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CONTINUED THERMAL MONITORING OF PRAIA DO FORTE, BAHIA, BRAZIL

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INTRODUCTION:

Sexual differentiation in sea turtles is determined by the temperature of the eggs during the middle third of incubation. This system of interest in both theoretical and practical terms, because the sex ratio of hatchlings produced by a nesting population has the potential to be far different from 1 male:1 female ratio predicted by the traditional theory of parental investment in offspring (Fisher, 1930). In practical terms, sea turtle management and conservation projects sometimes involve the manipulation of eggs or their incubation environment, which can alter the sex ratio by changing the thermal environment, either directly or indirectly. For these reasons, amongst others, it interesting to study the seasonal pattern of sex ratio production of sea turtle hatchlings on different nesting beaches.

In terms of the sea turtles nesting on mainland beaches in the state of Bahia, Brazil, previous estimates for loggerhead and hawksbill hatchling sex ratios have suggested a bias heavily skewed (>80%) towards females (Marcovaldi et al., 1997; Godfrey et al., 1999). These estimates were derived from data on pivotal incubation duration and incubation periods, and were validated directly by a limited study based on histological analysis of gonadal development of loggerhead hatchlings (Mrosovsky et al., 1999), and indirectly by a limited study of sand temperatures on nesting beaches (Naro-Maciel et al., 1999).

However, it is known that seasonal sex ratios of turtle hatchlings can vary widely over years (e.g. Janzen, 1994; Godfrey et al., 1996). Thus whenever possible, long-term monitoring of sex ratios, either directly or indirectly, should be conducted in order to uncover long term variations. In this spirit, we have continued to monitor the thermal environment of the nesting beach at Praia do Forte, Bahia, which is one of the main nesting areas for loggerhead and hawksbill sea turtles in Brazil.

MATERIALS AND METHODS:

For the 1998/1999 and 1999/2000 nesting seasons (which run from September through March), we monitored sand temperatures at 2 transects on the nesting beach at Praia do Forte. We used the same methodology as Naro-Maciel et al (1999), which is as follows: each transect was comprised of 3 sites (High, Mid, and Low), each of which was separated by 5-7 meters in distance. High corresponds to the vegetation line, Mid corresponds to middle open beach, and low corresponds to lower beach, close to the high tide line. At each site, we deployed Cu/Cn thermocouple probes at 30cm and 60cm depths, which is similar to other sand temperature monitoring projects (e.g. Mrosovsky and Provancha, 1992, Godfrey et al., 1996; Baptistotte et al., 1999; Naro-Maciel et al., 1999). The thermocouples were left in place the duration of the nesting season. Occasionally, thermocouples were replaced due to loss or damage, and in some cases, monitoring was halted due to excessive erosion by high tides.

The thermocouples were read at 07:30am, ±60 minutes, a minimum of 5 times per half month period. These readings were converted to mean daily temperature by adding a correction factor. The correction factor was derived by recording temperatures every 3 hours for a 24 hour period, and comparing the mean of all readings with the value at 07:30 am. Several "around the clock" readings were carried out during the 2 seasons, and the correction factors for the daily 07:30am readings were matched with the nearest "around the clock" reading. The thermocouples and digital reader (BAT-12, Omega Corporation) were calibrated against a mercury thermometer which turn was calibrated against a certified Hg thermometer.

For statistical analysis, comparisons were made for each site and depth between years, using one-way ANOVA, with a Student-Newman-Keuls post-hoc test.

RESULTS AND DISCUSSION:

During the 1998/99 sea turtle nesting season in Praia do Forte, sand temperatures at both 30cm and 60cm were well above the pivotal temperature of loggerheads and hawksbills (Figure 1). The upper limit of the transitional range of temperature (TRT - the range of incubation temperatures which result in both sexes) for loggerheads and hawksbills is 30.6 °C (Marcovaldi et al., 1997; Godfrey et al., 1999); therefore, sand temperatures above this temperature likely produces all females. In 1998/99, for both depths the sand temperature in Km 07 was above the TRT, likely producing all females. For Km 02, the low and mid transects were close to the TRT, so a majority of females were likely to be produced (more than 50%). This conforms to the previous studies which reported warm sand temperatures and short incubation durations, indicative of female-biased sex ratios of hatchlings.

During the 1999/00 nesting season in Praia do Forte, the sand temperatures at both transects and both depths were close to and sometimes below the pivotal temperature for both species (Figure 2). The cooler sand temperatures were the result of abnormally frequent rainfall during the months of October, November, and December. Although direct estimates of sex ratio are

not possible, it is likely that many more male hatchlings were produced in 1999/00 than in other years, at least during the first half of the nesting season. At the current time, a third of the nests are still incubating on the beach, a majority of which were laid by hawksbill sea turtles. It is possible that warm weather, which is normal for this period of year, during the remainder of the season will result in mostly female hawksbill hatchlings. Continued monitoring will resolve this question.

Statistical comparison between the two seasons showed that for all depths and sites there was a significant difference between the two seasons, except for the low sites at 60 cm depth for Km02 and also for Km07. In addition, on average the temperatures of Km02 were always cooler than Km 07. This is probably due to differences in sand colour and albedo between the areas (Maciel et al., 1999). Normally, the sand temperatures are far enough above pivotal temperature such that this slight thermal difference between the 2 areas does not have an impact on sex ratio. However, in abnormal seasons, such as 1999/00, when sand temperatures are closer to pivotal, different thermal characteristics between the 2 areas may result in different sex ratios.

Although the 1999/00 nesting season likely produced more male hatchlings than normal in Bahia, on average mostly female hatchlings are produced in this areas. This is in contrast to the nesting beaches in Espirito Santo, to the south, where sand temperatures are cooler (Baptistotte et al., 1999) and incubation durations of loggerhead nests are longer (Marcovaldi et al., 1997), which are suggestive of a greater production of male hatchlings. Further south, in the state of Rio de Janeiro, a large nesting population of loggerheads probably also produces a large proportion of male hatchlings, based on limited information of incubation durations in hatcheries (Eron Lima, personal communication). Future studies of sand temperatures in this region are planned.

In the case of hawksbill turtle nests, northern Bahia is home to more than 90% of all hawksbill nests laid in Brazil (Marcovaldi et al., 1999). Normally warm weather conditions produce nearly all female hatchlings (Godfrey et al., 1999); however, abnormally cool seasons that occur occasionally may be critical in producing male hatchlings needed to maintain the population. Studies of gene flow between this nesting population and other populations would reveal if there is interchange among wider populations, or if the number of mating males in the Brazilian population is limited by low male production on beaches in northern Bahia.

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Figure 1. Sand temperatures recorded at Praia do Forte, Bahia, Brazil, during the 1998/99 nesting season, at 30cm (upper) and 60cm (lower) depths. The lower histogram is the distribution of loggerhead (filled columns) and hawksbill (empty columns) sea turtle nests with the thermosensitive period for sexual differentiation for each particular half-month period (right-handed axis). Pivotal temperatures come from Marcovaldi et al. (1997) and Godfrey et al. (1999).

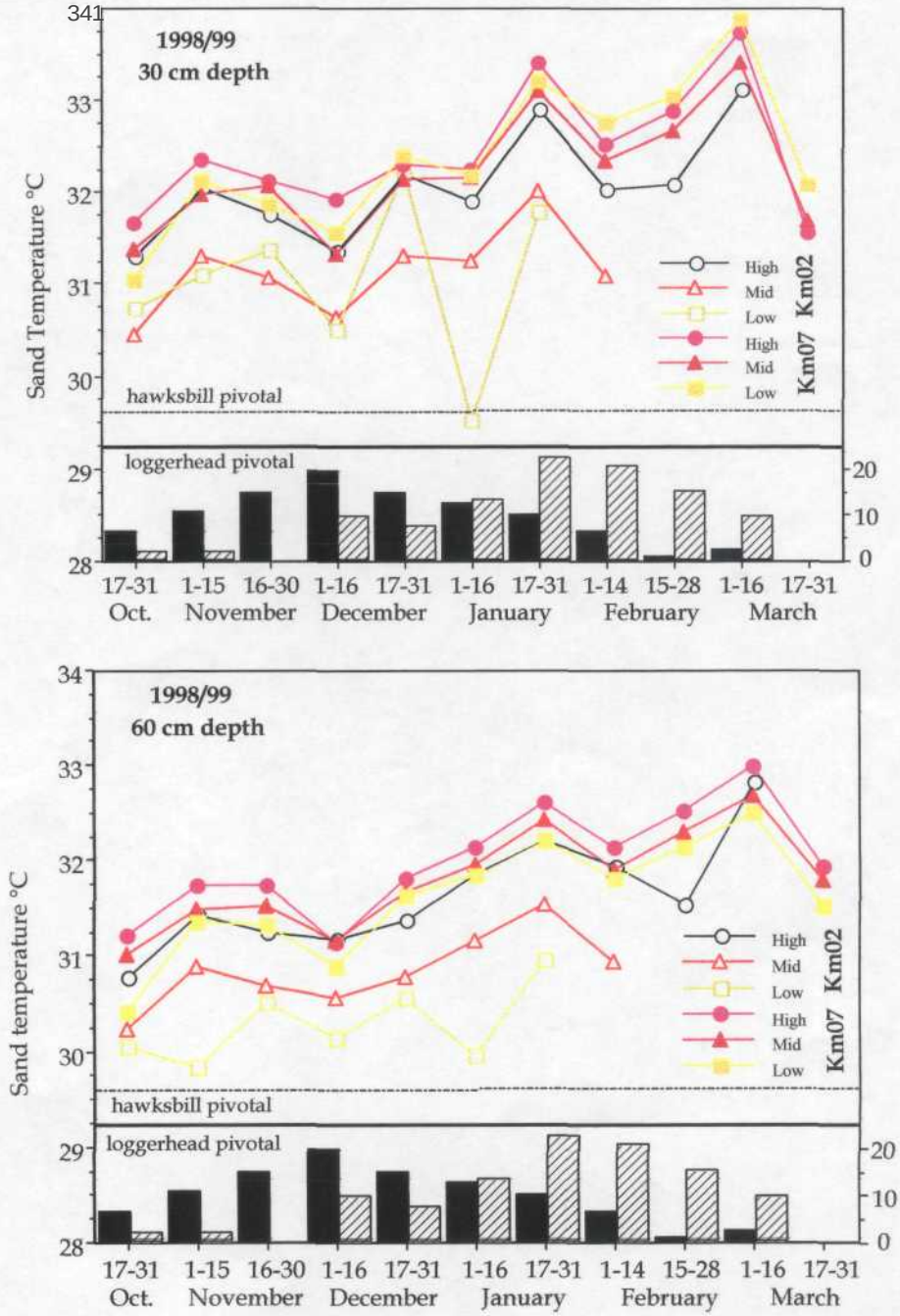

Figure 2. Sand temperature recorded at Praia do Forte, Bahia, Brazil, during the 1999/2000 nesting season, at 30cm (upper) and 60cm (lower) depths. At the time of writing, the nesting season was still in progress.