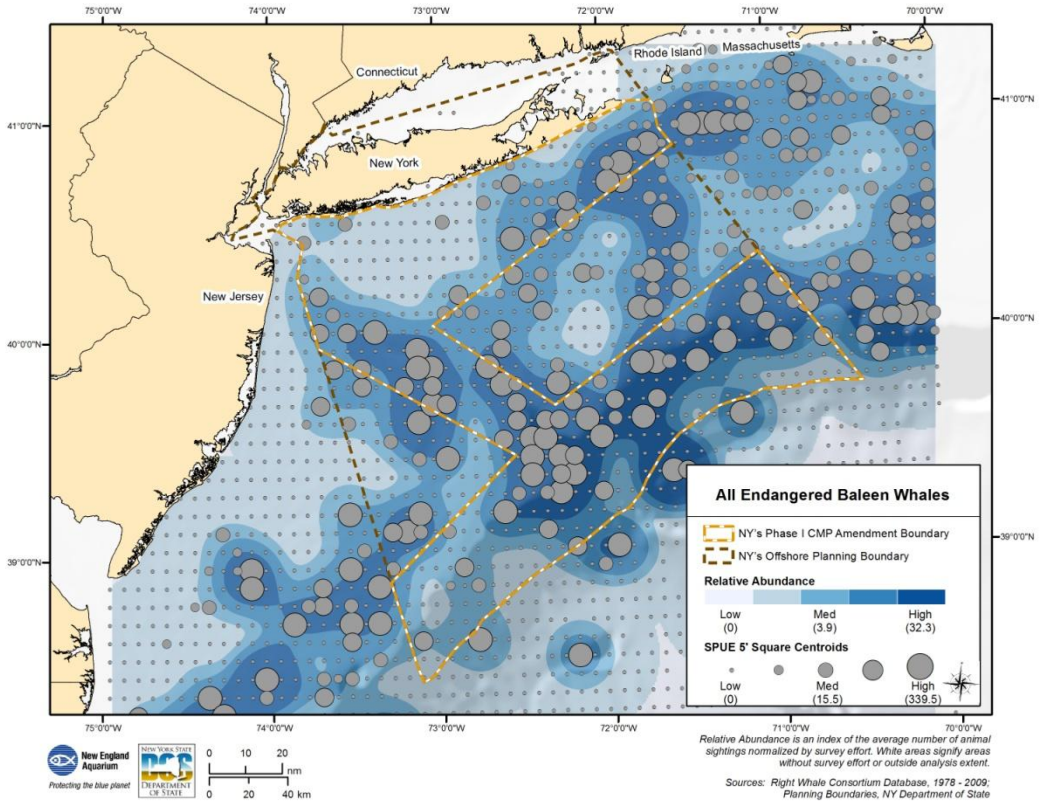
Technical Report for the Spatial Characterization of Marine Turtles, Mammals, and Large Pelagic Fish to Support Coastal and Marine Spatial Planning in New York



Relative Abundance is an index of the average number of animal sightings normalized by survey effort. White areas signify areas without survey effort or outside analysis extent.

Sources: Right Whale Consortium Database, 1978 - 2009; Planning Boundaries, NY Department of State

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Abstract

This New England Aquarium and Dr. Bob Kenney of the University of Rhode Island created relative species distribution data and maps to support the Marine Spatial Planning Efforts for New York Department of State. Number of sightings for relevant species and species groups were summarized at 5’ x 5’ spatial extents and normalized by the amount of survey effort within the same spatial extent throughout the New York State Offshore Planning Area. These summaries were compiled to GIS databases using latitude and longitude center points of each 5’ x 5’ extent. The point estimates of relative abundance of each species or species group were interpolated throughout the study area using Ordinary Kriging with a Gaussian Model and a Smoothing Neighborhood of 20 km. The relative abundance distributions were classified into quintiles and mapped to the study area. Error assessments of the interpolations were calculated using cross-validation and an assessment of agreement between the classified interpolations to the original point datasets. Species descriptions are provided for many of the species mapped based on previous technicalreports.

Contents

Sightings per Unit Effort Analysis

Most of the Sightings per Unit Effort Analysis and Species Descriptions were excerpted/adapted from: Marine Mammals and Sea Turtles of Narragansett Bay, Block Island Sound, Rhode Island Sound, and Nearby Waters: An Analysis of Existing Data for the Rhode Island Ocean Special Area Management Plan, by Robert D. Kenney and Kathleen J. Vigness-Raposa, Final Technical Report for the Rhode Island Ocean Special Area Management Plan, University of Rhode Island, Graduate School of Oceanography, Narragansett, RI (June 2010).

Data Sources

There have been aerial and shipboard surveys for marine mammals and turtles in southern New England waters since the late 1970s. Most of the existing survey data for the region have been obtained and archived by the North Atlantic Right Whale Consortium (NARWC, http://www.rightwhaleweb.org). The NARWC database is managed and continually updated at the University of Rhode Island Graduate School of Oceanography (Kenney, 2001), with funding support from the National Marine Fisheries Service. By definition, in addition to records of all target species (and sometimes non-target species) sighted, survey data include detailed information on the track of the survey platform (e.g., ship or aircraft) and associated environmental conditions, allowing for subsequent reconstruction of the survey and quantification of effort. The principal sources of survey data in the NARWC database from the southern New England are surveys in 1978–1982 by the Cetacean and Turtle Assessment Program (CETAP, 1982); surveys specifically focused on right whales and multi-species stock assessment surveys conducted since the 1990s by the National Marine Fisheries Service’s Northeast Fisheries Science Center (NMFS-NEFSC, Woods Hole, MA); surveys for seabirds and marine mammals conducted by Manomet Bird Observatory personnel aboard NMFS ships conducting fisheries, plankton, and oceanographic research in 1980–1988; and aerial surveys for right whales conducted in 2005 and 2006 by the Riverhead Foundation for Marine Research and Preservation (Riverhead, NY).

There are a couple of well-known historical literature sources for marine mammals of New York. James Ellsworth De Kay (1842) published the first comprehensive review of the mammal fauna of New York, although his treatment of the marine mammals was relatively incomplete and relied heavily on second-hand anecdotal sources, and consequently has a number of errors. Paul F. Connor published a comprehensive review of the mammals of Long Island in 1971, as one piece of a never-completed region-by-region review of the New York mammal fauna. Connor’s review summarized what was published in a variety of historical sources, evidence from contemporary strandings and other specimens, and reliable reports from fishermen and others.

Sightings per Unit Effort Methods

A major issue with the interpretation of distribution and habitat-use patterns based on raw sighting and stranding data is that the patterns are usually biased by the distribution of survey coverage (“effort”). One method to overcome this potential bias is to quantify survey effort, and then to correct sighting frequencies for differences in effort, producing an index termed sightings-per-unit-effort (SPUE). The units are numbers of animals sighted per unit length of survey track. To standardize the SPUE data even further, the data can be limited to only a subset of the survey tracklines which meet pre-defined criteria for “acceptability.” The effort criteria can vary between studies; ours included having at least one observer formally on watch, visibility of at least 2 nautical miles (3.7 km), sea state of Beaufort class 3 or below, and altitudes below 1,200 feet (366 m, applicable only to aerial surveys). SPUE values are computed for consistent spatial units and can therefore be mapped or be statistically compared across areas, seasons, years, etc. Development of this method was begun during CETAP (1982), and it has been used in a variety of analyses (Kenney and Winn, 1986; Winn et al., 1986; Kenney, 1990; Hain et al., 1992; Shoop & Kenney, 1992; Kraus et al., 1993; DoN, 2005; Pittman et al., 2006). Because the method requires regular location and environmental data to reconstruct the survey tracks and quantify effort, only a subset of sighting data can be included, and stranding data are entirely excluded.

The SPUE method involves partitioning the study area into a regular grid based on latitude and longitude. The grid size selected is a compromise between resolution (smaller cells) and sample sizes (larger cells), and cannot be determined without preliminary examination of the available survey data. Previous studies based on the NAWRC data have used cells ranging from 1 min X 1 min (1.9 X 1.4 km) to 10 min X 10 min (18.5 X 13.9 km). For this project we used a 5 min X 5 min grid (9.3 X 7.0 km). All acceptable aerial and shipboard survey tracks were parsed into grid cells and their lengths computed and summed by season. Sightings were similarly assigned to cells and the numbers of animals sighted were summed by cell and season. Finally, the number of animals in each cell/season was divided by the corresponding effort value, then multiplied by 1,000 to avoid small decimal values, generating a SPUE index in units of animals sighted per 1,000 km of survey track. All of this analysis was done using our own custom programs in SAS 9.1.3 (SAS Institute, Inc., Cary, NC).

It is possible to map the gridded SPUE data directly (e.g., Shoop & Kenney, 1992; Kraus et al., 1993), however the effort data and resulting SPUE data are often sparse and can be difficult to interpret. Interpolation can smooth out the relative density contours and fill in predicted values in some un-sampled areas. Pittman et al. (2006) used inverse-distance weighting to create interpolated relative density maps. For a Navy Marine Resources Assessment (DoN, 2005), the Kriging function in Spatial Analyst within the ArcGIS environment was used for that purpose (Watterson et al., in review).

Species Background

Kenney and Vigness Raposa (2010) reported that 49 species of marine mammals and sea turtles had been recorded or could potentially occur in the waters near and offshore of Rhode Island, southern Massachusetts, and eastern Long Island. They classified species based on the total number of records in the combined survey, opportunistic, historical, stranding, and bycatch data:

Common to abundant (> 100 records; N = 16):

- Cetaceans (11)—North Atlantic right whale (*Eubalaena glacialis*), humpback whale (*Megaptera novaeangliae*), fin whale (*Balaenoptera physalus*), common minke whale (*Balaenoptera acutorostrata*), sperm whale (*Physeter macrocephalus*), harbor porpoise (*Phocoena phocoena*), long-finned pilot whale (*Globicephala melas*), Risso's dolphin (*Grampus griseus*), Atlantic white-sided dolphin (*Lagenorhynchus acutus*), common bottlenose dolphin (*Tursiops truncatus*), short-beaked common dolphin (*Delphinus delphis*)
- Pinnipeds (3)—harbor seal (*Phoca vitulina*), gray seal (*Halichoerus grypus*), harp seal (*Pagophilus groenlandicus*)
- Sea Turtles (2)—leatherback sea turtle (*Dermochelys coriacea*), loggerhead sea turtle (*Caretta caretta*)

Regular (10–100 records; N = 6):

- Cetaceans (4)—sei whale (*Balaenoptera borealis*), pygmy sperm whale (*Kogia breviceps*), white-beaked dolphin (*Lagenorhynchus albirostris*), striped dolphin (*Stenella coeruleoalba*)
- Pinnipeds (1)—hooded seal (*Cystophora cristata*)
- Sea Turtles (1)—Kemp's ridley sea turtle (*Lepidochelys kempii*)

Rare or accidental (< 10 records; N = 18):

- Cetaceans (15)—blue whale (*Balaenoptera musculus*), Bryde's whale (*Balaenoptera brydei*), dwarf sperm whale (*Kogia sima*), northern bottlenose whale (*Hyperoodon ampullatus*), Cuvier's beaked whale (*Ziphius cavirostris*), Blainville's beaked whale (*Mesoplodon densirostris*), Gervais' beaked whale (*M. europaeus*), Sowerby's beaked whale (*M. bidens*), True's beaked whale (*M. mirus*), beluga whale (*Delphinapterus leucas*), short-finned pilot whale (*Globicephala macrorhynchus*), killer whale (*Orcinus orca*), false killer whale (*Pseudorca crassidens*), Atlantic spotted dolphin (*Stenella frontalis*), pan-tropical spotted dolphin (*S. attenuata*)
- Pinnipeds (1)—ringed seal (*Pusa hispida*)
- Sirenians (1)—West Indian manatee (*Trichechus manatus*)
- Sea Turtles (1)—green sea turtle (*Chelonia mydas*)

Extirpated (formerly present but now extinct in the North Atlantic; N = 1):

- Cetaceans (1)—gray whale (*Eschrichtius robustus*)

Hypothetical (no records, but with known occurrences within the northeastern U.S. region; N = 8):

- Cetaceans (5)—pygmy killer whale (*Feresa attenuata*), melon-headed whale (*Peponocephala electra*), rough-toothed dolphin (*Steno attenuata*), spinner dolphin (*Stenella longirostris*), and Clymene dolphin (*Stenella clymene*)
- Pinnipeds (2)—bearded seal (*Erignathus barbatus*) and walrus (*Odobenus rosmarus*)

- Sea turtles (1)—hawksbill sea turtle (*Eretmochelys imbricata*)

The following table summarizes the sighting frequencies from the NARWC database for the defined study area, including only sightings with associated survey effort and made during survey tracks under acceptable conditions (at least one observer on watch, visibility at least 2 nautical miles, sea state of Beaufort 3 or lower, and altitude below 1200 feet for aerial surveys). Not every species included by Kenney and Vigness-Raposa is on the list, because a number of them were never seen during surveys—including both rare (e.g., blue whale, Bryde's whale, beluga) and common (e.g., harp seal) species. The first species analyzed was right whale, and the number of sightings (16) was insufficient for the GIS interpolation. Subsequently, only species with substantially larger numbers of sightings were run through the analysis. We also created a number of pooled categories (second part of the table) by combining species together before the SPUE computation process. This increased sample sizes, and also enabled making use of rare species and of unidentified categories that are not particularly useful on their own.

Table 1: Frequencies of on-effort sightings of large marine species in the study area off southern New England, encompassed by 38°00–41°30 N and 70°00–75°00 W. Entries shaded in light blue are those run through the SPUE analysis and GIS interpolation process. Pooled categories are in the second part of the table; for those the Species Codes were created specifically for naming the data files, and the Notes column lists all of the individual species codes included in that category. **If a species distribution was created for the species not highlighted, please use caution using these data or maps because of the low number of sightings.**

Species Code	Species	N	Notes
Individual species and species categories			
LOTU	Loggerhead sea turtle (*Caretta caretta*)	1236	Threatened
OCSU	Ocean sunfish (*Mola mola*)	986	
UNDO	Unidentified dolphin/porpoise	486	
GRAM	Risso's dolphin (*Grampus griseus*)	375	
BODO	Bottlenose dolphin (*Tursiops truncatus*)	368	
SADO	Short-beaked common dolphin (*Delphinus delphis*)	307	
BASH	Basking shark (*Cetorhinus maximus*)	268	
FIWH	Fin whale (*Balaenoptera physalus*)	238	Endangered
UNSH	Unidentified shark	220	
PIWH	Pilot whale (*Globicephala* sp.)	208	
SPWH	Sperm whale (*Physeter macrocephalus*)	204	Endangered
UNSE	Unidentified seal (Phocidae)	179	
HAPO	Harbor porpoise (*Phocoena phocoena*)	178	

LETU	Leatherback sea turtle (*Dermochelys coriacea*)	169	Endangered
UNTU	Unidentified sea turtle	154	
WSDO	Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	129	
HHSH	Hammerhead shark (*Sphyrna* sp.)	121	
BLSH	Blue shark (*Prionace glauca*)	113	
MIWH	Common minke whale (*Balaenoptera acutorostrata*)	94	
UNLW	Unidentified large whale	87	Endangered
RITU	Kemp's ridley sea turtle (*Lepidochelys kempii*)	73	Endangered
UNFS	Fin or sei whale	67	Endangered
UNST	Unidentified *Stenella*	65	
STDO	Striped dolphin (*Stenella coeruleoalba*)	54	
HUWH	Humpback whale (*Megaptera novaeangliae*)	47	Endangered
UNBW	Unidentified beaked whale (Ziphiidae)	32	
UNCW	Common or white-sided dolphin	30	
UNMW	Unidentified medium whale	29	
UNWH	Unidentified whale	29	
SPDO	Spotted dolphin (*Stenella* sp.)	24	
HASE	Harbor seal (*Phoca vitulina*)	20	
RIWH	North Atlantic right whale (*Eubalaena glacialis*)	16	Endangered
UNRO	Unidentified rorqual (Balaenopteridae)	15	probably Endangered
BEWH	Beaked whale (*Mesoplodon* sp.)	8	
SEWH	Sei whale (*Balaenoptera borealis*)	8	Endangered
GOBW	Cuvier's beaked whale (*Ziphius cavirostris*)	7	
GRTU	Green sea turtle (*Chelonia mydas*)	7	Endangered
UNBA	Unidentified *Balaenoptera*	7	probably Endangered
UNKO	Unidentified Kogia	7	
SOBW	Sowerby's beaked whale (*Mesoplodon bidens*)	5	
UNGD	Bottlenose or spotted dolphin	5	
ASDO	Atlantic spotted dolphin (*Stenella frontalis*)	3	
KIWH	Killer whale (*Orcinus orca*)	2	
UNBF	Unidentified blackfish	2	
WBDO	White-beaked dolphin (*Lagenorhynchus albirostris*)	2	4

HATU	Hawksbill sea turtle (*Eretmochelys imbricata*)	1	Endangered
NBWH	Northern bottlenose whale (*Hyperoodon ampullatus*)	1	
PSWH	Pygmy sperm whale (*Kogia breviceps*)	1	
PYKW	Pygmy killer whale (*Feresa attenuata*)	1	
Pooled species categories			
PRSP	All protected species	4980	Pooled: ASDO, BEWH, BODO, FIWH, GOBW, GRAM, GRTU, HAPO, HASE, HATU, HUWH, KIWH, LETU, LOTU, MIWH, NBWH, PIWH, PSWH, PYKW, RITU, RIWH, SADO, SEWH, SOBW, SPDO, SPWH, STDO, UNBA, UNBF, UNBW, UNCW, UNDO, UNFS, UNGD, UNKO, UNLW, UNMW, UNRO, UNSE, UNST, UNTU, UNWH, WBDO, & WSDO
MARM	All marine mammals	3340	Pooled: ASDO, BEWH, BODO, FIWH, GOBW, GRAM, HAPO, HASE, HUWH, KIWH, MIWH, NBWH, PIWH, PSWH, PYKW, RIWH, SADO, SEWH, SOBW, SPDO, SPWH, STDO, UNBA, UNBF, UNBW, UNCW, UNDO, UNFS, UNGD, UNKO, UNLW, UNMW, UNRO, UNSE, UNST, UNWH, WBDO, & WSDO
CETA	All cetaceans	3141	Pooled: ASDO, BEWH, BODO, FIWH, GOBW, GRAM, HAPO, HUWH, KIWH, MIWH, NBWH, PIWH, PSWH, PYKW, RIWH, SADO, SEWH, SOBW, SPDO, SPWH, STDO, UNBA, UNBF, UNBW, UNCW, UNDO, UNFS, UNGD, UNKO, UNLW, UNMW, UNRO, UNST, UNWH, WBDO, & WSDO
ENDG	All endangered & threatened species	2329	Pooled: FIWH, GRTU, HATU, HUWH, LETU, LOTU, RITU, RIWH, SEWH, SPWH, UNBA, UNFS, UNLW, UNRO, & UNTU
DOLF	Small toothed whales	2245	Pooled: ASDO, BODO, GRAM, HAPO, PIWH, PSWH, PYKW, SADO,

			SPDO, STDO, WBDO, WSDO, UNBF, UNCW, UNDO, UNGD, UNKO, & UNST
TURT	All sea turtles	1640	Pooled: GRTU, HATU, LETU, LOTU, RITU, & UNTU
BALN	Endangered baleen whales	398	Pooled: FIWH, HUWH, RIWH, SEWH, UNBA, UNFS, & UNRO
LARG	Large toothed whales	359	Pooled: BEWH, GOBW, KIWH, NBWH, SOBW, SPWH, & UNBW
SEAL	All seals	199	Pooled: UNSE & HASE
BEAK	All beaked whales	53	Pooled: BEWH, GOBW, NBWH, SOBW, & UNBW

Interpolation Methods

The New England Aquarium (NEAq) created seasonal and annual distributions for marine mammals, turtles, and large pelagic fish in the marine waters off New York's shoreline using data from the Sightings per Unit Effort (SPUE) analysis described above from the Right Whale Consortium (RWC) database. The RWC database consists of sightings and survey effort from 1978 to 2009 and has been compiled from a multitude of agencies and organizations into a single database. SPUE was calculated for each 5' x 5' cell by determining the number of animals seen while on survey and normalizing by the kilometers of survey effort. Refer to the Sightings per Unit Effort Methods for more information about the SPUE methods and species descriptions mapped in this work.

The SPUE results were presented in dbase files, which were converted into ArcGIS files for distribution mapping. Distributions of each species or species group were mapped by interpolating the regularly spaced SPUE points to a continuous surface using Ordinary Kriging. These distributions were presented as maps of annual and seasonal patterns within and around the study area. Specifics about the preprocessing, interpolation, and results are presented below.

Preprocessing

Dbase Files to ArcGIS Files

Sightings per Unit Effort (SPUE) databases were delivered to the New England Aquarium as DBASE database files, one for each species or species group (Table 2). Each record in the file contained the SPUE calculation; latitude and longitude of the center of the 5' x 5' cell; season (All, Winter, Spring, Summer, Fall); number of animals, and kilometers of trackline effort.

The seasons were defined as:

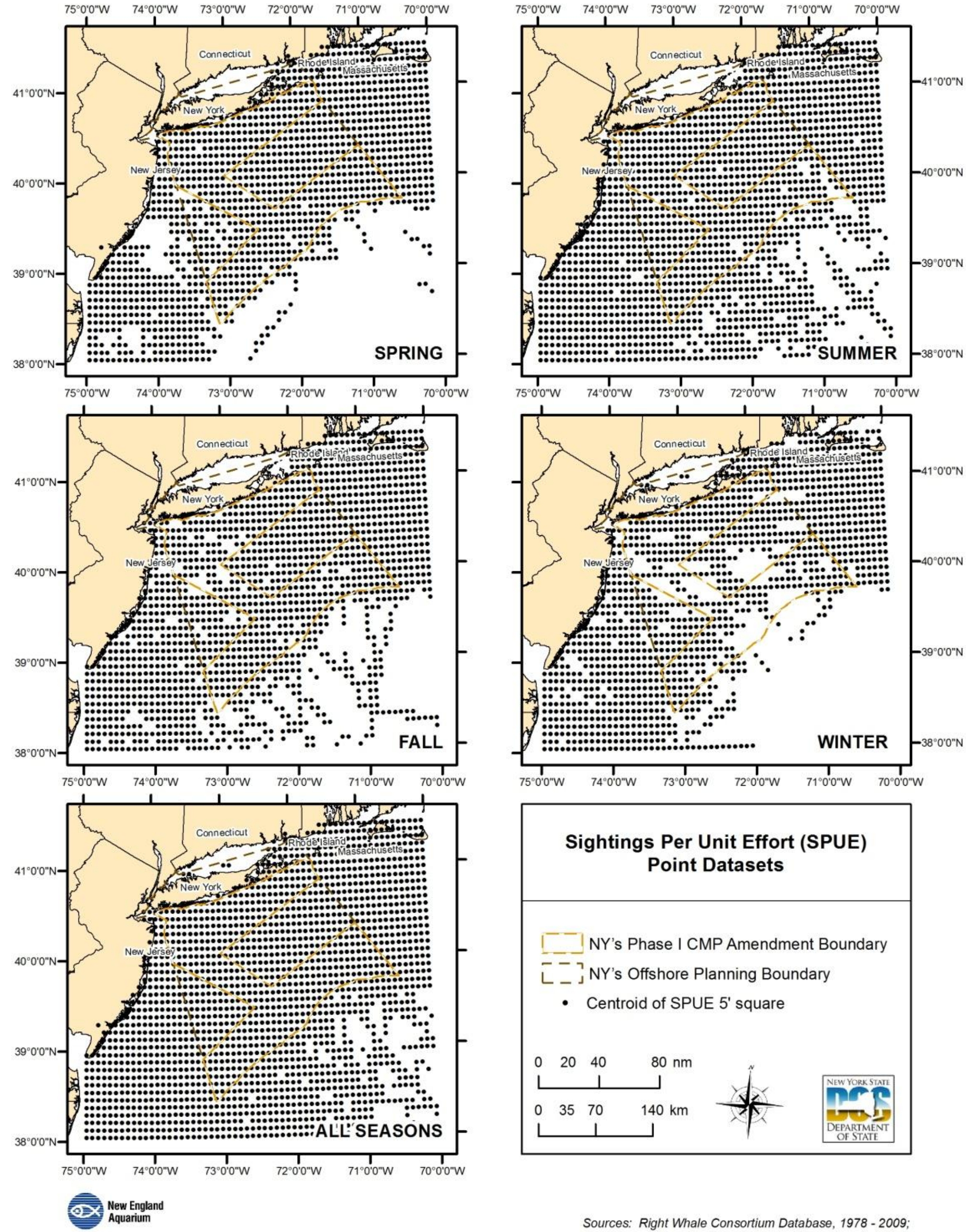
Fall = September, October, November.
Winter = December, January, February
Spring = March, April, May
Summer = June, July, and August

Table 2. Species and groupings that were mapped using SPUE calculations from the N.A. Right Whale Consortium.

Code	Species Groupings
BALN	All Endangered Baleen Whales
CETA	All Cetaceans
DOLF	Small Toothed Whales
ENDG	All ESA-listed species
LARG	Large Toothed Whales
MARM	All Marine Mammals (All Cetacean plus Seals)
PRSP	All Protected Species(All Marine Mammals plus

	Turtles)
TURT	All Turtles
Code	**Species**
BASH	Basking Shark (*Cetorhinus maximus*)
BEAK	Beaked Whale (*Mesoplodon sp.*)
BLSH	Blue Shark (Prionace glauca)
BODO	Bottlenose Dolphin (*Tursiops truncatus*)
FIWH	Fin Whale (*Balaenoptera physalus*)
GRAM	Risso's Dolphin (*Grampus griseus*)
HAPO	Harbor Porpoise (*Phocoena phocoena*)
HHSH	Hammerhead Shark (*Sphyrna* sp.)
HUWH	Humpback Whale (*Megaptera novaeangliae*)
LETU	Leatherback Turtle (*Dermochelys coriacea*)
LOTU	Loggerhead Turtle (*Caretta caretta*)
MIWH	Minke Whale (*Balaenoptera acutorostrata*)
OCSU	Ocean Sunfish/Sharp-tailed Mola (*Mola mola/lanceolata*)
PIWH	Pilot Whale (*Globicephala sp.*)
RITU	Kemp's Ridley Turtle (*Lepidochelys kempii*)
RIWH	North Atlantic Right Whale (*Eubalaena glacialis*)
SADO	Common Dolphin (*Delphinus delphis*)
SEAL	Seals (*Phocidae sp.*)
SPWH	Sperm Whale (*Physeter macrocephalus*)
STDO	Striped Dolphin (*Stenella coeruleoalba*)
WSDO	Atlantic White-Sided Dolphin (*Lagenorhynchus acutus*)

Each file was imported into GIS using the latitude and longitude coordinates of the WGS 1984 geographic coordinate system. The file was exported into an ArcGIS point feature class inside a 9.3.1 File Geodatabase. Each feature class was projected into UTM Zone 18, North American Datum 1983 for the Kriging interpolation. The resulting point dataset was a regular spaced grid of points with SPUE values for the annual and seasonal distribution for each species or grouping (Figure 1).

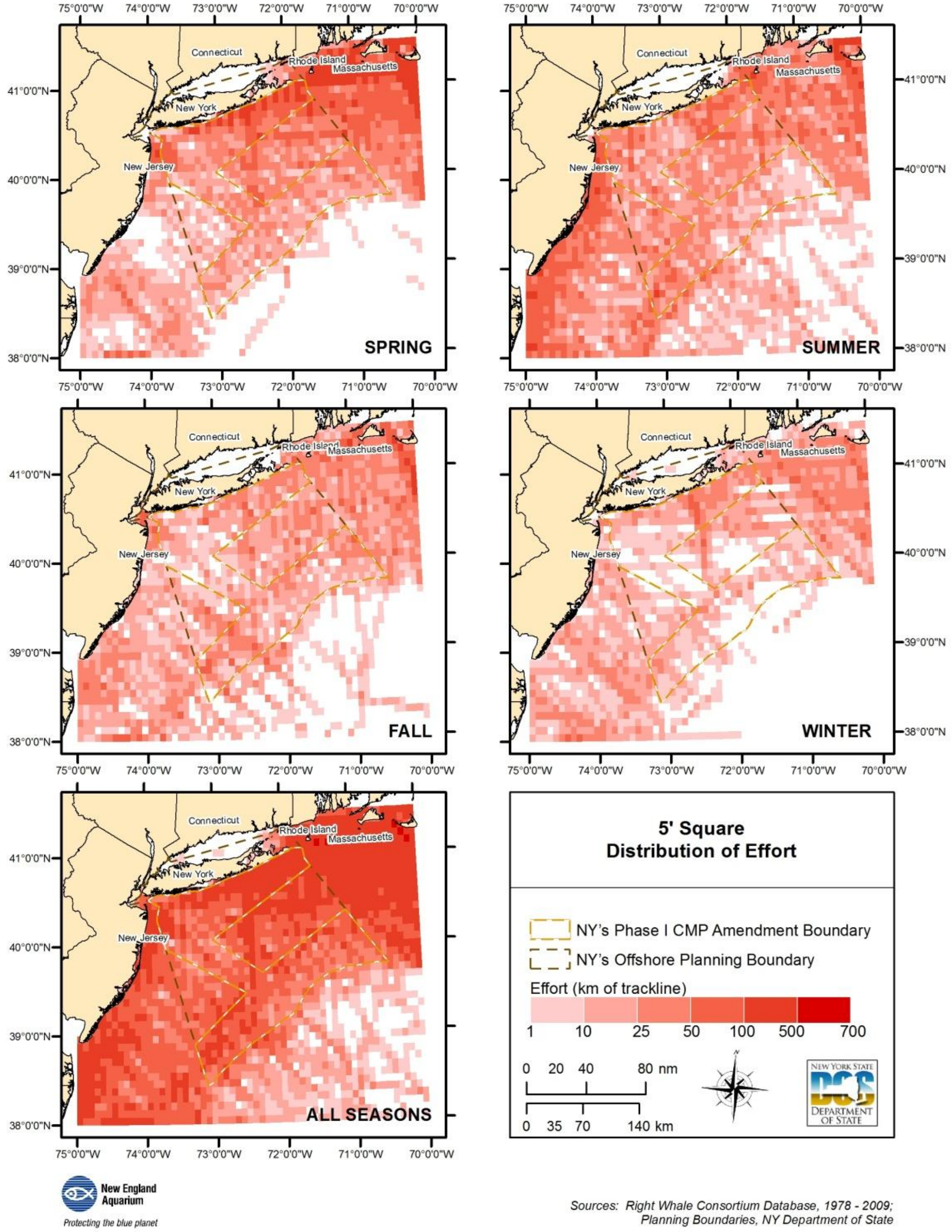


Sources: Right Whale Consortium Database, 1978 - 2009;
Planning Boundaries, NY Department of State

Figure 1. Map of the regular (5' x 5') distribution of SPUE points, the locations missing points do not have survey effort.

Assessment of Effort

The annual and seasonal distributions are influenced by the amount of survey effort in these data. If there was no survey in a certain geographic area or during a time period then there is no opportunity to see a species. Consequently, understanding the spatial patterns of the effort in the dataset is extremely important to understand the resulting species distribution maps. We investigated the survey effort by mapping each SPUE point to the 5' x 5' grid these data represent to visualize the patterns of effort influencing the annual and seasonal distributions (Figure 2).



Sources: Right Whale Consortium Database, 1978 - 2009; Planning Boundaries, NY Department of State

Figure 2. The amount of survey effort in the study area for each season and all seasons combined.

Creation of Annual and Seasonal Distribution Datasets

The goal of this work is to understand the average annual and seasonal distributions of marine mammal, sea turtles, and large pelagic fish in the study area. However, the SPUE analysis can create highly variable spatial data depending on the amount of effort and sightings. Especially in areas where there is low amount of effort, but a fair number of sightings during that survey effort. Since these species are highly migratory, we developed a methodology to smooth the local variability in the SPUE analysis to gain a picture of the overall pattern in the distribution.

We used ArcGIS' Geostatistical Analyst to create Ordinary Kriging interpolations of the distributions of species or species groups from the SPUE point data. Kriging is a geostatistical method that builds mathematical and statistical models of spatial autocorrelation and uses these relationships to create an interpolation surface (ESRI 2010). Spatial autocorrelation is the tendency of locations closer together to be similar in values, (i.e. SPUE values; Bolstad 2008) and this relationship can be modeled using a semivariogram during the Kriging process. The semivariogram is determined by plotting the average semivariance between all points used in the model at increasing distances (Figure 3). There are many properties to specify when modeling the semivariogram function, these include: type of model to fit (i.e. Guassian or Exponential), lag distance (the distance to bin data) and total the number of bins (lags). The semivariogram model is used to weight the points in the search neighborhood to determine the spatial prediction. We used a smoothing neighborhood for our predictions which adjusts the distance weights determined from the model using a sigmoidal function away from the prediction location up to a distance equal to 2 times the Major Semiaxis (ESRI 2010, Gribov and Krivoruchko 2004). For our predictions we used a smoothing factor of 1 (the highest) and a Major and Minor Semiaxis of 20 km to include at least 6 points into our calculations (Figure 4).

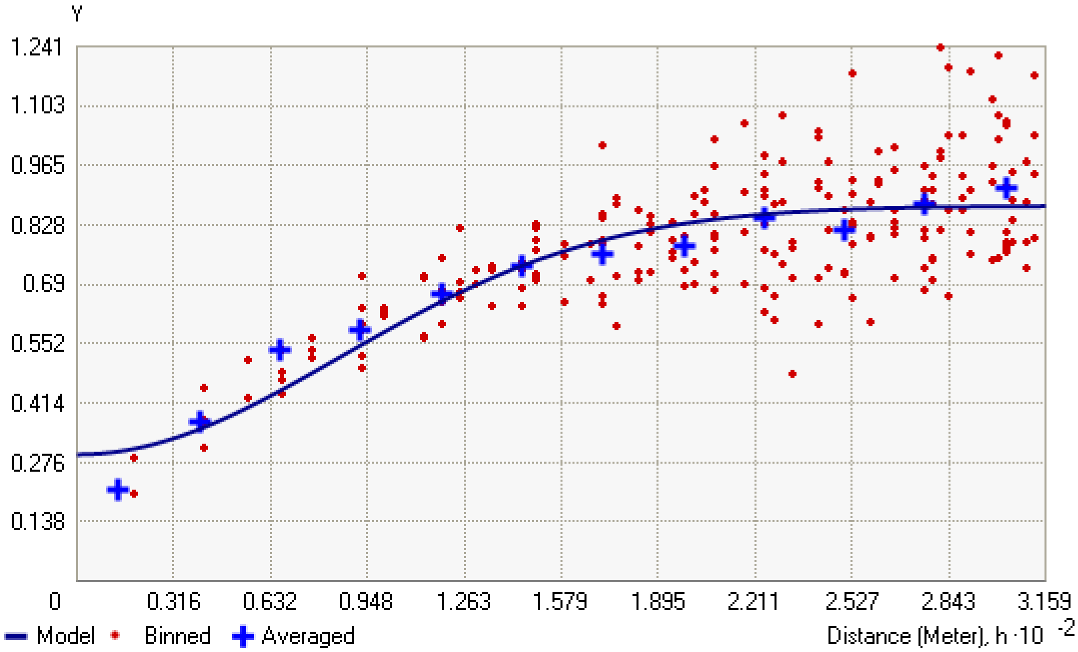
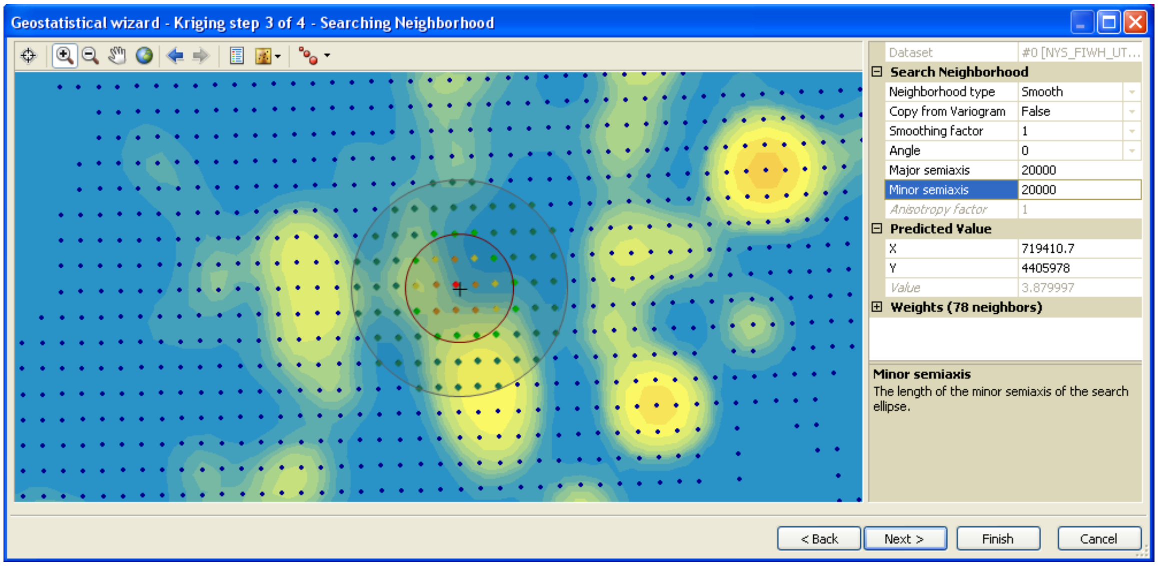


Figure 3. Empirical semivariogram and the Gaussian semivariogram model fitted to the data. The red dots are the semi-variance between two points within a certain bin, the crosses represent the average semi-variance of the bin, and the blue line is the model fitted to the averaged bin values. (Figure from ESRI)



Dataset	#0 [NYS_FIWH_UT...
Search Neighborhood	
Neighborhood type	Smooth
Copy from Variogram	False
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Minor semiaxis	20000
Anisotropy factor	1
Predicted Value	
X	719410.7
Y	4405978
Value	3.879997
Weights (78 neighbors)	

Minor semiaxis
The length of the minor semiaxis of the search ellipse.

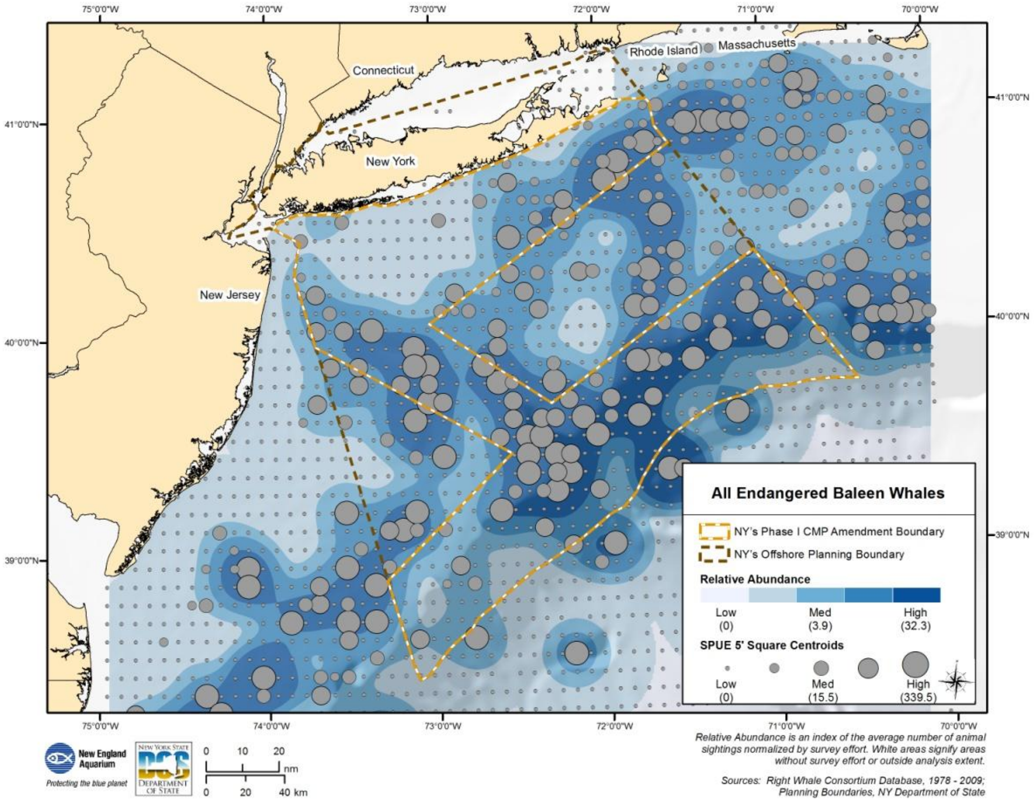
Figure 4. Example of the smoothing neighborhood in ArcGIS Geostatistical Analyst, which adjusts the distance weights determined from the model using a sigmoidal function away from the prediction location up to a distance equal to 2 times the Major and Minor Semiaxis. Our models used the highest smoothing factor of 1 and Major and Minor semi axis of 20 km.

Assessments of Interpolations

To assess the accuracy of the models we used cross-validation, which uses all the input data to estimate the error in the interpolation result. The process of cross-validation takes out one of the sample locations then predicts the location where the point was removed. This is repeated for all the sample locations to estimate the variability of SPUE predictions (ESRI 2010). We included the mean error, mean standard error, root mean square error, and root mean square standardized error for all of our interpolations in Appendix A.

Using the smoothing neighborhood in ArcGIS decreased the magnitude of our SPUE values in the interpolated surface by approximately a factor of 10. The distributions match the overall SPUE point distributions (Figure 5), so the interpolated surface still provides the relative abundance of a species or grouping. The final map products of the marine mammal, turtle distributions, and large pelagic fish were classified into quintiles, 20% of the data in each class.

The top 20% of the interpolated SPUE surface should match the top 20% of the original SPUE point data even if the overall range decreased. We assessed how well the interpolated top 20% matched the top 20% in the point values for the species grouping datasets, by classifying each dataset to a range of 1-5, then assessing the agreement between the categories (Table 3). This assessment is important in the context of marine spatial planning because the top 20% of the data is often used in determine important habitats (Massachusetts Ocean Plan 2009). The dataset with the lowest agreement was further examined to determine causes.



Relative Abundance is an index of the average number of animal sightings normalized by survey effort. White areas signify areas without survey effort or outside analysis extent.

Sources: Right Whale Consortium Database, 1978 - 2009; Planning Boundaries, NY Department of State

Figure 5. Example of the relative abundance distributions from Kriging and the SPUE point dataset used to produce the interpolated surface. Notice the magnitude difference in the legend between the point dataset and the interpolated surface. However, the interpolated distribution matched the pattern of the points.

Final Processing Steps.

The final models of the species average annual and seasonal distributions were exported from an ArcGIS Geostatistical Layer to an ArcGIS 9.3.1 raster grid. Each grid was subsequently projected back to the WGS 1984 Coordinate System and clipped to a smaller extent than the original data to eliminate any edge effects of interpolation. During this process the cell size and position were matched to the data template provided.

The final species and groupings were mapped to the study area with the data classified using quintiles to enhance the visualization of the datasets and allow for easy interpretation of the results.

Results

All the species or species groupings Sightings per Unit Effort values were interpolated to create relative abundance maps and datasets for average annual and seasonal distributions. The maps follow the text of this document. In addition, the total Sightings per Unit Effort was summarized for each species for the annual and seasonal distributions. These summaries allow for direct comparison of relative abundance over the seasons by species or species group (Table 3).

The protected species dataset had the lowest agreement between the classified SPUE points and interpolated surface, so this dataset was further examined. We found many of the high SPUE point values classified into the top 20% were solitary, consequently our interpolation smoothed those areas because they were next to many lower values. Since we are attempting to gain a general understanding of the distribution, we feel this is an appropriate result of creating relative distributions of time. However, with additional survey effort these areas might be found to be the most important for a certain species, so there should be some caution when interpreting these datasets.

Table 3. Percent agreement of the highest quintile (top 20%) class break between the interpolated species grouping datasets and the original SPUE points when reclassified into quintiles.

Dataset	Agreement (%)
BALN_ALL	78.9
CETA_ALL	63.6
DOLF_ALL	71.8
ENDG_ALL	83.0
LARG_ALL	100.0
MARM_ALL	68.1
PRSP_ALL	57.4
TURT_ALL	90.3

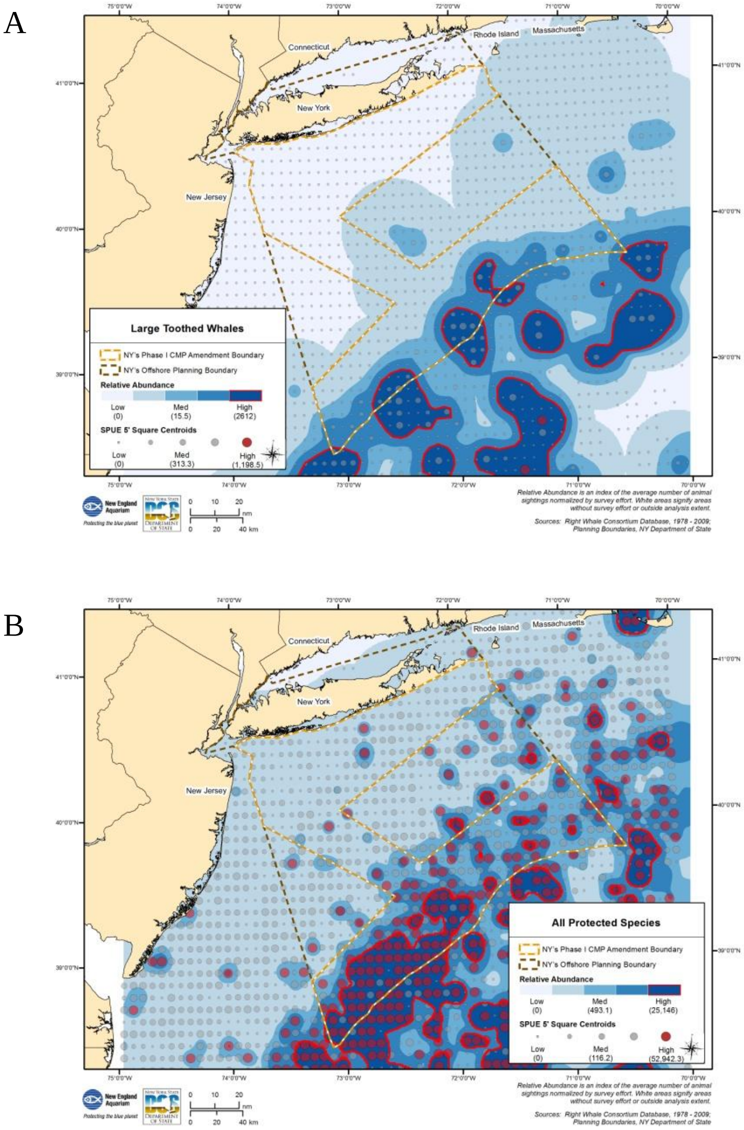


Figure 6. Example of agreement between the original point data sets and the interpolation surface. The red line highlights the area defined as the top 20% in the interpolated surface while the red points are classified as the top 20% in the SPUE points. The top map (A) had the highest level of agreement (Large Toothed Whales (100%)) between the two classifications and the lower map (B) had the least level of agreement (All Protected Species (57.4%)). In the bottom map

Anomalies for Interpolated datasets

Some of the datasets were not modeled because there were no SPUE values during the season of interest. The datasets were created with all values equal to 0, this allowed for the compilation of seasonal distributions maps for each species.

The species and seasons that required this technique were Winter Beaked whales, Winter Hammer Head Shark, Spring Hammer Head Shark, Winter Blue Shark, Spring Blue Shark, Fall Kemp's Ridley Turtle, Winter Kemp's Ridley Turtle, Spring Kemp's Ridley Turtle

Table 3. Summarized seasonal and annual Sightings per Unit for each species or species group.

Species/Group	Season				
	Spring	Summer	Fall	Winter	All
All Endangered Baleen Whales	6,507	12,036	1,956	4,130	7,572
All Cetaceans	552,210	1,474,961	666,754	505,472	1,162,547
Small Toothed Whales	540,117	1,410,133	661,999	499,019	1,125,830
All ESA-listed species	7,718	73,765	18,662	4,768	35,227
Large Toothed Whales	2,265	38,131	2,085	1,363	20,611
All Marine Mammals (All Cetacean plus Seals)	654,387	1,498,158	676,709	509,153	1,214,086
All Protected Species(All Marine Mammals plus Turtles)	654,968	1,555,753	692,808	509,298	1,239,706
All Turtles	581	57,596	16,098	145	25,620
Basking Shark (*Cetorhinus maximus*)	2,299	12,677	1,805	126	4,256
Beaked Whale (*Mesoplodon sp.*)	533	7,213	374	0	4,074
Blue Shark (*Prionace glauca*)	0	60,949	445	0	20,640
Bottlenose Dolphin (*Tursiops truncatus*)	68,098	101,560	83,139	8,656	94,563
Fin Whale (*Balaenoptera physalus*)	4,081	7,819	1,607	2,954	5,140
Risso's Dolphin (*Grampus griseus*)	20,022	130,914	101,807	55,869	106,222
Harbor Porpoise (*Phocena phocoena*)	3,564	524	144	1,209	1,855
Hammerhead Shark (*Sphyrna sp.*)	0	10,124	2,812	0	3,173

Humpback Whale (*Megaptera novaeangliae*)	813	618	66	503	441
Leatherback Turtle (*Dermochelys coriacea*)	59	3,606	2,277	27	2,177
Loggerhead Turtle (*Caretta caretta*)	422	47,239	12,727	58	20,062
Minke Whale (*Balaenoptera acutorostrata*)	1,836	3,331	105	157	1,899
Ocean Sunfish/Sharp-tailed Mola (*Mola mola/lanceolata*)	13,506	28,770	8,579	75	13,136
Pilot Whale (*Globicephala sp.*)	43,222	22,274	17,073	23,982	32,761
Kemp's Ridley Turtle (*Lepidochelys kempii*)	0	2,996	0	0	1,527
RIWH Right Whale (*Eubalaena glacialis*)	20	23	12	20	99
SADO Common Dolphin (*Delphinus delphis*)	180,686	172,806	147,236	88,001	198,252
Seals (*Phocidae sp.*)	102,177	23,197	9,955	3,681	51,539
Sperm Whale (*Physeter macrocephalus*)	1,732	30,918	1,084	1,363	16,388
Striped Dolphin (*Stenella coeruleoalba*)	735	205,456	47,849	19,507	149,961
Atlantic White-Sided Dolphin (*Lagenorhynchus acutus*)	47,800	16,006	8,742	12,988	24,735

Sightings per Unit Effort

🟩	0-1,000
🟩	1,001-10,000
🟩	10,001-100,000
🟩	100,001-1,000,000
🟩	>1,000,000

SPECIES ACCOUNTS

This includes only species with enough survey data to do the SPUE analysis and GIS mapping, i.e., those shaded on the first part of the preceding table plus beaked whales and harbor seals. Note: that we have no pre-existing text for the sharks or ocean sunfish. These species accounts will be followed by Relative Species Distribution Maps.

North Atlantic Right Whale *Eubalaena glacialis* (Müller 1776)

Description: North Atlantic right whale adults are 11–17 m long, with a maximum recorded length of 18 m (Cummings, 1985b; Jefferson et al., 1993; Wynne and Schwartz, 1999). Females are slightly larger than males. Calves are about 4.5 m in length and 800 kg in weight at birth. The body is very robust, with girth frequently exceeding half or even three-quarters of body length. The back is very broad and smooth, with no dorsal fin. The color is usually black, and some animals have irregular white patches on the belly. The head is relatively large, comprising about a quarter or third of the body length. The top of the head in front of the blowholes (the rostrum) is narrow and arched, and the curve of the mouth opening is very strongly arched. There are irregular whitish patches called "callosities" on the rostrum, on the chin, along the lower jaw, and over the eye, usually behind the blowholes, and sometimes on the lower lips. The callosities are patches of thickened, keratinized skin inhabited by dense populations of light-colored whale lice (Payne and Dorsey, 1983). The callosity patterns are individually distinctive and used for photographic identification of individuals (Payne et al., 1983; Kraus et al., 1986). The flippers are large (up to 1.7 m long) and squarish. The flukes are broad (up to 6 m across), black on both surfaces, and tapered to points with a smooth trailing edge and deep central notch. Right whale baleen plates are mostly dark gray to black and are relatively long and narrow (Nemoto, 1970; Pivorunas, 1979). The maximum length is 2.7 m, with the longest plates in the middle of the row (see Figs 21.3 and 21.5 in Reeves and Kenney, 2003). There are 200–270 plates in each row (Jefferson et al., 1993; Wynne and Schwartz, 1999). The fringing hairs are very fine, about the same thickness as human hair (Mayo et al., 2001).

Status: North Atlantic right whales are listed as Endangered under the U.S. Endangered Species Act, as Federally Endangered on the Rhode Island state list, and as Endangered on the IUCN Red List. They are considered to be one of the most imperiled mammals in the world (Clapham et al., 1999). The most recent SAR gives the minimum number known to be alive in the population in 2002 as 313, but work in progress shows the number to have increased to at least 345 in 2005 (Kenney et al., in preparation), and the current population is probably around 400 animals (NARWC, 2007).

North Atlantic right whales were the first targets of commercial whaling, beginning along the Bay of Biscay in about the 11th century (Aguilar, 1986). By the 16th century, right whaling had expanded throughout the North Atlantic (Barkham, 1984). Along the south shore of Long Island, a shore-based fishery for right whales operated from 1650 to 1924 (reviewed by Reeves and Mitchell, 1986), although the last whale landed was in 1918. At least 550 whales were taken over that period, although records before 1820 are incomplete and certainly underestimate the actual catch. The highest estimated catch in one year was 111 whales in 1707, and the total take over the entire period likely exceeded 2,000 animals. Right whales have been protected from commercial whaling since the first International Convention for the Regulation of Whaling was ratified in 1935 (Hain, 1975). Only six have been intentionally killed in the North Atlantic since that time (Moore, 1953; Brown, 1986; Mitchell et al., 1986).

Substantial anthropogenic mortality on North Atlantic right whales is continuing, and is suspected to be retarding recovery of the population (Kraus, 1990; Kenney and Kraus, 1993; IWC, 2001; Knowlton and Kraus, 2001; Laist et al., 2001; Kraus et al., 2005). The two most significant sources of mortality are collisions with ships and entanglement in commercial fishing gear. The average annual mortality in the western North Atlantic population during 2001–2005 was estimated as 1.4 killed by entanglement and 1.8 by ship strikes. A Take Reduction Plan is in effect to reduce fishery-related mortality, including closures and gear modification, with additional regulations due to take effect in April 2009 and others to be considered in the near future. A management regime to reduce mortalities from ship strikes, which includes limiting ship speed to 10 knots within 20 nautical miles of mid-Atlantic ports during right whale migration periods, took effect in December 2008. Other hypothesized anthropogenic impacts on right whales include toxic contaminants, habitat loss, and global climate change (Reeves et al., 2001a; Kenney, 2007).

Ecology and life history: Right whales in all oceans are strongly migratory, moving annually between high-latitude feeding grounds and low-latitude calving and breeding grounds (Cummings, 1985b; Kenney, 2009). The known feeding grounds in the North Atlantic are in the Gulf of Maine and adjacent waters, and the calving ground is in coastal waters off Florida and Georgia, but the location of breeding is unknown (Winn et al., 1986). Given the timing of births in winter and the 12–13 month gestation period, mating most likely occurs in November-January, when most adult males and non-calving adult females are absent from all known habitats (Winn et al. 1986, Brown et al. 2001).

Feeding by right whales is accomplished by “skimming” (Nemoto, 1970; Pivorunas, 1979), and the anatomy of the head, mouth, and baleen apparatus are all adapted to skim-feeding (Baumgartner et al., 2007). They feed by simply swimming forward with the mouth open. Water flows in through the opening at the front—below the rostrum, above and around the tongue, and between the two rows of baleen. Water then passes laterally through the baleen filter, straining prey organisms from the water and collecting them on the inside. The structure of the mouth appears to develop a pattern of pressure gradients that maintains smooth water flow through the baleen. Feeding can occur at or just below the surface (Watkins and Schevill, 1976, 1979; Mayo and Marx, 1990), where it can be observed easily, or more often at depth and out sight (Murison and Gaskin, 1989, Kenney et al., 1995; Nowacek et al., 2001; Baumgartner and Mate, 2003; Baumgartner et al., 2003a, 2003b, 2007). Typical feeding dives last for 10–20 minutes (Winn et al.; 1995).

Right whales are obligate planktivores, with the principal prey in the North Atlantic being large, late-stage juveniles and adults of the copepod *Calanus finmarchicus* (crustaceans approximately the size of a grain of rice). At times they also feed on other zooplankton, including smaller copepods, euphausiids (“krill”), barnacle larvae, and pteropods (Collett, 1909; Nemoto, 1970; Watkins and Schevill, 1976; Mayo and Marx, 1990). They can probably be somewhat opportunistic, feeding on any prey of a size that can be filtered efficiently by the baleen, which does not swim strongly enough to escape, and which is concentrated into sufficiently dense patches to trigger feeding behavior. On the other hand, they can also be considered as extremely specialized predators occupying a very narrow niche. The sizes of predator and prey differ by a factor of 50 billion, consequently right whales can feed successfully only in areas where their prey are aggregated into extremely dense concentrations (Kenney et al. 1986, 1995; Wishner et al. 1988, 1995; Kenney and Wishner 1995; Baumgartner et al., 2007). Studies of right whale feeding grounds have shown that prey aggregations result from a combination of bottom topography, water column structure and stratification, currents, and prey behavior (Kenney et al. 1986, 1995; Wishner et al. 1988, 1995; Murison and Gaskin, 1989; Kenney and Wishner, 1995; Beardsley et al., 1996). The sensory mechanisms involved in prey detection and foraging probably include at least sight and touch, if not also sound and possibly taste (Kenney et al., 2001).

Female right whales give birth to single calves in winter; most births are in December–February in the western North Atlantic, peaking in early January (Kraus et al., 1993, 2001; Knowlton et al., 1994). The gestation period of southern right whales is approximately 12–13 months (Best, 1994); mostly likely the same holds for North Atlantic and North Pacific right whales. Most calves are probably weaned toward the end of their first year of life (Hamilton et al., 1995, Burnell, 2001). Following weaning, the female typically takes a year to “rest”—feeding and rebuilding blubber stores before mating the following winter. The result is a 3-year interbirth interval under good conditions with adequate prey resources available. Calving intervals in southern right whales are generally 3–4 years (Best, 1990; R. Payne et al., 1990; Burnell, 2001, Cooke et al., 2001). The same was true of North Atlantic right whales until the early 1990s (Knowlton et al., 1994), but the average calving interval in the North Atlantic population increased to over 5 years by 2000 (Kraus et al., 2001), then returned to a predominance of 3-year intervals by 2004–2005 (Kraus et al., 2007). Environmentally driven interannual variability in prey resources appears to underlie the marked variability in calving success (Greene et al., 2003; Greene and Pershing, 2004; Kenney, 2007).

Distribution: North Atlantic right whales historically were widespread in continental shelf waters from subtropical to cold regions on both sides of the North Atlantic (Cummings, 1985b), but have been greatly reduced in number and range by centuries of whaling. Their original range extended from Florida and northwestern Africa north to the Gulf of Maine, Newfoundland, Labrador, Greenland, Iceland, the British Isles, and Norway (Kenney, 2009; Reeves and Kenney, 2003). The remnant population in the western North Atlantic occurs primarily between northeastern Florida and the Gulf of Maine region (Winn et al., 1986; Kenney et al., 2001). There is an annual migratory pattern from winter calving grounds in the nearshore waters off Florida and Georgia to feeding grounds in Cape Cod Bay (late winter-early spring), in the Great South Channel east of Cape Cod (late spring-early summer), and in the Bay of Fundy and Roseway Basin near Nova Scotia (late summer-fall). Other than the calving ground, habitat use during the winter is very poorly known. Migratory pathways between the calving/wintering and feeding areas are also poorly known. Other habitats in the Gulf of Maine also constitute feeding grounds in some years, and animals are occasionally observed in distant areas including deeper waters beyond the shelf edge, Gulf of Mexico, Gulf of St. Lawrence, Greenland, Iceland, Norway, and southwestern Europe (Reeves et al., 1978; Winn et al., 1986; Lien et al., 1989;

Martin and Walker, 1997; Mate et al., 1997; Slay and Kraus, 1998; Knowlton et al., 1992; Jacobsen et al., 2004).

The records of the Long Island right whale fishery clearly reflect what is known about the migratory pattern of the population (Reeves and Mitchell, 1986). Both De Kay (1842) and Connor (1971) were very aware of the Long Island right whale fishery, and it was their principal source of information for the species. Most of the kills occurred in winter and early spring, from January through May with a peak in April, and included a high proportion of mothers and calves. The fishery was primarily targeting northbound animals during the spring migration. The AMNH has a mounted skeleton that was originally collected from Amagansett whalers on 22 February 1907 by Roy Chapman Andrews (Andrews, 1908, 1909, 1916). That individual, at 16.5 m, is the largest right whale known from the western North Atlantic and the second largest from the entire North Atlantic.

Right whale occurrence in the region is consistent with both the historical record from the Long Island fishery (Reeves and Mitchell, 1986) and their known annual migratory cycle (Winn et al., 1986). Animals in this region are mainly migrating between winter calving grounds in the southeastern U.S. and feeding grounds in and around the Gulf of Maine. Winn et al. (1986) hypothesized that the southbound migration in fall was more diffuse and farther offshore than the spring migration. Additionally, traveling whales are believed to have a reduced probability of detection (Hain et al., 1999), therefore their presence in the region may be greater than apparent from the full sighting record.

Sightings in the mid-Atlantic tend to be concentrated relatively close to shore. Knowlton et al. (2002) reported that 94% of all right whale sightings between South Carolina and Nantucket were within 55.6 km (30 nautical miles) of the coastline and 64% were within 18.5 km (10 nautical miles). Some of that pattern is caused by the concentration of observers closer to shore. The proportion of sightings close to shore is significantly higher south of Cape Hatteras, North Carolina than to the north. One might hypothesize that northward migrating right whales in late winter and spring travel along shore until reaching Cape Hatteras, after which they spread out more, with some continuing to follow the coast while others take a more direct route towards Massachusetts. Right whales in the Rhode Island study area seem to show that pattern, with the majority of records in a band relatively close to shore, but others that are more offshore and may be on a migratory pathway between Cape Hatteras and the Great South Channel. Within the SAMP area, most right whales appear to remain in the offshore part of the area.

Humpback Whale *Megaptera novaeangliae* (Borowski, 1781)

Description: Humpback whales belong to the Balaenopteridae—collectively referred to as "rorquals," from the Norwegian meaning "furrow whale" in reference to the ventral grooves. Externally, the grooves look like long, parallel slits extending back from the tip of the lower jaw to as far as the umbilicus in some species, but are actually distensible pleats involved in feeding behavior. Rather than continuous, mouth-open skimming as in balaenids, rorquals are "gulpers" (Nemoto, 1970; Pivorunas, 1979; Lambertsen, 1983). The mouth is opened, engulfing a large volume of water and prey within the distended lower jaw and ventral pouch. Then the mouth is closed, the pouch contracted, and the water forced out through the baleen filter—retaining the prey on the inside.

Humpback whales are the easiest to identify of the rorquals and are clearly distinguished from *Balaenoptera* spp. based on morphology (Winn and Reichley, 1985; Jefferson et al., 1993; Wynne and Schwartz, 1999; Clapham, 2002), but genetic studies generally agree that they are not phylogenetically separate (Árnason and Best, 1991, Árnason et al., 1992, 1993; Árnason and Gullberg, 1994, 1996; Nikaido et al., 2001; Hatch et al., 2006; Sasaki et al., 2006). Adults typically range from 11 to 16 m in length. They have a more robust, stout body form than *Balaenoptera* spp., but are not as rotund as right whales. The body is black, often with some amount of white on the belly. The dorsal fin can be extremely variable in shape, from small and rounded to prominent to falcate or hooked. There is a prominent rounded hump in front of the dorsal, and a series of projections along the ridge from the dorsal fin to the tail. Their most distinctive features are their flippers, which are very long (about a third of the body length), with a relatively smooth trailing margin and a series of prominent bumps (the "knuckles") on the leading margin. The flippers usually white in North Atlantic humpbacks. The rostrum is broad and flat with a somewhat rounded tip. There are rows of rounded knobs down the center and along the edges of the rostrum and on the lower jaw. Each knob has a 1–3-cm stiff sensory hair in the center. There is also a prominent knob on the chin, which is covered by a clump of barnacles—actually by acorn barnacles attached to the whale and stalked barnacles attached to the acorn barnacles. There are also barnacles on the "knuckles" of the flippers, the margins of the flukes, the edges of the head, and scattered in other areas. The flukes have a deep central notch and a concave trailing edge with a ragged or serrated margin, and their underside is patterned in black and white (from all black to all white, most often black in the center and white toward the ends). The patterns are unique and can be used to identify individual whales (Katona et al., 1979). The ventral grooves extend all the way to the navel, and are more widely spaced than in any other rorquals, numbering only 12–36.

Status: Humpback whales are listed as Endangered under the U.S. Endangered Species Act, are classified as Federally Endangered on the Rhode Island state list, and are classified as Least Concern on the IUCN Red List. A review of the status of North Atlantic humpback stocks under the Endangered Species Act is being contemplated (Waring et al., 2008), and could potentially result in a proposal to down-list the North Atlantic humpback population to Threatened or even to de-list it completely. The number of humpback whales in the North Atlantic was estimated at 11,570 in 1992–93 by applying mark-recapture methods on the collection of photographs of known individuals (Stevick et al., 2003). That estimate is known to be negatively biased from spatial heterogeneity in sampling. In addition, the population appears to be increasing at 3% to as much as 6.5% per year (Barlow and Clapham, 1997; Stevick et al., 2001). North Pacific and Southern Ocean populations also appear to be growing (Clapham, 2002). Recent estimates of abundance for only the Gulf of Maine feeding stock are 850–900 whales (Waring et al., 2008).

Humpback whaling in the North Atlantic began in the 1600s in Bermuda and continued into the 20th Century (reviews by Mitchell and Reeves, 1983; Reeves and Smith, 2002). Many thousands were killed by 19th and 20th Century whalers, seriously depleting populations. Most North Atlantic humpback whaling occurred in the 19th Century. Yankee whalers hunted humpbacks on the wintering grounds in the West Indies and Cape Verdes between sperm whaling seasons, leaving behind traditional whale fisheries in both locations. North Atlantic humpback whaling in the 20th century was mainly from shore stations in Canada, Greenland, Iceland, the Faroe Islands, the British Isles, and Norway. Humpback whaling ended world-wide in 1966 (Clapham, 2002). The only North Atlantic hunting since the International Whaling Commission (IWC) instituted a moratorium on commercial whaling in 1986 (see the fin whale account for more details) has been the occasional subsistence take in West Greenland (1 each in 1988 and 1990–1992, 2 in 1989) and 1 or 2 a year by a small, traditional fishery that has survived in Bequia, St. Vincent and the Grenadines, West Indies (see Table 21.3 in Reeves and Kenney, 2003 for a summary of all North Atlantic whaling in 1986–2000; for subsequent years see the annual reports of the IWC in the supplement to each volume of *Journal of Cetacean Research and Management*).

The 2001–2005 average annual human-related mortality from the Gulf of Maine humpback stock was estimated as 2.8 killed by fishery entanglements and 1.4 by ship collisions (Waring et al., 2008). Fisheries involved in humpback entanglements have included pelagic driftnets, sink gillnets, and lobster traps. Biotoxins have also been implicated in humpback whale mortalities. In 1987, 14 humpback whales died acutely near Cape Cod and Nantucket after eating mackerel containing saxitoxin produced by *Alexandrium tamarense*, the “red tide” organism that is responsible for paralytic shellfish poisoning in humans (Geraci et al. 1989). Domoic acid, produced by the diatom *Pseudo-nitzschia* sp., has been hypothesized as a cause of death of 12–15 humpbacks offshore on Georges Bank in 2003, but the data were sparse and results inconclusive (Waring et al. 2008).

Ecology and life history: Humpback whale habitat use patterns and distributions on their feeding grounds are not static, but change over time. Along with shifts in the relative abundance of herring and sand lance, the two principal forage fish species in the Gulf of Maine system, the distribution of humpback whales has similarly changed (P. M. Payne et al. 1986, 1990; Kenney et al., 1996; Weinrich et al., 1997). Herring and mackerel stocks were severely depleted by commercial fisheries in the 1960s and early 1970s, and sand lance populations expanded greatly in response. Humpback whales shifted from feeding mostly in the northern Gulf of Maine to concentrating in Cape Cod Bay and east of Cape Cod. In the early 1980s, sand lance populations declined and herring began to recover. Humpback and fin whales declined around Cape Cod, and were nearly absent in 1986. Similar shifts in humpback distribution that coincided with changes in prey populations have been observed in Newfoundland (Lien et al., 1979; Whitehead and Lien, 1983) and southeastern Alaska (Bryant et al., 1981).

Humpbacks are gulp-feeders like the other rorquals (Nemoto 1970, Pivorunas 1979), but they display a much wider variety of feeding behaviors (Ingebrigtsen, 1929; Jurasz and Jurasz, 1979; Hain et al., 1982, 1995; Hays et al., 1985; Weinrich et al., 1992; Swingle et al., 1993). They may lunge violently with the mouth open, or surface open-mouthed very slowly and smoothly. They also routinely use bubbles in feeding—either columns of large bubbles in lines or partial or complete circles (“bubble-nets”) or large clouds of tiny bubbles that are apparently released from the mouth rather than exhaled through the blowholes (“bubble clouds”). Some whales add tail-slaps or other vigorous splashing to the feeding behaviors. There is evidence that feeding behaviors are learned from the mother (Weinrich et al., 1992).

Humpbacks feed on a variety of small, schooling prey, including krill and fish (Watkins and Schevill, 1979; Kenney et al., 1985a; Winn and Reichley, 1985; Clapham, 1996, 2002). The principal prey species in the Gulf of Maine are herring and sand lance (Overholtz and Nicolas, 1979; CETAP, 1982; Kenney and Winn, 1986; P. M. Payne et al. 1986, 1990; Kenney et al., 1985a, 1996; Weinrich et al., 1997). In the northern Gulf of Maine, euphausiids may also be important prey (Sutcliffe and Brodie, 1977; Paquet et al., 1997).

Sexual maturity in both male and female humpback whales is reached at about 5 years of age on average, ranging from 4 to 9 years (Clapham and Mayo 1987, 1990; Clapham 1992, 1996, 2002; Craig and Herman, 2000). Calving is strongly seasonal, with calves in the Northern Hemisphere born from January to March after a gestation period of about 11 or 12 months (Rice, 1967; Johnson and Wolman, 1984; Clapham 1996, 2002). Calves are born at about 4–5 m in length and reach 8–9 m by the time they are weaned (Winn and Reichley, 1985). Calves are fully weaned at about 1 year old, but begin to feed independently while still nursing at only 5 or 6 months old (Clapham, 1992). The intervals between calves are usually 2–3 years, although females occasionally give birth in successive years (Clapham and Mayo, 1990; Glockner-Ferrari and Ferrari, 1990; Clapham, 1996, Steiger and Calambokidis, 2000).

Distribution: Humpback whales occur in all of the world's oceans, making some of the longest migrations known for any mammal between high-latitude feeding grounds and low-latitude calving and breeding grounds (Kellogg, 1929; Jonsgård, 1966; Winn and Reichley, 1985; Rice, 1998; Clapham, 2002). North Atlantic humpbacks occur from the Caribbean Sea and Cape Verde Islands in the extreme south to as far north as Greenland, Iceland, Svalbard, and the Barents Sea (Jonsgård, 1966; Winn et al., 1975; Winn and Winn, 1978; Whitehead and Moore, 1982; Martin et al., 1984; Winn and Reichley, 1985; Katona and Beard, 1990; Clapham et al. 1992, 1993a, 1993b; Clapham, 1996; Palsbøll et al., 1997; Rice, 1998; Stevick et al., 1998; Smith et al., 1999). The vast majority of sightings in both the feeding and calving grounds are in nearshore and continental shelf waters, but the whales apparently migrate across deep oceanic regions. Reeves et al. (2004) mapped humpback whale sightings recorded in the logbooks of 18th and 19th Century sperm whalers. There were large numbers of sightings in the middle of the North Atlantic just west of the Mid-Atlantic Ridge, especially in April-July. The distribution confirmed migration routes far offshore, and also suggested that there might be offshore feeding grounds that are still unknown.

North Atlantic feeding grounds are occupied from spring through fall, and are located in continental shelf areas. The feeding range extends from southern New England and the British Isles north to Davis Strait, Greenland, Iceland, Svalbard, and Norway (Martin et al., 1984; Katona and Beard, 1990; Sigurjónsson and Gunnlaugsson, 1990; Clapham et al., 1992; Clapham, 1996; Palsbøll et al., 1997; Stevick et al., 1998). Humpbacks show strong matrilineal habitat fidelity (Baker et al. 1994). A calf learns the feeding grounds from its mother during its first year, and then tends to return to the same feeding areas each year (Clapham and Mayo, 1987). The result is genetically identifiable "feeding stocks," with very little interchange between stocks (Christensen et al., 1992; Palsbøll et al., 1995, 1997, 2001; Larsen et al., 1996). Separate feeding stocks have been recognized from the Gulf of Maine/Nova Scotia, Gulf of St. Lawrence, Newfoundland/Labrador, West Greenland, Iceland/Denmark Strait, and Norway. There is further subdivision on even finer scales. Clapham et al. (2003) showed that humpbacks in the Gulf of

Maine and on the Nova Scotian Shelf only partially overlap. Within feeding ranges, humpbacks tend to aggregate at specific locations where prey is most abundant.

During the winter, humpbacks from all North Atlantic feeding grounds migrate south to calving and breeding grounds on shallow banks in the West Indies/Caribbean region, where they mix together (Katona and Beard, 1990; Clapham et al., 1993b; Palsbøll et al., 1997; Stevick et al., 1998; Bérubé et al., 2004). The peak calving and breeding season is January–March, with some whales arriving as early as December and a few not leaving until June (Reeves et al., 2001b).

Historical occurrences of humpback whales in the southern New England region west of Massachusetts were very rare and were unknown to De Kay (1842), Linsley (1842), and Goodwin (1935). Allen (1916) reported only one from Rhode Island, in 1836. Cronan and Brooks (1968) reported that the only other humpback in Rhode Island was a calf stranded at Matunuck Beach in South Kingstown in June 1957. Connor (1971) reported that the 1957 Rhode Island stranding was the only humpback known from southern New England, but he suspected that humpbacks had occasionally been taken by Long Island shore whalers hunting right whales.

Humpback distributions in the Gulf of Maine have fluctuated markedly over the years, largely tracking patterns of abundance of their principal prey species—Atlantic herring, sand lance, and krill (P.M. Payne et al., 1986, 1990; Kenney et al., 1996). In the years during the 1980s when humpbacks were scarce off Cape Cod, there were numerous humpback sightings between Long Island and Martha's Vineyard by Montauk and Galilee whale-watch boats. The peak year for sightings from the Montauk boat was 1987, with 63 sightings (compared with 2 in 1986 and 9 in 1988), and 1987 was also the best year for the Galilee boat. In 1987, the whales targeted by the whale-watching boats slowly shifted eastward over the course of the season—from the southwestern part of the SAMP area near Montauk and Block Island to the eastern part, near Noman's Land off the southwestern corner of Martha's Vineyard (G. O. Klein, pers. comm.). Sand lance populations in Cape Cod waters subsequently recovered, then went through another decline and recovery in the early 1990s, closely tracked again by whale sighting frequencies in the same area (Weinrich et al., 1997). There was similarly another increase in humpback sightings off Montauk in 1992 and 1993, and less dramatically in 1994 and 1991.

Fin Whale *Balaenoptera physalus* (Linnaeus, 1758)

Description: Fin whales are the second-largest species of living whale, with adults 17–24 m long (Gambell, 1985a; Jefferson et al., 1993; Wynne and Schwartz, 1999; Aguilar, 2002). Females are slightly larger than males, with Northern Hemisphere adults averaging about 22.5 m for females and 21 m for males (Aguilar, 2002). There is evidence that the fin whales off the northeastern U.S. are smaller than animals from farther north (Hain et al., 1992). The mean adult length from animals measured from aerial photographs was 16.1 m, significantly smaller than fin whales taken in modern Icelandic whaling even after accounting for size selection by the whalers. Possible explanations suggested by Hain et al. (1992) included size differences between stocks or habitat segregation by age with the largest adults remaining farther offshore.

A fin whale has a very sleek, streamlined body with a flattened, tapered rostrum. The falcate dorsal fin is about 60 cm tall, set about two-thirds or even three-quarters of the way back on the body. There is a distinct ridge along the back from the dorsal fin to the tail. Fin whales are unique among mammals in being asymmetrically colored, with the lower jaw white on the right and dark on the left. The body color ranges from gray to brownish, with a much lighter belly. Above the flippers, there is a pale, forward-pointing V-shaped chevron on the back and swirls of lighter color on the sides, especially on the right side. There are 55–100 ventral grooves that extend back to the umbilicus.

Status: Fin whales are classified as Endangered under the U.S. Endangered Species Act, as Federally Endangered on the Rhode Island state list, and as Endangered on the IUCN Red List. There is no precise estimate of the total abundance of fin whales in the North Atlantic. Perry et al. (1999) estimated that there may be 50,000 to 60,000. Aguilar (2002) gave estimates of 3,500 in the western Mediterranean, 4,500 off northwestern Spain, 7,500 in the eastern temperate Atlantic, 700 around the Faeroe Islands, 1,850 off Norway, 15,600 in East Greenland and Iceland, 1,000 in West Greenland, and 10,800 off Nova Scotia, Newfoundland, and Labrador. Those estimates sum to 45,450. The most recent estimate for the U.S./Nova Scotia stock is 2,269, however that estimate did not include a correction factor for submerged animals that were missed during surveys. A more realistic estimate for the northeastern U.S. shelf in about 1979–1981, including a correction factor, would be on the order of 5,000–6,000 fin whales (CETAP, 1982; Hain et al., 1992; Kenney et al., 1997).

Fin whales began to be targeted after the depletion of blue whale stocks early in the modern whaling era, beginning off Norway in the 1870s (Tønnessen and Johnsen, 1982; Aguilar, 2002). The whaling stations in Norway closed by 1904 because nearby stocks were depleted, and the hunt expanded across the North Atlantic and into the Antarctic. Tens of thousands of Northern Hemisphere fin whales were taken during the 20th century. A total of 3,528 was taken from three shore whaling stations in eastern Canada in 1965–1971, with 1,402 at Blandford, Nova Scotia (Mitchell, 1974, Sutcliffe and Brodie, 1977). Fin whaling in U.S. Atlantic waters ended around the turn of the 20th Century (Allen, 1916).

In July 1982, the International Whaling Commission approved a measure setting whaling catch limits to zero for all stocks beginning in 1986 (IWC, 1983; Gambell, 1999), establishing a moratorium on all commercial whaling. Legal whaling since 1986 has been conducted only under (1) the exception for “aboriginal subsistence” whaling (Reeves, 2002), (2) scientific research permits, or (3) objection (under the terms of the Convention, nations that formally object to specific IWC regulations are not bound by them). After 1986, Iceland took 292 fin whales from 1986 to 1989 under a research permit, and subsequently withdrew from IWC membership (Reeves and Kenney, 2003). The subsistence hunt in West Greenland takes 10–15 fin whales per year (Aguilar, 2002). Iceland rejoined the IWC in 2002, and in October 2006 announced the intention to resume small-scale commercial whaling and issued licenses to take 9 fin whales in 2007. Seven were taken. No fin whale quota was set for 2008.

The average annual human-related mortality of fin whales from the U.S./Nova Scotia stock in 2001–2005 was 0.8 from fisheries entanglement and 1.6 from ship collisions. Ship-struck fin whale carcasses are sometimes discovered in New York harbor or nearby in New Jersey. Other serious conservation concerns are rare (Aguilar, 2002). There are detectible contaminant levels in fin whales from waters near industrialized coasts such as the Mediterranean and North Atlantic, but they appear to be relatively low. Feeding relatively low on the food chain makes them less likely to accumulate harmful concentrations.

Ecology and life history: Fin whales appear to be similar to humpback whales in exhibiting maternally-directed habitat fidelity. Agler et al. (1993) use photoidentification of individual whales to demonstrate that adult females showed preferences for either northern or southern Gulf of Maine feeding areas. They suggested that age and sex segregation occurred on local scales, similar to what Hain et al. (1992) suggested for broader geographic scales. Even though individual fin whales are more difficult to identify than humpbacks, both Seipt et al. (1990) and Clapham and Seipt (1991) were able to show relatively high resighting rates, concluding that females tend to return to the same feeding grounds consistently.

Habitat use patterns by fin whales off the northeastern U.S. have shifted significantly in some years. P. M. Payne et al. (1990) showed a decline in fin whale and humpback occurrence in the southern Gulf of Maine in 1985 and 1986, coinciding with a minimum in sand lance abundance. Kenney et al. (1996) hypothesized that changes in relative abundance of herring and sand lance in different portions of the Gulf of Maine, driven by past commercial fishery practices, led to changes in whale distribution. Fin whale sightings south of the Gulf of Maine from summer surveys during the 1990s were more concentrated along the shelf edge than they had been previously (Waring et al., 2008), which might suggest an additional habitat shift, however at least some of the difference is likely due to differences in survey design and timing. Coakes et al. (2005) reported unusual numbers of fin whales off Halifax, Nova Scotia in 1997, also correlated with unusually high local abundance of whale prey.

Fin whales are fast swimmers and capable of moving substantial distances in relatively short times. They normally swim at 5–8 knots (9–15 km/hr), but are capable of short bursts of 15 (28 km/hr) or even 20 knots (37 km/hr) (Gambell, 1985a; Aguilar, 2002). Watkins (1981) tracked a radio-tagged fin whale between Iceland and Greenland that traveled 2,095 km in ten days and covered 292 km in a single day.

Like the other rorquals, fin whales are gulp feeders (Nemoto, 1970; Pivorunas, 1979). They often roll onto their right sides during feeding. Mitchell (1972) speculated that their asymmetric coloration was related to feeding, maintaining counter-shading when rolled to the right. Tershy and Wiley (1992) did show quantitatively that fin whales rolled most often to the right (97% of the time in the North Pacific, 81% in the North Atlantic), but that symmetrically colored blue and Bryde's whales also did. While Southern Hemisphere fin whales feed mainly on euphausiid crustaceans (krill), Northern Hemisphere whales prey upon a wide variety of small, schooling prey, including many small fishes (herring, sand lance, capelin, sardine, etc.), squids, and crustaceans such as krill and copepods (Gambell, 1985a; review in Kenney et al., 1985a; Hain et al., 1992; Kawamura, 1994; Aguilar, 2002).

Fin whale calves are born in the late fall and winter, probably offshore (Mitchell, 1974; Haug, 1981; Gambell, 1985a; Hain et al., 1992; Aguilar, 2002). Length at birth is about 6 m and weight is 1,000 kg or more, and the gestation period is about 11 months. Calves are weaned at 6–11 months old and about doubled in length to 11–13 m (Best, 1966; Haug, 1981; Gambell, 1985a; Aguilar, 2002). Female fin whales mature at 7–8 years of age and males at 6–7, with the corresponding body lengths in the Northern Hemisphere around 17–18.5 m in females and somewhat smaller in males (Lockyer, 1972, 1984; Gambell, 1985a; Aguilar, 2002). Full physical maturity in both sexes might not be attained until around age 25. The inter-birth interval is usually 2 or 3 years (Christensen et al., 1992; Agler et al., 1993). The mean calving interval for identified individuals in the Gulf of Maine was 2.71 years, but may have been as low as 2.24 if potential missed calving years were taken into account.

Distribution: Fin whales are broadly distributed throughout the world's oceans, from the temperate regions poleward (Gambell, 1985a). Their range in the North Atlantic extends from the Gulf of Mexico, Caribbean Sea, and Mediterranean Sea in the south to Greenland, Iceland, and Norway in the north (Jonsgård, 1966; Gambell, 1985a). They are the most commonly sighted large whales in continental shelf waters from the Mid-Atlantic coast of the U.S. to Nova Scotia (Sergeant, 1977; Sutcliffe and Brodie, 1977; CETAP, 1982; Hain et al., 1992; Waring et al., 2008), which comprises the range of the U.S./Nova Scotia stock. Fin whales in other regions of the North Atlantic—Newfoundland/Labrador, West Greenland, East Greenland/Iceland, Norway, western Europe, and the Mediterranean—are believed to belong to different stocks (Donovan, 1991; Bérubé et al., 1998). Fin whales off the northeastern U.S. are most abundant from spring through fall, with smaller numbers of animals remaining through the winter (Hain et al., 1992). Most of the fin whales are believed to migrate offshore and south during the winter, which has been supported by passive acoustic tracking information developed in cooperation with the Navy (Clark, 1995).

Fin whales are the most common large whale in shelf waters of the mid-Atlantic region at the present time, and likely were common historically. Fin whales were not mentioned by De Kay (1842) or by Linsley (1842). Fin whales were commonly observed by the shore-based right whalers in eastern Long Island, but were rarely pursued because they were too fast and yielded less oil than right whales (Edwards and Rattray, 1932; Connor, 1971). Fin whales were not targeted by whaling in New England until the development of modern technology in the second half of the 19th Century, although the first recorded attempt to kill fin whales, which was unsuccessful, was by Capt. John Smith in 1614, off Monhegan Island, Maine (Allen, 1916).

Common Minke Whale *Balaenoptera acutorostrata* Lacépède 1804

Description: Common minke whales (There is a closely related species, the Antarctic minke whale *B. bonaerensis*, that has recently been accepted as a valid species, requiring the term "common" to designate this species.) are the smallest of the North Atlantic baleen whales, with adults generally 6–9 m long and reaching maximum lengths of 9–10 m (Stewart and Leatherwood, 1985; Jefferson et al., 1993; Wynne and Schwartz; 1999; Perrin and Brownell, 2002). The body is somewhat more robust than in the larger *Balaenoptera* species. The head is shorter relative to the body than in the other balaenopterids, and the rostrum is very sharply pointed with a prominent median ridge. The body is dark gray to black with a pale belly, and frequently shows pale areas on the sides that may extend up onto the back. The flippers are smooth and taper to a point, and the middle third of each flipper has a conspicuous bright white band. The dorsal fin is tall, prominent, and falcate, and is located about two-thirds of the way back along the body. The ventral grooves number 50–70, ending well forward of the navel. Minke whales were formerly known as little piked whales.

Status: Common minke whales are not listed under the U.S. Endangered Species Act or the Rhode Island state list, and are classified as Least Concern on the IUCN Red List. There are more than 180,000 minke whales in the North Atlantic (IUCN, 2008). The Northeast Atlantic stock is over 80,000 animals, the Central North Atlantic stock totals about 94,000, and the West Greenland stock is about 3,500. The Canadian East Coast stock includes the minke whales off the U.S. East Coast. The most recent estimate for a portion of the range from the Gulf of Maine to the Gulf of St. Lawrence is 3,312 (Waring et al., 2008), however that is likely to be a significant underestimate because minke whales tend to be under-sampled in most surveys. NMFS surveys in 1991 and 1992 designed specifically for harbor porpoises, also inconspicuous and difficult to detect, resulted in an estimate of 2,650 minke whales for just the northern Gulf of Maine and Bay of Fundy. Kenney et al. (1997) used those data in conjunction with CETAP (1982) density estimates to suggest that a more likely range for minke whale abundance off the northeast U.S. was 10,000 to as many as 13,000 animals.

Minke whales are the smallest of the rorquals and did not have great commercial value until modern industrial whaling in the Southern Ocean decimated populations of the larger whales. Antarctic whalers started taking minke whales in the 1970s (Perrin and Brownell, 2002). In the North Atlantic, there is a long history of hunting for minke whales (reviews in Stewart and Leatherwood, 1985; Horwood, 1990; Reeves and Kenney, 2003). Small-scale minke whaling in Norway dates back to at least the Middle Ages, and modern whaling methods were first developed in Norway in the mid-19th Century. In the 20th Century, over 100,000 North Atlantic minke whales were killed by whalers, mostly Norwegians, on the high seas. Whalers from shore stations in Canada and West Greenland took about 1,000 and 8,000, respectively. Canada ceased whaling in 1972.

After the IWC moratorium began, Norway filed an objection and took 379 minke whales in 1986 and 375 in 1987 (Reeves and Kenney, 2003). In 1988–1992, catches ranged from 1 to 95 per year under a research permit. Norway resumed commercial minke whaling under objection in 1993, and presently takes several hundred each year. There is also an aboriginal subsistence hunt in Greenland that takes at least 150 minke whales per year. Iceland rejoined the IWC in 2002 and began taking small numbers of minke whales under a research permit beginning in 2003, with annual takes of 37, 25, 39, 60, and 39 through 2007. In October 2006, they announced the intention to resume small-scale commercial whaling and issued licenses to take 30 minke whales in 2007, but only 7 were taken. In 2008 they took 39 from a quota of 40.

Minke whales are occasionally entangled, with some killed and some released alive, in several east coast commercial fisheries, including the sink gillnet, pelagic driftnet, tuna purse seine, herring weir, and lobster trap fisheries, and there are occasional ship-strike mortalities. The average human-related mortality in 2001–2005 from the Canadian East Coast minke whale stock was estimated at 2.4 whales per year from entanglement and 0.4 per year from ship strikes (Waring et al., 2008).

Ecology and life history: Minke whales are typical baleen whales, most often seen as solitary individuals (Perrin and Brownell, 2002). The average group size sighted off the northeastern U.S. was 1.5 whales (CETAP, 1982). Large groups are occasionally observed, but those are temporary aggregations in areas of rich food supplies, often associated with other species that feed on the same prey, including fin whales, humpback whales, Atlantic white-sided dolphins, and harbor porpoises (CETAP, 1982).

Minke whales feed on a wide variety of prey types, including copepods, krill, pteropods, squid, and many kinds of small and medium-sized fishes (reviewed in Horwood, 1990). In the northeastern North Atlantic, where stomach contents have been studied extensively, krill and herring are the principal prey, followed by several gadoids (including cod, haddock, and pollack), and capelin (Folkow et al., 2000). Off the northeastern U.S., primary prey species are most likely clupeids, gadoids, sand lance, and mackerel. Feeding is by the typical rorqual gulp-feeding mode (Nemoto, 1970; Pivorunas, 1979). Minke whales can probably be more flexible in their prey choices than the larger rorquals, since they require smaller prey schools to feed efficiently.

Minke whales mature at about 7 years of age and 7.2 m long in females and 6 years and 6.8 m for males (Stewart and Leatherwood, 1985; Horwood, 1990; Perrin and Brownell, 2002). Mating has not been observed, but the timing has been inferred from fetal development curves derived from whaling data. In the North Atlantic, mating occurs from October to March. The gestation period is 10–11 months, therefore births are concentrated in winter. Calves are born at about 2.4–2.7 m long, and are weaned in only 4–6 months. Pregnancy rates in adult females taking in commercial whaling range from about 85% up to nearly 100%, therefore most females in good condition give birth on an annual cycle.

Distribution: Common minke whales are broadly distributed in the Northern Hemisphere from the edge of the ice to the tropics (Stewart and Leatherwood, 1985; Horwood, 1990; Rice, 1998; Perrin and Brownell, 2002). The distribution of the dwarf minke (a sub-species) in the Southern Hemisphere is less well known, and is perhaps more coastal than Antarctic minkes (a separate species). In the western North Atlantic, minkes are common from Virginia north to the ice edge, and they occur as far south as the West Indies and Gulf of Mexico. In continental shelf waters off the northeast U.S. and eastern Canada, minke whales are abundant in spring and summer, less abundant but still common in fall, and largely absent in winter (CETAP, 1982). There are stranding records from the southeast U.S. Atlantic coast and Gulf of Mexico, as well as sightings and strandings from the West Indies and Caribbean, all of which are concentrated mainly in the winter. This had led to the hypothesis that minke whales migrate offshore and south to wintering grounds in the West Indies and deep water south and east of Bermuda (Mitchell, 1991).

The minke whale was included by De Kay (1842) as the “beaked rorqual (*Rorqualus rostratus*)”, with “swimming paws white in the middle.” He reported the capture of a 4.9–5.5-m animal in lower New York Bay in 1822 that was the basis for his description. Helmuth (1931) reported a specimen about 8 m long that was killed off Montauk Point and towed to shore on 16 August 1931. Connor (1971) knew of no additional New York records beyond those two, but said that minke whales were more frequent farther east in Rhode Island and Massachusetts.

Sperm Whale *Physeter macrocephalus* Linnaeus 1758

Description: Odontoceti (toothed whales) includes a variety of species known as whales, dolphins, and porpoises. They are characterized by having teeth in one or both jaws (although in some species teeth only erupt in adult males) and a single blowhole (Hooker, 2002). They use echolocation for navigation and foraging, producing mid- to high-frequency sounds and listening to the echoes. Many of the unique characters of the skull, lower jaw, and facial region of odontocetes are related to echolocation (Au, 2002). Sperm whales are the largest of the toothed whales and the most sexually dimorphic of all cetaceans (Rice, 1989; Jefferson et al., 1993; Wynne and Schwartz, 1999; Whitehead, 2002; Reeves and Read, 2003). They are the only odontocetes large enough to be included with the baleen whales among the so-called "great whales." Adult males may reach 18.3 m in length, and Tomilin (1967) reported males from the North Pacific of 19 or 20 m, while the maximum size for adult females is only 12.5 m. More typical adult sizes are 12–16 m in males and 8.5–11 m in females. The head is large and squarish, comprising up to a third of the body length, with a very narrow, underslung lower jaw. The body color is from medium to dark gray-brown, often with light areas on the belly and around the mouth. The skin on the head is smooth, but forms longitudinal wrinkles or corrugations on the rest of the body. The flippers are relatively short, rounded, paddle-like, and set relatively high on the body so they do not project down below the belly when viewed from the side. The dorsal fin is low, blunt, and triangular—so low that some sources say that a dorsal fin is absent (e.g., Leatherwood et al., 1976; Nowak, 1999). There are distinct "knuckles" on the ridge between the dorsal fin and the tail. The trailing edge of the flukes is generally very straight across with a deep notch in the center, although they may become damaged and irregular in older animals.

Status: Sperm whales are listed as Endangered under the U.S. Endangered Species Act, are not included on the Rhode Island state list, and are classified as Vulnerable on the IUCN Red List, although the analysis concluded that a Near Threatened classification was almost as well-supported. There are statistically reliable estimates of abundance of sperm whales only for rather limited portions of their entire range, and a wide variety of extrapolations to global populations. Rice (1989) summarized the extrapolated estimates available at that time as 190,000 in the North Atlantic, 930,000 in the North Pacific, and 780,000 in the Southern Ocean. The worldwide total of 1.9 million represents a reduction from a pre-whaling population of 2.8–3 million. Whitehead's (2002) range of estimates for current stocks is substantially lower at 200,000 to 1.5 million, and stocks in some areas like the eastern South Pacific appear to be still severely impacted by past whaling. The most recent abundance estimate for sperm whales off the east coast of the U.S. from Florida to Maine is 4,804, with an additional 1,665 in the Gulf of Mexico (Waring et al., 2008). Those estimates are minimum values because they are not adjusted for whales missed due to diving.

Sperm whales were the basis of Yankee whaling in the 18th and 19th Centuries, as memorialized in Melville's classic *Moby Dick*; hundreds of thousands have been killed worldwide since the early 18th Century. The total take in 1800–1910 was over 700,000, with an additional 600,000 or more killed since 1910 (Reeves and Read, 2003). Commercial hunting of sperm whales ended worldwide with the IWC moratorium in 1986. There is presently no hunting at all for any purpose in the North Atlantic, and a few are taken each year in the North Pacific under scientific research permits by the Japanese.

Sperm whales are occasionally entangled in fishing gear off the east coast of the U.S. or struck and killed by ships, but the level of mortality is not believed to be biologically significant (Waring et al., 2008). Sperm whales feed relatively high on the food chain and could potentially accumulate high levels of toxic contaminants, however they appear to have lower levels than odontocetes from more coastal waters (Whitehead, 2002). There is also concern that sperm whales could be subject to negative impacts from increasing levels of noise in the oceans, from sources including shipping, naval sonar, and seismic exploration for oil and gas (Reeves and Read, 2003).

Ecology and life history: Like most odontocetes, sperm whales are very social and live in permanent matrilineal groups (Caldwell et al., 1966; Best, 1979; Rice, 1989; Whitehead et al., 1991; Christal et al., 1998; Whitehead and Weilgart, 2000; Whitehead, 2002; Reeves and Read, 2003). Off the northeastern U.S., the average number of animals at a sighting was 3 (CETAP, 1982), and group sizes ranged as high as 100 whales. More than half of all sightings were solitary individuals, and typical group sizes were 2–10 whales. The basic unit of sperm whale social organization is the "mixed school" consisting of females of all ages and immature males (Best, 1979). Mixed schools are predominantly female, 70% or more. Adult females in the school are closely related, and the calves and immatures of both sexes are their offspring. Females in the mixed schools remain associated for their entire lives. Males leave the mixed schools as early as ages 4–5 and completely by age 15, forming bachelor schools. Whalers measured the size of a whale based on the oil yield. A New Bedford whaling captain quoted by Best (1979) indicated that the largest adult females or bulls in mixed schools yielded 35 barrels of oil. Bachelor bulls were caught in schools of same-sized animals, which decreased in number as the whales got larger. The largest bachelor schools were the 40-barrel bulls, and the next largest the 50-barrel bulls. Schools of 60-barrel bulls were generally 8–10 whales, 70-barrel bulls were in schools of 4–5 whales, and larger bulls were solitary or in pairs or trios. The whalers believed that mixed schools were "harems" controlled by a dominant bull, but mature males actually rove between mixed schools (Whitehead and Weilgart, 2000).

Sperm whales tend to remain relatively motionless at the surface or to swim ahead slowly during surface sequences, often tightly grouped. Surface sequences are generally much longer than in baleen whales, usually about 8–10 minutes but sometimes 15–60 minutes. Yankee whalers believed that a sperm whale needed to blow once for each minute spent submerged during the previous dive. Sperm whales are positively buoyant, and raise the flukes above the surface on the final dive in a surfacing sequence (Kenney and Winn, 1987b). Sperm whales are known to breach on rare occasions.

Sperm whales are prodigious divers (Watkins et al., 1985, 1993, 1999, 2002; Papastavrou et al., 1989; Rice, 1989; Whitehead, 2002; Amano and Yoshioka, 2003; Reeves and Read, 2003; Watwood et al., 2006). Dives are typically 30–40 minutes, but dives lasting an hour or more are relatively common, and Watkins et al. (1985) recorded one dive of 2 hours and 18 minutes. Dive depths depend on the depth of the water, as they are capable of diving to the bottom. Average dives are to about 400 m, but dives deeper than 2000 m are known. Descents and ascents may be nearly vertical. Watkins et al. (1999) tracked three sperm whales in the Caribbean using radio tags. Whales made relatively short surfacings of 7–10.5 minutes, both day and night, for respiration between long dives and for extended periods of rest and socializing during the day.

They spent about 27% of their time surfaced during daylight and 15–17% during the night. Watkins et al. (2002) tracked a tagged 12-m sperm whale in the Caribbean for 4.6 days in April–May 1995. During that time it traveled 295 km and made 158 dives longer than 3 minutes. There were 65 relatively shallow dives (< 200 m) and 93 deeper dives that averaged 990 m (range = 420–1330) and 44.4 min (18.2–65.3). The whale spent 23% of its time at or near the surface, 23% in shallow dives, and 54% in deep dives.

An important characteristic that separates mysticetes and odontocetes is the use of echolocation ("sonar") for foraging (Tyack, 1986, 1999; Au, 2002). Probably all cetaceans use sound for communication, but only odontocetes are known to echolocate. Echolocation involves the production of short-duration, high-amplitude, broadband pulses ("clicks") and listening for echoes returning from objects in the environment. Clicks are produced in the nasal complex of air sacs and associated structures in the facial region and focused into a relatively narrow beam by the melon or spermaceti organ, and the echoes are received at the posterior portion of the mandibles (Norris, 1968, Norris and Harvey, 1974; Cranford et al., 1996; Møhl et al., 1999; Cranford, 2000; Au, 2002; Frankel, 2002). Click duration, frequency range, bandwidth, repetition rate, and amplitude vary among species. Many odontocetes, but not all, also produce tonal sounds ("whistles," etc.) that are used for communication but have no role in echolocation. Sperm whales do not whistle, but use clicks for both echolocation and communication (Rice, 1989; Whitehead, 2002; Reeves and Read, 2003). Diving sperm whales click regularly once or twice per second as they search for prey. The whales in the school can certainly hear each other as they spread out during foraging dives, and they may be using clicks at the same time as contact calls. There are occasionally accelerating series of clicks ("creaks" or "buzzes") as a whale homes in on a prey item (Miller et al., 2004; Watwood et al., 2006). Socially interacting whales also produced patterned sequences of 3 to about 20 clicks called "codas" (Watkins and Schevill, 1977). Codas vary by region and between schools and are probably passed on culturally within matrilineal groups. There are also very loud and slow (6–8 seconds apart) clicks called "clangs" that appear to be produced by large males; their function is not clear.

The primary prey of sperm whales is squid (Rice, 1989; Whitehead, 2002; Reeves and Read, 2003). Many species of mesopelagic and demersal squid are consumed, including very large ones up to the size of giant squid. The majority of the diet consists of medium-sized squids with mantle lengths of 20 cm to 1 m. Males feed on larger prey than do females and juveniles. Medium to large demersal fishes, including rays, sharks, and a variety of bony fishes, comprise small portions of the diet in most regions, but may be the predominant prey in certain areas, especially in high latitudes where only male sperm whales tend to occur. Other prey items include benthic octopus, crabs, and other crustaceans. Sperm whales consume a wider variety of squid than do northern bottlenose whales or Cuvier's beaked whales, which correlates with range of movements within each species (Whitehead et al., 2003).

Feeding occurs at depth, apparently all the way to the bottom at times, since stomach contents sometime include stones, sediment, shells, and other non-food items from the sea floor. Feeding behavior has not been observed and can only be inferred or hypothesized (reviewed in Rice, 1989). Suction feeding is probably used. There are paired, expansible throat grooves that would allow rapid expansion of the buccal cavity. The teeth are apparently not necessary for feeding—stomachs often contain completely intact and unmarked prey items, and juveniles with no erupted teeth and adults with badly injured and useless lower jaws are able to feed effectively. Sperm whales may simply scan for prey using echolocation. An alternative suggestion is that the whale hangs motionless at depth with the mouth wide open, waiting for prey to be attracted to the white lips or the luminescent squid mucus on the jaw and teeth. The so-called "big bang" hypothesis is that a sperm whale (or smaller odontocete) can produce clicks of high enough intensity to stun prey items. Fristrup and Harbison (2002) suggested that sperm whale simply may use vision in feeding, either by searching upward for prey silhouetted against the brighter background or by searching for bioluminescence produced by prey species directly or indirectly by swimming through other bioluminescent organisms.

Sperm whales are at the extreme end of the mysticete-odontocete dichotomy in life histories (Caldwell et al., 1966; Best, 1974, 1979; Rice, 1989; Whitehead et al., 1991; Whitehead and Weilgart, 2000; Whitehead, 2002; Reeves and Read, 2003). Single calves are born at 4 m long following a 14–18-month gestation. In the Northern Hemisphere, mating occurs from December to August with a peak in March–May. Large mature bulls rove from one mixed school to the next. Adult females in a mixed school tend to come into estrus synchronously, and a bull's stay with a particular school might only be a few hours. Calves nurse for at least two years, but begin feeding on solid food at about a year old. Some calves may continue nursing much longer, past age 7 in females and 13 in males. Females reach sexual maturity at age 7–13 and at about 9 m long. Growth then slows until they reach maximum size at about age 30. Maturation in males is a prolonged process, beginning at about age 10 and lasting for 10 years. They continue to grow at a more rapid rate than females, and do not reach their full size and complete physical maturity until about age 50. Males generally do not begin breeding successfully until their late twenties. The interval between calves for prime-age females is about 5 years.

Distribution: Sperm whales are found from tropical to subpolar waters in all oceans of the world (Rice, 1989, 1998; Whitehead, 2002; Reeves and Read, 2003). In the western North Atlantic, they occur from the edge of the pack ice south to the Gulf of Mexico and Caribbean. Mature males penetrate farther into high-latitude waters than females or immatures (Best, 1974; 1979). The northern distributional limit of female/immature schools in the western North Atlantic is probably around Georges Bank and the Nova Scotian shelf (CETAP, 1982; Whitehead et al., 1992). Sperm whales are very wide-ranging and migratory, and it is likely that all sperm whales in the North Atlantic belong to a single population (Reeves and Whitehead, 1997; Dufault et al., 1999). A whale tagged off Nova Scotia in 1966 was captured off Spain in 1973 (Mitchell, 1975c). Even on a global scale, sperm whales show very low genetic variability (Lyrholm and Gyllensten, 1998; Lyrholm et al., 1999).

Most sperm whale sightings around the world are in waters deeper than 200 m, however significant numbers of sightings have occurred in shallow continental shelf waters south of New England and on the Nova Scotian shelf (CETAP, 1982; Whitehead et al., 1992; Scott and Sadove, 1997). Sightings on the shelf in waters shallower than 200 m occur in all four seasons, and many of them are aggregated in a relatively narrow band extending north-south along the shelf valley offshore of Montauk Point and Block Island. It is often speculated that sperm whale occurrence in shelf waters corresponds with inshore movements of spawning squid.Most sightings have been along the shelf break and the edge of the Gulf Stream, but there has been little or no survey effort farther seaward, and sperm whales can probably occur almost anywhere in the deep ocean.

Sperm whales occur year-round off the northeastern U.S., but with some seasonal variability (CETAP, 1982). They occur in highest numbers in spring and summer all the way from Cape Hatteras to Nova Scotia. In fall there are fewer whales, and the distribution contracts south and west of Georges Bank. The smallest numbers of sperm whales are in winter, and the sightings tend to be aggregated east of Cape Hatteras. There are few sightings south of Cape Hatteras, but that is more likely a result of little survey effort except relatively near shore (Waring et al., 2008). There are scattered strandings from North Carolina to Florida, and a few recent sightings far offshore south of Cape Hatteras. However the area east of South Carolina was very well known to the Yankee whalers (the "Charleston Grounds"). Sperm whales were taken there year-round, a few nearshore but very large numbers offshore (Townsend, 1935).

Given that sperm whales are primarily offshore animals and rarely seen near shore, the historical record is dominated by whaling takes. Sperm whales were probably rarely, if ever, taken or even seen by the shore-based Long Island right whalers. The tale, likely apocryphal, is that Yankee sperm whaling began in about 1712, when Capt. Christopher Hussey, while hunting right whales from Nantucket, was blown offshore in a storm and took the first sperm whale. The sperm whale fishery expanded greatly, with voyages from a number of southern New England ports including Sag Harbor, Long Island; New London and Stonington, Connecticut; several localities in Rhode Island; and Nantucket, Woods Hole, and New Bedford, Massachusetts (Starbuck, 1878; Clark, 1887).

De Kay (1842) claimed that sperm whales were formerly abundant near Long Island, but provided very little specific information. Connor (1971) gave the oldest New York record as a 12-m whale captured in Fishers Island Sound in December 1894, and knew of a stranding on Fire Island in February 1918. There was one earlier stranding from Long Island, a 4.8-m animal at East Hampton on 19 March 1891, extracted from an account published in the *East Hampton Star*.

Beaked Whales: Northern Bottlenose Whale *Hyperoodon ampullatus* (Forster, 1770); Cuvier's Beaked Whale *Ziphius cavirostris* G. Cuvier, 1823; Blainville's Beaked Whale *Mesoplodon densirostris* (Blainville, 1817); Gervais' Beaked Whale *Mesoplodon europaeus* (Gervais, 1855); Sowerby's Beaked Whale *Mesoplodon bidens* (Sowerby, 1804); True's Beaked Whale *Mesoplodon mirus* True, 1913

The beaked whales constitute the second most speciose family of Cetacea, with 6 genera and 21 species (most in *Mesoplodon*) now recognized (Mead, 2002). Some species are still known only from stranded specimens and have never been seen alive (or even as a completely intact carcass). They all occur in deep water, far offshore. Six species are known from the North Atlantic, and all six have occurred in southern New England. Many beaked whale species are difficult to differentiate with intact specimens at hand and nearly impossible to identify at sea, and sightings identified to species were extremely rare before the late 20th Century. All six species are considered together here.

Description: Except for a few larger species, including only *Hyperoodon ampullatus* in the North Atlantic, all of the beaked whales are medium-sized animals (adult lengths of 4–7 m) that share a number of distinctive characters (Mead, 1989a, 1989b, 2002; Heyning, 1989, 2002; Gowans, 2002; Pitman, 2002). They have tail flukes that lack a central notch and small triangular dorsal fins located in the rear third of the body. The flippers are relatively small, with relatively long arm bones and short digits. On the ventral surface of the lower jaw there are two so-called throat grooves, which likely are involved in expansion of the oral cavity for suction feeding. The head has a pronounced, elongated rostrum that is continuous with the forehead without a distinct break or crease. In most species there is only one more or less tusk-like tooth in each mandible, which erupts only in adult males.

Northern bottlenose whales are the largest of the Atlantic beaked whales, with males reaching a maximum length of 9.8 m and females reaching 8.7 m (Mead, 1989b; Jefferson et al., 1993; Wynne and Schwartz, 1999; Gowans, 2002). The body is robust with a relatively wide back. The head is rounded and bulbous, which becomes increasingly pronounced in older, larger animals and nearly square with a flattened, vertical forehead in adult males. The blowhole is located in a shallow depression on top of the head, and the blow is short and bushy, and may be angled slightly forward. There is a pronounced, elongate, dolphin-like beak. They are tan to dark chocolate brown in color, with a lighter belly and often with lighter blotches, scratches, and scars. The head and neck are whitish on large adults. The dorsal fin is prominent, falcate, darker in color than the body, and located about two-thirds of the way back along the body.

Adult Cuvier’s beaked whales reach 7–7.5 m long (Heyning, 1989, 2002; Jefferson et al., 1993; Wynne and Schwartz, 1999). They have relatively robust, cigar-shaped bodies with small conical heads and short, tapered flippers. There is often a visible concavity or depression at the top of the forehead. There is little or no distinct beak, and the line of the mouth is relatively short and curved upward toward the rear. The teeth of adult males may be visible at the tip of the lower jaw, and are sometimes covered by clumps of stalked barnacles. The body is tan to reddish brown to dark gray, often mottled and covered with circular white scars and parallel pairs of scratches. The head and neck are often white, especially in adults, with a dark patch around the eye. Much of the back may be whitish in older males.

Beaked whales in the genus *Mesoplodon* are much smaller than northern bottlenose whales and smaller than Cuvier’s beaked whales. In addition, they have elongate, tapered beaks which differ from both the very short conical head of Cuvier’s beaked whales and the bulbous head with a dolphin-like beak of bottlenose whales. Identifying individuals to species becomes much more difficult. All species are about the same size and have the same general shape, show indistinct blows, have relatively small triangular to falcate dorsal fins located about 2/3 back on the body, and have flippers that fit into shallow depressions on the side of the body (Mead, 1989a).

Blainville’s beaked whales may be the easiest of the four North Atlantic *Mesoplodon* species to differentiate, assuming a close look under optimum conditions (Mead, 1989a; Jefferson et al., 1993; Wynne and Schwartz, 1999; Pitman, 2002). They are up to 4.7 m long. The body is relative robust and spindle-shaped, with a relatively thick beak. The forehead appears flattened in front of the blowhole, and there is little or no obvious indentation at the blowhole. The rear half of the lower jaw has an obvious upward arch, which enlarges and extends higher than the top of the upper jaw in adult males. Adult males have two massive, flattened, triangular, forward-tilting teeth growing from the top of the arch in the lower jaw that are clearly visible when the mouth is closed. The color is dark gray to black on the back with lighter sides and a white belly. There may be a dark circular patch around the eye, and large oval scars and scratches are common.

Female Gervais' beaked whales are up to 5.2 m long, while males only reach 4.6 m (Mead, 1989a; Jefferson et al., 1993; Wynne and Schwartz, 1999; Norman and Mead, 2001; Pitman, 2002). The body is slender and laterally compressed, with an elongate, tapered beak and a prominent melon with a small indentation behind it at the blowhole. Gervais' and True's beaked whales are very similar, with the beak in the former having relatively flattened sides. The flippers are set very low on the body. The color is dark gray on the back and sides with irregular white patches and a lighter belly.

Sowerby's beaked whales are up to 5 m long (Mead, 1989a; Jefferson et al., 1993; Wynne and Schwartz, 1999; Pitman, 2002). The body is slender and spindle-shaped, with an elongate, tapered beak and a very prominent melon with a pronounced indentation behind it at the blowhole. The color is dark gray to brown on the back with somewhat lighter sides and an even lighter belly.

True's beaked whales are up to 5.2 m long (Mead, 1989a; Jefferson et al., 1993; Wynne and Schwartz, 1999; Pitman, 2002). The body is relatively robust and tapers noticeably toward the tail. There is an elongate, tapered, somewhat dolphin-like beak with rounded sides and a prominent melon with a small indentation behind it at the blowhole. There is a sharp ridge from dorsal fin to the flukes. The color is gray to brown, gradually paling from a dark back to lighter sides to a whitish belly, with a darker band down the center of the back. The dorsal fin, lips, and a circular eye patch are black.

Status: None of the North Atlantic beaked whales are listed under the U.S. Endangered Species Act and none are included on the Rhode Island state list. Northern bottlenose whales and all four *Mesoplodon* species are classified as Data Deficient on the IUCN Red List, but Cuvier's beaked whale is classified as Least Concern. Under the Species at Risk Act in Canada, the Scotian Shelf population of *Hyperoodon* is classified as Endangered and Sowerby's beaked whale is classified as Special Concern (CWS, 2006).

The original population of northern bottlenose whales prior to whaling may have been as many as 90,000, and the current number may be 40–50,000 (Mead, 1989b; Gowans, 2002; IUCN, 2008). The most recent estimate of the northern bottlenose whale population in the Gully, based on photoidentification of individual whales, is 163 animals (Whitehead and Wimmer, 2005). Genetic studies show that the populations in the Gully, Davis Strait, and Iceland are distinct, suggesting little interchange between the areas (Dalebout et al., 2006). There is no abundance estimate for U.S. waters in the SAR because they occur so rarely. There are no North Atlantic ocean-wide estimates of abundance for any of the other beaked whales, although the global abundance of *Ziphius* is believed to be over 100,000 animals. They are pooled in abundance estimates in U.S. Atlantic waters because of species identification issues; the most recent pooled abundance estimate for all five species combined is 3,513 whales from Florida to Georges Bank in summer 2004 (Waring et al., 2008). For the Gulf of Mexico, there are separate abundance estimates for *Ziphius*—95 in 1996–2001 and 65 in 2003–2004, *Mesoplodon* spp.—106 in 1996–2001 and 57 in 2003–2004, and unidentified beaked whales—146 in 1996–2001 and 337 in 2003–2004. None of those estimates are corrected for diving and beaked whales tend to be long divers, therefore the actual numbers are likely to be substantially greater. It is possible that some beaked whales are rather abundant and that their apparent rarity is due more to their offshore distribution, low detectability, and tendency to avoid ships.

Commercial whaling for northern bottlenose whales began in the second half of the 19th Century and lasted until 1973 (Mead, 1989b; Gowans, 2002). At least 80,000 were killed over that time, with peak catches in the 1890s. During 1962–1967, 87 were killed in the Gully by whalers from Nova Scotia (Mitchell, 1974). They are occasionally killed by small-scale whalers in the Faroe Islands, two in 2001 and six in 2002 (IWC, 2005, 2006). *Ziphius* was taken opportunistically in the Japanese fishery for North Pacific bottlenose whales, up to 35 in a single year (Heyning, 1989), and was occasionally taken by traditional whalers in the West Indies (Caldwell and Caldwell, 1971). There have been no directed hunts for *Mesoplodon* spp. (Mead, 1989a), although there have been occasional opportunistic takes in small cetacean fisheries, e.g. *M. bidens* in Newfoundland (Sergeant and Fisher, 1957).

Before it was shut down due to excessive marine mammal bycatch rates, the pelagic driftnet fishery for swordfish off the northeastern U.S. had a relatively high rate of beaked whale bycatch. Forty-six mortalities were recorded by NMFS fishery observers from 1989 to 1998, including 24 Sowerby's, 4 True's, and 1 Cuvier's, with 17 not identified to species (Waring et al., 2008). The extrapolated total annual average mortality from that fishery was 23 beaked whales killed per year. More recently, an average of 1.0 beaked whale per year strands along the U.S. Atlantic coast from human-caused mortality (ship collisions or entanglement in fishing gear), which is not thought to represent a serious impact on any of the species present.

There has been concern in recent years that very loud mid-frequency sounds, most notably naval active sonar and seismic exploration for oil and gas, could have serious impacts on beaked whales (Frantzis, 1998; Balcomb and Claridge, 2001; Evans and England, 2001). There have been several mass stranding events that have coincided with naval exercises—in the Bahamas, Canary Islands, and Mediterranean. Cuvier's beaked whales are most often affected, but some events have included Blainville's or Gervais' beaked whales. One hypothesis is that the loud sounds cause the whales to panic and surface very rapidly from depth, releasing nitrogen bubbles and causing the equivalent of the "bends" (Jepsen et al., 2003). The debilitated whales then strand, and eventually die from the physiological stresses associated with stranding (Cox et al., 2006). There may be other, more subtle impacts of anthropogenic sound. Aguilar Soto et al. (2006) suggested from their tagging study that intense ship noise might impact foraging behavior. On one of the dives by the tagged *Ziphius*, the animal made significantly fewer "buzzes" when the tag was receiving a high level of ship noise.

Ecology and life history: Northern bottlenose whales are usually encountered in small groups of up to four whales (Mead, 1989b). Short-lived aggregations of up to 20 animals are observed (Gowans, 2002). Associations between adult females tend to be short-lived, but some male associations persist for years, suggesting a fission-fusion social structure with male coalitions, similar to that of bottlenose dolphins (Gowans et al., 2001; Gowans, 2002). They typically spend

10 minutes or more on the surface before dives that may last 1–2 hours. The median dive depth is 1000 m, and they are likely diving to the bottom for foraging (Hooker and Baird, 1999).

Northern bottlenose whales specialize mostly on one genus of deep-water squid, *Gonatus* sp., especially *G. fabricii* (Mead, 1989b; Hooker et al., 2001), although they feed on other species of squid and deep-water fishes. Whitehead et al. (2003) concluded that northern bottlenose whales have a much narrower feeding niche (measured as number of genera of squid eaten) than either sperm whales or *Ziphius*. Their dietary specialization is probably related to their restricted distribution and movement patterns, foraging primarily along the 1000-m isobath.

Reproduction in *Hyperoodon* is the best known of the North Atlantic ziphiids from data collected during 20th Century commercial whaling (Mead, 1989b). Sexual maturity in females occurs at a minimum length of 6.0 m and average length and age of 6.9 m and 11 years. In males the minimum length at maturity is 7.3 m, and the averages are 7.5 m and 7–11 years. Gestation lasts about 12 months, and lactation lasts at least 1 year and is possibly prolonged. Calves average 3.5 m at birth. The mean calving interval is 2 years, although some females have been observed accompanied by newborns and yearlings simultaneously.

Given that observations of living animals are rare and that most species are believed to actively avoid close approaches by vessels, the behavior of most beaked whale species is very poorly known (Heyning, 1989, Mead, 1989a). Adult male beaked whales often bear multiple scars that match the spacing of the tusks in that species, indicating that the scars are inflicted during aggressive encounters between males (Mead, 1989a). Heyning (1984) concluded from the scarring that the blows were struck with the mouth closed, and that the dense, fused bones of the rostrum in adult males were adapted for intraspecific aggression. Cuvier’s beaked whales are typically observed in groups of 1–7 animals, with most groups of four or fewer (Heyning, 1989, 2002). *Mesoplodon* spp. tend to occur in small groups (1–6 whales, usually 2 or 3) of mixed large and small animals and probably have a social system like many other toothed whales (Mead, 1989a; Pitman, 2002). Groups at the surface tend to stay tightly clustered, no more than a body length or two apart (Pitman, 2002).

All beaked whales are probably capable of long and deep dives. *Ziphius* dive durations are generally 20–40 minutes (Heyning, 1989). *Mesoplodon* spp. dives are typically 20 to over 45 minutes, with groups of animals generally surfacing and diving simultaneously (Pitman, 2002). Recent telemetry tagging studies on *Ziphius cavirostris* and *Mesoplodon densirostris* show their use of echolocation during foraging dives is similar to that in sperm whales, with regular clicks produced continuously at depth and short series of closely spaced clicks (“buzzes”) when closing in on targeted prey items (Johnson et al., 2004; Madsen et al., 2005; Zimmer et al., 2005).

All species of beaked whales are squid specialists (Heyning, 1989, 2002; Mead, 1989a, 1989b; Gowans, 2002; Pitman, 2002). Data on stomach contents of *Mesoplodon* spp. are very sparse, but also show a predominance of deep-water squid and occasionally fish (Mead, 1989a), with some of the fish remains probably introduced secondarily in the stomach contents of squids consumed by the whale.

Data from Japanese whaling indicated mean lengths at maturity for *Ziphius* as 5.8 m in females and 5.5 m in males (Heyning, 1989). The data for females may have been biased, since a 5.1-m pregnant female stranded in Florida. Calves average 2.7 m at birth. Reproductive data for *Mesoplodon* spp. are extremely sparse (Mead, 1989a; Pitman, 2002). One stranded female *M. densirostris* was observed with 9 growth layers in the teeth and one corpus albicans in an ovary, indicating recent sexual maturity. *M. europaeus* is the only species with enough data to estimate mean size at maturity—4.5 m in females.

Distribution: Northern bottlenose whales occur only in the North Atlantic, from Nova Scotia and the British Isles in the south to Baffin Island, Greenland, Iceland, Jan Mayen, and Svalbard in the subarctic north (Mead, 1989b; Gowans, 2002). There are six known areas of aggregation—two near Norway, west of Svalbard, north of Iceland, in Davis Strait west of Greenland, and in the Gully, a large submarine canyon east of Sable Island off Nova Scotia. They occasionally occur south to the edge of Georges Bank, where sightings were recorded near the shelf break in 1980, 1993, and 1996, all in late spring or summer (CETAP, 1982; Waring et al., 2008). Seasonality is poorly known, however the known strandings in eastern Canada and New England are scattered throughout the year (Reeves et al., 1993). Bottlenose whales occur in the Gully year-round, and some individuals have been sighted in other canyons along the edge of the Nova Scotian shelf (Gowans et al., 2000; Hooker et al., 2002; Wimmer and Whitehead, 2004).

Cuvier's beaked whale is the most cosmopolitan of all beaked whales, occurring in cold temperate to tropical waters world-wide (Heyning, 1989, 2002). There were six identified sightings in 1979 and 1980 off the northeastern U.S. (CETAP, 1982), and a number of additional sightings in more recent surveys off the Northeast and in the Gulf of Mexico (Waring et al., 2008). Sightings have been in spring and summer, and concentrated in deeper waters from the shelf break to further offshore. They are also known from strandings along the east coast from Nova Scotia to Florida to the West Indies.

Blainville's beaked whale has the widest distribution of any *Mesoplodon* species, occurring world-wide in warm temperate to tropical waters (Moore, 1966; Mead, 1989a). In the North Atlantic, they are more common in North America than in Europe. Strandings in the western North Atlantic are known from Nova Scotia south to Florida, the Gulf of Mexico, the Bahamas, and the Caribbean.

Gervais's beaked whales were once thought to occur only in the North Atlantic, but there were three strandings on Ascension Island in the tropical South Atlantic in 1980. They are the most common beaked whale in the stranding record from the east coast of the U.S. (Moore, 1966; Mead, 1989a; Norman and Mead, 2001). Fisher's Island, New York is the northernmost occurrence. Strandings occur south to Florida, the Gulf of Mexico, the West Indies, and the Caribbean. Occurrences on the eastern side of the North Atlantic are rare and scattered, occurring in France, Spain, the Canary Islands, Mauritania, and Guinea-Bissau.

Sowerby's beaked whales are known from cold temperate waters on both sides of the North Atlantic, but are much more common on the European side than on the North American side (Moore, 1966; Mead, 1989a). In the western North Atlantic, strandings are known from southern New England north to Newfoundland and Labrador. There is one stranding record from the Gulf of Mexico coast of Florida, however that is believed to be a stray far outside the normal range of the species.

As with Gervais' beaked whale, True's beaked whales were believed to occur only in temperate North Atlantic waters, but recently specimens have been identified from strandings on the Indian Ocean coasts of South Africa and Australia. Strandings are known from the northeast Atlantic (Scotland, Ireland, and France) and in the western North Atlantic from Nova Scotia south to Florida and the Bahamas (Moore, 1966; Mead, 1989a).

The only documented historical records of northern bottlenose whale in southern New England were in Rhode Island in 1867—an 8.2-m animal was killed off Newport in February and a second was seen but escaped, and two 7.5-m animals stranded near the Stone Bridge in Tiverton on an unknown date. There was also a stranding within Cape Cod Bay at North Dennis, Massachusetts in January 1869 (Mitchell and Kozicki, 1975). These were the southernmost known occurrences for the species in the western North Atlantic (Mead, 1989b) until a sighting of two animals near the shelf break east of Cape May, New Jersey in June 1981 (CETAP, 1982). Connor (1971) concluded that all earlier published reports for Long Island were in error. For example, Goodwin (1935) wrote "Linsley (1842) reported a whale of this species at Stonington, Conn." He clearly mistook Linsley's account of a minke whale ("*Rorqualus costatus* [sic] Dekay, Beaked Whale") for *Balaena rostrata,* a once-commonly used junior synonym for bottlenose whale.

The general pattern for beaked whales in the southern New England area is strandings on the beaches and sightings at the shelf break and farther offshore, with a few scattered occurrences in between. Most records that are identified to species are strandings; conversely, very few sightings are identified to species. None of the individual species have enough sightings to conduct a valid analysis, therefore all six species were pooled into in single category along with sightings identified only as *Mesoplodon* sp. or as unidentified beaked whales.

Harbor Porpoise *Phocoena phocoena* (Linnaeus 1758):

Description: Porpoises are easily differentiated from dolphins by having spatulate rather than conical teeth (Read, 2002). Their skulls resemble the skulls of very young dolphins, with delayed fusion of cranial sutures. The rostrum of the skull is much shorter than in small dolphins, and there are paired rounded protuberances on the premaxillae just in front of the braincase, which is relatively large and rounded. Harbor porpoises are the smallest cetaceans occurring in the North Atlantic, reaching only 1.4–1.9 meters. They exhibit reverse sexual dimorphism; an average female is 160 cm and 60 kg, an average male is 145 cm and 50 kg, and the largest individual known was a 200-cm, 70-kg female (Bjørge and Tolley, 2002). The size ranges of mature porpoises from the Bay of Fundy were: females—131–168 cm (mean = 157, n = 32), 42–76 kg (mean = 62); males—129–157 cm (mean = 144, n = 62), 36–61 kg (mean = 49) (Read, 1999). The body is stocky, dark gray to black on the back and white on the belly with little or no distinctive patterning (Gaskin et al., 1974; Jefferson et al., 1993; Read, 1999; Wynne and Schwartz, 1999; Bjørge and Tolley, 2002). The sides may be mottled or simply transition gradually from dark to light. There are often one or more dark stripes from the corner of the mouth to the flipper. Individuals may show darker eye, chin, and lip patches. The head is bluntly conical with no distinct beak. The flippers are small and pointed, and the dorsal fin is small, triangular (sometimes slightly falcate), and located slightly behind the middle of the back.

Status: Harbor porpoises are not listed under the U.S. Endangered Species Act. A proposal made in 1993 to list the Gulf of Maine/Bay of Fundy stock as Threatened because of excessive bycatch mortality in the sink gillnet fishery was withdrawn in 1999 after an extensive review (NMFS, 1999) and the species was removed from the Candidate list in 2001 (NMFS, 2001). Harbor porpoises are not included on the Rhode Island state list and are classified as Least Concern on the IUCN Red List. Northwest Atlantic harbor porpoises are listed as Special Concern under the Species at Risk Act in Canada (CWS, 2006). The total number of harbor porpoises in the North Atlantic is likely to be over 500,000 (IUCN, 2008). The current estimate for the Gulf of Maine/Bay of Fundy stock is 89,054 (Waring et al., 2008).

Harbor porpoises were the subject of an organized hunt in Denmark for oil and meat from at least the 14th Century until World War II, and had probably been hunted in that area since the Stone Age (Kinze, 1995). Average annual catches probably exceeded 1,000 animals. Inuit subsistence hunters in Greenland took 1,607 porpoises in 2000, 1,946 in 2001, 1,373 in 2002, 2,320 in 2003, and 2,238 in 2004 (IWC, 2005, 2006). Micmac and Passamaquoddy Indians in the Bay of Fundy and along the coast of Maine hunted porpoises for both meat and oil in the 19th and 20th Centuries (reviewed by Reeves and Read, 2003). They hunted from canoes using shotguns, but there is no archeological evidence that hunting occurred before the introduction of firearms. The blubber was rendered down to 2–3 gallons of oil that was used for lighting and lubrication. Much more valuable was the “jaw oil” from the mandibular fat, which was used for lubricating clocks, watches, and other precision instruments. Jaw oil was obtained by hanging the lower jaw over a can and allowing the oil to drip out, producing about a half-pint per animal. Total takes were likely several hundred per year.

Mortality of harbor porpoises and other phocoenids as bycatch in commercial fisheries is a global concern (Perrin et al., 1994b; D’Agrosa et al., 1995; Read and Wade, 2000). The most significant fishery bycatch occurs in sink gillnet fisheries. As pointedly noted by Reeves and Read (2003), the first U.S. government fisheries report in 1886 detailing the efficiency of gillnet fishing for cod also reported incidental captures of harbor porpoises. The stock assessment for Gulf of Maine/Bay of Fundy harbor porpoise stock (Waring et al., 2008) reported annual average mortality of 725 porpoises in gillnet fisheries during 2001–2005—475 in the northeastern U.S., 177 in the mid-Atlantic, and 73 in Canada. There are also lower levels of mortality in other fisheries. A Take Reduction Plan is in effect in U.S. Atlantic waters, involving fishery closures in specific areas at times when the probability of porpoise bycatch is high, plus a requirement for the use of acoustic alarms (“pingers”) to alert porpoises to the presence of gear. Bycatch mortality did decline for a time, however then began to increase, perhaps due to declining compliance with the Take Reduction Plan.

Given that harbor porpoises live in coastal waters adjacent to areas with high human population densities and industrial development, the potential effects of toxic pollution are of concern. In some areas harbor porpoises do have high levels of organochlorines and heavy metals in their body tissues, but no correlations have been shown with adverse health effects or body condition (Read, 1999).

Ecology and life history: The most common harbor porpoise sighting off the northeastern U.S. is a single individual, with pairs and trios common (CETAP, 1982). This is consistent with observations in other areas (Read, 1999; Bjørge and Tolley, 2002). Groups of 6–10 are often observed, or even larger groups on rare occasions, however these are not stable social groupings as in many other toothed whales. Harbor porpoise groupings are fluid, short-term associations in a "fission-fusion" social structure (Reeves and Read, 2003). The largest reported groups are most likely aggregations of un-associated animals in areas of abundant prey.

Harbor porpoises exhibit a clear seasonal pattern of distribution and movement, however there is little evidence for a coordinated annual migration (Reeves and Reed, 2003). Off the northeastern U.S., porpoise abundance declines in the Gulf of Maine in winter, coincident with the peak occurrence in the mid-Atlantic region. However, evidence from genetic sampling of stranded and bycaught individuals shows that some proportion of the animals in the mid-Atlantic region do not come from the Gulf of Maine/Bay of Fundy stock (Rosel et al., 1999). In addition, the majority of stranded and bycaught porpoises in the mid-Atlantic are juveniles. Although juvenile mortality rates can be expected to be higher, there also may be age differences in seasonal movements, perhaps with younger animals wintering in more inshore areas than older animals.

Most dives by harbor porpoises are just about a minute or a little longer, but they are capable of diving for 5 minutes to depths exceeding 200 m (Westgate et al. 1995). Their surfacings are very brief. Read and Westgate (1997) studied movements of Gulf of Maine harbor porpoises using satellite-tracked radio tags. Average daily movements were 14–58 km. Tagged animals commonly remained resident in small, localized areas for extended periods, then made relatively rapid, directed movements lasting hours or days to different areas. Tagged porpoises ranged over the entire Bay of Fundy and Gulf of Maine area.

Harbor porpoises primarily feed on fish and secondarily on squid and crustaceans (Gaskin et al., 1974; Read, 1999; Bjørge and Tolley, 2002; Reeves and Read, 2003). They preferentially feed on non-spiny fishes with relatively high fat content that are less than 40 cm long (usually 10–30 cm). Clupeids and gadoids dominate. Their primary prey species in the Bay of Fundy are herring and silver hake. Other commonly eaten species include anchovies, sprat, sardines, and capelin, and calves apparently begin feeding on small crustaceans. Stomach contents of stranded porpoises in the Rhode Island study area frequently include herring and squid (Sadove and Cardinale, 1993). Harbor porpoises do not forage cooperatively, and often feed near the bottom (Read, 1999). Their daily ration ranges from 5% to 14% of body weight, and is highest in immatures and in pregnant and lactating females.

Harbor porpoise reproduction is strongly seasonal, with the timing varying between regions (Read, 1999; Reeves and Read, 2003). In the Gulf of Maine/Bay of Fundy population, ovulation occurs within a few weeks in late spring and early summer (Read, 1990a). Only the left ovary matures. There is also marked reproductive seasonality in the males, with testis mass and sperm production varying on an annual cycle and peaking at the same time as ovulation (Reeves and Read, 2003). At the peak of the breeding season, the testes in an adult male comprise about 4% of total body mass. The mating system is probably promiscuous with sperm competition occurring. Gestation is 10–11 months, with most calves born in May in the Gulf of Maine, and

June-July in Europe.

Porpoise life histories are more like those of mysticetes than like other odontocetes’, with early maturation, rapid growth, short inter-birth intervals, and a low degree of sociality (Read and Hohn, 1995). Calves are about 75 cm long and weigh about 6 kg at birth, and triple their weight in about 3 months (Read, 1999; Reeves and Read, 2003). Lactation lasts at least 8 months and possibly as long as a year, but weaning is gradual and calves begin feeding independently well before being completely weaned. Post-partum estrus and mating is common in harbor porpoise females, resulting in simultaneous pregnancy and lactation and 1-year intervals between calves. Most females give birth annually in the Gulf of Maine and European populations, but every other year in the California population (Read, 1990b; Read and Hohn, 1995).

Harbor porpoises typically reach sexual maturity in their third or fourth years, but are not physically mature until about age 5 in males and 7 in females (Read, 1999). The mean age at sexual maturity for Gulf of Maine/Bay of Fundy females is 3.44 years, at an average length of 143 cm (Read, 1990b).

Some harbor porpoises from the Bay of Fundy have tested positive for antibodies to morbillivirus (Duignan et al., 1995). A few porpoises died during the 1988 PDV epizootic in the North Sea harbor seals. Van Bressem et al. (2001) reported 16.7% morbillivirus seropositives in mature porpoises from the British Isles, but no positive tests in immatures from the British Isles or in either immatures or adults from the North Sea.

Distribution: Harbor porpoises are known from cool temperate to subpolar waters around both the North Atlantic and North Pacific (Gaskin et al., 1974; Read, 1999; Bjørge and Tolley, 2002; Reeves and Read, 2003). They occur most often in relatively shallow continental shelf and coastal waters. The sightings from the 1978–1981 CETAP surveys showed porpoises in spring most concentrated in the southwestern Gulf of Maine around Nantucket Shoals and western Georges Bank but also occurring throughout the Gulf of Maine and southern New England shelf, followed by a marked concentration into the northern Gulf of Maine and Bay of Fundy in the summer (CETAP, 1982). Sightings were much less frequent and extremely scattered in fall and winter, and it was hypothesized that many individuals migrated to the mid-Atlantic or offshore waters. Strandings are widespread from Maine to North Carolina. There are two stranding records for Florida in the 1980s and one in 2003 (Waring et al., 2008), however they are considered to be extralimital, since there are no other records south of North Carolina.

Historical accounts of harbor porpoises in southern New England must be treated with some level of skepticism because of the common use of the word “porpoise” to also refer to dolphins, as pointed out by Connor (1971) with regard to sighting reports for Long Island during summers in the 1950s and 1960s. In addition, the recent data show harbor porpoises to be relatively rare in summer (see below). Also somewhat suspect are the accounts of porpoises in large schools, sometimes up to hundreds of animals (e.g., Miller, 1899; Rowley, 1902; Turrell, 1939: as cited by Conner, 1971; Cronan and Brooks, 1968). De Kay (1842) reported that porpoises were “formerly so abundant on the shores of Long Island as to have induced the inhabitants to form establishments for their capture.” His account was derived from a 1792 report by E. L’Hommedieu in *Transactions of the Society in the State of New-York for the Promotion of*

Agriculture, Arts, and Manufactures, which described a net fishery in eastern Long Island taking small cetaceans for oil and leather. Mead (1975) concluded that the fishery was not for harbor porpoises, but was most likely for bottlenose dolphins, in part because the average oil yield reported (6 gallons) was too high for *Phocoena* but matched that from the Cape Hatteras *Tursiops* fishery. In addition, the capture method described matched what was used at Cape Hatteras.

Pilot Whales: Long-finned Pilot Whale *Globicephala melas* (Traill, 1809); Short-finned Pilot Whale *Globicephala macrorhynchus* Gray, 1846

Description: Pilot whales are easy to identify, but differentiating the long-finned and short-finned species in the field is exceedingly difficult (Jefferson et al., 1993; Bernard and Reilly, 1999; Wynne and Schwartz, 1999; Olson and Reilly, 2002). Both species are large, robust animals with a distinct “barrel-chested” appearance. Both are sexually dimorphic, with males larger than females. The head is rounded and bulbous with a very prominent melon, a slight beak, and an upturned mouth. The tailstock has prominent dorsal and ventral keels. The flippers are curved, tapered, and pointed. The dorsal fin is low, rounded to somewhat falcate, broad-based, and located well in front of the middle of the body. The color is black, dark gray, or brown overall, except for a whitish “anchor” mark on the chest, lighter gray “eyebrow” streaks from the eyes to the back, and a light gray “saddle” behind the dorsal fin.

Long-finned males may be as long as 7.6 m, while females reach a maximum of only 5.7 m. Their flippers are longer at about one-fifth of body length, with an obvious “elbow,” but the length ranges overlap, making the difference in flipper length nearly useless as a field character for sightings of live animals. Short-finned pilot whales are somewhat smaller, and possibly slightly more thick-bodied, with males up to 6 m and females up to 5.5 m. The flippers in short-fins are shorter (about one-sixth of body length) and more curved, but the length ranges overlap, making the difference in flipper length nearly useless as a field character for sightings of live animals. In both species, dorsal fin shape changes in older adult males, with a tendency to become more broad-based in long-fins and more broad-based and hooked in short-fins. Additionally, in at least some short-fins, the saddle and lighter streaks on the head may be more distinct, and the overall color more brown than black. Range may be helpful, but should not be relied upon for identification.

Status: Both long-finned and short-finned pilot whales are not listed under the U.S. Endangered Species Act and are classified as Data Deficient on the IUCN Red List. On the Rhode Island state list, long-finned pilot whales are classified as Unprotected, while short-finned pilots are not included.

The total abundance of either species of pilot whale in the North Atlantic is not well known, although the long-finned species is better known. Early estimates of the total size of the population impacted by directed harvests in eastern Canada concluded that there were 50,000–60,000 long-finned pilot whales in the western North Atlantic (Mitchell, 1974; Mercer, 1975). Hay (1982) estimated the abundance of long-finned pilot whales off Newfoundland and Labrador at 6,731–19,603; Kingsley and Reeves (1998) estimated 1,600 in the Gulf of St. Lawrence in late summer 1995; and Buckland et al. (1993) estimated 778,000 in the eastern and central North

Atlantic. Because of the difficulty in identifying pilot whales at sea, off the eastern U.S. the two species currently must be combined for estimating abundance. Based on a 2004 summer survey, the combined stocks of both species between Florida and the Bay of Fundy were estimated at 31,139 animals (Waring et al., 2008). Efforts are underway to use a combination of genetic data from biopsy sampling, spatial modeling, color differences, and morphometrics to partition the estimates by species. In the Gulf of Mexico only short-finned pilot whales occur; recent abundance estimates for parts of the Gulf are 2,388 in 1996–2001 and 716 in 2003–2004.

Directed pilot whale fisheries on both species have occurred in many places around the world (reviewed in Bernard and Reilly, 1999). A drive fishery in Newfoundland took almost 10,000 pilot whales in 1956 but declined during the 1960s and eventually ended. Small-scale pilot whale fisheries formerly took place in Norway, Greenland, Iceland, Ireland, and Cape Cod, and Inuit subsistence hunters in Greenland took 5 in 2000, 45 in 2001, 24 in 2002, 195 in 2003, and 208 in 2004 (IWC, 2005, 2006). The drive fishery for long-finned pilot whales in the Faroe Islands is the only substantial hunt still continuing in the North Atlantic. It dates back to at least the 16th Century. Catches were about 1,500 per year in the 1970s and 2,500 per year in the 1980s, with little evidence for any negative impacts on overall pilot whale stocks in the northeastern Atlantic. Annual catches in 2000–2003 were 588, 918, 626, and 503 (IWC, 2005, 2006). Short-finned pilot whales were hunted for centuries in Japan, and there are still catches of a few hundred per year (304 in 2000, 389 in 2001, 176 in 2002, 160 in 2003: IWC, 2005, 2006). In the North Atlantic, Yankee whalers left behind traditional fisheries in both the West Indies and the Azores that persisted into the 1980s.

Pilot whales are also impacted by bycatch in commercial fisheries. In U.S. Atlantic waters, average annual fishery-related mortality of both species combined in 2001–2005 was 163 animals. The predominant source of mortality is the pelagic long-line fishery for swordfish (86 per year), and pilot whales are also taken in bottom and mid-water trawl fisheries for squid, groundfish, and herring. Pilot whales were formerly taken in the pelagic swordfish driftnet and tuna pair-trawl fisheries, both now closed.

Ecology and life history: Pilot whales live in permanent social groups of about 10–50 animals, but at times pods join to form aggregations of hundreds of animals (Bernard and Reilly, 1999; Olson and Reilly, 2002). Off the northeastern U.S., group sizes observed ranged from 1 to 500, with a mode of 10 and mean of 20 (CETAP, 1982). In this region they commonly associate with other cetaceans. The most frequently observed mixed-species herds in the shelf-edge habitat off the northeastern U.S. were pilot whales and offshore bottlenose dolphins. They also have been observed associated with Risso’s, common, and spotted dolphins and sperm whales, as well as in the same areas as fin and humpback whales in more inshore waters.

Short-finned pilot whales that were trained by the U.S. Navy routinely dived to 300 m and were capable of dives of 15 minutes and to at least 500 m and probably over 600 m (Bernard and Reilly, 1999).

In the North Pacific, there are differences in northern and southern stocks of short-finned pilot whales off Japan in size, markings, and life history (Kasuya and Tai, 1993; Bernard and Reilly, 1999). In the southern stock, mating is mostly in April–May and births are in July–August, but some births occur year round. In the northern stock calving is more strictly seasonal, with breeding in September and calving in December. Calves are about 1.7 m long at birth. The age at weaning is longer than in long-fins at 3.5–5.5 years. An older female might nurse her last calf for as long as 15 years (Marsh and Kasuya, 1991). Females reach sexual maturity at 9 years on average and males at about 16 years. A significant proportion of females become senescent, ceasing reproduction during or after their 30s.

Details of the social structure of long-finned pilot whale herds have been examined by genetic sampling from groups killed in a fishery in the Faroe Islands (located in the northeastern North Atlantic between Scotland and Iceland) (Amos et al., 1993). Entire herds are driven into a fjord or bay and killed, providing a complete picture of the inter-relationships among group members. All of the adults in a pod are related to one another. The calves and juveniles are offspring of the adult females in the pod, but the pod's adult males are not their fathers. Both males and females remain with their mothers for their entire lives, similar to the situation in killer whales. It is believed that mating occurs in large temporary aggregations, when the adult males are able to breed with females in other pods. Pilot whales also are one of the only non-human mammals with evidence of reproductive senescence, with post-reproductive individuals contributing to the survival of the young. In this system, the long-term benefits of group-living, social facilitation, and learning are maximized while still avoiding inbreeding.

Both species of pilot whales are known to strand commonly in large groups (Geraci and Lounsbury, 1993; Bernard and Reilly, 1999; Perrin, 2002f). Mass stranding is a phenomenon that occurs only in social odontocetes, including sperm whales, pilot whales, false killer whales, and some dolphin species. The causes of mass strandings are not well understood, and there are numerous hypotheses, including disease, parasites, geomagnetic anomalies interfering with navigation, social cohesiveness, and others. It is likely that there is no single cause, and that multiple causes interact. A common site for long-finned pilot whale mass strandings is on the inside of Cape Cod. In fact, a tidal creek in Wellfleet is called Blackfish Creek for the pilot whale strandings that have happened in that area at least since colonial times. Stranding events there tend to happen in winter, after storms when the water is murky and visibility limited. The bottom slope is nearly flat, so that echolocation provides no cue as to which direction is offshore, which also means that very wide mud flats are exposed at low tide. There is a known area of geomagnetic anomalies. It also may be possible that the usual direction to safety offshore for western North Atlantic pilot whales is south and east, which does not hold true inside Cape Cod Bay. In some strandings, rescue attempts are unsuccessful as animals seem to intentionally beach themselves again. Sometimes it appears that one or more individuals may be debilitated by disease or other cause, and the rest of the herd is trying to stay together. The adaptive value of social cohesion may be maladaptive under those circumstances.

On two occasions long-finned finned pilot whales that stranded in New England were rehabilitated and then released with satellite-tracked radio tags that provided information on movements and diving. Mate et al. (2005) tagged a 3-m, 2-year-old male in a group of three juveniles released after 7 months in captivity. They were released together on 29 June 1987 on the outer edge of Georges Bank about 160 km southeast of Cape Cod. The tagged whale was tracked for 94.5 days and a minimum distance traveled of 3144 km. It spent 10 days on Georges Bank, then moved offshore beyond the shelf edge for 9 days, then traveled 2 days north into the central Gulf of Maine, where it remained for the next 67 days. On day 20 it was observed in a group of pilot whales. The percent of time spent at the surface per day ranged from 5 to 47%. The average dive time was only about 40 seconds, but the average included short respiratory dives between breaths at the surface. The overall range of dive times was 6 seconds to almost 28 minutes, with a higher probability of short dives during the daytime and longer dives at night.

Nawojchik et al. (2003) released two juvenile males on 20 October 17 km south of Montauk Point (they had stranded on 28 June). They first headed west along the Long Island shore, then turned east and traveled to Nantucket. At that point they moved offshore to the outer part of Georges Bank and around the eastern end of the back into the basins to its north in November–December, then made a clockwise loop around the northern Gulf of Maine in January and ended up in the Great South Channel area east of Cape Cod in February. Most dives were less than 2 minutes and shallower than 15 m. Both whales made dives exceeding 26 minutes. Their deepest dives were 312 and 320 m, which is approximately the depth to the bottom in the area where they were at the time.

The preferred prey of both pilot whale species is squid, although at least long-finned pilot whales have been observed to feed on fish in the North Atlantic (Sergeant, 1962; Mercer, 1975; Kenney et al., 1985a; Desportes and Mauritsen, 1993; Bernard and Reilly, 1999; Olson and Reilly, 2002). Pilot whales were commonly taken in foreign fishing activities that were conducted in December–May 1977–1991 along the shelf edge off the northeastern U.S., with 391 taken in the mackerel fishery and 41 taken in the squid fishery (Waring et al., 1990; Fairfield et al., 1993). It is unclear whether mackerel is an important prey item in winter in our region, or whether the whales were simply feeding opportunistically on mackerel scavenged from the trawl nets.
Based on samples from fisheries in Newfoundland and the Faroe Islands, long-finned pilot whale calves in the North Atlantic are born in July–October (Bernard and Reilly, 1999). Calves are about 1.7 m long at birth (Wynne and Schwartz, 1999). Estimates of gestation period range from 12 months to as long as 15–16 months. Calves are weaned at about 22 months, and females that are simultaneously pregnant and lactating are rare. The average inter-birth interval is about 40 months. Females reach sexual maturity at 6–8 years (3.6–3.8 m) and males at about 12–17 years (4.8 m) (Desportes et al., 1993; Martin and Rothery, 1993). The occurrence of reproductive senescence seems to be less common than in short-finned pilot whales; a pregnant 55-year-old was observed in the Faroes, though ovulations appear to be spaced further apart in older females.

Distribution: Long-finned and short-finned pilot whales have mostly parapatric distributions, but they overlap in several areas of the world (Rice, 1998; Bernard and Reilly, 1999; Olson and Reilly, 2002). Long-finned pilot whales occur in the entire Southern Ocean south of 40ºS and in the North Atlantic north of about 30ºN, overlapping with short-fins (see below) from Australia to South America in the South Pacific, on the Atlantic coast of South America, and around South Africa. The broadest overlap is in the North Atlantic, from the east coast of the U.S. across to the eastern North Atlantic from France to northwestern Africa. Long-finned pilot whales range from North Carolina north to Newfoundland, Greenland, and Iceland, with possibly extralimital occurrences represented by strandings in South Carolina and Georgia. Fullard et al. (2000) proposed that there were two stocks of long-finned pilot whale in the North Atlantic—a cold-water population distributed north and west of the Gulf Stream, and a warm-water population associated with the Gulf Stream across the basin from North America to Europe.

Short-fins are found world-wide in warm-temperate to tropical waters on both sides of the equator, primarily in deeper offshore areas. Their southern limit is about 40ºS latitude around the entire Southern Ocean, to about 50ºN in the North Pacific and 42ºN in the North Atlantic. In the western North Atlantic, the range of short-finned pilot whales includes the southern U.S., Gulf of Mexico, Caribbean, West Indies, and the coast of South America. The northern limit of the range off the Atlantic coast is not well known, but believed to be between Virginia and New Jersey, probably varying seasonally.

Off the northeastern U.S., pilot whales (both species combined) are found primarily along the shelf edge and around the edges of Georges Bank in all four seasons, most scattered in the winter (CETAP, 1982). Pilot whales occupied the most inshore depth zone of the shelf-edge cetaceans, along with common dolphins and offshore bottlenose dolphins (CETAP, 1982; Kenney, 1990). The patterns of seasonal distributions seen in the CETAP surveys and gaps in those patterns were suggestive of spatial partitioning between the species. In the winter, the densest concentration of sightings was offshore of New Jersey and southern New England, with scattered sightings along the edge of Georges Bank. South of New Jersey there were very few sightings except for a small cluster just off Cape Hatteras, North Carolina. In the spring, pilot whales were widespread from Maryland north to Georges Bank, and into shallower water on the shelf. There was a larger group of sightings off North Carolina than in winter, and still a hiatus in sightings east of Virginia. During the summer, there was a distinct concentration of pilot whales along the outer shelf from North Carolina to Delaware Bay, then a distinct gap south of Long Island and Cape Cod, and then sightings all around Georges Bank and into the central Gulf of Maine. Payne and Heinemann (1993) also noted the tendency for pilot whales to move into the deeper basins north of Georges Bank in late spring and summer. The pattern in fall was similar, except the gap in the middle was somewhat wider and extended farther south. More recent summer stock assessment surveys in 1998 and 2004 also showed a gap in pilot whale sightings approximately between the longitudes of eastern Long Island and Cape Cod (Waring et al., 2008). Those surveys also resulted in pilot whale sightings much farther offshore, mainly associated with the edge of the Gulf Stream.

The earliest pilot whale records for the region were reported by De Kay (1842), who described a stranding at Fairfield Beach, Connecticut in October 1832 and two animals captured at the eastern end of Long Island in 1834. Connor (1971) mentioned several 20th Century stranding records from New York plus reports of frequent sightings.

In the Rhode Island to New Jersey stranding data, the ratio of long-finned to short-finned pilot whale is 9:1, but with the exception of a single Rhode Island record, short-finned pilot whale strandings have occurred only in New Jersey, and mainly in the southern part of that state. While there is a likelihood that some strandings might be misidentified, it is probably justifiable to conclude that pilot whales in New York waters are usually the long-finned species, with short-fins occurring relatively rarely.

Risso’s Dolphin *Grampus griseus* (G. Cuvier, 1812)

Description: Risso’s dolphins are large, robust animals, 3–4 m in length, which are relatively easy to identify (Jefferson et al., 1993; Kruse et al., 1999; Wynne and Schwartz, 1999; Baird, 2002b). The body is thick and robust from the dorsal fin forward and relatively slender behind. The impression is that of a shorter, more barrel-chested pilot whale. The head is blunt with a squarish profile and a slight but distinctive vertical crease down the forehead. The mouth curves noticeably upward, and there is no beak. The flippers are very long and pointed but broader than in pilot whales, and the dorsal fin is very tall, slender, and falcate. The color pattern is distinctive and unique. Calves are uniformly light gray, and gradually darken to dark gray or brown with a white belly and white "anchor" mark on the chest as juveniles. Older animals get gradually whiter, mainly from scars and scratches, especially on the head. Old adults may be entirely white except for the dorsal fin, flippers, and flukes.

Status: Risso's dolphins are not listed under the U.S. Endangered Species Act or on the Rhode Island state list, and are classified as Least Concern on the IUCN Red List. There are no estimates of the total number of Risso's dolphins in the North Atlantic, and no information on stock separation. The most recent estimate of abundance of Risso's dolphins along the U.S. Atlantic coast was 20,479, with an additional 1,589 in the northern Gulf of Mexico (Waring et al., 2008). Surveys in 1998 estimated the Atlantic stock at 28,164.

Risso's dolphins have been taken in a number of small-cetacean fisheries around the world, but have never been the focus of a large-scale fishery (Kruse et al., 1999). They have been taken in Europe, Canada, the West Indies, the Azores, Peru, and Japan. Recent takes in Japanese small-cetacean fisheries were 506 in 2000, 474 in 2001, 386 in 2002, 373 in 2003, and 6 in 2004 (IWC, 2005, 2006). They are also subject to incidental take in variety of commercial fisheries (Read, 1996). The average annual fishery-related mortality of Risso's dolphins in U.S. Atlantic fisheries in 2001–2005 was 40 (Waring et al., 2008). Most mortality (37 per year on average) was in the pelagic swordfish long-line fishery, with the remainder in the sink gillnet fishery. There was formerly mortality in the pelagic swordfish driftnet and tuna pair-trawl fisheries, both of which are now closed.

Ecology and life history: Risso's dolphins generally occur in small groups of 10–50 animals, but may be sighted as single individuals and in herds of several hundred or more (Kruse et al., 1999; Baird, 2002b). Off the northeastern U.S. the mean group size was 17, with a range from 1 to 400 (CETAP, 1982). They frequently perform aerial behaviors such as breaching, spy-hopping, and lob-tailing, but rarely bow-ride. They were sighted at times in association with pilot whales, offshore bottlenose dolphins, and other species (CETAP, 1982). In the North Pacific they associate with many other species in mixed groups (Kruse et al., 1999).

There are almost no data on diving capabilities. They appear to be capable of dives up to 30 minutes (Kruse et al., 1999).

Risso's dolphins are believed to feed exclusively or almost exclusively on squid (Kruse et al., 1999; Baird, 2002b). Reduction in the number of teeth is believed to be an adaptation to the squid-feeding habit (Clarke, 1986). Based on observations of activity patterns off Santa Catalina Island, California, Risso's dolphins are mainly nocturnal feeders (Shane, 1995).

Life history data for Risso's dolphins are sparse (Kruse et al., 1999; Baird, 2002b). Calves are born at 110–150 cm, and calving may peak in the winter. Size at sexual maturity is 2.6–2.8 m in females and 2.6–3.0 m in males. There is no information on gestation or lactation periods or inter-birth intervals.

Amano and Miyazaki (2004) reported on a school of 79 killed in a drive fishery in Japan. There were 49 females and 30 males, for a sex ratio of 1.63:1. Of the females, 2 were pregnant, 9 lactating, 2 both pregnant and lactating, 14 resting, 14 immature, and 8 unknown (66% mature). Their age at maturity was probably 8–10 years, and the oldest was 34.5. Of the males, 23 were immature, 4 were maturing, 1 was mature, and 2 were unknown (18% mature). The estimated age at maturity was 10–12, but the sample size was very small. The oldest male was 16.5. The sex and age structure of the school suggests a life history pattern where males leave their natal groups when mature and remain segregated from schools of females and immatures.

Distribution: Risso's dolphins are found in tropical and temperate waters world-wide (Rice, 1998; Kruse et al., 1999; Baird, 2002b). In the Atlantic, they occur from Newfoundland and the British Isles south to the southern tips of Africa and South America, although the distribution is poorly known along the coasts of east-central South America and western Africa. Their distribution is primarily in deeper pelagic waters, and is poorly known in the central ocean regions. In the western North Atlantic they are found primarily along the shelf break, but are also sighted commonly in shallower waters to about mid-shelf, as well as much farther offshore. Off the northeastern U.S., Risso's dolphins occurred along the entire shelf in spring and summer, with dense concentrations from about Virginia to Cape Cod in spring and from Virginia to Georges Bank in summer (CETAP, 1982). In the fall, the number of sightings declined and the distribution contracted to Virginia–Long Island. There were many fewer sightings in winter, mostly east of Maryland and Virginia. Summer surveys in 1998, 1999, and 2004 extended farther offshore and resulted in numerous sightings, often associated with edges of the Gulf Stream and warm-core rings (Waring et al., 2008). The recent surveys also resulted in sightings offshore of the 100-m isobath off the southeastern U.S.

Neither De Kay (1842) nor Linsley (1842) mentioned the Risso's dolphins as occurring in New York or Connecticut. Schevill (1954) reported a sighting of more than 60 Risso's dolphins on 20 August 1952 about 140 km due south of Block Island near the shelf break. That record seemed to be the basis for conjectures about occurrence by Cronan and Brooks (1968), Waters and Rivard (1962), and Connor (1971). Historical stranding records are relatively common in New Jersey and less so in western Long Island. The only other historical sighting in the region was a group of 3 near Hudson Canyon on 29 May 1960 reported by Ulmer (1980).

Atlantic White-sided Dolphin *Lagenorhynchus acutus* (Gray, 1828)

Description: Atlantic white-sided dolphins have robust bodies about 2.5–2.8 m in length; prominent sharp keels on the top and bottom of the tailstock; short, thick beaks; and very prominent, tall, falcate, pointed, broad-based dorsal fins (Jefferson et al., 1993; Reeves et al., 1999a; Wynne and Schwartz, 1999; Cipriano, 2002). Females are about 20 cm shorter than males. The basic color pattern is three-banded, with a black cape, a gray band along the side, and a white belly, all with clear, distinct, relatively horizontal margins. On the flank, below and slightly behind the dorsal fin, there is a brilliant white patch or band below the edge of the cape, which extends up and back into the cape as a yellowish-tan band. The cape extends all the way back from the dorsal fin to the tail, though from above and behind it may look like a narrow black stripe along the dorsal keel between the two yellow bands on the sides. On the beak, the upper jaw is black and the lower is white. The eye is surrounded by a round black patch, which is connected by a narrow black stripe to the upper jaw. There may also be a narrow, less distinct gray stripe from the eye to the black flipper, and there is a black patch around the genital slit.

Status: Atlantic white-sided dolphins are not listed under the U.S. Endangered Species Act or on the Rhode Island state list, and are classified as Least Concern on the IUCN Red List. There are no precise estimates of the number of white-sided dolphins inhabiting the North Atlantic, though the number is roughly estimated as a few hundred thousand (Cipriano, 2002). They were one of the two most abundant dolphins observed during the CETAP studies (the other was the common dolphin), with seasonal abundances off the northeastern U.S. in spring through fall of 38,000 to 42,000 (CETAP, 1982; Kenney et al., 1997). The most recent estimates for the Gulf of Maine and surrounding area have been extremely variable—51,640 in 1999, 109,141 in 2002, 2,330 in 2004, and 17,594 in 2006 (Waring et al., 2008). Kingsley and Reeves (1998) estimated the number in the Gulf of St. Lawrence in 1995 at 11,740.

A directed fishery for Atlantic white-sided dolphins formerly occurred in Norway, and small numbers are taken by subsistence hunters in Greenland (Reeves et al., 1999a). Large numbers were taken in some years in the former pilot whale drive fishery in Newfoundland (Sergeant and Fisher, 1957). In the Faroe Islands, white-sided dolphins continue to be taken in their pilot whale drive fishery, with total takes of 255 in 2000, 546 in 2001, 714 in 2002, and 186 in 2003 (IWC, 2005, 2006).

White-sided dolphins are also taken as bycatch in commercial fisheries (Addink et al., 1997; Couperus, 1997; Palka et al., 1997; Reeves et al., 1999a). The 2001–2005 average annual mortality from incidental take in U.S. Atlantic commercial fisheries was 357, including 31 in sink gillnet fishery, 221 in bottom trawls, 103 in mid-water trawls, and 2 in herring trawls (Waring et al., 2008). There were earlier takes known in swordfish driftnets (fishery now closed), Canadian sink gillnets, and Spanish deepwater trawlers off the Grand Banks.

Ecology and life history: White-sided dolphins generally occur in groups of a few to 50 or 60 animals, with some differences between areas (Reeves et al., 1999a; Cipriano, 2002). In the Gulf of Maine, they appear to travel in tight groups of 6–10 animals that are sometimes loosely associated in larger herds. In the CETAP (1982) data, group sizes ranged from 1 to 800, with a mean of 54.3, but the most frequently observed group size was 8 dolphins. White-sided dolphins are very active, fast-swimming animals, and are known to breach and tail-slap, as well as to bow-ride in front of vessels and surf in their wakes. They have been observed swimming directly in front of large whales, which is thought to be the same bow-riding behavior seen in front of vessels.

White-sided dolphins have been observed in mixed-species aggregations with long-finned pilot whales in eastern Canadian waters, with white-beaked dolphins in the North Sea, and with white-beaked, bottlenose, and common dolphins off Ireland (Reeves et al., 1999a). In the Gulf of

Maine, white-sided dolphins are frequently (i.e., at about a quarter of all sightings) sighted in association with other species known to feed on sand lance and other small fishes, including fin, humpback, and minke whales (CETAP, 1982). This was the most commonly observed multi-species association during the CETAP surveys. The association in this case is fundamentally different from the mixed schools of pilot whales, bottlenose dolphins, and other delphinids seen in offshore waters. In mixed schools of shelf-edge delphinids, they clearly are swimming together in a coordinated group, and the group sizes of each species were not significantly different between associated and non-associated sightings (i.e., a mixed school of, e.g., *Globicephala* and *Tursiops* is simply a typical school of each that have joined together). In the baleen whale/white-sided dolphin associations, group sizes for each species are significantly larger when associated with other species than when not associated, suggested that the multi-species sightings are adventitious groups of animals that occur when each species individually aggregates to feed on the same patchy prey resource, but there is no true interaction.

Mass strandings of white-sided dolphins are relatively common. Such strandings have been known since antiquity, and are probably a naturally occurring phenomenon (Gaskin, 1992). Such occurrences show a clear spatial pattern, with about 85–90% of all stranded white-sided dolphins between North Carolina and Nova Scotia occurring in Massachusetts.

White-sided dolphins do not appear to be deep divers. A satellite-tracked tagged animal made no dive longer than 4 minutes and most of its dives were less than 1 minute (Mate et al., 1994).

White-sided dolphins feed on a wide variety of small fishes and squid, with differences in the species consumed between areas and seasons (reviewed by Reeves et al., 1999a). Sand lance is an important prey in the spring in the Gulf of Maine. Other fish prey include herring, smelt, mackerel, silver hake, and a variety of other gadoids.

Sergeant et al. (1980) and Perrin and Reilly (1994) summarized the available information on life history in white-sided dolphins. Calves are born at around 110 cm long in May to early August, peaking in June–July, however the calving period may be more prolonged in the northeastern Atlantic. The gestation period is 10–12 months. Lactation lasts about 18 months, and about a quarter of mature females are simultaneously pregnant and lactating. The resulting average inter-birth interval is 2–3 years. Sexual maturity in males is at 230–240 cm and 8–9 years of age; females mature at 201–222 cm and 6–8 years old.

Distribution: Atlantic white-sided dolphins and white-beaked dolphins are both found only in the North Atlantic, with broadly overlapping distributions (Rice, 1998; Reeves et al. 1999a, 1999b; Cipriano, 2002; Kinze, 2002). White-sided dolphins are found in temperate to subarctic waters on both sides of the basin, with the northern limits of the range not very clear, but probably very similar to the white-beaked dolphin's—to Newfoundland, Greenland, Iceland, Svalbard, and the North Cape of Norway. The southern distributional limit of white-sided dolphins is further south, at least on the western side of the North Atlantic, where they occur to the mid-Atlantic. Both species occur south to the Bay of Biscay on the eastern side of the basin. In the western North Atlantic, their range extends from the U.S. mid-Atlantic to Greenland. They are common in the Gulf of Maine and Gulf of St. Lawrence, but seem to be relatively rare along the Atlantic coast of Nova Scotia. Palka et al. (1997) suggested that there were separate stocks in the Gulf of Maine, Gulf of St. Lawrence, and Labrador Sea.

Off the northeastern U.S., white-sided dolphins occur regularly from Hudson Canyon east to Georges Bank and north to the Bay of Fundy (CETAP, 1982; Selzer and Payne, 1988; Waring et al., 2008). They are the most common and abundant dolphin in the Gulf of Maine. They occur throughout the Gulf, but are most concentrated in the western portions from the Great South Channel east of Cape Cod to the Maine coast. During the CETAP surveys in 1979–1981, the annual pattern showed strong aggregation between Cape Cod and Georges Bank in the spring, dispersal throughout the Gulf of Maine in summer, a weaker aggregation in the central Gulf in fall, and a near-absence in the winter. The distribution in those years may have been driven by the distribution of sand lance, which were extremely abundant at that time. Strandings in the mid-Atlantic were mainly in the winter, leading to an hypothesis for a winter migration offshore and to the south.

Prior to the 1970s, however, white-sided dolphins were very rarely seen within the Gulf of Maine. A sighting of a small group of about 12 east of Cape Cod was worthy of publication in the *Journal of Mammalogy* (Schevill, 1956), and their range was believed to be centered along the outer edge of the shelf, as is apparently the case off Newfoundland and Europe (Reeves et al., 1999a; Northridge et al., 1997). During the 1970s, white-beaked dolphins were more commonly observed in the Gulf of Maine. Kenney et al. (1996) hypothesized that white-sided and white-beaked dolphins in the Gulf of Maine shifted distributions after drastic changes in the stocks of small pelagic forage fishes caused by commercial fisheries. Intense fishing by foreign fleets in the 1960s and early 1970s caused a major decline in herring stocks, which were replaced by an explosion of sand lance (Sherman et al., 1981). The hypothesis was that white-beaked dolphins preferred herring, and moved east on the Nova Scotian shelf, and white-beaked dolphins shifted from an offshore to inshore habitat to fill the vacated niche. White-sided dolphins appeared in the stranding record in the mid-Atlantic during the 1970s and gradually expanded to the south, which seems to fit that same pattern of an offshore-to-inshore habitat shift, perhaps accompanied by growth of the population.

Neither De Kay (1842) nor Linsley (1842) included the white-sided dolphin as a species occurring in New York or Connecticut. Goodwin (1935) stated that the nearest record to Connecticut was from Cape Cod, Massachusetts. The nearest record Connor (1971) knew of was a stranding in Narragansett Pier, Rhode Island on 22 July 1967, reported by Cronan and Brooks (1968).

Common Bottlenose Dolphin *Tursiops truncatus* (Montagu, 1821)

At least one other species of bottlenose dolphin is recognized—the Indian Ocean bottlenose dolphin, *Tursiops aduncus*, and other species are likely to be (Rice, 1998). In addition, in many areas of the world including the western North Atlantic, there are diagnosable inshore and offshore populations (Mead and Potter, 1990, 1995; Rice, 1998). Off the eastern U.S. the inshore and offshore populations are currently considered to be “ecotypes” or “morphotypes” of a single species for management purposes (Waring et al., 2008). Recent genetic results, however, show them to be sufficiently distinct to be considered separate species (Kingston and Rosel, 2004). The type specimen of *T. truncatus* matches the characteristics of the offshore population;

available names for a separate inshore species include *T. erebennus* (Cope, 1865) and *T. subridens* (Flower, 1884) (Mead and Potter, 1995).

Description: Bottlenose dolphins are the "plainest" and least distinctively marked of all of the beaked dolphins in the North Atlantic (Jefferson et al., 1993; Wells and Scott, 1999, 2002; Wynne and Schwartz, 2002). Body size is extremely variable between populations; adults may be 2–3.8 m long. Offshore animals average about 15% larger than inshore animals along the U.S. Atlantic coast (Mead and Potter, 1995). The body is relatively thick and robust (especially in offshore animals), with a tall, falcate dorsal fin. The beak is well-defined and prominent, of moderate length (shorter than in *Stenella* and *Delphinus*, but significantly longer than in *Lagenorhynchus*), and stout. The body is basically gray to brownish, darkest on the back and lightest on the belly. There may be a clearly visible darker cape, or the color may simply fade gradually from the back to the belly. There may be indistinct stripes on the head or spots, and some animals may have a faint version of the spinal blaze that is seen prominently in striped and Atlantic spotted dolphins. In addition to consistent genetic and biochemical differences, inshore bottlenose dolphins in the western North Atlantic are significantly smaller than offshore animals, are usually lighter-colored, have flippers and beaks that are larger relative to body length, as well as narrower skulls and rostrums, feed on different types of prey, and carry different types of parasites (Hersh and Duffield, 1990; Mead and Potter, 1990, 1995; Hoelzel et al., 1998).

Status: Common bottlenose dolphins are not listed under the U.S. Endangered Species Act or on the Rhode Island state list, and are classified as Least Concern on the IUCN Red List. Coastal bottlenose dolphins along the U.S. Atlantic coast were designated as Depleted under the Marine Mammal Protection Act in 1993 (NMFS, 1993) because of high mortality in a 1987 epizootic (Scott et al., 1988). However, the impact of that event was seriously overestimated because the mortality occurred from Florida to New Jersey, but the only available estimate of abundance was for Cape Hatteras to New Jersey. In addition, no subsequent surveys have been able to detect a decrease in the abundance of coastal dolphins. A review of the depleted designation that is presently applied to all coastal stocks is needed (Waring et al., 2008). There are no reliable estimates of the total abundance of bottlenose dolphins in the North Atlantic. The existence of inshore and offshore populations (or species) and multiple stocks within populations makes it difficult to synoptically survey the entire region or to estimate the abundance of individual components. Mitchell (1975a) estimated the size of the stock subject to the North Carolina dolphin fishery in the 1880s at around 14,000. The CETAP data suggested that there were 11,000–13,000 bottlenose dolphins north of Cape Hatteras in spring and summer, with probably only 1,000 or fewer in the inshore stock (CETAP, 1982; Kenney, 1990). Subsequent surveys have been conducted in both inshore and offshore waters along the entire east coast (Waring et al., 2008). The Atlantic offshore population was estimated at 81,588 dolphins in 2002–2004 from Florida to Georges Bank. The total of all coastal stocks along the Atlantic coast was estimated at about 44,000 animals, including 17,466 in northern migratory stock—the only one that occurs in the mid-Atlantic. Additional bottlenose dolphin stocks occur in the Gulf of Mexico.

Bottlenose dolphins have been the targets of directed fisheries in several areas of the world (Wells and Scott, 1999, 2002; Reeves and Read, 2003). A fishery once existed in several countries around the Black Sea that took both bottlenose dolphins and harbor porpoises for oil, meat, and leather. Dolphin fisheries also exist in Peru, Sri Lanka, and Japan, taking dolphins for food, for bait in other fisheries, and to eliminate perceived competition for declining fish stocks. Recent takes of bottlenose dolphins in coastal small-cetacean fisheries in Japan have been 1,426 in 2000, 247 in 2001, 729 in 2002, 164 in 2003, and 16 in 2004 (IWC, 2005, 2006). There was a bottlenose dolphin fishery in operation at Cape Hatteras, North Carolina at least sporadically from 1797 to 1929 (Mead, 1975). A similar fishery was prosecuted at Cape May, New Jersey in 1884–1885, and one may have operated in the 18th Century or earlier in Long Island, depending on what De Kay (1842) and earlier writers were referring to regarding “porpoise” fisheries. Reeves and Read (2003) provide a good review of the fishery methods. Catches at Cape Hatteras were mostly in spring and fall, with very few in summer; so they were apparently targeting migrating animals moving north or south and not residents.

Another directed effort has been the live-capture dolphin fishery for public display and other purposes (including research and military use) (Reeves and Leatherwood, 1984; Reeves and Mead, 1999; Wells and Scott, 1999, 2002). Over 1,500 were captured between the late 1930s and early 1980s, mostly in the southeastern U.S. A May 2000 inventory by NMFS showed 392 captive bottlenose dolphins in 35 facilities in the U.S. alone, with at least several hundred more in at least 16 other countries.

Bottlenose dolphins are taken incidentally as bycatch in a number of different commercial fisheries around the world (Northridge, 1991; Perrin et al., 1994b; Wells and Scott, 2002). The average annual mortalities in 2001–2005 in U.S. Atlantic waters are summarized in Waring et al. (2008). One observed take of an offshore dolphin in 1991 in the New England sink gillnet fishery extrapolated to an annual average of 26 individuals. Previous takes included an annual average in the swordfish driftnet fishery in 1989–1998 of 31.7 (that fishery is now closed), an average of 38.4 in the pelagic tuna pair-trawl fishery in 1991–1995 (also now closed), and one animal taken in a bottom trawl in 1991 (extrapolated to a total estimated take that year of 91). There was one take in the mid-Atlantic coastal gillnet fishery in 1998 that was probably an offshore animal, and one take in 2001 in the coastal-offshore overlap zone that was not included in the extrapolated estimate for the fishery due to uncertainty as to the stock identity. Annual average takes of coastal bottlenose in the mid-Atlantic coastal gillnet fishery were 233 per year in 1996–2000 and 61 per year in 2001–2005, with all takes in North Carolina and north and most in North Carolina in the winter. Bottlenose dolphins are probably also killed or injured by recreational fishing gear, but it is not well quantified (Gorzelany, 1998; Wells et al, 1998).

Bottlenose dolphins are the most frequently stranded cetacean on the U.S. Atlantic coast—292 in 2003, 359 in 2004, and 284 in 2005 (Waring et al., 2008), occasionally in mass strandings and primarily from New Jersey south. Some proportion of stranded animals bear marks of netting or ropes and were probably killed by entanglement in fishing gear.

Ecology and life history: Bottlenose dolphins are gregarious, usually occurring in small groups of around 2–15 animals, but groups larger than 1000 have been reported (Wells et al., 1999; Wells and Scott, 1999, 2002). They generally are seen in smaller groups in bays and sounds than offshore, but group size is not a linear function of distance from shore. Off the northeastern U.S., the average group size was 14.8, with a mode of 2 and a range of 1–350 (CETAP, 1982), but that combined inshore and offshore sightings.

Group membership is dynamic, with sex, age, reproductive status, kinship, and affiliation history all involved (Wells et al., 1987; Scott et al., 1990; Wells and Scott, 1999, 2002; Connor et al., 2000; Reeves and Read, 2003). The social structure has been called a "fission-fusion" society. Some subgroups are stable for long terms, some may be repeated over periods of years, and others are more ephemeral. The basic social units are nursery schools of adult females and their calves, mixed-sex juvenile schools, and adult males, either solitary or in strongly bonded pairs and trios. Male-male bonds may last for decades, probably to enhance mating success and predator defense (Wells et al., 1987, 1990; Connor et al., 1992). There is no evidence for male coalitions in Moray Firth, Scotland, although those animals would be the same as the U.S. Atlantic offshore stock where there is very little information. Dominance hierarchies are observed in captivity—maintained by aggressive behaviors, including posturing, loud jaw claps, and physical contact.

Bottlenose dolphins commonly occur in mixed-species schools with other cetaceans. Scott and Chivers (1990) reported that bottlenose in the offshore eastern tropical Pacific were seen 16% of the time with one other species and 4% with two or more other species. They associated mostly with short-finned pilot whales, and pantropical spotted dolphins, and also with Risso's, rough-toothed, and spinner dolphins, sperm whales, and others. Norris and Prescott (1961) and Norris and Dohl (1980) similarly reported a common association of bottlenose dolphins and pilot whales in the North Pacific. Offshore bottlenose dolphins off the northeastern U.S. occur in mixed herds at 10% of all sightings, mostly with pilot whales, and also with Risso's, common, and striped dolphins (CETAP, 1982). Mixed delphinid schools often included calves and juveniles of one or both species.

There many reports on the prey of bottlenose dolphins, including observational studies and analyses of stomach contents, mostly dealing with inshore animals (Leatherwood, 1975; Leatherwood et al., 1978; Barros and Odell, 1990; Shane, 1990; Mead and Potter 1990, 1995; Barros and Wells, 1998; Walker et al., 1999; Wells and Scott, 1999, 2002; Reeves and Read, 2003). The dominant prey are fishes, primarily from three families—sciaenids (weakfish, croaker, spot, etc.), scombrids (mackerels), and mugilids (mullets). Mead and Potter (1990) reported 40 different families of bony fishes, plus skates, rays, sharks, squid, shrimp, and isopods in the stomachs of *Tursiops* from the U.S. Atlantic coast. The four principal prey species were all sciaenids, including weakfish (also known as spotted sea trout), Atlantic croaker, spot, and silver perch. Stomachs of offshore animals were dominated by myctophids and squid.

Female bottlenose dolphins give birth after a 1-year gestation to a single calf that is 84–140 cm at birth, with substantial differences between populations (Wells and Scott, 1999, 2002; Reeves and Read, 2003). In Gulf of Mexico coastal dolphins, calves average 110 cm at birth (Fernandez and Hohn, 1998). Calving seasonality varies between populations (Scott et al., 1990; Urian et al., 1996; Fernandez and Hohn, 1998; Connor et al., 2000). In the long-term stranding data, Mead and Potter (1990) recorded neonates of 106–132 cm, and estimated a mean size at birth of 117 cm and 20.4 kg. They reported a mode in neonate strandings in March, and suggested a prolonged calving season with a peak in spring, with no evidence of a fall peak. During the CETAP (1982) study off the northeastern U.S., bottlenose calves were seen all year, recorded at 12% of sightings in spring, 12% in summer, 16% in fall, and 5% in winter. Thayer et al. (2003) reported that neonate strandings in North Carolina peaked in April–May and were lowest in fall and winter, but that births to known females were in May–June with one in fall. They speculated that the differences could be because of the presence of multiple stocks, or due to bias because out of season births may be more likely to lead to neonate mortality.

Mothers and calves rarely separate during the first few months (Mann and Smuts, 1998). A calf may nurse for several years, but begins foraging independently during its first or second year, maybe as young as four months (Wells et al., 1987; Wells and Scott, 2002). A calf is generally weaned completely at around the time the mother gives birth to the next calf, with overall duration a function of the age, nutritional condition, and social status of the mother (Wells et al., 1987; Mann et al., 2000; Whitehead and Mann, 2000; Wells and Scott, 2002). The typical inter-birth interval is 3–6 years (Scott et al., 1990; Wells and Scott, 2002).

The mating system in both species of bottlenose dolphins appears to be promiscuous with "roving" males (Wells et al., 1987, 1999; Scott et al., 1990; Connor et al., 1992; 2000; Wells and Scott, 1999, 2002). Associations between males and females are extremely short-term. Coalitions of males travel more widely than any other groups, fighting for access to receptive females. Older males tend to be heavily scarred from fighting. In Australia, *T. aduncus* male coalitions aggressively separate receptive females from their bands and herd them away, which has not been observed in other populations.

In 1987–1988, there was a mass mortality of bottlenose dolphins along the U.S. Atlantic coast between New Jersey and Florida, which killed at least 740 animals (Scott et al., 1988). It was estimated at the time that the event killed 50% of the coastal migratory stock of *Tursiops*, however the only available abundance estimate (from CETAP, 1982) was for a much smaller area than that impacted by the epizootic. The dolphins died acutely from a wide variety of opportunistic viral and bacterial infections, but the underlying cause was first attributed to immune suppression caused by ingestion of prey containing a "red tide" toxin—brevitoxin produced by the dinoflagellate *Karenia* (formerly *Ptychodiscus*) *brevis* (Geraci, 1989). That finding was never widely accepted, particularly since there was no published literature showing a chronic immuno-suppressive effect of brevitoxin. In addition, bottlenose dolphins feed high on the food chain and could be subject to bioaccumulation of toxic contaminants. Animals in U.S. Atlantic waters have high concentrations of PCB's and PBB's (Kuehl et al., 1991; Lahvis et al., 1995). Organochlorines, even at relatively low levels, have the potential to affect immune response and may play a part in the apparent in increase in disease outbreaks (O'Shea et al., 1999; Wells and Scott, 2002). Males tend to accumulate higher loads than females, who reduce their own levels by transfer in milk lipids to their calves. In South African bottlenose dolphins, it was estimated that first-born calves received 80% of the mother's body burden of PCB's and dieldrin (Cockcroft et al., 1989). Subsequent reanalysis of archived tissue samples has suggested that morbillivirus may have played a role in the 1987–88 epizootic (Lipscomb et al., 1994). Morbillivirus has also been implicated in other bottlenose dolphin epizootics in the Gulf of Mexico (Duignan et al., 1996; Lipscomb et al., 1996).

Distribution: Bottlenose dolphins occur in temperate and tropical waters of all oceans of the world, as well as in the Mediterranean, Black, and Red Seas (Rice, 1998; Wells and Scott, 1999, 2002; Reeves and Read, 2003). The limit of the distribution in the Southern Hemisphere is around 40ºS. The distribution in the North Pacific extends north to the Sea of Okhotsk and Kuril

Islands in the west and to central California in the east. Because of very extensive surveys undertaken to assess the stocks of dolphins impacted by the tuna purse-seine fishery, there are substantial numbers of sightings of bottlenose dolphins across an immense area of the eastern tropical Pacific—as far as 3,000 km and more offshore (Scott and Chivers, 1990). In the North Atlantic their range extends north to southern Greenland, Iceland, and northern Norway. In the western North Atlantic, bottlenose dolphins occur from the equator north to at least Nova Scotia, with some records to Newfoundland.

Within that overall distribution, the picture is complicated by the existence of multiple species, populations, and/or stocks. Surveys in 1979–1981 showed clearly separated inshore and offshore bottlenose dolphins off the northeastern U.S. (CETAP, 1982; Kenney, 1990). There was one band of sightings very close to shore from Cape Hatteras to Delaware Bay and southern New Jersey, and a second band along the shelf break from Cape Hatteras to the Nova Scotian shelf, with scattered sightings far offshore in deep water. In the vicinity of Cape Hatteras, where the continental shelf becomes quite narrow, the two areas of sightings overlapped. South of Cape Hatteras the presence of coastal bottlenose dolphins was well known, but the continuous distribution of the offshore stock was not clear until NMFS conducted marine mammal stock assessment surveys beginning in the 1990s (Waring et al., 2008). The inshore and offshore dolphins are distinct, and possibly represent two different species (reviewed above). Kenney (1990) suggested that inshore and offshore dolphins could be split spatially by partitioning sightings into classes in waters deeper or shallower than 25 m, however no simple scheme has been successful. Torres et al. (2003) analyzed *Tursiops* skin biopsies collected both inshore and offshore from Florida to Georges Bank by incorporating the genetic results into a spatial model. Within 7.5 km from shore, only inshore animals were sampled. In areas more than 34 km offshore and in water deeper than 34 m, only offshore animals were sampled. In between was the "gray zone" where both types can occur, and there were three locations where both types were biopsied within the same school.

On top of the inshore-offshore pattern there is also a definite seasonal pattern to bottlenose distribution off the northeastern U.S. (CETAP, 1982; Kenney, 1990). Offshore dolphins occurred on the outer shelf along the entire study area from Hatteras to southern Nova Scotia in spring and summer. In the fall the distribution became sparser in the northern half of that range. In winter, sightings of offshore dolphins were very sparse, but still scattered along the entire shelf break. The seasonality was much more dramatic in the inshore distribution, which extended to Delaware Bay in spring and summer, contracted to Virginia and south in fall, and contracted completely to south of Hatteras in winter.

The bottlenose dolphin was not included by De Kay (1842) as part of New York's marine mammal fauna, unless it had been confused or inadvertently combined with the "common porpoise." Connor (1971) summarized a number of published and anecdotal records of bottlenose dolphins along the shores of Long Island and nearby, indicating that the species was rather common.

Short-beaked Common Dolphin *Delphinus delphis* Linnaeus 1758

Rice (1998) recognized three different species of *Delphinus*—the short-beaked common dolphin

(*D. delphis*), the long-beaked common dolphin (*D. capensis*), and the Indian Ocean common dolphin (*D. tropicalis*), which may actually be a longer-beaked subspecies of *D. capensis* endemic to the Indian Ocean (Heyning and Perrin, 1994; Jefferson and Van Waerebeek, 2002). Only *D. delphis* is known from the North Atlantic (Heyning and Perrin 1994; Perrin 2002c).

Description: Common dolphins have the typical form of oceanic dolphins, with a streamlined fusiform body, a distinct beak that is separated from the melon by a crease, and a prominent dorsal fin (Jefferson et al., 1993; Evans, 1994; Wynne and Schwartz, 1999; Perrin, 2002c). Short-beaked common dolphins are slender, and range up to 2.3–2.6 m in length, with males slightly larger than females. Their color pattern is striking and distinctive. William Perrin developed a scheme for systematically classifying the pigmentation patterns of small cetaceans (summarized in Perrin, 2002b). There are two areas of dorsal pigmentation—the "cape," which is generally smaller and more anterior, and the "dorsal overlay," which is larger and extends farther posteriorly. The overlap of the two results in the typical pattern for a particular species. In common dolphins the cape is yellowish-tan, with a lower margin that runs back from the forehead crease, just below the eye, slightly downward to a lowest point between the flippers and the dorsal fin, then curves up to the back midway between the dorsal fin and the tail. The dorsal overlay is light gray; its lower margin starts on the forehead, curves upward over the eye to its highest point in front of the dorsal fin, then curves back downward to the belly in the area of the genital slit. Where the two areas overlap, the color is dark gray to black, resulting in a dorsal field that is a rather narrow band from the head back that widens to a sharp point directly below the dorsal fin (the "saddle," where the margins of the cape and the dorsal overlay cross), then narrows to a point on the mid-back behind the dorsal fin. Anterior to the saddle the color on the side is yellowish tan (the cape alone), posterior to it and onto the back near the tail the color is gray (dorsal overlay alone). The belly is white. There is a prominent black blaze extending upward and forward from the genital slit to near the point of the saddle, which is thinner and paler in females. The complex pattern on the side of the animal gives rise to the alternative common names saddleback, hourglass, and criss-cross dolphin. The dorsal fin is tall, falcate, in the middle of the back, and black, often with a paler gray center. The lips, flippers, flukes, and a small circle around the eye are black. There are thin black stripes from the upper beak to the eye, and from chin to the flipper.

Status: Short-beaked common dolphins are not listed under the U.S. Endangered Species Act or on the Rhode Island state list, and are classified as Least Concern on the IUCN Red List. There is no estimate for the total abundance of short-beaked common dolphins in the North Atlantic. The CETAP (1982) survey results showed that common dolphins were one of the most abundant cetaceans off the northeastern U.S., with about 45,000 present in winter. More recent surveys (all in the summer) estimated a smaller population, until a summer shipboard survey from Florida to the Bay of Fundy in 2004 resulted in an estimate of 120,743 common dolphins (Waring et al., 2008).

There was a directed fishery (for human consumption) on common dolphins, bottlenose dolphins, and harbor porpoises in the Black Sea (Evans, 1994). The fishery began in the late 19th Century, and was conducted by Turkey, the Soviet Union, Romania, and Bulgaria. Tens of thousands of animals were taken annually, with peak kills perhaps as high as 200,000. The fishery ended in 1966, except in Turkey where it continued to 1983.

Common dolphins are taken incidentally in a number of commercial fisheries worldwide, in particular in gillnets (Perrin et al., 1994b) and in the eastern tropical Pacific tuna purse-seine fishery (Allen, 1985; NRC, 1992; Gosliner, 1999; Gerrodette, 2002). In the western North Atlantic, common dolphin bycatch mortalities occur in a number of different fisheries (Waring et al., 2008). The pelagic swordfish driftnet fishery killed an average of 303 annually in 1989–1998, but has since been shut down. An experimental mid-water pair-trawl fishery for tuna killed 16 per year in 1991–1995, but it has also been closed. The most recent five-year average fishery-related mortality of common dolphins for U.S. Atlantic waters was 151 per year for 2001–2005, primarily in trawl fisheries, with a few in sink gillnets.

Ecology and life history: Common dolphins are known to aggregate into extremely large herds at times, however those schools are composed of smaller groups of 20–30 related individuals (Evans, 1994; Perrin, 2002c). Large herds chased during tuna fishing operations would break up into successively smaller groups, but the smallest groups of 20–30 animals remained tightly aggregated and never separated. Offshore fishermen tell of seeing herds of common dolphins on Georges Bank that take hours to pass by. Off the northeastern U.S. in 1979–1981, the average group size sighted was 54.8 dolphins, but the average was skewed by a few sightings of groups as large as 2000 individuals (CETAP, 1982). The modal group size was 8 animals. Off the northeastern U.S. they were sighted in mixed groups less often than a number of other species (CETAP, 1982). Other cetaceans with which they were associated on four or five occasions included fin whales, pilot whales, striped dolphins, and Risso’s dolphins.

Common dolphins do not appear to be deep divers. Tagging studies show that most dives are to less than 50 m, with a few dives to as deep as 200 m.

Common dolphins feed on small fishes and squids, including species that school in near-surface waters and mesopelagic species that occur near the surface at night (Evans, 1994; Perrin, 2002c). Tagging studies in the North Pacific showed that foraging dives commenced at dusk and continued all night long. They were apparently feeding on deep-scattering layer fishes (dominated by myctophids or “lanternfishes”) that migrate upwards at dusk and return to mid-depths at dawn, as well as on the squid that were also feeding on the small fishes. Hassani et al. (1997) looked at the stomach contents of common and striped dolphins taken as bycatch in a pelagic driftnet fishery in the northeastern Atlantic. Both species fed primarily on squid (50% or more of the prey items). Secondary prey in common dolphins, about equal in occurrence, were crustaceans (shrimp and krill) and fish (especially myctophids). Major (1986) reported a school of common dolphins on the southern edge of Georges Bank attacking and feeding on squid that had been lured near a research vessel at night by bright lights.

Most information about reproduction and life history comes from populations where large numbers were taken in directed fisheries, as in the Black Sea, or as bycatch in commercial fisheries, as in the eastern tropical Pacific (Evans, 1994; Perrin, 2002c). Sexual maturity occurs at 6–7 years and 195–208 cm in females, and 7–12 years and about 200 cm in males. Ages at maturity appear to be significantly lower in the Black Sea, possibly a density-dependent response to high exploitation rates. Gestation is 10–11 months. Calves are born at about 80–90 cm in length, and wean in about 5 or 6 months, but begin feeding on solid food as young as 2–3 months. In the Pacific, there are two peaks in calving, in the spring and fall. At any one time, about 10% of adult females off California are "resting" (i.e., neither pregnant nor lactating); in the eastern tropical Pacific the proportion of resting females is about 17% in fall and winter and 30% in spring and summer.

Distribution: Common dolphins occur in tropical to temperate waters around the world, although understanding of distributional details is somewhat muddied by questions of species identity in the older data (Evans, 1994; Rice, 1998; Perrin, 2002c). Evans (1994) shows the Atlantic distribution as continuous from Norway to equatorial west Africa on the east and in Iceland, Greenland, Labrador, and Newfoundland, then continuous to Argentina in the west, but that includes both *D. delphis* and *D. capensis*. In the western North Atlantic, common dolphins occur from Iceland south, but the southern limit of the distribution is unclear and appears to vary between years. Older reports of common dolphins off Florida or in the Gulf of Mexico and Caribbean are likely to be misidentifications of Clymene dolphins (Jefferson et al., 1992; Jefferson, 1997; Jefferson and Curry, 2003). Off the northeast U.S., common dolphin sightings occur over the outer half of the continental shelf and continental slope from North Carolina to Nova Scotia, with occasional sightings in shallower waters in the Gulf of Maine (CETAP, 1982; Waring et al., 2008). Of all of the shelf-edge odontocetes of the region, common dolphins occurred in the zone closest to shore, a habitat they shared with pilot whales and offshore bottlenose dolphins (CETAP, 1982; Kenney, 1990). In the overall record for the broader mid-Atlantic, common dolphins are the most frequently stranded delphinid in Rhode Island and New York; while in New Jersey and south bottlenose dolphins are much more common.

Common dolphins have an atypical seasonal pattern off the northeastern U.S., with peak abundance in winter—very different from all other dolphin species (CETAP, 1982; Selzer and Payne, 1988). In spring during 1979–1981, intermediate densities of common dolphins occurred along the entire outer shelf from Virginia to Georges Bank. Sightings were widely scattered in summer, with very low densities. The animals were thought to move north and east along the Nova Scotian shelf, however recent surveys did not observe substantial numbers of common dolphins there (Waring et al., 2008). Perhaps they move even farther north and east, or more offshore. In the fall, they were concentrated on Georges Bank in very high densities, extending west to about the longitude of Montauk Point. They reached their peak abundance in the winter, when they were again distributed all along the outer shelf from Virginia north.

De Kay (1842) listed common dolphins as part of the New York fauna, but said they rarely came into shallow water. Linsley (1842) reported that they occurred in Long Island Sound, which Goodwin (1935) extrapolated to "it is probably not an uncommon visitor to the shores of this state [i.e., Connecticut]." Connor (1971) summarized a number of sighting, stranding, and capture records for New York from a variety of sources. Of note was the occurrence of a herd of 30–40 common dolphins seen in the Hudson River in October 1936, almost as far upriver as Albany (Stoner, 1938).

Striped Dolphin *Stenella coeruleoalba* (Meyen, 1833)

Description: Striped dolphins are typical of all the *Stenella* species in size and shape, and are very distinctively patterned (Jefferson et al., 1993; Perrin et al., 1994c; Archer and Perrin, 1999;

Wynne and Schwartz, 1999; Archer, 2002). They are slender and long-beaked, with tall falcate dorsal fins. Adults are up to 1.5–2.5 m long, with the largest animal known at 256 cm. Animals in the Mediterranean may be somewhat smaller than those in the North Atlantic. The cape is dark blue-gray, very narrow above the eye and widest in front of the dorsal fin (at about the midpoint of the flipper), and ends less than halfway back from the dorsal fin to the tail. There is a prominent pale band (the spinal blaze) extending from just above the flipper upward and backward into the cape toward the dorsal fin. Below and behind the cape, the sides and back are lighter gray, fading into a whitish (sometimes pink) belly. The upper beak is black, and the lower is gray to black. There is a bold black stripe from the upper jaw to the eye, where it divides into one stripe to the flipper, often a short thin stripe ending above the flipper, and a very bold stripe extending the length of the body back to the anus.

Status: Striped dolphins are not listed under the U.S. Endangered Species Act or on the Rhode Island state list and are classified as Least Concern the IUCN Red List. There are no reliable estimates of the total abundance of striped dolphins in the North Atlantic. The first abundance estimate off the U.S. Atlantic coast was from the CETAP (1982) surveys, which estimated that there were 4,300 striped dolphins in the spring. That number was negatively biased for two reasons. The CETAP study used only aerial surveys for estimating abundances, and many aerial sightings could only be identified to *Stenella* sp. Secondarily, the aerial surveys were almost entirely limited to continental shelf waters, and the majority of the striped dolphin sightings during the program were beyond the shelf (by shipboard observers). Kenney et al. (1997) attempted to address the first of those negative biases by partitioning the estimated abundances of unidentified *Stenella* sp. based on the proportions of identified sightings of striped, spotted, and spinner dolphins, which derived striped dolphin estimates of 6,491 in winter, 12,025 in spring, 16,320 in summer, and 13,482 in fall. More recent NMFS surveys for marine mammal stock assessments (Waring et al., 2008), using shipboard surveys that extended well beyond the edge of the shelf, produced estimates of striped dolphin abundance off the U.S. east coast of 49,945 in 1998 and 94,462 in 2004, with an additional 6,505 in the Gulf of Mexico.

There has been a directed small-cetacean fishery in a number of coastal villages in Japan, with records back to the mid-19th Century but probably dating back to at least the early 15th Century (Perrin et al., 1994c; Archer and Perrin, 1999). Takes averaged 8,000–9,000 annually along one section of the coast, and overall takes were about 14,000 per year, during the 1940s and 1950s, with peak catches of over 21,000 in 1942 and 1959 (Kishiro and Kasuya, 1993). Recent takes of striped dolphins in coastal small-cetacean fisheries in Japan were 300 in 2000, 484 in 2001, 642 in 2002, and 450 in 2003 (IWC, 2005, 2006). There have also been directed harvests in the Lesser Antilles and in the Mediterranean (Archer, 2002).

Mortality of striped dolphins as bycatch in commercial fisheries has been observed in a number of locations around the world (Archer and Perrin, 1999; Archer, 2002), including the Pacific tuna purse-seine fishery. There was no known bycatch mortality of striped dolphins in U.S. Atlantic commercial fisheries in 2001–2005 (Waring et al., 2008). In previous years, there was bycatch estimated in two fisheries. Two striped dolphins were killed in the bottom trawl fishery in 1991, which extrapolated to an estimated mortality for the entire fishery of 181 animals. The average annual striped dolphin mortality in the pelagic swordfish driftnet fishery in 1989–1998 (now closed) was 17.

A dolphin morbillivirus epizootic in the western Mediterranean Sea killed over 1,100 striped dolphins in 1990–1992 (Aguilar and Raga, 1993; Perrin et al., 1994c). A later survey estimated the Mediterranean population of striped dolphins at 225,000, which would suggest that the mortality rate from the epizootic was relatively insignificant (less than 0.5%). Toxic contaminants, particularly organochlorines, were suspected to have played a role, acting as an immunosuppressant that then allowed a naturally occurring virus to cause disease (Aguilar and Raga, 1993; Aguilar and Borrell, 1994). Blubber PCB levels as high as 2,500 ppm were measured in the stranded striped dolphins during that event, which were among the highest levels ever recorded in a cetacean.

Ecology and life history: Striped dolphins are gregarious and may be observed in very large herds. In the eastern tropical Pacific average school size was 28–83 animals (Wade and Gerrodette, 1992). The mean school size in Japan is about 100, while in the eastern North Atlantic it is only 10–30 (Perrin et al., 1994c; Archer and Perrin, 1999). The average school size observed off the northeastern U.S. was 64.9 (CETAP, 1982), with a range 1 to 500. This was the largest average school size of all species observed, nevertheless the modal group size was still relatively small at 20.

Striped dolphins are known to segregate into juvenile, adult, and mixed schools, and adult and mixed schools can be either breeding or non-breeding (Miyazaki and Nishiwaki, 1978; Perrin et al., 1994c; Archer and Perrin, 1999). Calves leave the mixed schools 1–2 years after weaning and join juvenile schools. Within breeding schools there are structured subgroups of only adult males or adult females.

Striped dolphins are very active and acrobatic, with frequent leaps, spins, and somersaults, and they may bow-ride (Perrin et al., 1994c; Archer and Perrin, 1999; Archer, 2002). They are known for an aerial behavior called "roto-tailing," which involves making a high jump while rapidly rotating the tail.

Striped dolphins sometimes associate with yellowfin tuna in the eastern tropical Pacific, but less than short-beaked common dolphins and much less than spinner or pan-tropical spotted dolphins (Archer and Perrin, 1999). They are known to occur commonly in mixed schools with short-beaked common dolphins off Japan and in the Mediterranean. Off the northeastern U.S. they were observed to be associated with other species only on a few occasions, usually with common dolphins (CETAP, 1982). Globally, striped and short-beaked common dolphins tend to occur in areas where spinner and pan-tropical spotted dolphins do not (Perrin et al., 1994c).

Mass strandings are rarely observed in striped dolphins (Archer, 2002). There was a stranding of a group of 12 striped dolphins in North Carolina in 2005 (Waring et al., 2008).

Striped dolphins overall feed on a very wide variety of fish and squid, including both pelagic and benthic species, with sharp differences among geographic regions (Perrin et al., 1994c; Archer and Perrin, 1999; Archer, 2002). The dominant prey items off Japan are mesopelagic myctophids ("lanternfishes"). In the northeastern Atlantic their main prey is cod, and in the Mediterranean they primarily eat squid. Extrapolating from prey species, they may commonly dive to 200–700 m for foraging. Stomachs of all stranded specimens examined in Long Island have contained squid beaks, suggesting a preference for squid in the Rhode Island study area (S. S. Sadove, pers. comm.).

Hassani et al. (1997) looked at the stomach contents of common and striped dolphins taken as bycatch in a pelagic driftnet fishery in the northeastern Atlantic. Both species fed primarily on squid, which comprised nearly 60% of the prey items in striped dolphins. Secondary prey in striped dolphins were crustaceans (shrimp and krill, about a third of diet), and fish were a relatively minor component.

The majority of the life-history data are derived from animals taken in the directed fishery in Japan, with additional data from animals caught in the tuna fishery (Perrin et al., 1994c; Archer and Perrin, 1999; Archer, 2002). Calves are born at 93–100 cm in length after a gestation period of 12–13 months. Calving may occur at almost any time of year with one or two diffuse peaks—winter and summer off Japan, spring or spring and fall in other areas. Lactation lasts for 1–1.5 years. Off Japan, calves grow to an average length of 166 cm at age 1, and to 180 cm at age 2. Between 2 and 3 years of age, males and females diverge in body size, with males growing larger and typically exceeding females by 10–15 cm as adults. Mean length at sexual maturity in females is 2.1–2.2 m. Maturity in females occurs at 5–13 years of age and in males at 7–15. Fecundity in females declines markedly at around age 30, but reproduction does not stop completely. In striped dolphins in Japan, the female age at maturity declined from 9.7 to 7.2 years, and the inter-birth interval dropped from 4 to 3 years, with both believed to be density-dependent responses to population declines caused by the small-cetacean fishery.

Distribution: Striped dolphins are distributed world-wide in temperate to tropical waters, although the distribution is poorly known in the South Atlantic where research has been sparse (Perrin et al., 1994c; Rice, 1998; Archer and Perrin, 1999; Archer, 2002). In the North Atlantic, they have the most temperate distribution of the five *Stenella* species, extending from northern South America to New England and Nova Scotia and from the Mediterranean to the British Isles. They are the most commonly sighted cetacean in the Mediterranean. There are a few sightings from Newfoundland, southern Greenland, Iceland, and the Faroe Islands, which may be extralimital. Striped dolphins are frequently sighted off the northeastern U.S. and Nova Scotia (CETAP, 1982; Gowans and Whitehead, 1995; Waring et al., 2008). Their distribution off the northeastern U.S. during the CETAP surveys was primarily along the outer shelf and into deeper waters, despite the very strong bias of the sampling to the shelf. Unlike all other cetaceans of the region, there was very little seasonal pattern to their distribution. In addition, their depth distribution in the CETAP data was significantly deeper than any other species, with an average sighting depth of 2,076 m and with 90% of the sightings between 101 and 3,749 m. There have been no sightings south of Cape Hatteras during any of the recent NMFS surveys, although there are strandings in Florida to North Carolina and striped dolphins do occur in the Gulf of Mexico (Waring et al. 2008). Nothing is known of stock structure, e.g., whether the animals seen in the Gulf of Mexico and off the northeastern U.S. come from the same or separate stocks.

Striped dolphins were not mentioned in De Kay (1842), Linsley (1842), or Goodwin (1935). Connor (1971) reported two historical stranding records for Long Island—in May 1929 at Bellport and on 6 May 1967 on the north side of Queens County near the Throgs Neck Bridge.

The Harvard Museum of Comparative Zoology has a specimen from a 62-kg animal collected about 150 km south of Block Island on 27 July 1961 by M. R. Bartlett (MCZ51071).

Pinnipeds

Pinnipedia includes three families of marine Carnivora that are characterized by retention of all four limbs as flattened, simplified flippers—Phocidae (seals), Otariidae (sea lions and fur seals), and Odobenidae (walrus). Pinnipeds are not as completely adapted to the marine habitat as are cetaceans or sirenians, since all species must leave the water to give birth, either to a terrestrial habitat or onto sea ice. Recent morphological and molecular studies have concluded that Pinnipedia belongs within Order Carnivora, Suborder Caniformia (Rice 1998; Wozencraft 2005).

Phocids are sometimes referred to as "hair seals," "earless seals," or "true seals." Phocids and otariids differ in a number of anatomical and life-history characteristics, with the walrus often intermediate (see Table 4 in Riedman, 1990 for a more detailed review). Otariids possess external ear pinnae, which are absent in seals and walrus. Seal flippers are completely furred with well-developed terminal claws. The hind-flippers are oriented directly backwards with opposed soles, and cannot be rotated underneath the body for locomotion on land, which is accomplished by caterpillar-like wriggling. In water, seals swim via alternating, lateral strokes of the hind-flippers, while using the fore-flippers mainly for maneuvering. Sea lions and fur seals have at least partially furless flippers with more rudimentary, subterminal claws. The pelvis and hind limbs can rotate underneath the body for walking on land. In water, they swim by simultaneous flapping of the long fore-flippers and use the hind limbs more as rudders. Seal coats have little underfur, and a seal is insulated by a thick layer of blubber. Fur seals have dense underfur for thermal insulation and the least developed blubber layer, while sea lions have less dense underfur and moderately thick blubber. The walrus moves on land like a sea lion and in the water like a seal. It is essentially hairless with thick blubber. Seal pups grow extremely fast and wean quickly. The mother fasts completely during lactation in almost all species. In otariids and walrus, lactation can last two years or more, pup growth is slower, and the mother feeds during lactation.

There are no sea lions or fur seals in the North Atlantic. Pinnipeds of the North Atlantic and adjacent waters include the walrus and nine species of Phocidae. Only five seal species are confirmed as occurring in southern New England. Three seal species have (or had) very restricted distributions—the Caspian seal (*Pusa caspica*), Mediterranean monk seal (*Monachus monachus*), and Caribbean monk seal (*Monachus tropicalis,* extinct since the mid-20th Century). The walrus (*Odobenus rosmarus*) and bearded seal (*Erignathus barbatus*) have Arctic distributions and occur rarely in U.S. waters but not south of Cape Cod. Although De Kay (1842) wrote that walrus "were formerly numerous on our coast, but are now scarcely ever found south of Cape Sable," there is no evidence to support his conjecture. Historical walrus breeding populations in the Gulf of St. Lawrence and on Sable Island off Nova Scotia were extirpated in the early 18th Century (Lavigne and Kovacs, 1988). The nearest recorded walrus occurrences to New York were in Massachusetts in 1734 and 1937 (Cardoza et al., 2006). Similarly, there is a bearded seal stranding record in Massachusetts in 2002 (Sardi and Merigo, 2006), but none in the mid-Atlantic.

The five seal species known to occur in southern New England are harbor seal (covered below in detail), gray seal (*Halichoerus grypus*), harp seal (*Pagophilus groenlandicus*), hooded seal (*Cystophora cristata*), and ringed seal (*Pusa hispida*). With the exception of harbor seals, they are known almost entirely from strandings, both live and dead. Harbor seals are the only seals truly resident in the region, occurring from fall through spring from Cape Cod to New Jersey. Gray seals are primarily recently weaned young juveniles dispersing in the spring from pupping areas on sandy islands near Nantucket and Cape Cod. Both harp seals and hooded seals primarily occur as starved or starving yearlings following their first winter, dispersing from pupping areas on the ice near Newfoundland and Greenland. Since the mid-1990s, harp seals have been the most common stranded marine mammal in the mid-Atlantic. Ringed seals are high-Arctic residents known from very rare strandings and sightings in Long Island.

Harbor Seal *Phoca vitulina* Linnaeus, 1758

Description: Harbor seals are relatively small animals, with adults 1.7–1.9 m long (Jefferson et al., 1993; Wynne and Schwartz, 1999). Males are slightly larger than females. Harbor seals vary in color from very light gray or tan to brown to almost black, with extensive spotting. The basic spotting pattern is light with dark spots. In some individuals the spots coalesce, particularly on the back, giving the appearance of a dark color with sparse, light mottling. In general the belly is lighter than the back. Whether an individual is wet or dry will greatly change its appearance, with completely dry individuals often light-colored. Pups shed their white fetal coat (lanugo) in utero and are born with the same spotted coat pattern as adults. A harbor seal has a rounded head with a concave puppy-like face and only a short distance from eyes to nose. Nostrils are close together at the bottom and look like the letter “V” when seen from head-on.

Status: Harbor seals are not listed under the U. S. Endangered Species Act or on the Rhode Island state list, and are classified as Least Concern on the IUCN Red List.

A peak count of 271 harbor seals between the Massachusetts-Rhode Island border and eastern Long Island Sound was reported for March 1987 (Payne and Selzer, 1989). They suggested an upper bound of 374 based on their highest counts at each haul-out. Only Fishers Island, New York consistently had more than 50 animals, with a peak of 101 in March 1986. Schroeder (2000) estimated that the total number present in Narragansett Bay in 1999 was between 825 and 1,047. Ronald and Gots (2003) reported that the total seal count in southern New England in the spring of 1999 was nearly 6,100 animals.

The increase in harbor seals south of Cape Cod parallels that observed in the population’s breeding range along the Maine coast. Gilbert et al. (2005) used aerial surveys to count seals hauled out on ledges along the entire Maine coast, and used radio-tagging data to correct for the proportion of seals hauled out at any given time. Between 1981 and 2001, seal counts increased from 10,543 to 38,014 (6.6% per year). Counts of pups increased at an even higher annual rate of 14.4%. The corrected estimate of the total abundance of harbor seals in Maine in late May and June of 2001 was 99,340 (95% CI = 83,118–121,397). The number of ledges used as haul-out sites also increased over that span of years, from 336 to 556, with the number used as pupping sites growing from 186 to 496.

Harbor seals were hunted by Native Americans for subsistence, then by early European settlers for oil, meat, and leather (Lavigne and Kovacs, 1988). In recent times, commercial hunting has never been of any great importance. Seals are commonly perceived as competitors for commercially valuable fish stocks. Bounties were paid on harbor (and gray) seals in both Maine and Massachusetts into the 1960s, resulting in depletion of the population overall and its extirpation from pupping sites in Massachusetts (Katona et al., 1993). Bounty payments in New Brunswick, Canada persisted until 1976 and were re-instituted in at least two years in the 1980s (Terhune, 1985). Harbor seals were also hunted for sport in the U.S. prior to passage of the Marine Mammal Protection Act in 1972, as reported for eastern Long Island by Connor (1971).

Harbor seals are taken as by-catch in a variety of U.S. and Canadian commercial fisheries, including gillnets, drift nets, long-lines, bottom trawls, midwater trawls, purse seines, trammel nets, fish traps, herring weirs, and even lobster traps (Woodley and Lavigne, 1991; Waring et al., 2008). The 2001–2005 estimate of average numbers of harbor seals killed annually in the northeastern U.S. sink gillnet fishery was 882, plus an undetermined number in the bottom trawl fishery. It is as yet unclear how much of the U.S. fishery-related mortality represents seals from breeding sites in the U.S. versus Canada. Other known sources of human-related mortality in the northeastern U.S. and Canada include boat strikes, entrainment in power plant intakes, entanglement in aquaculture facilities, and intentional shooting.

More is known about disease as a population impact for harbor seals than for other marine mammals (Bigg, 1981). A relatively large number of diseases are known, and there have been several significant epizootics. Epizootics where the underlying cause was never determined were reported in Iceland in 1918 (Dietz et al., 1989b) and in the Shetland Islands in the 1920s (Bonner, 1972). There have also been several recent epizootics where the cause has been determined.

At least 500 harbor seals died in New England in 1979–80 (Geraci et al., 1982). The epizootic began in Cape Cod Bay in December 1979 and spread north along the Maine coast. The animals died from bacterial pneumonia caused by *Mycoplasma* spp. These bacteria are normally present in healthy seals, and can cause an infection known as “seal finger” in humans who have been bitten by a seal (Hartley and Pitcher, 2002; Mazet et al., 2004). At least three different species have been isolated from harbor seals or humans bitten by harbor seals (Geibel et al., 1991; Ruhnke and Madoff, 1992; Baker et al., 1998). The seals that contracted pneumonia were also infected with a strain of influenza A, and the hypothesized explanation was that the influenza lowered their immune response to the *Mycoplasma*.

There was a second, smaller epizootic in New England harbor seals in 1982 that killed only about 60 animals (Hinshaw et al., 1984). It was first recognized in Narragansett Bay. In that case, the underlying cause was a different strain of influenza A virus that normally is found in birds.

The most significant epizootic to date in harbor seals occurred in the North Sea in 1988, killing about 18,000 seals (Dietz et al., 1989b; Heide-Jørgensen et al. 1992). It began in April on Anholt Island in the Kattegat between Denmark and Sweden. It spread from there to the north along the coast of Norway and west to the Netherlands, Great Britain, and Ireland. Seal counts declined by 60% in the Kattegat and Skagerrak. Some areas experienced 90% mortality in 40–60 days, and in the Wadden Sea the number of carcasses recovered exceeded the highest previous aerial survey count. The highest incidences occurred in areas where seals had congregated for pupping or molting, with less severe outbreaks where first introduced in the fall. The immediate cause of mortality was acute bacterial pneumonia, with *Bordetella bronchisepta* an important cause. There were secondary infections by herpes and picorna viruses, but the underlying cause appeared to be a morbillivirus. It was first identified as canine distemper virus (CDV) (Dickson, 1988; Osterhaus et al., 1988). Eventually the infectious agent was identified as a closely related morbillivirus now called phocine distemper virus (PDV) (Cosby et al., 1988; Osterhaus and Vedder, 1988). Dietz et al. (1989a) tested samples from 40 harp seals and 90 ringed seals collected in Greenland in 1985, prior to the 1988 epizootic, for the presence of antibodies to CDV, and found 30% positive in the harp seals and 4% in the ringed seals. It is now hypothesized that the virus was introduced to North Sea harbor seals from harp seals in a year when the harp seals dispersed unusually far southward (Heide-Jørgensen et al., 1992; Markussen and Have, 1992). A smaller PDV outbreak in the North Sea in 2002 killed hundreds of seals (Jensen et al., 2002).

Duignan et al. (1993) reported PDV in harbor seals from Long Island, New York. In an expanded study, Duignan et al. (1995) detected PDV antibodies in 37% of harbor seals and 73% of gray seals from New England, but not at all in Pacific harbor seals. There was usually little or no evidence of disease. In the winter of 1991–92, strandings increased in New England, and the PDV antibody detection rate increased to 83%. Morbillivirus lesions were observed in six animals, and a case of morbilliviral encephalitis was detected in archived tissue from an animal stranded in 1988. The authors hypothesized that high levels of PDV without disease outbreaks in gray seals are maintained by their large population size, high recruitment rate, and innate resistance, while infection is maintained in the smaller harbor seal population through contact with gray seals.

Dunn and Wolke (1976) reported seal heartworm infestation in harbor seals from New England. They found pulmonary, vascular, and hepatic lesions caused by both adult worms and microfilariae. The 1988 PDV epizootic in the North Sea provided very large sample sizes for parasite studies, and North Sea harbor seals carried a variety of nematodes, cestodes, trematodes, and acanthocephalans (Claussen et al., 1991a, 1991b). Five species of nematodes were very common. Seal heartworm was present in 32% of individuals. The lungworms *Otostrongylus* and *Parafilaroides* were present in 26% and 27%, respectively. The presence of heartworm and lungworm was inverse to age, with *Parafilaroides* and heartworms absent in adults. The two common gut nematodes, *Contracecum* and *Pseudoterranova* (sealworm), present in 10% and 88% of animals, increased in occurrence with age.

Ecology and life history: Harbor seals are generally solitary when in the water, but gregarious when hauled out (Bigg, 1981; Burns, 2002; Ronald and Gots, 2003). Unlike many other pinnipeds that haul out only for reproduction and molting, harbor seals regularly haul out for resting. When hauled out, seals are observed sleeping for short periods with intervals of scratching, vocalization, yawning, jostling for position, or scanning for predators or other disturbance. Sometimes there are gray seals mixed in at harbor seal haul-outs, especially from Massachusetts north. In the Rhode Island study area, however, gray seals are most often juveniles and are difficult to identify except by experienced observers. Groups of seals on haul-outs show no evidence of sociality or structuring, but are simply aggregations of individuals that come together in order to utilize a limited resource. In addition, hauling out in groups is believed to be an anti-predator strategy. Terhune (1985) showed that as the number of seals in the group increased, the duration of time spent scanning decreased and the intervals between scans increased.

Hauling-out behavior is a function of tide stage, wind, temperature, precipitation, and time of day (Pauli and Terhune, 1987a, 1987b; Schneider and Payne, 1983; Burns, 2002; Ronald and Gots, 2003). The largest numbers of seals are likely to be hauled out at low tide in late afternoon on a calm, sunny day. Haul-out use also drops off when air temperatures get very cold. The seals are also extremely sensitive to disturbance when hauled out, and they may retreat to the water with only slight provocation—by humans, boats, aircraft, or potential predators.

What appears to be a relatively simple behavior pattern of hauling out at low tide each day and returning to the water between haul-out periods, presumably for foraging, can actually be quite complex. Individual harbor seals have been rehabilitated after stranding and released with satellite-linked radio tags. Single individuals have been recorded as using multiple haul-outs between Cape Cod, Massachusetts and Downeast Maine, interspersed with apparent foraging trips to one or more consistent locations tens of kilometers offshore in the Gulf of Maine. (see the WhaleNet satellite tagging program page at http://whale.wheelock.edu/whalenet-stuff/stop_cover.html for both currently active tags on a variety of marine vertebrates and archived data and maps from previous tags.)

Harbor seals are relatively flexible in their selection of haul-outs, and can be found on rocky ledges and reefs, islets, mudflats, sand bars, gravel bars, sandy beaches, cobble beaches, glacial icebergs, sea ice, and man-made objects such as floating rafts and docks (Boulva and McLaren, 1979; Burns, 2002; Ronald and Gots, 2003). Important characteristics include protected locations that are relatively inaccessible from the land side and that have unobstructed access to water. Since harbor seals do not maintain breathing holes in the ice, when bays, inlets, and other nearshore waters freeze, the seals are pushed offshore where the ice edge provides water access (Ronald and Gots, 2003).

Annual molt occurs over two or three months from midsummer through early fall, after pupping (Bigg, 1981; Burns, 2002). Haul-out frequency increases somewhat during the molt. Yearlings molt first, followed by subadults, adult females, and then adult males. During molt there is an overlapping progression of age and sex classes.

Typical harbor seal dives last 3–4 minutes, but they are capable of diving for 30 minutes and to depths of 500 meters (Bigg, 1981; Burns, 2002). Frost et al. (2006) reported a study of Alaskan harbor seal pups using satellite-linked telemetry tags. Tagged pups increased their amount of time in the water and maximum dive depths during their first 3–6 months. Then time in the water and maximum dive depth both decreased, suggesting foraging seasonality. Percent time in the water was lowest in July (68%) and highest in November (89%). Tagged pups spent 50% of their swimming time diving in the upper third of the water column and only 5% in the deepest third, evidence that pups do not feed on or near the bottom during their first year.

Harbor seals are flexible in their prey selection (Bigg, 1981; Nowak, 1999; Burns, 2002; Ronald and Gots, 2003). Small to medium-sized fishes are the dominant prey, followed by squid and octopus, and then by crabs and shrimp. Types of fish eaten include a number of economically important commercial species. Among these are cods, hakes, mackerel, herring, sardines, anchovy, smelt, shad, capelin, sand lance, trout, salmon, rockfish, sculpins, and flounders. Shrimp may be particularly important prey for pups after weaning. Seals appear to feed on what is most abundant. Payne and Selzer (1989) collected scats from haul-outs in Maine and Massachusetts to look at prey preferences. They found clear geographic differences. Sand lance was the dominant prey at all three Cape Cod, Massachusetts sites: 87% of the diet at Race Point (tip of Cape Cod), 85% at Monomoy Island (at the "elbow"), and 50% at Jeremy Point (on the west side in the middle of the "forearm"). Squid comprised the next most abundant food item (22%) and then gadids, herring, and flounders in decreasing importance. Mackerel and skate were also eaten. At the Isles of Shoals off southern Maine (about 100 km from Race Point), there was no dominant prey type. Gadids and rockfishes were about equal at 22% each, flounders and herring both were >10% of the diet, and cunner, sand lance, and skate were also eaten. The diet of harbor seals along Long Island, based on stomach contents of stranded animals and some observations of feeding, includes herring, mackerel, squid, flounder, green crabs, mussels, cod, and silver hake (S. S. Sadove, pers. comm.).

Harbor seal pupping in the Gulf of Maine takes place in late May and June (Katona et al. 1993). Pupping occurs from the Isles of Shoals at the Maine/New Hampshire boundary northward into Canada. Pupping formerly occurred south to Cape Cod (Katona et al., 1993), and recent evidence indicates that pupping has resumed at Manomet, Massachusetts on the west side of Cape Cod Bay. Single pups are born approximately 70 cm long and weighing about 10 kg (Wynne and Schwartz, 1999). The white lanugo is shed in utero, and the pup is born in a spotted juvenile coat, essentially the same as the adult pattern.

Harbor seals are unique among phocids. In most other seals, pups remain at the birth site until after weaning, and the mother tends to remain with or close by the pup for the entire lactation period, feeding little or not at all (Riedman, 1990). Harbor seal pups are precocial, swimming and following the mother within hours of birth (Bigg, 1981; Riedman, 1990; Burns, 2002; Ronald and Gots, 2003). At many pupping sites the pup has no other option, since the location is submerged at high tide. After the mother and pup leave the birth site, the pup follows the mother closely, sometimes riding on her back during the first week. They haul out at intervals, when nursing takes place. Adult females spend a larger proportion of their time hauled out during lactation (Thompson et al., 1989), but are able to feed throughout lactation (Burns, 2002). Pups are weaned at 3–6 weeks of age (Bigg, 1981; Burns, 2002). Harbor seal pups may continue to remain with and follow their mothers for 2–4 weeks after weaning.

Ovulation and mating occur very soon after weaning (Bigg, 1981; Thompson, 1988; Riedman, 1990; Burns, 2002). Mating takes place in the water. Males are largely unable to defend breeding sites or females, resulting in a promiscuous or slightly polygynous mating system (Riedman, 1990). Implantation of the embryo is delayed for 1.5 to 3 months.

Female harbor seals become sexually mature at 2–5 years of age, most at age 3 or 4, and reach physical maturity at age 6 or 7 (Bigg, 1981; Burns, 2002). Males take about a year longer. Most

(85–92%) mature females give birth each year. First-year mortality rate is 20–60%, after which it is 5–20% (Boulva and McLaren, 1979), and the mortality rate in males is higher than in females after sexual maturity. It is commonly assumed that a large proportion or even a majority of the harbor seals in southern New England are juveniles, and there is some published support for this (Payne and Schneider, 1984; Whitman and Payne, 1990; Katona et al., 1993). Waring et al. (2006a) captured and radio-tagged 21 harbor seals and estimated age for 17 near Cape Cod, Massachusetts in March 2001. Fourteen (82%) were adults, one (6%) was a subadult, and two (12%) were juveniles. It is still possible that the proportion of juveniles is higher in the Rhode Island study area. Alternatively, perhaps perceptions of the age structure in the region are somewhat biased by the reliance on strandings for data. Adults, sub-adults, and juveniles cannot be easily differentiated except by close examination, and mortality and stranding rates can be expected to be higher for younger animals. Gilbert and Wynne (1987) reported that all of the harbor seals taken in the gillnet fishery in the Gulf of Maine were young of the year.

In harbor seals, predation impacts pups to a larger extent than adults. Predators of pups include polar bears, red foxes, Arctic foxes, Steller's sea lions, eagles, ravens, and gulls (Burns, 2002; Ronald and Gots, 2003). In eastern Canada, the three major sources of mortality in the pups are stillbirth, abandonment after birth, and sharks (Boulva and McLaren, 1979). Stobo and Lucas (2000) reported that the rate of shark predation (with Greenland shark an important predator) on harbor seal pups at Sable Island increased markedly, from 20% of pups in 1980–1993 to about 25% in 1994 and 1995 to 45% in 1996. Shark attacks on adult seals seem to be directed preferentially towards females. In recent years white shark occurrence near Cape Cod seems to have increased, presumed to be related to the increased summer abundance of both harbor seals and gray seals (G. Skomal, Massachusetts Div. of Marine Fisheries, pers. comm.).

Distribution: Harbor seals occur in coastal waters of both the North Atlantic and North Pacific (Bigg, 1981; Riedman, 1990; Burns, 2002; Ronald and Gots, 2003). In the western North Atlantic, they are common from southern New England north to Labrador, Greenland, and Iceland. They are mainly seen hauled out or relatively close to the shore. North of Cape Cod harbor seals can occur year-round. However, south of Cape Cod (Rhode Island to New Jersey) seals occur only during winter migration (October to early May) (Payne and Selzer, 1989). There are occasional records from as far south as Florida (Caldwell and Golley, 1965; Caldwell and Caldwell, 1969; Caldwell et al., 1971; Waring et al., 2008). As with pinnipeds in general, records of in-water observations are much less common than records of stranded animals or seals on haul-out sites. Harbor seal sighting and bycatch records away from shore are concentrated in relatively shallow water. Lens (1997) reported seven individuals taken in a Spanish deep-water trawl fishery on the southern edge of the Grand Banks, showing that harbor seals are capable of long-distance foraging movements and can occur far offshore.

The annual patterns of movement in the harbor seals of New England and Atlantic Canada are complex (Bigg, 1981; Riedman, 1990; Katona et al., 1993; Nowak, 1999; Burns, 2002; Ronald and Gots, 2003). Some sources call harbor seals migratory, while others say they are non-migratory, sometimes differentiating between migration and "seasonal movements." In Maine and Atlantic Canada, harbor seals can be observed year-round (Boulva and McLaren, 1979; Katona et al., 1993; Baird, 2001), while in southern New England they are very clearly seasonal, occurring from September to late April–early May (Payne and Schneider, 1984; Payne and

Selzer, 1989; Sadove and Cardinale, 1993; Schroeder, 2000). Only a minority of the population winters in the Rhode Island study area, and does not remain for pupping. However, since the 1990s, small numbers have been reported to remain around Long Island year-round and pupping has been observed on Great Gull Island and Fishers Island (S. S. Sadove, pers. comm.). One hypothesis for why harbor seals depart from the Rhode Island study area just prior to the time of pupping is the presence of predators. Many large predatory sharks are more common south of Cape Cod than to the north in the Gulf of Maine (Kenney et al., 1985b; Collette and Klein-MacPhee, 2002).

Harbor seals have long been recognized as common residents in the northeastern U.S. All historical sources concur that harbor seals were relatively common around Long Island and Connecticut (De Kay, 1842; Linsley, 1842; Allen, 1880; Merriam, 1884; Goodwin, 1935; Connor, 1971).

Although the harbor seal is generally referred to as a winter resident in the region, their period of occurrence is significantly broader. From counts on haul-outs in Narragansett Bay, Schroeder (2000) showed that seals usually start arriving in September, steadily increase in numbers until April, then depart relatively abruptly in May. Around the eastern end of Long Island, Payne and Selzer (1989) identified the most important haulouts in the 1980s, in order of decreasing counts, as Fishers Island, Great Gull Island, Montauk Point, Gardiners Island, Sag Harbor, and Falkner Island (CT). These continue to have the largest aggregations, and constitute locations where access is restricted by physical characteristics or by extensive private or government property holdings. There are other haul-outs all around the eastern end of Long Island and along both the Atlantic and Long Island Sound shores (Sadove and Cardinale, 1993). The numbers of individuals at Long Island haul-outs range from about 20 to 500 (S. S. Sadove, pers. comm.). There are also known haul-outs in Connecticut (A. Ferland, Maritime Aquarium, pers. comm., R. Nawojchik and H. Medic, Mystic Aquarium, pers. comm.).

Seals are very difficult to detect during surveys, since they tend to be solitary and the usual sighting cue is only the seal’s head above the surface. In addition, seals were specifically excluded from data collection efforts during CETAP, and there is no centralized repository for opportunistic seal sighting information outside of small localized collections. The vast majority of seal sightings during surveys come from aerial surveys flown by the National Marine Fisheries Service or the Provincetown Center for Coastal, focused primarily on right whales and mainly around Cape Cod. In addition to the difficulty in identifying seals at sea from an airplane, the survey crews very often do not take the time from their primary mission to identify hauled-out seals, consequently the majority of the survey sighting are of “unidentified seals.” All of the survey sightings of harbor and unidentified seals were combined in doing the SPUE and GIS analyses.

Leatherback sea turtle *Dermochelys coriacea* (Vandelli, 1761)

A turtle, encased within its shell (comprised of an upper carapace and a lower plastron), is something that is instantly recognizable to most people. The sea turtles include seven or eight species in two closely related families. Sea turtles spend their entire lives at sea except for nesting; adult females deposit their eggs in nests dug above the high-tide mark on sandy beaches in the tropics and sub-tropics. Their limbs are adapted for swimming—modified into simplified, flattened flippers. Sexes are generally indistinguishable, except that adult males usually can be identified by their very long tails. Only five species typically occur in the North Atlantic, although one other may occur accidentally in the West Indies (Ernst et al., 1994; Spotila, 2004). Five species are known from the Rhode Island study area—leatherback, loggerhead, Kemp's ridley, green, and hawksbill sea turtles. The leatherback and loggerhead are covered in detail below. The Kemp's ridley (*Lepidochelys kempii*) and green (*Chelonia mydas*) sea turtles occur in lower numbers. More importantly, they occur mostly as juveniles in shallow inshore habitats such as Peconic Bay in Long Island and Cape Cod Bay. They are generally below the size at which they can be readily detected from aerial surveys, and coastal bays are typically excluded from survey designs. The hawksbill sea turtle (*Eretmochelys imbricata*) is known from single historical stranding records in Massachusetts in 1968 (Lazell, 1980; McAlpine et al. 2007) and New York in 1938 (Morreale et al., 1992), and is considered to be hypothetical for this analysis.

Description: The leatherback sea turtle is one of the largest living reptiles, and is the only living species in its family, Dermochelyidae (Ernst et al., 1994). Leatherbacks differ from all other sea turtles in lacking the outer layer of keratin plates or scutes on the shell. The bony shell, composed of a mosaic of thousands of tiny dermal bones, is covered by a layer of soft, leathery skin. Carapace lengths (the standard for measuring a turtle is to measure the length and width of the carapace without including the head, tail, or limbs) of adults are up to 1.8–2 m or more, and large leatherbacks can reach weights of 1,000 kg (Wynne and Schwartz, 1999). The carapace tapers from front to back, and there are seven longitudinal ridges. The overall color is black, and there are usually white or pinkish spots, especially underneath. The front flippers are very long and flexible; both front and rear flippers lack claws.

Status: Leatherback sea turtles are classified as Endangered under the U.S. Endangered Species Act, as Federally Endangered on the Rhode Island state list, and as Critically Endangered on the IUCN Red List. The status of populations in the North Atlantic does not seem to be as precarious as it is for those in the Pacific, where nesting populations have declined by more than 80%. Estimates of the total number of adult females in the world declined from 115,000 in 1982 to 20–30,000 in 1996 (IUCN, 2008).

Estimates of sea turtle population abundance for any region are rare or non-existent. Sea turtles are wide-ranging, difficult to detect at sea, and capable of long submergences; in addition, aerial surveys detect only individuals above a certain size threshold—about 75 cm carapace lengths (Shoop and Kenney, 1992). The northeastern U.S. is one of a few locations where there have been published estimates of abundance of pelagic sea turtle populations, based on line-transect aerial surveys (CETAP, 1982). Shoop and Kenney (1992) summarized the CETAP estimates, which showed that 100–900 leatherbacks occurred off the northeastern U.S. in the summer. Those numbers are minimum values, since they do not account for animals missed because they were below the surface and not visible when the survey aircraft passed.

Abundance is more typically indexed by counts of nesting adult females. There are seven known leatherback nesting populations in the Atlantic (reviewed in TEWG, 2007; NMFS & USFWS, 2007c), with the total number of adults estimated at 34,000–94,000. The Florida population grew from 98 nests in 1988 to 800–900 per year in the early 2000s, with a 17% increase rate on index beaches. The Northern Caribbean population nests on Puerto Rico and the Virgin Islands. Nests in Puerto Rico increased at 10% annually, from 9 in 1978 to 469–882 in 2000–2005. Nesting in the U.S. Virgin Islands increased at 10% from 1986 to 2004, and at 13% from 1994 to 2001. There were 143 nests in 1990 and 1008 in 2001. The number of nests in the British Virgin Islands increased from a few in the late 1980s to 35–65 in the 2000s, at a rate of 20% in 1994–2004. The Western Caribbean populations nests from Honduras to Colombia, especially in Costa Rica, Panama, and Colombia, and shows declining trends. At the major nesting beach in Tortuguero, Costa Rica, nesting declined by 68% between 1995 and 2006. The Southern Caribbean population nests in Guyana, Suriname, French Guiana, Trinidad, Dominica, and Venezuela, with perhaps 40% of the world's leatherback nesting in Suriname and French Guyana. The trend is generally stable to a slight increase. The other three populations are in the South Atlantic—Brazil, West Africa, and South Africa.

All sea turtle species share a nearly identical suite of survival threats (reviews in NRC, 1990; Lutcavage et al., 1997; Spotila, 2004; NMFS & USFWS, 2007a, 2007b, 2007c, 2007d). Harvesting of adults and eggs depleted populations in many areas of the world, and continues in some places. Predators, both natural and introduced, take significant numbers of eggs, hatchlings, and juveniles. There are two additional significant anthropogenic impacts on sea turtles—loss or degradation of nesting habitat and incidental capture in fisheries. While there are natural sources of habitat loss (e.g., beach erosion, hurricanes), development of beachfronts for residences or tourism, beach armoring, disorientation of hatchlings by artificial lighting, sand mining, beach replenishment, and spread of non-native vegetation are much more serious. Sea turtles are captured frequently in many fisheries, including pelagic longlines, high-sea driftnets, sink gillnets, pound nets, trap and pots, and trawls; turtles can also be entangled in other types of persistent debris. Other anthropogenic impacts include boat strikes and plastic ingestion.

Lewison et al. (2004) estimated that 50,000 leatherbacks were killed in pelagic longline fisheries worldwide in 2005, mainly in the Pacific. About 3,000 a year were killed in the U.S. Atlantic and Gulf of Mexico shrimp fishery; leading NMFS to require a larger escape opening in Turtle Excluder Devices (TEDs) beginning in 2003 (NMFS & USFWS, 2007c). Morreale and Standora (1998) reported eight leatherback turtles that were entangled in fishing gear near Long Island during 1987–1992 and released after tagging. In Rhode Island waters, a leatherback entangled in buoy lines for lobster traps is the most common sea turtle entanglement.

Ecology and Life History: The basic picture of sea turtle life history has long been known, is very similar across all species, and has been well-described in the works of Archie Carr and his colleagues (Carr, 1967, 1980, 1986, 1987, 1995; Carr and Meylan, 1980; Hamner, 1988; Musick and Limpus, 1997). An adult female crawls up onto a sandy beach, digs a nest hole, deposits a clutch of eggs, covers it over, and returns to the sea. About two months later a batch of hatchlings emerges from the nest and scrambles down the beach and into the ocean. The hatchlings swim straight out to sea and disappear until they next show up as small juveniles—long termed the "lost year." Carr theorized, which was later confirmed, that hatchlings get passively carried in ocean current systems and collect in sargassum patches and other surface convergences, where they feed on a wide variety of plant parts and invertebrates. Pelagic post-hatchlings grow into small juveniles, who move into developmental habitats, usually in coastal waters, although leatherbacks and olive ridley remain pelagic during this phase. Larger juveniles move into the same foraging habitats as the adults.

Sea turtles are very difficult to age, so that the durations of the various life-stages were not known. For leatherbacks, growth seemed to be relatively fast, and the age at maturity had been estimated from as short as 2–3 years to as long as 13–14 years (Pritchard and Trebbau, 1984; Rhodin, 1985; Zug and Parham, 1996; Dutton et al., 2005). More recent work, however, suggests that the median age for first-time nesting females in the western North Atlantic is 24.5 to 29 years (Avens et al., 2009).

Adult leatherback sea turtles feed mainly on jellyfish and other gelatinous invertebrates, especially the lion's mane jelly *Cyanea capillata* (Bleakney, 1965; Lazell, 1980; Bjorndal, 1985; Mortimer, 1995).

Distribution: The leatherback sea turtle has the widest distribution of any species of sea turtle, extending worldwide from tropical and subtropical at least into cold-temperate waters and sometimes even more poleward (Ernst et al., 1994; Spotila, 2004; NMFS & USFWS, 2007c). In the North Atlantic, leatherbacks have been observed in waters of the U.S., Nova Scotia, Europe, the eastern Mediterranean, Newfoundland and Labrador, Greenland, the North Sea, and the Barents Sea (Bleakney, 1965; Brongersma, 1972, 1995; Threlfall, 1978; Goff and Lein, 1988; Marquez, 1990; Casale et al., 2003; Hays et al., 2004, 2006; James et al., 2005; McAlpine et al., 2007). They are capable of maintaining a body temperature well above ambient through a combination of anatomy, physiology, and behavior (Frair et al., 1972; Greer et al., 1973).
Off the northeastern U.S., leatherbacks were sighted commonly in summer in shelf waters from North Carolina to Maine, and in much lower numbers in spring and fall (Shoop and Kenney, 1992). The densest aggregation of sightings was in the nearshore waters south of central Long Island. Despite being present in much lower numbers than loggerheads (less than 5% of the number of sightings) leatherbacks were far more likely to occur within the Gulf of Maine north of Cape Cod—consistent with their known tolerance for colder water.

Lazell (1980) reported that the first recorded occurrence of a leatherback turtle in New England was in 1886 by the Monomoy lighthouse keeper. However, Babcock (1919) reported that the first New England occurrence was in Massachusetts Bay in 1824, and that the specimen was in the collection of the Boston Society of Natural History. He reported two earlier records—in 1811 at an unknown locality and in 1816 at Sandy Hook, New Jersey. He listed a total of 31 known records between 1811 and 1917, ranging from New Jersey to Maine.

Loggerhead sea turtle *Caretta caretta* (Linnaeus, 1758)

Description: The loggerhead sea turtle is one of the two species of larger shelled turtles found in the North Atlantic, with adult carapace lengths of 85-120 cm (Wynne and Schwartz, 1999), although the maximum known length was 213 cm (Ernst et al., 1994). The shell is shaped like a broad oval, tapering toward the rear. The head is much larger relative to body size than in the other sea turtle species, with broad crushing surfaces on both the upper and lower jaws. The color is a distinctive yellowish- to reddish-brown.

Status: Loggerhead sea turtles are classified as Threatened under the U.S. Endangered Species

Act, as Federally Threatened on the Rhode Island state list, and as Endangered on the IUCN Red List. Shoop and Kenney (1992) estimated the summer pelagic population off the northeastern U.S. of large juveniles and adults detectable from aerial surveys at 2,200–11,000, not accounting for diving behavior, with less than half as many in spring and fall. There are no more recent comparable estimates.

TEWG (2000), Ehrhart et al. (2003), and NMFS & USFWS (2007d) reviewed the status of loggerhead nesting populations in the North Atlantic. The largest is in the southeastern U.S. and Gulf of Mexico, which is the second largest loggerhead nesting population in the world after the one in the eastern Indian state of Orissa. The total numbers of nests and nesting females per year are estimated at 53,000–92,000 and 32,000–56,000, respectively. The population is divided into five sub-populations. The Northern sub-population nests in Georgia and the Carolinas. The average number of nests per year is 5,151, with a 1.9% declining trend over 1989–2005. The largest sub-population is South Florida, with an average of 65,460 nests and 15,966 females and a declining trend of 22.3% in 1989–2005. That decline may be accelerating. The Dry Tortugas sub-population shows no detectable trend and has annual averages of 246 nests and 60 females. The averages for the Florida Panhandle sub-population in 1995–2005 were 910 nests, 222 females, and a declining trend of 6.8%. The Yucatan sub-population increased from 903 nests in 1987 to 2,331 in 2001, but may currently be decreasing.

Other western North Atlantic populations include the eastern Bahamas, with 500–600 nests per year, and Cuba, with 250–300. Loggerheads formerly nested on Jamaica, Haiti, the Dominican Republic, and Puerto Rico, but no longer do so. The nesting population in northeastern Brazil has shown a long-term increase, with 4,837 nests in 2004. The only nesting population in the eastern North Atlantic is in the Cape Verde islands, with several thousand nests per year. Loggerheads also nest in the eastern Mediterranean, where nest counts can exceed 7,000 per year, although monitoring is incomplete.

Impacts on loggerheads are the same as for other sea turtles. Lewison et al. (2004) estimated that 60,000–80,000 loggerheads were killed annually by incidental capture in Atlantic pelagic longline fisheries, primarily in the western Mediterranean, and 200,000 globally. NRC (1990) estimated that, prior to regulations requiring TEDs, 5,000–50,000 loggerheads were killed each year in the southeastern U.S. and Gulf of Mexico shrimp trawl fishery.

In southern New England, juvenile sea turtles sometimes strand dead, comatose, or seemingly paralyzed. The event happens in the fall of the year, when water temperatures decline, and is referred to as “cold-stunning.” In 1985, 56 cold-stunned turtles stranded in eastern Long Island (Meylan, 1986), sparking the establishment of a monitoring, research, and rehabilitation program. A similar program exists in Cape Cod Bay.

Ecology and Life History: Loggerheads follow the typical sea turtle life history pattern. Post-hatchlings disperse and are entrained in ocean currents (Carr, 1986). Small juveniles are present in high abundance around the Azores (Bolten, 2003), where they remain resident for extended periods and feed on pelagic invertebrates such as siphonophores, jellies, salps, gastropods, barnacles, and isopods. Small juveniles may also congregate on the Grand Banks off Newfoundland. In the Mediterranean, genetic profiling has shown that small and medium juvenile loggerheads come from both the eastern Mediterranean nesting population and from western North Atlantic populations (B. W. Bowen et al., 1993). Eventually juveniles reach the size where they return to coastal waters, first into shallower developmental habitats in bays and estuaries and then into adult foraging habitats. The diet of juveniles in developmental habitats is dominated by crabs (Burke et al., 1993). Adults feed on a wide variety of benthic prey, including bivalves, gastropods, crabs, sea pens, anemones, and seaweeds (reviewed by Bjorndal, 1997).

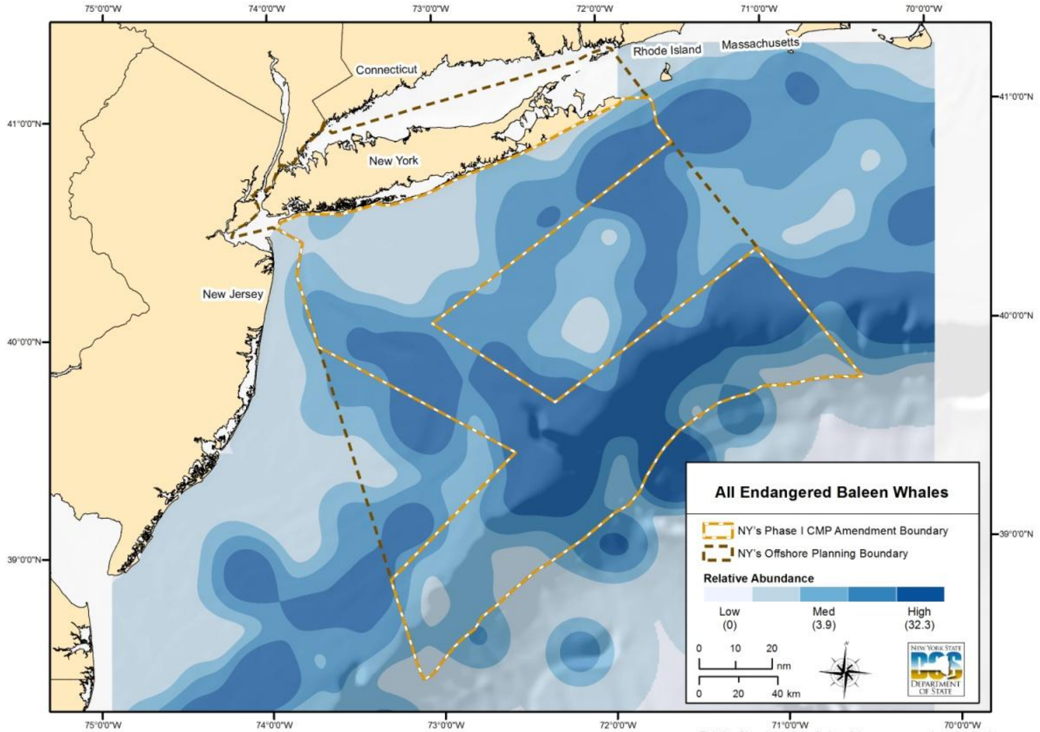
Distribution: Loggerhead sea turtles are distributed worldwide in subtropical and temperate waters (Ernst et al., 1994; Ehrhart et al., 2003). In the western North Atlantic, they are common off the southeastern U.S. and in the Gulf of Mexico. Off the northeastern U.S., there are few sightings north of the latitude of Long Island, and only one in the northern Gulf of Maine (CETAP, 1982; Shoop and Kenney, 1992), although there are inshore records from Nova Scotia and juveniles are commonly taken as bycatch in fisheries on the Newfoundland Grand Banks (Bleakney, 1965; Brongersma, 1972, 1995; Bolten, 2003; McAlpine et al., 2007).

From Long Island south to North Carolina, loggerhead occurrence is strongly seasonal (CETAP, 1982; Shoop and Kenney, 1992). They are nearly absent in winter. In spring they spread northward from south of Cape Hatteras. The distribution is most extensive in summer—from the shore to the mid-shelf area and also along the outer shelf. The distribution then contracts southward in the fall.

Babcock (1919) stated that loggerhead turtles “not uncommonly visit Long Island Sound and the Massachusetts coast.” He reported that “a number of specimens usually about two feet in length [were] taken every year” in fish traps in Menemsha Bight of the northwestern side of Martha’s Vineyard. He also included an interesting report that small loggerheads were “taken in Long Island Sound in a benumbed condition as late as December 4,” possibly one of the first reports of cold-stunning from the region.

Species Distributions

Species Groupings



Relative Abundance is an index of the average number of animal sightings normalized by survey effort. White areas signify areas without survey effort or outside analysis extent.

Sources: Right Whale Consortium Database, 1978 - 2009; Planning Boundaries, NY Department of State

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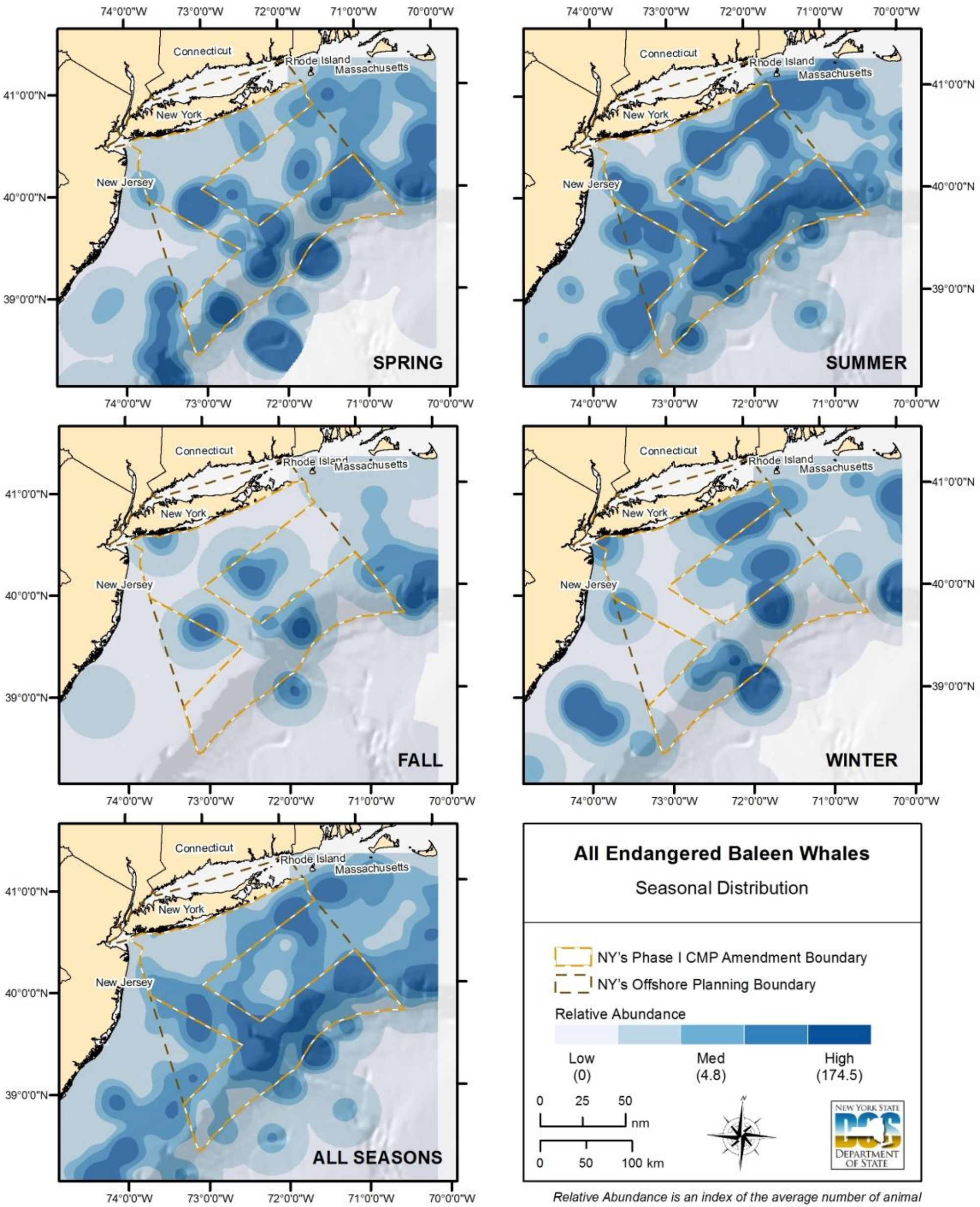

All Endangered Baleen Whales

Seasonal Distribution

Relative Abundance is an index of the average number of animal sightings normalized by survey effort. White areas signify areas without survey effort or outside analysis extent.

Sources: Right Whale Consortium Database, 1978 - 2009; Planning Boundaries, NY Department of State

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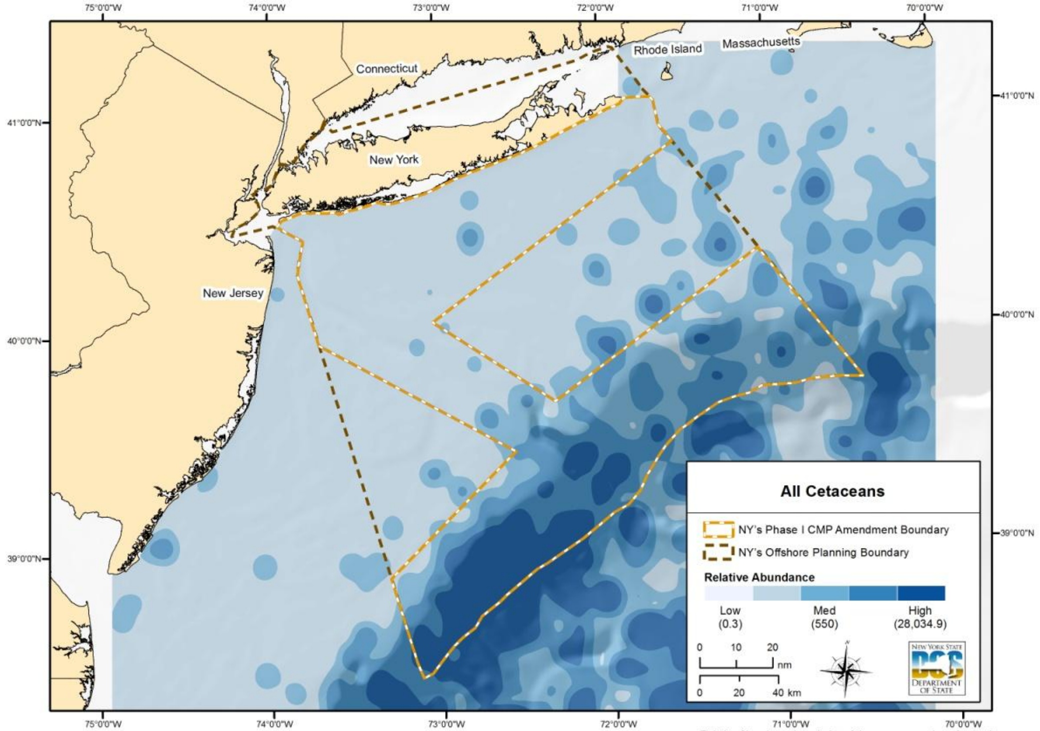

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Sources: Right Whale Consortium Database, 1978 - 2009; Planning Boundaries, NY Department of State

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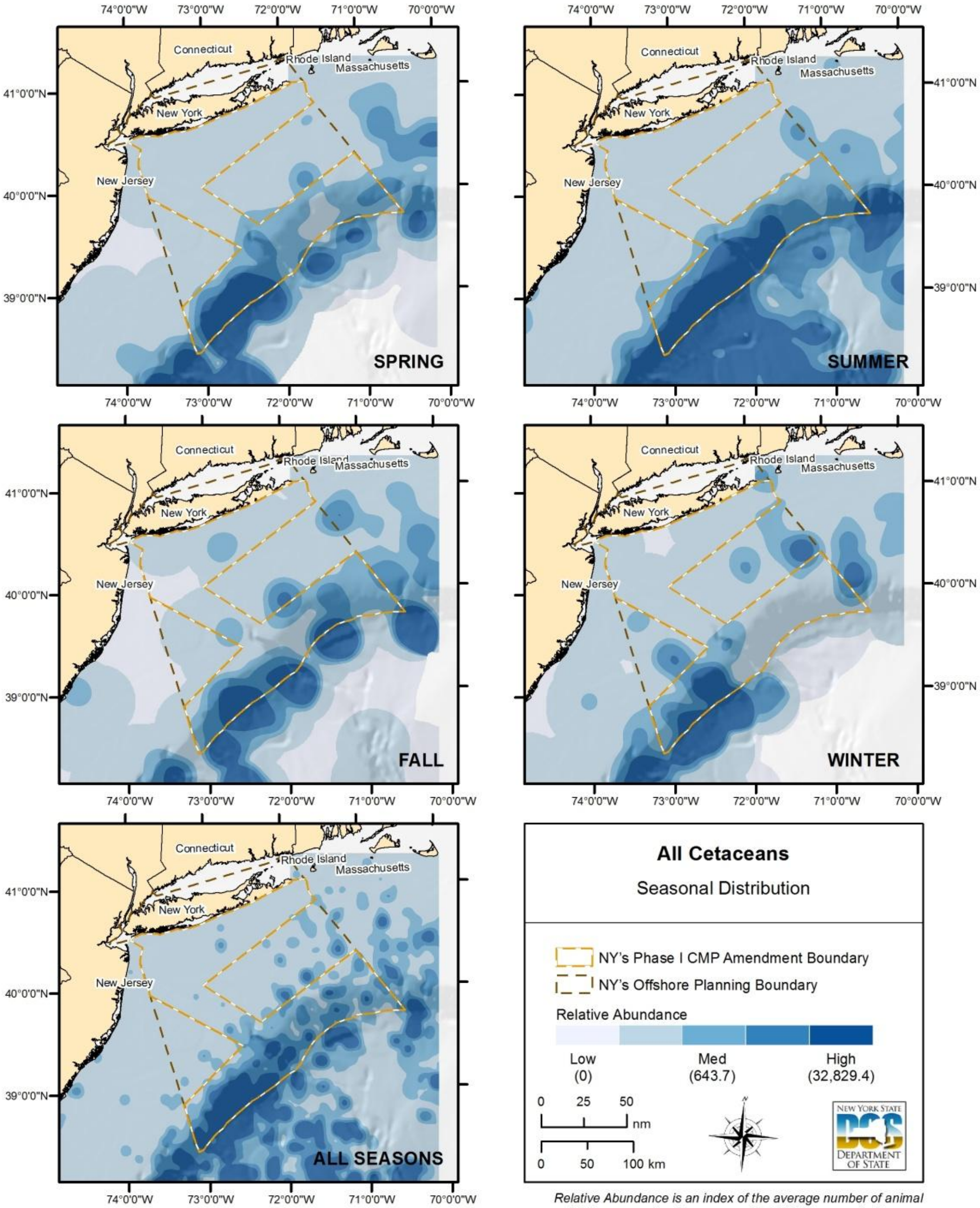

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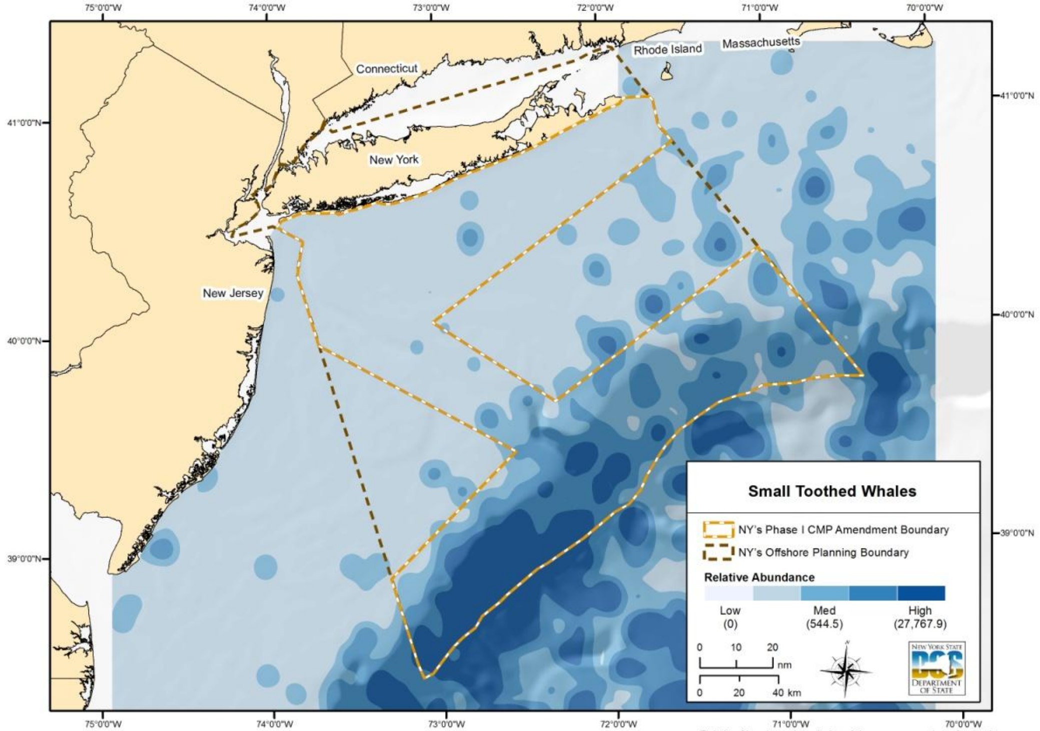

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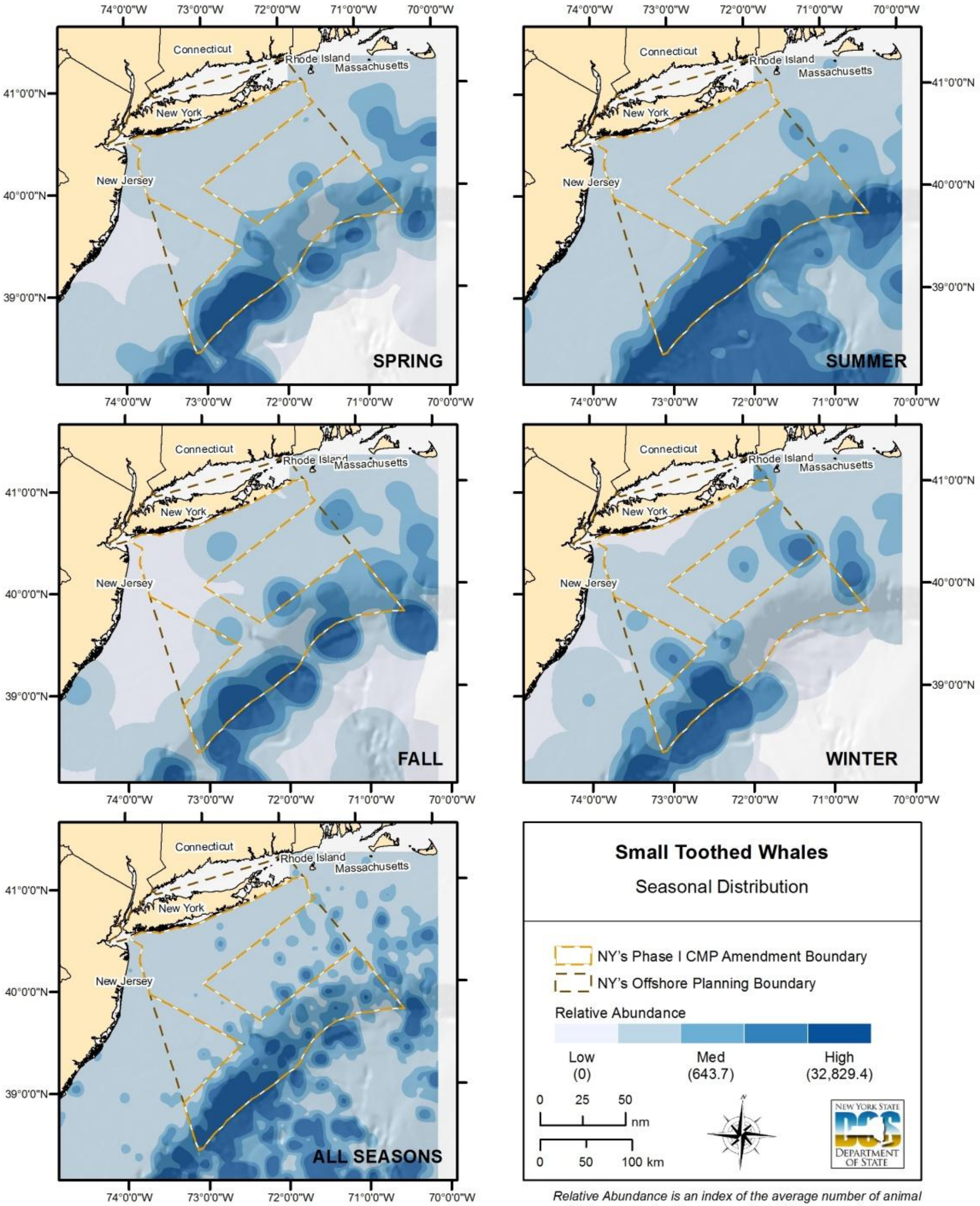

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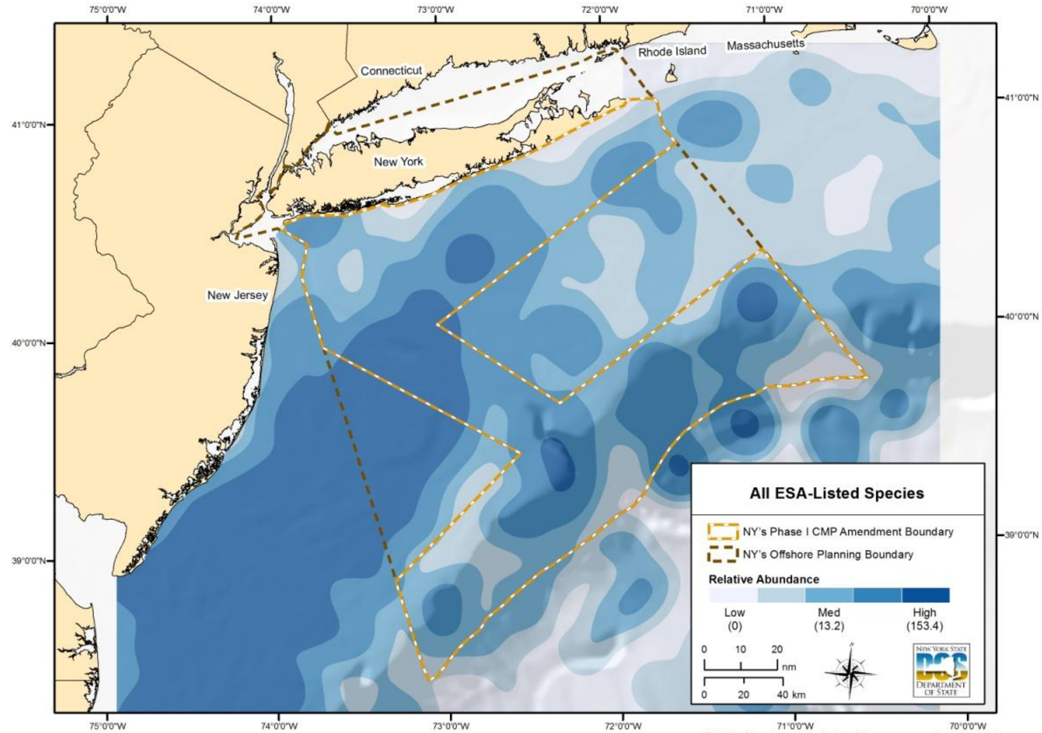

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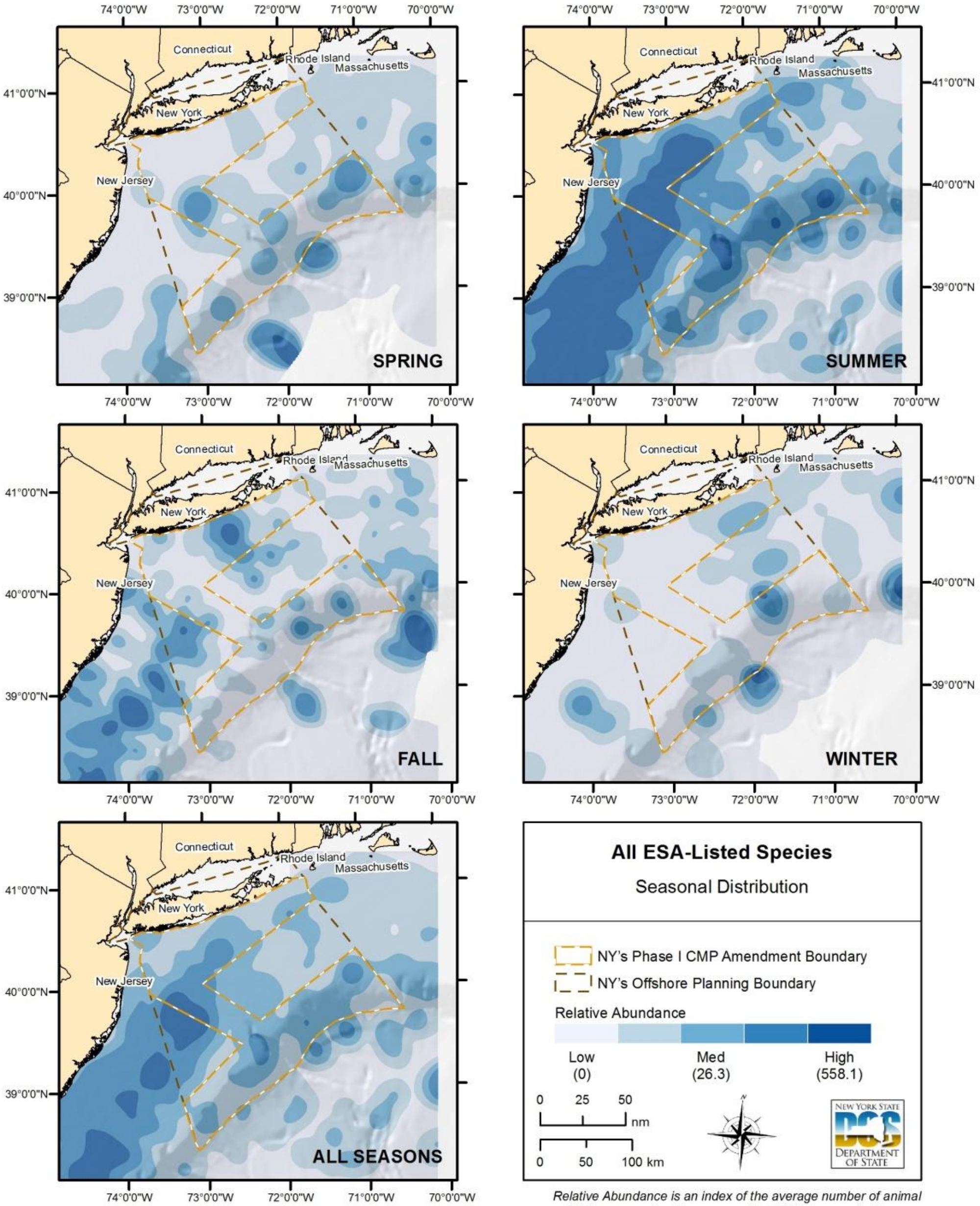

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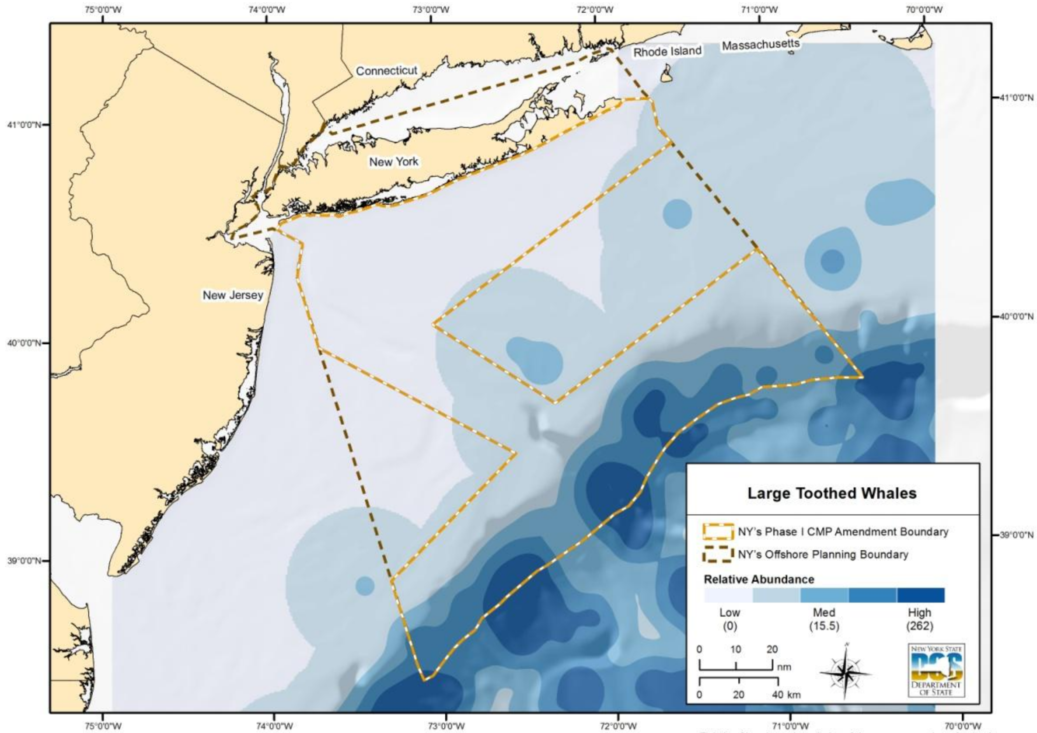

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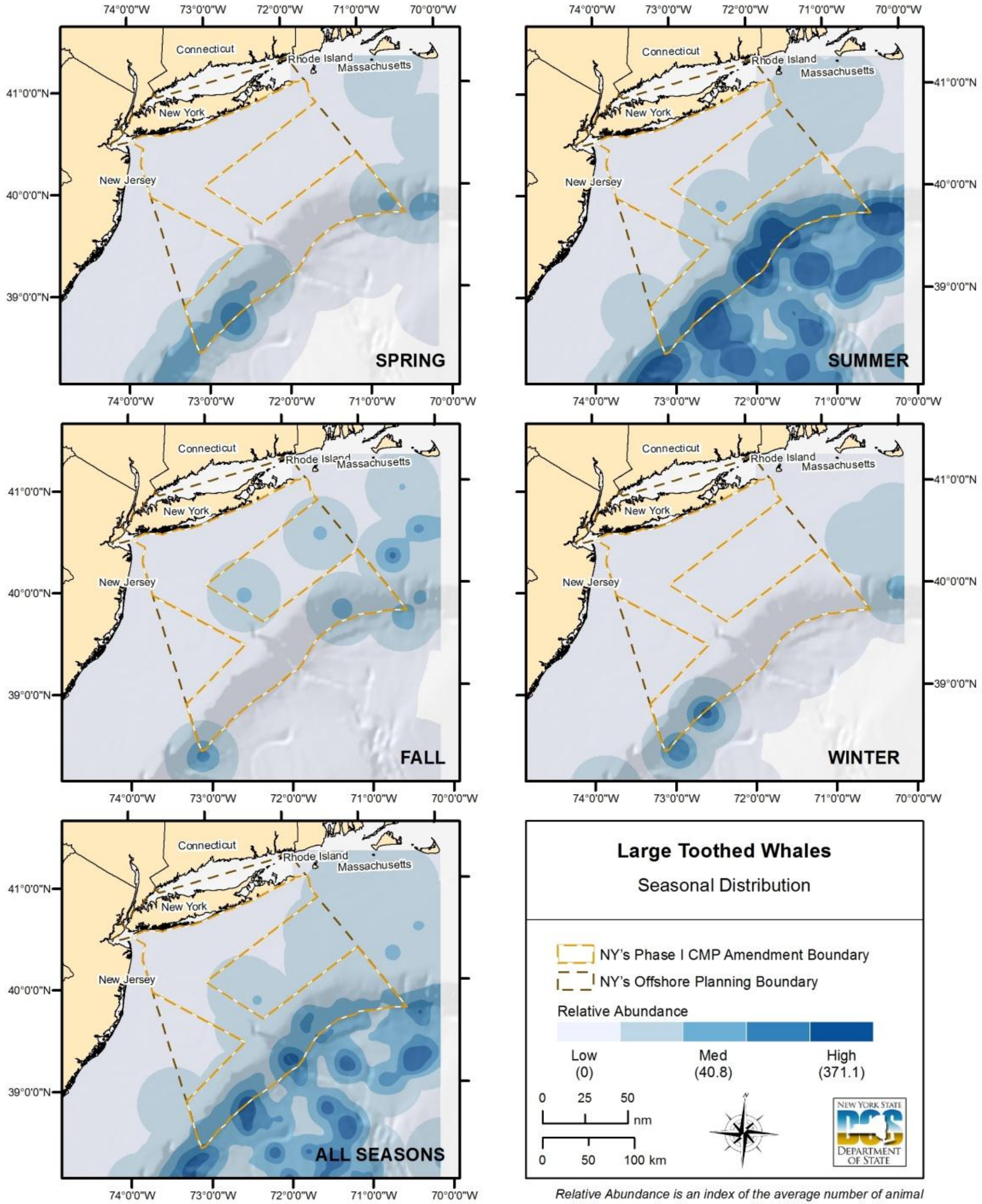

Large Toothed Whales

Seasonal Distribution

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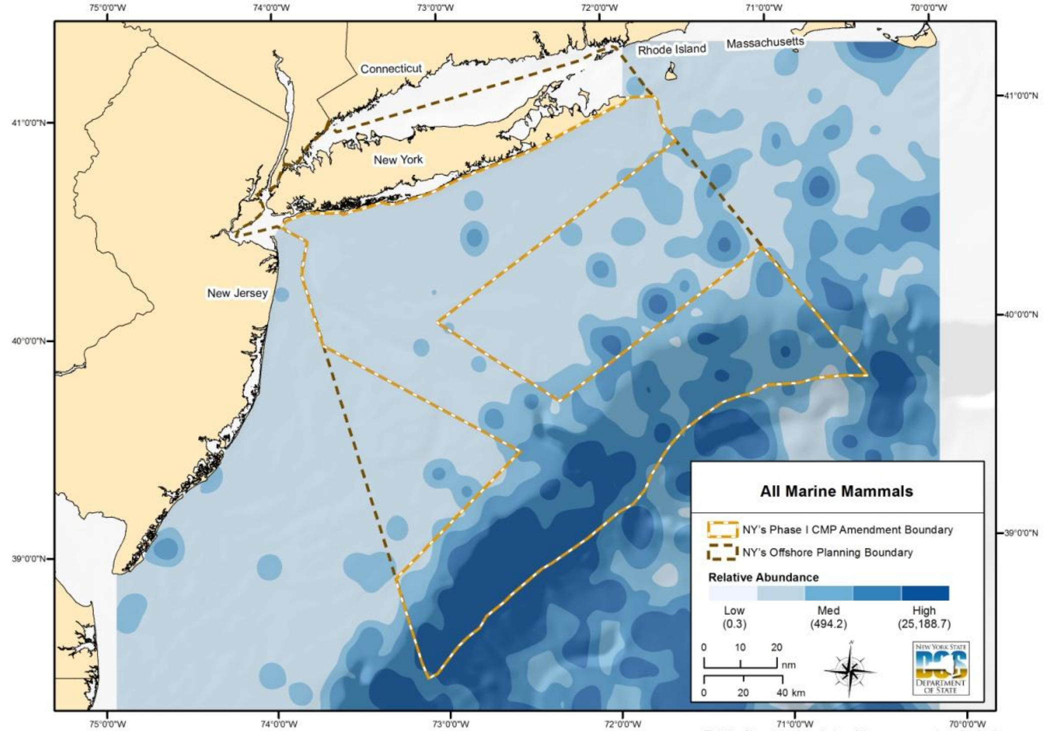

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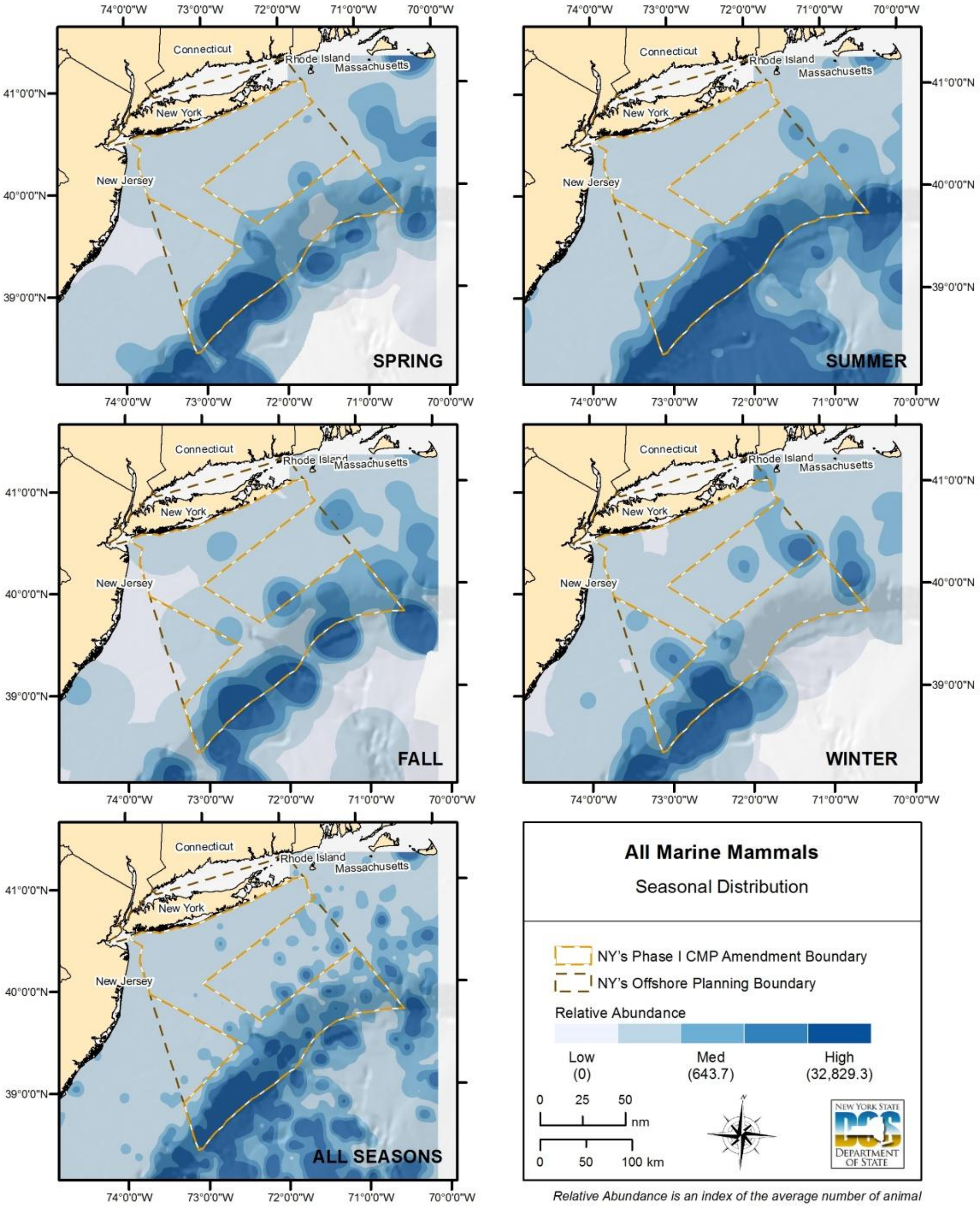

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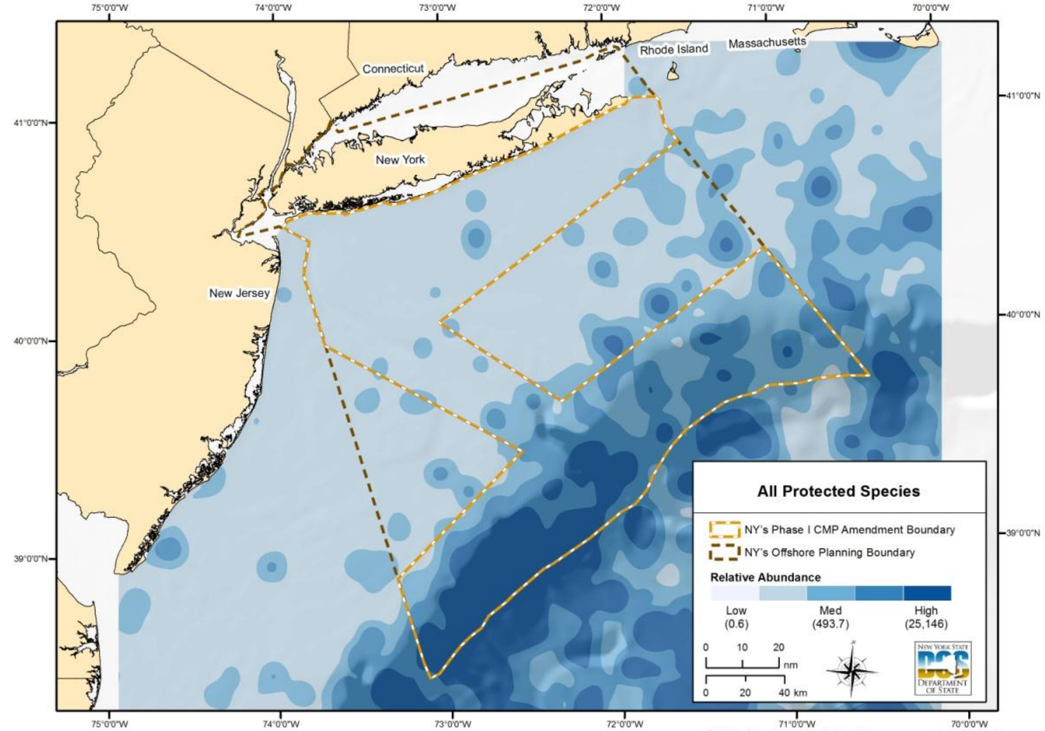

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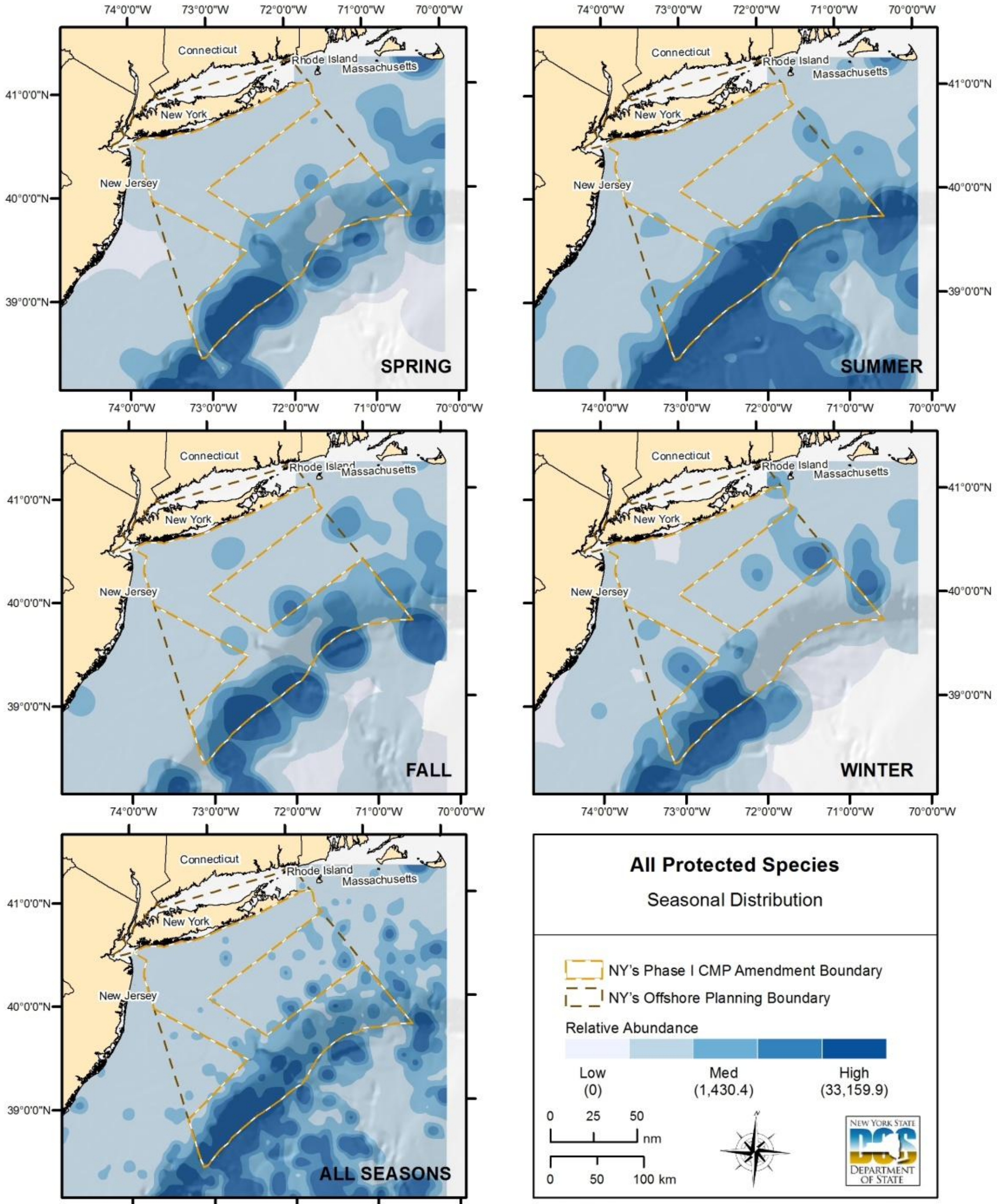

All Protected Species

Seasonal Distribution

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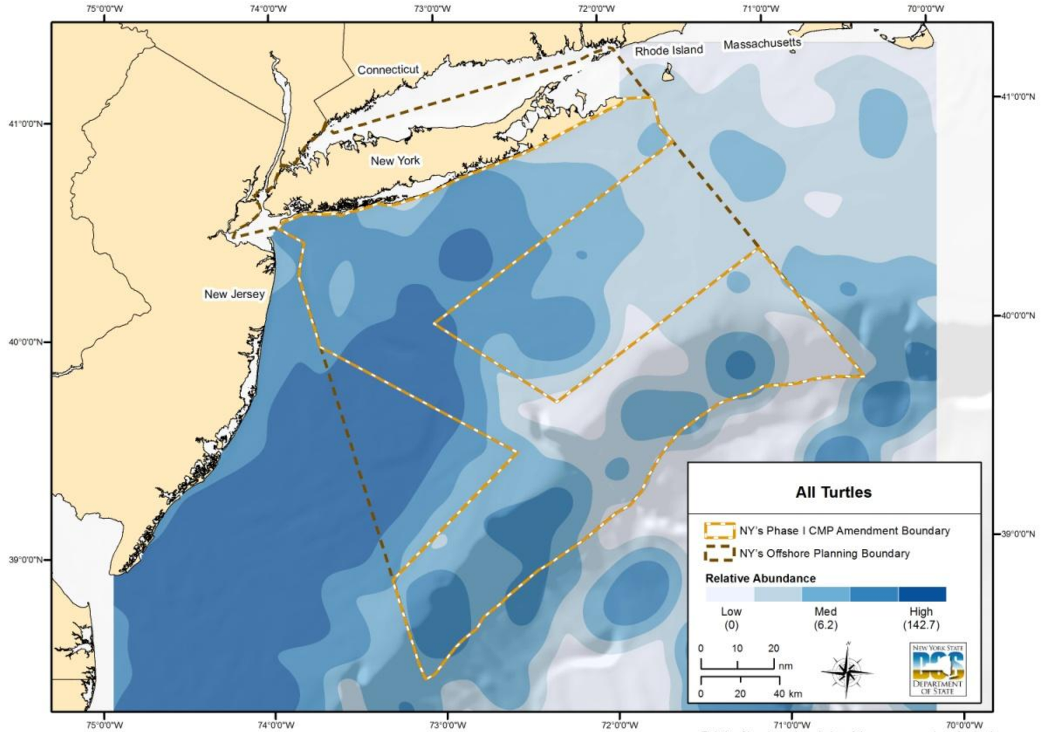
New England Aquarium

Protecting the blue planet



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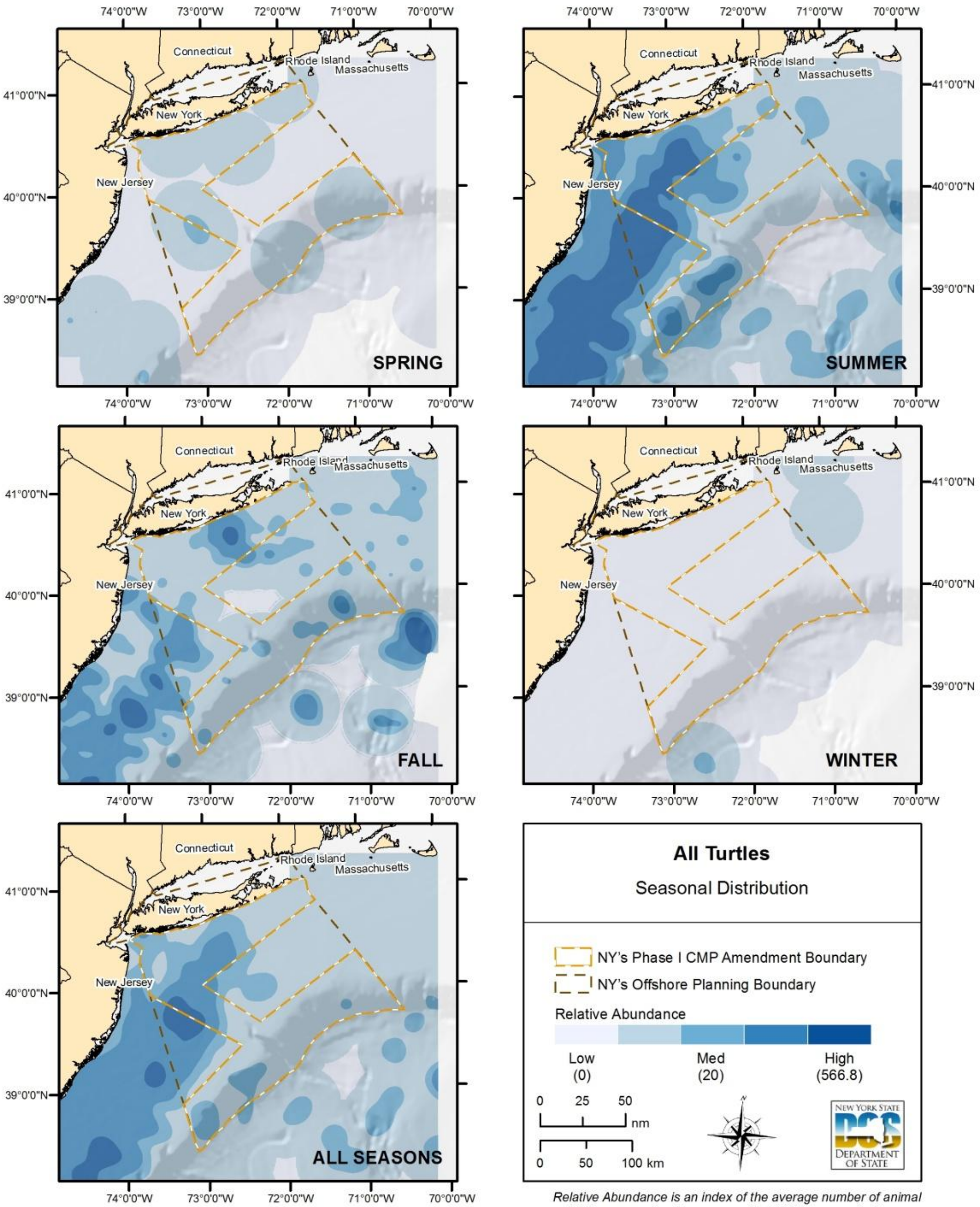

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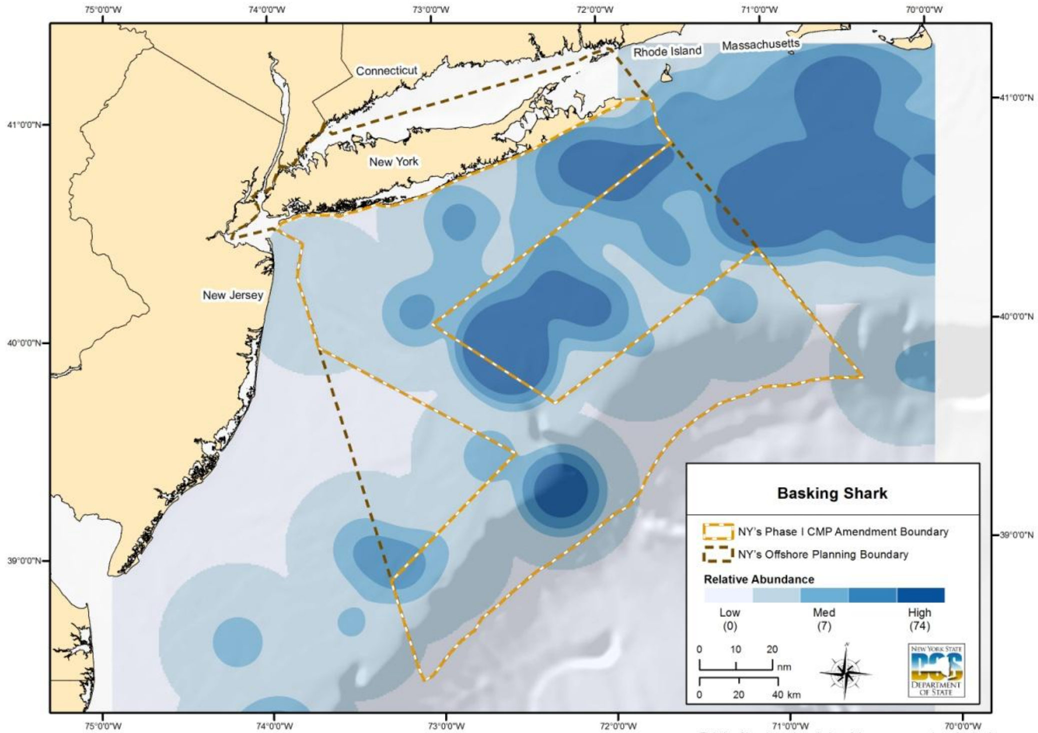
Species Distributions

Individual Species



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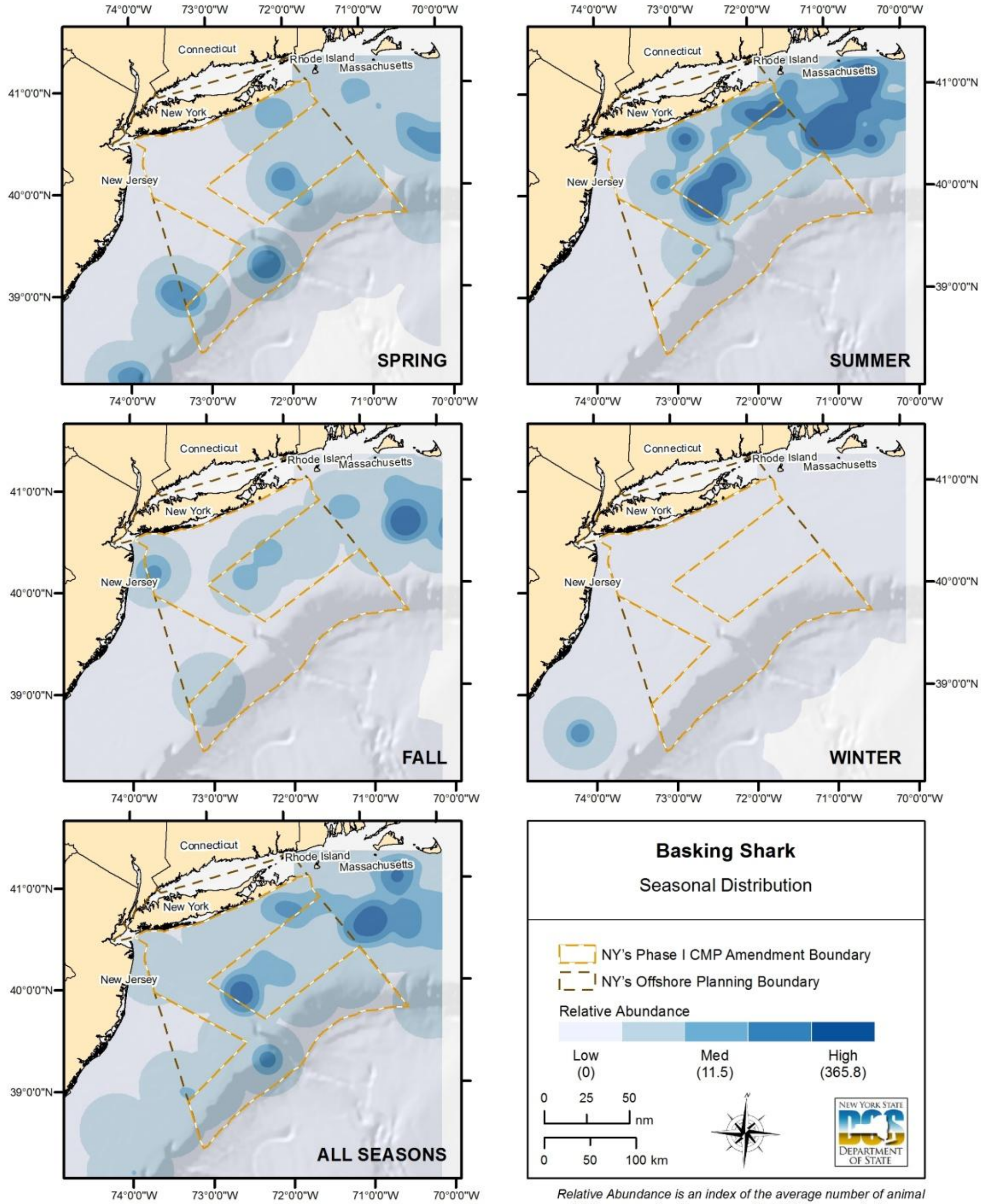

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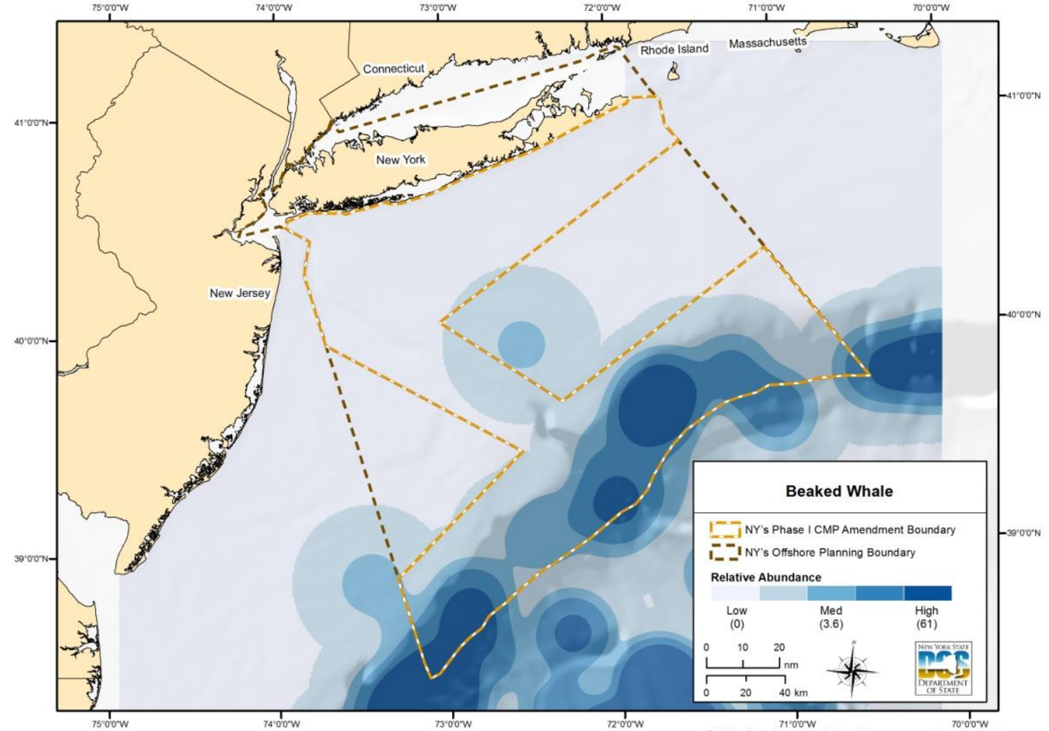

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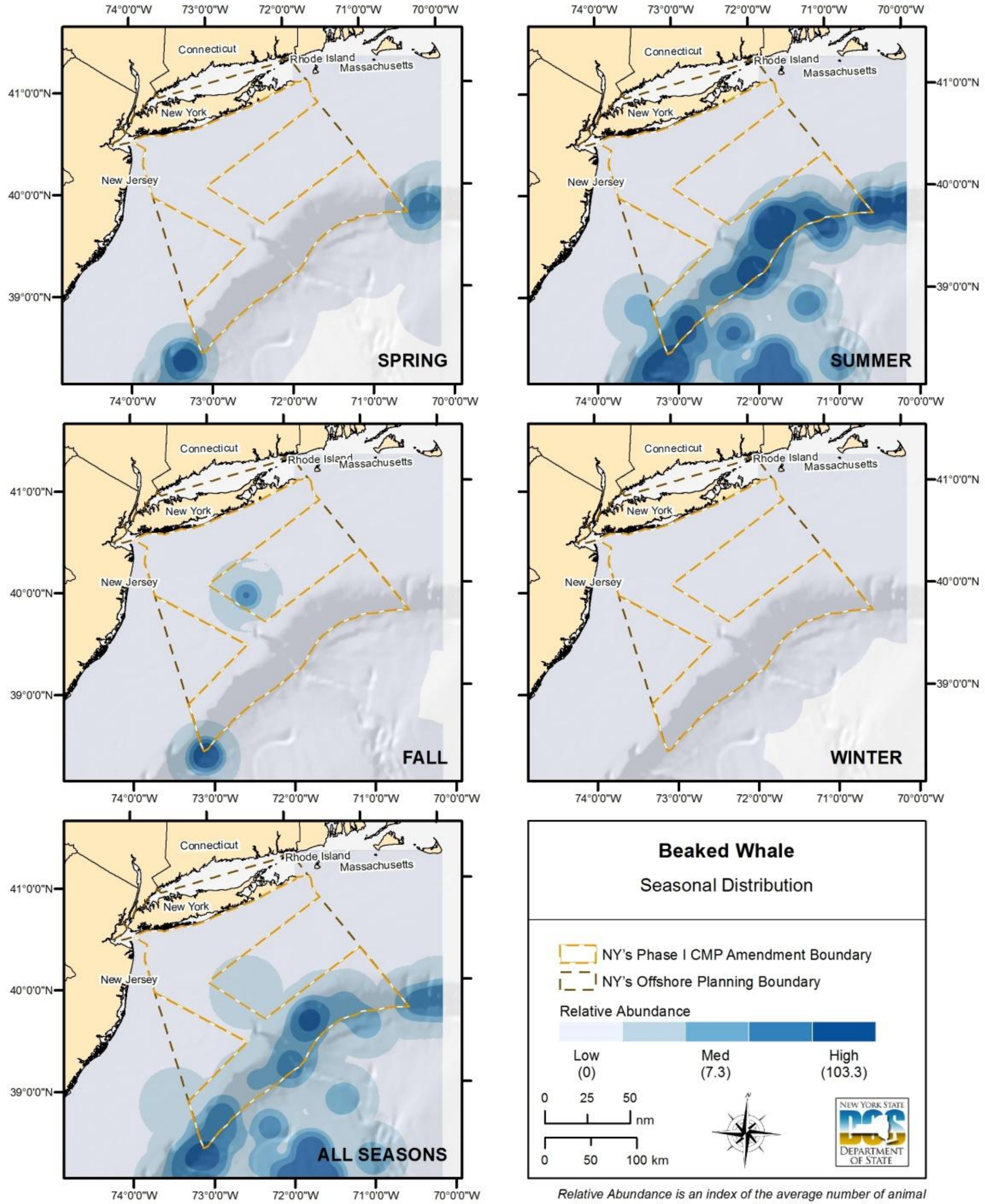

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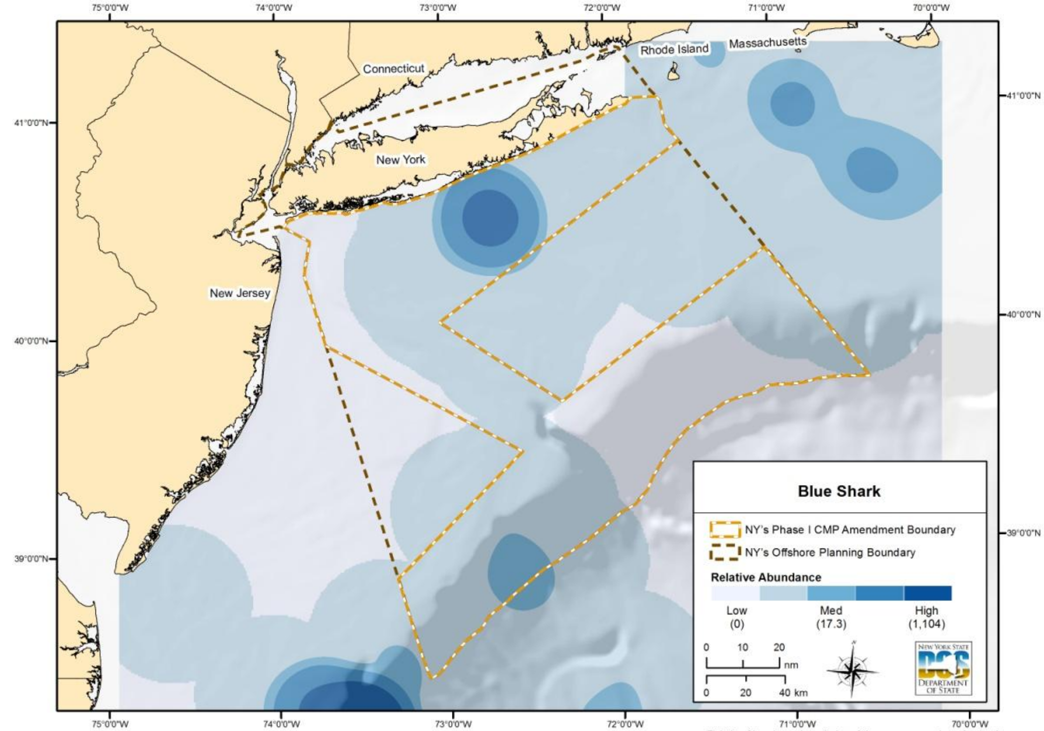

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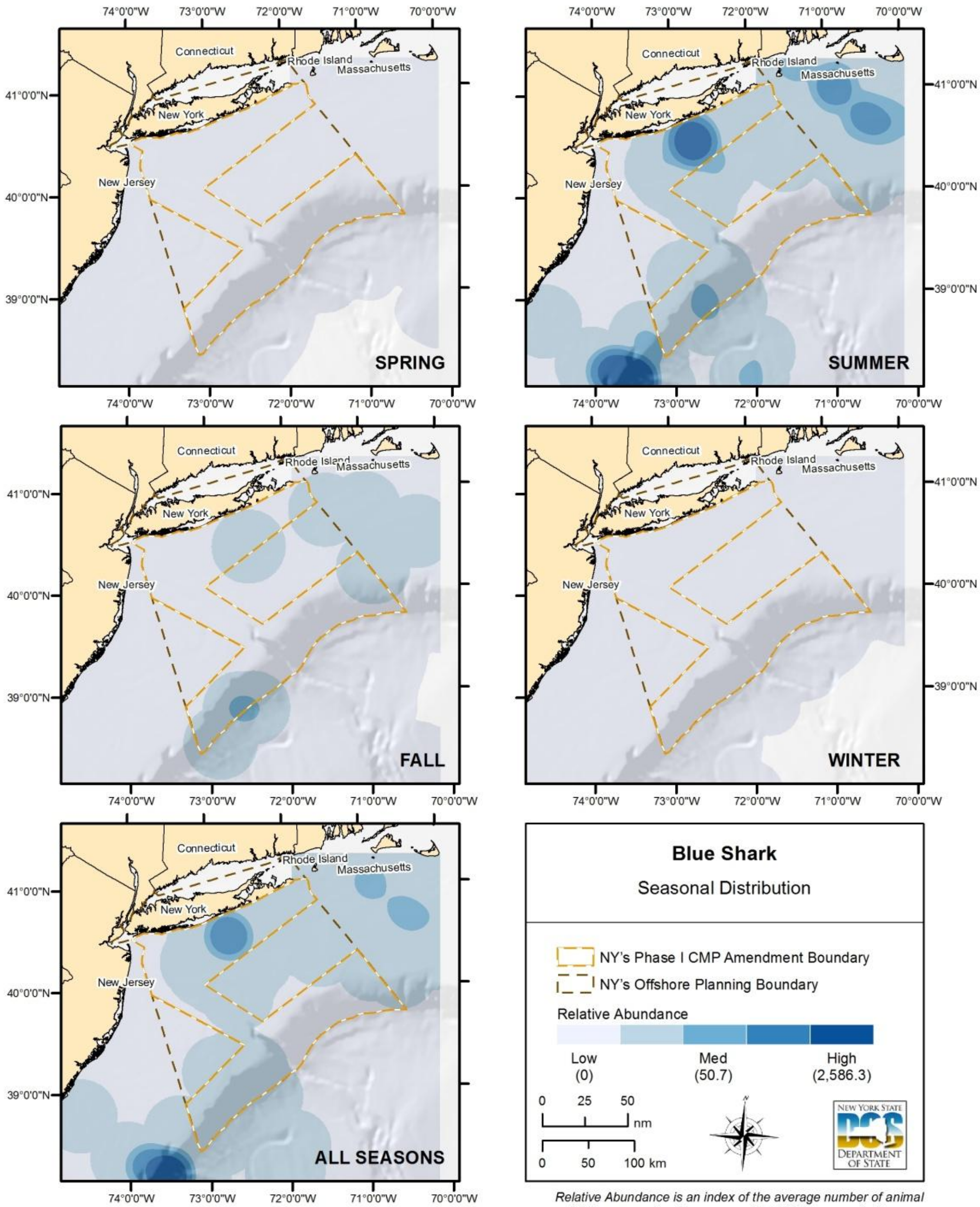

Blue Shark

Seasonal Distribution

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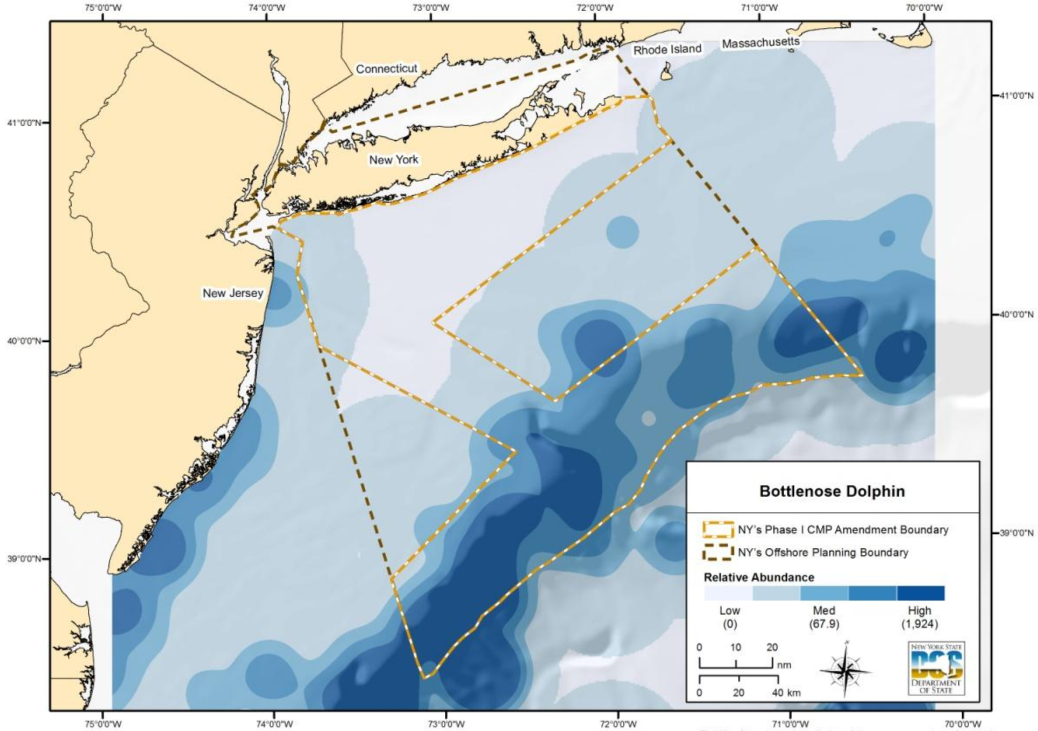
New England Aquarium

Protecting the blue planet



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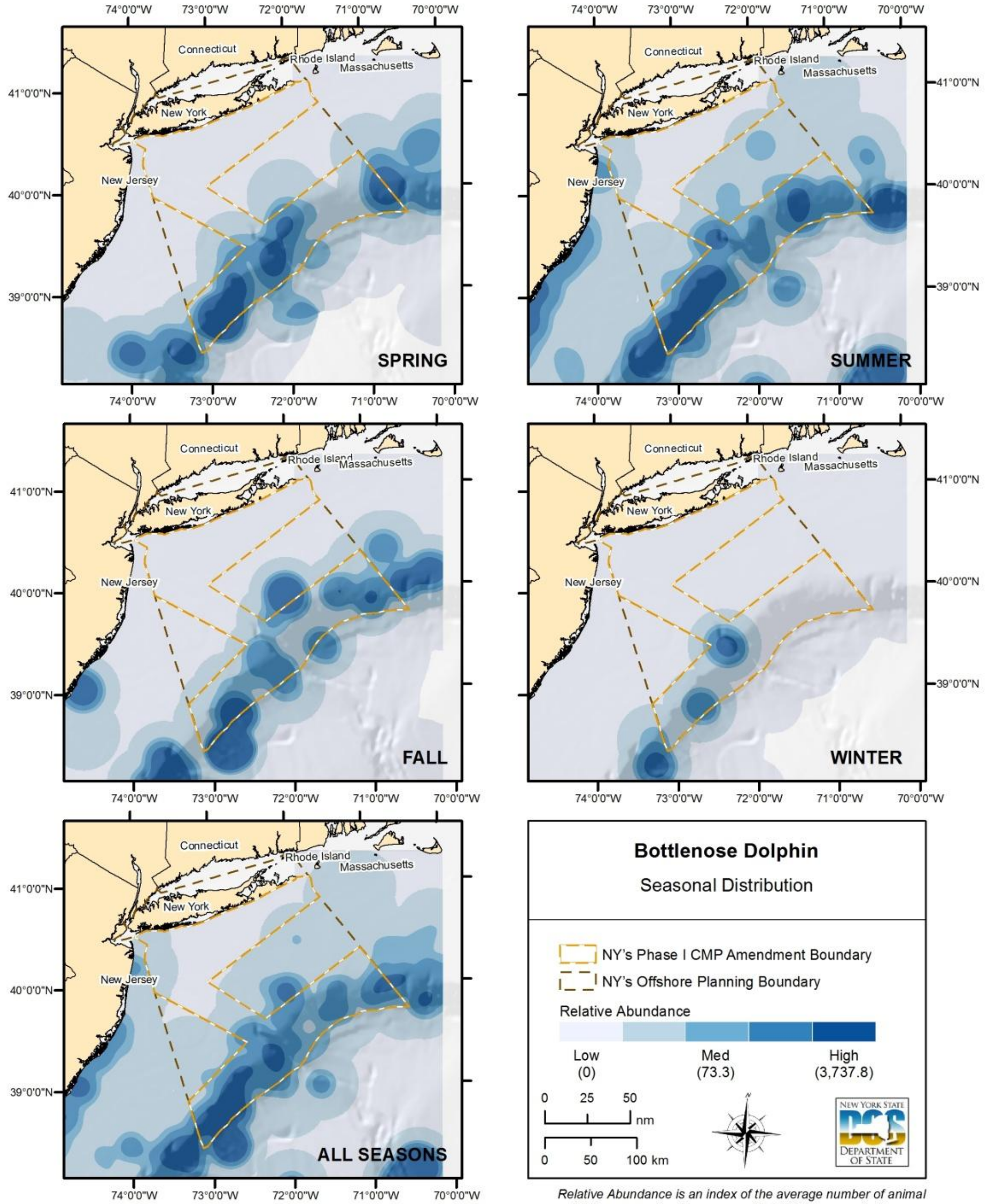

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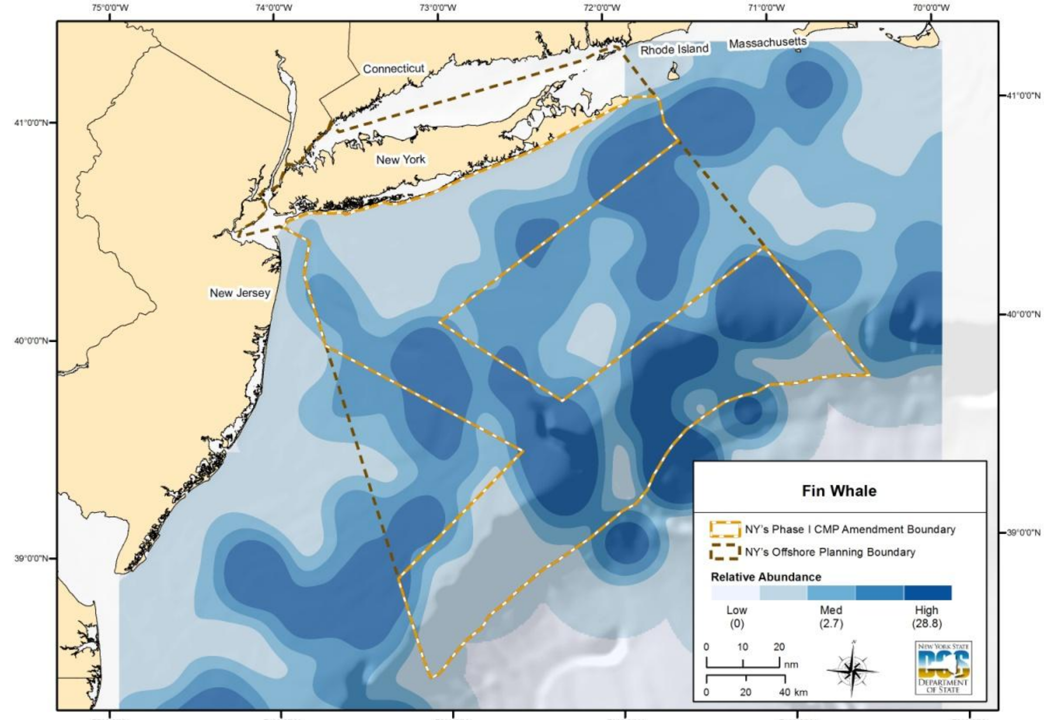

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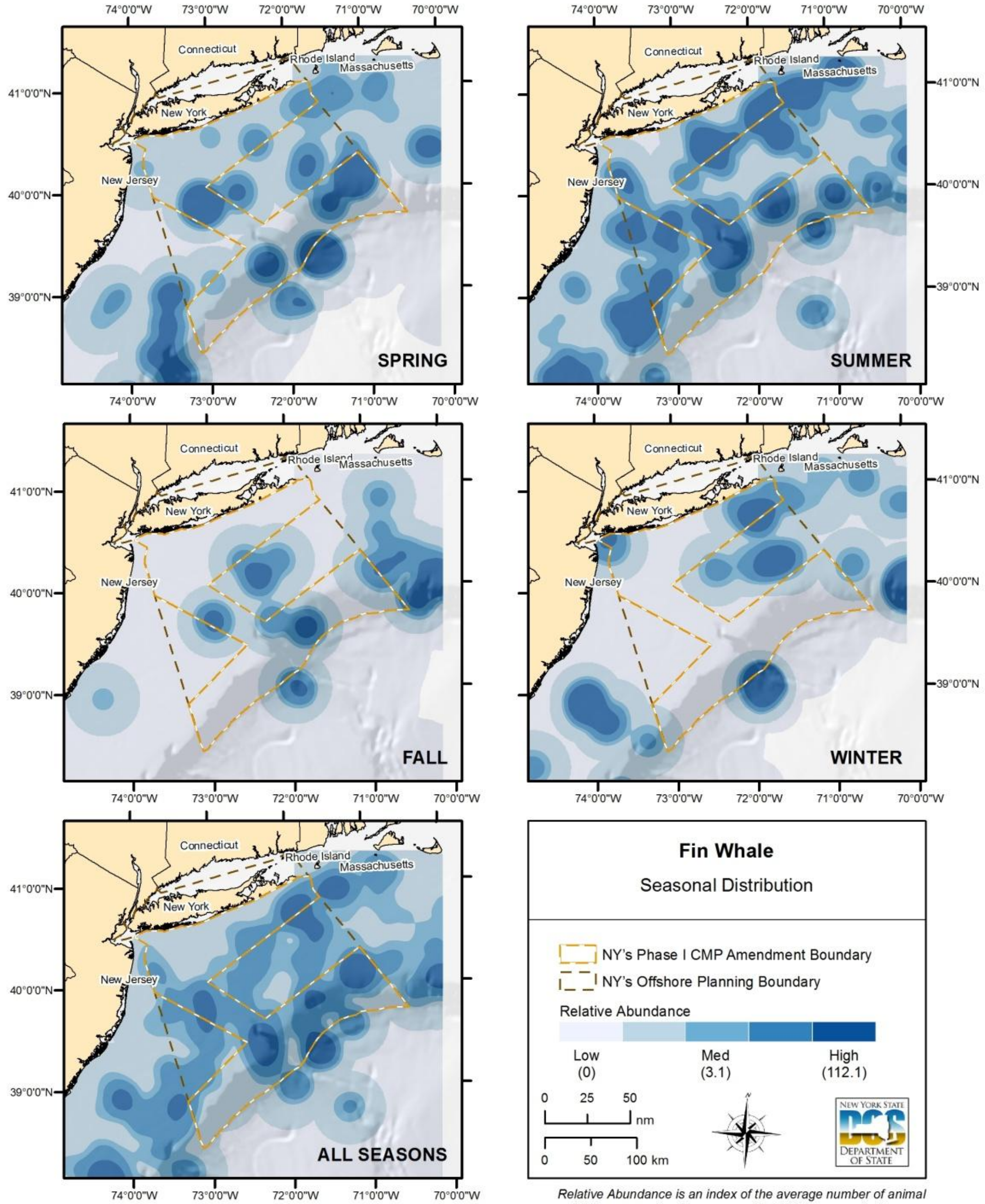

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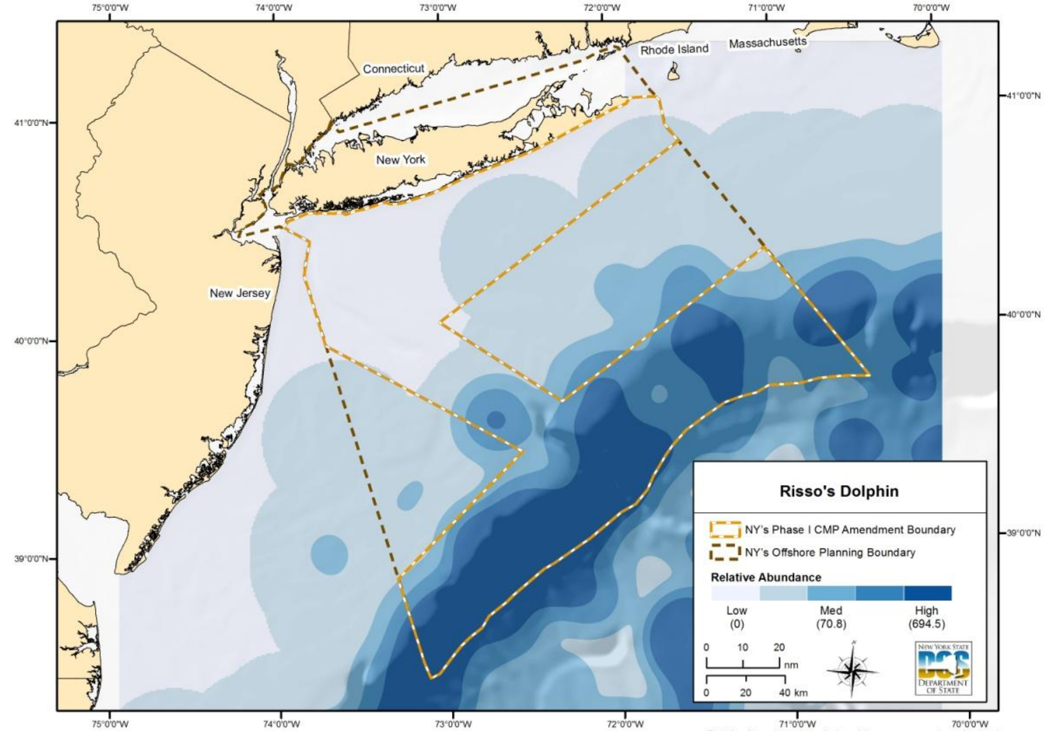

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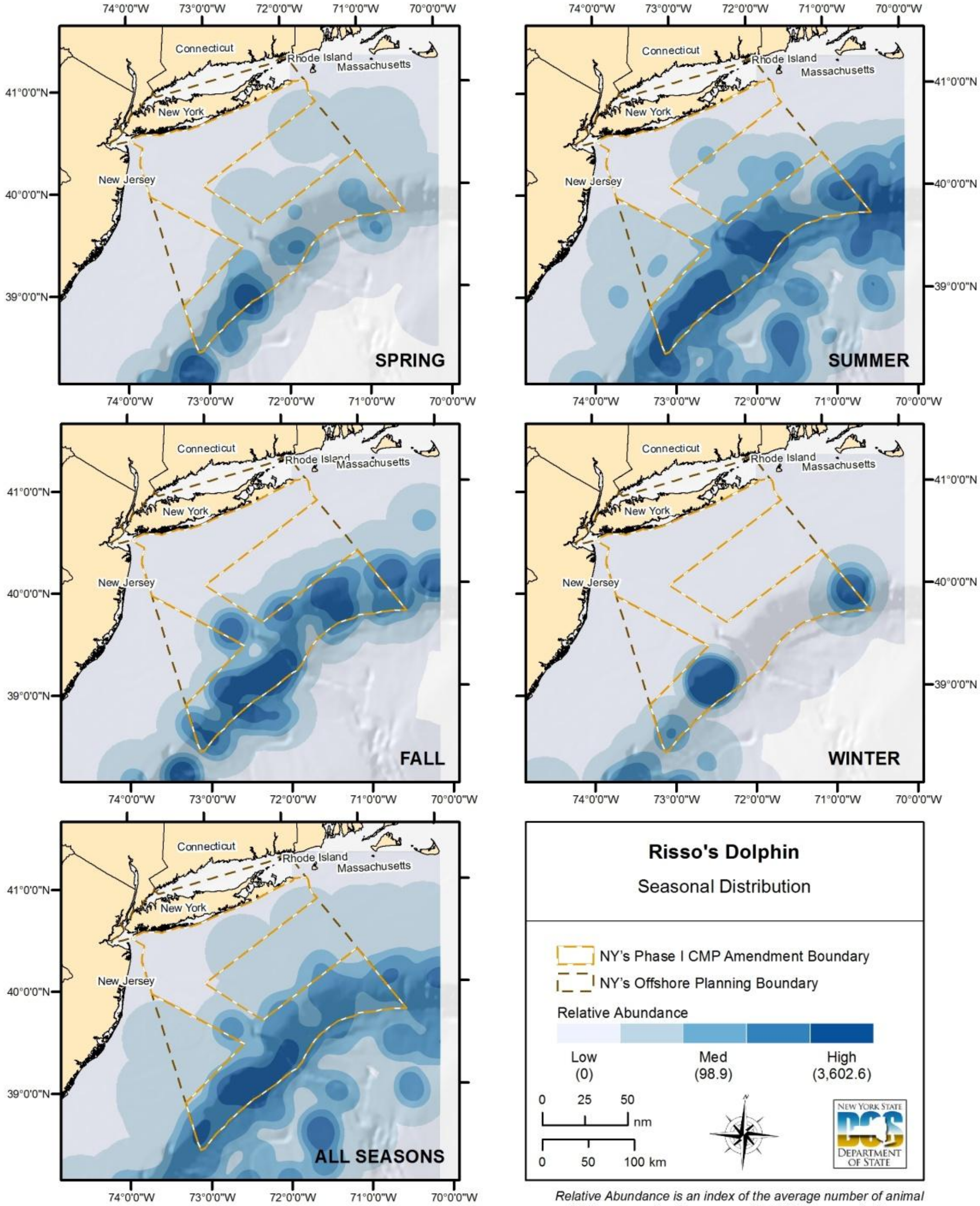

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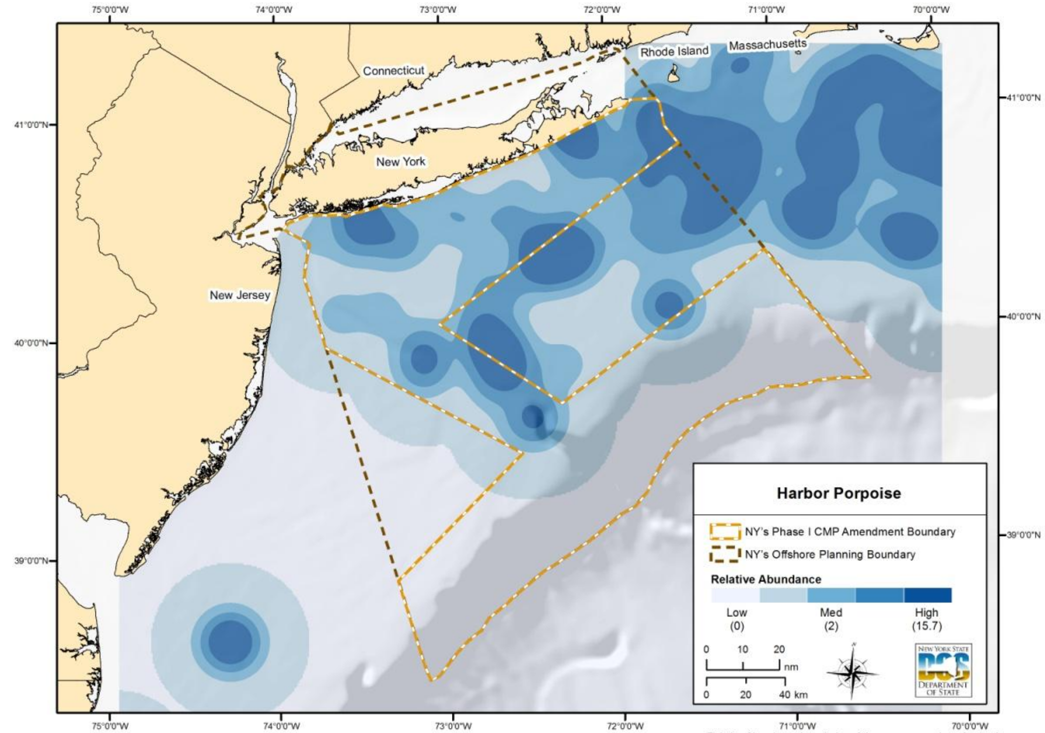

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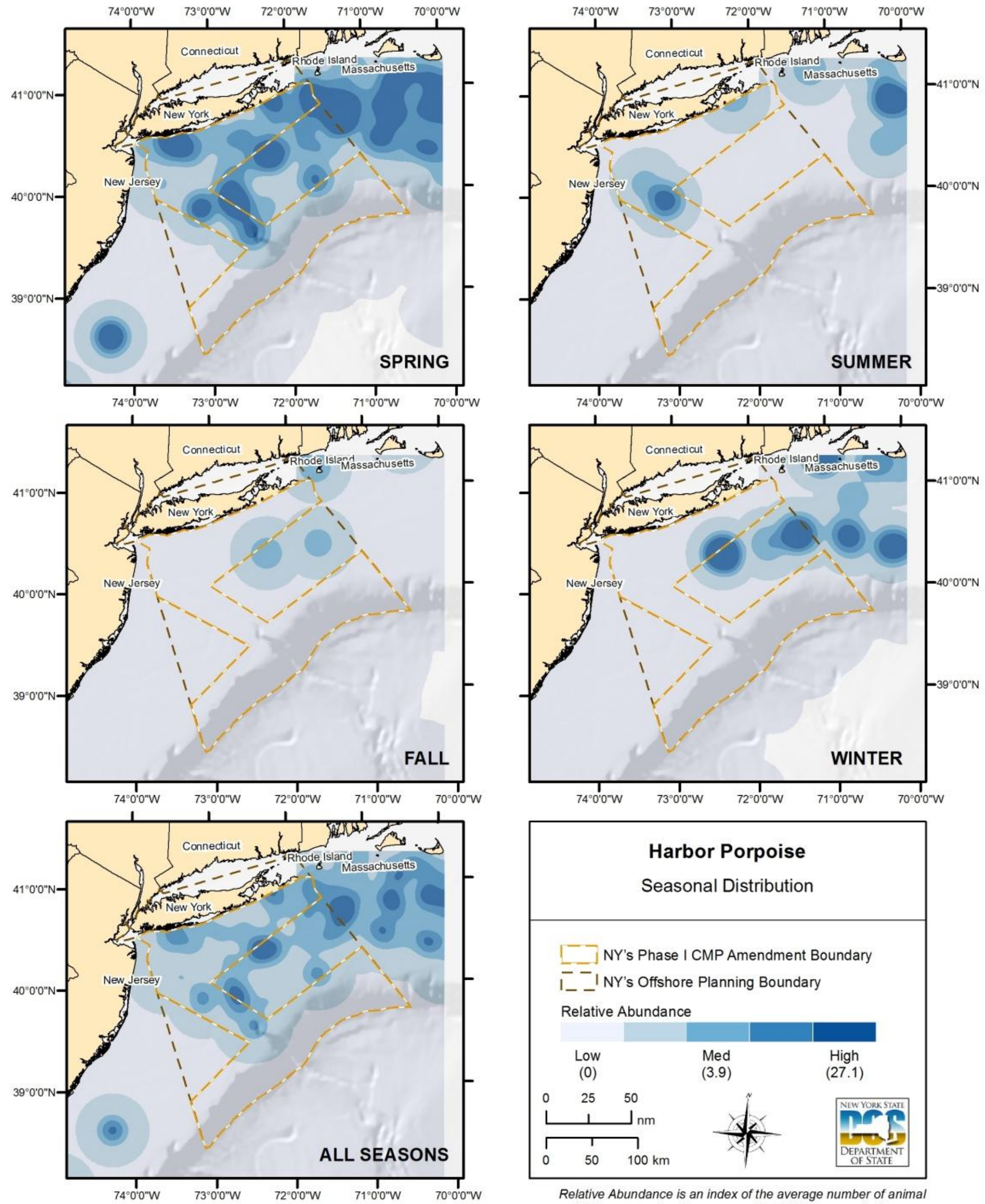

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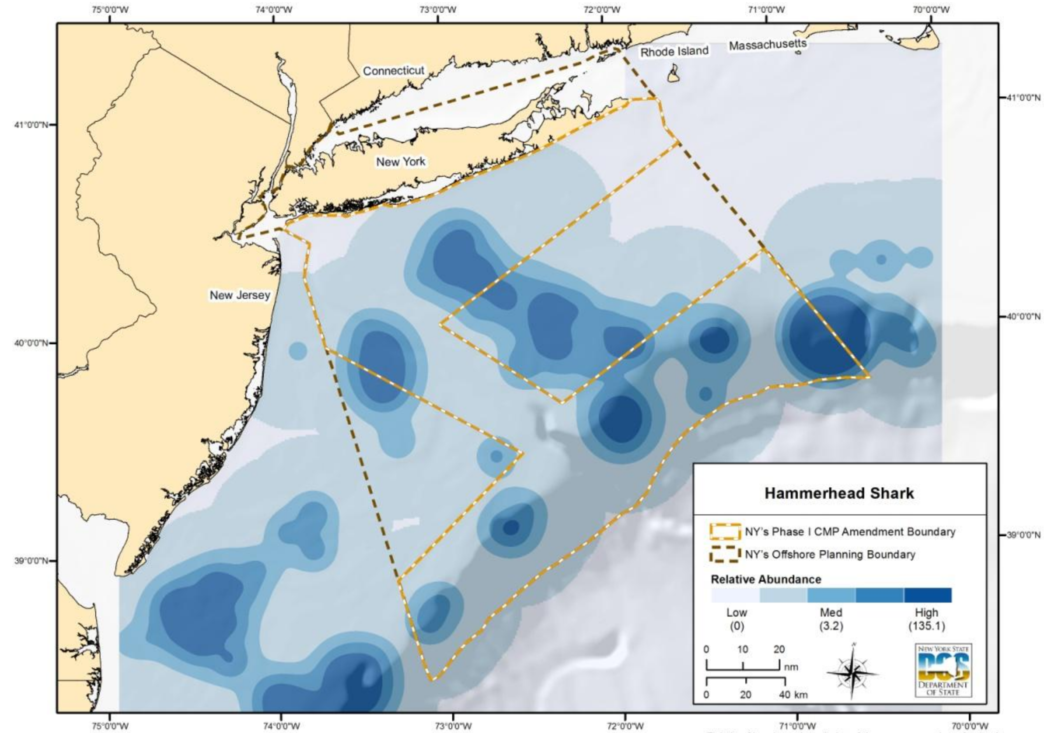

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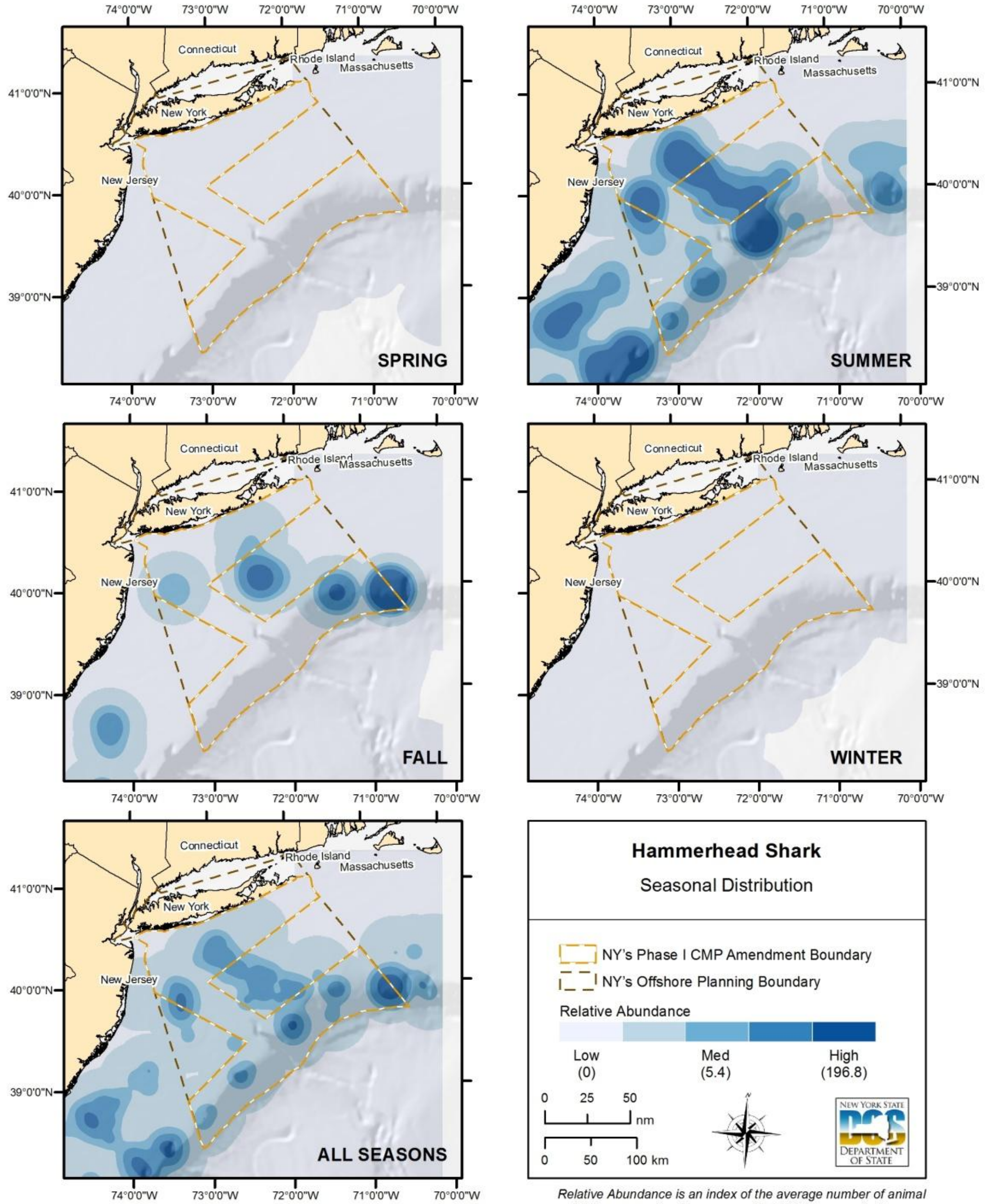

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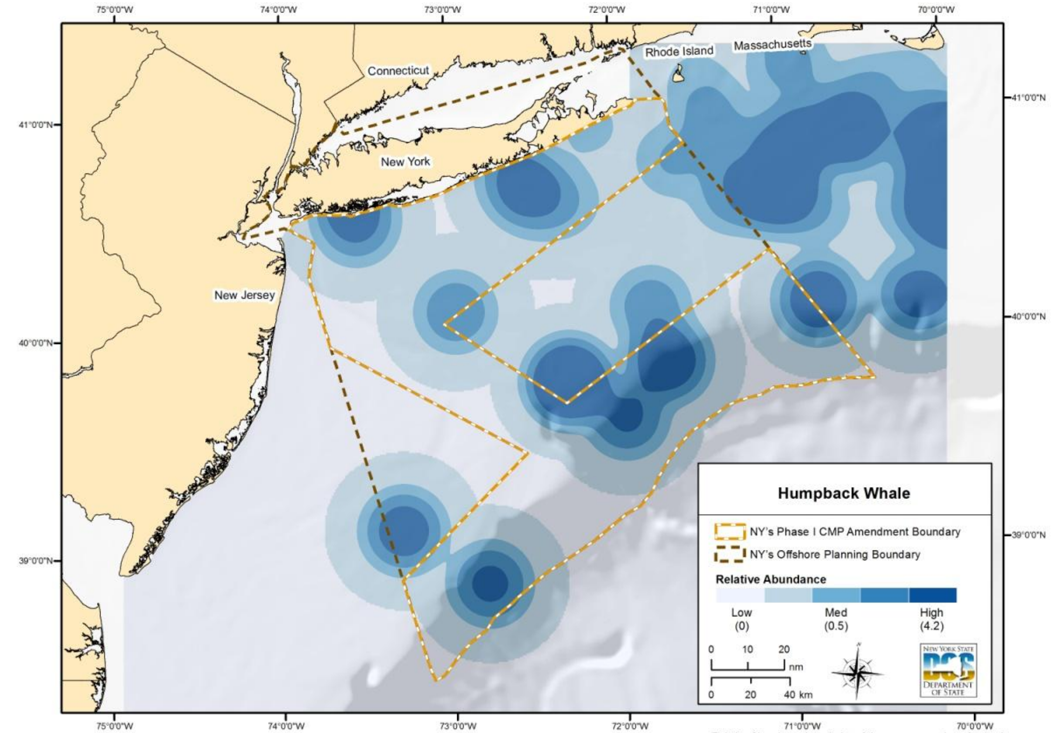

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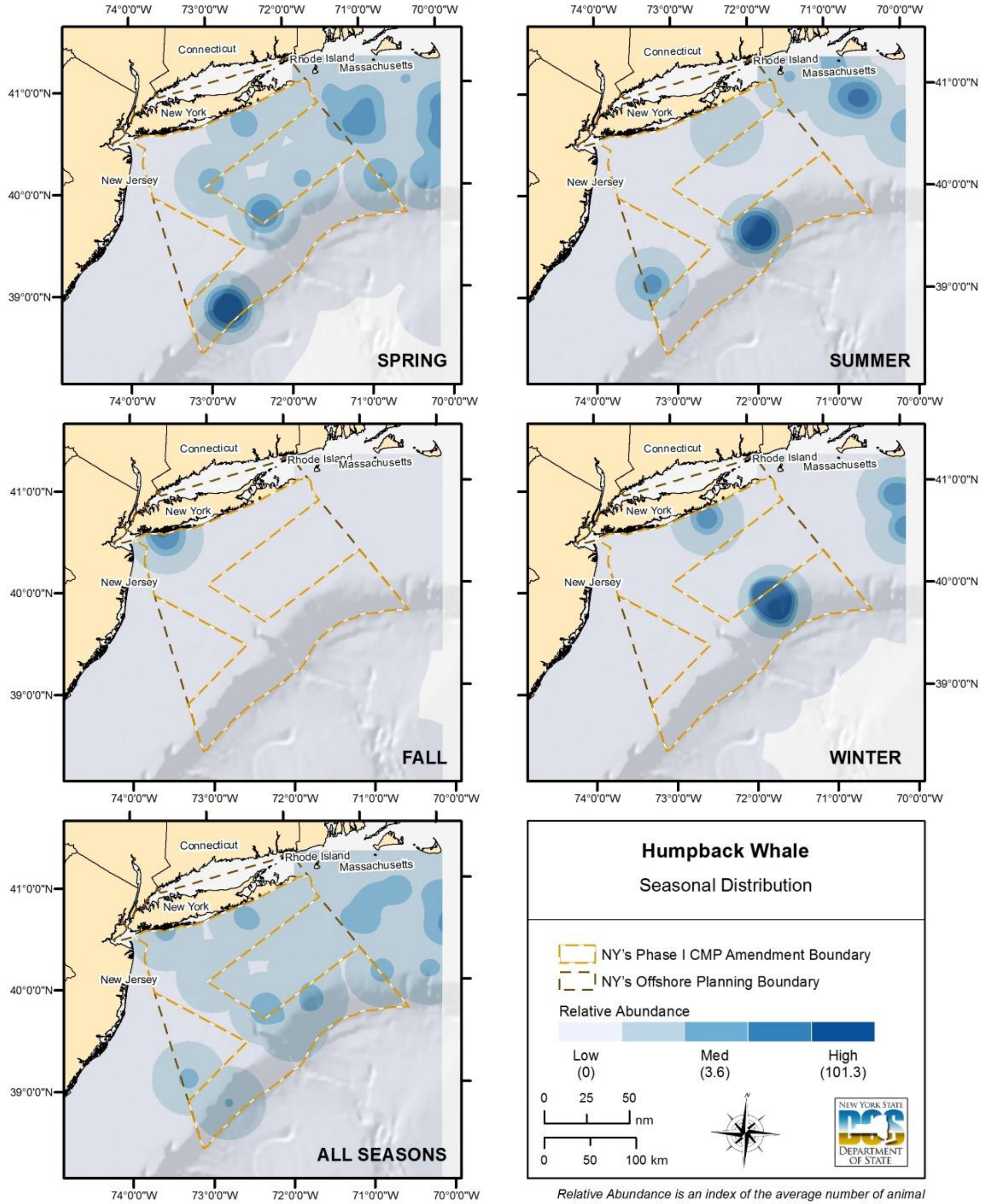

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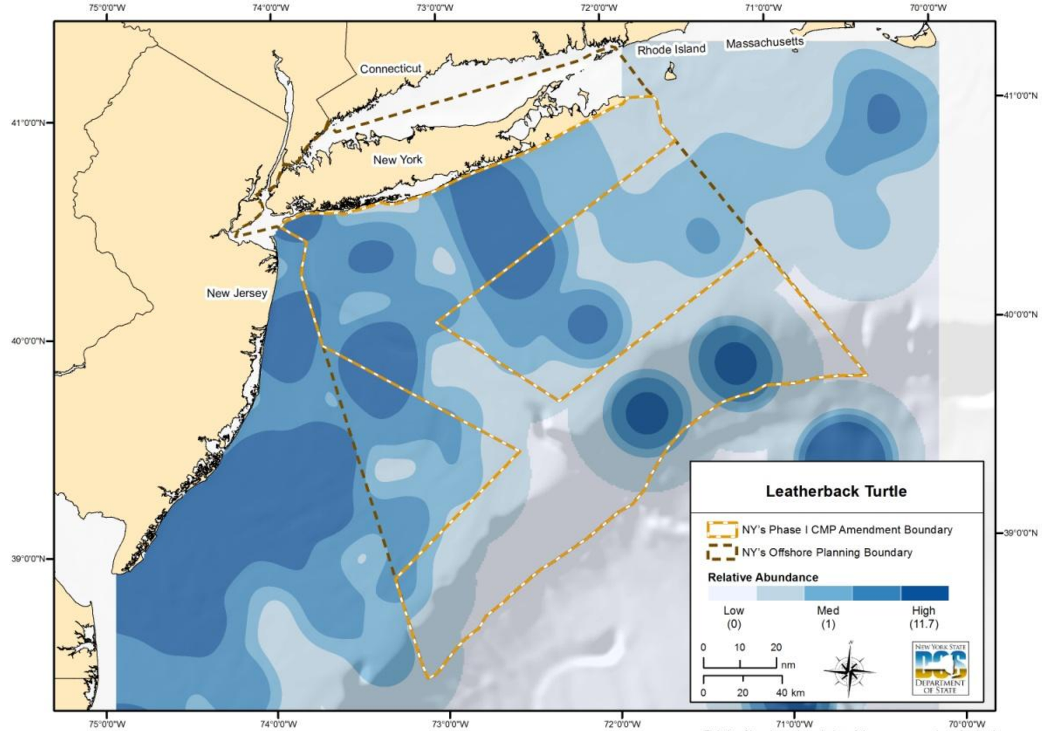

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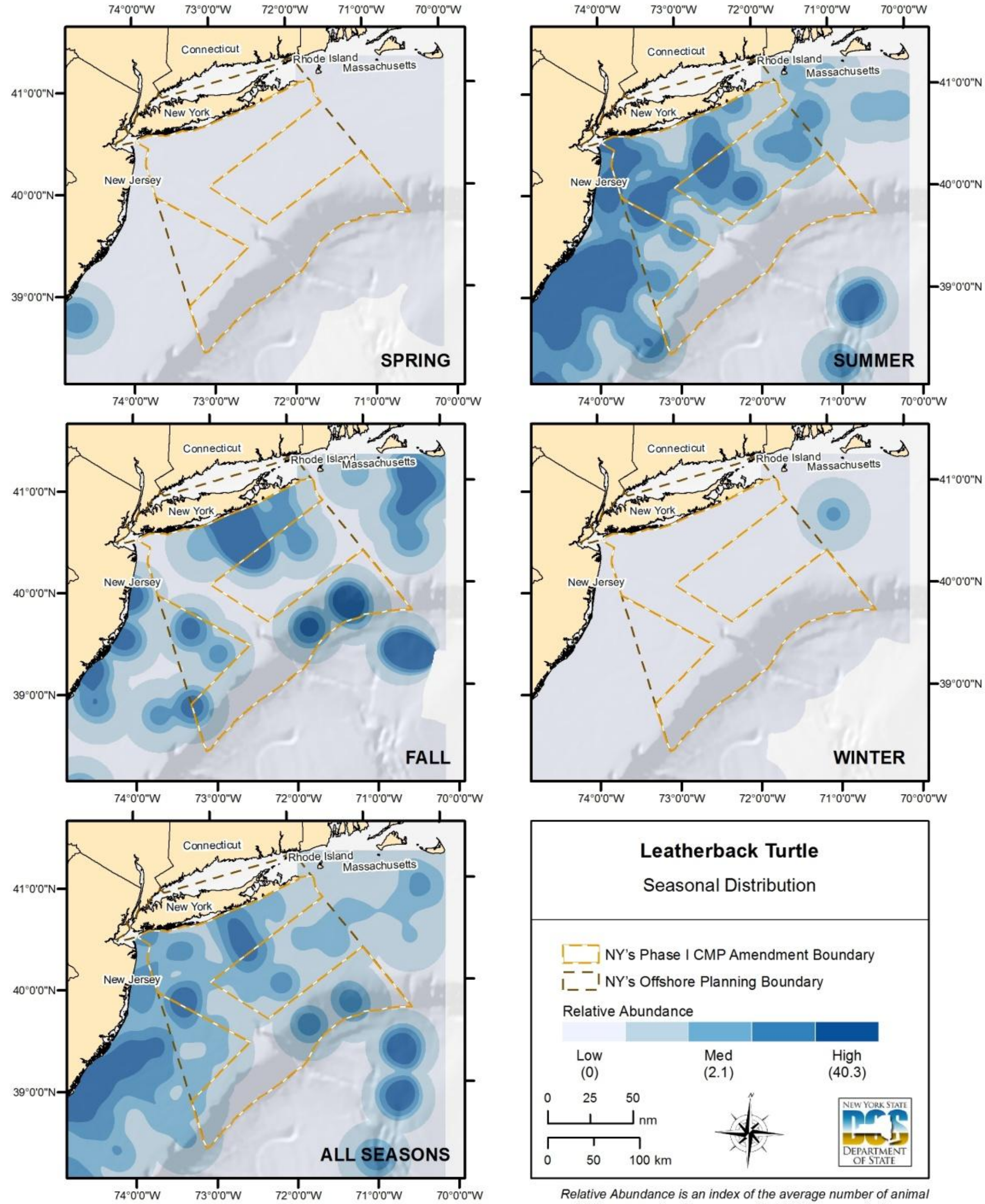

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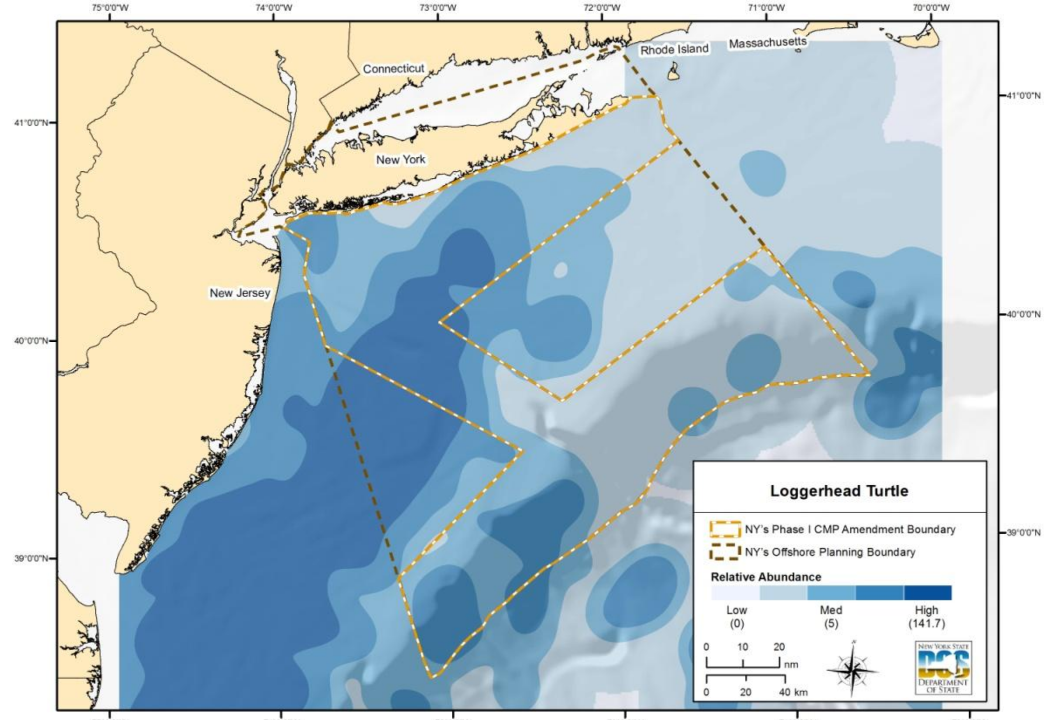

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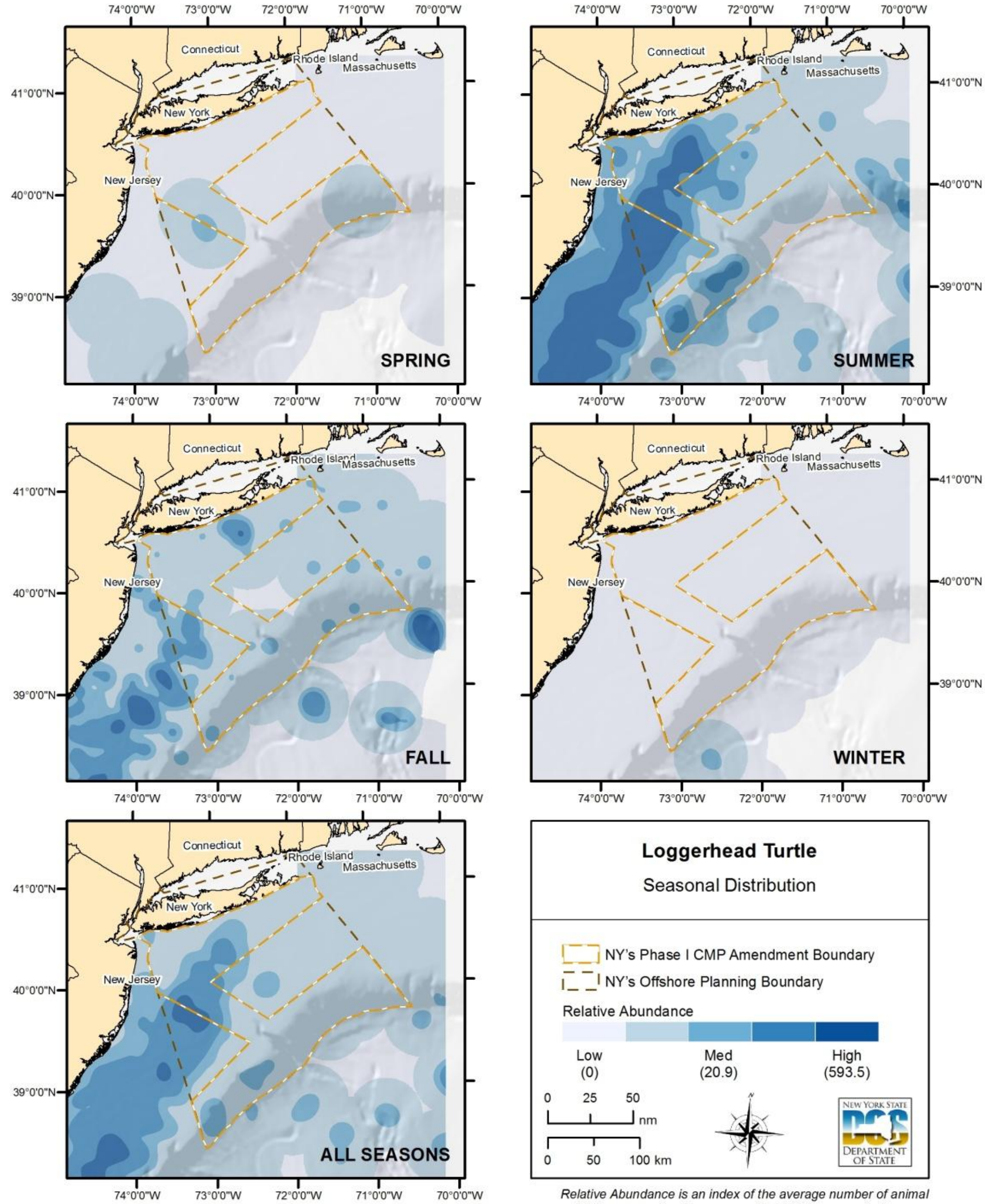

Loggerhead Turtle

Seasonal Distribution

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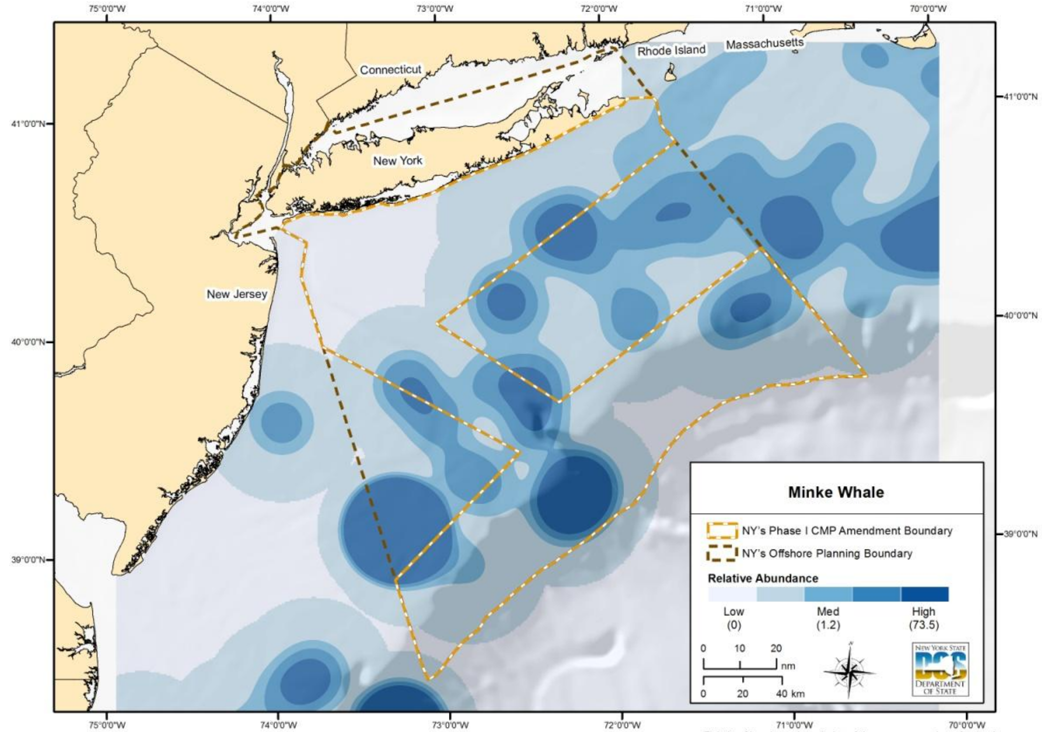

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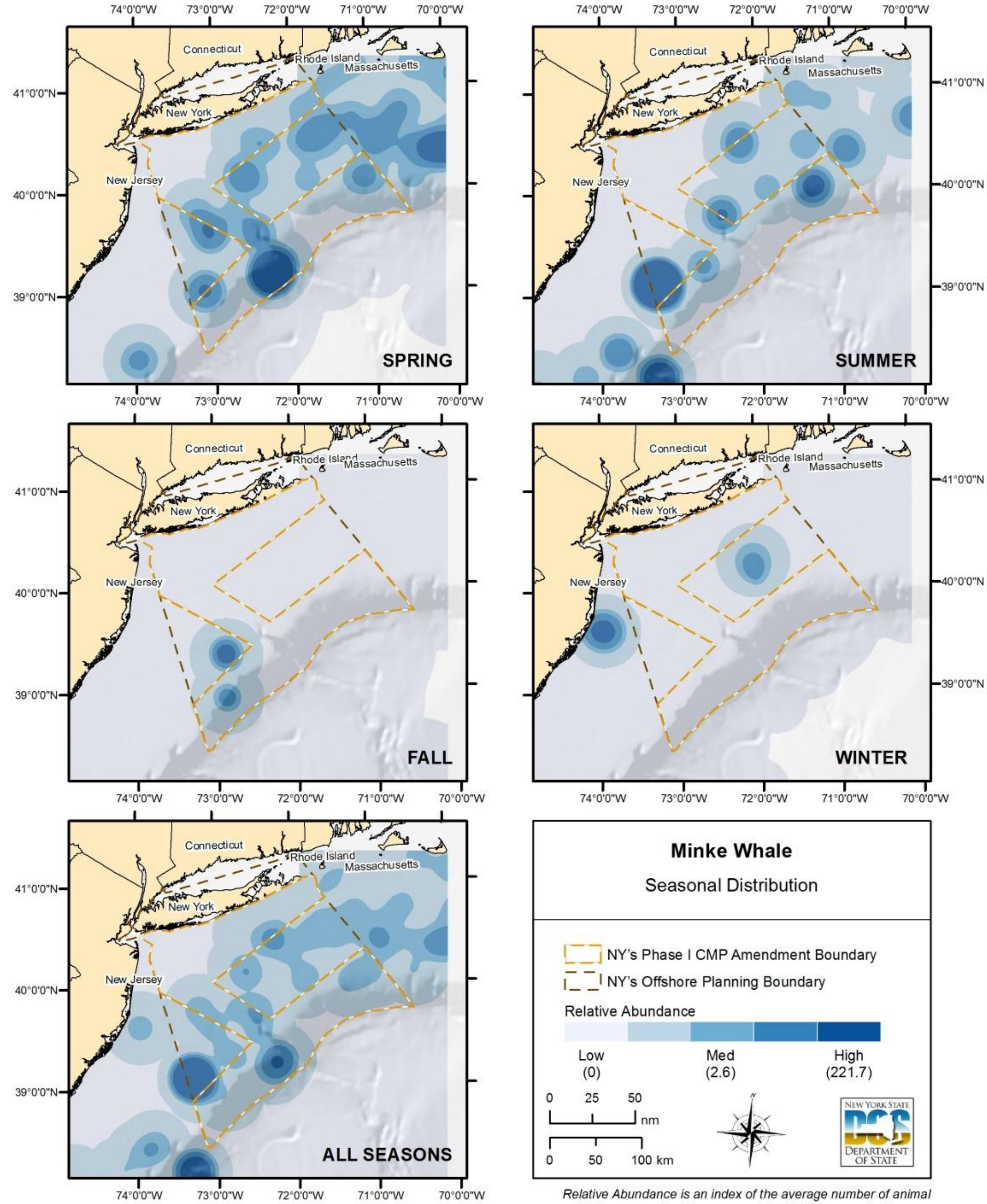

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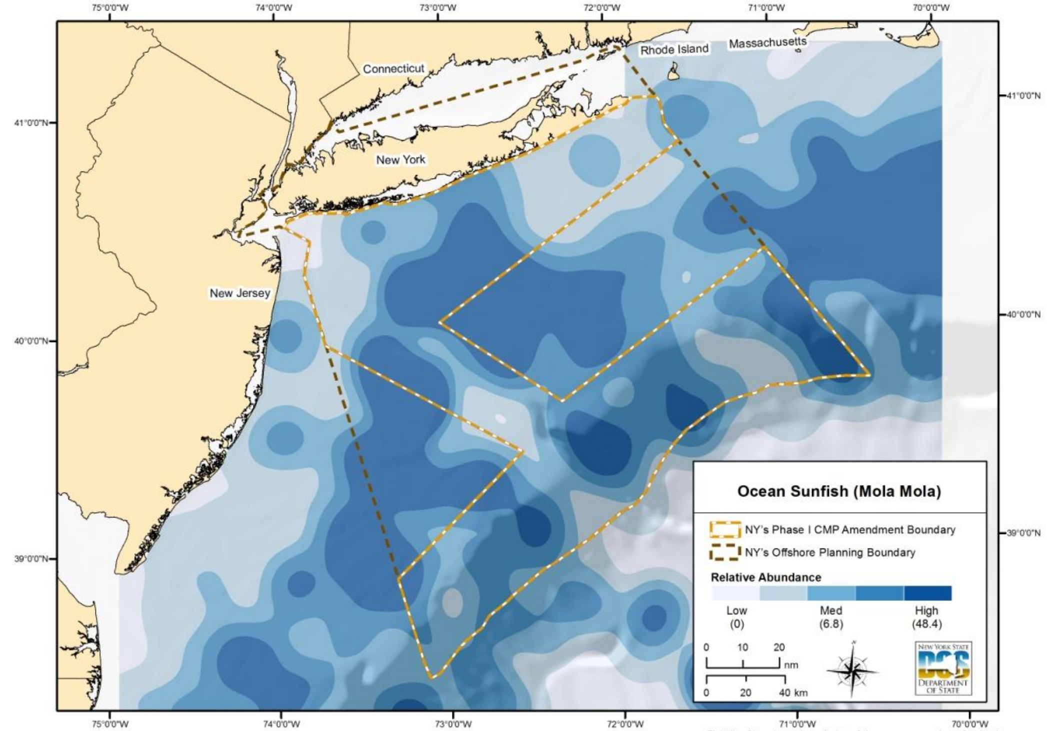

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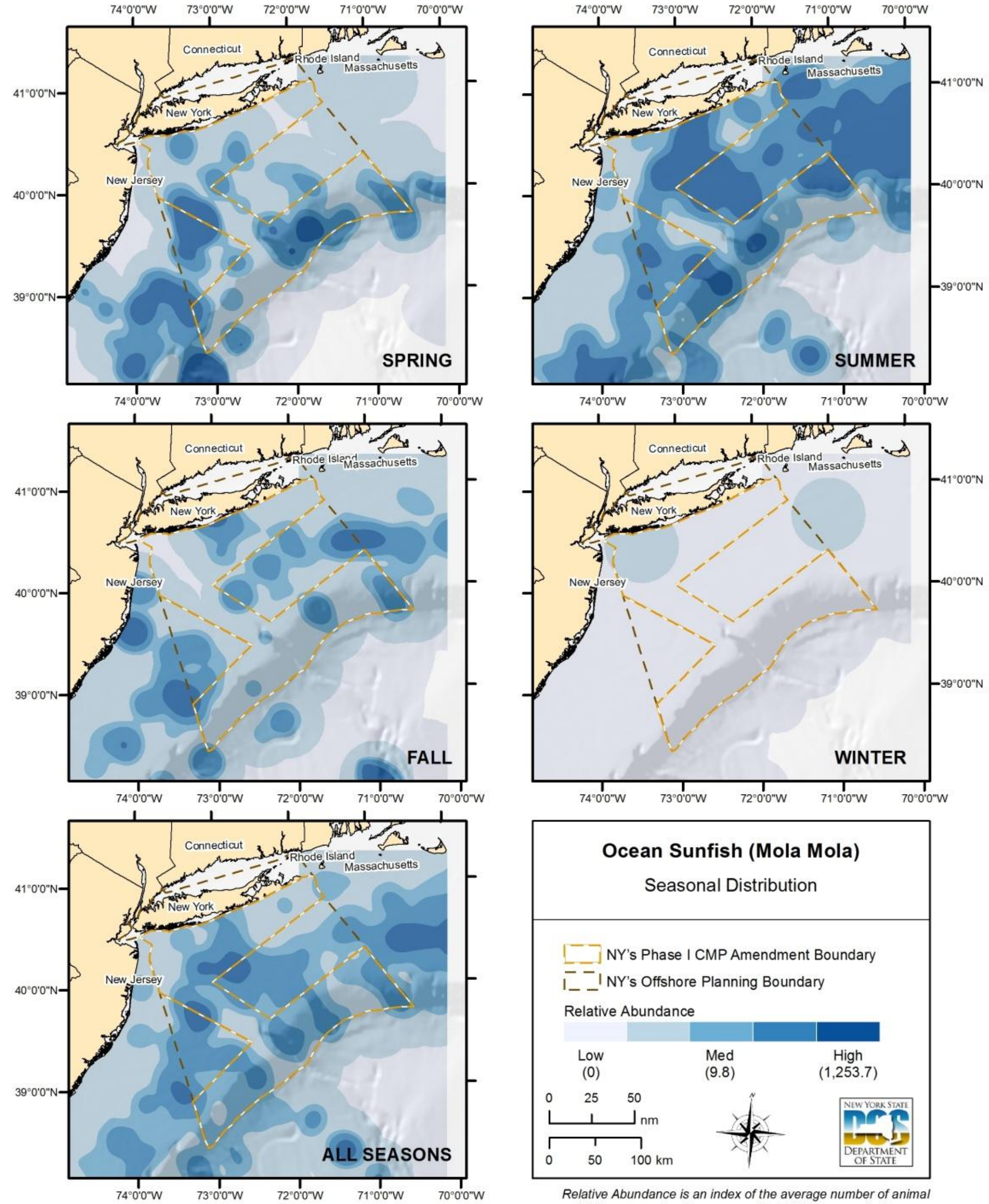

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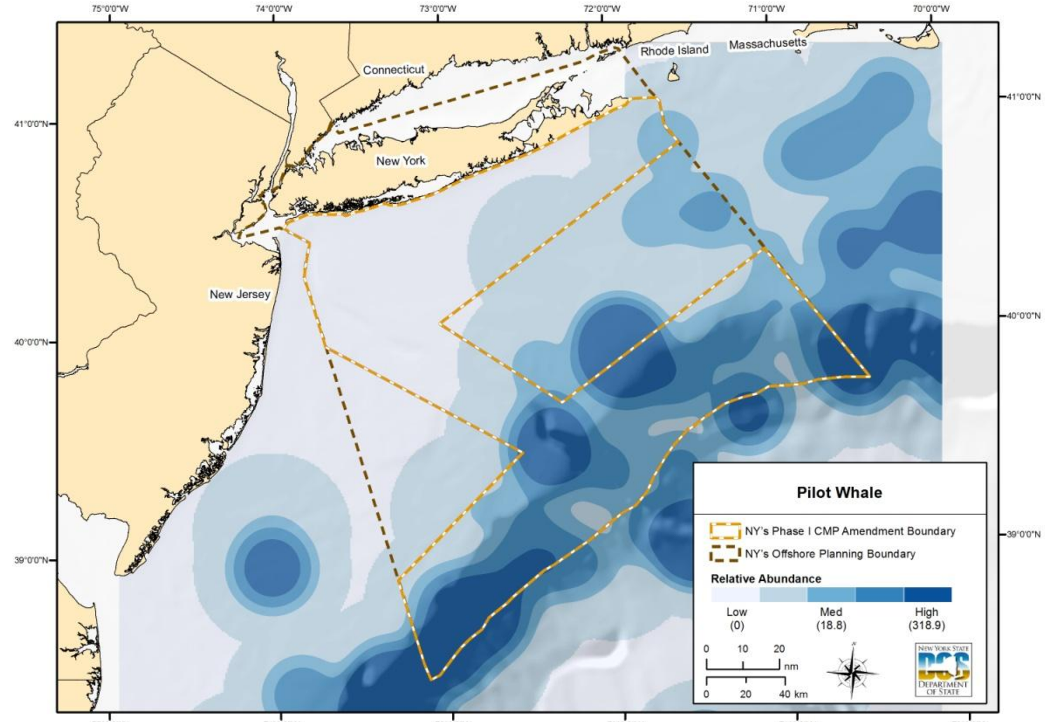

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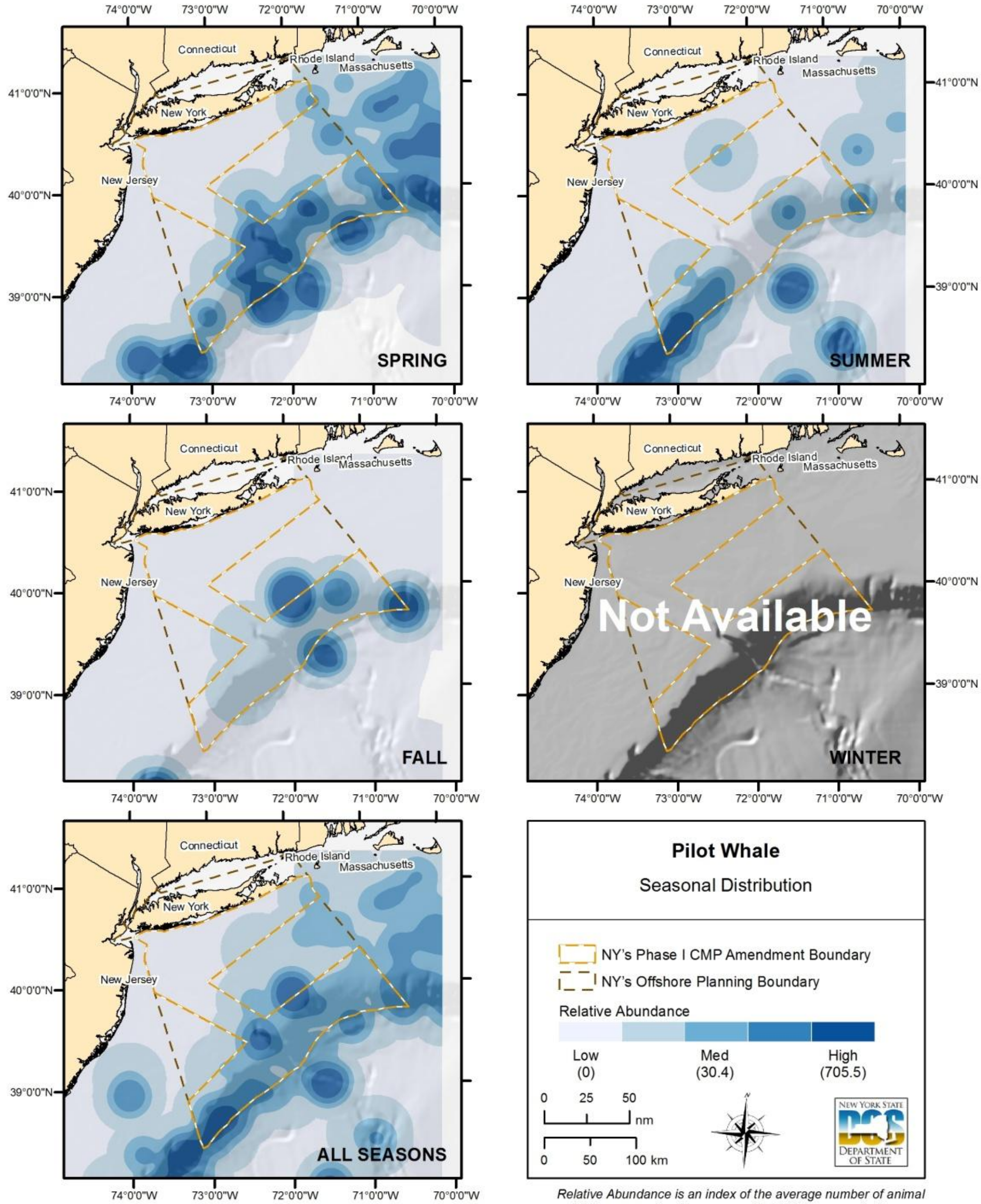

Pilot Whale

Seasonal Distribution

New England Aquarium

Protecting the blue planet

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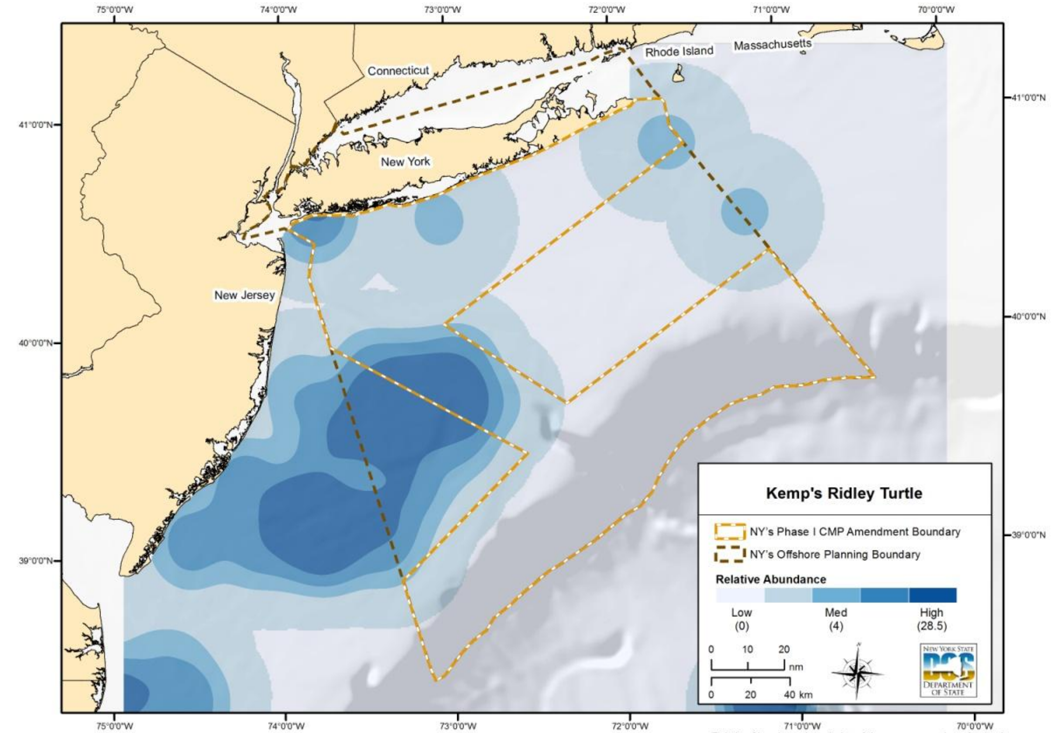

New England Aquarium
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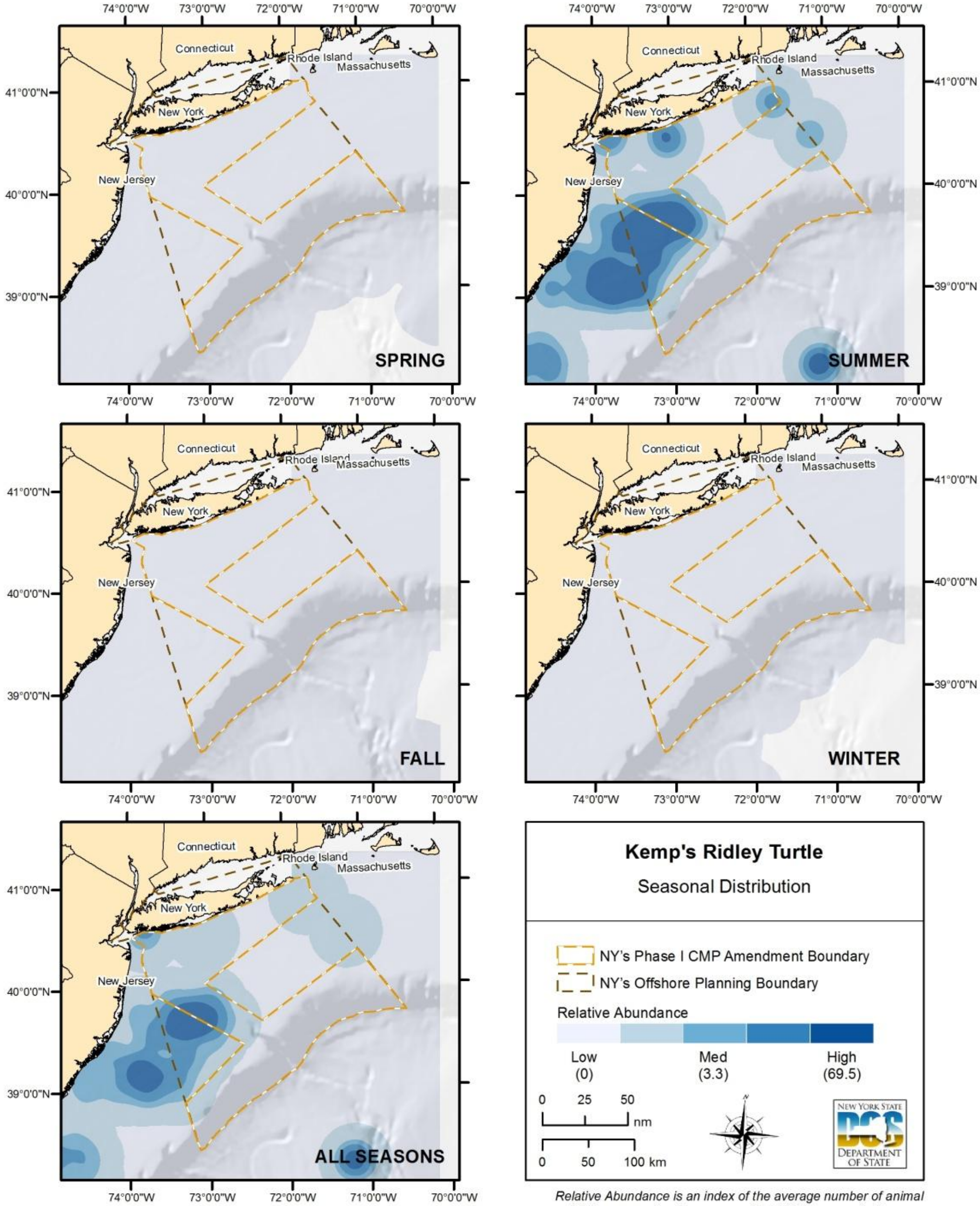

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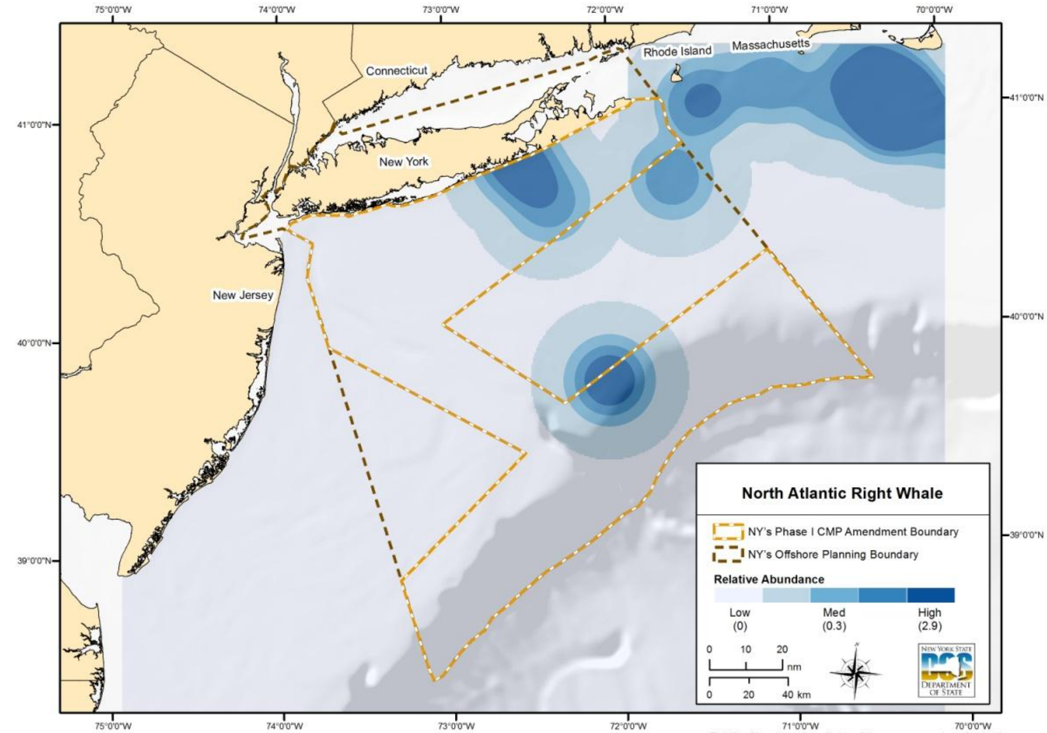

New England Aquarium

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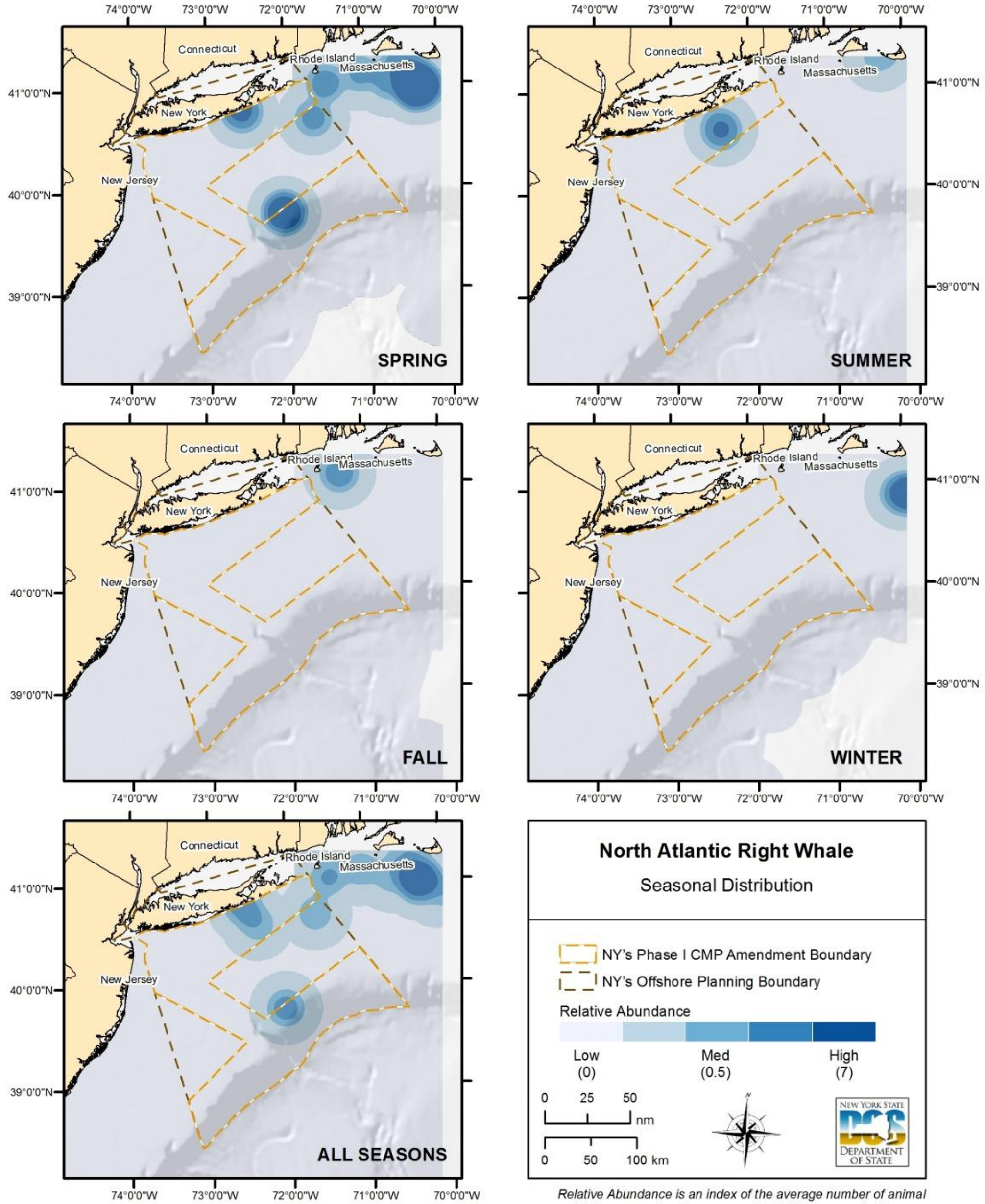

New England Aquarium

Protecting the blue planet

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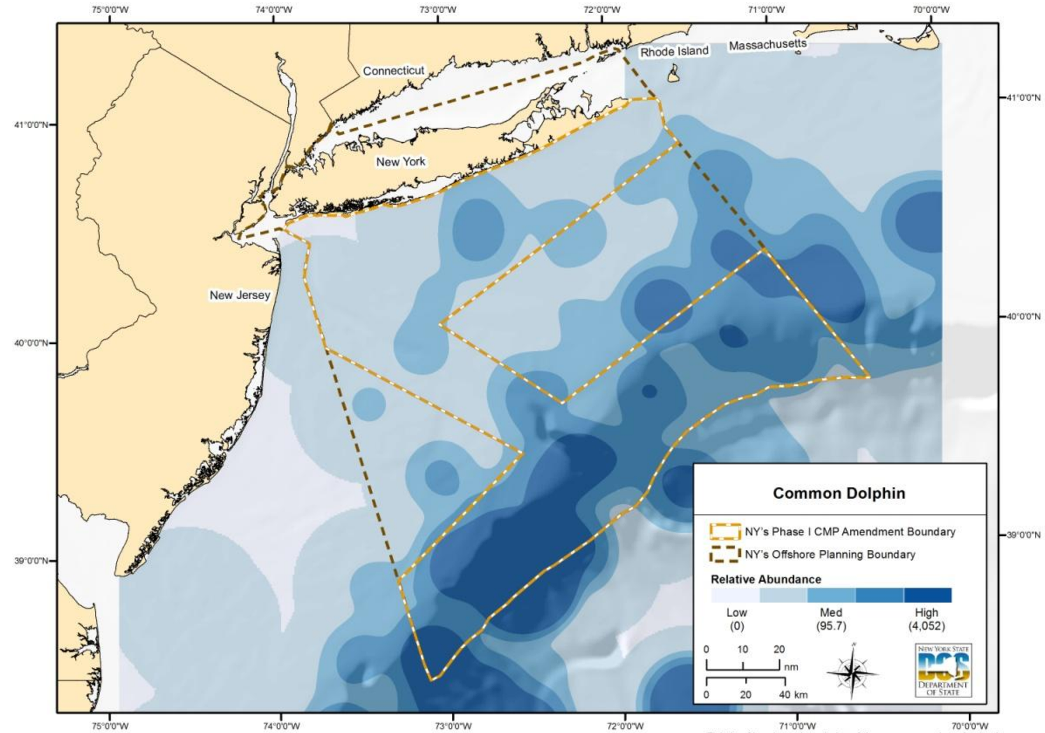
Sources: Right Whale Consortium Database, 1978 - 2009; Planning Boundaries, NY Department of State



New England Aquarium

Protecting the blue planet

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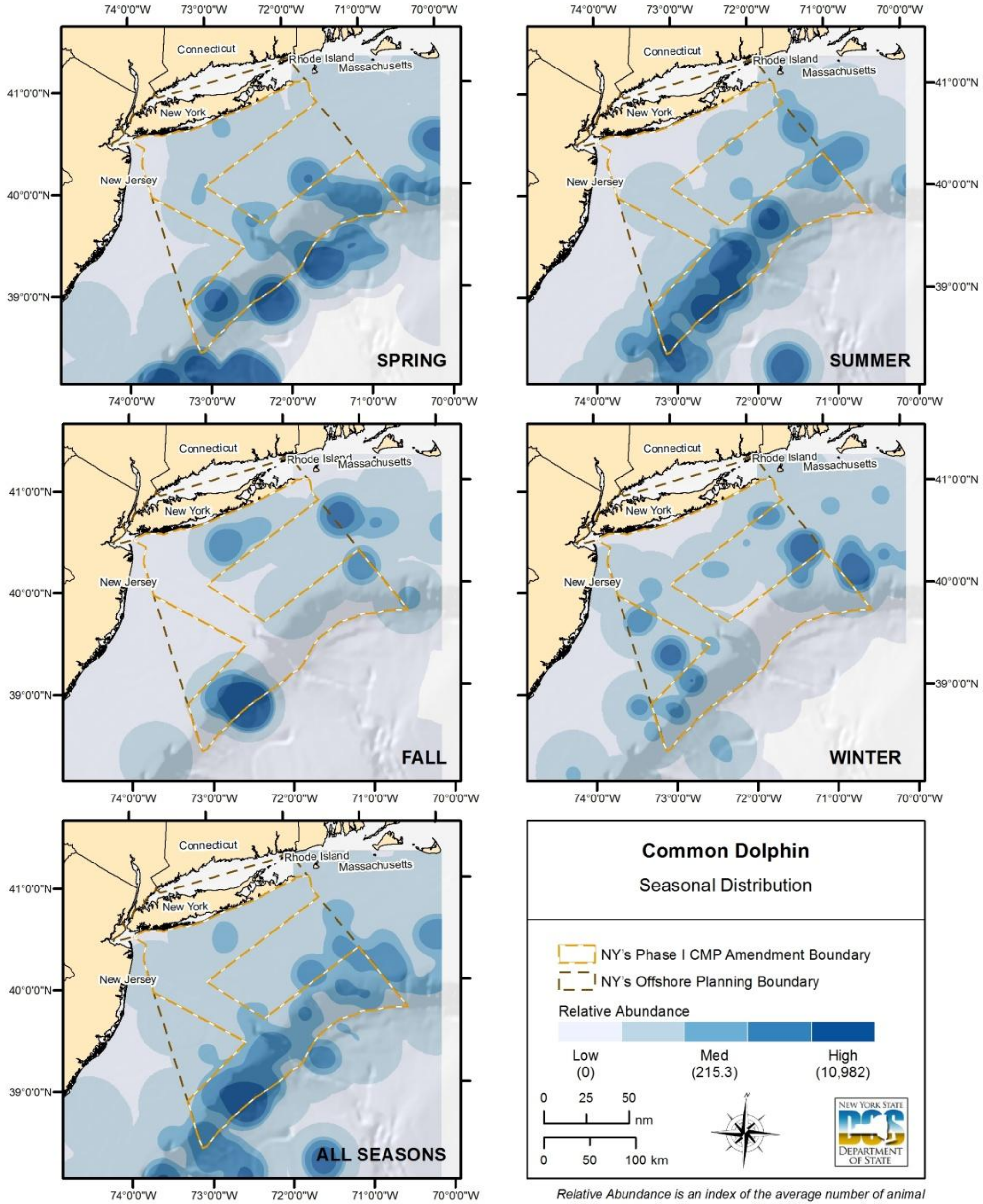

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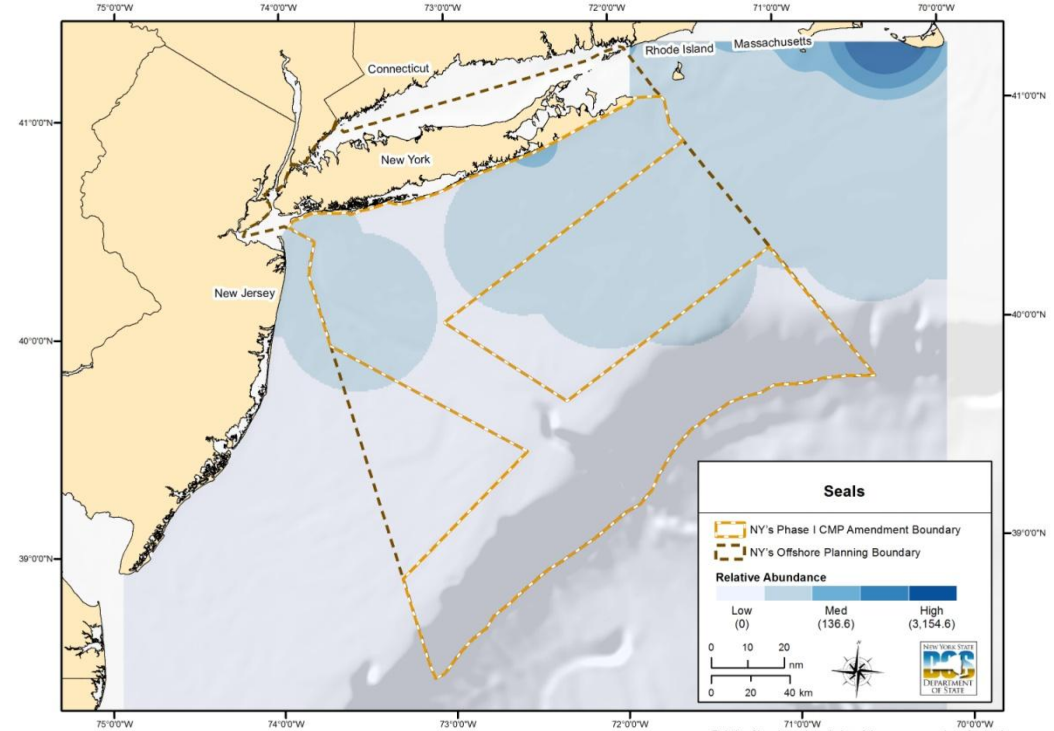

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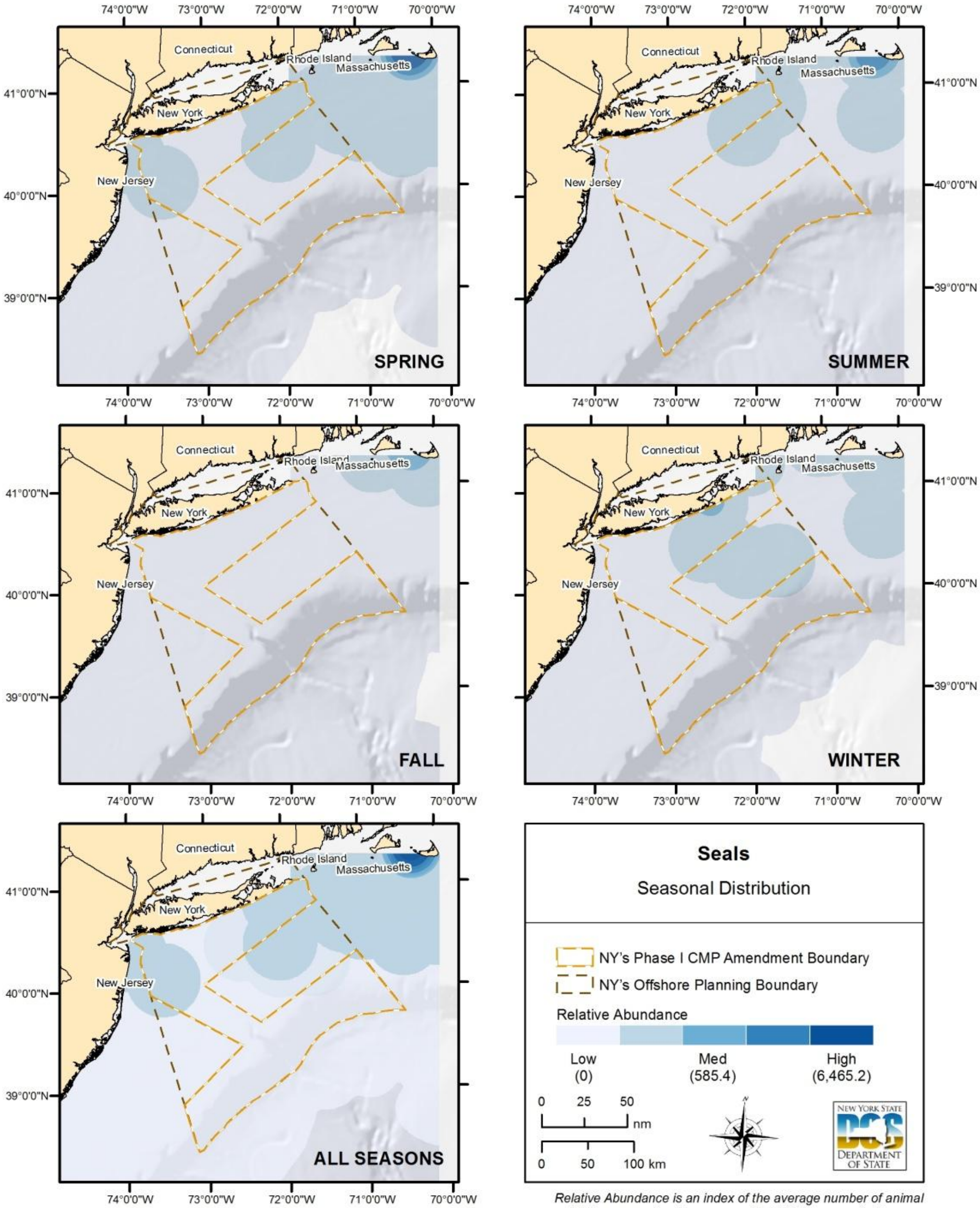

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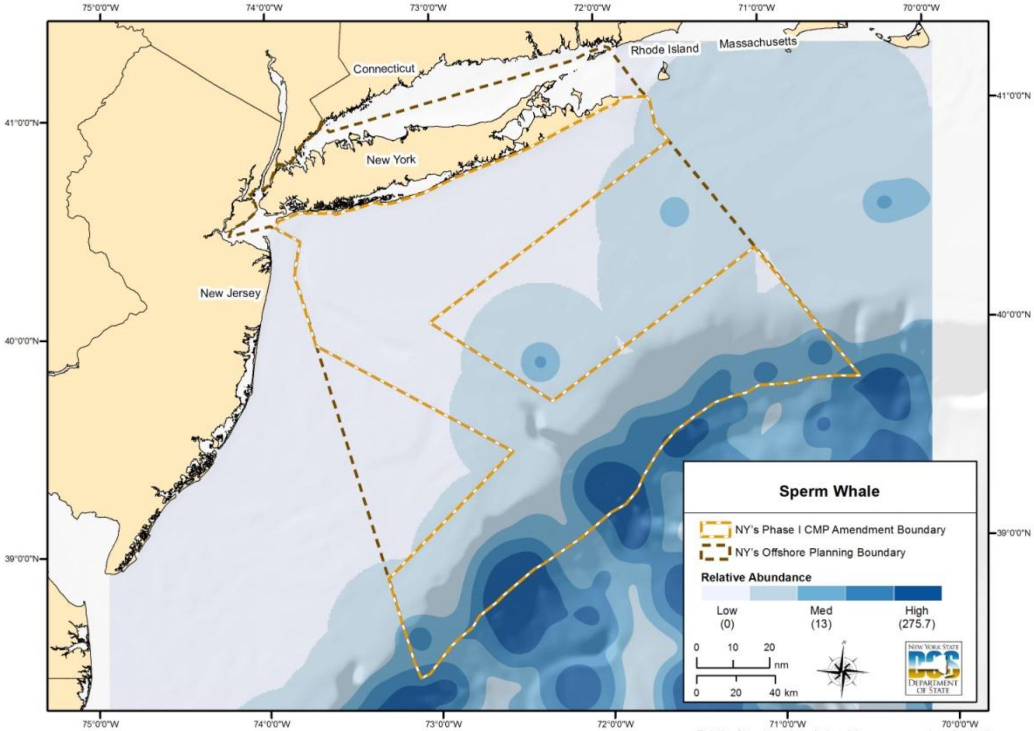

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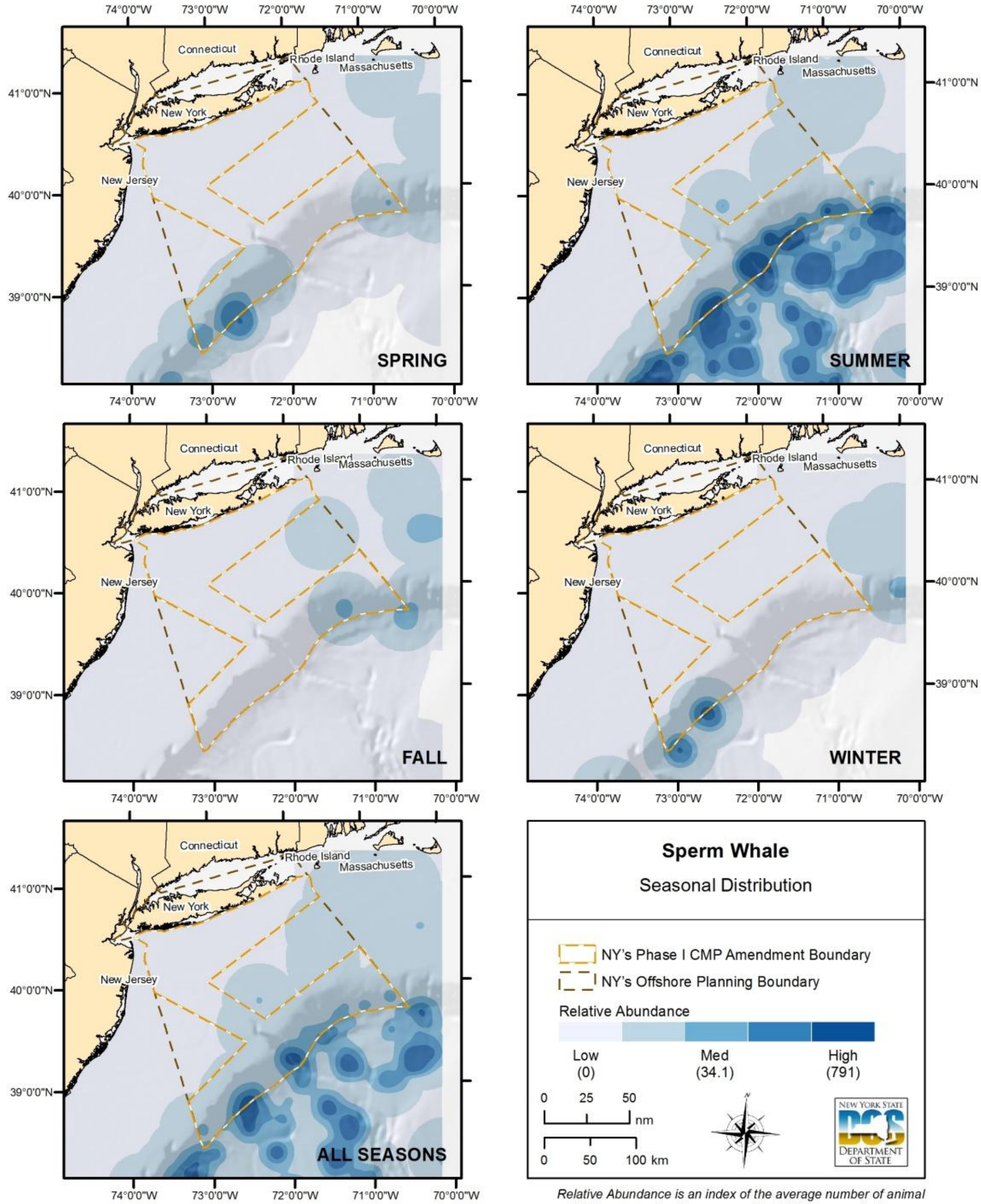

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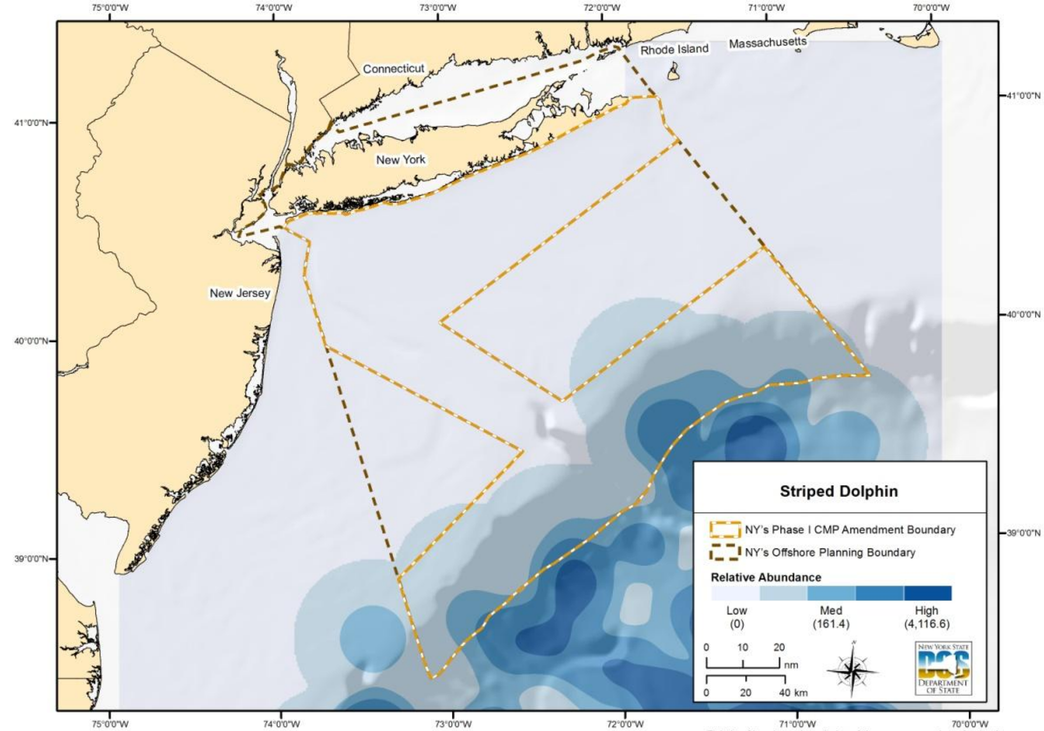

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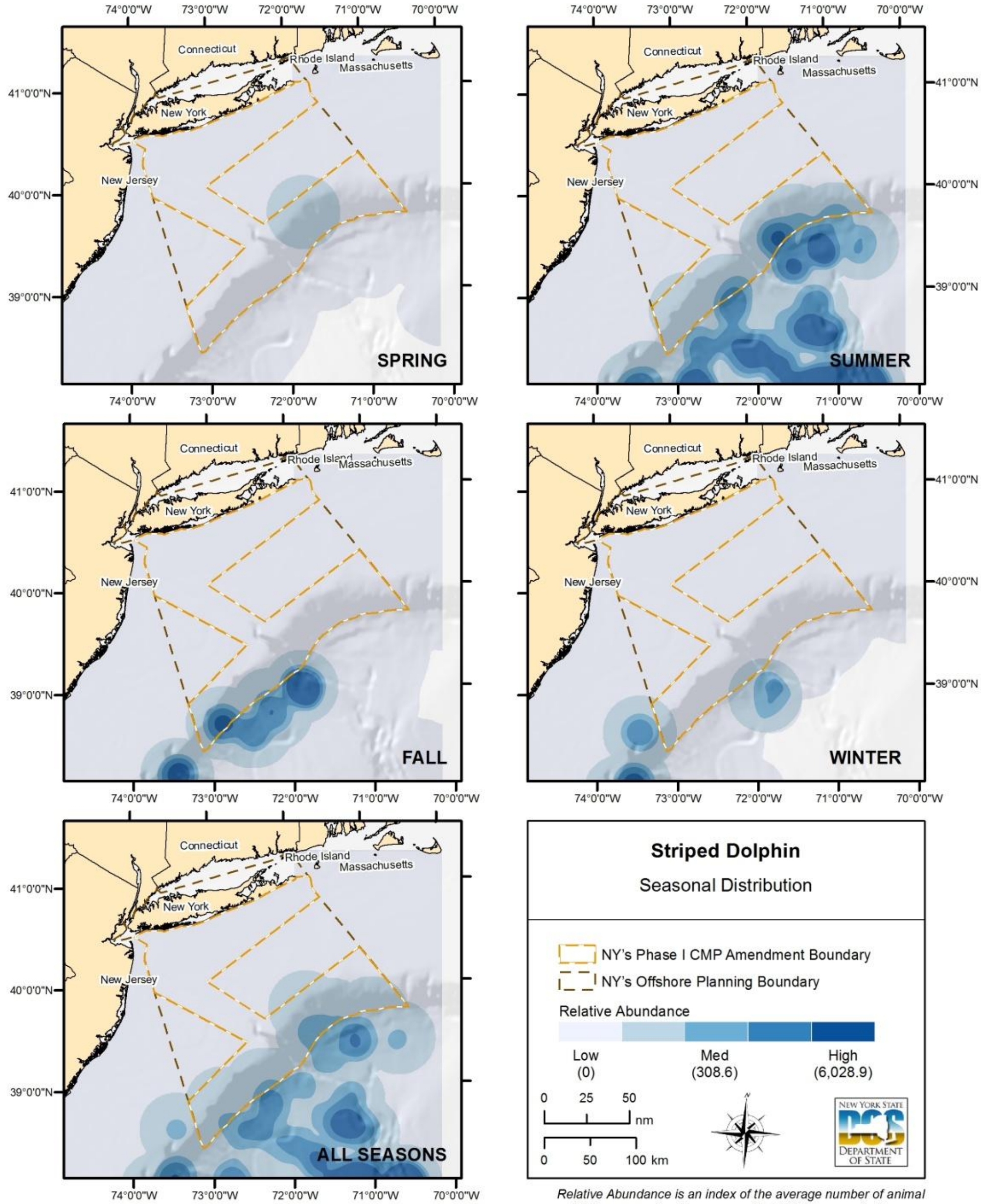

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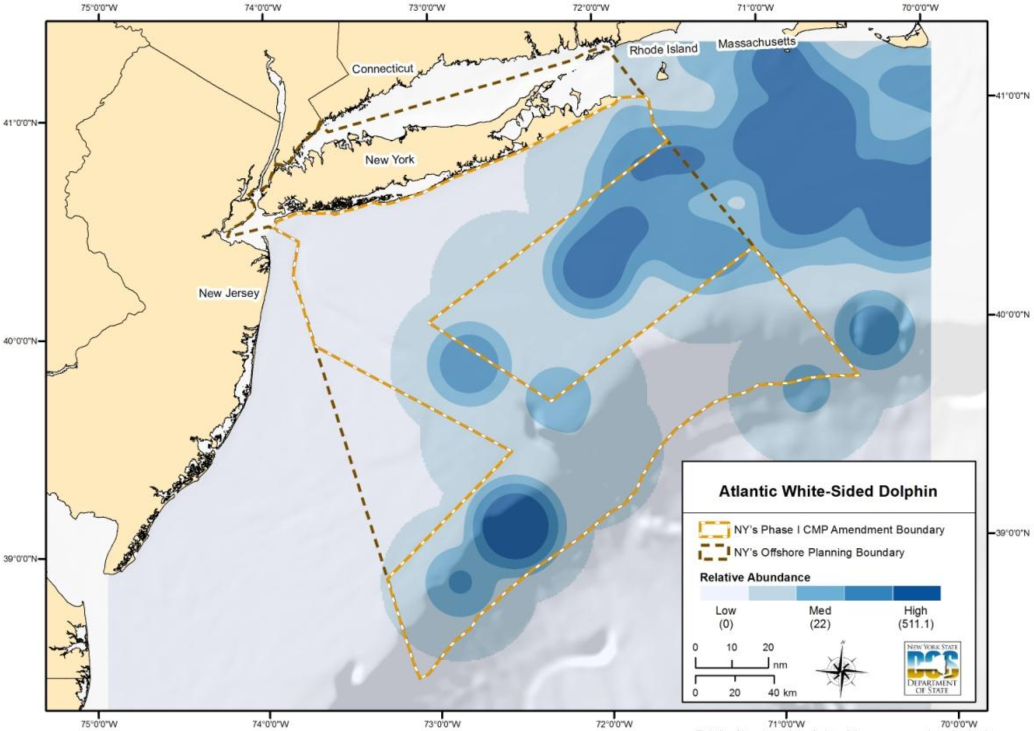

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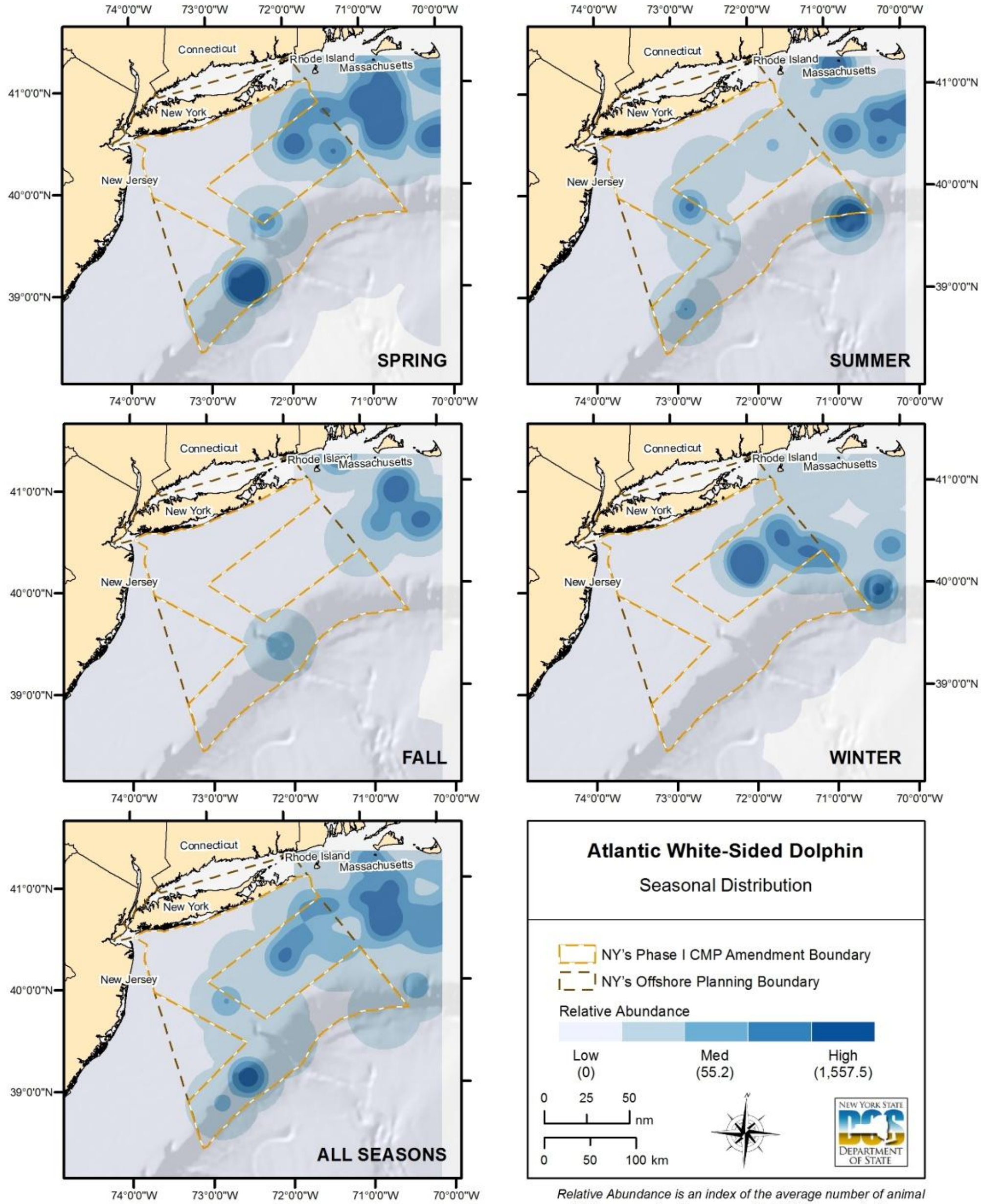

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Appendix A

Kriging pararmeters for each interpolation and assessment of error for each species or grouping. The parameters that did not change were the Guassian Neighborhood, smoothing neighborhood type, a smoothing factor of 1, and a major and minor axis of 20 km.

Analysis dataset	Sample size	Lag size	Number of lags	Mean error	Root-mean-squre error	Mean standardized error	Root-mean-square standardized error	Average standard error
BALN_ALL	1895	7170	12	0.026	16.315	0.001	0.964	17.011
BALN_FAL	1544	7186	12	0.023	12.647	0.002	1.005	12.638
BALN_SPR	1393	7158	12	0.126	32.085	0.004	0.978	32.850
BALN_SUM	1756	7175	12	0.034	34.915	0.001	0.962	36.475
BALN_WIN	1292	7165	12	-0.211	28.510	-0.008	1.106	25.655
BASH_ALL	1895	7170	12	0.004	20.712	0.000	0.957	21.776
BASH_FAL	1544	7186	12	-0.002	22.346	0.000	0.937	24.033
BASH_SPR	1393	7158	12	0.026	14.177	0.002	0.973	14.657
BASH_SUM	1756	7175	12	0.026	81.635	0.000	0.947	86.793
BASH_WIN	1292	7165	12	0.000	3.683	0.000	1.070	3.460
BEAK_ALL	1895	7170	12	0.039	22.607	0.002	1.071	21.122
BEAK_FAL	1544	7186	12	-0.015	7.410	-0.002	1.252	5.800
BEAK_SPR	1393	7158	12	0.036	9.393	0.004	1.150	8.167
BEAK_SUM	1756	7175	12	0.049	37.347	0.001	1.025	36.431
BEAK_WIN	1292	7165	12	N/A	N/A	N/A	N/A	N/A
BLSH_ALL	1895	7170	12	0.623	330.096	0.002	1.080	306.929
BLSH_FAL	1544	7186	12	0.005	5.483	0.001	0.935	5.900
BLSH_SPR	1393	7158	12	N/A	N/A	N/A	N/A	N/A
BLSH_SUM	1756	7175	12	1.786	801.529	0.002	1.061	759.021
BLSH_WIN	1292	7165	12	N/A	N/A	N/A	N/A	N/A
BODO_ALL	1895	7170	12	-0.334	359.220	-0.001	1.074	331.890
BODO_FAL	1544	7186	12	0.572	646.917	0.001	1.075	600.546
BODO_SPR	1393	7158	12	2.135	574.948	0.004	1.030	560.834
BODO_SUM	1756	7175	12	-0.675	407.753	-0.001	1.104	362.937
BODO_WIN	1292	7165	12	0.332	139.768	0.002	1.044	134.427
CETA_ALL	1895	7170	12	2.274	2332.072	0.001	1.042	2224.515
CETA_FAL	1544	7186	12	-8.968	3536.437	-0.003	1.049	3364.678
CETA_SPR	1393	7158	12	3.588	1895.027	0.002	1.120	1685.079
CETA_SUM	1756	7175	12	16.112	4384.547	0.004	1.070	4096.393
CETA_WIN	1292	7165	12	11.812	3514.802	0.004	1.183	2951.195
DOLF_ALL	1895	7170	12	2.182	2325.748	0.001	1.042	2218.090

DOLF_FAL	1544	7186	12	-9.030	3536.346	-0.003	1.049	3364.618
DOLF_SPR	1393	7158	12	3.301	1896.864	0.002	1.120	1686.461
DOLF_SUM	1756	7175	12	15.626	4377.691	0.004	1.072	4081.080
DOLF_WIN	1292	7165	12	12.028	3515.353	0.004	1.182	2952.048
ENDG_ALL	1895	7170	12	0.125	36.345	0.003	0.974	37.451
ENDG_FAL	1544	7186	12	0.051	44.223	0.001	0.986	44.947
ENDG_SPR	1393	7158	12	0.143	32.745	0.004	0.978	33.518
ENDG_SUM	1756	7175	12	0.281	126.072	0.002	0.969	130.823
ENDG_WIN	1292	7165	12	-0.209	29.240	-0.008	1.097	26.543
FIWH_ALL	1895	7170	12	0.021	14.651	0.001	0.972	15.145
FIWH_FAL	1544	7186	12	0.024	12.087	0.002	1.015	11.956
FIWH_SPR	1393	7158	12	0.059	29.084	0.002	0.963	30.381
FIWH_SUM	1756	7175	12	0.037	28.935	0.001	0.956	30.408
FIWH_WIN	1292	7165	12	-0.144	25.367	-0.006	1.120	22.545
GRAM_ALL	1895	7170	12	0.311	257.101	0.001	0.994	259.354
GRAM_FAL	1544	7186	12	0.380	551.335	0.001	0.990	559.280
GRAM_SPR	1393	7158	12	0.045	142.699	0.000	1.129	125.034
GRAM_SUM	1756	7175	12	0.637	335.587	0.002	1.020	328.917
GRAM_WIN	1292	7165	12	1.944	1155.183	0.002	1.021	1135.544
HAPO_ALL	1895	7170	12	0.007	5.039	0.001	0.960	5.272
HAPO_FAL	1544	7186	12	0.002	1.969	0.001	0.962	2.061
HAPO_SPR	1393	7158	12	0.003	12.340	0.000	0.959	12.943
HAPO_SUM	1756	7175	12	0.008	5.542	0.001	1.014	5.486
HAPO_WIN	1292	7165	12	0.043	12.293	0.003	0.968	12.807
HHSH_ALL	1895	7170	12	0.009	18.143	0.000	0.964	18.906
HHSH_FAL	1544	7186	12	-0.012	47.618	0.000	0.963	49.793
HHSH_SPR	1393	7158	12	N/A	N/A	N/A	N/A	N/A
HHSH_SUM	1756	7175	12	0.041	62.904	0.001	0.932	67.902
HHSH_WIN	1292	7165	12	N/A	N/A	N/A	N/A	N/A
HUWH_ALL	1895	7170	12	-0.003	1.966	-0.001	0.971	2.033
HUWH_FAL	1544	7186	12	-0.007	1.728	-0.005	1.264	1.359
HUWH_SPR	1393	7158	12	0.011	7.348	0.001	0.993	7.440
HUWH_SUM	1756	7175	12	-0.003	7.766	0.000	0.944	8.278
HUWH_WIN	1292	7165	12	-0.048	10.565	-0.006	1.325	7.791
LARG_ALL	1895	7170	12	0.046	63.660	0.001	1.031	61.736
LARG_FAL	1544	7186	12	0.012	20.628	0.001	0.956	21.684
LARG_SPR	1393	7158	12	0.143	24.758	0.006	1.108	22.344
LARG_SUM	1756	7175	12	0.142	125.315	0.001	1.027	121.815
LARG_WIN	1292	7165	12	-0.004	22.676	0.000	1.142	19.766
LETU_ALL	1895	7170	12	0.027	6.019	0.004	1.028	5.853
LETU_FAL	1544	7186	12	0.003	11.428	0.000	0.983	11.634
LETU_SPR	1393	7158	12	0.004	1.628	0.003	1.214	1.350
LETU_SUM	1756	7175	12	0.032	10.635	0.003	0.980	10.874

LETU_WIN	1292	7165	12	0.000	0.762	0.000	0.938	0.822
LOTU_ALL	1895	7170	12	0.051	26.895	0.002	0.975	27.687
LOTU_FAL	1544	7186	12	-0.015	39.151	0.000	0.992	39.492
LOTU_SPR	1393	7158	12	0.007	3.951	0.002	0.956	4.154
LOTU_SUM	1756	7175	12	0.170	111.612	0.001	0.966	116.201
LOTU_WIN	1292	7165	12	0.002	1.707	0.001	1.348	1.244
MARM_ALL	1895	7170	12	5.005	2384.400	0.002	1.032	2301.842
MARM_FAL	1544	7186	12	-8.262	3538.786	-0.003	1.049	3367.379
MARM_SPR	1393	7158	12	15.063	2400.463	0.007	1.104	2172.022
MARM_SUM	1756	7175	12	17.603	4398.006	0.004	1.071	4107.050
MARM_WIN	1292	7165	12	11.623	3515.629	0.004	1.183	2952.027
MIWH_ALL	1895	7170	12	0.006	20.269	0.000	0.975	20.890
MIWH_FAL	1544	7186	12	-0.002	2.148	-0.001	1.061	2.028
MIWH_SPR	1393	7158	12	0.021	14.442	0.001	0.977	14.870
MIWH_SUM	1756	7175	12	0.016	59.206	0.000	0.974	61.197
MIWH_WIN	1292	7165	12	0.005	3.584	0.001	1.020	3.535
OCSU_ALL	1895	7170	12	0.002	17.029	0.000	0.961	17.802
OCSU_FAL	1544	7186	12	0.045	25.260	0.002	0.975	25.953
OCSU_SPR	1393	7158	12	-0.426	116.115	-0.004	1.096	105.099
OCSU_SUM	1756	7175	12	-0.015	47.224	0.000	0.950	49.927
OCSU_WIN	1292	7165	12	0.003	1.531	0.002	0.995	1.549
PIWH_ALL	1895	7170	12	-0.184	116.901	-0.001	0.987	118.586
PIWH_FAL	1544	7186	12	-0.277	195.754	-0.001	0.933	210.953
PIWH_SPR	1393	7158	12	0.195	245.011	0.001	1.026	239.080
PIWH_SUM	1756	7175	12	-0.116	130.261	-0.001	1.052	123.464
PIWH_WIN	1292	7165	12	-1.798	465.707	-0.003	1.264	339.371
PRSP_ALL	1895	7170	12	5.130	2384.508	0.002	1.032	2302.150
PRSP_FAL	1544	7186	12	-8.180	3546.941	-0.002	1.049	3373.504
PRSP_SPR	1393	7158	12	15.074	2400.449	0.007	1.104	2171.990
PRSP_SUM	1756	7175	12	17.893	4399.310	0.004	1.071	4107.824
PRSP_WIN	1292	7165	12	11.629	3515.643	0.004	1.183	2952.001
RITU_ALL	1895	7170	12	-0.001	7.317	0.000	0.977	7.524
RITU_FAL	1544	7186	12	N/A	N/A	N/A	N/A	N/A
RITU_SPR	1393	7158	12	N/A	N/A	N/A	N/A	N/A
RITU_SUM	1756	7175	12	-0.003	15.865	0.000	0.979	16.290
RITU_WIN	1292	7165	12	N/A	N/A	N/A	N/A	N/A
RIWH_ALL	1895	7170	12	0.002	0.741	0.002	1.038	0.717
RIWH_FAL	1544	7186	12	0.000	0.317	0.000	0.976	0.327
RIWH_SPR	1393	7158	12	-0.006	2.158	0.003	0.977	2.224
RIWH_SUM	1756	7175	12	0.001	0.436	0.002	1.004	0.437
RIWH_WIN	1292	7165	12	-0.003	0.568	-0.006	1.171	0.482
SADO_ALL	1895	7170	12	0.791	1073.711	0.001	0.974	1106.809
SADO_FAL	1544	7186	12	1.064	2448.982	0.000	0.957	2574.492

SADO_SPR	1393	7158	12	3.040	1236.402	0.003	1.193	1028.064
SADO_SUM	1756	7175	12	0.523	848.586	0.001	0.996	854.169
SADO_WIN	1292	7165	12	-0.124	774.077	0.000	1.009	771.759
SEAL_ALL	1895	7170	12	3.478	568.803	0.007	1.182	482.635
SEAL_FAL	1544	7186	12	0.763	130.115	0.007	1.166	112.164
SEAL_SPR	1393	7158	12	11.283	1478.043	0.009	1.172	1267.532
SEAL_SUM	1756	7175	12	1.491	343.447	0.005	1.161	297.510
SEAL_WIN	1292	7165	12	-0.147	70.326	-0.002	1.154	60.436
SPWH_ALL	1895	7170	12	0.017	59.829	0.000	1.029	58.132
SPWH_FAL	1544	7186	12	0.040	10.828	0.004	0.999	10.903
SPWH_SPR	1393	7158	12	0.107	22.959	0.005	1.116	20.588
SPWH_SUM	1756	7175	12	0.101	120.596	0.001	1.024	117.559
SPWH_WIN	1292	7165	12	-0.004	22.676	0.000	1.142	19.766
STDO_ALL	1895	7170	12	-1.036	708.874	-0.001	1.160	603.634
STDO_FAL	1544	7186	12	-0.102	579.931	0.000	1.126	513.347
STDO_SPR	1393	7158	12	-0.006	20.361	0.000	0.993	20.643
STDO_SUM	1756	7175	12	-1.520	1033.577	-0.002	1.221	833.321
STDO_WIN	1292	7165	12	1.144	389.371	0.003	1.029	380.200
TURT_ALL	1895	7170	12	0.082	30.978	0.002	0.973	31.949
TURT_FAL	1544	7186	12	0.014	41.630	0.000	0.989	42.106
TURT_SPR	1393	7158	12	0.010	4.541	0.002	0.980	4.655
TURT_SUM	1756	7175	12	0.203	119.448	0.002	0.968	124.118
TURT_WIN	1292	7165	12	0.008	2.547	0.003	1.075	2.363
WSDO_ALL	1895	7170	12	0.033	145.213	0.000	0.963	151.567
WSDO_FAL	1544	7186	12	0.173	96.511	0.002	0.962	101.069
WSDO_SPR	1393	7158	12	0.057	518.798	0.000	0.961	543.794
WSDO_SUM	1756	7175	12	-0.537	147.919	-0.004	1.019	145.238
WSDO_WIN	1292	7165	12	0.232	179.140	0.001	1.066	168.574