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CORRELATIONS OF WEIGHT, LENGTH, AND OTHER BODY  
MEASUREMENTS IN THE WEAKFISH, CYNOSCION REGALIS



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# CORRELATIONS OF WEIGHT, LENGTH, AND OTHER BODY MEASUREMENTS IN THE WEAKFISH, *CYNOSCION REGALIS*.

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## INTRODUCTION.

During July and August, 1912, an opportunity was afforded at the United States Fisheries Laboratory, Beaufort, N. C., to make some studies on the correlation of external characters in the squeteague; the results are contained in the present paper.<sup>a</sup>

The weakfish, or squeteague (*Cynoscion regalis*) is common in Beaufort Harbor, and during July and August was taken almost every day from the pound net operated by the laboratory, in quantities up to 300. By far the greatest number of these fish were about 31 cm. long. The specimens used were therefore, to a certain degree, selected according to length, with a view to having a series covering as large a range as possible. Inasmuch as the squeteague is known to spawn in late spring, physiological disturbances due to spawning are negligible. All the fish examined (over 400) were either "spent" or unripe; so we are sure that none of the weights recorded are influenced by the ripening of the gonads.<sup>b</sup>

The material was brought from the pound in a live car and immediately removed to the laboratory. Measurements were made as rapidly as possible, the time for the complete measurement of a single fish rarely occupying more than five minutes. The possibility of shrinkage and of loss of weight through evaporation was carefully considered. To check this a number of fish were weighed and measured at 11 a. m., placed in a bucket, and covered (with a towel), our usual procedure, and four hours later no difference in measurements could be detected.

## CORRELATION OF WEIGHT AND LENGTH.

For the determination of the relation of weight to length, 390 fish were examined. Of these 274 were females, 111 were males, and 5 were too immature for sex identification. By length is meant total length, from tip of mandible of the closed mouth to the extreme end of the caudal fin. This was taken by placing the fish on a board, its body perpendicular to and the tips of its tail just touching a raised end piece. The length was read by means of a centimeter scale along the line from the mandible to the base of this end piece. "Weight" means weight after the surface water and mucous have been removed with a towel, and is corrected for the weight of the stomach contents. The weighing was done on a platform balance sensitive to 0.1 gm.

<sup>a</sup> We wish to thank Dr. J. F. Abbott, of St. Louis, for his advice in the biometrical treatment of the data; we are also indebted to Dr. A. J. Goldfarb, of New York, for his suggestions during the course of the work.

<sup>b</sup> Paton, D. Noël (Report of the Investigations on the life history of the salmon in fresh water, Fisheries Board for Scotland, p. 1, 1898), for example, notes that in the European salmon, during April and May, the ovaries are 1.2 per cent and the testes 0.15 per cent of the total weight of the fish, whereas in November, near the spawning period, they represent 23.3 and 3.3 per cent of the total weight, respectively.

The results are shown graphically in figure 1, where length is abscissa, and weight ordinate. A large number of the points represent duplicates, triplicates, and even quadruplicates, and in many cases include both sexes. For example, the point (24.5,

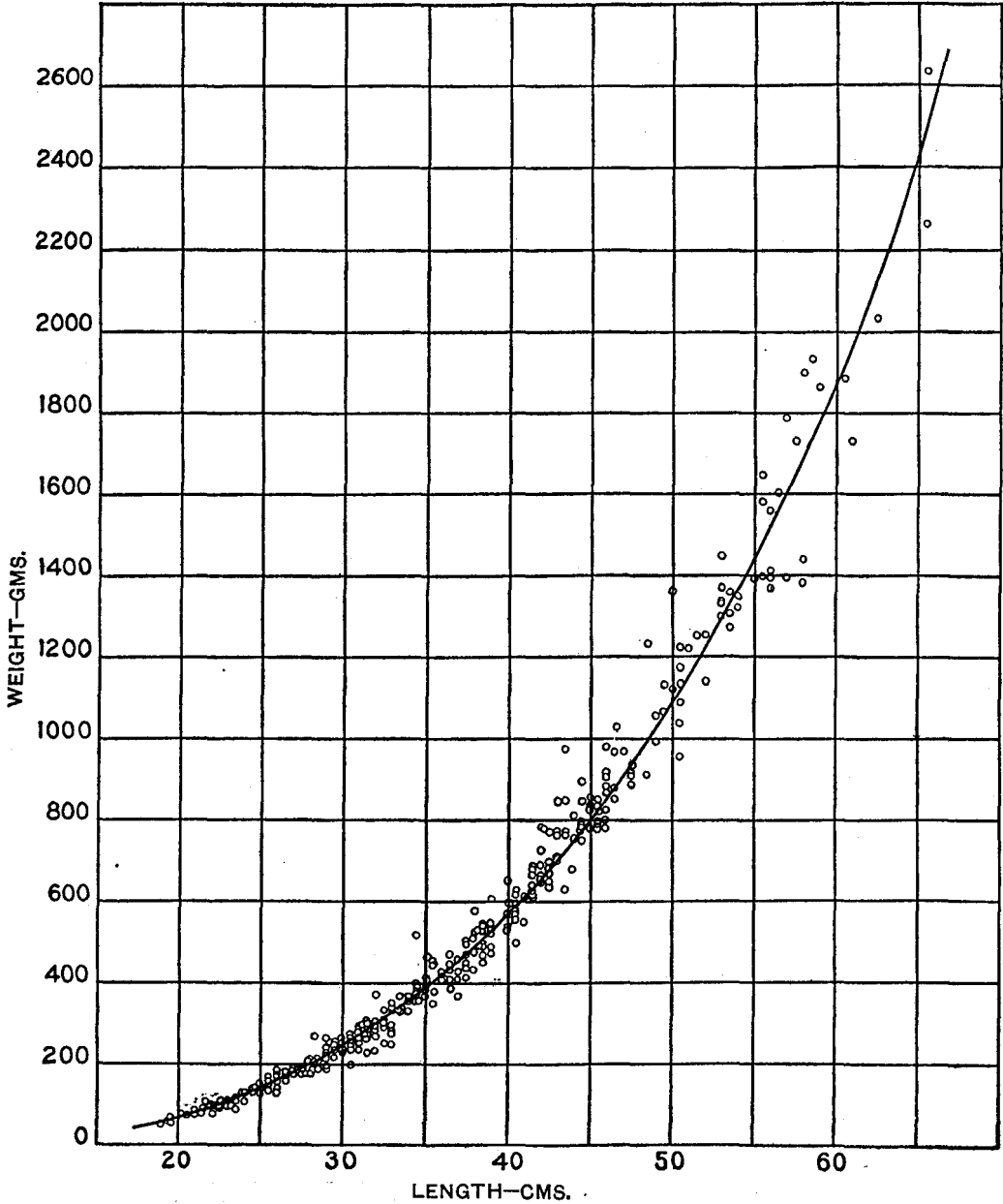


FIG. 1.—Showing relation of weight to length in 390 fish.

135) represents 2 females and 1 male; the point (41.5, 680) represents 2 males and 1 female; the point (27.0, 170) represents 2 males and 1 female; and the point (29.0, 220) represents 2 males and 2 females. From the distribution of the points about the smoothed

curve, it is clear that sex does not influence the relation between weight and length.<sup>a</sup> This does not mean that there is no difference in the weight and length of *Cynoscion regalis* of different sexes for the same age; it means that for a given length or weight of fish sex does not affect the correlation.

The regularity of the curve shown in figure 1 enables its mathematical equation to be calculated with considerable accuracy. Comparing the abscissas and ordinates of any two points on the curve, we find that the weight varies as the third power of the length. The equation therefore will be of the form  $y = ax^3$ , in which  $y$  represents weight,  $x$  length, and  $a$  is a constant, the value of which depends on the units used. When length

WEIGHT—GMS.

	0 to 150	150 to 300	300 to 450	450 to 600	600 to 750	750 to 900	900 to 1050	1050 to 1200	1200 to 1350	1350 to 1500	1500 to 1650	1650 to 1800	1800 to 1950	1950 to 2100	2100 to 2250	2250 to 2400	2400 to 2550	2550 to 2700	
15 to 20	4																		4
20 to 25	37																		37
25 to 30	11	77																	88
30 to 35		51	24	1															76
35 to 40			25	25	1														51
40 to 45				12	27	12	1												52
45 to 50						22	11	3	1										37
50 to 55							2	6	10	5									23
55 to 60										8	4	2	3						17
60 to 65												1	1	1					3
65 to 70																	1	1	2
	52	126	49	38	28	34	14	9	11	13	4	3	4	1	0	1	0	1	390

FIG. 2.—Correlation table showing closeness of relation between weight and length of fish represented in figure 1.

is measured in centimeters, and weight in grams,  $a$  has the value  $0.008771 \pm 0.000117$ , and the equation becomes,  $\text{weight} = (0.008771 \pm 0.000117) (\text{length})^3$ .

From this it is apparent that the weight in grams of a specimen of *Cynoscion regalis* may be obtained by multiplying the cube of its length, in centimeters, by approximately 0.009.

Paton, Fulton, and other investigators<sup>b</sup> refer to the approximation with which the weight of fishes vary as the cube of their lengths, but they present no comparable evidence from which such conclusions can be derived with any degree of accuracy.

<sup>a</sup> Kellicott, William E. (The growth of the brain and viscera in the smooth dogfish (*Mustelus canis*), American Journal of Anatomy, vol. 8, p. 319, 1908), has shown that in the smooth dogfish, the sexes can not be distinguished with respect to either absolute or relative weights of internal parts, except the gonads.

<sup>b</sup> Fulton, T. Wemyss: On the rate of growth of fishes, 24th Annual Report of the Fishery Board for Scotland, 1905, Pt. III, and in other reports. Paton, D. Noel: loc. cit., p. 6. Williamson, Charles H.: On the herrings of the Clyde and other districts, 27th Annual Report of the Fishery Board for Scotland, 1908, Pt. III.

As a measure of the closeness of the relation between weight and length, we have determined<sup>a</sup> the coefficient of correlation  $r$ , which is the index of relation between two variables, such that the amount of variation in one is a measure of the amount of variation in the other. Using length as the *type* and weight as the *array*, the correlation table (fig. 2) was constructed. In each square is given the number of specimens which fall within the weight group and length group indicated. From this arrangement of the data the coefficient of correlation is found to be  $r=0.952$ , with a probable error of  $\pm 0.0032$ . Remembering that unity represents a theoretically perfect correlation, it is apparent that this coefficient indicates an extremely high correlated variability.

#### RELATION OF BODY MEASUREMENTS TO TOTAL LENGTH.

With a view to discovering the relation between the dimensions of the external parts of the fish and its total length, a series of measurements was taken on 123 of the 390 specimens used in the work discussed above. Of these, 80 were females and 43 males.

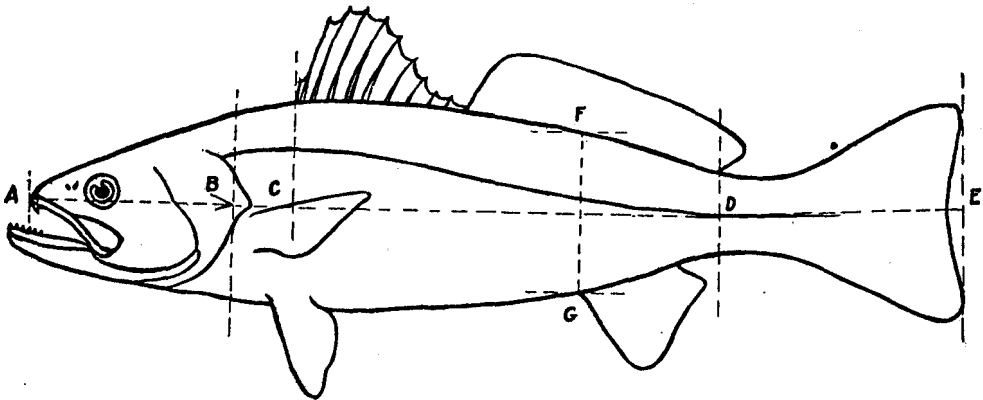


FIG. 3.—Showing parts of fish measured for comparisons plotted in figure 4.

Referring to the diagram, figure 3, the measurements, in addition to total length and weight, were:

1. Standard length, from tip of snout to end of last caudal vertebra.
2. Head length, AB, from tip of snout to end of opercular bone, i. e., excluding the opercular flap.
3. Body length, BD, from the end of the opercular bone to a point on the lateral line immediately below the posterior limit of the base of the soft dorsal fin.
4. Tail length, DE.
5. Body width, taken at the point C on the line AE, immediately below the origin of the spinous dorsal.
6. Depth, GF, from the origin of the anal fin, G, to F, on a line perpendicular to the long axis of the fish.

For the depth measurement, 73 specimens were examined; of these 49 were females and 24 males.<sup>b</sup>

<sup>a</sup> Davenport, Charles B.: Statistical methods, with special reference to biological variation, ch. 4, New York, 1904.

<sup>b</sup> As shown above, and also by the plots in figure 4, sex is a negligible factor in a discussion of this data.

The lengths were measured by means of a centimeter scale placed on the fish; width and depth were taken with the aid of spring calipers, using the same scale. For the measurement of width and depth it was necessary to secure points that would not be influenced by the amount of food material in the stomach. The abdomen of the squeegee is extremely elastic, and its volume varies considerably with the stomach contents. Significant measurements in this region of maximum depth are likewise impossible after the removal of the contents of the stomach. The places selected fulfilled the requirements suggested and were found to be sufficiently near the maxima for our purposes.

The curves shown in figure 4 were derived from the data obtained. For every specimen total length was plotted as abscissa and the other measurements detailed above as ordinates.<sup>a</sup> From the resulting straight lines it is at once apparent that there is a simple relation between the dimensions of the external parts of the fish and its total length. It is clear that with increasing length there is a constant, directly proportional increase in all the body measurements taken.

From the slopes of the lines the rates of growth of the corresponding parts relative to the growth of the total length may be calculated. Using the units shown on the plot, the "tangent" of any line is determined by dividing the vertical distance between two points on this line by the horizontal distance. These tangents are as follows:

Standard length.....	0.840
Body.....	.530
Tail.....	.273
Head.....	.215
Depth.....	.135
Width.....	.115

From this it is obvious that, of the body parts, the body has by far the greatest rate of growth, while the width has the least. It is also clear that the head and tail have approximately the same rates of growth, and that the depth and width also grow at about the same rate. It is, of course, to be understood that when the "rate of growth" is mentioned, we do not mean "rate" with regard to time, but relative growth per unit increase in total length. Thus, for every 10 cm. increase in total length the standard length will increase 8.40 cm., the body 5.30 cm., the tail 2.73 cm., the head 2.15 cm., the depth 1.3 cm., and the width 1.15 cm.

RELATION OF BODY MEASUREMENTS TO WEIGHT.

From the regularities shown in the previous section we may conclude that there exists a relation between any body measurement and weight similar to that which exists between total length and weight. Yet another relation, however, may be demonstrated. Since depth and width are each equal to a constant multiplied by the total length, we may substitute in the formula for the derivation of weight,<sup>b</sup> depth, and width divided by their respective "tangents," and thus secure a formula for the weight in terms of length, width, and depth. This formula is  $W = k \cdot l \cdot w \cdot d$ . By direct calculation from figures 4 and 1,  $k = 0.5513 \pm 0.0088$ , and the equation becomes weight =  $(0.5513 \pm 0.0088)$  (length) (width) (depth).

<sup>a</sup> Here also many of the points represent duplicates and triplicates.

<sup>b</sup> See p. 143.

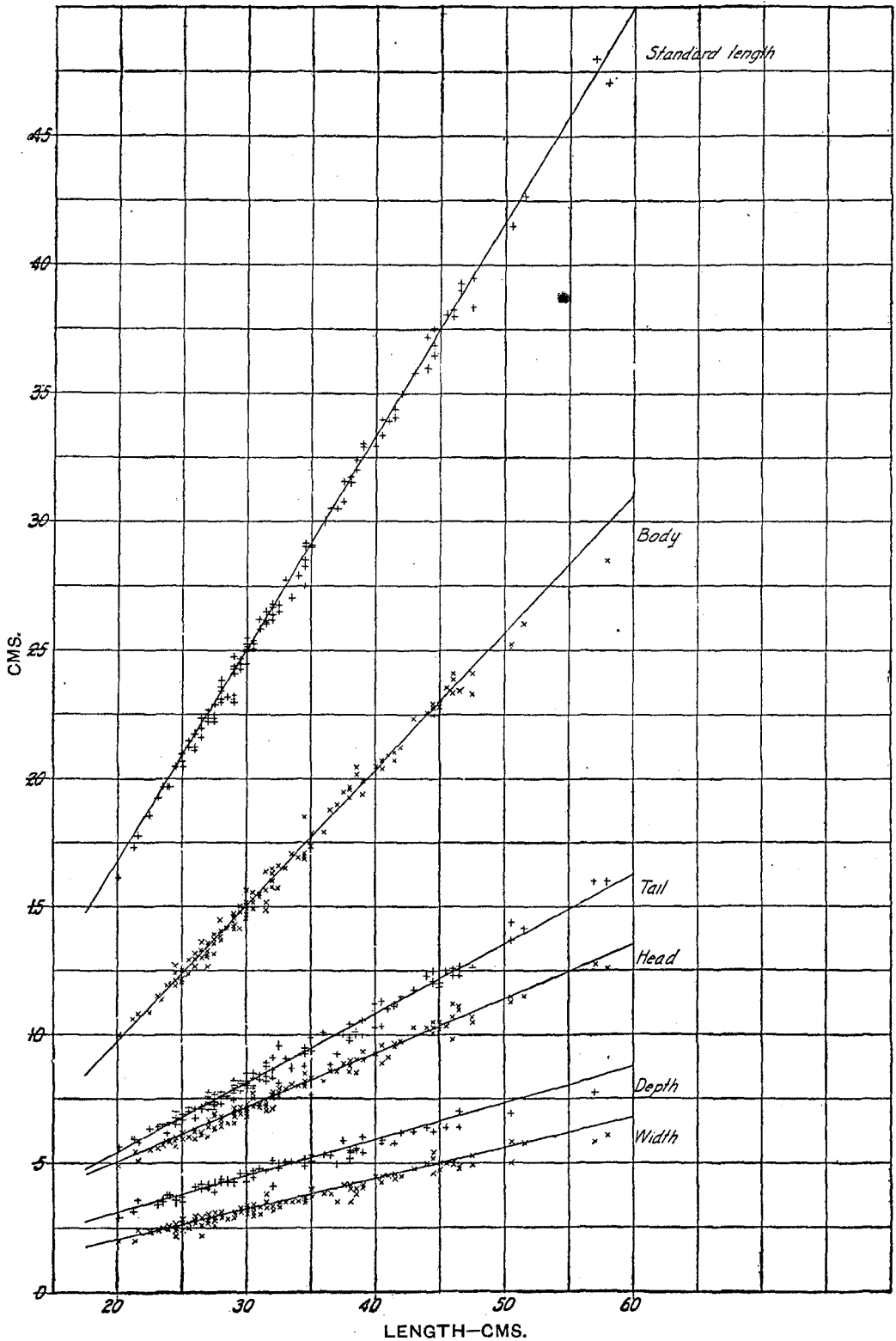


FIG. 4.—Showing relative size and proportional increase, or rate of growth, of various parts of fish as compared with length.



## SUMMARY.

1. In squeteague of both sexes, between the length of 15 and 70 cm., the correlation of weight and length is extremely close, as expressed by the coefficient of correlation,  $r=0.952$ .

2. Weight may be accurately expressed by the equation: Weight in gm. =  $(0.00877) \times (\text{length in cm.})^3$ .

3. Standard length, head length, body length, tail length, width, and depth, are directly proportional to total length. (See statements of tangent measurements, p. 145, and fig. 4.)

4. From the curves in figure 4 the growth of these parts relative to total length is readily calculated.

5. Weight, as a function of total length, width, and depth, is expressed by the equation: Weight =  $(0.5513) (\text{length}) (\text{width}) (\text{depth})$ .