Photo of a hawksbill (left) and loggerhead (right) hatchling. While these turtles are similar in color, both species can also appear much darker. Note their differences in shape. See pages 9-12 (J. Wynne photo).

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Report

Recent Publications
The Evolution of Hatchling Morphology

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Marine turtles combine contrasting life history characteristics. As adults they are K-selected animals that are large, powerful swimmers with few enemies and high probabilities of survival (Heppell et al. 2003). However, they show more r-selected characteristics during reproduction as each female produces hundreds to thousands of hatchlings but few of these survive to become adults. Such high mortality is typical of the dispersal stages of many migratory organisms (Dingle 2013). These observations suggest that hatchlings should be under strong selection pressure to evolve traits that provide even a small survival advantage.

One such trait that is consistently evident is their strong migratory drive: in most marine turtles, post-emergence hatchlings show a “frenzy” period of enhanced activity, much like the well-known Zugunruhe (migratory “restlessness”) hyperactivity shown by migratory birds. These highly specialized and rigidly programmed behavioral tendencies have rendered hatchling turtles (as well as migratory birds) ideal subjects for experiments to identify orientation cues (for review, see Lohmann et al. 2003), and to explore differences in migratory strategies among populations or species (Wynen et al. 2008; Chung et al. 2009; Salmon et al. 2009).

While these behavioral discoveries are both important and fascinating, hatchling morphology, another obvious trait that could impact hatchling migratory survival, has been largely ignored. It is well-known that the hatchlings of marine turtle species differ in size, shape and color. What is less understood is why such differences exist and what benefits they confer. These characteristics are often described, routinely measured, and faithfully reported in the published synopses on each species. But with few exceptions, they are rarely considered again other than in contexts such as life history studies (e.g., van Buskirk & Crowder 1991). Our goal here is to compare and contrast the morphological differences between two closely related species (Narco-Macié et al. 2008): hawksbills (Eretmochelys imbricata) and loggerheads (Caretta caretta; cover photograph). We then present a general hypothesis that relates those differences to presumed survival advantages. We suggest that many features of hatchling morphology probably have evolved for just that reason.

Our data come from measurements made in 2012 on naturally emerging hawksbills sampled from nests at Jumby Bay, Antigua, West Indies, and from naturally emerging loggerheads during the same year from nests in Boca Raton, Florida, U.S.A. We measured straight carapace length (SCL), straight carapace width (SCW), mass, and rear flipper area (RFA). RFA in mm² was calculated using the program Image J from scaled photographs of hatchlings. Sample sizes were 79 hawksbill hatchlings from 8 nests and 84 loggerhead hatchlings from 9 nests, except for loggerhead RFA/SCL, which was based on 40 hatchlings from 8 nests.

Our measurements confirm that hawksbills are on average smaller than loggerheads as they are significantly shorter in SCL and lighter in mass (Fig. 1, left two columns). The two species also differ in proportions that may be considered independently of their differences in size. Hawksbills are narrower for their length than loggerheads (SCL/SCW; Fig. 1, third column). We also determined that hawksbill rear flippers are proportionally larger in area, given the length of each species (based on RFA/SCL; Fig. 1, right column). Hawksbill average RFA (155.6 mm² ± 25.6 SD) is also absolutely larger than average loggerhead RFA (131.4 mm² ± 15.5 SD; t = 5.82, p < 0.0001). How might differences such as these provide a survival advantage?

We hypothesize that the survival advantages accrue both before and after emergence from the nest. In the Caribbean, where most hawksbills nest, females select sites near to or under a canopy of vegetation (Kamel 2013, Fig. 2) whereas in Florida, where most loggerheads nest, females select sites on the open beach between the
Figure 1. Morphological comparisons between Antigua hawksbill (H) and Florida loggerhead (L) hatchlings from the 2012 nesting season. Plots show the mean (filled circle), first standard deviation (box) and range (vertical line) of the measurements. All the comparisons are significantly different by a two-tailed T-test (at p < 0.001 or 0.0001). Abbreviations are: SCL= straight line carapace length in mm; SCL/SCW=SCL divided by straight line carapace width in mm; and RFA/ SCL, rear flipper area in mm² divided by straight line carapace length in mm.

Figure 2. Above, left: hawksbill hatchling crawling toward the sea. Note its narrow body shape. Above, right: nest under vegetation and surrounded by a screen to collect the hatchlings after an emergence. Below, excavated egg chamber showing its invasion by roots. (M. Reising, photos).
dune and the mean extent of high tide (Witherington et al. 2006). Hatchling loggerheads rarely must contend with the invasion of plant roots into the egg chamber. That is not the case with hawksbills where such invasions often occur (Fig. 2) and may select for smaller hatchlings. Animals that dig through substrates containing a labyrinth of obstructions benefit not only from being smaller but also by possessing a more rounded, cylindrical shape in cross section like an earthworm or a mole, or in this case a hawksbill, both because less soil must be displaced to make forward progress and because a barrel-shaped body is less likely to be impeded by small spaces between solid or (in areas thick with plant roots) filamentous obstructions (Dunn 2006; www.stuartsumaida.com). Sea turtles have the advantage of digging their way upward as a group but even so, individual hawksbill hatchlings must often negotiate their way through a maze of plant roots. Larger rear flippers should enable each turtle to exert greater upward pressure where that force is necessary. Broader rear flippers may also enable the turtles to more efficiently compact loose sediment behind them as they progress upward toward the surface.

After they emerge a smaller more cylindrical body shape and broader rear flippers may assist by expediting their crawl through a forest floor containing a maze of vines, leaves and branches (Fig. 2). Morphological characteristics may also confer survival advantages once the turtles begin migrating offshore. Hawkshill hatchlings are unusual in this respect. Behavioral studies from Malaysia show that after entering the sea, hawksbills initially swim with vigor using their most efficient front-flipper gait: powerstroking. Within an hour, swimming activity rapidly declines by ~ 30% and rear-flipper kicking takes over as the dominant mode of locomotion (Chung et al. 2009). Even though this mode of locomotion is less efficient, the possession of larger rear flippers should allow the hatchlings to distance themselves further from shallow water areas with their abundance of predators. After about 3 hours, the turtles are almost completely inactive and probably drift offshore with the prevailing currents. The result is slower progression away from shallow water and its abundant predators than other species. However, this escape strategy may render the turtles more difficult to detect by predators, especially those sensitive to prey movement.

In contrast, the dominant swimming gait shown by loggerheads (and hatchlings of all other species) after entering the sea is powerstroking, as confirmed by both laboratory (Wyneken 2003) and field (Witherington 1995) observations. In most populations, powerstroking persists for many hours or even days. We hope that these observations and suggestions inspire others to further explore possible relationships between hatchling morphology, ecology, behavior and survival. Much also remains to be learned by considering what happens next in their life histories - that is, how small and still vulnerable neonates change in shape during early growth. The results reported here, in previous studies on hatchlings (e.g., Wyneken et al. 1999), and on the morphology of young juveniles (Salmon & Scholl 2014; Salmon et al. 2015) suggest that shape change is common and accompanied by allometric (disproportionate) growth between the limbs and the body. We now need to better understand the functional significance of these diverse growth and form patterns in terms of their costs and benefits to each species.

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