

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

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Abstract

The objectives of this study were to determine what happened when Sexual Size Dimorphism (SSD) and body size changed with eco-geographical factors. Female volume, rainfall, and temperature in the coolest and warmest months of the year were correlated with latitude and longitude in the forest millipede genus *Sphaerotherium*. Positive relationships between female volume and latitude ($r = 0.75$; Z score = 1.96, $n = 7$, $p = 0.02$) and longitude ($r = 0.70$, Z score = 1.74, $n = 7$, $p = 0.04$) found. There was a correlation between lowest average temperature and latitude ($r=0.89$, Z score=2.80, $n=7$, $p<0.01$) and longitude ($r=0.88$, Z score=2.78, $n=7$, $p<0.01$). There was a correlation between highest average temperature and latitude ($r=0.92$, Z score=3.16, $n=7$, $p<0.01$) and longitude ($r=0.91$, Z score=3.07, $n=7$, $p<0.01$). There was a correlation between precipitation and latitude ($r=0.91$, Z score=3.02, $n=7$, $p<0.01$) and longitude ($r=0.71$, Z score=1.78, $n=7$, $p=0.04$). There was a correlation between temperature and latitude ($r=0.92$, Z score=3.14, $n=7$, $p<0.01$) and longitude ($r=0.91$, Z score=3.00, $n=7$, $p<0.01$). There was a correlation between the month with the highest number of rainy days and latitude ($r=0.76$, Z score=1.99, $n=7$, $p=0.02$) and not longitude and lowest hours of sunshine and latitude ($r=0.82$, Z score=2.34, $n=7$, $p<0.01$) and not longitude. Eco-geographical variance in the polygynandrous reproductive systems occurs with larger females and higher SSD co-occurring with the lowest average temperature, higher rainfall, and warmer temperatures.

Keywords: Dimorphic, eco-geography, gradient, size, species, volume.

INTRODUCTION

A forest genus of diplopods belonging to the Order Sphaerotheriida found along the eastern coast of southern Africa was the subject of this study. The millipede genus *Sphaerotherium* is found in the temperate South African subregion. 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 [18, 58, 59].

Female volume, lowest average temperature, rainfall, and temperature in the warmest month of the year are correlated with latitude and longitude in the sphaerotheriid millipede genus *Sphaerotherium* Brandt, 1833 [29]. Like other millipedes, these pill millipedes have female-biased SSD [18-21, 60]. The null hypothesis is that there are no correlations between female volume, lowest average temperature, rainfall, and temperature in the warmest month of the year and latitude or longitude.

MATERIALS AND METHODS

60 valid species were identified as belonging to the genus *Sphaerotherium* Brandt, 1833. Millipede-type localities were obtained from a checklist of southern African millipedes [29]. These were tabulated and known type localities also listed in Microsoft Word online (<https://office.live.com/start/Word.aspx>). GPS coordinates were obtained from internet sources for known type localities using google (<https://www.google.co.za/maps/place>). Female volume, the lowest average temperature, rainfall, and temperature in the warmest month of the year were obtained from <https://en.climate-data.org/search/?q=> and internet sources for known type localities using google (<https://www.google.co.za>). Female volume, lowest average temperature, rainfall, the temperature in the warmest month of the year, latitude, and longitude were checked for correlations using the Pearson Correlation Coefficient calculator (<https://www.gigacalculator.com/calculators/correlation-coefficient-calculator.php>).

RESULTS

There was a correlation between lowest average temperature and latitude (Figure 1: $r=0.88502020$, Z score= 2.79693738 , $n=7$, $p=0.00257954$) and longitude (Figure 2: $r=0.88346705$, Z score= 2.78269544 , $n=7$, $p=0.00269553$) across the distribution of *Sphaerotherium*. There was a correlation between precipitation and latitude (Figure 3: $r=0.90680285$, Z score= 3.01846603 , $n=7$, $p=0.00127036$) and longitude (Figure 4: $r=0.71113080$, Z score= 1.77893573 , $n=7$, $p=0.03762510$) across the distribution of *Sphaerotherium*. There was a correlation between temperature and latitude (Figure 5: $r=0.91726446$, Z score= 3.14300545 , $n=7$, $p=0.00083618$) and longitude (Figure 6: $r=0.90514637$, Z score= 2.99997918 , $n=7$, $p=0.00135006$) across the distribution of *Sphaerotherium*. Female volume was significantly related to latitude (Figure 7: $R = 0.75342985$; Z score = 1.96168254 , $n=7$, $P = 0.02489966$). The allometric equation generated for the genus was $\hat{y} = 873.39983811x + 31,125.46912075$. Female volume was significantly related to longitude (Figure 8: $R = 0.70126462$, Z score = 1.73956897 , $n = 7$, $P = 0.04096732$). The allometric equation generated for the genus was $\hat{y} = 266.73103251x - 4,124.29425132$. Female width was marginally related to longitude ($r=0.61406554$, Z score= 1.43084388 , $n=7$, $p=0.07623753$). Species body size was marginally related to longitude ($r=0.65114353$, Z score= 1.55456280 , $n=7$, $p=0.06002513$). There was a correlation between highest average temperature and latitude (Figure 9: $r=0.91826483$, Z score= 3.15569190 , $n=7$, $p=0.00080066$) and longitude (Figure 10: $r=0.91088511$, Z score= 3.06539533 , $n=7$, $p=0.00108698$). There was a correlation between month with the highest number of rainy days and latitude (Figure 11: $r=0.75846324$, Z score= 1.98517386 , $n=7$, $p=0.02356250$). There was correlation between lowest hours of sunshine and latitude (Figure 12: $r=0.82373651$, Z score= 2.33666274 , $n=7$, $p=0.00972834$),

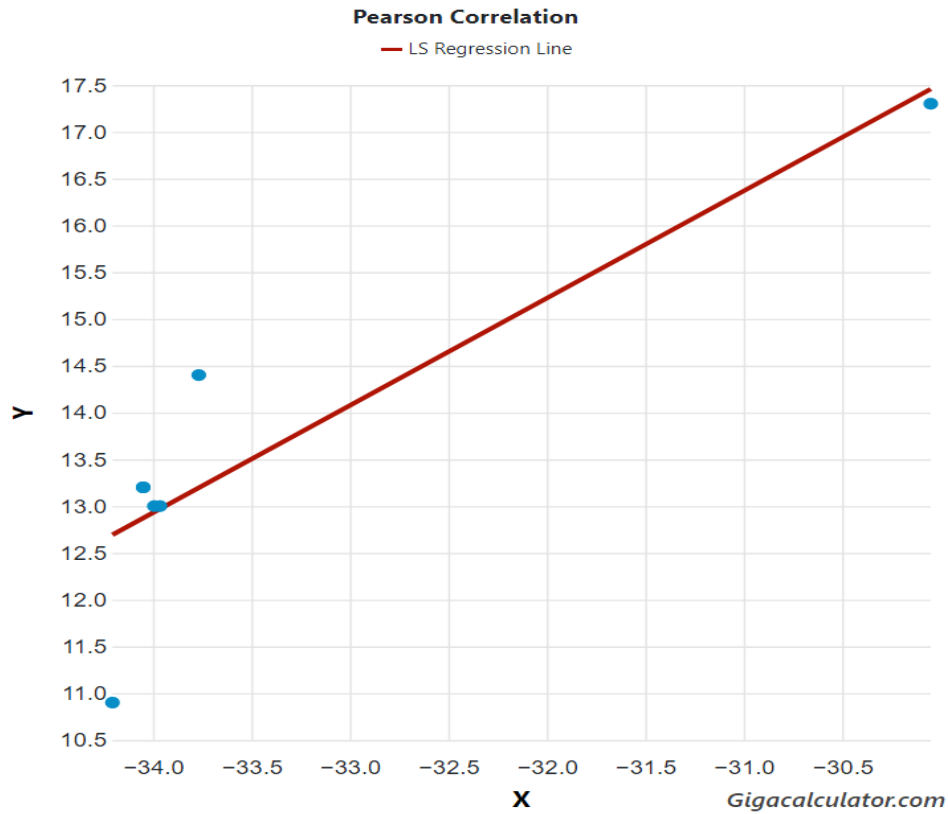


Figure 1. Correlation between lowest average temperature and latitude for *Sphaerotherium*.

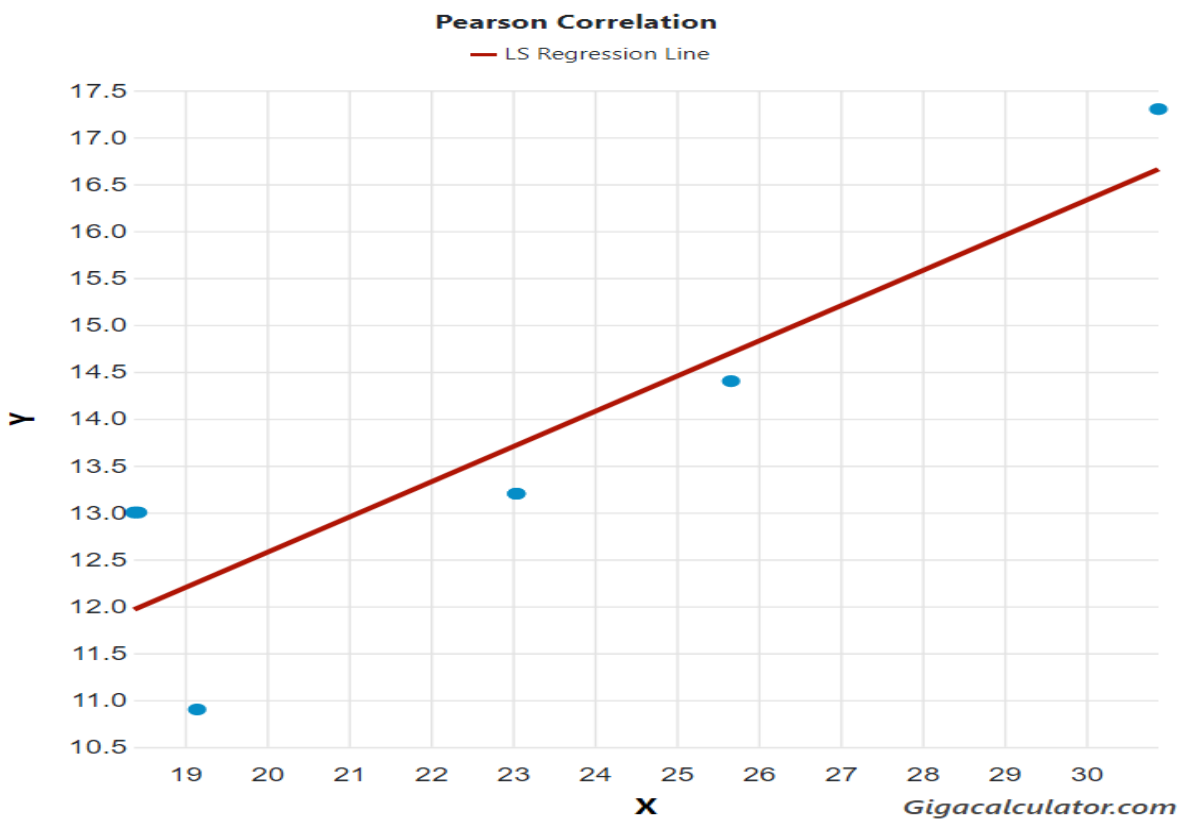


Figure 2. Correlation between lowest average temperature and longitude for *Sphaerotherium*.

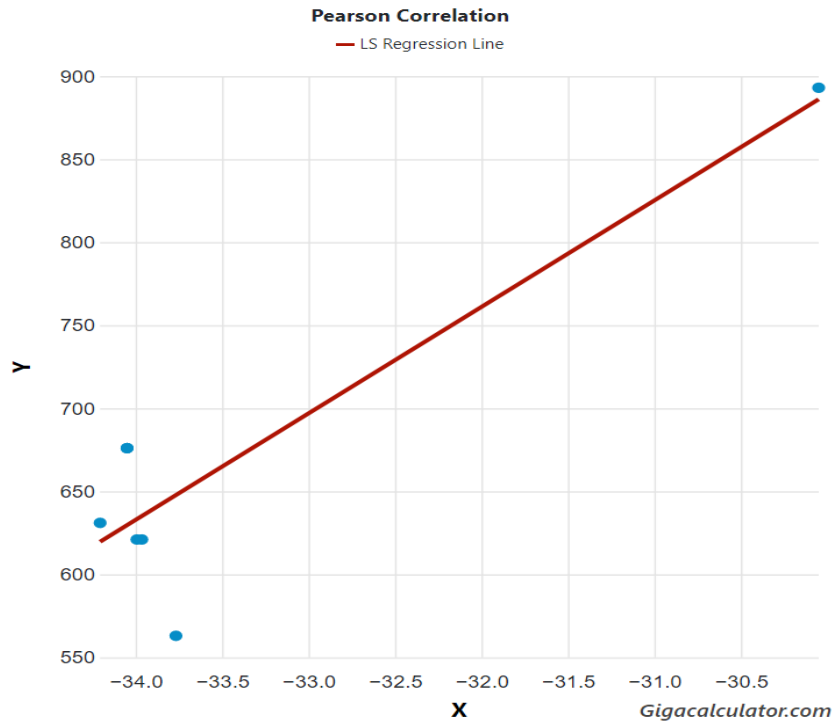


Figure 3. Correlation between precipitation and latitude for *Sphaerotherium*.

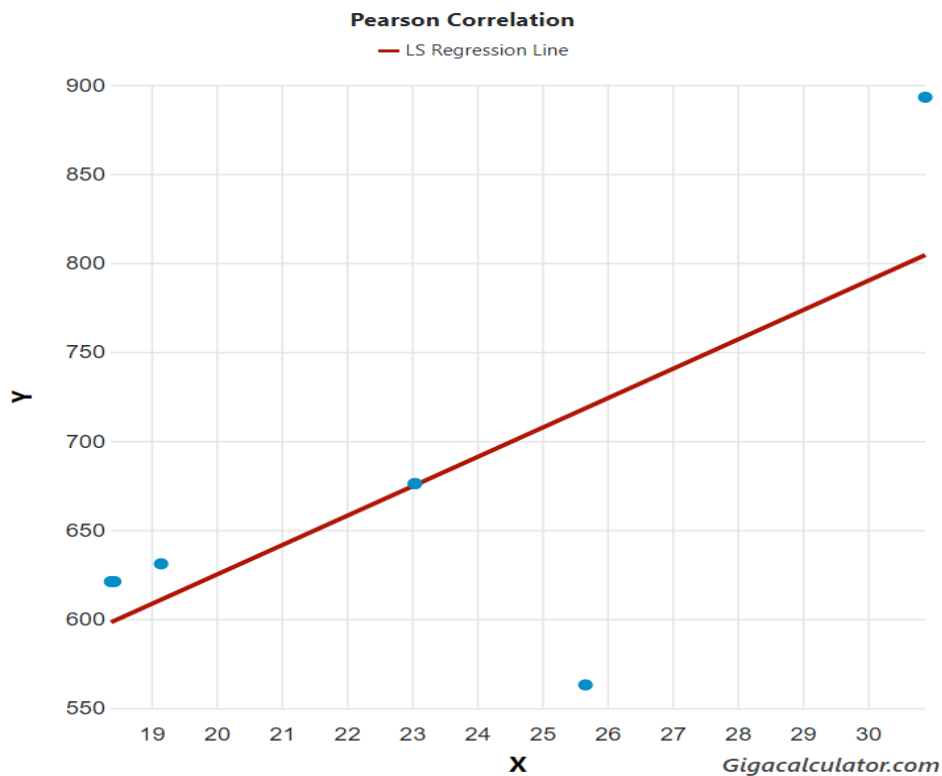


Figure 4. Correlation between precipitation and longitude for *Sphaerotherium*.

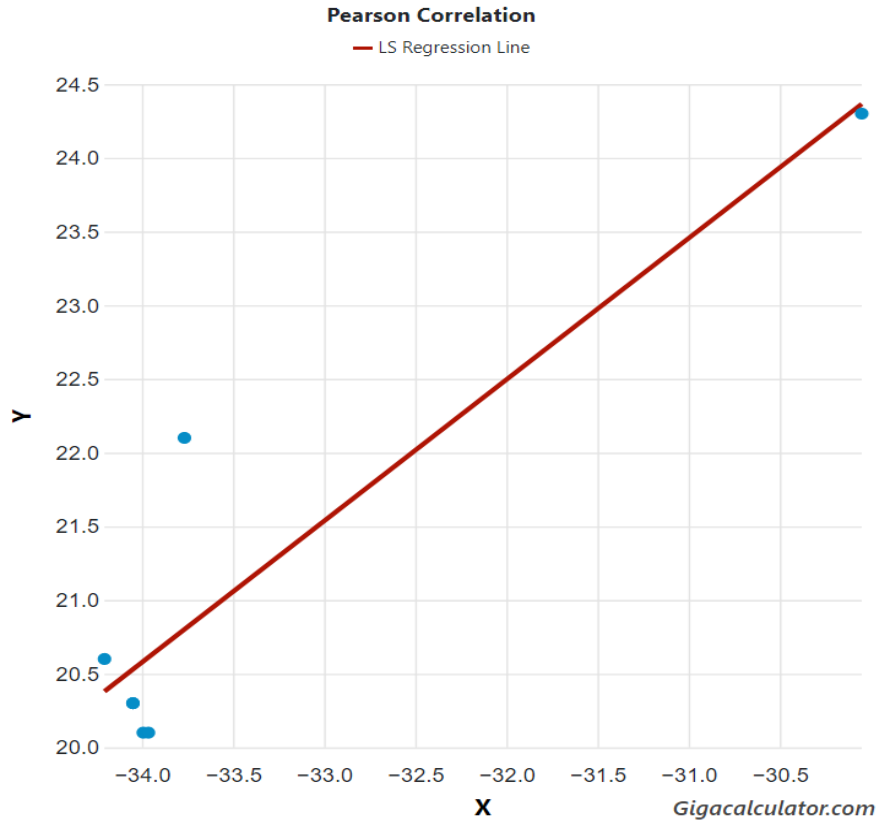


Figure 5. Correlation between temperature and latitude for *Sphaerotherium*.

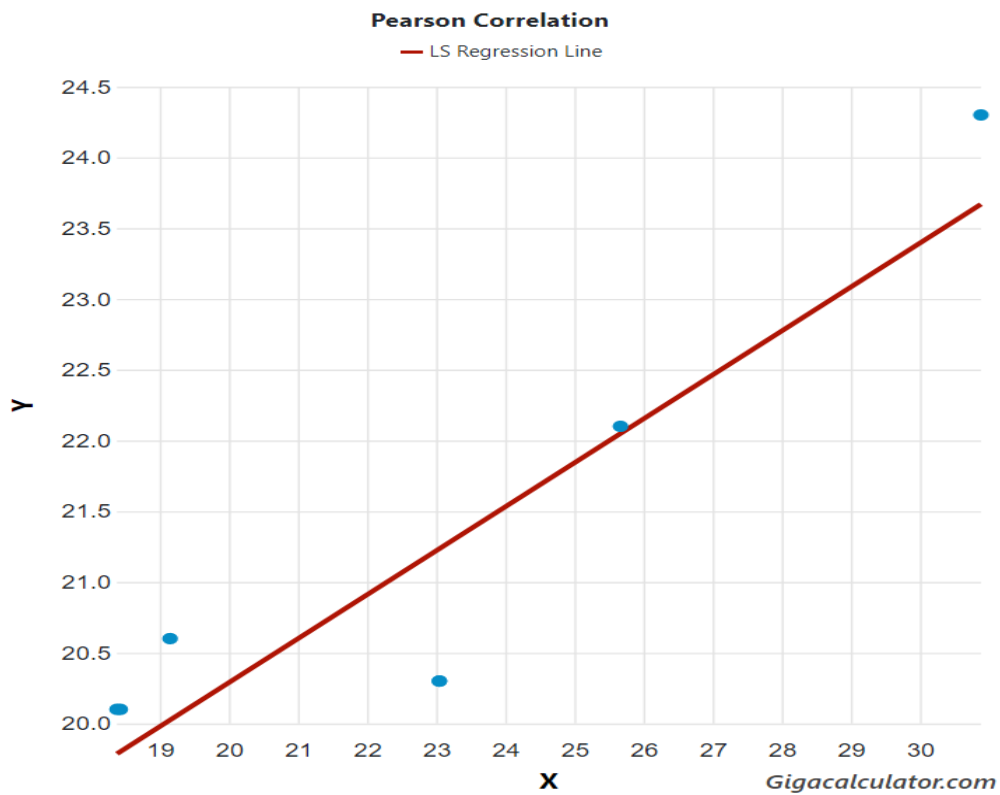


Figure 6. Correlation between temperature and longitude for *Sphaerotherium*.

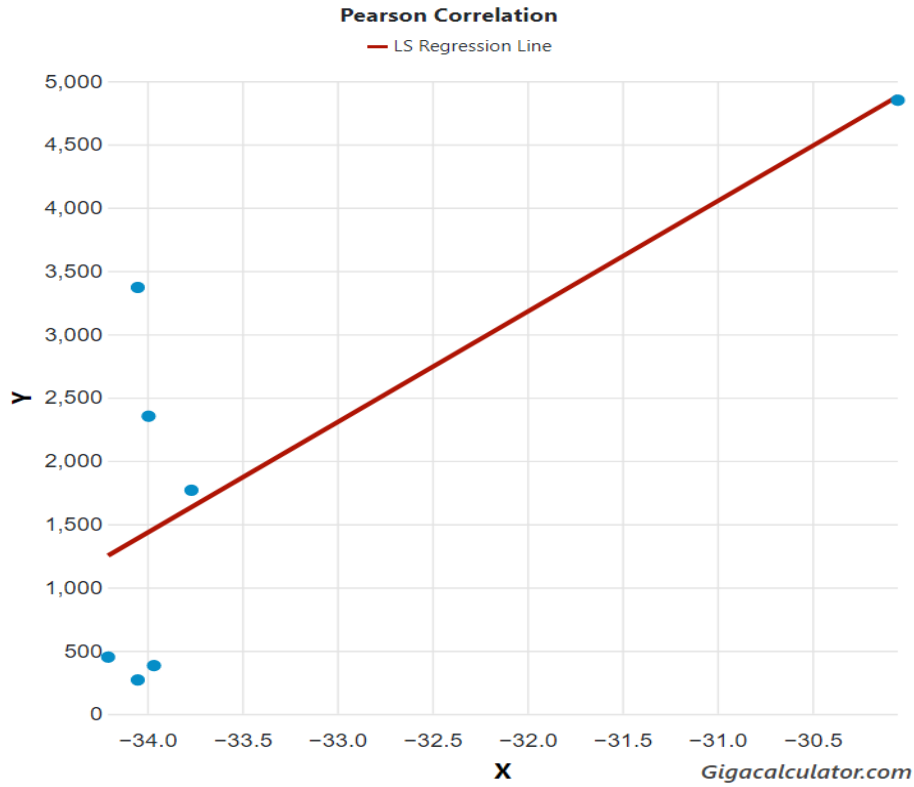


Figure 7. Relationship between female volume and latitude in *Sphaerotherium*.

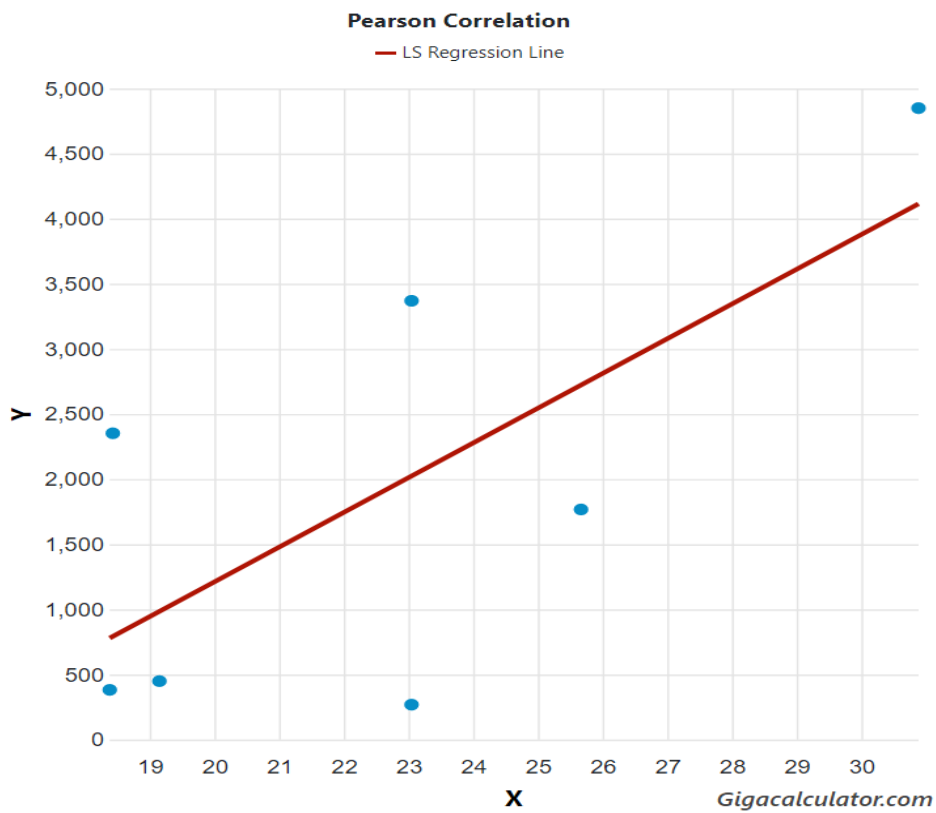


Figure 8. Relationship between female volume and longitude in *Sphaerotherium*.

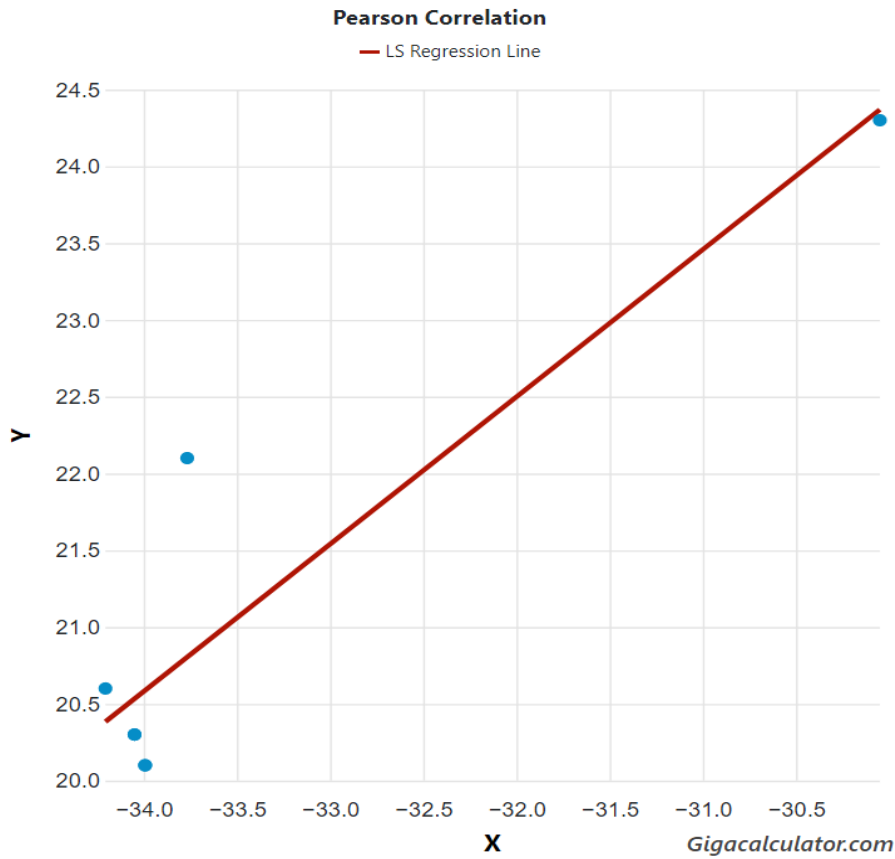


Figure 9. Relationship between highest average temperature and latitude in *Sphaerotherium*.

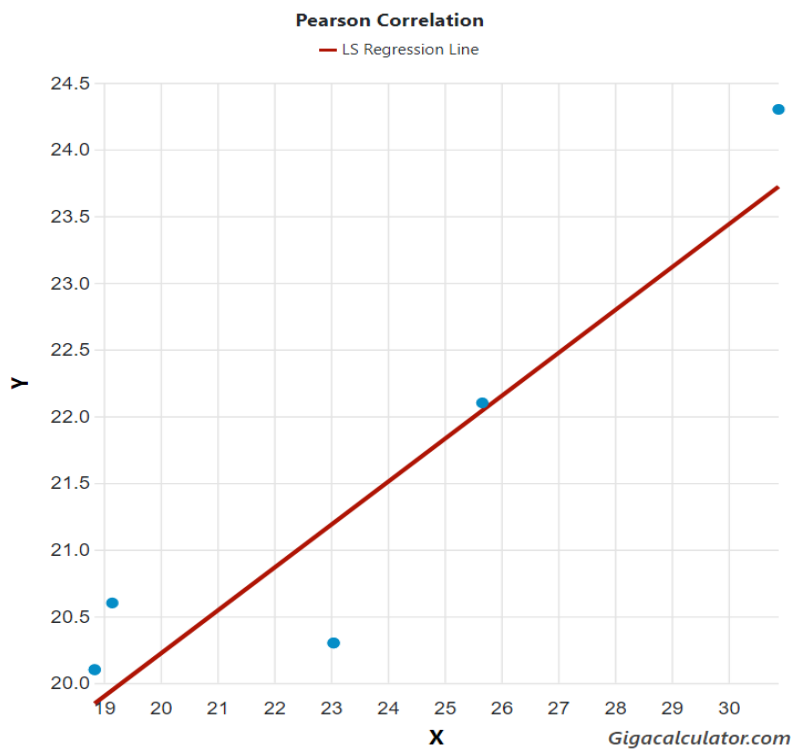


Figure 10. Relationship between highest average temperature and longitude in *Sphaerotherium*.

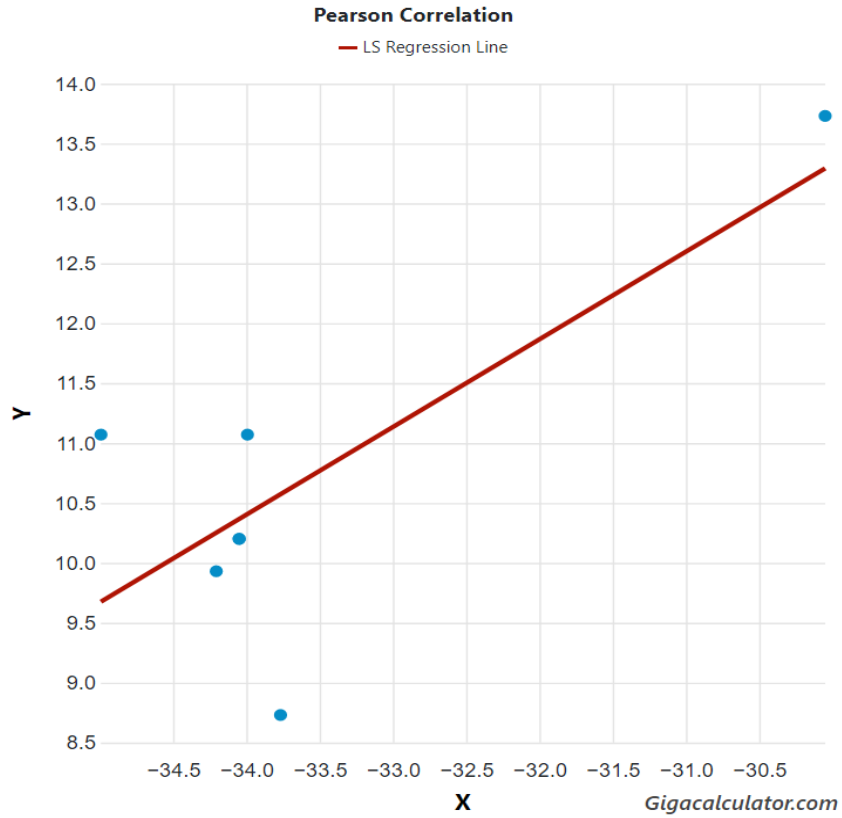


Figure 11. Relationship between a month with the highest number of rainy days and latitude in *Sphaerotherium*.

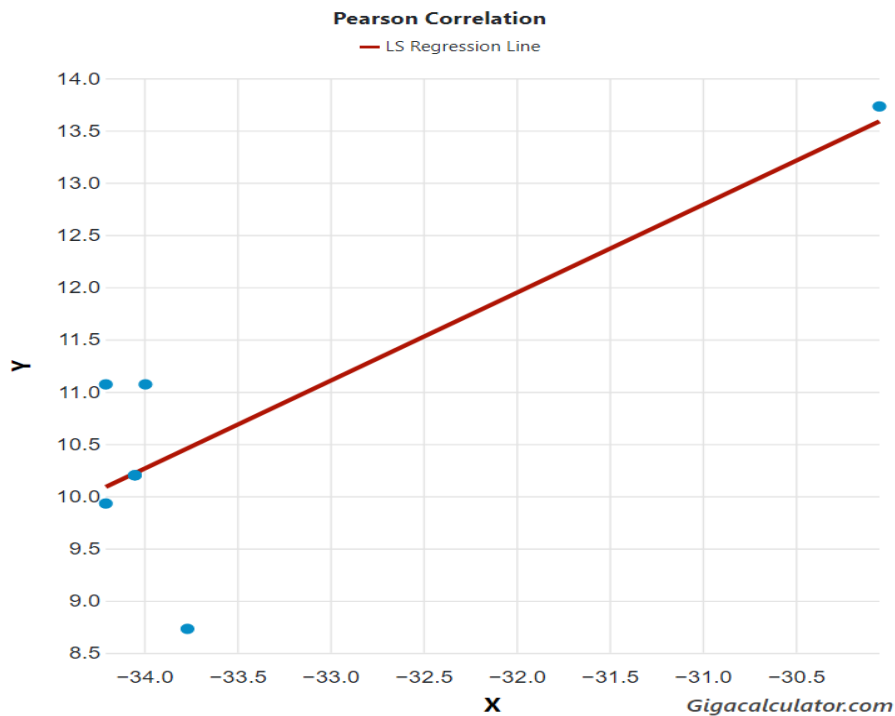


Figure 12. Correlation between lowest hours of sunshine (y) and latitude (x) for *Sphaerotherium*.

DISCUSSION

Ten pairs of positive relationships between female volume, highest and lowest average temperature, rainfall, the temperature in the warmest month of the year, and latitude and longitude were found in *Sphaerotherium*. Additionally, an eleventh relationship was found between a month with the highest number of rainy days and latitude but not longitude. Near Durban (latitude: 30.1 degrees East) there was the highest lowest average temperature (17.3 degrees Celsius), the highest temperature in the warmest month of the year (24.3 degrees Celsius), and the highest amount of precipitation (893 mm).

The correlations of female volume on latitude and longitude indicate positive correlations in *Sphaerotherium* and are comparable with some taxa having female-biased SSD [5, 9, 10, 24, 26, 27, 30, 32, 34-43, 45, 49-51, 53-54, 57]. Mean volume ratios in *Sphaerotherium* suggest a relatively high variance of SSD ranging from 1.49 in *S. tenuitarse* to 5.36 in *S. punctulatum* which were both larger than helminthomorph diplopods [17, 31]. The inclusion of many more taxa as new species from this genus is suggested to show support the trend of larger females as seen here. The identification of species-specific and intraspecific sexual size dimorphism patterns using a phylogenetic approach may provide useful information for exploring mating systems further [57]. Tree climbing behavior suggests interspecific competition drives the SSD [28]. Female volume is possibly linked to fecundity selection.

CONCLUSION

This study supports highs in the highest and lowest average temperature, the month with the highest number of rainy days, rainfall, and the highest temperature in the warmest month of the year as predictors of SSD in *Sphaerotherium*. Female volume coupled with the highest and lowest average temperature, the month with the highest number of rainy days, and rainfall may explain greater fecundity selection. Higher temperature and rainfall may be an explanation for activity in species showing sexual size dimorphism, such as millipedes.

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