OCS Study
BOEM 2021-033

Megafauna Aerial Surveys in the Wind Energy Areas of Massachusetts and Rhode Island with Emphasis on Large Whales: Summary Report Campaign 5, 2018-2019

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DISCLAIMER

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ABOUT THE COVER

Cover photo taken by NEAq aerial survey team under NOAA permit # 19674.

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List of Abbreviations and Acronyms

#	number of vertical photographs
95% CI	95% confidence interval
a	area sampled (in density calculations)
AIC	Akaike's information criterion
BOEM	Bureau of Ocean Energy Management
CCS	Center for Coastal Studies
cm	centimeter
CTD	Conductivity-temperature-depth
d	density (number of individuals per square kilometer)
ECOMON	Ecosystem Monitoring survey
ESA	Endangered Species Act
f(0)	probability density function evaluated at zero distance
ft	feet
G	number of groups sighted
g	average group size (in density calculations)
GPS	global positioning system
h	hours
I	number of individuals sighted
km	kilometer
kts	knots
L	length of transect (in density calculations)
m	meter
ml	milliliter
mm	millimeter
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MassCEC	Massachusetts Clean Energy Center
MAWEA	Massachusetts wind energy area
min	minutes
NARWC	North Atlantic Right Whale Consortium
N	estimated abundance
°N	degrees North
n	number (of animals/groups sighted during a transect)
nm	nautical mile
NEAq	New England Aquarium
NEFSC	Northeast Fisheries Science Cente
NOAA	National Oceanic and Atmospheric Administration
RIMA	Rhode Island Massachusetts wind energy area
s	second
S	number of sightings
SA	study area
SPUE	Sightings per unit effort
SR	Sighting rates
SE	Standard error
T	number of transects flown

URI	University of Rhode Island
°W	degrees West
WEA	wind energy area
WHOI	Woods Hole Oceanographic Institution

List of Definitions

Seasons

- Winter = December, January, and February
- Spring = March, April, and May
- Summer = June, July, and August
- Fall = September, October, and November

Survey leg stages

- Transit: travel in the survey area, to the first transect line or from the last transect line
- Transect: flight along a defined survey line
- Cross-leg: flight between two transect lines
- Circling: departure from a transect line to document a sighting

Campaign schedule

- Campaigns 1-3: October 2011 – June 2015
- Campaign 4: February 2017 – July 2018
- Campaign 5: October 2018 – August 2019

1 Introduction

Beginning in 2013, the Bureau of Ocean and Energy Management (BOEM) designated two wind energy areas (WEAs) in New England: one offshore of Massachusetts and the other offshore of both Rhode Island and Massachusetts. Currently, four offshore wind developers have lease agreements to build projects in the BOEM designated Massachusetts (MA) and the Rhode Island/Massachusetts (RIMA) wind energy areas. In August 2016, the Governor of Massachusetts, Charles Baker, signed energy diversity legislation that requires Massachusetts utilities to initiate a procurement of up to 1,600 megawatts of offshore wind energy by June 30, 2017. The authorized procurement amount was increased to 3,200 megawatts in 2019. As of July 2020, utilities in Massachusetts, Rhode Island, Connecticut and New York have contracted to purchase the output from over 4,000 megawatts of offshore wind from the WEAs, with additional procurements planned and in process.

Under the National Environmental Policy Act of 1969 (42 U.S.C. 4371 et seq.), BOEM and other relevant federal agencies are required to integrate environmental assessments into offshore development and construction plans. Offshore wind energy planning and development requires comprehensive assessments of biological resources within suitable development areas to identify and mitigate any potential effects of that development on marine species.

In anticipation of these requirements, the Massachusetts Clean Energy Center (MassCEC) used a competitive procurement process in early 2011 to select a team led by the New England Aquarium (NEAq) to conduct aerial and acoustic surveys of endangered whales and turtles in the MA WEA. Upon conclusion of these initial surveys (Campaign 1), MassCEC and BOEM extended the surveys for an additional two years and expanded the geographic scope of the survey area to include the RIMA WEA (Campaigns 2 and 3). For these three survey campaigns, 76 aerial surveys were conducted between October 2011 and June 2015.

The final report summarizing Campaigns 1-3, released on October 25, 2016, showed that the study area included seasonal aggregations of protected species of whales and sea turtles. It also showed that North Atlantic right whales (*Eubalaena glacialis*), a critically endangered species, occurred in the study area during winter and spring, with a peak in March. Based on these findings, the report provided recommendations for managing geological surveys and construction by scheduling those activities during off-peak right whale seasons to mitigate or avoid impacts. The 2016 final report also provided recommendations for additional surveys to address information gaps and for the collection of additional baseline data.

Acting upon the recommendations in the 2016 final report and with additional funding support from BOEM, MassCEC contracted with NEAq to conduct additional surveys for the period February 2017 through July 2018 (Campaign 4). A further report summarizing Campaign 4 was released in December 2019. This report showed continued usage of the study area by protected species of whales and sea turtles. The Campaign 4 report also showed an increase in the number of right whales in the study area and that right whales occurred in the study area throughout the year. To further understand species distribution and abundance patterns in the study area, additional aerial surveys using both observer sightings and automated vertical photography were conducted from October 2018 to August 2019 (Campaign 5, the subject of this report).

As part of Campaigns 4 and 5 and under sub-contracts to NEAq, the Woods Hole Oceanographic Institution (WHOI), in coordination with the Provincetown Center for Coastal Studies, conducted oceanographic surveys to assess the physical and biological characteristics of waters used by right whales in the study area. Right whales visit the study area annually during winter and spring, but little is known about why they come to this region. One hypothesis is that they use the region as a feeding habitat, but very few zooplankton samples have been collected in the area for the express purpose of determining right whale prey species and the life history, distribution, and abundance of those prey species. In response to this knowledge gap, WHOI conducted oceanographic and zooplankton sampling in the northern region of the study area from February to May 2017 for Campaign 4 and during the winter and spring of 2019 for Campaign 5.

This report, Summary Report: Campaign 5, 2018-2019**,** summarizes results from the Campaign 5 surveys conducted in the study area between October 2018 and August 2019. Specifically, this report includes the sightings and data information, plus analyses of effort corrected data, and includes maps of sightings per unit effort (SPUE), sighting rates, and calculations of density and abundance. This report also includes analysis of right whale prey species and oceanographic conditions near right whale aggregations during Campaign 4 and 5.

1.1 Research objectives

1. Estimate distribution and relative abundance of large whales (with a focus on right, humpback, fin, and minke whales) and turtles within the study area, which includes the Massachusetts (MA) and the Rhode Island/Massachusetts (RIMA) wind energy areas (WEA).

2. Assess prey species and oceanographic conditions near right whale aggregations in the WEA.

2 Methods

2.1 Aerial surveys

During the period of performance between October 2018 and August 2019, four types of aerial surveys were conducted within the study area. The study area is defined by a polygon surrounding the general and condensed surveys (shown in Figure 1A).

- General surveys were standardized line-transect surveys that were conducted on a monthly basis and covered the waters of the study area (5,811 km^2), including the MA and RIMA WEA. These surveys focused on all marine megafauna visible from the plane (excluding birds) and were comprised of ten north-south tracklines (Figure 1B) evenly spaced at approximately six nautical miles (nm). Eight survey options are available: each option shifts all 10 tracklines 0.75 nm east or west, but maintains the six nm spacing between tracklines. One of these options was selected at random before each survey.
- Condensed surveys were standardized line-transect surveys conducted in two smaller areas off Martha's Vineyard and Nantucket. These surveys focused on areas identified by Leiter et al. (2017) as having high densities of right whales (Figures 1C and 1D) and were compromised of 10-12 tracklines (western side: 10 tracklines, total length: 218 nm; eastern side: 12 tracklines, total length: 221.5 nm) evenly spaced at three nm. Four survey options are available: each option shifts all 10-12 tracklines 0.75 nm east or west, but maintains the three nm spacing between tracklines. One of these options was selected at random before each survey.
- Directed surveys were flown in areas of right whale aggregations, identified by NEFSC or found during General surveys. These surveys followed line-transect protocols, but the area, number of lines, and length of flight varied based on the location of the right whale aggregations.
- Opportunistic surveys were flown in response to reports of right whales near shore or to provide aerial support to oceanographic sampling of right whale aggregations. Opportunistic surveys were short and did not use planned tracklines.

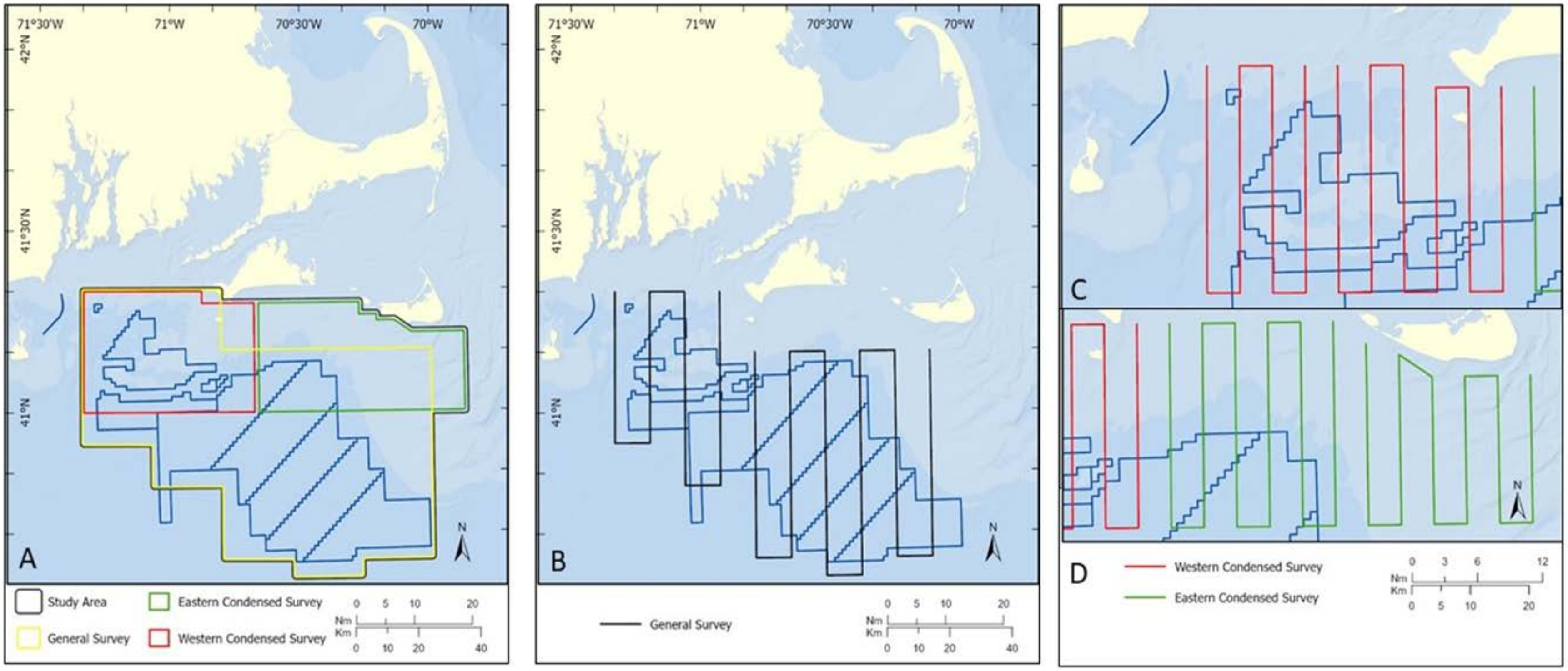

Figure 1. Study area in the offshore waters of Massachusetts and Rhode Island
A) Study area (black outline), with the region covered by general surveys depicted by a yellow polygon and regions covered by condensed surveys depicted by a red (western side) and a green (eastern side) polygon. Examples of tracklines for a B) general survey (tracklines are shown for option 1), C) western survey (tracklines are shown for option 1), and D) eastern survey (tracklines are shown for option 1). Note: Existing lease areas are depicted in blue.

2.1.1 Survey methods for aerial detections

All surveys were flown in a Cessna Skymaster 337 O-2A at an altitude of 305 m (1,000 ft) and a ground speed of approximately 185 km/h (100 kts) under Visual Flight Rules. Preferred survey conditions included winds of ≤10 kts, a Beaufort sea state of ≤ 4, a minimum cloud ceiling of ≥ 2,000 ft, and visibility ≥ 5 nm. A computer data-logger system (Taylor et al. 2014) automatically recorded flight parameters (e.g., time, latitude, longitude, heading, altitude, speed) at frequent intervals (every 2–5 sec). Two experienced aerial observers were positioned aft of each pilot on either side of the aircraft and scanned the water out to 3.7 km (2 nm) from the transect line.

2.1.2 Sightings: observers and vertical photography

Observers recorded sightings according to the North Atlantic Right Whale Consortium (NARWC) Database guidelines (Kenney 2010). A sighting is defined as an animal (or group of animals) or object (fishing gear, vessel, etc.) marked by the plane and could include multiple individuals. Sighting locations were added to a data log by remote keypads when the detected animal was abeam of the aircraft. The observer estimated distance from the transect line using calibrated markings on the wing strut (Mbugua 1996, Ridgway 2010). Distances (nm) were binned into the following classes: within ⅛, ⅛ to ¼, ¼ to ½, ½ to 1, 1 to 2, 2 to 4, and >4. The observer also noted whether the sighting occurred on the port or starboard side of the aircraft. All sightings recorded by observers were integrated into a single datasheet spanning the entire survey and are listed in a digital survey file.

Sightings, distances, environmental data, and survey parameters were recorded in a digital voice recorder and transcribed into the data log post-flight. Survey parameters included the four survey leg stages: transect (flight along a defined survey line); cross-leg (flight between two transect lines); circling (departure from a transect line to document a sighting); and transit (travel in the survey area, to the first transect line or from the last transect line). Survey parameters also included transect number and specific points of a given transect (begin, end, break off, or resume). Environmental data parameters included general weather conditions (clear, overcast, hazy, etc.), visibility, Beaufort sea state, cloud cover, and sun glare. Sighting data include species identification to the lowest taxonomic level possible, the reliability of that identification (definite, probable, possible), a count of individuals in the group, an index of the precision of that count (+/- 0, 1, 2, 5, 10, and so on), the number of calves, heading of the animal or group, whether or not photographs were taken, and notes on behaviors.

Observers were unable to see directly under the aircraft. Therefore, a Canon EOS 5D Mark III camera with a Zeiss-85 mm lens and polarizing filter was fitted in the built-in-camera port of the Cessna O-2A Skymaster. A forward motion compensation system was used to reduce motion blur. The system was integrated with a GPS, a Getac E119 Rugged tablet, and observer sighting buttons via a custom data-logging software (d-Tracker).

Vertical photographs were analyzed by trained observers for detections of marine species, fixed fishing gear, and debris using the program FastStone Image Viewer. Data recorded for each sighting included species, identification reliability, and number of individuals with an estimate of the level of confidence in the count, frame number, time, observer, and area of image. The vertical photograph sighting information was added to the corresponding event recorded in the survey file by d-Tracker. All detections were reviewed for accuracy and consistency by another trained expert. Completed data files were submitted to the NARWC Database.

Distance sampling protocols dictate how sightings data can be incorporated into abundance estimates. Surveys must have a randomized start point (i.e., a randomly chosen survey option); consequently, opportunistic and directed survey sightings are not used to estimate abundance. Sightings must be observed while on transect; consequently, sightings during transit, cross-leg, or circling are not used to estimate abundance. Hereafter, on effort refers to sightings that will be used for abundance estimates and off effort refers to sightings that will not be used for abundance estimates.

Two types of detections are defined: 1) observer detections are sightings marked by observers while in the plane and 2) camera detections are sightings found in vertical photographs during photo analysis and are unique from observer detections. All vertical photographs were analyzed for the presence of marine megafauna during Campaign 5 surveys. On effort photographs were additionally scrutinized for smaller objects, such as small fish, birds, debris, and fishing gear.

2.1.3 Right whale photo-identification

North Atlantic right whales were a primary target species of the surveys. The rostral callosity pattern and other obvious scars or markings were used to identify individual right whales. When observers spotted right whales, the plane deviated from the transect and observers attempted to photograph each whale for individual identification (Kraus et al. 1986) using a Nikon D500 camera equipped with a 300 mm f/2.8 telephoto lens (1.4×teleconverter; Figure 2). When photographic documentation was complete, the aircraft returned to the transect at the point of departure for that sighting and resumed the survey.

Figure 2. NEAq observer taking photographs during a whale sighting

2.1.4 Sightings per unit effort

To minimize bias from the uneven allocation of survey effort in both time and space, we calculated the sightings per unit effort (SPUE). This index of relative density is defined as the number of individuals per 1,000 km of effort and allows comparisons between discrete spatial units. We calculated SPUE in grid cells measuring 5 min of latitude (9.3 km) by 5 min of longitude (approximately 7 km narrowing slightly from south to north). The appropriate grid cell size can be determined by weighing the size of the survey area against the trackline spacing of the survey. The grid cell size used in this report was also used in analyses of data collected on Campaign 1-4 surveys funded by MassCEC/BOEM and allows for comparisons among years. We used all definite and probable sightings in the calculations and transects flown in the following conditions: altitude ≤ 366 m, visibility ≥ 3.7 km (2 nm), and sea state ≤ 3 (Kraus et al. 2016).

2.1.5 Animal density and abundance

We estimated density and abundance for baleen whales and common dolphins for Campaigns 4 and 5 following methodology in Buckland et al. (1993). Campaign 4 calculations are included here, rather than in the Campaign 4 report, because the sample size from the Campaign 4 data alone was too small to support these analyses. Density is defined as the estimated number of individuals per square kilometer. Abundance is computed by multiplying the estimated density by the size of the study area, and is defined as the estimated number of individuals in the study area.

To calculate density, we fit a detection function to our data using the R package *Distance* (R Development Core Team, 2018; Miller, 2020). A detection function models the relationship between the distance of an animal from the trackline and the probability it is detected. This key concept in distance sampling helps us account for animals that are not seen during a survey. To fit a detection function, it is necessary to have an adequate sample size: at least 25-30 detections, but ideally 60-80 detections. To achieve this sample size for low density species such as large cetaceans, species with similar sighting cues are often pooled. In previous work on this data set, all large whale detections (right, humpback, fin, sei and sperm whales) were pooled to achieve the sample size necessary to fit detection functions. For this report, using 2017-2019 data, we were able to fit a unique detection function for right whales and minke whales, and a pooled detection function for fin, sei and humpback whales. For common dolphins, there are not enough sightings in the Campaigns 4 and 5 data to fit a detection function, so we used data from Campaigns 1-5. After fitting several models and truncation distances, we used Akaike's information criterion (AIC) scores to choose the best model for each set of species. Having selected the best models, we were able to use seasonal encounter rates for each species to calculate abundance (Tables 5, 8-12).

An estimate of density (*d*, in individuals/km^2) of a given species was calculated for each survey transect line by:

$$d = \frac{n \cdot g \cdot f(0)}{2\,L}$$

where *n* is the number of groups sighted during the transect, *g* is the average group size for the species across all sightings during the study, *f(0)* is derived from the pooled or unpooled detection function, and *L* is the length of the transect (the length is multiplied by two to represent both sides of the trackline). Average density for the survey area was calculated using the weighted mean density of all survey transects. Abundance was then calculated by multiplying the density estimates by 5,811 km^2 – the size of the survey area for all flights between 2017-2019. To estimate density, we used sightings with definite or probable species identification that met the following criteria: collected during general surveys, collected on tracklines or during circling, altitude ≤ 366 m, visibility ≥ 3.7 km (2 nm), and sea state ≤ 3 (Kraus et al. 2016). Upper and lower 95% confidence limits for the abundance estimates were calculated using the weighted average of the variance in encounter rate for all transects flown during each season-year (Buckland et al. 1993).

2.1.6 Sighting rates and temporal variability

Sighting rates were calculated as the number of individuals divided by the distance traveled on effort. Sighting rates were multiplied by 1,000 to avoid working with small decimal values and are hereafter referred to as animals/km (Kraus et al. 2016, Leiter et al. 2017). Effort was defined as the total distance flown by the aircraft in km, including transects, transits, cross-legs, and circling when Beaufort sea state was ≤ 3. Only sightings identified as definite and probable were included in the analysis. Vertical camera detections were used in the calculations, including animals found in photographs while the plane was circling.

Seasonal sighting rates were calculated for species with at least 25 sightings. The six species included in the analysis were right whales, fin whales, sei whales, minke whales, humpback whales, and common dolphins. Seasons were defined as follows: winter = December, January, and February; spring = March, April, and May; summer = June, July, and August; and fall = September, October, and November.

2.1.7 Right whale photographs and demographics

Right whale images were uploaded and processed in the NARWC Catalog (Hamilton et al. 2007) and were compared by observers to catalogued right whales to identify individuals. Once matched, demographic information such as sex, age, and reproductive status were added to sighting information.

2.2 Oceanographic sampling

2.2.1 Sampling design

Zooplankton and oceanographic sampling occurred at four standard oceanographic stations (Table 1, Figure 3) as well as at stations adaptively located near North Atlantic right whales. The standard stations were located in the northern part of the study area to allow our sampling platforms, the F/V *Sea Holly* and the R/V *Tioga* based in Woods Hole, Massachusetts, to visit all of the stations and conduct additional adaptive sampling in a single day. We chose to sample at four stations distributed in the northern part of the study area to understand spatial variability in zooplankton distribution.

Table 1. Standard oceanographic sampling station locations

Station	Latitude	Longitude
1	41 08.8185 N	70 56.6727 W
2	41 01.9200 N	70 42.4440 W
3	41 07.8240 N	70 34.3920 W
4	41 13.7460 N	70 26.2680 W

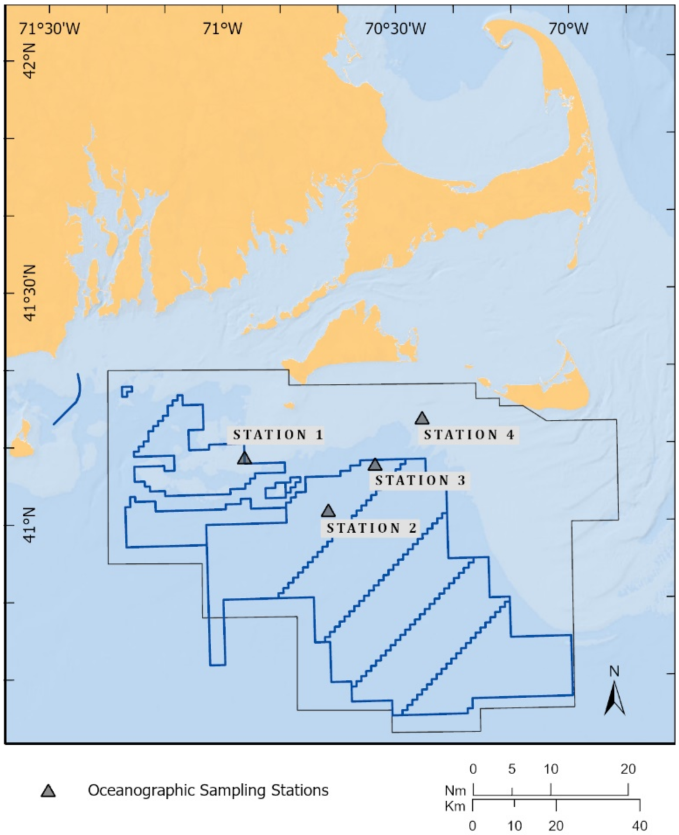

Figure 3. Location of four standard oceanographic sampling stations in the study area

Three types of survey trips were used: (1) full sampling trips that allowed sampling at all four standard stations and if available, sampling at two right whale sampling stations, (2) sampling trip to Station 1 only (called the Nomans station) and (3) right whale sampling trips that sampled at Station 1 and only at right whale sampling stations thereafter. Sampling trips were closely coordinated with the NEAq aerial survey team and the National Oceanic and Atmospheric Administration (NOAA) Northeast Fisheries Science Center (NEFSC) small boat team, who sometimes accompanied us to sea. Both of these groups were surveying for right whales and alerted us to the presence of right whales so that we could sample near them. At each station, a zooplankton sample and oceanographic observations were collected.

2.2.2 *In-situ* net sampling

Zooplankton net sampling was conducted with a 70-cm ring net outfitted with 333-micron mesh net hauled obliquely between the surface and the sea floor. A General Oceanics flowmeter was suspended in the middle of the ring net, and a Seabird SBE39 telemetering temperature-pressure instrument was affixed to the net tow cable to allow the net to sample close to the sea floor. Collected animals were transferred from the net cod end to a 333-micron (or smaller) mesh sieve, and then to a 1-liter sample jar. The sample was preserved with 50 ml of buffered formalin (creating a 5% formalin solution). After the field season, all samples were sent to the Atlantic Sorting Center at the Huntsman Marine Science Center in New Brunswick, Canada for identification and enumeration. All copepodid developmental stages of *Calanus finmarchicus* (C1-C6) were determined, enumerated, and recorded separately. Taxa abundance (equivalently concentration) was calculated as the total number of individuals collected divided by the volume filtered by the net (calculated as the product of the area of the net mouth opening and the distance traveled by the net as measured by the flowmeter).

2.2.3 *In-situ* oceanographic observations

Vertical profiles of temperature, conductivity (from which salinity is derived), and chlorophyll fluorescence were collected at each sampling station with a conductivity-temperature-depth (CTD) instrument (Figure 4). The instrument was also equipped with a chlorophyll fluorometer, which provides a relative measure of phytoplankton abundance.

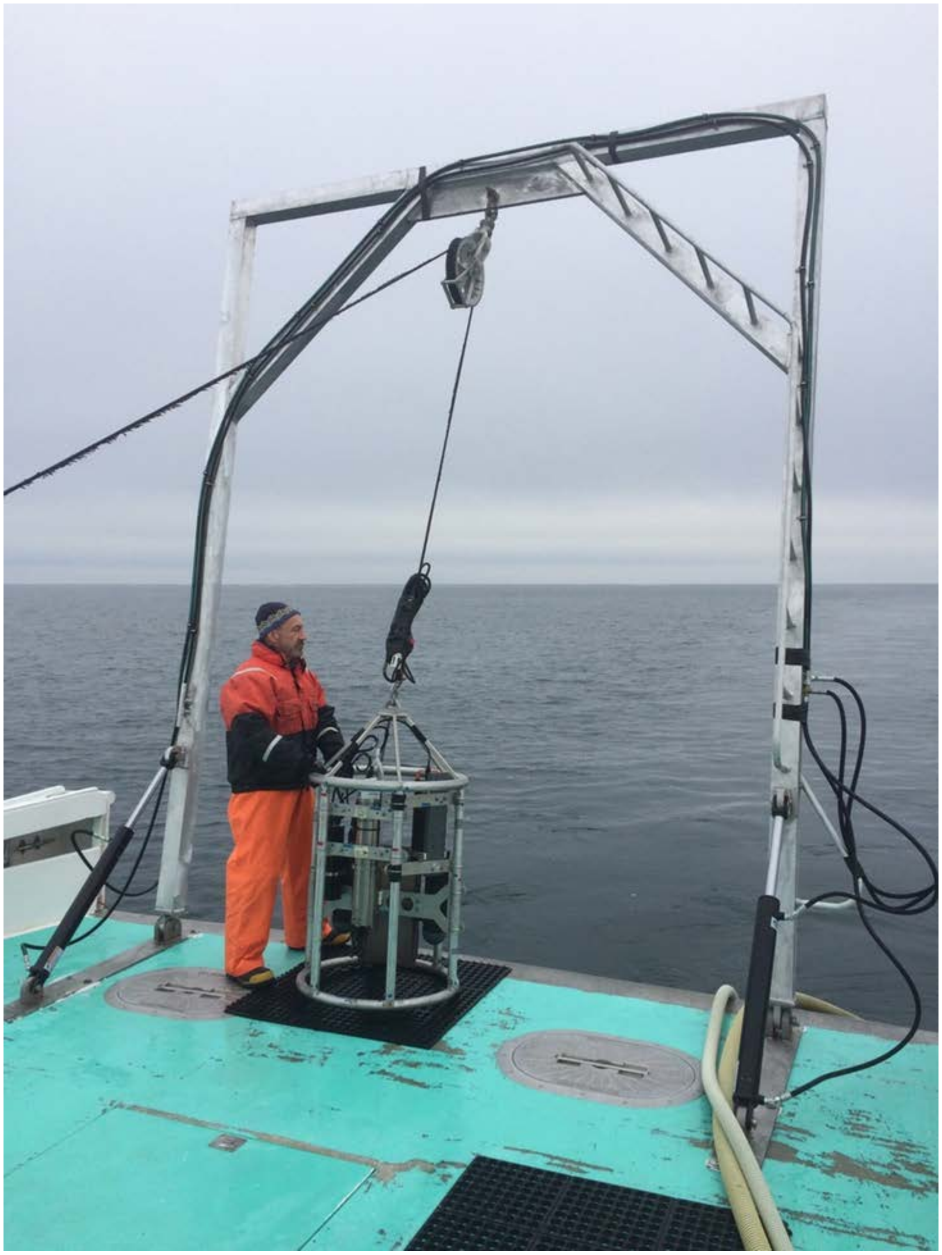

Figure 4. Deployment of the conductivity-temperature-depth (CTD) instrument at sea
WHOI technician Phil Alatalo prepares to deploy the instrument package containing the conductivity-temperature-depth (CTD) instrument from the stern of the F/V *Sea Holly* on a delightfully calm day at sea in February 2019.

2.2.4 Analyses

We used the *in-situ* observations from 2017 (Campaign 4) and 2019 (Campaign 5) to characterize both oceanographic conditions and zooplankton community composition and abundance for years of relatively high and low right whale abundance in the study area, respectively. Few right whales were encountered in the area immediately adjacent to the sampling stations in 2019, while right whale encounters were much more frequent in 2017. We used this contrast in years to infer what conditions made the area more or less attractive to right whales. Statistical comparisons between years was conducted for each month using t-tests on the base-10 log-transformed zooplankton abundances measured *in-situ*. Interannual comparisons were conducted with all samples collected in a month, including those at all of the standard stations as well as at the right whale stations.

3 Results

3.1 Aerial surveys

3.1.1 Field effort

A total of 40 aerial surveys were completed during Campaign 5 over 11 months between October 2018 and July 2019 (Table 2). Specifically, 11 general surveys totaling 68.5 hours (h) of flight time were conducted on a monthly basis from October 2018 to July 2019, 12 condensed surveys totaling 43.4 h of flight time were conducted from March to July 2019, 16 directed surveys totaling 71.4 h of flight time were conducted from January to August 2019, and one opportunistic survey totaling 2.5 h of flight time was flown in July 2019. No surveys were aborted; one general survey was split across two days (six days apart) after daylight restrictions on the first day required the plane to land prior to completing survey. General surveys took an average of 6.1 h (range = 4.5 – 7.5 h; values exclude the split survey), condensed surveys took an average of 3.6 h (range = 3.3 – 5.6 h), and directed surveys took an average of 4.5 h (range = 0.9 – 6.6 h). The total time and the total distance flown for all aerial surveys combined were approximately 185.8 h and 27,298.28 km, respectively (Table 2). During Campaign 5, 106,208 vertical photographs were taken by the vertical camera and 9,937 handheld photographs were taken by aerial observers for a total of 116,145 photographs.

Year	Month	General Surveys						Other Surveys					
		Total	Day	Direction	Option	Airtime (h)	Flight length (km)	Total	Day	Direction	Option	Airtime (h)	Flight length (km)
2018	October	1	26	W → E	1	5.1	905.6						
	November	1	24	E → W	7	5.1	723.8						
			30	W → E	7	2.7	423.7						
	December	2	1	E → W	8	7.0	974.5						
			20	E → W	8	6.3	846.9						
2019	January	1	15	W → E	8	6.4	975.1	2	13	E → W	NA	6.6	698.8
									27	W → E	NA	5	580.6
	February	1	4	E → W	7	5.8	924.5	3	3	W → E	NA	5.5	676.9
									11	E → W	NA	4.5	770.8
									17	W → E	NA	5	650.1
	March	1	28	E → W	3	4.5	685.4	3	18	W → E	NA	4.7	641.7
									27	W → E	3W	6	916.4
										W → E	3E	*	*
	April	1	7	W → E	7	6.1	876.0	5	2	E → W	4E	4.3	661.2
									7	W → E	NA	0.9	159.5
									25	W → E	3W	3.7	546.3
										W → E	3E	3.5	567.3
									29	W → E	NA	5.6	878.4
	May	1	7	W → E	6	5.8	923.6	5	1	W → E	2W	3.6	561.3
										W → E	2E	3.3	551.9
									15	W → E	NA	4.5	629.5
									25	W → E	NA	6.4	874.0
									28	W → E	NA	5.9	791.9
	June	1	12	E → W	5	7.5	1,036.9	3	7	E → W	NA	5.1	722.7
									24	W → E	1W	3.4	544.7
										W → E	1E	3.6	567.8
	July	1	25	W → E	4	6.2	971.9	5	9	W → E	4W	3.1	521.5
										W → E	4E	3.3	553.0
									15	E → W	2E	5.6	791.9
									16	NA	NA	2.5	343.6
									26	W → E	NA	2.9	434.3
	August	0						3	4	W → E	NA	3.1	521.5
									5	W → E	NA	3.3	462.1
									11	W → E	NA	2.4	410.8
Total		11				68.5	10,267.9	29				117.3	17,030.5

Table 2. Summary of aerial survey effort during Campaign 5

"Other Surveys" include condensed, directed, and opportunistic surveys. Note: W = west, E = east, NA = Not applicable. A blank in the Day column means that the survey was conducted on the day listed in the row above.
* Airtime and flight length combined.

3.1.2 Detections

Sightings and detections for Campaign 5 are split into two main categories: 1) sightings that can be incorporated into abundance estimates (on effort) and 2) all sightings during general, condensed, directed, and opportunistic surveys. For each species or group of species, sightings maps are provided for both categories; if sightings for a species occurred only on effort or only off effort, a single sightings map is provided.

3.1.2.1 On effort detections

A total of 409 sightings of marine megafauna (n = 1,924 individuals) were recorded, including both observer (81%, n = 331) and camera (19%, n =78) detections (Table A-1). Identification to the species level was possible for 317 sightings and resulted in 15 confirmed species: ten cetacean, two shark, one fish, and two sea turtle. Marine mammals were seen frequently, representing 44% of detections (n = 178) and 87% of all individuals tallied (n=1,684 individuals). Sharks/fish were seen more often (56% of detections, n =229), but in lower numbers (12% of individuals detected, n = 238). The remaining two detections were of two individual sea turtles.

3.1.2.2 All detections

A total of 3,124 detections of marine fauna (46.0%), human activity (41.2%), natural debris (10.4%), and unknown objects (2.4%) were observed during all Campaign 5 aerial surveys. Of these detections, 70% (n = 2,191) were observer detections and 30% (n = 933) were camera detections.

There were 1,436 detections of marine fauna totaling 10,940 individuals of 17 species (Table A-2). Marine fauna included several species of large whales, small cetaceans, birds, sharks/fish, and sea turtles. Marine mammals had the highest number of individuals observed (68%, n = 7,479), followed by birds (25%, n = 2,727), sharks/fish (7%, n = 726), and sea turtles (<1%, n = 8). The majority of marine mammal sightings were cetaceans (84%) and the rest were pinnipeds. Two additional species were detected only off effort: pilot whales (*Globicephala* sp.) and sei whales (*Balaenoptera borealis*). Birds were typically not marked by observers in the plane; consequently, reported sightings of birds are exclusively camera detections.

There were 1,670 observer and camera detections of human activity (80%) and natural debris (20%) during all Campaign 5 surveys (Table A-2). Debris detections are exclusively camera detections. Natural debris consisted mostly of floating sargassum and wood. The majority of human activity detections were related to commercial fishing (78%), which included fixed fishing gear and vessels that were transiting or actively fishing. Other types of vessels such as Coast Guard, merchant, and research vessels accounted for 8% of the human activity observed, while recreational vessels and anthropogenic debris each accounted for 7%.

The analysis of the vertical photographs from all surveys resulted in 520 detections of 4,677 animals and 404 detections of natural debris or human activity. Eleven species of marine megafauna (not including birds) were identified to the species level from vertical photographs.

For additional sighting information referring specifically to opportunistic and directed surveys or complete sighting information for general and condensed surveys including off effort sightings, please refer to tables A-3 and A-4 in Appendix A.

3.1.3 Cetacean detections

A total of 131 on effort sightings of 1,326 cetaceans were recorded during Campaign 5. When including off effort sightings, 494 sightings of 3,096 cetaceans were recorded. Identification to the species level was possible for 122 on effort sightings and resulted in 11 confirmed species (Table 3). Species ID could not be confirmed for nine sightings.

Right whales, minke whales (*Balaenoptera acutorostrata*), and common dolphins (*Delphinus delphis*) were sighted most frequently and accounted for 18%, 28%, and 21%, respectively, of on effort sightings (Figure 5). In contrast, the three dolphin species were the most abundant cetaceans, accounting for 51% (common dolphins), 24% (bottlenose dolphins, *Tursiops truncatus*), and 14% (white-sided dolphins, *Lagenorhynchus acutus*) of individual cetaceans sighted on effort (Figure 6).

Baleen whales were represented by five species of two families: Balaenidae and Balaenopteridae. One species of the Balaenidae family was sighted: the North Atlantic right whale. In total, 175 sightings of 321 right whales were recorded during Campaign 5, on and off effort. Right whales are discussed and seasonal sighting maps are shown below. Four species of the Balaenopteridae family or rorqual whales were sighted: fin whales (*Balaenoptera physalus*), sei whales, minke whales, and humpback whales (*Megaptera novaeangliae*). A total of 45 sightings of 52 rorqual whales were documented on effort and a total of 195 sightings of 262 rorqual whales were documented during all Campaign 5 surveys. Humpback, fin, and minke whales were sighted in more than half of the months surveyed (10, 6, and 6 months, respectively). In contrast, sei whales were sighted in only May and June (Table 3). Sei whales were only sighted on directed surveys; consequently, they are not included in any figures or tables that include only on effort sightings. Balaenopterid sightings are discussed below; seasonal sighting maps are not provided for Balaenopterid whales because typically only one or two seasons had high numbers of sightings.

Toothed whales were represented by seven species in three families: pilot whales, and common, bottlenose, and Atlantic white-sided dolphins (family Delphinidae); harbor porpoise (*Phocoena phocena*; family Phocoenidae); and sperm whales (family Physeteridae). Toothed whale sightings are discussed below.

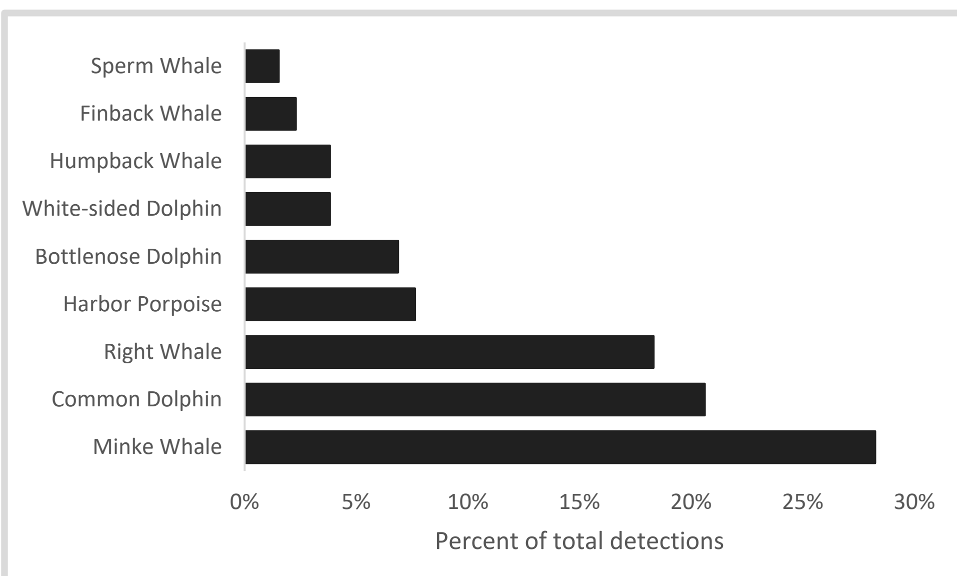

Figure 5. Percentage of on effort sightings per cetacean species identified during Campaign 5 aerial surveys

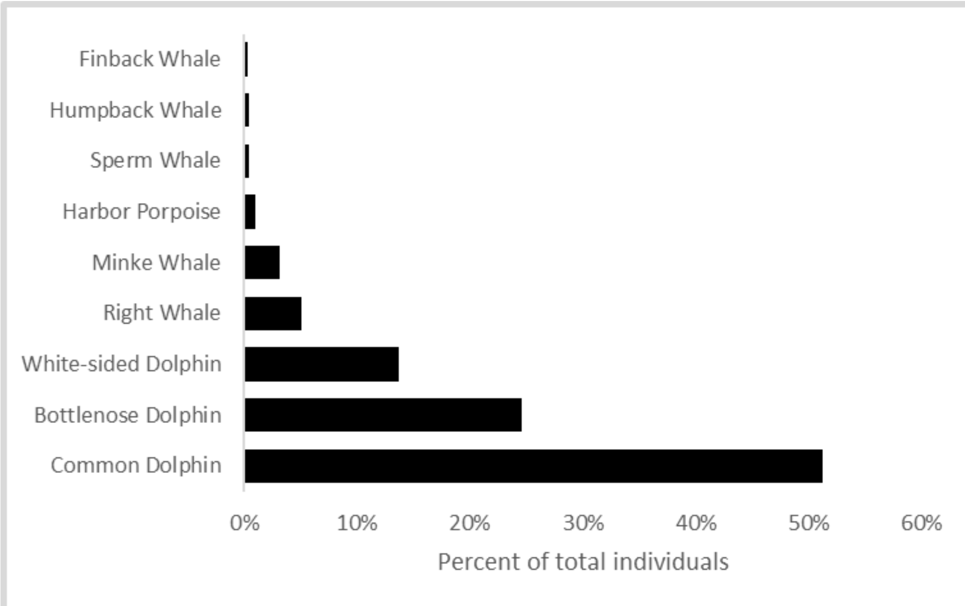

Figure 6. Percentage of individuals identified per cetacean species while on effort during Campaign 5 aerial surveys

Table 3. Monthly presence and absence of rorqual whales during Campaign 5 aerial surveys

Grey boxes indicate presence and white boxes indicate absence for each species in a given month.

Year/month		Fin whales	Sei whales	Humpback whales	Minke whales
2018	October				
	November				
	December				
2019	January				
	February				
	March				
	April				
	May				
	June				
	July				
	August				

3.1.3.1 North Atlantic right whales

In total, 24 on effort sightings of 67 right whales were recorded during Campaign 5 general and condensed surveys. During directed surveys, 112 sightings of 164 right whales were recorded. One opportunistic survey was flown, during which three sightings of three right whales were recorded. Sightings usually consisted of single right whales (67%).

Right whales were sighted in every season and in nine of eleven months surveyed. December, January, and February had the highest number of right whale sightings. No right whale sightings were recorded in June or October. Figure 7 shows monthly sighting totals for right whales (both on and off effort), which may include duplicate individuals between surveys. Seasonal sighting rates for right whales were highest in the winter (28.31 whales/km), followed by spring (8.70 whales/km) summer (6.26 whales/km), and fall (3.23 whales/km).

On effort and all right whale sightings are shown in Figure 8 and right whale sightings by season are shown in Figure 9. Seasonal sightings are shown for right whales, but are not shown for other species, because there were sightings of right whales in all seasons. Right whales were primarily found on the eastern side of the study area (Figures 8, 9) although their distribution changed seasonally (Figure 9). In winter, a large aggregation of right whales was observed on the southern portion of the Nantucket shoals. Although this aggregation fluctuated in size, it stayed in this area from December through February. In March, this aggregation moved slightly north, closer to Nantucket. This northward movement resulted in the observation of a large group skim feeding about 10 nm south of Nantucket in early April. After this observation, the feeding aggregation disappeared for a few weeks and then reappeared south of the usual survey area. The feeding aggregation persisted in this location for a few weeks, before a break in all right whale sightings for six weeks from June to mid-July. On July 15th, three right whales were sighted less than a mile south of Nantucket. Over the next several weeks, more whales arrived and the group drifted further south back to the Nantucket Shoals where they remained through the end of Campaign 5 surveys in August.

Most of the right whale sightings were close to, but outside of, the wind energy lease zones. Specifically, all sightings were within 20 nm of existing lease areas. The right whale sightings that did occur in the lease zones were either close to or inside the southeastern MA WEA lease zones. During Campaign 5, there was only one sighting of one right whale within the RIMA WEA lease zone.

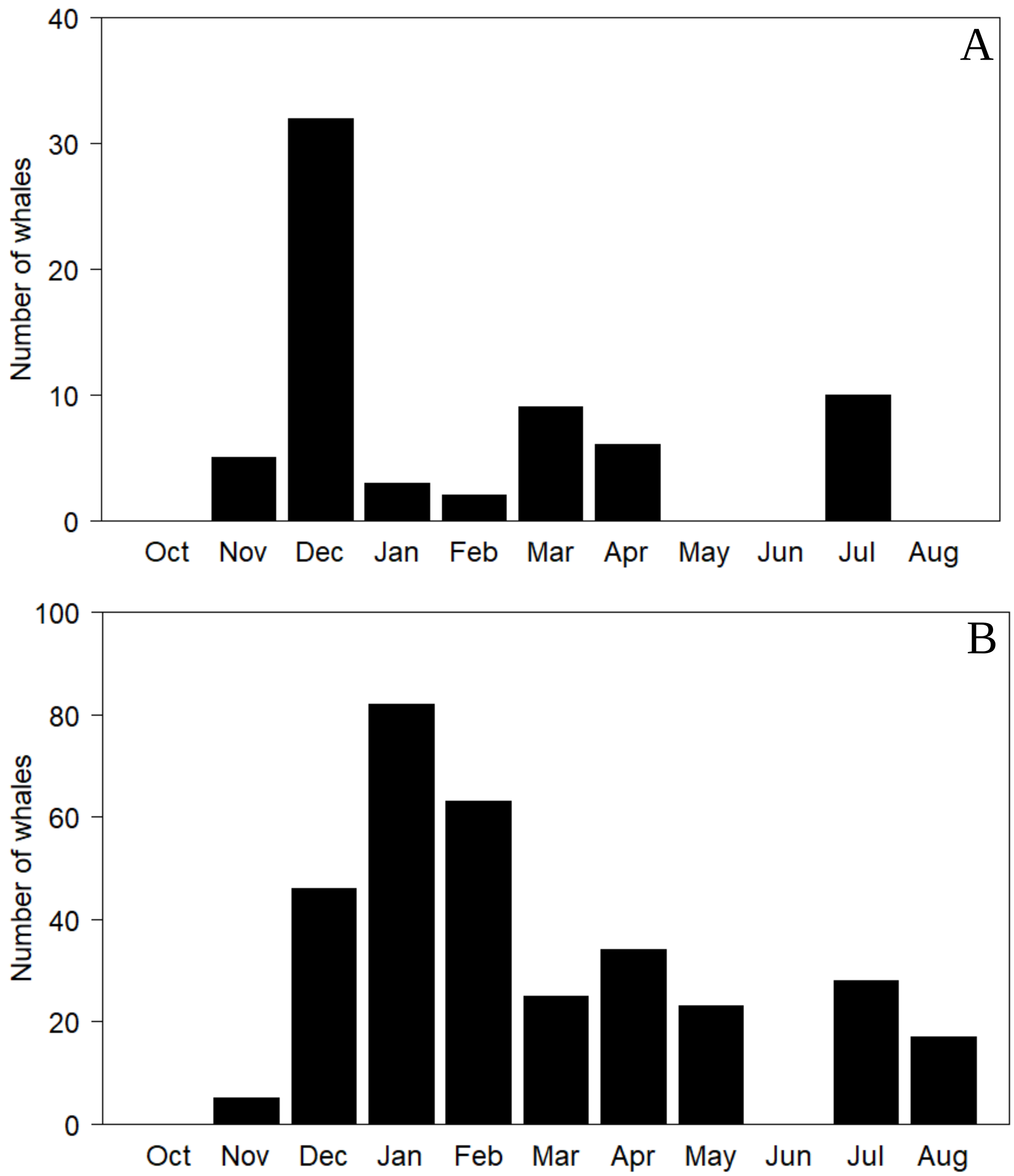

Figure 7. Right whale sightings per month during Campaign 5 aerial surveys
Summarized for A) on effort sightings and B) all sightings during Campaign 5.

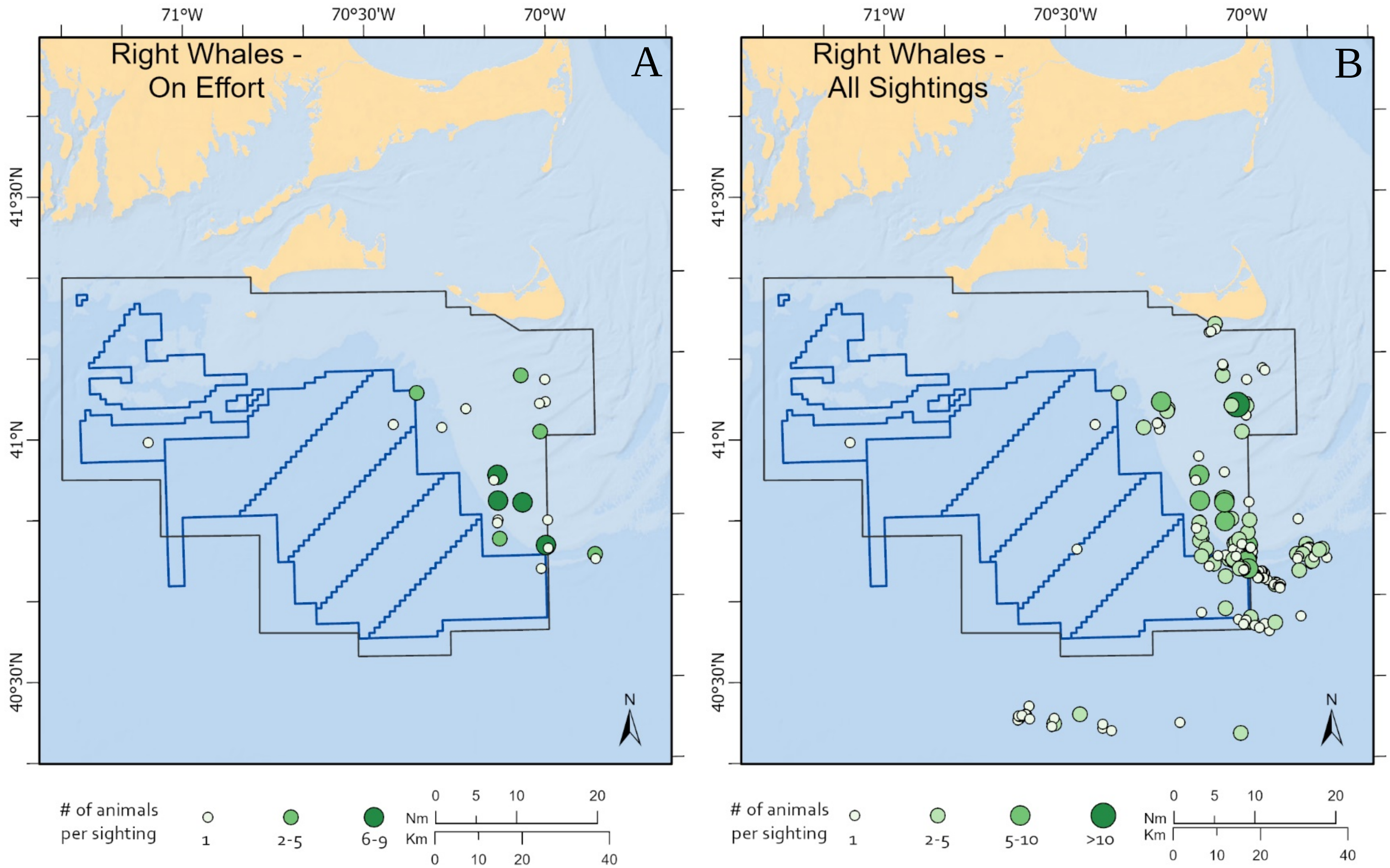

Figure 8. Maps of right whale sightings during Campaign 5 aerial surveys
Summarized for A) on effort and B) all sightings during Campaign 5.

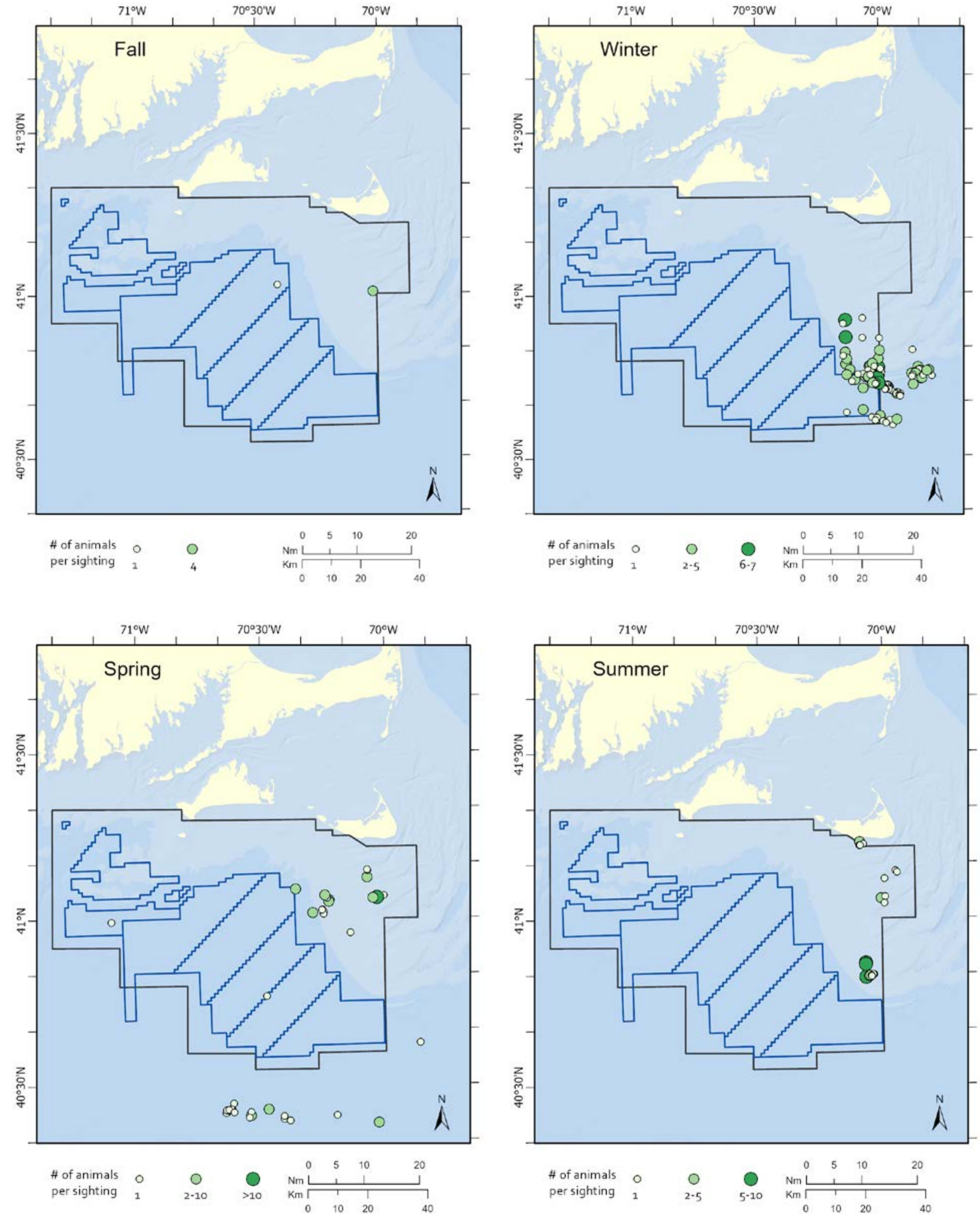

Figure 9. Seasonal sightings of right whales during all Campaign 5 aerial surveys

3.1.3.1.1 Relative and absolute abundance

Right whale relative abundance changed throughout the seasons, but they consistently occurred over the Nantucket Shoals on the eastern side of the survey area (Figure 10). Figure 10 also shows a cluster of animals using the area south of the MA WEA during the spring.

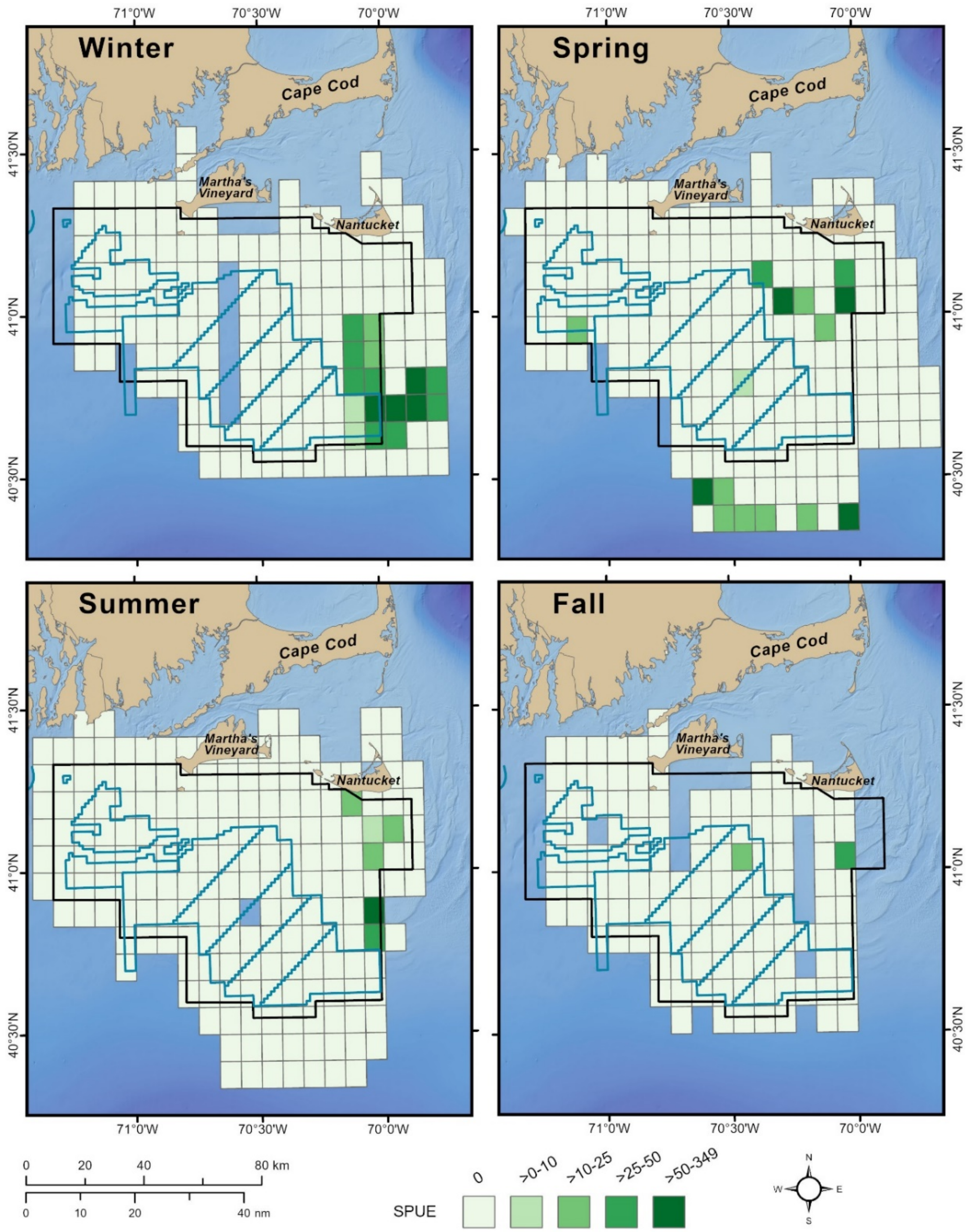

Figure 10. Sightings per unit effort for right whales during all Campaign 5 aerial surveys
Seasonal numbers of individuals per 1,000 km calculated in 5 x 5 min squares

Seasonal density and abundance estimates were calculated for right whales for Campaigns 4 and 5 (Table 4); estimates could be calculated for all seasons except summer and fall 2018 (when sightings were either not on general surveys or did not fall within the truncation distance). Right whale seasonal abundance in the study area was between two and 92 animals, with the highest abundances occurring consistently in winter and spring.

Table 4. Density and abundance of right whales during Campaigns 4 and 5 by season and year

Effort (km) is the summed on-effort distance surveyed for all transects. # detections is the number of sighting of one or more individual animals. # animals is the number of individual animals summed over all sightings and transects. Est. density is the number of individuals per km^2. Est. abundance is the number of individuals we estimated for the survey area. 95% CI= 95% confidence interval of abundance. * = no sightings on general surveys, ** = sightings present but they did not occur within the truncation distance.

Season-year	Effort (km)	# of detections	# of animals	Est. Density	Est. Abundance	95% CI
Winter – 17	531	3	7	0.0072	42	7-252
Spring – 17	3606	15	41	0.0062	36	15-85
Summer – 17	1787	1	1	0.0003	2	0-10
Fall – 17	1797	2	2	0.0006	4	1-13
Winter – 18	1579	10	27	0.0093	54	18-167
Spring – 18	1798	3	3	0.0009	5	2-15
Summer – 18	594	*	-	-	-	-
Fall – 18	1197	**	-	-	-	-
Winter – 19	2405	30	70	0.0159	92	38-223
Spring – 19	1202	3	23	0.0104	61	6-587
Summer – 19	1202	1	9	0.0041	24	4-135

3.1.3.1.2 Demographic and re-sighting patterns

Photo identification data has not yet been confirmed by the NARWC. This analysis is estimated to be completed in early 2021. Preliminary photo analysis identified 137 individual right whales during all Campaign 5 surveys. Most right whales were adults (75%, n = 103) and males (55%, n = 75) (Table 5).

Table 5. Number and percentage of different sex and age classes of right whales identified during Campaign 5 aerial surveys

Note: * includes one 2019 calf.

Sex	N	%	Adult	%	Juvenile	%	Age Unknown	%
Male	75	55	64	62	11	44	0	0
Female	46	33	34	33	10	40	2	25
Unknown	16	12	5	5	5*	16	6	75
Total	137	100	103	100	26	100	8	100

In March 2019, a right whale mother and calf pair were sighted (Figure 11). Catalog #4180 and calf were seen approximately 15 nm south of Nantucket on March 28th in the vicinity of several other skim feeding whales. Mothers with calves are not often sighted in the study area: calves have only been sighted in this area during two other years (2010, 2015) and this sighting of a mother and calf is the first in the study area by the NEAq aerial survey team. This pair was also seen in fall 2019 (after the conclusion of Campaign 5 surveys) near the Nantucket Shoals by NEFSC.

Figure 11. Right whale #4180 and her calf of the year at the surface side by side

Photo identification data has not been confirmed by the NARWC, but preliminary analysis suggests that many of the identified right whales (43%, n = 59) were resighted during Campaign 5 surveys. Most whales (n = 41) were resighted only once during Campaign 5, but some whales were resighted up to five times (n = 3). Of these resightings, most occurred in two separate months (n = 40) and one whale was resighted in four separate months (Figure 12).

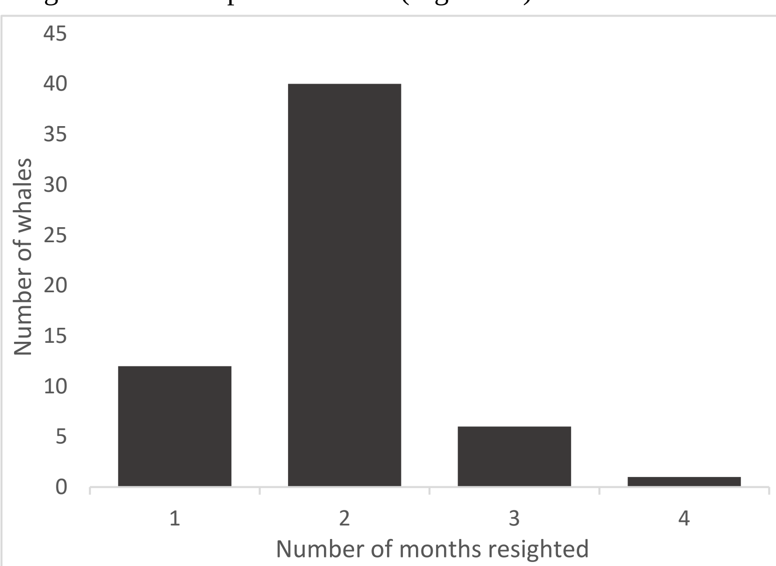

Figure 12. Number of individual right whales resighted across different months during Campaign 5 aerial surveys

One resighting was of an entangled whale; adult male, Catalog #2310, was first seen entangled in the study area on December 20th, 2018 (Figure 13). This sighting was the first documentation of this whale's entanglement and sighting data was sent to the Marine Animal Entanglement Response (MAER) team at Center for Coastal Studies (CCS). This whale was resighted on February 3rd, still entangled. Although the MAER team was able to mount a response during an April sighting in Cape Cod Bay, they were not able to resolve the entanglement. The whale has not been resighted since this disentanglement attempt.

Figure 13. Sightings of entangled right whale #2310
This adult male was first sighted entangled by NEAq in the study area on December 20th, 2018 (top). A line, indicated by the arrow, can be seen extending past the right side of the body. This whale was resighted on Febuary 3rd, 2019 by NEAq in the study area still entangled (bottom). In this sighting, a line can be seen exiting the left side of the mouth, and terminating half-way down the body.

3.1.3.2 Fin whales

Fin whales are the largest baleen whale observed in the study area. While on effort, three sightings of five fin whales were observed. A total of 32 sightings of 53 fin whales were seen during all Campaign 5 surveys, with group sizes ranging from one to four whales and an average group size of 1.7 whales. Fin whales were observed most often in the spring and summer (n = 24 whales for each season), while only five fin whales were sighted in the fall and none were seen during the winter (Figure 14). Seasonal sighting rates for fin whales were highest in the summer (3.48 whales/km), followed by spring (2.55 whales/km), fall (1.94 whales/km), and winter (0.30 whales/km). Fin whales were seen throughout the study area; however, the eastern part of the study area had the most fin whale sightings (Figure 15).

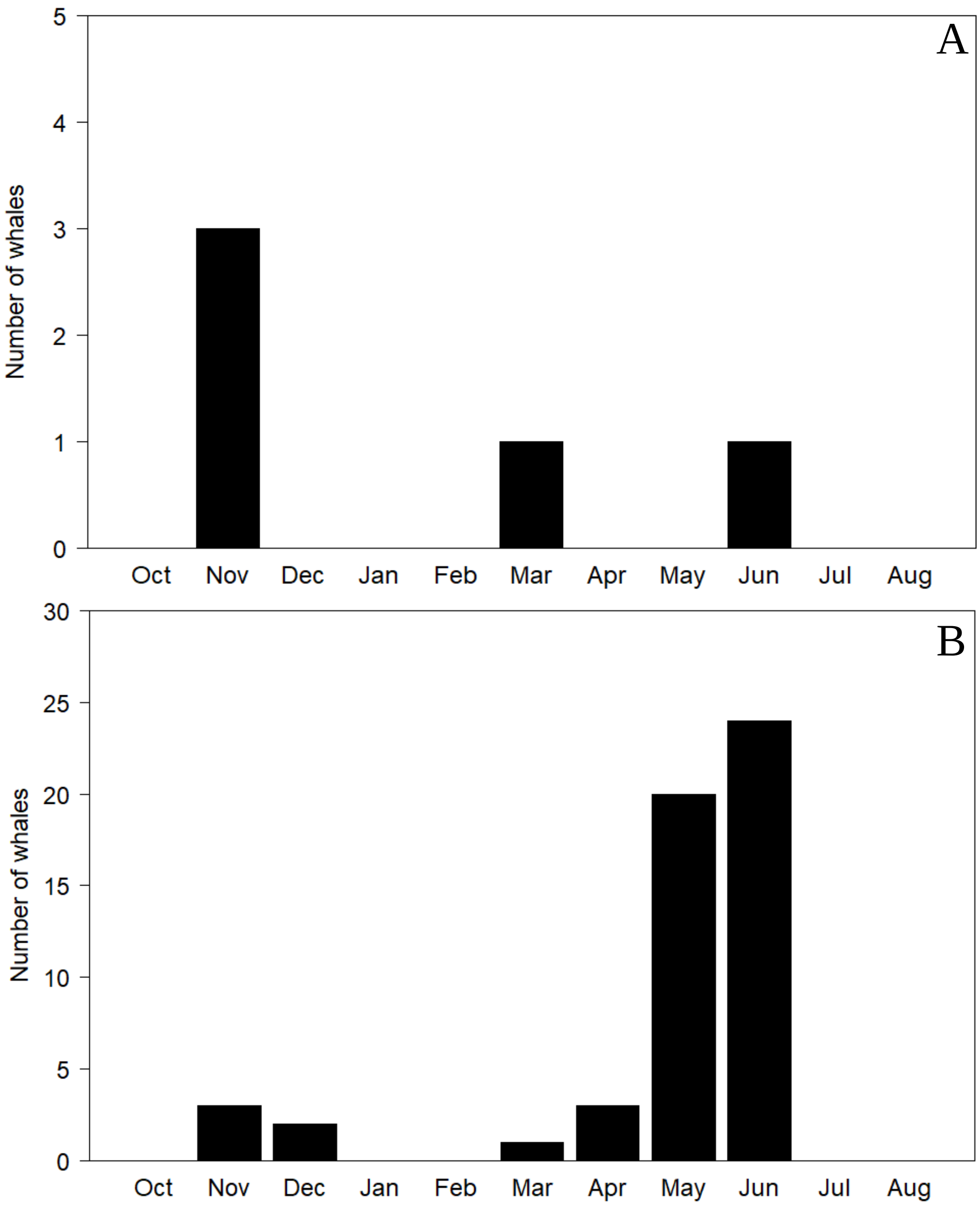

Figure 14. Fin whale sightings per month during Campaign 5 aerial surveys
Summarized for A) on effort sightings and B) all sightings during Campaign 5.

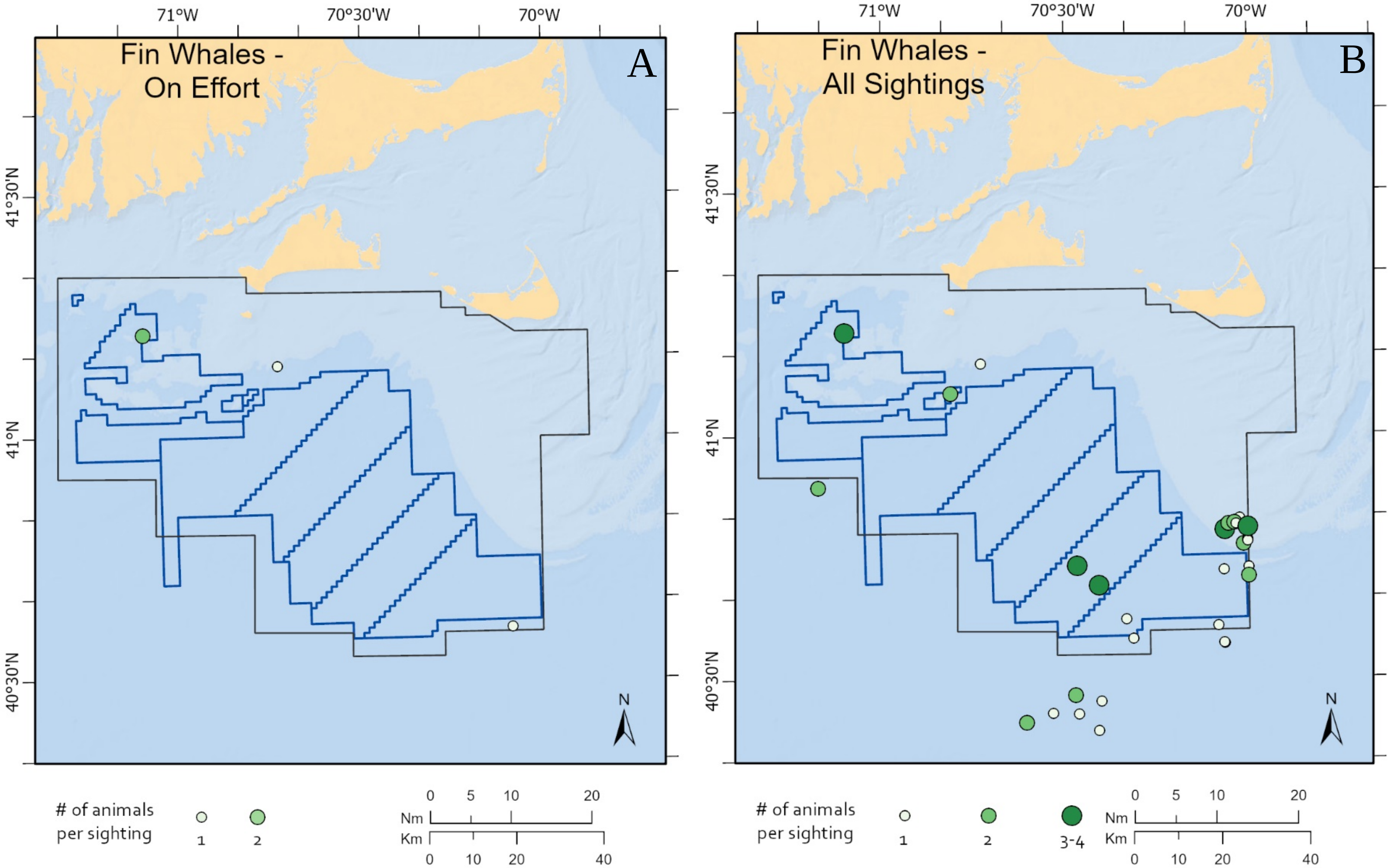

Figure 15. Map of fin whale sightings during Campaign 5 aerial surveys
Summarized for A) on effort and B) all sightings of fin whales during Campaign 5.

3.1.3.2.1 Relative and absolute abundance

Fin whale relative abundance was lowest during the winter and fall (Figure 16). It was highest in the spring and summer, when fin whales clustered in the southern and eastern parts of the study area.

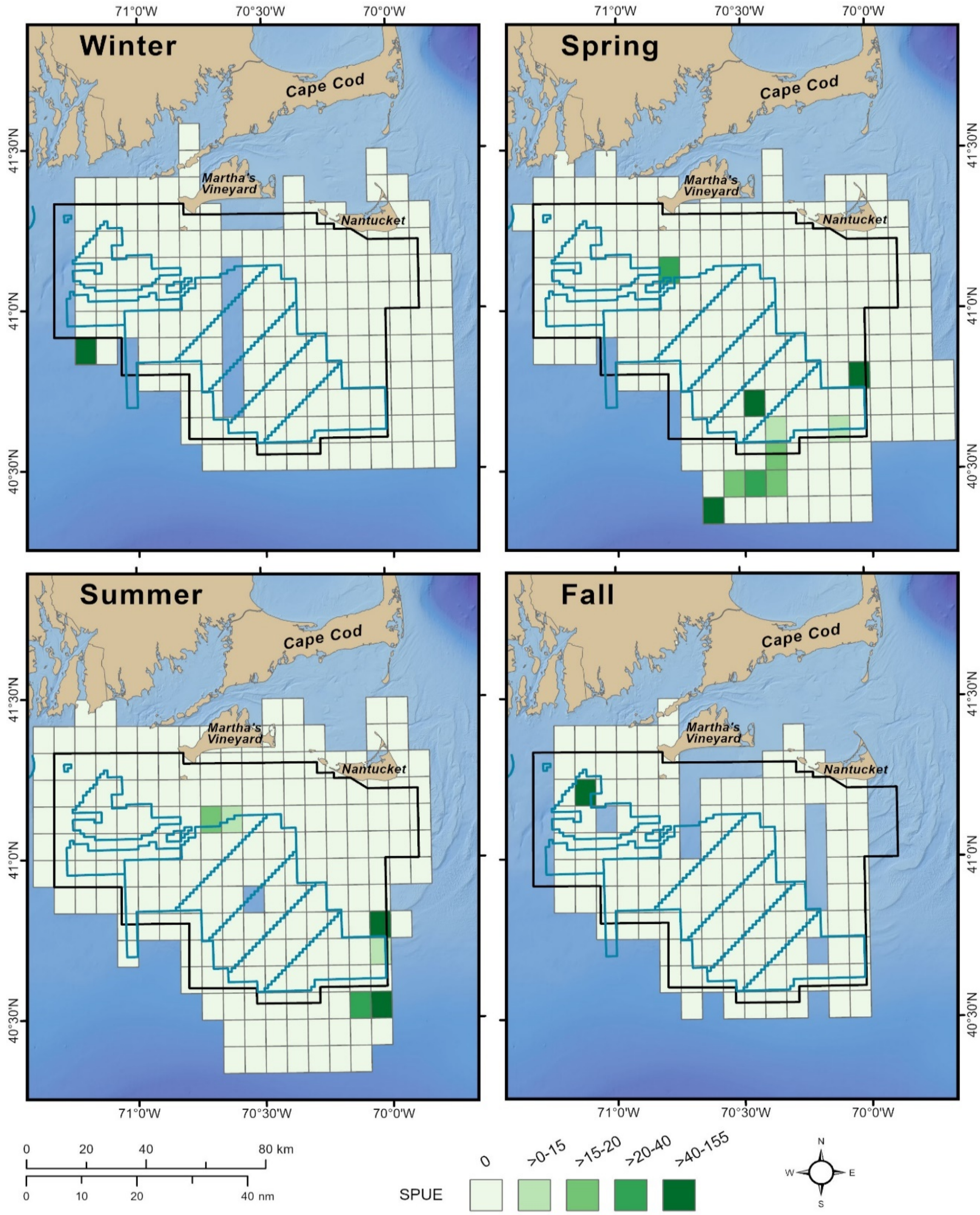

Figure 16. Sightings per unit effort for fin whales during all Campaign 5 aerial surveys
Seasonal numbers of individuals per 1,000 km calculated in 5 x 5 min squares

Seasonal density and abundance estimates were calculated for fin whales for Campaigns 4 and 5 (Table 6); estimates could be calculated for six of 11 season-years. Fin whale seasonal abundance in the study area was between two and 37 animals. In most years, fin whale abundance was highest during spring and summer, and lowest during fall and winter.

Table 6. Density and abundance of fin whales during Campaigns 4 and 5 by season and year

Effort (km) is the summed on-effort distance surveyed for all transects. # detections is the number of sighting of one or more individual animals. # animals is the number of individual animals summed over all sightings and transects. Est. density is the number of individuals per km^2. Est. abundance is the number of individuals we estimated for the survey area. 95% CI= 95% confidence interval of abundance. * = no sightings on general surveys, ** = sightings present but they did not occur within the truncation distance.

Season-year	Effort (km)	# of detections	# of animals	Density	Abundance	95% CI
Winter – 17	531	0	0	0	0	0
Spring – 17	3606	1	3	0.0003	2	0-11
Summer – 17	1787	15	27	0.0063	37	16-85
Fall – 17	1797	**	0	0	0	0
Winter – 18	1579	0	0	0	0	0
Spring – 18	1798	2	3	0.0007	4	2-17
Summer – 18	594	1	3	0.0021	12	2-84
Fall – 18	1197	1	3	0.001	6	1-36
Winter – 19	2405	0	0	0	0	0
Spring – 19	1202	**	0	0	0	0
Summer – 19	1202	2	2	0.0004	4	1-15

3.1.3.3 Sei whales

No sei whales were observed on effort during Campaign 5 surveys. Sei whales were only encountered on directed surveys. On these surveys, 28 sightings of 55 individuals were observed during two of the 11 months of aerial surveys. Sightings of one to 10 sei whales were observed and the average group size was two whales. Most sightings occurred in May (n = 51 whales) (Figure 17). Seasonal sighting rates for sei whales were highest in the spring (5.41 whales/km), followed by summer (0.56 whales/km). There were no sightings of sei whales in the winter or fall. Sei whales were seen only in the southern parts of the study area (Figure 18). Most of the sei whale sightings were south of the defined study area during directed surveys over an aggregation of right whales.

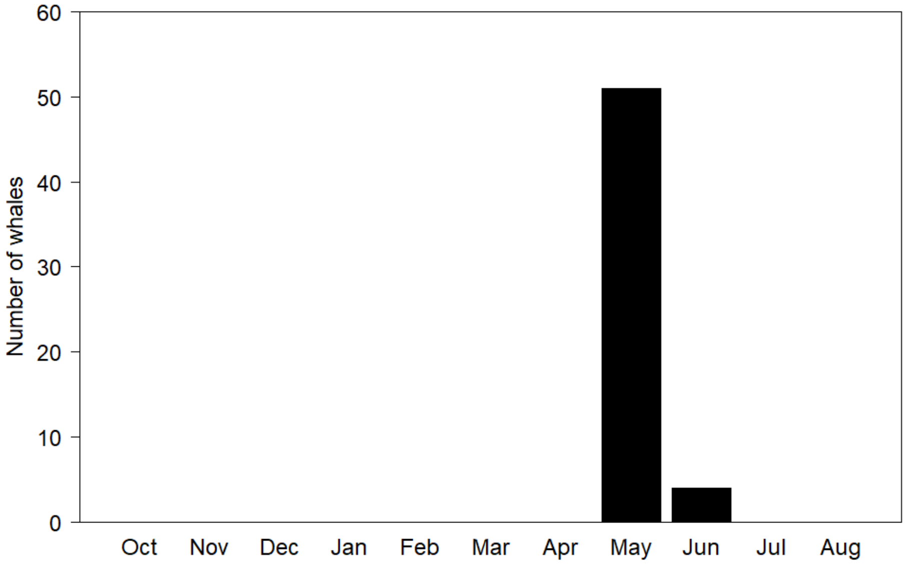

Figure 17. Sei whale sightings per month summarized for all sightings during Campaign 5 aerial surveys

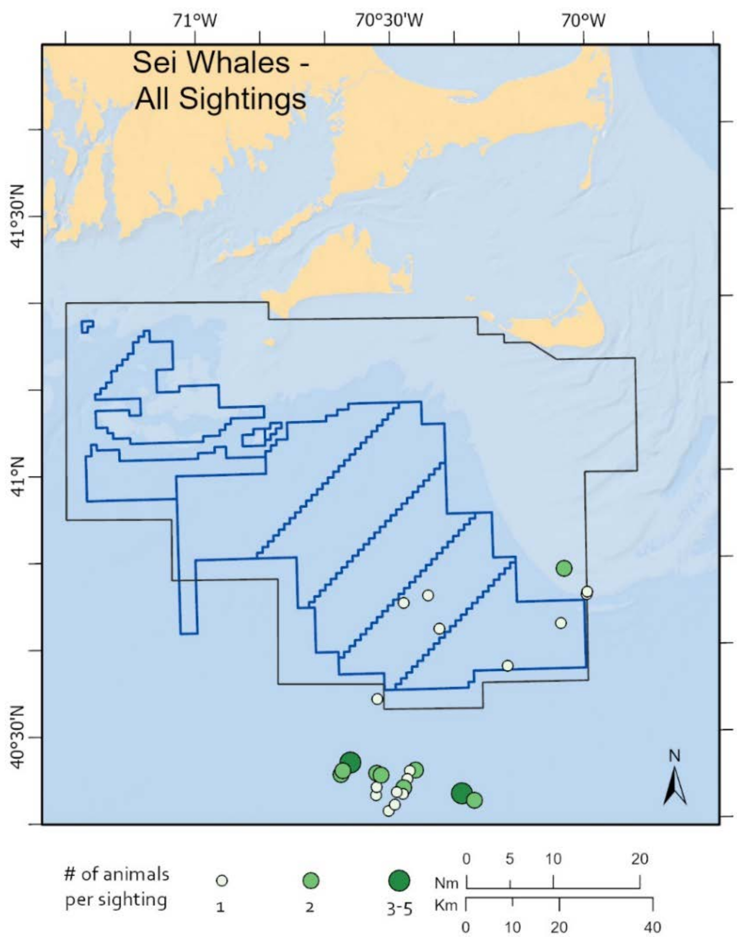

Figure 18. Sightings of sei whales during all Campaign 5 aerial surveys

There were no on effort sightings of sei whales during Campaign 5 because all sightings occurred on directed surveys.

3.1.3.3.1 Relative and absolute abundance

Sei whales were not sighted in the winter or fall surveys. Sei whale relative abundance was highest during the spring and lower during the summer (Figure 19). Sei whales were primarily clustered at the southeastern edge of the study area, below the MA WEA.

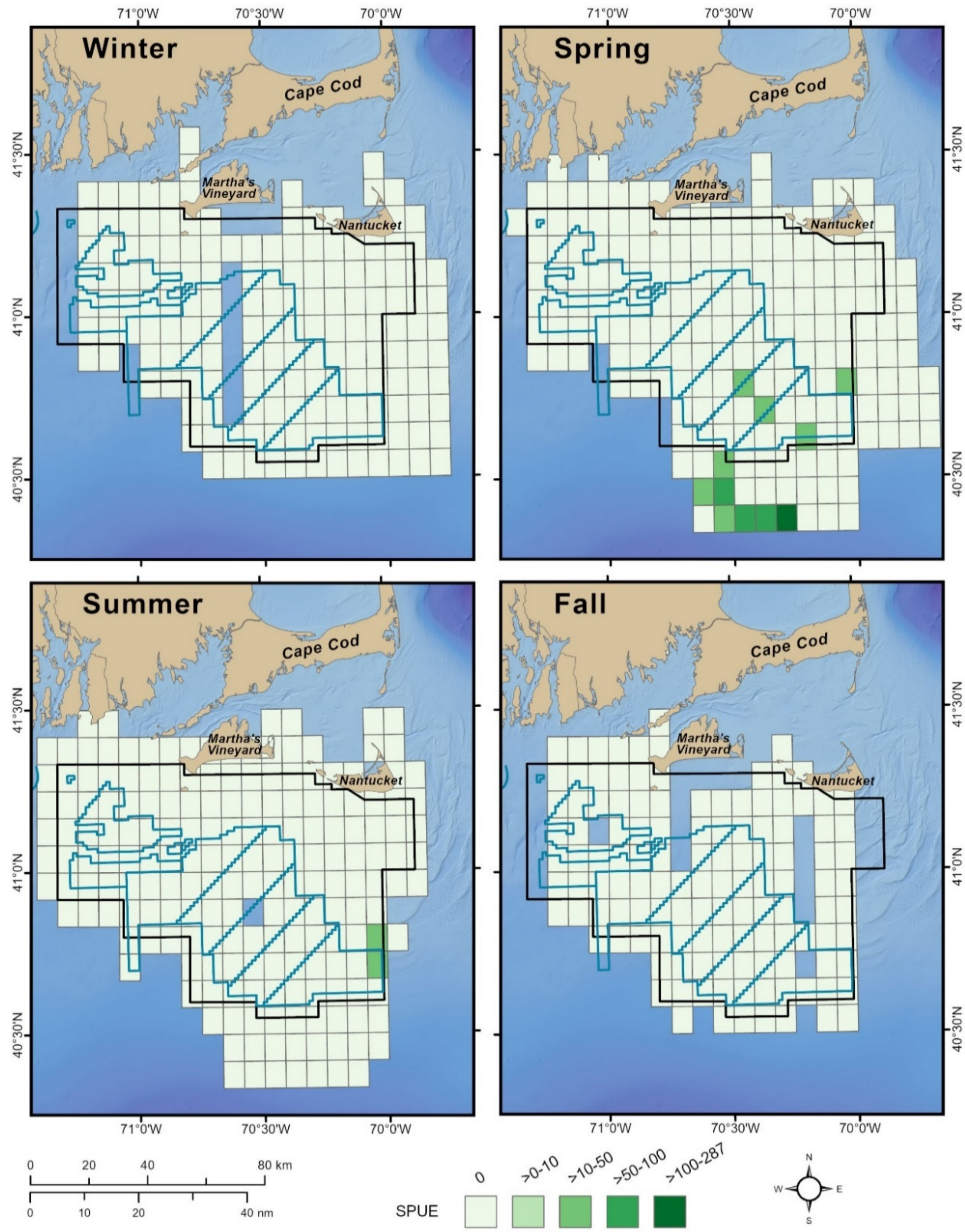

Figure 19. Sightings per unit effort for sei whales during all Campaign 5 aerial surveys
Seasonal numbers of individuals per 1,000 km calculated in 5 x 5 min squares

Seasonal density and abundance estimates were calculated for sei whales for Campaigns 4 and 5 (Table 7), but estimates could only be calculated for two seasons in 2017. Although sei whales were sighted during the spring in Campaign 5, these sightings were largely south of the study area on directed surveys and could not be included in abundance estimates.

Table 7. Density and abundance of sei whales Campaigns 4 and 5 by season and year

Effort (km) is the summed on-effort distance surveyed for all transects. # detections is the number of sighting of one or more individual animals. # animals is the number of individual animals summed over all sightings and transects. Est. density is the number of individuals per km^2. Est. abundance is the number of individuals we estimated for the survey area. 95% CI= 95% confidence interval of abundance. * = no sightings on general surveys, ** = sightings present but they did not occur within the truncation distance.

Season-year	Effort (km)	# of detections	# of animals	Density	Abundance	95% CI
Winter – 17	531	0	0	0	0	0
Spring – 17	3606	5	13	0.0015	9	3-26
Summer - 17	1787	2	8	0.0019	11	3-43
Fall – 17	1797	0	0	0	0	0
Winter – 18	1579	0	0	0	0	0
Spring - 18	1798	0	0	0	0	0
Summer – 18	594	0	0	0	0	0
Fall – 18	1197	0	0	0	0	0
Winter – 19	2405	0	0	0	0	0
Spring – 19	1202	*	*	0	0	0
Summer - 19	1202	0	0	0	0	0

3.1.3.4 Minke whales

Minke whales are the smallest baleen whale observed in the study area. There were 37 on effort detections of 41 whales. A total of 98 sightings of 115 whales were observed when including on and off effort sightings. Their group size varied from one to five whales with an average group size of 1.2 whales. Minke whales were the most frequently sighted rorqual whale in the study area. They were observed most frequently in the spring (n = 41 whales) and summer (n = 72 whales) with only two sightings of two whales in the winter and none in the fall (Figure 20). Most sightings occurred in the months of June (n = 54 sightings) and April (n = 21 sightings). Seasonal sighting rates for minke whales were highest in the summer (9.87 whales/km), followed by spring (4.35 whales/km), and winter (0.30 whales/km). There were no minke whales sighted in the fall. Minke whale sightings were distributed throughout the study area, mainly in the northern portion of the study area (Figure 21).

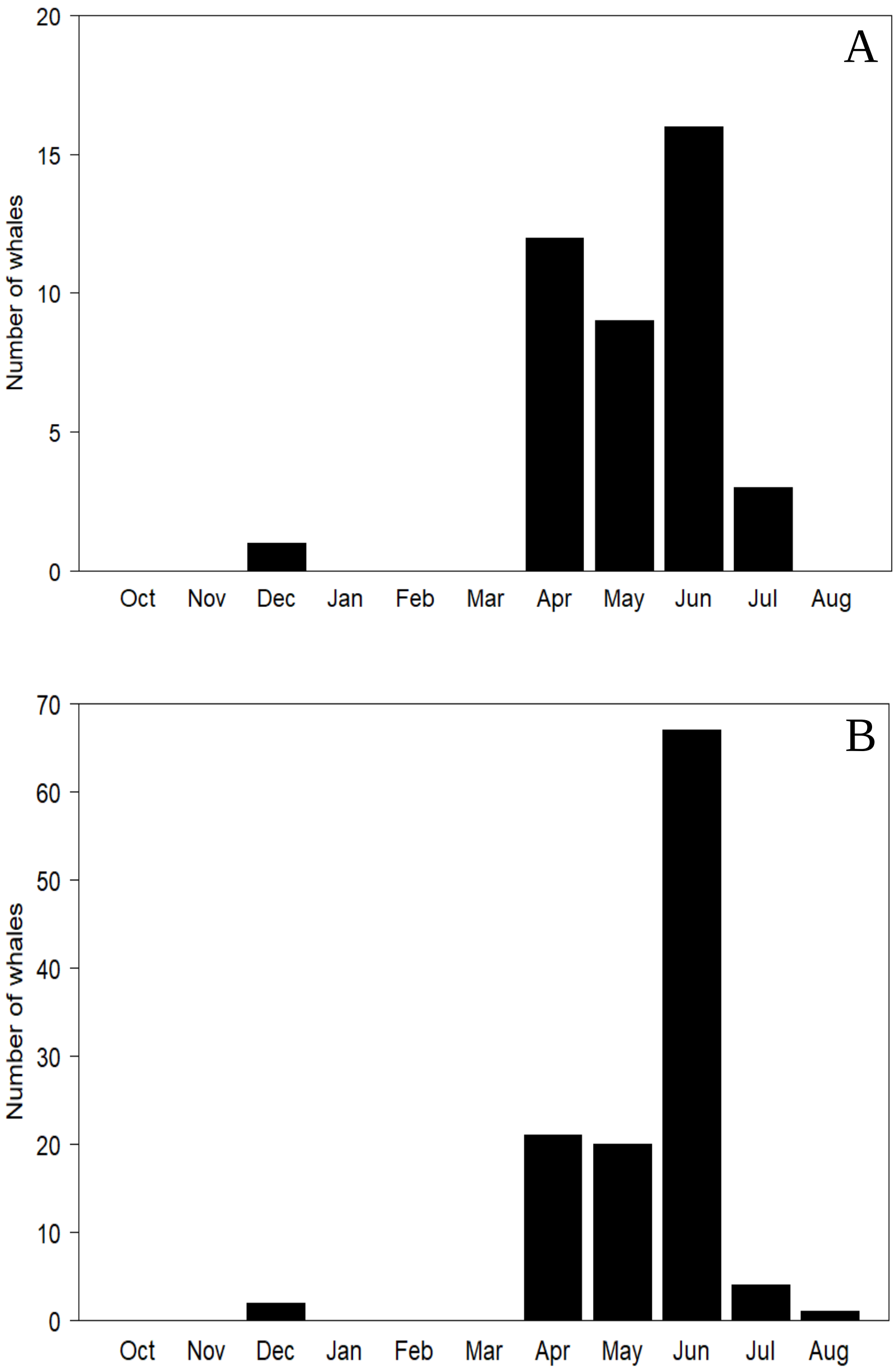

Figure 20. Minke whale sightings per month during all Campaign 5 aerial surveys
Summarized for A) on effort sightings and B) all sightings during Campaign 5.

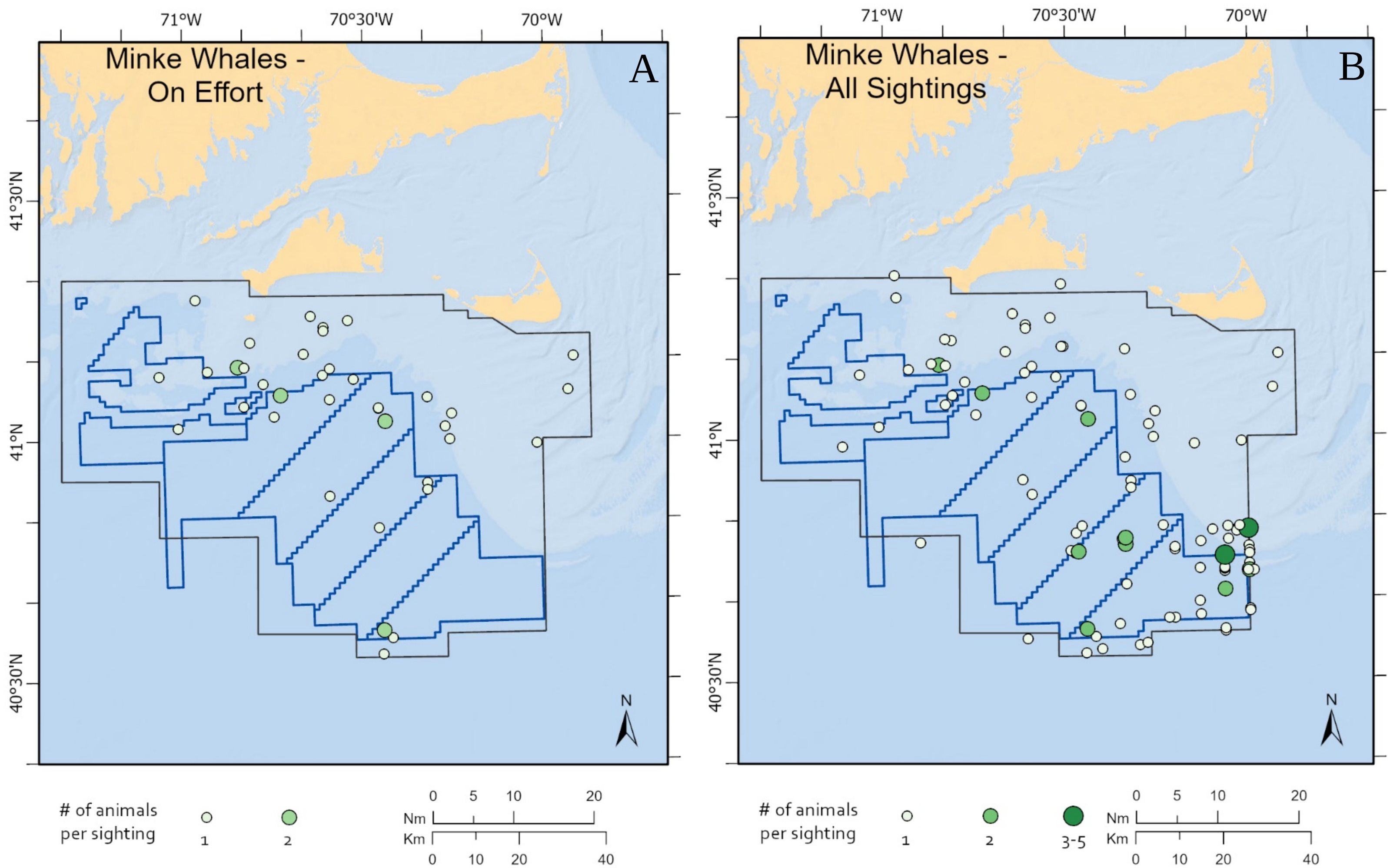

Figure 21. Map of minke whale sightings during Campaign 5 aerial surveys
Summarized for A) on effort and B) all sightings of minke whales during Campaign 5.

3.1.3.4.1 Relative and absolute abundance

Minke whale relative abundance was highest during the summer and lowest during the fall (Figure 22). Minke whales were generally evenly spread across the survey area.

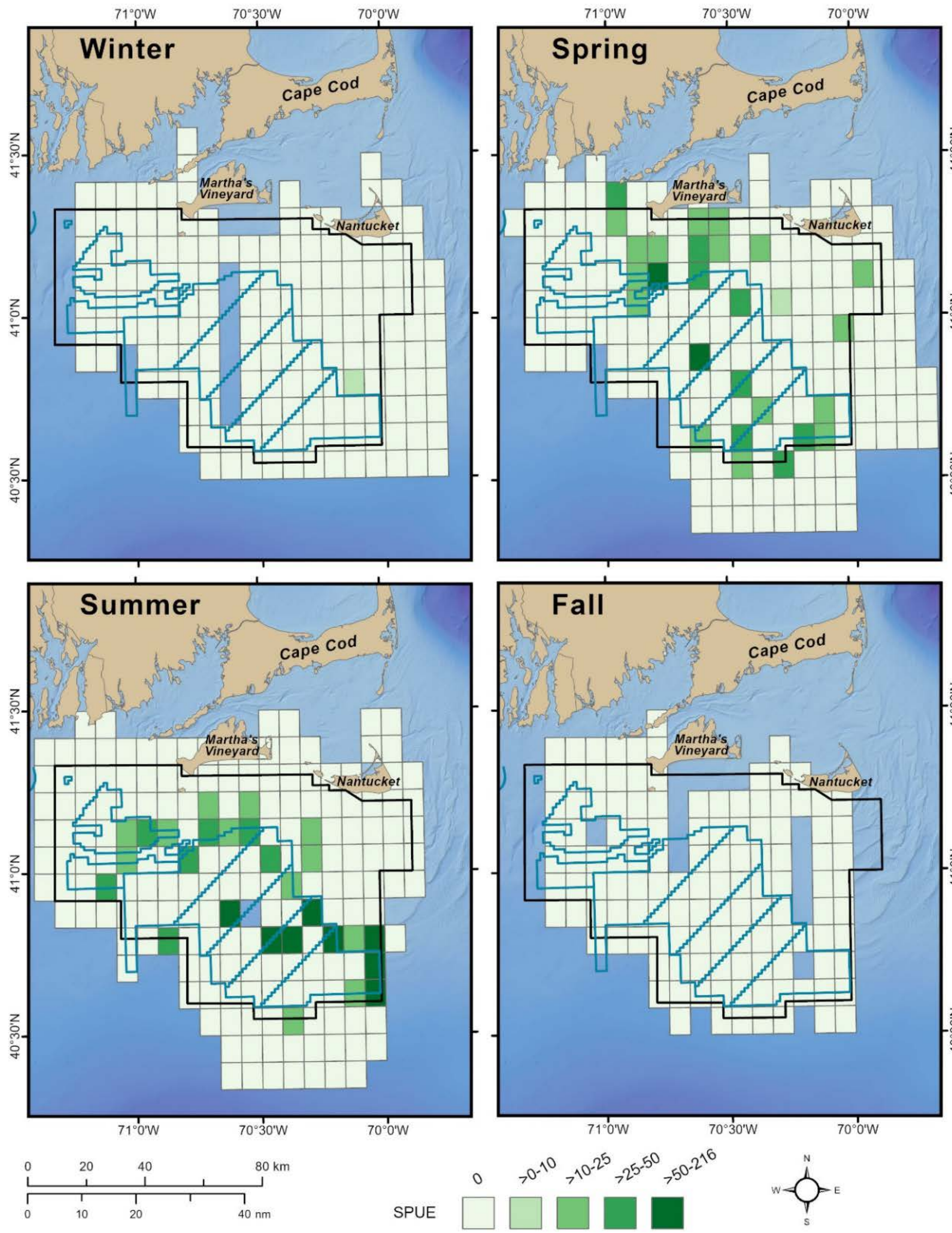

Figure 22. Sightings per unit effort for minke whales during all Campaign 5 aerial surveys
Seasonal numbers of individuals per 1,000 km calculated in 5 x 5 min squares

Seasonal density and abundance estimates were calculated for minke whales for Campaigns 4 and 5 (Table 8); estimates could be calculated for seven of 11 seasons. Minke whale seasonal abundance was between two and51 animals. Abundance was highest during spring and summer seasons; abundance was low or minke whales were absent during fall and winter.

Table 8. Density and abundance of minke whales during Campaigns 4 and 5 by season and year

Effort (km) is summed on-effort distance surveyed for all transects. # detections is the number of sighting events of one or more individual animals. # animals is the number of individual animals summed over all sightings and transects. Est. density is the number of individuals per trackline surveyed in km. Est. abundance is the number of individuals we estimated for the survey area. 95% CI= 95% confidence interval of abundance. * = no sightings on general surveys, ** = sightings present but they did not occur within the truncate distance.

Season-year	Effort (km)	# of detections	# of animals	Density	Abundance	95% CI
Winter – 17	531	0	0	0	0	0
Spring – 17	3606	6	7	0.0015	9	3-24
Summer - 17	1787	9	20	0.0087	51	10-253
Fall – 17	1797	0	0	0	0	0
Winter – 18	1579	0	0	0	0	0
Spring - 18	1798	4	4	0.0017	10	2-42
Summer – 18	594	1	1	0.0013	8	1-49
Fall – 18	1197	0	0	0	0	0
Winter – 19	2405	1	1	0.0003	2	0-11
Spring – 19	1202	8	10	0.0065	38	15-97
Summer - 19	1202	11	12	0.0078	45	18-112

3.1.3.5 Humpback whales

While on effort, five detections of six humpback whales were recorded. When including on and off effort sightings, a total of 30 sightings of 32 humpback whales were observed with at least one sighting in every season (Figure 23). Humpback whales were observed most frequently in the spring (n = 10 whales) and summer (n = 14 whales) and less frequently in the fall (n = 2 whales) and winter (n = 6 whales). The highest number of humpback whale sightings occurred in June (n = 9 detections, 30%). Seasonal sighting rates for humpback whales were highest in the summer (1.95 whales/km), followed by spring (1.06 whales/km), winter (1.05 whales/km), and fall (0.65 whales/km).

Four of the five on effort sightings occurred in existing WEA lease zones and one was just outside the RIMA lease zones (Figure 24). When including off effort sightings, humpback whale sightings were much more common on the eastern side of the study area.

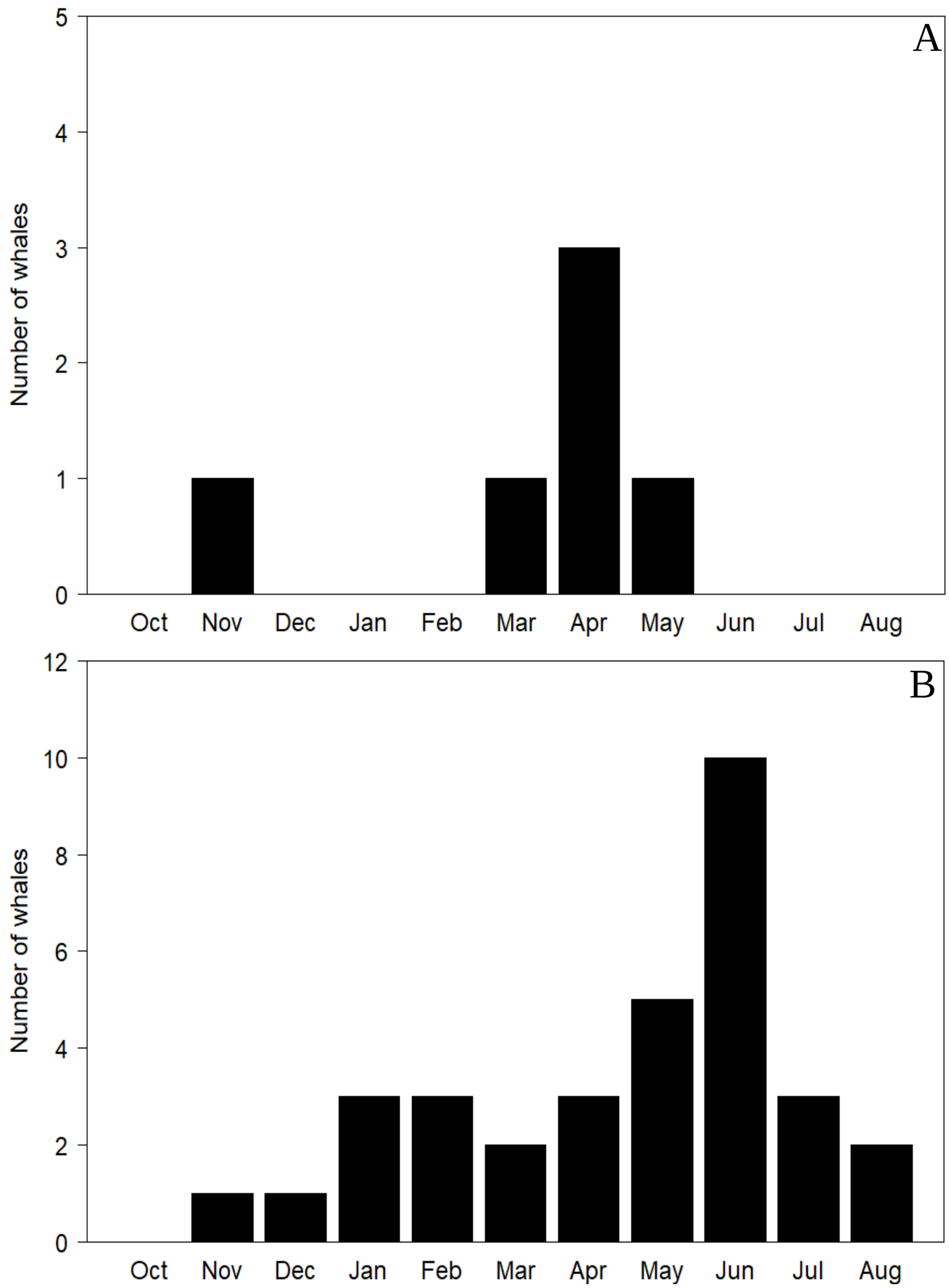

Figure 23. Humpback whale sightings per month during Campaign 5 aerial surveys
Summarized for A) on effort sightings and B) all sightings during Campaign 5.

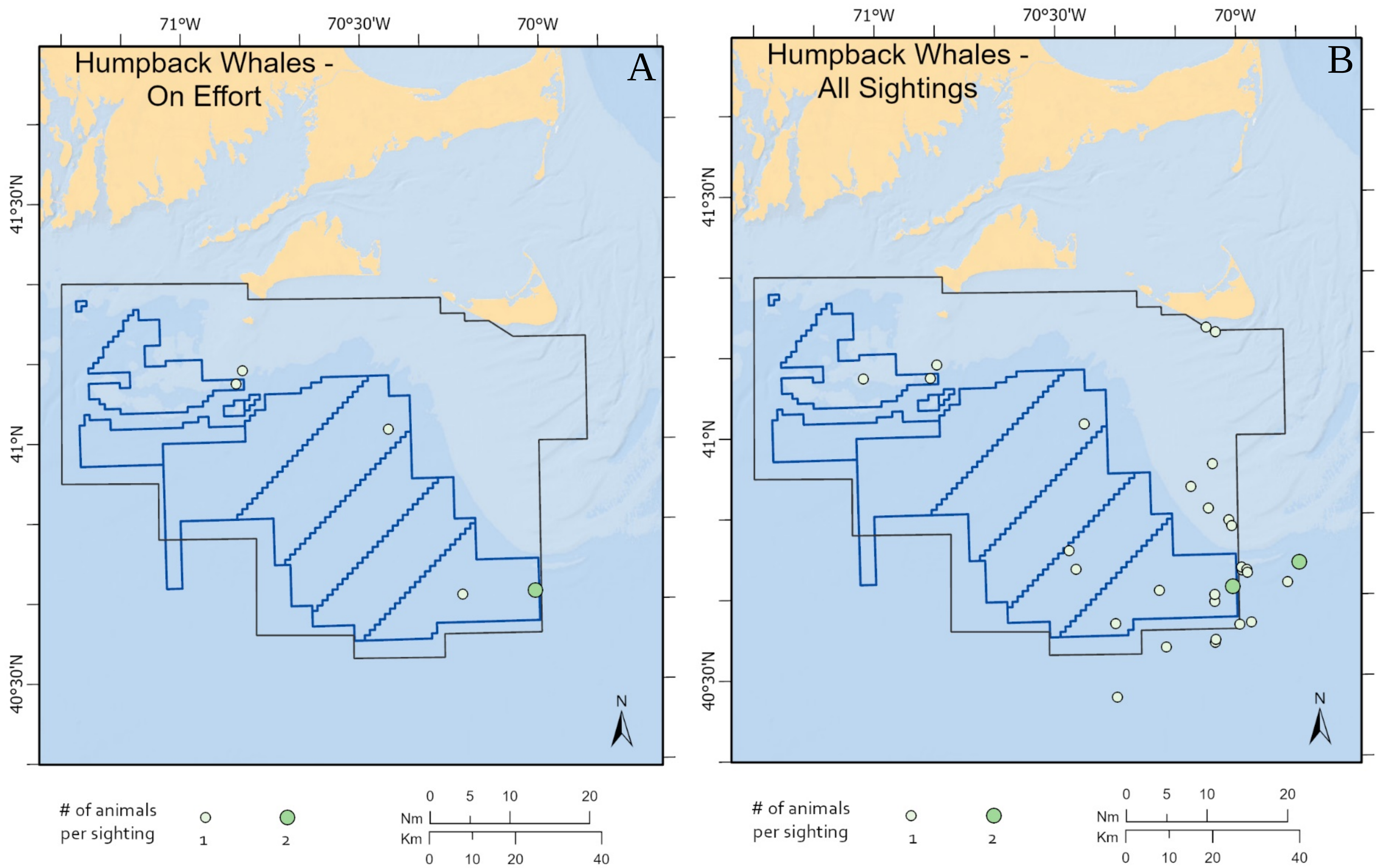

Figure 24. Map of humpback whale sightings during all Campaign 5 aerial surveys
Summarized for A) on effort and B) all sightings of humpback whales during Campaign 5.

3.1.3.5.1 Relative and absolute abundance

Humpback whale relative abundance was lowest during the fall and highest during the spring and summer (Figure 25). Humpback whales were primarily sighted on the eastern side of the study area.

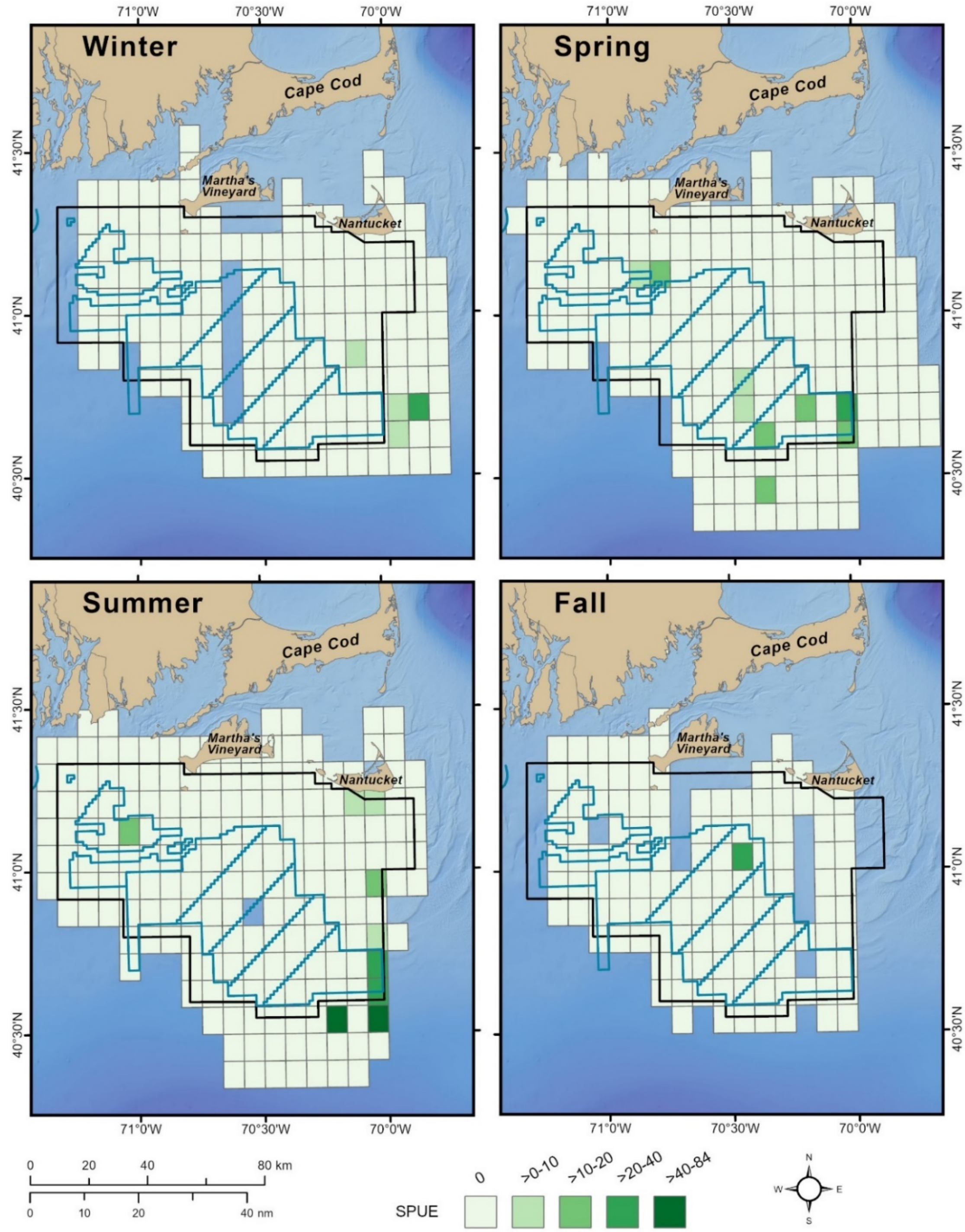

Figure 25. Sightings per unit effort for humpback whales during all Campaign 5 aerial surveys
Seasonal numbers of individuals per 1,000 km calculated in 5 x 5 min squares

Seasonal density and abundance estimates were calculated for humpback whales for Campaigns 4 and 5 (Table 9); estimates could be calculated for four of 11 seasons. Humpback whale seasonal abundance was highest during spring when it ranged from 10 to 32 animals. Humpback whales were generally absent during fall and winter. It should be noted that the wide confidence intervals for the spring 2018 estimate are a result of the large variation in group size between the two sightings.

Table 9. Density and abundance of humpback whales during Campaigns 4 and 5 by season and year

Effort (km) is the summed on-effort distance surveyed for all transects. # detections is the number of sighting of one or more individual animals. # animals is the number of individual animals summed over all sightings and transects. Est. density is the number of individuals per km^2. Est. abundance is the number of individuals we estimated for the survey area. 95% CI= 95% confidence interval of abundance. * = no sightings on general surveys, ** = sightings present but they did not occur within the truncation distance.

Season-year	Effort (km)	# of detections	# of animals	Density	Abundance	95% CI
Winter – 17	531	0	0	0	0	0
Spring – 17	3606	8	15	0.0017	10	3-32
Summer – 17	1787	6	17	0.0040	23	5-98
Fall – 17	1797	0	0	0	0	0
Winter – 18	1579	**	0	0	0	0
Spring – 18	1798	2	24	0.0056	32	3-333
Summer – 18	594	0	0	0	0	0
Fall – 18	1197	**	0	0	0	0
Winter – 19	2405	**	0	0	0	0
Spring – 19	1202	2	3	0.0010	6	1-26
Summer – 19	1202	**	-	-	-	-

3.1.4 Sperm whales

In June and July of 2019 the aerial team spotted two groups of sperm whales (*Physeter macrocephalus*) (Figure 26). A group of four sperm whales was sighted during a June 12th general survey and a pair of sperm whales was spotted during a July 15th condensed survey. Live sperm whales have been sighted in the study area by NEAq on only four other occasions (a sperm whale carcass was observed during Campaign 4).

Sperm whale sightings occurred close to shore in relatively shallow water, which is unusual because sperm whales generally occur in deep water. The June 12th sighting was 10 nm south of Nantucket Island and the July 15th sighting was 13 nm southwest of Nantucket. These two sightings were approximately five nm away from each other. Preliminary photo analysis suggests that each sighting contained unique individuals, meaning that at least six individual sperm whales were in the study area during 2019. Both groups of whales were observed milling at the surface and diving. In the June sighting, one whale was observed sleeping (Figure 27); sperm whales often sleep vertically in the water column, at or near the surface.

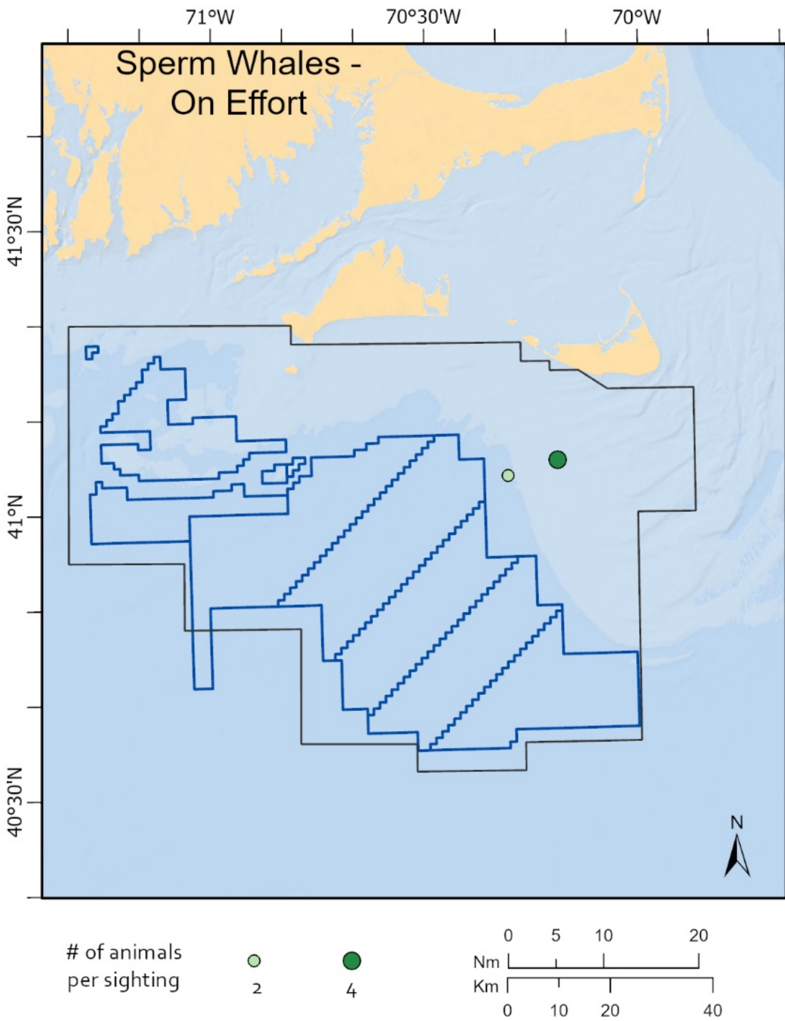

Figure 26. Sightings of sperm whales during all Campaign 5 aerial surveys

Figure 27. Two sperm whales sighted south of Nantucket on June 12, 2019
One whale (upper left-hand corner) was observed sleeping vertically in the water column.

3.1.4.1 Small cetaceans

3.1.4.1.1 On effort sightings

Sightings of small cetaceans accounted for 41% of cetacean detections (51 of 125 detections) and 89% of individual cetaceans (1,016 of 1,144 individuals). Three species were identified and belonged to two families: Phocoenidae and Delphinidae. Phocoenidae included harbor porpoises and Delphinidae included short-beaked common dolphins and bottlenose dolphins. Common dolphins accounted for 53% (n = 27) of the small cetacean sightings, followed by harbor porpoises (20%, n = 10), and bottlenose dolphins (18%, n = 9). Unidentified dolphin sightings accounted for 10% (n = 5) of small cetaceans and consisted of small groups of one to two dolphins that the plane did not break track to identify. All on effort harbor porpoise detections were camera detections.

3.1.4.1.2 All sightings

Patterns for all detections of small cetaceans were similar to those for on effort sightings. In particular, common dolphins, harbor porpoises, and bottlenose dolphins were the most common small cetacean detections (48%, 15%, and 15%, respectively). However, small cetaceans accounted for fewer cetacean detections overall (23%, 114 of 494 cetacean sightings). An additional two species were detected during off effort sightings: pilot whales and Atlantic white-sided dolphins. Small cetaceans were detected in larger groups, with group sizes ranging from one to 250 and an average group size of 22.

3.1.4.1.3 Seasonal and geographic patterns

Small cetacean species were sighted in higher numbers during the spring and summer (Figure 28). Three species, pilot whales, bottlenose dolphins, and Atlantic white-sided dolphins, were sighted only between the months of April and July. Common dolphins were seen in all seasons (Figure 29), while harbor porpoises were seen in the winter, spring, and summer. Seasonal sighting rates for common dolphins were highest in the summer (151.57 dolphins/km), followed by fall (65.84 dolphins/km), winter (45.84 dolphins/km), and spring (14.85 dolphins/km).

Distribution patterns of small cetacean species varied (Figure 30). Common (Figure 31) and bottlenose dolphins were seen throughout the study area. Harbor porpoises were distributed further north than any other small cetacean species, with many sightings occurring outside of the lease zones in the northernmost part of the study area. Pilot whales were seen only on the eastern side of the study area, south of the Nantucket shoals, and white-sided dolphins were seen only on the western side of the study area. However, we cannot infer general distribution patterns in the study area from the small number of sightings for these two species.

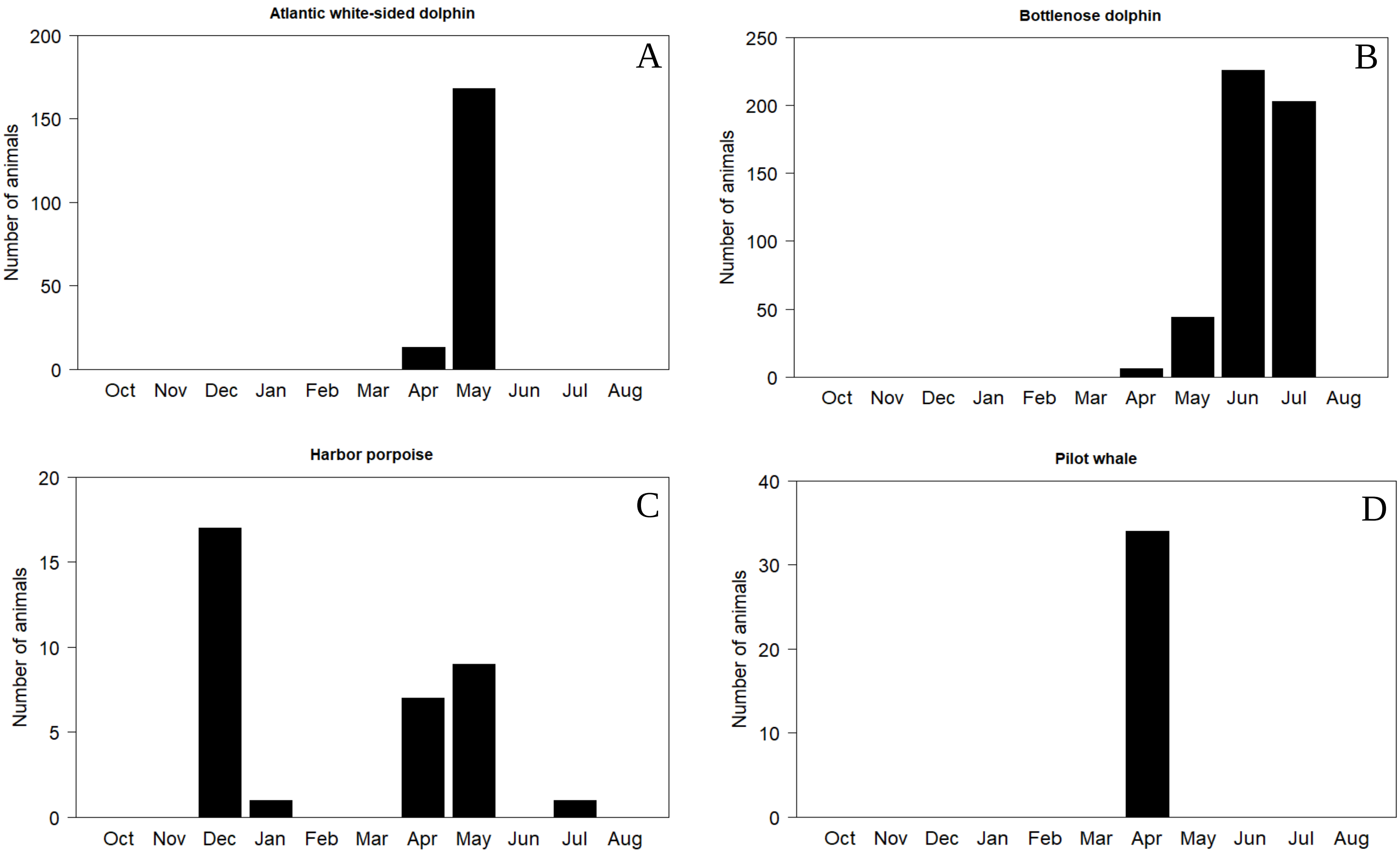

Figure 28. Sightings per month for four species of small cetaceans during all Campaign 5 aerial surveys

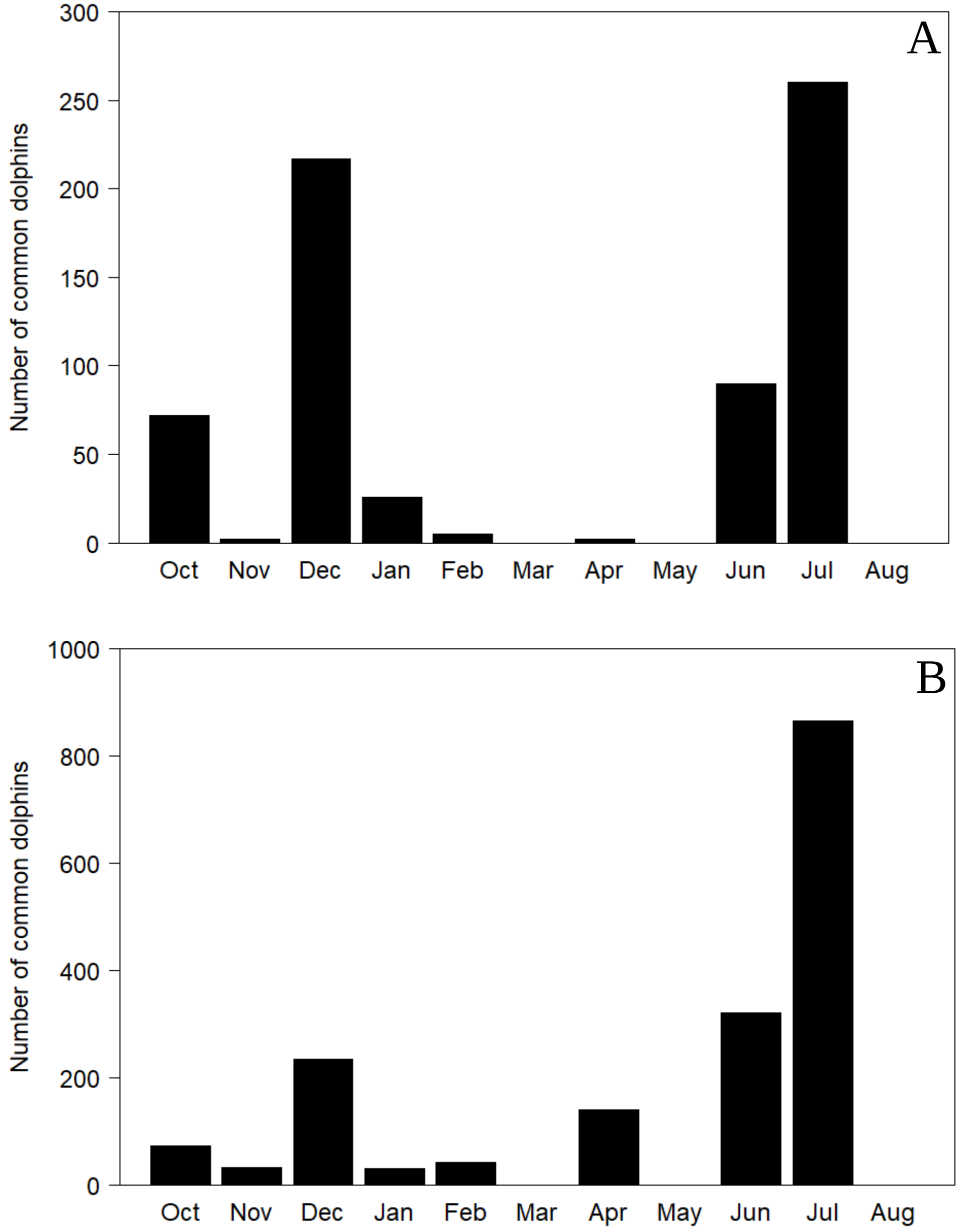

Figure 29. Common dolphin sightings per month during all Campaign 5 aerial surveys
Summarized for A) on effort sightings and B) all sightings during Campaign 5.

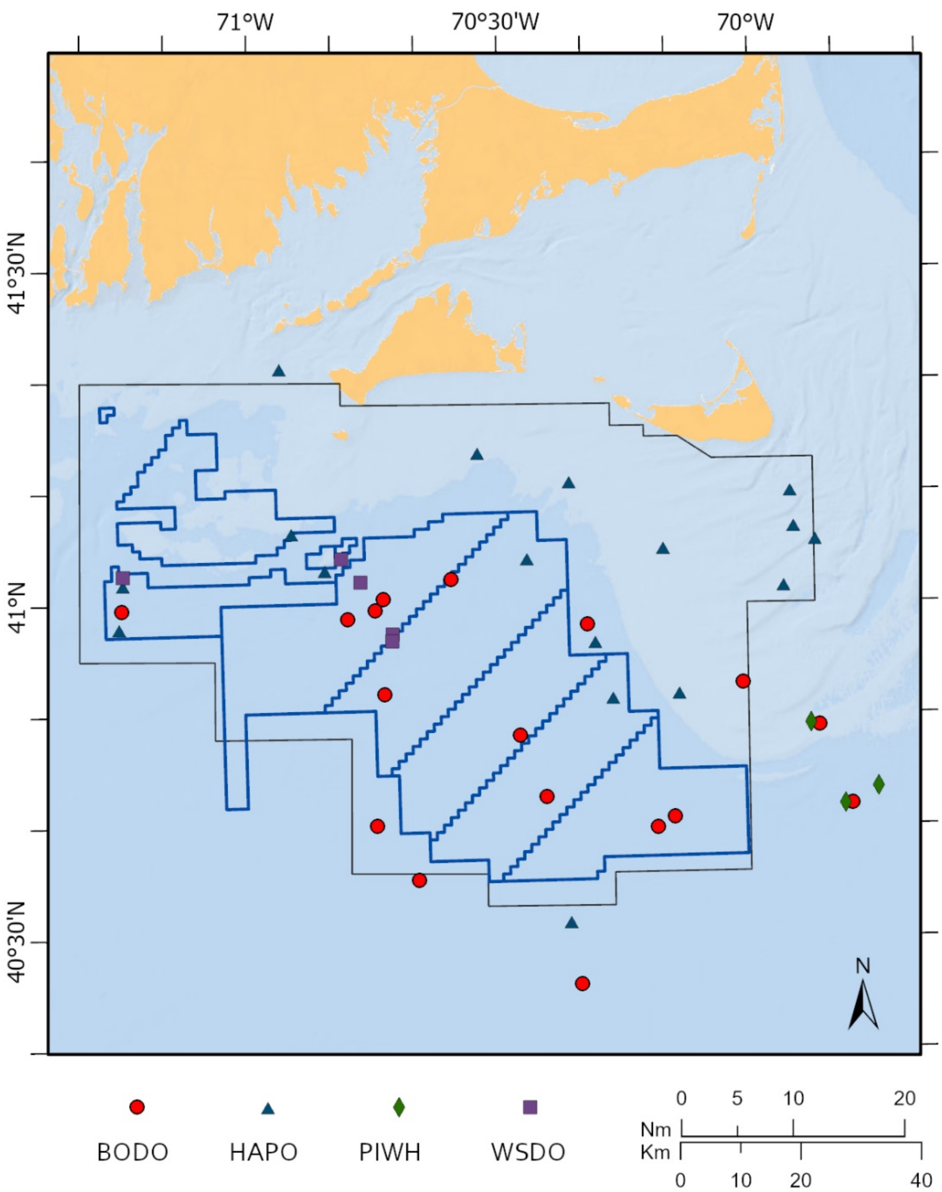

Figure 30. Sightings of small cetaceans during all Campaign 5 aerial surveys
(BODO - bottlenose dolphins, HAPO - harbor porpoises, PIWH - pilot whales, and WSDO – Atlantic white-sided dolphins)

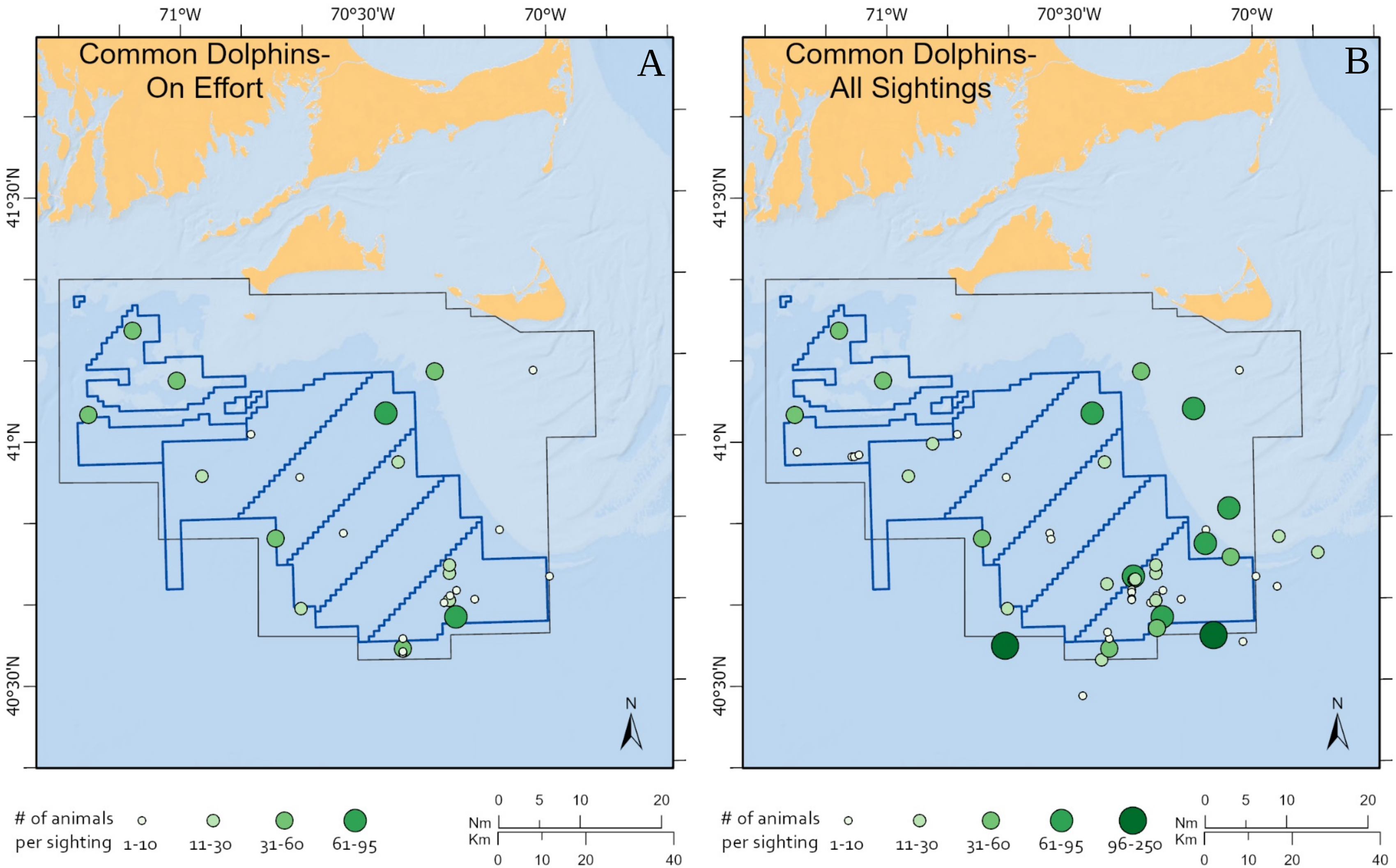

Figure 31. Map of common dolphin sightings during Campaign 5 aerial surveys
Summarized for A) on effort and B) all sightings during Campaign 5.

3.1.4.1.4 Relative and absolute abundance

Common dolphin relative abundance was highest during the winter and summer; it was lowest during the spring and fall (Figure 32). Common dolphins were distributed across the study area.

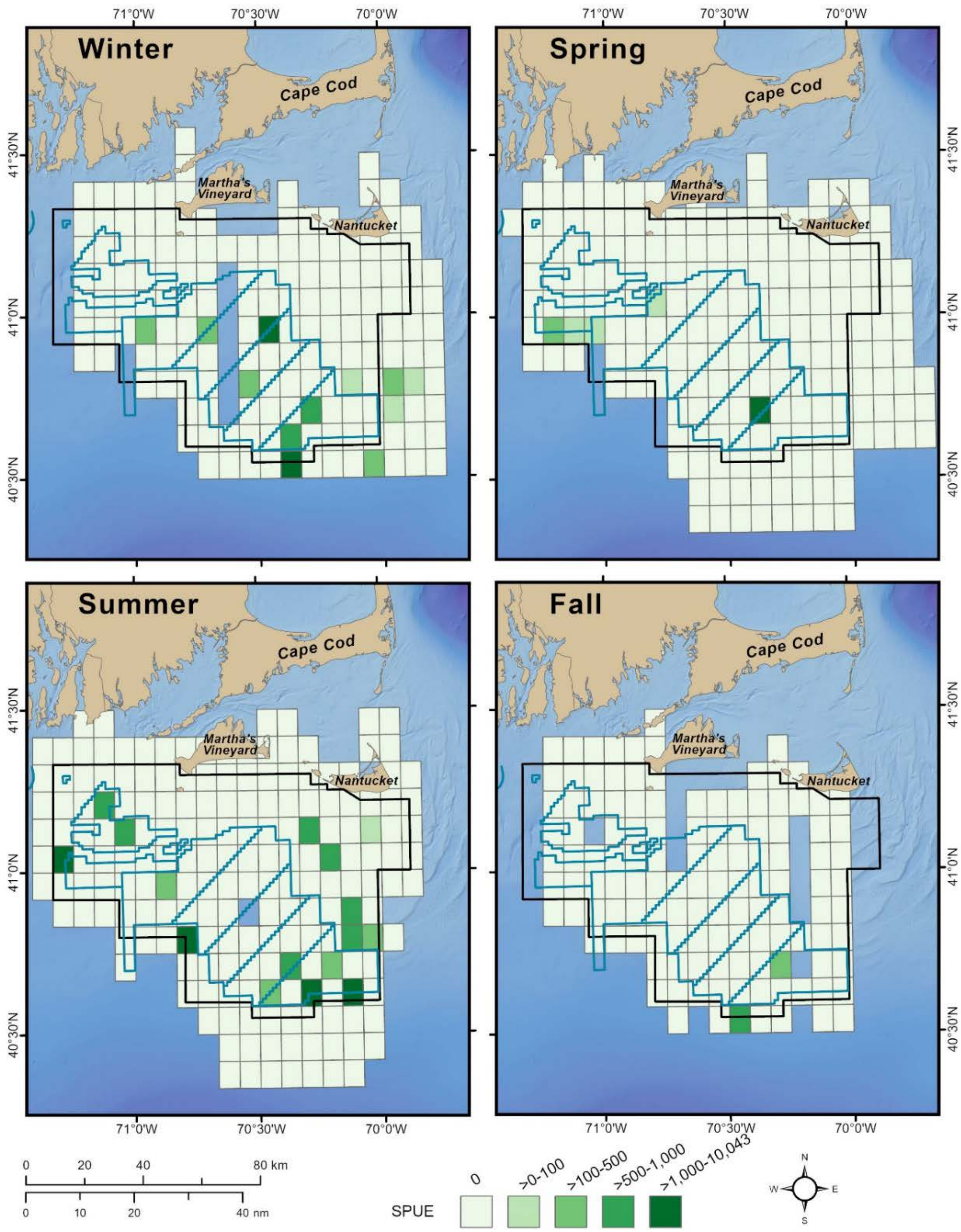

Figure 32. Sightings per unit effort for common dolphins during all Campaign 5 aerial surveys
Seasonal numbers of individuals per 1,000 km calculated in 5 x 5 min squares

Seasonal density and abundance estimates were calculated for common dolphins for Campaigns 4 and 5 (Table 10); estimates could be calculated for six of 11 seasons. Common dolphin abundance tended to be highest during the fall during 2017-2018. It tended to be low or zero during winter and spring. However, in 2019, abundance was fairly high in winter and summer.

Table 10. Density and abundance of common dolphins during Campaigns 4 and 5 by season and year

Effort (km) is the summed on-effort distance surveyed for all transects. # detections is the number of sighting of one or more individual animals. # animals is the number of individual animals summed over all sightings and transects. Est. density is the number of individuals per km^2. Est. abundance is the number of individuals we estimated for the survey area. 95% CI= 95% confidence interval of abundance. * = no sightings on general surveys, ** = sightings present but they did not occur within the truncation distance.

Season-year	Effort (km)	# of detections	# of animals	Density	Abundance	95% CI
Winter – 17	531	0	0	0	0	0
Spring – 17	3606	**	0	0	0	0
Summer –17	1787	2	38	0.0113	66	18-240
Fall – 17	1797	14	1028	0.3036	1764	676-4602
Winter – 18	1579	0	0	0	0	0
Spring – 18	1798	0	0	0	0	0
Summer – 18	594	1	8	0.0072	42	6-274
Fall – 18	1197	1	70	0.031	180	32-1032
Winter – 19	2405	6	159	0.0351	204	69-602
Spring – 19	1202	0	0	0	0	0
Summer – 19	1202	5	200	0.0883	513	200-1317

3.1.5 Sea turtles

Eight sea turtles from two species were identified during the Campaign 5 aerial surveys. One leatherback (*Dermochelys coriacea*) and one loggerhead (*Caretta caretta*) were observed on effort. An additional five leatherbacks and one loggerhead were observed off effort. All sightings occurred in June, July, and August with leatherbacks sighted in June and August while loggerheads were only sighted in July (Figure 33).

Leatherback turtles were sighted on three separate days, all directly south of Nantucket and fairly close to shore (within 10 nm). Only two loggerhead turtles were detected, on two separate days; one was north of the study area and the other was near the southern boundary of the study area. We cannot infer general distribution patterns in the study area from the small number of sightings for these two species (Figure 34).

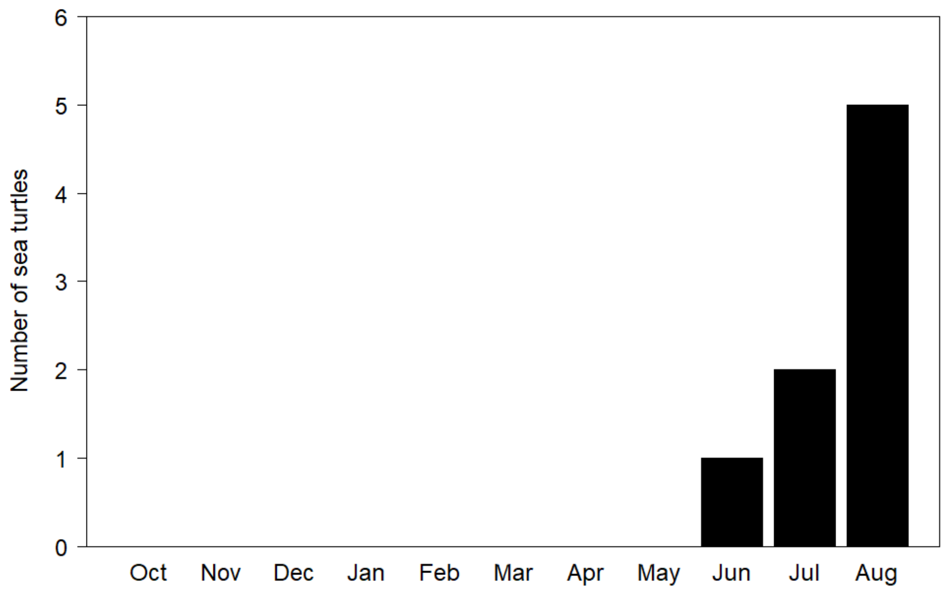

Figure 33. Sea turtle sightings per month summarized for all Campaign 5 aerial surveys

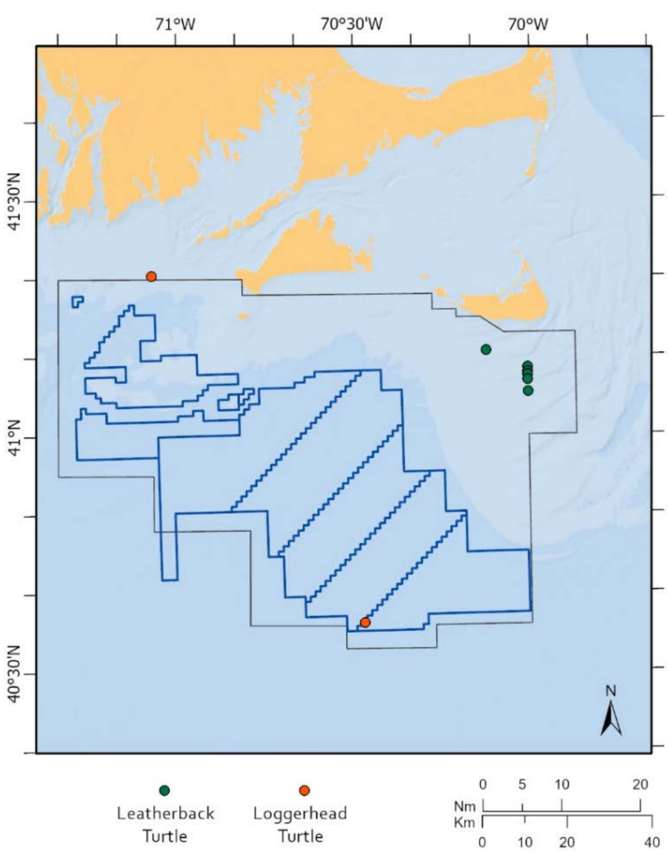

Figure 34. Map of sea turtle sightings during all Campaign 5 aerial surveys

3.1.6 Other marine megafauna

Several other species of marine megafauna were observed during Campaign 5 aerial surveys. On effort sightings include 59 basking sharks (*Cetorhinus maximus*), 79 blue sharks (*Prionace glauca*), one hammerhead shark (*Sphyrna* sp.), and 58 ocean sunfish (*Mola mola*) (Figure 35). An additional 85 basking sharks, 30 blue sharks, and 36 ocean sunfish were sighted off effort. The three most common species (basking sharks, blue sharks, and ocean sunfish) were seen in all parts of the study area (Figure 36). However, blue sharks tended to be more common on the western side of the study area and basking sharks tended to be more common in the eastern and southern parts of the study area.

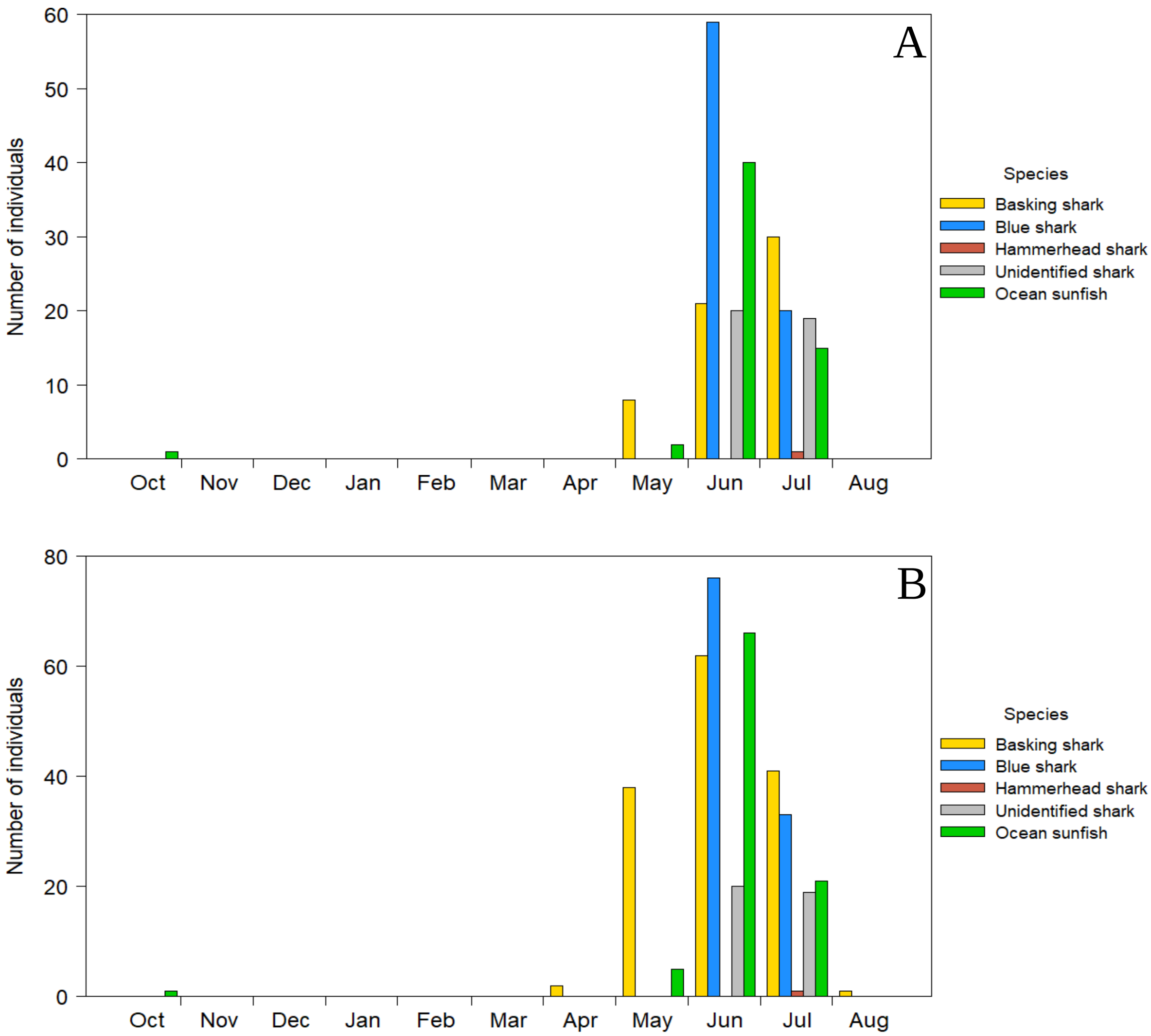

Figure 35. Shark and fish sightings per month during Campaign 5 aerial surveys
Summarized for A) on effort sightings and B) all sightings during Campaign 5.

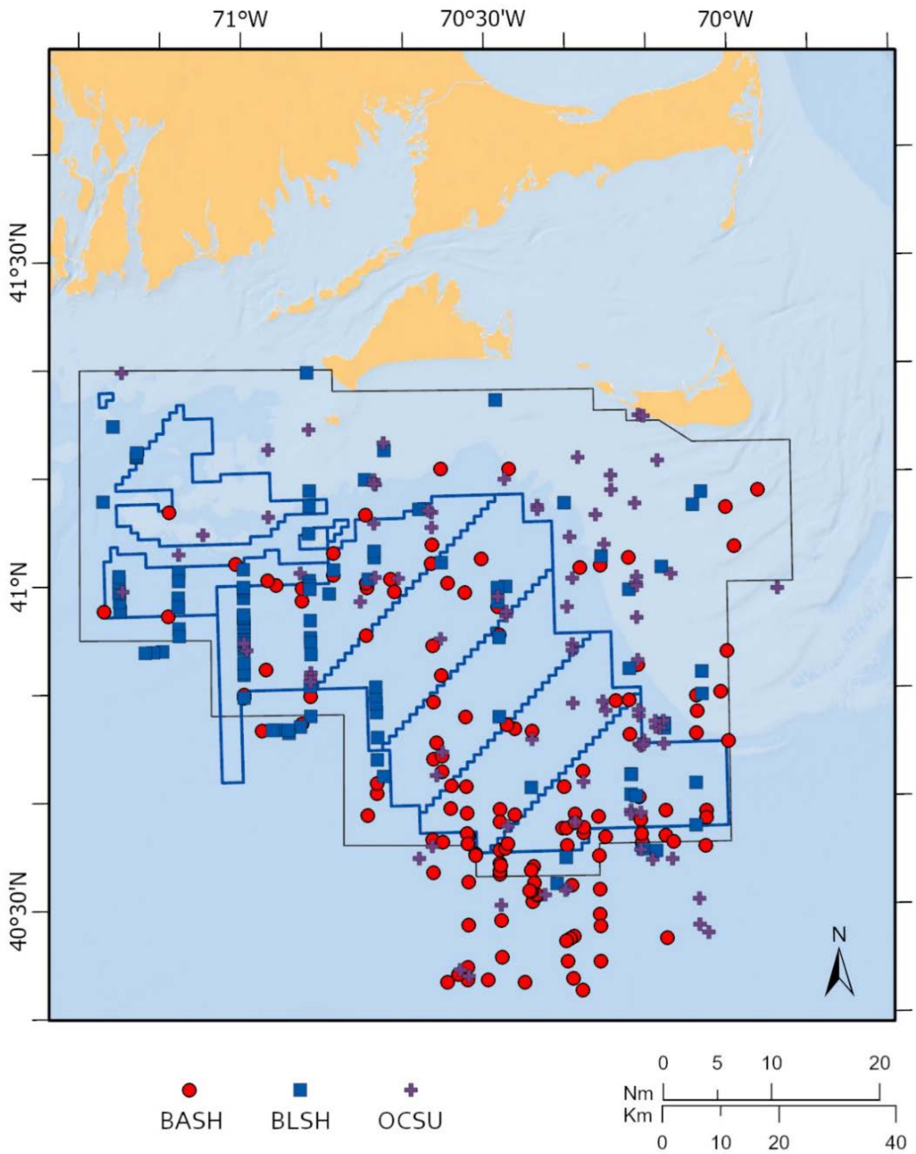

Figure 36. Map of shark and fish sightings during all Campaign 5 aerial surveys
BASH - basking sharks, BLSH - blue sharks, OCSU - ocean sunfish

3.2 Oceanographic Sampling

3.2.1 *In-situ* observations

A total of 30 sampling trips were conducted for this study, including 12 trips in 2017 (Campaign 4) and 18 trips in 2019 (Campaign 5) (Table 11). Fifteen zooplankton samples were collected in the presence of right whales while 96 samples were collected at the standard oceanographic stations. Fewer zooplankton samples were collected near right whales in 2019 owing to their lower abundance in the area immediately adjacent to the standard stations.

Table 11. Summary of oceanographic surveys during Campaign 5

Date	Survey type	Standard stations	Near-whale stations
2/14/17	Nomans only	1	0
2/21/17	Full	4	2
2/28/17	Nomans only	1	0
3/6/17	Full	4	2
3/13/17	Full	4	2
3/18/17	Full	4	0
3/28/17	Full	4	0
4/3/17	Full	4	0
4/10/17	Full	4	1
5/4/17	Nomans and right whales	1	3
5/9/17	Nomans only	1	0
5/11/17	Full	4	0
2/20/19	Full	4	0
2/27/19	Full	4	0
3/8/19	Full	4	0
3/14/19	Full	4	0
3/15/19	Right whales	0	2
3/18/19	Right whales	0	1
3/20/19	Full	4	0
3/28/19	Full	4	0
4/2/19	Full	4	0
4/5/19	Full	4	0
4/11/19	Full	4	0
4/17/19	Full	4	0
4/25/19	Full	4	0
5/9/19	Full	4	0
5/22/19	Full	4	0
6/4/19	Full	4	0
6/18/19	Full	4	0
7/16/19	Right whales	0	2
Total	30 trips	96	15

Observations from the conductivity-temperature-depth (CTD) instrument indicated that the water column was well mixed during February and March in both 2017 and 2019 (Figure 37). This well-mixed water column changed temperature regularly because of heating/cooling at the surface that was mechanically mixed throughout the water column from the wind during frequent storm events in late winter and early spring. The onset of vernal stratification occurred in early to mid-April (Figure 37), when the water column developed into a two-layer system with warm fresh water at the surface and cooler saltier water at the bottom. The seasonal evolution of temperature did not suggest the existence of a cold pool in the study area; the cold pool is a common feature of continental shelves in which very cold leftover winter water near the bottom becomes isolated from the surface due to surface warming and therefore remains cold. The bottom waters in the study area warmed from < 5°C in winter to > 10°C by the beginning of summer, suggesting that this area is either too shallow or advection from neighboring shallow areas (e.g., Nantucket Shoals) is too strong to support the formation or maintenance of a cold pool.

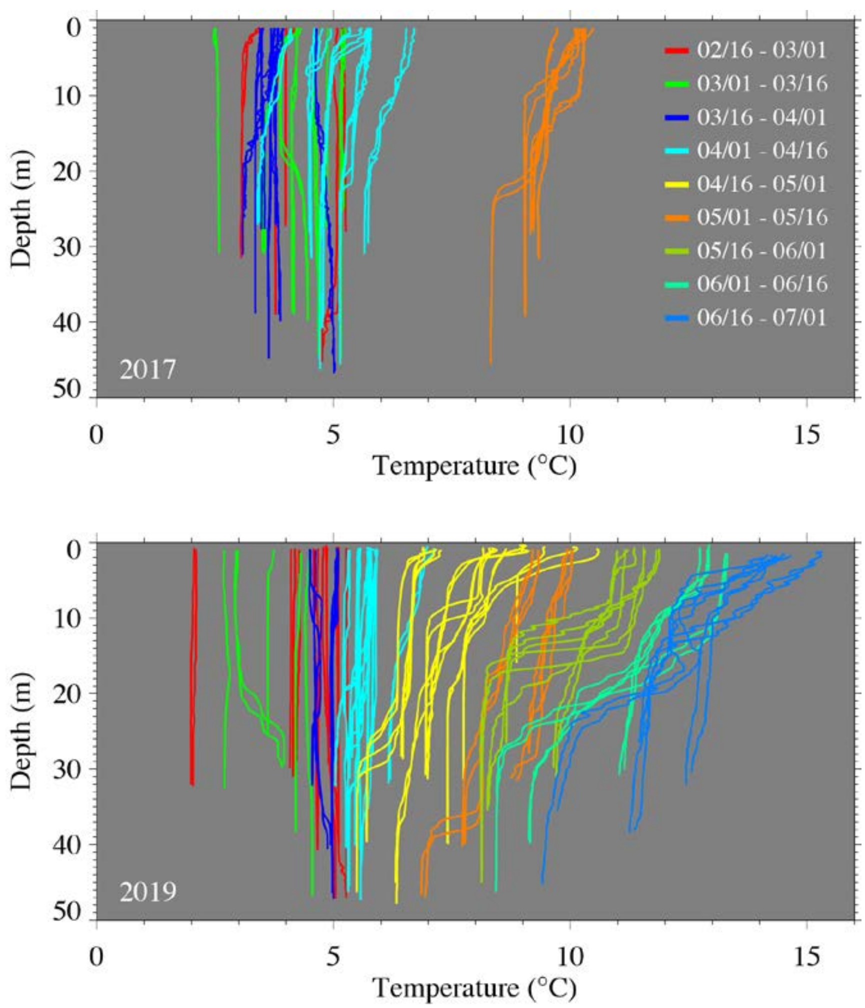

Figure 37. Temperature and salinity profiles collected at all stations in 2017 and 2019
The water column is well mixed throughout February and March. The onset of stratification begins in early April and is established by early May.

The zooplankton sample data showed distinct seasonal patterns of zooplankton species composition and abundance (Figure 38). Community composition in 2017 was dominated by *Centropages* spp. in February and March, but transitioned to predominance of *C. finmarchicus* in April around the onset of stratification. *C. finmarchicus* still dominated the zooplankton samples collected near right whales in early May, but the sampling at the standard stations indicated a shift back to *Centropages* spp. predominance. *Pseudocalanus* spp. were present during much of sampling period, as were barnacle nauplii. During 2019, the zooplankton community was numerically dominated by barnacle nauplii in February and March, with smaller contributions from *Centropages* spp. After the onset of stratification in early April, the zooplankton community became much more diverse, with stronger contributions from *Pseudocalanus* spp. Toward the end of spring and beginning of summer, *Centropages* spp. was more prevalent than most other species. *C. finmarchicus* was never numerically dominant at any time during the 2019 sampling.

Prior to stratification during February and March, *Centropages* spp. abundance was significantly higher in 2017 than in 2019 ($p = 0.0088$ in February, $p < 0.0001$ in March; Figure 39). No difference was observed in *Centropages* spp. abundance between the two years in April, but 2017 abundance was significantly higher than in 2019 for May ($p = 0.0011$). *Pseudocalanus* spp. abundance in 2017 was significantly higher than in 2019 during March and May ($p < 0.0001$ in March, $p = 0.0305$ in May), but no differences were observed in February and April (Figure 39). *C. finmarchicus* abundance was actually significantly lower in 2017 than in 2019 during February ($p = 0.\ 0024$), was similar between the two years in March, but was about two orders of magnitude higher in April 2017 than in 2019 ($p < 0.0001$). Samples taken near right whales in May 2017 contained the highest abundances of *C. finmarchicus* observed during the entire study, but these samples were surface tows taken immediately adjacent to skim-feeding right whales and therefore are not directly comparable to the oblique tows used for all other zooplankton sampling.

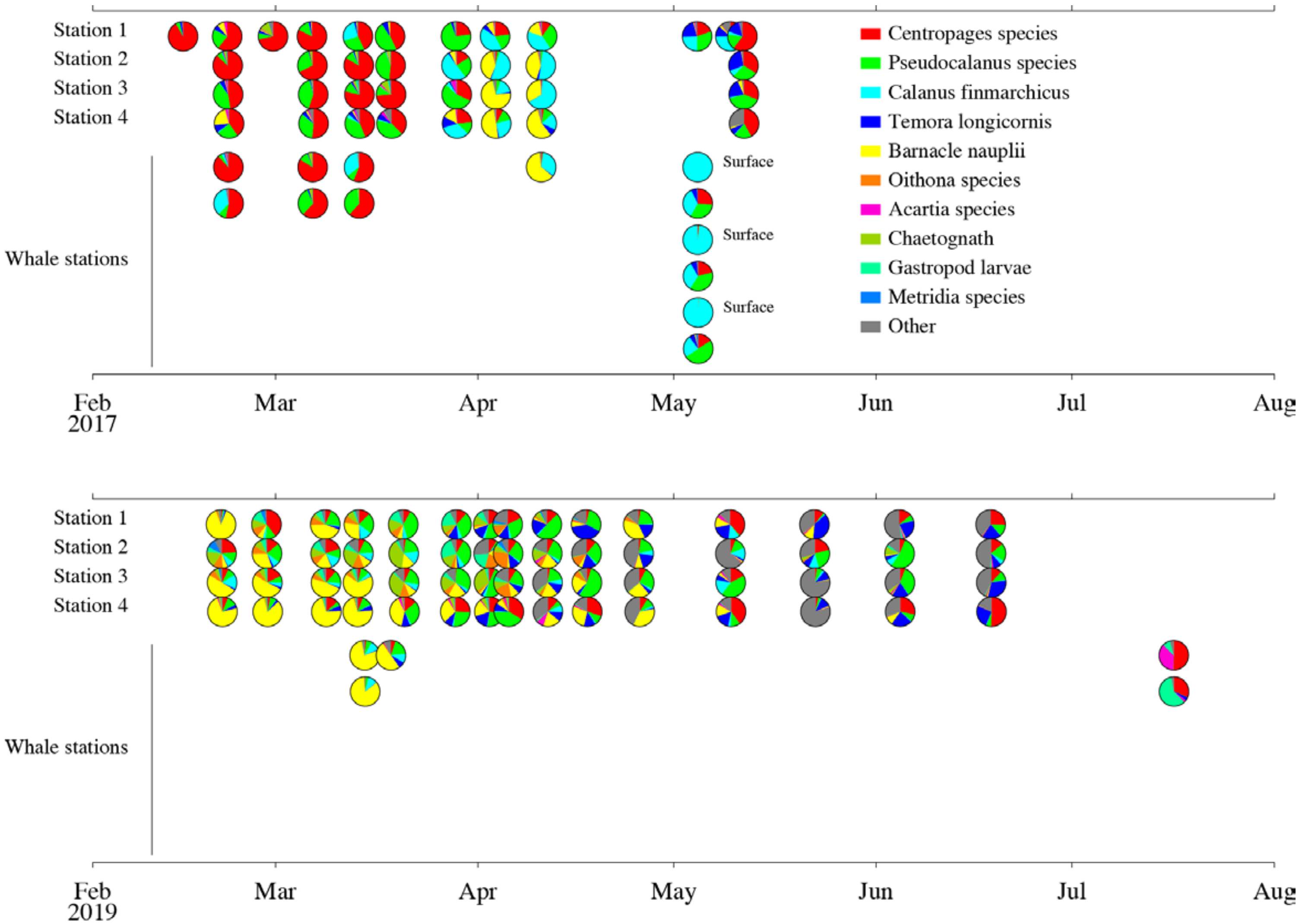

Figure 38. Zooplankton community composition at the four standard stations and at locations near right whales
The top graph represents 2017 data and the bottom graph represents 2019 data

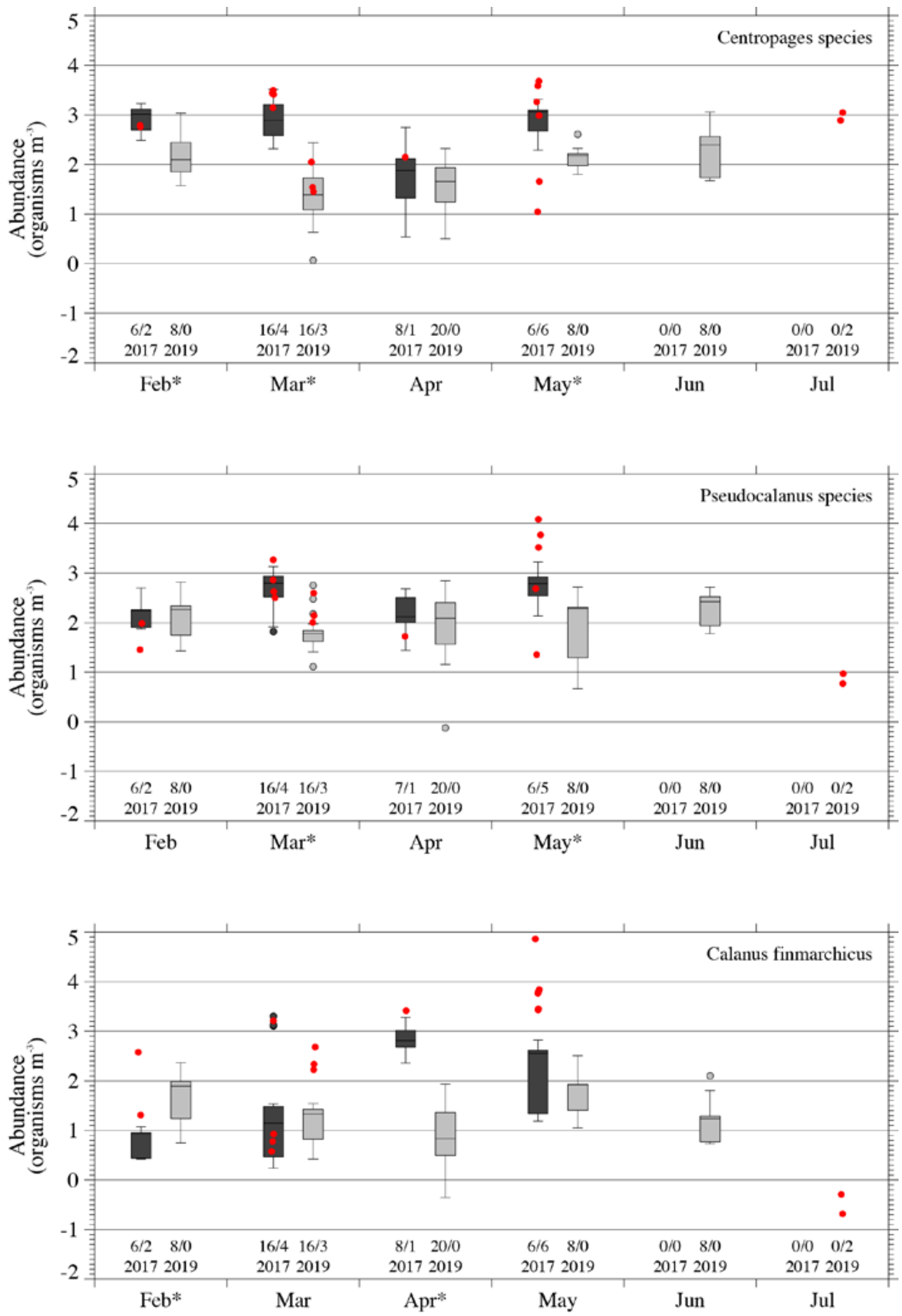

Figure 39. Interannual comparison of monthly base-10 log-transformed copepod abundance for *Calanus finmarchicus*, *Centropages spp.*, and *Pseudocalanus* spp.

Boxplots indicate the distribution of copepod abundance for standard stations, while red dots indicate copepod abundance assessed near right whales. The result of significant ($p < 0.05$) t-tests between monthly standard station abundances measured in 2017 and 2019 are indicated with an asterisk next to the month label. Sample sizes are shown just above the x-axis; the first number is the number of standard station samples and the second number is the number of samples collected near right whales.

In addition to significant interannual differences in abundance, the developmental stage distribution of *C. finmarchicus* showed different patterns during 2017 than during 2019 as well (Figure 40). Most notable was the near absence of adult (C6) *C. finmarchicus* and the lower proportion of C5 copepodids in the study area during 2019. Stage C5 is the developmental stage where the lipid sac of *C. finmarchicus* grows to its largest extent, and it is this stage that is targeted by right whales to maximize their energy ingestion.

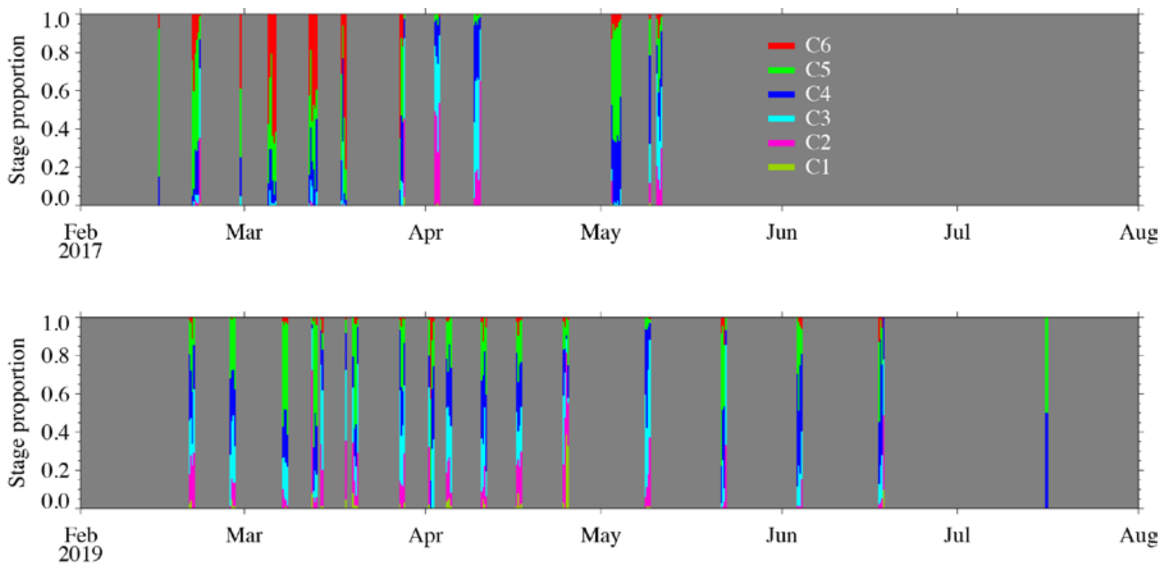

Figure 40. Proportion of developmental stages for *Calanus finmarchicus* collected during zooplankton sampling in 2017 (top) and 2019 (bottom)

Each vertical stripe is a single zooplankton sample. Stripes immediately adjacent to one another were collected on the same day. Data from both standard stations and whale stations are shown together.

4 Discussion

4.1 Aerial surveys

4.1.1 North Atlantic right whales

The most striking results were changes in right whale seasonal abundances and distributions. Campaigns 4-5 show that right whales are increasing their use of the eastern side of the study area (i.e., in and adjacent to Nantucket Shoals). In particular, we saw increases in both right whale densities and the amount of time spent in this area. Right whale density and abundance estimates calculated for Campaigns 4-5 show higher right whale densities in recent years (2017-2019) than in past years (2011-2015). While winter and spring right whale densities remained fairly stable during Campaign's 1-3 (Leiter et. al, 2017) winter and spring right whale density increased every year during Campaigns 4 and 5. In addition, right whales consistently occurred in the study area in summer and fall during Campaigns 4 and 5, but not during 2011-2015. Some summer and fall right whale densities during Campaigns 4 and 5 were relatively high: in the summer of 2019, right whale density (0.0041 animals/km^2) was similar to the highest density recorded between 2011-2015 (winter 2013, 0.0045 animals/km^2). However, it is important to note that the methods used to estimate density changed between 2011-2015 and 2017-2019. Work is underway to estimate density from all years of survey data using consistent methods, which will strengthen these comparisons.

The increased abundance of right whales is also supported by sightings rates. Summer sighting rates calculated for 2019 were higher than mean sighting rates for both winter and spring in 2011-2015, as reported in Kraus et al. (2016). While methods for calculating sighting rates have not changed, the inclusion of directed surveys flown to known right whale aggregations may bias 2017-2019 estimates slightly higher. Since right whales were observed in every season flown during Campaigns 4-5, the question has shifted from when right whales arrive in the study area to when the highest numbers of right whales occur in the study area.

Campaign 5 results also suggest some changes in right whale seasonal abundances and distributions. Specifically, right whales were sighted in the western side of the study area less frequently than the eastern side of the study area during all seasons. In previous Campaigns, right whales were present in the RIMA WEA on the western side of the survey area, usually during spring. However, during Campaign 5, only one animal was sighted in this area, and whales were primarily grouped over the Nantucket Shoals in all seasons. Right whales were also observed in an area where they had not been seen on previous surveys: south of the study area, much closer to the continental shelf break. This aggregation took place for a short time during the spring. While we have no reason to suspect there were sizable aggregations in this area in previous years, there was undoubtedly increased survey effort in this area during 2019.

Preliminary photo-ID data suggests that at least 137 unique whales were identified during Campaign 5 surveys (11 months) compared to 94 unique whales during Campaign 4 (18 months) and an annual average of 35 unique whales during Campaigns 1-3 (Leiter et al. 2017). Right whale sighting rates in Campaign 5 were higher in every season than in previous survey years. Campaign 4 and 5 results show that sighting rates are increasing and that an increasingly large segment of the right whale population uses or transits through this area.

Right whales were sighted more often than any other large whale species during Campaign 5. Specifically, right whale sighting rates and abundance estimates were higher in every season than any other large whale species. This is a similar pattern to Campaign 4, in which right whale sighting rates were highest in every season except summer (when fin whales were more common), but it is a departure from Campaigns 1-3, when right whales were only seen more often than other large whales during the winter.

4.1.2 Balaenopterid whales

Seasonal patterns in Balaenopterid abundance during Campaigns 4-5 were similar to those observed in previous years. Fin, humpback, and minke whales were most abundant in the spring and summer. Their seasonal sighting rates in Campaign 5 were generally consistent with previous surveys in timing and magnitude, with some exceptions. Humpback whales had lower sighting rates during spring and summer 2019 (1.06 and 1.95 animals/km respectively) as compared to Campaigns 1-4 (spring 3.96 – 4.26 animals/km, summer 4.61 – 4.98 animals/km). Minke whales had higher sighting rates in the summer (9.87 animals/km) than the spring (4.35 animals/km) in 2019, which was different from the previous pattern of spring having the highest sighting rate.

Distribution patterns for Balaenopterids appeared to differ between Campaign 5 and previous years. SPUE distributions for fin, sei, and humpback whales suggest that these species distributions have retracted into a smaller area on the eastern side of the study area. This pattern combined with the shift in right whale distributions to the eastern side of the study area, raises interesting questions about the conditions on the western side of the survey area.

We could not calculate abundance or sightings rates for sei whales because of the small number of sei whale sightings in all seasons except spring. Spring sei whale sighting rates continued to increase through Campaign 5. Specifically, sei whale sighting rates in spring 2019 were 5.41 animals/km, compared to 3.03 animals/km in Campaign 4 and an average of 0.10 animals/km in Campaigns 1-3. Sei whales were seen in low numbers during summer.

4.1.3 Small cetaceans

Sighting rates of common dolphins in Campaign 5 were highest during summer and fall. This pattern is consistent with seasonal sighting rates in previous surveys. However, Campaign 5 also documented a much higher sighting rate of common dolphins in the winter than in previous years. Winter sighting rates in 2019 were 45.84 dolphins/km; in contrast, the sighting rate was 0.56 animals/km in Campaign 4 and the average winter sighting rate in Campaigns 1-3 was 8.54 animals/km. Kenney and Vigness (2010) also found high numbers of this species in the northeastern United States region during the winter. Other small cetaceans sighted in Campaign 5 had similar seasonal patterns to Campaign 4, as well as Campaigns 1-3 (Stone et al., 2017): most sightings occurred during spring or summer.

4.1.4 Sea turtles

The downward trend in sea turtle sightings observed in Campaign 4 seemed to continue during Campaign 5. Additionally, Kemp's ridley turtles were only seen in Campaigns 1-3 and were not seen in Campaigns 4 or 5. We did not have enough sightings of turtle species to calculate sighting rates or abundance. The small number of turtle sightings in Campaign 5 may be a result of the lack of surveys flown in September, which is historically a month of high turtle sightings.

4.1.5 Other marine fauna

Shark and fish sightings during Campaign 5 peaked in June and were generally not seen outside of late spring and summer months. This pattern of a peak in fish sightings in the summer is consistent with previous years of data. The common species identified here, ocean sunfish, basking shark, and blue shark, are all easily identifiable. In one case, an identification of a hammerhead shark was possible from a vertical photograph because of its distinctive body shape. Our surveys likely miss some shark species because New England waters include many shark species that are difficult to differentiate, such as dusky and sandbar sharks. Consequently, these species are simply recorded as unidentified sharks.

4.1.6 Conclusion

It is clear that many species of marine megafauna continue to use the study area in high numbers. Analysis of aerial survey data has revealed an increased presence of right whales in all seasons, and a decrease in the presence of other large whales such as humpbacks. There also appears to be a shift in presence of all large whales towards the eastern side of the survey area. However, it is unclear whether this pattern will persist because it has only been observed during the most recent year of surveys.

4.2 Oceanographic Sampling

We observed significant differences in zooplankton community composition and abundance between 2017 and 2019 as well as interannual differences in observed right whale abundance and occurrence in the northern part of the study area where our zooplankton samples were collected. This presented an opportunity to infer right whale prey preferences by determining which zooplankton species were more prevalent during the year of high right whale abundance (2017) versus the year of low right whale abundance (2019). Our analysis indicated that there is not one single primary prey that right whales target in the study area. Like in Cape Cod Bay (an area right whales also frequent during winter and spring), there are several possible prey species, including *Centropages* spp., *Pseudocalanus* spp., and *C. finmarchicus*, and the importance of these species as a food source for right whales varies with the season. Based on our wintertime observations, lipid-rich *C. finmarchicus* abundance is low, and right whales appear to prey on *Centropages* spp. As stratification begins in early April, *C. finmarchicus* abundance increases dramatically. In April 2017, the abundance of *C. finmarchicus* (Figure 39) was comparable to that in other major right whale habitats during times of peak right whale presence (e.g., Bay of Fundy, Great South Channel; Wishner et al. 1995, Baumgartner et al. 2003). Later in the spring, the abundance of *C. finmarchicus* decreases, but we observed abundances of *Centropages* spp. and *Pseudocalanus* spp. in May 2017 that were comparable to those observed in March 2017, suggesting that suitable right whale prey may remain in the study area. However, unlike in winter, larger-bodied lipid-rich *C. finmarchicus* are readily available in the late spring in parts of the Gulf of Maine (e.g., historically the Great South Channel, but also the northern edge of Georges Bank; Wishner et al. 1995), so right whales may abandon the study area in May and June (Figure 41) for these other potentially more profitable foraging grounds.

It is important to keep in mind that we report numerical abundances for copepods, and the differences in body size and lipid content among all of these prey makes their biomasses and nutritional content quite different. *Centropages* and *Pseudocalanus* spp. are small copepods compared to *C. finmarchicus* (e.g., an adult female *Pseudocalanus* sp. is about 11 times smaller than an adult female *Calanus finmarchicus*). Since *C. finmarchicus* is not abundant (Figure 39) nor is it always in a developmental stage that is efficiently filtered by right whale baleen (Figure 40) during winter, it is not surprising that right whales feed on other, smaller, less nutritious organisms like *Centropages* sp., *Pseudocalanus* sp., and perhaps even barnacle nauplii at that time. Once later stage *C. finmarchicus* appear in high abundances in early spring, right whales will switch to this more nutritious prey and move anywhere they can to maximize their ingestion of this key species.

During 2019, right whales were observed in greater numbers near and on Nantucket Shoals, which was not part of the area we could regularly sample during the winter and spring. In recent years, right whales have been encountered on Nantucket Shoals in all seasons (Figure 10, Table 4), and there is growing interest in what may be attracting the whales to the area. We speculate that right whales may not be feeding on copepods in this area. The tidal currents on Nantucket Shoals are intense and the water column remains well mixed as a result of the tides throughout the year. Right whales depend on the formation of thin vertically compressed layers of copepods to efficiently feed (Baumgartner and Mate 2003, Baumgartner et al. 2017), which cannot form when the water column is well mixed. We know that right whales do feed on copepods in well-mixed waters during winter (e.g., this study), but that feeding is likely inefficient. In winter, when food resources are low, right whales may tolerate inefficient feeding simply to gain some nutrition, but during other times of the year when *C. finmarchicus* is available, right whales need to maximize their energy intake to make up for wintertime deficiencies and fuel movements and reproduction. Possible explanations for feeding on Nantucket Shoals then are (1) right whales are feeding on smaller copepods like *Centropages* spp. or *Pseudocalanus* spp. inefficiently because *C. finmarchicus* (or other lipid-rich copepods like *C. glacialis* or *C. hyperboreus*) are not available, or (2) they are feeding on a different non-copepod prey species that is more nutritious than *C. finmarchicus* or can be ingested efficiently despite the strong tidal currents (e.g., a large-bodied bottom associated/clinging amphipod). White and Veit (2020) recently described an association between sea duck distribution and abundant patches of *Gammarid* amphipods on the western edge of Nantucket Shoals where right whales are also found, suggesting that right whales may prey on these amphipods as well in this area.

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Appendix A: Aerial Sightings

Table A-1. Summary of all on effort aerial observer and vertical photograph detections of marine megafauna during Campaign 5 general and condensed aerial surveys

		Observers		Vertical photos		Totals	
Category	**Species**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**
Small cetaceans	Bottlenose dolphin (*Tursiops truncatus*)	9	323	--	--	9	323
	Common dolphin (*Delphinus delphis*)	19	641	8	33	27	674
	White-sided dolphin (*Lagenorhynchus acutus*)	5	181	--	--	5	181
	Unidentified dolphin	3	4	2	2	5	6
	Harbor porpoise (*Phocoena phocoena*)	0	0	10	13	10	13
Large cetaceans	Fin whale (*Balaenoptera physalus*)	3	5	--	--	3	5
	Minke whale (*Balaenoptera acutorostrata*)	36	40	1	1	37	41
	Humpback whale (*Megaptera novaeangliae)*	5	6	--	--	5	6
	Right whale (*Eubalaena glacialis*)	24	67	--	--	24	67
	Sperm whale (*Physeter macrocephalus*)	2	6	--	--	2	6
	Unidentified whale	3	3	1	1	4	4
Pinnipeds	Gray seal (*Halichoerus grypus*)	2	2	--	--	2	2
	Unidentified seal	36	147	8	208	44	355
Sea turtles	Leatherback sea turtle (*Dermachelys coriacea*)	1	1	--	--	1	1
	Loggerhead sea turtle (Caretta caretta)	--	--	1	1	1	1

Table A-1 continued. Summary of all on effort aerial observer and vertical photograph detections of marine megafauna during Campaign 5 general and condensed aerial surveys

		Observers		Vertical photos		Totals	
Category	**Species**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**
Sharks and fish	Basking shark (*Cetorhinus maximus*)	52	52	7	7	59	59
	Blue shark (*Prionace glauca*)	53	54	25	25	78	79
	Hammerhead shark (*Sphyrna* sp.)	--	--	1	1	1	1
	Ocean sunfish (*Mola mola*)	46	50	7	8	53	58
	Unidentified shark	31	33	6	6	37	39
	Unidentified tuna	--	--	1	2	1	2
Unknown	Unidentified marine mammal	1	1	--	--	1	1

Table A-2. Summary of all on and off effort aerial observer and vertical photograph detections during Campaign 5 general and condensed aerial surveys

Note: Individual items for natural debris were not tallied and are marked with "*".

		Observers		Vertical photos		Totals	
Category	**Species**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**
Small cetaceans	Bottlenose dolphin (*Tursiops truncatus*)	12	431	--	--	12	431
	Common dolphin (*Delphinus delphis*)	30	1,231	8	33	38	1,264
	White-sided dolphin (*Lagenorhynchus acutus*)	5	181	--	--	5	181
	Unidentified dolphin	3	4	5	8	8	12
	Harbor porpoise (*Phocoena phocoena*)	1	15	15	19	16	34
Large cetaceans	Fin whale (*Balaenoptera physalus*)	5	9	--	--	5	9
	Minke whale (*Balaenoptera acutorostrata*)	49	53	2	2	51	55

Table A-2 continued. Summary of all on and off effort aerial observer and vertical photograph detections during Campaign 5 general and condensed aerial surveys

Note: Individual items for natural debris were not tallied and are marked with "*".

		Observers		Vertical photos		Totals	
Category	**Species**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**
	Humpback whale (*Megaptera novaeangliae)*	9	10	--	--	9	10
	Right whale (*Eubalaena glacialis*)	62	156	--	--	62	156
	Sperm whale (*Physeter macrocephalus*)	2	6	--	--	2	6
	Unidentified large whale	1	1	2	2	3	3
	Unidentified whale	2	2	--	--	2	2
Pinnipeds	Gray seal (*Halichoerus grypus*)	2	2	1	1	3	3
	Unidentified seal	63	2,294	14	1,669	77	3,963
Sea turtles	Leatherback sea turtle (*Dermachelys coriacea*)	1	1	--	--	1	1
	Loggerhead sea turtle (Caretta caretta)	--	--	2	2	2	2
Sharks and fish	Basking shark (*Cetorhinus maximus*)	69	70	9	10	78	80
	Blue shark (*Prionace glauca*)	64	66	35	35	99	101
	Hammerhead shark (*Sphyrna* sp.)	--	--	1	1	1	1
	Ocean fish (*Mola mola*)	59	63	15	16	74	79
	Schools of fish	24	29	3	3	27	32
	Unidentified fish	--	--	14	201	14	201
	Unidentified shark	37	39	8	8	45	47
	Unidentified tuna	--	--	3	5	3	5
Birds	Great black-backed gull (*Larus marinus*)	--	--	2	2	2	2

Table A-2 continued. Summary of all on and off effort aerial observer and vertical photograph detections during Campaign 5 general and condensed aerial surveys

Note: Individual items for natural debris were not tallied and are marked with “*”.

		Observers		Vertical photos		Totals	
Category	**Species**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**
Birds	Long-tailed duck (*Clangula hyemalis*)	--	--	2	79	2	79
	Northern gannet (*Sula bassanus*)	--	--	15	16	15	16
	White-winged scoter (*Melanitta fusca*)	--	--	6	19	6	19
	Unidentified gull	--	--	16	29	16	29
	Unidentified storm-petrel	--	--	4	4	4	4
	Unidentified shearwater	--	--	4	4	4	4
	Unidentified tern	--	--	1	1	1	1
Human activity	Debris (different types)	22	22	57	58	79	80
	Fixed fishing gear	520	973	28	29	548	1,002
	Fishing vessel	331	354	4	4	335	358
	Recreational vessel	80	112	2	2	82	114
	Other types of vessels/data stations/coast guard	88	89	3	3	91	92
	Unknown vessel	2	2	--	--	2	2
Natural debris	Seaweed/wood/organic material	14	*	309	*	323	*
Unknown	Unidentified marine mammal	1	1	--	--	1	1
	Unknown object/animal	7	7	8	8	15	15

Table A-3. Summary of all aerial observer and vertical photograph detections during all Campaign 5 directed and opportunistic aerial surveys

Birds and debris are not included in photographic analysis from directed and opportunistic surveys.

		Observers		Vertical photos		Totals	
Category	**Species**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**
Small cetaceans	Bottlenose dolphin (*Tursiops truncatus*)	5	48	--	--	5	48
	Common dolphin (*Delphinus delphis*)	13	458	4	13	17	471
	Unidentified common or white-sided dolphin	3	13	--	--	3	13
	Unidentified dolphin	5	9	1	1	6	10
	Harbor porpoise (*Phocoena phocoena*)	--	--	1	1	1	1
	Pilot whale (*Globicephala* sp.)	3	34	--	--	3	34
Large cetaceans	Fin whale (*Balaenoptera physalus*)	5	9	--	--	5	9
	Minke whale (*Balaenoptera acutorostrata*)	49	53	2	2	51	55
	Sei whale (*Balaenoptera borealis*)	28	55	--	--	28	55
	Unidentified fin or sei whale	7	7	--	--	7	7
	Humpback whale (*Megaptera novaeangliae)*	21	22	--	--	21	22
	Right whale (*Eubalaena glacialis*)	113	165	2	2	115	167
	Unidentified medium whale	1	1	--	--	1	1
Pinnipeds	Unidentified seal	11	416	--	--	11	416
Sea turtles	Leatherback sea turtle (*Dermachelys coriacea*)	4	4	1	1	5	5
Sharks and fish	Basking shark (*Cetorhinus maximus*)	51	55	9	9	60	64
	Blue shark (*Prionace glauca*)	1	1	7	7	8	8
	Ocean fish (*Mola mola*)	9	9	6	6	15	15
	Unidentified shark	35	52	5	5	50	57

Table A-3 continued. Summary of aerial observer and vertical photograph detections during all Campaign 5 directed and opportunistic aerial surveys

		Observers		Vertical photos		Totals	
Category	**Species**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**
Human activity	Fixed fishing gear	128	139	--	--	128	139
	Fishing vessel	43	114	1	1	44	115
	Recreational vessel	7	8	--	--	7	8
	Other types of vessels/data stations/coast guard	17	18	--	--	17	18
Unknown	Unidentified animal	2	2	1	1	3	3

Table A-4. Summary of on and off effort aerial observer and vertical photograph detections during all Campaign 5 aerial surveys

Note: Individual items for natural debris were not tallied and are marked with *

		Observers		Vertical photos		Totals	
Category	**Species**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**
Small cetaceans	Bottlenose dolphin (*Tursiops truncatus*)	17	479	--	--	17	479
	Common dolphin (*Delphinus delphis*)	43	1,689	12	36	27	674
	White-sided dolphin (*Lagenorhynchus acutus*)	5	181	--	--	5	181
	Unidentified common or white-sided dolphin	3	13	--	--	3	13
	Unidentified dolphin	8	13	6	9	14	22
	Harbor porpoise (*Phocoena phocoena*)	1	15	16	20	17	35
	Pilot whale (*Globicephala* sp.)	3	34	--	--	3	34
Large cetaceans	Fin whale (*Balaenoptera physalus*)	32	53	--	--	32	53

Table A-4 continued. Summary of on and off effort aerial observer and vertical photograph detections during all Campaign 5 aerial surveys.

Note: Individual items for natural debris were not tallied and are marked with *

		Observers		Vertical photos		Totals	
Category	**Species**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**
Large cetaceans	Minke whale (*Balaenoptera acutorostrata*)	94	111	4	4	98	115
	Sei whale (*Balaenoptera borealis*)	28	55	--	--	28	55
	Unidentified fin or sei whale	7	7	--	--	7	7
	Sperm whale (*Physeter macrocephalus*)	2	6	--	--	2	6
	Humpback whale (*Megaptera novaeangliae*)	30	32	--	--	30	32
	Right whale (*Eubalaena glacialis*)	175	321	2	2	177	323
	Sperm whale (*Physeter macrocephalus*)	2	6	--	--	2	6
	Unidentified whale	4	4	2	2	6	6
Pinnipeds	Gray seal (*Halichoerus grypus*)	2	2	1	1	3	3
	Unidentified seal	74	2,710	14	1,669	88	4,379
Sea turtles	Leatherback sea turtle (*Dermachelys coriacea*)	5	5	1	1	6	6
	Loggerhead sea turtle (*Caretta caretta*)	--	--	2	2	2	2
Birds	Great Black-backed gull (*Larus marinus*)	--	--	2	2	2	2
	Long-tailed duck (*Clangula hyemalis*)	--	--	2	79	2	79
	Northern gannet (*Sula bassanus*)	--	--	15	16	15	16
	White-winged scoter (*Melanitta fusca*)	--	--	6	19	6	19

Table A-4 continued. Summary of on and off effort aerial observer and vertical photograph detections during all Campaign 5 aerial surveys

Note: Individual items for natural debris were not tallied and are marked with *

		Observers		Vertical photos		Totals	
Category	**Species**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**	**Number of detections**	**Number of individuals**
Birds	Unidentified bird	--	--	16	29	16	29
	Unidentified gull	--	--	304	2,470	304	2,470
Sharks and fish	Basking shark (*Cetorhinus maximus*)	120	125	18	19	138	144
	Blue shark (*Prionace glauca*)	65	67	42	42	107	109
	Hammerhead shark (*Sphyrna* sp.)	--	--	1	1	1	1
	Ocean fish (*Mola mola*)	68	72	21	22	89	94
	School of fish	52	65	3	3	55	68
	Unidentified fish	--	--	14	201	14	201
	Unidentified shark	72	91	13	13	85	104
	Unidentified tuna	--	--	3	5	3	5
Human activity	Debris (different types)	33	33	57	58	90	91
	Fixed fishing gear	648	1,112	28	29	676	1,141
	Fishing vessel	374	468	5	5	379	473
	Recreational vessel	87	120	2	2	89	122
	Other types of vessels/data stations/coast guard	105	107	3	3	108	110
	Unknown vessel	2	2	--	--	2	2
Natural debris	Seaweed/wood/organic material	17	*	309	*	326	*
Unknown	Unidentified animal	9	9	9	9	18	18
	Unknown marine mammal	1	1	--	--	1	1

Appendix B: Discussion section from Part 1 of report

B.1 Aerial surveys

Part one of the Campaign 5 report summarizes preliminary sightings data from 11 months of aerial surveys and oceanographic sampling at 65 stations over 7 months. A major caveat to the sightings data is that they have not been effort corrected. Reporting on relative abundance and density (e.g., sightings per unit effort and number of animals per trackline mile) will be included in part two of the Campaign 5 report. Here we discuss preliminary findings about animal sightings and distribution that are likely to be supported by the analyses that incorporate survey effort.

Some seasonal patterns in right whale distribution and numbers observed in Campaigns 1-4 were also observed during Campaign 5. In particular, right whales were distributed mainly over the Nantucket Shoals during the winter and the highest numbers of whales were spotted during winter and spring. In contrast to the earlier surveys (Campaigns 1-3, Kraus et al., 2016), the more recent surveys (Campaigns 4 and 5) show differences in the number of individual right whales, the size of right whale aggregations, and the length of time right whales are present in the study area. For example, Campaign 4 results and preliminary Campaign 5 results show more right whales in the study area during the winter and spring compared to Campaigns 1-3. They also show the presence of right whales in the study area during the summer and fall. In both Campaigns 4 and 5, a mid-summer aggregation of right whales was spotted south of Nantucket Island.

Preliminary Campaign 5 results also suggest some changes in right whale distribution and sightings patterns. Specifically, right whales were sighted in the western side of the study area less frequently than the eastern side of the study area during all seasons. While the magnitude of this pattern may be affected by a bias in effort away from the western side (this will be evaluated in the Part 2 report), it is probable that the overall pattern exists. In Campaign 4, right whales spread west across the study area during spring. In Campaign 5, this pattern was not observed. In general, very few right whales were observed west of the Nantucket Shoals and only one right whale was observed in the RIMA WEA zones during Campaign 5. Instead, during the spring of 2019, right whales were observed in an area where they had not been seen on previous surveys: south of the study area, in and around the shipping lane entering New York harbor. While we have no reason to suspect there were sizable aggregations in this area in previous years, there was undoubtedly increased survey effort in this area during 2019.

Right whales may also have been present in larger numbers in the study area during Campaign 5 than during the 2011-2015 surveys (Leiter et al. 2017, Stone et al. 2017) or during Campaign 4. Preliminary data suggests that at least 137 unique whales were identified during Campaign 5 surveys (11 months) compared to 94 unique whales during Campaign 4 (18 months) and an annual average of 35 unique whales during Campaigns 1-3 (Leiter et al. 2017). It should be noted that the number of right whales identified is likely biased upwards in Campaign 5 compared to other years because directed surveys were flown to known right whale aggregations. Regardless of the trend in the number of right whales in the study area, Campaign 4 and 5 results show that a large segment of the right whale population uses this area.

Right whales were sighted more often than any other large whale species. This result is in part due to the increased effort during times of high right whale density, which happens to occur during times of low density for other large whale species. However, even when looking at sightings only for general surveys, right whales were still sighted most often and in the highest numbers.

Patterns in the number of seasonal sightings of Balaenopterids were similar to those observed in previous years. Fin whales were seen most often in the late spring and early summer. Sei whales were seen for only a short period of time during May and June. Minke whales were seen most often in the spring and early summer and humpback whales were seen most often in May and June. For humpback whales, the peak in sightings was the same as in previous years. However, during Campaign 5, humpback whales were seen in more months.

Distribution patterns for Balaenopterids appeared to differ between Campaigns 4 and 5. Minke whales were distributed further north (i.e., closer to Martha's Vineyard and Nantucket) during Campaign 5 than during Campaign 4. Fin, sei, and humpback whale sightings were more common on the western side of the study area during Campaign 4 and more common on the eastern side of the study area during Campaign 5. However, the differences for all species may be the result of the increased effort on the eastern side of the study area during Campaign 5. Consequently, further assessment of these results is needed and will be conducted in Part 2 of the Campaign 5 report.

The highest numbers of common dolphins were observed in fall and summer during Campaigns 1-4. Similarly, Campaign 5 found the highest numbers of common dolphins in June and July; no surveys were conducted in September during Campaign 5. The results from our study area differ from the results of Kenney and Vigness (2010) that found high numbers of this species in the northeastern United States region during the winter. Other small cetaceans sighted in Campaign 5 had similar seasonal patterns to Campaign 4, as well as Campaigns 1-3 (Stone et al., 2017): most sightings occurred during spring or summer.

The downward trend in sea turtle sightings observed in Campaign 4 seemed to continue during Campaign 5. Additionally, Kemp's ridley turtles were only seen in Campaigns 1-3 and were not seen in Campaigns 4 or 5. The small number of turtle sightings in Campaign 5 may be a result of the lack of surveys flown in September, which is historically a month of high turtle sightings.

Shark and fish sightings during Campaign 5 peaked in June and were generally not seen outside of late spring and summer months. This pattern of a peak in fish sightings in the summer is consistent with previous years of data. The common species identified here, ocean sunfish, basking shark, and blue shark, are all easily identifiable. In one case, an identification of a hammerhead shark was possible from a vertical photograph because of its distinctive body shape. Our surveys likely miss some shark species because New England waters include many shark species that are difficult to differentiate, such as dusky and sandbar sharks. Consequently, these species are simply recorded as unidentified sharks.

It is clear that many species of marine megafauna continue to use the study area in high numbers. The patterns in seasonal and geographic distribution patterns for large whales are likely related to patterns of their prey. For right whales in particular, the presence of copepods likely explains the high number of animals observed and is an important predictor of right whale presence in the future.

B.2 Oceanographic sampling

Our data analysis is incomplete to date, as there is still much to be learned from comparing the results of our 2019 sampling with our similar work completed in 2017, as well as the examination of historical right whale occurrence and zooplankton community composition for publicly accessible datasets. These expanded analyses are ongoing, but we discuss here some preliminary observations from the 2019 sampling campaign.

The zooplankton abundances observed in the oceanographic study area were not particularly high (compared with abundances observed in other right whale habitats) and the zooplankton community was quite diverse, two factors that may explain why right whale occurrence and abundance was so low in the area of oceanographic sampling. Right whales were observed south of Nantucket for much of the winter and spring of 2019, but few were encountered in the area where our sampling occurred. The three zooplankton samples collected near right whales in March (Figure 36 and 37) were dominated by barnacle nauplii with some *C. finmarchicus* included. Both the barnacle nauplii and *C. finmarchicus* abundances in these near-whale samples were among the highest observed for these two taxa during the entire study period (Figure 37). The 2 samples collected near right whales in July were dominated by *Centropages* species (Figure 36), again at abundances that were near the highest observed for this taxon during the entire study period (Figure 37).

It appears that one of the important results from this and our 2017 study is that there is not one single primary prey that right whales target in the northern part of the study area. Like Cape Cod Bay, there are several possible prey species, including *Centropages* species, *Pseudocalanus* species, *C. finmarchicus*, and perhaps barnacle nauplii. It is important to keep in mind that we report numerical abundances here, and the differences in body size and lipid content among all of these potential prey makes their biomasses and nutritional content quite different. *Centropages* and *Pseudocalanus* spp. are small copepods compared to *C. finmarchicus* (e.g., an adult female *Pseudocalanus* sp. is about 11 times smaller than an adult female *C. finmarchicus*). Right whales use the study area during the late winter, a period of time when the larger lipid-rich *C. finmarchicus* is in developmental stages that are too small for right whales to efficiently filter, so it is not surprising that they feed on other, smaller, less nutritious organisms like *Centropages* sp., *Pseudocalanus* sp., and barnacle nauplii at that time. What is interesting about 2019 is that the abundance of *C. finmarchicus* did not increase dramatically in early spring, and right whales were generally absent from the northern study area. We are looking forward to putting these preliminary observations in the context of the 2017 sampling as well as the historical record of right whale occurrence and zooplankton abundance in the area as part of our remaining efforts on this project.

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