Article

Kurtosis and skew show longer males in *Centrobolus*

Mark Cooper
University of Johannesburg, South Africa
E-mail: cm.i@aol.com

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Abstract
Sexual Size Dimorphism (SSD) in the diplopod genus *Centrobolus* has a positive correlation with body size. Length, width and rings are the main components of interspecific variation in diplopod species. Interspecific variation in size was calculated in 6 species and data sets tested for skewness and kurtosis. 28 values were positively skew and had positive kurtosis while 8 were negatively skew and 4 had negative kurtosis. In 6 cases width was positively skewed and in four cases it was negatively skewed. Length was positively skewed in all 6 species except *C. titanophilus*. Longer males were thought to have increased reproductive success through female preference for larger size when there was size assortative mating behaviour.

Keywords Diplopod; horizontal; kurtosis; length; skew.

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1 Introduction

Diplopoda are important environmental indicators and under-represented in analyses of invertebrate Sexual Size Dimorphism (SSD) which is the condition where the two sexes of the same species exhibit different characteristics beyond the differences in their sexual organs, although common sexual differences are thought to occur in body mass, length, width and leg dimensions of over half the taxa studied (Adolph and Geber, 1995; Akkari and Enghoff, 2011; Barnett and Telford, 1994, 1996; Barnett et al., 1993, 1995; Cooper, 2014, 2015, 2016, 2017, 2018; Cooper and Telford, 2000; David, 1995; Dwarakanath, 1971; Enghoff, 1992, Hopkin and Read, 1992; Ilić, 2017; Javonovic et al., 2017; Rowe, 2010; Schubart, 1966; Telford and Dangerfield, 1990, 1993, 1994, 1996; Telford and Webb, 1998; Webb and Telford, 1995). Diplopods resemble the majority of invertebrates in SSD is mostly reversed (Cooper, 2018). Heavier-shorter-wider females are under a type of fecundity selection (Cooper, 2018). Larger males have increased reproductive success through female preference for lager size when there is size assortative mating behaviour (Telford and Dangerfield, 1993).

In the present study, SSD in the genus *Centrobolus* was investigated in 6 species and 2 factors determining a response in SSD (length and width) tested for skewness and kurtosis to determine when males are longer. The forest genus *Centrobolus*of millipedes belonging to the Order Spirobolida is distributed along the eastern coast of southern Africa (Cooper, 1998). They consist of brightly coloured (aposematic) species with

distributions concentrated around coastal bush or forests. Their terrestrial habits make them ideal organisms for laboratory studies because they are relatively easy to collect.

2 Materials and Methods

Two factors were obtained from 6 *Centrobolus* species: (1) body length (mm) in placing individuals collected in South Africa (Table 1) alongside a plastic rule (calibrated in mm); and (2) horizontal tergite width (mm) with Vernier calipers. These basic descriptive figures were statistically tested for skewness using a Kolmogorov-Smirnov Test Calculator. The skewness and kurtosis values of length and width was shown from extracted and published data for 6 species (Cooper, 2014, 2018; Schubart, 1966).

3 Results

In 6 species tests (Table 1) of male and female widths and lengths 28 values were positively skew and had positive kurtosis while 8 were negatively skew and 4 had negative kurtosis (Table 1). In 6 cases width was positively skewed and in four cases it was negatively skewed. Length was positively skewed in all 6 species except *C. titanophilus* males.

Table 1 Male and female length and widths tested for skewness and kurtosis in *Centrobolus spp*. Values given were averages (μ**)**, skewness and kurtosis. Original data based on Schubart (1966) and Cooper (2018).

Species	**Male**		**N**	**Female**		**N**
	Length	**Width**		**Length**	**Width**	
C. anulatus	69; 1.87356; 3.990522	5.3; -0.728589; 0.90432	5	76; 0.175191; -1.586521	5.9; -0.669118; 0.323841	12
C. digrammus	41; 0.310285; -2.270145	4.0; 0.590116; 0.178571	5	34; -0.385927; 2.53237	4.4; -0.052845; 0.114905	7
C. lawrencei	43; 0.666933; 0.976505	4.7; -0.070111; 1.685844	8	43	5.9	1
C. sagatinus	49	6.2	4	48; 0.848557; -0.666434	7.0; -1.185193; 0.513025	5
C. silvanus	46; -1.022372; 0.918367	4.4; -1.530931; 4.5	5	43.8; 0.073801; 0.017094	4.8; 0.017094; 0.628622	5
C. titanophilus	28; -0.75056; 1.156087	4.1; 0.843711; 0.325981	7	29; 0; 0.892734	4.3; 1.77534; 3.625557	5

4 Discussion

The positive skewness of length of the two sexes in five species is a finding which successfully illustrates the higher frequency of longer males in these members of the genus *Centrobolus*. The finding extends on studies which shows the size of Juliformia “has two main components: body diameter and number of” rings and provides new information on millipede length. This supports the idea of slenderness in juliform male

millipedes (Akkari and Enghoff, 2011). Other correlates of Juliform size include oxygen consumption, copulation duration, energetic cost of copulation, precipitation and temperature (Cooper, 2017; Dwarakanath, 1971; Penteado et al., 1991; Webb and Telford, 1995).

Size criteria are useful for determining species and sex of juliform diplopods. The prevalence of longer males with all other factors being approximately equal or the no different means male millipedes maximize size through an increase in the body length of the cylinder. In situations of sizeassortative mating in millipedes there was preference for larger size (Telford and Dangerfield, 1993). This was supported by the finding in *C. inscriptus* where males have a greater body length and are more slender and lighter than females and body mass is positively related to copulation duration (Cooper, 2016). Present research has illustrated length in size data sets determined sex of Juliforms (Cooper, 2019).

5 Conclusion

Size of *Centrobolus* has three main components: body diameter, length and number of rings. Larger body length is a reproductive parameter which co-varies with copulation duration in males of some coastal dunes forest species.

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