On the Relationship of Weight, Length and Girth of the Ringed Seal (*Pusa hispida*) of the Canadian Arctic

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ABSTRACT. The relationships between several body measurements of the ringed seal *(Pusa hispida)* are analysed to determine which provide the most reliable prediction of weight. A formula involving the two parameters, length and maximum girth, is the most precise predictor, whereas the best single indicator is girth.

RÉSUMÉ. *Rapports entre le poids, la longueur et la circonférence du phoque annelé (Pusa hispida) de l'Arctique canadien.* On analyse les rapports entre plusieurs mesures du corps chez le phoque annelé, de façon à déterminer lesquelles de ces mesures permettent de déduire le poids de l'animal. La formule qui relie les deux paramètres longueur et circonférence maximale est la plus précise, alors que la circonférence est le meilleur indice isolé.

РЕЗЮМЕ. *Соотношение веса, длины и окружности тела кольчатой нерпы* (*Pusa hispida*) *в Канадской Арктике.* Проводится анализ различных параметров тела кольчатой нерпы с целью установления, какой из них является наиболее достоверным индикатором веса животного. Уравнение, включающее два параметра — длину и максимальную окружность тела, дает наиболее точную оценку веса, в то время как окружность является наилучшим единичным индикатором.

INTRODUCTION

The seals are among the most remarkably streamlined of all the mammals. All the heavy muscles are integral to the torso, and the overall body form is extremely simple. Consequently, one would expect high correlations among various measurements of size and shape. McLaren has demonstrated the relationships between length and weight of ringed seals (*Pusa hispida hispida* Schreber) in the eastern Canadian Arctic (McLaren 1958a, pp. 55-57). He derived the formula

$$\log (\text{weight}) = 3.005 \log (\text{length}) - 2.9882$$

where weight is in pounds and length is in inches, as a means of estimating the weight of a seal when only the length has been or can be measured.

The weight of an animal is related not only to its length, but also to its condition. While investigating the ringed seal fishery at Sachs Harbour, Banks Island, Northwest Territories, a marked correlation was noticed between girth and weight, in addition to that between length and weight. Accordingly, a study was made to determine which of several body measurements, singly or in combination, provided the closest and most reliable indication of actual body weight.

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MATERIAL AND METHODS

Anderson (1942, p. 25) identified the seals of the Beaufort Sea as a distinct subspecies, *P. hispida beaufortiana* Anderson. King (1964, p. 56) recognized no subspeciation within the North American and Atlantic Arctic, and classed all ringed seals therein as *P. h. hispida* Schreber. Analysis is presented for a group of 73 ringed seal taken at Sachs Harbour in 1966 and early 1967. Seventy-one of the seals were shot in open water during August and September, 1966. One was shot in December, 1966 and another in January, 1967, both from the edge of fast ice. Virtually all were taken within 15 miles of Sachs Harbour.

A new analysis, parallel to that made for the Sachs Harbour seals, is presented for data on 61 seals collected in southwestern Baffin Island and northwestern Foxe Basin by McLaren in 1951-55, and previously examined by him (McLaren 1958b, pp. 86-88). Hereafter they are generally referred to as *the Baffin sample.*

The measurements made on the Sachs Harbour seals and the methods of their determination are as follows (all measurements are given in pounds and inches). The enumeration of the variables given below is used throughout the text.

X_1 = Weight. Total dead body weight determined by a spring scale of 200 pounds capacity, hung from a tripod. No estimate was made for loss of blood.

X_2 = Standard Length. Measured in a straight line, from tip of nose to tip of tail, with head and neck in natural position.

X_3 = Maximum Girth. Measured with the aid of a string around the apparent largest circumference of the chest or abdomen. In a few cases, where axillary girth proved the greatest, this measurement was also used as maximum girth.

X_4 = Axillary Girth. Measured with the aid of a string around the body directly behind the foreflippers, at the level of the axillae.

X_5 = Blubber Thickness. The distance from the bared bone of the sternum to the inner surface of the hide. Measured with the aid of a probe (usually a knife blade or match stick) inserted into an incision over the sternum.

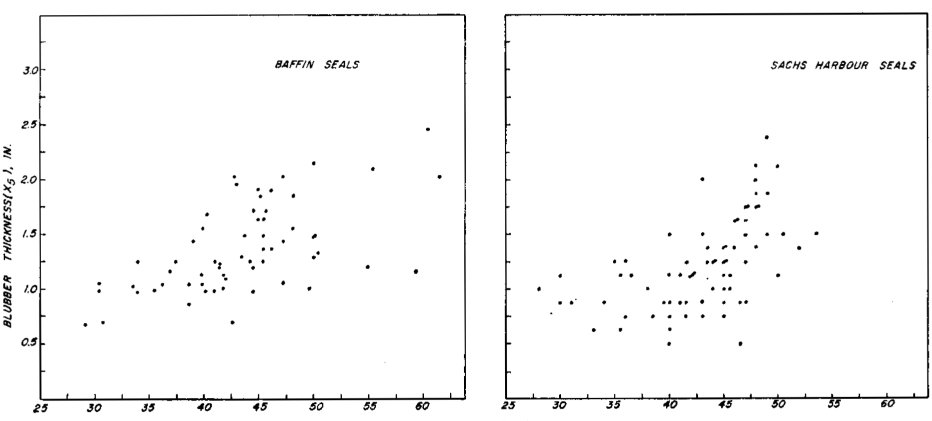


FIG. 1. Scattergrams of seal length vs. blubber thickness.

These variables are in accord with the criteria and methods used by McLaren (1958b, pp. 14-15). However they do not conform completely to the recommendations of the American Society of Mammalogists (1967).

All of the measurements reflect the relative maturity and condition of the animals. Length is above all a measure of growth or age, whereas blubber thickness reflects primarily the factor of condition. Girth measurements represent a combination of both factors. Quite variable condition is indicated in both samples by the scatter of the data on length and blubber thickness (Fig. 1). Age data, available for most of the Baffin seals, indicate an age spread for this sample from 3 months to over 20 years. No age data are available for the Sachs Harbour group. However, the youngest animals are 4 to 5 months old, whereas the largest animals are probably well past maturity.

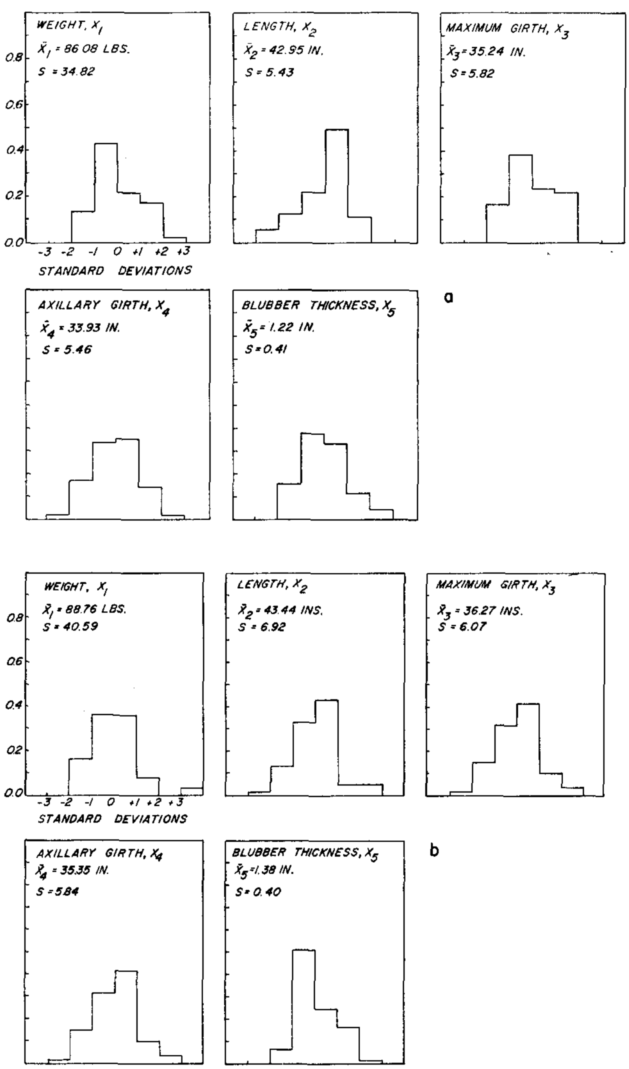


FIG. 2. Standardized frequency distributions of the combined sample measurements.
$\overline{X}$ indicates the mean and S indicates standard deviation.
a. Sachs Harbour Sample.
b. Baffin Sample.

ANALYSIS AND RESULTS

Each sample was subdivided into male and female groups for analysis, and then combined. The distributions of the measurements in the combined samples are shown in Fig. 2. The Kolmogorov-Smirnov test statistic for goodness of fit (Dixon and Massey 1957) detected no departure from an apparently normal distribution in any of the variable distributions. (All statistical tests were carried out at the confidence level $\alpha = 0.95$ unless otherwise stated.) The sample variances (see Fig. 2) were generally uniform, differing significantly only for length (X_2) in the Sachs Harbour males, and the combined Sachs Harbour sample compared with the Baffin combined sample, and for blubber thickness (X_5) between the Sachs Harbour males and females. The last-mentioned difference may either reflect a definite difference between the variability of the condition of the two sexes there, or may be entirely fortuitous. Details of the statistical tests used may be found in Snedecor and Cochran (1967).

TABLE 1. Correlation Arrays

	X_1	X_2	X_3	X_4	X_5
Sachs Harbour Females					
X_1	– – –	0.852	0.980	0.964	0.886
X_2	0.915	– – –	0.846	0.856	0.592
X_3	0.986	0.864	– – –	0.985	0.864
X_4	0.976	0.871	0.988	– – –	0.833
X_5	0.796	0.565	0.819	0.797	– – –
Sachs Harbour Males					
X_1	– – –	0.877	0.978	0.969	0.726
X_2	0.924	– – –	0.857	0.871	0.465
X_3	0.972	0.859	– – –	0.982	0.734
X_4	0.974	0.871	0.982	– – –	0.711
X_5	0.603	0.389*	0.678	0.654	– – –
Sachs Harbour Combined Sample					
X_1	– – –	0.859	0.978	0.965	0.830
X_2	0.917	– – –	0.845	0.857	0.545
X_3	0.979	0.858	– – –	0.984	0.826
X_4	0.974	0.868	0.986	– – –	0.797
X_5	0.727	0.500	0.773	0.750	– – –
Baffin Females					
X_1	– – –	0.912	0.980	0.984	0.861
X_2	0.961	– – –	0.891	0.909	0.717
X_3	0.983	0.909	– – –	0.995	0.867
X_4	0.986	0.920	0.966	– – –	0.856
X_5	0.853	0.757	0.863	0.852	– – –
Baffin Males					
X_1	– – –	0.941	0.968	0.971	0.743
X_2	0.939	– – –	0.912	0.916	0.565
X_3	0.983	0.901	– – –	0.988	0.760
X_4	0.978	0.908	0.987	– – –	0.751
X_5	0.705	0.532	0.742	0.733	– – –
Baffin Combined Sample					
X_1	– – –	0.932	0.963	0.973	0.764
X_2	0.952	– – –	0.901	0.915	0.598
X_3	0.983	0.907	– – –	0.990	0.792
X_4	0.982	0.917	0.991	– – –	0.780
X_5	0.757	0.613	0.786	0.775	– – –

All correlations are significant at the $\alpha = 0.99$ level except a single value which is marked*

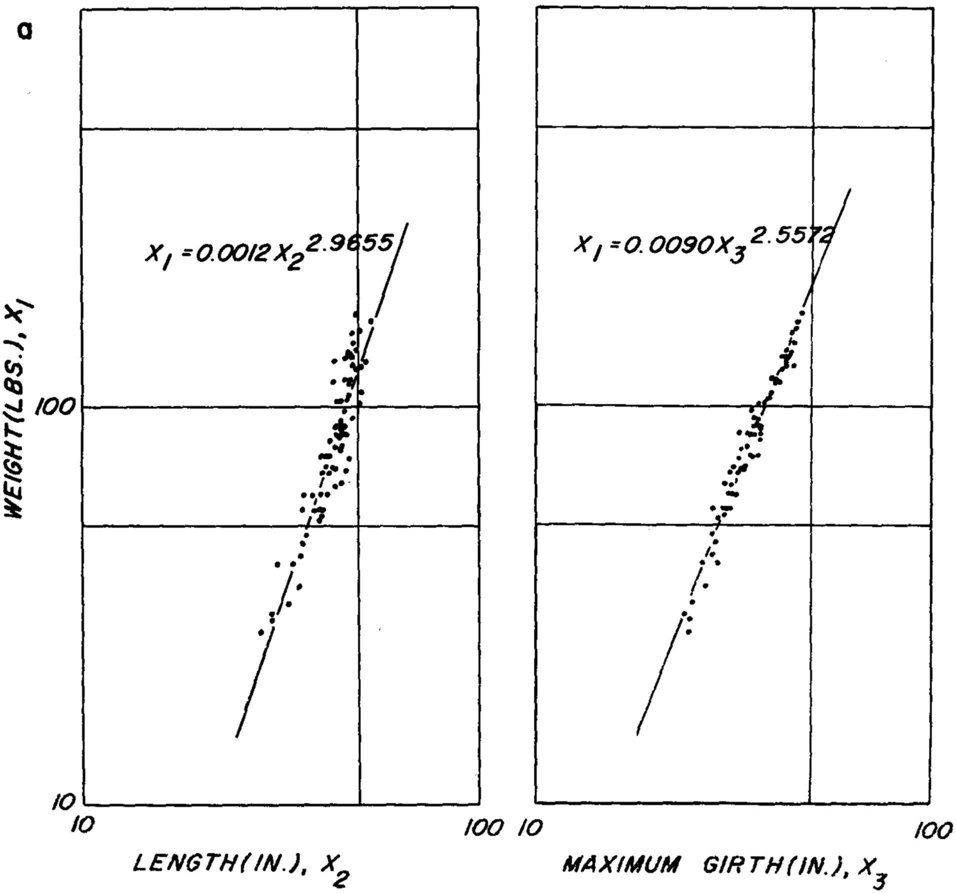
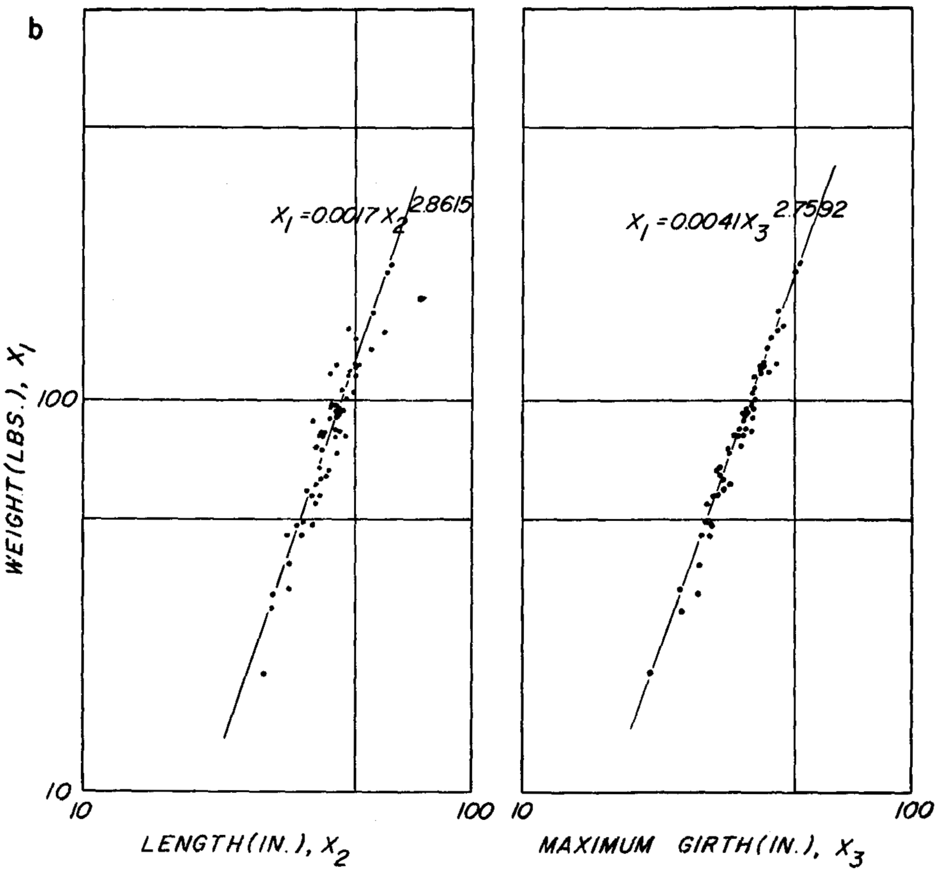


FIG. 3. Logarithmic linear regression of weight on length and on maximum girth for the combined samples. a. Sachs Harbour Sample. b. Baffin Sample.

The mean values of the sample measurements are hardly less uniform within each sample. The Baffin males appear to be systematically larger than their female counterparts, no doubt an effect of the disparate age distribution of the two groups (the mean age of McLaren's males is over a year more than that of his females). A major part of the difference may be ascribed to two very large male seals, both of which weighed more than 200 pounds. On the other hand, the Sachs Harbour females apparently tend to be larger — but not significantly so in the present sample. On the whole, the two samples are substantially similar in their structure.

The product-moment correlations among the variables were computed, both for the original data and for the values obtained under logarithm_{10} transformation. The correlations obtained are given in Table 1. The upper triangle (above the diagonal) contains the correlations of the original data, whereas the lower triangle contains the correlations of the transformed data. All are highly significant, as was expected. Marginally better results are obtained after the transformation for all values except those involving blubber thickness (X_5). It is interesting that



blubber thickness is the least tightly knit with the other variables, tending to confirm the suggestion that it is the least sensitive growth parameter, and more purely a condition factor. The improvement in the correlations among the other variables presumably reflects their common association with an approximately exponential growth pattern. This would require that relationships of the form

$$X_1 = aX_i^B \qquad [1]$$

hold among the variables, giving logarithmically linear relations. For both Sachs Harbour and Baffin seals, the best single indicator of weight is maximum girth (X_3). Single parameter predictor equations are given in Fig. 3. (Note that the relation between weight and length for the Baffin sample does not correspond with McLaren's equation 7 [McLaren 1958a, p. 55] as a different number of sample data were used by him to arrive at his result.)

To find an optimum predictor equation for weight, multiple regressions were carried out according to a logarithmic linear model of the multiple power relationship

$$X_1 = a \prod_{i=2} X_i^{B_i} \qquad [2]$$

TABLE 2. Multiple Regression Equations

Sample	log(a)	d	f	R^2	Std. error of estimate of Xi	Outside error of estimate of Xi
Sachs Harbour Females	—2.460	0.794	1.984	0.988	±0.023	—10.1 — +11.3%
Sachs Harbour Males	—2.755	1.110	1.849	0.976	±0.028	—12.3 — +13.4
Sachs Harbour Combined Sample	—2.574	0.944	1.903	0.982	±0.026	—11.4 — +12.8
Baffin Females	—2.909	1.301	1.737	0.992	±0.021	— 9.3 — +10.3
Baffin Males	—2.549	0.820	2.005	0.982	±0.025	—10.9 — +12.2
Baffin Combined Sample	—2.707	1.019	1.896	0.987	±0.024	—10.5 — +11.8
Grand Sample	—2.642	1.024	1.857	0.982	±0.027	—11.8 — +13.3

All regressions are significant at $\alpha=0.99$

For all the sample groups the optimum equation, confirmed by a stepwise regression, was

$$X_1 = aX_2^{d}X_3^{f} \qquad [3]$$

Regression values are given in Table 2. Since the exponents are not even powers, the logarithmic representation

$$\log(X_1) = \log(a) + d\cdot\log(X_2) + f\cdot\log(X_3)$$

is the most convenient computational form. The standard error of estimate of X_1 is accordingly given in log units. The outside errors of estimate, with confidence $\alpha = 0.95$, are given as proportional errors. The values are equal to 1.96 × (standard error of estimate). The coefficient of determination, R^2, shows that more than 97 per cent of the variance in weight is accounted for by corresponding variance in maximum girth and length in all cases. Confidence limit tests revealed that none of the coefficients of the male or female subsamples differs significantly from its combined sample counterpart. Hence, the single combined sample equation can stand as the optimum estimator for its sample.

Furthermore, all corresponding confidence ranges overlap between the 2 samples. There are grounds, then, for determining a single estimating equation appropriate for both the Sachs Harbour and the Baffin seals. The possibility for this is supported by the general similarity of the variances of each variable between the 2 samples. The equation (based on 134 sets of observations) was found to be

$$X_1 = 0.0023\ X_2^{1.024}X_3^{1.857} \qquad [4]$$

The logarithmic value of the coefficient is given in Table 2. Assuming the regression coefficients to be correct, an estimate of X_1 is given by this equation with an outside error of estimate of +13.3 per cent or −11.8 per cent. As a rule-of-thumb for field use, this equation may be approximated by

$$X_1 = \frac{3X_2X_3^2}{2000} \qquad [5]$$

Estimates of X_1 made from this equation are plotted in Fig. 4 against the true values, with the $\alpha=0.95$ range of the error of estimate of equation [4] also plotted. Most of the values fall within these limits and no apparent bias occurs in the estimates, indicating that equation [5] will provide reasonable estimates. Expected precision would be within about 12 per cent.

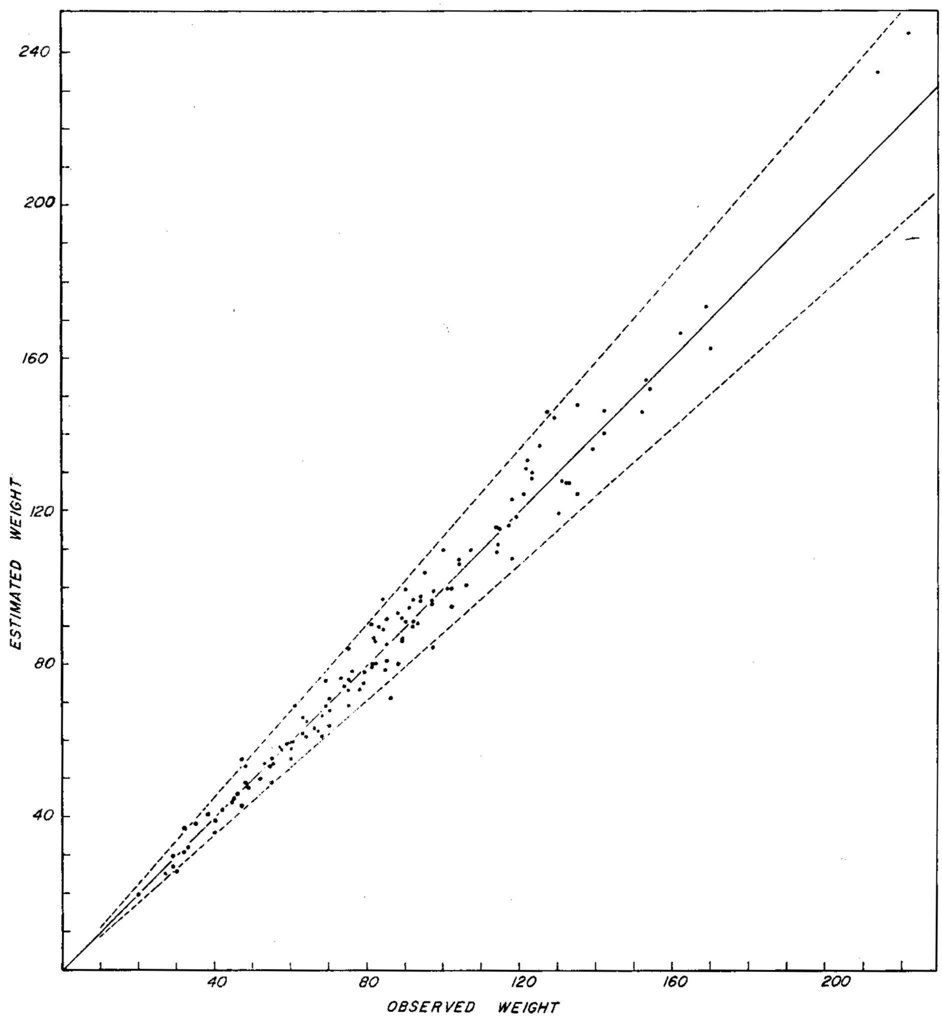


FIG. 4. The correspondence between observed seal weights and weights estimated by the approximate equation, $X_1 = 3X_2X_3/2000$. Data from both the Sachs Harbour and the Baffin samples are plotted on the graph.

DISCUSSION

The need to obtain seal weights is apparent in the context of either a commercial fishery or the investigation of the Eskimo subsistence economy. It is not always convenient or possible to have a scale on hand when making biological measurements of seals.

McLaren has provided a length-weight formula, which has the advantage of being easily used in field conditions by trained or untrained personnel. The disadvantage of the formula is that it takes no account of condition, which can vary yearly and seasonally, and even within a homogeneous population at one time. The formula involving length and girth presented here offers a reliable means of determining seal weights from two simple body measurements; measurements which are normally taken in the course of any biological study of a seal population.

It should be noted that the combined sample used here is composed predominantly of seals taken between April and October (132 out of 134). During the winter, when a considerably greater proportion of the seal's weight consists of blubber, its specific gravity is approximately 3 per cent less than in summer (McLaren 1958a, p. 70). Therefore the true weights of winter seals would average somewhat less than predicted by formulae [4] or [5].

An even simpler method of weight determination would be to use maximum girth alone as an index. It would be easy, using the relationship of these two variables, to devise a measuring tape showing weight directly, like a cattle tape. The formula expressing this relationship, based on data from both samples, is

$$\log(X_1) = 2.636 \log(X_3) - 2.179 \qquad [6]$$

with a proportional outside error of estimate of +21.0 per cent or −17.3 per cent at the $\alpha = 0.95$ confidence level. Tables showing the relationship between weight, length and girth, as derived from formulae [4] and [6], for use in the field, are presented in Usher and Church (1969).

Our investigations offer no evidence of regional subspeciation within the Canadian Arctic, as differences between the weight, length and girth relationships of the two populations are not statistically significant. Indeed, the relationships described here may hold good for all ringed seal populations.

The broad similarity of shape, growth and condition factors among all of the members of the family *Phocidae* suggests that, while the constants for each species will vary, the formula $X_1 = f(X_2, X_3)$ would probably be the best predictor of weight in each case, with maximum girth (combining factors of growth and condition) being the best single indicator.

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