Length-weight relationships for zooplanktonic species of a tropical Brazilian lake: Lake Monte Alegre.

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ABSTRACT Length-weight relationships for zooplanktonic species of a tropical Brazilian lake: Lake Monte Alegre. Equations on length-weight relationships are presented, in dry weight and carbon, for zooplankton species, the cladocerans Daphnia gessneri and D. ambigua, the cyclopoid copepod Tropocyclops prasinus, and the larval instars of the dipteran Chaoborus brasiliensis of a tropical Brazilian lake, Lake Monte Alegre. Zooplankton samples were collected with a 60 μm mesh net. Organisms were measured for identification of size classes, and then were dried and weighed on a microbalance. Carbon content of the organisms was measured on a Carlo Erba elemental analyzer. Regression equations for length-weight relationship, in dry weight and carbon, were obtained for each species. High correlation coefficients (R^2) have been obtained for all species.

Key-words: biomass, length-weight relationship, carbon content, Daphnia gessneri, Daphnia ambigua, Tropocyclops prasinus, Chaoborus brasiliensis.

RESUMO Relação entre o comprimento do corpo e o peso de espécies zooplanctônicas de um lago tropical do Brasil: Lago Monte Alegre. Neste estudo são apresentadas equações que descrevem a relação entre o comprimento do corpo e o peso, tanto em peso seco quanto em carbono, dos cladóceros Daphnia gessneri e D. ambigua, do copépodo Tropocyclops prasinus, e dos estádios larvais de Chaoborus brasiliensis. O zooplâncton foi coletado no Lago Monte Alegre com uma rede de 60 mm de malha. Os organismos foram medidos para identificação das classes de tamanho e, em seguida, secados e pesados em uma microbalança para avaliação do peso seco. O conteúdo de carbono dos organismos foi medido utilizando-se o aparelho Carlo Erba elemental analyzer. Foram obtidas equações de regressão para o comprimento do corpo e o peso, tanto em peso seco quanto em carbono, para cada uma das espécies. Altos valores de coeficiente de correlação (R^2) foram obtidos para todas as espécies.

Palavras-chave: biomassa, relação comprimento do corpo e peso, conteúdo em carbono, Daphnia gessneri, Daphnia ambigua, Tropocyclops prasinus, Chaoborus brasiliensis.

Introduction

Zooplankton biomass is a basic component in studies of aquatic communities, as are population density and development time (Bottrell et al., 1976). Zooplankton biomass, as dry weight or carbon, is essential to estimate secondary production and to develop models on energy flow and carbon within the zooplankton assemblage (Matsumura-Tundisi et al., 1989). Recently, great importance has been given to length-weight relationship to evaluate the conditions of daphnids in the field (Winder & Spaak, 2001), as well zooplankton sinking rates (Culver et al., 1985). These equations can be applied to estimate data on biomass, whenever measures of the body length are available. Therefore, equations that reflect specific length-weight relationship of zooplankton provide subsidies for ecological studies, mainly to those related to planktonic productivity.

Several equations have been already described for neotropical zooplankton species (Cressa & Lewis, 1984; Matsumura-Tundisi et al., 1989; Güntzel et al., 2003). However, the establishment of length-weight relationships for different zooplankton species allow the increase of the accuracy of dry weight estimation from length measurements.

The aim of the present study is to describe equations that express length-weight relationship, in dry weight and carbon, of some zooplankton species, including cladocerans (Daphnia gessneri and D. ambigua), a cyclopoid copepod (Tropocyclops prasinus) and larvae of the dipteran chaoborid (Chaoborus brasiliensis) of a tropical Brazilian lake, Lake Monte Alegre.

Material and methods

The study area

Lake Monte Alegre (21° 11'S, 47° 43'W) is located in southeastern Brazil, and was formed in 1942 by the damming of Laureano Creek of the River Pardo basin. The region is characterized by a tropical climate, marked by a cool–dry season (May to September) and a warm–wet one (October to April). It is a small, eutrophic, shallow (area = 7 ha, Z max. = 5 m), warm discontinuous polymictic reservoir. The lack of manipulation of the dam, as the lake is used only for teaching and research, the surface outlet, the small size, the low flow of the creek, and winds of low velocity without constant direction contribute to its stability (Arcifa et al., 1990).

From 1985 to 2002, ten planktonic microcrustacean species have been recorded in the lake in four annual studies (Arcifa et al., 1992; Arcifa et al., 1998; Fileto, 2001; Bunioto, 2003): the cladocerans Bosmina tubicen, Ceriodaphnia cornuta, C. richardi, Daphnia ambigua, D. gessneri, Diaphanosoma birgei, Moina micrura, and M. minuta; and the copepods Tropocyclops prasinus and Thermocyclops decipiens. Both Daphnia species, as well as T. prasinus, were abundant and frequent in the lake. Larvae of Chaoborus brasiliensis are important invertebrate predators and are relatively abundant, mostly during the warm period of the year.

Microcrustaceans and Chaoborus brasiliensis larvae were collected in the lake with a 60 mm mesh net. Fresh animals were narcotized and fixed (Gannon & Gannon, 1975) and analyzed for the determination of biomass and carbon content. Each animal was measured under a micrometric ocular coupled to the microscope and separated in size classes (Tabs. I and II). For cladocerans, individual total length was measured from the top of the head to the insertion of the tail spine (McCauley, 1984). For copepods, measurements were made from the posterior end of the cephalotorax to the end of the urosome, excluding the furcal rami (McCauley, 1984). For Chaoborus, cephalic capsule length and total body length were measured (Lasenby et al., 1994).

Table I: Means and standard deviation of the body length and biomass of the size classes of Daphnia gessneri, D. ambigua and Tropocyclops prasinus.

		Biomass		
	Body length (mm)	Dry weight (mg)	Carbon (mg)	N
Daphnia gessneri				
small	0.72 ± 0.06	1.43 ± 0.52	0.56 ± 0.20	30
medium	0.92 ± 0.05	3.53 ± 1.13	1.38 ± 0.44	36
large	1.17 ± 0.08	6.73 ± 2.57	2.62 ± 1.0	42
Daphnia ambigua				
small	0.55 ± 0.07	1.45 ± 0.78	0.66 ± 0.35	49
medium	0.78 ± 0.05	4.64 ± 1.67	2.11 ± 0.72	23
large	1.10 ± 0.16	8.27 ± 3.28	3.76 ± 1.49	38
Tropocyclops prasinus				
female	0.605 ± 0.003	1.11 ± 0.21	0.52 ± 0.10	45
male	0.470 ± 0.003	0.32 ± 0.04	0.15 ± 0.02	57
Copepodite 1	0.440 ± 0.002	0.48 ± 0.07	0.23 ± 0.03	50
Copepodite 2	0.360 ± 0.011	0.12 ± 0.03	0.05 ± 0.01	75
Copepodite 3	0.304 ± 0.010	0.10 ± 0.02	0.05 ± 0.01	118
Nauplius 1	0.133 ± 0.012	0.03 ± 0.01	0.02 ± 0.004	16
Nauplius 2	0.077 ± 0.010	0.008 ± 0.003	0.004 ± 0.002	22

Table II: Means and standard deviation of the body and cephalic capsule length and the biomass of Chaoborus brasiliensis.

Chaoborus brasiliensis	Length (mm)		Biomass		
	Body	Cephalic capsule	Dry weight (mg)	Carbon (mg)	N
Instar I	1.67 ± 0.20	0.160 ± 0.01	1.65 ± 1.32	0.73 ± 0.58	4
Instar II	2.64 ± 0.59	0.306 ± 0.09	4.97 ± 3.14	2.11 ± 1.42	57
Instar III	4.52 ± 0.45	0.520 ± 0.06	29.24 ± 9.75	12.86 ± 4.29	36
Instar IV	6.30 ± 0.62	0.870 ± 0.04	90.38 ± 41.54	39.76 ± 18.27	52

Nauplii and copepodite size classes grouped individuals with close sizes, not corresponding, however, to the development stage described as nauplii I, II, III, IV and copepodites I, II, III, IV, V.

Using a pipette, animals were separated and placed individually in labeled slides; the excess of water was absorbed with a paper filter and then the animals were dried at 60°C, for 18 hours. Groups of small animals (< 5 mg) were placed together on the same slides for attaining a minimum of 5 mg as recommended (Dumont et al., 1975). After drying the animals, the samples were placed in a desiccator for 1-2 hours, and then the animals were weighed on a microbalance individually or in groups (Mettler-Toledo, UMT-2, 0.1 mg of precision) for evaluating their dry weight (McCauley, 1984).

Several organisms of each species were separated with a pipette from lake samples for carbon analysis. The organisms were placed on slides and dried following the procedure already described. Then, they were transferred to tin capsules, which were weighed and analyzed on a Carlo Erba elemental analyzer (model 1110), for carbon quantification. All measurements of dry weight and carbon were made in replicates.

Length-weight relationships were obtained by fitting power and exponential equations, as follow:

$$W = a*L^b$$

Where a and b are constants, W is the weight (mg of dry weight or mg of carbon) an L the body length in mm.

Results

Mean lengths and biomass of each size class of Daphnia gessneri, D. ambigua and Tropocyclops prasinus are presented in Table I. D. gessneri size classes were always larger but lighter than D. ambigua. Differences were significant for size and biomass for the two species, even if their sizes were very close ($t = -2.98$, $p = 0.003$, $n = 67$ for size, and $t = 3.13$, $p = 0.002$, $n = 67$ for biomass). Copepod females were larger and heavier than males ($t = 70.43$, $p < 0.001$, $n = 45$ and $t = 7.4$, $p < 0.001$, $n = 45$, respectively).

The mean body and cephalic capsule lengths, as well as the biomass of each larval instar of C. brasiliensis are presented in Table II. Cephalic capsule increased at almost the same proportion of the total body length.

The length-weight relationships, in dry weight and in carbon, for D. gessneri were highly significant ($p < 0.001$), with more than 70% of the data ($R^2 = 0.73$) being explained by the equations (Fig. 1A and B). In a similar way, length-weight relationships were also significant for D. ambigua ($p < 0.001$), with high regression coefficient ($R^2 = 0.77$) and expressed by the equations of the Figure 2A and B.

The coefficients of the equations were very close to 1 for T. prasinus ($R^2 = 0.96$), and highly significant ($p < 0.001$) (Fig. 3A and B).

Regressions for C. brasiliensis were also statistically significant ($p < 0.001$) with $R^2 = 0.93$ for body length-weight (Fig. 4A and B) and of $R^2 = 0.86$ for cephalic capsule length-weight (Fig. 5A and B).

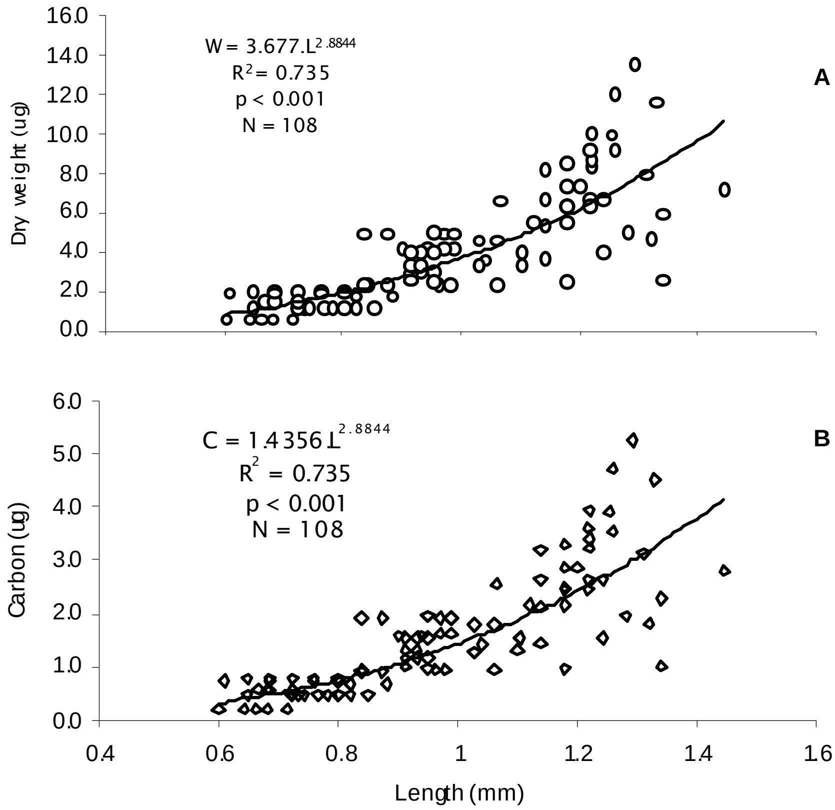

Figure 1: Length-dry weight (A) and length-carbon relationship (B) for D. gessneri.

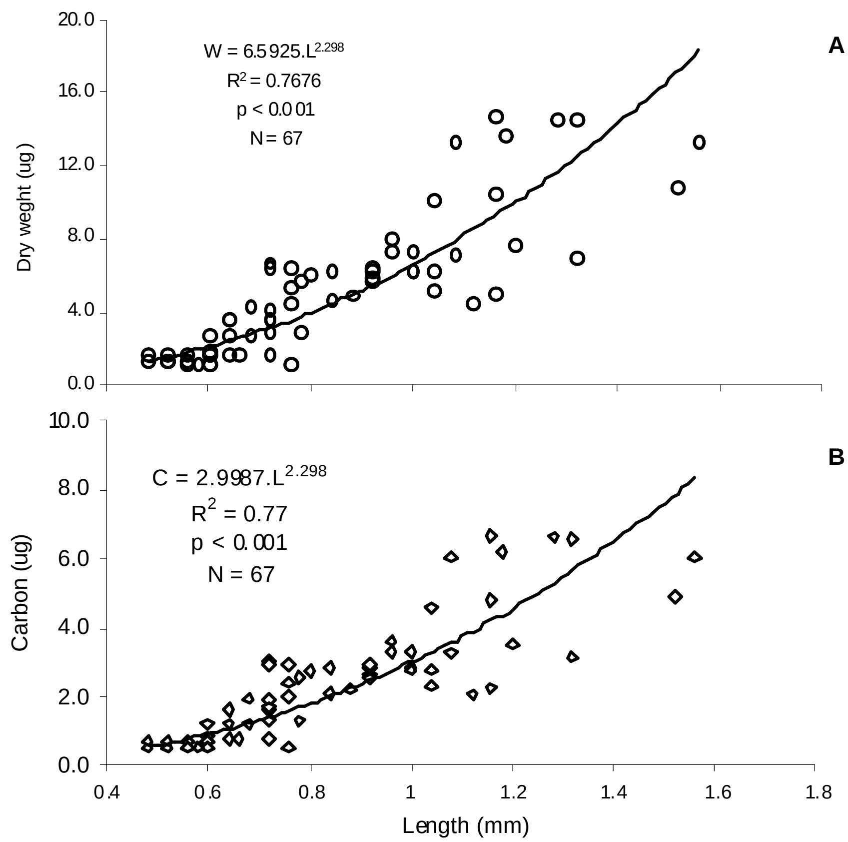

Figure 2: Length-dry weight (A) and length-carbon relationship (B) for D. ambigua

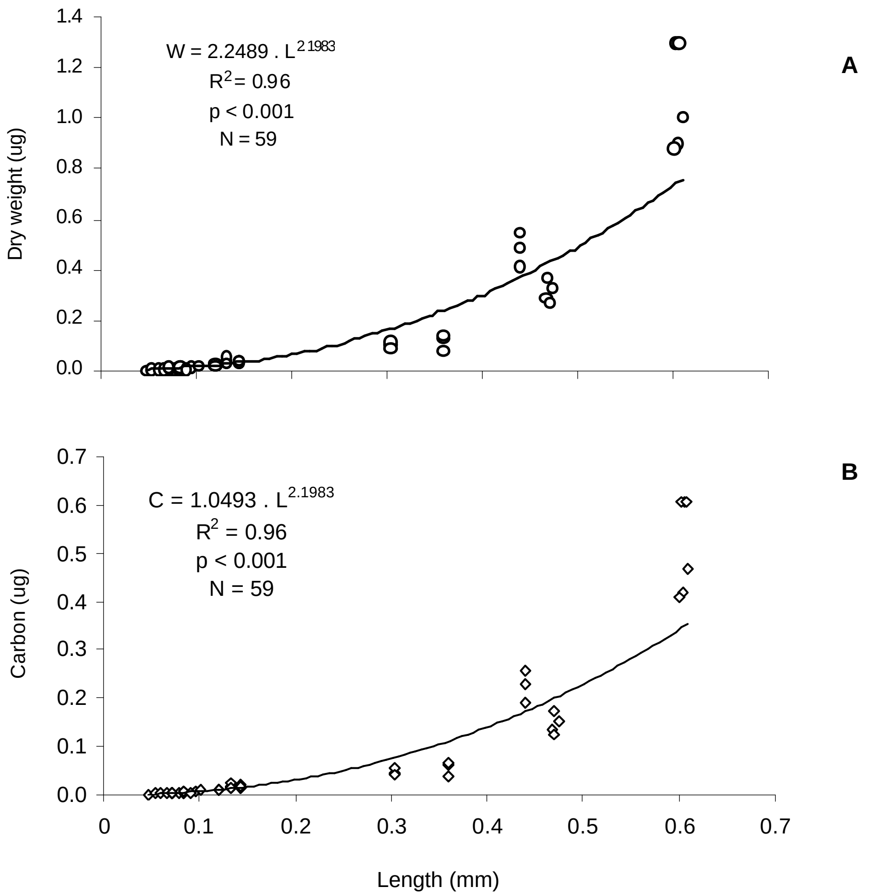

Figure 3: Length-dry weight (A) and length-carbon relationship (B) for T. prasinus.

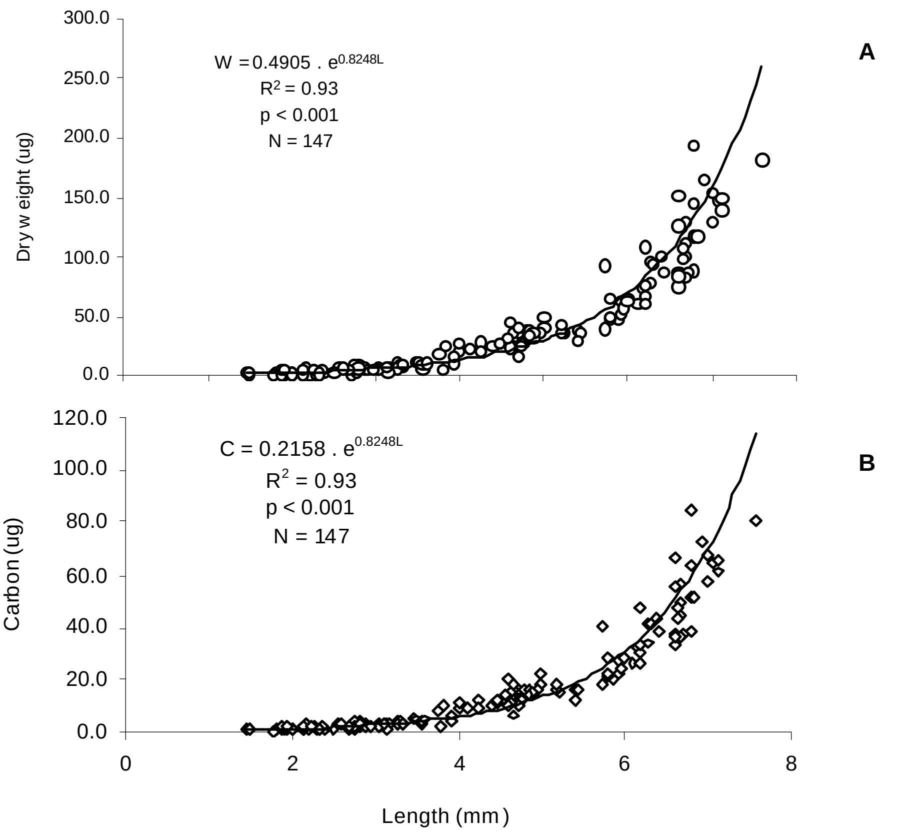

Figure 4: Body length-dry weight (A) and length-carbon relationship (B) for C. brasiliensis.

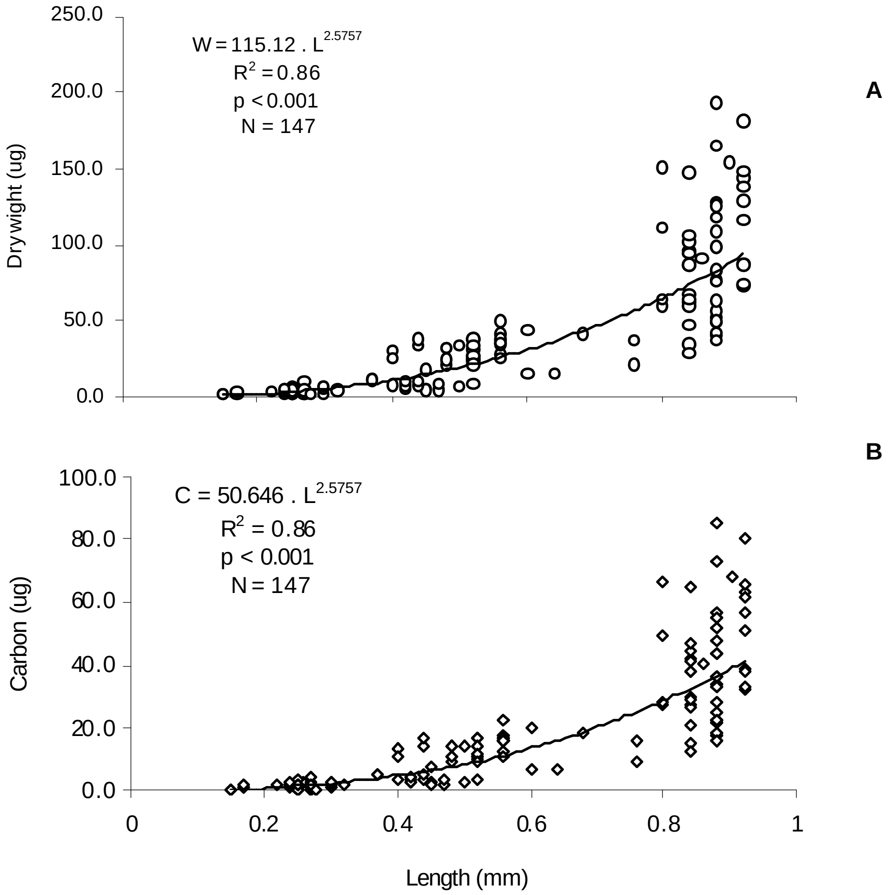

Figure 5: Cephalic capsule length-dry weight (A) and cephalic capsule length-carbon relationship (B) for C. brasiliensis

Discussion

As expected, the highly significant length-weight regressions and correlation coefficients close to 1, confirmed the relationship between size and biomass of the organisms.

Individuals of D. gessneri and D. ambigua from Lake Monte Alegre were larger in this study than the specimens collected in 1985/86 (Arcifa et al., 1992), corroborating observations of Fileto (2001) that there was an increase of Daphnia size in the nineties.

Although D. ambigua is smaller in body length, all size classes were larger in dry weight and in carbon than D. gessneri. The rounded body shape of D. ambigua could be the morphologic characteristic that results in larger biomass. Bottrell et al. (1976) also suggested that the larger elevation in the bosminid curve than that of Daphnia, observed in their studies, could be associated with the most robust carapaces of the former cladoceran.

The equations for the two Daphnia species are quite close and are in agreement with those found in the literature. Bottrell et al. (1976) demonstrated a high likeness among the equations of several Daphnia species. The value of b (2.3) for D. ambigua in this study was the same obtained by Dumont et al. (1975) and Bottrell et al. (1976) for the same species from other water bodies. Similar values of a in those studies confirm the likeness among the equation described above; the values of a and b for Daphnia hyalina galeata (Manca et al., 1997 and Manca & Comoli, 2000) were quite close to the ones found for D. ambigua in the present study.

Factors such as temperature, food and production of eggs can influence the length carbon relationship in daphnids (Geller & Muller, 1985). Significant variations were observed in length-carbon relationships for D. galeata (Winder & Spaak, 2001) and for D. hyalina-galeata (Manca et al., 1997), thorough the year, which were correlated with changes in the environmental conditions. Principal component analysis revealed four periods in Lake Monte Alegre, mainly characterized by variations in the stability of the stratification, with consequences for phytoplankton composition and biomass (Arcifa et al., 1998). Therefore, it is possible that length-carbon relationships for Daphnia population in the lake also present variations during the year, requiring additional seasonal investigations on carbon content.

Bottrell et al. (1976) and Matsumura-Tundisi et al. (1989) have found for other species of copepods values of b quite close to that found in the present study (2.2), indicating the same length-weight relationship pattern for Copepoda in general.

Body and cephalic capsule sizes of larvae III and IV of C. brasiliensis were larger than those described by Cressa & Lewis (1984) and Bezerra-Neto (2001) for other populations of the same species (Tab. III); for larvae I and II the data were quite similar among the studies.

Table III: Means and standard deviation of the body and cephalic capsule length of Chaoborus brasiliensis, found in the literature and in this study.

Body length (mm)			
Instar		Bezerra-Neto (2001)	This study
I		1.50 ± 0.34	1.67 ± 0.20
II		2.53 ± 0.41	2.64 ± 0.59
III		3.83 ± 0.55	4.52 ± 0.45
IV		5.73 ± 0.69	6.30 ± 0.62
Cephalic capsule length (mm)			
Instar	Cressa & Lewis (1984)	Bezerra-Neto (2001)	This study
I	0.167 ± 0.12	0.159 ± 0.02	0.160 ± 0.01
II	0.300 ± 0.47	0.259 ± 0.02	0.306 ± 0.09
III	0.478 ± 0.54	0.437 ± 0.02	0.520 ± 0.06
IV	0.749 ± 0.105	0.697 ± 0.03	0.870 ± 0.04

The body length-weight relationships presented a higher regression coefficient than the cephalic capsule length-weight relationships, indicating that measurements of body length are more adequate than cephalic capsule length to estimate biomass using the equation. Conversely, the cluster of points observed in Figure 5 indicates that measurements of cephalic capsule are better for identifying Chaoborus instars, corroborating other morphological studies (Hare & Carter, 1986 and Bezerra-Neto, 2001)

Regression equations for body length-weight and cephalic capsule length-weight relationships for Chaoborus, obtained in this study, are similar to those described by Cressa & Lewis (1984) for the same species.

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