MEASURING THE MUSCLES OF COTTONMOUTH PIT VIPERS AS THEY GROW

KYLIE ATKINSON AND DAVID A. PENNING

DEPARTMENT OF BIOLOGY AND ENVIRONMENTAL HEALTH, MISSOURI SOUTHERN STATE UNIVERSITY, JOPLIN MO 64801

Introduction

- **As an organism grows, different parts of its body grow at different rates relative to the rest of its body.**
  - For example, in humans, our heads grow with negative allometry to our body, where as, our legs grow with positive allometry to our body as we get older. An adult human has a larger head than an infant, however, in relation to the human body, the head appears smaller on an adult and larger on an infant. This is the same for many other organisms.
- **Across the ontogeny of a snake, it is possible for the growth of muscles to change with age.**
- **Our objective for this dissection and analysis was to better understand how the three of the largest muscles in the erector spinae group change across ontogeny in the Cottonmouth snake (*Agkistrodon piscivorus*).**
  - These muscles are used in both striking and constriction and are therefore of high functional importance.
  - By taking the cross-sectional area of the erector spinae muscles, we can better determine how these muscles change as snakes grow.
  - **Past research has shown that these muscles scale with positive allometry (Penning et al., 2019).**
- **We hypothesized that as cottonmouths increase in mass and length, they require more force in order to perform the necessary striking behaviors to capture and consume prey. Therefore, the erector spinae muscles must grow with positive allometry in relation to their body size.**

Materials and Methods

- **We used 11 fixed and preserved *Agkistrodon piscivorus***
  - **Mass range = 7.9-724 g**
  - **Snout-Vent Length (SVL) = 19-85.5 cm**
- **Each snake was dissected into 5 pieces at different percentages along the SVL. These percentages were 20%, 40%, 60%, 80% and 100% (Fig 1).**
  - **At each body section, we took digital images of the muscles.**
- **After collecting the necessary images, individual cross-sectional areas of the spinalis complex (the spinalis capitis and semi-spinalis capitis), longissimus dorsi, and iliocostalis muscles were quantified at each of the five locations along the body.**
  - **Data collection was done via ImageJ.**

Statistical Analyses

To evaluate the relationship between morphological variables, we used regression analyses. Specifically, we used Reduced Major Axis (RMA) regression because all of our variables are highly correlated and for any bivariate comparison, there is no true independent and dependent variable.

- **For scaling analyses, we used log10-transformed data and compared the regression slope to a predicted isometric slope**
  - We consider slopes to be significantly different if the predicted slope falls outside the 95% confidence interval of the calculated slope (Herrel et al., 2011).
- **For comparisons between body sections, we used an ANCOVA model to test for differences in muscle cross-sectional area at the five measured locations.**

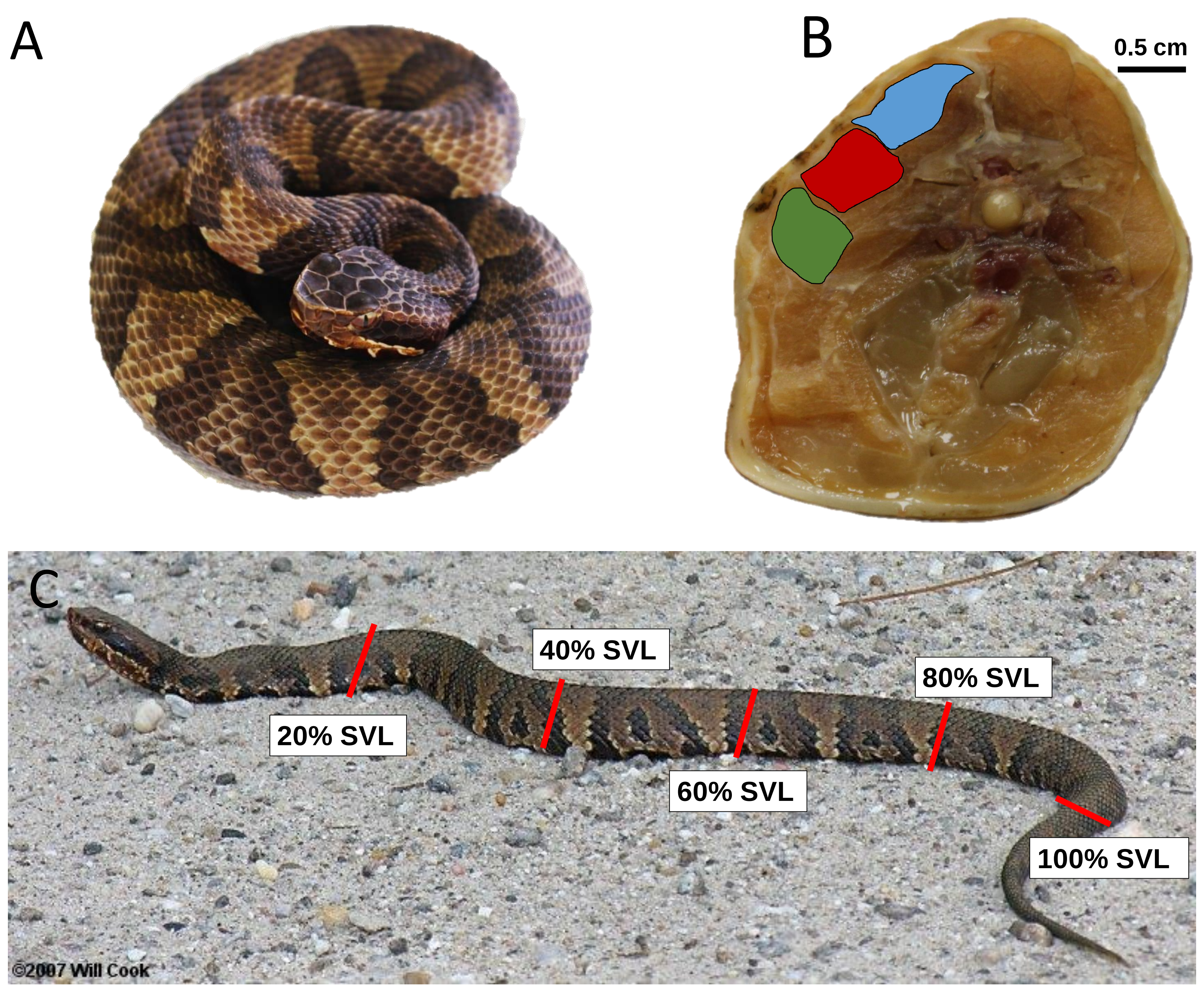

Fig 1– A representative size of a 60g *A. piscivorus* (A), a typical body cross-section (of a different snake species (B), and the relative position of the five locations along the body where measurements were taken (C).

Results and Discussion

Scaling of Body Mass:

Overall, longer snakes were heavier than shorter snakes.

- **Body mass scaled isometrically with Snout-Vent Length (slope = 3.06, CI = 2.8-4.2)**
  - For any given length, body mass increased proportionately (Fig 3A).

Scaling of Muscle Cross-Sectional Area:

Overall, longer snakes had larger muscles. However, at each body section, longer snakes had disproportionately more muscle for their size compared to smaller snakes (Fig 3B-F).

- **20% SVL: Positive Allometry** (slope = 2.68, CI = 2.3-3.6)
- **40% SVL: Positive Allometry** (slope = 2.87, CI = 2.3-3.2)
- **60% SVL: Positive Allometry** (slope = 3.3, CI = 2.2-3.7)
- **80% SVL: Positive Allometry** (slope = 2.83, CI = 2.5-4.5)
- **100% SVL: Positive Allometry** (slope = 2.94, CI = 2.4-3.8)

Comparing the Scaling of muscle cross-sectional area along the body:

At all locations along the body, muscle cross-sectional area scaled with positive allometry. Larger snakes had disproportionately more muscle than smaller snakes.

- **However, there was no significant difference between muscle CSA when compared across the body sections (p>0.59).**
- **The common slope of muscle CSA regressed against SVL is 2.95.**
- **At all locations in the body, muscles increased similarly (Fig 2).**

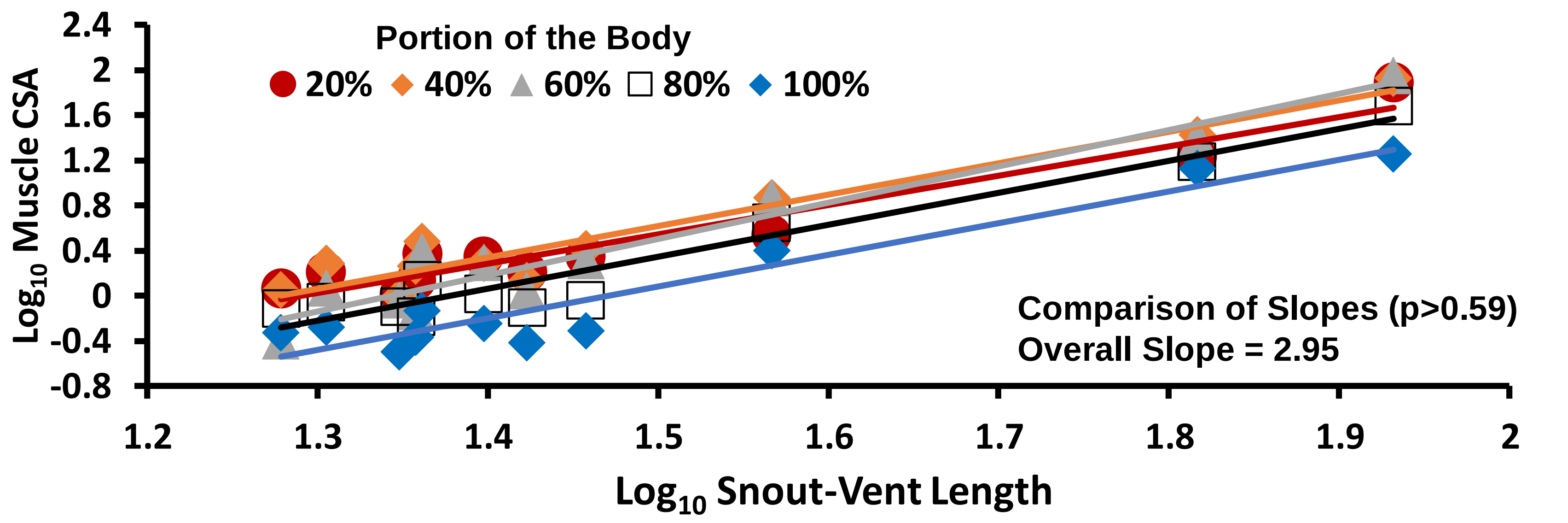

Fig 2.—Comparative scatterplot of log10-transformed muscle cross-sectional area (cm2) regressed against snout-vent length (cm). Each color denotes the percent of snout-vent length where measurements were taken.

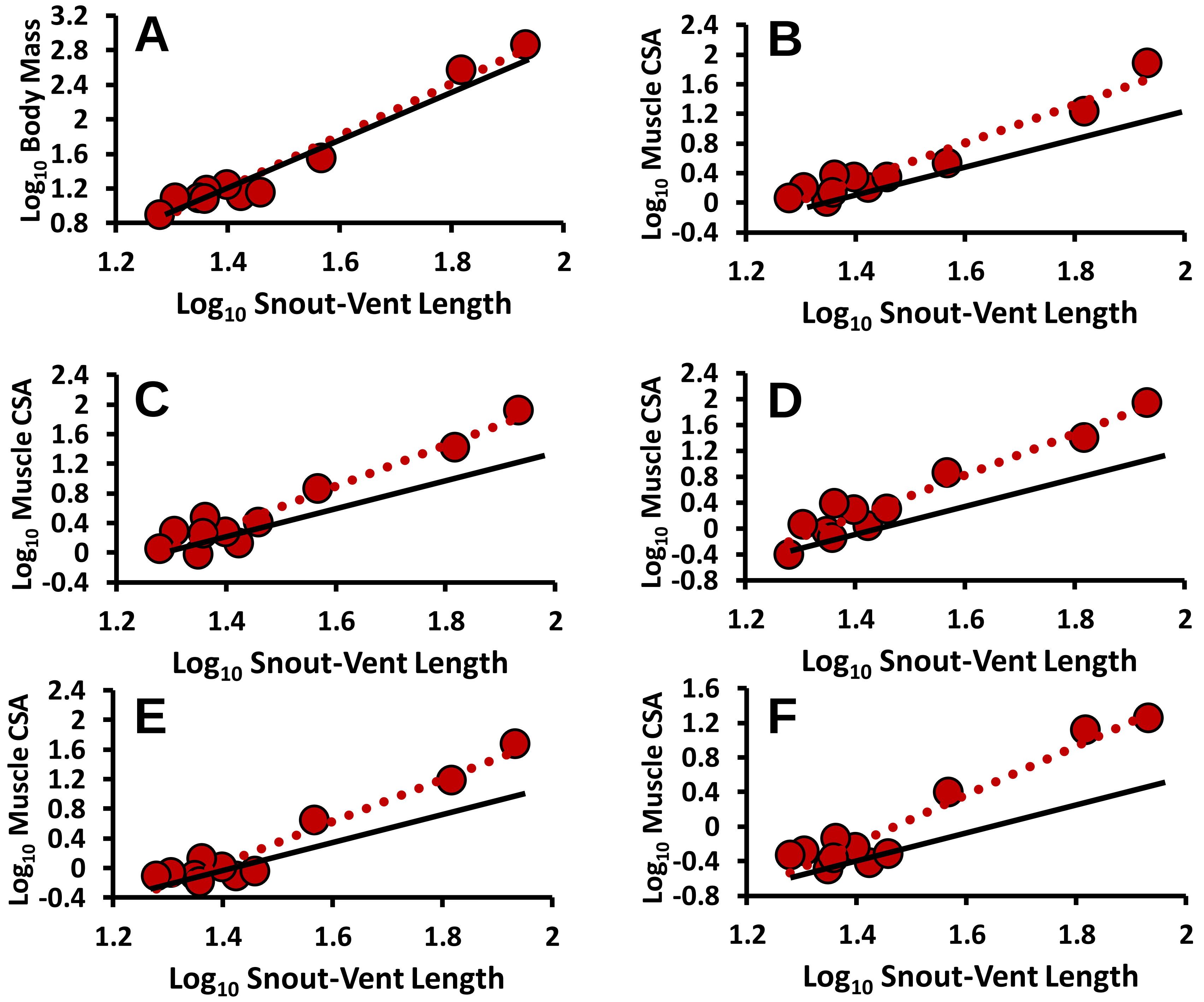

Fig 3.—Scatterplots of body mass (A) and muscle cross-sectional area (CSA) at 20% (B), 40% (C), 60% (D), 80% (E), and 100% (F) of the body regressed against snout-vent length. The black line represents the expected isometric scaling relationship between each set of variables.

Overall, as *A. piscivorus* increase in size, they gain disproportionately more muscle. These muscles are used to power striking behaviors and allow us to make predictions that larger snakes will generate higher forces during movements and likely display positive allometry in their striking performance as well.

References and Acknowledgments

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References

1. Herrel, A., Huyghe K., Oković P., Lisičić D., Tadić Z. 2011. Fast and Furious: Effects of Body Size on Strike Performance in an Arboreal Viper *Trimeresurus (Cryptelytrops) albolabris.* Journal of Experimental Zoology 315:22-19

2. Penning, D. A., Sawvel, B., & Moon, B. R. (2020). The scaling of terrestrial striking performance in western ratsnakes (*Pantherophis obsoletus*). *Journal of Experimental Zoology Part A: Ecological and Integrative Physiology*, *333*(2), 96-103.