Weight-length relations of eight spicies of spiders (Araneae) from Denmark

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Total length, dry- and werweights were measured in eight species of spiders from North Zealand, and formulas expressing the relations between these parameters are presented.

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Introduction

In biological investigations it is often necessary to know the weight of the animals. This is the case in estimates of biomass and production, or when a certain amount (weight) of animal is needed, for, e.g., chemical analysis.

Breymeyer (1967b) has calculated a weight-length formula for spiders, but the formula is based on several different species. The present paper investigates the weight-length and dryweight – wetweight relations of each of the eight most abundant species of spiders on linden trees *(Tilia)* in North Zealand, Denmark. On a weight basis the species constitute about 96% of the overwintering spiders. Knowledge of the weight-length relations of these spiders makes it possible to estimate the biomass of the spiders in this relatively simple ecosystem; moreover, it obviates the need for expensive weights and drying ovens.

Materials and methods

Total length (incl. chelicerae in closed position, and spinnerets), dryweight, and in some cases the wetweight were measured in the following eight species of spiders overwintering in crevices in bark of linden trees: *Araneus umbraticus* Clerck, 1757, *Philodromus* sp., Walckenaer, 1825, *Clubiona brevipes* Blackwall, 1841, *C. pallidula* (Clerck, 1757), *C. corticalis* (Walckenaer, 1802), *Steatoda bipunctata* (Linné, 1758), *Moebelia penicillata* (Westring, 1851) and *Segestria senoculata* (Linné, 1758).

The main part of the material was collected using pieces of waste cork i.e., the outer part of the cork often used in terraria, which were tied to the tree trunks 3 meters or more above ground in autumn, and taken down in February. The cork pieces were provided with corrugated paper on the side facing the tree. After being taken down the cork and paper pieces were brought to the laboratory where the spiders were driven out in Tullgren funnels and preserved in 75% alcohol. Measurements were made after about 2.5 years of preservation. One species, however, *A. umbraticus,* was collected individually and measured immediately after being killed in ethyl acetate. All specimens were dried at 50°C for 5 days in an oven supplied with silica gel. The wetweight of preserved specimens was determined as soon as the alcohol evaporated from the surface (as observed under the microscope).

A significance level of P= 0.05 was chosen as statistically significant.

Results

It was found that a linear relation exists between the natural logarithm (ln) to the weight (dry- og wet-) and ln to the length (Figs. 1-14), as well as between ln to the dryweight and ln to the wetweight (Figs. 15-19). In the weight-length relations (arithmetric scale), the curve grows steeper with increasing length, whereas in the dryweight – wetweight relations the curve grows less steep with increasing wetweight. The relations can be expressed by the general formula:

$$y \text{ (or } x) = c \cdot z^b \text{ (or } x^b)$$

y= dryweight (mg), x= wetweight (mg), z= length (mm) and c and b are constants.

Weight-length relations are shown in Figs. 1-14. The straight lines represent the functional regressions. The slope of the functional regression is $= \frac{b}{r}$, where b is the slope of the least squares regression, and r is the correlation coefficient. The line passes through the point $\bar{x},\bar{y}$, the mean values of x- and y-data respectively. Functional regression should be used when both x- and y data are subject to variation (Ricker, 1973). Is is seen that there is homogeneity of variances, whereas this is not the case on an arithmetric scale. Statistically, there were clear differences in the slopes of the regressions: $P << 0.001$ (dryweight-length) and $0.005 < P < 0.01$ (wetweight-length), analysis of covariance (Zar, 1974). The differences between slopes of the lines of species of *Clubiona* were not significant ($0.1 < P < 0.2$, analysis of covariance (dryweight-length) and $0.05 < P < 0.1$, t-test(wetweight-length)), and common regressions for these species have been calculated (Figs. 6 and 14). As can be seen in Figs. 6 and 14 the plots for the different species of *Clubiona* are distributed fairly evenly around the common regression lines. Also, there was no significant difference between the lines for preserved and fresh specimens of *A. umbraticus* ($P > 0.1$ (dryweight-length) and $0.05 < P < 0.1$ (wetweight-length), t-test). The wetweight-length regression of preserved animals has an apparent higher elevation than that of fresh specimens (Fig. 10), but the difference is not significant ($0.05 < P < 0.1$, t-test).

On an arithmetric scale the relations between dryweight and wetweight seem to form straight lines. But the variation of plots around the lines increases drastically with increasing weight, and thus a simple linear regression analysis is invalid. With logarithmic transformation of data the required homogeneity of variances is obtained, and the plots clearly form a straight line (Figs. 15-19). Equality of regression coefficients was extremely improbable ($P << 0.001$, analysis of covariance), while differences between slopes of »*Clubiona*-lines« were insignificant ($0.05 < P < 0.1$, t-test). Regressions

Fig.1

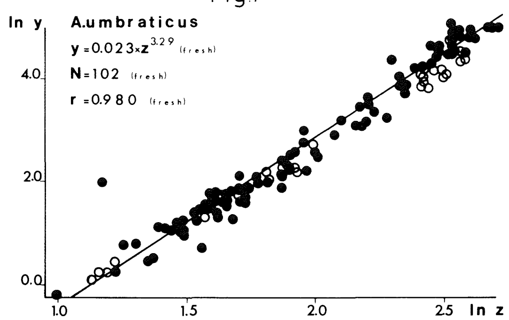


Fig.2

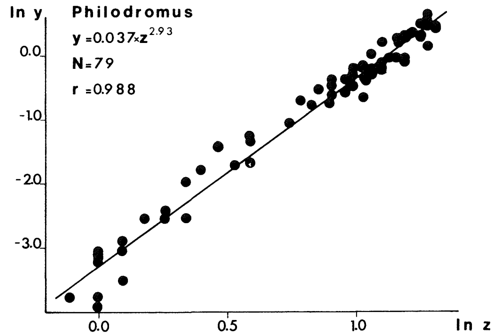


Fig.3

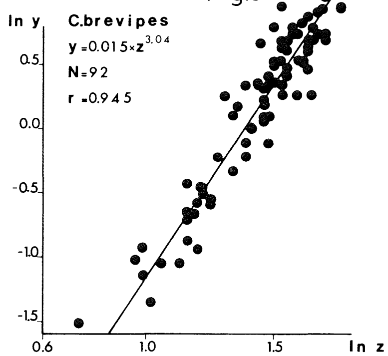


Fig.4

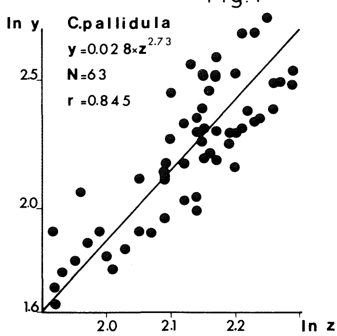


Fig.5

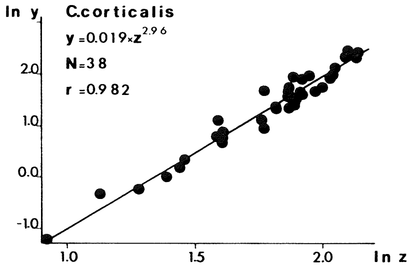


Fig.6

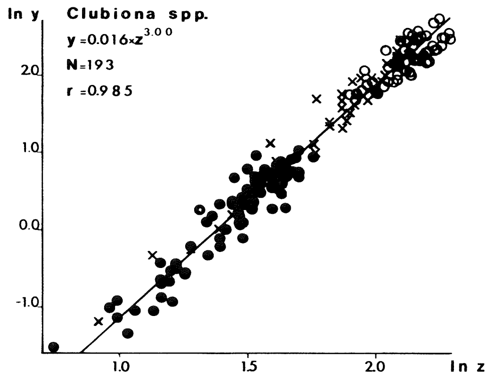


Fig.7

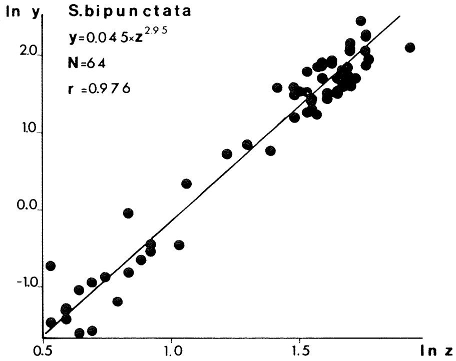


Fig.8

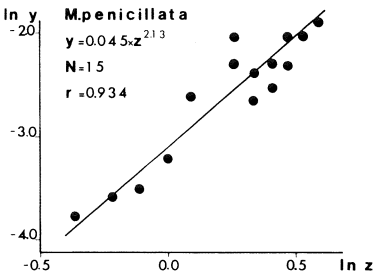
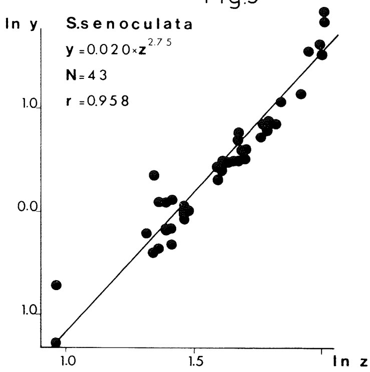


Fig.9

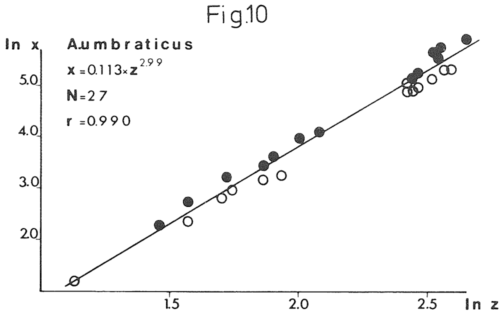


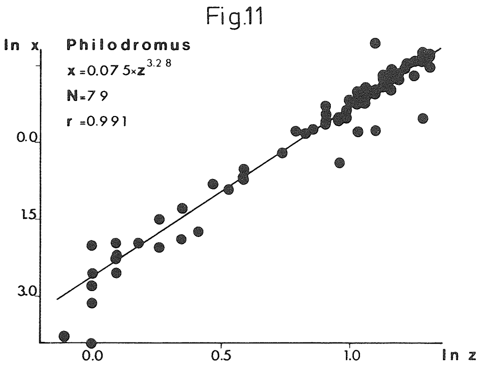
Figs. 1-9. The natural logarithm (ln) to the dry-weight (y) as a function of ln to the length (z). Fig. 1. *Araneus umbraticus* (dots: fresh specimens, circles: preserved specimens). Fig. 2. *Philodromus* sp. Fig. 3. *Clubiona brevipes*. Fig. 4. *C. pallidula*. Fig. 5. *C. corticalis*. Fig. 6. *Clubiona* spp.. (dots: *C. brevipes*, crosses: *C. cortilalis*, circles: *C. pallidula)*. Fig. 7. *Steatoda bipunctata*. Fig. 8. *Moebelia penicillata*. Fig. 9. *Segestria senoculata*. N= number of measurements, r= correlation coefficient. The significance level (P) of the correlation is in all cases less than 0.0005 The straight lines represent functional regressions.

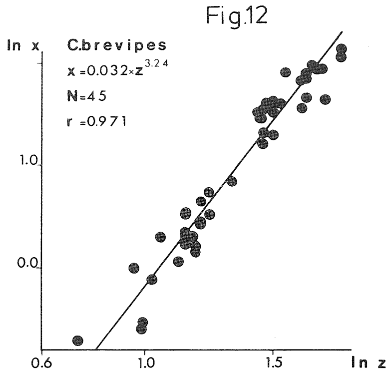
Figs. 1-9 Den naturlige logaritme (ln) til tørvægten (y) som funktion af ln til længden (z). Fig. 1. Araneus umbraticus. *(prikker: friske dyr, cirkler: konserverede dyr). Fig. 2.* Philodromus *sp. Fig. 3.* Clubiona brevipes. *Fig. 4.* C. pallidula. *Fig. 5* C. corticalis. *Fig. 6.* Clubiona *spp.. (prikker:* C. brevipes, *krydser:* C. corticalis, *cirkler:* C. pallidula). *Fig. 7.* Steatoda bipunctata. *Fig. 8.* Moebelia penicillata. *Fig. 9.* Segestria senoculata. *N= antal målinger, r= korrelationskoefficienten. Korrelationernes signifikansniveau (P) er i alle tilfælde mindre end 0.0005. De rette linier repræsenterer funktionelle regressioner.*

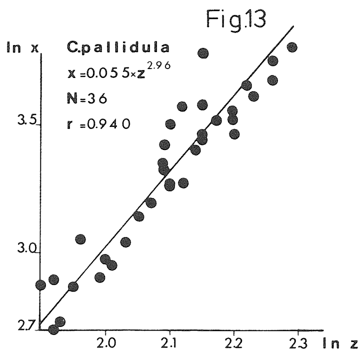
of preserved and fresh *A. umbraticus* have, statistically, identical slopes, but different elevations, and are thus parallel ($0.1 < P < 0.25$ and $P < 0.005$, respectively).

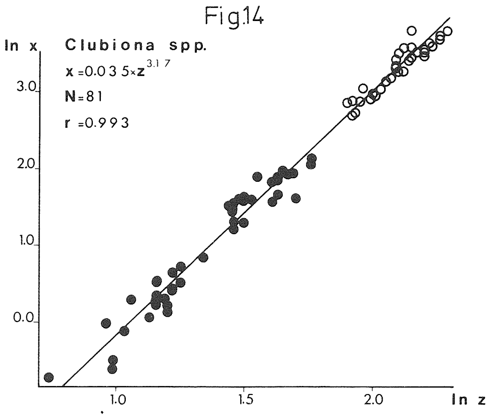
The dryweight-wetweight ratio (Table 1) was statistically different between all groups ($P \leq 0.005$, t-test), except between *Philodromus* sp. and preserved *A. umbraticus* ($P > 0.25$), and between *C. pallidula* and fresh *A. umbraticus* (identical).











Figs. 10-14. ln to the wetweight (x) as a function of ln to the lenght (z). Fig. 10. *A. umbraticus* (dots: fresh, circles: preserved). Fig. 11: *Philodromus* sp. Fig. 12. *C. brevipes.* Fig. 13. *C. pallidula.* Fig. 14. *Clubiona* spp. (dots: *C. brevipes,* circles: *C. pallidula*). N & r: see legend to Figs. 1-9. P. in all cases less than 0.0005 Straight lines as in Figs. 1-9.

Figs. 10-14. ln til vådvægten (x) som funktion af ln til længden (z). Fig. 10. A. umbraticus *(prikker: friske, cirkler: konserverede). Fig. 11.* Philodromus *sp.. Fig. 12.* C. brevipes. *Fig. 13.* C. pallidula. *Fig. 14.* Clubiona *spp. (prikker:* C. brevipes, *cirkler:* C. pallidula). *N & r: se tekst til Figs. 1-9. P i alle tilfælde mindre end 0,0005. Rette linier: som i Figs. 1-9.*

Discussion

Breymeyer (1967b) calculated a weight-length formula based on data from several different species of *Pardosa* C. L. Koch (called *Lycosa* Latreille in Breymeyer, 1967) and *Pirata* Sundevall (Lycosidae). My results suggest that such a procedure is invalid, and that calculations of this sort should be made species by species. Weight – length relations of closely related species may be congruent, though, as in the three species of *Clubiona*.

Breymeyer (1967b) calculated a formula for the dryweight-wetweight relation corresponding to $y = c \cdot x^b$, as in the present paper, but she did not explain how this was derived. Workman (1978) found a linear rela-

Fig15

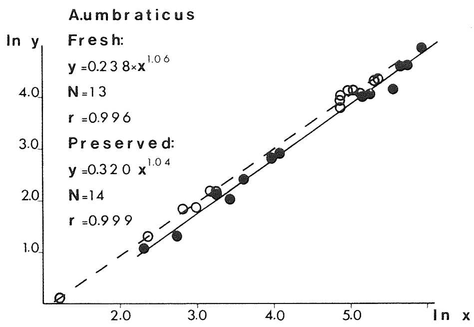


Fig16

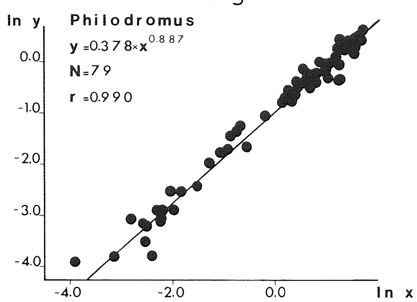


Fig17

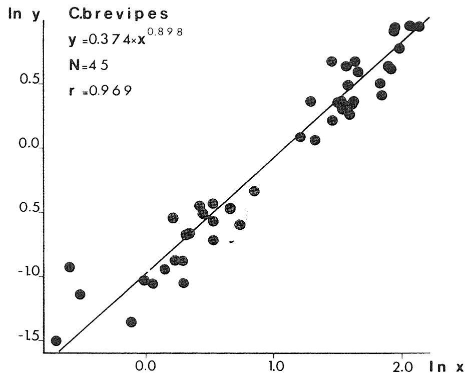


Fig18

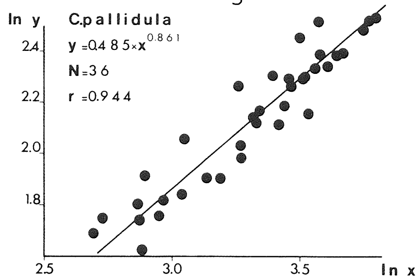
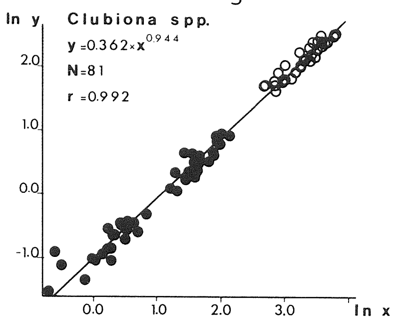


Fig19



Figs. 15-19. ln to the dryweight (y) as a function of ln to the wetweight (x). Fig. 15. *A. umbraticus* (dots: fresh, circles: preserved). Fig. 16. *Philodromus* sp. Fig. 17. *C. brevipes.* Fig. 18. *C. pallidula.* Fig. 19. *Clubiona* spp. (dots: *C. brevipes,* circles: *C. pallidula.* See legend to Figs. 1-9. P in all cases less than 0.0005. Straight lines as in Figs. 1-9.

Fig. 15-19. *ln til tørvægten (y) som funktion af ln til vådvægten (x). Fig. 15.* A. umbraticus *(prikker: friske, cirkler: konserverede. Fig. 16.* Philodromus *sp.. Fig. 17.* C. brevipes. *Fig. 18.* C. pallidula. Fig. 19. Clubiona *spp. (prikker:* C. brevipes, *cirkler:* C. pallidula). *Se iøvrigt tekst til Figs. 1-9. P i alle tilfælde mindre end 0.0005. Rette linier: som i Figs. 1-9.*

tionship on an arithmetic scale for *Trochosa terricola* Thorell, but in light of the present results it is doubtful if his data show homogeneity of the variances. Actually one would have expected a linear relationship between the two measures of weight. The reason why the line on arithmetic scale becomes less steep with increasing weight may be that the ratio of dry over wetweight increases with decreasing size of the specimens. In *Philodromus* sp. there is a significant negative correlation between dryweight

	Mean	S.E.	N
Araneus umbraticus, fresh	0.31	0.012	13
A. umbraticus, preserved	0.37	0.009	14
Philodromus sp.	0.38	0.012	79
Clubiona brevipes	0.35	0.013	45
C. pallidula	0.31	0.006	36

Table 1. Mean dryweight over wetweight. S.E.= standard error. N= number of measurements.

Tabel 1. Gennemsnitsværdier af tørvægt divideret med vådvægt. S.E.= standardfejl. N= antal målinger.

over wetweight and length (r= -0.917, $P<0.0005$, N=26), although in the other species the correlation was insignificant. With decreasing size, the exocuticle may make up a relatively greater part of the animal's weight because of the relatively greater surface. Also there may be a minimum thickness of the cuticle, which, in effect, will give the same result.

As the regressions of weight on length of fresh and preserved *Araneus umbraticus* were not significantly different, the relations of the other species can be used on fresh specimens with reasonable certainty, but the dryweight-wetweight relations most probably cannot be transferred directly to fresh animals.

The difference between dryweight-wetweight ratios of fresh and preserved *A. umbraticus* was significant ($P<0.001$, t-test). Surprisingly, the ratio was greater in specimens preserved in alcohol. One would have expected the opposite to be the case because of loss of dry matter during alcohol storage (Breymeyer, 1967a). The lower density of alcohol as compared to water might be an explanation. Also, the point at which alcohol-soaked animals were considered dry enough for determination of the wetweight might introduce errors.

Conclusion

The weight-length and dryweight-wetweight relations can be expressed by the general formula:

$$y \text{ (or } x) = c \cdot z^b \text{ (or } x^b)$$

y= dryweight, x= wetweight, z= length and c and b are constants.

There are clear differences in slopes of the regressions, and generally the relations should be worked out for single species, although differences between species of *Clubiona* were insignificant.

The weight-length regressions of alcohol preserved and fresh *Araneus umbraticus* were not statistically different, while the dryweight-wetweight regressions of preserved specimens exhibited a higher elevation due to a greater dryweight-wetweight ratio. The greater dryweight-wetweight ratio of alcohol stored specimens is possibly caused by the lower density of alcohol as compared to water.

Sammendrag

Vægt-længde relationer hos otte arter edderkopper (Araneae) fra Danmark

Totallængden (incl. chelicerer i lukket stilling og spindevorter), tørvægten og i nogle tilfælde vådvægten måltes hos otte edderkoppearter, der overvintrer på lindestammer *(Tilia)* i Nordsjælland, Danmark. Flertallet af dyrene blev målt efter ca. 2,5 år i sprit. Undtaget er dog hovedparten af *Araneus umbraticus* Clerck, der måltes umiddelbart efter indsamlingen.

Det blev fundet, at vægt-længde såvel som tørvægt-vådvægt relationerne kunne beskrives ved den generelle formel:

$$y \text{ (eller } x) = c \cdot z^b \text{ (eller } x^b)$$

hvor y= tørvægten, x= vådvægten, z= længden og c og b er konstanter.

Der var statistik sikre forskelle mellem regressionerne for de forskellige arter ($P<0{,}01$ i alle tilfælde, kovariansanalyse), og man bør generelt betragte hver art for sig. Der var dog ingen forskelle mellem regressionerne for de forskellige *Clubiona* arter.

Spritkonserveringen medførte tilsyneladende ingen ændring i vægt-længde relationerne, mens tørvægt-vådvægt forholdet derimod var større hos konserverede dyr. Det skyldes muligvis alkoholens mindre massefylde i forhold til vands.

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