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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

Length-Weight Relations of Haddock from Commercial Landings in New England, 1931-55

BRADFORD E. BROWN AND RICHARD C. HENNEMUTH

SEATTLE, WA.
August 1971

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LENGTH WEIGHT RELATIONS OF HADDOCK FROM COMMERCIAL LANDINGS IN NEW ENGLAND, 1931-55

By

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ABSTRACT

Length-weight relations (including the conversion of dressed to live weight) are needed to study the population dynamics of haddock on Georges and Browns Banks. Analyses of covariance were used to compare these relations among market categories, years, fishing areas, and months. There was considerable variation among samples taken on different trips and among subsamples taken on a single trip. Separate regression lines are recommended for market categories (large and scrod) and for Georges and Browns Banks. No yearly or seasonal trends were evident. Estimating equations are presented.

INTRODUCTION

Samples of length and weight measurements of haddock in commercial landings of United States otter trawlers were collected in several of the years from 1931 to 1955. A large part of these data was examined by Clark and Dietsch (1959), who reported that seasonal trends were evident in the length-weight relationships, and presented sets of weight at length tables for each month by special sampling areas (Figure 1) which have been used to convert length to weight in routine estimates of haddock statistics. It was desirable, however, to conduct a more critical and comprehensive analysis of all available length-weight data for haddock, particularly since studies of the dynamics of the haddock fishery depend on the use of these data to estimate from length-frequency samples and weight of landings the number landed. In the present study, variation among size categories, years, areas, and months was estimated, and statistical tests were applied to determine the degree of homogeneity and the most appropriate length-weight equations to be used in the study of population dynamics of haddock.

The estimation of factors for converting dressed weights, gutted or gilled and gutted, to live weight is also included.

COLLECTION OF DATA AND METHODS OF ANALYSIS

All measurements were taken from fish landed at the Port of Boston. Fork lengths were recorded to the nearest centimeter and weights to the nearest 0.1 pound. Haddock were landed either gutted, or gutted and gilled. From April to November the fish were required to be gutted and gilled, and they were frequently so treated in the winter months also. Only the data from the gutted and gilled

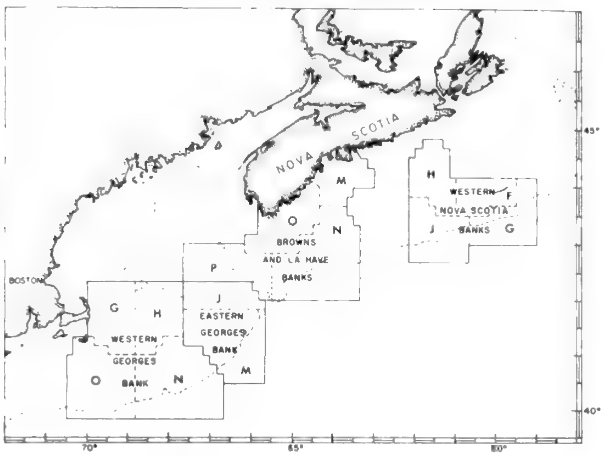

Figure 1.—Sampling areas.

category were sufficient for analysis. Commercial catches were sorted into scrod (those fish under approximately 2.5 pounds) and large size categories at sea by the fishermen. Fish of each size category were unloaded from the vessels in carts of about 500-pound capacity. A sample was composed of varying numbers of fish taken from one or more of these carts from a single vessel's trip.

There were 82 samples collected over the years for a total of 7,774 measurements. The distribution of these samples among the various factors is presented in Table 1. The geographical areas are outlined in Figure 1.

Samples were not taken in strictly random fashion. In order to treat these data statistically, we must assume the samples taken from each boat's catch to be representative of the total catch and the boats sampled were representative of all boats fishing.

To study the relation of dressed to round weights, lengths and weights of individual fish were recorded at sea while fresh and at the dock after the fish had been dressed and stored aboard commercial vessels for periods up to 10 days. In one case both sets of measurements were made at dock side. There were nine samples of fish with measurements of gutted and round weights, and two samples with gutted and gilled, and round weights (Table 4).

For the length-weight regressions, an equation of the form $W = cL^b$ was assumed, where:

W = weight in pounds, to the nearest tenth,

L = fork length in centimeters, and

c and b are constants to be estimated.

Regressions were fitted by the least squares method to the equation $Y = a + bX$, where:

$Y = \log_e W$

$X = \log_e L$

$a = \log_e c$

It is realized that the least squares fit to this equation is not the same as the least squares fit to the untransformed equation; however, it is convenient to deal with the linear form The regression statistics for each sample are given in Appendix A1. Notations for regressions and covariance analyses throughout this report follow Snedecor (1956). The term significant refers to a probability level less than 0.05.

Inadequate distribution of samples prevented the use of a factorial analysis to determine the existence and significance of interactions among the factors. Therefore, where data permitted, a separate analysis of covariance among the levels of a given factor (e.g., among years) was run within each of the other factor combinations, and the series of analyses thus obtained were pooled to yield a single result.

An approximate F test was used to take subsample variation into account when tests were made using samples from a single trip. The mean squares for the differences in regression coefficients and adjusted means were divided by the corresponding mean squares for differences among subsamples taken from Appendix Table A2 (see Appendix Table A3).

Since many of the sample cells (Table 1) contain only one or two samples, comparisons among them would not provide for adequate estimates of error variance. It seemed best to pool all the available estimates of sample-to-sample variation to provide a single denominator for all tests. In these cases the denominators in the F tests were the estimates of variations among samples taken from Appendix Table A3 (see Appendix Table A5).

In this paper, the term Approximate F Test refers to either of the aforementioned ratios. Because of the variable sample numbers, the probability levels are not exact, and thus the use of term approximate.

Table 1.—Number of trips sampled for haddock length-weight study.

Region	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Sept.	Dec.
Western	1931	1/1*	3/1	—	—	—	2/1	3/1	—	/1
Georges	1932	2/2	—	—	—	—	5/1	1/1	—	—
Bank	1933	—	—	1/	—	—	—	—	—	—
	1942	—	—	/1	—	—	—	—	—	—
Eastern	1931	—	5/	—	—	—	4/	—	3/3	/1
Georges	1932	1/1	—	—	1/	—	—	1/1	—	—
Bank	1941	—	—	—	—	—	—	—	—	2/1
	1942	—	—	3/3	5/	—	—	—	—	—
Browns	1931	—	—	—	—	1/	—	—	—	—
Bank	1932	—	—	—	1/	—	—	—	—	—
and	1933	—	—	2/	—	—	—	—	—	—
La Have	1942	—	—	2/1	1/	—	—	—	—	—
Bank	1955	—	—	1/1	1/1	—	—	—	—	—
Western	1931	—	—	—	—	—	—	1/	—	2/1
Bank of	1941	—	—	—	—	—	—	—	—	1/
Nova	1942	—	—	—	1/1	—	—	—	—	—
Scotia										

*large market category/scrod market category

When utilizing covariance analyses it is always possible that the difference is not due to the factor examined, for example area, but to some other factor. One possible confounding factor could be the different size of fish within the market category being examined contributing to differences in length-weight equations. The mean ln length of the samples are given in Appendix Table A1 and visual examination of these values does indicate large differences in the size of the different samples.

ESTIMATION OF SAMPLING VARIATION

Subsamples

The samples used in these pooled analyses were known to consist of fish from several carts for each trip. However, the data for each cart (subsample) were not recorded separately.

In April, 1942, landings of five trips from eastern Georges Bank were sampled in an attempt to measure variation within trips, i.e., among subsamples. These samples were taken over a 10-day period from landings of boats fishing in the same section of eastern Georges Bank in depths of 45 to 55 fathoms. Each subsample was composed of 25 fish taken from a single cart, and from four to eight subsamples were taken from each trip. All of these fish were in the large size category.

The analysis of covariance among subsamples is presented in Appendix Table A2. There was a significant difference among the adjusted means of the subsamples. The mean square among samples (trips) was not significant.

The differences found between subsamples could have been the result of varying lengths of time or the position that the fish were kept in the hold. Also, each part may have contained fish caught in different sections of the general area that the boat fished in.

The mean square for among subsamples is twice as large as that among samples. The assumptions of the model would be violated if, in fact, the difference was significant. The inverted F-ratio $(0.01222/0.0065 = 1.88)$, with 58 and 8 degrees of freedom does not, in fact, exceed the tabular F at the 5 percent probability level.

We may conclude that sample to sample variation is negligible. This is not surprising because the short time period and restricted area of collection would lead to time-area variations of catches within all the sampled trips to be the major source of error.

We shall utilize these estimates of subsample variations to test the significance of sample-to-sample variation in subsequent analyses.

Samples (between trips)

Analyses of covariance among samples were computed for each cell (each combination of given year, area, month, and size category) containing more than one sample (cf. Table 1). The pooled analysis of covariance showed significant adjusted mean differences among samples, or trips, for both large and scrod size categories (Appendix Table A3). The among sample mean squares of large and scrod haddock for this pooled analysis (0.0364 and 0.0369) were greater than that among the five samples used in the analysis of subsample variation (0.0065, cf., Table A2). This may have occurred because the five special samples came from a more restricted time and area within the sampling area than the general samples. The among sample mean square is also about five times larger than the within sample or common mean squares which are used for testing in a one-stage analysis.

COMPARISON AMONG FACTOR LEVELS

Size Categories

To determine whether separate length-weight equations should be used for scrod and large haddock, covariance analyses were computed for 16 trips from which both size categories were sampled. The pooled analysis is presented in Appendix Table A4; significant differences were found for adjusted means. Only subsample variation need be accounted for in this analysis as comparison was between large and scrod samples from the same boat.

The adjusted means were calculated and compared for each of these pairs of regression equations. In all cases the adjusted mean was greater for large than for scrod haddock (Table 2). The observed differences are to be expected if the fish were sorted primarily on the basis of heavy appearance, i.e., within the range of cull-sizes the short, plump fish would be considered large whereas the longer, slender individuals would be classed as scrod.

Table 2.—Natural logarithms of adjusted mean weights (pounds) for samples of large and scrod haddock.

Pair Number	Adjusted means for large haddock	Adjusted means for scrod haddock
1	0.8117	0.7597
2	1.2468	1.2221
3	0.8384	0.8359
4	1.0587	0.9788
5	0.7705	0.7378
6	1.0844	1.0240
7	0.9742	0.9438
8	0.8334	0.7952
9	1.0232	0.9705
10	1.1383	1.1261
11	1.1332	1.1171
12	1.0552	0.9996
13	1.1713	0.9983
14	1.0661	0.9674
15	0.6554	0.6228
16	1.1104	1.0369

Years

An analysis of covariance among years was computed within each month, area, and size category classification containing samples from two or more years. For example, comparisons between 1931 and 1932 were made for the western Georges Bank area in each of the months January, June, and July. A single regression equation was used for each year, combining several samples where required. The several analyses were then pooled and no significant differences were found when the differences among samples were taken into consideration in the Approximate *F* Test (Appendix Table A5). As the years tested contained time differentials from 1 to 22 years, both short- and long-term changes appear nonsignificant.

Areas

Comparisons were made between samples from eastern and western Georges Bank within year, month, and size category strata in the same manner as described above. No significant differences were found when the Approximate *F* Test using sample-to-sample differences was applied (Appendix Table A6).

The same procedure was followed to test

Table 3.—Duncan multiple range test between months for large haddock from Georges Bank (underlined values are homogeneous groups).

Months	Jan.	July	Mar.	Feb.	Sept.	June	Apr.	Dec.
Adjusted means	1.4893	1.4154	1.2744	1.2149	1.2053	1.1572	1.1336	1.0874
Individual comparisons of adjusted means	———	———						
			———	———	———			
				———	———	———		
					———	———	———	———

differences between samples from Browns Bank and the western banks of Nova Scotia. No significant differences were found between these areas (Appendix Table A7). However, comparisons were only possible between two samples for each size category.

A further series of covariance analyses were made between samples from Georges Bank and those for the Nova Scotian area within year and month and size category strata. The pooled analysis for large haddock showed a significant difference in adjusted means in the Approximate F Test (Appendix Table A8).

Months

To investigate the variation between months, all samples of large haddock from Georges Bank were utilized for each month, as yearly and area differences had been shown to be nonsignificant. Only for this size category and area were there enough data for a meaningful comparison. These monthly regressions were tested by covariance analyses and significant differences were found among adjusted means (Appendix Table A9). The adjusted monthly means of the $\log_e$ weights were then computed and compared using the multiple range test of Duncan (1955) with Kramer's (1956, 1957) adjustment for unequal sized samples and Finney's (1946) approximation for the variance term. There were no seasonal trends evident (Table 3). The lack of a seasonal trend is contrary to the conclusion of Clark and Dietsch (1959).

CONVERSION OF DRESSED AND ROUND WEIGHT FOR HADDOCK

In the United States, haddock are almost invariably landed in a dressed condition. For certain reports and research studies, it is necessary to use round (whole) weights. This section presents results of an analysis of available data to determine an estimator for converting dressed weights to round weights.

Lengths at Sea Versus Lengths Ashore

The average length of the 199 fish was 524 mm with a standard error of 8.0 when measured fresh at sea and was 521 mm with a standard error of 7.9 when measured after landing. The ratio of length measured at sea to that on shore was 1.005. The mean of the difference between the paired measurements was found to be within the realm of normal error of measurement and, thus, fresh measurements only were used in analysis.

Difference Between Round and Dressed Weight

The ratio of round weight (Y') to dressed weight (Y) for given length (X) may be written:

$$\frac{Y'}{Y} = \frac{C'}{C} X^{(b' - b)}, \text{ or} \qquad (1)$$

$$\log_e \frac{Y'}{Y} = \log_e \frac{C'}{C} + (b' - b) \log_e X. \qquad (2)$$

Linear regressions of (2) for each sample are presented in Table 4.

If the ratio of round to dressed weight does not differ with length, the slope of the regression ($b' - b$) would equal zero, and the antilogarithm of $\log_e \frac{C'}{C}$ would be an estimate of

Table 4.—Sample regressions of ratio of round to dressed weight on length.

Sample	Year	Month	No.	$\log_e \frac{C'}{C}$	$(b' - b)$	$S(b' - b)$	Mean ratio at mean length
Gutted							
1	1942	Apr.	46	-1.140	0.301*	0.122	1.16:1
2	1953	May	29	-0.419	0.151*	0.061	1.16:1
3	1953	June	22	0.151	0.010	0.072	1.21:1
4	1953	June	20	0.147	0.006	0.080	1.19:1
5	1953	Dec.	34	0.098	0.009	0.092	1.14:1
6	1954	Jan.	25	0.052	0.017	0.203	1.13:1
7	1954	Jan.	22	-1.075	0.291	0.176	1.12:1
8	1954	Feb.	23	-0.066	0.059	0.180	1.18:1
9	1954	June	39	-0.314	0.122	0.070	1.14:1
Total				0.129	0.004	0.020	1.16:1
Gutted and gilled							
1	1942	Apr.	21	-0.621	0.192*	0.060	1.17:1
2	1954	Apr.	46	-1.171	0.333	0.208	1.22:1
Total				-0.595	0.187*	0.061	1.20:1

*Significantly greater than zero ($P \leqslant .05$)

the desired conversion factor. Three of the 11 samples were found to have slope values $(b' - b)$ significantly greater than zero, and all samples had positive slopes. The slightly positive slopes, when extrapolated to zero length, gave negative or very low intercept values, which means a ratio of round to dressed less than or near unity, even though the total regression coefficient was not significantly greater than zero. Therefore, because landed fish range only from 40 to 80 cm, it is appropriate to use the mean ratios of round to gutted weight at the mean length of the samples (Table 4). No seasonal trends were evident. Thus, the overall ratio of 1.16:1 appears to be the best available estimate for converting gutted to round weights. The overall ratio estimated for converting gutted and gilled weight to round weight was 1.20:1.

In order to use the length-weight equations to estimate round weights, the following adjustments should be made:

$$\log_e Y' = \log_e C + 0.1442 + b \log_e X$$

for gutted, and

$$\log_e Y' = \log_e C + 0.1857 + b \log_e X$$

for gutted and gilled

$\log_e C$ is the intercept and b the coefficient of the regression of dressed weight on length.

CONCLUSIONS

Several conclusions were evident from these analyses:

1. Subsample differences were significant.
2. Large differences existed among samples (trips) within strata.
3. The sorting of fish into scrod and large categories produced significantly offset regression lines.
4. Year-to-year changes were not significant.
5. Samples within Georges Bank and Nova Scotian regions were homogeneous.
6. Differences were found between the Georges Bank and the Nova Scotian region.

7. Seasonal trends were not present.
8. The best available equations for converting dressed to live weights utilize the mean ratios of round to gutted lengths at the mean length of the samples.

Estimating equations and standard errors for scrod and large haddock from Georges Bank and from the Nova Scotian area are set forth in Table 5. A length-weight conversion table based on these equations is given in Appendix Table A10. It will be noted that all four equations estimate very similar weights for the same length. The loss of precision in using the total regression equations rather than using the separate equations derived from a sample from each trip is estimated in Table 6. The highest of these ratios of respective mean squares indicates a 43 percent loss. However, it would be impractical to try to obtain a regression equation for each trip landed, and for past data, this, of course, is impossible. There is no apparent statistical justification for using finer breakdowns into year or area strata, and samples for each month are not available. Such differences that may actually be present between these categories were obscured by the large variation among samples.

The differences found in the length-weight regressions between Georges Bank and the areas off Nova Scotia considered in this paper agree with other evidence on the separation of these stocks of haddock. Grosslein (1962) reported that tag returns indicated a small degree of movement between these two regions. Hennemuth *et al.* (1964) found growth rates of haddock collected from southern and central Nova Scotia to be similar to each other but differing from those on Georges Bank.

In view of the large sampling error, the use of length-weight regressions to compute the numbers of fish in the catch is inefficient. Since for this purpose what is needed is the average weight per fish in the length-frequency samples, a better procedure would be to obtain the total weight of all fish measured and divide by the number of fish to calculate the average weight per fish in each sample.

Table 5.—Regression statistics for haddock length-weight estimating equations ($\log_e$ units).

Description	Equation	Standard error of Y
Large haddock from Georges Bank	[1] $Y = -10.0580 + 2.8053X$	±0.0014
Scrod haddock from Georges Bank	[2] $Y = -9.2184 + 2.5864X$	±0.0027
Large haddock from Nova Scotia area	[3] $Y = -10.6191 + 2.9389X$	±0.0027
Scrod haddock from Nova Scotia area	[4] $Y = -9.4570 + 2.6362X$	±0.0043

1 Antilog$_e$ of a = 0.00004284

2 Antilog$_e$ of a = 0.00009920

3 Antilog$_e$ of a = 0.00002444

4 Antilog$_e$ of a = 0.00007814

Table 6.—Loss of precision in using total regression equations.

Category	Within sample mean square	Mean square for the total regression	Ratio total/samples	Number of Samples
Georges Bank large haddock	0.0072	0.0103	1.43	43
Georges Bank scrod haddock	0.0070	0.0090	1.28	20
Nova Scotia large haddock	0.0080	0.0089	1.11	14
Nova Scotia scrod haddock	0.0065	0.0065	1.00	5

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APPENDIX

Table A1.—Regression statistics of samples of haddock length-weight measurements.

Region	Area	Year	Month	Category	Mean ln length	No. of fish	Σx^2 [1]	Σxy [2]	Σy^2 [3]	SS [4]	MS [5]	b	a
Western Georges Bank	N*	1931	Jan	Large	4.041	97	0.697	1.996	6.273	0.5518	0.0058	2.866	-10.2213
	G	1932			4.060	194	1.485	4.392	13.877	0.8869	0.0046	2.958	-10.6201
	H				4.072	125	1.246	3.458	10.288	0.6943	0.0056	2.775	-9.8851
	GHNO	1931	Feb		4.062	94	0.712	2.002	6.244	0.6122	0.0067	2.812	-10.1013
	GHNO				3.965	73	0.684	1.905	5.774	0.4675	0.0066	2.785	-9.9533
	N				4.046	96	0.646	1.719	5.318	0.7408	0.0079	2.663	-9.5076
	N	1933	MAR		4.045	169	1.347	3.734	11.423	1.0741	0.0064	2.771	-9.9096
	GHNO	1931	Jun		4.020	201	1.819	4.950	14.722	1.2523	0.0063	2.721	-9.7826
	GHNO				4.133	143	1.195	3.350	10.676	1.2876	0.0091	2.803	-10.0235
	N	1932			4.031	50	0.850	2.468	7.508	0.3357	0.0070	2.906	-10.4949
	N				4.014	49	0.648	1.683	4.617	0.2425	0.0052	2.599	-9.1899
	N				4.041	50	0.864	2.374	6.719	0.1950	0.0041	2.748	-9.8133
	N				4.013	50	0.721	1.981	5.664	0.2252	0.0047	2.746	-10.1101
	H				4.088	62	0.652	1.814	5.519	0.4710	0.0079	2.783	-9.9241
	GHNO	1931	Jul		4.013	72	1.039	2.621	7.496	0.8875	0.0127	2.522	-8.9224
	O				4.203	99	0.687	1.748	5.152	0.7077	0.0073	2.543	-8.8846
	N				4.009	58	0.546	1.557	4.714	0.2738	0.0049	2.851	-9.8704
	GHNO	1932			4.002	240	4.843	13.297	38.129	1.6198	0.0068	2.746	-9.7420
Eastern Georges Bank	J	1932	Jan	Large	4.067	35	0.384	1.193	4.013	0.3124	0.0095	3.012	-11.1822
	JM	1931	Feb		3.993	75	0.629	1.720	5.167	0.4623	0.0063	2.735	-9.7012
	J				4.002	196	1.652	4.467	13.119	1.0427	0.0054	2.704	-9.5960
	J				4.004	275	3.999	11.267	34.459	2.7144	0.0099	2.817	-10.0953
	J				4.0 8	118	0.987	2.659	8.052	0.8889	0.0077	2.694	-9.5582
	J				4.002	104	1.127	3.117	9.622	1.0027	0.0098	2.765	-9.8919
	J	1942	Mar		3.974	99	0.586	1.534	4.402	0.3866	0.0040	2.618	-9.2798
	M				3.998	50	0.554	1.466	4.349	0.4732	0.0099	2.644	-9.4315
	M				4.079	100	0.805	2.222	6.907	0.7715	0.0079	2.761	-9.8542
	J	1932	Apr		4.052	105	1.228	3.476	10.513	0.6764	0.0066	2.830	-10.2625
	JM	1942			4.055	200	1.799	5.184	16.148	1.2120	0.0061	2.881	-10.4613
	JM				4.025	200	1.627	4.537	14.648	1.9917	0.0101	2.789	-10.0730
	M				4.025	150	1.611	4.634	14.607	1.2722	0.0086	2.877	-10.4294
	M				4.067	100	0.616	1.810	6.113	0.7921	0.0081	2.940	-10.6818
	M				4.018	200	1.398	3.777	11.793	1.5880	0.0080	2.701	-9.7184
	J	1931	Jun		3.945	116	0.835	2.394	7.417	0.5505	0.0048	2.868	-10.3246
	JM				3.987	178	1.447	4.142	13.181	1.3226	0.0075	2.863	-10.3401
	J				3.962	201	1.138	3.171	10.233	1.4002	0.0070	2.786	-10.0233
	J				3.980	136	1.118	3.119	9.623	0.9188	0.0069	2.791	-10.0379
	J	1932	Jul		4.048	70	0.543	1.472	4.434	0.4484	0.0066	2.708	-9.5508
	J	1931	Sep		3.968	79	0.904	2.324	6.513	0.5347	0.0069	2.572	-9.1186
	JM				4.076	92	1.050	2.694	7.797	0.8880	0.0099	2.565	-9.1099
	J				3.987	58	0.442	1.104	3.046	0.2907	0.0052	2.497	-8.8127
	M	1941	Dec		4.036	50	0.570	1.600	4.714	0.2238	0.0047	2.806	-10.0927
	M				3.970	50	0.340	0.909	2.601	0.1719	0.0036	2.671	-9.5562
Browns Bank and La Have	P	1933	Mar	Large	4.057	52	0.472	1.451	4.853	0.3928	0.0079	3.073	-11.0742
	P				4.029	154	1.194	3.300	9.999	0.8765	0.0058	2.764	-9.9195
	N	1942			4.067	50	0.542	1.555	4.784	0.3169	0.0066	2.872	-10.2904
	N				4.016	50	0.381	1.178	3.986	0.3381	0.0070	3.096	-11.2335
	MNOP	1955			4.076	57	0.588	1.608	5.181	0.7803	0.0142	2.736	-9.7603
	P	1932	Apr		4.025	71	0.804	2.343	7.339	0.5116	0.0074	2.914	-10.5049
	P	1942			3.965	46	0.470	1.379	4.413	0.3726	0.0085	2.931	-10.6855
	MNOP	1955			4.032	79	0.581	1.399	4.688	1.3186	0.0171	2.408	-8.4605
	MNOP	1931	May		4.024	167	1.895	5.265	16.162	1.5326	0.0093	2.778	-10.0248
Western Bank of Nova Scotia	HJ	1942	Mar	Large	4.143	50	0.828	2.499	7.912	0.3659	0.0076	3.019	-10.9492
	FGHJ	1931	Jul		4.078	193	2.461	7.091	21.691	1.2574	0.0066	2.881	-10.3617
	F	1931	Dec		4.052	107	0.971	3.001	9.874	0.6064	0.0058	3.089	-8.7696
	F				4.040	80	0.541	1.555	5.147	0.6767	0.0087	2.874	-10.3440
	H	1941			4.088	50	0.496	1.509	4.911	0.3230	0.0067	3.041	-10.9945

Table A1.—Regression statistics of samples of haddock length-weight measurements (Continued).

Region	Area	Year	Month	Category	Mean ln length	No. of fish	Σx^2 [1]	Σxy [2]	Σy^2 [3]	SS [4]	MS [5]	b	a
Western	N	1931	Jan	Scrod	3.759	27	0.074	0.214	0.783	0.1630	0.0065	2.893	-10.4952
Georges	G	1932			3.782	161	0.485	1.330	4.535	0.8865	0.0056	2.743	-9.8541
Bank	H				3.804	37	0.080	0.218	0.729	0.1341	0.0038	2.727	-9.7263
	N	1931	Feb		3.850	32	0.158	0.408	1.200	0.1466	0.0049	2.580	-9.1968
	N	1942	Mar		3.813	50	0.182	0.508	1.686	0.2718	0.0057	2.785	-10.0147
	GHNO	1931	Jun		3.784	25	0.125	0.271	0.780	0.1920	0.0083	2.168	-7.6498
	H	1932			3.818	50	0.200	0.591	2.114	0.3676	0.0077	2.954	-10.6612
	N	1931	Jul		3.800	27	0.200	0.453	1.223	0.2004	0.0080	2.260	-7.9739
	GHNO	1932			3.770	69	0.230	0.595	1.960	0.4207	0.0063	2.586	-9.1482
	GHNO	1931	Dec		3.807	112	0.827	2.176	6.968	1.2435	0.0113	2.631	-9.3670
Eastern	J	1932	Jan	Scrod	3.786	91	0.261	0.703	2.485	0.5903	0.0066	2.696	-9.6016
Georges	J	1942	Mar		3.804	50	0.684	2.142	0.243	0.2183	0.0045	2.812	-8.3442
Bank	M				3.839	50	0.203	0.587	2.091	0.3916	0.0082	2.892	-10.4287
	M				3.869	50	0.153	0.322	0.973	0.2978	0.0062	2.098	-7.3778
	J	1932	Jul		3.795	72	0.210	0.458	1.291	0.2932	0.0042	2.178	-7.5628
	J	1931	Sep		3.718	159	0.608	1.602	5.363	1.1398	0.0073	2.636	-9.3955
	J				3.723	38	0.115	0.371	1.314	0.1197	0.0033	3.216	-11.5416
	J				3.773	76	0.250	0.651	2.828	1.1310	0.0153	2.605	-9.2656
	M	1931	Dec		3.750	37	0.116	0.299	0.986	0.2198	0.0063	2.568	-9.1832
	M				3.791	50	0.161	0.466	1.542	0.1918	0.0040	2.894	-10.4463
Browns	N	1942	Mar	Scrod	3.835	50	0.142	0.368	1.111	0.1570	0.0033	2.592	-9.2951
Bank and	MNOP	1955			3.882	27	0.128	0.371	1.220	0.1389	0.0056	2.910	-10.5087
La Have	MNOP		Apr		3.833	48	0.205	0.522	2.003	0.6737	0.0146	2.545	-9.0916
Western	HJ	1942	Mar	Scrod	3.886	51	0.472	1.314	3.912	0.2548	0.0052	2.784	-10.0660
Bank of	F	1931	Dec		3.775	170	0.829	2.236	6.984	0.9547	0.0057	2.697	-9.6800
Nova	HJ	1942	Mar	Scrod	487	51	0.472	1.314	3.912	0.2548	0.0052	2.784	-10.0660
Scotia	F	1931	Dec		436	170	0.829	2.236	6.984	0.9547	0.0057	2.697	-9.6800

1 $\Sigma x^2 = \Sigma X^2 - (\Sigma X)^2/N$

2 $\Sigma xy = \Sigma XY - (\Sigma X)(\Sigma Y)/N1$

3 $\Sigma y^2 = \Sigma Y^2 - (\Sigma Y)^2/N$

4 $SS = \Sigma y^2 - (\Sigma xy)^2/\Sigma x^2$

5 $MS = SS/(N-2)$

*Letters correspond to areas in Figure 1.

Table A2.—Pooled analysis of covariance for subsample and sample variation for five selected trips.

Source of variation	DF	SS	MS	F
Total	848	6.908	0.0081	
Among samples	8	0.052	0.0065	1 NS
Among subsamples	58	0.707	0.0122	
Regression coefficients	29	0.236	0.0081	1.02 NS
Adjusted means	29	0.471	0.0162	2.05 **(1)
Within subsamples	782	6.149	0.0079	
Common subsample variation(2)	811	6.385	0.0079	

(1) * = significant at 5% level

** = significant at 1% level

NS = non-significant

(2) For testing adjusted means among subsamples

Table A3.—Pooled analysis of covariance among samples within each factor combination, i.e. each cell of Table 1.

Source of variation	DF	SS	MS
Large Haddock			
Total	4708	35.497	.0075
Common	4679	33.696	.0072
Within	4650	33.384	.0072
Between regression coefficients	29	0.312	0.0108
Between adjusted means	29	1.801	0.0624
Among samples	58	2.113	0.0364

Regression coefficients: $\frac{\text{Samples } 0.0108}{\text{Subsamples } 0.0081}$ F= 1.33 NS

Adjusted means: $\frac{\text{Samples } 0.0624 \ (df = 29)}{\text{Subsamples } 0.0162 \ (df = 29)}$ F = 3.85 **

Source of variation	DF	SS	MS
Scrod Haddock			
Total	615	4.688	0.0076
Common	610	4.422	0.0072
Within	605	4.319	0.0071
Between regression coefficients	5	0.103	0.0206
Between adjusted means	5	0.266	0.0532
Among samples	10	0.369	0.0369

Regression coefficients: $\frac{\text{Samples } 0.0206 \ (df = 5)}{\text{Subsamples } 0.0081 \ (df = 29)}$ F = 2.54 NS

Adjusted means: $\frac{\text{Samples } 0.0532 \ (df = 5)}{\text{Subsamples } 0.0162 \ (df = 29)}$ F = 3.28*

Table A4.—Pooled analysis of covariance between size categories.

Source of variation	DF	SS	MS
Total	2573	20.439	0.0079
Common	2557	18.146	0.0071
Within	2541	17.915	0.0070
Between regression coefficients	16	0.231	0.0144
Between adjusted means	16	2.293	0.1433

Approximate test

Regression coefficients: $\frac{\text{Size categories } 0.0144 (df = 16)}{\text{Subsamples } 0.0081 (df = 29)}$ F = 1.78 NS

Adjusted means: $\frac{\text{Size categories } 0.1433 (df = 16)}{\text{Subsamples } 0.0162 (df = 29)}$ F = 8.84 **

Table A5.—Pooled analysis of covariance between years for identical months and areas.

Source of variation	DF	SS	MS
Large Haddock			
Total	2992	23.928	0.0080
Common	2984	23.241	0.0078
Within	2976	23.061	0.0077
Between regression coefficients	8	0.180	0.0225
Between adjusted means	8	0.687	0.0859

Approximate test

Regression coefficients: $\frac{\text{Years } 0.0225 \ (df = 8)}{\text{Samples } 0.0108 \ (df = 29)}$ F = 2.08 NS

Adjusted means: $\frac{\text{Years } 0.0859 \ (df = 8)}{\text{Samples } 0.0624 \ (df = 29)}$ F = 1.38 NS

Source of variation	DF	SS	MS
Scrod Haddock			
Total	600	3.521	0.0059
Common	595	3.431	0.0058
Within	590	3.362	0.0057
Between regression coefficients	5	0.069	0.0138
Between adjusted means	5	0.090	0.0180

Approximate test

Regression coefficients: $\frac{\text{Years } .0138 \ (df = 5)}{\text{Samples } .0206 \ (df = 5)}$ F = <1 NS

Adjusted means: $\frac{\text{Years } 0.0180 \ (df = 5)}{\text{Samples } 0.0532 \ (df = 5)}$ F = <1 NS

Table A6.—Pooled analysis of covariance between eastern and western Georges Bank for identical months and years.

Source of variation	DF	SS	MS
Large Haddock			
Total	2541	19.647	0.0077
Common	2537	19.224	0.0076
Within	2533	19.207	0.0076
Between regression coefficients	4	0.017	0.0042
Between adjusted means	4	0.423	0.1058

Approximate test

Adjusted means: $\frac{\text{Areas } 0.1058 \text{ (df = 4)}}{\text{Samples } 0.0624 \text{ (df = 29)}}$ F = 1.70 NS

Source of variation	DF	SS	MS
Scrod Haddock			
Total	725	5.125	0.0071
Common	721	4.679	0.0065
Within	717	4.645	0.0065
Between regression coefficients	4	0.034	0.0085
Between adjusted means	4	0.446	0.1115

Approximate test

Adjusted means: $\frac{\text{Areas } 0.1115 \text{ (df = 4)}}{\text{Samples } 0.0532 \text{ (df = 5)}}$ F = 2.10 NS

Table A7.—Analysis of covariance between Browns Bank and LaHave and the Western Bank of Nova Scotia.

Source of variation	DF	SS	MS	F
Large Haddock				
Total	149	1.108	.0074	
Common	148	0.972	.0066	
Within	147	0.945	.0064	
Between regression coefficients	1	0.027	0.0270	
Between adjusted means	1	0.136	0.1360	

Approximate test

Regression coefficients: $\frac{\text{Areas } 0.0270 \text{ (df = 1)}}{\text{Samples } 0.0081 \text{ (df = 29)}}$ F = 3.33 NS

Adjusted means: $\frac{\text{Areas } 0.1360 \text{ (df = 1)}}{\text{Samples } 0.0624 \text{ (df = 29)}}$ F = 2.18 NS

Source of variation	DF	SS	MS	F
Scrod Haddock				
Total	99	0.606	0.0061	
Common	98	0.526	0.0054	
Within	97	0.526	0.0054	
Between regression coefficients	1	0.000	0.0000	
Between adjusted means	1	0.080	0.0800	

Approximate test

Adjusted means: $\frac{\text{Areas } 0.0800 \text{ (df = 1)}}{\text{Samples } 0.0532 \text{ (df = 29)}}$ F = 1.50 NS

Table A8.—Pooled analyses of covariance between Georges Bank and the Western Bank of Nova Scotia for identical months and years.

Source of variation	DF	SS	MS
Large Haddock			
Total	1219	9.276	0.0076
Common	1215	8.266	0.0068
Within	1211	8.229	0.0068
Between regression coefficients	4	0.037	0.0092
Between adjusted means	4	1.010	0.2525

Approximate test

Adjusted means: $\frac{\text{Areas } 0.2525 \text{ (df = 4)}}{\text{Samples } 0.0624 \text{ (df = 29)}}$ F = 4.05 **

Source of variation	DF	SS	MS
Scrod Haddock			
Total	577	4.785	0.0083
Common	574	4.069	0.0071
Within	571	3.996	0.0070
Between regression coefficients	3	0.073	0.0243
Between adjusted means	3	0.716	0.2386

Approximate test

Regression coefficient: $\frac{\text{Areas } 0.0243 \text{ (df = 3)}}{\text{Samples } 0.0206 \text{ (df = 5)}}$ F = 1.18 NS

Adjusted means: $\frac{\text{Areas } 0.2386 \text{ (df = 3)}}{\text{Samples } 0.0532 \text{ (df = 5)}}$ F = 4.49 NS

Table A9.—Analysis of covariance between months for large haddock from Georges Bank.

Source of variation	DF	SS	MS
Total	4957	50.996	0.0103
Common	4950	38.230	0.0077
Within	4943	38.090	0.0077
Between regression coefficients	7	0.140	0.0200
Between adjusted means	7	12.766	1.8237

Approximate test

Regression coefficient: $\frac{\text{Months } 0.0200 \text{(df = 7)}}{\text{Samples } 0.0108 \text{(df = 29)}}$ F = 1.85 NS

Adjusted means: $\frac{\text{Months } 1.8237 \text{(df = 7)}}{\text{Samples } 0.0624 \text{(df = 20)}}$ F = 29.22 **

Table A10.—Estimated weight at length for various categories of haddock based on equation given in Table 5. (weight in pounds).

Length CM	Large Georges Bank	Scrod Georges Bank	Large Nova Scotia	Scrod Nova Scotia
33		0.84		0.79
4		0.91		0.85
5		0.98		0.92
6		1.05		0.99
7		1.13		1.06
8		1.21		1.14
9		1.29		1.22
40		1.38		1.31
1		1.47		1.39
2		1.57		1.49
3		1.66		1.58
4		1.77		1.68
5		1.87		1.78
6	1.98	1.98	1.88	1.90
7	2.10	2.10	2.01	2.00
8	2.23	2.21	2.13	2.11
9	2.36	2.33	2.27	2.23
50	2.50	2.46	2.41	2.35
1	2.64	2.59	2.55	2.48
2	2.79	2.72	2.70	2.61
3	2.94	2.86	2.86	2.74
4	3.10	3.00	3.02	2.88
5	3.27	3.15	3.18	3.03
6	3.44		3.36	
7	3.61		3.54	
8	3.79		3.72	
9	3.98		3.91	
60	4.17		4.11	
1	4.38		4.32	
2	4.57		4.53	
3	4.78		4.75	
4	5.00		4.97	
5	5.22		5.20	
6	5.45		5.44	
7	5.68		5.69	
8	5.92		5.94	
9	6.17		6.20	
70	6.43		6.48	
1	6.67		6.74	
2	6.95		7.03	
3	7.23		7.32	
4	7.51		7.61	
5	7.80		7.92	
6	8.09		8.24	
7	8.40		8.56	
8	8.70		8.89	
9	9.02		9.23	
80	9.35		9.58	
1	9.68		9.93	
2	10.02		10.30	

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A Hydrographic Survey of the Galveston Bay System, Texas, 1963-66

E. J. PULLEN, W. L. TRENT, AND G. B. ADAMS

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