MEGAFAUNA AERIAL SURVEYS
IN THE WIND ENERGY AREAS OF MASSACHUSETTS AND RHODE ISLAND
WITH EMPASHIS ON LARGE WHALES
Summary Report – Campaign 4, 2017-2018

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BACKGROUND

The Bureau of Ocean and Energy Management (BOEM) designated two wind energy areas in New England: one offshore of Massachusetts and the other offshore of both Rhode Island and Massachusetts. In August 2016, Massachusetts Governor Baker signed energy diversity legislation that requires Massachusetts utilities to initiate a procurement of 1,600 megawatts of offshore wind energy by June 30, 2017. Since then, utilities in Massachusetts, Rhode Island, Connecticut and New York have contracted to purchase the output from over 1,600 megawatts of offshore wind, with additional procurements planned and in process. 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 (WEA).

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, in August of 2011, the Massachusetts Clean Energy Center (MassCEC), after a competitive procurement process, selected a team led by the New England Aquarium (NEAq) to conduct aerial and acoustic surveys of endangered whales and turtles. Upon conclusion of these initial surveys (campaign 1), MassCEC and BOEM extended the surveys for an additional two years and expanded the geographic scope to include the Rhode Island/Massachusetts Wind Energy Area (campaigns 2 and 3). For the 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, found that the Study area around the WEAs included seasonal aggregations of protected species of whales, turtles and seabirds in these areas. The surveys also found 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 altogether. The 2016 final report also provided recommendations for additional surveys to address information gaps and for the collection of additional baseline data.

From February 2017 to July 2018 (campaign 4), aerial surveys using both observer sightings and automated aerial photography were used to estimate distributions and relative abundance of right whales and other cetaceans in the two wind energy areas in New England. Under sub-contracts to NEAq, the Woods Hole Oceanographic Institution (WHOI), in coordination with the Provincetown Center for Coastal Studies, conducted concurrent oceanographic surveys from February to April 2017 to assess the physical and biological characteristics of the waters around the right whale distribution. Right whales visit the MA and RIMA WEA annually during winter and spring, but little is known about why they come to this region. It is likely the area is a feeding habitat, but prior to the current project (campaign 4), no zooplankton sampling had been conducted near right whales in the MAWEA to determine potential prey species and their abundances. In response to this knowledge gap, WHOI conducted oceanographic and zooplankton sampling in the northern region of the MAWEA during the winter and spring of 2017. This report summarizes the results of both the aerial surveys and the oceanographic sampling program.

RESEARCH OBJECTIVES

1. Estimate distribution and abundance of large whales (with a focus on right, humpback, fin and minke whales) and turtles in an area of outer continental shelf federal waters off the coast of Massachusetts - an area proposed for offshore wind energy development.
2. Assessment of prey species and oceanographic conditions around right whale aggregations.

This progress report includes preliminary results on the numbers and distribution of large whales and other mega fauna sighted in MA and RIMA WEAs for the period between February 1, 2017, and July 2018. It also includes a preliminary assessment of the prey species and oceanographic conditions near right whale aggregations.

METHODS

1. AERIAL SURVEYS

Standard line-transect aerial surveys were conducted on a monthly basis from February 2017 to June 2018. An opportunity survey was conducted in July 2018. The monthly standardized surveys also referred to as *general surveys* covered the waters of the MA and RIMA WEA study areas (Figure 1A). General surveys focused on all types of marine fauna visible from the plane, had ten long north-south track lines covering the entire study area (5,811 km^2), and track lines were evenly spaced at approximately 11 km (6 nm) (Figure 1B). Flight plans were selected at random from a pool of eight options. Additionally, from February to May 2017 and from March to April 2018, aerial surveys referred to as *supplementary surveys* were conducted in two smaller more concentrated areas south of Martha's Vineyard and Nantucket (Figure 1A). These shorter surveys had 10-12 short track lines (western side: 10 track lines, total length: 218 nm; eastern side: 12 track lines, total length: 221.5 nm) evenly spaced at 4 nm, and focused on areas commonly used by aggregations of the endangered right whales (Figures 1C and 1D). Flight plans were selected at random from a pool of four options.

1.1 Survey methods for aerial detections

All surveys were flown in a Cessna Skymaster 337 0-2A at an altitude of 305 m (1000 ft) and a ground speed of approximately 185 k/h (100 kts) under Visual Flight Rules. Surveys were made if winds were < 25 kts, Beaufort Sea state was ≤ 4, cloud ceiling was ≥ 2000 ft, and visibility was ≥ 5 nautical miles (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 each side of the aircraft, and scanned the water out to 3.7 km (2 nm) from the transect line.

1.2 Sightings: observers and vertical photography

Observers recorded sightings according with the North Atlantic Right Whale Consortium (NARWC) Database guidelines (Kenney 2010). Sighting locations were added into 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) using the following distance (nm) classes: within ⅛, ⅛ to ¼, ¼ to ½, ½ to 1, 1 to 2, 2 to 4, and >4, indicating port or starboard. All sightings recorded by observers were integrated into a single data spanning the entire survey and are listed in the digital file.

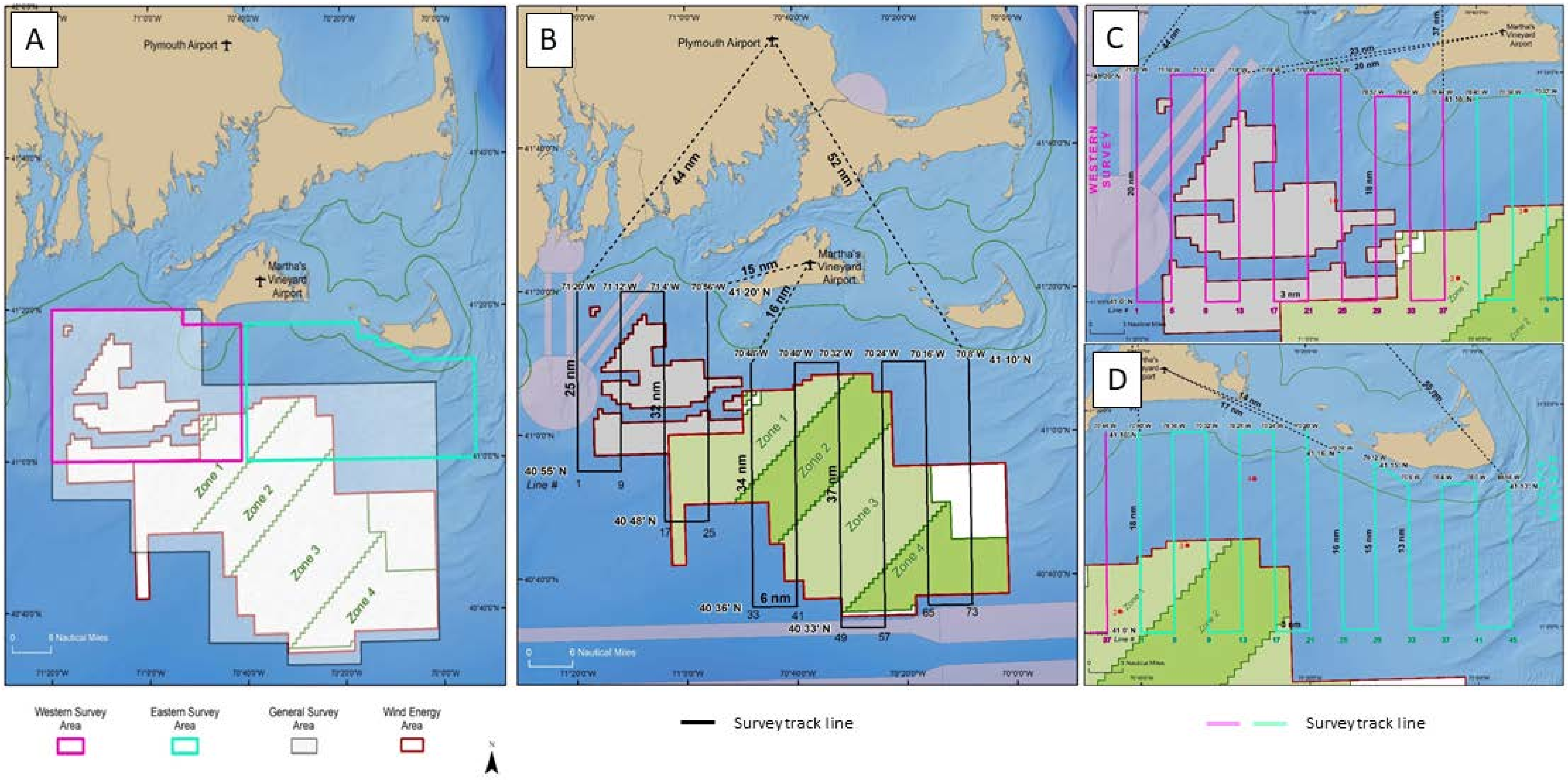


Figure 1. A) Wind energy study areas in the offshore waters of Massachusetts and Rhode Island. Study areas covered by general surveys are depicted by black line and areas covered by supplementary surveys are depicted by pink (western side) and green (eastern side) lines. Examples of a B) general survey option 1, C) western survey option 1, and D) eastern survey option 1. Note: Existing lease areas are depicted as Zones 1 to 4.

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 type of flight leg (transit, transect, cross-leg, or circling), transect number, and specific points of a given transect (begin, end, break off, or resume). Environmental data parameters included general weather conditions, 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, the number of calves or juveniles, heading of the animal or group, whether or not photographs were taken, and notes on behaviors.

Since observers were unable to see directly under the aircraft, a Cannon 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 geotagged and analyzed by trained observers for detections of marine species and fixed fishing gear using the program FastStone Image Viewer. Detections 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. The Chief Survey Scientist reviewed all detections for accuracy and consistency. All data were submitted to the NARWC Database.

1.3 Right whale photo-identifications

North Atlantic right whales were the 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) with a Nikon D500 with a 300 mm f/2.8 telephoto lens (1.4×teleconverter; Figure 2). When photographic documentation was completed, the aircraft resumed the survey at the point of departure for that sighting.

1.4 Data processing and analysis

Sighting rates and temporal variability

Sighting rate was defined *as the number of individuals sighted per survey multiplied by 1000* to avoid working with small decimal values, 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 is ≤ 4 as defined by Kraus et al. (2016) and Leiter et al. (2017). Only sightings identified as definite and probably were included in the analysis.

Seasonal sighting rates were calculated for species with at least 25 sightings to account for variability in sampling effort when making comparisons. 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.

Figure 2. NEAq observers taking photographs and recording locations of right whale sightings. Photographs by Angela Bostwick and Paul Nagelkirk, NEAq.

Sightings per unit effort

In order to minimize bias from the uneven allocation of survey effort in both time and space, the sightings-per-unit-effort or SPUE were calculated. SPUE is an index of relative density by quantifying the number of individuals sighted in 1000 km of effort within grid cells measuring 5 m of latitude (9.3 km) by 5 min of longitude (approximately 7 km narrowing slightly from south to north). SPUE allows comparisons between discrete spatial units. All definite or probable sightings during the same track segments were assigned to the 5x5 min cells. Survey transect segments were partitioned into the grid cells, limited to segments at the altitude of 366 m or lower, clear visibility to at least 3.7 km (2 nm) and a sea state ≤ 3 (Kraus et al. 2016).

Right whale photographs and demographics

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

2. OCEANOGRAPHIC SAMPLING

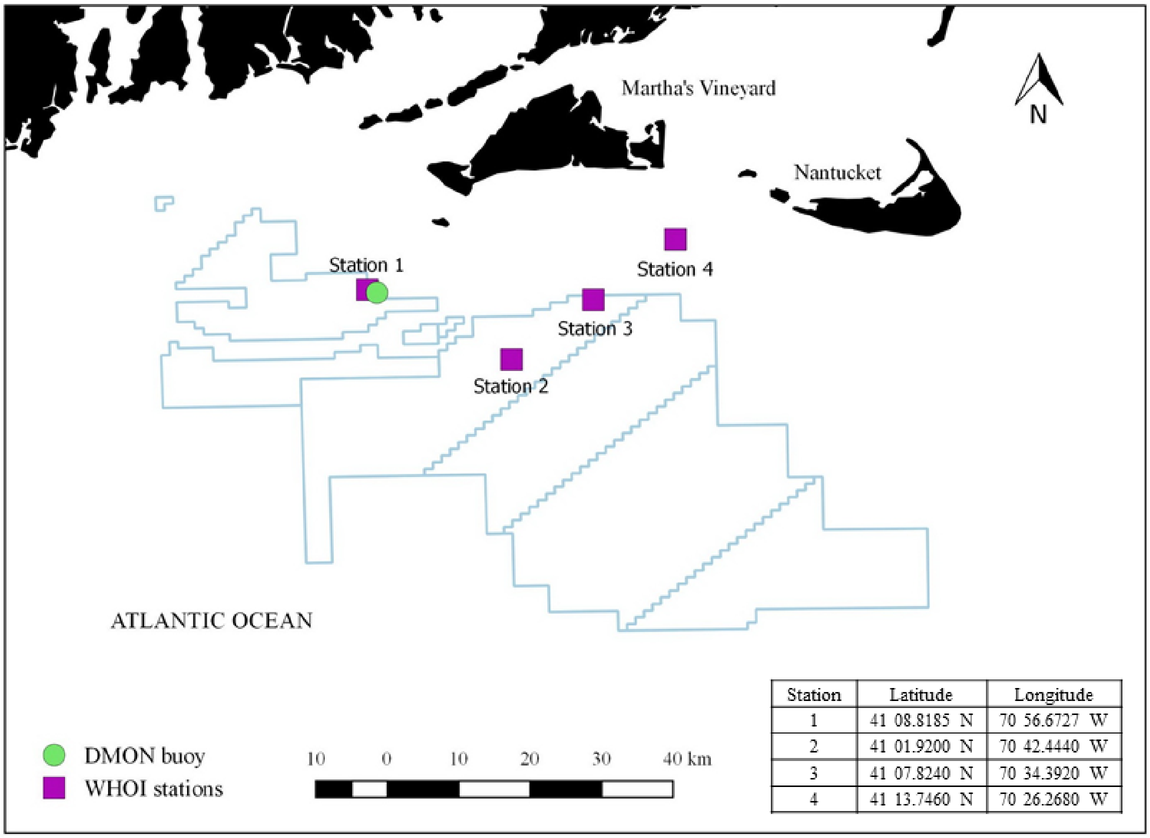
2.1 Sampling design

Zooplankton and oceanographic sampling occurred at four standard stations (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 RIMA and MA WEAs to allow the sampling platform, the R/V *Tioga* based in Woods Hole, Massachusetts, to visit all of the stations and conduct additional adaptive sampling in a single day. Station 1, called the Nomans Land station (near Nomans Land Island), was collocated with a near real-time passive acoustic whale detection buoy equipped with a digital acoustic monitoring (DMON) instrument, while stations 2-4 were located to the east of the DMON buoy. We chose to sample at four stations distributed in the northern part of the RIMA and MA WEAs to understand spatial variability in zooplankton distribution.

Three types of boat surveys were conducted:

1. Sampling trips that visited Station 1 only, surveys are referred to as Nomans only.
2. Full sampling trips that allowed sampling at all 4 standard stations and if available, sampling at 2 right whale sampling stations. Surveys are referred to as full surveys.
3. Right whale sampling trips that sampled at Station 1 and only at right whale sampling stations. Surveys are referred to as right whale surveys.

Sampling trips were closely coordinated with the New England Aquarium aerial survey team and the NOAA Northeast Fisheries Science Center small boat team, who sometimes accompanied us to sea. Both groups were surveying for right whales and alerted us to the presence of right whales so that we could sample near them.



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 4 standard stations used during the 2017 oceanographic surveys in the northern region of the Rhode Island and Massachusetts wind energy areas. Insert includes the geographical coordinates of each station.

At each station, zooplankton were collected throughout the water column with a 70-cm ring net towed from near the sea floor to the surface. In addition to the net sampling, two vertical profiles of temperature, salinity, chlorophyll fluorescence (a rough measure of phytoplankton abundance), and zooplankton distribution and abundance were collected with an instrument package consisting of a conductivity-temperature-depth (CTD) instrument equipped with a chlorophyll fluorometer, an optical plankton counter (OPC), and a video plankton recorder (VPR).

2.2 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 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. After the field season, all samples were sent to the Atlantic Sorting Center at the Huntsman Marine Science Center in New Brunswick, Canada for enumeration.

2.3 Zooplankton vertical profiles from instruments

The VPR is an underwater microscope attached to a video camera that takes digital photographs of a small volume of water approximately 20 times per second. The images can be used to count and identify zooplankton to taxa, and when profiled throughout the water column, the VPR can provide vertical profiles of species-specific abundance. Objects in VPR images are extracted automatically with detection software (Seascan, Inc.), and a human analyst classifies the objects in the images manually.

The OPC is an instrument that counts and sizes particles that pass through a sampling tunnel. When profiled, it can provide the vertical distribution of particles. In circumstances when a single uniquely sized organism dominates the zooplankton community, the OPC can be used to provide vertical profiles of the abundance of that organism. The OPC has proved useful in previous studies for sampling late-stage *Calanus finmarchicus* in proximity to right whales in other habitats, since late-stage *C. finmarchicus* is uniquely sized in the Gulf of Maine and is highly abundant near right whales.

2.4 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. The instrument was also equipped with an altimeter and a bottom contact switch to facilitate sampling within tens of centimeters of the sea floor. The CTD telemetered data back to the ship in real time so that the entire profiling instrument package could be purposely “flown” (e.g., lowered very close to the sea floor). The VPR was also equipped with a CTD and chlorophyll fluorometer, providing redundant observations of temperature, conductivity, and chlorophyll fluorescence.

RESULTS

1. AERIAL SURVEYS

1.1 Field effort

A total of 38 aerial surveys were completed in 18 months between February 2017 and July 2018 (Table 1). This included 21 general surveys and 17 supplementary surveys conducted in 134.9 h and 58.4 h, respectively. Of these, two general aerial surveys were aborted due to bad weather conditions and equipment problems. Excluding the aborted surveys, general surveys took an average of 6.4 h (range = 4.2 – 8.5 h) and a supplementary surveys took an average of 3.7 h (range = 2.9 – 5.8 h). The total time and the total distance flown for all aerial surveys combined were approximately 193.5 h and 30,076.67 km, respectively (Table 1).

1.2 Detections

A total of 7,415 sightings of marine fauna (28.8%), human activity (70.8%) and unknown objects (0.4%) compromising 48,706 individual animals/objects were detected. Of these, 2,139 (29%) included sightings made by the aerial observers and 5,252 (71%) included vertical camera detections. Vertical camera detections included 95,701 photographs taken in the general surveys and 47,011 photographs taken in the standardized surveys for a total of 142,712 photographs. It is important to note that the vertical photographic analysis was conducted only for the general surveys as agreed upon in the contract.

The analysis of the vertical photographs resulted in 5,250 vertical detections of 41,980 individual items (Table 2). Debris accounted for the majority of the detections (67%, n = 3,523) and of identifiable individual items (76%, n = 31,747). Twenty species of marine fauna were identified to the species level. Marine fauna included right whales, dolphins, harbor seals, several unidentified gulls, and unidentified turtles (Table 2).

When vertical and aerial observers observations of marine fauna were combined, the highest number of detections corresponded to birds (67%, n = 1,425) followed by marine mammals (20%, n = 435), sharks/fish (12%, n = 259) and sea turtles (1%, n = 20). In the case of marine mammals, 80% of the sightings were cetaceans and 20% of the sightings were pinnipeds. Overall, 11 species of marine mammals, two species of sea turtles, three species of sharks, and two species of fish were confirmed (Table 2).

Table 1. Summary of the aerial survey effort conducted in the wind energy study area offshore of Massachusetts and Rhode Island between February 2017 and July 2018. Note: W = west, E = east, * = survey aborted, NA = Not applicable.

		General Surveys						Supplementary Surveys					
Year	Month	Total	Day	Direction	Option	Airtime hours	Km	Total	Day	Direction	Option	Airtime hours	Km
2017	February	1	28	W → E	7	6.7	583.94	1	22	W → E	3E	4.3	989.89
	March	2	6	E → W	2	8.5	1,236.77	3	13	W → E	2W	3.4	599.86
			21	W → E	5	7.1	1,075.27		24	E → W	1E	3.7	627.09
									31	W → E	4W	1.6*	173.90
	April	3	3	W → E	5	6.3	1,058.60	4	9	E → W	4E	4.5	628.38
			14	E → W	7	7.5	1,062.31			E → W	1W	2.9	544.30
			30	W → E	7	6.5	980.63		19	W → E	3W	3.7	634.87
										W → E	3E	5.8	673.57
	May	1	27	E → W	8	5.8	947.30	4	4	W → E	3W	3.3	524.12
										W → E	3E	4.0	702.83
									9	W → E	2W	3.4	571.53
										W → E	2E	3.6	563.56
	June	1	15	E → W	6	6.2	995.64	NA					
	July	1	10	E → W	4	8.0	1,267.32	1	27	E → W	NA	2.0	172.24
	August	1	10	W → E	3	6.7	1,031.93	NA					
	September	1	12	W → E	1	6.6	1,000.64	NA					
	October	1	19	W → E	4	5.6	868.40	NA					
	November	1	28	E → W	6	6.7	1,060.46	NA					
	December	1	22	W → E	3	4.2	708.58	NA					
2018	January	1	21	W → E	8	6.9	986.93	NA					
	February	1	9	W → E	7	7.1	1,031.56	NA					
	March	1	29	W → E	6	6.7	1,018.79	1	20	W → E	4E	4.6	880.63
	April	2	10	W → E	8	1.2*	239.83	2	24	E → W	3W	3.4	581.34
	May	1	21	E → W	5	6.9	1,028.79	NA					
	June	1	30	E → W	2	7.6	1,035.82	NA					
	July	NA						1	8	E → W	NA	2.2	395.96
Total		21				134.9	20,217.17	17				58.4	9,859.49

Table 2. Summary of aerial observer and vertical photographic analysis detections during general line-transect aerial surveys conducted in the study area offshore of Massachusetts and Rhode Island. Results do not include detections while the plane was circling during a sighting.

		Observers		Vertical photos		Total	
Category	Species/Item	No. of detections	No. of individuals	No. of detections	No. of individuals	No. of detections	No. of individuals
Small cetaceans	Bottlenose dolphin (*Tursiops truncatus*)	4	51	3	9	7	60
	Common dolphin (*Delphinus delphis*)	26	1,690	15	45	41	1,735
	White-sided dolphin (*Lagenorhynchus acutus*)	2	76	2	42	4	118
	Unidentified dolphin	57	460	17	98	74	558
	Harbor porpoise (*Phocoena phocoena*)	2	2	11	14	13	16
	Pilot whale (*Globicephala melas*)	1	12	--	--	1	12
Large cetaceans	Fin whale (*Balaenoptera physalus*)	35	61	2	2	37	63
	Minke whale (*Balaenoptera acutorostrata*)	45	66	6	7	51	73
	Sei whale (*Balaenoptera borealis*)	16	34	1	1	17	35
	Unidentified fin or sei whale	1	1	--	--	1	1
	Humpback whale (*Megaptera novaeangliae*)	27	74	3	5	30	79
	Right whale (*Eubalaena glacialis*)	53	120	4	6	57	126
	Unidentified medium whale	1	1	--	--	1	1
	Unidentified large whale	17	18	--	--	17	18
Pinnipeds	Gray seal (*Halichoerus grypus*)	2	2	--	--	2	2
	Unidentified seal	54	1,371	30	59	84	1,430
Sea turtles	Leatherback turtle (*Dermachelys cariacea*)	12	15	1	1	13	16
	Loggerhead turtle (*Caretta caretta*)	2	2	2	2	4	4
	Unidentified turtle	3	3	2	2	3	3

Table 2 continuation. Summary of aerial observer and vertical photographic analysis detections during general line-transect aerial surveys conducted in the study area offshore of Massachusetts and Rhode Island. Results do not include detections while the plane was circling during a sighting.

Category	Species/Item	Observers		Vertical photos		Total	
		No. of detections	No. of individuals	No. of detections	No. of individuals	No. of detections	No. of individuals
Birds	Black scoter (*Melanitta nigra)*	--	--	8	45	8	45
	Northern gannet (*Sula bassanus*)	--	--	8	12	8	12
	Unidentified bird	8	111	1,306	7,784	1,314	7,895
	Unidentified goose	2	130	--	--	2	130
	Unidentified gull	3	200	90	1,020	93	1,220
Sharks/fish	Basking shark (*Cetorhinus maximus*)	55	67	8	13	63	80
	Blue shark (*Prionace glauca*)	4	6	20	20	24	26
	White shark (*Carcharadon carcharias*)	1	1	--	--	1	1
	Bluefin tuna (*Thunnus thynnus*)	1	4	--	--	1	4
	Ocean fish (*Mola mola*)	15	17	4	3	19	21
	School of fish	60	102	2	8	62	110
	Unidentified fish	2	2	12	660	14	662
	Unidentified shark	53	60	20	23	73	81
	Unidentified tuna	1	1	1	173	2	174
Human activity	Debris (different types)	101	123	3,523	31,747	3,624	31,870
	Fixed fishing gear	955	1,188	125	148	1,080	1,342
	Fishing vessel	412	508	4	4	416	512
	Recreational vessel	55	62	1	1	56	63
	Other types of vessels/ ferry/coast guard	79	82	--	--	79	82
Unknown	Unidentified animal	--	--	18	25	18	25
	Unknown object/animal	--	--	1	1	1	1

1.3 Marine mammal detections

Cetacean sightings

A total of 364 sightings including 2,911 cetaceans were recorded during 18 months of aerial surveys. Identification to the species level was possible for 258 sightings and resulted in 10 confirmed species (Table 2). Cetacean species could not be confirmed in 93 occasions. Baleen whales were represented by five species of two families, Balaenidae and Balaenopteridae. Toothed cetaceans were represented by five species in the Delphinidae and Phocoenidae families. Right whales (*Eubalaena glacialis*) and minke whales (*Balaenoptera acutorostrata*) were sighted most frequently and accounted for 22% and 20% respectively, of all cetacean sightings. In contrast, common dolphins (*Delphinus delphis*), right whales and white-sided dolphins (*Lagemorhynchus acustus*) were the most abundant species (75%, 5% and 5%, respectively).

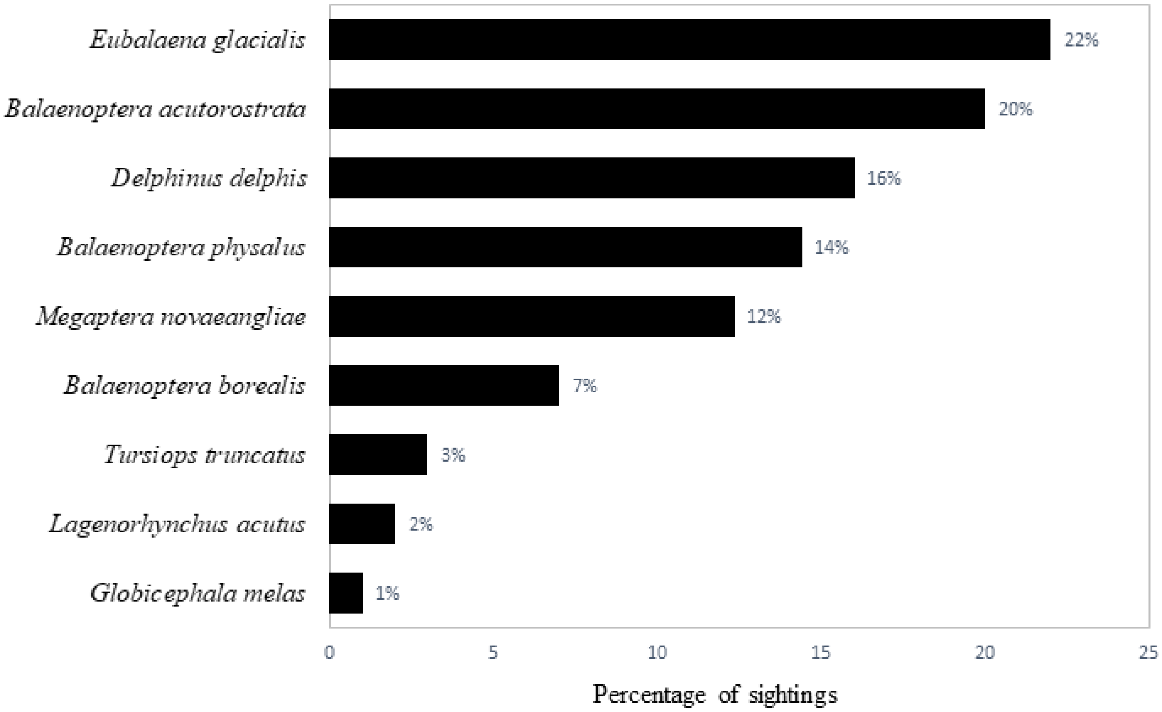


Figure 4. Percentage of sightings per cetacean species identified during aerial surveys conducted in the study area offshore of Massachusetts and Rhode Island between February 2017 and July 2018.

Family Balaenidae: North Atlantic right whales (*Eubalaena glacialis*)

In total, 77 sightings of 211 right whales were recorded. Sightings usually consisted of single right whales (54%) but groups of up to 20 individuals were also recorded. The large aggregations (≥ 10 individuals) accounted for less than 4% of all right whale sightings.

Right whales were sighted in every season and in 72% (14/18) of the months surveyed. Their sightings began in January and had a high mean sighting rate (as defined on page 5) in the winter (15.98 whales/km) followed by the spring (7.23 whales/km), summer (2.74 whales/km) and fall (0.84 whales/km). The number of monthly sightings varied from 1 to 60 (10.61 ± 3.53 sightings/month) when general and condensed surveys were combined. January, February, March and April had the highest number of right whale sightings, and no sightings were recorded in August, October and December (Figure 5). The caveat to any inter-annual comparisons is that no aerial surveys were conducted in January 2017 or in August-September 2018, and the October-December 2018 surveys are not part of this report.

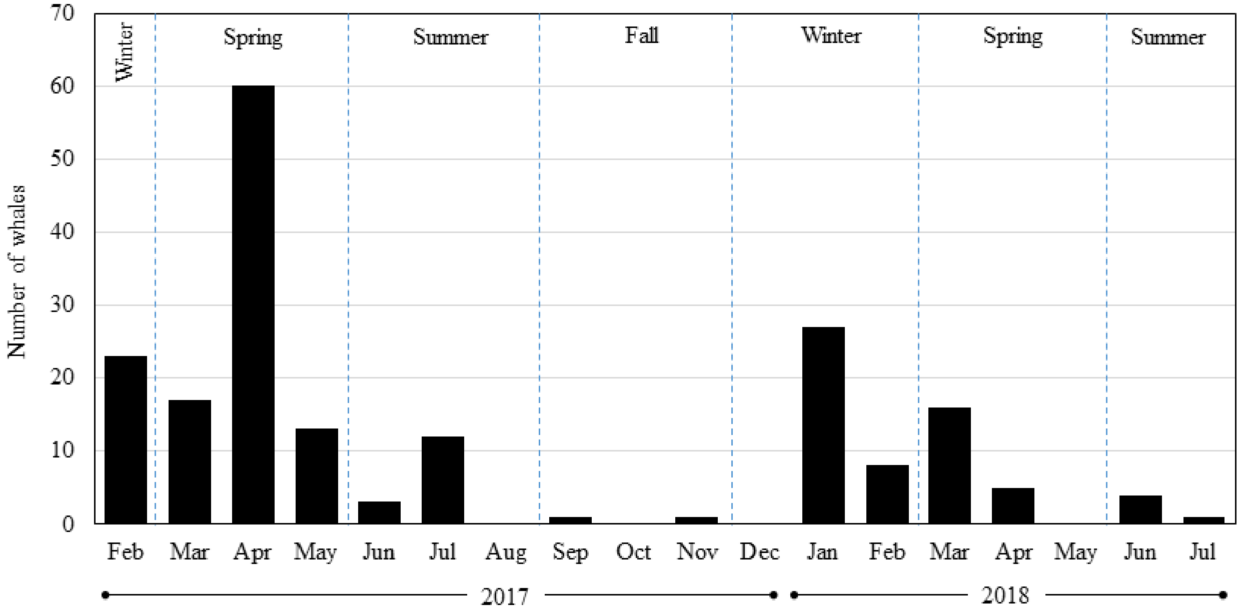


Figure 5. Total number of right whales (*Eubalaena glacialis*) sighted per month in the study area offshore of Massachusetts and Rhode Island based on aerial survey observations.

In the winter, right whales were more frequently sighted near the northern boundaries of the MA WEA (2017) and Nantucket shoals (2018) with a few sightings in the offshore waters of Martha’s Vineyard (Figure 6). In the 2017 spring, their distribution was more widely spread to the north and western portions of the WEA, near Cox Ledge. In 2018, most of their sightings occurred outside of WEA. Later, in the summer, no right whales were observed inside the WEA and an unusual number of the sightings were recorded south of Nantucket. In fact, 19 right whales were observed between June and July of 2017 and 2018 south of Nantucket. Their average group size was 1.3 and ranged from 1 to 3. In general, the overall sighting range of right whales in the study area was consistent between years but the pattern was less predominant in 2018 as seeing in the gap of sightings near and on the RIMA wind energy area (Figure 7). Further, the distribution of right whale sightings followed the bathymetric contour of depths ranging from 30 m to 50 m, and the sightings occurred mainly between latitudes 40°48’N and 41°13’N, and longitudes 71°20’W and 70°10’W (Figure 7). The sightings-per-unit-effort or SPUE analysis showed that the Nantucket Shoals, the northern boundaries of WEA and coastal waters of Nantucket are important right whale areas (Figure 8).

The percentage of right whale sightings inside WEA and “outside WEA but inside the study area” (hereafter referred to as outside WEA) were examined. In the case of the general surveys, when all seasonal observations were combined, the percentage of right whales sighted inside WEA was 76% (n = 84) and outside WEA was 24% (n = 26). In contrast, during the supplementary surveys, the percentage of right whales sighted inside WEA was 40% (n = 23) and outside WEA was 60% (n = 34). Differences in the percentage of sightings inside and outside WEA between survey types could reflect differences in the amount of WEA area covered by the two surveys.

Right whale sightings in previous years

For this progress report, a quantitative comparison of right whale distributions across multiple years of aerial surveys was included. NEAq conducted aerial surveys for MassCEC between October 2011 and June 2015. Since survey effort varied among years, a quantitative comparison across multiple years only provides a general idea of the distribution patterns of right whales. A formal analysis will be included in the report for Campaign 5. This preliminary analysis suggests that in some years (e.g. 2012, 2015, 2017), right whales were sighted throughout the different zones of the WEAs, mainly in the northern portion. Yet, in other years (e.g. 2013, 2014, 2018), they were mainly found on the eastern portion of the study area including the waters south of Nantucket, the Nantucket shoals, and the Muskeget channel (Figure 9). Interestingly, this is the same pattern of the SPUEs for the winter and spring months. In the winter, right whales tend to concentrate on the Nantucket shoals, but in the spring, they spread across the northern portion of the MA WEA and south of the RIMA WEA.

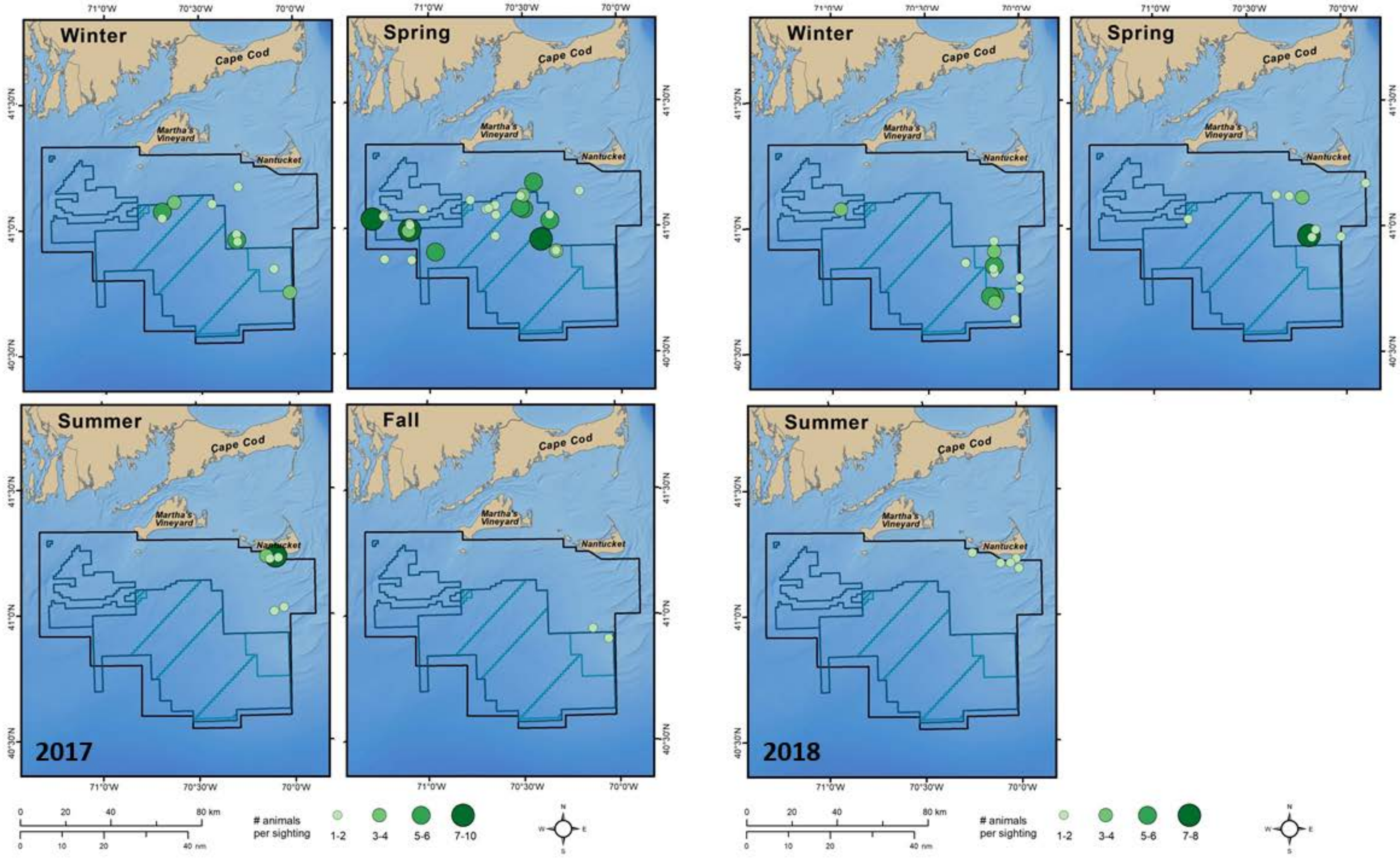


Figure 6. Seasonal sightings of right whales (*Eubalaena glacialis*) in and near the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations conducted between February 2017 and July 2018. Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

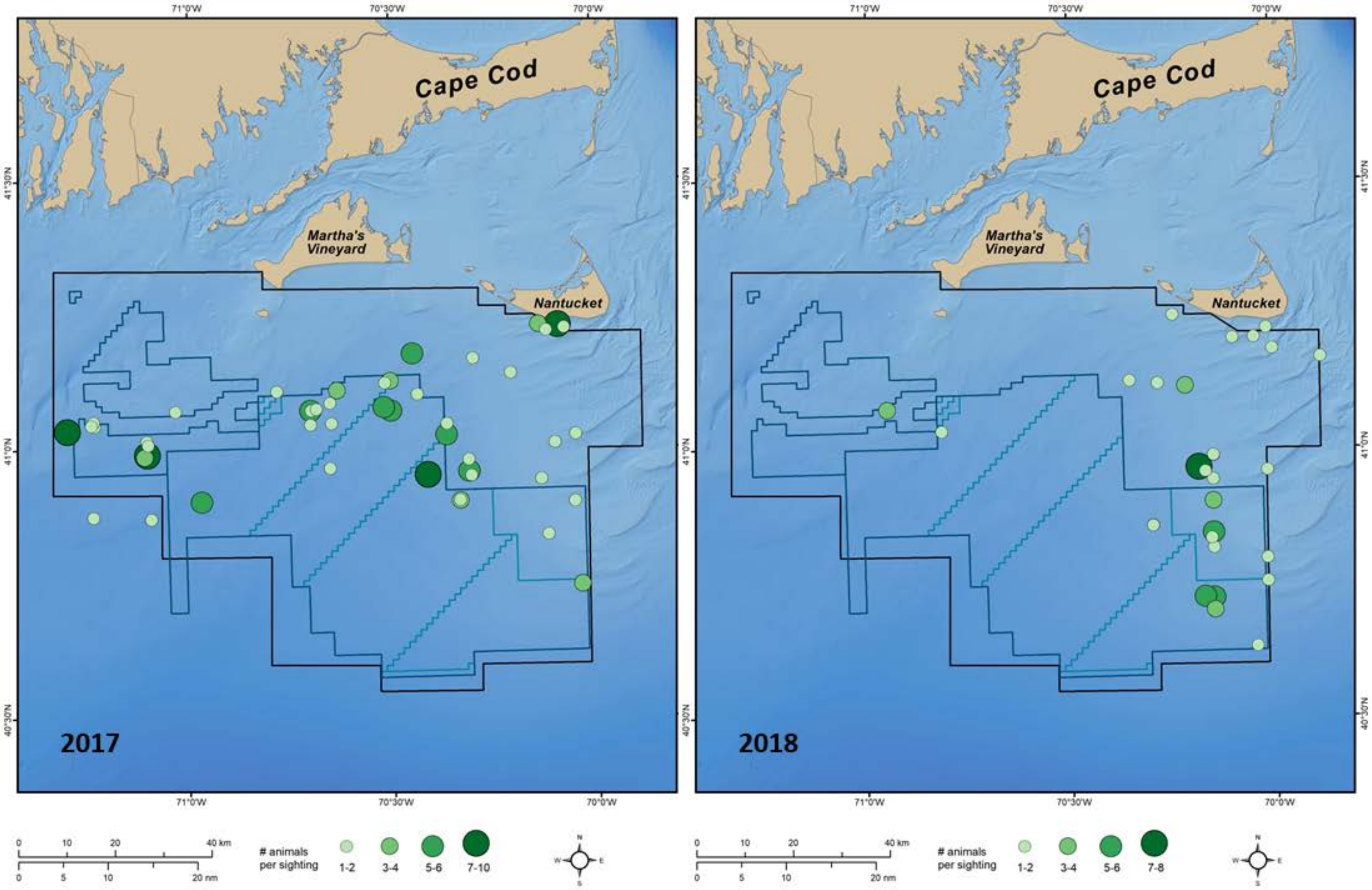


Figure 7. Annual sightings of North Atlantic right whales (*Eubaleana glacialis*) in and near the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations conducted between February 2017 and July 2018. Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

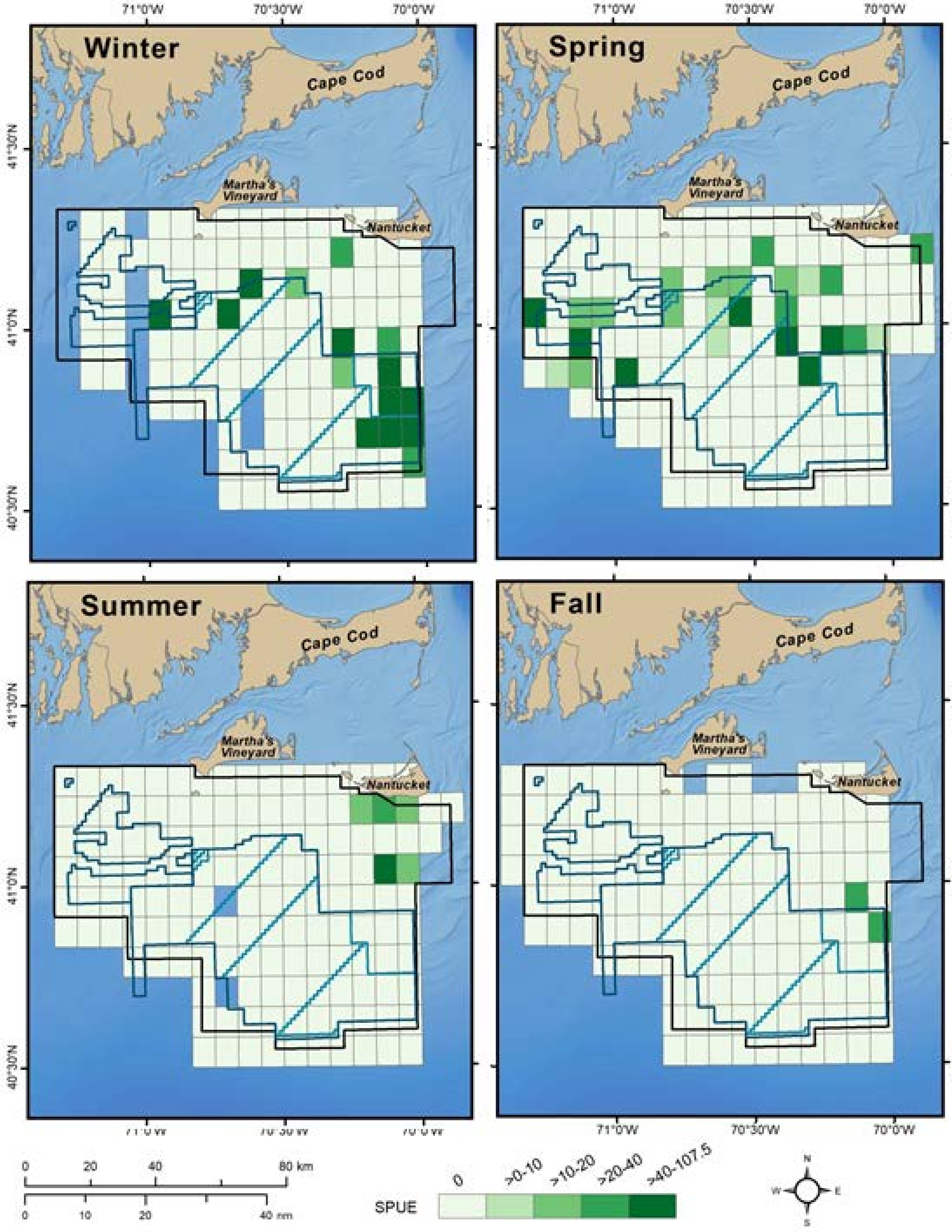


Figure 8. Seasonal sightings-per-unit-effort for right whales (*Eubalaena glacialis*) by 5-min squares inside and near the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations conducted between February 2017 and July 2018. Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

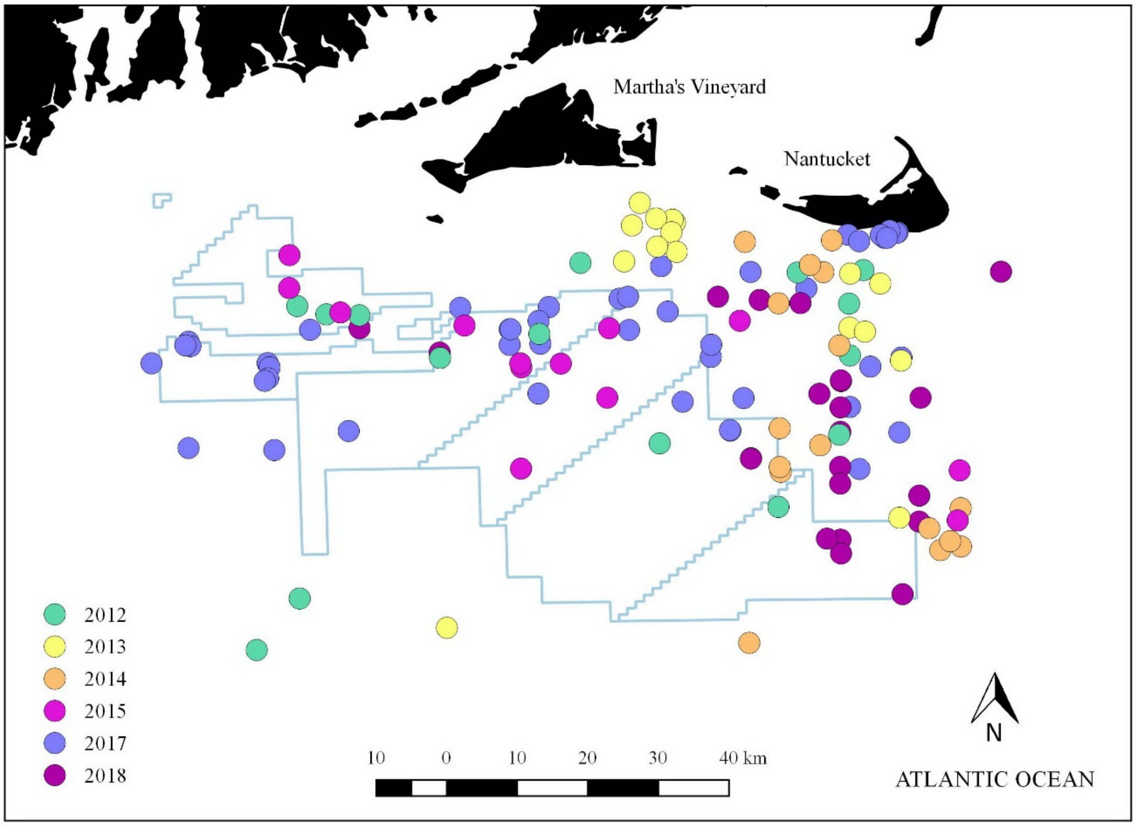


Figure 9. Sightings of North Atlantic right whales (*Eubalaena glacialis*) in and near the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations. Blue boxes represent the wind energy areas.

Demographic and resighting patterns

Preliminary photographic analysis identified 94 individual right whales in the 2017-2018 surveys. Most right whales were adults (83%, n = 78) and a majority of those were males (57%, n = 54) (Table 3; Appendix 1).

Table 3. Number and percentage of right whales of different gender and age identified in the wind energy areas offshore of Massachusetts and Rhode Island during aerial survey observations.

	N	%	Adult	%	Juvenile	%
Male	54	57	49	63	5	31
Female	33	35	27	35	6	38
Unknown	7	8	2	2	5	31
Total	94	100	78	100	16	100

Photographic analysis of right whales is still on-going but preliminary analysis suggests that the majority of the identified right whales (88%, n = 84) were sighted only once during the study in the WEA study area. A few right whales were resighted over two months (9%, n = 9) and one right whale was resighted in three months (Figure 10). Some of these right whales had not been observed anywhere else within their traditional range for a number of years. For example, in 2012, right whale EG3821 was sighted carrying a buoy line looped around its head (Figure 11A) and on February 22, 2017, the NEAq photographed the same whale (Figure 11B) apparently gear-free during the aerial survey and reported its re-sighting to the Marine Animal Entanglement Response Team at the Provincetown Center for Coastal Studies.

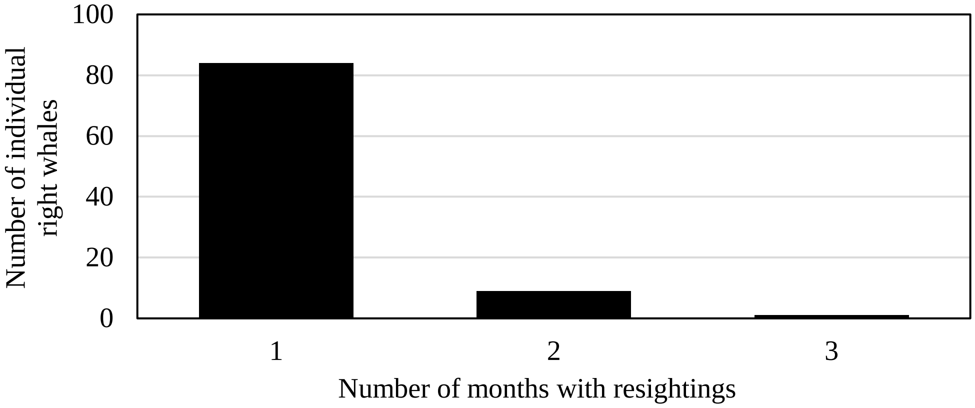


Figure 10. Monthly resighting patterns of identifiable right whales in the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations.

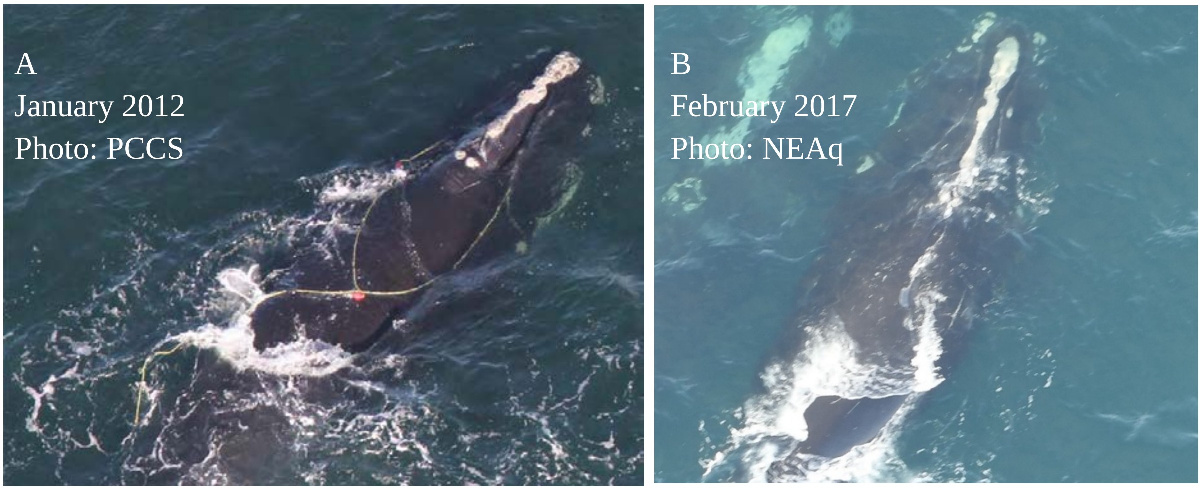


Figure 11. A. Right whale 3821 photographed in 2012 by the Provincetown Center for Coastal Studies. B. Same right whale photographed by the NEAq aerial survey team.

Some of the right whales identified included two individuals with an unusual skin color (Figure 12). One of them was identified as a female (Whale A) that has been coded as being slightly underweight for seven years. The other right whale was initially identified as a male (Whale B) that was last sighted in the Great South Chanel in 2016.

Figure 12. Right whales observed south of Nantucket on June 15, 2017. Both whales had an unusual skin color. Right whale A had patchy areas of pale color and the entire body of Right whale B was pale color. Photograph taken by the NEAq aerial survey team.

Family Balaenopteridae

The Balaenopteridae family is also known as the rorqual whales and four species were sighted during the study: fin whales (*B. physalus*), sei whales (*B. borealis*), minke whales, and humpback whales (*Megaptera novaeangliae*). Minke whales were recorded most often (38%, 51 sightings) whereas humpback whales were the most abundant species (n = 79, 32%). Minke and humpback whales were sighted in more than half of the months surveyed (humpback whales = 10 months, minke whales = 11 months). In contrast, sei and fin whales were sighted in only 4 and 5 months, respectively (Table 4).

Table 4. Monthly presence (grey boxes) and absence (white boxes) of rorqual whales in the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations.

Year/month		IUCN Conservation Status			
		Endangered		Least concern	
		Fin whales *Balaenoptera physalus*	Sei whales *Balaenoptera borealis*	Humpback whales *Megaptera novaeangliae*	Minke whale *Balaenoptera acutorostrata*
2017	February				
	March			■	■
	April		■	■	■
	May	■	■	■	■
	June				■
	July	■	■	■	■
	August	■		■	■
	September			■	■
	October				
	November		■		
	December				
2018	January			■	■
	February				
	March			■	
	April				■
	May	■		■	■
	June	■			■
	July			■	

Fin whales (*Balaenoptera physalus*)

Fin whales are the largest of the baleen whales observed in the study area. Sixty-three fin whales were seen with group sizes ranging from 1 to 4 and an average of 1.70. No fin whales were sighted in the winter, a few fin whales were sighted in the spring (n = 16) and in the fall (n = 1), but the highest count of fin whales occurred during the summer months, especially in July (n = 34) (Figure 13). Note that survey effort in the winter months did not cover some sections of the study area due to bad weather conditions (Figure 14) and which may have reduced the detections of fin whales during that season.

The SPUE analysis indicated that in the summer, fin whales were concentrated near and in the RIMA WEA study area (Figure 14) in waters ranging from about 40 to 60 m depth. In the spring, they were more concentrated in the deeper waters of the southern border of RIMA and MA WEAs study areas, and in the fall, they were mainly in the RIMA waters. There were no sightings of fin whales on the Nantucket shoals or north of Zones 3 and 4 of MA WEA (Figure 15). Overall, mean sighting rate (as defined on page 5) of fin whales was 1.16 whales/km in the spring, 10.20 whales/km in the summer, and 0.42 whales/km in the fall.

One sighting of fin whales included a mixed-species association with approximately 200 common dolphins (*Delphinus delphis*) (Figure 16). This was the first sighting that involved an association of baleen whales and dolphins. Although mixed-species associations are not uncommon, the association of those two species is rare.

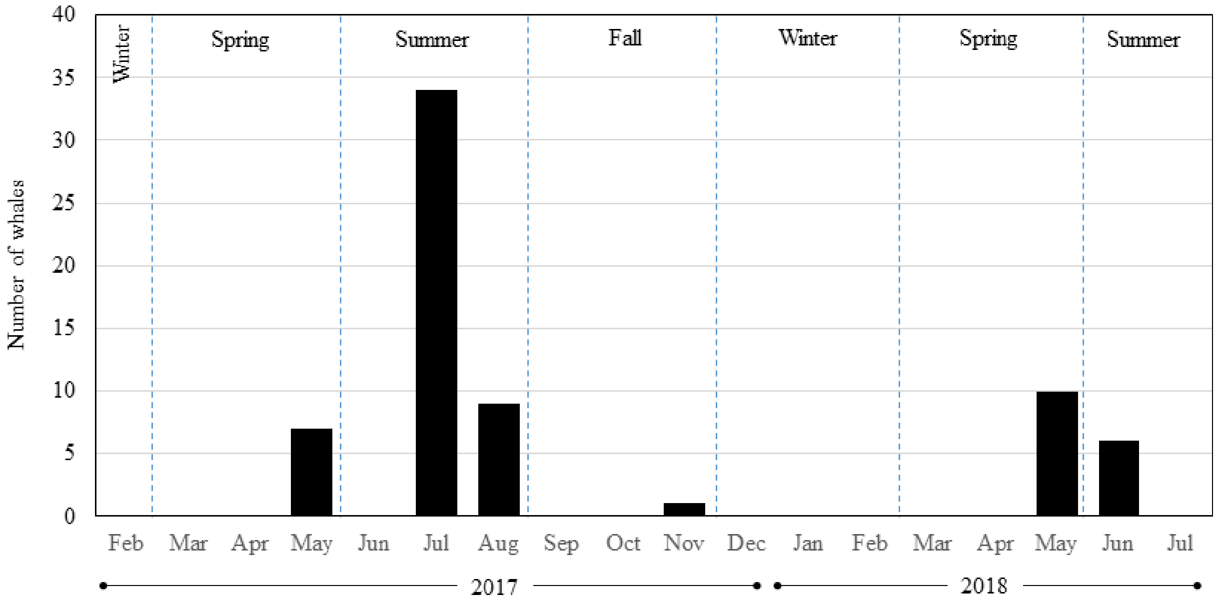


Figure 13. Total number of fin whales (*Balaenoptera physalus*) sighted per month in the wind energy study areas offshore of Massachusetts and Rhode Island based on aerial survey observations.

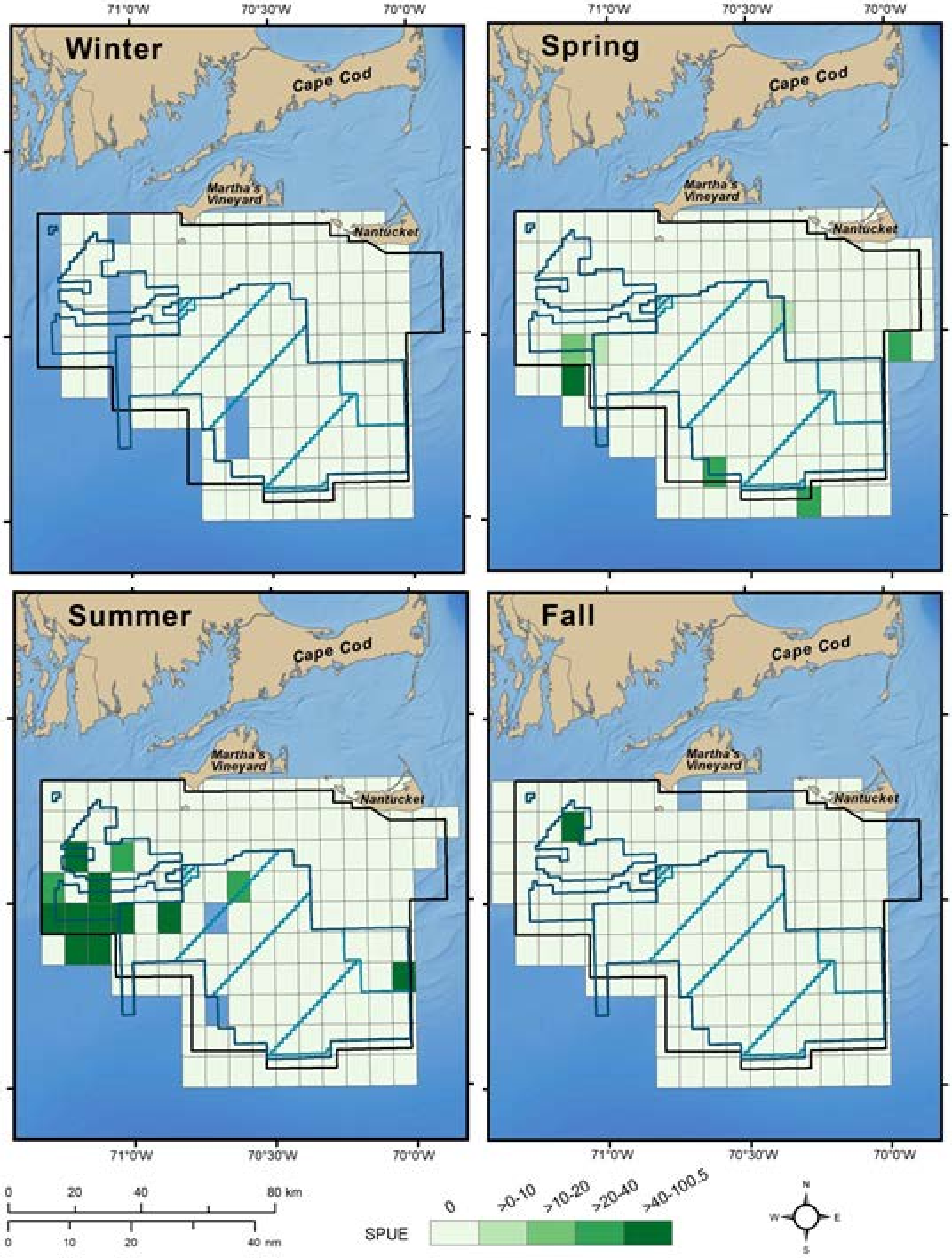


Figure 14. Sightings per unit effort of fin whales (*Balaenoptera physalus*) by 5-min squares shown seasonally for all years combined (February 2017 – July 2018). Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

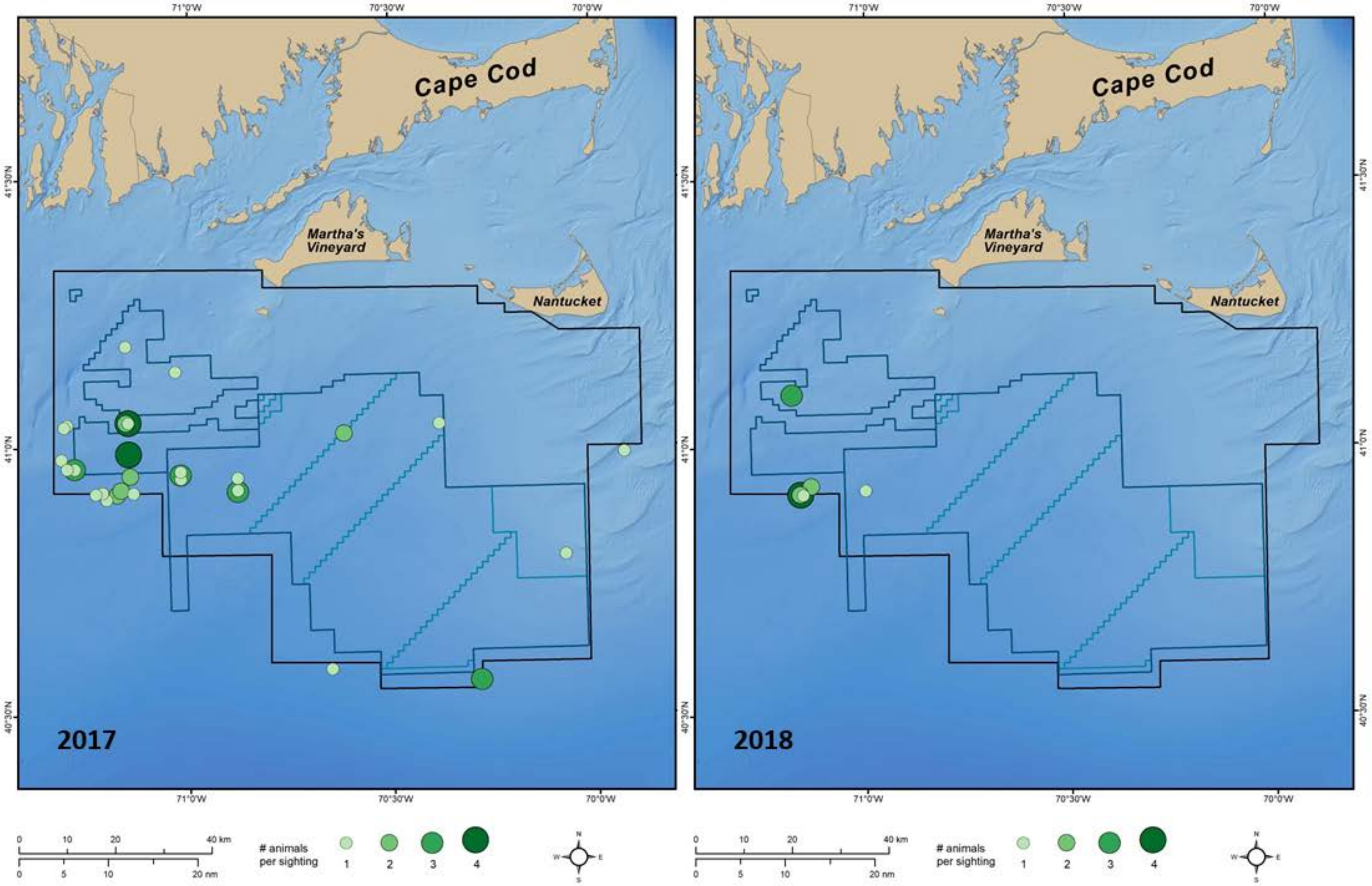


Figure 15. Annual sightings of fin whales (*Balaenoptera physalus*) in and near the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations conducted between February 2017 and July 2018. Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

Figure 16. A mixed-species association of fin whales (*Balaenoptera physalus*) and common dolphins (*Delphinus delphis*). In the top photograph, a great shearwater (*Ardenna gravis*) can be observed in the upper center.

Sei whales (*Balaenoptera borealis*)

Sei whales were encountered less frequently than other rorqual whales during the aerial surveys. There were 17 sightings of sei whales, which comprised 63 individuals. The species was sighted in only three of the 18 months of aerial surveys, which corresponded to the 2017 spring and summer months. The greatest number of sightings occurred in May (n = 29) followed by April (n = 18) and July (n = 8; Figure 17). There were no sightings of sei whales in other months or in 2018.

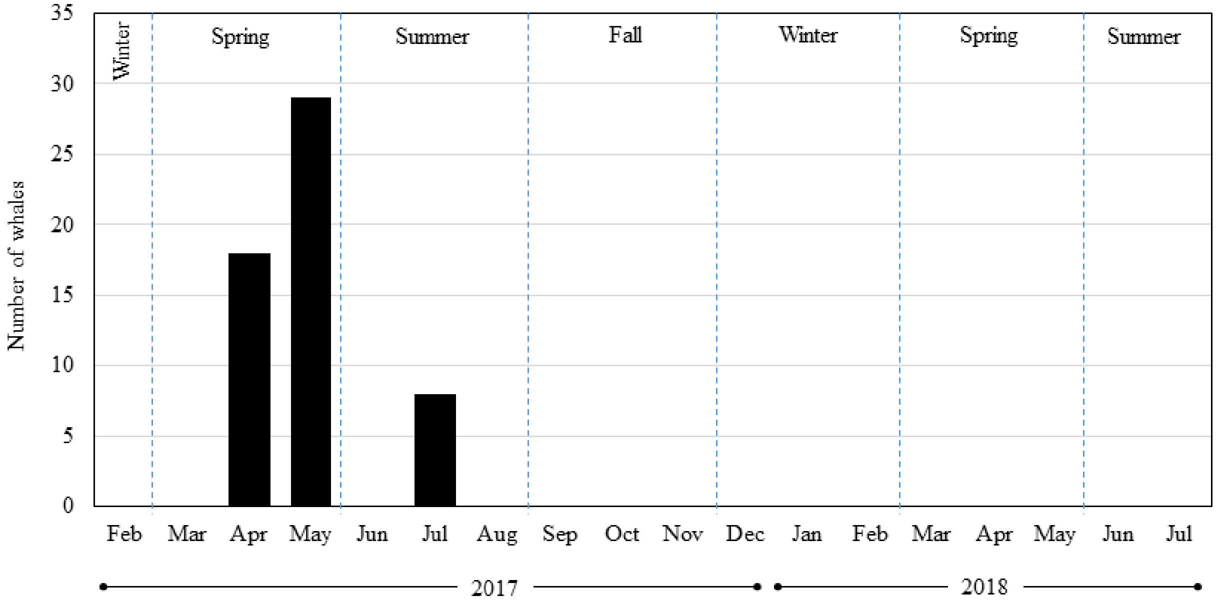


Figure 17. Total number of sei whale (*Balaenoptera borealis*) sightings per month in the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations.

Similarly to fin whales, sei whales were mainly concentrated in the offshore waters south of the study area, in the RIMA WEA, and zones 1 and 2 of MA WEA (Figure 18). However, sei whales were only sighted in the spring and summer and their distribution during those months is different to those of fin whales (Figure 19). Sei whales exhibited the lowest sighting rates (as defined on page 5) of all whale species and even small cetaceans. The sighting rates of sei whales were 1.99 whales/km in the summer and 3.03 whales/km in the spring.

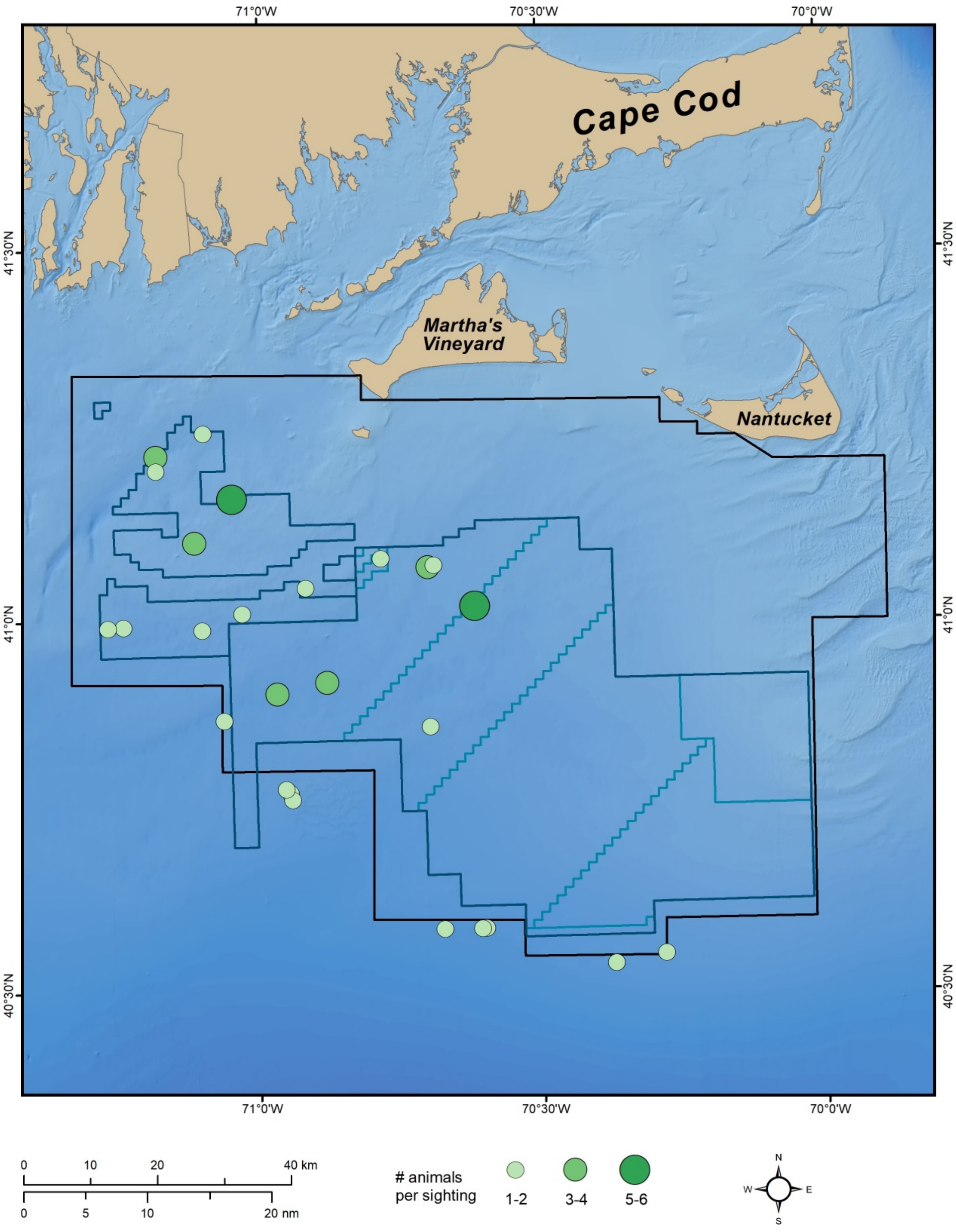


Figure 18. Sightings of sei whale (*Balaenoptera borealis*) in and near the wind energy areas offshore of Massachusetts and Rhode Island in 2017 based on aerial survey observations conducted between February 2017 and July 2018. No sei whales were sighted in 2018. Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

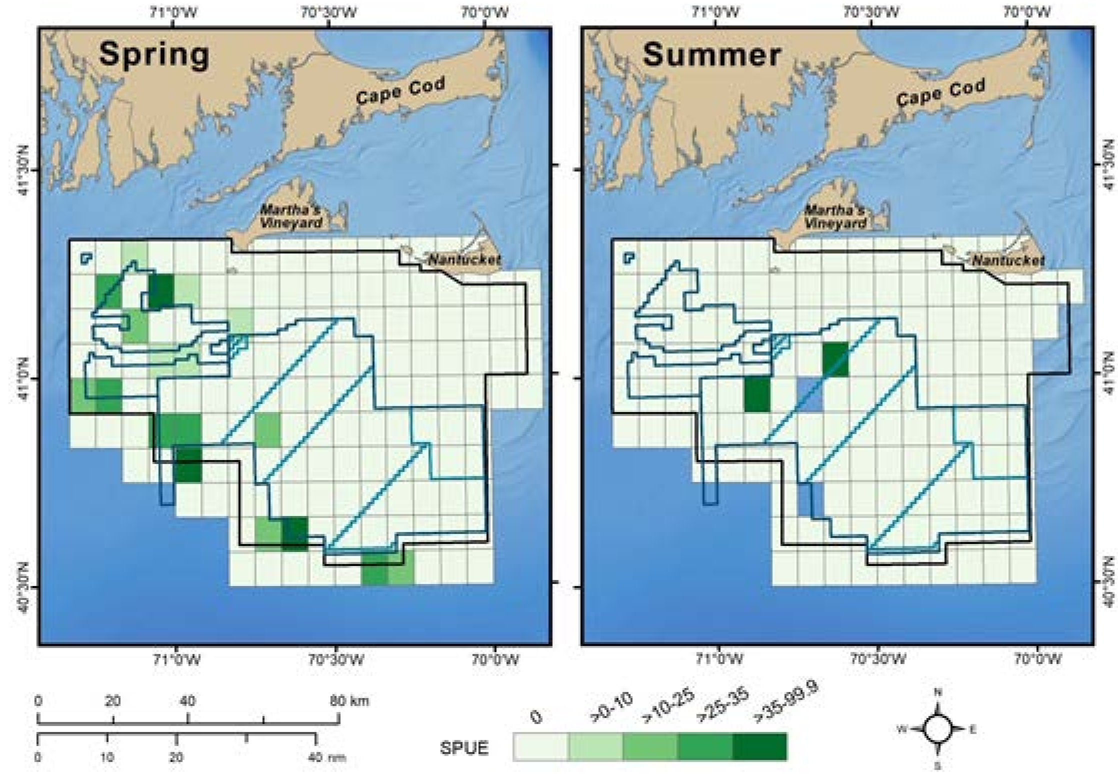


Figure 19. Sightings per unit effort of sei whales (*Balaenoptera borealis*) by 5-min squares shown seasonally in the spring and summer 2017. No sei whales were sighted in the fall-winter 2017 or in January-July 2018. Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

Minke whales (*Balaenoptera acutorostrata*)

Minke whales are the smallest of the baleen whales observed in the study area. Their group size varied from one to five with an average group size equal to 1.37 individuals. They were the second most frequently sighted whale in the wind energy area. One minke whale was sighted in the winter, 38 sightings of 49 minke whales were recorded in the spring, 18 sightings of 31 minke whales were recorded in the summer, and no minke whales were sighted in the fall (Figure 20). The greatest number of sightings occurred in the months of August (2017: n = 27) and May (2017: n = 16; 2018: n = 18) (Figure 20).

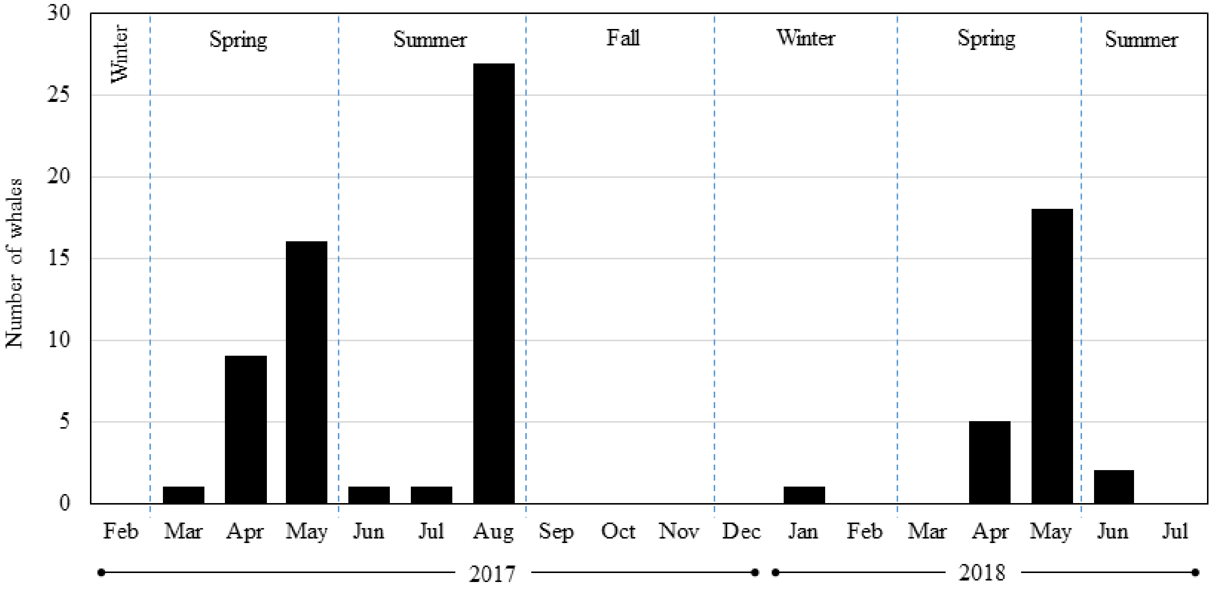


Figure 20. Total number of minke whale (*Balaenoptera acutorostrata*) sightings per month in the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations.

Minke whale sightings were scattered throughout the study area but in 2018, they were mainly inside WEA (Figure 21). Seasonal SPUEs showed that in the spring, the RIMA WEA and in Zone 1 of MA WEA were hotspots for minke whales (Figure 22). Their sighting rates (as defined on page 5) were relatively high in that season (6.72 whales/km). In the summer, few minke whales were also sighted in that area, the whales were more dispersed (Figure 22) and their sighting rate decreased by approximately 50% of that of the spring months (3.40 whales/km). Other whales also had high densities in the RIMA WE and Zone 1 MA WEA areas but the timing was not always the same (spring: sei whales, Figure 19; summer: fin whales, Figure 14).

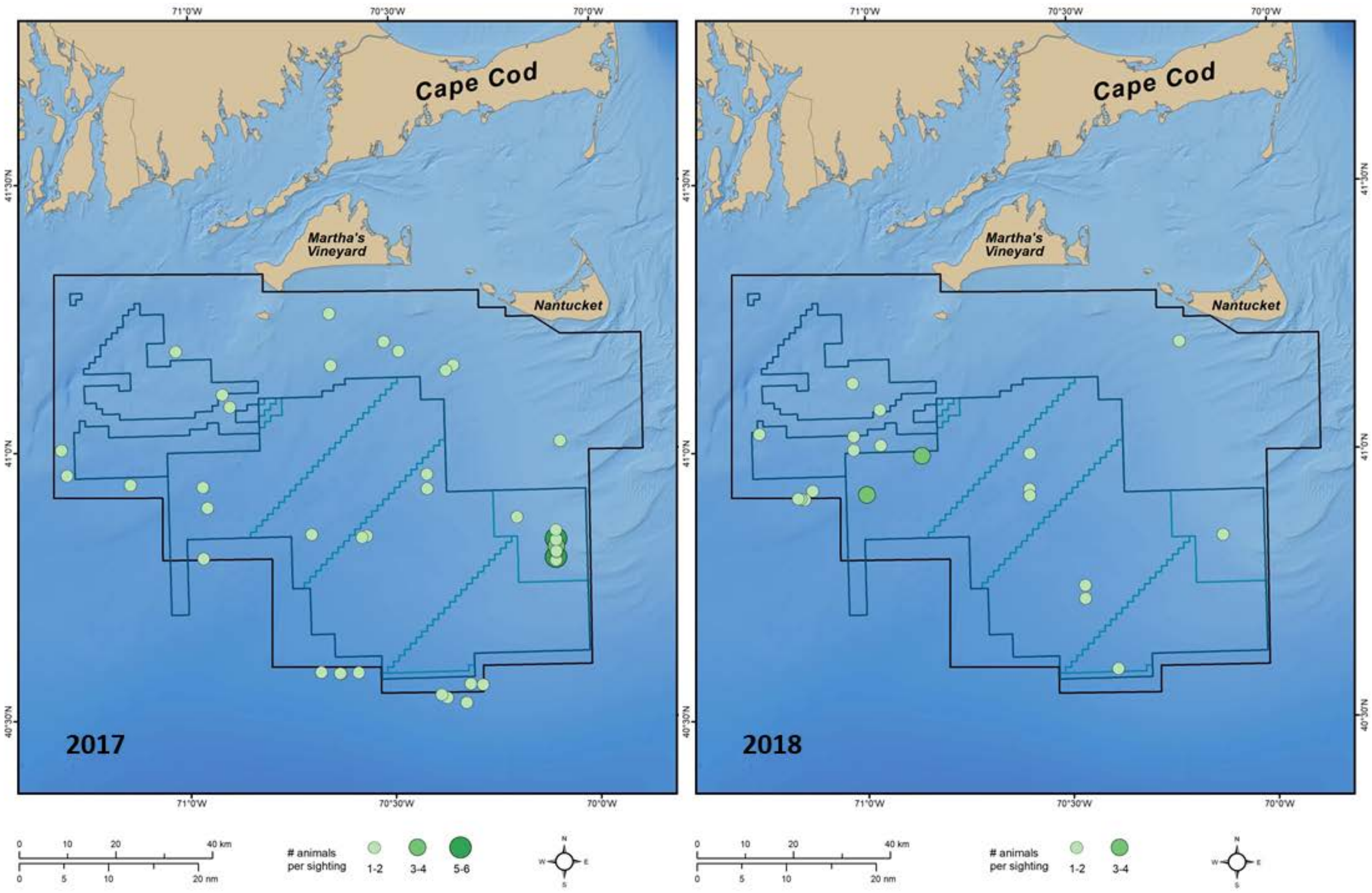


Figure 21. Annual sightings of minke whales (*Balaenoptera acutorostrata*) in and near the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations conducted between February 2017 and July 2018. Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

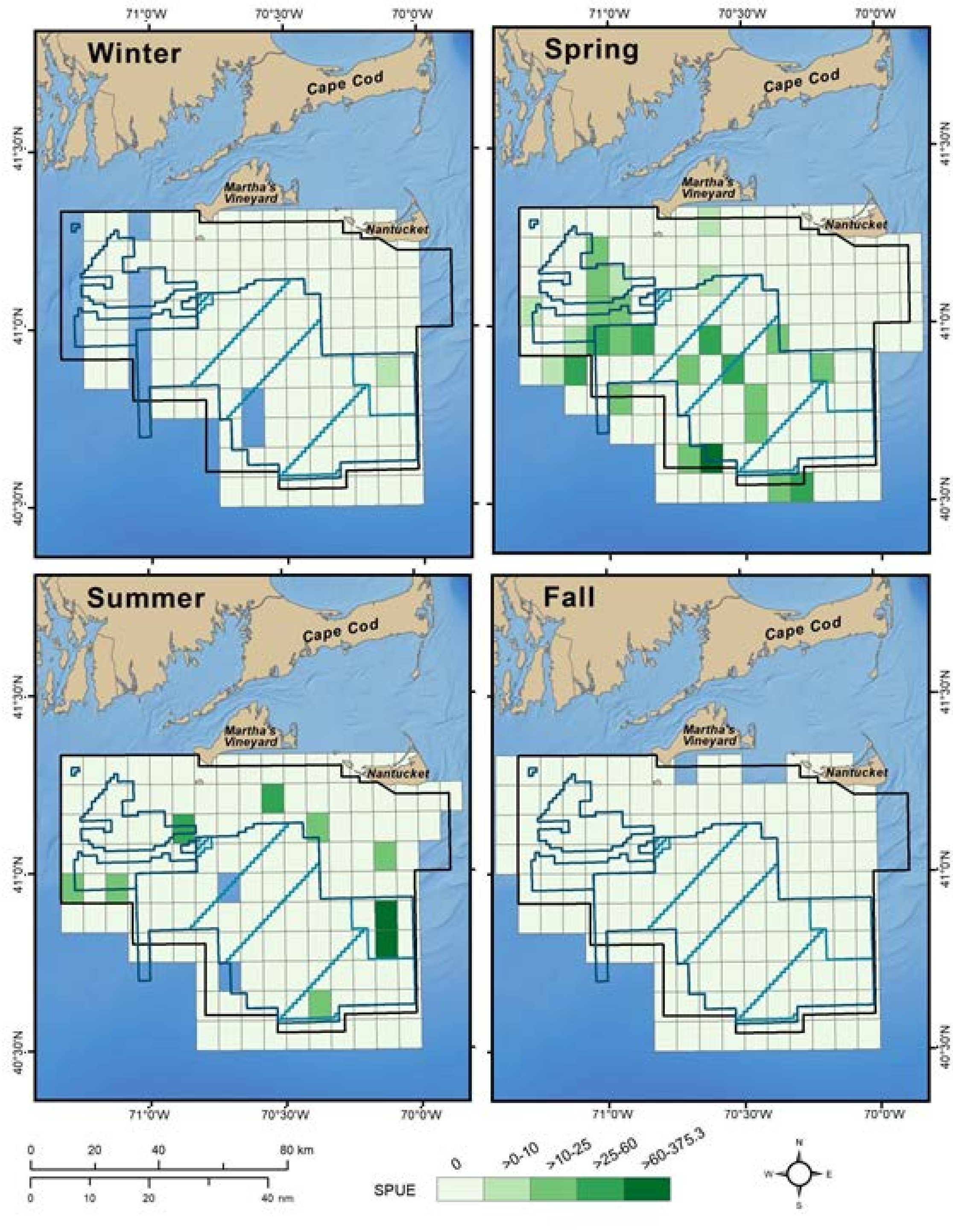


Figure 22. Sightings per unit effort of minke whales (*Balaenoptera acutorostrata*) shown seasonally for all years combined (February 2017 – July 2018). Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

Humpback whales (*Megaptera novaeangliae*)

Humpback whales were sighted on 30 occasions throughout the year and at least once in every season (Figure 23). The highest counts of humpback whales occurred in May 2017 (n = 24) and 2018 (n = 24). Group sized range from one to 20 whales and the largest size included individuals involved in bubble-net feeding. Mean group size was 2 whales.

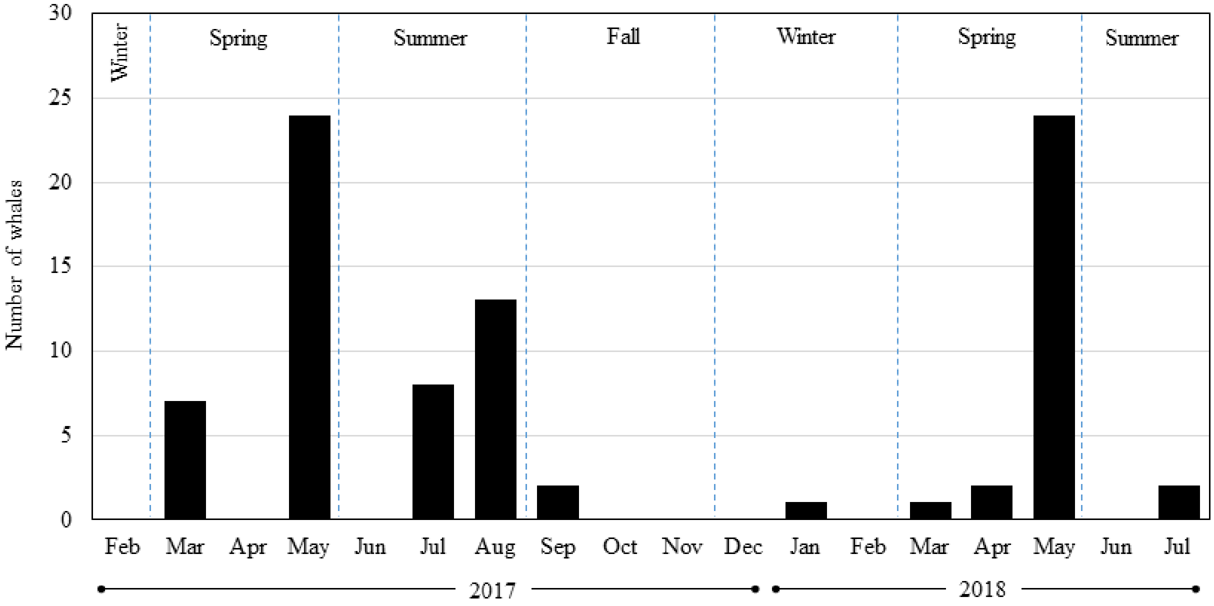


Figure 23. Total number of humpback whale (*Megaptera novaeangliae*) sightings per month in the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations.

Humpback whales had different distribution patterns in 2017 and 2018. In 2017, they were sighted throughout the study area but in 2018, they were sighted only on the western and eastern sides (Figure 24). In the winter and fall, humpback whales were sighted only in the offshore waters. In the spring, the distribution was spread across the entire WEA whereas in the summer, humpback whales were clustered near Cox Ledge (Figure 25). Although the two seasons had different distributions, the sighting rates (as defined on page 5) of humpback whales were similar (spring = 4.26 whales/km; summer = 4.98 whales/km).

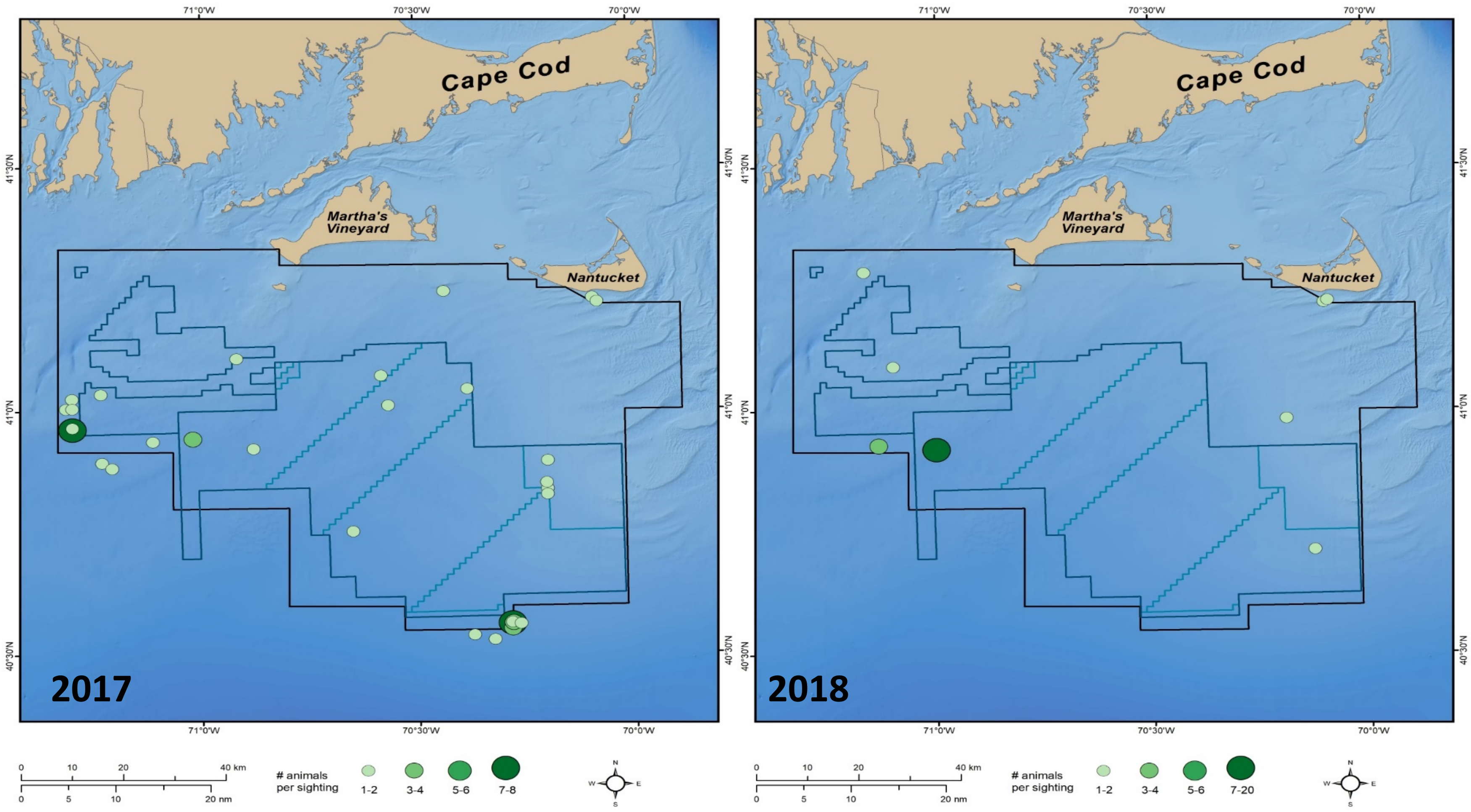


Figure 24. Annual sightings of humpback whales (*Megaptera novaeangliae*) in and near the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations conducted between February 2017 and July 2018. Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

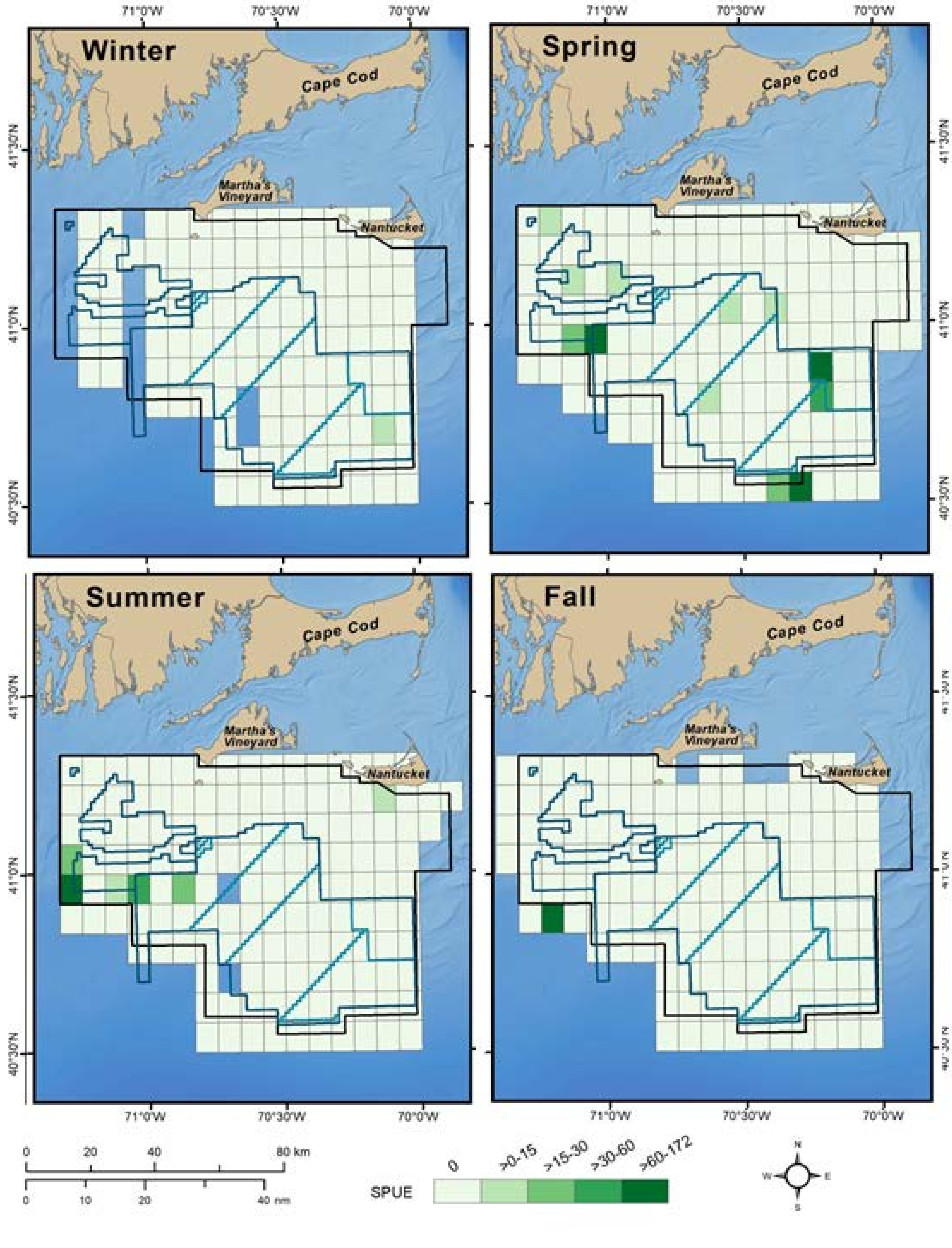


Figure 25. Sightings per unit effort of humpback whales (*Megaptera novaeangliae*) shown seasonally for all years combined (February 2017 – July 2018). Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

Small cetaceans

Sightings of small cetaceans accounted for 36% (n = 127) of all cetacean observations. Four species were identified and belonged to two families, Delphinidae and Phocoenidae. Phocoenidae included harbor porpoises (*Phocoena phocoena*), and Delphinidae included short-beaked common dolphins, bottlenose dolphins (*Tursiops truncatus*), and pilot whales **(***Globicephala* sp.)**.** Common dolphins accounted for 77% (n = 41) of the small cetacean sightings followed by bottlenose dolphins (13%, n = 7), white-sided dolphins (8%, n = 4) and pilot whales (2%, n = 1).

Common dolphins were sighted in 42 occasions and included 1,736 individuals. The majority of those sightings (95%, n = 40) occurred in 2017. Only 7% (n = 2) of the sightings were observed in 2018 (Figure 26). The average group size of common dolphins was 41 and the range was 1 to 300. This species had the largest group size of all cetaceans observed during the study.

Sightings of common dolphins were scattered throughout the study area (Figure 27). Average sighting rates were high in the fall (482.67 dolphins/km), low in the winter (0.56 dolphins/km), and intermediate in the other two seasons (14.88 to 39.80 dolphins/km). In the fall, common dolphins were more concentrated near and in Zone 4 of MA WEA. This could be related to the large group of animals sighted in those offshore waters. There was no clear pattern in the SPUEs of other seasons (Figure 28).

All bottlenose dolphin sightings (n = 7) were recorded in 2017. No bottlenose dolphins were sighted in 2018 (Figure 26). Average group size was 8.5 and the range was 1-35. Harbor porpoises were sighted 15 times and 80% of those sightings were recorded in 2017 (Figure 26). Average group size was 1.28 ranging from 1 to 3. Pilot whales were sighted only one time in April 2017 (Figure 26) in a group of 12 individuals.

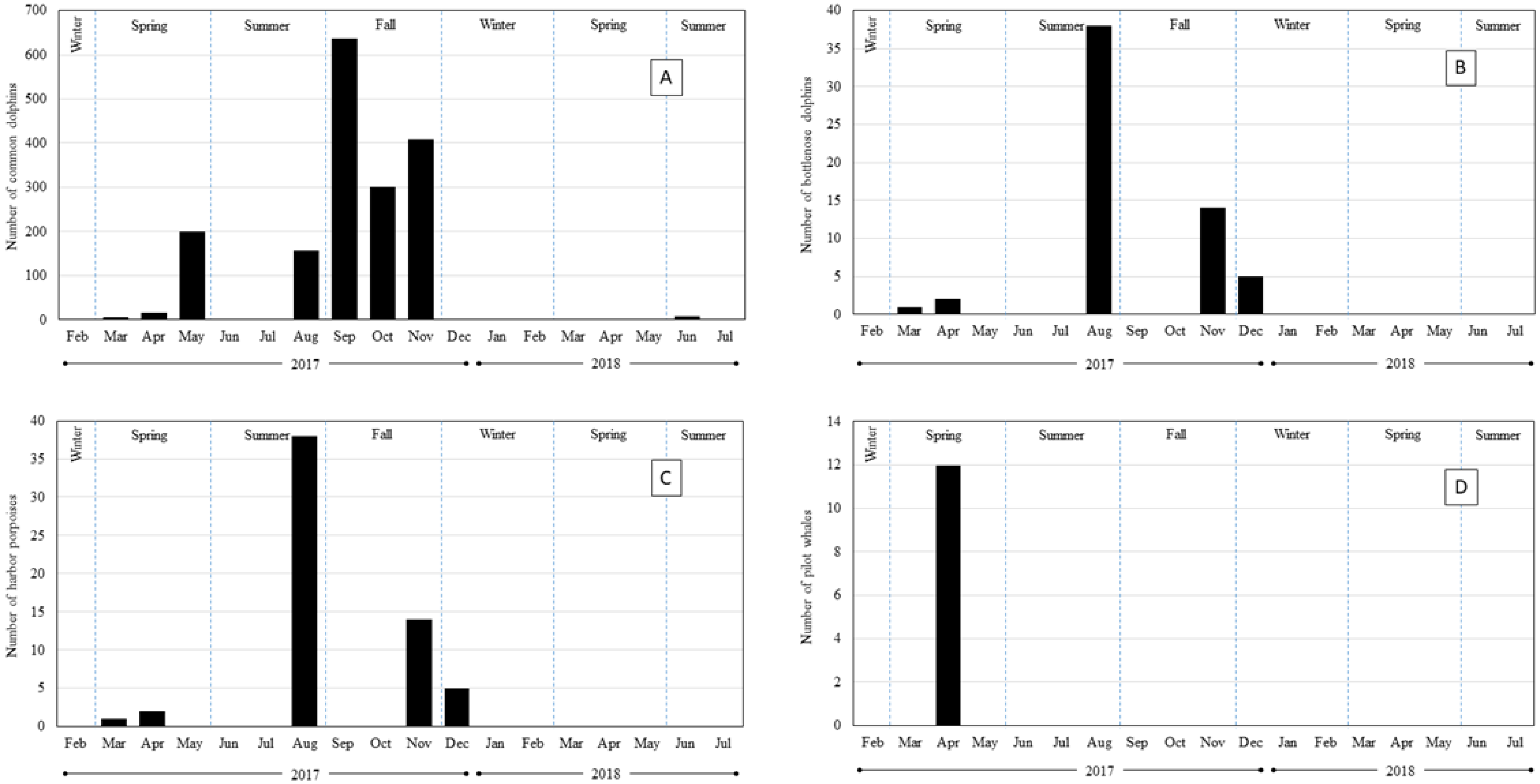


Figure 26. Monthly sightings of A) common dolphins (*Delphinus delphis*), B) bottlenose dolphins (*Tursiops truncatus*), C) harbor porpoises (*Phocoena phocoena*), and D) pilot whales (*Globicephala* sp.) in the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations.

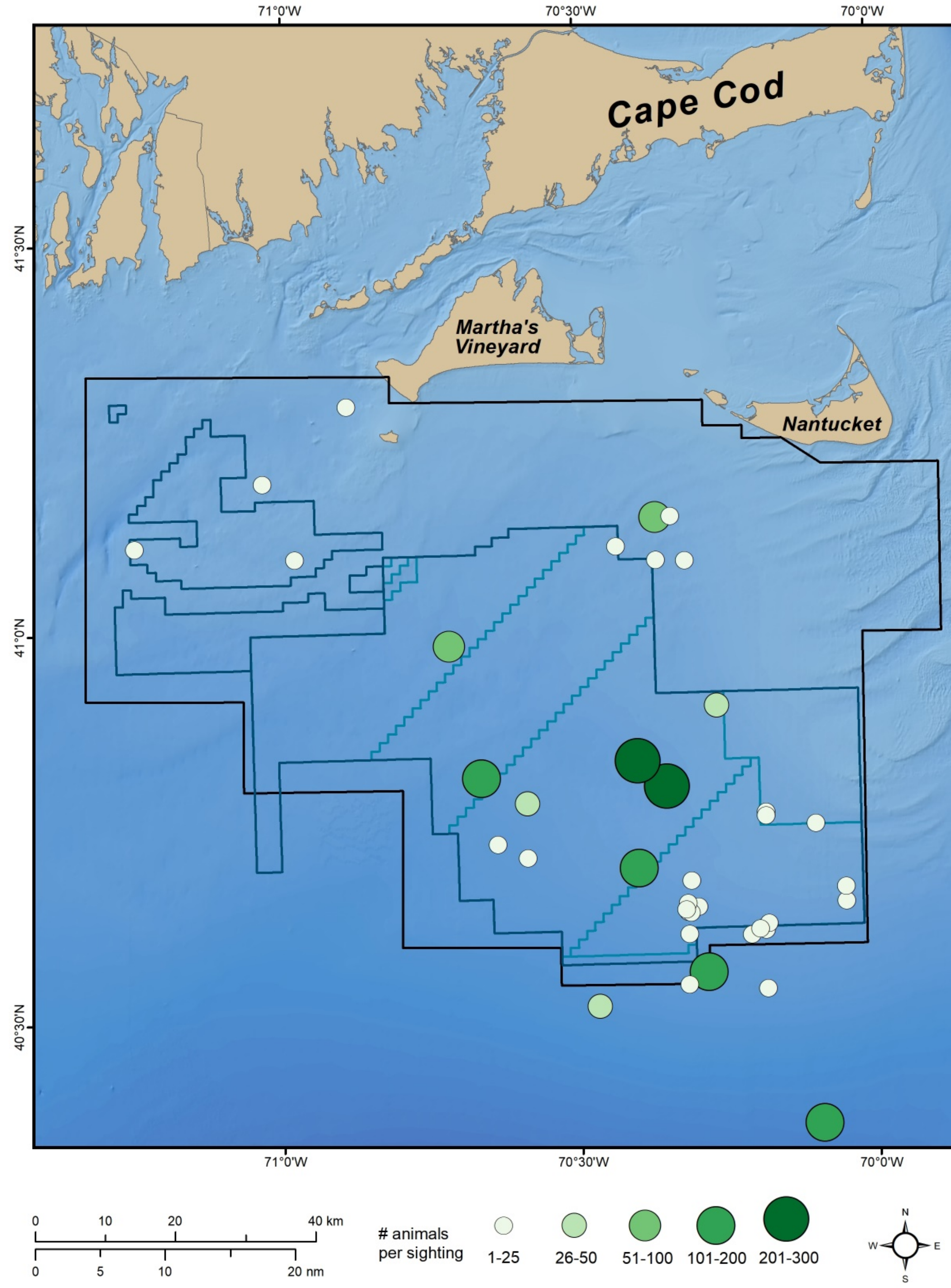


Figure 27. Sightings of common dolphins (*Delphinus delphis*) in and near the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations conducted between February 2017 and July 2018. Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

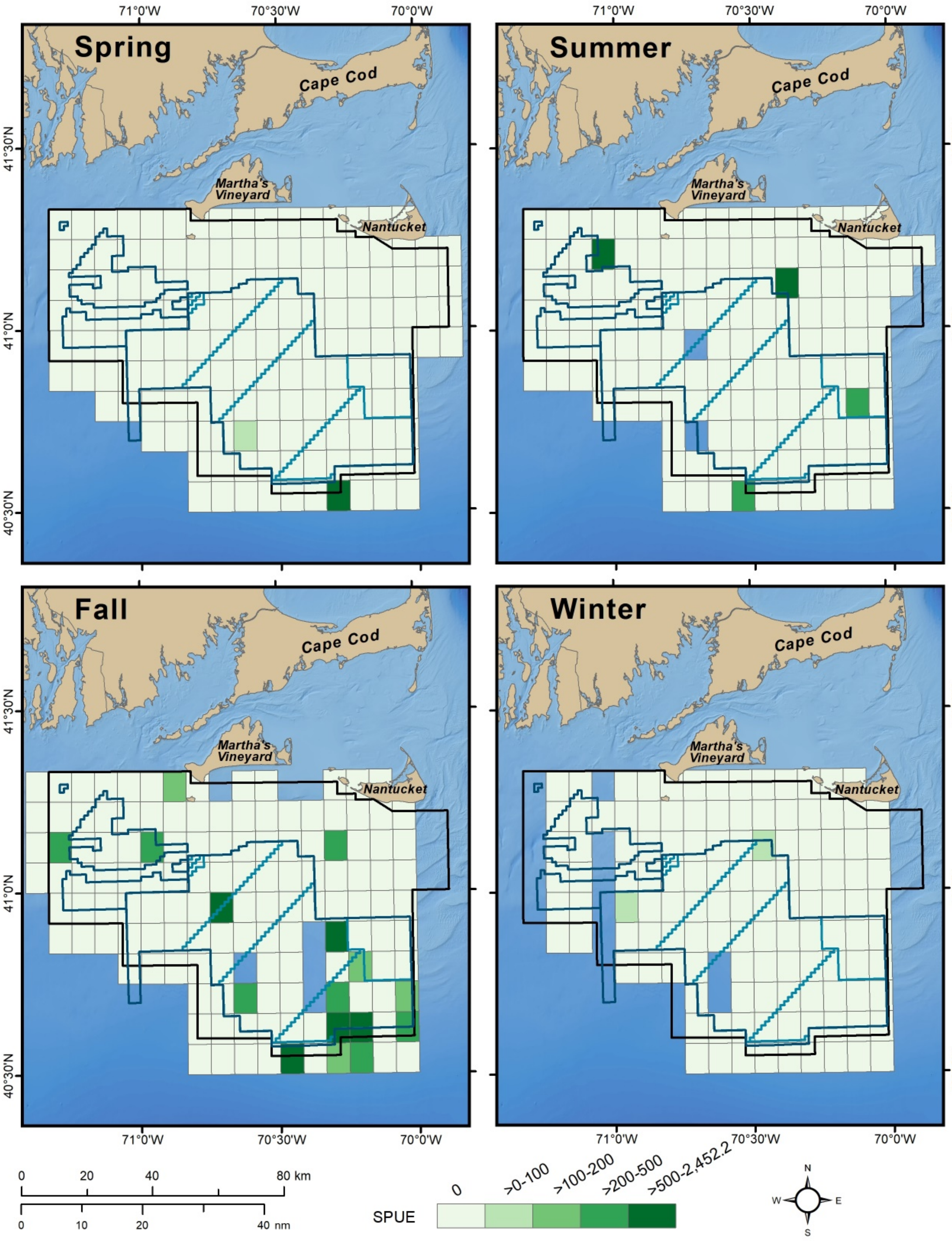


Figure 28. Sightings per unit effort of common dolphins (*Delphinus delphis*) shown seasonally for all years combined (February 2017 – July 2018). Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

Other cetacean sightings

The aerial team spotted three whale carcasses. The first carcass was spotted on May 4, 2017 and it was identified as a decomposing male sperm (Figure 29). The second carcass was spotted later in the month but the species could not be confirmed (Figure 30A). It did not appear to be a right whale based on its body size and the shapes of the mandible and head (Figure 30B). The following month, the NEAq aerial team spotted what it appeared to be the remains of the same carcass near Martha's Vineyard (Figure 30C). The sightings of the carcasses were reported to the U.S. Coast Guard, National Marine Fisheries Services, and the NEAq Rescue Program.

Figure 29. Deceased and decomposing male sperm whale (*Physeter macrocephalus*) observed by the NEAq aerial survey team south of Nantucket on May 4, 2017. Carcass is on its side and the narrow underslung lower jaw and dorsal hump are visible.

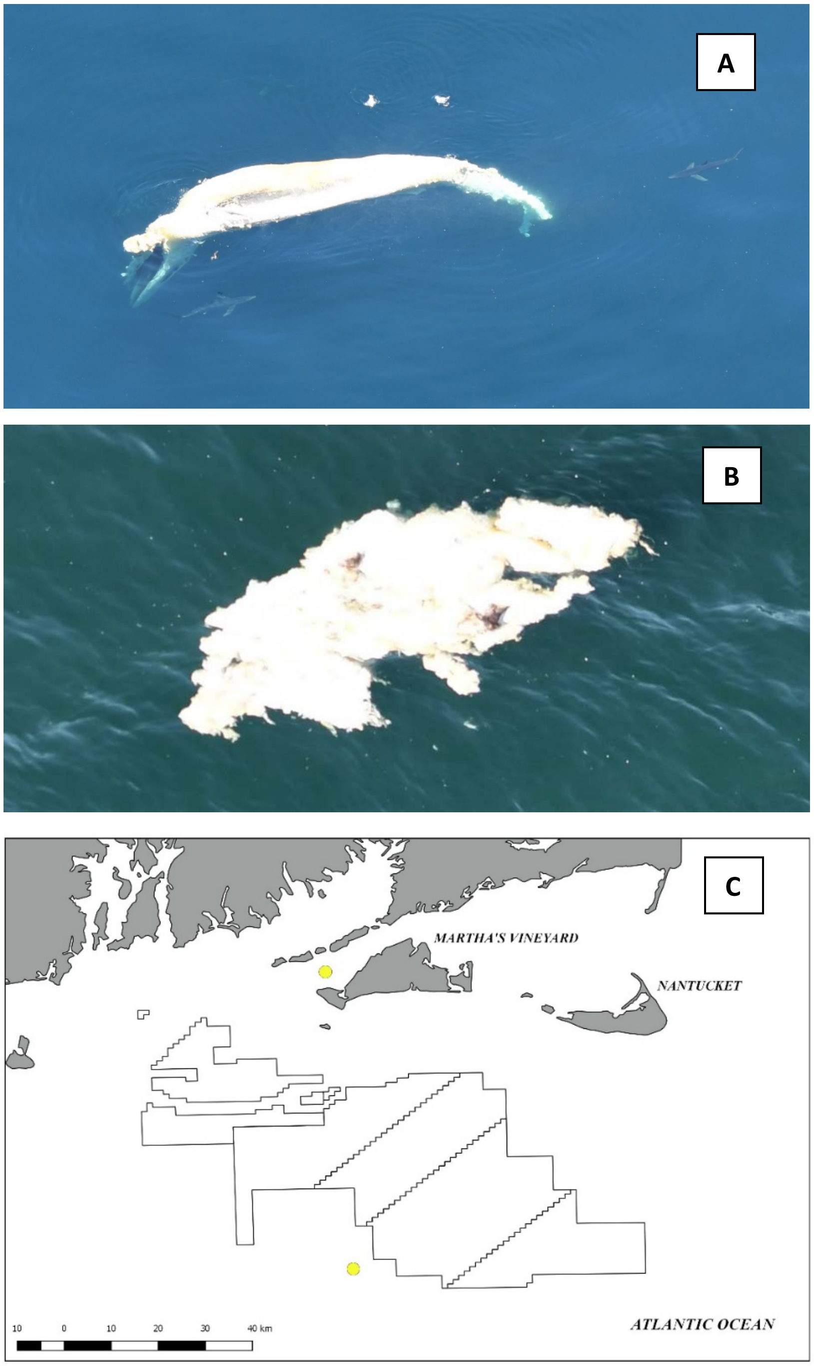


Figure 30. Decomposing baleen whale observed by the NEAq aerial survey team on May 27, 2017 (A) and June 15, 2017 (B). C. Sighting locations of the same carcass. Gray boxes represent the wind energy areas of Massachusetts and Rhode Island.

1.4 Sea turtles

Twenty-four sea turtles including two species were identified. Leatherback turtles (*Dermochelys coriacea*) were the most commonly sighted species (75%, n = 12 sightings of 16 leatherback turtles). Loggerhead turtles (*Caretta caretta*) were sighted only four times (25%). Five other sightings involved five unidentified sea turtles. Except for one sighting, all sightings occurred in May, June, August and September (spring-fall; Figure 31). Combined sighting rates (as defined on page 5) of all sea turtles were high in the summer (4.73 turtles/km), lower in the fall (1.68 turtles/km), and nearly zero in the spring (0.14 turtles/km) and winter (0.28 turtles/km).

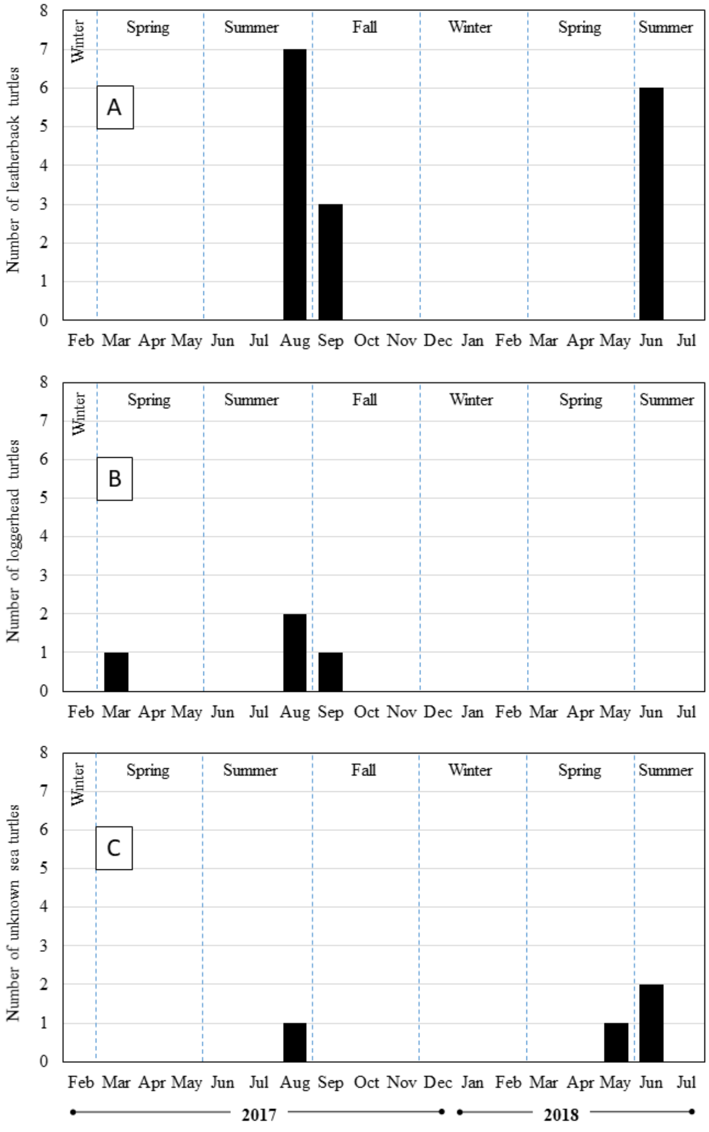


Figure 31. Monthly sightings of A) leatherback turtles (*Dermochelys coriacea*), B) loggerhead turtles (*Caretta caretta*) and C) unknown sea turtles sighted in the wind energy study areas offshore of Massachusetts and Rhode Island based on aerial survey observations.

Leatherback turtles were sighted throughout the study area (Figure 32) but only three sightings ocurred in the wind energy areas. In the case of loggerhead turtles, two of the four sightings were also in the wind energy areas. The combined SPUEs for all sea turtles showed that during the summer and fall, there was a clustering south of Nantucket which was likely due to the higher numbers of leatherback turtles in that area (Figure 33). The sightings tended to be more offshore in the spring and winter months.

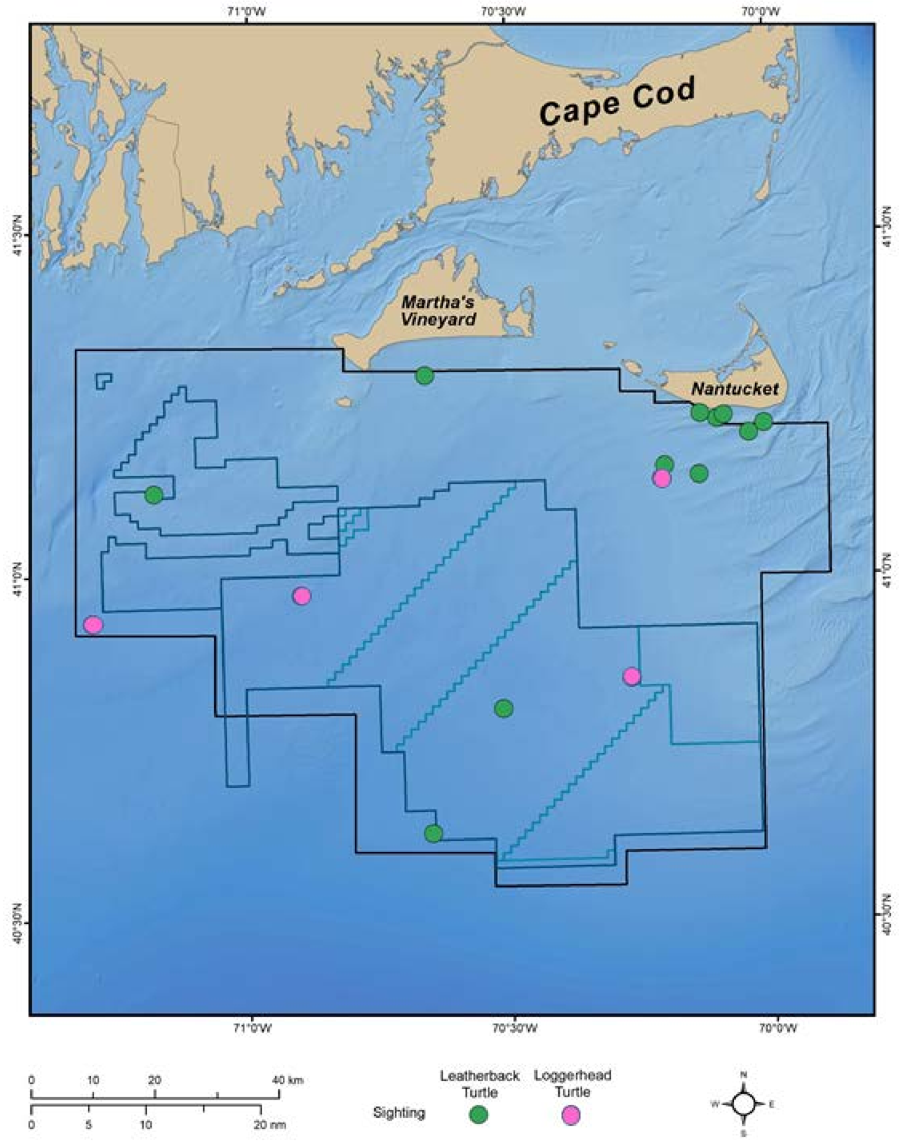


Figure 32. Sightings of loggerhead turtles (*Caretta caretta*) and leatherback turtles (*Dermochelys coriacea*) in and near the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations conducted between February 2017 and July 2018. Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

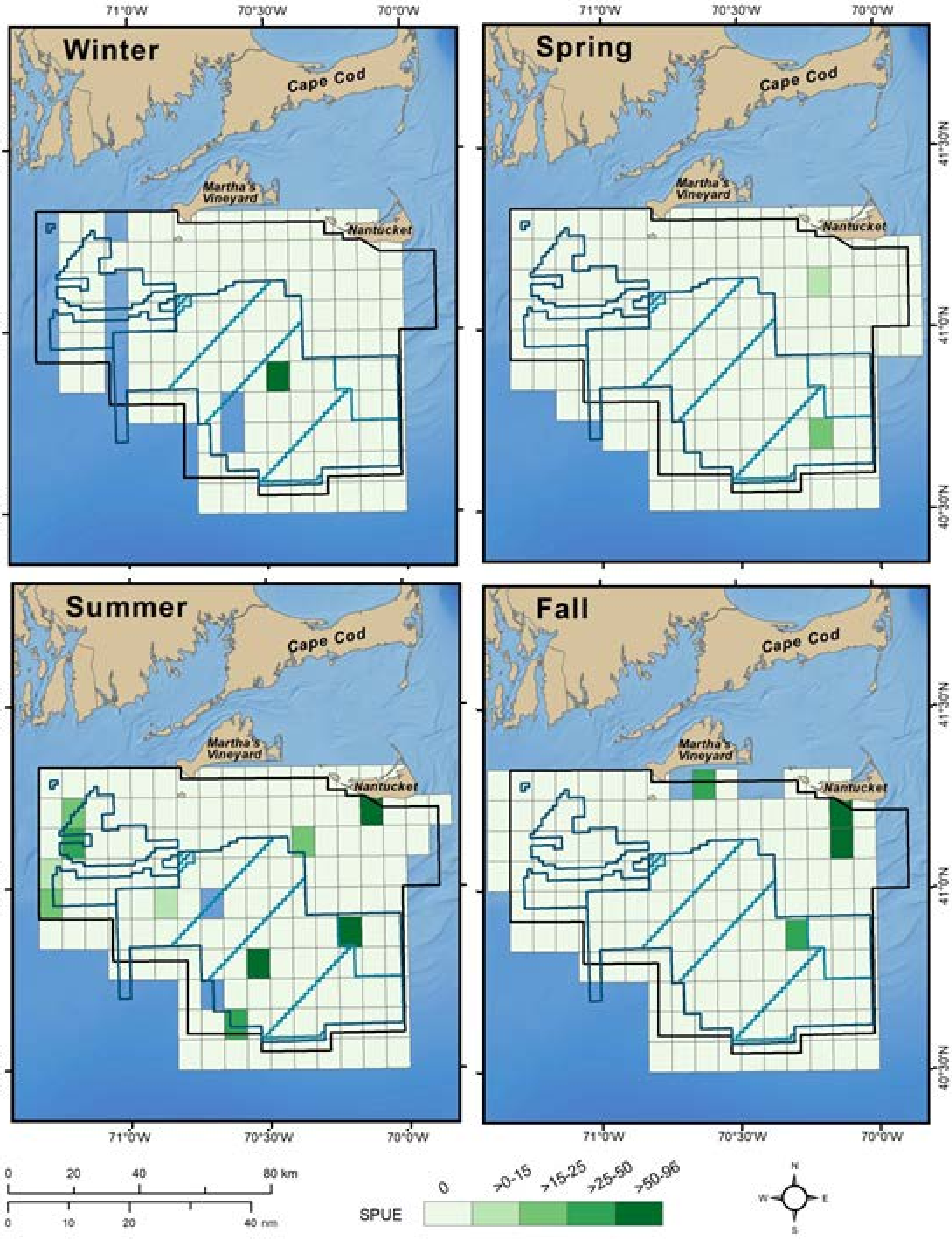


Figure 33. Sightings per unit effort for all sea turtles shown seasonally for all years combined (February 2017 – July 2018). Blue boxes represent the wind energy areas and the black box represents the study area covered by the general and supplementary aerial surveys.

1.5 Other marine megafauna

Other marine species observed included 85 basking sharks (*Cetorhinus maximus*), 26 blue sharks (*Prionace glauca*), one white shark (*Carcharadon carcharias*), four bluefin tuna (*Thunnus thynnus*) and 21 ocean fish (*Mola mola*). Those species were sighted in the late spring and summer (Table 5).

Table 5. Number of individual different species of shark, Bluefin tuna (*Thunnus thynnus*) and ocean fish (*Mola mola*) observed during the aerial surveys conducted in and near the wind energy areas offshore of Massachusetts and Rhode Island based on aerial survey observations.

Year	Month	Basking sharks (*Cetorhinus maximus*)	Blue sharks (*Prionace glauca*)	Great white shark (*Carcharodon carcharias*)	Unidentified sharks	Bluefin tuna (*Thunnus thynnus*)	Ocean fish (*Mola mola*)
2017	February						
	March						
	April	4		1			
	May	8	5		11		
	June				1		2
	July		2		1		
	August		5		36		8
	September		1		6		5
	October						
	November						1
	December						
2018	January						
	February						
	March						
	April						
	May	64	1		7		
	June	9	12		21	4	5
	July				1		

2. OCEANOGRAPHIC SAMPLING

Twelve oceanographic sampling surveys were conducted from February to May 2017 (Table 6). Sampling effort involved nine full day oceanographic surveys, and three half-day surveys.

Table 6. Summary of boat surveys conducted by Woods Hole Oceanographic Institution. Survey types NO = Nomans only, RW = right whale, and FS = full survey.

Date	No.	NO	RW	FS	Time on water (hours)	Standard stations	Near-whale stations
2/14/2017	1	■			4	1	0
2/21/2017	2			■	9	4	2
2/28/2017	3	■			4	1	0
3/06/2017	4			■	9	4	2
3/13/2017	5			■	9	4	2
3/18/2017	6			■	9	4	0
3/28/2017	7			■	9	4	0
4/03/2017	8			■	9	4	0
4/10/2017	9			■	9	4	1
5/04/2017	10	■	■		10	1	3
5/09/2017	11	■			4	1	0
5/11/2017	12			■	9	4	0

The zooplankton sample data were analyzed to elucidate the seasonal progression of zooplankton species composition. Figure 34 shows the temporal species composition of the 49 collected and enumerated samples. The results indicate dominance by *Centropages* sp., including *Centropages typicus* and *C. hamatus*, from mid-February to mid-March. *Pseudocalanus* sp. were also present. Toward the end of March, *Centropages* sp. all but disappeared rather abruptly, only to appear again in mid-May. During this same period, *Calanus finmarchicus* and barnacle nauplii became more important in the zooplankton community. In early May, the observations at the standard stations showed a diverse community composition with no one species dominating.

Near real-time acoustic detections from the Nomans Land DMON buoy (at Station 1) indicated that right whales were present throughout the sampling period (Figure 35a). Relative abundance of right whales over the larger WEA region (Figure 35b) showed similar presence throughout the sampling period, as well as similar temporal variability in right whale presence, when compared to the DMON buoy observations. Interestingly, right whale occurrence (from the DMON buoy) and relative abundance did not change dramatically with the change in zooplankton community composition in late March. While relative abundance increased in mid-April, there were also several days of no right whale sightings in April and May when *C. finmarchicus* was in the study area (Figure 35b). Relative abundance prior to the change in zooplankton community composition was comparable to relative abundance after the change: 0.93 whales per 100 km (stdev = 0.98) in February and March, and 1.03 whales per 100 km (stdev = 1.42) in April and May.

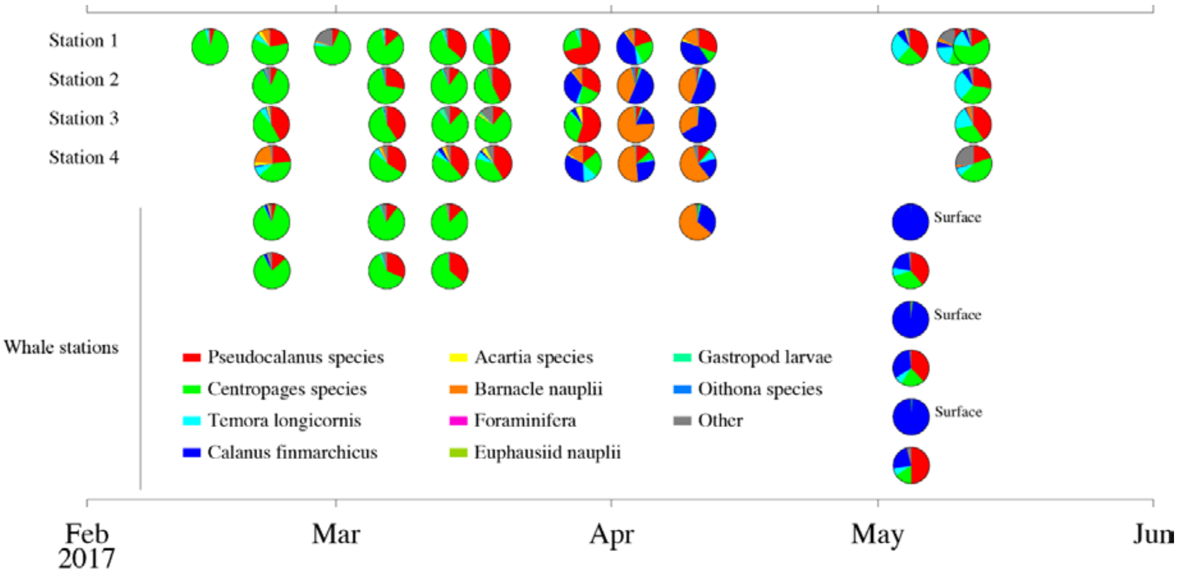


Figure 34. Zooplankton community composition at the four standard stations (upper pie diagrams) and at locations near right whales (lower pie diagrams).

Zooplankton samples collected in proximity to right whales during late February and March (Figure 34) strongly suggest right whales were feeding on *Centropages* sp. and perhaps *Pseudocalanus* sp. as well (although *Pseudocalanus* sp. seemed to be part of the background zooplankton community throughout the entire study period). Sampling near right whales in April indicated a mixed community of *C. finmarchicus* and barnacle nauplii. It is not impossible that right whales were feeding on barnacle nauplii at this time (this has been observed sometimes in Cape Cod Bay); however, it is more likely that right whales had begun to feed on *C. finmarchicus*. Despite the diverse background zooplankton community observed at the standard stations in early May, the sampling near right whales at that time clearly indicated a preference for *C. finmarchicus* by feeding whales. The prey resource and the timing of its availability in the area (*Centropages* and *Pseudocalanus* spp. in March, transition to *C. finmarchicus* in April and early May) were surprisingly similar to that observed in Cape Cod Bay (Mayo and Marx 1990, DeLorenzo Costa et al. 2006).

Some *C. finmarchicus* occurred in the region throughout the study period, but abundances did not grow large until April. The proportion of developmental stages (Figure 36) can help understand how the life history of *C. finmarchicus* may influence their availability in the region. In late February and March, *C. finmarchicus* was mostly in the later copepodid stages, primarily C4, C5, and adult (C6) stages. These were most likely first-of-the-year copepods that spawned in December or January and grew up throughout the winter. Abundances of *C. finmarchicus* were relatively low in the study area at this time. This first generation spawns a second generation, which appeared in the data as the increasing percentage of young copepodid stages, primarily C2 and C3, during early April. Being the second generation of the year, it was much more abundant than the first. Right whales likely began feeding on the second generation of copepods in the study area by mid-April when the second generation reached the C4- C5 stages (*C. finmarchicus* stages that can be efficiently filtered by right whale baleen). By early May, much of the *C. finmarchicus* population was in the C4-C5 stages, and right whales were actively feeding on them (Figure 34).

Observations from the conductivity-temperature-depth instrument at Station 1 indicated that the water column was well mixed during February, March, and early April (Figure 37). The well-mixed water column changed temperature and salinity regularly, likely from heating/cooling at the surface (temperature) and precipitation/runoff (salinity) mechanically mixed throughout the water column from the wind during frequent storm events in late winter and early spring. The onset of stratification occurred in late April or early May, and by May 11, the water column was structured as a two-layer system, with warm fresh water at the surface and cooler saltier water at the bottom. The changes in the water column likely have little to do with the arrival of *C. finmarchicus* in the area, as *C. finmarchicus* are transported from elsewhere (likely the Gulf of Maine).

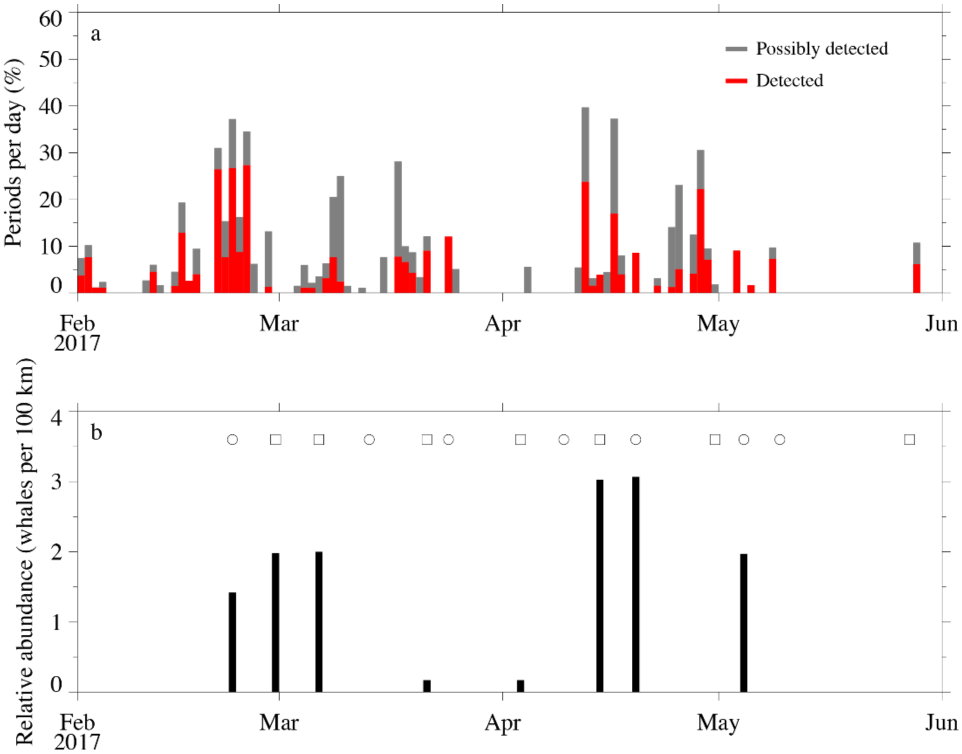


Figure 35. (a) Near real-time detections of right whales at the Nomans Land DMON buoy deployed at standard station 1. The bar height indicates the percentage of nominal 15-min periods monitored during the day when right whales were either detected or possibly detected. (b) Relative abundance of right whales from NEAq aerial surveys. Relative abundance = number of whales encountered on effort when Beaufort ≤4 sea state and < 2 miles visibility divided by the amount of trackline surveyed during the same conditions. Open circles = days with condensed surveys, and open squares = days with general surveys.

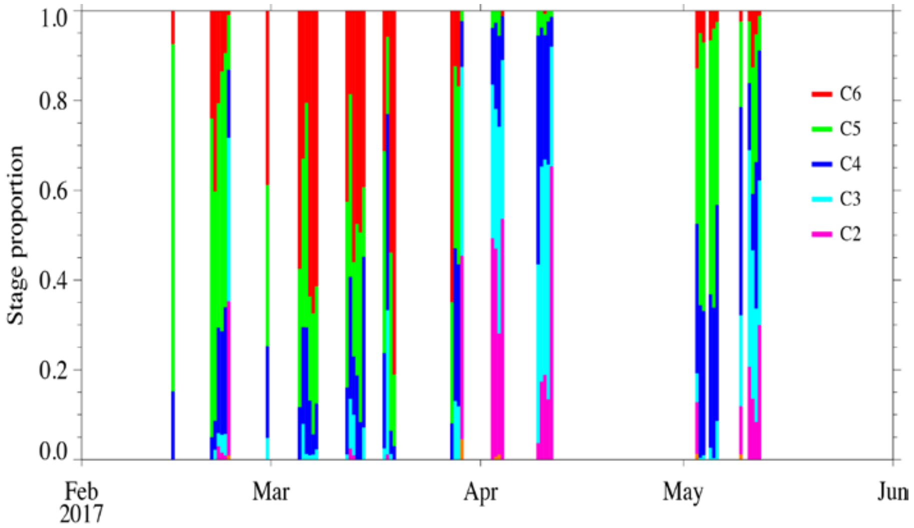


Figure 36. Proportion of developmental stages for *Calanus finmarchicus* collected. Each vertical stripe is a single zooplankton sample. Stripes immediately adjacent to one another were collected on the same day. Data from standard and whale stations are shown together.

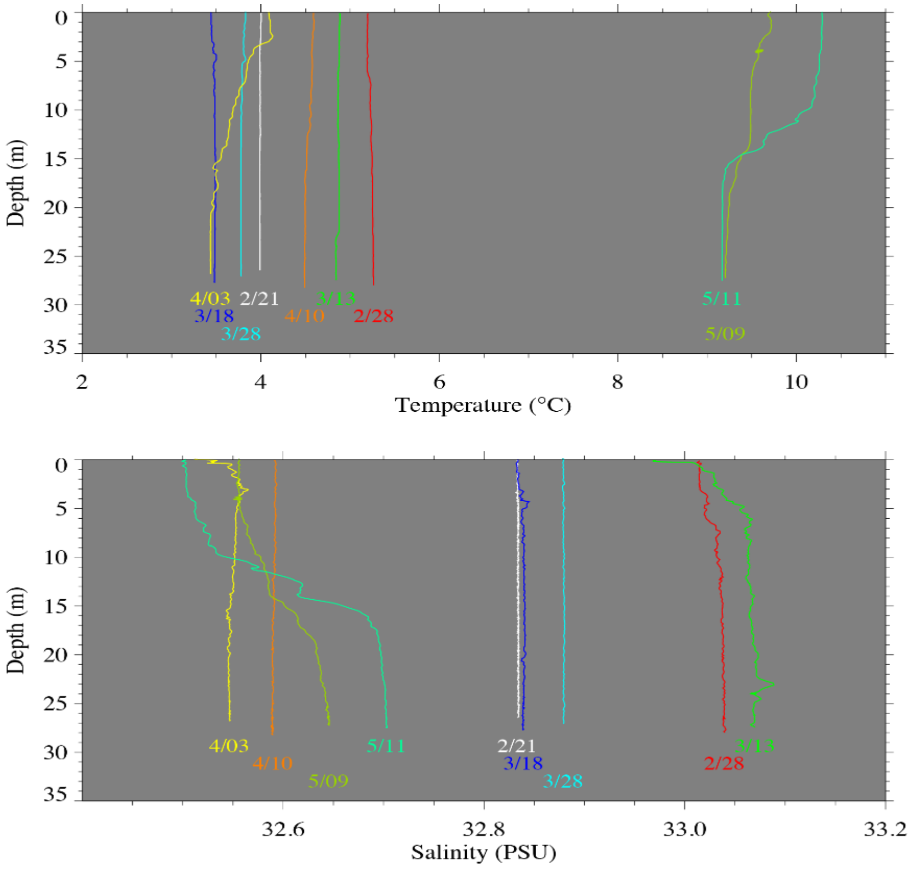


Figure 37. Temperature and salinity profiles collected at standard station 1 (collocated with the Nomans Land DMON buoy). The water column was well mixed throughout February, March, and early April. Stratification was not observed until May. Note: there was a gap in sampling between April 10 and May 9, 2017.

DISCUSSION

The on-going surveys continue to reveal important information on marine mammal and sea turtle distribution and relative density in the offshore waters south of New England. Observations of feeding (by all whale species and small cetaceans) and courtship (right whales) indicate that the study area is used by multiple species for activities that support their survival. In the case of the critically endangered right whale, a larger number of whales were identified in 2017-2018 in comparison with previous years (average SPUEs for all seasons 2017 – 2018 = 11.35; average SPUEs for all seasons 2011 – 2016 = 1.97, Leiter et al. 2017). Further, right whale sightings were not restricted to the winter and spring months as previous data suggested (Leiter et al. 2017). Instead, right whales were sighted throughout the year in the study area, including during the summer months at lower densities directly south of Nantucket. In other nearby locations (e.g. the coastal water of Rhode Island), they have also been reported opportunistically throughout the year (Kenney and Vigness 2010). In our study area, during the winter and spring months, the average sighting rates for right whales were higher than previously reported (Leiter et al. 2017). One feature of the results from both recent, i.e. campaign 4, and past surveys (campaigns 1-3) is that adult male right whales are the most common demographic group found in the study area, which is consistent with the male biased population sex ratio (Pace et al. 2017).

Right whale sightings in several traditional feeding habitats began to decline in 2012, causing speculation that a shift in right whale habitat usage was occurring (Meyer-Gutbrod et al. 2018). Scientists speculate that the shift was related to climate change and to changes in prey availability. In the study area, the high numbers of right whales, as indicated by the high SPUEs values, could be part of those changes as the species. In the winter, right whales were sighted at rates over three times those observed in previous years (Stone et al. 2017). However, their seasonal distribution within the study area during the winter and the spring months did not chnage. As in previous reports (Leiter et al. 2017), we found that right whales concentrate on the eastern portion of the area, near Nantucket shoals, as they start to appear in the winter. In the spring, right whale sightings increased across the northern portion of the MA WEA and south of RIMA WEA. In the summer, small numbers were found in the nearshore waters south of Nantucket, and in the fall, two whales were observed near Nantucket shoals. A preliminary analysis of the movements of the individual right whales identified in the WEA and sighted in at least one other location in the same year, indicates that some right whales had travelled from Cape Cod Bay (between January and April) and the Gulf of Maine (between November and January).

Right whales movements between feeding grounds might reflect the movement and availability of their prey based on oceanographic conditions and currents. In the study area, the results of the oceanographic surveys suggest that the primary prey of right whales is *Centropages* sp. in February and March, and late-stage *C. finmarchicus* in April and May. It seems likely that seasonal abundance and life histories of these two species have a strong influence on the occurrence of right whales in the MA WEA. This zooplankton community composition is similar to that of Cape Cod

Bay, which has long been recognized as a significant feeding, socializing, and nursery area for right whales (Mayo et al. 2018).

The similarities between the WEA and Cape Cod Bay with respect to oceanographic conditions, zooplankton community composition, and right whale occurrence were striking. However, questions remain about the relative use of the two areas. Cape Cod Bay appears to be more heavily frequented by right whales than the WEA. Our limited sampling in the WEA makes it difficult to directly compare zooplankton abundances with those observed for decades in Cape Cod Bay to explain this discrepancy, but it certainly appears that there are sufficient zooplankton resources in the WEA to attract right whales. Whether there is more prey available in Cape Cod Bay, or whether the prey resource remains consistently available over a longer period of time will require further study. Nevertheless, the 2017 oceanographic sampling was extremely informative, providing a general sense of the progression of the zooplankton community throughout the late winter and spring as well as an indication of the feeding preferences of right whales in the WEAs. It will likely take several years of data collection to understand the seasonality, variability, and oceanographic drivers of the zooplankton community composition in the WEA's.

In this study, right whales had highest relative densities of any whale species. Stone et al. (2017) reported that fin whales had the highest abundance of any large whale for any season in the period from 2011 - 2016 in the study area. Kenney and Vigness (2010) also suggested that fin whales were the most abundant whale in the southern New England waters. However, in this study, the average density of fin whales was similar to those of minke and humpback whales. Further, the density of all other whales (except for humpback whales) was at least twice and up to five times higher during their peak season than those densities reported by Stone et al. (2017). The higher numbers of right and other whales in the study area likely reflect changes in the environment, since some species occurred at times of year or in higher densities than what we expected from the previous surveys. This high variability between earlier surveys and the more recent ones suggest that more aerial survey work may be needed to determine if these are a temporary trends or a more permanent change within the study area.

Among the balaenopterids, fin whales had highest densities in the summer, while humpback, minke and sei whales had higher densities in both the spring and summer months. These three species had a noticeable peak in May of 2017, with sightings co-occurring in the western portions of the MA WEA, suggesting the possibility of a common prey species at that time. Sei whales were the least common whale species in the WEAs and they were primarily sighted in the spring. According to Kenney and Vigness (2010), most sei whale sightings in the southern waters of New England occur offshore from the middle of the continental shelf to the shelf break and slope. The shelf south of New England is about 80 nm wide and the mid-shelf is about 40 nm (R. Kenney pers. comm.). This might explain their infrequent occurrence in the WEA.

Over the 18-month survey period, fall and winter sightings of rorqual whales, ranged from zero to two for all species combined. As in the case of right whales, the presence of rorquals in the

WEAs is likely to be food dependent. Rorquals in the common name for members of the Balaenopteridae family including blue, Bryde’s, fin, humpback, minke and sei whales). Massachusetts waters are a known major feeding ground for many large whales (Kenney and Vigness 2010) and their distribution is likely to reflect the distribution and abundance of their prey. Minke whales were widely dispersed throughout the study area, especially during the spring months. The other rorquals were typically more concentrated farther from shore, closer to the southern border of MA WEA and near Cox Ledge.

Small cetacean sightings occurred less frequently than large whales but they usually involved the largest numbers of animals. Common dolphins were the only small cetacean species sighted in both years of surveys. Kenney and Vigness (2010) suggested that the species has an atypical seasonal pattern off the northeastern United States with peak abundance in winter, which is different from all other dolphin species. However, this was not the pattern observed during this study period. The density of common dolphins was higher in the fall and summer months and low in the winter. Stone et al. (2017) reported the similar high densities of common dolphins in the fall and summer. Other small cetaceans such as pilot whales were only sighted once during the study. Bottlenose dolphins and white-sided dolphins were mainly seen in the spring of 2017. similar to the temporal pattern previously reported for the area (Stone et al. 2017).

In contrast to Kraus et al. (2016), only two species of sea turtles were identified in this study period and their numbers were very low. Sixteen leatherback turtles and four loggerhead turtles were sighted, with some clustering south of Nantucket. No Kemp’s ridley sea turtles (*Lepidochelys kempii*) were detected by the observers or in the vertical camera photographs but their occurrence record may be under-represented for two reasons. First, they are typically very small, approximately the size of a dinner plate (28 cm; Dodge et al. 2008, Liu et al. 2018) and thus, they might not be easily sighted by the aerial observers. Second, they tend to use shallow bays and estuaries that are usually excluded from survey designs (Kenney and Vigness 2010). It is unclear if the low numbers of sightings for all sea turtle species reflect a change in environmental conditions. However, it is interesting that their combined totals were highest in the summer and not in the fall as reported in the previous surveys (Kraus et al. 2016).

Other marine fauna identified during the aerial surveys included three species of sharks including basking sharks, blue sharks and white sharks. Shark identification depends upon clear views of body parts, which can be difficult to see when they are beneath the surface, so 44% of shark sightings were not identified to the species level.

The high biodiversity of marine fauna highlights the biological importance of the study area, including the WEAs. The high variability in abundance and locations of the marine mammals and sea turtles between the early study period (2011-2015) and the recent years (2017-on going), suggests the need to identify the factor(s) affecting those changes. In the case of right whales, if the increasing trend continues in the coming years, a variety of stringent safety standards for construction and vessel traffic will be needed. Management strategies related to wind related construction activities may be dependent upon understanding, and perhaps predicting, the peak occurrence season for a number of the species. The effects of windfarm construction operations on large whales and sea turtles are unknown. For example, there are no published studies of the impact of pile-driving operations on marine species such as right whales. Studies on the impact of air guns on another balaenid mysticete, the bowhead whale *(Balaena mysticetus*) do exist. Richardson et al. (1999) showed that most migrating bowheads avoided air guns at a range of about 20 km at received levels ranging from ~116 to 135 dB (RMS) re 1 μPa. Madsen et al. (2006) suggested that right whales may show avoidance responses to transient signals from the pile-driving above 120 dB (RMS) re 1 μPa. They also suggested that pile-driving has the potential to affect right whales over large ranges, depending on the propagation conditions.

The effects on marine mammals and other marine megafauna from constructing and operating offshore wind farms is not fully understood, especially at the scale of projects proposed for the Massachusetts and Rhode Island wind energy areas. Peer-review studies have focused on only two small cetaceans (the harbor porpoise *Phocoena phocoena* and the bottlenose dolphin *Tursiops truncatus*; Thompson et al. 2010, Bailey et al. 2010, Vallejo et al. 2017, Wingfield et al. 2017) and two pinnipeds (the harbor seal *Phoca vitulina* and the ringed seal *Phoca hispida*; Edren et al. 2004, Thomsen et al. 2006). The on-going aerial surveys in the Massachusetts and Rhode Island offshore waters provide important baseline information on the distribution and abundance of the different species that occur there. However, additional studies designed to examine the consequences of acoustic exposure to construction noise are needed. Work is also needed to determine if wind farms alter the physical characteristics of the environment such as current patterns, causing displacement of whales to other areas. Studies before, and during construction, and after full operations have commenced, will help address questions about wind farm effects on large whales and sea turtles, and can be used to enhance best practices for alternative energy development in the ocean.

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APPENDIX

APPENDIX 1: Sightings and demographics of North Atlantic right whales preliminary identified. Note: A = adult, J = juvenile, M = male, F = female, U = undetermined.

|-------------------------- 2017 ----------------|----------- 2018 ----------|

EGNO	SEX	A/J	Age	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
1048	M	A	U	■													■			
1052	M	A	U															■		
1218	M	A	U			■														
1270	M	A	U		■															
1272	M	A	U						■											
1328	M	A	U												■					
1607	M	A	31			■														
1608	F	A	32																	■
1627	M	A	U	■		■	■													
1711	F	A	31												■					
1804	M	A	30												■					
1901	M	A	29												■					
1911	F	A	28			■														
1970	F	A	U			■									■					
2010	M	A	28													■				
2057	M	A	28			■														
2145	F	A	26			■														
2201	M	A	25		■				■											
2340	M	A	U		■															
2410	M	A	U										■							
2430	F	A	U			■														
2520	F	A	U			■														
2541	M	A	22			■														
2602	M	A	21			■														
2746	F	A	20				■													
2750	M	A	21														■			
2753	F	A	20		■															
2810	M	A	19	■																
2930	M	A	U															■		
3020	F	A	U	■																
3110	M	A	U			■														
3120	M	A	17												■					
3130	F	A	16	■																
3139	F	A	17						■											
3180	F	A	17												■					
3232	F	A	16												■					
3245	M	A	15		■															
3260	F	A	U			■														
3270	F	A	U		■															

APPENDIX 1 (continuation): Sightings and demographics of North Atlantic right whales preliminary identified. Note: A = adult, J = juvenile, M = male, F = female, U = undetermined.

|-------------------------- 2017 -----------------|----------- 2018 ----------|

EGNO	SEX	A/J	Age	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
3290	F	A	U			■														
3310	M	A	U			■														
3320	F	A	U													■				
3340	M	A	U			■														
3350	M	A	14		■															
3351	M	A	15													■				
3370	F	A	14		■															
3380	M	A	U			■														
3390	F	A	U												■					
3391	M	A	U												■					
3421	M	A	14			■														
3430	F	A	14			■														
3510	M	A	13												■					
3541	M	A	12			■														
3545	M	A	13													■				
3580	M	A	13			■														
3617	M	A	11			■														
3640	M	A	U			■														
3650	F	A	11		■															
3660	M	A	12														■			
3680	M	A	13			■														
3693	F	A	U		■															
3701	M	A	11		■															
3712	M	A	10	■																
3740	M	A	11													■	■			
3742	M	A	11			■														
3745	M	A	10			■														
3746	M	A	10	■																
3760	F	A	11													■				
3808	F	A	10	■	■															
3820	F	A	10														■			
3821	U	A	9	■																
3830	M	A	9						■							■				
3832	M	A	9	■																
3843	M	A	9		■															
3903	F	J	8	■																
3951	M	J	8						■											
3970	M	A	9			■														■

APPENDIX 1 (continuation): Sightings and demographics of North Atlantic right whales preliminary identified. Note: A = adult, J = juvenile, M = male, F = female, U = undetermined.

|-------------------------- 2017 -----------------|----------- 2018 ---------|

EGNO	SEX	A/J	Age	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
3989	M	A	9	■																
4030	F	J	7	■		■														
4040	U	A	U		■															
4050	F	J	8														■			
4060	M	J	8															■		
4091	F	J	8														■			
4120	F	J	7			■														
4140	M	J	7												■					
4150	F	A	U																	
4290	F	J	7			■														
4353	M	J	5																	
4523	M	J	7		■															
2016 Calf of 3450	U	J	2															■		
2015 Calf of 2605	U	J	3				■				■									
2017 Calf of 2614	U	J	1+														■			
2015 Calf of 2790	U	J	3				■													
2015 Calf of 3646	U	J	3														■			