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THE MOMENTS OF INERTIA TIE-UP WITH SEXUAL SIZE DIMORPHISM IN RED MILLIPEDES *CENTROBOLUS* COOK, 1897

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Abstract: **Body size is a correlate of copulation duration in *Centrobolus*. I tested for the presence of a relationship between sexual size dimorphism (SSD) and moments of inertia in *C. fulgidus* (n=11), *C. inscriptus* (n=88, 56+41), and *C. ruber* (n=18). Male moments of inertia correlated significantly with SSD (r=-0.99, Z score=-2.62, n=4, p<0.01). Females' moments of inertia did not. Larger males were suspected to be more competitive.**

Keywords: **Arthropods, body size, *Centrobolus*, sexual dimorphism.**

I. INTRODUCTION

Male and female body sizes can influence the duration of copulation in arthropods [9]. Body size and morph are known drivers of copulation duration [12]. These factors may be interdependent [11]. The interdependence of male and female body size on each other is manifest in the relationship between reversed sexual size dimorphism (SSD) and copulation duration [3]. Like other worm-like millipedes, *Centrobolus* shows female-biased SSD [2, 4-8]. Here I test for the presence of a relationship between moments of inertia and SSD across members of the millipede genus *Centrobolus*. The null hypothesis is there is no relationship between male moments of inertia and SSD in any of the matings.

II. MATERIALS AND METHODS

Millipedes were collected in KwaZulu/Natal. Live specimens of each sex were transported to the laboratory where conditions were kept under a constant regime of 25 °C temperature; 70 % relative humidity; 12: 12 hrs light-dark cycle. Food was provided in the form of fresh vegetable *ad libitum*. Individuals had unknown mating histories. Unisex groups were housed in plastic containers containing moist vermiculite (± 5 cm deep) for 10 days before commencing the first mating experiments. Three measurements were taken for all individuals once copula pairs had disengaged; body mass (accurate to 0.01 g), body length (mm), and dorsal tergite width (mm). Dorsal tergite width was measured horizontally using Vernier calipers. Animals were placed into glass mating arenas (30 X 22 X 22 mm). Individuals were marked on the posterior segments with colored tipex fluid (perfect A16) before mating. This allowed data from each individual to be integrated. Single, double, and artificially-terminated mating with females were allowed. Approximately five minutes after establishing copula pairs were removed from the mating arena and placed into plastic beakers (13 cm diameter). This prevented interference from other males and allowed easy timing of the copulation durations. Statistical analyses were performed using http://www.gigacalculator.com/calculators/correlation-coefficient-calculator.phpStatgraphics. Moments of inertia were calculated as half the mass multiplied by the square of the dorsal tergite width. SSD was calculated as female volume divided over male volume in cubic millimeters (mm). Morphometric and behavioral data were tested for normality (http://www.statskingdom.com/kolmogorov-smirnov-test-calculator.html). Female and male moments of inertia were compared at http://www.statskingdom.com/170median_mann_whitney.html.

III. RESULTS

Male moments of inertia for *C. fulgidus* (n=11), *C. inscriptus* (n=88, 56+41), and *C. ruber* (n=18) correlated significantly with SSD (Figure 1: r=-0.98944427, Z score=-2.61947076, n=4, p=0.00440335). Female moments of inertia were not correlated with SSD (r=-0.77856518, Z score=-1.04171699, n=4, p=0.14877148). Male width was normally distributed (D=0.2395, n=4, p=0.5771). A combination of male and female moments of inertia were marginally related to SSD (r=-0.53029064, Z score=-1.32050864, n=8, p=0.09333269). Male moments of inertia were not normally distributed (D=0.145, n=4, p-value=0.4171). Female moments of inertia were normally distributed (D=0.2758, n=4, p-value=0.3492). Male and female moments of inertia were not significantly different (U=10.5, Z=0.5879, n=8, p=0.5566).

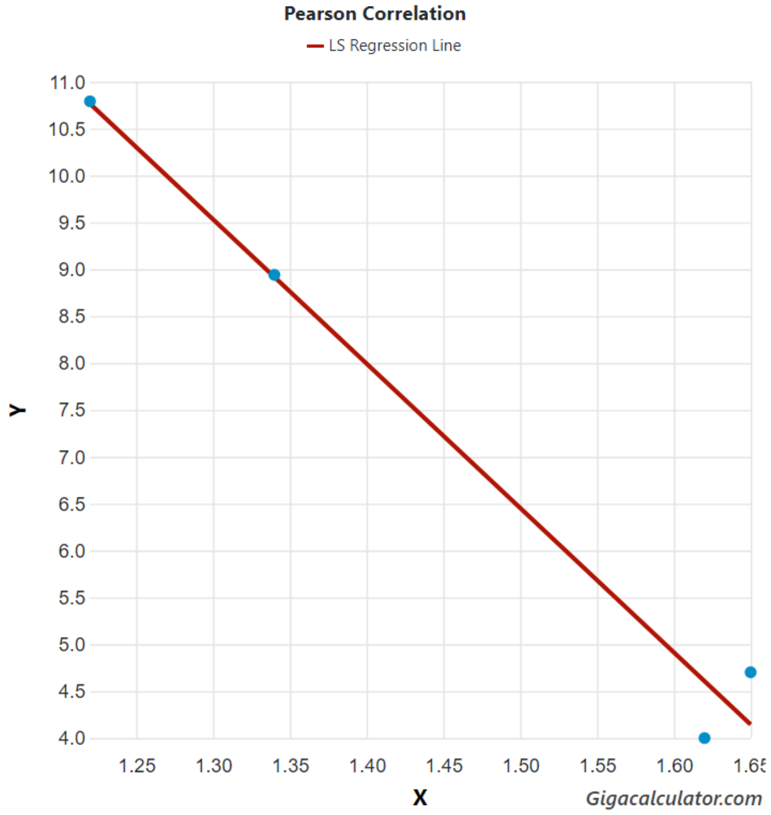

Figure 1: An inverse relationship between male moments of inertia and SSD across three species of *Centrobolus* (*C. fulgidus, C. inscriptus, C. ruber*).

IV. DISCUSSION

The null hypothesis is falsified and an inverse relationship between male moments of inertia and SSD is found. Males appear able to control copulations under their body size, which may relate to the male-male competition. One reason can be given for why male moments of inertia are negatively related to SSD: larger males endure to control the duration of copulation and benefit from reducing sperm competition through prolonged copulation. This may come about through maximizing ejaculate or some other nutrient-rich substance produced by the male; predicting a correlation between ejaculate volume or material benefits with copulation duration. Larger males are also expected to carry larger gonopods (Cooper, in press). There was no relationship between moments of inertia and copulation duration.

The two untested predictions of the mate-guarding hypothesis are prediction 7 (The More Costly the Defense of Mates In Terms Of Energy Expenditure, the Less Likely Males Are To Exhibit Mate Guarding) and prediction 10 (The Longer the Interval between Copulation and Oviposition, the Less Likely Males Are To Remain In Association with Their Partners after Copulation) [1]. In Prediction 7 it is given that if copulation is more costly in terms of energy expenditure there is a negative impact on mate-guarding, which is the case in *Alloporus uncinatus* males and it is estimated energy expenditure during copulation to be 30 % above resting levels in males and 14 % above resting levels in females [10]. In Prediction 10 it is given that a longer interval between copulation and oviposition will negatively impact mate-guarding which has not been tested in millipedes. It may be expected that longer intervals for the time between copulation and oviposition will be associated with higher moments of inertia and consequently lower SSD. In comparative cases of sympatric *Centrobolus* the longer the interval between copulation and oviposition the shorter the copulation duration may be. It is suspected there is a tie-up with the moments of inertia, SSD, and oviposition because moments of inertia are shown to be similar depending on precipitation (Cooper, *in prep*.).

V. CONCLUSION

Male moments of inertia may significantly relate to SSD in mating experiments of *C. fulgidus*, *C. inscriptus*, and *C. ruber*.

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