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RESEARCH NOTE

ESTIMATING LIVE SPIDER WEIGHT USING PRESERVED SPECIMENS

The feasibility of estimating live weight from preserved material is examined. One option for estimating live weight is presented by Greenstone et al. (1985a, b), where an estimated volume was determined by a series of measurements of several body dimensions which were then compared with the actual weight of specimens. This procedure involved extended manipulation of specimens and equipment. Rogers et al. (1977), using recently preserved specimens ("a few weeks later") calculated length-weight relationships for a variety of insects and spiders. They noted that "Clearly, power functions adequately describe length-weight relationships for adult invertebrates and for immature taxa exhibiting simple metamorphosis (nymphs)".

This study examines the degree to which preserved material using a power function provides useful data. The bulk of preserved material used was collected in 1989 and 1990 on Cape Cod, Massachusetts in connection with another study (Edwards 1993). Collection details are provided therein. A few specimens were collected earlier. All were preserved in 75% denatured ethanol, and all had their alcohol replaced at least once, typically within 48 hours of collection. The total length was measured from the clypeus to the distal tips of spinnerets, using an ocular micrometer for specimens <12 mm and vernier calipers for those >12 mm. The total length was measured to the nearest 0.1 mm, and the specimens damp dried on absorbent paper before weighing. Distorted

Table 1.—Fresh and preserved spiders examined. Number of individuals = *n*, lengths included in sample = range (mm).

	Preserved specimens			Fresh specimens		
Taxa	*n*	Genera	Range (mm)	*n*	Genera	Range (mm)
Agelenidae	39	3	3.0–13.5	25	5	4.5–13.5
Anyphaenidae	33	4	2.4–8.4	28	4	2.7–8.5
Araneidae	28	5	2.1–21.2	48	8	2.4–21.2
Clubionidae	27	7	2.5–9.0	40	5	2.2–8.8
Gnaphosidae	48	7	3.0–13.1	49	5	2.8–10.1
Linyphiidae	23	6	1.9–6.5	24	8	1.5–5.5
Lycosidae	19	7	4.0–21.5	50	9	2.0–23.5
Philodromidae	26	3	2.5–8.6	24	3	2.0–7.0
Pisauridae	9	2	2.0–12.5	7	2	4.0–11.1
Salticidae	24	3	4.0–13.0	46	7	4.0–10.1
Tetragnathidae	26	1	3.5–9.0	19	1	2.5–7.8
Theridiidae	33	6	1.5–7.5	42	7	2.1–7.6
Thomisidae	57	5	1.8–8.0	50	6	1.9–8.3
Total	405	59		454	70	
Random sample	300	59	1.8–21.5	300	70	1.5–23.5

Table 2.—Statistical parameters for spider weight-length equations, *ln weight* = *a* + *b*(*ln length*), for fresh and preserved material. Number of individuals = *n*, standard error = SE, coefficient of determination = r^2. Random sample taken from total data pool.

	n	*a*	SE *a*	*b*	SE *b*	r^2
Preserved specimens						
Agelenidae	39	−1.939	0.248	2.757	0.084	0.966
Anyphaenidae	33	−2.077	0.299	2.816	0.143	0.926
Araneidae	28	−1.512	0.329	2.760	0.102	0.966
Clubionidae	27	−1.599	0.287	2.542	0.166	0.903
Gnaphosidae	54	−2.616	0.301	3.008	0.152	0.905
Linyphiidae	23	−1.504	0.181	2.569	0.270	0.812
Lycosidae	19	−1.480	0.187	2.647	0.090	0.981
Philodromidae	26	−1.480	0.271	2.680	0.189	0.893
Pisauridae	9	−1.243	0.234	2.633	0.122	0.985
Salticidae	24	−1.611	0.290	2.782	0.180	0.916
Tetragnathidae	26	−1.243	0.281	2.119	0.219	0.795
Theridiidae	33	−1.229	0.232	2.697	0.105	0.955
Thomisidae	57	−1.655	0.220	2.986	0.086	0.957
Average	29.5	−1.630	0.259	2.692	0.147	0.920
Random sample	300	−1.533	0.420	2.651	0.051	0.901
Fresh specimens						
Agelenidae	25	−2.031	0.235	2.660	0.097	0.957
Anyphaenidae	28	−2.247	0.244	2.814	0.139	0.940
Araneidae	44	−1.923	0.434	2.923	0.111	0.938
Clubionidae	40	−2.156	0.188	2.653	0.102	0.947
Gnaphosidae	49	−2.830	0.200	3.055	0.098	0.954
Linyphiidae	24	−1.829	0.382	2.754	0.216	0.881
Lycosidae	50	−2.043	0.280	2.842	0.083	0.961
Philodromidae	24	−1.985	0.177	2.940	0.114	0.968
Pisauridae	7	−2.040	0.133	2.847	0.141	0.988
Salticidae	46	−2.184	0.238	2.901	0.150	0.895
Tetragnathidae	19	−2.615	0.186	2.574	0.144	0.950
Theridiidae	42	−1.577	0.268	2.907	0.105	0.951
Thomisidae	50	−1.644	0.294	2.973	0.132	0.914
Average	33.1	−2.098	0.237	2.845	0.126	0.946
Random sample	300	−1.844	0.506	2.711	0.053	0.898

specimens were not used. In those cases where the pedicel had elongated, the measurement was corrected for the separation of the thorax from the abdomen. All the measurements of preserved material were carried out in 1993 and 1994. Specimens of all the species used in this study have been deposited in the United States National Museum.

The fresh material for this study was collected in the months of June—September in 1993 and 1994 from the same area and habitats as the preserved material. The collections were made in the afternoon, the spiders immobilized in an ethyl acetate collecting jar, identified and measured to the nearest 0.1 mm in the evening, refrigerated overnight at 3 °C, and weighed the following morning on a Mettler A200 balance, accurate to 1 mg.

The families, genera, number of individuals weighed, and the range of total lengths are provided in Table 1. To the extent possible, for both preserved and fresh samples, the range of lengths used for each family was matched and included immatures and adults. A total of 1021 fresh and preserved specimens representing 79 genera and 13 families was weighed (Table 1). In addition, a random sample of 300 fresh weights and 300 preserved weights was selected from the data described above for separate analysis.

The weight-length equations obtained are included in Tables 1 and 2 in the category 'Random sample'.

The equation, *ln weight = ln a + b (ln length)*, was used to estimate weight at length. The results are provided in Table 2. The coefficient of determination (r^2) for the equations ranged from 0.795 (Tetragnathidae preserved) to 0.988 (Pisauridae fresh), with five less than $r^2 = 0.900$. The average values for constant *a* (intercept) and exponent *b* (slope) were less for preserved specimens than fresh specimens. The equations calculated using the randomly selected, large sample vary similarly. Variations in the weight of spiders at any particular size or instar or varying seasonal conditions have been documented by many authors, e.g., Jocque (1981) and Edgar (1971). It will be noted that the r^2 values for the samples in Table 2 suggest that the data were reasonably well fitted by the power function.

The relationship between exponent *b* for preserved spiders with *b* for fresh material was significant, $r^2 = 0.619$, ($F_{11,1} = 17.89$; $P < 0.01$) (Fig. 1A). Constant *a* for both preserved and fresh were barely significantly related, $r^2 = 0.287$, ($F_{11,1} = 4.44$; $P = 0.061$) (Fig. 1B). The lack of any relationship between coefficient *b* and constant *a*, $r^2 = 0.001$, for fresh material comes as no particular surprise. Different families generally have characteristic body shapes. A mix of genera with differing body shapes within a family, for example the Theridiidae with the stout-bodied genus *Steatoda* Sundevall 1833, and the relatively longer-legged, globular-bodied genera like *Achaearanea* Strand 1929, and *Theridion* Walckenaer 1805, make it desirable to consider basing the weight-length equations on genera. Although such genera may share a similar *b* exponent, they can differ considerably in weight at length (Edwards unpubl. data).

Rogers et al. (1977) calculated a length-weight equation for Araneida, based on 25 specimens not identified to genus or family, where

ln weight = −3.106 + 2.929 *(ln length).*

In this study the equation based on the random sample values for preserved specimens is

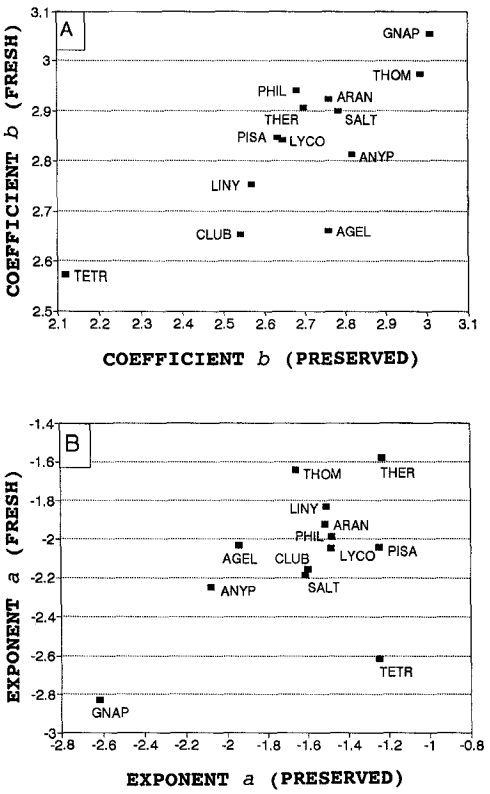

Figure 1.—Comparisons of the statistical parameters for the equation *ln weight = ln a + b (ln length)* for fresh and preserved spiders. The points shown are identified by the first four letters of the taxa listed in Table 1. A. Coefficient *b* (slope) for preserved material compared with coefficient *b* for fresh. B. Constant *a* (intercept) for preserved material compared with constant *a* for fresh material.

ln weight = −1.533 + 2.651 *(ln length)*

and for fresh material is

ln weight = −1.844 + 2.711 *(ln length)*

One general conclusion that may be drawn is that both fresh and preserved spiders tend to increase their length somewhat faster than they accrue weight (exponent $b < 3$) and that spiders preserved (in denatured alcohol at least) weigh more than live spiders.

To illustrate the potential usefulness of comparing different habitats in terms of preserved weight, data on the spiders taken from the trunks of pitch pine and scarlet oak are compared. Species of ten families contribute ±99% in numbers of spiders on these tree

Table 3.—Percent numbers and weight/quadrat in milligrams (mg) of spiders by family for Scarlet Oak and Pitch Pine trunk collections; 41 and 35 0.25 m^2 quadrats respectively. Percent number of individuals = *n*, weight preserved = p, weight fresh = f and ratio of fresh/preserved = f/p.

	%*n*	p, mg	f, mg	%p	%f	f/p
Pitch Pine trunk						
Araneidae	15.3	3.8	3.0	6.5	6.3	0.80
Clubionidae	8.1	5.3	3.8	9.1	8.0	0.72
Erigoninae	14.8	1.7	1.4	2.9	2.9	0.81
Gnaphosidae	2.6	2.3	2.0	3.9	4.2	0.88
Linyphiidae	1.7	0.2	0.2	0.4	0.4	0.83
Lycosidae	1.2	9.3	8.1	16.0	17.0	0.87
Philodromidae	12.7	9.9	8.6	17.1	18.1	0.87
Salticidae	5.3	15.0	10.7	25.8	22.6	0.71
Theridiidae	28.2	4.4	3.6	7.7	7.6	0.81
Thomisidae	8.9	6.1	6.1	10.5	12.8	1.00
Total	98.8	58.0	47.5	100.0	100.0	
Average						0.831 ± 0.0817
Scarlet Oak trunk						
Araneidae	11.0	3.7	3.0	5.6	5.5	0.80
Clubionidae	16.7	26.5	18.8	39.9	35.3	0.71
Erigoninae	12.9	1.8	1.5	2.7	2.8	0.83
Gnaphosidae	1.5	2.5	2.2	3.8	4.2	0.89
Linyphiidae	16.0	0.3	0.3	0.4	0.6	1.07
Lycosidae	1.7	20.9	18.8	31.5	35.3	0.90
Philodromidae	0.8	0.3	0.2	0.5	0.5	0.80
Salticidae	3.5	2.8	1.8	4.2	3.4	0.66
Theridiidae	34.2	5.9	5.0	8.9	9.3	0.84
Thomisidae	0.8	1.7	1.7	2.6	3.2	0.98
Total	99.1	66.4	53.2	100.0	100.0	
Average						0.847 ± 0.1211

trunks (see Table 3). The collection details for the habitats used in this comparison are provided in Edwards 1993. Weights were calculated using the appropriate weight-length parameters for fresh and preserved specimens (Table 2).

The regression of fresh weight on preserved weight had an r^2 of 0.977. Using the random sample equation for preserved material, the habitat comparison data was recalculated. The resulting comparison of fresh *versus* preserved weight had an $r^2 = 0.901$, a statistically significant reduction from the value of $r^2 = 0.977$ obtained using the separate family equations. The results are compared graphically in Fig. 2.

The ratio of fresh weight/preserved weight (*f/p*) for the various families sampled, with a few exceptions, increases as spiders increase in size (Table 4). In the case of the random sample, the difference between fresh and preserved weight ($f-p$) is described by the equation

$$ln(f-p) = -0.836 + ln(f)0.873,$$

$r^2 = 0.999$. The *f/p* ratio increases from 0.76 for weight at an average length of 2 mm to 0.84 at 10 mm, with different families varying considerably, one from the other. Clausen (1983) noted that "the ratio of dry over wet weight increases with decreasing size of the specimens", and suggested that "With decreasing size, the exocuticle may make up a relatively greater part of the animal's weight because of the relatively greater surface". The *f/p* data presented here further support Clausen's suggestion.

The procedure reported here serves to provide a first approximation of weight (biomass) for the purpose of comparing the species assemblages of different habitats. However, there are many potential variables to consider,

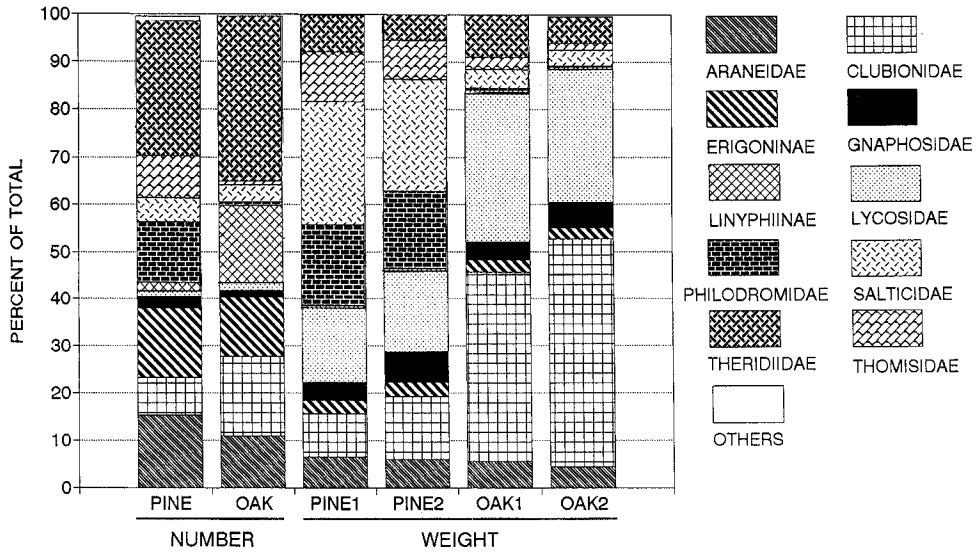

Figure 2.—Graphic comparison of proportional representation of families of spiders by density (number of individuals) and biomass (estimated weight in mg based on preserved specimens) on scarlet oak and pitch pine trunks. The nine families included account for virtually all spiders found in terms of numbers (±99%). The weight calculated using the equations for each family are shown as PINE1 and OAK1, those using the random sample equation labeled as PINE2 and OAK2. The subfamilies Erigoninae and Linyphiinae of the family Linyphiidae, now generally considered of doubtful taxonomic value, are used here to separate the small, rotund genera (e.g., *Ceraticelus* Simon 1884 and *Grammonota* Emerton 1882) from the larger, less rotund genera of the family (e.g., *Drapetisca* Menge 1866 and *Pityohyphantes* Simon 1929).

Table 4.—Ratio of spider fresh weightpreserved weight. Number of genera = genera, number of individuals = *n*. See text for details.

	Length				
	2 mm	6 mm	10 mm	Genera	*n*
Agelenidae	0.83	0.76	0.73	3	39
Anyphaenidae	0.84	0.84	0.84	4	33
Araneidae	0.77	0.90	0.97	5	28
Clubionidae	0.63	0.71	0.74	7	48
Gnaphosidae	0.84	0.88	0.90	7	48
Linyphiidae	0.86	1.02	1.12	6	23
Lycosidae	0.68	0.82	0.90	7	19
Philodromidae	0.77	0.98	1.11	3	26
Pisauridae	0.55	0.67	0.74	2	9
Salticidae	0.63	0.70	0.74	3	24
Tetragnathidae	0.38	0.59	0.74	1	26
Theridiidae	0.76	0.82	0.84	6	33
Thomisidae	1.00	0.99	0.98	5	57
Average	0.73	0.82	0.87	–	–
Random sample	0.76	0.82	0.84	59	300

not the least of which are the varied methods of preservation and the mix of instars and genera included in the sample. The degree of consistency found here between preserved weight and fresh weight is, however, encouraging.

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