COMMENTARIES AND REVIEWS

Editorial Comment. – This section has been established as a forum for the exchange of ideas, opinions, position statements, policy recommendations, and other reviews regarding turtle-related matters. Commentaries and points of view represent the personal opinions of the authors, and are peer-reviewed only to the extent necessary to help authors avoid clear errors or obvious misrepresentations or to improve the clarity of their submission, while allowing them the freedom to express opinions or conclusions that may be at significant variance with those of other authorities. We hope that controversial opinions expressed in this section will be counterbalanced by responsible replies from other specialists, and we encourage a productive dialogue in print between the interested parties. Shorter position statements, policy recommendations, book reviews, obituaries, and other reports are reviewed only by the editorial staff. The editors reserve the right to reject any submissions that do not meet clear standards of scientific professionalism.

Chelonian Conservation and Biology, 1999, 3(3):521–522

Estimating the Time Between Hatching and Emergence from the Nest of Sea Turtles: Effects of Ignoring Water Potential

ANTHONY C. STEYERMARK[1,2]

[1]*Department of Bioscience and Biotechnology, Drexel University, Philadelphia, Pennsylvania 19104 USA;*
[2]*Present Address: Department of Physiology, UCLA School of Medicine, University of California, Los Angeles, California 90095 USA*
[Fax: 310-206-5661; E-mail: Asteyermark@mednet.ucla.edu]

Godfrey and Mrosovsky (1997) recently introduced a method to estimate the time difference between sea turtle hatching and emergence from the nest. Previous estimates or direct observations of the time between hatching and emergence have resulted in manipulation of the nest in some fashion. Two main criticisms of previous methodologies emerged: 1) nest manipulation may disturb the nest and alter normal hatching and emergence, 2) some methodologies are expensive, labor intensive, and can only be used with relatively small numbers of nests.

The method Godfrey and Mrosovsky introduced is based on coupling the phenomena of temperature-dependent sex determination with the correlation of nest temperature and incubation time. With knowledge of a nest's sex ratio (obtained by histologically sexing a subset of hatchlings from a nest) the incubation temperature of the nest can be estimated. From the estimated nest temperature, the incubation period (days to hatching) can be estimated from laboratory studies. Finally, the difference between the estimated incubation period and observed time to emergence in the field yields an estimate of time between hatching and emergence. Godfrey and Mrosovsky claimed their method is suitable "for estimating mean hatching to emergence interval of large groups of nests."

Like most estimates, Godfrey and Mrosovsky's method was based on several assumptions, including little daily fluctuation in temperatures of natural nests, normal egg development of eggs used in laboratory studies, and that the sex ratio is correlated with incubation duration. It is this last assumption that proves problematic. Implicit in this third assumption is that only incubation temperature (which determines sex ratio) affects incubation duration.

Not addressed by Godfrey and Mrosovsky is that water relations can also have significant effects on incubation duration of turtle eggs. Freshwater turtle eggs incubated on wet substrates generally have a longer incubation period than eggs incubated on drier substrates (Morris et al., 1983; Packard et al., 1983, 1987; Gettinger et al., 1984; Packard and Packard, 1993; Janzen, 1993). Incubation duration is generally 2–4 days longer for eggs incubated on wet substrates (ca. -150 kPa) as compared to those incubated on dry substrates (ca. -900 kPa). While most experimental designs have incubated eggs on vermiculite, the results are applicable to eggs incubated on sand as well (Packard et al., 1987). Studies have also demonstrated that the position of the egg on the substrate can affect incubation duration; eggs incubated half-buried in the substrate had longer incubation periods than eggs resting on platforms above the substrate (Packard et al., 1983; Morris et al., 1983).

McGehee (1990) found that moisture regime had a significant effect on incubation duration of loggerhead (*Caretta caretta)* eggs: eggs incubated at -10 kPa took a mean of 62.4 days to hatch, eggs incubated at -4.8 kPa took a mean of 63.1 days to hatch, while eggs incubated at 0 kPa took a mean of 66.7 days to hatch. Data from Leslie et al. (1996) indicated that water potential of the leatherback nesting beach at Tortuguero, Costa Rica, during April through July, recorded at a 75 cm depth, ranged from approximately -8.5 kPa to -1.5 kPa, and decreased through the nesting season. In addition, water potential appeared to vary with regard to beach zone location: soil water potential rose after heavy rains in the low and open mid-beach zones, but remained more stable in the vegetated beach zone. Hence, if leatherback eggs react in similar fashion to the loggerhead eggs used by McGehee (1990), temporal and spatial variation in soil moisture alone at Tortuguero could potentially lead to differences in incubation duration of approximately 3 days.

From the above studies it is clear that water relations to which eggs are exposed to during incubation, and even whether eggs are in contact with the substrate, can have significant effects on incubation duration, independent of incubation temperature. Godfrey and Mrosovsky based their laboratory incubation duration on data from Mrosovsky (1988), in which eggs were incubated individually within a jar with a lid, and were apparently in contact with both a moistened sponge and surrounded by moist vermiculite. It is not possible to estimate the water potential of the incubation substrate used in the laboratory experiment, nor are data available on water potential of the sand from the natural nests used to measure incubation duration plus emergence time. Thus the potential for error of Godfrey and Mrosovsky's estimate of time between hatching and emergence can be on the order of several days since the moisture regime of both the laboratory and field experiments are not known.

At one potential extreme, eggs in the laboratory incubated on dry substrate would yield short incubation durations, while eggs from the field incubated in wet sand would yield long incubation durations. The estimated time between hatching and emergence would then be overestimated. At the other potential extreme, eggs in the laboratory incubated on wet substrate would yield long incubation durations, while eggs from the field incubated in dry sand would yield short incubation durations. The estimated time between hatching and emergence would then be underestimated. Data from previous studies on the effects of varying moisture regimes on eggs of both freshwater and sea turtles indicate that resultant differences in incubation duration at similar incubation temperatures could be up to four days, which is equal to Godfrey and Mrosovsky's estimated time between hatching and emergence.

It is apparent from previous work that substrate moisture regime is an important determinant of incubation duration. As such, any estimation of incubation duration must take not only temperature but also moisture regime of the incubation environment into account.

Literature Cited

GETTINGER, R.D., PAUKSTIS, G.L., AND GUTZKE, W.H.N. 1984. Influence of hydric environment on oxygen consumption by embryonic turtles *Chelydra serpentina* and *Trionyx spiniferus*. Physiol. Zool. 57:468-473.

GODFREY, M. H., AND MROSOVSKY, N. 1997. Estimating the time between hatching of sea turtles and their emergence from the nest. Chelonian Conservation and Biology 2:581-585.

JANZEN, F.J. 1993. An experimental analysis of natural selection on body size of hatchling turtles. Ecology 74:332-341.

LESLIE, A.J., PENICK, D.N., SPOTILA, J.R., AND PALADINO, F.V. 1996. Leatherback turtle, *Dermochelys coriacea*, nesting and nest success at Tortuguero, Costa Rica, 1990–1991. Chelonian Conservation and Biology 2:159-168.

MCGEHEE, M.A. 1990. Effects of moisture on eggs and hatchlings of loggerhead sea turtles (*Caretta caretta*). Herpetologica 46:251-258.

MORRIS, K.A., PACKARD, G.C., BOARDMAN, T.J., PAUKSTIS, G.L., AND PACKARD, M.J. 1983. Effect of the hydric environment on growth of embryonic snapping turtles (*Chelydra serpentina*). Herpetologica 39:272-285.

MROSOVSKY, N. 1988. Pivotal temperatures for loggerhead turtles (*Caretta caretta*) form northern and southern nesting beaches. Can. J. Zool. 66:661-669.

PACKARD, G.C., AND PACKARD, M.J. 1993. Sources of variation in laboratory measurements of water relations of reptilian eggs and embryos. Physiol. Zool. 66:115-127.

PACKARD, G.C., PACKARD, M.J., BOARDMAN, T.J., MORRIS, K.A., AND SHUMAN, R.D. 1983. Influence of water exchanges by flexible shelled eggs of painted turtles *Chrysemys picta* on metabolism on metabolism and growth of embryos. Physiol. Zool. 56:217-230.

PACKARD, G.C., PACKARD, M.J., MILLER, K., AND BOARDMAN, T.J. 1987. Influence of moisture, temperature, and substrate on snapping turtle eggs and embryos. Ecology 68:983-993.

Received: 28 February 1998
Reviewed: 8 September 1998
Revised and Accepted: 24 September 1998