Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
www.entomoljournal.com
JEZS 2021; 9(6): 190-192

Received: 16-09-2021
Accepted: 18-10-2021

Mark Cooper
School of Animal, Plant & Environmental Sciences, University of the Witwatersrand, Johannesburg 2050, South Africa

Corresponding Author:
Mark Cooper
School of Animal, Plant & Environmental Sciences, University of the Witwatersrand, Johannesburg 2050, South Africa

Mass covaries with volume in forest millipedes *Centrobolus* Cook, 1897

Mark Cooper

Abstract
The size of Juliformia has two main components, body diameter and the number of rings. Other components include mass and volume. Mean male and female mass (g) and volume (mm^3) were recorded in four species of *Centrobolus* and tested for correlations with volume. *Centrobolus* range in mass from *C. ruber* males (1.28g) to *C. inscriptus* females (2.61g). Adult body volumes (1,774.75±425.146mm^3) were positively correlated to mass (1.99±0.49g) (r=0.92, Z score=3.52, n=8, 8, p<0.01). Correlates of Juliform size include copulations duration, diet, the energetic cost of copulation, oxygen consumption, precipitation, sexual size dimorphism, temperature, and urbanization.

Keywords: *Centrobolus*, Juliformia, mass, Spirobolida, volume

Introduction
Diplopoda is an important environmental indicator and somewhat under-represented in analyses of invertebrate size. Sexual size dimorphism (SSD) is the condition where the two sexes of the same species exhibit different characteristics beyond the differences in their sexual organs, although common sexual differences are thought to occur in body mass, length, width and leg dimensions of over half the taxa studied [6-21]. Diplopods resemble the majority of invertebrates in SSD is mostly reversed [5]. Heavier-shorter-wider females are under a type of fecundity selection [3]. Larger males have increased reproductive success through a female preference for the larger size when there is size assortative mating behavior [19]. Mass can be a useful standard in millipedes and mass measurements are known for at least 15 taxa [1, 2-4, 13-21]. Millipedes (*Centrobolus fulgidus*, *Centrobolus richardii*, and *Spinotarsus* sp.) influence selected soil elements but the results of these millipede studies have illustrated no major species and sex-specific differences [18]. Here it is hypothesized and appears in *Centrobolus* spp. the mass correlates to volume. The particular sexual selection is thought to be a female preference for larger male size which operates when there are size-assortative mating behaviors. In the present study, mass in the genus *Centrobolus* was investigated in four available examples and mass volume correlation was analyzed. I wished to establish whether larger species were both voluminous and heavier. The null hypothesis states there was no correlation between millipede mass and volume.

Materials and Methods
Mean male and female mass (g) was recorded in males and females of four species of *Centrobolus* using a Mettler AC 100 Auto balance. Body volumes were calculated using the formula for a cylinder based on length (mm) and horizontal tergite width (mm) measurements. The length was measured by holding millipedes alongside a plastic rule calibrated in millimeters. Horizontal tergite width was measured with vernier calipers. These are made available here (Table 1). Body volume was obtained by calculating the cylindrical volumes using the lengths and widths of species which were inputted into the formula for a cylinder's volume (https://byjus.com/volume-of-a-cylinder-calculator). Body mass and volume were tested for normality using a Kolmogorov-Smirnov Test for Normality (https://www.socscistatistics.com/tests/kolmogorov/default.aspx). Covariation between mass and volume was calculated and plotted (https://www.gigacalculator.com/calculators/correlation-coefficient-calculator.php)

Table 1: Mass and volume measurements were used for correlations in *Centrobolus* Cook, 1897.

Species and sex	Mass (g)	Volume (mm^3)
C. inscriptus male	2.48	1841
C. inscriptus male	2.00	1841
C. fulgidus male	1.29	1147
C. ruber male	1.28	1141
C. inscriptus female	2.27	2245
C. inscriptus female	2.61	2245
C. fulgidus female	1.97	1888
C. ruber female	2.00	1850

Results

Mean body mass in *Centrobolus* was 1.9875 ± 0.4925 g. Mean body volume was 1,774.75 ± 425.1463 mm^3. Mean body volumes were positively correlated to adult mass (Figure 1: Spearman's r=0.71686747, Z score=1.95721788, n=8,8, p=0.02516086; Figure 2: Pearson's r=0.91751498, Z score=3.51752352, n=8, 8, p=0.00021784; Figure 3: Kendall's τ=0.59259259, Z score= 2.13769234, n=8, 8, p=0.01627080). Mass was normally distributed (D=0.23485, n=8, p=0.68701). Body volume was normally distributed (D=0.31615, n=8, p=0.32843). Sample covariance was 192.03214286. Population covariance was 168.028125. Male mass correlated to male volume (r=0.94226170, Z score=1.75784385, n=4, 4, p=0.039387) and female mass correlated to female volume (r=0.87822887, Z score=1.36797062, n=4, 4, p=0.08566069). There was no difference between the correlation coefficients of males and females (z=0.2757, n=4, 4, p=0.7828).

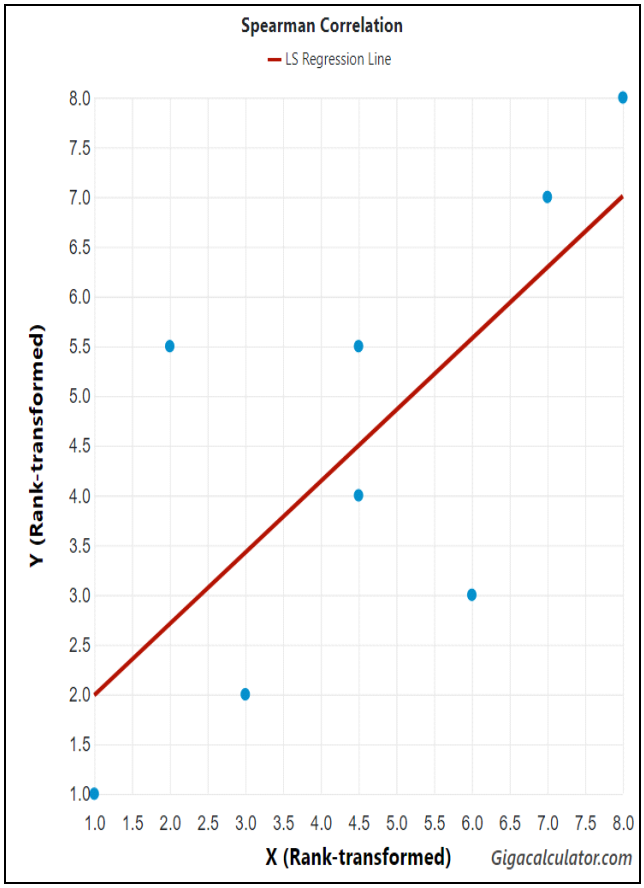

Fig 1: Spearman's correlation between volume (y-value: millimeters cubed) and mass (x-value: grams) in *Centrobolus.*

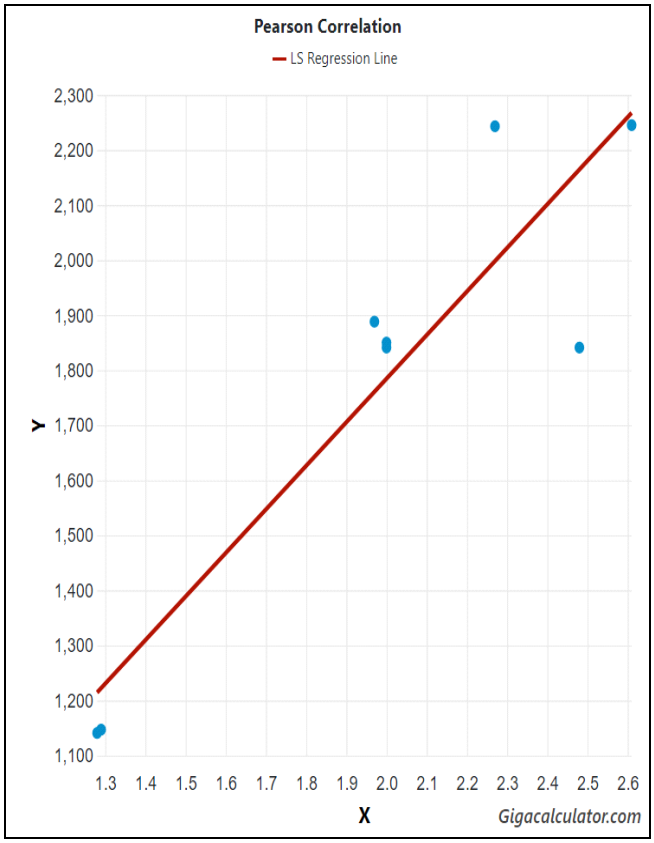

Fig 2: Pearson's correlation between volume (y-value: millimeters cubed) and mass (x-value: grams) in *Centrobolus.*

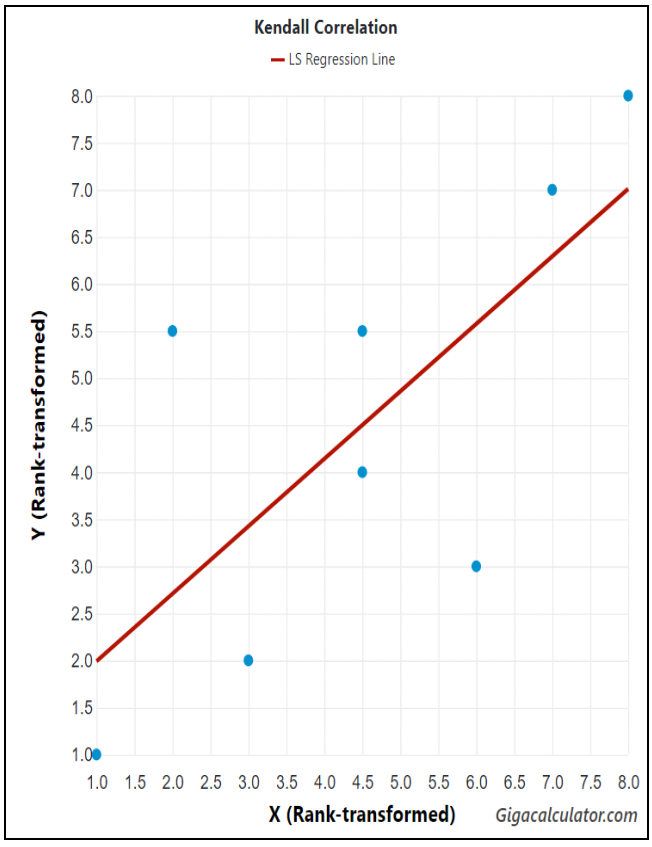

Fig 3. Kendall correlation between volume (y-value: millimetres cubed) and mass (x-value: grams) in *Centrobolus.*

Discussion

Mass is a useful size criterion for determining millipede volume and *vice versa*. All three correlation methods (Spearman, Pearson's, and Kendall) show a correlation between mass and volume with a 95% confidence interval. This means variation in body mass sufficiently explains the variation in body volumes and *vice versa*. The mass statistics of four species of *Centrobolus* were presented falsifying the null hypothesis *i. e.* showing mass correlated with volume and finding species-specific standards. The finding extends upon studies that show the size of Juliformia has two main components, body diameter and the number of rings, and provides new information on millipede mass and volume [12]. Correlates of Juliform size include copulations duration, diet, the energetic cost of copulation, oxygen consumption, precipitation, sexual size dimorphism, and temperature [1, 3-4, 10, 11, 18].

Conclusion

In *Centrobolus* spp. variation in body mass sufficiently explains the variation in body volumes and *vice versa*.

References

1. Adolph SC, Geber MA. Mate-Guarding, Mating Success and Body Size in the Tropical Millipede 'Nyssodesmus Pythos' (Peters) Polydesmida: Platyrhacidae). The Southwestern Naturalist. 1995;40(1):56-61.
2. Brygadyrenko V, Ivanyshyn V. Changes in the body mass of *Megaphyllum kievense* (Diplopoda, Julidae) and the granulometric composition of leaf litter subject to different concentrations of copper. Journal of Forest Science. 2015;61(9):369-376.
3. Cooper MI. Allometry of copulation in worm-like millipedes. Journal of Entomology and Zoology Studies. 2017;5(3):1720-1722.
4. Cooper MI. Heavier-shorter-wider females in the millipede *Centrobolus inscriptus* (Attems). Journal of Entomology and Zoology Studies. 2016;4(2):509-510. Zoology Studies. 2017;5(3):1264-1266.
5. Cooper M. *Centrobolus anulatus* reversed sexual size dimorphism. Journal of Entomology and Zoology Studies. 2018;6(4):1569-1572.
6. Cooper MI. Lawrence's red millipede *Centrobolus lawrencei* shows length-based variability and size dimorphism. Journal of Entomology and Zoology Studies. 2019;7(2):1037-1039.
7. Cooper M. *Centrobolus titanophilus* size dimorphism shows width-based variability. Arthropods. 2019;8(2):80-86.
8. David JF. Size criteria for the distinction between *Cylindroiulus londinensis* (Leach) and *Cylindroiulus caeruleocinctus* (Wood) (Diplopoda: Julidae), Journal of Natural History. 1995;29(4):983-991.
9. David JF, Gillon D. Annual feeding rate of the millipede *Glomeris marginata* on holm oak (*Quercus ilex*) leaf litter under Mediterranean conditions. Pedobiologica. 2002;46(1):45-52.
10. Dwarakanath SK. The influence of body size and temperature upon the oxygen consumption in the millipede, *Spirostreptus asthenes* (Pocock). Comparative Biochemistry and Physiology Part A: Physiology. 1971;38(2):351-358.
11. Echeverría KS, Ignacio C, Bueno-Villegas J. Relationship between millipede body size (Polydesmida: Xystodemidae: Rhysodesmus) and altitude, latitude, precipitation and temperature. 16th International Conference of Myriapodology. 2014.
12. Enghoff H. The Size of a Millipede. Berichte der naturhistorisch-medizinischen Vereins Innsbruck, Supplement. 1992, 10.
13. Ilić BS, Mitić BM, Makarov SE. Sexual dimorphism in *Apfelbeckia insculpta* (L. Koch, 1867) (Myriapoda: Diplopoda: Callipodida). Archives of Biological Sciences. 2017;69:23-33.
14. Ilić BS, Vujić VD, Javonovic Z, Pavković-Lučić SB, Dudić BD, Lucić LR *et al*. Sexual dimorphism in some morphological traits of three European millipedes (Diplopoda, Julida, Julidae). Animal Biology. DOI: 10.1163/15707563-20191113
15. Javonovic Z, Pavković-Lučić S, Ilić B, Vujić V, Dudić B, Makarov S *et al*. Mating behaviour and its relationship with morphological features in the millipede *Pachyiulus hungaricus* (Karsch, 1881) (Myriapoda, Diplopoda, Julida). Turkish Journal of Zoology. 2017;41:1010-1023.
16. Penteado CHS, Hebling-Beraldo MJA, Mendes EG. Oxygen consumption related to size and sex in the tropical millipede *Pseudonannolene tricolor* (Diplopoda, Spirostreptida), Comparative Biochemistry and Physiology Part A: Physiology. 1991;98(2):265-269.
17. Rowe M. Copulation, mating system and sexual dimorphism in an Australian millipede, *Cladethosoma clarum*. Australian Journal of Zoology. 2010;58(2):127-132.
18. Smit AM, van Aarde RJ. The influence of millipedes on selected soil elements: a microcosm study on three species occurring on coastal sand dunes. Functional Ecology. 2001;15(1):51-59.
19. Telford SR, Dangerfield JM. Mating behaviour and mate choice experiments in some tropical millipedes (Diplopoda: Spirostreptidae). South African Journal of Zoology. 1993;28(3):155-160.
20. Telford SR, Webb PI. The energetic cost of copulation in a polygynandrous millipede. Journal of Experimental Biology. 1998;201(11):1847-1849.
21. Vujić V, Ilić B, Jovanović Z, Pavković-Lučić S, Selaković S, Tomić V *et al*. Sexual behaviour and morphological variation in the millipede *Megaphyllum bosniense* (Verhoeff, 1897). Contributions to Zoology 2018;87(3):133-148.