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MORPHOLOGICAL CHARACTERISTICS OF THE CARAPACE OF THE HAWKSBILL TURTLE, *ERETMOCHELYS IMBRICATA*, FROM CUBAN WATERS

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ABSTRACT Hawksbill turtles, *Eretmochelys imbricata* (Linnaeus, 1766), from Cuban waters of the Caribbean were analyzed to determine the relationships between straight carapace length (SCL) and either straight carapace width (SCW) or body weight (Wt). The regression equations were SCW = 0.9136(SCL)$^{0.951}$ (R^2 = 0.923, n = 315) and Wt = 4.17 10^{-4}(SCL)$^{2.68}$ (R^2 = 0.798, n = 289), respectively. The regression equations between the first costal width (C1W) and either SCW or Wt were SCW = 3.223(C1W)$^{0.847}$ (R^2 = 0.919, n = 156) and Wt = 1.416 x 10^{-2}(C1W)$^{2.426}$ (R^2 = 0.740, n = 133), respectively. There was no difference in slopes of the C1W-SCL relationship between wild and captive raised turtles as analyzed by ANCOVA. Thus, I pooled the group data and re-calculated the C1W and SCL relationship as SCL = 4.353(C1W)$^{0.848}$ (R^2 = 0.953, n = 340). This result indicated that SCL measurements could be estimated based on C1W measurements and that the C1W-SCL relationship could be applied to captive raised or wild hawksbills. It is clear that the SCL-SCW and C1W-SCW relationships were more similar to the relationship in the hawksbill turtles from Puerto Rican waters than to those captured in Australian waters, although there was no significant geographic difference between specimens from the Caribbean and Australian

Introduction

The external morphology and sizes of marine turtles offer a great amount of useful biological information. Comparisons of the morphologies among populations provide a better understanding of evolutionary and genetic relationships, whereas comparisons of the body sizes among individuals and populations help to clarify physiological and ecological relationships. It has been reported that body size is connected to body temperature (Spotila and Standora 1985), metabolic rate (Prange and Jackson 1976), growth rate (Bjorndal and Bolten 1988), and clutch size (Witzell 1985). Because it is relatively easy to measure the morphological characteristics of marine turtles, there have been a number of studies of carapace size in various populations of the hawksbill turtle, *Eretmochelys imbricata* (Linnaeus, 1766) (Witzell 1985). However, because of the difficulty of gathering specimens and determining the sex of immature turtles, these studies often had only a small sample size and hadn't dealt with the distinction between females and males. Morphological studies of the carapace in the hawksbill have been compiled for Australia (Limpus 1992) and Puerto Rico (van Dam and Diez 1998). Until now, there has been no report on carapace shapes in turtles found in Cuban waters. Many wild adult hawksbill carapaces have been measured in Cuba but no immature turtle carapace measurement data are available. The goal of this study was to collect more data of wild and captive raised turtles, to analyze these data altogether, and to discuss geographical variations in the carapace morphology of hawksbill turtles.

Materials and Methods

To determine the relationships between straight carapace length (SCL) and straight carapace width (SCW), SCL and weight (Wt), and the first costal width (C1W) and SCW or between C1W and Wt, I used measurement data from 315 hawksbill turtles captured by fishery net in Cuban waters from 1995 to 1998. Thirty-two of the 315 were captured from Doce Leguas Key, southwest of Cuba in 1995 and 1998, 48 from Nuevitas, northeast of Cuba in 1995 and 1996, and 235 from Isla de Pinos, southeast of Cuba in 1996. For the relationship between C1W and SCL, I added measurements from 184 captive raised hawksbill turtles that had hatched on Doce Leguas Key and were raised at breeding facilities on Isla de Pinos. I did not classify turtles by sex because there is no sexual difference in the hawksbill carapace (Limpus 1992).

I measured select morphometrics of 156 wild and 184 captive raised hawksbill turtles (Figure 1). Measuring sites were SCL, SCW, Wt, and C1W (Figure 1). Vernier calipers (± 0.5 cm) were used to measure SCL and SCW, C1W was measured using a tape measure (± 0.1 cm) from whole turtle's carapaces, and Wt was measured using a spring scale (up to 20 kg ± 0.05 kg, from 20 kg to 90 kg ± 1kg) from turtles which were either drowned within 24 hrs or alive (see Figure 2).

I estimated the relationships between $\log_{10}$ SCL, $\log_{10}$ SCW, or $\log_{10}$ Wt and $\log_{10}$ C1W by calculating the allometry equation $Y = aX^b$ for the data presented in Table 1. Then I compared slopes of the regression lines $\log_{10}$ SCL vs $\log_{10}$ C1W between wild and captive raised individuals

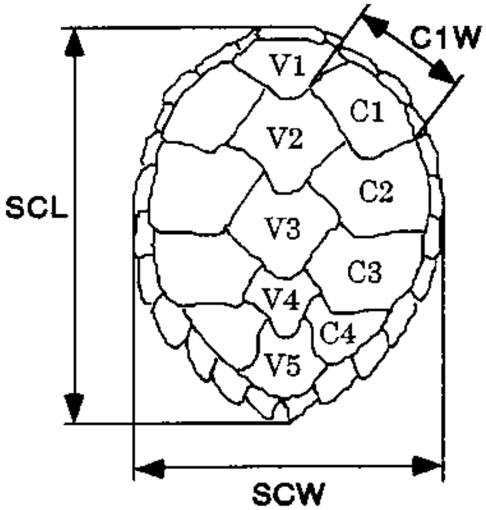

Figure 1. Measurements of hawksbill carapace. Straight carapace length (SCL) was measured between the nuchal notch to posteriormost marginal tip carapace length. Straight carapace width (SCW) was the maximum carapace width, and the first coastal scute width (C1W) was measured as the curved width of first costal.

with an analysis of covariance (ANCOVA), using $\log_{10}$ SCL as the coviarate.

RESULTS

The relationships between SCL and either SCW or Wt were: $SCW = 0.9136(SCL)^{0.951}$ ($R^2 = 0.923$, $n = 315$), and $Wt = 4.17 \times 10^{-4}$ $(SCL)^{2.68}$ ($R^2 = 0.798$, $n = 289$), respectively (Table 2). The relationships between C1W and either SCW or Wt were: $SCW = 3.223(C1W)^{0.847}$ ($R^2 = 0.919$, $n = 156$) and $Wt = 1.42 \times 10^{-2}$ $(C1W)^{2.43}$ ($R^2 = 0.740$, $n = 133$), respectively (Table 2).

Although the SCL range was different between wild and captive raised turtles (Figure 2), the C1W and SCL regression equations of those relationships showed no difference when compared with ANCOVA ($P > 0.05$, Figure 3). Thus, I pooled data from the wild and captive raised individuals and re-examined the relationship. The resulting equation was: $SCL = 4.353(C1W)^{0.848}$ ($R^2 = 0.953$, $n = 340$).

DISCUSSION

The relationships between SCL and SCW, SCL and Wt, C1W and SCL, and C1W and SCW were compared with those from the hawksbill population in the Puerto Rican sea of the Caribbean (van Dam and Diez 1998) and the Australian sea (Limpus and Miller 1990, Limpus 1992). I used the regression equations from the literature in which ranges of carapace sizes were noted as referenced. In the Australian sea, the curved carapace length (CCL) was used to estimate SCL, using $SCL = 0.9355 \times CCL + 0.4486$ (Limpus 1992). As expected, the SCL-SCW relationship of the Cuban hawksbill turtles was closer to those collected near Puerto Rico than those from Australian waters (Figure 4a). The SCL-Wt relationships of the turtles from all 3 areas, however, were not significantly different (Figure 4b). There was also no difference between C1W and SCL among these regions (Figure 4c), although the C1W-SCW relationships from Cuban and Puerto Rican hawksbill turtles were more similar (Figure 4d) than any other comparison.

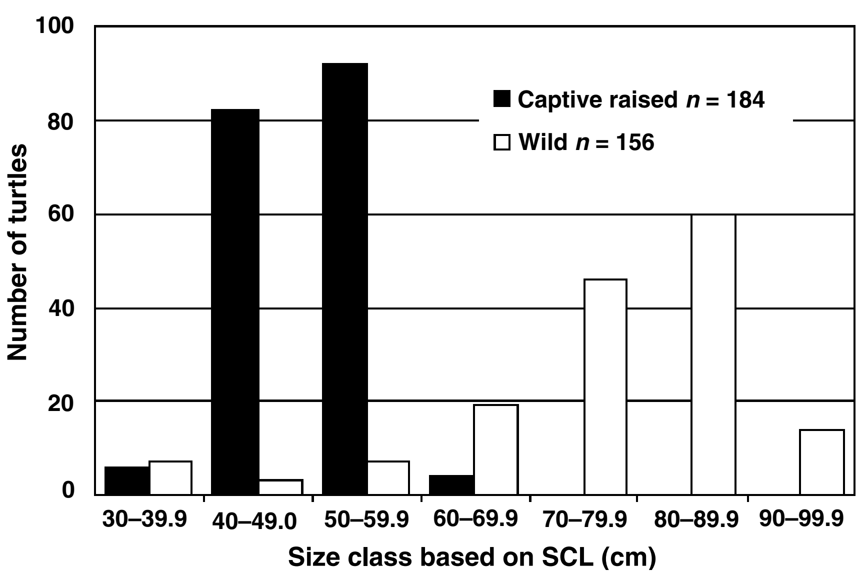

Figure 2. Straight carapace length (SCL) distribution of wild and captive raised hawksbill turtles collected from Cuba.

TABLE 1

Information of the mean, standard deviation (SD), maximum, and minimum values of each measurement by group. Straight carapace length (SCL), straight carapace width (SCW), weight (Wt), and the first costal scute width (C1W). ( )* indicates the measurement locations for calculation of the descriptive statistics.

		Group	*n*	Mean	SD	Max.	Min.
SCL	(SCW)*	Wild	315	64.5	13.9	89.3	19.7
	(Wt)*	Wild	289	65.9	12.2	89.3	19.7
	(C1W)*	Wild(Captive raised)	340(184)	52.6	16.7	87.2	22.1
SCW	(Wt)*	Wild	315	48.1	10.3	71.0	15.4
	(C1W)*	Wild	156	49.3	10.0	66.0	15.5
Wt	(SCL)*	Wild	289	37.1	16.6	84.0	1.0
	(C1W)*	Wild	133	42.1	15.2	84.0	6.0
C1W	(SCL)*	Wild(Captive raised)	340(184)	19.0	7.0	35.4	6.9
	(SCW)*	Wild	156	25.1	5.6	35.4	6.9
	(Wt)*	Wild	133	26.5	3.7	35.4	14.5

The SCL-SCW ratio (SCL/SCW = body shape) of hawksbill turtles collected near Puerto Rico tends to be greater than those collected near Australia (Limpus and Miller 1990) and southeast Africa (Hughes 1974, van Dam and Diez 1998). Hawksbill turtles collected near Cuba had similar body shape to those collected near Puerto Rico (Figure 4a). Although there is about 12%, 30%, and 31% mtDNA haplotype frequencies of Puerto Rican nesting populations in the southeast, southwest, and northeast populations of Cuban hawksbills, respectively (Díez-Fernández et al. 1998), there is little genetic exchange between the Cuban, Puerto Rican and Australian turtles (Bass et al. 1996). The SCL-SCW relationship showed a conspicuous geographic difference.

The C1W-SCL relationship varies little among Australian, Puerto Rican, and Cuban turtles. In other

TABLE 2

Regression equations in the form $Y = aX^b$ for estimating (Y) from selected scale measurements (X).

X	Y	a	b	*n*	R^2	F	*P*
SCL	SCW	0.914	0.951	315	0.923	3759	$P < 0.01$
SCL	Wt	4.17×10^{-4}	2.68	289	0.798	1128	$P < 0.01$
C1W	SCL	4.353	0.848	340	0.953	6836	$P < 0.01$
C1W	SCW	3.223	0.847	156	0.919	1747	$P < 0.01$
C1W	Wt	1.42×10^{-2}	2.43	133	0.740	372	$P < 0.01$

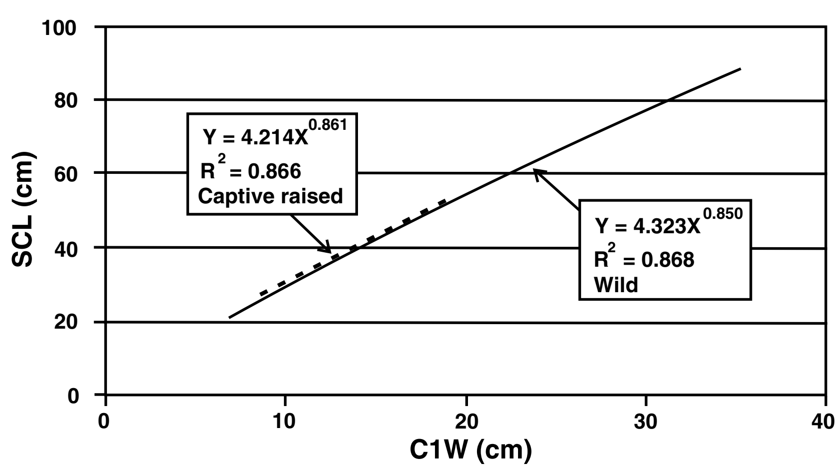

Figure 3. Plot of the C1W-SCL relationship between wild and captive raised turtles. The dotted line represents the regression of captive raised turtles whereas the solid line represents wild turtles.

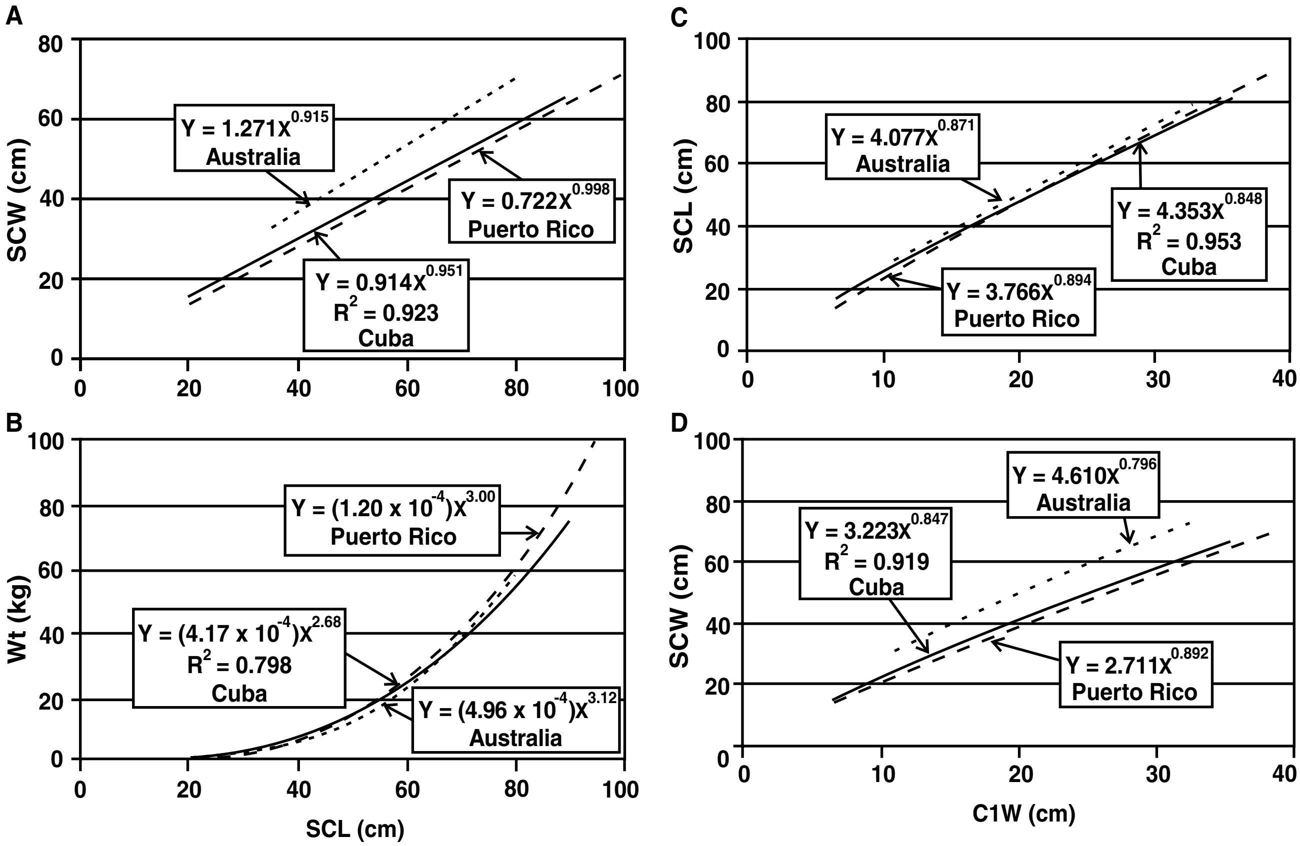

Figure 4. A) Plot of the relationships between straight carapace length (SCL) and straight carapace width (SCW). The solid line represents wild turtles from the Cuban waters, the dotted line represents a regression of Puerto Rican turtles (20 cm < SCL < 100 cm; van Dam and Diez 1998), and the shorter dotted line represents a regression of Australian turtles (28.5 cm < SCL < 86.6 cm; Limpus 1992). B) Plot of the relationship between SCL and weight (Wt). The solid line represents wild turtles from the Cuban waters, the dotted line represents Puerto Rican turtles (20 cm < SCL < 100 cm; van Dam and Diez 1998), and the shorter dotted line represents Australian turtles (28.5 cm < SCL < 86.6 cm; Limpus 1992). C) Plot of the relationship between the first costal width (C1W) and SCL. The solid line represents Cuban turtles, the dotted line represents Puerto Rican turtles (6.5 cm < C1W < 39.2 cm; van Dam and Diez 1998), and the shorter dotted line represents Australian turtles (11.3 cm < C1W < 34.3 cm; Limpus 1992; Limpus and Miller 1990). D) Plot of the relationship between C1W and SCW. The solid line represents Cuban turtles, the dotted line represents Puerto Rican turtles (6.5 cm < C1W < 39.2 cm; van Dam and Diez 1998), and the shorter dotted line represents Australian turtles (11.3 cm < C1W < 34.3 cm; Limpus 1992; Limpus and Miller 1990).

words, I have revealed that there are similar growth rates of C1W and SCL. At the same time, my results show that measuring C1W is sufficient to speculate on SCL using the C1W-SCL relationship. For example, when a dead turtle's body part is missing or its scutes are the only parts available, we can extract data on the body size. Carapace 1 (C1) is very peculiar in shape and easily distinguishable from other scutes. Furthermore, because of the speckled pattern of the C1 that is more visible on C1 than on other scutes (Kobayashi 2001), it is very possible that C1 may provide information on age. Extracting physical data from one piece of scute on the carapace is very significant in terms of monitoring and making the most of precious information.

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