International Journal of Recent Research in Thesis and Dissertation (IJRRTD)
Vol. 3, Issue 1, pp: (1-5), Month: January - June 2022, Available at: www.paperpublications.org

# Does sexual size dimorphism vary with longitude in forest millipedes *Centrobolus* Cook, 1897?

Mark Cooper[1]

[1]School of Animal, Plant & Environmental Sciences, University of the Witwatersrand, Johannesburg 2050, South Africa.

***Abstract:*** **The objectives of this study were to determine what happened when Bergmann's Rule meets Rensch's Rule if Sexual Size Dimorphism (SSD) and body size changed with a geographical factor. Longitude was correlated with body size and SSD in the forest millipede genus *Centrobolus*. There were significant positive correlations between SSD and longitude (r=0.37, Z score=1.71, n=22, p=0.04), temperature and longitude (r=0.522, Z score= 2.53, n=22, p<0.01), latitude and longitude (r=0.75, Z score=4.28, n=22, p<0.01), and precipitation and longitude (r=0.85, Z score=4.71, n=22, p<0.01). Geographical variance in the polygynandrous reproductive systems occurs with larger females and higher SSD occurring in eastern habitats.**

***Keywords:*** **Dimorphic; geography; gradient; longitude; size; species.**

## I. INTRODUCTION

A forest genus of diplopods belonging to the Order Spirobolida found along the eastern coast of southern Africa was the subject of this study. The millipede genus *Centrobolus* is found in the temperate South African subregion, its northern limits on the east coast of southern Africa being about -17° latitude S. It occurs in all the forests of the coastal belt from the Cape Peninsula to Beira in Mocambique. While the coastal forests of the South-West and Eastern Cape are mist belt temperate forests, those of the Transkei, Natal, Zululand, and Mocambique are somewhat different, being better described as East Coast Bush, they are developed almost entirely in a narrow strip of the litoral on a dune sand substratum, and are more tropical in aspect and composition than those to the west of them. There is a summer rainfall of 762-1016mm, a uniform temperature, and an absence of frost; the component trees of the coastal bush with their abundant creepers and lianes, while not usually reaching a height of more than 11 meters, provide a dense covering with abundant shade and humidity at ground level. As essentially shade-loving Diplopoda, the members of the genus are especially well represented in these litoral forests of the eastern half of the subcontinent [1].

Sexual size dimorphism (SSD) is correlated with longitude in the pachybolid millipede genus *Centrobolus* Cook, 1897 [2, 3, 1]. The null hypothesis is that there is no body size correlation with longitude.

## II. MATERIALS AND METHODS

39 valid species were identified as belonging to the genus *Centrobolus* Cook, 1897 [2]. Millipede-type localities were obtained from a checklist of southern African millipedes [3]. These were tabulated and known type localities also listed in Microsoft Word online (https://office.live.com/start/Word.aspx) (Table 1). Global Positioning System coordinates were obtained from internet sources for known type localities using google (https://www.google.co.za/maps/place). Mean annual precipitation and temperature values were obtained from https://en.climate-data.org/search/?q= and internet sources for known type localities using google (https://www.google.co.za). 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). SSD was calculated as the ratio of female volume to male volume. SSD and longitude were checked for correlations using the Pearson Correlation Coefficient calculator (https://www.gigacalculator.com/calculators/correlation-coefficient-calculator.php).

## III. RESULTS

There was a strong positive correlation between SSD and longitude (Fig. 1: r=0.37261732, Z score=1.70633012, n=22, p=0.04397328). *C. immaculatus* has the highest SSD (2.72) and is most eatsern (34.394°E) (Table 1). SSD of western species includes *C. promontorius* (0.69) (Table 1). Temperature was correlated with longitude (Fig. 2: r=0.52217735, Z score= 2.52523527, n=22, p=0.00578106). Latitude was correlated with longitude (Fig. 3: r=0.75356591, Z score=4.27676003, n=22, p=0.00000949). Precipitation was correlated to longitude (r=0.85040970, Z score=4.70562453, n=22, p=0.00000127). Longitude was normally distributed (D=0.26876, n=22, p=0.06808).

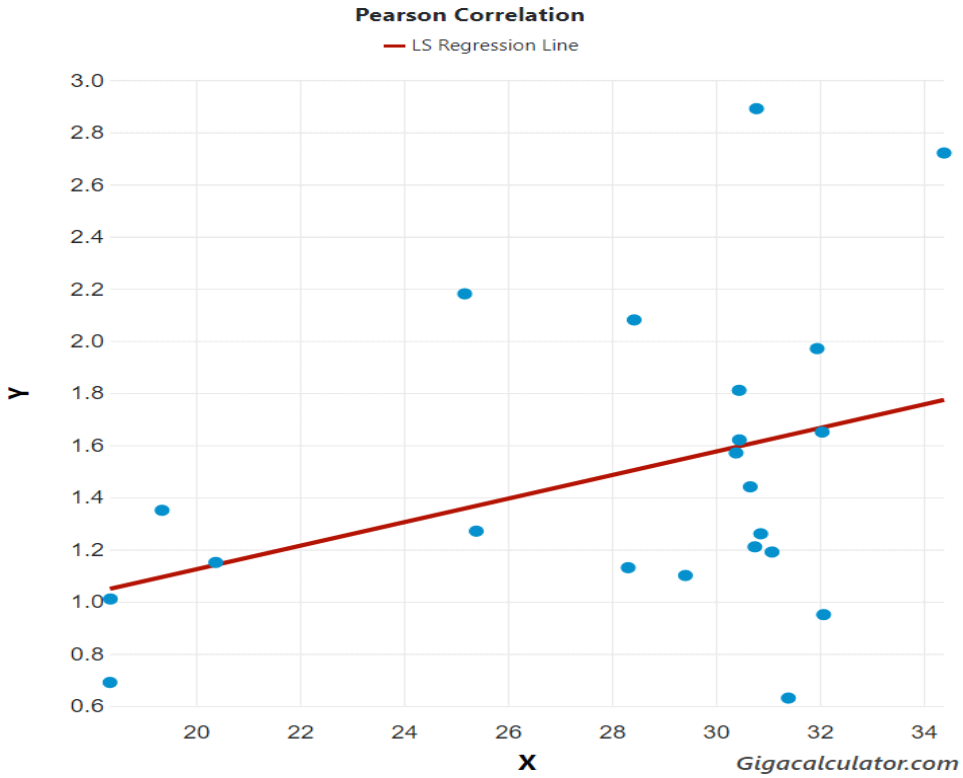


**Fig. 1: Relationship between Sexual Size Dimorphism (y-axis) and longitude (x-axis: °S) in *Centrobolus* Cook, 1897.**

**Table 1: Species in the millipede genus *Centrobolus* Cook, 1897, with SSD, type or collected localities GPS latitude and longitude points, temperature, and precipitation.**

| Species | SSD | Location | Latitude (°S) | Longitude (°E) | Temp. (°C ) | Precipitation (mm) |
|---|---|---|---|---|---|---|
| *C. albitarsis* | 2.89 | Lochiel | -26.150174 | 30.786 | 15.9 | 919 |
| *C. angelicus* | | Makhanda | -33.318134 | | | |
| *C. anulatus* | 1.19 | Umhlanga Rocks | -29.746190 | 31.084 | 20.4 | 893 |
| *C. atrophus* | | Signal Hill | -33.917273 | | | |
| *C. bifidus* | | Nkhandla | -28.728019 | | | |
| *C. coriaceus* | | caffraria | - | - | | |
| *C. decoratus* | 0.63 | Ngome Forest | -27.840258 | 31.400 | 16.6 | 962 |
| *C. digrammus* | 1.01 | Hout bay | -34.047685 | 18.357 | 16.4 | 498 |
| *C. dubius* | 1.35 | Gans bay | -34.584895 | 19.350 | 16.9 | 408 |
| *C. formosus* | | caffraria | - | - | | |
| *C. fulgidus* | 1.65 | Richards Bay | -28.778417 | 32.049 | 21.9 | 944 |
| *C. immaculuatus* | 2.72 | Gorongosa | -18.686597 | 34.394 | 22.8 | 1266 |
| *C. inscriptus* | 1.21 | Scottburgh | -30.280460 | 30.754 | 19.5 | 1015 |
| *C. inyanganus* | 1.44 | Inyanga village | -29.707964 | 30.666 | 16.6 | 893 |
| *C. lawrencei* | 1.57 | Pietermaritzburg | -29.630118 | 30.393 | 16.7 | 966 |
| *C. litoralis* | | Algoa Bay | -33.967135 | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| *C. luctuosus* | | Inhambambane | -23.900071 | | | |
| *C. lugubris* | 2.18 | Glenconnor | -33.932215 | 25.173 | 17.0 | 497 |
| *C. miniatomaculatus* | | Tsitsikamma | -32.220918 | | | |
| *C. pococki* | | Cape Peninsula | -34.244295 | | | |
| *C. promontorius* | 0.69 | Little Lions Head | -34.016370 | 18.348 | 16.4 | 621 |
| *C. pusillus* | 2.08 | Qolora River mouth | -32.571689 | 28.433 | 19.5 | 1050 |
| *C. richardii* | 0.95 | Richards Bay | -28.778417 | 32.078 | 21.9 | 944 |
| *C. ruber* | 1.62 | Port Shepstone | -30.715740 | 30.456 | 20.1 | 945 |
| *C. rubricollis* | | Karkloof waterfall | -29.399869 | | | |
| *C. rugulosus* | 1.97 | Hluhluwe | -28.024622 | 31.952 | 22.0 | 837 |
| *C. sagatinus* | 1.27 | Between Uitenhage and Addo | -33.636710 | 25.396 | 18.6 | 497 |
| *C. sanguineomarginatus* | | Bain's Kloof | -33.613179 | | | |
| *C. sanguinipes* | | Qolora River mouth | -32.571689 | | | |
| *C. saussurii* | | caffraria | - | - | | |
| *C. silvanus* | 1.13 | Kentani | -32.506398 | 28.317 | 19.0 | 956 |
| *C. splendidus* | | Masiene near Chai Chai | -25.615527 | | | |
| *C. strigosus* | | caffraria | - | - | | |
| *C. striolatus* | | Port St Johns | -31.633372 | | | |
| *C. titanophilus* | 1.15 | DeHoop vlei | -34.414179 | 20.383 | 17.0 | 401 |
| *C. transvaalicus* | 1.26 | Mariepskop | -24.539147 | 30.867 | 17.0 | 1200 |
| *C. tricolor* | 1.10 | Champaigne Castle | -29.093869 | 29.418 | 15.0 | 265 |
| *C. validus* | | Haroni River | -19.817644 | | | |
| *C. vastus* | 1.81 | Port St Johns | -31.633371 | 30.451 | 19.7 | 1089 |

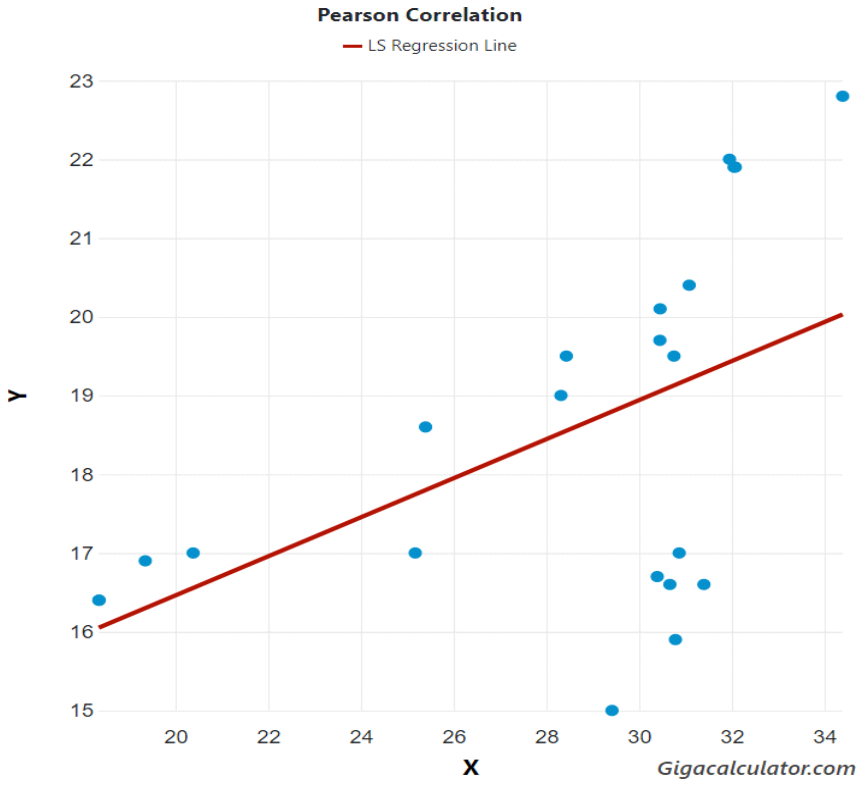


**Fig. 2: Relationship between temperature (y: °C) and longitude (x: °East) in *Centrobolus* Cook, 1897.**

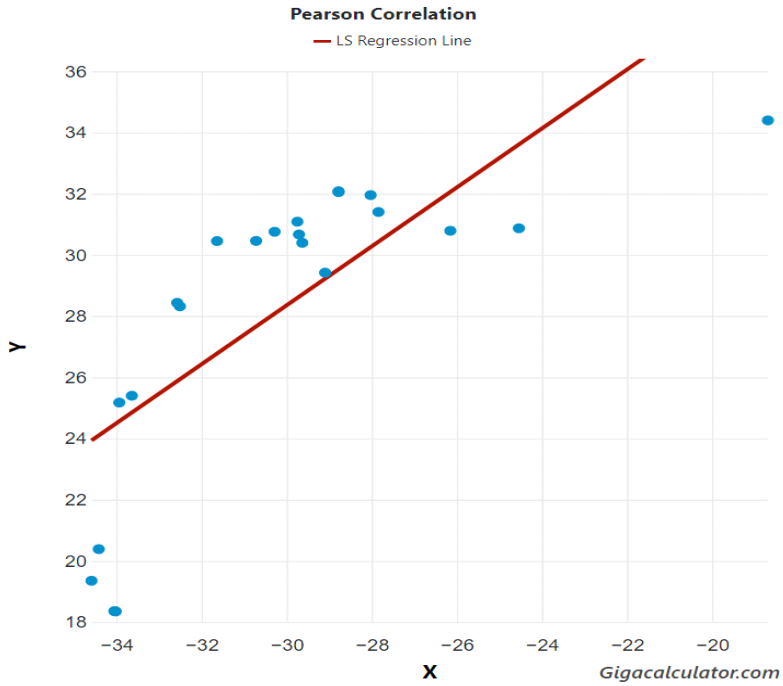


**Fig. 3: Relationship between latitude (x: °S) and longitude (y: °East) in *Centrobolus* Cook, 1897.**

## IV. DISCUSSION

There was an important significant positive relationship between SSD and longitude which did not differ from the SSD decline with latitude (Cooper, in press). *C. immaculatus* has the highest SSD (2.72) and is most eastern (34.394°E). SSD of western species includes *C. promontorius* (0.69). This study supports body size as a determiner of the longitudinal SSD gradient [4]. SSD increases with longitude and decreases with latitude with size increases across longitude (Cooper, in press). Positive-assortative mating based on width and length also determines the variance in polygynandrous mating systems across longitudes with larger females and higher SSD occurring at higher longitudes. The evidence is for a sexual selection regime shifting from favoring larger males in the east to favoring smaller males in the west [2] because SSD increased systematically with longitude and increased with body size [5].

In the treefrog, *Scinax fuscovarius* body size is negatively related to precipitation and varies with longitude [6]. Size-assortative mating based on width and male length determine the variance in millipede polygynandrous mating systems across a longitudinal gradient with higher SSD occurring eastwards due to sexual bimaturism and fertility selection [7, 9]. Precipitation and temperature may be explanations for skewed sex ratios in species showing sexual size dimorphism, such as millipedes, because these factors covary with longitude [8].

## V. CONCLUSION

SSD increased systematically with longitude, precipitation, and temperature and decreased systematically with latitude in *Centrobolus*. SSD increased with body size in this genus. Eco-geographical variance in the polygynandrous reproductive systems occurs if larger females and higher SSD occur in eastern habitats.

### COMPETING INTERESTS

The author has declared that no competing interests exist.

### REFERENCES

[1] R. F. Lawrence, "The Spiroboloidea (Diplopoda) of the eastern half of Southern Africa*," Annals of the Natal Museum, vol. 18, issue. 3, pp. 607-646, 1967.

[2] O. F. Cook, "New relatives of *Spirobolus giganteus*," Brandtia (A series of occasional papers an Diplopoda and other Arthropoda), vol. 18, pp. 73-75, 1897.

[3] M. L. Hamer, "Checklist of Southern African millipedes (Myriapoda: Diplopoda)," Annals of the Natal Museum, vol. 39, issue. 1, pp.11-82, 1998.

[4] H. Hillebrand and A. I. Azovsky, "Body size determines the strength of the latitudinal diversity gradient," Ecography, vol. 24 issue. 3, pp. 251-256, 2008.

[5] R. Dudaniec, A. R. Carey, E. I. Svensson, B. Hansson, C. J. Yong, L. T. Lancaster, "Latitudinal clines in sexual selection, sexual size dimorphism, and sex-specific genetic dispersal during a poleward range expansion," Journal of Animal Ecology, 2021. URL: https://doi.org/10.1111/1365-2656.13488.

[6] J. Goldberg, D. Cardozo, F. Brusquetti, B. Villafañe, A. C. Gini, C. Bianchi, "Body size variation and sexual size dimorphism across climatic gradients in the widespread treefrog *Scinax fuscovarius* (Anura, Hylidae)," Austral Ecology, vol. 43 issue. 1, pp. 35-45, 2018.

[7] M. I. Cooper, "Sexual bimaturism in the millipede *Centrobolus inscriptus* Attems (Spirobolida: Trigoniulidae)," Journal of Entomology and Zoology Studies, vol. 4, issue. 3, pp. :86-87, 2016.

[8] Chance DL. Understanding the effects of temperature on sex ratio in a sexually dimorphic fish species. URL: https://norriscenter.ucsc.edu/student-projects/chance-mosquito-fish.pdf.

[9] J. M. Monnet and M. I. Cherry, "Sexual size dimorphism in anurans," Proceedings of the Royal Society of London, vol. 269, pp. 2301-2307, 2002.