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Mark Cooper
School of Animal, Plant & Environmental Sciences, University of the Witwatersrand, Johannesburg, South Africa

Correspondence
Mark Cooper
School of Animal, Plant & Environmental Sciences, University of the Witwatersrand, Johannesburg, South Africa

Non-significant intersexual differences in millipede mass

Mark Cooper

Abstract
Mass (g) in the diplopod class was available in fifteen species *Apfelbeckia insculpta* (L. Koch, 1867), *Calostreptus sp.*, *Cladethosoma clarum* (Chamberlin, 1920), *Centrobolus digrammus* (Pocock, 1893), *C. fulgidus* (Lawrence, 1967), *C. inscriptus* (Attems, 1928), *C. ruber* (Attems, 1928), *Doratogonus uncinatus* (Attems, 1914), *Glomeris marginata* (Villers, 1789), *Megaphyllum kievense* (Lohmander, 1928), *Nyssodesmus python* (Peters, 1864), *Odontopyge sp.*, *Pachyiulus hungaricus* (Karsch, 1881) and *Spinotarsus sp.* Values were presented for intersexual comparison (Table 1). Species ranged in size from *Pachyiulus hungaricus* males (0.031g) to *Golmeris marginata* (11g). Invariably males were lighter than females but non-statistical significant differences from populations were found for independent tests (t=-0.02929; p=0.488353; n=23) and dependent tests (t=0.727822; p=0.23525; n=23).

Keywords: Diplopoda, heavier, lighter, sex

1. Introduction
Diplopoda are important environmental indicators and somewhat under-represented in analyses of invertebrate sexual size dimorphism. Sexual size dimorphism (SSD) is the condition where the two sexes of the same species exhibit different characteristics beyond the differences in their sexual organs, although common sexual differences are thought to occur in body mass, length, width and leg dimensions of over half the taxa studied [9-26]. Diplopods resemble the majority of invertebrates in SSD is mostly reversed [8]. Heavier-shorter-wider females are under a type of fecundity selection [5]. Larger males have increased reproductive success through female preference for larger size when there is size assortative mating behaviour [24].
Mass can be a useful standard in millipedes and mass measurements are known for at least 15 taxa [1, 3, 6, 17, 19, 21, 24]. Millipedes (*Centrobolus fulgidus, Centrobolus richardii* and *Spinotarsus* sp.) influence selected soil elements but the results of these millipede studies have illustrated no major sex-specific differences for individual species [23]. Here it is hypothesized and appears in *Centrobolus* sp. the males are almost always lighter than females, the lighter more slender males are expected to be under a type of sexual selection. Furthermore there appears to be a mass standard in sexual selection, basically implying species-specific mass measurements controlled through sexually selected factors [20]. The particular sexual selection is thought to be a female preference for larger male size which operates when there is size-assortative mating behaviours.
In the present study, mass in the class Diplopoda was investigated in fifteen available examples and mass SSD analysed. I wished to establish whether larger males were the lighter or heavier sex. The null hypothesis states there was no difference in millipede mass between the male and females.

2. Materials and Methods
2.1 Literature review
Mass (g) measurements were obtained from a literature review using the available literature. The basic descriptive figures (mean, standard deviation, sample size) shown for males and females were obtained for *Apfelbeckia insculpta* (L. Koch, 1867) [17], *Calostreptus sp.*, *Centrobolus spp.* [6], *Cladethosoma clarum* (Chamberlin, 1920) [22], *Doratogonus uncinatus* (Attems, 1914), *Glomeris marginata* (Villers, 1789), *Megaphyllum kievense* (Lohmander, 1928) [3], *Nyssodesmus python* (Peters, 1864) [1], *Odontopyge spp.*, *Pachyiulus hungaricus* (Karsch, 1881) [19] and *Spinotarsus sp.* [24] (Table 1).

2.2 Statistical tests

Statistical comparisons were made between males and female mean mass using a student's t-test for males and females treated as two independent means (https://www.socscistatistics.com/tests/studentttest/default2.aspx) and student's t-test for males and females treated as two dependent means (https://www.socscistatistics.com/tests/ttestdependent/default2.aspx).

3. Results

Male and female mass data was available for males and females from fifteen species (Table 1). Males were always lighter in twelve of these species and appeared no different in the other three. Although the sexes appear different non-significant (NS) statistical differences in mass between the males and females from populations were found when the sexes were treated as two independent means (t=-0.02929; p=0.488353; n=23) and when the sexes were treated as dependent means (t=0.727822; p=0.23525; n=23).

In the majority of species *Apfelbeckia insculpta*, *Calostreptus* sp., *Centrobolus digrammus, C. fulgidus, C. ruber*, *Cladethosoma clarum*, *Nyssodesmus python*, *Odontopyge sp. 2, Odontopyge sp. 3* all males were lighter than females. *Centrobolus inscriptus* has been dealt with separately and shows males are lighter than females (Cooper, in press). *Doratogonus uncinatus* (Mazowe) cannot be told apart on mass alone while in *D. uncinatus* (Hwange) males were shown to be lighter than females of the same species. *Odontopyge sp. 3* (Vic. Falls) cannot be told apart on mass alone while *Odontopyge sp. 3* (Marondera) males were shown to be lighter. *Pachyiulus hungaricus* showed males were much lighter than females. No significant differences between mass of males and females were found in *Megaphyllum kievense.*

Table 1: Male and female mass obtained from a literature review of the class Diplopoda (n=15 species). Values given are averages (μ) and standard deviation (SD) unless stated in parentheses.

Species	Male mass (μ; SD)	Female mass (μ; SD)	N
Apfelbeckia insculpta	0,61±0,04	0,91±0,05	
	0,64±0,04	1,02±0,05	
	0,58±0,04	0,78±0,07	
	0,51±0,03	0,74±0,06	
	1,16±0,05	1,71±0,11	
Calostreptus sp. Hwange Sengwe	0,8±0,1	1,2±0,2	29, 41
	0,6±0,1	0,9±0,1	29, 29
Centrobolus digrammus	0,68±0,05	1,02±0,23	6, 6
Centrobolus fulgidus	1,29±0,14	1.97±0.42	11, 11
Centrobolus inscriptus	2,48±0,57	2.27±0.28	88, 88
Centrobolus ruber	1,28±0,12	2,00±0,48	18, 18
Cladethosoma clarum	0.252±0.007	0.276±0.007	30, 40
Doratogonus uncinatus Mazowe	6,7±1,7	6,6±1,9	260, 261
Hwange	7,9±1,1	8,5±1,2	23, 31
Glomeris marginata	7	11	(Range)
Megaphyllum kievense	2,45	2,45	
Nyssodesmus python	4,25	5,6	(Median)
Odontopyge sp. 3 Vic. Falls	0,8±0,1	0,9±0,1	36, 37
Marondera	1,24±0,14	1,6±0,3	26, 18
Odontopyge sp. 2 Marondera	1,4±0,3	1,9±0,5	20, 41
Pachyiulus hungaricus PN	0.043 ± 0.010 0.031 ± 0.017	0.394 ± 0.010 0.369 ± 0.016	38, 39
Spinotarsus sp. 1 Marondera	0,8±0,1	0,7±0,1	17, 35

4. Discussion

Mass is clearly a useful size criterion for determining millipede SSD. The mass statistics of fifteen species of diplopods were presented falsifying the null hypothesis *i. e.* showing males are invariably lighter than females and finding a sex specific mass standard. The finding extends upon studies which shows the size of Juliformia has two main components, body diameter and number of rings and provides new information on millipede mass [15]. This supports the idea of slenderness in juliform male millipedes [2]. Correlates of Juliform size now include copulations duration, diet, energetic cost of copulation, mass, oxygen consumption, precipitation, sexual size dimorphism and temperature [3, 6-7, 13, 14, 21].

An abundance of lighter males may indicate male millipedes minimise size through a decrease in the body volume of the cylinder through shortening width and extending length [9, 10, 24]. Body mass is positively related to copulation duration which suggests mass is under directional selection in both sexes because if there is selection for lighter males they would be enduring shorter copulations which is what the prediction of the conflict of interest suggests [5].

In *D. uncinatus* it was found males were lighter or no different in body mass in single mating experiments (see Table 1 in Telford, Dangerfield) and lighter males ranked lower or later in the mating order [24]. Intraspecific variation in male mass can also contribute to reproductive success through possible selection for heavier males ranking higher in the mating order while interspecific variation has shown males are always lighter or otherwise no different in mass from females [24]. So it is almost certain there is a female preference based on mass. Evidence for selection on body mass is also found in variation with female mating status in the millipede *Megaphyllum bosniense* [26].

The interaction between sexual selection, body mass and molecular evolution produce biological diversity in birds [27, 28]. A similar scenario is suggested to occur in the diplopods based on what the current studies show.

5. Conclusion

Sexual size dimorphism of diplopods can be based upon body

mass which is lighter in male millipedes. A female preference based on mass is suggested to be the cause of this divergence. The interaction between sexual selection, body mass and molecular evolution are also suggested to explain millipede biodiversity.

6. References

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