Universe International Journal of Interdisciplinary Research
(Peer Reviewed Refereed Journal)

© UIJIR | ISSN (O) – 2582-6417
OCTOBER 2022 | Vol. 3 Issue 5
www.uijir.com

IS MASS CORRELATED WITH LENGTH AMONG RED MILLIPEDES *CENTROBOLUS* COOK, 1897?

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DOI No. – **08.2020-25662434**

Abstract

Body mass variation was correlated with male and female length in the red millipede genus Centrobolus. Mass and length (r=0.86, Z score=2.87, n=8, p<0.01) in males (r=0.97, Z score=2.99, n=5, p<0.01) and females (r=0.96, Z score=2.72, n=5, p<0.01) were correlated. C. inscriptus females have the largest length (67.4 mm) and the highest mass (2.61 g) while C. digrammus has the shortest length (49.9 mm) and the lightest mass (0.68 g). Because Sexual Size Dimorphism (SSD) was inversely correlated with mass, lighter individuals experienced greater competition which gave heavier individuals a competitive advantage.

Keywords: *Dimorphic; female; length; mass; morphology; ratio.*

INTRODUCTION

Red millipedes are found in the southern African subregion with northern limits on the east coast being about -17° latitude S and southern limits being -35° latitude S. They are well represented in the littoral forests of the eastern half of the subcontinent (Lawrence, 1967). It consists of taxonomically important species with 12 species considered threatened and includes nine vulnerable and three endangered species (Mailula, 2021). It occurs in all the forests of the coastal belt from the Cape Peninsula to Beira in Mocambique (Lawrence, 1967). In an analysis of four morphometric factors (male and female length and width), four positive correlations were found in the 22 species of *Centrobolus* (Cooper, 2022). Here, body mass is correlated with body length in *Centrobolus* Cook, 1897 (Cook, 1897; Hamer, 1998; Mailula, 2021). Like other millipedes, these worm-like millipedes have female-biased sexual size dimorphism (Cooper, 1998; 2014; 2015; 2016; 2017; 2018; 2019; 2021). One hypothesis is body length correlates with body mass. This may determine the fate of reproductive events (Cooper, 2016).

MATERIALS AND METHODS

Four valid species were identified as belonging to the genus *Centrobolus* Cook, 1897 (Table 1). Millipede collection localities were obtained from the Mating dynamics of South African forest millipedes *Centrobolus* (Diplopoda: Pachybolidae) (Cooper, 1998). Body mass was correlated with body width. Mean body mass was obtained by calculating the weight with a Mettler AC 100 Autobalance. Body length was measured by placing individuals alongside a plastic rule (mm) (Table 1). Body length and body mass were checked for correlations using the Pearson Correlation Coefficient calculator (https://www.gigacalculator.com/calculators/correlation-coefficient-calculator.php).

RESULTS

Body mass and length (Fig. 1: r=0.93760869, Z score=4.54511480, n=10, p=0.00000275) in males (Fig. 2: r=0.97112526, Z score=2.98638973, n=5, p=0.00141153) and females (Fig. 3: r=0.95830497, Z score=2.72197404, n=5, p=0.00324471) were related. Body length was normally

distributed (D=0.21722, n=10, p=0.65755). Body mass was normally distributed (D=0.23289, n=10, p=0.57311). Female length was normally distributed (D=0.36888, n=5, p=0.40287). Male length was normally distributed (D=0.26334, n=5, p=0.80102). Male mass was normally distributed (D=25851, n=5, p=0.81732). Body mass was normally distributed (D=0.23289, n=10, p=0.57311). Female mass was normally distributed (D=0.29699, n=5, p=0.67584).

Table 1. Species in the millipede genus Centrobolus Cook, 1897, with body length and body mass. Male followed by female body masses are given with sample sizes in parentheses. Two sets of measurements are included for C. inscriptus.

Species	length	Location	Body mass (g)
C. fulgidus	56.2 (11) 63.5 (11)	Richards Bay	1.29 (11), 1.97 (11)
C. inscriptus	67.4 (88) 67.0 (56) 63.0 (88) 65.0 (41)	Mtunzini	2.48 (88), 2.00 (56); 2.27 (88), 2.61 (41)
C. ruber	57.8 (18) 62.3 (18)	Port Shepstone	1.28 (18), 2.00 (18)
C. digrammus	49.9 (6) 54.5 (6)	Admirals Waterfall	0.68 (6) 1.02 (6)

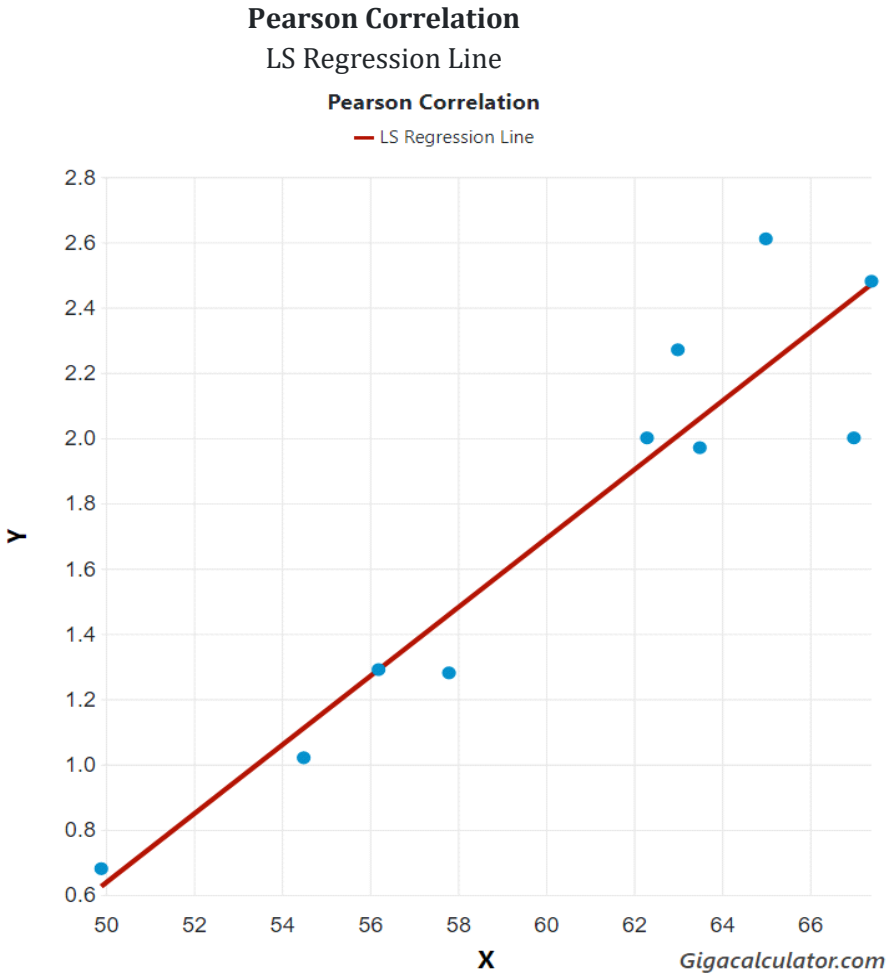

Figure 1. Relationship between body length (x-axis) and body mass (y-axis) in *Centrobolus* Cook, 1897.

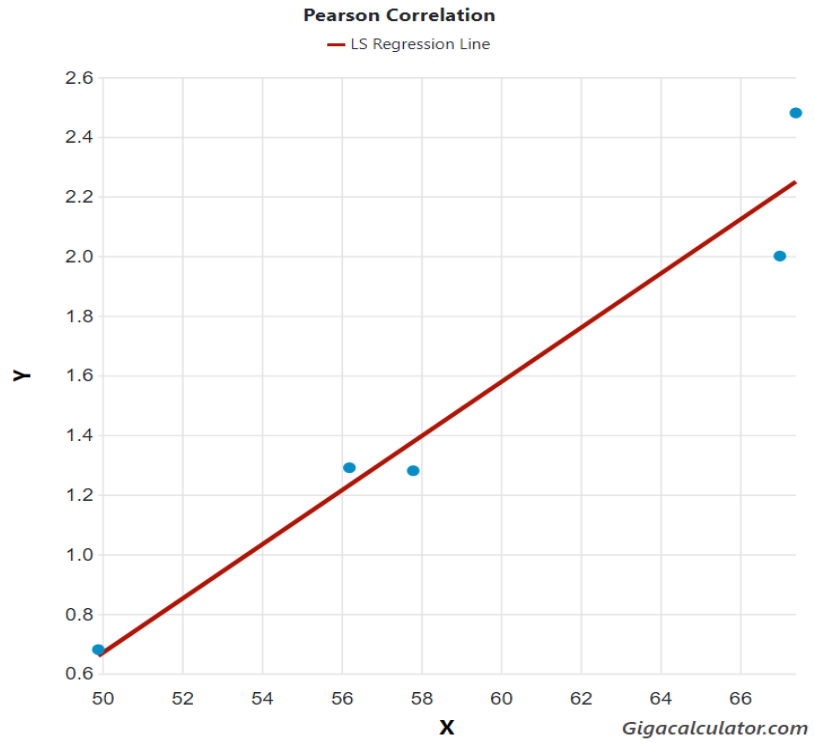

Figure 2. Relationship between male body length (x-axis) and male body mass (y-axis) in *Centrobolus* Cook, 1897.

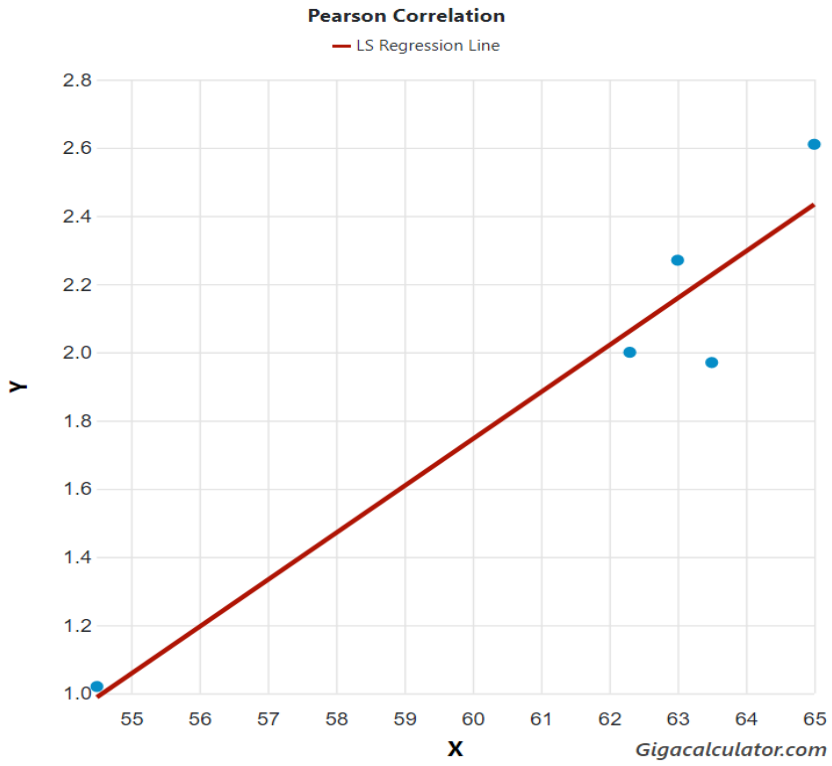

Figure 3. Relationship between female body length (x-axis) and female body mass (y-axis) in *Centrobolus* Cook, 1897.

DISCUSSION

A significant positive relationship between mass and length was found. *C. inscriptus* females have the largest length (67.4 mm), and the highest mass (2.61 g) while *C. digrammus* has the shortest length (49.9 mm), and the lightest mass (0.68 g). This study supports body mass and body length as predictable in *Centrobolus*.

Size-assortative mating based on body mass and body length determine the variance in millipede polygynandrous mating systems across a size gradient with lower body length occurring in lighter individuals. Body length increases with heavier body mass which is explained by a combination of copulatory guarding and fecundity selection. Because SSD is inversely correlated with mass, lighter individuals experience greater competition which gives heavier individuals a competitive advantage.

In Danish red foxes *Vulpes vuples* SSD varies with body mass at different population densities (Pagh et al. 2018). In the wandering albatross *Diomedea exulans* SSD varies with body mass with different adult survival, breeding probability, breeding success, chick mass, and juvenile survival (Cornioley et al. 2017). In microtines mass rather than length is used to measure SSD (Boonstra et al. 1993). In five species of *Drosphila,* the degree of dimorphism in development time was significantly correlated with dry weight and fecundity, with lighter species tending to be more dimorphic for development time as well as more fecund, both in absolute terms and terms of fecundity per unit weight (Bharathi et al. 2004). In Red-Eared Sliders *Trachemys scripta elegans* sexual dimorphism of size in favor of females is maintained for variables related to mass and size (Gradela et al. 2017). Millipedes resemble the patterns of mass and sexual dimorphism in adult dragonflies (Anholt et al. 2011). Sexual dimorphism in mass and protein content of the forelimb muscles is known in the northern leopard frog *Rana pipiens* (Blackburn, 1992). The influence of mass and mating systems has been documented in the most dimorphic mammals (Weckerly, 1998). Morphological variance in the polygynandrous reproductive system of male and female millipedes means lighter individuals have lower body width or heavier individuals have greater body width pointing toward the evolution of condition-dependent SSD (Bonduriansky, 2007).

CONCLUSION

Length varied systematically with mass in *Centrobolus*. Morphological variance in the polygynandrous reproductive systems of *Centrobolus* has lighter individuals with shorter body length, or conversely heavier individuals have greater body length. Mass (not length) impacts the moments of inertia.

COMPETING INTERESTS

The author has declared that no competing interests exist.

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