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Growth of Slider Turtles (*Trachemys scripta*) from Temperate and Tropical Populations

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The slider turtle (*Trachemys scripta*) is one of the most variable of all turtles with up to 18 recognized subspecies (Ernst and Barbour, 1989; Ernst, 1990; Legler, 1990). The species ranges from north-central Illinois to northern Florida and eastern Virginia south to Venezuela and Colombia (Ernst and Barbour, 1989; Conant and Collins, 1991; Ernst et al., 1994). Life histories of sliders from temperate North America have been studied in some detail for *T. s. elegans* (Cagle, 1937, 1944, 1950; Cahn, 1937; Webb, 1961; Thornhill, 1982; Tucker et al., 1995a, 1995b, 1998a, 1998b, 1998c; Tucker and Janzen, 1997; Tucker and Moll, 1997; Tucker and Packard, 1998). Work on *T. s. scripta* in South Carolina and Georgia (Gibbons, 1990) provided one of the most comprehensive treatments of any known turtle life histories. In contrast, less is known about slider turtle life histories in tropical regions. Significant exceptions are the work of Moll and Legler (1971), Vogt (1990), Moll (1990), and Moll (1994) on *T. scripta* subspecies from Panama, Mexico, Belize, and Costa Rica, respectively. All of these studies on sliders inhabiting tropical regions noted the large body size attained by *T. scripta* in the tropics.

The large size of tropical sliders has generally been attributed to greater productivity and a longer growing season in tropical habitats (Moll and Legler, 1971; Moll and Moll, 1990; Moll, 1994). Others have attributed large size to adaptations allowing coexistence with crocodilians or to fill the large herbivorous river turtle niche in regions where other large river turtles are absent (Pritchard and Trebbau, 1984). Regardless, no study has actually compared growth patterns of temperate and tropical sliders. The purpose of our study was to compare growth patterns in sliders collected in Illinois to those collected from three tropical populations. We were particularly interested in investigating the hypothesis that large size among tropical sliders is due primarily to longer growth seasons. If so, then we would expect growth patterns to show a gradual divergence as the tropical turtles outstrip their temperate relatives in size.

Methods and Materials. — Growth annuli were used to estimate age and Sergeev's (1937) formula (applied to past and present abdominal scute lengths) was used to estimate plastron length at the time growth annuli were formed. Methods used to determine growth patterns for sliders from Panama were previously reported by Moll and Legler (1971). Similar methods were used for growth determination for sliders from Belize and Costa Rica by D. Moll. Methods used for the Illinois sliders were published by Tucker and Moll (1997).

The utility of growth annuli for estimating age in sliders from temperate areas was established by Cagle (1946, 1950), but see Brooks et al. (1997) and Bury and Germano (1998) for more complete reviews. However, their utility in estimating age in tropical populations is more questionable because more than one growth annulus can be formed per year (i.e., Moll and Legler, 1971). Nonetheless, a major growth annulus is formed by annual scute shedding in tropical sliders from Panama (Moll and Legler, 1971). Major growth annuli are associated with annual cessation of growth during the wet season in Panama (Moll and Legler, 1971). Recaptures of marked Costa Rican sliders ($n = 12$) from year to year by D. Moll confirmed that major annuli were formed annually for this population, as well.

We used midline plastron length as a measure of turtle size. We compare data for females and juveniles in this paper. At each location, "juveniles" included those smaller turtles that could not be identified as males by secondary sexual characteristics and were not large enough to be confidently classified as females. Study areas for sliders from Panama, Belize, and Costa Rica were described in Moll and Legler (1971), Moll (1990), and Moll (1994), respectively. The Illinois study site was discussed by Tucker and Moll (1997) and Tucker (1997). Turtles from the three tropical locations were all identified as *T. s. venusta* (Legler, 1990), whereas those from Illinois were *T. s. elegans*.

Throughout this study we relied on graphical methods to compare growth patterns in these turtles rather than statistical comparisons (i.e., Dunham and Gibbons, 1990; Kennett, 1996). In part, this is necessary because data from one year class to another are not independent of each other within particular locations. This reflects our method of using growth annuli from a single individual to provide data points for more than one growth age (Tucker et al., 1995b). More importantly, relatively few individual turtles retain a complete set of growth annuli into maturity. Thus, sample size for ages 5–10 are too small for adequate statistical testing using this method.

Results and Discussion. — Growth rates varied among these four populations. In the fourth year following the season of hatching sliders from Illinois averaged 130.2 mm in plastron length compared to 136.1 mm for sliders from Belize, 146.0 mm for Panamanian sliders, and 181.4 mm for Costa Rican sliders (Fig. 1). Thus, after four years Costa Rican sliders were about 39% longer than those from Illinois. However, not all tropical sliders grew as fast as those from Costa Rica in the first four years. For instance, Panamanian sliders averaged about 12% longer than Illinois sliders

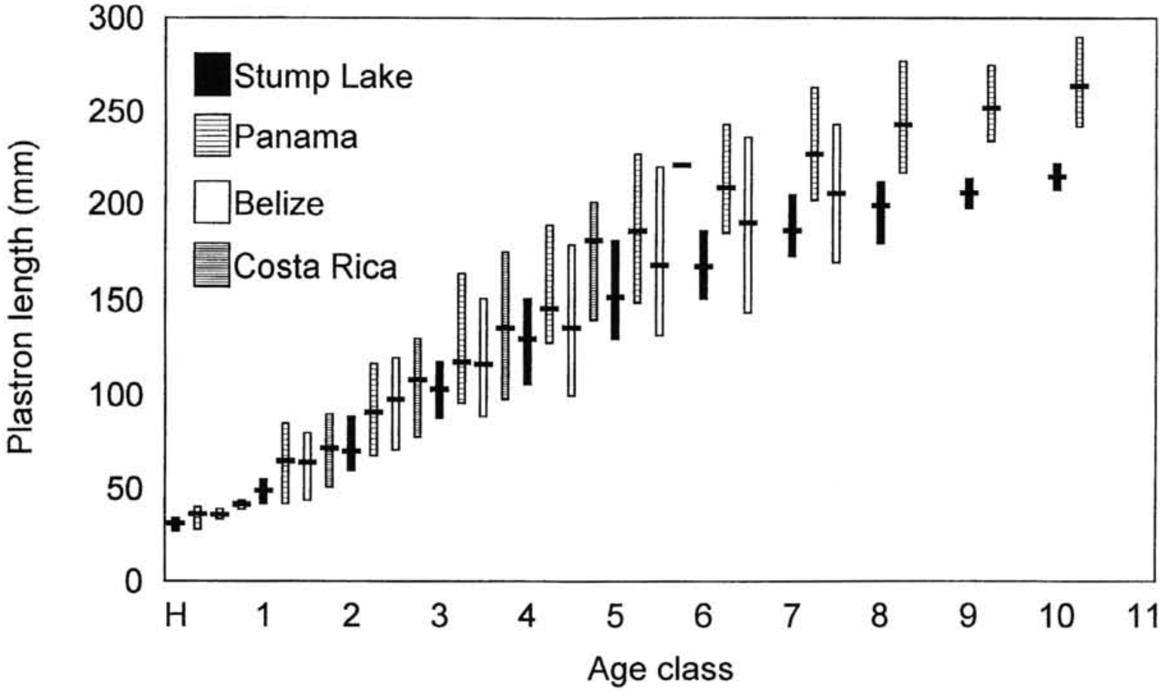

Figure 1. Growth of *Trachemys scripta* from three tropical sites and one temperate one (Stump Lake, Illinois) where the horizontal bar is the mean plastron length and the vertical bar is the range in plastron length for each age class. Sample sizes for each age class are listed in Table 1.

and sliders from Belize were only 4.5% longer than those from Illinois (Table 1).

By year seven after hatchling emergence, Panamanian sliders had increased their size discrepancy over Illinois sliders to 21.8% (Table 1). The primary reason for the greater size difference appears to be increased growth rate for Panamanian sliders (and to a lesser degree for Belize sliders) starting in year 5 (Fig. 2).

The tropical sliders we studied grew more rapidly (Fig. 1) and reach larger maximum sizes (Moll and Moll, 1990; Moll, 1994) than did those from Illinois. However, this size advantage was more pronounced at some tropical sites than others (Fig. 1). In particular, sliders from Belize and those from Illinois were more similar to each other in growth pattern (Fig. 1) and in sizes at equivalent ages than they were to sliders from Panama and to the even larger turtles from Costa Rica. Variation in adult size among Panamanian populations was also noted by Moll and Legler (1971).

Comparison of the cumulative increase in plastron length over initial hatchling size demonstrated that much of the difference between tropical and temperate sliders and among tropical sliders was not necessarily due to a regular divergence in size between sites (Fig. 2). For the first 3 (Costa Rica) or 4 (Panama) years of growth, most of the difference in size between tropical and temperate sliders was due to the difference between initial hatchling size and size at the end of the first year of growth (Fig. 2). We believe that the size advantage of tropical sliders during the first three or four years of life is due, in part, to overwintering of hatchlings of temperate sliders (Gibbons and Nelson, 1978). Hatchlings in Illinois emerge in May of the year following their hatching from eggs laid the previous year (Tucker, 1997). In contrast, tropical sliders emerge during the wet season shortly after hatching (Moll and Legler, 1971). As a consequence, temperate sliders completing their first year of growth are actually age equivalents of a tropical slider completing its second year of growth.

Although growth patterns in the first three or four years of growth for tropical and temperate sliders were similar, the growth patterns strongly diverged in the fourth (Costa Rica) or fifth year (Panama) of growth. Sliders from Panama and Costa Rica showed a change in growth rates in the third or fourth year, respectively (Fig. 2). The change in growth rates coincided with and may be due to habitat shifts previously reported for juvenile turtles from both locations (Moll and Legler, 1971; Moll, 1994). At each location, turtles move

Table 1. Plastron length for sliders (*Trachemys scripta*) from temperate (Illinois) and tropical regions (Belize, Costa Rica, and Panama). Ranges are given in Figure 1. The time spent in the nest prior to emergence is included in H.

Site:	Illinois		Belize		Panama		Costa Rica	
Age	*n*	Mean	*n*	Mean	*n*	Mean	*n*	Mean
H	179	31.2	30	36.0	42	36.5	18	41.8
1	12	49.1	28	64.3	77	65.0	12	72.1
2	16	70.4	23	98.0	48	91.0	10	108.4
3	24	103.4	18	116.8	27	118.0	6	135.8
4	24	130.2	18	136.1	16	146.0	5	181.4
5	16	152.1	14	168.4	10	186.0	1	221.0
6	9	167.8	11	190.3	13	209.0		
7	7	186.4	7	205.9	11	227.0		
8	4	199.5			10	243.0		
9	3	206.0			13	252.0		
10	2	215.0			12	264.0		

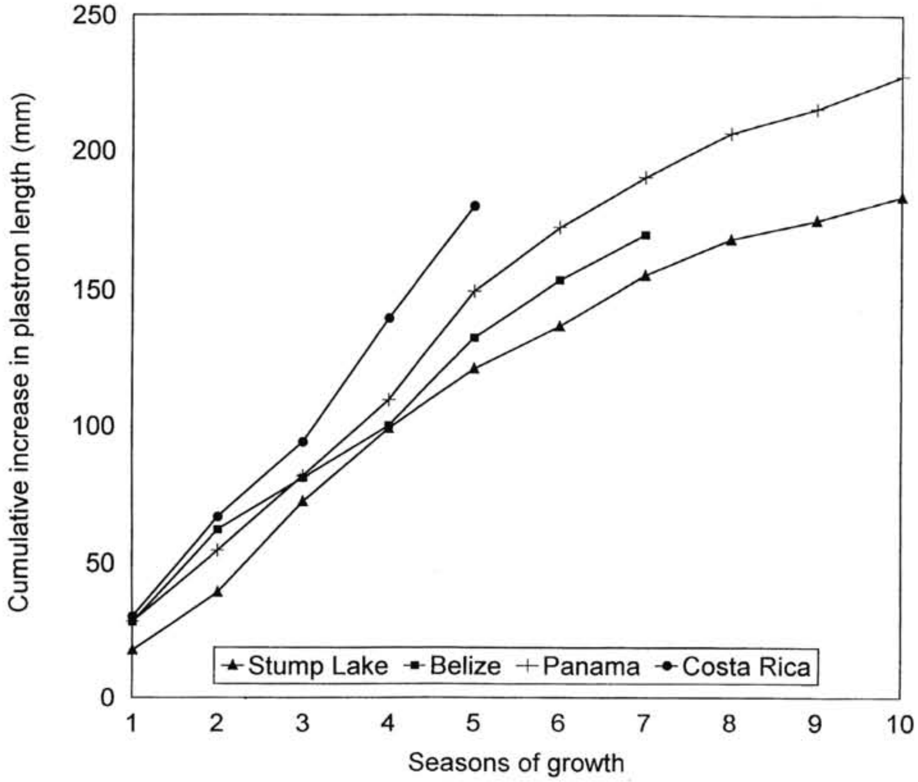

Figure 2. Cumulative increase in plastron length for *Trachemys scripta* from three tropical sites and one temperate site (Stump Lake, Illinois) determined by subtracting the mean plastron length at hatching from mean plastron length at the end of each subsequent year's growth for all age classes included in Fig. 1.

from lagoon or lentic environments to more open river environments (Moll and Legler, 1971; Moll, 1994). In contrast, juvenile sliders from the Belize site inhabit river environments throughout growth and do not show as distinct a change in growth rates (Moll, 1990).

Once the Panamanian and Costa Rican sliders complete the habitat change, the size differential between them and the sliders from Illinois diverge steadily, consistent with the suggestion that longer growing seasons or improved productivity leads to larger body size in tropical sliders. We cannot distinguish between the effect of the length of the growing season vs. productivity. However, the growth rates among age 1–3 or 4-yr old juvenile tropical sliders and temperate sliders are similar despite any difference in length of growth season. In contrast, the sudden change in growth pattern in older juveniles and adults suggests that the size advantage of tropical sliders is more likely due at least in part to increased productivity in their eventual adult habitats rather than any actual differences in length of growth season.

One problem inherent in comparisons of temperate and tropical habitats is determining the effective length of the growing season for turtles in tropical habitats. For tropical turtles their activity season does not necessarily correspond with their growth season. In contrast, the concordance between activity season and times of maximal growth is closer in temperate habitats where turtles enter hibernation each year. Tropical sliders in Panama are active throughout the year but growth is strongly influenced by the cooler cloudier wet season during which growth is relatively slow or stops (Moll and Legler, 1971). Thus, growth seasons for tropical and temperate sliders such as *T. scripta* may be effectively more similar than currently recognized.

Our study, consistent with findings of Moll and Legler (1971) for sliders from Panama, suggests that there is considerable variation in growth patterns among tropical sliders just as there is among temperate sliders from different locations (i.e., Dunham and Gibbons, 1990; Mitchell and Pague, 1990). For instance, the sliders from Belize (*T. s. venusta*) reach body sizes that are not much larger than body sizes among large bodied populations of *T. s. scripta* in South Carolina or Virginia (Mitchell and Pague, 1990). In contrast, sliders (*T. s. venusta*) in Caribbean Costa Rica may reach truly immense proportions (Pritchard and Trebbau, 1984; Moll, 1994). Furthermore, our results suggest that attributing size differences among sliders from temperate and tropical regions to differences in growing season alone is an over-simplification. Future studies of tropical sliders should concentrate on the influence of habitat shifts on productivity and growth and on understanding how these produce the marked shifts in growth rate that our analysis suggests occurs.

We have concentrated on the environmental influences on intraspecific growth comparisons but have not discussed the possible importance of genetics or patterns in attainment of sexual maturity. For instance, female red-bellied turtles (*Pseudemys rubriventris*) in Virginia at the northern limit of their range can reach plastron lengths of 326 mm (Mitchell, 1994). The growth season in northern Virginia is relatively short so the large size of this turtle cannot be due to length of the growth season. Rather the age at which females become sexually mature along with intrinsic growth rate may be more closely associated with size attained (Dunham and Congdon, 1990; Frazer et al., 1990).

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