MASS VARIATION WITH TIME IN RED MILLIPEDES CENTROBOLUS COOK, 1897

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Abstract-Mass variation with time was studied in red millipedes. Mass was checked for differences between time (1966-1998 CE) in the red millipede genus *Centrobolus*. There was an increase of 0.73 g in *C. digrammus* and an increase of 0.01 g in *C. ruber* estimated over 32 years. There was a significant difference in mass recorded at different times (T=-4.77, p<0.01). The estimated increase in mass of *C. digrammus* (from 0.40 g to 0.99 g (species equation) i. e. 0.59 g or from -0.18 g to 0.55 g (female equation) i. e. 0.73 g) was above the recorded standard deviation (S. D.) whereas the estimated increase in mass of *C. ruber* (from 2.03 g to 2.05 g (species equation) i. e. 0.01 g or from 1.83 g to 1.84 g (female equation) i. e. 0.01 g) was lower than the recorded S. D. This suggests the increase in mass estimated for *C. digrammus* is not an artifact of measurement error. An increase in the size of female *C. digrammus* was caused by competitive pressures or fecundity selection.

I. INTRODUCTION

Numerous studies are finding animal taxa have female-biased SSD and mostly disobey Rensch's rule including corvids and pinnipeds [1, 2, 5, 7-14, 84-88, 90-97, 99-104, 106-111, 112-114]. The finding of the converse or inverse Rensch rule implies SSD increases with body size when females are larger [1, 2, 5, 7-14, 84-88, 90-97, 99-104, 106-109, 112-114]. This has implications in the genus *Centrobolus* because females are larger than males and SSD increases hypoallometrically with body size [5-14].

The forest genus *Centrobolus* of diplopods belonging to the Order Spirobolida found along the eastern coast of southern Africa was the subject of this study. Its northern limits are on the east coast of southern Africa being -17° latitude South (S) and its southern limits -35° S; from the Cape Peninsula to Beira in Mocambique in all the forests of the coastal belt [4]. As essentially shade-loving Diplopoda, the members of the genus are represented by 39 species in these litoral forests of the eastern half of the subcontinent [4]. Mass (g) predicted from volumes is compared across time [3, 4, 18, 89]. The hypothesis that there is no mass change with time is tested here.

II. MATERIALS AND METHODS

Two valid species were identified as belonging to the genus *Centrobolus* Cook, 1897 (*C. digrammus*, *C. ruber*). Millipede localities were obtained from the Mating dynamics of South African forest millipedes *Centrobolus* (Diplopoda: Pachybolidae) [4]. Mass was estimated from the publication of volumes from morphometric data collected in material over three dates [4, 102, 108]. Mass was estimated from the volume which in turn was calculated from the ratio of female volume to male volume. Morphometrics and differences in time were checked for correlations with female body size using the Pearson Correlation Coefficient calculator (https://www.gigacalculator.com/calculators/correlation-coefficient-calculator.php). Only female collection dates were included at the same time in each species. Tests for normality were conducted (https://www.socscistatistics.com/tests/kolmogorov/default.aspx). A Lilliefors test was used to test for normality of time data at http://www.statskingdom.com/kolmogorov-smirnov-testcalculator.html. Two measurements for the time were 1966, and 1998. To test between divergent and convergent series a series integral test calculator was used (http://www.symbolab.com/solver/series-integral-test-calculator). Body sizes related to mass in males and females to generate linear equations into which body sizes were substituted to estimate mass differences over time. Standard deviations were given [4].

III. RESULTS

The relationships between female volume and mass are given in the (species) equation y=642.76693997x + 634.87814532 and between species mass and volume by the (female) equation y=791.86180083x + 200.92467085. *C. digrammus* increased from 0.398801064 g to 0.991694925 g (species equation) i. e. 0.592893861 g or from -

0.183827353 g to 0.546594914 g (female equation) i. e. 0.730420267 g. *C. ruber* females increased from a predicted 2.03445264 g to 2.0455278 g (species equation) i. e. 0.01107516g or from 1.83122649 g to 1.84487063 g (female equation) i. e. 0.01364414 g. There was a significant difference in mass recorded at different times (T=-4.769, p<0.0001).

IV. DISCUSSION

The null hypothesis is that mass did not vary significantly over time in one species (C. ruber) but did vary over time in the other species (C. digrammus). An increase in the sizes of females of each of the two species (*C. digrammus*, *C. ruber*) was estimated to have taken place over 32 years from 1966-1998. The estimated increase in mass of *C. digrammus* (0.59-0.73 g) was above the recorded standard deviation (S. D.) whereas the estimated increase in mass of *C. ruber* was lower than the recorded S. D. This suggests the increase in mass estimated for *C. digrammus* is not an artifact of measurement error. The mass of international rugby players has increased over 28 years (the same order of magnitude as this study) and the body mass of men's players has stabilized after initial increases due to selection for endurance, agility, and speed [110]. Population-level studies may provide further estimates of size to determine if the difference in mass is evolutionary significant or the result of measurement error [115]. Fecundity selection would successfully explain the increase in mass if this is not only the result of measurement error.

V. CONCLUSION

A possible increase in the sizes of females of each of the two millipede species (*C. digrammus*, *C. ruber*) was estimated to have taken place here.

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