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Comparison of Reported Length-Weight Relationships for the Dominant Copepod Prey of Larval Sea Herring in the Georges Bank-Gulf of Maine Area

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80-19

Abstract

Several existing length-weight relationships for the dominant copepod prey of Georges Bank-Gulf of Maine larval sea herring are compared and evaluated. Possible sources of variation among the relationships are discussed and equations for each species are recommended for use in investigations involving formalin-preserved samples

Ideally, length-weight determinations should be carried out on fresh specimens of each stage of each species at a particular time and location, and the results substituted into the general equation $Log_{10}W = bLog_{10}L + Log_{10}\, a$ (Landry, 1978). This procedure is too time-consuming and expensive for use in general monitoring studies, and should only be applied to smaller-scale studies involving a limited number of taxonomic groups. The *in situ* methods for recording standing crop in order to estimate productivity currently being developed will be more cost-effective for large-scale monitoring surveys.

Introduction

Bioenergetic studies of larval fish feeding and survival such as those conducted by Laurence (1977), Radtke and Dean (1979), and Lasker (1970) require estimates of the dry weight and caloric value of the prey consumed based upon gut contents. Knowledge of the prey biomass is also necessary for investigations into the relationships between larval fish feeding (gut contents) and their natural food supply (Ivlev, 1961). The Northeast Fisheries Center is currently conducting ecosystem dynamics studies on the Continental Shelf from the Gulf of Maine to Cape Hatteras which focus on the critical zooplankton-fish linkages and are based upon biomass measures (Sherman et al., 1977; Sherman, 1980). The literature contains numerous length-weight (biomass) conversion relationships for marine plankton because length is more easily and rapidly measured than weight.

In this paper, a comparison and evaluation is made of several existing length-weight conversion methods for the dominant species of copepods consumed by autumn-spawned larval sea herring in the Georges Bank-Gulf of Maine area. The length-weight conversion equations recommended here may be used as part of a larger investigation into the relationship between larval herring survival and their feeding dynamics, morphological condition and available food supply (see Cohen and Lough, 1979, for description of this program rationale and methodology). Ideally, the basic length-weight equation:

$$W = aL^b, \text{ or } \mathrm{Log}_{10}W = b\,\mathrm{Log}_{10}L + \mathrm{Log}_{10}a$$

a & b = constants

L = length (mm)

W = dry weight (mg)

(Landry, 1978) should be evaluated for each species in each sample collected at different locations or seasons prior to preservation.

Methods

The dominant food organisms of larval herring in the Georges Bank-Gulf of Maine area based on the work of Cohen and Lough (1979) are the adults and juveniles of the following copepod species:

1. Pseudocalanus sp.
2. Paracalanus parvus
3. Centropages typicus
4. Centropages hamatus
5. Oithona spp.
6. Calanus finmarchicus

Some recent work on Acartia clausi (Durbin and Durbin, 1978) also is included because the methods and results are clearly specified and reliable, and so they are useful in evaluating other earlier studies of this species.

Length-weight measurements of copepods from the Northwest Atlantic are used whenever possible because geographic and seasonal differences exist in body size and biomass (Comita et al., 1966; Conover, 1968; Siefkin and Armitage, 1969). There is a general lack of uniformity of laboratory methods in these studies which creates added variability in the data. In translations of several articles cited, it is not always clearly stated whether the values represent wet or dry weight (Anonymous, 1976; Gruzov and Alekseyeva, 1970; and Chislenko, 1968). Therefore, the studies of Durbin and Durbin (1978), Corkett and McLaren (1978), and Robertson (1968), where wet or dry weight and laboratory methods are clearly stated, are used as standards with which to compare the results of other authors for the same species.

Several length-weight regression equations for each species are available in the literature. These equations have been standardized to an exponential form for comparison, and L (in mm) and W (in mg) are substituted for length and weight, respectively, when other letters were used by the original authors. Durbin and Durbin (1978) and Robertson (1968) used fresh specimens in their investigations; all the other equations apply to formalin-preserved animals. Davis (personal communication) has recommended using the equation of Corkett and McLaren (1978) for Pseudocalanus sp. instead of his semi-logarithmic equation. Schwartz (1977) combined several stages in his work with Calanus finmarchicus causing his results to be less refined than those of the other authors.

Results

The wide variation in the length-weight relationships for the seven species
igs. 1-7 demonstrated in the graphs (Figs. 1-7) is to be expected because of all the inherent sources of variation in these data. Reported values represent a mixture of wet and dry weights, geographic locations, seasons, and laboratory processing methods. Unfortunately, a quantitative comparison of the curves is not possible because confidence intervals generally are not available. Divergence in the plotted curves tends to increase with increasing length in all species perhaps because the older animals have a wider range of lengths within the same stage, especially Pseudocalanus sp. (range for adult females can vary from 0.67 to 1.9 mm, Corkett and McLaren, 1978). Pearre (1980)

Tables 1-7

discusses the bases for several of the methods used to derive the equations cited. Tables 1-7 summarize these equations for the seven species of copepods along with the size and stages to which they apply and any seasonal and geographic information available. All the equations for a given species are plotted on individual graphs (Figs. 1-7) with the size restrictions indicated.

Discussion

One approach to assessing the energy content of larval herring prey items is to determine their biomass or dry weight by some method. Ideally, unpreserved individuals of all stages of each copepod species of interest from each field sample collected should be processed to determine their length-weight relationships. This information can then be substituted into the general equation, $Log_{10}W = bLog_{10}L + Log_{10}a$. Then only the mean length and number of individuals in each stage need to be recorded at a given location in order to calculate dry weight and convert the information into energy content (Landry, 1978; Durbin and Dubrin, 1978). Pearre (1980) points out that width would be a more appropriate linear measurement because: (1) it seems to be a critical dimension in prey selection by larval fish, and (2) it gives a better estimate of wet weight in his experiments. (3) Length is a somewhat ambiguous measurement because of the different morphologies of the major copepod groups and the variety of measuring conventions used in the literature. These problems are not encountered when measuring width.

Since this procedure is not possible with previously collected samples, an alternative method must be used. In the present study, an investigation was made into several L-W equations for each of the dominant copepod prey species of larval herring. Comparisons of these equations within species were difficult because of the sources of variability, biological and experimental, as stated previously. There are geographic and seasonal differences in copepod body size and biomass. Length and weight are inversely proportional to food concentrations when temperature is fairly constant (Deevey, 1960; Durbin and Durbin 1978; Mullin and Brooks, 1970; Landry, 1978; Bogorov, 1934). McLaren (1963) states that in general, food concentration indirectly determines the temperature which each developmental stage will experience by controlling growth rate of the organisms. The final size of a copepod is inversely proportional to the developmental temperature (Miller, 1977; Deevey, 1960; McLaren, 1963). Miller (1977) discusses the growth pattern found in several Acartia species and compares it to several other marine copepod genera. The lack of uniformity of laboratory methods creates an additional source of variability in these results. The difficulty of determining whether wet or dry weight was calculated was already mentioned. Botrell et al. (1978) have assumed that Chislenko's nomographs represent wet weights. Since the nomographs are derived from theoretical, not actual data, it is assumed in this study that they may be used to predict dry weight provided that the values obtained correspond to known weights obtained from other studies, and that the relationship between wet and dry weights is constant throughout the life of the organism.

Most authors agree that the cephalothorax length of copepods is not significantly affected by formalin preservation, but there is some question as to the extent of its effect on dry weight, carbon, nitrogen, and other chemical constituents (Lovegrove, 1966; Fudge, 1968). Mullin and Brooks (1970) and Durbin and Durbin (1978) found that the changes level off after the samples have equilibrated for several months. Corkett and McLaren (1978) suggest that the lack of a consistent relationship between preserved and unpreserved dry weight of copepods collected at the same time is due to the seasonally changing fat content (soluble in formalin). When fat content is low there will be less discrepancy between the weights than when it is high. Landry (1978) states that in high food concentrations, Acartia clausi copepodites accumulate excess carbon in a formalin-soluble form (probably lipid) which is not detected in the weight of formalin-in-preserved animals, and he further suggests that this accumulated carbon is a good measure of immediate condition. Durbin and Durbin (1978) recommend calculating a condition factor for copepods as is commonly done in fishery biology in order to obtain a better estimate of energy content.

Based upon all these considerations and the available information, we recommend the following equations for the dominant prey copepods of larval herring:

1. Pseudocalanus sp.

   $W = (0.0119)L^{3.64}$ (Corkett and McLaren, 1978)

   (Davis recommends this equation rather than his own and the other equations are for different geographic areas).

2. Paracalanus parvus

   $W = (0.0181)L^{3.064}$ (Chislenko, 1968)

   (Other equations are for different geographical areas and Robertson's equation applies to C5 and C6).

3. Centropages typicus

   $W = (0.02937)L^{3.011}$ (Chislenko, 1968)

   (Anonymous measurements are probably wet weight; other equations apply to other geographic areas).

4. Centropages hamatus

$$W = (0.02937)L^{3.011} \qquad \text{(Chislenko, 1968)}$$

(Other equations are for different geographic areas; Robertson's equation covers only C5 and C6).

5. Oithona spp.

$$W = (0.0309)L^{3.069} \qquad \text{(Chislenko, 1968)}$$

(Other equations are for other geographic areas).

6. Calanus finmarchius

$$W = (0.0181)L^{3.0694} \qquad \text{(Chislenko, 1968)}$$

(Anonymous values are probably wet weight; Schwartz combined several developmental stages; other equations are for other areas).

The theoretical equations of Chislenko (1968) were selected unless another equation was derived from data using dry weight of each stage at a suitable geographic location.

Vast amounts of time and money could be saved during future survey work if an in situ method of recording zooplankton biomass could be perfected (Mullin and Huntley, personal communication). This procedure - the "weight-dependent" method of estimating standing crop and secondary production - could be applied to preserved samples as they are sorted using image analysis techniques, or to data obtained from in situ electronic zooplankton counters such as the one described by Herman and Dauphinee (1980).

Beers (1970) has extensively reviewed and evaluated the literature in this general subject area and has made recommendations for future work basically in agreement with those suggested here. He suggests using more accurate, expensive, and time-consuming techniques of estimating biomass in studies involving a limited taxonomic group of organisms and encourages the development of *in situ* methods of biomass measurements for routine surveys.

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Table 1. Length-weight relationships for Pseudocalanus sp.

Author	Equation	Size range (mm)	Geographic location	Season
Anonymous (1976)	Pseudocalanus elongatus $W=(0.0237)L^{3.745}$		Georges Bank	
Robertson (1968)	Paracalanus-Pseudocalanus $W=(0.01816)L^{2.39}$	C5 & C6	North Atlantic & North Sea	
Gruzov & Alekseyeva (1970)	Pseudocalanidae $W=(0.015)L^{2.918}$ mean error = $\pm 17\%$		Gulf of Guinea	
Davis (1977)	Pseudocalanus minutus $W=e^{4.6097L-8.7551)}$ $r^2 = .95$		Georges Bank	Winter
Corkett & McLaren (1978)	$W=(0.0119)L^{3.64}$		Canadian Arctic	
Chislenko (1968)	Table XI #3 $W=(0.0181)L^{3.0694}$			

Table 2. Length-weight relationships for *Paracalanus parvus*.

Author	Equation	Size range (mm)	Geographic Location	Season
Shmeleva (1963)	$W=(0.034)L^{2.419}$		Adriatic Sea	
Robertson (1968)	*Paracalanus-Pseudocalanus* $W=(0.01816)L^{2.39}$ $r^2= .65$	C5 & C6	North Atlantic & North Sea	
Gruzov & Alekseyeva (1970)	Paracalanidae $W=(0.015)L^{2.918}$ mean error = $\pm 17\%$		Gulf of Guinea	
Chislenko (1968)	Table XI #7 $W=(0.0181)L^{3.0694}$			

Table 3. Length-weight relationships for *Centropages typicus*.

Author	Equation	Size range (mm)	Geographic location	Season
Anonymous (1976)	$W=(0.0214)L^{3.87}$		Georges Bank	
Gruzov & Alekseyeva (1970)	Centropagidae $W=(0.028)L^{3.009}$ mean error = $\pm$ 15%		Gulf of Guinea	
Chislenko (1968)	Table XI #9 $W=(0.02937)L^{3.0111}$			

Table 4. Length-weight relationships for *Centropages hamatus*.

Author	Equation	Size range (mm)	Geographic location	Season
Pertsova (1967)	$W=(0.334L+0.0142)^3$	0.4-1.4	White Sea	
Robertson (1968)	$W=(0.01816)L^{2.39}$ $r^2 = .65$	C5 & C6	North Atlantic & North Sea	
Gruzov & Alekeseyeva (1970)	Centropagidae $W=(0.028)^{3.009}$ mean error = $\pm$15%		Gulf of Guinea	
Chislenko (1968)	Table XI #9 $W=(0.02937)L^{3.0111}$			

Table 5. Length-weight relationships for *Oithona* spp.

Author	Equation	Size range (mm)	Geographic location	Season
Shmeleva (1963)	*Oithona* spp. $W=(0.013)L^{2.174}$		Atlantic & Adriatic Seas	
Shmeleva (1963)	*Oithona similis* $W=(0.016)L^{2.213}$		Adriatic	
Chislenko (1968)	Table XI #5 $W=(0.0309)L^{3.069}$			

Table 6. Length-weight relationships for *Calanus finmarchicus*.

Author	Equation	Size range (mm)	Geographic location	Season
Anonymous (1976)	$W=(0.0257)L^{3.141}$	1.3-4.0	Georges Bank	
Robertson (1968)	$W=(0.006458)L^{3.9}$ $r^2 = .77$	C5 & C6	North Atlantic & North Sea	
Gruzov & Alekseyeva (1970)	Calanidae $W=(0.015)L^{2.918}$ mean error = $\pm 17\%$		Gulf of Guinea	
Schwartz (1977)	$W=(0.002305)x10^{.6966L}$		Georges Bank	Spring
Chislenko (1968)	Table XI #7 $W=(0.0181)L^{3.0694}$			

Table 7. Length-weight relationships for *Acartia clausi*.

Author	Equation	Size range (mm)	Geographic location	Season
Robertson (1968)	$W=(0.01318)L^{2.86}$ $r^2 = .78$	C5 & C6	North Atlantic & North Sea	
Durbin & Durbin (1978)	$W=(0.013185)L^{3.1858}$ $r^2 = .77$	C1	Narragansett Bay	
Durbin & Durbin (1978)	$W=(0.009923)L^{3.0778}$ $r^2 = .98$	C2-C5	Narragansett Bay	
Durbin & Durbin (1978)	$W=(0.01237)L^{3.6276}$ $r^2 = .94$	C6	Narragansett Bay	
Gruzov & Alekseyeva (1970)	Acartiidae $W=(0.017)L^{3.066}$ mean error = $\pm20\%$		Gulf of Guinea	
Chislenko (1968)	Table XI #2 $W=(0.0090)L^{2.969}$			

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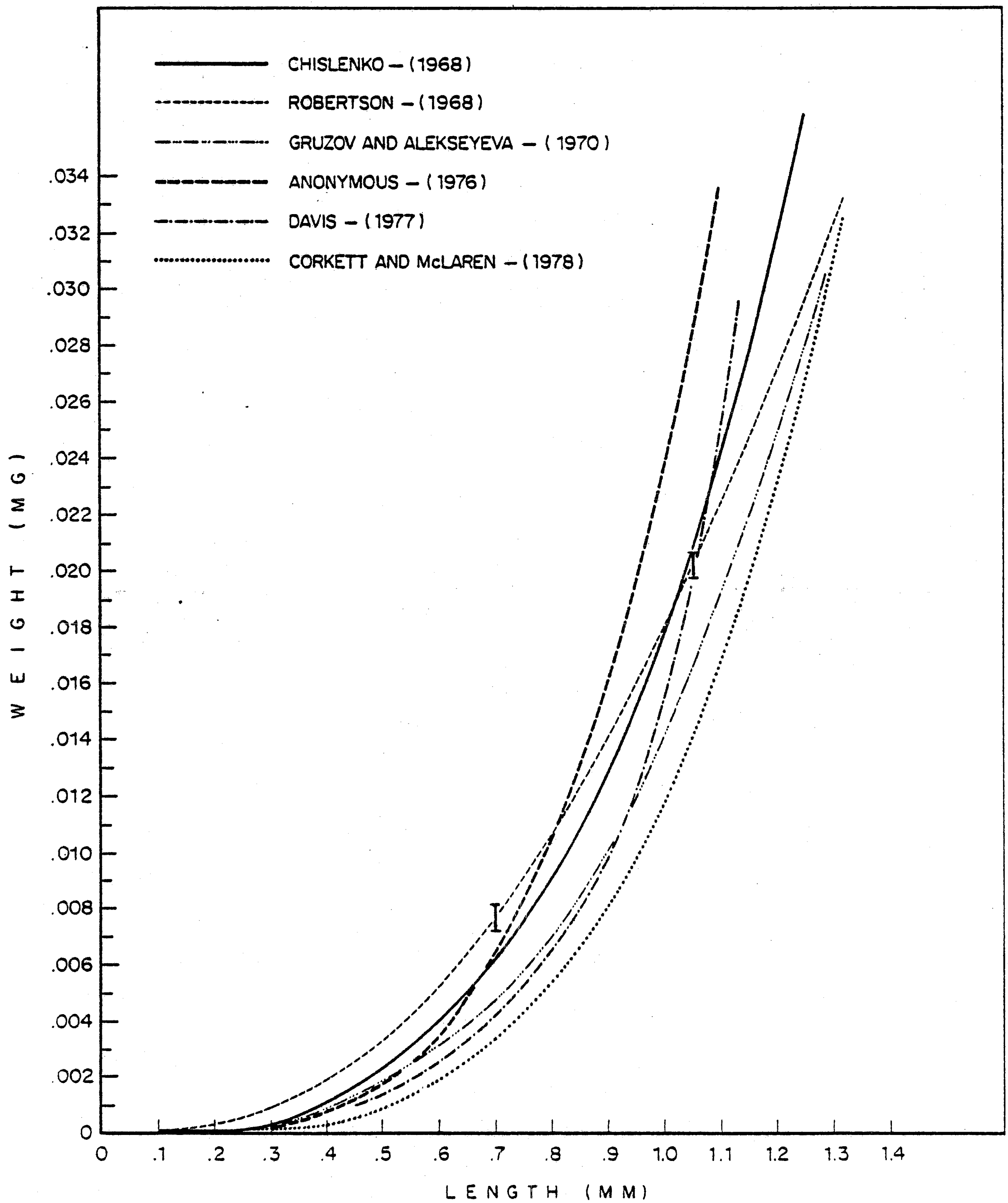

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ROBERTSON – (1968)
GRUZOV AND ALEKSEYEVA – (1970)
ANONYMOUS – (1976)
DAVIS – (1977)
CORKETT AND McLAREN – (1978)
WEIGHT (MG)
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.028
.026
.024
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.018
.016
.014
.012
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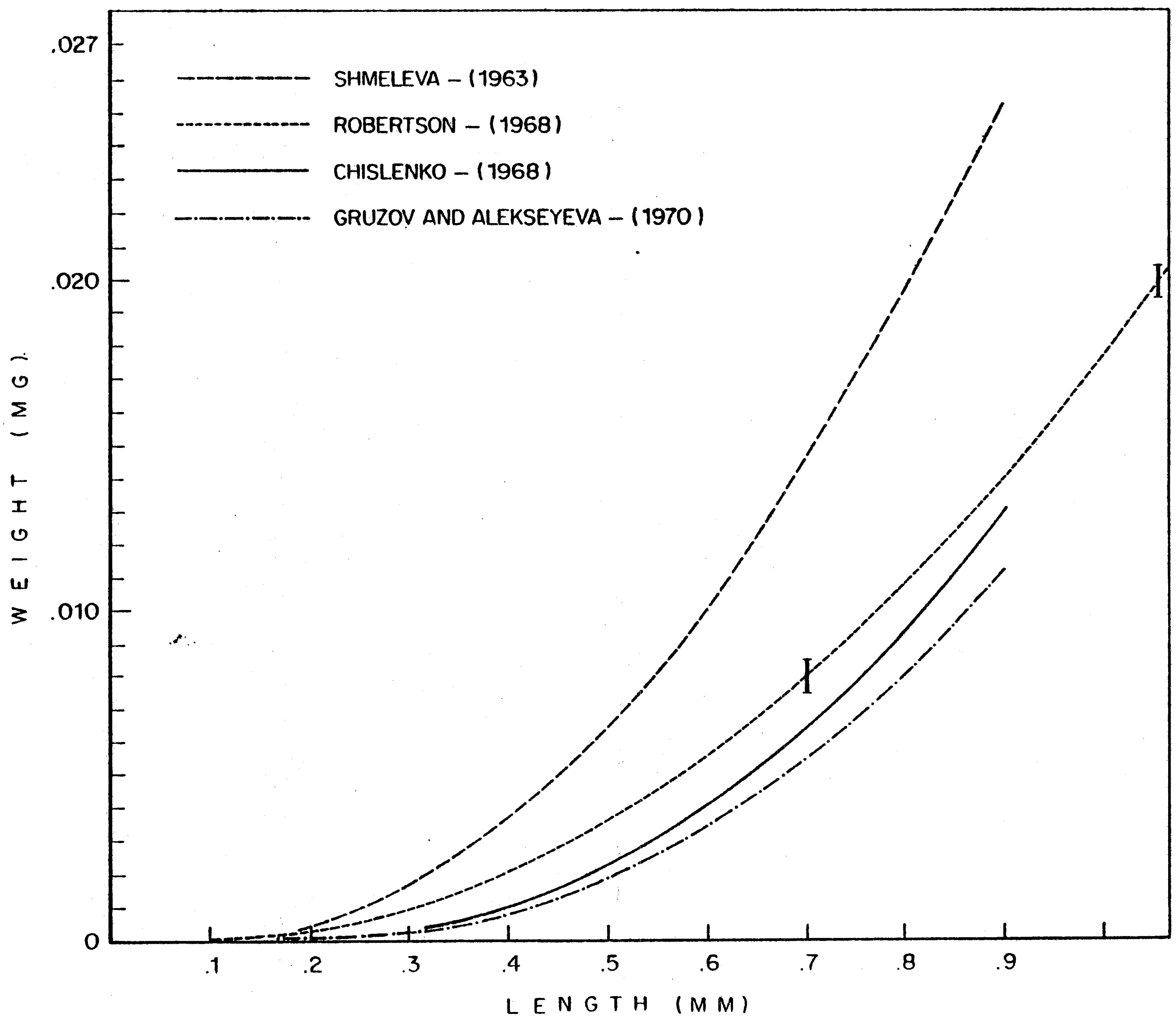
LENGTH (MM)



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GRUZOV AND ALEKSEYEVA – (1970)
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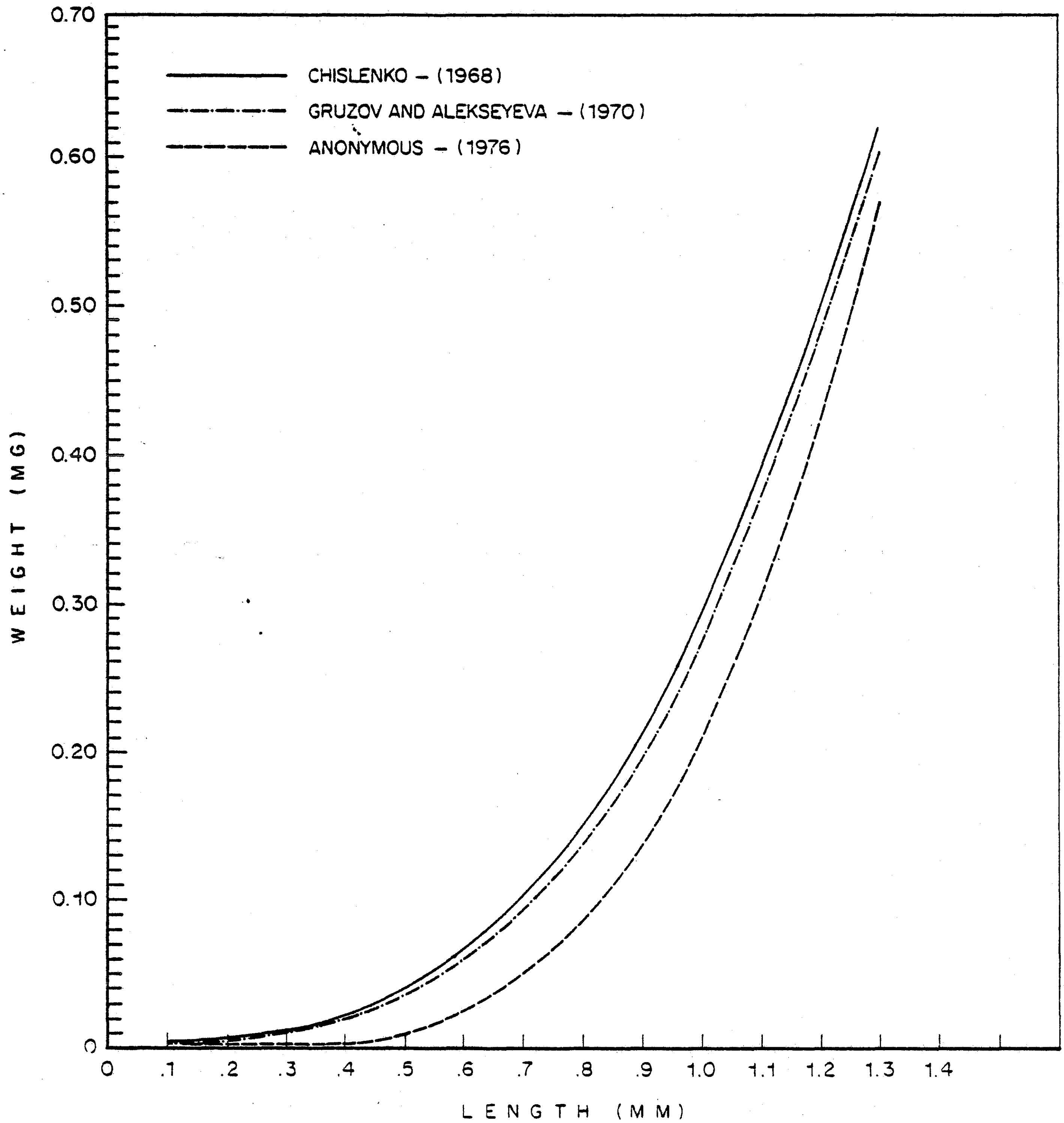
LENGTH (MM)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WEIGHT (MG)
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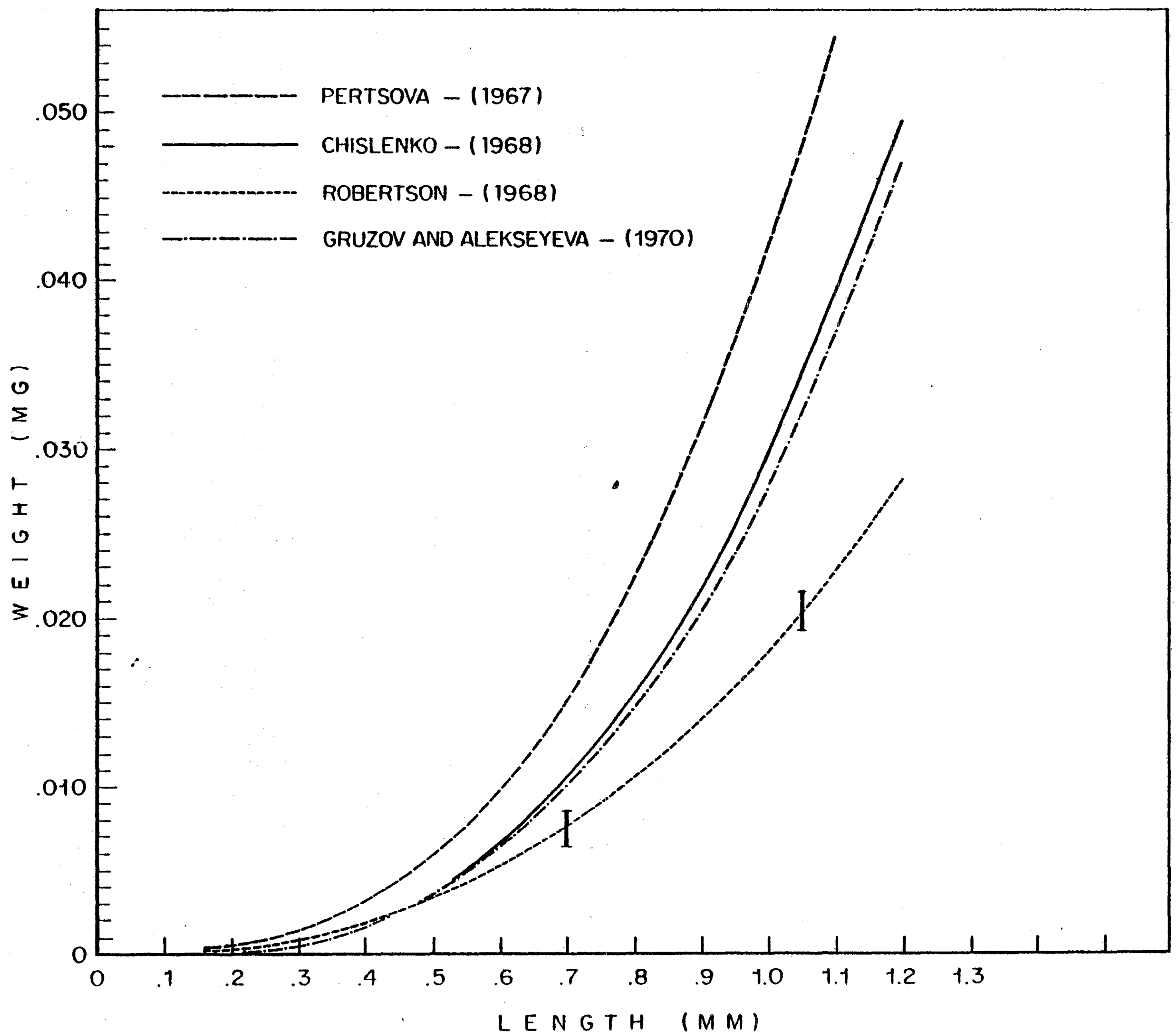
LENGTH (MM)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ROBERTSON – (1968)
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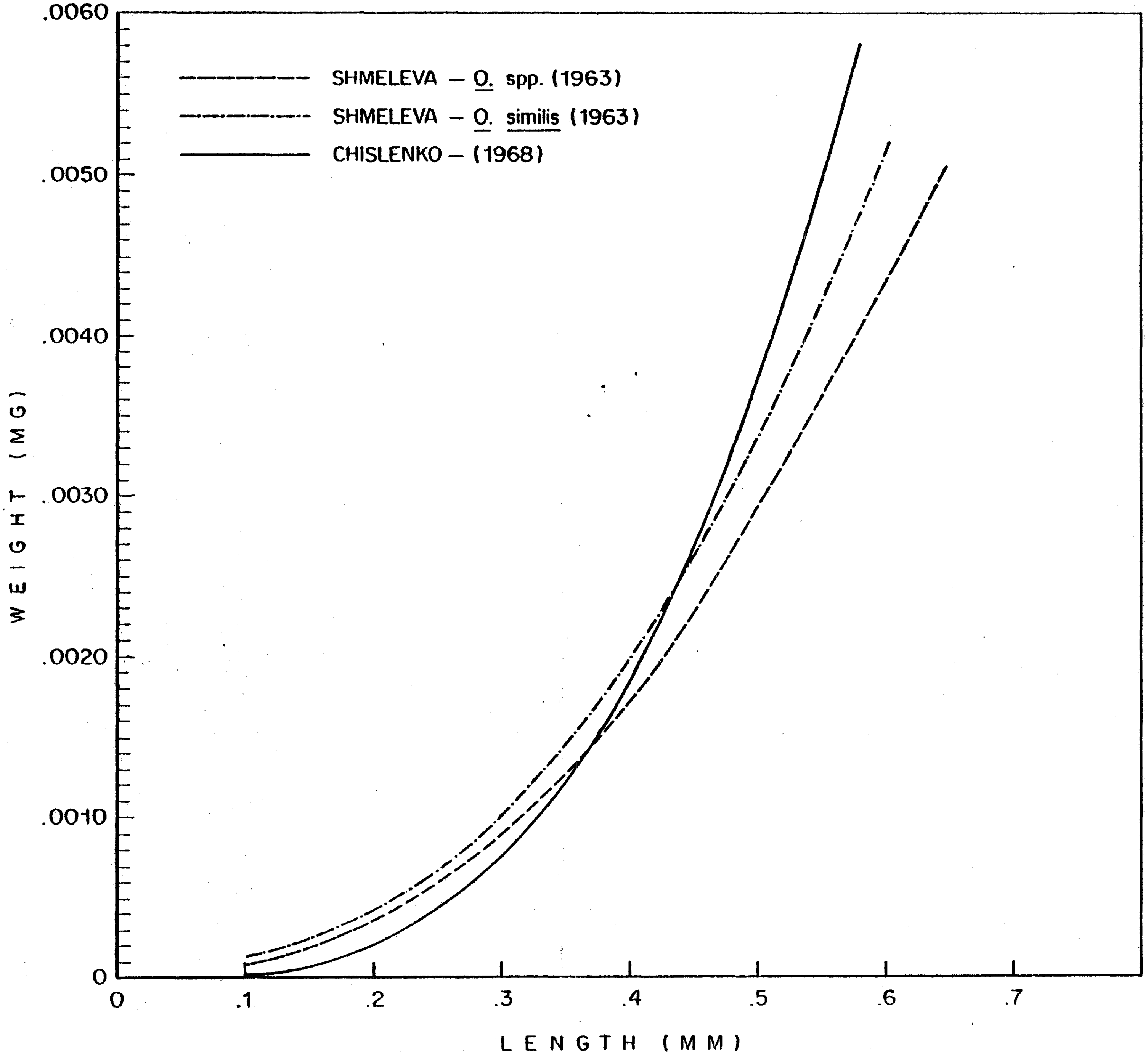

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SHMELEVA — O. similis (1963)
CHISLENKO — (1968)
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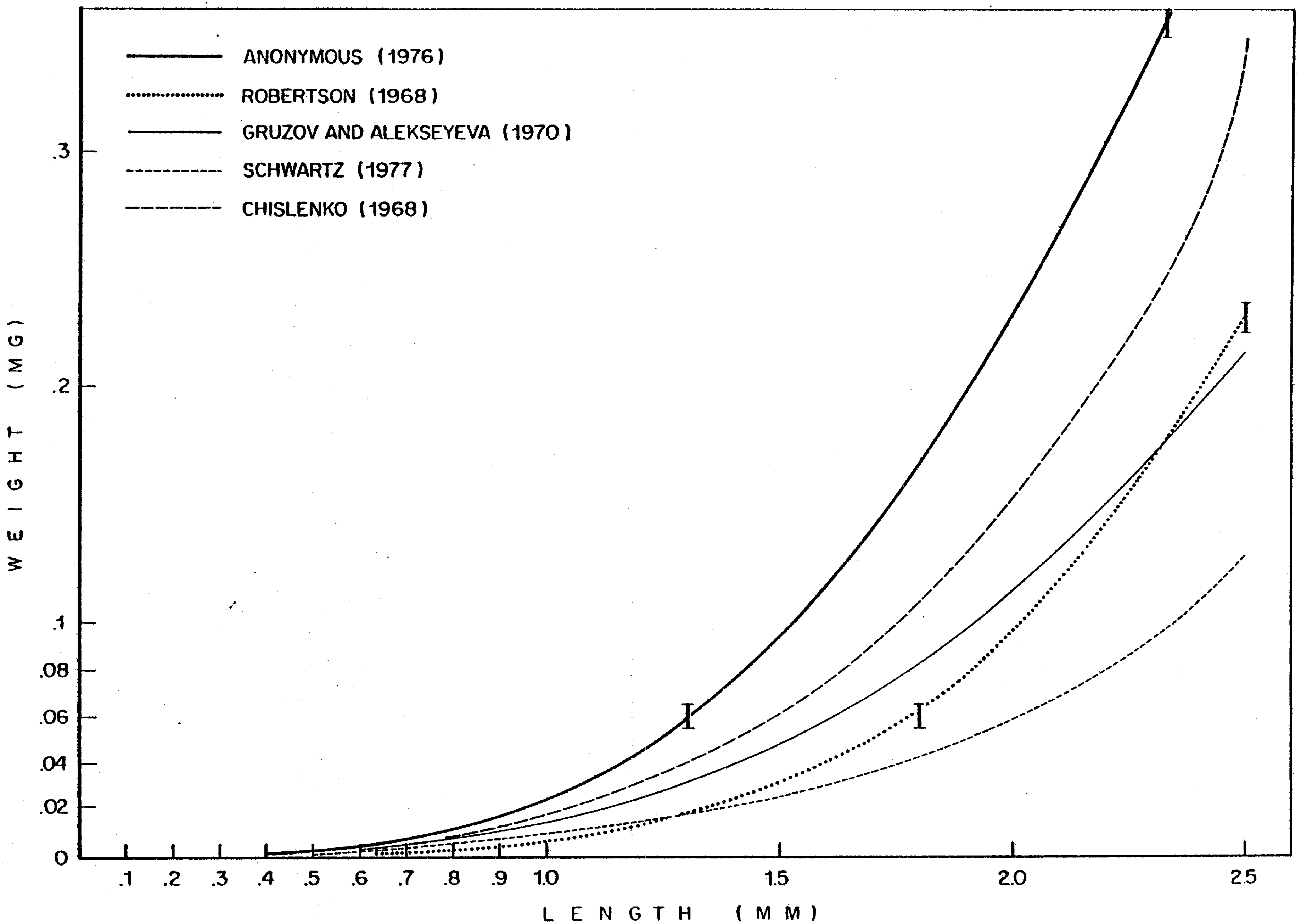
LENGTH (MM)



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GRUZOV AND ALEKSEYEVA (1970)
SCHWARTZ (1977)
CHISLENKO (1968)
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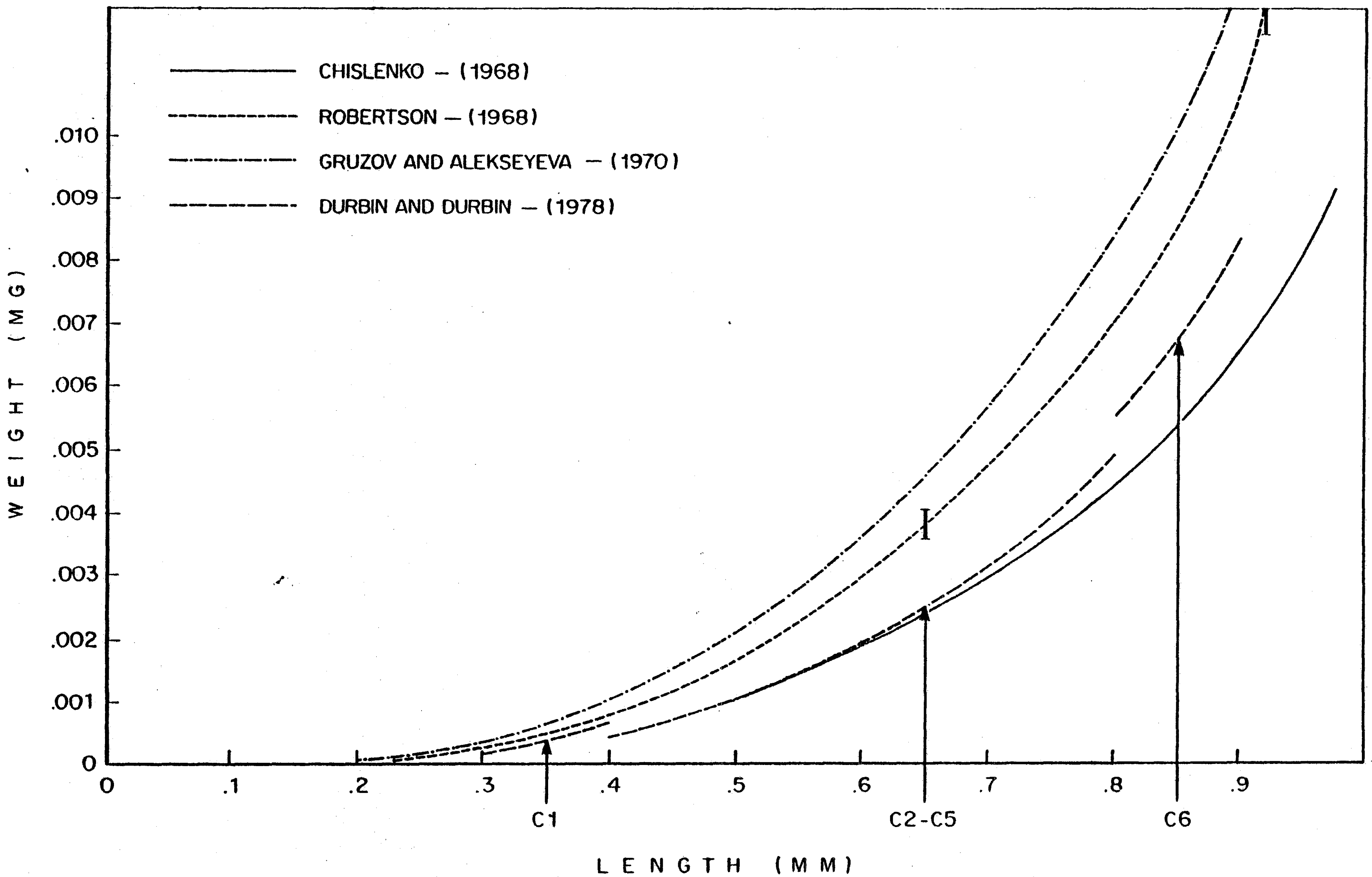
LENGTH (MM)



CHISLENKO — (1968)
ROBERTSON — (1968)
GRUZOV AND ALEKSEYEVA — (1970)
DURBIN AND DURBIN — (1978)
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.008
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.004
.003
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W E I G H T (M G)
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.5
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.7
.8
.9
C1
C2-C5
C6
L E N G T H (M M)