Occurrence of Baleen Whales along the Continental Shelf Region of the VACAPES OPAREA off Southern Virginia: Final Report

Submitted to:

Naval Facilities Engineering Command Atlantic
under Contract No. N62470-15-D-8006,
Task Order 048, issued to HDR, Inc.


All images NMFS Permit #16473

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July 2018

Suggested Citation:

Mallette, S.D., M. L. Burt, L. Thomas, R.J. McAlarney, G.G. Lockhart, E.W. Cummings, W.A. McLellan, D.A. Pabst, and S.G. Barco. 2018. Occurrence of Baleen Whales along the Continental Shelf Region of the VACAPES OPAREA off southern Virginia: Final Report. Prepared for U.S. Fleet Forces Command. Submitted to Naval Facilities Engineering Command Atlantic, Norfolk, Virginia, under Contract No. N62470-15-D-8006, Task Order 48, issued to HDR, Inc., Virginia Beach, Virginia. July 2018.

Cover Photo Credit:

Top left – North Atlantic right whale swimming with open mouth (NOAA Scientific Permit # 16473). Top right - Humpback whale feeding off the coast of Virginia. Bottom – Fin whale feeding (NOAA Scientific Permit # 16473). Photos collected by the Virginia Aquarium & Marine Science Center Foundation and captured by Sarah D. Mallette.

This project is funded by U.S. Fleet Forces Command and managed by Naval Facilities Engineering Command Atlantic as part of the U.S. Navy's marine species monitoring program.

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Acronyms and Abbreviations

BSS	Beaufort Sea State
CREEM	Centre for Research into Ecological and Environmental Modeling
CZM	Coastal Zone Management Program (in Virginia)
DS	Distance sampling
ESA	U. S. Endangered Species Act of 1973
GPS	Global Positioning System
km	kilometer(s)
m	meter(s)
MMPA	U. S. Marine Mammal Protection Act of 1972
NARW	North Atlantic right whale
NAVFAC	Naval Facilities Engineering Command
OPAREA	Operating Area
SD	standard deviation
SST	sea surface temperature
UNCW	University of North Carolina Wilmington
U.S.	United States
UTC	Coordinated Universal Time
VACAPES	Virginia Capes
VAQF	Virginia Aquarium & Marine Science Center Foundation, Inc.
VA WEA	Virginia Wind Energy Area

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1. Background

1.1 Baleen whales in the VACAPES OPAREA

Evidence of seasonal use, foraging, and site fidelity from mark-recapture efforts suggest the mid-Atlantic may provide important seasonal habitat for mysticetes (Swingle *et al*. 1993, Barco *et al*. 2002, Salisbury *et al*. 2015, Mallette *et al*. 2016). All baleen whale species are protected under the U.S. Marine Mammal Protection Act (MMPA 1972) and two species, the North Atlantic right whale (NARW) and fin whale are listed as endangered under the Endangered Species Act (ESA 1973). Four species of baleen whales have been documented during both vessel and aerial surveys off the coast of Virginia, including humpback, fin, right and minke whales. NARWs are the most endangered of the four baleen whale species documented during the surveys reported here, with approximately 450 individuals remaining (Pace *et al*. 2017, Corkeron and Pace 2018). Humpback whales that utilize mid-Atlantic Ocean waters are part of the West Indies Distinct Population Segment (DPS; Bettridge *et al*. 2015), although the West Indies DPS is no longer listed as endangered under the ESA (81 Federal Register 62,260, September 8, 2016), nor are minke whales that occur in the northwest Atlantic.

The largest U.S. Navy installation in the world is based out of Norfolk, VA. Naval training and testing activities occurring off the coast of Virginia which have the potential to impact cetaceans, including large whales. In addition to Navy vessels, commercial and recreational vessels also frequent the entrance of the Chesapeake Bay and coastal ocean waters. Norfolk is also one of the top ten busiest commercial ports in the U.S., and vessel interactions are a major conservation concern for baleen whales visiting and transiting through the mid-Atlantic region (Figure 1). Two of the major threats facing baleen whales are ship strikes and entanglement in fishing gear (DeMaster *et al.,* 2001, Robbins and Mattila 2004, Knowlton *et al.,* 2011, Van Waerebeek and Leaper 2008, van der Hoop *et al.* 2013). Injury and mortality attributed to both vessel and fisheries interactions have been documented for each of the four species reviewed in this synthesis (VAQ Unpublished data).

A Seasonal Management Area (SMA) was established off the coast of VA between November 1 and April 30 to reduce the likelihood of injury and mortality from vessels during the times NARWs are migrating through the mid-Atlantic (Merrick *et al*. 2001; **Figure 1**). Within the SMA, which extends approximately 37 km from the coast, vessels larger than 65 feet are required to reduce their speed to less than 10 knots. Dynamic Management Areas (DMA) are also designated when right whales are sighted over a period of time and/or in certain densities, however, compliance with a DMA is voluntary for mariners who are requested to reduce speed and avoid specific areas where whales have been sighted.

In addition, other anthropogenic stressors including climate change, marine pollution (*e.g.* ocean noise, debris, contaminants) and cumulative impacts are important to better understand and begin to develop baselines in order to mitigate negative interactions with whales in the region. It is important to note that Unusual Mortality Events (UME) are currently ongoing for three of the four baleen whale species (*i.e.* humpback, NARW, and minke whales) documented during aerial surveys in the western North Atlantic, including off the coast of Virginia (NOAA Fisheries, 2018). The causes of the UMEs are currently being investigated.

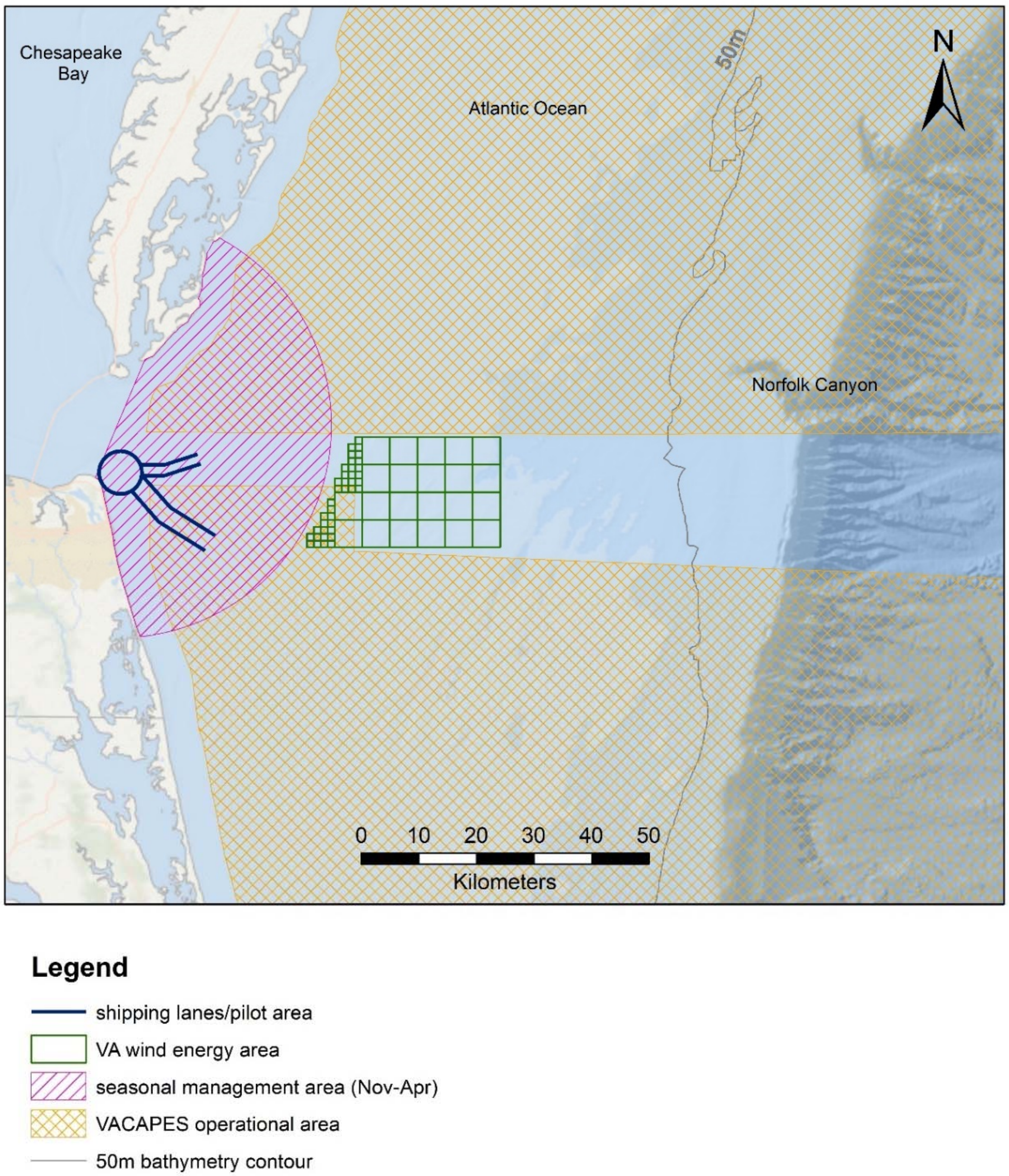

Figure 1. Study area with human use areas, including shipping lanes and pilot area, Virginia Wind Energy Area, Seasonal Management Area, and VACAPES OPAREA.

The data collected for this project contribute to regional mid-Atlantic ocean planning efforts (Read *et al.* 2014; Roberts *et al.* 2016) and complement existing Navy monitoring projects (Cummings *et al*. 2015, McAlarney *et al.* 2017). Monitoring efforts like those presented here, provide important information to the U.S. Navy for compliance with environmental laws, and development of mitigation measures. This report represents a synthesis of baleen whale seasonal occurrence and habitat use collected from visual surveys over multiple projects conducted between February 2001 and December 2017.

This document is a synthesized report to the U.S. Department of the Navy reviewing over 15 years (February 2001 and December 2017) of aerial and vessel survey effort documenting baleen whale seasonal occurrence and habitat use of ocean waters off the coast of Virginia, within the VACAPES OPAREA.

1.2 Available Datasets

To provide a baseline of species occurrence and seasonal presence in both coastal and pelagic marine habitat along the coast of Virginia (VA; U.S. east coast), we collated data from four existing aerial survey projects and one nearshore vessel dataset, which included effort off the coast of Virginia. The temporal scope of the combined datasets spanned over 15 years with varying degrees of effort (**Table 1**; **Figure 2**). A brief background of each of the four aerial survey datasets and one vessel dataset are discussed below in chronological order.

Baleen whale abundance estimates were calculated using two of the recent aerial survey datasets (CZM and Navy Coastal; **Table 1**). All datasets were then combined and summarized to provide a comprehensive spatio-temporal view of baleen whale occurrence off of the coast of Virginia.

The University of North Carolina Wilmington (UNCW) and the Virginia Aquarium Foundation (VAQF) conducted fixed-wing aerial line-transect surveys, using previously established distance-sampling protocols, to document the occurrence of marine mammals, sea turtles, other sightings (*e.g.* sharks, rays) and vessels. The main goal of these survey efforts were to provide a baseline of cetacean occurrence, seasonality, habitat use and abundance. VAQF worked closely with UNCW to maintain consistency among the safety, flight, and data-reporting protocols for existing Hatteras/Onslow/JAX baseline monitoring projects (McAlarney *et al.* 2013, 2014; Cummings *et al*. 2015, Mallette *et al*. 2018). The same survey methodology was used for each of the aerial surveys, although the survey areas were somewhat different among the projects.

Table 1. Details of survey datasets summarized for this effort. NARW and Navy Norfolk Canyon survey areas expanded south beyond the NC/VA border, however only effort and sightings from the NC/VA border and north are reported here.

Survey Datasets	Date Range	Funder	Primary Surveyor	Reference
NARW	Feb 2001 - Jun 2008	NMFS	UNCW	McLellan *et al.* 2001, 2002, 2003, 2006, 2007; Tatem *et al.* 2008.
***CZM**	Nov 2012 - Dec 2015	CZM	VAQF	Mallette *et al. 2014,* 2016*a*
***Navy Coastal**	Jan 2016 - Jun 2017	U.S. Navy	VAQF	Mallette *et al.* 2016*b,* 2017
Navy Offshore	Jan 2016 – Dec 2017	U.S. Navy	UNCW	McAlarney *et al.* 2017, 2018
Vessel cruises	Mar 2007 - Feb 2017	Private	VAQF	VAQF unpublished data

***Asterisks denote the two datasets (CZM and Navy Coastal) which were used to calculate abundance estimates.**

1.2.1 UNCW NARW Surveys

In multiple years from 2001 to 2008, UNCW conducted coastal aerial surveys with tracklines extending 50km offshore from perpendicular the coastline of North Carolina and Virginia. Only effort off the southeast coast of Virginia is included in this report. The surveys provide sightings documented over a decade ago offering valuable data on historical baleen whale occurrence. Effort in the Virginia portion of the survey area was not consistent and varied both within and between seasons. The goal of this project was to document seasonal occurrence of NARWs.

1.2.2 VAQF CZM Surveys

Between November 2012 and November 2015, VAQF in collaboration with UNCW conducted surveys in the proximity of the Virginia Wind Energy Area (VA WEA) encompassing a 10,000-square-kilometer area off the mouth of the Chesapeake Bay. Survey efforts were funded by the Coastal Zone Management Program (CZM) in the Virginia Department of Environmental Qualit*y*. The goal of this project was to establish a baseline of seasonal occurrence of baleen whales in the vicinity of the VA WEA, located 27 miles off the coast of Virginia. Surveys were primarily conducted in cooler months (Nov-Mar) with some effort in warmer water months. Surveys occurred in all months except July, although effort was not consistent among years.

1.2.3 VAQF Navy Coastal Surveys

As a continuation of the CZM effort, the United States (U.S.) Navy funded aerial surveys on the continental shelf off the mouth of the Chesapeake Bay from January 2016 through June 2017. The survey site included an approximately 6,500-square-kilometer area within the Virginia portion of the VACAPES OPAREA. The objective of these surveys was to complement existing U.S. Navy marine species monitoring efforts (Aerial Survey Baseline Monitoring- Atlantic Fleet Training and Testing) and support environmental planning and regulatory compliance along the

East Coast of the U.S. Effort occurred monthly in 2016 and from January through June of 2017. One day of effort occurred during May through November of 2016 and in May of 2017, while one and a half to two survey days were achieved in each of the remaining months.

Given the overlap in survey area and continuation of effort of these two projects (CZM and Navy Coastal), baleen whale sighting data collected during these surveys were combined for abundance estimation.

1.2.4 UNCW Navy Offshore Surveys

Survey effort of outer continental shelf waters and waters beyond the shelf break (**Figure 2**) was conducted by UNCW between January 2016 and September 2017 (McAlarney *et al.* 2017, 2018). The survey area was designed to create continuous coverage of the shelf break from the northern extent of the UNCW Cape Hatteras survey area to the northern extent of the Norfolk Canyon. To minimize overlap with VAQF Navy coastal surveys, the survey area excluded inshore waters. Although the Norfolk Canyon survey area extended south beyond the VA/NC boundary, only survey effort and sightings off the coast of Virginia that overlapped with the surveys listed above were included in this report.

1.2.5 VAQF Vessel Cruises

Baleen whale sightings documented from vessels during VAQF nearshore research cruises were also included for qualitative analyses. Vessel data included in the maps and species specific discussion spanned ten years, between March 2007 and March 2017. 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. VAQF vessel cruises were directed (*i.e.* most effort occurred where higher seasonal concentrations of whales have been historically documented) in nearshore ocean and Bay waters along the Virginia Beach coast and southern entrance of the Chesapeake Bay. Vessel cruises occurred seasonally based on timing of previous years' sightings and when whales were reported in the area.

Systematic documentation of whale sightings, georeferenced positions, and environmental data were collected during these cruises and since 2012, vessel track data has also been collected. These data are used in the species-specific results section however the vessel dataset was excluded for the seasonal occurrence discussion as effort was not consistently collected.

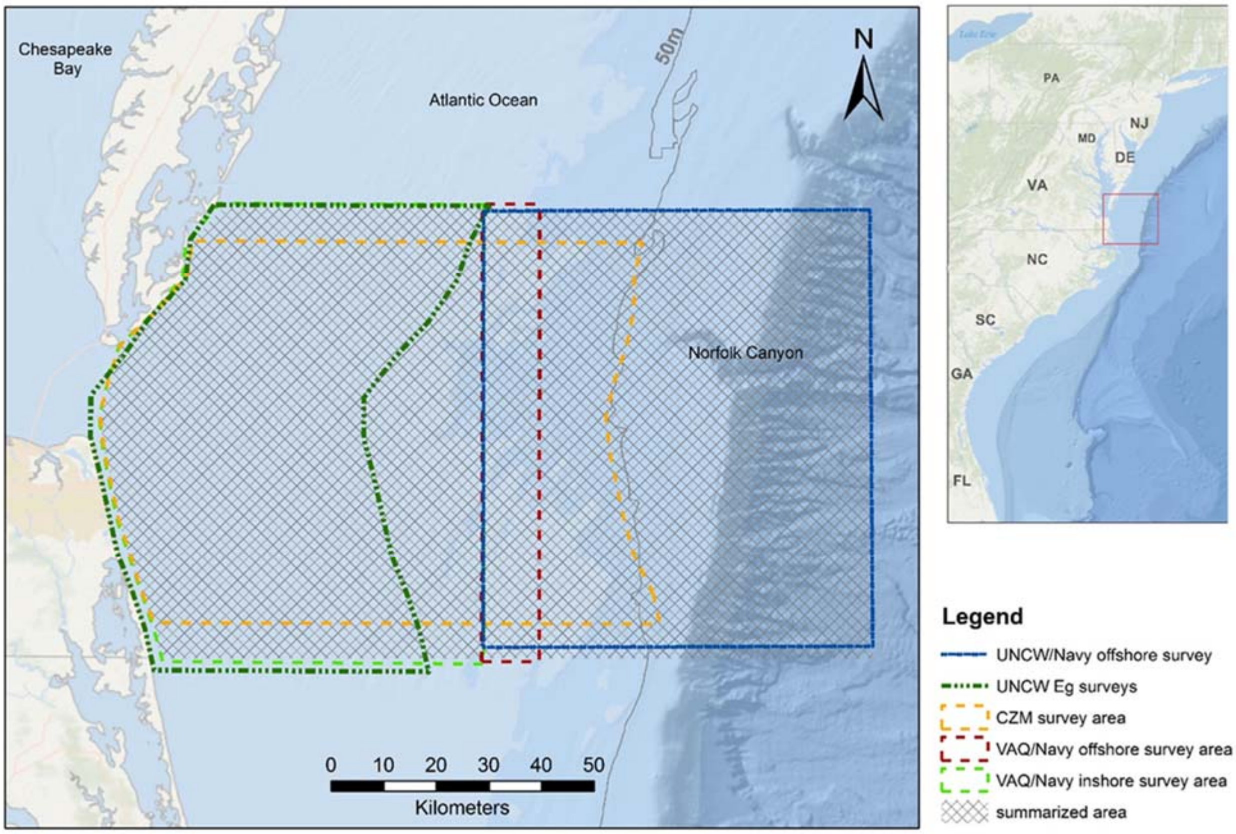

Figure 2. Boundaries for all aerial survey projects synthesized in this report. This includes, UNCW NARW, VAQF CZM, VAQF U.S. Navy Coastal, and UNCW Navy Norfolk Canyon surveys conducted off the coast of Virginia. The combined survey area analyzed for this project is shown in hatched gray.

2. Methods

2.1 Abundance Estimates

Abundance estimates were calculated using CZM and Navy Coastal Survey datasets. Although the survey areas were slightly different between the two projects (10,000 km^2 and 6,500 km^2 respectively), there was substantial overlap. Abundance was estimated from density assuming an area of 10,000 km^2.

Line transect distance sampling (DS) analysis methods (Buckland *et al*. 2001) were used to estimate individual density (D) as follows:

$$\widehat{D} = \frac{n}{2wL\hat{p}}.\hat{E}[s]$$

and abundance (N) as

$$\hat{N} = \hat{D}.A$$

where

- n is the number of groups (a group can be one or more animals) detected within perpendicular truncation distance w. Detections recorded as opportunistic sightings were not included.
- L is total survey effort
- $\hat{p}$ is the estimated average probability of detection within distance w of the trackline
- $\hat{E}[s]$ is the estimated population mean group size
- A is the area of the study region.

2.1.1 Perpendicular distance calculation

Exact distances from a detected individual/group to the trackline could be calculated for each whale detection, because when baleen whales were detected, search effort was suspended and the plane left the trackline and flew over the animals to obtain an accurate location. The perpendicular distance, x_d, was calculated from the distance between the location at suspension of effort and the location of the detected group, r, and the horizontal angle from the bearing of the plane to the detected group when effort was suspended, θ, as follows

$$x_d = r\,.\sin\theta$$

If the location at the suspension of search effort coincided with the location of the whale, the perpendicular distance was estimated to be zero (since the whale was on the center line of the trackline).

2.1.2 Probability of detection

Two critical assumption of DS methods are that all groups on the transect center line (*i.e.* at zero perpendicular distance) are detected with certainty and that distance measurements are exact. Given these assumptions, the distribution of perpendicular distances are used to model how the probability of detection decreases with increasing distance from the trackline.

The probability of detection, p, was estimated from a detection function model fitted to the observed distribution of perpendicular distances using exact distances for whales. Perpendicular distances were truncated, where required, to avoid a long tail in the detection function. The number of detections for each species/species group for each survey was small, and so perpendicular distances from all surveys were combined to obtain one detection function for each of the three combinations of whale species of interest. In each case, two forms of the detection function were considered (without adjustment terms), a hazard rate and a half normal, and the form that resulted in the smallest Akaike Information Criterion (AIC) was selected (see Buckland *et al*. 2001 for details of detection function models and model selection methods).

2.1.3 Estimated mean population group size

Population mean group size was estimated by regressing the natural logarithm of group size against estimated detection probability, and using the regression model to predict group size where detection probability is one (*i.e*. expected group size at the point where all groups, and hence all group sizes, are assumed to be detected). Observers recorded their minimum, maximum and best estimates of group size – the best estimates of group sizes were used in the analysis.

2.1.4 Density and abundance

Detections and search effort were pooled within each season and survey block to obtain encounter rates ($^{n}/_{L}$), and hence average estimates of density and abundance, by season. Seasonal densities and abundances were estimated for

- baleen whales (NARW; fin whales, humpback whales and minke whales),
- ESA listed whales (NARW; fin whales) and
- humpback whales

The analyses were performed using the program Distance version 7.2 Release 1 (Thomas *et al*. 2010) using the conventional distance sampling (CDS) analysis engine. Coefficients of variation (CV) were obtained using the delta method (Buckland *et al*. 2001). The encounter rate variance was estimated using the 'R2' estimator of Fewster *et al*. (2009) – the default estimator in CDS analysis.

2.2 Seasonal baleen whale occurrence

In addition to seasonal abundance estimates described above, all four aerial surveys were used to calculate an index of occurrence allowing qualitative seasonal comparisons despite differences in survey effort across seasons. Effort was calculated as km of trackline flown from the start and end locations of the tracklines (on effort) that were recorded by the observer on the left side of the plane. Effort recorded by the right observer was checked for consistency with the left observer. Vessel survey effort was not collected consistently, (specifically between 2001-2006) nor did vessels follow consistent tracklines. Thus, sightings from vessel cruises were not included in seasonal comparisons. For this analysis and abundance estimates, seasons were defined based on water temperatures and delineated as follows:

- **Winter** (January to March)
- **Spring** (April to June)
- **Summer** (July to September)
- **Autumn/Fall** (October to December)

2.3 Species distribution

Species distribution was qualitatively assessed by examining sightings spatially by species and collectively by season. We included total estimates of individual whales sighted during aerial and vessel surveys combined (including off-effort sightings) in the species-specific data analyses and corresponding maps. Baleen whale distribution was also considered relative to the SMA, shipping lanes, and the VACAPES OPAREA. Additional environmental covariates including: depth, distance from shore, and Sea Surface Temperature (SST), were acquired for each georeferenced baleen whale sighting (**Table 2**). For those whale sightings that had available environmental data, we summarized sightings relative to depth, distance from shore and sea surface temperature. Using ArcGIS, distance from shore (meters) was calculated for each sighting point and to the nearest NOAA CUPS shoreline. Mean, SD, and min/max values for each environmental variable were calculated.

Table 2. Depth and daily sea surface temperature (SST) sources used for qualitative assessment of patterns in whale occurrence.

Variable	Datasets	Data description	Data provider	Projection system/grid	Temporal coverage	Geographic coverage	Temporal resolution		Data format	Active
depth	ETOPO1	Topography and bathymetry	NASA	Regular grid (WGS84 ellipsoid)	1940–2008	90°N–90°S		1 arc-minute	NetCDF	**Yes**
						180°E–180°W				
day_sst	MODIS Ocean	Ocean surface, color, and productivity	NASA	Cylindrical Equidistant	2002–present	90°N–90°S	Daily, 8-day, monthly, yearly	4 km	NetCDF4	**Yes**
						180°E–180°W				
						0°–170°W				

3. Results

3.1 Abundance Estimation

The Virginia coastal surveys (CZM and Navy Coastal datasets) used for abundance estimation covered 536.5 tracklines totaling 40,901 km of effort over 65 survey days. Four baleen whale species - humpback (*Megaptera novaeangliae*), fin (*Balaenoptera physalus*), North Atlantic right (*Eubalaena glacialis*) and minke (*Balaenoptera acutorostrata*) - whales were observed in the survey area “on effort”, including 19 groups of humpback whales (27 individuals), 18 groups of fin whales (30 individuals), 7 groups of NARWs (10 individuals) and 2 groups of minke whales (3 individuals). The majority of these observations occurred during winter and spring (**Table 3**). No observations of baleen whales were made during summer surveys. The most frequent observations were single whales, but a group of four NARWs and a group of four humpback whales were also observed (**Figure 3**).

Table 3. Summary of surveys by season: search effort (*L*) and number of groups detected on search effort (*N*) by species.

Season	*L* (km)	*Number of groups observed (N)*			
		Humpback	Fin	NARW	Minke
Winter	12,257	10	6	6	1
Spring	15,184	6	12	1	1
Summer	5,605	0	0	0	0
Fall	7,856	3	0	0	0
Total	**40,901**	**19**	**18**	**7**	**2**

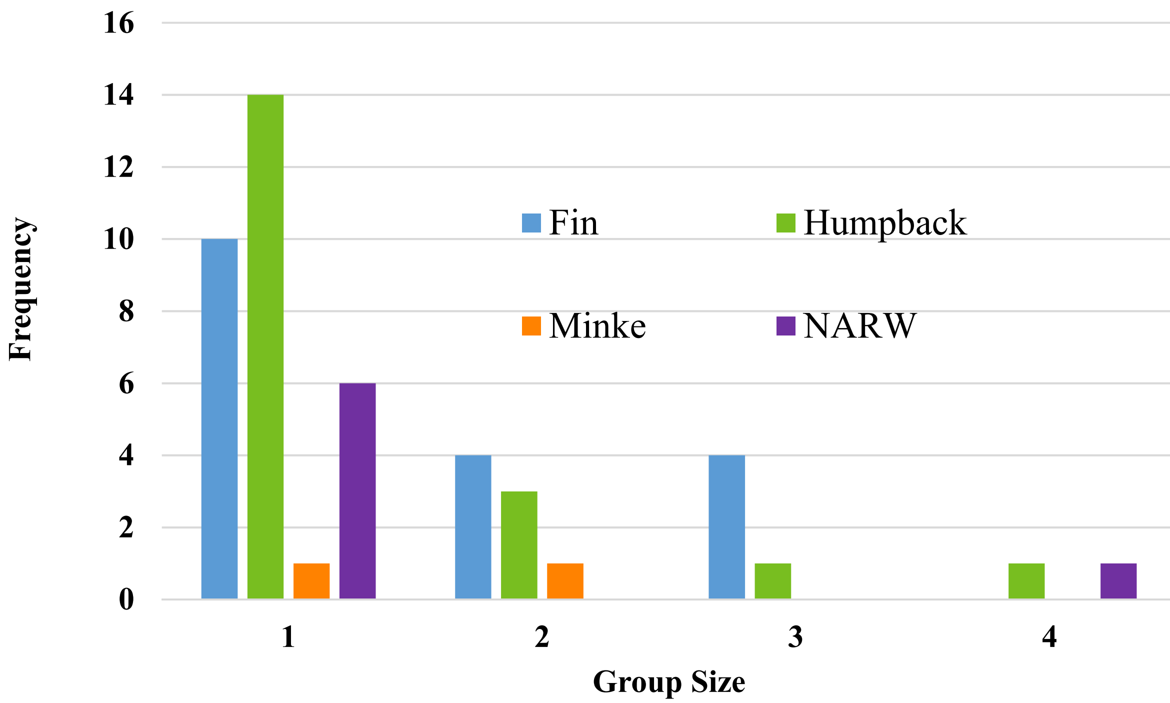

Figure 3. Distribution of group size by species. The maximum group size recorded was four, which was documented for both humpback whales and NARWs.

3.1.1 Probability of detection

Although the numbers of detected groups were relatively small for detection function estimation, detections functions were developed separately for all baleen whales, ESA listed baleen whales, and humpback whales which was the only species with enough detections for a species-specific abundance estimate.

The maximum distance from the trackline a baleen whale group was detected was 3,018 m and no truncation was used because so few groups were detected. A hazard rate detection function for baleen whales had a slightly lower AIC than the half-normal detection function and was selected (**Figure 4**; **Table 3**). This resulted in an overall probability of detection of baleen whale groups of 0.38 (CV = 0.19), which was equivalent to an estimated effective strip half-width (the distance at which the number of groups missed within it was equal to the number detected beyond it) of 1,135 m.

Whales were grouped into (1) baleen whales (NARW, fin, humpback and minke), (2) ESA listed baleen whales (NARW and fin), and (3) humpbacks whales. The majority of baleen whales were NARWs and fin whales and so the detection function for ESA listed baleen whales was similar to that for baleen whales. Similar to the estimate for all baleen whales, the hazard rate detection function was selected (**Figure 4**; **Table 3**). The estimated probability of detection for ESA listed baleen whales was 0.34 (CV=0.32).

The maximum distance a humpback whale was detected was 2,050 m and no truncation was used. A half-normal detection function was selected for humpback whales resulting in a probability of detection of 0.63 (CV=0.18).

Table 4. Summary of detection function fitting and group size estimation. Coefficients of variation are given in parentheses.

Species/species group	w	n	AIC		$\hat{p}$	$\bar{s}$	$\hat{E}[s]$
			HN	HR			
Baleen whales	3018	46	708.6	**705.9**	0.38 (0.19)	1.52 (0.08)	1.52 (0.07)
ESA listed baleen whales	3018	25	390.1	**386.9**	0.34 (0.32)	1.60 (0.11)	1.73 (0.11)
Humpback whales	2050	19	**288.0**	289.2	0.63 (0.18)	1.42 (0.14)	1.41 (0.11)

w - truncation distances (meters), n - number of groups used in detection function fitting, AIC - values for the half-normal (HN) and hazard rate (HR) detection functions, $\hat{p}$ – probability of detection (for the selected function (shown in bold), $\bar{s}$ - average group size, ($\hat{E}[s]$) - regression-based estimates

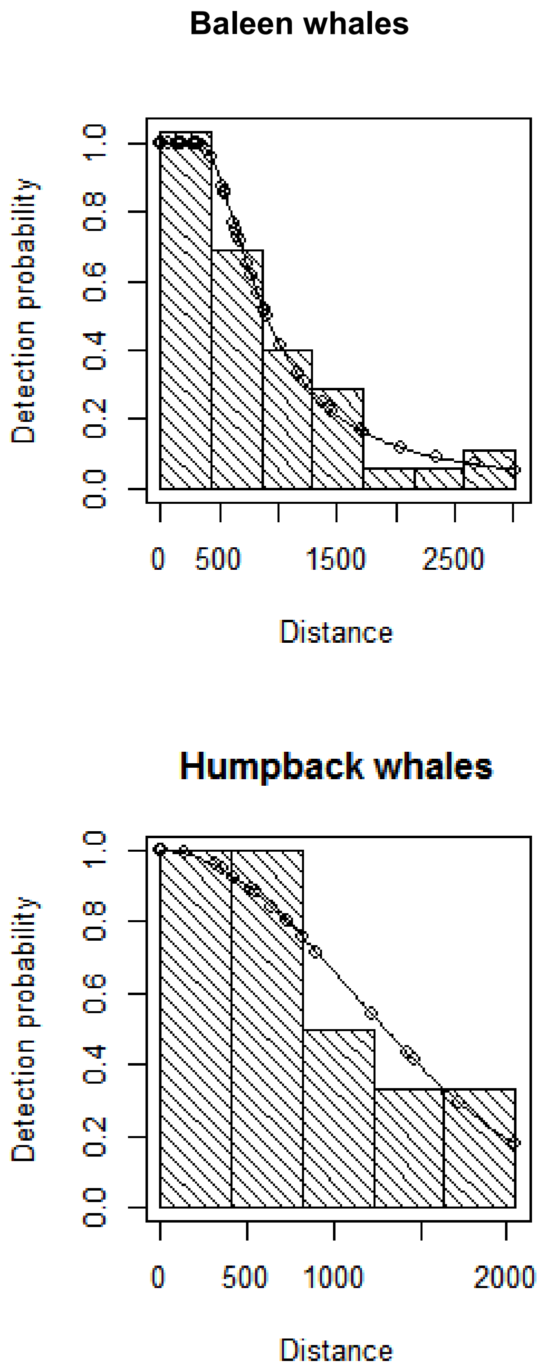

Figure 4. Estimated detection functions (black line) overlaid onto the scaled perpendicular distance (meters) distributions for baleen whales, ESA listed baleen whales, and humpback whales.

3.1.2 Estimated mean population group sizes

The group size regression estimates account for the tendency of smaller groups being missed at larger distances, and thus these estimates tend to be lower than the observed average group sizes.

This was not the case for ESA listed baleen whales, although the differences between the two estimates were small. The estimated group size used in the density estimator for baleen whales was 1.52 animals (CV=0.07), for ESA listed baleen whales it was 1.73 animals (0.11) and for humpback whales it was 1.41 animals (0.11; **Table 4)**

3.1.3 Density and abundance estimates

Average density estimates by season were obtained by using encounter rates for each season and applying the detection probabilities and estimated group sizes estimates described above. Summaries of seasonal encounter rates and densities for baleen whales, ESA listed baleen whales and humpback whales are given in **Table 5**. For all species/group combinations, the highest densities occurred in winter, followed by spring and fall. No detections of baleen whales occurred during summer surveys.

Table 5. Summary of baleen whale density and abundance by season and block: number of groups (*n*), encounter rate of groups (*n*/*L*; groups per km), estimated density ($\hat{D}$, individuals per km²). Coefficients of variation are in parentheses.

All baleen whales

Season	n	n/L	$\hat{D}$	$\hat{N}$	95% CI for N
Winter	23	0.0019 (0.32)	0.00126 (0.38)	13 (0.38)	6 - 26
Spring	20	0.0013 (0.36)	0.00088 (0.41)	9 (0.41)	4 - 19
Summer	0				
Fall	3	0.0004 (0.57)	0.00026 (0.61)	3 (0.61)	1- 8

ESA listed baleen whales

Season	n	n/L	$\hat{D}$	$\hat{N}$	95% CI for N
Winter	23	0.00098 (0.42)	0.00082 (0.54)	8 (0.54)	3 – 22
Spring	20	0.00086 (0.39)	0.00072 (0.52)	7 (0.52)	3 - 19
Summer	0				
Fall	0				

Humpback whales

Season	n	n/L	$\hat{D}$	$\hat{N}$	95% CI for N
Winter	10	0.00082 (0.31)	0.00044 (0.37)	4 (0.37)	2 – 9
Spring	6	0.00040 (0.47)	0.00021 (0.51)	2 (0.51)	1 – 6
Summer	0				
Fall	3	0.00038 (0.57)	0.00021 (0.61)	2 (0.61)	1 – 6

3.2 Synthesis of Survey Effort

Spatial coverage and effort varied between survey projects and across years/seasons (**Figure 5**). Cumulatively, 68,922.2 kilometers of trackline were flown between February 2001 and

December 2017. During 2016 and 2017, both U.S. Navy Coastal surveys and Navy Offshore Surveys were conducted with some overlap (**Figure 6**). The greatest survey effort occurred in 2017 (total 10,828 km) during the U.S. Navy Coastal Surveys (11,912 km), and U.S Navy Offshore Surveys (8441 km) while the least amount of effort occurred during the 2012 CZM surveys (760 km) which started in the fall of 2012.

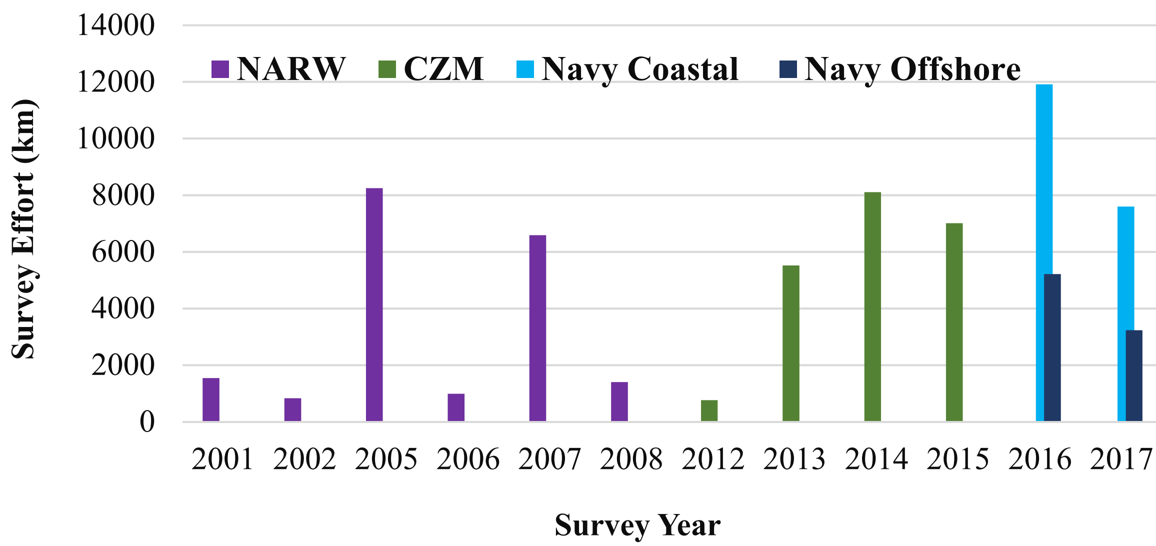

Figure 5. Effort (km flown) for aerial surveys conducted between 2001 and 2017.

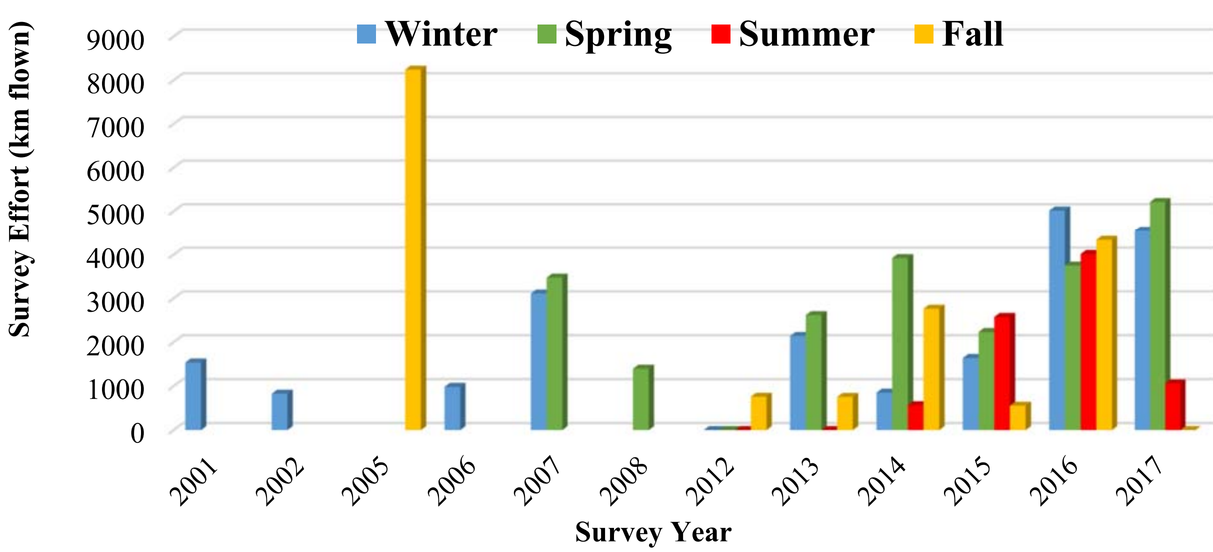

Figure 6. Seasonal survey effort (km flown) from 2001 through 2017 (winter=January-March; spring=April-June; summer=July-September; fall=October-December).

3.3 Seasonal baleen whale occurrence & distribution

Because the aerial surveys could be corrected for effort, these surveys were combined to examine seasonal baleen whale occurrence trends to compare with seasonal abundance estimates. Seasonally, the greatest survey effort occurred in the spring (33%) and winter (30%) while the lower effort occurred in fall (25%) and summer (12%; **Figure 7**).

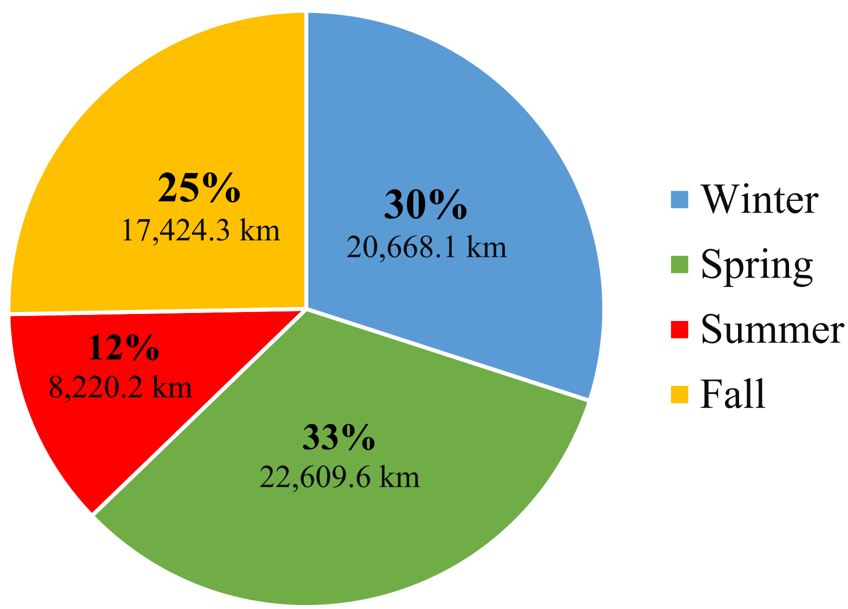

Figure 7. Percentage of total aerial survey effort (68,922.2 km flown) that occurred seasonally between 2001 and 2017 (winter=January-March; spring=April-June; summer=July-September; fall=October-December).

Sighting rates (*i.e.* # whale sightings/100 km flown) were calculated for each species of baleen whales and total whales using all aerial survey datasets. Most sightings of all whales combined occurred in winter (0.18/100km), followed by spring (0.12/100km), summer (0.06/100km), and fall (0.03/100km) respectively (**Table 6**).

WINTER

Overall sightings during winter months were distributed closer to shore and all sightings were west of the 50 m isobath (**Figure 8**). All baleen whale species except for minke whales were documented in the VACAPES OPAREA during winter. Winter sighting rates were highest for fin whales (0.08 whales/100 km), followed by humpback (0.6 whales/100 km), NARW (0.03 whales/100 km), and minke (0.005 whales/100 km) whales. Humpback and fin whales were recorded in the shipping channels and pilot area and within the SMA. Most sightings of these two species tended to be distributed near the southern entrance of the Chesapeake Bay. All right whale sightings except for one, were located east of the SMA.

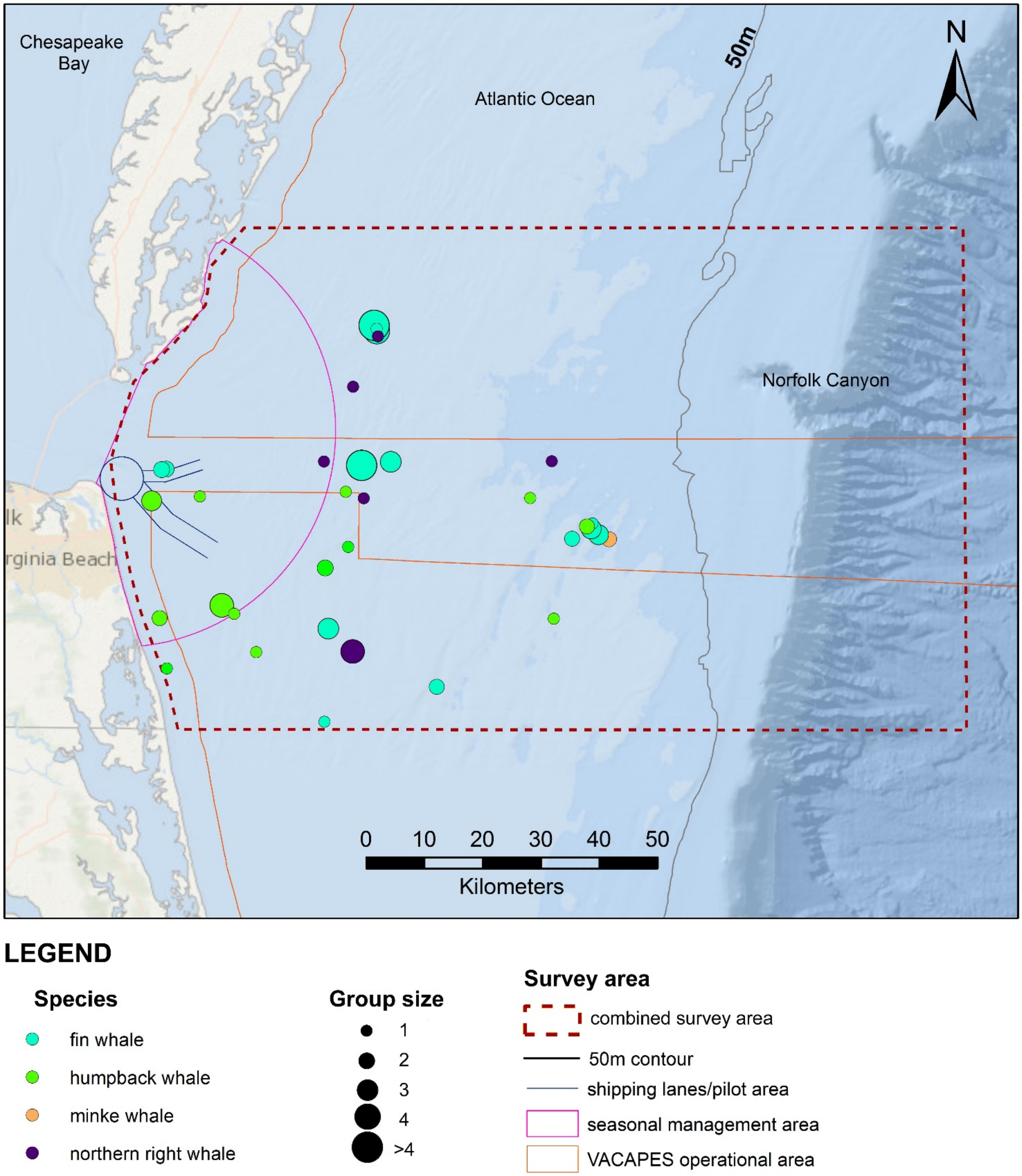

Figure 8. On-effort sightings of baleen whales during winter (January-March) aerial surveys between 2001- 2017.

SPRING

Spring exhibited the second to highest sighting rates for all whales (0.12/100 km). Whale distribution during spring tended to be farther offshore than winter, with a majority of sightings along the western side of the 50 m isobath (**Figure 9**). The majority of spring sightings were of fin whales with a sighting rate of 0.08/100 km, followed by humpback (0.03/100 km), NARW (0.01/100 km), and minke (0.04/100 km) whales. Fin, minke and humpback whales were documented within the VAPCAPES OPAREA, while there were no sightings of any species within the shipping channels or pilot area. There were two sightings of right whales documented, east of the SMA. Although there were few nearshore sightings, humpback whales were observed closest to shore.

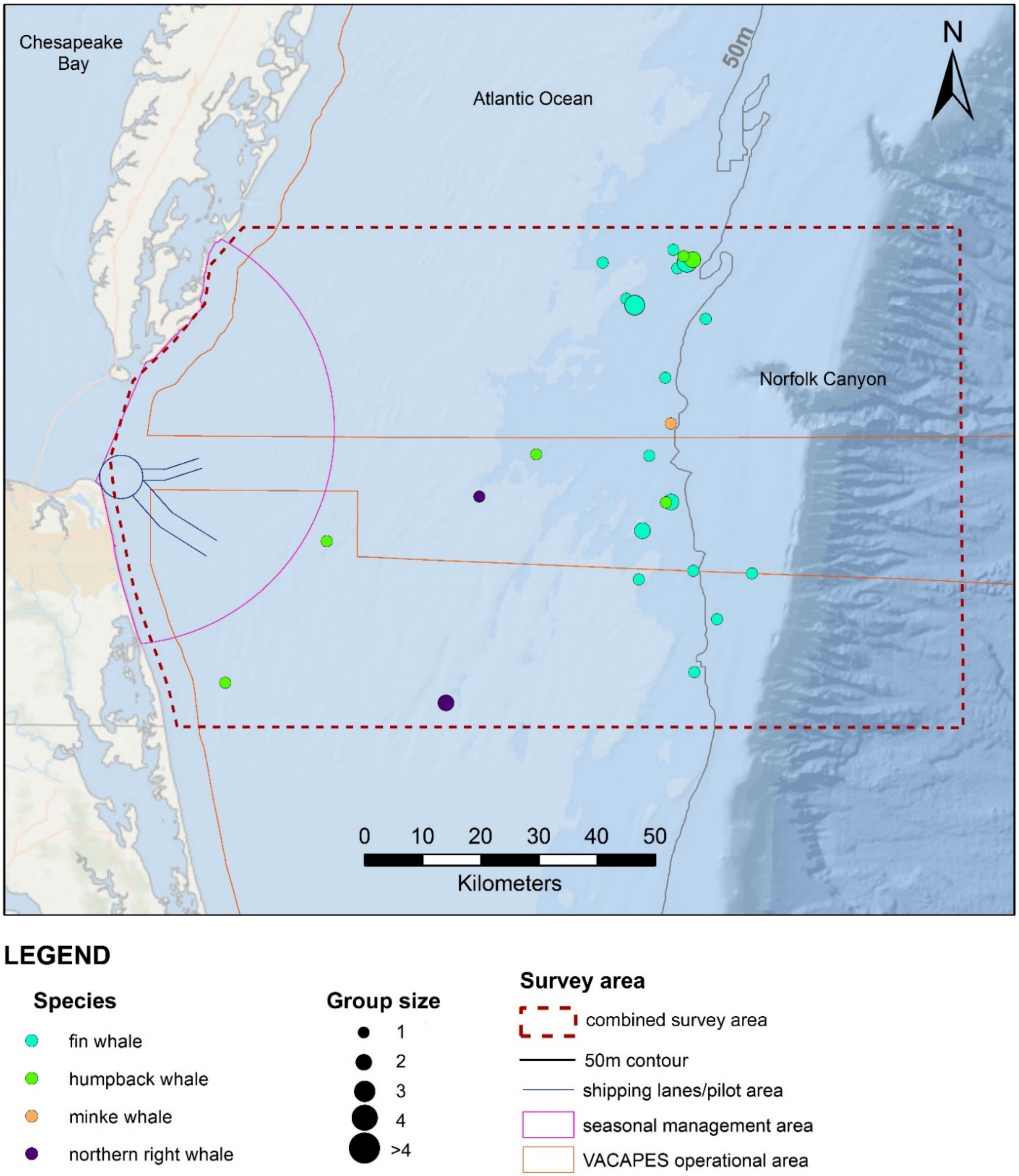

Figure 9. On-effort sightings of baleen whales during spring (April-June) aerial surveys between 2001- 2017.

SUMMER

Most summer effort occurred in recent years (2015- 2017) and more effort in the summer was conducted in the offshore (Norfolk Canyon) survey area than in inshore waters. Sighting rates in summer were highest for minke whales (0.02/100 km) followed by fin whales (0.04/100 km). These sightings were exclusively offshore in the Norfolk Canyon survey area (**Figure 10**; **Table 6**). Humpback and NARW's were not documented during summer months.

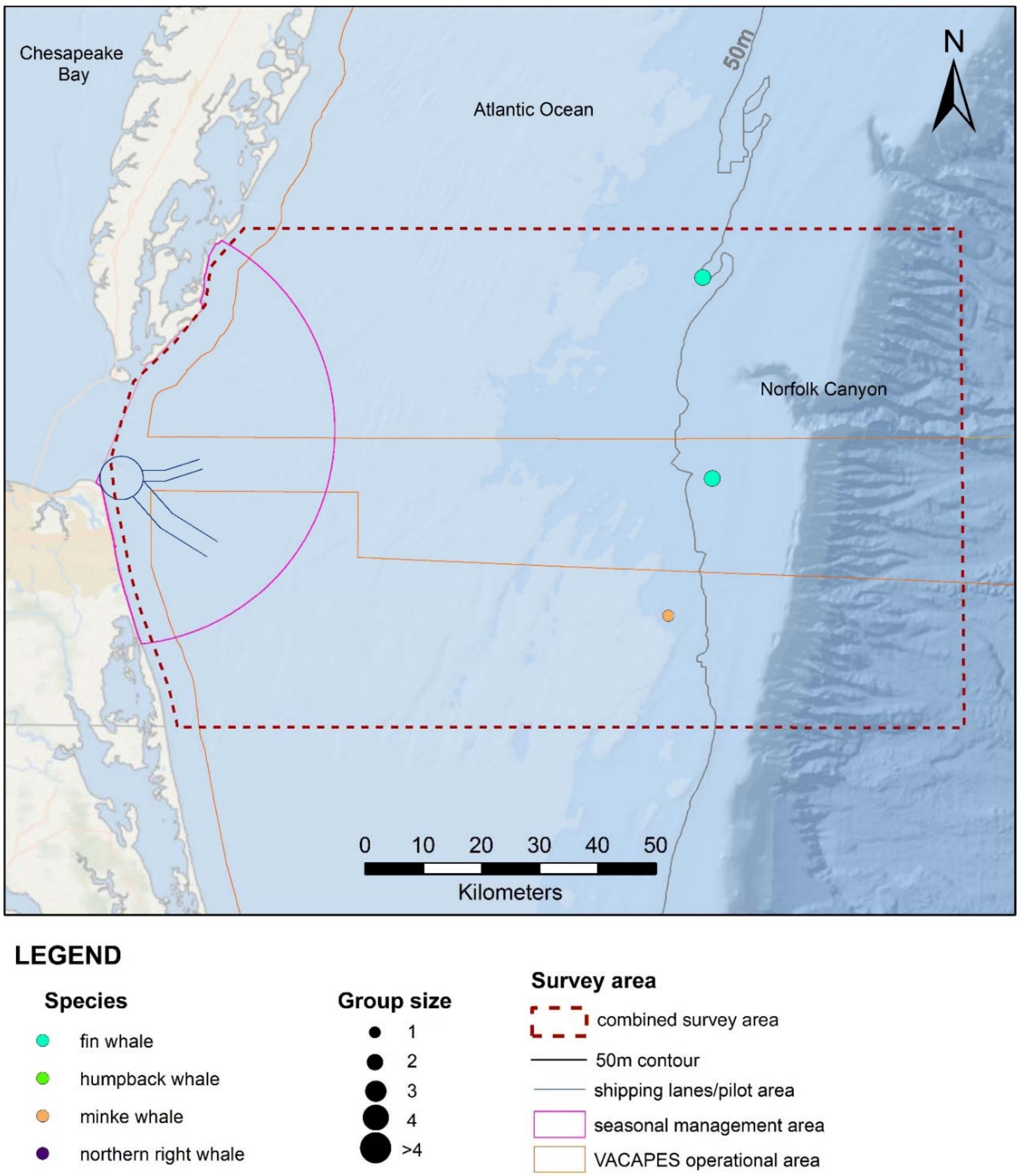

Figure 10. On-effort sightings of baleen whales during summer (July-September) aerial surveys between 2001- 2017.

FALL

Fall sightings included one humpback nearshore, along the border of the VACAPES OPAREA and a shipping channel (**Figure 11**). The sighting rate was 0.02/100 km.

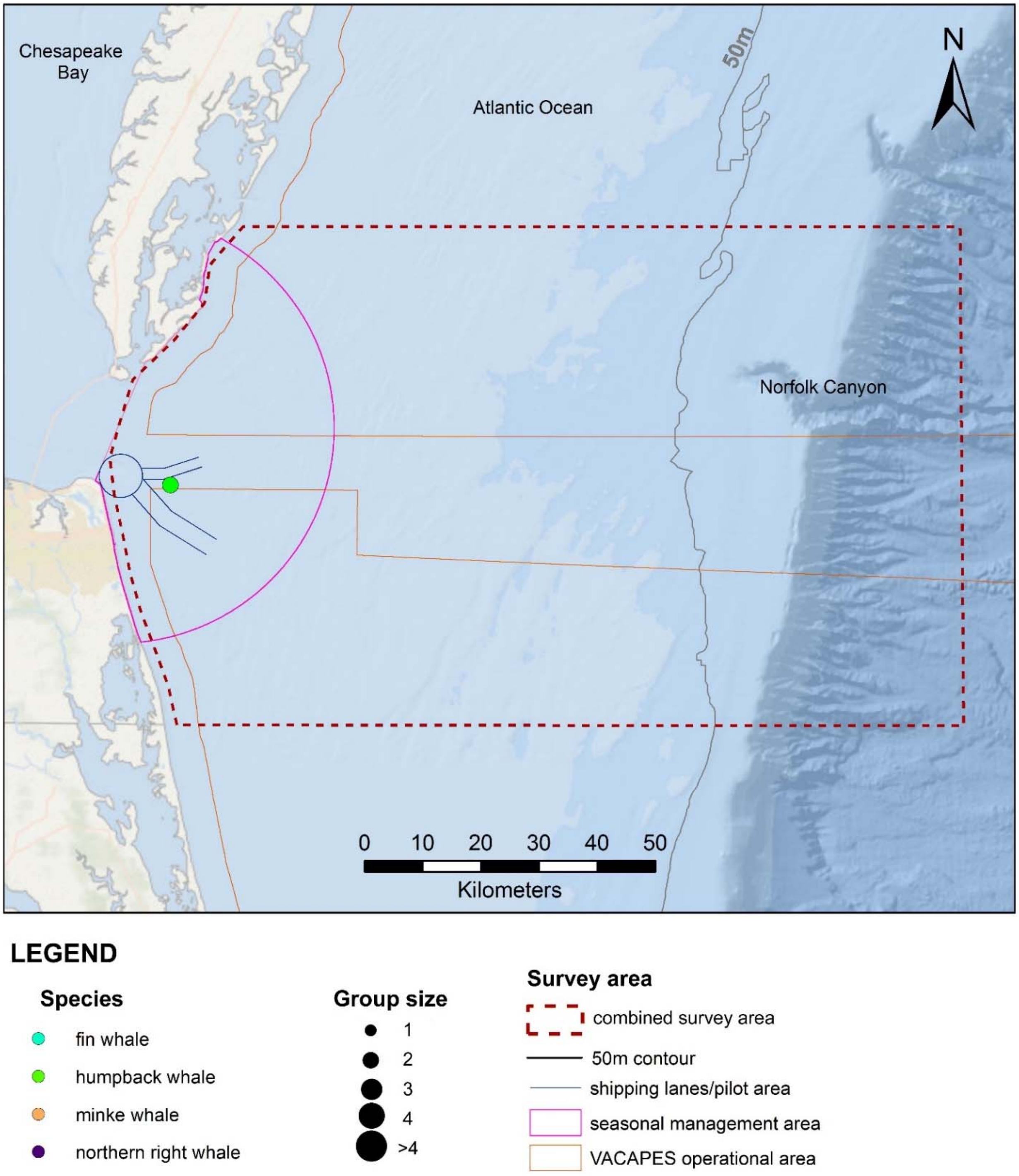

Figure 11. On-effort sightings of baleen whales during fall (Oct-Dec) aerial surveys between 2001-2017.

Table 6. Sighting rates (# whale sightings/100 km effort) of baleen whales sighted on-effort by season.

Season	Effort (km flown)	Humpback	Whales/ 100 km effort	Fin	Whales/ 100 km effort	NARW	Whales/ 100 km effort	Minke	Whales/ 100 km effort	All Whales	Whales/ 100 km effort
Spring	22609.6	7	0.03	17	0.08	2	0.01	1	0.00	27	0.12
Summer	8220.2	0	0.00	3	0.04	0	0.00	2	0.02	5	0.06
Fall	17424.3	4	0.02	1	0.01	0	0.00	0	0.00	5	0.03
Winter	20668.1	13	0.06	16	0.08	6	0.03	1	0.00	36	0.17
All Seasons	68922.2	24	0.03	37	0.05	8	0.01	4	0.01	73	0.11

3.4 Species-specific baleen whale occurrence

The combined aerial surveys covered 68,922.2 km of trackline over 135 days between 2001 and 2017. VAQF research cruises between 2007 and 2017 covered 5,745 km over 142 days. Together, these surveys documented an estimated total of 476 individual whales of four species, and seventy percent (N=476) of individual whales were humpback whales, followed by fin (23%; N=111), NARW (4%; N=19) and minke (2%; N=8; **Figure 12**).

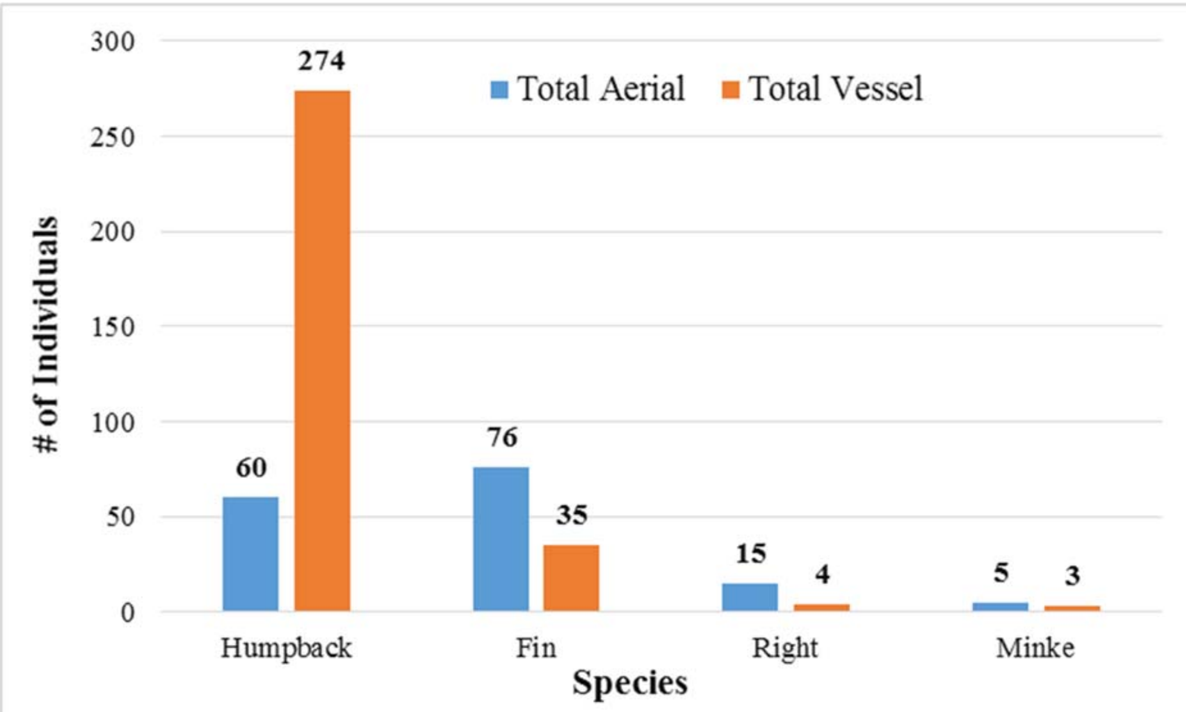

Figure 12. Number of individual whales documented during vessel and aerial surveys between February 2001 – December 2017.

Qualitative assessment of baleen whale distribution revealed species-specific differences, with a majority of humpback whales sighted nearshore, and fin and minke whales predominately offshore along the continental slope. NARWs were primarily observed in the central shelf region (**Figure 13-14**). Two sightings had higher SST than all other sightings, and both occurred in fall; one was a fin whale sighted in October where the SST was 21 °C, the other was a humpback whale in November where the SST was 19 °C. These values were above three standard deviations of the mean and therefore were considered outliers. When these two outliers were excluded, whales were sighted in sea surface temperatures (SST) ranging between 3 °C and 15 °C (mean=8.9±2.4 SD).

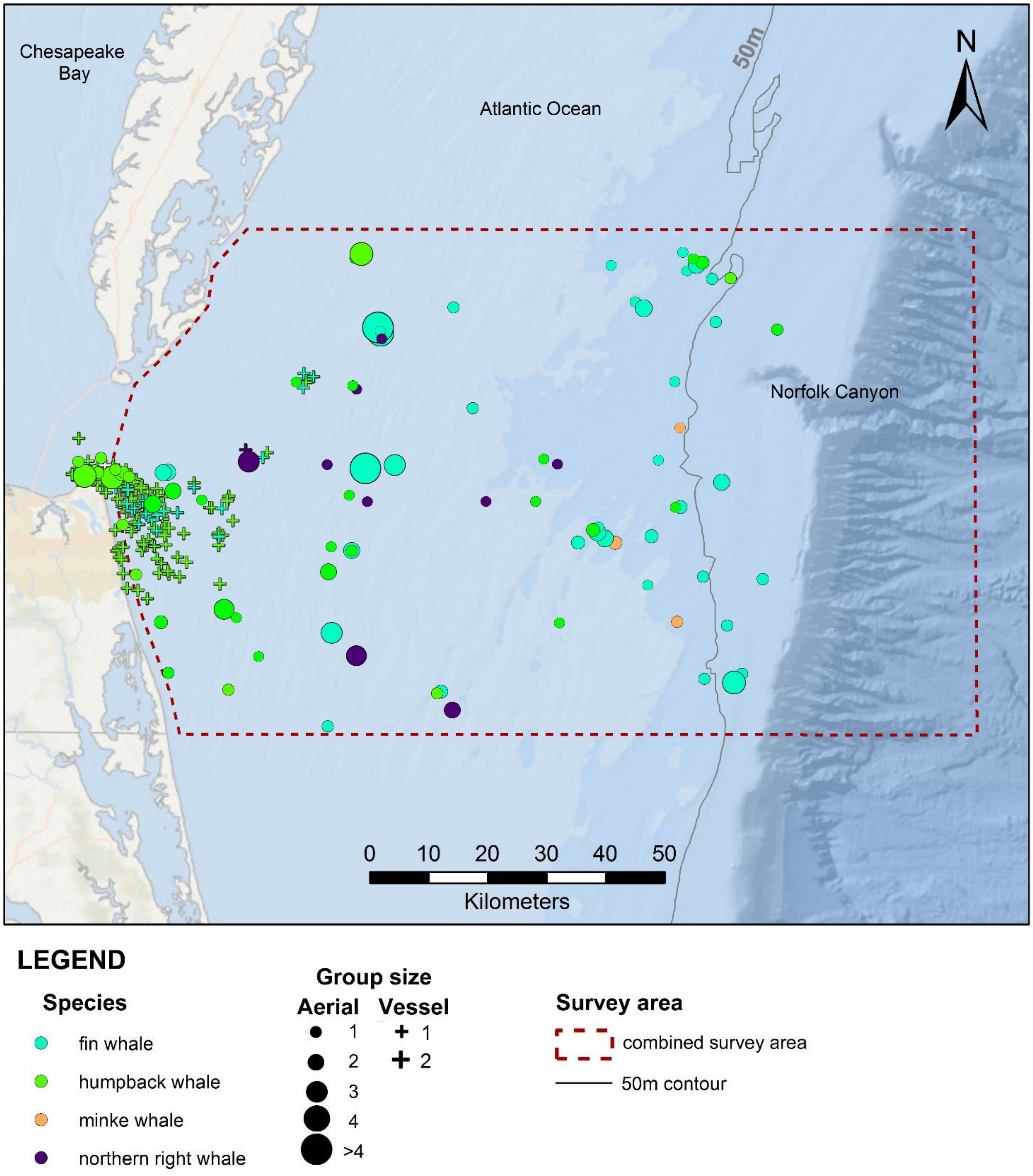

Figure 13. Baleen whale sightings. Sightings include all aerial survey projects and VAQF research vessel surveys.

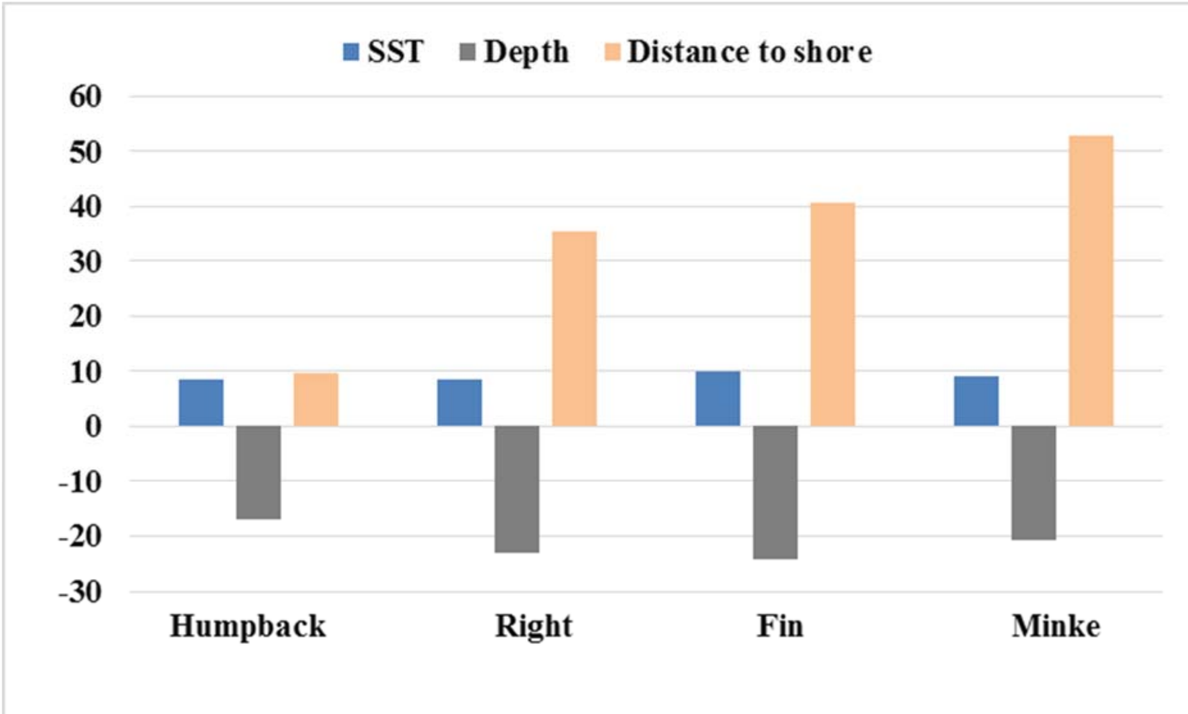

Figure 14. Species-specific baleen whale occurrence relative to mean sea surface temperature (degrees Celsius), depth (m), and distance from shore (km).

3.4.1 Humpback whale (*Megaptera novaeangliae*)

An estimated 334 individual humpback whales were recorded during the during the study period. Humpback whales were the most commonly sighted baleen whale species (**Figure 15**). Most sightings were concentrated near the southern entrance to the Chesapeake Bay, near or within the shipping channels. The majority of sightings located around the bay were recorded from vessel surveys, however aerial surveys also documented humpbacks in the same area. Aerial surveys resulted in detections further offshore than vessel surveys, mostly in spring, when few vessel surveys were conducted. The difference in distance from shore between winter and spring, also appears when only aerial survey data are considered, thus it is not solely an artifact of platform (see Figures 8 and 9). Mean sighting depth (±SD) and mean distance from shore (±SD) were 16.9 ± 8.4 m and 9.82 ± 14.4 km from shore respectively. Mean SST was 8.8 ± 3.3 °Celsius **(Figure 14)**.

Humpback whales were documented feeding (lunge and bubble net feeding), diving, breaching, and transiting through the survey area. Group size ranged from one to four individuals (mean=1.3). Whales appeared to be mostly juvenile and subadult animals, which aligns with findings from local photo-identification efforts (Barco *et al.* 2002, Swingle *et al.* 1993) and stranding records (VAQS unpublished data). No calves were observed over the course of the study period.

Since the humpback whale has been the focus of ongoing photo-identification work in the region, all efforts were made to document features on the animals that could aid in identifying individuals. Although identifying individual whales was not possible for every sighting and all images from the aerial survey datasets were not available, 18 of 38 identified whales were matched to the mid-Atlantic Humpback Whale Catalog (MAHWC).

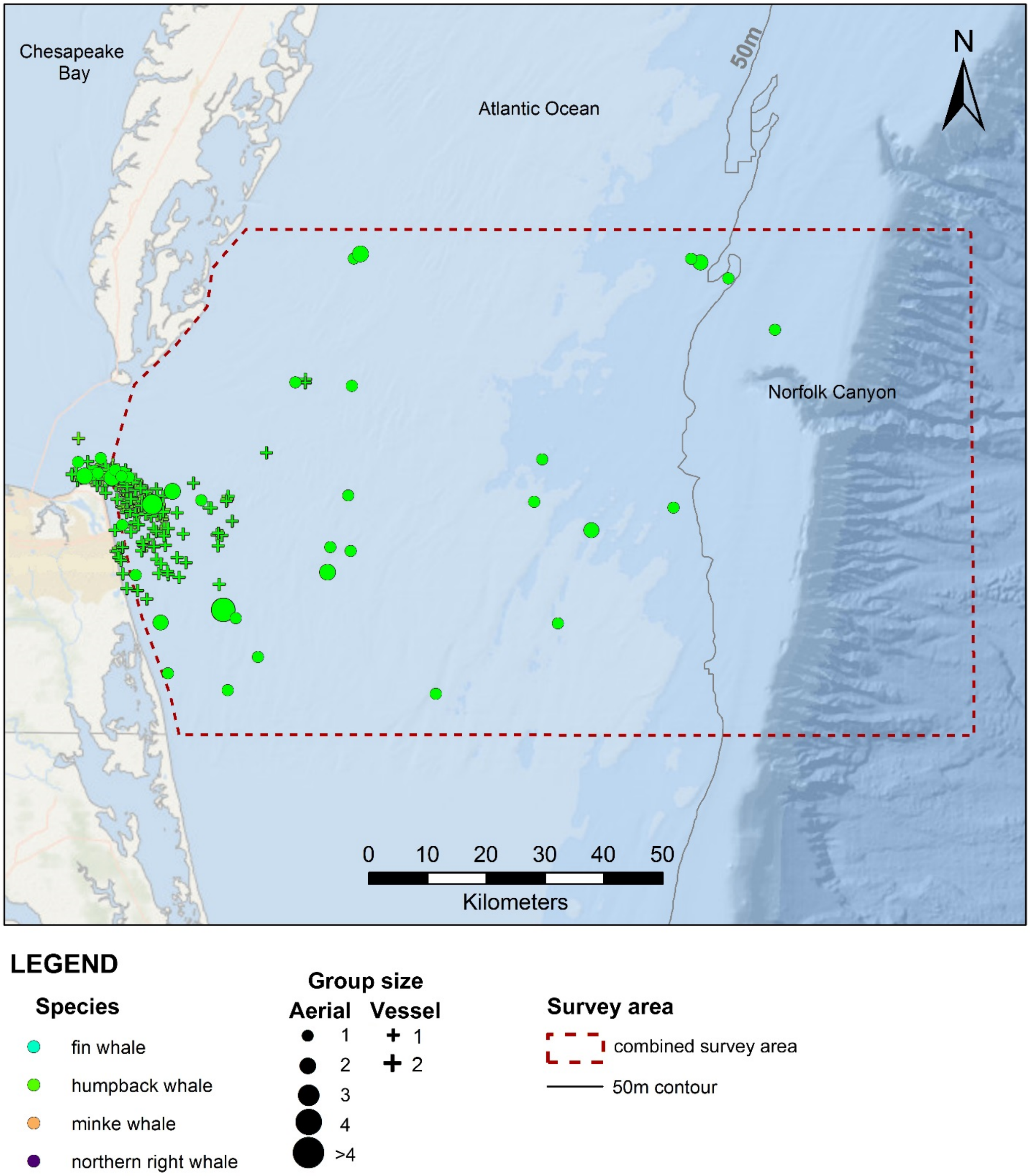

Figure 15. Humpback whale (*Megaptera novaeangliae*) sightings (334 individuals) in the combined survey area.

3.4.2 Fin whale (*Balaenoptera physalus*)

A total of 111 individual fin whales were documented in the study area (**Figure 16**). Fin whales tended to be distributed further offshore in spring than in winter (see **figures 8 – 9**). They were primarily sighted along the 50 m isobath during spring and nearshore around the southern approach to the Chesapeake Bay in winter. Mean sighting depth (±SD) and mean sighting distance from shore (±SD) were 24.1 ±15.3 m and 40.6 ± 34.1 km, respectively. Detections of fin whales occurred between 6 and 21 °C (mean=10.5 °C) **(see figure 14)**.

Behavioral observations included, feeding, defecating, and rolling at the surface. Group size ranged from one to six individuals (mean=1.9). On one occasion a closely associated pair of fin whales was sighted with one individual markedly smaller (approximately 2/3 the length) than the other whale, suggestive of a juvenile/adult pair. Observers recorded individuals as presumed adult, sub-adult and juvenile whales in sighting comments.

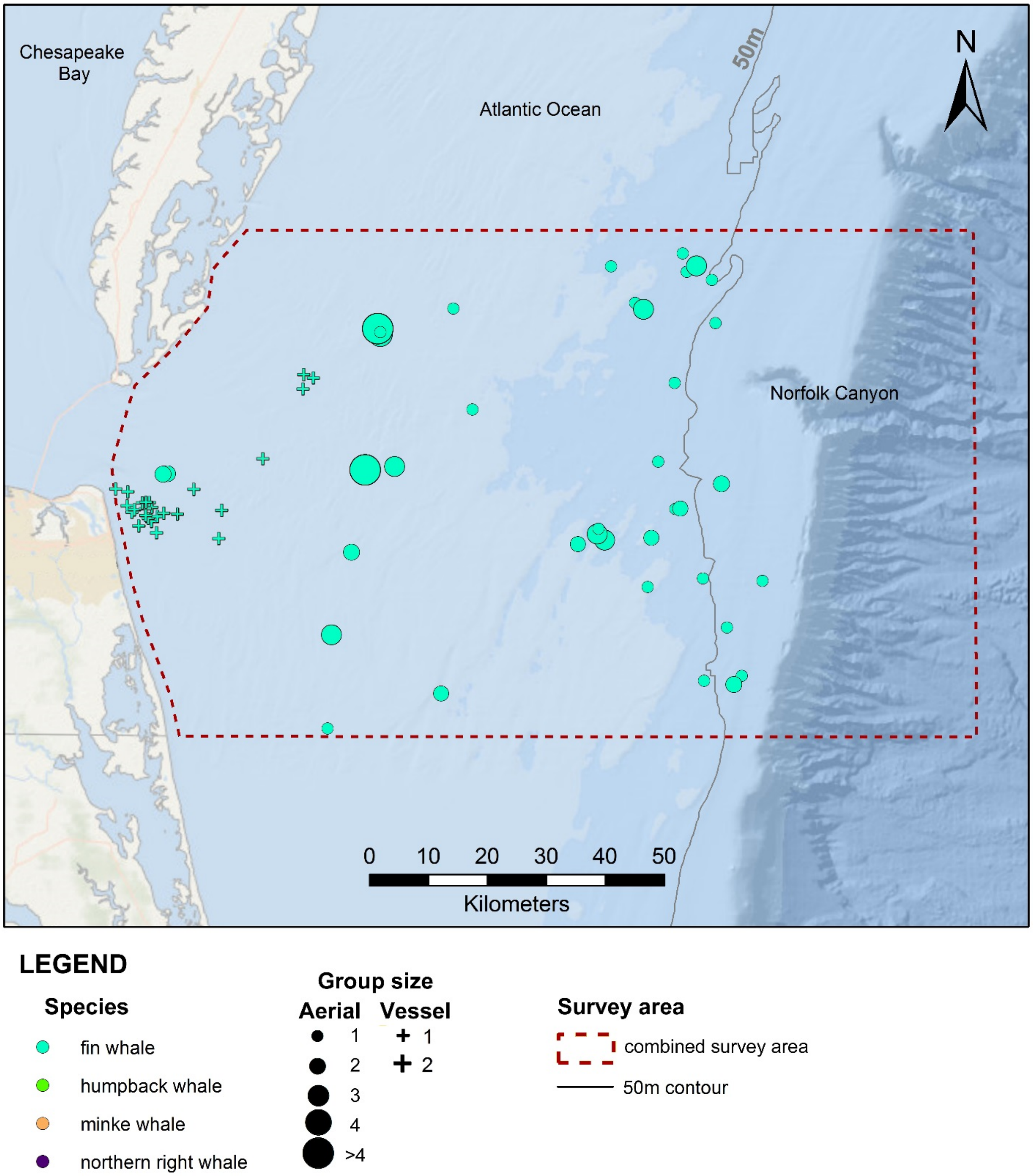

Figure 16. Fin whale (*Balaenoptera physalus*) sightings (111 individuals) in the combined survey area.

3.4.3 North Atlantic right whale (*Eubalaena glacialis*)

A total estimate of 19 individual NARWs were recorded in the survey area, but three individuals sighted during a vessel survey were documented at the same time by the NARW survey team and the vessel sighting data was eliminated from the map and analyses (**Figure 17**). NARWs were mostly observed in the central portion of the survey area along the mid-continental shelf. Mean sighting depth (±SD) and mean sighting distance from shore (±SD) were 22.9 ± 9.4 m and 35.5 ± 14.2 km, respectively. Mean SST (±SD) was 8.4 ± 1.5 °C (see Figure 14). NARWs were documented open mouth swimming, on at least nine occasions, behavior consistent with feeding. On one occasion, in April 2007, a mom and calf right whale pair was documented. Juvenile and sub-adult whales were also documented. Group size ranged from one to four individuals. All images of NARWs taken during surveys were submitted to the Right Whale Consortium and at least five were known individuals.

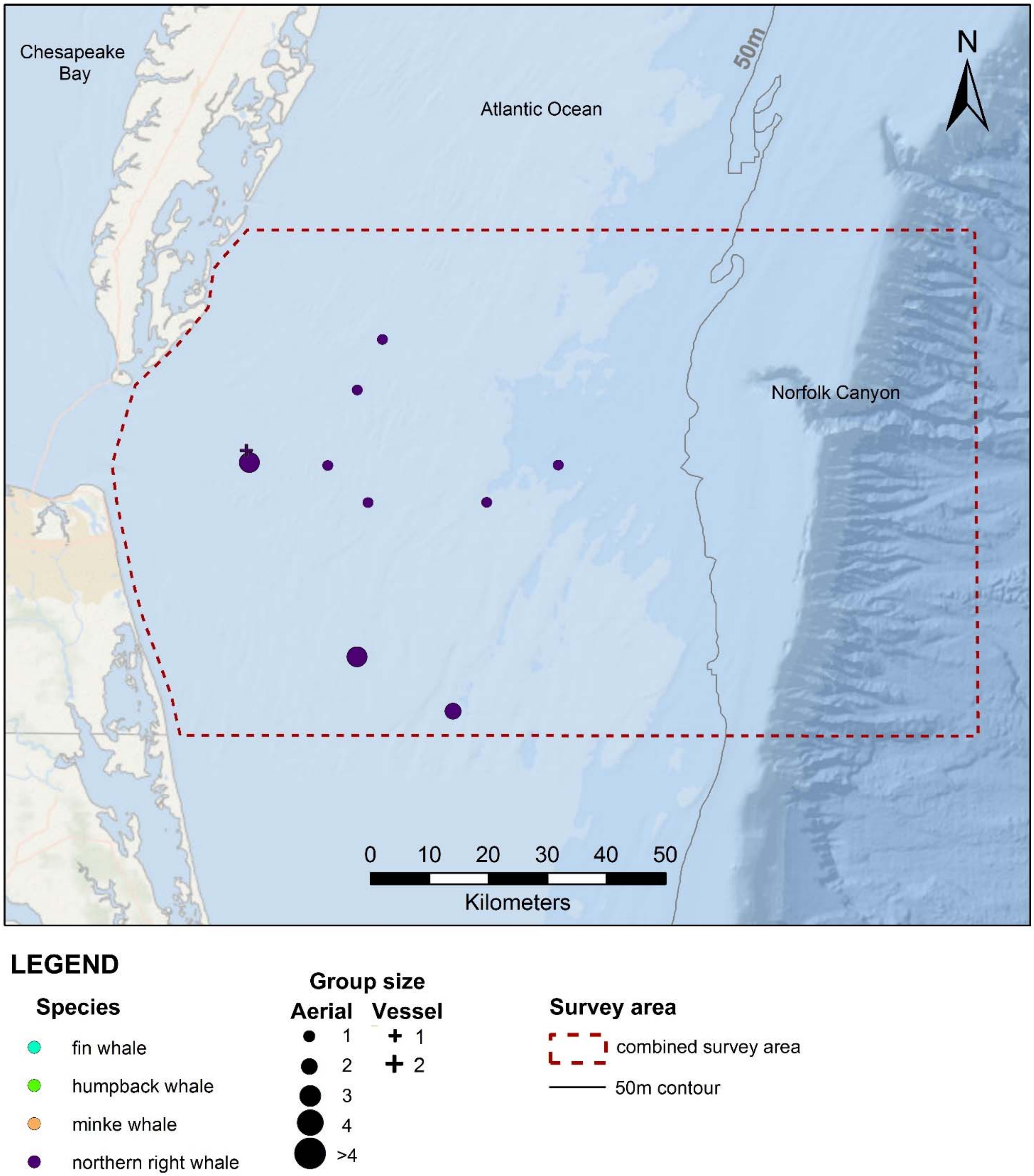

Figure 17. North Atlantic right whale (*Eubalaena glacialis*) sightings (19 individuals) in the combined survey area.

3.4.4 Minke (*Balaenoptera acutorostrata*)

Minke whales had the fewest sightings of any species. Seven minke whales were documented in the combined survey area (**Figure 18**). Minke whales were documented in offshore waters in winter, spring, and summer months during aerial surveys and in nearshore waters in winter during vessel surveys. All sightings of minke whales recorded off the coast of Virginia were west of the 50 m isoboath. Mean sighting distance from the coastline (52.9 km ±43.57) was greater than all other species, although mean sighting depth was only greater than that of humpback whales (**Figure 14**).

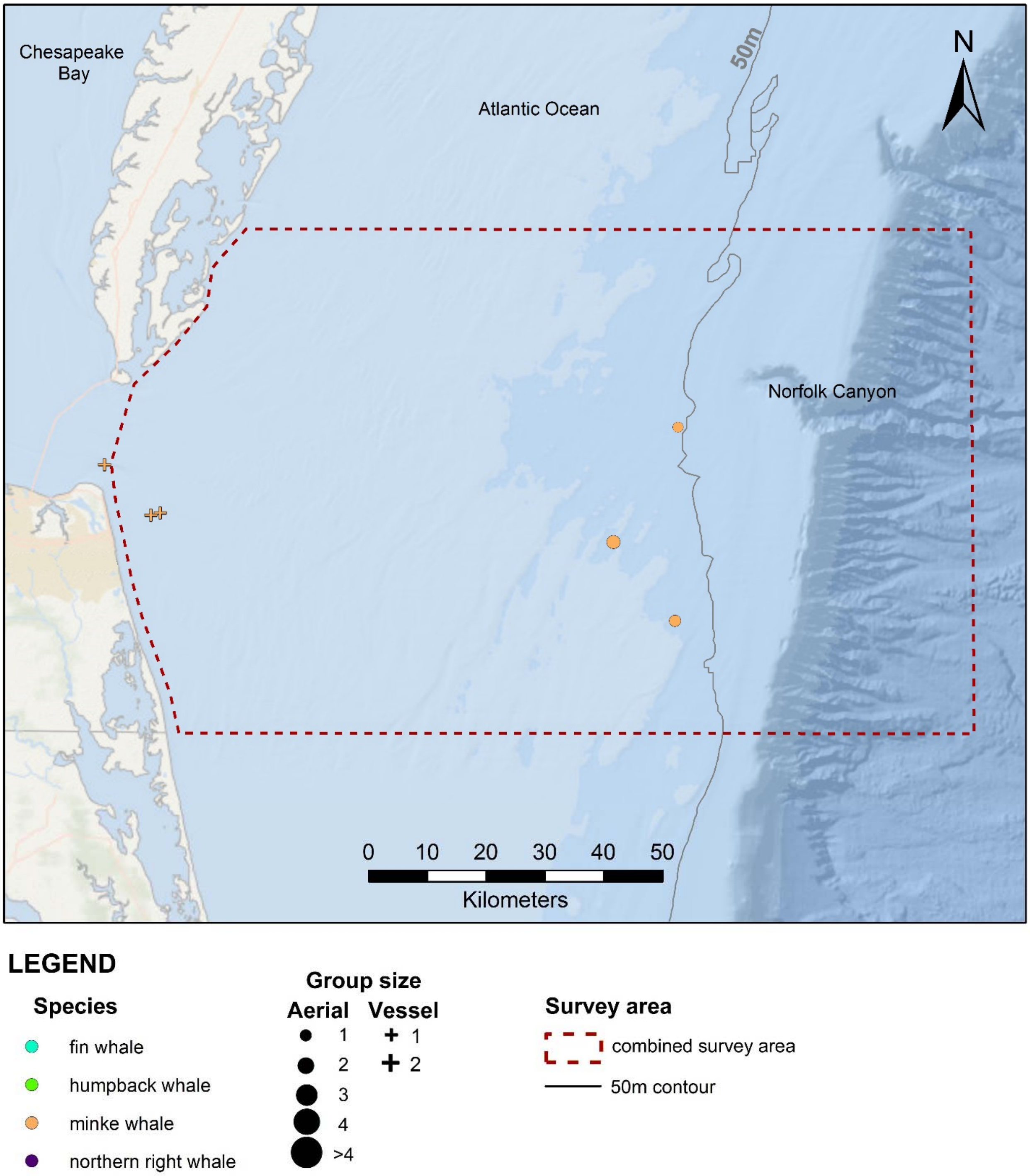

Figure 18. Minke (*Balaenoptera acutorostrata*) whale sightings (8 individuals) in the combined survey area.

4. Discussion

4.1 Differences between survey platforms

Aerial surveys covered larger areas, more quickly, and with systematic effort along established tracklines, in both continental shelf and slope waters. Vessel surveys were conducted during cooler water months and were directed to areas within approximately 25 km of shore providing more intense coverage of nearshore waters. Often vessels would transit to areas where whales were known to occur relatively consistently or to areas where they had been recently reported. Thus, aerial surveys offered a broad view of species distribution across all seasons, and provided means of effort-correction to compare seasonal occurrence of baleen whales. Vessel surveys targeted whales in high human-use areas and allowed for greater contact time with individuals. Vessel surveys offer a complimentary and finer-scale view of habitat use than aerial surveys and allow for the opportunity to investigate questions related to residency, site fidelity, behavior, and body condition, through focal follows and photo-identification.

Together, the data collected from both aerial and vessel platforms offer a more comprehensive view of baleen whale seasonal occurrence, distribution and habitat use than either platform alone. Broad scale aerial surveys conducted a few days per month resulted in relatively few baleen whale sightings close to shore where they are at greatest risk of negative human interaction, especially vessel interactions. It is likely if we had not surveyed from a vessel with dedicated nearshore effort, we would have otherwise completely missed sightings of fin and minke whales inshore. On the contrary, had we not conducted aerial surveys we would have missed right whales within the central section of the survey area and fin whales offshore. Utilizing both platforms permitted us to combine broader scale questions related to abundance and distribution with a fine scale view of habitat use, individual identity, movement, and health.

4.2 Abundance Estimation

Approximately 60 detections are required to fit a detection function for robust, reliable abundance estimates (Buckland *et al*. 2001). There were too few detections in the two datasets that were used for these estimates to obtain robust detection functions. Therefore, the density estimates generated may not be accurate. Thus, the range of abundance and density generated as the 95% confidence intervals provides a more appropriate estimator for comparison.

Because an average estimate of detection probability and estimated group size from the entire dataset was used to develop each seasonal estimate, additional uncertainty in the seasonal abundance estimates may exist.

Additionally, a key assumption of line transect distance sampling is that if an animal is available on the trackline (*i.e*. at zero perpendicular distance) it is certain to be detected. Without a clear understanding of the concurrent relationship among the number of animals counted at the surface and the proportion of surface animals detected by observers, abundance data are significantly biased (Buckland *et al*. 2001). Errors of detection are collectively referred to as visibility bias. The bias created by failure to detect visible animals at the surface is referred to as perception bias. Failing to account for animals invisible to observers (*e.g*. sub-surface below detection depth) will also result in an underestimate of abundance. The bias associated with non-visible or unavailable animals is called availability bias (Laake *et al*. 1997, Marsh and Sinclair 1989). The surveys conducted here did not account for either perception or availability bias (Burt *et al*. 2014). These errors may be relatively low for baleen whale detections in the mid-Atlantic region, but they are unlikely to be zero, especially in fairly turbid water near the mouth of Chesapeake Bay.

The seasonal density estimates represent an average density over each three month season. Seasonal encounter rates and estimated densities were highest in the winter, followed by spring and fall. No detections of whales occurred in summer. Although the abundance estimate only included a subset of the combined dataset discussed below, calculated sighting rates of the combined dataset resulted in a similar occurrence pattern with the highest sightings for all whales in winter and spring.

These data provide a useful record of occurrence in the region of interest through different seasons, but, due to the small number of detections for each species, these estimates provide, at best, an approximate estimate of abundance and density of baleen whales. The confidence intervals, although possibly negatively biased due to reasons stated above, may be more appropriate estimates.

One possibility to boost the number of detections used in detection function fitting would be to include opportunistic sightings, as long as exactly the same protocol was used to record the sighting information. Including opportunistic (off-effort) sightings and additional detections from the combined (aerial survey portion of the) dataset would approximately double the number of detections for all whales, humpback and fin whales which could provide a more accurate abundance estimate. Continued systematic aerial survey effort over the combined survey area and inclusion of the resulting detections would further improve the abundance and density estimates for the survey area.

4.3 Seasonal patterns of species occurrence and distribution

When corrected for effort, the larger, combined data set, resulted in seasonal differences in sighting rate and whale distribution. Sighting rates were highest in winter (January – March) followed by spring (April –June). The abundance estimates, which were based on a sub-set of these data, were similar. Although the actual abundance and density of the formal estimates may not be robust, the relationship of density among the seasons appears to be accurate. Both fall (October-December) and summer (July-September) had five or fewer total sightings and both estimated abundance and sighting rate were substantially lower than winter and spring. Although an insufficient sample size to assess, this could possibly be explained by species-specific differences in seasonal presence within the study area, as a humpback whale was the only aerial survey sighting during fall (nearshore), while fin and minke whales were sighted in summer months (offshore). Offshore vessel sightings of the Norfolk Canyon conducted by HDR, Inc. also detected fall sightings of humpback whales and late spring/early summer sightings of minke and fin whales (Engelhaupt *et al*. 2018).

Comments about animal size and feeding behaviors recorded by observers during sightings, suggest that ocean waters of the mid-Atlantic are neither merely migratory transit areas between feeding and breeding areas, nor is it a foraging area for non-breeding juvenile baleen whales (Swingle *et al*. 1993), but it serves as seasonal foraging habitat (Whitt *et al*. 2013, Hodge *et al*. 2015) for multiple species and age classes of baleen whales.

During aerial surveys, fall and winter were the only seasons whales were found within the shipping channels and SMA, however including sightings from vessels in nearshore waters, humpback whales were recorded within the shipping channels and SMA during the shoulder months around winter. Detections of whales (particularly humpback whales) in the fall and spring in the shipping channels, and within the SMA has also been documented during local vessel-based surveys and tagging efforts (Aschettino *et al*. 2018), an example of how if only one survey platform was used, it may appear that there were no sightings in fall and spring. Of the NARW's observed during the past 15 years of aerial surveys, all but one sighting was outside of the current SMA established to reduce the likelihood of interactions with vessels. Instead right whales were observed east of the SMA. Thus, these data have important management implications and expansion of the SMA should be considered.

Both humpback and NARW were sighted during winter months relatively close to shore, co-occurring with the area of highest density of vessel traffic entering and leaving the mouth of the Chesapeake Bay (Barco *et al*. 2012). NARWs have been acoustically detected in all months of the year in waters off of the Virginia coast (Salisbury *et al*. 2018). Visual detections of right whales from the combined surveys occurred in winter and spring months which coincided with the peak acoustic detections between November and April (Salisbury *et al*. 2018). Further, sightings of right whales from this project coincided with peak presence as detected from passive acoustic monitoring off the coast of Virginia (Salisbury *et al*. 2018). Since the relationship between vocalization rates and physical presence in the area is unclear in the mid-Atlantic region, similar seasonal peaks in detections for baleen whale species from surveys and passive acoustic monitoring is encouraging. Year round presence of right whales in the acoustic data set provides support for abundance being underestimated. It is important to remember that the monthly aerial surveys consisted of one to four days of flights per month which is relatively low coverage especially if species or individuals are transiting through the area instead of residing in the area.

Fin whales exhibited a bimodal distribution with spring sightings mostly offshore and winter sightings located just east of the SMA and in the central portion of the survey area. It appears expansion of the SMA in winter would benefit this species as well. Minke whales had far fewer detections and were nearshore within the SMA or offshore along or just west of the 50 m isobath. Although there were few observations, minke whales were observed in all seasons except for fall. Lower minke whale numbers could reflect that there are fewer minke whales in the survey area, similar to results from acoustic detections in the survey area (Salisbury *et al*. 2018), or detection rates for this species could be lower because of their fast swimming/surfacing behavior and relatively low profile (Salisbury *et al*. 2018).

5. Summary

These findings, although qualitatively informative, provide support for continuing to monitor baleen whale presence in the region. Expanding vessel and/or aerial coverage, between 20 and 50 km offshore in winter and early spring may increase detections of all species, but especially right whales. Increased aerial detections would allow for robust seasonal, species-specific abundance estimates and additional behavioral observations. Tagging, and photo-identification from vessels will increase data on habitat use and animal movement. Together, these efforts provide strategic opportunities for a robust, longitudinal research program permitting rare opportunities to assess inter-annual variation and perturbations in abundance and distribution over time.

In the context of the mid-Atlantic, NARW shifts in distribution have been detected in recent years (Davis *et al*. 2017, Pace *et al*. 2017, Meyer-Gutbrod *et al*. 2018), with decreased time spent in 'typical' habitats such as the Gulf of Maine and increased presence in regions between New York and North Carolina (IWC 2017). Using passive acoustic data collected between 2004 - 2014, Davis *et al*. (2017) demonstrated shifts in NARW distribution from the Gulf of Maine and Bay of Fundy to the U.S. mid-Atlantic cost in winter months. In January of 2015, 11 right whales were observed on an aerial survey off the coast of Maryland (Barco *et al*. 2015), and no right whales were sighted the next day. In April of 2018, HDR, Inc. also documented 8 right whales during aerial surveys of the Norfolk Canyon (*pers comm* Mark Cotter; U.S. Navy Marine Species Monitoring website). These two sightings suggest that, at times, this species may travel in pulses, making detections during broadly separated surveys less likely. As changes in NARW distribution persist, and calving continues to be low in traditional winter breeding areas of the southeast U.S., the mid-Atlantic region may become or could continue to be an important area, as has been previously suggested (Watkins and Schevill 1982, Reeves and Mitchel 1986, 1988; Kenney 2002) for this endangered species. Thus, monitoring, management and conservation efforts in the mid-Atlantic region are critically important for a species vulnerable to anthropogenic threats (Mead 1986, Kraus 1990, Kraus *et al*. 2005, 2016; Knowlton *et al*. 2012, Rolland *et al*. 2012, Hatch *et al*. 2012, Van der Hoop *et al*. 2017, Pace 2014, Meyer-Gutbrod *et al*. 2018) and co-occurring in an area of high human-use. Given approximately 451 individuals remaining (Corkeron and Pace 2018) and less than 200 females still alive, with only a subset of the 200 females being sexually mature (Pace *et al*. 2017, Pettis *et al*. 2017), this species requires monitoring, because even a single mortality is detrimental to the existence of the species (Waring *et al*. 2014).

If right whale distribution expands in the mid-Atlantic region, real-time alerting for mariners and during military exercises (similar to winter efforts in the Jacksonville, FL area and spring efforts in the Cape Cod Bay and Great South Channel areas off Massachusetts) may be warranted. Based on observation data reported here, consideration should be given to extend the SMA eastward during winter months to encompass all documented NARW sightings off of the coast of Virginia. Expansion of the SMA would also overlap with winter sightings of fin, humpback and minke whales. Currently the SMA does not extend into Chesapeake Bay and, increased baleen whale sightings within the Bay over recent years (Aschettino *et al*. 2018), coupled with documented ship strike mortalities (VAQF unpublished data), suggest that more effort to understand ship behavior in the lower Chesapeake Bay is warranted. If ships are increasing speed to above 10 kt after leaving the inshore SMA boundary, inshore expansion of the SMA may also be warranted.

Humpback whales are more consistently observed nearshore off the coast of Virginia, thus provide a logistically accessible subject for future research. Long-term visual surveys, photo-identification, and stranding datasets exist for humpback whales documented in and around Virginia (Barco *et al*. 2002, Mallette *et al*. 2008, VAQF unpublished data). In addition to the types of data presented here, sighting histories elucidating both fine and broader scale movement patterns, detailed data on life history from stranded specimens, and samples from known individuals (both live and stranded specimens) offer a rare and valuable long term dataset, as well as strategic foundation for continued longitudinal studies. Current research efforts focused on satellite tagging and passive acoustics (Salisbury *et al*. 2016; Mallette *et al*. 2018, Aschettino *et al*. 2018) provide complimentary datasets for understanding baleen whale occurrence and habitat use. Updated analyses of visual and acoustic datasets within the study area should be considered as the current acoustic monitoring array is configured to localize vocalizations for offshore energy site assessment and planning (Rice *et al*. 2018).

Long-term baseline datasets lay the framework for a more comprehensive understanding of baleen whale ecology which is essential for understanding potential responses from anthropogenic pressures. As the U.S. Navy considers using Virginia Beach, Virginia and humpback whales as a potential Behavioral Response Studie (BRS) site and study subject in future years, these baseline data will be important to better understand perturbations in occurrence, abundance, distribution and health as well as provide a basis for understanding whales response to controlled sound exposure studies and other military training activities. These data can be integrated into PCoD models (NRC 2005) and would serve as a useful baseline for potential Behavioral Response Studies; therefore continued long-term monitoring is complimentary to such studies.

6. Acknowledgements

We thank U.S. Fleet Forces Command and Joel Bell (NAVFAC Atlantic) for support of this work. We thank our VAQF aerial survey observers Kristy Phillips, Sarah Rose, and Erin Bates and VAQF fellow Noelle Mathies. We thank both VAQS and UNCW staff and faculty for being ground control during surveys, including Alex Epple, Alex Costidis, Ann Pabst and Tiffany Keenen-Bateman. We thank those who assisted with research vessel trips including captains (Jeff Thompson, Maureen Fender) and crew (VAQ staff and volunteers). We thank local whale watch vessel captains (Skip Feller, VAQ Whale Watch Captains) and crew, especially Alexis Rabon and Kristin Rayfield for relaying sightings while conducting research trips. We thank our colleagues at St. Andrews University (Charles Paxton) for guidance on survey design. We thank Ed Coffman, owner and operator of Orion Aviation, and his highly skilled pilots: Rocky Walker, John Estes, Richard Waterman, Stan Huddle, Dave Huddle, and Bob Stickle, for excellent flying and a high level of professionalism. Surveys were conducted under National Marine Fisheries Service Scientific Permit No. 948-1692-00 and 16473, held by Dr. D. Ann Pabst at the University of North Carolina Wilmington, and National Marine Fisheries Service Scientific General Authorization permit No. 17325 issued to VAQF. Photo-identification and biopsy activities on vessel surveys were conducted under NOAA Scientific Research Permit No. 16325 issued to Dr. Jooke Robbins at the Center for Coastal Studies. We thank the Coastal Zone Management Program for providing funding and Laura McKay for her support of this important research. The CZM aerial survey project was funded by the Virginia Coastal Zone Management Program at the Department of Environmental Quality through Task1 of Grant NA12NOS4190027, NA13NOS4190135, NA14NOS4190141, of the U.S. Department of Commerce, National Oceanic and Atmospheric Administration, under the Coastal Zone Management Act of 1972, as amended.

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