LENGTH-WEIGHT RELATION OF HADDOCK COLLECTED FROM COMMERCIAL LANDINGS IN NEW ENGLAND

by

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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 1955. 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 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 and gilled and gutted, is presented in an appendix.

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 category were sufficient for analysis. Commercial landings were sorted into scrod (those fish under approximately 2.5 pounds) and large size categories by the fishermen at sea. 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 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.

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

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. (Continued)

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	-	-	-	-	-	-

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 statistics for each 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, where data permitted, 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.

Analyses of Sampling Variation

Subsamples (within trips)

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.

Table 2. Regression statistics of samples of haddock length-weight measurements.

Region	Area	Year	Month	Category	No. Fish	Σx^2 1/	Σxy 2/	Σy^2 3/	SS 4/	MS 5/	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

Table 2. (Continued)

Region	Area	Year	Month	Category	No. Fish	Σx^2 1/	Σxy 2/	Σy^2 3/	SS 4/	MS 5/	b	a
Eastern Georges Bank	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
	M				150	1.611	4.634	14.607	1.2722	0.0086	2.877	-10.4294
	M				100	0.616	1.810	6.113	0.7921	0.0081	2.940	-10.6818
	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 Bank and La Have	P	1933	Mar.	Large	52	0.472	1.451	4.853	0.3928	0.0079	3.073	-11.0742
	P				154	1.194	3.300	9.999	0.8765	0.0058	2.764	-9.9195
	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 Bank of Nova Scotia	HJ	1942	March	Large	50	0.828	2.499	7.912	0.3659	0.0076	3.019	-10.9492
	FGHJ	1931	July		193	2.461	7.091	21.691	1.2574	0.0066	2.881	-10.3617
	F	1931	Dec.		107	0.971	3.001	9.874	0.6064	0.0058	3.089	-8.7696
	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	Area	Year	Month	Category	No. Fish	Σx^2 1/	Σxy 2/	Σy^2 3/	SS 4/	MS 5/	b	a
Western Georges Bank	N	1931	Jan.	Scrod	27	0.074	0.214	0.783	0.1630	0.0065	2.893	-10.4952
	G	1932			161	0.485	1.330	4.535	0.8865	0.0056	2.743	-9.8541
	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 Georges Bank	J	1932	Jan.	Scrod	91	0.261	0.703	2.485	0.5903	0.0066	2.696	-9.6016
	J	1942	Mar.		50	0.684	2.142	0.243	0.2183	0.0045	2.812	-8.3442
	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 Bank and La Have	N	1942	Mar.	Scrod	50	0.142	0.368	1.111	0.1570	0.0033	2.592	-9.2951
	MNOP	1955			27	0.128	0.371	1.220	0.1389	0.0056	2.910	-10.5087
	MNOP		April		48	0.205	0.522	2.003	0.6737	0.0146	2.545	-9.0916

Table 2. (Continued)

Region	Area	Year	Month	Category	No. Fish	Σx^2 1/	Σxy 2/	Σy^2 3/	SS 4/	MS 5/	b	a
Western Bank of Nova Scotia	HJ	1942	Mar.	Scrod	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.

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. Also, each cart 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 (.0122/.0065 = 1.88), with 58 and 8 degrees of freedom does not, in fact, exceed the tabular F at the 5 percent probability level.

About the best we can say is that for this set of data subsample differences are about the same as sample differences.

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 (c.f., Table 1). The pooled analysis of covariance showed significant adjusted mean differences among samples, or trips, for both large and scrod size categories (Table 4). The among sample mean square of large haddock for this pooled analysis (0.0364) was greater than that among the five samples used in the analysis of subsample variation (0.0065, c.f., Table 3). This probably occurred because the five special samples came from a more restricted time and area within the sampling area than the general samples.

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	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 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: $\frac{\text{Samples } .0200 \text{ (df = 5)}}{\text{Subsamples } .0081 \text{ (df = 29)}}$ F = 2.54 NS

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

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

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

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

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).

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., in the range of sizes near the cut-off size, 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 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 from Table 4 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 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 [illegible]. No significant differences

were

Table 6.--Adjusted mean weights (natural logarithms) 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

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	Years 0.0225 (df = 8) / Samples 0.0108 (df = 29)	F = 2.08 NS
Adjusted means	Years 0.0859 (df = 8) / Samples 0.0624 (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	Years .0138 (df = 5) / Samples .0206 (df = 5)	F = $<$1 NS
Adjusted means	Years 0.0180 (df = 5) / Samples 0.0532 (df = 5)	F = $<$1 NS

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 and the western banks of Nova Scotia. No significant differences were found between these areas (Table 9). 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 (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.

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)

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	Areas 0.1058 (df = 4) / Samples 0.0624 (df = 29)		F = 1.70 NS	
		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	Areas 0.1115 (df = 4) / 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	Areas	0.0270	(df = 1)	F = 3.33 NS
	Samples	0.0081	(df = 29)	
Adjusted means	Areas	0.1360	(df = 1)	F = 2.18 NS
	Samples	0.0624	(df = 29)	

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	Areas	0.0800	(df = 1)	F = 1.50 NS
	Samples	0.0532	(df = 29)	

Table 10.--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	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	Areas 0.2525 (df = 4) / Samples 0.0624 (df = 29)	F = 4.05 **	

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

Approximate test

Regression coefficient	Areas 0.0243 (df = 3) / Samples 0.0206 (df = 5)	F = 1.18 NS
Adjusted means	Areas 0.2386 (df = 3) / Samples 0.0532 (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 $\frac{\text{Months } 1.8237 \text{ (df = 7)}}{\text{Samples } 0.0624 \text{ (df = 20)}}$ F = 29.22 ** adjustment for unequal sized samples and Finney's (1946) approximation for the variance term. There were no seasonal trends evident (Table 12). 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 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. The loss of precision in using the total regression equations rather than using the separate equations for each trip sampled is estimated in Table 14. The highest of these ratios of respective mean squares indicates a 43 percent loss. 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

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 ($\log_e$ units).

Description	Equation	Standard error of Y at the mean of X	Standard error of Y at the mean of X	$C = e^2$
Large haddock from Georges Bank	$Y = -10.0580 + 2.8053X$ 1/	± 0.0014	± 0.1015	--
Scrod haddock from Georges Bank	$Y = -9.2184 + 2.5864X$ 2/	± 0.0027	± 0.0949	--
Large haddock from Nova Scotia area	$Y = -10.6191 + 2.9389X$ 3/	± 0.0027	± 0.0943	--
Scrod haddock from Nova Scotia area	$Y = -9.4570 + 2.6362X$ 4/	± 0.0043	± 0.0255	--

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 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

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 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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APPENDIX

Conversion of Dressed and Round Weight for Haddock

Bradford E. Brown

Introduction

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 report presents results of an analysis of available data to determine an estimate for converting dressed weights to round weights.

Methods of Collection

Individual fish were measured and weighed at sea while fresh and before dressing, and at the dock after the fish had been cleaned and stored aboard the vessel for periods up to ten days. In one case both sets of measurements were made at dock side. Fork lengths were recorded in millimeters and the weights to the nearest tenth pound. The list of samples used in this study is presented in Table A-1. There were eight samples of fish with measurements of gutted and round weights, and two samples with gutted and gilled and round weights.

Table A-1.--Samples of haddock available for weight conversion study.

Date	Number of fish	Round		Gutted		Gutted & Gilled	
		Weight	Length	Weight	Length	Weight	Length
April, 1942	46	x	x	x		x	
May, 1953	29	x	x	x	x		
June, 1953	22	x	x	x			
June, 1953	20	x	x	x			
December, 1953	34	x	x	x	x		
January, 1954	48	x	x	x	x		
February, 1954	23	x	x	x	x		
April, 1954	21	x	x			x	x
June, 1954	39	x	x	x			

Lengths at sea versus lengths ashore

The average length of the 199 fish was 524 millimeters with a standard error of 8.0 when measured fresh at sea and was 521 millimeters with a standard error of 7.9 when measured after landing. The ratio of length at sea to those on shore was 1.005. The mean of the differences between the paired measurements (2.6 mm) was found to be within the realm of error of measurement and thus was taken to be zero in subsequent analysis.

Difference between round and dressed weight

The ratio of round weight (Y_1) to dressed weight (Y_2) for given length (X) may be written.

$$\frac{Y_1}{Y_2} = \frac{C_1}{C_2} X^{(b_1 - b_2)}, \text{ or} \qquad (1)$$

$$\log_e \frac{Y_1}{Y_2} = \log_e \frac{c_1}{c_2} + (b_1 - b_2) \log_e X \qquad (2)$$

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

If the ratio of round to dressed weight does not differ with length, the slope of the regression ($b_1 - b_2$) would equal zero and the antilogarithmn of $\log_e \frac{C_1}{C_2}$ would be an estimate of the desired conversion factor. Six of the eight samples were found to have slope values ($b_1 - b_2$) not significantly greater than zero, which is a strong indication that the ratio of round to dressed weights is constant.

Table A-2.--Regression coefficients for the differences between round and dressed fish versus length

Year	Month	$\log_e \frac{C_1}{C_2}$	$(b_1 - b_2)$	$S_{(b_1 - b_2)}$ [1]
1942	April	-1.140	0.3007 *	0.1216
1953	May	-0.419	0.1511 *	0.0607
1953	June	0.151	0.0098	0.0720
1953	June	0.147	0.0063	0.0799
1953	December	0.098	0.0092	0.0922
1954	January	-0.250	0.0901	0.0847
1954	February	-0.066	0.0586	0.1801
1954	June	-0.314	0.1225	0.0701

*Significantly different from zero (α = .05)

1 $S_b = \sqrt{\frac{M.S.}{\Sigma x^2}}$

Although the slope values were judged to be statistically not significantly different from zero, the calculated values were slightly positive. Therefore, the actual ratios of round to gutted weight, equation (1), were computed for each sample regardless of the size of the fish involved, instead of using the antilogarithmn of the $\frac{C_1}{C_2}$ values. These values are presented in Table A-3. No seasonal trends were evident. Thus the overall ratio of 1.15 appears to be the best available estimation for converting gutted to round weights. The overall ratio estimated for converting gutted and gilled weight to round weight was 1.18.

Table A-3.--Ratios of round to dressed weight

Year	Month	Number	Ratio: round to gutted	Ratio: round to gutted & gilled
1942	April	46	1.16	
1953	May	29	1.18	
1953	June	22	1.22	
1953	June	20	1.18	
1953	December	34	1.14	
1954	January	48	1.13	
1954	February	23	1.20	
1954	June	39	1.14	
Total			1.15	
1942	April	46		1.19
1954	April	21		1.18
Total				1.18