J. Biosci., Vol. 22, Number 2, March 1997, pp 219–224. © Printed in India.

Biomass estimates of terrestrial arthropods based on body length

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MS received 5 July 1995; revised 13 August 1996

Abstract. The relationship between body length and biomass (dry weight) was investigated for nineteen taxa of terrestrail arthropods and for the combined sample that included all insect taxa. The specimens were collected from forests of Bicholim taluk of Goa. Four models were evaluated, a linear function, a logarithmic function, a power function and an exponential function. The linear function best describes dry weights in the order Isopoda of class Crustacea and dictyopteran, coleopteran larvae of class Insecta. The logarithmic function fits well for only one group namely Opiliones of class Arachnida. The power functions fits best for Scutigeromorpha and Scolopendromorpha of class Chilopoda, Araneae of class Arachnida, Collembola, Thysanura, Orthoptera, Hemiptera, Homoptera, coleopteran adults, Diptera, lepidopteran adults and Hymenoptera of class Insecta and the combined data on adult insects. An exponential function fits well for the dermapteran and lepidopteran larvae of class Insecta. The usefulness of these estimates of Arthropod biomass in community ecology is discussed.

Keywords. Arthropoda; biomass; body length.

1. Introduction

Biomass estimation of communities is an important parameter for population studies involving estimates of energy and mineral transfer, and prey-predator relationships. The estimation of biomass of small and numerous animals is too laborious and time consuming and there is the further problem that rare specimens cannot be destroyed. To overcome this difficulty, general length-dry weight relationships have been established by some workers, e.g., Rogers *et al* (1976, 1977) for Shrub Steppe invertebrates and Sage (1982) for insects and spiders which are food items of lizards. The generalized regression equation for adult insects proposed by Rogers *et al* (1976) is used by community ecologists [e.g., Basset and Arthington (1992) in estimating biomass of the arthropod community of an Australian rain forest tree]. Gowing and Recher (1985) suggest that the estimates from tropical areas should not be applied to temperate fauna because the former have longer and thinner bodies. They suggest two precautions to be taken in biomass estimation: (i) in using length weight regression to calculate biomass, the best approach is to derive the regressions from the fauna sampled and (ii) when it is necessary to use generalized regressions, those used should be selected from places as similar as possible in continent of origin, climatic zone and vegetation characteristics to the communities being studied.

The present study therefore provides length-dry relationships weight for common arthropod taxa inhabiting our study area in Goa. A series of regression coefficients for estimating the biomass of nineteen frequently observed groups of Arthropoda are provided so that the biomass estimates could be made as accurate as possible for each group.

2. Materials and methods

Arthropods samples were collected during a study carried out to assess the impact of iron ore mining on the faunal composition in Goa (Ganihar 1990). The sampling techniques used were pitfall traps, water traps, scented traps, sweep-nets and hand collection. Specimens preserved in 70% isopropyl alcohol, were sorted to their morphospecies levels with the help of Tikader (1987) for spiders and Scutigeromorpha, Lefroy and Howlet (1971), Mani (1972, 1974), Borror *et al* (1981) for insects and Jangi (1966) for Scolopendromorpha. The identification of "species" by simple visual inspecttion is probably sufficiently accurate for the purpose of this analysis. Any cryptic, biological species that might have been lumped together because they have the same external features, are likely to have the same weight-length relationships (Sage 1982).

Twenty taxonomic categories were used to estimate the weights of arthropods of diverse shapes. The categories were based on taxonomy, general shape, type of life

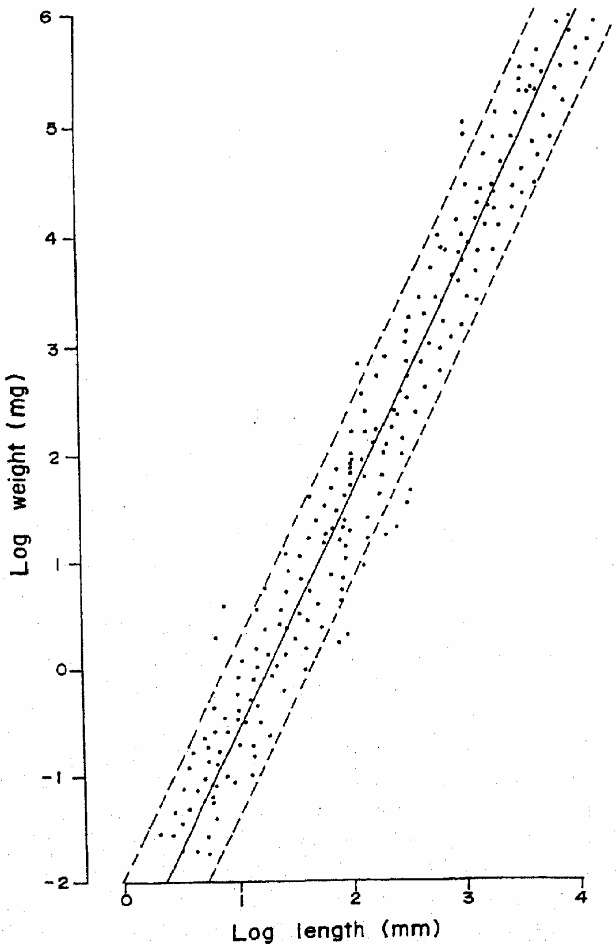

Figure 1 Scatter plot of adult insect biomass (dry wight) against body length (item 20 in table 1). The dry weights (dots), regression line (based on model 3 as in table 1) and the 95% confidence interval (dashed lines) are shown.

cycle, and biology. Thus, the resulting categories were as distinct as possible, consisting of different taxonomic groups or different stages in the life cycle of the same taxon. For example, the family Formicidae was used as a separate category because these insects have a shape and behaviour (non flying) quite different from most other species in the order Hymenoptera. The two larval categories used (Coleoptera and Lepidoptera) also reflect significant differences in shape at an alternate stage of life cycle from the adult animals. Finally, all adult insects which were used in the more restrictive categories (items 6–19 in table 1) plus a few samples of species of orders Diplura, Ephemeroptera, Odonata, Isoptera, Embioptera, Psocoptera, Thysanoptera and Neuroptera of class Insecta are considered together as category 20. Body lengths were measured using a vernier callipers (for specimens greater than 5 mm) or an ocular micrometer fitted to a dissecting binocular microscope (for specimens less than 5 mm). Measurements were made to the nearest 0·05 mm from the most anterior part of the head to the anus. Appendages extending beyond these points (wings, ovipositors, caudal cerci, styles, etc.) were disregarded. The specimens were oven dried for 48 h at 65 °C and weighed to the nearest 0·01 mg on Dhona analytical balance. Care was taken to prevent the entry of moisture from the atmosphere by keeping the samples in a desiccator with $CaCl_2$.

A total of 625 specimens (representing 5 classes, 24 orders, 99 families and over 300 species of phylum Arthropoda) were used. In cases were a range of size classes within a species was present e.g., larvae of Lepidoptera and Coleoptera, Scutigeromorpha and Scolopendromorpha, sub-groups were formed with similar sized individuals. Mean values from the measurement of 2–10 individuals were used in the regression analysis.

The 4 models considered were the linear, logarithmic, power and exponential, which are respectively expressed as:

$$\text{Linear function, (weight)} = b_0 + b_i\,(\mathit{length}) \tag{1}$$

$$\text{Logarithmic function, (weight)} = b_{oa} + b_1 \cdot 1\text{n (length)} \tag{2}$$

$$\text{Power function, (weight)} = b_o + (\text{lengthy})^{b1} \tag{3}$$

$$\text{Exponential function, (weight)} = b_o + (\text{e})^{b1\,(\text{length})} \tag{4}$$

where b_o and b_1 are the parameters of the models. In order to perform linear regression analyses, equations (3) and (4) were transformed to a linear form by taking the natural logarithm of both sides (Rogers *et al* 1977):

$$\text{In (weight)} = \text{In } b_0 + b_1 \text{ an (length)} \tag{5}$$

$$\text{Ink (weight)} = \text{In } b_0 + b_1 \text{ (length)} \tag{6}$$

All four models were then expressed in the linear form

$$Y = B_0 + B_1 X, \tag{7}$$

where Y, X, B_o and B_1 were equated as follows:

Model (5)	Model (6)	Model (1)	Model (2)
$Y = \ln$ (weight)	$Y = \ln$ (weight)	$Y =$ weight	$Y =$ weight
$X = \ln$ (length)	$X =$ length	$X =$ length	$X = \ln$ (length)
$B_0 = \ln b_0$	$B_0 = \ln b_0$	$B_0 = b_0$	$B_0 = b_0$
$B_1 = b_1$	$B_1 = b_1$	$B_1 = b_1$	$B_1 = b_1$

Table 1. Regression statistics of biomass (mg) [W] of Arthropod groups based on body length (mm) [L].

Taxonomic category	No. of samples	Range of length (mm)	Model	$B_0 \pm$ SE	$B_1 \pm$ SE	Residual SE	R^2
Crustaceae							
1. Isopoda	10	2·44 – 9·00	1	– 1·1167 ± 0·278	0·4762 ± 0·0503	0·1035	0·92
Chilopoda							
2. Scutigeromorpha	25	4·00 – 20·00	3	– 3·2882 ± 0·2492	2·1006 ± 0·1060	0·2588	0·95
3. Scolopendromorpha	10	13·00 – 48·00	3	– 6·7041 ± 0·6286	2·8420 ± 0·1966	0·2046	0·96
Arachnida							
4. Opiliones	10	4·90 – 8·60	2	– 11·0291 ± 2·7436	9·2243 ± 1·5355	0·7983	0·82
5. Araneae	114	1·00 – 12·70	3	– 3·2105 ± 0·1075	2·4681 ± 0·0756	0·4159	0·89
Insecta							
6. Collembola	10	1·16 – 2·48	3	– 1·8749 ± 0·1868	2·3002 ± 0·3014	0·2130	0·85
7. Thysanura	10	6·00 – 13·00	3	– 2·5938 ± 1·0150	1·6729 ± 0·4501	0·3156	0·84
8. Orthoptera	10	5·00 – 34·00	3	– 3·5338 ± 0·2668	2·4619 ± 0·1002	0·1716	0·98
9. Dictyoptera	10	7·00 – 23·00	1	– 6·6427 ± 1·7074	1·3361 ± 0·1023	0·5177	0·95
10. Dermaptera	8	7·00 – 22·00	4	– 0·4524 ± 0·0733	0·2037 ± 0·0259	0·2857	0·92
11. Hemiptera	43	2·00 – 22·00	3	– 3·8893 ± 0·3387	2·7642 ± 0·3113	0·5944	0·85
12. Homoptera	40	1·64 – 9·00	3	– 3·1984 ± 0·1174	2·3487 ± 0·0779	0·2161	0·96
13. Coleoptera larvae	10	9·00 – 20·00	1	– 7·1392 ± 0·8661	0·8095 ± 0·0610	0·5615	0·96
14. Coleoptera adults	175	1·20 – 22·00	3	– 3·2689 ± 0·0659	2·4625 ± 0·0415	0·3693	0·94
15. Diptera	20	1·80 – 16·00	3	– 3·4294 ± 0·01994	2·5943 ± 0·0334	0·0317	0·99
16. Lepidoptera larvae	10	6·00 – 30·00	4	– 0·5631 ± 0·2098	0·1315 ± 0·0139	0·2768	0·92
17. Lepidoptera adults	10	7·00 – 48·00	3	– 4·7915 ± 0·7507	2·8585 ± 0·2567	0·4568	0·93
18. Hymenoptera (except ants)	26	2·40 – 10·00	3	– 3·5917 ± 0·1646	2·6429 ± 0·1127	0·2430	0·94
19. Formicidae	25	2·37 – 13·50	3	– 3·1415 ± 0·1795	2·3447 ± 0·0979	0·2409	0·96
20. Insects, adults	401	1·16 – 48·00	3	– 3·0710 ± 0·0561	2·2968 ± 0·0319	0·4654	0·92

Model 1, Linear; model 2, logarithmic; model 3, power; model 4, exponential function.

The parameters B_0 and B_1 were estimated for each model by the method of least squares, the Standard error (SE) of B_0 and B_1 residual SE were obtained, a *'t'* test for the significance of b_0 and b_1 in each case was conducted, squared correlation coefficient (R^2) between observed and estimated values and 95 % confidence intervals were also calculated (Draper and Smith 1981). The data were tested for their goodness of fit to four regression models in each category by plotting residual values against the *dependent variable,* as recommended by Draper and Smith (1981). The criteria used to choose between the four models were high values of squared correlation coefficient (R^2) and the satisfactory behaviour of residual checked by plotting the residuals against the fitted values as illustrated in Draper and Smith (1981). The values of b_0 and b_1 which showed significance ($P < 0{\cdot}05$) are considered.

3. Results and discussion

In general, the power function (model 3) appears to be a better predictor of biomass than other three models viz., linear, logarithmic and exponential models (table 1). The linear function best describes the groups which have animals with uniformly thick body e.g., Coleoptera larvae, as also observed by Rogers *et al* (1977). However, in the present study linear function also best describes the flat and thin, oblong bodies of the Isopoda and Dictyoptera even though their body is not elongated as much as in Coleoptera larvae. The group Opiliones is the only one for which the logarithmic function fits well. This may be not only due to their peculiar body shape with light weight but also due to their predatory behaviour i.e., these animals have to be active to chase their prey. The exponential function fits well for two groups viz; Dermaptera and Lepidoptera larvae. In Dermaptera this may be due to the presence of heavy forceps like appendages at the posterior end of the body, whereas the Lepidoptera larvae collected in the present study appear to be stouter ones with herbivorous habits and non flying behaviour. The length-weight relationships in arthropoda appears to be influenced by many factors like body shape, size range, feeding habits (herbivorous or predatory), behaviour (flying and non flying), life stages (larvae and adults) and the metabolic rate of animals etc. (Sage 1982). Therefore it is difficult to conclude, simply by looking at general shape and say for example that uniformly thick or thin animals e.g. *Scolopendromorpha* (Centipede) are best described by linear function; infact the power model is the best model to describe biomass of these groups (see table 1).

Gowing and Recher (1985) stated that there was no significant difference in length-weight regressions over a wide range of taxa of two temperate zone habitats located far apart (Australia and North America). Schoener (1980) found that length-weight relationships of tropical insects differed from those of the temperate and he postulated that tropical faunas contain more insects with long thin bodies than those in temperate habitats. The purpose of determining these coefficients was therefore to present parameter estimates of length-weight-models developed for common arthropod taxa inhabiting our study area which may perhaps be applicable to other habitats in India. I know of no other length-weight regression analyses covering such variety of taxa and range of body lengths of Indian arthropods.

Acknowledgments

I am indebted to G V Nadkarni and Prof. S M Shetty for laboratory facilities, Dr S N Harkantra and Dr Arvind Ghosh (NIO) for computer analyses and

Dr Ramanmurthy (NIO) and Dr Durgaprasad, Department of Statistics and Evaluation, Government of Goa for statistical analysis and Dr S M Karisiddaiah (NIO) for valuable suggestions. This research was funded by Department of Environment, Forest and Wild Life, New Delhi.

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