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Length-Weight Relationships of Haddock Collected from U.S. Commercial Landings

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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 1935. A large part of these data were 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). 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 past history of the haddock fishery depend on the use of these data. In the present study variation among size category, year, area, and month strata 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.

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 generally landed either gutted, or gutted and gilled. From April to November the fish were required to be gutted and gilled, and they were frequently gilled in the winter months also. Only the data from the gutted and gilled category were sufficient for analysis. Commercial landings were sorted into scrod (those fish under approximately 2.5 pounds) and large size categories. Fish of each size category were unloaded from the vessels into 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 for a total of 7,774 measurements. The distribution of these samples among the various strata is presented in Table 1. The areas considered are outlined in Figure 1.

Sampling done under existing port conditions was of necessity irregular, and the 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 that the boats sampled were representative of all boats fishing in a given stratum.

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

W = weight in tenths of pounds
l = fork length in centimeters
C and b are constants

Data were transformed by natural logarithms and regressions were fitted by the least squares method to the equation $Y = a + bX$, where:

$$Y = \log_e W$$
$$X = \log_e l$$
$$a = \log_e C$$

The regression equations for each length weight sample are given in Table 2. Covariance analyses were used to test significance of differences between various strata. Notations for regression and covariance analyses throughout this report follow Snedecor (1956).

Inadequate distribution of samples prevented the use of a factorial analysis to determine the existence and significance of interactions among the strata. Therefore, a separate analysis of covariance among the elements of a given type of stratum (e.g., among years) was run within each of the other strata, and the series of analyses thus obtained were pooled to yield a single result. Strata were combined only where between-strata differences were shown to be nonsignificant.

Analyses of Sampling Variation

Subsamples (within trips)

In April 1942, 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 catches 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 carts were sampled from each trip. All of these fish were in the large size-category.

The analysis of covariance for these data is presented in Table 3. 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. In addition, each cart may have contained fish caught in different sections of the general area that the boat fished in.

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Samples (between trips)

In many instances several trips were sampled within the same stratum (c.f., Table 1). Covariance analyses were computed for each cell (each single combination of year, area, month, and size category) containing more than one sample. The pooled analysis of covariance for both large and scrod showed significant adjusted mean differences among samples, or trips (Table 4). The among sample mean square for this pooled analysis was greater than that among the five samples used in the analysis of subsample variation. This probably occurred because the five special samples came from a more restricted time and area than the general samples.

The samples used in the pooled analysis above were known to consist of fish from several carts for each trip. However, the data were not recorded separately for each cart (subsample). An approximate F test was used to take subsample variation into account. The mean square for the differences in regression coefficients and adjusted means among samples were divided by the corresponding mean square for differences among subsamples taken from Table 3 (see Table 4). The difference among adjusted means was still significant; however, the difference among regression coefficients was not significant. In the following sections of this paper the term Approximate F Test, refers to the ratio of the mean square for differences among strata to the corresponding mean square for either among sample (from Table 4) or among subsample (from Table 3) differences, whichever is appropriate. 1/

Comparison Among Strata

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 Table 5, and significant differences were found both for adjusted means and regression coefficients. Only subsample variation need be accounted for in this analysis as both the large and scrod samples were from the same boat. The subsample variation was taken into consideration by using the Approximate F Test described earlier and using the mean square among subsamples taken from Table 3. The highly significant differences in adjusted means remained, but the difference among regression coefficients was not judged significant in this test (Table 5).

1/ -- The use of this approximate test was suggested by Richard C. Hennemuth, Bureau of Commercial Fisheries Biological Laboratory, Woods Hole, Massachusetts.

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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 6). The observed differences are to be expected if the fish were sorted primarily on the basis of heavy appearance, i.e., the short, plump fish would be considered large whereas the longer, slender individuals would be classed as scrod.

Years

An analysis of covariance among years was computed within each month, area, and size category classification containing two or more years. For example, comparisons between 1931 and 1932 were made for the Western Georges Bank area in 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 significant differences were found; however, these did not hold up when the differences among samples were taken into consideration in the Approximate F Test (Table 7). As the years tested contained time differentials from 1 to 22 years, both short and long term changes appear non-significant.

Areas

Comparisons were made between samples from eastern and western Georges Bank (both regions in ICNAF Division 5 Z) 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 (Table 8).

The same procedure was followed to test differences between samples from Browns Bank (ICNAF Division 4X) and the Western Banks of Nova Scotia (ICNAF Division 4 W). No significant differences were found between these areas (Table 9). However, comparisons were only possible between the 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 (Table 10). Although the adjusted means were significantly different for scrod haddock in the original test, this was not true for the Approximate F Test. However, the degrees of freedom in the latter case (3,5) were very small.

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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 non-significant. Only for this size category and area strata were there enough data for a meaningful comparison. These monthly regressions were tested by covariance analyses and significant differences were found among adjusted means (Table 11). 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 12), e.g., non-significant groupings such as January and July existed while the adjusted means for January and February were different. The lack of a seasonal trend is contrary to the conclusion of Clark and Dietsch (1959).

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 the Nova Scotian regions were homogenous,
6. Differences were found between the Georges Bank and the Nova Scotian region,
7. Seasonal trends were not present.

Equations and standard errors for scrod and large haddock from Georges Bank and for the Nova Scotian area are set forth in Table 13. There was a loss of precision in three of the four total equations over using the separate equations for each trip sampled. The highest of these ratios of respective mean squares was 1.43 (Table 14). However, it would be impractical to try and 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.

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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. (in press) 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 of the given 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 of each sample.

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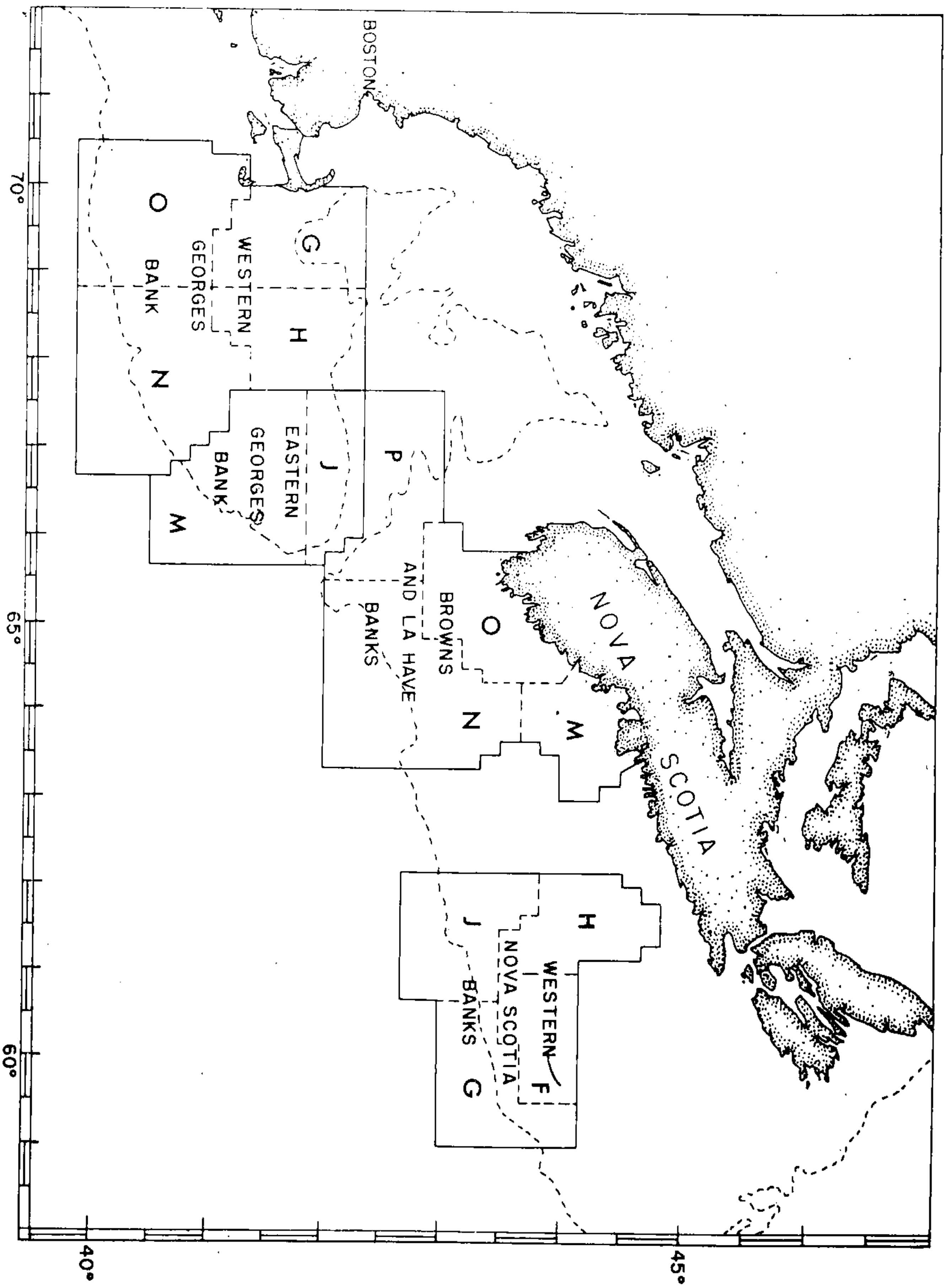

Figure 1 -- Sam ng areas

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

Large Market Category

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

Table 1. (cont'd)

		Scrod Market Category								
Area	Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Sept.	Dec.
Western Georges Bank	1931	1	1	-	-	-	1	1	-	1
	1932	2	-	-	-	-	1	1	-	-
	1942	-	-	1	-	-	-	-	-	-
Eastern Georges Bank	1931	-	-	-	-	-	-	-	3	1
	1932	1	-	-	-	-	-	1	-	-
	1941	-	-	-	-	-	-	-	-	1
	1942	-	-	3	-	-	-	-	-	-
Browns Bank and La Have	1942	-	-	1	-	-	-	-	-	-
	1955	-	-	1	1	-	-	-	-	-
Western Bank of Nova Scotia	1931	-	-	-	-	-	-	-	-	1
	1942	-	-	1	-	-	-	-	-	-

Table 2. Regression statistics for trips sampled for haddock length-weight measurements.

Region	Letter Area	Year	Month	Category	No.	1/ Σx^2	2/ Σxy	3/ Σy^2	4/ SS	5/ MS	b	a
Western	N*	1931	Jan.	Large	97	0.697	1.996	6.273	0.5518	0.0058	2.866	-10.2213
Georges	G	1932			194	1.485	4.392	13.877	0.8869	0.0046	2.958	-10,6201
Bank	H				125	1.246	3.458	10.288	0.6943	0.0056	2.775	-9.8851
	GHNO	1931	Feb.		94	0.712	2.002	6.244	0.6122	0.0067	2.812	-10.1013
	GHNO				73	0.684	1.905	5.774	0.4675	0.0066	2.785	-9.9533
	N				96	0.646	1.719	5.318	0.7408	0.0079	2.663	-9.5076
	N	1933	Mar.		169	1.347	3.734	11.423	1.0741	0.0064	2.771	-9.9096
	GHNO	1931	June		201	1.819	4.950	14.722	1.2523	0.0063	2.721	-9.7826
	GHNO				143	1.195	3.350	10.676	1.2876	0.0091	2.803	-10.0235
	N	1932			50	0.850	2.468	7.508	0.3357	0.0070	2.906	-10.4949
	N				49	0.648	1.683	4.617	0.2425	0.0052	2.599	-9.1899
	N				50	0.864	2.374	6.719	0.1950	0.0041	2.748	-9.8133
	N				50	0.721	1.981	5.664	0.2252	0.0047	2.746	-10.1101
	H				62	0.652	1.814	5.519	0.4710	0.0079	2.783	-9.9241
	GHNO	1931	July		72	1.039	2.621	7.496	0.8875	0.0127	2.522	-8.9224
	O				99	0.687	1.748	5.152	0.7077	0.0073	2.543	-8.8846
	N				58	0.546	1.557	4.714	0.2738	0.0049	2.851	-9.8704
	GHNO	1932			240	4.843	13.297	38.129	1.6198	0.0068	2.746	-9.7420
Eastern	J	1932	Jan.	Large	35	0.384	1.193	4.013	0.3124	0.0095	3.012	-11.1822
Georges	JM	1931	Feb.		75	0.629	1.720	5.167	0.4623	0.0063	2.735	-9.7012
Bank	J				196	1.652	4.467	13.119	1.0427	0.0054	2.704	-9.5960
	J				275	3.999	11.267	34.459	2.7144	0.0099	2.817	-10.0953
	J				118	0.987	2.659	8.052	0.8889	0.0077	2.694	-9.5582
	J				104	1.127	3.117	9.622	1.0027	0.0098	2.765	-9.8919
	J	1942	March		99	0.586	1.534	4.402	0.3866	0.0040	2.618	-9.2798
	M				50	0.554	1.466	4.349	0.4732	0.0099	2.644	-9.4315
	M				100	0.805	2.222	6.907	0.7715	0.0079	2.761	-9.8542
	J	1932	April		105	1.228	3.476	10.513	0.6764	0.0066	2.830	-10.2625
	JM	1942			200	1.799	5.184	16.148	1.2120	0.0061	2.881	-10.4613
	JM				200	1.627	4.537	14.648	1.9917	0.0101	2.789	-10.0730

Table 2. (Continued)

Region	Letter Area	Year	Month	Category	No.	Σx^2 1/	Σxy 2/	Σy^2 3/	SS 4/	MS 5/	b	a
Eastern	M				150	1.611	4.634	14.607	1.2722	0.0086	2.877	-10.4294
Georges	M				100	0.616	1.810	6.113	0.7921	0.0081	2.940	-10.6818
Bank	M				200	1.398	3.777	11.793	1.5880	0.0080	2.701	-9.7184
	J	1931	June		116	0.835	2.394	7.417	0.5505	0.0048	2.868	-10.3246
	JM				178	1.447	4.142	13.181	1.3226	0.0075	2.863	-10.3401
	J				201	1.138	3.171	10.233	1.4002	0.0070	2.786	-10.0233
	J				136	1.118	3.119	9.623	0.9188	0.0069	2.791	-10.0379
	J	1932	July		70	0.543	1.472	4.434	0.4484	0.0066	2.708	-9.5508
	J	1931	Sept.		79	0.904	2.324	6.513	0.5347	0.0069	2.572	-9.1186
	JM				92	1.050	2.694	7.797	0.8880	0.0099	2.565	-9.1099
	J				58	0.442	1.104	3.046	0.2907	0.0052	2.497	-8.8127
	M	1941	Dec.		50	0.570	1.600	4.714	0.2238	0.0047	2.806	-10.0927
	M				50	0.340	0.909	2.601	0.1719	0.0036	2.671	-9.5562
Browns	P	1933	Mar.	Large	52	0.472	1.451	4.853	0.3928	0.0079	3.073	-11.0742
Bank and	P				154	1.194	3.300	9.999	0.8765	0.0058	2.764	-9.9195
La Have	N	1942			50	0.542	1.555	4.784	0.3169	0.0066	2.872	-10.2904
	N				50	0.381	1.178	3.986	0.3381	0.0070	3.096	-11.2335
	MNOP	1955			57	0.588	1.608	5.181	0.7803	0.0142	2.736	-9.7603
	P	1932	April		71	0.804	2.343	7.339	0.5116	0.0074	2.914	-10.5049
	P	1942			46	0.470	1.379	4.413	0.3726	0.0085	2.931	-10.6855
	MNOP	1955			79	0.581	1.399	4.688	1.3186	0.0171	2.408	-8.4605
	MNOP	1931	May		167	1.895	5.265	16.162	1.5326	0.0093	2.778	-10.0248
Western	HJ	1942	March	Large	50	0.828	2.499	7.912	0.3659	0.0076	3.019	-10.9492
Bank of	FGHJ	1931	July		193	2.461	7.091	21.691	1.2574	0.0066	2.881	-10.3617
Nova	F	1931	Dec.		107	0.971	3.001	9.874	0.6064	0.0058	3.089	-8.7696
Scotia	F				80	0.541	1.555	5.147	0.6767	0.0087	2.874	-10.3440
	H	1941			50	0.496	1.509	4.911	0.3230	0.0067	3.041	-10.9945

Table 2. (Continued)

Region	Letter Area	Year	Month	Category	No.	Σx^2 1/	Σxy 2/	Σy^2 3/	SS 4/	MS 5/	b	a
Western	N	1931	Jan.	Scrod	27	0.074	0.214	0.783	0.1630	0.0065	2.893	-10.4952
Georges	G	1932			161	0.485	1.330	4.535	0.8865	0.0056	2.743	-9.8541
Bank	H				37	0.080	0.218	0.729	0.1341	0.0038	2.727	-9.7263
	N	1931	Feb.		32	0.158	0.408	1.200	0.1466	0.0049	2.580	-9.1968
	N	1942	March		50	0.182	0.508	1.686	0.2718	0.0057	2.785	-10.0147
	GHNO	1931	June		25	0.125	0.271	0.780	0.1920	0.0083	2.168	-7.6498
	H	1932			50	0.200	0.591	2.114	0.3676	0.0077	2.954	-10.6612
	N	1931	July		27	0.200	0.453	1.223	0.2004	0.0080	2.260	-7.9739
	GHNO	1932			69	0.230	0.595	1.960	0.4207	0.0063	2.586	-9.1482
	GHNO	1931	Dec.		112	0.827	2.176	6.968	1.2435	0.0113	2.631	-9.3670
Eastern	J	1932	Jan.	Scrod	91	0.261	0.703	2.485	0.5903	0.0066	2.696	-9.6016
Georges	J	1942	Mar.		50	0.684	2.142	0.243	0.2183	0.0045	2.812	-8.3442
Bank	M				50	0.203	0.587	2.091	0.3916	0.0082	2.892	-10.4287
	M				50	0.153	0.322	0.973	0.2978	0.0062	2.098	-7.3778
	J	1932	July		72	0.210	0.458	1.291	0.2932	0.0042	2.178	-7.5628
	J	1931	Sept.		159	0.608	1.602	5.363	1.1398	0.0073	2.636	-9.3955
	J				38	0.115	0.371	1.314	0.1197	0.0033	3.216	-11.5416
	J				76	0.250	0.651	2.828	1.1310	0.0153	2.605	-9.2656
	M	1931	Dec.		37	0.116	0.299	0.986	0.2198	0.0063	2.568	-9.1832
	M				50	0.161	0.466	1.542	0.1918	0.0040	2.894	-10.4463
Browns	N	1942	Mar.	Scrod	50	0.142	0.368	1.111	0.1570	0.0033	2.592	-9.2951
Bank and	MNOP	1955			27	0.128	0.371	1.220	0.1389	0.0056	2.910	-10.5087
La Have	MNOP		April		48	0.205	0.522	2.003	0.6737	0.0146	2.545	-9.0916

Table 2. (Continued)

Region	Letter Area	Year	Month	Category	No.	Σx^2 1/	Σxy 2/	Σy^2 3/	SS 4/	MS 5/	b	a
Western Banks of Nova Scotia	HJ	1942	Mar.		51	0.472	1.314	3.912	0.2548	0.0052	2.784	-10.0660
	F	1931	Dec.		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 3.--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		
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	
(2) Common subsample variation	811	6.385	0.0079	

(1) * = significant at 5% level

** = significant at 1% level

(2) For testing adjusted means among subsamples

Table 4.--Pooled analysis of covariance among samples.

Source of variation	DF	SS	MS	F
	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	1.50 NS
Between adjusted means	29	1.801	0.0624	8.67 **
Among samples	58	2.113	0.0364	

Approximate test

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

Source of variation	DF	SS	MS	F
	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	2.90 *
Between adjusted means	5	0.266	0.0532	7.39 **

Approximate test

Regression coefficients: $\frac{\text{Samples } .0206 \text{ (df = 5)}}{\text{Subsamples } .0081 \text{ (df = 29)}}$ F = 2.54 NS

Adjusted means: $\frac{\text{Samples } .0532 \text{ (df = 5)}}{\text{Subsamples } .0162 \text{ (df = 29)}}$ F = 3.28 *

Table 5.--Pooled analysis of covariance between size categories.

Source of variation	DF	SS	MS	F
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	2.06 **
Between adjusted means	16	2.293	0.1433	20.18 **

Approximate test

Regression coefficients	Size categories / Subsamples	0.0144 (df = 16) / 0.0081 (df = 29)	F = 1.78 NS
Adjusted means	Size categories / Subsamples	0.1433 (df = 16) / 0.0162 (df = 29)	F = 8.84 **

Table 6.--Adjusted mean weights (natural logarithms) for samples of large and scrod haddock.

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

Table 7.--Pooled analysis of covariance between years for identical months and areas.

Source of variation	DF	SS	MS	F
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	2.92 **
Between adjusted means	8	0.687	0.0859	11.01 **

Approximate test

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

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

Source of variation	DF	SS	MS	F
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	2.42 *
Between adjusted means	5	0.090	0.0180	3.10 **

Approximate test

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

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

Table 8.--Pooled analysis of covariance between eastern and western Georges Bank for identical months and years.

Source of variation	DF	SS	MS	F
	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	<1 NS
Between adjusted means	4	0.423	0.1058	13.92 **

Approximate test

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

Source of variation	DF	SS	MS	F
	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	1.31 NS
Between adjusted means	4	0.446	0.1115	17.15 **

Approximate test

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

Table 9.--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	4.22 *
Between adjusted means	1	0.136	0.1360	20.61 **

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	<1 NS
Between adjusted means	1	0.080	0.0800	14.81 **

Approximate test

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

Table 10.--Pooled analyses of covariance between Georges Bank and the Western Bank of Nova Scotia for identical months and years.

Sources of variation	DF	SS	MS	F
		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	1.35 NS
Between adjusted means	4	1.010	0.2525	37.13 **

Approximate test

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

Scrod Haddock

Sources of variation	DF	SS	MS	F
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	3.47 *
Between adjusted means	3	0.716	0.2386	33.60 **

Approximate test

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

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

Table 11.--Analysis of covariance between months for large haddock from Georges Bank.

Source of variation	DF	SS	MS	F
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	2.60 *
Between adjusted means	7	12.766	1.8237	236.84 **

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 $\frac{\text{Months } 1.8237 \text{ (df = 7)}}{\text{Samples } 0.0624 \text{ (df = 29)}}$ F = 29.22 **

Table 12.--Duncan multiple range test between months for large haddock from Georges Bank (Underlined values are homogenous groups).

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

Table 13.--Regression statistics for haddock length-weight estimating equations.

Description	Equation	Stand. error of $\hat{Y}$ at the mean of X	Stand. error of Y at the mean of X
Large haddock from Georges Bank	$\hat{Y}=-10.0580+2.8053X$	± 0.0014	± 0.1015
Scrod haddock from Georges Bank	$\hat{Y}=-9.2184+2.5864X$	± 0.0027	± 0.0949
Large haddock from Nova Scotia area	$\hat{Y}=-10.6191+2.9389X$	± 0.0027	± 0.0943
Scrod haddock from Nova Scotia area	$\hat{Y}=-9.4570+2.6362X$	± 0.0043	± 0.0255

Table 14.--Loss of precision in using total regression equations.

Category	Within mean square for all trips samples	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