



## **Centrobolus dubius (Schubart, 1966) Monomorphism**

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**Abstract:** Present research aimed to study relative sexual size dimorphism of *Centrobolus dubius* compared to congeners. Millipedes illustrated reversed sexual size dimorphism (SSD) as females were larger than males and broke the rule as this dimorphism increased with body size. SSD was calculated in 18 species of the genus *Centrobolus* and illustrated as a regression. The approximate relative position of *C. dubius* was shown from measurements taken in South Africa. The average size of *C. dubius* was 45 X 4.825 mm (n=8) and logged ( $x/y = 3.0319063$ ). Males were 45 X 4.825 mm (n=4) and females 50.75 X 57.32348 mm (n=4). The SSD index was 1,040266. Log volume measurements were (females/x = 2.43688 mm<sup>3</sup>; males/y = 2.392273 mm<sup>3</sup>). The difference between the correlation coefficients for the species and the genus were not highly significant ( $r_a = 1$ ,  $r_b = 0.85$ ;  $n_a = 8$ ,  $n_b = 18$ ;  $Z = 4.93$ ;  $P = 0$ ). The mean volume ratio for *C. dubius* was 1,040266 which did not differ from 1 ( $t=1.82574$ ;  $p$ -value = 0.097855; NS  $p < .01$ ;  $n=8$ ). The evidence cannot be used to suggest sexual bimaturism or competition as causal for SSD in *C. dubius*.

**Keywords:** *Centrobolus*, dimorphism, *dubius*, millipede, SSD, size

### **1. INTRODUCTION**

Sexual size dimorphism is prevalent in arthropods and females are usually larger than males. Behavioural patterns such as provisioning versus non-provisioning relate to SSD. Millipedes illustrate reversed sexual size dimorphism (SSD) and females are larger than males<sup>[1-4]</sup>. Diplopoda are underrepresented in allometric analyses of sexual size dimorphism (SSD), although sexual size differences are known in body mass, length, width and leg dimensions of over half the taxa studied<sup>[1-2, 5-10]</sup>. Size differences correlate with factors such as color, sexes, species, urbanisation and water relations<sup>[4, 10-12]</sup>. Diplopoda resemble the majority of invertebrates where SSD is reversed<sup>[25]</sup>. SSD has consequences for outcomes of sexual encounters in diplopod mating<sup>[2-4, 5-9, 10-11, 13-14, 15]</sup>. The allometry of SSD involves the detection of a relationship between body size and SSD and is known by Rensch's rule<sup>[16]</sup>. Rensch's rule may be explained by sexual selection and fecundity selection<sup>[17, 20]</sup>. The macro-evolutionary pattern is unresolved in Diplopoda. Here, Rensch's rule was tested in predicting SSD was not negatively correlated with diplopod body size in African forest and savanna taxa. SSD in the forest genus *Centrobolus* was investigated. SSD in forest millipedes have successfully been understood as volumetric measurements using *Centrobolus* to test Rensch's rule. The trend of SSD has been calculated for *Centrobolus* and bimaturism shown<sup>[7]</sup>. The present study was aimed to illustrate the trend of SSD for the genus *Centrobolus* and estimate the position of *C. dubius* relative to 18 congeners in order to determine whether species follow the trend of Rensch's rule.

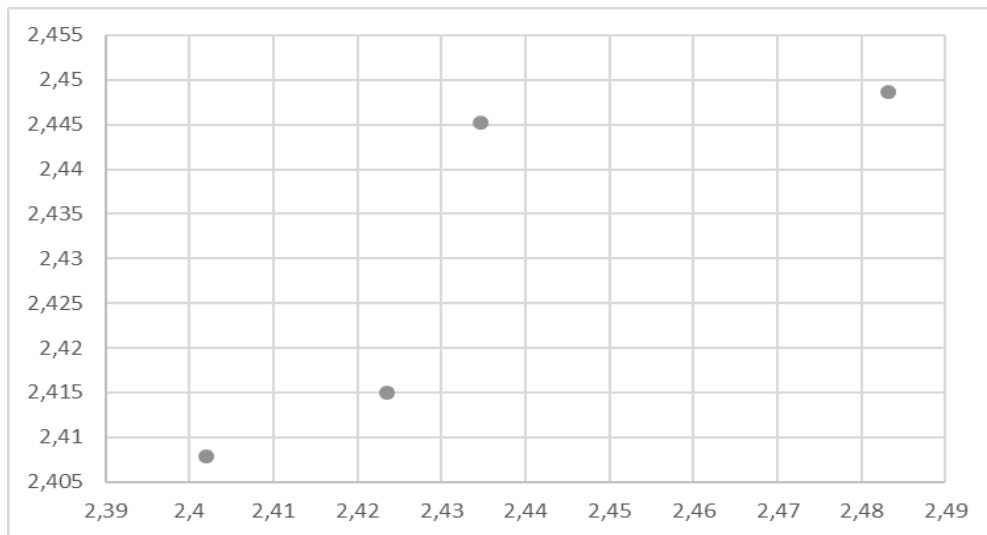
### **2. MATERIALS AND METHODS**

Two factors were measured from *Centrobolus dubius*: (1) body length (mm) of individuals collected in South Africa (Table 1) and (2) width (mm). *C. dubius* (Schubart) were collected at Fransches Kraal near Gans Bay, South Africa. Millipede SSD was also calculated in the genus *Centrobolus* [5-9, 18-19]. A regression of male volume on female volume was used to show the position of 18 species and the size of *C. dubius* was taken as volumetric measurement and inserted into a Microsoft (MS) Excel spreadsheet and converted using the log (mathematical) equation. The chart for SSD in species was captured, copied and exported using the snapshot function in the programme Soda Portable Document File (PDF) 8. It was pasted in a MS file.

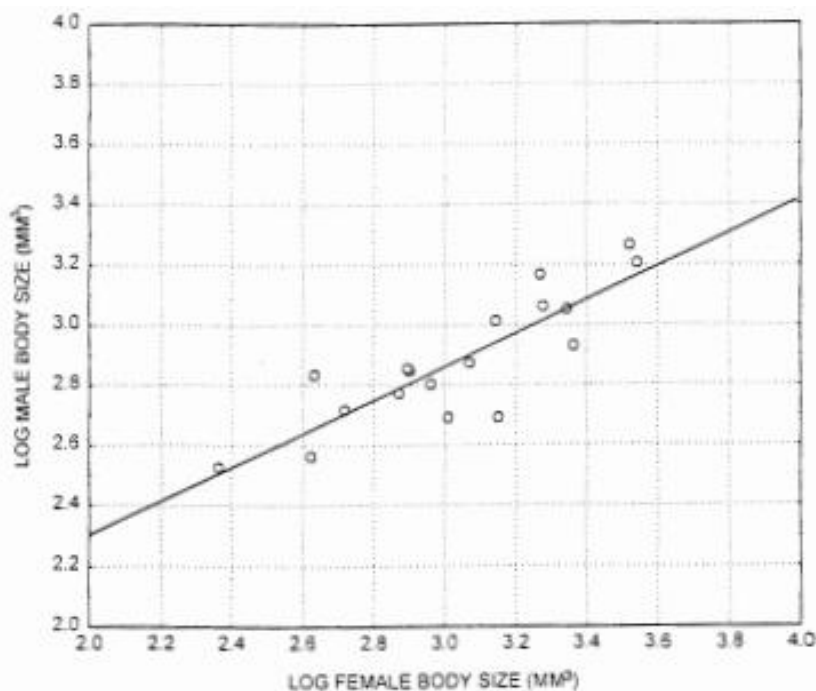
Statistical Analysis

The basic descriptive figures were statistically compared using Statistica. Body length: width ratios were inputted into the formula for a cylinder. The values of length and width were obtained for 8 individuals of *C. dubius*. Size was perceived as body volume and calculated based on the formula for a cylinder ( $h \cdot \pi \cdot r^2$ ) where h is body length and r half of the width. SSD was estimated as the mean female volume divided by mean male volume and converted into a SSD index. Allometry for SSD was based on an allometric model where male size =  $\alpha$  (female) <sup>$\beta$</sup> . A Spearman's Rho calculation was made in order to test the correlation between the male and female volumes at <http://www.socscistatistics.com/tests/spearman/Default3.aspx>. Correlation coefficients were compared at <http://vassarstats.net/rdiff.html>. SSD was compared against to 1 using a two-tailed t-test at <http://www.socscistatistics.com/tests/studentttest/Default2.aspx>.

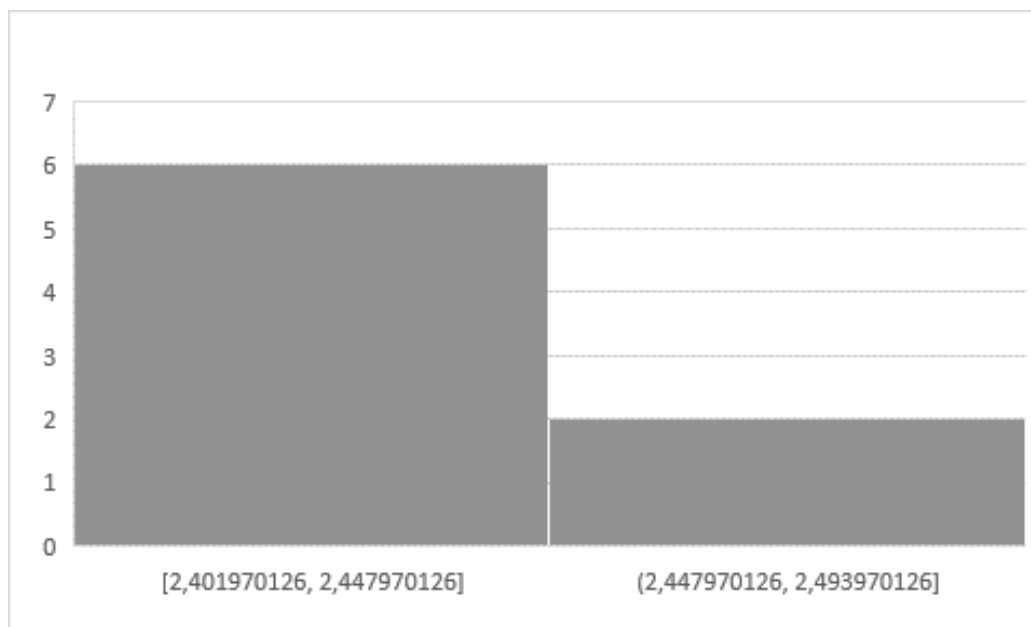
3. RESULTS



**Figure1.** Quantitative resolution of sexual size dimorphism for 8 specimens of the millipede *Centrobolus dubius*. Isometry for sexual size dimorphism (SSD) is based on the allometric model [20], male size =  $\alpha$  (female) <sup>$\beta$</sup> ; correlation coefficient,  $r = 1$ .



**Figure2.** Quantitative resolution of sexual size dimorphism for 18 species of millipedes of the genus *Centrobolus*. Isometry for sexual size dimorphism (SSD) is based on the allometric model<sup>[23]</sup>, male size =  $\alpha$  (female size) <sup>$\beta$</sup> ; correlation coefficient,  $r = 0.85$ .



**Figure3.** Distribution frequency histogram for male and female volumes of *Centrobolus dubius*.

The quantitative resolution of Rensch's rule for 18 species of *Centrobolus* together with the relative estimated position of *C. dubius* is shown in Fig. 2. The average size of *C. dubius* was 45 X 4.825 mm (n=8) and logged ( $x/y = 3.0319063$ ). Males were 45 X 4.825 mm (n=4) and females 50.75 X 57.32348 mm (n=4). The SSD index was 1,040266. Log volume measurements were (females/x = 2.43688 mm<sup>3</sup>; males/y = 2.392273 mm<sup>3</sup>). SSD was visible with the naked eye. There was a correlation between the log values for male and female volumes ( $R = 1$ ). The difference between the correlation coefficients for the species and the genus were not highly significant ( $r_a = 1$ ,  $r_b = 0.85$ ;  $n_a = 8$ ,  $n_b = 18$ ;  $Z = 4.93$ ;  $P = 0$ ). The mean volume ratio for *C. dubius* was 1,040266 which did not differ from 1 ( $t=1.82574$ ;  $p$ -value = .097855; NS  $p < .01$ ;  $n=8$ ).

#### 4. DISCUSSION

Previous studies on SSD in invertebrates and these results consistently give a positive correlation and break the rule [5, 21-25, 26]. Figure 1 shows the finding for *Centrobolus dubius* where the regression of log male volume on log female volume was highly significant with a positive slope of 1. Females get larger than males with an increase in body size [7-8, 18-19]. SSD was not significantly different from 1 in this species. Mean volume ratio of 1.040266 for *C. dubius* was a trend for the genus in Fig. 2. As a proximate cause for SSD in millipedes the evidence cannot suggest the sexual bimaturism hypothesis [7]. As ultimate cause for SSD this together with ecological evidence cannot suggest intersexual competition [7]. No evidence for sexual selection on dimorphism based on the relative size dimorphism in *C. dubius* could imply size would be important in determining the outcome of mating [4, 15, 27]. This is unlike the mechanism based on a conflict of interests is known in *C. inscriptus* [8]. In the millipede *Doratogonus uncinatus* female choice for mating partners is "size selective" [29]. The cross-mating experiments in *Centrobolus* suggest a combination of size assortative mating without a size based preference operates [2]. *C. dubius* does not resemble the majority of Diplopoda where SSD is reversed [28-30]. Studies of diplopod sexual dimorphism may include more taxa and make use of the length and width measurements to calculate volumes using the geometric morphometric approach shown here for finding causal relationships of dimorphism.

#### 5. CONCLUSION

Schubart's (1966) measurements for *C. dubius* did not show sexual size dimorphism.

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