A SURVEY OF TERN ACTIVITY

WITHIN NANTUCKET SOUND, MASSACHUSETTS

DURING THE 2003 FALL STAGING PERIOD

Final Report for Massachusetts Technology Collaborative

(Post-Peer Review)

10 September 2004

Simon Perkins, Taber Allison, Andrea Jones, and Giancarlo Sadoti

Division of Conservation Science and Ecological Management
Massachusetts Audubon Society
208 South Great Road
Lincoln, MA 01773

INTRODUCTION

A proposed wind farm on Horseshoe Shoal in Nantucket Sound would be the largest offshore wind farm in the United States and one of the largest in the world. Few, if any, data are available to assess the potential risks that this offshore wind farm may pose to birds using the Sound. A survey of terns and waterfowl in Nantucket Sound is an important step in assessing the potential avian impacts of the proposed wind farm's construction and deployment.

Several of the largest tern colonies in New England are found within 20 miles of Horseshoe Shoal. Approximately 50% of the North American population of federally endangered Roseate Terns breeds within Buzzards Bay in Massachusetts (USFWS 1998), and in 2003, approximately 10,000 pairs of Common Terns nested at Monomoy Island NWR, Chatham (Carolyn Mostello, *personal communication*). Common and Roseate terns forage within or pass through the Sound between early May and late September as they move to and from their colonies, foraging areas, and staging sites. Little is known, however, about the actual abundance, dispersal, and daily movements of these terns during these months. In addition, the areas where they focus their feeding activities within the breeding season, fall staging period, or during spring and fall migration are poorly known.

In an effort to fill some of these data gaps, we began systematic surveys of the use of Nantucket Sound and Horseshoe Shoal by terns in August 2002. The majority of terns recorded during those surveys were observed near Monomoy Island NWR or the south shore of Cape Cod (Perkins, et al. 2002). Fewer terns were seen on Horseshoe Shoal indicating that the Shoal were used less frequently than other portions of the Sound during the survey window. Because of potentially significant variation in environmental variables such as weather, and food availability and distribution, it is crucial to repeat surveys over a minimum of three years to determine whether the observations in any single year are repeated in other years. For example, the numbers of terns staging at Chatham in 2002 were substantially lower than have typically been recorded.

In 2003, we resumed surveys of tern distribution and abundance in Nantucket Sound. In addition to repeating the surveys during the migratory staging period, we initiated aerial and boat surveys during the nesting season. We expected that this full season of surveys would provide us with a more comprehensive picture of the use of Nantucket Sound by terns during both premigratory and nesting seasons. Details of the results of the nesting season surveys are reported elsewhere (Perkins, et al. 2004). In this report we focus on the second year of surveys during the premigratory staging period.

Thirteen aerial surveys were conducted between August 7 and September 25, 2003. The primary objective of the aerial surveys has been to determine the general distribution and to estimate the abundance of Common and Roseate terns within Nantucket Sound during the staging period, and to record variation in these parameters during the survey window. Between August 29 and September 17, we conducted four boat surveys in the waters on and in the immediate vicinity of Horseshoe Shoal in an

effort to observe the behaviors of the terns (e.g., traveling or actively feeding), and to estimate the heights at which the birds were flying.

The timing of these surveys was based on the hypothesis that Common and Roseate terns approach their maximum abundance within the Sound in late summer as they move from their breeding colonies and summer feeding grounds to their primary premigratory staging areas on or near South Beach in Chatham (Trull, et al., 1999). For example, previous surveys of staging birds in Chatham have produced estimates of up to 7,000 Roseate Terns in early September (Veit and Petersen, 1993). Higher totals of Roseate Terns in September (e.g., 15,000) published in Bird Observer (Gove, et al., 1984) and cited by Trull, et al. (1999) actually refer to mixed flocks of Common and Roseate terns and the ratio of Common to Roseate Terns in these flocks were not recorded (Blair Nikula *personal communication*). Color-banding studies have demonstrated that the Roseate Terns that stage in Chatham come from colonies throughout the northeastern United States and Canadian Maritime Provinces as well as from Massachusetts colonies, and that every year, these late-summer congregations may comprise nearly the entire North American population (Trull, et al., 1999).

Initially, we intended to start these surveys in the first week of August and end them at the approximate date when most of the terns would depart on their southbound migration. In most years this exodus typically occurs in the third or fourth week of September. Foggy weather persisting over Nantucket Sound through the first 14 days of August delayed our first complete survey until August 15, although this was three days earlier than the start date in 2002.

METHODS

Tern behavior, distribution, and abundance on Horseshoe Shoal were estimated primarily using aerial surveys. In general, our methods described below were identical to the protocol developed for our first survey of terns during the 2002 pre-migratory staging period (Perkins, et al. 2003) with two important modifications. These modifications were made to enhance our ability to estimate tern abundance and to increase our accuracy in spatially locating terns recorded during the surveys.

1. Defined transect width for aerial surveys

In aerial surveys in 2002, we counted all birds visible to the naked eye or with the aid of binoculars. In 2003, we strictly defined the transect width as 600 ft at or near the water surface, recording only those birds seen within a 300 ft-wide transect corridor on each side of the plane. Each of these corridor's inner and outer margins were visually fixed with a clinometer by measuring the angle visible at the lower edge of the window (70 degrees from the horizontal) to a point 46 degrees from the horizontal, or a total of 23 degrees (Figure 1).

Criteria used for the selection of the 300 ft-wide transect corridors included:

1) The distance perpendicular to the transect centerline at which birds (especially terns) were detectable with the naked eye (after initial detection, identification sometimes required binoculars).
2) Total width was narrow enough to avoid situations in which birds were too abundant and/or were spread over too wide an area to count accurately.

We counted all terns that we saw within this 600-foot wide transect as we flew along our grid lines. As we counted, we generally focused our attention on or near the water surface. Terns flying at height were occasionally seen and counted, but our detectability of highflying terns could have been lower than detectability for terns seen at or near the water surface. The results of our boat surveys indicated that very few terns occur at altitude (e.g., Perkins et al., 2003).

2. Improved data entry system.

In 2002, we entered data directly into an Excel spreadsheet, manually recording all pertinent data including the latitudes and longitudes. In 2003, we purchased a customized data entry program, "dLOG" software created by R.G. Ford Consulting, Inc., Portland, OR, which was designed specifically for aerial and boat surveys of waterbirds. The program automatically records latitude and longitude generated from an onboard GPS unit, and enables us to record species and their numbers using one- or two-key species codes. This significantly reduces the recording time for each data point and increases the accuracy of the recorded location of each sighting.

In addition to these two modifications, we were more selective about weather conditions: we conducted surveys only on days when the wind did not exceed 15 knots. This adjustment was based on our experience in year one that higher winds created sea conditions that reduced the visibility of the birds and negatively effected our ability to detect birds (detection rate).

Aerial Surveys

Aerial surveys were conducted along sixteen fixed, parallel transects oriented north to south. Taken as a whole, this survey grid comprised approximately 70 percent of Nantucket Sound; the transects began just seaward of the south shore of Cape Cod and extended southward to an east-west line roughly even with Great Point, Nantucket (Figure 2). Individual transects were positioned at 7,500 foot intervals, and the total combined linear length of all 16 transects was 247.4 miles. The length of the longest transect was 18.2 miles; the shortest transect was 4.5 miles in length. The actual sample area, calculated as the width of the transects (600 ft) multiplied by their combined length (247 miles) is approximately 28 sq miles. Thus, the area surveyed in 2003 represented approximately 6 percent of the area of the Sound.

Aerial surveys were flown with a high-winged, twin-engine aircraft (Cessna Sky Master 337) at an altitude of 500 feet, and at an average airspeed of 90 knots. The chosen altitude allowed us to identify birds on the sea surface but also 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 (not exceeding 15 knots) and on days with good atmospheric clarity (visibility >10 miles) – by definition we did not attempt to conduct our surveys under randomly chosen weather conditions. Flights usually commenced mid morning and the average duration of each survey was roughly 2.5 hrs. We recorded all birds seen within the north-south transects out to a distance of 300 feet on each side of the plane. Individual birds were identified with the aid of binoculars as necessary. Counts of birds were briefly suspended while we were flying the short, east-west legs between transects. Non-avian species, such as sea turtles, were also recorded along the transects.

Each aerial survey team was composed of a pilot, a recorder in the co-pilot seat, and two experienced observers. The two observers were 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 immediately entered this information onto a laptop computer. Geographical location was automatically logged by the computer program, dLog, as described above. Recorded information included all species of birds, their abundances, and their behavior (traveling, sitting, or actively feeding). We also recorded starting and ending times, wind direction and velocity, sea state (Beaufort scale), visibility, and cloud cover for each transect on every survey. Surveys were conducted over a wide range of tidal stages.

Common and Roseate terns were distinguished by their different flight behavior, shape, and plumage characteristics. We recorded all birds to species whenever possible, but it was not possible to always differentiate between the Roseate and Common terns. When we could not distinguish between the two species, we lumped our observations into the category of Roseate/Common Tern (Tern spp.).

For the purposes of calculating tern abundance from aerial survey data on Horseshoe Shoal we defined a rectangular polygon that included the area of Horseshoe Shoal; the polygon extended from 41.45 to 41.57 degrees N and 70.40 to 70.24 degrees W (Figure 2). This rectangle included the boat survey area on the Shoal (as described below) as well as adjacent deeper-water areas outside the boat survey area.

Boat surveys

We conducted four boat surveys along a series of transects oriented in two approximately parallel tracks, one mile apart. The positions and dimensions of these transects were selected to sample all the waters over Horseshoe Shoal as well as the waters in the immediate vicinity of the Shoal (see Figure 2). For the purposes of this study, we defined the Shoal as the area described by the 20-ft bathymetry line. The boat surveys began and ended at waypoints in the northeast portion of Horseshoe Shoal, and followed a roughly crescent-shaped route out to and back from waypoints near the southeastern portion of the Shoal, just west of Halfmoon Shoal. Surveys were conducted

from a 33 ft powerboat, cruising at an average speed of roughly 17 knots. Surveys lasted approximately 1.5 hours. The total linear length of all transects was 24.9 miles.

The boat survey teams consisted of two observers and one recorder, and data collected included numbers of birds seen by species, behavior (feeding, sitting, or traveling), flight altitudes, survey starting and ending times, weather (e.g., rain, sunny, cloudy), wind speed and direction, water temperature, sea state, and visibility. The observers, positioned on each side of the boat immediately aft of the wheelhouse, verbally communicated all bird sightings to the recorder. Data were recorded using dLog as described above for the aerial surveys. All birds observed within 0.5 mile on either side of the vessel were recorded. This distance was periodically checked with the range-finding function of the onboard radar in reference to visible objects such as buoys. Flight heights of the birds were estimated by referencing objects of known height such as the top of the wheelhouse, navigational buoys, and the Cape Wind test tower. Observers used binoculars as needed.

Boat surveys were conducted under weather conditions comparable to that of aerial surveys. Sampling under a variety of weather conditions, including inclement weather would have been desirable had time and resources permitted. Given the limitations on the latter, we chose to focus our surveys to maximize the detectability of birds in Nantucket Sound and Horseshoe Shoal.

RESULTS

Aerial Surveys

Thirteen aerial surveys were conducted between August 7 and September 25. Surveys flown on August 7th and August 27th were not completed due to deteriorating weather conditions during those surveys, but the data from those surveys for the portion completed have been included in our analyses. During the survey period, we observed 10,067 terns along the transects including 1,792 Common Terns, 376 Roseate Terns, and 7,899 Common-Roseate-type terns (Table 1). The highest single-day count of 2,377 birds was recorded on September 9, and the second highest count of 1,435 birds was recorded on September 17 (Figure 3).

Over the survey period, the majority (61.7%) of terns were seen along transects 14-16 close to Monomoy Island; 38.3% of all terns were counted within transects 1-13 (e.g., Figure 4). The numbers of terns recorded during a survey tended to increase as we approached Monomoy Island NWR, and this distributional pattern became increasingly prevalent on the later survey dates (Figure 4). Tern sightings also tended to be slightly higher within a few miles of the southern shore of Cape Cod, in the northern portion of our survey area. One hundred twenty three of 10,067 terns (or 1.2%) observed during all aerial surveys combined were counted over Horseshoe Shoal (as defined by the area covered by boat surveys).

Among the 1,792 Common Terns counted in all surveys, 64.3% were diving/feeding, 35.6% were flying, and 0.1% were resting. Of the 376 Roseate Terns counted, 51.1% were diving/feeding, 48.9% were flying, and 0% were resting. Of the 7,899 Common/Roseate type terns counted, 68.0% were diving/feeding, 29.7% were flying, and 1.8% were resting on the water (0.4% were near vessels). See Figure 5 for the general distribution of feeding and flying terns observed during the survey period.

We analyzed behavior of terns recorded only in transects 1-13, excluding transects 14-16 which traversed shallow water close to Chatham's staging, feeding, and resting areas. These transects were excluded from this analysis because terns observed on these transects are more likely to be feeding locally within the shallows off Monomoy as well as being local breeders. Of 856 Common Terns counted within transects 1-13, 45.9% were diving/feeding, 54.0% were flying, and 0.1% were resting. Of 44 Roseate Terns counted on these transects, 18.2% were diving/feeding, and 81.8% were flying. Of 2,944 Common/Roseate type terns, 63.7% were diving/feeding, 31.4% were flying, 3.8% were sitting, and 1.1% were located near fishing vessels.

We did not attempt to estimate flight heights of terns 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. On four aerial surveys (September 3rd, 9th, 10th, and 25th) 31 Common Terns and 45 Common/Roseate Terns were recorded between approximately 300 and 500 ft.

We counted 75% more terns in 2003 than in 2002 (Table 2), but fewer Roseate Terns were counted or identified in 2003. Although our aerial surveys covered the same transects in 2002 and 2003, results between the two years are not directly comparable because we counted a defined transect width in 2003 and, in 2002, we counted every bird we could see.

Number of terns counted per unit distance was calculated for each of the two years (Table 3). Despite counting birds in 2003 over a smaller area of Nantucket Sound, the number of terns observed per survey mile was substantially higher in 2003. When data are summarized by transect the median number of terns over Horseshoe Shoal was 0.3 versus 1.5 for the Sound as a whole and 0.8 for transects 1-13. Of those terns that were recorded over the Shoal, the majority (209) were fishing, and 150 of those fishing birds comprised a single flock (see Table 4).

During the aerial surveys, we observed 17 other species of birds (see Table 5) and 28 sea turtles (Table 6, Figure 6). The breakdown of counts of non-tern species by survey date can be obtained by contacting gsadoti@massaudubon.org

Boat Surveys

We completed four boat surveys within the survey period: August 29, September 9, September 10, and September 17. Terns were recorded on two out of the four boat

surveys. The total of 24 terns, all Common Terns, included 15 that were fishing on September 9, and on September 10, eight that were traveling, and one that was sitting. The flock of eight Common Terns was traveling at 30 feet. Nine other species of birds were recorded during these four surveys including 18 Scoters and nine Gulls (Table 7).

DISCUSSION

The distribution of terns across Nantucket Sound as observed during aerial surveys in 2003 was generally consistent with the distribution observed in 2002. Compared to the Sound as a whole, relatively few terns (Table 3) were observed by plane over the Horseshoe Shoal polygon (see above) during the premigratory staging period. Of those observed, the majority (209) were fishing, and 150 of the birds observed fishing occurred in a single flock.

Very few data have been collected on tern use of Nantucket Sound. Heinemann (1992) reported that feeding sites of Roseate Terns foraging from their colonies in Buzzards Bay included portions of Nantucket Sound. During their feeding forays, the terns ranged up to roughly 20 miles from their colonies during the nesting period (Gochfeld et. al. 1998). During the staging period, recent tern totals derived from various land-based counts at South Beach in Chatham have numbered in the tens of thousands (e.g., Trull et al. 1999).

The west-to-east shift in tern abundance that we observed during the survey period may have been attributable to the terns' tendency to spend increasing amounts of time at or near their staging sites near Chatham as their migratory departure date drew closer. The attraction to Chatham is thought to be due, in part, to the presence of numerous sandbars, the shallows they create, and the favorable fishing conditions these bathymetric features produce. Likewise, the clustering of terns in the northern portion of the survey area was likely related to terns' preference for feeding in the Sound's shallower margins.

The terns noted at high altitudes were engaged in behavior unknown to these authors. Like the high-flying birds observed in the 2002 season, they appeared to be "kettling" on thermals, but unlike the 2002 terns, those in 2003 were noted on more than one day. Seventy-six terns were observed "kettling" at or above 300 ft. on four surveys (9/3, 9/9, 9/10, and 9/25). These high-flying birds were only observed in the latter part of the staging period, suggesting these individuals were preparing to depart on migration.

In 2002, the only birds that were recorded "sitting" or "resting" were birds observed standing on sand flats in the Chatham area; 641 sitting/resting terns were recorded in 2002, all in the Chatham/Monomoy area. In 2003, only birds seen sitting on the sea surface were recorded as "resting". That is, in 2003, we did not record terns standing on sandbars in the immediate vicinity of Monomoy, because it was concluded that these birds were not, technically, using the Sound *per se*.

We saw 75% more terns during the 2003 aerial surveys than we observed in 2002. As the calculations presented in Table 3 indicated, the overall higher tern totals recorded in 2003 cannot be accounted for by the two additional flights (13 in 2003 versus 11 in 2002). For reasons described earlier, we counted terns in a smaller area along each transect in 2003. For the sake of a preliminary comparison of tern abundance between the two years we assumed that we surveyed the same, if not a greater, area of the Sound in 2002. Data were then summarized based on two different sampling units – per transect and per unit linear transect mile.

It is clear from this preliminary analysis (Table 3) that the definition of the sampling unit influences both median and mean values. For example, summarizing data in one-mile segments leads to lower median values than when data are summarized by transect. Regardless of the unit of measurement it is apparent that the overall number of terns observed in 2003 was higher than in 2002, and we conclude that in both years, the abundance of terns over Horseshoe Shoal was lower than within the Sound as a whole or than the abundance observed in transects 1 –13.

The spatially explicit nature of our data will allow us to do a detailed analysis of our tern counts in four dimensions – east-west, north-south, abundance, and time. We anticipate completing a third year of aerial surveys of terns during the 2004 staging period using the same methods as used in 2003. More detailed statistical analysis of the data will be completed at that time.

Although not demonstrated with statistical certainty, it is apparent that tern abundance does vary annually. The considerable annual variation in tern abundance between 2002 and 2003 surveys illustrates the importance of at least three years of surveys to determine whether the 2002 or 2003 data were more representative of the abundance of terns in Nantucket Sound during the staging period, or whether a third pattern will be observed. Understanding the causes of this variation would require studies much more detailed than those discussed in this report.

Finally, similarities in the general distribution of terns between the 2002 and 2003 staging periods provide additional support for the hypothesis proposed in our 2002 report (Perkins, et al. 2003) that Horseshoe Shoal is not a primary feeding area or travel route for terns during the fall staging period.

ACKNOWLEDGMENTS

The authors wish to thank the Massachusetts Technology Collaborative and the Island Foundation for their financial support of this research. We thank the following for their assistance as either recorders or observers during surveys: Julia Auckland, Matt Bailey, Robert Buchsbaum, Lara Davis, Nat Donkin, Ron Donovan, Paul Fitzgerald, Peter Flood, Seward Highley, Brant Jones, Steve Liptay, Wayne Petersen, and Ted Raymond. Jeff Collins provided invaluable assistance with mapping. Carolyn Mostello, and Dr. Jeremy Hatch, and Dr. Ian Nisbet provided valuable consultation and advice. We are very grateful to Ambroult Aviation and pilots John Ambroult, Jack O'Brian, and

Chan Lofland for skillfully and safely flying the planes, and to Len Greiner for the boat charter services.

LITERATURE CITED

Gochfeld, M., J. Burger, and I. C. T. Nisbet. 1998. Roseate Tern *(Sterna dougallii*). In The Birds of North America, No. 370 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Gove, G. W., R. H. Stymiest, and L. E. Taylor. 1984. Field Records September 1984. Bird Observer of Eastern Massachusetts 12 (6): 337-350.

Heinemann, D. 1992. Foraging Ecology of Roseate Terns on Bird Island, Buzzards Bay, Massachusetts. Unpublished Report to U. S. Fish and Wildlife Service, Newton Corner, MA.

Perkins, S., T. Allison, A. Jones, G. Sadoti. 2004. A survey of tern activity within Nantucket Sound, Massachusetts during the 2003 Breeding Season. Final report to Massachusetts Technology Collaborative. Massachusetts Audubon Society, Lincoln, MA, 17 pages.

Perkins, S., Jones, A., and T. Allison. 2003. Survey of Tern Activity Within Nantucket Sound, Massachusetts, During Pre-Migratory Fall Staging. Final report to Massachusetts Technology Collaborative. Massachusetts Audubon Society, Lincoln, MA, 19 pages.

Trull P., S. Hecker, M.J. Watson & I.C.T. Nisbet. 1999. Staging of Roseate Terns *Sterna dougallii* in post-breeding period around Cape Cod, Massachusetts, USA. Atlantic Seabirds 1(4): 145-158.

U.S. Fish and Wildlife Service. 1998. Roseate Tern Recovery Plan: Northeastern population, First Update. USFWS, Hadley, MA.

Veit, R. R., and W. R. Petersen. 1993. Birds of Massachusetts. Massachusetts Audubon Society, Lincoln, MA.

Table 1: Number of terns seen by species and date of survey during aerial surveys in 2003 premigratory staging season. Flight dates marked with an asterisk represent incomplete surveys due to deteriorating weather conditions. August 7 was terminated at the end of transect 7 and August 27 was terminated halfway through transect 11.

DATE	Common Tern	Roseate Tern	Tern spp.	Totals
7-Aug-03*	1	3	14	18
15-Aug-03	8	3	20	31
20-Aug-03	150	2	52	204
21-Aug-03	108	3	187	298
26-Aug-03	101	7	96	204
27-Aug-03*	39	0	11	50
3-Sep-03	179	31	578	788
9-Sep-03	476	70	2356	2,902
10-Sep-03	179	12	2186	2,377
11-Sep-03	195	36	602	833
17-Sep-03	240	76	1119	1435
24-Sep-03	65	121	394	580
25-Sep-03	51	12	284	347
Totals	1,792	376	7,899	10,067

* Surveys not completed due to deterioration in weather conditions during flight.

.

Table 2: Total number of terns counted along all transects combined in 2002 and 2003.

Year	Common Terns	Roseate Tern	Tern spp.	All Terns
2002 (not including resting terns)	1,761	621	2,689	5,071
2002 (including resting terns	1,767	634	3,311	5,712
2003	1,792	376	7,899	10,067

Table 3: Median and mean number of terns counted per mile during aerial surveys for Nantucket Sound, Horseshoe Shoal, transects adjacent to Monomoy NWR (14-16), and transects not including those near Monomoy (1-13). Number of terns counted on aerial surveys were summed in one-mile increments along each transect or summed by transect. Resulting sums were divided by the number of times each mile segment or transect was flown. Median, mean, and standard deviation were then calculated for the entire Sound, Horseshoe Shoal (as defined in the text), transects 1-13, and transects 14-16 (near Monomoy).

2002

Terns per	Summed by 1 Mile Segment (n=247)		Summed by Transect (n=16)	
	Median (range in parentheses)	Mean (SD)	Median (range in parentheses)	Mean (SD)*
Entire sound	0.2 (0-117.6)	2.0 (8.0)	0.8 (0.3-22.8)	2.8 (5.7)
Horseshoe Shoal	0.1 (0-5.5)	0.5 (1.2)	0.6 (0.1-0.8)	0.5 (0.3)
Transects 1-13	0.1 (0-15.3)	0.9 (2.2)	0.8 (0.3-2.8)	0.9 (0.6)
Transects 14-16	3.5 (0-117.6)	9.3 (20.6)	8.3 (1.3-22.8)**	10.8 (11)**

2003

Terns per	Summed by 1 Mile Segment (n=247)		Summed by Transect (n=16)	
	Median (range in parentheses)	Mean (SD)	Median (range in parentheses)	Mean (SD)*
Entire sound	0.2 (0-65.5)	3.2 (8.6)	1.5 (0.1-29.1)	4.6 (7.7)
Horseshoe Shoal	0.0 (0-11.6)	0.5 (1.7)	0.3 (0-2.7)	0.7 (1)
Transects 1-13	0.1 (0-19.8)	1.4 (3.1)	0.8 (0.1-5.2)	1.4 (1.6)
Transects 14-16	7.1 (0-65.5)	15.7 (18.4)	13.4 (12.2-29.1)	18.2 (9.5)

* Each transect was given the same weight in calculations of means. If weighted by transect length, mean values are the same as those calculated for one-mile samples.
** If sitting birds are excluded from transect counts in 2002, median (min-max) terns per survey-mile were 8.3 (1.3-16.4) and mean (SD) terns per survey mile were 8.7 (7.5).

Table 4: Behavior of terns observed over Horseshoe Shoal (as defined in the text).

SPECIES	FISHING	TRAVELING	Grand Total
Common Tern	34	53	87
Roseate Tern	0	3	3
Tern spp.	175	47	222
Total	209	103	312

Table 5: Number of all birds seen by species during 2003 premigratory staging period aerial surveys (13 trips: 8/7 – 9/25/03).

Species	Total
Common Loon	3
Wilson's Storm-Petrel	2
Double-crested Cormorant	46
Common Eider	1
Surf Scoter	4
White-winged Scoter	41
Red-breasted Merganser	1
Osprey	1
American Oystercatcher	24
Shorebird species	19
Jaeger species	1
Laughing Gull	6
Bonaparte's Gull	2
Herring Gull	243
Great Black-backed Gull	442
Gull species	69
Roseate Tern	**376**
Common Tern	**1792**
Least Tern	**63**
Tern species	**7899**
Passerines	1
Total	11036

Table 6: Non-avian species observed during 2003 premigratory staging season aerial surveys.

Taxa/Species	Total
Sharks	2
Sea Turtles	28
Seals	4
Ocean Sunfish	9

Table 7: Number of all birds seen by species during 2003 premigratory staging period boat surveys (four surveys – August 29, September 9, September 10, and September 17).

Species	Number Observed
White-winged Scoter	6
Scoter species	12
Double-crested Cormorant	1
Common Tern	24
Greater Black-backed Gull	5
Herring Gull	2
Gull species	2
Songbirds	2

Figure 1. Viewing angles and distances used in aerial surveys (derived from figure drawn by Doug Forsell, U. S. Fish and Wildlife Service)

)

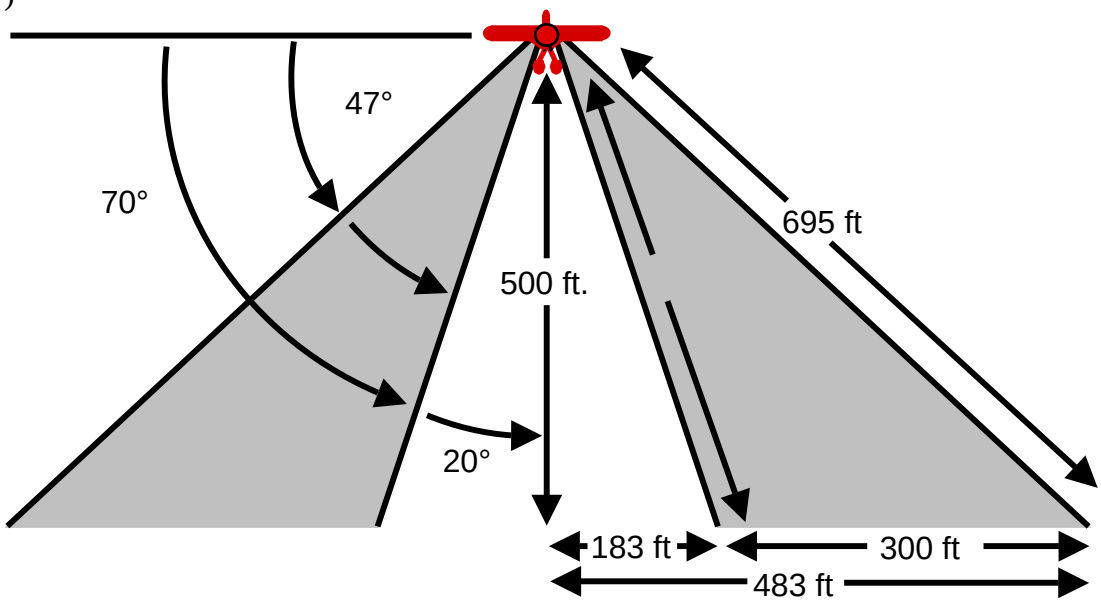

Figure 2: Nantucket Sound study area and associated features, including aerial and boat transect routes, area of proposed wind farm, major tern colonies, and polygon used for analysis of tern abundance on Horseshoe Shoal.

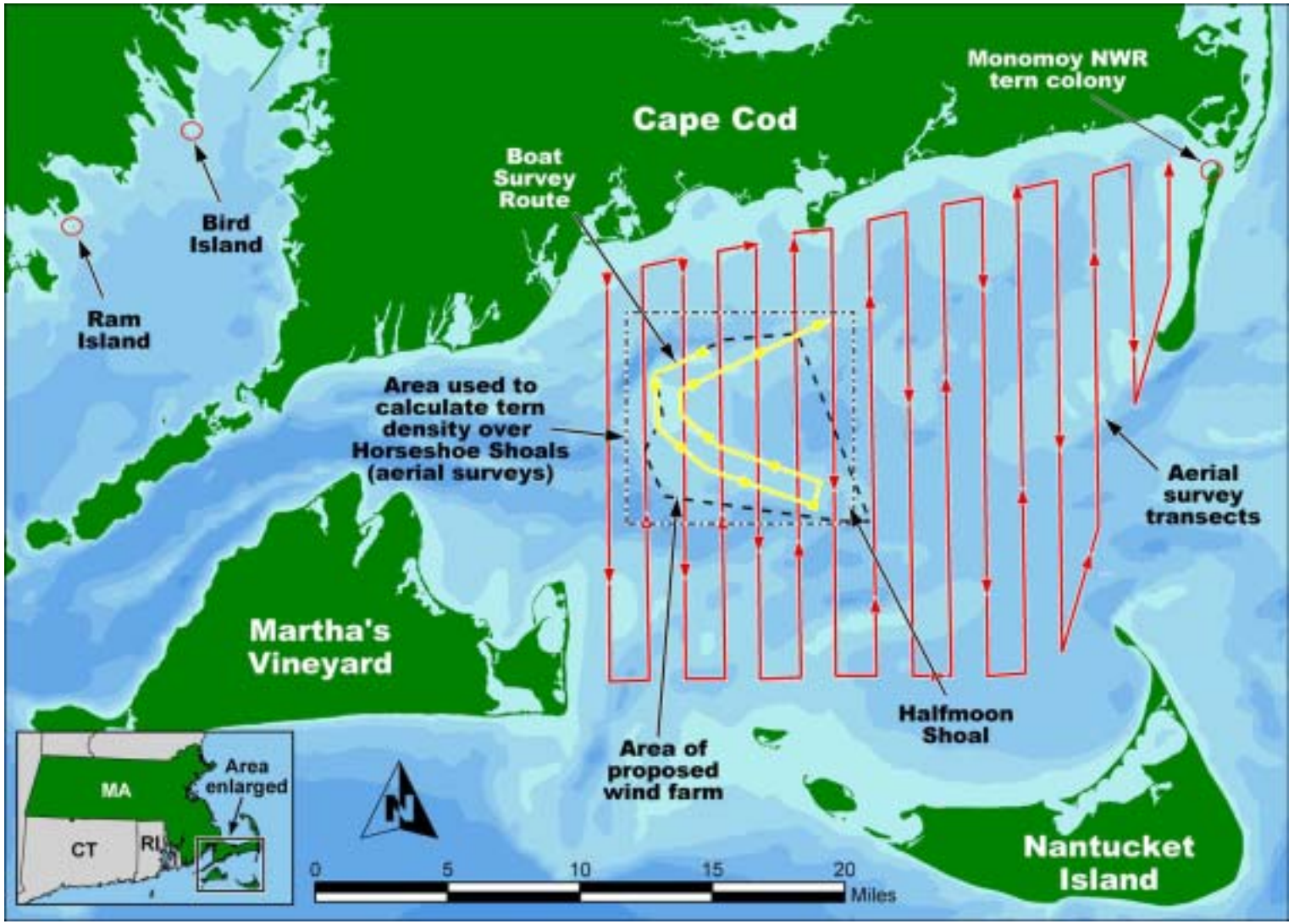

Figure 3: Total numbers of each tern species recorded during aerial surveys of Nantucket sound, August 7 – September 25, 2003

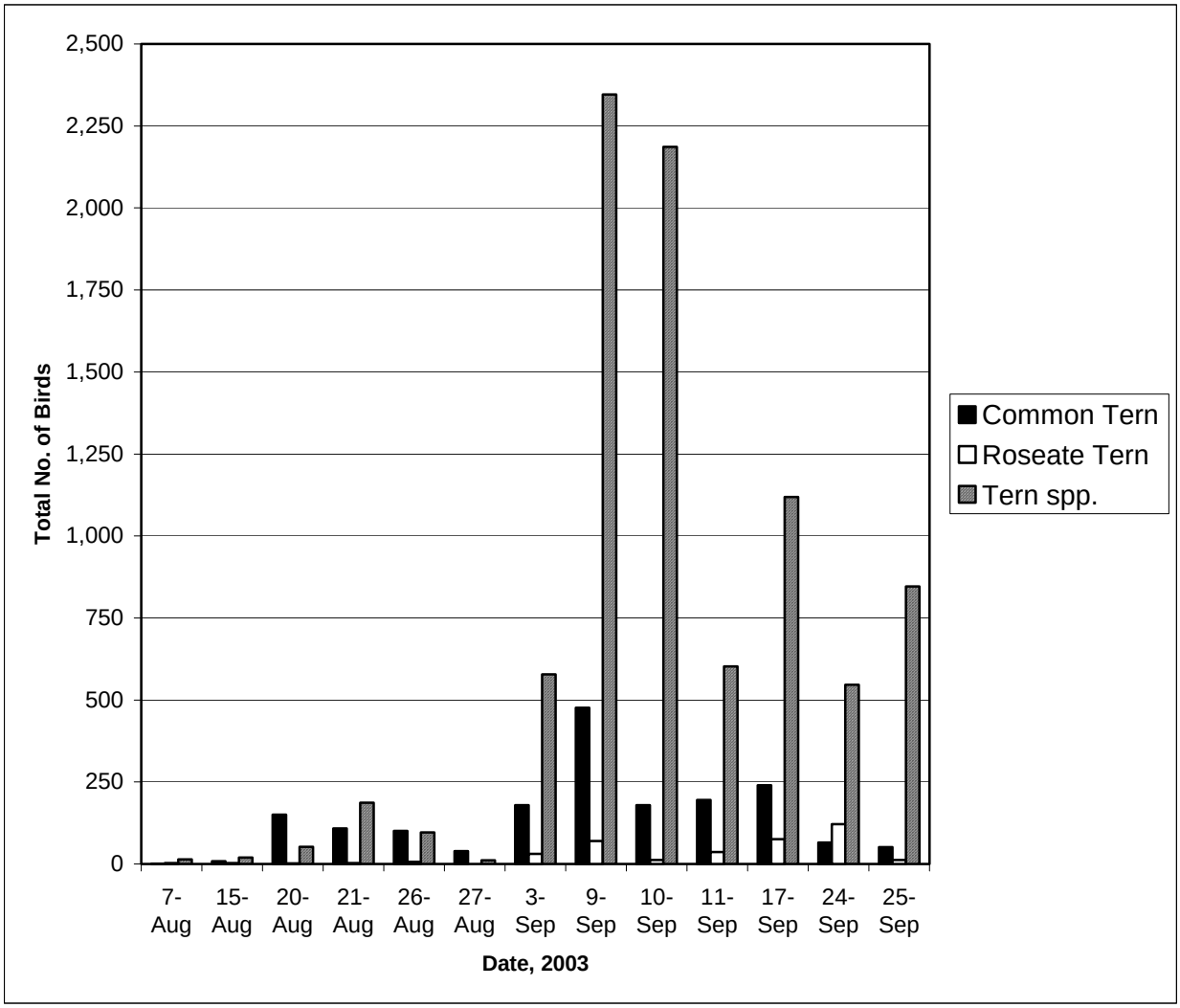

Figure 4: Locations and numbers of Roseate and Common terns and Tern Species observed during all aerial surveys of Nantucket Sound during the tern migration period, 2003.

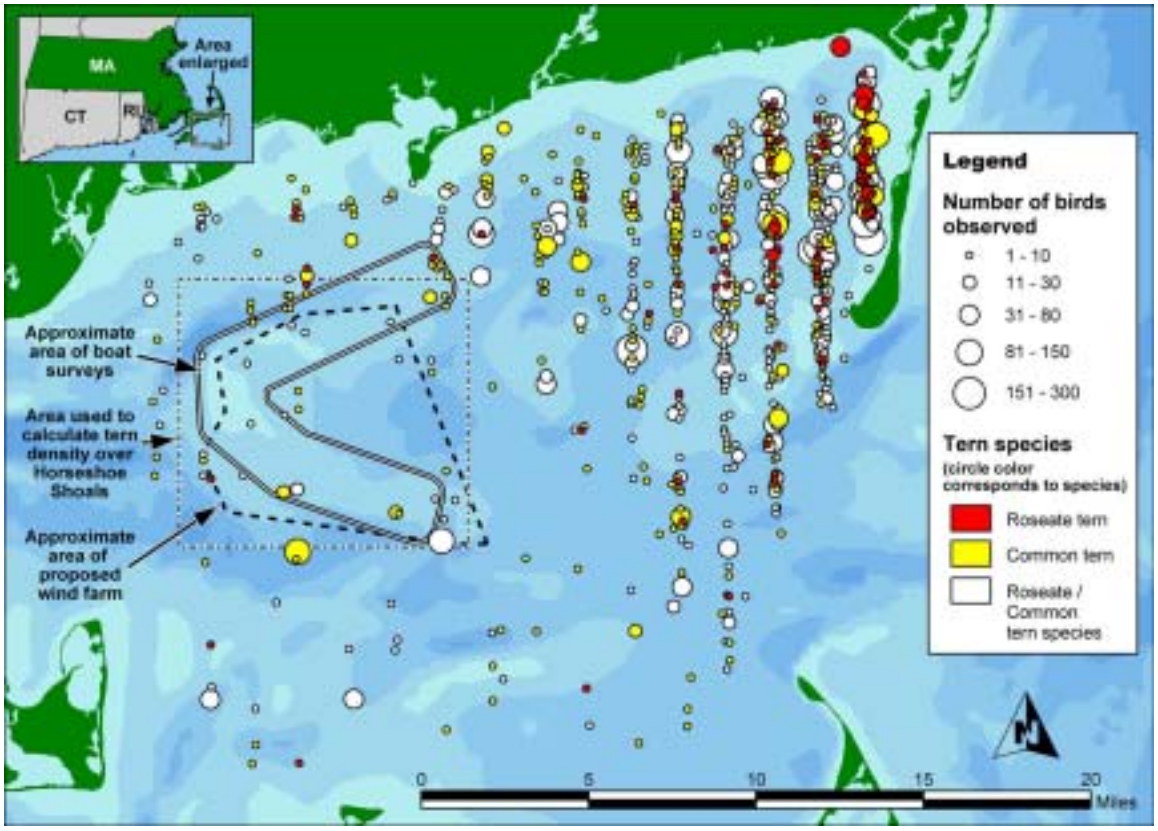

Figure 5: Numbers and behaviors of terns observed over Nantucket Sound during all aerial surveys of the tern staging period, 2003.

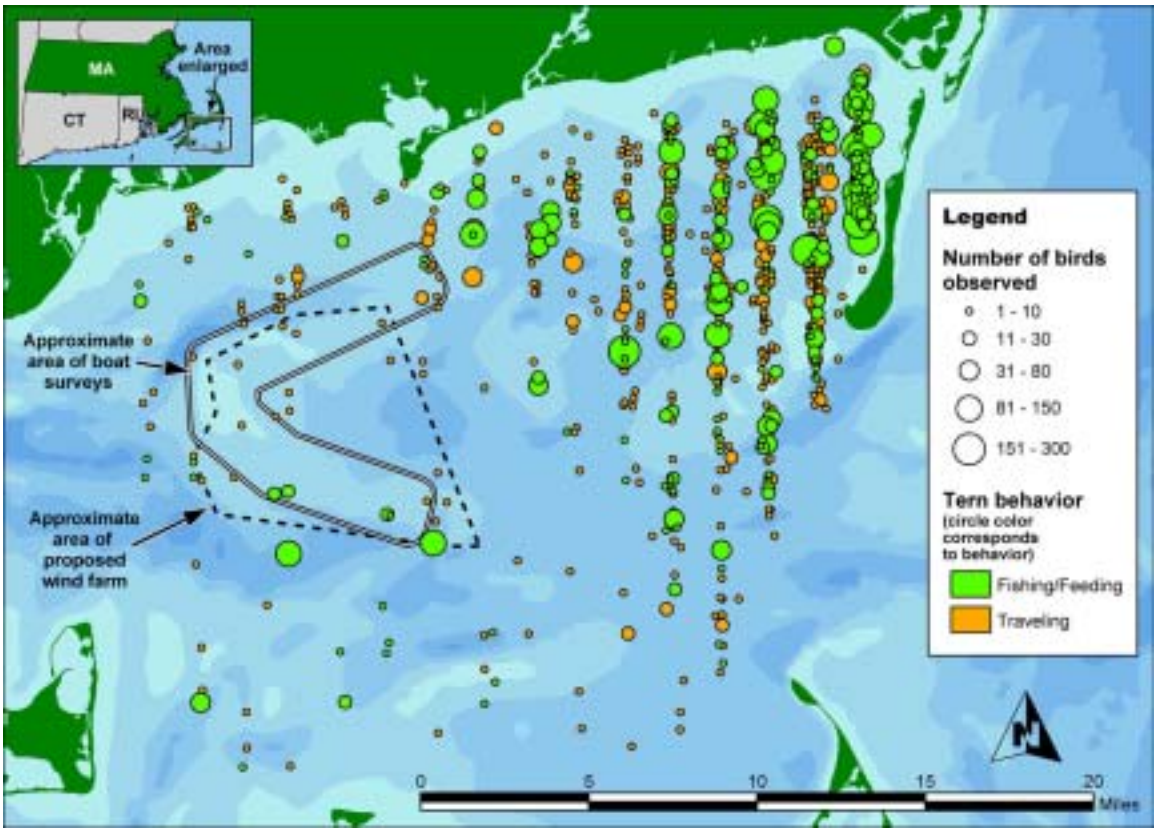

Figure 6: Locations of 28 sea turtles observed during all aerial surveys of the tern staging period, 2003. All observations were of single individuals.