WARREN WILSON COLLEGE

DEPARTMENT OF
ENVIRONMENTAL STUDIES

May 27, 2002

Sally Murphy
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Sally and Charlotte:

Charlotte asked me to send a copy of Emily Nicar's paper on the fitness study which she just submitted to J. Herpetology. I am sorry that this draft did not include acknowledgments. Emily finished the draft on the day before graduation and forgot the acknowledgments, but promised to include a section thanking all appropriate people if the paper gets accepted. Emily will be getting married this summer, and **if her paper gets published it will be by the name of Emily Sanford.** Danna Baxley also submitted a manuscript to J. Herp. which is enclosed.

Thank you both for the help you have given Danna, Emily, and now Arlette in providing this influential internship experience. Danna and Emily both graduated last week, with Danna honored as having the highest GPA for the class of 2002, the largest class ever to graduate from WWC. Danna graduated with a major in Environmental Studies, concentration in Conservation Biology, one of only 16 students so far to graduate from WWC in this new concentration. Emily graduated with a major in Biology.

I hope to visit Arlette at Yawkey on approximately June 15.

Sincerely,

Louise M. Weber, Ph.D.
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Hatchling Fitness of Loggerhead Sea Turtles from Nests with Different Incubation Durations

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Hatchling Fitness of Loggerhead Sea Turtles from Nests with Different Incubation Durations

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Abstract:

Loggerhead Sea Turtles (*Caretta caretta)* have been a threatened species since 1978. One of the many beach management strategies used to increase hatch success is nest relocation from an unsuitable to a more suitable location on the beach. Once relocated the incubation conditions of a nest could have great impacts on developing embryos. Warmer temperatures cause shorter incubation durations and cooler temperatures cause longer incubation durations which might influence fitness. Our objective was to determine if Loggerhead Sea Turtles were more fit at certain incubation durations. A speed test was used to compare hatchling performance as a measure of fitness. We used 20 randomly selected hatchlings from 12 different nests throughout the summer of 2001. We ran the hatchlings on an 8-meter track split into two 4-meter sections. Three times were taken, orientation time (the first 4 meters), speed time (the second four meters), and overall time (the full 8 meters). Average clutch speeds were then analyzed. Significant correlations were found between incubation duration and orientation time (P=0.01), incubation duration and speed time (P=0.04), and incubation duration and overall time (P=0.005) once an outlier was removed. Our results indicate that longer incubation durations, produced by cooler incubation environments, resulted in faster hatchlings. If being fast is a fitness advantage, nests could be moved to cooler incubation environments to increase fitness. Until the strategy's effect on sex ratio is determined, management based on these results should be applied cautiously.

Introduction:

Loggerhead sea turtles (*Caretta caretta*) have been listed on the endangered species list as threatened since 1978 (NWFS 1978). Threats include beach lighting, habitat loss, the shrimping and fishing industries, poaching, and predation. Management strategies to improve hatch success include nest screening and nest caging, to prevent depredation, and relocation (So. Car. DNR 2001). In South Carolina, nest relocation is a management technique of last resort and done only if the likelihood of the nest surviving to hatch is zero (So.Car. DNR 2001). Nests laid below the spring high tide line (seaward of the debris line), in wash out areas, or under scarped dunes are moved to a more suitable location on the beach, ideally above the high tide line on a dune with an ocean facing slope (So.Car. DNR 2001).

Temperature regime within these nests varies depending on placement (Foley 1998). Nests at the top of a dune have a slightly higher mean temperature than nests at the base of dunes (Nicar and Murphy, own data). Nests low on the beach or very high under beach vegetation have the coolest temperatures at clutch depth (Foley 1998). Nest temperature affects incubation duration which is a measure of the rate of development, the time elapsed between the laying of the eggs and the emergence of hatchlings from the nest (Mrosovsky et al. 1999). Incubation duration may affect fitness. Temperature would therefore be an important factor to consider when relocating a nest.

Previous research has indeed found that thermal environment experienced by developing reptilian embryos exerts dramatic effects on numerous phenotypic aspects including morphological features, physical performance, and behavior (Foley 1998; Rhen and Lang 1999; Janzen 1993). Incubation temperatures correlate with subsequent growth which in turn correlates with adult size and fitness (Mrosovsky 1994). Turtle embryos in species that lay flexible shelled eggs frequently hatch at a larger size when they are incubated in relatively cool, wet environments than when they are incubated in relatively warm, dry environments (Rhen and Lang 1999).

In the smooth softshell turtle (*Apalone mutica*), the measures of locomotor performance (running and swimming speed) were significantly influenced by incubation temperatures, such that warmer temperatures produced faster hatchlings (Janzen 1993). Hatchling speed in sea turtles may also be influenced by incubation temperatures which could affect fitness. Sea turtles emerge from underground nests and confront two problems, they must locate the ocean and crawl to it (Lohmann et. al. 1990), and avoid predators such as crabs, sea birds, raccoons, and foxes.

To study the effects of thermal environment on hatchling turtles, speed tests can be used as a measure of fitness at hatching (Foley 1998, Janzen 1993, 1995). Our objective was to determine if Loggerhead Sea Turtles hatchlings were more fit at certain incubation durations by using a speed test as a measure of fitness. If certain incubation durations produced higher fitness, this would have implications on management, specifically relocation efforts.

Methods:

Research was completed on South Island at Tom Yawkey Wildlife Center in Georgetown County, South Carolina (U.S.A.). South Island has a 7.3 km ocean facing beach with no development or artificial lighting. Of the 95 Loggerhead Sea Turtle nests laid on South Island in 2001, 20 hatchlings from each of 12 nests were used in speed tests.

To obtain the hatchlings for sampling we caged each nest when the incubation date reached 40 days. This was done at 40 days to prevent any stimulation from ground shifting due to the placement of the cage. A large plastic tub with the bottom cut out served as a cage. The top opening was covered with metal screen to prevent depredation. The exact location of the nest cavity was found by locating the soft surface tunnel that led to the egg chamber. This is the tunnel which the hatchlings use to emerge from the nest, thus the cage was centered around the tunnel and buried approximately 15 cm below the surface of the sand. By following this channel, the hatchlings went into the cage and were trapped. Once a cage was placed, it was checked daily before dawn.

When a major emergence had occurred (>60 hatchlings), 20 were randomly selected as the hatchlings were being moved out of the cage. The intervals at which hatchlings were selected depended upon the number of hatchlings in the major emergence and were intended to allow an even sampling of hatchlings from across the emergence. For example, if the emergence had 114 hatchlings, every fifth turtle was held which resulted in 22 hatchlings. Then, from the 22 selected hatchlings, every eleventh turtle was released, which resulted in 20 randomly selected hatchlings. The turtles were chosen out of the bucket in a haphazard fashion with eyes closed. The trial turtles were placed in another bucket and the others were released on the beach.

The selected hatchlings were then taken to the trial area. For each nest the trial was done at the same location on the beach to keep the profile and slope of the beach similar. The track for the speed test was made in the intertidal zone to keep a similar texture, moisture, and hardness of the sand. The speed test was done on an eight meter track with two sections of four meters. Any debris was cleared from track before running the turtles. The first four meters were measured and recorded as orientation time. This gave the hatchlings time to orient seaward on the beach and start crawling in a decided direction. The last four meters were recorded as the speed time. By the second section of the track, the turtles were crawling in a decided direction and could be used for a more accurate measure of speed. The overall time, the full eight meters, were also recorded. All turtles were started at the same location along the start line of the track. Time was started as soon as the turtle made contact with the sand. We observed from 10 paces north of the track during every trial. Time of day for each speed test was always between the hours of 6:00 a.m. and 8:00 a.m.

conditions of held hatchling prior to test

Results:

There was no correlation (*P*= 0.28) between incubation duration and overall time (full 8 m, Figure 1), mean orientation time (*P*= 0.26, Figure 2), or mean speed test time (second 4 m of track, *P*= 0.66, Figure 3) when Nest 7 was included. When Nest 7 was removed as an outlier, there was a correlation between incubation duration and mean overall time (*P*= 0.005, Figure 4), mean orientation time (*P*= 0.01, Figure 5), and mean speed test time (*P*= 0.04, Figure 6). Nest #7 had an incubation duration of 68 days, which was at least six days longer than all other trial nests. It also had a much longer incubation duration than nests laid at about the same time and was not in a location on the beach that would give it a cool environment and therefore a longer incubation duration. For these reasons, we removed Nest 7 from the data set. The long incubation in Nest 7 may be explained by a hard cap. The "hard cap phenomenon" was seen on several nests last summer, probably because of heavy rain during the season. Normally, when the eggs in a nest hatched, the soft sand on top fell into the nest cavity. The sand that fell acted as a ladder for the hatchlings to use as they emerged from the nest. When a nest had a hard cap the sand did not fall which left the hatchlings trapped in the nest cavity with no emergence route. If Nest 7 had a hard cap, this would make the nest seem to have a longer incubation duration. The hard cap could have spontaneously fell a few days after the hatchlings were actually ready to emerge, but by this time they would have been dehydrated, which could have had an impact on their behavior in the speed test.

what did these hatchlings do different.

Discussion:

The results indicate that longer incubation durations, produced by cooler nesting environments, produced faster hatchlings. If being fast is a fitness advantage, nests that are relocated could be moved to areas on the beach with the coolest nesting environments to increase hatchling fitness. However, we are not suggesting this as a management strategy until further research is done. One reason for caution is that it is not known how the relocation strategy affects sex ratio. In turtles, low temperatures result in males (Mrosovsky 1988). Moving nests intentionally to the coolest environments with the hopes of increasing hatchling fitness may bias the sex ratio towards males. Another reason for hesitancy is that it is not known if faster hatchlings actually have a fitness advantage over slower hatchlings for Loggerhead Sea Turtles. While it is assumed that faster sea turtle hatchlings are able to avoid more predators and therefore are more likely to survive to maturity and have a greater fitness, this has not been verified. The smooth softshell turtle, *Apalone mutica,* relies on speed to flee predators (Janzen 1993). As a consequence, faster smooth softshell turtles probably have a greater relative fitness than slower turtles thus, the former would tend to leave more offspring than the latter (Janzen 1993).

Phenotypic plasticity of incubation duration is an important component to consider in the reproductive strategies of sea turtles (Foley 1998). Foley (1998) suggests that perhaps sea turtles risk some of their many clutches on the lower and higher parts of the beach to increase the expression of phenotypic plasticity among their hatchlings. This may be a selected nesting strategy to increase the odds of producing the right hatchling characteristics at the right time (Foley 1998). This would maintain offspring variability and produce a range of characteristics that are able to adapt to a variety of post-hatchling environments. If so, relocation efforts may have a great effect on the plasticity of hatchlings by moving them from their original environments. If a nest is certain to be destroyed, then relocation probably has no negative impact on the nesting strategy of the female (Foley 1998). Questions remain about what to do about nests in positions where only 5-10% of the eggs will produce hatchlings. At certain times and places, nests with a 5-10% hatching success may produce more recruits to the reproducing population than nests with a 95% hatching success because of variation in environmentally induced characteristics among hatchlings (Foley 1998). Sea turtles are a slowly maturing species, which makes it hard to determine how incubation duration is correlated with lifelong fitness. For this reason, relocation efforts could have unseen effects on the reproductive success of sea turtles by seeming to increase fitness by increasing hatch success, but actually decreasing lifelong fitness.

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Figure Captions

Figure 1. Downward trend of incubation duration (time in nest) and overall speed (the full eight meters of track in speed test) including outlier Nest #7 on South Island, South Carolina, U.S.A.

Figure 2. Incubation duration (time in nest) and orientation time (first four meters of track in speed test) including outlier Nest #7 for hatchlings on South Island, South Carolina, U.S.A.

Figure 3. Incubation duration (time in nest) and speed time (last four meters of track in speed test) including outlier Nest #7 on South Island, South Carolina, U.S.A.

Figure 4. Incubation duration (time in nest) and overall speed (full eight meters of track in speed test) for hatchlings on South Island, South Carolina, U.S.A. excluding Nest 7.

Figure 5. Downward trend of incubation duration (time in nest) and orientation time (first four meters of track in speed test) for hatchlings on South Island, South Carolina, U.S.A. excluding Nest 7.

Figure 6. Downward trend of incubation duration (time in nest) and speed time (last four meters of track in speed test) for hatchlings on South Island, South Carolina, U.S.A. excluding Nest 7.

Figure 1

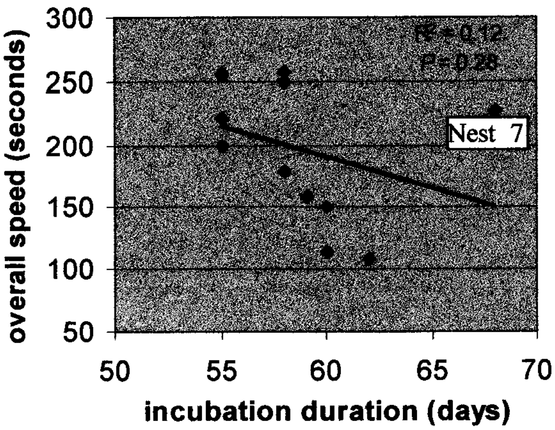
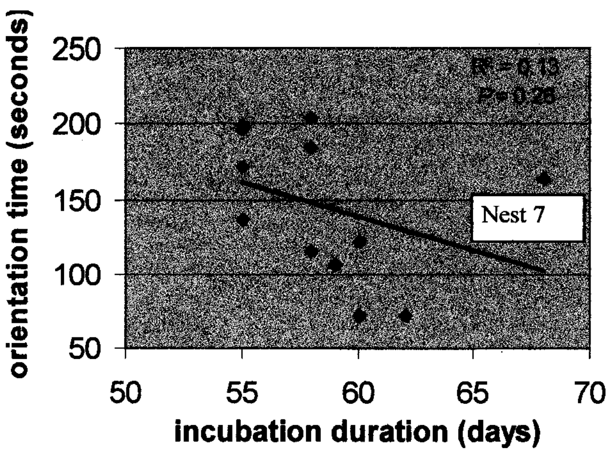

R² = 0.12
P=0.28
Nest 7
overall speed (seconds)
300
250
200
150
100
50
50
55
60
65
70
incubation duration (days)

Figure 2



orientation time (seconds)
250
200
150
100
50
50
55
60
65
70
incubation duration (days)
R² = 0.13
P = 0.28
Nest 7

Figure 3

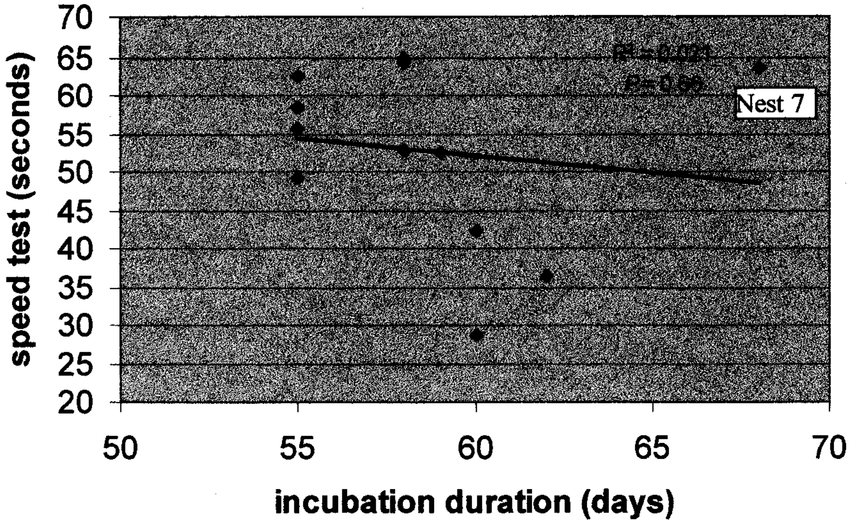

70
65
60
55
50
45
40
35
30
25
20
speed test (seconds)
Nest 7
50
55
60
65
70
incubation duration (days)

Figure 4

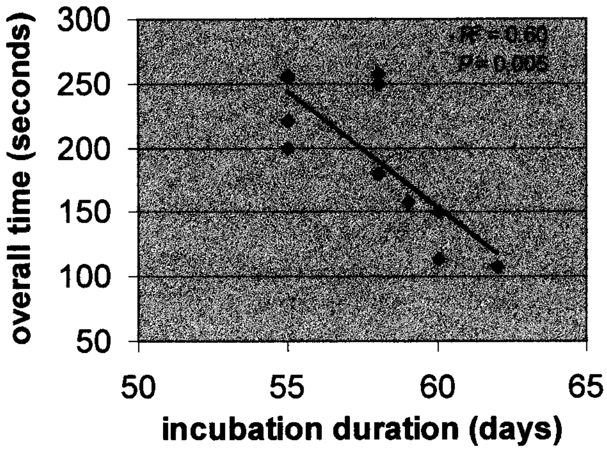

R² = 0.60
P = 0.006
300
250
200
150
100
50
overall time (seconds)
50
55
60
65
incubation duration (days)

Figure 5

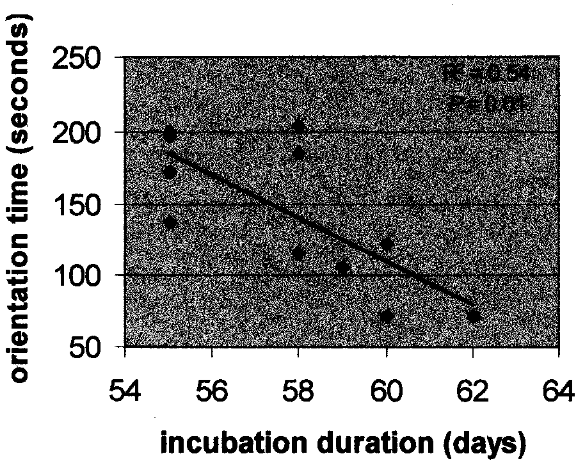
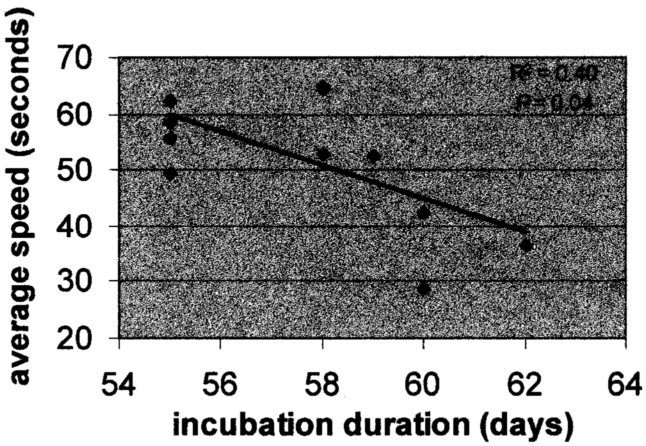

R² = 0.54
P = 0.01
250
200
150
100
50
orientation time (seconds)
54
56
58
60
62
64
incubation duration (days)

Figure 6


R² = 0.40
P = 0.04
70
60
50
40
30
20
average speed (seconds)
54
56
58
60
62
64
incubation duration (days)