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MORPHOMETRY OF GROWTH IN HATCHLING STRIPED PLATEAU LIZARDS

(IGUANIDAE: *SCELOPORUS VIRGATUS*)

Geoffrey R. Smith

School of Biological Sciences
University of Nebraska–Lincoln
Lincoln, Nebraska 68588-0118

ABSTRACT

I studied the ontogenetic development of body shape and the influence of food availability on the development of body shape in hatchling striped plateau lizards (*Sceloporus virgatus*) over the first seven to eight weeks of their life. Body mass showed positive growth relative to snout–vent length. Head width, head length, and femur length showed negative growth relative to snout–vent length. No sexual differences were evident in relative growth in any body part or trait. Food availability did not influence the relative growth of body parts or traits.

† † †

Many organisms change size and shape throughout their lifetimes. Some of the most dramatic changes involve complete or nearly complete changes in morphology between stages such as lepidopteran or amphibian metamorphosis. Other changes are much more subtle, involving changes in the ratios of body parts. For example, in humans, the head grows at a slower relative rate than the rest of the body.

An important aspect of ontogenetic shape change arises when one considers the mechanism behind sexual dimorphism in body proportions. For example, in lizards, males often have larger heads (relative to body size) than females (e.g., Anderson and Vitt, 1990; Cooper and Vitt, 1989; Griffith, 1991; Shine, 1989; G. Smith, 1992; Vial and Stewart, 1989; Vitt and Cooper, 1985). Such sexual dimorphism could arise in two ways: (1) Males are smaller (or larger) and thus by simple allometry their heads are proportionally larger (i.e., females would have the same relative head sizes at similar body sizes). In this case the rate at which the ratio of head width to body size changes would be the same in males and females; (2) The heads of males grow at a different relative rate than they do in females. In this case the rate at which the ratio of head width to body size changes would be different in males and females.

Exposure to environmental pressures can influence the development of an organism's size and shape. Food availability and abundance can influence some polymorphisms observed in nature. For example, spadefoot toad tadpoles (*Scaphiopus multiplicatus*) become carnivorous morphs if shrimp density in their pool is above a certain threshold density, but otherwise they become omnivorous morphs (Pfennig, 1990). Similar effects have been observed in the development of jaw morphology in several species of fish (e.g., Meyer, 1987; Wainwright, 1988, 1991; Wainwright et al., 1991), head size and shape in insects and salamanders (e.g., Bernays, 1986; Walls et al., 1993a, Walls et al., 1993b), and body morph in lepidopterans (e.g., Greene, 1989). Morphology can also be dependent upon the presence or absence of predators (e.g., cyclomorphosis in daphnids; S. Dodson, 1989).

Environmentally induced variation in growth allometry may have implications for the reproductive success of males in territorial species or in species with female mate choice. Often, larger males are more successful in obtaining mates than smaller males (e.g., Anderson and Vitt, 1990; Cooper and Vitt, 1993; Olsson, 1992). This also applies to males with larger heads (e.g., Anderson and Vitt, 1990; Vitt and Cooper, 1985). Food acquisition or availability can influence body size of male lizards (Ballinger and Congdon, 1980; Dunham, 1978; Guyer, 1988a,b; Stamps and Tanaka, 1981). If food availability can also influence relative head size in males, then males growing in territories with lower food levels might not only be smaller but also have the "wrong" head proportions, thereby having a reduced ability to attract mates. Therefore, knowledge of the influence of food availability on body proportions could be useful in understanding how different territories result in differential success of their inhabitants.

In this study, I consider changes in body shape of laboratory-reared *Sceloporus virgatus* hatchlings. I

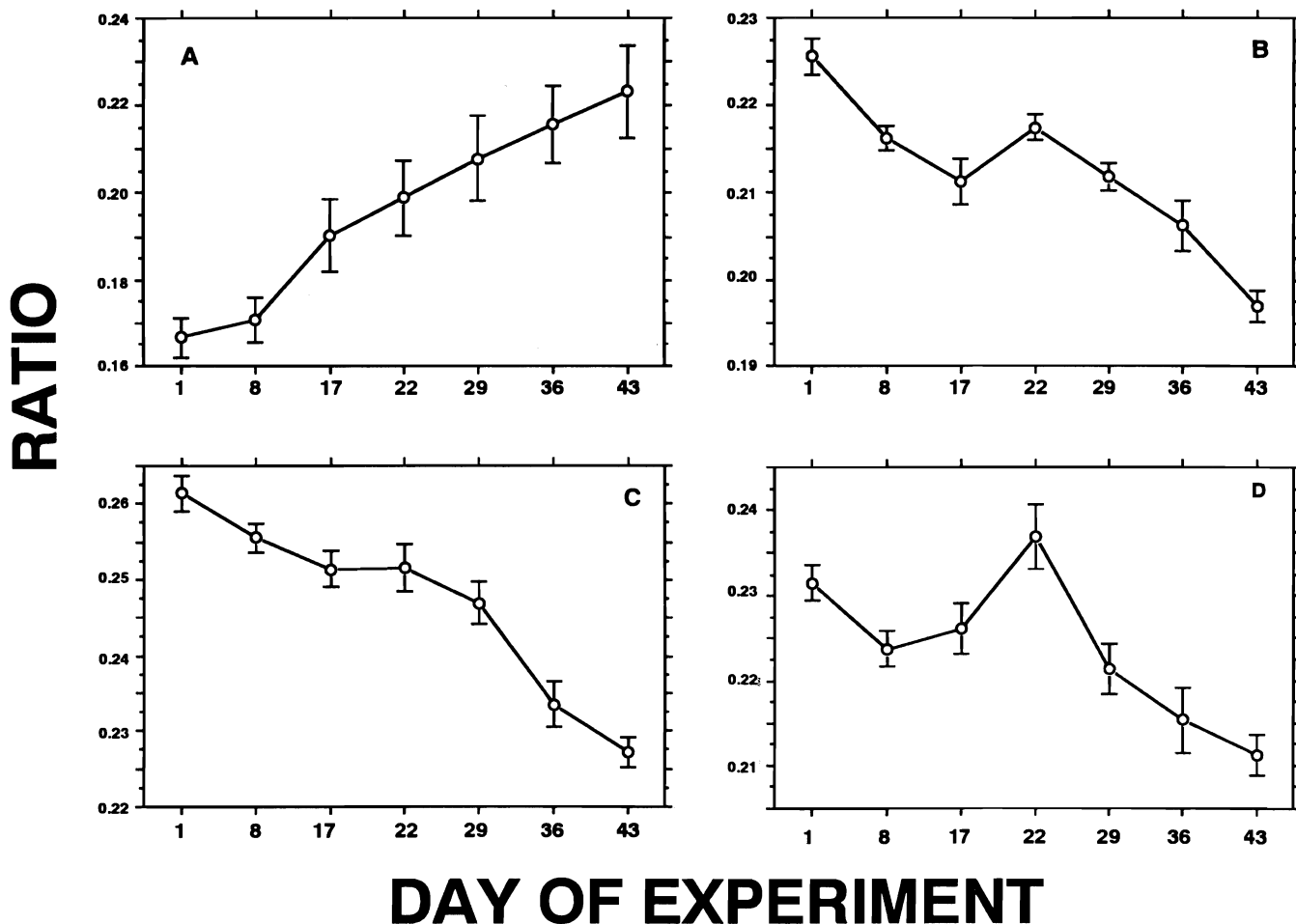


Figure 1. Change in body shape over the course of the experiment in hatchling *Sceloporus virgatus*: (A) BM:SVL, (B) HW:SVL, (C) HL:SVL, and (D) RFL:SVL. Bars are ± 1 SE.

also investigate differences between male and female hatchlings, and the effects of food availability on changes in body shape in these hatchlings.

MATERIALS AND METHODS

Gravid female *S. virgatus* were obtained from the Chiricahua Mountains of southeastern Arizona. Gravid females were allowed to oviposit on sand. Eggs were incubated on a 50:50 mixture (by mass) of water and vermiculite that was placed in glass dishes. The glass dishes were sealed in plastic bags and placed in an environmental chamber set at approximately 30° C. Moisture of the substrate was checked and maintained throughout incubation. Hatchlings were individually kept in plastic cages (30 × 16 × 8 cm) and provided with water and 10 hours radiant heat per day (75 W bulb suspended 30 cm above the substrate). The position of the light bulb at one end of the cage generated a temperature gradient (20 to 40°C) in which hatchlings could thermoregulate. Hatchlings were randomly as-

signed to one of three treatments: fed five crickets (dusted with a calcium and phosphorus supplement): (1) every day (high food level) (N = 6), (2) every other day (medium food level) (N = 6), or (3) every third day (low food level) (N = 6). Crickets were left in cages for 24 h, and if any crickets remained at the end of the 24 h, they were removed from the cage. The number of crickets eaten in each 24-h period was recorded. Size of crickets fed hatchlings increased throughout the study. Initially, crickets each weighed on average 0.0043 g, then 0.0182 g, and finally 0.0245 g.

Hatchlings were measured weekly. Measurements included: snout-vent length (SVL; to nearest 0.1 mm), body mass (BM; to nearest 0.1 g), head width (HW; measured at widest point of head; to nearest 0.01 mm), head length (HL; measured from anterior edge of ear to tip of snout; to nearest 0.01 mm), and rear femur length (RFL; from knee to center of body; to nearest 0.01 mm). Hatchlings were sexed by the presence of enlarged post-anal scales in males. I calculated the following

DISCUSSION

ratios: BM:SVL, HW:SVL, HL:SVL, and RFL:SVL. To investigate the change in body shape, I calculated the rate of change in the ratios by dividing the difference between the initial ratio and the final ratio by the number of days between the initial and final measurements (i.e., $\Delta\text{ratio}/\text{days}$). Data were analyzed using two-factor analyses of variance (ANOVA) with sex and treatment as the factors.

RESULTS

At the initial measurement used in the analyses, there was no statistically significant sexual dimorphism in any ratio ($P > 0.15$ in all cases; $N_{\text{males}} = 8$; $N_{\text{females}} = 9$). Also, there were no differences between treatments in any ratio ($P > 0.15$ in all cases).

The ratio of BM to SVL increased as the study progressed (Fig. 1a; mean: $0.00056 \pm 0.00032 \text{ d}^{-1}$; $N = 17$; range: -0.0016 to 0.0029). There was no difference in the change of the BM:SVL ratio between males and females ($F_{1,11} = 0.20$, $P = 0.66$). Treatment did not significantly affect the change in this ratio ($F_{2,11} = 2.12$, $P = 0.17$). There was no significant interaction between sex and treatment ($F_{2,11} = 3.62$, $P = 0.06$).

The ratio of HW to SVL decreased with time (Fig. 1b; mean: $-0.00065 \pm 0.0001 \text{ d}^{-1}$; $N = 17$; range: -0.0014 to 0.0005). The ratio in females did not change at a different rate than in males ($F_{1,11} = 1.46$, $P = 0.25$). Food treatment level also did not have a significant effect on the change in the ratio of HW to SVL ($F_{2,11} = 0.45$, $P = 0.65$). There was no significant interaction between sex and treatment ($F_{2,11} = 1.65$, $P = 0.24$).

The ratio of HL to SVL also decreased with time (Fig. 1c; mean rate: $-0.00072 \pm 0.0002 \text{ d}^{-1}$; $N = 17$; range: -0.0021 to 0.0012). Males and females did not have significantly different rates of change in the ratio ($F_{1,11} = 0.11$, $P = 0.74$). Food treatment level had no significant effect on the rate of change in the ratio ($F_{2,11} = 0.12$, $P = 0.89$). The interaction between sex and food treatment was not statistically significant ($F_{2,11} = 0.33$, $P = 0.73$).

The length of the femur decreased relative to SVL with time (Fig. 1d; mean rate = $-0.00053 \pm 0.0002 \text{ d}^{-1}$; $N = 17$; range = -0.0026 to 0.0008). Males and females did not have significantly different rates of change ($F_{1,11} = 1.88$, $P = 0.20$), nor did food level have a significant effect on the rate of change ($F_{2,11} = 2.54$, $P = 0.10$). There was also not a significant interaction between sex and treatment ($F_{2,11} = 0.72$, $P = 0.51$).

Adult *Sceloporus virgatus* are sexually dimorphic, with females larger than males (Fitch, 1978). Body size dimorphism in this species appears to be related to differences in the growth rates of the sexes. Females grow faster than males in the wild (Rose, 1981; D. Smith, 1981). No studies have considered sexual dimorphism in body shape (such as relative head size) in *S. virgatus*. However, males in other *Sceloporus* species have larger heads than females, e.g., *S. undulatus* (Cooper and Vitt, 1989; P. Dodson, 1975), *S. olivaceus* (P. Dodson, 1975). Using static techniques (i.e., taking measurements in several individuals at one instant of time), other studies have shown that in species with sexual head dimorphism males and females often have different growth allometries (e.g., Cooper and Vitt, 1989; Griffith, 1991; Vial and Stewart, 1989; see also Carothers, 1984). Those studies focused on adults and lumped juveniles together in the analyses. My results using dynamic techniques (i.e., following an individual through a period of time) suggest that head dimorphism may not begin to be expressed until later in ontogeny, if at all in *Sceloporus virgatus*.

The allometry of growth in hatchling *Sceloporus virgatus* showed no influence of the quantity of food available. The rate of relative growth of several body parts (e.g., head width, head length) did not depend on the level of food provided to hatchlings. My results that indicate no effect of the environment on allometry are similar to those of Blouin and Loeb (1991) and Arnold and Peterson (1989). Blouin and Loeb (1991) did not find any effects of food availability on shape change in frog tadpoles and juveniles. Arnold and Peterson (1989) found that temperature had no influence on shape changes in garter snakes (*Thamnophis sirtalis*).

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