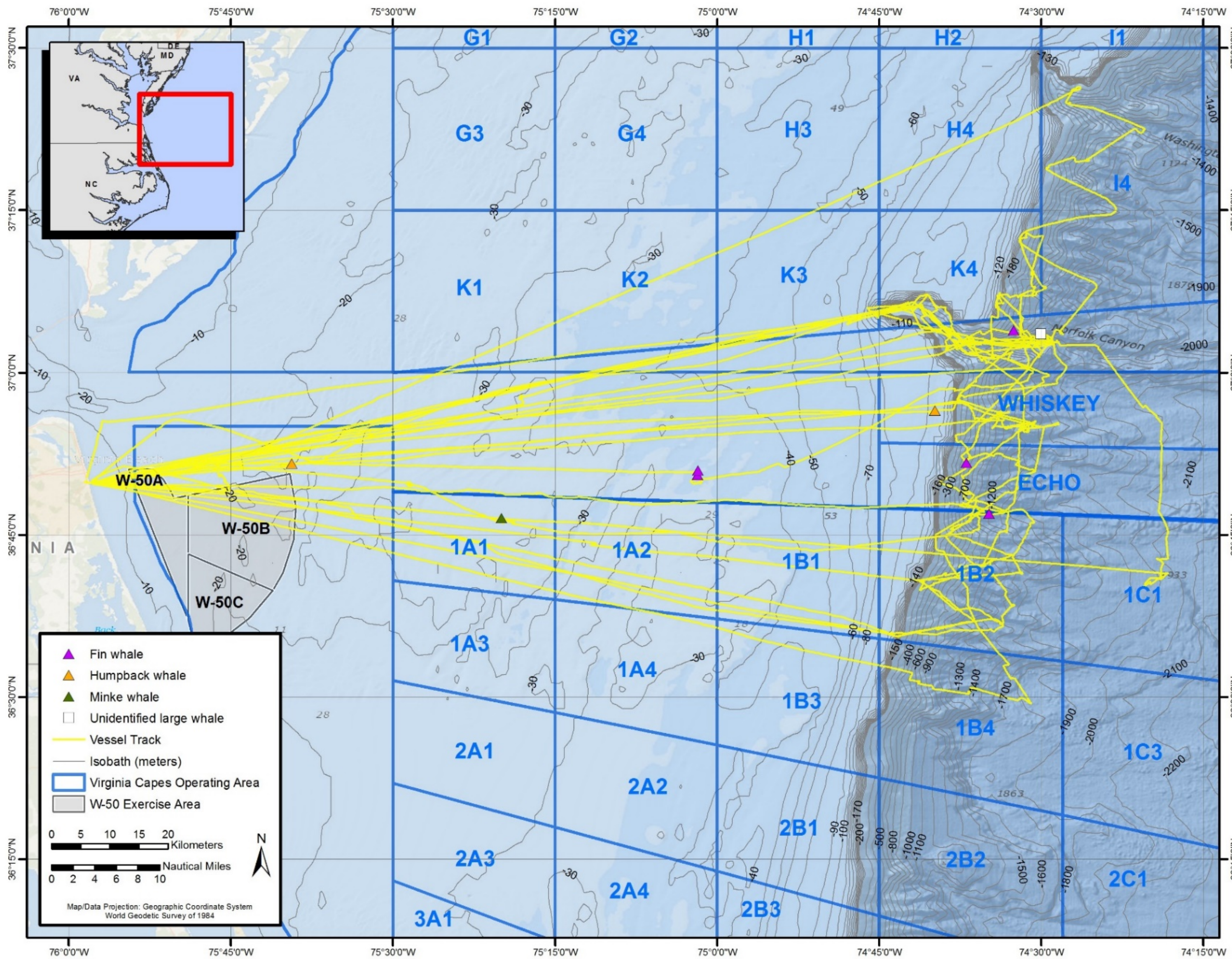


Figure 65. Offshore survey tracks and locations of all baleen whale (*n*=9) sightings: April 2015–November 2016.

Sightings

A total of 193 marine mammal sightings and 35 sea turtle sightings was recorded during these vessel surveys (**Figures 65 through 67**). Thirteen cetacean taxa were identified (in order of decreasing frequency): including unidentified pilot whales (*Globicephala* sp.) (*n*=69), bottlenose dolphin (*n*=52), Atlantic spotted dolphin (*n*=12), short-finned pilot whale (*n*=14), short-beaked common dolphin (*n*=14), Risso's dolphin (*n*=5), fin whale (*n*=5), striped dolphin (*n*=1), minke whale (*n*=1), humpback whale (*n*=2), sperm whale (*n*=1), Cuvier's beaked whale (*n*=1), long-finned pilot whale (*Globicephala melas*) (*n*=1), and harbor porpoise (*n*=1). In addition, there were 14 sightings of unconfirmed species: unidentified delphinids (*n*=6), unidentified cetaceans (*n*=4), unidentified medium whales (*n*=2), an unidentified large whale, and a probable sperm whale. The loggerhead turtle was the most frequently sighted sea turtle species (*n*=29) followed by unidentified hardshell turtles (*n*=4) and the leatherback turtle (*n*=2).

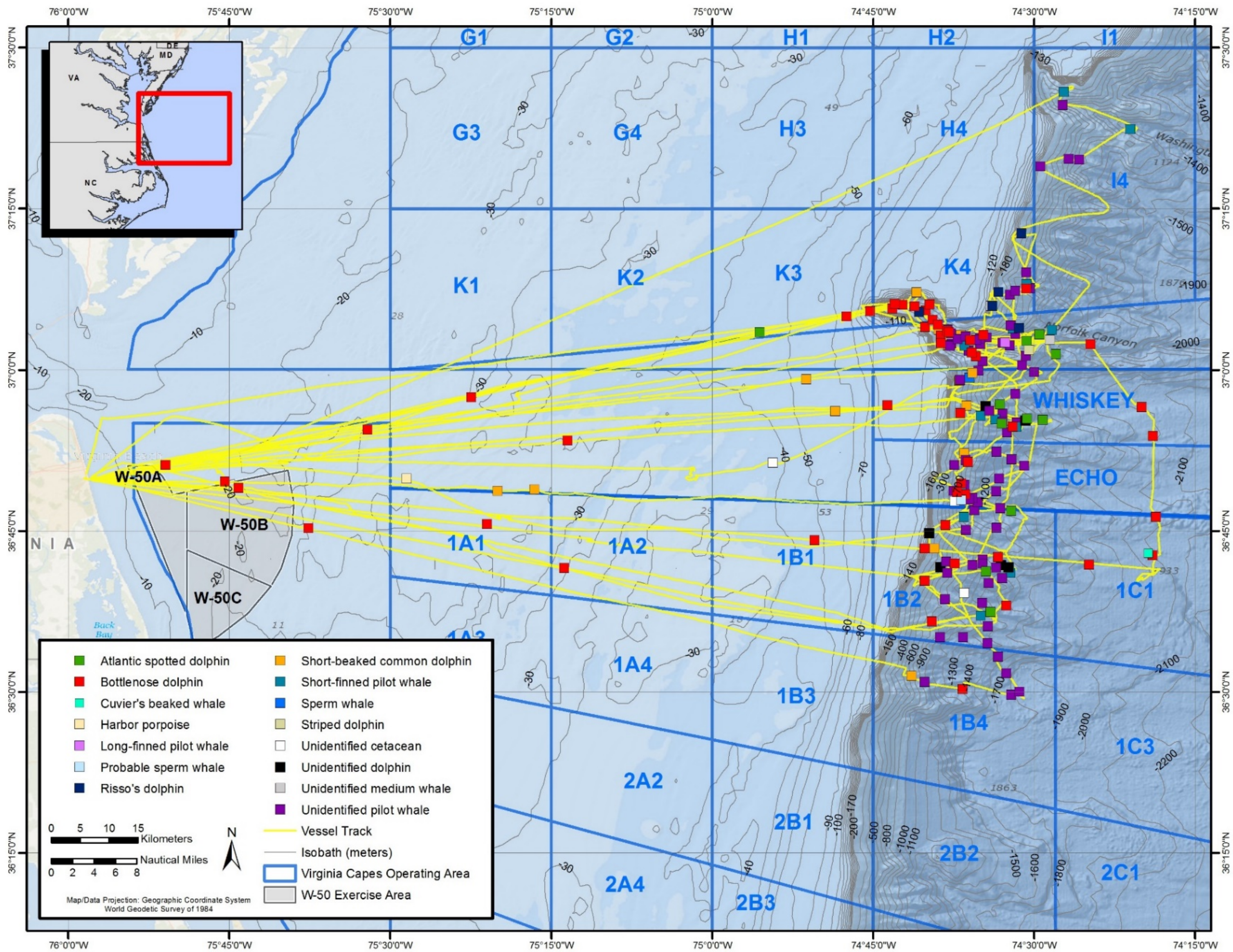


Figure 66. Offshore survey tracks and locations of odontocete sightings (*n*=184): April 2015–November 2016.

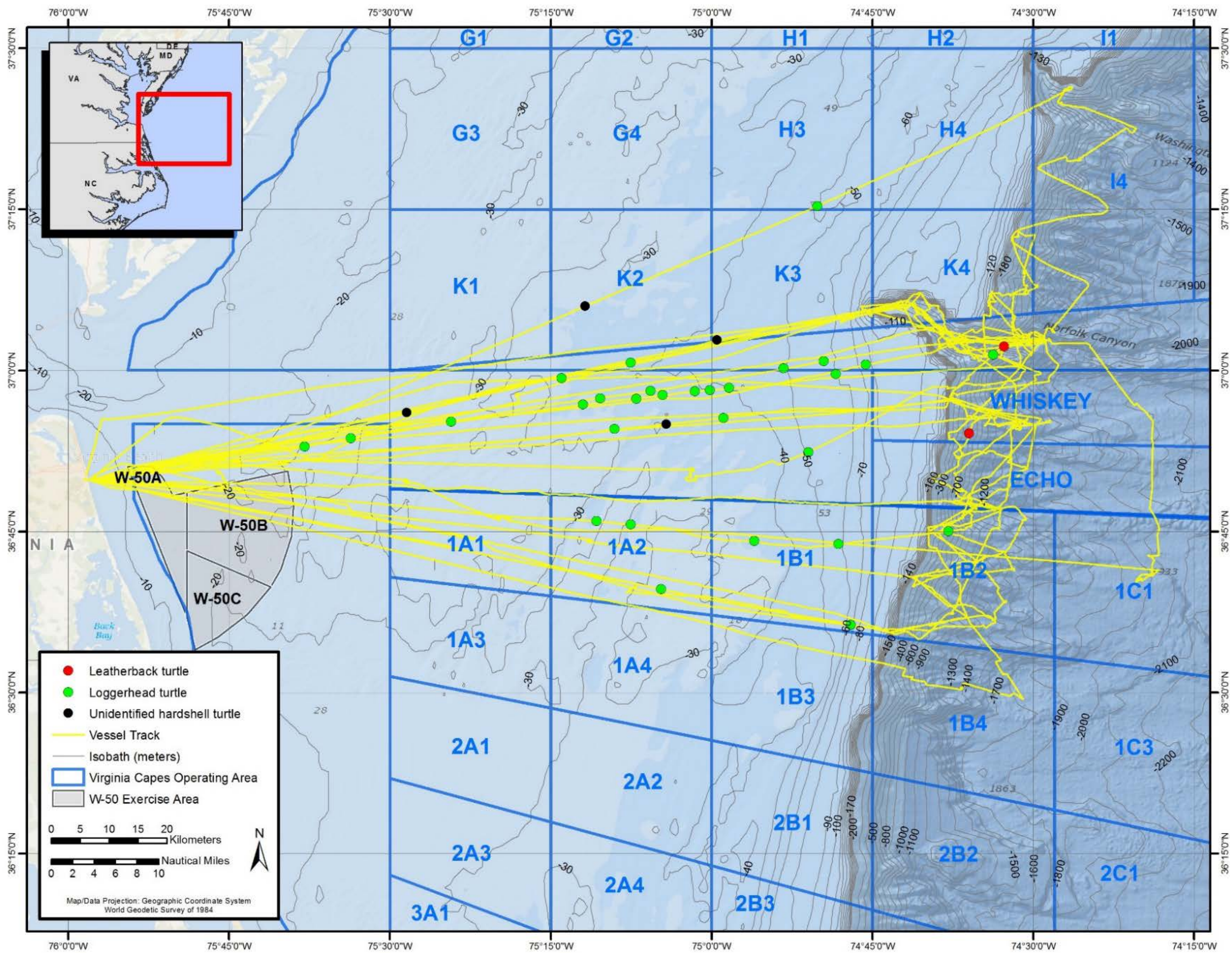


Figure 67. Offshore survey tracks and locations of sea turtle sightings: April 2015–November 2016.

Focal Follows

One objective of this study is to conduct focal follows on high-priority species (e.g., baleen whales, sperm whales, and beaked whales) when possible. To date, focal follows have been performed on two fin whales and one minke whale for a total of 163 min of effort. These data are currently being examined for any emerging patterns in habitat utilization and primary behaviors.

Photo-ID

Photo-ID images were collected during 129 of 193 marine mammal sightings. Images of pilot whales recorded through November 2015 have been shared with Duke University for matching to their existing catalog of pilot whales from Cape Hatteras, North Carolina. Images of other odontocete species have been archived for future processing. The baleen whale images were added to HDR's existing catalogs which now contain 12 unique fin whales, four unique minke whales, and two unique sei whales. Fin whale images from the HDR catalog were compared to the Center for Coastal Studies fin whale catalog, but no matches were found. One of the humpback whales sighted during the offshore survey on 21 October 2015 was previously seen during nearshore surveys on 11 April 2015. HDR plans to share the images with other known regional catalogs, including the Gulf of Maine catalog managed by Center for Coastal Studies, NAHWC managed by Allied Whale, MAHWC curated by VAQF, and additional Duke University cetacean photo-ID catalogs.

Biopsy Samples

One fin whale biopsy was collected. The sample was sent to Duke University, the University of Groningen, and SEFSC for stable isotope analyses, genetic analyses, and pollutant studies, respectively. Results of Duke University's analyses are presented in **Section 2.2.3** and Waples (2017), while other analyses are currently in progress

Tagging

One Argos-linked location-only SPOT6 tag has been deployed on a fin whale on 27 June 2016. During the 13.7 days of transmission, the whale spent time in waters over the continental shelf and moved along and beyond the shelf break (**Figure 68**).

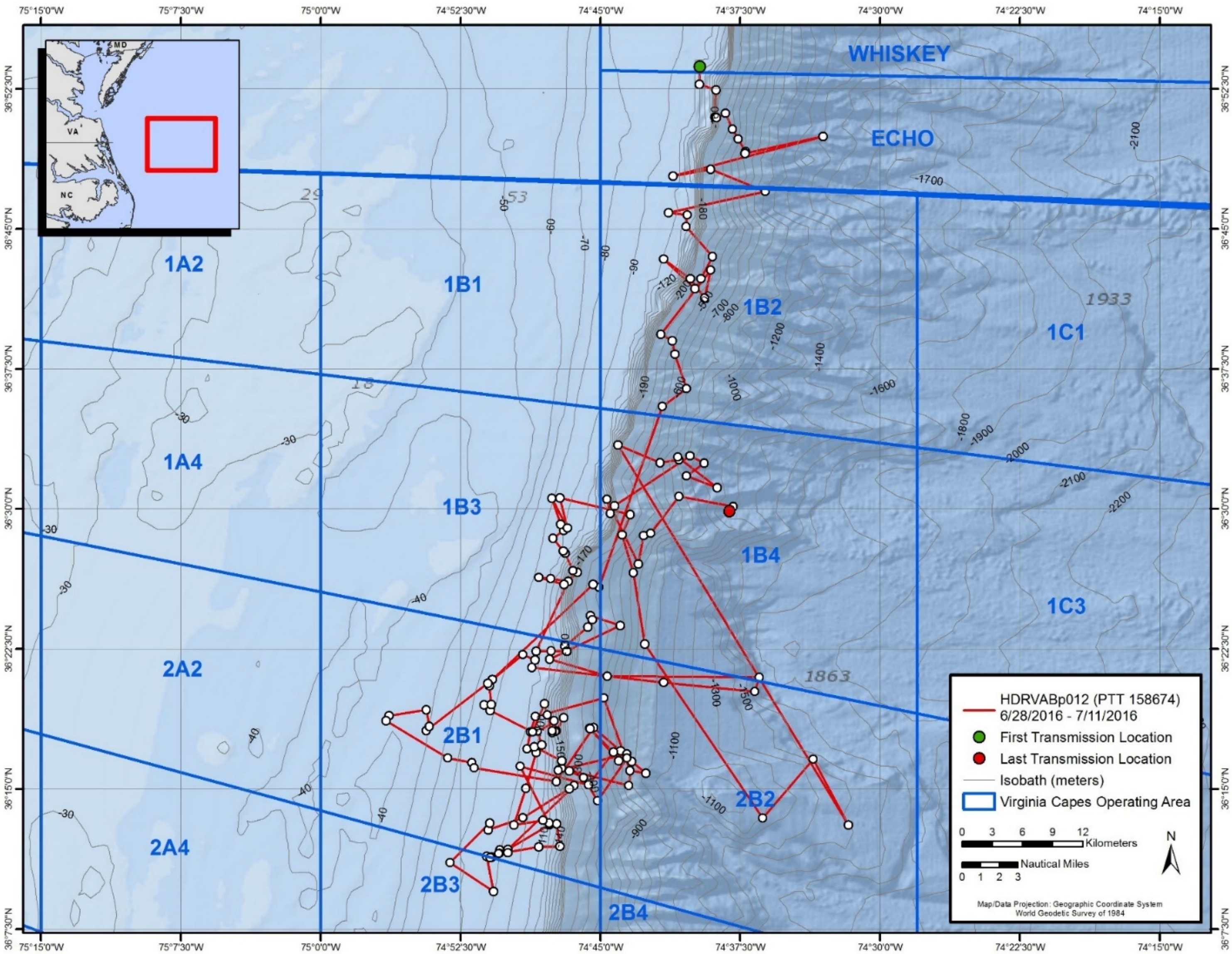


Figure 68. Filtered locations of tagged fin whale HDRVABp012 from 28 June 2016 through 11 July 2016, with consecutive locations joined by a line.

Fieldwork and data-analysis efforts for this project are ongoing. Preliminary results show a high diversity of marine mammal species in the study area, which is an important high-use area for the U.S. Navy training and testing activities. As expected, there was a concentration of sightings, especially pilot whales, near and beyond the shelf break. Baleen whale sightings were recorded both on the shelf and offshore of the shelf break; the tagged fin whale moved through both areas. Although survey effort in the range boxes near Norfolk Canyon was limited due to U.S. Navy training exercises, numerous sightings were still recorded in this region. In addition to U.S. Navy training exercises, the Canyon is used by recreational and charter fishing vessels. As additional surveys are conducted across each season, more satellite tags will be deployed and knowledge of seasonal occurrence patterns and movements will improve so that the U.S. Navy can make more informed decisions to minimize potential impacts to marine mammals and sea turtles.

For more information on this study, refer to the annual progress report for this project (Engelhaupt et al. 2017).

2.2.5 Sea Turtle Tagging—Chesapeake Bay and Coastal Virginia

Researchers from the Virginia Aquarium and Naval facilities Engineering Command Atlantic have been collaborating on a project to tag and track sea turtles in lower Chesapeake Bay and coastal Virginia waters since 2013. The goal of this project is to assess the occurrence, habitat use, and behavior of loggerhead, green (*Chelonia mydas*), and Kemp's ridley (*Lepidochelys kempii*) turtles in this region Research methods include the use of satellite telemetry to characterize broad-scale movement patterns and the use of both satellite- and acoustic-telemetry data to characterize the occurrence of turtles in specific areas of interest to the U.S. Navy.

Turtles for this multi-year project have been acquired in three ways: 1) direct capture by researchers, 2) incidental capture in commercial fisheries, recreational fisheries, or trawl operations associated with dredging, or 3) rehabilitation and release of stranded animals. In addition, data from five tags deployed on green and Kemp’s ridley turtles prior to 2013 is being incorporated into the analysis.

2.2.5.1 Tagging Progress and Results

Tagging efforts for the 2016 field season were focused on Kemp's ridley and green turtles with four satellite tags deployed on Kemp's ridley turtles (refer to **Tables 46 and 47**). All tags were programed to collect continuous location and sensor data. SPOT tags were programed to record the percentages of time over 6-hr periods that turtles spent within defined ambient water temperature bins. Depth-recording SPLASH were programed to record the percentages of time over 6-hr periods that turtles spent in defined depth as well as temperature bins. Sirtrack tags were used as location only tags, and we did not utilize sensors.

Table 46. Kemp's ridley and green turtles satellite tagged by VAQF, 2007–2016.

Field Number	PTT	Species	SCL-NT (cm)	Weight (kg)	Name	Source	Reason/ Method	Project
VAQS20132227	138114	Lk	40.2	12.8	Loki	stranded	cold stun	2014 Navy
VAQS20132229	132367	Lk	34.0	7.0	Gaia	stranded	cold stun	2014 Navy
VAQS20142152	138117	Lk	35.1	6.5	Joffrey	stranded	hooked	2014 Navy
VAQR201503	148882	Lk	36.2	ND	Iggy Pop	captured	dip net	2015 Navy
VAQR201504	148880	Lk	34.2	ND	Bob Marley	captured	dip net	2015 Navy
VAQR201505	148886	Lk	51.0	18.0	Jerry Garcia	captured	dip net	2015 Navy
VAQS20142244	148889	Lk	44.0	16.4	Racer 5	stranded	cold stun	2015 Navy
VAQS20152008	148881	Lk	38.1	7.2	Friar Tuck	stranded	hooked	2015 Navy
VAQS20152049	150767	Lk	35.0	6.2	Sven	stranded	hooked	2015 Navy
VAQS20162016	159709	Lk	49.4	16.3	Sage	stranded	hooked	2016 Navy
VAQS20162029	164721	Lk	33.7	5.6	Salt	stranded	hooked	2016 Navy
VAQS20162039	159705	Lk	33.8	5.6	Hops	stranded	hooked	2016 Navy
VAQS20162089	159708	Lk	45.4	11.9	Lemongrass	stranded	hooked	2016 Navy
VAQS20072055	65799	Cm	106.0	150.0	Tiki Jr.	stranded	entangled	historic
VAQS20082129	65800	Cm	34.0	6.0	Kermit	stranded	debris ingestion	historic
VAQS20112010	108054	Lk	36.9	6.5	Argentum	stranded	cold stun	historic
VAQS20122001	117180	Cm	32.5	4.9	Makahiki	stranded	cold stun	historic
VAQS20122175	129021	Lk	44.0	14.0	Caramel	stranded	cold stun	historic

Key: Cm=*Chelonia mydas* (green turtle); Lk=*Lepidochelys kempii* (Kemp's ridley turtle); ND=not determined; PTT=platform transmitter terminal; SCL-NT=straight carapace length notch-to-tip.

Table 47. Details of satellite-tag deployments on Kemp's ridley and green turtles.

Field Number	PTT	Species	Release Date	Date of Last Transmission	Days	Project	Tag Manufacturer	Tag Model
VAQS20132227	138114	Lk	10/20/2014	06/06/2015	229	2014 Navy	Wildlife Computers	SPLASH-10
VAQS20132229	132367	Lk	07/09/2014	08/15/2014	37	2014 Navy	Wildlife Computers	SPOT-5
VAQS20142152	138117	Lk	09/02/2014	10/10/2014	38	2014 Navy	Wildlife Computers	SPOT-5
VAQR201503	148882	Lk	05/18/2015	05/30/2015	11	2015 Navy	Microwave Telemetry	9.5g Solar PTTs
VAQR201504	148880	Lk	05/18/2015	NA	0	2015 Navy	Microwave Telemetry	9.5g Solar PTTs
VAQR201505	148886	Lk	05/29/2015	07/12/2015	44	2015 Navy	Wildlife Computers	SPLASH-10
VAQS20142244	148889	Lk	05/16/2015	07/14/2015	59	2015 Navy	Wildlife Computers	SPLASH-10
VAQS20152008	148881	Lk	05/16/2015	06/23/2015	38	2015 Navy	Microwave Telemetry	9.5g Solar PTTs
VAQS20152049	150767	Lk	06/24/2015	07/05/2015	11	2015 Navy	Wildlife Computers	SPOT-6 278C
VAQS20162016	159709	Lk	07/26/2016	08/27/2016	32	2016 Navy	Wildlife Computers	SPLASH-10
VAQS20162029	164721	Lk	07/26/2016	08/27/2016	40	2016 Navy	Sirtrack	K2G 273
VAQS20162039	159705	Lk	07/22/2016	07/23/2016	1	2016 Navy	Wildlife Computers	SPOT-6 278C
VAQS20162089	159708	Lk	07/02/2016	08/05/2016	34	2016 Navy	Wildlife Computers	SPLASH-10
VAQS20072055	65799	Cm	10/20/2007	02/24/2008	127	historic	Telonics	A-1010
VAQS20082129	65800	Cm	06/22/2009	08/17/2009	56	historic	Telonics	A-1010
VAQS20112010	108054	Lk	06/29/2011	07/15/2011	16	historic	Wildlife Computers	SPLASH-100
VAQS20122001	117180	Cm	06/14/2012	NA	0	historic	Wildlife Computers	SPLASH-100
VAQS20122175	129021	Lk	06/21/2013	07/12/2013	21	historic	Wildlife Computers	SPLASH-284A

Key: Cm=*Chelonia mydas* (green turtle); Lk=*Lepidochelys kempii* (Kemp's ridley turtle); PTT=platform transmitter terminal; SPOT= Smart Position and Temperature.

Analyses to Date

A total of 13 tags have been deployed on juvenile Kemp's ridley turtles for this project, in addition to three green turtles and two Kemp's ridley turtles tagged prior to 2013 (**Table 46**). Of the 18 tags deployed thus far, two failed to transmit for more than 48 hr and one transmitted for one day after the initial 48-hr period (which usually is eliminated from analysis). The 15 remaining tags transmitted for 11 to 229 days post-release with a mean of 58 days (SD=±56) and a median of 38 days. The two longest retention times were for Kemp's ridley turtles that were released in October and did not spend much time in Chesapeake Bay, but instead migrated south. The mean and median for turtles released May through September was 34 (SD=±15) and 37 days, respectively (**Table 47**). This short tag retention time is consistent with earlier tagging efforts by Dr. Jack Musick and colleagues at the Virginia Institute of Marine Science (Dr. Kate Mansfield, University of Central Florida, personal communication).

Short tag transmission times may be related to antenna fouling, where debris such as dead eelgrass causes the flexible whip-like antenna on Wildlife Computers tags to lay flat on a turtle's carapace preventing data transmission. For this reason, VAQF has invested in Sirtrack Kiwisat tags, which have stiffer, more upright, antennae. Another possibility for low transmission times in Chesapeake Bay is that the complex environment with multiple structures in the form of bridges, pilings, concrete fish habitat, and stationary vessels provide numerous surfaces upon which turtles can rub and harm or remove epibiota and attached tags.

Preliminary analysis of satellite-telemetry data filtered for location quality suggests that there may be some areas used by Kemp's ridley turtles for foraging that are not well utilized by loggerhead turtles (**Figure 69**).

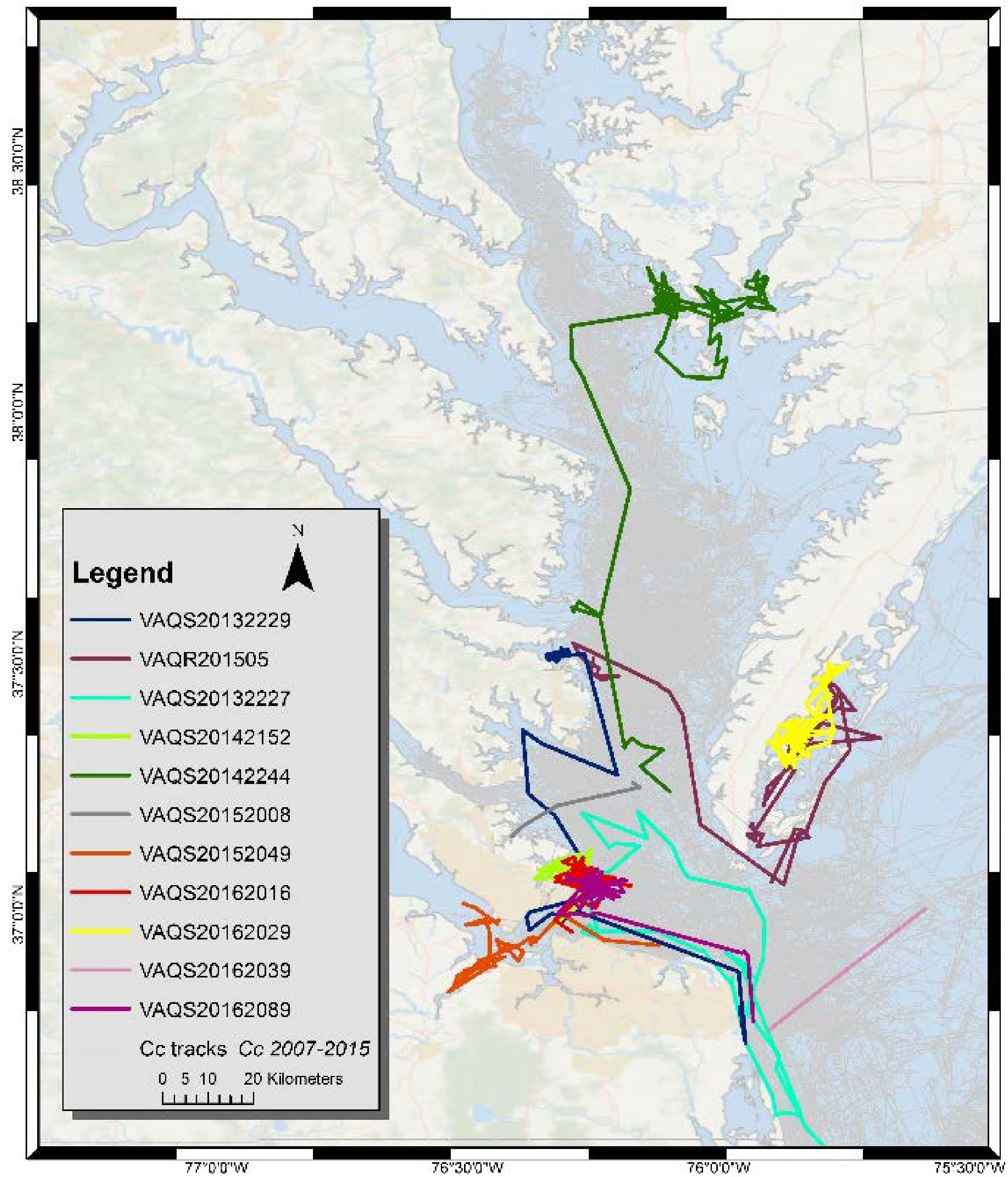


Figure 69. Tracks of 11 Kemp's ridley turtles tagged from 2014 to 2016 overlaid on pale loggerhead tracks from this project (gray lines) to compare distribution.

Researchers will continue to deploy additional tags on green and smaller Kemp's ridley turtles in 2017 to increase the sample size for analysis. In addition, researchers will again be using acoustic telemetry to track these smaller turtles. The goal is to develop a large enough data set to conduct species-specific foraging analyses similar to that previously conducted for loggerhead turtles (Barco and Lockhart 2016).

2.2.5.2 Home range analysis and foraging behavior of loggerhead turtles

Satellite-telemetry data was used to examine seasonal foraging behavior of loggerhead turtles by applying a switching state-space model (SSSM) approach and calculating monthly home ranges using only the satellite telemetry points that were identified by the SSSM as foraging behavior. The monthly foraging home ranges from each tagged turtle were combined to identify relative levels of foraging for turtles tagged and released in Virginia and North Carolina waters. The analysis included loggerhead turtles that were released in Virginia or North Carolina, with tags that transmitted more than 21 days, and that remained between the U.S. shore and the 200-m isobath (n=44). The number of turtles used to create the monthly foraging grids varied from month-to-month and ranged from a low of 13 in March to a high of 27 in July.

Foraging maps for the entire data set clearly show that the highest RFA levels were located off the northern coasts of Virginia and Maryland, throughout the Chesapeake Bay, off Cape Hatteras, North Carolina, and in Onslow Bay off the coast of southern North Carolina (**Figure 70**).

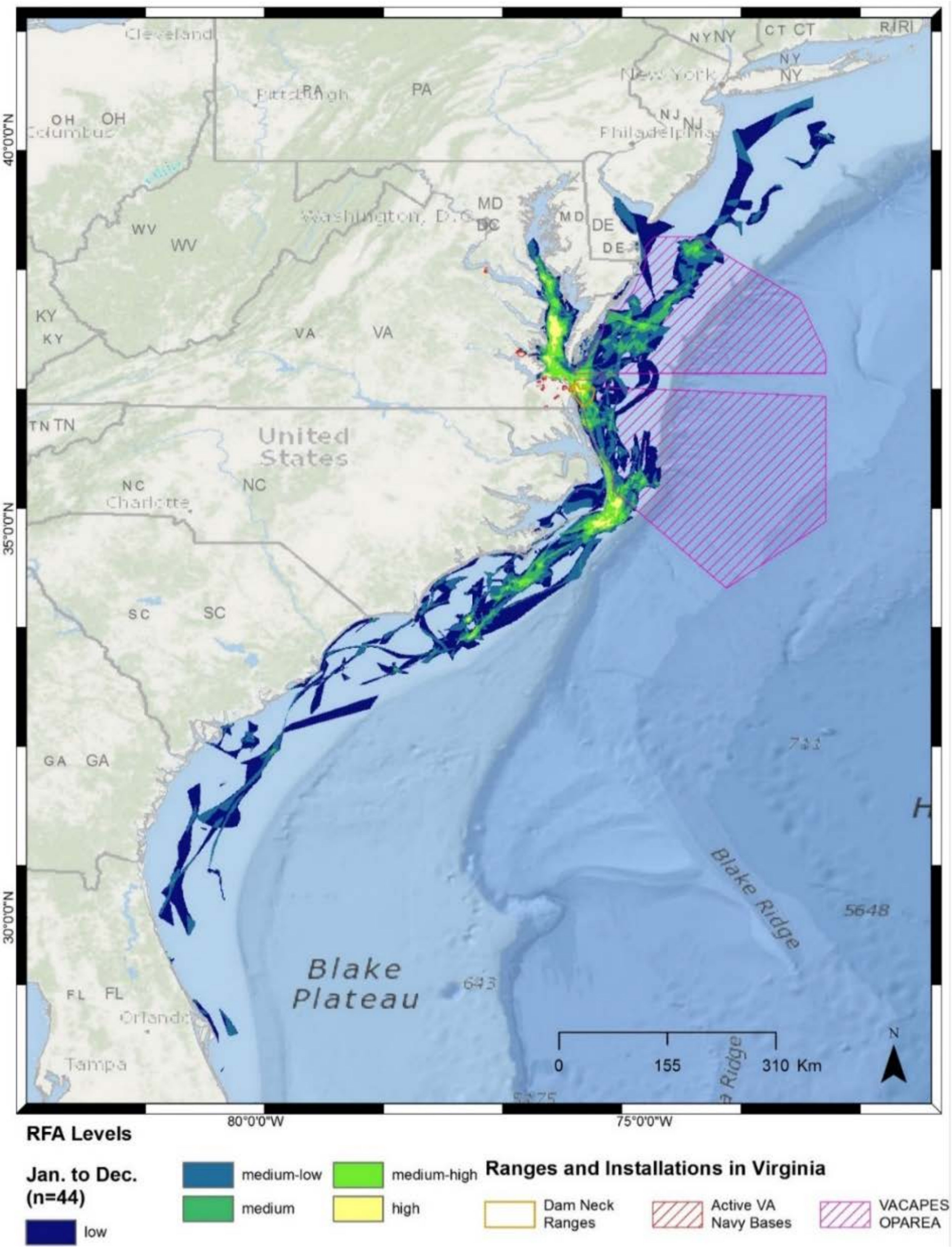


Figure 70. Relative foraging areas for all loggerhead turtles used in the analyses, with all months combined.

Foraging within the Chesapeake Bay was constrained by physical barriers making the spatial patterns less diffuse and denser than patterns in the ocean, with the exception of the area around Cape Hatteras. Higher ocean-RFA levels were clearly focused around Cape Hatteras, suggesting that the area offers habitat characteristics favorable for sea turtle foraging which occurs primarily in the winter and early spring. The analysis all foraging activity suggests that similar high levels of relative foraging intensity occur in Chesapeake Bay and off Cape Hatteras and similar medium-high levels occur in ocean waters of Virginia through Delaware and Onslow Bay (southern North Carolina). Many of the loggerhead turtles that were released in Virginia spent cooler months off Cape Hatteras and/or in Onslow Bay suggesting a restricted home range for some of these migratory animals with complimentary levels of foraging in each area at different times of the year.

When the RFAs were divided by season, a clear shift in foraging among the geographic zones was seen among seasons. In the winter, 100 percent of foraging activity occurred south of 36° N, primarily in North Carolina, with 48 percent in spring, 19 percent in summer, and 71 percent in fall **(Figure 71)**. In contrast, 52 percent of the RFA was in the Chesapeake Bay and the northern ocean zone in spring, with 78 percent and 29 percent in the summer and fall respectively (**Figure 72**). Although there was likely a bias in the amount of foraging that occurred in Chesapeake Bay since most of the turtles were captured or stranded in or near the bay, these data clearly show the seasonal use of southern mid-Atlantic waters by loggerhead turtles.

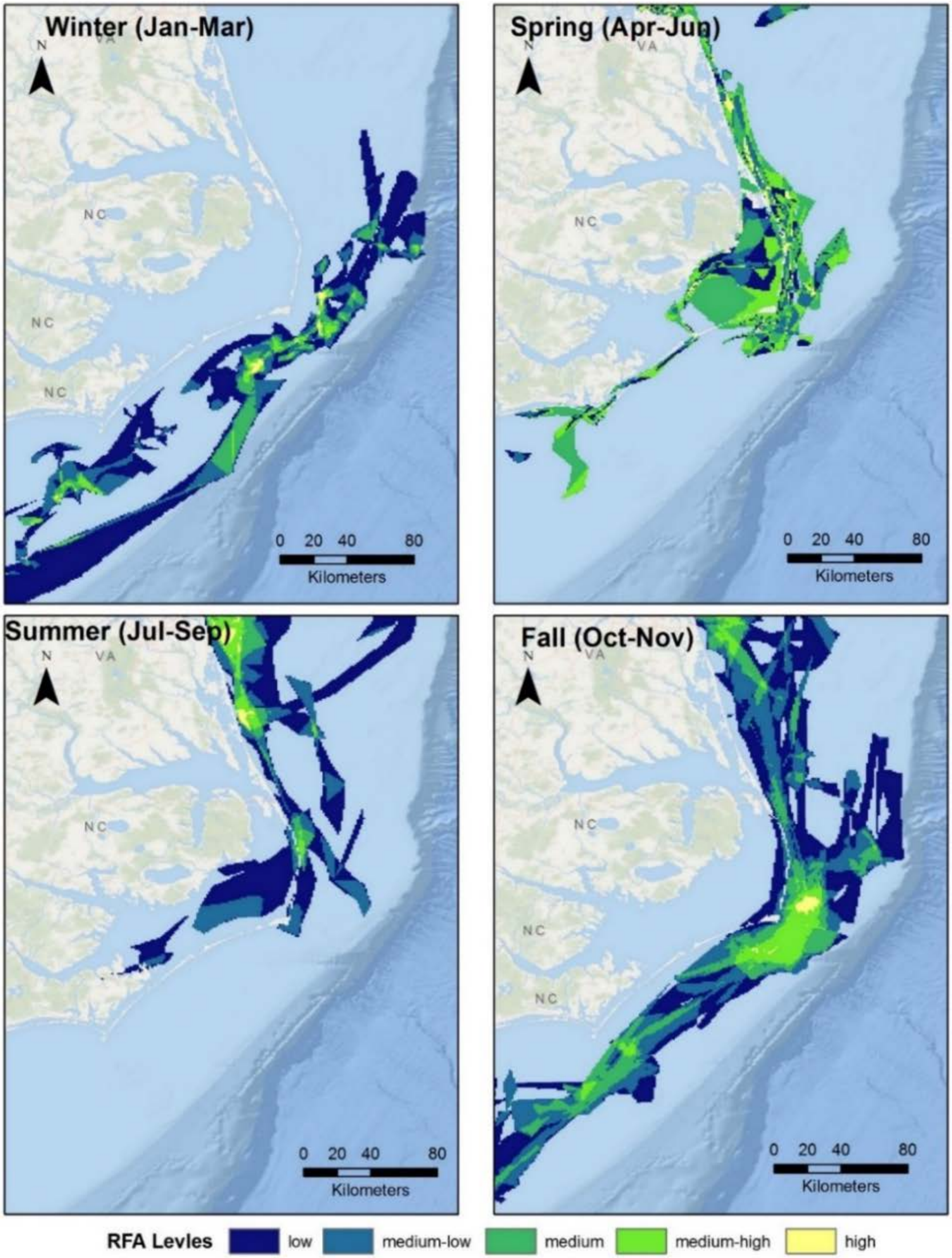


Figure 71. Relative foraging areas (RFAs) by season. The extent in each season shows all RFAs in North Carolina waters.

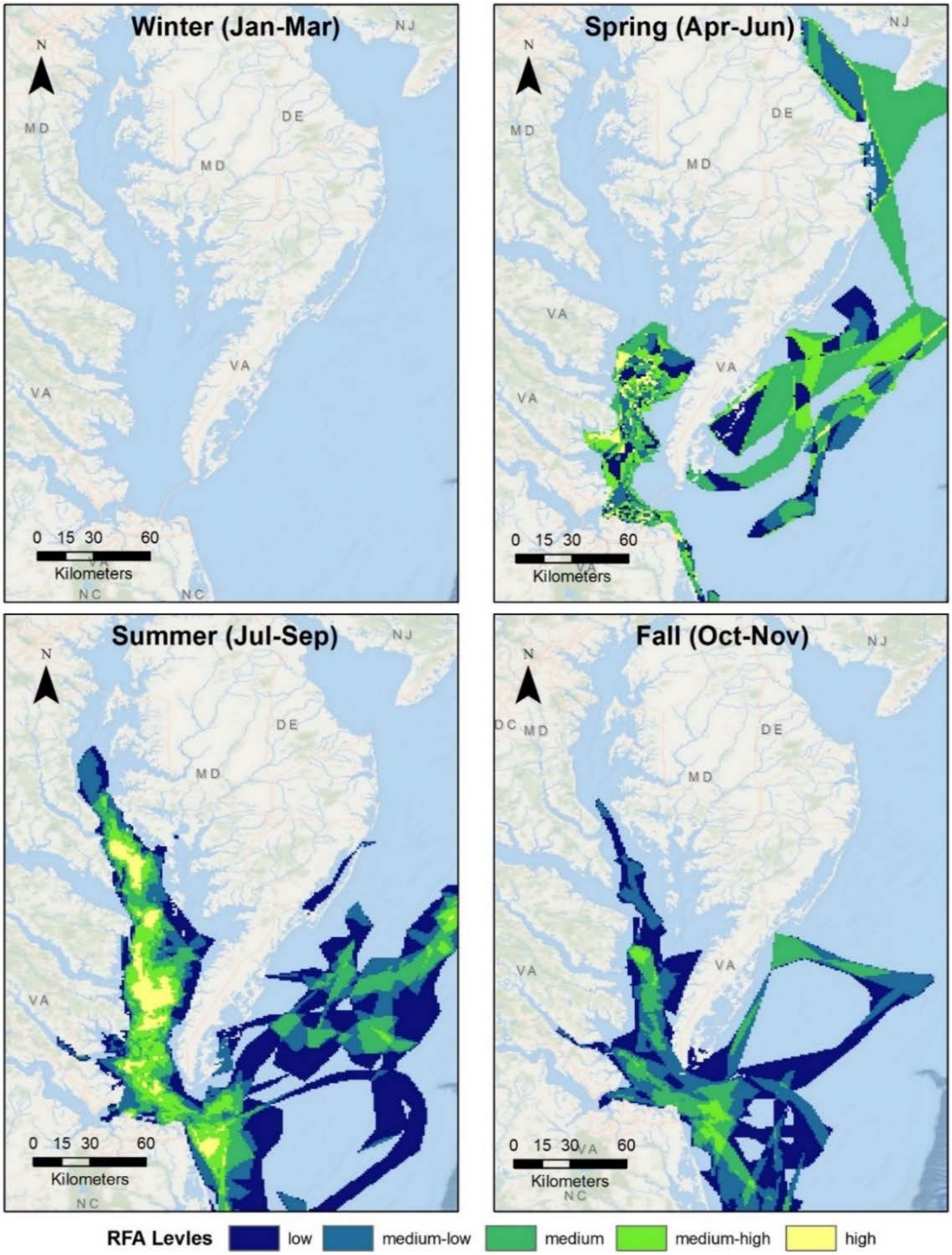


Figure 72. Relative foraging areas (RFAs) by season. The extent, in each season shows all RFAs in Virginia, Maryland, and Delaware waters.

For more information on the 2016 research efforts, refer to the annual progress report for this project (Barco et al. 2017). For more information on acoustic tag assessments and loggerhead turtle foraging behavior, refer to the final report for the project (Barco and Lockhart 2017).

2.3 Passive Acoustic Monitoring

Passive acoustic monitoring has been a significant component of the U.S. Navy's MSM program in the Atlantic since it began in 2007. Although initially primarily used to collect baseline data on the occurrence of various species, more recently statistical methods have been developed to begin examining potential changes in vocalization behaviors that could represent a response to training and testing activities. In addition, the Marine Mammal Monitoring on Navy Ranges project (M3R) has been leveraging permanent fixed acoustic training ranges to develop a suite of tools and techniques and support various projects addressing specific questions related to marine species monitoring and interactions with training and testing activities.

All current and past deployments of passive acoustic monitoring devices including High-frequency Acoustic Recording Packages (HARPs), Marine Autonomous Recording Units (MARUs), Autonomous Multichannel Acoustic Recorders (AMARs), Ecological Acoustic Recorders (EARs), automated click detectors (C-PODs), can be explored, along with accompanying metadata and links to analyses and reports, through a data viewer on the U.S. Navy's MSM program web portal.

2.3.1 High-Frequency Acoustic Recording Packages

Duke University and Scripps Institution of Oceanography began a long-term program using HARPs as part of a multi-disciplined monitoring effort for Onslow Bay in 2007, which was later expanded to the Jacksonville OPAREA in 2009, Cape Hatteras in 2012, and Norfolk Canyon in 2014. Deployments were subsequently ended at the Onslow Bay site in 2013 but continue at the other locations. The primary objective of deployments at all locations has been to determine patterns of occurrence and distribution of cetacean species throughout areas of interest. During 2016, HARP data were collected at the Norfolk Canyon, Cape Hatteras, and Jacksonville sites over a bandwidth from 10 Hertz (Hz) up to 160 kilohertz (kHz); they are capable of approximately 300 days of continuous data storage. Deployment details and links to available detailed analyses from all HARP deployments can be found through the HARP data explorer on the U.S. Navy's marine species monitoring program web portal.

2.3.1.1 Norfolk Canyon

Data Collection (Norfolk Canyon)

The HARP initially deployed on 19 June 2014 near Norfolk Canyon at a depth of 982 m at 37.1662° N, 74.4669° W (Site A) was recovered on 07 April 2015 (**Table 48, Figure 73**), yielding a deployment period of over 290 days (approximately 10 months). The HARP at Norfolk Canyon Site A was redeployed on 30 April 2016 at 37.1652° N, 74.4666° W at a depth of 968 m (**Table 48, Figure 73**). This instrument is still in the field and is expected to be recovered in June 2017.

Table 48. Deployment details for the Norfolk Canyon HARP deployments and analyses included in this report.

Site	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date	Latitude (N)	Longitude (W)	Depth (m)	Sampling Rate	Duty Cycle
01A	19-Jun-14	07-Apr-15	19-Jun-14	05-Apr-15	37.1662	74.4669	982	200 kHz	continuous
02A	30-Apr-16	N/A	30-Apr-16	N/A	37.1652	74.4666	968	200 kHz	continuous

Key: Apr = April; Jun = June; kHz = kilohertz; m = meter(s) N/A = not applicable.

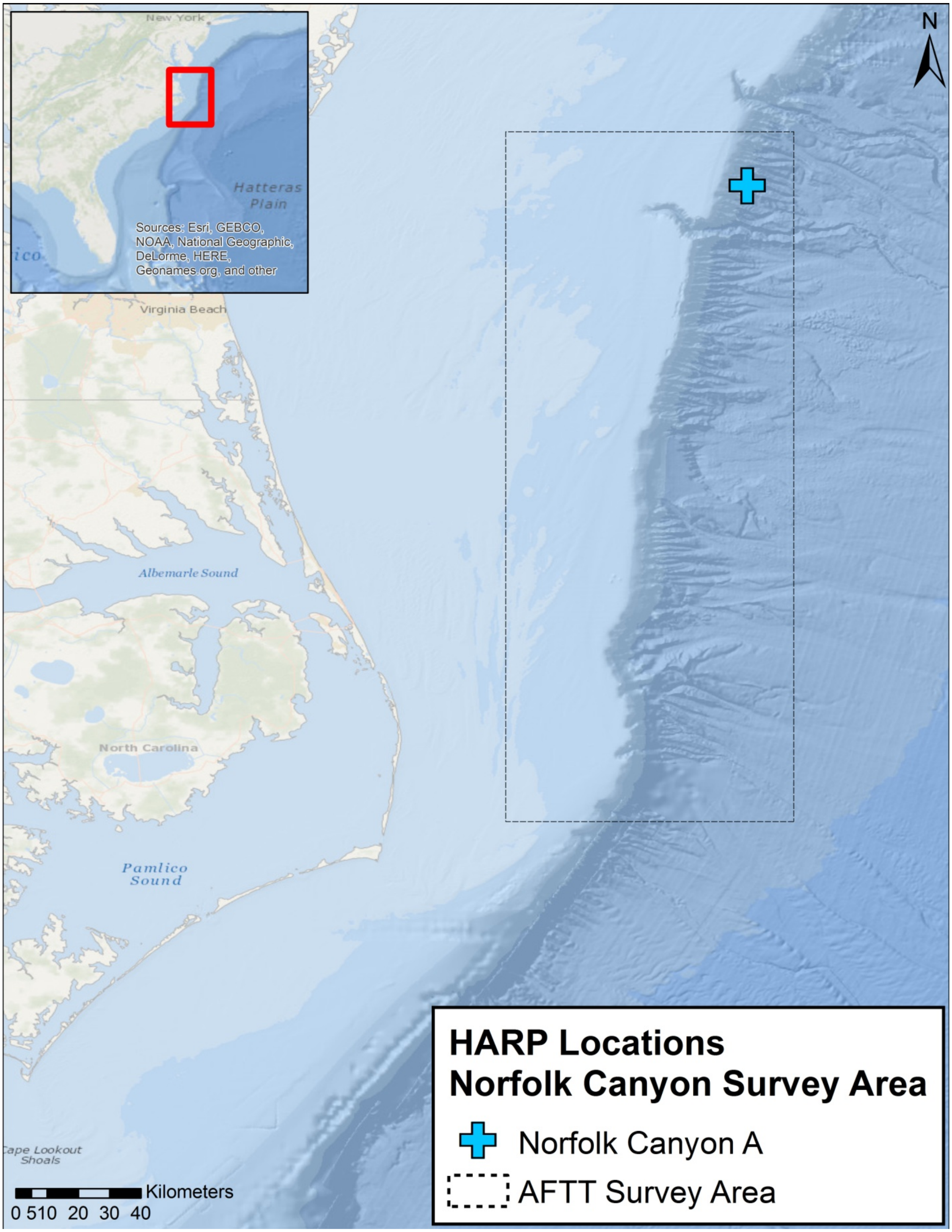


Figure 73. Location of the HARP deployment site near Norfolk Canyon.

Data Analysis (Norfolk Canyon)

The June 2014–April 2015 deployment yielded 6,951 hr of recording time. Analysis of marine mammals (except odontocete whistles) and anthropogenic sounds were reported previously by Hodge et al. (2016) and Debich et al. (2016), Odontocete whistle analysis of the June 2014–April 2015 deployment is reported here.

Unidentified whistles were present nearly continuously throughout the June 2014–April 2015 deployment (**Table 49**). Detections of whistles lower than 5 kHz in frequency peaked in October 2014, while whistles greater than 5 kHz peaked November–December 2014 (Debich et al. 2016). No diel pattern was detected for whistles less than 5 kHz in frequency (**Figure 74**). While whistles above 5 kHz occurred throughout all hours of the day, these whistles were detected slightly more often during nighttime hours (**Figure 75**).

Table 49. Summary of detections of unidentified odontocete whistles at Site A in Norfolk Canyon for June 2014–April 2015.

Species	Call Type	Total Duration of Vocalizations (hr)*	Percent of Recording Duration*	Days with Vocalizations	Percent of Total Recording Days
Unidentified odontocete	whistles	2,541.07	36.57	289	99.31

*Total duration of vocalizations (hours) and percent of recording duration are based on data analyzed in minute bins.

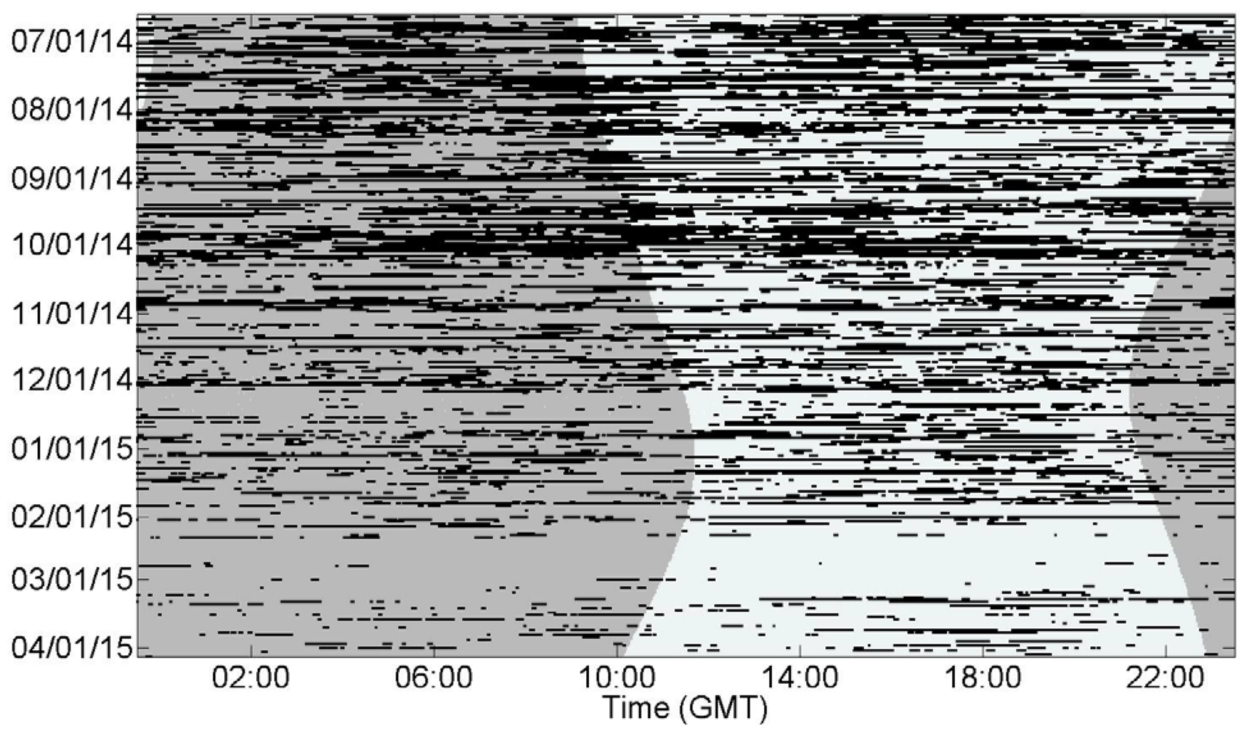


Figure 74. Unidentified odontocete whistles that were lower than 5 kHz (black bars) in 1-min bins within the June 2014–April 2015 Norfolk Canyon Site A dataset. Gray shading indicates periods of darkness, determined from the U.S. Naval Observatory (http://aa.usno.navy.mil).

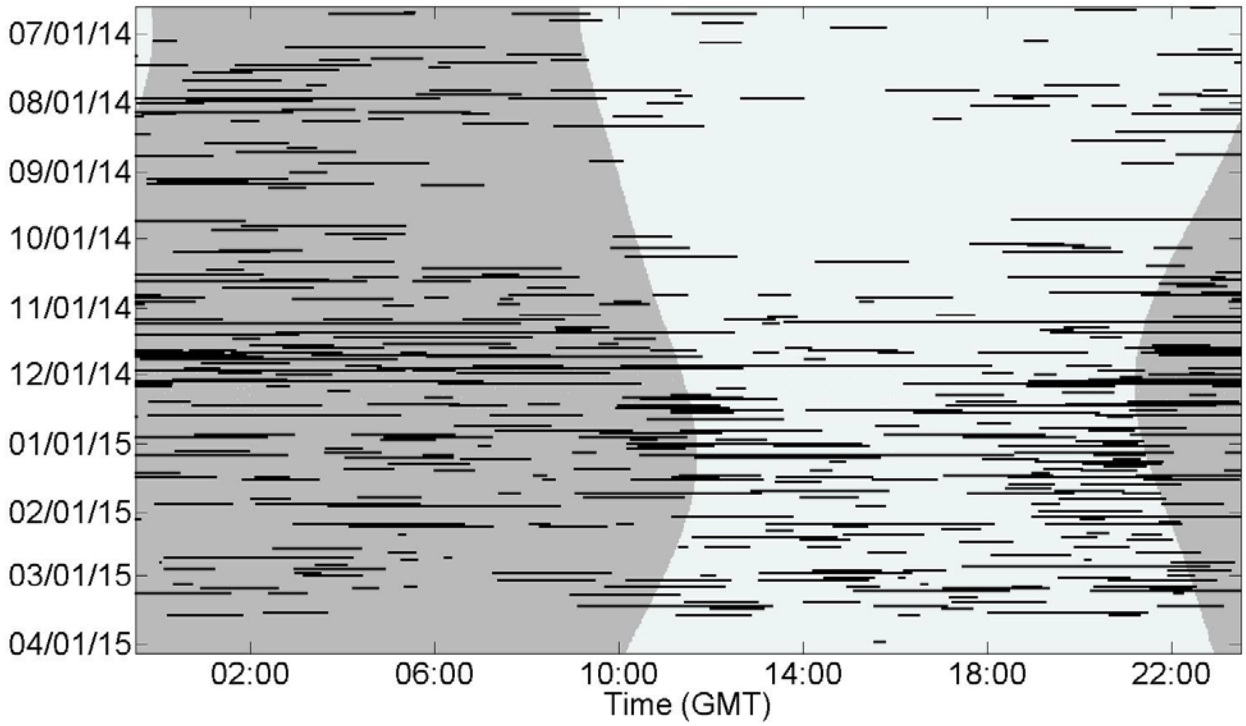


Figure 75. Unidentified odontocete whistles that were higher than 5 kHz (black bars) in 1-min bins within the June 2014–April 2015 Norfolk Canyon Site A dataset.

2.3.1.2 Cape Hatteras

Data Collection (Cape Hatteras)

The HARP previously deployed in April 2015 at Cape Hatteras Site A was recovered and redeployed in April 2016 at the same site (35.3057° N, 74.8776° W) at a depth of approximately 1,020 m (**Table 50, Figure 76**). This instrument is still in the field and is expected to be recovered in June 2017.

Table 50. Deployment details for the Cape Hatteras HARP deployments and analyses included in this report.

Site	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date	Latitude (N)	Longitude (W)	Depth (m)	Sampling Rate	Duty Cycle
02A	09-Oct-12	29-May-13	09-Oct-12	09-May-13	35.3406	74.8559	970	200 kHz	continuous
03A	29-May-13	08-May-14	29-May-13	15-Mar-14	35.3444	74.8521	970	200 kHz	continuous
04A	08-May-14	06-Apr-15	09-May-14	11-Dec-14	35.3467	74.8480	850	200 kHz	continuous
05A	06-Apr-15	29-Apr-16	07-Apr-15	29-Jan-16	35.3421	74.8572	980	200 kHz	continuous
06A	29-Apr-16	N/A	29-Apr-16	N/A	35.3057	74.8776	~1,020	200 kHz	continuous

Key: Apr=April; Dec=December; Jan=January; kHz=kilohertz; m=meter(s); Mar=March; N/A=not applicable; Oct=October.

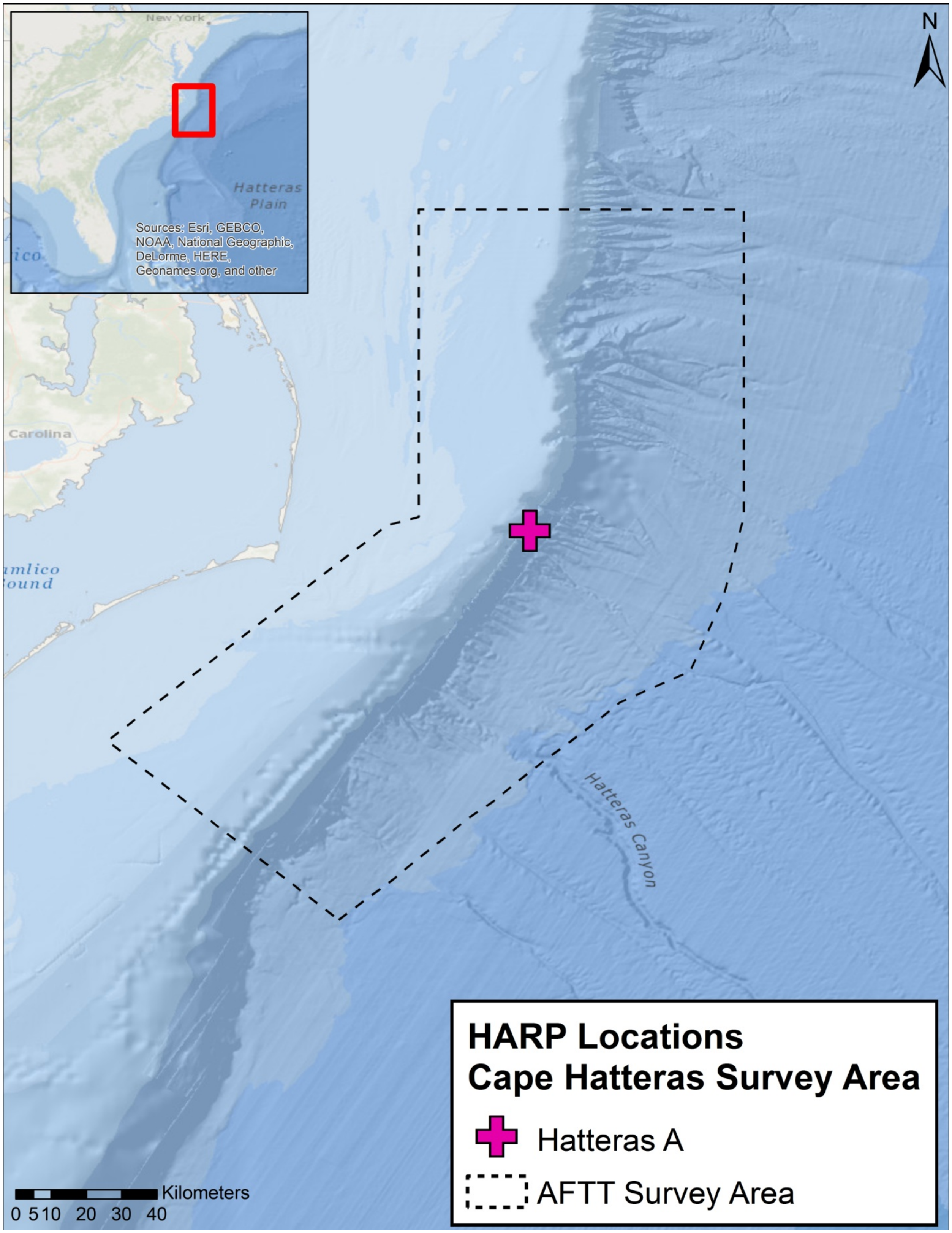


Figure 76. Location of the HARP deployment site in the Cape Hatteras study area.

Data Analysis (Cape Hatteras)

Four datasets from deployments at Site A in Cape Hatteras have been analyzed for marine mammal and anthropogenic sounds. For three of these datasets (October 2012–May 2013, May 2013–March 2014, and May–December 2014), all sounds were reported previously in the 2015 annual report except for odontocete whistles, which will be reported here as a summary of Debich et al. (2016). **Table 51** gives details on the detected odontocete whistles during the October 2012–May 2013, May 2013–March 2014, and May–December 2014 datasets. Unidentified odontocete whistles were detected throughout the recordings at each site. Detections of whistles >5 kHz peaked in October–December 2012 and in October–November 2013 (Debich et al. 2016). There was no diel pattern detected for whistles less than 5 kHz. While whistles greater than 5 kHz occurred throughout all hours of the day, these whistles were detected slightly more often during nighttime hours.

Table 51. Details for the unidentified odontocete whistles at Cape Hatteras Site A for deployments covering October 2012–December 2014. Total duration of vocalizations (hours) and percent of recording duration are based on data analyzed in minute bins.

Deployment	Call Type	Total Duration of Vocalizations (hr)*	Percent of Recording Duration*	Days with Vocalizations	Percent of Total Recording Days
October 2012–May 2013	whistles	2,567.68	50.42	212	99.53
May 2013–March 2014	whistles	2,991.53	43.09	279	99.58
May–December 2014	whistles	955.88	18.36	196	90.32

*Total duration of vocalizations (hours) and percent of recording duration are based on data analyzed in minute bins.

The April 2015–April 2016 deployment yielded 6,948 hr of recording time over 290 days (**Table 52**)**.** Mysticete detections included fin whales, minke whales, and sei whales (*Balaenoptera borealis*). Fin whale 20-Hz pulses (as measured by the acoustic index) were detected throughout the deployment, with detections ramping up in November and peaking in January 2016. Minke whale pulse trains showed a strong seasonal pattern, with detections from the beginning of recording (April 2015) through May 2015 and starting again in October 2015 and lasting through the end of recording (January 2016). Sei whale downsweeps were detected starting in December 2015 and lasting through the end of the recording period in January 2016.

Table 52. Summary of detections of marine mammal vocalizations at Cape Hatteras Site A for April 2015–January 2016. Fin whale 20-Hz pulses are not included as they were reported as an acoustic index and not logged with a start and end time to individual detection events.

Species	Call Type	Total Duration of Vocalizations (hr)*	Percent of Recording Duration*	Days with Vocalizations	Percent of Total Recording Days
Minke whale	pulse train (slow-down, speed-up, regular)	1,277	18.38	105	36.21
Sei whale	downsweep	49	0.71	12	4.14
Unidentified odontocete	clicks	1,580.02	22.75	281	96.90
Unidentified odontocete	whistles	4,804.38	69.17	288	99.31
Kogia sp.	clicks	1.55	0.02	26	8.97
Risso's dolphin	clicks	16.42	0.24	6	2.07
Sperm whale	clicks	582.93	8.39	162	55.86
Cuvier's beaked whale	clicks	1,375.5	19.80	287	98.97
Gervais' beaked whale	clicks	1,08.85	1.57	142	48.97
Blainville's beaked whale	clicks	0.45	0.006	1	0.34

Key: Hz=Hertz; sp.=species. * For all mysticetes except humpback whales, total duration of vocalizations (hours) and percent of recording duration are based on data analyzed in hourly bins; for humpback whales and odontocetes, total duration of vocalizations (hours) and percent of recording duration are based on data analyzed in minute bins.

Detected odontocete vocalizations were classified as *Kogia* sp., Risso's dolphins, sperm whales, Cuvier's beaked whales, Gervais' beaked whales, Blainville's beaked whales (*Mesoplodon densirostris*), and unidentified odontocete clicks and whistles. Many of the odontocete click detections could not be classified to species, but the unclassified clicks were being divided into five main groups based on spectral patterns. Altogether, these unclassified clicks were present nearly continuously throughout each recording period. For more details on each of the five groups of clicks and which species may have produced them, see Frasier et al. (2017). Unidentified odontocete whistles both lower and higher than 5 kHz occurred very regularly throughout the April 2015–January 2016 dataset, although there were many more whistles higher than 5 kHz. Clicks produced by *Kogia* sp. were detected sporadically throughout the deployment. Risso's dolphin clicks were detected only between May and July 2015. Sperm whales were detected throughout the deployment during both day and night, with peaks in click detections between late July and early August as well as from late December to the end of recording in January. There were also click detections assigned to three species of beaked whales. Cuvier's beaked whale clicks occurred regularly throughout this deployment, with a slight increase in detections between September and December, as in previous years, as well as between April and May 2015. Gervais' beaked whale clicks occurred less frequently than Cuvier's beaked whale clicks. Most Gervais' beaked whale detections occurred between April and July 2015 and between November 2015 and January 2016. Unlike Cuvier's beaked whales, there were very few detections of Gervais' beaked whales between

August and October 2015, similar to previous years. Blainville's beaked whale clicks were detected only on one day in January 2016.

Detected anthropogenic sounds included MFA and low-frequency active (LFA) sonar, as well as seismic survey airguns. MFA sonar was detected intermittently throughout the April 2015–January 2016 dataset, with a peak in detections occurring in October. LFA sonar higher than 500 Hz was detected on one day in September 2015. Airguns were detected throughout the deployment during both day and night, with peaks in detections in April 2015 and between June and September 2015.

2.3.1.3 Jacksonville OPAREA

Data Collection (JAX)

The small-mooring HARP deployed at Site D in the Jacksonville OPAREA was recovered and deployed twice from August 2014 through April 2016 and data from those recoveries was analyzed in 2016 (**Table 53, Figure 77**).

Table 53. HARP datasets from the JAX survey area included in this report.

Site	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date	Latitude (N)	Longitude (W)	Depth (m)	Sampling Rate	Duty Cycle
11D	23-Aug-14	02-Jul-15	23-Aug-14	22-May-15	30.1506	79.7700	~806	200 kHz	continuous
12D	02-Jul-15	26-Apr-16	03-Jul-15	04-Nov-15	30.1489	79.7711	800	200 kHz	continuous
13D	26-Apr-16	N/A	26-Apr-16	N/A	30.1518	79.7702	736	200 kHz	continuous

Key: Apr=April; Aug=August; Jul=July; kHz = kilohertz; m = meter(s); N/A = not applicable

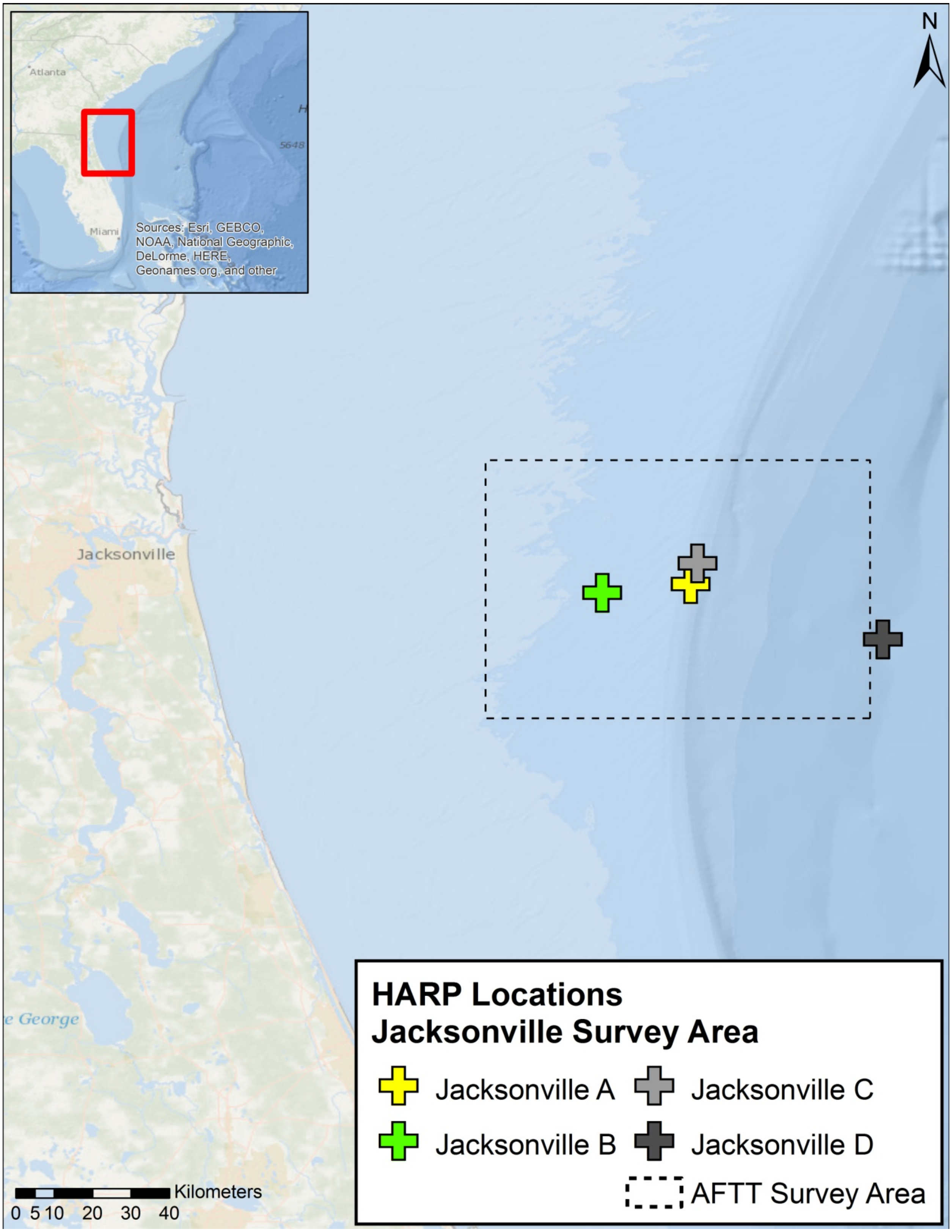


Figure 77. Locations of HARP deployment sites in the JAX survey area. All data included in this report was collected at Site D.

Data Analysis and Results (JAX)

The August 2014–July 2015 deployment yielded 6,697 hr of recording time over 280 days (August 2014–May 2015), while the July 2015–April 2016 deployment yielded 2,995 hr of recording time over 125 days (July 2015–November 2015).

Data from the August 2014–July 2015 and July 2015–April 2016 deployments in the Jacksonville survey area were analyzed for marine mammal and anthropogenic sounds and are reported here as a summary of Frasier et al. (2016) and Varga et al. (2017), with beaked whale analysis for the August 2014–May 2015 dataset performed by Dr. Joy Stanistreet (Duke University). Technical malfunctions resulted in loss of some data approximately three days into the July 2015–April 2016 deployment, the low-frequency stage of the hydrophone failed. The majority of the remaining data has little to no sensitivity in the lower frequencies (less than approximately 12 kHz), and occasional broadband masking from electronic noise. Despite the failure of the low-frequency component of the hydrophone, it remained sensitive to acoustic signals between approximately 12 and 100 kHz. For these reasons, the July 2015–April 2016 deployment dataset could not be analyzed for mysticetes, LFA sonar, MFA sonar, or ships. Data analysis consisted of analyst scans of long-term spectral averages (LTSAs) and spectrograms, and automated computer algorithm detection when possible. Three frequency bands were analyzed for marine mammal vocalizations and anthropogenic sounds: (1) low-frequency (between 10 and 300 Hz), (2) mid-frequency (between 10 and 5,000 Hz), and (3) high-frequency (between 1 and 100 kHz). See Frasier et al. (2016) and Varga et al. (2017) for a more detailed description of analysis methods.

Only the August 2014–May 2015 dataset could be inspected for mysticete calls. Mysticete calls could not be inspected for within the July 2015–April 2016 dataset because the low frequency stage of the hydrophone failed three days after the HARP was deployed, creating little to no sensitivity in the lower frequencies (< ~12 kHz). Within the August 2014–May 2015 dataset, three baleen whale species were detected: fin, minke, and sei whales (**Table 54**). Fin whale 20-Hz pulses were detected between January and March 2015. Minke whale pulse trains were detected first in October 2014, with detections ramping up to almost continuous (on an hourly basis) in December and remaining at elevated levels through March 2015. Minke whale pulse trains started decreasing in April and were not detected after early May 2015. Sei whale downsweeps were detected between November 2014 and January 2015, with a peak in detections in January. No diel patterns were noted for the detected mysticete calls (Frasier et al. 2016).

Table 54. Summary of detections of marine mammal vocalizations at JAX Site D for the August 2014–May 2015 HARP deployment.

Species	Call Type	Total Duration of Vocalizations (hours)*	Percent of Recording Duration*	Days with Vocalizations	Percent of Total Recording Days
Fin whale	20 Hz	76	1.1	13	4.6
Minke whale	pulse train (slow-down, speed-up, regular)	3,654	54.6	184	65.7
Sei whale	downsweep	88	1.3	17	6.1
Unidentified odontocete	clicks	382.2	5.7	218	77.9
Unidentified odontocete	whistles	423.3	6.3	181	64.6
Kogia sp.	clicks	10.5	0.2	80	28.6
Risso's dolphin	clicks	93.3	1.4	131	46.8
Sperm whale	clicks	28.6	0.4	11	3.9
Blainville's beaked whale	clicks	0.7	0.01	2	0.7
Gervais' beaked whale	clicks	2.2	0.03	4	1.4

Key: Hz=Hertz; sp.=species. * For all mysticetes, total duration of vocalizations (hours) and percent of recording duration are based on data analyzed in hourly bins; for odontocetes, total duration of vocalizations (hours) and percent of recording duration are based on data analyzed in minute bins.

In both the August 2014–May 2015 and July–November 2015 datasets, detected odontocete vocalizations included clicks and whistles. Most of these detections were assigned to the "unidentified odontocete" category (**Tables 54 and 55**), with clicks being divided into three main groups based on spectral patterns in the August 2014–May 2015 dataset and into two main groups based on spectral patterns in the July–November 2015 dataset (refer to Frasier et al. (2016) and Varga et al. (2017) for more details). Unidentified odontocete whistles lower than 5 kHz were detected mainly between March and May 2015 in the August 2014–May 2015 dataset, during late night and early morning hours. There were not many detections of unidentified whistles lower than 5 kHz during the July–November 2015 dataset, but that is likely due to the hydrophone failure mentioned previously that undoubtedly resulted in many missed detections. Unidentified odontocete whistles higher than 5 kHz were detected throughout both the August 2014–May 2015 and July–November 2015 datasets, with peaks in detections between March and May 2015. Once again, though, there were possibly missed detections in this category during the July–November 2015 dataset if the whistles did not extend above 12 kHz.

Table 55. Summary of detections of marine mammal vocalizations at Site D in JAX for the July–November 2015 HARP deployment.

Species	Call Type	Total Duration of Vocalizations (hr)*	Percent of Recording Duration*	Days with Vocalizations	Percent of Total Recording Days
Unidentified odontocete	clicks	73.70	2.46	87	69.6
Unidentified odontocete	whistles	23.92	0.80	33	26.4
Kogia sp.	clicks	14.92	0.15	100	80
Risso's dolphin	clicks	144.75	1.49	180	144
Sperm whale	clicks	79.78	0.82	23	10.4
Blainville's beaked whale	clicks	0.68	0.007	2	1.6
Cuvier's beaked whale	clicks	0.48	0.005	3	2.4
Gervais' beaked whale	clicks	3.58	0.04	8	6.4

Key: sp.=species. * Total duration of vocalizations (hours) and percent of recording duration are based on data analyzed in minute bins. Note that detections of unidentified odontocete whistles less than 5 kHz were likely missed due to a hydrophone failure.

Kogia clicks were detected throughout both datasets, with the highest numbers of detections occurring between October 2014 and April 2015. Risso's dolphins were detected in low numbers between August 2014 and April 2015 and in higher numbers in late April through May 2015 and in July 2015, with detections primarily at night. Sperm whales were detected intermittently throughout both deployments. Blainville's beaked whales were detected on only two days during the August 2014–May 2015 dataset and never during the July–November 2015 dataset. Conversely, Cuvier's beaked whale clicks were not detected during the August 2014–May 2015 dataset and detected on only 3 days during the July–November 2015 dataset. Gervais' beaked whales were detected on four days during the August 2014–May 2015 dataset and three days during the July–November 2015 dataset. Most beaked whale detections during these deployments occurred at night.

In the August 2014–May 2015 dataset, detected anthropogenic sounds included broadband ship noise, MFA sonar below 5 kHz, high-frequency active sonar, echosounders, and explosions. MFA sonar could not be analyzed in the July–November 2015 dataset due to the hydrophone failure. MFA sonar below 5 kHz was detected in almost every month with peaks in September 2014 and January 2015. High-frequency active sonar was detected on one day during the August 2014–May 2015 dataset.

For the next reporting period, Scripps Institution of Oceanography will analyze the April 2016 datasets from Norfolk Canyon Site A, Cape Hatteras Site A, and Jacksonville Site D once they are recovered in June 2017. Detailed and technical reports will be available once the analyses of the datasets are complete.

For more information on the HARP program, refer to the annual progress report for this project (Hodge et al. 2017). A metadata viewer including links to individual technical reports of HARP deployments is available at: http://www.navymarinespeciesmonitoring.us/data-access1/passive-acoustic-data/harp-reports/.

2.3.2 *Tursiops* Monitoring in the VACAPES MINEX W-50 Training Range

MINEX activities that utilize underwater detonations (UNDET) have the potential to injure or kill marine mammals occurring in close proximity. To better understand the impact of MINEX training on marine mammals, an effort was begun in August 2012 by Oceanwide Science Institute to monitor odontocete activity at the VACAPES Range Complex MINEX site using passive acoustic methods. The initial objectives of the project were to establish the daily and seasonal patterns of occurrence of dolphins in the VACAPES W-50 MINEX range, to detect explosions related to MINEX activities, and to determine whether dolphins in the area show evidence of a response to MINEX events.

Between 2012 and 2016, Ecological Acoustic Recorders (EARs) programmed to achieve continuous monitoring were deployed and refurbished approximately every two months. The data were analyzed manually for the daily presence/absence of dolphins, and their acoustic activity was quantified in detail for specific periods prior to, during, and after MINEX training events, which can occur on the range multiple times per month.

A second phase of the project began in September 2013 to determine whether the responses observed at 1 km from the epicenter also occur at greater distances and whether a spatial redistribution of animals takes place. In addition, a localization array was implemented to examine the spatial distribution of dolphins near the epicenter shortly before and after UNDETs. Alternating two-month deployments through 2015 consisted of two different EAR configurations. In the first configuration, four EARs were arranged in a linear array at distances of 1 km, 3 km, 6 km, and 12 km from the primary MINEX training epicenter in order to examine whether animals are responding and/or redistributing along the coast or offshore during training events (**Figure 78**). In the second configuration, EARs were arranged in a localization array to measure the distances that animals occur from MINEX training activities (**Figure 79**).

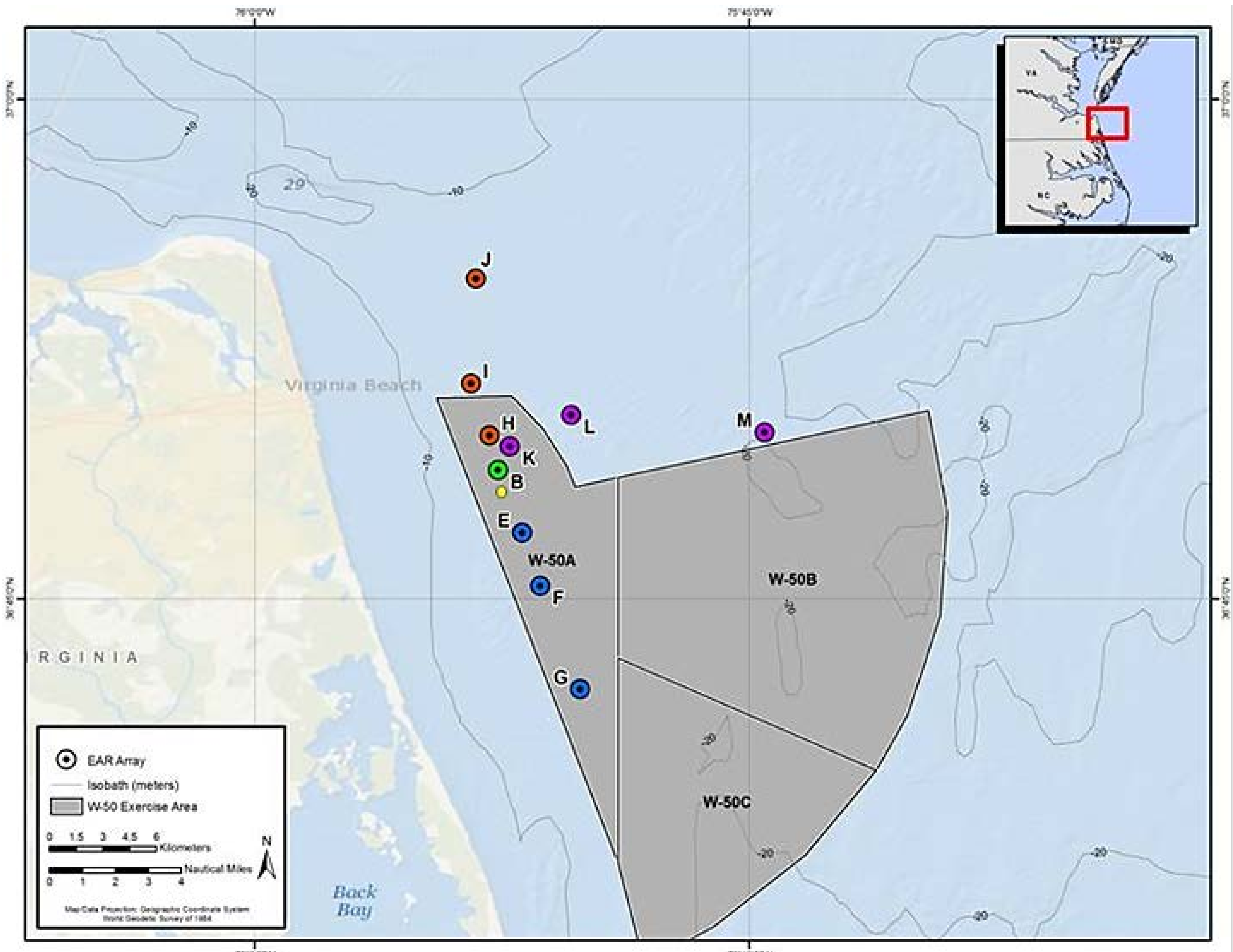


Figure 78. Spatial configuration of three linear EAR arrays deployed during the second and third years of the project. Site B (green) remained constant; the north array is shown as red (B–H–I–J), east as purple (B–K–L–M), and south as blue (B–E–F–G). The yellow dot represents the position of the "epicenter."

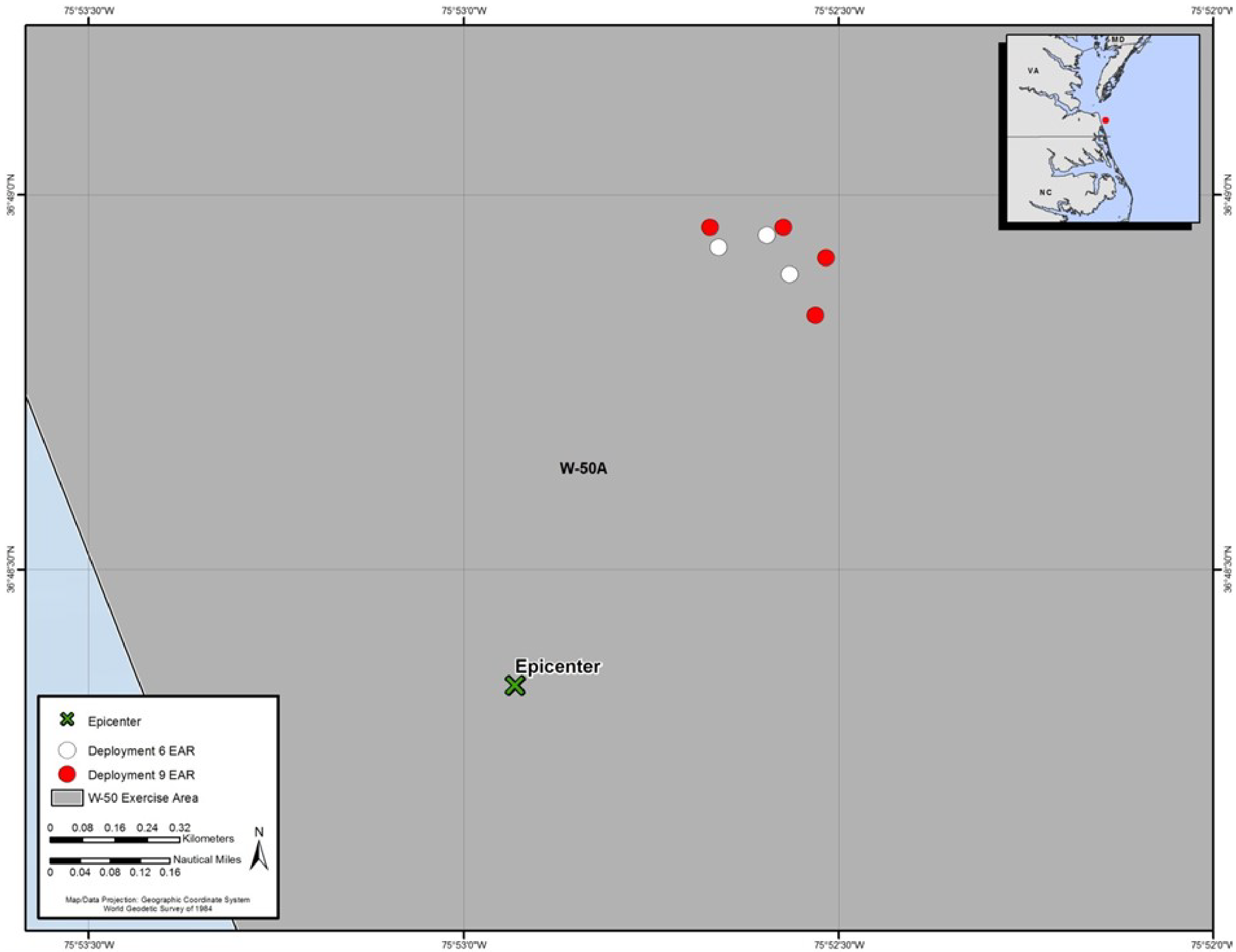


Figure 79. Spatial configurations of the two localization EAR arrays relative to the location of the epicenter of MINEX training activities.

Fifteen EAR deployment cycles were conducted during the study period, totaling 53 individual EAR deployments. In total, 609,584 3-min recordings were made among all EARs totaling 30,479 hr of data. Four instruments were lost during the study period and seven stopped recording prematurely, malfunctioned, or were erroneously recovered prematurely.

A clear seasonal trend was observed in the mean number of daily dolphin detections each month (**Figure 80**). Dolphins were most commonly detected between the months of April and October. Detection rates dropped substantially between November and March and were lowest during the month of February. However, it should be noted that although the number of daily detections decreased during winter months, dolphins were still detected in the area nearly daily throughout the year. This finding is consistent with seasonal trends in bottlenose dolphin abundance off Virginia Beach (Barco et al. 1999; Engelhaupt et al. 2016). From year to year, differences were observed between a few of the same months, suggesting some inter-annual variability of the occurrence of dolphins in the area immediately around the epicenter.

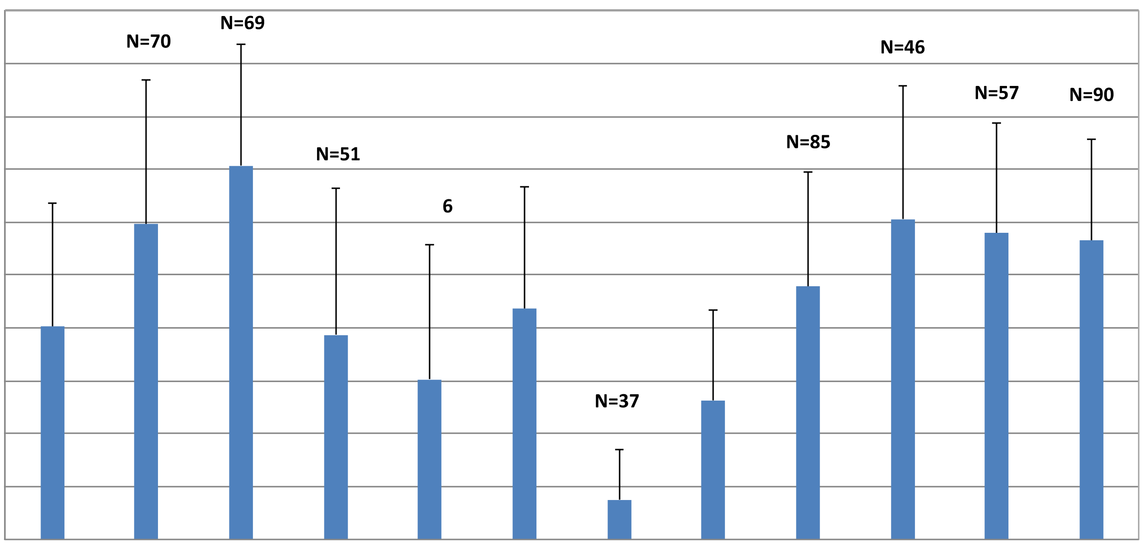


Figure 80. Mean number of daily dolphin detections at site B averaged by month for the three years of data collection between 15 August 2012 and 30 August 2015. Error bars represent one standard deviation. N values give the total number of days that were monitored during each month.

The data obtained from the seven linear-array deployments between September 2013 and March 2016 were examined to establish the presence of UNDETs in the recordings and to assess dolphin acoustic activity before, during, and after MINEX training events. Data from unit B continued to be analyzed for the presence of dolphin signals to maintain consistency with the data time series. The recordings corresponding to the day before, day of, and the two days following an UNDET were examined in detail and each recording was given an acoustic activity index value based on the criteria in **Table 56**.

Table 56. Index values used to quantify dolphin acoustic activity for each 3-minute recording made the day before, during, and after detected explosions, based on the abundance of dolphin whistles, burst pulses (BP), and echolocation clicks.

Acoustic Category	Index Value
1–20 whistles	1
BP only < 10	1
Echolocation only < 2 clicks/second	1
21–40 whistles	1.5
Echolocation only > 2 clicks/second	1.5
BP only > 10	1.5
Echolocation & BP < 10	1.5
1–20 whistles & echolocation or BP	2
> 41 whistles	2.5
Echolocation & BP > 10	2.5
1–20 whistles, echolocation, & BP	3
21–40 whistles & echolocation or BP	3
21–40 whistles, echolocation, & BP	3.5
> 41 whistles & echolocation or BP	3.5
> 41 whistles, echolocation, & BP	4

Data from the four locations in each linear array were also used to determine whether or not there was a re-distribution of animals following MINEX training activities. The acoustic activity index was averaged by EAR location and pooled by the distance from the epicenter of training exercises for the days before, during and after an UNDET event. This allowed an examination of animal presence at each distance from the epicenter following MINEX events irrespective of the direction of the linear array.

2.3.2.1 Localization Array Results

The first localization-array deployment took place between 16 November 2013 and 23 January 2014. Localizations of dolphin signals could not be attempted for this deployment due to loss of equipment and the inability to synchronize the EAR clocks. The second localization-array deployment was made between 16 August 2014 and 07 November 2014 and included an acoustic pinger to facilitate synchronizing the individual units. EARs B and Q recorded successfully during the entire deployment. EAR R recorded for 10 days and then unexpectedly stopped. No explosions were detected during the 10-day period with three operational EARs, and therefore no data were available for localization of signals surrounding any UNDET events. The third localization array was deployed between 25 June 2015 and 21 August 2015, with the pinger co-located with EAR R. Five explosions were detected within the first month when the units were recording concurrently; two occurred on 07 July 2015 approximately 2 hr apart, and three occurred within a 7-hr span on 14 July 2015. Dolphin whistles were also detected on both days of the explosions, but candidate whistles for localization were only available in the 4-hr period surrounding the first explosion on 07 July. Although dolphin whistles were detected in multiple other recordings on days with explosions, most did not co-occur with pings and therefore localization in relation to these other events was not possible.

Whistle detections surrounding the first explosion event on 07 July 2015 are tabulated in **Table 57**. Whistles were detected in three files co-occurring with synchronization pings: two files before the explosion (at approximately 1.5 hr and 1 hr before, respectively) and one 6 min after the explosion. There were 12 total whistles available for localization in the two files before the explosion, half of which were subjectively rated as having "poor" signal-to-noise ratios (SNR), i.e., not visible or barely visible in the spectrogram on one or more hydrophones (e.g., **Figure 81**). In the file following the explosion, there were approximately 10 whistles detected, six of which received "poor" SNR ratings (**Figure 81**). Realistic position estimates were not obtained for these whistles. In addition, the explosion itself occurred in a file without pings, which precluded time-alignment and localization of the explosion using EAR data. It may still be possible to estimate distances of dolphins to the explosion if the location of the UNDET is known, but due to the limited sample size of suitable files for localization and whistles within those files, further analyses are unlikely to provide additional statistical power.

Table 57. Whistle detections in recordings containing pings used for time-alignment before and after an UNDET event in July 2015.

File Name	File Time	Number of Whistles Suitable for Localization	Signal-to-Noise Ratio Rating
File 2990	07/07/15 11:00 (1.5 hour before explosion)	10	5 poor, 5 moderate
File 2995	07/07/15 11:30 (1 hour before explosion)	2	1 poor, 1 moderate
File 3005	07/07/15 12:30 (6 minutes after explosion)	10	6 poor, 4 moderate

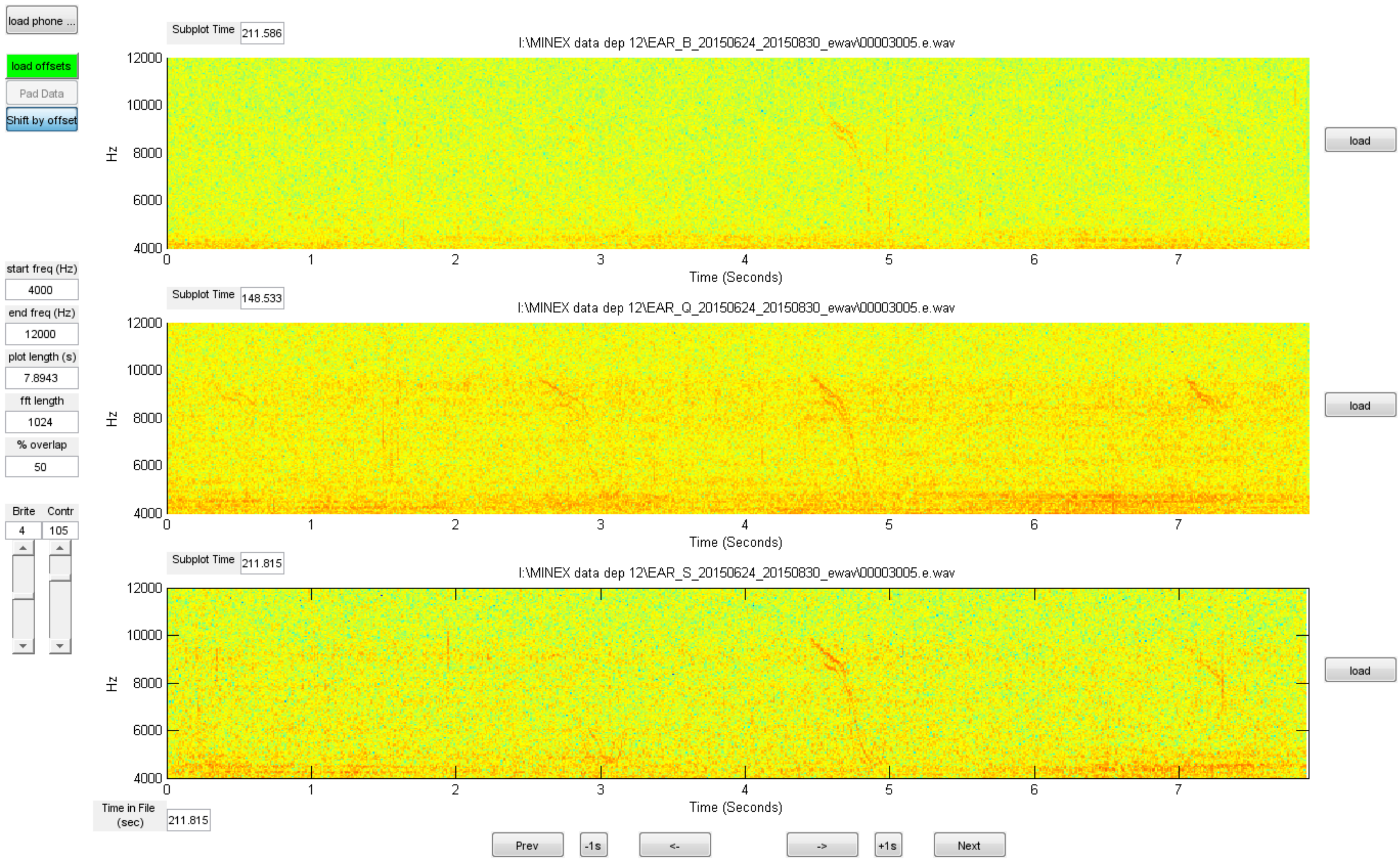


Figure 81. Time-aligned spectrograms from three following an explosion. Note the low SNR of the whistles at 0.5 seconds and 2.7 seconds on EARs B (top panel) and S (bottom panel).

The fourth and final localization array was deployed between 13 June 2016 and 08 July 2016, with the pinger co-located with EAR R. three EARs (R, Q, and S) were recording during the two UNDET events detected on 16 June 2016 and 24 June 2016. The first recorded explosion on 16 June 2016 occurred at approximately 11:00 Eastern Daylight Time (EDT), and took place south of the EAR array (exact location to be determined). In the 24 hr surrounding this explosion (12 hr before and 12 hr after), 11 files contained dolphin signals suitable for localization. These included seven files within a 10-hr period prior to the explosion, the 1 file during which the explosion occurred, and three files in the 6 hr after the explosion. The second recorded explosion was on 24 June 2016 at approximately 10:00 EDT. However, only two files in the 24-hr period surrounding this explosion contained whistles suitable for localization, and of these, one file also contained the explosion. Due to the limited sample size of dolphin signals recorded before and after the second explosion, analysis efforts focused on only the first explosion.

2.3.2.2 Acoustic Response to Explosions

In total, 74 UNDETs were detected in the data between 15 August 2012 and 08 July 2016 (**Table 58**) representing 38 MINEX training events. . Of the 38 training events recorded across all EARs, 31 coincided with data successfully obtained from site B (1 km from the epicenter). The mean hourly acoustic activity indices of dolphins during the day prior, the day of, and the two days after the 31 analyzed training events at site B are shown in **Figure 82**. During the day prior to an event, dolphins were most active during mid-day and nighttime hours. On the day of MINEX training and the following day, the daytime peak in activity was reduced or absent. In contrast, the nighttime peak persisted following MINEX training events, suggesting that the animals in the area resumed normal activity during these hours. During the second day following a training event the hourly acoustic activity levels were significantly higher than the levels observed during the day before the event (see next paragraph), suggesting that animals were more active and/or abundant in the area during this time than during the baseline period (the day before an exercise).

Table 58. UNDETs detected during all deployments, including the site at which it was detected, the date and time of the explosion, and whether dolphin signals were observed in the same recording.

Deployment	Location Detected	Recording #	Explosion Date & Time (EDT)	Dolphins present?
1	B	5163	9/5/12 12:21	Yes
1	B	5208	9/5/12 16:51	Yes
1	B	5214	9/5/12 17:27	Yes
1	B	6590	9/11/12 11:03	No
1	B	6591	9/11/12 11:09	Yes
1	B	6641	9/11/12 16:09	Yes
1	B	6822	9/12/12 10:15	Yes
1	B	8031	9/17/12 11:09	No
1	B	10715	9/28/12 15:33	Yes
1	B	12126	10/4/12 12:39	Yes
2	A	633	12/10/12 19:09	No
2	B	631	12/10/12 15:09	No
2	B	8591	1/12/13 19:09	Yes
3	B	3247	3/29/13 12:45	Yes
3	B	4448	4/3/13 12:53	Yes
4	A	4433	6/19/13 11:20	Yes
4	B	371	6/11/13 13:10	No
4	B	12129	7/30/13 12:57	No
4	B	12385	7/31/13 14:33	Yes
4	B	12871	8/2/13 15:09	No
5	G	8279	10/25/13 11:58	No
6	B	1420	11/22/13 10:31	No
6	B	1429	11/22/13 11:24	No
6	B	1431	11/22/13 11:37	No
6	B	1460	11/22/13 14:32	No
6	B	5985	12/11/13 11:02	No
6	B	5999	12/11/13 12:25	No
6	B	14895	1/17/14 14:00	No
6	B	14899	1/17/14 14:24	No
7	K	4938	3/9/14 13:51	Yes
7	K	4945	3/9/14 14:35	Yes
7	K	12364	4/9/14 12:28	Yes
7	K	12395	4/9/14 15:33	No
7	K	15894	4/24/14 14:46	Yes
8	B	403	5/20/14 16:20	Yes
8	B	423	5/20/14 18:20	Yes
8	B	4426	6/6/14 10:38	Yes

Deployment	Location Detected	Recording #	Explosion Date & Time (EDT)	Dolphins present?
8	B	4437	6/6/14 11:44	No
8	B	13794	7/15/14 11:25	Yes
8	B	14546	7/18/14 14:38	Yes
8	H	647	5/21/14 16:45	No
8	H	654	5/21/14 17:27	Yes
8	H	659	5/21/14 17:57	Yes
8	H	662	5/21/14 18:17	No
8	H	2778	5/30/14 13:51	Yes
8	H	12365	7/9/14 12:33	No
8	H	12381	7/9/14 14:09	No
8	H	14289	7/17/14 12:59	Yes
8	H	14299	7/17/14 13:58	Yes
8	H	14528	7/18/14 12:51	Yes
8	H	15247	7/21/14 12:45	Yes
9	B	9093	9/22/14 21:19	No
9	B	9110	9/22/14 23:01	Yes
9	B	16452	10/23/14 13:13	No
9	B	16460	10/23/14 14:01	No
10	B	14043	1/7/15 12:19	Yes
11	B	17406	5/20/15 12:36	Yes
11	B	17414	5/20/15 13:26	Yes
11	H	17170	5/19/15 13:03	Yes
12	B	3004	7/7/15 12:24	No
12	B	3027	7/7/15 14:43	No
12	B	4659	7/14/15 9:56	Yes
12	B	4682	7/14/15 12:14	No
12	B	4730	7/14/15 17:01	No
13	B	5450	11/4/15 17:01	Yes
13	L	5450	11/4/15 17:00	Yes
14	E	4346	2/19/16 14:40	No
14	E	6941	3/1/16 10:11	No
14	E	7181	3/2/16 10:10	Yes
14	E	11026	3/18/16 10:45	No
14	E	11027	3/18/16 10:45	No
14	F	5995	2/26/16 11:33	No
15	Q	00000141_20160616105447	6/16/16 10:54	No
15	Q	00000524_20160624101238	6/24/16 10:12	Yes

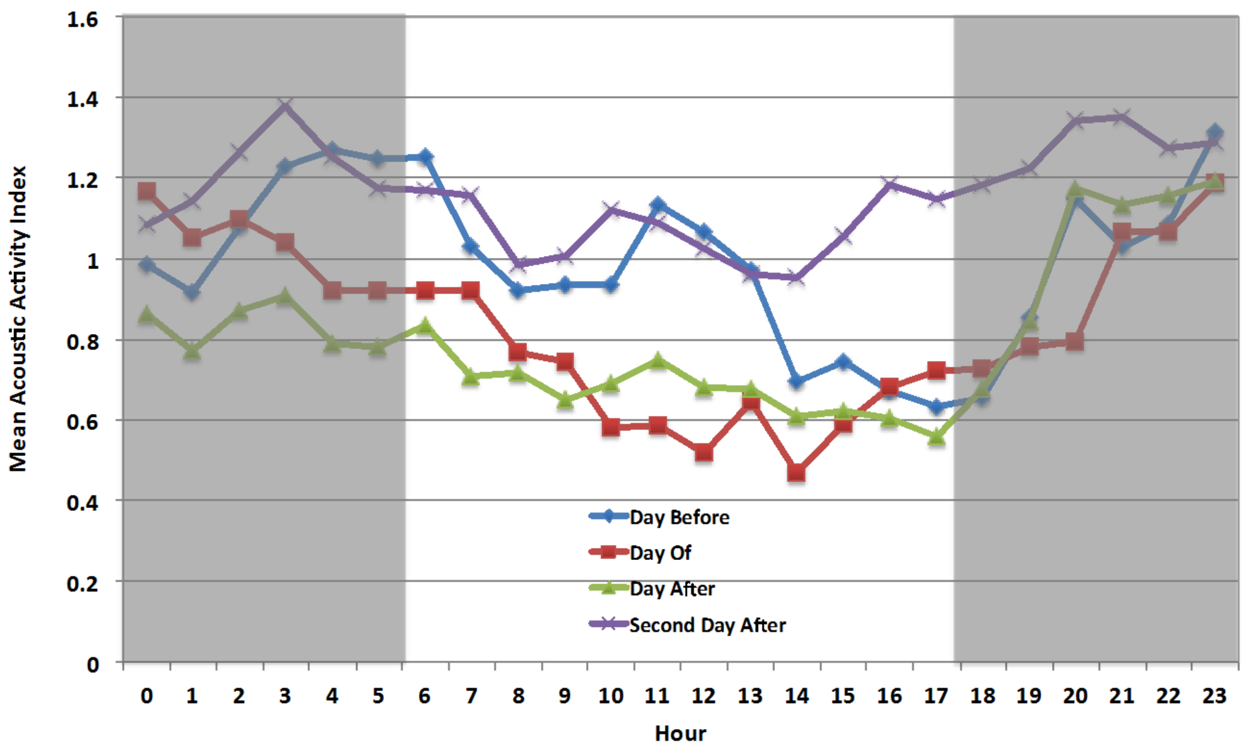


Figure 82. The mean hourly dolphin acoustic activity at site B over the 24-hr period of the days before (N = 31), the days of (N = 31), and the first (N = 30) and second (N = 29) days after MINEX training events. Shaded periods represent approximate twilight/nighttime hours.

To determine whether the observed differences are statistically significant, the hourly indices for each "day before," "day of," "day after" and "second day after" were averaged for 12-hr approximate daytime (06:00–17:59 EDT) and nighttime (18:00–05:59 EDT) periods. The "day before" values were then matched with the corresponding "day of", "day after" and "second day after" values and either a parametric paired t-test or a non-parametric Wilcoxon matched pairs test was performed. For the daytime hours, the "day before" acoustic indices were significantly higher than the "day of" (Wilcoxon matched pairs test, N=31, Z=3.46, p<0.001) and the "day after" (Wilcoxon matched pairs test, N=30, Z=2.15, p=0.032), but significantly lower that the "second day after" (Wilcoxon matched pairs test, N=28, Z=2.07, p=0.038). For the nighttime hours, the "day before" acoustic indices were not significantly different from the "day of" (paired t-test, t=1.092, DF=30, p=0.283), "day after" (paired t-test, t=0.692, DF=30, p=0.494) or "second day after" (paired t-test, t=1.642, DF=27, p=0.112).

Figure 83 presents the average hourly dolphin acoustic activity observed on the linear-array EARs as a function of the three additional monitored distances (3 km, 6 km, and 12 km) from the epicenter of MINEX training for the days before, of, and after a training event. The data are pooled among array orientations (north, south, and east) for each distance from the epicenter.

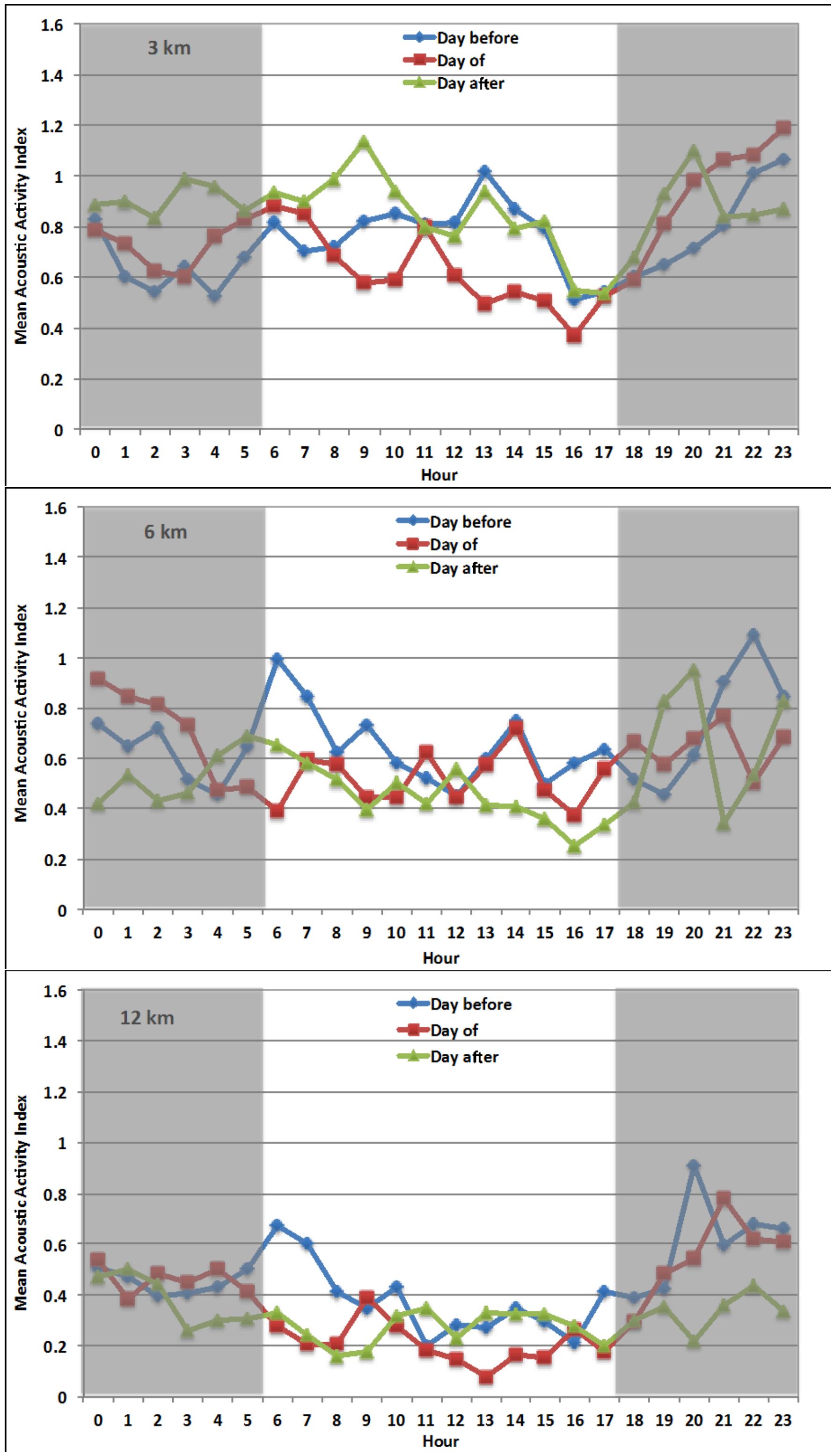


Figure 83. The mean hourly dolphin acoustic activity observed over the 24-hr period of the days before, the days of, and the days after MINEX training events, pooled across sites 3 km (top, N=15), 6 km (middle, N=10), and 12 km (bottom, N=14) from the epicenter of training activities.

To statistically infer whether training events influenced dolphin acoustic activity at these distances from the epicenter, the hourly indices for each “day before,” “day of,” and “day after” were averaged for the daytime and nighttime. Because more than 90 percent of recorded UNDETs occurred between 10:00 and 17:59, the hypothesis was tested that daytime effects would more likely be observed between these hours at distances farther away from the epicenter on the “day of” the training event. The “day before” values were then matched with the corresponding “day of” and “day after” values, and either a parametric paired t-test or a non-parametric Wilcoxon matched pairs test was performed.

For the pooled 3-km data (N=15 MINEX training events recorded), a significant decrease occurred in the mean daytime dolphin acoustic activity between the day before and the day of the training event (paired t-test, t=2.26, DF=14, p=0.040). No significant differences were found between the daytime hours of the “day before” and the “day after,” or between the nighttime hours of the “day before” and either the “day of” or “day after.” Similarly for the pooled acoustic activity recorded 6 km from the epicenter (N=10 MINEX training events recorded), no significant differences were found between the “day before” and either the “day of” or “day after” for either the daytime or nighttime periods. Lastly, for the pooled 12-km data (N=14 MINEX training events recorded), a significant decrease occurred in the mean daytime dolphin acoustic activity between the day before and the day of the training event (Wilcoxon matched pairs test, N=14, Z=2.41, p=0.016). However, no significant differences were found between the daytime hours of the “day before” and the “day after,” or between the nighttime hours of the “day before” and either the “day of” or “day after.”

To further explore the significantly lower acoustic activity observed between the “day before” and “day of” daytime periods in the 12-km data, the data were grouped according to the linear array orientation (north, south, and east). **Figure 84** shows the mean acoustic activity observed during the “day before” and the “day of” for the northern (J), southern (G), and eastern (M) sites. The northern site (site J) had more than three times the baseline dolphin acoustic activity of the southern site (site G) and more than 18 times the activity observed at the eastern site (site M). At both the northern and southern sites, mean daytime dolphin acoustic activity dropped by nearly half during the day of a training event. At the eastern site (site M) activity levels remained low and unchanged.

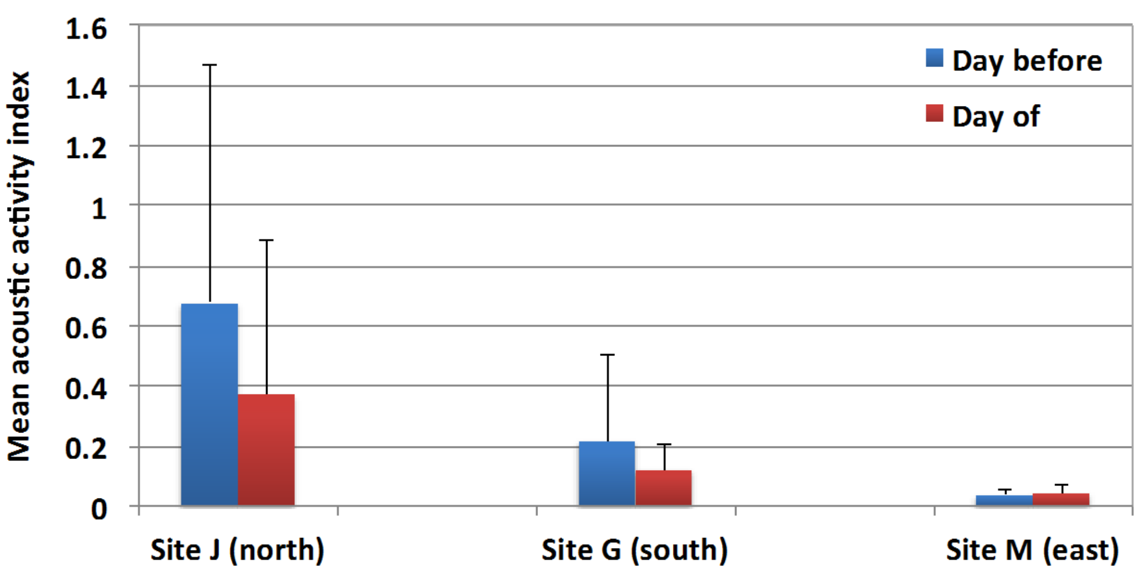


Figure 84. The mean acoustic activity index observed at sites J (N=6), G (N=5) and M (N=3) during the day before and the day of MINEX training events.

There is strong evidence that dolphins respond behaviourally to MINEX training events. The data from site B, comprising 31 monitored training events in 4 years of data collection, paint a clear picture: dolphins either moved away or became less acoustically active during the daytime hours of a day with one or more UNDETs. Dolphin acoustic activity returned to baseline levels in the evening and night-time hours of that day. However, during the daytime hours of the following day, acoustic activity was again reduced compared to baseline levels, but activity normalised again in the evening and at night. It cannot be determined with certainty from these data whether the decrease in acoustic activity represents individuals moving away from the area, a change in acoustic signaling behavior, or both. In captive animals, stressful events can lead to periods of reduced or no acoustic activity lasting hours or even days (Sidorova et al. 1990, Castellote and Fossa 2006). Studies of free-ranging delphinids provided some evidence that individuals alter their whistle production rates and other parameters after exposure to simulated MFAS (and in some cases mimic MFAS signals), but effects varied depending on species and behavioral state (DeRuiter et al. 2013a). Dolphins may also alter their whistle production rates in response to stressful events, as in a study that found increased signature whistle rates after brief capture-and-releases (Esch et al. 2009). Interestingly, during daytime hours of the second day following a training event, dolphin acoustic activity at site B was generally higher than the baseline period. The higher acoustic activity levels observed two days after a training event could indicate more frequent signalling by individual dolphins, perhaps reflecting increased social cohesion, cautiousness, exploratory behavior, stress, or other differences in behavioral state compared to the baseline.

If the assumption is made that reduced acoustic activity is indicative of fewer dolphins occurring in an area, then the patterns observed suggest that dolphins temporarily move away from the epicenter during the day of the training event, but return during nighttime hours. Perhaps because training events often occur over multiple days, dolphins may anticipate additional UNDETs beyond the final day of the training event, which could explain the reduced acoustic activity observed during the first day following the final UNDET. In other words, dolphins may hedge against potential future exposure to an UNDET by avoiding the area. The fact that dolphin activity near the epicenter is higher during the second day following the training event than during the baseline period is curious and may indicate that dolphins occupy the area in greater numbers, perhaps to exploit prey fauna killed during the training event by the blast wave of UNDETs (however, no evidence for or against this explanation presently exists).

The data obtained from the EARs located 3 km, 6 km, and 12 km away from the epicenter further help inform the response by dolphins to MINEX training events. There is evidence that dolphin acoustic activity is reduced 3 km away from the epicenter during the day of an UNDET, but not 6 km away, suggesting that the radius of potential avoidance by dolphins is between 3 km and 6 km. Of note, however, is that a significant reduction in acoustic activity on the day of an UNDET also was observed at the two 12-km sites towards the north and south of the epicenter. This suggests that animals occurring near the 12-km sites responded to UNDETs occurring relatively far away. It is unclear why this is or what the response represents, but one possibility is that the animals may be moving from more distant areas toward the epicenter to exploit prey fauna killed by the UNDET, perhaps during the nighttime hours in between or after training days. Another possibility is that habituation to UNDETs exists among animals typically occurring ~6 km away, but not among those substantially further away, which may be exposed to training events less frequently.

Data from the localization-array deployments (and other deployments) indicate that dolphins were sometimes present in the minutes surrounding an UNDET event within the EAR detection area, which is likely within 1 or 2 km of the UNDET source. Unfortunately, data from the first three localization-array deployments were insufficient to address more accurately the question related to the distance from

MINEX explosions where dolphins occur. Some of the reasons for this were instrument-related, including unexpected early cessation of recording, instrument noise, and low precision and accuracy of internal EAR clocks. Some limitations also were related to the recording parameters, including the EAR recording duty cycle and the pinger schedule, which reduced the amount of usable data for localization. Finally, some of the limitations were inherent in the data themselves: only a small number of UNDET events were detected, and dolphin signals with the potential to be localized were limited by low sample size and challenging to work with due to low SNR and overlapping/distorted whistle contours.

Some of these issues were addressed in the fourth and final localization array by altering the EAR recording schedule, such that recording was continuous and for 30 min in each cycle. This ensured that each recording would contain pings for time-synchronization, and that any explosion during the deployment period also would also be recorded.

The fourth and final deployment of the localization array yielded usable data for localizing dolphin groups relative to explosions. Two explosions were recorded during this array deployment, but only the first was associated with sufficient quantity and quality of dolphin whistles available for localization. The resulting dolphin localizations suggest potential movement of dolphin groups relative to the EAR array during the time period from 10 hr before the explosion to about 6 hr afterward, but do not demonstrate any significant differences in distance or direction of dolphin localizations before and after the explosion. A larger sample size of explosions (and dolphin signals) would be needed to statistically analyze whether dolphin movements show any pattern or trend in response to UNDET events.

For more information on this study, refer to the final report for this project (Lammers et al. 2017).

2.3.3 *Tursiops* Monitoring in Chesapeake Bay Near NAS Patuxent River

An aerial survey monitoring project was initiated in 2015 to provide quantitative data and information on the seasonal occurrence, distribution, and density of marine mammals and sea turtles in Chesapeake Bay waters near NAS Patuxent River (see **Section 2.1.1.5**). HDR is conducting PAM using C-PODs (click detection data loggers, Chelonia Limited, Mousehole, United Kingdom) to complement the aerial surveys by assessing the seasonality and occurrence of echolocating cetaceans in the study area on a continuous basis through the duration of the project. Additionally, HDR has collected opportunistic sighting photographs of bottlenose dolphins during the first C-POD deployment and will continue to collect photo-ID data if additional sightings occur during subsequent field efforts to recover and deploy C-PODs (see **Section 2.1.2.5**).

Five C-PODs initially were deployed in July 2015 and subsequently recovered/redeployed on intervals of approximately four months, the most recent of which was December 2016. Two additional deployments will collect data through July 2017. Several additional locations were included in the project planning permit application to allow for flexibility of survey design after the initial deployments were completed at the end of the first year. In July 2016, one unit was shifted from site 6 to site 7 for the remainder of the project (**Figure 85**).

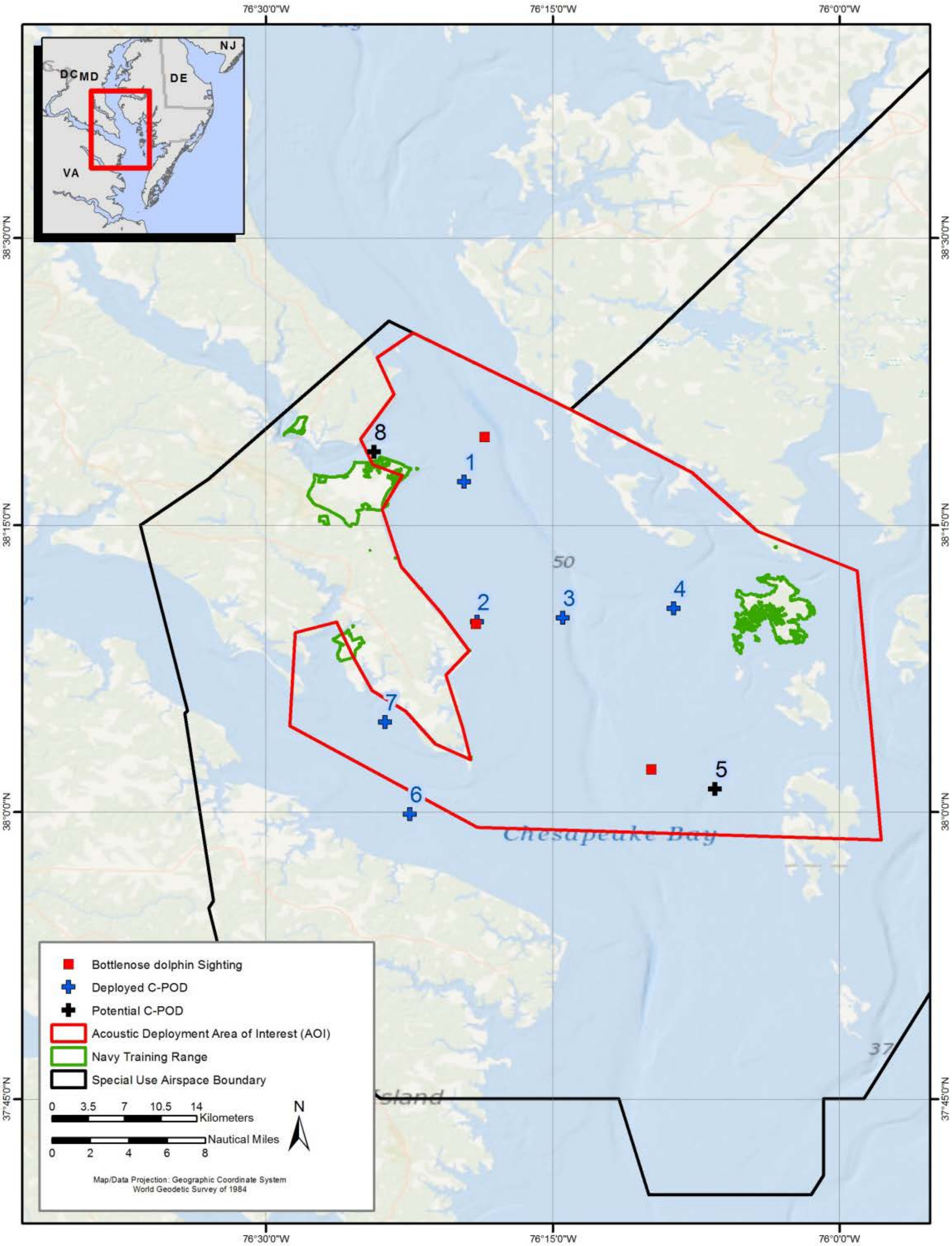


Figure 85. Locations of C-POD deployments around NAS Patuxent in 2016 and alternative deployment sites permitted for flexibility (black +).

The first year of results (cumulative including data from 2015) show that all C-PODs have recorded good quality data. The raw click data are imported into custom analysis software and processed using the KERNO classifier (custom function built into proprietary software) to detect click trains and identify their likely sources. A secondary classifier called 'GENENC' (Chelonia Limited) (which uses a longer time window) can improve the detection performance; it was applied to the NAS Patuxent River C-POD data and assessed for its effectiveness for correct classification of *Tursiops*. Additional quality control (QC) and detection validation has been conducted by an experienced C-POD analyst. In this case the KERNO classifier was found to work better than the 'GENENC' classifier, and the results were filtered for moderate- and high-quality click trains with specific sound pressure levels (SPLs). This was to remove weak boat sonar that could otherwise be misclassified as dolphins. Dolphins were detected on each of the C-PODs at some point throughout the year.

In general, even when the dolphins are expected to be present in the summer months, the C-PODs detected very low dolphin occurrence, measured by the presence of clicks within 1-min blocks of data (detection-positive minutes [DPM]). Due to the low number of detections, the data were able to be visually inspected for data validation. Very few detections were attributed to being false positives, and all data presented here were verified to be correctly classified as dolphins.

As expected for this area, dolphin occurrence was higher during the warmer summer months (**Figure 86**). The summertime occurrence associated with increased water temperatures and **Figure 87** shows one year of mean water temperatures, recorded by each C-POD, from November 2015 through November 2016. Detections decreased precipitously in the fall and no detections were made after November in either 2015 or 2016. There was a diel pattern evident in the data, generally with more detections during nighttime periods (**Figure 88**).

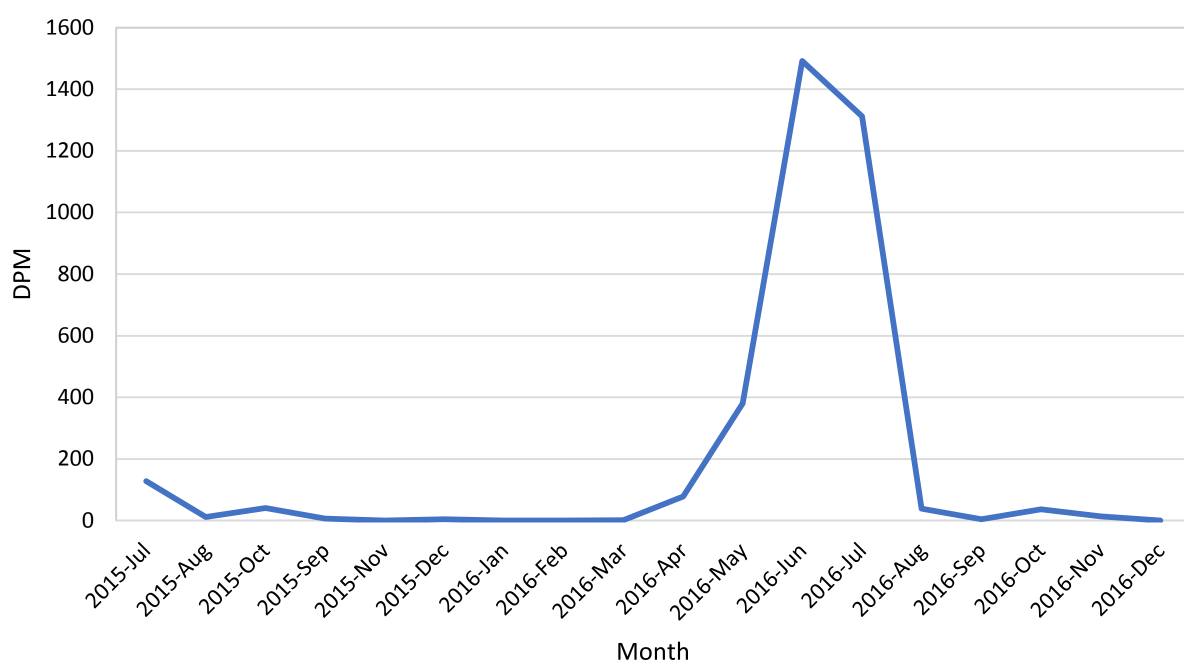


Figure 86. Number of dolphin detection-positive minutes, summed across all sites by month from July 2015 through December 2016 (total *n*=3,555).

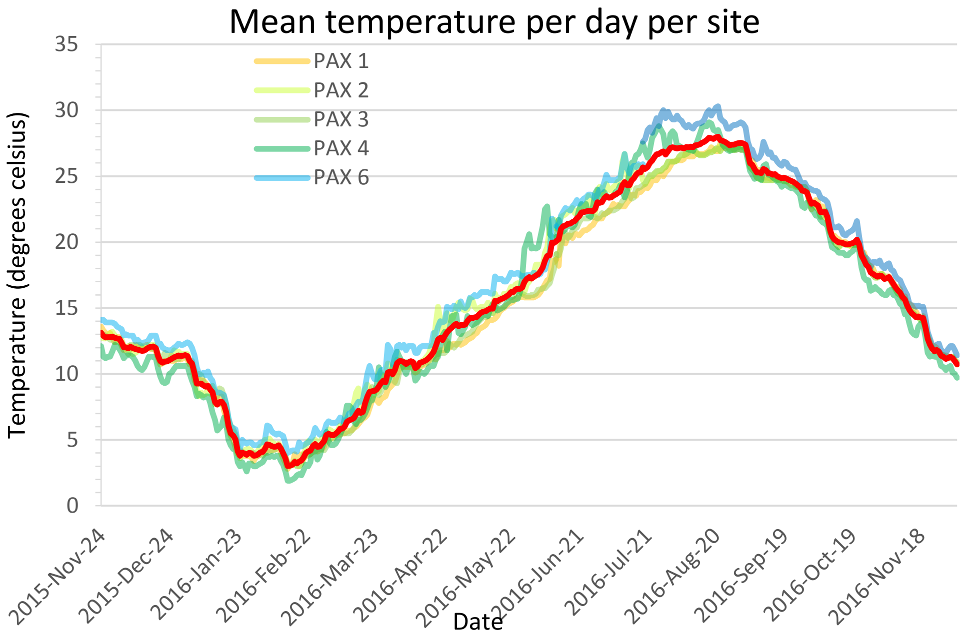


Figure 87. Mean daily temperature readings made by the C-PODs at all six deployment sites from November 2015 through November 2016. The red line is the average daily mean temperature for all sites combined.

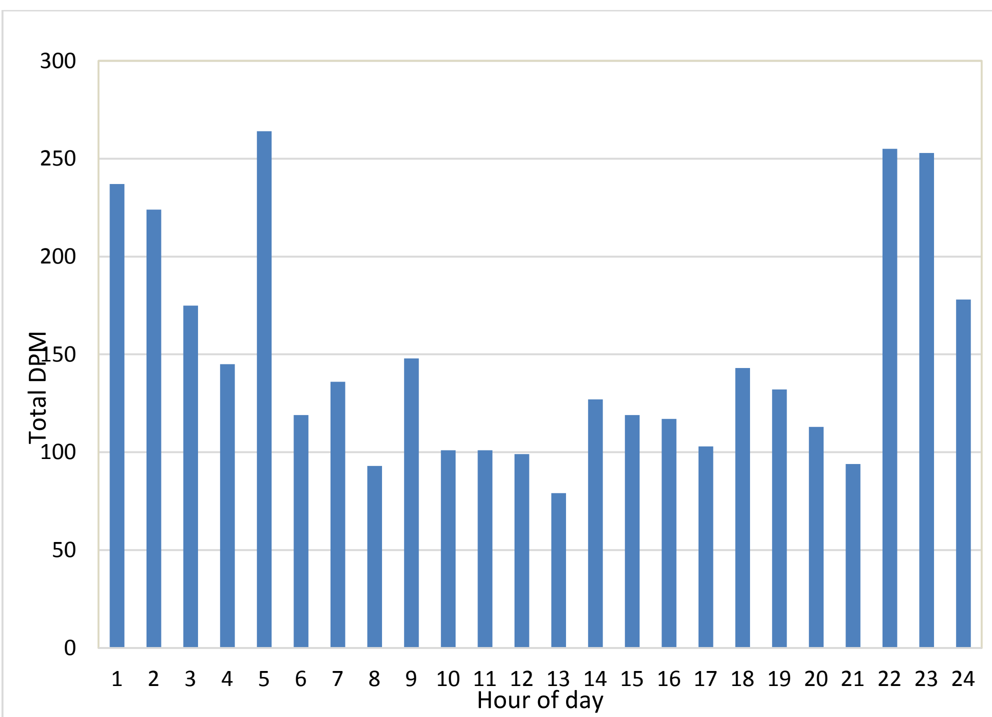


Figure 88. Dolphin detection-positive minutes per hour of the day (starting at midnight) summed across all NAS Patuxent River sites for the duration of the project to date, 11 July 2015 through 04 December 2016 (total *n*=3,555).

For more information, refer to the annual progress report for this project (Richlen et al. 2017a).

2.3.4 Right Whale Occurrence in the Cape Hatteras Study Area

In fall 2013, a PAM effort was initiated by Duke University and NMFS' NEFSC to detect North Atlantic right whales migrating past Cape Hatteras during their seasonal movements to and from winter breeding grounds off Florida. The objectives of this project were to investigate the timing of North Atlantic right whale migration through the mid-Atlantic region, as well as the relative distance from shore and acoustic behavior of migrating whales. This effort helps to fill a data gap in the central portion of the potential migratory corridor, and contributes to a broader understanding of the seasonal occurrence of North Atlantic right whales along the U.S. Atlantic Coast.

Passive acoustic data were collected using four deployments of five MARUs sampling continuously at 2 kHz and arranged in a linear configuration across the continental shelf off Cape Hatteras from October 2013 through August 2015 (**Table 59, Figure 89**). Analysis was completed in 2016, and results from the entire project are being prepared for publication. Additionally, these data have been integrated into a broad-scale analysis of right whale seasonal occurrence along the U.S East Coast led by researchers at NMFS' NEFSC, which is being prepared for publication.

Table 59. MARU array deployments off Cape Hatteras, North Carolina from October 2013 through August 2015.

Deployment	Deployment Date	Retrieval Date	Recording Start Date	Recording End Date
01	04-Oct-13	23-Feb-14	04-Oct-13	23-Feb-14
02	23-Feb-14	07-Jun-14	23-Feb-14	07-Jun-14
03	06-Oct-14	09-Mar-15	06-Oct-14	09-Mar-15
04	09-Mar-15	20-Aug-15	09-Mar-15	20-Aug-15

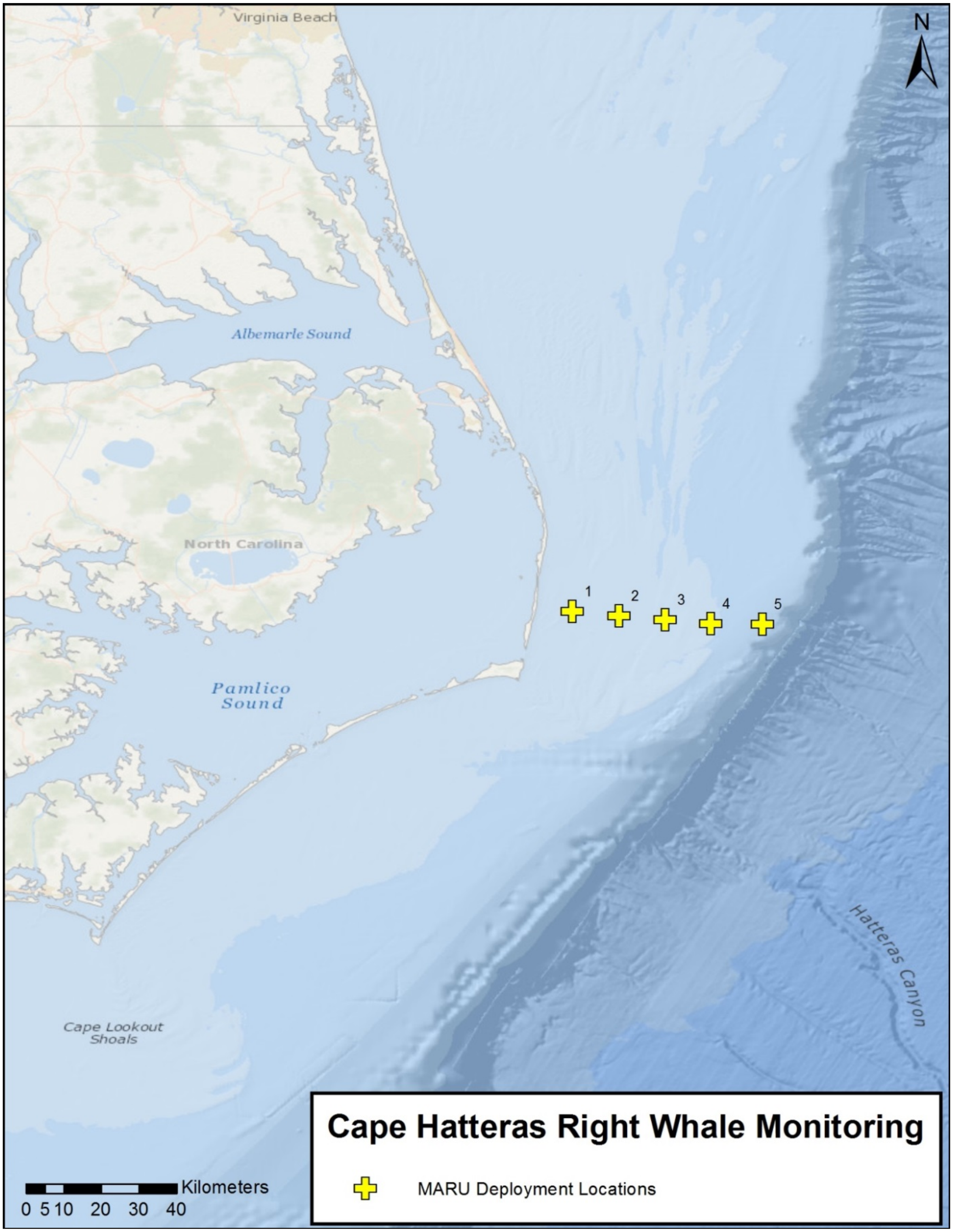


Figure 89. Locations of the MARU deployment sites off Cape Hatteras.

Data from all deployments were analyzed for North Atlantic right whale up-calls using an automated low-frequency detection and classification system (Baumgartner and Mussoline 2011).

Up-calls were detected at one or more MARU sites on 110 of 560 days with recordings (20 percent of recording days) during the four deployment periods. Right whale acoustic presence was highly seasonal, with all detections occurring between October and April. There were unique up-call detections across all five sites, and consistent spatiotemporal patterns were observed in both project years. Hourly presence of up-call detections was highest at site 2, peaking in January and February (**Figure 90**). There were fewer detections at sites 4 and 5, and these generally occurred later in the season, with a peak at site 5 in mid-February, particularly in 2015 (**Figure 90**). Analysis of the diel occurrence of detected up-calls across all sites and recording periods showed calling activity across all hours of the day, with an increase during the late afternoon and evening hours (**Figure 91**).

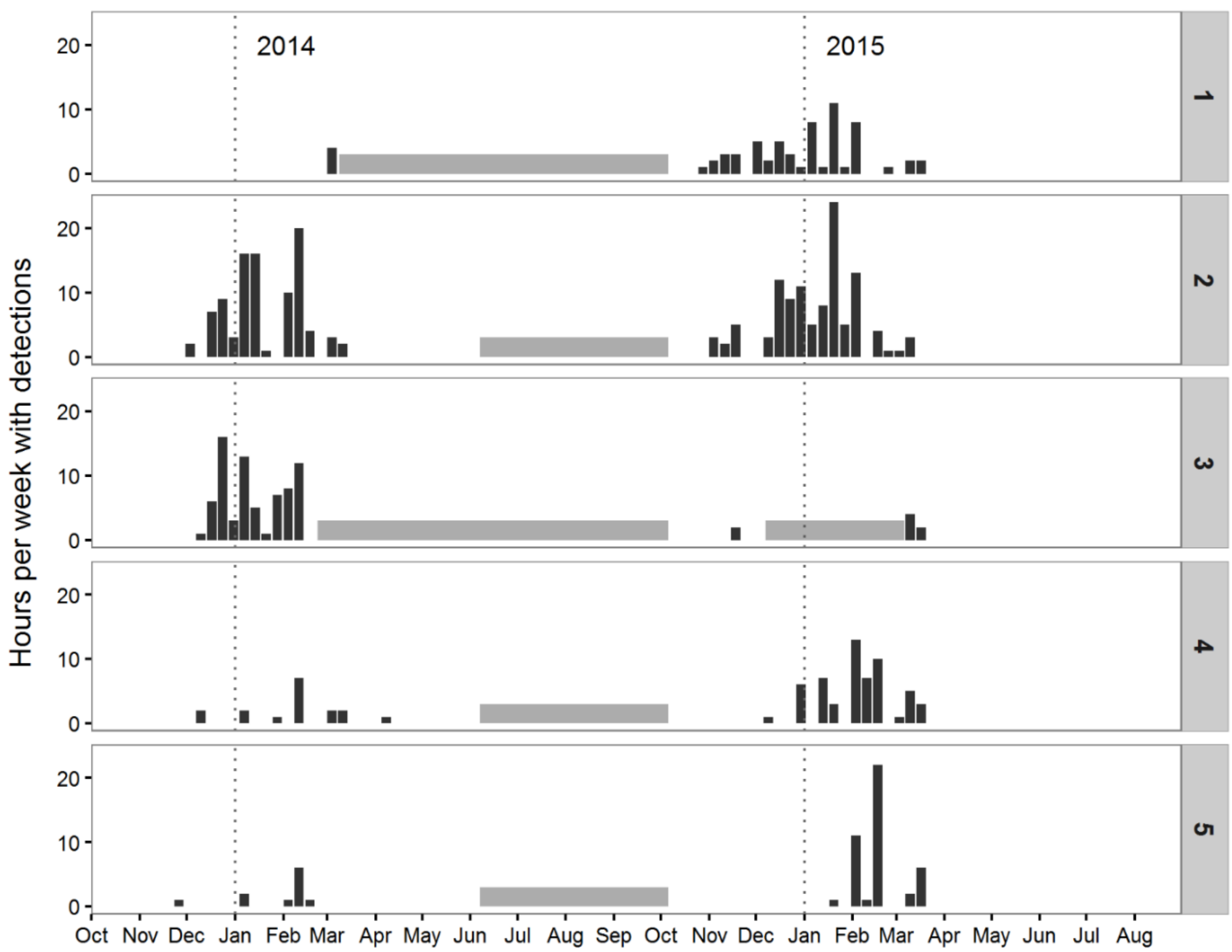


Figure 90. Number of hours per week with up-call detections across MARU sites 1 (top) through 5 (bottom) between October 2013 and August 2015. Gray bars indicate periods with no recording effort or where no data were recovered.

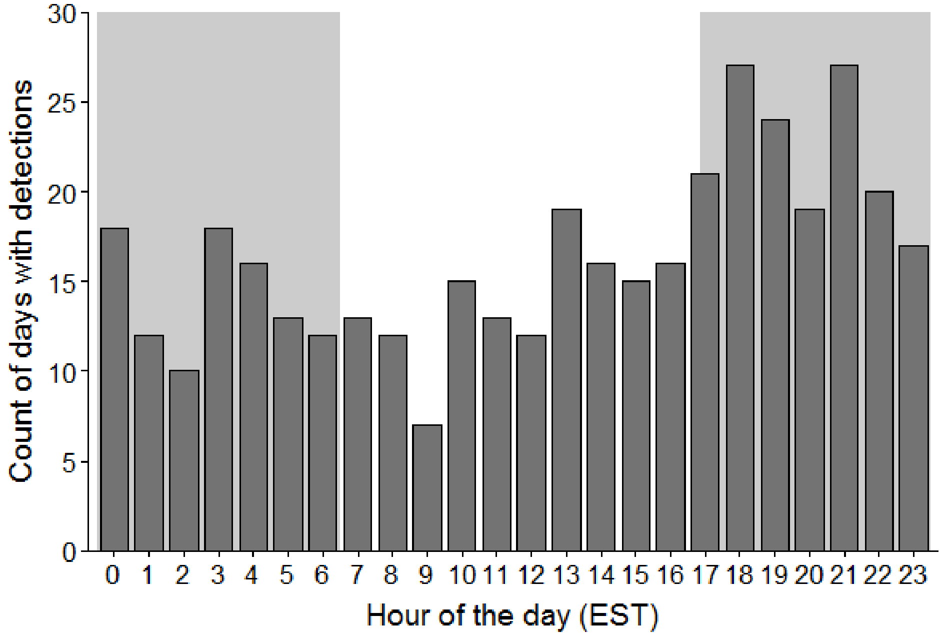


Figure 91. Number of days with up-calls detected within each hour of the day (Eastern Standard Time), summed across all MARU sites and recording periods. Gray background shading indicates darkness and white background indicates daylight, based on the mean sunrise and sunset times across all dates with detections.

These results indicate that North Atlantic right whales are seasonally present off Cape Hatteras. From October through December, most up-calls were detected on the nearshore recording sites, suggesting that right whales may remain relatively close to the coastline during their expected southward migration through this region. From January through April, up-calls were detected across all recording sites, indicating a broader distribution of right whales across the continental shelf later in the season, potentially corresponding to the northward movement of individuals through the region.

2.3.5 Passive Acoustic Monitoring for Cetaceans on the Continental Shelf off Virginia

Similar to many mid-Atlantic states, little is known about the seasonal and spatial occurrence of marine mammals off the coast of Virginia, especially in offshore areas. This data gap presents a challenge for effective marine spatial planning. Consequently, collecting baseline data on spatial and temporal trends of cetacean occurrence in these areas is critical to minimize or mitigate risks to protected species. The Bureau of Ocean Energy Management (BOEM) and U.S. Navy have collaboratively funded The Bioacoustics Research Program (BRP) at the Cornell Lab of Ornithology to undertake a three-year PAM study of the occurrence cetaceans in continental shelf waters in and around the VA WEA and across the continental shelf off the mouth of Chesapeake Bay.

Ten bottom-mounted passive acoustic recorders are currently deployed off the coast of Virginia and will be maintained for years (**Figure 92**). A combination of high-frequency AMARs, and low-frequency MARUs are deployed in two spatial configurations, with the AMARs in a linear array extending east from the mouth of the Chesapeake Bay across the continental shelf, and MARUs deployed as a synchronized localization array within the VA WEA.

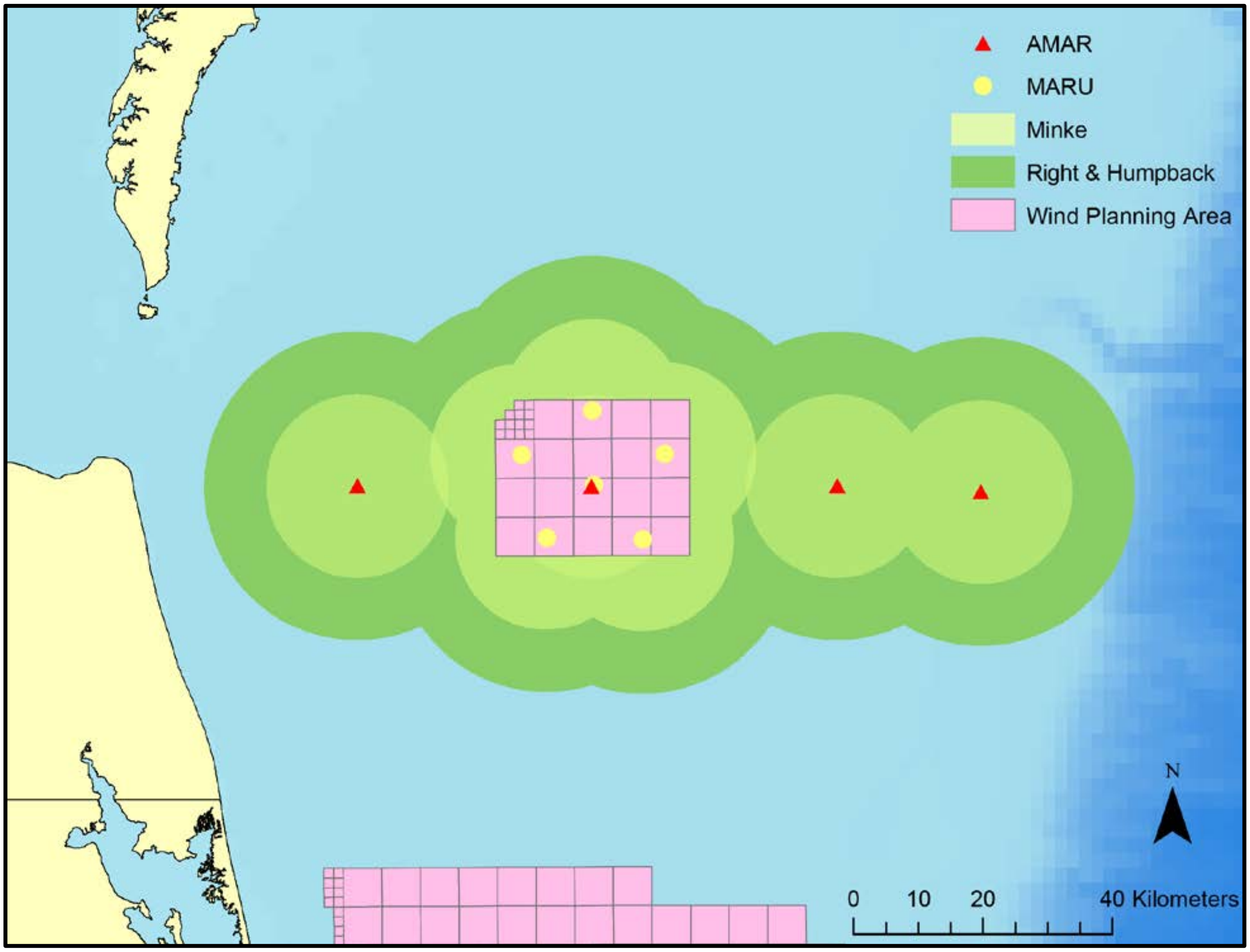


Figure 92. Map of low-frequency (MARU) and high-frequency (AMAR) passive acoustic recorders deployed across the continental shelf off the mouth of Chesapeake Bay. Green shading indicates estimate detection ranges for minke, Atlantic right, and humpback whales.

The initial deployment made in July 2015 was recovered in May 2016 and is currently being analyzed using a combination of human analysts and automated approaches to describe the occurrence of: (1) four species of mysticetes: fin, humpback, minke, and North Atlantic right whales; odontocetes; and U.S. Navy sonar signals.

The large geographic and temporal scale of the study enables a comparison of seasonal trends in cetacean presence across the continental shelf off the coast of Virginia, as well as inter-annual variability for this region. These results will help inform the U.S. Navy and BOEM of species occurrence, highly active seasonal periods, and high-use regions or corridors to assist with environmental regulatory compliance and spatial planning. More details on the preliminary results of the first deployment can be found in Klinck et al. (2017).

2.3.5.1 Mysticete species

Preliminary results from analysis of the initial deployment revealed that North Atlantic right whales were most common in the area in January through March (>90 percent days in the month of February).

Fin whales maintained a presence of greater than 50 percent of days of the month in October, November, January, and February. Humpback whales had low levels of presence in the fall, with some moderate (>30 percent of days) occurrence in January and April. Minke whales were detected on <10 percent of days in November.

2.3.5.2 Odontocete species

The high-frequency AMAR data is being collected at a sampling rate of 375 kHz and a duty cycle of 86 seconds (sec) every 685 sec is being analyzed as follows:

- High-frequency odontocetes (>100 kHz) - An automated click detector is being used to detect click trains of harbor porpoise and *Kogia* sp. in the data set. Every detection is visually reviewed by an analyst to confirm the detection and, if possible, to classify the signals to a species level.
- Mid-frequency odontocetes (<100 kHz) - LTSA plots with a temporal resolution of 5 sec and a frequency resolution of 200 Hz are calculated using the Triton Software Package (Scripps Whale Acoustics Lab, La Jolla, California). Data are visually- and aurally-inspected by experienced analysts for odontocete sounds. After initial screening data containing odontocete whistles and clicks are analyzed using the Real-time Odontocete Call Classification Algorithm (ROCCA) software to potentially classify signals top a species level.

Preliminary results indicate a high number of odontocete encounters in the data sets. For the first six months of data (July 2015 to January 2016), there was a clear inshore-offshore pattern in total number of encounters. During this period, a total of approximately 600 encounters were detected in the inshore data set recorded with AMAR1. For the same period, the AMAR2 data set contained approximately 330 encounters and the AMAR3 data set detected roughly 260 encounters. The data set collected furthest offshore (AMAR4) is still being analyzed.

Ongoing analysis efforts focus on deriving seasonality patterns as well as inshore-offshore differences in species composition.

2.3.5.3 Sonar analysis

A wide variety of sonar signals was recorded by the AMARs during the deployment. An example is shown in **Figure 93**. A band-limited energy detector in the Raven Sound Analysis software (Cornell University, Ithaca, New York) was trained to detect these signals of interest. The performance of the detector (precision-recall) is currently being analyzed using the initial six months of high-frequency data and will be compared to the performance of the SonarFinder software (Biowaves Inc., Encinitas, California).

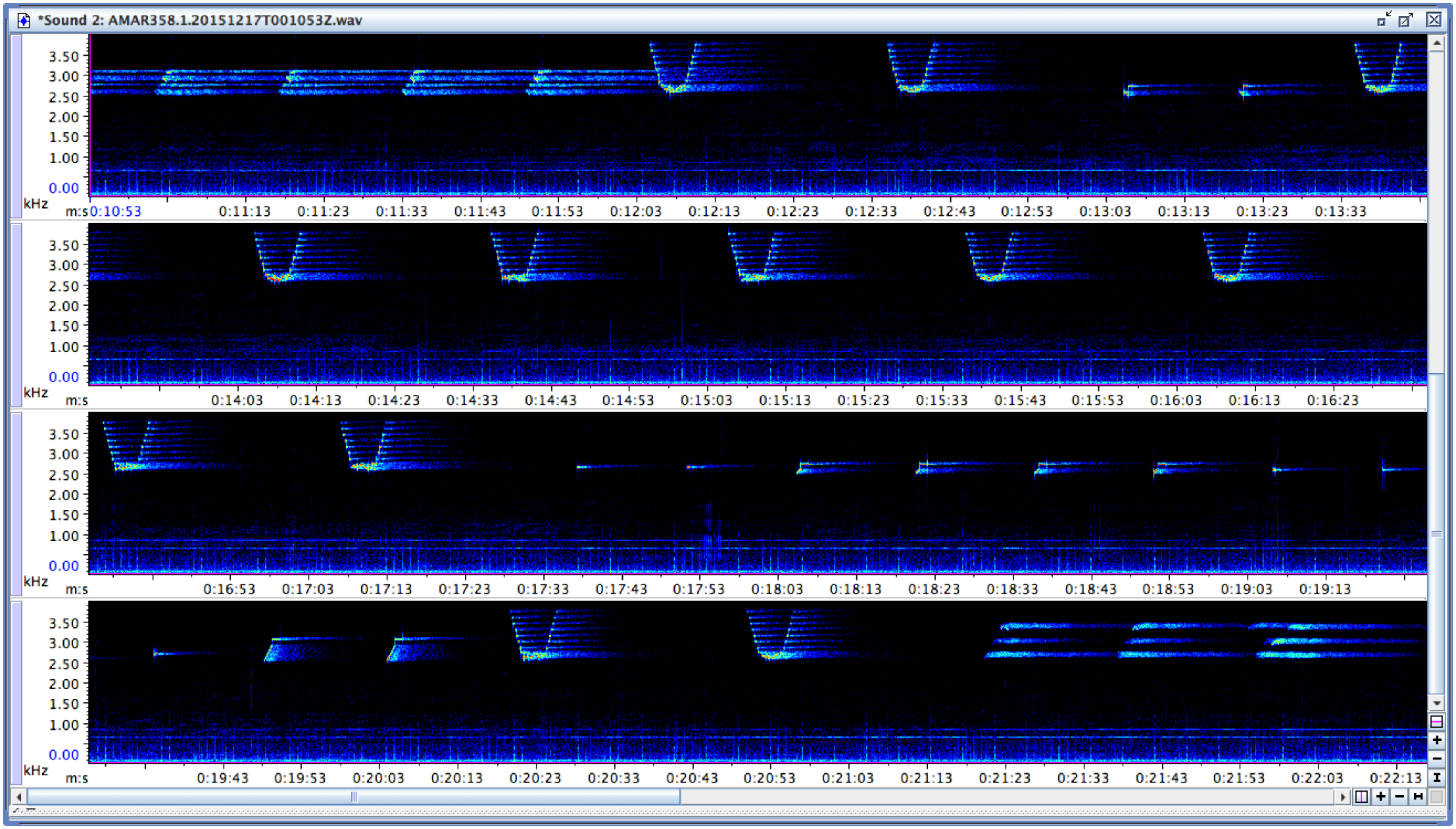


Figure 93. Example of U.S. Navy sonar signals recorded off the Virginia coast in December 2015.

2.3.6 Examining Factors that Could Affect Effect Identification of Odontocetes on Bottom-moored Recorders

Passive acoustic monitoring is used extensively to collect information regarding marine mammal occurrence, distribution and behavior in areas with high naval activity, and mitigation efforts rely heavily on data obtained by seafloor recorders. However, the suitability of automated species classifiers trained using surface data from towed arrays for analyzing recordings obtained at depth is currently unknown. If classifiers perform differently on data recorded at depth, it may be necessary to re-train them to ensure accurate results. Similarly, if the behavior of animals or signal propagation affects the identification of species using echolocation clicks, this must be understood and integrated into analysis methods.

A two-year study was initiated in 2015 to explore some of the factors that may contribute to ambiguity in odontocete species identification using whistles and echolocation clicks. This project is a collaboration between Bio-Waves, Inc. and Oceanwide Science Institute, with support from the National Marine Mammal Foundation, and is jointly funded by U.S. Fleet Forces Command under the U.S. Navy's MSM program, ONR, and the U.S. Navy's LMR Program.

Two types of vertical arrays were used to obtain recordings of whistles and echolocation clicks at different depths: (1) a surface array of microMARS recorders (http://www.desertstar.com/acoustic-recorders.html), and (2) a bottom array of second-generation EARs (EAR2s). Four data collection efforts were conducted: (1) off the island of Lanai in the Main Hawaiian Islands from 02 August through 12 August 2015 (pilot study); (2) off the Kona (west) coast of the island of Hawaii from 02 to 14 November 2015; (3) off the coast of San Diego, California from 15 to 27 May 2016; and (4) a controlled data-collection experiment in collaboration with the U.S. Navy's Marine Mammal Program off Point Loma, California.

During the Lanai pilot field effort (**Figure 94**), the bottom-moored EAR2 array was deployed approximately 5.6 km south of the island of Lanai in waters 355 m deep. After deployment of the bottom array, over six days of 31 hr of effort, visual surveys were conducted off the islands of Maui and Lanai using a 7.9-m R/V (the *Aloha Kai*) and a 6.4-m R/V (the *Coho*; due to engine problems on the *Aloha Kai*). The surface microMARS array was used to record groups of odontocetes that were encountered during these surveys. There were four encounters with odontocetes that included two groups of pantropical spotted dolphins, one group of spinner dolphins (*Stenella longirostris*), and one group of short-finned pilot whales. All EAR2s recorded successfully during the deployment period, yielding 2,063 2-min files, or approximately 68.7 hr of data per recorder. These recordings contained 28 delphinid acoustic encounters.

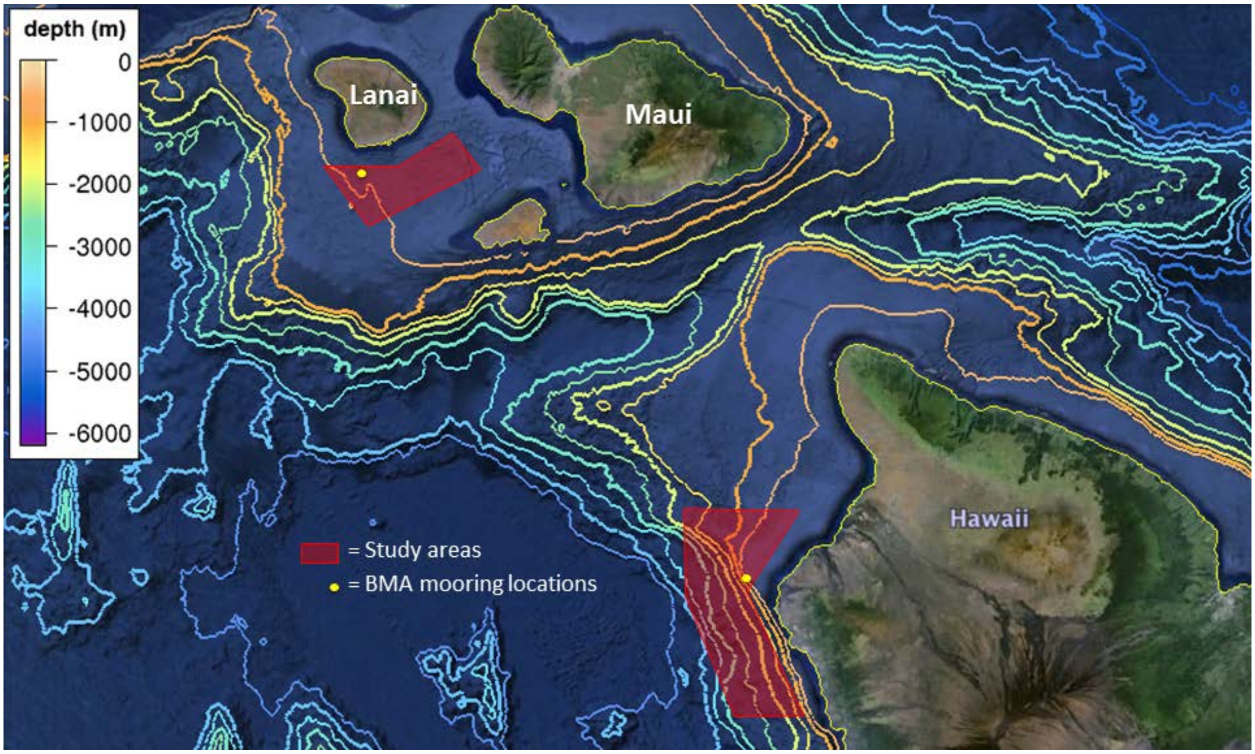


Figure 94. Lanai and Kona coast study areas. Bottom-moored array locations are shown as yellow circles.

During the Kona field effort (**Figure 94**), 80 hr of survey effort was spent over eight days. Odontocetes were encountered and recorded with the surface microMARS array on 14 occasions. These encounters included seven groups of pantropical spotted dolphins, three of short-finned pilot whales, and one encounter each with rough-toothed dolphin, false killer whale (*Pseudorca crassidens*), spinner dolphin, and pygmy killer whale (*Feresa attenuata*). The EAR2 recordings yielded 538 10-min files, or approximately 90 hr of data per recorder.

During the San Diego effort, the EAR2 array was moored on the sea floor approximately 13 km off La Jolla, California (**Figure 95**), in a water depth of 465 m and recorded for 10 min every 30 min. Visual surveys were conducted between Point Loma and La Jolla, and on the leeward (east) side of Catalina Island using one of two 8.5-m sport-fishing vessels (the *Seasons* and the *Ugly Guy*). The surface microMARS array was deployed near groups of odontocetes that were encountered during these surveys. Approximately 75 hr of survey effort were spent searching for and/or recording odontocetes over 11 days. Odontocetes were encountered and recorded with the surface microMARS array on 16 occasions. Common dolphins dominated the sightings, with eight sightings of unidentified common dolphins, three of confirmed short-beaked common dolphins, and two of confirmed long-beaked common dolphins. Also encountered were two groups of bottlenose dolphins and one of unidentified odontocetes. The EAR2s yielded 521 10-min files, or approximately 87 hr of data per recorder. Analyses are underway and will be presented in a future report.

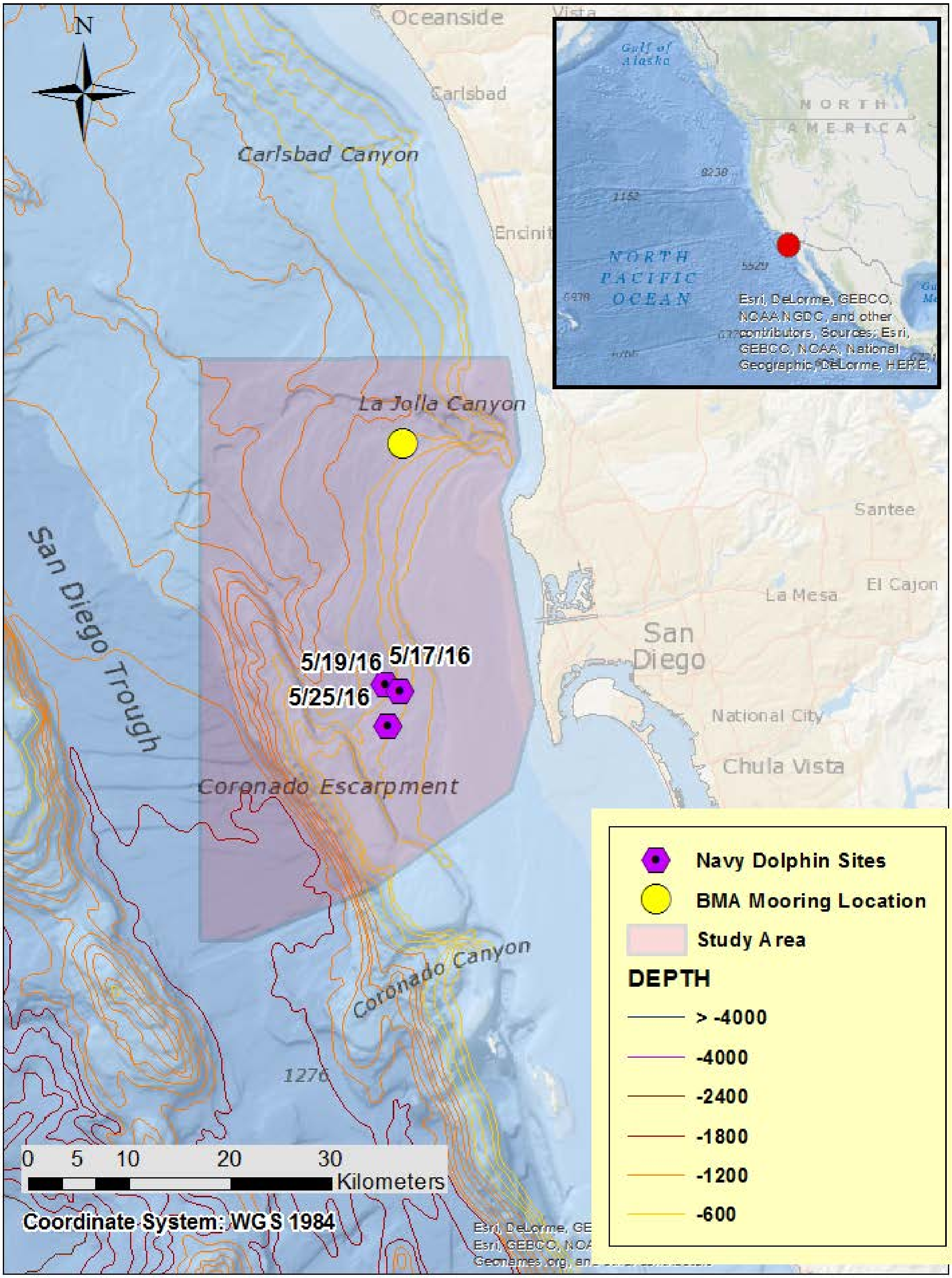


Figure 95. Map of San Diego study area with location of the bottom-mounted EAR2 array and Navy dolphin trials.

In addition to the vessel surveys, a controlled data-collection experiment was conducted in collaboration with the U.S. Navy Marine Mammal Program. A trained U.S. Navy bottlenose dolphin was transported by boat to an open-water location (approximately 1,000 m in depth) off Point Loma (**Figure 95**). Whistles were recorded using the surface microMARS array at distances of approximately 50, 100, 250 and 400 m from the dolphin. The dolphin was oriented in two positions: 1) facing directly towards the array and, 2) facing directly away from the array. Approximately 8 of the 75 total survey hr (10.6 percent) were spent working with the U.S. Navy dolphin to collect controlled data. Results of these trials will be analyzed and included in a later report.

Initial whistle analysis has focused on data recorded during the Lanai pilot study deployment. The surface microMARS array that was used during the Lanai pilot field effort contained hydrophones (of different sensitivities and frequency ranges) deployed at different depths. Because of the differences in microMARS sensitivities and configurations throughout the pilot study work, it was not possible to compare whistles and clicks among depths for the surface microMARS.

For each encounter recorded on the bottom-moored EAR2 array during the Lanai pilot field effort, whistles were measured and classified from 20 of the 28 recorded encounters. Eight of the 28 encounters did not contain enough whistles to be included in the analysis. Whistle contours were extracted and measured using the ROCCA (Oswald et al. 2013) module in the acoustic data processing software platform, PAMGuard (Gillespie et al. 2008). The whistles obtained were characterized on the basis of their spectral properties and duration for each recording depth and also compared among different instruments deployed at the same depth.

In the 20 encounters that were included in the analysis, not all whistles were detected on all EAR2s. For some encounters, a high percentage of whistles was detected on all four EAR2s, but for others, the majority of whistles was detected on only one EAR2. In most cases, the greatest number of whistles was detected on the deepest EAR2. **Figure 96** shows an example of a whistle that was detected on more than one EAR2, but with only a portion of the contour evident in some of the recordings.

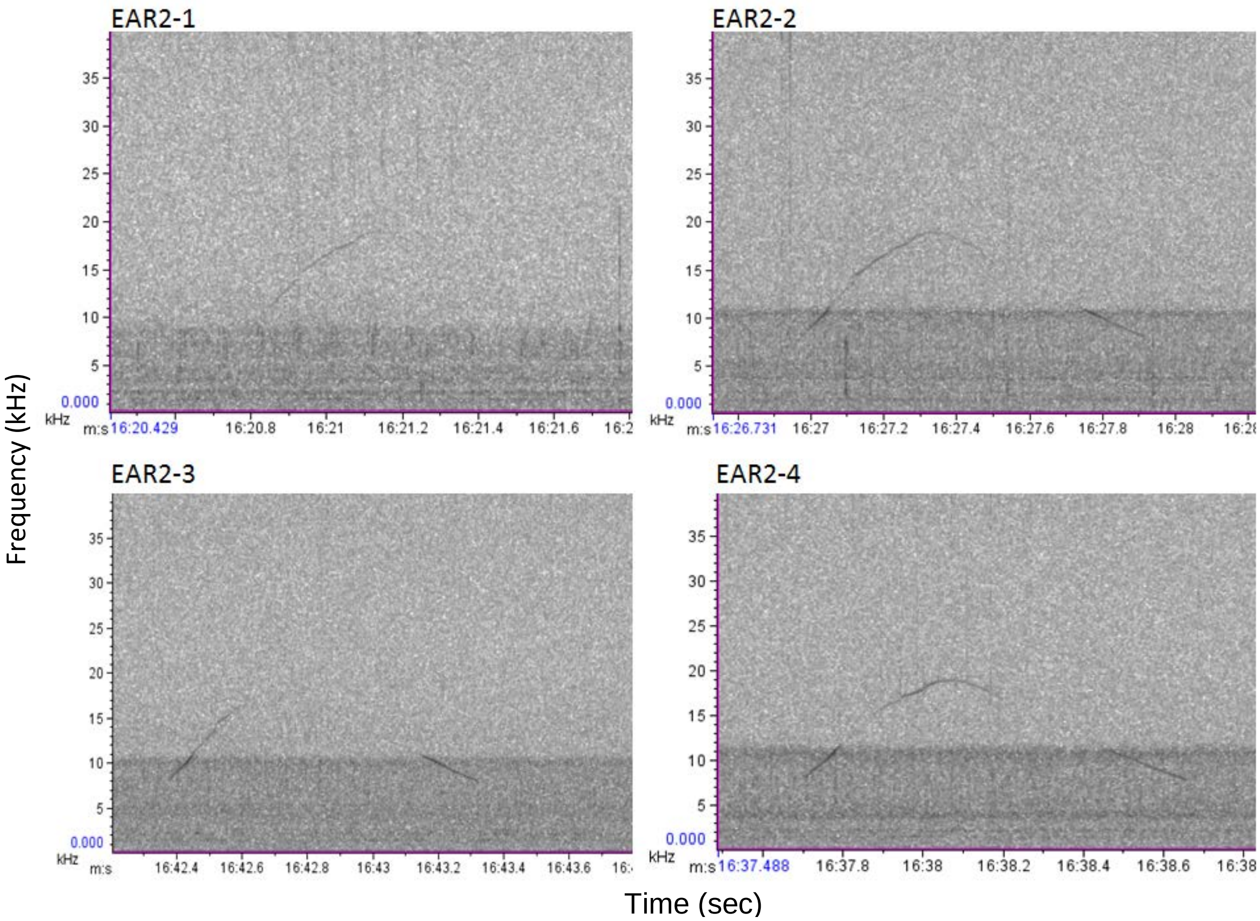


Figure 96. Example of a whistle detected on more than one EAR2, but with only a portion of the contour evident in some of the recordings.

For all whistles measured for each encounter, one or more variables were significantly different (Kruskall-Wallis test and post-hoc Dunn's tests with Bonferonni correction, α=0.05) when compared among EAR2s for eight of the 20 encounters (40 percent). Most of the significant differences were for variables measuring frequency characteristics; mean, median and center frequency were significantly different among EAR2s for six of the encounters. Slope variables, duration, and other frequency variables also were significantly different for some of the encounters. For only those whistles that appeared on all four EAR2s, only one of the 13 encounters (8 percent) showed a significant difference (Kruskall-Wallis test and post-hoc Dunn's tests with Bonferonni correction, α=0.05).

Whistle variables also were used to classify whistles to species using a random-forest classifier within ROCCA. The random-forest classifier used in this analysis was a two-stage classifier trained using whistles recorded from single-species schools in the tropical Pacific Ocean. Six species were included in the model: short-finned pilot whale, false killer whale, pantropical spotted dolphin, bottlenose dolphin, rough-toothed dolphin, and spinner dolphin. The first stage consisted of classifying whistles to one of two categories: 'large delphinids-*Steno'* (including false killer whale, pilot whale and rough-toothed dolphin) and '*Stenella-Tursiops*' (including spinner, spotted, and bottlenose dolphins). In stage two of the model, whistles within each category then were classified to species (**Figure 97**).

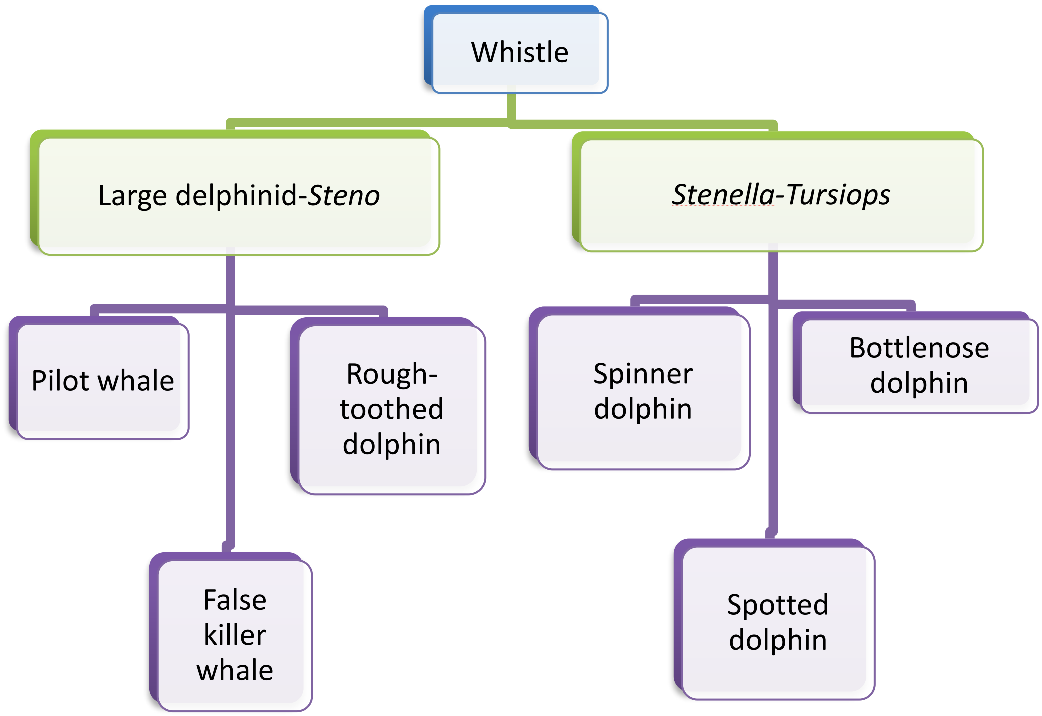


Figure 97. Schematic diagram of the two-stage random-forest classifier. In stage one, whistles are classified to one of two broad categories ('large delphinid-*Steno*' or '*Stenella-Tursiops*'). In stage two, whistles within each category are classified to individual species or species-group.

For 10 of the 20 encounters (50 percent), ROCCA classified the encounter as a different species based on whistles recorded at different depths. Usually, one out of the four EAR2s had a different classification result. Four of the 10 encounters (40 percent) that were classified differently on different EAR2s had significant differences in whistle variables and six (60 percent) did not. Of the 10 encounters that were classified as the same species on all four EAR2s, four (40 percent) had significant differences in whistle variables among EAR2s. When classification results were different on one or more of the EAR2s, the percent of tree votes was often similar for the two species that the encounter was classified as on the different EAR2s.

Thirteen of the 20 (65 percent) encounters included a sufficient number of whistles that were detected on all four EAR2s (at least 10 whistles). Variables from only the whistles that occurred on all four EAR2s were compared statistically to determine if there were any significant differences in the characteristics of the contours. Significant differences were found in only one encounter (8 percent) and for only one variable; minimum frequency was significantly different (p=0.04) between EAR2-1 and EAR2-3 (average deployment depths of 70 m and 250 m, respectively).

However, this difference did not affect classification success as all four EARs classified the encounter as the same species. Four of the encounters (31 percent) were classified as one species for three of the EAR2s and as a different species on the fourth EAR2. The EAR2 that differed was not consistent among encounters. For all four of these encounters, the percent of trees votes was similar for the two species in question. The remaining nine encounters (69 percent) were classified as the same species on all four EAR2s.

The analyses presented for the Lanai EAR2 dataset are currently being performed on the Kona and San Diego EAR2 and microMARS datasets. Differences in whistle variables and classification results at different depths will likely be affected by the position of the animals relative to the hydrophone array. Upcoming analyses include localizing whistles in order to examine these relationships, as well as performing sound propagation analyses to investigate further the causes of the observed differences and similarities in relation to recording depths. The analyses will be performed for the Lanai, Kona, and San Diego datasets and presented in a future report.

For more information on this study, refer to the annual progress report for this project (Oswald et al. 2016a).

2.3.7 Development of Statistical Methods for Examining Relationships Between Cetacean Vocal Behavior and Navy Sonar Signals

Changes in vocal behavior in response to U.S. Navy active sonar signals have been observed for several species of marine mammals (e.g., Rendell and Gordon 1999; Miller et al. 2000; Clark and Altman 2006; Di Iorio and Clark 2010; McCarthy et al. 2011; Tyack et al. 2011; Melcón et al. 2012; DeRuiter et al. 2013a, 2013b; Stimpert et al. 2014; S.W. Martin et al. 2015; Isojunno et al. 2016). In a previous collaborative effort with the University of St. Andrews and Cornell University, statistical methods were compared to determine the best approach for examining the effects of MFA sonar on delphinid vocal behavior (Oswald et al. 2015). Passive acoustic data analyzed in that study were collected during two deployments of MARUs off the coast of Jacksonville and one deployment of MARUs in Onslow Bay. To identify potential changes in cetacean acoustic behaviors in association with MFA sonar, the occurrence of sonar pings and cetacean sounds during sonar exercises and 24 hr after the end of sonar exercises were compared to observations from a 24-hr control period prior to the commencement of sonar exercises. Results of that analysis indicated there was low statistical power by which to detect response effects primarily due to the limited number of independent sonar events available in the Jacksonville and Onslow Bay datasets.

The current work was conducted to: a) increase the sample size of sonar and cetacean encounters, b) add additional species in order to examine species-specific differences in responses, and c) further develop and refine robust statistical methods previously developed in a related earlier study to evaluate the effects of MFA sonar on the acoustic occurrence of cetaceans.

2.3.7.1 Methods

For this study, Duke University provided recordings from four HARPs that were deployed coincident with U.S. Navy sonar training events between 2010 and 2012. One HARP was deployed off the coast of Cape Hatteras (HAT01A), one off the coast of Jacksonville (JAX05A), and two in Onslow Bay (USWTR05A and USWTR06E) (**Table 60**).

Table 60. HARPs and sonar events used for analysis. Total duration of sonar period represents the total period analyzed from the start of the first sonar event to the end of the last sonar event.

Site Number	Site ID	Deployment Start	Deployment End	Sample Rate (kHz)	Depth (m)	Latitude (°N)	Longitude (°W)	Sonar Start	Sonar End	Total Duration of Sonar Period (h)
1	Cape Hatteras (HAT01A)	03/15/2012 12:48	03/23/2012 00:12	200	950	35.34054	74.85761	03/17/2012 13:33	03/20/2012 14:30	72:57
2	Jacksonville (JAX05A)	10/06/2010 00:47	10/26/2010 1:35	200	91	30.26819	80.20894	10/07/2010 18:30	10/24/2010 13:49	403:19
3	Onslow Bay 1 (USWTR05A)	02/12/2011 23:20	02/21/2011 1:10	200	171	33.79316	76.51620	02/16/2011 02:22	02/18/2011 03:54	49:32
4	Onslow Bay 2 (USWTR06E)	08/18/2011 00:01	09/19/2011 1:11	200	952	33.77794	75.92641	08/21/2011 21:20	08/23/2011 04:04	30:44

Trained analysts scrolled through LTSAs using the software package Triton (Wiggins 2007) with a 30-min resolution setting to identify sonar events and acoustic encounters for minke whales, sperm whales, beaked whales, and delphinid species. Detections were grouped into "acoustic encounters," where an acoustic encounter was defined as a series of sounds produced by one species with less than 30 min between sounds. For delphinid acoustic encounters the number of sounds (i.e., whistles, clicks, buzzes) per minute within each encounter was tallied using PAMGuard's automated whistle & moan detector and click detector modules, as well as a custom written MATLAB script (Bin-it Counter.m). For beaked whales and sperm whales, classifiers within PAMGuard were used to classify clicks, which were subsequently marked by encounters. Clicks were analyzed and tallied for each encounter. Minke whale encounters were "sub-logged" (e.g., examined at a finer scale) to identify the start time, end time for each pulse train, and type of pulse trains within each encounter. Spectrogram correlation templates for four types of active sonar (e.g., in frequency bands: 1 to 3 kHz, 3 to 5 kHz, 5 to 7 kHz, and 7 to 10 kHz) were created to detect individual sonar pings in the dataset. Sonar events were reviewed manually to ensure there were no missed pings and that any false detections were removed. Variables describing frequency content, duration, and received SPL were measured from all true positive sonar detections using the MATLAB program SonarFinder (Bio-Waves, Inc. 2013). Detected sonar pings were categorized by frequency (Type 1: $\leq$4 kHz, Type 2: 4 to 7 kHz, Type 3: $\geq$7 kHz) and duration (Short: $\leq$1.5 sec; Medium: 1.5–4.0 sec; and Long: $\geq$4.0 sec).

Once data had been logged and characterized, five distinct statistical analyses were conducted across four cetacean taxa: delphinids, beaked whales, minke whales, and sperm whales. First, a regression analysis was conducted of cetacean acoustic absence or presence to address whether sonar activity influenced acoustic presence. Second, a hidden Markov model (HMM) analysis of cetacean acoustic absence or presence was performed to address the same question using a different statistical method. The third analysis was a comparison of minke whale pulse train duration with and without sonar present. The fourth analysis was a regression analysis of dolphin signal type (i.e., whistles, clicks, and buzzes) presence-absence in a given acoustic encounter to address whether sonar occurrence influenced the occurrence of a particular signal type. Finally, a regression analysis of a composite index of delphinid whistles was conducted to examine whether whistle characteristics changed in the presence of U.S. Navy sonar.

Various covariates related or unrelated to sonar were used as potential explanatory covariates. Those related to sonar included the time period relative to sonar activity as well as various features of the sonar such as signal type and SPL. When appropriate, data from this study were added to similar datasets from earlier studies collected by Bio-Waves, Inc. and Cornell University using MARUs in order to increase the sample size.

2.3.7.2 Results

Sonar

A total of 57 sonar events were identified in the entire dataset, with an overall cumulative sonar event duration of approximately 157 hr (**Table 61**).

Table 61. Summary of sonar events per site. The total sonar duration per site represents the cumulative duration of the actual sonar events, excluding gaps between events.

Site ID	Total Number of Sonar Events Per Site	Total Sonar Duration Per Site (hh:mm:ss)	Total Number of Pings Per Site	Mean SPL Per Site (dB re: 1 µPa)	Median SPL Per Site (dB re: 1 µPa)
Cape Hatteras (HAT01A)	13	21:39:12	1391	71.7	70.4
Jacksonville (JAX05A)	36	115:58:06	4740	81.3	78.8
Onslow Bay 1 (USWTR05A)	6	6:59:23	127	86.2	83.2
Onslow Bay 2 (USWTR06E)	2	12:23:45	759	78.7	75.7

Cetaceans

<u>Delphinids</u>

A total of 44 delphinid encounters contained enough whistles to be included in the ROCCA analysis. Most of these encounters (*n*=28) were recorded on the HARP deployed off Jacksonville. The majority of these encounters (61 percent) were classified as Atlantic spotted dolphins or bottlenose dolphins, and small percentages of encounters were classified as pilot whales or striped dolphins (**Figure 98)**. There were six encounters analyzed from the Onslow Bay 1 data and six encounters analyzed from the Onslow Bay 2 data. Most of the encounters were classified as bottlenose dolphins and a small percentage were classified as pilot whales or striped dolphins at both sites (**Figure 98**). One Onslow Bay 2 encounter was classified as spotted dolphins. All of the five encounters analyzed from the Cape Hatteras data were classified as bottlenose dolphins.

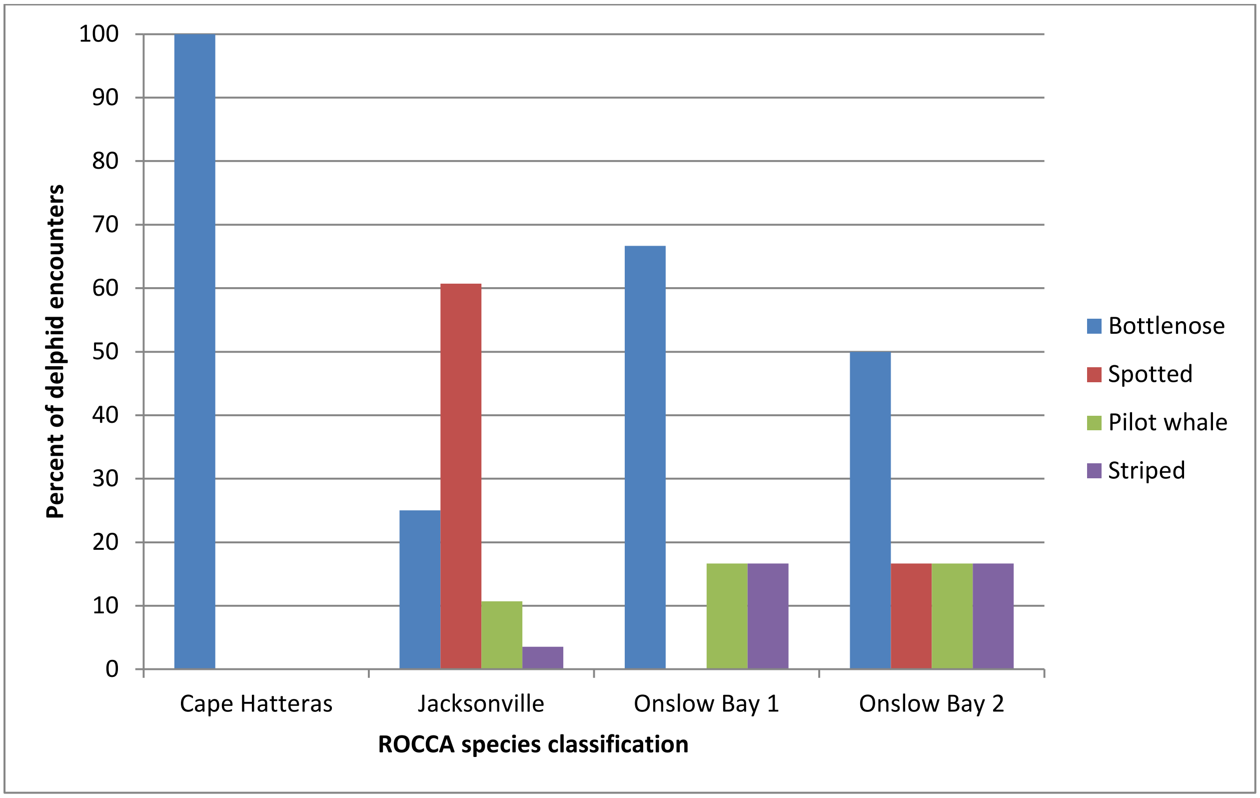


Figure 98. Percentage of delphinid acoustic encounters classified by species for Cape Hatteras (n=5), Jacksonville (*n*=28), and Onslow Bay 1 (*n*=6), Onslow Bay 2 (*n*=6).

Beaked Whales

A total of 61 beaked whale encounters with an overall duration of approximately 37 hr was logged in the dataset. Identified species included Cuvier's beaked whale, *Mesoplodon* sp., and Sowerby's beaked whale.

Minke Whale

A total of 50 minke whale encounters was logged in the dataset with an overall duration of approximately 124 hr. Minke whale pulse trains were not detected in the Jacksonville and Onslow Bay 2 datasets.

Sperm Whale

A total of 49 sperm whale encounters with an overall duration of approximately 79 hr was logged in the dataset

Cetaceans and Sonar

Delphinids

A direct influence of sonar activity (measured as a change in the response variable before, during, between and after sonar activity) on delphinids was not found. Detection of delphinid whistles, clicks, and buzzes increased during sonar activity, particularly in the presence of Type 1 long or Type 2 long sonar signals. Detection of whistles was negatively associated with the presence of clicks and positively associated with the presence of buzzes. When the effect of a specific component of sonar could be detected, the component was always a long signal.

Beaked Whales

Acoustic detection of beaked whales showed a noticeable decline during periods of sonar activity (this was possibly a response to the Type 1 long signal component), with no evidence of recovery over the course of monitoring. This result is not surprising, given the known sensitivity of this taxon to MFA sonar and other types of acoustic events (Tyack et al. 2011; DeRuiter et al. 2013b, Stimpert et al. 2014). It appears that the occurrence of the long MFA sonar signal resulted in decreased acoustic detections. Previous work during controlled exposure experiments has shown observed behavioral (vigorous swimming, directed travel, changes in dive behavior) and acoustic responses (cessation of echolocation activity) from multiple beaked whale species, including Cuvier's (DeRuiter et al. 2013b), Blainville's (Tyack et al. 2011), and Baird's (*Berardius bairdii*) (Stimpert et al. 2014) beaked whales. There was also a marked diurnal pattern in acoustic detections in this taxon, showing a decrease in vocal activity between 10:00 and 20:00 hr, as well as a site effect, with the deeper Hatteras site recording more detections, which is in agreement with the observational data (McLellan et al. in prep.) for the region.

No effect of MFA sonar on beaked whales was detected at any site using the HMM method despite the known sensitivity of beaked whales.

Minke Whale

Minke whale detections showed a decline once sonar activity started, but with some indication of subsequent recovery in the 24 hr after sonar ended. The HMM detected an MFA sonar effect at both HARP sites where minke whales occurred. We also found that minke whales at HAT01A tend to spend more time in the "silent" state both during and between MFA sonar exposures. However, there was no MFA sonar effect on minke pulse train duration, merely a difference in durations between sites. These results are consistent with other observations of minke whale response to naval sonar. For example, progressive aversion of minke whales to sonar playback has been shown, whereby the tagged animal increased speed and changed dive patterns to move away from the sound source (Sivle et al. 2015). Additionally, the density of minke whales, as evidenced by pulse train detections, has been shown to decrease in response to U.S. Navy sonar activity (S.W. Martin et al. 2015). Opportunistic observations of minke whale displacement and avoidance in response to MFA sonar have also been noted (Dolman et al. 2011, Parsons et al. 2000).

Sperm Whale

No effect of sonar on sperm whales was detected; these results are consistent with previous studies that did not detect changes in sperm whale foraging behavior in response to MFA sonar (Isojunno et al. 2016, Sivle et al. 2012). There was a marked difference between the numbers of day and night acoustic detections. The significantly higher probability of detecting sperm whale clicks at night is in line with previous studies, which have shown that sperm whales in the northwestern Atlantic exhibit a diel foraging behavior pattern (Hodge et al. 2013, Yack et al. 2016).

The results of this study have provided some insights to species-specific responses to U.S. Navy sonar and have resulted in the development of innovative statistical methods for assessing the impacts of a U.S. Navy MFA sonar on some of the parameters describing the acoustic detections of cetaceans. The statistical methods used here can be applied to additional datasets in other geographic regions to provide further insights into the effects of U.S. Navy MFA sonar on marine mammals.

For more information on this study, refer to the final report for this project (Oswald et al. 2016b).

2.3.8 Sperm Whale Response Analysis

In an effort designed to examine the vocal behavior of sperm whales, existing passive-acoustic datasets from JAX, Onslow Bay (OB), and Cape Hatteras (HAT) were analyzed to assess the presence and diel patterns of foraging behavior of sperm whales in the coastal Atlantic Ocean off the mid-Atlantic and southeastern United States. These acoustic recordings were made off Jacksonville, Florida (12 September–04 October 2009 and 04–26 December 2009) and in Onslow Bay, North Carolina (05–27 July 2008) using MARUs sampling at 32kHz, and off Cape Hatteras, North Carolina (16 November–19 December 2013) using AMARs sampling at 128 kHz (**Table 62, Figure 99**). Detailed analysis was conducted using a combination of automated and semi-automated methods to characterize the vocal behavior of sperm whales, using foraging buzzes as indicators of active prey-capture attempts.

Table 62. Deployment information for MARUs (JAX and OB) and AMARs (HAT) used to collect the data supplied for analysis of sperm whale vocal behavior.

Region	Recorder/Site	Latitude (N)	Longitude (W)	Recorder Depth (m)	Deployment	Recording Start	Recording End	No. Recording Days
JAX-1	2 (Site 4)	30° 21.435′	80° 09.331′	168	1	12-Sep-09	04-Oct-09	23
JAX-1	74 (Site 5)	30° 14.505′	80° 10.879′	201	1	12-Sep-09	04-Oct-09	23
JAX-1	96 (Site 6)	30° 07.594′	80° 12.486′	192	1	12-Sep-09	04-Oct-09	23
JAX-2	2 (Site 4)	30° 21.357′	80° 09.170′	168	2	04-Dec-09	26-Dec-09	23
JAX-2	74 (Site 5)	30° 14.480′	80° 10.843′	201	2	04-Dec-09	26-Dec-09	23
JAX-2	96 (Site 6)	30° 07.609′	80° 12.503′	192	2	04-Dec-09	26-Dec-09	23
OB	PU152 (Site 1)	33˚ 43.546′	76˚ 22.132′	365	-	05-Jul-08	27-Jul-08	23
OB	PU154 (Site 2)	33˚ 40.454′	76˚ 35.382′	236	-	05-Jul-08	27-Jul-08	23
OB	PU159 (Site 3)	33˚ 34.164′	76˚ 33.309′	365	-	05-Jul-08	27-Jul-08	23
HAT	A3 (Site 1)	35° 45.414′	74° 49.080′	626	-	16-Nov-13	19-Dec-13	34

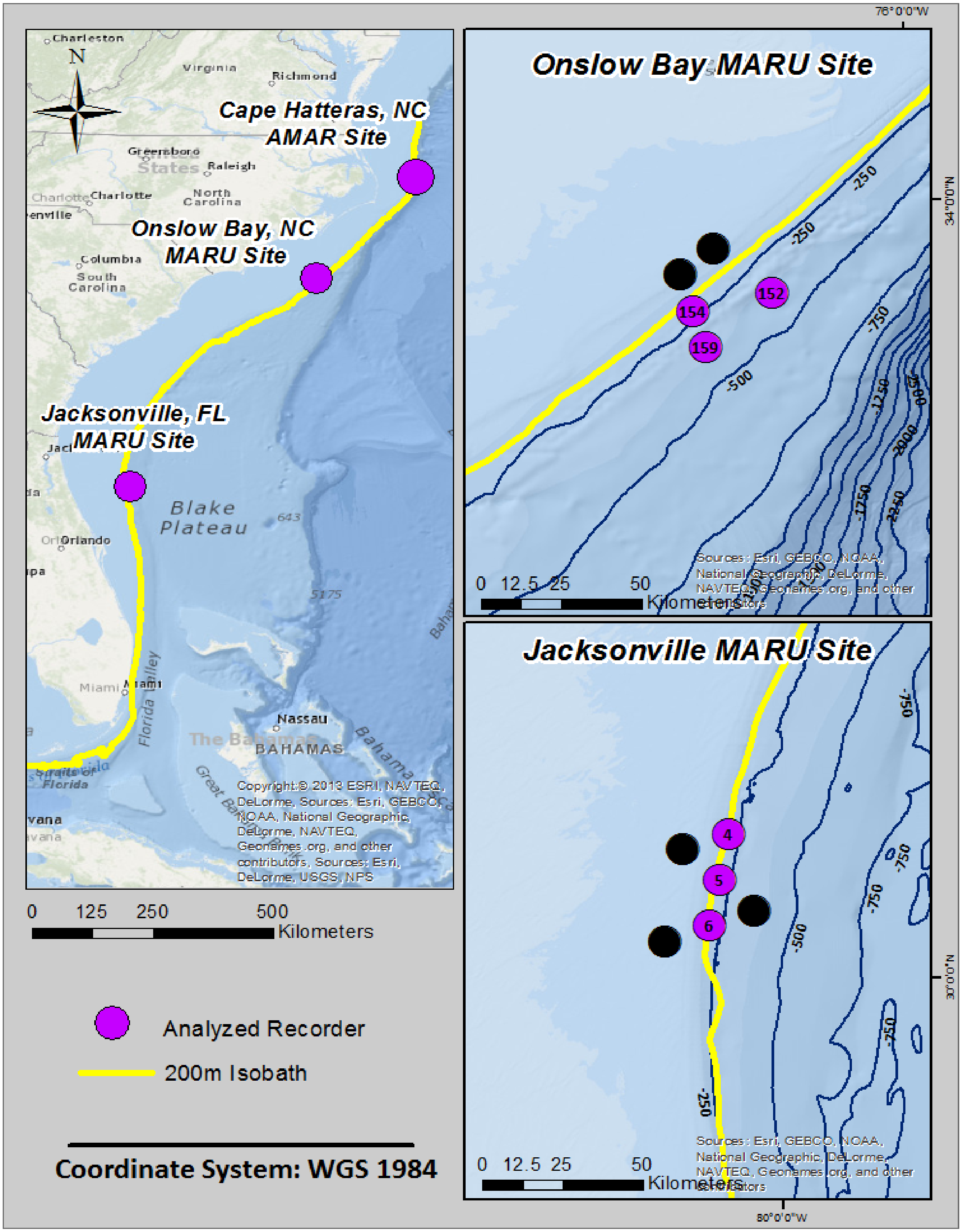


Figure 99. Location of passive acoustic data collection analyzed for sperm whale vocal behavior.

Nine MARUs were deployed off JAX during the fall and winter, and five MARUs were deployed off OB during the summer. The MARUs were deployed in shallow (44 to 73 m), mid-water (160 to 236 m), and deep-water sites (>300 m). Off JAX, three recorders were deployed at each of the three depth ranges, for a total of nine MARUs for each of the two (fall and winter) deployment periods. The units recorded using a 32-kHz sampling rate (32-kHz recorders). In OB, two MARUs were deployed in shallow-water, one in mid-depth water, and two in deep-water sites. Each MARU sampled continuously at a high-frequency rate of 32 kHz.

The four AMARs were deployed off HAT during the winter (B. Martin et al. 2015). The AMARs recorded continuously at 128 kHz. Three recorders were deployed in an equilateral triangle at 1-km distance from each other with a fourth recorder located in the center of the triangle. The recorders were deployed at depths between 427 and 626 m. Because the recorders were deployed within relatively close proximity to each other, it was assumed that most click events were detected on all recorders. Therefore, acoustic data from only the deepest (626 m) deployed AMAR was used in this analysis (**Table 62**).

All encounters were processed using PAMGuard, and each encounter was further processed in PAMGuard's Viewer Mode software to mark click-train and foraging-buzz events in the dataset. After identifying all click trains and foraging buzzes in an encounter, clicks were exported to ROCCA, a module in PAMGuard, which was used to obtain click counts, echolocation click measurements, and detailed time and duration information.

Diel patterns were examined in the occurrence of vocal events at each site by dividing the recordings into 3-hr and 1-hr time bins, as well as photoperiods (i.e., daylight versus dark) and obtaining click counts for each period. The number of clicks in each time bin was calculated for each day using custom MATLAB code 'Bin-It Counter.' Photoperiod (day versus night) was assigned to each 3-hr time bin to broadly categorize bins as either light or dark as follows: 00:00–03:00, 03:00–06:00, 18:00–21:00, and 21:00–24:00 were designated as "dark" time bins, the other four bins were designated as "daylight" time bins. For each calendar date, we summed the number of clicks within each photoperiod (daylight versus dark). The data violated the parametric assumption that modelled residuals conform to a normal distribution, so a Kruskal-Wallis test was used to determine if there were significant differences in the number of clicks among: (1) 3-hr bins within and among sites, (2) photo-periods within and among sites, and (3) hourly bins within and among sites. Multiple comparison Dunn's tests with Bonferroni corrections also were performed to determine how diel patterns varied among sites.

Vocal behavior varied both within and among the regions/deployments compared. Overall the highest number of encounters and highest total duration of encounters occurred during JAX-1 (n=90 encounters, approximately 113 hr), followed by JAX-2 (n=46 encounters, approximately 68 hr), OB (n=39 encounters, approximately 50 hr), and HAT (n=28 encounters, approximately 23.5 hr), respectively. A total of 4,108 click train events and 43 foraging buzz events were identified

The proportion of days with click trains and foraging buzzes present was highest overall at the JAX sites, followed by HAT and OB, respectively. The percentage of recording days with vocal activity varied by recording site and geographic region (**Figure 100**). Click trains were present every day of the JAX-2-6 recorder deployment, 91 percent of days at OB site 1-2, and 83 percent of days at JAX 1-4. Foraging buzzes were present during the highest percentage of days overall during both JAX deployments (10 percent), followed by HAT (3 percent) and OB (1 percent) (**Figure 100**).

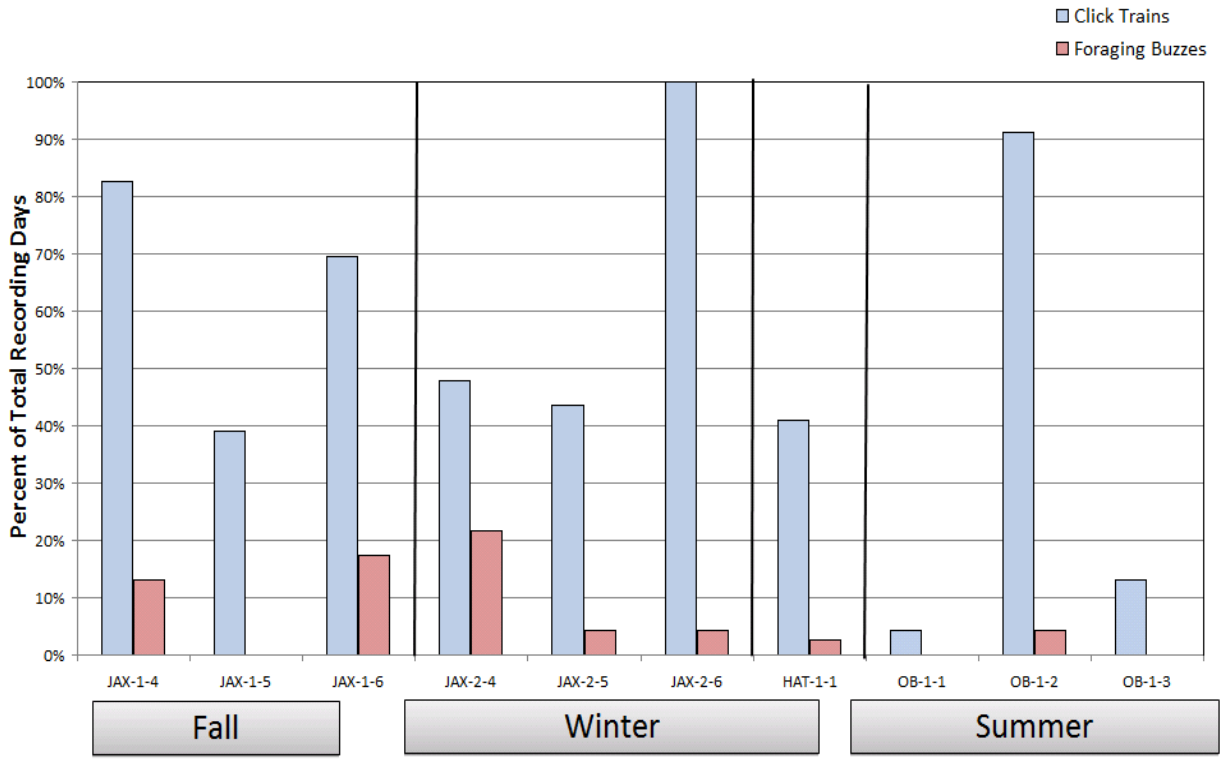


Figure 100. Percentage of recording days with vocal activity by recording site and geographic region.

The data suggest that there are strong diel patterns of sperm whale vocal activity in the JAX and OB regions. There were only significant differences in click counts within daylight periods at OB compared to all other sites and overall among regions. There were only significant differences within dark periods at HAT compared to all other sites and overall among sites.

Randomization tests showed that all regular click parameters were significantly different overall among regions. Peak frequency was significantly different (p<0.05) only between OB and all other deployments, and the number of zero crossings was not significantly different between the two JAX deployments. Kruskal-Wallis test results showed significant variability among deployments for all six of the regular echolocation click parameters. The Dunn's test results showed statistically significant pair-wise difference between deployments for all of the regular echolocation click parameters, except for peak frequency between the JAX-2 deployment and HAT.

For more information on this study, refer to the annual progress report for this project (Yack et al. 2016).

2.3.9 Development of Atlantic Odontocete Whistle Classifiers

In 2013, two (one manual, one automatic) random-forest classifiers were developed by Bio-Waves, Inc. to identify the whistles of five species of odontocetes (bottlenose dolphin, Atlantic spotted dolphin, striped dolphin, short-beaked common dolphin, and short-finned pilot whale) recorded in the western North Atlantic Ocean (Oswald 2013). When both of these classifiers were tested using four-fold cross validation, 86 percent and 91 percent of encounters were classified correctly for the manual classifier and the automated classifier, respectively. Since the initial development of these classifiers, additional visual and acoustic shipboard surveys have occurred in the northwest Atlantic Ocean through the Atlantic Marine Assessment Program for Protected Species (AMAPPS). This new data allowed Bio-Waves, Inc. to test the performance of the existing classifiers, add new species to the classifiers, and use the manual classifier to identify AMAPPS 2013 acoustic encounters that did not have visual confirmation of species identity. The AMAPPS 2013 survey was a visual and acoustic line-transect marine mammal abundance survey that was conducted from 01 July to 15 September 2013 by the NMFS' SEFSC and the NEFSC. These surveys covered waters of the northern Atlantic continental shelf-break, from the 100-m depth contour to the edge of the EEZ, and ranged from South Carolina in the south to the southern tip of Nova Scotia, Canada, in the north. Passive acoustic data were collected using towed hydrophone arrays (NEFSC and SEFSC 2013).

Whistles were detected and extracted manually from the AMAPPS 2013 passive acoustic dataset using the Raven Pro Software (Version 1.4; Bioacoustics Research Program 2011), and the PAMGuard ROCCA module. They also were detected and extracted automatically using PAMGuard's WMD module. Acoustic encounters with visual confirmation of species identity were classified using both the manual and automated classifier approaches. Recordings for four out of the five species that were included in the Atlantic classifiers (with the exception of short-finned pilot whales) were available. Small sample sizes made it difficult to evaluate classifier performance for short-beaked common dolphins and striped dolphins.

The manual classifier performed relatively well, correctly classifying 77 percent of Atlantic spotted dolphin encounters and 93 percent of bottlenose dolphin encounters (**Table 63**). The automated classifier misclassified every encounter as pilot whales. This is likely due to the fact that different versions of PAMGuard were used to detect and extract whistles for the Atlantic classifier training dataset and the AMAPPS 2013 test dataset. Determining the exact cause of these discrepancies within PAMGuard was beyond the scope of this project but should be investigated further.

Table 63. Number of acoustic encounters and whistles with visual confirmation of visual identity measured manually and using automated methods from the AMAPPS 2013 dataset.

Species	Manual		Automated	
	Number of Encounters	Number of Whistles	Number of Encounters	Number of Whistles
Short-beaked common dolphin	3	59	3	179
Risso's dolphin	2	50	2	283
Pantropical spotted dolphin	2	61	2	2,560
Rough-toothed dolphin	4	176	4	2,832
Striped dolphin	2	72	2	348
Clymene dolphin	3	136	3	15,956
Atlantic spotted dolphin	13	510	13	5,745
Bottlenose dolphin	35	1,350	35	25,900
Unidentified*	20	441	n/a	n/a
Total	**84**	**2,855**	**62**	**54,037**

*=Unidentified encounters are those that did not have visual confirmation of species identity.

Addition of the AMAPPS 2013 dataset allowed three species (Risso's dolphin, rough-toothed dolphin, and Clymene dolphin) to be added to the manual classifier. The new classifier had an overall correct classification score of 55 percent and individual species correct classification scores that ranged from 3 percent for Risso's dolphins to 84 percent for short-finned pilot whales (**Table 64**). Although the correct classification score for Risso's dolphin was very low, this species was included in the classifier because few encounters from other species were misclassified as Risso's dolphin, and when a classifier that did not include Risso's dolphin was trained, correct classification scores for the other species were similar to correct classification results using a classifier with Risso's dolphin included (**Table 65**). Including Risso's dolphin in the classifier provides the potential for Risso's dolphin encounters to be classified without significantly reducing correct classification scores for other species. Adding other information such as echolocation click measurements may increase correct classification scores for Risso's dolphin and other species, and this is being pursued by Bio-Waves, Inc. in a separate project sponsored by ONR and the LMR Program.

Table 64. Confusion matrix for the new manual Atlantic classifier, including additional species from AMAPPS 2013 data.

Actual Species	Percentage classified as[1]								
	Short-beaked common dolphin	Risso's dolphin	Short-finned pilot whale	Clymene dolphin	Striped dolphin	Rough-toothed dolphin	Atlantic spotted dolphin	Bottle-nose dolphin	*n*
Short-beaked common dolphin	**77.6 (8.1)**	0.3 (1.9)	0 (0)	0 (0)	3.1 (5.4)	8.2 (7.4)	6.6 (6.6)	4.2 (5.8)	12
Risso's dolphin	12.4 (7.4)	**3.2 (4.7)**	22.9 (8.5)	10.9 (6.3)	19.9 (9.8)	1.8 (3.8)	14.2 (9.1)	14.4 (7.5)	12
Short-finned pilot whale	0 (0)	0.9 (2.4)	**84.2 (6.3)**	0.2 (1.2)	5.5 (3.6)	6.3 (5.8)	2.1 (3.0)	0.7 (2.2)	16
Clymene dolphin	0 (0)	3.5 (8.7)	0 (0)	**47.2 (9.3)**	21.7 (8.4)	24.5 (3.5)	0 (0)	3.0 (8.2)	5
Striped dolphin	27.3 (8.6)	2.8 (4.4)	3.7 (4.4)	5.9 (6.2)	**44.6 (10.2)**	3.1 (4.3)	8.2 (6.9)	4.2 (5.4)	14
Rough-toothed dolphin	0 (0)	0.2 (2.0)	25.8 (16.4)	4.0 (8.0)	0 (0)	**70.0 (18.1)**	0 (0)	0 (0)	7
Atlantic spotted dolphin	3.7 (2.6)	4.4 (3.2)	5.1 (2.7)	3.3 (2.7)	3.1 (2.3)	9.3 (3.7)	**61.2 (7.6)**	9.6 (4.2)	59
Bottle-nose dolphin	12.6 (3.5)	3.4 (2.4)	2.8 (2.1)	9.4 (3.2)	4.7 (2.2)	3.6 (2.0)	11.0 (2.8)	**52.4 (4.7)**	109

[1] The percentage of encounters classified as each species, with SD in parenthesis, is given based on 100 iterations of dividing data into training and testing datasets. The percentages of encounters correctly classified are in bold on the diagonal.

Table 65. Confusion matrix for the new manual Atlantic classifier, including additional species from AMAPPS 2013 data but not including Risso's dolphin. The percentage of encounters classified as each species, with SD in parenthesis, is given based on 100 iterations of dividing data into training and testing datasets. The percentages of encounters correctly classified are in bold on the diagonal.

Actual Species	Short-beaked common dolphin	Short-finned pilot whale	Clymene dolphin	Striped dolphin	Rough-toothed dolphin	Atlantic spotted dolphin	Bottlenose dolphin	*n*
Short-beaked common dolphin	**78.4 (8.4)**	0 (0)	0 (0)	4.1 (5.8)	0.5 (2.4)	11.7 (3.8)	5.3 (5.7)	9
Short-finned pilot whale	0 (0)	**85.2 (5.4)**	0.1 (0.1)	6.0 (3.8)	4.7 (4.9)	2.7 (3.3)	1.3 (2.5)	16
Clymene dolphin	0 (0)	0 (0)	**51.0 (14.2)**	24.7 (2.5)	20.2 (9.9)	0 (0)	4.0 (9.2)	4
Striped dolphin	29.1 (8.2)	2.9 (4.3)	5.3 (7.0)	**47.6 (11.4)**	1.6 (3.3)	9.9 (5.9)	3.5 (4.8)	13
Rough-toothed dolphin	0 (0)	18.0 (10.8)	2.8 (7.0)	0 (0)	**79.2 (14.5)**	0 (0)	0 (0)	5
Atlantic spotted dolphin	3.9 (2.3)	5.4 (3.1)	2.7 (2.4)	3.7 (2.6)	7.4 (3.8)	**67.0 (7.0)**	9.8 (4.3)	44
Bottlenose dolphin	12.7 (3.5)	2.6 (1.7)	10.6 (3.3)	5.9 (2.7)	2.5 (1.7)	11.7 (3.4)	**53.9 (5.3)**	73

This new eight-species classifier was used to identify AMAPPS 2013 encounters that did not have visual confirmation of species identity. Most (18 out of 20) of these encounters were classified as striped dolphins. The remaining two encounters were classified as Clymene dolphin and short-finned pilot whale. Striped dolphins were one of the most commonly detected small cetaceans during the northern leg of the AMAPPS 2013 survey, both visually and acoustically (NEFSC and SEFSC 2013). All but two of the non-sighted acoustic encounters that were classified as striped dolphins were north of 36°N and offshore of the continental shelf, which is where all of the visual detections of striped dolphins also occurred. Based on their locations, we believe that the two southernmost non-sighted acoustic encounters that were classified as striped dolphins may have been misclassifications. This suggests that geographic location may be another variable that could be useful for improving classification success of the classifiers. This possibility is currently being investigated by Bio-Waves, Inc. in the ONR-sponsored project mentioned above.

All whistles manually extracted from AMAPPS 2013 encounters that had visual confirmation of species identity and that were produced by a species that is included in the original Atlantic classifier were analyzed with the manual classifier to test the performance of this classifier with a novel dataset. A total of 53 acoustic encounters was included in this analysis. Overall, 73.6 percent of these encounters were classified to the correct species (**Table 66**).

Table 66. Classification results for AMAPPS 2013 encounters with visual confirmation of species identity, based on whistles measured using ROCCA's manual method. Confusion matrix shows percentage of encounters that were classified as each species. Percent of encounters correctly classified are in bold on the diagonal. Overall, 73.6 percent of encounters were correctly classified.

Actual Species	Percent classified as					
	Short-beaked common dolphin	Striped dolphin	Short-finned pilot whale	Atlantic spotted dolphin	Bottlenose dolphin	*n*
Short-beaked common dolphin	**33.3**	0.0	66.7	0.0	0.0	3
Striped dolphin	0.0	**50.0**	0.0	50.0	0.0	2
Short-finned pilot whale	n/a	n/a	**n/a**	n/a	n/a	0
Atlantic spotted dolphin	0.0	0.0	15.3	**69.4**	15.3	13
Bottlenose dolphin	2.9	2.9	8.6	5.6	**80**	35

Whistles were measured from 20 acoustic encounters that did not have visual confirmation of species identity collected from the AMAPPS 2013 cruises. Some of these dolphins were not seen at all and some had associated visual observations, but species identification was not possible due to elusive animal behavior, poor sighting conditions, or other factors. Due to time constraints, a maximum of 30 whistles was measured using ROCCA's manual method from each encounter. These whistles were classified using the new Atlantic classifier that included eight species (**Table 64**). Eighteen of the twenty encounters were classified as striped dolphins (**Table 67**), which was one of the most commonly sighted delphinid species during the northern legs of the AMAPPS 2013 survey (NEFSC and SEFSC 2013). Most of the non-sighted acoustic encounters included in this analysis occurred in the northern part of the study area, over and offshore of the continental slope. The locations of these encounters are consistent with the locations of visual observations of striped dolphins during the northern legs of the survey.

Table 67. Classification results for whistles measured manually from AMAPPS 2013 encounters that did not have visual confirmation of species identity. Results include the number of whistles included in the analysis, the species that the encounters was classified as by ROCCA's manual classifier and the certainty score for the acoustic classification.

Encounter ID	Number of whistles	Classified as	Certainty score
GU1304_UD_001	25	Striped dolphin	5
GU1304_UD_002	30	Striped dolphin	4
GU1304_UD_003	30	Striped dolphin	5
GU1304_UD_005	30	Striped dolphin	5
GU1304_UD_006	2	Striped dolphin	2
GU1304_UD_007	4	Clymene dolphin	2
HB1303_UD_008	25	Short-finned pilot whale	5
HB1303_UD_009	14	Striped dolphin	5
HB1303_UD_010	10	Striped dolphin	5
HB1303_UD_011	17	Striped dolphin	5
HB1303_UD_012	29	Striped dolphin	5
HB1303_UD_013	30	Striped dolphin	5
HB1303_UD_014	30	Striped dolphin	5
HB1303_UD_015	30	Striped dolphin	5
HB1303_UD_016	30	Striped dolphin	5
HB1303_UD_017	30	Striped dolphin	5
HB1303_UD_018	11	Striped dolphin	5
HB1303_UD_019	19	Striped dolphin	5
HB1303_UD_020	15	Striped dolphin	5
HB1303_UD_021	30	Striped dolphin	5

When the 53 AMAPPS 2013 encounters that had visual confirmation of species identity were analyzed using PAMGuard's automated WMD, every encounter was classified as short-finned pilot whale. One of the outputs of a random-forest analysis is the Gini Variable Importance Index. This index provides a relative measure of the degree to which each variable contributes to the classifier (Breiman et al. 1984). Comparisons of the six variables that are most important to the classifier (duration, maximum frequency, center frequency, mean frequency, mean positive slope, absolute value of the slope; Oswald 2013) showed that almost all variables were significantly different for every species between the original classifier training dataset and the AMAPPS 2013 dataset (Mann-Whitney U test, p<0.0001). The only exceptions to this were maximum frequency for Atlantic spotted dolphins (Mann-Whitney U test, p=0.57) and center frequency (Mann-Whitney U test, p=0.28) and mean frequency (Mann-Whitney U test, p=0.87) for striped dolphins. Because of these differences, combining the datasets to train a new classifier was not possible and it was not appropriate to use this classifier to identify encounters that did not have associated visual observations.

The automated classifier performed well with the original Atlantic testing and training datasets, as described in Oswald (2013). However, it classified every visually validated AMAPPS 2013 encounter incorrectly as pilot whales. Comparisons of the Atlantic classifier and AMAPPS 2013 datasets suggest that the version of PAMGuard used to analyze the data may have a significant effect on contour extraction and measurement and therefore on classifier performance. It will be crucial to be consistent with PAMGuard versions when using the Atlantic classifier.

The results of this study provide valuable information on the performance of two whistle classifiers for delphinid species in the western North Atlantic Ocean. Although the manual classifier requires more time and effort for the detection and extraction of whistles, it proved to be more generalizable to novel datasets than the automated classifier and also allowed identification of acoustic encounters that did not have associated visual observations (i.e., non-sighted encounters). The ability to identify non-sighted encounters allows a more complete understanding of species distribution as well as providing information about which species are more difficult to detect using visual methods. These results highlight the complementary nature of visual and acoustic methods, which if used together allow more and improved information about the distribution of marine mammals to be collected from vessel-based surveys.

For more information on this study, refer to the final report for this project (Oswald et al. 2016c).

2.3.10 Marine Mammal Monitoring on Navy Ranges (M3R) Passive Acoustic Monitoring

Passive acoustic methods are being combined with visual observations and satellite telemetry at the Atlantic Undersea Test and Evaluation Center (AUTEC) to document the near and long-term effect of sonar on marine mammals. A M3R signal processor has been installed at AUTEC as a means of developing marine mammal passive acoustic systems and applying them to long-term monitoring of cetaceans in an area of frequent sonar use. In addition, an M3R system has been designed, built and tested for the planned USWTR being developed for a 500 square nautical mile (1,715 km^2) area on the continental shelf boundary, approximately 50 nautical miles (93 km) east of Jacksonville, Florida.

The AUTEC acoustic range is located in a deep ocean canyon known as the Tongue Of The Ocean, which forms the southern branch of the Great Bahama Canyon among the islands of the northern Bahamas. The range consists of an array of 91 widely-spaced, bottom-mounted hydrophones that are designed to track undersea vehicles. The range is being leveraged for a multi-disciplinary study of cetaceans that combines M3R passive acoustics; expert visual on-water observers collecting individual-based photo-ID data; and the deployment of satellite tags. This work is filling key data gaps to determine the effect of sonar on cetaceans and developing techniques for long-term range monitoring.

The M3R system is being used to monitor the AUTEC hydrophones for vocalizations using real-time passive acoustic tools developed by the program. Trained at-sea visual observers are vectored to vocalizing animals isolated using the M3R system. By combining passive acoustics with visual observations, detected vocalizations are being associated with the species of origin. Significant progress has been made along these lines; however, uncertainty still remains with delphinid species vocalizations. The expert observers provide data on group composition and surface behavior and collect photo-ID data and biopsy samples for analysis. The satellite tags provide direct data on the movement and diving of animals around active sonar operations.

In 2016, the following M3R project tasks were completed for AUTEC and the Jacksonville USWTR:

1. Blainville's beaked whale detection statistics (probability of detection and false alarm rate) for M3R's Auto-Grouper program were derived and correction factors were calculated from beaked whale detections at AUTEC (Moretti and Fothergill in preparation). Archived data were analyzed and the correction factors applied to derive a Blainville's beaked whale abundance estimate using the dive start method (Moretti et al. 2010).
2. An analysis of mark-recapture sighting data was completed by the Bahamas Marine Mammal Research Organisation (BMMRO 2017). An update to the prior demographic analysis (Claridge 2013) was completed. A comparison of the ratio of dependent calves to adult female was provided and is being used to inform the Population Consequences of Acoustic Disturbance (PCAD) model for Blainville's beaked whales at AUTEC.
3. An initial analysis of the behavioral risk function for lower transmit level small-sources including dipping helicopter sonar and (Directional Command Activated Sonobuoy System (DICASS) sonobuoys was initiated using AUTEC data. The risk function calculates the probability of a behavioral disturbance (i.e., dive start disruption) as a function of MFA sonar root mean square received level (RLrms) (Moretti et al. 2014). Initial analysis suggests that the risk function presented in Moretti et al. (2014) shifts approximately 10 dB re µPa lower for smaller sources such as dipping helicopter sonar and DICASS sonobuoys.
4. An M3R signal processor was installed on a three-node evaluation array installed in August 2016 as part of the Jacksonville USWTR development. The processor is collecting both high- and low-frequency archives that will allow the evaluation of vocalizations including North Atlantic right whales. Multiple right whale detection algorithms were also reviewed for implementation at the USWTR including an 'edge' detector algorithm, a pitch tracking algorithm, and a multistage feature vector testing algorithm. Additionally, discussions with NMFS' NEFSC were held for input on NMFS experience implementing these detectors on autonomous platforms. Based on the evaluation and discussions with NMFS, a real-time detector based on Urazghildiiev et al. (2008) is being targeted for inclusion into the final M3R system software build.

Additional details on M3R project progress for Atlantic ranges and associated references can be found in Moretti (2017).

2.3.11 Near-Real Time Passive Acoustic Monitoring of Baleen Whales in the Gulf of Maine (Environmental Security Technology Certification Program and LMR funded)

A related project, funded by the DOD's Environmental Security Technology Certification Program and the U.S. Navy's LMR Program is underway, with the goal of evaluating near real-time detection and classification technology for eventual adoption into the U.S. Navy's MSM program. Initial fieldwork for this demonstration and validation project began in March 2015, with the objective of evaluating the performance of the digital acoustic monitoring (DMON) instrument and low-frequency detection and classification system (LFDCS), a combined hardware/software package, on three different autonomous seagoing platforms. Detections will be cross-checked between platforms and visually validated with traditional aerial, shipboard, and land-based survey methods.

The DMON/LFDCS uses dynamic programming to estimate a pitch track for any type of narrowband call. A pitch track is a compact representation of a sound (analogous to a series of notes on a page of sheet music) derived from an audio spectrogram; it consists of a time series of frequency-amplitude pairs that describe the frequency and amplitude modulation of a sound. Attributes of the pitch track (e.g., start frequency, end frequency, duration, slope of frequency variation) can be extracted and compared to the attributes of known call types, using quadratic discriminant function analysis. The call library can contain hundreds of these known call types, allowing the LFDCS to efficiently detect and classify many different calls produced by numerous species. Baumgartner and Mussoline (2011) compared the performance of the LFDCS to that of several human analysts for low-frequency sei whale downsweeps and right whale upcalls, and found that the accuracy of the LFDCS was similar to that of an analyst. In addition to right whale upcalls and sei whale downsweeps, Baumgartner et al. (2013) found that the LFDCS performs quite well for fin whale 20-Hertz pulses and several types of humpback whale tonal calls. The system is programmed to look for the calls of these four species (sei, right, fin, and humpback whales) during this study.

This study involves deployment of three types of autonomous platforms – a wave glider (Willcox et al. 2009), a Slocum glider, and a moored buoy. Each platform is equipped with a DMON/LFDCS capable of detecting, classifying, and reporting calls produced by right, fin, humpback, and sei whales. Detection data (i.e., pitch tracks), summary classification data, and analyst-generated predicted occurrence from each platform are reported in both graphical and tabular form on a publicly accessible web site (http://www.dcs.whoi.edu/) as soon as the data are relayed to the shore-side computer. General deployment locations are shown in **Figure 101.**

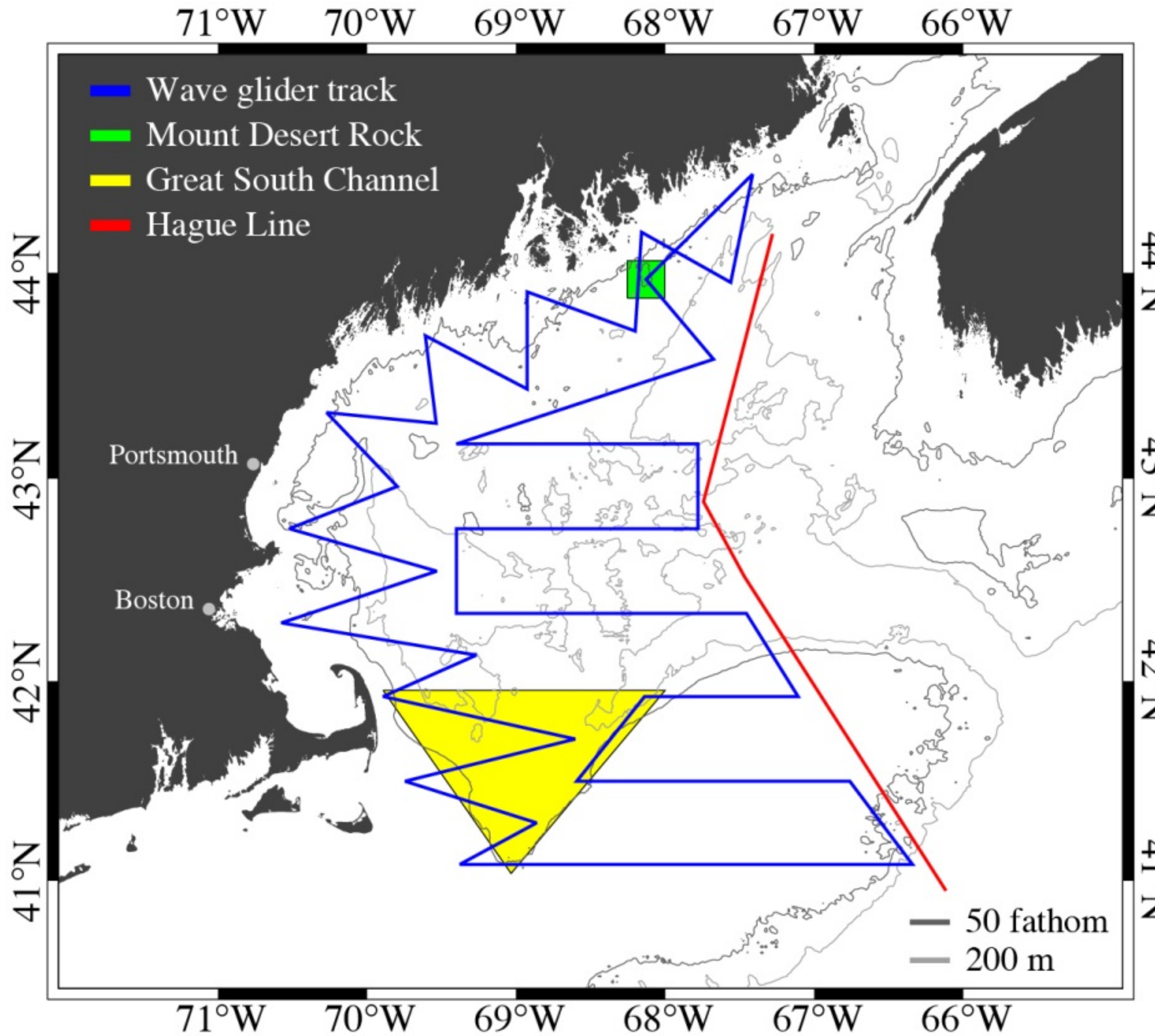


Figure 101. Map of waveglider tracks and Slocum Glider and moored buoy platform locations in the Gulf of Maine. Visual surveys will also be conducted in the Great South Channel (vessel-based) and Mount Desert Rock (shore-based) locations. Aerial surveys will cover the entire region.

Original deployments occurred during 2015, when a wave glider and a Slocum Glider equipped with DMON/LFDCS systems were deployed in the Great South Channel. A moored buoy was also deployed to the north of Mount Desert Rock in Maine. Subsequent deployments have involved refurbishing the buoy as needed, and an additional successful Slocum Glider deployments during the spring of 2016. The 2016 deployment also included a second Slocum Glider owned and piloted by the Naval Oceanographic Office as a demonstration of the viability of the technology operating on a U.S. Navy asset. During the 2016 deployment, visual observations were conducted from the NOAA Ship *Gordon Gunter*, allowing for ground-truthing of the acoustic detections relayed by the gliders.

Preliminary results from the 2015 and 2016 deployments of the Slocum Gliders and moored buoy indicate that the near real-time detections based on the pitch track data are very accurate when compared with the archival acoustic data that is recovered with the platforms. There are very few false detections, and a moderate number of missed calls. The missed call rate is expected to be higher than the false detections because of the DMON/LFDCS signal to noise ratio threshold, and because the system has been designed to minimize false detections. Comparison of near real-time data with visual ground-truthing surveys is in progress.

During 2017, expectations are to re-deploy the wave glider and complete analysis of the previous deployments. This project will be completed during 2018 and peer-reviewed publications will be available at the conclusion of the project.

For more information on this study, please see the project profile on the Environmental Security Technology Certification Program website (RC-201446).

2.3.12 Pile Driving Sound Source Measurements

The potential impacts from pile driving noise on marine mammals are currently a relevant topic driving a number of environmental assessments and MMPA permit applications for different parts of the U.S. Navy. However, there is uncertainty as to whether the existing data on source levels from various types and sizes of piles are applicable to the projects of concern, because most of the data were gathered on the U.S. West Coast, with significantly different bathymetry, sediments, and other environmental conditions. This project was initiated in 2012 to determine whether or not the extensive data library of source levels from pile driving collected on the U.S. West Coast (Caltrans 2012 and Washington State Department of Transportation reports) is also representative of noise levels on the U.S. East coast, and to evaluate existing noise conditions at several U.S. Navy installations on the U.S. East Coast. The project specifies six data collection efforts during pile driving projects at U.S. Navy installations on the U.S. East Coast. The final report is now available for this project (Illingworth and Rodkin, Inc. 2017).

In May 2013, researchers conducted monitoring on two installations, measuring vibratory installation of steel sheet and H-piles at JEB-LC and impact testing of a single concrete pile at Craney Island. Underwater measurements were made at short- (approximately 10-m) and long-distance (approximately 50- to 200-m) ranges from the piles being driven at both installations. Airborne noise measurements were taken only at JEB-LC. For the steel piles at JEB-LC, the source levels for vibratory driving ranged from 115 to 121 decibels referenced to 1 micro Pascal (dB re: 1 µPa) root-mean-squared (RMS). For the impact driving of the concrete pile, source levels averaged between 162 and 169 dB re: 1 µPa RMS. For more information on this project, see Illingworth and Rodkin, Inc. (2013).

Researchers conducted similar monitoring efforts at the Philadelphia Naval Shipyard and NSN in fall 2014. At the Philadelphia Naval Shipyard, monitoring included large (48-inch diameter) steel pipe piles, while monitoring at NSN targeted vibratory driving of small diameter (12- to 16-inch diameter) timber piles and impact driving of 24-inch diameter square concrete piles. For more information on these monitoring projects, please see Illingworth and Rodkin, Inc. (2015a, 2015b).

In 2015, measurements were taken at the temporary pier constructed during training for the Joint Logistics Over The Shore (JLOTS) exercise performed at JEB-LC. In September 2015, measurements of vibratory extraction of 24-inch diameter steel pipe piles were taken. Vibratory extraction measured approximately 145 dB re: 1 µPa RMS (Illingworth and Rodkin, Inc. 2015c). Installation of piles for JLOTS was measured during April 2016. Average sound levels during installation were 196 dB re 1µPa RMS and 212 dB re 1 µPa peak (Illingworth and Rodkin, Inc. 2016).

The interim reports from each monitoring event and the compared data were published in a single comprehensive final report, which is now available for download (Illingworth and Rodkin, Inc. 2017).

SECTION 3 – DATA MANAGEMENT

Large amounts of visual and acoustic monitoring data are acquired under the U.S. Navy's MSM program. These data inform the U.S. Navy's environmental planning decisions, and the data also contribute to our general knowledge of marine species distribution and behavior. The MSM Data Management Plan (DMP; HDR 2014), outlines procedures related to the collection, QC, formatting, security, classification, governance, processing, archiving, and reporting of data acquired under the U.S. Navy's MSM program. The DMP provides the necessary framework to manage effectively all data acquired under the U.S. Navy MSM program, from the initial step of data collection through the final step of data archival. The DMP establishes the method by which data flow through the management system and the controls applied to the data during the process. Additionally, the DMP is an important tool that promotes the fullest utilization of the data through data sharing and integration amongst U.S. Navy departments, environmental planners, and researchers. This is achieved in part via the documentation and standardization of data-collection techniques among various researchers. Procedures related to MSM data collection and data management continue to evolve due to refined survey methodologies, improved technologies, and an expanded knowledge base. The DMP is a living document that reflects this evolution, and periodic revisions are driven by adaptive data management based on maturation of the program, and evolving U.S. Navy guidance on specific data-management procedures, including those outlined in the following subsections.

3.1 Data Standards Development

The U.S. Navy MSM program requires that all acquired data be maintained for ready dissemination to U.S. Navy environmental planners, analysts, and researchers and formatted to ensure compatibility with existing marine databases (HDR 2014). Starting in 2013, the U.S. Navy developed a MSM Data Standard applicable to survey data acquired under the U.S. Navy MSM program. The data standard lists all potential data elements collected under the program (e.g., species, sighting location, platform location environmental variables, etc.), their definitions, required formats for each data element, and any notes, background information, or instructions associated with data collection or data entry for each element. Marine species data are collected under the U.S. Navy MSM program by a variety of researchers, using multiple visual-survey platforms (vessel, aerial, shore-based), following a range of survey protocols. Standardization of the multiple data types associated with the U.S. Navy MSM program provides a common vocabulary for data collectors and analysis, and allows large datasets to be compiled for analysis and interpretation. Standardization across all research efforts in every naval range also enables U.S. Navy data managers to ensure that these datasets comply and are compatible with any applicable Federal data standards and data-management frameworks. Examples of standards and frameworks include the multi-DOD service Spatial Data Standards for Facilities, Infrastructure, and Environment; the DOD's Environmental Information Management System (EIMS); the Navy Marine Species Density Database (NMSDD); the Navy Marine Corps Intranet data network and information transfer system; and NOAA's Protected Species Observer and Data Management Program (Baker et al. 2013). This consistent data organization across surveys facilitates back-end data processing and analysis, and streamlines reporting and information sharing among various researchers and stakeholders.

Survey data typically fall into three broad categories: sightings, survey effort, and environmental information. Examples of sighting information include species, sighting location, number of animals, presence of calves, and behavioral state. Survey effort refers to the amount of time spent looking for animals, platform type, number of observers, distance traveled, and effort type (e.g., random, systematic, or transiting). Environmental conditions are also recorded, including sea state, visibility, glare, and cloud cover. The data standard specifies the required field header names for each data variable, units in which the data are expressed, and formats for each field (numeric, text, Boolean, etc.). The U.S. Navy's MSM Data Standard is designed primarily to accommodate visual survey data, including biopsy (i.e., tissue sample) and tag deployment data. The U.S. Navy's MSM Data Standard does not apply to PAM data collected under the U.S. Navy MSM program, which are subject to a different set of data-collection and data-management guidelines.

3.2 Survey Data Collection Software

The U.S. Navy identified the need for development of a survey data-collection system that fully meets U.S. Navy's MSM Data Standard. The objectives were to streamline data-collection procedures, minimize manual data-management requirements, and increase the standardization and repeatability of data-collection efforts. In response to this need, HDR has developed a survey toolkit called *COMPASS (Cetacean Observation and Marine Protected Animal Survey Software). COMPASS* is designed to be an integrated survey data-collection and data-management system to facilitate work conducted during MSM surveys. The COMPASS survey toolkit integrates current mobile and web technologies to allow efficient real-time collection, processing, reporting, and delivery of marine species data. The final product will include a mobile platform for data collection in the field; a web portal to design, plan, and execute surveys and access data products; and a server-hosted database-management system for QC, team collaboration, and preliminary data processing/ reporting.

The surveys conducted within the U.S. Navy MSM program include a variety of data-collection scenarios and technologies. The preliminary version of the *COMPASS* system addresses the needs for the most common survey types: shore-based (theodolite), vessel-based, and aerial-based. The data-collection routines for each survey type are designed to maintain consistency with the U.S. Navy's MSM Data Standard, which specifies field names, aliases, data types, measurement units, and descriptions for data that are collected in the field (**Figure 102**). Each data-collection scenario will use some subset of fields specified in the U.S. Navy's MSM Data Standard.

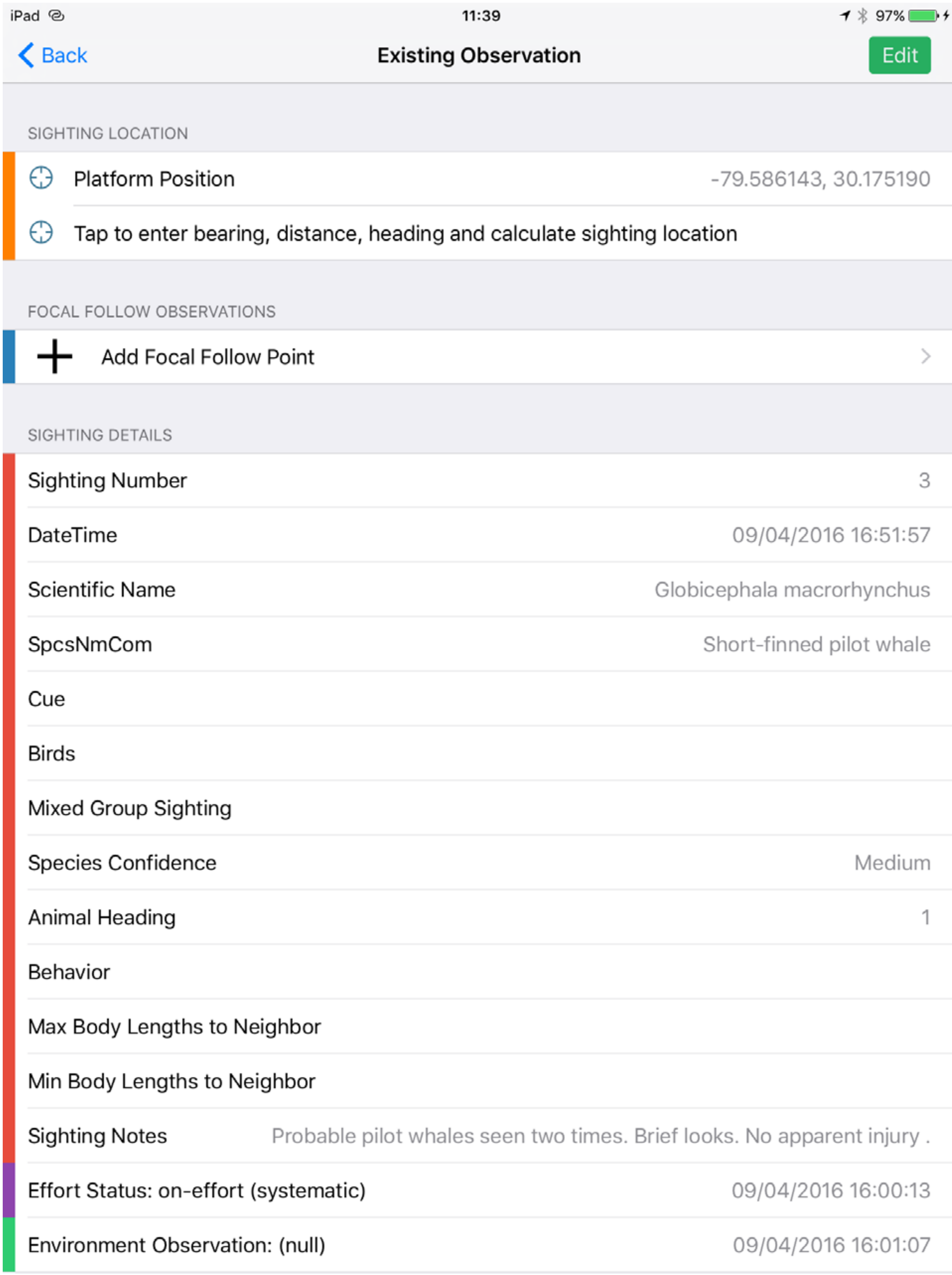


Figure 102. Screenshot of the *COMPASS* field app showing data entry fields for an observation.

The mobile app runs on the Apple iPad® platform, a widely available and familiar tablet computer. It is the primary interface for the collection of field data. The mobile app includes mapping capabilities for navigation and data collection, and functions in areas without network or cellular connectivity. It can display the data stream (e.g., sightings and effort), relevant auxiliary data (e.g., range complex boundaries, exclusion zones, passive acoustic monitoring stations, pinnacles, etc.), and customizable base-map layers (e.g., bathymetry, ortho-imagery) (**Figure 103**). Users can pan and zoom on the map, and control the visibility of data layers on the map. Users are able to search the attributes of collected data and auxiliary data, and zoom to the search results.

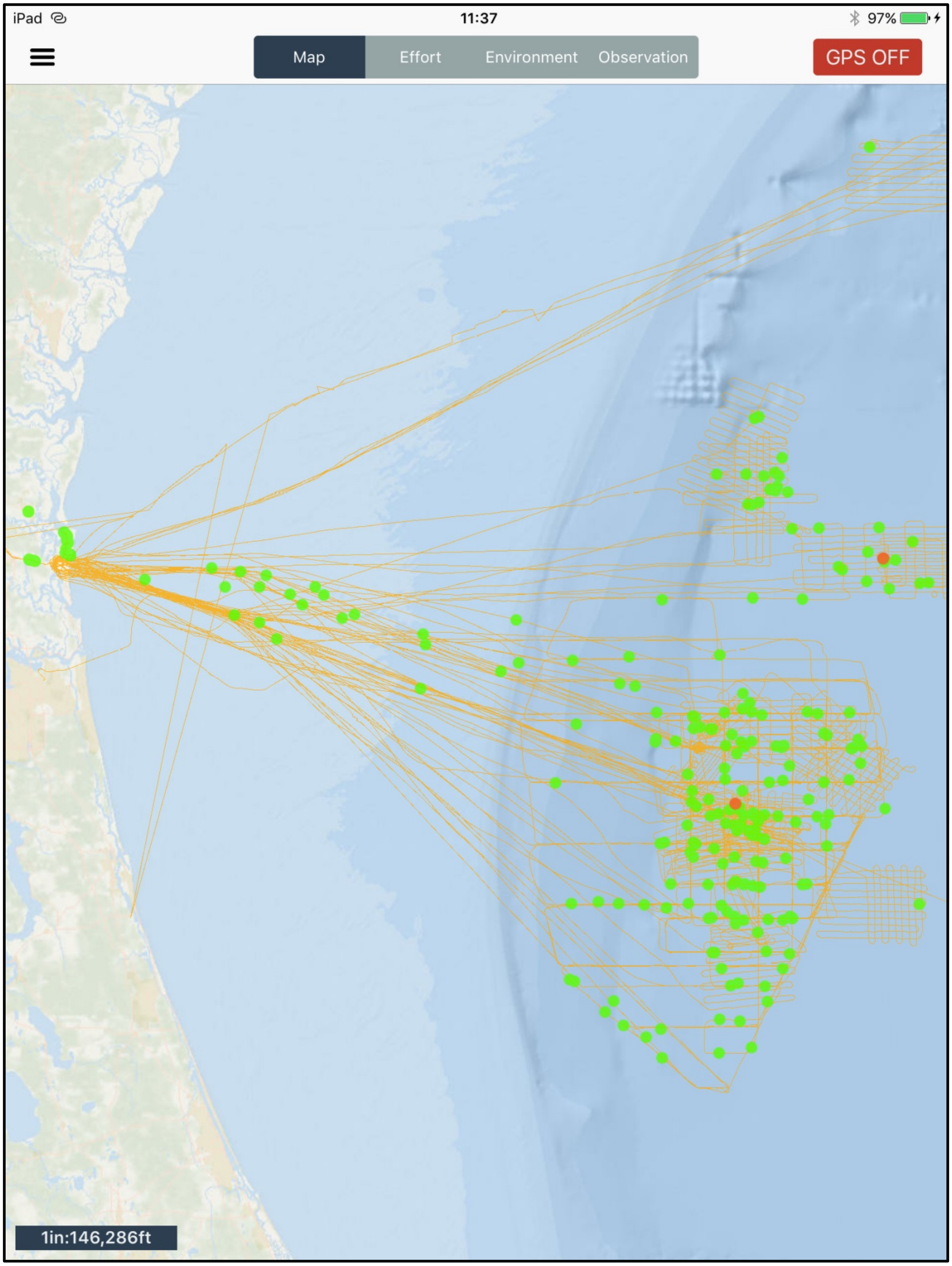


Figure 103. Screenshot from *COMPASS* field app showing the tracklines and sightings made during the Full Ship Shock Trial aerial survey efforts in summer 2016. Green dots indicate sightings, red dots indicate resightings, and orange lines are the survey tracklines flown.

Customizable data fields allow users to collect data relevant to each of the survey types including ancillary tasks (e.g., focal-follow studies, biopsy collection, satellite tagging, etc.). All data are stored in relational databases adhering to the U.S. Navy's MSM Data Standard.

Data collected with the mobile app are synchronized to a central database server via Wi-Fi, cellular data connection, or direct Universal Serial Bus connection. Transmitting collected data as soon as possible after a survey ensures that information is archived and protected, while allowing for collaborative QC review and editing through a web-based user interface. Alternatively, data can be backed up, edited, and managed locally, when web connectivity is unavailable.

The web-based application is the central interface for the management of marine species surveys and data. It allows access from any Internet-connected computer, allowing field crews, biologists, and program managers from multiple locations to collaborate on active surveys. New users may be added easily, and authorization control will be implemented in order to designate specified users able to access different aspects of the surveys and data management.

Field crews may use the web application to verify and perform QC checks on data uploaded from the mobile app. Accessing these data via the web allows field crews to verify that collected data have been transmitted successfully to the server and also provides an opportunity to review, as well as annotate field data from laptop computers. If Internet access is unavailable, QC checks in the field can be conducted in the mobile app.

Prior to initiating a survey, the web portal is used to set up a new survey, assign authorized users of the system for that survey, and configure survey-specific information including species lists, equipment descriptions, etc. The web portal will provide instructions for the loading of pre-built base-maps, which will be created for the most common survey areas. Pre-built base-maps will cover the instrumented U.S. Navy training ranges and other areas of interest. The web portal will also provide instructions to load any additional feature data required for the survey including tidal data, tracklines, waypoints of interest, passive acoustic mooring positions, etc.

After the survey is completed and the data are synced to a central database server, primary access to the survey data will occur through a web-based interface. This user interface allows access to the centralized back-end database, and facilitates QC review and editing. It allows a broader set of specified users (e.g., field crews, biologists, program managers, external clients) access to the data, while controlling access through the use of user accounts and permissions. Project managers will use the web application interface to monitor data collection and QC activity, and to export data.

Programming for the web application, as well as the mobile field application (including the three survey platforms: aerial, vessel, and shore-based) is ongoing, with continual input from HDR field researchers. In 2016, development of the mobile app and web portal reached the internal beta-testing stage. This included the creation and management of multiple projects via the web portal, and the ability to load multiple projects within the mobile app. The web portal also has been configured with user management capabilities, the ability to produce daily summary maps for surveys, and a function that creates data exports in GIS for further processing and analysis.

Also in 2016, programmers and biologists completed initial testing of the app in the aerial-survey configuration, and *COMPASS* was used to document all survey activity for monitoring of a U.S. Navy training exercise near Jacksonville, Florida. Configuration of the app for vessel surveys is currently underway, with rigorous field testing planned for early 2017. The theodolite-survey app also is being updated and prepared for field trials. User guides are being generated for *COMPASS* and will be updated as functionality and user input increase.

For more information, refer to the annual progress report for this project (Richlen et al. 2017b).

3.3 Data Archiving and Access

All visual-survey data collected under the U.S. Navy MSM program are provided to EIMS, a GIS-based toolset to support U.S. Navy environmental and range-sustainment programs, including environmental planning for at-sea training/testing and at-sea regulatory compliance. Data are uploaded to EIMS in the form of personal geodatabase files, containing feature classes for sightings (points) and survey tracklines (polylines). Source data from all surveys also are uploaded for archival purposes, accompanied by all relevant metadata. Marine species data maintained in this centralized location allow the U.S. Navy to track all MSM data collected in various training ranges and to use this information to build the NMSDD. Under U.S. Federal laws, the U.S. Navy is required to estimate the impacts of U.S. Navy-generated underwater sound on protected marine species, and to calculate the numbers of animals that may be affected by the sound generated during U.S. Navy training and testing activities. In order to calculate accurate "take" estimates, the U.S. Navy must consider marine species density estimates (number of animals per unit area) for all U.S. Navy training and testing ranges. The NMSDD provides the U.S. Navy with data necessary to quantify impacts of sound on protected marine species. In range complexes where density information is lacking, the NMSDD can be used to extrapolate or predict densities to calculate takes where little or no information exists.

The U.S. Navy MSM data-management team effectively disseminates data to facilitate information sharing among stakeholders, and to advance the general knowledge of marine species distribution and behavior. This information dissemination is achieved in part by the delivery of U.S. Navy MSM visual survey data to the OBIS-SEAMAP database, a spatially and temporally interactive online archive for marine mammal, sea turtle, and seabird data. Researchers worldwide contribute datasets to Duke University's Marine Geospatial Ecology and Marine Conservation Ecology Laboratories, which maintain OBIS-SEAMAP. The U.S. Navy contributes all MSM survey data to OBIS-SEAMAP to contribute to expanding the knowledge of global patterns of marine species distribution and biodiversity. Once these datasets are provided to OBIS-SEAMAP and have been through a review process, the information is published at http://seamap.env.duke.edu/partner/NAVY.

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SECTION 4 – ADAPTIVE MANAGEMENT AND STRATEGIC PLANNING PROCESS

4.1 Adaptive Management

Adaptive management is an iterative process of optimal decision-making in the face of uncertainty, with an aim to reduce uncertainty over time via system monitoring and feedback. Within the natural resource management community, adaptive management involves ongoing, real-time learning and knowledge creation, both in a substantive sense and in terms of the adaptive process itself. Adaptive management focuses on learning and adapting, through partnerships of managers, scientists, and other stakeholders. Adaptive management helps managers maintain flexibility in their decisions, knowing that uncertainties exist, and provides managers the latitude to change direction so as to improve understanding of ecological systems to achieve management objectives. Taking action to improve progress toward desired outcomes is another function of adaptive management.

The AMR process involves NMFS, the Marine Mammal Commission (MMC), and other experts in the scientific community through technical review meetings and ongoing discussions. Dynamic revisions to the compliance monitoring structure as a result of AMR include the development of the Strategic Planning Process (DoN 2013d*),* which is a planning tool for selection and management of monitoring projects, and its incorporation into the ICMP. Phase II monitoring addresses the ICMP top-level goals through a collection of specific regional and ocean basin studies based on scientific objectives. The AMR process and reporting requirements serve as the basis for evaluating performance and compliance.

4.2 Strategic Planning Process

The U.S. Navy MSM program has evolved and improved as a result of the AMR process through changes including:

- Recognizing the limitations of effort-based compliance metrics;
- Developing a conceptual framework based on recommendations from the Scientific Advisory Group (DoN 2013d);
- Shifting focus to projects based on scientific objectives that facilitate generation of statistically meaningful results upon which natural resources management decisions may be based;
- Focusing on priority species or areas of interest as well as best opportunities to address specific monitoring objectives in order to maximize return on investment; and
- Increasing transparency of the program and management standards, improving collaboration among participating researchers, and improving accessibility to data and information resulting from monitoring activities.

As a result, U.S. Navy's compliance monitoring has undergone a transition with the implementation of the Strategic Planning Process under MMPA Authorizations for AFTT and Hawaii-Southern California Training and Testing. Under this process, Intermediate Scientific Objectives serve as the basis for developing and executing new monitoring projects across the U.S. Navy's training and testing ranges (both Atlantic and Pacific). Implementation of the Strategic Planning Process involves coordination among Fleets, systems commands, Chief of Naval Operations Energy and Environmental Readiness Division (CNO-N45), NMFS, and the MMC and has five primary steps:

1. **Identify overarching intermediate scientific objectives**–Through the adaptive management process, the U.S. Navy coordinates with NMFS as well as the MMC to review and revise the list of intermediate scientific objectives that are used to guide development of individual monitoring projects. Examples include addressing information gaps in species occurrence and density, evaluating behavioral response of marine mammals to U.S. Navy training and testing activities, and developing tools and techniques for passive acoustic monitoring.
2. **Develop individual monitoring project concepts**–This step generally takes the form of soliciting input from the scientific community in terms of potential monitoring projects that address one or more of the intermediate scientific objectives. This can be accomplished through a variety of forums including professional societies, regional scientific advisory groups, and contractor support.
3. **Evaluate, prioritize, and select monitoring projects**–U.S. Navy technical experts and program managers review and evaluate all monitoring project concepts and develop a prioritized ranking. The goal of this step is to establish a suite of monitoring projects that address a cross-section of intermediate scientific objectives spread over a variety of range complexes.
4. **Execute and manage selected monitoring projects**–Individual projects are initiated through appropriate funding mechanisms and include clearly defined objectives and deliverables (e.g., data, reports, publications).
5. **Report and evaluate progress and results**–Progress on individual monitoring projects is updated through the U.S. Navy's marine species monitoring web portal as well as annual monitoring reports submitted to NMFS. Both internal review and discussions with NMFS through the adaptive management process are used to evaluate progress toward addressing the primary objectives of the ICMP and serve to periodically recalibrate the focus on the U.S. Navy's MSM program.

These steps serve three primary purposes: 1) to facilitate the U.S. Navy in developing specific projects addressing one or more intermediate scientific objectives; 2) to establish a more structured and collaborative framework for developing, evaluating, and selecting monitoring projects across all areas where the U.S. Navy conducts training and testing activities; and 3) to maximize the opportunity for input and involvement across the research community, academia, and industry. Furthermore, this process is designed to integrate various elements including:

- Integrated Comprehensive Monitoring Program top-level goals
- Scientific Advisory Group recommendations
- Integration of regional scientific expert input
- Ongoing AMR dialog between NMFS and U.S. Navy
- Lessons learned from past and future monitoring at U.S. Navy training and testing ranges
- Leverage research and lessons learned from other U.S. Navy-funded science programs

The Strategic Planning Process will continue to shape the future of the U.S. Navy's MSM program and serve as the primary decision-making tool for guiding investments. **Table 68** summarizes U.S. Navy MSM projects currently underway in the Atlantic for 2017. Additional details on these projects as well as results, reports, and publications can be accessed through the U.S. Navy's marine species monitoring web portal as they become available.

Table 68. Summary of monitoring projects underway in the Atlantic for 2017.

Project Description	Intermediate Scientific Objectives	Status
Title: Tagging and Tracking of Endangered North Atlantic Right Whales in Florida Waters **Location**: JAX Range Complex **Objectives**: Assess movement patterns of right whales in coastal waters off Florida, rates of travel of individual whales, dive depths, and rates of sound production **Methods**: Observational methods combined with short-term (ca. 24 hr) non-invasive suction cup attached multi-sensor acoustic recording tags with Fastloc® GPS **Performing Organizations**: Duke University, Syracuse University **Timeline**: 2014 through 2017 **Funding**: FY13 - $335K, FY14 - $390K, FY15 - $505K, FY16 - $390K, FY17 - TBD	• Establish the baseline habitat uses and movement patterns of marine mammals where Navy training and testing activities occur • Establish the baseline vocalization behavior of marine mammals and sea turtles where Navy training and testing activities occur • Establish the baseline behavior (foraging, dive patterns, etc.) of marine mammals where Navy training and testing activities occur	**Field work - winters 2014–2017** • Technical progress reports available – 2014–2016 • 2017 field summary available
Title: Lower Chesapeake Bay Sea Turtle Tagging and Tracking **Location**: Lower Chesapeake Bay (Hampton Roads) **Objectives**: Assess occurrence and behavior of loggerhead, green, and Kemp's ridley sea turtles in the Hampton Roads region of Chesapeake Bay and coastal Atlantic Ocean **Methods**: Satellite, GPS, and acoustic telemetry tags **Performing Organizations**: Virginia Aquarium and Marine Science Center Foundation, NAVFAC Atlantic **Timeline**: 2013 through 2017 **Funding**: FY13 - $180K, FY14 - $195K, FY15 - $70K, FY16 - $183K	• Estimate the density of marine mammals and sea turtles in Navy range complexes and in specific training areas • Establish the baseline habitat uses and movement patterns of marine mammals and sea turtles where Navy training and testing activities occur • Evaluate trends in distribution and abundance of populations that are regularly exposed to sonar and underwater explosives	**Field work summers 2013–2017** • Technical progress reports available–2013–2016 • Loggerhead analysis complete

Project Description	Intermediate Scientific Objectives	Status
Title: Occurrence, Ecology, and Behavior of Deep Diving Odontocetes **Location**: Cape Hatteras **Objectives**: Establish behavioral baseline and foraging ecology. Assess behavioral response to acoustic stimuli and Navy training activities **Methods**: Visual surveys, biopsy sampling, DTAGs, satellite tags **Performing Organizations**: Duke University, Woods Hole Oceanographic Institution, Cascadia Research Collective **Timeline**: 2013-2017 **Funding**: FY12 - $275K, FY13 - $250K, FY14 - $510K, FY15 - $520K, FY16 - $420K	• Determine what populations of marine mammals are exposed to Navy training and testing activities • Establish the baseline behavior (foraging, dive patterns, etc.) of marine mammals where Navy training and testing activities occur • Evaluate behavioral responses by marine mammals exposed to Navy training and testing activities	**Field work spring/summer 2013–2017** • Technical progress reports available - 2013–2016
Title: Atlantic Behavioral Response Study **Location**: Cape Hatteras **Objectives**: Assess behavioral response of beaked and pilot whales to mid-frequency tactical sonar **Methods**: Controlled exposure experiments **Performing Organizations**: Duke University, Woods Hole Oceanographic Institution, Cascadia Research Collective **Timeline**: 2017-2020 **Funding**: FY16 - $35K, FY17 - $1.4M	• Evaluate behavioral responses by marine mammals exposed to Navy training and testing activities	**New start 2017** • Initial field sessions planned for May and Sept 2017
Title: NAS Patuxent River Marine Species Surveys **Location**: Chesapeake Bay (NAS Patuxent River) **Objectives**: Assess occurrence, seasonality, and abundance of *Tursiops* in the waters near NAS Patuxent River **Methods**: Aerial surveys, photo-ID, passive acoustics **Performing Organizations**: UNC Wilmington, HDR Inc. **Timeline**: 2015-2017 **Funding**: $675K	• Estimate the density of marine mammals and sea turtles in Navy range complexes and in specific training areas • Determine what species and populations of marine mammals and sea turtles are present in Navy range complexes • Establish the baseline habitat uses and movement patterns of marine mammals and sea turtles where Navy training and testing activities occur	**Field work began April 2015** • Technical progress reports available - 2015, 2016

Project Description	Intermediate Scientific Objectives	Status
Title: Bottlenose Dolphin Occurrence in Estuarine and Coastal Waters near Panama City, Florida **Location**: St. Andrew Bay and nearshore waters of Panama City, Florida **Objectives**: Determine species occurrence, and distribution, habitat use, and abundance of *Tursiops* in St. Andrew Bay and coastal waters adjacent to the Naval Surface Warfare Center, Panama City Division. **Methods**: Small-vessel visual line transect surveys, photo-ID, biopsy sampling **Performing Organizations**: NOAA Hollings Marine Laboratory **Timeline**: 2015-2017 **Funding**: FY15 - $112K, FY16 - $210K	• Determine what species and populations of marine mammals and sea turtles are present in Navy range complexes • Establish the baseline habitat uses and movement patterns of marine mammals where Navy training and testing activities occur • Estimate the density of marine mammals and sea turtles in Navy range complexes and in specific training areas.	**Field work complete** • 2015 technical progress report available • Final analysis in progress
Title: Baseline Monitoring for Marine Mammals in the East Coast Range Complexes – Aerial Surveys **Location**: Virginia Capes, Cherry Point, and Jacksonville Range Complexes **Objectives**: Assess occurrence, habitat associations, and density of marine mammals and sea turtles in key areas of Navy range complexes **Methods**: Visual surveys (aerial) **Performing Organizations**: UNC Wilmington, CREEM - University of St. Andrews **Timeline**: Ongoing **Funding**: FY13 - $685K, FY14 - $375K, FY15 - $808K, FY16 - $368K, FY17 - $312K	• Determine what species and populations of marine mammals and sea turtles are present in Navy range complexes • Estimate the density of marine mammals and sea turtles in Navy range complexes and in specific training areas • Determine what populations of marine mammals are exposed to Navy training and testing activities • Evaluate trends in distribution and abundance of populations that are regularly exposed to sonar and underwater explosives	**Ongoing** • Began in 2008 as preliminary USWTR baseline monitoring • Current focus - Norfolk Canyon, Hatteras, Jacksonville • Technical progress report series available

Project Description	Intermediate Scientific Objectives	Status
Title: Baseline Monitoring for Marine Mammals in the East Coast Range Complexes – Vessel Surveys **Location**: Virginia Capes, Cherry Point, and Jacksonville Range Complexes **Objectives**: Assess occurrence, habitat associations, and stock structure of marine mammals and sea turtles in key areas of Navy range complexes **Methods**: Aerial and vessel visual surveys, biopsy sampling, photo-ID **Performing Organizations**: Duke University **Timeline**: Ongoing **Funding**: FY13 - 275K, FY14 - $350K, FY15 - $250M, FY16 - $220K, FY17 - TBD	• Determine what species and populations of marine mammals and sea turtles are present in Navy range complexes • Estimate the density of marine mammals and sea turtles in Navy range complexes and in specific training areas • Determine what populations of marine mammals are exposed to Navy training and testing activities • Evaluate trends in distribution and abundance of populations that are regularly exposed to sonar and underwater explosives	**Ongoing** • Began in 2008 as preliminary USWTR baseline monitoring • Current focus - Jacksonville USWTR • Technical progress report series available
Title: Baseline Monitoring for Marine Mammals in the East Coast Range Complexes – Passive Acoustics **Location**: Virginia Capes, Cherry Point, and Jacksonville Range Complexes **Objectives**: Assess occurrence, habitat associations, density, stock structure, and vocal activity of marine mammal and sea turtle in key areas of Navy range complexes **Methods**: Passive acoustic monitoring **Performing Organizations**: Duke University, Scripps Institute of Oceanography **Timeline**: Ongoing **Funding**: FY13 - $780K, FY14 - $800K, FY15 - $680K, FY16 - $596K, FY17 - TBD	• Determine what species and populations of marine mammals and sea turtles are present in Navy range complexes • Establish the baseline vocalization behavior of marine mammals where Navy training and testing activities occur • Evaluate trends in distribution and abundance of populations that are regularly exposed to sonar and underwater explosives	**Ongoing** • Began in 2008 as preliminary USWTR baseline monitoring • Current focus – Norfolk Canyon, Hatteras, Jacksonville • Technical progress report series available
Title: Mid-Atlantic Humpback Whale Monitoring **Location**: VACAPES Range Complex **Objectives**: Assess occurrence, habitat use, and baseline behavior of humpback whales in the mid-Atlantic region **Methods**: Focal follow observational methods, photo-ID, biopsy sampling, satellite tagging **Performing Organizations**: HDR Inc. **Timeline**: 2014 through 2018 **Funding**: FY14 - $320K, FY15 - 260K, FY16 - $370K, FY17 - TBD	• Establish the baseline habitat uses and movement patterns of marine mammals where Navy training and testing activities occur • Establish the baseline behavior (foraging, dive patterns, etc.) of marine mammals where Navy training and testing activities occur	**Field work 2015-18** • First field season winter 2015 • Satellite tagging component added 2015/16 field season • Technical progress reports available – 2014-16

Project Description	Intermediate Scientific Objectives	Status
Title: VACAPES Continental Shelf Break Cetacean Study **Location**: VACAPES Range Complex **Objectives**: Assess occurrence, habitat use, and baseline behavior of cetaceans in the mid-Atlantic region **Methods**: Visual surveys, focal follow observational methods, photo-ID, biopsy sampling, satellite tagging **Performing Organizations**: HDR Inc. **Timeline**: 2015 through 2018 **Funding**: FY15 - $75K; FY16 - $645K	• Determine what species and populations of marine mammals and sea turtles are present in Navy range complexes • Establish the baseline habitat uses and movement patterns of marine mammals where Navy training and testing activities occur • Establish the baseline behavior (foraging, dive patterns, etc.) of marine mammals where Navy training and testing activities occur	**Field work 2016-18** • Pilot project initiated 2015 • 2016 technical progress report available
Title: Haul Out Counts and Photo-Identification of Pinnipeds in Chesapeake Bay, Virginia **Location**: Chesapeake Bay **Objectives**: Document seasonal occurrence, habitat use, and haul-out patterns of seals **Methods**: Visual surveys, photo-ID **Performing Organizations**: NAVFAC Atlantic **Timeline**: 2014-2017 **Funding**: FY15 - $52K, FY16 - $57K	• Estimate the density of marine mammals and sea turtles in Navy range complexes and in specific training areas • Establish the baseline habitat uses and movement patterns of marine mammals and sea turtles where Navy training and testing activities occur • Evaluate trends in distribution and abundance of populations that are regularly exposed to sonar and underwater explosives	**New start winter 2014-15** • 2015-16 annual progress report available
Title: Seal Tagging and Tracking in Virginia **Location**: Lower Chesapeake Bay (Hampton Roads) **Objectives**: Document habitat use, movement and haul-out patterns of seals in the Hampton Roads region of Chesapeake Bay and coastal Atlantic Ocean **Methods**: Photo-ID, tagging **Performing Organizations**: Virginia Aquarium & Marine Science Center Foundation **Timeline**: 2016-2017 **Funding**: FY16 - $40K	• Estimate the density of marine mammals and sea turtles in Navy range complexes and in specific training areas • Establish the baseline habitat uses and movement patterns of marine mammals and sea turtles where Navy training and testing activities occur • Evaluate trends in distribution and abundance of populations that are regularly exposed to sonar and underwater explosives	**New start winter 2016-2017**

Project Description	Intermediate Scientific Objectives	Status
Title: Haul Out Counts and Photo-Identification of Pinnipeds in Narragansett Bay, RI **Location**: Narragansett Bay **Objectives**: Document seasonal occurrence, habitat use, and haul-out patterns of seals **Methods**: Visual surveys, photo-ID **Performing Organizations**: NUWC Newport **Timeline**: 2014-2017 **Funding**: FY15 - $45K, FY16 - $102K	• Estimate the density of marine mammals and sea turtles in Navy range complexes and in specific training areas • Establish the baseline habitat uses and movement patterns of marine mammals and sea turtles where Navy training and testing activities occur • Evaluate trends in distribution and abundance of populations that are regularly exposed to sonar and underwater explosives	**New start winter 2014-15** 2015-16 annual progress report available

SECTION 5 – REFERENCES

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APPENDIX A

RECENT PUBLICATIONS AND PRESENTATIONS RESULTING FROM AFTT-RELATED MONITORING INVESTMENTS

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Barco, S., G. Lockhart, C. Watterson, S. Rose, and A. DiMatteo. 2016. Evidence of pier fidelity in hooked and released loggerhead and Kemp's ridley sea turtles using acoustic and satellite telemetry. Oral presentation, 3rd Southeast Regional Sea Turtle Meeting (SERSTM). 9-12 February 2016. Mobile, Alabama.

Hotchkin, C.F., J. Bort Thornton, A. Kumar, M. Richlen, and K. Pommerenck. 2016. Source levels and spectral characteristics of sound produced during pile driving at US East Coast Navy installations. Abstracts, Fourth International Conference on the Effects of Noise on Aquatic Life. 10-15 July 2016. Dublin, Ireland.

Lammers, M., M. Howe, A. Engelhaupt, E. Zang, L. Munger, E. Nosal, and J. Bell. 2016. Response by coastal dolphins to naval mine exercise (MINEX) training activities off Virginia Beach, USA. Abstracts, Fourth International Conference on the Effects of Noise on Aquatic Life. 10-15 July 2016. Dublin, Ireland.

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Lammers, M., J.N. Oswald, A. Kuegler, and E.M. Nosal. 2016. The characteristics of dolphin clicks compared across recording depths and instruments. Journal of the Acoustical Society of America 139(4,Part 2):3131.

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Oswald, J., T.F. Norris, T. M. Yack, E.L. Ferguson, A. Kumar, J. Nissen, and J. Bell. 2016. Patterns of occurrence and marine mammal acoustic behavior in relation to Navy sonar activity off Jacksonville, Florida. Pages 791-799 in A.N. Popper and A. Hawkins, eds. The Effects of Noise on Aquatic Life II. Springer, New York.

Oswald, J.N., M.O. Lammers, A. Kügler, C. Hom-Weaver, and R. Walker. 2016. Does depth matter? Investigating the effect of recording depth on delphinid whistle characteristics and classifier performance. Journal of the Acoustical Society of America 139(4,Part 2):2060-2061.

Stanistreet, J.E., D.P. Nowacek, A.J. Read, S. Baumann-Pickering, H.B. Moors-Murphy, and S.M. Van Parijs. 2016. Effects of duty-cycled passive acoustic recordings on detecting the presence of beaked whales in the northwest Atlantic. Journal of the Acoustical Society of America 140(1):EL31-EL37.

Yack, T.M., K. Dunleavy, and J.N. Oswald. 2016. Inter and intra specific variation in echolocation signals among odontocete species in Hawaii, the northwest Atlantic and the temperate Pacific. Journal of the Acoustical Society of America 139 (4, Part 2):2061.

Publications and presentations from previous years also are available in the reading room of the U.S. Navy's Marine Species Monitoring Program website:

http://www.navymarinespeciesmonitoring.us/reading-room/publications