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## Quasi-experimental determination of a mass standard in the forest millipede *Centrobolus inscriptus*

**Mark I Cooper****Abstract**

Sexual size dimorphism (SSD) in the diplopod species *Centrobolus inscriptus* has a positive correlation with body size. Intraspecific intersexual variation in mass was calculated twice in this species (males:  $2.48 \pm 0.57\text{g}$ ;  $2.00 \pm 0.22\text{g}$ ; females:  $2.27 \pm 0.28\text{g}$ ;  $2.61 \pm 0.42\text{g}$ ) and data sets tested for SSD. Males differed significantly from females in body mass (students t-test:  $t=9.38$ , d.f.=95,  $p<0.05$ ). This was again found in the larger sample where males and females differed significantly from each other in mass (Wilcoxon matched pairs test:  $T=554$ ,  $n=88$ ,  $P=0.00$ ). When the two data sets were pooled and the mean's compared, a difference was found ( $t=2.3162$ ,  $n=273$ ;  $p=0.020918$ ). It was found males were lighter and have higher reproductive success through female preference for larger males when there was size assortative mating behaviour. Conformity to the mass standard in sexual selection was suggested. Millipedes may influence concentrations of soil elements through sex-specific difference.

**Keywords:** Diplopod, lighter, horizontal, mass**1. Introduction**

Diplopoda are interesting 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<sup>[1-15]</sup>. Worm-like millipedes resemble the majority of invertebrates in SSD is mostly reversed<sup>[7, 8]</sup>. Heavier-shorter-wider females are under a type of fecundity selection<sup>[4]</sup>. Larger males have increased reproductive success through female preference for larger size when there is size assortative mating behaviour.

Mass can be a useful standard in millipedes and mass measurements are known for at least 15 taxa (Cooper, unpublished). Although millipedes (*Centrobolus fulgidus*, *Centrobolus richardii* and *Spinotarsus* sp.) influence selected soil elements, the results of millipede these studies have illustrated no major sex-specific differences for individual species<sup>[16]</sup>. Here it is hypothesized and appears in *Centrobolus* sp. the males are almost always lighter than females and the lighter more slender males are expected to be under a type of sexual selection. Furthermore there appears to be a mass standard in sexual selection, basically implying species-specific mass measurements controlled through sexually selected factors<sup>[13]</sup>. The particular sexual selection is thought to be a female preference for larger male size which operates when there is size-assortative mating behaviour.

In the present communication, SSD in the species *Centrobolus inscriptus* was investigated and the effect of mass in determining a response in SSD tested. I wished to establish a mass standard in sexual selection of millipedes.

**2. Materials and Methods**

*Centrobolus inscriptus* (Attems, 1928) millipedes were collected in April 1995 from Zululand (Twin streams farm, Mtunzini) in South Africa, where they occur in indigenous coastal forest ( $28^{\circ}59'13.4''\text{S}$ ,  $31^{\circ}43'41.3''\text{E}$ ). Live specimens of each sex were transported to the laboratory where conditions were kept under a constant regime of  $25^{\circ}\text{C}$  temperature; 70% relative humidity; 12:12 hrs light-dark cycle. Food was provided in the form of fresh vegetables *ad libitum*. Individuals had unknown mating histories. Unisex groups were housed in plastic containers containing moist vermiculite ( $\pm 5\text{cm}$  deep).

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## 2.1 Mass measurements

*Centrobolus inscriptus* mass (accurate to 0.01 g) was obtained using a Mettler balance calibrated accurate to 0.01g. Mass measurements were recorded after performing mating experiments. Individuals were placed in a 13cm plastic container which had been zeroed on the balance and the measurement recorded. Measurements were taken from *Centrobolus inscriptus* and the basic descriptive figures were statistically tested males versus females using a parametric followed by a non-parametric test.

## 2.2 Statistical tests

Statistical analyses were performed using (1) Statgraphics (version 6.0) and (2) Statistica (A 1997 version). Morphometric (mass) data were tested for normality using a Kolmogorov-Smirnov test before comparing male and female mass data from two sets of mating experiments using a Student's t-test and Wilcoxon matched pairs test.

## 3. Results

**Table 1:** Male and female mass in *Centrobolus inscriptus*. Values given are averages ( $\mu$ ) and Standard Deviation (SD) with sample sizes (N) on the right.

Species	Male	Female	N
	Mass ( $\mu$ ; SD)	Mass ( $\mu$ ; SD)	
<i>C. inscriptus</i>	2.48 $\pm$ 0.57	2.27 $\pm$ 0.28	88, 88
	2.00 $\pm$ 0.22	2.61 $\pm$ 0.42	56, 41

Males differed significantly from females in body mass (students t-test:  $t=9.38$ ,  $d.f.=95$ ,  $p<0.05$ ). This was again found in the larger sample where males and females differed significantly from each other in mass (Wilcoxon matched pairs test:  $T=554$ ,  $n=88$ ,  $P=0.00$ ). When the two data sets were pooled and the mean mass compared, the difference was found and illustrated ( $t=2.3162$ ,  $n=273$ ;  $p=0.020918$ ; see Table 1). Overall male *C. inscriptus* were significantly lighter than females in mass measurements.

## 4. Discussion

The mass in the males in *Centrobolus inscriptus* extends on studies which shows the size of Juliformia “has two main components: body diameter and number of” rings and provides a standard in millipede mass [12]. This supports the idea of slenderness in juliform male millipedes [2]. Correlates of Juliform size include oxygen consumption, copulation duration, energetic cost of copulation, precipitation, sexual dimorphism and temperature [7, 8, 10, 11, 14]. Size criteria are useful for determining species of Juliformia diplopods and research has illustrated mass in size data sets can always determine sex in *Centrobolus*. The two measurements pooled thus conform to the mass standard in sexual selection [13]. *C. inscriptus* males have a greater body length and are slender and lighter than females and body mass which is positively related to copulation duration and SSD [6-8].

The mass in the males in *Centrobolus inscriptus* extends on studies which illustrated no major sex-specific differences for individual species [16]. It can be hypothesized that millipedes influence concentrations of soil elements through sex-specific differential effects and patterns related to composition and species richness may reflect sex-specific differences because “the rate at which soil elements increase in the microcosms suggests that millipede activity may accelerate the release of

elements in areas undergoing vegetation development on coastal dune forests [16].

The mass in the males in *Centrobolus inscriptus* is similar to studies on sexual selection on mass have shown in mice heavier females produced more offspring, while males of intermediate mass have higher fitness suggesting an aspect of natural selection acts to decrease body mass with the upper and lower boundaries of male mass constrained by sexual selection [15]. Sexual selection for body mass also reduces litter size in mammals [3]. Because copulation duration correlates with female size in millipedes litter size will predictably increase.

## 5. Conclusion

Size of *Centrobolus inscriptus* conforms to a mass standard in sexual selection. Body mass in males is a reproductive parameter co-varying with copulation duration and order of mating. Millipedes may influence concentrations of soil elements through sex-specific differential effects.

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