Article

Centrobolus titanophilus size dimorphism shows width-based variability

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Abstract
The present research aimed to study the sexual size dimorphism of *Centrobolus titanophilus*. Diplopoda illustrated reversed sexual size dimorphism (SSD) where one sex was larger than an other. The SSD of *C. titanophilus* was shown from data taken in the Cape Province, South Africa. The average size of *C. titanophilus* was 285 × 41.875 mm (n=8); the smaller sex was 276.6667 × 40.6667 mm (n = 5) and the larger sex was 290 × 42.6 mm (n = 3). Absolute size was estimated (x=418.3596 mm^3; y=359.3327 mm^3) and used to calculate the difference between the sexes based on differences in tergite width (t=1.85901, p=0.084172, n=8). The SSD ratio for *C. titanophilus* was 1.164268 which differed from 1 (t=2.70801, p=0.012845, n=8).

Keywords *Centrobolus titanophilus*; dimorphism; SSD; size.

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1 Introduction

Sexual size dimorphism is prevalent in arthropods and one sex is usually larger than the other (Cooper, 2019). Behavioural patterns such as provisioning versus non-provisioning relate to sexual size dimorphism (SSD). Diplopoda illustrate reversed SSD and one sex is usually larger (Telford and Dangerfield, 1990; Hopkin and Read, 1992; Mori et al., 2017). Diplopoda are underrepresented in allometric analyses of SSD, although SSD is known in body weight, length, width and legs of over half the taxa studied (Enghoff, 1992; Hopkin and Read, 1992; Cooper and Telford, 2000; Cooper, 2015a-b, 2016a-r). SSD correlates with factors such as color, copulation duration, sexes, species, urbanisation and water relations (Telford and Dangerfield, 1990; Enghoff, 1992; David, 1995; Rowe, 2010; Cooper, 2016, 2016a-c, 2017).

Diplopoda tend to be similar to the majority of invertebrates where SSD is reversed (Cooper, 2017c-f; Cooper, 2018a-c). It has consequences for outcomes of sexual encounters in diplopod mating (Telford and Dangerfield, 1990; Enghoff, 1992; Hopkin and Read, 1992; David, 1995; Akkari and Enghoff, 2011; Cooper, 2016f, h, i, r; Cooper, 2017a, b, f, g; Mori et al., 2017). The allometry of SSD involves the detection of a

relationship between body size and SSD and is known by a rule (Rensch, 1947; Seifan et al., 2009; Werner et al., 2016; Faiman et al., 2018). This rule may be explained by sexual selection and fecundity selection (Dale et al., 2007; Pincheiro-Donoso and Hunt, 2015). The evolutionary pattern is being resolved in Diplopoda. Here, the rulewas tested in predicting SSD was not negatively correlated with diplopod body size in African forest taxa. SSD in the forest genus *Centrobolus* was investigated where SSD is understood as cylindrical sizes to test biological rules (Cooper, 2014b; 2016f, h-q; 2017a-h, i; 2018a-m).

A case of SSD has been calculated for *Centrobolus* and bimaturism predicted (Cooper, 2016*h*).The present study illustrated the variation in size and SSD of *C. titanophilus*.

2 Materials and Methods

Two factors were analysed from *Centrobolus titanophilus*: (1) body length and (2) width. *C. titanophilus* were collected in the Cape Provinces, South Africa (Schubart, 1966). The basic descriptive figures were statistically compared using Socscistatistics.com. Body length and width data were inputted into the equation for a cylinder in an Excel spreadsheet. The average values of length and width were obtained for 8 individuals of *C. titanophilus* (Schubart, 1966). Size was calculated based on the formula for a cylinder ($h.\pi.r^2$) where h is body length and r half of the width. SSD was calculated as the average size ratio or converted into a SSD ratio.

SSD was tested against 1 using a two-tailed t-test for 2 averages at http://www.socscistatistics.com/tests/studentttest/Default2.aspx after testing the data for normality with a Kolmogorov-Smirnov test at https://www.socscistatistics.com/tests/kolmogorov/Default.aspx.

3 Results

SSD for *Centrobolus titanophilus* is shown in Table 1. Sex width data was normal (D=0.27948, p=0.57256, n=3) and the larger sex width data was normal (D=0.22929, p=0.90257, n=5). The average size of *C. titanophilus* was 285 × 41.875 mm (n=8); the one sex was 276.6667 × 40.6667 mm (n=5) and the larger sex was 290 × 42.6 mm (n=3). Sizes of the respective sexes were 359.3327 mm^3 and 418.3596 mm^3. The difference between the sexes was based on differences in tergite width (t=1.85901, p=0.084172, n=8). The ratio of the larger sex to smaller sex tergite width was 1.047541. The larger sex was more variable in size (Fig. 1). Size variation is based on differences in width (Fig. 2) and not length (Fig. 3).

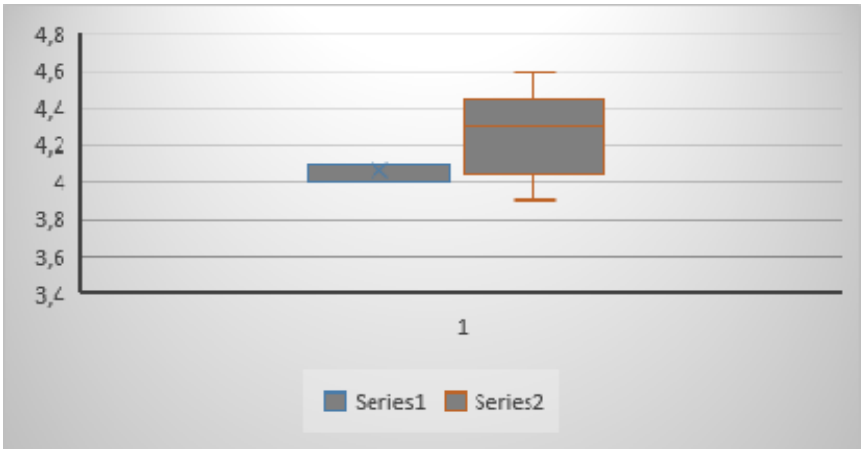

Fig. 1 *Centrobolus titanophilus* sizes (mm3) showing the one sex (left) and the larger sex (right).

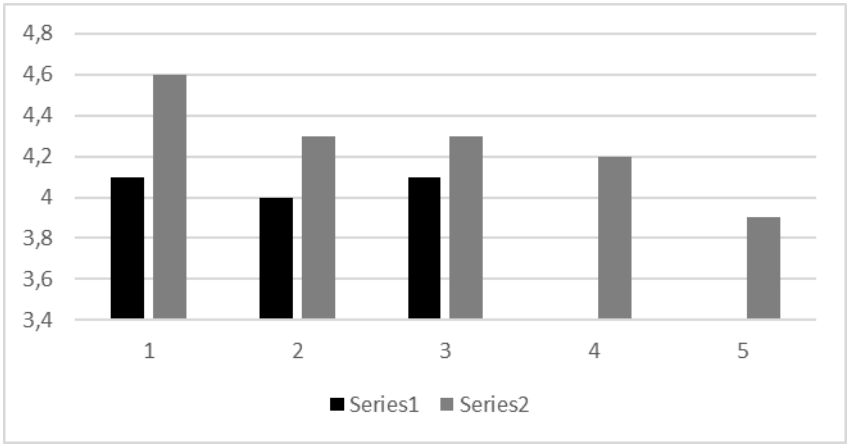

Fig. 2 *Centrobolus titanophilus* widths showing one sex (series 1) and a larger sex (series 2) in cm.

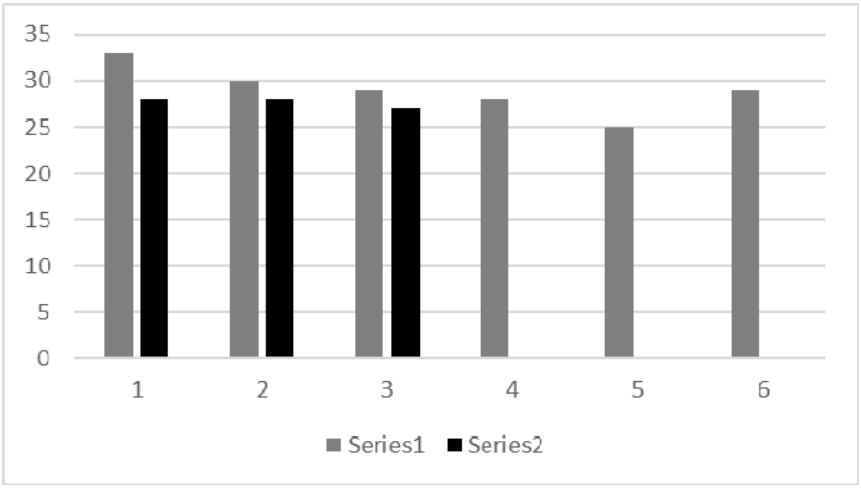

Fig. 3 *Centrobolus titanophilus* lengths showing marginal but non-significant differences in length (cm).

Table 1 *Centrobolus titanophilus* morphological data of Schubart (1966).

Male length (mm)	Male Width (mm)	Female length (mm)	Female width (mm)
280	41	330	46
280	40	300	43
270	41	290	43
		280	42
		250	39
		290	42,6

4 Discussion

The previous studies on SSD in invertebrates consistently give a positive allometric correlation and break the biological rule (Webb and Freckleton, 2007; Cooper, 2016d; 2017b-h; 2018d-f, h). The finding for *Centrobolustitanophilus* shows one sex gets larger than the other with an increase in body size (Cooper, 2014a-b, 2016h). SSD was significantly different from 1 in this species and an average size ratio of 1.164268 was calculated for *C. titanophilus*. A suggested cause for SSD in diplopods is sexual bimaturism (Cooper, 2016*h*). Another cause for SSD is ecological intersexual competition (Cooper, 2014a). Evidence for sexual selection on the relative size dimorphism in *C. titanophilus* indicates size may affect copulation (Telford and Dangerfield, 1990, 1993; Cooper, 2017a-b). A conflict of interests based on size is seen in C. inscriptus (Cooper, 2016h). In *Doratogonus uncinatus* choice for partners is "size selective" (Telford and Dangerfield, 1993). Cross-mating *Centrobolus* appears to have size assortative copulation (Cooper, 2014a).

Studies of diplopod sexual dimorphism now include SSD from nine taxa and show tergite widths determine size (Cooper, 2016r, 2017c-e, 2018g, i-k, m). This affects allometry (Cooper, 2017g, h; 2018a, l).

5 Conclusion

Precise data for *C. titanophilus* shows SSD based on variation in tergite width.

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