

FACTORS RELATED TO TEMPERATURE IN FOREST RED MILLIPEDES *CENTROBOLUS* COOK, 1897

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Abstract- Six factors were tested for a correlation with maximum temperature, seven factors were tested for a correlation with minimum temperature, and eight factors were tested for a correlation with average temperature in red millipedes *Centrobolus*. Minimum temperature ($r=0.7518$, $r^2=0.5652$, $n=22$, $p=0.000055$), lowest relative humidity ($r=-0.5861$, $r^2=0.3435$, $n=22$, $p=0.004159$), highest ocean water temperature ($r=0.70442272$, Z score= 2.14581602 , $n=9$, $p=0.01594377$), mean ocean water temperature ($r=0.99347126$, Z score= 7.56872480 , $n=10$, $p=0$), minimum ocean water temperature ($r=0.99458129$, Z score= 7.23619985 , $n=9$, $p=0$), and moments of inertia ($r=-0.6603$, $r^2=0.436$, $n=10$, $p=0.037826$) were correlated with maximum temperature. Minimum ocean water temperature ($r=0.99186007$, Z score= 6.73614916 , $n=9$, $p=0$), mean ocean water temperature ($r=0.97655914$, Z score= 5.86646695 , $n=10$, $p=0$), highest ocean water temperature ($r=0.66674886$, Z score= 1.97151325 , $n=9$, $p=0.02433253$) volume ($r=0.5753$, $r^2=0.331$, $n=8$, $p=0.005119$), latitude ($r=0.496$, $r^2=0.246$, $n=22$, $p=0.018891$), and longitude ($r=0.6798$, $r^2=0.4621$, $n=22$, $p=0.000498$) were related to minimum temperature. Surface-area-to-volume ratio was not related to minimum temperature in males (Spearman's $r=-0.27303561$, Z score= -1.18604347 , $n=22$, $p=0.11780263$) and was related in females (Spearman's $r=-0.37298673$, Z score= -1.65915079 , $n=22$, $p=0.04854269$). Highest ocean water temperature ($r=0.936$, $r^2=0.8761$, $n=7$, $p=0.001922$), minimum ocean water temperature ($r=0.73472497$, Z score= 2.48414491 , $n=10$, $p=0.00649316$), surface-area-to-volume ratio (was marginally related) in males (Spearman's $r=-0.33692008$, Z score= -1.48440801 , $n=22$, $p=0.06885039$) and was related in females (Spearman's $r=-0.38692405$, Z score= -1.72811582 , $n=22$, $p=0.04198369$), altitude ($r=0.4754$, $r^2=0.226$, $n=22$, $p=0.025346$), minimum temperature ($r=0.7421$, $r^2=0.5507$, $n=22$, $p=0.000077$), maximum temperature ($r=0.4757$, $r^2=0.2263$, $n=22$, $p=0.025136$), longitude ($r=0.5222$, $r^2=0.2727$, $n=22$, $p=0.012706$), and mean ocean water temperature ($r=0.73989009$, Z score= 2.51408942 , $n=10$, $p=0.00596703$), were correlated with temperature.

Keywords: surface area, Red Millipedes, temperature.

I. INTRODUCTION

Red millipedes are found in the southern African subregion with northern limits on the east coast being about -17° latitude S and southern limits being -35° latitude S. They are well represented in the littoral forests of the eastern half of the subcontinent [1-297]. It consists of taxonomically important species with 12 species considered threatened and includes nine vulnerable and three endangered species [226]. It occurs in all the forests of the coastal belt from the Cape Peninsula to Beira in Mocambique [225]. These worm-like millipedes have female-biased sexual size dimorphism [57].

Here, six factors are correlated with maximum temperature, seven factors are correlated with minimum temperature, and eight factors are correlated with average temperature (variation) in *Centrobolus* Cook, 1897.

II. MATERIALS AND METHODS

Horizontal tergite width measurements for 22 species of southern African *Centrobolus* were obtained from published material [57]. These were halved to get radii (r). The surface areas (mm^2) were calculated based on the equation $2 \cdot \pi \cdot r \cdot (r + h)$ for males and females. A correlation between six factors and maximum temperature, seven factors with minimum temperature and eight factors with average temperature were generated at <https://www.gigacalculator.com/calculators/correlation-coefficient-calculator.php> (Appendix 1-26).

III. RESULTS

Minimum temperature was related to maximum temperature (Figure 1: $r=0.7518$, $r^2=0.5652$, $n=22$, $p=0.000055$).

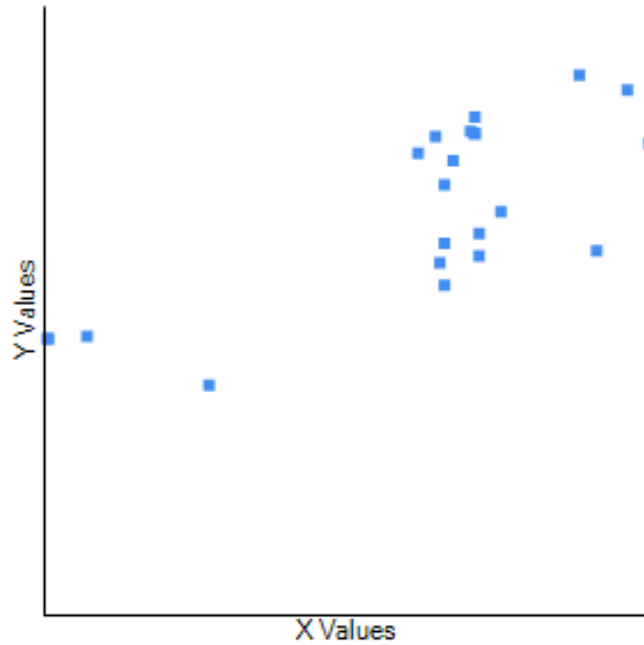


Fig. 1. Correlation between minimum temperature and maximum temperature across the range of *Centrobolus* Cook, 1897.

Lowest relative humidity was related to maximum temperature (Fig. 2: $r=-0.5861$, $r^2=0.3435$, $n=22$, $p=0.004159$).

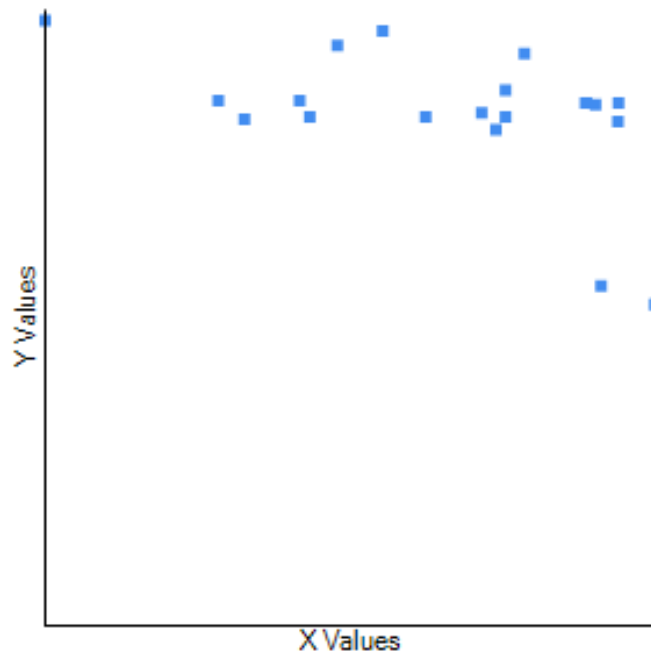


Fig. 2. Correlation between lowest relative humidity (%) and maximum temperature across the range of *Centrobolus* Cook, 1897.

Highest ocean water temperature was related to maximum temperature (Fig. 3: $r=0.70442272$, Z score= 2.14581602 , $n=9$, $p=0.01594377$).

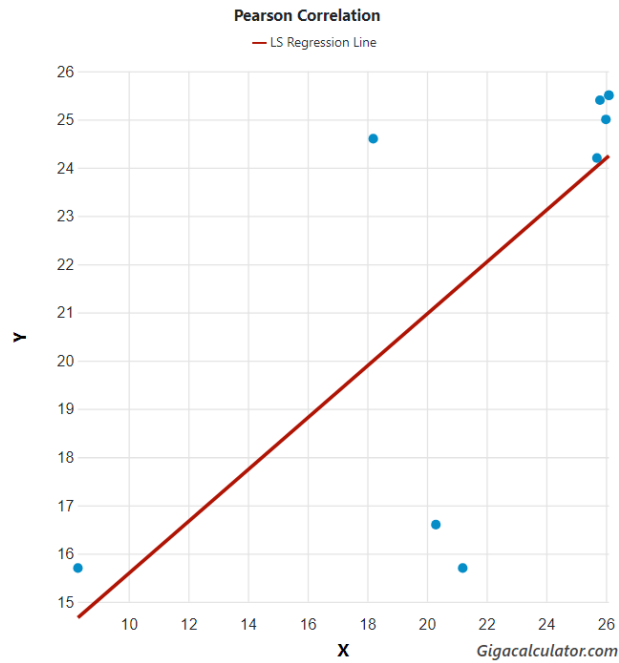


Fig. 3. Correlation between highest ocean water temperature and maximum temperature variation in *Centrobolus* Cook, 1897.

Mean ocean water temperature was related to maximum temperature (Fig. 4: $r=0.99347126$, Z score= 7.56872480 , $n=10$, $p=0$).

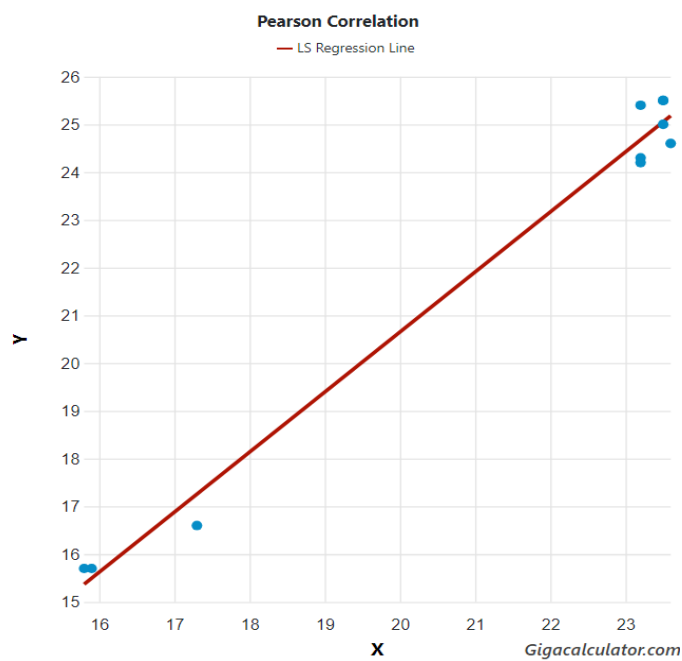


Fig. 4. Correlation between mean ocean water temperature and maximum temperature variation in *Centrobolus* Cook, 1897.

Moments of inertia were correlated with maximum temperature (Fig. 5: $r=-0.6603$, $r^2=0.436$, $n=10$, $p=0.037826$).

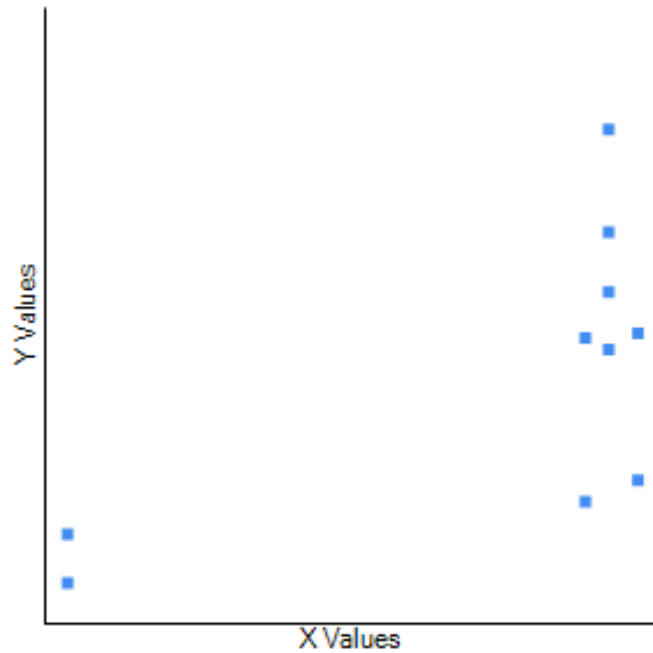


Fig. 5. Correlation between moments of inertia (y) and maximum temperature (x) across the range of *Centrobolus* Cook, 1897.

Minimum ocean water temperature was related to maximum temperature (Fig. 6: $r = 0.99458129$, Z score = 7.23619985, $n = 9$, $p = 0$).

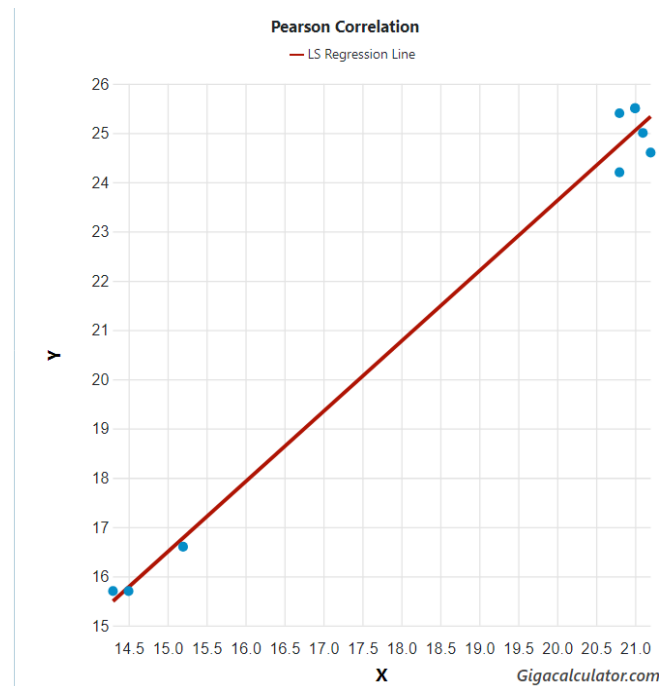


Fig. 6. Correlation between minimum ocean water temperature and maximum temperature variation in *Centrobolus* Cook, 1897.

Minimum ocean water temperature was related to minimum temperature (Fig. 7: $r=0.99186007$, Z score= 6.73614916 , $n=9$, $p=0$).

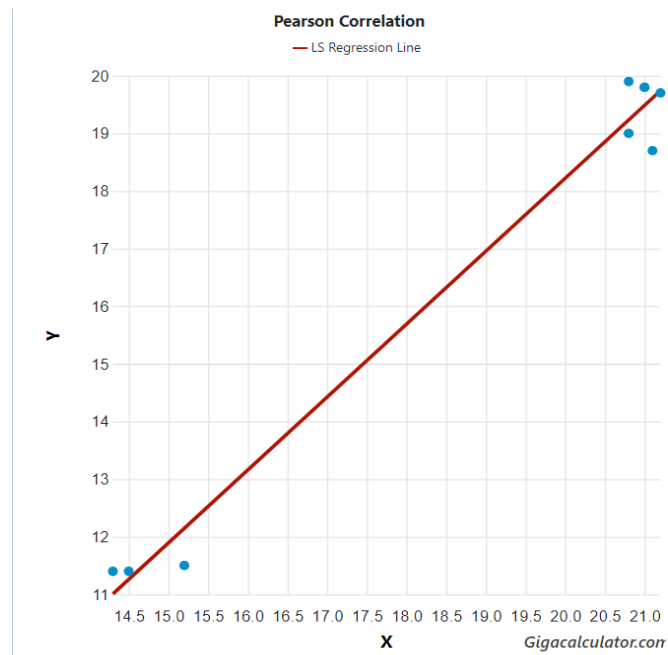


Fig. 7. Correlation between minimum ocean water temperature and minimum temperature variation in *Centrobolus* Cook, 1897.

Volume was correlated with the minimum temperature (Fig. 8: $r=-0.5753$, $r^2=0.331$, $n=8$, $p=0.005119$).

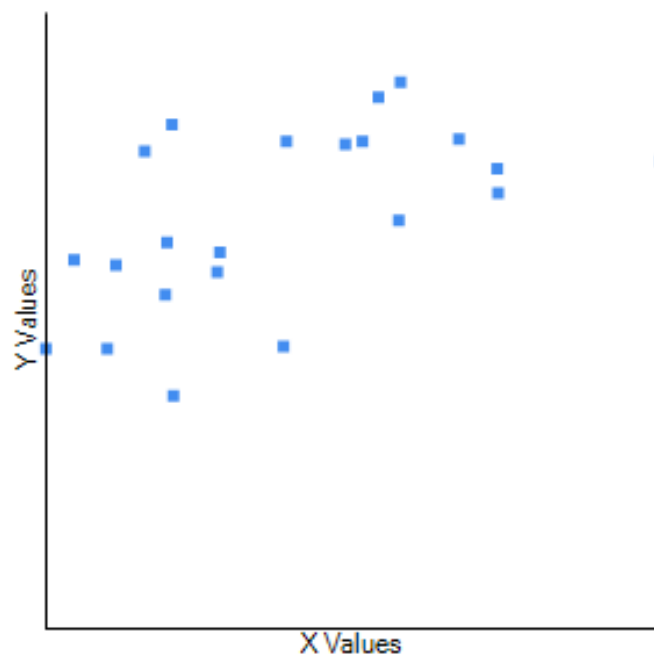


Fig. 8. Correlation between volume (X) and minimum temperature (Y) across therange of *Centrobolus* Cook, 1897.

Minimum temperature was related to longitude (Fig. 9: $r=0.6798$, $r^2=0.4621$, $n=22$, $p=0.000498$).

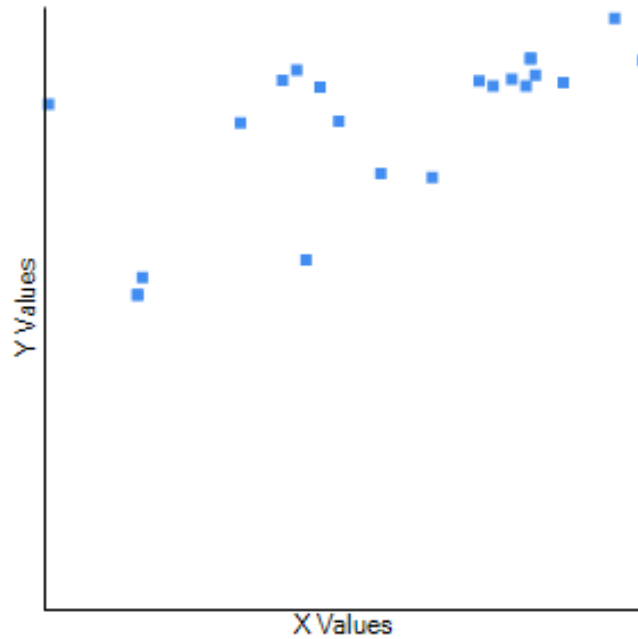


Fig. 9. Correlation between minimum temperature (degrees Celsius) and longitude across therange of *Centrobolus* Cook, 1897.

Mean ocean water temperature was related to minimum temperature (Fig. 10: $r=0.97655914$, Z score= 5.86646695 , $n=10$, $p=0$).

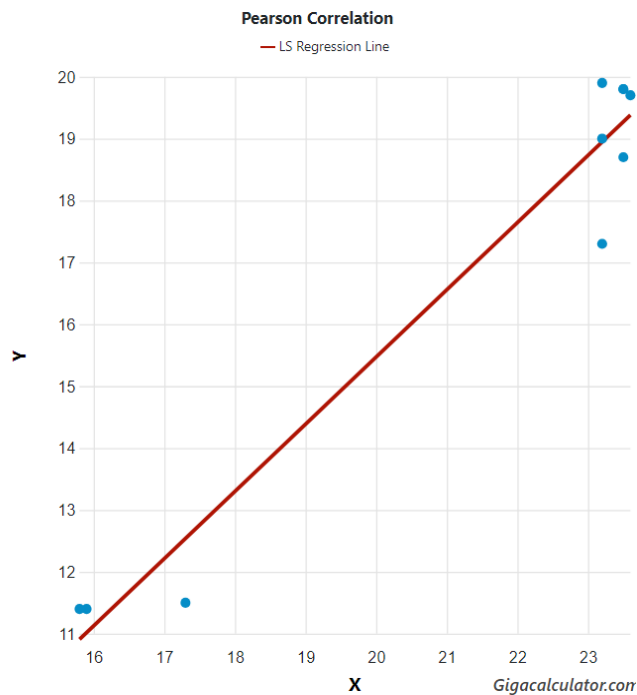


Fig. 10. Correlation between mean ocean water temperature and minimum temperature variation in *Centrobolus* Cook, 1897.

Minimum temperature was related to latitude (Fig. 11: $r=0.496$, $r^2=0.246$, $n=22$, $p=0.018891$).

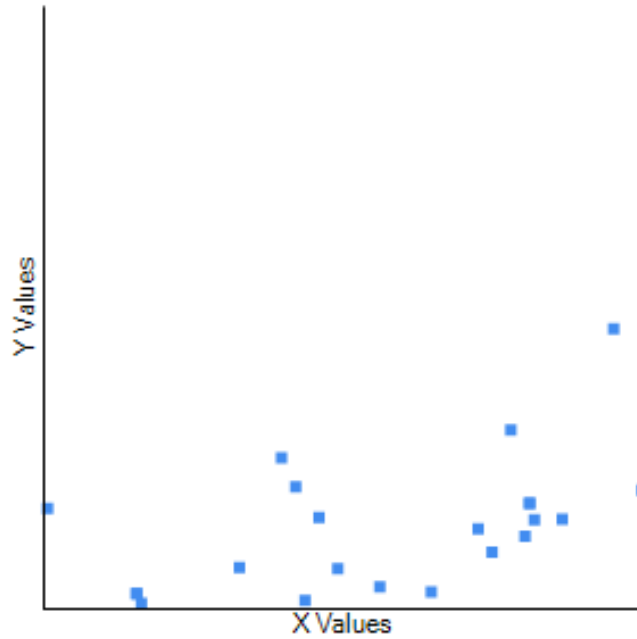


Fig. 11. Correlation between minimum temperature (degrees Celsius) and latitude across the range of *Centrobolus* Cook, 1897.

Highest ocean water temperature was related to minimum temperature (Fig. 12: $r=0.66674886$, Z score 1.97151325, $n=9$, $p=0.02433253$).

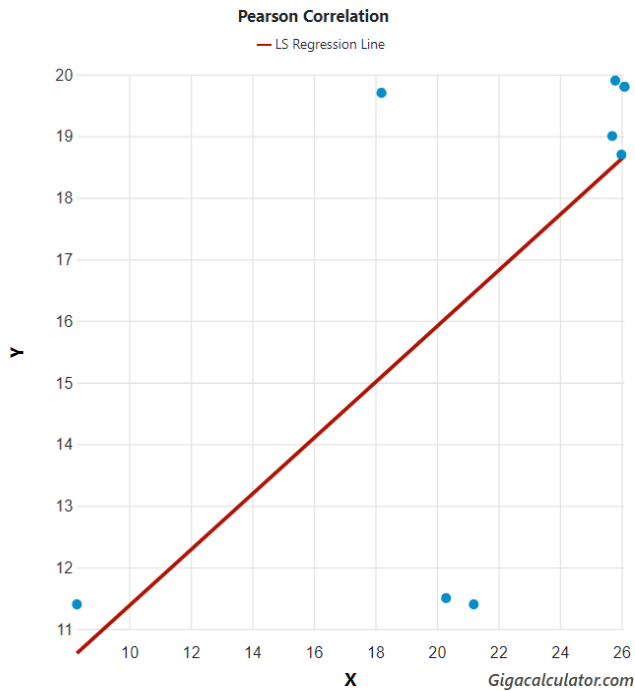


Fig. 12. Correlation between highest ocean water temperature and minimum temperature variation in *Centrobolus* Cook, 1897.

Surface-area-to-volume ratio was not related to minimum temperature in males (Fig. 13: Spearman's $r=-0.27303561$, Z score=-1.18604347, $n=22$, $p=0.11780263$) and was related in females (Fig. 14: Spearman's $r=-0.37298673$, Z score=-1.65915079, $n=22$, $p=0.04854269$).

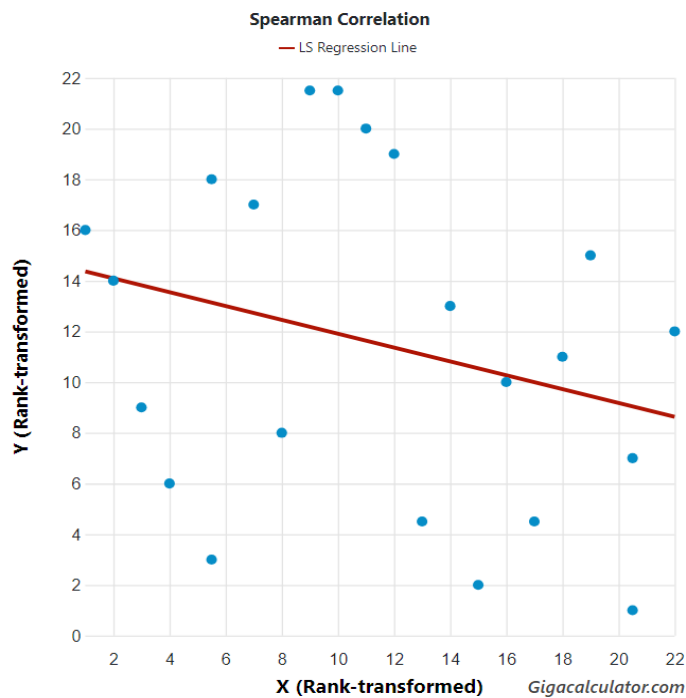


Fig. 13. Surface-area-to-volume ratio marginally correlated with minimum temperature in male *Centrobolus* Cook, 1897.

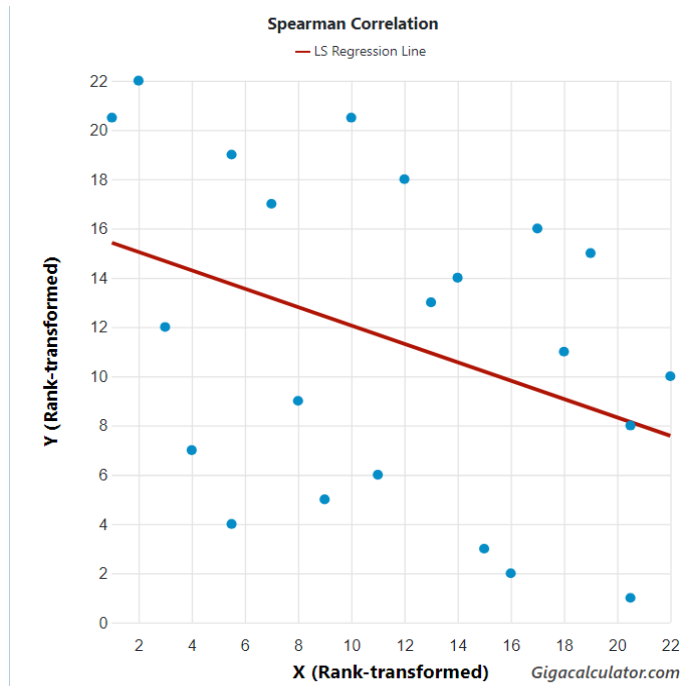


Fig. 14. Surface-area-to-volume ratio correlated to minimum temperature in female *Centrobolus* Cook, 1897.

Highest ocean water temperature was related to average temperature (Fig. 15: $r=0.936$, $r^2=0.8761$, $n=7$, $p=0.001922$).

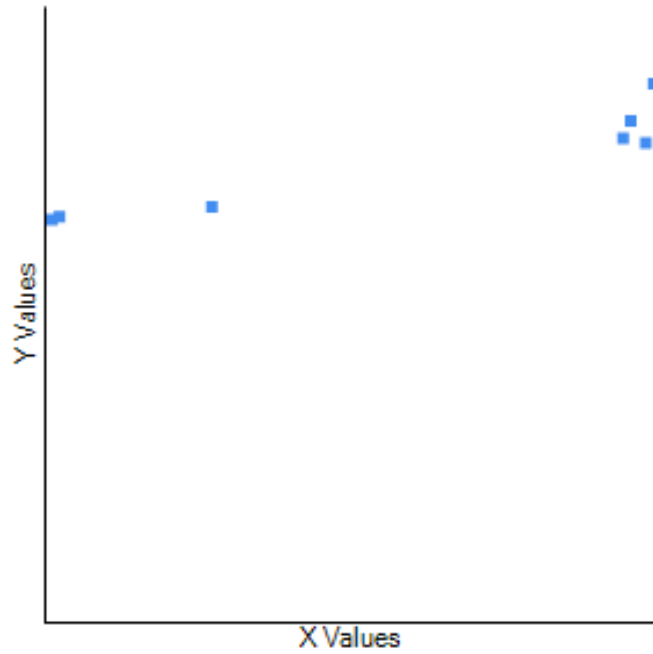


Fig. 15. Correlation between highest ocean water temperature and average temperature variation in *Centrobolus* Cook, 1897.

The minimum ocean water temperature was correlated with temperature (Fig. 16: $r= 0.73472497$, Z score= 2.48414491 , $n=10$, $p=0.00649316$).

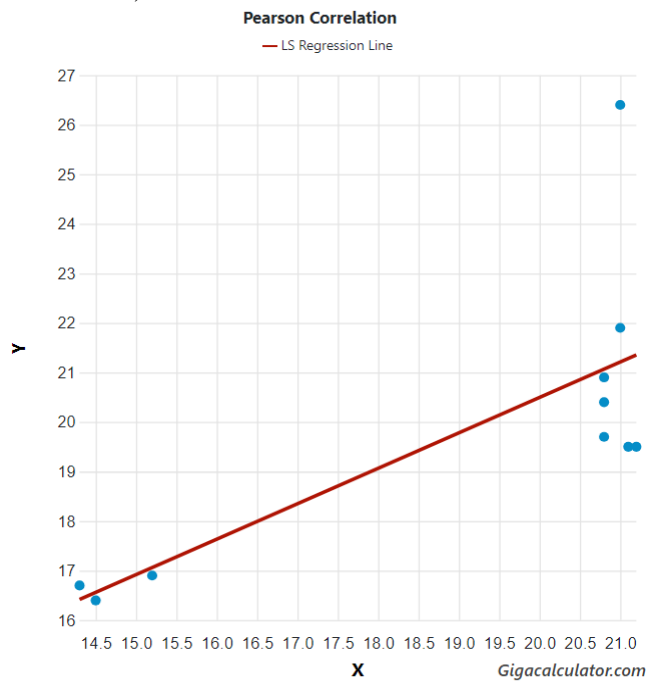


Fig. 16. Correlation between the minimum ocean water temperature (X) and average temperature (Y) across the range of *Centrobolus* Cook, 1897.

Surface-area-to-volume ratio was marginally related to temperature in males (Fig. 17: Spearman's $r=-0.33692008$, Z score=-1.48440801, $n=22$, $p=0.06885039$) and was related in females (Fig. 18: Spearman's $r=-0.38692405$, Z score=-1.72811582, $n=22$, $p=0.04198369$).

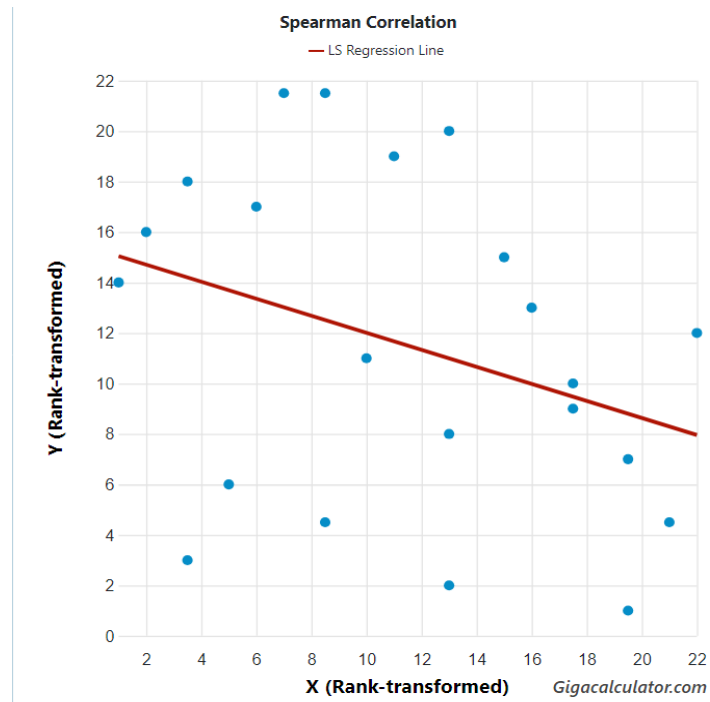


Fig. 17. Surface-area-to-volume ratio marginally correlated with temperature in male *Centrobolus* Cook, 1897.

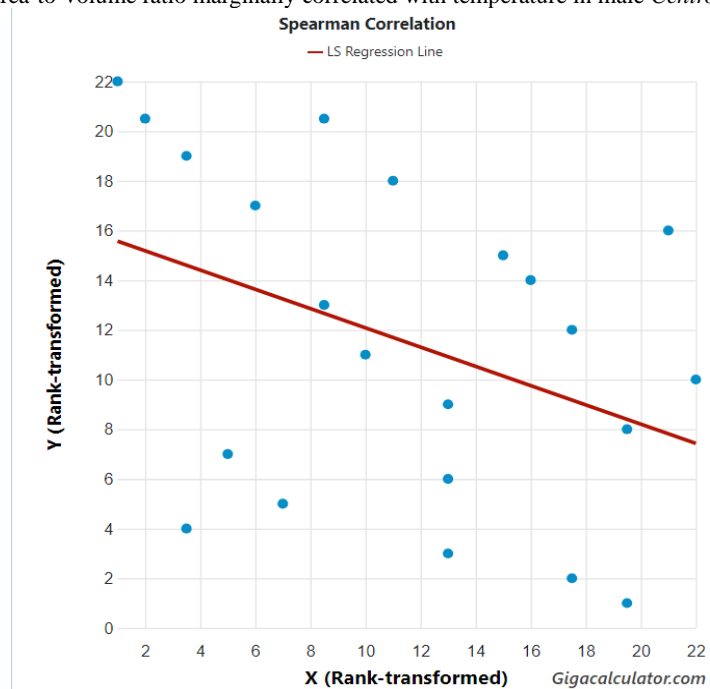


Fig. 18. Surface-area-to-volume ratio correlated to temperature in female *Centrobolus* Cook, 1897.

The altitude was correlated with average temperature variation (Fig. 19: $r= 0.4754$, $r^2=0.226$, $n=22$, $p=0.025346$).

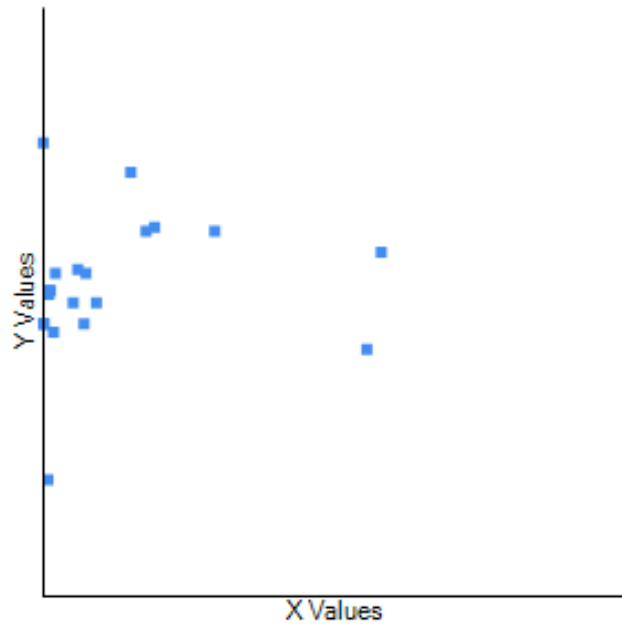


Fig. 19. Correlation between the altitude (X) and average temperature variation (Y) across the range of *Centrobolus* Cook, 1897.

The minimum temperature was correlated with temperature (Fig. 20: $r= 0.7421$, $r^2=0.5507$, $n=22$, $p=0.000077$).

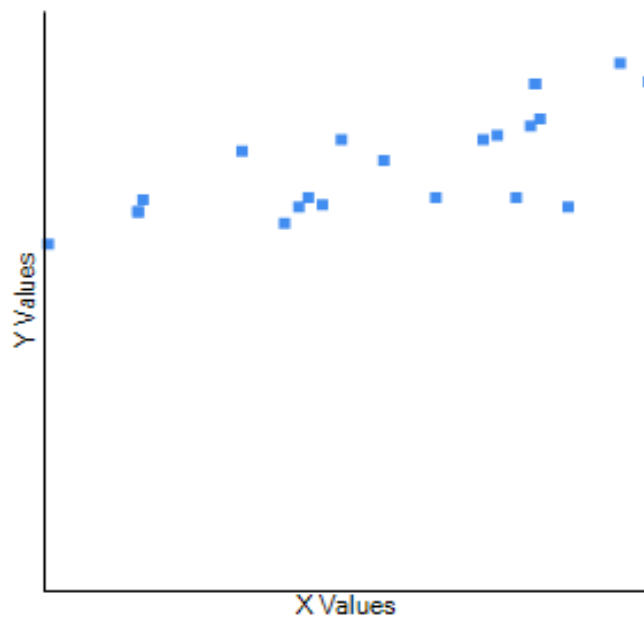


Fig. 20. Correlation between the minimum temperature (X) and average temperature (Y) across the range of *Centrobolus* Cook, 1897.

The maximum temperature was correlated with temperature (Fig. 21: $r = 0.4757$, $r^2 = 0.2263$, $n = 22$, $p = 0.025136$).

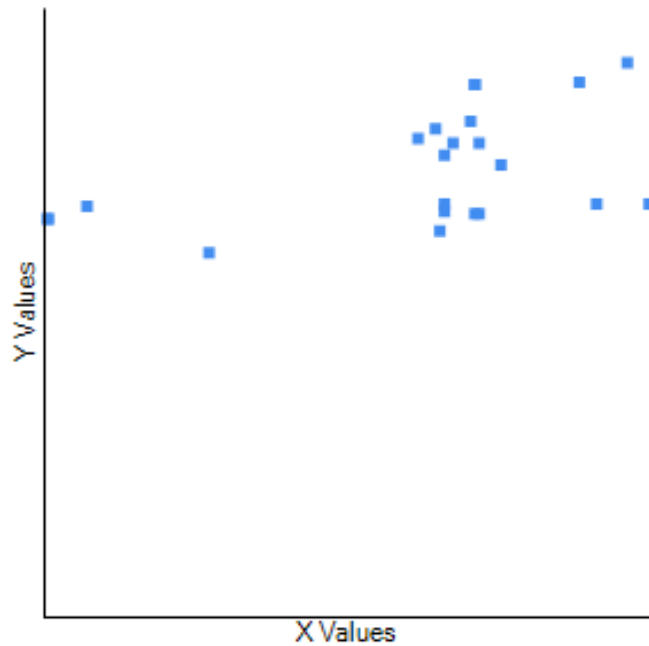


Fig. 21. Correlation between the maximum temperature (X) and average temperature (Y) across the range of *Centrobolus* Cook, 1897.

Temperature was related to longitude (Fig. 22: $r = 0.5222$, $r^2 = 0.2727$, $n = 22$, $p = 0.012706$).

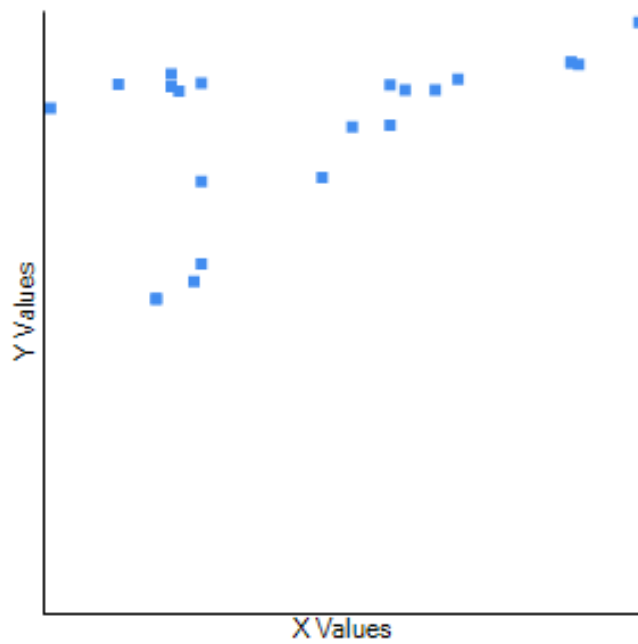


Fig. 22. Correlation between temperature (degrees Celsius) and longitude across the range of *Centrobolus* Cook, 1897.

The mean ocean water temperature was correlated with temperature (Fig. 23: $r= 0.73989009$, Z score= 2.51408942 , $n=10$, $p=0.00596703$).

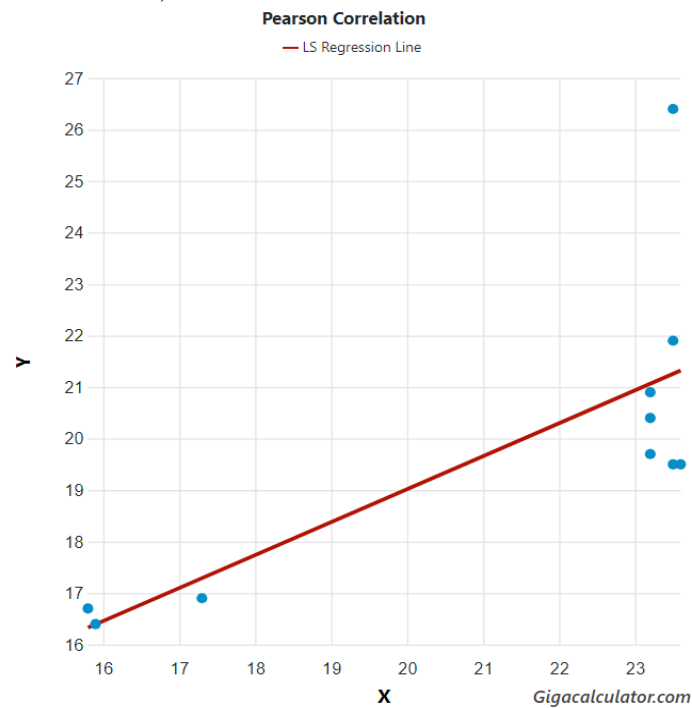


Fig. 23. Correlation between the mean ocean water temperature (X) and average temperature (Y) across therange of *Centrobolus* Cook, 1897.

IV. DISCUSSION

There is a correlation between six factors and maximum temperature, seven factors and minimum temperature, and eight factors and average temperature.

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APPENDIX 1. Minimum temperature (degrees Celsius) across the range of *Centrobolus* Cook, 1897.

14.5
 19.9
 14.8
 11.4
 11.5
 19.8
 21.6
 18.7
 20.5
 15.3
 17.7
 11.4
 15.7
 19.8
 19.7
 22.2
 16.6
 13.6
 15.0
 19.4
 9.5
 19.0

APPENDIX 2. Maximum temperature (degrees Celsius) across the range of *Centrobolus* Cook, 1897.

24.7
 25.4
 25.6
 15.7
 16.6
 25.5
 29.0
 25.0

25.5
24.8
24.8
15.7
25.6
25.5
24.6
27.9
26.1
24.8
28.3
29.5
19.4
24.2

APPENDIX 3. Lowest relative humidity across the range of *Centrobolus* Cook, 1897.24.7

51.38
68.65
50.09
71.60
68.93
68.18
58.18
63.06
69.79
60.29
64.23
71.60
54.10
68.18
69.75
65.15
64.23
54.60
55.95
41.57
71.84
63.75

APPENDIX 4. Highest ocean temperature (degrees Celsius) followed by maximum temperature (degrees Celsius) in *Centrobolus* Cook, 1897.

25.80, 25.4
8.30, 15.7
20.30, 16.6
26.10, 25.5
26.00, 25.0
21.20, 15.7

26.10, 25.5

18.20, 24.6

25.70, 24.2

APPENDIX 5. Mean ocean temperature (degrees Celsius) followed by maximum temperature (degrees Celsius) in *Centrobolus* Cook, 1897.

23.20, 25.4

15.90, 15.7

17.30, 16.6

23.50, 25.5

23.50, 25.0

23.20, 24.3

15.80, 15.7

23.50, 25.5

23.60, 24.6

23.20, 24.2

APPENDIX 6. The moments of inertia in *Centrobolus* Cook, 1897.

1.36

4.70205

8.9401

4

2.9376

9.46585

16.077730

9.3025

12.737537

10.7911

APPENDIX 7. Minimum ocean temperature (degrees Celsius) followed by maximum temperature (degrees Celsius) in *Centrobolus* Cook, 1897.

20.80, 25.4

14.50, 15.7

15.20, 16.6

21.00, 25.5

21.10, 25.0

14.30, 15.7

21.00, 25.5

21.20, 24.6

20.80, 24.2

APPENDIX 8. Minimum ocean temperature (degrees Celsius) followed by minimum temperature (degrees Celsius) in *Centrobolus* Cook, 1897.

20.80, 19.9

14.50, 11.4

15.20, 11.5

21.00, 19.8

21.10, 18.7

14.30, 11.4

21.00, 19.8

21.20, 19.7

20.80, 19.0

APPENDIX 9. Volume (mm³) in *Centrobolus* Cook, 1897.

952

1894

557

522

1210

1518

1580

2043

775

962

2046

284

756

1221

1451

1666

1659

749

393

669

781

2683

APPENDIX 10. Longitude across the range of *Centrobolus* Cook, 1897.

30.786

31.084

31.400

18.357

19.350

32.049

34.394

30.754

30.666

30.393

25.173

18.348

28.433

32.078

30.456

31.952

25.396

28.317

20.383
30.867
29.418
30.451

APPENDIX 11. Mean ocean temperature (degrees Celsius) followed by minimum temperature (degrees Celsius) in *Centrobolus* Cook, 1897.

23.20, 19.9
15.90, 11.4
17.30, 11.5
23.50, 19.8
23.50, 18.7
23.20, 17.3
15.80, 11.4
23.50, 19.8
23.60, 19.7
23.20, 19.0

APPENDIX 12. Latitude across the range of *Centrobolus* Cook, 1897.

-26.1502
-29.7462
-27.8403
-34.0477
-34.5849
-28.7784
-18.6866
-30.2805
-29.7080
-29.6301
-33.9322
-34.0164
-32.5717
-28.7784
-30.7157
-28.0246
-33.6367
-32.5064
-34.4142
-24.5392
-29.0939
-31.6334

APPENDIX 13. Highest ocean temperature (degrees Celsius) followed by minimum temperature (degrees Celsius) in *Centrobolus* Cook, 1897.

25.80, 19.9
8.30, 11.4
20.30, 11.5
26.10, 19.8

26.00, 18.7
21.20, 11.4
26.10, 19.8
18.20, 19.7
25.70, 19.0

APPENDIX 14. Male surface-area-to-volume ratios preceded by minimum temperature (degrees Celsius) for 22 species of *Centrobolus* Cook, 1897.

14.5, 0.000510
19.9, 0.000486
14.8, 0.000365
11.4, 0.000485
11.5, 0.000245
19.8, 0.000218
21.6, 0.000294
18.7, 0.000136
20.5, 0.000393
15.3, 0.000335
17.7, 0.000156
11.4 0.616435
15.7, 0.000510
19.8, 0.418711
19.7, 0.000220
22.2, 0.000223
16.6, 0.000169
13.6, 0.000357
15.0, 0.559114
19.4, 0.000422
9.5, 0.000349
19.0, 0.000136

APPENDIX 15. Female surface-area-to-volume ratios preceded by minimum temperature (degrees Celsius) for 22 species of *Centrobolus* Cook, 1897.

14.5, 0.000177
19.9, 0.000578
14.8, 0.540690
11.4, 0.000484
11.5, 0.000179
19.8, 0.000132
21.6, 0.000108
18.7, 0.000113
20.5, 0.000274
15.3, 0.000213
17.7, 0.000716
11.4, 0.679931
15.7, 0.000245

19.8, 0.4103607
19.7, 0.000138
22.2, 0.000113
16.6, 0.000135
13.6, 0.000314
15.0, 0.533940
19.4, 0.000335
9.5, 0.000318
19.0, 0.000751

APPENDIX 16. Highest ocean temperature (degrees Celsius) in *Centrobolus* Cook, 1897.

25.80
18.30
20.30
26.10
26.00
18.20
25.70

Appendix 17 Average temperature (degrees Celsius) in coastal *Centrobolus* Cook, 1897.

20.4
16.5
16.9
21.9
19.5
16.4
19.7

APPENDIX 18. Minimum ocean water temperature (degrees Celsius) followed by temperature (degrees Celsius) across the range of *Centrobolus* Cook, 1897.

20.80, 20.4
14.50, 16.4
15.20, 16.9
21.00, 21.9
21.10, 19.5
20.80, 20.9
14.30, 16.7
21.00, 26.4
21.20, 19.5
20.80, 19.7

APPENDIX 19. Male surface-area-to-volume ratios preceded by temperature (degrees Celsius) for 22 species of *Centrobolus* Cook, 1897.

15.9, 0.000510
20.4, 0.000486
16.6, 0.000365
16.4, 0.000485
16.9, 0.000245

21.9, 0.000218
22.8, 0.000294
19.5, 0.000136
16.6, 0.000393
16.7, 0.000335
17.0, 0.000156
16.4, 0.616435
19.5, 0.000510
21.9, 0.418711
20.1, 0.000220
22.0, 0.000223
18.6, 0.000169
19.0, 0.000357
17.0, 0.559114
17.0, 0.000422
15.0, 0.000349
19.7, 0.000136

APPENDIX 20. Female surface-area-to-volume ratios preceded by temperature (degrees Celsius) for 22 species of *Centrobolus* Cook, 1897.

15.9, 0.000177
20.4, 0.000578
16.6, 0.540690
16.4, 0.000484
16.9, 0.000179
21.9, 0.000132
22.8, 0.000108
19.5, 0.000113
16.6, 0.000274
16.7, 0.000213
17.0, 0.000716
16.4, 0.679931
19.5, 0.000245
21.9, 0.4103607
20.1, 0.000138
22.0, 0.000113
18.6, 0.000135
19.0, 0.000314
17.0, 0.533940
17.0, 0.000335
15.0, 0.000318
19.7, 0.000751

APPENDIX 21. Altitude (m) in *Centrobolus* Cook, 1897.

646
38
990

178
34
9
1863
48
312
596
252
240
206
9
38
65
76
509
6
1947
3377
9

APPENDIX 22. Average temperature variation (degrees Celsius) in *Centrobolus* Cook, 1897.

8.8
7.3
8.7
7.0
2.8
6.5
5.9
7.3
7.0
8.7
7.7
6.5
7.8
6.5
7.2
6.3
7.7
10.1
10.8
8.2
12.0
6.5

APPENDIX 23. Minimum temperature across the range of *Centrobolus* Cook, 1897.

14.5
19.9

14.8
11.4
11.5
19.8
21.6
18.7
20.5
15.3
17.7
11.4
15.7
19.8
19.7
22.2
16.6
13.6
15.0
19.4
9.5
19.0

APPENDIX 24. Maximum temperature across the range of *Centrobolus* Cook, 1897.

24.7
25.4
25.6
15.7
16.6
25.5
29.0
25.0
25.5
24.8
24.8
15.7
25.6
25.5
24.6
27.9
26.1
24.8
28.3
29.5
19.4
24.2

APPENDIX 25. Longitude across the range of *Centrobolus* Cook, 1897.

30.786

31.084
31.400
18.357
19.350
32.049
34.394
30.754
30.666
30.393
25.173
18.348
28.433
32.078
30.456
31.952
25.396
28.317
20.383
30.867
29.418
30.451

APPENDIX 26. Mean ocean water temperature (degrees Celsius) followed by temperature (degrees Celsius) across the range of *Centrobolus* Cook, 1897.

23.20, 20.4
15.90, 16.4
17.30, 16.9
23.50, 21.9
23.50, 19.5
23.20, 20.9
15.80, 16.7
23.50, 26.4
23.60, 19.5
23.20, 19.7