Intrapopulation Reproductive Traits of Green Turtles (*Chelonia mydas*) at Tortuguero, Costa Rica[1]

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ABSTRACT

Some aspects of the reproductive biology of green turtles (*Chelonia mydas*) nesting at Tortuguero, Costa Rica, were studied. Ten relationships involving reproductive and morphologic traits of recruits (first-time nesters) were analyzed. Statistically significant positive relationships were found between clutch sizes and carapace lengths of recruits, but significant negative relationships were found between sizes of hatchlings and sizes of recruits. The relative clutch mass of recruits was between 3.42 and 5.54 percent, and no significant size dependence was detected.

RESUMEN

Se estudiaron algunos aspectos de la biología reproductiva de las tortugas verdes (*Chelonia mydas*) que anidan en Tortuguero, Costa Rica. Se analizaron diez relaciones entre rasgos reproductivos y morfológicos de reclutas (aquéllas que anidan por primera vez). Se encontraron relaciones positivas y estadísticamente significantes entre el número de huevos puestos y las longitudes de los carapachos de las reclutas, pero se encontraron relaciones negativas y significantes entre los tamaños de los neonatos y los de las reclutas. El relación entre el peso de los huevos y el peso de la hembra de las reclutas fué entre 3.42 y 5.54 por ciento y no se descubrió ninguna dependencia significante respecto al tamaño.

OF PARTICULAR INTEREST IN EVOLUTIONARY ECOLOGY are the degrees of reproductive and morphologic variation within a population. Green turtles (*Chelonia mydas*) are interesting reptiles to work with in this regard because nesting demes are reproductively isolated from each other, and pertinent biological information can easily be obtained during the nesting season.

The green turtle research program at Tortuguero, Costa Rica, is now in its thirtieth year. The major emphasis here has been on tagging turtles, and this has provided information on population dynamics, nest site fidelity, and remigration patterns, among other things (Carr *et al.* 1978). The nesting beach extends about 35 km from the Río Tortuguero to the Río Parismina, and the peak of the nesting season is from mid-July to mid-September.

During the early years of the tagging program it was observed that untagged females emerging to nest varied widely in size. Later, Carr and Goodman (1970) stated that "it now appears that some green turtles mature at small, and others at large sizes; and that once they are mature—that is, once they have made their first trip to the nesting beach—their growth becomes negligible, as compared with individual variation in maturity-size."

In this paper I describe some of the reproductive traits of these newly matured recruit turtles. Because carapace length is the most common measurement taken of nesting sea turtles at Tortuguero and elsewhere, I give special attention to some reproductive traits predicted by carapace length. The main purposes of this study were (1) to analyze the relationships among different sizes of recruits, clutches, eggs, and hatchlings, and (2) to determine the relative clutch mass (RCM) of green turtles.

METHODS

A recruit is a turtle presumed to be nesting for the first time at Tortuguero (and presumed to be nesting for the first time in its life). The 20 recruits analyzed in this study laid eggs between 1 and 25 July 1985 on the beach extending 2.4 km south of Río Tortuguero. A renester is a turtle ovipositing more than once during a nesting season. I am fairly certain that the turtles identified as recruits were indeed first-time nesters at Tortuguero because: they bore no tags or tagging scars; the study beach was thoroughly monitored (and the high degree of nest site fidelity exhibited by these 20 individuals in their renestings suggest that they did not nest previously on an unmonitored section of the coast); these 20 individuals were found at the beginning of the nesting season (making it unlikely that they nested elsewhere previously); and the study beach has been carefully monitored in previous years.

The carapace length of nesters was accurately measured (±0.5 cm) by extending calipers from the most anterior to the most posterior projections of the shell (*i.e.*, a total straight line). This is the customary carapace length measurement taken at Tortuguero. The carapace length of hatchlings was taken with vernier calipers extending along

[1] Received 18 November 1986, revision accepted 31 May 1987.

TABLE 1. *Regressions (Y on X) of reproductive and morphologic characteristics of green turtles at Tortuguero, Costa Rica. Equation is the form Y = a + bX, where a is the intercept and b the slope. Carapace length and weight are abbreviated cl and wt.*

	Regression	Intercept	Slope	N	t	r^2	Range of X values
A.	Clutch (Y) recruit cl, cm (X)	−59.9600	1.7969	20	3.428[a]	0.395[a]	85–112
B.	Log wt clutch, kg (Y) recruit cl, cm (X)	−0.0085	0.0077	20	3.457[a]	0.399[a]	85–112
C.	Egg diameter, mm (Y) clutch size (X)	45.0215	−0.0171	400	−3.849[a]	0.036[a]	79–149
D.	Log egg wt, g (Y) clutch size (X)	1.7530	−0.0006	400	−4.065[a]	0.040[a]	79–149
E.	Arcsine % emergence (Y) clutch size (X)	1.5633	−0.0061	20	−1.462	0.106	79–149
F.	Hatchling cl, mm (Y) recruit cl, cm (X)	56.5195	−0.0471	400	−2.959[a]	0.022[a]	85–112
G.	Log hatchling wt, g (Y) recruit cl, cm (X)	1.5438	−0.0014	400	−3.398[a]	0.028[a]	85–112
H.	Log body wt, kg (Y) recruit cl, cm (X)	1.1185	0.0100	20	8.484[a]	0.800[a]	85–112
I.	Log body wt, kg (Y) renester cl, cm (X)	1.0287	0.0107	18	5.548[a]	0.658[a]	90–109.5
J.	Log wt clutch, kg (Y) log wt recruit, kg (X)	−0.7825	0.7271	20	3.711[a]	0.434[a]	88.5–175
K.	Arcsine RCM (Y) recruit cl, cm (X)	0.0691	−0.0003	20	−1.151	0.069	85–112

[a] For these values, $P < 0.01$.

the midline from the anterior notch to the most posterior projection of the shell (*i.e.,* a standard straight line).

All eggs and hatchlings were measured (±0.5 mm) and weighed (±0.05 g) within 4 hr after deposition and emergence, respectively. Loose sand was carefully wiped from eggs and hatchlings before cataloguing. The weights of adults were recorded to the nearest 0.5 kg.

Statistical analyses were performed on a computer using the SPSS[x] Version 2.0, and some data were transformed to common logarithms and arcsines to satisfy statistical assumptions. Statistical significance was set at the 5 percent level. The abbreviation SD represents one standard deviation. Regression analysis best suited the questions I asked.

RESULTS

A strong positive relationship was found between the clutch sizes of recruits and their carapace lengths (Table 1, A); similar relationships have been found within other green turtle nesting populations (Hirth 1980). As expected the total weight of the clutch was also highly related to the size of the recruit (Table 1, B). Approximately 40 percent of the variation in the clutch mass can be accounted for by carapace length.

Twenty eggs were selected from the nests of the 20 recruits (5 eggs were picked at random from approximately each quarter of the clutch, moving from the top to the bottom of the clutch). The mean diameter of these 400 eggs was 43.05 mm (SD = 1.53, range 39–48), which is similar to the average diameters of green turtle eggs recorded on other nesting beaches (Hirth 1980). The mean egg weight of this sample was 48.82 g (SD = 5.70, range 35–66). Both egg diameter and weight were negatively related to the sizes of the clutches from which they were obtained (Table 1, C and D).

The hatchlings in the recruit nests emerged on the sand surface after about 2 mo ($\bar{x}$ = 62.2 days, SD = 1.77). No significant relationship was found between emergence success and the size of the clutch (Table 1, E). On the average, 71.15 percent (SD = 25.80) of the eggs in each clutch produced viable hatchlings. Working on the same beach, Fowler (1979) also reported that emergence success was not related to clutch size.

A sample of 20 hatchlings was obtained from each of the 20 recruit nests (hatchlings were numbered and samples picked using a table of random numbers). The mean carapace length of the 400 neonates was 51.52 mm (SD = 1.87, range 47–56), and the mean weight was 25.87 g (SD = 3.00, range 15–31). These measurements are similar to the average sizes of green turtle hatchlings at other localities (Hirth 1980). The carapace lengths and weights of the hatchlings were negatively related to the carapace lengths of the recruit nesters (Table 1, F and G).

Six species of marine turtles exhibit a positive relationship between adult body weight and shell length (Hirth

1982). This relationship was confirmed at Tortuguero by weighing the 20 recruit nesters in the early morning after oviposition (Table 1, H).

Twelve renesters were weighed after their second nesting and 6 turtles were weighed after laying their third clutch. These 18 females were weighed between 2 and 8 August 1985, and none of them were the recruits weighed earlier. The average interval between their renestings was 12 days (SD = 1.03). The relationship between their weight and shell length was also significant (Table 1, I). These two regression lines (Table 1, H and I) were compared after confirming homogeneity of residual variances in a two-tailed *F*-test, and no statistically significant differences were uncovered between slopes or elevations (respectively, $F = 0.0932$; df = 1, 34; n.s.; and $F = 3.64$; df = 1, 35; n.s.). Since no food source has been identified in the longshore waters at Tortuguero (Meylan 1982), we can assume that little feeding takes place during the internesting periods. The turtles probably subsist on the fat they accumulated during their sojourn on the Nicaraguan feeding pastures.

The relationship between total clutch weights and body weights was significant (Table 1, J). To determine the proportional relationships among clutch weights, body weights and carapace lengths a regression of RCM on shell length was made, and the result was not significant (Table 1, K). RCM is defined as the ratio of clutch weight (kg) to body weight not including the clutch (kg).

DISCUSSION

The scaling of reproductive traits to body sizes can illuminate important parameters of a sea turtle nesting population. Five reproductive variables are predicted by the body sizes of recruits in the Tortuguero population.

Large recruit turtles nesting at Tortuguero lay more eggs and produce more hatchlings than small turtles, but the hatchlings of larger recruits are slightly smaller than the hatchlings of smaller recruits. The trade-offs between clutch size and neonate size fall within the framework of evolutionary theory and could help explain how polymorphism is maintained among the nesters at Tortuguero. Other factors, no doubt, influence hatchling size and could account for some of the low r^2 values in Table 1. For example, hydric, thermal, and respiratory variables within the egg chamber may directly affect the size of turtle hatchlings (Ackerman 1980, Packard *et al.* 1982, Morris *et al.* 1983, Hotaling *et al.* 1985, Tracy & Snell 1985). Also, turtles laying small clutches may better provision their eggs than females laying large clutches in such a way that could directly affect the size and survival of hatchlings. Virtually nothing is known about the ecology and survival rates of marine turtle hatchlings once they enter the sea. Larger hatchlings may be better swimmers, experience faster growth, and have fewer predators than smaller hatchlings, but this should be investigated. The fitness of renesters and remigrants should also be studied.

The RCM of green turtles at their first nesting varied from 3.42 to 5.54 percent. These values are slightly lower than those reported for freshwater and terrestrial turtles (Congdon & Gibbons 1985). No statistically significant size dependence of RCM was found, suggesting natural selection for a relatively constant proportional reproductive allocation in green turtles. Swimming skills of ovigerous females may be one of the ecological factors involved in selection for RCM. These swimming skills may include mating behavior, avoidance of a turbulent sea surface and strong longshore currents, and travel between nesting emergences. Meylan (1982) recorded longshore travel distances of up to 10 km in the internesting habitat at Tortuguero, and she computed a mean continuous travel speed of 2 km/hr.

ACKNOWLEDGMENTS

I thank Arturo Beachman, Carlos Diez, Mario Espinal, Hector Gonzalez, Kazuo Horikoshi, Madeleine Krüger, and Edwin Lezama for help in weighing turtles. I also thank Drs. Jeff Jensen, Douglas Samson, and Jon Seger for their constructive comments on an earlier version of the manuscript.

This research was financially aided by grants from Wildlife Conservation International of the New York Zoological Society and from the Caribbean Conservation Corporation.

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