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SURFACE-AREA-TO-VOLUME IS RELATED TO SEXUAL SIZE DIMORPHISM ACROSS *CENTROBOLUS* COOK, 1897

Author's Name: Mark I. Cooper

Affiliation: University Of Stellenbosch, South Africa.

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Abstract

In this paper I test for a relationship between sexual size dimorphism (SSD) and surface-area-to-volume ratios in red millipedes Centrobolus Cook, 1897. SSD was related to surface-area-to-volume ratios in males (r=-0.39, Z score=-1.80, n=22, p=0.036)(y = -0.13x + 0.26). SSD was related to surface- area-to-volume ratios in females (r=-0.53, Z score=-2.56, n=22, p<0.01)(y = -0.19x + 0.39). Volumes were related to surface-area to volume ratios when males and female data were pooled (r=-0.46, Z score=-3.20, n=44, p<0.01) (y = -0.16 x + 0.32).

Key words: *sexual size, dimorphism, red millipedes, male, female*

INTRODUCTION

The forest genus of diplopods belonging to the Order Spirobolida found along the eastern coast of southern Africa was the subject of this study. The millipede genus Centrobolus is found in the temperate South African subregion, its northern limits on the east coast of southern Africa being about -17° latitude S. It occurs in all the forests of the coastal belt from the Cape Peninsula to Beira in Mocambique. While the coastal forests of the South-West and Eastern Cape are mist belt temperate forests, those of the Transkei, Natal, Zululand and Mocambique are somewhat different, being better described as East Coast Bush, they are developed almost entirely in a narrow strip of the litoral on a dune sand substratum, and are more tropical in aspect and composition than those to the west of them. There is a summer rainfall of 762-1016mm, a uniform temperature, and an absence of frost; the component trees of the coastal bush with their abundant creepers and lianes, while not usually reaching a height of more than 11 meters, provide a dense covering with abundant shade and humidity at ground level. As essentially shade-loving Diplopoda, the members of the genus are especially well represented in these littoral forests of the eastern half of the subcontinent (Lawrence, 1967). Members of the genus all have polygynandrous mating systems with sperm competition and cryptic female choice (Cooper, 2016; Cooper, 2017; Cooper, 2019).

MATERIALS AND METHODS

Two morphometric parameters were used to obtain measurements, length and width, both of which were obtained from the published literature (Cooper, 2018; Cooper, 2019; Lawrence, 1967; Schubart, 1966). Surface areas were calculated based on the formula for the same cylinder SA = $2\pi r(r+h)$ in *C. anulatus* Attems, 1934, and *C. inscriptus* Attems, 1928 (Cooper, 2019). These were divided by volumes (Cooper, 2019). The data were collected during the rainy season because in southern Africa millipede surface activity is strongly seasonal and related to feeding and reproduction (Dangerfield & Telford, 1991; Dangerfield et al. 1993) and this is also when population densities peak (Dangerfield, 1989). The two species of millipedes were sampled in their indigenous tropical coastal forest habitat at Twin Streams Farm, Mtunzini, South Africa (28°55'S; 31 °45'E). It is within this part of the typical coastal forest belt (Acocks, 1975) that *C. anulatus* and *C. inscriptus* are in geographical sympatry. An area of forest with continuous tree canopy cover was delimited and all sampling occurred within those bounds. In the first season, two temporally

separate sampling efforts were made. In the following season a single sampling effort involved hand collecting all individual millipedes on the ground and in shrubs and trees separately, with the former measured on the ground and the latter as in the trees (>30cm but <3m above ground surface). The two species were morphologically separated based upon the presence of yellow flashes, red legs, and red heads (*C. inscriptus*) vs. discrete red-black annulations without yellow flashes, black legs, and blackheads (*C. anulatus*). Surface-area-to-volume ratios were tested against volumes for correlations at https://www.gigacalculator.com/calculators/correlation-coefficient-calculator.php.

RESULTS

SSD was related to surface-area-to-volume ratios in males (Figure 1: r=-0.39163242, Z score=-1.80339304, n=22, p=0.03566320)(y = -0.12592366 · x + 0.26088089). SSD was related to surface-area-to-volume ratios in females (Figure 2: r=-0.52735362, Z score=-2.55637294, n=22, p=0.00528851)(y = -0.19471847 · x + 0.38900207). Volumes were related to surface-area to volume ratios when males and female data were pooled (Figure 3: r=-0.46215720, Z score=-3.20188813, n=44, p=0.00068271) (y = -0.16032716 · x + 0.32497403).

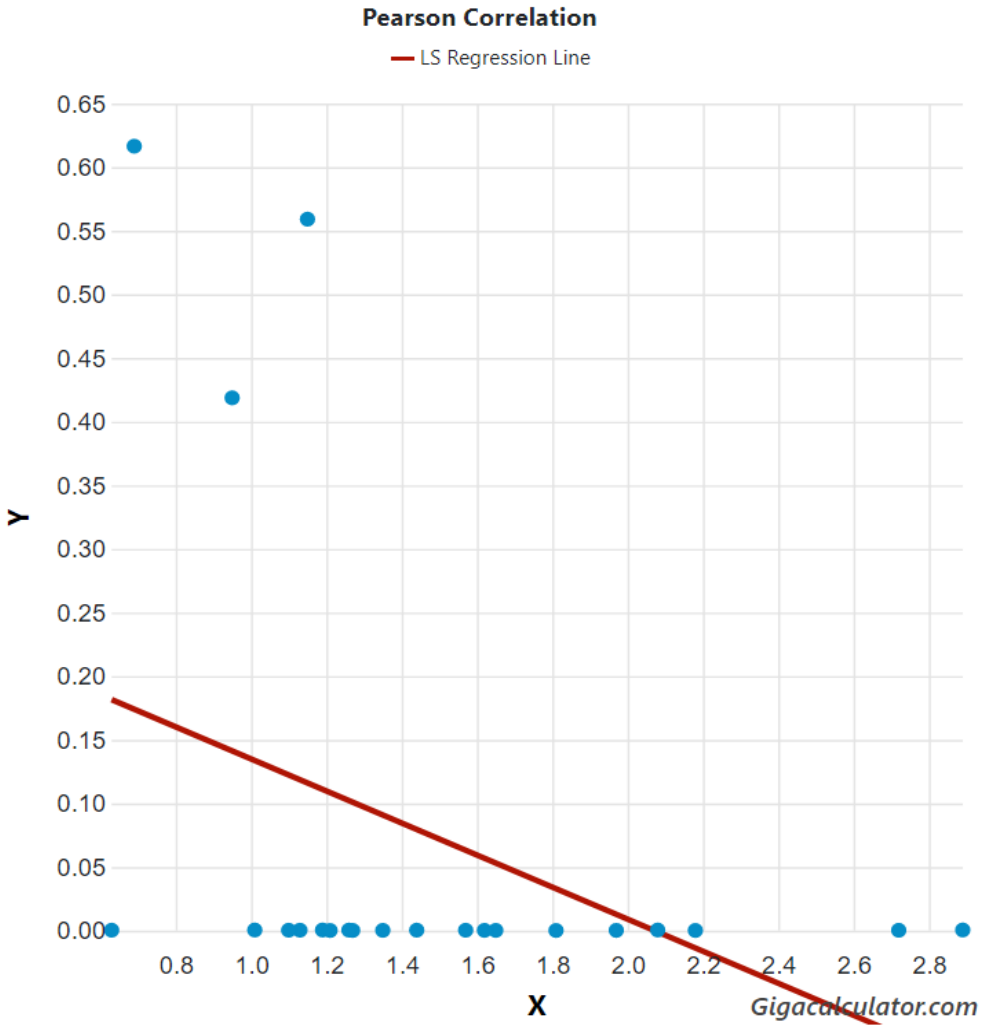

Figure 1. Relationship between SSD and surface-area-to-volume ratios in males in *Centrobolus* Cook, 1897.

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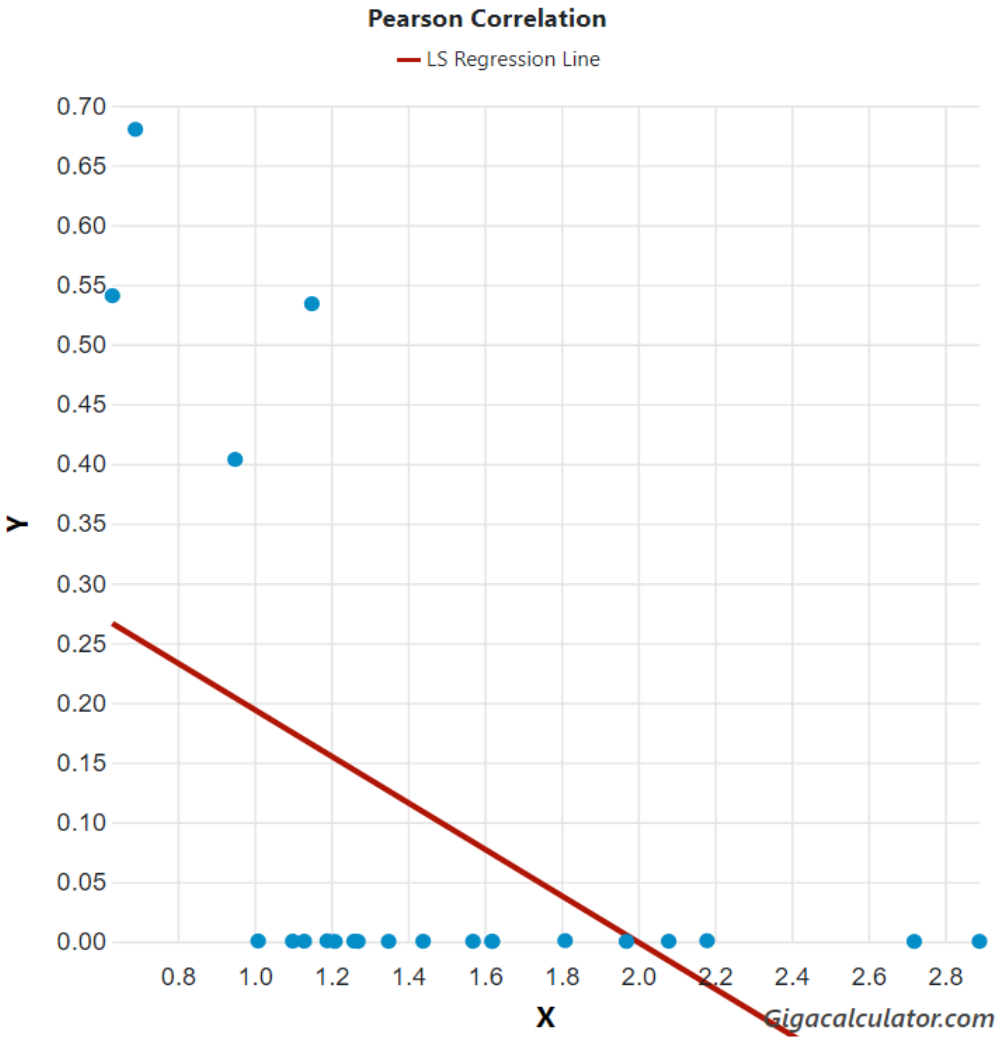

Figure 2. Relationship between SSD and surface-area-to-volume ratios in females in *Centrobolus* Cook, 1897.

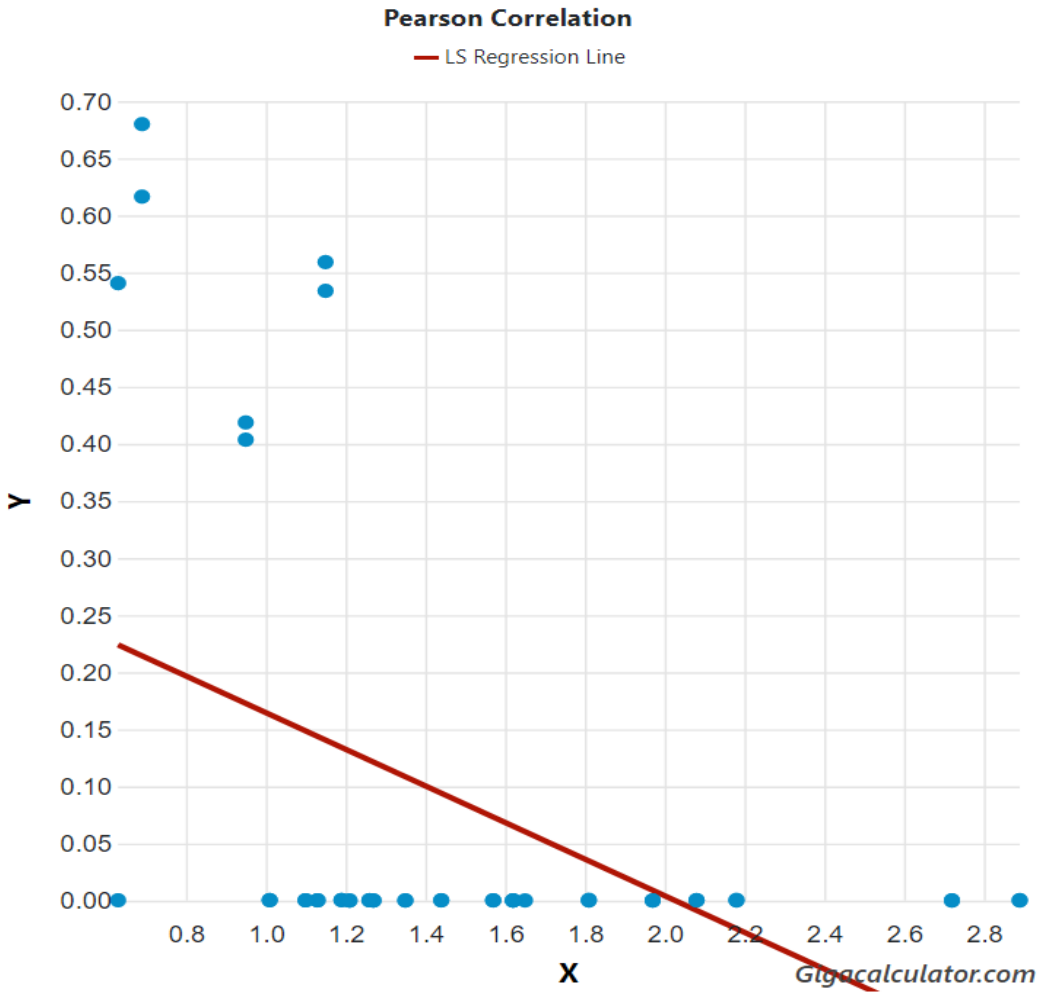

Figure 3. Relationship between SSD and surface-area-to-volume ratios in *Centrobolus* Cook, 1897.

DISCUSSION

New relationships between SSD and surface-area-to-volume ratios are documented here in both males and females in the genus of red millipedes *Centrobolus*. Four species showed above average surface-area-to-volume ratios; including *C. promontorius*, *C. richardii*, and *C. titanophilus* males as well as *C. decoratus*, *C. promontorius*, *C. richardii*, and *C. titanophilus* females.

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