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Growth Rates of Juvenile Loggerheads, *Caretta caretta*, in the Southern Bahamas

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Measuring growth rates of sea turtles under natural conditions has received increased attention since it became clear that growth rates of wild turtles are much slower than those of captive sea turtles (Balazs, 1979; Limpus, 1979). Estimates of the age at which marine turtles attain sexual maturity based on captive growth rates have had to be revised. Knowledge of natural growth rates and age at sexual maturity are fundamental for understanding demography, assessing habitat quality, and designing appropriate management plans and conservation measures for these endangered species.

Data on growth rates for non-captive loggerheads, *Caretta caretta*, have been limited to turtles larger than 50 cm straight-line carapace length (CL) (Limpus, 1979, 1985; Mendonca, 1981; Frazer and Ehrhart, 1985). Based on these studies, the age at sexual maturity has been estimated to be 10 to 50 years.

Data on growth rates of 24 cm CL loggerheads are presented in this note. This size represents a transitional stage for loggerheads when they first leave the pelagic habitat and arrive at benthic feeding grounds (Carr, 1986). Growth rates of these smaller loggerheads are more rapid than those reported for larger turtles and result in significantly shorter estimates for the time necessary for loggerheads to grow from 25 to 75 cm and, thus, for a younger age at sexual maturity.

In 1975, three loggerheads that had hatched from eggs collected in Florida and that had been raised in a laboratory at the University of Florida were taken to Union Creek, Great Inagua, Bahamas (with all necessary permits). Union Creek, protected by the Bahamas National Trust as a wildlife sanctuary, is a saltwater bay of approximately 20 km^2 located on the north coast of Great Inagua, the southernmost island in the Bahamas. Union Creek is covered with seagrass beds (primarily *Thalassia testudinum*) and is surrounded by mangroves. These habitats support a rich invertebrate fauna on which loggerheads feed. Union Creek is a natural feeding area for all sizes of loggerheads, green turtles (*Chelonia mydas*), and hawksbills (*Eretmochelys imbricata*) (pers. observs. and pers. comms. from island inhabitants). In 1964, Union Creek was fenced off to provide a protected area in which sea turtles could be studied on natural feeding grounds.

The loggerheads were tagged for identification and initially introduced into a confined area (approximately 2 ha) of Union Creek to monitor their adjustment to free-living conditions. Following an initial decrease in mass, the turtles regained their original mass at the end of three months and were judged to be ready for release into Union Creek. Measurements at the time of release were used as the initial values in measuring growth rates; the adjustment period was not included. CL was measured as straight-line distance from the mid-point of the anterior carapace (nuchal notch) to the end of the posterior marginal. Carapace width (CW) was straight-line distance at the widest point.

The loggerheads were not seen again for nearly three years; 35 months after release all were recaptured, weighed, and measured. One turtle was recaptured after an additional 10 months; another after an additional 24 months.

Data from the three loggerheads (Table 1) indicate that rates of growth of both CL and CW decrease greatly with increasing size, but the rate of mass gain remains constant with increasing size. Mendonca (1981) also reported that growth in CL decreased with increasing size in loggerheads, but she worked with larger animals, and the decrease was not as dramatic.

There are no published records of growth rates in CW or body mass with which we can compare our data. A comparison of CL growth rates for loggerheads from the southern Bahamas and Florida is presented in Table 2. Similar values are reported for the larger size class (70 to 80 cm). Although our data do not allow direct comparisons for the smaller size classes, smaller loggerheads grow more slowly in Florida than in the southern Bahamas. Loggerheads grew from 25 to 75 cm in 3 to 4 years at our study site in the Bahamas (Table 1). This growth rate is faster than that reported for the Florida population (Mendonca, 1981; Frazer and Ehrhart, 1985). Mendonca (1981) calculated that Florida loggerheads took 5 years

TABLE 1. Measurements, recapture intervals, and growth rates for three loggerheads in Union Creek, Great Inagua, Bahamas. CL_1 and CL_2 are initial and recapture straight-line carapace lengths, respectively; CW is straight-line carapace width; RI is recapture interval; GR is growth rate.

Turtle number	CL_1 (cm)	CL_2 (cm)	CW_1 (cm)	CW_2 (cm)	$Mass_1$ (kg)	$Mass_2$ (kg)	RI (mos)	CL GR (cm/yr)	CW GR (cm/yr)	Mass GR (kg/yr)
1	24.8	68.5	20.3	53.5	2.2	39.0	35	15.0	11.4	12.6
2	24.8	75.0	20.3	59.5	2.2	49.5	35	17.2	13.4	16.2
3	23.8	67.0	19.7	52.0	2.2	35.5	35	14.8	11.1	11.4
1	68.5	81.0	53.5	58.8	39.0	68.0	26	5.8	2.4	13.4
2	75.0	78.8	59.5	60.6	49.5	62.5	10	4.6	1.3	15.6

to grow from 50 to 75 cm. Using nearly the same data set as Mendonca, Frazer and Ehrhart (1985) estimated the interval of time needed to grow from 25 to 75 cm as 10 years (Von Bertalanffy model) or 16 years (logistic model).

The geographic differences in growth rates for smaller size classes of loggerheads (up to 70 cm CL) in the southern Bahamas compared with Florida may be a result of environmental differences (e.g., temperature, food availability, or seasonality), a lack of small turtles in the Florida sample, small sample sizes, or a combination of these factors. However, the similarity of growth rates for 70 to 80 cm CL turtles from the two areas suggests that, if there is an environmental effect, it may not be as great for large turtles as for small turtles.

We do not know what effect genotype may have on the difference in growth rates for small size classes of loggerheads. Although the growth rates measured in the southern Bahamas are for loggerheads from Florida nests, the natal beach of the juvenile turtles studied in Florida by Mendonca (1981) and Frazer and Ehrhart (1985) is unknown.

Comparison of loggerhead growth rates from other geographic regions is limited to data from Australia. Limpus (1985) reports that the growth rates for 70 to 80 cm CL loggerheads is 0.9 cm/yr (N = 10). These data are based on curved carapace measurements and so are not strictly comparable to the straight-line data from Great Inagua and Florida. Nevertheless, the Australian loggerhead population appears to be growing at a very slow rate—possibly one-fifth the rate reported for the southern Bahamas or Florida. We can offer no explanation for this slow rate at this time.

TABLE 2. Loggerhead straight-line carapace length (CL) growth rates. Florida data are from Mendonca (1981). CL is mean of initial and recapture CL; N is sample size; GR is growth rate in cm/yr, mean ± standard deviation.

	Great Inagua		Florida	
CL (cm)	N	GR	N	GR
40–50	3	15.7 ± 1.3		—
50–60		—	2	7.4 ± 1.4
60–70		—	7	6.0 ± 2.3
70–80	2	5.2 ± 0.8	4	5.0 ± 3.5

Growth data also have been collected for green turtles and hawksbills in Union Creek (Bjorndal and Bolten, 1988). As in loggerheads, growth rates for CL and CW decrease with increasing size, but mass growth rates remain constant. However, the loggerhead (a carnivore feeding primarily on benthic molluscs) grows much more rapidly than either the hawksbill (a carnivore feeding on a lower quality sponge diet) or the herbivorous green turtle. Rate of mass gain is approximately four times greater in loggerheads than in green turtles and about three times greater than in hawksbills.

Although we are not willing to extrapolate from our data set to estimate an age at sexual maturity for loggerheads, it is clear that any estimate from our data would be much shorter than earlier estimates based on growth rates from larger turtles from other geographic regions. More data are needed before complete growth models can be developed and compared for loggerheads throughout their range. Although based on small sample sizes, the differences in growth rates presented here among size classes and among geographic regions indicate that caution must be used when extrapolating growth rates to other size classes or to other geographic areas.

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Geographic Variation in the Seasonal Activity Cycle of Spotted Turtles, *Clemmys guttata*

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The spotted turtle (*Clemmys guttata*) is a small semiaquatic species that typically inhabits shallow wetlands (Ernst and Barbour, 1972). They are widely distributed in suitable habitats from southern Ontario to northern Florida, and west through Pennsylvania and the lower Great Lakes region to northeastern Illinois (Ernst, 1972). Previous investigators have noted that northern populations of *C. guttata* are active primarily during the spring (Conant, 1951; Nemuras, 1966; Ernst, 1976), and appear to shun high environmental temperatures (Ward et al., 1976; Ernst, 1982). However, there are no published accounts regarding the seasonal activity cycle of this essentially northern species in the southern part of its range. If aversion to high temperature is consistent in the species, then turtles at lower latitudes should initiate their activity cycle earlier than populations at higher latitudes. The objective of this study was to compare the seasonal activity cycles of *C. guttata* from various geographic regions.

Previously published seasonal activity cycles for *C. guttata* (Ohio—Conant, 1951; Maryland—Nemuras, 1966; Pennsylvania—Ernst, 1976) were compared, along with unpublished records for South Carolina. Records for South Carolina were based on live animals captured on or near the Savannah River Plant in Aiken and Barnwell Counties, and data associated with preserved specimens in the Charleston Museum from other sites in the state. Seasonal activity in each state was measured by the number of captures per month. Data for each state are based on collecting activities spanning two or more years. Frequencies between states were compared using contingency table analysis (Zar, 1984) under the null hypothesis that levels in any time interval were independent with respect to geographic region, assuming no collector bias or significant year-to-year variation. Multiple comparisons of all possible pairs of states were then made using Gabriel's (1966) simultaneous test procedures. The resulting log likelihood ratio statistics, $2I$ (=G), were compared with critical values of χ^2 at an alpha level of 0.10 due to the conservative nature of the test. Confidence intervals of the binomial parameter π were plotted for significant comparisons, using graphical procedures proposed by Snee (1974), to determine which time intervals contributed most of the observed heterogeneity between populations.

Climatological data for the period 1951-80 were obtained from tables published by the National Climatic Data Center (Publication No. 81 [by state]). Mean monthly and annual normal air temperatures (AT) reported in this paper for Maryland and Pennsylvania populations were taken from the recording station nearest to the study sites of Nemuras (1966) and Ernst (1976): Owing's Ferry Landing, Maryland; and Landisville, Pennsylvania, respectively. In Ohio and South Carolina these values were calculated as the mean of all recording stations within the statewide distribution of the species, since *C. guttata* activity data for these states were obtained from numerous widely scattered localities. Predicted cloacal temperatures (CT) were calculated using the formula

$$CT = 5.20 + 0.82(AT)$$

reported by Ernst (1982) for feeding *C. guttata* where AT is the mean monthly air temperature discussed above.

Levels of spotted turtle activity as measured by frequency of capture were highest in the spring for all states (Fig. 1). In Maryland, 74% of all activity occurs from March to May, inclusive. During the same period in Pennsylvania and Ohio, the frequencies are 68% and 93%, respectively. In South Carolina, over 50% of yearly captures were made in February and March. Activity peaks occurred in May for all populations sampled except South Carolina which reached a maximum in March. Activity levels decline in June for all populations except South Carolina which begins to decline in April.

An overall test of independence revealed significant heterogeneity ($P < 0.10$) among the various activity cycles suggesting that levels of activity are strongly dependent on geographic locality. In addition, all pairwise comparisons between states were significant except for Pennsylvania vs. Maryland (Table 1). Most of the heterogeneity observed between South Carolina and other states is due to comparatively low levels of activity from April-July in the former (Fig. 2). Low levels of activity in Ohio during June and July contrast significantly with those observed in Maryland and Pennsylvania.

Activity levels peak when the mean monthly air temperature (AT) is between 13.1°-18.0°C ($\bar{x}$ = 15.5) (Table 2), which is at least two months earlier than the month with highest mean AT. Levels of activity begin to decline when the mean monthly AT is between 17.8°-22.3°C ($\bar{x}$ = 20.3), and then approach or reach a minimal level during the month with highest mean AT.

The thermal ecology and seasonal activity cycle of