ARE MATING FREQUENCIES RELATED TO MOMENTS OF INERTIA ACROSS THE SEXES IN CENTROBOLUS COOK, 1897?

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***Abstract*- One species of *Centrobolus* was identified (*C. inscriptus*) based on morphology and confirmed using Scanning Electron Microscopy (SEM) of gonopods. Two sets of measurements were made from data: (1) mating frequencies, and (2) moments of inertia; for males and females. Male and female mating frequencies and female and male moments of inertia were correlated for early and late in a season (r=0.79, Z score=2.42, n=8, p<0.01). Male and female mating frequencies and female and male moments of inertia were correlated for early and late on the ground (r=0.82, Z score=3.44, n=12, p<0.01).**

I. INTRODUCTION

The red millipede genus *Centrobolus* is well known for studies on sexual size dimorphism (SSD) and displays prolonged copulation durations for pairs of individuals of the species [5-10]. *Centrobolus* is distributed in temperate southern Africa with northern limits on the east coast of southern Africa at -17° latitude South (S) and southern limits at -35° latitude S. It consists of taxonomically important species with 12 species considered threatened and includes nine vulnerable and three endangered species [25]. It occurs in all the forests of the coastal belt from the Cape Peninsula to Beira in Mocambique [24]. Spirobolida has two pairs of legs modified into gonopods on the eighth and ninth diplosegments [27]. In *Centrobolus* the coleopods are the anterior gonopods of leg-pair eight. They can be classed as paragonopods or peltogonopods because they are fused into a single plate-like structure and play a subsidiary role as inseminating devices. In contrast, leg-pair nine is sperm-transferring [2]. The sternites (or stigma-carrying plates [26]) prevent lateral shifting (stabilizer) and stretch the vulva sac in a medial plane [5].

These worm-like millipedes have female-biased SSD [5-10, 13-20, 22]. *C. ruber* SSD is a golden ratio [10]. From the results, correlations between male and female moments of inertia and mating frequencies were checked for correlations.

II. MATERIALS AND METHODS

Millipedes were hand collected in coastal forest habitat at Mtunzini (28° 55' S; 31° 45' E) during the summer season (1995-1996). Individual millipedes were identified as species and sexed based on the presence of gonopods in males and their absence in females. Individuals were counted as either on or above ground (>30cm but <3m above ground surface). The number of mating pairs was recorded. The total number of adults was used to estimate the relative abundance. Intercalary males were excluded from the counts. One species of *Centrobolus* was identified based on morphology and confirmed using Scanning Electron Microscopy (SEM) of gonopod structure (*C. inscriptus*). The gonopods were dissected from males of this one species and prepared for SEM. Specimens were fixed, first in 2.5% glutaraldehyde (pH 7.4 phosphate-buffered saline) at 4 °C for 24 hours, then in osmium tetroxide (2%). Dehydration through a graded alcohol series (50%, 60%, 70%, 80%, 90% to 100% ethanol) and critical point drying followed. Specimens were mounted on stubs and sputter coated with gold palladium. Gonopods were viewed under a Cambridge S200 SEM. SEM micrographs were examined and the individual components of the gonopods were identified according to the available species description. Four sets of measurements were made (1) female moments of inertia, (2) male moments of inertia, (3) male mating frequencies, and (4) female mating frequencies. Male moments of inertia, female

moments of inertia, and female and male mating frequencies were correlated using Pearson's Correlation Coefficient (https://www.gigacalculator.com/calculators/correlation-coefficient-calculator.php).

III. RESULTS

Male and female mating frequencies and female and male moments of inertia were correlated for early and late in a season (Figure 1: r=0.79482343, Z score=2.42478206, n=8, p=0.00765879). Male and female mating frequencies and female and male moments of inertia were not correlated for ground and trees (r=-0.21571897, Z score=-0.49006058, n=8, p=0.31204551). Male and female mating frequencies and female and male moments of inertia were correlated for early and late on the ground (Figure 2: r=0.81697184, Z score=3.44292982, n=12, p=0.00028777). Male and female mating frequencies and female and male moments of inertia were not correlated for early and late in the trees (r=0, Z score=0, n=12, p=0.50). Male and female mating frequencies and female and male moments of inertia were not correlated for early on the ground and in the trees (r=-0.13058625, Z score=-0.39400867, n=12, p=0.34678736) or late on the ground and in the trees (r=-0.04198803, Z score=-0.12603819, n=12, p=0.44985081). Male and female mating frequencies and female and male moments of inertia were marginally correlated early (r=0.85956771, Z score=1.29168692, n=4, p=0.09823286), and late (r=0.85956771, Z score=1.29168692, n=4, p=0.09823286). Male and female mating frequencies and female and male moments of inertia were marginally correlated on the ground (r=0.85956771, Z score=1.29168692, n=4, p=0.09823286), and marginally correlated in the trees (r=-0.85956771, Z score=-1.29168692, n=4, p=0.09823286).

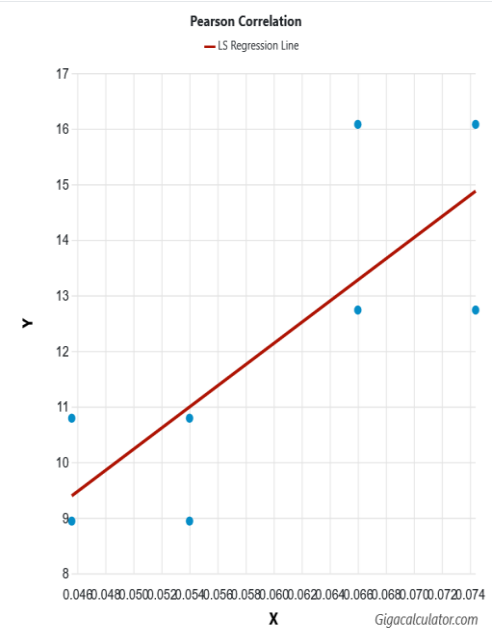

Figure 1. Correlation between mating frequencies and moments of inertia across sexes early and late in a season in *C. inscriptus*.

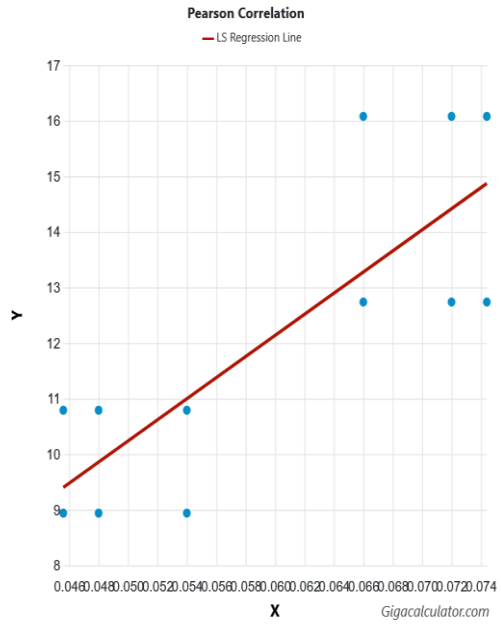

Figure 2. Correlation between mating frequencies and moments of inertia across sexes early and late on the ground in *C. inscriptus*.

IV. DISCUSSION

The male and female moments of inertia are important characters of *Centrobolus*. The male and female moments of inertia and mating frequencies were estimated in one *Centrobolus* species [3]. A

direct relationship between the factors (mating frequencies, and moments of inertia) in the millipedes is compared which certainly supports two relationships. A relationship between these behavioral and morphological factors is present across the sexes in this species. *C. inscriptus* males had higher mating frequencies and females had lower moments of inertia. There were two positive relationships between male and female moments of inertia and mating frequencies across the sexes. One was early and late together while the second was early and late combined with ground measurements of mating frequencies. This suggests this species may have a preference for mating on the ground and probably does not exhibit any above-ground mate avoidance.

V. CONCLUSION

New relationships between male and female moments of inertia and mating frequencies across sexes in the millipede *Centrobolus inscriptus* were discovered.

APPENDIX.

Male and female mating frequencies (early, and late in a season, on the ground, and in the trees), in two species of *Centrobolus* followed by two measurements for female and then male moments of inertia ($kg.m^2$).
0.066, 12.7375375, 16.0777305 (*C. inscriptus*).
0.054, 10.7911, 8.9401 (*C. inscriptus*).
0.0744, 12.7375375, 16.0777305 (*C. inscriptus*).
0.0456, 10.7911, 8.9401 (*C. inscriptus*).
0.072, 12.7375375, 16.0777305 (*C. inscriptus*).
0.048, 10.7911, 8.9401 (*C. inscriptus*).
0.0396, 12.7375375, 16.0777305 (*C. inscriptus*).
0.0804, 10.7911, 8.9401 (*C. inscriptus*).

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