Allometry in *Centrobolus*

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**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 \((h \pi r^2)\) 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 an allometric model where \(m = \alpha (\text{female})\). 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. sagatius*, *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: \(\hat{y} = 0.41324X + 356.35007\).

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 uncinitus* 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. sagatius* 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
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