Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2018; 6(6): 284-286

Received: 18-09-2018
Accepted: 19-10-2018

Mark Cooper
City of Johannesburg,
Johannesburg, South Africa

Correspondence
Mark Cooper
City of Johannesbrg,
Johannesburg, South Africa

Allometry in *Centrobolus*

Mark Cooper

Abstract
Sexual size dimorphism (SSD) was investigated in the forest genus *Centrobolus* of millipedes belonging to the Order Spirobolida distributed along the eastern coast of southern Africa. The specific status of 21 *Centrobolus* (Table 1) were categorised using size measurements based on width and length data. I suggest width is the primary factor and length secondary in achieving larger size differences.

Keywords: Category, measure, millipede, Spirobolida

1. Introduction
Concepts and current dimensions in the identification of millipede species include detail-imaging of gonopod structure [2]. Detail of the gonopods has been considered too inclusive and an alternative way for identification of species is suggested in support of biodiversity inventories and specific states [14]. For these reasons I further another approach affiliated with the geometric morphometrics and classical morphometrics which is presented to determine the size of species. SSD is prevalent in arthropods and *Centrobolus* millipedes exemplify reversed SSD as females are larger than males [3, 5]. Diplopoda allometric analyses of SSD are known in body mass, length, width and leg dimensions of over half the taxa studied [4-7]. Size differences correlate with factors such as color, sexes, species, urbanisation and water relations [1, 5]. SSD has consequences for outcomes of sexual encounters in diplopod mating [6, 16]. The allometry of SSD involves the detection of a relationship between body size and SSD and is known as a Rensch's rule. Rensch's rule may be explained as sexual selection and fecundity selection [8, 13]. The macro-evolutionary pattern is being resolved in Diplopoda. Here, Rensch's rule was tested, predicting SSD was not negatively correlated with diplopod body size in African forest and savanna taxa. The forest genus of millipedes belonging to the Order Spirobolida found along the eastern coast of southern Africa was the subject of this study [12].
Morphometric data in the form of length and width measurements is 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) is considered a *desideratum* after 39 species were recognised [10-11]. In steps towards a complete revision of the genus I present size measurements of these 21 species. SSD in forest millipedes have successfully been understood as size measurements using *Centrobolus* to test this rule. The trend of SSD has been calculated for *Centrobolus* and bimaturism shown [5]. The present study was aimed to illustrate the trend of SSD for the genus *Centrobolus* and estimate the size of *C. sagatinus* relative to 20 of congenerics in order to determine if the species followed the trend of a rule [3].

2. Materials and methods
21 species of *Centrobolus* were identified based on length and width alone. To sets of linear measurements were made from combinations of live specimens and museum specimens [3, 7]. The sizes for each species were obtained from the literature as precise measurements of body length (mm) and horizontal tergite width (mm) and combined and computed into a cylindrical formula to get estimates of size. SSD was calculated for each species and plotted for the 21 published species as a linear regression. The chart for SSD in 21 species was constructed.

2.1 Statistical Analysis
The basic descriptive figures were statistically compared using Statistica 13. Body length: width ratios were inserted into the formula for a cylinder.

The mean values of length and width was obtained for 21 species of *Centrobolus*. Size is perceived based on the formula for a cylinder (h.π.r^2) where h is body length and r half of the width. SSD was estimated as the mean female size divided by mean male size and converted into a SSD index. Allometry for SSD was based on a allometric model where male size = α (female)^{β}. A regression was performed in order to test the relationship between the male and female sizes at http://www.socscistatistics.com.

3. Results

Informative sizes were estimated in the 21 published 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*. SSD is shown (Figure 1). For the data, the regression equation for *Y* is: $\hat{y} = 0.41324X + 356.35007$.

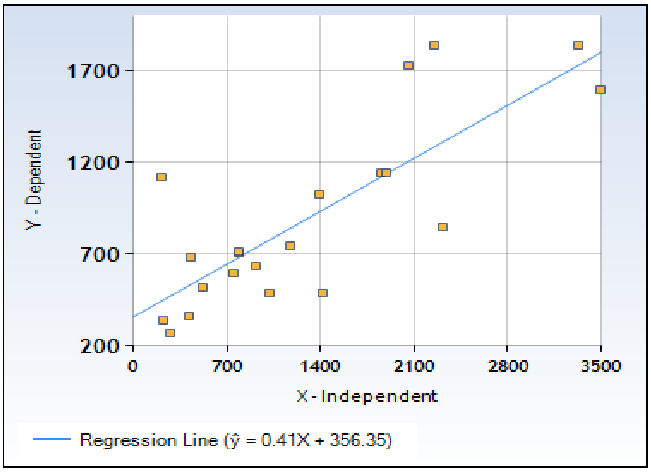

Fig 1: Quantitative resolution of sexual size dimorphism for 21 species of millipedes of the genus *Centrobolus*. Allometry for sexual size dimorphism (SSD) is based on the allometric model male size = α (female size)^{β}; X – Independent female; Y – Dependent male.

Table 1: Body size, sexual size dimorphism (SSD) and SSD index for *Centrobolus* Cook, 1897.

Species	Body size (mm^3)	SSD	SSD-1	Sample size (n)
C. albitarsus	952	2.89	1.89	2
C. anulatus	1885.609	1.02342521	0.0 2342521	17
C. decoratus	557	0.63	-0.37	2
C. digrammus	522	1.01	0.01	6
C. dubius	1210	1.35	0.35	8
C. fulgidus	1518	1.65	0.65	11
C. immaculatus	1580	2.72	1.72	10
C. inscriptus	2023	1.22	0.22	176
C. inyanganus	775	1.44	0.44	17
C. lawrencei	962	1.57	0.57	9
C. lugubris	2046	2.18	1.18	2
C. promontorius	284	0.69	-0.31	2
C. pusillus	756	2.08	1.08	4
C. ruber	1450.5	1.62	0.62	36
C. rugulosus	1666	1.97	0.97	16
C. sagatinus	1659	1.27	0.27	9
C. silvanus	749	1.13	0.13	8
C. titanophilus	393	1.15	0.15	8
C. transvaalicus	669	1.26	0.26	3
C. tricolor	781	1.10	0.10	3
C. vastus	2683	1.81	0.81	5

4. Discussion

21 species often have disparate mean sizes making them clearly and perhaps reproductively recognisable [3-7]. No known cases of hybridisation are reported in *Centrobolus* and size can confirm the validity of each species. The positive relationship found between female and male body sizes in this genus of millipedes which has mostly larger females means this is the exception to the commonly known Rensch's rule [9, 18, 20]. Studies on SSD in invertebrates and these results consistently give a positive correlation and show the exception to the rule [19]. Figure 1 shows females get larger than males with an increase in body size. SSD in *Centrobolus* millipedes is thought to result from small differences in dorsal tergite widths because of sexual bimaturism while intersexual ecological competition is suggested as the ultimate causal factor of millipede dimorphism [4]. Cross-mating experiments *C. anulatus X C. inscriptus* suggest a combination of size assortative mating without a size based preference occurs [4].
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 the size which is similar to the millipede *Doratogonus uncinatus* where female choice for mating partners is "size selective [20]." Sexual dimorphism resembles *C. inscriptus* female width which is positively related to copulation duration and larger females are probably more fecund [6]. Sexual dimorphism in *Apfelbeckia insculpta* showed female-biased SSD with longer and wider females [12]. On the basis of the findings in *C. sagatinus* I suggest width is the primary factor and length secondary in achieving size differences [21].
Studies of diplopod sexual dimorphism may include less taxa and make use of the length and width measurements to calculate sizes using the approach shown here for finding dimorphism.

5. Conclusion

Centrobolus measurements show sexual size dimorphism with small males and larger females in line with the trend for the genus. I suggest width is the primary factor – and length secondary – in achieving millipede size differences.

6. Acknowledgement
The staff of Stellenbosch University were thanked for providing an online interlibrary loan.

7. 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:e0135243.
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. Fire millipedes obey the female sooner norm in cross mating *Centrobolus* Cook. Journal of Entomology and Zoology Studies. 2016; 4:173-174.
5. Cooper MI. Sexual bimaturism in the millipede *Centrobolus inscriptus* (Attems). Journal of Entomology and Zoology Studies. 2016; 4(3):86-87.
6. Cooper MI. Sexual conflict over the duration of copulation in *Centrobolus inscriptus* (Attems). Journal of Entomology and Zoology Studies. 2016; 4(6):852-854.
7. Cooper M. *Centrobolus anulatus* (Attems, 1934) reversed sexual size dimorphism. Journal of Entomology and Zoology Studies. 2018; 6(4):1569-1572.
8. 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.
9. 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.
10. Hamer ML. Checklist of Southern African millipedes. Annals of the Natal Museum. 1998; 39:11-82.
11. Hoffman RL. A note on the status of the name *Centrobolus* Cook, 1897 Spirobolida, Pachybolidae. Myriapodologica. 2001; 7:49-52.
12. Lawrence RF. The Spiroboloidea (Diplopoda) of the eastern half of southern Africa. Annals of the Natal Museum. 1967; 18:607-646.
13. 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.
14. 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.
15. Pincheira-Donoso D, Hunt J. Fecundity selection theory: concepts and evidence. Biological Reviews. 2015; 92:341-356.
16. Rowe M. Copulation, mating system and sexual dimorphism in an Australian millipede, *Cladethosoma clarum*. Australian Journal of Zoology. 2010; 58:127-132.
17. Schubart O. Diplopoda III. Psephalognatha, Opisthospermomorpha, Colobognatha. South African Animal Life. 1966; 12:7-227.
18. 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.
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 M. *Centrobolus sagatinus* sexual size dimorphism based on differences in dorsal tergite widths. Journal of Entomology and Zoology Studies. 2018, 6(6):