RESTRICTED

INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

Serial No. 1514
(D. c. 9)

Research Document No. 50

ANNUAL MEETING - JUNE 1965

Changes in the Measurements of Length and Weight of Maine Sardines due to Freezing, Brining, and Salting

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Sampling of the Maine sardine fishery is done by State inspectors at the sardine canneries where a minimum of 100 fish from each catch are placed, properly labeled, into a freezer unit provided by the Bureau of Commercial Fisheries. The samples are usually gathered bi-weekly from all freezing units along the coast and are brought back to the laboratory where they are sorted and selected for analysis on an area and time basis. Within a few weeks to several months each sample is thawed in water (for 5 to 10 minutes) at about 20°C and examined for certain morphometric and meristic data. All samples collected in this fashion are salted when they are caught and held in a brine solution for varying periods of time before freezing. The effects on the length and weight of the fish due to salting, brining, and freezing are unknown. To test these effects, in the summer of 1964 several samples of fresh, unsalted herring were measured and weighed prior to being frozen and later after being thawed both in air and water. Samples were also brined and salted before being frozen to test the joint effects of salt, water and freezing.

Freezing Effects on Length and Weight

Seven samples were tested for the effects of freezing only, (Table 1). Samples 1 through 5 were measured and weighed fresh and again after being frozen for three months at -16°C and thawed in warm fresh water. In all cases the length and weight of the individual samples decreased (Table 2).

The length decrease varied from 2.40% to 4.10% with an average value of 3.32% for fish from 120 to 190 cm in total length. Covariance tests for the first 5 samples indicated that the regression slopes were similar but the intercepts differed so that the samples could not be combined. Although the samples reacted differently to the freezing process such samples are combined in this report for the changes in length and also for weight. The usability of these data then depends on the confidence limits. Such irregular pooling causes the confidence limits to be very wide (Fig. 1). The 95% confidence limits for the grouped length regression slope are 0.9698 and 1.0186. The 95% slope confidence limits of the grouped weight data are 0.9618 and 1.0320. All regression lines are constructed with the Y variable as the original or prior measurement since it is this measurement we desire from fish that have been brined, salted, etc.

Paired t tests were run on individual samples to test for significant changes in length and weight due to the freezing process. Highly significant values ($P < .01$) were obtained in all cases.

The weight decrease fluctuated from 0.13% to 5.97% with an average change of 2.95%. These samples gave F value of 53.68 ($P < .01$) for the test of a common line and 20.60 ($P < .01$) for the test of parallel lines. Paired t tests were significant ($P < .01$) for samples 1, 3, 4 and 5. Sample 2 (0.13% weight change) gave a t value of 1.405 which was not significant ($P < .20$).

Table 1. Sample Description and Percentage Changes in Length and Weight due to Freezing, Brining and Salting.

Sample	Time in brine (hours)	Time in salt (hours)	Frozen storage time (months)	Method of thawing	Number of fish	True mean length* (mm)	Variance	Length range	True mean weight (grams)	Variance	Weight range
1	-	-	3	Water	50	150.16	149.7347	127-179	20.53	31.5420	11.9-35.7
2	-	-	3	Water	100	143.61	127.7374	123-184	17.11	21.8025	9.8-37.9
3	-	-	3	Water	100	150.88	121.3838	130-187	20.11	25.3147	12.3-39.0
4	-	-	3	Water	100	148.28	158.8889	121-186	19.60	26.1728	11.1-38.6
5	-	-	3	Water	100	144.88	168.2525	119-178	17.70	38.5657	9.9-36.2
6	-	-	3	Air	50	144.00	142.2245	121-172	20.44	22.6528	12.0-35.5
7	-	-	1	Air	100	140.03	59.2829	115-167	20.61	10.7873	10.9-32.3
8	21	-	1	Air	100	139.61	97.2121	110-165	19.66	16.3806	9.4-29.8
9	21	-	1	Air	100	225.50	80.1717	209-241	80.71	92.8286	63.0-102.1
10	22	-	1	Water	100	138.74	88.5354	107-157	19.43	14.2964	10.9-29.0
11	19	-	1	Water	100	227.28	56.3232	211-239	82.40	69.6167	65.0-99.5
12	23	-	3	Water	50	152.52	69.3878	139-172	21.04	15.8445	15.0-31.6
13	68	-	-	-	50	149.16	82.4898	135-165	20.22	10.0586	14.9-27.0
14	-	21	1	Air	100	139.42	68.7172	111.166	20.56	14.1036	10.0-34.0
15	-	20	1	Water	100	140.31	70.0404	117-164	19.84	12.8976	11.1-32.9

* The total length used was Natural Total Length with the lobes of the tail in the normal position.

Samples 6 and 7 were frozen for 3 months and 1 month respectively and then thawed at room temperature. The two samples reacted very differently to the freezing and thawing as sample 6 decreased in length 4.46% to only 1.25% for sample 7. The weight decrease was just the reverse with sample 7 decreasing 11.16% to 6.36% for sample 6. Significant F values ($P < .01$) were obtained for the tests of common lines and parallel regression lines for both the length and weight data. Because a common line does not exist for each method of thawing, any differential effects due to thawing in air as opposed to thawing in water were not evident and could not be tested. Individual regression lines and confidence limits for the slopes for samples 1 through 7 for both length and weight are given in Table 3.

Brine and Brine-Freezing Effects on Length and Weight

Six samples of fish (8 through 13) were taken and placed in brine solutions and then frozen (Table 1). These fish were measured and weighed fresh, after brining, and after freezing. Samples 8 through 11 were held in a 16% salt (1.116 specific gravity at 20°/4°C) brine for 19 to 22 hours, measured and weighed and immediately frozen. After brining the average length decrease was 3.56% with the samples varying from 3.15% to 4.20% (Table 2).

The average weight decrease after brining for samples 8 through 11 was 4.76% with the individual samples varying from 3.54% to 5.15%. Weber (1921) held herring in a 23.5% (specific gravity of 1.1729) brine for 8 hours and found that the weight of the fish decreased 8.2%. This greater percentage decrease was apparently due to the stronger brine solution indicating that time in brine is of minor significance when compared with brine strength.

After one month samples 8 and 9 were thawed in air and samples 10 and 11 were thawed in water. However, there was a greater disparity within samples thawed in air and water than between samples. For example, samples 9 and 11 decreased an additional 1.23% and 0.45% in length respectively since brining while samples 8 and 10 increased in length 0.43% and 0.19% respectively. Samples 9 and 11 decreased an additional 4.34% and 0.80% in weight while samples 8 and 10 decreased 20.81% and 8.70% respectively. This disparity was apparently due to fish size. Samples 8 and 10 contained fish with natural total length ranges of 110 to 165 mm and 107 to 157 mm, respectively. The fish in samples 9 and 11 were larger with length ranges of 209 to 241 mm for sample 9 and 211 to 239 mm for sample 11. As the smaller fish thawed they lost a greater percentage of their body weight than the larger fish but at the same time increased slightly in length. All changes in length and weight were significant ($P < .01$) by the paired t test except the 0.19% length increase for sample 10 caused by freezing. The length regressions due to brining for samples 8 through 11 were not the same ($P < .01$) and were not parallel ($P < .05$). After freezing, the regression lines for the additional changes in length were the same for samples 8 and 10 but different ($P < .01$) for samples 9 and 11 although parallel. The weight regressions due to brining for samples 8 through 11 were also significantly different ($P < .01$) and were not parallel ($P < .05$). After freezing, the regression lines for the additional changes in weight were significantly different (.01) for all four samples. All regression lines were parallel ($P < .25$), however.

The length and weight regressions and the 95% limits for individual Y values for the combined samples 8 through 11 are given in Fig. 2. The 95% confidence limits for the grouped length slope are 1.0226 and 1.0322. The limits for the weight data are 1.0494 and 1.0554.

Samples 12 and 13 were held in 5.5% salt (1.038 specific gravity at 20°/4°C) brine for 23 and 67 hours, respectively. In both cases the fish gained in weight and lost in length. Sample 13 which was held in brine almost three times longer than sample 12 increased in weight 12.09% and decreased in length 2.45%. Sample 12 increased 8.84% in weight while decreasing 2.45% in length. Covariance tests for common lines and parallel lines produced significances ($P < .01$) in all cases except for the test for parallel lines for the weight data. Apparently the brine was not strong enough to replace the water in the tissues of the fish and the fish gained in weight due to the addition of water. Reay (1936) showed that in concentrations of brine up to 8% (1.056 specific gravity of 20°/4°C) a definite increase in weight took place, i.e., up to 30% in 10 days. Table 3 gives individual regression lines of length and weight and slope confidence limits for the effects due to brining for samples 8 through 13.

Sample 12 reacted to the freezing process in the same manner as samples 1 through 7 which had not been held in a brine solution. The length decreased an additional 3.14% after brining as compared with an average value of 3.09% for samples 1 through 7 and 0.40% for brined samples 8 through 11. The weight, however, decreased an additional 10.20% as compared with 4.70% for samples 1 through 7 and 4.92% for samples 8 through 11. While this weight decrease was greater than samples 1 through 7 or 8 through 11 it probably was related to the large gain in weight obtained while soaking in the light brine solution. Sample 13 was not frozen but discarded after brining. The individual regression lines and slope confidence limits for the effects due to brining and freezing are given in Table 3. All changes in length and weight due to brining, freezing or both were significant.

Salt and Salt-Freezing Effects on Length and Weight[1]

Samples 14 and 15 were held in dry salt to test for maximum shrinkage for 21 and 20 hours, frozen and thawed in air and water, respectively. The salt caused a decrease in weight of 28.52% for sample 14 and 27.89% for sample 15 (Table 2). The change in length was 3.69% for sample 14 and 4.68% for sample 15. Although the length regression lines were parallel the Y intercepts were different ($P < .01$) so that a common line could not be fitted to the data. The regression lines for the weight data were identical, however. All changes in length and weight due to the salt were significant. Freezing restored some of the length; 0.14% in the case of sample 14 and 0.73% for sample 15. This caused an overall decrease from fresh to frozen of 3.56% for sample 14 and 3.99% for sample 15. Freezing caused the weight to decrease further; 11.14% in the case of sample 14 and 2.42% for sample 15. The overall change from fresh to frozen was a reduction of 36.48% for sample 14 and 30.31% for sample 15. All changes in length and weight were significant ($P > .01$) except the length increase (0.14%) from brining to freezing for sample 14. All regression lines were parallel but differed in elevation ($P > .01$). The individual length and weight regression lines and slope confidence limits for the effects of salting, and salting and freezing combined, are given in Table 3. Fig. 3 gives the combined sample regression lines for changes in length and weight caused by salting. The 95% slope confidence limits for the grouped length data are 0.9137 and 0.9835. For the grouped weight data they are 1.2215 and 1.3015.

In 1951 similar experiments on length and weight changes were conducted at this laboratory including changes in cooking, drying, etc. Two samples of herring (100 fish total) were held in dry salt for 17.5 hours. The length and weight ranges of the fresh fish were 91 to 178 mm and 6.7 to 65.5 g. The average decrease in length and weight was 3.78% and 20.[illegible]%, respectively. Nikkilä (1951) salted herring (mean weight of 34 g an[illegible]20 to 180 mm) with various quantities of salt and found that the minimum weight was reached in 2 to 3 days after a shrinkage of about 20% in weight.

Conclusions:

The use of length composition data in age-length keys, length frequency modes, etc. can be seriously biased by the processes of freezing, brining and salting. In this study the freezing process along (-16°C for 3 months) decreased the total average length of a 100-fish sample by 3.1% and the weight by 4.7%. When herring were held in brine for about 20 hours the length decreased by 3.6% and the weight decreased 4.8%. Freezing the fish after they had been brined resulted in a small length increase (0.3%) for small fish (107-165 mm) and a small decrease (9.8%) for large fish (209-241 mm). The small fish lost an additional 14.7% in weight due to freezing while the larger fish lost an additional 2.6%. Holding the fish

[1]The salt used in these experiments was "Watkins Granulated Salt" from the Watkins Salt Company, Watkins Glen, N.Y.

in dry salt (20-21 hours) caused the biggest decrease in length and weight. The average weight loss was 28.2% with the length decrease 4.2%. Freezing the fish after salting increased the total length slightly (0.4%) and further decreased the weight by 7.3% to a total of 33.4%, a very significant change.

Weight-length regressions were computed for each sample before and after freezing, brining or salting to test for changes in the allometry coefficient (exponent in weight-length growth formula) but no pattern to the changes was evident. The value for the exponent decreased for 9 samples and increased for six with the greatest change occurring with sample 8 where after an almost equal length and weight percentage change due to brining alone, the freezing process caused a small increase in length (0.4%), but a very large decrease (20.8%) in weight. This caused the exponent to increase from 3.01 to 3.63. The average absolute change, however, was only 0.14.

When comparing the lengths and weights of the fish before and after freezing, brining or salting through the use of paired t tests, significant differences were obtained in all cases ($P < .01$) except the weight change in sample 2 due to freezing, the length change in sample 10 due to freezing after brining and the length change due to freezing after salting for sample 14.

Of the 22 length regression lines given in Table 3, only 5 slopes were significantly different ($P < .05$) from 1. Thirteen of the 22 slopes for weight regressions were significantly different from 1. A slope of 1 indicates that the length and weight is reduced by a given amount regardless of size (within the limits of the experiment) and that the percentage shrinkage decreases with increase in fish size.

Because of the numerous significances between samples throughout the experiments it was difficult to statistically compare the effect on changes in length and weight by thawing at room temperature against thawing in water. The percentage length decrease when thawed in air was less than that obtained from thawing in water for the freezing experiment (samples 1 through 7) but greater for the brining and salting experiments. The weight change was greater in all experiments for the samples thawed in air. When all of the experiments were combined the weight decrease was 7.4% for samples held in water and 15.1% for samples thawed in air. The length decreases were nearly the same.

This study has pointed out the need for further examination of length and weight changes due to freezing, brining and salting by sizes of fish, intermediate brine strengths (10% to 14% salt) and the thawing method. The brine strengths were nearly extremes since effects of brining on length and weight were unknown. In order to apply corrections to the routine sample data the amount of length and weight changes due to the various individual plant brines remains to be defined. Most of the fish used in this study were 12 to 18 cm in total length and further testing will be done of both larger and smaller fish in lieu of extrapolation. It was also felt during the study that the time elapsed after the fish were caught until they were frozen was an important factor in the length and weight changes. Since this time varied slightly due to the examination of large batches of fish, additional tests will be conducted with fish of one size measured at exactly the same time after death in an attempt to remove some of the individual sample variability. Eventually suitable regression lines will be constructed according to brine strengths and the time the fish are held either fresh, salted or brined prior to being frozen. These regression lines will then be used to correct the routine sample data either as individual fish or as summary data according to fish sizes.

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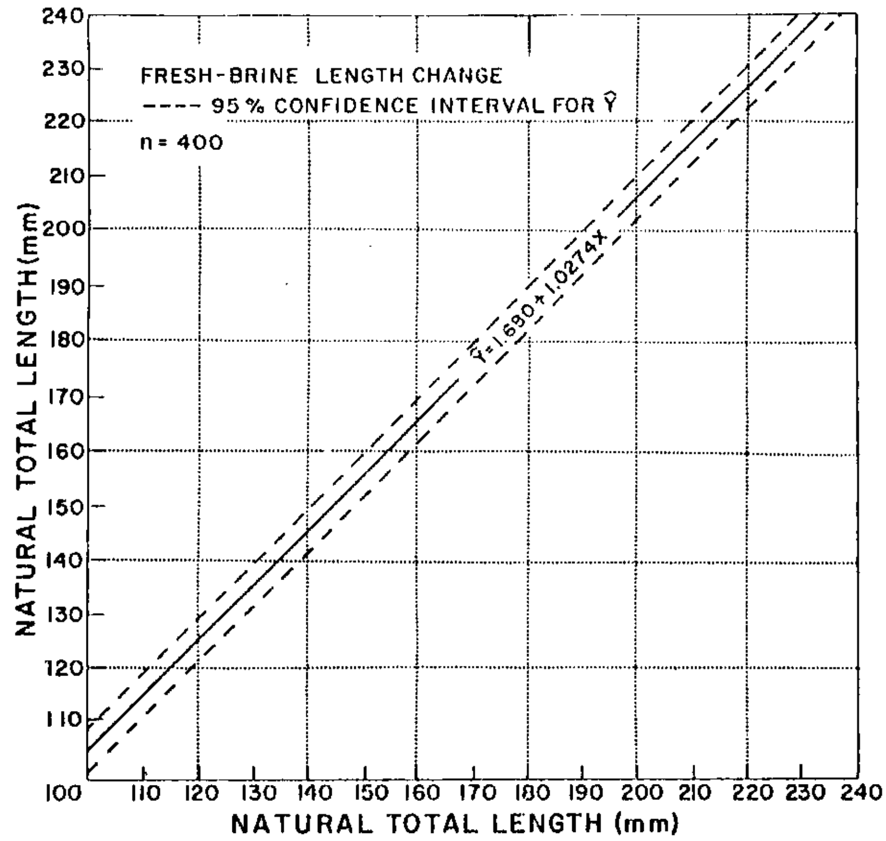
Table 2. Total Sample Percent Changes in Length and Weight due to Freezing, Brining and Salting.

Sample	Percent Length Change			Percent Weight Change		
Freezing only			Fresh-Frozen			Fresh-Frozen
1			-4.10			-0.45
2			-3.78			-0.13
3			-3.41			-5.97
4			-2.40			-4.66
5			-3.35			-1.81
6			-4.46			-6.36
7			-1.25			-11.16
Brining and Freezing	Fresh-Brine	Brine-Frozen	Fresh-(Brine)-Frozen	Fresh-Brine	Brine-Frozen	Fresh-(Brine)-Frozen
8	-4.20	+0.43	-3.79	-4.94	-20.81	-24.72
9	-3.49	-1.23	-4.67	-5.15	-4.34	-9.28
10	-3.15	+0.19	-3.22	-3.54	-8.70	-11.93
11	-3.34	-0.45	-3.77	-4.63	-0.80	-5.40
12	-1.89	-3.14	-4.97	+8.84	-10.20	-2.26
13	-2.45	-	-	+12.09	-	-
Salting and Freezing	Fresh-salt	Salt-Frozen	Fresh-(Salt)-Frozen	Fresh-Salt	Salt-Frozen	Fresh-(Salt)-Frozen
14	-3.69	+0.14	-3.56	-28.52	-11.14	-36.48
15	-4.68	+0.73	-3.99	-27.89	-2.42	-30.31

Table 3. Regression Lines and 95% Slope Confidence Limits for Effects of Freezing, Brining, Brining and Freezing, Salting and Salting and Freezing.

Sample	Method of Holding*	Natural Total Lengths: Regression lines ($\hat{Y}$)	Natural Total Lengths: Slope Limits	Weights: Regression Lines ($\hat{Y}$)	Weights: Slope Limits
1	F	7.64+0.9897X	(0.9566, 1.0228)	1.0061X-0.03	(0.9967, 1.0155)
2	F	2.67+1.0212X	(0.9993, 1.0431)	0.31+0.9802X	(0.9315, 1.0289)
3	F	6.61+0.9917X	(0.9587, 1.0247)	1.39+0.9893X	(0.9568, 1.0218)
4	F	10.80+0.9527X	(0.9203, 0.9851)	1.85+0.9509X	(0.9245, 0.9773)
5	F	0.65+1.0346X	(1.0136, 1.0556)	1.0190X-0.03	(0.9000, 1.1380)
6	F	7.10+0.9964X	(0.9651, 1.0277)	0.62+1.0313X	(1.0171, 1.0455)
7	F	1.0556X-6.53	(1.0137, 1.0977)	0.65+1.0872X	(1.0588, 1.1156)
8	B	3.20+1.0192X	(0.9629, 1.0755)	1.16+0.9929X	(0.9760, 1.0098)
9	B	10.76+0.9867X	(0.9500, 1.0234)	1.04+1.0408X	(1.0174, 1.0642)
10	B	2.05+1.0197X	(0.9790, 1.0604)	1.06+0.9814X	(0.9645, 0.9983)
11	B	14.90+0.9667X	(0.9124, 1.0210)	1.13+1.0342X	(1.0017, 1.0667)
12	B	2.88+1.0018X	(0.9842, 1.0554)	0.9617X-0.94	(0.9309, 0.9925)
13	B	1.0757X-7.89	(0.8335, 1.3179)	0.9245X-0.63	(0.8763, 0.9727)
8	B-F	4.79+0.9625X	(0.9299, 0.9951)	3.45+1.0330X	(0.9681, 1.0979)
9	B-F	0.05+1.0122X	(0.9748, 1.0496)	3.31+1.0002X	(0.9800, 1.0204)
10	B-F	1.08+0.9893X	(0.9601, 1.0185)	0.60+1.0601X	(1.0514, 1.0688)
11	B-F	2.23+0.9943X	(0.9475, 1.0411)	0.58+1.0007X	(0.9854, 1.0160)
12	B-F	6.15+0.9973X	(0.9582, 1.0364)	15.14+1.0440X	(1.0064, 1.0816)
14	S	9.00+0.9721X	(0.9260, 1.0182)	1.90+1.2722X	(1.2149, 1.3295)
15	S	14.50+0.9457X	(0.8959, 0.9955)	2.10+1.2448X	(1.1888, 1.3008)
14	S-F	6.34+0.9930X	(0.9377, 1.0483)	5.41+1.1566X	(0.9589, 1.3543)
15	S-F	9.58+0.9724X	(0.9234, 1.0214)	0.62+1.3913X	(1.3166, 1.4660)

*F = Freezing, B = Brining, B-F = Freezing after brining, S = Salting, S-F = Freezing after salting.



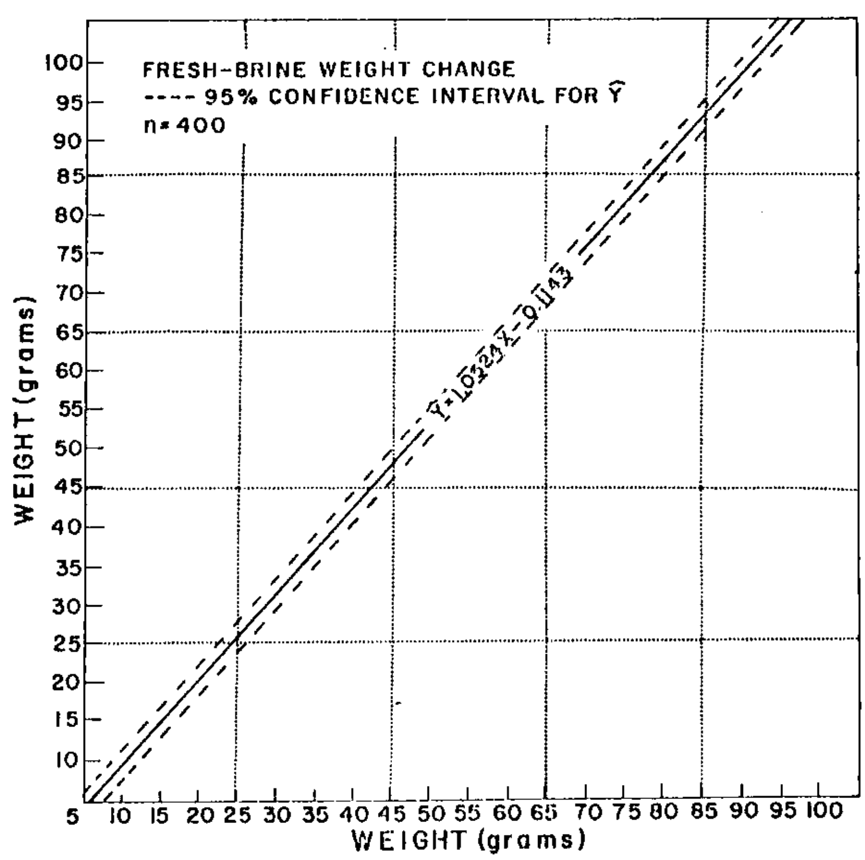
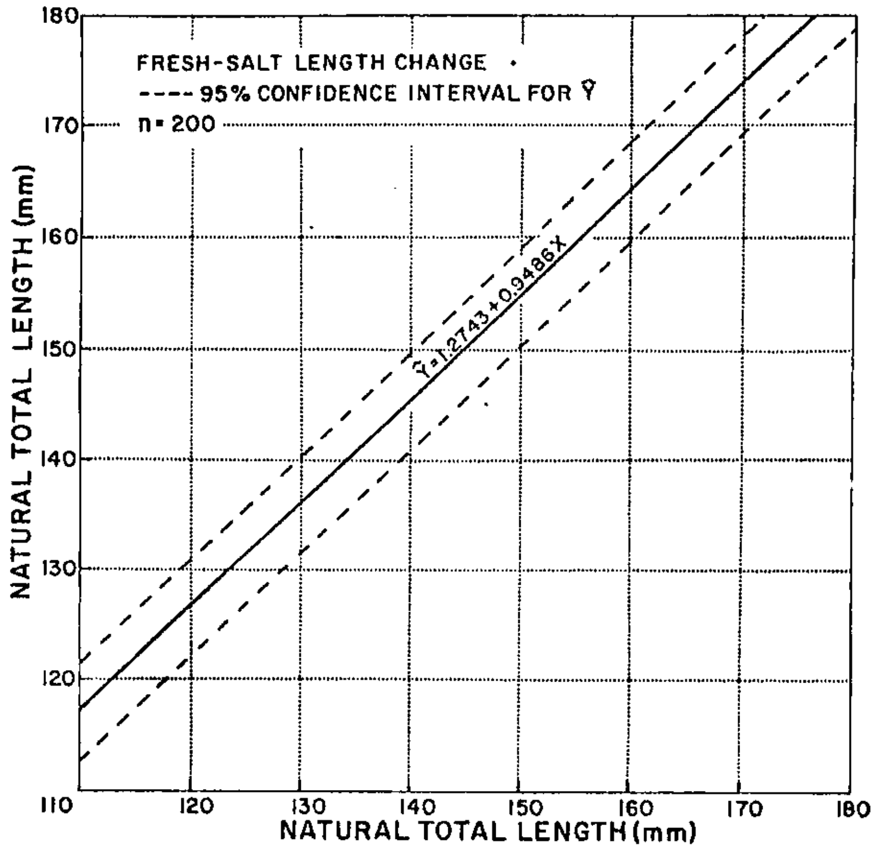


Figure 2. Regression lines and individual $\hat{Y}$ confidence intervals for length and weight changes due to brining.



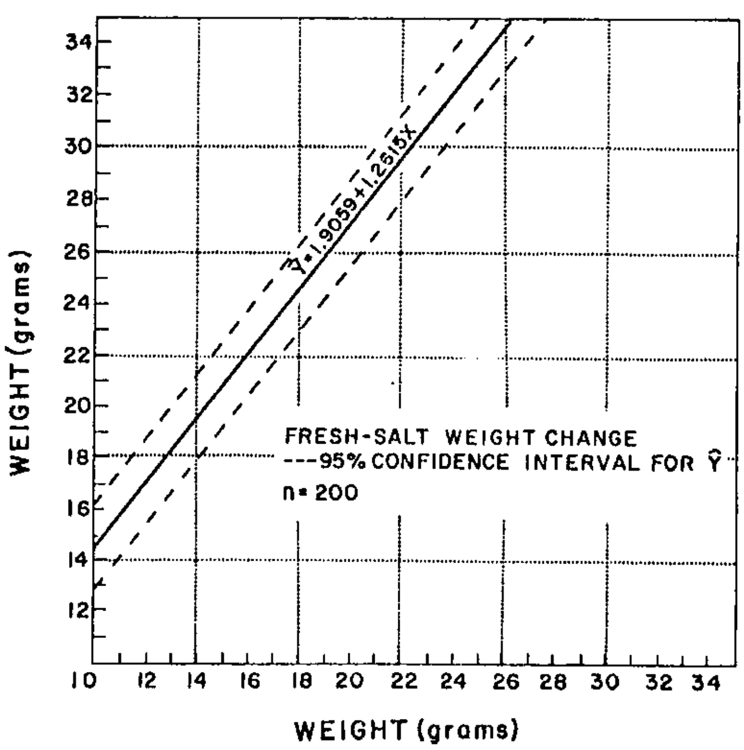


Figure 3. Regression lines and individual $\hat{Y}$ confidence intervals for length and weight changes due to salting.

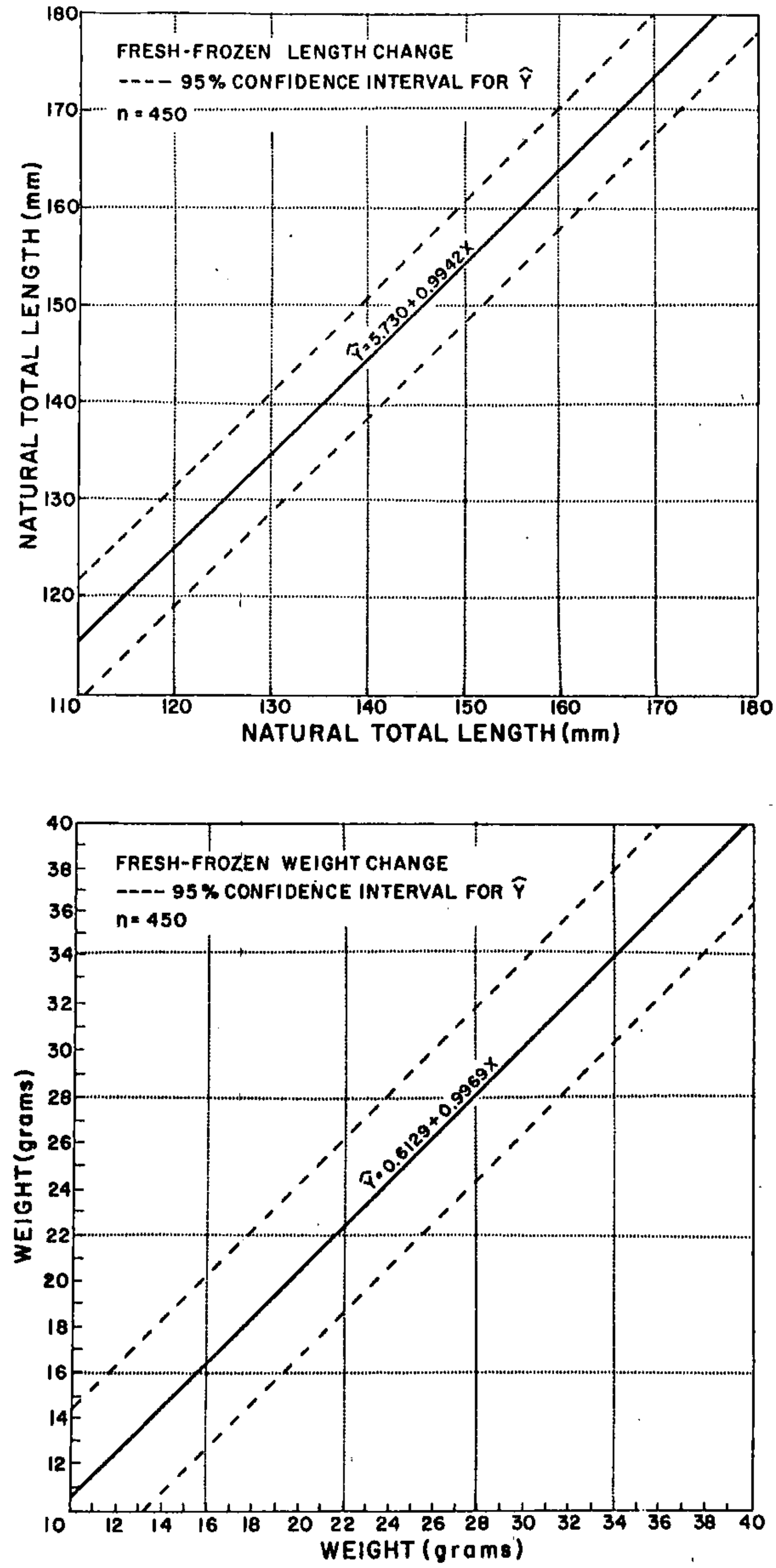


Figure 1. Regression lines and individual $\hat{Y}$ confidence intervals for length and weight changes due to freezing.