SURFACE AREA IS RELATED TO SPECIES RICHNESS ACROSS *CENTROBOLUS* COOK, 1897

MARK IAN COOPER
UNIVERSITY OF STELLENBOSCH, SOUTH AFRICA.

Abstract- In this paper, I test for a relationship between surface area and species richness in red millipedes *Centrobolus* Cook, 1897. Surface area was negatively related to species richness (r=-0.62, Z score=-4.19, n=37, p<0.01) (y=-0.00711055x + 26.2); across species (r=-0.55, Z score=-2.70, n=22, p<0.01) (y=-0.00886731x + 29.3) and females (r=-0.55, Z score=-2.70, n=22, p<0.01) (y=-0.00484857x + 22.8). The mean species surface area at high species richness was 1804 mm^2 (S.D.=203 mm^2). The mean female surface area at high species richness was 1961 mm^2 (S.D.=371 mm^2). Female surface area at high species richness was very different from species surface area at high species richness (t=4.09, n=19, p<0.01). Female surface area at low species richness was not significantly different from species surface area at low species richness (t=-2.57, n=3, p=0.12). The mean female surface area at low species richness was 2741.6811207 mm^2 (S.D.=619.56066078139 mm^2) was significantly different from the female surface area at high species richness (t=-3.116, n=19, 3, p=0.0054). The mean species surface area at low species richness was 2509.916172 mm^2 (S.D.=338.96352202721) was not significantly different from the specific surface area at high species richness (t=-3.5111, n=3, 3, p=0.06162).

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 all species [4-9, 20-86]. *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 [89]. It occurs in all the forests of the coastal belt from the Cape Peninsula to Beira in Mozambique [88]. Spirobolida has two pairs of legs modified into gonopods on the eighth and ninth diplosegments [90]. In Centrobolus the coleopods are the anterior gonopods of leg-pair eight and 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 while leg-pair nine are sperm-transferring [1]. The sternites (or stigma-carrying plates [92]) prevent lateral shifting (stabilizer) and stretch the vulva sac in a medial plane [3]. They facilitate insemination during prolonged size-selected copulations [2, 19, 93]. From the results, correlations between species richness and surface area were checked.

II. MATERIALS AND METHODS

Two morphometric parameters were used to obtain measurements, length and width, both of which were obtained from the published literature [18, 88, 94]. Surface areas (mm^2) were calculated based on the formula for the same cylinder SA = 2πr(r+h) in 22 *Centrobolus* species. The 22 species of millipedes were given SSD. The 22 species were morphologically separated based on the distinct morphological characters. Surface areas were equated against SSD and SSD were substituted into the equation for the SSD relationship to surface area in females (y = 846.83487449 · x + 802.42925798) and the equation for SSD relationship to surface areas when males and female data were pooled (y = 463.30593540 · x + 1,170.96201833). Equations were solved at https://www.mathpapa.com/equation-solver/. Surface area data were tested for normality at https://www.statskingdom.com/kolmogorov-smirnov-test-calculator.html.

III. RESULTS

Female and female and male (species) surface areas for low and high species richness were calculated (Appendix 1 & 2). Surface area was negatively related to species richness (Figure 1: r=-0.61573870, Z score=-4.18727869, n=37, p=0.00001412) (y=-0.00711055x + 26.18488137); across species (Figure 2: r=-0.55126786, Z score=-2.70339286, n=22, p=0.00343183) (y=-0.00886731 · x + 29.30599652) and females (Figure 3: r=-0.55019591, Z score=-2.69668617, n=22, p=0.00350171) (y=-0.00484857x + 22.82072887). The mean species surface area at high species richness was 1803.5385615mm^2 (S.D.=203.369mm^2). The mean female surface area

at high species richness was 1961.2559284^2 (S.D.=371.43215mm^2). The mean species surface area at low species richness was 2509.916172 mm^2 (S.D.=338.96352202721) was not significantly different from the specific surface area at high species richness (t=-3.5111, n=3, 3, p=0.06162). The mean female surface area at low species richness was 2741.6811207 mm^2 (S.D.=619.56066078139 mm^2) was significantly different from the female surface area at high species richness (t=-3.116, n=19, 3, p=0.0054). Female surface area at high species richness was significantly different from species surface area at high species richness (t=4.0855, n=19, p=0.006943). Female surface area at low species richness was not significantly different from species surface area at low species richness (t=-2.5691, n=3, p=0.124). Female surface areas for low species richness were normally distributed (D=0.351, n=3, p=0.1523). Species surface areas for low species richness were normally distributed (D=0.351, n=3, p=0.1523). Female surface areas for high species richness were normally distributed (D=0.1151, n=19, p=0.7258). Species surface areas for high species richness were normally distributed (D=0.1456, n=19, p=0.36).

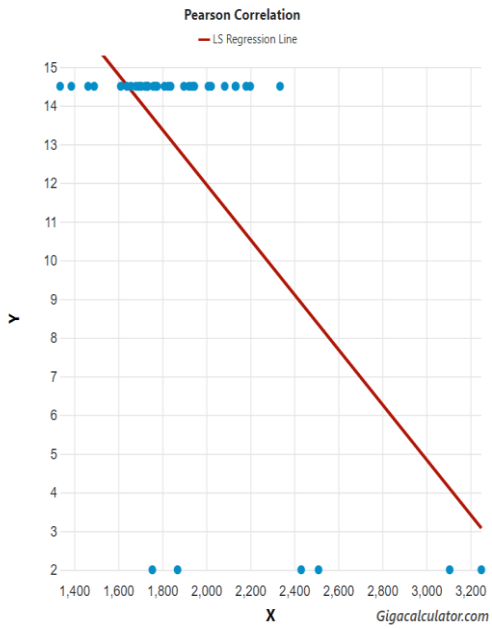

Figure 1. Relationship between species richness and surface area in *Centrobolus* Cook, 1897.

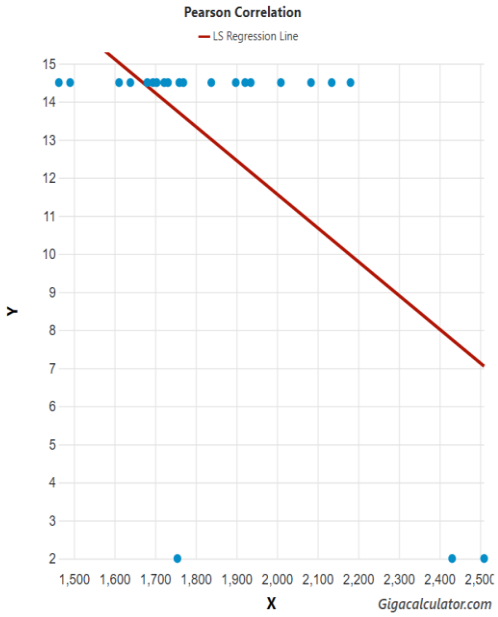

Figure 2. Relationship between species richness and surface area in *Centrobolus* Cook, 1897 species.

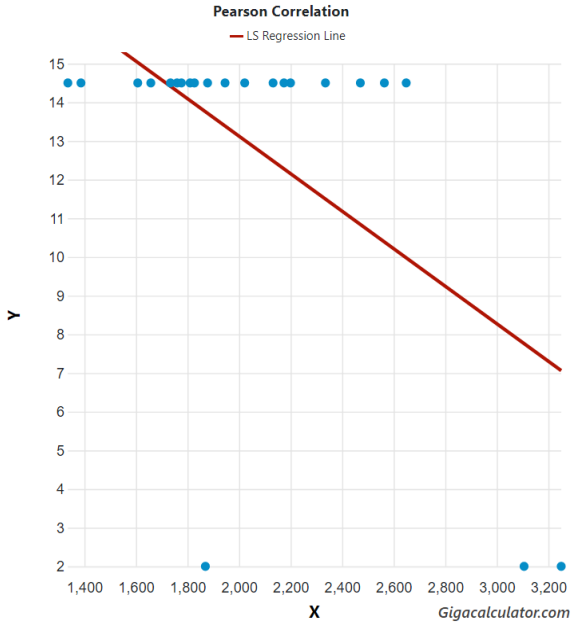

Figure 3. Relationship between species richness and surface area in *Centrobolus* Cook, 1897 females.

IV. DISCUSSION

New relationships between species richness and surface areas are documented here in both females and species in the genus of red millipedes *Centrobolus*. The surface area was negatively related to species richness across species and females. Mean surface areas were estimated from SSD-surface area equations at low and high species

richness. The mean species surface area at high species richness was 1803.5385615 mm^2 (S.D.=203.369mm^2) while the mean female surface area at high species richness was 1961.2559284^2 (S.D.=371.43215mm^2). The mean species surface area at low species richness was 2509.916172 mm^2 (S.D.=338.96352202721). Mean female surface area at high species richness was significantly different to species surface area at high species richness but the female surface area at low species richness was not very different to species surface area at low species richness. This emphasizes the importance of female surface area-species relationships in this genus. A difference of -780.425 mm^2 was found between female surface areas at low versus high species richness.

REFERENCES

[1] M. I. Cooper, "Mating dynamics of South African forest millipedes *Centrobolus* (Diplopoda: Pachybolidae)," The University of Cape Town, pp. 1-141, 1998.
[2] M. I. Cooper, "Elaborate gonopods in the myriapod genus *Chersastus* (Diplopoda: Trigoniulidae)," Journal of Entomology and Zoology Studies, vol. 3, no. 4, pp. 235-238, 2015.
[3] M. Cooper, "Julid millipede and spirobolid millipede gonopod functional equivalents," Journal of Entomology and Zoology Studies, vol. 7, no. 4, pp. 333-335, 2019.
[4] M. I. Cooper, "Sexual size dimorphism and corroboration of Rensch's rule in *Chersastus* millipedes," Journal of Entomology and Zoology Studies, vol. 2, no. 6, pp. 264-266, 2014.
[5] M. I. Cooper, "Copulation and sexual size dimorphism in worm-like millipedes," Journal of Entomology and Zoology Studies, vol. 5, no. 3, pp. 1264-1266, 2017.
[6] M. Cooper, "*Centrobolus anulatus* (Attems, 1934) reversed sexual size dimorphism," Journal of Entomology and Zoology Studies, vol. 6, no. 4, pp. 1569-1572, 2018.
[7] M. I. Cooper, "The relative sexual size dimorphism of *Centrobolus inscriptus* compared to 18 congenerics," Journal of Entomology and Zoology Studies, vol. 4, no. 6, pp. 504-505, 2016.
[8] M. I. Cooper, "Relative sexual size dimorphism in *Centrobolus fulgidus* (Lawrence) compared to 18 congenerics," Journal of Entomology and Zoology Studies, vol. 5, no. 3, pp. 77-79, 2017.
[9] M. I. Cooper, "Relative sexual size dimorphism *Centrobolus ruber* (Attems) compared to 18 congenerics," Journal of Entomology and Zoology Studies, vol. 5, no. 3, pp. 180-182, 2017.
[10] M. I. Cooper, "Competition affected by re-mating interval in a myriapod," Journal of Entomology and Zoology Studies, vol. 3, no. 4, pp. 77-78, 2015.
[11] M. Cooper M, "Re-assessment of rensch's rule in *Centrobolus*," Journal of Entomology and Zoology Studies, vol. 5, no. 6, pp. 2408-1410. 2017.
[12] M. I. Cooper, "Sexual size dimorphism and the rejection of Rensch's rule in Diplopoda," Journal of Entomology and Zoology Studies, vol. 6, no. 1, pp. 1582-1587, 2018.
[13] M. I. Cooper, "Allometry for sexual dimorphism in millipedes," Journal of Entomology and Zoology Studies, vol. 6, no. 1, pp. 91-96, 2018.
[14] M. I. Cooper, "Trigoniulid size dimorphism breaks Rensch," Journal of Entomology and Zoology Studies, vol. 6, no. 3, pp. 1232-1234, 2018.
[15] M. Cooper, "A review of studies on the fire millipede genus centrobolus (diplopoda: trigoniulidae)," Journal of Entomology and Zoology Studies, vol. 6, no. 4, pp. 126-129, 2018.
[16] M. Cooper, "*Centrobolus sagatinus* sexual size dimorphism based on differences in horizontal tergite widths," Journal of Entomology and Zoology Studies, vol. 6, no. 6, pp. 275-277, 2018.
[17] M. Cooper, "*Centrobolus silvanus* dimorphism based on tergite width," Global Journal of Zoology, vol. 3, no. 1, pp. 003-005, 2018.
[18] M. Cooper, "Xylophagous millipede surface area to volume ratios are size dependent in forest," Arthropods, vol. 8, no. 4, pp. 127-136, 2019.
[19] M. I. Cooper, "Allometry of copulation in worm-like millipedes," Journal of Entomology and Zoology Studies, vol. 5, no. 3, pp. 1720-1722, 2017.
[20] M. Cooper, "Does sexual size dimorphism vary with longitude in forest millipedes *Centrobolus* Cook, 1897?" International Journal of Recent Research in Thesis and Dissertation, vol. 3, no. 1, pp. 1-5, 2022.
[21] M. Cooper, "Does sexual size dimorphism vary with latitude in forest millipedes *Centrobolus* Cook,1897?" Int. J. Re. Res. Thesis Diss., vol. 3, no. 1, pp. 6-11, 2022. https://www.paperpublications.org/issue/IJRRTD/Issue-1-January-2022-June-2022.
[22] M. Cooper, "Does sexual size dimorphism vary with temperature in forest millipedes *Centrobolus* Cook, 1897?" Acta Entomol. Zool., vol 3, no. 1, pp. 08-11, 2022. https://doi.org/10.33545/27080013.2022.v3.i1a.51.
[23] M. Cooper, "DOES SEXUAL SIZE DIMORPHISM VARY WITH MONTH WITH THE HIGHEST NUMBER OF RAINY DAYS IN FOREST MILLIPEDES *CENTROBOLUS* COOK, 1897," Universe Int. J. Interdiscip. Res., vol. 2, no. 9, pp. 9-14, 2022. https://www.doi-ds.org/doilink/03.2022-63261534/UIJIR.
[24] M. Cooper, "PAIR-WISE COMPARISON OF SEXUAL SIZE DIMORPHISM AMONG NINE FACTORS IN FOREST MILLIPEDES *CENTROBOLUS* COOK, 1897," Universe Int. J. Interdiscip. Res., vol. 2, no. 9, pp. 31-33, 2022. https://www.doi-ds.org/doilink/03.2022-75935617/UIJIR.
[25] M. Cooper, "Does sexual size dimorphism vary with female size in forest millipedes *Centrobolus* Cook, 1897?" Acta Entomol. Zool., vol. 3, no. 1, pp. 15-18, 2022. https://doi.org/10.33545/27080013.2022.v3.i1a.57.
[26] M. Cooper, "Does sexual size dimorphism vary with hours of sunshine throughout the year in forest millipedes *Centrobolus* Cook, 1897?" Acta Entomol. Zool., vol. 3, no. 1, pp. 19-25, 2022. DOI: https://doi.org/10.33545/27080013.2022.v3.i1a.58.
[27] M. Cooper, "DOES SEXUAL SIZE DIMORPHISM VARY WITH SPECIES RICHNESS IN FOREST MILLIPEDES *CENTROBOLUS* COOK, 1897?" Universe Int. J. Interdiscip. Res., vol. 2, no. 10, pp. 25-29, 2022. https://www.doi-ds.org/doilink/04.2022-91496952/UIJIR.

[28] M. Cooper, "PAIR-WISE COMPARISON OF SEXUAL SHAPE DIMORPHISM AMONG FIFTEEN FACTORS IN FOREST MILLIPEDES *CENTROBOLUS* COOK, 1897," Universe Int. J.Interdiscip. Res., vol. 2, no. 10, pp. 9-14, 2022. https://www.doi-ds.org/doilink/04.2022-18727172/UIJIR.
[29] M. I. Cooper, "Five factors effecting copulation duration in the breeding season in forest millipedes *Centrobolus* Cook, 1897," Zoological and Entomological Letters, vol. 2, no. 1, pp. 17-22, 2022. https://www.zoologicaljournal.com/archives/2022.v2.i1.A.26.
[30] M. Cooper, "Does sexual size dimorphism vary with time in red millipedes *Centrobolus* Cook,1897?" Zool. Entomol. Lett., vol 2, no. 1, pp. 30-35, 2022. https://www.zoologicaljournal.com/archives/2022.v2.i1.A.29..
[31] M. Cooper, "Mating frequencies of sympatric red millipedes differ across substrate due to absolute abundances," Acta Entomol. Zool., vol. 3, no. 1, pp. 34-39, 2022. https://doi.org/10.33545/27080013.2022.v3.i1a.62.
[32] M. Cooper, "Does sexual size dimorphism vary with maximum and minimum temperatures in red millipedes *Centrobolus* Cook, 1897?" Zool. Entomol. Lett., vol. 2, no. 1, pp. 60-65, 2022. https://www.zoologicaljournal.com/archives/2022.v2.i1.B.34.
[33] M. Cooper, "Does sexual size dimorphism vary with sex ratio in red millipedes *Centrobolus* Cook, 1897?" Zool. Entomol. Lett., vol. 2, no. 1, pp. 66-68, 2022. https://www.zoologicaljournal.com/archives/2022.v2.i1.B.35.
[34] M. Cooper, "Millipede mass: Intersexual differences," Zool. Entomol. Lett., vol. 2, no. 1, pp. 69-70, 2022. https://www.zoologicaljournal.com/archives/2022.v2.i1.B.36.
[35] M. I. Cooper, "Do copulation duration and sexual size dimorphism vary with absolute abundance in red millipedes *Centrobolus* Cook, 1897?" Acta Entomol. Zool., vol. 3, no. 1, pp. 51-54, 2022. https://www.actajournal.com/archives/2022.v3.i1.A.64. https://doi.org/10.33545/27080013.2022.v3.i1a.64.
[36] M. Cooper, "DOES SEXUAL SIZE DIMORPHISM VARY WITH FEMALE LENGTH IN FOREST MILLIPEDES *CENTROBOLUS* COOK, 1897?" Universe Int. J. Interdiscip. Res., vol. 2, no. 12, pp. 1-7, 2022. https://www.doi-ds.org/doilink/05.2022-69939779/UIJIR.
[37] M. Cooper, "DOES SEXUAL SIZE DIMORPHISM VARY WITH PRECIPITATION IN FOREST MILLIPEDES *CENTROBOLUS* COOK, 1897?" Munis Entomology and Zoology, vol 17, no. 2, pp. 1185-1189, 2022. https://www.munisentzool.org/Issue/abstract/does-sexual-size-dimorphism-vary-with-precipitation-in-forest-millipedes-centrobolus-cook-189713813.
[38] M. I. Cooper, "Do copulation durations of sympatric red millipedes vary seasonally with mating frequencies?" Int. J. Re. Res. Thesis Diss., vol. 3, no. 1, pp. 85-90, 2022. https://doi.org/10.5281/zenodo.6613001.
[39] M. I. Cooper, "The inverse latitudinal gradients in species richness of Southern African millipedes," Int. J. Re. Res. Thesis Diss., vol. 3, no. 1, pp. 91-112, 2022. https://doi.org/10.5281/zenodo.6613064.
[40] M. I. Cooper, "DOES SEXUAL SIZE DIMORPHISM VARY WITH LOG SEXUAL SIZE DIMORPHISM IN RED MILLIPEDES *CENTROBOLUS* COOK, 1897?" Universe Int. J. Interdiscip. Res., vol. 2, no. 12, pp. 52-54,2022. https://www.doi-ds.org/doilink/06.2022-83544225/UIJIR.
[41] M. I. Cooper, "Do copulation duration and sexual size dimorphism vary with absolute abundance in red millipedes *Centrobolus* Cook, 1897?" Acta Entomol. Zool., vol. 3, no. 1, pp. 51-54, 2022. https://www.actajournal.com/archives/2022.v3.i1.A.64. https://doi.org/10.33545/27080013.2022.v3.i1a.64.46).
[42] M. Cooper, "DOES SEXUAL SIZE DIMORPHISM VARY WITH FEMALE LENGTH IN FOREST MILLIPEDES *CENTROBOLUS* COOK, 1897?" Universe Int. J. Interdiscip. Res., vol. 2, no. 12, pp. 1-7, 2022. https://www.doi-ds.org/doilink/05.2022-69939779/UIJIR.
[43] M. Cooper, "DOES SEXUAL SIZE DIMORPHISM VARY WITH PRECIPITATION IN FOREST MILLIPEDES *CENTROBOLUS* COOK, 1897?" Munis Entomology and Zoology, vol. 17, no. 2, pp. 1185-1189, 2022. https://www.munisentzool.org/Issue/abstract/does-sexual-size-dimorphism-vary-with-precipitation-in-forest-millipedes-centrobolus-cook-1897_13813.48.
[44] M. I. Cooper, "Do copulation durations of sympatric red millipedes vary seasonally with matingfrequencies?" Int. J. Re. Res. Thesis Diss., vol. 3, no. 1, pp. 85-90, 2022. https://doi.org/10.5281/zenodo.6613001.49).
[45] M. I. Cooper, "The inverse latitudinal gradients in species richness of Southern African millipedes," Int. J. Re. Res. Thesis Diss., vol. 3, no. 1, pp. 91-112, 2022. https://doi.org/10.5281/zenodo.6613064.
[46] M. I. Cooper, "DOES SEXUAL SIZE DIMORPHISM VARY WITH LOG SEXUAL SIZE DIMORPHISM IN RED MILLIPEDES *CENTROBOLUS* COOK, 1897?" Universe Int. J. Interdiscip. Res., vol. 2, no. 12, pp. 52-54, 2022. https://www.doi-ds.org/doilink/06.2022-83544225/UIJIR.
[47] M. I. Cooper, "FEMALE VOLUME, LOWEST HOURS OF SUNSHINE, MONTH WITH THE HIGHEST NUMBER OF RAINY DAYS, RAINFALL, AND TEMPERATURES IN THE COOLEST AND WARMEST MONTHS OF THE YEAR ARE RELATED TO LATITUDE (AND LONGITUDE) ACROSS THE DISTRIBUTION OF PILL MILLIPEDES *SPHAEROTHERIUM* BRANDT, 1833," Universe Int. J. Interdiscip. Res., vol. 3, no. 1, pp. 11-22, 2022. https://www.doi-ds.org/doilink/06.2022-51527898/UIJIR. URL: http://hdl.handle.net/10019.1/125464.58).
[48] M. Cooper, "THE TIE-IN OF MALE BODY WIDTH ON COPULATION DURATION IN *CENTROBOLUS* COOK, 1897," Universe Int. J. Interdiscip. Res., vol. 3, no. 1, pp. 45-47, 2022. https://www.doi-ds.org/doilink/06.2022-88932399/UIJIR.59).
[49] M. I. Cooper, "IS A PROMINENT STERNITE RELATED TO MOMENTS OF INERTIA IN *CENTROBOLUS* COOK, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 8, no. 12, pp. 26-28, 2022. http://www.ijesird.com/1_june_22.PDF.
[50] M. I. Cooper, "IS COPULATION DURATION RELATED TO MOMENTS OF INERTIA IN *CENTROBOLUS* COOK, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 8, no. 12, pp. 29-31, 2022. http://www.ijesird.com/2_june_22.PDF.
[51] M. I. Cooper, "COPULATION DURATION IS RELATED TO EJACULATING VOLUME IN *CENTROBOLUS INSCRIPTUS* (ATTEMS, 1928)," International Journal of Engineering ScienceInvention Research & Development, vol. 8, no. 12, pp. 32-40, 2022. http://www.ijesird.com/3_june_22.PDF.
[52] M. I. Cooper, "Is a prominent sternite related to mass in *Centrobolus* Cook, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 1-4, 2022. http://www.ijesird.com/1_jul_22.PDF.
[53] M. I. Cooper, "Does sex ratio vary with absolute abundance in red millipedes *Centrobolus* Cook,1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 5-8, 2022. http://www.ijesird.com/2_jul_22.PDF.
[54] M. I. Cooper, "Does copulation duration vary with absolute abundance in red millipedes *Centrobolus* Cook, 1897?" International

Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 9-11, 2022. http://www.ijesird.com/3_jul_22.PDF.
[55] M. I. Cooper, "Are a prominent sternite, coleopod spine length, and spine number related to mating frequencies in *Centrobolus* Cook, 1897?" International Journal of Engineering Science Invention Research& Development, vol. 9, no. 1, pp. 12-15, 2022. http://www.ijesird.com/4_jul_22.PDF.
[56] M. I. Cooper, "Are coleopod spine length and number related to weather in *Centrobolus* Cook, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 16-23, 2022. http://www.ijesird.com/5_jul_22.PDF.
[57] M. I. Cooper, "Are coleopod spine length and number related to mass in *Centrobolus* Cook, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 24-26, 2022. http://www.ijesird.com/6_jul_22.PDF.
[58] M. I. Cooper, "Is mass related to latitude, longitude, and weather in *Centrobolus* Cook, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 27-32, 2022. https://www.ijesird.com/7_jul_22.PDF.
[59] M. I. Cooper, "ARE MATING FREQUENCIES RELATED TO ABSOLUTE ABUNDANCE IN *CENTROBOLUS* COOK, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 33-37, 2022. https://www.ijesird.com/8_jul-22.PDF.
[60] M. I. Cooper, "Does sex ratio vary with absolute abundance in red millipedes *Centrobolus* Cook,1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 5-8, 2022. http://www.ijesird.com/2_jul_22.PDF.
[61] M. I. Cooper, "Does copulation duration vary with absolute abundance in red millipedes *Centrobolus* Cook, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 9-11, 2022. http://www.ijesird.com/3_jul_22.PDF.65).
[62] M. I. Cooper, "Are a prominent sternite, coleopod spine length, and spine number related to mating frequencies in *Centrobolus* Cook, 1897?" International Journal of Engineering Science Invention Research& Development, vol. 9, no. 1, pp. 12-15, 2022. http://www.ijesird.com/4_jul_22.PDF.
[63] M. I. Cooper, "Are coleopod spine length and number related to weather in *Centrobolus* Cook, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 16-23, 2022. http://www.ijesird.com/5_jul_22.PDF.
[64] M. I. Cooper, "Are coleopod spine length and number related to mass in *Centrobolus* Cook, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 24-26, 2022. http://www.ijesird.com/6_jul_22.PDF.
[65] M. I. Cooper, "Is mass related to latitude, longitude, and weather in *Centrobolus* Cook, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 27-32, 2022. https://www.ijesird.com/7_jul_22.PDF.
[66] M. I. Cooper, "ARE MATING FREQUENCIES RELATED TO ABSOLUTE ABUNDANCE IN *CENTROBOLUS* COOK, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 33-37, 2022. https://www.ijesird.com/8_jul-22.PDF.
[67] M. I. Cooper, "DOES COPULATION DURATION VARY WITH SEX RATIO IN THE RED MILLIPEDE *CENTROBOLUS* INSCRIPTUS (ATTEMS, 1928)?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 38-40, 2022. https://www.ijesird.com/9_jul_22.PDF.
[68] M. I. Cooper, "IS A PROMINENT STERNITE RELATED TO WEATHER IN *CENTROBOLUS* COOK, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 41-44, 2022. https://www.ijesird.com/10_jul_22.PDF.
[69] M. I. Cooper, "ARE MATING FREQUENCIES RELATED TO SEX RATIO IN *CENTROBOLUS* COOK, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 45-48, 2022. https://www.ijesird.com/11_jul_22.PDF.
[70] M. I. Cooper, "ARE MATING FREQUENCIES RELATED TO SEXUAL SIZE DIMOROPHISM IN *CENTROBOLUS* COOK, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 49-51, 2022. https://www.ijesird.com/12_jul_22.PDF.
[71] M. Cooper, "ARE MATING FREQUENCIES RELATED TO MOMENTS OF INERTIA ACROSS THE SEXES IN CENTROBOLUS COOK, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 1, pp. 52-55, 2022. https://www.ijesird.com/13_jul_22.PDF.
[72] M. I. Cooper, "ARE MATING FREQUENCIES RELATED TO TARSAL PAD LENGTH IN *CENTROBOLUS* COOK, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 2, pp. 1-4, 2022. https://www.ijesird.com/1_aug_22.PDF.
[73] M. Cooper, "IS COPULATION DURATION RELATED TO TARSAL PAD LENGTH IN *CENTROBOLUS* COOK, 1897?" International Journal of Engineering Science Invention Research &Development, vol. 9, no. 2, pp. 65-67, 2022. https://www.ijesird.com/3_aug_22.PDF.
[74] M. Cooper, "ARE ABSOLUTE ABUNDANCES RELATED TO TARSAL PAD LENGTH IN *CENTROBOLUS* COOK, 1897?" International Journal of Engineering Science Invention Research &Development, vol. 9, no. 2, pp. 68-70, 2022. https://www.ijesird.com/4_aug_22.PDF.
[75] M. I. Cooper, "ARE MATING FREQUENCIES RELATED TO MALE AND FEMALE SIZE IN *CENTROBOLUS* COOK, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 2, pp. 71-76, 2022. https://www.ijesird.com/5_aug_22.PDF.
[76] M. Cooper, "DOES EJACULATE VOLUME VARY WITH ABSOLUTE ABUNDANCE IN RED MILLIPEDES *CENTROBOLUS* COOK, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 2, pp. 77-79, 2022. https://www.ijesird.com/6_aug_22.PDF.
[77] M. I. Cooper, "THE MOMENTS OF INERTIA TIE-UP WITH FEMALE SIZE, HOURS OF SUNSHINE THROUGHOUT THE YEAR, LATITUDE, LONGITUDE, AND MINIMUM TEMPERATURE IN RED MILLIPEDES *CENTROBOLUS* COOK, 1897," Universe Int. J. Interdiscip. Res., vol. 3, no. 2, pp. 6-12, 2022. https://www.doi-ds.org/doilink/08.2022-76913842/UIJIR.
[78] M. I. COOPER, "ARE MATING FREQUENCIES RELATED TO EJACULATE VOLUMES IN *CENTROBOLUS* COOK, 1897?" International Journal of Engineering ScienceInvention Research & Development, vol. 9, no. 3, pp. 93-95, 2022. https://www.ijesird.com/aug_ten.PDF.
[79] M. Cooper, "DOES SEXUAL SIZE DIMORPHISM VARY WITH FEMALE WIDTH IN FOREST MILLIPEDES *CENTROBOLUS* COOK, 1897?" Munis Entomol. Zool., vol. 17(supplement), pp. 1562-1565, 2022. https://www.munisentzool.org/Issue/abstract/does-sexual-size-dimorphism-vary-with-female-width-in-forest-millipedes-centrobolus-cook-1897_13854.
[80] M. Cooper, "DOES SEXUAL SIZE DIMORPHISM VARY WITH THE HIGHEST TOTAL HOURS OF SUNSHINE IN A MONTH IN FOREST MILLIPEDES *CENTROBOLUS* COOK,

1897?" Munis Entomol. Zool., vol. 17(supplement), pp. 1596-1602, 2022. https://www.munisentzool.org/Issue/abstract/does-sexual-size-dimorphism-vary-with-the-highest-total-hours-of-sunshine-in-a-month-in-forest-millipedes-centrobolus-cook-1897_13858.
[81] M. Cooper, "DOES SEXUAL SIZE DIMORPHISM VARY WITH BODY MASS IN FOREST MILLIPEDES *CENTROBOLUS* COOK, 1897?" Munis Entomol. Zool. Suppl., vol. 17(supplement), pp. 1621-1624, 2022. https://www.munisentzool.org/Issue/abstract/does-sexual-size-dimorphism-vary-with-body-mass-in-forest-millipedes-centrobolus-cook-1897_13861.
[82] M. COOPER, "IS SIZE OR SSD RELATED TO ABUNDANCE IN *CENTROBOLUS* COOK,1897?" International Journal of Engineering Science Invention Research & Development., vol. 9, no. 3, pp. 96-102, 2022. https://www.ijesird.com/sep_one.PDF.
[83] M. I. COOPER, "IS A PROMINENT STERNITE RELATED TO SEX RATIOS ANDABUNDANCE IN *CENTROBOLUS* COOK, 1897?" International Journal of Engineering Science Invention Research & Development, vol. 9, no. 3, pp. 103-106, 2022. https://www.ijesird.com/sep_two_6.PDF.
[84] M. I. Cooper, "DOES SEXUAL SIZE DIMORPHISM VARY WITH FEWEST DAILY HOURS OF SUNSHINE IN RED MILLIPEDES *CENTROBOLUS* COOK, 1897?" Universe Int. J. Interdiscip. Res., vol. 3, no. 3, pp. 89-92, 2022. https://www.doi-ds.org/doilink/09.2022-94655978/UIJIR.
[85] M. COOPER, "DOES (PREDICTED) MASS CORRELATE WITH MATING FREQUENCIES IN *CENTROBOLUS* COOK, 1897?" Universe Int. J. Interdiscip. Res., vol. 3, no. 4, 141-19.
[86] M. I. COOPER, "IS MASS CORRELATED WITH LENGTH AMONG RED MILLIPEDES *CENTROBOLUS* COOK, 1897?" (SUBMITTED).
[87] M. I. Cooper, "Sexual conflict over the duration of copulation in Centrobolus inscriptus," JOURNAL OF ENTOMOLOGY AND ZOOLOGY STUDIES, vol. 4, no. 6, pp. 852-854, 2016. DOI: 10.22271/j.ento.2016.v4.i6l.04.
[88] R. F. Lawrence, "The Spiroboloidea (Diplopoda) of the eastern half of Southern Africa*," Annals of the Natal Museum, vol. 18, no. 3, pp. 607-646, 1967.
[89] R. P. Mailula, "Taxonomic revision and Red List assessment of the 'red millipede' genus *Centrobolus* (Spirobolida:Pachybolidae) of South Africa," The University of Kwazulu natal, pp. xxiii+289, 2021.
[90] P. Sierwald, J. E. Bond, "Current Status of the Myriapod Class Diplopoda (Millipedes): Taxonomic Diversity and Phylogeny," Annual Review of Entomology, vol. 52, no. 1, pp. 401-420, 2007.
[91] T. Wesener, P. Sierwald, J-F. Wägele, "Sternites and spiracles–The unclear homology of ventral sclerites in the basal millipede order Glomeridesmida (Myriapoda, Diplopoda)," Arthropod Structure & Development, vol. 43, no. 1, pp. 87-95, 2014.
[92] X. J. Zahnle, P. Sierwald, S. Ware, J. E. Bond, "Genital morphology and the mechanics of copulation in the millipede genus Pseudopolydesmus (Diplopoda: Polydesmida: Polydesmidae)," Arthropod Structure & Development, vol. 54, pp. 100913, 2020.
[93] M. Cooper, "Post-insemination associations between males and females in Diplopoda: A remark on Alcock's (1994) predictions of the mate-guarding hypothesis," JOURNAL OF ENTOMOLOGY AND ZOOLOGY STUDIES, vol. 4, no. 2, pp. 283-285, 2016.
[94] O. Schubart, "Diplopoda III," South African Animal Life, vol. 12, pp. 1-227, 1966.

Appendix 1. Surface areas (mm^2) for females and species in *Centrobolus* at low species richness.

SPECIES	FEMALE SA	SPECIES SA
C. albitarsus	3249.782045	2509.916172
C. immaculatus	3105.820117	2431.154163
C. transvaalicus	1869.4412	1754.727497

Appendix 2. Surface areas (mm^2) for females and species in *Centrobolus* at high species richness.

SPECIES	FEMALE SA	SPECIES SA
C. anulatus	1810.162759	1722.296081
C. decoratus	1335.935229	1462.844758
C. digrammus	1657.732481	1638.901013
C. dubius	1945.656339	1769.425031
C. fulgidus	2199.706801	1935.416812
C. inscriptus	1827.099456	1731.5622
C. inyanganus	2021.871477	1838.122565
C. lawrencei	2131.960011	1898.352337
C. lugubris	2648.529284	2180.968958
C. promontorius	1386.745321	1490.643114
C. pusillus	2563.845797	2134.638364
C. richardii	1606.922389	1611.102657
C. ruber	2174.301755	1921.517634
C. rugulosus	2470.693961	2083.674711
C. sagatinus	1877.909549	1759.360556
C. silvanus	1759.352666	1694.497725

C. titanophilus	1776.289364	1703.763844
C. tricolor	1733.94762	1680.598547
C. vastus	2335.200381	2009.545761