Length-weight regressions for zooplankton biomass calculations – A review and a suggestion for standard equations.

James Watkins, Lars Rudstam and Kristen Holeck
Cornell Biological Field Station, Department of Natural Resources, Cornell University, 900 Shackelton Point Road, Bridgeport, New York.
Email lgr1@cornell.edu, jmw237@cornell.edu, kth1@cornell.edu

Introduction.

Due to the diversity and wide size range of planktonic organisms, simple density estimates do not provide all of the information required for biological models of energy flow. Individual length is routinely measured with a microscope, but accurate dry weights are much more problematic to obtain as part of routine measurements. Therefore, limnologists have developed species-specific relationships of length and dry weight for individual zooplankton species to calculate biomass (McCauley 1984). These conversion equations follow the general power equation:

$$W = \alpha L^{\beta}$$

or in its logarithmic transformation

$$Ln(W) = Ln(\alpha) + \beta\, Ln(L)$$

where W = dry weight in μg, L= length in mm, β is the slope of the logarithmic relationship, and Ln(α) is the intercept. Since this equation relates a linear measure (length) to a volumetric measure (weight), we expect W to be related to L to the third power. Large deviations from 3 are questionable and only possible if the animals change shape as it gets larger.

It is worth noting two properties of this equation that are helpful when comparing parameters from different equations. First, W = α μg when L = 1 mm. For a constant β, the animal with the higher α is heavier at all lengths. However, for a constant α, the animal with the highest β is heavier when L>1. When L is < 1, the species with the larger β is lighter. Remember that the two parameters α and β are not independent and cannot be compared on their own. We therefore show graphs and a table with weights calculated for a 0.2, 0.5, 1.0 and 1.5 mm animal to facilitate comparisons among equations.

Several sets of these L-W equations are used in the Great Lakes region. In particular, the US Environmental Protection Agency Great Lakes National Program Office use one set of equations (EPA GLNPO 2003) for EPA standard surveys and Canada's Department of Fisheries and Oceans uses another (Johannsson et al. unpublished). These two sets are not identical. We refer to these two sets as EPA SOP and ONTARIO. Since we collaborate with both agencies and require comparability with previously collected data, we reviewed these two sets of equations and the publications that were used to develop them. In doing so, we found one error in the translation from the original publication, and some equations that lacked source documentation. Therefore, we suggest one set of standard equation here (hereafter Cornell Standard (CBFS STD)). In choosing between available equations we favored equations that had published documentation (statistics, number of samples, methods, range of lengths used), could be applied for many species, and were developed over large length ranges. This document presents these equations and the source documentation for them. We also show how they compare with the EPA SOP and ONTARIO equations and with other relationships available in the literature.

Methodology.

There are several main sources for L-W relationships of freshwater zooplankton from North America and Northern Europe. Dumont et al. (1975, Dum75) reported values for lakes in Belgium. Bottrell et al. (1976, Bot76) compiled several studies from the International Biological Programme section on freshwater production (IBP/PF). Persson and Ekbohm (1980, P&E80) investigated lakes in northern Sweden. Pace and Orcutt (1981, P&O81) reported values for zooplankton from Lake Oglethorpe in Georgia, USA. Rosen (1981, Ros81) studied zooplankton in the Connecticut River of Massachusetts. McCauley (1984) included all of these studies in his review of the subject. In addition, Culver et al. (1985, Cul85) reported values for Lake Erie and the Bay of Quinte that have not been used in the EPA SOP or ONTARIO tables.

Each study provides equations for a range of copepod and cladoceran species. For example, Pace and Orcutt (1981) include only two cladocerans and two copepods, and Persson and Ekkbohm (1980) includes only two cladocerans and three copepods. The other studies generally include more than ten different zooplankton species.

The studies vary in the equation format used. For example, the equations in Rosen (1981) used log base 10 and dry weight is in g rather than μg. The equations of Persson and Ekbohm (1980) use length in μm rather than mm. Some studies present α rather than $\ln \alpha$ (Dumont et al. 1975 and Culver et al. 1985). All equations presented here have been translated from the original citation to the mm:μg format adopted by ONTARIO and EPA SOP. The translation error discovered in the ONTARIO table was the result of one such conversion.

The amount of statistical information provided by each study varies. Most provide size ranges, a count of individuals measured, and assessment of precision. However, Dumont et al. (1975) does not provide this important information. Pace and Orcutt (1981) does not provide size ranges. Bottrell et al. (1976) provides a RMS (root mean square) error but not an r^2. Confidence limits (95% c.l.) are commonly presented for β (Bottrell et al. (1976), Persson and Ekbohm (1980), and Culver et al. (1985)) but not for $\ln \alpha$. McCauley (1984) evaluated the extent of the error of L-W equations in the literature. He emphasized that small errors in length measurements at the upper end of the regression can have dramatic effects on weight estimates due to the power relationship.

Protocols for length measurement were generally consistent among studies. Adult copepods were measured from the top of the head to base of the caudal spines (including rami). Some studies do not include the rami in the measurement. Cladoceran length was measured from the top of the head to the base of the caudal spine or the end of the carapace. Total length of forked *Leptodora* is measured as the sum of two line segments. Length protocols varied for *Holopedium*, *Bythotrephes*, and *Cercopagis*. For *Holopedium*, our station's measurement protocols use total length rather than the "rigid foot" that the equation of Persson and Ekbohm (1980) is based on. Our protocol for measuring *Bythotrephes* and *Cercopagis* measures body length without including the long spine.

Routine length measurements are generally conducted on zooplankton preserved in formalin, although ethanol has increasingly replaced formalin due to health concerns. Using preserved rather than fresh organisms has a much debated effect on both length and weight measurements (McCauley 1984). Dumont et al. (1975), Bottrell et al. (1976), Rosen (1981), and Culver et al. (1985) measured zooplankton preserved in sugared formalin. Pace and Orcutt (1981) and Persson and Ekbohm (1980) used fresh animals. All of the studies used dry weight after drying in a 60 C oven for a time period ranging from 2 hours (Persson and Ekbohm 1980, Dumont et al. 1975, Culver et al. 1985) to 48 hours (Rosen 1981) followed by time with a dessicant. Generally, individuals were sorted into narrow size classes and pooled for weighing on microbalances. For example, Rosen (1981) pooled 50-100 individuals for small (0.1-0.4 mm) size classes and 10-25 individuals for the largest (1.0-5.0 mm) size classes.

Cornell Standard L-W Equations.

Many of the CBFS STD coefficients were selected from a single reference (Bottrell et al. 1976) that reviewed the information available at the time. Bottrell et al. included size ranges and error estimates, pooled equations as well as equations for individual species. In developing CBFS STD, we often found that the error presented did not justify using a "splitting" approach (the use of several species-specific equations). Thus we favor a "lumping" approach that pools many species and included a broad size range. We do not think it is worthwhile to use separate species-specific equation from various sources given the differences present in studies from different authors (see McCauley 1984). We are likely to find differences in L-W regressions associated with changing growth conditions of the animals even among years or seasons in any one lake. We consider zooplankton biomass estimated from L-W regression as approximations. If more exact values are required, it is necessary to make measurements directly on the collected zooplankton.

Bottrell et al. (1976) presented the following "generic" coefficients (Figure 1) and the size ranges, number of individuals, and error of the relationships are as follows:

Taxa	size (mm)	n	Ln α	β (+/-95% C.L.)	RMS
Copepods	**0.14-2.45**	**535**	**1.953**	**2.399 (0.085)**	**0.257**
Daphnia	**0.6-4.00**	**1303**	**1.468**	**2.829 (0.072)**	**0.266**
Bosmina	**0.28-0.95**	**77**	**3.090**	**3.039 (0.212)**	**0.087**
Ceriodaphnia	**0.3-0.7**	**9**	**2.562**	**3.338 (0.682)**	**0.146**
Diaphanosoma	**0.44-1.44**	**106**	**1.624**	**3.047 (0.302)**	**0.137**

These equations are different for some groups from both the EPA SOP and the ONTARIO equations (Table 1). Differences and similarities are described below in addition to our reasoning for selecting other equations for particular groups. The CBFS-STD equations yield copepods that are "heavier" than *Daphnia* of the same size (Figure 1). The equation for the cladoceran *Diaphanosoma* lies between those of copepods and *Daphnia*. Note that *Bosmina* and *Ceriodaphnia* are very "heavy" relative to other taxa as size increases. These species are very small in size. Care needs to be taken not to extend the equations outside of the typical size range. Measurement errors producing unusually large individuals of these species could lead to large errors in biomass estimates.

Copepods (Figure 2)

The EPA SOP table uses several species-specific equations for calanoid (Pace and Orcutt 1981) and cyclopoid (Persson and Ekbohm 1980, Rosen 1981) copepods that result in large differences in weights from the same length (Table 2). Some of those equations are based on rather poor correlations and small length ranges. For example the Pace and Orcutt (1981) equation used for many copepods in EPA SOP has an r^2 of 0.59 and an unspecified length range. The ONTARIO set used a generic copepod equation suggested by Dr. Gary Sprules that was an average of many available equations (Sprules, pers. comm.). Unfortunately, there is no published documentation for that equation. The relationship developed by Bottrell et al. (1976) used in CBFS STD pooled several species of both groups and includes a wide size range.

CBFS STD	Bot76 (pooled)	Ln(α) =1.953, β =2.40, 0.1-2.5 mm
EPA SOP	P&O81 (*D. siciloides*)	Ln(α) =1.050, β =2.46, r^2=0.59
EPA SOP	P&E80 (*C. scutifer*)	Ln(α) =1.492, β =1.99, r^2=0.81
EPA SOP	Ros81 (*M. edax)*	Ln(α) =1.660, β =3.97, 0.3-1.5 mm, r^2=0.97
EPA SOP	Ros81 (*A. vernalis*)	Ln(α) =2.227, β =3.23, 0.4-1.2 mm, r^2=0.99
ONTARIO	Sprules unpub. (generic)	Ln(α) =1.705, β =2.46
not used	Cul85 (*M. edax)*	Ln(α) =1.896, β =2.89, 0.5-1.1 mm, r^2=0.99

The EPA SOP uses a constant for nauplii of 0.40 μg (Hawkins and Evans 1979). ONTARIO uses an equation with Ln(α) =1.435, β =2.48 from Lewis (1979). The Bottrell et al. (1976) copepod equation includes nauplii, copepodites, and adult stages.

Daphnia **(Figure 3)**

The EPA SOP table uses four species-specific equations from different sources for *Daphnia* (Table 1). The equation for *D. pulicaria* yields much heavier individuals at a standard length than other *Daphnia* species, and individuals of *D. longiremis* are particularly light. The ONTARIO set uses a pooled value from Dumont et al. (1975). It is comparable to the CBFS STD equation from Bottrell et al. (1976) and EPA SOP species-specific equations from Dumont et al. (1975) and Rosen (1981). O&N74 refer to O'Brien and deNoyelles (1974).

CBFS STD	Bot76 (pooled)	$\ln(\alpha)$ =1.468, β =2.83, 0.6-4.0 mm
ONTARIO	Dum75 (pooled)	$\ln(\alpha)$ =1.609, β =2.84
EPA SOP	Dum75 (*D. galeata*)	$\ln(\alpha)$ =1.510, β =2.56
EPA SOP	O&N74 (*D. pulicaria*)	$\ln(\alpha)$ =1.945, β =2.72
EPA SOP	Bot76 (*D. longispina*)	$\ln(\alpha)$ =1.073, β =2.89, 0.6-2.4 mm
EPA SOP	Ros81 (*D. retrocurva*)	$\ln(\alpha)$ =1.432, β =3.13, 0.5-2.0 mm, r^2=0.95

***Bosmina/Eubosmina* (Figure 4)**

The CBFS STD equation uses Bottrell et al. (1976)'s pooled equation. EPA SOP instead uses Bottrell et al. (1976)'s equation for *B. longirostris*. ONTARIO uses Dumont et al. (1975)'s equation for *B. longirostris* for *Eubosmina* and for *Bosmina* uses an equation developed for "low food" Lake Erie (DFO). All four equations yield comparable weights of individuals of standard length (Table 2). The Culver et al. (1985) equation, considered representing "high food" Lake Erie, yields heavier individuals.

CBFS STD	Bot76 (pooled)	$\ln(\alpha)$ =3.090, β =3.04, 0.3-1.0 mm
EPA SOP	Bot76 (*B. longirostris*)	$\ln(\alpha)$ =2.712, β =2.53, 0.3-0.5 mm
ONTARIO	Dum75 (*B. longirostris*)	$\ln(\alpha)$ =3.281, β =3.13
ONTARIO	DFO Erie 96	$\ln(\alpha)$ =2.370, β =2.12
not used	Cul85 (*B. longirostris*)	$\ln(\alpha)$ =2.229, β =2.88, 0.2-0.4 mm, r^2=0.98

Ceriodaphnia

CBFS STD uses the equation from Bottrell et al. (1976). EPA SOP uses Pace and Orcutt (1981). The CBFS STD equation yields lighter individuals <0.5 mm and intermediate weights for individuals at 1 mm relative to the other two L-W sets (Table 3). Culver et al. (1985) equations yields relatively light individuals.

CBFS STD	Bot76 (*C. quadrangula*)	$\ln(\alpha)$ =2.562, β =3.34, 0.3-0.7 mm
EPA SOP	P&O81 (*C. reticulata*)	$\ln(\alpha)$ =2.830, β =3.15, r^2=0.90
ONTARIO	(undoc.)	$\ln(\alpha)$ =2.237, β =2.26
not used	Cul85 (*C. lacustris*)	$\ln(\alpha)$ =1.392, β =1.98, 0.3-0.5 mm, r^2=0.99

Diaphanosoma

CBFS-STD uses the equation from Bottrell et al. (1976). EPA SOP uses Rosen (1981). ONTARIO used a generic *Daphnia* equation (Dumont et al. 1975). The CBFS STD and ONTARIO equations are comparable while the EPA SOP equation yields lighter individuals. The equation from Culver et al. (1985) is nearly linear (β near 1) and therefore suspect.

CBFS STD	Bot76 (*D. brachyurum*)	Ln(α) =1.624,β =3.05, 0.4-1.4 mm
EPA SOP	Ros81 (*D. brachyurum*)	Ln(α) =1.289,β =3.04, 0.4-1.2 mm, r^2=0.91
ONTARIO	Dum75 (*Daphnia*)	Ln(α) =1.609, β =2.84
not used	Cul85 (*D. leuchtenbergianum*)	Ln(α) =1.624, β =1.05, 0.3-0.5 mm, r^2=0.97

Taxa not included in Bottrell et al. (1976)

The Bottrell et al. (1976) study did not include or was not appropriate for some species, so we used other sources for those species.

Holopedium

ONTARIO uses an undocumented equation (Yan, DFO, Ln(α) =2.417, β =3.04 based on total length. Equations cited in Bottrell et al. (1976) and Persson and Ekbohm (1980) use "foot" length (distance between setae natatores and the terminal claw of the post-abdomen) rather than total length. EPA SOP uses the Persson and Ekbohm (1980) equation but multiplies total length by 0.25 to convert to foot length but does not show where that conversion originated from. For comparisons, we have made that adjustment within the equation by changing Ln(α) from 6.4957 to 2.073 (Table 1). The Yan equation yields slightly heavier individuals (Table 3). CBFS STD follows the EPA SOP's use of the Persson and Ekbohm (1980) after conversion for use with total length.

Alona, Chydorus, and Camptocercus

ONTARIO uses the equation for *Alona rectangular* from Dumont et al. (1975) for these three species. ONTARIO had an incorrect Ln(α) =1.391 that has been corrected in our Table 1. CBFS STD uses the corrected equation for *Alona* and *Camptocercus*, but uses the equation from Dumont et al. (1975) for *Chydorus sphaericus*. EPA SOP uses equations from Rosen (1981) for *C. sphaericus* and *Alona.* Using the Rosen (1981) *Chydorus* equation for *Alona* yields much heavier individuals than the CBFS STD *Alona* equation (Table 3). The CBFS STD equation for *Chydorus* is comparable to the EPA SOP *Chydorus* equation. ONTARIO uses a generic *Daphnia* equation for *Chydorus* that yields much lighter individuals.

ONTARIO/CBFS	Dum75 (*A. rectangula*)	Ln(α) =3.391, β =3.48
CBFS STD	Dum75 (*C. sphaericus*)	Ln(α) =4.493, β =3.93
EPA SOP	Ros81 (*C. sphaericus*)	Ln(α) =4.543, β =3.636, 0.2-0.4 mm, r^2=0.97
not used	Cul85 (*C. sphaericus*)	Ln(α) =2.645, β =1.98, 0.2-0.3 mm, r^2=0.99

Sida crystallina

The CBFS STD table follows EPA SOP use of Rosen (1981). ONTARIO uses the generic daphnid equation of Dumont et al. (1975) that yields lighter individuals of standard lengths.

CBFS/EPA	Ros81 (*S. crystallina*)	$\text{Ln}(\alpha) = 2.0539$, $\beta = 2.189$, 0.8-2.3 mm, $r^2 = 0.90$
ONTARIO	Dum75 (*Daphnia*)	$\text{Ln}(\alpha) = 1.609$, $\beta = 2.84$

Polyphemus pediculus

CBFS STD follows EPA SOP's use of the equation of Rosen (1981). ONTARIO used Dumont et al. (1975).

CBFS/EPA	Ros81 (*P. pediculus*)	$\text{Ln}(\alpha) = 2.7792$, $\beta = 2.152$, 0.3-1.1 mm, $r^2 = 0.98$
ONTARIO	Dum75 (*P. pediculus*)	$\text{Ln}(\alpha) = 1.936$, $\beta = 2.15$

Leptodora kindtii

CBFS STD follows ONTARIO and EPA SOP in using equation from Rosen (1981).

All three	Ros81 (*L.kindtii*)	$\text{Ln}(\alpha) = -0.821$, $\beta = 2.67$,1-5 mm, $r^2 = 0.96$
Not used	Cul85 (*L. kindtii*)	$\text{Ln}(\alpha) = 0.445$, $\beta = 1.873$, 2.2-6.8 mm, $r^2 = 0.99$

Bythotrephes cederstroemi

CBFS STD and EPA SOP use the equation from Makarewicz and Jones (2000, M&J00) that does not include the spine in the length measurement. Equations used in ONTARIO (Yan and Sprules, pers. comm) include the spine in the length measurement so are not directly comparable.

CBFS/EPA	M&J00	$\text{Ln}(\alpha) = 2.83$, $\beta = 2.09$, , n=50, 1-3 mm, $r^2 = 0.63$
ONTARIO	Yan and Sprules	$\text{Ln}(\alpha) = 2.25$, $\beta = 3.11$

Cercopagis pengoi

CBFS STD follows EPA SOP and ONTARIO by using Makarewicz et al. (2001, Mak01). The equation used is based on unpreserved nearshore specimens. The length measurement is described as " peak of head to base of caudal process", therefore the spine was not included in body measurement. Makarewicz et al. (2001) also show that alcohol preservation lead to an average 42% weight loss.

Mak01 $\text{Ln}(\alpha) = 1.716$, $\beta = 2.37$ size range 0.8-2.0 mm, $r^2 = 0.79$, n=18

Older EPA SOP equations include the spine in the length measurement.

Simm and Ojaveer (unpub)	$Ln(\alpha) = -4.017$, $\beta = 3.01$ (entire spine included)
Ojaveer et al. 2001	$Ln(\alpha) = 0.49$, $\beta = 2.98$ (tip of head to tip of 3rd

articular spine)

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Table 1. Three sets of L-W Coefficients for Great Lakes zooplankton and their sources.

Species Name	CBFS STD Ln(α)	CBFS STD β	CBFS STD Source	EPA SOP Ln(α)	EPA SOP β	EPA SOP Source	ONTARIO Ln(α)	ONTARIO β	ONTARIO Source
Cyclopoid Copepods									
Acanthocyclops vernalis	1.953	2.40	Bot76	2.227	3.23	Ros81	1.656	2.15	?
Cyclopoid copepodid	1.953	2.40	Bot76	1.66	3.97	Ros81	1.705	2.46	Spr
Diacyclops thomasi	1.953	2.40	Bot76	1.492	1.99	P&E 80	1.705	2.46	Spr
Eucyclops sp.	1.953	2.40	Bot76	1.492	1.99	P&E 80	1.705	2.46	Spr
Mesocyclops edax	1.953	2.40	Bot76	1.66	3.97	Ros81	1.896	2.89	Cul85
Tropocyclops prasinus	1.953	2.40	Bot76	2.227	3.23	Ros81	1.705	2.46	Spr
Calanoid Copepods									
Calanoid copepodid	1.953	2.40	Bot76	1.05	2.46	P&O81	1.705	2.46	Spr
Diaptomus sp.	1.953	2.40	Bot76	1.05	2.46	P&O81	1.705	2.46	Spr
Epischura sp.	1.953	2.40	Bot76	1.05	2.46	P&O81	1.87	2.63	?
Eurytemora affinis	1.953	2.40	Bot76	1.05	2.46	P&O81	1.705	2.46	Spr
Limnocalanus macrurus	1.953	2.40	Bot76	1.05	2.46	P&O81	1.705	2.46	Spr
Nauplii	1.953	2.40	Bot76	0.4	0	Haw79	1.435	2.48	Lew79
Harpacticoid copepod	1.953	2.40	Bot76	1.05	2.46	P&O81	1.705	2.46	Spr
Cladocerans - Daphnids									
Daphnia ambigua	1.468	2.83	Bot76	1.51	2.56	Dum75	1.609	2.84	Dum75
Daphnia longiremis	1.468	2.83	Bot76	1.073	2.89	Bot76	2.265	2.20	?
Daphnia mendotae	1.468	2.83	Bot76	1.51	2.56	Dum75	1.609	2.84	Dum75
Daphnia pulicaria	1.468	2.83	Bot76	1.945	2.72	O&N74	1.609	2.84	Dum75
Daphnia retrocurva	1.468	2.83	Bot76	1.432	3.13	Ros81	1.609	2.84	Dum75
Daphnia schodleri	1.468	2.83	Bot76	1.51	2.56	Dum75	1.609	2.84	Dum75
Daphnia sp.	1.468	2.83	Bot76	1.51	2.56	Dum75	1.609	2.84	Dum75
Cladocerans - Bosminids									
Bosmina longirostris	3.09	3.04	Bot76	2.712	2.53	Bot76	2.37	2.12	Erie96
Eubosmina sp.	3.09	3.04	Bot76	2.712	2.53	Bot76	3.281	3.13	Dum75
Cladocerans - Other									
Alona sp.	3.391	3.48	Dum75	4.543	3.64	Ros81	3.391	3.48	Dum75
Camptocercus sp.	3.391	3.48	Dum75	3.391	3.48	n/a	3.391	3.48	Dum75
Ceriodaphnia sp.	2.562	3.34	Bot76	2.83	3.15	P&O81	2.237	2.26	?
Chydorus sphaericus	4.493	3.93	Dum75	4.543	3.64	Ros81	3.391	3.48	Dum75
Diaphanosoma sp.	1.624	3.05	Bot76	1.289	3.04	Ros81	1.609	2.84	Dum75
Holopedium gibberum	2.073	3.19	P&E80	2.073	3.19	P&E80	2.417	3.04	Yan
Moina sp.	2.562	3.34	Bot76	2.83	3.15	P&O81	2.237	2.26	?
Sida crystallina	2.054	2.19	Ros81	2.054	2.19	Ros81	1.609	2.84	Dum75
Predatory Cladocerans									
Bythotrephes longimanus	2.83	2.09	Mak00	2.83	2.09	Mak00	2.41	2.77	Mak00
Cercopagis pengoi	1.716	2.37	Mak01	1.716	2.37	Mak01	1.716	2.37	Mak01
Leptodora kindtii	-0.821	2.67	Ros81	-0.821	2.67	Ros81	-0.821	2.67	Ros81
Polyphemus pediculus	2.779	2.15	Ros81	2.779	2.15	Ros81	1.936	2.15	Yan

Table 2. Dry weight (in μg) of taxa of standard lengths from L-W coefficients sets.

Source	Table	Taxa	0.2 mm	0.5 mm	1.0 mm	1.5 mm
Copepod Equations						
Bot76	CBFS STD	pooled	0.15	1.34	7.05	18.66
Spr	ONTARIO	pooled	0.10	1.00	5.50	14.92
P&E 80	EPA SOP	*C. scutifer*	0.18	1.12	4.45	9.94
P&O81	EPA SOP	*D. siciloides*	0.05	0.52	2.86	7.75
Ros81	EPA SOP	*A. vernalis*	0.05	0.99	9.27	34.34
Ros81	EPA SOP	*M. edax*	0.01	0.34	5.26	26.29
Daphnia Equations						
Bot76	CBFS STD	pooled	0.05	0.61	4.34	13.67
Dum75	ONTARIO	pooled	0.05	0.70	5.00	15.81
Dum75	EPA SOP	*D. g. mendotae*	0.07	0.77	4.53	12.78
Bot76	EPA SOP	*D. longiremis*	0.03	0.39	2.92	9.44
Ros81	EPA SOP	*D. retrocurva*	0.03	0.48	4.19	14.89
O&N74	EPA SOP	*D. pulicaria*	0.09	1.06	6.99	21.06
Bosmina Equations						
Bot76	CBFS STD	pooled	0.16	2.67	> max	> max
Erie 96	ONTARIO	*Bosmina*	0.35	2.46	> max	> max
Dum75	ONTARIO	*Eubosmina*	0.17	3.04	> max	> max
Bot76	EPA SOP	*B. longirostris*	0.26	2.61	> max	> max
Cul85		*B. longirostris*	0.49	3.78	> max	> max

Table 3. Dry weight (in µg) of other cladocerans of standard lengths from L-W coefficients sets.

Source	Table	Taxa	0.2 mm	0.5 mm	1.0 mm	1.5 mm
Alona						
Dum75	CBFS/ONTARIO	*A. rectangula*	0.11	2.66	29.70	> max
Ros81	EPA SOP	*Chydorus*	0.27	7.56	93.97	> max
Ceriodaphnia						
Bot76	CBFS STD	*C. quadrangula*	0.06	1.28	12.97	> max
P&O81	EPA SOP	*C. reticulata*	0.11	1.91	16.95	> max
Oneida Lake	ONTARIO		0.25	1.96	9.37	> max
Cul85		*C. lacustris*	0.17	1.02	4.01	> max
Chydorus						
Dum75	CBFS STD	*Chydorus*	0.16	5.85	> max	> max
Ros81	EPA SOP	*Chydorus*	0.27	7.56	> max	> max
Dum75	ONTARIO	*Daphnia*	0.05	0.70	> max	> max
Cul85		*C. sphaericus*				
Diaphanosoma						
Bot76	CBFS STD	*D. brachyurum*	0.04	0.61	5.07	> max
Ros81	EPA SOP	*D. brachyurum*	0.03	0.44	3.63	> max
Dum75	ONTARIO	*Daphnia*	0.05	0.70	5.00	> max
Cul85		*D. leuchten…*	0.94	2.46	5.07	> max
Holopedium						
Yan	CBFS/ONTARIO	*H. gibberum*	0.08	1.36	11.21	> max
P&E80	EPA SOP	*H. gibberum*	0.05	0.87	7.95	> max
Sida						
Ros81	CBFS/EPA	*S. crystallina*	0.23	1.71	7.80	18.94
Dum75	ONTARIO	*Daphnia*	0.05	0.70	5.00	15.81

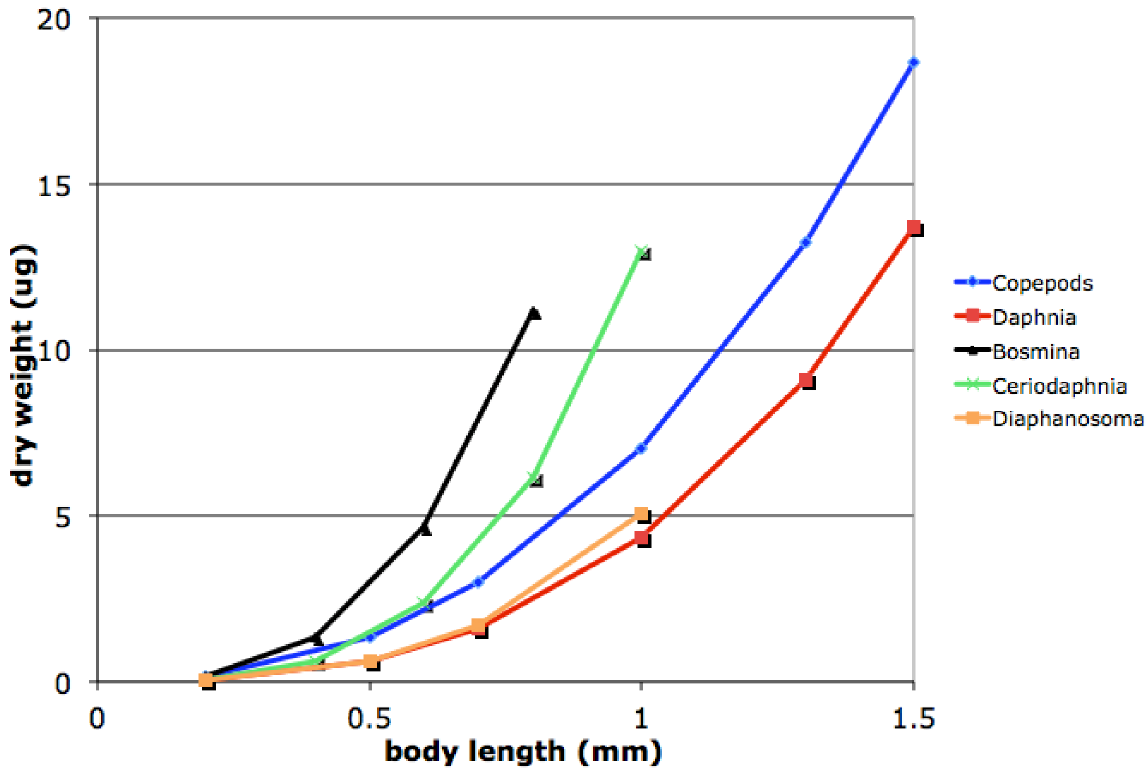

Figure 1. CBFS STD L-W equations for five taxa based on Bottrell et al. (1976).

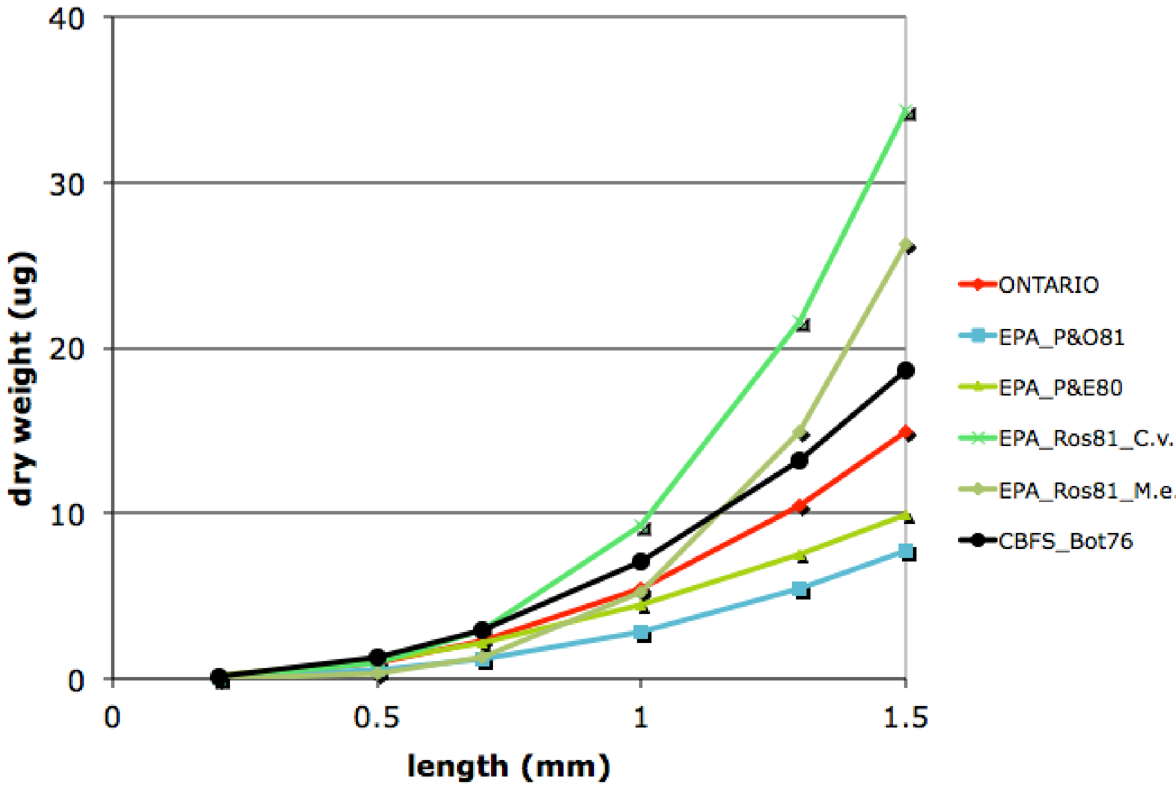

Figure 2. L-W Equations for copepods. EPA SOP (green shades) uses four sources while ONTARIO (red line) is based on Sprules and CBFS STD (black line) is based on Bottrell et al. (1976). Abbreviations of sources explained in text.

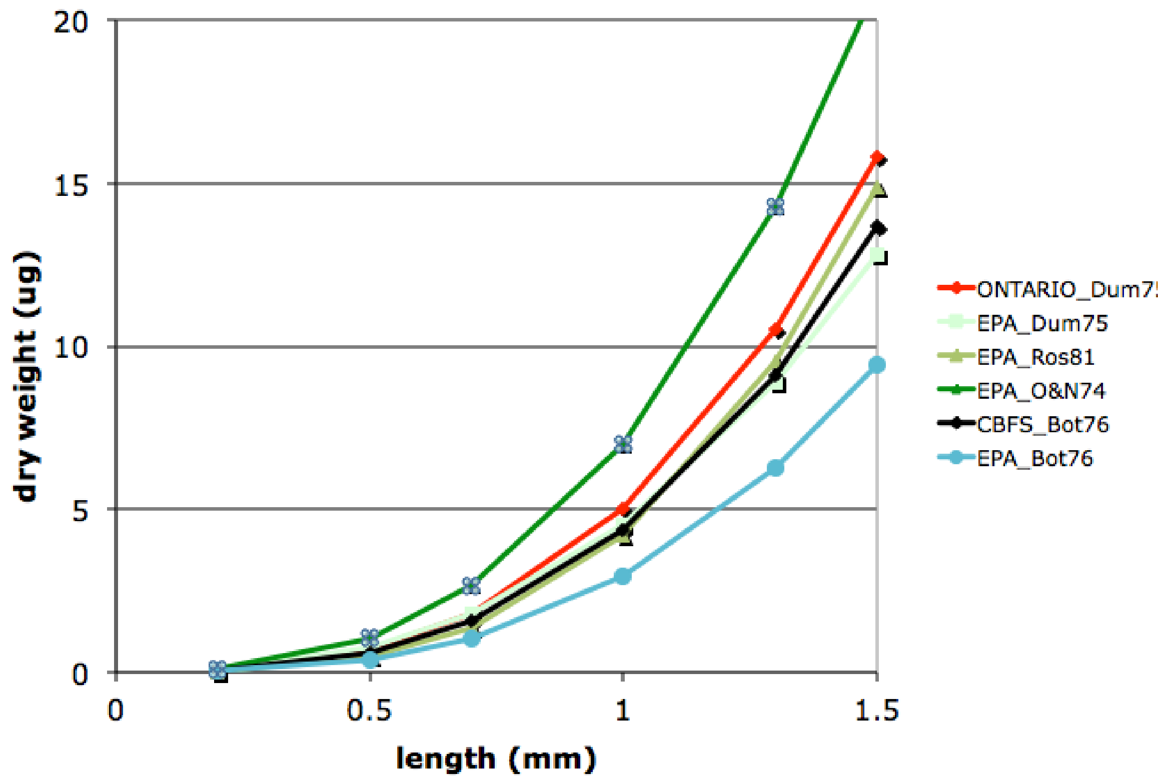

Figure 3. L-W equations for *Daphnia*. EPA SOP uses four equations (green shades), CBFS STD (black line) uses pooled value in Bottrell et al. (1976) and ONTARIO (red line) uses pooled value in Dumont et al. (1975). Abbreviations of sources explained in text.

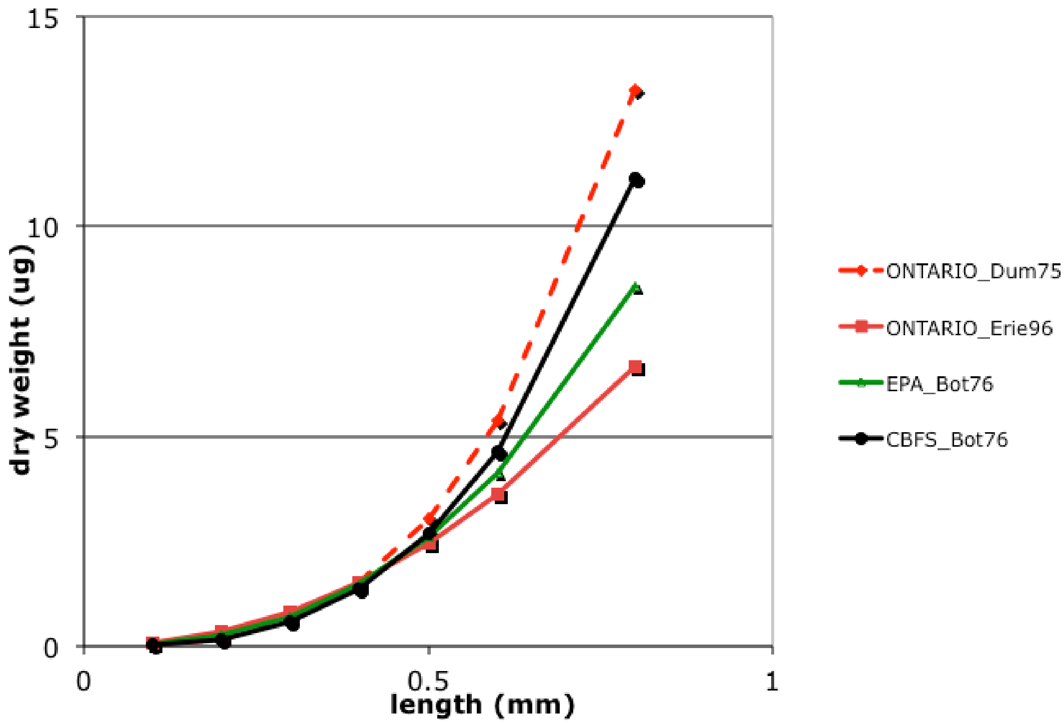

Figure 4. L-W equations for *Bosmina/Eubosmina*. CBFS STD (black line) uses pooled value in Bottrell et al. (1976), EPA SOP (green line) uses *B. longirostris* value in Bottrell et al. (1976), and ONTARIO (red lines) uses Dumont et al. (1975) for *Eubosmina* (dashed) and Erie 96 value for *Bosmina* (solid). Abbreviations of sources explained in text.