4c - Hash
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Dr. Royce

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THE EFFECT OF LAMPREY ATTACKS UPON LAKE TROUT IN SENECA LAKE, NEW YORK

By William F. Royce
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Fish and Wildlife Service
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Everyone who has caught a fish carrying the ugly red sore caused by the rasping mouth of a lamprey probably has speculated on the effect of such vicious attacks on the future of his fishing. With the thought in mind that such an attack must permanently injure the fish, then it is natural to blame the disappearance of game and food species on the lampreys, if they are abundant enough to attack many fish.

The sea lamprey (Petromyzon marinus) migrates from the sea to fresh water streams for spawning. In the many lakes where it has become landlocked (some investigators think since post glacial periods) it is generally known as the lake lamprey. The landlocked form is the one injurious to fresh water fish (Gage, 1928), since the anadromous form comes to fresh water only for spawning and does not feed at that time. Because of the widespread belief that lampreys are responsible for the disappearance of fish, it seems worth while to report on the effect of lampreys on lake trout in a lake where they have existed in good numbers for many years and apparently are in reasonable equilibrium.

Many anglers think the best lake trout fishing in New York State is found in Seneca Lake, which supports a large population of rapidly growing (Royce, 1943) lake trout. And yet, paradoxically, this lake with an area of 68 square miles and a maximum depth of 618 feet also supports a large lamprey population. Gage (1928) writes that he found lake lampreys in Seneca Lake in 1894, and in some years it was possible to pick up 500 in a couple of hours while they were on their spawning migration in a tributary stream. The relative abundance of lake trout and lampreys may be judged from the incidence of attack. Gage (1928) notes that 34 out of 38 (90 percent) lake trout captured in Seneca Lake in 1927 bore lamprey scars. My data (table 1) indicate that 58 out of 66 (88 percent) mature male lake trout had been attacked, most of them more than once. In fact the 66 trout averaged 2.8 scars each.

The opportunity to collect data on the effect of lamprey attacks on lake trout occurred during my investigation of the life history of the lake trout in New York State. In early October, 1941, the New York State Conservation Department was gill netting large numbers of lake trout near Peach Orchard Point in Seneca Lake for spawn-taking. It was obvious that lampreys were numerous in the lake. There were scars on the fish and over 100 lampreys, ranging from 14 to 18 inches long, were captured still attached to the trout. In cooperation with the Conservation Department, records were obtained of the total length, weight, and number of lamprey marks for each captured lake trout. These data were collected in order to investigate the effect of lamprey attacks on the lake trout.

TABLE 1.--The length and weight of mature male lake trout according to the total number of lamprey marks.

Length is the total length in centimeters and weight is in pounds and ounces.

Taken from Seneca Lake, N. Y. In October, 1941.

Number of lamprey marks	None		One		Two		Three		Four		Five		Six		Seven		Eight		Ten	
	L.	Wt.	L.	Wt.	L.	Wt.	L.	Wt.	L.	Wt.	L.	Wt.	L.	Wt.	L.	Wt.	L.	Wt.	L.	Wt.
	62.5	5-0	62.5	4-14	77.5	8-8	68.5	5-1	73.5	6-15	72.5	6-10	71.0	8-0	72.0	7-0	78.5	7-13	83.5	10-0
	67.0	5-12	63.5	5-9	76.5	9-3	73.5	8-1	73.0	7-5	74.5	8-1	78.5	9-15	81.0	9-6	..	..	..	..
	60.5	4-6	68.0	6-8	70.5	5-3	61.5	4-14	74.0	7-15	74.5	7-6	..	..	78.5	9-2	..	..	..	..
	70.5	5-10	68.0	6-6	62.0	5-8	68.0	5-15	80.5	10-15	..	1/ ..	..	..	..	..	..	..	..	..
	60.5	3-14	80.5	10-14	72.0	7-8	76.5	8-0	71.5	6-15	87.5	13+	..	..	..	..	..	..	..	..
	68.0	5-15	64.5	4-14	72.0	6-15	77.5	9-15	79.5	8-7	..	..	..	..	..	..	..	..	..	..
	57.5	3-7	73.0	6-10	64.5	5-5	70.5	7-5	84.5	10-14	..	..	..	..	..	..	..	..	..	..
	62.5	4-11	60.0	4-10	61.0	3-12	69.5	6-7	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	61.5	3-13	76.5	9-3	70.5	7-14	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	57.0	3-13	67.0	6-2	81.0	10-6	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	66.0	5-10	69.0	5-11	69.5	6-14	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	60.0	4-10	69.5	6-2	60.5	4-0	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	78.0	8-14	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	64.5	4-15	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	77.5	8-5	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	75.0	7-14	..	..	..	..	..	..	..	..	..	..	..	..
Number	8		12		12		16		7						10 (11)		Total		65 (66)	
Mean Length 2/	63.0		65.1		69.6		71.1		76.5						76.4				70.0	
Mean weight in pounds	4.76		5.39		6.38		6.93		8.34						8.25				6.52	
Estimated weight in pounds at 69.0 cm.	5.93		6.45		6.21		6.32		6.18						6.51				6.24	

1/ Omitted from calculations because of estimated weight.

2/ Means are geometric means taken from the calculations for the analysis of covariance.

Since the lamprey, after attaching to a fish, rasps its way through the skin, drinks its fill of blood, and then departs leaving a large wound to be healed, it is a reasonable hypothesis that a fish which has been attacked will be thinner than average. In order to test this hypothesis, the length weight relationship was computed for groups of the lake trout which were found with different numbers of lamprey marks. The original data were transformed to common logarithms in order to avoid the effects of curvilinear regression. A regression line was fitted to the transformed data for each group, and from each regression the weight at a length of 69.0 centimeters (table 1) was computed. The mean weights for the six groups vary from 5.93 to 6.51 pounds, but there appears to be little, if any, relation to the number of lamprey marks.

A critical test to determine the significance of this difference in the mean weight (adjusted for differences in length) according to the number of lamprey marks may be made by the analysis of covariance. Such an analysis has been made (table 2) following the methods and using the same symbols as Snedecor (1946). In this analysis it is possible to obtain a variance attributable to the number of lamprey attacks and another to sampling variation. The F-test is used to compare these two sources of variation (mean square) and, in this case, to test the hypothesis that the differences in the mean weight (adjusted for differences in length) of lake trout between the groups with different numbers of lamprey marks is not greater than would be expected from sampling variation. The very small F value indicates that this hypothesis is true. There is no demonstrable difference in the mean weights of the various groups which had differing numbers of lamprey scars in this sample.

TABLE 2.--The analysis of covariance showing the test of significance for the difference among the adjusted mean weights of lake trout with different numbers of lamprey marks of all kinds.

Source of Variation	DF	Sx^2	Sxy	Sy^2	Sum of Squares	DF	Mean Square
Total	64	.120545	.348029	1.102966	.098328	63	
Marks	5	.051734	.148169	.428210			
Sampling	59	.068811	.199860	.674756	.094267	58	.001528
Difference for test of significance					.004061	5	.000812

$$F = \frac{.000812}{.001528} = .53 \text{ (Not significant)}$$

A preliminary examination of these data, which indicated that this was probably the case, led to the thought that the effect of lamprey attacks might have become obscured by counting all marks. Old scars which might have been present for years were counted as well as fresh, unhealed ones. Thus if the ill effects were immediate, a more critical test could be made by classifying the lake trout according to the number of fresh, unhealed marks only. Since observations of fresh-versus-healed scars were not made on the first group of lake trout, a second set of data was collected in which only the unhealed sores were counted (table 3).

Computation of the estimated weight at a length of 69.0 centimeters from these data shows a maximum difference of only 0.25 pound in the average weight, and a test of significance by the analysis of covariance (table 4) shows again that the differences in the mean weights are not associated with the number of unhealed lamprey wounds.

These two tests, which fail to show any correlation between the incidence of lamprey attack and the mean weight adjusted for length, are the more suprising when one considers that Schuck (1942), using an identical method of analysis, found a highly significant difference in the adjusted mean weight of two groups of trout, one group of which had been tagged with jaw tags for a period of from 1 to 2 years. The tagged trout were significantly thinner than the normal, untagged trout.

It is to be noted also in table 1, where the lake trout are tabulated according to the total number of lamprey marks, that there is an increase in mean length associated with the number of lamprey marks. Lake trout without lamprey marks averaged 63.0 centimeters, with a gradual increase in the mean length to 76.5 centimeters for those with four lamprey marks. This is an average increase in length of 3.4 centimeters per lamprey mark. An analysis of variance (table 5) indicates that these differences in the mean length are much larger than would be expected from chance variation.

Age data on these fish (Royce, 1943) indicate that most of the spawning males captured in this manner were five or six years old, although younger and older fish were found in smaller numbers. Those with five annuli averaged 64.5 centimeters in length and those with six averaged 72.0 centimeters. If we assume from this that the mature male lake trout were growing about 7.5 centimeters per year and acquiring one lamprey mark per 3.4 centimeters increase in length, it may be estimated roughly that the lake trout in this sample, on the average, acquired about 2 lamprey marks per year commencing at age five.

A similar examination of the average length of lake trout classified according to the number of unhealed lamprey marks (table 3) indicates a tendency for the larger lake trout in this sample to have a greater number of unhealed marks. An analysis of variance (table 6) also indicates that the differences are much greater than would be expected from chance variation. If we assume that the lamprey marks heal in a few weeks (Gage, 1928 found that lampreys remained attached only a few days) then we find that the larger lake trout in this sample were more vulnerable to attack.

TABLE 3.--The length and weight of mature male lake trout according to the the number of fresh unhealed lamprey marks. Length is the total length in centimeters and the weight is in pounds and ounces. Taken from Seneca Lake, N. Y. in October 1941.

Number of lamprey marks	None		One		Two		Three		Four	
	L.	Wt.	L.	Wt.	L.	Wt.	L.	Wt.	L.	Wt.
	63.5	5-0	60.0	4-6	64.0	5-8	67.0	6-7	80.5	9-2
	82.5	10-10	68.0	7-5	61.0	4-10	72.0	6-5	..	..
	66.0	5-12	57.5	3-13	77.0	8-5	76.5	7-10	..	..
	71.0	7-4	65.5	5-13	67.0	6-3	71.5	6-11	..	..
	68.0	6-4	66.0	4-12	64.0	5-5	83.5	11-8	..	..
	79.5	9-2	65.0	5-6	71.5	7-12	..	..	..	..
	66.5	5-6	69.5	7-1	66.5	6-1	..	..	..	..
	58.0	3-8	64.0	4-15	70.5	6-6	..	..	..	..
	59.0	4-8	62.0	4-13	69.5	6-8	..	..	..	..
	59.5	4-3	72.0	7-0	63.5	5-4	..	..	..	..
	63.5	5-7	74.5	7-14	80.5	10-3	..	..	..	..
	58.5	4-1	62.0	5-0	71.5	7-6	..	..	..	..
	66.0	5-11	71.5	6-0	81.5	9-1	..	..	..	..
	72.5	7-3	58.5	4-12	69.5	6-6	..	..	..	..
	67.0	5-13	75.5	8-5	73.0	6-9	..	..	..	..
	58.5	4-1	71.0	6-12	71.5	7-0	..	..	..	..
	59.5	4-4	62.0	4-13	..	..	..	..	..	..
	66.0	6-2	..	..	..	..	..	..	..	..
	72.0	7-15	..	..	..	..	..	..	...	..
	60.5	4-4	90.0	1/ 15+	..	..	..	..	..	..
	63.5	5-10	..	..	..	..	..	..	..	..
	77.5	7-11	..	..	..	...	..	..	..	..
	65.0	5-13	...	..	..	..	..	..	..	..
	61.5	4-7	..	..	..	..	..	..	..	..
	58.5	4-8	..	..	..	..	..	..	..	..
	59.0	4-8	..	..	..	..	..	..	..	..
	66.0	5-4	..	..	..	..	..	..	..	..
Number	27		17 (18)		16		6		Total	66 (67)
Mean Length 2/	65.2		65.9		69.9		75.0			67.3
Mean weight in pounds	5.56		5.67		6.64		7.75			6.01
Estimated weight in pounds at 69 cm.	6.47		6.31		6.44		6.22			6.40

1/Omitted from calculations because of estimated weight.

2/Means are geometric means taken from the calculations for the analysis of covariance.

TABLE 4.--The analysis of covariance showing the test of significance for the difference among the adjusted mean weights of lake trout with different numbers of unhealed lamprey marks.

Source of Variation	DF	Sx^2	Sxy	Sy^2	Sum of Squares	DF	Mean Square
Total	65	.118987	.302039	.853979	.087277	64	
Marks	3	.024060	.058812	.144187			
Sampling	62	.094927	.243227	.709792	.086583	61	.001419
Difference for test of significance					.000694	3	.000231

$$F = \frac{.000231}{.001419} = .163 \text{ (Not significant)}$$

TABLE 5.--The analysis of variance showing the test of significance for the difference among the mean lengths of lake trout with different numbers of lamprey marks of all kinds.

Source of Variation	DF	Sx^2	Mean Square
Total	64	.120545	. . .
Marks	5	.051734	.010347
Sampling	59	.068811	.001166

$$F = \frac{.010347}{.001166} = 8.87 \text{ (Highly significant)}$$

TABLE 6.—The analysis of variance showing the test of significance for the difference among the mean lengths of lake trout with different numbers of unhealed lamprey marks.

Source of Variation	DF	Sx^2	Mean Square
Total	65	.118987	[illegible]
Marks	3	.024060	.008020
Sampling	62	.094927	.001531

$$F = \frac{.008020}{.001531} = 5.24 \text{ (Highly significant)}$$

If we compare the incidence of attack, we find that the lake trout (table 1) averaged 2.8 total lamprey marks per fish and 1.0 unhealed sores (table 3). If we assume again that a sore remains unhealed only one month, then it appears that these lake trout possessed more unhealed sores in proportion to healed scars than would be expected from a random distribution of incidence of attack throughout the year. A random distribution of two attacks each year should cause about one-sixth of the marks to be unhealed rather than more than one-third. Possibly the concentration of spawning lake trout attracts lampreys and the spawning urge makes a fish take less notice of attacks.

In summarizing the data from these two samples we find:

1. These lake trout suffered up to ten successful lamprey attacks and possessed up to four unhealed sores caused by lampreys while showing no indication that they were thinner as a result of such attacks.
2. Larger lake trout suffered more attacks and were more vulnerable to attack.
3. It is suggested that the lake trout in this sample acquired about two lamprey marks per year commencing at age five and were somewhat more vulnerable to attack when spawning.

Extrapolation of these sample data to form conclusions about the population in Seneca Lake is difficult. First, the sample consisted of mature males caught on the spawning migration by a gill net of uniform size. Thus, it was not representative of the sexes or even of the complete size range of the mature males. Secondly, the lake trout which are included represent only those which have survived lamprey attacks, and the data provide absolutely no information on those which may have died.

It is a fact, nevertheless, that the lake trout in Seneca Lake can survive numerous attacks, including up to four at about the same time. It is a further fact that despite the presence of lampreys for more than fifty years, Seneca Lake provides good lake trout angling. And, if lamprey attacks are often fatal, it is strange indeed that lake trout should show no indication of thinness after repeated attacks, even in such a restricted sample. Perhaps the lamprey succeeds in perpetuating its own food supply by not killing as many of its hosts as popular conception would have us believe!

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Number of Lamprey Marks, Length, and Weight of Ripe ♂ Lake Trout taken in Seneca Lake off Rock Orchard Point - Fall 1941

Number of Lamprey Marks. Three and	None		One		Two		Three		Four	
	L.	Wt.	L.	Wt	L.	Wt.	L.	Wt	L.	Wt.
1 2	127	5-	120	4-6	128	5-8	134	6-7	161	9-2
2 3	165	10-10	136	7-5	122	4-10	144	6-5		
3 4	132	5-12	115	3-13	154	8-5	153	7-10		
4 5	142	7-4	131	5-13	134	6-3	143	6-11		
5 6	136	6-4	132	4-12	128	5-5	167	11-8		
6 7	159	9-2	130	5-6	143	7-12				
7 8	133	5-6	139	7-1	133	6-1				
8 9	116	3-8	128	4-15	141	6-6				
9 10	118	4-8	124	4-13	139	6-8				
10 1	119	4-3	144	7-	127	5-4				
11 2	127	5-7	149	7-14	161	10-3				
12 3	117	4-1	124	5-	143	7-6				
13 4	132	5-11	143	6-	163	9-1				
14 5	145	7-3	117	4-12	139	6-6				
15 6	134	5-13	151	8-5	146	6-9				
16 7	117	4-1	142	6-12	143	7-				
17 8	119	4-4	124	4-13						
18 9	132	6-2								
19 20	144	7-15								
20 1	121	4-4								
21 2	127	5-10								
22 3	155	7-11								
23 4	130	5-13								
24 5	123	4-7								
25 6	117	4-8								
26 7	118	4-8								
27 8	132	5-4	180	15-4						
9										
30										
n	27		18		16		5		1	~~5~~ ~~66~~ 67

Only Fresh Lamprey Marks Counted

Lengths in half centimeters

Weight in pounds - ounces.

Lamprey Marks - Length - Weight of L. T. - Ripe Males - Seneca Lake
Peach Orchard Point - Fall 1941

Number of Lamprey Marks.	None ✓		One ✓		Two ✓		Three ✓		Four ✓		Five 5-10		Six		Seven		Eight		Nine	
	L.	Wt	L.	Wt	L.	Wt.	L.	Wt.	L.	Wt	L.	Wt.	L.	Wt.	L.	Wt.	L.	Wt.	L.	Wt.
1			125	4-14	155	8-8	137	5-1	147	6-15	145	6-10	142	8-0	144	7-0	157	7-13		
2			127	5-9	153	9-3	147	8-1	146	7-5	149	8-1	157	9-15	162	9-6				
3			136	6-8	141	5-3	123	4-14	148	7-15	149	7-6			157	9-2				
4			136	6-6	124	5-8	136	5-15	161	10-15										
5			161	10-14	144	7-8	153	8-0	143	6-15										
6			129	4-14	144	6-15	155	9-15	159	8-7										
7			146	6-10	129	5-5	141	7-5	169	10-14										
8			120	4-10	122	3-12	139	6-7												
9			123	3-13	153	9-3	141	7-14											Ten	
10			114	3-13	134	6-2	162	10-6											169	10-0
11			132	5-10	138	5-11	139	6-14												
12			120	4-0	139	6-2	121	4-0												
13							156	8-14												
14							129	4-15												
15							155	8-5												
16							150	7-14												
17											175	13+								
18																			Eleven	
19																				
20																				
																			Twelve	
n		8		12		12		16		7		3		2		3		1		1
																Total				65

All Lamprey Marks Counted
Weights in pounds-ounces
Lengths in half centimeters

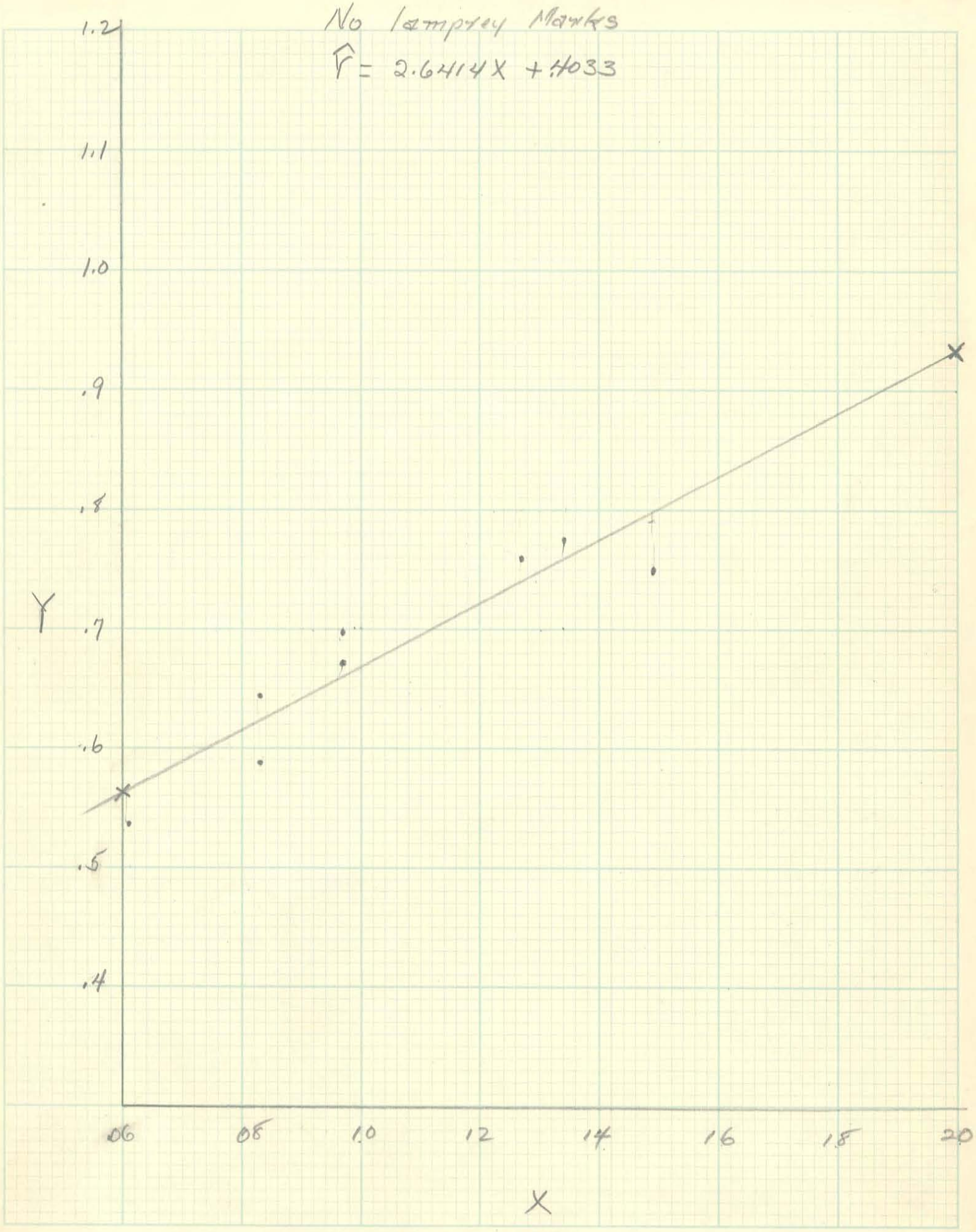
Covariance Analysis - Lamprey Marks - Length - Weight of Seneca Lake Lake Trout

Source of Variation	DF.	Sums of Squares & Products $S x^2$	$S xy$	$S y^2$	Errors of Estimate Sum of Squares	DF	Mean Square
Total	47	.080094	.206070	.569489	.039301	46	
Marks	2	.010064	.027604	.076332			
Error -		.070030	.178466	.493157	.038350	44	.000872
Fur Test of Significance of Adjusted means					.000951	2	.000486

$$F = \frac{.000486}{.000872} = .557 \text{ - not Significant.}$$

No lamprey Marks

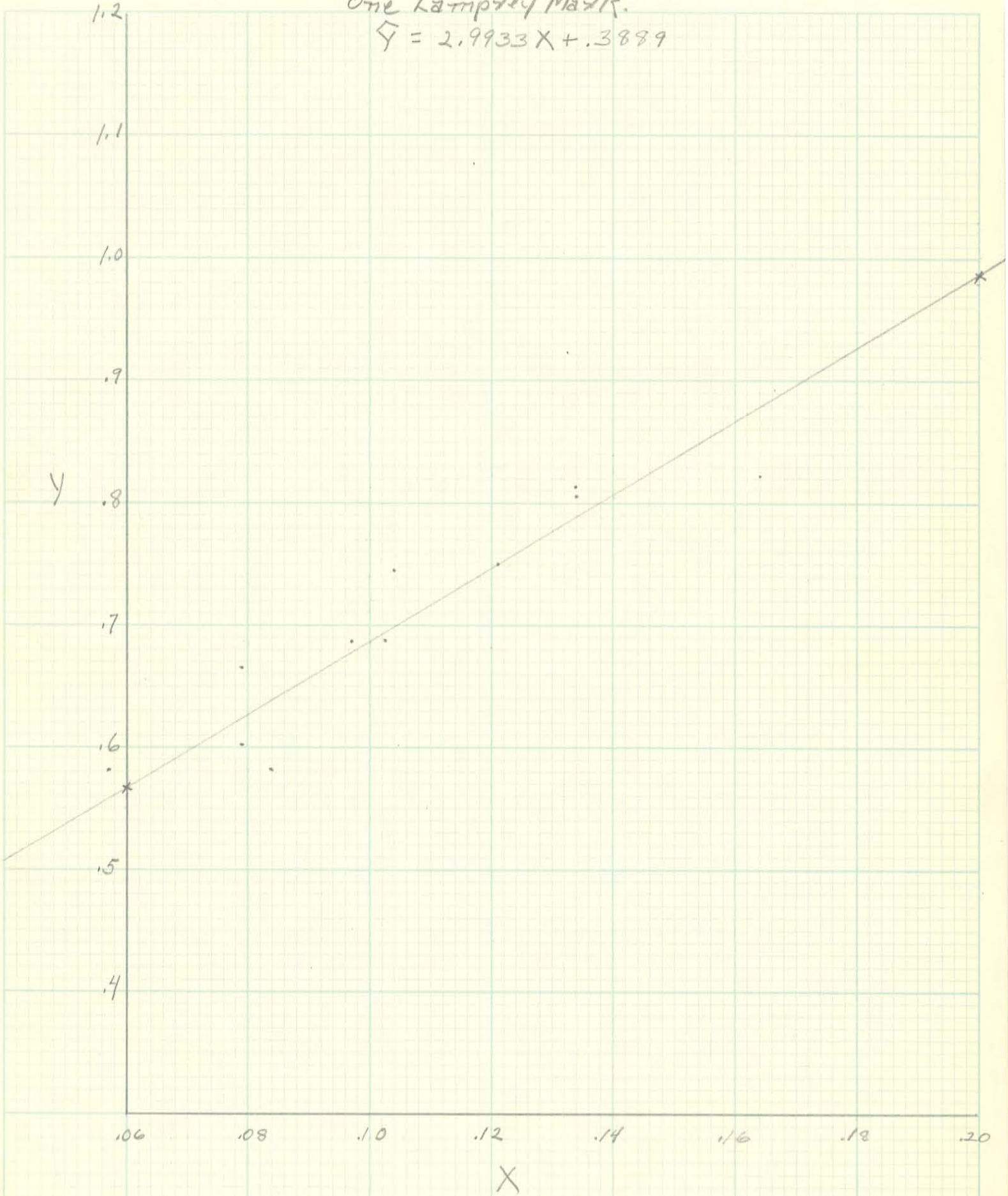
$\hat{Y} = 2.6414X + .4033$



EUGENE DIETZGEN CO. NO. 375

One Lamprey Mark.

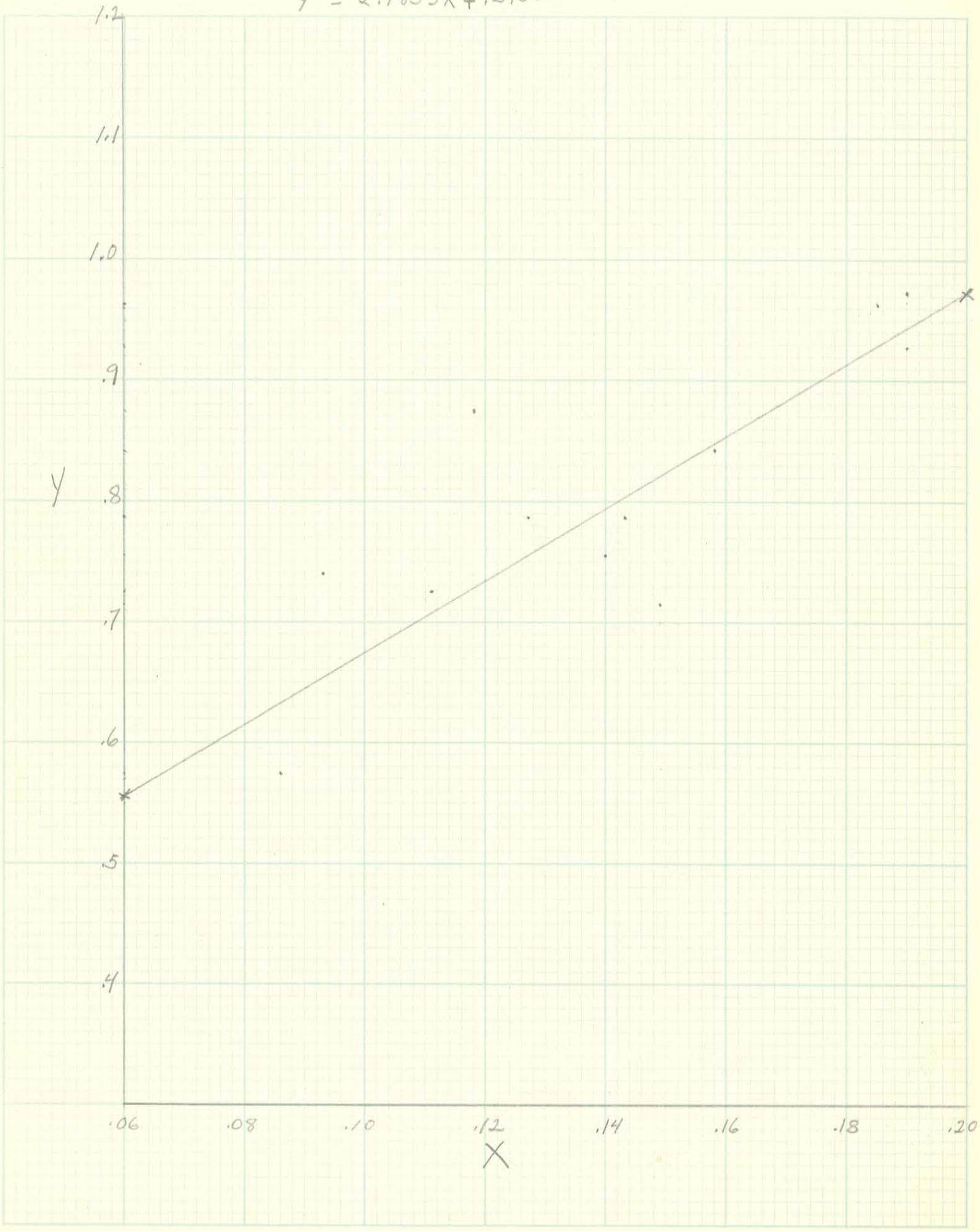
$\hat{Y} = 2.9933X + .3889$



EUGENE DIETZGEN CO. NO. 375

Two Lamprey Marks

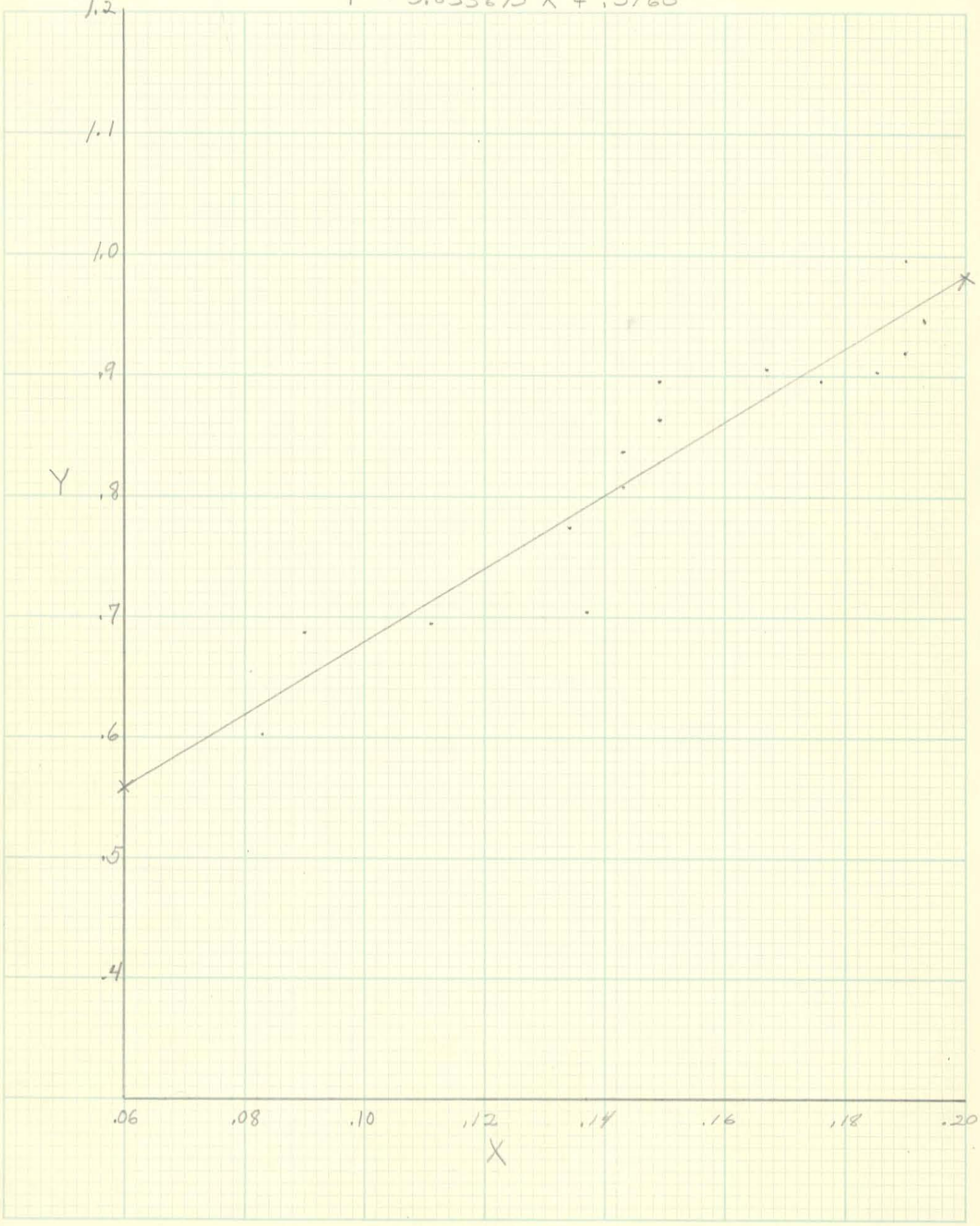
$\hat{Y} = 2.9853X + .3752$



EUGENE DIETZGEN CO. NO. 375

Three Lamprey Marks

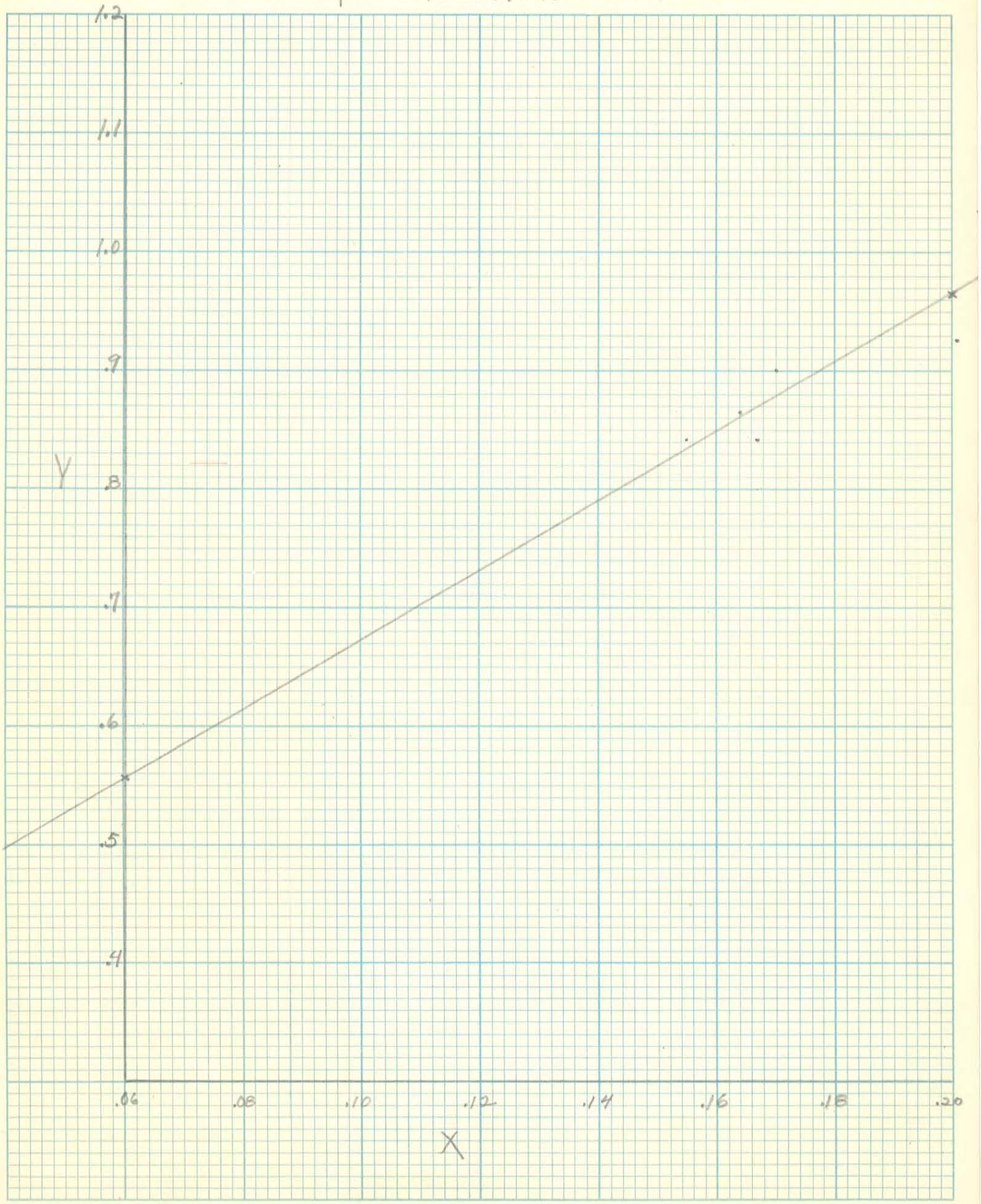
$\hat{Y} = 3.033673\,X + .3765$



EUGENE DIETZGEN CO. NO. 375

Four Lamprey Marks

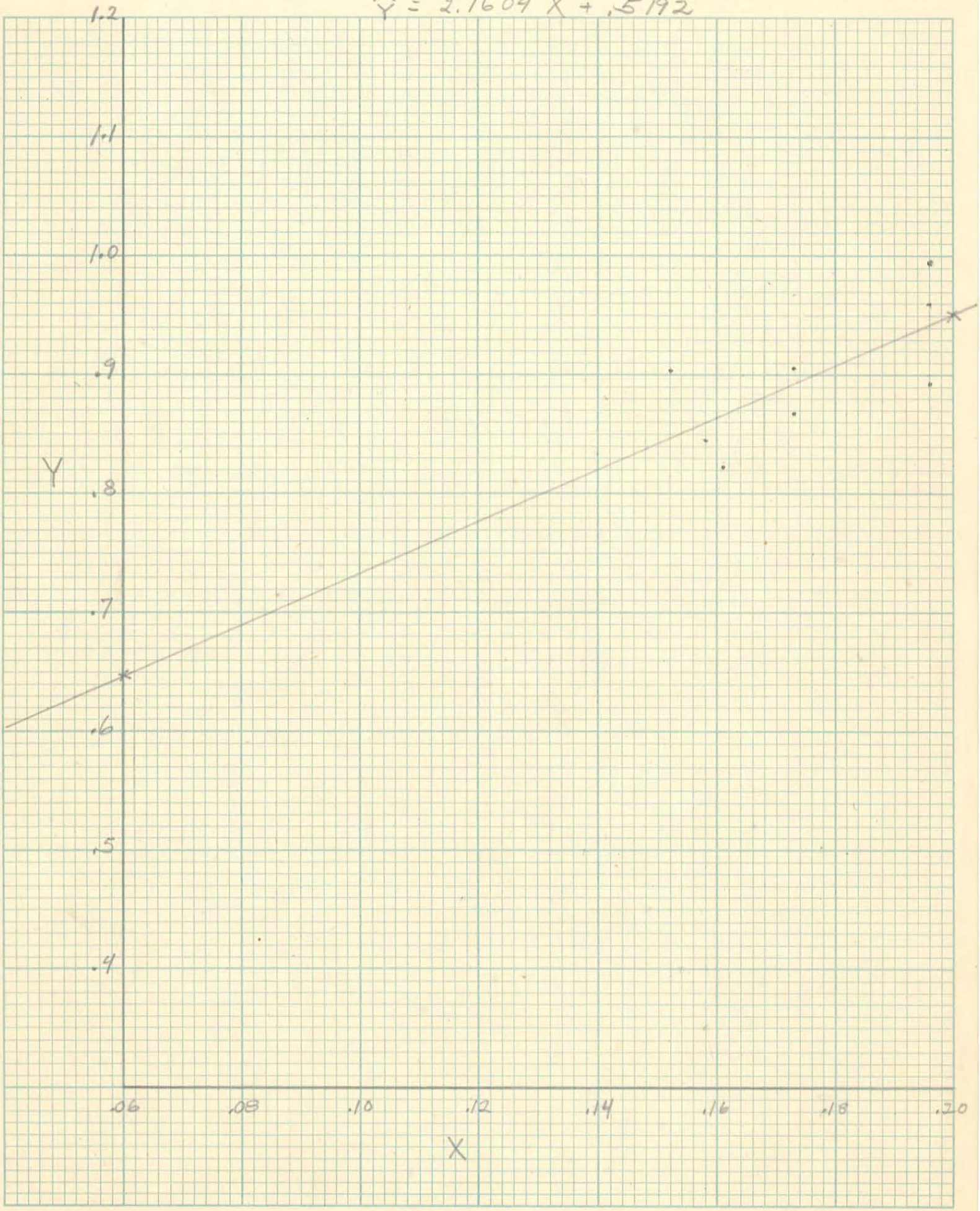
$\hat{Y} = 2.9069X + .3845$



EUGENE DIETZGEN CO. NO. 375

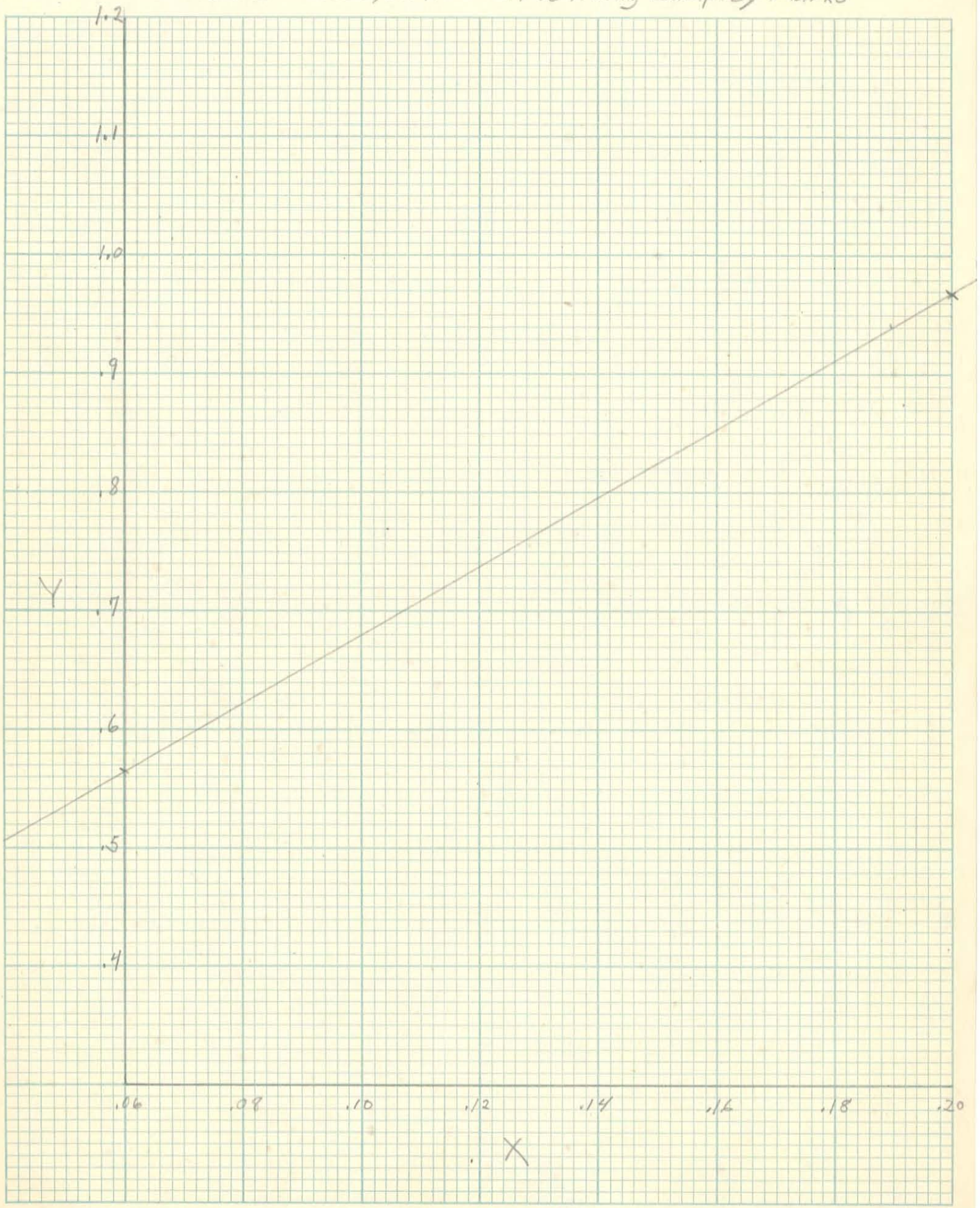
Five to Ten Lamprey Marks

$\hat{Y} = 2.1604\,X + .5192$



EUGENE DIETZGEN CO. NO. 375

Regression of Weight on Length of 65 Lake Trout from Lake Seneca, N.Y. - 87.7% Having Lamprey Marks



EUGENE DIETZGEN CO. NO. 375

Fresh Lamprey Marks

Number of Lamprey Marks	X Three and Four		Y		
	L.	Log. L	W. Lbs. Oz	Lbs.	Log.
1	134	.127	6-7	6.44	.809
2	144	.158	6-5	6.31	.800
3	153	.185	7-10	7.62	.882
4	143	.155	6-11	6.69	.825
5	167	.223	11-8	11.50	.061
6	161	.207	9-2	9.12	.960
7					

n	6	6
SX	1.055	5.337
$\bar{x}$	.175833	.889500
SX^2	.191921	4.800351
$(SX)^2/n$	.185504	4.747261
Sx^2	.006417	.053090
Av. L. & W.	149.91	7.754
	741	
SXY	.955511	
$(SX)(SY)/n$	.938422	
Sxy	.017089	
Sxy/Sx^2	2.663082	
$(Sxy)^2/Sx^2$	.045509	

$\hat{Y} = .889500 + 2.663082(X - .175833)$

$2.6631X + .4212$

$X = .06 \quad .13988$

$\hat{Y} = .5810 \quad .7937$

6.219

Totals

	X	Y
$n =$	66	66
$SX =$	8.528	SY 51.425
$\bar{x}$	.12920	$\bar{y}$ .77918
SX^2	1.2209	SY^2 40.9226
$(SX)^2/n$	1.1019	$(SY)^2/n$ 40.0686
Sx^2	.1190	Sy^2 .8540
Av. L.	134.65	Av. W. 6.0145
SXY	6.9468	
$(SX)(SY)/n$	6.6447	
Sxy	.3021	
Sxy/Sx^2	2.5386	
$(Sxy)^2$	.09126	

$\hat{Y} = .7792 + 2.5386(X - .1292)$

$X = .06 \quad .13988$

$\hat{Y} = .6035 \quad .8063$

6.402

Fresh Lamprey Marks : Lake Seneca Lake Trout

Number of Lamprey Marks →	X None		Y			X One		Y			X Two		Y		
	L. (Cm.×2)	Log.	Wt. Lbs.Oz	Lbs.	Log.	L. (Cm.×2)	Log.	Wt. Lbs.Oz	Lbs.	Log.	L. (Cm.×2)	Log.	Wt. Lbs.Oz	Lbs.	Log
1	127	.104	5-	5.00	.699	120	.079	4-6	4.38	.642	128	.107	5-8	5.50	.740
2	165	.218	10-10	10.62	1.026	136	.134	7-5	7.31	.864	122	.086	4-10	4.62	.665
3	132	.121	5-12	5.75	.760	115	.061	3-13	3.81	.581	154	.188	8-5	8.31	.920
4	142	.152	7-4	7.25	.860	131	.117	5-13	5.81	.764	134	.127	6-3	6.19	.792
5	136	.133	6-4	6.25	.796	132	.121	4-12	4.75	.677	128	.107	5-5	5.31	.725
6	159	.201	9-2	9.12	.960	130	.114	5-6	5.38	.731	143	.155	7-12	7.75	.889
7	133	.124	5-6	5.38	.731	139	.143	7-1	7.06	.849	133	.124	6-1	6.06	.782
8	116	.064	3-8	3.50	.544	128	.107	4-15	4.94	.694	141	.149	6-6	6.38	.805
9	118	.072	4-8	4.50	.653	124	.093	4-13	4.81	.682	139	.143	6-8	6.50	.813
10	119	.076	4-3	4.19	.622	144	.158	7-0	7.00	.845	127	.104	5-4	5.25	.720
11	127	.104	5-7	5.44	.736	149	.173	7-14	7.88	.896	161	.207	10-3	10.19	1.008
12	117	.068	4-1	4.06	.608	124	.093	5-0	5.00	.699	143	.155	7-6	7.38	.868
13	132	.121	5-11	5.69	.755	143	.155	6-0	6.00	.778	163	.212	9-1	9.06	.957
14	145	.161	7-3	7.19	.857	117	.068	4-12	4.75	.677	139	.143	6-6	6.38	.805
15	134	.127	5-13	5.81	.764	151	.179	8-5	8.31	.920	146	.164	6-9	6.56	.817
16	117	.068	4-1	4.06	.608	142	.152	6-12	6.75	.829	143	.155	7-0	7.00	.845
17	119	.076	4-4	4.25	.628	124	.093	4-13	4.81	.682					
18	132	.121	6-2	6.12	.787										
19	144	.158	7-15	7.94	.900										
20	121	.083	4-4	4.25	.628										
21	127	.104	5-10	7.62	.882										
22	155	.190	7-11	7.69	.886										
23	130	.114	5-13	5.81	.764										
24	123	.086	4-7	4.44	.647										
25	117	.068	4-8	4.50	.653										
26	118	.072	4-8	4.50	.653										
27	132	.121	5-4	5.25	.720										
n	27		n	27		17		17			16		16		
SX	3.107	130.34	SY	20.127		2.040	136.83	12.810			2.326	139.76	13.151		
$\bar{X}$	.11507		$\bar{Y}$	.745444		.12000		.75353			.145375		.821937		
SX^2	.405389		SY^2	15.381057		.265776		9.807988			.357822		10.933229		
$(SX)^2/n$	.357535		$(SY)^2/n$	15.003560		.244800		9.652712			.338142		10.809300		
Sx^2	.047854		Sy^2	.377497		.020976		.155276			.019680		.123929		
Av. L+W.	130			5.54		132		5.669			140		6.64 / 6.36		
SXY			2.441837					1.589930					1.959494		
$(SX)(SY)/n$			2.316096					1.537200					1.911827		
SXY			.125741					.052730					.047667		
Sxy/Sx^2			2.627596					2.513825					2.422104		
$(Sxy)^2/Sx^2$			33.039660					17.906521					.115454		
$\hat{Y}$ =	.745444 + 2.627596(X - .115)					.75353 + 2.5138(X - .120)					.82194 + 2.4221(X - .14538)				
=	2.6276X + .4437					2.5138X + .4519					2.4221X + .4698				
Assumed X =	.06		.13988			.06		.13988			.06		.13988		
$\hat{Y}$ =	.6008		.8107			.6038		.8035			.616		.8086		
			Wt	6.467				6.314					6.436		

Analysis of Covariance
Fresh Lamprey Marks

Experiment Totals.

n	66								
SX	8.528		SY	51.425		$S[(SX)^2/n]$	1.125981	$S[(SY)^2/n]$	40.212833
$\bar{x}$			$\bar{y}$				1.101921		40.068646
SX^2	1.220908		SY^2	40.922625			.024060		.144187
$(SX)^2/n$	1.101921		$(SY)^2/n$	40.068646					
Sx^2	.118987		Sy^2	.853979		$S[(SX)(SY)/n]$	6.703545		
							6.644733		
							.058812		
SXY	6.946772								
$(SX)(SY)/n$	6.644733								
Sxy	.302039					$S[Sx^2]$	.094927	$S[Sy^2]$	.709792
Sxy/Sx^2									
$(Sxy)^2/Sx^2$						$S[Sxy]$	.243227		

Regression Formula

$$\hat{Y} = \bar{y} + \frac{S_{xy}}{S_{x^2}}(X - \bar{x})$$

	Total		X	y
n	65	n 65		
SX	9.509 R	SY 52.918 R		
$\bar{x}$	.14629 / ~~140.05~~	$\bar{y}$ .81412		
SX^2	1.511689 R	SY^2 44.184731 R	$S[(SX)^2/n]$ 1.442828 R	43.509975 R
$(SX)^2/n$	1.391094	$(SY)^2/n$ 43.081765	1.391094	43.081765
S_{x^2}	.120545	S_{y^2} 1.102766	.051734	.428210
SXY	8.089525		$S[(SX)(SY)/n]$ 9.889665 R	
$(SX)(SY)/n$	7.741496		7.741496	
S_{xy}	.348029		.148169	
S_{xy}/S_{x^2}	2.887129			
$(S_{xy})^2/S_{x^2}$	1.004805		$S[S_{x^2}]$ .068811 R	$S[S_{y^2}]$ .674756 R
			$S[S_{xy}]$ .199860 R	

$$\hat{Y} = \bar{y} + \frac{S_{xy}}{S_{x^2}}(X - \bar{x})$$

$$= .8141 + 2.8866(X - .1463)$$

$$= 2.8866X + .3918$$

Assumed X	.06	.20	.14629
$\hat{Y}$ =	.5650	.9691	

$$\hat{Y} = .8141 + 2.887(X - .14629)$$

$$2.8871X + .3917$$

Assumed X	.06	.20	.13988
$\hat{Y}$	.5649	.96912	.7955
			6.24

Covariance Analysis - Lamprey Marks - Length - Weight - Seneca Lake Trout.

Lamprey Marks	None		One		Two	
	length X	wt. Y	X	Y	X	Y
1	127	5.00	120	4.38	128	5.50
2	165	10.62	136	7.31	122	4.62
3	132	5.75	115	3.81	154	8.31
4	142	7.25	131	5.81	134	6.19
5	133	5.38	130	5.38	128	5.31
6	116	3.50	139	7.06	143	7.75
7	118	4.50	128	4.94	133	6.06
8	119	4.19	124	4.81	141	6.38
9	127	5.44	144	7.00	139	6.50
10	132	5.69	149	7.88	127	5.25
11	119	4.25	124	5.00	161	10.19
12	132	6.12	143	6.00	143	7.38
13	121	4.25	117	4.75	163	9.06
14	155	7.69	151	8.31	139	6.35
15	123	4.44	142	6.75	146	6.56
16	117	4.50	124	4.81	143	7.00

Transformation to Logarithms

	None X	None Y	One X	One Y	Two X	Two Y
1	.104	.699	.079	.642	.107	.740
2	.218	1.026	.134	.864	.086	.665
3	.121	.760	.061	.581	.188	.920
4	.152	.860	.117	.764	.127	.792
5	.124	.731	.114	.731	.107	.725
6	.064	.544	.143	.849	.155	.889
7	.072	.653	.107	.694	.124	.782
8	.076	.622	.093	.652	.149	.805
9	.104	.736	.158	.845	.143	.813
10	.121	.755	.173	.896	.104	.720
11	.076	.628	.093	.699	.207	1.008
12	.121	.787	.155	.778	.155	.868
13	.083	.628	.068	.677	.212	.957
14	.190	.886	.179	.920	.143	.805
15	.086	.647	.152	.829	.164	.817
16	.068	.653	.093	.682	.155	.845
Sums	1.780	11.615	1.919	12.133	2.326	13.151
SX^2	.227400		.251135		.357822	
SY^2		8.651939		9.349659		10.933229
SXY	1.370156		1.509013		1.959494	

Experiment Totals

SX	6.025
SY	36.899
SX^2	.836357
SY^2	28.934827
SXY	4.837663

Corrections

X	.756263
Y	28.365338
XY	4.631593

$\bar{x}$	
$\bar{y}$	
Sx^2	.080094
Sy^2	.569489
Sxy	.206070

Analysis of Effect of Lamprey Marks on Lake Trout

No. Lamprey Marks	X None Length Cmx2	Log	Y Weight lbs-oz	lbs	Log	x One Length CmX2	Log	y Weight Lbs.Oz	Lbs.	Log	x Two Length CmX2	Log	y Weight Lbs.Oz	Lbs.	Log
1	125	.097	5-0	5.00	.699	125	.097	4-14	4.88	.688	155	.190	8.8	8.50	.929
2	134	.127	5-12	5.75	.760	127	.104	5-9	5.56	.745	153	.185	9.3	9.19	.963
3	121	.083	4-6	4.38	.642	136	.134	6-8	6.50	.813	141	.149	5.3	5.19	.715
4	141	.149	5-10	5.62	.750	136	.134	6-6	6.38	.805	124	.093	5.8	5.50	.740
5	121	.083	3-14	3.88	.589	161	.207	10-14	10.88	1.037	144	.158	7.8	7.50	.875
6	136	.134	5-15	5.94	.774	129	.111	4-14	4.88	.688	144	.158	6.15	6.94	.841
7	115	.061	3-7	3.44	.537	146	.164	6-10	6.62	.821	129	.111	5.5	5.31	.725
8	125	.097	4-11	4.69	.671	120	.079	4-10	4.62	.665	122	.086	3.12	3.75	.574
9						123	.086	3-13	3.81	.581	153	.185	9.3	9.19	.963
10						114	.057	3-13	3.81	.581	134	.127	6.2	6.12	.787
11						132	.121	5-10	5.62	.750	138	.140	5.11	5.69	.755
12						120	.079	4-0	4.0	.602	139	.143	6.2	6.12	.787
13															
14															
15															
16															
actual Averages	127.0					130.1					6.962 / 13.924				
n	8			y	8	12			y	12	12			y	12
SX	.831	SY			5.422	1.373				8.776	1.725				9.654
$\bar{x}$	.1039	$\bar{y}$			.6777	.114416				.731333	.1438				.8045
SX^2	.092603	SY^2			3.725472	.175971				6.602368	.261223				7.913374
$(SX)^2/n$	.086320	$(SY)^2/n$			3.674760	.157094				6.418181	.247968				7.766640
Sx^2	.006283	Sy^2			.050712	.018877				.184187	.013255				.146734
Av. Length and Wt.	127			4.75		130			5.38		139			6.37	
SXY			.579806					1.060625					1.427332		
$(SX)(SY)/n$			.563210					1.004121					1.387762		
Sxy			.016596					.056504					.039570		
Sxy/Sx^2	2.641413					3.067752					2.985288				
$(Sxy)^2/Sx^2$	.04384					.01733402					.118127868				

$\hat{Y} = .6777 + 2.641413(X - .1039)$ | $.7313 + 3.0678(X - .1144)$ | $.8045 + 2.985288(X - .1438)$

$\hat{Y} = 2.6414X + .4033$ | $\hat{Y} = 3.0678X + .3803$ | $\hat{Y} = 2.9853X + .3752$

Assumed X	.06	.20	.06	.20	.06	.20
$\hat{Y}$	.5618	.9316	$\hat{Y} = .5644$	.9939	$\hat{Y} = .5543$	.9723

Assumed X = .13988 | X .13988 | X = .13988

$\hat{Y} = .7728$ 5.927 | $\hat{Y}$ .8094 6.448 | $\hat{Y} = .79278$ 6.206

Analysis of Effect of Lamprey Marks on Lake Trout

No. Lamprey Marks →	X Three		Y			X Four		Y			X Five to Ten		Y		
	Length		Weight			Length		Weight			Length		Weight		
	Cm.X2	Log.	Lbs.Oz	Lbs.	Log	Cm.X2	Log.	Lbs.Oz	Lbs.	Log	Cm.X2	Log	Lbs.Oz	Lbs.	Log
1	137	.137	5-1	5.06	.704	147	.167	6-15	6.94	.841	145	.161	6-10	6.62	.821
2	147	.167	8-1	8.06	.906	146	.164	7-5	7.31	.864	149	.173	8-1	8.06	.906
3	123	.090	4-14	4.88	.688	148	.170	7-15	7.94	.900	149	.173	7-6	7.38	.868
4	136	.134	5-15	5.94	.774	161	.207	10-15	10.94	1.039	142	.152	8-0	8.00	.903
5	153	.185	8-0	8.00	.903	143	.155	6-15	6.94	.841	157	.196	9-15	9.88	.995
6	155	.190	9-15	9.94	.997	159	.201	8-7	8.44	.926	144	.158	7-0	7.00	.845
7	141	.149	7-5	7.31	.864	169	.228	10-14	10.88	1.037	162	.210	9-6	9.38	.972
8	139	.143	6-7	6.44	.809						157	.196	9-2	9.12	.960
9	141	.149	7-14	7.88	.896						157	.196	7-13	7.81	.893
10	162	.270	10-6	10.38	1.016						167	.223	10-0	10.00	1.000
11	139	.143	6-14	6.88	.838										
12	121	.083	4-0	4.00	.602										
13	156	.193	8-14	8.88	.948										
14	129	.111	4-15	4.94	.694										
15	155	.190	8-5	8.31	.920										
16	150	.176	7-14	7.88	.896										
		1423					1530					1527			
n		16		y	16		7		y	7		10		y	10
S X		2.450			13.455		1.292			6.448		1.838			9.163
$\bar{X}$		.1531			.84094		.1846			.92114		.1838			.9163
SX^2		.395774			11.538509		.242944			5.983424		.342924			8.431593
$(SX)^2/n$		.375156			11.314814		.238446			5.938529		.337824			8.396051
Sx^2		.020618			.213686		.004478			.044895		.005100			.035542
Av. L. & Wt.	142			6.93		153			8.34		152			8.24	
SXY			2.123452					1.203133					1.695177		
$(SX)(SY)/n$			2.060297					1.190116					1.684159		
Sxy			.063155					.013017					.011018		
Sxy/Sx^2	3.033673					2.906878					2.160392				
$(Sxy)^2/Sx^2$	.191592					.037839					.023803				
$\hat{Y}$ =	.8409 + 3.033673(X-.1531)					.92114 + 2.906878(X-.1846)					.9163 + 2.160392(X-.1838)				
$\hat{Y}$ =	3.033673X + .3765					2.9069X + .38453					2.1604X + .5192				
Assumed X		.06		.20			.06		.20			.06		.20	
$\hat{Y}$		.5585		.9832			.5589		.9659			.6488		.9513	
X			.13988					.13988					.13988		
$\hat{Y}$			.8009	6.323				.7911	6.182				.8138	6.513	