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Centrobolus sagatinus sexual size dimorphism based on differences in horizontal tergite widths

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Abstract
The forest genus *Centrobolus* of millipedes belonging to the Order Spirobolida is distributed along the eastern coast of southern Africa. Sexual size dimorphism (SSD) can be explained by mate-guarding in the form of prolonged copulation and fecundity selection. Width and length were analysed in *Centrobolus* to derive SSD in 21 species. The size of *C. sagatinus* collected in South Africa was calculated as 48, 33333 X 6,64444mm (n=9) according to the formula for a cylinder. Males measured 48,5 ± 1,732051 X 6,225 ± 0,170783 mm (μ ± σ; n=4) and females 48,2 ± 4,636809 X 6,98 ± 0,248998 mm (μ ± σ; n=5). An analysis from data presently available showed average SSD for *C. sagatinus* was 1,009222, differing from 1 (t=-2, 645751; p=0,033146; *p*≤0, 05; n=4). *C. sagatinus* dimorphism was based on a 0, 75 ± 0, 25 mm difference in horizontal tergite width (t=-1.91326; p=0.036891; n=9). This sexual dimorphism resembles *C. inscriptus* female width which is positively related to copulation duration and larger females are more fecund.

Keywords: *C. sagatinus*, horizontal tergite width

1. Introduction
Size differences of diplopods correlate with factors such as color, sexes, species, urbanisation and water relations [1, 4]. SSD has consequences for outcomes of sexual encounters in diplopod mating [5, 15, 18]. The allometry of SSD involves the detection of a relationship between body size and SSD and is known as Rensch's rule which may be explained as sexual selection and fecundity selection [7, 12]. This allometric rule predicts SSD is negatively correlated with body size [8, 17, 20]. The forest genus of millipedes belonging to the Order Spirobolida found along the eastern coast of southern Africa was the subject of this study [11]. Length and width data are known in 21 species (*Centrobolus albitarsus, C. anulatus, C. decoratus, C. digrammus, C. dubius, C. fulgidus, C. immaculatus, C. inscriptus, C. inyanganus, C. lawrencei, C. lugubris, C. promontorius, C. pusillus, C. ruber, C. rugulosus, C. sagatinus, C. silvanus, C. titanophilus, C. transvaalicus, C. tricolor*, and *C. vastus*). The revision of the genus *Centrobolus* (Cook, 1897) was part of this data [9-11, 16]. SSD in these forest millipedes have been understood as size measurements using *Centrobolus* to test body side relationships and the trend of SSD has been calculated for *Centrobolus* [4]. The present study re-illustrates the trend of SSD for the genus *Centrobolus* and shows the sizes of *C. sagatinus* relative to 20 of congenerics in order to express how species do not follow the trend of Rensch's rule [3].

2. Materials and methods
Two factors were measured from *Centrobolus sagatinus*: (1) body length (mm), and (2) horizontal tergite width (mm). *C. sagatinus* (Schubart) were collected between Addo and Uitenhage in the Eastern Cape, South Africa. SSD was re-calculated based on the measurements for 21 species in the genus *Centrobolus* [3, 6].

2.3 Statistical Analysis
The basic descriptive figures including body length and horizontal tergite width were inserted into the formula for a cylinder. The average and standard deviation of width was obtained for 9 individuals of *C. sagatinus*. Size was based on the formula for a cylinder ($h.\pi.r^2$) where h is body length and r half of the width. SSD was estimated as the average female size divided by average male size and converted into a SSD index. Allometry for SSD was based on an allometric model where male size = α (female) $^{\beta}$. A linear regression was performed in order to test the relationship between sexual sizes at http://www.socscistatistics.com. Correlation

Coefficients were compared at http://vassarstats.net/rdiff.html.
SSD was compared to 1 using a t-test for 2 dependent means at http://www.socscistatistics.com/tests/studentttest/Default2.aspx.

3. Results

Sizes were estimated in the following 21 taxa: *Centrobolus albitarsus*, *C. anulatus*, *C. decoratus*, *C. digrammus*, *C. dubius*, *C. fulgidus*, *C. immaculatus*, *C. inscriptus*, *C. inyanganus*, *C. lawrencei*, *C. lugubris*, *C. promontorius*, *C. pusillus*, *C. ruber*, *C. rugulosus*, *C. sagatinus*, *C. silvanus*, *C. titanophilus*, *C. transvaalicus*, *C. tricolor*, and *C. vastus*. SSD is shown in figure 1. For the data, the regression equation for *Y* was: $\hat{y} = 0.41324X + 356.35007$. The quantitative resolution of the allometric rule for *Centrobolus* species together with the relative estimated position of *C. sagatinus* is shown in Figures 1-2. The average size of *C. sagatinus* was 48.33333 X 6.64444 mm (n=9); males measured 48,5±1,732051 X 6,225 ± 0,170783 mm (μ ± σ; n=4) and females 48,2 ± 4,636809 X 6,98 ± 0,248998 mm (μ ± σ; n=5). Log measurements were (females/x = 2.451956 mm^3; males/y = 2.429551 mm^3). The mean size ratio for *C. sagatinus* was 1,009222. There was a correlation between the log values for male and female sizes. The value of R was 0.83333 and the two-tailed value of P is 0.01018. In normal standards, the association between the two variables is statistically significant. The difference between the correlation coefficients for the species and the genus is not significant ($r_a = 0.83333$, $r_b = 0.834687$; $n_a = 8$, $n_b = 21$; Z = 0.46; P (one-tailed) = 0.496 (two-tailed) = 0.992). SSD is significantly different from 1 (t=-2.645751; p=0.033146; $p \leq 0.05$; n=4).

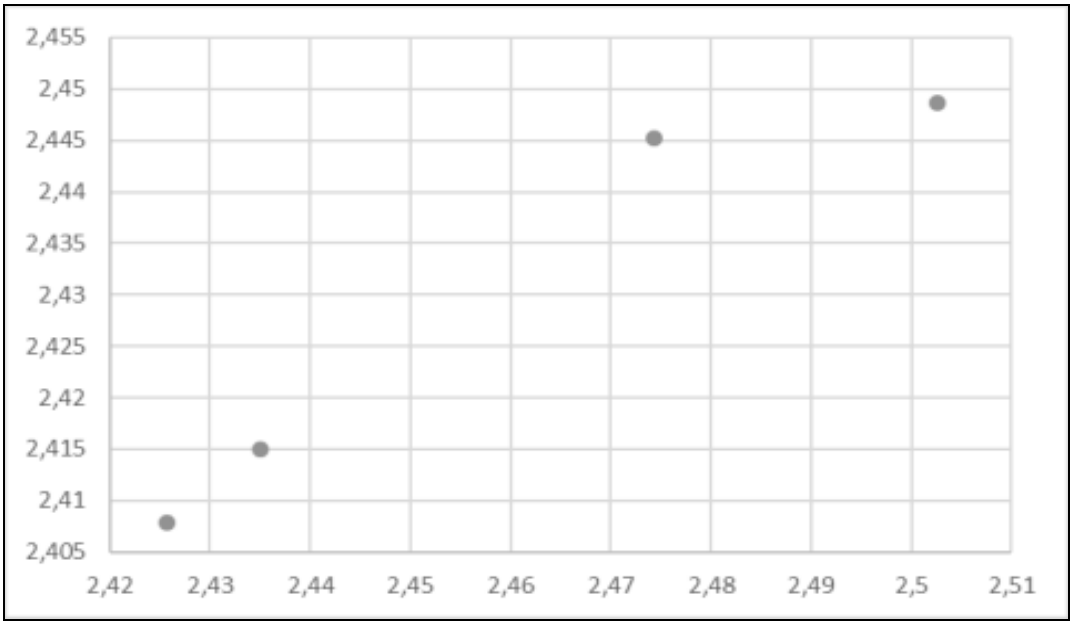

Fig. 1: Allometry for sexual size dimorphism (SSD) in *Centrobolus sagatinus* based on the allometric model male size = α (female size) $^{\beta}$; correlation coefficient, r = 0.83333.

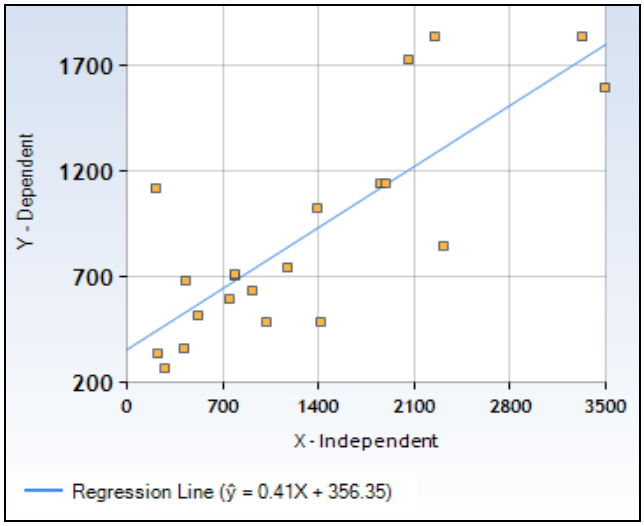

Fig. 2: Sexual size dimorphism for 21 species of millipedes of the genus *Centrobolus* where allometry for sexual size dimorphism (SSD) was based on the allometric model male size = α (female size) $^{\beta}$; correlation coefficient, r = 0.855126. X – Independent female; Y – Dependent male.

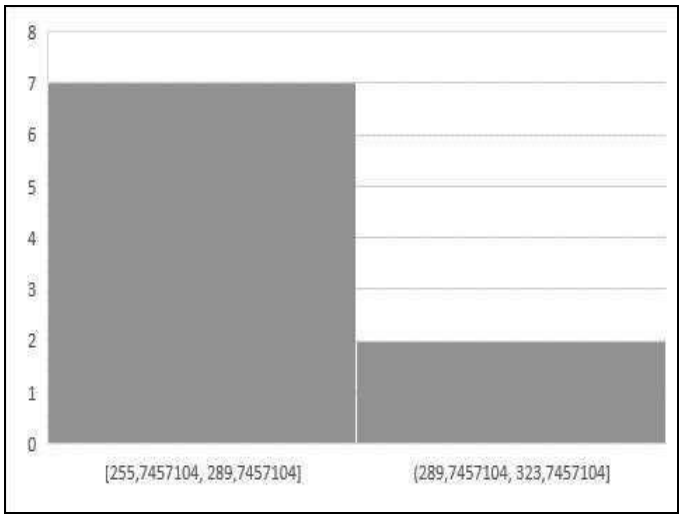

Fig. 3: Distribution frequency histogram for male and female sizes of *Centrobolus sagatinus* showing the majority of specimens were low-sizes.

4. Discussion

Centrobolus species based on tergite width are clearly recognisable [3-6]. Because SSD was significantly different from 1 in the species, the average size ratio of 1.009222 for *C. sagatinus* indicates dimorphism. The positive relationship between female and male body sizes in this genus of millipedes is the exception to Rensch's rule [8, 17, 20]. Studies on SSD in other invertebrates have a positive correlation [19]. Figure 1 shows the finding for *C. sagatinus* where the regression of log male size on log female size was significant with a positive slope of 0.83333 showing females get larger than males with an increase in body size.

The analysis presented here shows SSD based on the horizontal tergite width and size may be a primary determinant in mating because the radius of a cylinder can be more powerful in attempts to increase size which is similar to the millipede *Doratogonus uncinatus* where female choice for mating partners is "size selective [18]." Sexual dimorphism resembles *C. inscriptus* female width which is positively related to copulation duration and larger females are probably more fecund [21]. Sexual dimorphism in *Apfelbeckia insculpta* showed female-biased SSD with longer and wider females [22]. On the basis of the findings in *C. sagatinus* I suggest width is the primary factor and length secondary in achieving size differences.

5. Conclusion

C. sagatinus [16] shows sexual size dimorphism with small males and larger females based on the finding of differences in horizontal tergite width. Sexual dimorphism resembles *C. inscriptus* female width which is positively related to copulation duration and larger females are probably more fecund.

6. References

1. Akkari N, Enghoff H. Copulatory-copulatory male succession and male slenderness in *Ommatoiulus sempervirilis* n. sp., a new insular millipede from Tunisia (Diplopoda: Julida: Julidae). Journal of Zoological Systematics and Evolutionary Research. 2011; 49:285-291.
2. Akkari N, Enghoff H, Metscher BD. A New Dimension in Documenting New Species: High Detail Imaging for Myriapod Taxonomy and First 3D Cybertype of a New Millipede Species (Diplopoda, Julida, Julidae). PLoS ONE 2015; 10:0135243.
3. Cooper MI. Sexual size dimorphism and corroboration of Rensch's rule in *Chersastus* millipedes (Diplopoda: Pachybolidae). Journal of Entomology and Zoology Studies. 2014; 2(6):264-266.
4. Cooper MI. Sexual bimaturism in the millipede *Centrobolus inscriptus* (Attems). Journal of Entomology and Zoology Studies. 2016; 4(3):86-87.
5. Cooper MI. Sexual conflict over the duration of copulation in *Centrobolus inscriptus* (Attems). Journal of Entomology and Zoology Studies. 2016; 4(6):852-854.
6. Cooper M. *Centrobolus anulatus* (Attems, 1934) reversed sexual size dimorphism. Journal of Entomology and Zoology Studies. 2018; 6(4):1569-1572.
7. Dale J, Dunn PO, Figuerola J, Lislevand T, Székely T, Whittingham LA. Sexual selection explains Rensch's rule of allometry for sexual size dimorphism. Proceedings of the Royal Society B. 2007; 274: 2971-2979.
8. Faiman R, Abergil D, Babocsay G, Razzetti E, Seligman H, Werner YL. A review of sexual dimorphism of eye size in Colubroidea snakes. Vertebrate Biology; 2018 68:91-108.
9. Hamer ML. Checklist of Southern African millipedes. Annals of the Natal Museum. 1998; 39:11-82.
10. Hoffman RL. A note on the status of the name *Centrobolus* Cook, 1897 Spirobolida, Pachybolidae. Myriapodologica. 2001; 7:49-52.
11. Lawrence RF. The Spiroboloidea (Diplopoda) of the eastern half of southern Africa. Annals of the Natal Museum. 1967; 18:607-646.
12. Mori E, Mazza G, Lovari S. Sexual Dimorphism. In: Vonk J, and Shakelford T (ed.) Encyclopedia of Animal Cognition and Behavior. Switzerland: Springer International Publishing, 2017, 1-7.
13. Mwabvu T, Lamb J, Slotow R, Hamer M, Barraclough D. Is millipede taxonomy based on gonopod morphology too inclusive? Observations on genetic variation and cryptic speciation in *Bicoxidens flavicollis* (Diplopoda: Spirostreptida: Spirostreptidae). African Invertebrates. 2013; 54:349-356.
14. Pincheira-Donoso D, Hunt J. Fecundity selection theory: concepts and evidence. Biological Reviews. 2015; 92:341-356.
15. Rowe M. Copulation, mating system and sexual dimorphism in an Australian millipede, *Cladethosoma clarum.* Australian Journal of Zoology. 2010; 58:127-132.
16. Schubart O. Diplopoda III. Psephalognatha, Opisthospermomorpha, Colobognatha. South African Animal Life. 1966; 12:7-227.
17. Seifan M, Gilad A, Klass K, Werner YL. Ontogenetically stable dimorphism in a lacertid Lizard (*Acanthodactylus boskianus*) with tests of methodology and comments on life-history. Biological Journal of the Linnean Society. 2009; 97:275–288.
18. Telford SR, Dangerfield JM. Mating Tactics in the Tropical Millipede *Alloporus uncinatus* (Diplopoda: Spirostreptidae). Behaviour. 1993; 124:45-56.
19. Webb TJ, Freckleton RP. Only Half Right: Species with Female-Biased Sexual Size Dimorphism Consistently Break Rensch's Rule. PLoS ONE. 2007; 2:897.
20. Werner YL, Korolker N, Sion G, Göçmen B. Bergmann's and Rensch's rules and the spur-thighed tortoise (*Testudo graeca*). Biological Journal of the Linnean Society. 2016; 117:796–811.
21. Cooper MI. The affect of female body width on copulation duration in *Centrobolus inscriptus*. Journal of Entomology and Zoology Studies. 2017; 5(1):732-733.
22. Ilić BS, Mitić BM, Makarov SE. Sexual dimorphism in *Apfelbeckia insculpta* (L. Koch, 1867) (Myriapoda: Diplopoda: Callipodida). Archives of Biological Sciences. 2017; 69(1):23-33.