Appendix 5.7-N

Massachusetts Audubon Society
Nantucket Sound Tern Surveys

Survey of Tern Activity Within Nantucket Sound, Massachusetts, During Pre-Migratory Fall Staging

Final Report for Massachusetts Technology Collaborative

8 January 2003

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INTRODUCTION

A proposed wind farm on Horseshoe Shoals in Nantucket Sound would be the largest in the United States and one of the largest in the world. Few if any data are available to assess the potential risks to North American birds posed by this offshore wind farm. A survey of terns and waterfowl in Nantucket Sound is a critical 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 Shoals. Approximately 50% of the North American population of Roseate Terns breeds within Buzzards Bay in Massachusetts (USFWS 1998), and in 2001, 7812 pairs of Common Terns nested at Monomoy Island NWR, Chatham (Blodget, 2001). 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 about the actual abundance, dispersal, and daily movements of these terns during migration. In addition, the areas where they focus their feeding activities both within the breeding season and during spring and fall migration are poorly known.

In an effort to fill some of these data gaps, we conducted aerial surveys of Nantucket Sound between August 19 and September 19, 2002. The primary objectives of this study were to ascertain the abundance and distribution of Common and Roseate terns within the Sound during fall migration and staging and to detect any temporal variation in these parameters. During this same period, we conducted four boat surveys in the waters on, and in the immediate vicinity of, Horseshoe Shoals in an effort to observe the behaviors of the terns (e.g., traveling or actively feeding) and determine the heights at which the birds were flying.

The timing of the tern survey 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 pre-migration 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 (1984) and cited by Trull (1999) actually refer to mixed flocks of Common and Roseate terns and the ratios of these flocks were not recorded (B. Nikula pers. comm.). Color-banding studies have demonstrated that the Roseate Terns that stage in Chatham come from colonies throughout the northeastern United States and Canadian Maritimes 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, our study was intended to cover the period between early August and the approximate date when most of the terns would depart on their southbound migration. In most years this exodus typically occurs in the third week of September (S. Hecker

pers. comm.). Because we did not receive notification of funding until early August, we did not begin our aerial surveys until August 19.

METHODS

Aerial Surveys

Aerial surveys were conducted along sixteen fixed, parallel transects oriented north to south. This grid encompassed nearly all the waters south of Cape Cod between Martha's Vineyard and the Monomoy Island NWR in Chatham; the transects extended south to an east-west line roughly even with Great Point, Nantucket (Fig. 1). 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 was 4.5, and the mean length of all sixteen transects was 15.4 miles (Fig. 1).

Aerial surveys were flown with a high-winged, twin-engine aircraft (Cessna Sky Master 337) at an average altitude of 500 feet, and at an average airspeed of 90 kts. Flights were conducted only on days with light to moderate winds (not exceeding 20-25 kts) and on days with good atmospheric clarity (visibility >10 miles). Flights usually commenced mid morning and the average duration of each survey was roughly 2.5 hrs. We recorded all birds seen along or on either side of the north-south transects out to a distance estimated to be roughly 3500 feet on each side of the plane, a distance approximately half way between adjacent transects. Some individual birds were detected and identified only with the aid of binoculars. Other non-avian species, such as sea turtles, were also recorded. We did not count any species observed while we were flying the short, east-west legs between transects.

Common and Roseate terns were distinguished by their different flight behavior 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.).

Each 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 and the geographical location of the plane at the time of each sighting into an Excel spreadsheet on a laptop computer; geographical location was determined using an onboard Global Positioning System (GPS). Recorded information included all species, number of birds, and their behavior (traveling or actively feeding). We also recorded starting and ending times, ground temperature, wind direction and velocity, sea state, visibility, and cloud cover for each transect on every survey. Surveys were conducted over a wide range of tidal stages.

Boat surveys

We conducted four boat surveys along a series of transects oriented in two approximately parallel tracks, one mile apart; the position of these transects were selected in order to "capture" all the waters over Horseshoe Shoals as well as the waters in the immediate vicinity of the Shoals (see Fig. 1). Surveys were conducted using a 40 ft powerboat, cruising at an average speed of roughly 15 kts. Surveys lasted approximately 1.5 hours. The total linear length of all transects was 24.9 miles. The survey teams consisted of at least one observer and one recorder, and data collected included all bird species, their numbers, and their flight altitudes, and starting and ending time, weather (e.g., rain, sunny, cloudy), wind speed and direction, temperature, sea state, and visibility. For each bird sighted, the recorder entered a corresponding geographical location determined by an onboard GPS system. All birds observed within approximately 0.5 miles on either side of the transects were recorded. Observers used binoculars whenever necessary.

RESULTS

Aerial Surveys

Eleven aerial surveys were completed before the majority of birds departed on or around September 19. During this period, we observed 5,721 terns in the study area including 1,767 Common Terns, 634 Roseate Terns, and 3,311 Common-Roseate-type terns (Table 1).

Terns were recorded on all aerial surveys. The highest single-day count of 1,302 birds was recorded on August 26, and the second highest count of 1,089 birds was recorded on September 9 (Fig. 2). Common Terns were recorded more frequently than Roseate Terns (Fig. 3). On the last survey, September 19, only one Common Tern was recorded. Transect number 16 (closest to Monomoy Island NWR) (see Figs.1 and 4) contained the largest counts of terns over the course of the study period. The numbers of terns recorded on any given day tended to increase as we approached Monomoy Island NWR, and this distributional pattern became increasingly prevalent during the latter surveys when, in the final few days, the birds began departing the region on migration (Figs. 4, 6-9). Tern abundance also tended to be higher within a few miles of the southern shore of Cape Cod, in the northern portion of our survey area, while relatively few terns were detected directly over Horseshoe Shoals (see Figs. 6-9).

Over the survey period, the majority (59.4%) of birds were seen close to Monomoy Island within transects 14-16; 40.6% were counted within transects 1-13. Among the 1,767 Common Terns counted over the entire survey period, 57.2% were diving/feeding, 39.2% were flying, and 3.6 % were resting. Of the 634 Roseate Terns counted, 59.0% were diving/feeding, 39.0% were flying, and 2.0% were resting. Of the 3,433 Common/Roseate type terns counted, 35.0% were diving/feeding, 46.8% were flying, and 18.1% were resting. All resting birds were sighted near Monomoy Island, where they were standing on exposed sandbars.

An analysis of terns recorded only in transects 1-13 (i.e., excluding transects 14-16 which traversed shallow water close to Chatham's staging, feeding, and resting areas) revealed a much lower percentage of actively feeding birds as compared to the percentage of feeding birds recorded over all sixteen transects. Of 737 Common Terns counted within transects 1-13, 29.4% were diving/feeding, 62.7% were flying, and 7.9% were resting. Of 127 Roseate Terns counted in this area, 27.6% were diving/feeding, and 72.4% were flying. Of 1,504 Common/Roseate type terns, 45.4% were diving/feeding, and 54.6% were flying.

The majority of birds observed during aerial surveys were flying at low altitudes (estimated at less than 100 feet) over the water. On August 28, however, several flocks of terns were detected high aloft. One flock composed of an estimated 120 terns extended from roughly sea level to an altitude equal to or slightly above our own (500 feet). This flock was recorded along transect 11 (coordinates 41º 28' 34" N; 70º 8' 53" W). In another flock of 18 Common Terns recorded along transect 13, three birds were observed at roughly 400 feet (coordinates 41º 32' 22" N; 70º 5' 26" W). The birds appeared to be "kettling" on thermals, but why they were found aloft on that day and not on other days is unknown. During the same time, we also observed a flock of 25 Double-crested Cormorants flying at roughly 500 feet, apparently migrating. Other avian species observed during aerial flights included loons, storm-petrels, gannets, sea ducks, jaegers, gulls, and shorebirds (see Table 2).

A cumulative total of 34 sea turtles were observed (Table 3). We recorded turtles on nine of the eleven aerial surveys. The turtles were distributed throughout the Sound, including several on Horseshoe Shoals (Fig. 10), although most were loosely clustered in an area to the west of the south end of Monomoy Island NWR, Chatham.

Boat surveys

Four boat surveys were conducted, spaced throughout the study period: August 21 and 26, and September 6 and 20. A combined total of 42 terns were observed directly over Horseshoe Shoals (Table 4) on Aug. 21 and 26; no terns were sighted on the latter two surveys. Of the terns seen, 19 were observed in direct flight (traveling) and 23 were actively feeding within the shoals. The altitude range of all observed terns was between 5 and 50 feet high. Four other avian species were observed during boat surveys (Table 5). Three boat surveys were conducted concurrently with aerial surveys, but ground-truthing efforts by means of establishing radio or cell phone communications between the plane and the boat in attempts to correlate simultaneous observations failed.

DISCUSSION

The majority of terns recorded during this study were observed near Monomoy Island NWR or the south shore of Cape Cod. Fewer terns were seen on Horseshoe Shoals indicating that the Shoals were used less frequently than other portions of the Sound during this survey window. Our results suggest that a) Horseshoe Shoals may not be a primary feeding location for terns during the time period of our survey; b)

numbers of terns staging at Chatham this year were substantially lower than average; and/or c) because of the late start of our surveys the birds had already dispersed to their staging areas and were foraging elsewhere.

Our observations of tern activity suggest that, during this survey window, feeding activity is concentrated near staging areas in Chatham. Terns were feeding in the Sound, but most birds seen may have been flying through the sound to feeding sites located nearer the staging area. 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 (Gochfeld et. al. 1998).

In recent years, 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). For reasons yet unknown, data from this study, as well as data collected concurrently during land-based counts in Chatham, indicated that the numbers of terns at South Beach during the survey period were much lower than usual. For example, maximum counts among land-based surveys by local birders included 800 Roseate Terns and 3000 Common Terns (Bird Observer) at South Beach in late August 2002. No such systematic counts of Common Terns were submitted in September (when numbers typically peak) due to the lower-than-normal numbers of birds found there (P. Flood, B. Nikula, pers. comm.) In past years, >20,000 Common/Roseate-type terns have been estimated in Chatham during August and September (e.g., Gove, et al. 1984).

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 near. 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.

We had hoped to begin our surveys in early August, more than two weeks earlier than our start date, to observe tern use of Nantucket Sound through the entire staging period. The effect of this late start on the east-west distribution of tern sights and on our assessment of tern activity in the Sound is unknowable at present. We plan to begin 2003 surveys in April and continue through mid-September to obtain a more complete understanding of the use of Nantucket Sound and Horseshoe Shoals by terns. We believe that adequate assessment of the use of the Sound by terns will require at least three years of surveys, during spring migration, the breeding season, and through the full staging period. For example, tern distribution may shift annually as a function of shifts in the local distribution of fish, and the fish distribution may in turn be influenced by factors such as annual variations in water temperatures. A minimum of a three-year study period may enable us to detect these annual variations and to distinguish between alternative explanations for the patterns that we have observed.

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Table 1. Numbers of Common, Roseate, and Least terns, and Tern spp. (Common/Roseate type) counted during aerial surveys of Nantucket Sound, Aug. 19 – Sept. 19, 2002.

DATE	Common Tern	Roseate Tern	Tern spp.	Least Tern	ALL TERNS
19-Aug-02	0	92	534	1	627
21-Aug-02	0	7	977	0	984
26-Aug-02	438	193	671	1	1,303
28-Aug-02	332	29	460	0	821
5-Sep-02	24	17	149	1	191
6-Sep-02	43	10	172	5	230
7-Sep-02	87	18	329	0	434
9-Sep-02	825	260	3	1	1,089
13-Sep-02	10	7	14	0	31
18-Sep-02	6	0	3	0	9
19-Sep-02	1	0	0	0	1
TOTALS	**1,767**	**634**	**3,311**	**9**	**5,721**

Table 2. Number of individuals of other species of birds observed during aerial surveys of Nantucket Sound, Aug. 19 – Sept. 19, 2002.

Species	**Number**
Northern Gannet	13
Double-crested Cormorant	2,702
Common Eider	8
White-winged Scoter	14
American Oystercatcher	4
Laughing Gull	22
Bonaparte's Gull	5
Herring Gull	198
Great Black-backed Gull	290
Black Tern	4
Gull species	199
Jaeger species	2
Loon species	1
Shorebird Species	154
Wilson's Storm Petrel	7
Grand Total	**3,623**

Table 3. Non-avian species observed during aerial surveys of Nantucket Sound, Aug. 19 – Sept. 19, 2002.

Species	Number
Large sea turtle - unidentified species	20
Kemp Ridley's Sea Turtle	1
Leatherback Sea Turtle	8
Loggerhead Sea Turtle	5
Ocean Sunfish	4
Seals	5

Table 4. Numbers and altitudes of Common and Roseate terns and Tern spp. (Common/Roseate type) counted during boat surveys on Horseshoe Shoals, Aug. 19 – Sept. 19, 2002.

Date	Number	Species	Altitude (ft.)
21-Aug-02	11	Common Tern	5-30
	1	Common Tern	1
	4	Common Tern	0-5
28-Aug-02	14	Common Tern	10-50
	1	Roseate Tern	10
	11	Tern spp.	15-50
6-Sep-02	*0*	*No terns seen.*	
20-Sep-02	*0*	*No terns seen.*	
TOTAL	**42**		

Table 5. Species and number of other birds observed during boat surveys of Horseshoe Shoals, Aug. 19 – Sept. 19, 200.

Date	Number	Species	Altitude (ft.)
28-Aug-02	1	Wilson's Storm-Petrel	2
6-Sep-02	11	Double-crested Cormorant	0-30
6-Sep-02	4	Herring Gull	0-30
6-Sep-02	15	White-winged Scoter	20

Figure 1. Locations of aerial and boat transects used for surveys of Nantucket Sound, Aug. 19 – Sept. 19, 2002.

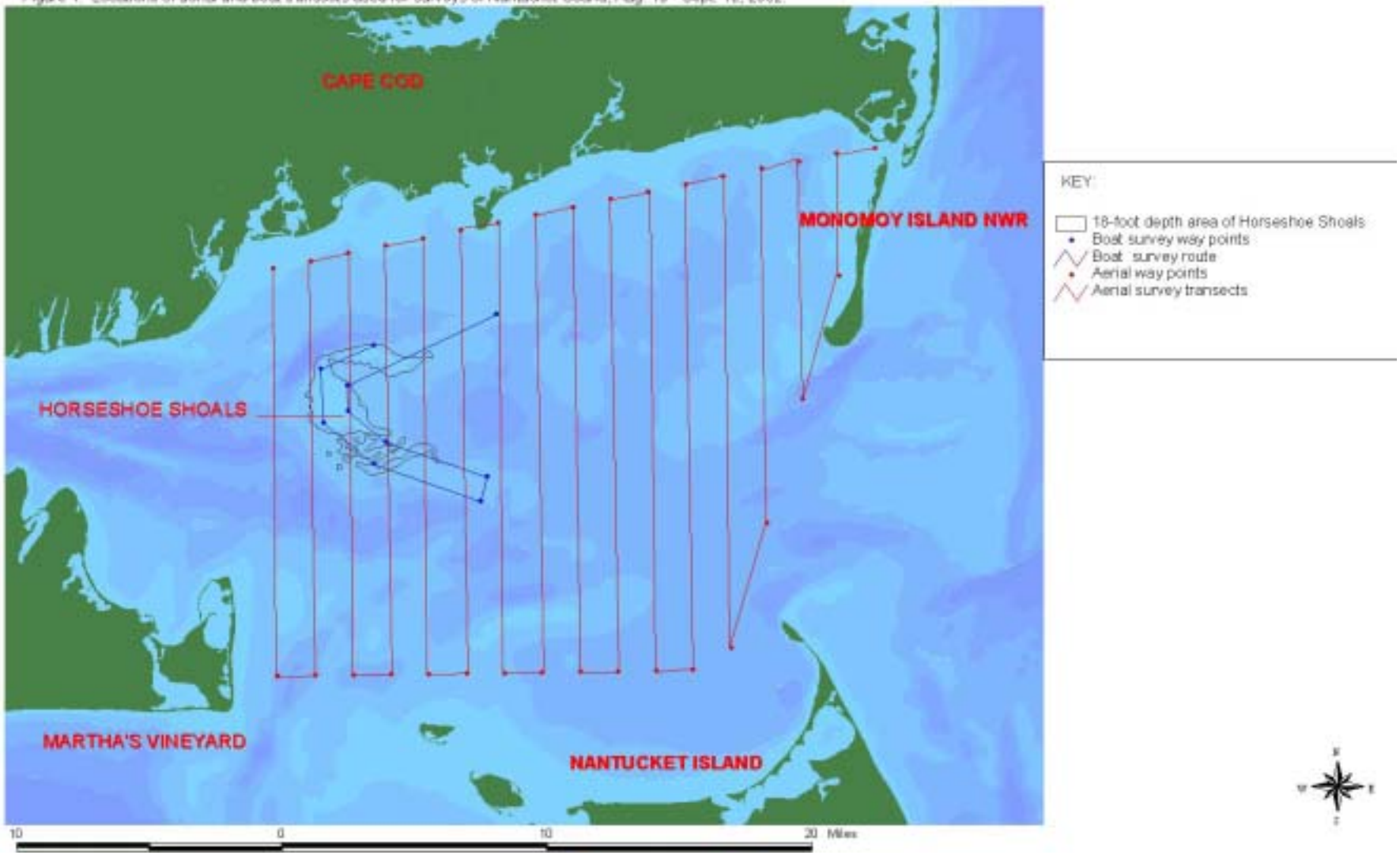


Figure 2. Total numbers of all terns counted during aerial surveys over Nantucket Sound, Aug. 19 – Sept. 19, 2002.

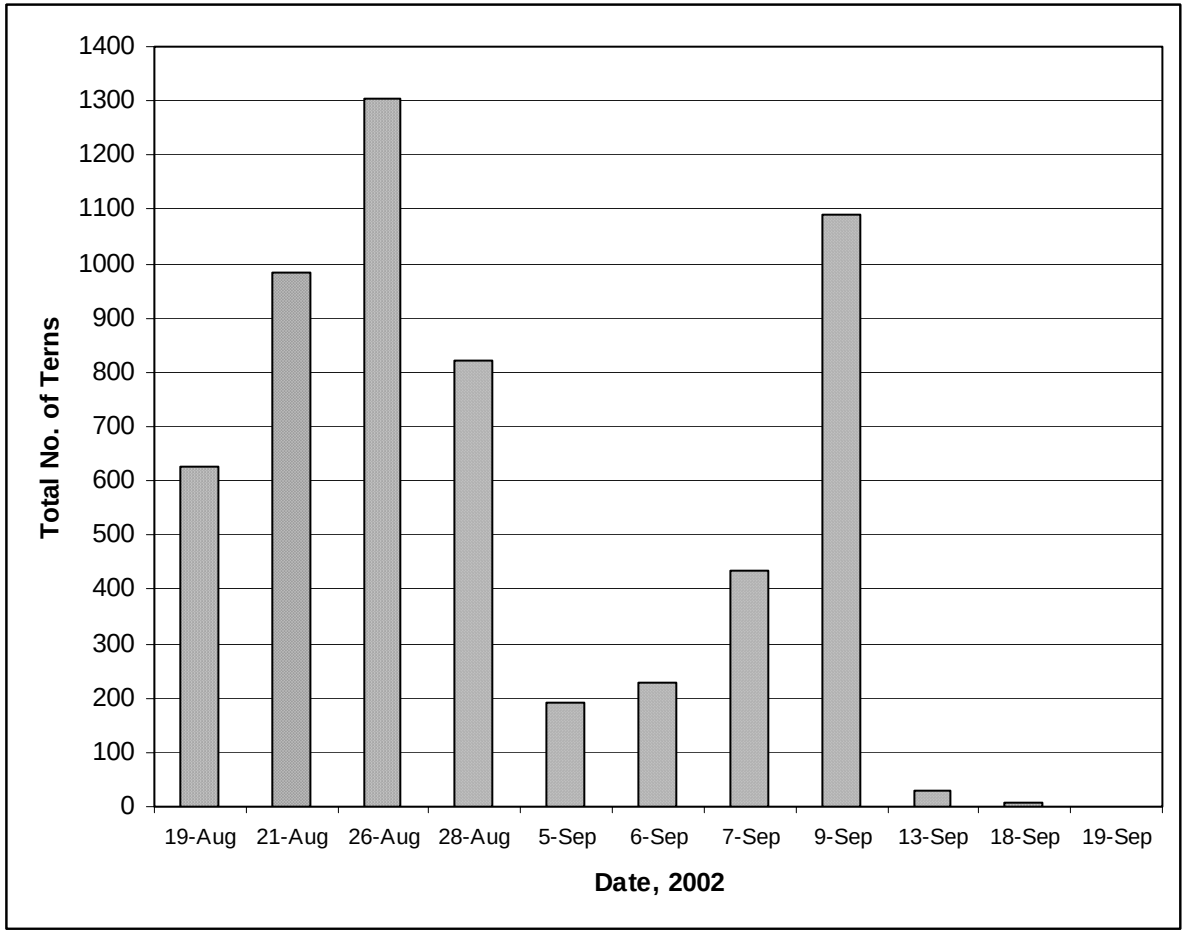


Figure 3. Total numbers of Common/Roseate type terns, Roseate Terns, and Least Terns counted during aerial surveys over Nantucket Sound, Aug. 19 – Sept. 19, 2002.

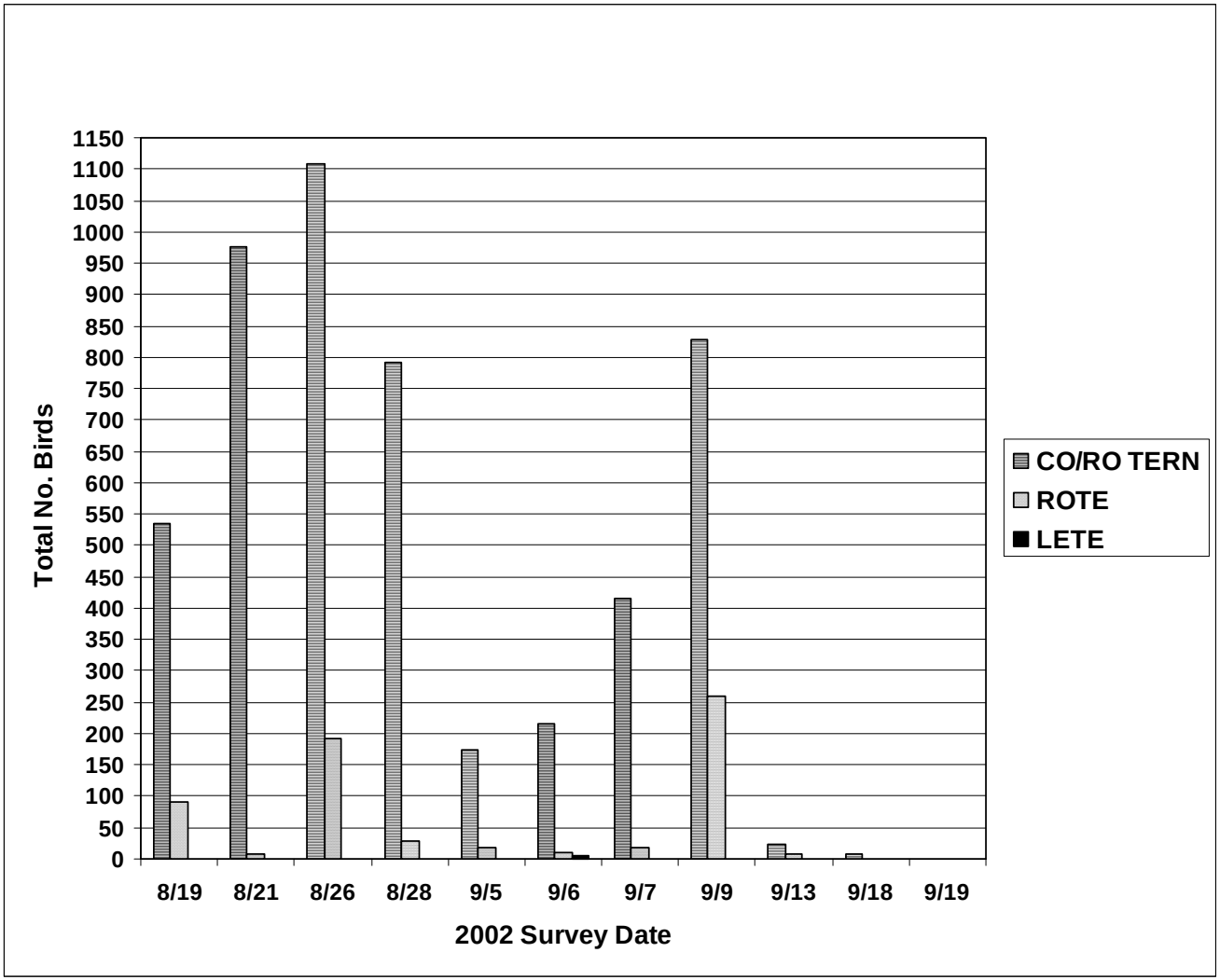


Figure 4. Total number of terns counted across each aerial transect line within Nantucket Sound on 11 survey days, from Aug. 19 – Sept. 19, 2002.

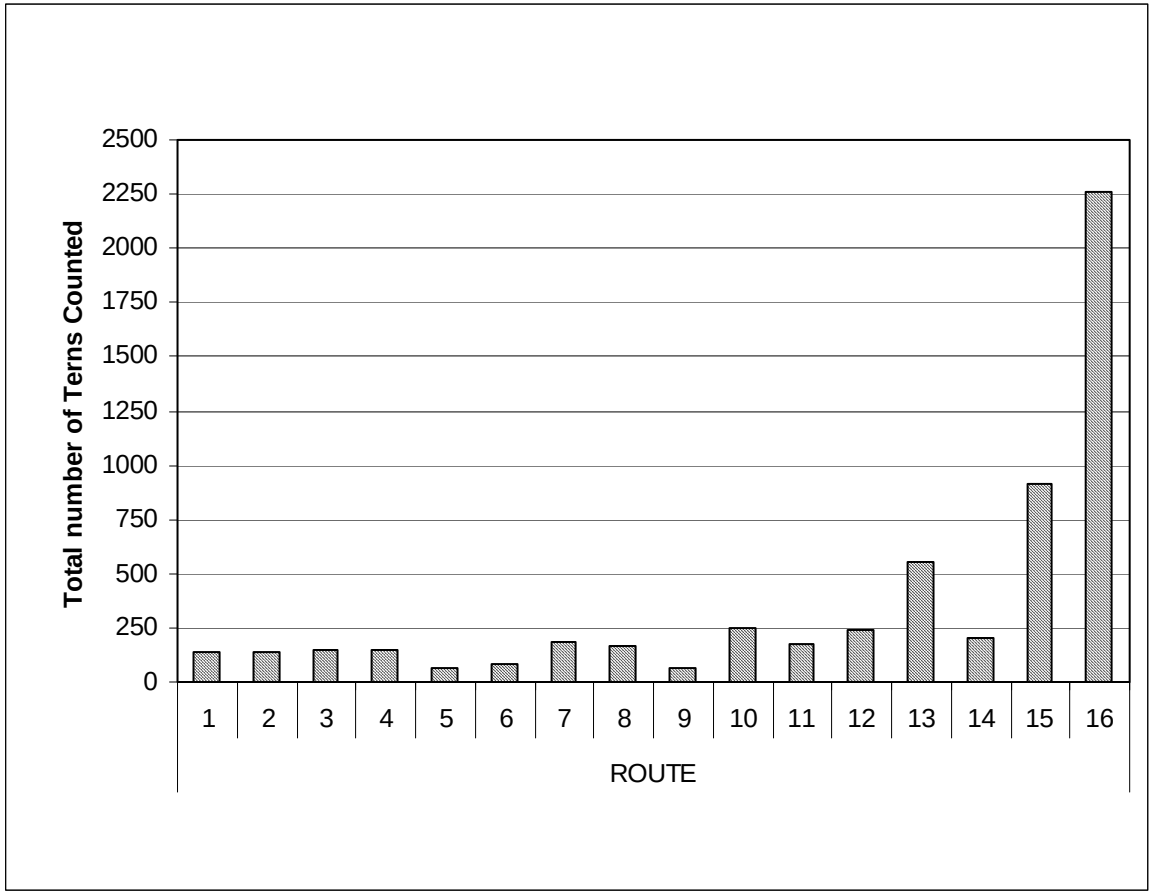


Figure 5. Number of terns counted on each aerial transect over Nantucket Sound, by date, from Aug. 19 – Sept. 19, 2002.

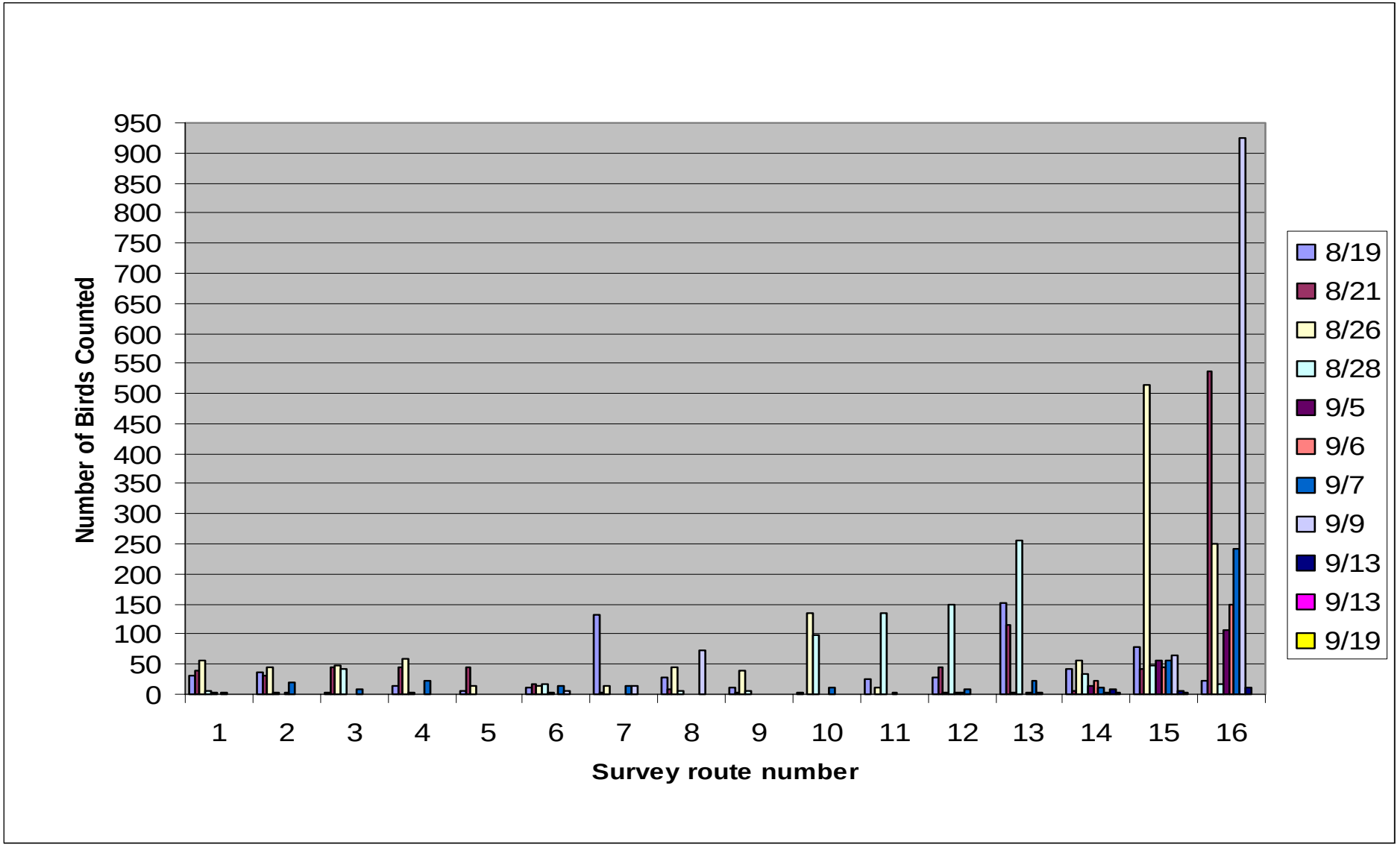


Figure 6. Numbers, dates, and locations of Common Terns observed during aerial surveys of Nantucket Sound, Aug. 19 - Sept. 19, 2002.

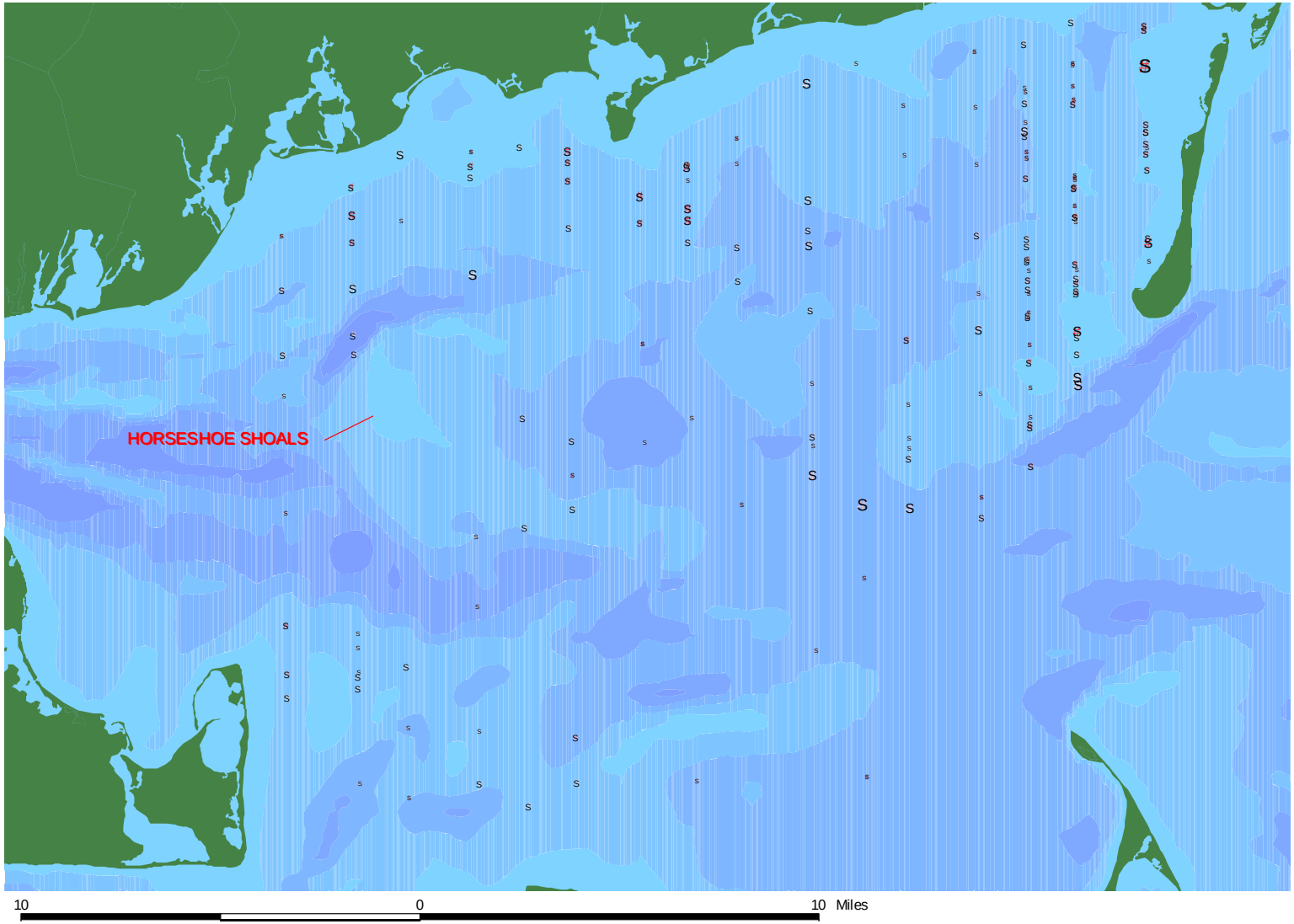


Figure 7. Locations, numbers, and dates of Roseate Tern sightings during aerial surveys of Nantucket Sound, Aug. 19 - Sept. 19, 2002.

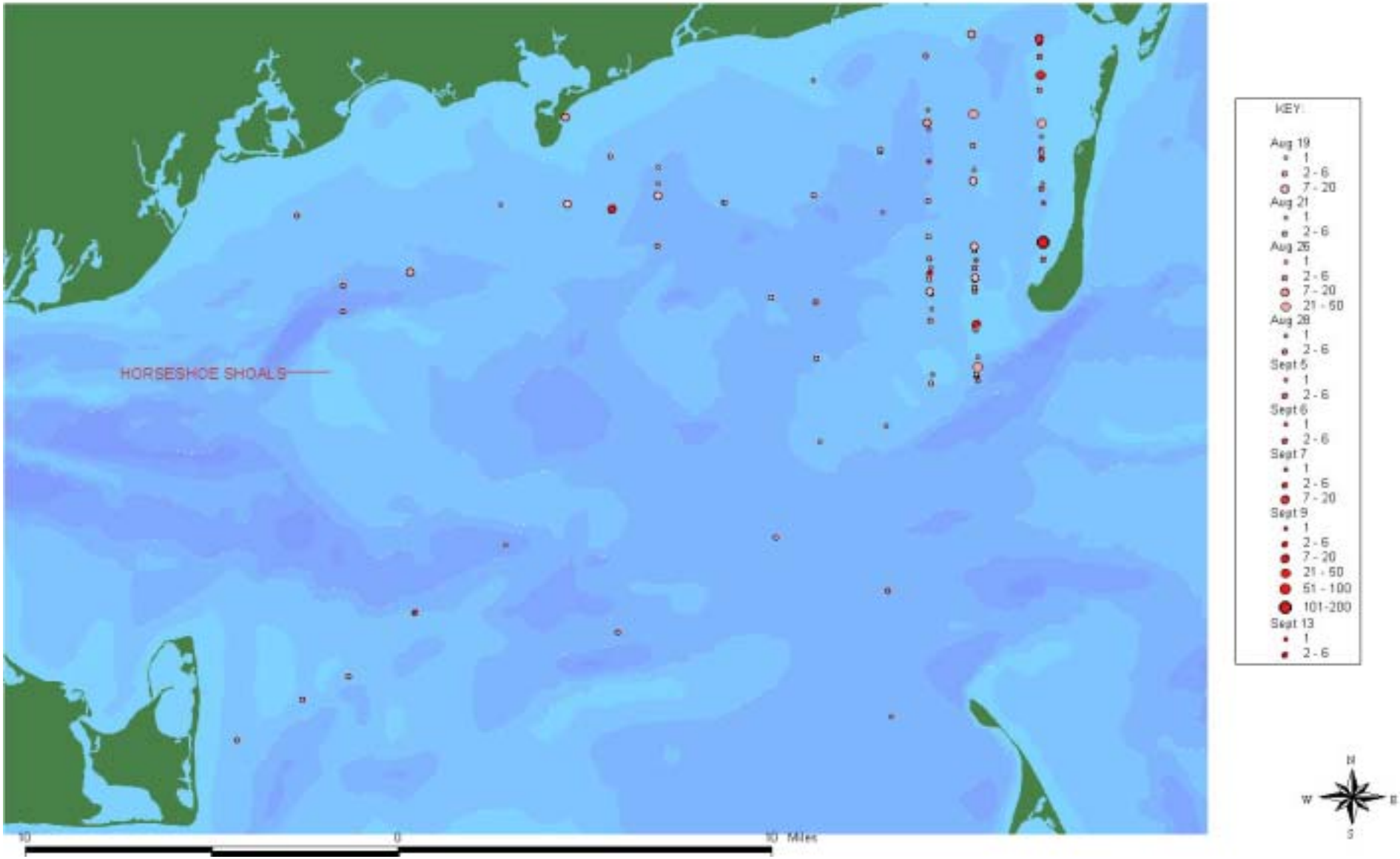


Figure 8. Numbers, dates, and locations of Common/Roseate type terns observed during aerial surveys of Nantucket Sound, Aug. 19 - Sept. 19, 2002.

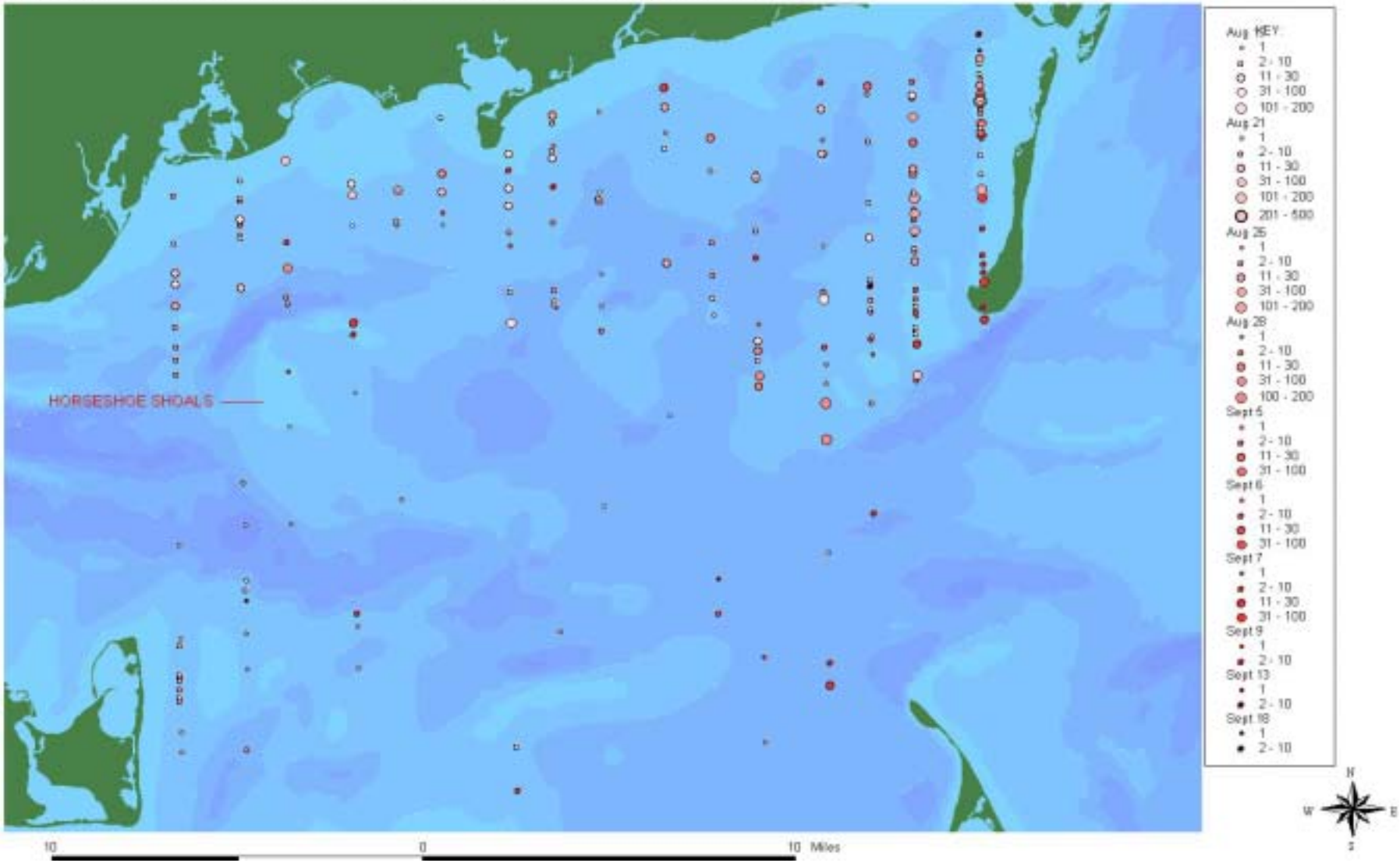


Figure 9. Numbers, dates, and locations of Least Terns observed during aerial surveys of Nantucket Sound, Aug. 19 - Sept. 19, 2002.

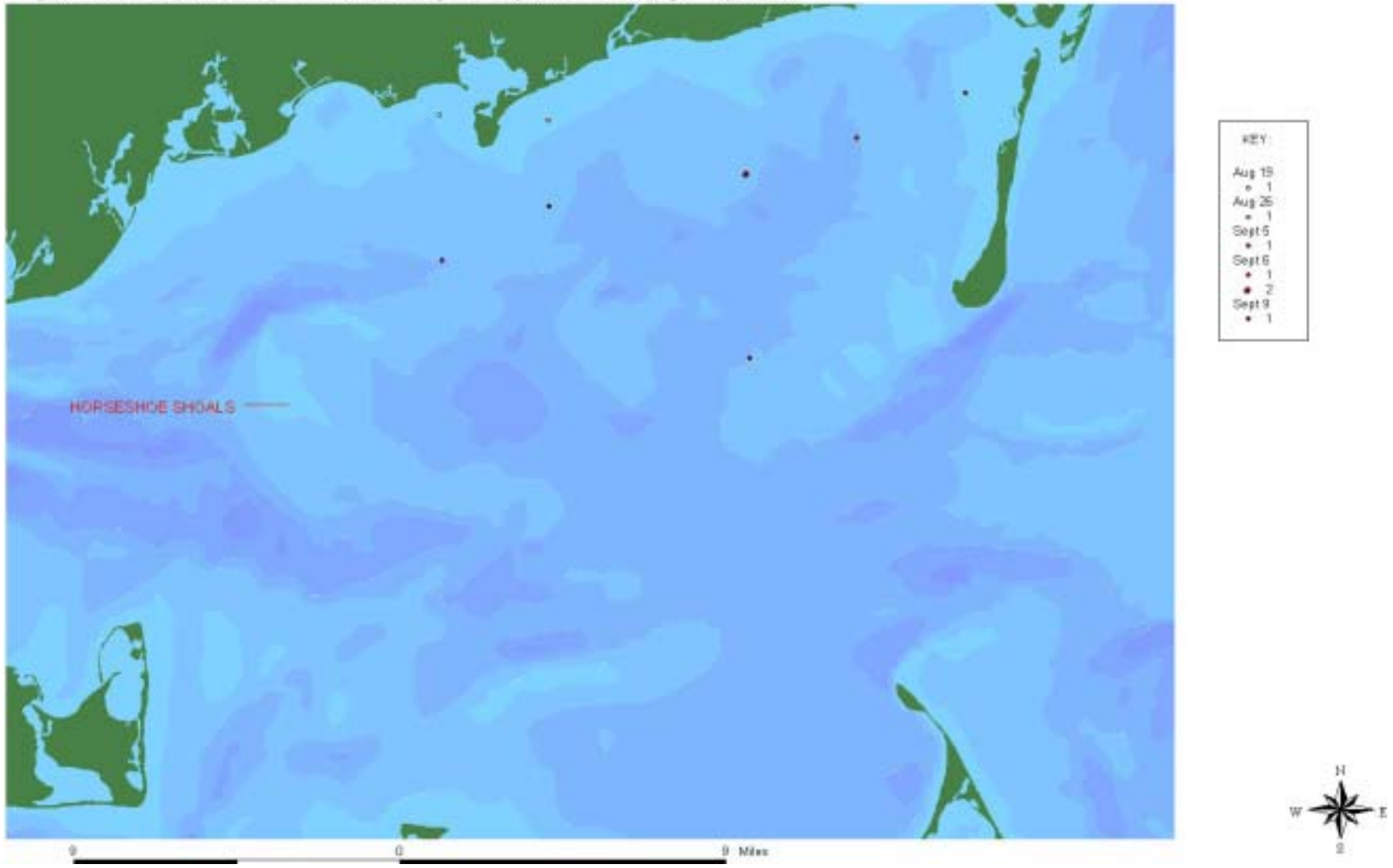
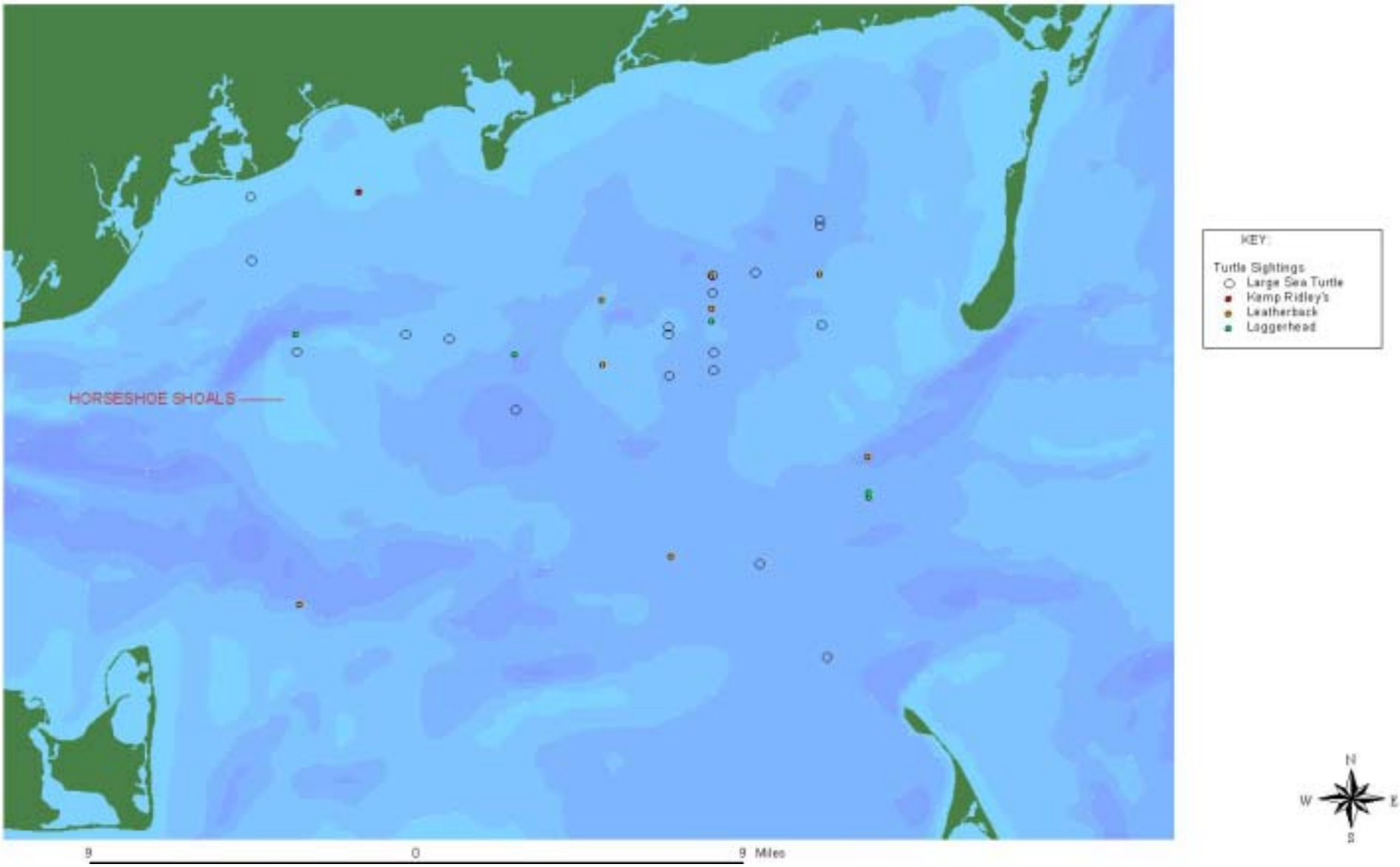


Figure 10. Locations of sea turtle sightings during aerial surveys of Nantucket Sound, Aug. 19 - Sept. 19, 2002.



A SURVEY OF TERN ACTIVITY WITHIN NANTUCKET SOUND, MASSACHUSETTS, DURING THE 2003 BREEDING SEASON

Final Report for Massachusetts Technology Collaborative

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INTRODUCTION

A proposed wind farm on Horseshoe Shoals in Nantucket Sound, Massachusetts, 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 Shoals. 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. Color-banding studies have demonstrated that the Roseate Terns that stage in Chatham come from colonies throughout the northeastern United States and Canadian Maritimes 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). 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 resumed systematic tern surveys of the Sound that we initiated in August 2002 during the pre-migratory staging period. Between May 15 and July 31, 2003, we conducted 13 boat surveys on Horseshoe Shoals and three aerial surveys across a broader area within a designated flight grid over Nantucket Sound (see Figure 1). We had planned to conduct our first surveys in the first week of May, but our involvement with emergency cleanup efforts relating to a late-April oil spill in and around Buzzards Bay delayed the start of our surveys. The boat surveys were designed to assess the use of the Shoals by newly arrived migrant terns and resident terns foraging from their colonies. The three aerial surveys provided an overview of the distribution of the terns within the sample area of Nantucket Sound on a given day.

Our specific objectives were:

1) To estimate the abundance and distribution of Common and Roseate terns on Horseshoe Shoals within the breeding season
2) To observe the behaviors of the terns (e.g., traveling, feeding, resting) on Horseshoe Shoals
3) To determine the heights at which the birds were flying, and
4) To detect any temporal variation in these parameters.

The timing of these surveys was based on the known average arrival dates of terns returning to Massachusetts from their wintering quarters at the beginning of the breeding season (late April - early May), and the known dates at which both adults and juvenile birds begin to disperse from the colonies at the end of the breeding season (late July-early August) (Gochfeld et. al. 1998).

METHODS

Tern behavior, distribution, and abundance on Horseshoe Shoals were estimated primarily using boat surveys supplemented by three aerial surveys. In general, our methods, described below, were identical to the protocols developed for our first survey of terns during the 2002 pre-migratory staging period (Perkins, et al. 2002), 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 counted during the surveys.

1. Defined transect width for aerial surveys

As part of our methods during aerial surveys in 2002, we counted all birds visible to the naked eye or with the aid of binoculars along each transect. In 2003, we strictly defined the transect width as 600 feet, 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. This approximated the lower one-third of the visible water surface along a vertical field of view (Figure 2).

Criteria used for the selection of transect width 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.

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 Glenn Ford Consulting, Inc., Portland, OR, which was designed specifically for aerial and boat surveys of waterbirds. The program automatically recorded latitude and longitude generated from an onboard GPS unit, and enabled us to record species and their numbers using one- or two-key species codes. This significantly reduced the recording time for each data point and increased the accuracy of the location of each sighting.

In addition to these two modifications, we were more selective about weather conditions: we conducted boat and plane 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.

Boat surveys

We conducted 13 boat surveys along a series of transects oriented in two parallel tracks, one mile apart. The positions of these transects were selected to sample all the waters over Horseshoe Shoals as well as the waters in the immediate vicinity of the Shoals (see Figure 1). For the purposes of this study, we defined the Shoals as the area described by the 20-ft bathymetry line. 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 the boat transects was 24.9 miles.

The survey teams consisted of two observers and one recorder. Data collected included numbers of birds seen by species, behavior (traveling, feeding, or sitting), their 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. The recorder immediately entered this information onto a laptop computer; geographical location of each observation was automatically logged by the computer program (dLog). 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 to confirm identification to species as needed.

Common and Roseate Terns were distinguished by their different flight behaviors, shapes, and plumage characteristics. We recorded all birds to species whenever possible, but it was not always possible to differentiate between Roseate and Common terns. When we could not determine with certainty whether the bird was a Roseate or Common tern we placed the sighting in a separate category of Tern species.

Aerial Surveys

Three aerial surveys were conducted along sixteen fixed, parallel transects oriented north to south. The sample grid comprised approximately 70 percent of Nantucket Sound; the transects extended from points just seaward of the south shore of Cape Cod, southward to an east-west line roughly even with Great Point, Nantucket (Figure 1). Individual transects were separated 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, and the mean length of all sixteen transects was 15.4 miles (Figure 1). The actual sample area, defined by the width

of the transects (600 feet) times their combined length (247 miles) equaled 28 square miles comprising approximately 6 percent of the area of Nantucket Sound.

Aerial surveys were flown with a high-winged, twin-engine aircraft (Cessna Sky Master 337) cruising at an average 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). Flights usually began mid morning, and the average duration of each survey was roughly 2.5 hrs. We recorded birds seen along or on either side of 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 needed. We did not count any species observed while we were flying the short, east-west legs between transects. Roseate and Common Tern sightings were treated as described for the boat surveys. Observations of non-avian species, such as sea turtles, were also recorded.

Each 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. Data were recorded using 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, visibility, and cloud cover for each transect on every survey. Surveys were conducted over a wide range of tidal stages.

RESULTS

Boat surveys

Thirteen boat surveys were conducted on Horseshoe Shoals between May 15 and July 31. A cumulative total of 250 terns were observed on the Shoals (Table 1), and terns were recorded on all but four surveys (June 18 and 25, and July 29 and 31 (Table 1, Figure 3). Of the terns seen on all nine surveys, 134 (53.6%) were traveling, 88 (35.2%) were actively feeding, and 28 (11.2%) were resting on the sea surface (Table 2). The altitude range of all traveling terns was between 5 and 250 feet (Figure 4) with an average height of 29 ft (SD=31, median = 25). The lowest point of the turbine rotors above the water surface would be approximately 70 feet (Jeff Burm, *personal communication*); over 90% of traveling terns were flying lower than 70 feet.

Over the course of the entire survey period, terns were generally distributed throughout the entire Shoal area, although more were observed in the southern portions (Figure 5). Twelve non-tern species of birds, including three species of land birds (all swallows), were recorded during the boat surveys (Table 3).

Wind speed during all boat surveys did not exceed 15 knots except on May 29, when it gusted occasionally to 20 knots. Sea states (Beaufort Scale) ranged between 0 and 5. As in all of our surveys, we did not attempt to control for tidal variation during the boat surveys.

Aerial Surveys

Three aerial surveys were conducted on June 3, July 14, and July 30. Terns were recorded on all three surveys. We observed 680 terns comprising 472 Common Terns, nine Roseate Terns, and 199 Common-Roseate-type terns, i.e., Tern species (see Methods for detail) (Table 4). Three hundred and seventy terns were recorded on July 14; 281 birds were recorded on June 3; and on July 30, the last aerial survey, only 29 terns were observed. During the survey period, sea state conditions never exceeded 3 on the Beaufort scale.

Seventy-eight percent of the terns observed on aerial surveys were recorded in the northeastern quadrant of the survey area. Specifically, 66.3% of all terns were recorded along transects 14-16, near Monomoy Island, and 54.9% of birds were seen along transect 16 alone; 33.7% were counted within transects 1-13. Only seven terns (1.0%) were observed directly over Horseshoe Shoals (see Figure 6).

Of the four hundred and seventy two Common Terns counted during the three aerial surveys 63.3% of the terns were feeding, 35.4% were traveling, and 1.3% were sitting on the water. Of the nine Roseate Terns counted during aerial surveys, three were observed actively fishing and six were traveling. Of the 199 Tern species counted, 67.8% were feeding, 31.7% were traveling, and 0.5% were resting (Table 4).

DISCUSSION

Three species of terns were observed within the area described by Horseshoe Shoals. Two sets of data lend themselves to assessing the specific nature of these observations: Figure 3 indicates that the highest numbers of birds on the Shoals were recorded by boat early in the survey period, and that tern abundance decreased thereafter, with the exception of one peak in late July. Table 2 reveals that most of the birds observed on the Shoals were traveling versus fishing or sitting. Although the data are limited, we hypothesize that the majority of terns observed on the Shoals were either passage migrants moving through these waters to breeding colonies farther north and east, and/or recently returned Massachusetts breeding residents.

It was surprising to find terns occasionally sitting ("rafting") on the water over Horseshoe Shoals during the boat surveys. When they are within close proximity to their colonies in Massachusetts, terns rarely alight on the water (Ian Nisbet, *personal communication*). Possible explanations for these observations include that these birds were resting migrants that eventually continued their northward migration, or that the terns were recently arrived local breeders that were resting on the water. Rafting

behavior was most prevalent early in the breeding season, at a time when many terns were just arriving back into local waters.

The slightly higher numbers of birds recorded on the southern half of the Shoals during the boat surveys may have reflected the stronger currents that typically flow across the southern half of the Shoals (Len Greiner, *personal communication*). Stronger currents create stronger upwelling, and areas of upwelling often bring plankton and baitfish near the surface within capture range of the feeding terns.

During the three plane surveys, the greatest numbers of terns were found near Monomoy Island NWR. This is not surprising given that, in 2003, the Monomoy colony contained roughly 63 percent of all the breeding Common Terns in Massachusetts (approximately 10,000 pairs). This distributional pattern also may have been due to the terns' preference for foraging in Nantucket Sound's shallow margins, especially near Monomoy, where the feeding conditions are especially favorable.

The data from this year's boat and aerial surveys suggest the hypothesis that Horseshoe Shoals is more important as a migratory stopover point or "refueling" area for terns than as a feeding area for locally nesting resident terns. This hypothesis cannot be tested fully without marking and tracking individual terns. We plan additional surveys in 2004 and will begin our boat surveys earlier. Beginning our surveys at an earlier date may provide additional information on the use of Horseshoe Shoals by migratory terns. We also will increase the number of aerial surveys. A second year of surveys will help us determine whether our observations this past breeding season are consistent from year to year, or if there is a shift in local distribution or abundance of terns based on availability of food or other factors.

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Table 1: Terns observed during the 2003 breeding season boat surveys on Horseshoe Shoals by date.

Date	Common Tern	Roseate Tern	Tern Sp.	ALL TERNS
15-May-03	37	0	53	90
22-May-03	49	0	6	55
29-May-03	45	1	6	52
5-Jun-03	15	0	2	17
11-Jun-03	3	0	0	3
18-Jun-03	0	0	0	0
25-Jun-03	0	0	0	0
2-Jul-03	0	2	0	2
10-Jul-03	2	0	2	4
17-Jul-03	1	0	0	1
28-Jul-03	20	5	1	26
29-Jul-03	0	0	0	0
31-Jul-03	0	0	0	0
Totals	172	8	70	250

Table 2: Frequency of behavior of terns observed during 2003 breeding season boat surveys on Horseshoe Shoals, Nantucket Sound. Vessel refers to birds observed following a fishing boat.

Species	**FEEDING**	**SITTING**	**TRAVELING**	**VESSEL**
Common Tern	24.4%	13.4%	62.2%	0%
Roseate Tern	0%	0%	100.0%	0%
Tern species	64.3%	7.1%	27.1%	1.4%
All Terns	35.2%	11.2%	53.6%	

Table 3: Non-tern bird species and numbers observed during 2003 breeding season boat surveys on Horseshoe Shoals, Nantucket Sound.

Species	**Number**
Red-throated Loon	4
Common Loon	44
Wilson's Storm-Petrel	20
Northern Gannet	7
Double-crested Cormorant	19
White-winged Scoter	35
Laughing Gull	1
Herring Gull	36
Great Black-backed Gull	142
Gull species	10
Tree Swallow	1
Purple Martin	1
Barn Swallow	2
Total	322

Table 4. Bird species and numbers observed during 2003 breeding season aerial surveys over Nantucket Sound (3 flights: 6/3, 7/14, 7/30).

Species	Number
Common Loon	32
Wilson's Storm Petrel	1
Northern Gannet	1
Double-crested Cormorant	258
Laughing Gull	16
Herring Gull	84
Great Black-backed Gull	213
Gull species	56
Roseate Tern	9
Common Tern	472
Least Tern	2
Tern sp.	199

Figure 1. Nantucket Sound study area and associated features, including aerial and boat transect routes, and area of proposed wind farm, major tern colonies.

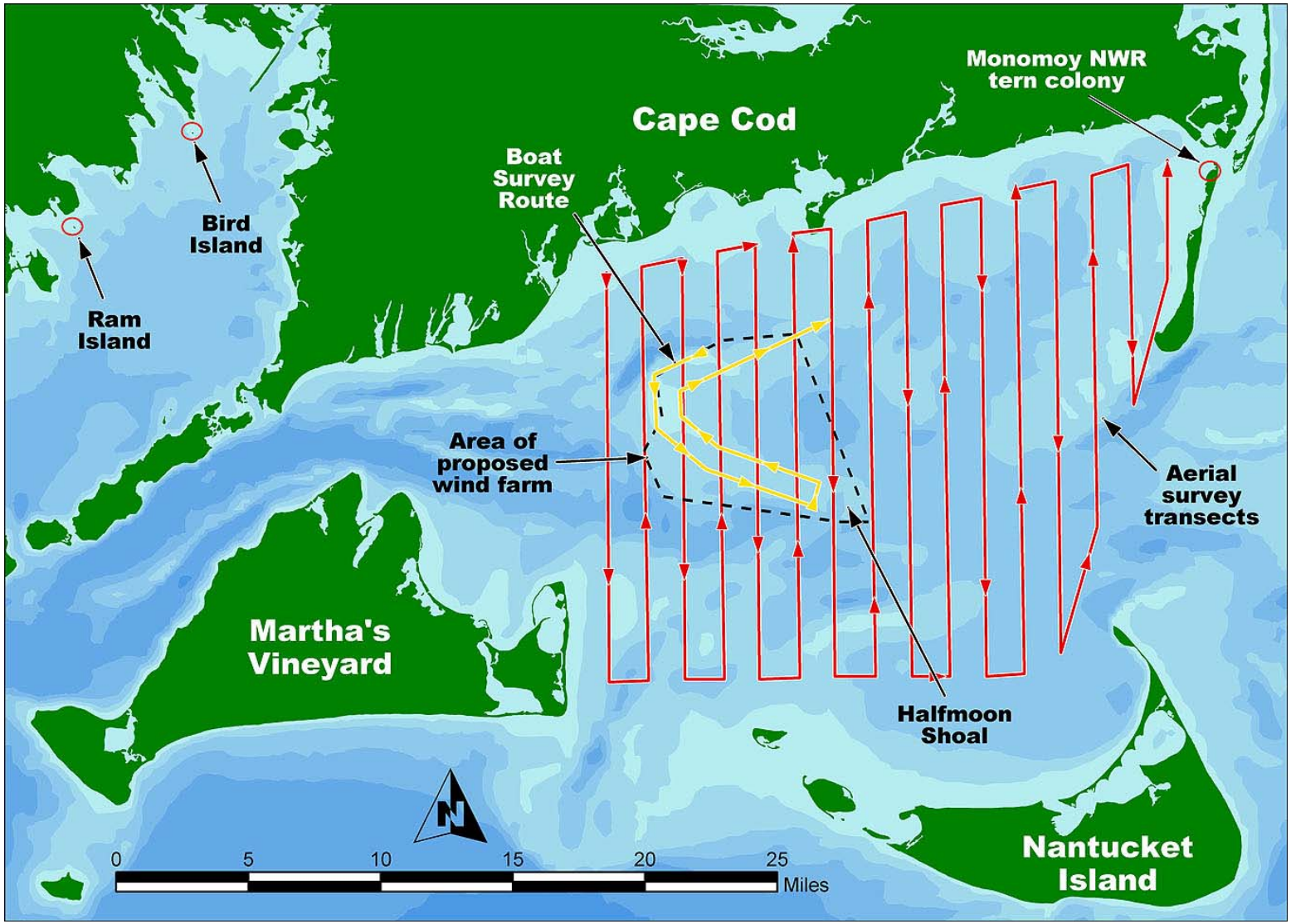

Figure 2. Viewing angles and distances used in aerial surveys.

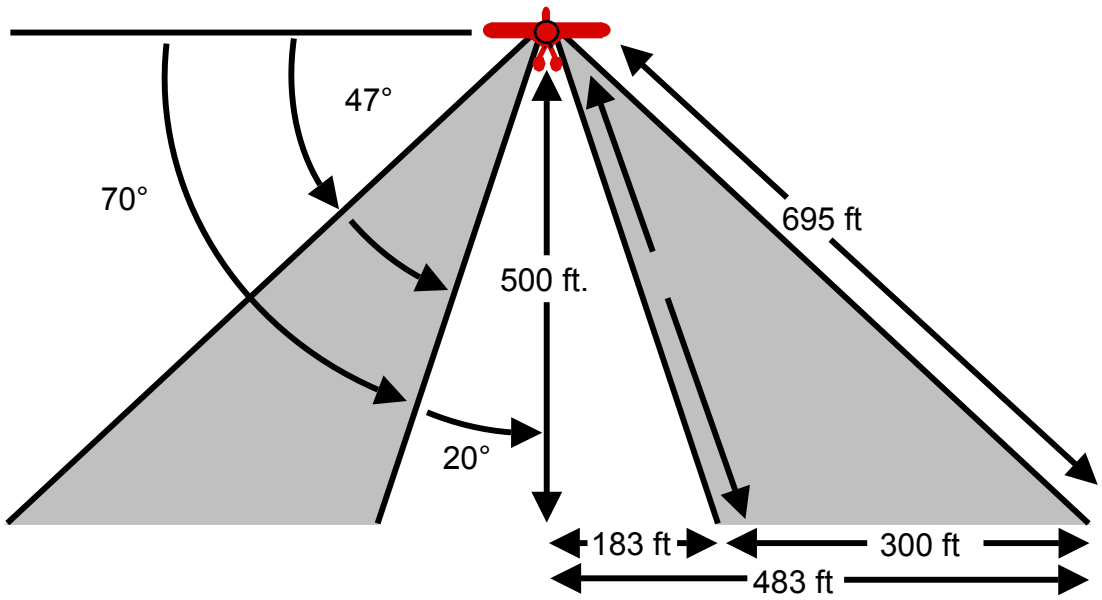

Figure 3. Total numbers of terns observed during 2003 breeding season boat surveys on Horseshoe Shoals, Nantucket Sound by date.

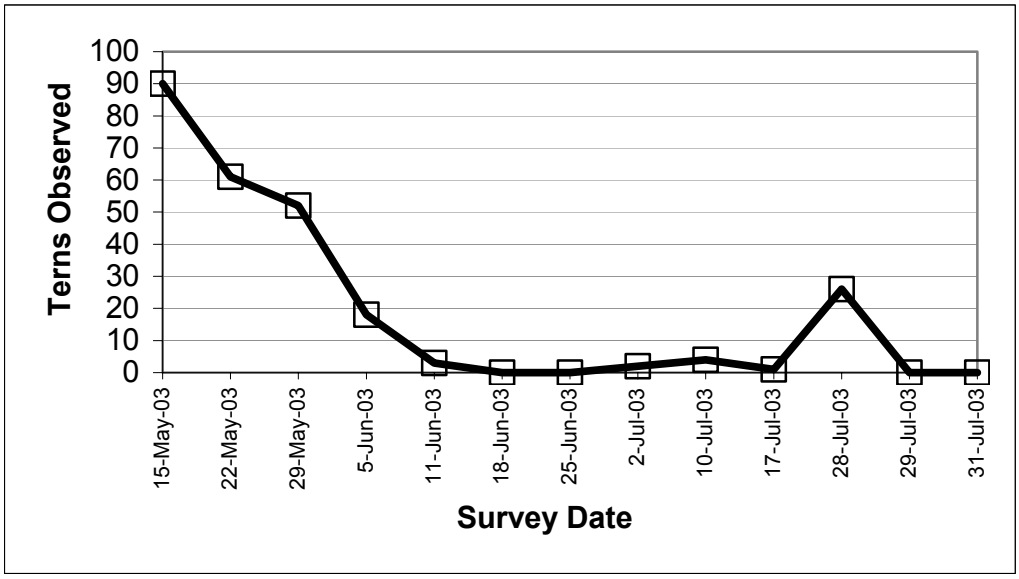

Figure 4. Frequency distribution of flight heights of terns (in feet) observed during 2003 breeding season boat surveys on Horseshoe Shoals, Nantucket Sound. Numbers are based on all surveys combined.

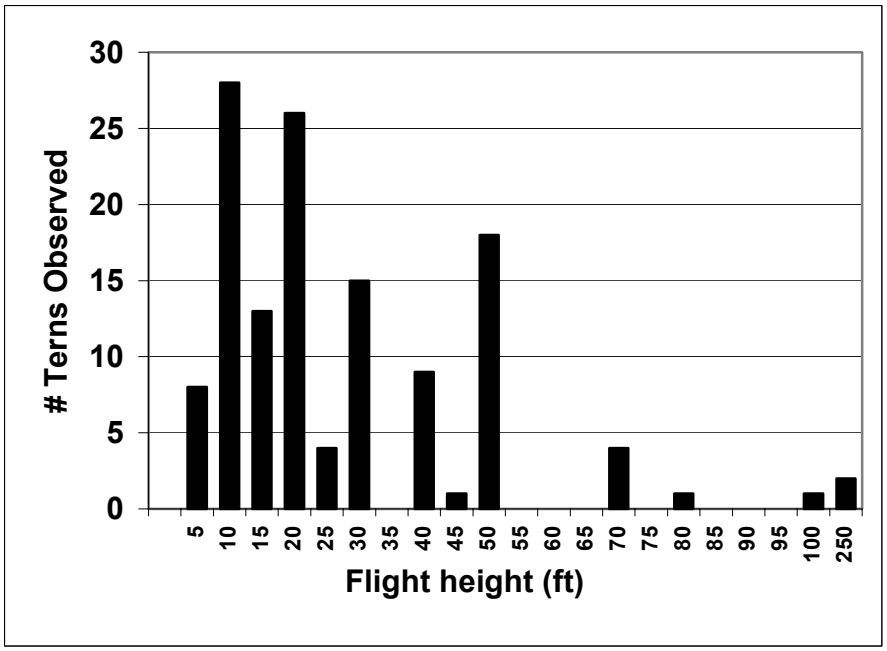

Figure 5. Distribution of tern sightings by species observed during 2003 boat surveys of Horseshoe Shoals, Nantucket Sound. Numbers of terns seen is indicated by the circle diameter and are based on all surveys combined.

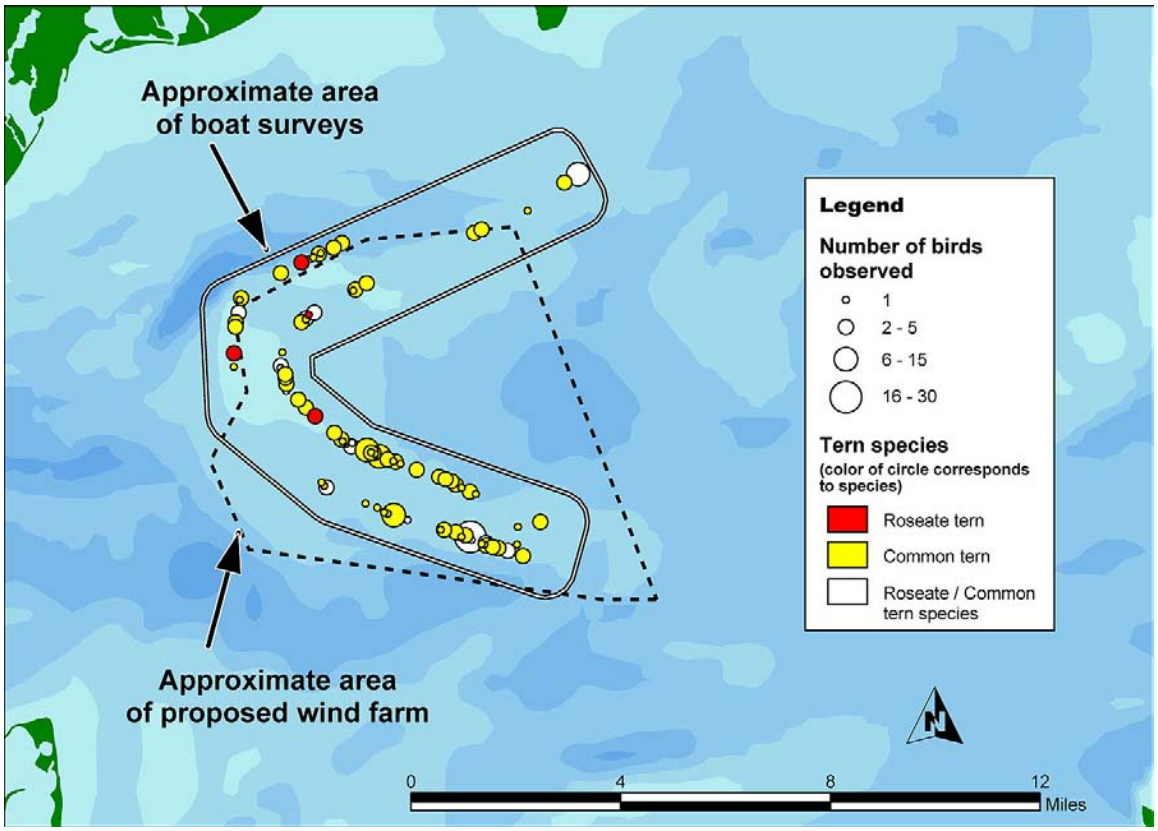

Figure 6. Summary distribution map of terns by species observed during 2003 breeding season aerial surveys of Nantucket Sound. Number of terns seen at any one location represents the combined total of three aerial surveys and the magnitude indicated by the diameter of the circle.