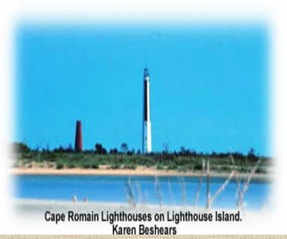
Caretta caretta Nest Temperatures in Hatcheries at Cape Romain South Carolina, USA: Determinants of Spatial and Temporal Variability

Coastal Carolina University

Eric Koepfler[1], Paul Hoffman[1] ☺, and Sarah Dawsey[2]

[1] Coastal Carolina University, Marine Science Department, Conway, SC 29528, USA
[2] U.S. Fish & Wildlife Service, Cape Romain National Wildlife Refuge, Awendaw, SC 29429, USA
☺ Corresponding author: pthoffma@coastal.edu



Abstract: A high intensity sampling of loggerhead nest temperatures were obtained from hatcheries at Cape Romain National Wildlife Refuge in South Carolina during the summer of 2007. This site represents the single most important nesting beach for *Caretta caretta* in South Carolina, USA. The experimental design involved datalogger placement in every other nest in two major hatcheries established over the nesting season. Within each nest loggers were placed at the top, middle, side, and bottom of the clutch. Variation in temperature by space was accessed to determine 3D nest thermal regimes as well as broad-scale whole nest temperatures - potentially associated with conductive heat transfer from metabolic heat generation from the interior of nests. Variation in temperature by time was investigated based upon seasonal nest placement within each hatchery and correlation of temperature conditions within nests to recorded meteorologic conditions. Initial results at the time of abstract submission indicate a highly female skewed population of hatchlings being generated from the cooler first quartile period, with small numbers of males being confined to the bottom of clutches. The estimated sex ratio demographics from the hatcheries over the entire season are expected to be highly female skewed. Initial results also suggest that metabolic heat generation becomes important in the last third of the incubation period as evidenced by a switch to higher temperatures in lower lying clutch regions. These results will be interpreted with regards to a contemporaneous natural nest study at this site to provide information that could be used for hatchery designs aimed at particular sex ratio outcomes.

Figure 1. Map of Cape Romain refuge showing Cape and Lighthouse Island regions. Inset shows location of the refuge within South Carolina and relative to the U.S. east coast.

The Site: The Cape Romain Wildlife Refuge was established in 1932 and is situated between the Santee Delta and Bulls Bay along the north central South Carolina coast. A portion of the refuge, Cape Island is home to the largest nesting population of turtles within the distinctive genetic northern subpopulation of the southeastern U.S. The island, accessible by boat from McClellanville, S.C., is 9km long and was divided into two sections when Hurricane Bertha skirted the coast in 1996. The northern subpopulation, or nesting aggregation, consists of those Loggerheads which nest from North Carolina to around Cape Canaveral, Florida. These turtles are isolated from all other nesting turtles in the southeast based on genetic studies involving mitochondrial DNA. With an average of 1000 nests per year, Cape Island is the most significant Loggerhead nesting beach north of Cape Canaveral.

Methodology: During the 2007 nesting season LogTag TRIX-8 temperature data-loggers (Figure 2) were placed into 76 nests associated with 2 Hatcheries (Figure 3). Within 42 nests 4 loggers were placed at locations including; top, center, bottom, and outside-mid depth of the clutch. Other nests had single loggers into variable positions to serve as a predictive model validation dataset (not discussed in this poster). In the establishment of each hatchery, loggers were placed in roughly every other nest, after being programmed to record at 30 minute intervals. Weather station data was obtained through both a Hobo Micro-weather station, as well as acquired from the NOAA National Climatic Data Center.

Measurement Range	–40°C to 85°C
Resolution	0.1°C for –40°C to +40°C 0.2°C for 40°C to 80°C
Accuracy	±0.5°C for -10°C to +40°C ±0.7°C for -10°C~ -30°C & +40°C~+60°C, ±0.8°C for -30°C~ -40°C & +60°C~+80°C
Sensor Reaction Time	Typically less than 5 minutes (T90) in moving air.
Capacity	8000 Readings (16000 bytes Memory)
Sampling Frequency	30 seconds to 18 Hours

Figure 2. Picture of LogTag temperature data-logger above, and logger specifications below.

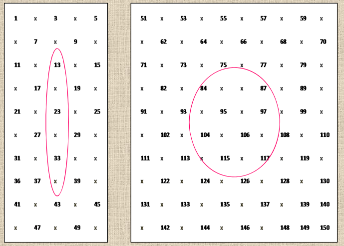


Figure 3. Location of logger emplaced nests (left) within the two hatcheries established between June 8th and July 13th of 2007. Red ellipses indicate region of interior nests used to test vs outer margin nests for metabolic heat effects.

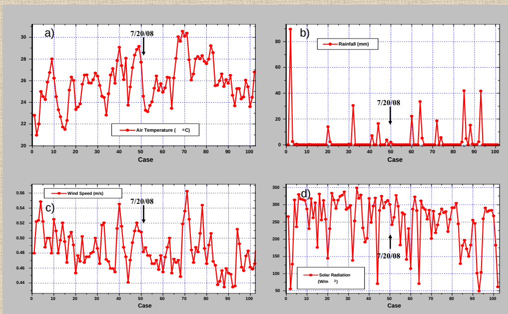


Figure 4. Daily weather time series data from McClellanville, SC which adjoins Cape Romain. Dates are from 6/1/07 through 9/31/07. Attributes include daily; a) Mean Temperature, b) Total rainfall, c) Mean Wind Speed, and d) Mean Solar Insolation. 7/20/07 is highlighted for reference to within nest temperature time series below. Data was obtained from the NOAA National Climatic Data Center.

Results and Discussion: The summer of 2007 was characterized by extreme drought and by the first of September all but 2 counties within the state were in the severe drought category. These unusual weather conditions obviously limit the extrapolation of this years study to more normal wetter years. Spatial variability examined in this study included positions within the hatchery (Figure 3) as well as logger placement within nests. Temperatures within hatcheries were examined because of concern that metabolic heat generation from interior nests could produce higher temperatures in those regions compared to nests on the outer periphery. Results of a 1 way ANOVA indicated no significant temperature differences between interior (Figure 3) versus randomly selected outer edge nest locations. Spatial variability due to position within nests (Figures 5 and 6) did show significant variation. ANOVA of mean nest temperatures based upon trimester periods (as in Figure 6) found significant positional and time (week) effects for each trimester. No significant interaction effect was observed during any trimester. Despite the lack of evidence for a metabolic heat effect upon nest temperatures across the hatchery, metabolic heat generation within nests were suggested by increasing temperatures in the mid clutch regions which were significantly higher than all other logger positions in the third trimester. Regression of surface logger versus mid-depth loggers average temperatures (Figure 7) based upon the entire incubation interval resulted in a highly significant regression ($y=1.24(x)-7.67$; $R^2=0.96$, $p<1e^{-50}$). This result has practical management applications because the most non-invasive method to estimate spatial variability in nest temperature conditions is preferred and reducing logger placement within the central clutch region would accomplish this aim. However, comparison of this "entire duration" regression (Figure 7) to those derived for the individual trimesters (color coded within) indicate that the relationship between surface and mid clutch thermal relationships changed over time. Weather conditions (Figure 4) changed markedly over the hatchery operation period. Factors responsible for temporal variability in each logger placement region are indicated in Table 1. Multiple regression results for clutch and meteorological factors in influencing "in nest" temperatures indicated that the biological and physical factors controlling nest microclimate also change over time (Table 1). Unfortunately, regression relationships were least well defined during the second trimester, where only 2 of 30 possible significant regression coefficients were observed. First and third trimester relationships were more frequent (8 and 14 of 30 respectively), but these regressions also indicated changes in important independent factors. Trimester 1 nest temperatures were more influenced by air temperature and solar radiation, while trimester 3 were better described by hatching success, precipitation, and solar radiation. Trimester 2 temperatures observed from all loggers (N=164) within the nests during this study (Figure 8), suggest a very female skewed sex ratio of hatchlings. Only 4 of the 164 mean temperatures were <29.7°C.

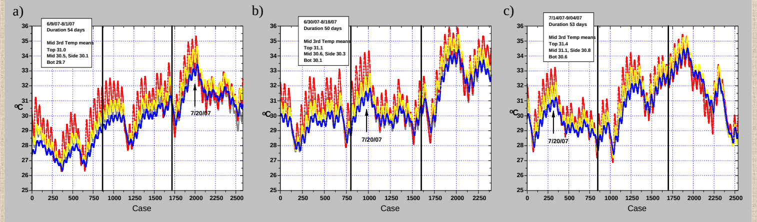


Figure 5. Representative 3-D temperature time series from: a) early, b) mid, and c) late hatchery nest emplacements. Series are color coded indicating logger location with red (top), yellow (mid), blue (bottom), and grey (mid-side) of clutch positions. Vertical lines indicate trimesters and statistical data in boxes include incubation duration and mean logger temperatures by positions. The date 7/20/07 is indicated as a fixed point reference for each panel.

In the next century the conservation of sea turtles, like many other marine species, will face the myriad of assaults from local to global anthropogenic impacts. Global impacts such as warming and sea level rise will present extreme challenges to sea turtle populations which are expected to become increasingly skewed towards female regarding sexual demographics, and which because of sea level rise will require more dramatic "hatchery based" conservation practices. Understanding how hatchery design and abiological factors influence sex ratio under these conditions will be a necessity to preserve the species.

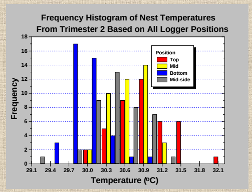


Figure 8. Histogram of nest temperatures during Trimester 2, indicating the small number of nests which would have produced females. Also note the similar pattern of temperatures from top and mid clutch positions.

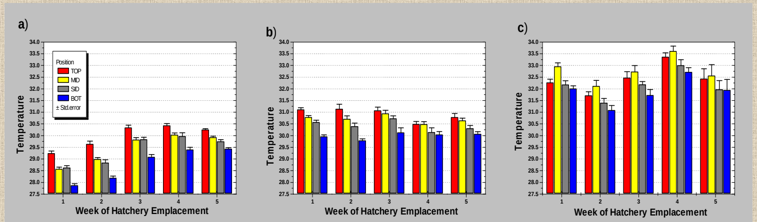


Figure 6. Mean positional temperatures in degrees C for nests emplaced during the 5 weeks of hatchery establishment from June 8th through July 13th. Panels include; a) first, b) second, and c) third trimester temperature records from each weekly nest series (x axis). Bars are color coded by position as in Figure 5. Note temperature increases over the 3 trimester periods, and that change in rank order of lowest to highest logger temperatures occur over the three trimesters.

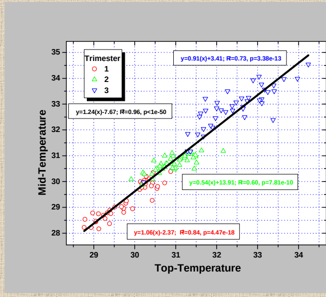


Figure 7. Linear regressions between mean temperature from top versus mid positioned loggers based upon the total record (black) and color coded trimester periods. Note the change in slope between the different trimesters.

TEMPORAL SPATIAL	R^2	CLUTCH #	HATCHING %	TEMP	PRECIP	WIND	SOLAR	CONSTANT
1-TOP	0.77	7.92e-4	0.62	0.72	-19.58	-2.74e-2	-1.55e-3	20.81
1-MID	0.89	1.42e-3	0.51	0.78	-3.74	-1.86e-2	-1.04e-2	13.29
1-BOT	0.89	3.89e-4	0.10	0.82	-3.53	-0.12	2.11e-2	15.25
1-SID	0.82	2.63e-3	1.32	0.76	6.68	-5.63e-2	-1.10e-2	8.29
2-TOP	0.41	-3.46e-3	2.54e-3	0.11	14.77	-2.90e-2	1.70e-2	16.60
2-MID	0.49	1.71e-3	0.68	-0.12	44.40	-9.69e-2	-7.96e-3	13.77
2-BOT	0.14	4.20e-4	0.41	0.12	-21.3	-5.88e-3	-2.54e-3	37.74
2-SID	0.24	1.75e-3	0.97	-0.13	40.45	-5.86e-2	-5.47e-3	14.77
3-TOP	0.42	-1.56e-3	1.49e-2	-0.12	86.05	-0.27	-4.55e-2	5.30
3-MID	0.47	1.63e-2	3.32	-0.32	90.44	-0.38	-4.31e-2	5.04
3-BOT	0.32	8.90e-3	2.25	-0.34	95.02	-0.40	-5.26e-2	6.79
3-SID	0.41	1.05e-2	2.93	-0.27	92.08	-0.34	-4.41e-2	3.44
1-ALL	0.90	-5.70e-4	0.37	0.80	-5.49	-8.39e-2	-1.05e-2	14.09
2-ALL	0.28	7.34e-4	0.51	2.93e-2	17.38	-3.41e-2	2.16e-3	20.30
3-ALL	0.34	7.42e-3	2.14	-0.28	96.79	-0.31	-4.06e-2	3.44

Table 1. Multiple regression analysis (Direct method; N=41) of clutch related and meteorologic factors on mean "in nest" temperatures based upon temporal and spatial groupings. Numbers in the first column refer to trimester period and are followed by logger locations within nests. R^2 and β coefficients for independent factors, are indicated in additional columns. Unshaded coefficients are statistically insignificant in within nest temperature prediction. Shaded significance values for coefficients of orange are; $0.05>p\geq0.001$, green are $0.001>p\geq0.00001$, and blue are $0.00001>p$.

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