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Otolith Length and Fish Length of Pacific Halibut

by

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ABSTRACT

In 1971, the method used to estimate fish length from otolith length was found to overestimate the length of large fish and underestimate the length of small fish. A more exact relation between fish length and otolith length was obtained with a cubic equation. Statistical testing indicated a common line could not represent the relation in different geographical areas. Separate relationships were determined for four areas and confidence intervals were computed for each line. As the otolith-fish length relation is dependent on the growth rate and the growth rate has changed with time, the regressions are not valid for estimating fish lengths from otoliths collected during the early years of the fishery.

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INTRODUCTION

Since 1933 the Halibut Commission has sampled commercial landings of halibut to obtain age and length data. In the past most of the data were gathered by 3- or 4-man field crews who measured fish and collected otoliths at several ports along the coast. In the late 1950's, a limited budget necessitated a reduction in field crew size. Several schemes were then tried to obtain the required data at reduced cost (Hardman and Southward, 1965). In 1962, a relationship between the otolith radius and fish length (snout to fork of tail) was determined to study the growth of halibut and this relationship was used to calculate fish lengths from otoliths collected from commercial landings. However, measuring the radius was slow and tedious and it was often difficult to locate the nucleus of the otolith. An obvious extension of the otolith-radius technique was to determine a relationship between fish length and the more easily measured otolith length.

In 1968 a linear equation was used to describe the relationship between halibut length and otolith length. This equation was fitted to data from British Columbia, southeastern Alaska, Gulf of Alaska, and the Bering Sea. Scatter diagrams of the data indicated that both variables should be transformed logarithmically. The logarithms of the data points were fitted by standard least squares and orthogonal techniques. Visual examination of the two fitted lines, plotted against a scatter diagram of the data for each region, indicated that the orthogonal line was a "better" fit. The orthogonal regression line for the different regions and a common orthogonal line were compared. Differences between regions were considered too small to warrant the difficulty of applying individual regressions and the common line was accepted. This line is:

$$\log (L) = -1.223460 + 2.259208 \log (O) \qquad (1)$$

where O = otolith length in millimeters and L = fish in centimeters.

This regression line (equation 1) was used in the analysis of length and age data in 1968, 1969 and 1970. In 1971, Skud and Myhre (personal communication) found that the equation overestimated the lengths of fish from the larger otoliths and underestimated the fish lengths from the smaller otoliths. A more adequate fitting procedure has been developed and is described in this paper.

DATA AND ANALYSIS

A double sampling technique has been utilized in sampling the commercial landings since the beginning of the program. In the present scheme, an otolith is collected from each fish chosen for the length frequency sample. The length of the fish is computed from the otolith length by a regression equation. The sample of otoliths for age determination is then chosen randomly from the otoliths collected for the length frequency sample.

Body-scale or body-otolith relations have been used extensively in fisheries research to calculate the growth of fish. Hile (1970) gives a brief review of these relations and some underlying principles connected with their use. Southward (1962) presents an otolith-radius body-length relationship used to study the growth of halibut.

Ricker (1973) discussed the use of regression in biological situations where both the X variable and the Y variable were subject to error. He suggested the use of a functional regression rather than the predictive regression, the Y on X relation say, of regression analysis to handle this situation. In our opinion, the functional form requires unnecessary biological interpretation of the regression relation when the only need is for a prediction of fish length given an otolith length. Berkson (1950) developed a technique of handling the error: the X variable is considered fixed and the error associated with it is added to the error in the Y variable; least squares procedures for regressing Y on X are then acceptable. The resulting equation has a greater standard error of estimate than would be the case if the error in the X variable did not exist, but does not attach biological significance to the coefficients. Berkson's technique was used to determine the regression of fish length on otolith length.

Sets of paired measurements of otolith and fish lengths were selected from each of four broad geographical regions encompassing the commercial range of Pacific halibut: British Columbia, southeastern Alaska, the Gulf of Alaska and the Bering Sea. Each region has had a distinctive history of fishing and the age composition of

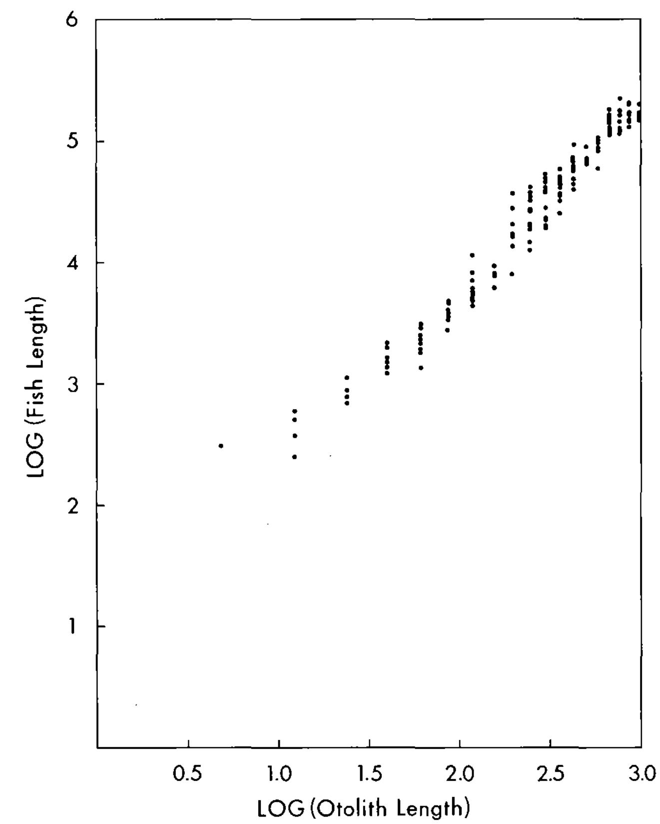

Figure 1. Relation of fish length and otolith length, Gulf of Alaska data.

the catches from each are different. No attempt was made to measure annual variation among the samples within each region. Sizes of halibut ranging from 10 to over 200 cm were obtained from each of these regions. Otolith lengths were stratified in 1 mm intervals and approximately 12 fish lengths were randomly selected for each interval. The mid-point of the interval was accepted as the value of the X variable. The bivariate variability associated with the pairing of otolith and fish lengths is not lost by using the mid-point as the measure of the X variable because the interval width is small. Fish obtained from commercial landings and research catches were measured to the nearest centimeter. The otoliths were measured along the longitudinal axis to the nearest 0.01 mm with a machinist's dial-reading caliper.

The nonlinearity of the measurements was evident in a scatter diagram. A logarithmic transformation of both variables, illustrated by data from the Gulf of Alaska, showed that the transformed data also are not described by a straight line (Figure 1). Because of the curvature in the scatter of the transformed data, a third degree polynomial equation was fitted for each geographical region. The significance of the second and third degree terms of the polynomial was examined by analysis of variance (Table 1). The cubic term is highly significant for data from the Gulf of Alaska, but is not significant for data from British Columbia, southeastern Alaska or the Bering Sea. In the Bering Sea data, however, the probability of the F ratio is near the rejection probability. Deviations about regression are nearly the same for all areas.

Table 1. Analysis of variance of a cubic regression by region.

	Degrees of Freedom	Mean Square	F
British Columbia			
Linear term	1	62.60568	5902
Quadratic term	1	1.63025	153
Cubic term	1	0.000013030	0.001
Deviation about regression	151	0.010607	
Southeastern Alaska			
Linear term	1	117.50649	9614
Quadratic term	1	1.12647	92
Cubic term	1	0.0091378	0.75
Deviation about regression	193	0.012222	
Gulf of Alaska			
Linear term	1	120.35001	9532
Quadratic term	1	0.75953	60
Cubic term	1	0.39518	31.3
Deviation about regression	192	0.012626	
Bering Sea			
Linear term	1	100.77052	8313
Quadratic term	1	0.75077	62
Cubic term	1	0.024324	2.01
Deviation about regression	180	0.012121	

A cubic term in the regression describes a reduction in growth in fish length at large otolith sizes, correcting the bias encountered in the earlier equation for fish length. Therefore, we retained the cubic term in the equations, even though the analysis implied that it was nonsignificant for some regions.

The regression equations for the different regions are:

British Columbia

$$\log(L) = 2.06035 + 0.27736 \log(O) + 0.26648 [\log(O)]^2 + 0.00160 [\log(O)]^3 \quad (2)$$

Southeastern Alaska

$$\log(L) = 1.62676 + 0.90838 \log(O) - 0.03469 [\log(O)]^2 + 0.04949 [\log(O)]^3 \quad (3)$$

Gulf of Alaska

$$\log(L) = 3.46510 - 2.30676 \log(O) + 1.68946 [\log(O)]^2 - 0.23942 [\log(O)]^3 \quad (4)$$

Bering Sea

$$\log(L) = 2.29027 - 0.27978 \log(O) + 0.61843 [\log(O)]^2 - 0.06415 [\log(O)]^3 \quad (5)$$

where O = otolith length in millimeters and L = fish length in centimeters.

The question of whether the four regions could be represented by a common regression line was examined by analysis of covariance (Table 2) and the hypothesis of a common line was rejected ($F_{.95\,(12,716)} = 51.31$). Therefore, separate regression lines are necessary for each region. The representation of British Columbia and southeastern Alaska or southeastern Alaska and the Gulf of Alaska by a common line was also rejected. Additional combinations or separations were not examined. Confidence intervals were determined for each line and are given in Table 3 for

Table 3. Confidence limits of otolith length and fish length relationship for different geographical regions.

Otolith Length (mm)	Estimated Fish Length (cm)	Confidence Limits (cm) 95 Percent
	BRITISH COLUMBIA	
4.06	19.7	18.2 – 21.2
11.82	81.5	79.5 – 83.4
18.17	170.7	165.6 – 176.0
	SOUTHEASTERN ALASKA	
4.06	19.5	18.8 – 20.2
9.87	61.6	60.1 – 63.0
18.17	177.7	172.3 – 183.3
	GULF OF ALASKA	
4.06	18.0	17.3 – 18.7
10.59	72.2	70.4 – 74.1
18.17	170.7	166.1 – 175.5
	THE BERING SEA	
4.06	18.7	18.0 – 19.4
10.00	62.8	62.2 – 64.4
18.17	165.6	159.9 – 171.6

Table 2. Analysis of covariance on the otolith length-fork length, all areas.

Source	Sum of Squares	d.f.	Mean Square	F
Full model	13863.61846			
Reduced model	13856.25998			
Due to fitting coefficients	7.35848	12	0.61321	51.27
Residual	8.56656	716	0.01196	

selected otolith lengths. The confidence intervals for each of the regions are nearly the same width at each point, about 5% of the predicted value.

The average size of halibut by age has increased since the beginning of the fishery in the early 1900's, as well as differing among the grounds between British Columbia and the Bering Sea (Southward, 1967). The determination that separate regression lines are needed for current data from regions where the growth rates differ implies that the relationship between the otolith and fish length is dependent on the growth rate. Further, this indicates that the regressions described in this report must be validated from time to time and that these regressions cannot be used to estimate fish length from otoliths collected during earlier periods of the fishery.

VALIDATION OF THE PREDICTING EQUATIONS

The reliability of the polynomial regressions for predicting fish length of halibut from the otolith length was checked by regressions of predicted fish length on measured fish length. If the measured lengths were predicted accurately over the entire range of otolith lengths one would expect a linear regression with a zero intercept and a slope of 1.0, as illustrated with a scatter plot of data from the Gulf of Alaska (Figure 2). These hypotheses were tested for each region by t-tests. The values of t for both the intercept and the slope in each instance were near the critical value for rejection of

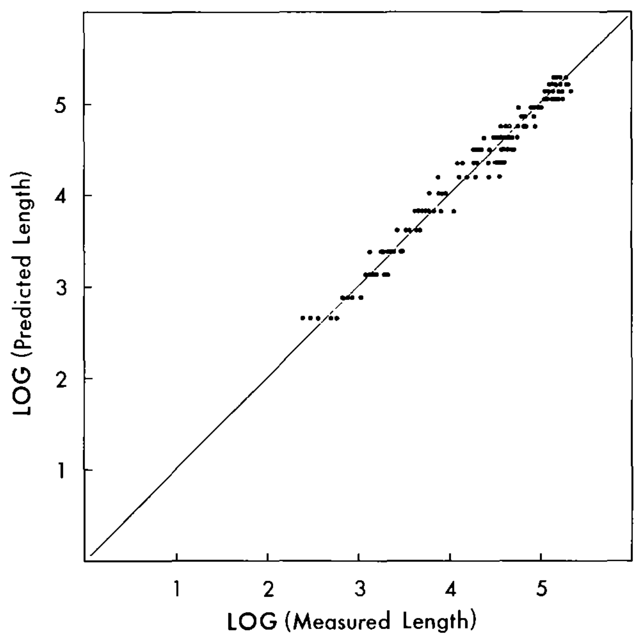

Figure 2. Relation of predicted length and measured length, Gulf of Alaska data.

the hypotheses. The slopes for data from each region were slightly below 1.0, approximately 0.98, and the intercepts were approximately 0.01. The consistency of the departure of the intercepts and slopes from the expected values of 0.0 and 1.0 and the results of the t-tests indicate that the third degree polynomial slightly underestimates fish size at large otolith sizes. The underestimation is about 2%for fish sizes of approximately 200 cm, that is, about 4 cm and is considered acceptable.

SUMMARY

To reduce the cost of obtaining length composition data, lengths of halibut were calculated using a relationship between otolith radius and fish length. Later a relationship expressed in terms of otolith length was adopted. In 1971, it was discovered that lengths of large fish were being overestimated and lengths of small fish underestimated.

The relationship was reexamined and a third degree polynomial was fitted to natural logarithms of the paired measurements of otolith length and fish length. The significance of the higher order terms was examined by analysis of variance techniques. The 95% confidence interval is narrow, approximately 5% of the predicted value. The differences among regressions for various sections of the coast were too great for a common predicting equation for the entire coast. Different regressions for sections of the coast where growth rate has been shown to differ implies that the otolith-fish length relationship is dependent on growth. Consequently, the regressions cannot be used to calculate lengths from otoliths collected in earlier years when the growth rate was lower.

LITERATURE CITED

Berkson, Joseph

1950 Are there two regressions? American Statistical Association Journal 45: 164-180.

Hardman, William H. and G. Morris Southward

1965 Sampling the commercial catch and use of calculated lengths in stock composition studies of Pacific halibut. Report. International Pacific Halibut Commission (37): 32 p.

Hile, Ralph

1970 Body-scale relation and calculation of growth in fishes. Transactions. American Fisheries Society 99(3): 468-474.

Ricker, W. E.

1973 Linear regressions in fishery research. Journal Fisheries Research Board of Canada 30(3): 409-434.

Southward, G. Morris

1962 A method of calculating body lengths from otolith measurements for Pacific halibut and its application to Portlock-Albatross grounds data between 1935 and 1957. Journal Fisheries Research Board of Canada 19(2): 335-338.

Southward, G. Morris

1967 Growth of Pacific halibut. Report. International Pacific Halibut Commission (43): 40 p.