The Pattern of Emergence by Loggerhead Turtle (Caretta caretta) Hatchlings on Cephalonia, Greece

Author(s): Graeme C. Hays, John R. Speakman and Jack P. Hayes


Published by: Allen Press on behalf of the Herpetologists' League


Accessed: 20-11-2015 16:10 UTC

REFERENCES

Linked references are available on JSTOR for this article:

You may need to log in to JSTOR to access the linked references.
THE PATTERN OF EMERGENCE BY LOGGERHEAD TURTLE (CARETTA CARETTA) HATCHLINGS ON CEPHALONIA, GREECE

Graeme C. Hays, John R. Speakman, and Jack P. Hayes

Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen AB9 2TN, U.K.

ABSTRACT: We examined the emergence pattern of hatchling loggerhead turtles (Caretta caretta) on the Mediterranean island of Cephalonia. Hatchlings usually emerged at night. Hatchlings emerged from each nest on more than one night (n = 10 nests, x = 8.3 nights for emergence of all hatchlings, range = 5–11 nights). The number of nights over which hatchlings emerged increased as the distance of the nest from the sea decreased. Hatchlings did not always emerge as a single group from each nest on any night. When hatchlings emerged later in the night, the sand (depth measures = 3–15 cm) was cooler. This reflected the cooling of the sand during the night and suggested that there was no fixed sand temperature that initiated emergence. However, the time that the first hatchlings emerged each night was significantly correlated with the rate of change of sand temperature in the evening at 15 cm: i.e., when the sand at 15 cm cooled more rapidly in the evening, hatchlings emerged earlier.

Key words: Reptile; Caretta; Loggerhead turtle; Hatchling emergence; Nest; Sand temperature

Sea turtles lay their eggs in a chamber which the female excavates in the sand. After hatching, the young typically take several (3–7) days to dig to the surface (Balazs and Ross, 1974; Christens, 1990; Diamond, 1976; Kraemer and Richardson, 1979; Raj, 1976). Upon emerging from the sand, the hatchlings use light cues to orientate to the sea (Mrosovsky, 1978) and then swim almost continuously out to sea for around 20 h (Dodd, 1988), a behavior termed the swimming frenzy. It is often suggested that the hatchlings emerge en masse from a single nest (e.g., Carr, 1986; Dodd, 1988; LeBuff, 1990; Nelson, 1988). However, this suggestion is largely based on anecdotal observations of groups of hatchlings crawling across the beach together (e.g., Limpus, 1985). Rarely has the temporal pattern of emergence from nests been quantified.

Hatchlings from a nest certainly do not always emerge together. For loggerheads (Caretta caretta), Limpus (1985) reported that a few stragglers emerged on nights subsequent to the main emergence, while Witherington et al. (1990) reported that 1–3 emergence events commonly occur per nest. For green turtles (Chelonia mydas), Hendrickson (1958) reported that about half of all nests produced hatchlings at the surface on more than one night, with some nests producing hatchlings on up to five different nights over a span of up to eight days. For two hawksbill (Eretomochelys imbricata) nests, Diamond (1976) found that young left the nest over a period of up to four days.

Emergence of hatchlings at night is believed to be advantageous by reducing the possibility of heat stress, desiccation, or predation on the beach (Bustard, 1967; Hendrickson, 1958). Sand temperature is believed to be involved initiating emergence (Bustard, 1967; Hendrickson, 1958; Mrosovsky, 1968; Witherington et al., 1990). However, the specific thermal cues used by emerging hatchlings are unknown (Witherington et al., 1990). There may be a fixed absolute thermal threshold below which emergence occurs (Mrosovsky, 1968), or alternatively emergence may be triggered by the rate of cooling of the sand (Witherington et al., 1990).

We investigated the pattern of emergence by hatchling loggerhead turtles on the Mediterranean island of Cephalonia, Greece (38°09' N, 20°33' E). We also examined the thermal environment of the sand adjacent to nests in an attempt to
reveal the thermal cues used by the emerging hatchlings.

MATERIALS AND METHODS
Between 1 June and 31 August 1990, we monitored the loggerhead turtles nesting on Potamakia beach, Cephalonia. Carefully excavating and handling eggs of sea turtles soon (<3 h) after they have been laid has been shown not to reduce subsequent hatchling success (Harry and Limpuss, 1989; Parmenter, 1980). Therefore the number of eggs laid in each nest was ascertained by carefully excavating the eggs immediately after we observed laying. We then carefully replaced the eggs in the original egg chamber and covered up the site with the original sand. At the time of laying, the distance from the nest to the sea was measured with a 30 m flexible tape measure. We were unable to detect any tidal variation in sea height, which is consistent with the negligible tidal fluctuations reported for the eastern Mediterranean (Couper, 1983).

The minimum incubation time reported for loggerheads is 49 days (Dodd, 1988). Hatchling emergence was therefore only monitored rigorously after 45 days from the date of laying. Hatchling emergence was monitored in three ways. Firstly, to establish the number of hatchlings emerging from nests each night, we placed large (approximately 70 cm diameter, 30 cm high) inverted plastic bowls over nest sites. Bowls were placed over the nest sites between 2030 h and 2100 h each evening, and were removed between 0700 h and 0730 h in the morning. Emerging hatchlings were trapped under the bowls. Nests were checked throughout the night at intervals of no longer than 3 h. We counted the hatchlings that emerged and measured their straight line carapace length (anterior of the precentral scute at the carapace mid-line to the posterior of the postcentrals) to the nearest 0.1 mm with dial calipers. The hatchlings were then released adjacent to the nest site.

Secondly, to establish the timing of hatchling emergence, we used a small (approximately 2 kg), battery powered radar (model 22, Mariner Radar Ltd., Lowestoft, England). The radar produced a continuous emission of linearly polarized microwaves (wavelength 32 mm, frequency 9.41 GHz) radiated via a 13 cm long horn antenna. As they crawled towards the sea, hatchlings were funneled by a wire mesh into a trap (a 50 cm diameter plastic bowl sunk in the sand) in which the radar was placed. The time when the first hatchling(s) fell into the trap was recorded as a change in the signal detected by the radar. Direct observation showed that the time interval between the first hatchlings emerging fully from the sand and falling into the trap was <30 s. The radar output was recorded on a battery powered data logger (Grant Squirrel: Grant Instruments Ltd.). We simultaneously recorded sand temperatures adjacent to the nest at depths of 3, 5, 10, and 15 cm, using thermistor probes linked to the same data logger. Both radar and temperature readings at each depth were taken every 10 s throughout the night (0900–0730 h). These 10-s readings were averaged every 10 min and the 10-min averages were recorded by the logger. The trap was checked regularly (maximum 3 h interval) throughout the night, and any hatchlings found were measured and released adjacent to the nest site. We were thus able to record the time when the first hatchling(s) emerged from a nest to an accuracy of 10 min, and, after those hatchlings had been released, the time that the next hatchling(s) emerged, and so on through the night.

Before releasing hatchlings from the traps, we switched off all lights so that the hatchlings were not disorientated (Mrosovsky, 1978). The proportion of emerged hatchlings that successfully reached the sea was then determined by direct observation.

Thirdly, to record the small (<20) numbers of hatchlings that sometimes emerged from nests during the day, we counted the tracks leading from nests at approximately 1200 h and then at approximately 2030 h, prior to the placement of the hatchling traps at the nests. The number of day-time emerging hatchlings that died on the beach was ascertained by recording how many of these tracks failed to reach the sea. In
Cu, 300
E
1
FIG. 1.—The mean number (±1 SE) of hatchlings emerging from nests in relation to the number of nights since the first emergence from that nest (night one = the first night of hatching emergence from each nest; nights = 1200–1200 h); log (mean number emerging + 1) = 1.69−0.205 number of nights since the first emergence (F = 264, df = 1, 9, r² = 0.97, P < 0.01).

Results

We monitored hatching emergence at 10 nests. At two of these nests, we failed to catch and count the hatchlings that emerged on one night because they emerged outside of the trap. For the eight nests for which we had complete data, a total of 887 eggs were laid and a total of 635 hatchlings emerged: i.e., hatchling success averaged 71.6%. Of the hatchlings that emerged, most (88.2%) came out between 2030 h and 0730 h. A significantly higher proportion of hatchlings that emerged between 2030–0730 h reached the sea (560 out of 560 = 100%) than those that emerged between 0730–2030 h (72 out of 75 = 96%): G = 8.74, df = 1, P < 0.01.

Hatchlings from individual nests always emerged on more than one night (defined forthwith as 1200–1200 h) from individual nests (n = 10 nests, mean interval between the first and last night of emergence from a nest = 8.3 nights, range 5–11 nights, SE = 0.63). The mean nightly number of hatchlings that emerged following the first night of emergence showed a significant exponential decline (Fig. 1). The number of hatchlings that emerged each night was not significantly different between nests covered with an inverted bowl and those not covered [analysis of covariance of log (number emerging) against number of nights since first emergence and whether nests were covered or uncovered: nights since first emergence, F = 91.5, df = 1,105, P < 0.01; covered or uncovered, F = 0.1, df = 1,105, P > 0.05]. The number of nights over which hatchlings emerged increased significantly as the distance of the nest from the sea decreased (Fig. 2).

Mean hatchling size on each night was not linearly correlated with the number of hatchlings emerging on that night (F = 0.01, df = 1,60, P > 0.05), the number of nights since the first emergence from the nest (F = 0.04, df = 1,60, P > 0.05), or a combination of these two factors (F = 0.05, df = 2,59, P > 0.05).

The number of hatchlings caught in the radar trap increased significantly both as the time interval over which they had emerged and the total number emerging from the nest on that night increased. The total number emerging that night explained 49.7%, and the length of the sampling interval 11.9%, of the variation in the number caught in a single interval. The complete equation was:

Number caught per interval = 0.385 number emerging that night + 0.06
length of time interval (min) = 2.42
\(F = 20.1, \ df = 2.25, r^2 = 0.616, P < 0.01\) (eq. 1)

We recorded the time of the first hatching emergence on 11 separate nights (\(n = 5\) different nests). Sand temperatures at all four depths at the time of the first emergence were significantly cooler when this first emergence occurred later in the night (Fig. 3), reflecting the cooling of the sand during the night: i.e., there was no fixed absolute sand temperature at any of these depths at which the first emergence occurred. At the time of the first emergence, the sand temperature ranged from 20.2–28.1 C at 3 cm, 21.8–29.7 C at 5 cm, 25.2–31.9 C at 10 cm, and 27.9–32.0 C at 15 cm.

The time of the first emergence was not correlated with the mean sand temperature at 3, 5, 10, or 15 cm between 2100 h and 2300 h (\(F = 0.29, 0.01, 0.00, 0.33\) respectively, \(df = 1.9; P > 0.05\) in all cases). Thus the first hatchlings did not emerge later or earlier depending on the absolute evening temperatures of the sand at any of these depths. The time of the initial hatching emergence was also not correlated with the rate of sand cooling (C per h) between 2100 h and 2300 h at 3, 5, or 10 cm (\(F = 0.53, 0.78,\) and 2.16 respectively, \(df = 1.9; P > 0.05\) in all cases), but was significantly correlated with the rate of sand cooling at 15 cm (Fig. 4). Thus when the evening temperature at 15 cm declined rapidly, the initial emergence occurred significantly earlier on that night.

**DISCUSSION**

It has been suggested that hatchling sea turtles remain in the egg chamber until their siblings hatch, so that individuals emerge as part of a group and not singly (Carr and Hirth, 1961). Alternatively group emergence may simply reflect synchrony in the time that eggs in a nest take to hatch (Carr and Ogren, 1960). For hatchlings of green turtles, Carr and Hirth (1961) showed that those attempting to emerge singly had a reduced chance of reaching the surface. They therefore suggested that group emergence may reduce the energy expended in emerging from a nest, and hence be advantageous. However, if hatchlings wait in the egg chamber for a long time, then the energy expended while waiting for siblings to hatch may exceed that saved by digging out as part of a group. In other words, hatchlings may minimize their energy expenditure by limiting the length of time that they wait for their siblings to hatch.
We found that hatchlings emerged from all the nests on more than one night (Fig. 1). In addition, the increase in the number of hatchlings caught as the length of the sampling interval increased (eq. 1), showed that on each night hatchlings did not always emerge as a single group. These results therefore suggest that, firstly, there was variation within nests in the time to hatching, and secondly, that there were factors limiting the time that siblings waited for one another to hatch.

The energy expended by green turtle hatchlings while at rest after hatching and while actively swimming has been quantified by Prange and Ackerman (1974). Hatchlings expended an average of 0.099 ml O₂ g⁻¹ h⁻¹ while at rest and 0.337 ml O₂ g⁻¹ h⁻¹ while swimming. The total energy expended during 20 h of continuous swimming (i.e., the swimming frenzy) would therefore be 6.74 ml O₂ g⁻¹. The longer that green turtle hatchlings spend in the egg chamber, the more energy they will utilize. Thus if the length of time that a green turtle hatchling spent in the egg chamber rose from 1–11 days, then the energy expended in the egg chamber would increase from 2.38–26.14 ml O₂ g⁻¹; i.e., from 35.3–387.8% of the energy expended in the swimming frenzy. Thus it would appear that in green turtles, the energy expended while remaining in the egg chamber is certainly not trivial. The same is most probably true for loggerhead turtles, and hence this is likely to be a major factor limiting the time that hatchlings wait for their siblings. In addition, the longer a hatchling remains buried, the greater may be the probability that it is detected and excavated by predators.

The marked asynchrony in emergence that we observed, with hatchlings emerging over a maximum of 11 days, has not been reported previously. However, hatchlings have been observed to emerge from a single nest on more than one night, both in other populations of loggerhead turtles (Limpus, 1985; Witherington et al., 1990), in green turtles (Hendrickson, 1958), and in hawksbills (Diamond, 1976). This suggests that emergence asynchrony may be widespread in other populations of sea turtles.

Comparison of covered with uncovered nests suggested that covering the nests did not influence the nightly number of hatchlings that emerged. We do not know why emergence asynchrony was most marked for nests laid closer to the sea (Fig. 2). Incubation time for sea turtle eggs is influenced by temperature (Mrosovsky and Yntema, 1980) and oxygen levels (Ackerman, 1980). For nests laid closer to the sea, there may therefore have been a wider range of temperatures and/or oxygen levels in different parts of the nest, and hence greater variation in the intra-nest time to hatching.

Hatchling size did not vary with either the number of hatchlings emerging from a nest on that night or with the number of nights since the first emergence. This suggests that variations in hatchling size within a nest were not the cause of the emergence asynchrony. For example, hatchlings emerging on the first few nights or those emerging in larger nightly groups were not different in size to those emerging in later nights or in smaller nightly groups.

We found that the majority of hatchlings emerged at night, which is consistent with previous reports for loggerhead (Limpus, 1985) and green turtles (Bustard, 1967). Hatchlings that emerged during the day were significantly more likely to die on the beach, as Hendrickson (1958) and Bustard (1967) suggested. However, mortality on the beach was low both at night (0%) and during the day (4%).

It has been suggested that emergence of hatchlings during the day may be inhibited by high sand temperatures, and that thermal cues may also be used by hatchlings to time their night-time emergence (Bustard, 1967; Mrosovsky, 1968; Witherington et al., 1990). We found that the time of the first emergence was not correlated with any fixed absolute sand temperature (Fig. 3). Hatchlings may emerge from a single beach over several months (Witherington et al., 1990). Over such a time, there may be significant changes in the absolute temperature of the sand, and thus a single absolute temperature cue may not reliably ensure that emergence occurs at night.
When the sand at 15 cm cooled rapidly in the evening, the first hatchlings emerged earlier in the night (Fig. 4). However, no such correlation was found at any of the shallower depths. This suggests that on the night of emergence the hatchlings were digging their way out from a depth of at least 15 cm. In humans, the ability to perceive cold or warm sensations is influenced by the rate of change of temperature (Hensel, 1981). For example, if temperature is lowered slowly, it takes longer for a cold sensation to be perceived than if temperature is lowered more rapidly. Such a system might also explain the pattern of hatchling emergence that we recorded (Fig. 4). Thus when sand temperature dropped rapidly, hatchlings may have been able to perceive “cooling” sooner than when temperature dropped more slowly. If “cooling” induced emergence, hatchlings would therefore emerge earlier when the sand temperature dropped rapidly (Fig. 4).

Responding to the rate of change of sand temperature, rather than the absolute sand temperature, may be a more reliable way of ensuring that emergence occurs at night. This would also explain the anecdotal reports of hatchlings emerging during the day following rain showers (Carr, 1986; Witherington et al., 1990), as the rain may cause a rapid cooling of the sand.

Acknowledgments.—We thank all the volunteers who helped with field work. The senior author was supported by an Aberdeen University Studentship.

LITERATURE CITED


Accepted: 10 December 1991
Associate Editor: H. Carl Gerhardt