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IS SIZE OR SSD RELATED TO ABUNDANCE IN *CENTROBOLUS* COOK, 1897?

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***Abstract-* Two species of *Centrobolus* were identified (*C. anulatus*, *C. inscriptus*) based on morphology and confirmed using Scanning Electron Microscopy (SEM) of the gonopod structure. Two sets of linear measurements were made: (1) size, and (2) absolute abundance. Male and female sizes in two species were gaged. Male size and absolute abundance were positively related (r=0.63, Z score=1.66, n=8, p<0.05). Female size and absolute abundances were related (r=0.63046242, Z score=1.65957221, n=8, p=0.04850025). Male and female lengths were correlated with absolute abundances (r=-0.50192206, Z score=-1.98980348, n=16, p=0.02330622). Male length was related to abundance (r=-0.63046242, Z score=-1.65957221, n=8, p=0.04850025). Female length was related to abundance (r=-0.63046242, Z score=-1.65957221, n=8, p=0.04850025). Male and female widths were correlated with absolute abundances (r=0.443547, Z score=1.71854248, n=16, p=0.04284882). Male width was related to abundance (r=0.63046242, Z score=1.65957221, n=8, p=0.04850025). Female width was related to abundance (r=0.63046242, Z score=1.65957221, n=8, p=0.04850025). Sexual Size Dimorphism (SSD) was related to abundance (r=0.63, Z score=1.66, n=8, p<0.05).**

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 [4-10]. *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 [32]. It occurs in all the forests of the coastal belt from the Cape Peninsula to Beira in Mocambique [31]. Spirobolida has two pairs of legs modified into gonopods on the eighth and ninth diplosegments [35]. 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 [1]. The sternites (or stigma-carrying plates [35]) prevent lateral shifting (stabilizer) and stretch the vulva sac in a medial plane [3]. The genital morphology and mechanics of copulation were figured in two endangered *Centrobolus* species [1, 2, 32]. These worm-like millipedes have female-biased SSD [4-25, 30]. From the results, correlations between male and female size, SSD, and absolute abundances were checked for correlations.

II. MATERIALS AND METHODS

Two species of *Centrobolus* were identified based on morphology and confirmed using Scanning Electron Microscopy (SEM) of the gonopod structure (*C. anulatus*, *C. inscriptus*). The gonopods were dissected from males of these two 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. Three sets of measurements were made (1) female size, (2) male size, and the third set included field data for (3) absolute abundances. Additionally, size (Appendix 1) was broken down into lengths (Appendix 2) and widths (Appendix 3) for each sex. Male size, female size, (and their components), and absolute abundances were correlated here using Pearson's Correlation Coefficient (https://www.gigacalculator.com/calculators/correlation-coefficient-calculator.php).

III. RESULTS

Male size and absolute abundance were correlated (Figure 1: r=0.63046242, Z score=1.65957221, n=8, p=0.04850025). Female size and absolute abundances were related (Figure 2: r=0.63046242, Z score=1.65957221, n=8, p=0.04850025). Male and female lengths were correlated with absolute abundances (Figure 3: r=-0.50192206, Z score=-1.98980348, n=16, p=0.02330622). Male length was related to abundance (r=-0.63046242, Z score=-1.65957221, n=8, p=0.04850025). Female length was related to abundance (r=-0.63046242, Z score=-1.65957221, n=8, p=0.04850025). Male and female widths were correlated with absolute abundances (Figure 4: r=0.443547, Z score=1.71854248, n=16, p=0.04284882). Male width was related to abundance (r=0.63046242, Z score=1.65957221, n=8, p=0.04850025). Female width was related to abundance (r=0.63046242, Z score=1.65957221, n=8, p=0.04850025). SSD was related to abundance (Figure 5: r=0.63046242, Z score=1.65957221, n=8, p=0.04850025).

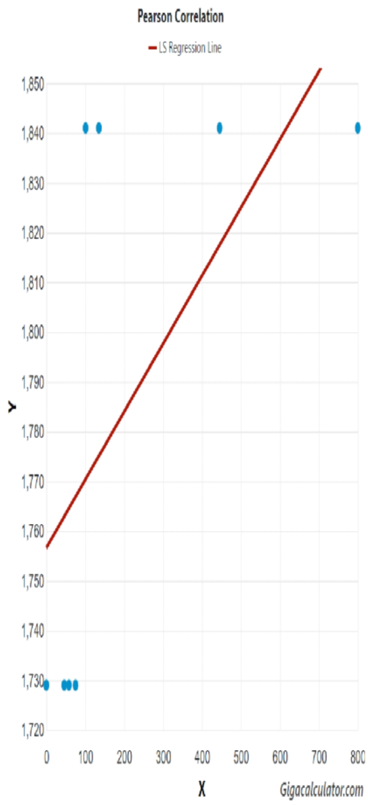
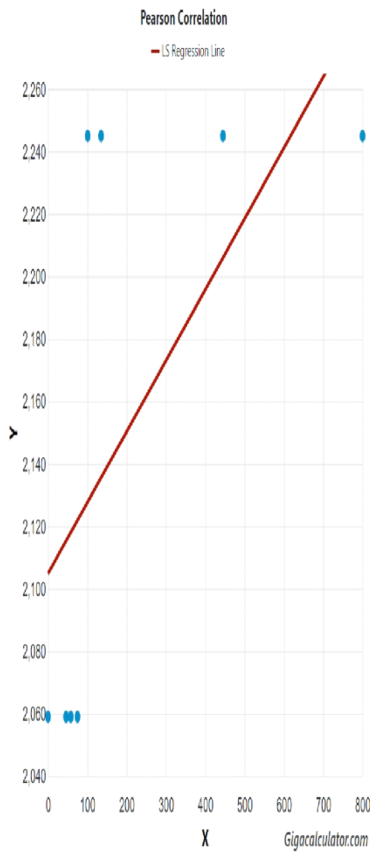


Figure 1. Relationship between male size (mm^3) and absolute abundance (x) in *Centrobolus*.



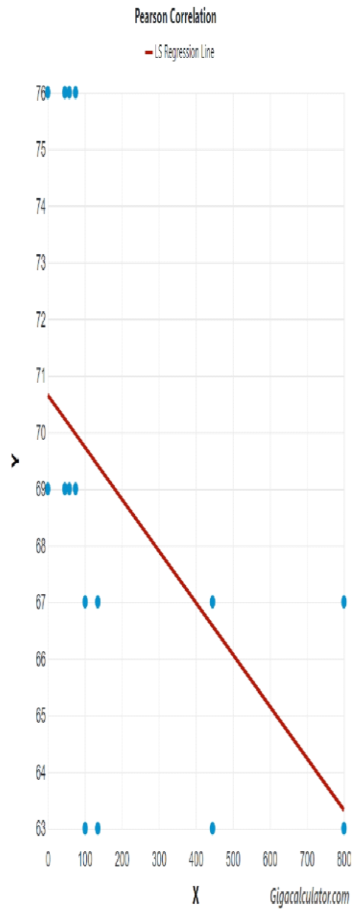


Figure 2. Marginal relationship between female size (mm^3) and absolute abundance (x) in *Centrobolus*.

Figure 3. Relationship between male and female length (mm) and absolute abundance (x) in *Centrobolus*.

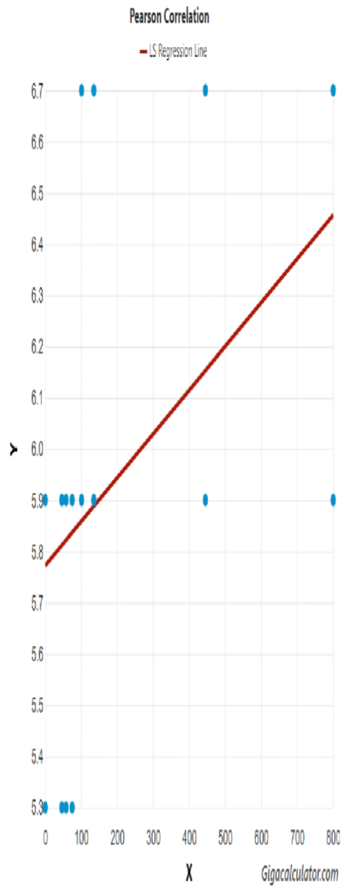


Figure 4. Relationship between male and female width (mm) and absolute abundance (x) in *Centrobolus*.

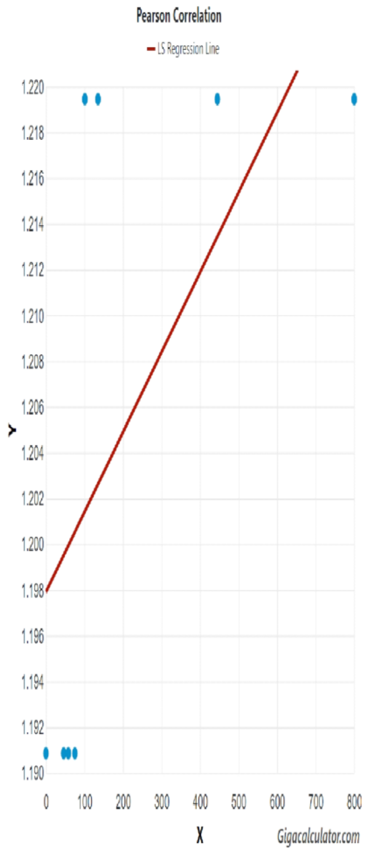


Figure 5. Relationship between SSD and absolute abundance (x) in *Centrobolus*.

IV. DISCUSSION

The genital morphology and mechanics of copulation were figured in two *Centrobolus* species [1, 2]. Direct relationships between size (length and width) and SSD and absolute abundance in the millipedes are compared which certainly supports size (length and/or width) as adapted to mating [11, 38]. Species stacking, whereby the development of a size-abundance peak depends on the existence of an abundance peak of smaller organisms as a food source, is suggested [30, 37].

Local size-density relationships (LSDRs) often show either weak power law relationships with exponents and the observed deviations from energetic equivalence in the LSDR are suggestive of size biases in resource acquisition that could be driven by size asymmetries in competition or family [33, 36]. No global size-density relationships (GSDRs) are known in this class.

V. CONCLUSION

New relationships between size (length and width) and SSD and absolute abundances among the *Centrobolus* millipedes support the function of size (broader width and shorter length) adapted toward negating sperm competition and assuring paternity among various abundances.

APPENDIX.

Absolute abundances (on the ground, in the trees, early, and late in a season) and the male followed by female size (mm^3) in two species of *Centrobolus*.
0, 1729, 2059 (*C. anulatus*).
58, 1729, 2059 (*C. anulatus*).
101, 1841, 2245 (*C. inscriptus*).
445, 1841, 2245 (*C. inscriptus*).
75, 1729, 2059 (*C. anulatus*).
46, 1729, 2059 (*C. anulatus*).
800, 1841, 2245 (*C. inscriptus*).
135, 1841, 2245 (*C. inscriptus*).

APPENDIX II.

Absolute abundances (on the ground, in the trees, early, and late in a season) and the male followed by female length (mm) in two species of *Centrobolus*.
0, 69 (*C. anulatus*).
0, 76 (*C. anulatus*).
58, 69 (*C. anulatus*).
58, 76 (*C. anulatus*).
101, 67 (*C. inscriptus*).
101, 63 (*C. inscriptus*).
445, 67 (*C. inscriptus*).
445, 63 (*C. inscriptus*).
75, 69 (*C. anulatus*).
75, 76 (*C. anulatus*).
46, 67 (*C. anulatus*).
46, 63 (*C. anulatus*).
800, 69 (*C. inscriptus*).
800, 76 (*C. inscriptus*).
135, 67 (*C. inscriptus*).
135, 63 (*C. inscriptus*).

APPENDIX III.

Absolute abundances (on the ground, in the trees, early, and late in a season) and the male followed by female width (mm) in two species of *Centrobolus*.
0, 5.3 (*C. anulatus*).
0, 5.9 (*C. anulatus*).
58, 5.3 (*C. anulatus*).
58, 5.9 (*C. anulatus*).
101, 5.9 (*C. inscriptus*).
101, 6.7 (*C. inscriptus*).
445, 5.9 (*C. inscriptus*).
445, 6.7 (*C. inscriptus*).
75, 5.3 (*C. anulatus*).

75, 5.9 (*C. anulatus*).
46, 5.3 (*C. anulatus*).
46, 5.9 (*C. anulatus*).
800, 5.9 (*C. inscriptus*).
800, 6.7 (*C. inscriptus*).
135, 5.9 (*C. inscriptus*).
135, 6.7 (*C. inscriptus*).

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