Size dimorphism in six juliform millipedes

Mark Cooper
School of Animal, Plant & Environmental Sciences University of the Witwatersrand, Johannesburg 2050, South Africa
Email: cm.i@aol.com

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Abstract
Sexual Size Dimorphism (SSD) in the diplopod genera Bicoxidens, Doratogonus, Harpagophora, Julomorpha and Orthoporoides has length, width and rings as the main components of interspecific variation. Interspecific variation in size observed in B. bricki Schubart, 1966, D. annulipes Carl, 1917, H. spirobolina (Karsch, 1881), J. hilaris Attems, 1928, J. panda (Attems, 1928) and O. tabulinus (Attems, 1914) and the data sets were tested for normality. Male lengths differed from female lengths in all except J. hilaris which had different widths. Juliform millipedes appear to have decreased in size over evolutionary time and this study presents an interesting finding showing sexual dimorphism based on length in larger species and sexual dimorphism based on width in the smaller species. The reason for this has to do with the constraints imposed through a cylindrical body form which can be changed more powerfully through reducing width rather than length.

Keywords diplopod; horizontal; length; tergite.

1 Introduction
Diplopoda are important environmental indicators and under-represented in analyses of invertebrate Sexual Size Dimorphism (SSD) which 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 (Telford and Dangerfield, 1990; Hopkin and Read, 1992; Barnett and Telford, 1993; Barnett et al., 1993; Telford and Dangerfield, 1993; Barnett and Telford, 1994; Telford and Dangerfield, 1994; Barnett et al., 1995; Webb and Telford, 1995; Aarde et al., 1996; Barnett and Telford, 1996; Telford and Dangerfield, 1996; Telford and Webb, 1998; Cooper, 2014-2019). Diplopods resemble the majority of invertebrates in SSD is mostly reversed (Cooper, 2018). Larger females are thought to result from fecundity selection (Mauritz, 2011). In the present study, SSD in the superorder Juliformia was investigated in B. bricki Schubart, 1966, D. annulipes Carl, 1917, H. spirobolina (Karsch, 1881), J. hilaris Attems, 1928, J. panda (Attems, 1928) and O. tabulinus (Attems, 1914) and 2 factors determining a response in SSD (length and width) tested.
2 Materials and Methods
Two factors were obtained from B. bricki, D. annulipes, H. spirobolina, J. hilaris, J. panda and O. tabulinus: (1) body length (mm) (calibrated in mm); and (2) horizontal tergite width (mm). These basic descriptive figures were statistically tested for normality using a Kolmogorov-Smirnov Test Calculator. The D values of length and width was shown from extracted and published data for B. bricki, D. annulipes, H. spirobolina, J. hilaris, J. panda and O. tabulinus (Schubart, 1966). The factors were compared using a t-test for independent means or Mann-Whitney U-test depending on if the data was parametric or non-parametric, respectively.

3 Results
In 6 tests of male and female widths and lengths the following were found:
B. bricki Schubart, 1966
Mean male length was 93.28571 mm (SD=10.111286) and was normal (D=0.28694; p=0.52037; n=7). Mean female length was 83.75 mm (SD=18.468119) and was normal (D=0.20156; p=0.84199; n=6). Mean male width was 5.92857 mm (SD=3.173551) and was normal (D=0.25091; p=0.29003; n=7). Mean female width was 5.9375 mm (SD=2.88603) and was normally distributed (D=0.14811; p=0.82514; n=7). Widths were not different (t=0.00807; p=0.496809; n=13). Lengths were significantly different (t=1.79492; p=0.04797; n=13).

D. annulipes Carl, 1917
Tests of male and female widths and lengths all were normal. Mean male length was 104.1667 mm (SD=14.972196) and was normal (D=0.19567; p=0.94162; n=6). Mean female length was 89.28571 mm (SD=26.367368) and was normal (D=0.21382; p=0.84574; n=7). Mean male width was 5.5 mm (SD=3.580249) and was normal (D=0.18377; p=0.74842; n=6). Mean female width was 5.92857 mm (SD=2.37403) and was normally distributed (D=0.16272; p=0.79716; n=7). Male length differed from female length (t=1.46963; p=0.084837; n=13). Male widths and female widths were not different (t=-0.32851; p=0.37686; n=13).

H. spirobolina (Karsch, 1881)
Tests of male and female widths and lengths all were normal. Mean male length was 71.66667 mm (SD=9.617692) and was normal (D=0.15725; p=0.99764; n=5). Mean male width was 4.41667 mm (SD=2.712206) and was normal (D=0.25676; p=0.34669; n=6). Mean female width was 5.9 mm (SD=3.17805) and was normally distributed (D=0.24239; p=0.52305; n=5). Widths were not different (t=1.26653; p=0.109937; n=11). Lengths were significantly different (t=-1.61942; p=0.069905; n=11).

J. hilaris Attems, 1928
Tests of male and female widths and lengths all were normal. Mean male length was 26.2 (SD=3.563706) and was normal (D=0.2834; p=0.72834; n=5). Mean female length was 27.8 mm (SD=5.215362) and was normal (D=0.21604; p=0.93275; n=5). Mean Male width was 2.4 mm (SD=1.349897) and was normal (D=0.32261; p=0.19988; n=5). Mean female width was 3.7 mm (SD=2.668749) and was normally distributed (D=0.30891; p=0.24086; n=5). Widths were different (t=1.37457; p=0.093069; n=10). Lengths were not significantly different (t=-0.56639; p=0.29333; n=10).

J. panda (Attems, 1928)
Tests of male and female widths and lengths all were normal. Mean male length was 32 mm (SD=3.807887) and was normal (D=0.32147; p=0.57919; n=5). Mean female length was 37.8 mm (SD=2.280351) and was normal (D=0.25963; p=0.8136; n=5). Mean Male width was 2.7 mm (SD=1.418136) and was normally distributed (D=0.28823; p=0.31349; n=5). Widths were not different (t=1.27136; p=0.109891). Lengths were significantly different (t=-2.922; p=0.009616; n=10).
**O. tabulinus** (Attems, 1914)
Tests of male and female widths and lengths all were normal. Mean male length was 63.4 375 mm (SD=16.124515) and was normal (D=0.21459; p=0.39631; n=16). Mean female length was 70.25 mm (SD=13.325381) and was normal (D=0.19271; p=0.39686; n=20). Mean male width was 5.09375 mm (SD=1.731719) and was normal (D=0.18187; p=0.21297; n=16). Mean female width was 4.95 mm (SD=2.489851) and was not normally distributed (D=0.2666; p=0.00529; n=20). Widths were not different (U=588; z=0.58362; p=0.28096). Lengths were significantly different (U=103; z=1.79872; p=0.03593).

4 Discussion
The normality of length and width of the two sexes in this species is a finding which successfully confirms the analysis of previous data sets and allows predictive power for the morphological data set in the 6 juliform genera. SSD was found based on length only. The finding does not entirely support studies which shows the size of Juliformia “has two main components: body diameter and number of” rings but includes length as a third component of Juliform size (Enghoff, 1992; Ilić et al., 2017). Other correlates of Juliform size include oxygen consumption, precipitation and temperature (Dwarakanath, 1971; Penteado et al., 1991; Echeverría et al., 2014). Size criteria are useful for determining species of Juliformia diplopods (Cooper, 2014-2019). The present research has illustrated what the minimum sizes of data sets need to be in order to be useful for determining sex of juliforms.

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