GENERAL LENGTH-WEIGHT RELATIONSHIP OF THREE MAJOR CARPS OF INDIA.[1]

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Contents.

Introduction.

This paper deals with the study of the relationship between the furcal length[2] and weight of the Indian Cyprinids *Catla catla* (Ham.), *Cirrhina mrigala* (Ham.) and *Labeo rohita* (Ham.). The main object here has been to derive appropriate mathematical formulae, correlating the two variables length and weight, in a very general manner, for calculating one from the other within a certain range of error. The related issue of 'condition' of fish has not been touched in this study. In view of the object of this paper, mentioned above, an extensive size range, for each species, has been included in this study; collections from different localities were taken; the sex factor was not reckoned as also the gonadial condition and gut contents. The material is, therefore, heterogeneous. It is recognised that a single general value of n in the general length-weight equation: $W = cL^n$ (see 'Historical') not only does not apply for all lengths of fish with uniform accuracy, but fluctuates from habitat to habitat. The former general fact which has been elucidated by Clark (1928), Walford (1932) and Schultz (1933) for other species has also been indicated in the present study. In the present work, however, only single general values of c and n have been derived. The fluctuations of these factors will be worked out in a separate paper as soon as additional data from varying habitats are compiled.

Historical.

Ever since Herbert Spencer first enunciated the 'cube law' in 1871 its application to fish measurements has been carried out by numerous workers.

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[2] The expression furcal length denotes the length of the fish between the anterior extremity of the snout and the point where the caudal fin bifurcates. This has been chosen in place of total length or standard length because the former is often vitiated by wear and tear and the latter though very reliable and accurate is difficult to ascertain by external examination.

According to this law the weight of a fish equals the cube of the length times a constant. Symbolically it is expressed as: $W = aL^3$, where W = Weight, L = length and a = constant. This relationship assumes a constancy of form and specific gravity on the part of the fish. Reibisch (1908) found no appreciable seasonal variation in the specific gravity of the plaice. Keys (1928) stated that there can be little change in the specific gravity of the fish so long as it remains in the same environment. During the earlier investigations on the applicability of the 'cube law' to fish, beginning with Hensen in 1899, the constant a was found to fluctuate and Heincke, in 1908, proposed the use of this factor as an index of the well-being of fish. This factor has been variously termed as coefficient of condition, condition, length-weight factor, etc. Crozier and Hecht (1913) and Hecht (1916) found the cube law applicable to the fishes they investigated, but these instances appear to be exceptions rather than the rule. Fulton, in 1904, showed the inadequacy of the 'cube law' in describing the length-weight relationship of fishes. In recent years a much more satisfactory way of describing the length-weight relationship of fishes has been developed through the use of a more general equation: $W = cL^n$, where W = Weight, L = Length and c and n = constants. The values of c and the exponent n are determinable empirically. Such a relationship has been worked by a host of workers on different fishes who, among others, include Järvi (1920), Tjurin (1927), Clark (1928), Keys (1928), Fraser (1931), Hart (1931 and 1932), Tester (1932), Walford (1932), Shultz (1933), Hile (1936 and 1941), Hile and Jobes (1940 and 1941), Foerster (1936), Van Oosten (1942), Beckman (1942 and 1945), Deason and Hile (1944), and Jobes (1946 and 1947). Most of the above stated authors, besides determining the length-weight relationship of the fish they investigated, have also determined the condition factor of the fish. A great deal of confusion appears to have arisen in describing the condition of a fish and the expression of the length-weight relationship. Hile (1936, page 240) has thrown light by elaborating upon the theme 'coefficients based on empirical exponents fail to reflect differences in form or relative heaviness while those based on cube relationship offer a direct measure of relative heaviness independent of general length-weight relationship and comparable as measures of relative heaviness between fish of any length'.

In India very little work has been done on the length-weight relationship of different species of fish and this is mainly on Mahseer *Barbus* (Tor) *putitora* (Ham.) for which Lacey and Cretin (1905) and Treven (1925) have advanced some formulae. The formula mentioned by Lacey and Cretin is:

$$\frac{\text{Length and one-third length} \times \text{girth squared in inches}}{1{,}000} = \text{Weight.}$$

According to the latter authority $1\frac{1}{4}$ length of the fish multiplied by the square of the girth in inches and divided by 1,000 gives the weight of the fish in pounds. Hamid Khan and Hussain (1945) studied the length-weight relationship of *Labeo rohita* and *Cirrhina mrigala* from the departmental fish farm at Chhenawan, Punjab, India. His conclusions are that the weight (in chhataks) [1] of these fish can be known at a certain length (in cm.) by multiplying the cube of the length with the weight-length factor, which are:

(1) *Labeo rohita* .. .. ·000238
(2) *Cirrhina mrigala* .. ·000180

Material and Methods.

The specimens studied include those from natural unfertilised waters like rivers and canals and from untreated tanks and ponds. Specimens of *Catla catla*

[1] A chhatak = about 2 oz.

smaller than 129·5 mm., of *Cirrhina mrigala* smaller than 133 mm. and of *Labeo rohita* smaller than 176 mm., each in furcal length, for this study, were secured from the Moat at Cuttack, in Autumn and Winter of 1949 and in Spring of 1950. Those of *Catla catla* larger than 129·5 mm., of *Cirrhina mrigala* larger than 133 mm. and of *Labeo rohita* larger than 176 mm. were mostly got from Tank No. 3 at Jobra, Cuttack in Winter, 1949. Some of the specimens of *Cirrhina mrigala* and *Labeo rohita* larger than 133 and 176 millimetres respectively were secured in part from one of the Pulta Water Works settling tanks and in part from other sources like the Ganges at Dhulian Ganges in Murshidabad District, West Bengal. No specimen of *Catla catla* came from either of the latter sources.

The Moat at Cuttack is a canal encircling the old fort, about 3/4ths of a mile long and about 50 feet wide. It is fed by the river Mahanadi. It was stocked with major carp fry for the first time in summer, 1949. Prior to then it was an unutilised piece of water. Tank number 3 at Jobra, Cuttack, is one of the nine tanks existing there for a long time and contained fish stocked from a variety of sources during the past three or four years.

The measurements of the fish given in this paper were made on the usual fish-measuring board, divided into millimetres. The fish captured from the Moat, Cuttack, were preserved in 5% formalin in the field. They were subsequently dried for half a minute in the folds of a blotting paper, and then measured and weighed on a platform balance to the nearest 1/10th of a gram. Fish longer than 160 mm. in furcal length were weighed fresh either with a spring balance or on a platform balance. No allowance for shrinkage was made in the case of fish preserved in formalin. The calculated values of weights were rounded at the first decimal place.

Correlation tables were used throughout this study for the calculation of various factors necessary for the expression of length-weight relationship. Length was used as the type and weight as the array. The equation adopted in all the three cases was that of the general parabola: $W = cL^n$, explained under the heading entitled 'Historical' in this paper. This equation when expressed in logarithmic form becomes: Log W = Log $c + n$ Log L, which when graphically represented assumes a linear form. The values of c and n were determined empirically. In the absence of a calculating machine coding had to be resorted to. The following formulae (Simpson & Roe, 1939) were used to determine the exponents:

1. $\log C = M_y - (n)\, M_x$ where M_y = mean of y and M_x mean of x, and

2. $n = r\,\dfrac{\sigma_y}{\sigma_x}$ where r = coefficient of correlation,

σ_y = standard deviation of y, and
σ_x = standard deviation of x

$$r = \frac{\Sigma(dA_x \cdot dA_y)}{N(\sigma_x \cdot \sigma_y)} - Cl_x \cdot Cl_y.$$

$$\sigma_x \text{ (or } \sigma_y) = i\,\frac{\sqrt{\Sigma(fd^2A)}}{N} - C_1{}^2$$

where i = the class interval
dA = deviation of assumed mean in terms of class interval and
Cl = difference between mean and assumed mean in terms of class interval.

The details of calculations are not given, being of a routine nature and well known.

LENGTH-WEIGHT RELATIONSHIP OF *Catla catla* (HAM.).

The data on *Catla catla* consisted of measurements of 172 specimens ranging in furcal length from 41 mm. to 405 mm. and in weight from 1·5 gm. to 1,672·625 gm. The formula correlating length and weight of this species is given below:

$$\text{Weight} = 0{\cdot}8917 \times 10^{-5} \times \text{Length}^{3{\cdot}15172}$$

The logarithmic form of the above equation is:

$$\text{Log Weight} = -5{\cdot}04976177242 + 3{\cdot}15172 \text{ Log Length}$$

The coefficient of correlation between the log length and log weight is 0·988. The standard error of estimate in terms of logs is ±0·09415. Figure 1 presents the directly observed length and weight values on an ordinary arithmetic grid. The curve shown in this figure corresponds to the equation specific for *Catla catla* given above.

LENGTH-WEIGHT RELATIONSHIP OF *Cirrhina mrigala* (HAM.).

The data on *Cirrhina mrigala* consisted of measurements of 347 specimens ranging in furcal length from 46 mm. to 790 mm. and in weight from 1·2 gm. to 7,427·576 gm. The formula correlating length and weight of this species has been found to be:

$$\text{Weight} = 1{\cdot}196 \times 10^{-5} \times \text{Length}^{3{\cdot}0248352}$$

The logarithmic form of the above equation is:

$$\text{Log Weight} = -4{\cdot}922212022 + 3{\cdot}0248352 \text{ Log Length}$$

The coefficient of correlation between the log length and log weight is 0·992 and the standard error of estimate in terms of logs is ±0·0754. Figures 2 and 3 show the observed length and weight values. The curves drawn in these figures are in accordance to the formula given above.

LENGTH-WEIGHT RELATIONSHIP OF *Labeo rohita* (HAM.).

The data on *L. rohita* consisted of observations on 275 specimens varying in furcal length from 50 mm. to 620 mm. and in weight from 2·0 gm. to 4,989·6 gm. The formula correlating length and weight of this species was determined to be:

$$\text{Weight} = 1{\cdot}554 \times 10^{-5} \times \text{Length}^{3{\cdot}0140028}$$

The logarithmic form of the above equation is:

$$\text{Log Weight} = -4{\cdot}80836464485 + 3{\cdot}0140028 \text{ Log Length}$$

The coefficient of correlation between log length and log weight is 0·994 and the standard error of estimate in terms of logs is ±0·0739. Figure 4 shows a plot of observed weights against the observed length values. The curve drawn in this figure is in accordance with the equation derived for *Labeo rohita*.

GENERAL REMARKS.

The reliability of the equations derived in this paper would be seen to be high from the coefficient of correlation values in all the three cases.

It is seen in Figure 1 that the weight values of *Catla catla* corresponding to the length values ranging from 80 mm. to 120 mm. have a tendency to group below the line of calculated weights. The reverse tendency for weight values to exceed those calculated is discernible at the size range, 120 mm. to 150 mm., as is seen in Figure 1. The trend for observed weight values to concentrate above the line in the case of *Cirrhina mrigala* is seen opposite the furcal length range, 60 mm. to 97 mm., in Figure 2. The trend in the opposite direction in the case of this species is seen clearly against the length range 115 mm. to 138 mm. In the case of *Labeo rohita* there appears to be a poor agreement between recorded weights for fish larger than 490 mm. as is seen in Figure 4, the observed weight values generally exceeding the calculated ones. All these observations appear to indicate that single values of c and n do not hold for the entire size range of fish. Similar trends have been pointed out in the case of the California *Sardine caerulea*, by Clark (1928). Walford (1932) and Schultz (1933) have also indicated similar trends in the cases of California Barracuda, *Sphraena argentia* and *Athrinops affinis oregonia* respectively. In order to elucidate this point in the cases of fishes reported upon in the present paper a greater mass of data is required for those size ranges where the calculated weights do not hold in a general manner. These points will be dealt with as soon as more data is available.

It is evident from the values of the exponents n in the general length-weight equation: $W = Cl^n$, that *Catla catla* departs most from the 'cube law'. Next in the sequence is *Cirrhina mrigala* and finally comes *Labeo rohita*, which departs least from the 'cube law'.

For the sake of comparison of relative weights of the three major carps studied, weights of the three species for 100, 200, 300, 400 and 500 millimetres furcal lengths have been calculated and are presented in Table I. Figure 5 gives the graphic representation of the same data for all the three species of Indian carps.

TABLE I.

Weights of the three major carps of a few selected lengths.

Furcal Length in mm.	Weight in grams.		
	Catla catla.	*Labeo rohita.*	*Cirrhina mrigala.*
100 ..	17·9	16·6	13·4
200 ..	159·4	134·0	109·2
300 ..	572·0	454·6	371·9
400 ..	1,417·0	1,081·0	889·2
500 ..	2,863·0	2,119·0	1,745·0

The comparative increase in weight as compared to length is, therefore, most in *Catla catla*, next in *Labeo rohita* and least in *Cirrhina mrigala*. It may be recorded that Hamid Khan and Hussain (1945) also found that length for length *Labeo rohita* is heavier than *Cirrhina mrigala*. This paper, therefore, confirms Hamid Khan's observations in this respect. These authors, however, did not empirically determine the value of n in the general length-weight equation and stated that the weights of *Labeo rohita* and *Cirrhina mrigala* tend to increase approximately to the cube of the length. This paper gives the exact values of the exponents of L in the three species of major carps studied in the general formula: $W = cL^n$. The 'cube law' is clearly an obsolete conception in describing the length-weight relationship of fishes. Hamid Khan used total length as the measure of fish length. In the present study, however, furcal lengths were used and hence the results are not comparable. It is necessary to work out conversion factors between the different fish lengths commonly used in fisheries work before the data gathered on different length measures can be mutually compared.

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SUMMARY.

1. Analysis of 172 specimens of *Catla catla*, ranging in furcal length from 41 mm. to 405 mm. shows that the formula, correlating length with weight, specific for this fish within this size range is:

$\text{Weight} = 0{\cdot}8917 \times 10^{-5} \times \text{Length}^{3{\cdot}15172}$ which in logarithmic form is:

$\text{Log Weight} = -5{\cdot}04976177242 + 3{\cdot}15172 \text{ Log Length}.$

The standard error of estimate in terms of logs is $\pm 0{\cdot}09425$.

2. Analysis of 347 specimens of *Cirrhina mrigala*, ranging in furcal length from 46 mm. to 790 mm. shows that the formula, correlating length with weight, specific for this fish within this size range is:

$\text{Weight} = 1{\cdot}196 \times 10^{-5} \times \text{Length}^{3{\cdot}0248352}$ which in logarithmic form is:

$\text{Log Weight} = -4{\cdot}922212022 + 3{\cdot}0248352 \text{ Log Length}.$

The standard error of estimate in terms of logs is $\pm 0{\cdot}0754$.

3. Analysis of 275 specimens of *Labeo rohita*, ranging in furcal length from 50 mm. to 620 mm. shows that the formula, correlating length with weight, specific for this fish within this size range is:

$\text{Weight} = 1{\cdot}554 \times 10^{-5} \times \text{Length}^{3{\cdot}0149928}$, which in logarithmic form is:

$\text{Log Weight} = -4{\cdot}80836464485 + 3{\cdot}0149928 \text{ Log Length}.$

The standard error of estimate in terms of logs is $\pm 0{\cdot}0739$.

4. The coefficients of correlation between log length and log weight of *Catla catla*, *Cirrhina mrigala* and *Labeo rohita* are: 0·988, 0·992 and 0·994 respectively. The high values of correlation coefficient shows that the reliability of the equations derived in this report is high.

5. Single values of c and n in the general length-weight equation, Weight $= c$ Length^n do not appear to hold good for the entire length range of fish with uniform accuracy.

6. *Catla catla* departs most from the 'cube law'. *Cirrhina mrigala* comes next and *Labeo rohita* stands last in this respect, deviating least from the 'cube law'.

7. In the order of heaviness *Catla catla* comes first, next is *Labeo rohita* and last is *Cirrhina mrigala*.

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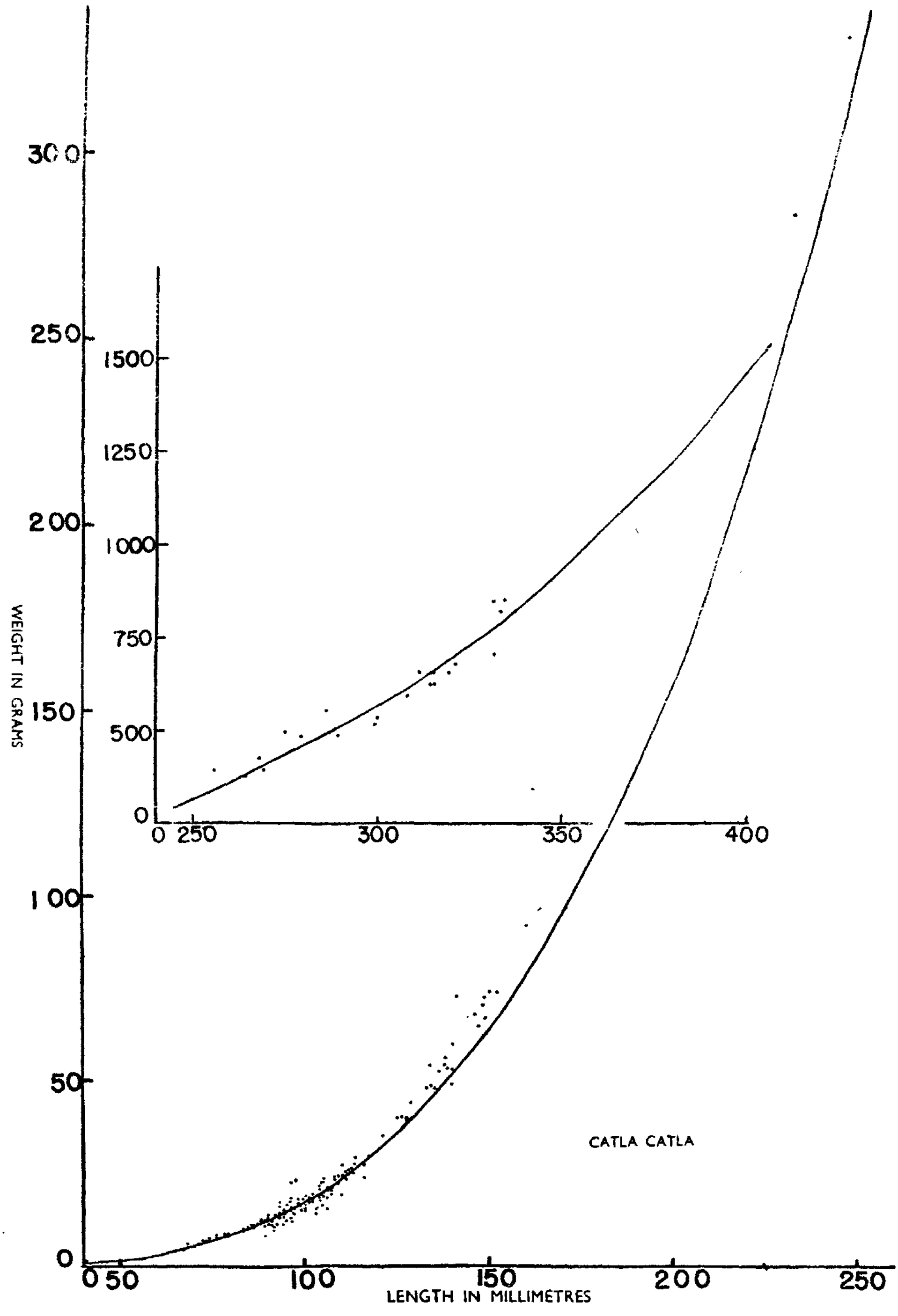
WEIGHT IN GRAMS
300
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200
150
100
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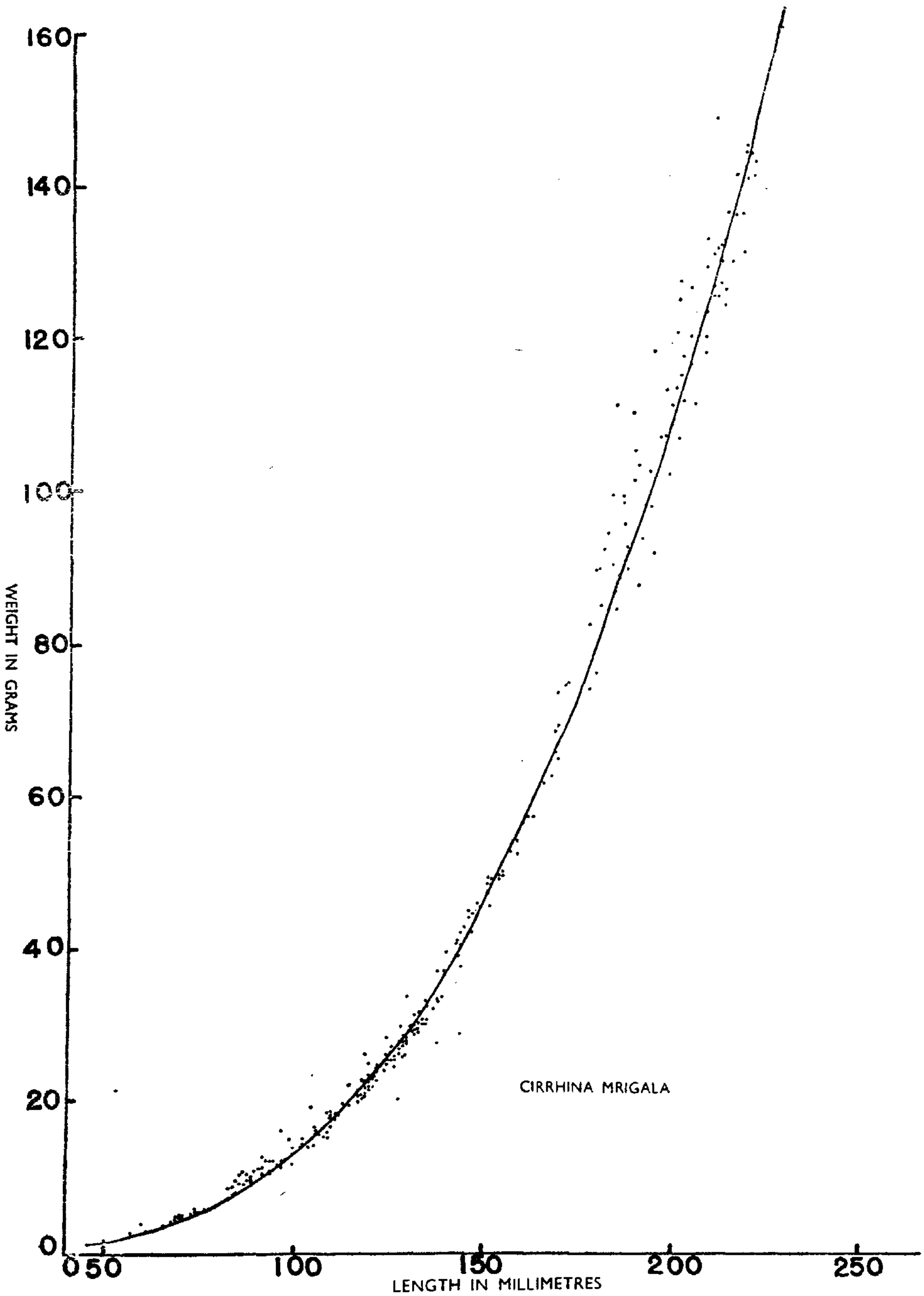
0
1500
1250
1000
750
500
0
0 250
300
350
400
CATLA CATLA
0 50
100
150
200
250
LENGTH IN MILLIMETRES

FIGURE 1


160
140
120
100
80
60
40
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WEIGHT IN GRAMS
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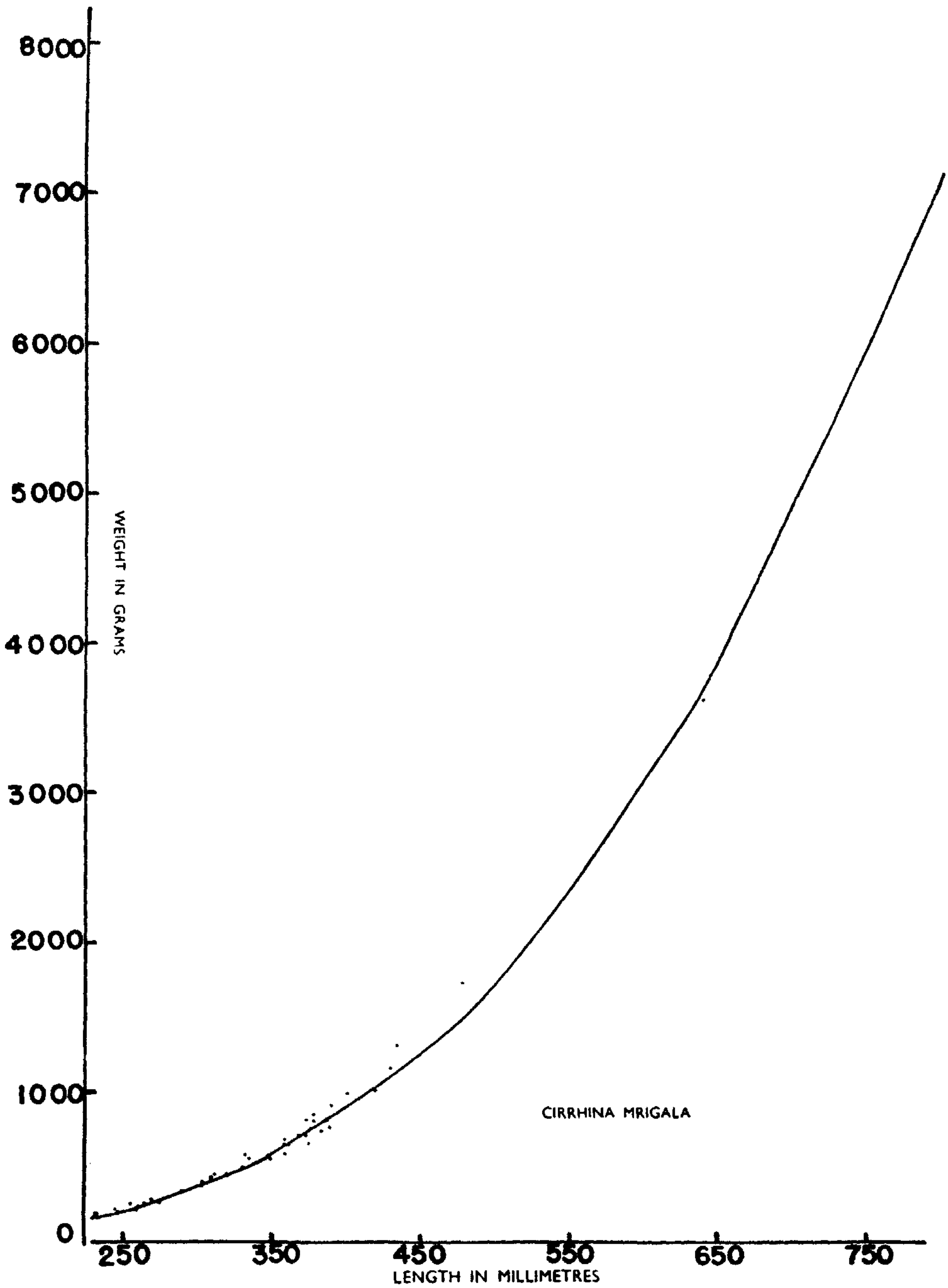
100
150
200
250
LENGTH IN MILLIMETRES
CIRRHINA MRIGALA

FIGURE 2


8000
7000
6000
5000
4000
3000
2000
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WEIGHT IN GRAMS
CIRRHINA MRIGALA
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450
550
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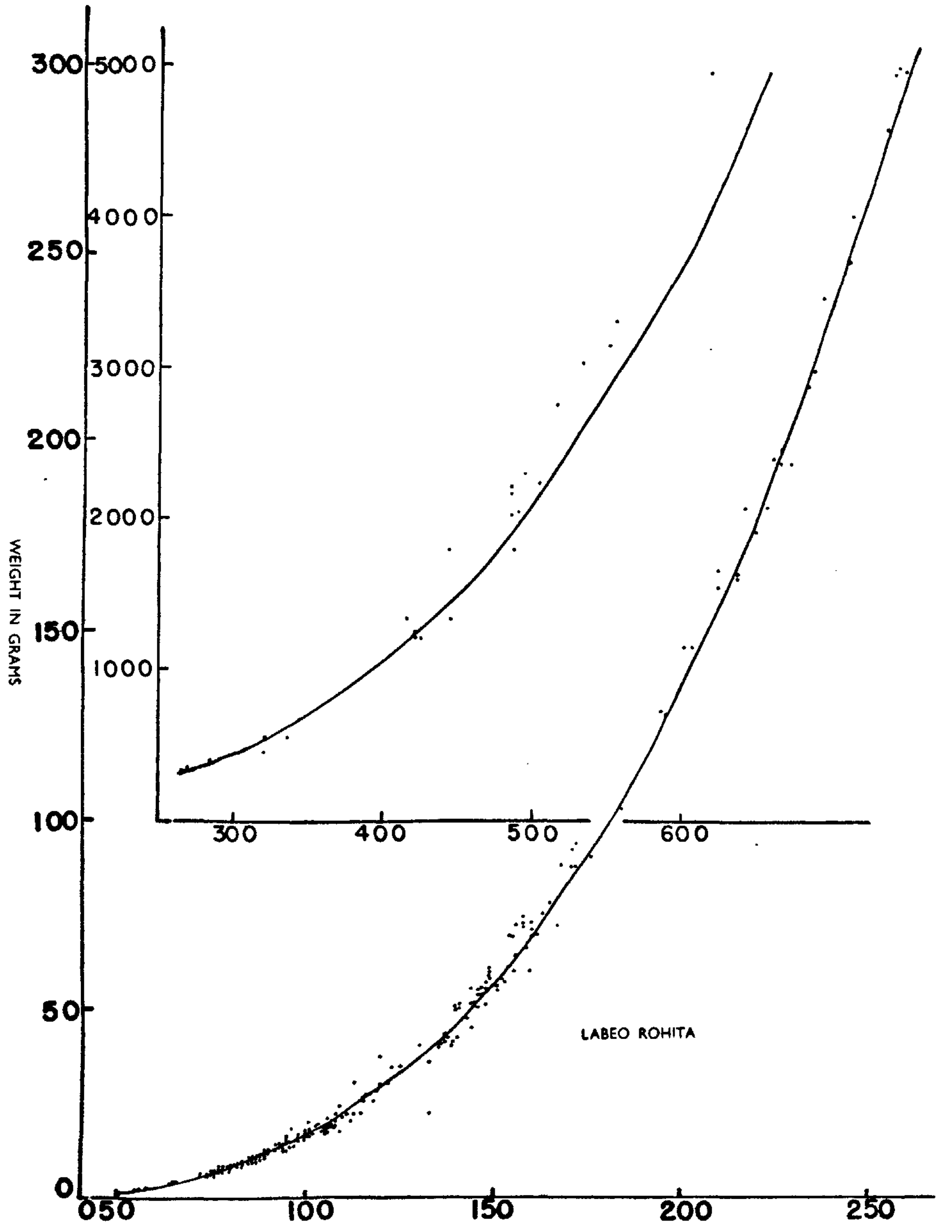
750
LENGTH IN MILLIMETRES

FIGURE 3



300
250
200
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100
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5000
4000
3000
2000
1000
300
400
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600
WEIGHT IN GRAMS
LABEO ROHITA
050
100
150
200
250
LENGTH IN MILLIMETRES

FIGURE 4

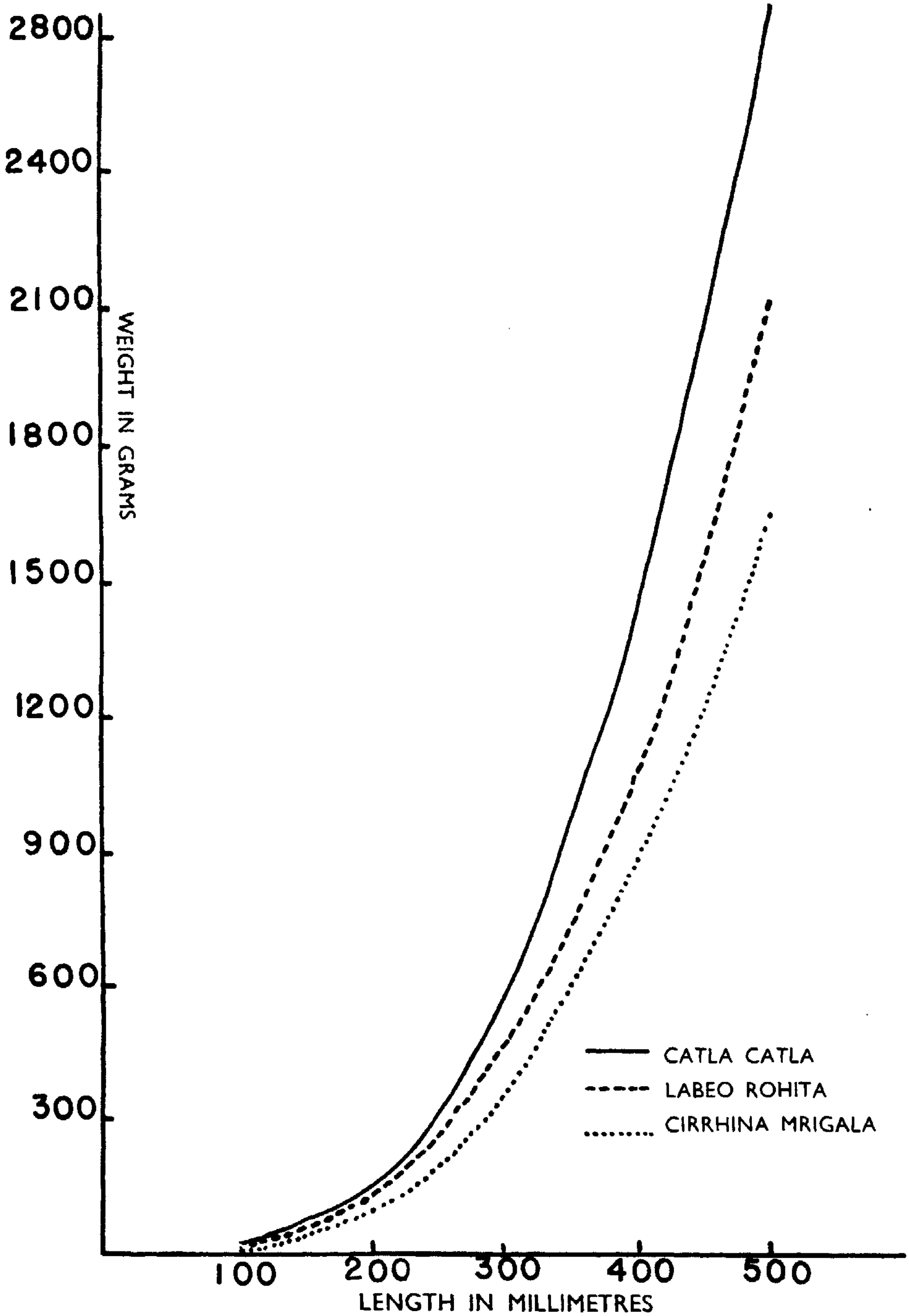
2800
2400
2100
1800
1500
1200
900
600
300
WEIGHT IN GRAMS
CATLA CATLA
LABEO ROHITA
CIRRHINA MRIGALA
100
200
300
400
500
LENGTH IN MILLIMETRES

FIGURE 5