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THE SURFACE AREA IS RELATED TO MATING FREQUENCIES ACROSS SYMPATRIC *CENTROBOLUS ANULATUS* (ATTEMS, 1934) AND *C. INSCRIPTUS* (ATTEMS, 1928)

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Abstract

In this paper, I test for a relationship between surface area and mating frequencies in two species of red millipedes Centrobolus Cook, 1897 (C. anulatus and C. inscriptus). Female surface areas were positively related to mating frequencies (r=0.92554221, Z score=5.86394325, n=16, p=0) (y=276.35152998 · x + 1,809.30424336). Species surface areas were positively related to mating frequencies (r=0.92554221, Z score=5.86394325, n=16, p=0) (y=151.19277169 · x + 1,721.82638446). This emphasizes the importance of female and species surface area relationships in predicting mating frequencies in this genus.

Keywords: *relationship, species, mating frequencies, surface area*

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 mating frequencies and surface area were checked.

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 = $2\pi r(r+h)$ in 2 *Centrobolus* species. The 2 species of millipedes were given SSD. The 2 species were morphologically separated based on their distinct morphological characters. Surface areas were equated against SSD and SSD was 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. Correlations between mating frequencies and female and species' surface area were checked at https://www.gigacalculator.com/calculators/correlation-coefficient-calculator.php.

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RESULTS

Female and female and male (species) surface areas were calculated (Appendix 1 & 2). Female surface areas were positively related to mating frequencies (Figure 1: r=0.92554221, Z score=5.86394325, n=16, p=0) (y=276.35152998 · x + 1,809.30424336). Species surface areas were positively related to mating frequencies (Figure 2: r=0.92554221, Z score=5.86394325, n=16, p=0) (y=151.19277169 · x + 1,721.82638446).

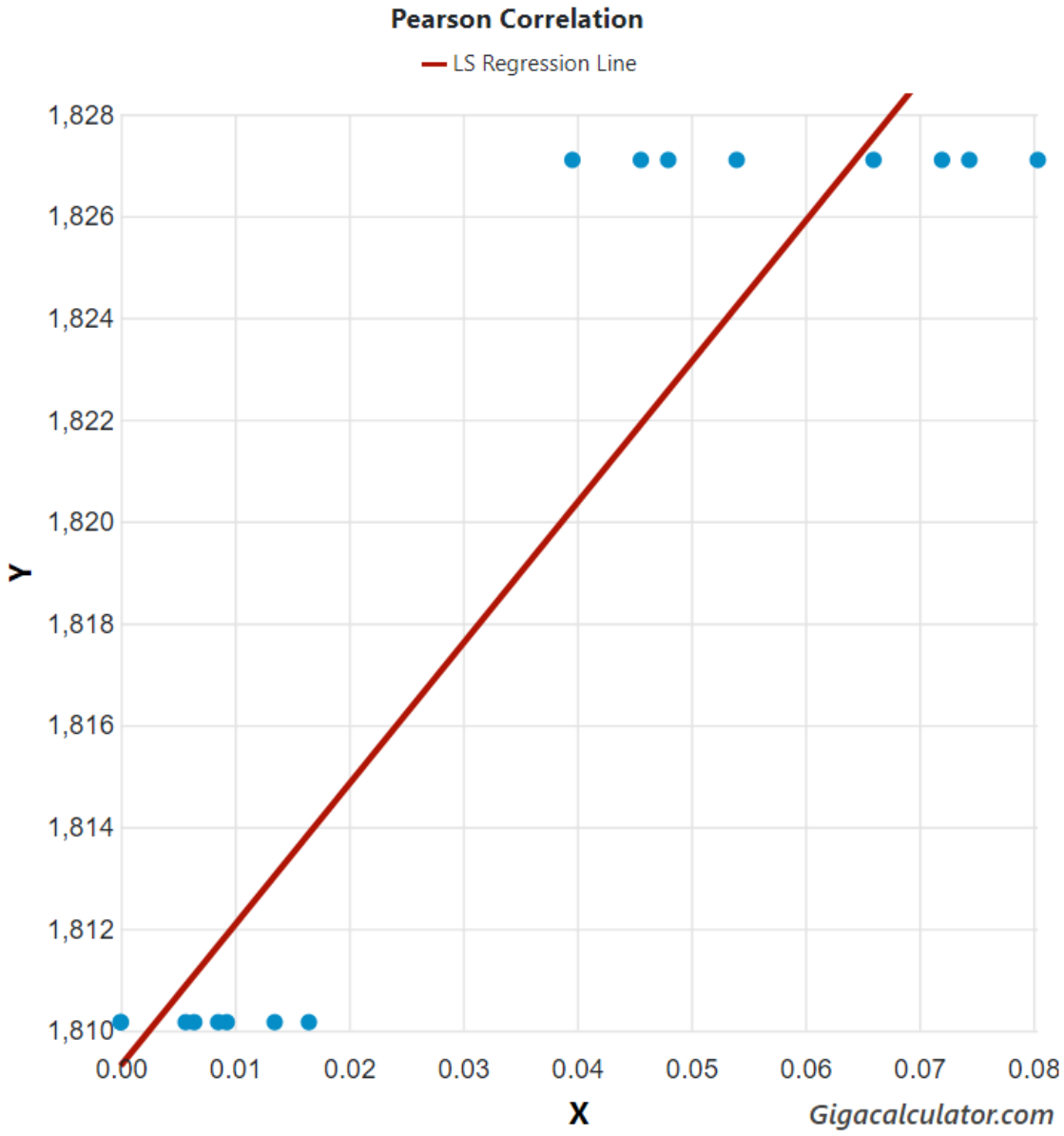

Figure 1. Relationship between mating frequencies and female surface area in *Centrobolus* Cook, 1897.

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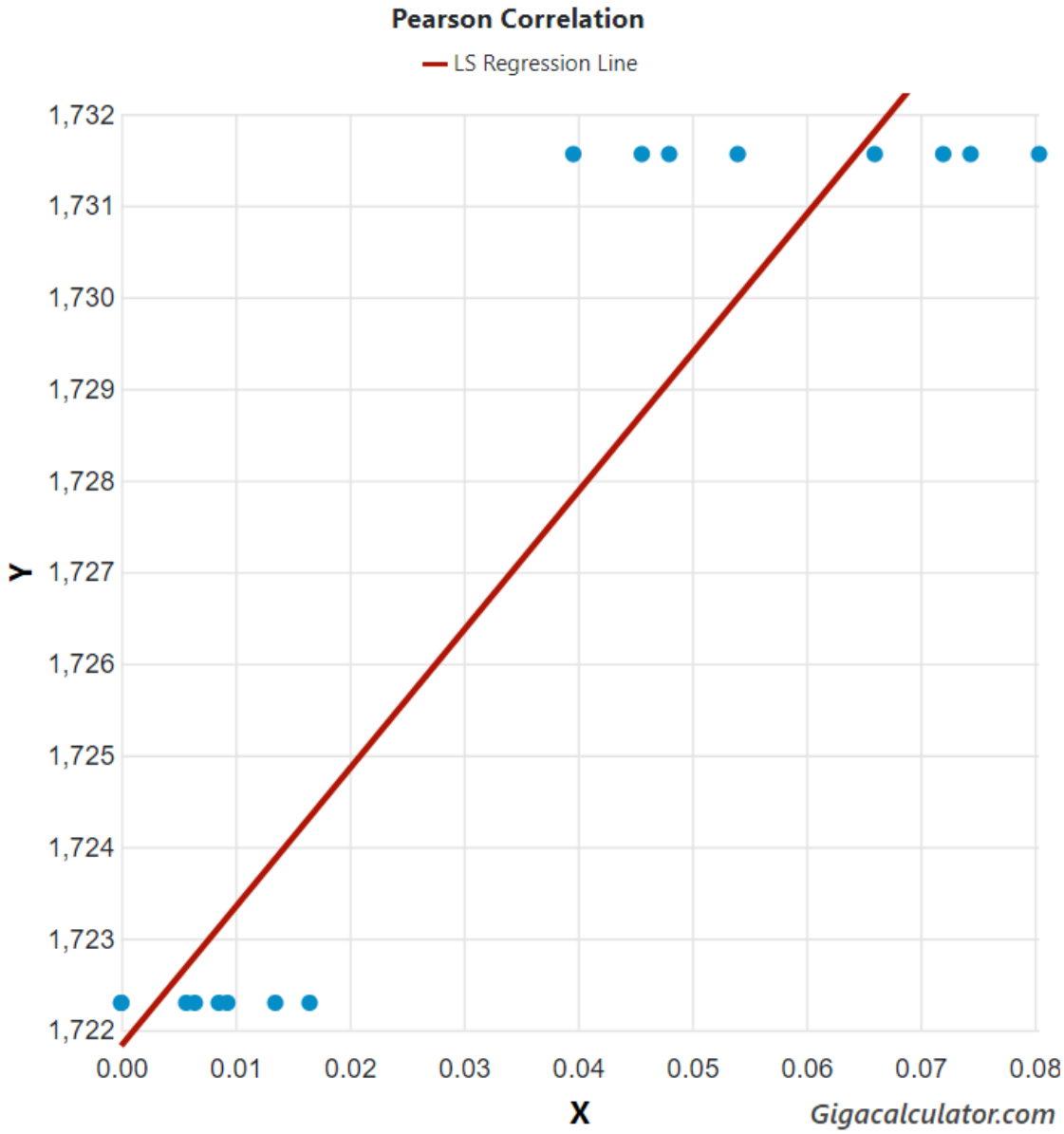

Figure 2. Relationship between mating frequencies species and surface area in *Centrobolus* Cook, 1897 species.

DISCUSSION

New relationships between mating frequencies and surface areas are documented here in both females and species in the genus of red millipedes *Centrobolus*. The surface area was positively related to mating frequencies across species and females. Mean surface areas were estimated from SSD-surface area equations. This emphasizes the importance of female and species surface area relationships in predicting mating frequencies in this genus.

APPENDIX I. Mating frequencies recorded in *Centrobolus* (first eight are *C. anulatus,* second eight are *C. inscriptus*) followed by female surface areas.

0, 1810.162759
0, 1810.162759
0.0165, 1810.162759

0.0135, 1810.162759
0.0093, 1810.162759
0.00855, 1810.162759
0.00645, 1810.162759
0.0057, 1810.162759
0.066, 1827.099456
0.054, 1827.099456
0.0744, 1827.099456
0.0456, 1827.099456
0.072, 1827.099456
0.048, 1827.099456
0.0396, 1827.099456
0.0804, 1827.099456

APPENDIX II. Mating frequencies recorded in *Centrobolus* (first eight are *C. anulatus,* second eight are *C. inscriptus*) followed by species surface areas.
0, 1722.296081
0, 1722.296081
0.0165, 1722.296081
0.0135, 1722.296081
0.0093, 1722.296081
0.00855, 1722.296081
0.00645, 1722.296081
0.0057, 1722.296081
0.066, 1731.5622
0.054, 1731.5622
0.0744, 1731.5622
0.0456, 1731.5622
0.072, 1731.5622
0.048, 1731.5622
0.0396, 1731.5622
0.0804, 1731.5622

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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