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Trigoniulid size dimorphism breaks Rensch

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Abstract

This present research aims to clarify the relative sexual size dimorphism of *Centrobolus* (Cook) in 18 congeners. Millipedes illustrated reversed sexual size dimorphism (SSD) where females were larger than males; and break Rensch's rule as this dimorphism increased with body size. SSD was calculated in 18 species of the genus *Centrobolus* and illustrated was illustrated in 2 regressions: (1) male versus female SSD and (2) SSD and body size. The allometric equation for *Centrobolus* was (1) $\hat{y}=0.00051X0.01071$. SSD ranged from 0.63–2.89 (1.55±0.63; n≥18) and was not negatively correlated (R=0.70485; P=0.00109; n=18 spp.) with a volumetric index of body size ranging from 284–2683 mm³ (1097.89±638.06; 18). The rejection of the rule appears consistent in some animals.

Keywords: Dimorphism, millipede, SSD, size

1. Introduction

Sexual size dimorphism (SSD) is prevalent in arthropods and females are usually larger than males *e. g.* *Ammothea hilgendorfi*^[1]; *Limnebius*^[2]. Behavioural patterns such as provisioning versus non-provisioning relate to SSD^[3]. Millipedes illustrate reversed SSD and females are larger than males^[4-9]. SSD in forest millipedes has successfully been understood as volumetric measurements using *Centrobolus* to reject Rensch's rule^[4-7]. This rule maintains there should be a negative relationship between body size and SSD when females are larger, which is often not the case in Invertebrates^[14]. Based on equal developmental rates in males and females, the proximate cause for Rensch's rule is sexual bimaturism^[10-11, 14]. 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* in 18 congeners in order to highlight how males and females disobey the trend of Rensch's rule.

The trends for this allometric rule when females are larger than males as is the case in almost all orders of Diplopoda is a negative one. Thus it can be expected there will be a negative relationship between SSD and body size. However, this is most often not the case in animals like invertebrates and revision of higher taxa above species relationships is now being clarified. The combined results from two previously published papers are illustrated here together in order to clarify the result of a test of Rensch's rule in the fire millipede genus *Centrobolus*.

2. Materials and Methods

Two factors were measured from *Centrobolus* species (1) body length (mm) by placing individuals collected in South Africa (1998-2018) alongside a plastic rule (calibrated in mm); and (2) width (mm) with Vernier calipers was measured in South Africa (1998-2018). Millipede SSD was 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 volumetric measurements inserted into a Microsoft (MS) Excel spreadsheet and converted using the logarithmic (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) Desktop on a Proline computer (Model No IP-S600AQ3-0). It was pasted into the Microsoft file.

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 and width 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

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formula for a cylinder ($l\pi r^2$) 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) ^{β} .

3. Results

The quantitative resolution of Rensch's rule for 18 species of *Centrobolus* is shown in Fig. 1. The positive relationship between SSD and body size is shown in Fig. 2. The allometric equation for *Centrobolus* was (1) $\hat{y}=0.00051X^{0.01071}$. SSD ranged from 0.63–2.89 (1.55 ± 0.63 ; $n\geq 18$) and was not negatively correlated ($R=0.70485$; $P=0.00109$; $n=18$ spp.) with volume ranging from 284–2683 mm³ (1097.89 ± 638.06 ; 18).

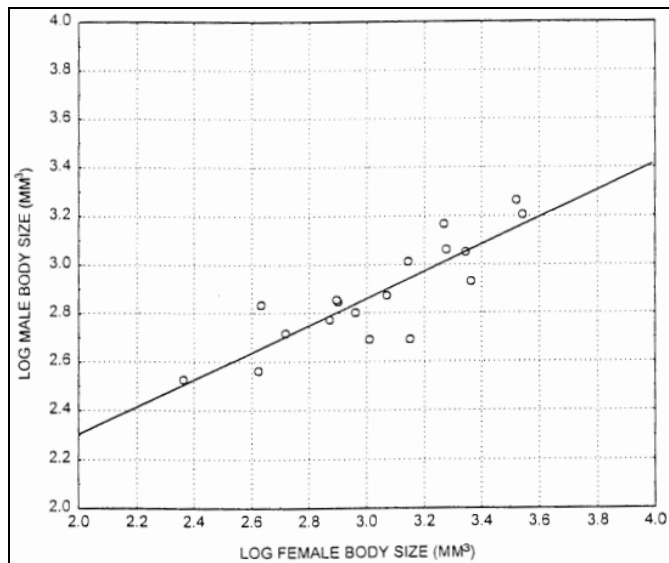


Fig 1: Quantitative resolution of Rensch's rule for 18 species of millipedes of the genus *Centrobolus*. Allometry for sexual size dimorphism (SSD) is based on the general model^[12-13], male size = α (female size) ^{β} ; correlation coefficient, $r = 0.85$. The regression of log (female size) on log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

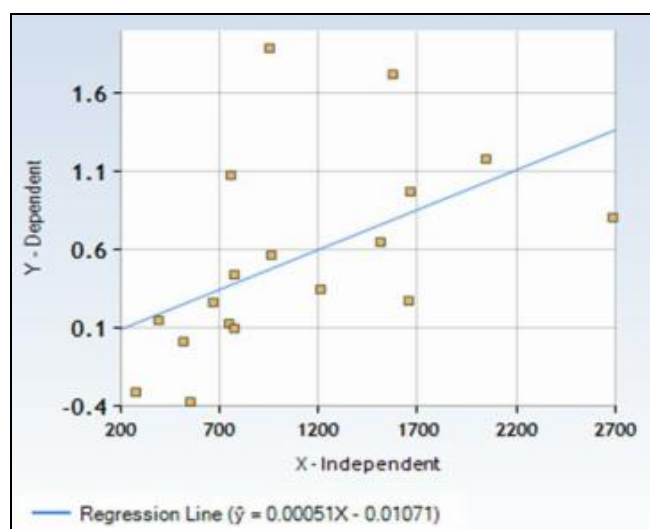


Fig 2: Regression showing the relationship between sexual size dimorphism and body size (volume) in *Centrobolus*¹⁵.

4. Discussion

The results consistently reject Rensch's rule. 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 above 1.0 was a trend for the genus. This study is similar to numerous studies which have found animal families having female biased SSD mostly disobey Rensch's rule including acciptridae, anatids, anguids, apodids, ardeids, bufonids, caprimulgids, chameleonids, charadriids, columbids, corvids, cracids, cuculids, fringillids, falconidae, funariidae, gasterosteids, glareolids, gripopterygids, gruids, hydropsychids, larids, muscicapids, odontophorids, passerids, phasianids, picids, pinnipeds, psittacids, rallids, salamandrids, scolopacids, strigidae, sylviids, tenebrionids, thamnophilids, tinamids, trochilids, tyrannids, and viviparids^[16-39].

5. Conclusion

Centrobolus males and females break Rensch's rule as was the case in some animals.

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