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DOES SEXUAL SIZE DIMORPHISM VARY WITH MONTH WITH THE HIGHEST NUMBER OF RAINY DAYS IN FOREST MILLIPEDES *CENTROBOLUS* COOK, 1897

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Abstract

The objectives of this study were to determine what happened when Bergmann's Rule met Rensch's Rule if Sexual Size Dimorphism (SSD) and body size changed with an eco-geographical factor. The month with the highest number of rainy days was correlated with body size and SSD in the forest millipede genus Centrobolus. *There was a significant positive correlation between SSD and the month with the highest number of rainy days (r=0.37, Z score=1.71, n=22, p=0.04). Eco-geographical variance in the polygynandrous reproductive systems occurs with larger females and higher SSD occurring in the month with the highest number of rainy days.*

Keywords: *Dimorphic; eco-geography; gradient; precipitation; size; species.*

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 76.2-101.6 cm, 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 [6].

Sexual size dimorphism (SSD) is correlated with the month with the highest number of rainy days in the pachybolid millipede genus *Centrobolus* Cook, 1897 [2, 5, 6]. The null hypothesis is that there is no body size correlation with the month with the highest number of rainy days.

MATERIALS AND METHODS

39 valid species were identified as belonging to the genus *Centrobolus* Cook, 1897. Millipede-type localities were obtained from a checklist of southern African millipedes [5]. These were tabulated and known type localities also listed in Microsoft Word online (https://office.live.com/start/Word.aspx) (Table 1). GPS coordinates were obtained from internet

sources for known type localities using google (https://www.google.co.za/maps/place). The month with the highest number of rainy days, mean annual precipitation, and temperature values were obtained from https://en.climate-data.org/search/?q=. 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 latitude, longitude, precipitation, and temperature were checked for correlations using the Pearson Correlation Coefficient calculator (https://www.gigacalculator.com/calculators/correlation-coefficient-calculator.php).

RESULTS

There was a significant positive correlation between SSD and the month with the highest number of rainy days (Fig. 1: r=0.37383618, Z score=1.71250287, n=22, p=0.04340198). There was no difference between the correlation coefficients of SSD with month with the highest number of rainy days month and the highest number of rainy days with temperature (z=0.8247, p=0.4095), SSD with month with the highest number of rainy days and month with the highest number of rainy days with latitude (z=-1.2711, p=0.2037), or SSD with month with the highest number of rainy days and month with the highest number of rainy days with longitude (z=-1.1738, p=0.2405). The most number of rainy days in a month correlated with precipitation (Fig. 2: r=0.46440263, Z score=2.19213378, n=22, p=0.01418487), latitude (Fig. 3: r=0.66697254, Z score=3.51008942, n=22, p=0.00022402), and longitude (Fig. 4: r=0.64907296, Z score=3.37245882, n=22, p=0.00037255), but not temperature (r=0.12464321, Z score=0.54614729, n=22, p=0.29248232). The data for the month with the highest number of rainy days was normally distributed (D=0.13066, n=22, p=0.13351). SSD was normally distributed (D=0.15168, n=22, p=0.80092).

Table 1. Species in the millipede genus *Centrobolus* Cook, 1897, with SSD, type or collected localities GPS latitude and longitude points, the month with the highest number of rainy days, and precipitation.

Species	SSD	Location	Latitude (°S)	Longitude (°E)	The month with highest number of rainy days	Precipitation (mm)
C. albitarsis	2.89	Lochiel	-26.150174	30.786	19.90 (Dec.)	919
C. angelicus		Makhanda	-33.318134			
C. anulatus	1.19	Umhlanga Rocks	-29.746190	31.084	13.73 (Dec.)	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	19.33 (Dec.)	962
C. digrammus	1.01	Hout bay	-34.047685	18.357	10.50 (June)	498
C. dubius	1.35	Gans bay	-34.584895	19.350	10.40 (June)	408
C. formosus		caffraria	-	-		
C. fulgidus	1.65	Richards Bay	-28.778417	32.049	13.97 (Nov.)	944
C. immaculuatus	2.72	Gorongosa	-18.686597	34.394	21.03 (Jan.)	1266
C. inscriptus	1.21	Scottburgh	-30.280460	30.754	15.23 (Dec.)	1015
C. inyanganus	1.44	Inyanga village	-29.707964	30.666	13.73 (Dec.)	893
C. lawrencei	1.57	Pietermaritzburg	-29.630118	30.393	19.27 (Dec.)	966
C. litoralis		Algoa Bay	-33.967135			
C. luctuosus		Inhambambane	-23.900071			
C. lugubris	2.18	Glenconnor	-33.932215	25.173	8.67 (Mar.)	497
C. miniatomaculatus		Tsitsikamma	-32.220918			

C. pococki		Cape Peninsula	-34.244295			
C. promontorius	0.69	Little Lions Head	-34.016370	18.348	11.07 (June)	621
C. pusillus	2.08	Qolora River mouth	-32.571689	28.433	14.07 (Jan.)	1050
C. richardii	0.95	Richards Bay	-28.778417	32.078	13.97 (Nov.)	944
C. ruber	1.62	Port Shepstone	-30.715740	30.456	14.67 (Dec.)	945
C. rubricollis		Karkloof waterfall	-29.399869			
C. rugulosus	1.97	Hluhluwe	-28.024622	31.952	13.77 (Jan.)	837
C. sagatinus	1.27	Between Uitenhage and Addo	-33.636710	25.396	8.67 (Mar.)	497
C. sanguineomarginatus		Bain's Kloof	-33.613179		11.07 (June)	
C. sanguinipes		Qolora River mouth	-32.571689			
C. saussurii		caffraria	-	-		
C. silvanus	1.13	Kentani	-32.506398	28.317	8.67 (Mar.)	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	7.10 (Mar.)	401
C. transvaalicus	1.26	Mariepskop	-24.539147	30.867	10.10 (Dec.)	1200
C. tricolor	1.10	Champaigne Castle	-29.093869	29.418	18.50 (Dec.)	265
C. validus		Haroni River	-19.817644			
C. vastus	1.81	Port St Johns	-31.633371	30.451	16.97 (Dec.)	1089

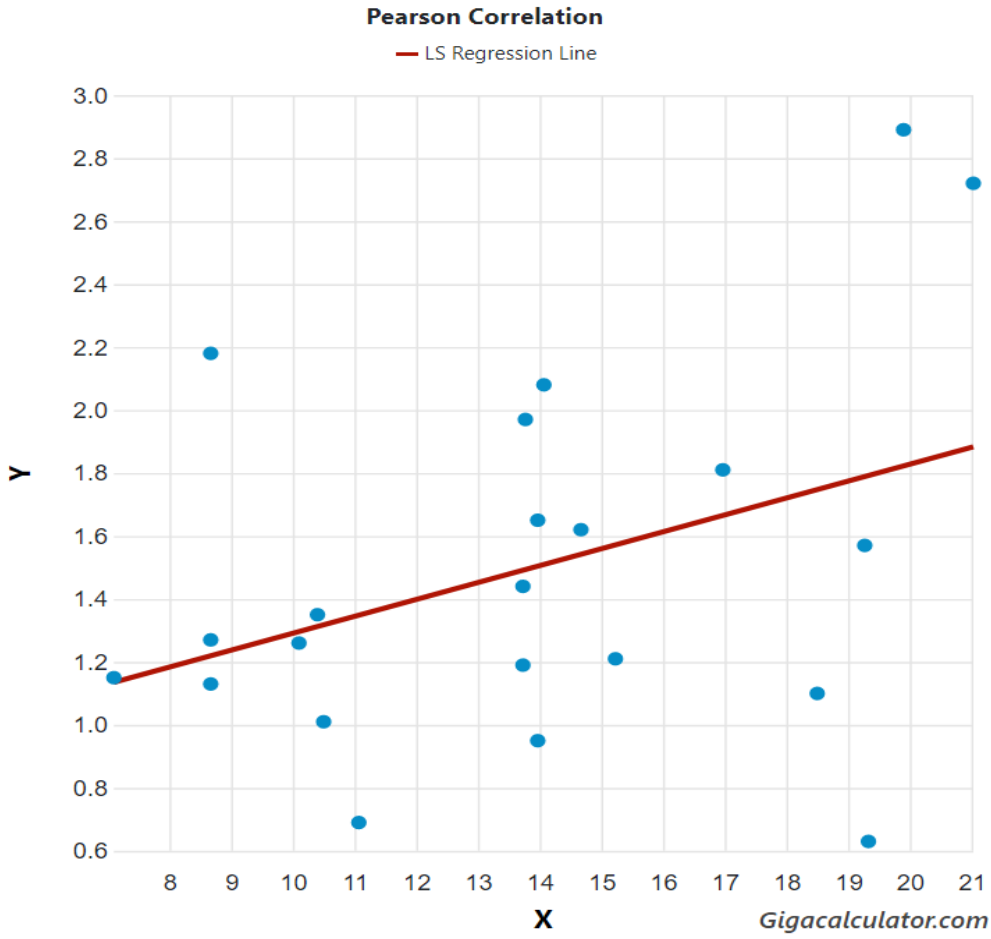

Fig. 1. Relationship between Sexual Size Dimorphism (y-axis) and month with the highest number of rainy days (x-axis) in *Centrobolus* Cook, 1897.

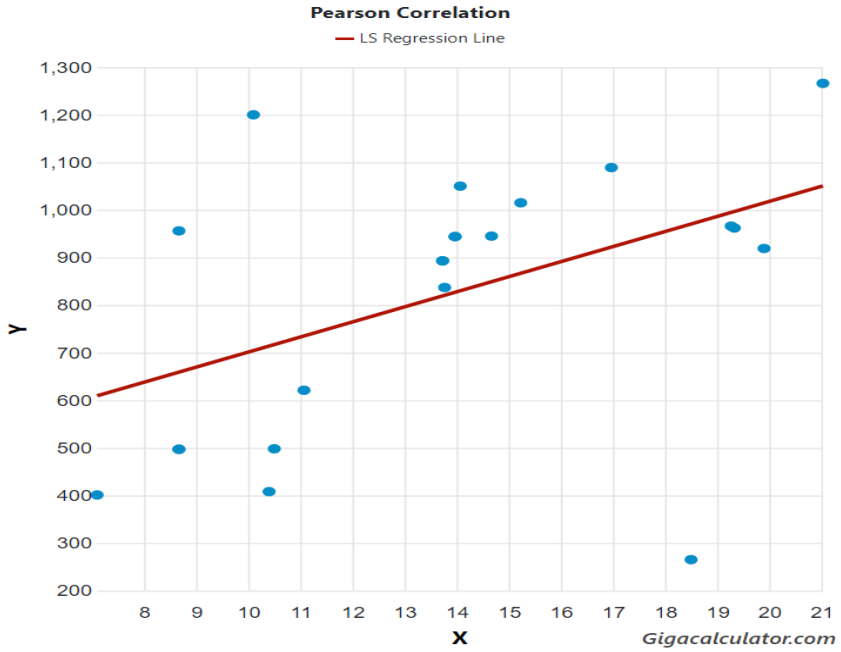

Figure 2. Relationship between precipitation (y: millimeters) and most number of rainy days in a month (x) in *Centrobolus* Cook, 1897.

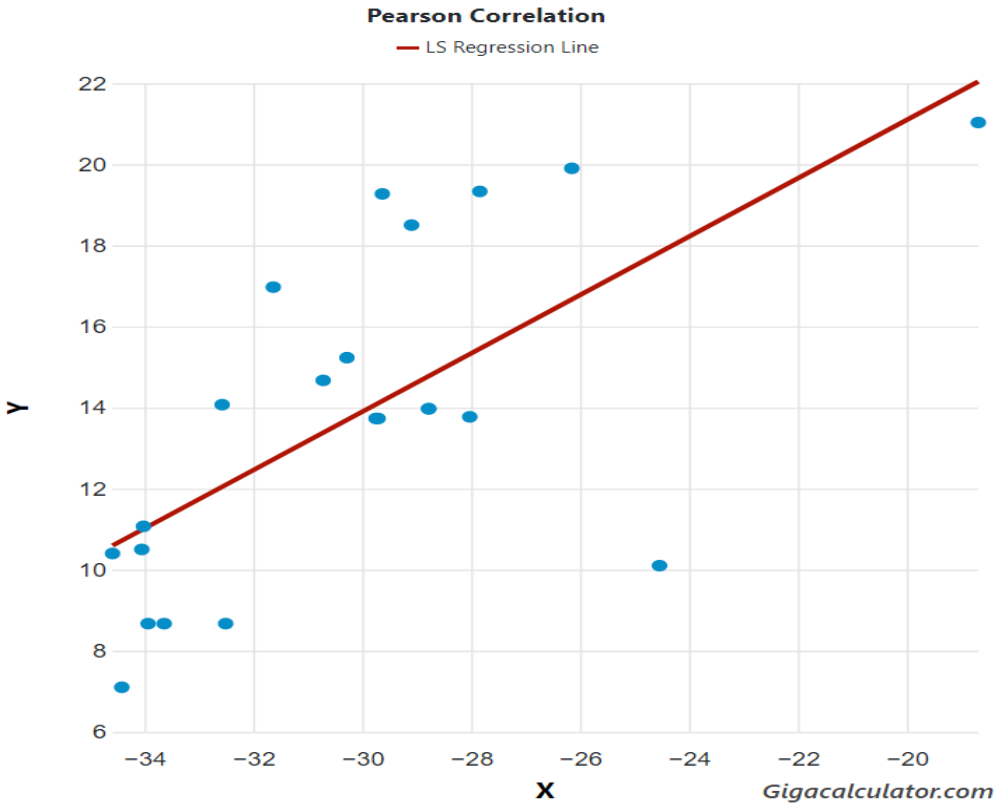

Fig. 3. Relationship between a month with the highest number of rainy days (y) and latitude (x: °South) in *Centrobolus* Cook, 1897.

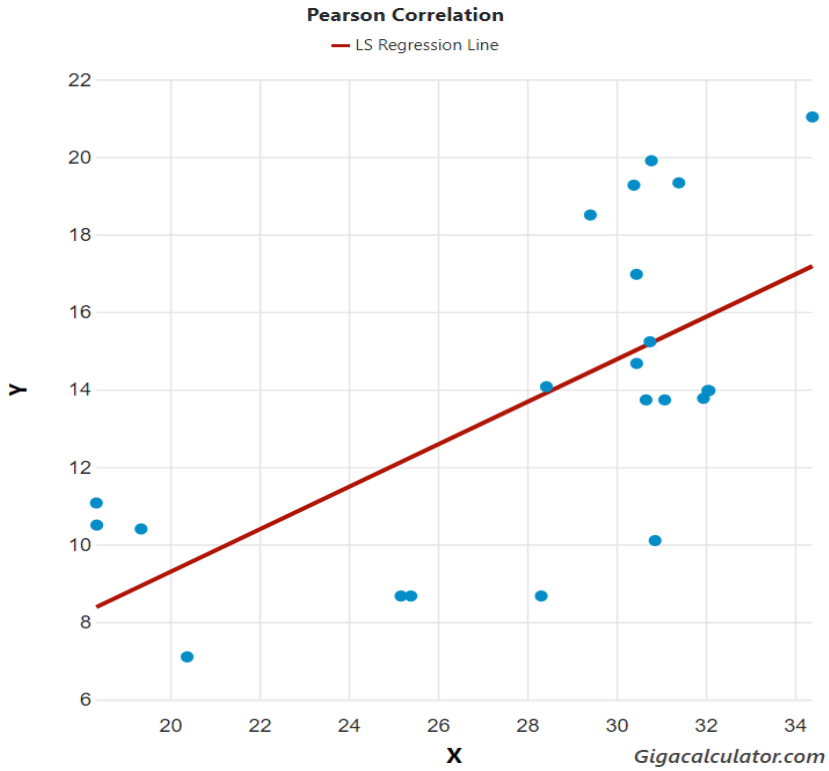

Fig. 4. Relationship between a month with the highest number of rainy days (y) and longitude (x: °East) in *Centrobolus* Cook, 1897.

DISCUSSION

Four relationships between body size and month with the most number of rainy days were found with positive correlations between SSD and latitude, longitude and month with the most number of rainy days. *C. immaculatus* has the highest SSD (2.72) and occurred in the month with the rainiest days (21.03 in January). SSD was second-lowest in *C. promontorius* (0.69) which occurred at 11.07 rainy days. This study supports the month with the most number of rainy days across latitude, longitude, and precipitation as predictors of SSD in *Centrobolus*.

In the treefrog *Scinax fuscovarius* body size is negatively related to precipitation [4]. In turtles, wetter climates are associated with male-biased SSD [1]. Geographic variation in body size and SSD of a Seed-feeding Beetle is related to precipitation [8]. Size-assortative mating based on width and male length determine the variance in millipede polygynandrous mating systems across the most number of rainy days in a month's gradient with higher SSD occurring at higher rainfall possibly due to sexual bimaturism [3]. Swarming and mating behavior is dependent on precipitation at the onset of the breeding season [7]. SSD increase with precipitation may explain greater mate competition. The number of rainy days in a month may be an explanation for skewed sex ratios in species showing sexual size dimorphism, such as millipedes.

CONCLUSION

SSD increased systematically with the month with the rainiest days 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 the month with the highest number of rainy days.

COMPETING INTERESTS

The author has declared that no competing interests exist.

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