Digital Aerial Baseline Survey of Marine Wildlife in Support of Offshore Wind Energy:

Spatial and Temporal Marine Wildlife Distributions in the New York Offshore Planning Area, Summer 2016–Spring 2019

Final Report | Volume 1: Methods, General Results, Limitations, and Discussion

Report Number 21-07a | October 2021

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NORMANDEAU ASSOCIATES ENVIRONMENTAL CONSULTANTS

APEM

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Volume 1: Methods, General Results, Limitations, and Discussion

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Abstract

NYSERDA tasked Normandeau Associates, Inc., and their teaming partner APEM Ltd. to collect aerial digital imagery over the New York Offshore Planning Area during 12 surveys spaced seasonally over three years between 2016 and 2019. Imagery was captured at a resolution of 1.5 cm at the sea surface and provides information on spatial and temporal abundances of birds, marine mammals, turtles, rays, sharks, large bony fishes, and fish shoals. Spatial patterns were analyzed within distance from shore and water depth zones and reference the proposed Call Areas within the surveyed planning area identified by BOEM at the time of writing. Seasonal density comparisons highlight the differences among zones for each species group. Except for turtles, densities were generally lower in the zone containing the identified BOEM Call Areas. Full Summary and Final Reports can also be found on remote.normandeau.com https://remote.normandeau.com/aer_docs.php?pj=6

Keywords

Marine mammals; Birds; Turtles; Rays; Sharks; Aerial Digital Surveys; NYSERDA; Normandeau; APEM; Call Area; Density; Distribution; Abundance; Marine Wildlife; Offshore Wind

Acknowledgments

Normandeau Associates, Inc., and APEM Ltd. would like to thank NYSERDA for this opportunity, which, at the beginning of the project, was the largest survey of its type ever undertaken in the world. During the project, QA/QC protocols were developed that created confidence in data quality, and data sharing platforms evolved that allowed easy information sharing to all.

Normandeau would also like to thank Dr. Greg Skomal, Dr. Robert Kenney, Calusa Horn, Jessica Pate, and Dr. Nick Farmer for their taxonomic expertise and for their interest in the data generated by these surveys. Special thanks to Greg Lampman of NYSERDA for his help and support throughout the project. Normandeau would also like to thank the Project Advisory Committee for their interest and advice throughout the project.

All aerial images were collected by APEM Ltd., and flight height calculation methodology information was provided by APEM Ltd.

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

APEM	APEM Ltd.
BOEM	Bureau of Ocean Energy Management
BTO	British Trust for Ornithology
ESA	Endangered Species Act
FAA	Federal Aviation Administration
FHC	flight height calculator
GPS	Global Positioning System
GSD	ground sampling distance
km^2	kilometers squared
m	meters
Normandeau	Normandeau Associates, Inc.
NYSERDA	New York State Energy Research and Development Authority
OPA	offshore planning area
OSW	offshore wind
QC	quality control
RSZ	rotor swept zone
VHF	very high frequency
WEA	wind energy area
WTG	wind turbine generator

1 Introduction

There is growing interest in developing offshore wind (OSW) energy in New York State and across the country. However, it is still unclear what impacts OSW development have on wildlife, including coral, birds, bats, sea turtles, fish, and marine mammals. Data gaps interfere with federal and State regulator efforts to avoid or minimize potential negative impacts on wildlife from OSW development. There have been several efforts in New York and along the Atlantic coast to identify and fill these gaps in recent years, but many research needs are still unmet. One of the most pressing needs is baseline data on potential wildlife exposure. Knowledge about species presence and absence in development areas helps regulators form site-specific questions to be addressed by developers. Regional-scale baseline information on wildlife distributions, abundance, and movements by season can reveal the relative biodiversity of development sites. These surveys also provide a better understanding of the potential effects of individual projects and any potential cumulative effects of multiple projects.

The New York State Energy Research and Development Authority (NYSERDA) contracted with Normandeau Associates Inc. (Normandeau) and teaming partner APEM Ltd. (APEM) to use high-resolution aerial digital imagery to collect data on birds, marine mammals, sea turtles, cartilaginous fish, and other taxa encountered offshore. Surveys were conducted four times annually over three years. The surveys considered available historical data, using the latest digital and sensor technology to provide the highest possible identification success.

All information from the 12 surveys (Summer 2016 through Spring 2019) has been submitted to these data portals and public sector information hubs:

- OBIS-SEAMAP
- Northwest Atlantic Seabirds Catalog
- DOS
- DEC

This report summarizes methods used for data collection and analyses, an overview of the general results from the 12 surveys and discusses merits of the methodology, potential future research, and policy implications. This document is volume 1 of five volumes with subsequent volumes presenting taxon-specific results:

- Volume 1: Methods, General Results, Limitations, and Discussion
- Volume 2: Results (Birds)
- Volume 3: Results (Turtles)
- Volume 4: Results (Marine Mammals)
- Volume 5: Results (Sharks and Rays)

The final report on large bony fishes and fish shoals is a separate document and may be found at https://remote.normandeau.com/docs/NYSERDA_BonyFish_and_Shoal_Report.pdf

All five volumes draw on information in documents prepared on behalf of NYSERDA by Normandeau's team and available at https://remote.normandeau.com/nys_docs.php

Reports used to prepare this document include:

- Summer 2016 Survey 1
    - Survey Summary Report
    - Target Extraction Summary Report
    - Taxonomic Analysis Summary Report
- Fall 2016 Survey 2
    - Survey Summary Report
    - Target Extraction Summary Report
    - Taxonomic Analysis Summary Report
- First Semiannual Report Summer and Fall 2016
- Winter 2016–2017 Survey 3
    - Survey Summary Report
    - Target Extraction Summary Report
    - Taxonomic Analysis Summary Report
- Spring 2017 Survey 4
    - Survey Summary Report
    - Target Extraction Summary Report
    - Taxonomic Analysis Summary Report
- Second Semiannual Report Summer 2016 through Spring 2017
- Summer 2017 Survey 5
    - Survey Summary Report
    - Target Extraction Summary Report
    - Taxonomic Analysis Summary Report

- Fall 2017 Survey 6
    - Survey Summary Report
    - Target Extraction Summary Report
    - Taxonomic Analysis Summary Report
- Third Semiannual Report Summer 2016 through Fall 2017
- Winter 2017–2018 Survey 7
    - Survey Summary Report
    - Target Extraction Summary Report
    - Taxonomic Analysis Summary Report
- Spring 2018 Survey 8
    - Survey Summary Report
    - Target Extraction Summary Report
    - Taxonomic Analysis Summary Report
- Fourth Semiannual Report Summer 2016 through Spring 2018
- Summer 2018 Survey 9
    - Survey Summary Report
    - Target Extraction Summary Report
    - Taxonomic Analysis Summary Report
- Fall 2018 Survey 10
    - Survey Summary Report
    - Target Extraction Summary Report
    - Taxonomic Analysis Summary Report
- Fifth Semiannual Report Summer 2016 through Fall 2018
- Winter 2018–2019 2018 Survey 11
    - Survey Summary Report
    - Target Extraction Summary Report
    - Taxonomic Analysis Summary Report
- Spring 2019 Survey 12
    - Survey Summary Report
    - Target Extraction Summary Report
    - Taxonomic Analysis Summary Report
- Large Bony Fish and Fish Shoals Final Report 2016–2019
- Sixth Semiannual Report Summer 2016 through Spring 2019

2 Methods

2.1 Data Collection

The New York Offshore Planning Area (OPA), including a 300-m buffer, covers 43,745.20 km^2 (12,754.06 mi^2). During the first year, the New York Wind Energy Area (WEA), including a 4-km buffer, was also surveyed in a grid pattern covering 850.92 km^2 (248.09 mi^2). After the lease was awarded, survey effort over the WEA was reduced to the same pattern as the rest of the OPA. Twelve surveys were completed within this reporting period (Table 1). There were differences in duration among surveys. Initially, the primary reason was a different camera with a narrower field of view was used for the Summer 2016 survey, which required more flying to achieve the target 7% coverage of the OPA. Minor differences over the following two surveys were attributable to adjustments for achieving correct coverage using a new camera system. Other factors continuing to affect survey duration include weather conditions and day length. For all surveys, transects of the OPA covered approximately 3,062 km^2 (1,182.25 mi^2).

Two APEM camera systems were used for the surveys. The Shearwater II camera system was used during the Summer 2016 survey, and the new Shearwater III camera system was used for all subsequent surveys. Both systems collected data at 1.5-cm ground sampling distance (GSD), and both surveys used a Piper Aztec twin engine aircraft. In addition, during the Summer 2016 survey of the OPA, data were collected at 0.75-cm GSD on near shore sample lines, which were flown at the lower altitude of approximately 152 m (500 ft) to accommodate restrictions imposed in controlled airspace around the John F. Kennedy Airport. Flight altitude for the remaining survey lines of the Summer survey was at 310.9 m (1,020 ft), and data were captured at 414.5 m (1,360 ft) for the subsequent surveys described in this report.

The survey team was based out of MacArthur Airport in Long Island, New York, during surveys. Because there are several local airfields on Long Island, the Federal Aviation Administration (FAA) imposes varying altitude restrictions that survey aircraft must obey. These are designated according to distance from the airfield. Flights parallel to the shoreline within the restricted zone ensure the survey aircraft can maintain constant altitude over a complete transect, thus ensuring consistency in image resolution and areal coverage along transect. GPS accuracy for aircraft location is 2.5 m on the X and Y position, and 5 m on the Z location. For all surveys, nearshore transects were flown parallel to the shoreline, and for the Fall 2016, Winter 2016–2017, Spring 2017, Summer 2017, Fall 2017, Winter 2017–2018, Spring 2018, Summer 2018, Fall 2018, Winter 2018–2019, and Spring 2019 surveys, these were split into east and west segments (Figure 1, Figure 2). FAA-controlled altitude restrictions cease to be an issue several miles offshore. Transects were oriented perpendicular to the shoreline and consequently to the bathymetry, providing optimal orientation for expected clines in the distribution of target species (Figure 3).

Daily survey time maximized crew hours and avoided mid-day when glare/glint was most prevalent, and surveys were not conducted when Douglas sea scale was ≥4, cloud base was <426.7 m (<1,400 ft), visibility was <5 km (3.1 mi), or wind speed was >30 knots (34.5 mph). The onboard APEM camera technician continuously monitored the images collected and if they ceased to be of sufficient quality, image acquisition stopped until suitable conditions returned. At each capture point, surplus images are collected to allow for replacement of any image found unsuitable for analysis. Data collected for the OPA included a 300-m buffer. All data capture points within the 300-m buffer of the OPA are included for analysis. The shape of the survey area sometimes means a small part of the very large image might be outside of the 300-m buffer. Following each daily survey, sample imagery was evaluated by an APEM camera technician to make sure it was good quality for analysis. Data were backed up daily and shipped for analysis.

Table 1. Starting and Ending Dates and Number of Days to Complete Each Survey

Season	Reference Month	Date Started	Date Completed	# Days to Complete
Year 1				
Summer 2016	Aug 2016	26 Jul 2016	9 Aug 2016	13
Fall 2016	Nov 2016	5 Nov 2016	27 Nov 2016	10
Winter 2016–2017	Mar 2017	6 Mar 2017	3 Apr 2017	10
Spring 2017	May 2017	4 May 2017	21 May 2017	9
Year 2				
Summer 2017	Aug 2017	6 Aug 2017	21 Aug 2017	8
Fall 2017	Nov 2017	9 Nov 2017	27 Nov 2017	8
Winter 2017–2018	Feb 2018	18 Feb 2018	1 Mar 2018	6
Spring 2018	May 2018	21 Apr 2018	26 Apr 2018	5
Year 3				
Summer 2018	Aug 2018	29 Jul 2018	16 Aug 2018	8
Fall 2018	Nov 2018	11 Nov 2018 [a]	7 Dec 2018	12
Winter 2018-2019	Mar 2019	3 Feb 2019	17 Feb 2019	8
Spring 2019	May 2019	27 Apr 2019	7 May 2019	5

[a] Although partial transect survey was flown on November 11, 2018 (Fall 2018), no data were processed from this flight. Processed data commenced on November 14, 2018. This is the only survey with a discrepancy between date flown and dates of data analyzed.

Figure 1. Flight Plan Used for Near Shore East

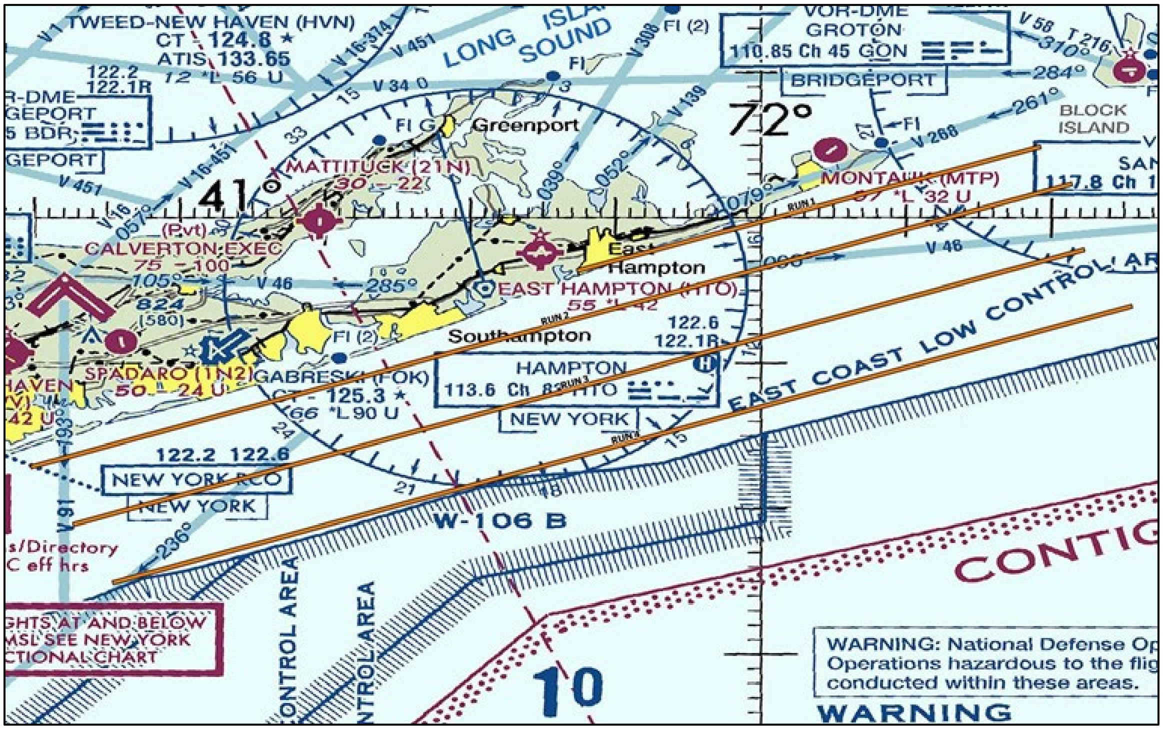


Figure 2. Flight Plan Used for Near Shore West

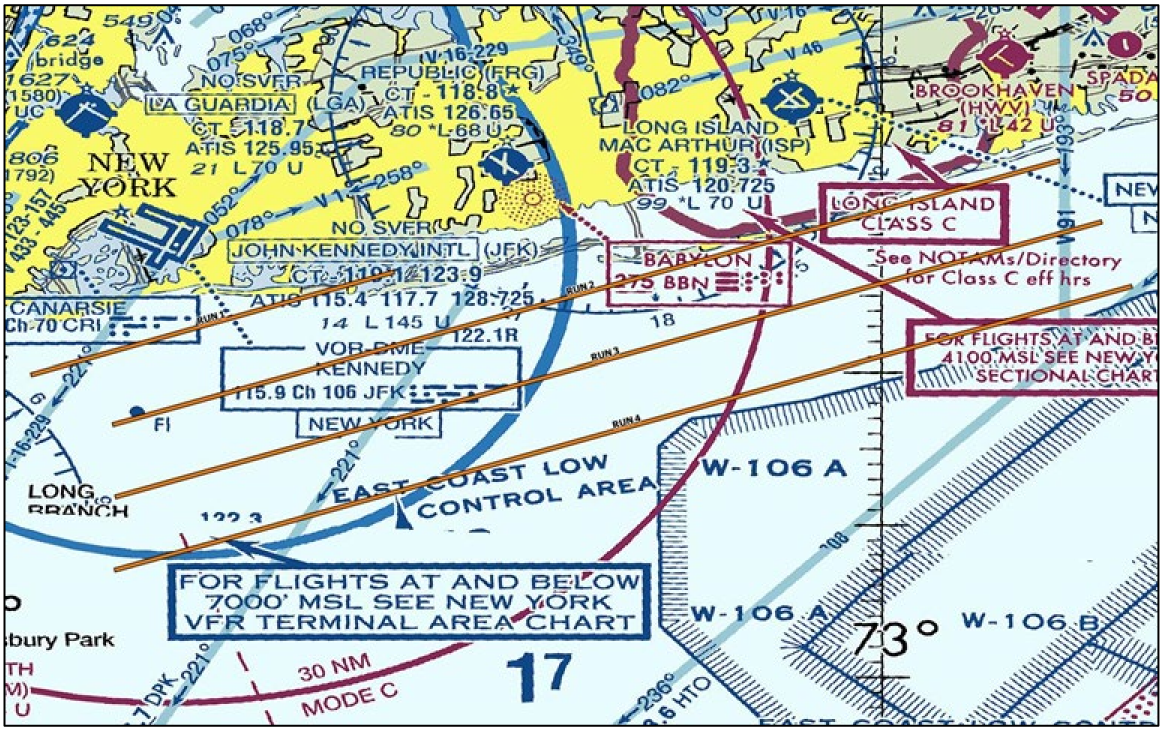
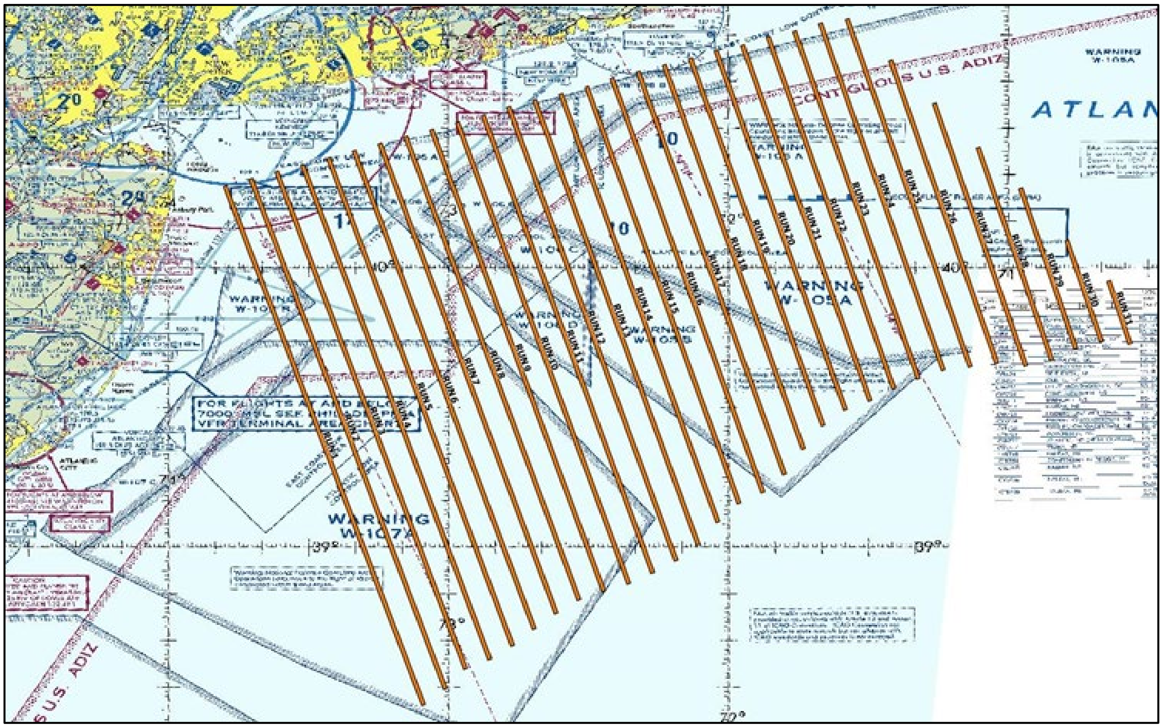


Figure 3. Flight Plan Used for the Offshore Planning Area



2.2 Target Extraction and Quality Control

Target extraction is accomplished using automated and manual target identification and extraction methods, and all survey data undergo quality control. To continue monitoring the success of the automated and manual target extraction and ensure data are not lost during the extraction process, a minimum of 10% of the blank images are screened for quality control. By contract, Normandeau’s quality control of target extraction had to meet a minimum agreement of 90%, but self-imposed higher levels of agreement during the extraction process meant that any unusual slippage in agreement below 98% to 99% triggered a review of the analysts involved and early action was taken. This helped maintain high confidence in the target extraction process. Once the target extraction was complete, all images found to contain organisms were transmitted to taxonomists for identification using the ReMOTe portal (https://remote.normandeau.com) for data management, identification, and reporting. Initial extraction categorizes targets into taxonomic groups and a cropped image of the animal is posted for identification (Figure 4).

2.3 Target Classification and Identification

Targets were categorized into ten groups representing birds, bats, turtles, marine mammals, rays, sharks, large bony fish, fish shoals, vessels, and fixed structures. These were then accessed for identification by highly experienced biologists in their taxonomic group, and identifications of species listed as "endangered" or "threatened" by the State or under the Endangered Species Act (ESA) were flagged (Figure 4). The identification of large bony fish was added later to the scope of work. For this reason, large bony fish and fish shoals are reported independently. Vessels were also a group not initially classified. Reports for large bony fish can be found on the documents tab at https://remote.normandeau.com/

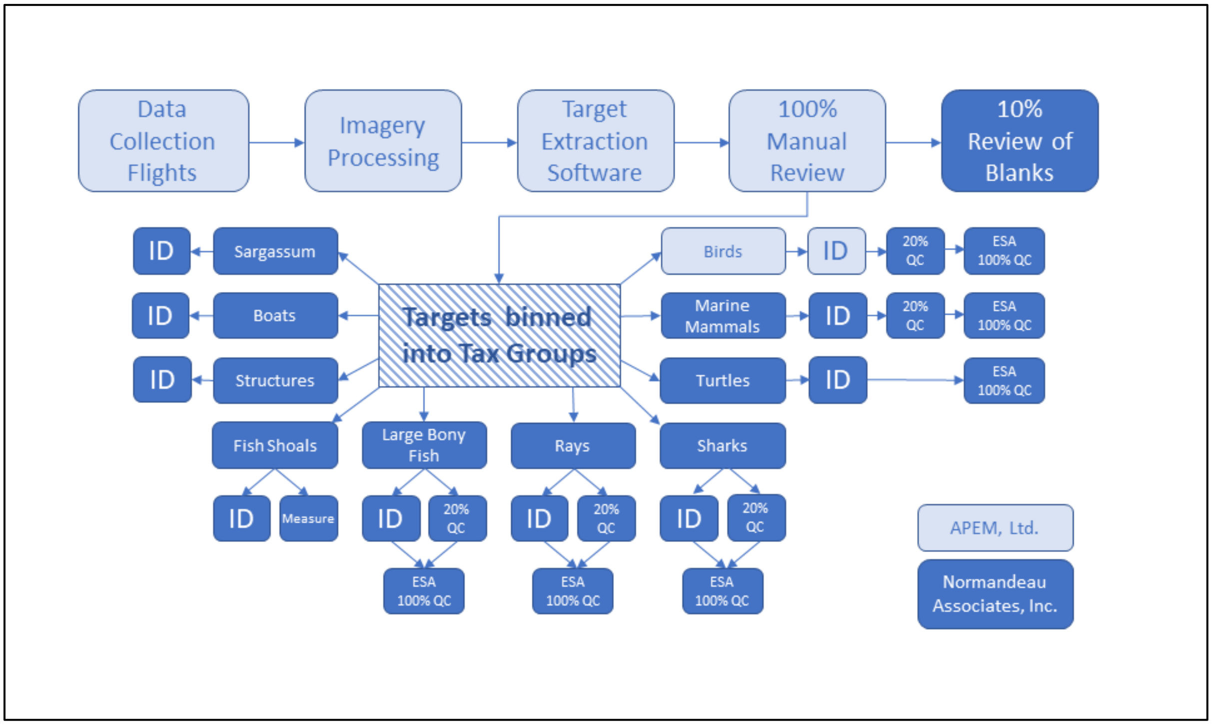
2.4 Identification Quality Control

A minimum of 20% of all images identified were reviewed by a second taxonomic expert, and taxonomic agreement had to meet a minimum of 90% concurrence. Failure to reach this would trigger a review of 100% of identifications made by the initial taxonomist. The 20% review included quality control review of 100% of ESA and State-listed species, and for endangered species a 100% agreement had to be reached on identifications (Figure 4). Additional experts in the species concerned were called in to arbitrate identifications when concurrence could not be reached.

Accuracy assessments were done at three taxonomic levels: types (birds, marine mammals, sea turtles, sharks, and rays); species groups within each type (e.g., phalaropes, shearwaters, etc.) within the bird type); and species level within each type. Species group and species-level accuracy assessments were done independently for each type. For each species group and species-level accuracy assessment, we created a confusion matrix with the rows representing the initially identified target and the columns representing the quality control identified target. Confusion matrices were used to calculate the accuracies of the initial identifications and the QC identifications (Story and Congalton 1986). Finally, an overall accuracy for each type was calculated based on both the species and species group confusion matrices.

In addition, the potential of the first-time observer effect was examined in data where observers may have reduced identification skills during the first season compared to subsequent seasons (Kendall et al. 1996). To examine for this effect, the overall accuracy assessments was calculated by type in three temporal intervals: across all seasons, for the first season, and all seasons excluding the first season. Comparisons were not done at the species group and species levels because a reduced number of observations during the first seasons limited our ability to make meaningful comparisons for most groups.

Figure 4. Methodological Steps from Data Collection to Final Quality Control Review

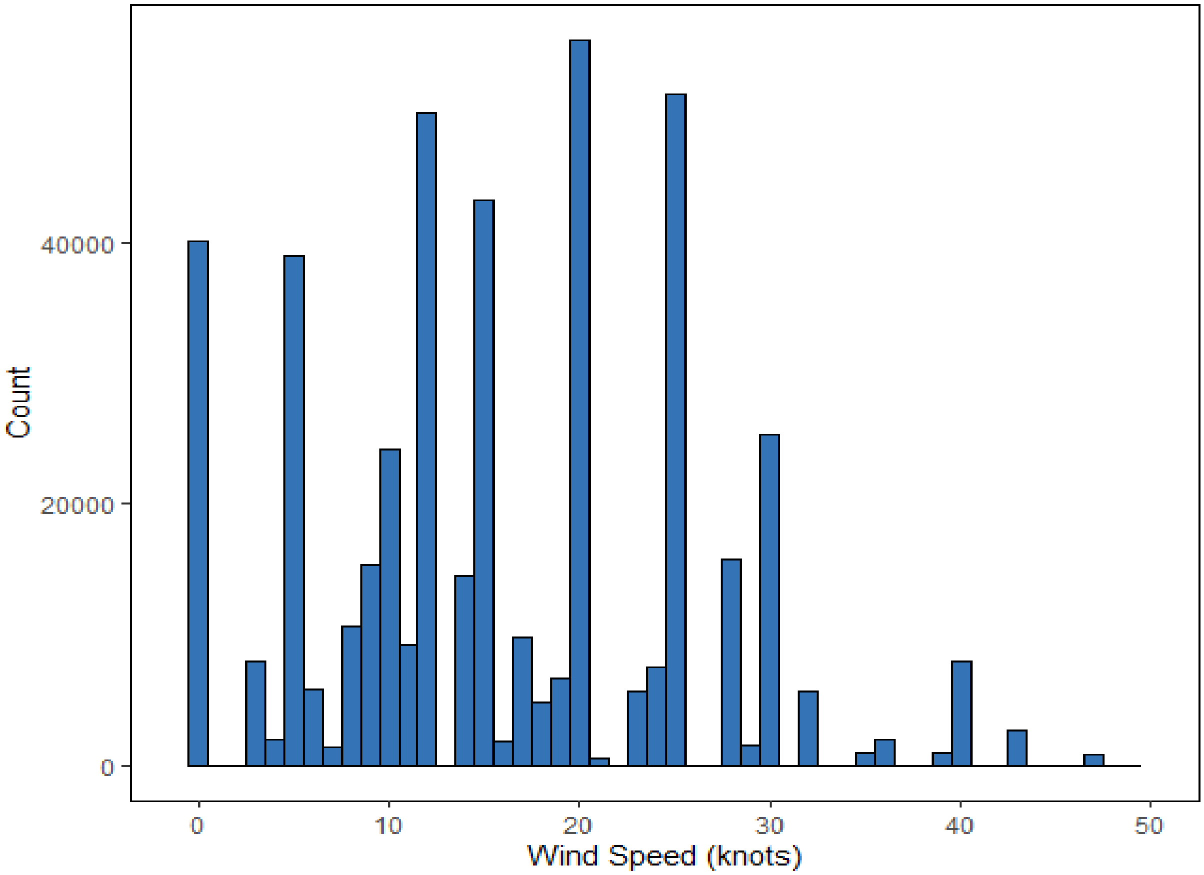


2.5 Camera Performance Analysis

Results for two camera performance metrics are presented to investigate potential inherent and environmental biases in the detection probabilities/capacities for all captured images. This was done by first determining whether all cameras of the array are equally likely to produce positive images and thus account for trades-offs in footprint and resolution inherent to the array design, and second by determining whether positive images were negatively correlated with wind speed. Analyses of both metrics were constrained to include only bony fishes and further by omitting data from Summer 2016 because a different camera system was used.

To determine whether each camera on the array was equally likely to capture positive images (image containing an animal), a series of proof-of-concept analyses was conducted considering the bony fishes data set beginning with the second survey (see section 1 for past reports list). These analyses were conducted to investigate any biases in the camera array due to an inherent image size resolution trade-off as cameras will have different image characteristics depending on where it is positioned on the camera array system. The farther a camera is positioned away from the array centroid, the larger the area captured in the image footprint but the lower the total resolution of the image leads to a negatively correlated relationship. We wanted to ensure that the camera array system design was not inherently biasing cameras with larger footprints to detect an increased number of bony fishes or fish shoals or conversely that cameras with the greatest footprint were not under-performing and detecting fewer individuals due to low image resolution (i.e., more likely to generate false negatives). Further, surveys were recommended when wind speeds were below 30 knots. Occasionally, logistical constraints led the flight team to conduct surveys or parts of surveys when wind speed was greater than 30 knots (Figure 5). To determine whether wind speed influenced the number of bony fishes imaged, the number of individuals imaged at each recorded wind speed were quantified and the proportion was calculated to control for differences in the number of total images pooled across all cameras captured at each wind speed.

Figure 5. Total Number of Images Obtained at Each Wind Speed



2.6 Treatment of Unidentified Animals Closely Resembling Listed Species

The categorization of ESA or State-listed species was conservative, incorporating "*Sterna* tern;" "hammerhead shark (unid.)," and "whale-species unknown." These unidentified groups could possibly represent roseate tern, scalloped hammerhead shark and blue, fin, sperm, or North Atlantic right whale. During the first six surveys, all unknown *Sterna* terns were lumped together; however, for the later surveys, two categories were added to differentiate *Sterna* terns that were not roseate terns, thus reducing the number classed as such. Inability to identify the *Sterna* tern group to individual species was usually a result of the angle of the bird and inability to see the head and bill. With subsurface animals, the angle or water depth often obscured characteristics required to differentiate species; although, identifying several hammerhead sharks is difficult, even in proximity.

2.7 Sensitivity Mapping

Once an offshore wind farm is operational, it has the potential to impact birds. Population-sensitive birds are species whose population status is already compromised. Collision-sensitive species are those most apt to fly within the rotor swept zone (RSZ). Displacement-sensitive species are those whose reaction to turbines would be to divert their flight patterns to avoid the wind farm. On behalf of BOEM, Normandeau developed a method to quantify the vulnerability of seabirds to offshore wind development on the Atlantic Outer Continental Shelf (Robinson Willmott et al. 2013). The method used data on bird species ecology that influenced sensitivity of species to population loss, collision, and displacement. To create the sensitivity maps, we divided the OPA into a grid of 10×10-km sampling units. Each bird observed within the sampling grid was assigned to a grid cell, and recorded species were ranked in descending order by sensitivity score. The total abundance of the 20% most sensitive species was computed for each sampling unit for each sensitivity index. For maps that show aggregated values across seasons, the average abundance per season was used instead of a total abundance. This was done to smooth inter-seasonal variation so the color ramp classifications would work across all maps. Collision sensitivity analysis was restricted to birds flying in the RSZ (23–320 m), and spatial variation in abundance of birds sensitive to different impacts was mapped across the survey area. Birds sensitive to population, collision, and displacement impacts were reviewed and overlaid on the sensitivity maps.

2.8 Zonal Stratification and Comparisons of Densities

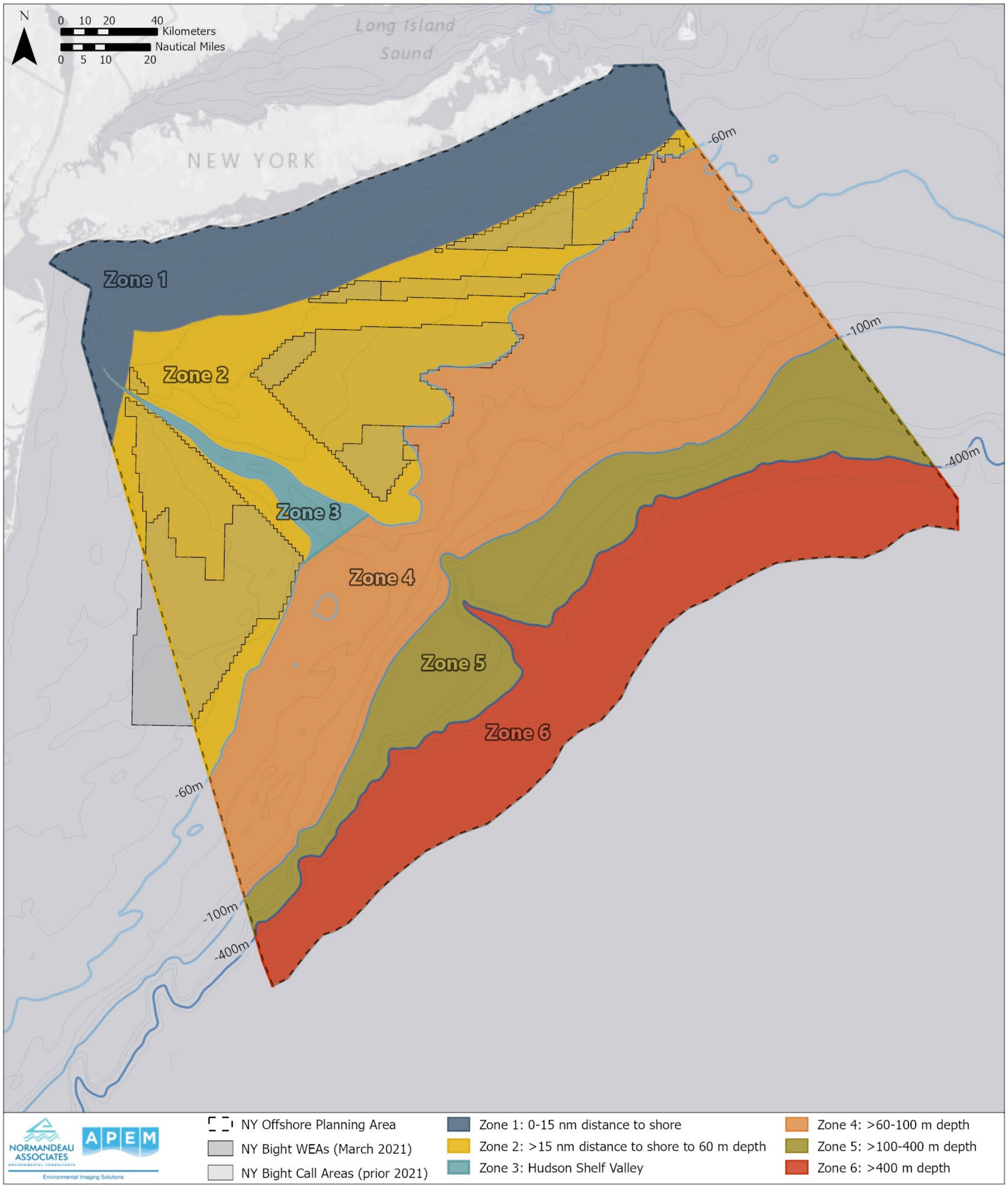
The areas of activity defined in NYSERDA (2017) broadly categorized distributions and densities into zones. Using a combination of distance from shore and bathymetry, six zones are defined (Figure 6):

- Zone 1: Coastal Zone
- Zone 2: Area for Consideration Zone
- Zone 3: Hudson Shelf Valley Zone
- Zone 4: Shelf Zone
- Zone 5: Shelf Slope Zone
- Zone 6: Shelf Break Zone

The BOEM-selected Areas for Consideration were refined into potential Call Areas and are all in Zone 2. Spatial distributions and densities of animals were reviewed and compared between zones. This approach provides insight into areas of importance for each species or species group.

All taxonomic groups and species with over 30 total occurrences were quantified across the three-year survey effort. Density estimates were calculated by dividing the number of individuals within the strip transect by the area of the transect. The mean density estimates for each zone and total OPA are presented in distribution maps and tables. On the resulting heat maps, density is scaled to the maximum density across all seasons for each taxa.

Figure 6. Zones Defined in the Analyses and Location of the Call Areas



2.9 Persistent Species Density Hotspots

Seasonal species density was considered as the number of species per sampling effort (otherwise called species density). To quantify species density (i.e., number of species per km^2 surveyed), a 5×5-km grid was projected onto the OPA. The grid was then cut to each zone so each grid cell was contained within one of the six zones (resulting in some variation in grid cell sizes). For each season the number of unique species was divided by the total effort within each grid cell to determine the number of species per km^2 of effort ± standard error of the mean. Grid cells with less than 1.0 km^2 of total survey effort were removed to avoid extreme values.

2.10 Weather Associations

While detailed weather data were collected during the surveys, we did not relate species composition and abundance to weather variables. This was because surveys were scheduled so weather conditions would be favorable for aerial surveys to identify marine fauna: a cloud base >1,400 ft, visibility >5 km, wind speed <30 knots, and Douglas sea scale ≥4. Requiring these conditions for each survey minimizes the weather variability among surveys, and therefore, variation in weather conditions to relate to species composition, abundance, and distribution is lacking.

2.11 Flight Height Analyses Methods

2.11.1 Flight Height Calculation Methods

APEM created a custom avian flight height calculator (FHC) for flying targets recorded in digital aerial surveys, which was developed in-house aided by an Imperial College mathematician using trigonometry and more complex mathematics.

Using the program to calculate flight height depends on the size of the bird species and the size of the bird relative to the image. The basic premise is that the higher the bird is flying, the greater the proportion of its reference body length will be in the image. The program uses the Global Positioning System (GPS) height of the aircraft, which is accurate to 5 m on the Z axis. This is combined with analyst bird measurements from the imagery to estimate the flight height for each individual flying bird. It is not possible to estimate flight heights for birds diving or turning sharply, as these individuals are not fully stretched out and therefore the measured lengths are unlikely to be comparable to the reference length of the species.

Besides the GPS height of the aircraft, other important variables used in the FHC include camera specifications (business confidential) and species reference lengths from literature, and these are combined to provide an estimated error for each species and each survey (Table 2). For the FHC to estimate flight heights, the minimum and maximum expected body length of each species must be known, this is called the bird reference length. Previously, reference lengths from one source (Sibley 2001) were used in the FHC for US flight heights calculations. However, following a review of the comparison between reference lengths from different sources this was deemed inadequate, and a wider review of literature determined additional sources that would bolster the variability in body lengths that can be accounted for in the FHC (Table 2). Following a review of the literature, new bird reference lengths were produced by extracting the minimum and maximum body length from four sources for each avian species that could be expected in the areas we operate. The four sources used were the Collins Bird Guide (Svensson et al. 2010), The Sibley Guide to Birds (Sibley 2001), the Cornell Lab (Cornell University 2020), and the British Trust for Ornithology (BTO 2020).

The Collins Bird Guide is a well-known identification guide across Europe, and many species found in this book are comparable to species found in the US. Both the Collins and Sibley books are widely regarded as the best ornithology guides available (Dingle 2001). The Collins Bird Guide indicated that most bird lengths were collected from skins, recently killed, or living birds (Svensson et al. 2010); measurements were taken from tip of the bill to the outstretched tail, which is the same method taken by APEM when measuring birds in the imagery. Due to the highly regarded reputation and scientific approach of both the Collins and Sibley books, these sources were judged as appropriate to use as a basis for the bird reference lengths in the FHC program.

Two other sources were used in addition to the Collins and Sibley books to revise the list of reference lengths, one of these was BTO's BirdFacts (BTO 2020). The BTO's mission statement (BTO 2020) is:

> "We are a non-campaigning organisation and our aim is to conduct all of our work with the highest scientific rigour in order to produce robust evidence that can be used by anyone wishing to understand birds, other wildlife, their habitats and how different interventions may affect them."

The BTO regularly produces peer-reviewed papers, and therefore, it was concluded that the data on their website is suitable for incorporating into revision on the FHC bird reference lengths. The fourth source used was the Cornell Lab, similar to the BTO, the Cornell Lab is a highly regarded organization that studies birds and aims to conserve and educate, the Cornell Lab mission statement is "Our mission is to interpret and conserve the earth's biological diversity through research, education, and citizen science focused on birds" (Cornell University 2020). Like the BTO, the Cornell Lab supports the publication of peer-reviewed papers and was therefore accepted as a reliable source to help revise the reference lengths (Cornell University 2020). In some cases, only three sources existed for a species. When a source gave a range for body length, the lowest and highest values in the range were used to ensure that all possible variations in bird length were accounted for. When birds only had an average length, the highest and lowest values from the sources were used. When calculating the body length of terns, the lengths of tail streamers were removed as these may not be present year-round, and therefore, were not included as part of the reference length.

This review and update of flight height calculations was implemented after surveys had been completed and mostly reported. Therefore, there might be some discrepancies between flight altitudes calculated in earlier reports compared to this report. The greatest difference between previous and present flight height calculations is a general reduction in flight altitudes that has resulted in no birds found to be flying above the RSZ. Also, protocols reported mean flight altitudes, and throughout this report, the median flight altitudes are calculated.

Table 2. Comparison Between the Mean Original Bird Body Reference Length from One Source and Revised Bird Body Reference Length from Four Sources Used to Estimate Flight Height

Grouping	Common Name	Mean Body Reference Lengths		Difference
		From One Source	From Four Sources	
GOOSE	Brant	63.5	68.25	4.75
	Canada Goose	114.3	92.13	-22.17
SWAN	Tundra Swan	124.46	128.86	4.4
DUCK	American Black Duck	58.42	57.23	-1.19
	Mallard	58.42	57.23	-1.19
	Lesser Scaup	41.91	41.98	0.07
	King Eider	55.88	56.35	0.46
	Common Eider	60.96	61.63	0.67
	Surf Scoter	50.8	51.33	0.53
	White-winged Scoter	53.34	51.96	-1.38
	Black Scoter	48.26	47.57	-0.7
	Long-tailed Duck	41.91	43.1	1.19
	Common Goldeneye	46.99	45.62	-1.37
	Common Merganser	63.5	62.75	-0.75
	Red-breasted Merganser	58.42	56.48	-1.94

(continued)

Table 2 continued

Grouping	Common Name	Mean Body Reference Lengths		Difference
		From One Source	From Four Sources	
LOON	Red-throated Loon	63.5	62.38	-1.13
	Common Loon	81.28	75.93	-5.35
GREBE	Horned Grebe	35.56	34.38	-1.19
FULMAR	Northern Fulmar	45.72	46.43	0.71
PETREL	Black-capped Petrel	40.64	40.64	0
SHEARWATER	Cory's Shearwater	48.26	48.24	-0.02
	Great Shearwater	45.72	46.57	0.85
	Sooty Shearwater	44.45	44.73	0.28
	Manx Shearwater	34.29	37.93	3.64
	Audubon's Shearwater	31.75	30.48	-1.27
STORM-PETREL	Wilson's Storm-Petrel	17.78	17.56	-0.23
	White-faced Storm-Petrel	19.69	19.68	0
	Leach's Storm-Petrel	20.32	19.94	-0.38
	Band-rumped Storm-Petrel	20.32	21.43	1.11
BOOBY	Brown Booby	76.2	73.57	-2.63
GANNET	Northern Gannet	93.98	94.31	0.33
CORMORANT	Double-crested Cormorant	83.82	81.94	-1.88
PELICAN	Brown Pelican	129.54	124.02	-5.52
ARDEIDAE	Great Blue Heron	137.16	123.61	-13.55
	Snowy Egret	60.96	60.65	-0.31
RAPTOR	Osprey	58.42	56.61	-1.82
	Bald Eagle	78.74	75.81	-2.93
SHOREBIRD	American Oystercatcher	44.45	42.65	-1.8
	Black-bellied Plover	29.21	28.86	-0.36
	Semipalmated Plover	18.42	17.85	-0.56
	Piping Plover	18.42	17.96	-0.46
	Ruddy Turnstone	24.13	21.71	-2.42
	Sanderling	20.32	19.71	-0.62
	Dunlin	21.59	19.4	-2.19
PHALAROPE	Red-necked Phalarope	19.69	18.55	-1.14
	Red Phalarope	21.59	21.2	-0.39
SKUA	Great Skua	58.42	56.14	-2.28
	Pomarine Jaeger	46	41.12	-4.88
	Parasitic Jaeger	40.5	36.84	-3.66

(continued)

Table 2 continued

Grouping	Common Name	Mean Body Reference Lengths		Difference
		From One Source	From Four Sources	
AUK	Dovekie	20.96	19.99	-0.97
	Common Murre	44.45	41.74	-2.71
	Razorbill	43.18	41.17	-2.01
	Black Guillemot	33.02	32.51	-0.52
	Atlantic Puffin	31.75	29.56	-2.19
GULL	Black-legged Kittiwake	43.18	40.17	-3.01
	Bonaparte's Gull	34.29	33.36	-0.93
	Little Gull	27.94	27.36	-0.58
	Laughing Gull	41.91	40.23	-1.68
	Ring-billed Gull	44.45	45.74	1.29
	Herring Gull	63.5	61	-2.5
	Iceland Gull	55.88	55.72	-0.16
	Lesser Black-backed Gull	53.34	55.34	2
	Glaucous Gull	68.58	64	-4.58
	Great Black-backed Gull	76.2	68.25	-7.95
TERN	Least Tern	22.86	22.43	-0.43
	Black Tern	24.77	24.19	-0.57
	Royal Tern	50.8	48.08	-2.72
STERNA TERN	Roseate Tern	31.75	34.81	3.06
	Common Tern	30.48	33.5	3.02
	Forster's Tern	33.02	34.13	1.11

2.11.2 Flight Heights and the Rotor Swept Zone

Turbine RSZ varies depending on type of turbine selected by any project and the tidal state. The air gap between the highest astronomical tide (spring tide) and the lowest blade tip is smaller than for a mean high tide. Similarly, the blade tip height at its highest point is higher from sea level during the lowest low tides (neap tide) than for a mean low tide. For this reason, turbine specifications and tidal fluctuations were reviewed and represent the RSZ as between 23 m and 320 m. Examples of available turbine specifications can be found in Table 3, and to keep bird flight height reporting relevant in the light of ever-changing turbine specification, we also present flight height data in 20-m bands.

Table 3. Turbine Specifications at Time of Writing (2021) in Order of MW Output

Turbine	MW	Max RD (m)	Air Draft ASL (m min) (approximate)	Max Blade Tip Height ASL (m) (approximate)	Swept Area (m^2)
Siemens Gamesa [a]	10	193	28	221	29,255
Siemens Gamesa [b]	11	200	28	228	31,416
Haliade X [c]	12, 13, 14	220	28	248	38,013
Siemens Gamesa [d]	14	222	28	250	38,708
MHI Vestas [e]	13.6–15	236	25	261	43,000

[a] https://www.siemensgamesa.com/en-int/newsroom/2019/01/new-siemens-gamesa-10-mw-offshore-wind-turbine-sg-10-0-193-dd

[b] https://www.siemensgamesa.com/products-and-services/offshore/wind-turbine-sg-11-0-200-dd

[c] https://www.ge.com/renewableenergy/wind-energy/offshore-wind/haliade-x-offshore-turbine

[d] https://www.siemensgamesa.com/products-and-services/offshore/wind-turbine-sg-14-222-dd

[e] https://mhivestasoffshore.com/innovations/

3 Results

3.1 Data Collection

Table 4 lists the data collected in the OPA during the 12 surveys. Variations in flight heights meant there were fluctuations in areal coverage, which was always more than 7% and up to 9.04% (Table 4).

Some daily survey protocols were exceeded. Protocol for sea state was to avoid ≥4 on the Douglas sea scale (wind sea); this was exceeded during four surveys, usually at the end of runs or at the end of surveys when weather changed (see highlights in Table 5). Protocol for wind speed was to avoid speeds >30 knots (34.5 mph); this was exceeded five times (see highlights in Table 5).

Table 4. Data Collected for Each Survey in the OPA

Survey	Size (km^2)	# Images	Image Area Size (km^2)	% Area Imaged	# Blank	% Blank
Summer 2016	43,745.20	289,393	3,204.02	7.32	285,818	98.76
Fall 2016	43,745.20	396,079	3,890.58	8.89	391,474	98.84
Winter 2016–2017	43,745.20	400,657	3,952.98	9.04	389,253	97.15
Spring 2017	43,745.20	338,141	3,293.25	7.53	334,050	98.79
Summer 2017	43,745.20	318,741	3,133.50	7.16	311,832	97.83
Fall 2017	43,745.20	323,554	3,168.68	7.24	319,811	98.84
Winter 2017–2018	43,745.20	320,107	3,147.14	7.19	315,434	98.54
Spring 2018	43,745.20	318,455	3,126.71	7.15	308,772	96.96
Summer 2018	43,745.20	320,453	3,150.38	7.20	315,371	98.41
Fall 2018	43,745.20	323,702	3,192.36	7.30	314,907	97.28
Winter 2018–2019	43,745.20	319,941	3,145.41	7.19	314,221	98.21
Spring 2019	43,745.20	320,793	3,153.84	7.21	313,983	97.88

Table 5. Minimum and Maximum Weather Variable Measurements During Surveys

Yellow highlights represent exceeded protocols.

Season	Visibility (km)		Sea State (0–4)		Glint (%)		Turbidity (0–3)		Precipitation (mins)		Cloud (%)		Outside Air Temp (°C)		Pressure (Hg)		Wind Speed (kts)		Wind Direction (degrees)	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	1	2
Year 1																				
Summer 2016	10	10	1	3	0	100	0	2	0	10	0	100	18.9	28.9	29.82	30.24	0	15	0	330
Fall 2016	10	10	0.5	3.5	0	30	1	3	0	2	0	100	0.0	12.7	29.75	30.35	3	30	0	335
Winter 2016-17	10	10	1	3.5	0	40	0.5	2.5	0	0	0	100	-7.0	11.1	29.91	30.61	0	53	0	335
Spring 2017	8	10	0.5	3	0	40	0.5	2	0	0	5	100	7.4	28.0	29.61	30.37	14	30	0	335
Year 2																				
Summer 2017	5	10	0.5	2.5	0	80	0.5	2	0	0	0	90	17.0	25.4	29.93	30.2	0	17	90	315
Fall 2017	10	10	1	3.5	0	40	1	3	0	1	0	100	-1.7	15.0	29.87	30.51	6	36	0	315
Winter 2017-18	10	10	1	4	0	40	1	2	0	1	0	100	2.2	12.8	29.86	30.54	0	32	0	330
Spring 2018	10	10	1	2	0	50	0	1	0	0	0	80	5.0	13.3	29.68	30.48	0	12	170	360
Year 3																				
Summer 2018	6	10	0.5	3	0	40	1	2	0	0	0	95	21.7	28.3	29.78	30.13	5	20	0	315
Fall 2018	6	10	0.5	4	0	20	0	2	0	0	2	100	-4.0	11.0	29.63	30.6	0	40	0	340
Winter 2018-19	10	10	1	4	0	30	0	2	0	0	0	100	-5.0	15.0	20.23	30.67	0	43	0	315
Spring 2019	10	10	1	4	0	40	0.5	2	0	0	0	100	7.0	16.0	29.56	39.54	0	30	20	315

3.2 Target Extraction and Quality Control (QC)

Across all surveys, most images contained no evidence of living organisms, vessels, or structures. Table 6 shows the number of images collected, number and percentage of blank images detected, and the number of images sent for QC for each survey. The percentage of blank images from within the OPA during the 12 surveys ranged from 96.96 during Spring 2018 to 98.84 during Fall 2016 and Fall 2017.

Table 6. Number of Images Collected, Number and Percentage of Blank Images Detected, and Number Sent for QC Review for each Survey in the OPA

Survey	Number of Images in Survey Area	Blank Images			
		Number	Percent	Number QC'd	Percent QC'd
Summer 2016	289,393	285,818	98.76	30,357	10.62
Fall 2016	396,079	391,474	98.84	39,480	10.08
Winter 2016–2017	400,657	389,253	97.15	39,052	10.03
Spring 2017	338,141	334,050	98.79	33,427	10.01
Summer 2017	318,741	311,832	97.83	31,271	10.03
Fall 2017	323,554	319,811	98.84	31,985	10.00
Winter 2017–2018	320,107	315,434	98.54	31,604	10.02
Spring 2018	318,455	308,772	96.96	30,912	10.01
Summer 2018	320,453	315,371	98.41	31,750	10.07
Fall 2018	323,702	314,907	97.28	31,502	10.00
Winter 2018-2019	319,941	314,221	98.21	31,437	10.00
Spring 2019	320,793	313,983	97.88	31,409	10.00

During Summer 2016 blank review, 70 of the 30,357 images were determined to contain targets missed in the initial target extraction (Table 7). The overall quality rate of the initial extraction was 99.77%, well within the QC criteria established for the project (Table 7). Similar QC agreement was reached for all subsequent surveys. When target extraction QC agreement numbers dropped, preemptive review action was taken and the relevant analyst's data underwent further QC review. This preemptive action was taken during QC for the Summer 2018. All target extraction exceeded QC criteria (Table 7).

Table 7. Number of Blank Images Sent for QC Review, Number Found to be Blank/Not Blank, and Percent Agreement Reached for Each Survey

Survey	Number of Images			% Agreement Reached
	For QC	QC'd as Blank	QC'd Not Blank	
Summer 2016	30,357	30,287	70	99.77%
Fall 2016	39,480	39,452	28	99.93%
Winter 2016–2017	39,052	39,009	43	99.89%
Spring 2017	33,427	33,362	65	99.81%
Summer 2017	31,271	31,199	72	99.77%
Fall 2017	31,985	31,926	59	99.82%
Winter 2017–2018	31,604	31,573	31	99.90%
Spring 2018	30,912	30,840	72	99.77%
Summer 2018	31,750	31,375	375	98.82%
Fall 2018	31,502	31,413	89	99.72%
Winter 2018-2019	31,437	31,300	137	99.56%
Spring 2019	31,409	31,365	44	99.86%

Of the 70 images containing organisms from the Summer 2016 blanks review, most contained fish (n= 38), turtles (n=19), and birds (n=10). Only three contained marine mammals (Table 8). In the Fall 2016 data, 23 images contained birds, three contained fish, and two contained marine mammals. In the Winter 2016–2017 data, 32 images contained birds, six contained fish, and five contained marine mammals (Table 8). Except for the 50 images containing fish, numbers of missed organisms were lower in the Spring 2017 data with only 10 images containing birds, three containing turtles, and two containing marine mammals. Similarly, the Summer 2017 data had 48 images containing fish but otherwise QC'd images contained five birds and 17 turtles (Table 8). The Fall 2017 QC'd data contained 19 bony fish, two turtles, two marine mammals, and 36 birds (Table 8). Of the 31 images from the Winter 2017–2018 data, 24 contained birds, four contained marine mammals, two contained fish, and one contained a shark (Table 8). The 72 images from the Spring 2018 data contained 52 birds, seven fish, six sharks, four rays, and three marine mammals (Table 8). During the Summer 2018 survey, there were 375 images with 86 fish, 86 birds, 34 marine mammals, 64 turtles, 31 sharks, and 74 rays (Table 8). Of the 89 images found during the Fall 2018, 81 were birds with one marine mammal, one ray, and six fish (Table 8). There were 137 images reviewed from the Winter 2018–2019 survey that contained targets, which consisted of 118 birds, 15 mammals, and four fish (Table 8). The Summer 2019 QC effort revealed 24 birds, five sharks, and 15 fish (Table 8).

Number of individuals found during target extraction are presented by taxonomic group and by season (Table 9). Across all 12 seasons, 205,277 animals were sent to taxonomic experts for identification including 140,372 birds, 15,360 marine mammals, 1,885 turtles, 26,121 sharks, and 21,539 rays (Table 9); threatened and endangered species found during target extraction QC are included.

Table 8. Number of Individuals within Reported Taxonomic Groups Found During QC Process for Each Survey in the OPA

Survey	Taxonomic Group					Total
	Avian	Mammal	Turtle	Shark	Ray	
Summer 2016	10	3	19	0	0	32
Summer 2017	5	0	17	0	0	22
Summer 2018	86	34	64	31	74	289
Fall 2016	23	2	0	0	0	25
Fall 2017	36	2	2	0	0	40
Fall 2018	81	1	0	0	1	83
Winter 2016–2017	32	5	0	0	0	37
Winter 2017–2018	24	4	0	1	0	29
Winter 2018–2019	118	15	0	0	0	133
Spring 2017	10	2	3	0	0	15
Spring 2018	52	3	0	6	4	65
Spring 2019	24	0	0	5	0	29
Totals	**501**	**71**	**105**	**43**	**79**	**799**

Table 9. Number of Individuals by Taxonomic Group by Season in the OPA

Survey	Taxonomic Group					Total
	Avian	Mammal	Turtle	Shark	Ray	
Summer 2016	1,860	924	560	643	8,103	12,090
Summer 2017	2,964	1,446	711	1,382	7,624	14,127
Summer 2018	4,871	2,165	547	413	5,797	13,793
Fall 2016	12,245	1,118	39	4	4	13,410
Fall 2017	9,337	1,243	13	13	2	10,608
Fall 2018	24,688	1,121	0	2	8	25,819
Winter 2016–2017	20,919	1,609	1	26	0	22,555
Winter 2017–2018	11,218	1,082	0	11	0	12,311
Winter 2018–2019	15,094	1,306	0	1	0	16,401
Spring 2017	3,668	1,687	10	180	0	5,545
Spring 2018	21,489	845	1	22,934	0	45,269
Spring 2019	12,019	814	3	512	1	13,349
Totals	**140,372**	**15,360**	**1,885**	**26,121**	**21,539**	**205,277**

3.3 Camera Performance Analysis

3.3.1 Trade-Offs in Image Footprint and Image Resolution Across the Camera Array

The range of image footprint sizes across the camera array is not large; however, over time there could be some bias associated with these differences. If the camera footprint biases the number of times it can detect an animal, we would expect that, on average, cameras with larger areal extent would be more likely to capture an image containing an animal. Thus, we would predict that over time the cameras with the larger footprints would have a greater proportion of images containing a bony fish. To determine whether camera footprint (i.e., the image coverage area) influences the number of bony fishes imaged, the total number of times each camera detected one or more bony fishes was quantified (Figure 7). When comparing the proportion of images with one or more bony fishes present across all cameras on the array, we found no difference in the relative number of bony fishes imaged across the Fall 2016 through Spring 2019 surveys ($F_{8,77} = 0.23$, $p = 0.98$), suggesting that each camera is just as likely to detect bony fishes independent of camera footprint.

It is possible that slightly higher resolution cameras are more proficient at detecting multiple objects within an image. It could be imagined that both computer software and human image inspectors could pick out the hardest-to-see bony fishes only when photo resolution is highest, leading to a higher total count of bony fishes. To determine whether resolution was correlated with total number of animals imaged, the proportion of bony fishes associated with each camera was quantified over the total number of photos imaged per camera (Figure 8). We find that total number of bony fishes imaged by each camera does not differ by cameras throughout the Fall 2016 through Spring 2019 surveys ($F_{8,77} = 0.19$, $P = 0.99$), suggesting that camera resolution does not bias detection probability.

Although no resolution bias appears to be present across the array, we wanted to determine whether cameras with the highest resolution had a higher species identification success rate. Identifying imaged animals to species could be made more difficult with slight changes in resolution. The data set was constrained to include only bony fishes successfully identified to species and the proportion of species-identified individuals was compared across all cameras (Figure 9). Positively identified images were not correlated with camera resolution ($F_{8,75} = 0.14$, $P = 0.99$), suggesting that the differences in image resolution are not severe enough to bias the data set.

Figure 7. Proportion of Times a Camera Captured an Image of One or More Bony Fishes Over the Total Number of Times a Camera Took a Picture During a Given Survey

The order of data does not reflect the location of each camera in the array. Boxplots represent minimum, maximum, 25th percentile, 75th percentile, and median (50th percentile) with points representing outliers.

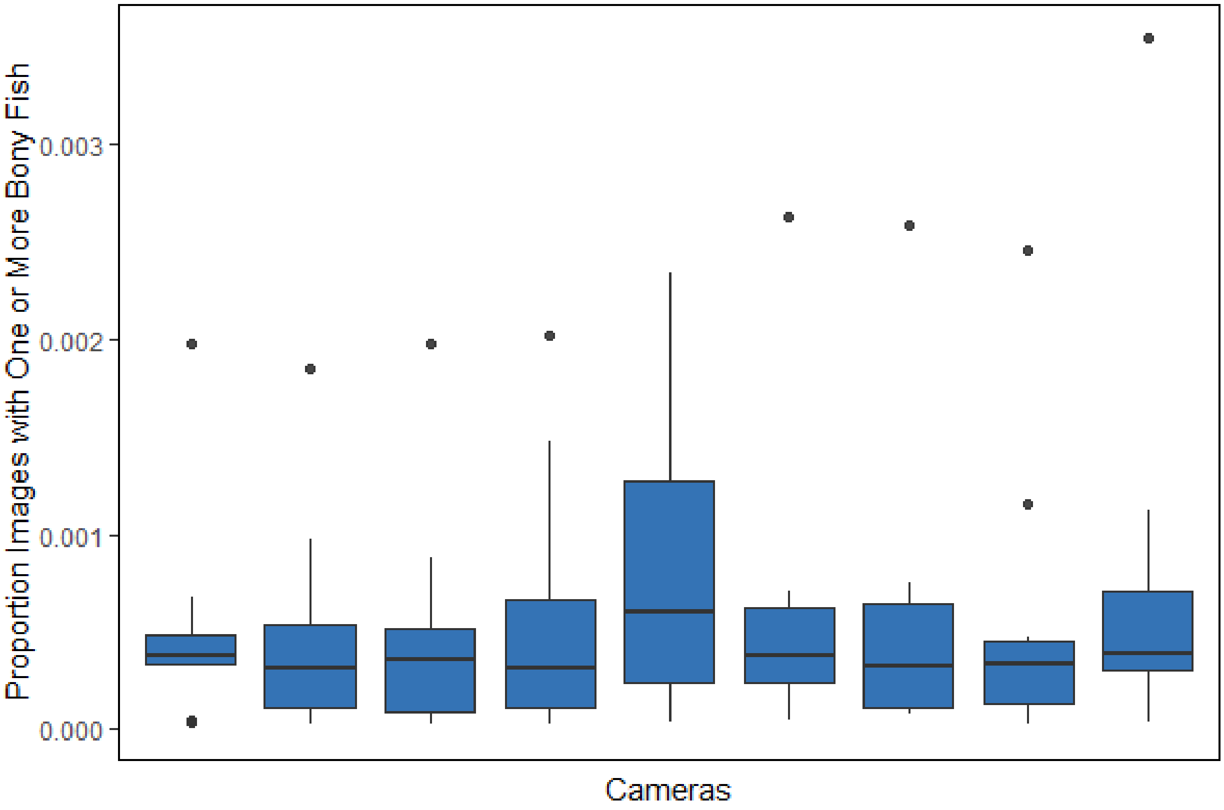


Figure 8. Proportion of Bony Fishes Imaged by Each Camera Across All Surveys

The order of data does not reflect the location of each camera in the array. Boxplots represent minimum, maximum, 25th percentile, 75th percentile, and median (50th percentile) with points representing outliers.

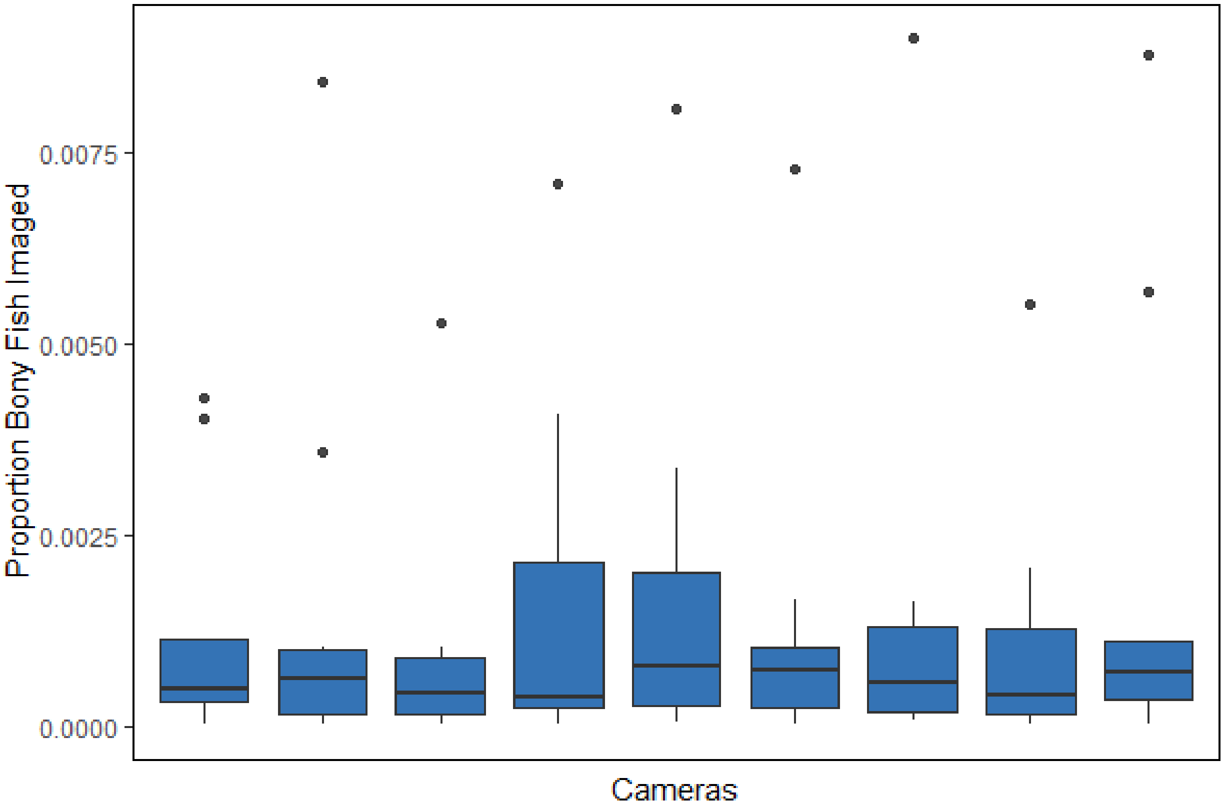
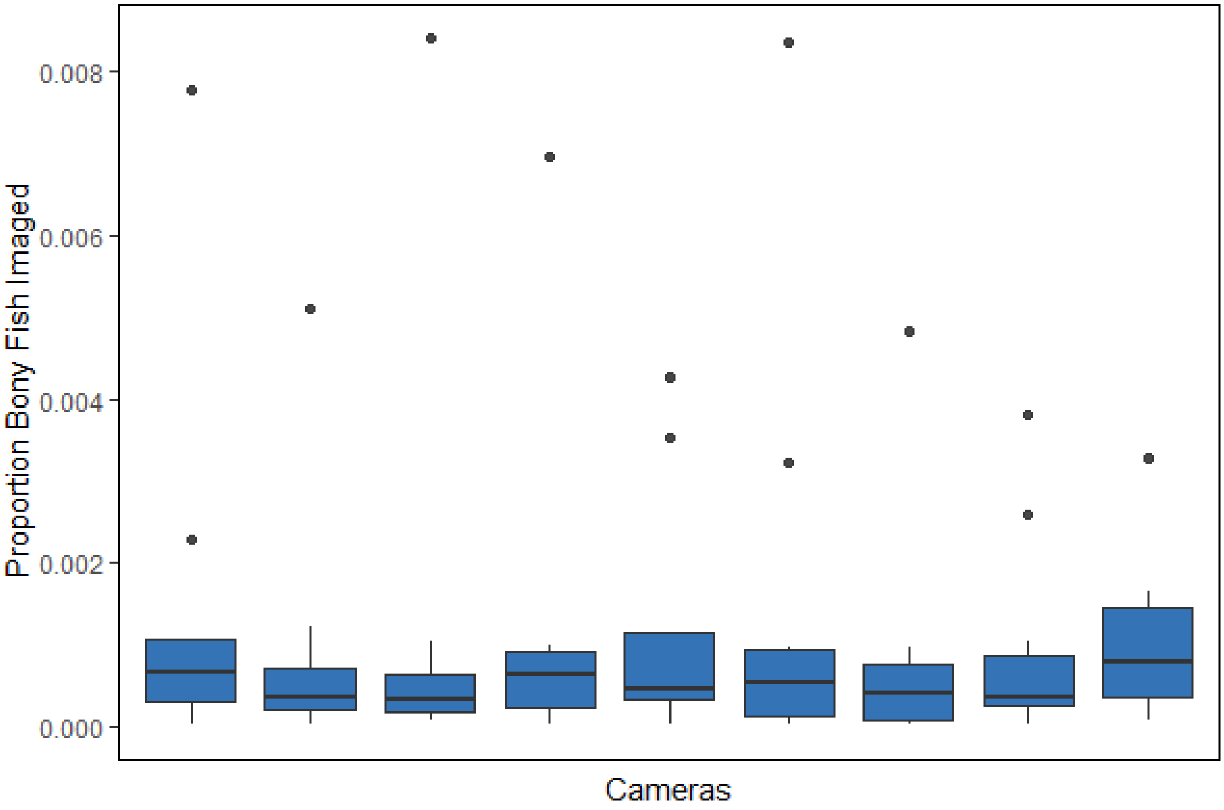


Figure 9. Proportion of Instances a Camera Captured an Image of a Species-Identified Bony Fish

The order of data does not reflect the location of each camera in the array. Boxplots represent minimum, maximum, 25th percentile, 75th percentile, and median (50th percentile) with points representing outliers.

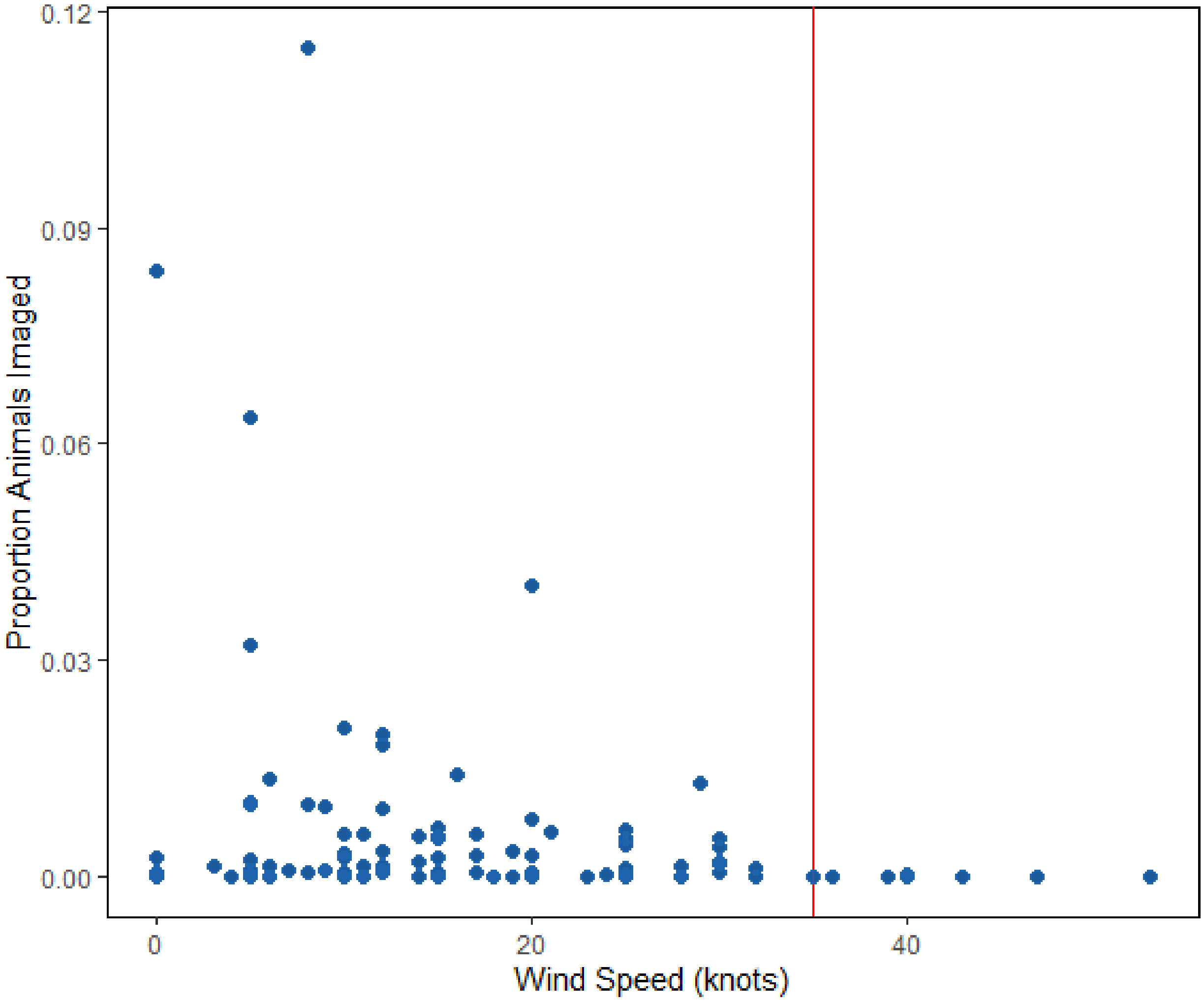


3.3.2 Wind Speed

To determine whether wind speed influenced the number of bony fishes imaged, the images at each recorded wind speed were quantified and the proportion was calculated to control for differences in the total number of images captured at each wind speed (Figure 10). There was a very weak negative correlation between camera performance and wind speed ($F_{1,99} = 5.095$, $P = 0.026$, Adj. $R^2 = 0.039$; Logistic regression), possibly driven by rougher water surface conditions (Figure 10). However, when the data set is constrained to images captured at wind speeds of 35 knots and less, there was no statistical relationship between proportion of animals imaged and wind speed ($F_{1,91} = 3.849$, $P = 0.053$, Adj. $R^2 = 0.030$; Logistic regression), suggesting that overall, surveys that occur five knots above the recommended survey wind speed of 30 knots are not less likely to image bony fishes.

Figure 10. Proportion of Bony Fishes Imaged at Each Wind Speed (Knots) for All Surveys

The red vertical line represents the maximum wind speed (35 knots) at which there is no significant statistical relationship between the wind and the probability of imaging an individual bony fish.



3.4 Identification Success

There were 205,277 animals sent for identification with 43,551 going through QC (Table 10). Of these, 3,763 were threatened or endangered species at a state or federal level, either identified as a listed species or in the same genus as a listed species where species-level identification was not possible (such as hammerhead [unid.] and *Sterna* tern) (Table 11). A new species was added for endangered QC for the Summer 2017 survey: giant manta ray, of which four were identified in the Summer 2016 survey, two were found in the Summer 2017 survey, and one was found during the Summer 2018 survey (volume 5). All identifications reached and exceeded their targeted percent agreement (Table 10, Table 11) (see Appendix A for a list of species in taxonomic groups).

Table 10. Total Number of Images by Taxonomic Group, Number Reviewed, and Percent Identification Agreement Reached in the OPA

Taxonomic Group	Summer 2016–Spring 2019		
	Total Individuals	Number of Images for QC	% Agreement (rounded)
Avian	140,372	28,898	99
Marine Mammals	15,360	3,101	99
Turtles	1,885	1,885	100
Sharks	26,121	5,582	100
Rays	21,539	4,088	99
Total	**205,277**	**43,554**	**99**

Table 11. Number of Individuals of Threatened and Endangered Species by Taxonomic Group, Number Reviewed, and Percent Identification Agreement Reached

Survey	Taxonomic Group					Total
	Avian	Mammal	Turtle	Shark	Ray	
Summer 2016	141	10	560	143	4	858
Summer 2017	13	8	711	459	2	1,193
Summer 2018	56	13	547	127	1	744
Fall 2016	0	9	39	1	0	49
Fall 2017	1	7	13	3	0	24
Fall 2018	0	3	0	0	0	3
Winter 2016–2017	0	12	1	0	0	13
Winter 2017–2018	0	2	0	0	0	2
Winter 2018–2019	0	4	0	0	0	4
Spring 2017	721	8	10	0	0	739
Spring 2018	44	14	1	0	0	59
Spring 2019	72	7	3	0	0	82
% Agreement Reached	**100**	**100**	**100**	**100**	**100**	**3,770**

Identification success varied by taxonomic group and by depth of subsurface animals. All identifications had a level of certainty ascribed to them (e.g., possible, probable, and definite). Some animals were identified as possible when several conspecifics had been identified within that group (see Figure 11 for an example) and there was no evidence in literature that the animal moved in mixed species groups. Several rays fell into this category. The probable certainty level was ascribed to species when physical characters available in the imagery and a high probability of a specific species' presence strongly suggested that identification. The definite certainty level was ascribed when all characters were present and the taxonomist was confident in the identification.

Subsurface animals were ranked as breaching, near surface, or significantly submerged (see Figure 11 for an example). These categorizations allowed evaluation of whether image quality, angle of the animal at point of capture, or depth in the water was the major factor affecting the ability to identify animals to species. Digital imagery captured from downward-pointing sensors sees through the water column more effectively than angled sensors and more animals are observed. Visual surveyors from boats and digital imagery captured by angled lenses will see fewer animals to a greater or lesser degree because subsurface animals are hidden by the water column. However, this improvement in reporting animal presence by downward-facing lenses sometimes costs species identification because of the depth of the animal. Identification success results are presented by species group in Sections 3.5 through 3.9.

Figure 11. Example of Image Showing Difficulty of Identification of Deeply Submerged Animals

Deeply submerged animals would be ascribed a certainty of probable if in a group of conspecifics and ranked as significantly submerged.

Accuracy assessments showed 100% agreement when comparing the initial identification and the QC identification by type (e.g., all targets initially identified as birds were QC'd as birds, though 52 targets were QC'd to an unknown or other category). Overall accuracy at the species group level, showed a high level of agreement between the initial identifications and the QC identifications with all animal types showing >99% accuracy. Accuracy was lower when assessing identification accuracy at the species level with birds having the lowest species-level identification accuracy at 84.8% and sharks having the highest at 98.4% (Table 12).

Evidence for a first-time observer effect was inconclusive. At the species group level, only marine mammals and rays had lower accuracy during the first season compared to subsequent seasons. Other animal types had higher accuracy during the first season, though all differences were small. Similar findings occurred when identifying targets to species, although the accuracy during the first season for sharks was 11.7 percentage points lower compared to subsequent seasons. Marine mammals, sea turtles, and rays also showed lower accuracy during the first season, but the difference was small (<3.4 percentage points), while birds targets had higher accuracy during the first season (5.2 percentage points higher than subsequent seasons) (Table 12). Further assessments looking at accuracy at the subtype and species levels are presented in their respective report sections.

Table 12. Overall Accuracy Assessments by Animal Type Among All Seasons, the First Season, and All Seasons Excluding the First Season

Percentages reflect the agreement between the initial identification the identification made during QC. Species group comparisons compare the ability to identify a target in the appropriate species group (e.g., shearwaters, phalaropes, etc.) while species-level comparisons assess the accuracy of species-level identifications.

Animal Type	Species Group Level			Species Level		
	All Seasons	First Season	Excluding First Season	All Seasons	First Season	Excluding First Season
Birds	99.6% n=28,898	100% n=458	99.6% n=28,440	84.8% n=28,898	90.8% n=458	84.7% n=28,440
Marine Mammals	99.1% n=3,101	96.1 n=131	99.2% n=2,970	95.5% n=3,101	94.7% n=131	95.5% n=2,970
Sea Turtles	100% n=1,885	100% n=560	100% n=1,325	94.8% n=1,885	94.6% n=560	94.9% n=1,325
Sharks	99.8% n=5,579	100% n=84	99.8% n=5,495	98.4% n=5,579	86.9% n=84	98.6% n=5,495
Rays	99.9% n=4,088	99.8% n=1,351	100% n=2,737	96.8% n=4,088	94.5% n=1,351	97.8% n=2,737

3.5 Relative Abundance of Animals

The relative abundance of each taxonomic group differed among seasons. We have corrected these numbers to assume equal coverage (effort) of the entire area as described in the methods. In the Summer 2016, Summer 2017, and Summer 2018 surveys, ray encounters were the most frequent, totaling 64%, 48%, and 40% respectively, of animals found in imagery (Table 13). In the Summer surveys, after rays, the most frequently encountered groups were birds (15%, 19%, and 34% respectively), marine mammals (7%, 9%, and 15% respectively), sharks (5%, 9%, and 3% respectively), and turtles (4%, 4%, and 4% respectively). During the Fall 2016, Fall 2017, and Fall 2018 surveys, rays, turtles and sharks represented <1% of organisms observed, birds represented 90%, 87%, and 95% of encounters respectively, and marine mammals 8%, 12%, and 4% respectively (Table 13). The Winter 2016–2017, Winter 2017–2018, and Winter 2018–2019 surveys were dominated by birds (93%, 91%, and 92%, respectively) followed by marine mammals (7%, 9%, and 8%, respectively). The remaining taxonomic groups represented <1% of organisms observed (Table 13). In the Spring 2017 surveys, birds still dominated the sample representing 60% of organisms, with marine mammals representing over 27% of the sample. The Spring 2018 survey was quite different, with sharks representing 50% of the sample and birds representing 47% of the sample (Table 13). For the Spring 2019 survey, birds were dominant representing 88% of the sample followed by mammals (6%) and sharks (4%). Both turtles and rays represent <1% of observed organisms (Table 13). No bats were found in imagery.

Table 13. Total Density (per km^2) and Percent of Sample Represented by Individuals in Each Taxonomic Group by Survey in the OPA

Survey	Avian		Mammal		Turtle		Shark		Ray		Total
	Density	%	Density	%	Density	%	Density	%	Density	%	
Summer 2016	0.5805	14.68	0.2884	7.29	0.1748	4.42	0.2007	5.08	2.5290	63.97	0.75468
Summer 2017	0.9459	18.63	0.4615	9.09	0.2269	4.47	0.4410	8.68	2.4331	47.91	0.90168
Summer 2018	1.5462	34.11	0.6872	15.16	0.1736	3.83	0.1311	2.89	1.8401	40.59	0.87564
Fall 2016	3.1473	90.16	0.2874	8.23	0.0100	0.29	0.0010	0.03	0.0010	0.03	0.68934
Fall 2017	2.9467	87.05	0.3923	11.59	0.0041	0.12	0.0041	0.12	0.0006	0.02	0.66956
Fall 2018	7.7335	95.47	0.3512	4.33	-	-	0.0006	0.01	0.0025	0.03	1.61756
Winter 2016-2017	5.2920	92.68	0.4070	7.13	0.0003	0	0.0066	0.12	-	-	1.14118
Winter 2017-2018	3.5645	91.06	0.3438	8.78	-	-	0.0035	0.09	-	-	0.78236
Winter 2018-2019	4.7987	92.00	0.4152	7.96	-	-	0.0003	0.01	-	-	1.04284
Spring 2017	1.1138	59.29	0.5123	27.27	0.0030	0.16	0.0547	2.91	-	-	0.33676
Spring 2018	6.8727	46.79	0.2703	1.84	0.0003	0	7.3349	49.94	-	-	2.89564
Spring 2019	3.8109	87.66	0.2581	5.94	0.0010	0.02	0.1623	3.73	0.0003	0.01	0.84652

3.6 Species Density Hotspots

Species density was relatively consistent across all seasons with the greatest species density during Winter surveys (x̄ = 0.74 ± 0.02 species/km^2), followed by Fall (x̄ = 0.62 ± 0.01 species/km^2), Summer (x̄ = 0.69 ± 0.02 species/km^2), and Spring (x̄ = 0.72 ± 0.02 species/km^2) (Figure 12, Figure 13). Across all seasons, Zone 1 was consistently more species-dense relative to the mean species density across the entire OPA (Figure 12, Figure 13). In the Fall, Zone 3 had the greatest species density throughout the OPA (x̄ = 1.21 ± 0.21 species/km^2), consistent with patterns of avian density (Figure 12). Zone 5 had above average species density in both Winter (x̄ = 0.98 ± 0.06 species/km^2) and Spring (x̄ = 0.97 ± 0.06 species/km^2), also consistent with patterns of avian density (Figure 12, Figure 13). Overall, Summer species density was driven by marine mammals, rays, and turtles, as birds are relatively absent during Summer compared to the other seasons. During Summer, Zone 2 had the second highest species density (x̄ = 0.80 ± 0.03 species/km^2).

Figure 12. Species Density (Species/km^2) During Fall and Winter by Zone and Proximity to Call Areas

Inset figure shows estimated species densities (species/km^2) within each zone.

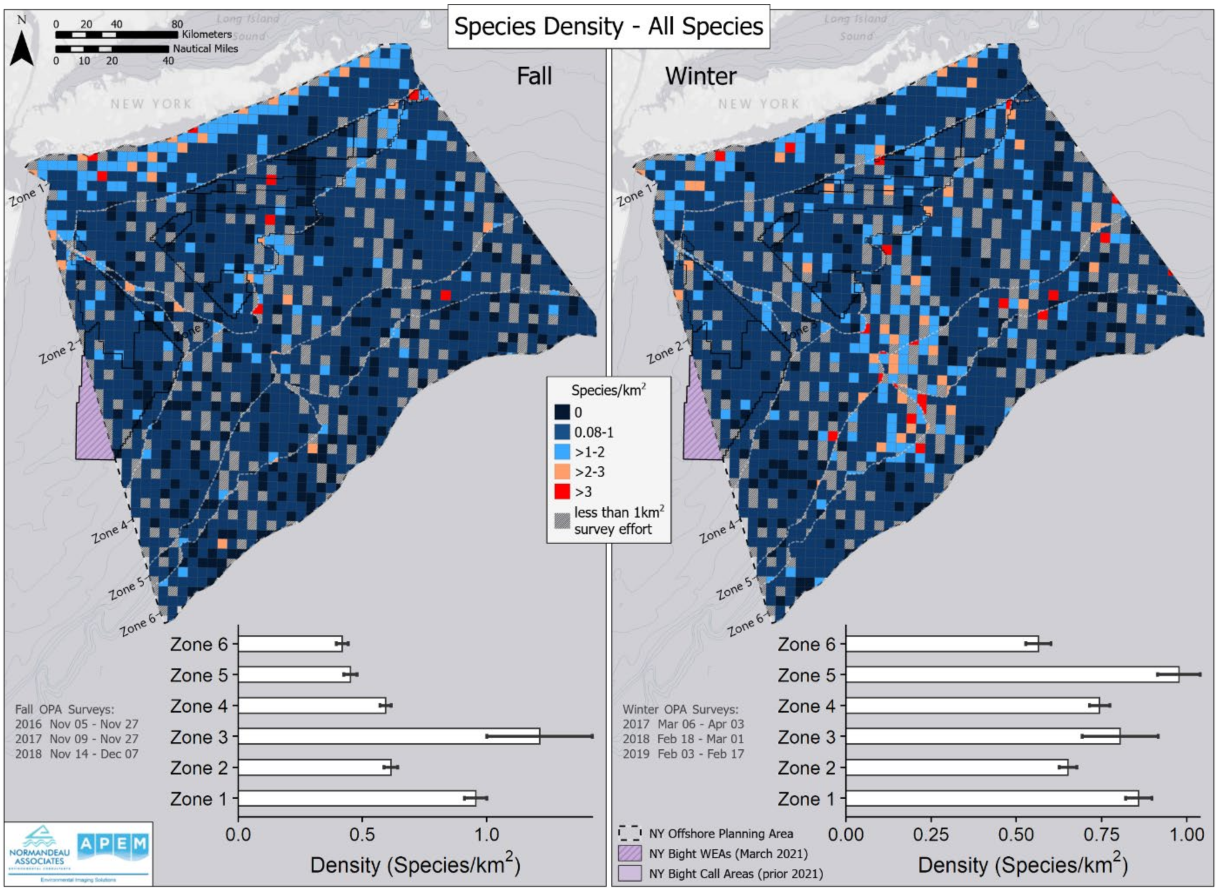
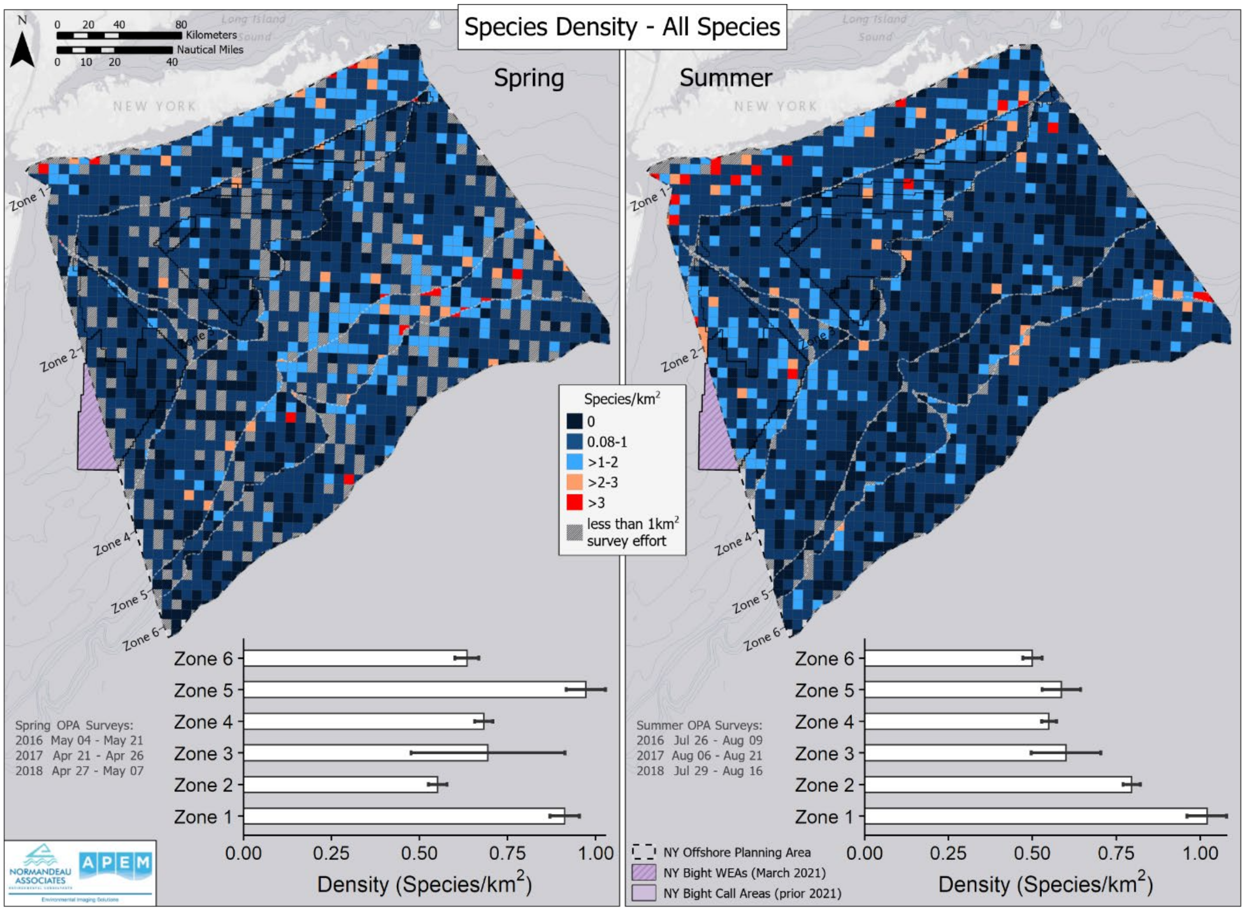


Figure 13. Species Density (Species/km^2) During Spring and Summer by Zone and Proximity to Call Areas

Inset figure shows estimated species densities (species/km^2) within each zone.



4 Limitations

Data collected using aerial digital surveys are unbiased by observer limitations and provide a snapshot in time that can be validated and revisited. The speed of survey coverage minimizes double counting, and the altitude at which data can be collected reduces startle or attraction or repulsion effects. The same survey design may be used both pre- and postconstruction of offshore wind turbine generators (WTGs). Imagery allows species identifications to be revisited when taxonomic resolution is revised by the broader scientific community, and examples of this did occur during the timeframe of this project; larger rays were recategorized and reidentified by different taxonomic experts as taxonomic resolution changed.

The process of target extraction uses a combination of automated detection software and manual review. Automated software may get challenged depending on sea state, sea color, turbidity, and weeds and trash, all of which may cause false positives or negatives. The manual review is time consuming, and as with all manual tasks, each image analyst performs slightly differently. Although the data management process allows for full trackability, any triggered reanalysis brought about by the QC process further adds time and expense to the target extraction process. However, missed targets in aerial digital data have associated quantifiable and trackable error, unlike those of visual surveys where the number or species missed at the point of detection is an unknown quantity.

Aerial digital data may only be collected within certain weather conditions, making any meaningful correlation between activity and weather difficult. This is also true with flight height information associated with birds. Within a broadly categorized margin of error for each species per survey, flight heights themselves may not be correlated with wind speed, thus leaving a gap in our understanding of how flight heights may vary depending on weather condition.

Aerial digital data using this camera system may only collect imagery during daylight hours. Although these data provide an unparalleled insight into behavior and species presence within the OPA, the activity of biota at night remains unsurveyed.

Although a GSD of 1.5 cm provides excellent species-specific identification potential, smaller animals remain largely unidentifiable. This, combined with only diurnal and seasonal temporal coverage, means that species such as smaller shorebirds and migratory passerines are not represented or fully identified in the data set.

Depth in the water column of animals combined with speed of transit by the aircraft means that species of deep-diving mammals, turtles, rays, and sharks may be underrepresented in this data set. Some deep-diving mammals are likely to be rarer than other species (e.g., North Atlantic right whale [*Eubalaena glacialis*]), which, at time of writing, has an estimated population of approximately 400 individuals and may only surface to breath once in any hour (NOAA 2021). The likely encounter rate of rarer species such as the North Atlantic right whale using this survey design is quite low, given spatial scale of the surveys, and speed of transit through the area. This being said, the aerial digital surveys of the OPA recorded seven North Atlantic right whales over the 12 surveys: six in March, April, and May 2017, and one in April 2019 (volume 4).

Spatial coverage for these surveys were driven by many factors. The OPA, including a 300-m buffer, covers 43,745.20 km^2 (12,754.06 mi^2), and imaging 7% of the area represents over 3,000 km^2 (over 1,500 mi^2) of imagery per survey. This spatial scale seemed practical from both a cost and spatial-coverage guidance perspective. However, some of the finer scale associations with bathymetry or foraging opportunities are more difficult to understand at lower spatial resolution and lowers the likelihood of encountering rarer species. The grid survey design of the WEA used in the first year provides more evenly distributed survey effort. If effort was further increased using a grid pattern, then there could be greater understanding of drivers of species distributions and higher likelihood of encountering rarer species present.

Seasonal surveys represent a snapshot in time, and some species transit through areas in discrete periods which might not be captured using seasonal surveys. For example, no bats were recorded during these seasonal surveys. Offshore acoustic and boat-based studies show peak activity for bats through the autumn migration period between August and October, with most activity during September (Sjollema et al. 2014; Peterson et al. 2014, 2016) and data collected by aerial digital surveys during 2012 and 2013 recorded 15 bats in September in both years but not during any other of the 15 surveys (Williams et al. 2015). None of the seasonal surveys in the OPA occurred during September. Monthly surveys are frequently used to capture information on species of interest with discrete temporal movements, with more than one survey per month conducted to maximize opportunity to collect some species-specific activity. However, given the size of the OPA and the time to analyze aerial digital data, greater temporal granularity might be challenging at several levels, along with securing a fleet of aircraft, cameras, and analysts required to collect and review data.

For the data collected in this study there is little temporal granularity and peak abundances of some species might have been missed. However, the seasonally collected three years of data do show interesting patterns and variability in spatial and temporal activity and highlight the potential for shifts in distributions and densities among years and among seasons. This natural variation also makes it challenging to separate changes in spatial and temporal distribution because of behavioral adaptation to WTGs from those occurring naturally.

To summarize, limitations of this survey methodology to collect and interpret baseline data can be broadly categorized into four main areas:

1. Low identification rates for smaller species. Even with 1.5 cm GSD, smaller birds such as shorebirds and songbirds and rarely identified to species.
2. No coverage of nocturnal activity. With no nighttime coverage, nocturnal animal activity is not sampled, which represents a gap in information for all species groups including migratory birds, mammals, sharks, rays, and turtles.
3. Finer temporal scale information is absent with seasonal surveys. Although these surveys were timed to potentially coincide with periods of peak abundance of some species, those species with fairly narrow periods of transit through the OPA might be missed, especially considering that seasonal movements can be impacted by weather events at either end of migratory strategies or what might represent a peak abundance month in one year might change by several weeks in another.
4. Finer spatial scale data is absent making rarer species less likely to be encountered on survey and reducing granularity on species' associations with other environmental covariates. With only ≈7% of the OPA surveyed using a transect design, rarer species are even less likely to be encountered.

5 Research Needs

To accommodate some of the limitations of aerial digital surveys mentioned, further studies using different monitoring techniques could be undertaken and are described below. Monitoring migrant songbirds and shorebirds could be implemented using these approaches:

- Acoustic receivers deployed on offshore structures including buoys.
- VHF tagging of species and radio tracking receivers deployed on offshore structures including buoys.
- GPS tagging of species and using satellite tracking.
- Radar systems deployed on structures offshore.

These approaches for migrant songbirds and shorebirds could also monitor nocturnal activity of all species groups. In addition, acoustics and tagging studies are appropriate for all species groups. Monitoring species with discretely timed patterns of movement or rarer species could be done using any survey platform including aerial digital surveys.

There is no full understanding of the distance and magnitude of potential displacement of species from areas occupied by WTGs. To understand this requires postconstruction monitoring at multiple sites and covering a buffer that extends well beyond the project boundaries. Published data from Europe show it is possible for some sensitive species of birds to be displaced up to 20 km, but this varies by species and by area (Skov et al. 2018; Heinänen et al. 2020; Peschko et al. 2020; Vilela et al. 2020). Getting a regional aerial digital survey strategy at multiple sites collecting information on the scale of displacement and the species involved would contribute to our understanding of displacement.

One purpose of collecting data such as these is to understand both the potential for impacts from offshore WTGs, and to understand how species densities and distributions naturally fluctuate between years. Added to uncertainty is the role of rapidly changing environmental conditions on species densities and distributions at all stages of their life history, as climate changes. Separating natural from anthropogenic stressors on species and separating those impacts from the impacts of offshore WTGs is complicated. Long-term monitoring at more frequent temporal intervals within areas outside of the influence of WTGs (control sites) undertaken alongside long-term monitoring surveys at more frequent temporal intervals within similar areas of influence of WTGs could provide insight into the relationships between these different impacts, whether positive or negative. This coordinated monitoring requires regional approaches and collaborations.

6 Policy Implications

High-resolution aerial digital imagery provides an image footprint of a known size that allows for accurate assessment of survey effort in any one area. The rapid transect and data collection also reduces the likelihood of double counting. This combination allows for fewer uncertainties within data when analyzing differences in distributions and densities between lease areas and is a useful tool for siting at regional and site-specific scales.

Flight altitude flexibility allows for the same survey design both pre- and postconstruction, again providing more certainty when looking at changes in distributions and densities. Understanding species displacement by instituting rigorous postconstruction monitoring at multiple sites using fine temporal resolutions would allow for better-targeted conservation, mitigation, and compensatory efforts for those species involved.

Implementing control sites outside of the region of influence of WTGs would allow for a very visible and powerful message surrounding the regional shifts in species densities and distributions and the challenges facing many species as environmental conditions change. Isolating these natural stressors from the region of influence of WTGs will provide information and data allowing for a better-informed public opinion on the impacts of offshore wind on wildlife and again allow for better-targeted conservation, mitigation, and compensatory efforts for species most challenged.

The National Offshore Wind Research and Development Consortium is a non-profit public-private alliance dedicated to responsible, cost-effective offshore wind energy and technology research in the US. Current funding for the Consortium includes $18.5 million from the US Department of Energy provided through and matched by NYSERDA and contributions from Virginia, Massachusetts, and Maryland. This Consortium is useful for moving some of the research goals forward, providing coordination between state agencies and developers to design and implement studies that can separate the impacts of WTGs from other natural and anthropogenic stressors.

7 Conclusions

High-resolution aerial digital surveys provide a robust solution for sampling large areas of the ocean for marine wildlife. In support of New York State's commitment to incorporating offshore wind into its energy portfolio, NYSERDA embarked on a multi-year ultra-high–resolution aerial digital survey of marine resources in a 43,745.20 km^2 (12,754.06 mi^2) OPA in 2016. For each survey, approximately 300,000 images were collected within the OPA using a transect design. Across all surveys, 98% of images contained no target species groups, vessels, or structures. Less than 2% of images contained target taxonomic groups. During the 12 surveys from 2016 to 2019, biota included:

- 76 species of birds
- 15 species of sharks
- 9 species of dolphins
- 9 species of whales
- 4 species of sea turtles
- 6 species of rays
- 3 species of seals

Some seasonal patterns were evident. In the Summer surveys, ray encounters were the most frequent, with the next most frequently encountered groups being birds, marine mammals, sharks, and turtles. During the Fall surveys bird encounters were the most frequent, followed by marine mammals. The Winter surveys were also dominated by birds followed by marine mammals. In the Spring surveys, birds still mostly dominated the sample, and there was a higher proportion of marine mammals, but the Spring 2018 survey was quite different, with sharks, mostly spurdogs, representing most of the sample followed by birds. No bats were found in imagery.

Results from aerial high-resolution surveys can provide insight into spatial and temporal animal distributions within a surveyed area. Data from these surveys can inform wind turbine siting decisions at a high level and site level through better understanding of species composition, relative abundance, and animal movements. This information can also be used in developing project-specific environmental documents such as Environmental Assessments and Environmental Impact Statements should the need arise.

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Appendix A. Common and Scientific Names for Taxa Identified in Surveys

Table A–1. Common and Scientific Names for Taxa Identified in the Summer 2016 through Spring 2019 Surveys

Species highlighted in light gray are ESA or State-Listed Species.

Common Name	Scientific Name
BIRDS	Aves
Goose	
Brant	*Branta bernicla*
Canada Goose	*Branta canadensis*
Swan	
Tundra Swan	*Cygnus columbianus*
Duck	
Gadwall	*Mareca strepera*
Mallard	*Anas platyrhynchos*
American Black Duck	*Anas rubripes*
Lesser Scaup	*Aythya affinis*
King Eider	*Somateria spectabilis*
Common Eider	*Somateria mollissima*
Surf Scoter	*Melanitta perspicillata*
White-winged Scoter	*Melanitta fusca*
Black Scoter	*Melanitta americana*
Long-tailed Duck	*Clangula hyemalis*
Bufflehead	*Bucephala albeola*
Common Goldeneye	*Bucephala clangula*
Common Merganser	*Mergus merganser*
Red-breasted Merganser	*Mergus serrator*
Loon	
Red-throated Loon	*Gavia stellata*
Common Loon	*Gavia immer*
Grebe	
Horned Grebe	*Podiceps auritus*
Fulmar	
Northern Fulmar	*Fulmarus glacialis*
Petrel	
Trindade Petrel	*Pterodroma arminjoniana*
Black-capped Petrel	*Pterodroma hasitata*

(continued)

Table A–1 continued

Common Name	Scientific Name
Shearwater	
Cory's Shearwater	*Calonectris diomedea*
Great Shearwater	*Ardenna gravis*
Sooty Shearwater	*Ardenna grisea*
Manx Shearwater	*Puffinus puffinus*
Audubon's Shearwater	*Puffinus lherminieri*
Storm-petrel	
Wilson's Storm-Petrel	*Oceanites oceanicus*
White-faced Storm-Petrel	*Pelagodroma marina*
Leach's Storm-Petrel	*Oceanodroma leucorhoa*
Band-rumped Storm-Petrel	*Oceanodroma castro*
Booby	
Brown Booby	*Sula leucogaster*
Gannet	
Northern Gannet	*Morus bassanus*
Cormorant	
Double-crested Cormorant	*Phalacrocorax auritus*
Pelican	
Brown Pelican	*Pelecanus occidentalis*
Ardeidae	
Great Blue Heron	*Ardea herodias*
Snowy Egret	*Egretta thula*
Raptor	
Osprey	*Pandion haliaetus*
Bald Eagle	*Haliaeetus leucocephalus*
Shorebird	
American Oystercatcher	*Haematopus palliatus*
Black-bellied Plover	*Pluvialis squatarola*
Semipalmated Plover	*Charadrius semipalmatus*
Piping Plover	*Charadrius melodus*
Ruddy Turnstone	*Arenaria interpres*
Sanderling	*Calidris alba*
Dunlin	*Calidris alpina*
Phalarope	
Red-necked Phalarope	*Phalaropus lobatus*
Red Phalarope	*Phalaropus fulicarius*
Skua	
Great Skua	*Stercorarius skua*
South Polar Skua	*Stercorarius maccormicki*

Table A–1 continued

Common Name	Scientific Name
Pomarine Jaeger	*Stercorarius pomarinus*
Parasitic Jaeger	*Stercorarius parasiticus*
Auk	
Dovekie	*Alle alle*
Common Murre	*Uria aalge*
Razorbill	*Alca torda*
Black Guillemot	*Cepphus grylle*
Atlantic Puffin	*Fratercula arctica*
Gull	
Black-legged Kittiwake	*Rissa tridactyla*
Bonaparte's Gull	*Chroicocephalus philadelphia*
Little Gull	*Hydrocoloeus minutus*
Laughing Gull	*Leucophaeus atricilla*
Ring-billed Gull	*Larus delawarensis*
Herring Gull	*Larus argentatus*
Iceland Gull	*Larus glaucoides*
Lesser Black-backed Gull	*Larus fuscus*
Glaucous Gull	*Larus hyperboreus*
Great Black-backed Gull	*Larus marinus*
Tern	
Least Tern	*Sternula antillarum*
Black Tern	*Chlidonias niger*
Royal Tern	*Thalasseus maximus*
Sterna Tern	
Roseate Tern	*Sterna dougallii*
Common Tern	*Sterna hirundo*
Forster's Tern	*Sterna forsteri*
Nightjar	
Common Nighthawk	*Chordeiles minor*
Passerine	
Snow Bunting	*Plectrophenax nivalis*
MARINE MAMMALS	Mammalia
Seals	
Gray Seal	*Halichoerus grypus*
Harp Seal	*Pagophilus groenlandicus*
Harbor Seal	*Phoca vitulina*
Whales	
North Atlantic Right Whale	*Eubalaena glacialis*
Blue Whale	*Balaenoptera musculus*
Common Minke Whale	*Balaenoptera acutorostrata*
Fin Whale	*Balaenoptera physalus*
Sei Whale	*Balaenoptera borealis*

Table A-1 continued

Common Name	Scientific Name
Humpback Whale	*Megaptera novaeangliae*
Dwarf Sperm Whale	*Kogia sima*
Pygmy Sperm Whale	*Kogia breviceps*
Sperm Whale	*Physeter macrocephalus*
Dolphins	
Common Dolphin	*Delphinus delphis*
Short-finned Pilot Whale	*Globicephala macrorhynchus*
Risso's Dolphin	*Grampus griseus*
Atlantic White-sided Dolphin	*Lagenorhynchus acutus*
Rough-toothed dolphin	*Steno bredanensis*
Atlantic Spotted Dolphin	*Stenella frontalis*
Striped Dolphin	*Stenella coeruleoalba*
Bottlenose Dolphin	*Tursiops truncatus*
Harbor Porpoise	*Phocoena phocoena*
TURTLES	Reptilia
Soft-shell Turtle	
Leatherback Turtle	*Dermochelys coriacea*
Hard-shell Turtle	
Loggerhead Turtle	*Caretta caretta*
Green Turtle	*Chelonia mydas*
Kemp's Ridley Turtle	*Lepidochelys kempii*
SHARKS AND RAYS	Chondrichthyes
Sharks	
Whale Shark	*Rhincodon typus*
Sand Tiger Shark	*Carcharias taurus*
Thresher Shark	*Alopias vulpinus*
Basking Shark	*Cetorhinus maximus*
White Shark	*Carcharodon carcharias*
Shortfin Mako	*Isurus oxyrinchus*
Blue Shark	*Prionace glauca*
Dusky Shark	*Carcharhinus obscurus*
Oceanic Whitetip Shark	*Carcharhinus longimanus*
Sandbar Shark	*Carcharhinus plumbeus*
Tiger Shark	*Galeocerdo cuvier*
Great Hammerhead	*Sphyrna mokarran*
Smooth Hammerhead	*Sphyrna zygaena*
Scalloped Hammerhead	*Sphyrna lewini*
Spurdog	*Squalus acanthias*

Table A-1 continued

Common Name	Scientific Name
Rays	
Bluntnose Stingray	*Dasyatis say*
Giant Manta Ray	*Manta birostris*
Giant Devil Ray	*Mobula mobula*
Chilean Devil Ray	*Mobula tarapacana*
Bullnose Ray	*Myliobatis freminvillii*
Cownose Ray	*Rhinoptera bonasus*

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