Do copulation duration and sexual size dimorphism vary with absolute abundance in red millipedes *Centrobolus* Cook, 1897?

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DOI: https://doi.org/10.33545/27080013.2022.v3.i1a.64

Abstract

Sexual Size Dimorphism (SSD), copulation duration, and absolute abundance were checked for correlations in the red millipede genus *Centrobolus*. There was a significant relationship between SSD and absolute abundance (*r* =0.63, *Z* score=1.66, *n*=8, *p*<0.05). Greater SSD was related to a higher absolute abundance of *C. inscriptus* over *C. anulatus*. There was an absolute difference (326) (*T*-score=1.99, d. f. = 6, *p*<0.05) and a relative difference (7.27) in absolute abundances between species (*T*-score=3.60, d. f. =6, *p*<0.01). Absolute abundances were higher in the trees (*Z* score=2.46, d. f. =10, *p*<0.01). Absolute densities were higher late in the season (*Z* score=124, *n*=6, *p*=0). Copulation duration increased with absolute abundance (*r* =0.63, *Z* score=1.66, *n*=8, *p*=0.049).

Keywords: Dimorphic, eco-geography, gradient, absolute abundance, size, species

1. 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, 8, 13]. It consists of taxonomically important species with 12 species considered threatened and includes nine vulnerable and three endangered species [14]. It occurs in all the forests of the coastal belt from the Cape Peninsula to Beira in Mocambique [13]. Common with worm-like millipedes is the absolute abundance which is known to differ in several populations of the genus [5]. Absolute abundance is seasonal and determines the sex ratio which in turn determines the copulation durations for pairs of individuals of each species at any one time [6-8]. Sexual size dimorphism (SSD) and copulation duration are tested for a correlation with absolute abundance during the breeding season in the pachybolid millipede genus *Centrobolus*. The aim is to determine if there is a correlation between absolute abundance and SSD as well as a correlation between absolute abundance and copulation duration across species.

2. Materials and Methods

Two species were identified as belonging to the genus *Centrobolus* Cook, 1897 [3]. The absolute abundance during the breeding season was obtained for *C. anulatus* and *C. inscriptus* [5]. 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) [4]. SSD was calculated as the ratio of female volume to male volume [4]. SSD 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/correlation-coefficient-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-value-significance-calculator.php).
3. Results
The mean absolute abundance for *C. anulatus* was 44.75 and for *C. inscriptus* was 370.25. There was a relationship between SSD and absolute abundance (Fig. 1: \( r=0.63046242, Z \text{ score}=1.65957221, n=8, p=0.04850025 \)). There was a marginally significant relationship between absolute abundance on the ground and in the trees pooled with those from early in the season and SSD (\( r=0.70553681, Z \text{ score}=1.52115733, n=6, p=0.06411020 \)). There was a marginally significant relationship between absolute abundance on the ground and in the trees pooled with those from late in the season and SSD (\( r=0.65527536, Z \text{ score}=1.35877368, n=6, p=0.08710922 \)). There was a marginally significant relationship between absolute abundance in the trees pooled with early and late sex ratios and SSD (\( r=0.72113613, Z \text{ score}=1.57618023, n=6, p=0.05749214 \)). There was no relationship between absolute abundances and SSD (\( r=0.55496829, Z \text{ score}=1.08345398, n=6, p=0.13930352 \)). There was an absolute difference (325.50) between the species in absolute abundance (T-score=1.989528, d. f. = 6, p=0.046889). There was a relative difference (7.273743) in absolute abundances between the species (T-score=3.596695, d. f. =6, p=0.005706). There was no absolute difference between absolute abundances on the ground (192.833333) compared to the trees (259.833333) (Z score=0.385371, d. f.=10, p=0.350648). There was a relative difference between absolute abundances on the ground compared in the trees (Z score=2.462243, d. f. =10, p=0.006904). There was no absolute difference between absolute densities early (130.833333) and late (246.50) in the season (Z score=-0.803377, n=6, 6, p=0.210878). There was a relative difference between absolute densities early and late in the season (Z score=-124.425395, n=6, 6, p=0). Copulation duration was related to absolute abundance (Fig. 2: \( r=0.63046242, Z \text{ score}=1.65957221, n=8, p=0.04850025 \)). SSD was normally distributed (D=0.15168, n=22, p=0.20477). Absolute abundances were normally distributed (D=0.36059, n=8, p=0.19432).

Fig 1: Correlation between SSD (x) and absolute abundance in *Centrobolus*.
4. Discussion
A non-overlapping relationship was found between absolute abundance and SSD in sympatric Centrobolus. C. anulatus has the lower SSD (1.19086177) and occurred in a lower absolute abundance (0-75). C. inscriptus has the higher SSD (1.2194459) and occurred in higher absolute abundances (101-800). This study found absolute abundance recorded in C. anulatus and C. inscriptus were positively related to SSD. So the absolute abundance probably determined sex ratio bias in these species with the greater female-biased sexually size dimorphic species being in the trees. This study supports using absolute abundance as a correlate of SSD across Centrobolus. Examples of sexually dimorphic traits varying with absolute abundance are lacking [18]. SSD variation with the absolute abundance occurs during seasonal activity patterns in species showing SSD [1, 6, 7, 10], and daily activity patterns [2, 15]. Absolute abundance can bias the sex ratio and covary with SSD depending on the time and place in the season. Spatial changes in habitat preference are known in C. fulgidus and C. richardii [8]. 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 [10]. This implies the probability of a female remating is a function of male density [17].

5. Conclusion
SSD varied systematically with the absolute abundance in two Centrobolus species. Increase in the copulation duration occurs when larger females and higher SSD correlate with higher absolute abundance.

6. References
1. Ashwini KM, Sridhar KR. Seasonal abundance and activity of pill millipedes (Arthrophaera magna) in mixed plantation and semi-evergreen forest of southern India. Acta Oecologica. 2006;29(1):27-32.
2. Baker G. The activity patterns of Ommatoiulus moreletii (Diplopoda: Iulidae) in South Australia. Journal of Zoology. 2009;188(2):173-183.
3. Cook OF. New relatives of Spirobolus giganteus. Brandtia (A series of occasional papers on Diplopoda and other Arthropoda). 1897;18:73-75.
4. Cooper M. Centrobolus silvanus dimorphism based on tergite width. Global Journal of Zoology. 2018;3(1):003-005.
5. Cooper MI. Sex ratios, mating frequencies and relative abundance of sympatric millipedes in the genus...
Chersastus (Diplopoda: Pachybolidae). Arthropods. 2014;3(4):174–176.

6. Dangerfield JM, Telford SR. Seasonal activity patterns of julid millipedes in Zimbabwe. Journal of Tropical Ecology. 1991;7(2):281-285.

7. Dangerfield JM, Milner AE, Matthews R. Seasonal activity patterns and behaviour of juliform millipedes in south-eastern Botswana. Journal of Tropical Ecology. 1992;8(4):451-464.

8. Greyling MD, Van Aarde RJ, Ferreira SM. Seasonal changes in habitat preferences of two closely related millipede species. African Journal of Ecology. 2001;39(1):51-58.

9. Hamer ML. Checklist of Southern African millipedes (Myriapoda: Diplopoda). Annals of the Natal Museum. 1998;39(1):11-82.

10. Kadamannaya BS, Sridhar KR. Diurnal periodicity of three endemic species of pill millipedes (Arthrosphaera) in Western Ghats, India. Tropical and Subtropical Agroecosystems. 2009;10(3):505-513.

11. Kadamannaya BS, Sridhar KR, Seena S. Seasonal Periodicity of Pill Millipedes (Arthrosphaera) and Earthworms of the Western Ghats, India. World Journal of Zoology. 2009;4(2):63-69.

12. Kania G, Kłapeć T. Seasonal activity of millipedes (Diplopoda) – their economic and medical significance. Annals of Agricultural and Environmental Medicine. 2012;19(4):646-650.

13. Lawrence RF. The Spiroboloidea (Diplopoda) of the eastern half of Southern Africa*. Annals of the Natal Museum. 1967;18(3):607-646.

14. Mailula RP. Taxonomic revision and Red List assessment of the ‘red millipede’ genus Centrobolus (Spirobolida: Pachybolidae) of South Africa. University of KwaZulu Natal, 2021, xxiii+289.

15. Mammola S, Isaia M. Day–night and seasonal variations of a subterranean invertebrate community in the twilight zone. Subterranean Biology. 2018;27(3):31-51.

16. McLain DK. Prolonged copulation as a post-insemination guarding tactic in a natural population of the ragwort seed bug. Animal Behaviour. 1989;38(4):659-664.

17. Wolf LL, Waltz EC, Wakeley K, Klockowski D. Copulation Duration and Sperm Competition in White-Faced Dragonflies (Leucorrhinia intacta; Odonata: Libellulidae). Behavioral Ecology and Sociobiology. 1989;24(1):63-68.

18. Wylie G, Casazza M, Gregory C, Halstead B. Abundance and Sexual Size Dimorphism of the Giant Gartersnake (Thamnophis gigas) in the Sacramento Valley of California. Journal of Herpetology. 2010;44(1):94-103.