

Abundance and Distribution of Seabirds off Southeastern Massachusetts, 2011-2015

Final Report

Richard R. Veit¹, Timothy P. White^{1,2}, Simon A. Perkins^{1,3} and Shannon Curley¹

¹Biology Department, College of Staten Island, City University of New York, 2800 Victory Boulevard, Staten Island, NY 10314; and CUNY Graduate Center, 365 Fifth Avenue, New York, NY 10016; ²NOAA, National Centers for Coastal Ocean Science 1305 East West Highway, SSMC IV Silver Spring, MD 20910 ³Notice Nature, Inc., 61 Elm Brook Lane, Concord, MA 01742.

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Abstract:

We conducted 38 aerial surveys of seabirds south of the islands of Nantucket and Martha's Vineyard, Massachusetts between 22 November 2011 and 14 January 2015. The study area, which extends approximately 85 kilometer (km) offshore to the 60 meter (m) depth contour, has been designated as a "Wind Energy Area" (WEA) by the Federal Bureau of Ocean Energy Management (BOEM lease blocks in Figure 1). We sampled approximately 23,000 linear km of transect over the three years. We mapped the distribution of all birds from data sampled along standardized strip transects. One of our goals was to detect the presence of persistent "Hotspots" of seabird activity; that is, locations where larger than average aggregations of seabirds occurred on a regular or repeated basis. We identified two Hotspots of seabird abundance: one near the western edge of the Nantucket Shoals, consisting mainly of Long-tailed Ducks and White-winged Scoters during winter, and Common and Roseate Terns during spring, and a second one in the Muskeget Channel area, consisting of scoters and eiders, loons, and terns. Overall densities of seabirds in the area were similar between years (Kruskal-Wallis ANOVA, $p > 0.1$).

I. Introduction

The purpose of the study was to provide data that might be used to inform renewable energy development activities in the WEA. Our goal was to quantify the distribution and abundance of seabirds over the federal waters (> 3 nautical miles from land) that comprise the WEA south of the islands of Nantucket and Martha's Vineyard, and to identify locations that persistently attracted higher than average numbers of birds (e.g., Hotspots; Santora & Veit 2013).

Hotspots of seabird abundance have been defined in several ways, but almost always including a component of persistence through time. For example, Hotspots have been quantitatively described as grid cells within a larger survey area in which seabird density, averaged over time, exceeds the mean density for the entire survey area by 2 standard deviation units (Santora & Veit 2013). Because densities are averaged over time, statistical support of a Hotspot requires repeated sampling of the same area, preferably with multiple samples per year. We used this definition, and identified two Hotspots of abundance, at the Nantucket Shoals and over the Muskeget Channel (see Results).

I.1 Study Area

The main study area encompasses approximately 3300 square-kilometers (km²) of federal waters south of Martha's Vineyard and Nantucket Islands, and spans from roughly 20 km to 85 km offshore (WEA, BOEM lease blocks). We also surveyed two much smaller areas north of the main study area. The first, the Northeast Offshore Renewable Energy Innovation Zone (NOREIZ), consists of three federal lease blocks located southwest of Nantucket Island totaling an area of 70km², and the second, totaling an area of 17.5 km², was centered in Muskeget Channel (Muskeget Turbine Area; see Figure 1).

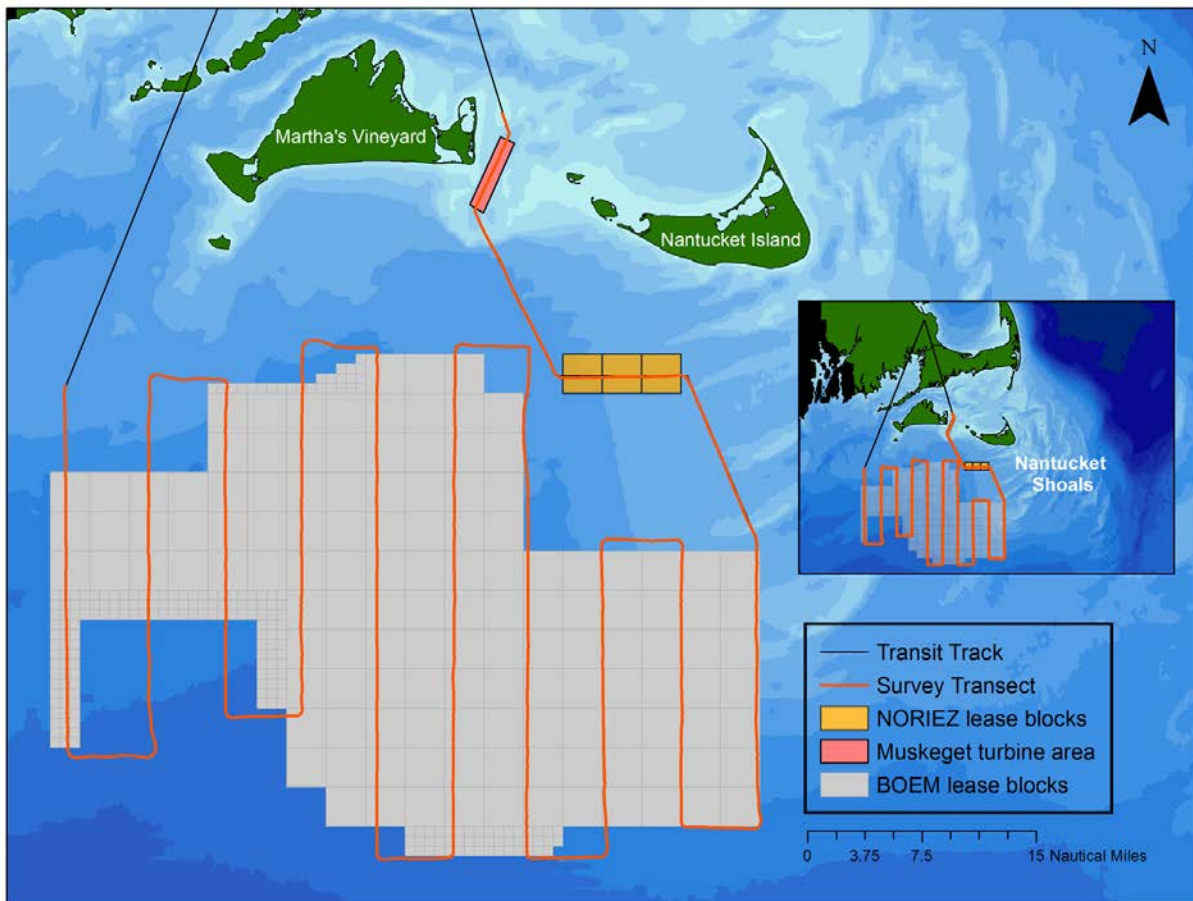


Figure 1.) Study Areas and configuration of transect lines.

The area we surveyed lies on the inner portion of the Outer Continental Shelf (OCS), south of Massachusetts. The area is relatively shallow (<70 m) with mainly sandy bottom and numerous sandy shoals. The water column is thoroughly mixed during winter and stratified during summer. There are strong tidal currents in the area, especially at the eastern end near the Nantucket Shoals and in the Muskeget Channel. While the nearby coastal waters of Nantucket Sound and Buzzards Bay often freeze, at least partly, during winter, the area we surveyed remains ice free all winter. The Nantucket Shoals, and to a somewhat lesser extent, Nantucket Sound and the Muskeget Channel, have been known to be areas of high biological activity at least as far back as the 18th century when they were frequented by cod fishermen (Powers & Brown 1987; Veit & Petersen 1993; Perkins et al. 2004, 2005; Nisbet et al. 2013). Recent analysis of the Nantucket Shoals has shown that a persistent temperature front on the western edge of the Shoals enhances primary productivity, and the enhanced productivity provides for a persistent Hotspot of *gammariid* amphipod abundance (White et al. 2009, White 2013). These

swarming, pelagic amphipods are an important resource for Long-tailed Ducks (White et al. 2009) and perhaps other birds such as terns (see below) and other marine predators such as basking sharks and baleen whales.

The only other quantitative data on seabirds from the area we surveyed are from a “ships of opportunity” effort initiated by the Manomet Bird Observatory in the mid-1970s (Powers 1983, Powers & Backus 1987, Powers & Brown 1987), and more recently from a series of aircraft surveys conducted by the US Fish & Wildlife Service (White 2013). Data from the Manomet project were collected through the late 1980s and are available in a database maintained at the USGS Patuxent Wildlife Center in Laurel, MD (O’Connell et al. 2009).

2. Methods

We collected data from a high-winged, O2 version of a Cessna 337 “Skymaster” aircraft, along 10 fixed, north-to-south, parallel transects spaced at 9 km intervals. The average flight speed during all surveys was 100 knots (kts) and the altitude was 90 m (~300 ft). We conducted surveys only on days with light to moderate winds (≤ 20 kts) and on days with good atmospheric clarity; most were conducted between 0900 EST and 1500 EST when the sun was highest in the sky to minimize glare on either side of the plane. Two observers, positioned opposite one another at the rear windows, recorded all birds seen within two 200 m strips, one on either side of the plane (see Figure 2). Only birds observed within those two corridors were counted, and we summed numbers from both strips to estimate species densities. The data were logged with voice- recording software on a dedicated laptop.

With few exceptions, we flew the main survey grid from west to east, starting at the northwest-most waypoint flying southbound, and ending at the northeastern waypoint flying northbound. We then flew the single NOREIZ transect line east to west before finishing northbound along the Muskeget Channel transect. We deviated from this pattern only in response to local weather phenomena such as showers. All surveys began and ended at the Plymouth Municipal Airport in Plymouth, Massachusetts.

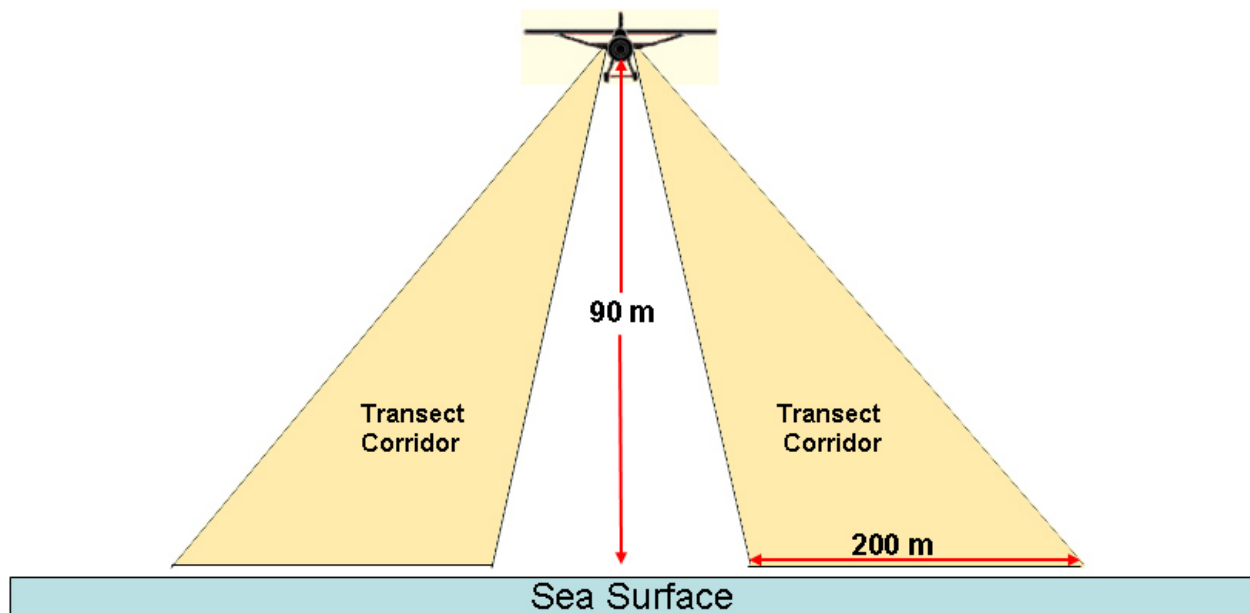


Figure 2.) Transect strips or “corridors” as viewed by each observer from plane.

We modified our methods described in our original proposal with respect to two components: environmental data and distance sampling. In previous studies, we recorded environmental data such as wind speed, cloud cover, and sea state, to estimate the quality of “observation conditions”; in some weather conditions, birds are more easily detected than in others. However, there is no standard way of quantifying the effect of variables such as cloud cover on the detectability of birds at sea. Instead, we assessed the combination of all the environmental variables and ranked the real-time observation conditions on a scale from 1 to 5. Ultimately, any bias due to these variables was probably very low because we flew our surveys only on days with favorable winds and good visibility; the observation conditions, and the detectability of birds, varied little. Our transects were oriented north-south, so the effects of glare were minimized; further, we flew at approximately the same time of day each survey so any effect was consistent across surveys.

Initially, we planned on using “distance sampling” during our surveys, in which the distance and angle to each bird is measured or estimated. However, we found that, at 300 feet and 100 kts, the rate at which we passed the birds did not allow us to record these types of data without missing substantial numbers of birds. Therefore, we counted all birds seen within each 200 m strip, and assumed that the number of individuals missed was very small (a reasonable assumption, despite suggestions to the contrary; Clarke et al. 2003). Our previous work

suggests that birds missed during strip sampling amounts to less than 5% of the total, even for small species like storm-petrels.

2.1 Hotspots

To identify Hotspots, we used the following procedure: find areas where large aggregations of seabirds were persistent, where the words “large” and “persistent” are specifically defined. We defined a “large” aggregation as a density more than one standard deviation larger than the mean density for the area surveyed within a season. We defined “persistent” as occurring in more than 80 percent of the surveys within the season(s) in which the species was present. We emphasize in the Discussion section places that were Hotspots for more than a single species of bird.

The maps represent the densities of birds with units given in birds per km². Table 1 includes species densities by season, and each species’ seasonality given as the mean abundance of each species counted on all surveys. The data were “binned” over 3 km intervals. The total width of the survey strip was 400 m (two 200 m strips), so the area of each bin was 1.2 km² (3 km x 0.4 km). The choice of bin size was largely arbitrary, but the scale was small enough to allow us to correlate the locations of birds with oceanographic features such as hydrographic fronts (White 2013). The maps represent species densities averaged over the entire year. The size of dots in the legend represents the density scale. The density breaks are mapped based on equal interval breaks of bird abundance.

3. Results

We conducted a total of 38 surveys between 22 November 2011 and 14 January 2015, averaging roughly four surveys per season. We sampled approximately 23,000 linear km of transect. Each survey covered approximately 625 linear km, and took roughly four hours to complete, not including the transit times to and from the airport in Plymouth. We recorded 25 species of seabirds (see Table 2), and the abundances of the 15 most numerous species are shown in Table 1.

We identified two Hotspots of seabird abundance, as defined above: one on the western side of the Nantucket Shoals, and a second in the Muskeget Channel, between the islands of Martha’s Vineyard and Muskeget (see Figure 3). The Nantucket Shoals were a Hotspot for Long-tailed Ducks and White-winged Scoters. They is also likely a Hotspot for Common and Roseate Terns, which occurred in dense aggregations there during May in Years 1 and 2. We did not sample the area in May during the third year of sampling, so did not record significant

aggregations in 80 percent of surveys; nevertheless it seems very likely that the Nantucket Shoals are an important feeding area for terns in May, and given that we found high densities of terns during both springs that we sampled, the Nantucket Shoals should be considered a Hotspot for Common and Roseate Terns. Muskeget Channel is a Hotspot for Common Eiders, Black Scoters, Long-tailed Ducks, Common and Red-throated Loons, and Common and Roseate Terns. The NOREIZ lease blocks had large aggregations of Long-tailed Ducks and loons during our second year of sampling.

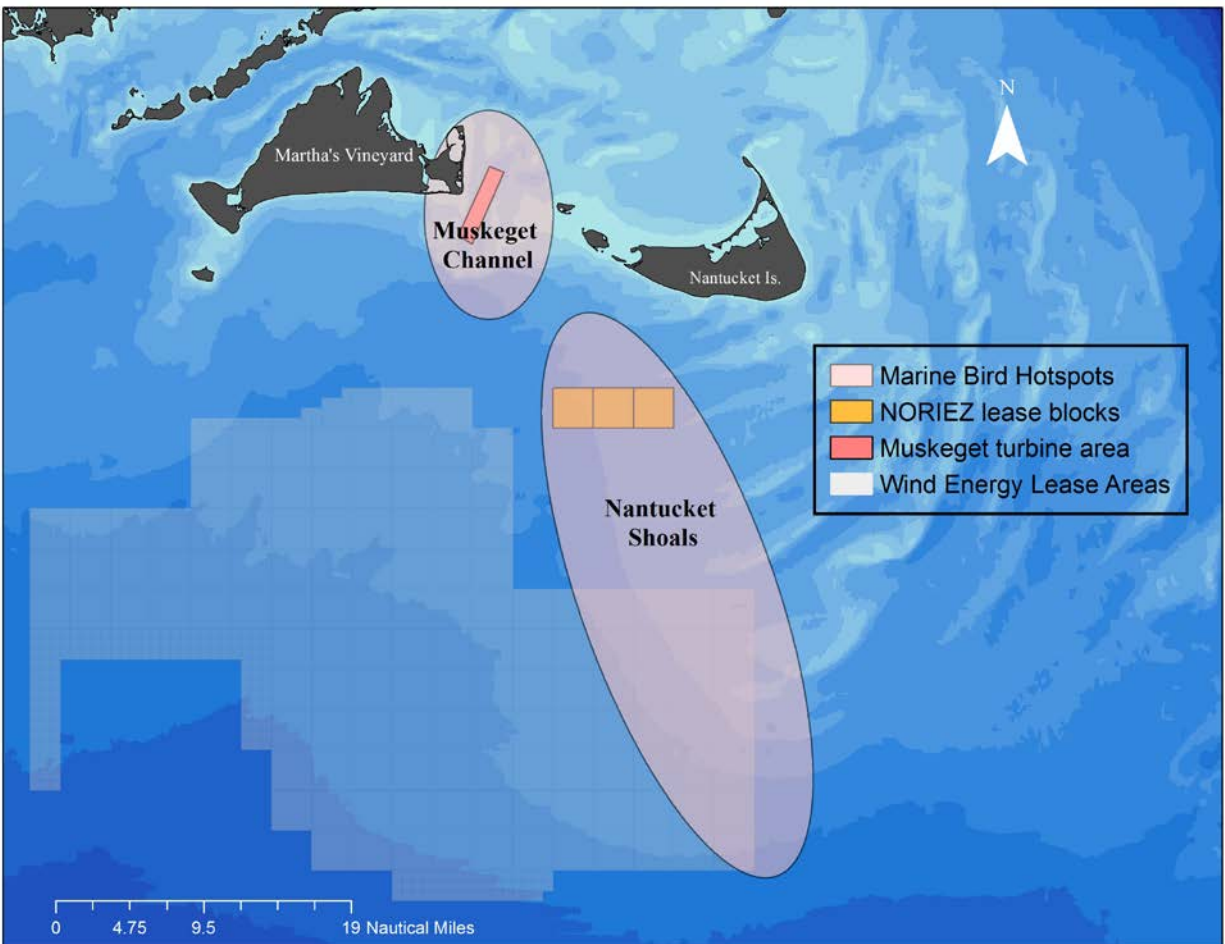


Figure 3.) Hotspots of seabird abundance. Within each Hotspot, abundance of multiple species exceeded mean abundance by $>$ one standard deviation in $>$ 80 percent of surveys within the season of occurrence for each species.

3.1 Spatial Distribution

Common Eiders occurred much closer to shore than other species of sea ducks in the survey area; most were concentrated within the Muskeget Channel (see Figure 4b). The area we surveyed abutted the more inshore waters surveyed by Perkins et al. (2005); we found densities of 5-10 eiders per km² in the Muskeget Channel, compared to densities in the hundreds per km² in Nantucket Sound (Perkins et al. 2005). Common Eiders feed primarily on Blue Mussels (*Mytilus edulis*) (Goudie et al. 2000), thus, their inshore distribution likely reflects the availability of these bivalves. The abundance of Common Eider in southeastern Massachusetts has fluctuated a great deal. Christmas Bird Count data (<http://birds.audubon.org/christmas-bird-count>) - indicate that peak numbers in Massachusetts waters of nearly 500,000 birds in the 1950s, then dropped to tens of thousands for 25 years, peaked at 200,000 to 300,000 in 1985 (mostly at Tuckernuck), and then have exceeded 100,000 birds in 4 winters since 2004. The recent increase in wintering birds has been accompanied by southward expansion of the breeding range, with first nests in Boston Harbor in 1982, and a subsequent increase to a few hundred pairs now nesting in Massachusetts, including about 5 pairs on Muskeget (Nisbet et al. 2013).

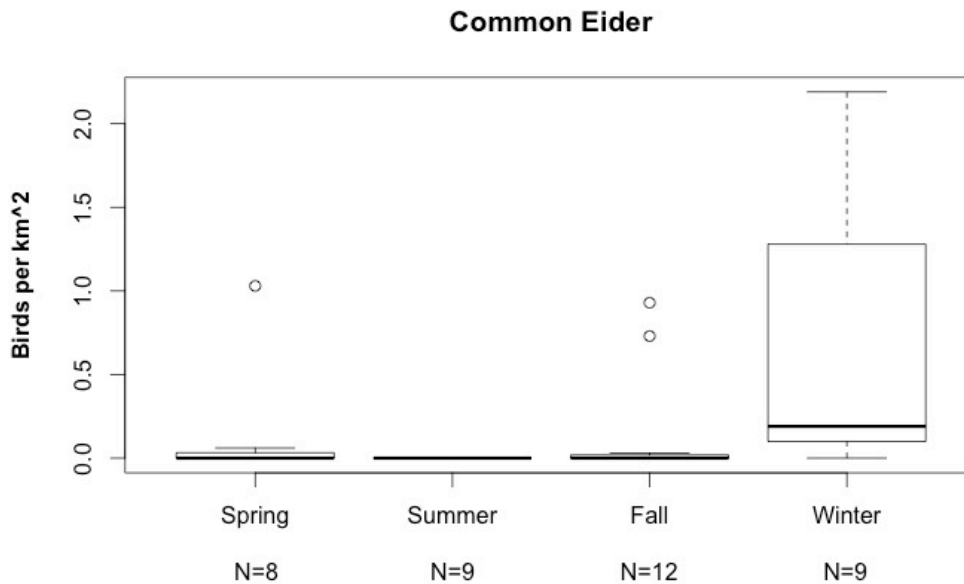


Figure 4a.) Seasonal occurrence of Common Eiders off Massachusetts, 2011-2015.

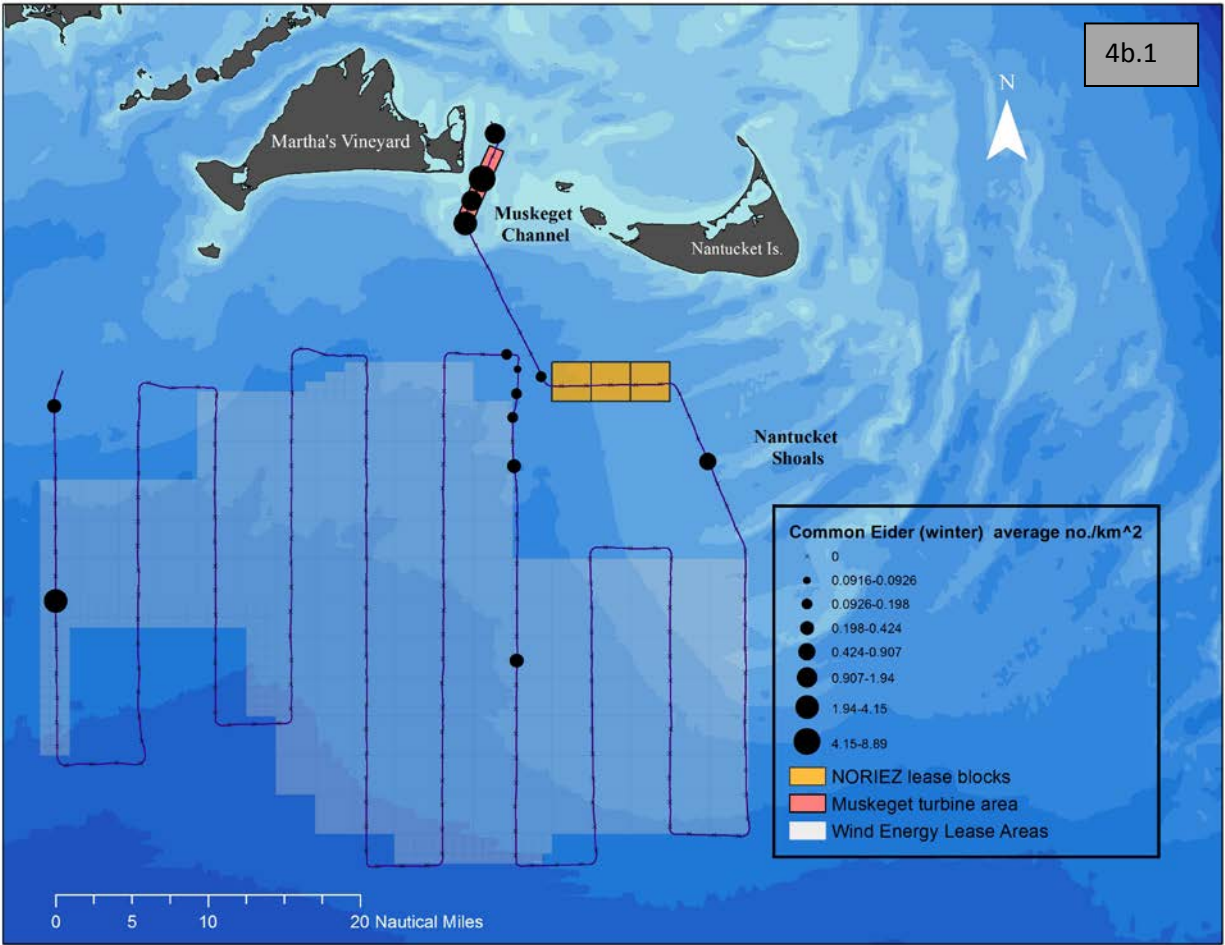


Figure 4b.) Distribution of Common Eiders in winter (4b.1), spring (4b.2), and fall (4b.3).

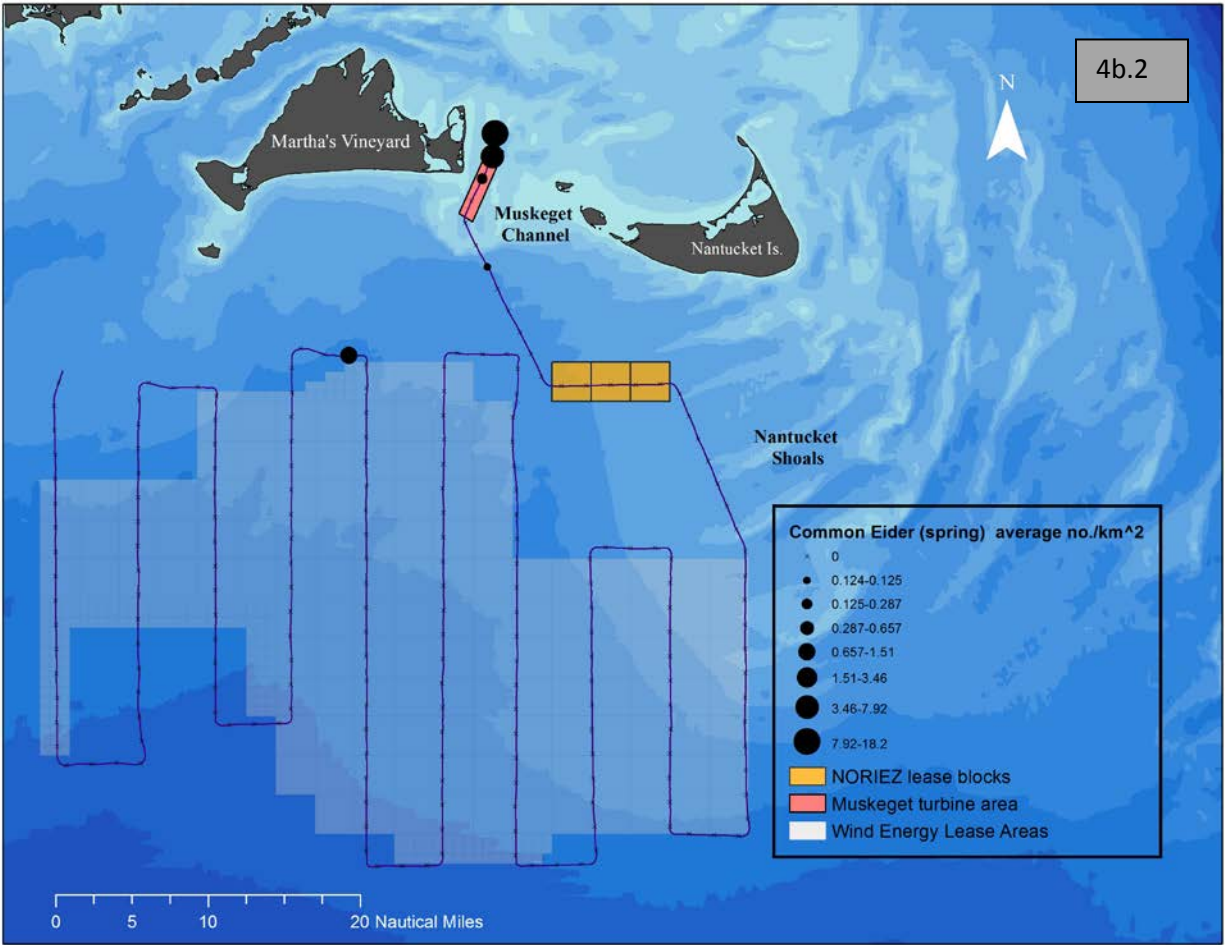


Figure 4b.) Distribution of Common Eiders in winter (4b.1), spring (4b.2), and fall (4b.3).

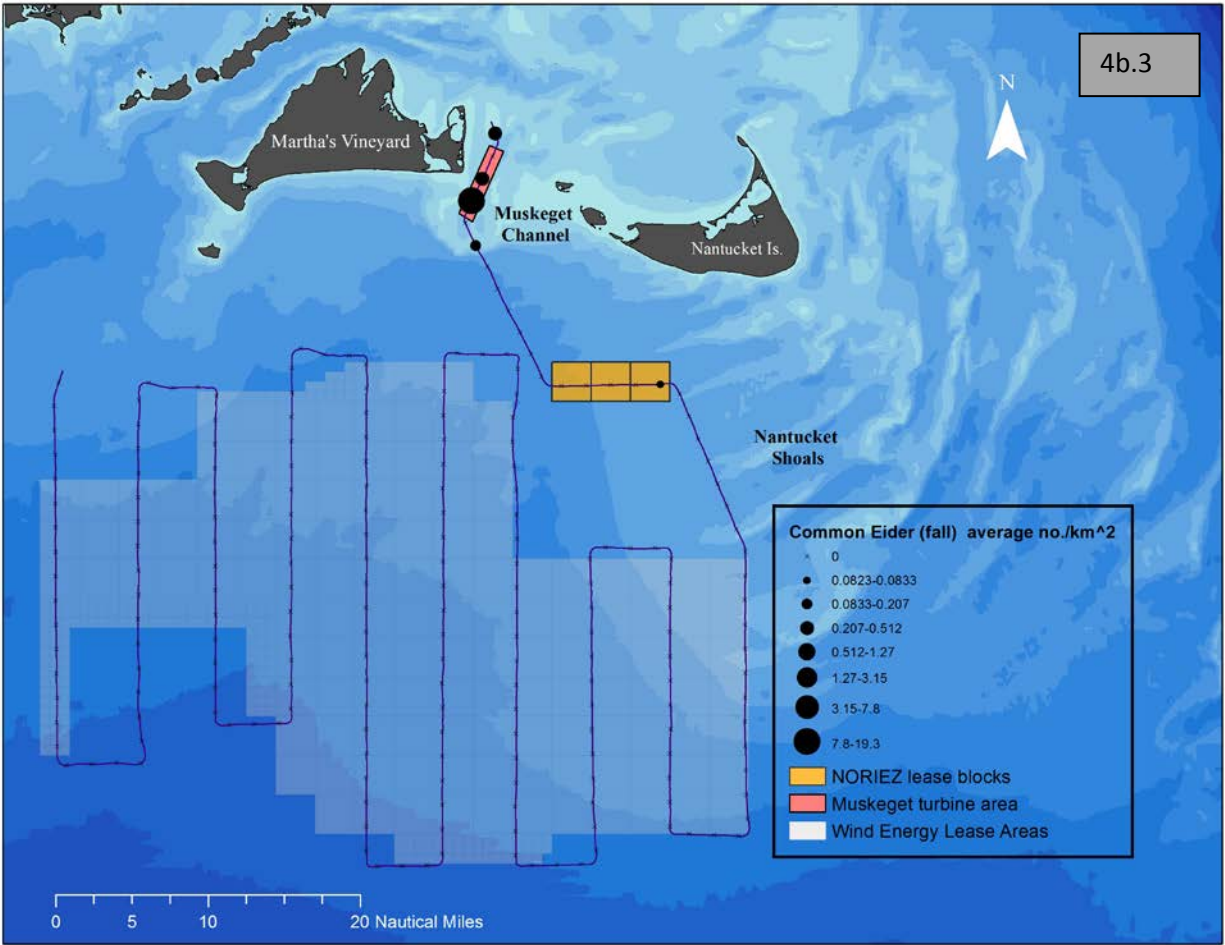


Figure 4b.) Distribution of Common Eiders in winter (4b.1), spring (4b.2), and fall (4b.3).

Surf Scoters were the second most numerous scoter species on our surveys, after White-winged Scoter. They were distributed farther offshore than Black Scoters, and further inshore than White-wing Scoters. These birds were seen during fall (November) and may have been migrants passing through the area, unlike White-winged Scoters which typically spend the winter here.

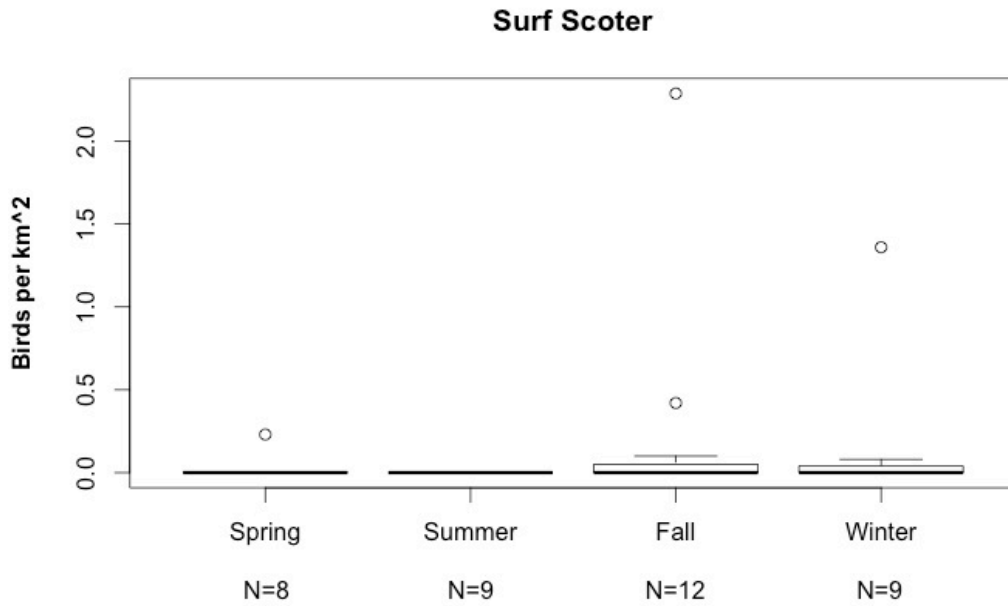


Figure 5a.) Seasonal occurrence of Surf Scoters off Massachusetts, 2011-2015.

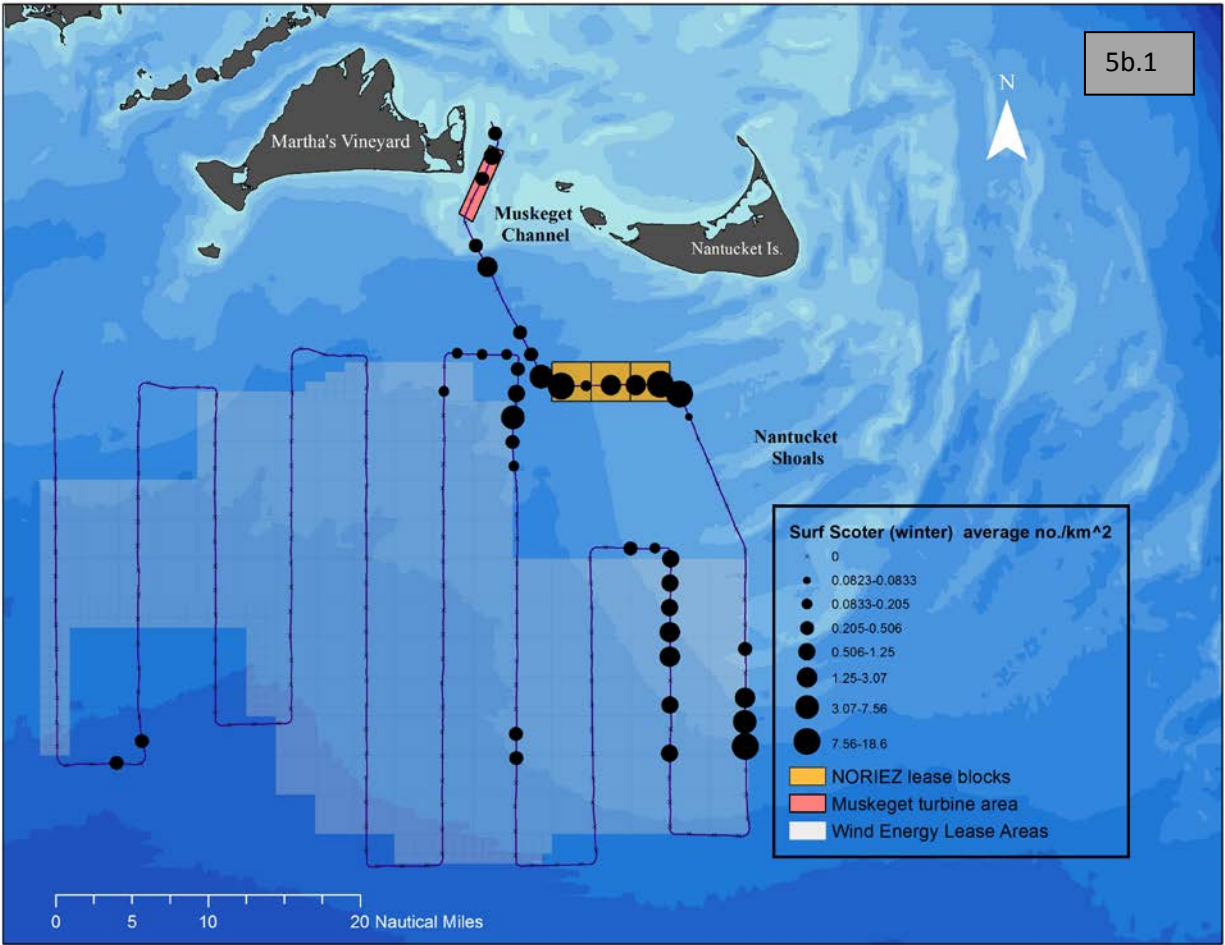


Figure 5b.) Distribution of Surf Scoters in winter (5b.1), spring (5b.2), and fall (5b.3).

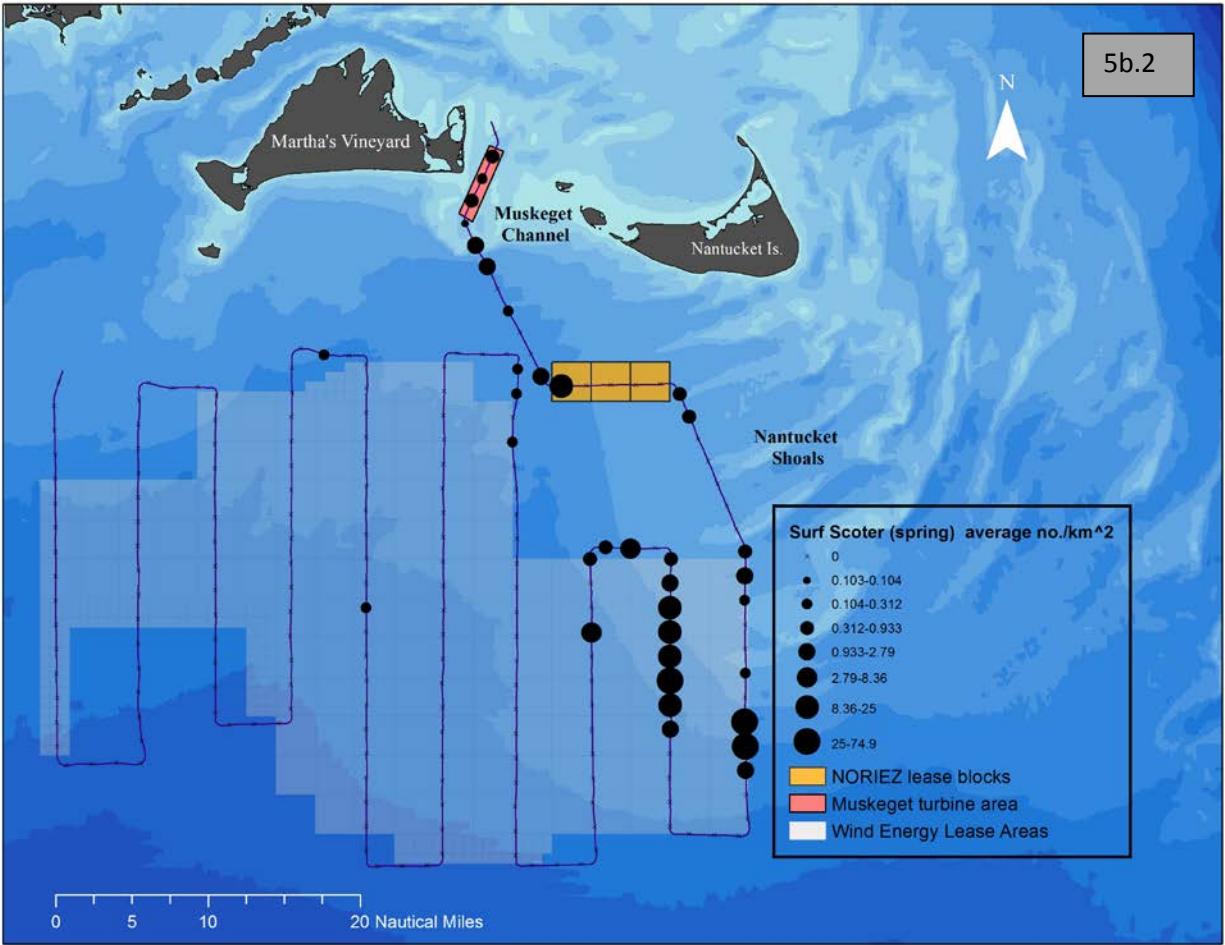


Figure 5b.) Distribution of Surf Scoters in winter (5b.1), spring (5b.2), and fall (5b.3).

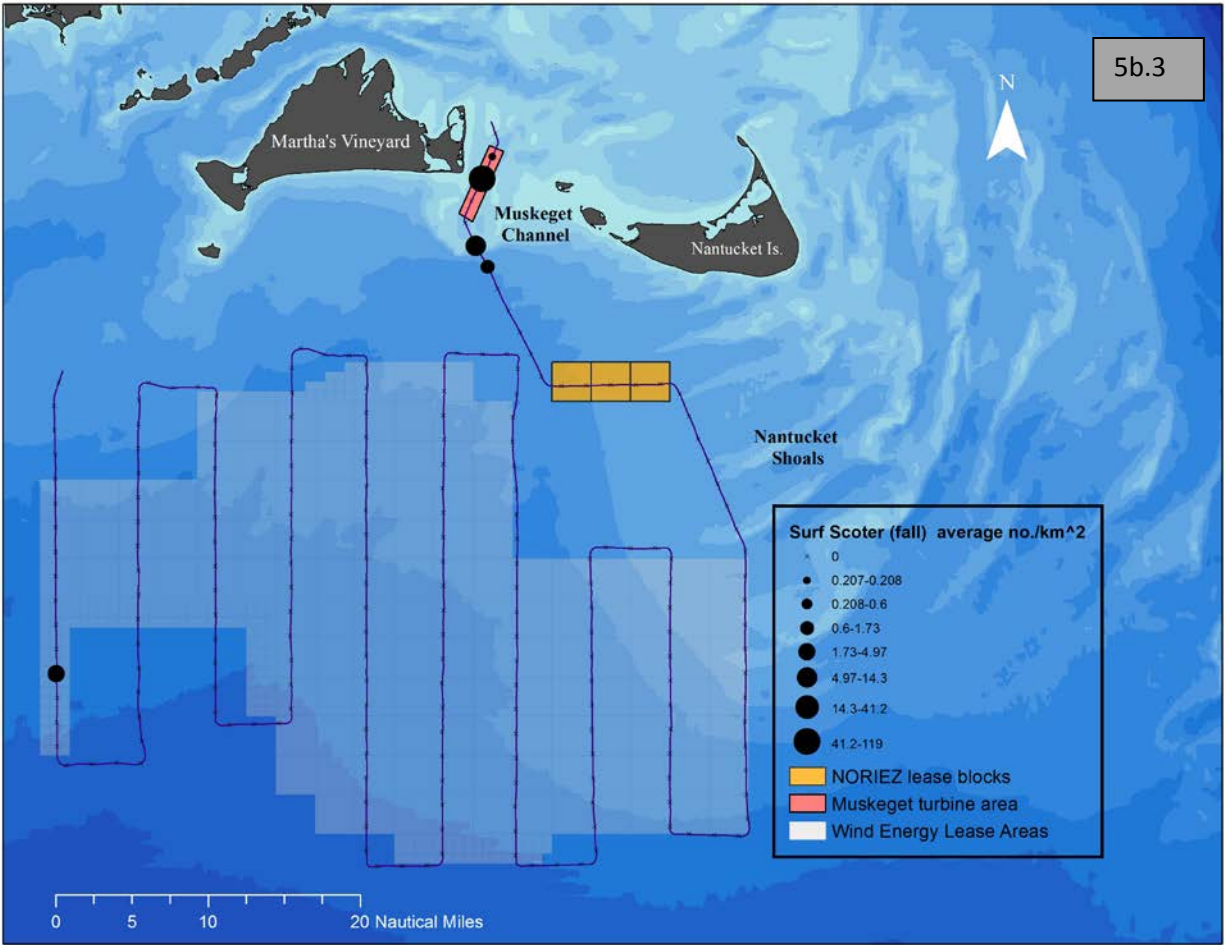


Figure 5b.) Distribution of Surf Scoters in winter (5b.1), spring (5b.2), and fall (5b.3).

White-winged Scoters were the most numerous scoters observed, and the most pelagic. They reached densities of over 20 birds per km² on the western edge of the Nantucket Shoals (see Figure 6b). White-winged Scoters were often associating with Long-tailed Ducks. Although Long-tailed Ducks in the area feed on pelagic amphipods (White et al. 2009, White 2013), we have no data on White-winged Scoter diet from the area. However, the distribution of White-winged scoters on the western shoals suggests that they possibly feed on amphipods. The observed close spatial association between White-winged scoters and Long-tailed ducks in our data also suggests facilitation: using each other as cues to the location of prey. White-winged Scoters were approximately five times more numerous this year than last, mainly due to a high counts recorded in spring 2013 (Year 2). The presence of multi-species aggregations is an important element of the definition of Persistent Hotspots, and this area is a clear example of a Persistent Hotspot (see above; Santora & Veit 2013 and references therein).

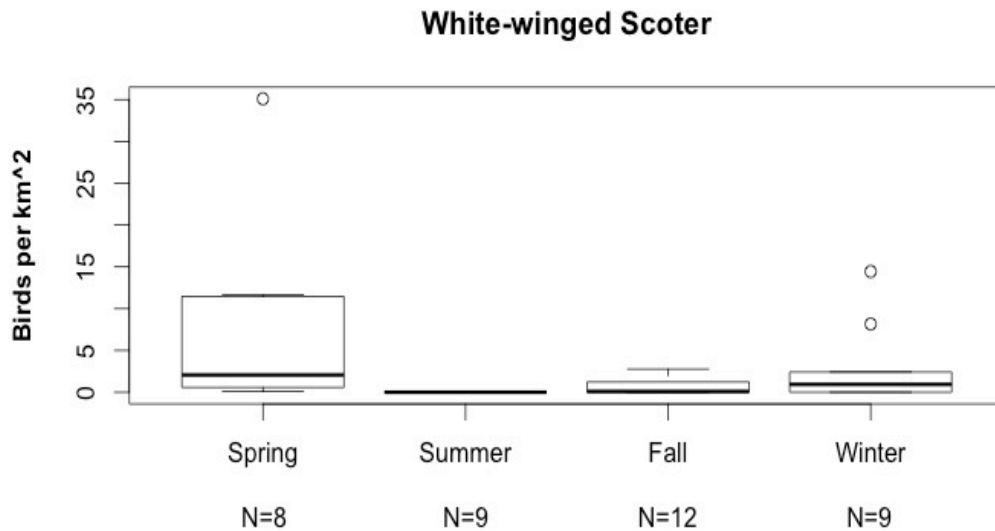


Figure 6a.) Seasonal occurrence of White-winged Scoters off Massachusetts, 2011-2015.

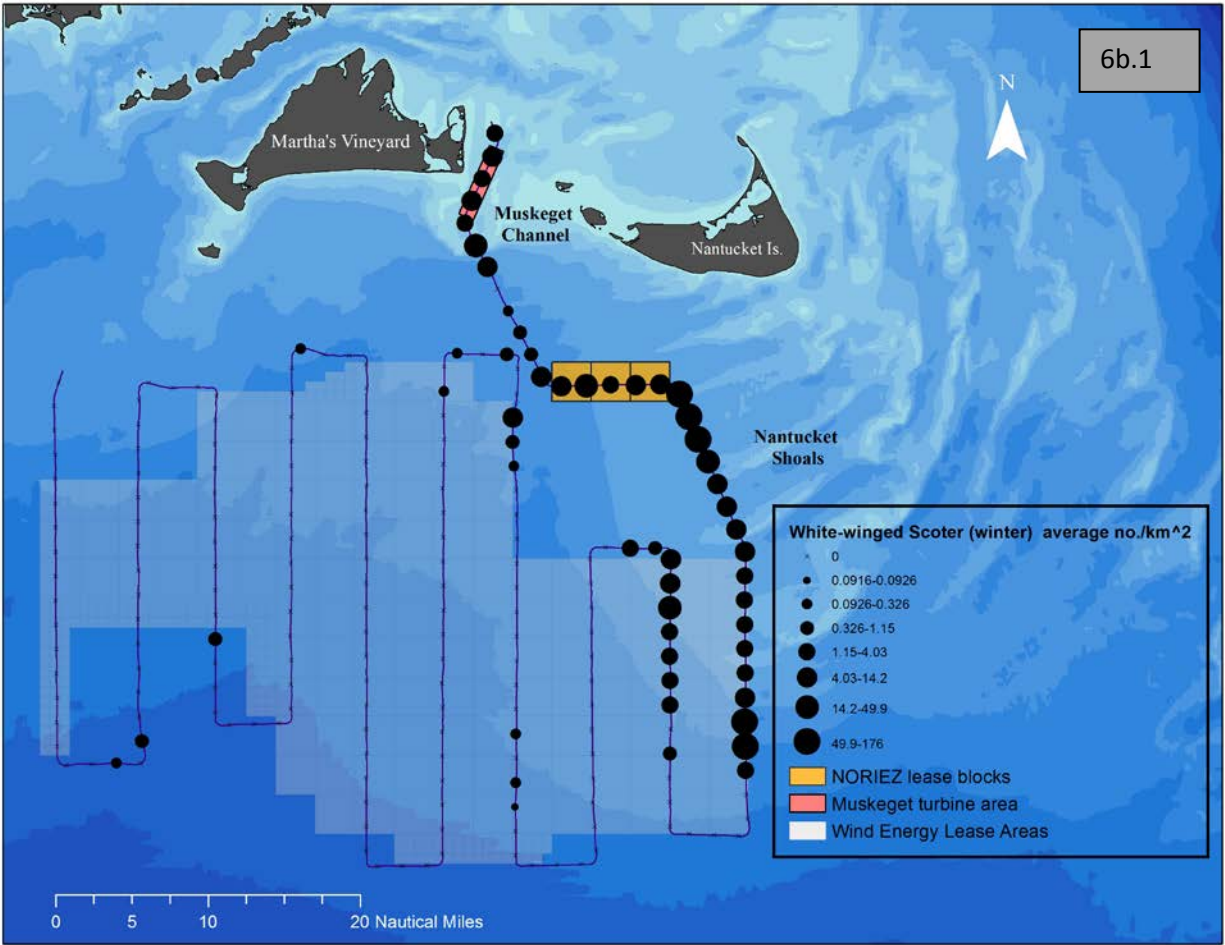


Figure 6b.) Distribution of White-winged Scoters in winter (6b.1), spring (6b.2), and fall (6b.3).

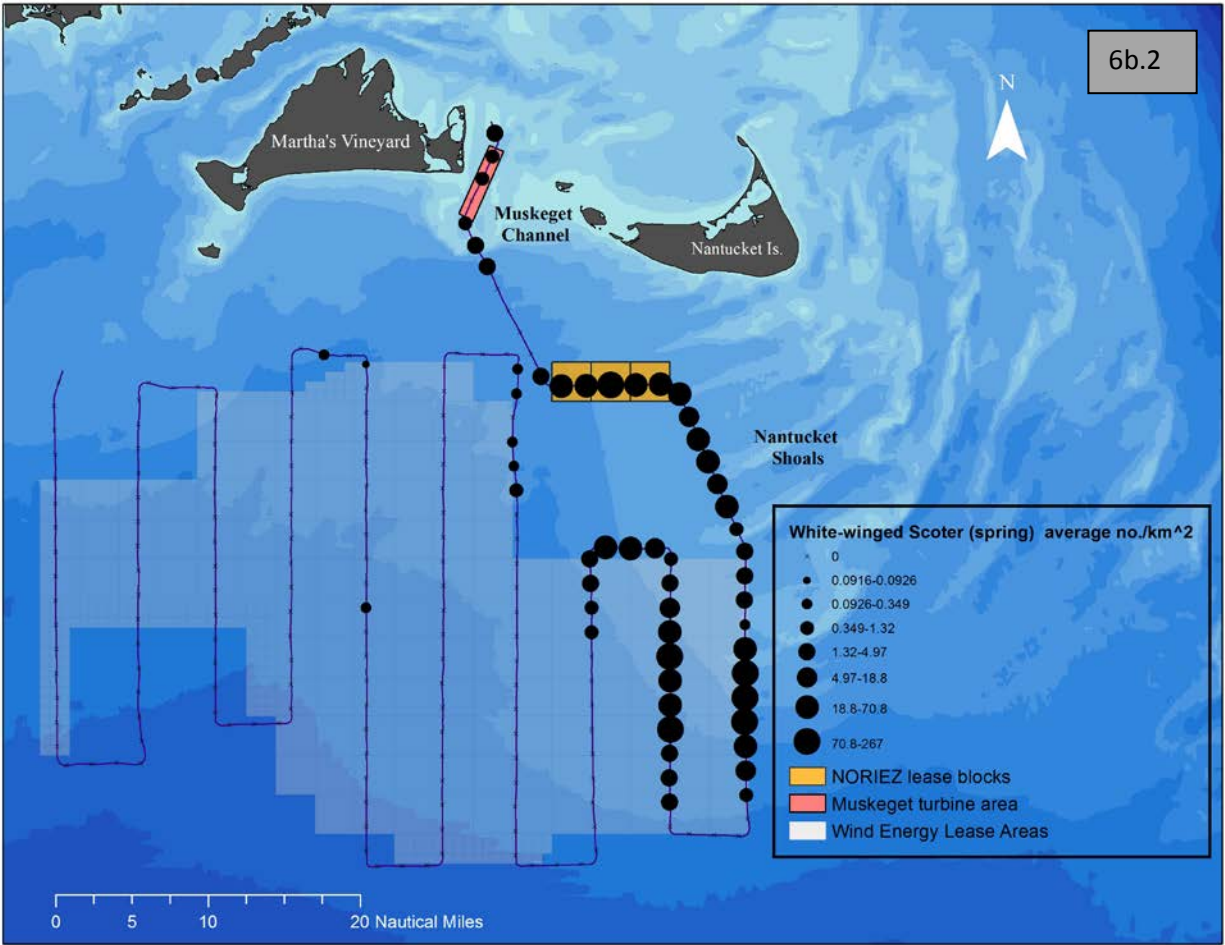


Figure 6b.) Distribution of White-winged Scoters in winter (6b.1), spring (6b.2), and fall (6b.3).

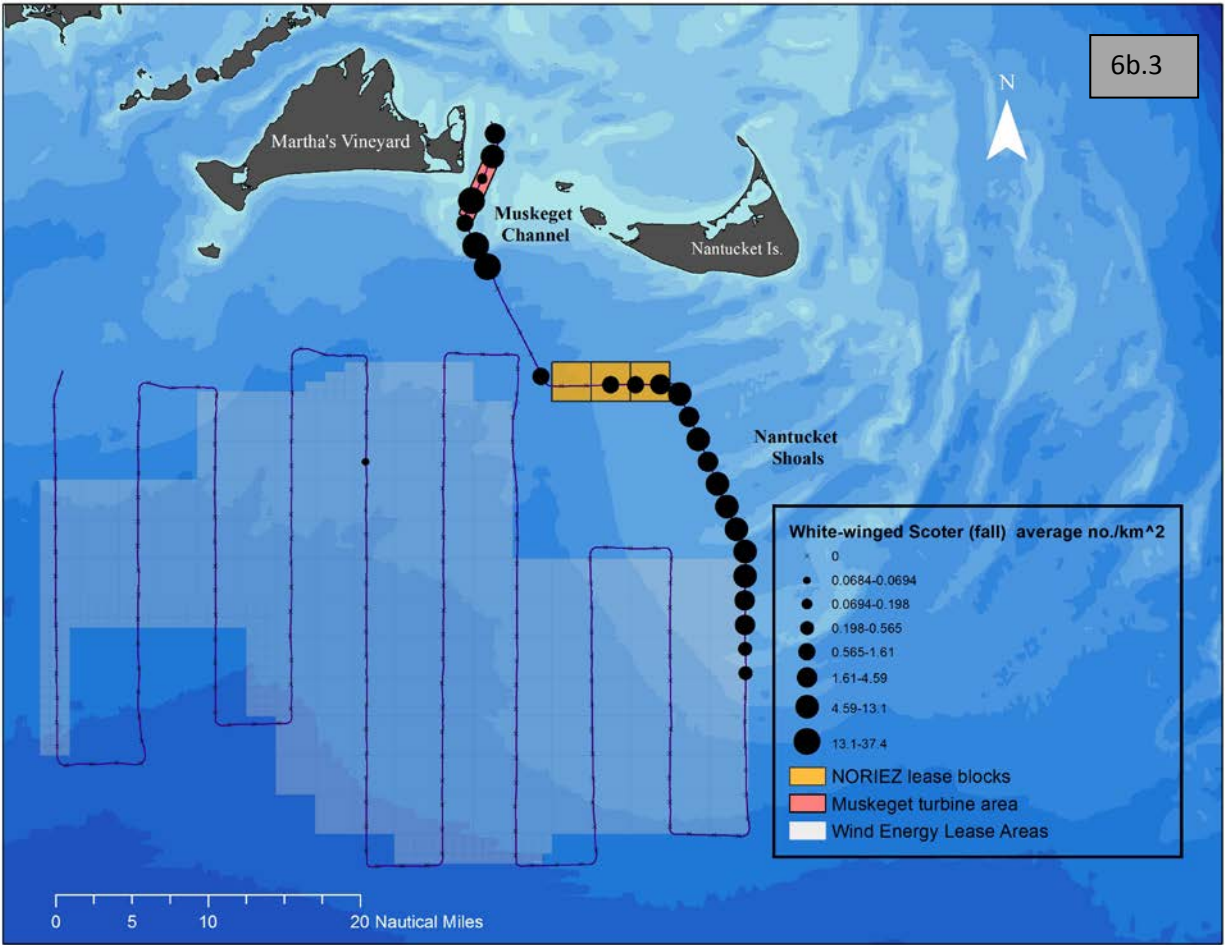


Figure 6b.) Distribution of White-winged Scoters in winter (6b.1), spring (6b.2), and fall (6b.3).

Black Scoters were the least numerous species of scoter observed. The few that we did see were in the Muskeget Channel area (see Figure 7b). Recent plane surveys (2003-2004; Perkins et al. 2005) of the Nantucket Sound, as well as land-based surveys from Tuckernuck and Muskeget islands (2010-present), have shown aggregations of tens of thousands of Black Scoters in that particular area (S. A. Perkins pers. obs; R.R. Veit pers. obs.).

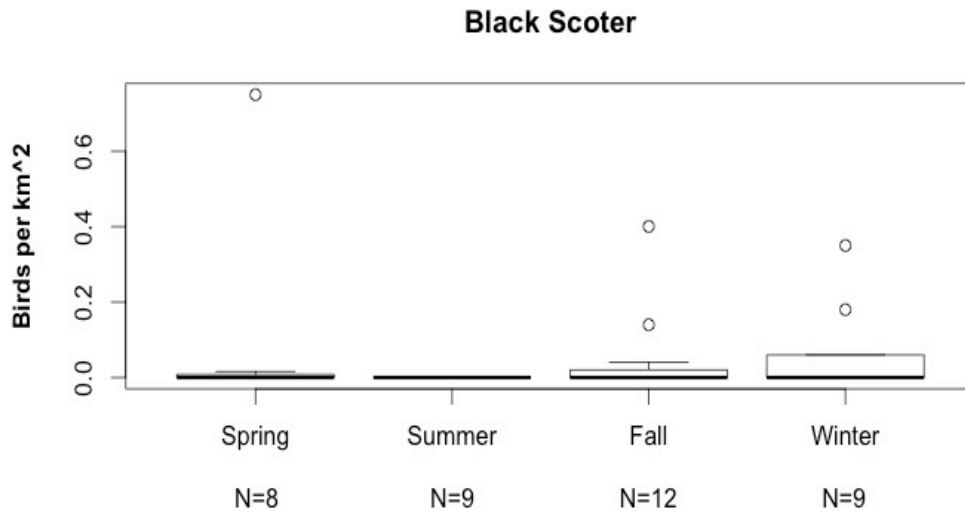


Figure 7a.) Seasonal occurrence of Black Scoters off Massachusetts, 2011-2015.

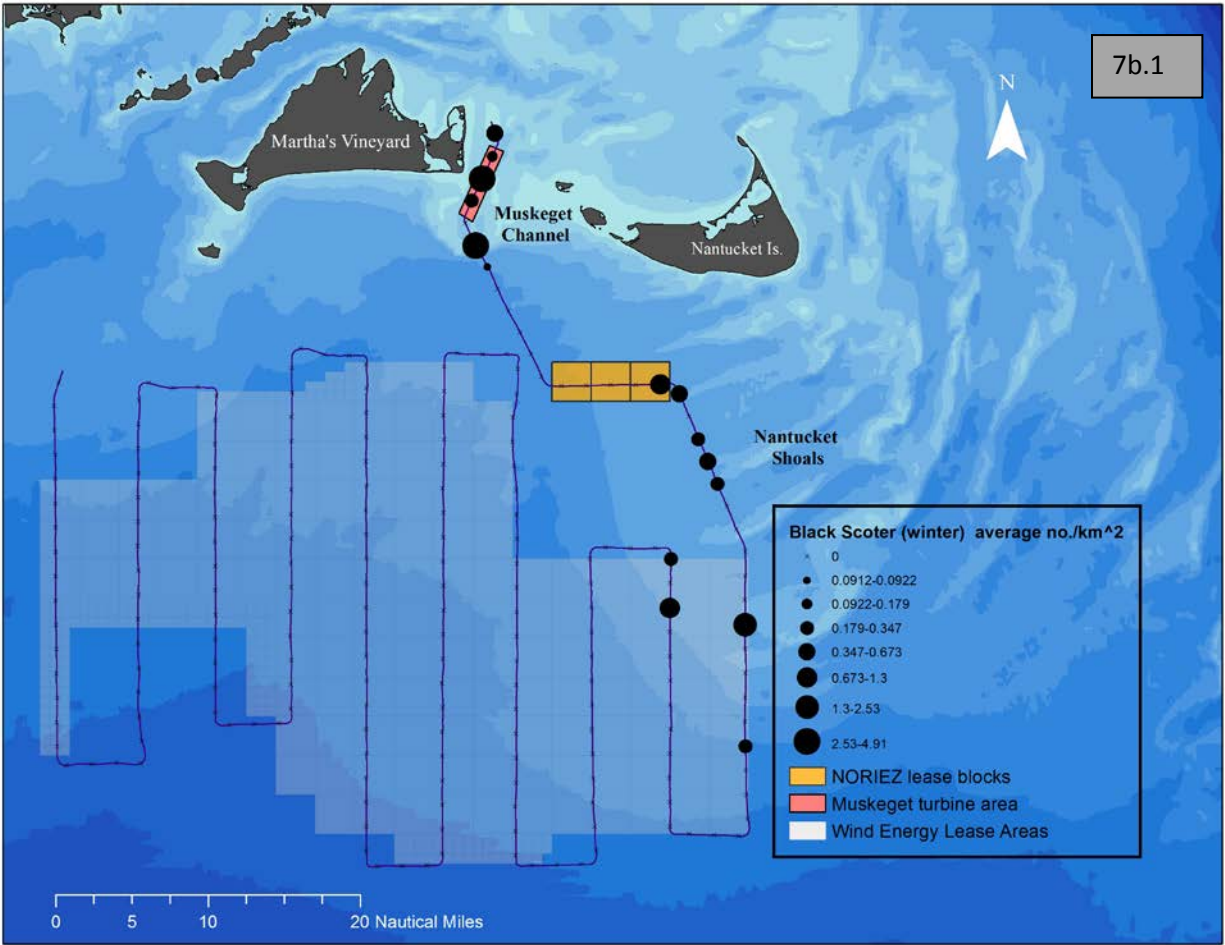


Figure 7b.) Distribution of Black Scoters in winter (7b.1), spring (7b.2), and fall (7b.3).

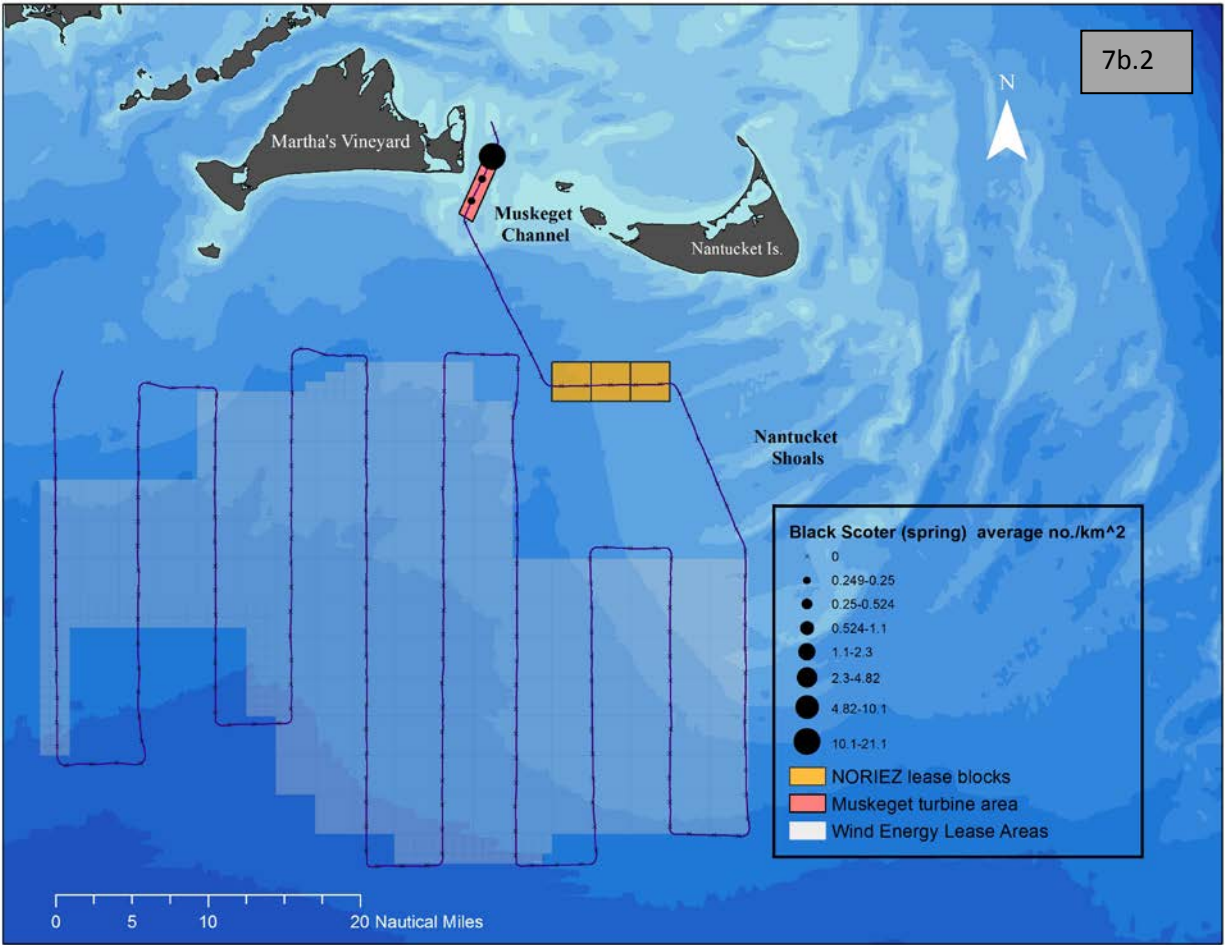


Figure 7b.) Distribution of Black Scoters in winter (7b.1), spring (7b.2), and fall (7b.3).

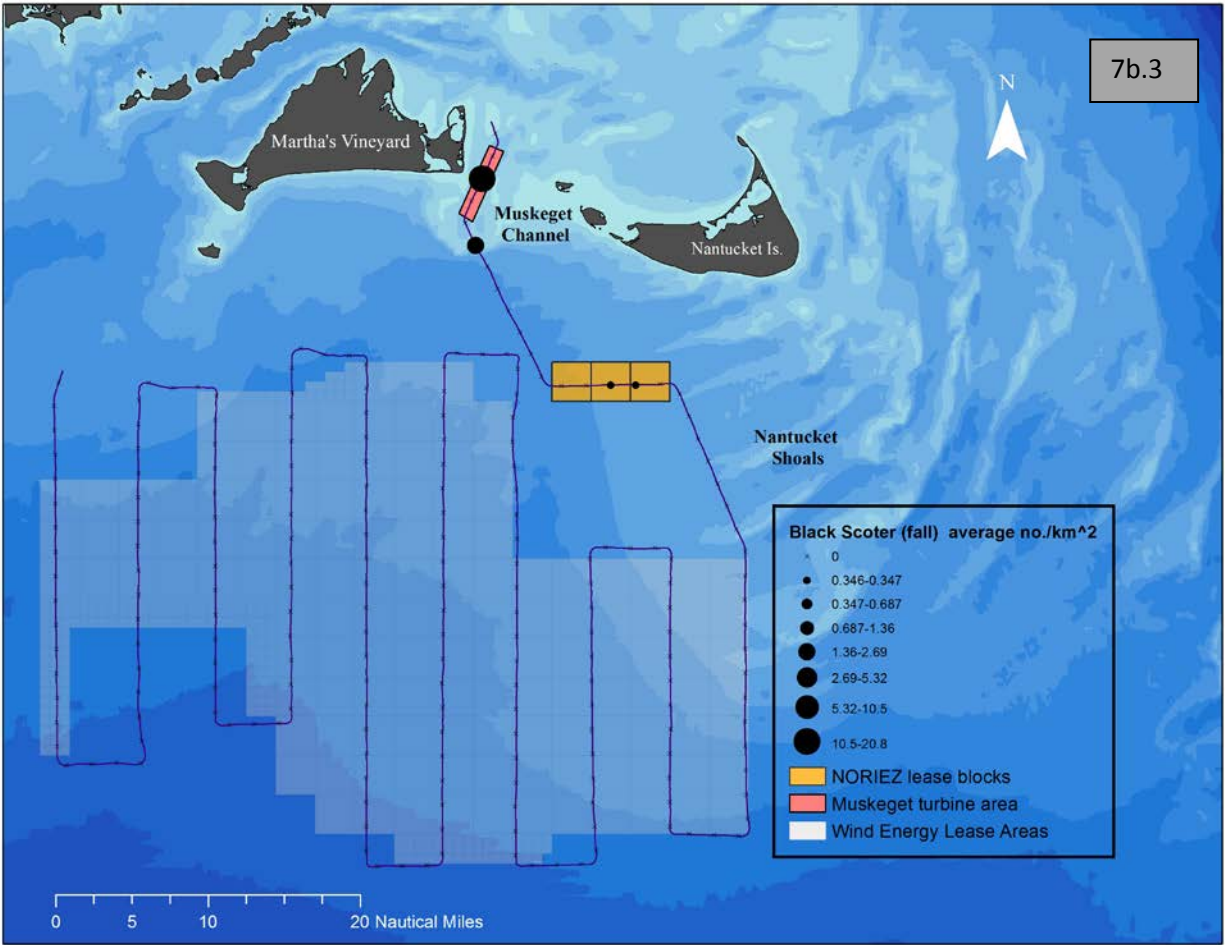


Figure 7b.) Distribution of Black Scoters in winter (7b.1), spring (7b.2), and fall (7b.3).

Long-tailed Ducks were distributed along the western edge of the Nantucket Shoals and in the Muskeget Channel. During 2013-2014, a concentration of more than 150 birds per km² was in the NOREIZ block area (see Figure 8b). During the winter of 2013-2014, there were record low numbers of Long-tailed Ducks seen at Nantucket (pers. obs., Christmas Bird Count data), and those that were seen were much closer to the shore than normal. This onshore distributional pattern is broadly consistent with the cluster over the NOREIZ blocks, which are closer to shore than the Nantucket Shoals where the birds have foraged 1975-2010 (White et al. 2009, White 2013). A long term trend of greatly increased abundance of Long-tailed Ducks near Nantucket began in about 1975 and was followed by a steep decline in about 2012 or 2013 (see Figure 19). This change seems to reflect ocean climate, as indicated by indices such as the North Atlantic Multidecadal Oscillation (https://commons.wikimedia.org/wiki/File:Atlantic_Multidecadal_Oscillation.svg; Veit & Manne 2015). If so, the likely link would be through the pelagic amphipods upon which the ducks feed (White et al 2009, White 2013).

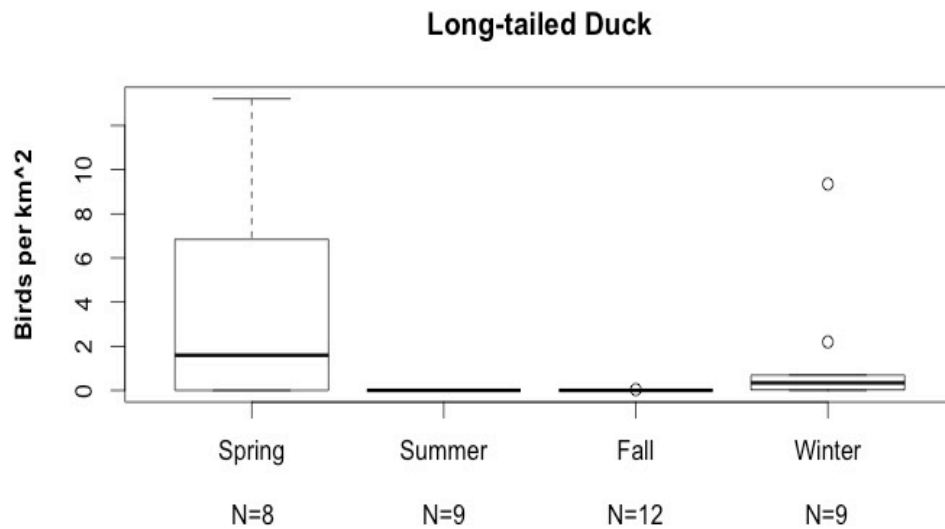


Figure 8a.) Seasonal occurrence of Long-tailed Ducks off Massachusetts, 2011-2015.

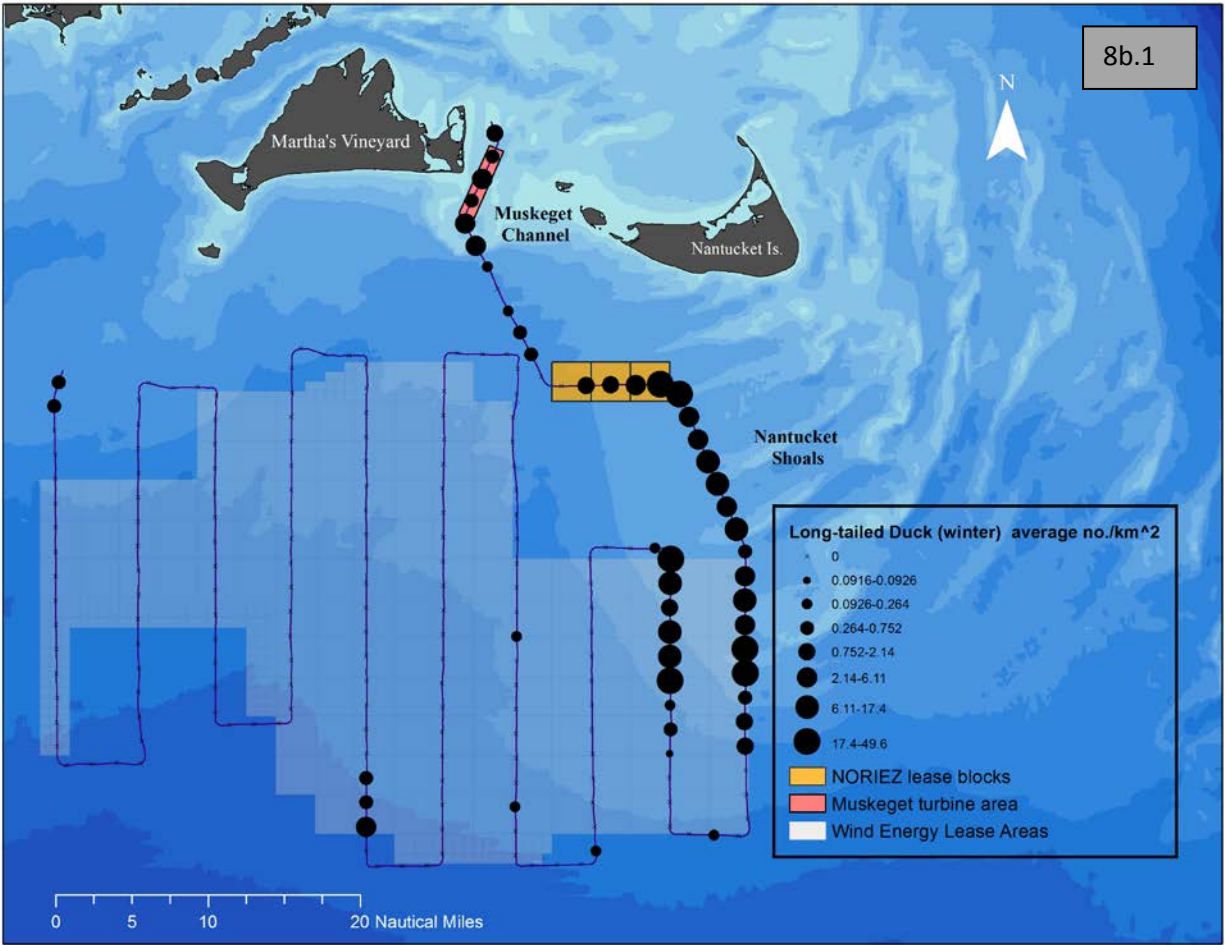


Figure 8b.) Distribution of Long-tailed Ducks in winter (8b.1), spring (8b.2), and fall (8b.3).

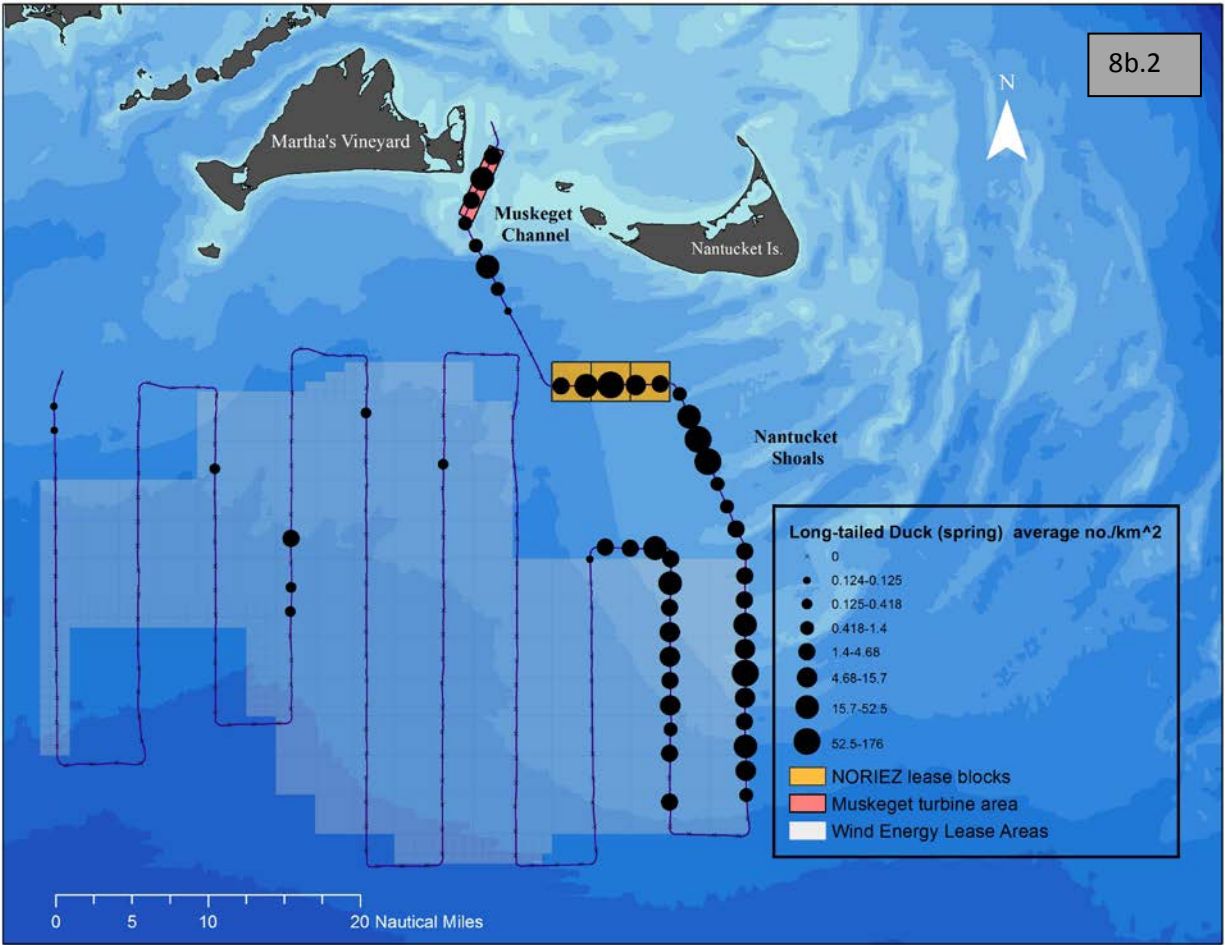


Figure 8b.) Distribution of Long-tailed Ducks in winter (8b.1), spring (8b.2), and fall (8b.3).

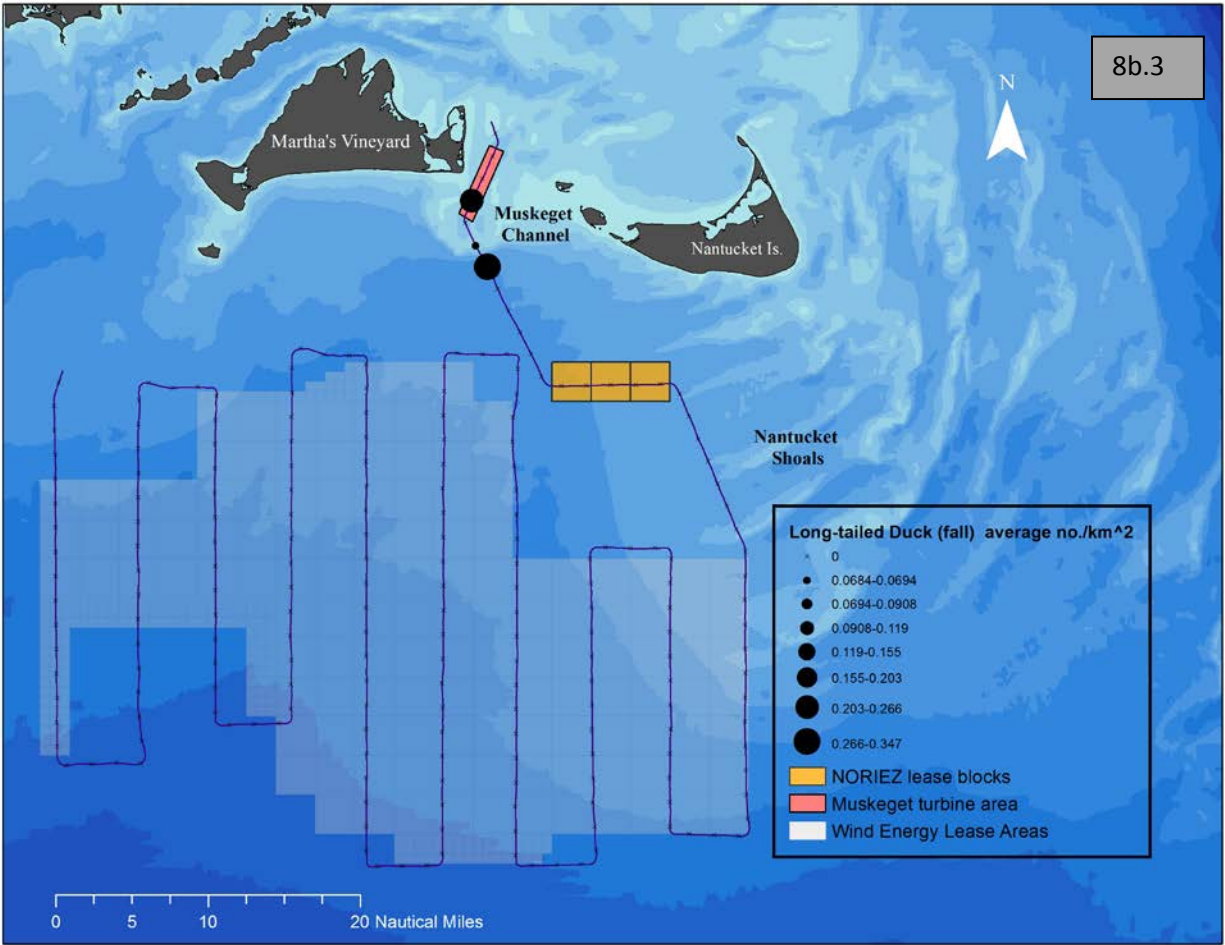


Figure 8b.) Distribution of Long-tailed Ducks in winter (8b.1), spring (8b.2), and fall (8b.3).

Loons were difficult to identify to species from the plane. Overall, loons did not vary much in abundance between years. The majority of loons in the Muskeget Channel area, over the NOREIZ lease blocks and along the western edge of the Nantucket Shoals, were likely Red-throated (Winiarski et al. 2011; Sollman et al. *in press*, Goyert et al. *in press*) based on their more inshore distribution, while those farther offshore with the area we surveyed were likely mostly Common Loons (see Figure 9b). The densities of loons we observed offshore, within the BOEM lease blocks, were not that much different from average densities found in Nantucket Sound (0.2 birds per km²; Perkins et al. 2005). This suggests that the BOEM lease blocks represent important wintering habitat for loons of both species.

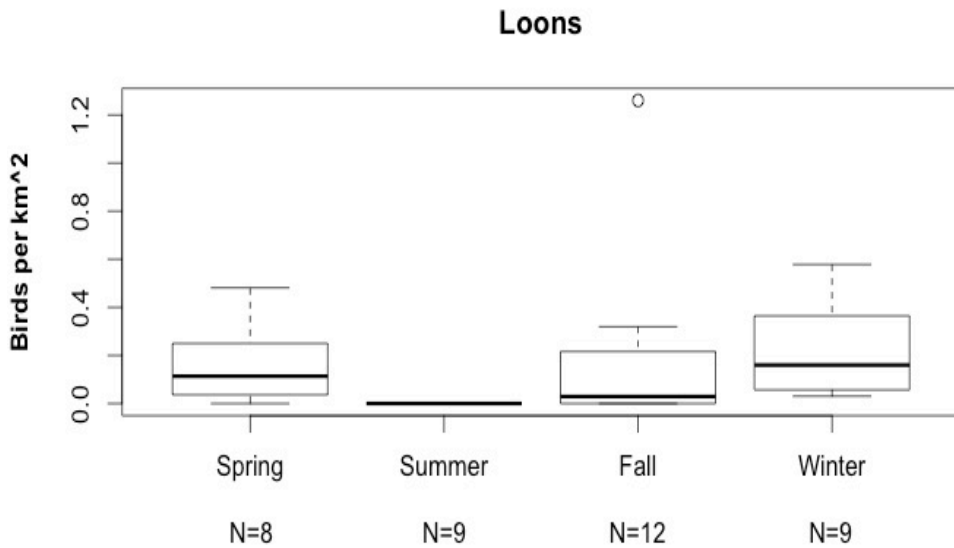


Figure 9a.) Seasonal occurrence of Common and Red-throated Loons off Massachusetts, 2011-2015.

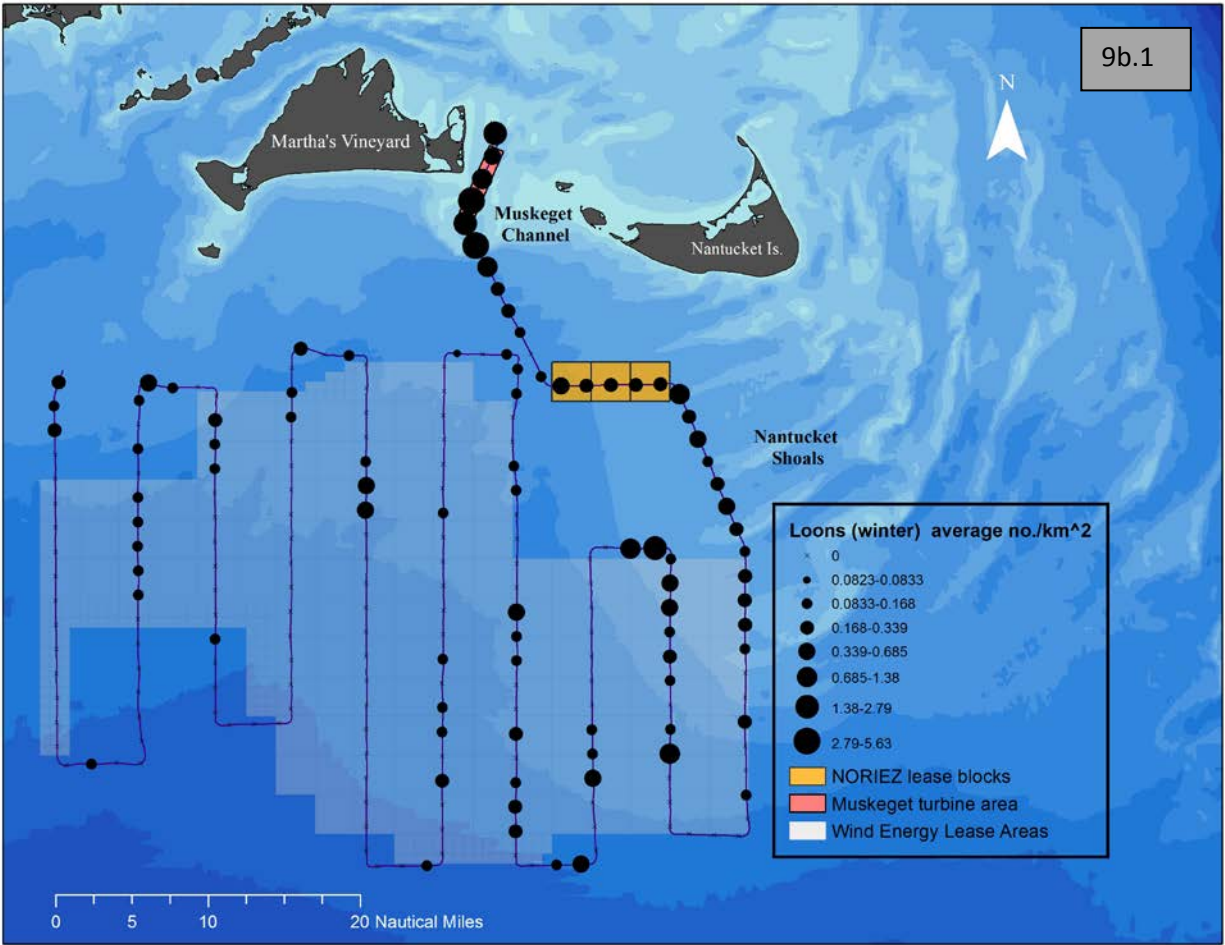


Figure 9b.) Distribution of loons in winter (9b.1), spring (9b.2), fall (9b.3) and summer (9b.4).

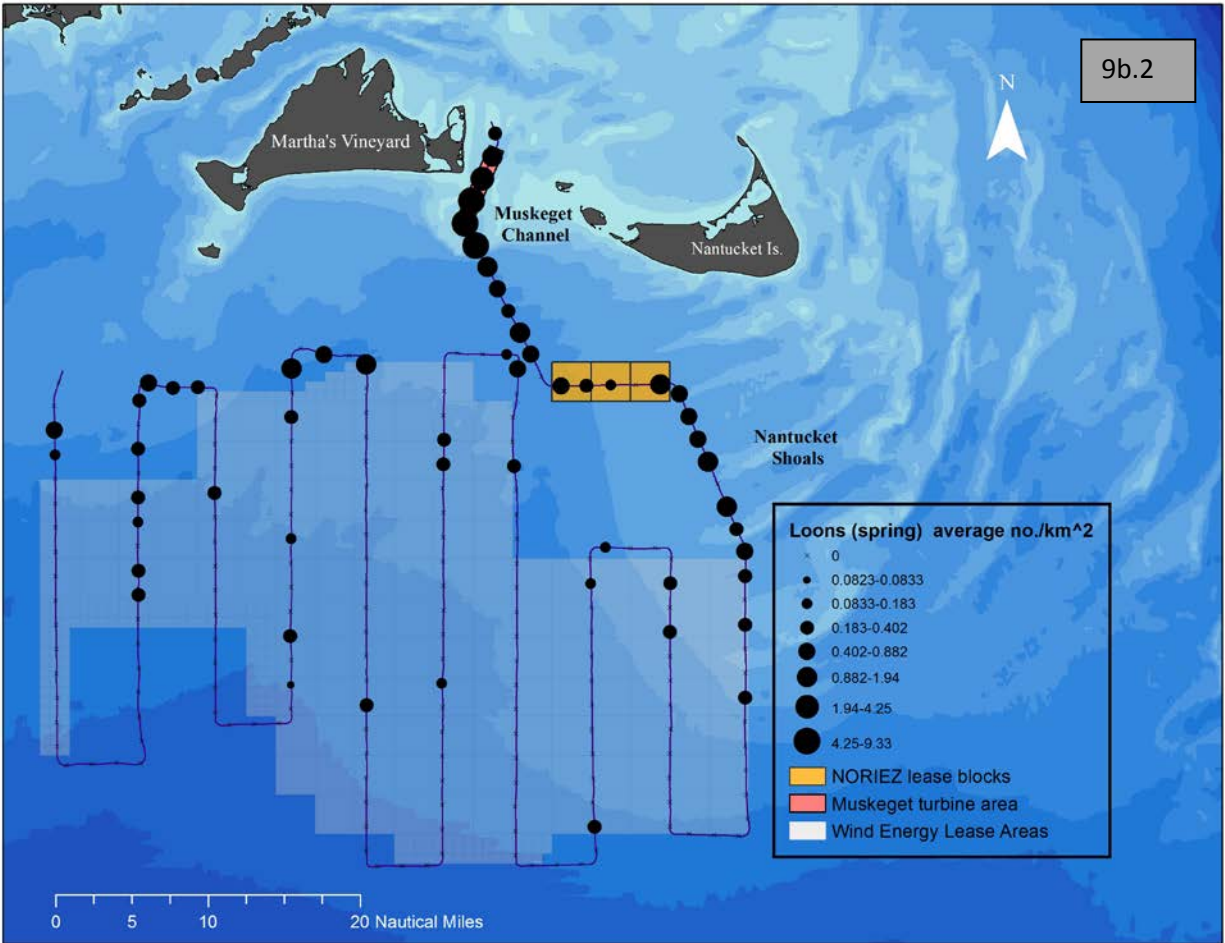


Figure 9b.) Distribution of loons in winter (9b.1), spring (9b.2), fall (9b.3) and summer (9b.4).

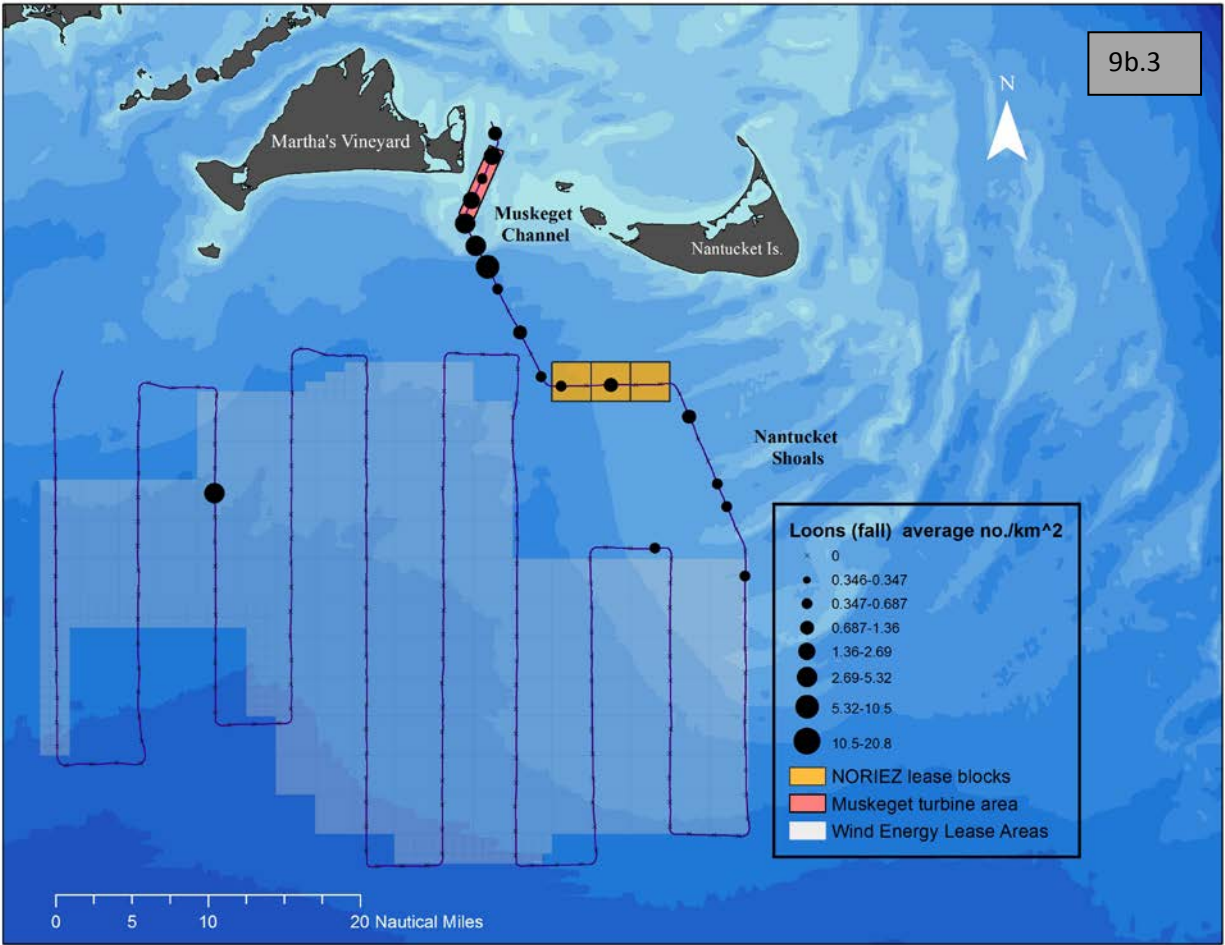


Figure 9b.) Distribution of loons in winter (9b.1), spring (9b.2), fall (9b.3) and summer (9b.4).

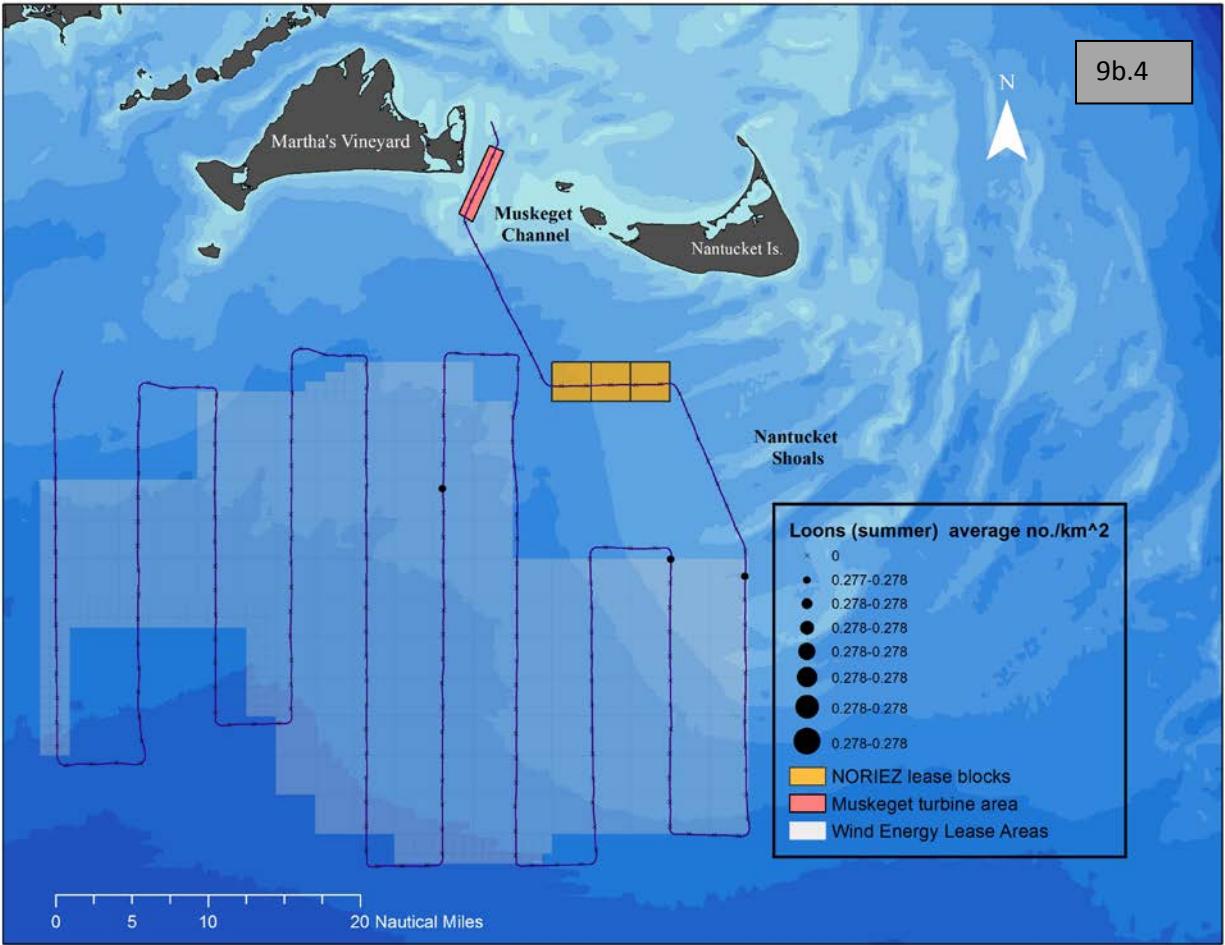


Figure 9b.) Distribution of loons in winter (9b.1), spring (9b.2), fall (9b.3) and summer (9b.4).

Northern Fulmars were more numerous in 2013-2014 than during other times that we surveyed (see Figure 10b), yet they were broadly distributed and common compared to their abundance in the region 30 years ago (Powers 1983). The long term increase likely reflects both oceanographic conditions, and the distribution of fishing vessels (Nisbet et al. 2013).

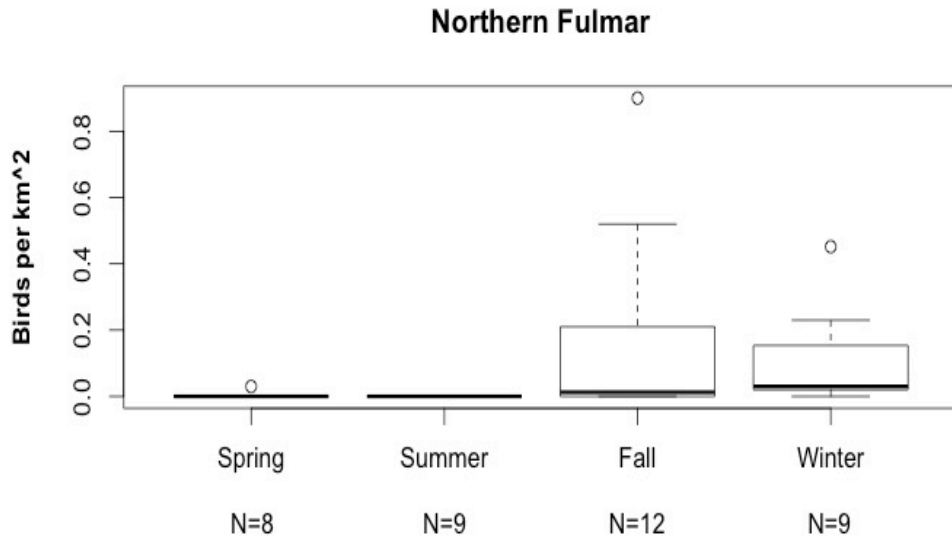


Figure 10a.) Seasonal occurrence of Northern Fulmars off Massachusetts, 2011-2015.

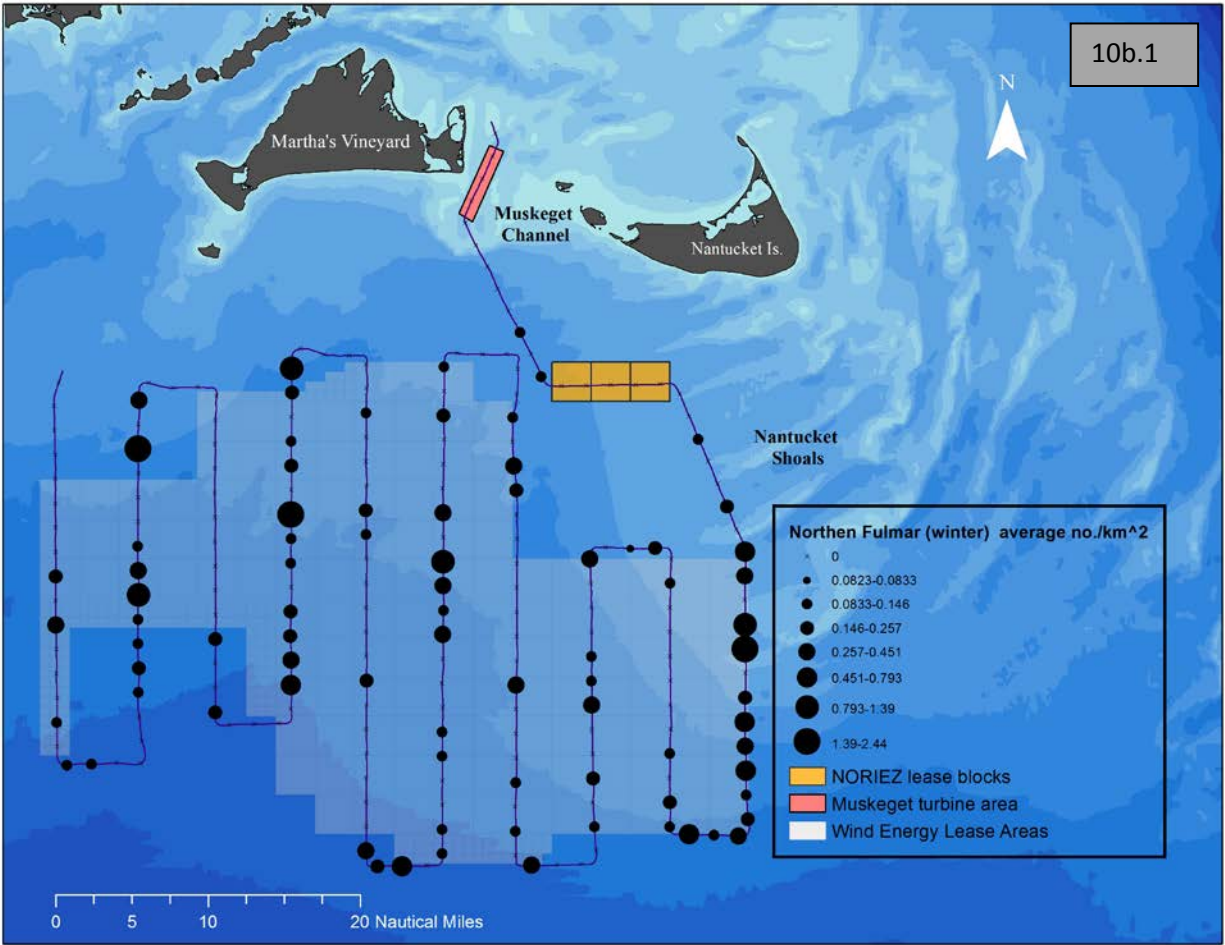


Figure 10b.) Distribution of Northern Fulmars in winter (10b.1) and fall (10b.2).

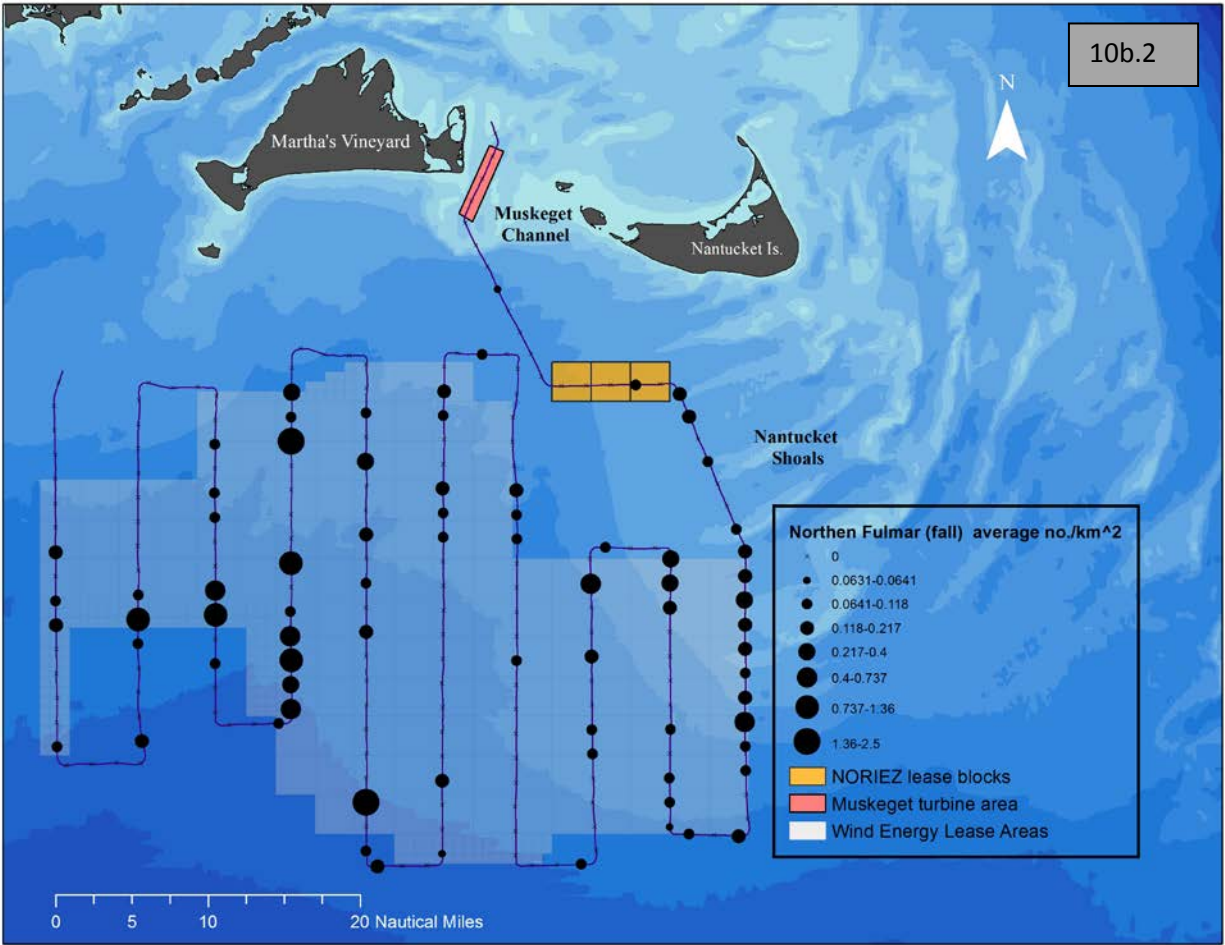


Figure 10b.) Distribution of Northern Fulmars in winter (10b.1) and fall (10b.2).

Great and Cory's Shearwaters (see Figure 11b) were widely distributed and the most numerous birds in summer over the area surveyed (see Table 1, Veit et al. 2013). The largest aggregations were in the vicinity of commercial fishing vessels.

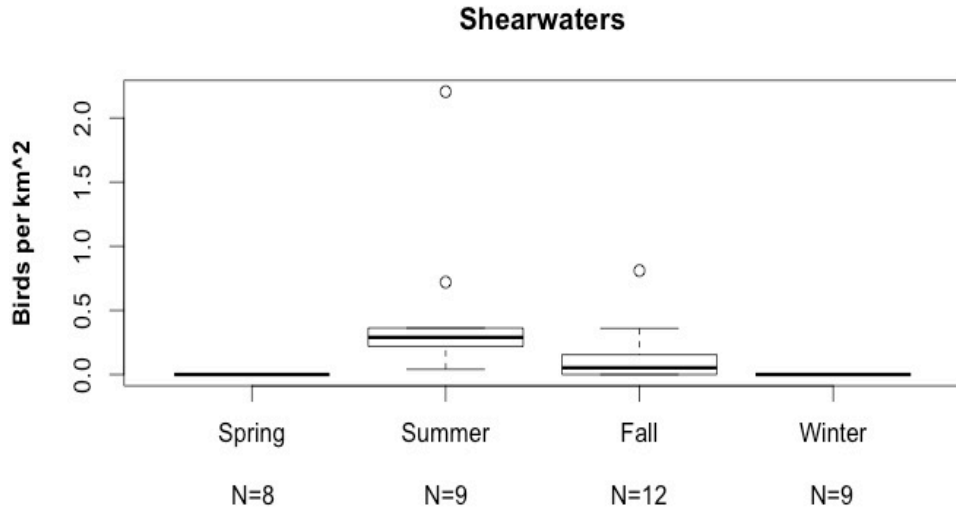


Figure 11a.) Seasonal occurrence of Great and Cory's Shearwaters off Massachusetts, 2011-2015.

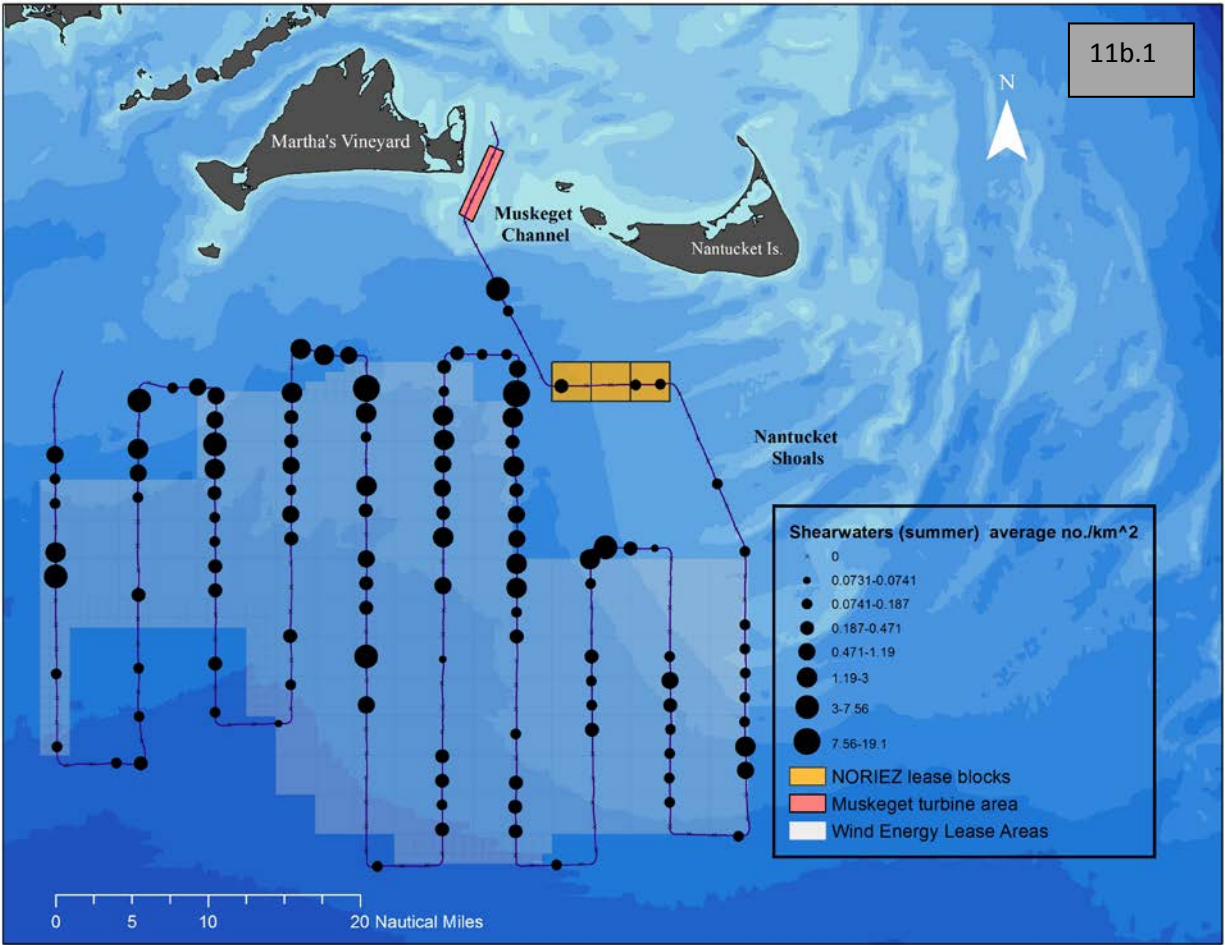


Figure 11b.) Distribution of shearwaters in summer (11b.1) and fall (11b.2).

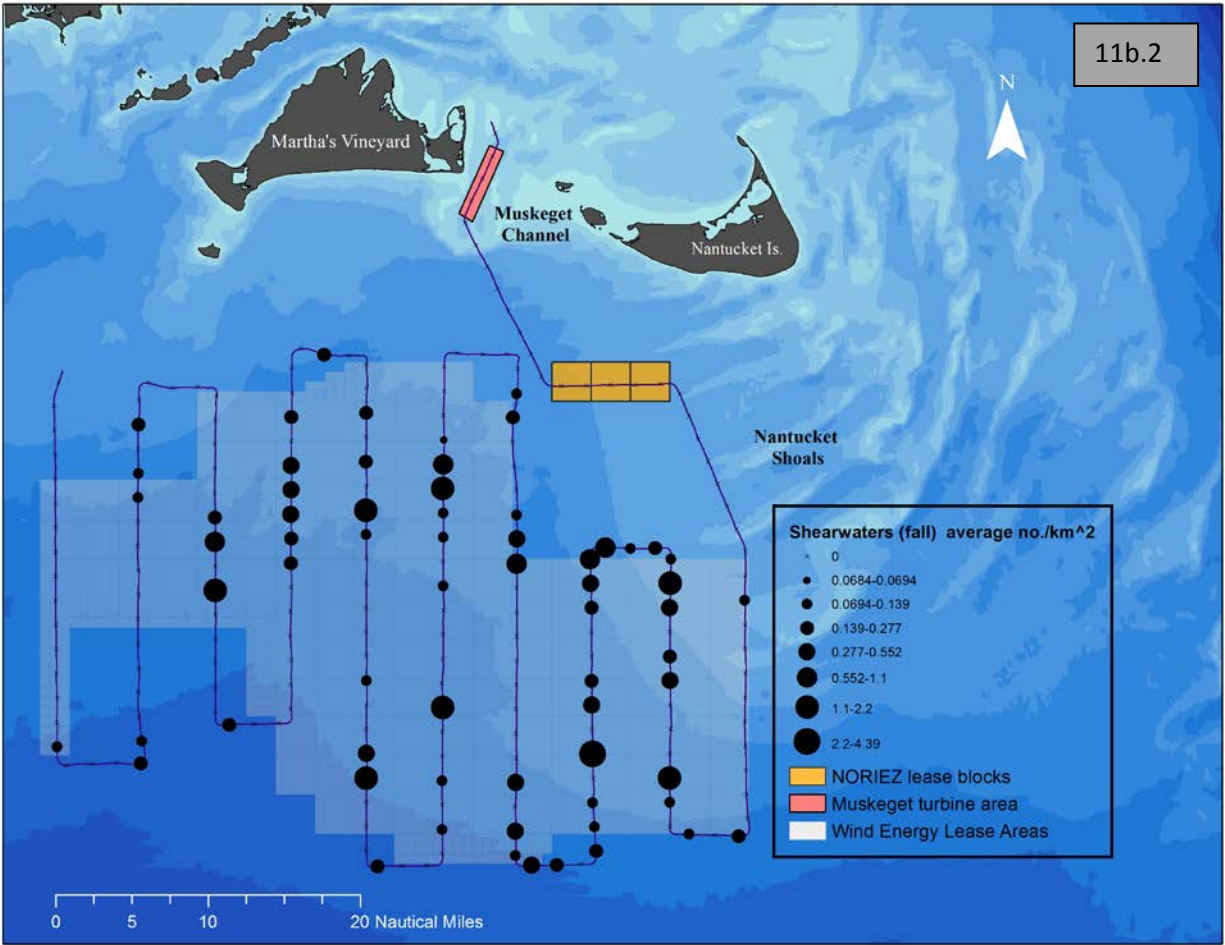


Figure 11b.) Distribution of shearwaters in summer (11b.1) and fall (11b.2).

Wilson's Storm-Petrels, along with Great and Cory's Shearwaters, were the numerically dominant species over the surveyed area during the summer months. Also, like the shearwaters, they tended to stay 10 km or more offshore.

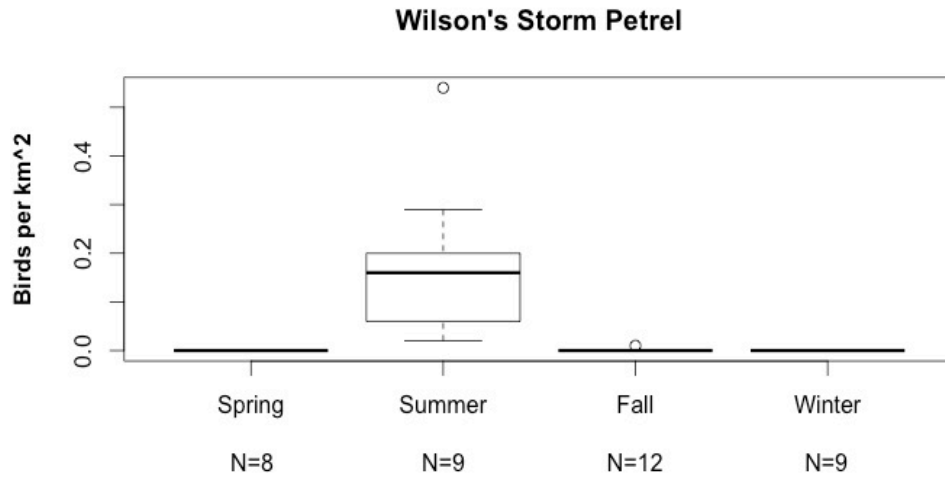


Figure 12a.) Seasonal occurrence of Wilson's Storm-Petrels off Massachusetts, 2011-2015.

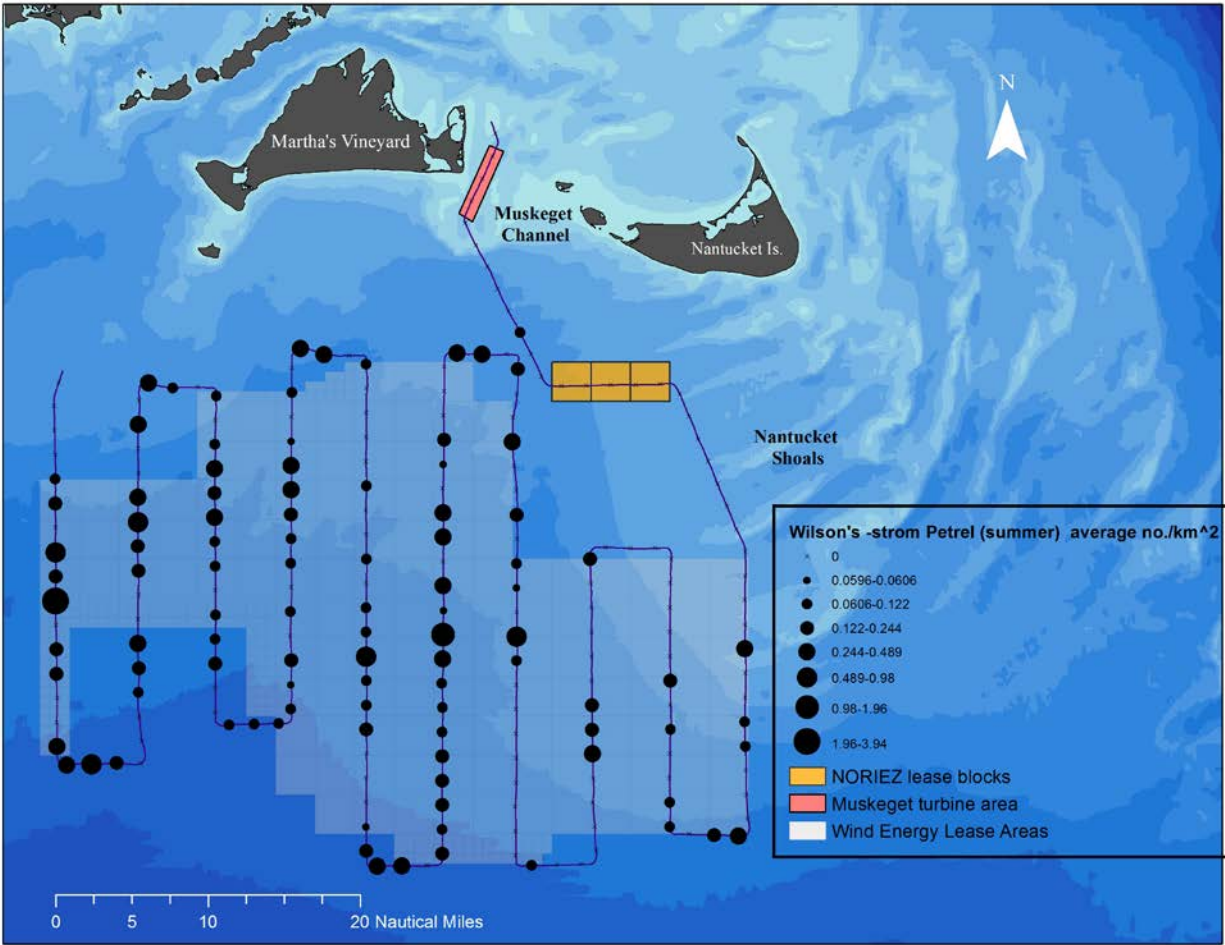


Figure 12b.) Distribution of Wilson's Storm-Petrels in summer.

Northern Gannets (see Figure 13b) were distributed uniformly at fairly low densities throughout the survey area. Northern Gannets have increased substantially over the past ~30 years, at least in part due to climate change (Montevecchi & Myers 1997, Nisbet et al. 2013). This increase has been accompanied by a shoreward shift in its distribution, likely due to the decline of commercial fishing near the continental slope where they clustered around trawlers and fed on by-catch (Nisbet et al. 2013).

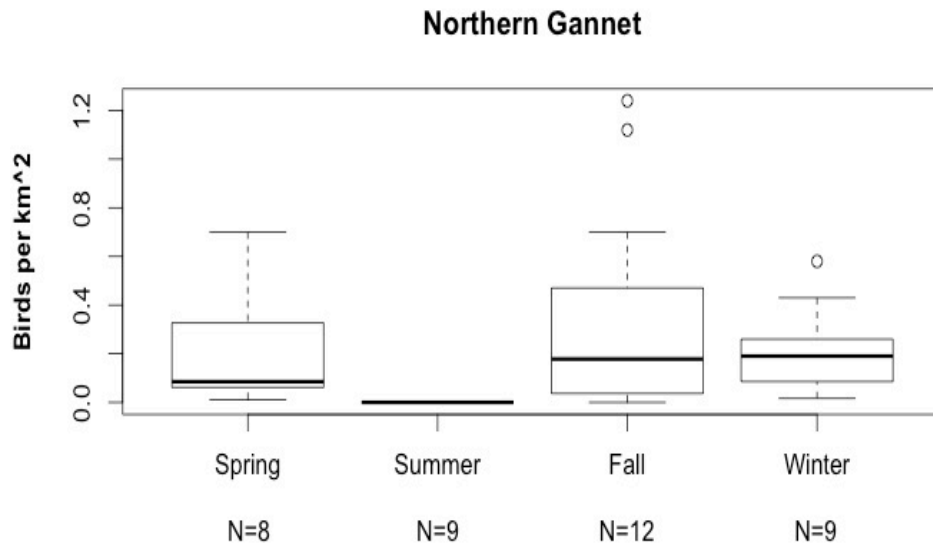


Figure 13a.) Seasonal occurrence of Northern Gannets off Massachusetts, 2011-2015.

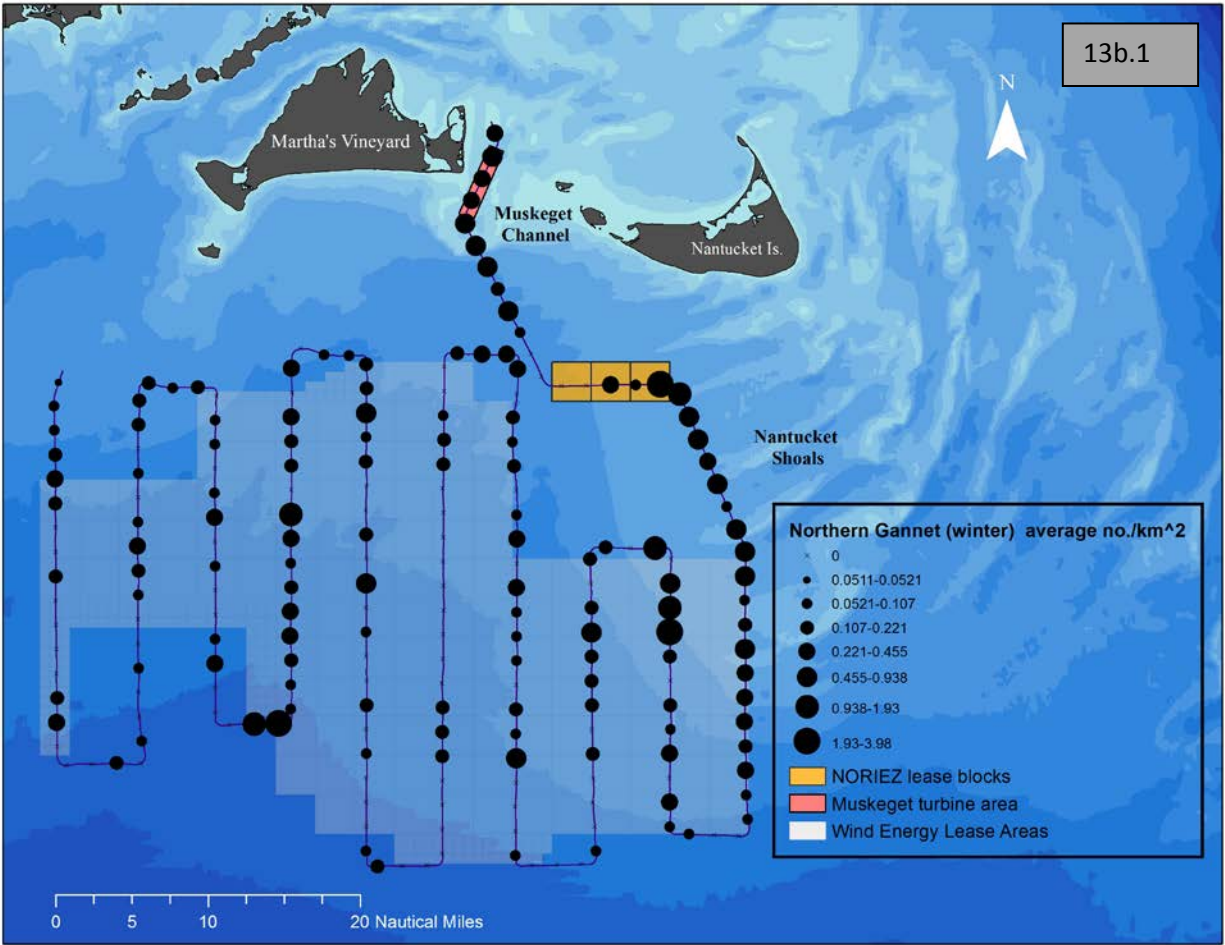


Figure 13b.) Distribution of Northern Gannets in winter (13b.1), spring (13b.2), and fall (13b.3).

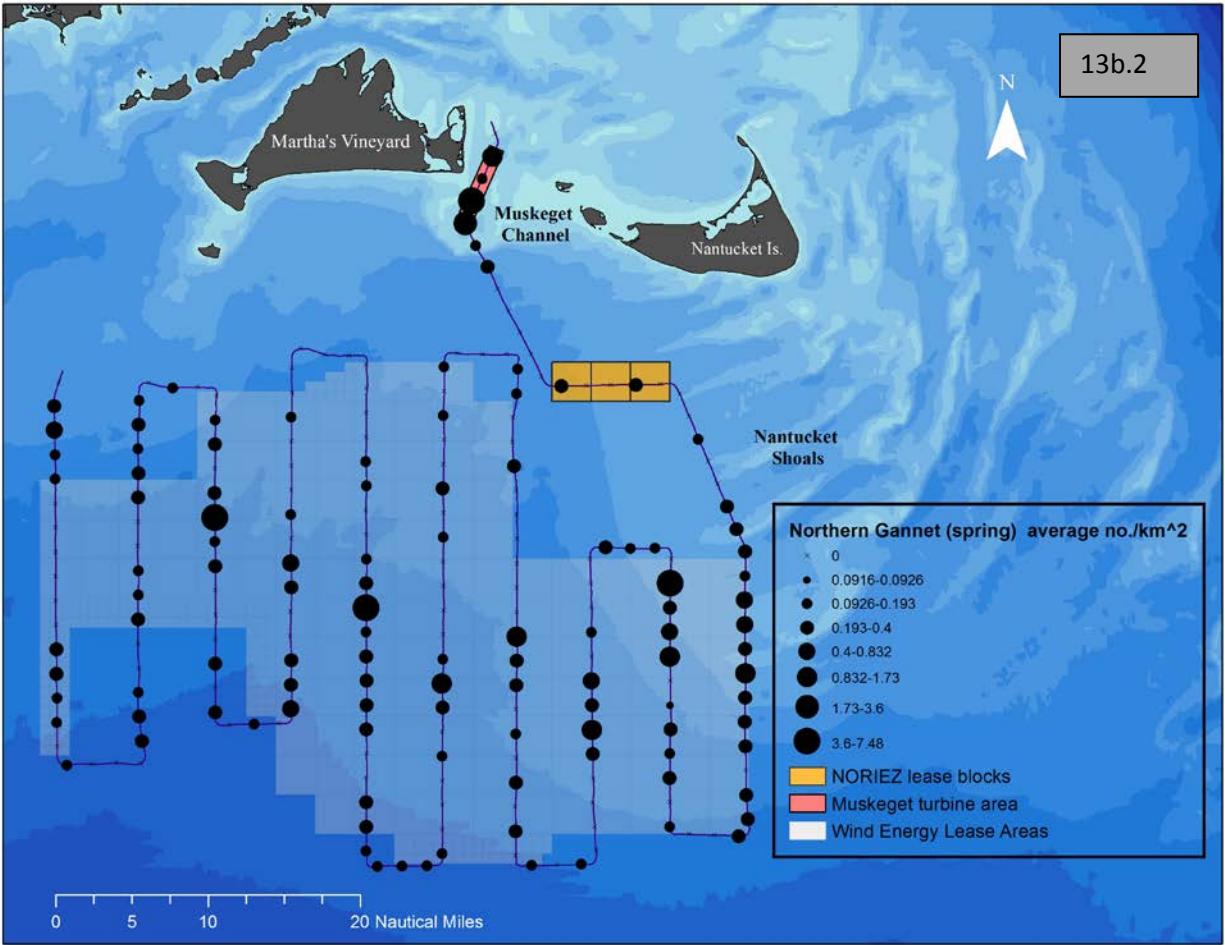


Figure 13b.) Distribution of Northern Gannets in winter (13b.1), spring (13b.2), and fall (13b.3).

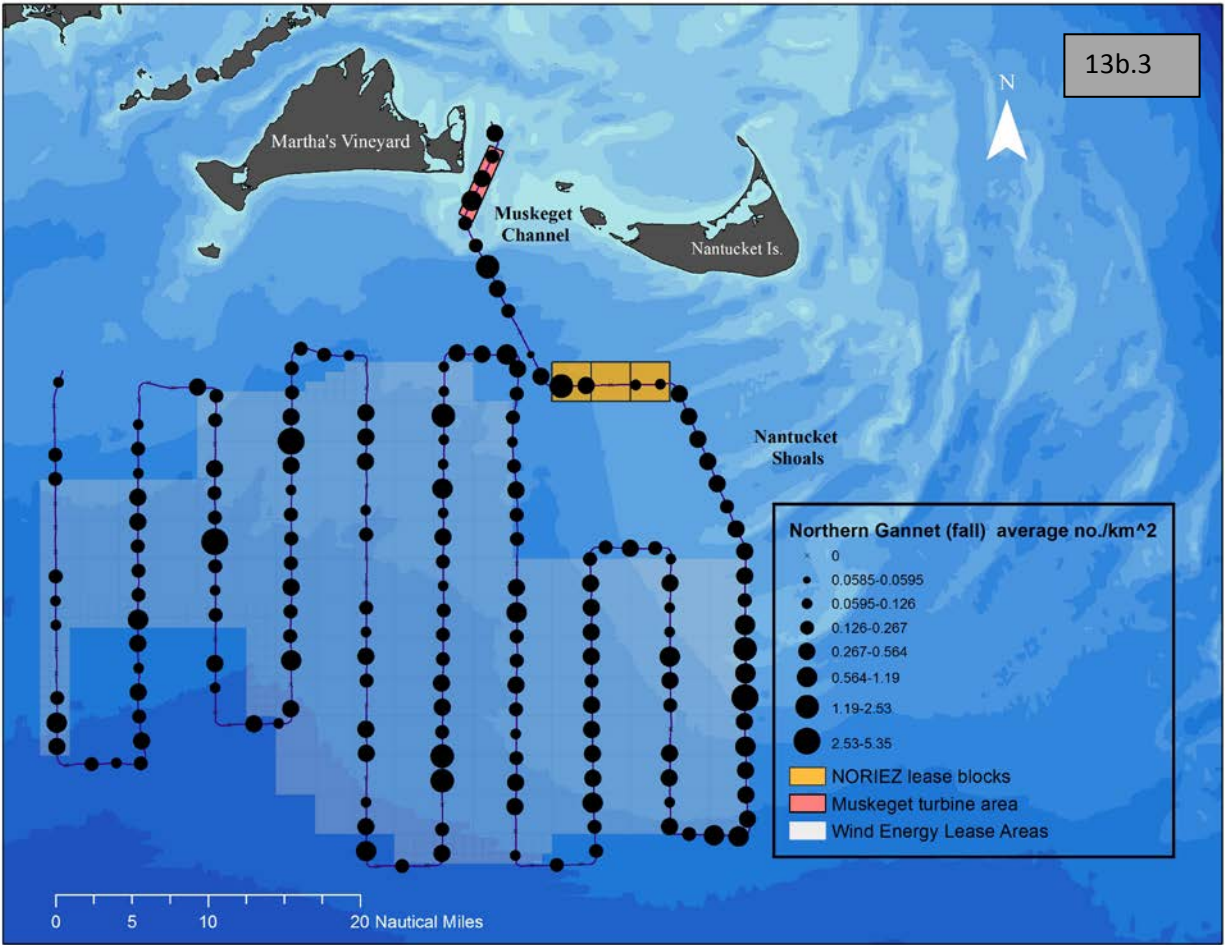


Figure 13b.) Distribution of Northern Gannets in winter (13b.1), spring (13b.2), and fall (13b.3).

Phalaropes, primarily Red Phalaropes on the basis of the date when they were observed, were more numerous during spring in the second and third year of surveys than during the first year (see Figure 14b). Substantial aggregations (~ 20 birds per km²) were found in the lease blocks area surveyed, and a smaller one over the NOREIZ (see Figure 14b).

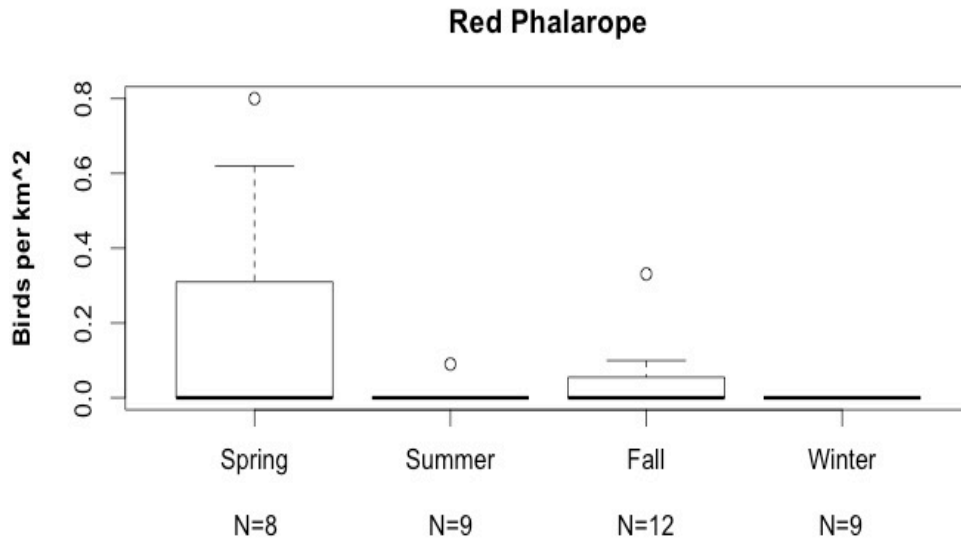


Figure 14a.) Seasonal occurrence of phalaropes (mainly Red Phalaropes) off Massachusetts, 2011-2015.

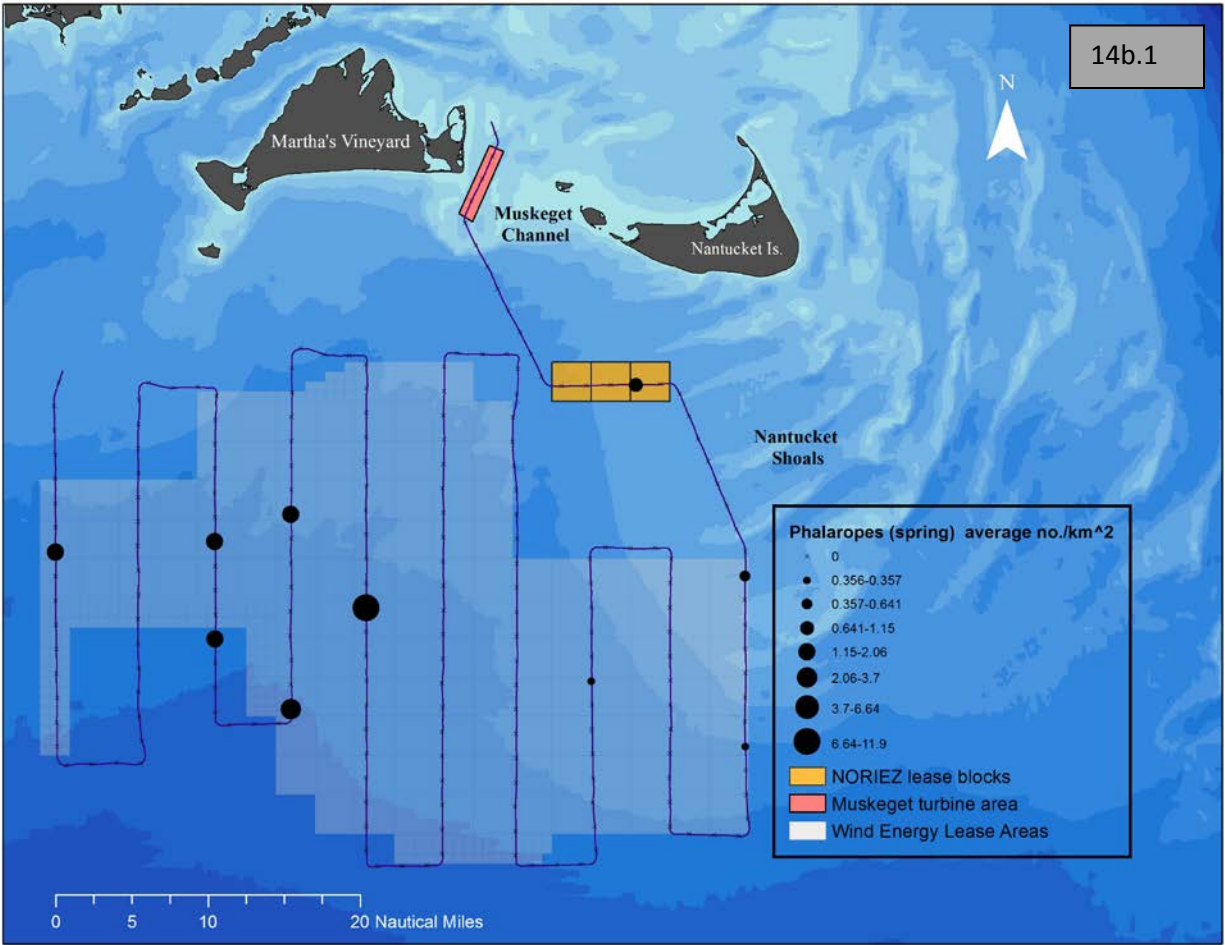


Figure 14b.) Distribution of phalaropes (mostly Red Phalaropes) in spring (14b.1) and fall (14b.2).

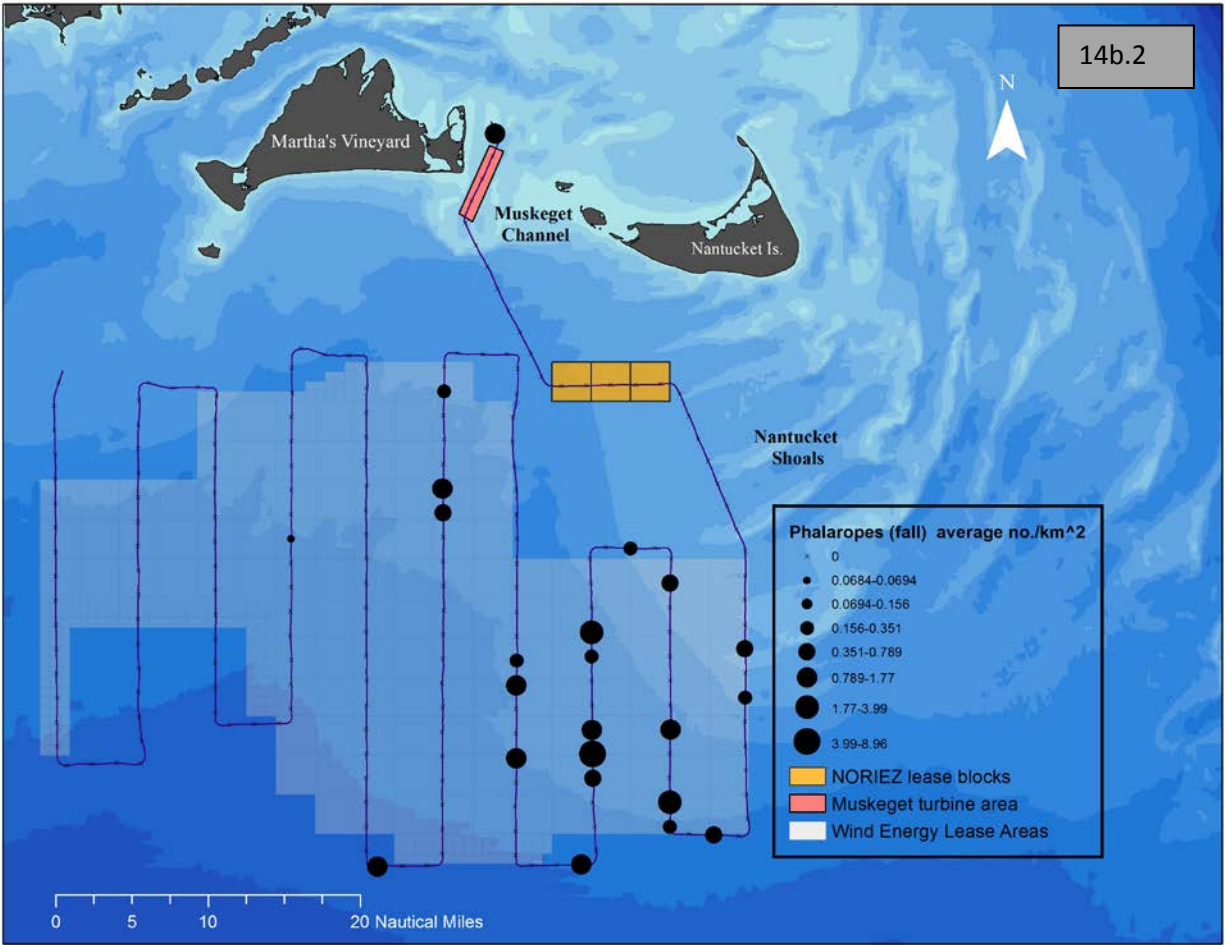


Figure 14b.) Distribution of phalaropes (mostly Red Phalaropes) in spring (14b.1) and fall (14b.2).

Black-legged Kittiwakes were broadly distributed over the survey area during November-April, and also in smaller number inshore to the Muskeget Channel.

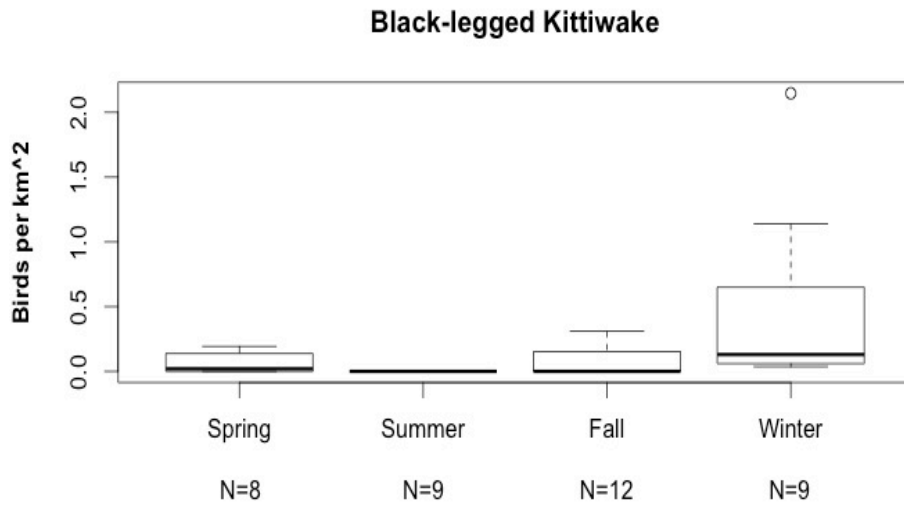


Figure 15a.) Seasonal occurrence of Black-legged Kittiwakes off Massachusetts, 2011-2015.

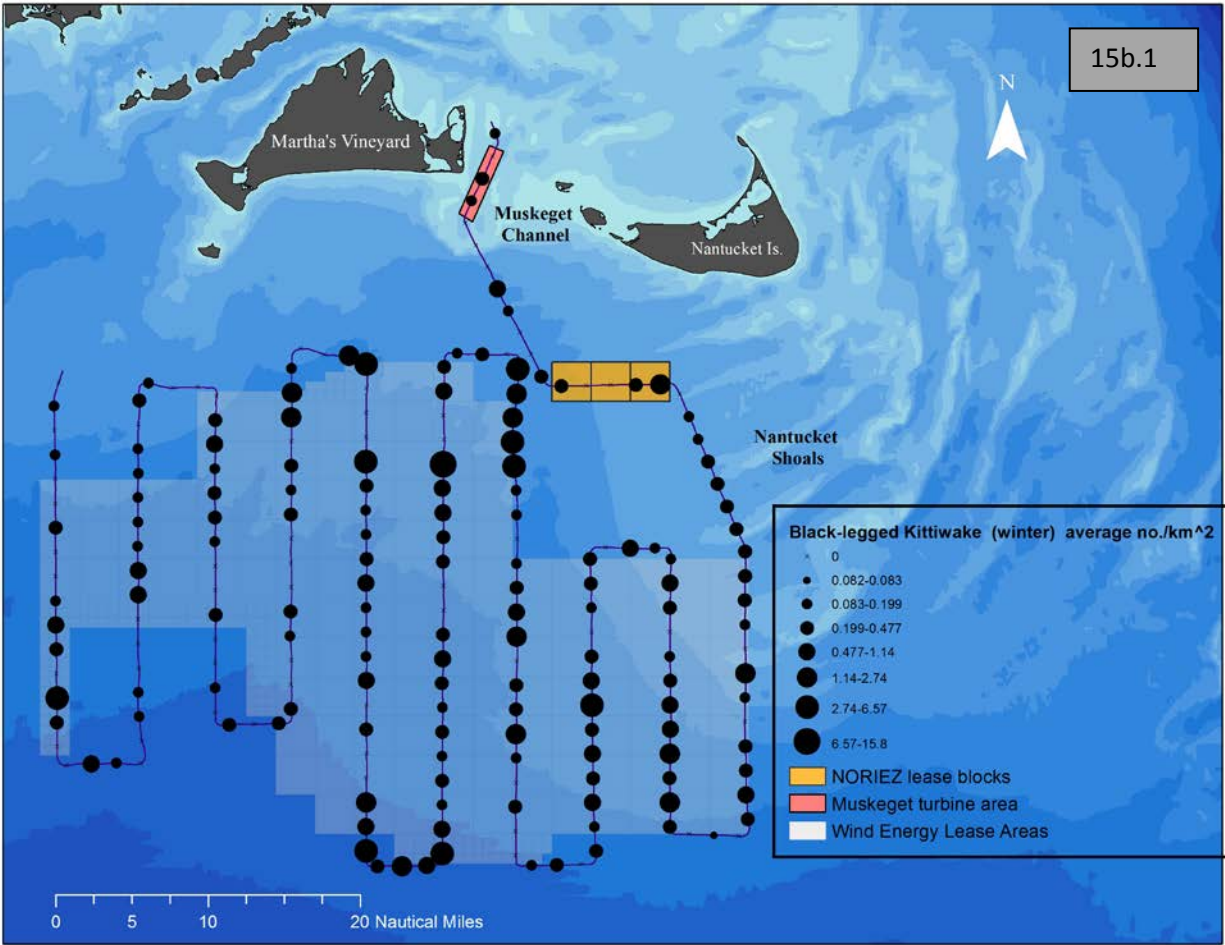


Figure 15b.) Distribution of Black-legged Kittiwakes in winter (15b.1), spring (15b.2), and fall (15b.3).

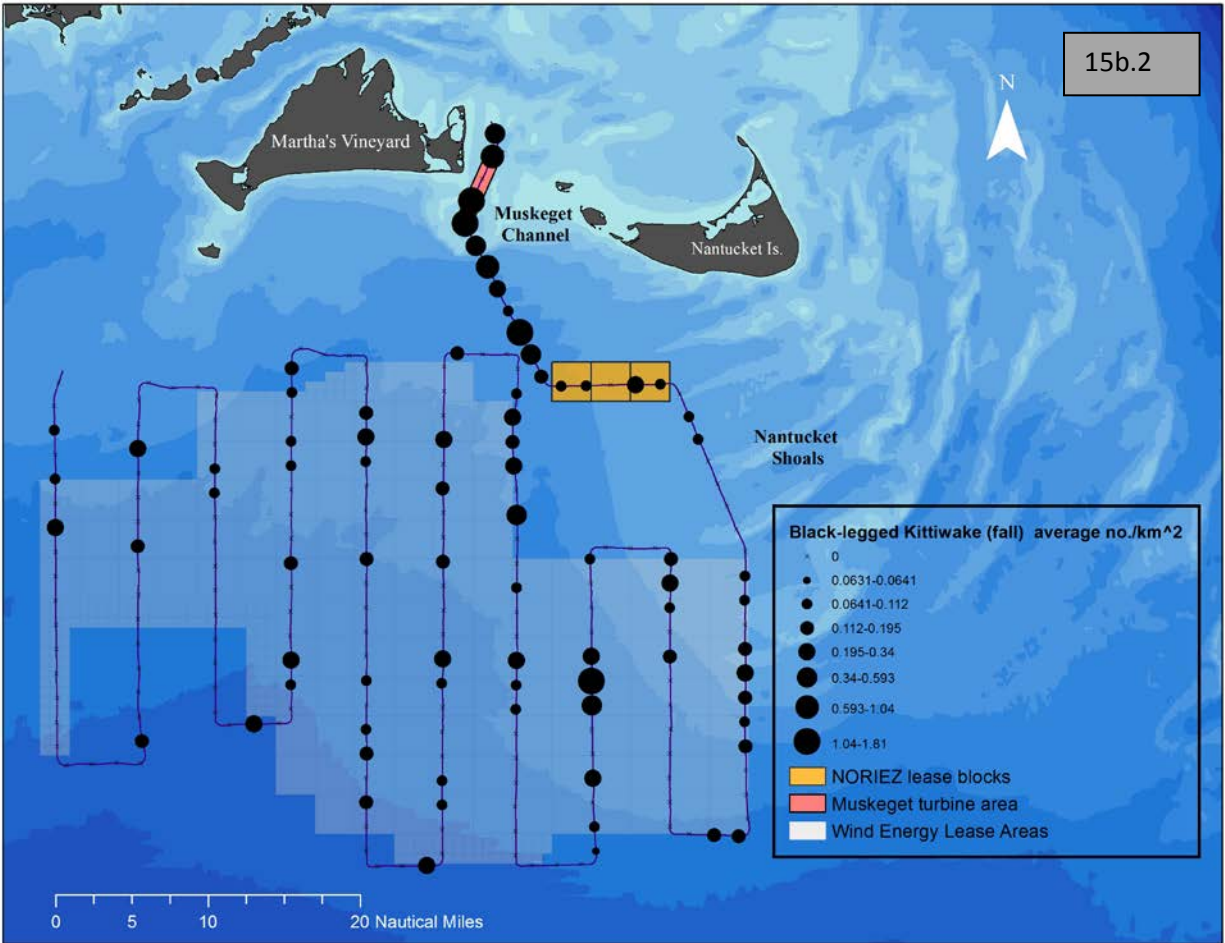


Figure 15b.) Distribution of Black-legged Kittiwakes in winter (15b.1), spring (15b.2), and fall (15b.3).

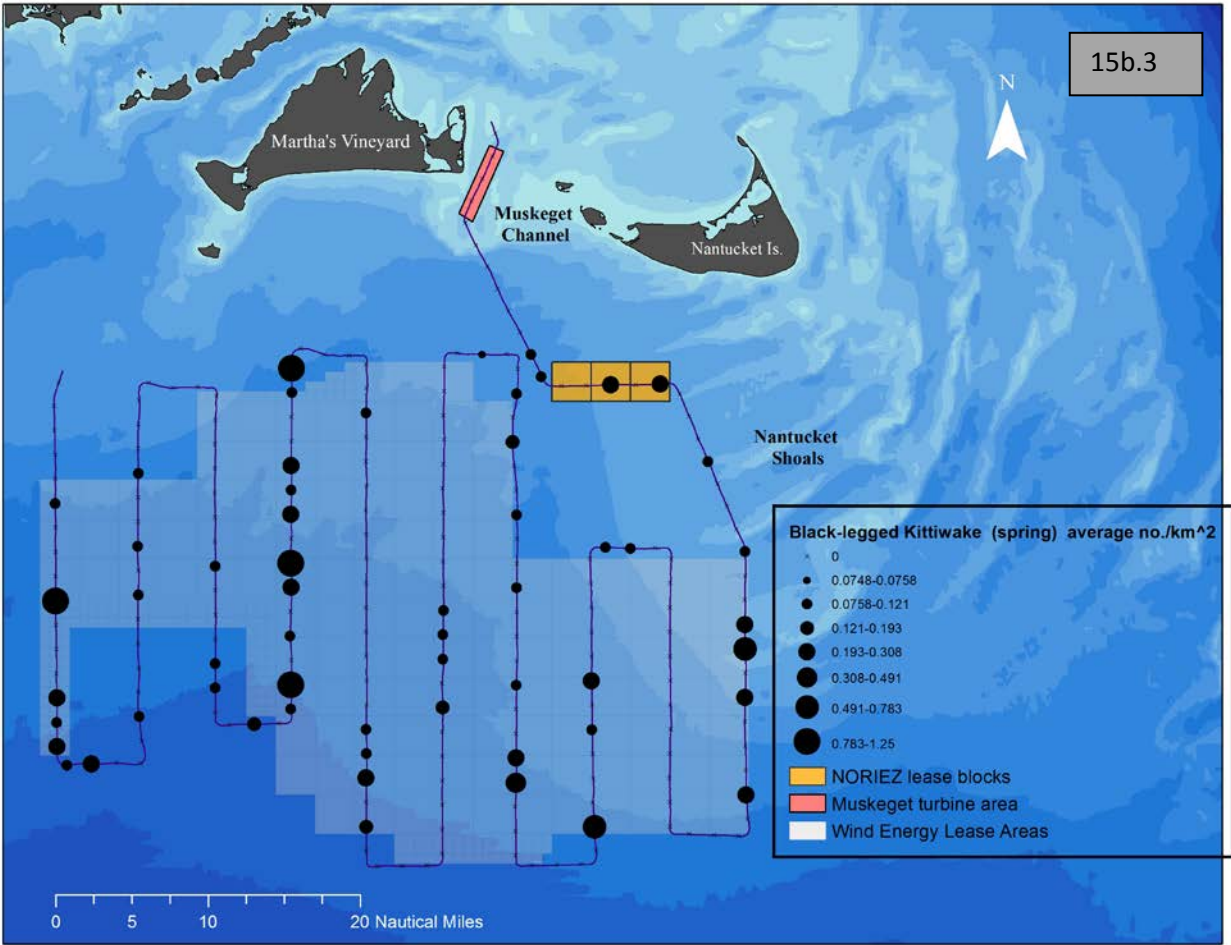


Figure 15b.) Distribution of Black-legged Kittiwakes in winter (15b.1), spring (15b.2), and fall (15b.3).

During summer large gulls remained close to shore. Outside of the breeding season (April to July) they were broadly distributed offshore, often associated with shearwaters near fishing trawlers (see Figure 16b).

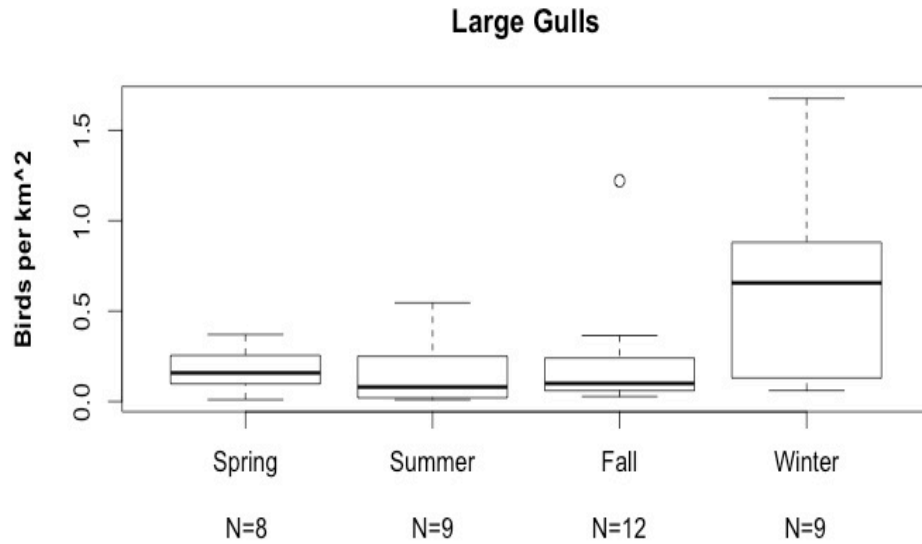


Figure 16a.) Seasonal occurrence of Herring and Great Black-backed Gulls off Massachusetts, 2011-2015.

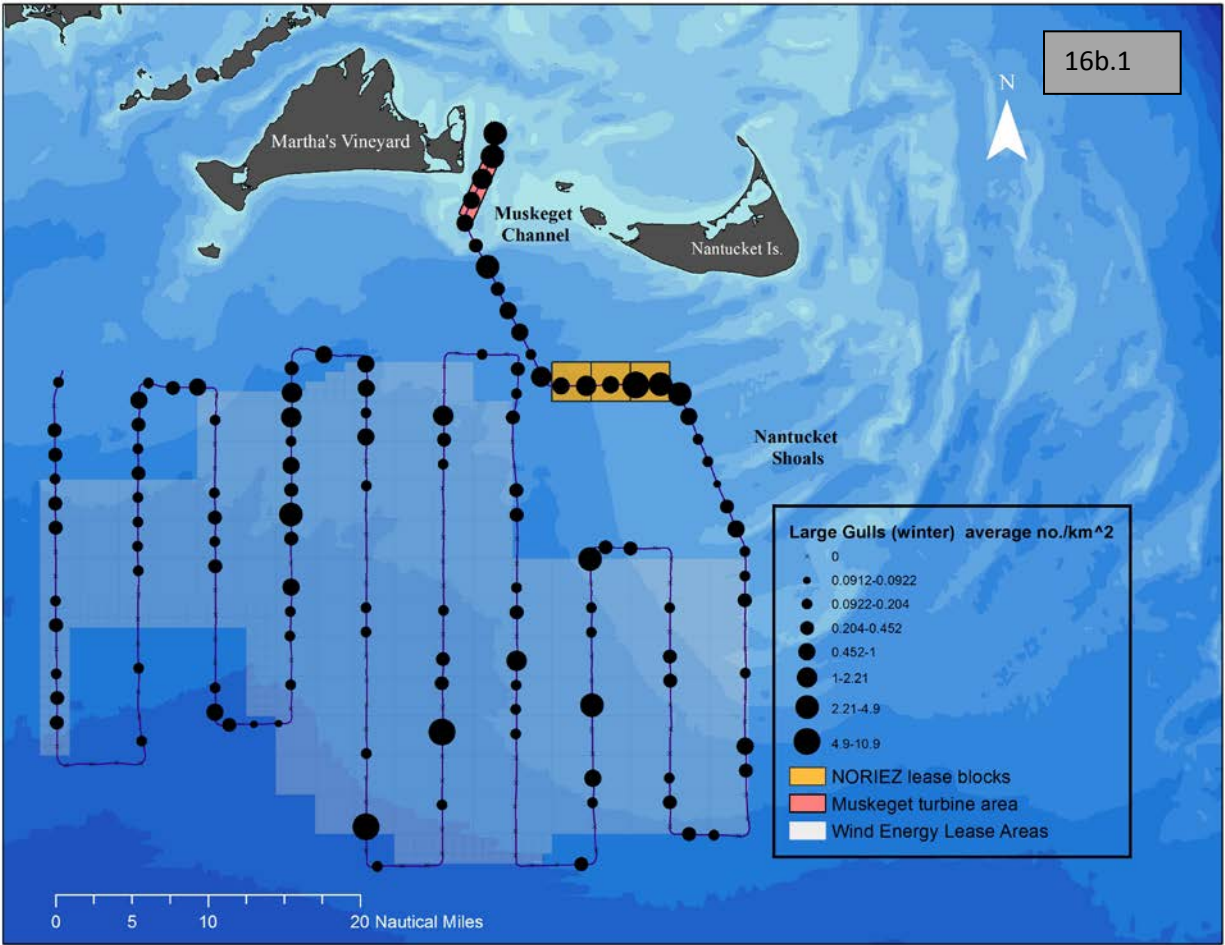


Figure 16b.) Distribution of Great Black-backed and Herring Gulls in winter (16b.1), spring (16b.2), summer (16b.3), and fall (16b.4).

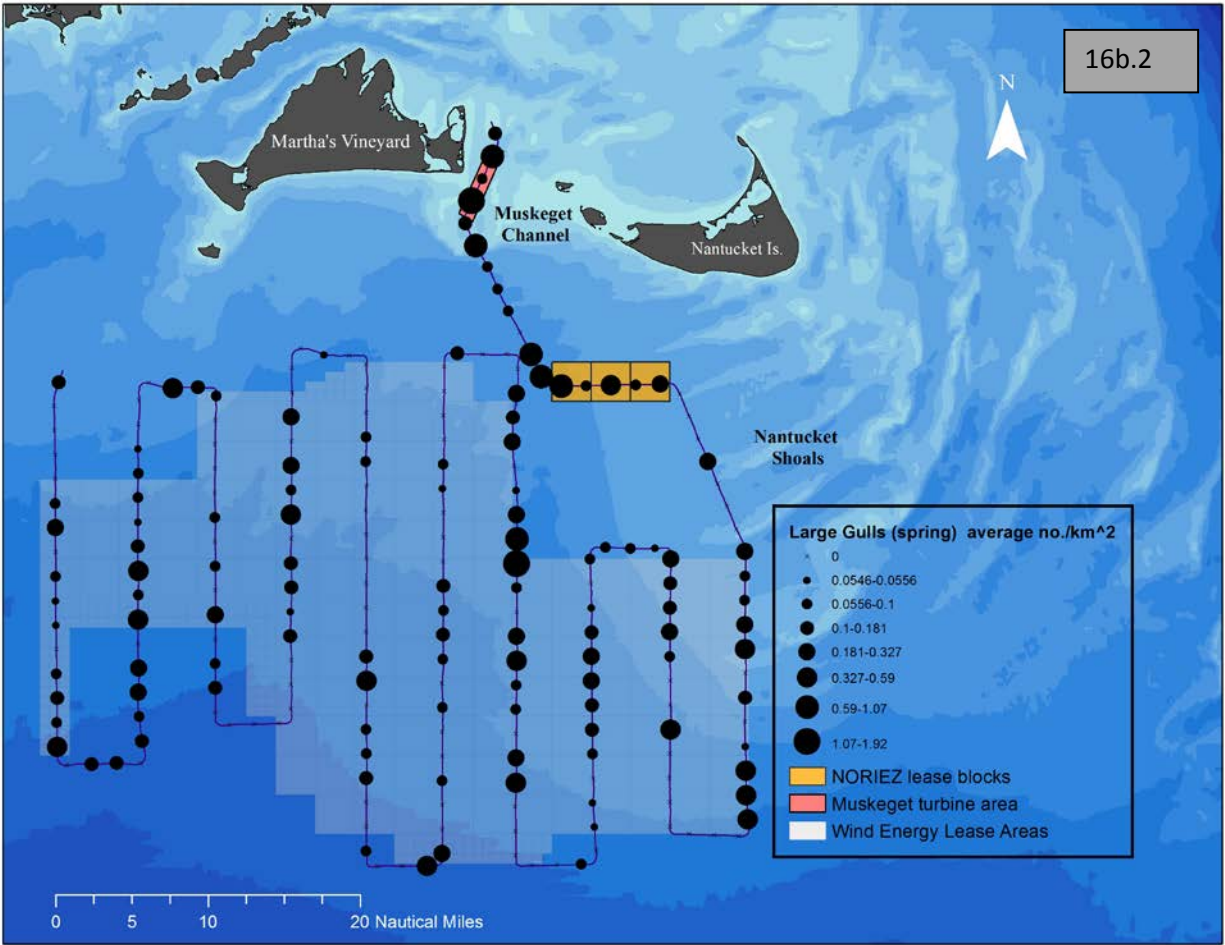


Figure 16b.) Distribution of Great Black-backed and Herring Gulls in winter (16b.1), spring (16b.2), summer (16b.3), and fall (16b.4).

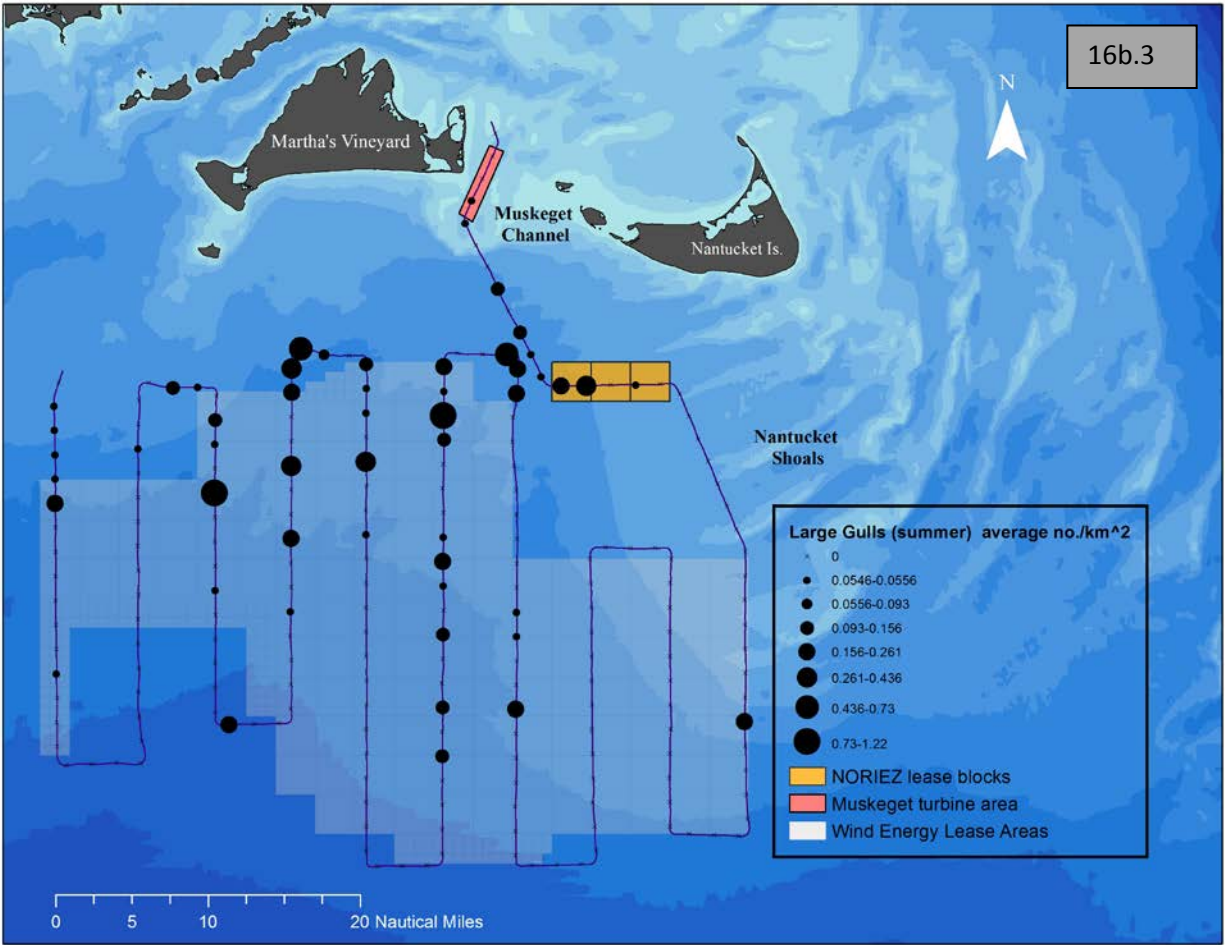


Figure 16b.) Distribution of Great Black-backed and Herring Gulls in winter (16b.1), spring (16b.2), summer (16b.3), and fall (16b.4).

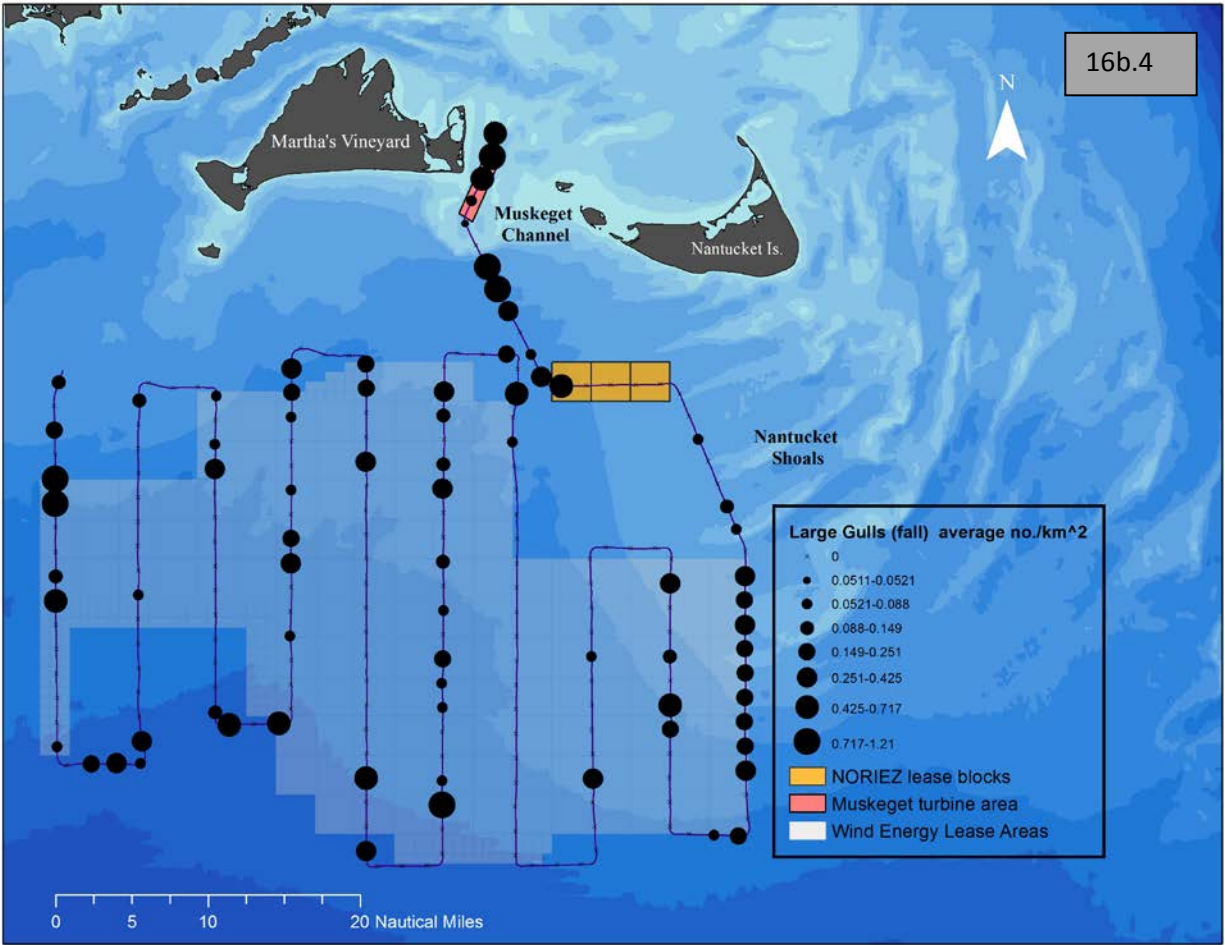


Figure 16b.) Distribution of Great Black-backed and Herring Gulls in winter (16b.1), spring (16b.2), summer (16b.3), and fall (16b.4).

We found Common and Roseate Terns aggregated in the Muskeget Channel area and also, during May, along the western edge of the Nantucket Shoals, in the same general area where we found aggregations of Long-tailed Ducks and White-winged Scoters (Veit et al. 2013). Thus, our data (see Figure 17b) indicate that migrating terns use this highly productive pelagic area during spring on a regular basis.

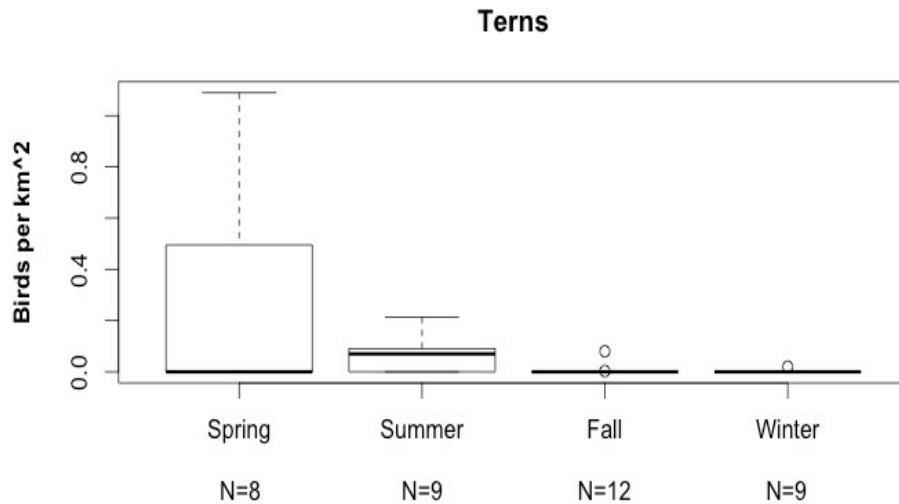


Figure 17a.) Seasonal occurrence of Common and Roseate Terns off Massachusetts, 2011-2015.

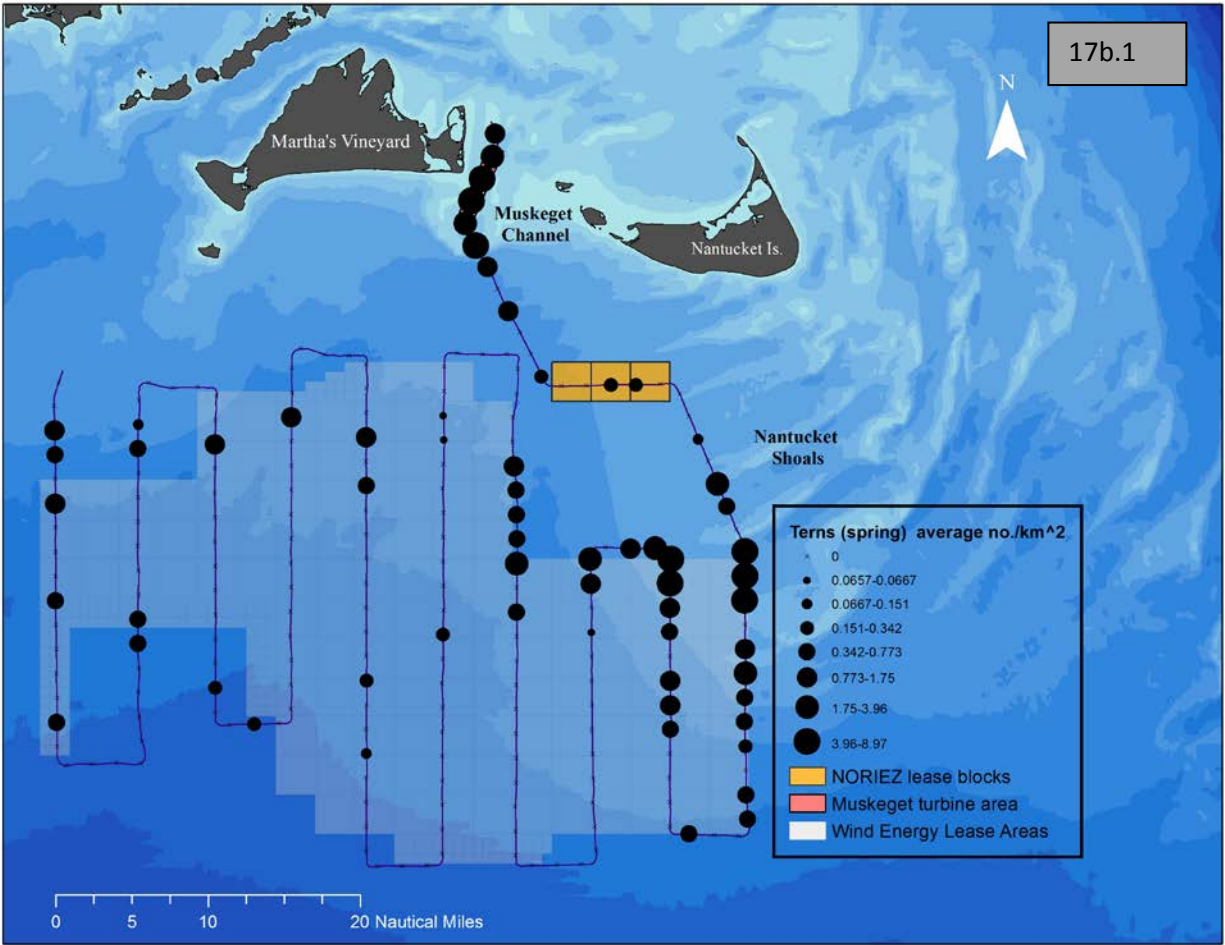


Figure 17b.) Distribution of Common and Roseate Terns in spring (17b.1), summer (17b.2), and fall (17b.3).

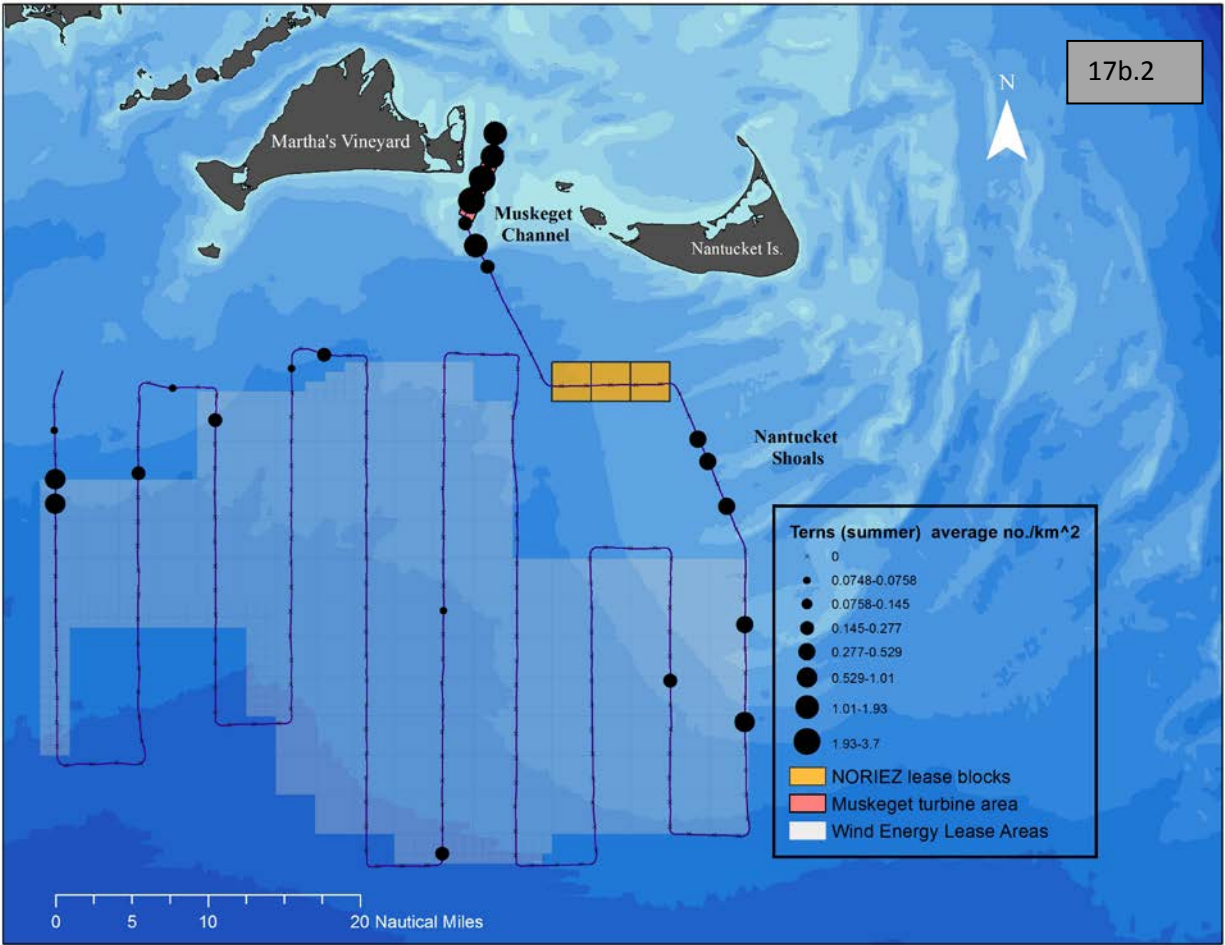


Figure 17b.) Distribution of Common and Roseate Terns in spring (17b.1), summer (17b.2), and fall (17b.3).

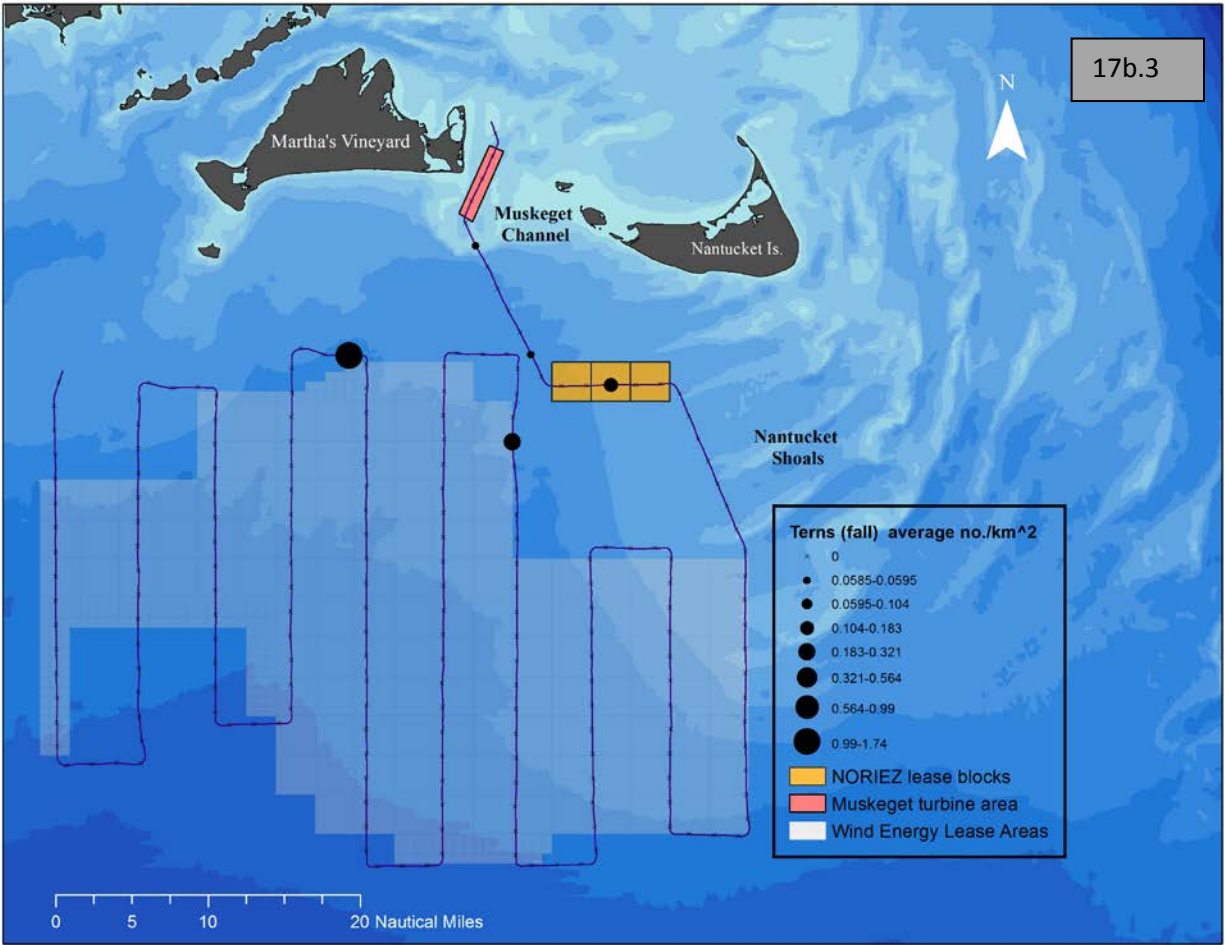


Figure 17b.) Distribution of Common and Roseate Terns in spring (17b.1), summer (17b.2), and fall (17b.3).

Razorbills were present in exceptional abundance in the waters south of Nantucket during the winter of 2012-2013 (Years 1 and 2). They were slightly less numerous during 2013-2014, but still common and widespread (see Figure 18b). While Razorbills were broadly distributed throughout the area surveyed, there was, nevertheless, a concentration at the western edge of the Nantucket Shoals, again attesting to the importance of that area for foraging seabirds.

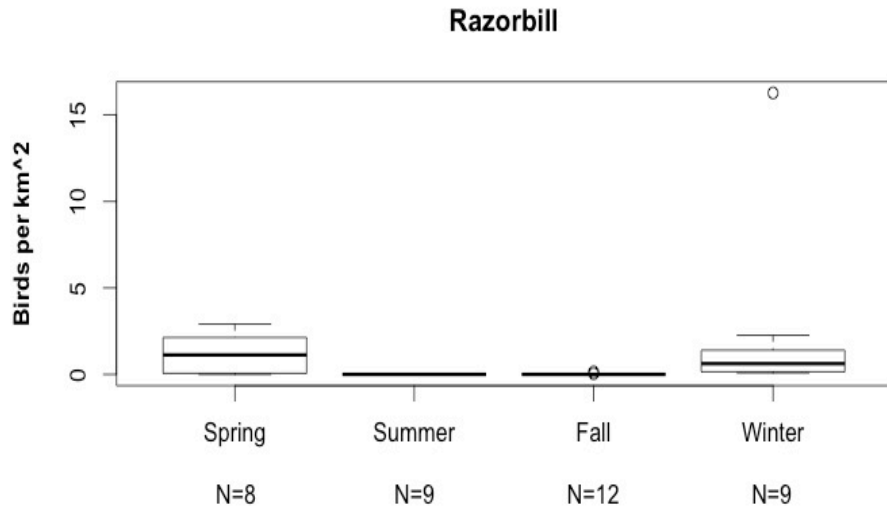


Figure 18a.) Seasonal occurrence of Razorbills off Massachusetts, 2011-2015.

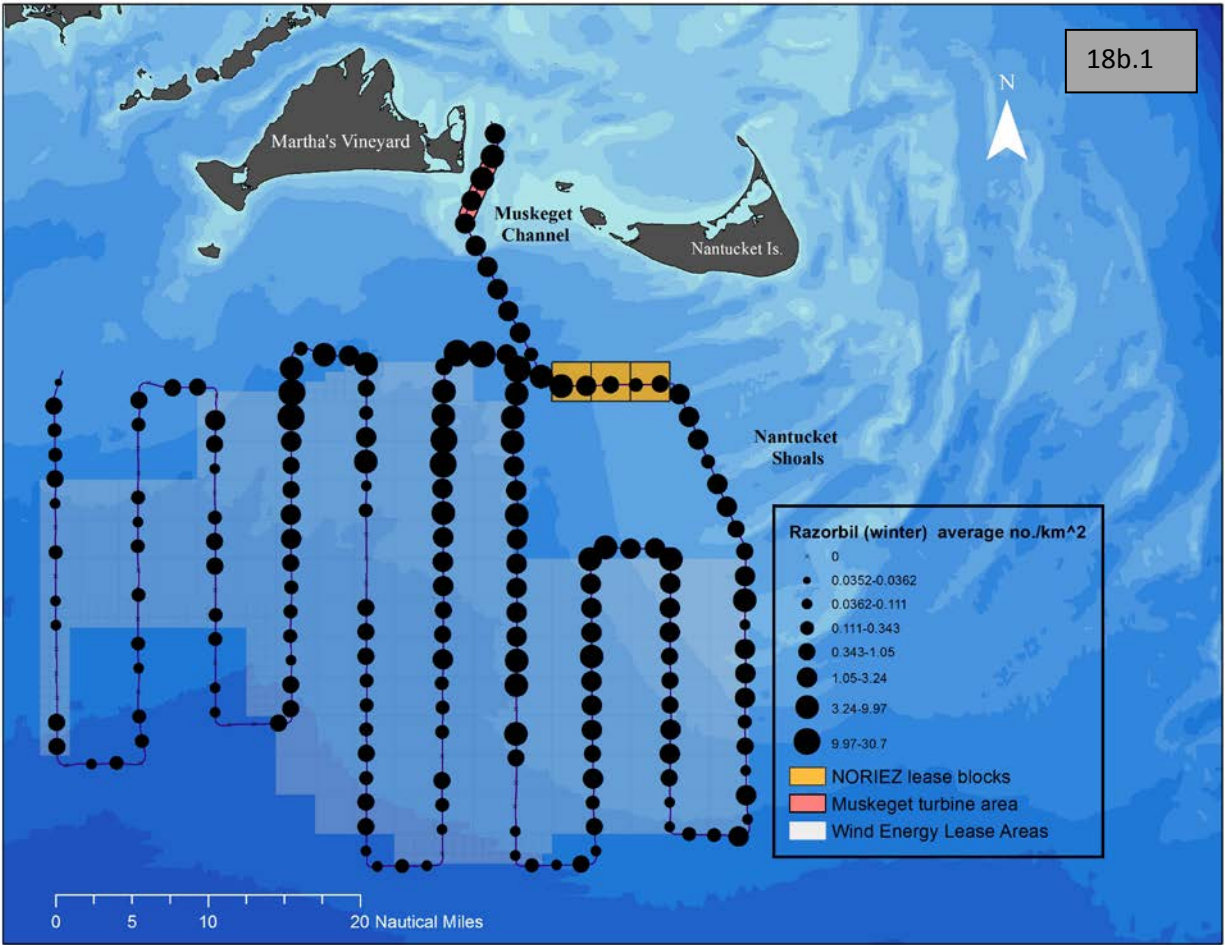


Figure 18b.) Distribution of Razorbills in winter (18b.1), spring (18b.2) and fall (18b.3).

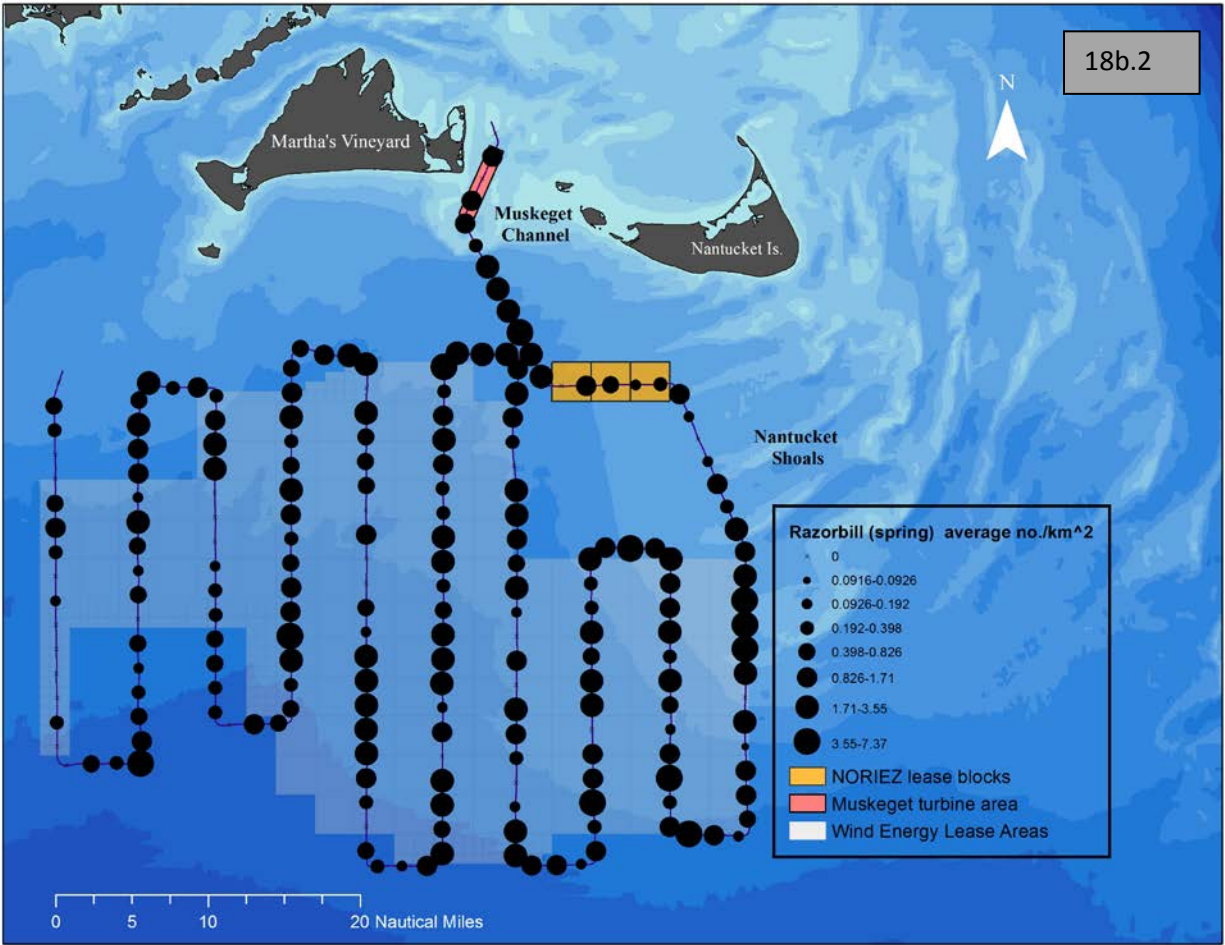


Figure 18b.) Distribution of Razorbills in winter (18b.1), spring (18b.2) and fall (18b.3).

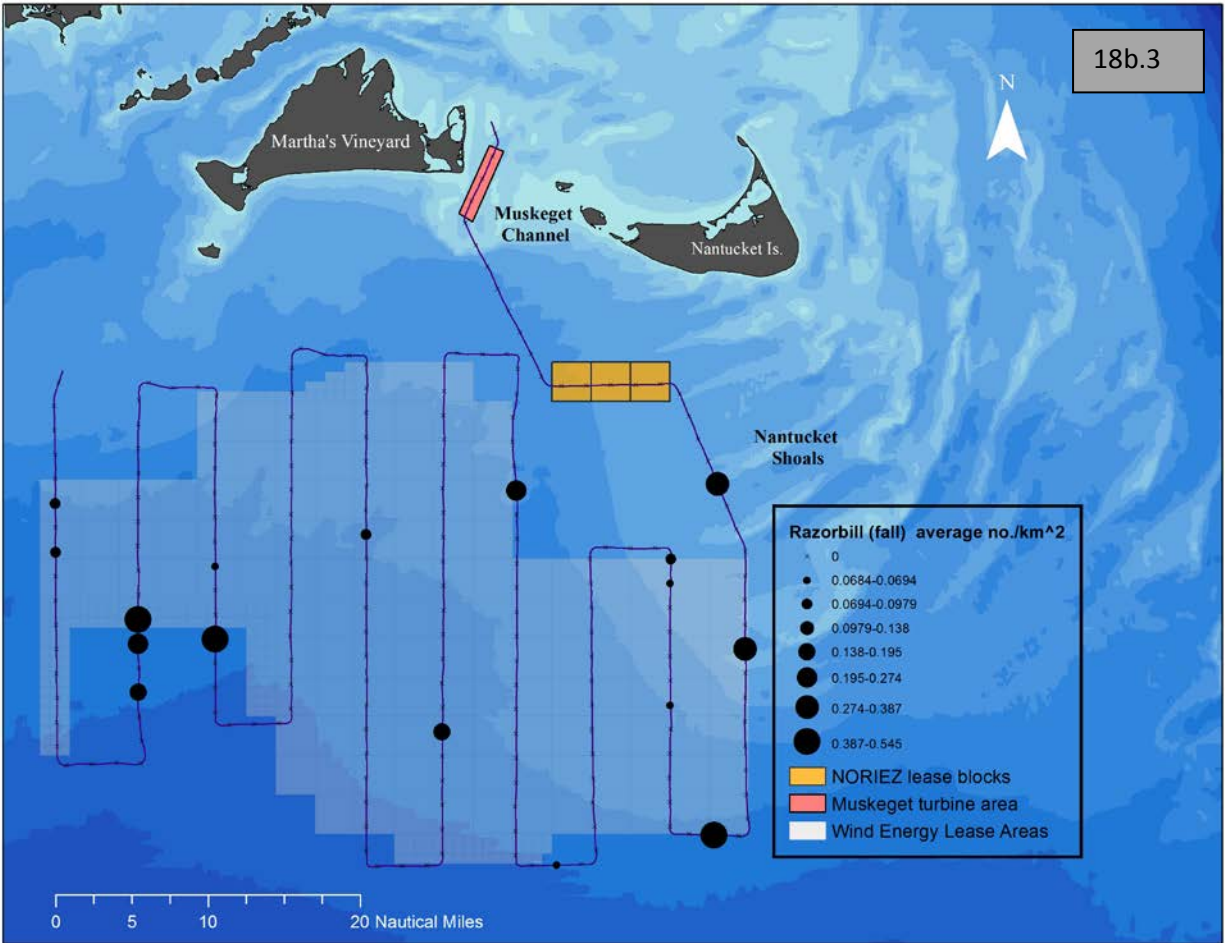


Figure 18b.) Distribution of Razorbills in winter (18b.1), spring (18b.2) and fall (18b.3).

3.2 Seasonality

Within the study period, birds occurred in much greater numbers during the winter months than at any other season. The most numerous species were Razorbills, Long-tailed Ducks, and scoters (mostly White-winged). The seasonality of the ten most numerous taxa are represented in Figures 13-22. We calculated mean densities as the sum of all 3 km abundances, divided by the number of 3 km samples.

4. Discussion

The western edge of the Nantucket Shoals emerged as an obvious Hotspot for Long-tailed Ducks, White-winged Scoters, Northern Gannets, and Razorbills. We found Roseate and Common Terns in high abundance there in both Year 1 and Year 2, but did not survey the area during May of Year 3. On this basis, we conclude that the Nantucket Shoals are a Hotspot for these terns during May. The Nantucket Shoals are known as a highly biologically productive region due to upwelling of nutrient rich water from the Gulf of Maine that occurs there (Kenney & Wishner 1995; Townsend et al. 2004), and the Shoals have been identified as an important fishing ground foraging area for seabirds (Ecosystem Assessment Program 2009; White et al. 2009, White 2013). The Muskeget Channel, situated between Martha's Vineyard and Muskeget, is the major south facing entrance to Nantucket Sound, through which substantial tidal flow passes. It is also a Hotspot for Common Eiders, Long-tailed Ducks, and Common and Roseate Terns. Tens of thousands of Black and White-winged Scoters also concentrate there in some years (Perkins et al. 2005; Martin & Ellison 2014).

The area of the NOREIZ lease blocks did not qualify as a Hotspot for seabirds, using our criteria. However, large aggregations of Long-tailed Ducks and Common and Red-throated Loons occurred there during 2013-2014.

Since the area we surveyed has not been surveyed at this fine scale previously, we are somewhat limited as to what we can say about changes in abundance over the historical period. However, we can make comparisons with surveys conducted recently in Nantucket Sound (Perkins et al. 2005), Rhode Island (Winiarski et al. 2011), New York (Kinlan et al. 2012), and Delaware, Maryland, and Virginia (Goyert et al. *in press*, Sollman et al. *in press*), and some changes have been so dramatic as to allow comparisons with previous, broader scale surveys from the 1970s (Powers 1983).

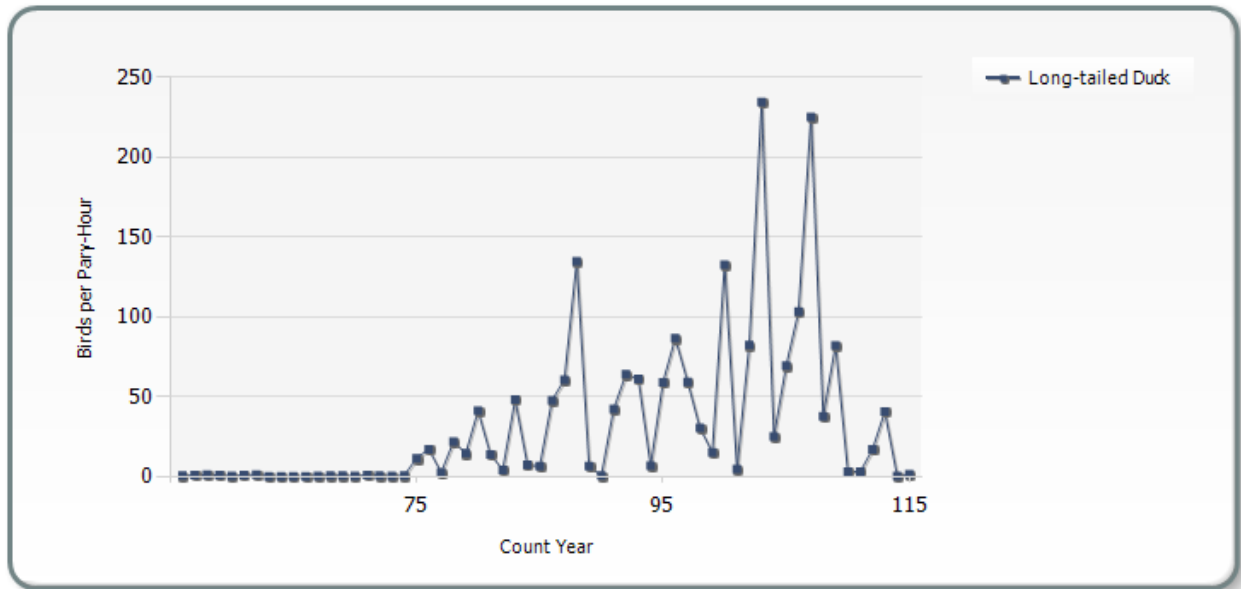


Figure 19.) Abundance of Long-tailed Ducks on all Christmas Bird Counts in Massachusetts, 1955-2015. Source: National Audubon Society Christmas Bird Counts.

Species that stand out for the high abundance we recorded south of Nantucket and Martha’s Vineyard are White-winged Scoters, Long-tailed Ducks, Northern Gannets, and Razorbills. White-winged Scoters and Long-tailed Ducks were more abundant off Massachusetts than elsewhere along the east coast in recent years, and also more numerous in Massachusetts than during the 1970s and 1980s (Powers 1983). The Manomet Bird Observatory (MBO) surveys summarized by Powers (1983) did not survey the area that we surveyed with anything like the intensity that we did; nevertheless, it is clear from other sources of data (see Figure 19) that Long-tailed Ducks substantially increased within our area beginning in about 1975, reached peak abundance about 5 years ago, and have since declined. White-winged Scoters do not show such a long-term trend, but their spatial association with Long-tailed Ducks suggests the increased abundance of the two species could have a common cause. The period of Long-tailed Duck abundance corresponds to a long stretch of positive values in the North Atlantic Multidecadal Index (https://commons.wikimedia.org/wiki/File:Atlantic_Multidecadal_Oscillation.svg) and therefore may be related to long term climate shifts in the North Atlantic.

Northern Gannets have increased substantially over the past 50 years (Monetvecchi & Myers 1997, Nisbet et al. 2013) and their distribution has shifted more inshore (Veit et al. 2011), but the densities we recorded south of Massachusetts (0.2-0.5 birds per km²) were lower than those reported off New York and the mid-Atlantic states in recent years.

Razorbills have been steadily increasing and extending their range south for 30-40 years (Nisbet et al. 2013; Veit & Manne 2015). Within the context of this long-term trend, the

winter of 2012-2013 (Year 1 and 2) was truly exceptional for abundance of Razorbills off the U.S. coast, with unprecedented numbers seen off Nantucket and vagrants recorded south to Florida and the Gulf of Mexico (Anderson 2013). Increasing abundance of Razorbills likely is the result of multiple factors including changing oceanic climate, decreased mortality in gill nets off Newfoundland, and perhaps increasing abundance of sand lance off New England. In any event, the abundance of Razorbills recorded off Nantucket and Martha's Vineyard during our surveys in 2011-2015 were higher than any recorded elsewhere along the U.S. east coast and higher than those recorded by Powers in this general area in the 1970s and 1980s.

The increase of Black-legged Kittiwakes south of Massachusetts in 2012-2013 (Year 1 and 2), on the other hand, seems to have been a shorter term event. Abundance in fall 2012 to winter 2013 (Year 1 and 2) probably was the result of oceanographic conditions (strongly negative North Atlantic Oscillation [NAO] values) and does not seem to be part of a long-term trend, as observed for Razorbills.

Many of the aggregations that we observed along the west side of the Nantucket Shoals, mainly of Long-tailed Ducks, White-winged Scoters, terns, and Razorbills, were in the same general area of Basking Sharks and sea turtles recorded by the cetacean group (Kraus et al. 2016), which supports the importance of the biological Hotspot associated with the Nantucket Shoals.

Our results large agree with those of Kinlan et al. (2012), with the following exceptions. Black-legged Kittiwakes, though notoriously variable in abundance from year to year off New England, are numerous off the south shore of Nantucket and along the east shore of Cape Cod. This disparity is probably due to lack of sampling in these areas, apart from that covered by this survey. Kinlan et al.'s map for Common Loon shows a suspicious absence of loons from southeastern Massachusetts, as well as an isolated peak off Virginia Beach. We suspect the high density off Virginia Beach reflects intensive sampling there; Common Loons are almost as numerous off Long Island, Rhode Island, Cape Cod, and Nantucket, as they are off Virginia. Similarly, we are suspicious of Common Terns being much more numerous off central New Jersey than they are off Long Island or southeastern Massachusetts, and what is probably the largest aggregation anywhere on the east coast, at Provincetown, Massachusetts, does not even appear in Kinlan et al.'s map. Great Shearwaters are common south of Nantucket; they are not as numerous as on the northern edge of Georges Bank, but more common than the zero density implied by Kinlan et al. Kinlan et al.'s maps for Long-tailed Ducks and White-winged Scoters correspond well with our data. Northern Fulmars are more common in the area south of Nantucket that we surveyed than implied by Kinlan et al. Red Phalaropes are more common close to Nantucket than implied by Kinlan et al. Kinlan et al.'s map for Roseate Tern is problematic, and this is at least partly a database problem. Roseates occur almost exclusively in mixed flocks with Common Terns and are often recorded during at-sea surveys as "unidentified terns", so therefore do not appear in modeled distributions. In any event, there are three to

four thousand Roseate Terns nesting in New York and Massachusetts now (Nisbet et al. 2013), but one would not know this from the maps, and the likely importance of the Nantucket Shoals to these and to Common Terns is not evident from maps in Kinlan et al. Finally, the map of Wilson's Storm-Petrel in Kinlan et al. is peculiar and reflects over-dependence on environmental data within a distribution model. They are common south of Nantucket during summer, probably as numerous as anywhere else in the Gulf of Maine.

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Table 1

Mean density of seabirds per km² (+/- 1 standard deviation) from aerial surveys off southeastern Massachusetts, November 2011-January 2015.

Species	Spring (Mar-May) (N=8)	Summer (June-Aug) (N=9)	Fall (Sep-Nov) (N=12)	Winter (Dec-Jan) (N=9)
Common Eider	0.14 +/- 0.37	0	0.14 +/- 0.38	0.71 +/- 0.8
Surf Scoter	0.03 +/- 0.17	0	0.23 +/- 0.7	0.02 +/- 0.43
White-winged Scoter	7.92 +/- 2.81	0	0.65 +/- 1.11	3.38 +/- 4.84
Black Scoter	0.1 +/- 0.31	0	0.5 +/- 0.14	0.7 +/- 0.12
Long-tailed Duck	3.76 +/- 1.94	0	0.003 +/- 0.1	1.48 +/- 2.86
Common and Red throated Loons	0.16 +/- 0.40	0	0.18 +/- 0.40	0.23 +/- 0.19
Northern Fulmar	0.004 +/- 0.61	0	0.16 +/- 0.37	0.11 +/- 0.15
Shearwaters ²	0	0.5 +/- .71	0.14 +/- 0.27	0
Wilson's Storm-Petrel	0	0.18 +/- 0.42	0.001 +/- 0.4	0
Northern Gannet	0.21 +/- 0.46	0	0.33 +/- 0.44	0.23 +/- 0.17
Red Phalarope	0.18 +/- 0.42	0.01 +/- 0.1	0.05 +/- 0.12	0
Large Gulls ³	0.18 +/- 0.42	0.15 +/- 0.39	0.22 +/- 0.32	0.67 +/- 0.55
Black-legged Kittiwake	0.06 +/- 0.25	0	0.08 +/- 0.19	0.5 +/- 0.68
Common and Roseate Terns	0.26 +/- 0.51	0.7 +/- .42	0.01 +/- 0.3	0
Razorbill	1.19 +/- 1.09		0.17 +/- 0.06	2.4 +/- 5.0

Table 2

List of all species and scientific names.

Common name	Scientific name
Common Eider	<i>Somateria mollissima</i>
Surf Scoter	<i>Melanitta perspicillata</i>
White-winged Scoter	<i>Melanitta deglandi</i>
Black Scoter	<i>Melanitta nigra</i>
Long-tailed Duck	<i>Clangula hyemalis</i>
Red-breasted Merganser	<i>Mergus serrator</i>
Red-throated Loon	<i>Gavia stellata</i>
Common Loon	<i>Gavia immer</i>
Red-necked Grebe	<i>Podiceps grisegena</i>
Northern Fulmar	<i>Fulmarus glacialis</i>
Cory's Shearwater	<i>Calonectris diomedea</i>
Great Shearwater	<i>Puffinus gravis</i>
Manx Shearwater	<i>Puffinus puffinus</i>
Sooty Shearwater	<i>Ardenna griseus</i>
Wilson's Storm-petrel	<i>Oceanites oceanicus</i>
Double-crested Cormorant	<i>Phalacrocorax auritus</i>
Northern Gannet	<i>Morus bassanus</i>
Red Phalarope	<i>Phalaropus fulicaria</i>
Red-necked Phalarope	<i>Phalaropus lobatus</i>
Black-legged Kittiwake	<i>Rissa tridactyla</i>
Herring Gull	<i>Larus argentatus</i>
Great Black-backed	<i>Gull Larus marinus</i>
Razorbill	<i>Alca torda</i>
Dovekie	<i>Alle alle</i>
Common Murre	<i>Uria lomvia</i>

Table 3

List of Surveys and proportion of total birds seen flying and proportion seen feeding. We did not record behavior of birds until the 7 May 2012 survey.

Survey Number	Date	Number of Individuals	Percent Flying	Percent Feeding
1	11/22/2011	77	Not recorded	Not recorded
2	12/9/2011	139	"	"
3	1/11/2012	638	"	"
4	2/16/2012	6004	"	"
5	3/12/2012	2584	"	"
6	3/17/2012	1963	"	"
7	5/7/2012	308	69.80%	14.90%
8	5/12/2012	460	65.40%	0.40%
9	6/28/2012	42	97.60%	2.30%
10	7/31/2012	104	66.30%	0
11	8/22/2012	149	67.80%	0
12	10/2/2012	129	48.40%	0
13	10/26/2012	1505	4.60%	0.10%
14	11/5/2012	389	87.60%	0.30%
15	11/12/2012	331	29.60%	0.60%
16	1/21/2013	3847	0.90%	0
17	3/30/2013	4811	2.20%	0.80%
18	4/15/2013	4728	5.00%	0.20%
19	5/15/2013	1487	50.80%	11.10%
20	6/22/2013	75	84%	0
21	7/31/2013	232	46.10%	0
22	8/19/2013	91	53.80%	19.80%
23	9/11/2013	279	49.10%	0
24	10/15/2013	97	63.90%	16.50%
25	10/29/2013	1424	81.00%	0.10%
26	11/6/2013	674	16.00%	0.30%
27	11/26/2013	599	23.20%	0.20%
28	11/30/2013	1350	16.40%	4.80%
29	12/29/2013	1225	15.00%	3.00%
30	1/30/2014	3753	3.50%	0
31	4/7/2014	14674	2.00%	0.04%
32	6/23/2014	675	31.60%	41.20%
33	7/19/2014	185	41.10%	18.90%
34	8/25/2014	450	62%	7.30%
35	9/29/2014	114	51.00%	37.70%
36	12/5/2014	1883	28.80%	12.70%
37	1/3/2015	1232	15.70%	5.80%
38	1/14/2015	4134	6.90%	1.50%

Appendix I. Abundance of birds by Survey Year.

