Does allometric growth in juvenile marine turtles have survival benefits? A morphological test with a gape-limited predator

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Introduction

As they develop many animals change their body proportions through a process known as *allometric* growth[1]. These growth patterns evolve for a variety of reasons having in common that they improve the chances of survival and/or reproductive success compared to the alternative (*isometric growth*) pattern, in which animals simply become proportionately larger.

Green turtles (*Chelonia mydas*) and loggerheads (*Caretta caretta*) produce many small, defenseless offspring vulnerable to a variety of oceanic predators. They improve their chances of survival by hiding in *Sargassum* (a floating algae) weedlines[2]. The dolphin fish (*Coryphaena hippurus*) is a well known gape-limited predator that swallows small turtles whole. While raising turtles for other studies, we noticed that they appeared to change body shape disproportionately, perhaps in a way that might make them more difficult for dolphin to swallow. Those observations prompted us to test the hypothesis that allometric growth in juvenile sea turtles might thwart gape-limited predators.

Methods

We reared green and loggerhead turtles in the lab for 13 weeks. All of the turtles came from nests deposited on a beach in Boca Raton, Florida, during the Summer and Fall of 2011 and 2012. Ten hatchlings were selected from each of 12 loggerhead and 12 green sea turtle nests. Straight line carapace length (SCL) and carapace width (SCW) were measured weekly (Fig. 1). The first SCL and SCW measurement, taken from hatchlings, was used to determine an expected growth trajectory assuming isometry (a proportional change in SCW with larger SCL). The measurements we observed were used to determine if SCW changed allometrically as the turtles grew.

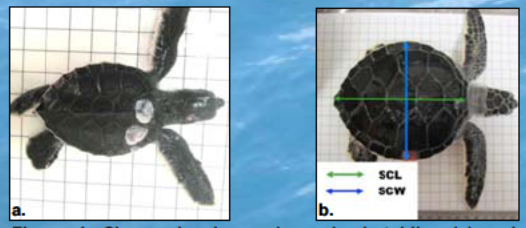


Figure 1. Change in shape shown by hatchling (a) and juvenile (b) green turtles. SCW appears to increase faster than SCL. Scale, 1 cm².

We measured dolphin fish fork length (Fig. 2a) and mouth gape (Fig. 2c-d) at several sport fishing tournaments, using a flexible cone (Fig. 2b). We then used linear regression to relate these values to one another, and to estimate fish gape when only length was reported in the literature[3]. Mouth diameter was estimated from mouth gape to compare with turtle SCW.

Figure 2. Measuring dolphin length and gape. See the text for details.

Results

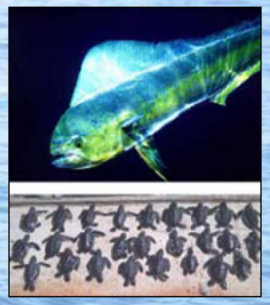


Figure 3. Dolphin on the line (above) and green turtles found in its stomach (below).

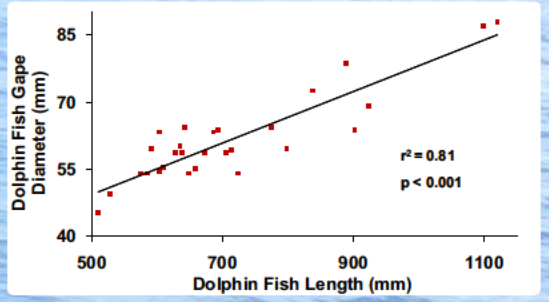


Figure 4. Dolphin fish gape (mm) regressed against its fork length (mm). The relationship is statistically significant.

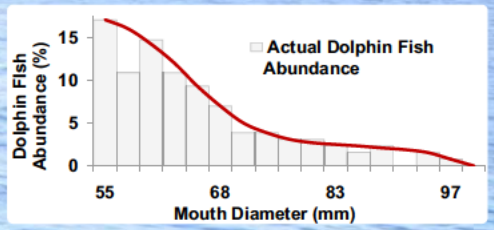
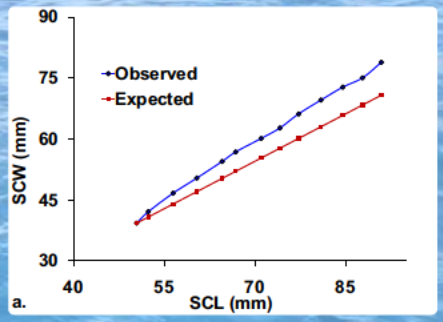


Figure 7. Estimated abundance in the population of dolphin with a given gape width. Data are based upon capture frequencies in the Straits of Florida (Beardsley[3]).



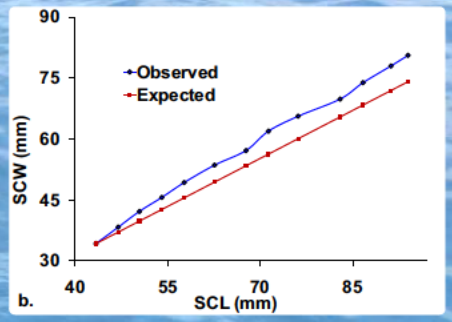
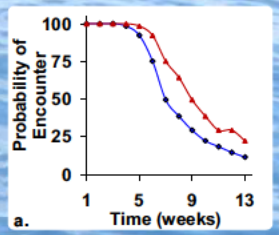


Figure 5a, b. *Observed* mean SCW (blue line) versus *expected* SCW (red line) as a function of increased SCL as green turtles (a) and loggerheads (b) grow over 13 weeks. The graphs above are taken from one representative nest of each species (and its 10 turtles). For each species, data were obtained from 12 nests (n = 120 turtles) and the slopes analyzed using paired t-tests. For each species, the observed slope was significantly steeper than the expected slope (green turtles: $p < 0.01$, $t = 6.1$, $df = 11$; loggerheads: $p < 0.01$, $t = 10.4$, $df = 11$), which retains the hatchling proportions with growth. Thus, SCW increases proportionally faster than SCL, showing that growth in both species is positively allometric.



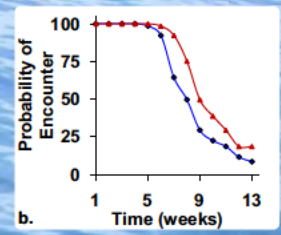
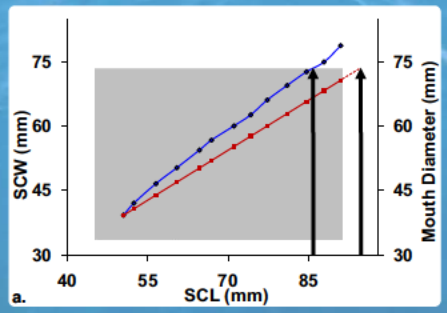


Figure 8a, b. Graphs show the probability that an encountered dolphin fish will be large enough to swallow a green turtle (a) or a loggerhead (b) growing isometrically (red) or allometrically (blue). In both species differences appear after ~ 5 weeks of growth and peak at ~ 7 weeks. Turtles growing allometrically should have enhanced probabilities of survival as their chances of encountering a fish that can swallow them declines faster.



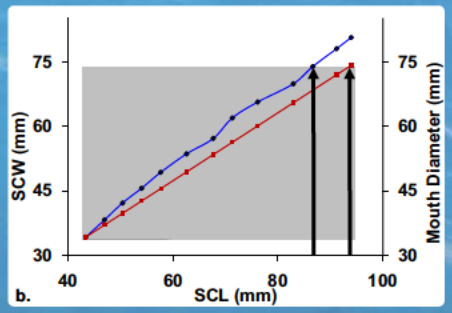


Figure 6a, b. Range of dolphin gape diameter (shaded area) relative to turtle SCW across the time of turtle growth for green turtles (a) and loggerheads (b). The shaded region represents the gape size range of about 70% of the dolphin fish in Florida waters[3]. Any turtle with an SCW that falls within the shaded area might be swallowed by a dolphin. These graphs are averages for one cohort of 10 turtles all from the same (representative) nest. Similar graphs were created for each nest and the slopes were analyzed. On average, allometric growth (blue) affords protection from dolphin almost 3 weeks earlier for green turtles, and 2 weeks earlier for loggerheads, than isometric growth (red; space between arrows on x-axis).

Conclusions

- There have been several studies describing the growth of juvenile marine turtles, but this study is the first to present a plausible hypothesis for why an *allometric growth pattern* should evolve. It has survival value!
- This pattern occurs in all hard-shelled marine turtle species.
- Both green turtles and loggerheads display positive allometric growth in which SCW increases proportionally faster than SCL (Fig. 5a, b).
- This growth pattern should reduce the time that small turtles are vulnerable to gape-limited predators like dolphin (Fig. 6a, b). Allometric growth also should decrease the probability that a dolphin encountered by a juvenile turtle will be large enough to ingest that turtle (Fig. 8).

References

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Acknowledgements

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