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SHELL LENGTH — MEAT WEIGHT RELATIONSHIPS OF OCEAN QUAHOGS, *ARCTICA ISLANDICA*, FROM THE MIDDLE ATLANTIC SHELF

Steven A. Murawski and Fredric M. Serchuk

U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL MARINE FISHERIES SERVICE
NORTHEAST FISHERIES CENTER
WOODS HOLE, MASSACHUSETTS 02543

ABSTRACT

Shell length — drained meat weight relationships were calculated from 2,564 ocean quahogs, Arctica islandica, *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 areas.*

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 to 256 m (Merrill and Ropes, 1969). Studies of the life history and in particular the population dynamics of this species are few. Aspects of 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, New York. However, results of systematic quantitative meat yield investigations have not been reported. 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 empirical data.

METHODS

Ocean quahog samples for length-weight analysis were collected from the Middle Atlantic shelf (Cape Cod to Cape Hatteras) during the

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shellfish assessment survey of the R/V DELAWARE II from 4 January to 11 February 1978 (Figure 1). 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 selected randomly within area/depth strata; the dredge was towed for 4 minutes at approximately 0.5 m s $^{-1}$ at each site. Ocean quahogs were collected in depths ranging from 13 to 75 m. Subsamples of the catches 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 subsamples of the survey catches, but regression equations are probably more accurate over a wider size range of quahogs than those from simple stratified random samples.

Shell dimensions were recorded to the nearest mm, and all soft parts of each quahog shucked into an individual plastic bag. 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 regression equations were fitted with length and weight data converted to natural logarithms. The form of the length-weight equation was assumed to be:

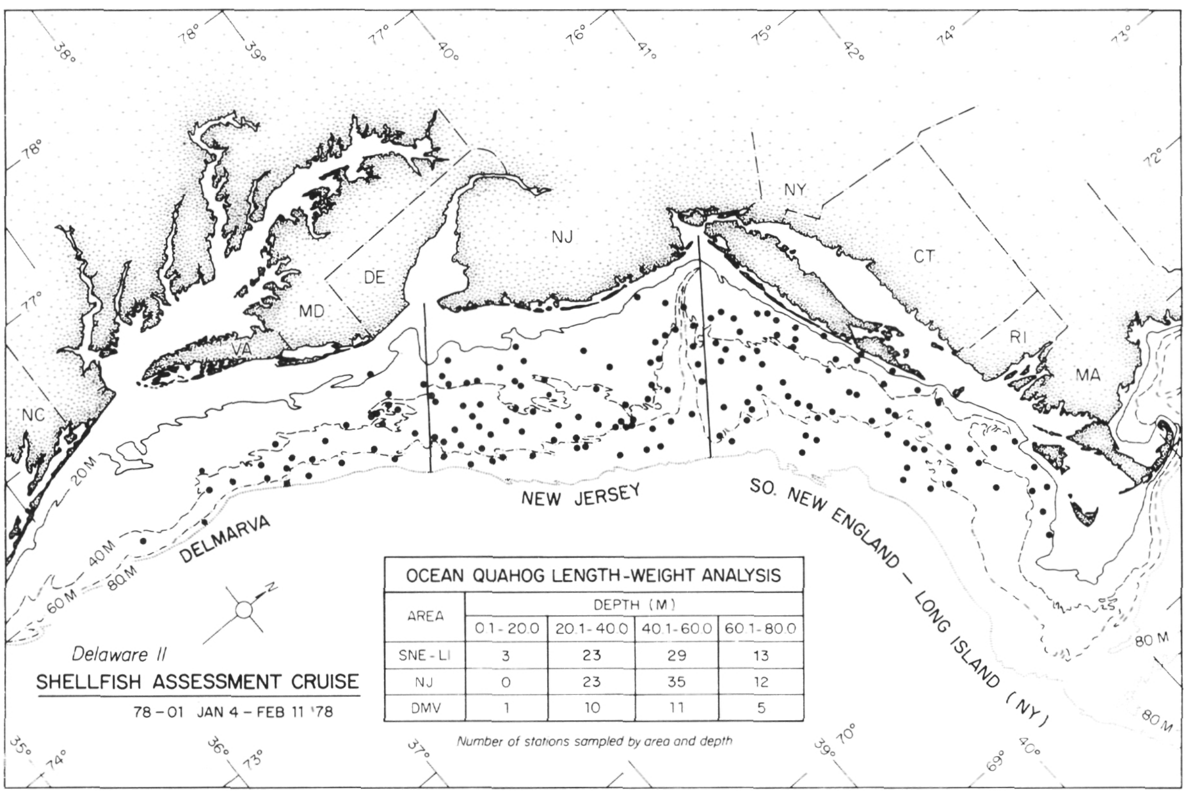
$W = cL^b$

where,

W = drained meat weight (g),

L = shell length (mm),

c and b = coefficients to be estimated from regression.



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

FIGURE 1. *Locations of survey stations where ocean quahogs were sampled for length-weight analysis, January-February 1978.*

TABLE 1. *Summary statistics of ocean quahog length-weight data by area caught.*

Area	Shell Length (mm)					Meat Weight (g)			
	n	$\bar{x}$	σ	Min.	Max.	$\bar{x}$	σ	Min.	Max.
Southern New England									
Long Island	1,351	80.73	16.30	17	117	23.77	12.77	0.3	77.6
New Jersey	982	88.87	15.20	30	131	32.39	15.28	1.0	89.4
Delmarva	231	95.76	10.68	59	124	41.02	12.96	7.6	98.6
All Areas	2,564	85.20	16.26	17	131	28.62	14.90	0.3	98.6

Isometric growth (i.e. slope of length-weight regression = 3.0, implying unchanging ratios of linear measurements as the organism grows [Ricker, 1975]) was tested employing Student's t with n-2 degrees of freedom (Steel and Torrie, 1960). Covariance analyses (Snedecor and Cochran, 1967) were conducted to determine the significance of differences between slopes and adjusted means of various length-weight equations. The one-way analysis of covariance computer program BMDP1V was used for all these calculations (Dixon, 1975).

Empirical weights were compared to weights derived from regression equations applied to the shell lengths of samples from several different areas. Empirical weights were totaled for quahogs from the three major areas and for all areas combined. Corresponding total calculated weights were computed by:

$$TCW = \sum_{i=1}^{n} L_i^{\,b} \text{ Antilog}_e \, a$$

where,

TCW = total calculated weight (g),

L_i = shell length of individual, i, in the length frequency, where i = 1, 2, 3, ...n,

b = slope of the length-weight regression specific for the area being studied,

Antilog_e a = antilog_e of the intercept of the length-weight equation used in the analysis (=c).

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 by area and 20 m depth interval (Figure 1). Area designations generally correspond to beds frequented by commercial fishermen from the various coastal states, and thus may serve to delimit fisheries. 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. The total number of quahogs weighed and measured was 2,564.

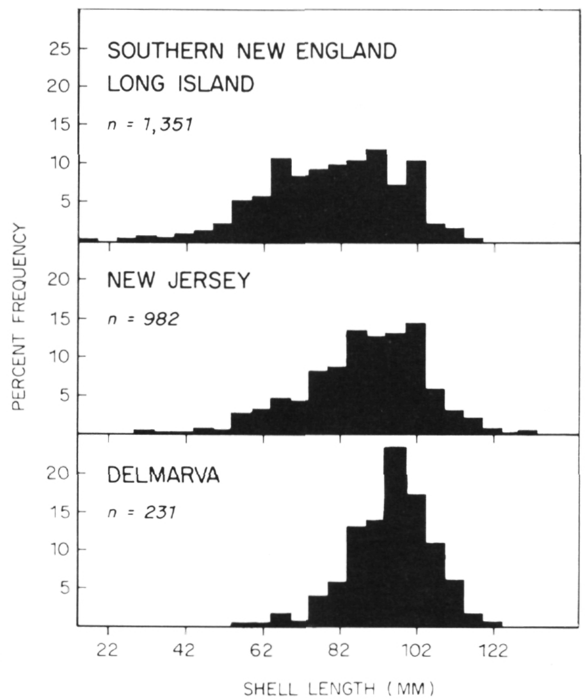


FIGURE 2. *Length frequencies of ocean quahogs sampled for length-weight analysis from the Middle Atlantic shelf.*

Summary Statistics

Statistical summaries of length and weight data for the three major areas, and all data, are presented in Table 1. Smallest mean lengths and weights were sampled from Southern New England—Long Island, with average sizes, as well as modal lengths (Figure 2), increasing to the south. Shell lengths ranged from 17 to 131 mm; the overall average length was 85.20 mm. Meat weights ranged from 0.3 to 98.6 g (mean = 28.62 g). The length frequency from the Delmarva area shows a pronounced mode 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. Length-weight regression statistics for each area and the overall equation are expressed in Table 2. Regression equations for individual 20 m depth intervals are given in Murawski et al. (1978). Slopes of regression equations for the major areas were significantly ($P<0.01$) less than 3.0, except for New Jersey. Thus allometric growth functions apply for quahogs from Southern New England—Long Island, Delmarva, and for all data.

Covariance Analyses

Regression equations were tested to determine if significant differences among lines existed due to area and/or depth of capture. In tests among the three major areas, the only significant difference in slopes was between Southern New England—Long Island and New Jersey (Table 3). The slope of the New Jersey equation was significantly greater than that for the Southern New England—Long Island location, indicating the two regression lines were statistically different, with New Jersey quahogs generally containing more meat per unit shell length for the range of lengths considered. Predicted meat weights for New Jersey quahogs smaller than 63 mm were less than corresponding values for Southern New England—Long Island, but this difference may be due to the paucity of these sizes sampled off New Jersey (Figure 2). The adjusted mean of the Delmarva equation was significantly greater than those of the Southern New England—Long Island, and New Jersey equations in paired comparisons (Table 3). Thus separate equations apply for the three areas, and computed meat weights for the range of shell lengths sampled generally increase from Southern New England—Long Island to Delmarva. Results of tests between areas for each of the three 20 m depth strata from 20.1-80.0 m were generally similar to those with all depths combined (Murawski et al., 1978). Differences in regressions due to depth of capture were examined by comparing samples from the three major areas that fell within the four 20 m depth intervals, and by comparing depth groups within each area (Murawski et al., 1978). However, results of these tests revealed no obvious trends in the significance of differences between slopes or adjusted means. Depth of occurrence may directly or indirectly influence the length-weight relationship, but the ef-

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

Area	Regression Statistics				
	Intercept (a)	Slope (b)	S.E. of b	Antilog$_e$ of a	Correlation Coefficient (r)
Southern New England					
Long Island	−9.124283	2.774989	0.0199	0.000108987	0.9670
New Jersey	−9.847183	2.949540	0.0294	0.000052896	0.9546
Delmarva	−9.042313	2.787987	0.0800	0.000118297	0.9172
All Areas	−9.589618	2.888016	0.0159	0.000068436	0.9635

TABLE 3. *Results of covariance analysis of adjusted means and slopes of ocean quahog length-weight regression equations between pairs of areas.*

Areas	Test of Adjusted Means: Adjusted Mean	F-Ratio	df	Significance Level	Test of Slopes: F-Ratio	df	Significance Level
Southern New England Long Island vs. New Jersey	NOT APPLICABLE				24.971	1,2329	P<0.01
Southern New England Long Island	3.073						
vs.		139.171	1,1579	P<0.01	0.011	1,1578	n.s.
Delmarva	3.214						
New Jersey	3.387						
vs.		31.256	1,1210	P<0.01	2.691	1,1209	n.s.
Delmarva	3.456						

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

fects were not similar among inter-area and intra-area comparisons.

Precision of Computed Weights

Correlation coefficients indicate that from 84 to 94% ($r^2 \cdot 100$) of the variation between shell length and meat weight is accounted for by the regression equations (Table 2). Predicted weights were, however, 0.8, 1.1, 1.3, and 1.4% smaller than the total of empirical weights for Delmarva, New Jersey, Southern New England—Long Island, and all areas, respectively. A slight negative bias is suggested by the fact that all sums of empirical weights were greater than their calculated counterparts, but the magnitude of the differences is quite small. The residuals about the regression lines were plotted against the dependent variable for the three major areas (Figure 3). In all cases the residuals appear normally distributed around 0; no obvious biases appear to exist when the log-linear model is assumed. Thus, the use of our regression equations results in relatively precise approximations of empirical data when converting shell length to meat weight.

DISCUSSION

Results of these analyses indicate meat weights for similar sized quahogs generally increase 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 temperature 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 sampled 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 in-

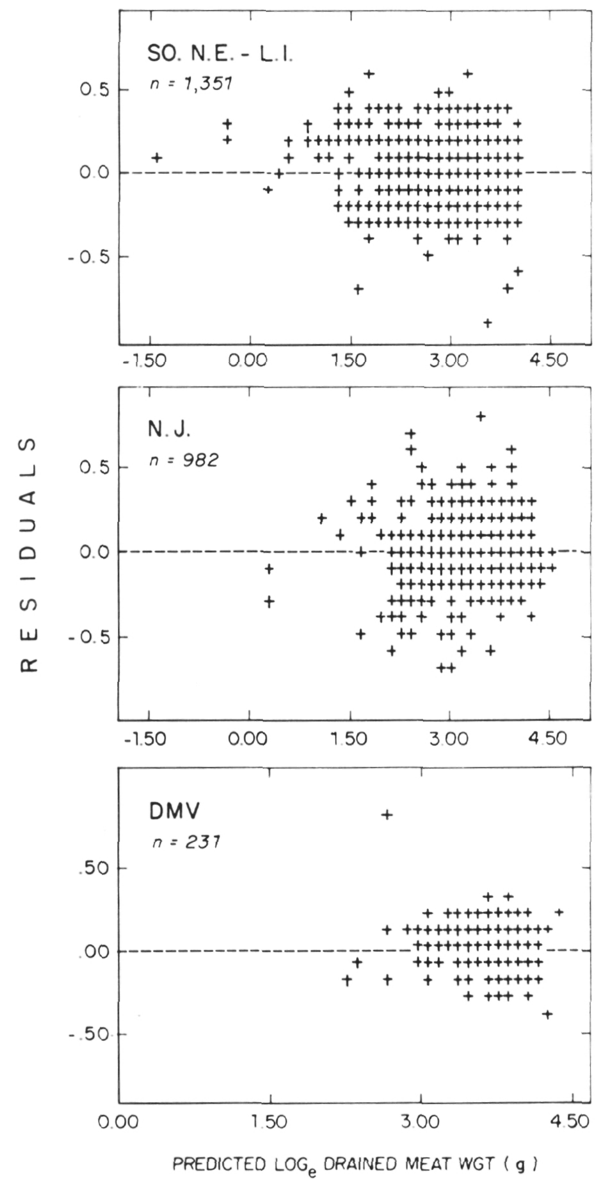


FIGURE 3. *Plots of residual differences between predicted and actual $\log_e$ meat weights for ocean quahogs from the Middle Atlantic shelf.*

crease 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:

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

Computed meat weights for shell lengths he analyzed ($\bar{x} = 90.5$ mm, $\sigma = 8.3$ mm) were slightly greater for Rhode Island than comparable values from our length-weight equations. The higher meat weights off Rhode Island may reflect the greater productivity of these 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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CONTENTS