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Relative sexual size dimorphism in *Centrobolus digrammus* (Pocock) compared to 18 congenerics

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Abstract
The present research was aimed to study relative sexual size dimorphism of *Centrobolus digrammus* (Pocock) compared to 18 congenerics. Millipedes illustrate reversed sexual size dimorphism (SSD) as females are larger than males; and corroborate Rensch's rule as this dimorphism increases with body size. SSD was calculated in 18 species of the genus *Centrobolus* and illustrated as a regression. The approximate relative position of *C. digrammus* was shown from measurements taken at Simon's Town Waterfall, South Africa (March 1997). The size of *C. digrammus* was 49.9 X 4 mm: 54.5 X 4.8 mm (males: females; n=6) and logged (females/x = 2.993; males/y = 2.790). The mean volume ratio for *C. digrammus* was 1.599. The evidence suggests the proximate cause for SSD in *C. ruber* is sexual bimaturism while the ultimate cause in *Centrobolus* is intersexual competition.

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

1. Introduction
Sexual size dimorphism is prevalent in arthropods and females are usually larger than males *e. g.* beetles [1], sea spiders [2], orthopterans [15]. Behavioural patterns such as provisioning versus non- provisioning relate to SSD [3]. Millipedes illustrate reversed sexual size dimorphism (SSD) and females are larger than males [4-9]. SSD in forest millipedes has successfully been understood as volumetric measurements using *Centrobolus* to corrobrate Rensch's rule [4-7]. Based on the assumption of equal developmental rates in males and females, the proximate cause for Rensch's rule is sexual bimaturism [10-11]. The general trend of SSD has been calculated for *Centrobolus* and bimaturism shown [7, 11]. The present study was aimed to illustrate the trend of SSD for the genus *Centrobolus* and pinpoint the position of *C. digrammus* relative to 18 congenerics in order to determine whether males and/or females follow the trend of Rensch's rule.

2. Materials and Methods
Three factors were measured from 19 Centrobolus species: (1) body length (mm) by placing individuals collected in South Africa (1996-1998) alongside a plastic rule (calibrated in mm); (2) width (mm) with Vernier calipers; and (3) mass (accurate to 0.01 g) was measured with a Mettler balance. *C. digrammus* (Pocock) were collected at Simon's Town Waterfall, South Africa (March 1997). Millipede SSD was also calculated in the genus *Centrobolus* [4, 7]. A regression of male volume on female volume was used to show the position of 18 species and the size of *C. digrammus* was taken as a volumetric measurement and inserted into a Microsoft (MS) Excel spreadsheet and converted using the logorithmic (mathematical) equation. The chart for SSD in 18 species was captured, copied and exported using the snapshot function in the programme Soda Portable Document File (PDF) 8. It was pasted into a MS Word file and the position of *C. digrammus* pinpointed.

2.1 Statistical Analysis
The basic descriptive figures were statistically compared using Statistica. Body length: width ratios were compared on arcsine transformed data. The mean values of length, width and number of segments was extracted from published data for 18 species intersexual comparisons performed using Wilcoxon matched pairs tests. Size was perceived as body volume and calculated based on the formula for a cylinder ($l.\pi.r$) where l 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 by subtracting 1. Allometry for SSD was based on a general allometric model where male size = α (female) $^{\beta}$.

3. Results

The quantitative resolution of Rensch's rule for 18 species of *Centrobolus* together with the relative estimated position of *C. digrammus* is shown in Fig. 1. The size of *C. digrammus* was 49.9 X 4 mm: 54.5 X 4.8 mm (males: females; n=6) and logged (females/x = 2.790; males/y = 2.993) and plotted (Fig. 1). The mean volume ratio (female volume/male volume) for *C. digrammus* was 1.599. SSD was visible with the naked eye (Fig. 2).

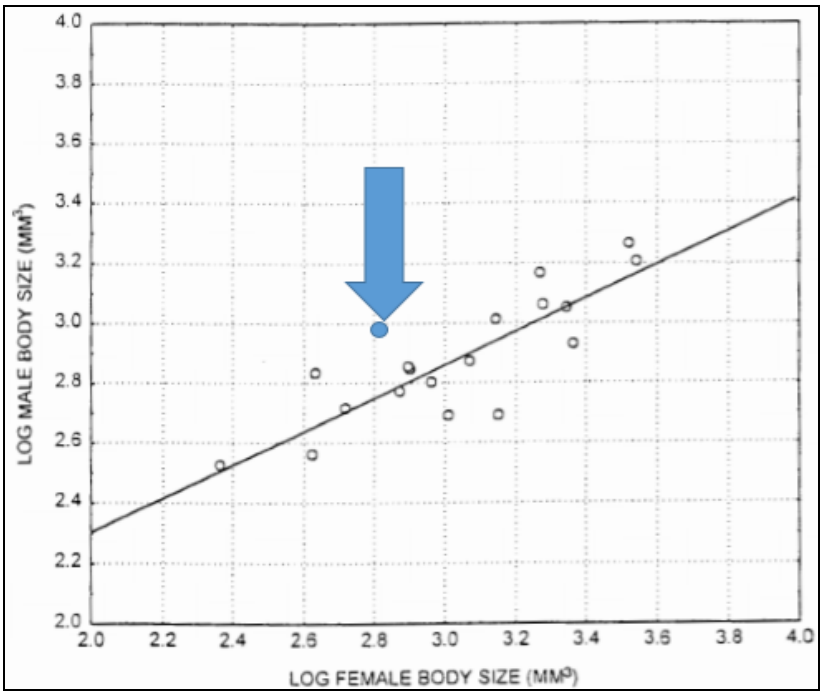

Fig 1: Quantitative resolution of Rensch's rule for 18 species of spirobolidan millipedes of the genus *Centrobolus*. Isometry for sexual size dimorphism (SSD) is based on the general allometric model [12-13], male size = α (female size) $^{\beta}$; correlation coefficient, r = 0.85. The regression of log (female size) on log (male size) would generate an identical relationship with $\beta < 1$. The estimated position of *C. digrammus* is shown by the arrow and filled circle.

Fig 2: SSD in *Centrobolus digrammus* (male above; female below).

4. Discussion

Unlike previous studies on SSD in invertebrates these results consistently corroborated Rensch's rule [18]. Figure 1 shows the finding for *Centrobolus* where mean volume ratios ranged from 0.63-2.72 with the regression of log male volume on log female volume was highly significant with a positive slope less than 1; showing females get larger than males with an increase in body size [4, 7, 9]. The mean volume ratio of 1.599 was at the middle region of the trend for the genus. *C. digrammus* SSD was unlike *C. fulgidus* and *C. inscriptus* with ordinarily small males and larger females which are similar compared to the other 18 *Centrobolus* species for which data is available. Importantly, because the position of *C. fulgidus* was above the line corroborating Rensch's rule it suggested females were larger than males or males were smaller than females relative to other members of the genus. As a proximate cause for SSD in millipedes the evidence corroborated the sexual bimaturism hypothesis [11]. As an ultimate cause for SSD this together with ecological evidence corroborated the intersexual competition hypothesis [14-16]. The small-male mating advantage may apply in this species [17].

5. Conclusion

C. digrammus was unlike *C. inscriptus* with ordinarily small males and larger females which are similar compared to the other 18 *Centrobolus* species for which data is available.

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