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## Body Size, Reproductive Variation, and Growth in the Slider Turtle at the Northeastern Edge of Its Range

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### Abstract

Variation in body size and relationships of clutch size and egg size to female body size were compared in two populations of *Trachemys scripta* in southeastern Virginia. Sliders from both populations consist of large females (200–255 mm in plastron length) and males (92–189 mm). Clutch size and total clutch mass do not differ between populations and are not related to body size. Length, width, and wet mass of eggs do not differ between populations but are positively and significantly related to parental body size. Some females in each population produce at least two clutches in a single season. Juvenile growth rate (ages 1 through 6) averages about 13 mm per year. Possible causes of large-bodied adults are presented. Problems encountered demonstrate that caution must be taken when constructing generalizations about cause and effect in turtle life histories based on a limited number of comparisons. Comparisons of growth and reproductive characteristics with South Carolina sliders show concordance in most aspects. Differences can be explained on the basis of sample composition.

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### Introduction

Much of what is known about the life histories of animals has been gained from comparative studies of populations in different parts of the species' range (e.g., Tinkle and Ballinger, 1972; Leggett and Carscadden, 1978; M. Murphy, 1983). We can provide insights into the causes and relationships of these phenomena by comparing the varia-

tion in life history attributes among widely separated populations once the regional variation is known. Our focus in this paper is to provide comparative data on selected life history attributes of the slider turtle so we can evaluate environmental effects on these traits.

The northeastern margin of the range of *Trachemys scripta* is in southeastern Virginia (Conant, 1975) in the area roughly corresponding with the 5° C isotherm (Gibbons, 1983a). Natural populations of *T. s. scripta* occupy freshwater habitats in rural and urban areas of the state from the Atlantic coast westward to about the Fall Line. This paper summarizes our current knowledge of the reproductive variation of two *T. s. scripta* populations at the northeastern edge of its range. Introgressive hybridization with the introduced *T. s. elegans* is apparently affecting the genetic structure of urban populations in southeastern Virginia (Mitchell and Pague, pers. obs.). However, there appears to be little influence of *T. s. elegans* on the populations chosen for study. We compare differences in body size, and relationships of reproductive characteristics to parental size, between a coastal barrier population and an interior population. These parameters, as well as growth rates from the barrier population, are compared with published information from elsewhere in *T. scripta*'s range.

## Materials and Methods

The coastal barrier population we studied is located in Back Bay National Wildlife Refuge and adjacent False Cape State Park, Virginia Beach, Virginia. This area is bordered to the north by the community of Sandbridge and to the south by the Virginia–North Carolina state line on the Currituck Spit. This landmass separates the Back Bay estuary from the Atlantic Ocean. Sliders primarily occupy the freshwater impoundments and canals but also are occasionally seen in the mostly clear, variably brackish bay. The second population is located in the Virginia portion of the Great Dismal Swamp National Wildlife Refuge, Suffolk, Virginia, 53 km west of the Back Bay–False Cape population. Here sliders are found in the freshwater canals crisscrossing the forested refuge and occasionally in Lake Drummond. The water in Dismal Swamp is dark and acidic.

We studied the Back Bay–False Cape population from 1980 to 1983 and in 1986. The Dismal Swamp population was studied in 1985 and 1986. In Back Bay–False Cape we captured sliders with sardine-baited funnel traps (Iverson, 1979a), with fyke nets, and by hand. Traps were set in the canals and in the bay, but turtles were captured only in freshwater sites. Most turtles were individually marked by notching the margins of the carapace (Mitchell, 1982) and released at the capture site. In both study areas we captured ovigerous females while they were on land seeking nest sites or nesting. We measured carapace length (CL), plastron length (PL), and length of

all visible annuli on the right abdominal scute (to the nearest 0.1 mm). Body mass was recorded to the nearest gram with Pesola scales. Eggs were obtained by dissection of gravid females and from females that had just finished nesting. Each egg was measured (length and width to the nearest 0.1 mm) and weighed (to the nearest 0.1 g). Total clutch mass is the sum of the individual egg masses for each clutch. Individually numbered eggs were incubated in vermiculite (1:1 with water by weight) at 27° ± 3° C until hatching. Hatchlings were measured (CL, PL) and weighed (to the nearest 0.1 g), and many were released.

We determined growth rates for juveniles (unsexed) by counting clearly distinguishable annuli on the plastron. Assigning ages to individuals with this method is reliable only for the first few years of life because of the loss of annuli due to wear (Moll and Legler, 1971; Wilbur, 1975b). We were confident in our age assignments for most sliders through age 6 and for three specimens at ages 7 and 8.

Statistics follow Zar (1974) and were performed with SPSS\* programs (SPSS, 1986). Nonparametric statistics were used when assumptions of normality were not met. Statistical significance was established at  $p \leq .05$  unless otherwise noted. Reported means are followed by ± one standard error.

## Results

### BODY SIZE

Mature females from both populations were similar in body size. Mean carapace length for Back Bay–False Cape ovigerous females (248.2 ± 11.5 mm, 232–272 mm,  $N = 21$ ) did not differ significantly from mean carapace length of Dismal Swamp females (252.6 ± 12.7 mm, 226–273,  $N = 23$ ;  $t = -1.04$ ,  $p = .304$ ). Average carapace length for both populations combined was 250.8 ± 12.2 mm ( $N = 44$ ). Plastron lengths showed a similar relationship (Table 11.1, Back Bay–False Cape, 215–250 mm; Dismal Swamp, 204–254 mm) and were not significantly different ( $t = -0.51$ ,  $p = .613$ ).

Mature males at Back Bay–False Cape averaged 158.4 ± 30.6 mm CL (102–215 mm,  $N = 20$ ) and 143.5 ± 27.8 mm PL (94–189 mm,  $N = 20$ ). A single male from the Dismal Swamp site measured 161 mm CL and 147 mm PL.

### REPRODUCTIVE VARIATION

Clutch size for southeastern Virginia sliders ranged from 6 to 15 but showed an insignificant relationship with female body size (Fig. 11.1, Table 11.2). There was no significant difference in clutch sizes between populations (Mann-Whitney  $U$  test,  $U = 180.0$ ,  $p = .144$ ). A Kruskal-Wallis test revealed a significant difference in clutch means among years (each yearly sample coded sepa-

Table 11.1. Body size and reproductive characteristics for *Trachemys scripta* from two southeastern Virginia populations

Sample	N	Plastron length	Clutch size	Egg length	Egg width	Egg wet mass	Clutch wet mass
<b>Back Bay-False Cape</b>							
1983	7	230.0	9.29	34.47	22.93	10.51	96.76
		4.7	0.60	0.50	0.53	0.54	6.04
1986	14	233.5	9.93	34.07	23.26	11.01	111.50
		3.3	0.67	0.43	0.25	0.41	7.83
Combined	21	232.2	9.71	34.20	23.14	10.84	106.59
		2.4	0.43	0.29	0.22	0.29	5.00
<b>Dismal Swamp</b>							
1985	13	238.0	9.54	34.82 <sup>a</sup>	23.41 <sup>a</sup>	10.97 <sup>a</sup>	105.14 <sup>a</sup>
		3.3	0.58	0.42	0.27	0.36	6.14
1986	10	229.3	12.30	33.74	23.18	10.43	127.20
		4.3	0.68	0.47	0.32	0.41	6.98
Combined	23	234.2	10.74	34.33 <sup>b</sup>	23.20 <sup>b</sup>	10.73 <sup>b</sup>	115.17 <sup>b</sup>
		2.7	0.52	0.33	0.20	0.27	5.07
<b>All samples</b>							
	44	233.3	10.25	34.27 <sup>c</sup>	23.23 <sup>c</sup>	10.78 <sup>c</sup>	110.98 <sup>c</sup>
		1.8	0.35	0.22	0.15	0.20	3.58

Note: Upper number is the mean, and lower number is one standard error. Sizes are in mm, and masses are in g.

<sup>a</sup>N = 12.

<sup>b</sup>N = 22.

<sup>c</sup>N = 43.

rately;  $\chi^2 = 9.872$ ,  $df = 3$ ,  $p = .0197$ ). The 1986 Dismal Swamp sample contained a significantly larger mean clutch size (Table 11.1) than the other three yearly samples.

Each measure of egg size and egg wet mass (Table 11.1) exhibited positive and significant relationships with plastron length (Fig. 11.1, Table 11.2). The amount of variation ( $r^2$ ) explained by plastron length ranged from 18% to 29%. Analysis of covariance with plastron length as the covariate revealed no significant differences between populations or among years for egg length ( $p = .801$ , .422), egg width ( $p = .758$ , .736), or egg wet mass ( $p = .468$ , .835). Egg length (EL) decreased significantly as clutch size (CS) increased ( $\bar{x}_{EL} = 36.78 - 0.244 [CS]$ ,  $r^2 = .151$ ,  $p = .0101$ ). However, the relationships with clutch size were insignificant for egg width (EW;  $p = .293$ ) and egg wet mass ( $p = .066$ ). Egg wet mass (EWM) was positively and significantly related to egg length ( $\bar{x}_{EWM} = -15.811 + 0.7780 [EL]$ ,  $r^2 = .741$ ,  $p < .001$ ,  $N = 43$ ) and egg width ( $\bar{x}_{EWM} = -16.612 + 1.1793 [EW]$ ,  $r^2 = .7866$ ,  $p < .001$ ,  $N = 43$ ).

Total clutch wet mass was insignificantly related to plastron length (Table 11.2). Analysis of variance indicated that clutch wet mass (Table 11.1) did not differ significantly between populations ( $F_{1,41} = 1.415$ ,  $p = .2411$ ) but did differ significantly among years ( $F_{1,39} = 3.010$ ,  $p = .0416$ ). Tukey's Honestly Significant Difference test indicated ( $\alpha = .05$ ) that only the 1986 Dismal Swamp sample was significantly different from the other yearly samples.

Females from both populations were found to produce multiple clutches, as evidenced by the presence of two distinct sets of corpora lutea on the ovaries. In Back Bay-False Cape, 94% of 17 females caught 11-25 June produced multiple clutches. Of 11 Dismal Swamp females caught 5-7 June, 36% produced multiple clutches.

#### GROWTH

Hatchlings from eggs maintained in the laboratory averaged  $29.2 \pm 0.38$  mm PL (26-33 mm,  $N = 120$ ). Plastron lengths of two hatchlings (28.6 mm, 30.6 mm) caught in Back Bay-False Cape while still showing umbilical scars agree well with this size range. Mean PL of sliders caught during their first year in the population was  $57.4 \pm 1.78$  mm (46-71 mm,  $N = 16$ ). Annual growth from ages 1 through 6 (Fig. 11.2) averaged  $13.1 \pm 2.15$  mm PL. The largest sliders in each of ages 3 through 6 were immature females. Males age 5 and older that had plastron lengths greater than 100 mm were mature. The 8-year-old female was immature.

#### Discussion

##### BODY SIZE

Variation in body size of adult *T. scripta* among populations has been demonstrated by Cagle (1950), Moll and Legler (1971), Gibbons et al. (1979), and Gibbons et al.

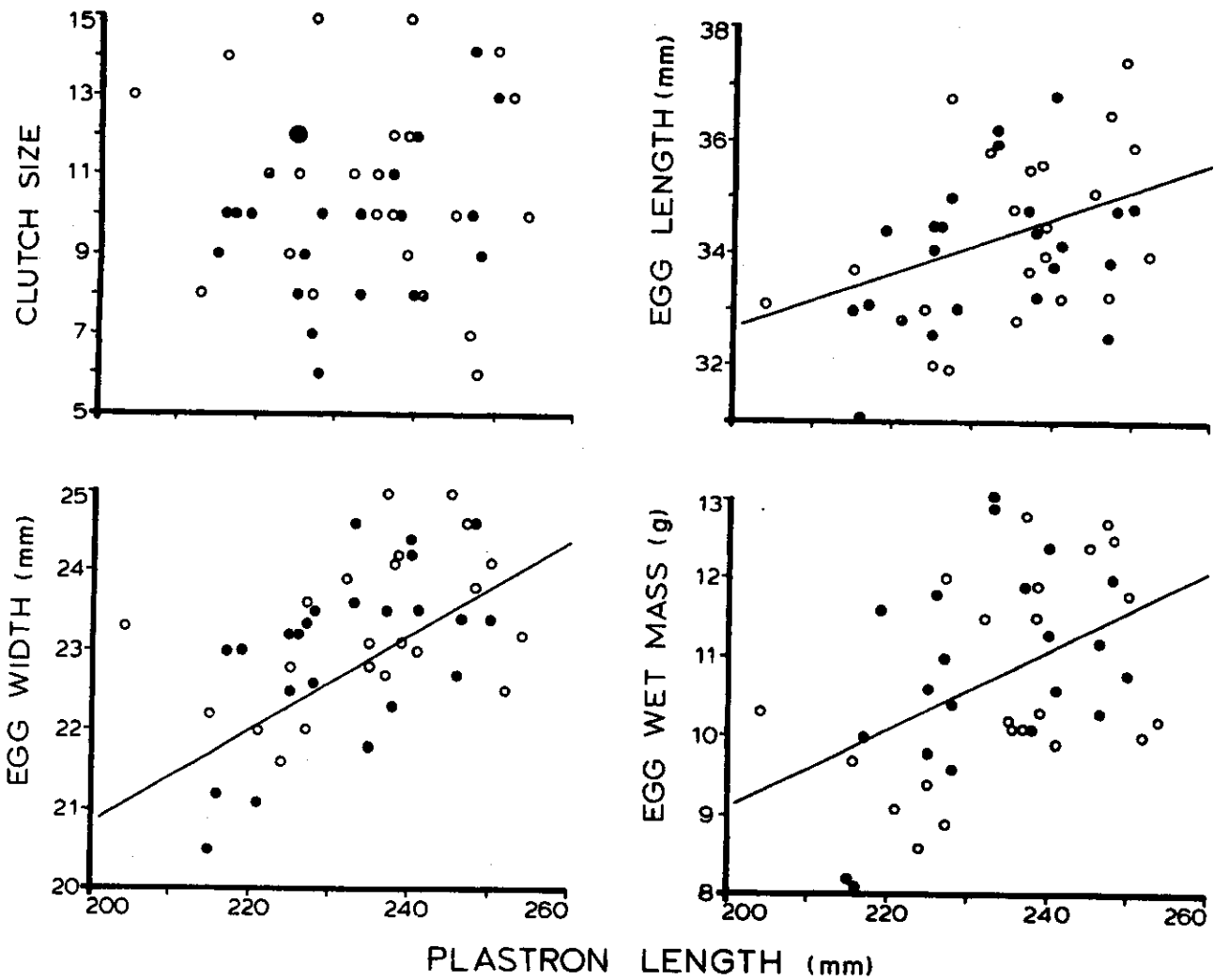


FIGURE 11.1. Relationships of clutch size, egg measurements, and egg wet mass with plastron length in *Trachemys scripta* from southeastern Virginia. Solid circles represent Back Bay-False Cape samples, and hollow circles represent samples from Dismal Swamp. The large circle represents two observations, and half-filled circles indicate identical measurements for both populations. Table 11.2 provides sample sizes and linear statistics for the regression lines.

(1982). In the eastern portion of its range, populations of large-bodied females have been associated with thermally influenced reservoirs (Gibbons, 1970b) and barrier islands (Gibbons et al., 1979). Thus, we had not expected to find large-bodied female *T. scripta* in both Back Bay-False Cape, which is a coastal barrier system, and Dismal

Swamp, an interior system. The range of body sizes for mature females in these two populations is most like that reported for Par Pond on the Savannah River Plant in South Carolina; it receives thermal effluent from a nuclear reactor (Gibbons, 1970b; Gibbons et al., 1979). The range of body sizes for mature males from the Back Bay-False

Table 11.2. Linear relationships of reproductive characteristics with female body size (plastron length) in *Trachemys scripta* from southeastern Virginia

Characteristic	N	Intercept (SE)	Slope (SE)	r <sup>2</sup>	p
Clutch size	44	8.605 (6.889)	0.0071 (.029)	.0014	.8122
Egg width	43	13.207 (2.617)	0.0429 (.012)	.2639	.0004
Egg length	43	22.935 (4.137)	0.0485 (.018)	.1550	.0090
Egg wet mass	43	-0.854 (3.624)	0.4977 (.016)	.2013	.0026
Clutch wet mass	43	-11.535 (71.647)	0.5241 (.306)	.0667	.0944

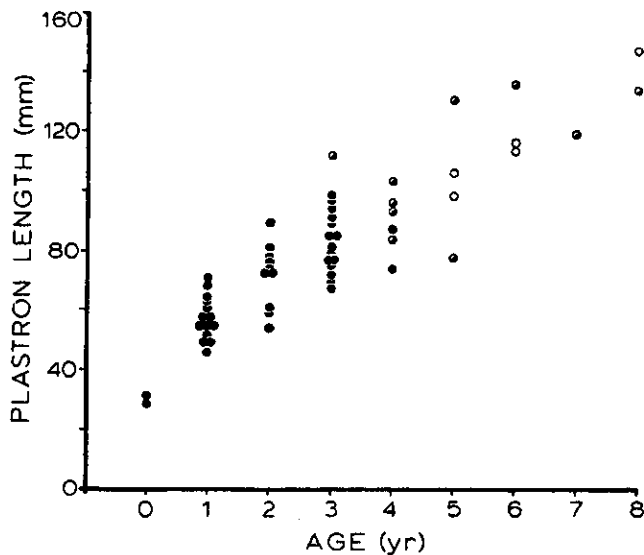


FIGURE 11.2. Relationship of plastron length to age in *Trachemys scripta* from the Back Bay–False Cape population in southeastern Virginia. Open circles are males, half-shaded circles are females, and closed circles are unsexed individuals. Each age category indicates the year of growth.

Cape population is also most like that of the Par Pond population (Gibbons et al., 1979). If all freshwater ponds and impoundments in barrier ecosystems provide sliders with a source of high-protein food and if fish in the diet contribute to greater growth rates and body sizes (Parmenter, 1980), then the large sliders found in the Back Bay–False Cape barrier ecosystem are not unusual. Their somewhat smaller size range relative to sliders on South Carolina barrier islands is consistent with the prediction of Gibbons et al. (1979) that growth rates and body sizes “should diminish in a northerly direction due to progressively lower temperatures.”

Why, however, are Dismal Swamp sliders equally as large as those in Back Bay–False Cape? There may be several possible explanations. The Dismal Swamp ecosystem may be enriched by agricultural runoff, which may increase productivity and turtle food resources. However, such runoff contains pesticides, as well as nitrogen, and is limited to a small portion of the refuge (M. K. Garrett, pers. com.). First, sliders in Dismal Swamp occur in much lower densities than in Back Bay–False Cape (Mitchell and Pague, pers. obs.), so they may have similar amounts of energy available per individual. Second, our sample may be biased in favor of large females, although the refuge personnel assisted us in slider collection and reported none smaller. Another possibility is that Dismal Swamp sliders are simply older and thus larger. Third, we question whether there may be a genetic basis for faster growth rates and large body sizes in some populations. Could the sliders in Dismal Swamp have evolved from a

large-bodied lineage? Samples of large-bodied and small-bodied females in Congdon and Gibbons (1983) possessed different reproductive characteristics because of the variation in body size. Although the sets of samples correspond well with environmental differences, it has not been proven that thermal enhancement and high-protein diet are the causes of large-bodied sliders. We have observed considerably less aquatic vegetation in Dismal Swamp than in Back Bay–False Cape and have found plant fragments in the feces of sliders from both areas. We do not know, however, if sliders in both populations eat similar amounts of protein. Comparative studies of growth related to natural resource utilization, as well as comparisons of the size structure of slider populations throughout southeastern North America, are needed to elucidate the causes of body size variation. In addition, experimental studies could provide insight into this question.

#### REPRODUCTIVE VARIATION

Until recently, descriptions of the relationships of reproductive characteristics to body size have been limited to clutch size and, for some, egg length (e.g., Moll and Legler, 1971; Iverson, 1977b). Because the suggestion that egg width may be closely related to the size of the female pelvic opening (Tucker et al., 1978), more-recent papers have examined the relationships of a variety of egg and clutch characteristics to body size (e.g., Congdon and Tinkle, 1982b; Congdon et al., 1983a; Mitchell, 1985a,b; Schwarzkopff and Brooks, 1986). Congdon and Gibbons (1985) demonstrated positive relationships of egg and clutch size within and among the 12 species studied, including *T. scripta*.

Clutch size has been shown to be positively related to body size in *T. scripta* by Gibbons (1970b), Moll and Legler (1971), Gibbons (1982), Gibbons et al. (1982), and Congdon and Gibbons (1983, 1985). Slider populations in Virginia more closely resemble sliders from Par Pond, South Carolina, in body size and clutch size than other populations studied by Gibbons and his co-workers. Although most of the papers noted above on South Carolina sliders combine large- and small-bodied population samples, Gibbons et al. (1982) reported results for two populations separately. The sample of large-bodied females from Par Pond exhibited a positive relationship of clutch size to plastron length, although only 12% of the variation was explained by the linear regression model. This contrasts with the combined sample from southeastern Virginia, which showed no significant relationship. Gibbons et al. (1982) suggested that their large sample size played a major role in demonstrating the subtle relationship.

Measurements of egg size (length and width) and egg wet mass were positively and significantly related to body size in both southeastern Virginia populations. Except for

egg length, Congdon and Gibbons (1983) found similar results for a combined sample of large- and small-bodied *T. scripta* from South Carolina. In the Virginia populations there was a positive but insignificant relationship of total clutch wet mass with body size, even though egg size increased significantly with body size; a significant relationship was reported by Congdon and Gibbons (1983). Variation in egg number over the range of body sizes probably contributed to the insignificant relationship.

The applicability of optimal-egg-size theory (Smith and Fretwell, 1974; Brockleman, 1975) to freshwater turtles has been examined by Congdon and Tinkle (1982b), Congdon et al. (1983a), and Congdon and Gibbons (1985). They conclude that turtles appear to be exceptions to the prediction that variation in reproductive output should result from variation in egg number rather than in egg size. Our results for southeastern Virginia populations of *T. scripta* conform to the pattern being established for turtles. Our comparisons between Back Bay-False Cape and Dismal Swamp turtles suggest that reproductive investment in eggs and clutches is the same between these two populations, despite the differences in habitats described above.

#### GROWTH

Shapes of growth trajectories for those freshwater turtles exhibiting strong sexual size dimorphism (female larger), like *T. scripta* (Berry and Shine, 1980) tend to be similar. Growth is rapid early in life until maturity is reached, at which time growth slows but never completely stops (e.g., Wilbur, 1975b; Gibbons et al., 1981; Mitchell, 1982). Comparisons of the early growth curve for the Back Bay-False Cape population with the growth curves in Gibbons et al. (1981) suggest a trajectory that lies between those plotted for Par Pond and Ellenton Bay populations in South Carolina. Growth for juveniles between hatching and their first year in the population encompasses the

entire range of variation shown in Gibbons et al. (1981) for this age group.

If growth trajectories for males and females continue to fall between those in Gibbons et al. (1981), then Back Bay-False Cape males should mature at 4 or 5 years of age, and females should mature at about age 8 but at sizes intermediate to those in Par Pond and Ellenton Bay. Our results suggest that the projection is correct for males. We had insufficient data to confirm age at maturity for females.

Our study of *Trachemys scripta* in Virginia leads to two conclusions. Studies of reproductive variation should be conducted over several years so that variation among yearly samples is taken into account. Our difficulty in ascertaining why Dismal Swamp sliders are as large-bodied as those in Back Bay-False Cape and those in Par Pond, South Carolina, suggests that we should be cautious about using only a few comparisons as the basis of generalizations about the causes of such traits. The question is, how many populations must be studied before we can make such generalizations?

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