FINAL REPORT
South Carolina Wildlife Grant T-44-R-1
October 1, 2008—September 30, 2010

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TITLE: Least tern reproductive success on roof-tops

GRANT OBJECTIVES:

1. Determine how post-fledging survival and movements from rooftop sites compare to those at beach colonies.
2. Determine whether rooftop-nesting terns or their young accumulate larger amounts of chemical contaminants than beach-nesters and the effect such contaminants have on the health of the birds.
3. Gather other information on the biology of rooftop-nesting terns, especially information that may inform future management strategies.

SUMMARY:

We were unable to show any differences in post-fledging survival from rooftops and beaches, nor any differences in movements. However, widespread colony failures and persistent problems in radiotracking meant that we had limited data on movements and sometimes flawed measurements of survival, and from fewer sites than our original goals. We cannot say definitively that postfledging survival and movements differ or do not differ between the two types of colonies.

Eggs from all sites had few measurable chemical contaminants. In 2009 we tested 16 eggs for a wide variety of possible contaminants, and found no biologically significant levels of 20 pesticides or 20 polycyclic aromatic hydrocarbons, but some suggestion of possible high levels of some metal ions. We tested 35 eggs in 2010 to follow up on the first year results, and found measurable levels of Zn, Mn, Hg, Fe, and Cu, but no biologically significant contamination by heavy metals, and no clear pattern of variation that could be ascribed to the type of colony (roof or beach, saltwater or inland) an egg came from.

Nesting Least Terns fed locally. By salvaging discarded fish and radiotracking young birds, we showed that birds at a successful colony 20 km from the ocean relied on freshwater fish rather than commuting to brackish or saltwater sites. Birds using a rooftop 1.5 km from the beach and 4.5 km from the nearest part of a tidal inlet had a varied diet, with freshwater, brackish and saltwater fish all represented. Adults from the inland colony did not feed heavily at the closest water bodies to the colony, but used many (usually man-made) water bodies in the surrounding area. We tracked two young terns from that colony. Each commuted with its parents and

other adults to separate ponds about 6 km from the rooftop, returning repeatedly to those sites in the first week after they fledged.

Nest counts showed that colony occupancy and size in the Grand Strand region were dynamic rather than stable. There was a tendency for a decrease in the size of one colony to be associated with an increase in other nearby colonies. In the course of the study, we located several previously unknown rooftop nesting sites.

In a small sample of monitored rooftop nests, incubation patterns differed between a successful colony and several colonies where essentially no chicks fledged (though many may have hatched). The incubation patterns suggest that predation pressure, rather than weather or food, may have been the cause of whole-colony failures.

Acknowledgements

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We are grateful to Mary Catherine Martin and Mark Spinks for help in the field and to Richard Moore and Erin Burge for help with fish identification.

For facilitating access to tern colonies we thank Sara Dawsey at Cape Romain National Wildlife Refuge, Aaron Given and Jim Jordan at Kiawah, Kim Counts and Bess Kellett at Botany Bay Plantation, Bruce Fowler at the Myrtle Beach Post Office, Sam Gardner at Blue Cross/Blue Shield, Russ Smith at Springmaid Resort, and especially Kevin Brown at HGTC, as well as property owners and managers at all other rooftop sites. We are especially grateful to Gillian Brooks and her advisor Patrick Jodice for encouraging us to work alongside her at Middle White Banks in 2009.

Significant deviations: Objective one yielded limited data due to injuries incurred with transmitter attachment. Different techniques were explored in the second year with limited success resulting in a recommendation to conclude the study and not extend.

Estimated Federal Cost (grant level): $9,546

Recommendations: end grant.

Detailed Results of the Study

Study Sites

Although we counted nests at as many rooftop sites as we could locate (Fig. 1; we also participated in counts elsewhere in SC, not shown), and monitored activity at all Grand Strand colonies (by ground level checks), studies involving transmitters were limited to three sites: the roof of the 1100 building at Horry-Georgetown Technical Community College, Conway Campus (hereafter: Conway); an oyster shell island in Cape Romain National Wildlife Refuge, Middle White Banks; and the the rooftop of the offices of Blue Cross and Blue Shield in Surfside Beach (hereafter: Surfside).

Colonies Surveyed, Population Trends In Grand Strand Region

With the assistance of Mary Catherine Martin of the SCDNR, CEH and CCU graduate student Alex Kohorst located and when possible, counted nests at all known active colonies in Horry and Georgetown Counties. Counts were done during the normal egg peak in mid to late May. Three colonies were located too late in the summer of 2010 to count nests, but were active. One colony, active in both years, was only counted in 2010.

The total number of nests counted in 2009 was 476, with one known colony uncounted. In 2010, the total was 383, with three known colonies uncounted.

In comparing 2009 with counts from 6 and 7 years earlier, it appears that declines at several colonies (complete loss of Colonial Mall, temporary abandonment of Springmaid Resort, decline in numbers at Blue Cross/Blue Shield) corresponded to the rise in numbers at The Surfside Piggly Wiggly, which had an impressive 378 nests in 2009. (Although I know that site was counted before 2009, as I participated in one count with SCDNR there, I do not have the data. There were never as many as 378 nests there in past years, though). Likewise, the decline of the Surfside Piggly Wiggly colony from 378 to 211 nests from 2009-2010 coincides with the discovery of three previously unknown colonies (Advance Auto, MB Higher Ed. Center, Kroger Carolina Forest) and increases in nests at Horry-Georgetown Tech and Springmaid. Declines at one colony may be due to movement to other nearby colonies, which emphasizes the need for thorough coverage of as many colonies as possible if the goal is monitoring of overall population trends.

Colony Success

While we did not track nesting success of individual pairs, we did track colonies. At only three sites were we able to visit the rooftops even once during the late chick period, so most inferences of colony success had to be made from periodic (every 1-2 weeks) ground-level visits to colony sites. During these checks we were limited to noting presence or absence of adults and fledglings, and adult behaviors associated with courtship and breeding such as carrying fish. Since incubation takes 19-25 days and the normal time from hatching to dispersal is about 40 days, we considered colonies to have failed to produce any fledgelings if the colony was abandoned less than 50 days after the egg peak. For colonies that were active for at least 50 days, we noted presence of fledgelings and timing of colony desertion by adults. This method is of limited value – one can confirm failure of a colony (by early desertion) but confirmation of fledging success requires viewing flying young, which is difficult. Nonetheless, we report our best estimates of colony fate. It appeared that the Conway site at Horry-Georgetown Tech was the only rooftop in Horry or Georgetown County that fledged more more than a handful of young in 2009 or 2010 (it produced perhaps two dozen fledgelings each year). Middle White Banks was also very successful in 2009, though less so in 2010 (Gillian Brooks, pers. comm.). By contrast, the large colony at the Surfside Piggly Wiggly appeared to fail completely both years, the Blue Cross/Blue Shield Building likewise, as did the North Myrtle Beach Kroger in 2009. Our overall impression was of widespread rooftop colony failure both years, except at Conway.

Causes of Colony Failure: Incubation Data Showing Nocturnal Desertion Implicate Predators

In 2010 we deployed iButton temperature loggers encased in clay eggs in 20 nests at 5 rooftop Least Tern colonies, and also deployed an additional 20 loggers to record ambient temperatures in sun and in shade, on 6 rooftops and at two beach colonies. We recovered only 16 of these 40 loggers, and obtained data from only 12 of the 16, with six of those providing good data from nests. Despite the low recovery rate of loggers, the data suggested consistently different incubation behavior at the successful Conway colony when compared with less successful rooftops. Both Conway birds (Fig. 2) incubated continuously for the duration of recording (about 10 days), each maintaining nest temperatures within a range of 32-37°C, except for very brief drops probably associated with heavy rains on May 23. In contrast, all loggers from 3 unsuccessful colonies (Figs. 3 and 4) showed repeated abandonment of eggs for periods of up to 8 hours, always during the night, during which time the nest cooled to between 14 and 20° C. Overnight nest desertion is known to occur in other species of terns in response to predation threats (Nisbet and Welton 1984; Nisbet 2002), particularly if the predator (e.g., an owl) is capable of killing adults as well as young and eggs. The correlation of consistent, frequent and lengthy nighttime abandonment of nests with colony-wide failure of nests suggests predators as a likely explanation.

Transmitters

Over the two years of the study, we equipped 32 least terns with 1.05g radio transmitters with 15 cm whip antennas (14 at White Banks and 14 at Conway in 2009, 3 at Conway and one at Surfside in 2010). In 2009 we mounted transmitters to USFWS aluminum bands and applied the band to the tibiotarsus of chicks whose estimated age was 12-19 days (16.7 ± 2.0, mean ± SD). Transmitter-caused leg injuries caused us to remove 5 of the transmitters and consider different mounting strategies for 2010. In 2010, we attempted to attach transmitters to terns that were older: fledged or on the verge of fledging (25 days or older), and we used three mounting methods: 1) the same as in 2009; 2) band-mounted as in 2009, but with the whip antenna trimmed to 10 cm, and 3) glue on transmitters attached above the synsacrum with epoxy. Capture success in 2010 was low. In limited observations, we observed no band-related injuries or handicaps in 2010.

Transmittered birds were tracked by two methods. At Conway in 2009 and 2010 and at Middle White Banks in 2009 we deployed stationary recording receivers (ATS Model R4500S; atstrack.com) with dipole antennas. These recorded presence or absence of transmittered terns at the nesting colonies throughout the nesting season. Away from colonies, we tracked terns on foot, by car and by boat, using handheld receivers (Communications Specialists model R1000) and 5-element Yagi antennas. For one attempt to track terns from an airplane we used two strut-mounted yagi antennas connected to an R4500S receiver.

Transmitter range was low, usually 0.5 km or less, even from the airplane. Essentially, terns that flew out of sight left telemetry range within about one minute. Terns could be followed by taking a bearing on a tern flying out of range, then driving in that direction to intercept the projected flight path, as roads allowed. Two observers could sometimes leapfrog this way and track a tern 1-3 km from the nesting colony. Occasionally, terns could be located by systematic searches away from the colony, particularly by extending searches along a previously documented directional morning flightline away from the colony, but normally that strategy, whether on land near Conway or by boat near Middle White Banks, located at most one tern per day of effort.

Survival of Transmittered Chicks

In 2009, we confirmed fledging of 6 of 13 (46%) transmittered chicks at the rooftop site in Conway, all of which we recorded coming and going from the colony from 5 to (exceptionally) 10 days (6.2 ± 2.2, mean ± SD; Fig. 5) after they first flew well enough to get out of transmitter range. This behavioral pattern corresponds with what has been observed in a study of the period from fledging to dispersal in Forster's Terns (Ackerman et al. 2009) . The other transmittered chicks apparently all died before or immediately after fledging (date of death was often apparent from cycling of transmitter pulse frequency with temperature; data not shown). We recovered the remains of three transmittered chicks, all of which were in landscaped sites at the base of the two-story building on which they had been hatched. One had had its wing feathers sheared, apparently by a weed-trimmer (possibly after death). Another was recovered from wood-chip mulch in a daycare playground. The third was recovered from within a brick planter with a 20 cm raised lip and thick plantings, which might have offered limited ability for a young tern to escape.

In 2009 at the shell island site, Middle White Banks, we confirmed fledging of 4 of 10 (40%) transmittered chicks. Those chicks also continued to come and go from the nesting colony from 4-15 days (7.5 ± 5.1, mean ± SD). Although signals from two dead chicks persisted for a while at White Banks, we were unable to recover the remains of those or any of the other dead chicks at Middle White Banks.

In 2010, at least one and probably two of three chicks successfully fledged at Conway and the only chick transmittered at Surfside also fledged. One transmittered chick at Conway gradually became independent of the colony according to the usual pattern (as in Fig. 5; see account below). A second, captured by mist-net when already capable of flight, disappeared immediately after transmitter attachment. We think it likely with the second bird that we caught an older fledgeling who was near dispersal age and thus missed the usual transitional period of fledging. We recovered the transmitter from one chick (but no carcass) in 10 cm of water at the edge of a detention pond 130 m from the nesting roof.

Survival rates did not differ significantly between sites and years, and the possibility of an effect of transmitters on survival suggests caution in drawing conclusions from what data we did gather.

Movement of Transmittered Fledgelings

Characteristically, upon achieving flight, young terns began a transitional period during which they left the colony for most of the day, often leaving at dawn, but returned to sleep at the colony at night (Fig. 5). We tracked two terns from the rooftop colony in Conway to freshwater ponds during this transitional period. Each of those ponds was 6.0 km from the colony site (one North, one West). Each young tern returned on multiple days to the same pond, and was fed there by adults, presumably its parents. At one pond, a 4 ha water hazard on a golf course, we observed about 8 terns including 6 adults and 2 fledgelings. At the other, a 12 ha manmade lake at a new housing development, we observed as many as 24 terns, including as many as 6 fledgelings. At each site terns alternated between foraging and loafing on a bridge (at the golf course pond), or a road and the roof peak of an unoccupied house (at the development).

Near Middle White Banks, we located one transmittered tern away from the colony, in tidal marsh habitat between the Intracoastal Waterway and the McClellanville mainland. We inferred from changes in the strength of the radio signal that the bird was flying, but could not approach by boat close enough to make any behavioral observations. That tern, as well, was site-faithful, as we located it in the same place three times during a 5 hour radiotracking survey.

Resource Use

Based on dropped fish recovered from the rooftop, terns at the Conway colony fed on freshwater fish (Table 2). Conway terns were also observed bringing many (freshwater) mosquitofish (*Gambusia affinis*) to feed their chicks. Fish recovered from rooftops within 3 km of salt water (Table 3) indicated a mixed diet of fresh, brackish and marine (surf) fish. Although the differing diet at Conway might seem unsurprising, some terns are known long-distance commuters (Gochfield et al. 1998) and Least Terns have been observed 60 miles off the SC coast in June (P. Jodice, pers. comm.). One could imagine terns nesting at a site 20 km from the coast commuting to more brackish or saltwater to feed. These recovered fish, however, as well as incidental observations of foraging adults and tracking to sites where young terns were fed by parents, suggest that area exploited by a colony is largely local, perhaps mostly within a 5-10 km radius.

The more than 8,000 stormwater detention ponds in the coastal plain of South Carolina (Siewicki et al. 2007), many of which contain abundant small fish, such as *G. affinis*, may provide a resource unavailable to Least Terns before widespread landscape alterations in the 20th and 21st centuries.

Chemical Contaminants

We collected 16 Least Tern eggs in 2009 and combined them into 7 samples that were tested by GEL laboratories of Charleston, SC for a broad spectrum of chemical contaminants. We targeted chemicals that have been found at biologically significant levels in other seabirds, and particularly compounds that have been found at biologically significant levels in some South Carolina stormwater detention ponds (Weinstein et al. 2008), thinking that if rooftop terns relied on nearby detention ponds, those compounds might represent a previously undocumented threat. Our initial screen included 19 polycyclic aromatic hydrocarbons (PAH's), 20 organochlorine pesticides and 9 heavy metals. Seventeen of the PAH's were not present in detectable levels (Table 4). The two compounds that were detectable in one sample, Benzo(ghi)perylene and Indeno(1,2,3-cd)pyrene, were below levels of human and wildlife concern. None of the 20 organochlorine pesticides we tested for (table 4) were present at detectable levels. However, of 9 heavy metals tested for in six samples, all but lead and cadmium were detected, and levels of zinc were high though not threatening (Table 5).

In 2010 we collected a larger sample, 35 eggs. Each egg was tested individually for 9 metals (Table 6) by the California Animal Health and Food Safety Laboratory at the University of California, Davis. Lead, arsenic, molybdenum and cadmium were undetectable in all samples. Manganese, iron, mercury, zinc and copper were each detectable in all 35 samples, but none were at levels thought to cause health problems to humans or wildlife (Table 6, Figs 6-8). Below I will discuss variation in mercury levels within this study and compare mercury levels in this study to amounts measured in other studies. I will also address whether levels of contaminants varied systematically between beach-nesting and rooftop-nesting terns.

Concentrations of mercury measured in 2009 varied more than 20-fold, from undetectable to 0.2 ppm. This variability in the levels among only a few samples, many of which were mixed samples (which should reduce extreme readings compared to individual eggs) differs from many other studies of mercury in least terns, where intersample variation is more often from 50% to 6-fold (Hothem and Zador 1995; Hothem and Powell 2000; Thyen et al. 2000). Concentrations of mercury measured in 2010 were radically different from in 2009: about two orders of magnitude higher and consistent across samples (the highest mercury reading was less than four times the lowest). A change of two orders of magnitude in concentrations from one year to the next seems implausible. The Charleston, SC laboratory doing the testing in 2009 won the competitive bid process, but seemed disorganized, signing off on a bid to do the testing, then making multiple changes in the proposed testing plan, and also changing the pricing structure twice after contracting to do the work. Not anticipating a discrepancy between results from the two laboratories, I did not reserve any samples for testing by a third laboratory. Although there is no way to be sure in retrospect whether any or all of the results are reliable, I frankly have little confidence in the lab that did the 2009 testing. The 2010 results are much more in line with the levels of mercury found in Least Terns in California, which ranged from 0.6-3.2 ppm dw in 26 samples (Hothem and Zador 1995). I therefore report all results in tables below, but will use the 2010 results only for comparison with other studies.

The mercury concentrations measured in this study (mean ± SD 2.4 ± 0.9 ppm, range 1.6-5.9) were higher than measured in Least Terns at three California sites: San Francisco Bay (mean 1.9 ppm, range 1.3-3.2) and San Diego Bay (mean 1.1 ppm, range 0.6-2.8) (Hothem and Zador 1995) and southern California near San Diego (0.5-0.7 ppm) (Hothem and Powell 2000). The mercury levels we measured were also higher than those measured in Forster's Terns in Louisiana (0.34 ppm) (King et al. 1991), in Little Terns in the western Baltic Sea (mean ± SD 0.8 ± 0.2 ppm) (Thyen et al. 2000) but lower than in Common Terns at contaminated sites in Germany (6.2 ppm) (Becker et al. 1993b). Even in the study with 6.2 ppm of mercury, however, mercury was not thought to have affected hatching success (Becker et al. 1993a). Levels of mercury in eggs reflect amounts present in maternal tissues during oogenesis, and mercury declines in chicks as they grow, partly due to elimination into growing down and feathers (Becker and Sperveslage 1989; Becker et al. 1993a). Overall, despite values higher than in many other North American studies of terns, the mercury levels we observed were unlikely to affect hatching or development of young terns.

Of more specific interest was whether mercury or other chemicals varied according to the nesting site. In comparing 12 eggs from two beach sites (Kiawah Island, Botany Bay Plantation) with 21 eggs from five rooftop sites (two colonies in Surfside Beach, one each in North Myrtle Beach, Georgetown and Conway), we found no evidence that any contaminant was present in significantly higher levels at rooftop colonies (Table 7). In fact, the only significant difference found between beach and rooftop colonies was that manganese levels werer lower at rooftop colonies for unknown reasons. Figures 6,7 and 8 plot the observed concentrations of manganese, mercury and zinc for all 35 sites, with sites sorted by type and location.

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Table 1: Nest counts at rooftop Least Tern Colonies in Horry and Georgetown Counties, SC, in 2009 and 2010, with historical (2002-2003) counts for comparison. Sites are listed from southwest to northeast. Colonies that were active in a given year but not counted are denoted by a "+." Blank cells indicate no data, not that the site was necessarily unused. Colonial Mall no was reroofed between 2003 and 2009 and no longer has substrate suitable for terns.

Town	Site	Historical Data: Nest Counts in 2002	Historical Data: Nest Counts in 2003	This Study: Nest Counts in 2009	This Study: Nest Counts in 2010
Georgetown	High School and Career Center		18	21	13
Surfside Beach	Glenn's Bay Rd. Piggly Wiggly			378	211
Surfside Beach	Blue Cross/Blue Shield	170	92	29	29
Myrtle Beach	Springmaid Resort	90	67	0	19
Conway	Horry Georgetown Tech			39	52
Myrtle Beach	Kroger Carolina Forest				+
Myrtle Beach	Post Office			9	0
Myrtle Beach	Advance Auto Parts, 3rd. Ave				+
Myrtle Beach	MB Higher Ed. Center				+
Myrtle Beach	Colonial Mall	220	87	0	0
N. Myrtle Beach	Kroger			+	59

Table 2. Fish recovered from a rooftop Least Tern nesting colony at Conway, SC, 20 km from salt water.

Fish Species (count)	Common Name	Fish Habitat
Dorosoma petense (2)	threadfin shad	Fresh
Micropterus salmoides (1)	largemouth bass	Fresh
Enneacanthus gloriosus (1)	blue-spotted sunfish	Fresh

Table 3. Fish recovered from three rooftop Least Tern nesting colonies in Surfside Beach and Myrtle Beach, SC, each colony 1.5-2.5 km from salt water.

Fish Species (count)	Common Name	Fish Habitat
Lagodon rhomboides (3)	pinfish	surf/inlets
Brevoortia tyrannus (1)	menhaden	surf or inlets
Fundulus confluentus (1)	killifish	freshwater, moving or tidal
Hyporhamphus meeki (2)	halfbeak	surf or inlets
Membras martinica (3)	rough silversides	surf or inlets
Opisthonema oglinum (1)	thread herring	salt
Mugil cephalus (1)	striped mullet	inlets, creeks
Pomatomus saltatrix (3)	bluefish	surf
Pomoxis nigromacularis (1)	black crappie	fresh

Table 4. Levels of 19 Polycyclic aromatic hydrocarbons (1-methylnapthalene through Pyrene) and 20 organochlorine pesticides (4,4'-DDD through Lindane) in Least Tern Eggs collected from nests in South Carolina in 2009.

Compound	# Samples tested	No. samples with detectable levels	Concentration (ppm dw)
1-Methylnapthlene	5[1]	0	
2-Chloronapthalene	5	0	
2-Methylnapthalene	5	0	
Acenaphthene	5	0	
Acenaphthylene	5	0	
Anthracene	5	0	
Benzo(a)anthracene	5	0	
Benzo(a)pyrene	5	0	
Benzo(b)fluoranthene	5	0	
Benzo(ghi)perylene	5	1	1.3
Benzo(k)fluoranthene	5	0	
Chrysene	5	0	
Dibenzo(a,h)anthracene	5	0	
Fluoranthene	5	0	
Fluorene	5	0	
Indeno(1,2,3-cd)pyrene	5	1	1.2
Napthalene	5	0	
Phenanthrene	5	0	
Pyrene	5	0	
4,4'-DDD	4[2]	0	
4,4'-DDE	4	0	
4,4'-DDT	4	0	
Aldrin	4	0	
Chlordane (tech.)	4	0	
Dieldrin	4	0	
Endosulfan I	4	0	
Endosulfan II	4	0	
Enosulfan sulfate	4	0	
Endrin	4	0	
Endrin aldehyde	4	0	
Endrin ketone	4	0	
Heptachlor	4	0	
Heptachlor epoxide	4	0	
Methoxychlor	4	0	
Toxaphene	4	0	
alpha-BHC	4	0	
beta-BHC	4	0	
delta-BHC	4	0	
gamma-BHC (Lindane)	4	0	

1. Of the five samples tested for PAH compounds, one was a single egg, the other four were mixed samples. Mixtures were of 3 eggs from the same site.
2. The four samples tested for chlorinated hydrocarbon pesticides were each mixtures of three eggs from the same site.

Table 5. Metals detected in Least Tern eggs collected in South Carolina in 2009. Concentrations in ppm dry weight basis from four mixed samples composed of three eggs each and one single egg sample (sample 5).

Compound	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Arithmetic Mean
Mercury	ND	0.2	0.01	0.1	ND	0.06	0.08
Arsenic	0.4	0.7	0.9	1.0	1.0	0.9	0.8
Barium	1.7	1.1	1.2	0.6	0.4	0.6	0.9
Cadmium	ND	ND	ND	ND	ND	ND	
Chromium	1.4	1.7	1.4	1.5	1.4	1.3	1.4
Copper	3.0	3.5	3.1	2.9	3.1	2.3	3.0
Lead	ND	ND	ND	ND	ND	ND	
Selenium	2.6	2.9	3.5	3.3	2.8	2.6	2.9
Zinc	62.9	56.0	55.8	55.8	44.4	58.4	55.5

Table 6. Metals detected in Least Tern eggs collected in 2010 in South Carolina. All concentrations reported in ppm dry weight basis.

Element	Samples Tested	Samples where detected	Minimum concentration	Maximum Concentration	Arithmetic Mean ± SD
Manganese	35	35	1.7	4.7	2.8 ± 0.8
Iron	35	35	98	220	130 ± 25
Mercury	35	35	1.6	5.9	2.4 ± 0.9
Zinc	35	35	52	89	69 ± 9.1
Copper	35	35	2.3	4.5	3.2 ±0.4
Lead	35	0			
Arsenic	35	0			
Molybdenum	35	1	0.82	0.82	
Cadmium	35	0			

Table 7. Comparison of levels of metals measured in eggs from beach nesting terns (n= 12 eggs at two colonies) and rooftop nesting terns (n = 21 eggs from 5 colonies) in South Carolina.

Element	Mean Concentration (Beaches)	Mean Concentration (Rooftops)	t	d.f.	p
Manganese	3.2 ppm	2.5 ppm	2.41	31	0.02
Iron	139 ppm	125 ppm	1.44	31	0.11
Mercury	2.1 ppm	2.5 ppm	1.27	31	0.21
Zinc	71 ppm	67 ppm	1.04	31	0.24
Copper	3.3 ppm	3.1 ppm	1.59	31	0.09

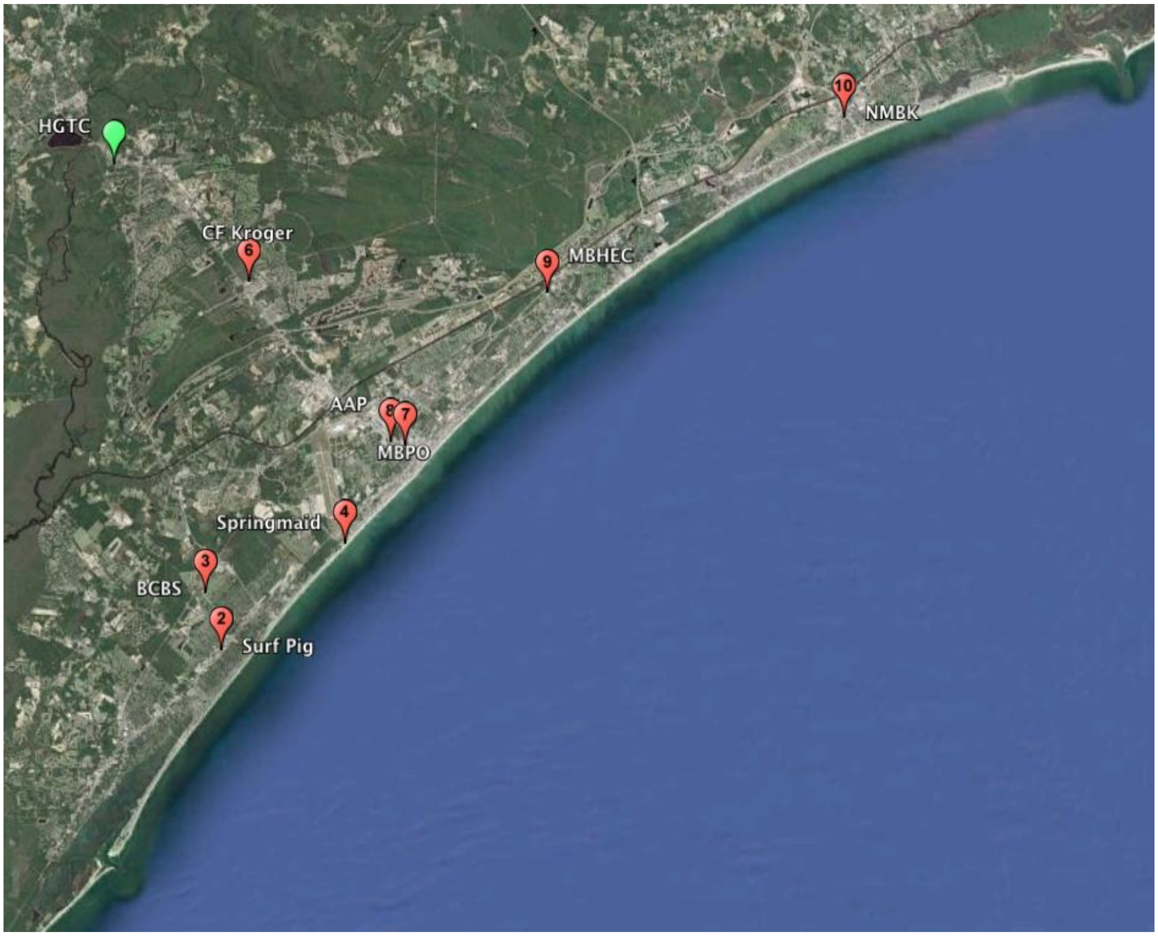
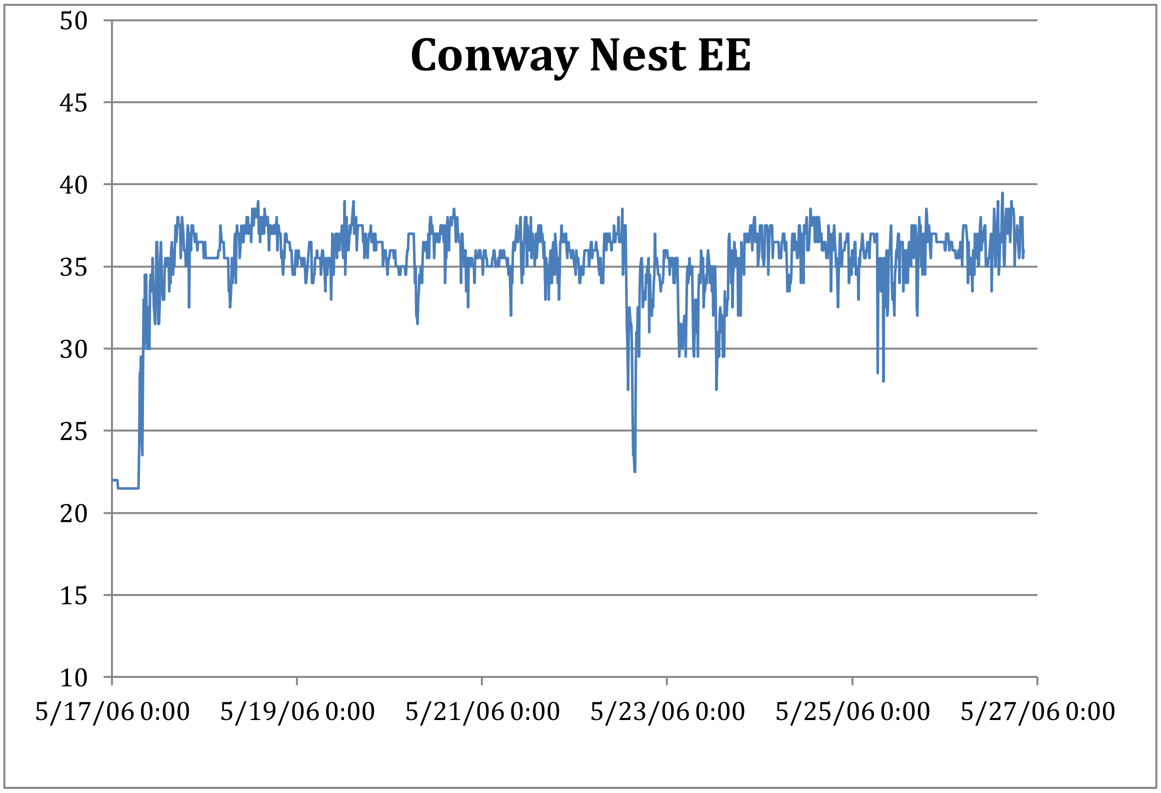


Figure 1. The South Carolina Coast from Murrels Inlet to Hog Inlet and the North Carolina Border, showing sites of 2009 and 2010 rooftop tern colonies (Georgetown High School is out of the picture to the Southwest).



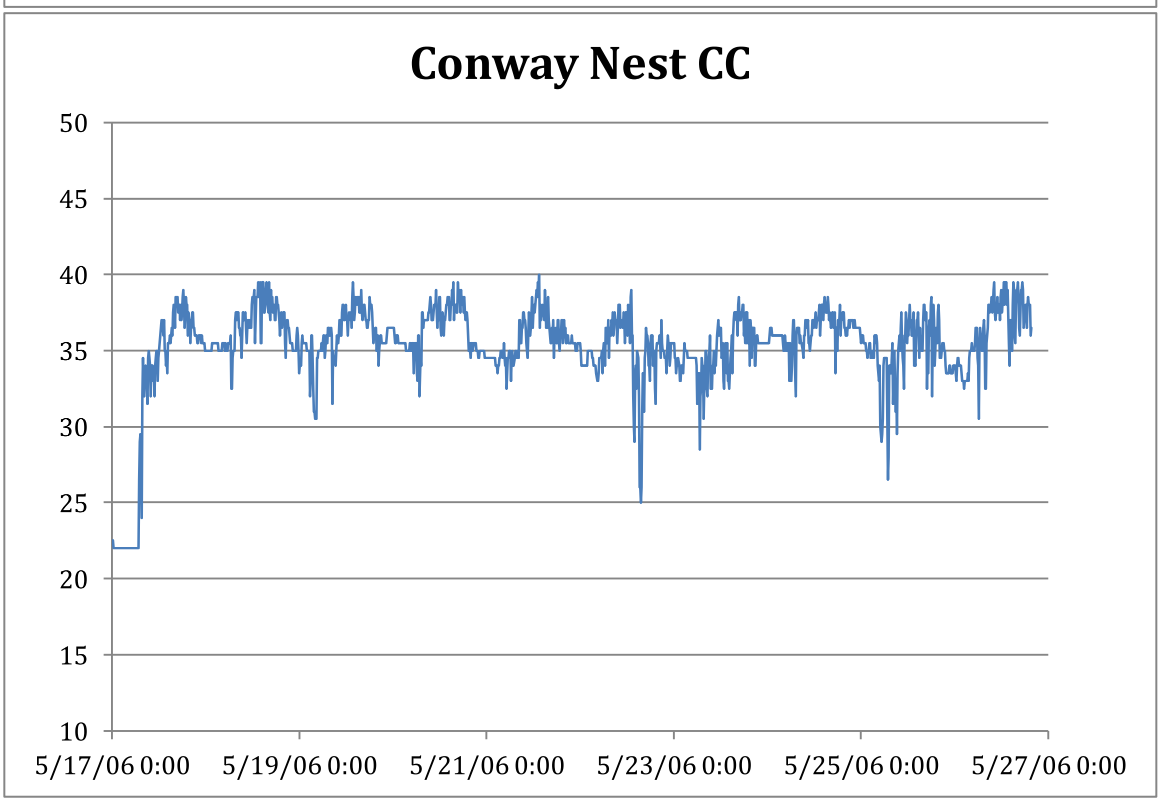
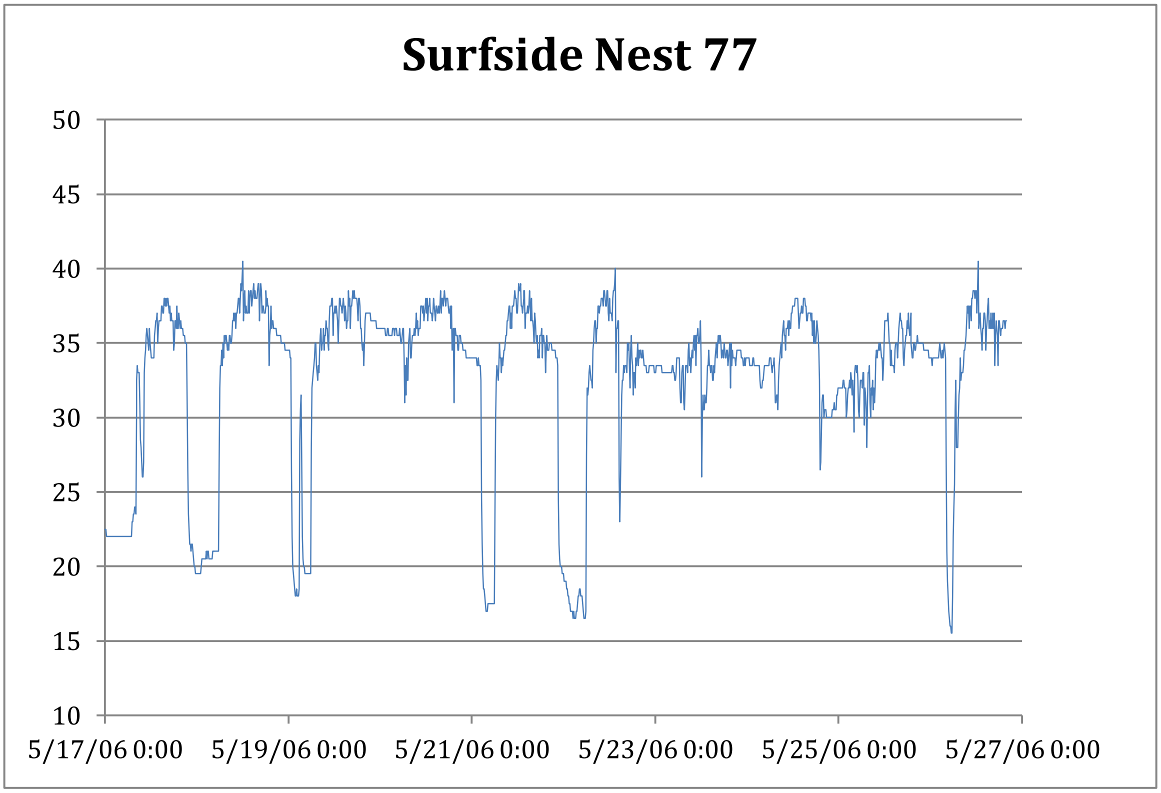


Figure 2. Incubation record of two rooftop Least Tern nests at Horry Georgetown Technical Community College, Conway, SC. Vertical axis in degrees Celsius.



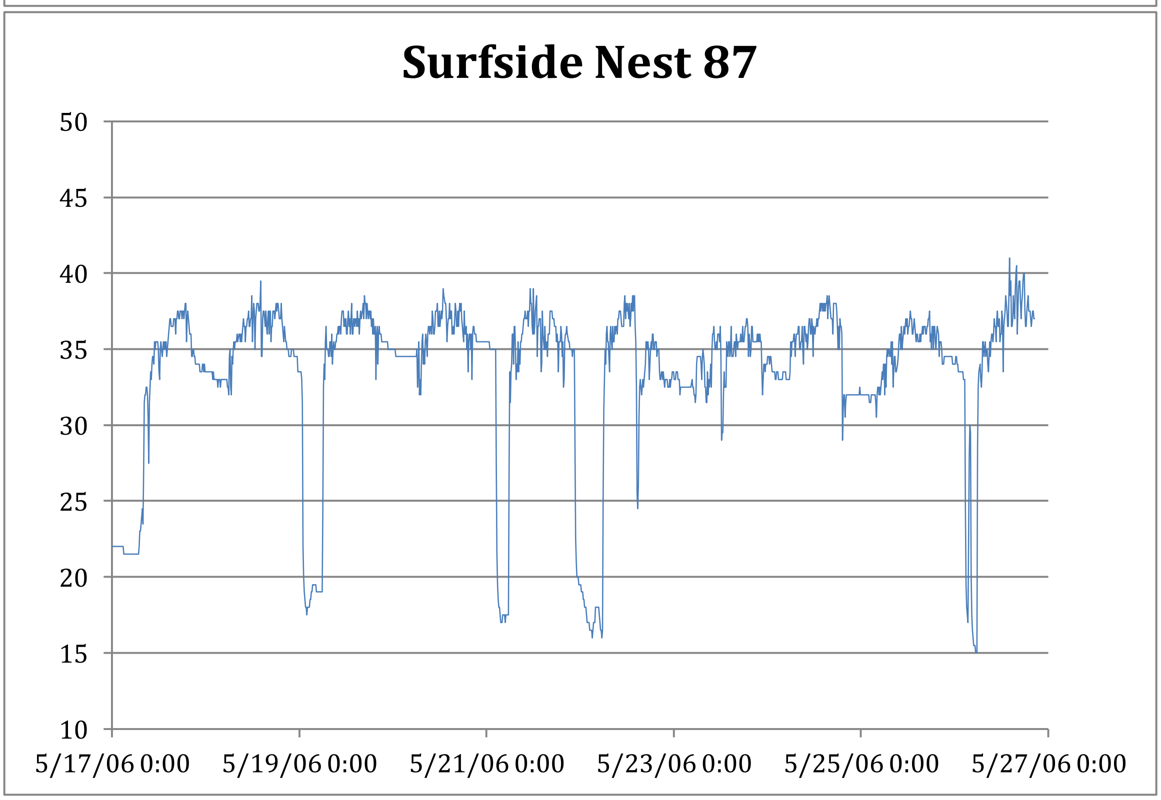


Figure 3. Incubation record of two rooftop Least Tern nests at Blue Cross/Blue Shield offices, Surfside Beach, SC. Vertical axis in degrees Celsius.

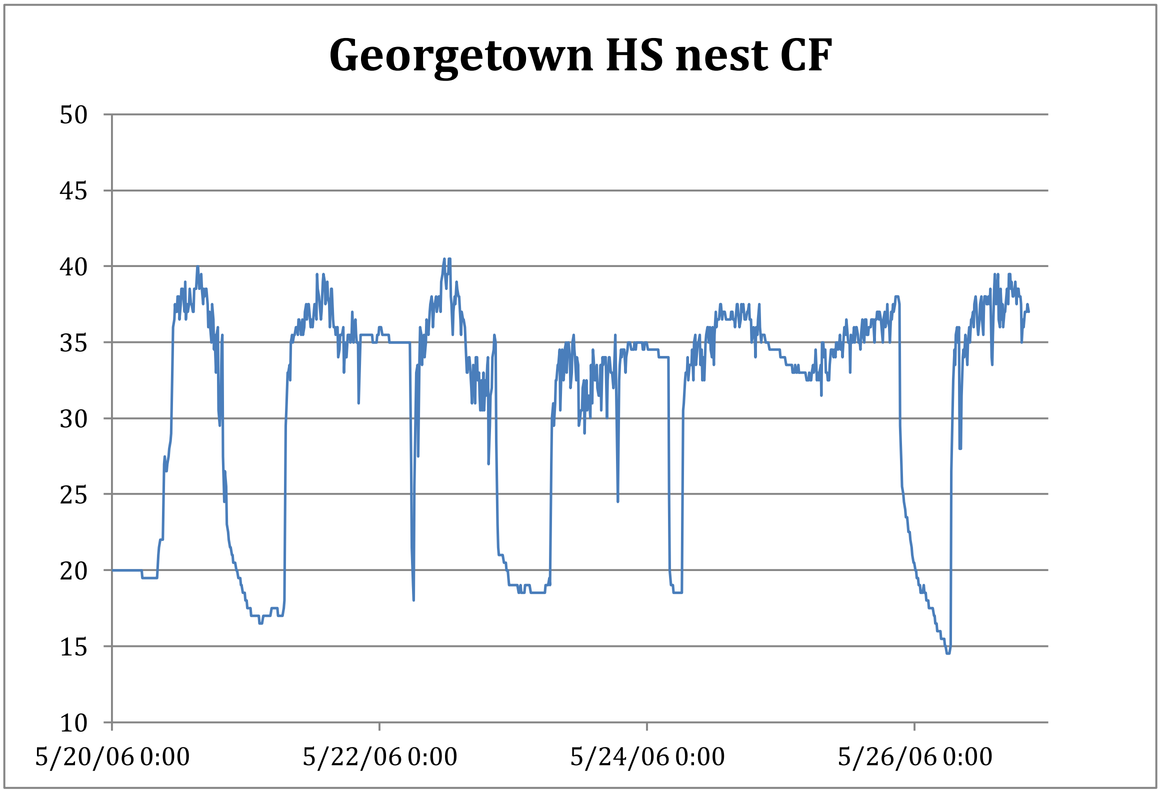


Figure 4. Incubation record of a rooftop Least Tern nest at Georgetown High School, SC. Vertical axis in degrees C.

Age	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
HGTC Birds																																				
151.096								**19**															**34**													
151.240					**16**																								**40**							
151.279					**16**																								**40**							
151.360		**13**																			**32**															
151.401					**16**																			**35**												
151.739							**18**																**34**													
MWB Birds																																				
151.160								**19**												nd	nd				**36**											
151.220						**17**												nd	nd								**38**									
151.299								**19**												nd	nd											**43**				
151.499				**15**																nd	nd							**39**								

(yellow)	in colony 24/7 (with age at banding at left)
(blue)	left and did not come back for the night (with age)
(hatched)	left in the day, but back at night
(pale yellow)	sporadic visits of one hour or less
nd	no data

Figure 5. Colony attendance by age of 10 radiotransmittered terns at a South Carolina rooftop nesting colony (at Conway, n=6 birds, top) and an oyster shell island colony (Middle White Banks, n = 4 birds, bottom). Ages at banding estimated by relationship between wing chord and age established in California Least Terns (C. Collins, unpub. data).

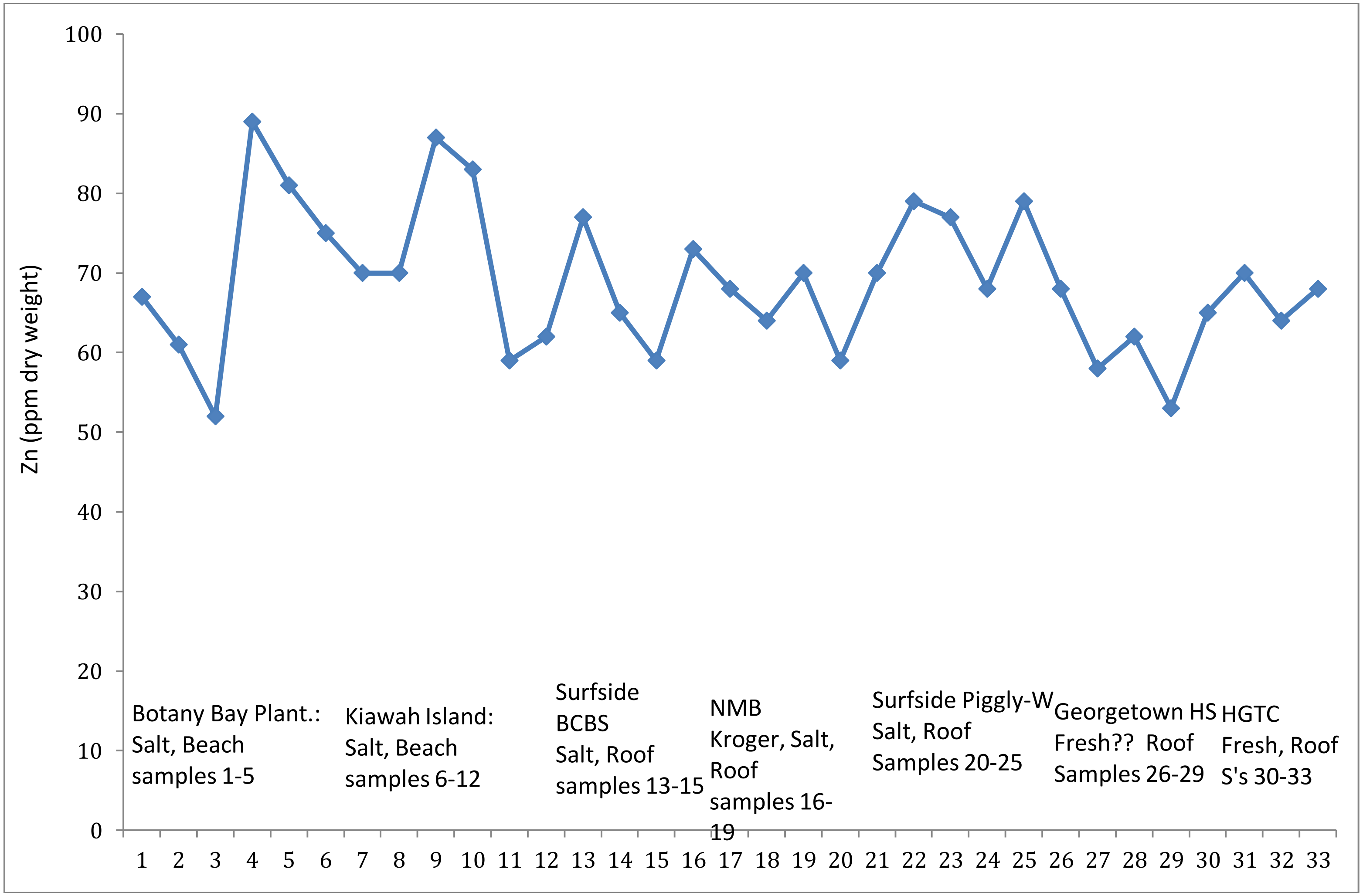


Figure 6. Concentrations of zinc measured in 33 Least Tern eggs from 7 South Carolina nesting colonies. Beach colonies to left, rooftop colonies to right; rooftops probably or definitely associated with freshwater food sources to far right.

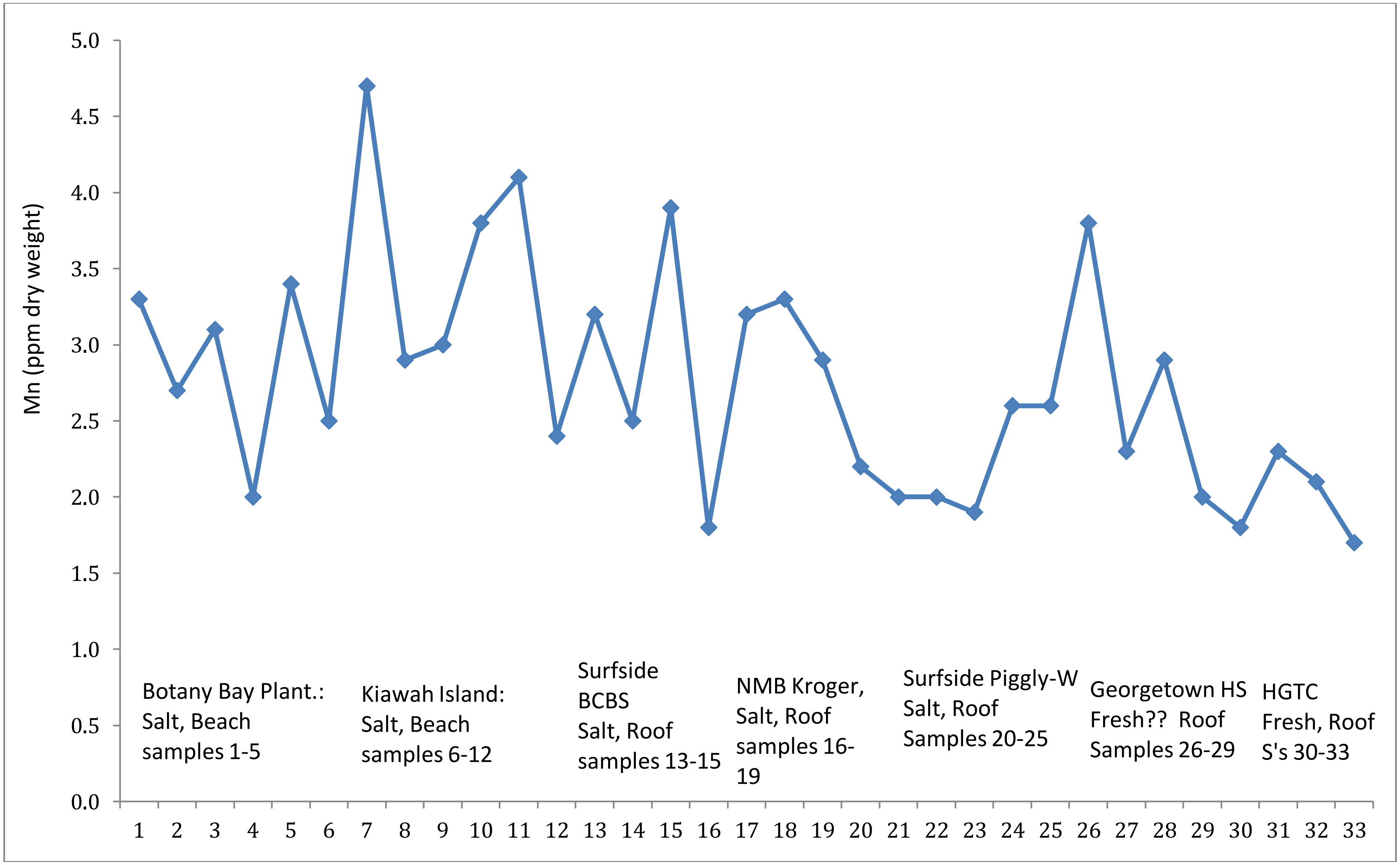


Figure 7. Concentrations of manganese measured in 33 Least Tern eggs from 7 South Carolina nesting colonies. Beach colonies to left, rooftop colonies to right; rooftops probably or definitely associated with freshwater food sources to far right.

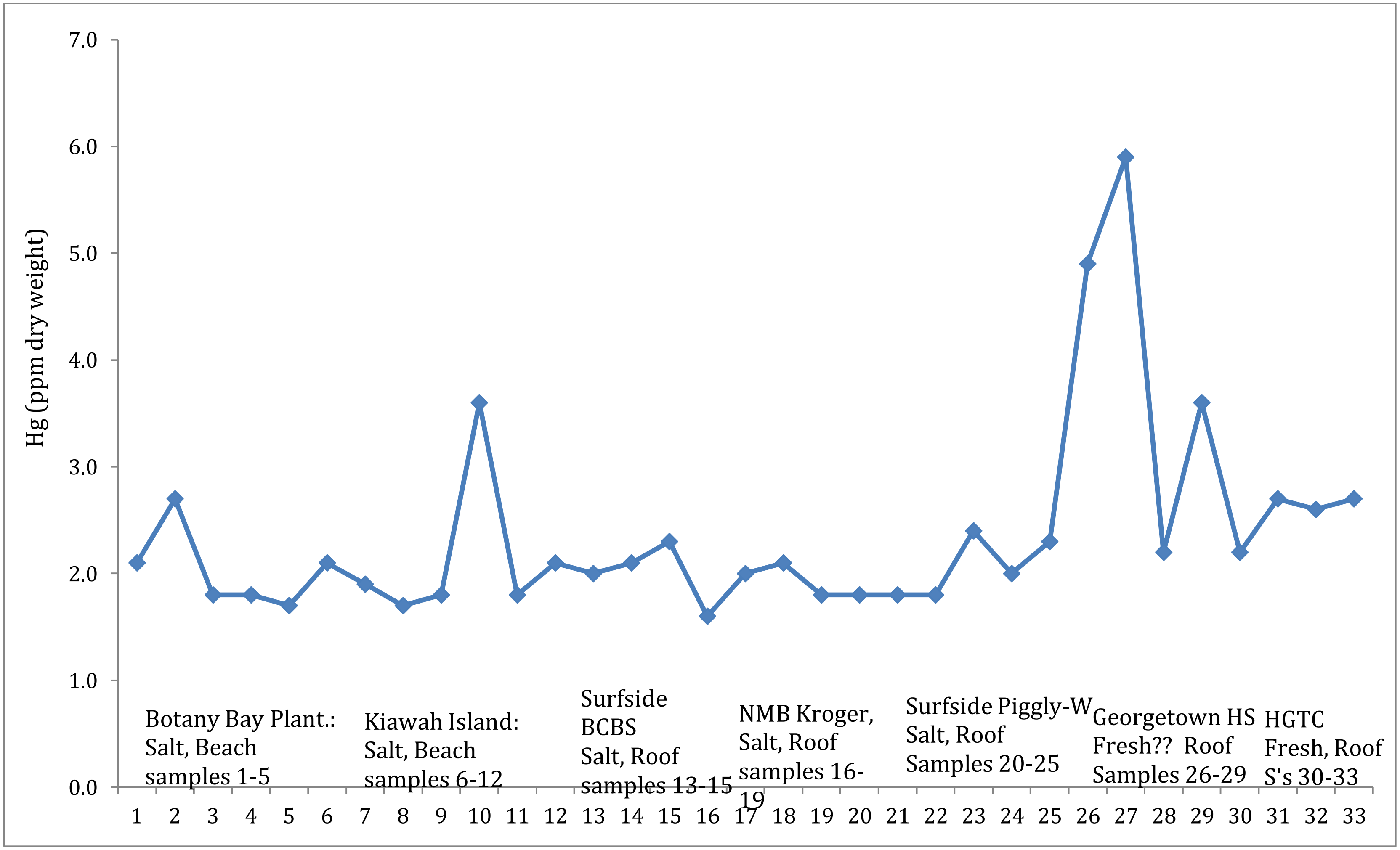


Figure 8. Concentrations of mercury measured in 33 Least Tern eggs from 7 South Carolina nesting colonies. Beach colonies to left, rooftop colonies to right; rooftops probably or definitely associated with freshwater food sources to far right.