International Council for the Exploration of the Sea

C.M 1995/K: 26
Shellfish Committee

SHELL LENGTH-MEAT WEIGHT RELATIONSHIPS OF OCEAN QUAHOG, *ARCTICA ISLANDICA* (LINNAEUS), FROM ICELANDIC WATERS

by
Gudrún G. Thórarinsdottir
and
Gardar Jóhannesson

Marine Research Institute, P.O.Box. 1390
Skúlagata 4, 121 Reykjavík, Iceland

ABSTRACT

Shell length - meat weight relationships were calculated for ocean quahog, *Arctica islandica*, at the north-west, north and east coasts of Iceland during January - June 1994.

The estimated length-weight relationship for the three areas were:

Northwest area $W = 0.0000567\ L^{3.08}$ ($r^2 = 0.967$)

North area $W = 0.000173\ L^{2.75}$ ($r^2 = 0.779$)

East area $W = 0.0000929\ L^{2.92}$ ($r^2 = 0.725$)

No significant difference was observed when compairing the mean shell length for the quahogs from the three areas but the length frequency distribution for the northwestern area was different from the two others which were not significant different. An allometric growth was found for the northwestern area, an isometric growth for the eastern area, but the results from the northern coast were not as clear, the growth curve being intermediate between allometric and isometric in shape. If isometric growth was assumed, significant difference was found between condition factors in the regression equations for the northern and eastern areas respectively. The greatest relative meat weight for similar sized quahogs was observed in the northwestern area. This may be due to higher productivity in northwest Iceland compaired with the northern and eastern areas.

INTRODUCTION

The ocean quahog, *Arctica islandica*, is a cold water species and one of the largest bivalve species inhabiting the marine waters of Europe and North America. It is boreally distributed pelecypod occurring in the North Atlantic ocean from the the Bay of Cadiz in Spain intermittently to Cape Hatteras (Merill and Ropes 1969).

The ocean quahog supports a commercial fishery on the Atlantic coast of North America where the majority of landings have been from the Middle Atlantic Bight (Anon. 1993). Catches have been recorded from as shallow as 4 m to as deep as 256 m but conncentrations supporting commercial fisheries exist in the continental shelf in waters from about 25-60 m depth (Merill and Ropes 1969). Until recently this species has not been utilized in Iceland but investigations on distribution and abundance have indicatrd a major resourch which could support a commercial fishery (Thórarinsdottir and Einarsson 1994 a and b).

Studies on life history and particular population dynamics of this species are few. Aspects in ocean quahog density and distribution along the eastern coast of North America were reviewed by Merill and Ropes (1969, 1970), Rowell and Chaisson (1983) and by Fogarty (1981). Shell lenght-meat weight relationship of ocean quahogs from the middle Atlantic Shelf have been examined by Murawski and Serchuk (1979) but such investigations have never been undertaken in Iceland.

The aims of this study were to:

1. Study the shell length frequency distributions of *Arctica islandica* at the northwestern, northern and eastern coasts of Iceland.

2. Study the shell length - meat weight relationship in the species in the different areas.

3. Test if there was a significant difference in the mean meat weight calculated from direct observation and mean meat weight calculated by using length distribution and length-weight relationship.

MATERIAL AND METHODS

Ocean quahog samples for the length-weight analysis were collected from Icelandic waters during shellfish assessment surveys. The samples were collected in the northwestern area from January to March 1994 and in the northern and eastern areas from May to June 1994.

For comparative purposes, the three main geographically seperate survey areas were divided into five to seven subareas each consistent of seprate fjords (Figure 1). A hydraulic dredge, measuring 5.9 m in overall length and having a 1.5 m wide cutting blade, was used for the sampling. Sampling banks were identified on sea charts according to the bottom topography and depths, tows were then made from water depths ranging from 5 to 50 m. From each subarea approximately 300-600 individuals were taken for shell lenght measurements and weight measurement at site, depending on the size of the subareas. Subsamples, of about 30 individuals, were sampled from each subarea for shell length and meat weight determinations. These samples were frozen and taken to the laboratory where they were thawed. Shell length was recorded to the nearest mm, and the total wet meat weight was determined to the nearest 0.1 g. The number of length- and length and meat weight measurements from each area are shown in Table 1.

Table 1. The number of shell length- (on site mes.) and shell and meat weight measurements (subsamp.) in each main sampling area.

	NW	N	E	Total
Length	2216	1100	1439	4805
Length and meat weight	277	134	259	670

To compare the length frequency distributions for the three areas two methods were applied:

- Mean length and standard deviation in each area were compared.
- Difference in shape of distributions were tested by applying Kolmogorov-Smirnov two sample test.

The Kolmogorov-Smirnov two sample test is based on the statistic D , defined as: the maximum difference between two observed cumlative distributions (Lindgren, 1993).

The H_0 hypothesis, stating that the length frequency distributions are equal, will then be rejected at a test level α (e.g. α = 0.05, 5%) if approximately:

$$D > [-0.5 \ (1/m+1/n) \ \log(\alpha/2) \ ]^{1/2},$$

where m and n are the sample sizes of the two observed distributions.

The relationship between meat weight and shell lengthwas assumed to be of the form:

$$W = c \cdot L^p ,$$

where,

W: drained meat weight (g),
L: shell length (mm),
c and p: coefficients to be estimated from regression.

To test if the growth was isometric (i.e. slope in length-weight regression = 3.0, implying unchanged ratios of linear measurements as the organism grows [Ricker, 1975]), two types of length-weight relationship were estimated by the regression:

$$\log(W) = \log(c) + 3.0 \log(L) \text{ and } \log(W) = \log(c) + p \log(L)$$

The first model only estimates the condition factor (c), while the second model estimates both the condition factor and the slope (p). The total sum square error (SSE) of the two models was then compared be applying F-test (see e.g. Lindgren 1993), where a significant reduction in SSE when estimating the slope, would indicate non- isometric growth (i.e. allometric growth).

To determine if the length-weight relationship between areas was different, the total sum square errors (SSE's) of different regression models, where data from one or more regions have been combined into one data set, were compaired. That is, when comparing two areas, the two data sets can be combined and the condition factor (c) and the slope (p) from one regression can be estimated:

$$\log(W) = \log(c) + p \log(L)$$

From this regression equation the SSE can be computed. This SSE can then be compared to $SSE_1 + SSE_2$, where SSE_1 and SSE_2 are the SSE's when regressing each of the two areas separately. The existence of significant difference between SSE and $SSE_1 + SSE_2$ can then be tested by applying F-test.

If the length-weight relationship is known for an area then it is possible to estimate the mean meat weight from a sample which is only measured for length. This is simply done by applying the length-weight relationship to the length measurements and then calculate the mean weight of the resulting numbers. This was done for each of the three areas and the resulting value compared to the calculated mean weight from the measured meat weights.

RESULTS

Shell length frequency distributions

No significant difference was observed when comparing the mean shell lenght for *A. islandica* in the northwestern, northern and eastern areas (Table 2). A Student's-t test gave $p= 0.7$ when comparing the northern and eastern areas and $p = 0.11$ and 0.054 when comparing the measurements from the northwestern area with the northern and eastern areas, respectively. These mean values are not assumed to be statistically different at the 5% level.

Table 2. Mean shell length (μ), standard deviation (σ) and range of *A. islandica* off the northwestern, northern and eastern coasts of Iceland (on site measurements).

Shell length (mm)				
Area	μ	σ	min	max
NW	75.4	14.8	17	118
N	74.7	11.5	32	107
E	74.5	14.1	17	108
All areas	74.9	13.9	17	118

The shell length frequency distributions for the ocean quahogs in the three areas are shown in Fig. 2. When applying the Kolmogorov-Smirnoff test to the three length frequency distributions, the p-values show that the distribution from the northwestern area is significant different from the others ($p < 0.01$). The shell length distributions from the north and east area are, however, not significantly different from each other at 5% test level (Table 3).

Table 3. The Kolmogorov-Smirnoff statistic (maximum difference between two cumulative distributions) for the three length frequency distributions.

	Northwest	North
North	0.082 (p-value <0.01)	-
East	0.078 (p-value < 0.01)	0.045 (p-value ≈0.16)

Length-meat weight relationship – isometric or allometric growth

The length-meat weight relationship for the ocean quahog and the estimated relationship of the form:

$W = c \cdot L^3$, (for isometric growth) and $W = c \cdot L^p$, (for allometric growth) are shown in Fig. 3

An allometric growth curve was observed for the quahogs from the northwestern area ($p = 0.018 < 0.05$) and an isometric relationship for the eastern area ($p = 0.50 > 0.05$) (Table 4). The results from the northern area, however, were inconclusive ($p = 0.054$, Table 4).

The estimated slope (p) was highest in the northwestern area, followed by the eastern and lowest for the quahogs from the northern area. In contrast the condition factor (c) is highest in the north, followed by the east and northwest (Table 4).

Table 4. The estimated length-weight relationship: type of relationship, the natural logarithmic of the condition factor (c) and it's std. error in brackets, the condition factor, the slope and it's std. error (if estimated), R-squared, total sum-square-error (SSE) and p-value from a F-test indicating the significance of using allometric relationship.

Length-meat weight relationship							
Area	Type	log(cond.)	cond.	slope	r^2	SSE	P-value
NW	isom.	-9.45 (0.014)	0.0790E-3	3.00 (fixed)	0.966	14.20	
-	allom.	-9.78 (0.14)	0.0567E-3	3.08 (0.034)	0.967	13.91	0.018
N	isom.	-9.74 (0.020)	0.0588E-3	3.00 (fixed)	0.773	7.07	
-	allom.	-8.66 (0.55)	0.173E-3	2.75 (0.13)	0.779	6.87	0.054
E	isom.	-9.61 (0.018)	0.0667E-3	3.00 (fixed)	0.725	21.66	
-	allom.	-9.28 (0.49)	0.0929E-3	2.92 (0.11)	0.725	21.62	0.50
All areas	isom.	-9.57 (0.011)	0.0698	3.00 (fixed)	0.914	51.64	
-	allom.	-9.11 (0.15)	0.0110E-3	2.89 (0.34)	0.915	50.87	0.002

Length-meat weight relationship - geographical variation

The slope (p) for the length-meat weight equation for the quahogs from the northwestern area was significantly greater than the slopes from the equations from the two other areas, indicating that the quahogs from this area generally contained more meat per unit shell length for the range of lengths considered. The shells from the northern area had the lowest slope and contained less meat at given shell length (Fig. 4).

When assuming allometric growth in each area, the length-weight relationship was significantly different between all of the areas (Fig. 3, Table 4). The same significant difference was observed when assuming isometric growth in all areas.

Mean meat weight by areas

The mean meat-weight of each area was estimated by using length-weight relationship along with the observed length frequency distributions. To test if this method is consistent with the results obtained by calculating the mean weight from empirical data, the mean meat-weight was calculated for the meat-weight data set of the three areas by the two methods, using data from the subsamples and data from the on site measurements. The results are shown in Table 5.

Table 5. Mean meat weight of ocean quahogs from the three areas off Iceland and in the total area calculated by using (1) the observed meat weights in the subsample, (2) the shell length distribution and the estimated length-weight relationship, both from the subsample and (3) the on-site length distribution with the estimated length-weight relationship from the on-site measurements.

Mean meat weight (g)				
	NW	N	E	All areas
Meat weight (obs. from subsamp)	26.5 (s.e. = 1.1)	30.1 (s.e. = 1.6)	37.0 (s.e. = 1.2)	31.3 (s.e. = 0.74)
Meat weight (length dist. & $W = c\ L^p$, from subsamp.)	25.8	29.5	35.3	30.2
Meat weight (length dist. & $W = c\ L^p$, from on site meas.)	38.5	26.1	30.2	31.7

As seen in Table 5 the two types of mean meat weights calculated for the meat weight subsample are very similar, the second method is always within two s.e. from the first method (95% confidence interval.) When applying the length-weight relationship to the on-site length distribution, the northwestern area has the highest mean meat-weight (38,5 g) then the eastern (30,2 g) and the northern area the lowest meat weight (26,1 g).

DISCUSSION

The results from these analyses indicate that there was no difference in the mean length of quahogs from the northwestern, northern and eastern areas, respectively. However, a difference in length frequency distributions was observed between quahogs from northwestern area on the one hand and the other two areas. This difference seems to be partly due to large individuals in the northwestern area and relatively high number of small individuals sampled.

An allometric growth curve was observed for the quahogs from the norhtwestern area but an isometric curve for the eastern area. In the north, however, no such clear pattern of allometric or isometric growth curve was observed, which might be due to small sample size. Difference in growth curves between different populations of the same species may be associated with their nutritinal conditions (Ricker 1975).

The estimated length-weight relationship was found to be different between the three main areas. The meat weight for similar sized quahogs were highest in the northwestern area, followed in the east, the lowest weight beeing observed in the northern area. Possible factors influencing the geographical variation in relative condition of the quahogs include physical and biological variables such as temperature, salinity, water depth and food supply. The knowledge of the physical oceanography of inshore waters off the Icelandic coast is rather sparse. Temperature profiles which have been reported in the years 1908-1973 from stations within the three areas studied here, indicate that the temperature range at about 70 m depth is from 2.2°C to 7.4°C in the northwestern area, 1.5-6.7°C in the north and 1.2-6.9 in the eastern area (Stefánsson and Jónsdóttir 1974). The primary production is also highest in the northwestern area (mean 184 gC/m^2/year) followed by the eastern (150 gC/m^2/year) and northern area (90 gC/m^2/year), respectively (Thórdardóttir 1976).

More favourable thermal environment and higher productivity may thus be an important factor governing metabolic processes and ulitmately the growth, resulting in the highest relative meat yields in quahogs at the northwest area. The high meat yield in quahogs in the northwest may also by related to the season of capture, as these samples were taken from January to March while the samples from north and east were taken from May to June. The state of sexual maturity around the year as well as spawning time of the ocean quahog off the coast of Iceland are unknown. Further sudies are therefore necessary to determine if relationships vary significantly on a seasonal or annual basis, or with the state of sexual maturity.

Murawski and Serchuk (1979) calculated the length-weigth relationship from quahogs samples off the Middle Atlantic Shelf. The meat weight for similar sized quahogs increased from north to south. As the stability of the bottom temperature increased in the same direction they concluded that the stability of the termal environment caused the increased growth. The length-meat weight relationship in quahogs collected during winter in the Middle Atlantic Shelf region (all areas studied combined) was decribed as $W = 0.00006843\ L^{2.888}$, which is similar to what was observed for quahogs from all areas combined in present study ($W= 0.000110\ L^{2.890}$).

Density dependent factors may limit growth in ocean quahogs in northern waters (Merrill and Ropes 1970). The density of ocean quahogs observed off the shore of the Middle Atlantic Shelf is in the order of magnitude less than 0.5 kg (Anon. 1993). The density of the quahogs in Icelandic waters is much greater or 3.0 kg/m^2 in the northwest, 2.8 kg/m^2 in the north and 4.4 kg/m^2 in the east area, respectively (Thórarinsdóttir and Einarsson 1994 a and b).

The direct effect of environmental variables, density and sexual maturity on growth and condition factors of ocean quahogs are yet to be studied.

REFERENCES

Anon. 1993. Report of the 15th Northeast Regional Stock Assessment Workshop (15th SAW), 1993. Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NOAA/National Marine Fisheries Service. Northeast Fisheries Science Center. Woods Hole, MA 02543-1097, 33 pp.

Fogarty, M.J. 1981. Distribution and relative abundance of the ocean quahog *Arctica islandica* in Rhode Island sound and off Martha's Vineyard, Massachusetts. Journal of Shellfish Research, 1 (1): 33-39.

Lindgren, B. W. 1993. Statistical Theory, 4th Ed., London: Chapman & Hall, 1993.

Merill, A.S. & Ropes, J.W. 1969. The general distribution of the surf clam and ocean quahog. Proc. Nat. Shell. Assoc., 59: 40-45.

Merill, A.S. & Ropes, J.W. 1970. The distribution and density of ocean quahog, *Arctica islandica*. Amer. Malacol. Union Bulletin, 36:19.

Murawski, S.A. & Serchuk, F.M. 1979. Shell length-meat weight relationships of ocean quahogs, *Arctica islandica*, from the middle Atlantic shelf. Proc. Nat. Shell. Assoc., 69: 40-46.

Ricker, W.E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Board Can., 191, 382 pp.

Rowell, T.W. & Chaisson, D.R. 1983. Distribution and abundance of the ocean quahaug (*Arctica islandica*) and Stimpson's surf clam (*Spisula polynyma*) resource on the Scotian Shelf. Canadian Industry Report of Fisheries and Aquatic Sciences,142: 75 pp.

Stefánsson, U. & Jónsdóttir, S. 1974. Near-bottom temperature around Iceland. Rit Fiskideildar, 5 (2).

Thórarinsdóttir, G.G. & Einarsson, S.T. 1994 a. Kúfskeljarannsóknir á Norðvesturlandi janúar til mars 1994. Hafrannsóknastofnunin, unpublished manus. (in Icelandic), 29 pp.

Thórarinsdóttir, G.G. & Einarsson, S.T., 1994 b. Kúfskeljarannsóknir á Austur- og Norðurlandi maí til júní 1994. Hafrannsóknastofnunin, unpublished manus. (in Icelandic), 27 pp.

Thórdardóttir, T. 1976. Preliminary assessment of the annual production in the shelf area around Iceland. International Council for the Exploration of the Sea. CM1976/L:32, 4 pp.

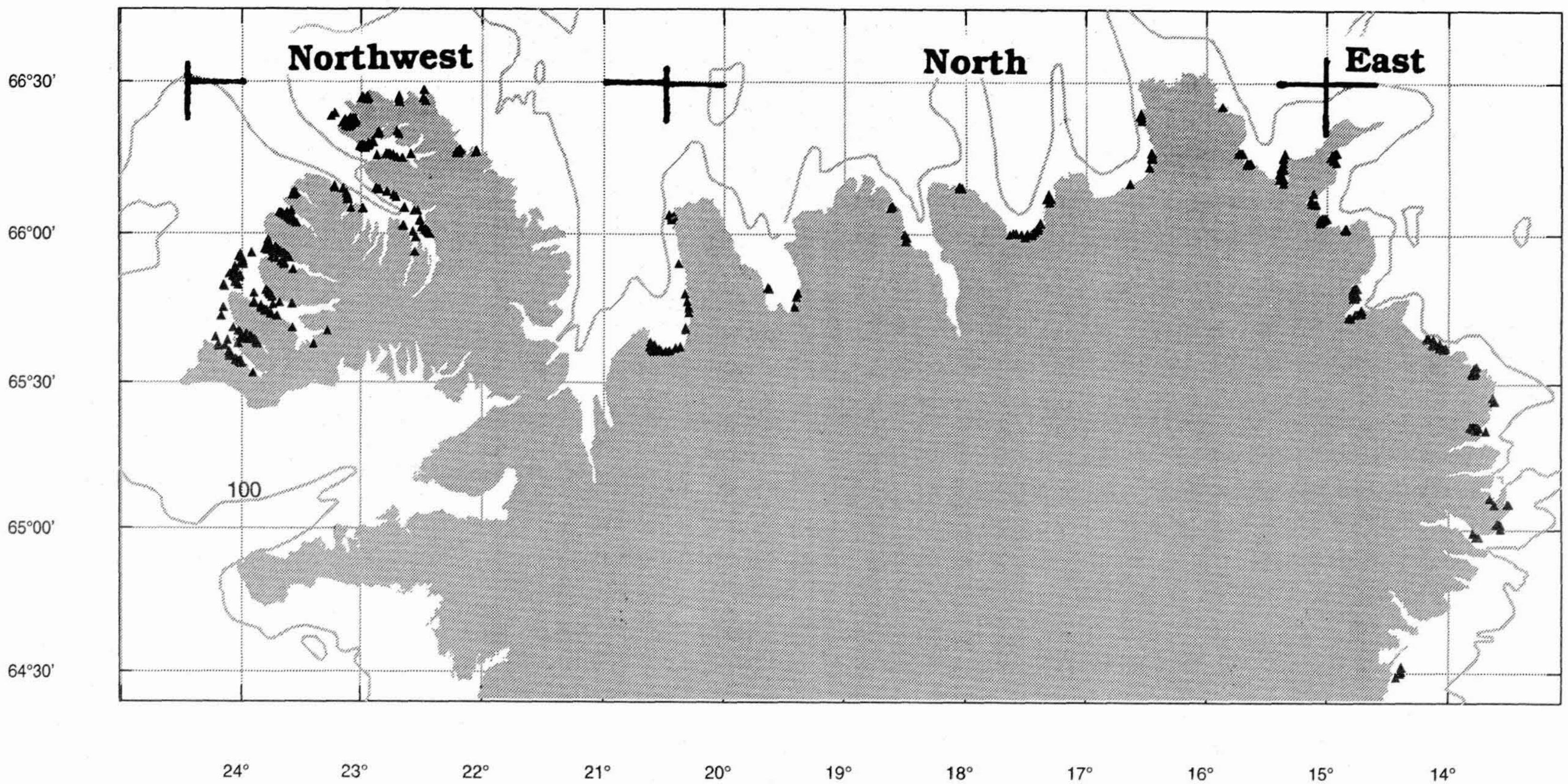

Figure 1. **The locations of sample sites for *Arctica islandica*, in Northwest, North and East Iceland, surveyed from January to June 1994.**

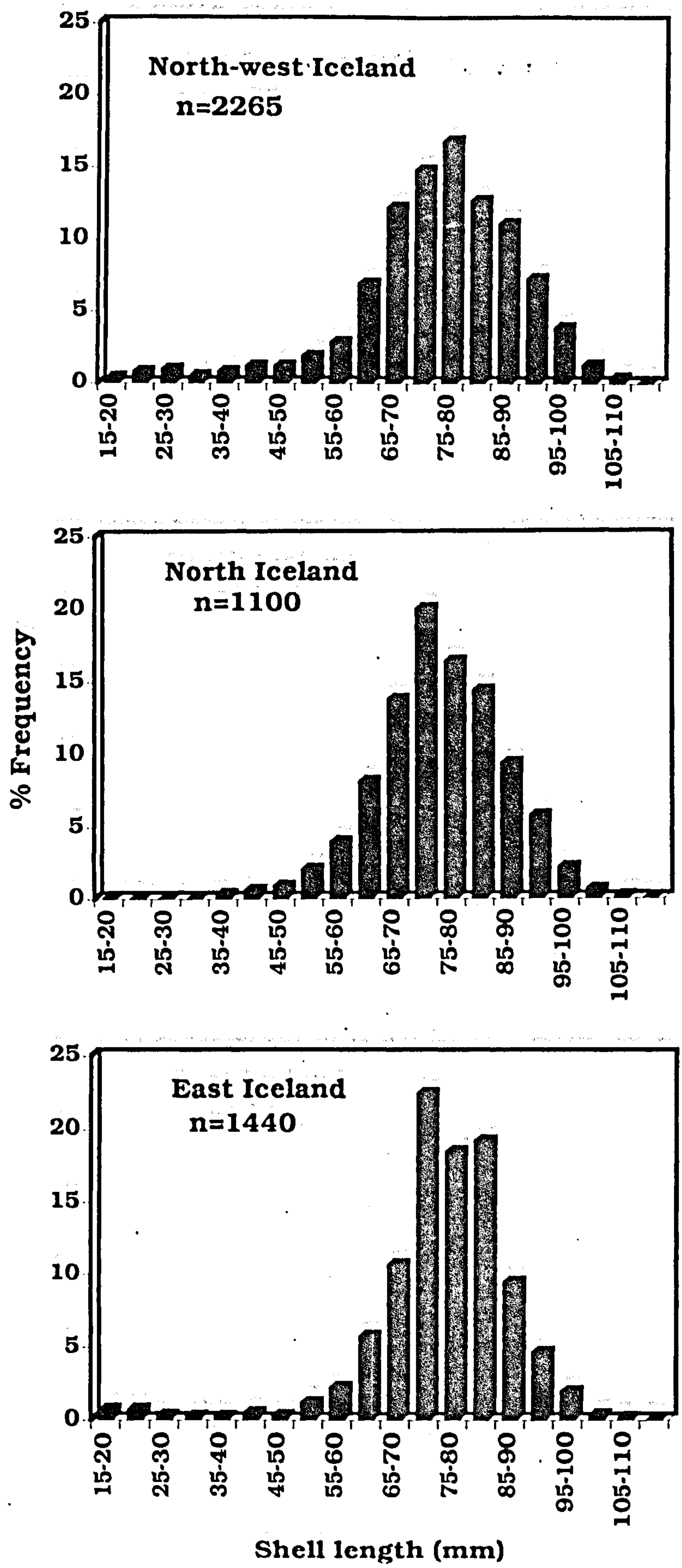

Figure 2. Shell length-frequency distribution for 5 mm size classes of *Arctica islandica* from Northwest, North and East Iceland.

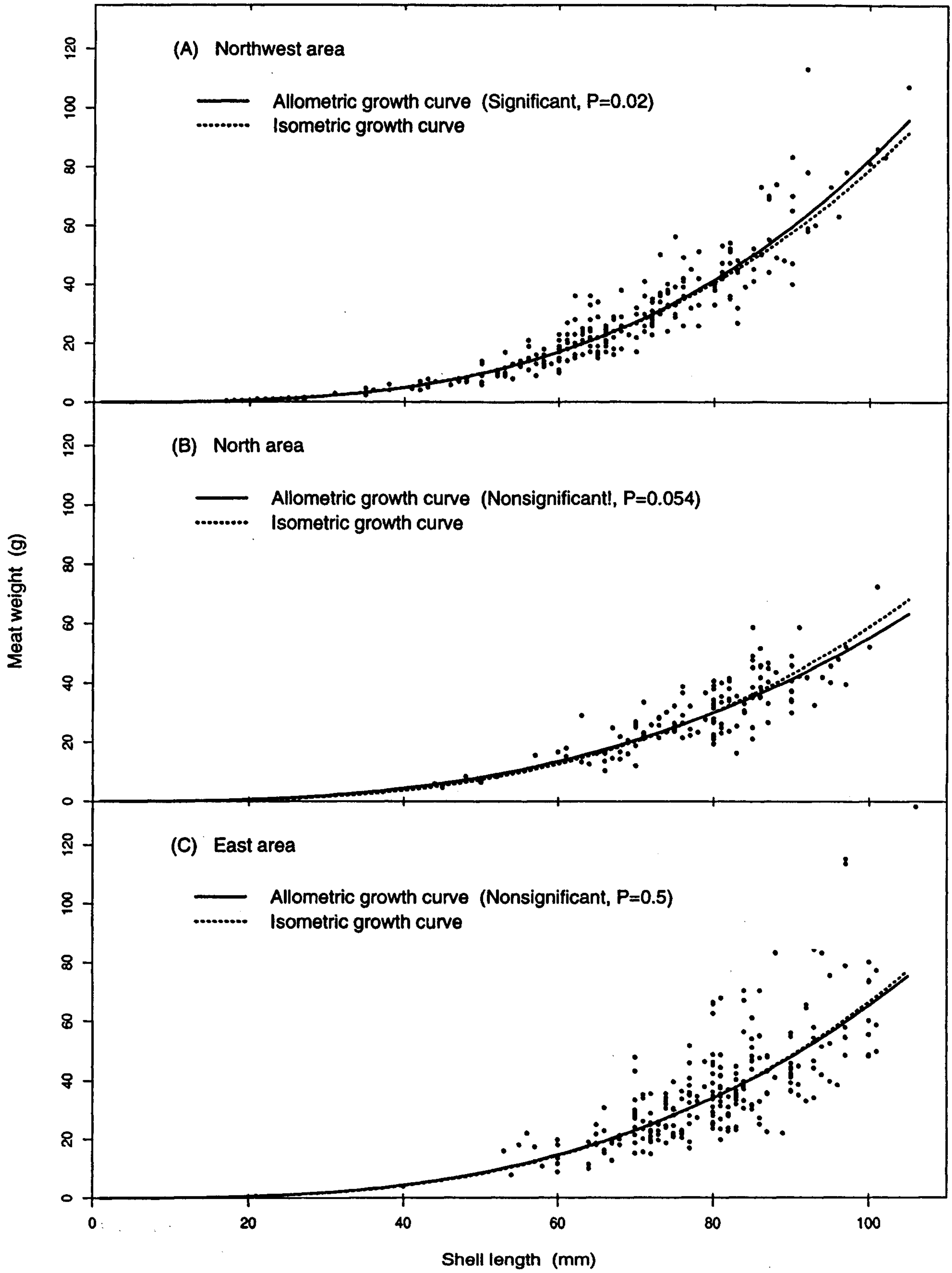

Figure 3. **Estimated length-meat weight relationship for *Arctica islandica* from Northwest, North and East Iceland.**

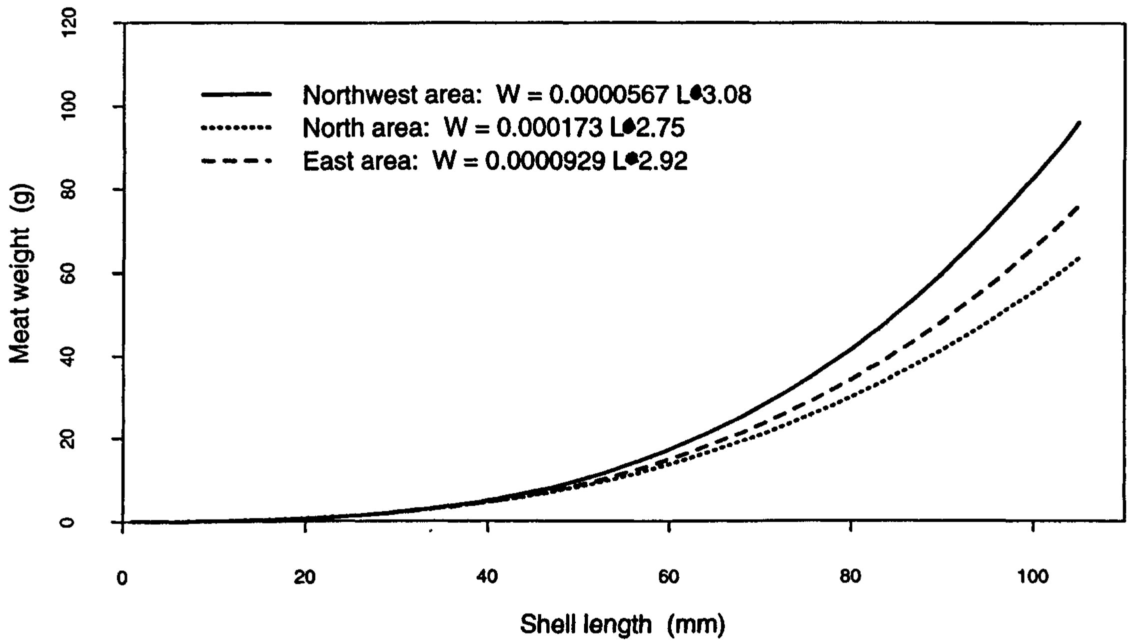

Figure 4. **The length-meat weight relationship for *Arctica islandica* (W=c•LP) from Northwest, North and East Iceland.**