RELATIVE WATERFOWL ABUNDANCE WITHIN NANTUCKET SOUND, MASSACHUSETTS DURING THE 2004-2005 WINTER SEASON

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INTRODUCTION

A proposed wind farm on Horseshoe Shoal in Nantucket Sound, Massachusetts would be the largest offshore wind farm in the United States and one of the largest in the world. Systematically obtained data on the use of Nantucket Sound that would enable an accurate assessment of the risk of this wind farm to the birds utilizing Nantucket Sound have not been available until recently (e.g., Cape Wind Draft Environmental Impact Statement, 2004). Annual and seasonal surveys of avian species inhabiting the waters of Nantucket Sound are important steps necessary to evaluate possible impacts of the proposed wind farm's construction and operation on birds. This report describes the results of our second year of winter surveys of the waterfowl within Nantucket Sound; the data reported here provide an important supplement to the data presented in the 2004 draft Environmental Impact Statement prepared by the Army Corps of Engineers.

If the proposed wind farm is constructed, wintering waterfowl and other birds could be directly or indirectly affected in a number of ways. Negative impacts include 1) flying birds could strike turbine blades or support towers and become injured or die; 2) the construction and deployment of turbines could result in a decline in, or a spatial displacement of the benthic and pelagic food resources of Horseshoe Shoals; 3) turbines could result in temporary or permanent displacement of the birds from their wintering habitat; and 4) an array of turbines could create a flight barrier and alter traditional flight patterns of local and migrant waterfowl. All of these potential impacts could be ecologically significant.

According to Christmas Bird Count data collected from various land points around Nantucket Sound, hundreds of thousands of ducks occupy the Sound for most of each winter. For example, Griscom and Snyder (1955), cited in Bellrose (1976), reported 500,000 common eiders wintering off the coast of Massachusetts. Land-based Christmas Bird Count totals of Long-tailed Ducks from Nantucket Island have exceeded one-half million individuals (525,505 in 2002; http://audubon2.org/birds/cbc/hr/count_table.html). Additionally, large numbers of other sea ducks including Surf, White-winged, and Black Scoters are often seen from land on Cape Cod and the Islands during winter months. The actual abundance, distribution, and movement of these species of ducks within the Sound, particularly in relation to Horseshoe Shoal, are poorly known.

We conducted aerial surveys of Nantucket Sound following designated survey routes between mid-November 2004 and mid-April 2005 (Figure 1). Our specific objectives were to estimate the relative seasonal abundance and distribution of wintering waterfowl that use the Sound during the winter months and to determine whether these patterns vary seasonally. The timing of these surveys corresponded to the period in which long-term birding records indicate the occurrence of waterfowl within the Sound (Bird Observer Records, M. Rines, personal communication). Where appropriate, we attempted to compare our results from this field season with those derived from our 2003-04 season.

Study Area

Nantucket Sound is a relatively shallow water body that encompasses approximately 600 square miles. It is surrounded by the southern shore of Cape Cod to the north, Monomoy National Wildlife Refuge and Nantucket Island to the east and south, Tuckernuck and Muskeget Islands to the

southwest, and Martha's Vineyard to the west (Figure 1). Within Nantucket Sound we focused on three areas described as alternate sites for the wind farm: 1) Horseshoe Shoal – the site preferred by the applicant, Cape Wind Inc.; 2) Tuckernuck Shoal; and 3) Monomoy-Handkerchief Shoal. The bottom substrate of the Sound is mostly sand, with a few areas, including Horseshoe Shoal, that have a higher proportion of gravel (USGS 2003). The coarser material on Horseshoe Shoal may account for the Shoal's relative geologic stability compared to the sandier areas in this region. The abundance of scoters and Common Eiders observed in the Sound indicates that mollusks such as mussels, scallops, and clams, crabs, fish and other food sources are abundant. The benthic sampling reported in the draft Environmental Impact Statement for this project (USACE, 2004) supports this view and also indicates that the benthic fauna varies seasonally and spatially.

METHODS

Waterfowl distribution and relative abundance in the Sound and the alternate project sites were estimated from data collected on aerial surveys. Methods were identical to the protocols developed for winter surveys conducted in 2003 – 2004 (e.g., Perkins et al., 2004).

Aerial Surveys

Our study area included approximately 340 mi^2, or 60% of the waters of Nantucket Sound. Twelve aerial surveys were conducted during the period between November 18 and April 18 along 15 fixed, parallel transects, oriented north to south (Fig. 1). Individual transects were separated at 7,500 ft intervals; the total combined length of all 15 transects was 249.2 mi. The area of the Sound that we surveyed was 30 mi^2, or approximately 8.7 percent. This area was calculated by multiplying the transect width (600 ft) by the combined length of all transects (249.2 mi).

Aerial surveys were flown with a high-wing, twin-engine aircraft (Cessna Sky Master 337), cruising at an average altitude of 500 ft and at an average airspeed of 90 kts. This altitude allowed us to identify most birds at the sea surface and reduced the possibility of flushing the birds from the water surface to another part of the Sound where they might have been recounted. The airspeed was the slowest at which the aircraft could safely fly. Flights were conducted only on days with light to moderate winds ($\leq$15 kts) and on days with good atmospheric clarity (visibility >10 miles). Flights usually began mid-morning to reduced glare due to low sun angles, and the average duration of each survey was approximately 2.5 hrs.

We recorded birds observed along either side of the north-south transects out to a distance of 300 ft from each side of the plane (Fig. 2). Individual birds were identified with the aid of binoculars as needed. Criteria used for the selection of transect width included:

1. Determination of the distance perpendicular to the transect centerline at which birds were detectable and identifiable with the naked eye for observers.
2. A total width narrow enough to avoid situations in which birds were too abundant and/or were spread over too wide an area to count accurately. This was especially important because sea ducks occasionally congregate in large flocks or rafts.

Each survey team was composed of a pilot, a recorder in the co-pilot seat, and two experienced observers positioned opposite one another on each side of the plane. All members of the team communicated through an onboard intercom system. The observers verbally communicated all bird sightings to the recorder. The recorder entered number of birds observed, species, behavior (sitting on the water, traveling or actively feeding), and precise geographic location into a laptop computer equipped with dLog (v.2.0, R.G. Ford Consulting, Portland, OR) that was linked to the plane's onboard GPS unit. This software enabled us to automatically and accurately enter the geographical location of the plane as data were entered at the time of the sighting. Additional information recorded included starting and ending times of the survey, wind direction and velocity (kts), sea state (Beaufort scale), visibility (mi), and % cloud cover for every survey. Surveys were conducted over a wide range of tidal stages, although no attempt was made to control for this variable due to weather and time constraints. We did not attempt to estimate flight heights of waterfowl during plane surveys *unless* the birds were relatively high (300 ft or higher), such that more accurate height estimates were possible. Most flying birds observed during aerial surveys were at or near the water surface, and accurate estimation of their flight height from 500 feet was not practical.

With the exception of scoters, observers were able to identify most birds to species. Scoters were identified to the species level whenever possible, but otherwise they were recorded as "Scoter spp". Birds were recorded continuously along transects. We did not count any birds observed while we were flying the short, east-west legs between transects. Observations of marine mammals and fish were also recorded, but the results are not reported here. These data are available from the authors upon request.

Boat Surveys

No boat surveys were conducted in the 2004-05 field season because we determined in the first year that the disturbance to the ducks caused by the presence of the boat strongly influenced the ducks' behavior and therefore biased the data so as to render them useless.

RESULTS

Aerial Surveys

Twelve aerial surveys were conducted between November 18 and April 18, of which eleven were completed. Our intention was to survey at one-week intervals throughout the survey period, but some surveys were postponed or cancelled due to poor weather. We conducted no surveys between December 22 to February 7 due a prolonged period of storms and high winds. Snow squalls in the Sound on February 18 allowed us to survey only 65% of the survey area.

Analysis of Aerial Survey Data

Birds are probably not distributed across the Sound randomly. Further, the transects were not laid out randomly, nor did we vary the way we covered the survey grid; we always began our surveys at the western edge of the study area and worked east. These factors may introduce some unknown bias into the results.

We compared waterfowl abundance on each of the three proposed project sites (Horseshoe Shoal and each of the two other "alternate" sites, Tuckernuck Shoal and Monomoy-Handkerchief Shoal) with waterfowl abundance within the entire survey area (Table 2). From raw observational data, we represented waterfowl abundance in two ways: proportional abundance (birds counted in each of the three project sites as a proportion of the totals within the entire survey area) and birds-per-mile (number of birds per survey mile).

Proportional waterfowl abundance (the proportion of the total waterfowl observed within each project site) was calculated first by overlaying the boundaries of the three project sites over all point data collected during the surveys. Using data from the completed surveys only, the total number of birds of a given species observed within each project site was divided by the total number observed within the entire survey grid. These proportions were compared to the proportional area of each respective project site to examine the distribution of sea ducks across the project sites and the waters outside those sites.

Relative waterfowl abundance was also calculated as the number of birds per mile. Each transect of the survey route was subdivided into single-mile transect segments and all bird observations were assigned to a mile segment within each transect. To answer the question of whether bird distribution varied spatially across Nantucket Sound, we calculated relative abundance of each bird species as number of birds-per-mile for the entire Sound and for the three alternate project sites.

Relative Waterfowl Abundance

We observed 20 species of sea ducks and other waterbirds during the field season (Table 1). The most abundant ducks were scoters, with a combined (all three species) total of approximately 280,000 scoters counted over all surveys. (All duck numbers are rounded to the nearest one or two digits. Raw numbers are given in Table 1). This figure represented roughly 54% of the approximate total of 531,000 (all waterfowl species) recorded during the survey period. The seasonal total of 204,000 eider also comprised a large proportion (39.8%) of the overall number of recorded waterfowl. The highest waterfowl count recorded during a single survey day was made on November 30, 2005, when a total of roughly 116,000 ducks were counted (Appendix 1). This survey also yielded the highest single-day total for scoters (approximately 86,000) and fifth highest for eiders (approximately 24,000).

Relative abundance of birds ranged widely between surveys. When results from completed surveys were standardized by birds per survey mile, Common Eider numbers per survey ranged from three to 183 birds per mile (median = 61/mi), Scoter (all species) counts ranged from two to 344 bird per mile (median = 39/mi), and the number of Long-tailed Ducks ranged from 0.2 to 23 birds per mile (median = 10/mi) (Fig. 3).

Waterfowl Distribution in the Sound

Waterfowl were observed over virtually all of the survey area during the survey period. Nearly eighty-two percent (81.9%) of all scoters and 75.5% of all eiders were observed in rafts over 1,000 birds in size. Eiders were absent from 35 transect miles (approximately 14% of the survey

area), while scoters were absent from only 8 transect miles (3% of survey area). Long-tailed Ducks were absent from fewer transect miles (2, or 1% of survey area) than the two other groups.

Numbers of birds in individual mile segments of the survey route ranged widely and provided another perspective on distribution of ducks in the Sound. When averaged across all surveys, both scoters and Common Eiders were recorded in the highest abundances in any mile segments (roughly 9,000 and 15,000 birds, respectively) in the extreme southwestern corner of the study area near the eastern shore of Chappaquiddick Island. Other areas with periodically high waterfowl numbers throughout the survey period were in the northeastern quadrant of the study area (for both scoters and eiders) and parts of the northwestern quadrant (for Eiders) (Figure 4). The highest average number of Long-tailed Ducks was 184 per mile segment, this value coming from counts northeast of Muskeget Island in the south-central part of the study area.

While the distribution patterns of all species of waterfowl changed throughout the field season, when taken as a group and measured over the entire season, waterfowl were generally less abundant on Horseshoe Shoal than they would have been if they had been distributed evenly across the sound. Among the approximate total of 479,000 ducks observed over the entire survey period (not including data from the incomplete survey on Feb. 18), 2.1% of all waterfowl counted were observed on Horseshoe Shoal, an area comprising 11.4% of the survey area; among scoters and eiders, the proportion on Horseshoe Shoal was 2.7% and 0.7% respectively. For Long-tailed Ducks, however, the proportion of birds on Horseshoe Shoal throughout the season was 11.6%, and from February to April, 15.0% of the observations for this species were observed in the Horseshoe Shoal project area.

By far the highest and most temporally stable concentrations of both scoters and eiders occurred in the southwestern section of the Sound adjacent to Chappaquiddick Island (Figure 4). scoters also occurred in relatively high concentrations within a broad band extending between the northeastern and the southwestern quarters of the Sound (Figure 6). No large concentrations of Long-tailed Ducks occurred consistently throughout the survey period, though they were recorded periodically in disproportionately higher numbers on Horseshoe, Tuckernuck, and Monomoy-Handkerchief Shoals (Figure 3).

Analysis of Dispersion

We statistically analyzed the spatial distribution of sea ducks in Horseshoe Shoal relative to Nantucket Sound as a whole to determine whether the most abundant species showed a “preference” or “avoidance” of Horseshoe Shoal in the two years of our surveys. We calculated Jacob’s selectivity index (D) which yields a value ranging from –1.0 to 1.0, and which compares the percentage of observations of particular species in the Shoal with the percentage of the survey area comprising the Shoal (11.4% as describe above). For example, a significant, negative index indicates that a species was observed less than expected in Horseshoe Shoal based on its distribution throughout Nantucket Sound.

The significance of the index is tested with a one-sample Chi-square test using observed and expected values for the Shoal and the rest of the Sound. The conclusions of this test are sensitive to whether one uses observations (clusters ranging from 1 to 1000’s) or numbers of individuals. The

chi-square test requires independence amongst observations, and we assume that birds within clusters are not distributed independently. We calculated this index and conducted the goodness-of-fit test on clusters of observations as well as on numbers of birds. Significance levels were adjusted for the number of tests to $p < 0.002$ (see Petersen, I. K. 2005, *Bird numbers and distributions in the Horns Rev offshore wind farm area Subtitle: Annual status report 2004. National Environmental Research Institute Ministry of Environment, 38 pp*., for additional details).

When clusters of observations were examined, scoters used Horseshoe Shoal less than expected in both years, while Common Eiders used the Shoal more than expected. In 2003-2004, Gulls were observed less than expected over Horseshoe Shoal, while Northern Gannets were observed more than expected. No other comparisons were significantly different. When numbers of birds were examined, Common Eiders were observed less than expected on the Shoal in both years, while Scoters in 2003-2004 were observed more than expected (Table 4).

Intra- and Inter-Annual Abundance

Seasonal changes in abundance of ducks were examined by dividing the survey period into two periods. We arbitrarily designated the six-week period between November 18 and December 23 as the first half of the 2004-2005 season, and the period between February 7 and April 18 as the latter half. As noted above, because of unfavorable flying conditions, no surveys were conducted between December 23 and February 7. The average number of Common Eiders per survey mile decreased only slightly between the two periods from 87.8 birds to 84.4 birds (Fig. 5), while average Scoter abundances were substantially lower in the second half of the season (216 vs. 28.3) (Fig. 6). The number of Long-tailed Ducks increased slightly between these periods from 8.2 birds per mile in November-December to 9.9 birds per mile in February-April.

For the purposes of comparing the above results to the analogous data set from the previous season, we selected data from surveys conducted within similar periods in each of the two field seasons. In 2004-05, we selected the data from surveys conducted between November 30 and December 23, and February 7 - March 18. The range of dates in 2003-04 that most closely corresponded to those above was December 5 - December 23, and February 10 - March 23.

As a group, scoters showed substantial intra annual variability in abundance in both years. Common Eider and Long-tailed Ducks varied within-season in 2003-2004, but showed little change between periods in the 2004-2005 survey season.

DISCUSSION

Common Eider, scoter spp., and Long-tailed Ducks comprised nearly all (96.7%) of the waterfowl recorded during these surveys. To place the number of ducks observed in Nantucket Sound into a broader geographical context, Bellrose (1976) estimated that there are 1.5-2 million Common Eiders in North America Sea Duck Joint Venture's (SDJV) Common Eider fact sheet states that estimates of Northern race eiders wintering in eastern Canada and Greenland are approximately 400,000 - 500,000. The American race is estimated at about 280,000 birds in eastern Canada with another 57,000 in the northeastern United States. Our highest count of approximately 43,000 Common Eiders on one day in the Sound, therefore, may represent as much as 10% of the total number of

Common Eider in eastern North America. Bellrose estimated the North American scoter (all species) population at approximately 1.5 million and Long-tailed Duck at 3-4 million. SDJV fact sheet for Scoters states that more than one million birds, with 200,000 of those breeding in Alaska The single-day high count of roughly 85,000 scoters would, therefore represent approximately nine percent of that population.

Overall, fewer ducks used Horseshoe Shoal in 2004-2005 than in 2003-2004, and in both years, substantial seasonal variation occurred in waterfowl abundance and distribution. These inter- and intra-annual shifts were probably related to changes in the local distribution and/or abundance of available food resources (see Food, below), as has been demonstrated by waterfowl studies in Denmark (Guillemette, et al. 1999).

Though the CBC data indicate that counts of Long-tailed Ducks within the Sound have exceeded a half a million individuals (it is possible that these numbers are overestimates), our surveys yielded relatively low numbers of this species compared to Eiders and Scoters. These results were expected given the local diurnal foraging patterns of Long-tailed Ducks. The majority of wintering Long-tailed Ducks observed in the waters around Nantucket likely spend at least a portion of each night roosting within the Sound. But, each morning they can be observed departing the Sound via the west end of Nantucket to feeding areas outside our study area, presumably on Nantucket Shoals to the south and southeast of Nantucket. Since we conducted our surveys only during daylight hours the vast majority of the Long-tails were probably outside the Sound (and our study area) during our flights (see Further Study, below). The data we did record indicated that the distribution and abundance of Long-tailed Ducks in the Sound remained fairly stable during the survey season. This finding was consistent with results from the previous season.

The numbers of scoters recorded within the study area varied greatly during the course of the season (Figure 6). However, observers continued to note large numbers of eiders in the general vicinity of Chappaquiddick Island, so the substantial fluctuations in the overall numbers of all waterfowl recorded during the course of the field season were probably largely attributable to slight shifts in the distribution of the largest eider flocks off Chappaquiddick, the area that supported the vast majority of the ducks within the Sound. Seventy-four percent of all the ducks counted during the course of the 2004-2005 field season were recorded within the three southern-most cells on the western-most transect, an area representing only 2.1% of the total survey area (Figure 6).

The abundance of scoters within the survey area declined significantly between the first and second halves of the season (Table 3). Unlike the fluctuations in the numbers of eiders, we believe the decline in scoter numbers was not due to small-scale movements of large rafts in the area off Chappaquiddick. This assumption is based on anecdotal observations during the plane surveys that the large numbers of scoters that were present early in the survey period were greatly diminished later in the season. When scoters departed the Sound in the winter of 2003-04, we suggested that the shift might have been due to a mid-winter cold snap that caused most of the Sound to freeze, during which the ducks were forced to relocate to ice-free areas. Presumably, once they moved to other feeding areas, the scoters chose to remain there for the balance of the winter instead of returning to the Sound. This year, however, in the absence of ice, we surmise that, when the scoters left, either they moved to other New England waters, or they were initially present in the Sound only as migrants moving through to points farther south on the Atlantic Seaboard. If they were migrants, these

observations suggest that Nantucket Sound could be a very important stopover area for migrant scoters.

While the abundance of eiders varied during the course of the season, the overall distribution of eiders was relatively stable, especially when compared to the 2003-04 season. The biggest rafts of eiders in the southwest corner remained there for most of the season (Figure 5), and two other areas within the Sound supported significant numbers of eiders throughout the survey season. These were located on and around the periphery of Horseshoe Shoal, and off the southwest end of South Monomoy Island (Figure 5).

Comparisons between the 2003-2004 and 2004-2005 field seasons revealed that the areas in which the highest densities of eiders and scoters occurred were very different (Figures 5 and 6), but the pattern of dispersion (range of density values) was very similar (Table 3).

Because, at the time of the surveys, the observers were preoccupied with attempts to estimate overall duck numbers within and outside the survey transect zones, no accurate record of scoter species ratios was made when estimating numbers within the largest rafts. A series of aerial photographs taken on November 30 has since shown that, before the scoters dispersed later in the season, the vast majority were Black Scoters. However, many, if not most of these ducks were outside the actual survey transects, and therefore, were not recorded as part of the survey totals.

Food

A local duck hunter donated a male Common Eider and a male Black Scoter that he had shot from one of the large feeding rafts east of Chappaquiddick Island on March 30. Food items found between their gullets and gizzards included, almost exclusively, Blue Mussels. Those found in the scoter had already been partially crushed and digested making it difficult to determine whether the bird had obtained the food from the immediate vicinity. However, the eider contained roughly 40 intact mussels, several of which were still in its gullet, indicating that the bird had recently obtained them in the immediate vicinity. Local birders have long suspected that mussels were the main food source for the occasionally huge numbers of sea ducks (especially eiders) in the waters around Cape Cod and the Islands. These findings support that hypothesis.

Further study

During the scoping phase of the environmental review of the Cape Wind project, Mass Audubon and the U.S. Fish and Wildlife Service strongly recommended that three years of avian surveys was the minimum period necessary to begin to understand the short-term dynamics of avian use of Nantucket Sound and Horseshoe Shoal. We will continue our winter waterfowl surveys for at least one more year. In particular, we hope to determine the extent to which the distribution of ducks shifts within the Sound, presumably in response to shifts in food availability.

We now have two years of quantitative survey data, and these data provide a more substantially detailed picture of the distribution and abundance of winter sea ducks in Nantucket Sound and in relation to the proposed project area and possible alternative sites. The data are not without limitations, primarily that the surveys are limited to a particular time of day and under fair

weather conditions; conclusions about the importance of Horseshoe Shoal as a roosting and feeding location should be tentatively drawn.. The biggest data gap in our knowledge of wintering waterfowl in Nantucket Sound continues to be the nighttime distribution of Long-tailed Ducks. We will explore possible methods, including infrared imaging or telemetry, for filling this gap. Also, having identified the Sound as a potentially important stopover site for migrant Black Scoters, we will focus on this issue in our future waterfowl surveys.

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Table 1: Total bird numbers observed on aerial surveys of Nantucket Sound, winter 2003-2004 (n=13 surveys) and 2004-2005 (n=12 surveys). Numbers are totals from all surveys.

Species	Winter 2003-2004 Total	Winter 2004-2005 Total
Brant	7	0
Common Eider	277,177	203,977
Surf scoter	7,736	2,947
White-winged scoter	604	403
Black scoter	271*	62
Scoter (undifferentiated)	82,633	277,259
Long-tailed Duck	33,379*	28,077
Red-breasted Merganser	55	33
Common Loon	160	183
Red-throated Loon	154*	609
Loon (undifferentiated)	3,442	6,132
Red-necked Grebe	1	1
Horned Grebe	1	3
Grebe (undifferentiated)	4	10
Northern Gannet	629	1,299
Double-crested Cormorant	1	0
Great Cormorant	3*	0
Cormorant (undifferentiated)	3	2
American Oystercatcher	0	4
Shorebird (undifferentiated)	3	13
Bonaparte's Gull	33	40
Herring Gull	628	723
Great Black-backed Gull	168*	654
Black-legged Kittiwake	577	696
Gull (undifferentiated)	2,226	4,598
Dovekie	0	3
Razorbill	2,576	2,751
Alcid (undifferentiated)	4	2
Total	412,475	530,481

* = Numbers include estimated numbers not recorded on December 5, 2003 due to computer errors. An estimated 40 Red-throated Loons, 2 Great Cormorants, 100 Black scoters, 1,000 Long-tailed ducks, and 15 Black-legged Kittiwakes are included.

Table 2: Relative waterfowl abundance observed in three alternative Cape Wind project sites and the remaining non-project area on eleven aerial surveys of Nantucket Sound from November 18, 2004 to April 18, 2005. Survey periods include the following survey dates: 1) 11/18, 11/30, 12/9, 12/16, and 12/30; and 2) 2/7, 2/28, 3/10, 3/18, 4/5, and 4/18. Data from one incomplete survey (2/18) are not included. Relative abundances greater than the proportional area are shown in bold.

			Proposed Cape Wind project areas		
		Non-shoals (183.1 miles)	**Horseshoe Shoal (28.7 miles)**	**Monomoy-Handkerchief Shoal (15.7 miles)**	**Tuckernuck Shoal (23.5 miles)**
		Proportional area			
		72.9%	11.4%	6.3%	9.4%
Species	**Survey Period**	**Proportion of waterfowl observed**			
Common Eider	1	97.5%	2.2%	0.3%	0.1%
	2	96.0%	3.2%	0.6%	0.1%
	All	96.8%	2.7%	0.5%	0.1%
Long-tailed Duck	1	82.9%	8.2%	4.0%	4.9%
	2	74.2%	**15.0%**	4.7%	6.0%
	All	78.7%	**11.6%**	4.3%	5.5%
Scoter species	1	95.7%	0.6%	2.0%	1.8%
	2	84.0%	1.8%	**10.7%**	3.5%
	All	94.1%	0.7%	3.2%	2.0%
Total	1	95.6%	1.3%	1.6%	1.5%
	2	90.6%	3.9%	3.8%	1.7%
	All	94.2%	2.1%	2.2%	1.5%

Table 3: Inter and intra annual averages of numbers of birds per mile within survey area. Values were calculated as described in the text.

Season	Period	Common Eider	Long-tailed Duck	Scoter species	All waterfowl
2003-2004	1	48.8 (33.1)	7.5 (3.4)	41.9 (22.9)	7.5 (3.4)
	2	101.3 (33.3)	14.4 (8.6)	11.4 (8.5)	14.4 (8.6)
	All	83.8 (40.9)	12.5 (8.0)	21.6 (20.4)	116.9 (41.2)
2004-2005	1	84.4 (49.3)	8.2 (3.1)	216.0 (146.1)	308.6 (190.8)
	2	87.8 (77.1)	9.9 (4.7)	28.3 (19.3)	126.0 (89.5)
	All	86.4 (64.2)	9.2 (4.0)	103.3 (129.3)	199.0 (159.7)

Table 4: Results of calculations of Jacob's Selectivity Index (D) and Chi-Square Goodness of Fit tests for selected species in 2003-2004 and 2004-2005 comparing Horseshoe Shoal percentage of observations to Nantucket Sound as a whole. Calculations were based on clusters of observations, not numbers of birds observed. N is the number of clusters observed during all surveys within a season. Significance levels were adjusted for the number of tests to $p < 0.002$.

Survey Year	**2003-2004**					**2004-2005**				
	% HS	**D**	**N**	**X^2**	**P**	**% HS**	**D**	**N**	**X^2**	**P**
Melanitta spp.	7.7%	*-0.212*	3,430	45.47	***	7.5%	*-0.227*	3,081	46.07	***
Common Eider	21.2%	**0.354**	1,526	145.08	***	19.5%	**0.306**	1,467	94.39	***
Long-tailed Duck	12.0%	0.030	2,397	0.84	n.s.	12.5%	0.054	2,951	3.76	0.06
Gavia spp.	11.1%	-0.016	920	0.06	n.s.	9.8%	-0.085	2,236	5.55	0.02
Larus spp.	8.7%	*-0.148*	1,376	9.51	**	13.3%	0.086	1,380	4.55	0.03
Northern Gannet	10.8%	-0.030	185	0.02	n.s.	19.3%	**0.300**	482	28.96	***
Razorbill	8.9%	-0.139	429	2.49	n.s.	15.4%	0.174	246	3.60	0.06
Grand Total	11.3%	-0.006	10,263	0.15	n.s.	12.0%	0.029	11,843	4.03	0.04

n. s. - not significant
**** p < .003**
***** p < .001**

Figure 1: Nantucket Sound study area and surrounding features. Project area polygons based on information from Cape Wind Associates.

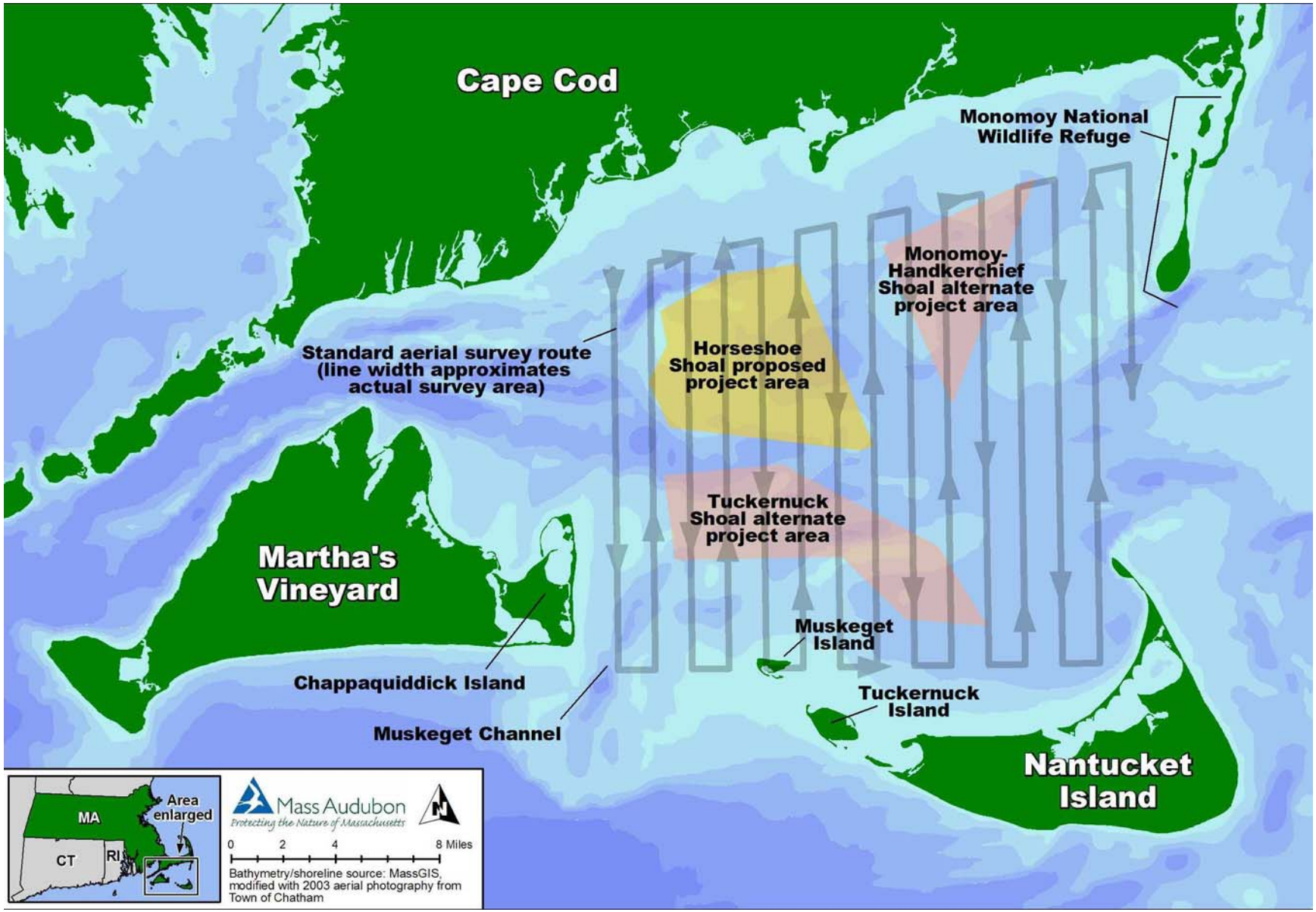


Figure 2: Diagram illustrating observation angles and distances of aerial surveys of Nantucket Sound.

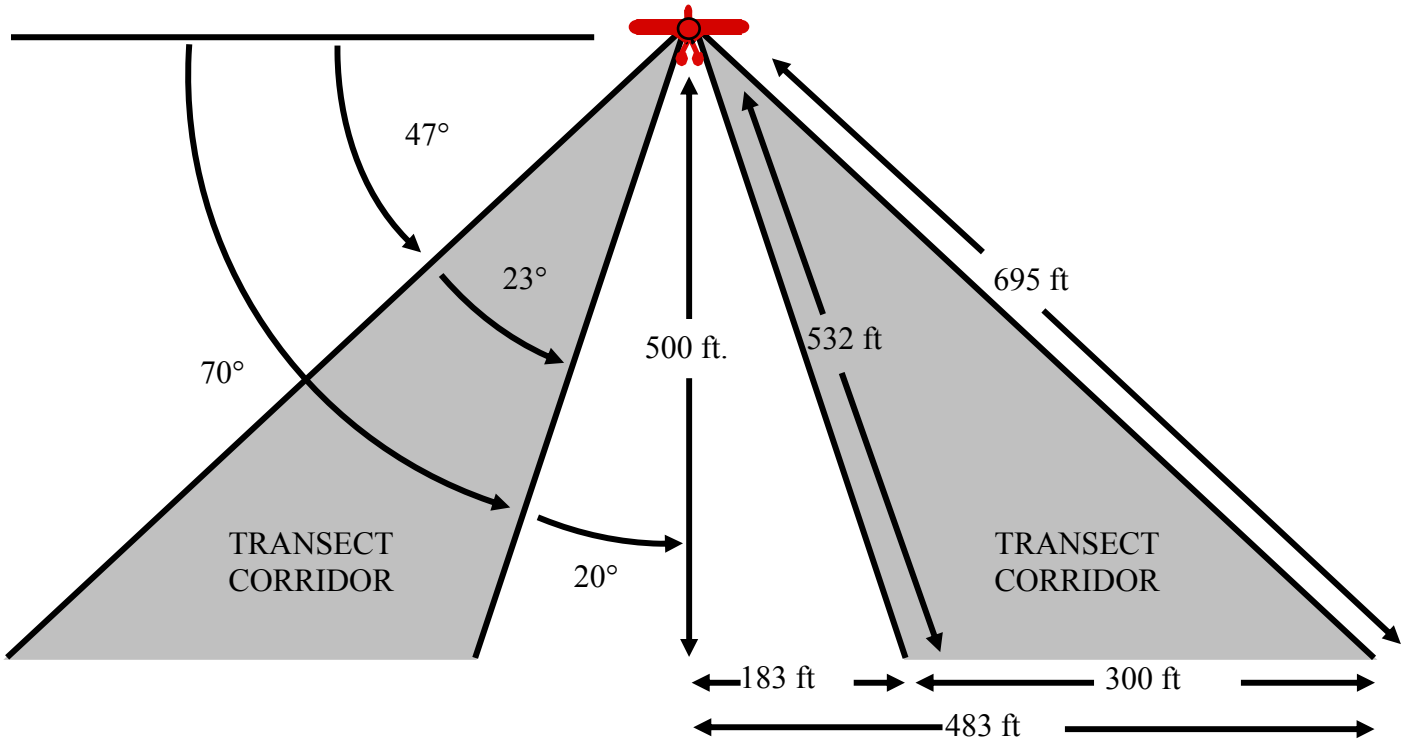


Figure 3: Abundance of Common Eiders, scoters (all species), Long-tailed Ducks, and waterfowl (all species combined) expressed in terms of birds per mile surveyed in Nantucket Sound, Massachusetts, November 2004 - April 2005. The February 18 survey was incomplete due to deteriorating weather conditions and data have been corrected accordingly. Data from this day are from 54% and 61% of Non-shoals and Monomoy-Handkerchief shoal, respectively. Asterisks above project area bars represent days when bird-per-mile values in those areas exceeded overall bird-per-mile values for the overall study area on that survey day.

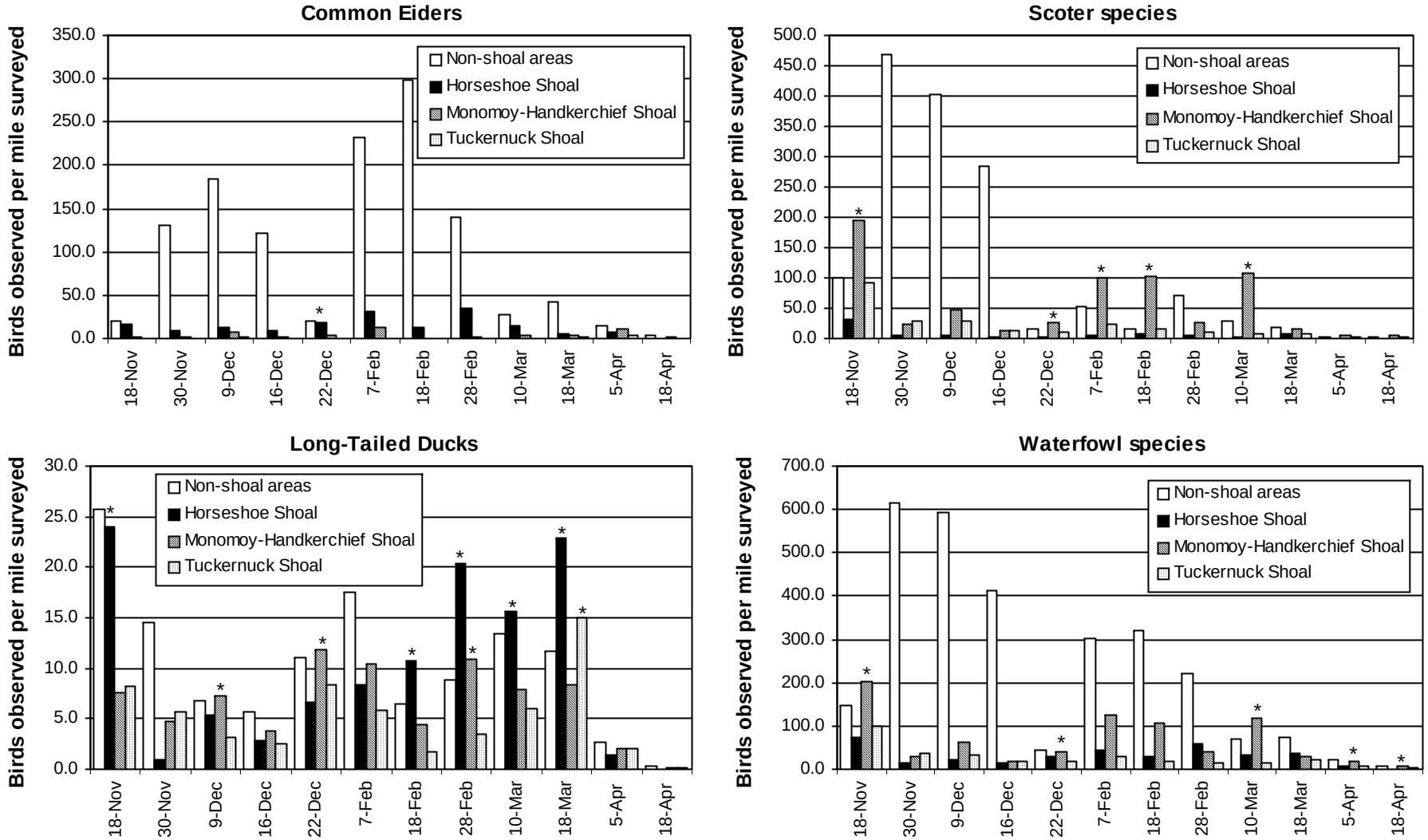


Figure 4. Distribution and abundance of approximately 200,000 Common Eiders, 300,000 scoters (all species), 28,000 Long-tailed ducks, and all waterfowl species combined (528,000) recorded on 12 aerial surveys, November 2004 - April 2005. Data are presented as average number of birds observed per mile surveyed.

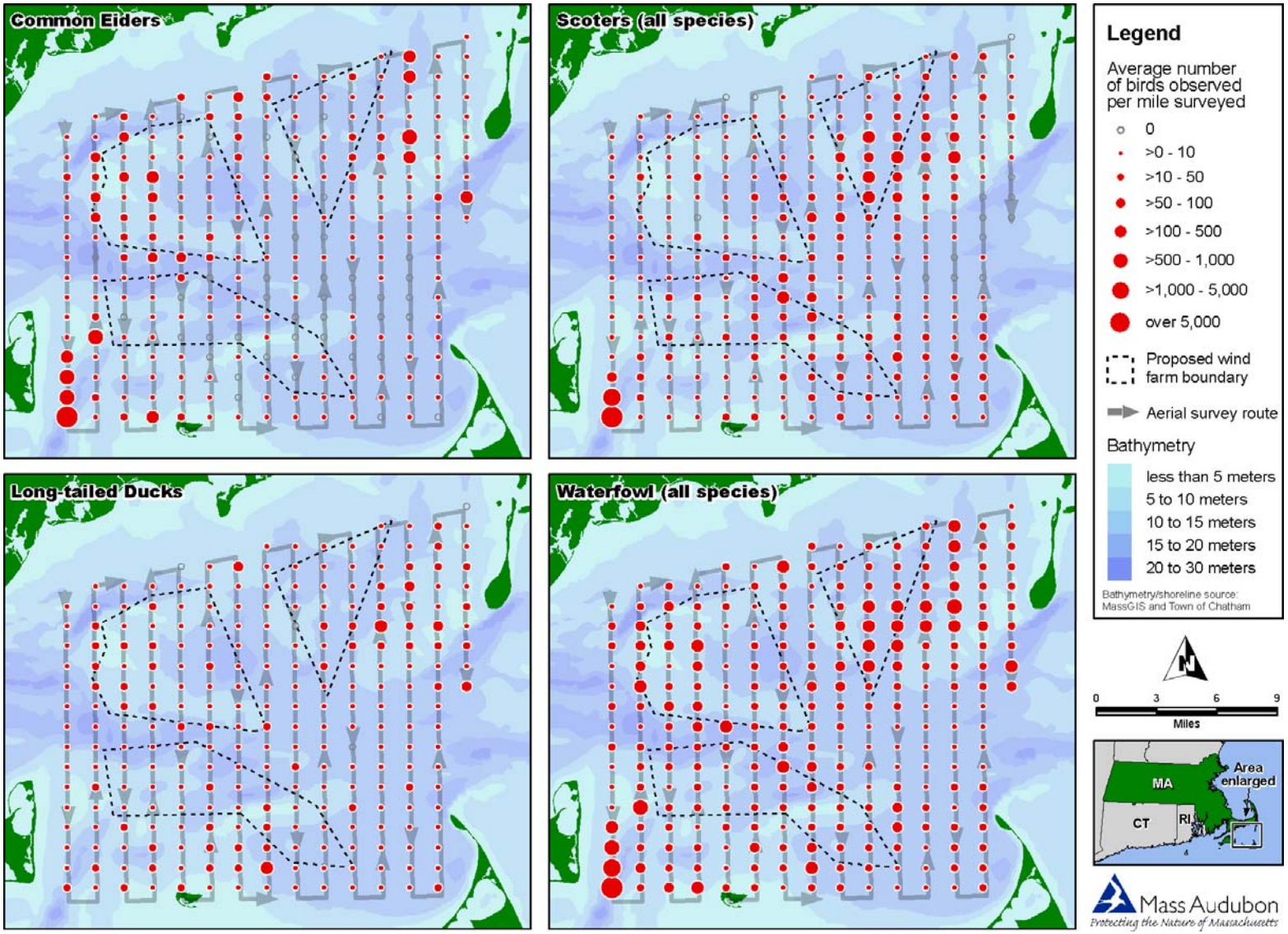


Figure 5: Comparison of Common Eider distribution and abundance in early (Period 1) vs. late (Period 2) season surveys in 2003-2004 (Season 1) and 2004-2005 (Season 2) surveys of Nantucket Sound. Dates for each period are indicated below.

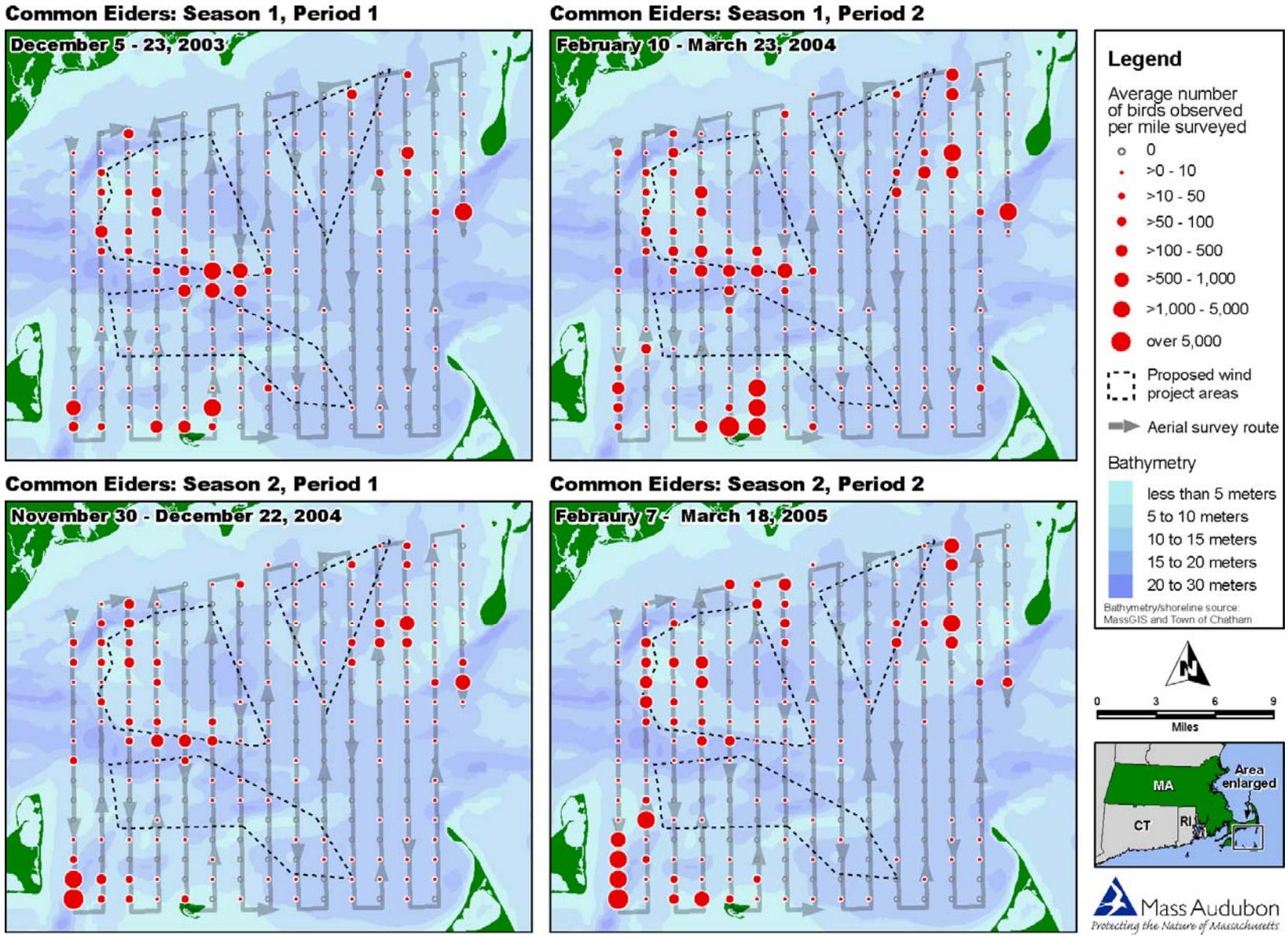
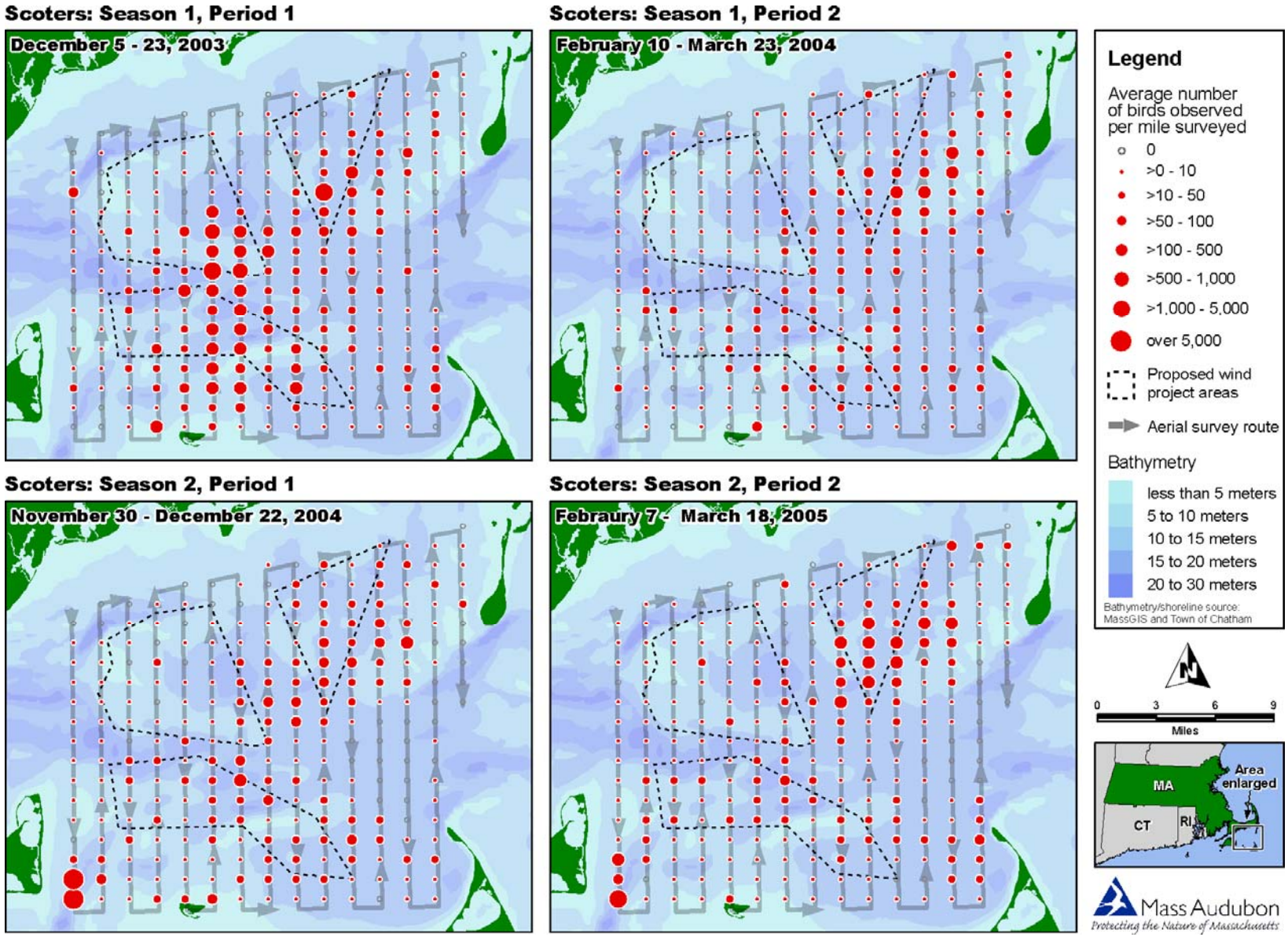


Figure 6: Comparison of Scoter (all species) distribution and abundance in early (Period 1) vs. late (Period 2) season surveys in 2003-2004 (Season 1) and 2004-2005 (Season 2) surveys of Nantucket Sound. Dates for each period are indicated below.



Appendix I

Individuals recorded by species on 12 aerial surveys between November 18, 2004 and April 18, 2005. The February 18, 2005 survey was 66% complete due to deteriorating weather conditions.

Species	11/18/04	11/30/04	12/9/04	12/16/04	12/22/04	2/7/05	2/18/05	2/28/05	3/10/05	3/18/05	4/5/05	4/18/05	Grand Total
Common Eider	4,265	23,993	33,562	22,377	4,143	43,031	29,338	26,155	5,503	7,884	3,102	624	203,977
Surf Scoter	134	1,576	0	92	534	96	59	26	0	157	62	211	2,947
White-winged Scoter	129	18	116	24	12	27	6	19	7	31	13	1	403
Black Scoter	1	23	0	1	16	1	2	3	0	8	7	0	62
Scoter (undifferentiated)	24,063	84,122	74,056	51,790	2,861	11,473	3,009	13,595	7,219	3,899	809	363	277,259
Long-tailed Duck	5,644	2,842	1,575	1,216	2,568	3,707	1,026	2,441	3,131	3,248	617	62	28,077
Red-breasted Merganser	1	22	0	0	1	1	0	0	1	0	0	7	33
Red-throated Loon	2	368	0	5	20	1	2	0	2	1	208	0	609
Common Loon	18	76	0	22	16	9	3	12	21	2	4	0	183
Loon (undifferentiated)	1,902	1,410	741	179	281	354	48	93	160	251	429	284	6,132
Horned Grebe	0	0	0	0	0	0	0	0	0	0	0	3	3
Red-necked Grebe	0	1	0	0	0	0	0	0	0	0	0	0	1
Grebe (undifferentiated)	2	0	0	0	0	0	0	4	2	2	0	0	10
Northern Gannet	475	94	42	31	5	1	1	3	2	7	253	385	1,299
Cormorant (undifferentiated)	0	0	0	0	0	0	0	0	2	0	0	0	2
American Oystercatcher	0	0	0	0	0	0	0	0	0	0	0	4	4
Shorebird (undifferentiated)	0	0	0	1	0	0	0	0	0	0	5	7	13
Bonaparte's Gull	0	30	0	1	8	0	1	0	0	0	0	0	40
Herring Gull	95	184	41	70	172	27	5	17	12	15	34	51	723
Greater Black-backed Gull	331	41	47	13	38	17	8	10	10	4	27	108	654
Black-legged Kittiwake	1	327	27	86	221	3	17	11	0	1	2	0	696
Gull (undifferentiated)	2,162	841	517	396	313	139	26	20	13	105	33	33	4,598
Dovekie	0	2	0	0	0	0	0	0	1	0	0	0	3
Razorbill	55	880	238	341	281	236	99	199	46	244	108	24	2,751
Alcid (undifferentiated)	0	0	0	2	0	0	0	0	0	0	0	0	2
Grand Total	39,280	116,850	110,962	76,647	11,490	59,123	33,650	42,608	16,132	15,859	5,713	2,167	530,481