Methods for Determining New Biovolumes for Copepods and Cladocerans

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ABSTRACT

Zooplankton are an important component of the food web in freshwater lake ecosystems. Despite there being an abundance of density data for zooplankton taxa in these lakes, there is very little information that exists about pelagic zooplankton biovolume or biomass in temperate lakes. Biovolume is a useful estimate of biomass energy because it determines how much space a species occupies. For this research, we developed new biovolume techniques for freshwater zooplankton based on body size and geometric shape. These techniques were applied to two groups of crustacean zooplankton, the copepods and the cladocerans. Copepod biovolume is broken into two formulas: the ellipsoid formula and the cone formula. For the cladocerans, two formulas were used: one for the Bosminidae family and one for Daphnidae family. Daphnia biovolume is composed of two formulas: the ellipsoid formula and the cylinder formula. The Bosminid family biovolume formula is the same as the ellipsoid formula. These new biovolume fomulas proved to be a useful measurement of zooplankton community structure when compared with density data.

Key Words: zooplankton; Lake Champlain; biovolume formulas; density

INTRODUCTION

Zooplankton species are microscopic drifters in the water column and are responsible for the transfer of energy from primary producers (phytoplankton) to higher trophic organisms (planktivorous fish like smelt and cisco) (Clark et al. 2001). Lake Champlain contains approximately 56 assorted zooplankton species, which are divided into three main groups: Copepoda (20 taxa), Cladocera (17 taxa) and Rotifera (19 taxa) (Carling 2004). This lake is the sixth largest freshwater lake in the United States and is located in the basin between the Adirondack mountains of New York and the Green moutains of Vermont (Figure 1). The lake discharges into the Richelieu River of Quebec and after that into the St. Lawrence River. Then it flows to the Gulf of St. Lawrence and finally the Atlantic Ocean (Myers and Gruendling 1979). Lake Champlain is divided into five sections: South Lake, Main Lake, Mallets Bay, Inland Sea and Missisquoi Bay.

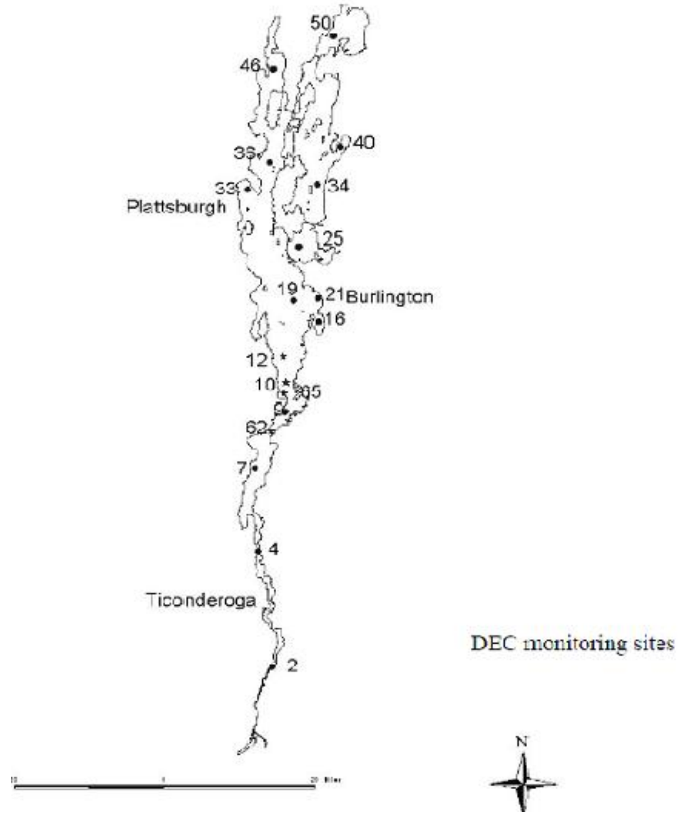

Figure 1. Map of Lake Champlain and zooplankton collecting sites (Source: Carling 2004)

Cladocerans, or water fleas, are one of three major zooplankton groups in Lake Champlain. The key distinction of cladocerans from other groups is the presence of the carapace, a folded shell-like structure (Balcer et al. 1984). The carapace turns into a shell spine in the posterior region. Most have a helmet, an extended segment of the anterior portion of the head. Along with the helmet they have a rostrum, a pointed beak. They have to antennae. The first antennae have olfactory setae, whereas the second antennae are used for swimming (Balcer et al 1984). All cladocerans reproduce parthenogenetically and several undergo cyclomorphosis, changes in morphology throughout the seasons (Allan 1976).

Copepods are also common in Lake Champlain. They are grouped into three suborders: Calanoida, Cyclopodia and Harpacticoida (Balcer et al. 1984). Copepods are divided into segments. The cephalic segment is the first segment and is fuse to the head (Balcer et al. 1984). Each segment on the second to sixth thoracic segment has one pair of thoracic legs. This is the metasome region of the copepod (Figure 1). It is then followed by the genital segment and abdominal segments located below them, which compose the urosome region (Carling 2004). The last appendage contains two caudal rami with lateral setae and caudal setae located on the end of the rami.

Invasive species, nutrient loading, global climate change and increase in salinity concentration are just some of the challenges Lake Champlain is currently struggling with. Therefore, there is a need to do quantitative work on zooplankton species composition. Zooplankton species are indicators of lentic food webs, so a change in zooplankton composition or richness would create a trophic cascade. Although data exist on taxonomic density and density trends, there is no information on zooplankton for biovolume or biomass in Lake Champlain and very little information in temperate lake ecosystems, specifically for copepods and cladocerans (McCauley 1984). Biovolume formulas for the phylum rotifers were previously constructed and recorded by McCauley (1984).

Biovolume is the amount of space a species takes up in a given area and provides a link for determining biomass. It can be used to estimate biomass and can also be more useful than density, because biovolume is an estimate of mass while density is a measure of abundance. Changes in zooplankton biovolume can exemplify changes in an environment's biotic or abiotic factors, due to selection pressure. A zooplankton species could decline in biovolume despite there being no changes in density. This could indicate the introduction of an invasive planktivore fish species, such as the alewife.

METHODS

Zooplankton Sampling

Field samples were collected by the New York State Department of Environmental Conservation (DEC) as part of the Lake Champlain Monitoring program. Samples were collected using a 30 cm diameter, 153 µm mesh net. The net was suspended through the water column from bottom to top with a net retrieval rate of 1 meter per second. Samples were then placed into bottles and formalin-rose Bengal solution was added.

Developing Biovolume Formulas

Using McCauley's (1984) technique of developing biovolume formulas for rotifers, a similar method was developed for cladocerans and copepods. Different species of rotifers have different formulas. McCauley (1984) developed the formulas based on the geometric shapes the rotifers resembled. The formula of the geometric shape the rotifer resembled represented the biovolume formula for that rotifer. This is the same technique that was used to develop the biovolume formula for copepods and cladocerans.

Developing Copepoda Formula

The biovolume for copepods was broken into two formulas (Figure 2). The first formula relates to the metasome. The metasome is shaped like an ellipsoid. Therefore the first part of the biovolume formula is the volume formula for an ellipsoid. Hence the formula for the first part is $(4\pi R_1 R_2 R_3) / 3$. R_1 is the length of the metasome, from the top of the cephalic segment to the top of the genital segment. R_2 is the diameter or width of the cephalic segment at the widest point. R_3 is equal to the value of R_2. For all R values, the full length or width is measured. When the values are entered, those values are divided in half to get the radius.

The second part of the biovolume formula is $(r^2\pi h)/3$. This is the formula to calculate the volume of a cone, since the urosome resembles this shape. The r value represents the diameter of the base at the urosome. The h value is the length of the urosome to the base of the cadual setae.

The total biovolume is both parts added together (Figure 2). Therefore the formula is $((4\pi R_1 R_2 R_3) / 3) + ((r^2\pi h)/3)$.

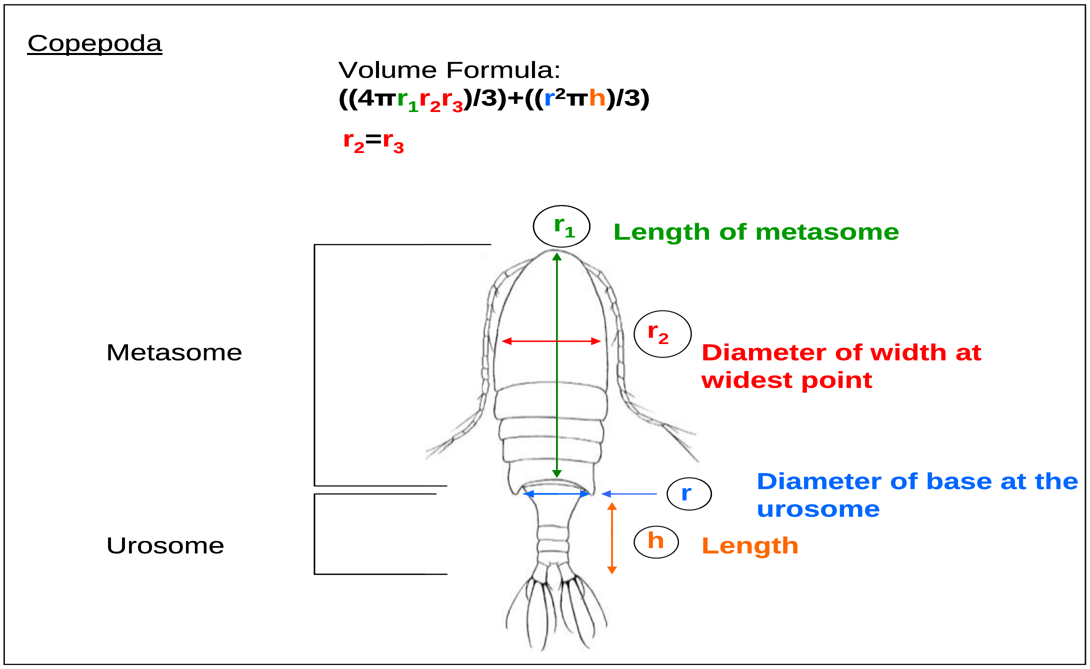

Figure 2. Method of measuring different structures of Copepoda to calculate its biovolume (Source: Copepoda drawing from (Carling 2004)).

Developing Daphnidae Formula

The daphnia biovolume formula is broken into two parts (Figure 3). The first one has to do with the head of the daphnia. The head closely resembles a cylinder. Thus the first formula is $(\pi r^2 h) / 4$. The r value is the diameter of the base of the head, right below the rostrum. The height or h value is the length of the head and helmet.

The second formula represents the rest of the daphnid body, which most closely resembles an ellipsoid. Thus the second formula is $(4\pi R_1 R_2 R_3) / 3)$. R1 represents the base of the spine to the bottom of the head. The R_2 value equals the diameter or width of the daphnia at the widest point. R_3 equals the same value as R_2.

The total biovolume is both parts added together (Figure 3). Therefore the formula is $((4\pi R_1 R_2 R_3) / 3) + ((r^2\pi h)/4)$.

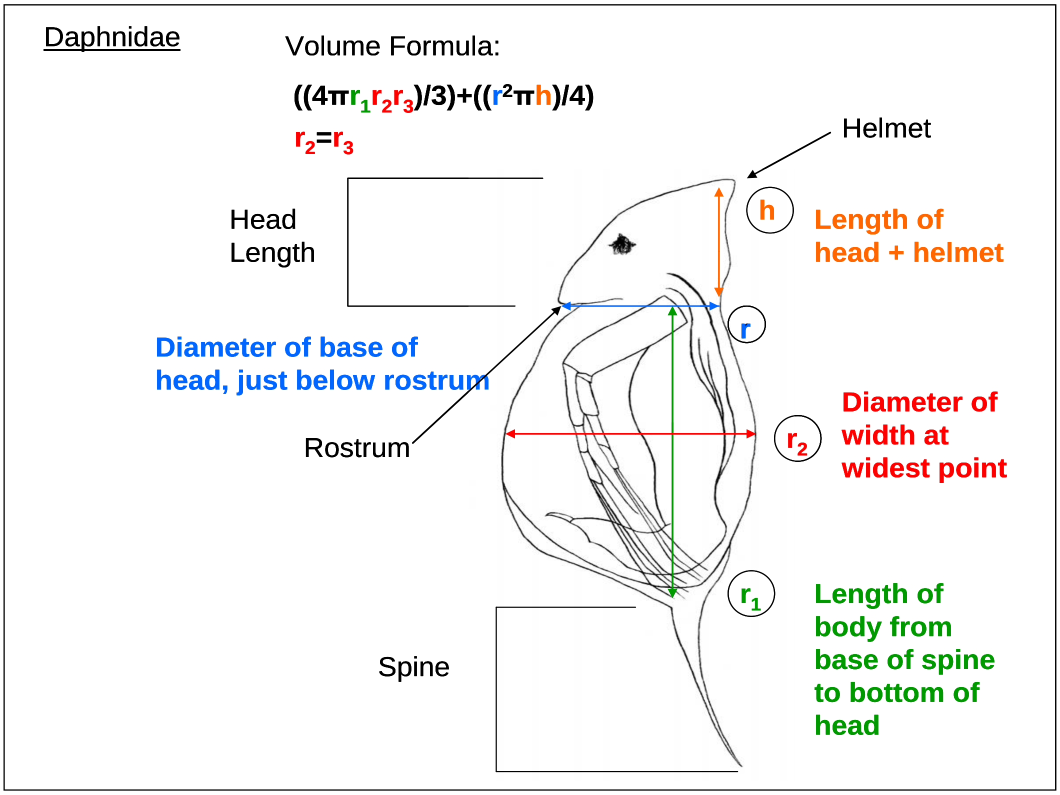

Figure 3. Method of measuring different structures of Daphnidae to calculate its biovolume (Source: Daphnidae drawing from (Carling 2004)).

Developing Bosminidae Formula

The same technique was applied to a specific group in the cladocerans, the family Bosminidae. The whole body resembles an ellipsoid, except for the first antennae (Figure 3), which resembles a tusk-like structure (Figure 4). There is only one part to the biovolume formula and that is $(4\pi R_1 R_2 R_3) / 3$). The R_1 value is the length of the entire bosmina body. R_2 value is the width or diameter at the widest point. R_3 represents the same value as R_2 (Figure4).

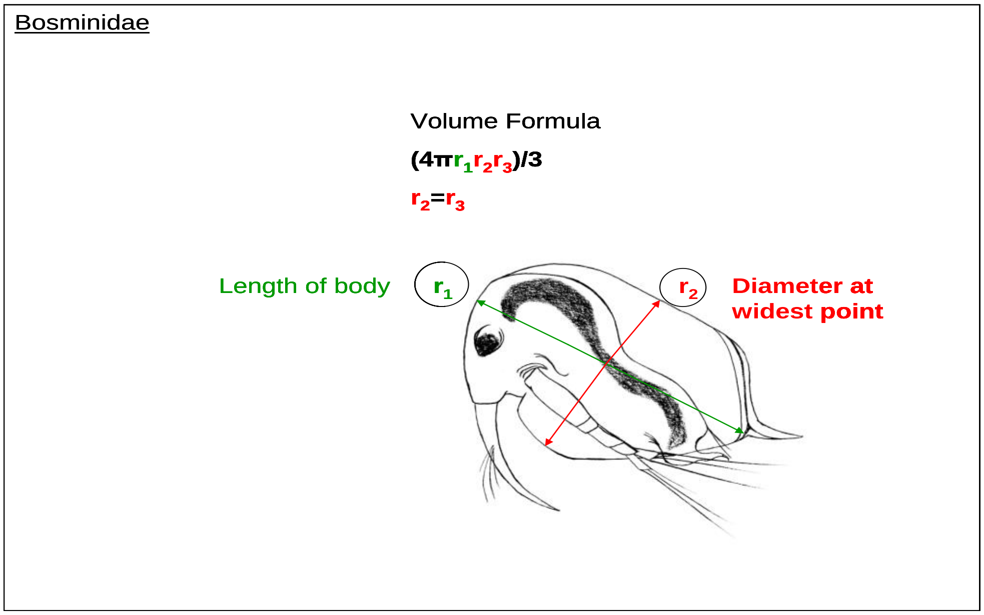

Figure 4. Method of measuring different structures of Bosminidae to calculate its biovolume (Source: Bosminidae drawing from (Carling 2004)).

RESULTS

Figure 5 and Figure 6 show the relationship between biovolume and density for *Daphnia retrocurva* and *Leptodiaptomus* spp., respectively. A linear regression was used to display the correlation. The R values were -0.6691 and -0.465, both values are not statistically significant. As a result, there is no relationship between density and biovolume for these two species.

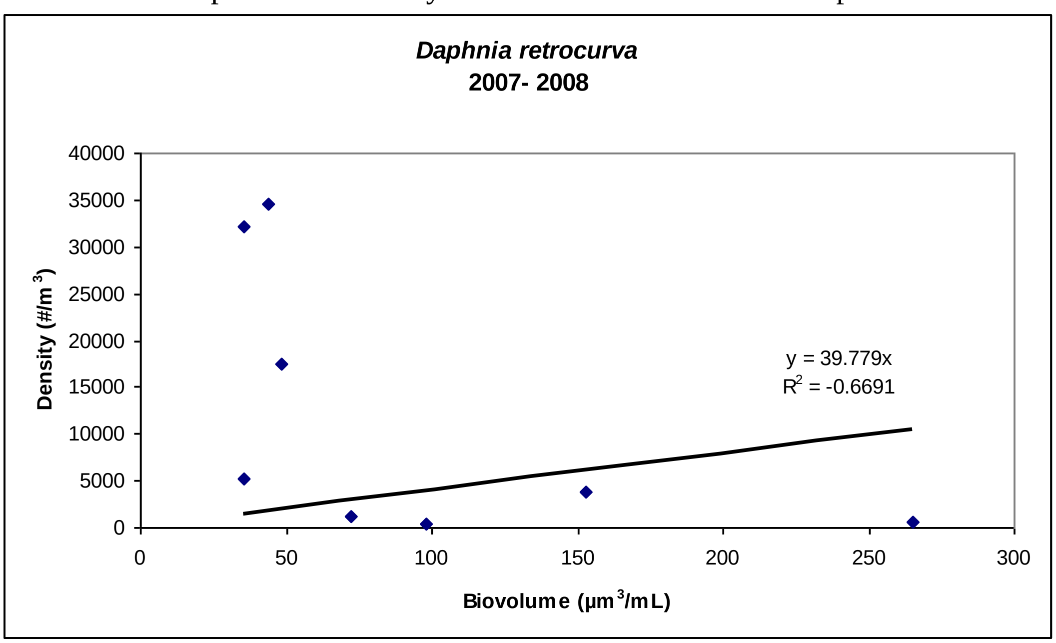

Figure 5. A linear regression of the relationship between density and biovolume in *Daphnia retrocurva*.

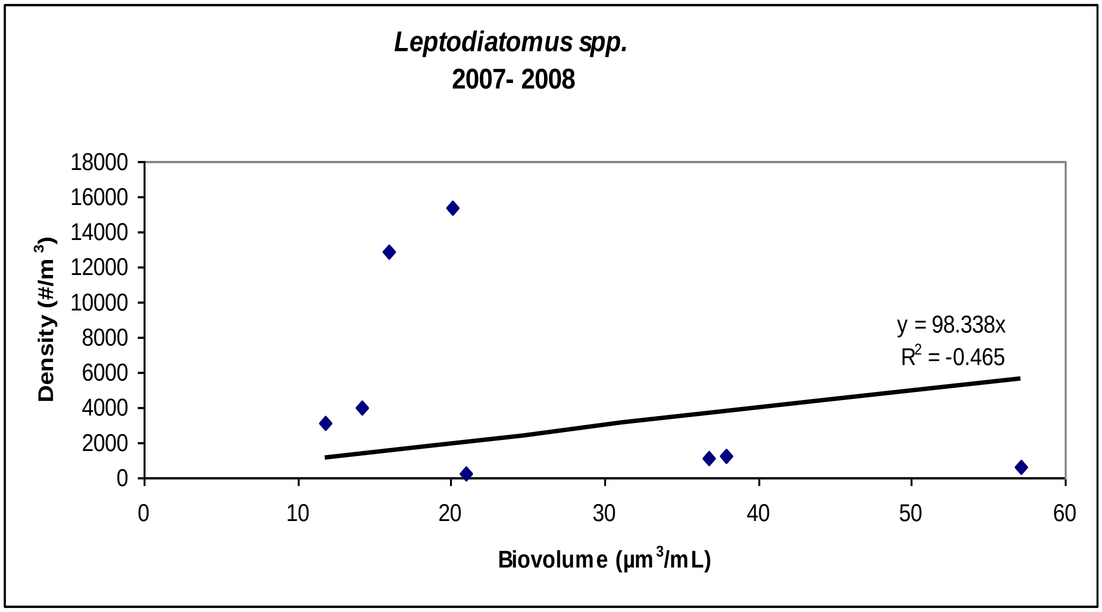

Figure 6. A linear regression of the relationship between density and biovolume in *Leptodiaptomus* spp.

Figure 7 displays the trend for biovolume and density for *Diaphanosoma birgei* at site 50 (Figure 1) for over eight years, on a log scale. The trend biovolume displays is different than the trend density displays throughout the eight year period. From 2004-2005, biovolume is increasing. However, for density that year is increasing in value during that time period. The same pattern is seen for both density and biovolume from 2007-2008. During the 2005-2006 time period, biovolume is increasing. On the other hand, density is decreasing.

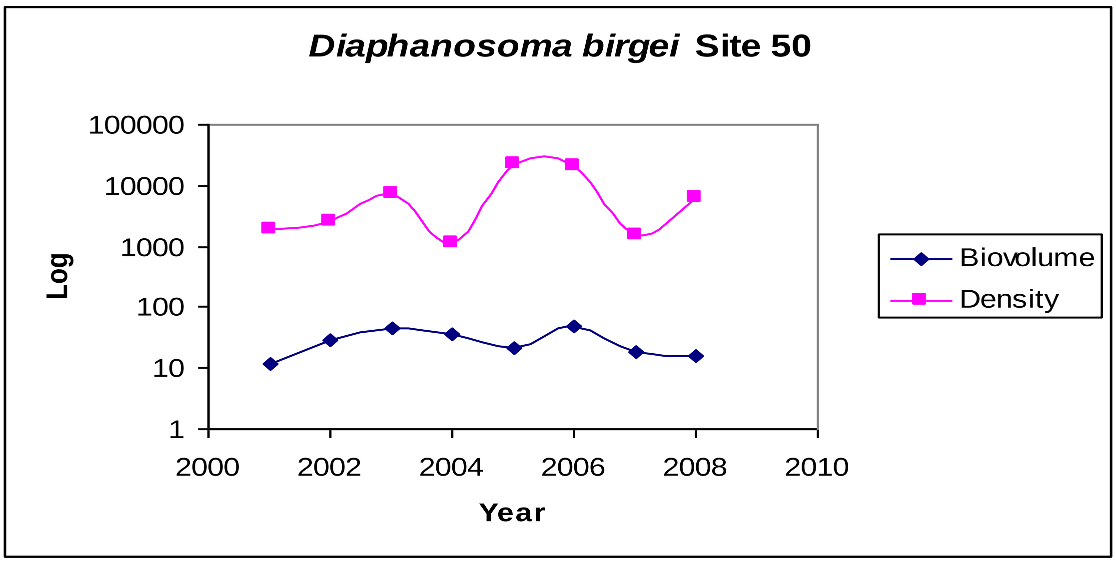

Figure 7. A log scale comparing biovolume and density from 2001- 2008 for *Diaphanosoma birgei* at site 50.

DISCUSSION

There was no correlation found between biovolume and density for any zooplankton taxa, including *Daphnia retrocurva* (Figure 5) and *Leptodiaptomus* spp. (Figure 5). Different trends were displayed for *Diaphanosoma birgei* at site 50 (Figure 7). Therefore biovolume provides information on biomass and energetics whereas density provides only information on abundance. If there is a change in abundance, there are a variety of abiotic and biotic factors that potentially could be responsible for it. However, if there is a change in biovolumes then it is more than likely due to selective pressure. For this reason, it is important to continue to measure biovolumes along with density on zooplankton taxa.

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