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DOES SEX RATIO VARY WITH ABSOLUTE ABUNDANCE IN RED MILLIPEDES CENTROBOLUS COOK, 1897?

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Abstract- **Sex ratio and absolute abundances were checked for correlations in the red millipede genus *Centrobolus*. There was a marginally significant relationship between male and female abundances (pooled) with sex ratio (r=0.38, Z score=1.44, n=16, p=0.07). No relationship between male absolute abundances and sex ration (r=0.39, Z score=0.93, n=8, p=0.18) or female absolute abundances (r=0.36, Z score=0.85, n=8, p=0.20) suggest a complex pattern between absolute abundance and sex ratio is probable. In *C. annulatus* absolute male abundance was marginally related to sex ratio (r=0.93, Z score=1.63, n=4, p=0.051) and absolute female abundance was related to sex ratio (r=0.97, Z score=2.12, n=4, p=0.02). In *C. annulatus* absolute abundance was related to sex ratio on the ground (r=0.88927347, Z score=2.45681378, n=3, p=0.00700877) not in the trees (r=0.53572763, Z score=1.03601597, n=3, p=0.15009737). In *C. inscriptus* absolute male abundance was not related to sex ratio (r=0.66, Z score=0.80, n=4, p=0.21) and absolute female abundance was not related to sex ratio (r=0.49, Z score=0.54, n=4, p=0.30). In *C. inscriptus* absolute male and female abundances were not related to sex ratio in the trees or on the ground. When the zero abundances (0) for *C. annulatus* were justified as a sex ratio of 1:1 there was no relationship between absolute abundance and sex ratio (r=0.14, Z score=0.51, n=16, p=0.30). In *C. annulatus* male and female absolute abundance on the ground was negatively related to sex ratio when this justification was given as one (r=-0.82, Z score=-2.02, n=6, p=0.02) or positively related to sex ratio on the ground when zero (r=0.89, Z score=2.46, n=3, p<0.01).**

I. INTRODUCTION

The millipede genus *Centrobolus* Cook, 1897 is found in the temperate South African subregion, its northern limits on the east coast of southern Africa being about -17° latitude South (S) and its southern limits being about -35° latitude S [3, 11]. It consists of taxonomically important species with 12 species considered threatened and includes nine vulnerable and three endangered species [11]. It occurs in all the forests of the coastal belt from the Cape Peninsula to Beira in Mocambique [10]. Common with worm-like millipedes is the absolute abundance known to differ in several populations of the genus [6]. Absolute abundance is seasonal and may determine the sex ratio which may determine the copulation durations for pairs of individuals of each species at any one time [7-9].

Sex ratio and absolute abundance are tested for a correlation with each other during the breeding season in the pachybolid millipede genus *Centrobolus*. The aim is to determine if there is a correlation between absolute abundance and sex ratio across several species.

II. MATERIALS AND METHODS

Two species belonged to the genus *Centrobolus* Cook, 1897 [1]. The absolute abundance during the breeding season was obtained for *C. anulatus* and *C. inscriptus* [3]. The number of individual millipedes was hand collected, counted, and sexed in situ from the Mick's Park Conservation area in Twin Streams farm (Mtunzini) over a period of up to 3 days early and late in a season. Body size was obtained by calculating the volumes (cylindrical) using the lengths and widths of species which were inputted into the formula for a cylinder's volume (https://byjus.com/volume-of-a-cylinder-calculator) [2]. The sex ratio was calculated as the ratio of male to female individuals [3]. Sex ratio and absolute abundance during early and late in the breeding season were checked for correlations using the Pearson Correlation Coefficient calculator (https://www.gigacalculator.com/calculators/correlationcoefficient-calculator.php). Tests for normality were conducted. Differences between absolute abundances were compared across time (early and late) and space (ground or trees) using the P-value calculator (https://www.gigacalculator.com/calculators/p-valuesignificance-calculator.php).

III. RESULTS

There was a marginally significant relationship between male and female abundances (pooled) with sex ratio (Figure 1: r=0.38005812, Z score=1.44268051, n=16, p=0.07455529). No relationship between male absolute abundances and sex ration (r=0.39393060, Z score=0.93119742, n=8, p=0.17587570) or female absolute abundances (r=0.36317885, Z score=0.85091979, n=8, p=0.19740691) suggest a complex pattern between absolute abundance and sex ratio is probable. In *C. annulatus* absolute male abundance was marginally related to sex ratio (Figure 2: r=0.92669055, Z score=1.63443480, n=4, p=0.05108378) and absolute female abundance was related to sex ratio (Figure 3: r=0.97163663, Z score=2.12076042, n=4, p=0.01697092). In *C. annulatus* absolute abundance was related to sex ratio on the ground (Figure 4: r=0.88927347, Z score=2.45681378, n=3, p=0.00700877) not in the trees (r=0.53572763, Z score=1.03601597, n=3, p=0.15009737). In *C. annulatus* absolute female abundance was not related to sex ratio in the trees (r=0.46632137, Z score=0, n=3, p=0.50) and absolute male abundance was not related to sex ratio in the trees (r=0.84615385, Z score=0, n=3, p=0.50). In *C. inscriptus* absolute male abundance was not related to sex ratio (r=0.66367723, Z score=0.79935716, n=4, p=0.21204161) and absolute female abundance was not related to sex ratio (r=0.48938516, Z score=0.53525156, n=4, p=0.29623793). In *C. inscriptus* absolute female abundance was not related to sex ratio in on the ground (r=0.51875947, Z score=0, n=3, p=0.50) and absolute male abundance was not related to sex ratio on the ground (r=0.65991710, Z score=0, n=3, p=0.50). In *C. inscriptus* absolute female abundance was not related to sex ratio in the trees (r=0.72194688, Z score=0, n=3, p=0.50) and absolute male abundance was not related to sex ratio in the trees (r=0.85275505, Z score=0, n=3, p=0.50). When the zero abundances (0) for *C. annulatus* were justified as a sex ratio of 1 there was no relationship between absolute abundance and sex ratio (r=0.14184203, Z score=0.51489049, n=16, p=0.30331476). This was the case for female abundance and sex ratio (r=-0.19978762, Z score=-0.45282911, n=8, p=0.32533592) and male abundance and sex ratio (r=-0.17979377, Z score=-0.40644910, n=8, p=0.34220636); in the trees regarding males (r=0.84615385, Z score=0, n=3, p=0.50) and females (r=0.46632137, Z score=0, n=3, p=0.50) and/or on the ground regarding males (r=-0.84256533, Z score=0, n=3, p=0.50) and females (r=-0.92583888, Z score=0, n=3, p=0.50). In *C. annulatus* male and female absolute abundance on the ground was negatively related to sex ratio when this justification was given as one (Figure 5: r=-0.82237901, Z score=-2.01632024, n=6, p=0.02188318).

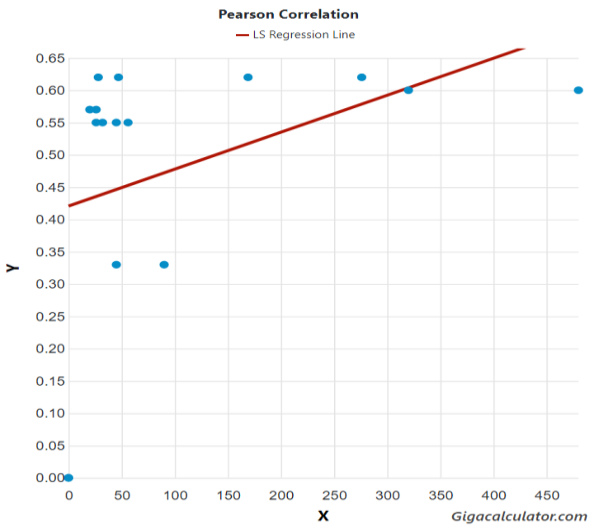

Figure 1. Marginal relationship between absolute abundance and sex ratio in sympatric *Centrobolus annulatus* and *C. inscriptus*.

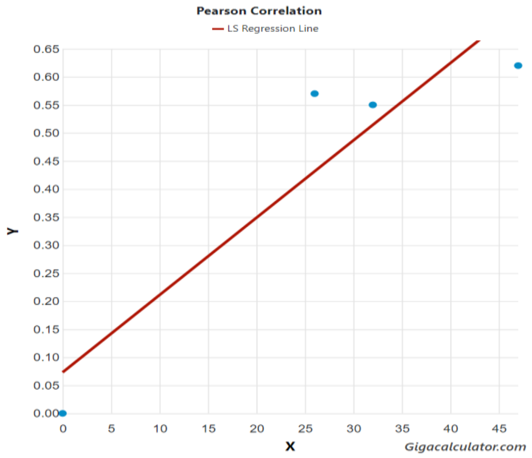

Figure 2. Relationship between absolute abundance of males and sex ratio in *C. annulatus*.

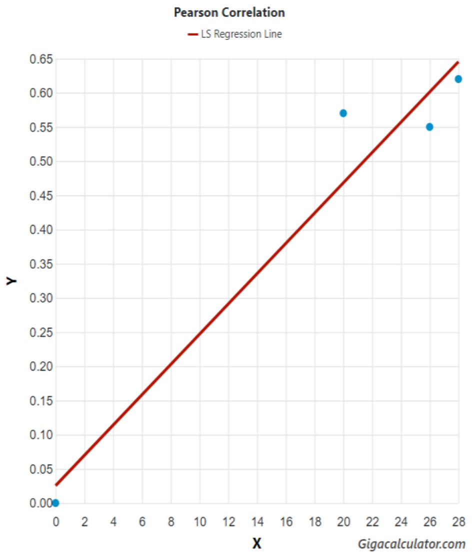

Figure 3. Relationship between absolute abundance of females and sex ratio in *C. annulatus*.

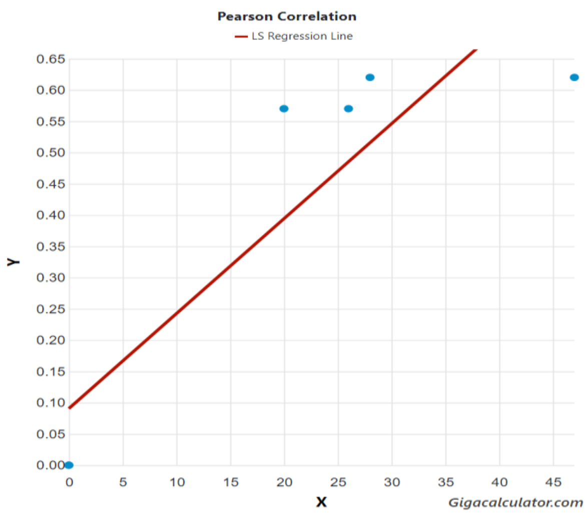

Figure 4. Relationship between absolute abundance on the ground and sex ratio in *C. annulatus*.

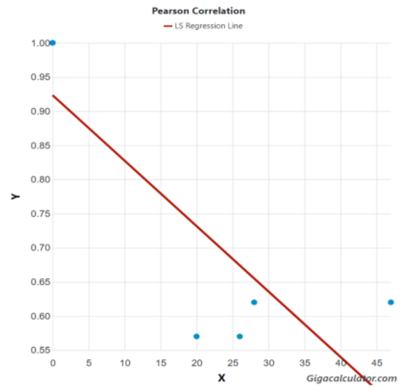

Figure 5. Alternative relationship between absolute abundance on the ground and sex ratio in *C. annulatus*.

IV. DISCUSSION

A marginal relationship was found between absolute abundance and sex ratio in sympatric *Centrobolus* when an undefined outlier was included. *C. anulatus* has absolute abundances which correlate with sex ratio. This study found absolute abundance recorded in *C. anulatus* was either negatively or positively related to sex ratio. So the absolute abundance probably determined the sex ratio in these species with the greater biased sex ratios. This study supports using absolute abundance as a correlate of sex ratio across in *C. annulatus* when an undefined data point is justified as zero or one. Examples of sex ratios varying with absolute abundance are unknown. Sex ratio variation with the absolute abundance occurs during seasonal activity patterns in species such as millipedes [5, 6]. Absolute abundance can bias the sex ratio and covary with many other factors depending on the time and place in the season. Spatial changes in habitat preference are known in *C. fulgidus* and *C. richardii* [7]. These differences are linked to the effects of SSD differences (65%) between the latter two species. Similarly, sex ratios may be usefully investigated and compared with this study. Copulation duration was positively related to absolute abundances across *Centrobolus*. Short copulations (*C. anulatus*) were associated with low absolute abundances and long copulations (*C. inscriptus*) were associated with high absolute abundances. This suggests the pattern of mate guarding is positively associated with absolute abundance and the intensity of intra-male competition [12]. This implies the probability of a female remating is a function of male density [13]. One outlier is seen in this study where no individuals of *C. annulatus* occurred on the ground. The ratio of 0:0 gives the most common possibility as 1 or leaving the expression undefined, with justifications existing for each, depending on context. Here the ratio was inputted as zero and one which is justified in both instances. Fisher's principle explains why for most species, the sex ratio is approximately 1:1 which was expounded in 1967 paper on "Extraordinary sex ratios" [9].

V. CONCLUSION

Sex ratio varied systematically with the absolute abundance in two *Centrobolus* species. An increase in the copulation duration occurs if biased sex ratios correlate with higher absolute abundance.

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