Megafauna Aerial Surveys in the Wind Energy Areas of Massachusetts and Rhode Island with Emphasis on Large Whales: Final Report Campaign 6B, 2020-2021

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Authors:
Orla O'Brien[1], Katherine McKenna[1], Dan Pendleton[1], Laura Ganley[1], and Jessica Redfern[1]

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By
[1]New England Aquarium
Anderson Cabot Center for Ocean Life
1 Central Wharf
Boston, MA 02110

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Executive Summary

BRIEF ABSTRACT: The Bureau of Ocean and Energy Management (BOEM) has designated two wind energy areas (WEAs) in New England: one offshore of Massachusetts and the other offshore of both Rhode Island and Massachusetts. Currently, five[1] offshore wind developers have lease agreements to build projects in these areas. The New England Aquarium has conducted systematic aerial surveys of endangered whales, including the critically endangered North Atlantic right whale (*Eubalaena glacialis*, hereafter, "right whale"), and sea turtles in these areas since 2011. This report, Final Report: Campaign 6B, 2021, summarizes results from the Campaign 6B surveys conducted in the study area between Fall 2020 and Fall 2021. Patterns in baleen whale density and sighting rates were largely similar those previously reported. Right whale abundance was similar to the past few years, and was highest during winter and spring. Right whales were seen over the Nantucket Shoals during winter, summer, and fall, and were also seen in wind energy lease areas south of Martha's Vineyard in the spring. Right whales have been seen in the study area in every season since 2017. This year-round occurrence in the study area no longer appears anomalous. Instead, it appears to represent the current pattern for the study area.

BACKGROUND: 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 early 2011, the Massachusetts Clean Energy Center (MassCEC) selected a team led by the New England Aquarium (NEAq) to conduct aerial surveys of endangered whales and turtles in the MA WEA. A report released in October 2016 showed that the study area included seasonal aggregations of protected species of whales and sea turtles. It also showed that right whales occurred in the study area during winter and spring. Acting upon the recommendations in this report, MassCEC contracted with NEAq to conduct additional aerial surveys for the period February 2017 through July 2018 (Campaign 4), October 2018 to August 2019 (Campaign 5), March to October 2020 (Campaign 6A), and November 2020 to October 2021 (Campaign 6B, the subject of this report).

OBJECTIVES: 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) wind energy area (WEA), Rhode Island/Massachusetts (RIMA) WEA, and surrounding waters including the Nantucket Shoals.

METHODS: The analysis considers aerial surveys conducted within the study area (Figure 1) between September 2020[2] and October 2021. Three types of surveys were conducted: general surveys were strict standardized line-transect surveys that were used to calculate sighting rates, and density and abundance estimates; condensed or directed surveys followed line-transect protocols but did not use randomized line placement and so were only used to calculate sighting rates; calibration surveys were conducted to estimate the effect of changing altitude on an observer's ability to detect different species, and were not used to calculate density, abundance, or sighting rates in the WEA survey area.

[1] There were previously four developers active in the MAWEA/RIMA – Equinor, Ørsted, Mayflower Wind and Vineyard Wind. In October 2021, Avangrid, Inc. and Copenhagen Infrastructure Partners announced a restructuring of their Vineyard Wind joint venture partnership. The restructuring results in a fifth developer, Avangrid, assuming control of certain projects in the wind energy areas.

[2] For analysis and reporting on Campaign 6B, we have included data from September and October 2020 surveys, which were conducted as part of Campaign 6A. Including these data allows us to capture the complete fall 2020 season (September – November) in the analyses.

During surveys, observers recorded sightings of marine megafauna and human activity (ships, fishing gear, and debris). Concurrently during flights, a camera in a belly port in the aircraft, fitted with forward motion compensating equipment, took photos under the aircraft every 5 seconds. These vertical photographs were analyzed after flights for detections of marine animals and human activity. Right whales were a primary focus of the surveys; when observers spotted right whales, the plane deviated from the transect and observers attempted to photograph each whale for individual identification.

Sightings of marine mammals along with effort-corrected trackline distance were used to calculate animal sighting rates, density, and abundance. Sighting rates were calculated as the number of individuals divided by the total survey distance, multiplied by 1000. Density is defined as the estimated number of individuals per square kilometer, using sightings from general survey transect lines. 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.

RESULTS: A total of 46 aerial surveys were completed during the Campaign 6B analysis period: September 2020 to October 2021. A total of 83,150 vertical photographs were taken by the vertical camera and 4,811 handheld photographs were taken by aerial observers for a total of 87,961 photographs. There were 1,318 detections of marine fauna totaling 10,750 individuals of 23 species. There were 332 detections of 5,206 cetaceans of eight species recorded in the study area. Right whales, humpback whales, and common dolphins were sighted most frequently and accounted for 27%, 20%, and 15%, respectively, of cetacean sightings. The most abundant cetaceans were common and bottlenose dolphins, accounting for 76% and 10%, respectively, of individual cetaceans sighted. In total, 199 sightings of five species of baleen whales (318 individual whales) were recorded during Campaign 6B surveys. Balaenopterid abundance was highest in the summer, followed by the spring, for all species. Right whales were sighted in five of five seasons and in ten of 14 months surveyed. Right whale sightings occurred in all except one wind energy lease and over the Nantucket Shoals. Right whale seasonal abundance in the study area was estimated between ten and 103 animals; the highest right whale abundance occurred in the spring.

CONCLUSIONS: This report represents part of a decade long effort to characterize use of the study area by marine megafauna. With the completion of the Campaign 6B surveys, we can divide the time series of aerial surveys conducted in the study area into two time periods of approximately equal duration: 2011-2015 (Campaigns 1-3) and 2017-2021 (Campaigns 4-6). Right whales were present in smaller numbers and only sighted in the survey area in the winter and spring during the 2011-2015 time period (Leiter et al., 2017). In contrast, the Campaign 6B surveys represent the fifth year of surveys during the 2017-2021 time period to document increased winter and spring right whale abundances and the temporal expansion of right whale sightings within the survey area into summer and fall (O’Brien et al., 2020; O'Brien et al., 2021; O'Brien et al., In Review; Quintana-Rizzo et al., 2021). This increase in right whale abundance and year-round occurrence in the study area no longer appears anomalous. Instead, it appears to represent the current pattern for the survey area.

The timing and distribution of sightings many species, including rorqual whales and sharks were generally similar to patterns observed in previous years: rorqual whale density was highest in summer and spring, although fin and humpback whales were present in winter which is unusual. Rorqual whales were distributed across the study area fairly evenly, with some exceptions. Humpback whales demonstrated a similar tendency to right whales to gather over the Nantucket Shoals in the summer and fall. Sightings of sharks and large bony fishes were most common during the summer; sharks appeared to be more common in deeper parts of the study area and ocean sunfish appeared to be more common over the shallower Nantucket Shoals. During Campaign 6N, larger numbers of hammerhead sharks continued to be observed. Leatherback turtle sighting rates during summer and fall of Campaign 6B were comparable with previous years, and aggregations of leatherback turtles were documented close to Nantucket. The Campaign 6B surveys collected valuable data during the summer-fall transition, which is critical for documenting sea turtle presence and, more recently, year-round right whale presence.

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List of Abbreviations and Acronyms

#	number
95% CI	95% confidence interval
a	area sampled (in density calculations)
BOEM	Bureau of Ocean Energy Management
d	density (number of individuals per square kilometer)
f(0)	probability density function evaluated at zero distance
GPS	global positioning system
h	hours
km	kilometer
kts	knots
L	length of transect (in density calculations)
MA	Massachusetts
MassCEC	Massachusetts Clean Energy Center
m	meter
mm	millimeter
NARWC	North Atlantic Right Whale Consortium
°N	degrees North
n	number (of animals/groups sighted during a transect)
nm	nautical mile
NEAq	New England Aquarium
NEFSC	Northeast Fisheries Science Center
RIMA	Rhode Island / Massachusetts wind energy area
s	average group size (in density calculations)
°W	degrees West
WEA	wind energy area

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 study 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
- Campaign 6A: March – October 2020
- Campaign 6B: November 2020 – October 2021

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, offshore wind developers have lease agreements to build projects in the BOEM designated Massachusetts (MA) and the Rhode Island/Massachusetts (RIMA) wind energy areas. Onshore construction on the first project, Vineyard Wind 1, has begun and it is expected to be operational in 2023.

Under the National Environmental Policy Act of 1969 (42 U.S.C. 4371 et seq.), BOEM and other relevant federal agencies are required to conduct environmental assessments for offshore wind construction and operations plans. Offshore wind energy planning, development, and ongoing operations require comprehensive assessments of biological resources within suitable development areas to identify and mitigate any potential effects on marine species. To contribute to meeting this requirement, BOEM and the Massachusetts Clean Energy Center (MassCEC) provided funding and MassCEC contracted New England Aquarium (NEAq) to conduct aerial surveys from 2011-2020. In 2020, four wind energy developers (Vineyard Wind, Mayflower Wind, Ørsted, and Equinor) also contributed funding for a series of aerial surveys comprising Campaign 6B.

Analyses of the survey data have shown that the study area (which encompasses the MA/RIMA WEAs and a buffer around the WEAs that includes the Nantucket Shoals; see Figure 1) includes seasonal aggregations of protected species of whales and sea turtles. Early surveys (2011-2015) showed that North Atlantic right whales (*Eubalaena glacialis*), a critically endangered species, occurred in the study area during winter and spring; more recent surveys (2017-2021) show that right whales occur in the study area in all seasons, with the highest density occurring in winter and spring. Evidence of right whales feeding or socializing has been observed in the study area in every season. Other protected baleen whales are present in the study area, largely in the spring and summer. Endangered sea turtles are present in the study area in the summer and fall.

During turbine installation and while turbines are operational in the WEAs, aerial survey altitude will need to increase from 1,000 ft to at least 1,500 ft for aircraft safety. There are few studies on the effect of different survey altitudes on animal detection rates and none on our study species. Therefore, in Campaign 6B, NEAq conducted a series of calibration surveys to estimate the effects of increased altitude on an observer's ability to detect species of interest.

This report, "Megafauna Aerial Surveys in the Wind Energy Areas of Massachusetts and Rhode Island with Emphasis on Large Whales: Final Report Campaign 6B, 2020-2021"**,** summarizes results from fall 2020 through fall 2021. This report covers all surveys conducted with Campaign 6B funding (spanning November 2020 through October 2021) as well as two months of Campaign 6A surveys (September and October 2020). We include two months from Campaign 6A to ensure our analyses include the entire fall 2020 season. All references to Campaign 6B hereafter in this report are assumed to refer to surveys conducted during the period September 2020 through October 2021. This report contains summaries of survey effort, summaries of sightings (e.g., sightings maps), a summary of calibration flights, and analyses of effort-corrected data, including sighting rates and calculations of density and abundance.

1.1 Research objectives

1. Estimate distribution and abundance of large whales (with a focus on right; humpback, *Megaptera novaeangliae*; fin, *Balaenoptera physalus*; and minke whales, *Balaenoptera*

acutorostrata) and sea turtles within the study area, which encompasses the MA/RIMA WEAs and a buffer around the WEAs that includes the Nantucket Shoals (Figure 1).
2. Conduct calibration surveys to estimate the effect of changing altitude on observers' ability to detect different species.

2 Methods

2.1 Aerial surveys

During the current reporting period (September 2020 to October 2021), five types of aerial surveys were conducted. General, directed, and condensed surveys were conducted in the main study area, defined by a polygon surrounding the general and condensed surveys (shown in Figure 1). Calibration surveys were conducted in Massachusetts Bay (Figure 2A) and time-in-view surveys were conducted in Massachusetts Bay, Cape Cod Bay, and Nantucket Sound (Figures 2B-D).

- <u>General surveys</u> were standardized line-transect surveys that were conducted on a monthly basis and covered the waters of the study area (9,002 km^2), which encompasses the MA/RIMA WEAs and a buffer around the WEAs that includes the Nantucket Shoals (Figure 1). These surveys focused on all marine megafauna visible from the plane (excluding birds) and were comprised of twelve north-south tracklines (Figure 1) evenly spaced at approximately six nautical miles (nm). Eight survey options are available: each option shifts all 12 tracklines 0.75 nm east or west, but maintains the six nm spacing between tracklines. Survey options were selected at random before each survey.

- <u>Condensed surveys</u> were standardized line-transect surveys flown in areas used by aggregations of right whales to better determine demographic, distribution, and behavior patterns in the study area. These surveys were comprised of 10–12 tracklines that were 3 nm apart. In Campaign 6B NEAq expanded the temporal and spatial extent of these surveys to better capture observed changes in right whale distributions (e.g., summer aggregations over the Nantucket Shoals).

- <u>Directed surveys</u> were flown in areas of right whale aggregations, identified by NEFSC or found during general or condensed 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.

- <u>Calibration surveys</u> were conducted to estimate the effect of changing altitude on an observer's ability to detect different species. The same set of tracklines were flown back to back on one day: first at 457 m (1,500 ft) and then at the standard 305 m (1,000 ft). The majority of these surveys were flown in Massachusetts Bay to maximize the number of large whale detections. One general survey was flown at 457m and is also included in the calibration survey totals.

- <u>Time-in-view surveys</u> were conducted to complement calibration surveys. The probability that an observer will detect an animal is affected by the amount of time that an animal is in view. Specifically, an animal's time in view may increase as survey altitude increases and result in an increased probability of detection. The purpose of these surveys was to determine whether there is a difference in time-in-view between 305 m (1,000 ft) and 457 m (1,500 ft).

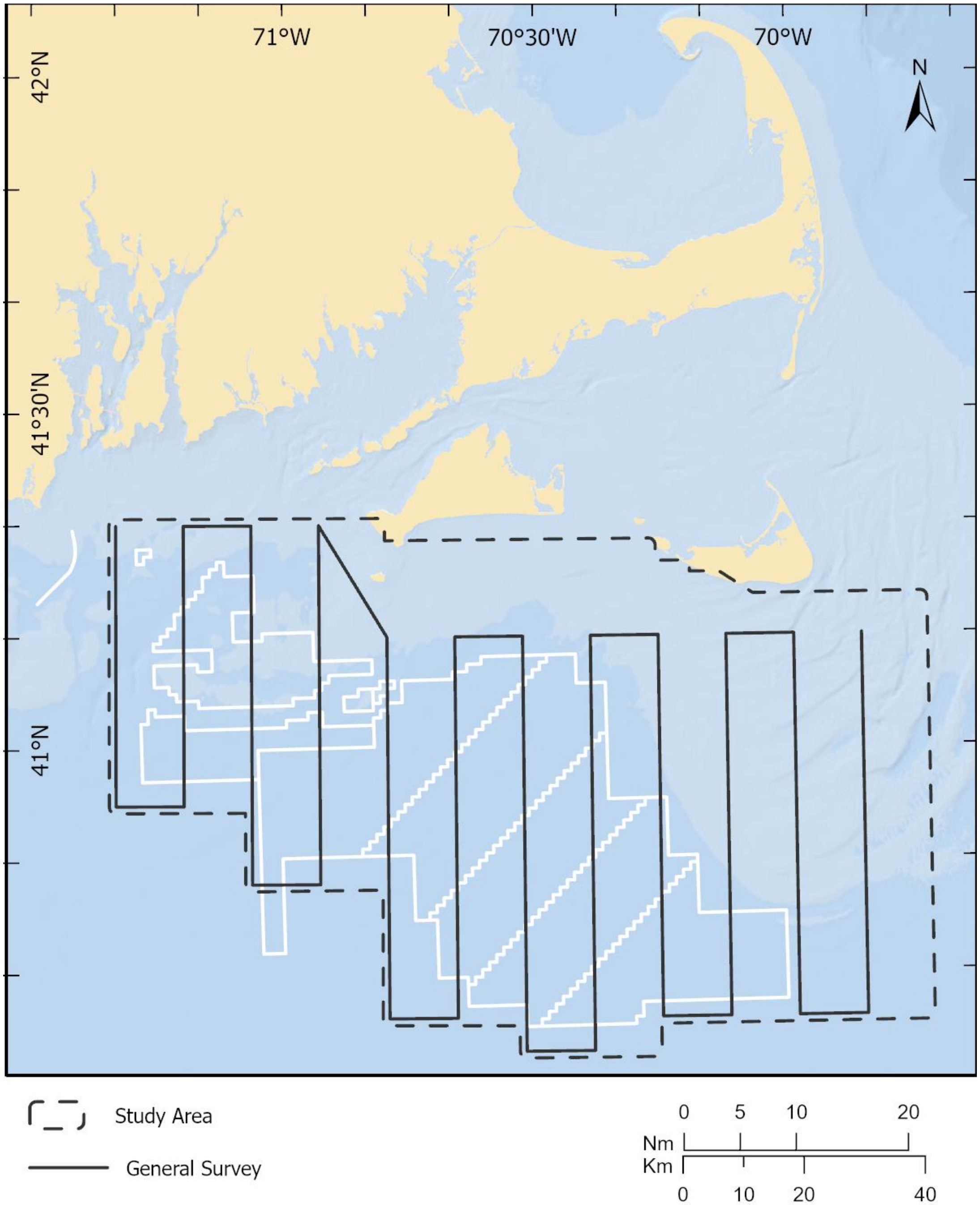

Figure 1. Study area in the offshore waters of Massachusetts and Rhode Island
Study area (dashed black outline) and example general survey lines (black lines). Note: Existing lease areas are depicted in white.

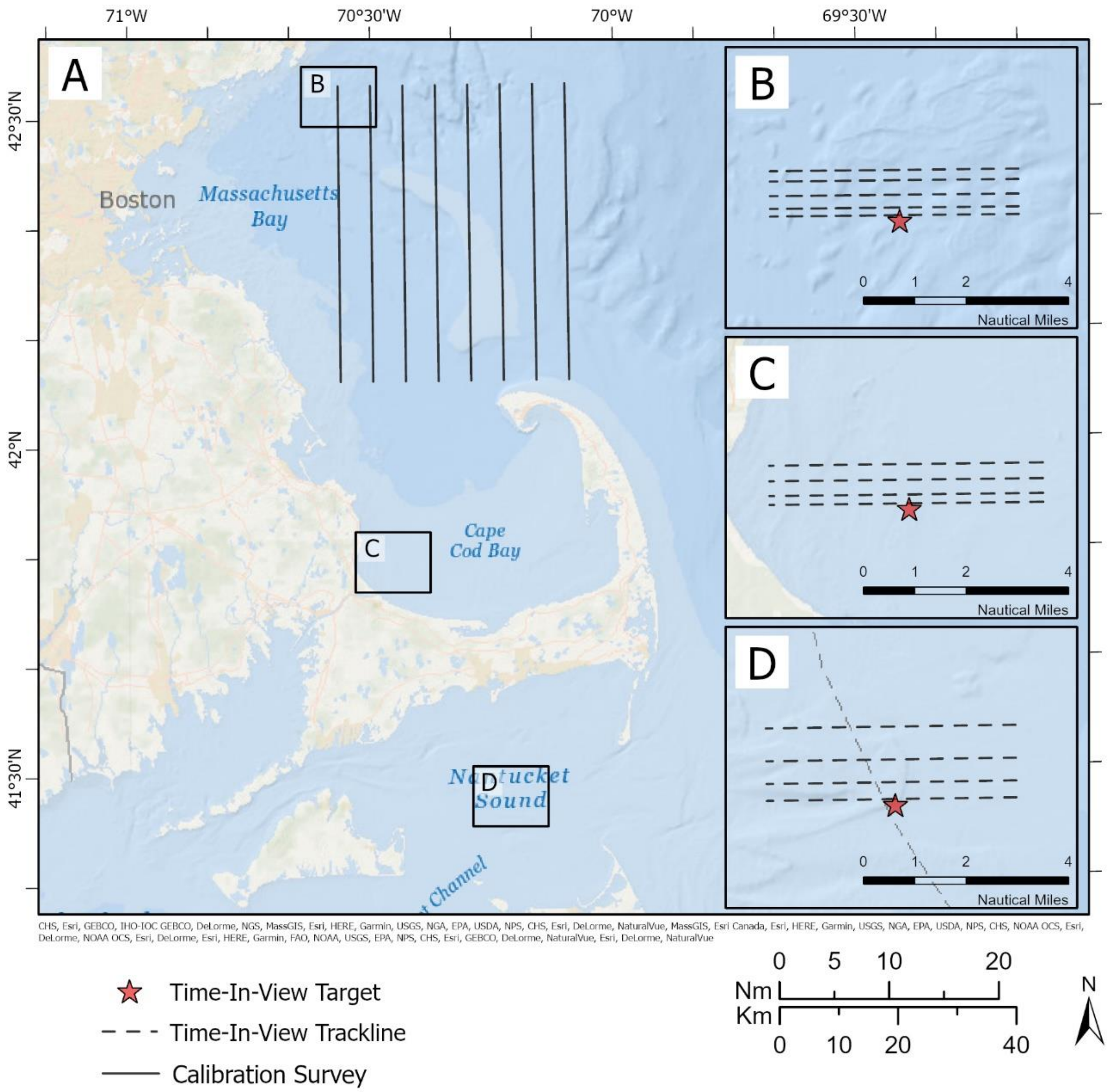

Figure 2. Calibration survey and time-in-view study areas

A) Example calibration survey tracklines over Massachusetts Bay and Stellwagen Bank. Time-in-view survey lines around navigational buoys in B) Massachusetts Bay, C) Cape Cod Bay, and D) Nantucket Sound.

2.1.1 Survey methods for aerial detections

Surveys were flown in a Cessna Skymaster 337 O-2A and a Partenavia P68. Surveys from September 2020 to March 2021 were flown in the Skymaster and surveys from April to October 2021 were flown in the Partenavia. Surveys were flown either at an altitude of 305 m (1,000 ft) or 457 m (1,500 ft) and a ground speed of approximately 185 km/h (100 kts) under Visual Flight Rules. Preferred survey conditions included winds of ≤10 kts, Beaufort sea state ≤ 4, minimum cloud ceiling ≥ 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, 2021). 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 process for estimating sighting distance differed between aircraft. From the Skymaster, 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. From the Partenavia, which does not have wing struts, the observer recorded sighting angle using a declinometer (Dohl et al., 1986). Sighting angle can be used to calculate sighting distance from a known altitude. In both methods, 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, distance bins or declination angles, 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 study 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.

While flying in the Skymaster, 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 (to accommodate for increased altitude during calibration surveys, a Canon 5DS camera with a Canon 85mm lens was utilized beginning April 2021). A forward motion compensation (FMC) 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). The Partenavia has bubble-windows, which allowed the observers to see directly below the aircraft. However, the FMC mount and camera system were maintained for continuity of data collection methods.

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, 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 not be geographically biased towards any part of the study area and must have a randomized start point (i.e., a randomly chosen survey option). Consequently, sightings from condensed surveys and directed surveys (both of which are geographically biased) are not used to estimate the abundance of animals in the WEA. Sightings must also be observed while on transect; consequently, sightings during transit or cross-legs are not used to estimate abundance. For most species, sightings detected while circling from a trackline were not used. However, since every right whale sighting was circled, we used all right whale sightings 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 6B surveys. On-effort photographs from general, condensed, and directed surveys were additionally scrutinized for smaller objects, such as small fishes, 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). When photographic documentation was complete, the aircraft returned to the transect at the point of departure for that sighting and resumed the survey.

2.1.4 Animal density and abundance in the study area

We estimated density and abundance for baleen whales, common dolphins (*Delphinus delphis*), and bottlenose dolphins (*Tursiops truncatus*) for Campaign 6B following methodology in Buckland et al. (1993). 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 in the study area, we fit two detection functions to our data using the R package *Distance* (Miller et al., 2019; R Development Core Team, 2018). We used multiple-covariate distance sampling to estimate a separate detection function for each aircraft, using aircraft type as a covariate[3]. 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. To achieve appropriate sample size for density estimation, we fit a pooled detection function for right, fin, and humpback whales, and a pooled detection function for bottlenose and common dolphins (using group size as a covariate). To estimate minke whale detection, we used the detection function previously fit in the Campaign 6A report (minke whale sample size from Campaign 6B was not high enough to fit a detection function). We used these detection functions and seasonal encounter rates for each species to calculate abundance.

[3] Some differences in methodology are able to be incorporated into a single detection function by distance sampling methodology. However, sighting data from survey platforms with different fields of view cannot be combined. The Skymaster has a blind spot underneath the plane, while the Partenavia has bubble-windows, which results in different fields of view. Two detection functions had to be fit to the data to account for these differences.

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

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

where n is the number of groups sighted during the transect, s is the average group size for the species across all sightings, $f(0)$ is derived from the 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 study area was calculated using the weighted mean density of all survey transects. Abundance was then calculated by multiplying the density estimates by 9,002 km^2 – the size of the study area in 2020-2021. 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 (for right whales), altitude ≤ 366 m, visibility ≥ 3.7 km (2 nm), and sea state ≤ 3 (Leiter et al., 2017; Stone et al., 2017). 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).

2.1.5 Sighting rates and temporal variability in the study area

Sighting rates were calculated as the number of individuals divided by the total survey distance. Sighting rates were multiplied by 1,000 to avoid working with small decimal values and are hereafter referred to as animals/km (Leiter et al., 2017; Stone 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.

Seasonal sighting rates were calculated for species in the study area with at least 25 sightings during the pooled Campaigns 4-6B study period. We used data from Campaigns 4-6B, rather than data from all Campaigns, to ensure that the sightings rates reflect recent sightings patterns. The species included in the analysis were right whales, fin whales, humpback whales, minke whales, common and bottlenose dolphins, and leatherback turtles (*Dermochelys coriacea*). 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.

2.1.6 Right whale photographs and demographics

Right whale images were uploaded and processed in the NARWC Catalog (Hamilton et al., 2010) 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.

2.1.7 Calibration surveys

Aerial surveys must be flown at an altitude higher than our current survey altitude (i.e., 305 m or 1,000 ft) during and after turbine construction. We flew calibration surveys to explore the effect of altitude on animal detection. Several initial calibration surveys were conducted in the general study area. Few large whales were seen during these calibration surveys and it became clear that continuing to fly calibration surveys in this area would not result in the sample size needed to assess differences in altitude. We shifted the location of the calibration surveys to Massachusetts Bay, an area with concentrated large whale sightings during the summer, to increase the possibility of obtaining the necessary sample size.

Calibration surveys consisted of up to eight north-south tracklines (exact number was weather dependent) that were 46 km (25 nm) long and 5.5 km (3 nm) apart. Tracklines for each calibration survey were drawn from a set of four options centered over the Stellwagen Bank National Marine Sanctuary. Each option shifts all eight tracklines 0.75 nm east or west, but maintains the 3 nm spacing between tracklines. Survey options were selected at random before each survey. Each trackline was flown first at 457 m (1,500 ft) and then immediately flown again at 305 m (1,000 ft). The side of the trackline visible to observers was unique at each altitude, and observers did not share sighting information with each other to reduce bias.

The probability that an observer will detect an animal is affected in part by the amount of time an animal is in view (Ganley et al., 2019; Robertson et al., 2015). An animal's time-in-view may increase as survey altitude increases and result in an increased probability of detection. This increase in detection could offset a possible decrease in detection caused by animals appearing smaller at 1,500 ft versus 1,000 ft. Consequently, time-in-view surveys are an important complement to altitude calibration surveys.

We conducted time-in-view surveys to determine whether there is a significant difference in time-in-view between 1,000 ft and 1,500 ft. Time-in-view surveys used lines spaced randomly from 0–3.7 km (0–2.0 nm) from a navigational marker (exact distance was measured after the flight). Tracklines were flown at both 305 m (1,000 ft) and 457 m (1,500 ft). For each trackline, the observers marked the time when the navigational marker first came in view, when it passed abeam of the aircraft, and when it disappeared from sight behind the aircraft.

3 Results

3.1 Field Effort

There were a total of 46 survey days during Campaign 6B between September 2020 and October 2021 (Table 1). Surveys were distributed among months according to the contracted schedule: two broad-scale surveys per month from November to March and one survey per month during the remainder of the year, a maximum of 10 condensed surveys when right whales were in the study area, a maximum of six directed surveys to respond to right whale aggregations, and a maximum of 10 calibration surveys. Specifically, we conducted twenty-one general surveys totaling 112.3 hours (h) of flight time, five condensed surveys totaling 26.8 h of flight time, four directed surveys totaling 19.6 h of flight time, and nine calibration surveys (including one general survey flown at 457 m) totaling 47.0 h of flight time, and six time-in-view calibration surveys totaling 7.7 h of flight time. One survey was aborted due to widespread fog. General surveys took an average of 5.4 h (range = 2.3 – 7.2 h), condensed surveys took an average of 5.4 h (range = 3.7 – 7.3 h), directed surveys took an average of 4.9 h (range = 2.1 – 7.8 h), calibration surveys took an average of 5.2 h (range = 2.6 – 6.6 h), and time-in-view surveys took an average of 1.3 h (range = 0.7 – 2.0 h). The total time and the total distance flown for all aerial surveys combined were approximately 214.7 h and 37,491.6 km, respectively (Table 1). During Campaign 6B, 83,150 vertical photographs were taken by the vertical camera and 4,811 handheld photographs were taken by aerial observers for a total of 87,961 photographs.

Year	Month	General Surveys						Other Surveys						
		Total	Day	Direction	Option	Airtime (h)	Flight length (km)	Total	Day	Direction	Type	Option	Airtime (h)	Flight length (km)
2020	September	1	17	W → E	2	6.6	1,137.3	2	08	NA	*	NA	1.3	240.2
									24	E → W	C	8E	5.8	832.1
	October	1	04	E → W	11	7.1	1,133.6							
	November	2	19	W → E	8	2.3	393.2							
			29	W → E	8	4.9	821.9							
	December	2	14	W → E	4	5.6	973.8							
			19	W → E	1	7.1	1,088.6							
2021	January	2	08	E → W	15	7.0	1,088.6	1	13	W → E	C	1W	5.1	829.1
			31	W → E	3	6.2	1,075.1							
	February	2	12	W → E	8	4.5	752.1	2	09	W → E	C	3E	3.7	676.7
			28	E → W	13	7.1	1,172.9		26	W → E	C	1E	4.9	796.2
	March	2	07	W → E	2	5.0	781.2	2	10	E → W	C	7E	7.3	1,040.1
			16	W → E	6	7.2	973.6		21	W → E	D	NA	7.8	1,257.5
	April	1	28	W → E	4	2.8	548.7							
	May	1	03	W → E	4	4.0	751.5	6	03	W → E	Cal	7	2.6	479.3
									06	E → W	Cal	8	4.8	943.0
									20	E → W	Cal	5	5.8	601.3
									23	W → E	Cal	3	6.1	1,152.3
									24	W → E	Cal	1	6.6	1,229.5
									27	NA	TIV	NA	2.0	401.0
	June	1	23	W → E	7	6.6	1,227.9	4	20	W → E	Cal	8	5.0	796.5
									20	NA	TIV	NA	1.2	305.0
									24	E → W	Cal	6	4.5	759.3
									24	NA	TIV	NA	1.6	430.0
	July	2	22	E → W	2 + 6	5.6	1,075.1	3	20	W → E	Cal	1	6.2	1,219.0
			23	W → E	2	4.3	814.3		20	NA	TIV	NA	0.7	131.1
									24	E → W	D	NA	2.1	402.3
	August	2	25	E → W	4 + 8	6.4	1,223.2	4	26	W → E	Cal	3	5.4	976.4
			29	W → E	8	2.5	477.8		26	NA	TIV	NA	1.5	240.9
									29	W → E	D	NA	3.4	609.3
									29	NA	TIV	NA	0.7	144.3
	September	1	25	W → E	5	3.2	592.3							
	October	1	01	W → E	1 + 5	6.3	1,198.2	1	03	E → W	D	NA	6.30	1,186.0
		21				112.3	19,300.9	25					102.4	17,678.4

Table 1. Summary of aerial survey effort during Campaign 6B

“Other Surveys” include calibration, condensed, directed, and time in view surveys. Note: W = west, E = east, C = Condensed, Cal = Calibration, D = Directed, TIV = time in view, NA = Not applicable, * = aborted. Note that more than one survey type may have been flown on a single survey day.

3.2 Wind Energy Area Aerial Surveys

3.2.1 Detections

Sightings and detections for Campaign 6B are split into two categories: 1) sightings from all survey effort and 2) the subset of sightings that can be incorporated into abundance estimates (“on-effort”). For each species or group of species, a single sightings map is provided showing observer detections and total gridded survey effort (“Survey Effort” in map legends) from all surveys and effort types.

3.2.1.1 All detections

A total of 2,734 detections of marine fauna (48%) and human activity (52%) were observed in the study area during all Campaign 6B aerial surveys. Of these detections, 65% (n = 1,783) were observer detections and 35% (n = 951) were camera detections.

There were 1,318 observer and camera detections of marine fauna totaling 10,744 individuals of 23 species (Table A-2). Marine fauna included large whales, small cetaceans, birds, sharks, fishes, and sea turtles. Marine mammals had the highest number of individuals observed (83%, n = 8,941), followed by birds (13%, n = 1,425), sharks and fishes (3%, n = 327), and sea turtles (<1%, n = 51). The majority of marine mammal sightings were cetaceans (80%) and the rest were pinnipeds. Birds were not marked by observers in the plane; consequently, reported sightings of birds are exclusively camera detections.

There were 1,416 observer and camera detections of human activity in the study area during all Campaign 6B surveys (Table A-2). Natural debris such as floating sargassum were excluded from debris totals. The majority of human activity detections were related to commercial fishing (67%), which included fixed fishing gear and vessels that were transiting or actively fishing. Recreational vessels accounted for 11% of human activity while other types of vessels such as military, merchant, and research vessels accounted for 7% and anthropogenic debris accounted for 14%.

The analysis of the vertical photographs from all surveys resulted in 705 detections of 2,331 animals and 246 detections of human activity. Thirteen species of marine megafauna (not including birds) were identified to the species level from vertical photographs. Detailed analysis of vertical photographs is included in Table A-2.

3.2.1.2 On-effort detections

A total of 406 sightings of marine megafauna (n = 4,862 individuals) were recorded on-effort, including both observer (78%, n = 317) and camera (22%, n =89) detections (Table A-1). Identification to the species level was possible for 261 sightings and resulted in 15 confirmed species: seven cetacean, five shark, one pinniped, one fish, and one sea turtle. Marine mammals represented 48% of detections (n = 194) and 88% of all individuals tallied (n = 4,624 individuals). Sharks and fishes were seen as often (48% of detections, n =194), but in lower numbers (5% of individuals detected, n = 219). The remaining 18 detections were of 19 sea turtles.

3.2.2 Cetacean detections

A total of 332 sightings of 5,206 cetaceans were recorded in the study area during Campaign 6B. This total includes 21 sightings by the vertical camera of 111 individuals from five species. There were 178 cetacean sightings on-effort during general surveys, totaling 3,780 individuals. Identification to the species level was possible for 270 sightings and resulted in eight confirmed species. Species ID could not be confirmed for 62 sightings.

Right whales, humpback whales, and common dolphins were sighted most frequently and accounted for 27%, 20%, and 15%, respectively, of cetacean sightings. The most abundant cetaceans were common and bottlenose dolphins, accounting for 76% and 10%, respectively, of individual cetaceans sighted; right whales were the most common large cetacean, but only accounted for 3% of all individual cetaceans sighted.

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, 90 sightings of 169 right whales were recorded during Campaign 6B. Right whales are discussed and sighting maps are shown below. Four species of the Balaenopteridae family, or rorqual whales, were sighted: fin whales, sei whales (*Balaenoptera borealis*), minke whales, and humpback whales. A total of 109 sightings of 149 rorqual whales were documented in the study area during Campaign 6B surveys. Further details of rorqual whale sightings are discussed below.

Toothed whales were represented by three species in two families: common and bottlenose dolphins (family Delphinidae); and harbor porpoise (*Phocoena phocoena*; family Phocoenidae). Toothed whale sightings are discussed below.

3.2.2.1 North Atlantic right whales

Right whales were the most commonly sighted whale in the study area during Campaign 6B. In total, 90 sightings (54 on-effort) totaling 169 right whales (112 on-effort) were recorded during Campaign 6B. One sighting of two right whales occurred while off-effort during a general survey. The remainder of off-effort right whale sightings were recorded during condensed (22 sightings of 35 whales) and directed (13 sightings of 20 whales) surveys. Group size ranged from one to nine; average group size was 1.9 whales.

Right whales were sighted in every season and in ten of fourteen months surveyed. Seasonal right whale sightings rates were 2.9 whales/km (fall 2020), 8.3 whales/km (winter), 7.6 whales/km (spring), 2.8 whales/km (summer), and 9.2 whales/km (fall 2021).

Right whale sightings are shown in Figure 3. During Campaign 6B, right whales were sighted across the entire study area: both inside the WEA and outside the WEA, including over the Nantucket Shoals. However, there was a distinct seasonal pattern to the distributions. During the summer and fall, right whales were sighted over the Nantucket Shoals (with the exception of one sighting of three right whales on November 29, 2020 in the MA WEA). During the winter, the majority of right whale sightings were over the Nantucket Shoals. However, right whales were also sighted within the RIMA and MA WEAs, and between the MA WEAs and Martha’s Vineyard. In the spring, no right whales were seen over Nantucket Shoals; instead, right whale aggregations were sighted in and near the WEA.

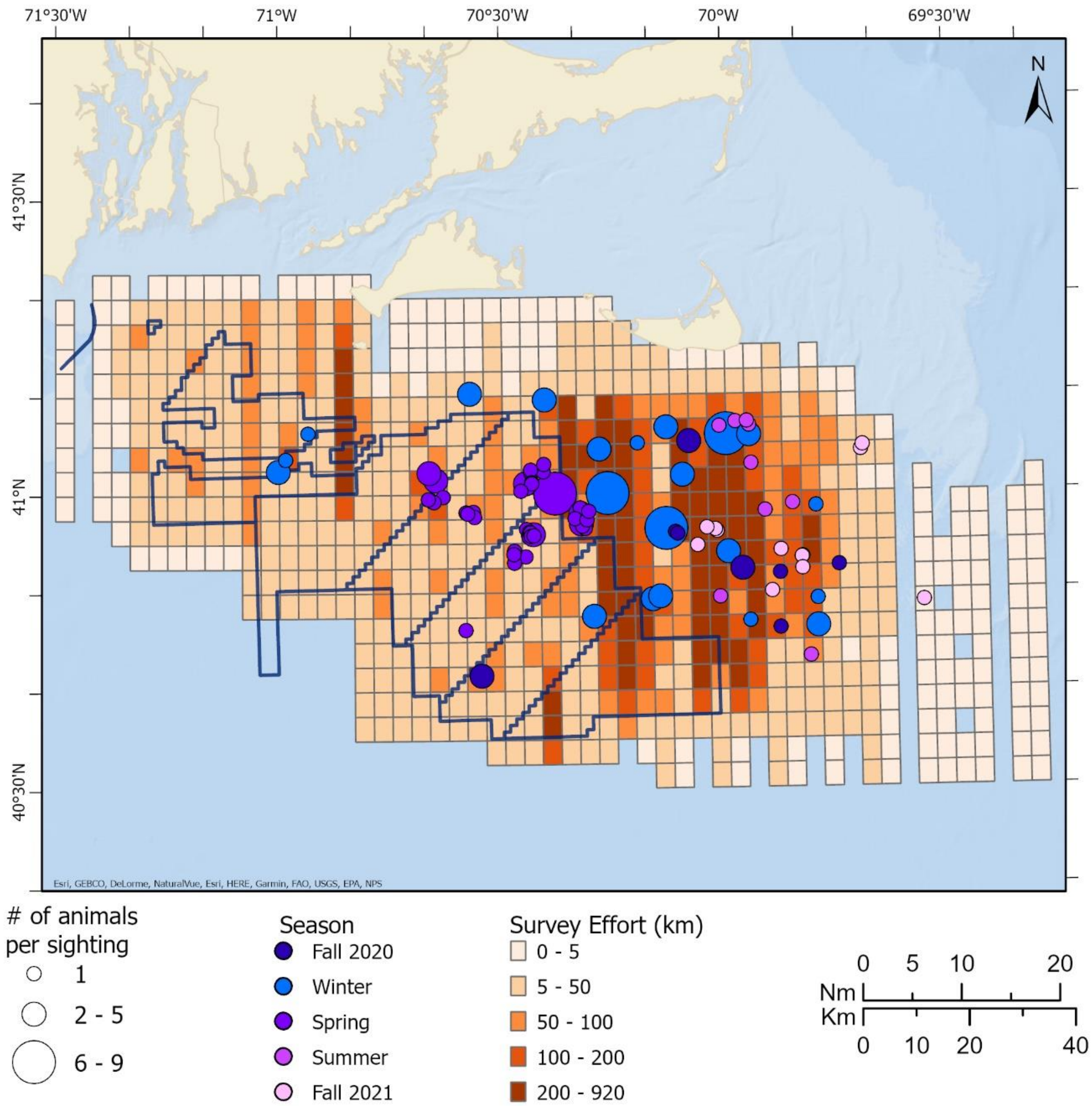

Figure 3. Map of right whale sightings during Campaign 6B aerial surveys

3.2.2.1.1 Abundance estimates

Seasonal density and abundance estimates were calculated for right whales for Campaign 6B (Table 2). Estimates were calculated for five seasons; the fall 2020 estimate includes data from Campaign 6A. Right whale seasonal abundance in the study area ranged from ten (summer) to 103 (spring) animals.

Table 2. Density and abundance of right whales during Campaign 6B by season

Effort (km) is the summed on-effort distance surveyed for all transects. # of detections is the number of sightings of one or more animals. # of animals is the sum of the number of animals used to calculate abundance. Est. density is the estimated number of individuals per km². Est. abundance is the estimated number of animals for the study area. 95% CI= 95% confidence interval of abundance.

Season-year	Effort (km)	# of detections	# of animals	Est. Density	Est. Abundance	95% CI
Fall – 2020	2,010	4	8	0.0018	16	5 - 56
Winter – 2021	3,779	13	45	0.0054	49	24 - 96
Spring – 2021	1,142	24	29	0.0114	103	53 - 197
Summer – 2021	2,744	4	7	0.0011	10	3 - 40
Fall – 2021	896	1	3	0.0016	13	2 - 77

3.2.2.1.2 Demographic and re-sighting patterns

Preliminary photo analysis identified 101 unique right whales during all Campaign 6B surveys. Most right whales were adults (76%, n = 77) and males (58%, n = 59) (Table 3).

Table 3. Number and percentage of different sex and age classes of right whales identified during Campaign 6B aerial surveys

Sex	N	%	Adult	%	Juvenile	%	Age Unknown	%
Male	59	58	47	46	12	12	0	0
Female	35	35	26	26	8	8	1	1
Unknown	7	7	4	4	1*	1	2	2
Total	101	100	77	76	21	21	3	3

Photo identification data has not yet been confirmed by the NARWC. Preliminary photo analysis suggests that many of the individual right whales displayed a strongly seasonal use of the study area. During Campaign 6B surveys, 82% (n=83) of individuals were seen in only one season. Winter had the highest number of individual right whales (n=51) identified. Many of these individuals were not resighted outside of this season.

Of the 101 right whales preliminarily identified during Campaign 6B, 78% (n=78) have been identified previously in the study area in two or more years and 95% (n=96) had been sighted at least once in the study area prior to 2020. There were five individuals identified for the first time inside the study area, including a mother and her 2021 calf, two adult males, and a juvenile male born in 2019.

Additionally, at least two pregnant females were sighted in the study area during Campaign 6B. Right whale catalog #1245 (“Slalom”) was sighted in October 2021 (Figure 4); she was later documented off South Carolina on November 24, 2021 with her 13th calf. Right whale catalog #2360 (“Derecha”) was sighted twice in March 2021; she was documented off Florida on December 18, 2021 with her fifth calf.

Figure 4. Right whale catalog #1245 ("Slalom") photographed on October 3, 2021
This whale was pregnant at the time of this sighting and was later observed with a calf on November 24, 2021 off the coast of South Carolina (photo taken under NMFS Permit #19674).

3.2.2.2 Fin whales

During Campaign 6B surveys, 18 sightings (nine on-effort) totaling 27 fin whales (16 on-effort) were recorded. One fin whale carcass was detected during Campaign 6B, but was not included in these totals. Group size ranged from one to five with an average group size of 1.5 whales. Fin whales were seen in seven of the fourteen months surveyed and sighted during the winter, spring, and summer seasons. The majority of fin whale sightings occurred in the summer: 10 sightings of 19 whales. Fin whale sighting rates were 0.3 whales/km (winter), 0.8 whales/km (spring), and 4.0 whales/km (summer). No fin whales were sighted in the fall. During Campaign 6B, fin whales were mostly sighted in the western part of the study area (Figure 5).

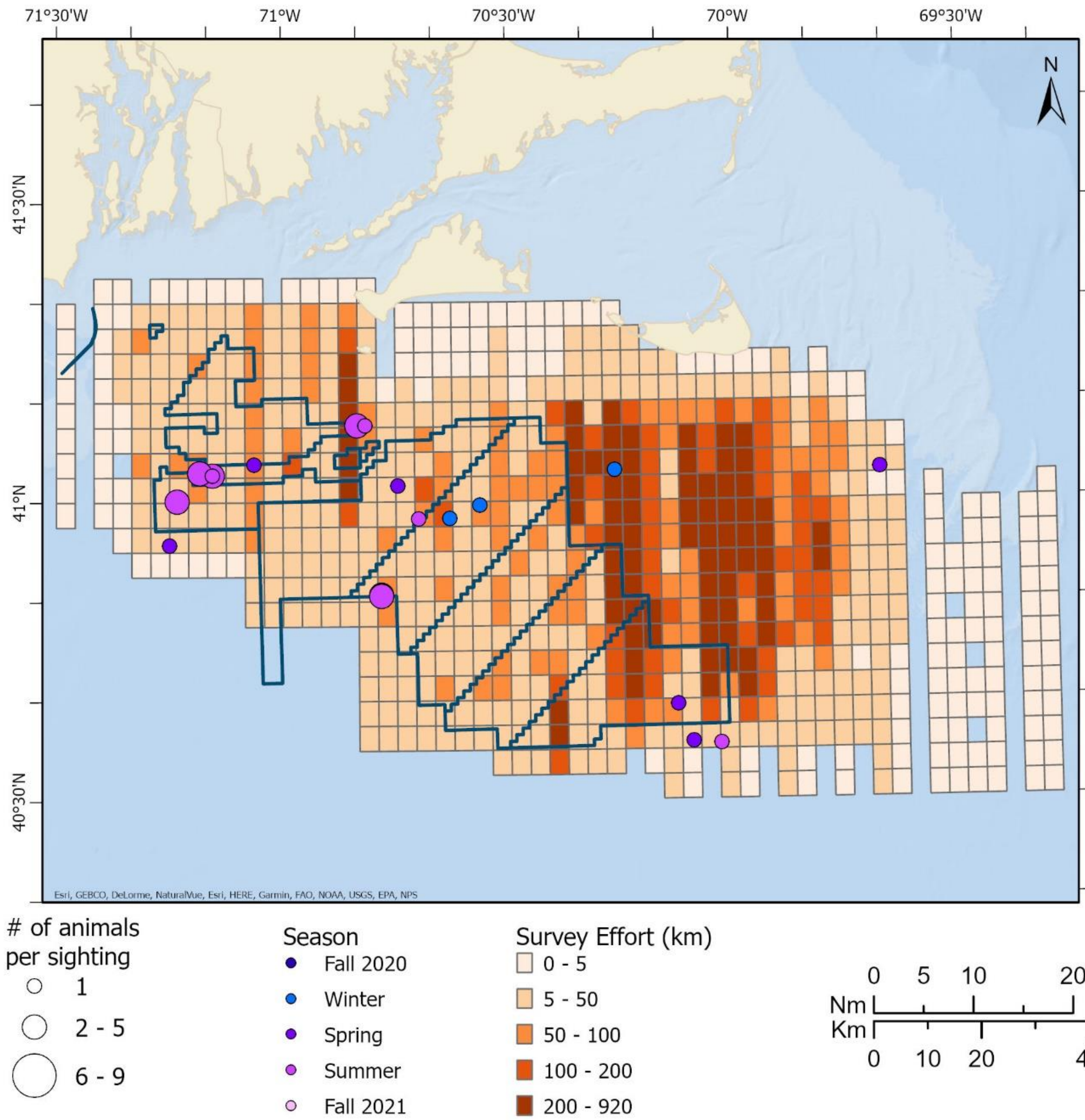

Figure 5. Map of fin whale sightings during Campaign 6B aerial surveys

3.2.2.2.1 Abundance estimates

Seasonal density and abundance estimates were calculated for fin whales for Campaign 6B (Table 4). Estimates were calculated for five seasons; the fall 2020 estimate includes data from Campaign 6A. Fin whale seasonal abundance in the study area ranged from two (winter) to 17 (summer) animals.

Table 4. Density and abundance of fin whales during Campaign 6B by season

Effort (km) is the summed on-effort distance surveyed for all transects. # of detections is the number of sightings of one or more animals. # of animals is the sum of the number of animals used to calculate abundance. Est. density is the estimated number of individuals per km^2. Est. abundance is the estimated number of animals for the study area. 95% CI= 95% confidence interval of abundance.

Season-year	Effort (km)	# of detections	# of animals	Density	Abundance	95% CI
Fall – 2020	2,010	0	0	-	-	-
Winter – 2021	3,779	2	2	0.0002	2	1 – 7
Spring – 2021	1,142	1	1	0.0004	4	1 – 20
Summer – 2021	2,744	6	12	0.0019	17	5 – 52
Fall – 2021	896	0	0	-	-	-

3.2.2.3 Sei whales

During Campaign 6B surveys, one sei whale was sighted in Spring 2021 (Figure 6).

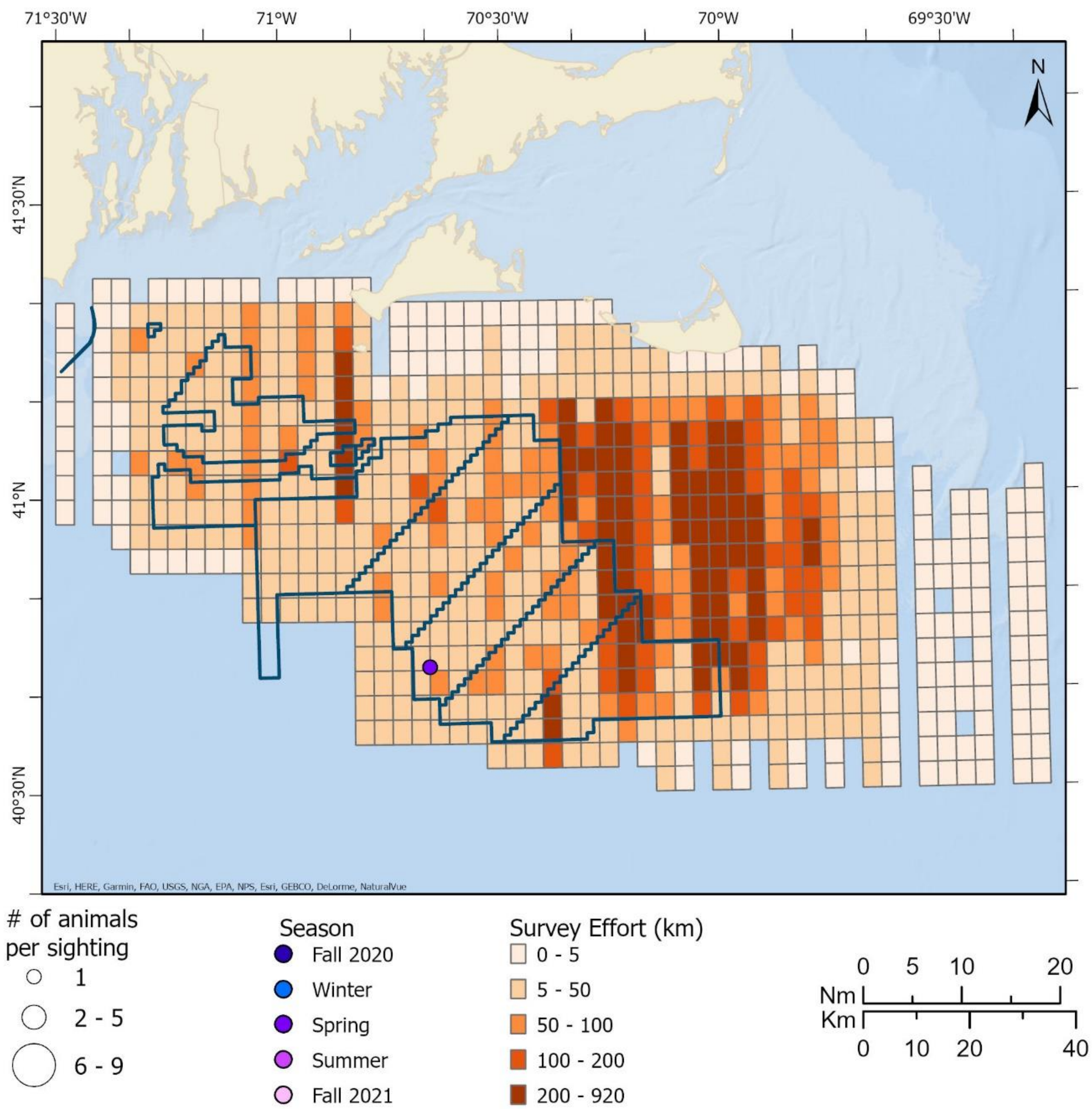

Figure 6. Map of sei whale sighting during Campaign 6B aerial surveys

3.2.2.4 Minke whales

During Campaign 6B surveys, 24 sightings (six on-effort) totaling 24 minke whales (six on-effort) were recorded (Figure 7). One minke whale carcass was detected during Campaign 6B, but was not included in these totals. Minke whales were seen in ten of fourteen months surveyed and were sighted in every season. Seasonal sighting rates for minke whales were 0.2 whales/km (fall 2020), 0.3 whales/km (winter), 1.5 whales/km (spring), summer (1.3 whales/km), and fall 2021 (1.7 whales/km). The majority of the minke whale sightings, though not all, occurred in the Nantucket Shoals. However, this area also has a higher level of survey effort.

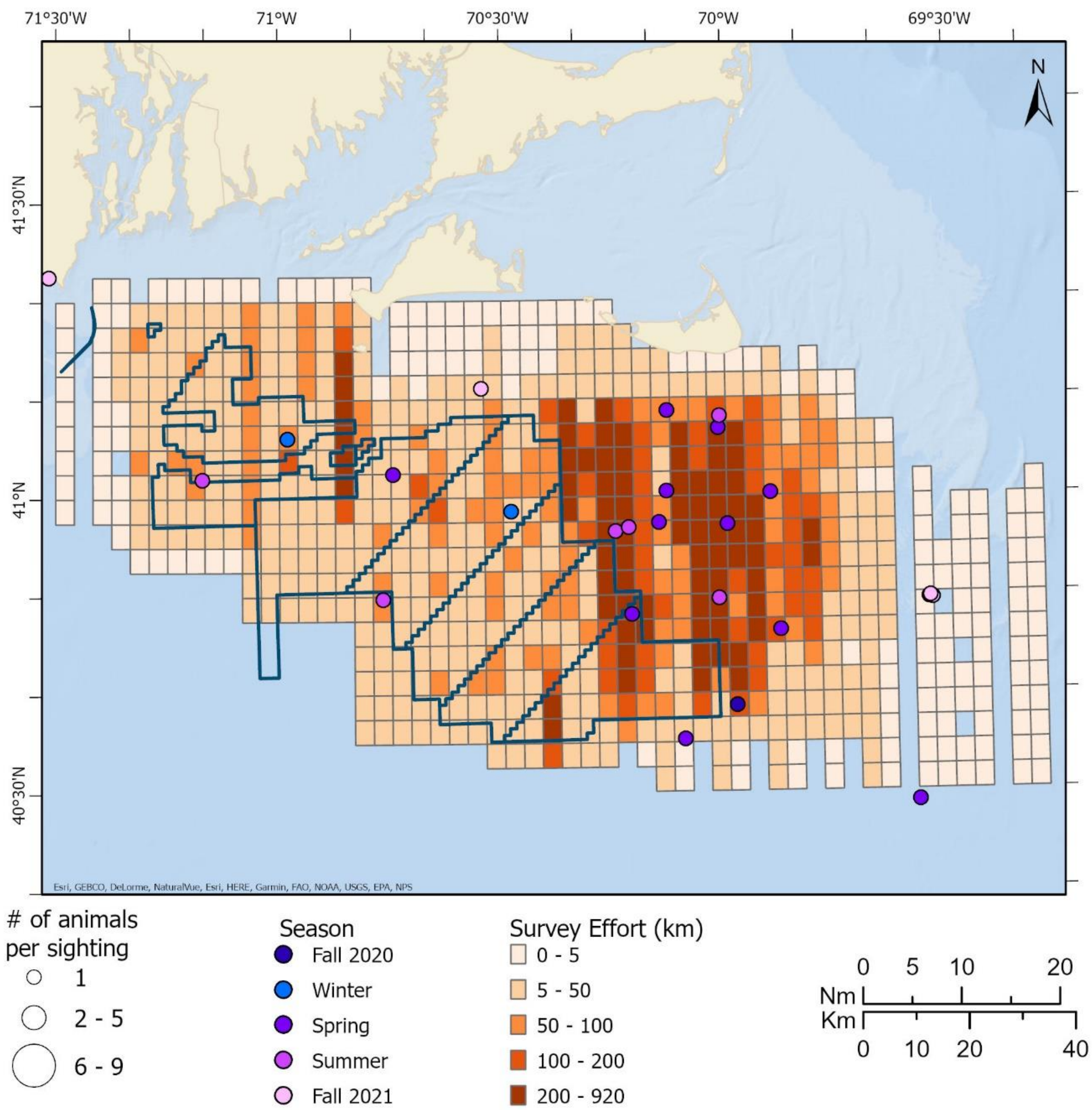

Figure 7. Map of minke whale sightings during Campaign 6B aerial surveys

3.2.2.4.1 Abundance estimates

Seasonal density and abundance estimates were calculated for minke whales for Campaign 6B (Table 5). Estimates were calculated for five seasons; the fall 2020 estimate includes data from Campaign 6A. Minke whale seasonal abundance estimates ranged from four (fall 2020) to seven (summer) animals.

Table 5. Density and abundance of minke whales during Campaign 6B by season

Effort (km) is the summed on-effort distance surveyed for all transects. # of detections is the number of sightings of one or more animals. # of animals is the sum of the number of animals used to calculate abundance. Est. density is the estimated number of individuals per km^2. Est. abundance is the estimated number of animals for the study area. 95% CI= 95% confidence interval of abundance.

Season-year	Effort (km)	# of detections	# of animals	Density	Abundance	95% CI
Fall – 2020	2,010	1	1	0.0004	4	1 - 19
Winter – 2021	3,779	0	0	-	-	-
Spring – 2021	1,142	1	1	0.0007	6	1 – 59
Summer – 2021	2,744	3	3	0.0008	7	3 – 19
Fall – 2021	896	0	0	-	-	-

3.2.2.5 Humpback whales

During Campaign 6B aerial surveys, 66 sightings (20 on-effort) of 97 humpback whales (29 on-effort) were recorded during all surveys (Figure 8). Two humpback carcasses were detected during Campaign 6B (one of which was mentioned in the Campaign 6A report), but are not included in these totals.

Humpback whales were sighted in thirteen of fourteen months surveyed and in every season. Seasonal sighting rates for humpback whales were 0.8 whales/km (fall 2020), 0.9 whales/km (winter), 4.2 whales/km (spring), 7.6 whales/km (summer), and 8.3 whales/km (fall 2021). Humpback whale group size ranged from 1-4, with an average group size of 1.5 whales. In May and June 2021, there were several sightings of humpback whales bubble-feeding, either as individuals or in small groups of 2-3 whales. Four humpback mother-calf pairs were documented in the summer.

During Campaign 6B, humpback whales were sighted across the entire study area (Figure 8), but distribution patterns shifted seasonally. In both fall seasons, humpback whales were seen almost entirely over the Nantucket shoals. However, in spring and summer, humpback whales were spread more evenly across the entire study area.

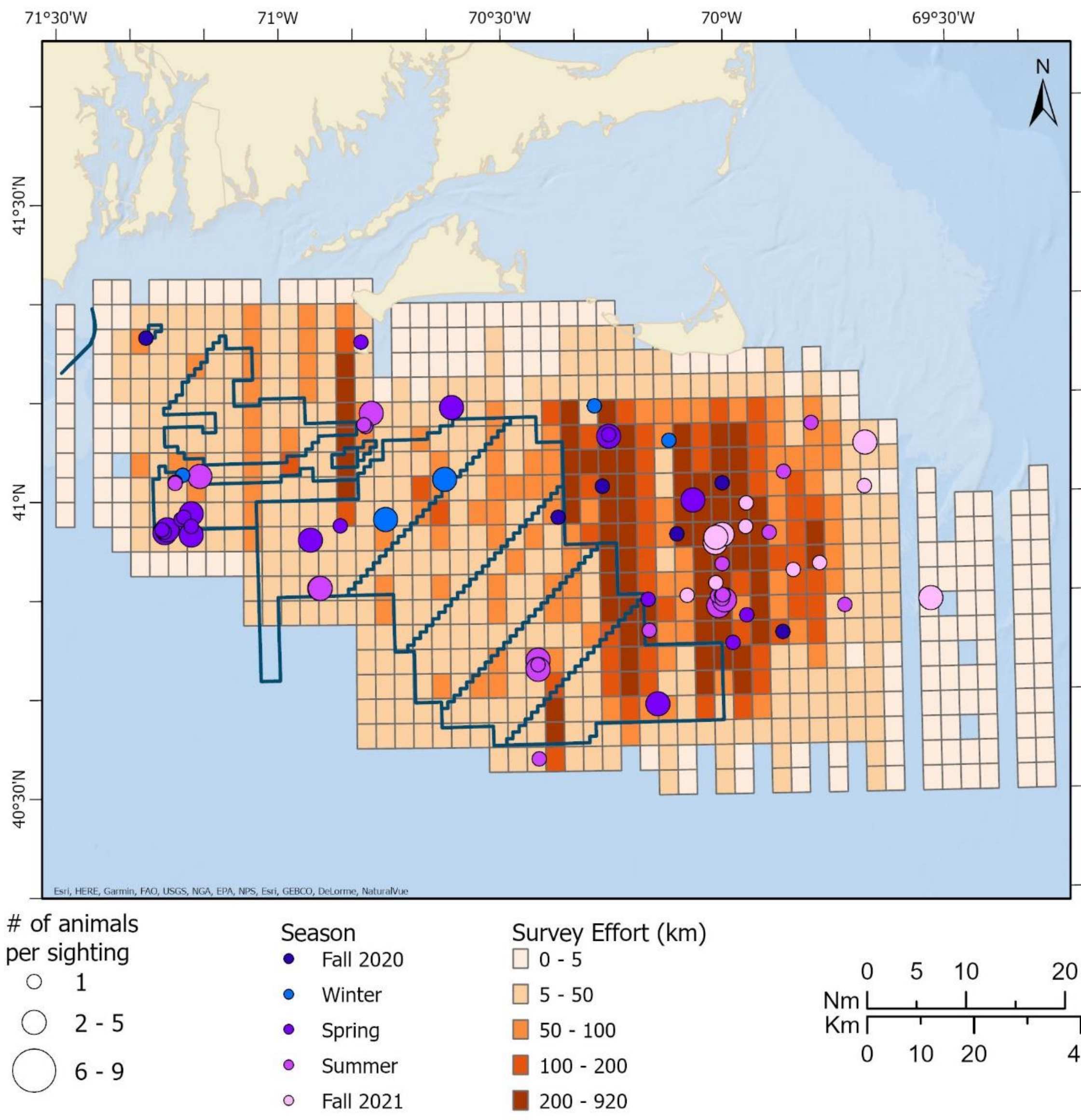

Figure 8. Map of humpback whale sightings during Campaign 6B aerial surveys

3.2.2.5.1 Abundance estimates

Seasonal density and abundance estimates were calculated for humpback whales for Campaign 6B (Table 6). Estimates were calculated for five seasons; the fall 2020 estimate includes data from Campaign 6A. Humpback whale seasonal abundance ranged from six (fall 2020, winter) to 18 (summer) individuals.

Table 6. Density and abundance of humpback whales during Campaign 6B

Effort (km) is the summed on-effort distance surveyed for all transects. # of detections is the number of sightings of one or more animals. # of animals is the sum of the number of animals used to calculate abundance. Est. density is the estimated number of individuals per km². Est. abundance is the estimated number of animals for the study area. 95% CI= 95% confidence interval of abundance.

Season-year	Effort (km)	# of detections	# of animals	Density	Abundance	95% CI
Fall – 2020	2,010	3	3	0.0003	6	2 – 18
Winter – 2021	3,779	4	6	0.0007	6	3 – 17
Spring – 2021	1,142	2	3	0.0011	10	2 – 56
Summer – 2021	2,744	8	13	0.0020	18	7 – 49
Fall – 2021	896	0	0	-	-	-

3.2.2.5.2 Carcass detections

During Campaign 6B aerial surveys, four whale carcasses were documented. One humpback whale was observed on September 17, 2020 and was previously mentioned in the Campaign 6A report. A second humpback whale carcass was seen on November 29, 2020 approximately 15 nm southwest of Nantucket. This carcass was moderately decomposed and had evidence of shark scavenging (Figure 9A). In 2021, a fresh fin whale carcass was sighted on January 8th approximately 22 nm south of Martha's Vineyard (Figure 9B) and a fresh dead minke whale carcass entangled in fishing gear was sighted on September 25th just offshore of East Matunuck State Beach in Pt. Judith, Rhode Island (Figure 9C). Coordinates and photos of the carcasses were sent to NMFS after the completion of each aerial survey.

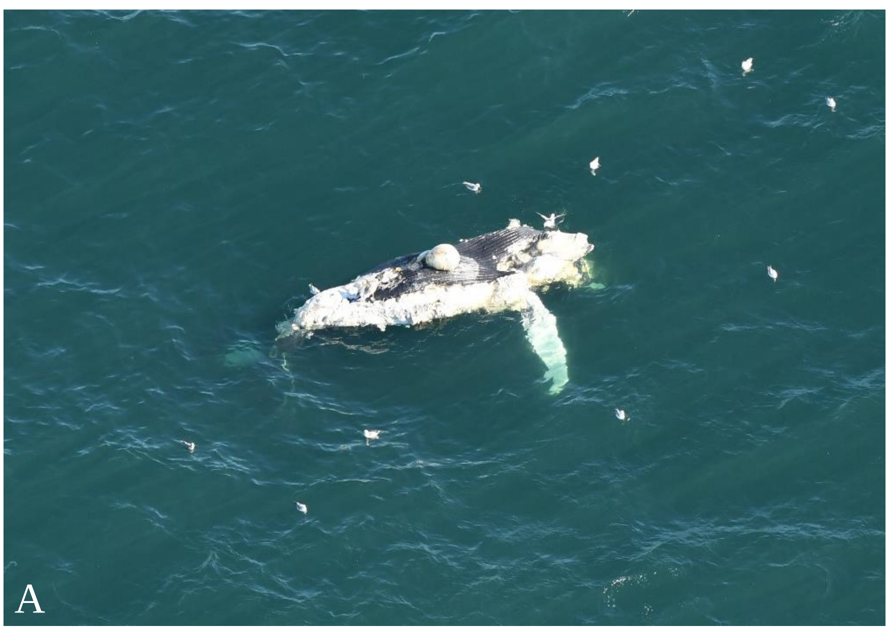

Figure 9. Whale carcasses observed during Campaign 6B aerial surveys
A) Humpback whale carcass observed November 29th, 2021. B) Fin whale carcass observed on January 8th, 2021. C) Entangled minke whale carcass observed on September 25th, 2021.

3.2.2.6 Small cetaceans

3.2.2.6.1 Detections

A total of 129 sightings of 4,884 small cetaceans were recorded in the study area during all Campaign 6B surveys. This total includes 19 sightings by the vertical camera of 109 individuals. Eighty-eight of the 129 sightings were on-effort during general surveys, totaling 3,616 individuals. Small cetacean sightings accounted for 39% of all cetacean detections (129 of 332 detections) and 49% of on-effort cetacean detections (88 of 178 detections). Identification to the species level was possible for 71 sightings and resulted in three confirmed species. Unidentified dolphins accounted for 58 sightings and consisted of small groups of dolphins that the plane did not break track to identify. The three species identified belonged to two families: Phocoenidae and Delphinidae. Phocoenidae included harbor porpoises and Delphinidae included short-beaked common dolphins and bottlenose dolphins.

During Campaign 6B surveys, common and bottlenose dolphins were the most commonly detected small cetaceans (39%, n=50, and 10%, n=13, respectively) followed by harbor porpoises (6%, n=8). Small cetaceans were detected in larger groups, with group sizes ranging from one to 500 individuals. The average group size was 32.

3.2.2.6.2 Seasonal and geographic patterns

Small cetacean species were sighted most frequently during the summer. Common dolphins were seen in all seasons, while bottlenose dolphins and harbor porpoises were seen in every season except fall.

Seasonal dolphin sighting rates were 46.9 common dolphins/km (fall 2020); 15.4 common dolphins/km, 2.3 bottlenose dolphins/km (winter); 75.5 common dolphins/km, 14.0 bottlenose dolphins/km (spring); 385.0 common dolphins/km; 85.7 bottlenose dolphins/km (summer); and 511.4 common dolphins/km (fall 2021).

Distribution patterns of dolphin species varied. Common dolphins were seen throughout the study area (Figure 10), whereas bottlenose dolphins were more common in the southern part of the study area (Figure 11). However, for both species, sightings were more common in the WEA than the Nantucket Shoals.

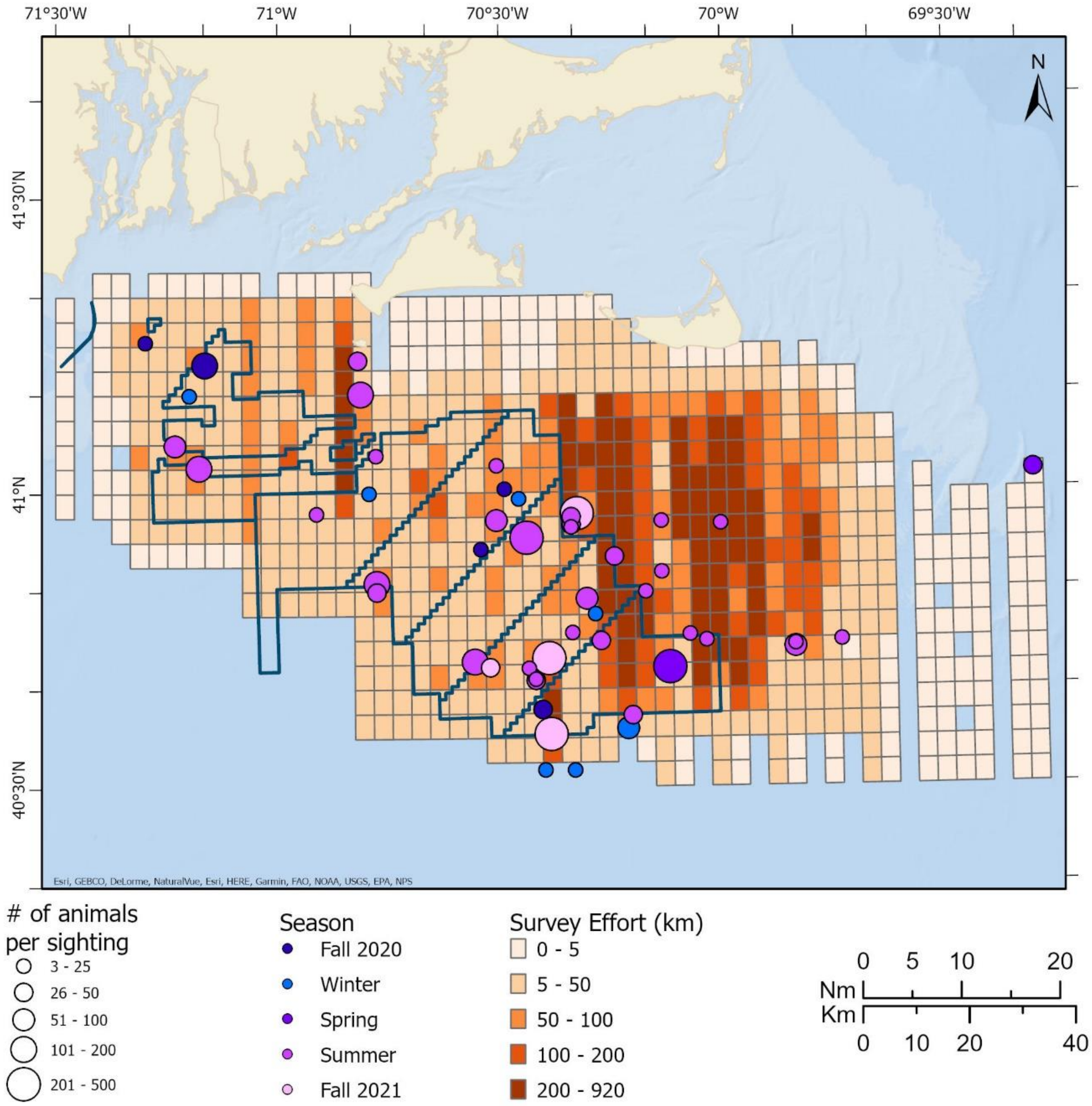

Figure 10. Map of common dolphin sightings during Campaign 6B aerial surveys

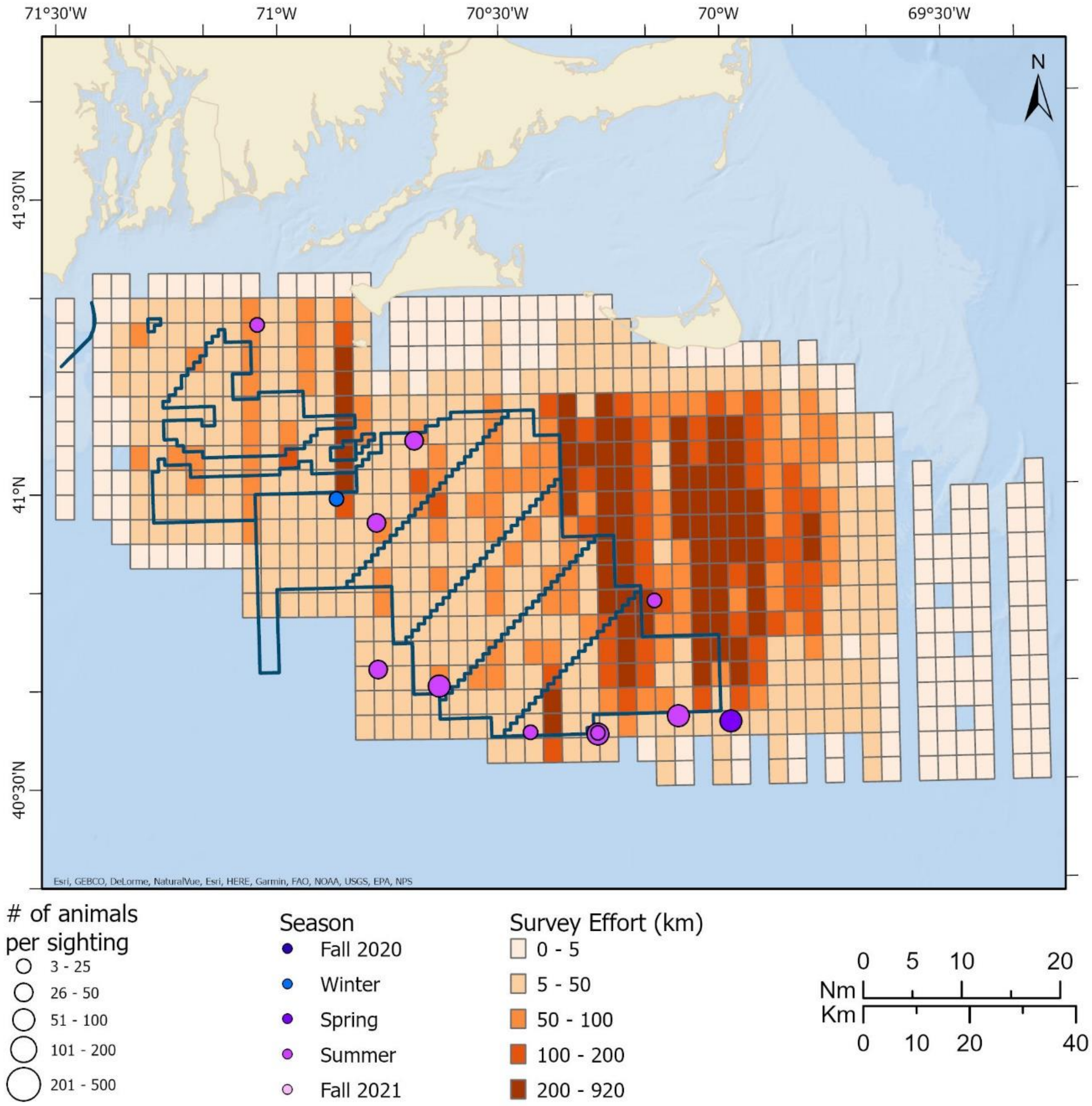

Figure 11. Map of bottlenose dolphin sightings during Campaign 6B aerial surveys

3.2.2.6.3 Abundance estimates

Seasonal density and abundance estimates were calculated for common dolphins for Campaign 6B (Table 7). Estimates were calculated for five seasons; the fall 2020 estimate includes data from Campaign 6A. Common dolphin abundance was highest in the fall (2,585 animals) and lowest in the winter (nine animals). Fall estimates varied widely: fall 2020 abundance was estimated at 213 animals, but fall 2021 abundance was estimated at 2,585 animals.

Table 7. Density and abundance of common dolphins during Campaign 6B

Effort (km) is the summed on-effort distance surveyed for all transects. # of detections is the number of sightings of one or more animals. # of animals is the sum of the number of animals used to calculate abundance. Est. density is the estimated number of individuals per km^2. Est. abundance is the estimated number of animals for the study area. 95% CI= 95% confidence interval of abundance.

Season-year	Effort (km)	# of detections	# of animals	Density	Abundance	95% CI
Fall – 2020	2,010	4	90	0.0237	213	74 – 618
Winter – 2021	3,779	1	4	0.001	9	2 – 41
Spring – 2021	1,142	0	0	-	-	-
Summer – 2021	2,744	21	1,272	0.1564	1,408	612 – 3,237
Fall – 2021	896	3	930	0.2872	2,585	631 – 10,587

Seasonal density and abundance estimates were calculated for bottlenose dolphins for Campaign 6B (Table 8). Estimates were calculated for five seasons; the fall 2020 estimate includes data from Campaign 6A. Bottlenose dolphin abundance was zero in all seasons except summer, when abundance was estimated at 455 dolphins.

Table 8. Density and abundance of bottlenose dolphins during Campaign 6B

Effort (km) is the summed on-effort distance surveyed for all transects. # of detections is the number of sightings of one or more animals. # of animals is the sum of the number of animals used to calculate abundance. Est. density is the estimated number of individuals per km^2. Est. abundance is the estimated number of animals for the study area. 95% CI= 95% confidence interval of abundance.

Season-year	Effort (km)	# of detections	# of animals	Density	Abundance	95% CI
Fall – 2020	2,010	0	0	-	-	-
Winter – 2021	3,779	0	0	-	-	-
Spring – 2021	1,142	0	0	-	-	-
Summer – 2021	2,744	8	390	0.0506	455	211 – 986
Fall – 2021	896	0	0	-	-	-

3.2.3 Sea turtles

During all Campaign 6B aerial surveys, there were 45 detections of 51 sea turtles recorded, which includes 15 camera detections of 15 leatherback turtles. Eighteen sightings of 19 leatherback turtles were observed while on-effort during general surveys (five of these sightings were from the vertical camera). Sea turtles were sighted in five months and in both summer (25 sightings of 26 individuals) and fall (20 sightings of 25 individuals).

Leatherback turtles were predominantly sighted over the Nantucket Shoals (Figure 12). Seasonal sighting rates were 3.3 turtles/km (fall 2020), 5.3 turtles/km (summer) and 2.9 turtles/km (fall 2021); no turtles were sighted in winter or spring. One loggerhead (*Caretta caretta*) and one unidentified sea turtle were detected during Campaign 6B; both of these sightings were in the Nantucket Shoals area.

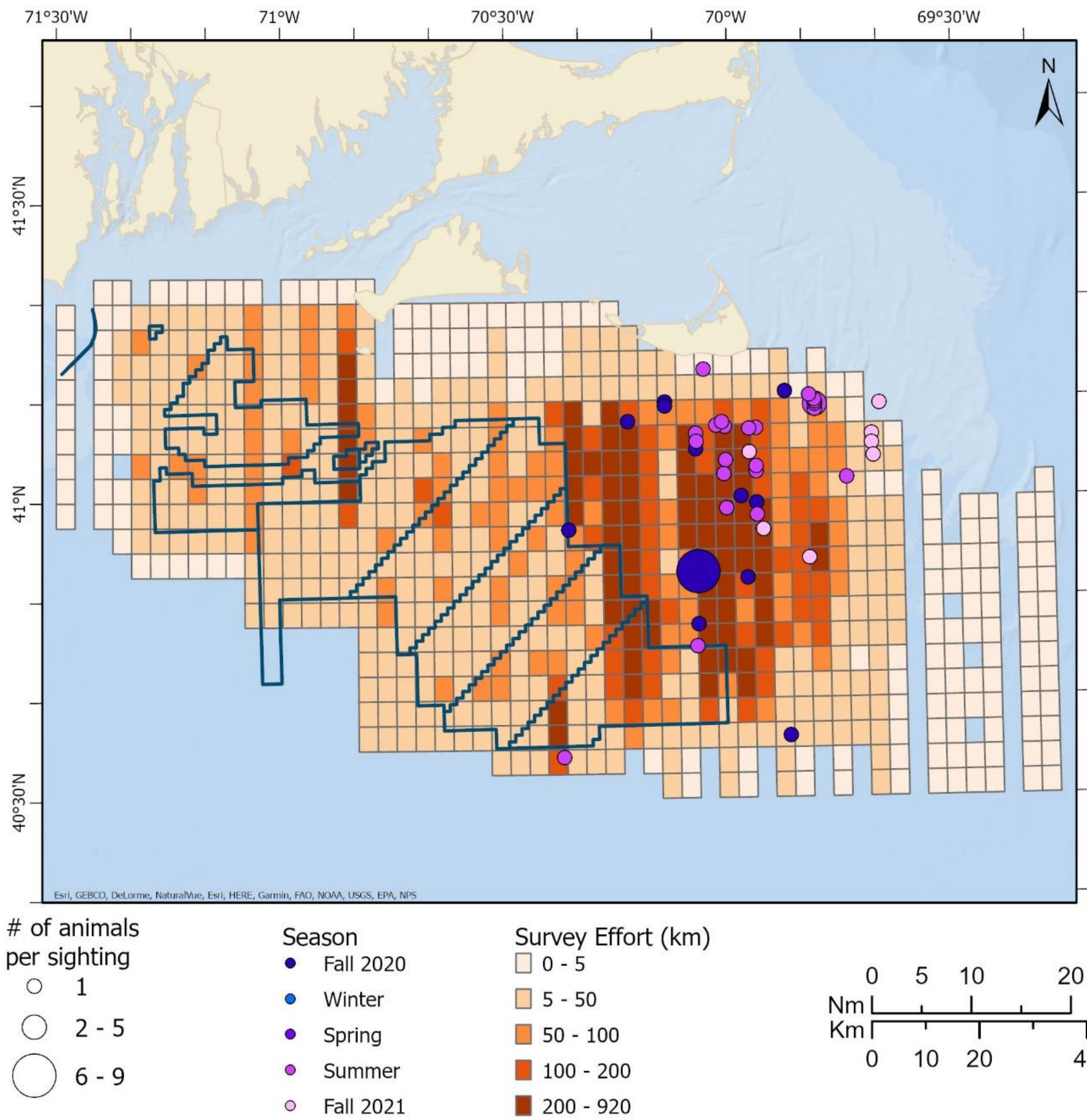

Figure 12. Map of leatherback turtle sightings during Campaign 6B aerial surveys

3.2.4 Other marine megafauna

Several species of sharks and bony fishes were observed during Campaign 6B aerial surveys. During all Campaign 6B aerial surveys, 17 basking sharks (*Cetorhinus maximus*), 13 blue sharks (*Prionace glauca*), 48 hammerhead sharks (*Sphyrna* sp.), two great white sharks (*Carcharodon carcharias*), 153 unidentified sharks, and 55 ocean sunfish (*Mola mola*) were sighted by observers and the camera. One sighting of three unidentified tuna and six sightings of 17 unidentified fishes were spotted by the vertical camera.

Sharks and bony fish had different distribution patterns: sharks were sighted more often in the deeper waters of the study area (outside of the Nantucket Shoals) whereas ocean sunfish were sighted more often over the Nantucket Shoals (Figure 13). The first tiger shark (*Galeocerdo cuvier*) recorded by the surveys was found as a camera detection in September 2020 (this sighting was previously reported in the Campaign 6A report).

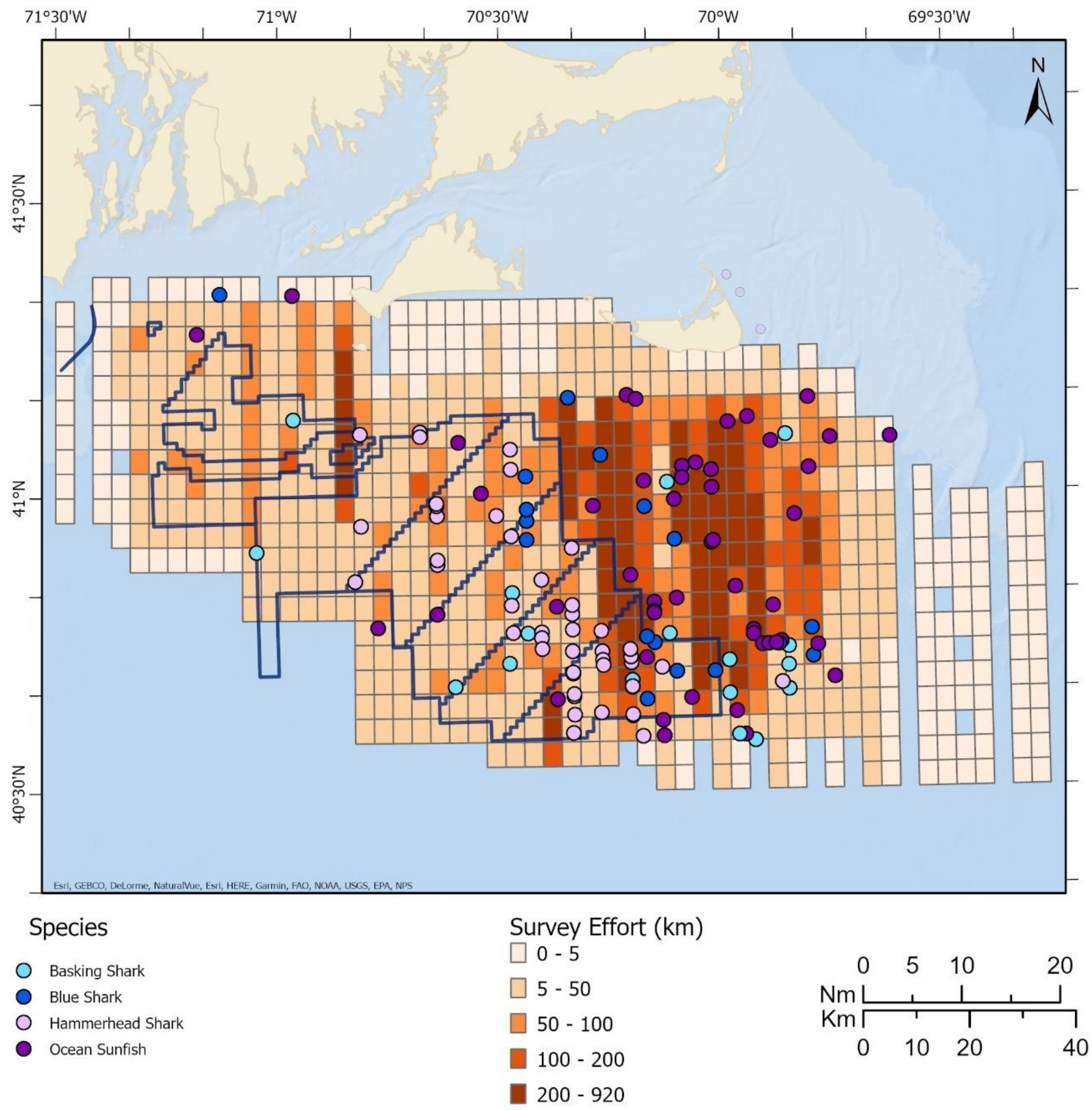

Figure 13. Map of shark and ocean sunfish sightings during Campaign 6B aerial surveys

3.3 Calibration Surveys

3.3.1 Detections

There were 301 detections of marine megafauna totaling 631 individuals recorded while on-effort during Campaign 6B calibration surveys in Massachusetts Bay. Of these detections, 93% (n = 281) were observer detections and 7% (n = 20) were camera detections. A summary of sightings, including the number of sightings at 305 m (1,000 ft) and 457 m (1,500 ft), is in Table A-3.

Marine megafauna included several species of large whales, small cetaceans, sharks, fishes, and sea turtles. Marine mammals were the most common individuals observed (75%, n = 474) followed by sharks and fishes (25%, n = 156), and sea turtles (<1%, n = 1). The majority of marine mammal sightings were cetaceans (95%) and the rest were pinnipeds. Identification to the species level was possible for 242 sightings and resulted in nine confirmed species. Birds and human activity were not marked by observers in the plane during Massachusetts Bay calibration surveys: consequently, these sightings are exclusively vertical camera detections.

During Campaign 6B, NEAq upgraded the vertical camera equipment to ensure appropriate resolution at higher altitude. The Canon Mark III was replaced with a Canon 5DS; this change in the camera increased pixel resolution at 305 m (1,000 ft) from 22 mm to 15 mm, and resulted in a resolution of 22 mm at 457 m (1,500 ft). Observers were able to detect and identify megafauna in vertical photos taken at 457 m (1,500 ft): an example of a humpback whale photographed during a trackline flown at 457 m (1,500 ft) is shown in Figure 14.

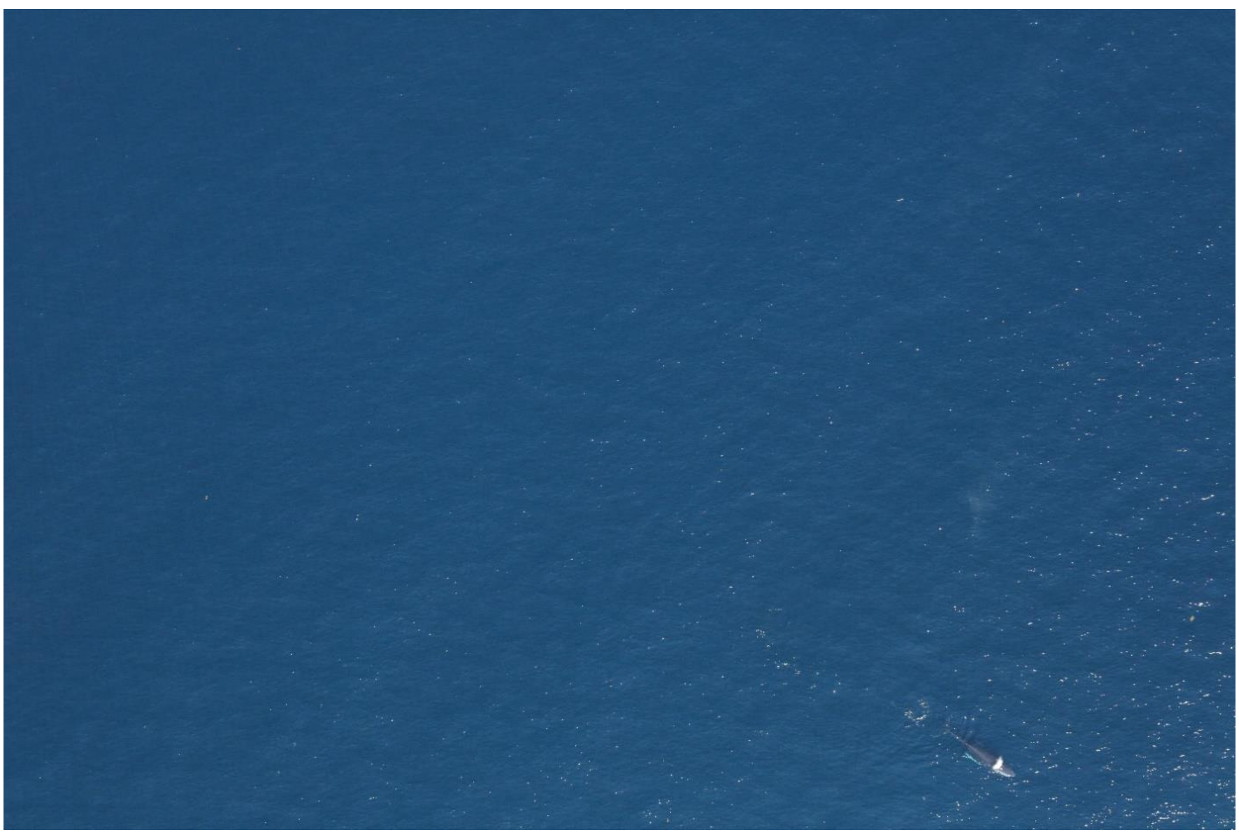

Figure 14. Example of a humpback whale detected in a vertical photograph at 457 m (1,500 ft).

3.3.2 Effect of survey altitude on detection probability

The purpose of the calibration surveys was to determine whether flying at an increased altitude during and after construction of wind turbines would have any effect on detection probability of marine mammals. Six calibration surveys in Massachusetts Bay resulted in an adequate sample size to model the detection probability for large whale sightings (fin, humpback, and unidentified whale) at 305 m (1,000 ft) and 457 m (1,500 ft). Thirty-five on-effort detections of 48 whales were recorded at 305 m and 58 on-effort detections of 72 whales were recorded at 457 m. We have begun preliminary analyses to explore the effect of altitude on density estimation. In these preliminary analyses, we used multiple-covariate distance sampling to estimate detection functions at each altitude (Figure 15). Average detection probability of the detection function at 305 m was 0.55, and the average detection probability of the detection function at 457 m was 0.61.

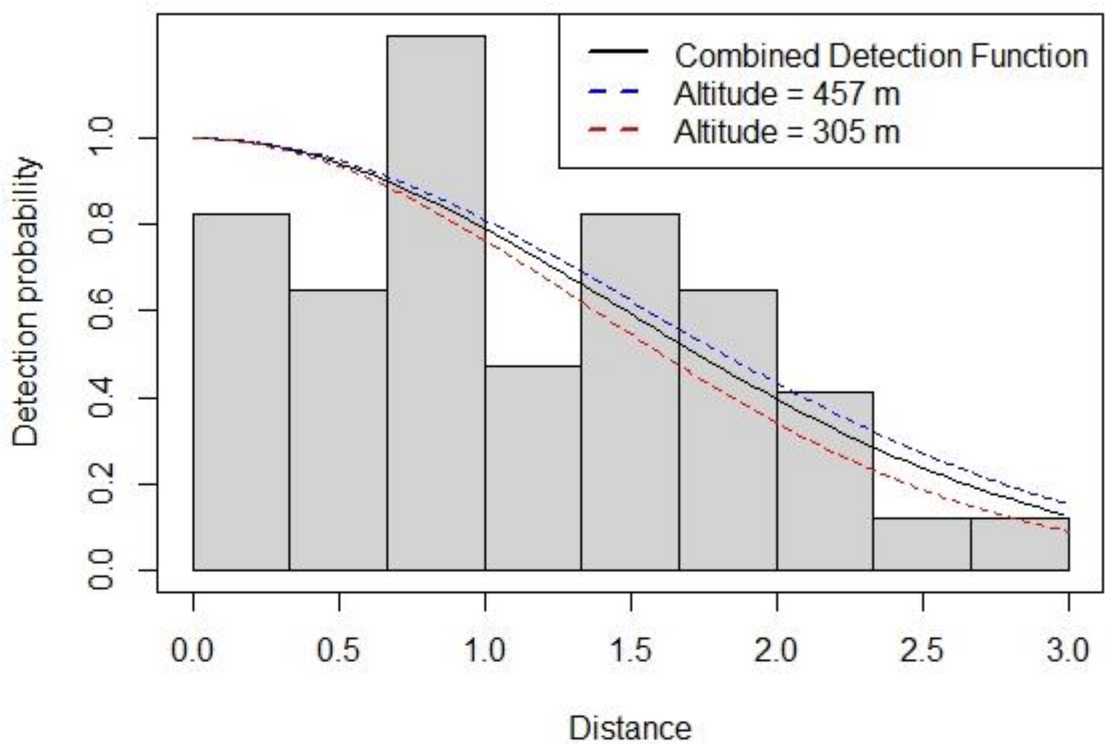

Figure 15. Large whale detection probability with an estimated detection function for each calibration survey altitude (305 m and 457 m).

Using the altitude-specific detection functions, we calculated density and abundance of fin and humpback whales in Massachusetts Bay during the period of the calibration surveys (April – August 2021) (Table 9). Although average detection probability was higher at 305 m, abundance estimates at each altitude were almost identical in both species.

Table 9. Density and abundance of humpback and fin whales at two different altitudes

Altitude is the target altitude of the trackline, # of detections is the number of sightings of one or more individual animals, # of animals is the number of individual animals summed over all sightings and transects, density is the estimated number of individuals per km^2, abundance is the estimated number of individuals in the calibration study area (1945 km^2), and 95% CI is the 95% confidence interval of the estimated abundance.

Species	Altitude (m)	# of detections	# of animals	Density	Abundance	95% CI
Humpback	305	19	30	0.0042	8	3 – 21
Humpback	457	36	46	0.0060	12	6 – 21
Fin whale	305	10	11	0.0015	3	2 – 6
Fin whale	457	8	11	0.0014	3	1 – 6

4 Discussion

4.1 Cetaceans

With the completion of the Campaign 6B surveys, we can divide the time series of aerial surveys conducted in the study area into two time periods of approximately equal duration: 2011-2015 (Campaigns 1-3) and 2017-2021 (Campaigns 4-6). Right whales were present in smaller numbers and only used the study area in the winter and spring during the 2011-2015 time period (Leiter et al., 2017). In contrast, the Campaign 6B surveys represent the fifth year of surveys during the 2017-2021 time period to document increased winter and spring right whale abundances and the temporal expansion of right whale use of the study area into summer and fall (O’Brien et al., 2020; O'Brien et al., 2021; O'Brien et al., In Review; Quintana-Rizzo et al., 2021). This increase in right whale abundance and year-round occurrence in the study area no longer appears anomalous. Instead, it appears to represent the current pattern for the study area.

While the right whale abundance and temporal habitat use patterns reported here are consistent with previous reports from the 2017-2021 time period, variation continues to be observed in seasonal spatial distributions. Summer, fall, and winter sightings typically occur over the Nantucket Shoals. However, right whale aggregations during the spring have been observed over the Nantucket Shoals (2013, 2014, 2018, 2019) and in the middle of the study area south of Martha’s Vineyard (2012, 2015, 2017, 2021) (Leiter et al., 2017; O’Brien et al., 2020; O'Brien et al., 2021; Quintana-Rizzo et al., 2021; data reported here). Previous oceanographic analyses suggests that this geographic shift may be related to the presence of high-quality prey items, such as *Calanus finmarchicus* (Quintana et al., 2019). Further research is needed about right whale distributions in the study area to differentiate the effects of wind energy construction from climate-related changes in right whale distributions. Understanding the mechanisms determining right whale distributions, including a better understanding of prey distribution and abundance, is also needed to support successful mitigation of the effects of wind energy construction on right whales.

Rorqual density and sighting rates followed previously observed seasonal patterns with some exceptions. Fin whale summer density (0.0019 whales/km) was within the range observed during previous campaigns (0.0004 – 0.0076 whales/km; Stone et al., 2017) and was zero in both fall seasons. Humpback whale density was highest during the summer (0.002 whales/km) and was within the range of densities observed since 2011 (0 - 0.0056 whales/km). Both fin whales and humpback whales were present in winter 2021 (0.0002 and 0.0007 whales/km, respectively), which is unusual. Fin whales were previously absent in the winter and humpbacks were previously only observed in winter 2015 (density = 0.0011 whales/km). Minke whale density in spring and summer 2021 (0.0007 and 0.0008 whales/km) was low: previous spring and summer estimates ranged between 0.0009 and 0.0087 whales/km.

Rorqual whales were distributed across the study area fairly evenly, with some exceptions. Humpback whales demonstrated a similar tendency to right whales to gather over the Nantucket Shoals in the summer and fall. However, humpbacks were seen both over the Nantucket Shoals and in the WEAs in the summer. In the fall, they were typically observed over the Nantucket Shoals. Additionally, humpback whales were observed in close proximity to feeding right whales on the Shoals, and were observed defecating, suggesting that they were feeding as well. This behavioral observation is interesting because the primary prey for right whales and humpback whales are different.

4.2 Turtles and fishes

Sea turtle sightings during Campaign 6B consisted mostly of leatherback turtles and occurred in both the summer and fall. Leatherback turtle sighting rates were slightly higher in summer 2021 (5.3 turtles/km), than in previous years (4.65 – 4.7 turtles/km); fall sighting rates were within the range of previous fall sightings rates (2021: 2.9 – 3.3 turtles/km, compared to 1.68 - 4.59 turtles/km). Most of the sightings occurred south of Nantucket, which is similar to sightings locations in previous years.

Sightings of sharks and large bony fishes were most common during the summer, which is similar to the timing of sightings in previous years. While sharks and bony fishes tended to be distributed across the study area, sharks appeared to be more common in deeper parts of the study area and ocean sunfish appeared to be more common over the shallower Nantucket Shoals. In the Campaign 6A report, we noted that more hammerhead sharks were recorded in summer 2020 than in all previous seasons combined. In Campaign 6B, we continued to observe large numbers of hammerhead sharks. Specifically, 48 hammerhead sharks were detected in summer 2021, compared to a total of 23 hammerhead sharks recorded by observers in all surveys prior to 2021. Additionally, observers noted an unusually low number of basking sharks in Campaign 6B (17 sightings compared to 73 in Campaign 6A). Basking shark and hammerhead shark species may both respond to changes in sea surface temperature (Austin et al., 2019; Osgood et al., 2021). Consequently, these changes in numbers of detections may indicate the beginning of a distribution shift.

4.3 Calibration surveys

Analysis of the altitude calibration surveys is ongoing. While initial analysis of the data collected in Massachusetts Bay suggests that increasing altitude from 305 m to 457 m will not have a significant effect on observers' ability to detect large whales, additional data collection and analyses are needed. The ability of an observer to detect an object from the aircraft depends on the size of the object and the amount of time it is in view. While an increase in altitude may decrease the size of an object, it will also increase the amount of time it is available for an observer to detect. It is possible that the increase in altitude from 305 m to 457 m changes both the size of objects and the time they are in view in a way that results in similar overall detectability at both altitudes. We are in the process of analyzing whether the time in view changes significantly between these two altitudes. We also need to finalize the detection probability analyses and determine whether the sample size for large whales is adequate. Finally, we need to collect additional data about small cetaceans and turtles to enable similar analyses for these species. Continuing to collect and analyze detection probability data at different altitudes is important for designing surveys that can detect potential displacement of species during wind energy construction.

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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 6B general 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	395	2	11	11	406
	Common dolphin (*Delphinus delphis*)	34	2,856	3	47	37	2,903
	Harbor porpoise (*Phocoena phocoena*)	2	4	4	6	6	10
	Unidentified common or white-sided dolphin	--	--	1	1	1	1
	Unidentified dolphin	30	290	3	6	33	296
Large cetaceans	Fin whale (*Balaenoptera physalus*)	9	16	--	--	9	16
	Minke whale (*Balaenoptera acutorostrata*)	6	6	--	--	6	6
	Humpback whale (*Megaptera novaeangliae)*	20	29	--	--	20	29
	Right whale (*Eubalaena glacialis*)	54	112	--	--	54	112
	Unidentified whale	1	1	--	--	1	1
Pinnipeds	Gray seal (*Halichoerus grypus*)	4	183	2	2	6	185
	Unidentified seal	5	5	5	654	10	659
Sea turtles	Leatherback sea turtle (*Dermochelys coriacea*)	13	14	5	5	18	19

Table A-1 continued. Summary of all on-effort aerial observer and vertical photograph detections of marine megafauna during Campaign 6B general 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 fishes	Basking shark (*Cetorhinus maximus*)	3	3	2	2	5	5
	Blue shark (*Prionace glauca*)	8	8	8	8	16	16
	Hammerhead shark (*Sphyrna* sp.)	38	39	7	7	45	46
	Ocean sunfish (*Mola mola*)	18	20	7	7	25	27
	Tiger shark (*Galeocerdo cuvier*)	--	--	1	1	1	1
	Great white shark (*Carcharodon Carcharias*)	1	1	1	1	2	2
	Unidentified shark	62	75	37	44	99	119
	Unidentified tuna	--	--	1	3	1	3

Table A-2. Summary of on and off-effort aerial observer and vertical photograph detections during all Campaign 6B 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*)	10	495	3	29	13	524
	Common dolphin (*Delphinus delphis*)	45	3,890	5	63	50	3,953
	Harbor porpoise (*Phocoena phocoena*)	3	8	5	7	8	15
	Unidentified common or white-sided dolphin	--	--	1	1	1	1
	Unidentified dolphin	52	382	5	9	57	391
Large cetaceans	Fin whale (*Balaenoptera physalus*)	17	26	1	1	18	27
	Minke whale (*Balaenoptera acutorostrata*)	23	23	1	1	24	24
	Humpback whale (*Megaptera novaeangliae*)	66	97	--	--	66	97
	Right whale (*Eubalaena glacialis*)	90	169	--	--	90	169
	Sei whale (*Balaenoptera borealis*)	1	1	--	--	1	1
	Unidentified whale	4	4	--	--	4	4
Pinnipeds	Gray seal (*Halichoerus grypus*)	22	1,498	3	4	25	1,502
	Unidentified seal	50	1,573	10	659	60	2,232
Sea turtles	Leatherback sea turtle (*Dermochelys coriacea*)	28	34	15	15	43	49
	Loggerhead sea turtle (*Caretta caretta*)	1	1	--	--	1	1
Birds	Great Black-backed gull (*Larus marinus*)	--	--	6	6	6	6
	Herring gull (*Larus argentatus*)	--	--	1	1	1	1
	Northern fulmar (*Fulmarus glacialis*)	--	--	2	2	2	2
	Northern gannet (*Morus bassanus*)	--	--	18	19	18	19
	Unidentified bird	--	--	519	1,384	519	1,384

Table A-2 continued. Summary of on and off-effort aerial observer and vertical photograph detections during all Campaign 6B aerial surveys

Category	Species	Observers: Number of detections	Observers: Number of individuals	Vertical photos: Number of detections	Vertical photos: Number of individuals	Totals: Number of detections	Totals: Number of individuals
Birds	Unidentified gull	--	--	12	12	12	12
	White-winged scoter (*Melanitta deglandi*)	--	--	1	1	1	1
Sharks and fishes	Basking shark (*Cetorhinus maximus*)	14	14	3	3	17	17
	Blue shark (*Prionace glauca*)	8	8	11	11	19	19
	Hammerhead shark (*Sphyrna* sp.)	39	40	8	8	47	48
	Ocean sunfish (*Mola mola*)	39	42	13	13	52	55
	Tiger shark (*Galeocerdo cuvier*)	--	--	1	1	1	1
	Great white shark (*Carcharodon Carcharias*)	1	1	1	1	2	2
	Schools of fish	5	5	7	7	12	12
	Unidentified fish	--	--	6	17	6	17
	Unidentified shark	88	101	45	52	133	153
	Unidentified tuna	--	--	1	3	1	3
Human activity	Debris (different types)	1	1	203	212	204	213
	Fixed fishing gear	567	1,181	43	43	610	1,224
	Fishing vessel	333	351	--	--	333	351
	Recreational vessel	156	186	--	--	156	186
	Other types of vessels/data stations/coast guard	113	114	--	--	113	114
Unknown	Unidentified animal	6	6	--	--	6	6
	Unidentified marine mammal	--	--	1	1	1	1

Table A-3. Summary of all on-effort aerial observer and vertical photograph detections during Campaign 6B Massachusetts Bay calibration 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	Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	0 (0)	0 (0)	0 (1)	0 (9)	0 (1)	0 (9)
	Unidentified dolphin	9 (10)	140 (155)	0 (0)	0 (0)	9 (10)	140 (155)
Large cetaceans	Fin whale (*Balaenoptera physalus*)	11 (8)	12 (11)	0 (0)	0 (0)	11 (8)	12 (11)
	Minke whale (*Balaenoptera acutorostrata*)	14 (15)	14 (15)	0 (0)	0 (0)	14 (15)	14 (15)
	Humpback whale (*Megaptera novaeangliae)*	22 (40)	35 (51)	1 (0)	1 (0)	23 (40)	36 (51)
	Unidentified whale	7 (15)	8 (15)	0 (0)	0 (0)	7 (15)	8 (15)
Pinnipeds	Gray seal (*Halichoerus grypus*)	1 (0)	1 (0)	0 (0)	0 (0)	1 (0)	1 (0)
	Unidentified seal	6 (1)	6 (1)	0 (0)	0 (0)	6 (1)	6 (1)
Sea turtles	Kemp's ridley sea turtle (*Lepidochelys kempii*)	0 (0)	0 (0)	1 (0)	1 (0)	1 (0)	1 (0)
Sharks and fishes	Basking shark (*Cetorhinus maximus*)	23 (33)	23 (34)	1 (3)	1 (3)	24 (36)	24 (37)
	Blue shark (*Prionace glauca*)	2 (1)	14 (1)	2 (2)	2 (2)	4 (3)	16 (3)
	Ocean sunfish (*Mola mola*)	39 (16)	39 (17)	3 (3)	3 (3)	42 (19)	42 (20)
	Unidentified fish	0 (0)	0 (0)	0 (1)	0 (1)	0 (1)	0 (1)
	Unidentified shark	4 (4)	4 (4)	0 (2)	0 (2)	4 (6)	4 (6)
	Unidentified tuna	0 (0)	0 (0)	1 (0)	4 (0)	1 (0)	4 (0)

Note: Numbers without parentheses are sightings at 1,000 feet and numbers within parentheses are sightings at 1,500 feet. Sightings from vertical photos that were also seen by observers are not included in these counts.

Table A-3 continued. Summary of all on-effort aerial observer and vertical photograph detections during Campaign 6B Massachusetts Bay calibration 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**
Birds	Unidentified gull	--	--	2 (0)	2 (0)	2 (0)	2 (0)
	Unidentified bird	--	--	10 (16)	17 (19)	10 (16)	17 (19)
Human activity	Debris (different types)	--	--	9 (11)	10 (11)	9 (11)	10 (11)
	Fixed fishing gear	--	--	4 (19)	4 (22)	4 (19)	4 (22)
	Recreational vessel	--	--	1 (5)	1 (5)	1 (5)	1 (5)
	Whale watching vessel	--	--	1 (0)	1 (0)	1 (0)	1 (0)

Note: Numbers without parentheses are sightings at 1,000 feet and numbers within parentheses are sightings at 1,500 feet. Sightings from vertical photos that were also seen by observers are not included in these count