Shell Length - Meat Weight Relationships of Ocean Quahogs, *Arctica islandica*, from the Middle Atlantic Shelf

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Laboratory Reference No. 78-38
July 14, 1978

Abstract

Shell length - drained meat weight relations were calculated from 2,564 ocean quahog, *Arctica islandica,* samples taken from the Middle Atlantic shelf during January-February 1978. Significant differences between regression equations were evident among three sub-areas (southern New England-Long Island, New Jersey, Delmarva). No consistent trends were noted when depth was the major criterion of separation. An increase in relative meat weight for similar sized quahogs along a north to south cline may be indicative of the more stable thermal regime in southern areas, or related to density dependent factors. The overall shell length (L, mm) - meat weight (W, g) regression equation for all Middle Atlantic specimens is ($r = 0.9635$): $\log_e W = 9.589618 + 2.888016 \log_e L$. Allometric growth between shell length and meat weight was confirmed for most area/depth strata.

INTRODUCTION

The ocean quahog, *Arctica islandica* (Linnaeus) is a boreally distributed pelecypod occurring in the North Atlantic Ocean from the Bay of Cadiz (southwest Spain) intermittently to Cape Hatteras (Merrill and Ropes, 1969; Nicol 1951; Zatsepin and Filatova 1961). In the Middle Atlantic region off the U.S. coast, commercial concentrations exist in waters from 25 to 61 m deep, although the maximum limits of live quahogs appear to be 15-234 m (Merrill and Ropes 1969). Studies of the life history and in particular the population dynamics of this species are few. Loosanoff (1953) described the reproductive biology of specimens off Point Judith, R.I., and aspects ocean quahog density and distribution in the Middle Atlantic are reviewed by Merrill and Ropes (1969; 1970) and Parker and McRae (1970). Ropes (1971) calculated total solids and the dry meat-shell length relationship for samples from off Long Island, N.Y. Systematic quantitative meat yield investigations have not, however, been conducted.

Exploitation of ocean quahogs in U.S. waters began in 1943 with the World War II food production program. Nearly all of the catch from 1943-1975 was from Rhode Island and to a lesser extent Cape Cod (Parker and McRae 1970). Landings from 1956-1975 averaged 262 mt of shucked meats per year. Total production increased dramatically from 569 mt in 1975 to 2,593 mt in 1976. Overfishing of surf clam, *Spisula solidissima*, populations in the Middle Atlantic, combined with a severe kill of the surf clam resource off New Jersey in 1976 led to the increase in ocean quahog utilization. Landings in 1977 again increased significantly to 8,074 mt. New Jersey production accounted for 72% and 77% of the total U.S. landings in 1976 and 1977 respectively (National Marine Fisheries Service unpublished data).

Objectives of our study were to: (1) calculate shell length-drained meat yield regressions for ocean quahog samples from the Middle Atlantic, (2) investigate the variability associated with the area and depth of capture, and (3) determine the precision of utilizing the computed regression equations to describe the empirical data.

METHODS

Ocean quahog samples for length-weight analysis were collected from the Middle Atlantic shelf (Cape Cod to Cape Hatteras) during the shellfish assessment cruise of the R/V DELAWARE II from 4 January to 11 February 1978 (National Marine Fisheries Service 1978). Sampling gear was a commercial-type hydraulic clam dredge with a 1.2 m (48 inch) wide knife and 30 mm spacing between bars of the cage. Stations were randomly selected within area/depth strata; the dredge was towed for 4 minutes at approximately 0.5 ms^{-1} at each site. Ocean quahogs were collected in depths ranging from 13-75 m. Subsamples of the catch for length-weight determinations were stratified by 10 mm shell length class (longest dimension). Generally, five intact individuals in each 10 mm length interval (10-19 mm, etc.) were selected at each station, when large numbers of small (<50 mm) or large (>115 mm) quahogs were taken additional samples were retained to increase the total numbers of these sizes. Thus length-weight data should not be considered random with respect to the available population or as unbiased sub-samples of the survey catches.

Shell dimensions were recorded to the nearest mm, and all soft parts of each quahog shucked into individual plastic bags. Frozen samples were returned to the laboratory, thawed, and drained on toweling. Total drained meat weight was determined to the nearest 0.1 g. Samples contaminated with sand from the dredging process were rinsed prior to draining.

Linear regressions were fitted to length and weight data converted to natural logarithms. The form of the length weight equation was assumed to be: $W = cL^b$

where;

W = drained meat weight (g),

L = shell length (mm),

c and b = coefficients to be estimated from regression.

Least squares regressions were fitted to the equation $Y = a + b X$, where;

$$Y = \log_e W,$$

$$X = \log_e L,$$

$$a = \log_e c.$$

The assumption of isometric growth between shell length and meat weight (Ricker 1975) was tested employing the Student's t with n-2 degrees of freedom (Steel and Torrie 1960):

$$t = \frac{b - 3.0}{\sqrt{s^2_{y.x}/\Sigma x^2}}$$

Covariance analyses were conducted to determine the significance of differences between slopes and adjusted means of various length-weight regression equations (Snedecor and Cochran 1967). The one-way analysis of covariance computer program BMDP1V was used for all these calculations (Dixon 1975).

Empirical mean weights were compared to those derived from regressions equations for samples from several different areas. The arithmetic mean empirical weights were computed for each 5 mm interval of the length frequency distribution. Corresponding mean calculated weights were computed by:

$$MCW = \frac{\sum_{i=1}^{n} SL_i^{\,b}.\text{Antilog}_e\, a}{n}$$

where;

MCW = mean calculated weight (g),

SL_i = shell length of individual, i, in the 5 mm length interval, where i = 1,2,3...n,

b = slope of the length-weight equation specific for the area/depth being studied,

$Antilog_e a$ = $antilog_e$ of the intercept of the length-weight equation used in the analysis.[1]

RESULTS

A total of 192 stations occupied during the cruise yielded ocean quahog catches, of which 165 (86%) were sampled for the length-weight study. Sampling locations were classified, arbitrarily, by area and 20 m depth interval (Figure 1). Largest total numbers, and numbers per station were taken from off southern New England-Long Island with smaller sample sizes to the south reflecting the relative densities of quahogs among the three areas (Merrill and Ropes 1970; Figure 1; Table 1). The 40.1-60.0 m depth interval accounted for most of the samples from all areas. Only one sample was taken in the 0.1-20.0 m zone from the New Jersey and Delmarva areas. The total number of quahogs weighed and measured from all depths and areas was 2,564.

Summary Statistics

Statistical summaries of length and weight data are presented in Table 1. Smallest mean lengths and weights (all depths combined) were derived from southern New England-Long Island, with average sizes increasing to the south. Within all areas the 20.1-40.0 m interval contained the largest quahogs sampled. Shell lengths ranged from 17 to 131 mm; the overall average length

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[1] The $antilog_e$ of a is a biased estimate of c since the expected value of e^a is $ce^{\sigma^2/2}$; where σ^2 is the variance of a (Brownlee 1965). However, this bias was investigated and determined to have a negligible effect of the results of our analyses.

was 85.20 mm. Drained meat weights varied from 0.3 to 98.6g, the mean was 28.62g. Length frequencies (5 mm intervals) of ocean quahogs from the three areas, and depths from 20.1-80.0 m are presented in Figure 2. Frequencies from the Delmarva area show pronounced modes and the range of sizes is less than in samples from the two northern locations. Samples from southern New England-Long Island show the most even distribution among size classes. No significant trends appear to exist between depths within areas.

Length-weight regression statistics for each area/depth stratum, and overall equations are expressed in Table 2. Tests of allometric growth (Appendix A1) are significant for most areas and depths, with slope (b) values generally less than 3.0. The New Jersey 60.1-80.0 m stratum is the exception with a b value significantly greater than 3.0. Slopes of equations for the southern New England-Long Island and Delmarva areas, and the overall regression (all depths combined) indicate significant allometric growth functions apply.

Covariance Analyses

Regression equations were tested to determine if significant differences among lines existed due to area and/or depth of capture. Differences between areas were examined by combining all quahogs from the depth strata within each area. Significant differences ($P<0.01$) were evident among the adjusted means of the three areas, with the largest value from Delmarva, followed by New Jersey and southern New England-Long Island (Table 3). The only significant difference in slopes was between southern New England-Long Island and New Jersey. Since both the slopes and adjusted means of the New Jersey area are significantly greater than those for the southern New England-Long Island location in the pooled analysis, the meat weight per unit shell length for New Jersey quahogs is greater than for Southern New England-Long Island.

Tests between areas, within each of the three 20 m depth strata from 20.1 to 80.0 m are summarized in Appendix A2. Results are similar to those with all depths combined; only two sets of adjusted means were not different at the 1% level. In all paired comparisons, adjusted means were larger for the more southern area. Slopes of New Jersey regressions were either the same or greater than those from southern New England-Long Island. The only aberrant slope test was between New Jersey and Delmarva 60.1-80.0 m depth intervals. In the pooled analysis adjusted means were similar in rank to the mean shell lengths and meat weights of the three areas (Tables 1 and 3).

Differences in regressions due to depth were examined by combining samples from all areas that fell within the four 20 m depth intervals. No differences were detected between slopes of paired comparisons, but tests of adjusted means indicated quahogs from the 20.1-40.0 m zone were more robust than others. However, analyses between depth groups within areas (Appendix A3) reveal no obvious trends in the significance of tests of slopes or adjusted means. Thus, although depth may in fact influence the length-weight relation, the effects are not similar among inter-area, and intra-area comparisons. Snedecor and Cochran (1967) have shown that the probability of an erroneous conclusion is increased in repetitive tests of pairs of means, particularly at the 5% level. Therefore, the validity of 5% differences in our study should be noted with caution.

Precision of Computed Weights

Comparisons of predicted and observed weights for quahogs from each area with all depths combined are given in Table 5. Differences between mean observed and predicted weights for 5 mm shell length intervals range from 0.09 to 34.61%. However, if only size classes with 10 or more quahogs are considered, differences are from 0.09 to 13.27%. Correlation coefficients indicate that from 71 to 95% (r^2 .100) of the variation between shell length and meat weight is accounted for by the regression equations. (Table 2). Predicted weights for all quahogs sampled were 0.8%, 1.1%, 1.4%, and 1.4% smaller than the total of observed weights for Delmarva, New Jersey, So. New England-Long Island, and all areas respectively (Table 5). Thus, the use of regression equations results in relatively precise approximations of empirical data when converting shell lengths to meat weights.

DISCUSSION

Results of these analyses indicate meat weights for similar sized quahogs increase significantly from southern New England-Long Island to Delmarva. The consistency of this trend in tests within depth zones and in pooled comparisons suggests differences are probably not merely statistical artifacts. Possible factors affecting the relative condition of quahogs between areas include physical and biological variables such as temperature, salinity, pressure, nutrients, and food supply. The physical oceanography of the Middle Atlantic has been reviewed in detail (Beardsley et al 1976), and temperature profiles of the area reported by Walford and Wicklund (1968) and Colton and Stoddard (1973) among others. The annual variation in bottom water temperatures on the continental shelf within the depth range of ocean quahogs that we sampled is much greater off Long Island and southern New England (Colton and Stoddard 1973) than further to the south as indicated from transects off Cape May, Cape Charles, and Cape Hatteras (Walford and Wicklund 1968). The seasonal minimum and maximum bottom water temperatures within the range of ocean quahog occurrence are approximately 2°C and 19°C off southern New England-Long Island, but off Cape Charles are about 7.5° and 17.5°. Stability of the thermal environment may be an important factor governing metabolic processes and ultimately growth, resulting in an increase in relative meat yields to the south. Density dependent factors may limit growth in more northern waters, but evidence is only circumstantial (Merrill and Ropes 1970). The direct effects of environmental variables on growth and condition factors of ocean quahogs are yet to be studied.

Bearse (1976) calculated the length-weight relation from inshore Rhode Island samples (n = 129) as :

$$\log_{10}W = -3.0391 + 2.355 \log_{10}W$$

Computed meat weights for shell lengths he analyzed ($\bar{x}$ = 90.5 mm, σ = 8.3 mm) were slightly greater for Rhode Island than comparable values from our length-weight equations for southern New England-Long Island, New Jersey and Delmarva. The higher meat weights off Rhode Island may reflect the greater productivity of inshore waters, or the season of capture, as his samples were taken in summer and autumn. Further study of ocean quahog lengths and weights from the Middle Atlantic area is necessary to determine if relationships vary significantly on a seasonal or annual basis, or with the state of sexual maturity.

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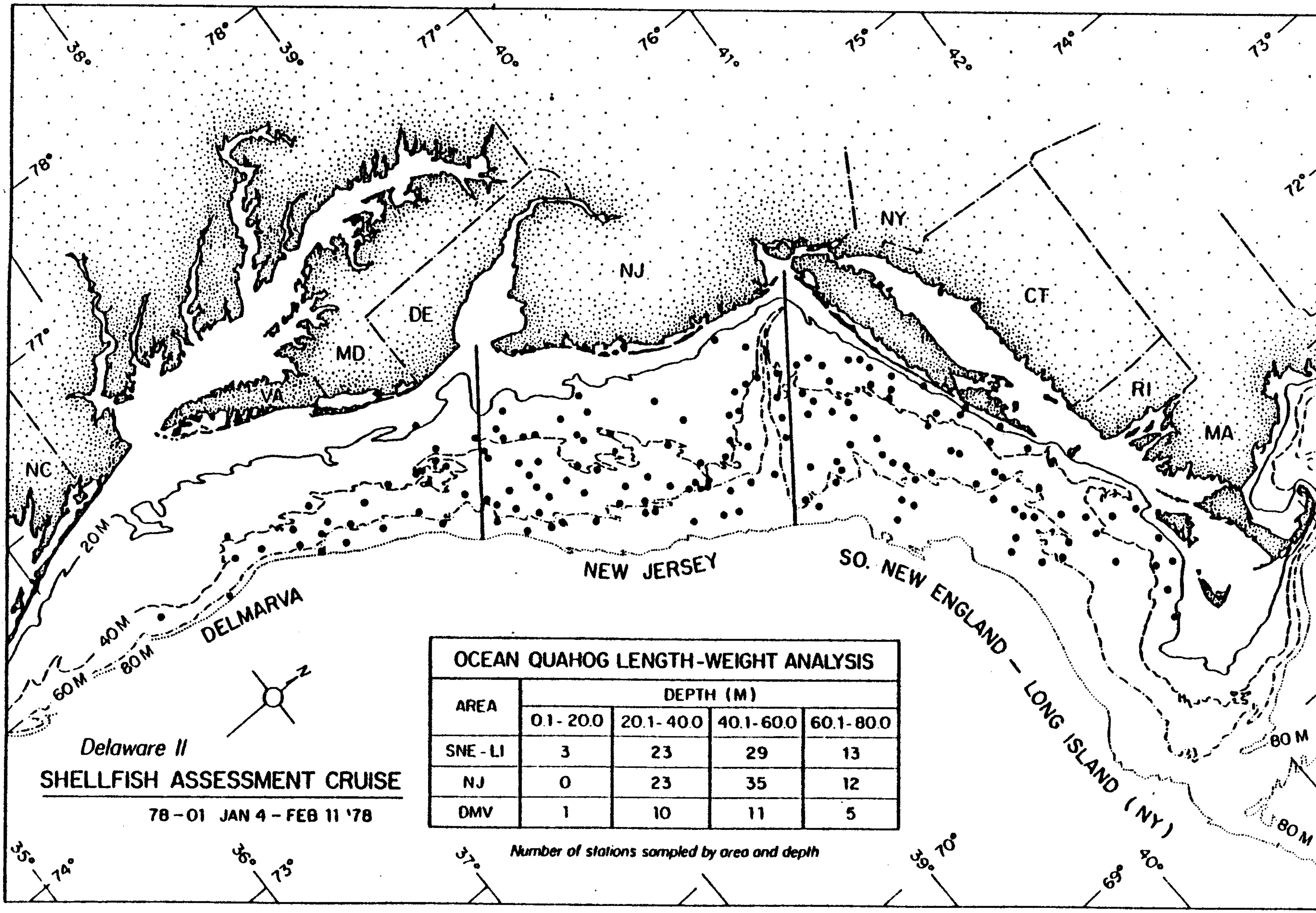
Table 1. Summary statistics of ocean quahog length-weight data by area and depth caught.

Area		Shell Length (mm)						Meat Weight (g)					
(Depth, meters)	n	$\bar{x}$	S.D.	S.E.	C.V.	Min	Max	$\bar{x}$	S.D.	S.E.	C.V.	Min	Max
So. NE.-LI.													
0.1-20.0	28	76.14	10.53	1.99	13.83	60	97	19.30	7.87	1.49	40.76	9.3	39.9
20.1-40.0	439	84.24	14.75	0.70	17.51	41	117	28.33	13.74	0.66	48.49	3.6	77.6
40.1-60.0	663	80.11	16.89	0.66	21.09	17	115	22.58	12.19	0.47	53.99	0.3	58.8
60.1-80.0	221	76.19	16.61	1.12	21.80	33	111	18.84	9.88	0.66	52.42	2.1	54.0
All Depths	1,351	80.73	16.30	0.44	20.19	17	117	23.77	12.77	0.35	53.73	0.3	77.6
New Jersey													
0.1-20.0	0	-	-	-	-	-	-	-	-	-	-	-	-
20.1-40.0	187	94.84	16.09	1.18	16.96	39	131	39.68	16.94	1.24	42.70	3.5	89.4
40.1-60.0	603	88.65	14.05	0.57	15.85	30	130	31.95	14.45	0.59	45.24	1.2	86.2
60.1-80.0	192	83.75	15.81	1.14	18.88	30	116	26.68	13.27	0.96	49.74	1.0	57.5
All Depths	982	88.87	15.20	0.48	17.10	30	131	32.39	15.28	0.49	47.18	1.0	89.4
Delmarva													
0.1-20.0	1	94.00	-	-	-	94	94	39.80	-	-	-	39.8	39.8
20.1-40.0	82	99.79	9.14	1.01	9.16	63	124	47.53	12.83	1.42	27.00	10.2	98.6
40.1-60.0	106	92.95	11.62	1.13	12.51	59	115	36.57	12.57	1.22	34.37	7.6	68.5
60.1-80.0	42	95.02	8.66	1.34	9.11	76	120	39.56	8.65	1.33	21.87	19.6	56.6
All Depths	231	95.76	10.68	0.70	11.15	59	124	41.02	12.96	0.85	31.61	7.6	98.6
All Areas													
0.1-20.0	29	76.76	10.86	2.02	14.15	60	97	20.01	8.61	1.60	43.05	9.3	39.9
20.1-40.0	708	88.84	15.78	0.59	17.76	39	131	33.55	16.15	0.61	48.14	3.5	98.6
40.1-60.0	1,372	84.85	16.04	0.43	18.90	17	130	27.78	14.22	0.38	51.20	0.3	86.2
60.1-80.0	455	81.12	16.68	0.78	20.56	30	120	24.06	12.90	0.60	53.63	1.0	57.5
All Depths	2,564	85.20	16.26	0.32	19.08	17	131	28.62	14.90	0.29	52.06	0.3	98.6



OCEAN QUAHOG LENGTH-WEIGHT ANALYSIS				
AREA	DEPTH (M)			
	0.1-20.0	20.1-40.0	40.1-60.0	60.1-80.0
SNE-LI	3	23	29	13
NJ	0	23	35	12
DMV	1	10	11	5

Number of stations sampled by area and depth

Figure 1. Locations of survey stations where ocean quahog catches were sampled for length-weight analysis, January-February 1978.

Table 2. Statistics describing regression equations between shell length (mm) and drained meat weight (g) for ocean quahogs.

Area (Depth, Meters)	Regression Statistics				
	Intercept(a)	Slope(b)	S.E. of b	Antilog$_e$ of a	Correlation Coefficient(
So.NE.-LI.					
0.1-20.0	-8.904549	2.726880	0.1722	0.000135770	0.9519
20.1-40.0	-9.200337	2.810010	0.0413	0.000101005	0.9559
40.1-60.0	-9.148425	2.772700	0.0245	0.000106387	0.9752
60.1-80.0	-8.094217	2.522978	0.0416	0.000305300	0.9715
All Depths	-9.124283	2.774989	0.0199	0.000108987	0.9670
New Jersey					
0.1-20.0	-	-	-	-	-
20.1-40.0	-8.843453	2.734179	0.0693	0.000144324	0.9454
40.1-60.0	-9.490559	2.871530	0.0384	0.000075562	0.9503
60.1-80.0	-10.948815	3.187898	0.0603	0.000017579	0.9676
All Depths	-9.847183	2.949540	0.0294	0.000052896	0.9546
Delmarva					
0.1-20.0	-	-	-	-	-
20.1-40.0	-8.982059	2.784504	0.1342	0.000125644	0.9183
40.1-60.0	-8.907830	2.749699	0.1143	0.000135325	0.9206
60.1-80.0	-6.100883	2.143729	0.2152	0.002240888	0.8443
All Depths	-9.042313	2.787987	0.0800	0.000118297	0.9172
All Areas					
0.1-20.0	-9.234804	2.804718	0.1688	0.000097583	0.9544
20.1-40.0	-9.300081	2.835711	0.0323	0.000091417	0.9571
40.1-60.0	-9.538888	2.873336	0.0207	0.000071997	0.9664
60.1-80.0	-9.519757	2.862046	0.0372	0.000073387	0.9637
All Depths	-9.589618	2.888016	0.0159	0.000068436	0.9635

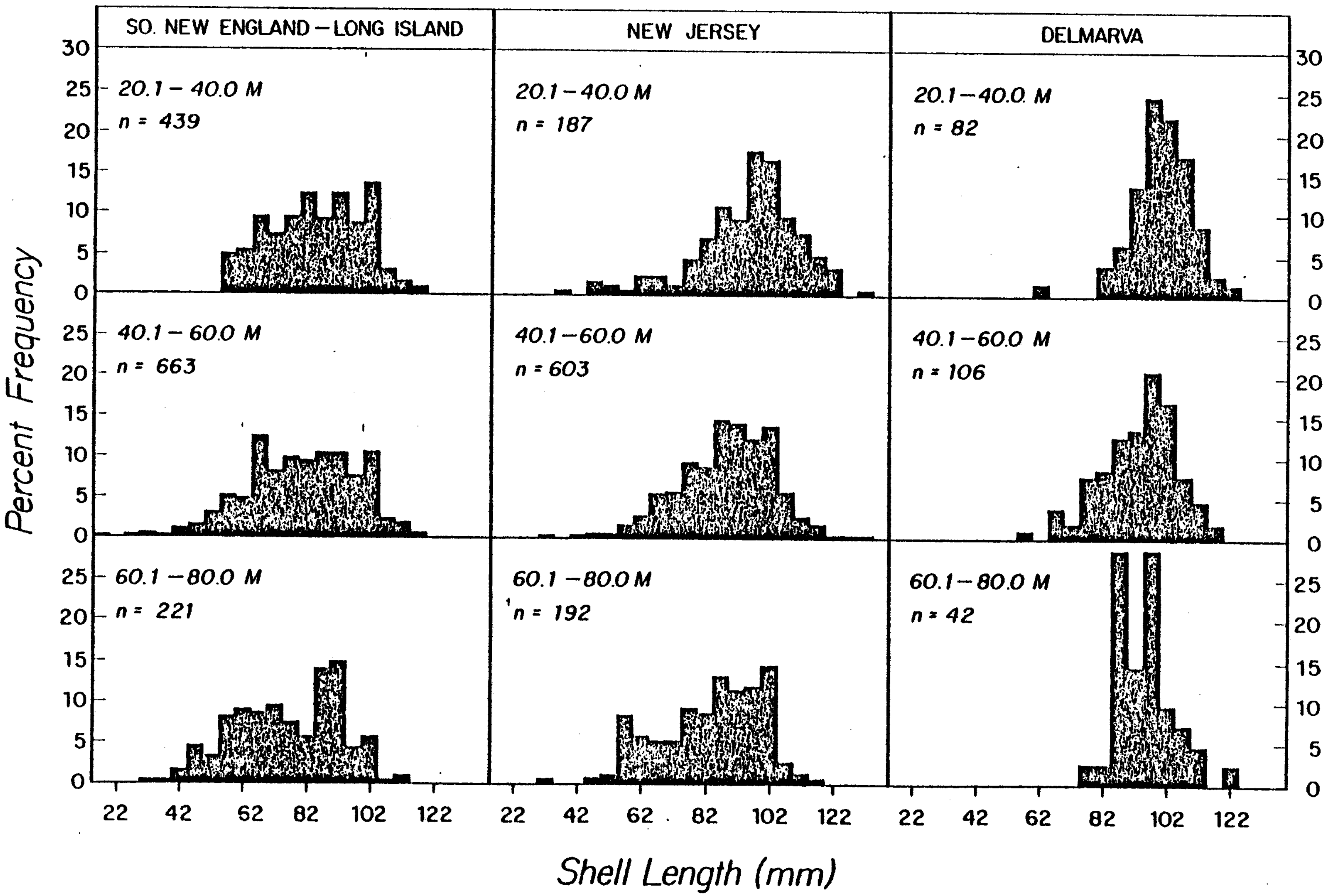


Figure 2. Length frequency distributions of ocean quahog samples taken for length-weight analysis from the Middle Atlantic shelf, January-February 1978.

Table 3. Results of covariance analysis of adjusted means and slopes of ocean quahog length-weight regression equations between pairs of areas (all depths combined), and simultaneous comparisons of adjusted means among areas.

	Test of Adjusted Means			Test of Slopes		
Area	F-Ratio	df	Significance Level	F-Ratio	df	Significance Level
So.NE-LI vs. New Jersey	49.954	1,2330	P<0.01	24.971	1,2329	P<0.01
So.NE-LI vs. Delmarva	139.171	1,1579	P<0.01	0.011	1,1578	n.s.
New Jersey vs. Delmarva	31.256	1,1210	P<0.01	2.691	1,1209	n.s.

Comparisons of Adjusted Means

	Southern New England-Long Island		New Jersey		Delmarva
Adjusted Mean	3.156		3.208		3.286
S.E.	0.005		0.005		0.011
t matrix					
So.NE-LI	-				
NJ	7.188	P<0.01	-		
DMV	10.657	P<0.01	6.435	P<0.01	-

P<0.01 = Significant at 1% level
P<0.05 = Significant at 5% level
n.s. = non-significant

Table 4. Results of covariance analyses of adjusted means and slopes of ocean quahog length-weight regression equations between depth intervals (all areas combined), and simultaneous comparisons of adjusted means among depths.

Depth (meters)	Test of Adjusted Means			Test of Slope		
	F-Ratio	df	Significance Level	F-Ratio	df	Significance Level
0.1-20.0 vs. 20.1-40.0	4.939	1,734	P<0.05	0.018	1,733	n.s.
0.1-20.0 vs. 40.1-60.0	0.037	1,1398	n.s.	0.086	1,1397	n.s.
0.1-20.0 vs. 60.1-80.0	1.152	1,481	n.s.	0.055	1,480	n.s.
20.1-40.0 vs. 40.1-60.0	87.250	1,2077	P<0.01	0.966	1,2076	n.s.
20.1-40.0 vs. 60.1-80.0	96.706	1,1160	P<0.01	0.3012	1,1159	n.s.
40.1-60.0 vs. 60.1-80.0	11.497	1,1824	P<0.01	0.076	1,1823	n.s.

Comparisons of Adjusted Means

	0.1-20.0m	20.1-40.0m	40.1-60.0m	60.1-80.0m
Adjusted Mean	3.179	3.245	3.174	3.142
S.E.	0.031	0.006	0.004	0.008
t matrix				
0.1-20.0m	-			
20.1-40.0m	2.085 P<0.05	-		
40.1-60.0m	-0.171 n.s.	-9.203 P<0.01	-	
60.1-80.0m	-1.149 n.s.	-10.135 P<0.01	-3.464 P<0.01	-

P<0.01 = Significant at 1% level
P<0.05 = Significant at 5% level
n.s. = non-significant

Table 5. Comparisons of mean empirical and mean calculated weights (g) from regression equations for ocean quahogs from the Middle Atlantic shelf.

Length Interval (mm)	So. NE. - LI. n	$\bar{x}$ Length	$\bar{x}$ Empirical Weight	$\bar{x}$ Calculated Weight	New Jersey n	$\bar{x}$ Length	$\bar{x}$ Empirical Weight	$\bar{x}$ Calculated Weight	Delmarva n	$\bar{x}$ Length	$\bar{x}$ Empirical Weight	$\bar{x}$ Calculated Weight	All Data n	$\bar{x}$ Length	$\bar{x}$ Empirical Weight	$\bar{x}$ Calculated Weight
15-19	1	17.00	0.30	0.28	-	-	-	-	-	-	-	-	1	17.00	0.30	0.24
20-24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
25-29	2	25.00	0.95	0.83	-	-	-	-	-	-	-	-	2	25.00	0.95	0.75
30-34	4	32.50	1.73	1.71	2	30.00	1.10	1.20	-	-	-	-	6	31.67	1.52	1.48
35-39	3	37.67	3.00	2.58	1	39.00	3.50	2.61	-	-	-	-	4	38.00	3.13	2.50
40-44	12	42.17	3.89	3.53	1	43.00	4.30	3.48	-	-	-	-	13	42.23	3.92	3.40
45-49	20	47.10	4.86	4.79	6	47.00	5.48	5.54	-	-	-	-	26	47.08	5.00	4.65
50-54	28	52.46	6.95	6.47	6	52.00	7.62	6.10	-	-	-	-	34	52.38	7.07	6.33
55-59	74	57.72	8.32	8.42	27	57.26	7.33	8.11	1	59.00	7.60	10.23	102	57.61	8.05	8.32
60-64	80	61.95	10.10	10.25	31	62.29	10.35	10.39	1	63.00	10.20	12.29	112	62.05	10.17	10.31
65-69	147	67.10	12.75	12.79	47	67.11	12.81	12.95	4	68.50	18.03	15.52	198	67.13	12.87	12.94
70-74	115	71.90	15.33	15.50	46	72.33	16.90	16.14	2	73.00	19.20	18.53	163	72.04	15.82	15.87
75-79	126	76.90	19.11	18.67	82	77.12	19.27	19.51	9	77.33	20.97	21.78	217	77.00	19.25	19.23
80-84	134	82.07	23.20	22.37	83	82.14	24.68	23.49	13	81.69	26.30	25.38	230	82.08	23.91	23.12
85-89	143	86.92	26.92	26.22	134	87.07	28.80	27.89	30	87.27	31.57	30.50	307	87.02	28.20	27.36
90-94	159	91.99	30.76	30.69	124	92.15	34.14	32.97	32	92.00	34.79	35.34	315	92.06	32.50	32.20
95-99	101	96.56	35.79	35.11	130	96.95	38.62	38.29	54	97.02	42.17	40.98	285	96.82	38.29	37.25
100-104	142	101.50	41.47	40.32	143	101.55	43.94	43.90	40	102.10	47.82	47.24	325	101.60	43.34	42.80
105-109	30	106.33	44.98	45.87	57	106.49	52.33	50.50	25	106.92	54.06	53.72	112	106.54	50.74	49.09
110-114	23	111.48	51.16	52.29	31	111.39	54.79	57.65	14	111.21	56.06	59.95	68	111.38	53.83	55.80
115-119	7	115.71	57.90	57.98	21	117.19	65.41	66.96	4	115.50	70.25	66.60	32	116.66	64.37	63.78
120-124	-	-	-	-	7	121.14	71.16	73.83	2	122.00	74.15	77.63	9	121.33	71.82	71.45
125-129	-	-	-	-	1	125.00	73.60	80.97	-	-	-	-	1	125.00	73.60	77.84
130-134	-	-	-	-	2	130.50	85.00	91.94	-	-	-	-	2	130.50	85.00	88.15

Appendix A1. Tests of allometric growth of shell length and meat weight of ocean quahogs (Ho:slope (b) of regression equal to 3.0).

Area (Depth, meters)	Test of Allometric Growth		
	t - Value	df	Significance Level
So.NE.-LI.			
0.1-20.0	- 1.586	26	n.s.
20.1-40.0	- 4.598	437	P<0.01
40.1-60.0	- 9.294	661	P<0.01
60.1-80.0	-11.459	219	P<0.01
All Depths	-11.302	1,349	P<0.01
New Jersey			
0.1-20.0	-	-	-
20.1-40.0	- 3.834	185	P<0.01
40.1-60.0	- 3.346	601	P<0.01
60.1-80.0	3.114	190	P<0.01
All Depths	- 1.71	980	n.s.
Delmarva			
0.1-20.0	-	-	-
20.1-40.0	- 1.605	80	n.s.
40.1-60.0	- 2.189	104	P<0.05
60.1-80.0	- 3.979	40	P<0.01
All Depths	- 2.649	229	P<0.01
All Areas			
0.1-20.0	- 1.157	27	n.s.
20.1-40.0	- 5.083	706	P<0.01
40.1-60.0	- 6.130	1,370	P<0.01
60.1-80.0	- 3.705	453	P<0.01
All Depths	- 7.064	2,562	P<0.01

P<0.01 = Significant at 1% level
P<0.05 = Significant at 5% level
n.s. = non-significant

Appendix A2. Results of covariance analyses of adjusted means and slopes of ocean quahog length-weight regression equations within depth strata, between areas.

Depth Strata (meters) (Area)	Adjusted Mean	Test of Adjusted Means: F-Ratio	df	Significance Level	Test of Slopes: F-Ratio	df	Significance Level
<u>20.1-40.0</u>							
So.NE.-LI.	3.311	1.092	1,623	n.s.	0.994	1,622	n.s.
vs.							
New Jersey	3.326						
So.NE.-LI.	3.293						
vs.		26.507	1 518	P<0.01	0.022	1,517	n.s.
Delmarva	3.394						
New Jersey	3.609						
vs.		16.886	1,226	P<0.01	0.064	1,265	n.s.
Delmarva	3.702						
<u>40.1-60.0</u>							
So.NE.-LI.	3.085	112.613	1,1263	P<0.01	4.860	1,1262	P<0.05
vs.							
New Jersey	3.182						
So.NE-LI.	2.998						
vs.		71.227	1,766	P<0.01	0.037	1,765	n.s.
Delmarva	3.134						
New Jersey	3.370						
vs.		3.547	1 706	n.s.	0.948	1,705	n.s.
Delmarva	3.402						
<u>60.1-80.0</u>							
So.NE.-LI.	2.903						
vs.		7.715	1,410	P<0.01	86.085	1,409	P<0.01
New Jersey	2.952						
So.NE.-LI.	2.870						
vs.		108.478	1,260	P<0.01	2.278	1,259	n.s.
Delmarva	3.140						
New Jersey	3.183						
vs.		11.548	1,231	P<0.01	12.512	1,230	P<0.01
Delmarva	3.286						

P<0.01 = Significant at 1% level
P<0.05 = Significant at 5% level
n.s. = non-significant

Appendix A3. Results of covariance analyses of adjusted means and slopes of ocean quahog length-weight regerssion equations between depth strata, within areas.

Area (Depth, meters)	Test of Adjusted Means: Adjusted Mean	F-Ratio	df	Significance Level	Test of Slopes: F-Ratio	df	Significance Level
So.NE.-LI.							
0.1-20.0	3.133						
vs.		4.364	1,464	P<0.05	0.135	1,463	n.s.
20.1-40.0	3.197						
0.1-20.0	2.976	2.519	1,688	n.s.	0.043	1,687	n.s.
vs.							
40.1-60.0	2.930						
0.1-20.0	2.848						
vs.		6.129	1,246	P<0.05	0.971	1,245	n.s.
60.1-80.0	2.777						
20.1-40.0	3.113						
vs.		139.643	1,1099	P<0.01	0.619	1,1098	n.s.
40.1-60.0	3.000						
20.1-40.0	3.114						
vs.		117.568	1,657	P<0.01	23.111	1,656	P<0.01
60.1-80.0	2.969						
40.1-60.0	2.900						
vs.		4.408	1,881	P<0.05	26.017	1,880	P<0.01
60.1-80.0	2.875						
New Jersey							
20.1-40.0	3.417						
vs.		3.517	1,787	n.s.	3.434	1,786	n.s.
40.1-60.0	3.391						
20.1-40.0	3.364						
vs.		13.964	1,376	P<0.01	24.510	1,375	P<0.01
60.1-80.0	3.290						
40.1-60.0	3.302						
vs.		17.069	1,792	P<0.01	20.900	1,791	P<0.01
60.1-80.0	3.245						
Delmarva							
20.1-40.0	3.707						
vs.		15.874	1,185	P<0.01	0.033	1,184	n.s.
40.1-60.0	3.621						
20.1-40.0	3.780						
vs.		3.411	1,121	n.s.	6.650	1,120	P<0.05
60.1-80.0	3.737						
40.1-60.0	3.551						
vs.		3.710	1,145	n.s.	4.807	1,144	P<0.05
60.1-80.0	3.603						

P<0.01 = Significant at 1% level
P<0.05 = Significant at 5% level
n.s. = non-significant