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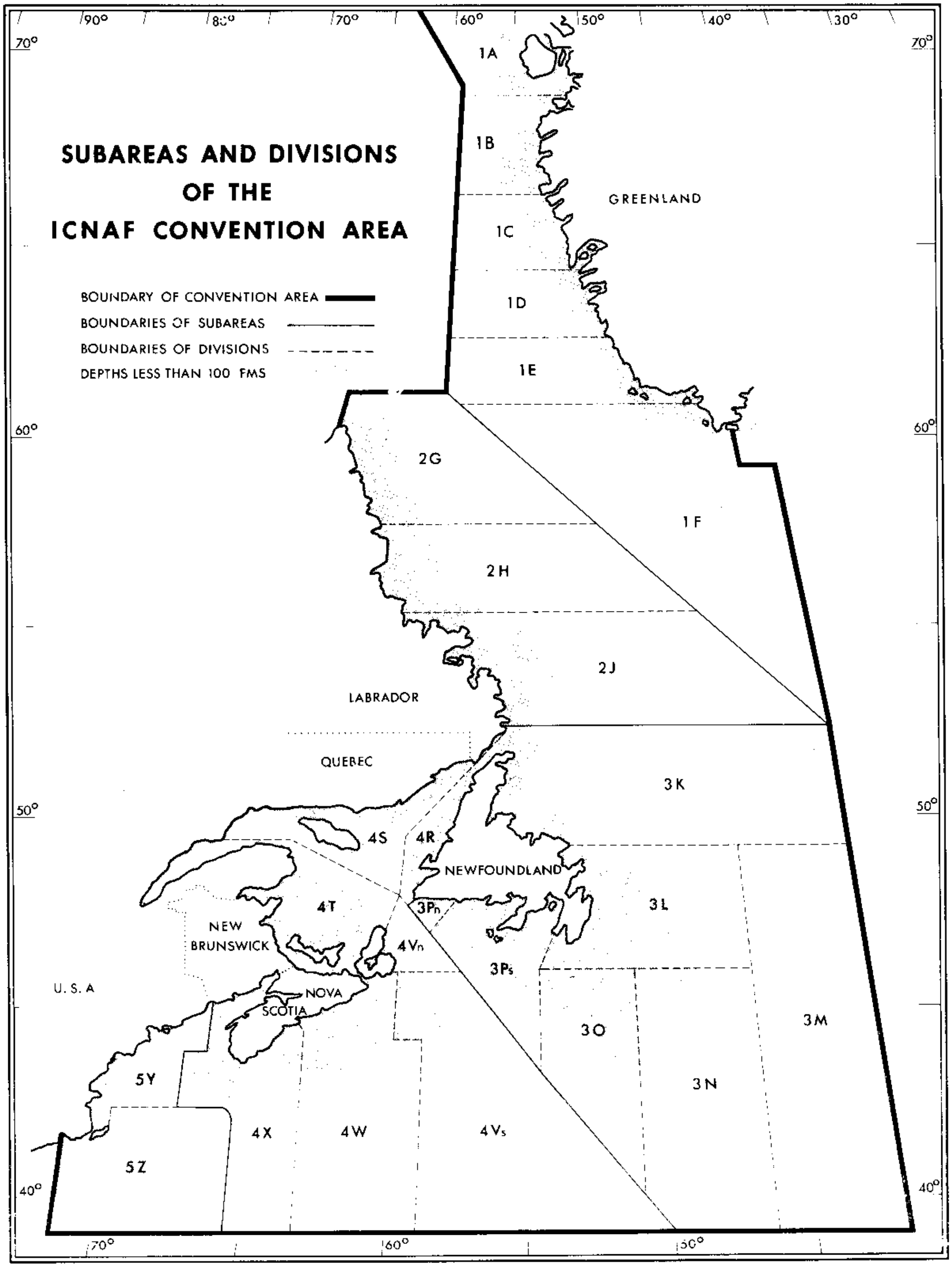
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1C
1D
1E
1F
GREENLAND
2G
2H
2J
LABRADOR
QUEBEC
3K
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3M
3N
3O
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Contents

ROBSON, D. S. Estimation of the Relative Fishing Power of Individual Ships 5

BOURNE, Neil. Relative Fishing Efficiency and Selection of Three Types of Scallop Drags 15

ZAKHAROV, G. P. The Distribution of Pelagic Redfish Fry in the East and West Greenland Areas 26

HAYNES, Evan B. Length-Weight Relation of the Sea Scallop, *Placopecten magellanicus* (Gmelin) 32

SAVVATIMSKY, P. I., and I. N. SIDORENKO. Results of Investigations on Deep-sea Redfish 49

HODDER, V. M. Trends in the Haddock Fishery of ICNAF Subarea 3 55

TOKAREVA, G. I. Data on the Distribution of Young *Sebastes mentella* Tr. in the Labrador-Newfoundland Area 64

TRUSKANOV, M. D., and M. N. SCHERBINO. Methods of Direct Calculation of Fish Concentrations by Means of Hydroacoustic Apparatus 70

CHRZAN, Feliks, and Czeslaw ZUKOWSKI. Some Characteristics of Argentine, *Argentina silus* Ascanius, Occurring in the Region off Nova Scotia 81

JENSEN A. C., and R. C. HENNEMUTH. Size Selection and Retainment of Silver and Red Hake in Nylon Codends of Trawl Nets 86

Notes

POWLES, P. M. Validity of Ageing Young American Plaice from Otoliths 103

NETZEL, Jan, and Eugeniusz STANEK. Some Biological Characteristics of Blueback, *Pomolobus aestivalis* (Mitch.) and Alewife, *Pomolobus pseudoharengus* (Wils.), from Georges Bank, July and October, 1964 106

FRITZ, Raymond L. Occurrence of *Sphyrion lumpi* on Silver Hake, *Merluccius bilinearis* 111

Instructions to Authors 113

Estimation of the Relative Fishing Power of Individual Ships

BY D. S. ROBSON[1]

Abstract

Commercial catch statistics for individual vessels and individual fishing trips may be converted to catch per standard unit of effort by estimating and adjusting for the effects of such factors as tonnage, class, design, age of vessel, skipper, and location of fishing grounds. Available data indicate that the most efficient statistical procedure for estimating and testing the effects of these factors is the method of least squares regression analysis or, equivalently, the factorial analysis of variance for unequal subclass numbers. This procedure is illustrated in detail here by a four-factor analysis which may be readily programmed for an electronic computer.

Introduction

The use of commercial catch statistics in constructing indices of fish abundance such as catch per unit of effort requires that the unit of effort be well defined and constant through time. Since the total commercial catch for a year is made up of the individual annual catches of a number of ships of varying types and sizes, and working several different kinds of gear, this requirement for a standard unit of effort raises difficulties. Beverton and Holt (1957) consider this problem in connection with the analysis of catch statistics from the plaice fishery of the North Sea, and point up the need for a statistically efficient method of estimating the relative fishing power of each vessel, so that the actual effort of the vessel can be transformed into standard units on a scale comparable to that of all other vessels.

The problem is neatly illustrated by Beverton and Holt (1957) with an example in which the total catch and hours of effort is known for six fishing trips involving three different vessels and three different locations in time and space (Table 1). They suggest that one of the trips, say ship A at location I, be arbitrarily selected as a standard for comparison and the fishing power of the other two vessels then be expressed relative to the fishing power of vessel A. Thus, four possible estimates of the fishing power of vessel C are listed as

(i) $\frac{B_1}{A_1} \times \frac{C_3}{B_3}$ (ii) $\frac{B_2}{A_2} \times \frac{C_3}{B_3}$

(iii) $\frac{1}{2}\left(\frac{B_1}{A_1} + \frac{B_2}{A_2}\right) \times \frac{C_3}{B_3}$ (iv) $\frac{B_1 + B_2}{A_1 + A_2} \times \frac{C_3}{B_3}$

with the suggestion that (iv) might be "as good as any." We shall show that for this problem the estimator

$$\text{(v)} \quad \frac{C_3}{B_3}\sqrt{\frac{B_1B_2}{A_1A_2}}$$

is likely to be more efficient than any of the others, and shall indicate the general method by which such efficient estimators are constructed. This method is an extension of the techniques employed by Gulland (1956) in his analysis of fishing power of vessels in the English demersal fisheries.

TABLE 1. The catch rate for six different fishing trips.

Ship	Location I	II	III
A	A_1	A_2	—
B	B_1	B_2	B_3
C	—	—	C_3

A Statistical Model for Catch Rates

The model upon which the four estimators of Beverton and Holt (1957) are based is the multiplicative model for a two-way classification without interaction. Thus, the model asserts that one location is expected to yield a catch rate which is a fixed percentage higher than another location for every vessel and, equivalently, that one vessel is expected to achieve

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a catch rate which is a fixed percentage higher than that of another vessel at every location. So, denoting P_i as the power factor of the ith vessel and Q_j as the power factor of the jth location we obtain the model shown in Table 2, where C is a constant and E is a random variable having an expected value of unity. If the trip of ship number 1 (ship A) to location number 1 is to be taken as the standard for comparison, then all other power factors P and Q are to be expressed as a fraction of P_1 and Q_1; hence, in this instance we would set $P_1=Q_1=1$ and obtain for this example the model shown in Table 3. Putting the errors E all equal to 1 then reveals the intuitive basis of the estimators (i)–(v) given earlier.

TABLE 2. Multiplicative model for the catch rates of three vessels at three locations.

	Location		
Ship	1	2	3
1	$CP_1Q_1E_{11}$	$CP_1Q_2E_{12}$	$CP_1Q_3E_{13}$
2	$CP_2Q_1E_{21}$	$CP_2Q_2E_{22}$	$CP_2Q_3E_{23}$
3	$CP_3Q_1E_{31}$	$CP_3Q_2E_{32}$	$CP_3Q_3E_{33}$

TABLE 3. Multiplicative model for the six trips with ship A and location I taken as standard.

	Location		
Ship	I	II	III
A	$A_1=CE_{11}$	$A_2=CQ_2E_{12}$	—
B	$B_1=CP_2E_{21}$	$B_2=CP_2Q_2E$	$B_3=CP_2Q_3E_{23}$
C	—	—	$C_3=CP_3Q_3E_{33}$

Empirical evidence in support of this multiplicative model for catch statistics of plaice was presented by Beverton and Holt (1957); they found that when fishing power statistics were classified according to tonnage and method of propulsion of the vessels the distribution of errors within these classes was log normal—i.e. on the logarithmic scale the within-class distribution of power factors was normal with constant variance. Their subsequent analyses were therefore performed on the log scale, and on the basis of this finding it is now apparent that a more efficient method of estimating power factors would have been to transform to the logarithmic scale at the beginning and compute the least squares or maximum likelihood estimators of fishing power. On this scale the multiplicative model of Table 2 becomes additive as shown in Table 4, where lower case letters are used to denote logarithms ($x=\log X$). According to the evidence presented by Beverton and Holt, the errors e are normally distributed with zero mean and constant variance.

TABLE 4. Additive model for catch rates on the logarithmic scale.

	Location		
Ship	1 1	2	3
1	$c+p_1+q_1+e_{11}$	$c+p_1+q_2+e_{12}$	$c+p_1+q_3+e_{13}$
2	$c+p_2+q_1+e_{21}$	$c+p_2+q_2+e_{22}$	$c+p_2+q_3+e_{23}$
3	$c+p_3+q_1+e_{31}$	$c+p_3+q_2+e_{32}$	$c+p_3+q_3+e_{33}$

Relative fishing power may be defined for this model in almost any way that is convenient, the only formal requirements being that the definition impose linear restraints on the p's and q's. The most conventional linear restrictions are

$$p_1+p_2+p_3=0, \quad q_1+q_2+q_3=0$$

which amount to using the row and column means as standards for comparison; under these restrictions the constant c in the model then represents the average log catch rate for the set of three ships and three locations. The procedure suggested earlier of choosing one ship and one location as the standards for comparison is perhaps equally convenient, though seemingly more arbitrary. Such a choice as ship number 1 and location number 1 is then equivalent to imposing the linear restrictions

$$p_1=\log\ P_1=\log 1=0, \quad q_1=\log\ Q_1=\log 1=0.$$

The choice of linear restraints is irrelevant except from the standpoint of computational convenience, for using the statistically most efficient method of estimation will produce the same *relative* fishing powers regardless of the choice; i.e. the differnece between two estimates p_1-p_2 will be independent of the choice of linear restrictions. This point will be illustrated with the example involving six fishing trips.

Least Squares or Maximum Likelihood Estimation of Fishing Power

The method of estimating the parameters of an additive two-factor model with missing cells appears in standard textbooks on statistical methodology (e.g. Steel and Torrie, 1960, p. 289) usually under the name of "the method of fitting constants." This procedure is an application of the least squares method of multiple regression which, under the normality assumptions mentioned earlier, also yields maximum likelihood estimates. The method is algebraically simple, but is computationally fairly tedious, involving matrix inversion, though with electronic computers this too becomes a relatively simple operation.

In the textbook treatment of this topic the emphasis is ordinarily placed upon hypothesis testing rather than point estimation, and is presented under the general heading of "analysis of variance." For estimation purposes it is perhaps more convenient to regard this problem as a special case of the general multiple regression problem expressed by the model

$$Y_i=\beta_0 X_{oi}+\beta_1 X_{1i}+\ldots+\beta_k X_{ki}+\epsilon_i$$

where the expected value of an observation Y depends linearly upon the levels of $k+1$ factors, and each observed Y_i is obtained at a different set of levels $X_{oi},X_{1i}, \ldots,X_{ki}$ of these factors. The X's are known constants, the β's are unknown and to be estimated, and the ϵ's are independent identically distributed errors. If n observations $Y_1 \ldots, Y_n$ are available then the best unbiased estimator of $\beta'=(\beta_0,\beta_1, \ldots\beta_k)$ is, in matrix notation, $\hat{\beta}=(X'X)^{-1}X'Y$; if the ϵ's are normally distributed then this is also the maximum likelihood estimator and is statistically efficient. We illustrate this estimation procedure first with the data of Table 3 transformed to logarithms as shown in Table 5. The role of the β parameters is now taken by $\beta'=(c,p_2,p_3,q_2,q_3)$ and the X matrix of coefficients of these parameters is then given by Table 6. Taking the sums of squares and crossproducts of the columns of this matrix, we then obtain the matrix X'X shown in Table 7; and inverting this, an operation which would require only a second or two on a high-speed

TABLE 5. Additive model for the log catch rates of six fishing trips with ship A and location 1 taken as standard.

Ship	Location 1	2	3
A	$a_1=c+e_{11}$	$a_2=c+q_2+e_{12}$	$b_3=c+p_2+q_3+e_{23}$
B	$b_1=c+p_2+e_{21}$	$b_2=c+p_2+q_2+e_{22}$	$c_3=c+p_3+q_3+e_{33}$
C	—	—	—

TABLE 6. Matrix X of coefficients of the parameters in a linear additive model.

Observation	Parameter c	p_2	p_3	q_2	q_3
a_1	1	0	0	0	0
a_2	1	0	0	1	0
b_1	1	1	0	0	0
b_2	1	1	0	1	0
b_3	1	1	0	0	1
c	1	0	1	0	1

TABLE 7. Matrix X'X of sums of squares and crossproducts of the columns of X and the inverse $(X'X)^{-}$.

Column	Column c	p_2	p_3	q_2	q_3
c	6	3	1	2	2
p_2	3	3	0	1	1
p_3	1	0	1	0	1
q_2	2	1	0	2	0
q_3	2	1	1	0	2

The inverse of X'X

	c	p_2	p_3	q_2	q_3
c	3/4	–1/2	–1/2	–1/2	–1/4
p_2	–1/2	1	1	0	–1/2
p_3	–1/2	1	3	0	–3/2
q_2	–1/2	0	0	1	1/2
q_3	–1/4	–1/2	–3/2	1/2	7/4

computer, we obtain the matrix $(X'X)^{-1}$ shown in Table 7. Finally, the product of $(X'X)^{-1}$ with the crossproducts

$$X'Y = \begin{bmatrix} a_1+a_2+b_1+b_2+b_3+c_3 \\ b_1+b_2+b_3 \\ c_3 \\ a_2+b_2 \\ b_3+c_3 \end{bmatrix}$$

gives the estimates

Log scale	Original scale
$\hat{c}=\frac{1}{4}\ (3a_1+a_2+b_1-b_2)$	
$\hat{p}_2=\frac{1}{2}(b_1+b_2-a_1-a_2)$	$\hat{P}_2=\sqrt{B_1B_2/A_1A_2}$
$\hat{p}_3=\hat{p}_2-b_3+c_3$	$\hat{P}_3=\hat{P}_2C_3/B_3$
$\hat{q}_2=\frac{1}{2}\ (b_1-b_2-a_1+a_2$	
$\hat{q}_3=b_3-\frac{1}{4}\ (a_1-a_2+3b_1+b_2)$	

The variance of these estimates on the logarithmic scale is σ^2_ϵ times the diagonal elements of $(X'X)^{-1}$; thus, $\sigma^2_{\hat{c}}=3\sigma^2_\epsilon/4$, $\sigma^2_{\hat{p}_2}=\sigma^2_\epsilon$, $\sigma^2_{\hat{p}_3}= 3\sigma^2_\epsilon$, etc. Covariances between estimates are likewise computed as σ^2_ϵ times the corresponding element of $(X'X)^{-1}$; thus, $\sigma_{\hat{p}_2,\hat{p}_3}=\sigma^2_\epsilon$, $\sigma_{\hat{p}_2,\hat{q}_2}=0$, $\sigma_{\hat{p}_3,\ \hat{q}_3}=-3\sigma^2_\epsilon/2$, etc.,

and so $\sigma^2_{\hat{p}_2-\hat{p}_3}=\sigma^2_{\hat{p}_2}+\sigma^2_{\hat{p}_3}-2\sigma_{\hat{p}_2,\hat{p}_3}=2\sigma^2_\epsilon$

If instead of the restriction $p_1=q_1=0$ we impose the restriction $p_1+p_2+p_3=q_1+q_2+q_3=0$ then essentially the same results will be obtained. The X matrix for this case is shown in Table 8, along with the inverse of X'X, from which we obtain the estimates in Table 8. We note that the fishing power of ship B relative to ship A is again estimated by

$$\hat{p}_2-\hat{p}_1=1/2(b_1+b_2-a_1-a_2)$$

$$\sigma^2_{\hat{p}_2-\hat{p}_1}=\sigma^2_{\hat{p}_1}+\sigma^2_{\hat{p}_2}-2\sigma_{\hat{p}_1,\hat{p}_2}=\sigma^2_\epsilon$$

so $$\frac{\hat{P}_2}{\hat{P}_1}=\sqrt{\frac{B_1B_2}{A_1A_2}}$$

as before, and

$$\hat{p}_3-\hat{p}_1= -2\hat{p}_1-\hat{p}_2= \hat{p}_2-\hat{p}_1-b_3+c_3,\ \sigma^2_{\hat{p}_3-\hat{p}_1}=4\sigma^2_{\hat{p}_1}+\sigma^2_{\hat{p}_2}+4\sigma_{\hat{p}_1,\hat{p}_2}=3\sigma^2_\epsilon$$

so, as before,

$$\frac{\hat{P}_3}{\hat{P}_1}=\frac{C_3}{B_3}\sqrt{\frac{B_1B_2}{A_1A_2}}$$

The residual variance σ^2_ϵ is estimated in the general regression problem by $(Y'Y-\hat{\beta}X'Y)/(n-k-l)$. In the present example $n=6$, and $k+1=5$ parameters are being estimated so the residual sum of squares

$$(a_1^2+a_2^2+b_1^2+b_2^2+b_3^2+c_3^2)-\hat{c}(a_1+a_2+b_1+b_2+b_3+c_3)$$
$$-\hat{p}_1(a_1+a_2-c_3)-\hat{p}_2(b_1+b_2+b_3-c_3)\ -\hat{q}_1(a_1+b_1-b_3-c_3)-\hat{q}_2(a_2+b_2-b_3-c_3)$$

has only 1 degree of freedom. An analagous form for the residual applies to the earlier analysis with $p_1=q_1=0$ and gives the same value for $\hat{\sigma}^2_\epsilon$. For purposes of hypothesis testing it is pertinent that $\hat{\sigma}^2_\epsilon$ is statistically independent of the other estimates. For example, under the hypothesis that

$p_1=p_3$ the ratio $(\hat{p}_1-\hat{p}_3)/\sqrt{3\hat{\sigma}^2_\epsilon}$ is distributed as Student's t with 1 degree of freedom.

Modifications of the Model

Beverton and Holt list a number of factors such as tonnage, class, design, age, and skipper which might explain the variation in fishing power of the different vessels, suggesting that a classification of vessels into various groups should be introduced into the model to determine the effect of such factors. The collection of fishing locations in time and space might also be further classified, at least according to time and geographic location, to determine the effects of these factors on catch rates; since the same principles apply to the subclassification of ships and locations, however, it will suffice to consider only the former.

In the North Sea plaice fishery a major factor affecting catch rate was the means of propulsion of the vessel; Beverton and Holt distinguished two classes for this factor, the steam trawler and the diesel powered motor trawler. To illustrate the modification of the model required to incorporate this factor we enlarge our earlier example to include five ships, say three steam trawlers and two motor trawlers as shown in Table 9. The earlier model of Tables 2 and 4 would still suffice for the three steam trawlers and an entirely similar model should hold for the two motor trawlers; that is, the additive model of Table 4 should now be extended to include the table shown at the top of page 10 where, under the conventional linear restrictions,

$$p_4+p_5=0,\ q_4+q_5=0.$$

The constant c, representing the average log catch rate, should however be different for steam and motor trawlers if method of propulsion actually does affect catch rate. We therefore identify these two constants as c_1 and c_2, respectively, and taking $c=(c_1+c_2)/2$ as our standard for comparison we let

$$c_1=c+(c_1-c)=c+d_1\ ,\quad c_2=c+(c_2-c)=c+d_2\ ,$$

$$d_1+d_2=0$$

The additive model for the log catch rates of Table 9 which incorporates this d-effect due to method of propulsion is shown in Table 10; with the five linear restrictions which have been imposed there are only seven independent parameters in this table, and their estimation proceeds as before by the methods of multiple regression. A test of the significance of the effect of method of propulsion would then be obtained from the regression analysis as a t-or F-test of the hypothesis that the "regression coefficient" d_1 is equal to zero.

TABLE 8. The matrices X and $(X'X)^{-1}$ for the case $p_1+p_2+p_3=q_1+q_2+q_3=0$.

X

Observation	Parameter c	p_1	p_2	q_1	q_2
a_1	1	1	0	1	0
a_2	1	1	0	0	1
b_1	1	0	1	1	0
b_2	1	0	1	0	1
b_3	1	0	1	–1	–1
c_3	1	–1	–1	–1	–1

$(X'X)^{-1}$

Parameter	Parameter c	p_1	p_2	q_1	q_2
c	2/9	–1/9	–1/9	1/18	1/18
p_1	–1/9	2/3	0	2/9	–2/9
p_2	–1/9	0	1/3	–1/18	–1/18
q_1	1/18	–2/9	–1/18	5/12	–1/12
q_2	1/18	–2/9	–1/18	–1/12	5/12

Estimates

$\hat{c}=1/6\ [a_1+a_2+b_1+b_2+2c_3]$ $\quad \sigma^2_{\hat{c}}=1/6\sigma^2_\epsilon$

$\hat{p}_1=1/3\ [a_1+a_2-b_1-b_2+b_3-c_3]$ $\quad \sigma^2_{\hat{p}_1}=2/3\sigma^2_\epsilon$

$\hat{p}_2=1/3\ [1/2(b_1+b_2-a_1-a_2)+b_3-c_3]$ $\quad \sigma^2_{\hat{p}_2}=1/3\sigma^2_\epsilon$

$\hat{q}_1=1/12[3a_1-3a_2+5b_1-b_2-4b_3]$ $\quad \sigma^2_{\hat{q}_1}=5/12\sigma^2_\epsilon$

$\hat{q}_2=1/12[3a_2-3a_1-b_1+5b_2-4b_3]$ $\quad \sigma^2_{\hat{q}_2}=5/12\sigma^2_\epsilon$

$\hat{p}_3=-\hat{p}_1-\hat{p}_2$ $\quad \sigma^2_{\hat{p}_3}=\sigma^2_{\hat{p}_1}+\sigma^2_{\hat{p}_2}+2\sigma_{\hat{p}_1\hat{p}_2}=\sigma^2_\epsilon$

$\hat{q}_3=-\hat{q}_2-\hat{q}_3$ $\quad \sigma^2_{\hat{q}_3}=\sigma^2_{\hat{q}_1}+\sigma^2_{\hat{q}_2}+2\sigma_{\hat{q}_1,\hat{q}_2}=2/3\sigma^2_\epsilon$

TABLE 9. The catch rates of two types of vessels at three locations.

Ship	Type	Location I	II	III
A	Steam	A_1	A_2	—
B	Steam	B_1	B_2	B_3
C	Steam	—	—	C_3
F	Motor	F_1	—	F_3
G	Motor	—	G_2	—

Ship	Type	Location I	II	III
F	motor	$c+p_4+q_1+e_{41}$	$c+p_4+q_2+e_{42}$	$c+p_4+q_3+e_{43}$
G	motor	$c+p_5+q_1+e_{51}$	$c+p_5+q_2+e_{52}$	$c+p_5+q_3+e_{53}$

Another factor which proved to have a significant effect upon catch rate was the size of the ship as measured by its tonnage; in fact, it was found that the power factor P was directly proportional to tonnage, on the average, with different proportionality factors for steam and motor trawlers. The constants d_1 and d_2 of the above model would represent these two proportionality factors on the log scale, and incorporation into the model of the assumption that the power factor P_i is proportional to the tonnage T_i would then consist of replacing the p-parameters by the log tonnage deviates,

$$p_1=(t_1-t_s) \qquad p_4=(t_4-t_m)$$
$$p_2=(t_2-t_s) \qquad p_5=(t_5-t_m)$$
$$p_3=(t_3-t_s)$$

where $t_i=\log T_i$ and

$$t_s=(t_1+t_2+t_3)/3 \qquad t_m=(t_4+t_5)/2$$

The procedure for fitting this modified model would be to deduct the log tonnage deviate t_i-t from each of the observed log catch rates of that ship, eliminate all p's from the model and proceed with a multiple regression analysis. The difference between the residual sum of squares from this analysis and the residual sum of squares from the analysis of Table 10 represents the reduction in residual sum of squares which is attained due to fitting the p's instead of simply assuming that the p's are equal to the corresponding known constants t_i-t. The degrees of freedom in this difference of residuals is equal to the number of ships minus the number of types, or 5–2=3 in this case, and the mean square obtained by dividing by degrees of freedom may then be tested for significance against the residual mean square from the analysis of Table 10. The entire procedure is illustrated by a numerical example in the next section.

Numerical Illustration

The preceding analysis is illustrated here with an artificial set of data for Table 10; these data, shown in Table 11, were generated by assigning arbitrary values to the c, d, q, and t parameters of Table 10, and taking the p parameters approximately equal to the log tonnage deviates t_i-t within each type of vessel. Observed log catch rates (Y) were then constructed by combining the parameters in the

TABLE 10. Additive model for log catch rate of two types of ships.

Ship	Type	Location I	II	III	Log tonnage
A	Steam	$c+d_1+p_1+q_1+e_{11}$	$c+d_1+p_1+q_2+e_{12}$	—	t_1
B	Steam	$c+d_1+p_2+q_1+e_{21}$	$c+d_1+p_2+q_2+e_{22}$	$c+d_1+p_2+q_3+e_{23}$	t_2
C	Steam	—	—	$c+d_1+p_3+q_3+e_{33}$	t_3
F	Motor	$c+d_2+p_4+q_1+e_{41}$	—	$c+d_2+p_4+q_3+e_{43}$	t_4
G	Motor	—	$c+d_2+p_5+q_2+e_{52}$	—	t_5

TABLE 11. Log catch rates of five ships at three locations.

Ship	Type	Y=log catch rate Location I	II	III	Log tonnage	Y=log catch rate adjusted[a] Location I	II	III
A	steam	.020	.120	—	1.954	.207	.307	—
B	steam	.503	.463	.238	2.322	.322	.282	.057
C	steam	—	—	.251	2.146	—	—	.246
		Mean log tonnage			2.141			
F	motor	.188	—	.142	1.778	.356	—	.310
G	motor	—	.544	—	2.114	—	.376	—
		Mean log tonnage			1.946			

[a]Adjusted log catch rate = log catch rate − log tonnage + mean log tonnage.

TABLE 12. Coefficients of the unknown parameters (Table 10) and their cross-products with log catch rates.

Catch rate Y	Y*	Parameter c	d_1	p_1	p_2	q_1	q_2	p_4
.020	.207	1	1	1	0	1	0	0
.120	.307	1	1	1	0	0	1	0
.503	.322	1	1	0	1	1	0	0
.463	.282	1	1	0	1	0	1	0
.238	.057	1	1	0	1	−1	−1	0
.251	.246	1	1	−1	−1	−1	−1	0
.188	.356	1	−1	0	0	1	0	1
.142	.310	1	−1	0	0	−1	−1	1
.544	.376	1	−1	0	0	0	1	−1
ΣXY		2.469	.721	−.111	.953	.080	.496	−.214
	ΣXY*	2.463	.379			.272	.352	

Crossproducts of coefficients of the parameters
X′X

Parameter	Parameter c	d_1	p_1	p_2	q_1	q_2	p_4
c	9	3	1	2	0	0	1
d_1	3	9	1	2	0	0	−1
p_1	1	1	3	1	2	2	0
p_2	2	2	1	4	1	1	0
q_1	0	0	2	1	6	3	0
q_2	0	0	2	1	3	6	−2
p_4	1	−1	0	0	0	−2	3

manner indicated in Table 10 and adding to each a random normal deviate e.

The first phase of the analysis consists of setting out the coefficients of the unknown parameters in matrix form (Table 12) and computing crossproducts among these coefficients and between the coefficients and the observations. This matrix of crossproducts is then inverted by standard methods and multiplied by the vector of crossproducts between coefficients and observations to obtain the parameter estimates. Thus, in Table 13, the estimate $\hat{p}_1=-.111$ is obtained as the sum of crossproducts of the inverse elements in the p_1 column times the elements of the ΣXY column,

$$\hat{p}_1=[(-10)(2.469)+(-34)(.721)+\ldots\ldots+(-72)(-.213)]/540=-.111$$

Goodness of fit of the model may be measured by the ratio

$$R^2=\frac{\text{Residual S.S. after fitting } (c)-\text{Residual S.S. after fitting } (c,d_1,p_1,p_2,q_1,q_2,p_4)}{\text{Residual S.S. after fitting } c}$$

The residual sum of squares (S.S.) after fitting the constant c (the mean) is simply the corrected sum of squares of the nine observations,

$$\text{Res. S. S. after fitting } (c)=\Sigma^9{}_1 Y^2{}_i-{}^1\!/_9(\Sigma Y)^2$$
$$=.953267-\ (2.469)^2=.275938 \quad (\text{d.f.}=8)$$

and the residual sum of squares after fitting all seven parameters is, from Table 13,

$$.953267-[(.297)(2.469)+(-.037)(.721)+\ldots+(-.126)(-.214)]$$
$$=.953267-.939339=.013928 \quad (\text{d.f.}=2)$$

giving

$$R^2=\frac{.275938-.013928}{.275938}=\frac{.262010}{.275938}=.95$$

TABLE 13. Solution to the multiple regression problem of Table 12.

Inverse matrix of crossproducts of coefficients (×540)

$(X'X)^{-1}$

Parameter	c	d_1	p_1	p_2	q_1	q_2	p_4	ΣXY	Estimate
c	80	–25	–10	–25	15	–15	–45	2.469	.297
d_1	–25	86	–34	–31	–3	39	63	.721	–.037
p_1	–10	–34	296	–16	–48	–96	–72	–.111	–.247
p_2	–25	–31	–16	176	–12	–24	–18	.953	.142
q_1	15	– 3	–48	–12	144	–72	–54	.080	.030
q_2	–15	39	–96	–24	–72	216	162	.496	.084
p_4	–45	63	–72	–18	–54	162	324	–.214	–.126

Inverse of deleted matrix of crossproducts of coefficients (×72)

Parameter	c	d_1	q_1	q_2	ΣXY	Estimate
c	9	–3	0	0	2.469	.279
d_1	–3	9	0	0	.721	–.013
q_1	0	0	16	–8	.080	–.037
q_2	0	0	–8	16	.496	.101
ΣXY	2.463	.379	.272	.352		
Estimate	.292	–.055	.021	.048		

Thus, 95% of the variance among the 9 observations is accounted for by the six parameters d_1, p_1, p_2, q_1, q_2, and p_4; this, however, is not statistically significant when tested by the F-test

$$F=\frac{\text{Mean Square due to fitting } d_1,p_1,p_2,q_1,q_2,p_4}{\text{Residual Mean Square after fitting } d_1,p_1,p_2,q_1,q_2,p_4}$$

$$=\frac{.262010/6}{.013928/2}=\frac{.043668}{.006964}=6.2$$

because of the small number of degrees of freedom in the residual.

Analogous methods may be used to test the significance of more specific features of the model; for example, to determine the fraction of the total variance which is due specifically to variation of fishing power among ships of like method of propulsion we compute

$$\frac{\text{Res. S.S. after fitting } (c,d_1,q_1,q_2) \text{ Res. S.S. after fitting } (c,d_1,p_1,p_2,q_1,q_2,p_4)}{\text{Res. S.S. after fitting } c}$$

This computation involves another matrix inversion; we simply drop the p's from the model and so reduce the coefficient matrix by deleting the blocks indicated in Table 12. Estimates of c, d_1, q_1, and q_2 obtained from the inverse of the deleted matrix are given in Table 13; thus

$$\hat{c}=[9(2.469)-3(.721)+0(.080)+0(.496)]/72$$
$$=.279$$

and the residual S.S. after fitting only c, d_1, q_1, and q_2 is then

$$.953267-[(.279)(2.469)+(-.013)(.721)+(-.037)(.080)+(.101)(.496)]=.227363$$

with 9–4=5 degrees of freedom. The fraction of the total variance which is due specifically to the p-parameters is therefore

$$\frac{.227363-.013928}{.275938}=\frac{.213435}{.275938}=.77$$

and the significance of this may be tested by

$$F=\frac{\text{M.S. due to } (p_1,p_2,p_4)}{\text{Res. M.S.}}=\frac{.213435/3}{.013928/2}=10.2$$

Even with 2 degrees of freedom in the residual, the variation in the p's is detected at the 10% significance level.

The difference between the average log catch rate of steam and motor trawlers is measured by the parameter d_1, which may be tested for significance in the above manner. For a single parameter, however, the test procedure illustrated above simplifies to an F-test of the form

$$F=\frac{(\hat{d}_1)^2}{\frac{86}{540}\text{ Res. M.S.}}=\frac{(-.037)^2}{\frac{86}{540}(.006964)}=1.23$$

which is non-significant. The fraction 86/540 is the d_1 diagonal element of the inverse matrix of Table 13.

Finally, we illustrate the procedure for testing the hypothesis that within types of vessels, the fishing power of a ship is proportional to its tonnage. On the log scale, this is equivalent to the hypothesis that within types of vessels, $p_i=t_i-t$. This hypothesis is tested by replacing p_i by t_i-t in the model and comparing the resulting residual M.S. with the residual M.S. of .006964 obtained with no restrictions on p_1, p_2, and p_4. Since the deviates t_i-t are known constants then the replacement of p_i by t_i-t in the model is equivalent to subtracting t_i-t from the observed log catch rates of ship number i; the resulting adjusted catch rates are shown in Table 11 and denoted by Y*. With the p-parameters thus deducted from the model, the matrix of parameter coefficients becomes the deleted matrix considered previously, and the computations follow the same pattern but with Y replaced by Y*. The parameter estimates so obtained (Table 13) then give

Res. S.S. after fitting $(c^*,d_1^*,p_1=-.187,\ p_2=.181,\ q_1^*,q_2^*,p_4=-.168)$

$$=\sum_1^9 Y^{*2}-c^*(2.463)-d_1^*(.379)-q_1^*(.272)-q_2^*(.352)$$
$$=.748283-(.292)(2.463)-(-.055)(.379)-(.021)(.272)-(.048)(.352)=.027123)$$

Permitting p_1, p_2, and p_4 to vary arbitrarily in the model thus reduces the residual sum of squares by only

$$.027123-.013928=.013195$$

and this sum of squares with 3 degrees of freedom is not significant when tested against the residual for the unrestricted model,

$$F=\frac{.013195/3}{.013928/2}=.63$$

Another way of expressing this result is that while the best fitting p-parameters accounted for 77% of the variation in log catch rate, fixing the p-parameters by making them equal to the log tonnage deviates reduced this percentage only to 72%,

$$\frac{.213435-.013195}{.375938}=.72$$

and the reduction was not significant.

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Relative Fishing Efficiency and Selection of Three Types of Scallop Drags

BY NEIL BOURNE[1]

Abstract

The fishing efficiency and selection of five sets of scallop drags (offshore; 3-ft (0.91-m) tumbler; 4-ft (1.22-m) tumbler; 4-inch-(102-mm-) mesh-trawl net, and 5-inch-(127-mm-) mesh-trawl net) were compared in the Gulf of St. Lawrence (4T) and on Georges Bank (5Z). The offshore drag was the most efficient drag, followed by the tumblers and the trawl nets. All five drags gave poor selection. The trawl nets caught moderate quantities of groundfish and the possibility of a dual fishery for scallops and groundfish with these nets is pointed out.

Introduction

Recently there has been a rapid increase in Canadian sea scallop landings from Georges Bank (5Z), due mainly to a sharp increase in effort. Addition of the Canadian effort to that of the existing United States fishery caused concern among some scientists and in the industry. They felt that Georges Bank scallop stocks were being overexploited and that some form of management was necessary to control the minimum size of scallops being taken. Furthermore, it was postulated that delaying the age at which scallops are first used for 1 or 2 years would substantially increase yield up to 25% annually. Selection experiments were undertaken to determine whether increasing the size of ring on standard offshore drags would give this delay in age at first capture but effective selection was not achieved when the inside diameter of the rings was increased from 3 to 4 inches (76–102 mm) (Bourne, 1965).

In the Canadian sea scallop fisheries, two major types of drags are employed: offshore drags, sometimes called New Bedford or Georges Bank drags (Bourne, 1964), and tumbler drags, sometimes called Digby-style drags (MacPhail, 1954). A third type, a modified otter trawl, is used in some fisheries (Rivers, 1962). Experiments with tumbler drags on inshore grounds (Medcof, 1952) showed that when the inside diameter of the rings was increased from 2⅝ to 3¼ inches (66.8 to 82.5 mm), small scallops were released effectively It also seemed possible that the otter trawl gear might release small scallops and that a delay in age at first capture might be achieved by using tumbler drags or trawl nets.

The tumbler drags and trawl nets would have to be at least equal in fishing efficiency to the offshore drag if they were to be readily acceptable to industry. Comparisons of the fishing efficiencies of these three types of drags had never been carried out although preliminary studies indicated the offshore drag might be more efficient than tumbler drags (Dickie and MacInnes, MS, 1958).

A series of experiments was carried out to test the fishing efficiency and selection of these three types of scallop gear—offshore drag, tumbler drag, and a trawl net.

Gear and Methods

Gear

Offshore drag. The standard offshore drag has been described in detail by Bourne (1964). Essentially, the offshore drag consists of a heavy metal frame 10–13 ft (3–4 m) wide with a bag attached. Part of the back of the bag is made with rope webbing (rope back) and the remainder of the bag is knit with steel rings. In these trials an 8-ft (2.44-m) drag was used in the Gulf of St. Lawrence and an 11-ft (3.35-m) drag on Georges Bank. The bags of both drags were knit with standard offshore rings, 5/16-inch (7.9-mm) wire with an inside ring diameter of 3 inches (76.2 mm). Rings in the top of the bag were joined by a single 5/16-inch (7.9-mm) split link and those in the bottom by two links.

Tumbler drag. There are no set dimensions for tumbler drags and they may vary in width from 2 to 10 ft (0.6 to 3 m) (MacPhail, 1954; Bullis and Cummins, 1961). Two different sizes of tumbler drags were used in this work, 3 and 4 ft (0.91 and 1.22 m). The frame

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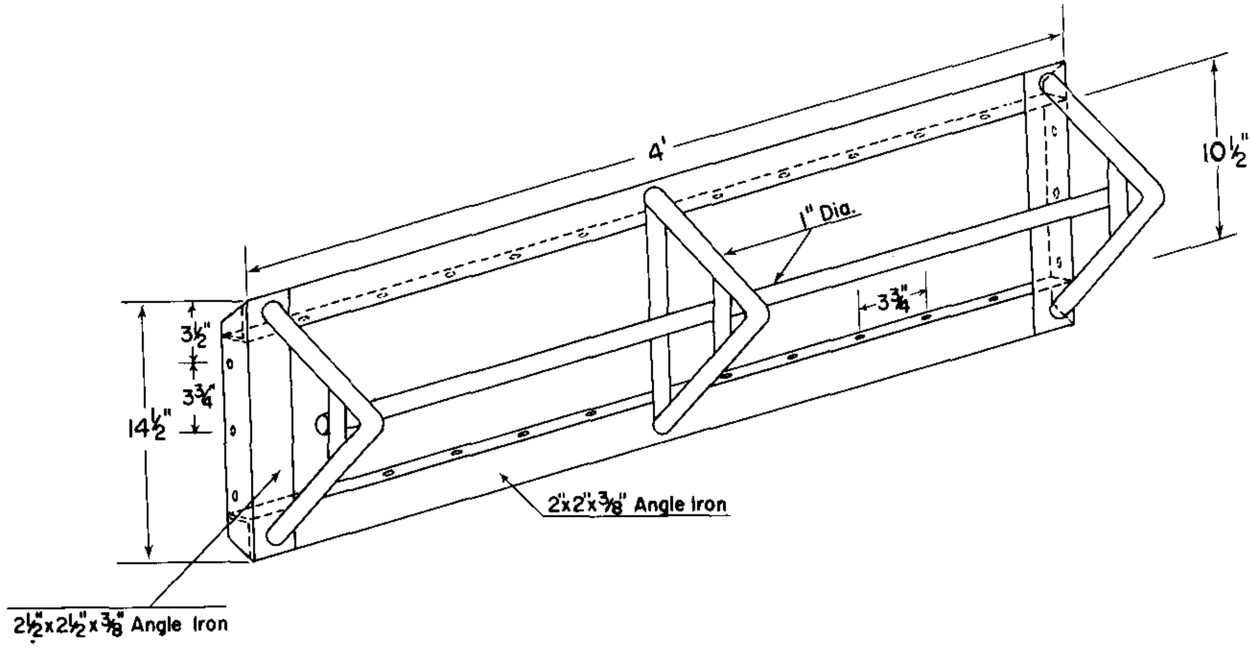

Fig. 1. Details of the frame of the 4-ft-tumbler drag, ('=feet) ("=inches).

of each drag has a scraping edge on the top and bottom and the dimensions of the 4-ft tumbler drag are shown in Fig. 1. The overall dimensions of the two frames were 3 ft × 14½ inches and 4 ft × 14½ inches (0.91 × 0.37 and 1.22 × 0.37 m).

The bag of each drag was attached directly to the frame on all four sides at 3¾-inch (95-mm) centres and was knit with standard offshore rings. The 3-ft tumblers had nine rows of rings along the two scraping edges and three along each side; the 4-ft tumblers, 11 rows of rings along the two scraping edges and three along each side. Each bag was eight rings deep and the rings were joined by a single 5/16-inch- (7.9-mm-) wire split link. The clubsticks were similar to those on offshore drags but were either 3 or 4 ft (0.91 or 1.22 m) in length. Single tail chains were attached to each clubstick to permit dumping.

Both tumbler drags were modified slightly for the Georges Bank work. The end pieces of the frames were redrilled and the 3-inch (76.2-mm) rings replaced with 4-inch (102-mm) inside diameter rings. The bags of both tumbler drags were knit with two split links.

More than one tumbler drag can be towed from a single tow bar as is done in the Digby, Nova Scotia, fishery (MacPhail, 1954). We used a gang of three 3-ft tumblers attached to a single tow bar and two 4-ft tumblers attached to another. Each individual tumbler had a bridle of three lengths of 3/8-inch (9.6-mm) wire chain attached to the ends and centre of the frame. The centre chain was 2 ft (0.6 m) in length and the three chains were joined to a ring and swivel and then to the tow bar. The tow bars were made of 2-inch (50.8-mm) schedule 80 pipe and were 7 ft (2.4 m) for the 3-ft tumblers and 4½ ft (1.6 m) for the 4-ft tumblers. Three ½-inch (12.7-mm) wire chains, ending in a ring and swivel, served as a bridle for the tow bars. The centre chain was 5 ft (1.5 m) in length.

Early in the Georges Bank work, one of the 3-ft tumblers was lost and subsequently only

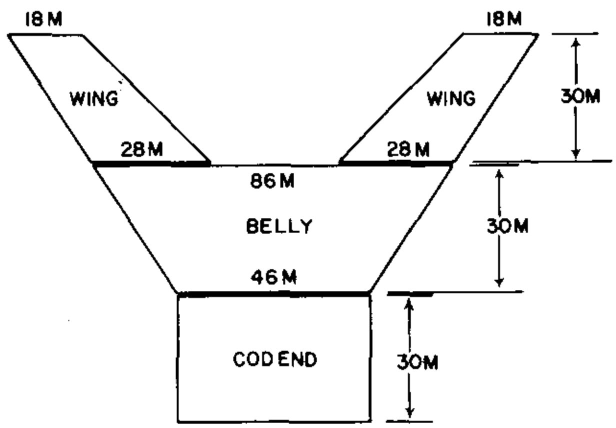

Fig. 2. Plan of the bottom half of the 4-inch-mesh-trawl net, (M=meshes).

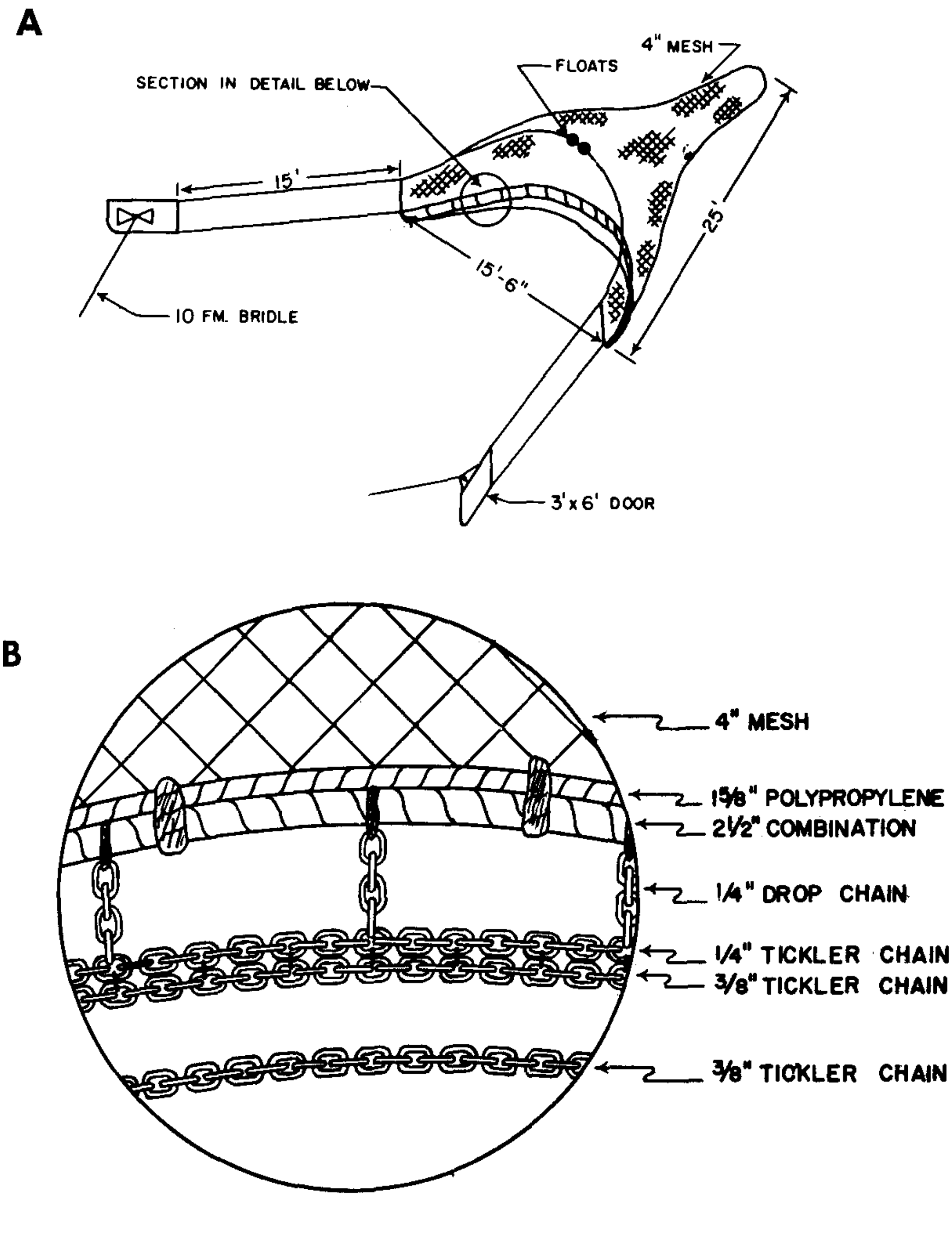

Fig. 3. **A.** Diagram of the 4-inch-mesh-trawl net. **B.** Details of the groundrope and tickler chains on the 4-inch-mesh-trawl net.

two 3-ft tumblers were towed from the one tow bar.

Trawl net. The trawl nets were similar to those used in the calico scallop (*Pecten (Aequipecten) gibbus)* fishery off North Carolina (Rivers, 1962). We used nets of two different mesh sizes, 4 and 5 inches (101.6 and 127 mm); the mesh size was the same throughout each net. They were made of 15/24 courlene and each net was approximately 25 ft (7.62 m) in length (Fig. 2 and 3A). The top and bottom sections of each net (i.e. wings, bellies, and codends) were identical so that the net could be reversed as one side wore.

The bolch line was a 1⅝-inch circumference (41.3-mm) polypropylene rope and the ground line a 2½-inch (63.5-mm) circumference combination rope (Fig. 3B). A ¼-inch (6.3-mm) diameter tickler chain was joined to the ground line at 2-ft intervals by four links of ¼-inch (6.3-mm) chain. Another ⅜-inch (9.5-mm) tickler chain, about 18 inches shorter than the ground rope was attached to the tow leg shackles. In preliminary fishing trials the groundrope proved too light and consequently another ⅜-inch (9.5-mm) chain was seized to the ¼-inch (6.3-mm) tickler chain (Fig. 3B).

One foot (0.3 m) strands of 15/24 courlene were tied to the belly and codend for chafing gear. Two small floats were attached to the centre of the headrope. The otter boards measured 3 × 6 ft (0.91 × 1.6 m) and weighed about 200 lb. (90 kg) each. The tow legs were 15 ft (4.6 m) and the net was fished from a single wire warp using a 10-fathom (18-m) bridle.

Comparative Fishing Trials

Comparative fishing between the three types of gear (offshore drag, tumbler drag, and trawl nets) was carried out in the southern Gulf of St. Lawrence (4T) in June–July 1963 from the research vessel M.V. *Harengus*. Comparisons between the offshore and tumbler drags were also made on the northern edge of Georges Bank (5Z) in August 1963 from the research vessel A. T. *Cameron*.

In the Gulf of St. Lawrence a single towing area (towing strip) could not be used to compare the gear because of the presence of an active fishery of 10 small boats on the rather small bed (Richibucto bed). This fleet removed approximately 150–200 tons (whole weight) of scallops from the bed during the 3-week period. Although the activity of this commercial fleet must be kept in mind when considering our results, we do not believe it seriously affected our results because the following procedure was adopted.

After initial explorations, three stations, two, three, and five nautical miles apart were established and marked with buoys. At each station, three separate courses were marked off by compass so that nine separate towing strips were established. Each towing strip was one nautical mile in length as measured by radar. The nine towing strips were in 21–21.9 m (11½–12 fathoms) of water and the bottom was similar for all, fairly smooth with moderate amounts of trash. No towing strips were on rocky bottom.

Originally it was planned to change the gear after each haul so that the five sets of gear would be fished successively on each of the nine towing strips. This was impossible but the gear was changed regularly, usually after each day. A drag was fished on as many towing strips as possible during one day and another drag used the next day. It was planned to fish each set of gear at least once on each of the nine towing strips but time did not permit this. However, each drag was fished on at least two towing strips at each station.

On Georges Bank a single towing strip was established in 68–77 m (37–42 fathoms) of water and marked by two spot buoys, one nautical mile apart. The bottom was smooth but very trashy. A total of 11 hauls were made there to compare the fishing efficiency and selection of the offshore and tumbler drags. Two additional hauls were made with the 4-ft tumblers to determine the rate of filling of these drags. One haul was half the distance between the two buoys and the other one-third the distance. Six tows were made on very rocky bottom on the northern edge with these drags.

Measurement of Catch

After each haul, the catch was sorted and the amount of scallops and trash recorded by bushels. The shell height (distance from the umbone to the ventral margin of the shell) of all or a specific fraction of the scallop catch was measured. The catch of groundfish by the two trawl nets was also recorded.

Results

Fishing efficiencies

In the Gulf of St. Lawrence (4T) 36 hauls were made to compare the efficiencies of the

TABLE 1. Catches (in bushels) of scallops (S), trash (T), and groundfish (GF) by five types of scallop drags when towed on nine different courses on the Richibucto bed, Gulf of St. Lawrence, June–July 1963.

Gear		Station 1			Station 2			Station 3		
		Course			Course			Course		
		90°	135°	70°	315°	45°	0°	0°	55°	110°
8-ft	S	3¾	3½		3½	3¾		6½	7⅛	
offshore	T	8½	13		3½	4		8	7	
3-ft	S		2¾	2¼		2 1/16	3¼	7	6	7¼ 7¼
tumblers	T		6½	6½		4½	10	8	8	7½ 10½
4-ft	S	1¾ 2		3¾ 4	3¾ 3¾		2 2	4½		4
tumblers	T	7½ 8½		5½ 16	6 4¾		6½ 6¼	6		8¼
4-inch-mesh	S	2		4	2¼	3½			1½	4
trawl	T	4		4½	2	7			3½	7
	GF	1		1¼	1¼	1½			2	2½
5-inch-mesh	S		¼	½	⅓		¼		1¾	½
trawl	T		1	2	1½		1½		3	3
	GF		¼	½	1		¼		½	

TABLE 2. Catches (in bushels) of scallops and trash by four types of scallop gear when they were fished on the same course, on the Richibucto bed, Gulf of St. Lawrence, June–July 1963. Table gives actual catch and catch adjusted for standard width of bottom fished.

Gear	Width of bottom scraped (ft)	Actual catch		Adjusted catch	
		Scallops	Trash	Scallops	Trash
8-ft offshore	7.80	20.88	32	20.88	32
3-ft tumblers	7.75	17.92	27	18.03	27.18
8-ft offshore	7.80	13.75	20	13.75	20
4-ft tumblers	7.17	10.13	19.38	11.03	21.08
8-ft offshore	7.80	18.13	23	18.13	23
4-inch-mesh trawl	15.50	9.25	16.5	4.65	8.3
3-ft tumblers	7.75	19.75	33.5	19.88	33.72
4-ft tumblers	7.17	14.71	31.38	16.00	31.14
3-ft tumblers	7.75	17.67	28	17.78	28.18
4-inch-mesh trawl	15.50	13.00	22	6.54	11.07
4-ft tumblers	7.17	13.50	32.28	14.69	35.22
4-inch-mesh trawl	15.50	12.25	17.5	6.16	8.81

five sets of gear (i.e.) the catch of scallops per haul). Results of these 36 hauls are summarized in Table 1.

When two drags fished similar towing strips their catches and relative fishing efficiencies were compared (Table 2). In columns two and three of Table 2 there is a direct comparison of the catch per haul between the various arrangements of gear used. The relative fishing efficiency may also be compared when the catch per haul is adjusted to an equivalent area of bottom fished; i.e. the width of all the drags is standardized. The fishing width of each drag is shown in column four of Table 2. The width of the offshore drag (7.7 ft; 2.38 m) was used as a standard and catches of scallops and trash by the other gears adjusted to it using a simple ratio. The adjusted catches for the various arrangements of gear used are shown in columns five and six of Table 2.

When the adjusted catches were compared, the offshore drag was the most efficient scallop drag (i.e. caught the most scallops per haul) followed by the 3-ft tumblers, the 4-ft tumblers, the 4-inch-mesh trawl net and the 5-inch-mesh trawl net, in that order. (The scallop catch by the 5-inch-mesh trawl net was much less than by other gear and is not considered in the following analysis.) The offshore and tumbler drags caught about equal amounts of trash but the trawl nets caught the least amount of trash. Groundfish are not included in the measurement of trash caught by the trawl nets.

The adjusted catches were analyzed statistically using a t distribution test. To allow for possible differences in catches made early and late in the work, a standard deviation was calculated and included in the t test. This standard deviation was calculated by comparing two sets of catches by the 4-ft tumblers, one collected early and the other later in the work. The standard deviation had a value of 0.379.

The t test had the formula

$$t = \frac{\dfrac{(\Sigma G - \Sigma T_3)}{N}}{\hat{\sigma}\sqrt{\dfrac{1}{N}}}$$

ΣG = sum of the scallop catch in bushels by the offshore drag when fishing the same courses as the 3-ft tumbler drag.

ΣT_3 = sum of the scallop catch in bushels by the 3-ft tumbler drag when fishing the same courses as the offshore drag.

The adjusted catches of the offshore drag and the 3- and 4-ft tumbler drags are significantly different at the 5% level and those of the offshore drag and the 4-inch-mesh trawl at the 1% level. The adjusted catches of the 3-ft tumbler drag are significantly different to those of the 4-ft tumbler drag and 4-inch-mesh trawl at the 1% level; the adjusted catches of the 4-ft tumbler drag and the 4-inch-mesh trawl are significantly different at the 1% level. Differences in catches then are real and reflect differences in the relative fishing efficiencies of the drags.

Results of the 11 hauls on Georges Bank are summarized in Table 3. There is a direct comparison of catches by the three drags in columns three and four and of the catches adjusted to an equivalent area of bottom fished in columns six and seven. Again the width of the offshore drag was used as the standard. Comparing the adjusted catches, the offshore drag caught approximately three times as many scallops as either tumbler drag, and the 3-ft

TABLE 3. Mean catch per haul of scallops and trash (in bushels) by three types of drags on the northern edge of Georges Bank, August 1963. Table gives actual catch and catch adjusted for standard width of bottom fished.

Gear	Number of tows	Width of bottom scraped (ft)	Actual catch		Adjusted catch	
			Scallops	Trash	Scallops	Trash
11-ft offshore	5	10.80	7.35	22.2	7.35	22.2
3-ft tumblers	3	5.17	1.33	18.67	2.78	37.02
4-ft tumblers	3	7.17	1.45	17.0	2.19	25.67

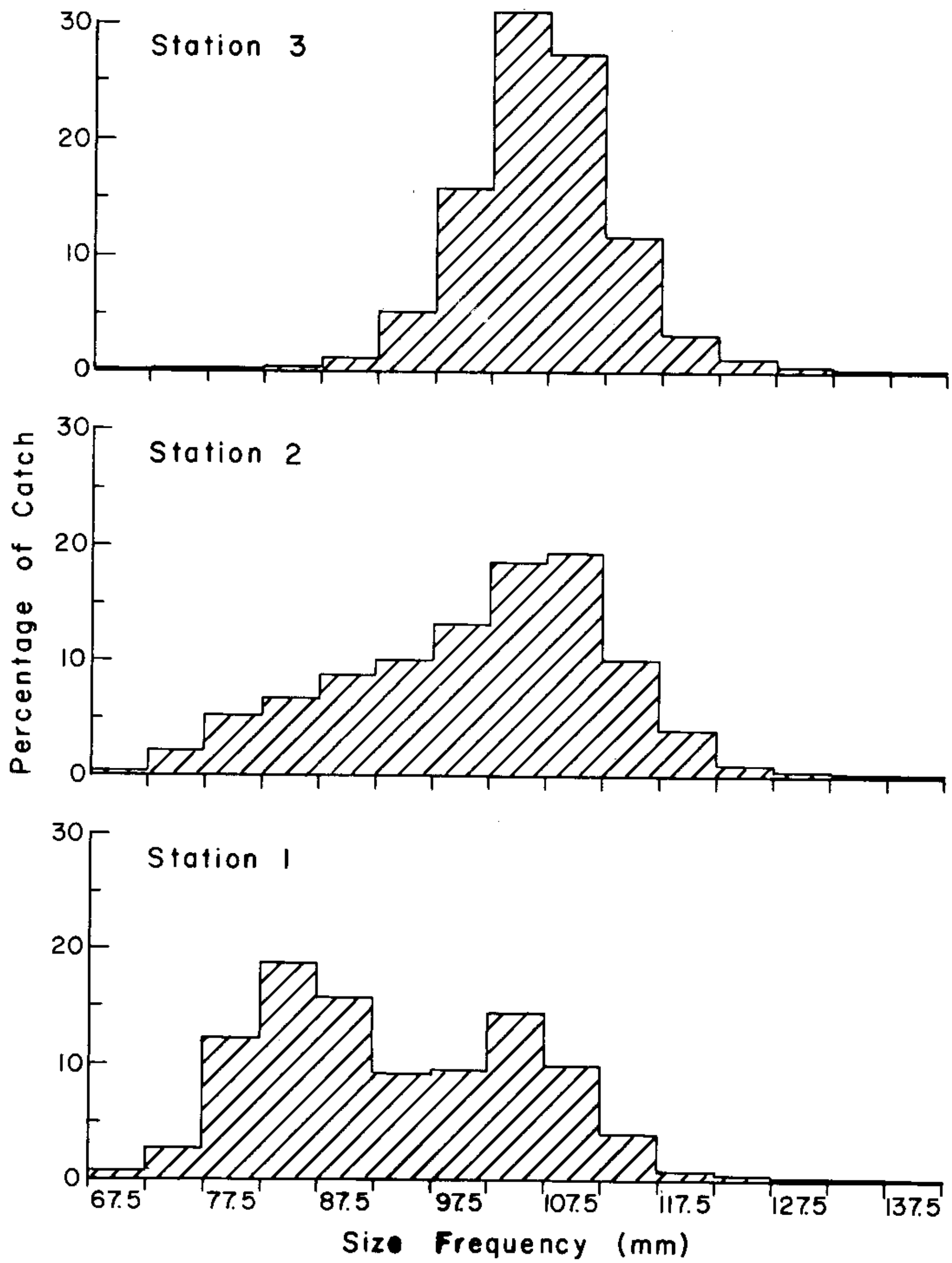

Fig. 4. Size-frequency distribution, in 5-mm groups, of scallops caught by the offshore and 3- and 4-ft tumbler drags, at the three stations on the Richibucto bed, Gulf of St. Lawrence, June–July 1963.

tumbler drag caught slightly more scallops than the 4-ft tumbler. The offshore drag caught slightly less trash than the 4-ft tumbler and much less than the 3-ft tumbler.

When the 4-ft tumbler drag was towed one-half and one-third the distance between the buoys, it was filled both times, although it was just barely filled when towed one-third the distance. The catch of scallops and trash was approximately the same as when the drag was towed the full distance. The offshore drag was only about half filled when towed the complete distance between the two buoys.

Only six tows (two with the offshore, one with the 3-ft tumblers, and three with the 4-ft tumblers) were made on rocky bottom before both sets of tumblers were lost. None of the tows was completed before the drags were caught solidly on the bottom.

Selection

In the Gulf of St. Lawrence the size-distribution of scallops from the three towing strips at any one station was similar for each particular gear but there was a difference in scallop sizes between the three stations (Fig. 4). Small- and medium-size scallops (i.e. scallops under 100-mm shell height) were most abundant at Station 1 and uncommon at Station 3.

The proportion of small- and medium-size scallops in the catch of the offshore and tumbler drags at any one station was approximately the same (Table 4): 70% at Station 1, 46% at Station 2, and 25% at Station 3. However, the 4-inch-mesh trawl caught a higher proportion of small- and medium-size scallops at all three stations: 78% at Station 1, 70% at Station 2, and 28% at Station 3. All the drags caught approximately the same proportion of medium-size scallops (85–99 mm) (Table 4) but the 4-inch-mesh trawl caught a higher percentage of small scallops (less than 85 mm) than the other three drags.

On Georges Bank the size-distribution of scallops caught by all drags was similar, approximately 20% of the catch of each drag was small and medium (under 100 mm).

Tumbler drags

Frequently a gradation in catches by the tumbler drags was observed, particularly in the Gulf of St. Lawrence. On several occasions the inside drag of a set of tumblers was full but the outside drag was only half full. Sometimes this gradation was noticeable even in an individual drag—the drag was full at the inside corner but only two-thirds full at the outside. No explanation can be given for this gradation. It was felt that it might be due to the corners of the individual drags locking together during

TABLE 4. Percentage size-composition of catches of scallops (small, medium, and large) by four different drags at the three stations on the Richibucto bed, Gulf of St. Lawrence, June–July 1963.

Size range of scallops (mm)	Station 1				Station 2				Station 3			
	Per cent of catch				Per cent of catch				Per cent of catch			
	8-ft offshore	3-ft tumblers	4-ft tumblers	4-inch mesh trawl	8-ft offshore	3-ft tumblers	4-ft tumblers	4-inch-mesh trawl	8-ft offshore	3-ft tumblers	4-ft tumblers	4-inch-mesh trawl
Small < 85	35.3	29.2	37.2	49.0	17.0	13.1	13.6	29.6	1.5	0.5	0.4	2.3
Medium 85–89	35.2	42.3	30.9	28.6	31.0	31.8	32.4	40.6	23.3	25.3	23.2	25.8
Large > 100	29.4	28.4	31.7	22.3	51.9	55.0	53.9	29.7	75.0	74.1	76.2	71.7

a tow but after the corners were cut off the gradation continued.

Many of the scallops caught by the tumblers, particularly in the Gulf of St. Lawrence, were badly broken. In some tows as many as 25% of the scallops were badly damaged and often it was impossible to shuck these animals.

Trawl nets

Both trawl nets caught moderate quantities of groundfish, mostly cod, *Gadus morhua*, and flounders (Table 1). The chafing gear was inadequate and the net was badly worn in a few places. Both nets were easily torn on rough bottom.

Discussion

Fishing efficiency

The offshore drag was the most efficient of the three types of drags for catching sea scallops, which may be partly explained by differences in towing characteristics of the drags. The rigid frame of tumbler drags, with rings attached on all four sides, probably causes these drags to dig into the bottom more so than offshore drags, quickly fill, and for the remainder of the tow they simply bulldoze along the bottom. This quick filling would reduce their fishing efficiency. The offshore drag rests on two or three shoes and the belly of the bag is not attached directly to the frame but to a flexible sweep chain. This design allows the drag to remain close to the bottom and catch scallops but does not cause the drag to fill as quickly with trash as the tumbler drags.

The quick filling of the tumbler drags is seen in the Georges Bank work. When the 4-ft tumblers were towed one-half and one-third the distance between the buoys, it was filled (barely filled when towed one-third the distance), although the offshore drag was only half filled, with a smaller amount of trash, when towed the complete distance. In the Gulf of St. Lawrence neither tumbler drag was filled on any tows but the bottom was much less trashy.

The offshore drag was slightly more efficient than the tumbler drags in the Gulf of St. Lawrence but approximately three times more efficient on Georges Bank. However, the 4-ft tumblers were filled when towed only one-third the distance there. The scallop catch from this short haul by the 4-ft tumblers was slightly less than one-third the catch of the offshore drag and hence the results of the Gulf of St. Lawrence and Georges Bank work are in close agreement. Tumbler drags were not only slightly less efficient than the offshore drag but they would have to be dumped three times as frequently. This extra handling would reduce the amount of towing time and further decrease their overall efficiency.

The trawl nets were the least effective of the three types of gear although Rivers (1962) found them efficient for catching calico scallops. Trawl nets may be better suited to catch calico scallops than sea scallops or further adjustments may be needed to our trawl nets to make them more efficient. The poor efficiency of the 5-inch-mesh net was probably due to scallops escaping through the mesh particularly in the wings. Trawl nets are probably not suited to the offshore fishery since they are more easily damaged and harder to handle than the offshore drag.

The offshore drag was the most efficient of the three types of drags but we have no measure of its absolute fishing efficiency. Dickie (1955) concluded the efficiency of Digby drags ranged from 5 to 15%, depending on the type of bottom. On smooth bottom the fishing efficiency of the offshore drag is probably greater than 15%.

Trash and fish

The trawl nets caught the least amount of trash, probably because they ride over the bottom better than the offshore and tumbler drags and avoid catching trash. In the Gulf of St. Lawrence the tumbler drags caught about the same amount of trash as the offshore drag but on Georges Bank they caught more trash. This accumulation of trash reduced selection and fishing efficiency and also made the catch harder to sort.

The trawl nets did catch moderate quantities of groundfish. A dual type of fishery for scallops and groundfish (mostly cod and flounders) is frequently carried on by small boats in the southern Gulf of St. Lawrence using old otter-trawl nets. In October 1963 we undertook further experiments with the 4-inch-mesh trawl to determine if it could be used to profitably fish for both scallops and groundfish. The belly and codend were reinforced with automobile inner tube strips and all the hauls were made on the three courses of Station 1 on the Richibucto bed. This work was done from the research vessel, M. V. *Pandalus II*.

This work was not exhaustive but it was encouraging. A total of 16 hauls were made and the average catch was 2¼ bu of scallops, ⅔ bu of marketable groundfish and 1⅓ bu of trash. There was little wear on the net but the work was abruptly terminated when the net was badly torn after catching a large rock. Further modifications to this net might make it an efficient piece of gear for small boats to catch scallops and groundfish in local areas such as the Gulf of St. Lawrence. The major disadvantage is that it is easily damaged on rough bottom.

Selection

One would not expect sharp selection by the offshore and tumbler drags since the accumulation of trash and scallops in offshore drags plugs them and eliminates escapement of small scallops (Bourne, 1965). However, the 4-inch-mesh trawl caught less trash than either the offshore or tumbler drags but it also caught more small scallops (Table 4). This agrees with observations by Dickie (personal communication). He attached hoods along the scraping edges of Digby-style drags; the hoods were the same width as the drag, approximately 10 inches in height and had a manila twine bag which was as deep as the ordinary bag. The drags were fished so the hoods were on the topside of the drags. He frequently found as many scallops in the hoods as in the drags themselves. Furthermore, most of the scallops in the hoods were small.

Underwater television and scuba diving observations have shown that scallops are sufficiently adept swimmers to avoid capture by tumbler drags. We believe that small scallops are more active swimmers than large scallops and as the drags approach they "jump up" and avoid them. Apparently small scallops can jump high enough and quickly enough off the bottom to avoid capture by offshore and tumbler drags but the headrope of the trawl net was too high (30 inches; 76.2 cm) and they were captured.

Bullis and Cummins (1961) did not observe excessive breakage of calico scallops in their tumbler drag catches. Calico scallops are smaller than sea scallops, have more highly arched valves and may be able to resist breakage better than sea scallops. The excessive breakage we noted may have been due in part to too narrow a taper in the bag at the clubstick. We attempted to correct this in the Georges Bank work by redrilling the end pieces of the frame and using 4-inch (120-mm) rings instead of 3-inch (76.2-mm) rings in the sides of the bags. This gave a fuller bag with a wider taper at the clubstick. The amount of breakage was reduced but there was still more in these drags than in the offshore drag. If we had used a clubstick similar in design to those used on Digby drags (a piece of 2 × 4 inch × 2 ft 6 inches (50.8 mm × 102 mm × .76 m) hardwood) the excessive breakage might have been eliminated since it is not commonly observed in Digby drag catches.

Assessment

Results of these experiments show the offshore drag was the most efficient of the three types of gear tested. All three types of gear exhibited poor selection. Tumbler drags appear to have no particular advantage to warrant their adoption by the offshore fishery. The trawl nets are unsuited to the offshore fishery but improvements to them might produce a net which could be used advantageously by small boats to fish both scallops and groundfish on suitable bottom.

Studies are needed to measure the absolute fishing efficiency and towing characteristics of the offshore drag on both smooth and rough bottom.

Acknowledgments

Several people have assisted with this work but in particular I would like to thank Mr J. S. MacPhail who helped design the tumbler drags and trawl nets and who carried out much of the work in the Gulf of St. Lawrence, Mr T. W. Rowell for his help in collecting the data, Mr E. Cadima for assistance in designing the experimental procedures used in the Gulf of St. Lawrence, and Dr F. D. McCracken for criticism of the manuscript. I am also indebted to the Industrial Development Service of the Department of Fisheries of Canada for their support. The co-operation of the skippers and crews of the three vessels is gratefully acknowledged.

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The Distribution of Pelagic Redfish Fry in the East and West Greenland Areas

BY G. P. ZAKHAROV[1]

Abstract

During the cruise of the R/V *Sevastopol* in September–October 1964, the drift of redfish fry was observed off East and West Greenland. Everywhere off the slope some tens or hundreds of specimens of redfish fry were taken per haul with a mid-water trawl. The fry were drifting in the middle of the Irminger Current mainly at a depth of 200 m. Their size was 4–6 cm, (mode 5 cm) and age 0+ years. The species name of the redfish fry caught off Greenland is still not known. Some data on adult redfish caught off Greenland above great depths are given.

It is a well-known fact that the waters off East and West Greenland are mainly inhabited by *Sebastes marinus* (L). At present redfish do not breed off West Greenland (Tåning, 1951; Travin *et al.*, 1961; Zakharov, 1962*a*, *b*), while in the 1920's the breeding of redfish did take place there (Jensen, 1926; Tåning, 1948). Off East Greenland also only an insignificant number of redfish breed (Magnusson, 1959, 1961). The main breeding grounds of *S. marinus* (L) in the North Atlantic are located in the open areas off Southwest Iceland (Kotthaus, 1958; Magnusson, 1959). From there, redfish larvae drift in the stream of the warm Irminger current towards Greenland (Einarsson, 1960). Redfish resources in the Greenland waters are greatly dependent upon the number of fry carried there with the current (Tåning after Templeman, 1959). Therefore, the study of the distribution and abundance of larvae and pelagic fry off East and West Greenland is of great importance.

In recent years extensive investigations have been carried out into the distribution and abundance of redfish larvae in the North Atlantic from April to July (Einarsson, 1960, 1961; Henderson, 1961*a*, 1964*a*, *b*; Hansen and Andersen, 1961; Glover, 1962; Kotthaus, 1961; Magnusson, 1962). We know much less about the occurrence of pelagic fry during the later period.

In October 1913 off East Greenland in the Angmagssalik Area, Jensen (1922) caught 127 small redfish, 29–45 mm long. In July–August in the upper water layers along the west side of Denmark Strait, Tåning (after Templeman, 1959) took, with a 2-m stramin net, thousands of redfish fry, 20–45 mm long. Einarsson (1960) gives two charts of the distribution of redfish larvae, with a mean length of 20–29 mm, which were taken by a stramin net off East Greenland in July and August.

Off West Greenland in September, young redfish 27–49 mm long were often caught in the upper water layers (Jensen, 1922). Hansen (1953, 1957, 1958) states that in August 1930 off Southwest Greenland in the Julianehåb Area a great deal of dead redfish were found drifting at the surface. Their mean length was 35.6 mm. In September 1951, in the same area (Julianehaab), redfish fry with a mean length of 43.6 mm were collected from cod stomachs (Hansen, 1957, 1958). Hansen thinks that the fry caught in August 1930 and September 1951 belonged to the O-group. Tåning (after Templeman, 1959) informs that off Southwest Greenland great numbers of rather large redfish fry are carried to the shore in autumn. In the Greenland fjords great masses of drifting small redfish are carried to the shores and Greenlanders gather them.

Based on the materials collected by Jensen, Templeman (1959) came to the conclusion that in the Greenland waters young redfish up to 45–50 mm in length keep in the water layers. He explains this phenomenon by the fact that either young fish in the cold areas keep in the surface layers until they reach greater sizes or fry grow weaker in the cold water and cannot escape fishing gears.

From July to October 1964, during the cruise of the R/V *Sevastopol*, 55 hauls with a 20-m midwater trawl were made in the areas of

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East and West Greenland. A nylon 5-mm mesh net was inserted into the codend. All hauls were 1 hr long. The majority of hauls was performed beyond the slope in water 200–250 m deep. Figure 1 shows the distribution and abundance of redfish fry sampled off Greenland in July, and September–October 1964.

The first hauls were made on 20 July off East Greenland, 65°N, 33°W. In three catches made at 175–225 m, redfish fry 2.5–4.8 cm long (mode 3.5 cm) were found. On 26 July, east of the Bille Bank at 100–200 m, 100 fry 2.7–4.8 cm (mode 4.0 cm) in length were taken.

Later hauls made in the southward direction along Southeast Greenland gave no results though depths from 100–600 m were covered. Hauls performed on 5 September off Baffin Island and on 11 September in Davis Strait about 65°N at 250–300 m were also blank.

Off West Greenland from 64°N to the south (15–26 September) scores and hundreds of redfish fry were found in almost every haul. Off East Greenland (27 September–7 October) redfish fry were encountered everywhere to 65°N, 35°W. East of this position no fry were observed.

While approaching the slope the number of fry increased. Evidently, fry drifted mainly in the core of the warm Irminger Current. To determine the layers at which redfish fry drift a series of hauls were made off South Greenland at 100, 200, 300, and 400 m. The bulk of fry were found to be drifting at 200 m (Table 1).

However, off East Greenland on the Bille

TABLE 1. Distribution of redfish fry by depths, September 1964.

Date	Position		Fishing depth	No. of trawl hauls	Mean no. of fry per 1-hr trawling
			m		
24	59°25′N	46°38′W	100	1	8
24–26	59°28′N 59°26′N	45°40′W 43°10′W	200	2	311
24	59°19′N 59°09′N	44°02′W 41°52′W	300	2	85
27	59°17′N	41°58′W	400	1	32

TABLE 2. Fishing area, size and maturity of adult *S. mentella* Travin taken in September 1964.

Date	Position		Fishing depth	Fish length	Sex and stages of maturity
			m	*cm*	
15	63°40′N	55°00′W	300	36 20 18	♂IV ♂ I ♀ I
16	63°44′N	53°30′W	200	41 33 26	♀III ♂IV ♂ II
17	63°10′N	55°00′W	300	27	♂ II
21	62°16′N	51°07′W	300	39	♀III
24	59°25′N	46°38′W	100	41	♀III
27	61°00′N	40°54′W	200	46	♀IX–II

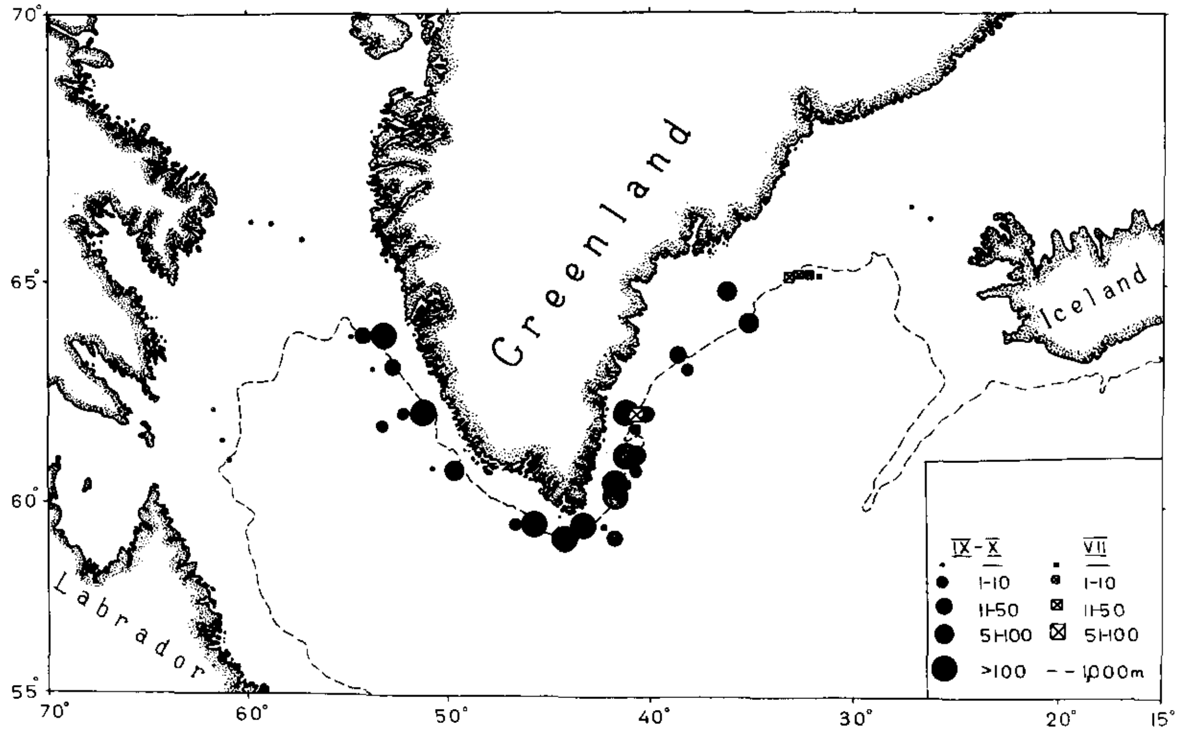

Fig. 1. Distribution of redfish fry taken by midwater trawl in the Greenland Area in July and September-October 1964.

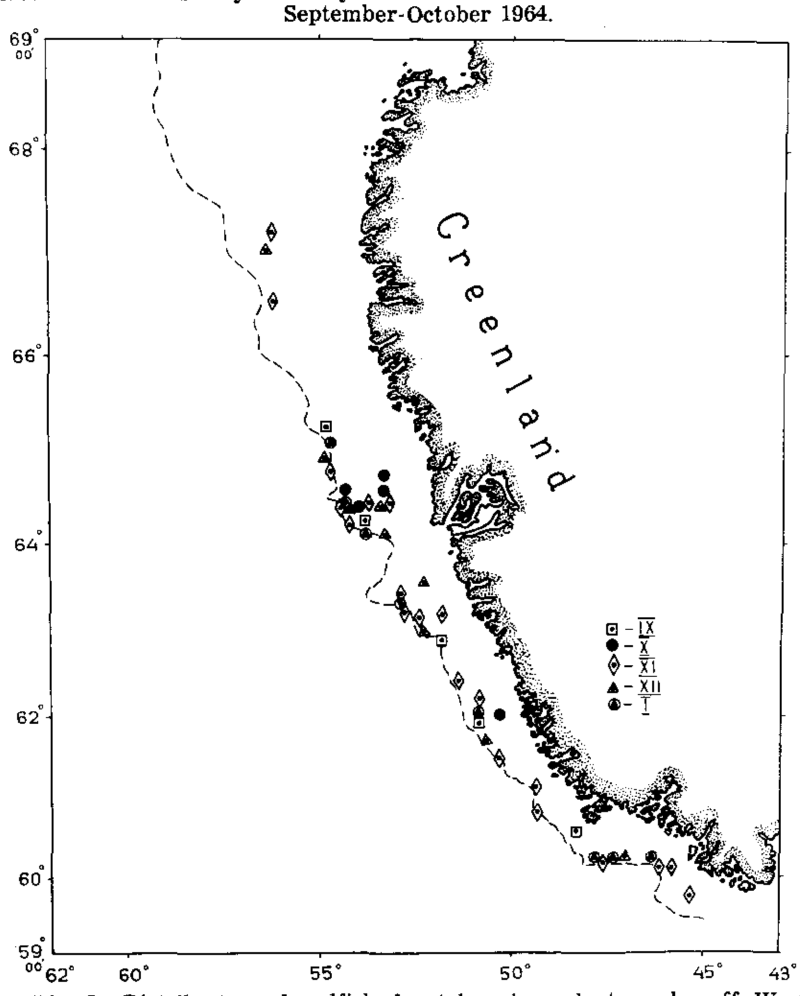

Fig. 2. Distribution of redfish fry taken in cod stomachs off West Greenland by months during 1958-64.

Bank at a point where the depth was 200 m, in two hauls made at 70 and 100 m, 400 and 500 fry were taken. Probably the water flowing from the north ascended there to pass over the Bank and the fry appeared to be at shallower depths.

The sizes of redfish fry taken in September–October were 4.0–6.0 cm, the mode being at 5.0 cm. No difference was observed between the length of fry taken off West and East Greenland.

It was found that scales begin to form in redfish fry when they reach a length of 4.5–5.0 cm. The scales appear in the form of round tiny plates in the skin. A central plate with a single sclerite was found in a few specimens of the above-mentioned length. No rings were observed on the otoliths. Fry, 5.5–6.0 cm in length, had five to seven wide sclerites on the scales. These fry were of age 0+. In a single redfish fry 7.2 cm in length, of orange colour, six to eight sclerites were followed by four narrow sclerites followed in their turn by seven wide sclerites. The age of this specimen was 1+.

The occurrence of redfish fry in the stomachs of cod taken off West Greenland from 1958 to 1964 gives some indication of how far northward redfish fry are carried with the current. The results are shown by months in Fig. 2.

It was found that in December redfish fry occurred on the Store-Hellefiske Bank (68°N). Hansen and Hermann (1953) state that slightly to the north, in the bight of the Disco Island (69°N), young redfish are highly abundant. We

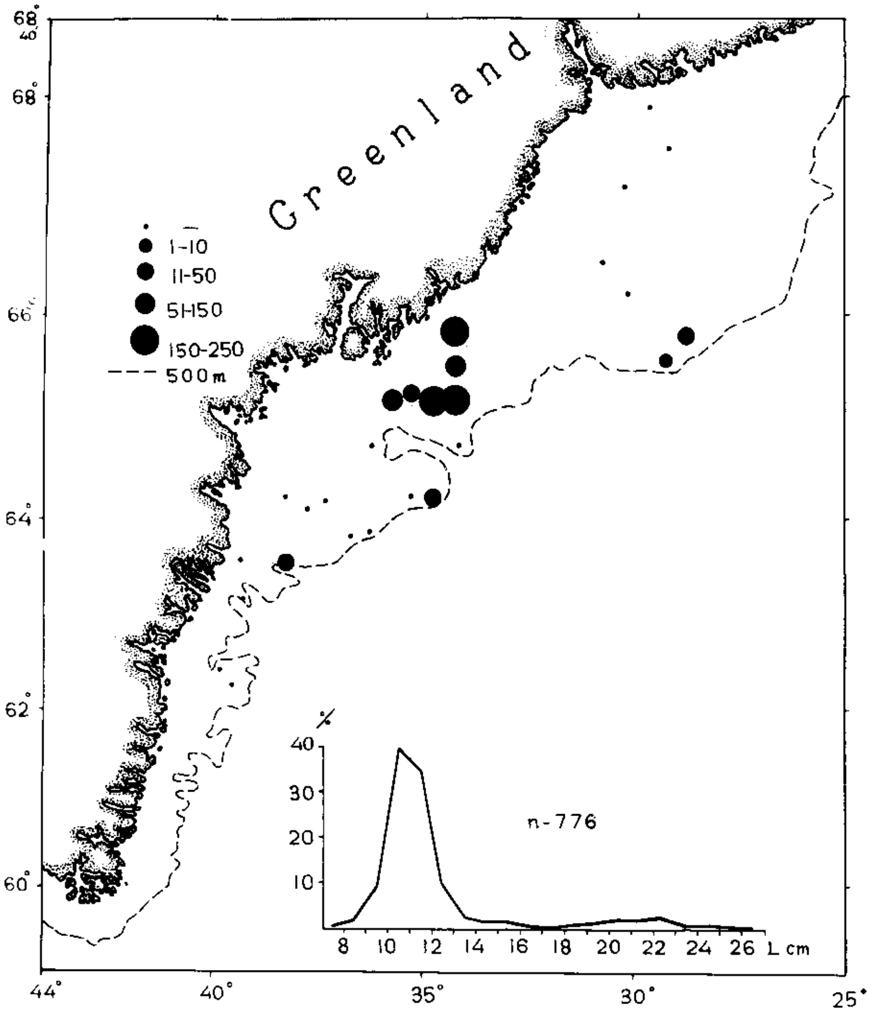

Fig. 3. Distribution and size composition of young *S. marinus* (L) taken per 1-hr-bottom-trawl hauls off East Greenland in October 1964.

think they are the grown fry carried by the current from the south every year.

It is not yet known to what species the pelagic fry taken off East and West Greenland belong. The predominance of adult *S. marinus* (L) in those areas gives reason to suppose that the drifting fry are also *S. marinus* (L). Our materials collected during this cruise also confirm this supposition. In October, on the East Greenland Shelf in the Angmagssalik Bank area at 200–300 m an average of 167 (maximum 291) young redfish were taken per hour trawling with a bottom trawl with a 10-mm mesh net inserted. Their sizes were 7–27 cm, mode at 10–11 cm (Fig. 3). From their appearance they were considered to belong to *S. marinus* (L). The serological blood analysis of these young redfish carried out during this cruise by Ju. P. Altukhov also confirmed the primary species identification. Small specimens of *S. mentella* Travin occurred very seldom on the East Greenland shelf.

Henderson (1964*b*) supposed that redfish larvae taken near the Reykjanes Ridge are *S. mentella* Travin. Therefore a part of the pelagic fry drifting in Greenland waters may be *S. mentella* Travin. It is very likely that in Greenland waters in June–July larvae of mainly *S. marinus* (L) drift from the breeding grounds of East Greenland and Southwest Iceland. Later, in autumn, larvae of *S. mentella* Travin are likely to drift off Southwest Greenland from the breeding grounds in the Irminger Sea. But the future fate of *S. mentella* Travin in the Greenland waters remains unknown.

Occurrence of Adult Redfish

During the whole period of our investigations no specimens of *S. marinus* (L) were caught. On six occasions a total of 10 specimens of *S. mentella* Travin were taken. The data on these redfish are presented in Table 2.

Beyond the slope small specimens (18–27 cm) of *S. mentella* Travin were encountered, the phenomenon which had not been observed before (Hansen and Andersen, 1961; Zakharov, 1963, 1964; Henderson and Jones, 1964).

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Length-Weight Relation of the Sea Scallop, *Placopecten magellanicus* (Gmelin)

BY EVAN B. HAYNES[1]

Abstract

The relationship between length of shell and weight of adductor muscle of sea scallops was determined from scallops collected at Georges Bank, Cape Cod Bay, Stellwagen Bank, the inshore waters of Maine, and off Block Island. Weights of the muscle for a given shell length were practically the same for males and females. Differences of the length-weight relation were significant between scallops collected in different seasons from Georges Bank. Scallops from Cape Cod Bay, Maine, and Block Island appear to differ significantly in their length-weight relations from those of Georges Bank. Meat weights of the adductor muscles of scallops from Canadian waters usually are somewhat less for a given shell length than those of scallops from the areas studied in this paper.

Introduction

Since 1949, biologists of the Bureau of Commercial Fisheries have been accumulating length-weight data on the sea scallop, *Placopecten magellanicus* (Gmelin). The samples were collected from Maine to Rhode Island on commercial scallop boats, chartered vessels, and research vessels; most samples were from Georges Bank off Massachusetts (Fig. 1). Although the samples were collected over several years, most are from 1961 and 1962.

The objectives of this paper are (1) to determine if differences exist in the length-weight relation of the sea scallop between sexes, by state of gonads, and in various areas of the fishery, and (2) to provide a set of estimating equations.

The weights in this paper are those of the adductor muscle of the sea scallop (Fig. 2). This is the only part of the animal retained by the fishermen; the rest of the viscera and the shell are discarded at sea. The muscle usually makes up about 10–15% of the total weight of the scallop and about 30% of the viscera. Fishermen shucking the scallops at sea usually leave 2–10% of meat attached to the shell. We attempted to duplicate commercial practice and estimate that we lost about 3%. Each shucked scallop meat was weighed to an accuracy of $\pm$ 0.03 g. Length, here defined as the greatest distance between the umbo and the shell margin (Fig. 2), was measured to the nearest millimeter.

The sexes are separate in the sea scallop and, in mature individuals, are easily identified; in males, the gonad (Fig. 2) is creamy white and in females is bright red. Identification of the sexes is difficult or impossible immediately after spawning and for immature scallops.

Less than 0.7% of the scallops used in this study were immature (smaller than 50 mm), so the results are applicable only to adults. All scallops were live or fresh. Studies of all samples, excluding those from Maine which were examined at their port of landing, were conducted at the Bureau of Commercial Fisheries Biological Laboratory, Woods Hole, Massachusetts.

The statistical analyses in this study are based on 8,868 measurements, and consist primarily of the comparison of length-weight relation by the analysis of covariance. Description of the samples, including the regression constants of the logarithmic equation $\log_e W = a + b \log_e L$ are shown in Table 1. Length-weight distributions for the major fishing areas and each season considered in this study are shown in Table 2. An IBM type 7090 computer was programmed to calculate the length-weight regression for each sample by date, location, and sex. Individual meat weights and measurements of shell length were used as point values in the calculations. Length-weight comparisons were then made, between sexes, according to state of gonads, and among the various fishing grounds of Georges Bank, the inshore waters of the Gulf of Maine, and off Block Island. Too few samples were collected in certain years to permit study of year-to-year variation in the length-weight relation. The annual data have not, therefore,

[1]Fishery Biologist, Bureau of Commercial Fisheries, Biological Laboratory, Woods Hole, Massachusetts, USA.

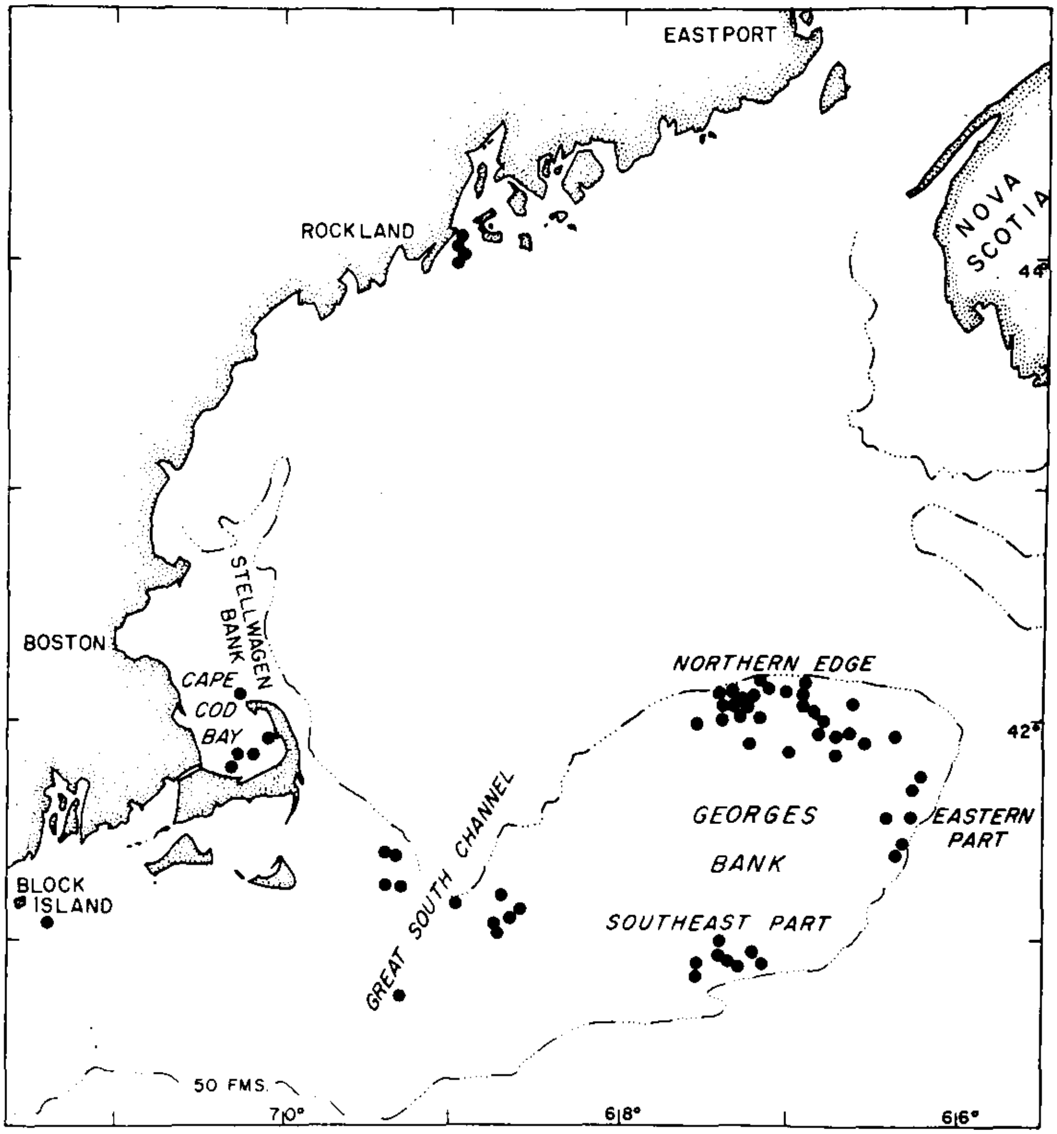

Fig. 1. Location of the samples used in this study.

been separated. Statistical methods and terminology follow those of Snedecor (1956).

Differences Between Sexes

The first analysis was made to determine if the length-weight relations of male and female scallops differed significantly. Data were available for 3,319 males and 3,002 females. Samples which included sex information were pooled by sex and the following regressions calculated:

Males: $\log_e W = -10.0234 + 2.996 \log_e L$

Females: $\log_e W = -10.0529 + 3.003 \log_e L$

The analysis of covariance showed that differences between sexes in the slope and adjusted mean weights were not significant. The data on males and females were therefore combined in all subsequent analyses.

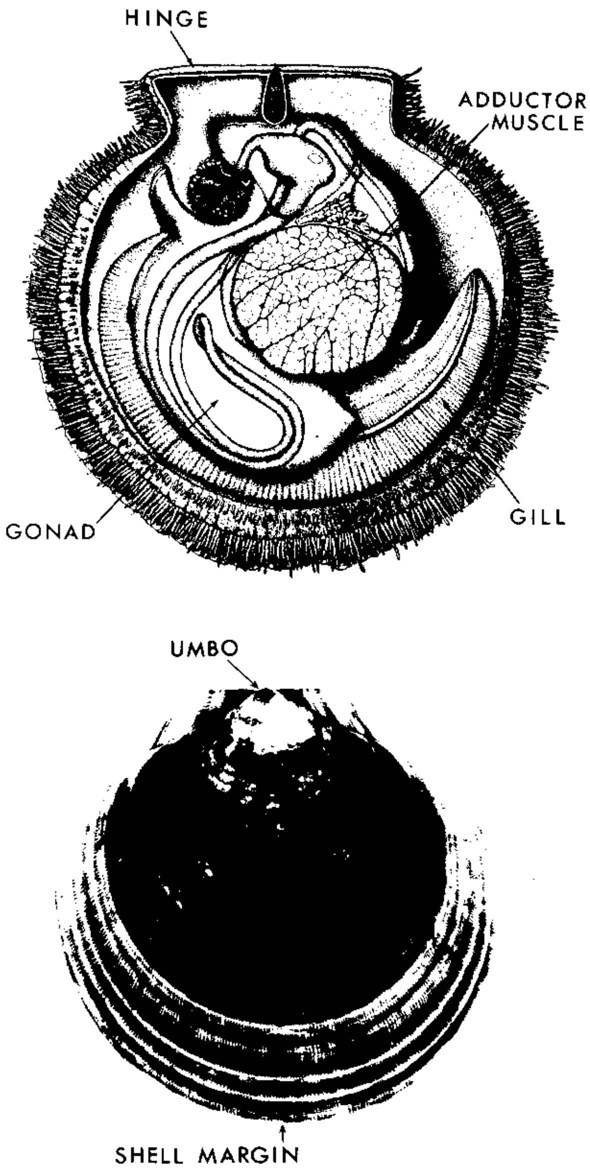

Fig. 2. Mantle cavity of the sea scallop as seen from the left side after removal of the left mantle lobe. Also shown is outer surface of the left valve.

Differences by Seasons and Areas

Georges Bank

Unpublished data on file at this Laboratory show that for each of the fishing grounds studied in this paper, spawning of scallops usually begins in late September and is completed in October. Recovery of the gonads begins in November and continues through March. From April through most of September the gonads are full and plump. Consequently, October was designated the spawning season, November through March the ripening season, and April through September the season of maturity. For ease of identification the seasons were designated S, R, and M respectively.

To detect possible seasonal trends in slope, the values for each sample were plotted against the months in which the sample was taken (Fig. 3). Since the greatest numbers of collections were made during seasons R and M on Georges Bank (Table 3) the study was restricted to these samples. The sample-to-sample variation was large but no trend is apparent for the slope values of those samples within a season.

The tests for seasonal differences in the length-weight relation of the sea scallop were based only on samples collected from the four geographical areas of Georges Bank (Table 3). As a convenience the areas of Georges Bank were designated as the Northern Edge, Eastern Part, Southeast Part, and the Great South Channel (Fig. 1).

Highly significant differences were frequent between samples within each area and season. Therefore, for each of the areas of Georges Bank a pooled mean square for differences between samples was formed for testing seasonal differences. The ratio of the estimated mean square differences between seasons to the pooled mean square differences between samples indicated whether significant differences in the regression constants exist among the seasons for the particular area tested.

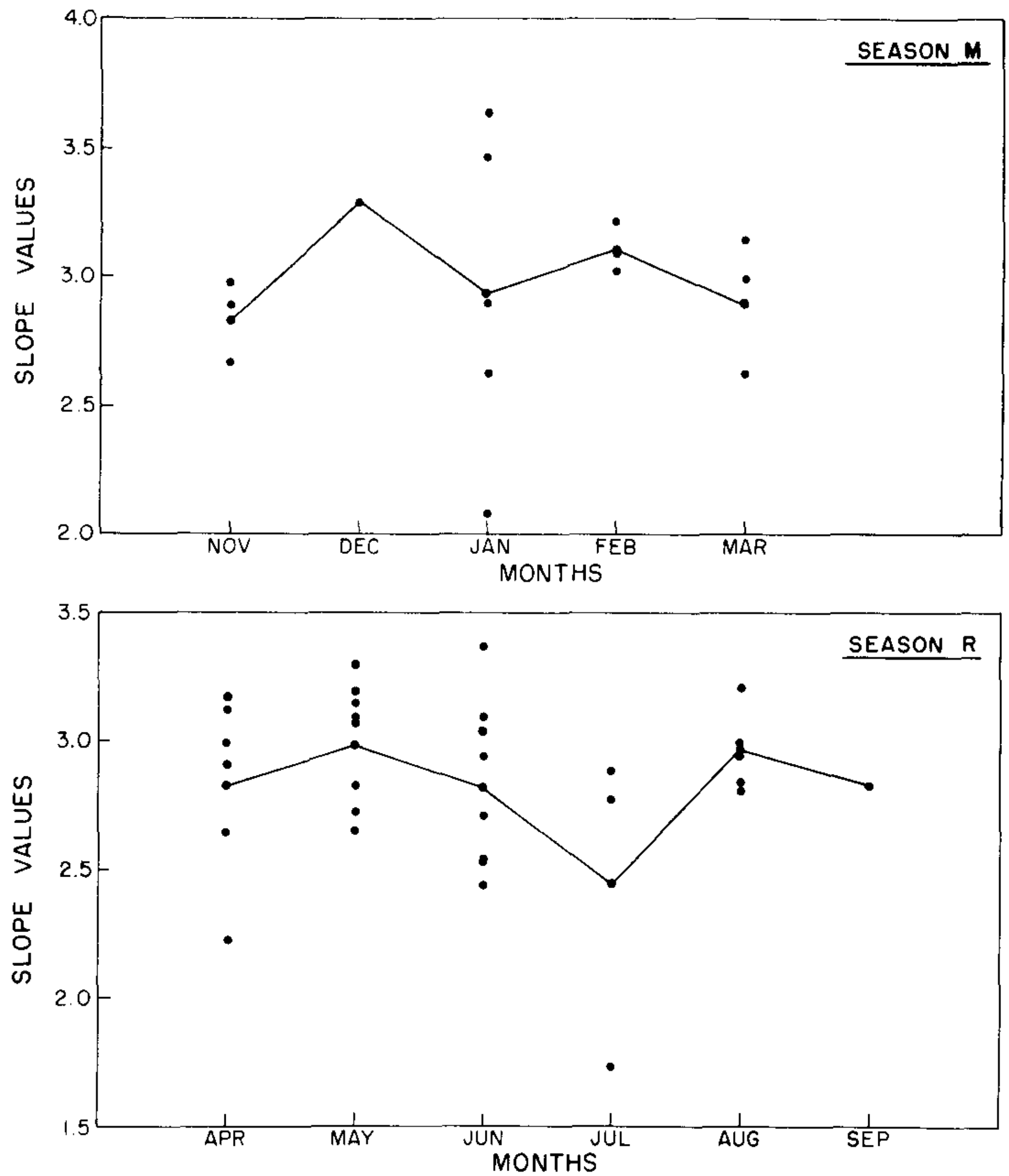

Fig. 3. Slope values plotted by month for samples taken during the ripening season, November-March (R), and season of maturity, April-September (M) on Georges Bank.

TABLE 1. Location of sampling stations, date of collection, and number of sea scallops used for length-weight analyses. The regression constants are based on the entire sample; sexes combined.

Date	Position		Number of scallops	Regression constants	
	Lat N	Long W		Slope	Intercept
		Northern Edge of Georges Bank			
1958					
May	42°05′	67°15′	222	3.063	-11.5812
1959					
Nov.	42°01′	67°12′	540	2.656	- 9.5355
1960					
Jan.	42°05′	67°21′	133	2.606	- 9.3600
Aug.	41°53′	67°14′	96	2.996	-11.1169
Oct.	41°59′	67°33′	135	2.728	- 9.8258
Oct.	42°04′	67°24′	79	2.773	-10.0407
1961					
Jan.	41°56′	66°24′	50	2.070	- 6.5203
Feb.	41°56′	66°49′	51	3.018	-11.0869
Mar.	41°59′	66°49′	59	2.599	- 8.9895
Apr.	42°08′	67°10′	85	2.223	- 7.3676
May	42°08′	66°54′	156	3.073	-11.3330
May	42°09′	67°06′	122	2.649	- 9.4276
June	42°07′	67°02′	106	2.705	- 9.7699
June	42°01′	67°24′	148	2.436	- 8.5492
Aug.	41°56′	66°42′	195	2.976	-10.8362
Aug.	41°59′	66°49′	90	2.975	-10.5112
Aug.	42°05′	66°39′	185	2.806	-10.1625
Aug.	42°06′	67°21′	74	3.198	-12.0128
Nov.	42°02′	67°17′	94	2.959	-10.9132
Dec.	42°01′	66°50′	113	3.298	-12.5065
1962					
Mar.	41°51′	66°45′	114	2.996	-11.0260
Mar.	41°56′	66°43′	71	2.892	-10.5524
Apr.	41°56′	66°42′	83	3.108	-11.5805
Apr.	42°05′	67°24′	134	2.642	- 9.3911
Apr.	42°06′	67°20′	131	2.888	-10.5242
May	41°54′	66°36′	82	2.810	- 9.9988
May	42°03′	66°57′	87	2.719	- 9.4362
June	42°07′	66°57′	104	2.934	-10.6349
June	42°03′	67°17′	98	2.526	- 8.5837
July	41°52′	67°02′	83	2.889	-10.3990
		Great South Channel			
1957					
Aug.	41°15′	69°25′	53	2.821	-10.4052
1960					
Oct.	40°46′	69°21′	40	2.429	- 8.5862
Oct.	41°10′	68°00′	130	2.646	- 9.6656
Oct.	41°23′	69°23′	122	2.622	- 9.7407
Oct.	41°22′	69°22′	107	1.287	- 3.3621
Apr.	41°07′	68°39′	115	3.143	-11.5544
Apr.	41°09′	68°37′	75	2.996	-10.8818

TABLE 1. (continued)

Date	Position: Lat N	Position: Long W	Number of scallops	Regression constants: Slope	Regression constants: Intercept
		Great South Channel (continued)			
1961					
May	41°12′	68°43′	211	3.184	-11.7909
Sept.	41°15′	69°21′	57	2.804	-10.1032
Oct.	41°02′	68°45′	200	2.938	-10.8976
Nov.	41°04′	68°46′	96	2.878	-10.6776
		Eastern Part of Georges Bank			
1961					
Jan.	41°33′	66°26′	72	2.892	-10.5923
Feb.	41°36′	66°18′	66	3.080	-11.4674
May	41°45′	66°15′	283	3.143	-11.5670
July	41°26′	66°23′	96	1.724	- 5.1385
1962					
June	41°27′	66°22′	213	3.031	-11.1318
June	41°42′	66°17′	98	2.526	- 8.5849
		Southeast Part of Georges Bank			
1959					
Mar.	40°57′	67°25′	67	3.134	-11.7892
1961					
May	40°52′	67°34′	164	3.292	-12.2719
1962					
Jan.	40°57′	67°12′	112	3.464	-13.3898
Jan.	40°56′	67°11′	113	3.685	-14.4960
Feb.	40°55′	67°33′	107	3.212	-12.3300
June	40°55′	67°22′	147	3.078	-11.4220
June	40°55′	67°19′	46	3.364	-12.7172
July	41°01′	67°26′	136	2.765	- 9.9953
		Cape Cod Bay			
1949					
Dec.	41°55′	70°05′	101	2.965	-10.8539
1960					
Oct.	41°51′	70°12′	157	3.026	-11.0604
Oct.	41°47′	70°19′	99	2.957	-10.7354
Nov.	41°47′	70°19′	55	2.935	-10.5918
1962					
Apr.	41°49′	70°16′	43	3.225	-11.9235
		Stellwagen Bank			
1950					
Aug.	42°07′	70°16′	79	2.791	-10.0516
		Maine (Penobscot Bay)			
1960					
Jan.	44°04′	69°00′	228	3.535	-13.8370
Feb.	44°00′	69°00′	220	3.541	-13.8955

TABLE 1. (continued)

Date	Position		Number of scallops	Regression constants	
	Lat N	Long W		Slope	Intercept
	Maine (Penobscot Bay) (continued)				
1960					
Mar.	44°03′	69°00′	213	3.524	−13.7823
Apr.	44°54′	67°03′	261	2.995	−11.0317
1961					
Feb.	44°01′	69°01′	185	2.869	−10.3246
	Block Island				
1958					
May	41°05′	71°24′	138	2.320	− 8.0971
July	41°05′	71°24′	133	3.050	−11.3942
Aug.	41°05′	71°24′	149	3.071	−11.5560
Sept.	41°05′	71°24′	100	2.892	−10.8200
Dec.	41°05′	71°24′	61	3.035	− 7.0630

TABLE 2. Length-weight distributions of sea scallops for three seasons (based on state of gonads) for sea scallops from Georges Bank and the distributions for seasons combined for sea scallops from Georges Bank, Maine, Cape Cod Bay, Stellwagen Bank, and Block Island.

	Georges Bank					
	October			November–March		
Shell length	Number of scallops	Mean weight	Range	Number of scallops	Mean weight	Range
(mm)		*(g)*	*(g)*		*(g)*	*(g)*
20–24	—	—	—	—	—	—
25–29	—	—	—	—	—	—
30–34	—	—	—	—	—	—
35–39	—	—	—	—	—	—
40–44	—	—	—	—	—	—
45–49	—	—	—	—	—	—
50–54	—	—	—	—	—	—
55–59	2	3.2	3.1–3.4	—	—	—
60–64	7	3.9	3.2–4.4	—	—	—
65–69	6	5.0	4.4–5.4	2	4.9	4.7–5.2
70–74	4	6.5	6.1–7.2	12	6.2	4.8–9.6
75–79	3	7.6	6.4–8.6	18	7.4	4.4–14.4
80–84	11	9.4	7.9–10.9	48	7.8	5.1–9.5
85–89	18	11.1	6.1–13.8	45	10.1	4.7–13.6
90–94	85	11.1	8.1–15.2	145	11.3	6.2–19.5
95–99	153	12.1	8.4–18.4	440	12.6	6.6–21.2
100–104	212	13.2	8.8–23.7	443	14.6	9.4–23.6
105–109	116	15.6	9.7–23.4	290	17.4	11.2–28.8
110–114	75	17.8	13.0–27.3	129	20.5	13.3–31.3
115–119	37	22.7	15.6–29.5	64	25.3	15.6–38.6
120–124	41	25.1	18.9–34.0	72	28.9	14.3–42.9

TABLE 2. (continued)

	Georges Bank					
	October			November–March		
Shell length	Number of scallops	Mean weight	Range	Number of scallops	Mean weight	Range
(mm)		*(g)*	*(g)*		*(g)*	*(g)*
125–129	20	29.7	21.1–40.8	70	32.4	20.8–47.0
130–134	15	33.2	23.8–39.3	49	36.0	25.8–50.1
135–139	6	31.4	26.3–40.7	16	39.9	28.1–54.4
140–144	2	37.5	33.0–42.0	13	42.2	27.3–49.5
145–149	—	—	—	1	45.6	45.6
150–154	—	—	—	1	38.5	38.5
155–159	—	—	—	—	—	—
160–164	—	—	—	—	—	—
165–169	—	—	—	—	—	—

	Georges Bank					
	April–September			All months		
20–24	1	0.2	0.2	1	0.2	0.2
25–29	2	0.3	0.2–0.4	2	0.3	0.2–0.4
30–34	—	—	—	—	—	—
35–39	2	0.7	0.6–0.8	2	0.7	0.6–0.8
40–44	4	1.2	1.1–1.2	4	1.2	1.1–1.2
45–49	12	1.7	1.2–2.1	12	1.7	1.2–2.1
50–54	23	2.2	1.4–2.8	23	2.2	1.4–2.8
55–59	43	3.3	1.9–3.6	45	3.3	1.9–3.6
60–64	78	4.0	1.9–5.2	85	4.0	1.9–5.2
65–69	81	5.0	2.7–6.3	89	5.0	2.7–6.3
70–74	100	6.3	3.6–15.4	116	6.3	3.6–15.4
75–79	171	7.0	2.7–9.9	192	7.1	2.7–14.4
80–84	138	9.4	2.1–15.2	197	9.0	2.1–15.2
85–89	226	11.3	5.3–19.6	289	11.1	4.7–19.6
90–94	407	13.4	6.3–31.9	637	12.6	6.2–31.9
95–99	510	15.3	6.8–25.3	1103	12.8	6.6–25.3
100–104	546	17.3	8.7–30.0	1201	15.5	8.7–30.0
105–109	416	19.3	11.0–30.1	822	18.1	9.7–30.1
110–114	371	22.4	10.4–42.9	575	21.4	10.4–42.9
115–119	220	25.8	12.0–50.1	321	25.4	12.0–50.1
120–124	203	29.7	14.6–50.1	316	28.9	14.3–50.1
125–129	183	34.9	16.4–52.6	273	33.8	16.4–52.6
130–134	128	39.6	10.7–51.9	192	38.1	10.7–51.9
135–139	72	42.8	22.6–59.4	94	41.4	22.6–59.4
140–144	30	45.7	33.6–62.6	45	44.3	27.3–62.6
145–149	7	52.3	43.1–61.8	8	51.4	43.1–61.8
150–154	1	43.0	43.0	2	40.8	38.5–43.0
155–159	—	—	—	—	—	—
160–164	—	—	—	—	—	—
165–169	—	—	—	—	—	—

TABLE 2. (continued)

	Maine			Cape Cod Bay		
Shell length	Number of scallops	Mean weight	Range	Number of scallops	Mean weight	Range
(mm)		(g)	(g)		(g)	(g)
20–24	—	—	—	—	—	—
25–29	—	—	—	—	—	—
30–34	—	—	—	—	—	—
35–39	—	—	—	—	—	—
40–44	—	—	—	—	—	—
45–49	—	—	—	1	1.9	1.9
50–54	—	—	—	1	1.9	1.9
55–59	—	—	—	1	3.2	3.2
60–64	—	—	—	2	3.3	3.3
65–69	—	—	—	10	4.8	3.2–5.7
70–74	—	—	—	10	6.6	5.2–8.4
75–79	—	—	—	4	7.8	7.3–8.4
80–84	4	6.1	5.1–7.0	8	10.3	9.6–11.7
85–89	9	7.4	5.5–9.3	9	12.4	10.1–15.4
90–94	27	8.6	6.3–13.0	19	14.7	11.8–20.6
95–99	93	10.5	7.3–19.9	17	16.8	13.3–20.5
100–104	123	13.4	8.6–22.6	25	19.2	14.8–28.0
105–109	145	16.2	10.6–25.5	46	20.9	14.6–26.8
110–114	181	18.7	9.8–29.6	52	24.0	17.7–35.4
115–119	126	24.3	13.5–39.0	32	28.3	21.9–37.1
120–124	139	27.2	18.0–39.1	31	33.2	25.1–42.2
125–129	104	30.4	14.4–45.0	29	36.4	26.3–47.1
130–134	78	34.5	22.3–48.6	40	43.3	32.7–58.6
135–139	41	38.6	22.4–52.9	34	46.4	33.7–55.8
140–144	21	45.0	28.0–65.3	34	50.4	33.1–67.7
145–149	6	43.3	36.6–48.2	25	58.8	42.7–76.0
150–154	9	44.2	34.9–56.6	16	60.1	47.8–78.6
155–159	1	37.2	37.2	3	71.8	54.2–81.4
165–169	—	—	—	3	80.9	72.5–90.6

	Stellwagen Bank			Block Island		
20–24	—	—	—	—	—	—
25–29	—	—	—	—	—	—
30–34	—	—	—	3	1.1	1.1–2.2
35–39	—	—	—	6	1.5	1.3–1.7
40–44	—	—	—	15	1.4	1.0–2.3
45–49	—	—	—	11	1.7	1.1–6.0
50–54	—	—	—	13	1.8	1.2–2.6
55–59	—	—	—	10	3.3	1.7–6.1
60–64	—	—	—	8	2.8	1.8–3.6
65–69	—	—	—	12	2.9	2.7–5.1
70–74	—	—	—	21	4.9	4.0–6.9
75–79	—	—	—	51	6.0	4.5–11.9
80–84	1	9.6	9.6	50	7.2	5.4–8.5
85–89	1	12.7	12.7	74	8.7	6.5–18.5

TABLE 2. (continued)

	Stellwagen Bank			Block Island		
Shell length	Number of scallops	Mean weight	Range	Number of scallops	Mean weight	Range
(mm)		*(g)*	*(g)*		*(g)*	*(g)*
90–94	1	11.8	11.8	54	10.0	8.1–13.3
95–99	6	16.5	15.3–17.9	31	12.2	10.0–14.9
100–104	10	17.7	14.8–20.8	42	15.1	9.2–19.5
105–109	22	18.5	14.6–23.3	68	17.0	11.6–22.0
110–114	24	22.4	18.6–28.2	57	19.1	13.3–24.6
115–119	10	25.9	21.9–31.6	19	19.2	14.3–24.8
120–124	1	25.6	25.6	14	24.1	11.2–30.0
125–129	—	—	—	4	24.7	17.6–31.9
130–134	1	43.1	43.1	10	26.7	15.3–43.2
135–139	—	—	—	4	32.8	24.7–38.4
140–144	—	—	—	3	36.0	29.6–41.0
145–149	—	—	—	1	35.7	35.7
150–154	2	56.3	54.0–58.6	—	—	—
155–159	—	—	—	—	—	—
160–164	—	—	—	—	—	—
165–169	—	—	—	—	—	—

TABLE 3. Number of samples and specimens (in parenthesis) in each area by season.

	Georges Bank							
Season	Northern Edge	Eastern Part	Southeast Part	Great South Channel	Cape Cod Bay	Stellwagen Bank	Maine	Block Island
Oct.	2 (214)	—	—	5 (599)	2 (256)	—	—	—
Nov.–Mar.	9 (1,225)	2 (138)	4 (399)	1 (96)	2 (156)	—	4 (846)	1 (61)
Apr.–Sept.	19 (2,281)	4 (690)	4 (493)	5 (511)	1 (43)	1 (79)	1 (261)	4 (520)

Significant differences were found between seasons for all but the Eastern Part. The reason for the lack of significant differences in this area is unknown. Nevertheless, the significance of the differences between seasons in three of the four areas strongly suggest that they are real.

Similarly, differences between areas were tested within each season. None of the differences was significant.

The length-weight equations for scallops from Georges Bank, by season, are:

Season S: $\log_e W = -10.2516 + 2.785 \log_e L$ (Oct.)

Season M: $\log_e W = -11.7472 + 3.131 \log_e L$ (Nov.–Mar.)

Season R: $\log_e W = -10.9926 + 2.995 \log_e L$ (Apr.–Sept.)

Maine Coast, Cape Cod Bay, Block Island, and Stellwagen Bank

The numbers of samples from each season for each fishing area (Table 3) are too few to permit testing of the variations among all areas for each season. It is possible, nevertheless, to examine differences in meat weights between certain areas within a particular season.

The areas of Cape Cod Bay, Maine, and Block Island were tested against the Georges Bank areas to determine if the length-weight relations of sea scallops differed significantly from those of Georges Bank for a particular season. Suitable records were available for seasons S and M for Cape Cod Bay, season M for Maine, and season R for Block Island.

For both seasons tested, the length-weight relation of sea scallops from Cape Cod Bay did not differ significantly from that of scallops from Georges Bank with respect to the regression coefficient. They did differ significantly in the adjusted mean weights. Regression coefficients of sea scallops from Maine and Block Island differed significantly from those of Georges Bank. The results suggest that for the seasons tested sea scallops from Cape Cod Bay, the Maine Coast, and off Block Island possess real differences in their meat weights for a given shell length as compared with those from Georges Bank. The length-weight equations for these areas are:

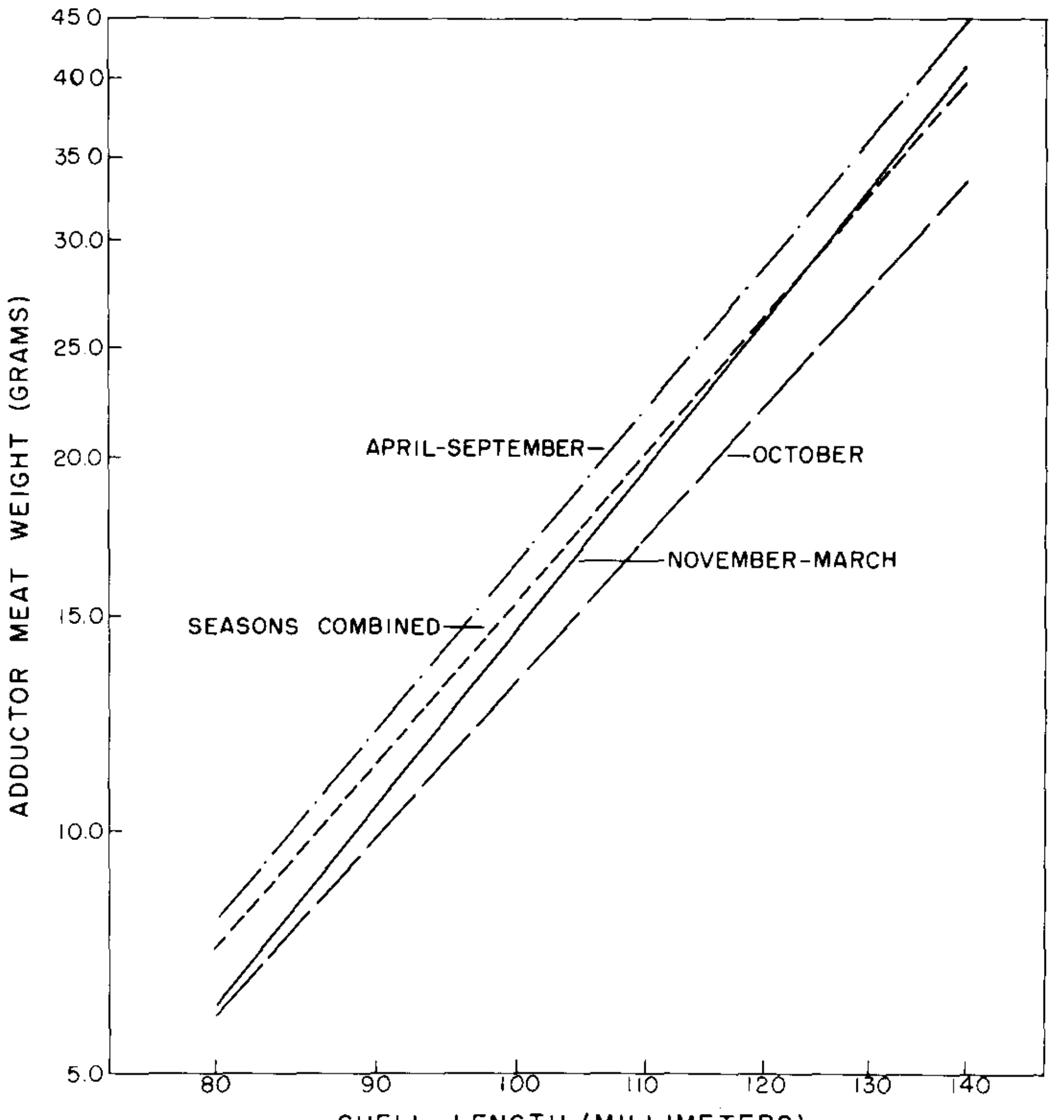

Fig. 4. Regressions of weight on shell length for three seasons (based on state of gonads) and the regression for seasons combined for sea scallops from Georges Bank.

Cape Cod Bay

Season S: $\log_e W = -10.8845 + 2.989 \log_e L$ (Oct.)

Season M: $\log_e W = -11.2666 + 3.062 \log_e L$ (Nov.–Mar.)

Maine

Season M: $\log_e W = -8.5392 + 2.427 \log_e L$ (Nov.–Mar.)

Block Island

Season R: $\log_e W = -9.7660 + 2.683 \log_e L$ (Apr.–Sept.)

The data on sea scallops from Stellwagen Bank are based on only one sample and, therefore, have not been used in any statistical tests. The regression equation is:

$$\log_e W = -10.0516 + 2.791 \log_e L$$

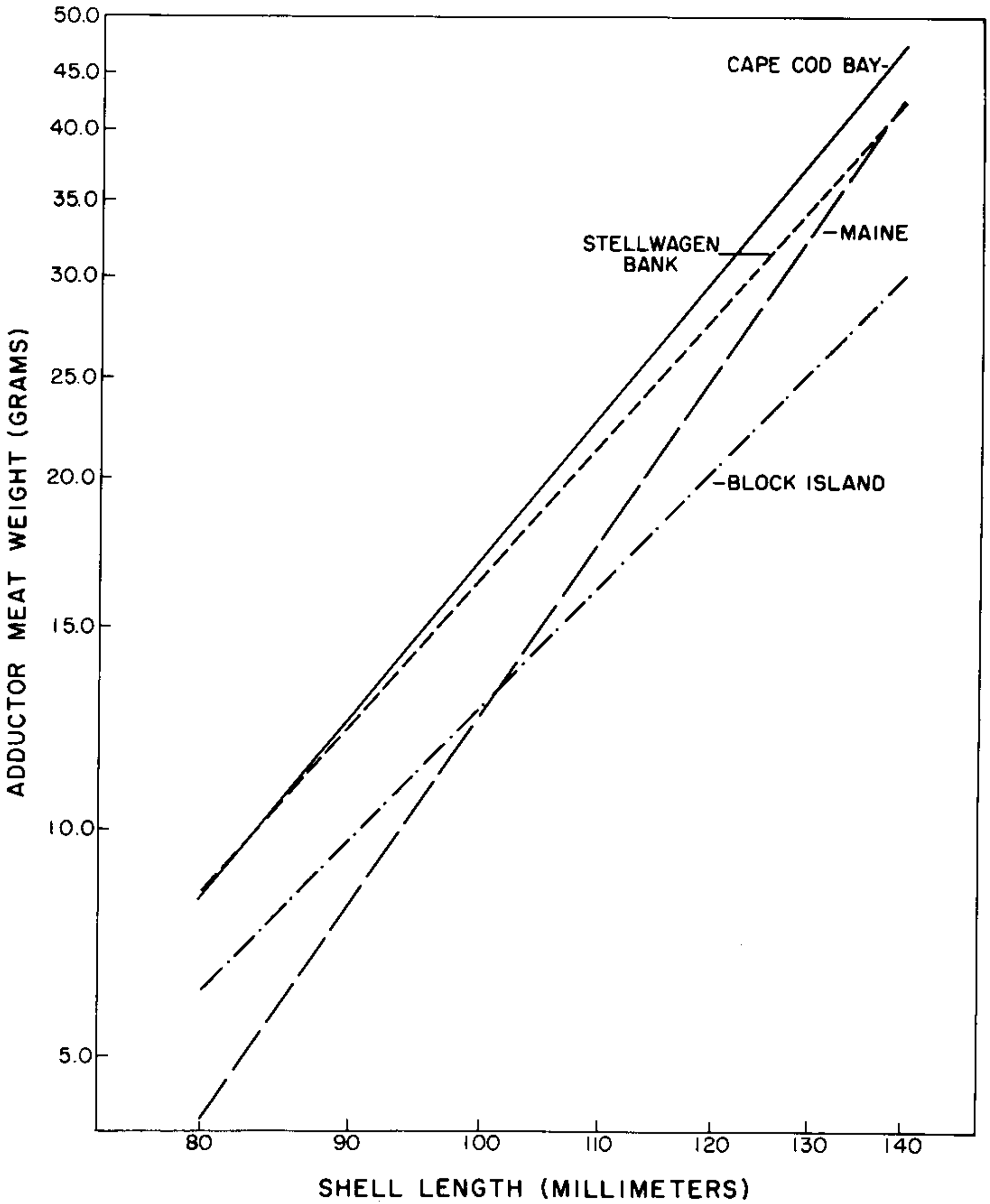

Fig. 5. Regressions of weight on shell length for sea scallops from Cape Cod Bay, Stellwagen Bank, the inshore waters of Maine, and off Block Island.

For certain purposes a single length-weight equation may be desirable for Georges Bank and also for each of the other fishing grounds considered in this paper; all samples from each area were pooled, therefore, to obtain length-weight equations. The equations are shown in Table 4; graphs of these equations appear in Fig. 4 and 5.

Ninety-five percent confidence belts were calculated for the Georges Bank regression, all seasons and areas combined (Fig. 6). The

TABLE 4. Length-weight regressions for the sea scallops taken from Georges Bank, Cape Cod Bay, Stellwagen Bank, Maine, and Block Island, data for all seasons combined.

Area	Regression equation	Number of scallops
Georges Bank	$\log_e W = -10.8421 + 2.949 \log_e L$	6,646
Cape Cod Bay	$\log_e W = -11.2441 + 3.059 \log_e L$	455
Stellwagen Bank	$\log_e W = -10.0516 + 2.791 \log_e L$	79
Block Island	$\log_e W = -9.1393 + 2.549 \log_e L$	581
Maine	$\log_e W = -14.3451 + 3.664 \log_e L$	1,107

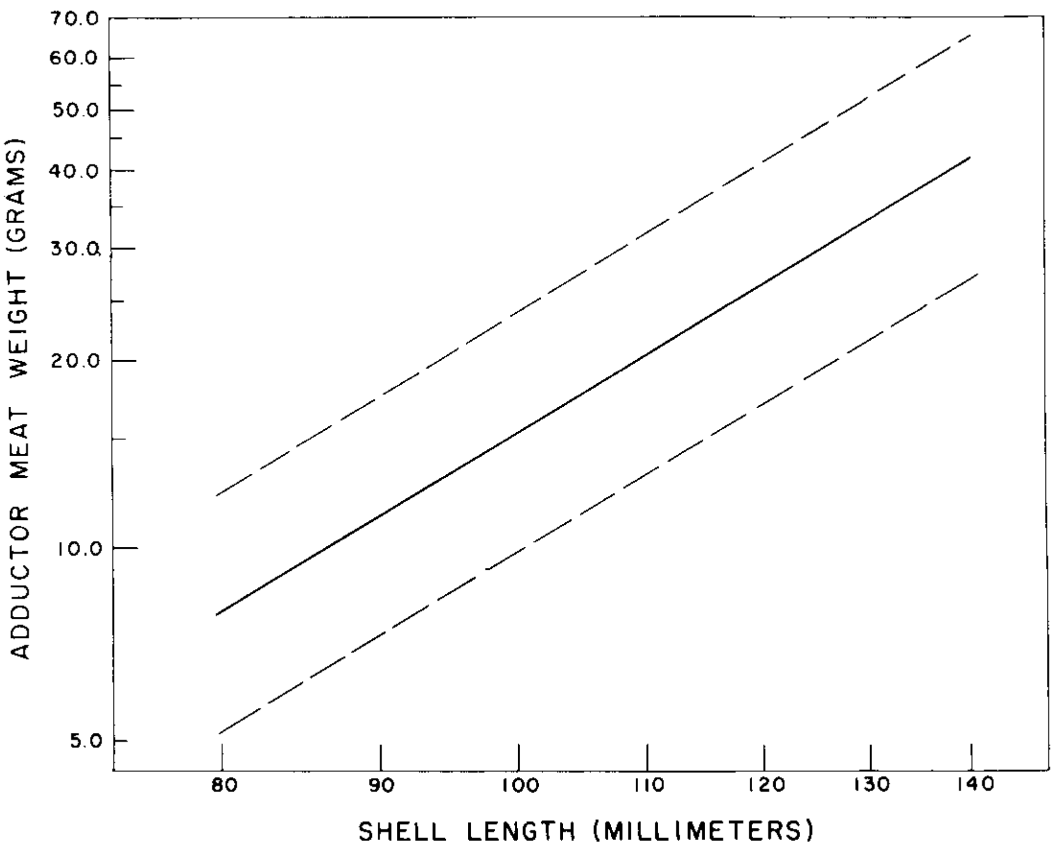

Fig. 6. Regression line for Georges Bank, all seasons and areas combined. The broken lines show the limits within which 95% of the meat weights may be expected to fall.

broken lines show the limits within which 95% of the meat weights would be expected to fall.

Figure 7 shows the expected frequency distribution of meat weights around the means corresponding to sea scallops of 95, 110, and 120 mm in shell length. The inner and outer broken lines show the limits within which 68 and 95% respectively of the meat weights would be expected to fall.

A measure of the number of organisms per unit weight is useful in studies of an exploited population. Values calculated from the length-weight regression equations for sea scallops from each fishing area and also the regression

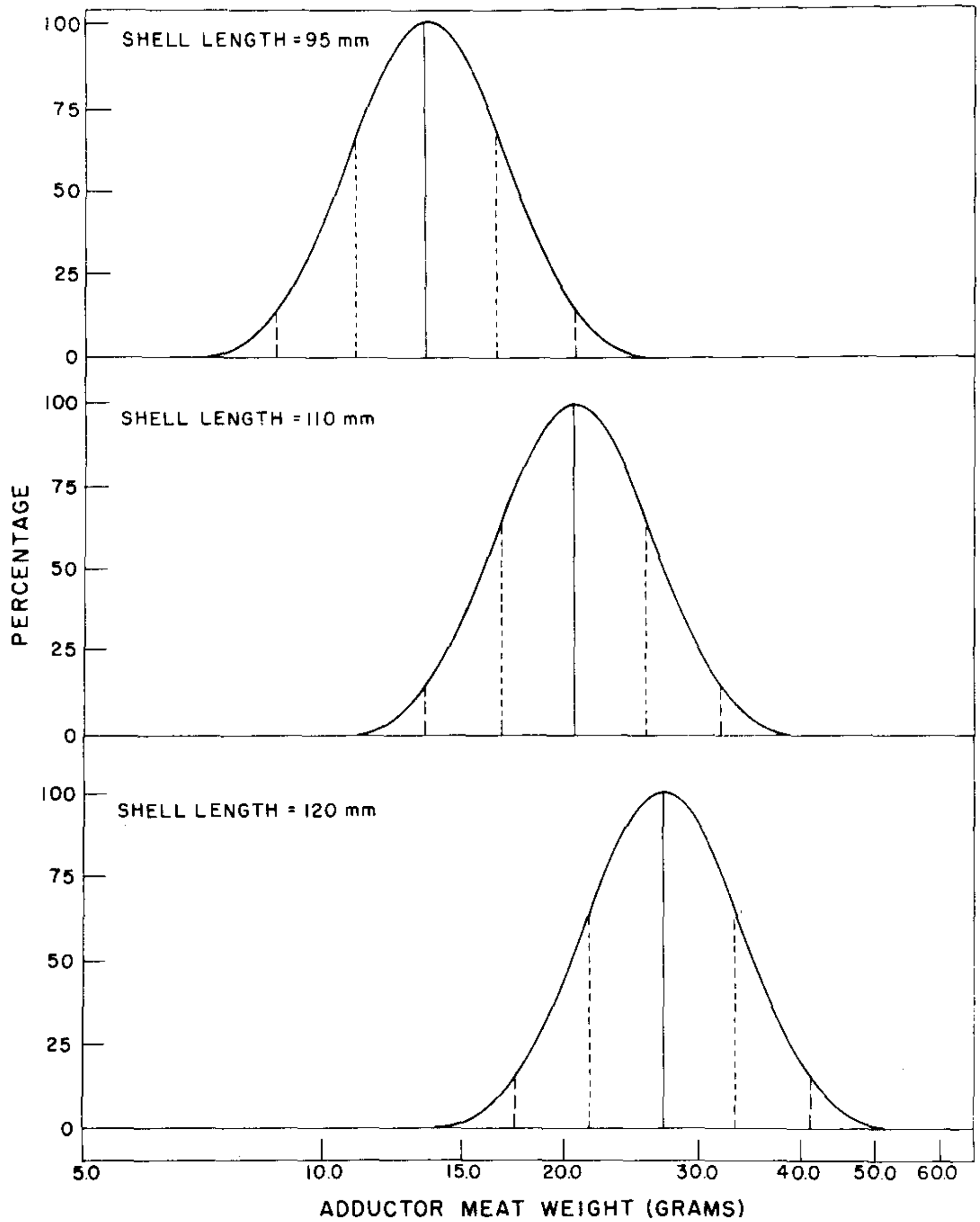

Fig. 7. Expected frequency distribution of meat weights around the means corresponding to sea scallops of 95, 110, and 120 mm in shell length. The inner and outer broken lines show the limits within which 68 and 95% respectively of the meat weights would be expected to fall.

equations for each season (in relation to state of gonads) on Georges Bank, have been used to derive the number of scallop meats per pound by 5-mm size groups from 80 to 150 mm (Table 5).

Comparison with Earlier Studies of Weights of Sea Scallop Meats

Baird (1954) published data on the length-weight relations of Maine sea scallops which differ widely from those of this study (see Fig. 8 for a comparison of the two sets of data). I fitted the line to Baird's data by eye, but disregarded the 90-mm value, which appears to be in error. Meat weights from Baird's data averaged about 32% greater than mine over the range of 80–140 mm. The locations of the sample collections differed; those of Baird came mostly from Linekin Bay, whereas mine were largely from Penobscot Bay. According to Baird, however, "The Linekin figures have since been compared with enough Penobscot figures

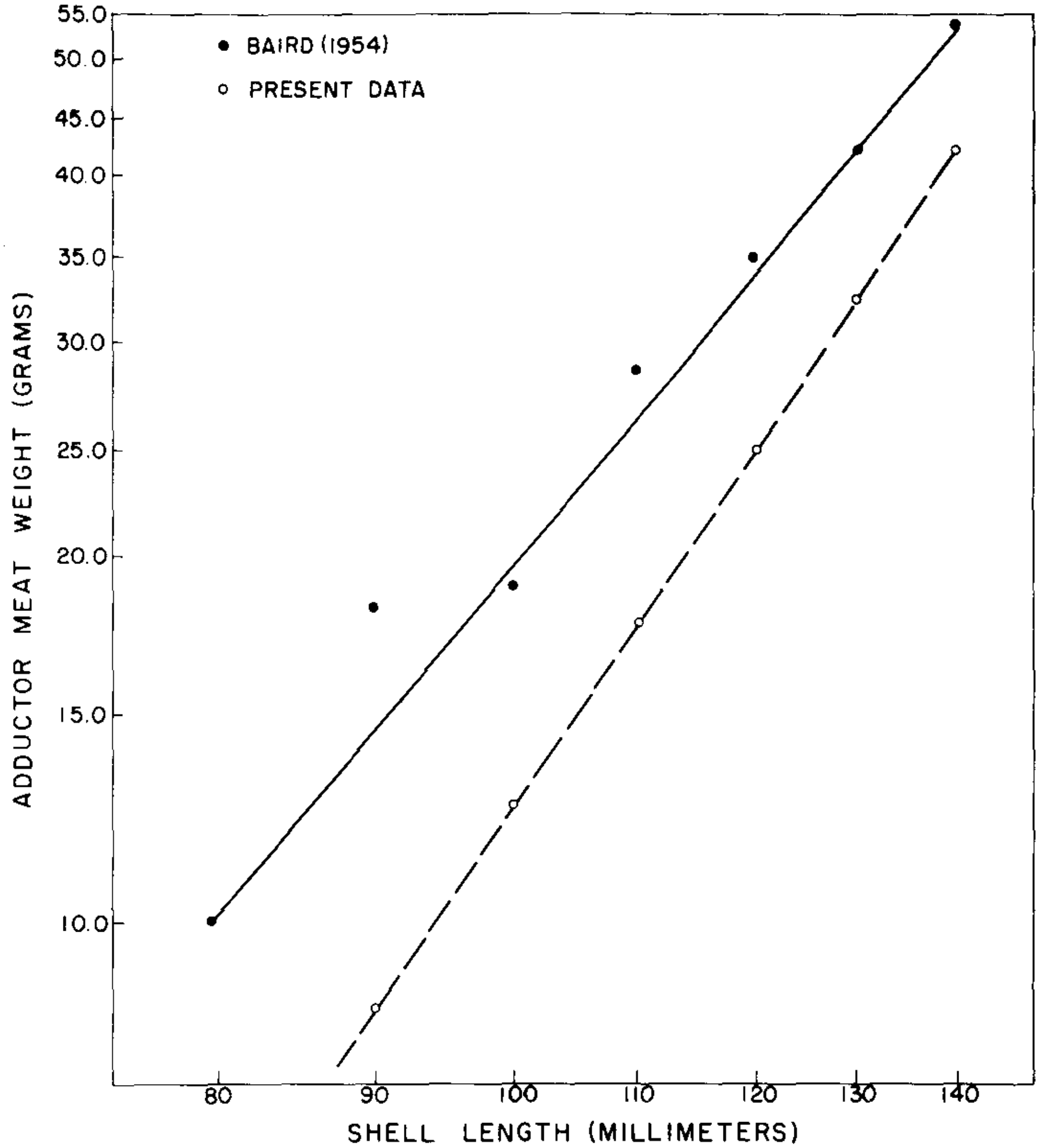

Fig. 8. Comparison of regressions of weight on length from sea scallops taken from the inshore waters of Maine.

TABLE 5. Number of meats per pound for scallops 80–150 mm long from the fishing areas of Georges Bank, Maine, Block Island, Cape Cod Bay and Stellwagen Bank.

	Georges Bank							
Shell length	Oct.	Nov.–Mar.	Apr.–Sept.	All months	Maine	Cape Cod Bay	Stellwagen Bank	Block Island
(mm)								
80–85	59.2	57.5	49.3	56.7	82.5	52.1	51.5	63.0
85–90	50.4	47.8	41.2	47.2	65.7	43.7	43.3	54.0
90–95	42.8	40.1	34.9	40.2	53.5	36.2	36.3	46.3
95–100	40.5	33.9	29.8	34.1	43.7	31.1	31.7	40.5
100–105	32.4	28.9	25.6	29.4	36.6	26.5	27.5	35.4
105–110	28.2	25.1	22.2	25.5	30.2	22.8	24.1	31.3
110–115	24.9	21.7	19.4	22.1	25.5	19.7	21.1	27.9
115–120	22.0	18.9	17.0	19.5	21.7	17.2	18.7	24.9
120–125	19.6	16.6	15.0	17.2	18.5	15.1	16.6	22.3
125–130	17.6	14.7	13.4	15.2	16.0	13.4	14.8	20.1
130–135	15.8	13.0	11.8	13.6	13.8	11.8	13.3	18.2
135–140	14.2	11.6	10.6	12.1	12.0	10.5	11.9	16.5
140–145	12.9	10.3	9.6	10.9	10.6	9.4	10.8	15.1
145–150	11.8	9.3	8.6	9.8	9.3	8.5	9.8	13.8

to convince the author that there is no significant difference in meat yield between the two areas." Also, Baird's data were apparently collected in July and August, whereas mine were taken from January to April. The seasonal differences in meat weights in this study were too small to make it likely that the total discrepancy between the two sets of data could be caused by season of collection alone.

Other data on the length-weight relation of sea scallops have been given by Posgay (1953) for Cape Cod Bay, and by Medcof (1949), and Dickie (1953) for the inshore Canadian waters (Digby area). The single regression of weight on length in this study for Cape Cod Bay is almost identical with that shown by Posgay, who used only the 1949 sample (included also in my study— Table 1). Data shown by Medcof (1949) and Dickie (1955) for the inshore Canadian waters indicate, with one exception, that the meat weights of Canadian sea scallops are generally somewhat smaller at a given length than those in the present study. The exception is the Block Island region where the adductor muscles of sea scallops weighed about 12% less than for sea scallops from Canadian waters, particularly in the larger sizes, 130–140 mm.

Summary

Samples for study of the relation between shell length and weight of the adductor muscle of the sea scallop were collected at Georges Bank, Cape Cod Bay, Stellwagen Bank, the inshore waters of Maine, and off Block Island. The samples permitted comparisons of the adductor meat weights for a given shell length between sexes, according to state of gonads, and area of collection.

Males and females had no significant differences in weights of adductor meat for a given shell length.

Analyses of length-weight data among sea scallops representing the gonad conditions of "spawning," "ripening," and "mature" were based on the samples from the Northern Edge, Eastern Part, and Southeast Part of Georges Bank, and the Great South Channel. With one exception, meat weights differed significantly among the scallops representing each gonadal state for each of the above areas. This fact strongly suggests that significant differences in meat weights for a given shell length do exist among sea scallops according to season.

Differences of meat weights among the above areas within each season were not significant.

The data were too scant for tests of the variation among all areas by season. It was possible, nevertheless, to study for certain seasons only, the differences among Cape Cod Bay, Maine, and Block Island against those of Georges Bank. For each area meat weights differed significantly from those of Georges Bank either in the regression coefficients or in the adjusted mean weights.

A pooled regression was computed from the pooled samples for each fishing ground.

The number of sea scallop meats per pound by 5-mm size groups from 80 to 150 mm are also shown for each of the fishing grounds considered in the present study.

Differences of meat weight for a given shell length were large between the data in this paper and those of Baird (1954) for the inshore waters of Maine. Although the two sets of data were collected at different seasons, it is unlikely that this difference would account for the total discrepancy.

The pooled regression of weight on length as shown in this study for Cape Cod Bay is nearly identical with that shown by Posgay (1953) who used the 1949 sample included in the present study.

Meat weights of Canadian sea scallops are generally somewhat smaller for a given length than those in the present study. An exception is offered by sea scallops from Block Island in the larger sizes of 130–140 mm, whose meat weights average about 12% less than those from Canadian waters.

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Results of Investigations on Deep-sea Redfish

BY P. I. SAVVATIMSKY[1] AND I. N. SIDORENKO[1]

Abstract

As a result of investigations carried out from 1962 to 1964 by the Murmansk research and scouting vessels, considerable and relatively stable concentrations of redfish were found in the deep-sea areas of the North Newfoundland and South Labrador shelves. Except for a few specimens, all redfish caught on Hamilton Bank at depths more than 500 m and in the Ritu Bank area at depths more than 600 m were immature. Their lengths (28–50 cm) and age (10–23 years) compositions ranged approximately within the same limits as those for mature redfish taken at shallower depths.

Coincidence of the length frequencies of males and females and the absence of differences in their growth rate indicate that immature redfish concentrate typically in deep water.

The absence of any signs of gonad ripeness even in the largest specimens of the deep-sea concentrations, the great similarity between their length and age compositions and those of redfish caught at depths of 200–500 m as well as some peculiarities in the growth rate make it doubtful that these redfish are able to reproduce.

One reason for the absence of ripe specimens may be sterility caused by the natural hybridization of the two main redfish species —*Sebastes marinus* and *Sebastes mentella*. However, it can also be suggested that the deep-sea immature group of redfish may be in fact a late-ripening form of common "beaked" redfish, *S. mentella*.

Introduction

Redfish (*Sebastes mentella* Travin) is one of the main commercial objects in the Northwest Atlantic (Table 1).

As Table 1 shows, the intensive fishery for redfish in the Labrador and Newfoundland areas started in 1958 and in 1959 reached its maximum of about 300,000 metric tons. Since 1960 the catch has decreased more than four times.

Many investigators state a very important fact that, while the banks are being exploited the size composition of redfish changes insignificantly. Templeman (1959) believes that this fact may be explained by the peculiarities of redfish distribution by depths as the fishery is carried out on stocks only at certain depths where the groups of fish of similar sizes concentrate.

Tåning, taking into account the data on wide distribution of larvae and young redfish in the open part of the ocean and beyond the limits of the continental slope and also the single specimens of adult redfish caught above the ocean depths, hypothesized the presence of great concentrations of pelagic redfish of commercial sizes. These hypotheses greatly affected the trend and course of investigations.

Successful attempts were made to find redfish concentrations in the slope area at depths greater than those where the fishery was previously carried out.

During the last 2 years, vessels of the German Democratic Republic (GDR) and Polish People's Republic (PPR) periodically carried out a fishery for redfish at great depths in the North Newfoundland area.

As Voss and Draffehn (1963) report, in July–August 1963, the vessels of GDR and PPR made large catches of redfish on the eastern slope of Ritu Bank at 600–800 m. From 17 to 31 July, the average daily catch by Polish vessels was 33.4 tons and from 1 to 11 August, 21.6

TABLE 1. The yield of redfish (000's tons) taken by all countries in the Labrador and Newfoundland Areas.

Years:	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962	1963
Yield:	46.2	45.6	37.2	17.6	29.8	57.7	236.3	298.9	182.2	115.5	69.0	74.8

[1]Polar Research Institute of Marine Fisheries and Oceanography (PINRO), Murmansk, USSR.

tons. Redfish were large (mode 41–43 cm) and immature.

Results

In 1962–63, the Murman research-scouting vessels regularly made hauls at depths of 500–700 m but, due to insufficient and scattered data, no important results on the deep-sea distribution of redfish during these years were obtained.

In 1964, the investigations on redfish at great depths were carried out on a large scale. In June 1964, fish concentrations at 600–800 m in the North Newfoundland area were found by the trawler *Pobeda* (the vessel of side-trawling). Concentrations of relatively large redfish were met north-east of Ritu Bank at 600–700 m (near-bottom temperature was 3.7°C). Catches ranged up to 5 tons per 2 hr trawling. At 700–800 m, catches decreased to 1 ton. Research in the area continued from 16 to 18 June when the size of the catches did not change.

Similar redfish concentrations were found by the scouting vessel *Novorossiisk* at 500–600 m on northeastern Hamilton Bank (South Labrador) in July. In October–December 1964, the vessel *Pobeda* again made a number of deep-sea hauls in the South and North Newfoundland areas; at that time as in summer the concentrations of large redfish were found on the slope. In all areas, samples were taken for determination of size composition, maturity, and age of redfish. The results of analyses are represented in Fig. 1, 2, and Tables 2, 3.

For comparison of the biological indices of deep-sea redfish data characterizing redfish encountered at shallow depths in the neighbouring areas are given. The sampling locations are shown in Fig. 1.

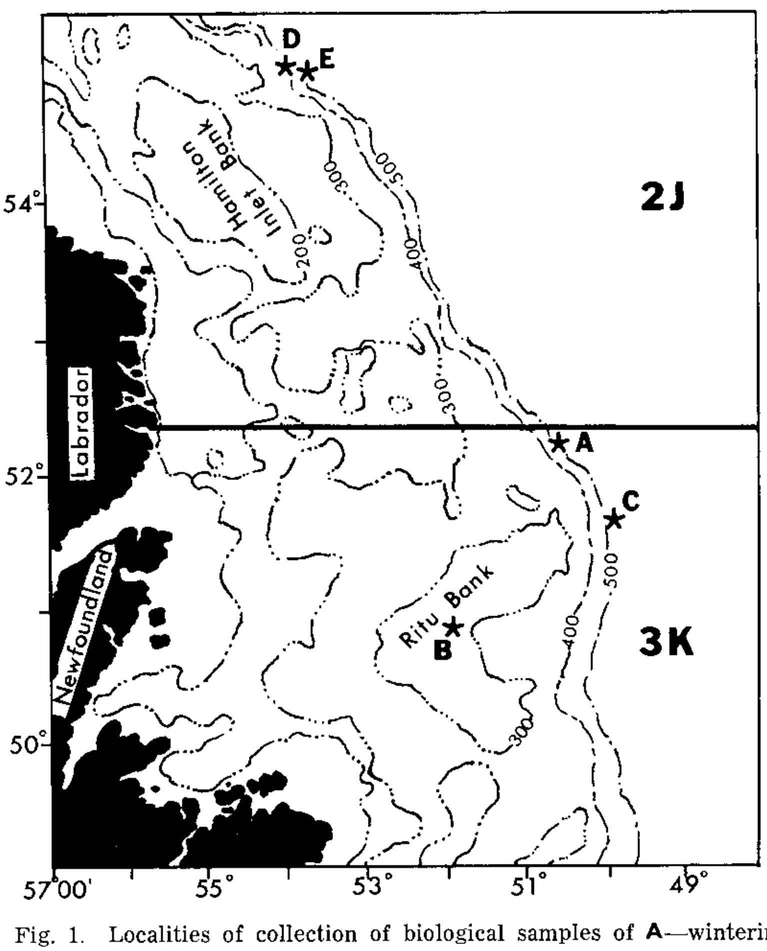

Fig. 1. Localities of collection of biological samples of **A**—wintering concentration of redfish, **B**—spawning concentration, **C**—deep-sea concentration, **D**—feeding concentration (mixed), **E**—deep-sea concentration.

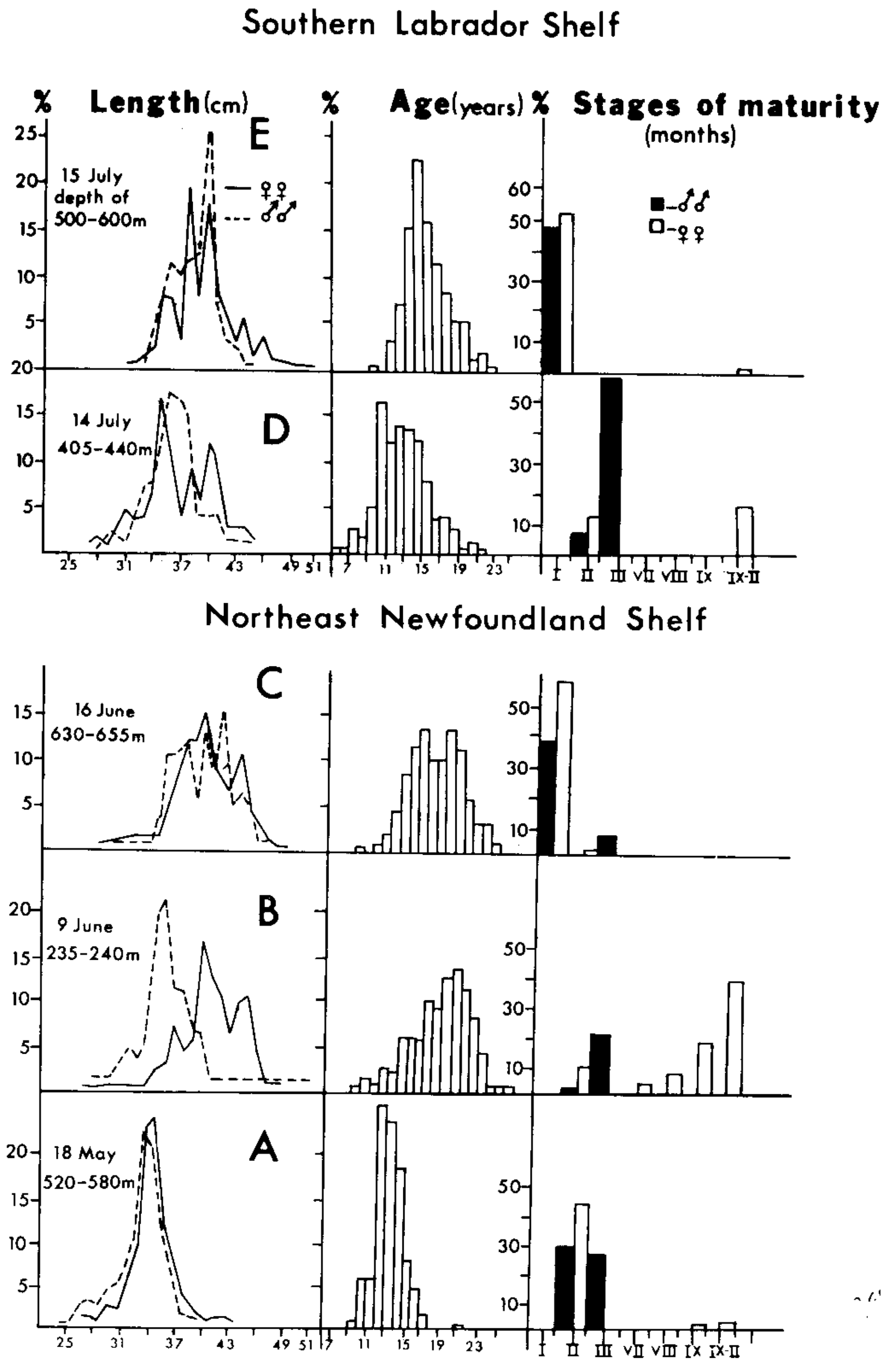

Fig. 2. Biological characteristics of redfish of different concentrations (the maturity stages: I–II—for males and females (immature); III—the stage of ripening; VII–VIII—the pre-spawning stage for females; IX—the spawning stage for females; IX–II—the post-spawning stage for females.)

TABLE 2. Growth rates (cm) of male and female redfish of two depth ranges in the South Labrador Area.

Depth	Age (year):	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	Total no. fish
m																				
500–600	♂♂	—	—	—	—	—	34.7	36.1	36.6	37.5	39.0	39.4	39.8	41.2	42.0	42.0	43.0	—	—	89
405–440	♂♂	—	—	29.3	32.0	32.5	33.2	34.4	35.9	36.6	37.6	38.7	39.4	40.8	41.5	41.0	41.0	45.0	—	182
500–600	♀♀	—	—	—	31.0	—	32.0	35.4	36.7	37.3	39.2	39.8	40.2	41.8	44.7	44.0	43.8	45.0	48.0	103
405–440	♀♀	27.0	29.0	29.0	31.0	31.4	34.3	35.1	36.3	37.5	39.1	40.8	39.5	40.7	42.2	41.0	43.3	45.0	—	102

TABLE 3. Growth rates (cm) of male and female redfish at two depth ranges in the North Newfoundland Area.

Depth	Age (year):	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	Total no. fish
m																						
630–655	♂♂	—	—	33.0	—	33.0	34.0	35.8	36.5	37.2	38.5	39.4	40.6	41.9	42.1	43.2	44.0	44.5	—	—	—	123
235–240	♂♂	—	—	28.0	30.0	32.0	32.3	35.0	35.4	36.3	38.0	38.3	38.0	40.0	—	—	—	—	—	—	40.0	40
630–655	♀♀	—	—	33.0	—	33.0	33.5	35.8	37.4	37.7	38.8	40.1	40.7	42.2	43.0	42.3	43.4	44.8	45.7	—	—	166
235–240	♀♀	—	—	—	28.3	32.0	33.5	35.3	36.4	37.7	37.9	40.0	40.3	41.3	41.5	43.0	44.2	45.3	44.5	48.0	—	187

By their appearance the deep-sea redfish almost do not differ from the common beaked redfish. However, as a result of a dissection it was found out that the deep-sea redfish differ greatly from redfish caught at shallow depths: redfish taken at depths above 500 m on Hamilton Bank and at depths above 600 m in the Ritu Bank area were immature (except for a very few specimens) and without any indications of ripening gonads. The determination of sex of redfish without dissection is more difficult than in fish caught at shallower depths.

Length frequencies of deep-sea redfish are rather long (28–50 cm) and little like the size composition of mature redfish taken in the shelf area (Fig. 1, 2 B, C) the prevailing sizes in both cases are 35–45 cm. However, there are no differences in sizes of males and females caught at great depths, their size curves almost coincide (Fig. 2 C, E). The similar coincidence of size-frequencies is observed while studying the concentrations of redfish wintering at usual depths and including immature females, immature and ripening males, that is, that part of the redfish stock which remains in the wintering areas after the mature fishes migrated to the spawning areas (Fig. 2, A).

Analysing the redfish mean sizes according to age-groups (Tables 2, 3) one can conclude that males and females of redfish have almost no differences in their growth rate. It is known that the growth rate of redfish taken at shallower depths decreases with the approach of maturity, e.g. the growth rate of males at about 12 years of age starts to drop behind that of females. Such a conformity was not observed in the growth of deep-sea redfish. Average sizes of males and females almost in all size-groups investigated are equal. In general, the growth of deep-sea redfish differs little from that of redfish caught at shallower depths. The growth of females taken at different depths is approximately similar. The males offer some exception. Their growth rate is rather different. The average sizes of deep-sea redfish males are 1.5–2 cm more than those of redfish of similar age taken at shallower depths.

The age composition of redfish in deep-sea concentrations is rather various and much like the age composition of redfish in the feeding concentrations observed at shallower depths—in both cases the 13–23 age-classes prevail.

It should be noted that due to the low transparency of scales, the determination of age of deep-sea redfish is more difficult than the age determination of redfish taken at shallower depths.

Discussion

Thus, the sharp difference between the deep-sea redfish and redfish at shallow depths as shown by the degree of ripeness of gonads, the peculiarities of growth rate and a number of other factors, indicate the isolation of this redfish group from the redfish caught at depths of 200–500 m and in some areas down to 600 m and more.

The absence of any signs of the ripening of gonads even in large specimens makes the problem of reproductive ability of these redfish doubtful.

As known, mass natural hybridization takes place in the South Labrador and North Newfoundland areas (author's observations in 1957–64). The different intermediate forms of redfish are often found in large quantities in commercial catches especially taken on the oceanic shelf in the Belle Isle area. By their appearance, some forms are much like *Sebastes marinus*, others the beaked redfish. Nevertheless, the differences between all these forms and typical forms of both species (*Sebastes marinus* and *Sebastes mentella*) are evident.

As known, because the strong flow of the cold Labrador Current occupies the great water layers and extends far into the ocean, the severe hydrological regime is observed on the Labrador shelf. It is quite natural that because of the low near-bottom temperatures, the usual area of occurrence of *Sebastes marinus* (depth of 100–300 m), can be displaced to greater depths in the area of distribution of beaked redfish where their mixing is observed. This fact may be one of the causes of the mass hybridization of redfish.

The main mass of hybrids caught at depths of 200–450 m and investigated by the authors were quite fecund and able to hatch.

It is known that in many cases the hybridization of closely related species does not lead to sterility. On the contrary, forms are born which are more viable and have a fast growth rate and are quite reproduceable.

Nevertheless, thinking over the hard-to-explain phenomenon of deep-sea immature redfish, one can suppose that the natural hybridization observed mostly in the areas of Labrador and North Newfoundland can ultimately create a form which is not able to be reproduced and which is localized in some parts of the slope.

However, it is not excluded that redfish observed at great depths may represent a form of common beaked redfish which ripen later. To solve this problem, extended investigations revealing the nature of these redfish are necessary.

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Trends in the Haddock Fishery of ICNAF Subarea 3

BY V. M. HODDER[1]

Abstract

In the short 20-year history of the haddock fishery in Subarea 3, great fluctuations have occurred in the annual yields. Size and age composition data show that these fluctuations were largely the result of great variations in year-class survival. The most recent outstanding year-classes of haddock on the Grand Bank were those of 1949 and 1955 with moderate survival in 1952 and somewhat smaller year-classes in 1953 and 1956, the others between 1949 and 1963 being complete failures or very small. Estimates of the total mortality coefficient for the significant year-classes ranged between 0.75 and 1.00.

The haddock fishery in Subarea 3 has now entered a period when yields must remain at a relatively low level until year-classes undergo a much higher degree of survival than has been the case since 1955. While the causative factors that affect brood production and survival are not definitely known, it appears that the failure of year-classes may be due to the precarious position occupied by the stocks on the southwest slopes of the banks with cold water on the banks to the north and very deep water to the south. Since the 1955 and 1956 year-classes were very heavily exploited in 1960 and 1961 when they were approaching their first

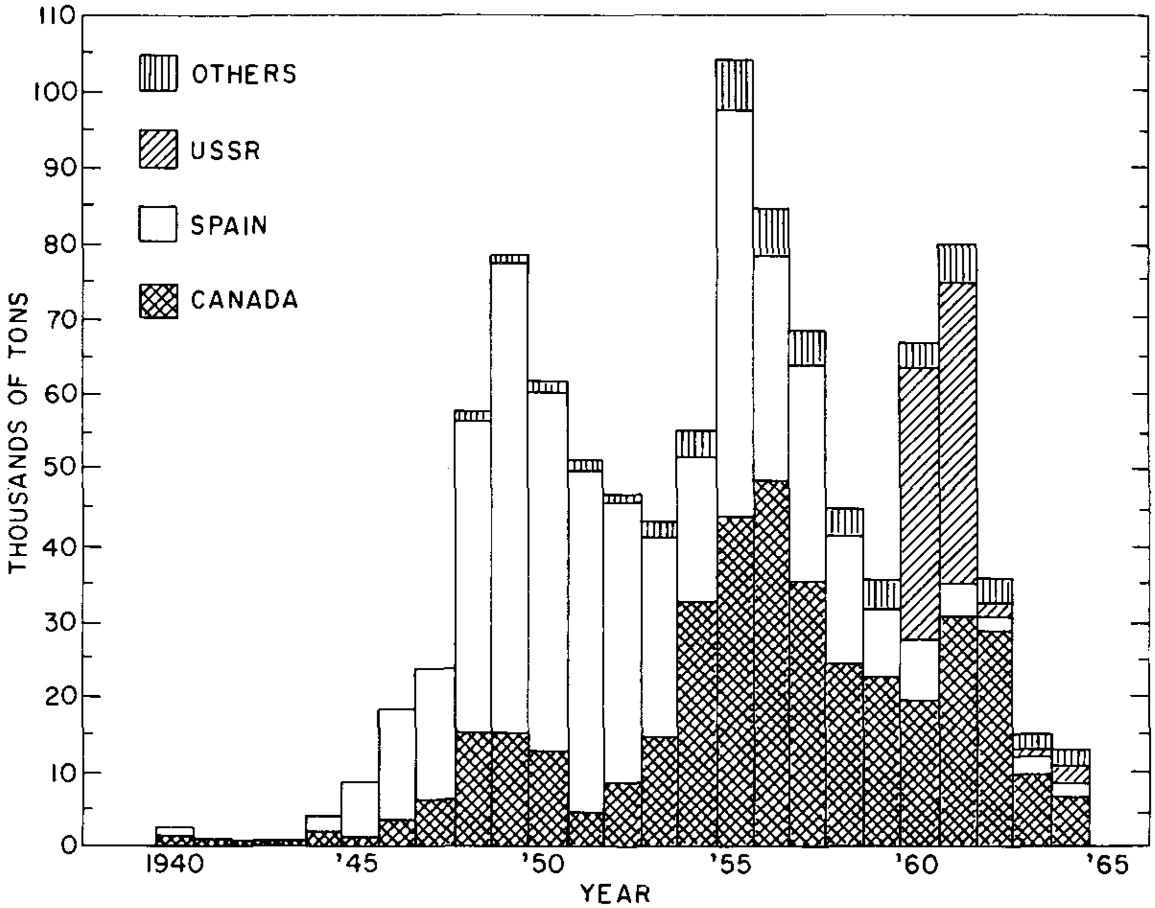

Fig. 1. Landings of haddock from the Newfoundland Banks (Subarea 3) during 1940–64.

[1]Fisheries Research Board of Canada, Biological Station, St. John's, Newfoundland, Canada.

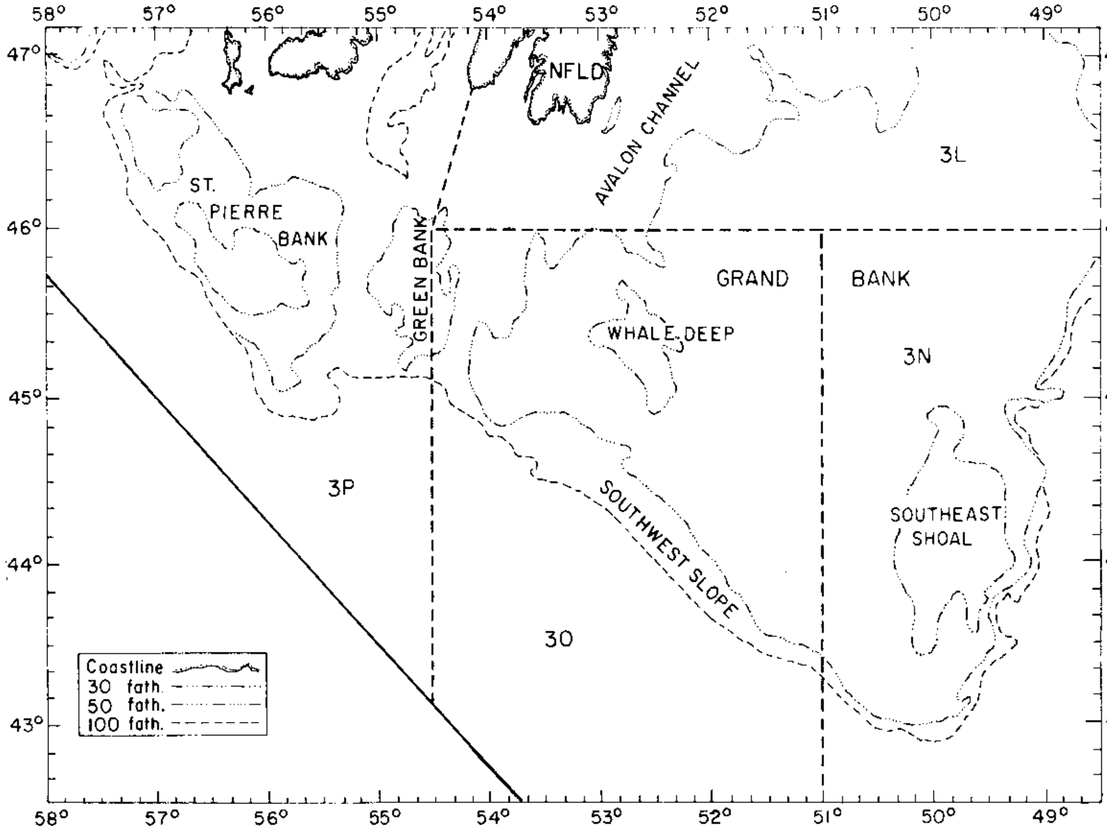

Fig. 2. The southern part of Subarea 3 showing the ICNAF divisions and the location of places mentioned in the text.

spawning age, it is suggested that the poor survival since 1960 may in part be due to the lack of an adequate spawning stock.

Introduction

Although haddock were known to be abundant on the southern part of the Grand Bank in the 1930's (Thompson, 1939), exploitation of the stock did not begin on a large scale until 1946, after which landings increased rapidly to 78,000 metric tons in 1949 (Fig. 1). As is usual after the initial exploitation of a virgin stock, the decline in numbers of large fish in the catches and some relaxation in fishing effort resulted in a decline in haddock landings to 43,000 tons in 1953. Up to that time most of the haddock landed were taken on the Grand Bank portion of Subarea 3 (Fig. 2). However, the recruitment to the fishery of a very abundant year-class resulted in haddock being abundant not only on the Grand Bank (Divisions 3N and 3O) but also on St. Pierre Bank (Division 3P). A great increase in fishing intensity subsequently occurred and by 1955 landings had reached a peak of 105,000 tons. This was followed by a decline to 35,000 tons in 1959. Due to the recruitment of another large year-class with subsequent increase in effort, landings in 1960 and 1961 rose to 66,000 and 80,000 tons respectively, but the haddock yield dropped to 35,000 tons in 1962 and 14,000 tons in 1963. It remained at a low level of 12,000 tons in 1964.

Except for very insignificant quantities taken inshore along the south coast of Newfoundland, the haddock fishery is strictly an offshore trawl fishery and up to 1959 was carried on almost exclusively by Canadian and Spanish trawlers. In 1960 and 1961 USSR trawlers entered the haddock fishery and landings increased substantially in these years, but since then they have decreased to the lowest level since the start of the fishery.

Early in the exploitation of the Subarea 3 haddock stocks, biologists of the St. John's Biological Station initiated length and age sampling of the commercial landings. Also by means of log books placed on board of most of the trawlers landing in Canadian (Newfoundland) ports, statistics of landings and effort for the major commercial species, including haddock, have been available since about 1954. These are the only effort statistics pertinent to the Subarea 3 haddock fishery, since Spanish and USSR data pertain to mixed fisheries with no separation of the effort devoted mainly to haddock fishing. This is unfortunate, as we shall see later, since the Canadian fishery takes place mainly during the winter and spring in Division 3O while the Spanish and USSR fisheries for haddock usually take place during summer and autumn in Division 3N.

This paper presents the results of a preliminary analysis of the available length and age data and an assessment of the stocks in so far as it is possible from the information available. While some data for the St. Pierre Bank stock are presented, emphasis has been placed on the Grand Bank stock which has been the mainstay of the haddock fishery during its short history.

Nature of the Subarea 3 Haddock Stocks

In Subarea 3, where the most northern of the haddock stocks of the Northwest Atlantic are located, the main haddock fishery normally occurs on the southern half of the Grand Bank in Divisions 3N and 3O (Fig. 2); but during the period 1954–56 there was a substantial fishery for haddock on St. Pierre Bank in Division 3P as well (Table 1), almost exclusively on the very abundant 1949 year-class. Only small quantities of haddock were landed from the latter bank before 1953 and no significant fishery for haddock has taken place there since 1957.

TABLE 1. Subarea 3 haddock landings by country, 1954–64.

	Grand Bank (mainly 3N–O)					St. Pierre Bank (3P)					Division NK	Subarea 3
Year	Canada	Spain	USSR	Others	Total	Canada	Spain	USSR	Others	Total	Others	Total
1954	5,760	18,665	—	1,285	25,710	26,510	685	—	4	27,199	2,426[a]	55,335
1955	3,205	40,146	—	966	44,317	39,948	15,637	—	2,212	57,797	2,357[a]	104,471
1956	23,219	26,817	—	460	50,496	25,177	3,531	—	1,232	29,940	3,846[a]	84,282
1957	30,332	27,655	—	397	58,384	4,271	1,474	—	334	6,079	3,623[a]	68,086
1958	23,037	16,789	—	147	39,973	368	496	—	92	956	3,455[a]	44,384
1959	20,604	7,604	—	144	28,352	1,726	956	—	95	2,777	3,911[a]	35,040
1960	16,984	5,854	36,306	3,135	62,279	1,986	1,945	—	228	4,159	46	66,484
1961	29,366	2,953	39,913	4,559	76,791	1,048	1,530	—	280	2,858	5	79,654
1962	27,653	1,645	1,614	2,489	33,401	768	613	—	176	1,557	187	35,145
1963	8,563	2,207	369	1,187	12,326	712	1,003	3	300	2,018	87	14,431
1964	5,781	1,255	1,943	815	9,794	1,083	650	—	625	2,358	—	12,152

[a]Mostly 151–500 OT of France (St. P & M).

Growth and otolith studies indicate that the adult haddock on the Grand Bank and on St. Pierre Bank are relatively distinct groups. Some mixing may occur on the slope area in the deep water (south of Green Bank) between the Grand Bank and St. Pierre Bank, but the generally low temperature of the water (<0°C) in the channels between the banks tends to limit the extent of mixing. Since haddock were not known to exist in abundance on St. Pierre Bank prior to 1950, it is the author's opinion that the water current pattern, immediately following the Grand Bank spawning in 1949, was such that haddock larvae in great numbers drifted in the general direction of St. Pierre Bank and the young settled on the bottom there in the autumn of 1949, the population subsequently developing its own distinctive growth characteristics. There has been no significant survival of year-classes on St. Pierre Bank since 1949 and no significant fishery since 1957, when the abundance of the 1949 year-class was reduced to a low level.

The Grand Bank (3N and 3O) stock is usually located along the southwest slope (3O) during winter and spring, when the shallow areas of the bank are covered by cold water of unfavourable temperatures, generally less than 1°C (Templeman and Hodder, 1965); the haddock are thus concentrated in depths greater than 50 fathoms (91 m) along a narrow band of the southwest slope, where most of the haddock landed by Canadian vessels are taken. Usually by June, sometimes earlier, when the shallow bank water has warmed sufficiently, the winter and spring concentrations disperse and most of the haddock move eastward across the Grand Bank coincident with the incursion of slope water (Templeman and Hodder, 1965). By midsummer and later, haddock are usually concentrated again but now on the southeast shoal of the Grand Bank (3N) in shallow water of about 25 fathoms (46 m), where they feed largely on capelin and capelin eggs. Here they were exploited almost exclusively by Spanish trawlers up to 1959 and by USSR trawlers in 1960 and 1961. As the autumn progresses and the shallow bank water becomes colder, the haddock are gradually forced to retreat to their winter-quarters in the deeper water along the southwest slope of the Bank. The above is generally the picture, but hydrographic conditions are variable and the haddock schools may in an unusually cold year remain concentrated along the slope for a longer than normal period, thus favouring the spring fishery for them; in an unusually warm year the haddock may disperse earlier in the spring and remain spread out over the bank for a longer than normal period, thus hampering the fishery.

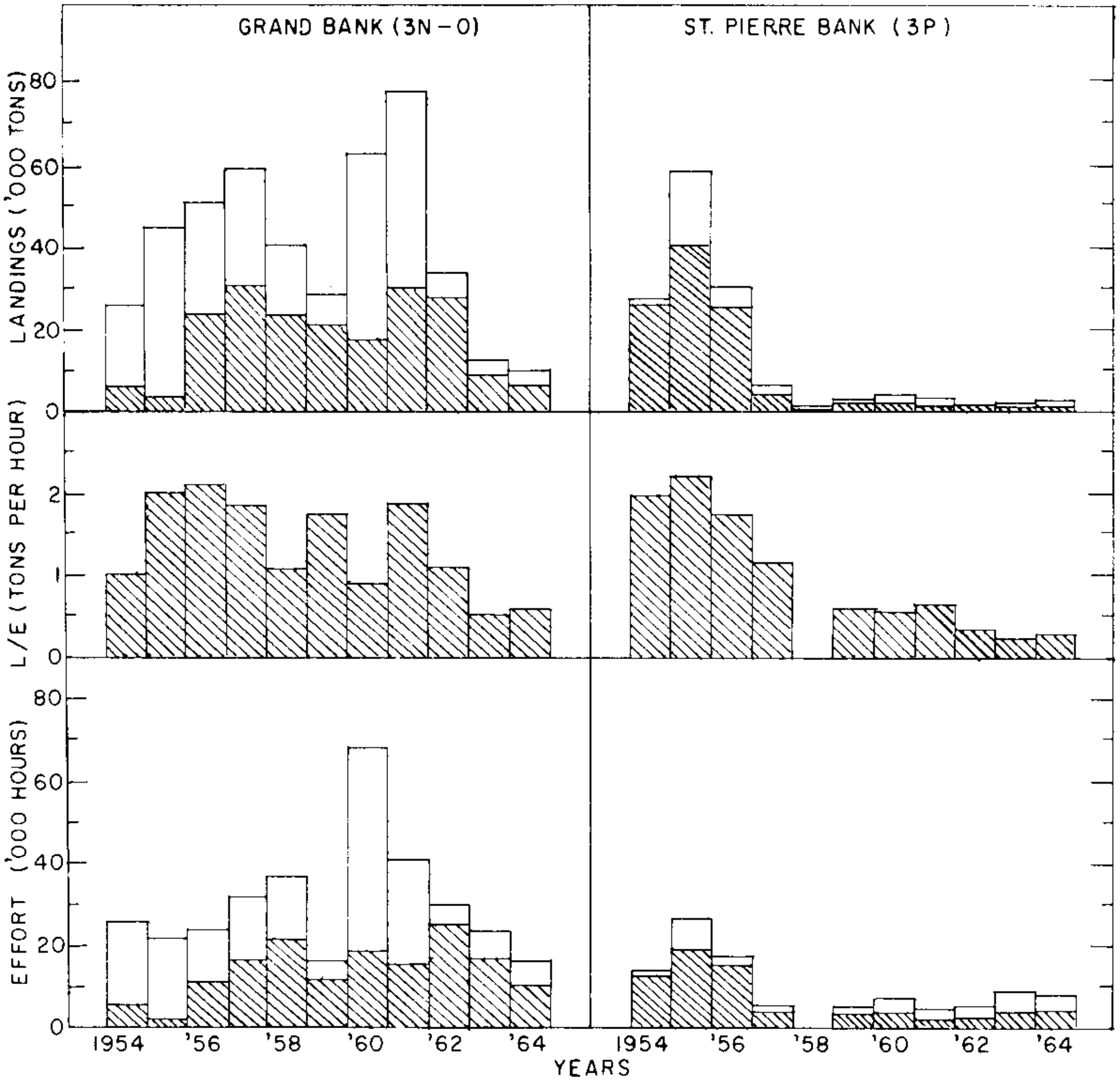

Fig. 3. Haddock landings, landings per unit effort of Newfoundland trawlers, and estimated total effort for the period 1954–64 in Subarea 3. (Canadian data are crosshatched.)

Index of Relative Abundance

As an index of relative abundance, the only landing-per-unit-effort data available are those for Canadian (Nfld.) trawlers since 1954. While the ICNAF Statistical Bulletins contain effort data for trawlers of other countries (mainly Spain and USSR) which have exploited the Subarea 3 haddock stocks, it has not been possible to utilize such data in this analysis because they pertain to mixed fishing with no separation of effort devoted mainly to haddock. Consequently the landings-per-unit-effort are based on statistics of effort and landings which represent less than 40% of the total haddock yield during 1954–64. Although a few trawlers of the 51–150 tonnage class participated in the Canadian fishery for haddock at various times, the effort and landing data are essentially those for trawlers of the 151–500 tonnage class into which most of the Newfoundland trawlers fall.

The landings, estimated efforts in hours fished, and landings-per-unit-effort for the Canadian fleet during 1954–64 are shown (cross-hatched) in Fig. 3, together with the total annual haddock landings and estimated annual effort, the latter values having been obtained by dividing the total annual landings by the corresponding landings-per-hour-fished of Canadian (Nfld.) trawlers.

On St. Pierre Bank the landing-per-unit-effort was at a high level (approximately 2 tons per hour) during 1954–56, but it rapidly decreased to a low level after 1957 and the haddock fishery there has been negligible since then.

On the Grand Bank the best and most consistent fishing occurred during 1955–57 (averaging 1.7 to 2.2 tons per hour). In 1958 and 1960 the average landings-per-hour-fished were down to 1.1 and 0.9 tons respectively, but during 1959 and 1961 they were near the 1955–57 level. The low values in 1958 and 1960 were due largely to hydrographic conditions in the winter and spring, when water temperatures were higher than usual and haddock were thus less concentrated in the fishing areas than normal. However, the rapid decline in landing-per-unit-effort after 1961 is most certainly due to decreased abundance of commercial-sized haddock.

Year-class Survival

For purposes of studying the contribution of year-classes to the commercial haddock fishery, length and age sampling of commercial landings was begun in the early 1950's and continued to the present time. Except for the discarding of unmarketable fish at sea, haddock are landed without culling into market categories. During the unloading process a "grab" sample of 300–400 haddock is usually taken, from which length measurements are obtained together with otoliths and scales from a random sample of these for subsequent age determinations. Ages are based largely on otolith readings but scale readings were also made on many of the specimens in order to verify ages, particularly when there was the slightest doubt in otolith interpretation.

Since the current interest in haddock is focused on the state of the Grand Bank stock (the transitory fishery on St. Pierre Bank having been largely due to the abundance of one year-class), only the year-class survival of Grand Bank haddock is considered here. Table 2 gives the numbers of samples and numbers of haddock measured and aged for the January–June period of 1955–64, and in Fig. 4 are shown the corresponding length and age compositions in terms of the average landings-per-unit-effort. The age compositions were obtained by applying age-length keys to the corresponding length compositions. The January–June period was selected for comparison of abundance of year-classes in successive years, because it is the period of the most intensive fishery by Canadian trawlers and also because it is the period when growth is practically negligible.

TABLE 2. Numbers of samples and numbers of haddock measured and aged from the landings of Canadian (Nfld.) trawlers from the Grand Bank during January - June of 1955–64.

Year	No. of samples	No. of fish measured	No. of fish aged
1955	16	4,514	320
1956	57	15,486	698
1957	95	31,477	1,582
1958	53	22,028	938
1959	52	15,558	839
1960	64	25,400	1,349
1961	56	24,866	2,110
1962	54	22,114	2,286
1963	22	6,792	841
1964	17	4,996	498

On the Grand Bank the most recent outstanding year-classes were those of 1949 and 1955 with moderate survival in 1952 and somewhat smaller year-classes in 1953 and 1956 (Fig. 4). Other year-classes between 1949 and 1963 were either complete failures or very small. During 1954–58, the 1949 year-class to a large degree and the 1952 and 1953 year-classes to a

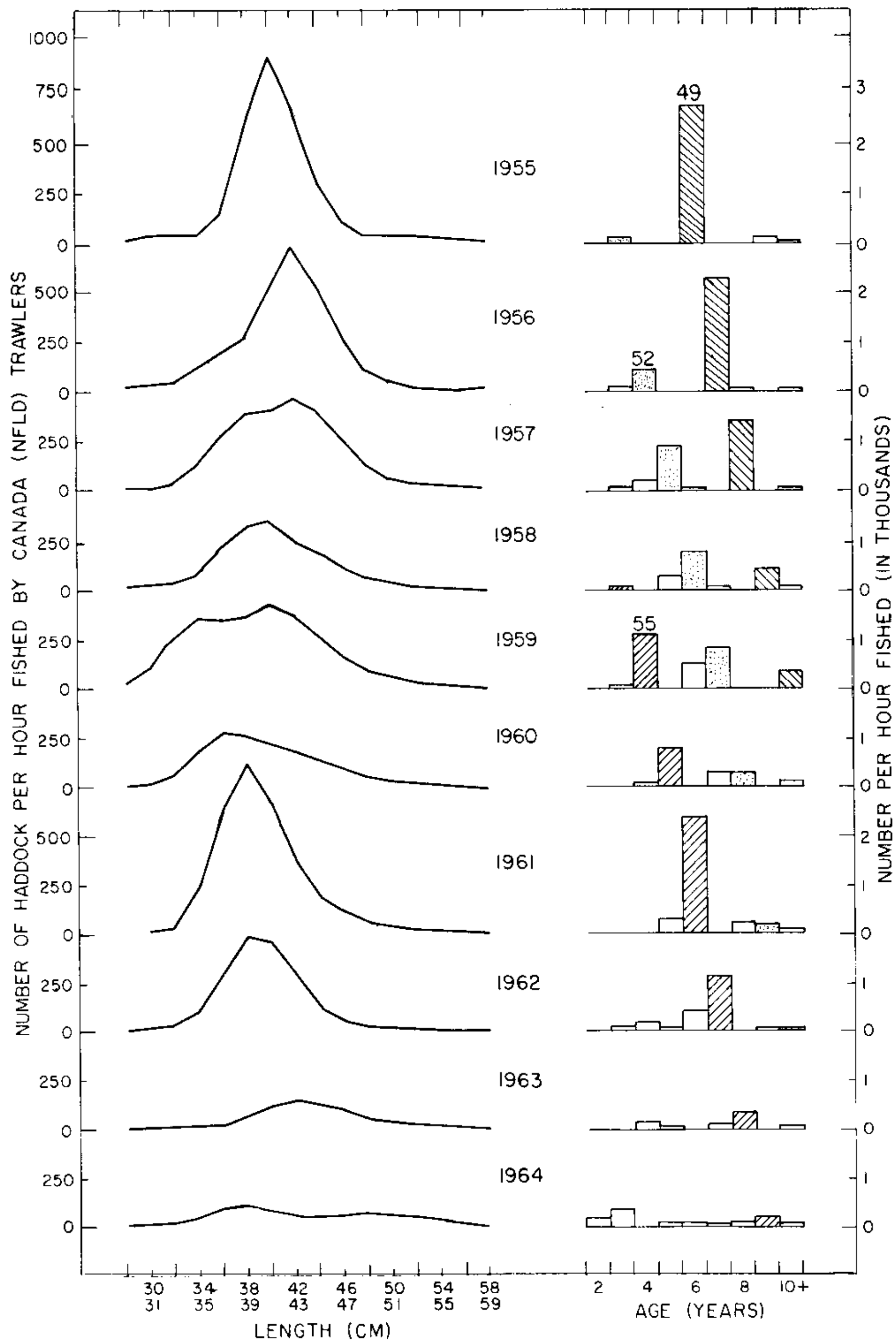

Fig. 4. Relative abundance of length and age groups of haddock in the landings of Canadian (Nfld.) trawlers from the Grand Bank (Divisions 3N–O) during 1955–64.

lesser extent were dominant in the landings. In 1959, while these older year-classes formed a significant part of the landings by weight the 1955 year-class showed up in abundance in the commercial landings for the first time and this year-class continued to dominate in the samples up to 1963. While samples from commercial landings are not suitable for predicting the success or failure of the more recent year-classes, research vessel surveys, using codends lined with 25-mm nylon netting, have particularly since 1961 confirmed the rapid decrease in abundance of commercial-sized haddock as well as the poor survival of recent year-classes up to 1964 (Templeman, 1965*a*).

Mortality Estimates

The natural logarithms of the numbers per hour fished (of Fig. 4) for the significant year-

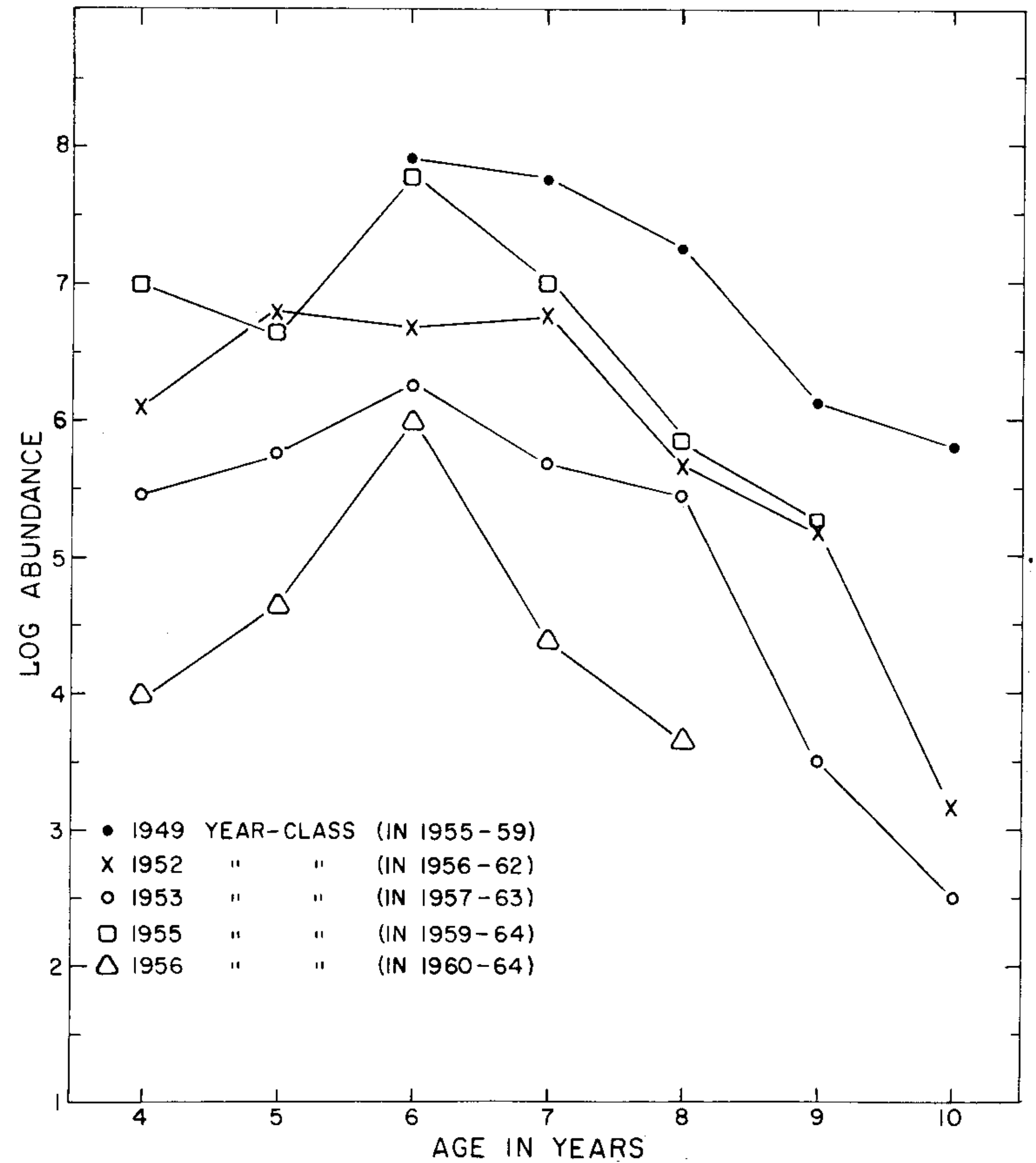

Fig. 5. Plots of relative abundance against age (up to age 10) for the significant year-classes of haddock in the landings of Canadian (Nfld.) trawlers from the Grand Bank during 1955–64.

classes are plotted against age in Fig. 5. The peaks of the curves occur at age six and recruitment is considered to be essentially complete at this age although trawl selection may have been incomplete for the smaller sizes of fish in this age group and some discarding at sea may have occurred. Although there is some deviation from linearity in the relative abundance of successive age groups (ages 6–10) of the year-classes, the data show a rapid decrease in abundance with age. While a total mortality coefficient (Z) of 0.75 is estimated from the decrease in abundance of the 1949 year-class between 1956 and 1959 (ages 7–10), values of between 0.9 and 1.0 are obtained for the more recent year-classes. Unfortunately the data are not adequate to provide a sufficiently reliable separation of Z into its natural and fishing components.

Discussion

There is no doubt that the haddock fishery in Subarea 3 has entered a period when yields from the stocks must remain at a relatively low level for the next few years or until such a time as year-classes undergo a much higher degree of survival than has been the case since 1955. While annual landings have fluctuated greatly during the short 20-year history of the fishery, year-class survival has fluctuated much more severely. Considerable differences in year-class survival occur in all haddock stocks of the Northwest Atlantic (Walford, 1938; Hennemuth *et al.*, 1964), but these variations seem to be much more extreme in the northern than in the southern parts of the range of haddock in the ICNAF Area.

The problems of determining the causes of fluctuations in year-class survival are extremely complex. The many factors that could conceivably affect brood production and survival make the formulation of theories about the causes of fluctuations extremely difficult. Although many workers in the field of fishery science have attempted to relate brood strength to such factors as water temperature, currents, wind drift, etc., during the early pelagic phase of development, it is not surprising that no real clear-cut relationships have evolved. Much of the difficulty lies in the absence of suitable data on the various causative factors concurrent with data on the time and duration of spawning, the distribution of eggs and larvae and the subsequent settling of young fish on the bank plateaus and slopes. It is obvious that the acquisition of such data would require for any one stock the use of much research vessel time and man-power resources spread over a long period of years; and, even if the actual basic causes were determined, it is unlikely that much, if anything, could be done to improve the situation. Lacking the necessary resources to conduct such widespread and long-term explorations, one must resort to speculation in the light of generally-known environmental conditions.

In the Georges Bank area Walford (1938) has demonstrated the importance of currents in the widespread dispersion of haddock eggs and larvae during the several months between spawning and the settling to the bottom of juvenile haddock. In the North Sea the importance of wind drift in the movement of the upper layers of water containing haddock eggs and larvae was shown by Carruthers *et al.* (1951). Templeman (1955) observes that all the haddock populations of the Northwest Atlantic live and spawn on the northern edge of the Gulf Stream. Large eddies are known to exist between the Gulf Stream and the slopes of the banks on which haddock spawn. In certain years these eddies may during the pelagic phase of haddock development result in the relocation over oceanic depths of water masses containing the young fish. Inevitably, when several months after hatching these young haddock seek the bottom to take up a bottom-feeding existence, they must perish if they are not over bank or slope areas of less than perhaps 150 fathoms (274 m).

Haddock of the Grand Bank in Subarea 3 spend the winter and spawn on the southwest slope of the bank. It is only necessary for the water mass containing the eggs and larvae to shift a few miles to the southwest before oceanic depths are encountered. However, if the water currents are such that the water layers containing the young pelagic haddock drift northward and by settling time are located over the northern half of the Grand Bank, unfavourable temperatures may limit survival. May (1965) notes that fluctuations in year-class survival of haddock on the southern Grand Bank generally correspond with the fluctuations in year-class survival of cod (the 1949 and 1955 year-classes of both haddock and cod were the most successful of all year-classes in recent years), but the variations in cod survival are much less extreme than for haddock, due probably to recruitment of young cod from northern areas. Since cod and haddock of the southern Grand Bank spawn in approximately the same areas and at about the same time (May–June), it is not unreasonable to assume that the same factors whcih affect the survival of haddock probably also affect survival of cod in the area.

It has been often asserted that the size of the spawning population is of little or no importance in the production of good or poor year-classes. This may be true for certain stocks to which recruitment is relatively stable from one spawning to the next. However, with the almost complete loss of frequent year-classes before settling, it may well be important that Grand Bank haddock should spawn in as great a quantity as possible and especially over as wide an area as possible. In view of the lack of sufficient production of recruits to the haddock fishery of the southern Grand Bank since 1955–56, Templeman (1965*b*) wonders whether it is not dangerous to reduce the mature population of a species beyond a certain size, especially at the northern and southern outposts of a species. While a large spawning stock of haddock does not guarantee the production of good year-classes regularly, it would seem obvious that the chances of obtaining some good year-classes are much better when the spawning population is large.

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Data on the Distribution of Young *Sebastes mentella* Tr. in the Labrador-Newfoundland Area

BY G. I. TOKAREVA[1]

Abstract

From January to April 1964, in ICNAF Divisions 2J, 3K, 3L, 3M, 3O, and 3P, i.e. in the areas of distribution of the main local stocks of *Sebastes mentella* Tr., investigations revealed some distribution patterns of the immature portion of these stocks.

In the northern areas (Div. 3K and 3L), the "young" redfish, 6–15 cm long, were dominant at 200–250 m and a water temperature of 2°C. The "small" redfish, more than 15 cm long, were found at greater depths and at higher temperatures (+3°C).

On the south slope of the Newfoundland Bank (3O) and Saint Pierre Bank (3P), immature redfish were distributed, as a rule, at lesser depths than the large fish, but not so regularly as in northern areas.

Temperatures were similar at all depths in the Flemish Cap area (3M) and the relationship between depth and distribution of the young was not observed there. It is suggested that the temperature should be considered as an indicator of water masses of different origin and that the distribution of redfish is closely connected with the different water masses. The grown redfish descend deeper to more than 300m, where the Atlantic Current water predominates and has optimum near-bottom temperatures for spawning.

Redfish of the northern areas develop at lower temperatures, and they become mature considerably later (at 10 years of age), than in the southern areas (at 6–7 years of age).

Redfish which mature late have a longer life span and spend more time in the fishery.

From January to April 1964, in ICNAF Div. 2J, 3K, 3L, 3M, 3O, and 3P, i.e. in the areas of distribution of the main local stocks of *Sebastes mentella* Tr., several investigations were undertaken which revealed some distribution patterns of the immature portion of these stocks. The material obtained should serve as a basis for the rational fishing of redfish. Redfish more than 12 cm long *were identified* as to species from the distinguishing adult characteristics. Specimens less than 12 cm long, which were found in catches in small numbers, were identified as *S. mentella* Tr.; as that yield consisted mainly of adult specimens of *S. mentella* (more than 80% in comparison with *S. marinus*) throughout the areas investigated and in all seasons of the year.

As is known, in the northern Div. 2J, 3K, 3L, and in the southern Div. 3O, 3P, and 3M, redfish do not mature at the same time. Therefore, to have an idea of the part of the redfish stock to be considered "immature", it was necessary to determine the length and age of specimens at first maturity in each of the above mentioned divisions during autumn, winter, and spring of 1959–62. The maturity of specimens was determined by using a scale developed by Sorokin (1958). The "immature" part of the stock consisted of specimens at Sorokin's maturity stages I and II. The "mature" portion of the stock consisted of specimens at Sorokin's maturity stages III and higher.

It was found (Table 1 and 2) that, in the south Labrador area (Div. 2J) in the most northern region of our investigations, the males apparently mature at a length of 26 cm, being mainly 8-years old. When 35 cm long and 13-years old 82% of the males are mature.

Females also begin maturing at 8 years of age, but only 5% are mature at a length of 27 cm, while 60% are mature at 13 years of age.

To the south of Labrador, the length and age of both males and females at first maturity decreases. Thus, in Div. 3O (southern slope of the Newfoundland Bank) the males begin to mature at 6 years of age being 21–22 cm long (25%). By 11 years of age, all the males 30 cm long have become mature. Females also mature by 6 years of age but in fewer numbers (9%) and at greater lengths, 23–24 cm. Females become mature at 31 cm.

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In the Flemish Cap area (Div. 3M) males begin maturing at 6 years of age, but in fewer numbers than in Div. 3O. At 14 years of age, 95% of the males are mature. Females mature at 7 years at a length of 23 cm. At 14 years of age 88% of the females are mature.

Thus, the immature portion of the northern local stock, apparently, consists of males and females up to 10 years of age with lengths to 30 cm. In the Flemish Cap area (3M), the immature portion consists of males and females with lengths to 25 cm and ages to 7 years, while on the southwestern slope of the Newfoundland Bank (3O) and the Saint Pierre Bank (3P) which the southern local stock inhabits, the males and females with a length of up to 20 cm and at the age of up to 6 years form the immature portion.

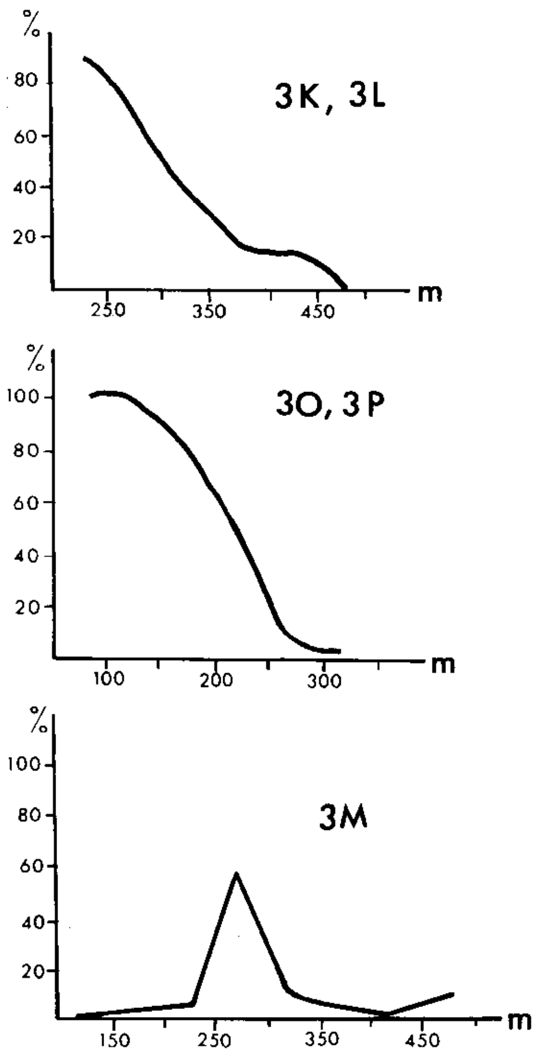

Fig. 1. Number of immature redfish in catches (percentage of mature fish) at different depths, January–March, 1964.

Furthermore, by analogy with the Barents Sea, we have called, "the young", the redfish specimens with lengths to 15 cm, while specimens of 16–30 cm in the northern areas and 20–25 cm in the southern areas were called "small redfish".

The investigations have demonstrated that in the northern (3K and 3L) and southern (3O and 3P) Divisions, the number of immature redfish decreases in catches with depth (Fig. 1, Table 3). In the north (3K and 3L) the richest catches of these redfish took place at depths to 300 m and in the south (3O and 3P) at depths to 200 m. In the Flemish Cap area, however, the bulk of immature redfish were at 250–300 m. At all depths below or above this level, they were found in very small numbers. Because, in the northern areas, fishing for *S. mentella* Tr. during the January to March period is carried out at depths greater than 350 m, it follows from Fig. 1 that the by-catch of immature fish does not exceed 20%. In the Flemish Cap area, the main fishing for redfish is conducted during the same period at 250–400 m, i.e. in the places of greatest concentrations of young redfish (Fig. 1) which, undoubtedly, is bound to tell on the level of their stocks.

A more detailed examination of the data on the distribution of immature redfish by depths according to length of fish is of great interest.

Since the size range of immature redfish was very great, the young and small-sized redfish in the catches were combined into size groups with a class interval of 5 cm. Such a division, to a considerable extent, simplified the analysis of the available data.

Table 3 shows that young fish of 6–15 cm length in the northern divisions (3K and 3L) predominated at depths of 200–250 m at water temperatures of 2°C. The small-sized fish more than 15 cm long were found at greater depths and at higher temperatures (+3°C).

On the south slope of the Newfoundland Bank (3O) and Saint Pierre Bank (3P) the immature redfish were distributed, as a rule, at lesser depths than the large fish (Table 3). However, the attachment of the immature redfish to the definite depths depending on their size, as noted in the northern areas, was not observed here.

In the Flemish Cap area (3M) no correlation was observed between the distribution of immature redfish of different sizes and the depths they occupied (Table 3). The temperature at all depths during the period of our investigations was 3.8°C.

Thus, in all of the areas examined, except Flemish Cap Bank, it was possible to trace a definite trend towards a reduction of the quantity of immature redfish with the increase of depth. Also, in the northern areas, there was noted a direct correlation between the distribution of young and small-sized redfish of different lengths and the depths and temperatures.

Similar distribution of redfish was observed in 1963 (Table 4).

But the bottom temperature at different depths changes with years (Table 3 and 4),

TABLE 1. Percentage number of mature *S. mentella* Tr. of different sizes in autumn, winter, and spring of 1959–62.

Div.	Sex	Length (cm) 21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
2J	♂						20	30	40	50	55	54	60	64	66	82
	♀							5	20	31	37	42	42	50	54	60
3K	♂					9	15	20	50	68	70	78	80	84	87	94
3L	♀						13	18	30	60	63	66	70	73	78	89
3M	♂		2		15	37	40	50	48	55	64	82	87	90	93	95
	♀			10				37	36	49	57	76	80	88	87	88
3O	♂	20	25	50	76	80	88	90	95	93	100					
	♀		9	30	40	56	63	90	93	95	97	100				

TABLE 2. Percentage number of mature *S. mentella* Tr. by age (size from 21 to 35 cm).

Div.	Sex	Age (years) 6	7	8	9	10	11	12	13	14
2J	♂			25	45	55	58	64	76	
	♀			5	25	39	42	53	60	
3K	♂		9	24	47	70	79	84	90	
3L	♀			15	30	40	70	76	89	
3M	♂	2	15	38	49	59	82	88	93	95
	♀		10		36	53	78	88	87	88
3O	♂	16	63	86	90	94	100			
	♀	9	35	59	90	95	97	100		

while the distribution of redfish by depths in relation to the size of fish remains steady annually. In this connection the temperature apparently should be considered not in its absolute meaning, but as an indicator of water masses of different origin. All the plankton and benthos organisms which serve as food for the redfish of the Labrador-Newfoundland area are

TABLE 3. Mean catch of immature *S. mentella* Tr. (specimens per hour of hauling) by ICNAF Divisions, January–April, 1964 (Data from VNIRO).

Depth	No. of hauls	Near bottom temperature	Percentage of young and small redfish in catches			Length-groups (cm)					Mean catch of specimens per hour of hauling
						6–10	11–15	16–20	21–25	26–30	
m		°C		♂	♀						
					Division 3K						
200–250	4	2.0	79.5	60	40	4.5	20.0	10.0	6.5	4.0	9.0
250–300	8	3.0	79.5	58	42	3.6	6.2	21.7	30.5	14.7	15.3
300–350	13	3.2	38.0	52	48	3.0	1.0	4.3	32.0	157.5	12.1
400–500	5	3.5	—			—	—	—	—	—	—
					Division 3L						
190–200	5	−1.0–2.1	100	72	28	1.3	2.0	1.3	0.3	0.3	1.0
200–250	5	1.3–3.4	100	62	38	0.6	3.6	5.6	7.6	1.3	3.7
250–300	10	0.5–3.1	66.0	68	32	0.3	0.6	18.3	24.1	18.1	12.3
300–350	6	0.8–3.4	34.0	66	34	—	—	2.6	30.0	22.0	10.6
350–400	3	3.1	20.0	64	36	—	—	—	5.0	23.0	5.0
400–420	4	3.2	14.0	58	42	—	—	—	7.9	28.0	7.2
					Division 3M						
100–150	2	3.9	0.9			—	—	—	3.0	—	0.7
150–200	3	3.8	—			—	—	—	—	—	—
200–250	5	3.7	1.5	61	39	—	1.4	1.6	1.0	—	1.0
250–300	5	3.2–4.5	60.0	59	41	—	3.7	23.2	49.2	—	19.0
300–350	7	3.7	10.0	70	30	—	3.6	12.4	2.0	—	4.5
350–400	3	3.9	2.0	100	—	—	—	—	1.0	—	0.2
400–450	3	3.8	0.5	60	40	—	—	0.2	1.2	—	0.3
450–600	9	—	5.0	60	40	—	—	7.5	11.5	—	4.7
					Division 3P						
50–100	5	−0.2–1.0	—	—	—	—	—	—	—	—	—
100–150	5	−0.4–1.0	100	ju		1.0	0.4	0.6			0.7
150–200	5	0.2–2.3	80.0	56	44	3.0	31.0	100.5			44.8
200–250	2	3.0	45.0	72	28	2.5	26.5	36.0			21.6
250–300	3	−1.2–1.7	10.0	100	—	—	3.3	2.7			2.0
350–400	3	3.8	—	—	—	—	—	—			—
					Division 3O						
50–100	14	0.1	100	89	11	—	1.2	0.8			0.6
100–150	4	0.8	100	ju		1.0	1.0	—			0.7
150–200	4	1.0	84	55	45	210.0	516.0	735.5			486.5
200–250	3	1.3	—	—	—	—	—	—			—
250–300	2	1.8	1.0	100	—	—	3.0	3.0			2.0
300–350	2	3.2	1.0	83	17	—	6.0	12.0			6.0

TABLE 4. Mean numbers of immature *S. mentella* Tr. per hour of hauling by ICNAF Divisions, December 1962–March, 1963.

Depth	No. of hauls	Near bottom temperatures	Length-groups (cm) 6–10	11–15	16–20	21–25	26–30	Mean catch of specimens per hour of hauling
m		°C						
				Division 3K				
200–250	1	1.0	18.0	29.0		6.0	2.0	14.4
250–300	2	2.4	—	—	17.0	—	0.5	0.1
300–350	3	2.7	—	0.3	1.1	17.6	14.3	6.6
400–500	—	—	—	—	—	—	—	—
				Division 3L				
200	1	-0.1		0.3	—	—	—	0.6
200–250	1	0.5	—	—	4.0	1.0	3.0	1.6
250–300	2	1.5	—	—	7.5	8.5	15.0	6.2
300–350	1	3.8	—	—	—	7.0	44.0	10.2
350–400	2	3.8	—	—	0.5	0.5	4.0	1.0
				Division 3M				
200–250	1	3.9	—	17.0	4.0	2.0	—	5.7
250–300	2	3.9	5.0	55.0	105.0	178.0	—	85.7
300–350	1	4.9	—	12.0	28.0	4.0	—	11.0
300–500	1	4.0	2.0	3.0	23.0	23.0	—	12.7
				Division 3P				
100–150	2	-0.2	182.0	116.0	16.0	—	—	103.0
150–200	2	3.5	112.0	9.5	0.5			
250–300	2	5.4	—	—	18.5			6.1
500–550	1	2.3	—	—	10.7			3.2
50–100	1	2.1	11.0	—	—			3.3
100–150	1	3.2	5.0	12.0	—			5.6
150–200	2	5.4	74.0	96.0	34.5			68.1
200–250	1	4.9	1.0	26.0	14.0			13.6
300–475	1	4.4	—	4.0	16.0			6.3

TABLE 5. Mean age of *S. mentella* Tr. in ICNAF Divisions in 1960–62.

Mean age in:	1960		1961		1962	
Div.	♂♂	♀♀	♂♂	♀♀	♂♂	♀♀
2J	—	—	15.0	16.8	13.2	1.6?
3K	14.1	16.1	14.3	17.7	14.6	17.7
3L	15.3	18.2	14.6	18.0	11.7	13.0
3M	13.2	14.2	11.9	13.6	12.5	14.0
3O	13.3	14.9	8.9	10.9	11.5	14.0
3P	10.4	11.4	9.7	10.4	8.0	10.2

N.B. Thus, from the redfish data, there is further evidence that the life span of fish and the period of their mortality by fishing is connected with their different maturity rates.

also very closely connected in their distribution with different water masses (Nesis, 1962; Semyonova, 1962).

The presence of Arctic and Atlantic water masses moving southward and forming a frontal zone in their interaction creates different living conditions for young redfish at different stages of their development. Therefore, the mass larvae extrusion takes place at the depths of more than 300–350 m in the near-bottom-water layers at temperatures of not less than 3°C which apparently owe their origin to the Atlantic Current. After extrusion the larvae ascend into the upper-cooler-water layers and drift until they settle at the fry stage. The largest concentrations of the smallest redfish (up to 15 cm) are also found in the lesser depths at lower temperatures (Table 3).

During the growing period, the young fish move to the frontal, most productive zone (Elizarov, 1963), where they stay for a long time (in the northern areas, apparently, even for 7–8 years; Table 3). Later the grown redfish descend to more than 300 m where the Atlantic Current water predominates with the near-bottom temperature optimal for their spawning.

In the northern areas, a considerable time interval elapses (up to 10 years) between the period of the settling of young fish when the redfish are more connected with the cold Labrador Current and their growth in the mixed waters and their spawning in the waters of the Atlantic origin. During this time the redfish of different ages and lengths are connected with definite depths in accordance with the character of the water masses.

On the south slope of the Newfoundland Bank (3O) and Saint Pierre Bank (3P) there is an interaction of waters of the polar and tropical origin; but the most important for the formation of the regime in that area is the last factor.

Here, the immature redfish, as in the north, are found in lesser depths; but the bulk of young and small-sized redfish was found there in the frontal zone at 150–200 m depth.

The effect of tropical waters at these depths is extremely great, the temperature in winter sometimes reaches 6–7°C.

Thus, the young fish of the southern stock, before recruitment, are under relatively homogeneous conditions. They are associated less with the Arctic waters than the young fish of the northern areas and are relatively less attached to definite depths.

Flemish Cap Bank has on its north, west, and east sides, the comparatively warm waters of the Atlantic Current. Its southern slopes are under the influence of the warm mixed waters. The hydrological regime here displays a higher consistency and no difference in the distribution of immature redfish with length was observed, as was the case in the northern area.

Thus, the redfish of the northern area develop under lower temperatures than on Flemish Cap Bank and in Div. 3O and 3P. They mature here considerably later (at 10 years of age), than in the south (at 6–7 years of age). The peculiarities of development to maturity of redfish in Div. 2J, 3K, 3L, 3O, 3P, and 3M apparently form one of the requisites for the formation of their local stocks. Also, because the redfish mature later in the northern areas, their life span increases which means that the redfish, apparently, will be available to the fishery for longer periods (Table 5).

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Methods of Direct Calculation of Fish Concentrations by Means of Hydroacoustic Apparatus

BY M. D. TRUSKANOV[1] AND M. N. SCHERBINO[1]

Abstract

The possibilities and results of application of a method of direct calculation of the number of commercial fish by means of hydroacoustic apparatuses are presented.

The method is considered in the following sequence: determination of parameters of hydrolocators, direct hydroacoustic survey of the commercial area, treatment of echograms, determination of the volume and of the density of fish concentrations, and analysis of errors.

Results of conducting such echometric surveys in different areas of the Barents and Norwegian Seas and recommendations for their use in different areas of the West and Northwest Atlantic are given.

Use of this method of calculating numbers of fish in commercial fish concentrations in fisheries investigations would allow more precise long- and short-term forecasts of the state of commercial stocks.

Every method is in the long run determined by a complex of means and facilities available to the investigator. New technical means of research, such as hydroacoustic fish detection techniques make it possible to work out the new methods. At present, various countries with developed oceanic fisheries have designed hydrolocation gear of high resolving power which provide a dependable means of fish detection at any fishable depth.

Since 1957, the authors have been engaged in developing a hydroacoustic method of determining the numbers of fish in both dense and dispersed concentrations. In 1961, the method was formally adopted for assessment of the state of the Atlanto-Scandian herring stock.

The hydroacoustic method of determining numerical strength of fish is a method of direct calculation of the number of fish in the shoal and is largely free from the defects of earlier methods of direct calculation of numerical strength which had one great disadvantage. They used data that only indirectly characterized the quantitative composition of a given stock. The accuracy of such methods depends on a great number of factors which very often cannot be quantitatively assessed.

The hydroacoustic method of determining fish abundance is a direct method allowing information to be obtained on the numerical strength of fish in a given area of the sea by means of hydrolocators and electronic apparatus.

Commercially important fishes are known to form concentrations of different density. The range of density varies widely from one specimen per hundreds and thousands of cubic meters of water to a score or two in one cubic meter.

Pelagic fishes as a rule form denser concentrations than bottom fishes. Generally the density of a fish concentration is inversely proportional to the size of the specimens making up the concentration. It is also known that the density of concentration of the various species of commercially important fishes depends on the season. Spawning shoals are almost always denser than feeding shoals, etc. Dense local concentrations are formed on the spawning or wintering grounds while the same number of specimens may become rather evenly distributed over a very large area of sea during the feeding period.

In this connection all echograms can be divided into two categories:

(a) echograms of scattered concentrations which permit visual calculation of the number of fish within the range of operation of the echo sounder (Fig. 1);

(b) echograms of dense concentrations which do not permit visual calculation of the number of fish within the range of operation of the echo sounder, although, in

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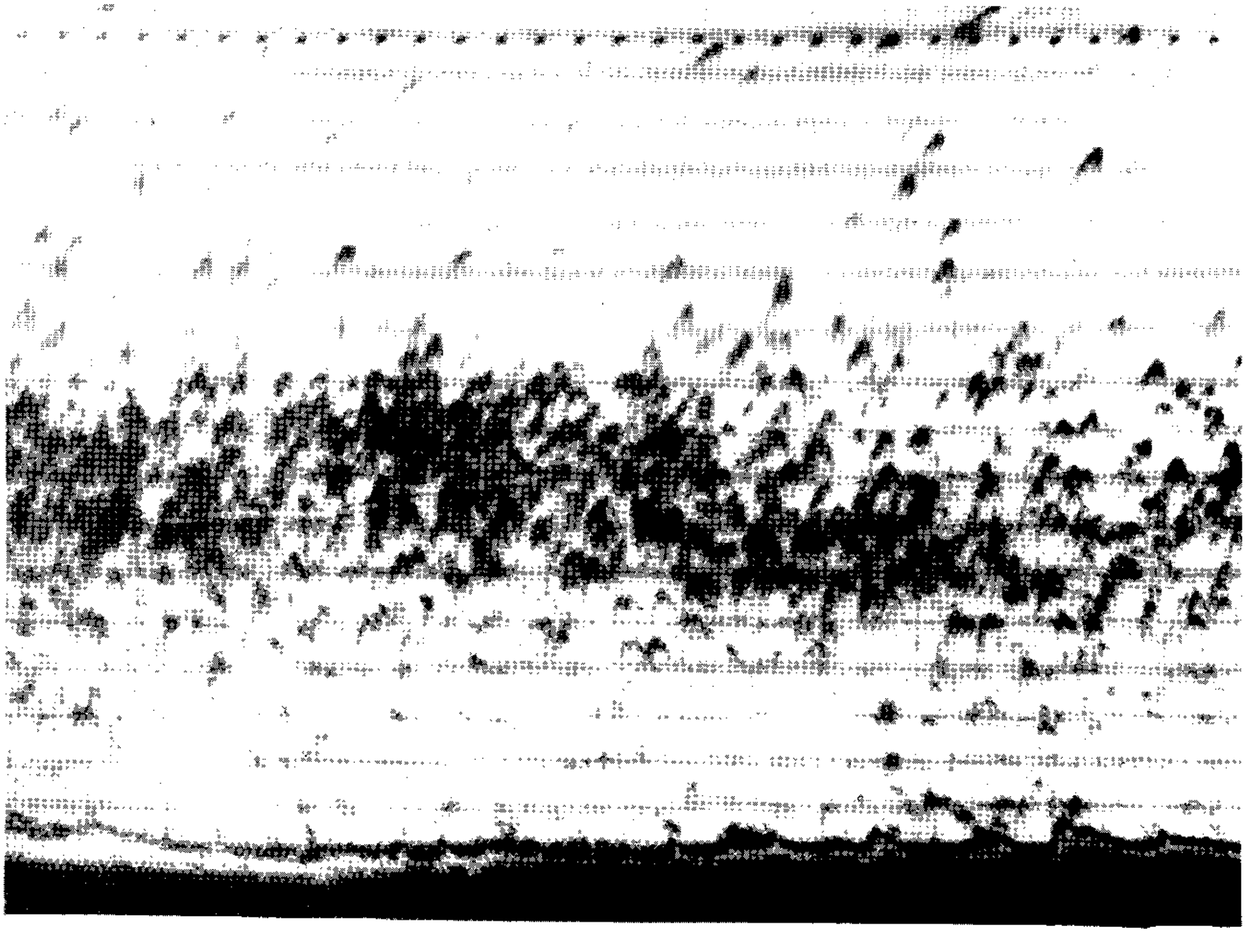


Fig. 1. Typical echotrace of dispersed cod concentrations.

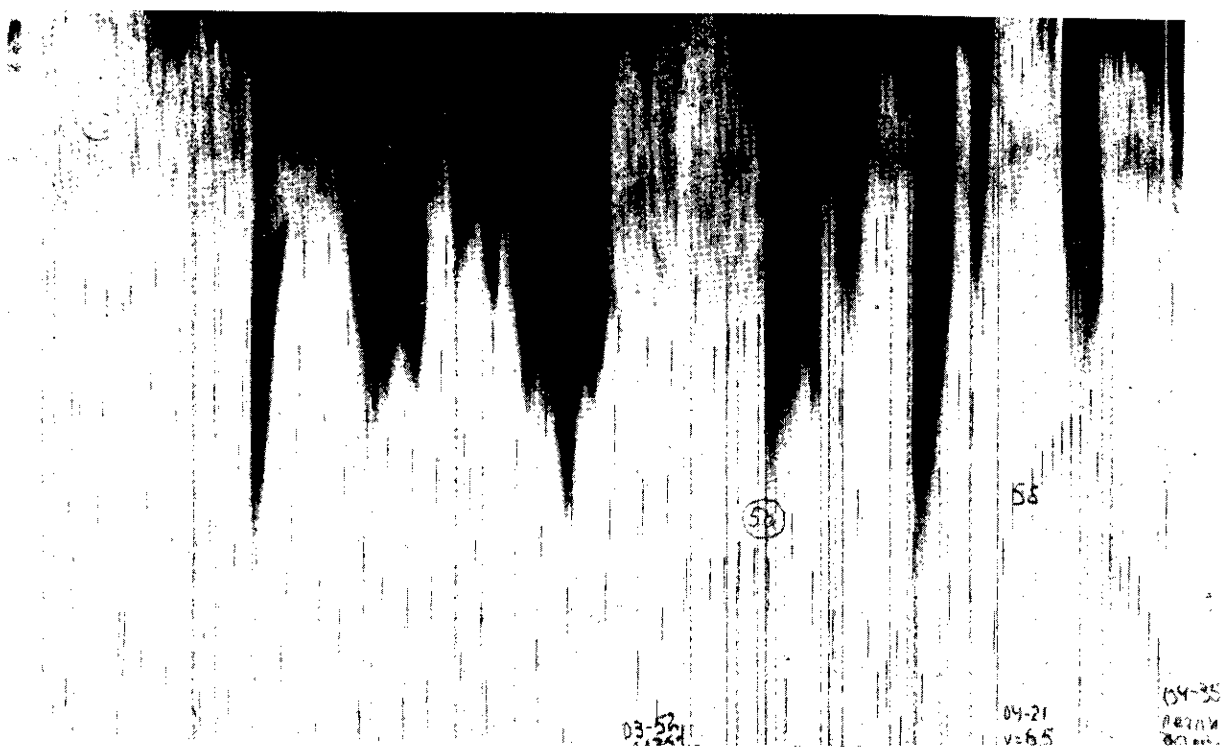


Fig. 2. Typical echotrace of dense concentrations of herring.

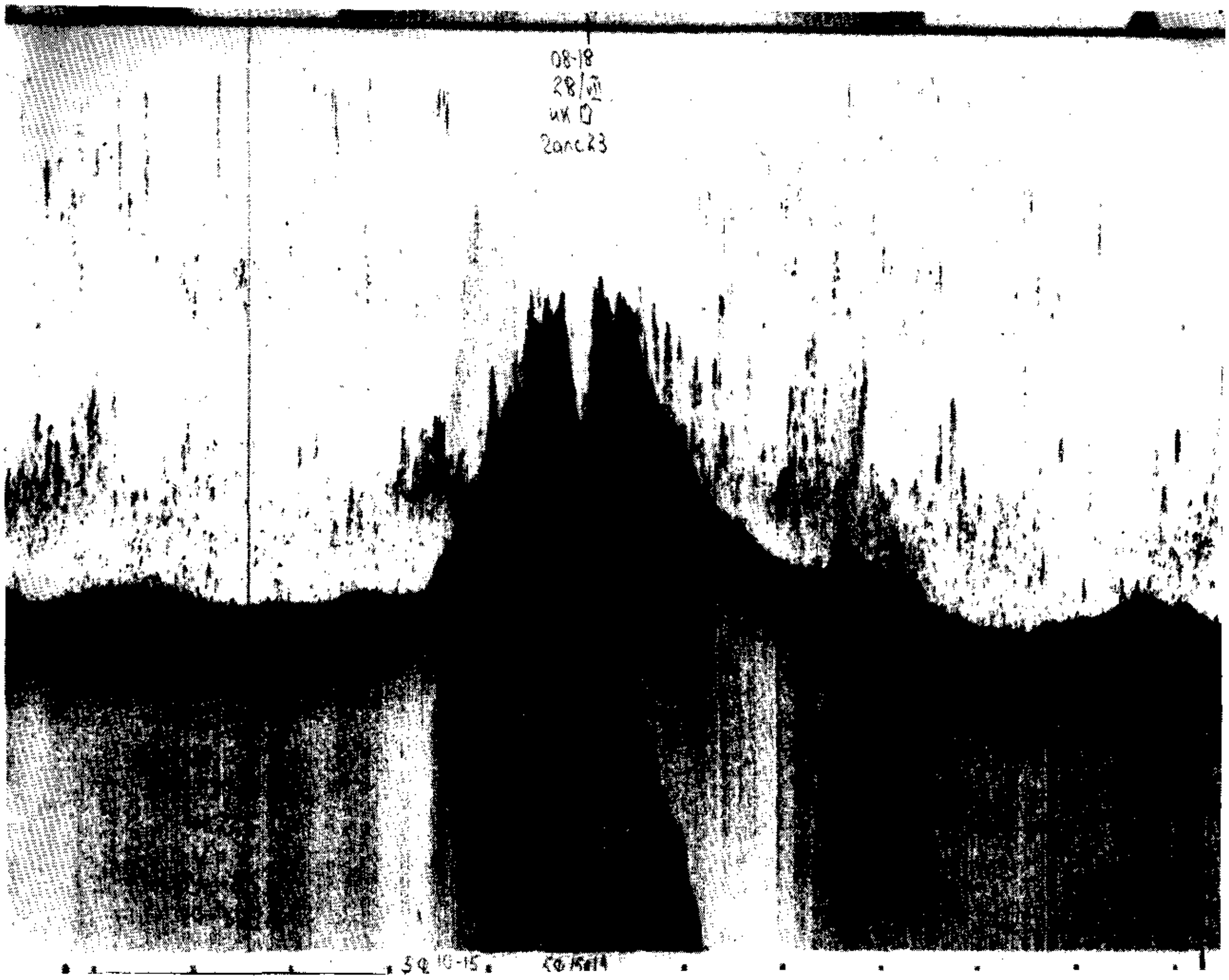
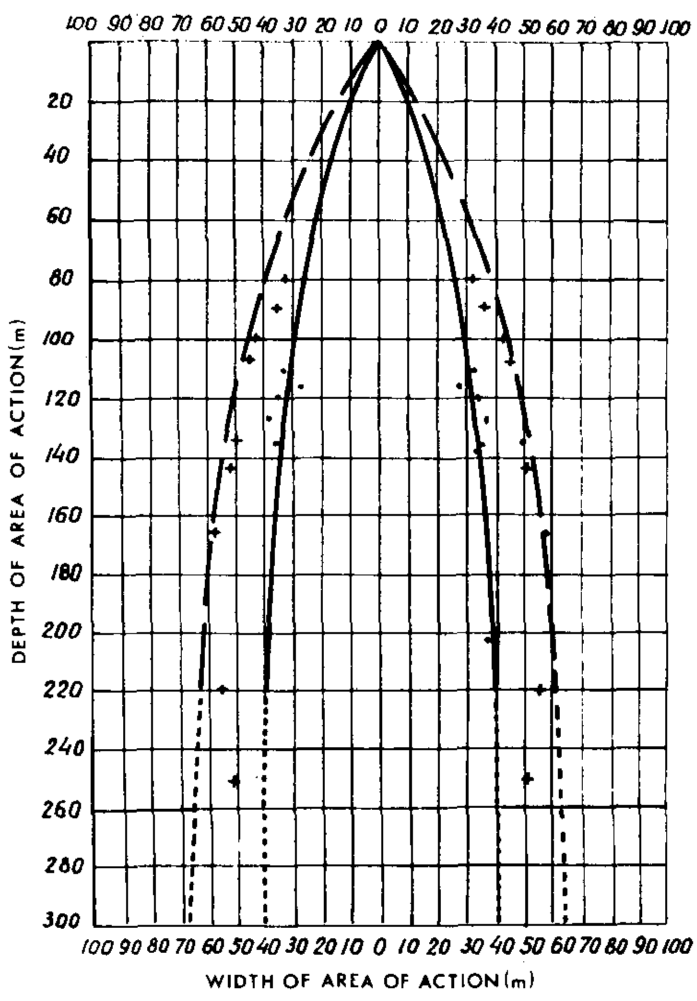


Fig. 3. Dense shoals in dispersed concentration.



● Points taken from the echograms when the larger side of the vibrator is turned toward the movement of the vessel.

+ Points taken from the echograms when the smaller side of the vibrator is turned toward the movement of the vessel.

— area of action along the vessel.

- - - area of action across the vessel.

Fig. 4. Range of action of the *Paltus*.

this case, the echo traces also provide some information on the number of dispersed objects, i.e. fish (Fig. 2).

Numerous commercially important species assemble in certain areas of the sea during certain periods in their lifetime and their concentrations may be patterned accurately enough by means of hydrolocators, i.e. it is possible, by means of echometric surveys, to calculate the number of fish in a shoal by assessing its size and density.

The authors used different methods of echo surveying depending on whether the various concentrations of species of commercial fish were dense or scattered. A short description of the different methods is given below.

Determination of the Number of Fish in Scattered Concentrations

Systematic observations using hydroacoustic and underwater apparatuses showed that bottom fish rising off the bottom scattered, making conditions favourable for calculating the number of fish. During this period, the density of fish is so low that a fish detection echo sounder can record individual specimens.

Sometimes, when a denser shoal is found in a scattered concentration (Fig. 3), it is necessary to use a high-frequency echo sounder, the working frequency of which is 150–200 kc/sec.

There are four stages in the method of calculation of the number of fish in scattered concentrations:

The first stage

Preliminary echo sounding is carried out to determine the range of operation of the echo sounder and its resolving power by distance and angle, as well as to ascertain the area of stock distribution. Control trawlings are conducted during the daytime and at nighttime to determine the number of fish off the bottom and the size composition of fish under investigation.

It is known that individual fish give distinctive marks (hyperbolae) on an echo sounder record. This occurs because as the vessel moves the fish pass into the sounder beam, change range and pass out again.

By analysing the recordings from individual fish specimens, it is possible to determine the effective width of the insonified layer. This is produced by the directionality of the transceiver system, but instead of a directivity plot, the width of the track swept by the sounder for a layer at any depth is required. Each echo sounder used requires a chart of its own such as that shown in Fig. 4 (Kiseljev, Truskanov, and Scherbino, 1962).

Resolving power of the apparatus is mainly characterized by the duration of the impulse and is calculated from the following formula:

$$S = \frac{c\tau}{2}$$

where S — resolving power (m)

τ — duration of the impulse (sec)

c — velocity of sound in water (1,500 m/sec).

Knowledge of the resolving power is required to judge the possibility of recording separate objects in a vertical plane.

Each vessel participating in echo surveying should have the effective width and the resolving power of its echo sounders determined.

The second stage

During the main echo survey, a recording of the whole concentration is made by means of the echo sounders installed on board the vessels. It is advisable to have two echo sounders, one with a working frequency of 25–30 kc/sec and the other, of 150–200 kc/sec. The area of distribution of each shoal is found from a grid of tracks covering the location of the shoal. Each track is ended 5–7 min after fish are no longer recorded by the echo sounder. All the tracks made by each vessel are then plotted on a detailed chart-board with a special mark at the beginning and at the end of recorded concentrations. By connecting all the beginning and the end points the pattern of the shoal is obtained. The area of the concentration is found on the chart-board by means of a planimeter.

The third stage

The echograms obtained are then treated and analysed. Knowing the width of the insonified arc of the echo sounder in deep waters near the upper and lower edges of the concentration, the course run by the vessel, and the number of fish per unit of the course traced by the echo sounder which were taken from the diagram of the area of operation of the echo sounder, it is possible to determine the density of the concentration by the formula:

$$\rho = \frac{N}{V}, \text{ where}$$

ρ — density of fish (number of fish/ m^3);

V — volume of water with fish (m^3);

N — number of fish.

Volume of water with fish, in turn, may be calculated as follows:

$$V = t.H.v \left(\frac{D_1+D_2}{2}\right), \quad \text{where}$$

v — speed of the vessel (m/sec);

t time (sec);

D_1+D_2 — width of insonified area (m) at upper and lower edges of the concentration;

H — thickness or vertical range of the concentration (m)

It is desirable to determine the density for each minute along the course. When these densities do not differ from each other, the intervals between the echo surveys can be longer (up to 2 min), with the speed of the vessel being from 6 to 8 knots.

The density values obtained are then plotted on a chart showing areas of equal density (Fig. 5). The size and volume of the areas are determined. From the density and volume for each area of concentration, the number of fish in a shoal can be determined by the following formula:

$$N_{total} = \Sigma V\rho = V_1\rho_1 + V_2\rho_2 + \ldots + V_n\rho_n,$$

where V_1, V_2, ...V_n — the volumes of areas of different density,

ρ_1, ρ_2, ... ρ_n — density of areas

The fourth stage

The analysis of errors is then made. When fish are close to the bottom, the calculations must be corrected for an obscuring effect of the bottom. If the ground is very rough and most of the fish of a scattered concentration keep close to the bottom, it is necessary to resort to special measures, e.g. to use different types of echo sounder selectors of bottom traces: "the white line", "differential chain", "fish filtre" types, etc. The electronic fish-tracer allows us to distinguish fish from the bottom and to record a quantitative estimation of the specimens.

The echo survey, conducted in the inshore area of the Barents Sea, in August 1962, can serve as an example. This echo survey was made in two stages. During the first stage, the area of work was investigated, the area of fish distribution was ascertained, control trawlings and experimental work such as underwater observations to determine the relation between the incoming signal and the number of haddock were conducted. Observations were made at depths from 100 to 180 m. Control trawlings showed that haddock about 30–35 cm were in this area. The second stage of the echo survey was aimed at determining the number of haddock in a limited area between the Bolshoy Oleny and Harlov Islands. A total of 27 tracks was made over an area, about 143.8 sq miles in size and 32 miles in extent.

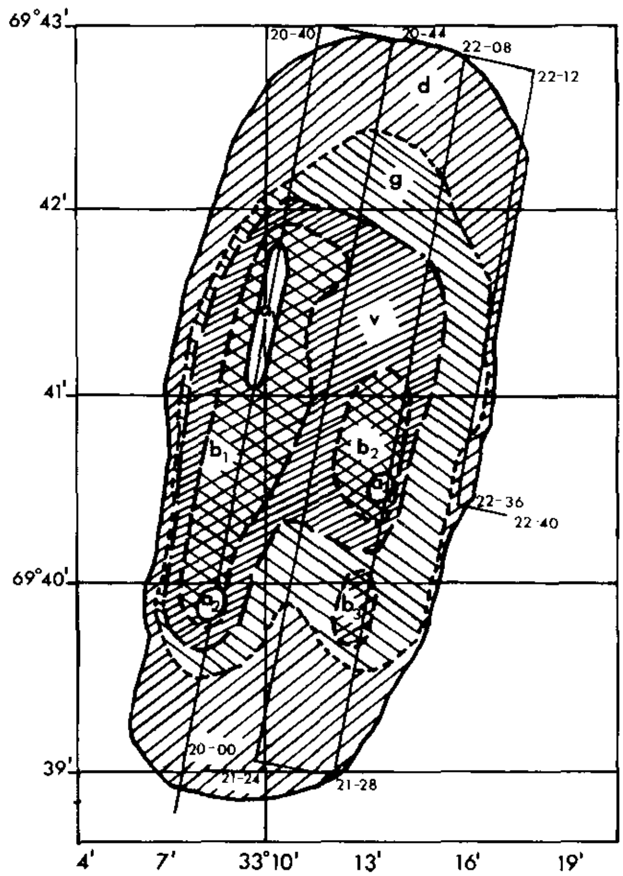


Fig. 5. Chart board of dispersed concentrations.

The extent of the concentration was determined with a "Lodar" hydrolocator (working frequency of 20 kc/sec) while the densities were determined with two echo sounders, "Atlas-658" (working frequency of 30 kc/sec) and "F-805" (working frequency of 200 kc/sec).

From the data obtained, it was calculated that there were 72.95×10^3 fish in the shoal. The area of 143.8 sq miles may be divided into several zones of different density. The first zone (the zone of the least density) was 74.5 sq miles, the second zone 53.2 sq miles, the third zone 9.4 sq miles and the fourth zone 6.7 sq miles. The density of fish in these zones was 0.8×10^{-5}, 1.6×10^{-5}, 3.8×10^{-5}, 26.8×10^{-5} specimens/m^3 respectively.

The high frequency echo sounder made it possible to record individual specimens in the shoal where the density was 40.0×10^{-5} to 60.0×10^{-5} specimens/m^3.

The electronic fish-tracer helped to give better records of specimens close to the bottom and better estimates of the near-bottom concentration.

The method of determination of the numerical strength of scattered concentrations was tested in different parts of the Barents Sea. Surveys were conducted on concentrations which, due to vertical migrations, were scattered throughout the depth of the water. As a result of 10 echo surveys, the numerical strength of separate local concentrations was defined. For example, the concentration in shallow waters near Murmansk numbered about 200,000 specimens of average-sized cod in the near-bottom layer. The maximum density was 3.2×10^{-5} specimens/m^3. The distance between specimens was 25–30 m.

Table 1 gives the data obtained during the surveys.

Determination of the Numerical Strength of Dense Concentrations

As a rule, prespawning and spawning shoals of pelagic fish form quite compact concentrations in a small area in comparison with the area occupied by the shoals of these fish during the other periods of their life. Such peculiarities in behaviour of pelagic fish is the main factor in determining the method which can be used to calculate the numerical strength of these concentrations by means of the echo surveying.

The method used in this survey includes five main stages:

First stage

A preliminary echo survey was conducted by a few vessels and covered an area larger than that occupied by concentrations of fish. Based on the results of this survey, it is possible to define the area of concentration and the sizes of fish shoals most characteristic for the period. At the same time a hydrographic survey of the investigated area is made from one of the vessels. The geometrical range of the hydrolocator apparatus may be calculated from hydrological data on the area surveyed.

TABLE 1. Density and numbers of cod, haddock, and redfish in local concentrations in the Barents Sea.

Concentration investigated	Density of fish (specimens/m^3) min	max	No. of individual fish in local concentrations
Small cod, shallow waters, Murmansk Area	0.20×10^{-5}	4.0×10^{-5}	39,100
Small haddock, inshore area	0.60×10^{-5}	50.0×10^{-5}	72,950
Average-size cod, Rybatchya Bank	0.20×10^{-5}	3.3×10^{-5}	102,300
Average-size cod, shallow waters, Murmansk Area	0.20×10^{-5}	3.2×10^{-5}	200,000
Large cod, Finmarken Bank	0.08×10^{-5}	1.2×10^{-5}	307,800
Large redfish, Rybatchya Bank	0.80×10^{-5}	5.5×10^{-5}	500,000

From the size of the sea area occupied by a shoal and from the given actual distance of the echo ranging, it is possible to calculate the required frequency of the echo tracks and the number of vessels needed for the survey.

The character of the shoals and their depth determine the working range and the optimum coefficient of the amplification of the echo sounder.

Second stage

The main echo survey of the fish concentration is carried out as quickly as possible, otherwise, undesirable changes in distribution of separate shoals within the main concentration may take place during the survey.

Vessels conducting the main survey should be equipped with the following apparatus:

(a) hydrolocator apparatus for determining the shoal in depth and horizontal range;

(b) echo sounder for obtaining vertical sections of the located shoals and for determining their depth and density;

(c) navigation equipment;

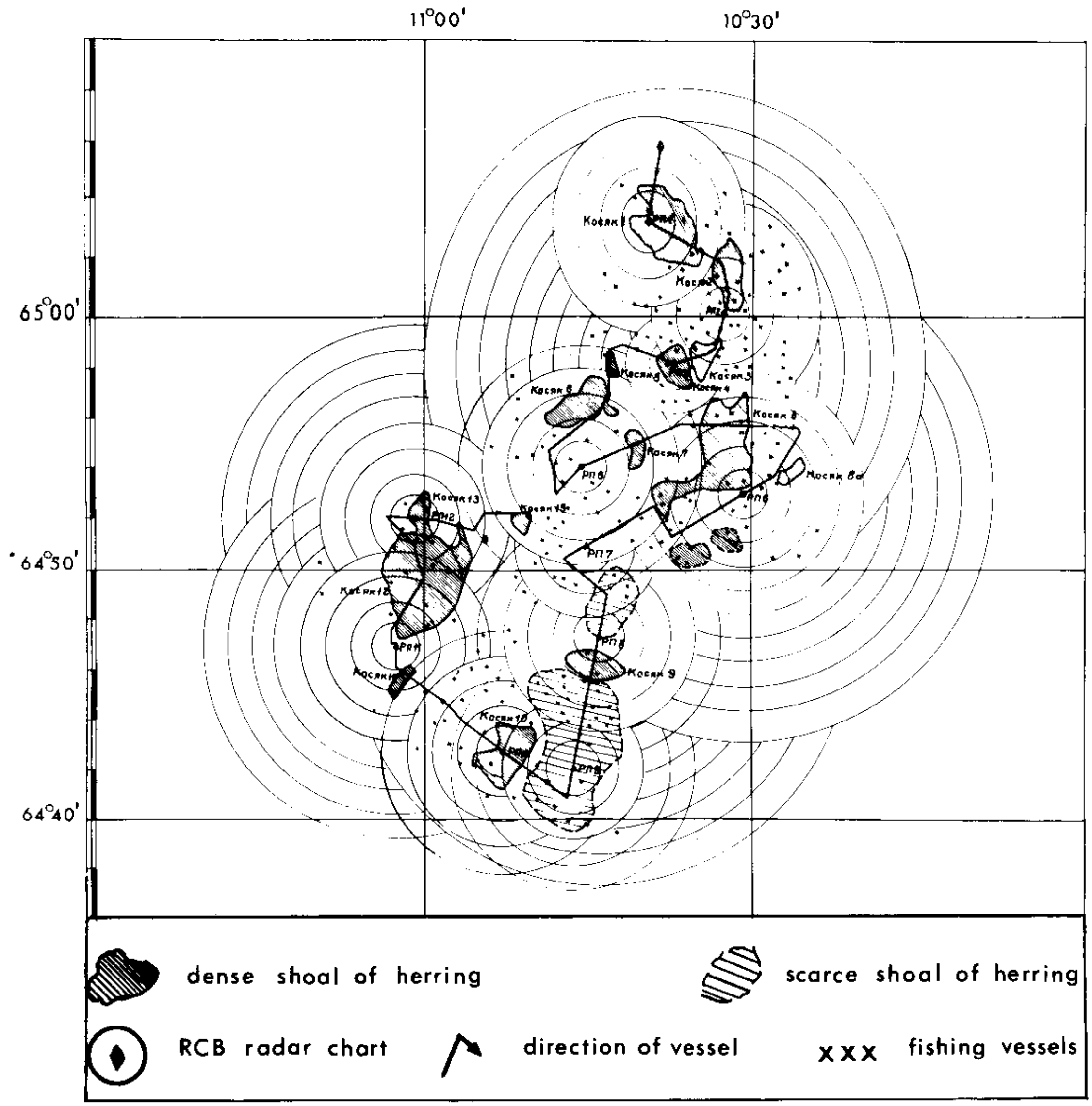


Fig. 6. Chart board of fish echo survey carried out by M. D. Truskanov, M. N. Scherbino, and D. E. Shatoba from BMRT-251 *Gogol* during the night of 9–10 December 1964.

(d) radar for additional orientation in making tracks and drawing radio-location charts of the position of fishing vessels in relation to the distribution of the shoal;

(e) automatic submarine camera or deep-water gear for observing the fish (hydrostate, submarine boat etc.).

The survey requires a high degree of navigational skill to gain the greatest accuracy for this method. Thus, a "Loran" or "Decca" receiver is also desirable.

When the main survey is completed a detailed chart-board with a grid of tracks is drawn up by each vessel, where all the shoals and their sizes, obtained by means of the hydrolocator and the echo sounder, are recorded. With the hydrolocator, it is possible to survey a zone of 3,000–4,000 m in width along the course of a vessel, and determine the horizontal range of each shoal thereby reducing considerably the number of tracks required and vessels participating in the surveys.

When a chart-board is drawn, the time serves as the main synchronous criterion. The size of separate shoals, as well as the total size of the concentration, are determined by means of the chart-board and the vertical sizes of the concentration are determined by the echo sounder (Fig. 6).

Third stage

The density of shoals, i.e. the number of fish per unit of volume, is then determined. Since the accuracy of determination of the density of schools is of great importance, the authors have worked out three different methods, to determine the number of fish per unit of volume, which supplement and define each other.

The first method to determine the absolute density is based on the combined use of an automatic underwater camera and a ship's stationary echo sounder. By calculating the number of fish in a still photograph and having estimated in advance the volume of water in which specimens are recorded, the density can be calculated with sufficient accuracy (Fig. 7).

In practice, this is done as follows: the underwater camera is lowered into the same layer occupied by shoals of different density and

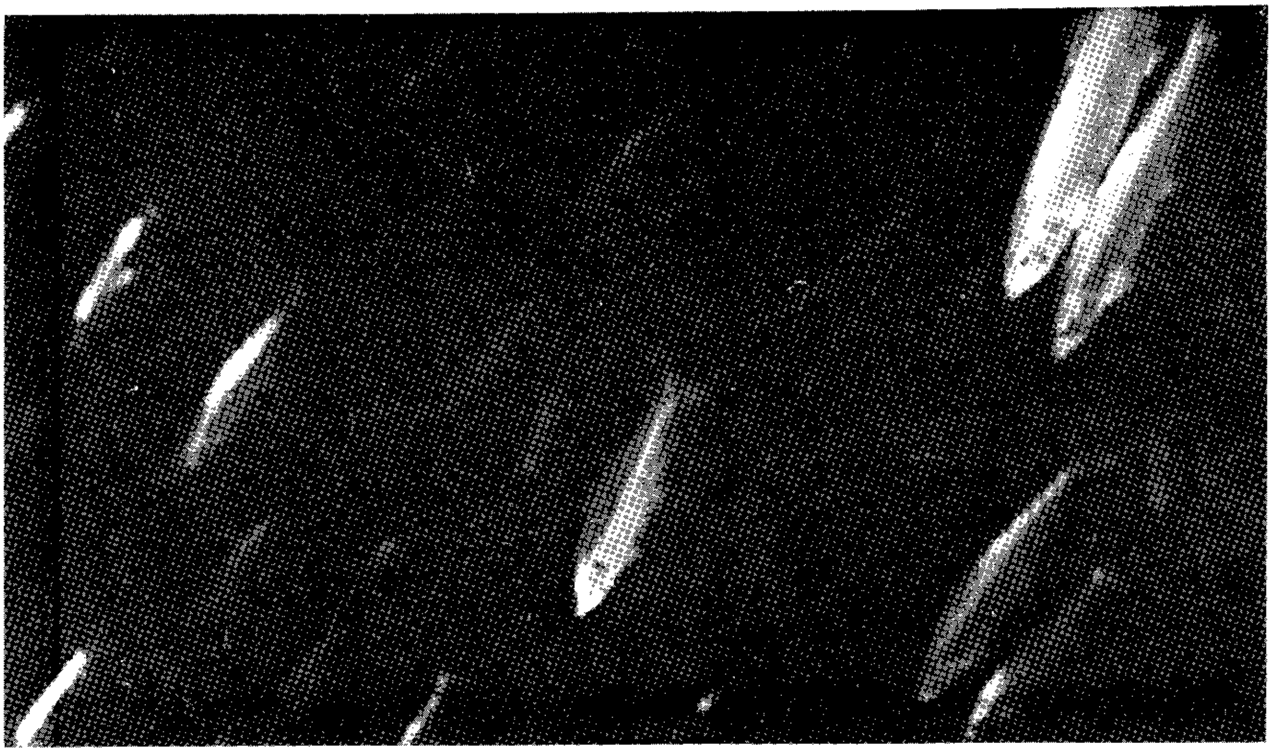


Fig. 7. Underwater photo of herring.

serves to measure the amount of re-echoing material from the shoal.

From the data so obtained the relation of the amplitude of the incoming echo received by the echo sounder amplifier to the density of the stock is determined.

The second method is based on placing the transciever system on the ship's echo sounder directly in the concentration of fish. This greatly improves the angular discrimination of the echo sounder, owing to the lesser number of objects within the operational range in comparison with the method of operation from the surface.

In practice, this is done by lowering the vibrator of an additional echo sounder, in a special installation or without it, directly into the mass of a shoal in different layers. This allows one to apply the method used for dispersed concentrations and to determine the density.

An additional echo sounder is operated simultaneously with the ship's stationary echo sounder equipped with an electronic fish-tracer. Their indices are used for determining the relation of the amplitude of the incoming echo received by an amplifier to the density of the concentration.

The third method is based on density determination by means of the echo sounder, calibrated in advance with standard equi-models that had been selected on the basis of experimental data derived from calculations.

In this case the degree of dispersion, the area of reflecting surface and the coefficient of fish reflection are taken into account. In density determinations, especially during the first echometric surveys, it is advisable to use the data obtained by all three above-mentioned methods. These data are used for calculating the relation of the value of the incoming signal to the density of fish concentration by means of the following formula:

$$U_{inc} = K\sqrt{\rho}$$

where U_{inc}—amplitude of the incoming echo received by the amplifier of the echo sounder (v) microvolts

ρ—density of fish concentration (numbers/m^3)

K —coefficient, the value of which depends on the beam pattern of the echo sounder and the aspect of the object of survey.

After determining the dependence of U_{inc} and ρ, it is possible to determine the density of the shoal, while taking tracks in every point of the concentration.

Fourth stage

This stage includes the treatment of the data obtained with sufficient accuracy. The detailed analysis of possible errors is made taking into account the accuracy of the angular echo ranging, errors in distance determination, errors made during the echo sounding and in determining the length of the shoal in following tracks by means of the echo sounder. Errors during navigation are taken into account.

The volume of each shoal located is calculated according to the size of shoals and their vertical range. Then a total volume of concentration is determined. The next stage is a precise treatment of the data along the following general line: horizontal and vertical sections of fish concentrations are plotted and the density values are entered after the corrections were made for navigation and instrumental errors. Then, zones of equal density are plotted and the size of each zone is calculated separately. Then the number of fish is determined in each zone, in the shoal and, finally, in the concentration as a whole. Size and age compositions of the concentrations are obtained from control trawlings. Finally, the number of fish is converted into weight units. This is a general outline of the sequence of operations of the hydroacoustic method of calculation of stock abundance in dense concentrations.

Figure 6 shows a chart-board of an echo survey of wintering Atlanto-Scandian herring in the East Icelandic Current (to the southeast of Iceland), which was conducted by the authors from BMRT *Gogol* in December 1964.

The survey began at lat 64°57'N; long 10°40'W and moved southward during the night (2130 hr) of 9–10 December 1964. A shoal was found 8 min after the vessel started to move. The size of this shoal was determined as the vessel moved along it. This shoal had the greatest density which at different points amounted to five specimens/m^3. Its size was 17.76×10^6m^2 and its volume was 3.53×10^9 m^3. Then, a second shoal was found and examined. As a result of 12 subsequent tracks, eight more shoals were found and examined. This stage of the work was followed by an hour passage, after that four more shoals were investigated. A large

TABLE 2. Results of echo surveys of Atlanto-Scandian herring in the waters of the East Icelandic Current southeast of Iceland in December of 1958 and 1961–64

Indices	1958 (31 Dec.)	1961 (12–13 Dec.)	1962 (18–19 Dec.)	1963 (13–14 Dec.)	1964 (9–10 Dec.)
Length of echo recording per unit of way (%)	85	53	50	32.5	80
Average thickness of concentrations (m)	70	85	107	114	116
Total size of concentration (km^2)	260	142	267.2	20.5	239.5
Total volume of concentration (km^3)	18.5	15.5	21.3	20.5	23.7
Density (specimens in 1,000 m^3)	950	450	680	785	1,166
Total stock of herring in millions of specimens	17,575	6,975	14,485	16,092	27,640
Average weight of one specimen (g)	344	359	196.5	202	246
Total stock of herring (thousands of centners) [a]	60,110	25,040	28,475	32,565	67,995

[a]Estimation of the total stock was made by summarizing the number of fish in each shoal in accordance with the method described. Values of the thickness, size and volume of the total shoal, which are given in the Table, characterize the total stock in the different years.

shoal was also found farther to the south and investigated by making five tracks. The extent of the shoal from north to south was about 6 miles. The average density of the shoal was about 1.27 specimen/m^3, size of shoal was 42.5 $\times 10^6$ m^2.

The results of echo surveys of wintering Atlanto-Scandian herring conducted by the authors during 1958 and 1961–64 using their methods are given in Table 2. The wintering stock represented the bulk of the Atlanto-Scandian herring spawning stock.

Conclusions

In conclusion, it is necessary to discuss in more detail the possibilities and prospects of this hydroacoustic method. While the other methods of direct determination of numerical strength are based on the theory of random sampling and are limited by the number of samples (possible number of experimental trawlings or purse seine hauls), the number of samples in the hydroacoustic method is very great (a few score per minute). This is because every impulse of the echo sounder is, in a sense, a sample by itself. In determining the density of a concentration by means of experimental trawlings, the result may depend on a large number of factors, e.g. on the selection of the area of the fishing, on the design and catching capacity of fishing gears, which, often, are not calculated. In the method described, it is possible to determine quite accurately the density and the limits of fish concentrations throughout the area they occupy. Based on the result of this work, it seems possible to determine the numerical strength of any concentration with no less degree of accuracy than 10–15%, if the number of vessels available is sufficient and, if the echo survey is carried out thoroughly.

As this method requires a synchronous survey, increase in the duration of the survey may result in errors that cannot be taken into account. The survey must be completed within 1 or 2 days.

The method does not require too much effort except for a rather complicated process of treatment of the data obtained. The process of collection and treatment of material in echo surveying has now been automated by the authors. A method of automation of the surveying of dispersed concentrations is also being developed.

Experimental echo surveying in the Barents and Norwegian Seas showed that this method can be successfully applied in determining the numerical strength of a number of pelagic and bottom fishes in different fishery basins. In particular, it would be possible to determine the numerical strength of herring or silver hake on Georges Bank in pre-spawning and spawning periods. The abundance of pre-spawning cod concentrations remaining in the pelagic layers in 200–400-m depths of Southwest Greenland from March to May could be calculated.

It would also be possible to calculate the numerical strength of pre-spawning cod concentrations in 300–500 m off North Labrador.

Introduction of hydroacoustic methods of calculating the abundance of commercial fish stocks can improve long-term and short-term forecasts of fish resources.

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Some Characteristics of Argentine, *Argentina silus* Ascanius, Occurring in the Region off Nova Scotia

BY FELIKS CHRZAN[1] AND CZESLAW ZUKOWSKI[1]

Introduction

During the trip of the research trawler M/T *Wieczno* some observations were made on argentine on the fishing grounds off Nova Scotia from Sable Island Bank to Browns Bank. In the period of our observations argentine were not found in large or dense concentrations but were a by-catch among other species. The only exception in this respect was on the deeper fishing ground in the region of Browns Bank, where the catch was almost 100% argentine. It is known that the largest concentrations of argentine appear in this region in autumn-winter seasons. They are exploited by commercial fisheries for their high nutritious value and for the market demand. Accordingly, our observations may be helpful in the biological characteristic of this species.

Material and Methods

This paper is based on material collected from 1 to 19 July 1964. The observations included investigation of the catch composition, catch per unit effort, measurements of total length, and determination of the age and maturity stage of gonads.

The samples and the number of fish measured from particular fishing grounds are given below.

Fishing ground	Argentine measured	Argentine analysed in detail
	no.	*no.*
Sable Island Bank	207	60
Emerald Bank—northwestern slopes	81	—
Sambro Bank	239	—
Browns Bank—120-m depth	1,154	103
Browns Bank—220-m depth	446	108

On Sable Island, Emerald, and Sambro Banks, bottom trawls were used with 100-mm mesh in the codend. On Browns Bank, trawls of 70-mm mesh in the codend were used. The average duration of haul was 2 hr. To determine the sexual maturity of the fish, Maier's scale of 8 degrees was used. The age of these fish was estimated from otoliths.

Fish Size on the Fishing Grounds

Figure 1 shows the length composition of the fish occurring on particular fishing grounds.

In the region of Sable Island Bank the catch was made from 100 to 460 m. In this catch 207 individuals were measured. The length composition of these fish varied considerably. The length ranged from 18 to 43 cm (average length 29.6 cm). The great range of fish length seems to have been the result of fishing at different depths.

Over the northwestern slopes of Emerald Bank rather slight variation of fish length (from 18 to 30 cm) was found. The average length of these fish was 23.3 cm and they were caught from 120 to 250 m.

On Sambro Bank, which has a more or less even bottom and depth of 260 m, the captured fish were 18–38 cm long. The length-frequency curve shows that most individuals were 21–25 cm long (average length 23.6 cm).

In the region of Browns Bank, catches were made on two fishing grounds, one at 120-m depth and the other at 220-m depth. The same type of trawl was used on both grounds. Nevertheless, the size of fish varied with depth. At 120 m the length of fish ranged from 15 to 28 cm with two peaks, which represent two different age-groups. The first peak represents the fish of 17–18-cm length, whereas, the second peak represents those of 21–23 cm length. The average length of fish accurring on this shallow ground was 20 cm.

In the catches made at 220 m, the fish were considerably larger (from 23 to 38 cm). The length-frequency curve shows one peak only. The average length of fish was 32.4 cm.

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Sexual Maturity

The results of investigations on the stage of maturity of gonads are shown in Table 1. The data show that the argentine were in I and II stages of maturity in the shallower fishing ground (120 m) of Browns Bank. In the deeper parts of this fishing ground (220 m) fish in stage I were not found and most of the fish were in stage II. Relatively large numbers of fish had their gonads in the stage VIII indicating that spawning had only recently occurred. Other stages of maturity were represented by single individuals.

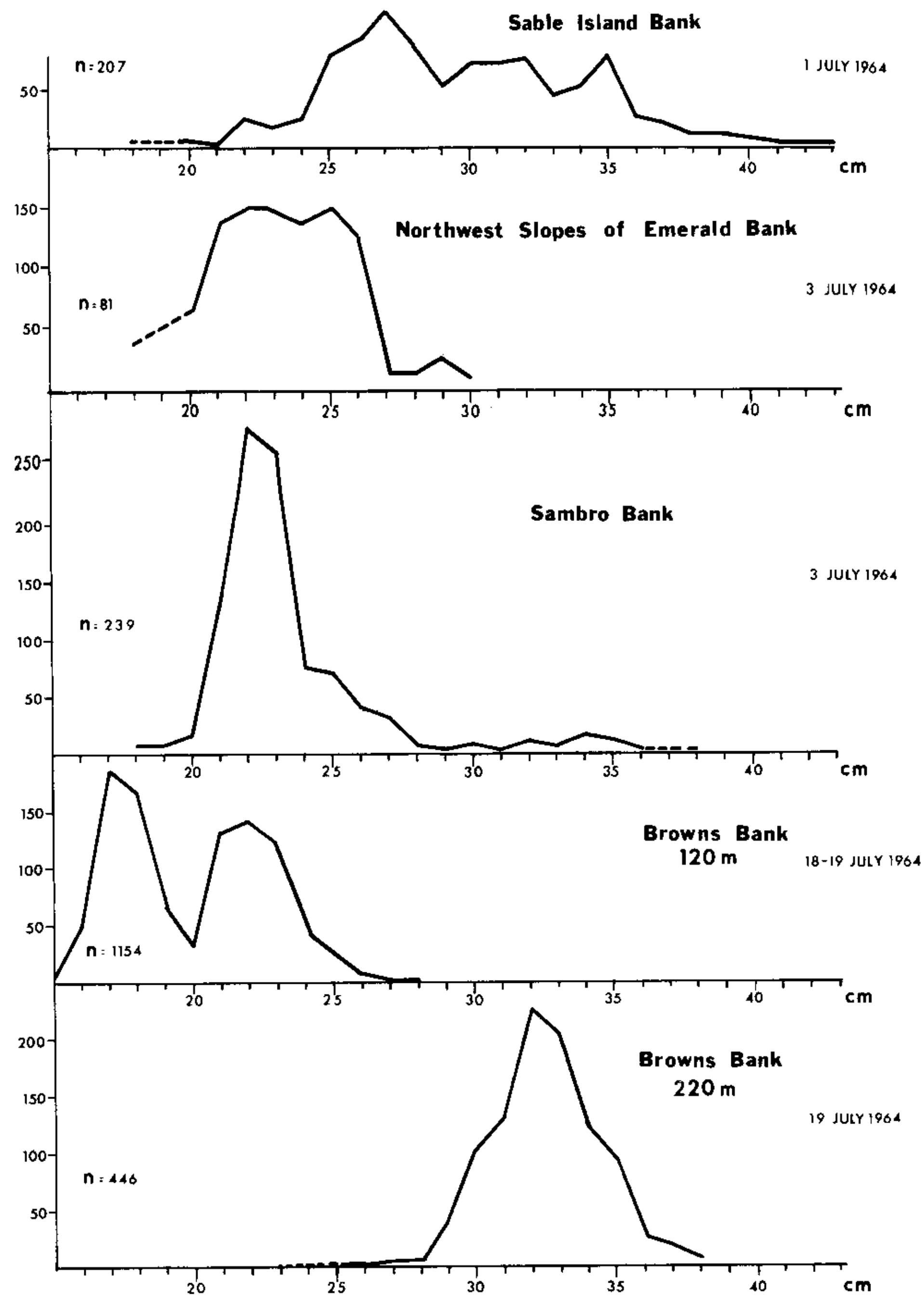

Fig. 1. Length composition of argentine on the fishing banks off Nova Scotia.

On Sable Island Bank the fish were almost exclusively in stages I and II. Only one individual was in stage IV. The smaller fish (18–26 cm) had gonads in stage I, while the fish 22–34 cm long had gonads in stage II.

Females were decidedly more numerous on the shallower fishing grounds of Browns Bank in contrast to the predominance of males in the deeper waters. On Sable Island Bank males were more numerous (76%).

Age

Age was estimated from otolith readings. The age composition of fish from Sable Island and Browns Bank is given in Table 2 and Fig. 2.

Table 2 shows that, on Sable Island Bank, the fish belonged to age-groups II–VIII. The 3-year-old fish were found in the smallest numbers and the 7-year-old fish were the most abundant.

TABLE 1. Results of investigations on the stage of maturity of gonads.

Fishing ground	Sex	Stage of maturity I: Occurrence	I: Length	II: Occurrence	II: Length	III: Occurrence	III: Length	VI: Occurrence	VI: Length	VII: Occurrence	VII: Length	VIII: Occurrence	VIII: Length
		%	cm	%	cm	%	cm	%	cm	%	cm	%	cm
Browns Bank 120 m	♂	21.4	17–23	12.6	20–28	—	—	—	—	—	—	—	—
	♀	33.0	16–25	33.0	17–25	—	—	—	—	—	—	—	—
Browns Bank 120 m	♂	—	—	44.5	23–36	0.9	33	1.8	33	1.8	32–34	10.2	29–33
	♀	—	—	37.1	29–36	0.9	32	—	—	—	—	2.8	33–34
Sable Island Bank 100—460 m	♂	22.0	18–26	54.3	22–32								
	♀	6.8	20–22	15.2	23–34	1.7	34						

TABLE 2. The length of age-groups of argentine from fishing grounds off Nova Scotia.

Age-group	Sable Island Bank 100–460 m: Range of length	Average length	No. of fish	Browns Bank 120 m: Range of length	Average length	No. of fish	Browns Bank 220 m: Range of length	Average length	No. of fish
	cm	cm		cm	cm		cm	cm	
II	—	—	—	16–23	19.1	14			
III	18–22	20.2	5	16–24	20.2	49			
IV	20–27	22.7	12	19–25	22.2	27			
V	23–28	25.7	9	22–24	22.4	11	23–32	28.6	3
VI	25–27	26.3	10	22	22.0	1	28–36	30.7	8
VII	24–31	27.0	15	28.0	28.0	1	28–34	31.1	12
VIII	26–34	29.3	9	—	—	—	29–36	32.2	24
IX	—	—	—	—	—	—	30–35	32.5	20
X	—	—	—	—	—	—	30–36	32.8	28
XI	—	—	—	—	—	—	31–36	33.8	11
XII	—	—	—	—	—	—	31–33	32.0	2

At 120 m on Browns Bank, the fish were mainly 3- and 4-year-old individuals. Here, age-groups II–IV consisted mainly of females, age-group V was mainly males and age-groups VI and VII was exclusively males. In the same area at 220 m, larger and older fish were taken. Here 8-, 9-, and 10-year-old fish were the most numerous group. Contrary to the findings for the shallow fishing grounds on Browns Bank, males were more numerous than females.

Occurrence and Yield on the Fishing Grounds

During the research cruise, catches were made on many fishing grounds off Nova Scotia, but argentine occurred in only a few of them.

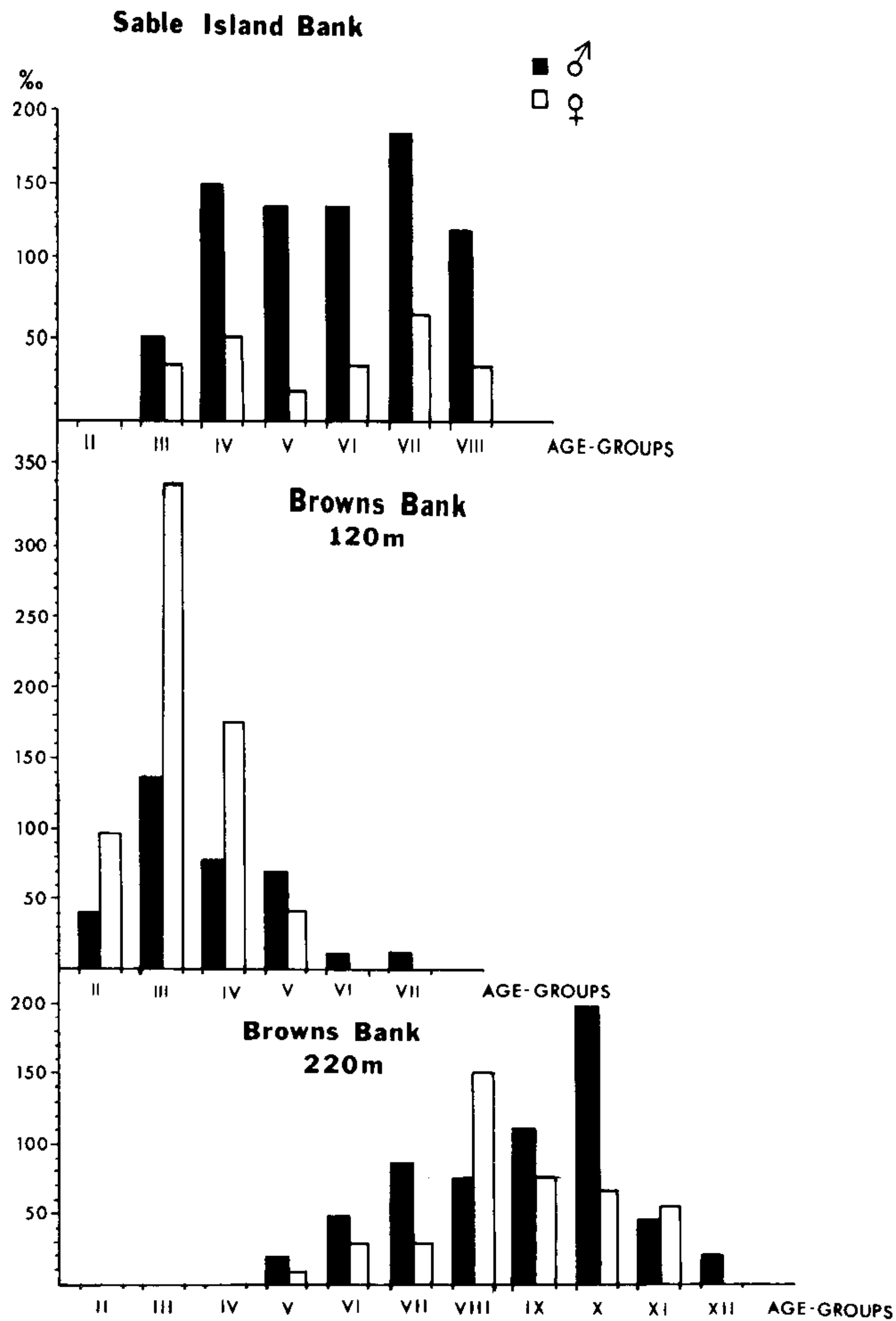

Fig. 2. Age and sex composition of argentine on the fishing banks off Nova Scotia.

On some fishing grounds, only single individuals were encountered. The fishing grounds from which this species was taken in larger amounts are given in Table 3.

TABLE 3. The catch per unit effort and the occurrence of argentine.

Fishing ground	Catch per 1-hr trawling all species (kg)	Percentage argentine in the catch
Sable Island Bank	370	6.0
Emerald Bank—north-western slopes	100	8.0
Sambro Bank	700	3.2
Browns Bank—120-m depth		
Browns Bank—220-m depth	150	100.0

Most of the argentine were found in the deeper waters of Browns Bank. In the shallower fishing grounds of Browns Bank, over the northwestern slopes of Emerald Bank and on Sable Island Bank, argentine was taken as a by-catch only, while the main mass of the landings consisted of such fish as redfish (*mentella*-type) and haddock.

In only one catch was there 100% argentine. This catch was made in the deeper parts of Browns Bank.

On Sable Island Bank, the catch included various fish species, mainly silver hake (57.8%) and also, small flatfish and redfish (*mentella*-type) (11.1%). There was a small by-catch of haddock, coal-fish, cod, herring, and argentine. The yield per 1-hr trawling amounted to about 370 kg.

On the grounds between Sable Island Bank and Emerald Bank the main mass of the landings consisted of silver hake and small argentine, totalling 87.9% with a small number of haddock, cod, redfish (*mentella*-type), and flatfish. The yield per 1-hr trawling was low here, about 100 kg.

On Emerald Bank the main part of the catches (90%) were haddock and pollack. There were very few cod, silver hake, and flatfish. Argentine made up about 8% of the total catch. The yield of all species per 1-hr trawling was about 100 kg.

On Sambro Bank, the highest catch per unit effort, amounting to 700 kg per 1-hr trawling, was obtained. There was a marked domination of small redfish (*mentella*-type) (84.3%). Next in importance were red hake (4.3%), argentine (3.2%) and haddock (2.3%), pollock, other demersal fish and a few herring.

The catch from Browns Bank at 120 m amounted to 200 kg per 1-hr trawling. The catch consisted mainly of haddock; argentine made up 10.8% with silver hake and flatfish as a by-catch.

In the deeper part of Browns Bank (220 m) argentine was the only species taken. The yield was 150 kg per 1-hr trawling.

Size Selection and Retainment of Silver and Red Hake in Nylon Codends of Trawl Nets

ALBERT C. JENSEN[1] AND RICHARD C. HENNEMUTH[2]

Abstract

Three experiments were conducted to determine the size-selectivity and relative catching efficiency of 52-, 71-, and 73-mm mesh, nylon codends for silver and red hake. A research vessel was used in the first experiment to estimate retainment in the 52- and 73-mm codends, and to compare results with covered and uncovered codends. Commercial fishing vessels were used for two experiments to estimate selectivity of a 71-mm mesh in actual commercial operations.

The covered codend retained proportionately more of the smaller fish than did the uncovered codends. The alternate tows with uncovered codends provided some evidence of an increased catch with the larger meshes. However, the 71–73-mm codends release a large proportion (up to 50%) of fish in the 25–35-cm length group, which contains the bulk of fish available to commercial trawl nets. The release of fish less than 25 cm in length is not much greater in the 71-mm codends than in the 52-mm codends. The conclusion is that the 52-mm codends are near the optimal size for these species.

These experiments were conducted by personnel of the Bureau of Commercial Fisheries Biological Laboratory, Woods Hole, Massachusetts, during 1964 to determine the size-selectivity and relative catching efficiency of 52-, 71-, and 73-mm mesh (2.0, 2.8, and 2.9 inches)[3], nylon codends for silver hake, *Merluccius bilinearis*, and red hake, *Urophycis chuss*. This information was needed to assess the effect of the larger mesh on commercial catches.

The *Delaware*, a research vessel of the Bureau, was used for the first experiment, in which personnel of the Exploratory Fishing and Gear Research Base at Gloucester, Massachusetts, cooperated. The objectives were to estimate selectivity of the 52- and 73-mm mesh codends, and to compare estimates obtained with covered and uncovered codends. Commercial fishing vessels were used for the two subsequent experiments to estimate selectivity of a 71-mm mesh nylon codend in actual commercial operations.

A typical vessel in the Gloucester, Mass., fleet was chosen for the first of the commercial trials. This fleet currently uses a 50-mm (2.0-inches) mesh, nylon codend and lands silver hake almost exclusively for human food. Two typical vessels of the Pt. Judith, Rhode Island, fleet were used in the second commercial trial. This fleet lands silver hake and red hake primarily for industrial purposes (i.e., meal and animal food), and currently uses a small mesh (33 mm, 1.3 inches) nylon liner in the codend.

Fishing areas providing a high proportion of silver hake in catches were chosen, because this species was of primary interest. Red hake were caught incidentally during the *Delaware* experiment, and a 1-day experiment at Pt. Judith was conducted to provide additional data. Relatively small amounts of other species were caught, but are not considered herein.

This paper presents the procedures and results of the three experiments, and considers the probable effects on commercial catches of the use of the larger mesh.

Experimental Procedure and Methods of Analysis

Delaware experiment

The experiment was conducted from 29 June through 6 August in the near-shore area of the Gulf of Maine. The trawl net was similar in construction to that used by commercial fishermen, with 64-mm (2.5-inches) mesh of No. 54 thread, cotton equivalent nylon throughout the wings and body.

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[2]US Bureau of Commercial Fisheries, Woods Hole, Massachusetts, USA.
[3]Stretch measure of wet mesh, after use, using an ICES gauge (Westhoff, *et al.*, 1962) at 4.4 kg of pressure.

Two series of 30 tows were completed. Within each series, five successive tows on both the port and starboard sides of the vessel were to be made with each of three types of codends; a 52-mm mesh covered with a 31-mm mesh (Clark, 1963*a* for method of attachment), a 52-mm mesh, and a 73-mm mesh, both without covers. The codends and vessel sides were used in random order; the tows averaged about three-quarters of an hour.

As with most experiments at sea, operational exigencies modified the procedure. Two serious tear-ups caused more tows to be made on the starboard side than the port side in the second series. The resulting array of tows was as follows:

Codend mesh (mm):	52/31[a]		52		73		Total
Side:	Port	Stbd.	Port	Stbd.	Port	Stbd.	
Series 1	5	5	5	5	5	5	30
Series 2	2	8	5	5	4	6	30
Total	7	13	10	10	9	11	60

[a]52 mm covered with 31 mm.

All fish from a representative, 2-bu[4] sample from each tow were weighed, measured, and counted. In occasional catches of less than 2 bu, all fish were measured and counted. The total number of bushels in each tow also was counted. The total number and total weight of silver hake and red hake in the tow were estimated by multiplying the average number and weight of fish per sample bushel by the total number of bushels. The length-frequencies of the fish in the sample were used to estimate total numbers caught per 3-cm length interval.

Retention curves for the 52- and 73-mm mesh codends without covers were drawn by plotting for each 3-cm interval the ratios of the estimated numbers of fish retained in the larger mesh codend to that retained in the codend covered with the 31-mm mesh (including fish in the cover). The 31-mm mesh is fine enough to retain nearly all of the sizes of fish available to the trawl.

The selection curve for the covered 52-mm mesh codend was derived by estimating the ratios of the number retained in the cover to that retained in the codend and cover.

The average length at which 50% of the fish were retained was estimated from lines drawn by inspection through points of the retention ratios plotted on probability paper. The selection factor is the quotient of the 50% length divided by the mesh size.

Gloucester experiment

To make the results of this experiment meaningful in relation to the silver hake commercial fishery, it was important that the experiment be conducted during normal fishing operations. This was accomplished by placing a Bureau observer aboard a cooperating Gloucester vessel, the *Frances R.*, a wooden dragger of 57 gross tons, during two regular 1-day trips. The vessel used the experimental 71-mm mesh codend on the first day (30 September) and the standard 50-mm mesh codend on the second day (2 October). No changes were made in the net itself, and no covers were used. The vessel fished in an area about 12 miles south-southeast of Gloucester. Eight tows of 2 hr each were made with each codend.

The procedure for sampling the catch was the same as that followed aboard the *Delaware* except that 2-bu samples of silver hake only were measured and counted on all tows; the catches were all large, and almost 95% silver hake. The mean weight per fish in each sample was estimated by using a length-weight relation obtained from a special sample of fish. The captain's estimate of the weight of the total catch —usually a reliable estimate—was divided by the mean weight per fish to estimate the total number of fish in the catch. This procedure was necessary because it was impractical to count and measure the entire catch.

Pt. Judith experiment

Two typical commercial vessels, the *Nyanza* and *David D.*, wooden draggers of 39 and 27 gross tons, respectively, cooperated in this experiment. Observers from the Bureau accompanied both vessels on three, one-day trips, during which the vessels fished within 1 km of each other on commercial grounds.

[4]1 bushel=about 30 kg of fish.

On the first of the silver hake trips (19 October), one vessel used the experimental 71-mm mesh codend attached to the net normally used in fishing. The other used the standard codend, 127-mm nylon mesh lined with a 33-mm nylon mesh. On the second trip the vessels exchanged codends. In all, 21 tows of about 1 hr each were completed, of which 16 were sampled.

The red hake experiments were completed on a single subsequent day (22 October), during which one vessel used the large mesh codend and one the small mesh codend liner. Each vessel completed four tows of about one hour's duration.

The sampling and estimating procedures were the same as those outlined for the Gloucester experiment.

Results

Silver hake

The data on catch and selectivity for each experiment and type of codend are presented in Table 1 and Fig.1–4. There are several aspects of particular interest.

TABLE 1. Catch and selectivity of silver hake for three experiments.

	Delaware			Gloucester		Pt. Judith	
Mesh size (mm):	31	52	73	50	71	33	71
Length int. mid-point				Numbers caught			
cm							
12	136	—	—	—	—	97	—
15	1,170	125	59	70	14	422	48
18	2,183	417	79	496	82	2,558	174
21	1,365	313	89	936	125	6,815	341
24	3,496	793	463	2,380	792	12,553	2,614
27	9,084	5,239	2,424	19,640	5,842	17,111	5,828
30	4,696	5,156	2,168	18,410	7,035	26,585	14,889
33	3,496	5,260	2,484	7,085	4,138	11,728	11,054
36	1,558	2,380	1,222	1,275	725	4,685	4,733
39	586	730	473	192	123	1,688	3,043
42	229	209	118	—	37	642	1,101
45	102	104	89	—	34	212	400
48	76	42	59	—	111	47	200
51	51	42	49	—	20	67	—
54	—	21	29	141	—	—	—
57	—	21	10	—	14	—	9
60	—	—	10	—	—	—	—
Total	28,228	20,852	9,825	50,625	19,092	85,210	44,434
Total weight:							
kg	4,472	4,254	1,975	7,713	3,176	20,417	10,662
lb.	9,856	9,376	4,352	17,000	7,000	45,000	23,500
No. tows	20	20	20	4	4	11	10
Hours towed	14.7	14.6	14.4	8.0	7.0	12.0	12.1
Weight per hour:							
kg	304	291	137	965	454	1,702	882
lb.	670	642	302	2,125	1,000	3,750	1,942
Ratio of weight per hour[a]	—	0.96	0.45	—	0.47	—	0.52
Selectivity:							
50% length (cm)	15.8	26.4	30.4	—	31.8	—	29.3
selection factor	3.2	5.08	4.16	—	4.27	—	4.13

[a]Ratio of catch of larger mesh to smallest mesh in each experiment.

The selection curve for the 52-mm mesh obtained from tows with the covered codend is quite different from that obtained from alternate tows without the cover (Fig. 1). Both the 50% length and the selection factor are lower for the former (15.8 and 3.2 vs. 26.4 and 5.08, respectively); the covered codend is retaining proportionately more of the smaller fish. Escapement may be reduced by a "masking" effect of the cover; small fish may also re-enter the codend when vessel speed is reduced during haul-back. Clark (1963*b*) also observed this effect in similar experiments with 80-mm codends.

There is a rather sharp size-selection in the uncovered 52-mm mesh; the 25–100% retention is within a length range of 5 cm, whereas the range is about 10 cm for the 73-mm mesh, which exhibits a more gradual retention curve.

Retention ratios greater than one were observed for the 52-mm mesh in the *Delaware* experiments and for the 71-mm mesh in the Pt. Judith experiments (Fig. 1, 3). In alternate tow experiments, the retention ratios are the resultant of two factors—escapement through the mesh and catch rate. Ratios greater than one imply the larger mesh is more efficient, providing both nets fished the same average population density. Even if relative efficiency is an important factor, it will be apparent in retention curves only when the increased catch more than compensates for escapement, i.e., generally towards the upper limb of the curve, and this may not obtain for the larger meshes over the observed size range of fish. Unfortunately, the data are not consistent enough to substantiate or estimate the implied increased efficiency.

Regardless of the underlying causes, the retention curves from alternate tows do portray, within limits of sampling error, the expected effect in commercial application. This may not be so for the covered codend results.

Another important result is the observed effects on total catch rate. The 71- and 73-mm mesh codends caused a loss of about 50% by weight compared to the 31- or 33-mm meshes. In contrast, the *Delaware* experiment indicated a loss of less than 5% with the 52-mm mesh (Table 1).

The reduction of catch is also evident in comparisons of catches made by the *Frances R.* using the 71-mm codend with those of three other vessels of similar size and horsepower fishing nearby with 50-mm codends:

Vessel	Hours towed	Catch	
		kg	*lb.*
Frances R.	1.7	636	1,400
Little Flower	1.6	909	2,000
Frances R.	2.0	1,137	2,500
Sebastiana C.	2.0	1,362	3,000
Frances R.	7.0	3,181	7,000
Barbara C.	7.0	6,820	15,000

The difference in catch rate is important in application, but, of course, depends on the length-frequency of the available population. This subject will be taken up again in the subsequent section on commercial fishery application.

The retention curves obtained on the 2 days at Pt. Judith are very nearly coincident and the data were pooled to provide a single curve (Fig. 3).

The overall uniformity of results of the several independent sets of data for the 71- and 73-mm mesh codends (at least for fish up to 36 cm) provides a fair measure of confidence in the results (Fig. 4). The retention ratios of the 71-mm mesh obtained in the Gloucester experiment cannot be directly compared to the others because a larger base mesh was used (50 mm vs. 31 and 33 mm); therefore, the retention ratios in Fig. 4 have been adjusted by the retention ratios of the 52-mm mesh estimated from the *Delaware* experiment to make them comparable to a 31-mm base net. The remaining small differences in mesh size between experiments (31 vs. 33 mm, 50 vs. 52 mm, 71 vs. 73 mm) are of little consequence in the final results. Thus, for a codend of nylon mesh averaging 72 mm, the 50% length and selection factor may be taken as the average of those in Table 1, 29.8 cm and 4.2, respectively.

Small numbers of fish larger than 39 cm in the catches preclude firm estimates of retention and relative catch of fish for those sizes. Note also the small catches in the *Delaware* experiment compared to the commercial experiments. This might affect the retention characteristics, although it is not apparent that it has done so.

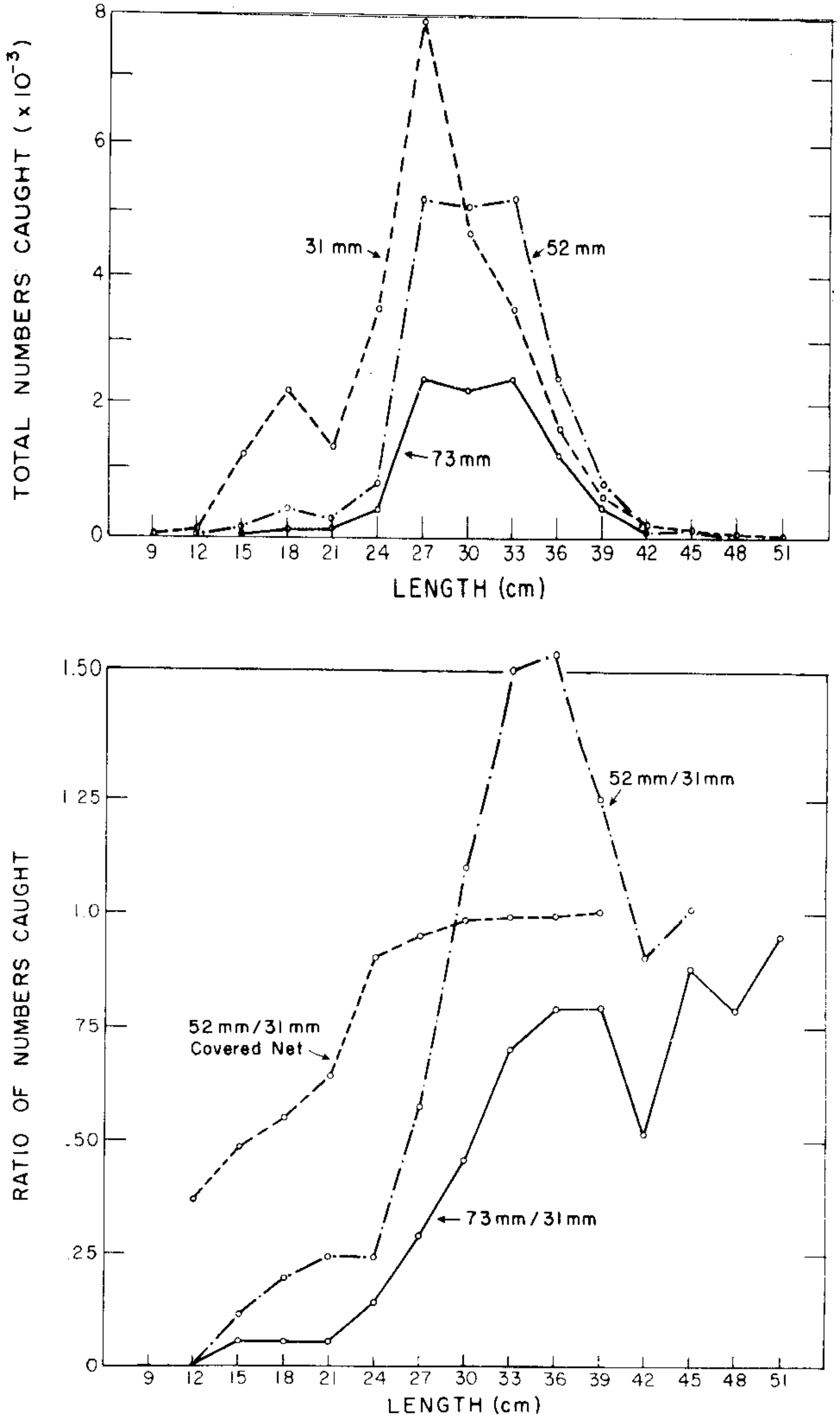

Fig. 1. Retention of silver hake in 52-mm and 73-mm nylon codends, *Delaware*.

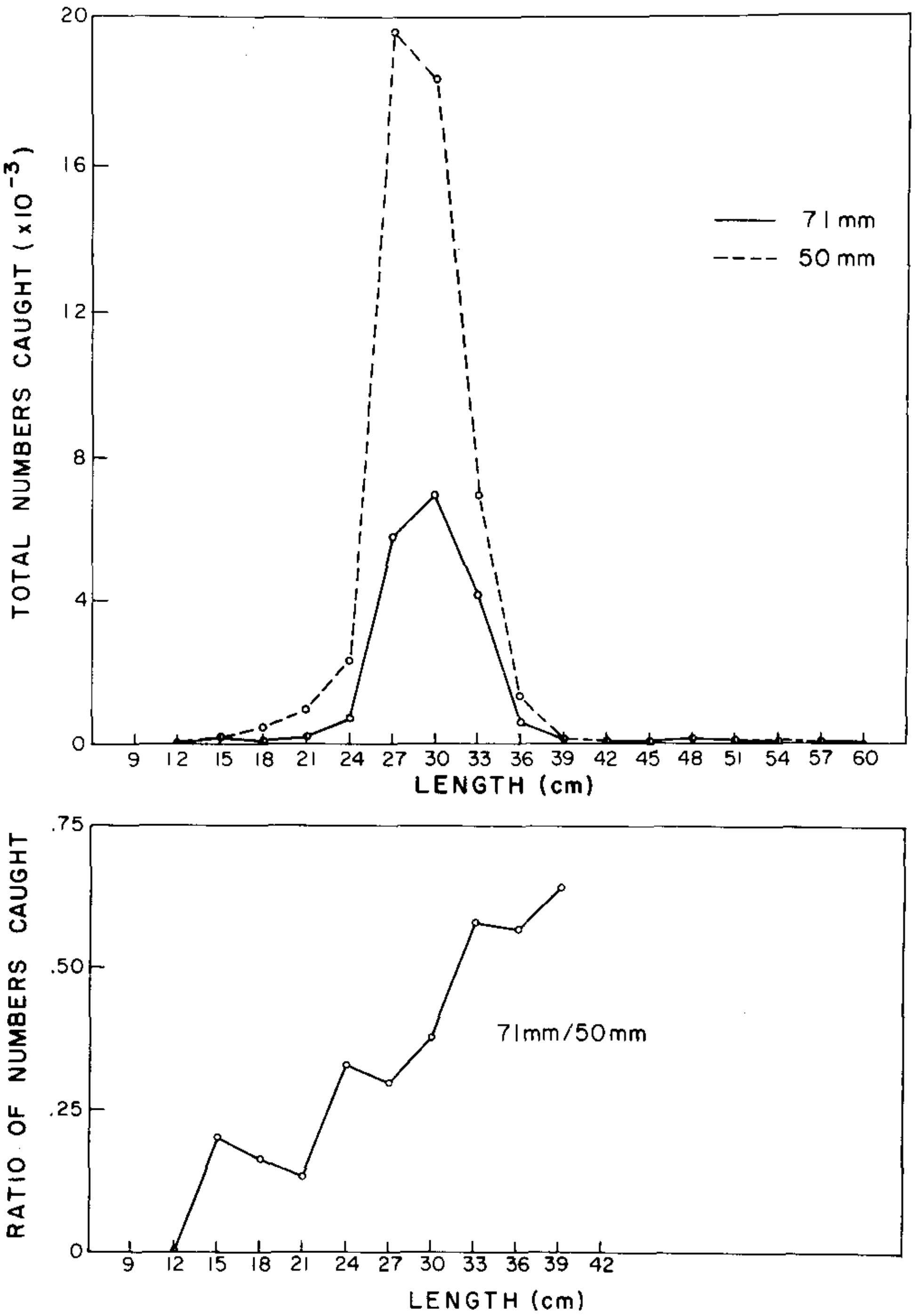

Fig. 2. Retention of silver hake in 50-mm and 71-mm nylon codends, Gloucester.

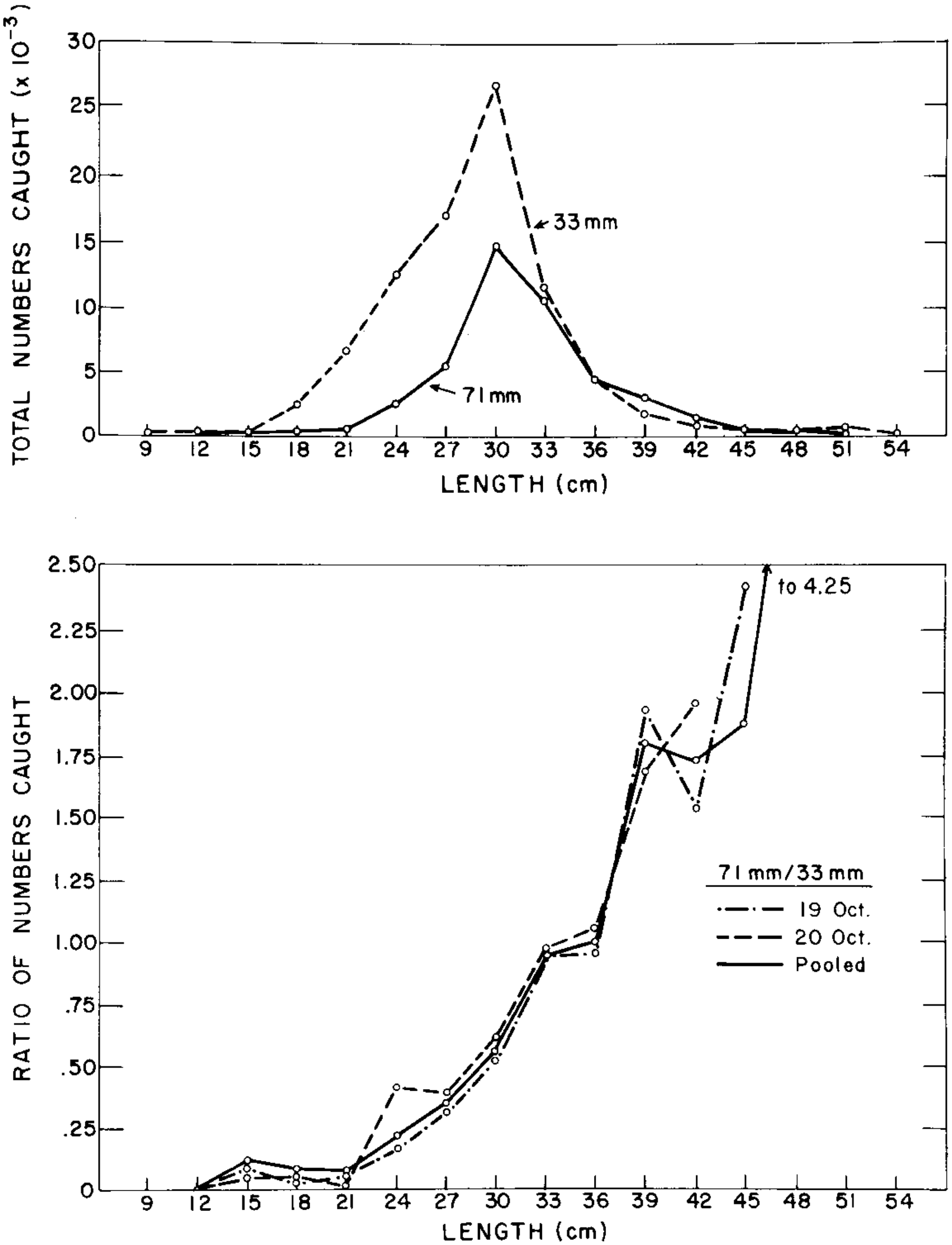

Fig. 3. Retention of silver hake in 33-mm and 71-mm nylon codends, Pt. Judith.

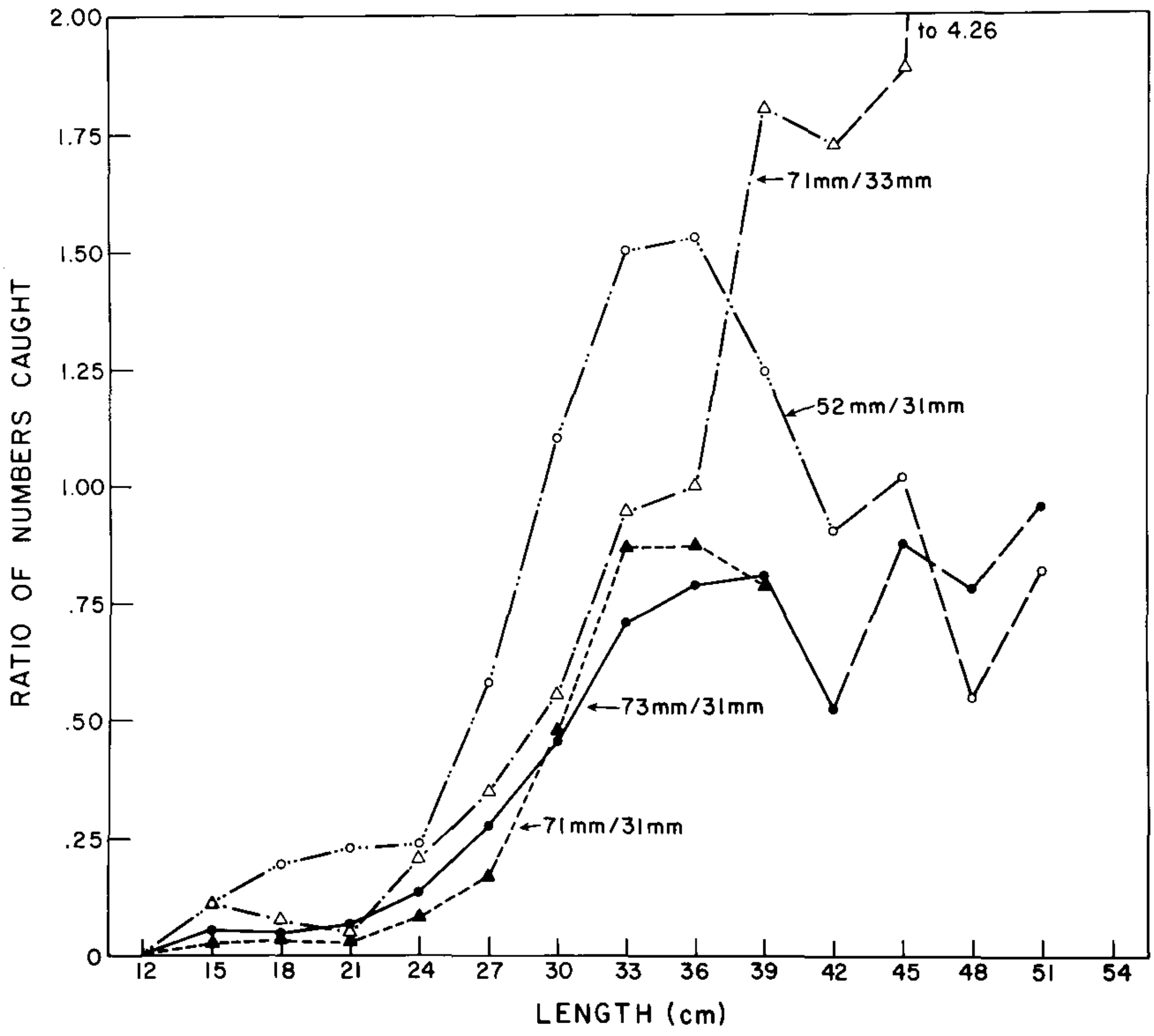

Fig. 4. Estimated retention curves for silver hake in nylon codends.

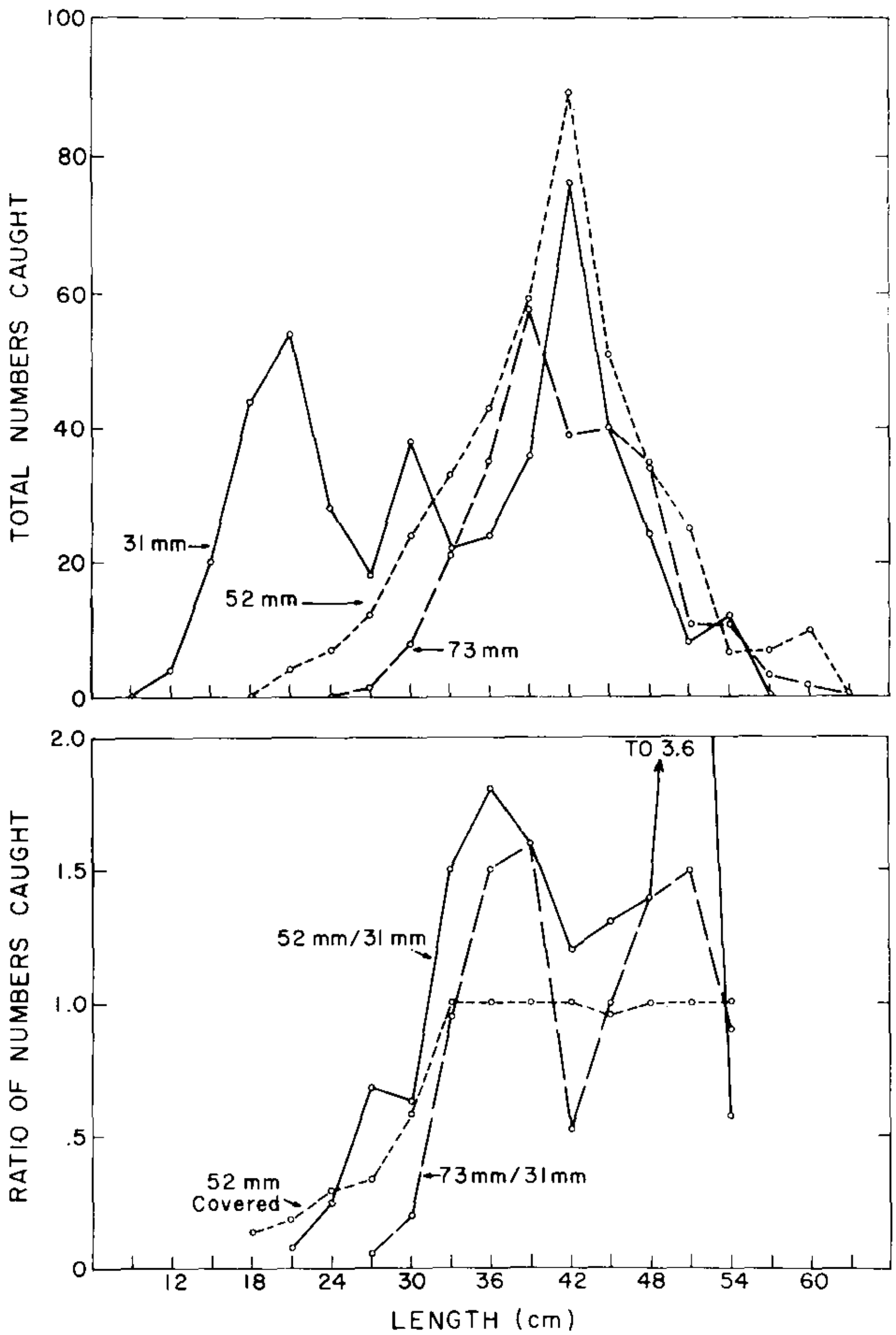

Fig. 5. Retention of red hake in 52-mm and 73-mm nylon codends, *Delaware*.

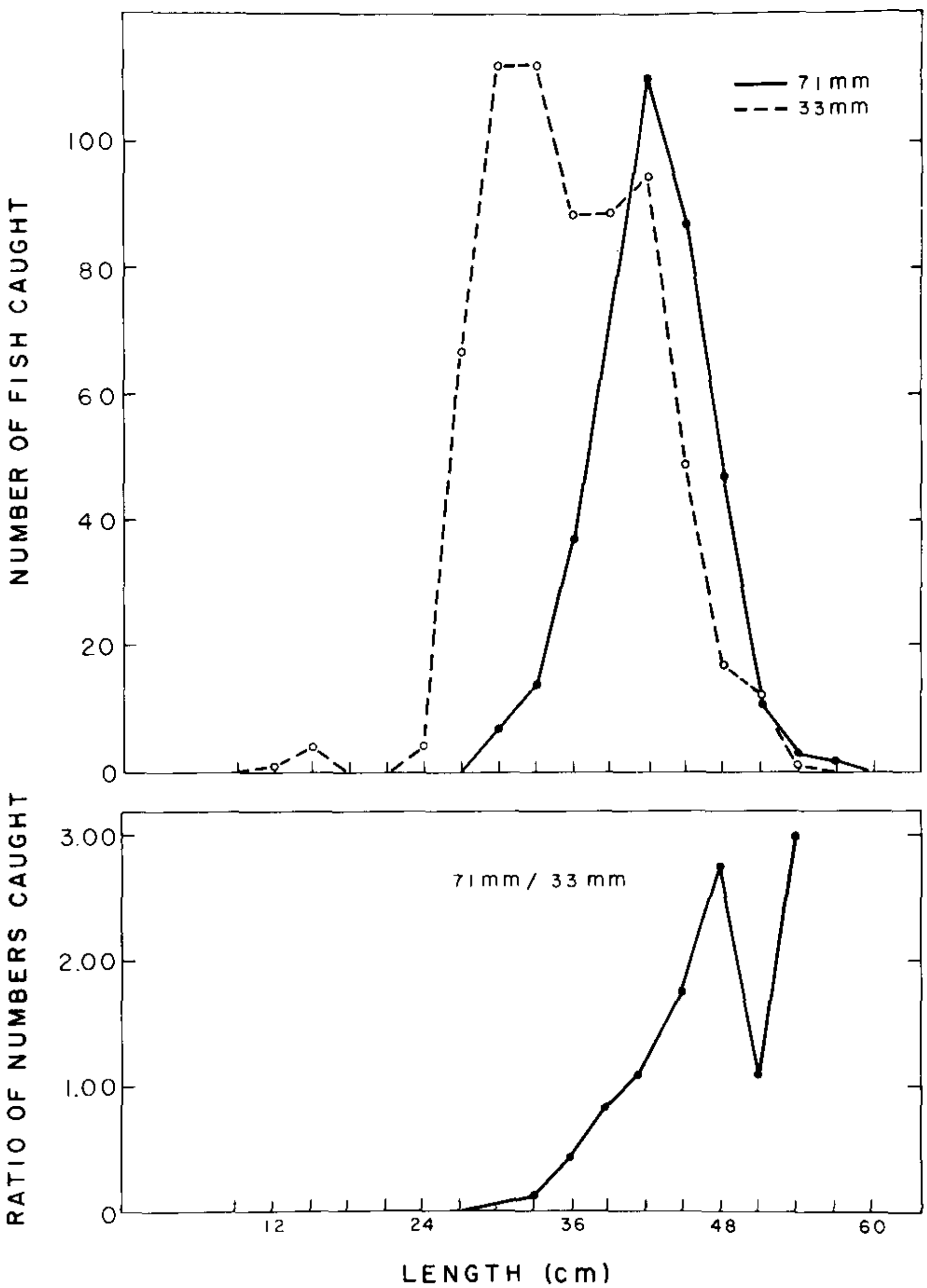

Fig. 6. Retention of red hake in 33-mm and 71-mm nylon codends, Pt. Judith.

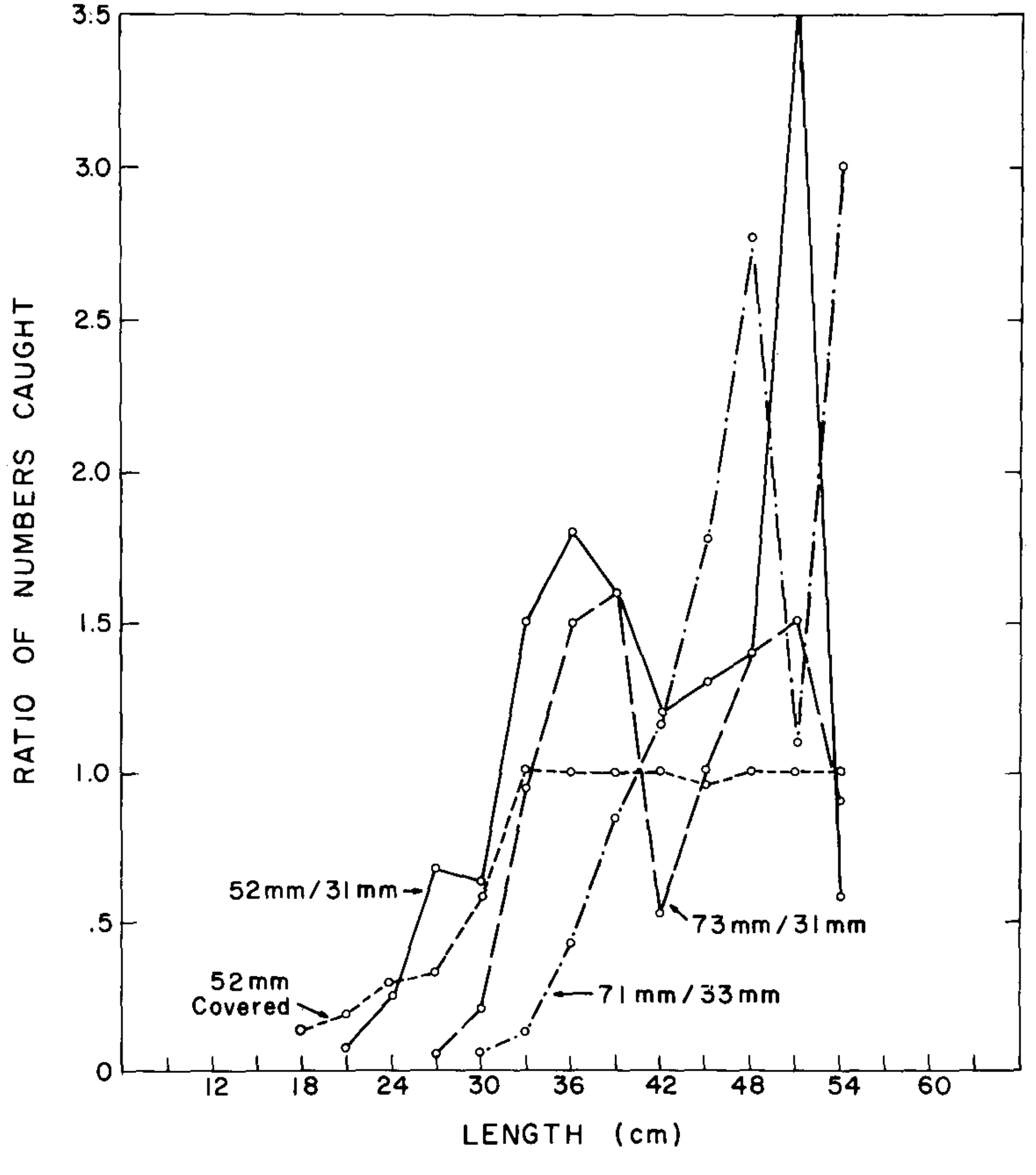

Fig. 7. Estimated retention curves for red hake in nylon codends.

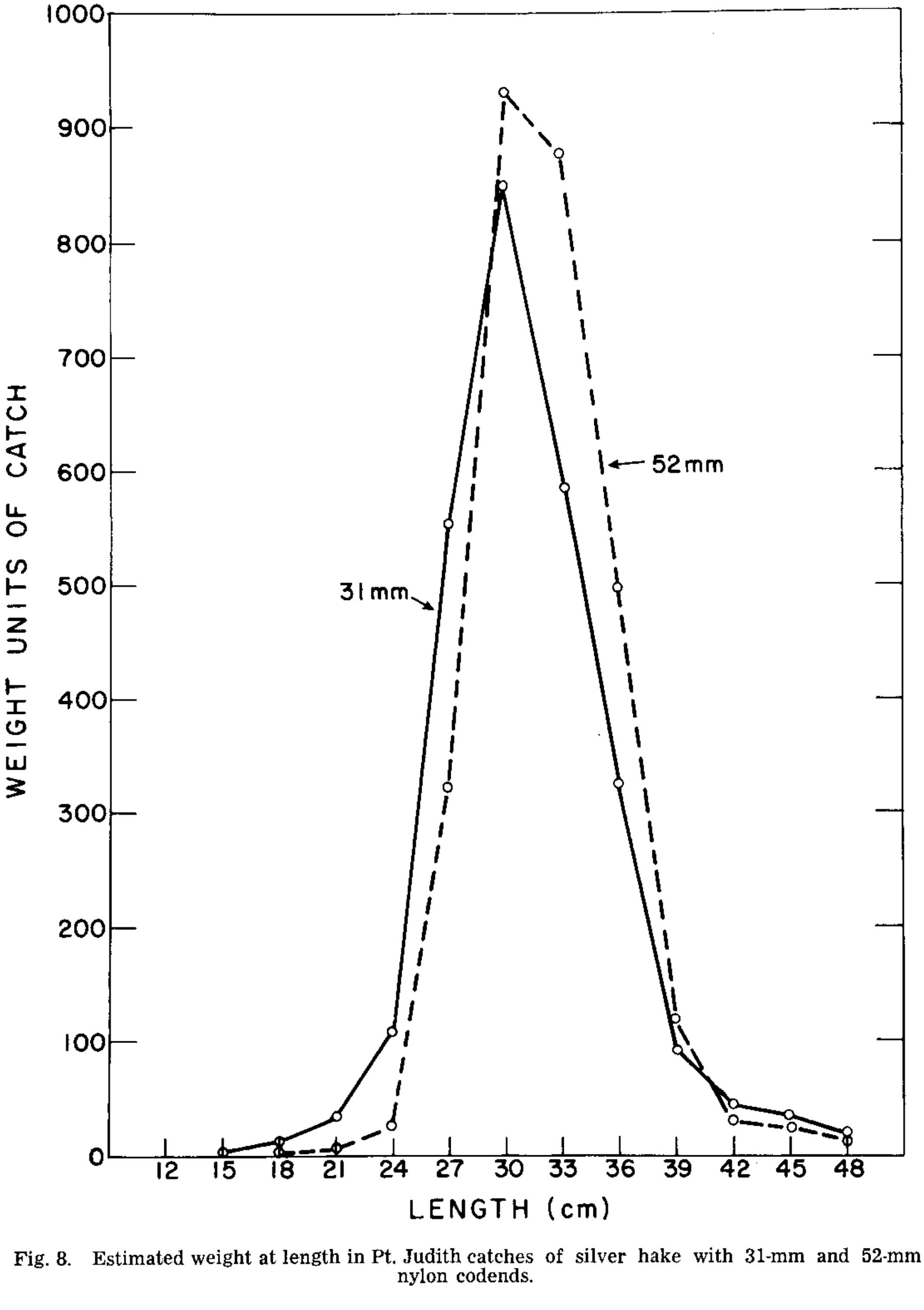

Fig. 8. Estimated weight at length in Pt. Judith catches of silver hake with 31-mm and 52-mm nylon codends.

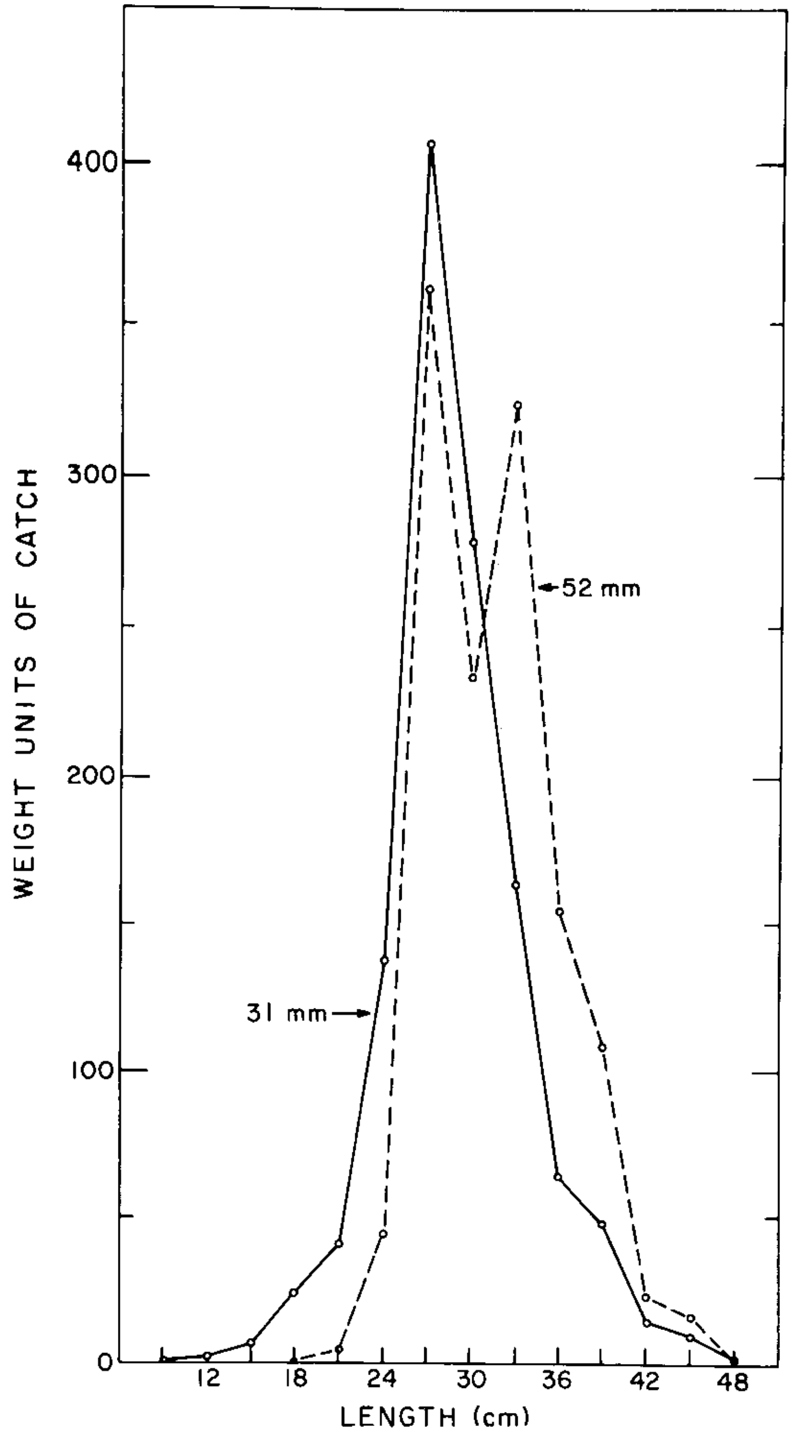

Fig. 9. Estimated weight at length in Pt. Judith catches of red hake with 31-mm and 52-mm nylon codends.

Extensive gilling of fish sometimes is observed in meshes that permit some escapement. In all three experiments, gilling of silver hake in the 71- and 73-mm codends was of the order of 0.1%; certainly not of a magnitude to cause concern. Those that were gilled were 26–41 cm in length, with a modal length of 33 cm, which is somewhat greater than the 50% length. More fish were gilled in the forward parts of the net than in the codend, a fact which does indicate escapement through the forward parts, but is of no practical concern here. These fish were 27–39 cm in length, with a modal length of 33 cm.

Red hake

The catch and selectivity data for each experiment and type of codend are shown in Table 2 and Fig. 5–8. The total number of red hake caught by the *Delaware* and the Pt. Judith vessels (no red hake were caught in the Gloucester experiment) was far less than the number of silver hake caught. The *Delaware* fished known

TABLE 2. Catch and selectivity of red hake, 1964.

	Delaware			Pt. Judith	
Mesh size (mm):	31	52	73	33	71
Length int. mid-point	Numbers caught[a]				
cm					
12	4	—	—	1	—
15	20	—	—	4	—
18	44	—	—	—	—
21	54	4	—	—	—
24	28	7	—	4	—
27	18	12	1	67	—
30	38	24	8	112	7
33	22	33	21	112	14
36	24	43	35	89	37
39	36	59	59	89	73
42	76	89	39	95	110
45	40	51	40	49	87
48	24	34	34	17	47
51	8	25	11	10	11
54	12	7	11	1	3
57	—	7	3	—	2
60	—	10	2	—	—
Total	448	405	264	650	391
Total weight:					
kg	—	—	—	508	189
lb.	—	—	—	1,117	415
No. tows	10	13	18	4	4
Hours towed	6.6	8.8	13.1	4.0	5.6
Weight per hour:					
kg	—	—	—	127	34
lb.	—	—	—	279	74
Ratio of weight per hour[b]	—	—	—	—	0.27
Selectivity:					
50% length (cm)	29.1	25.7	31.0	—	36.5
selection factor	5.6	4.9	4.2	—	5.1

[a]Numbers adjusted to compensate for different fishing time.

[b]Ratio of catch of large mesh to small mesh.

silver hake grounds and red hake were an incidental by-catch. The Pt. Judith vessels fished a ground that usually produces red hake but the fish were scarce the day the experiment took place. Thus, the volume of fish considered in these experiments is less than commercial quantities and less than needed for firm conclusions.

The selection curve of the 52-mm mesh derived from the covered codend tows is not very different from the retention curves of the same size mesh fished without the cover, at least up to the 100% point (Fig. 5). The 50% lengths differ by about 3 cm and the selection factors differ by 0.7. In each case the covered codend values are lower.

Size selection is rather sharp for the 73-mm mesh. The 25–100% retention lengths are within 3 cm, whereas the same span for the 52-mm covered and the 52-mm uncovered codends are 10 cm and 7.5 cm respectively. Also, the retention curve for the 73-mm mesh is displaced to the right of the curve for the 52-mm mesh by only about 4 cm. All of these results are in sharp contrast to those observed for silver hake.

The retention curve for the 71-mm codend used in the Pt. Judith experiments indicates again a rather sharp selection (Fig. 6). We also note a proportionately greater release of smaller fish compared to the 73-mm mesh in the *Delaware* experiments; the 50% points are 37 and 31 cm, respectively (Fig. 7, Table 2).

In all retention curves based on uncovered codends, ratios exceeding unity were observed, and perhaps indicate a higher catching efficiency. However, the ratios from the *Delaware* experiment are quite erratic for lengths greater than about 39 cm, and therefore, do not provide clear-cut results. The data points for the Pt. Judith experiment are somewhat better in this regard, and indicate the same trends as observed for the silver hake.

The total catch per hour for all species in the Pt. Judith experiment was 1,931 kg (4,250 lb.) for the 33-mm mesh codend and 503 kg (1,107 lb.) for the 71-mm mesh codend. This is a rather drastic reduction; however, it is mostly due to the reduction in catch of species other than red hake—silver hake, flounders, butterfish, and skates. The catch of red hake in the 71-mm mesh codend was estimated to be 8% less than the catch in the 33-mm codend. The average length of red hake in the 1964 industrial landings was less than that observed during our experiments; thus, in actual practice the losses would be somewhat greater than 8%.

There was no opportunity to exchange codends between the two Pt. Judith vessels to average out differences in catch rate. Therefore, we must consider the results as provisional.

We have no observations of gilled red hake in the *Delaware* experiment but we made some measurements in the Pt. Judith experiment. The fish gilled only in the 71-mm codend. At the end of a 1.3 hr tow, 62 red hake were gilled in the meshes. The gilled fish ranged from 33 to 46 cm in length with the mode at 42 cm. The codend catch for that tow consisted of 454 kg (1,000 lb.) of silver hake, flounders, miscellaneous fishes, and 113 red hake from 33 to 56 cm long.

Conclusions

Silver hake

Silver hake is the most important single species in the industrial catches off southern New England and is the basis of an important food-fish fishery at Gloucester, Massachusetts (Edwards, 1958; Edwards and Lux, 1958; Edwards and Lawday, 1960; Fritz, 1960).

The results of the experiments make it readily apparent that the 71- and 73-mm meshes release a large proportion of the fish in the 25–35-cm length interval—the size group which forms the bulk of fish available to commercial trawl nets. The larger meshes do not release very many more of the fish less than 25 cm in length than does the 52-mm mesh.

We do not know the magnitude of long-term benefits—the gross gain in weight less natural mortality—which might be obtained by postponing capture with the use of 71- or 73-mm mesh codends. However, judging from preliminary estimates, the growth rate of fish above 25 cm is rather slow and mortality is not low; therefore, it would be rather optimistic to expect the benefits to compensate for the large immediate loss of about 50%.

It is of interest however, to consider the use of 52-mm mesh in place of the 33-mm mesh. The Pt. Judith fishery is particularly concerned, and we have calculated the immediate effects for such a change by applying the retention ratios for the 52-mm mesh estimated from the

Delaware experiments to the average length-frequencies of the Pt. Judith catches in 1964 (Fig. 8). The weight units are in terms of lengths cubed, and do not represent absolute catches, but are assumed to be proportional to them.

A gain of about 8% by weight is estimated for the larger mesh. This is brought about by the apparent increase in catching efficiency, expressed in the retention ratios greater than one which coincide with the peak length frequencies. Almost all fish below 25 cm would be released, but they do not contribute much to the weight of catch.

Red hake

Red hake contribute about 20% of the annual landings from the inshore grounds at Pt. Judith (Edwards, 1958; Edwards and Lawday, 1960). They make up about one-third of the landings in May–July. Therefore, the expected immediate loss with the 71-mm codend would be important to the industrial fishery. Our data for the 71- and 73-mm mesh codends show considerable loss of red hake less than about 30–35 cm, but little loss with the 52-mm codend.

To estimate the effect of a 52-mm mesh on the catch of red hake by the industrial fleet at Pt. Judith, we applied the retention ratios estimated from the 52-mm mesh aboard the *Delaware* to the average length-frequencies of the 1964 Pt. Judith red hake landings. The weight units are in terms of lengths cubed and are assumed to be proportional to the absolute catches (Fig. 9).

The immediate effect of the larger mesh is a loss estimated to be about 8%. A large proportion of the fish below 24 cm would be released and enough of the sizes smaller than 33 cm to offset the gain in catch of fish between 33 cm and 42 cm.

Acknowledgements

The authors wish to acknowledge the fine cooperation of William E. Ragusa, Captain of the *Frances R.*, John Dykstra, Captain of the *Nyanza,* Robert D. Smith, Captain of the *David D.*, and their crews, who enabled these experiments to be conducted effectively.

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Notes

Validity of Ageing Young American Plaice from Otoliths

Introduction

Validation of ageing methods is essential in studies of fish populations. Graham (1956) reviewed seven techniques for demonstrating the reliability of otoliths and scales for ageing fish. Powles (1965) applied two of these to American plaice, *Hippoglossoides platessoides* F., from the southern Gulf of St. Lawrence (ICNAF Division 4T). These demonstrated the validity of the methods and interpretations used in reading otoliths of intermediate-aged plaice. Otoliths from younger stages were examined in the present study, and provide additional evidence for young plaice in this particular area.

Several methods were used to obtain the necessary samples of the various small stages of plaice. Young-of-the-year and 1-year-olds were taken by Isaacs-Kidd trawl and from stomachs of the more common predators (cod, skate, and eelpout); 2- to 5-year-old plaice were captured by lined otter trawl (2.9 cm internal mesh).

Growth increments over a 10-month period for plaice were deduced from changes in their modal sizes. This group of fish (primarily 2- to 6-year-olds) was sampled off Grande Rivière, Que., by special small-mesh bottom drag. Little commercial fishing is carried out in the exact sampling area, and such fish are virtually non-migratory (Powles, 1965).

Shifts in size-modes were then compared to mean lengths-at-age and age ranges obtained from the special samples used in the study of otolith growth and seasonal annuli formation.

Results

Table 1 shows mean lengths and length ranges corresponding to the number of large hyaline zones (Jensen, 1965) observed on the otoliths of American plaice. The appearance of the outer portion of the majority of otoliths is also listed by quarter to show seasonal changes. During May–October, opaque material was built

TABLE 1. Summary of the seasonal appearance of otoliths of young American plaice together with related size data. Samples were taken by Isaacs-Kidd trawl and from stomachs of predators.

May to July	Length range *(cm)*	1.7–2.3	2.6–3.8	7.1–10.7
	Mean length *(No.)*	2.0 (6)	3.5 (5)	8.5 (23)
	Main edge type	NO[a]	NO	NO
	No. hyaline bands	Nucleus only	1	2
	Age estimate	O	1	2
August to October	Length range *(cm)*	—	4.3–5.0	7.6–12.1
	Mean length *(No.)*	—	4.6 (3)	9.9 (3)
	Main edge type	—	WO[b]	WO
	No. hyaline bands	—	1	2
	Age estimate	—	1	2
November to January	Length range *(cm)*	3.0–3.5	5.1–7.0	—
	Mean length *(No.)*	3.2 (2)	6.0 (3)	—
	Main edge type	NH[c]	NH	NH ?
	No. hyaline bands	1	2	3 ?
	Age estimate	O	2	2 ?

[a]NO=narrow opaque; [b]WO=wide opaque; [c]NH=narrow hyaline.

up on the otolith. During November–January (and also February–April, not shown) a hyaline edge was observed. The formation of consecutive opaque and hyaline bands was therefore as-

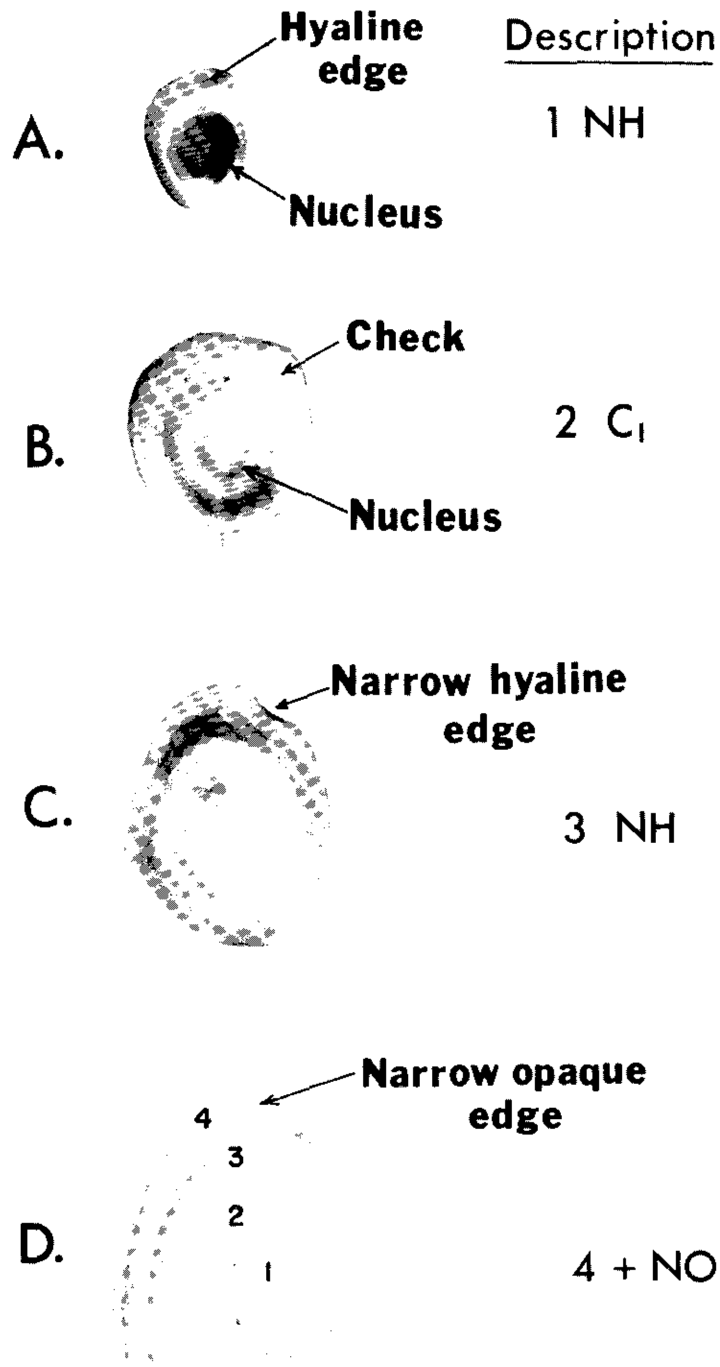

Fig. 1. American plaice otoliths at various stages (reflected light). **A.** From a fish 3.2 cm in length taken in January 1960. The central nucleus is surrounded by a thin band of summer (opaque) growth. The first winter (hyaline) band is forming at the outer edge. **B.** A 6.2-cm fish captured in January, showing a nucleus and two hyaline zones separated by a check. **C.** A 2-year-old captured in January with third hyaline zone forming. **D.** A 4-year-old plaice captured in June and showing an outer narrow opaque summer band.

sociated with two particular seasons each year: the hyaline with winter growth, and the opaque with summer growth.

In May–July young-of-the-year plaice are in pelagic larval stages. The larvae ranged from 1.7 to 2.3 cm in length. Although their otoliths could scarcely be seen with the naked eye, they showed an almost completely formed hyaline nucleus. In August–October no young-of-the-year were captured, but in November–January, a number were taken. These measured from 3.0 to 3.5 cm in length and their otoliths showed a small nucleus surrounded by an opaque band (white in Fig. 1A) and a narrow hyaline edge (dark in Fig. 1A).

The central nucleus was interpreted as a structure formed during the early pelagic phase. The first strong hyaline zone was associated with the first winter of life. If otoliths are magnified too much (more than the usual 10X) the nucleus may appear to be made up of a hyaline ring containing a small opaque dot (Fig. 1B). It would thus resemble a first annulus but is not counted as such. Too high a magnification therefore may complicate age reading.

In January earbones from fish which had reached the bottom-dwelling stage and measured from 5.1 to 7.0 cm in length showed two hyaline zones (Fig. 1B). Quite often the main hyaline zones were preceded by checks (Fig. 1B). However, the length modes of Fig. 2 (to be discussed later) suggested that these checks be ignored in ageing.

The above interpretations agree well with estimates of growth obtained from the size frequency distributions of Fig. 2. The modes representing 2-year-old fish (Fig. 2B and 2C) correspond to the mean lengths-at-age shown in Table 1. Similarly, peaks assumed to be 4-year-old fish correspond to the plaice showing four hyaline zones on the otoliths and have the same length range. The methods and interpretation used to age American plaice in the Magdalen Shallows are therefore considered reliable, and the possibility of counting extra rings or missing early ones is remote.

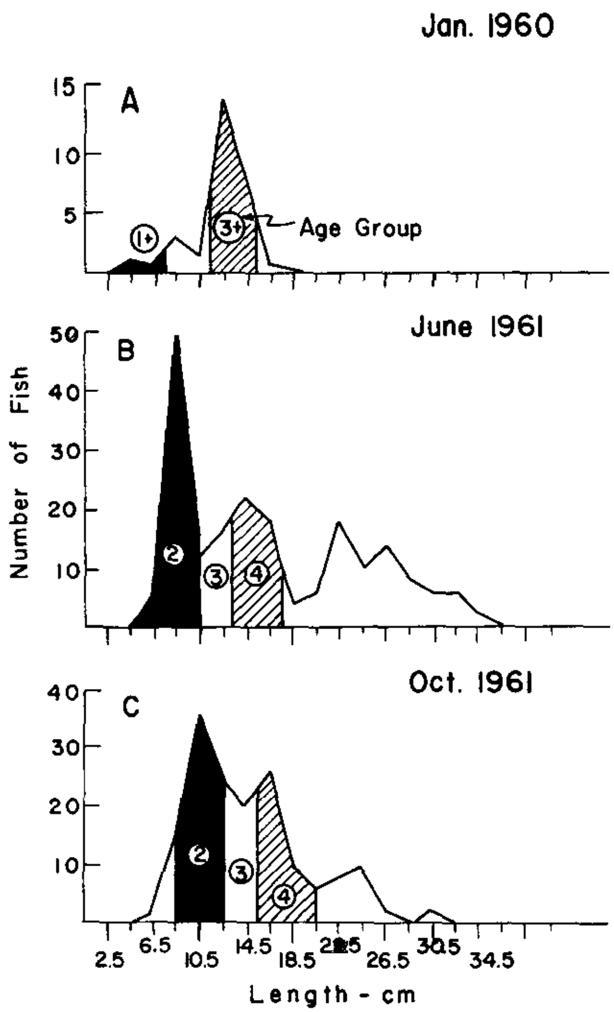

Fig. 2. Length distributions of small American plaice sampled by small-mesh drag. Measurements are in total length to the nearest 0.1 cm.

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Some Biological Characteristics of Blueback, *Pomolobus aestivalis* (Mitch.), and Alewife, *Pomolobus pseudoharengus* (Wils.), from Georges Bank, July and October, 1964

Introduction

To determine the biological characteristics of blueback, *Pomolobus aestivalis* (Mitch.), and alewife, *Pomolobus pseudoharengus* (Wils.), materials were collected in July, 1964, during the research trip of M/T *Wieczno* and during the October operation of M/T *Uran*. Both ships were fishing with bottom trawls on the fishing grounds off Nova Scotia and Georges Bank.

The differentiation of both the species is not easy, for they are similar. In order to identify alewife and blueback the characteristic features, given by Bigelow and Schroeder (1953) were used. According to these authors alewife has larger eyes, and its peritoneum is of pear colour. The peritoneum of blueback is black. Therefore all the fish were identified by the size of eyes and the colour of peritoneum. Additionally it was noted that the external appearance of alewife is slightly different, with fish the same length alewife has a slightly higher body than blueback.

In the samples, total fish body length, sex and the stage of maturity (according to Maier's scale) were taken into consideration. For age determination otoliths were taken. Also the degree of fullness of the stomachs was estimated and recorded according to a 5-degree scale. In respect of alewife, investigated in October, the degree of fattening of the digestive tract and fish body weight were determined. A total of 550 blueback and 347 alewife were measured, and biological characteristics of 115 blueback and 255 alewife were determined.

Occurrence in the Catches

Mass occurrence of blueback and alewife was found in the catches on the western slopes of Georges Bank (41°29′N, 68°34′W) only. Few blueback were captured on Middle Ground, on the northern (41°58′N, 67°09′W) and southeastern slopes of Georges Bank (40°44′N, 67°24′W). Also, few alewife occurred in the catches on the southern slopes of Georges Bank (40°26′N, 68°50′W). The results of observations on the occurrence of blueback and alewife on Nova Scotia Banks and Georges Bank are given in Table 1.

TABLE 1. Occurrence of blueback and alewife in the catches in July, 1964.

Fishing Ground	Blueback	Alewife
Sable Island Bank	—	—
Middle Ground	few	—
Emerald Bank—southern slopes	—	—
Emerald Bank—northwestern slopes	—	—
Sambro Bank	—	—
Browns Bank	—	—
Georges Bank—41°58′N, 67°09′W	few	—
Georges Bank—41°29′N, 68°34′W	mass occurrence	mass occurrence
Georges Bank—40°26′N, 68°50′W	—	few
Georges Bank—40°44′N, 67°24′W	few	—
Corsair Canyon	—	—

In October 1964 during 35 fishing days of factory trawler M/T *Uran* on the fishing grounds off Nova Scotia, and mainly on Georges Bank, 13 tons of alewife and blueback were captured. Analysis of the catches showed a decided dominance of alewife.

Both in July and October, blueback and alewife were captured along with herring.

Length Composition

Length composition of captured fish is shown in Fig. 1 and 2.

Blueback, captured in July, were 22–33 cm long, while most of the fish in the catches were 28–29 cm long (mean length 28.6 cm).

Alewife were, in general, similar in length to blueback. In July, alewife were 17–33 cm long with the largest number 29–30 cm long (mean length 29.3 cm). In October, alewife were 25–34 cm long (mean length 28.8 cm) and were slightly smaller than those captured during the summer.

The females of both blueback and alewife were longer than males (Table 2).

TABLE 2. Mean length (in cm) of males and females blueback and alewife.

Species	Captured	Mean length ♂	♀	♂ + ♀
Blueback	July	27.5	29.0	28.6
Alewife	July	28.0	29.8	29.3
Alewife	October	28.2	29.2	28.8

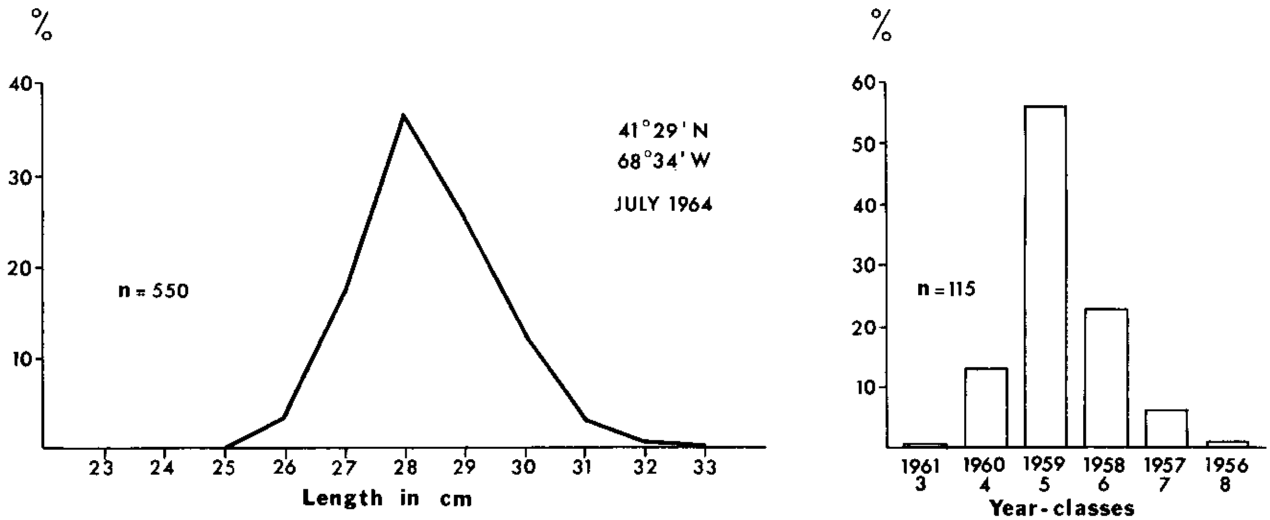

Fig. 1. Length and age composition of blueback on Georges Bank, July 1964.

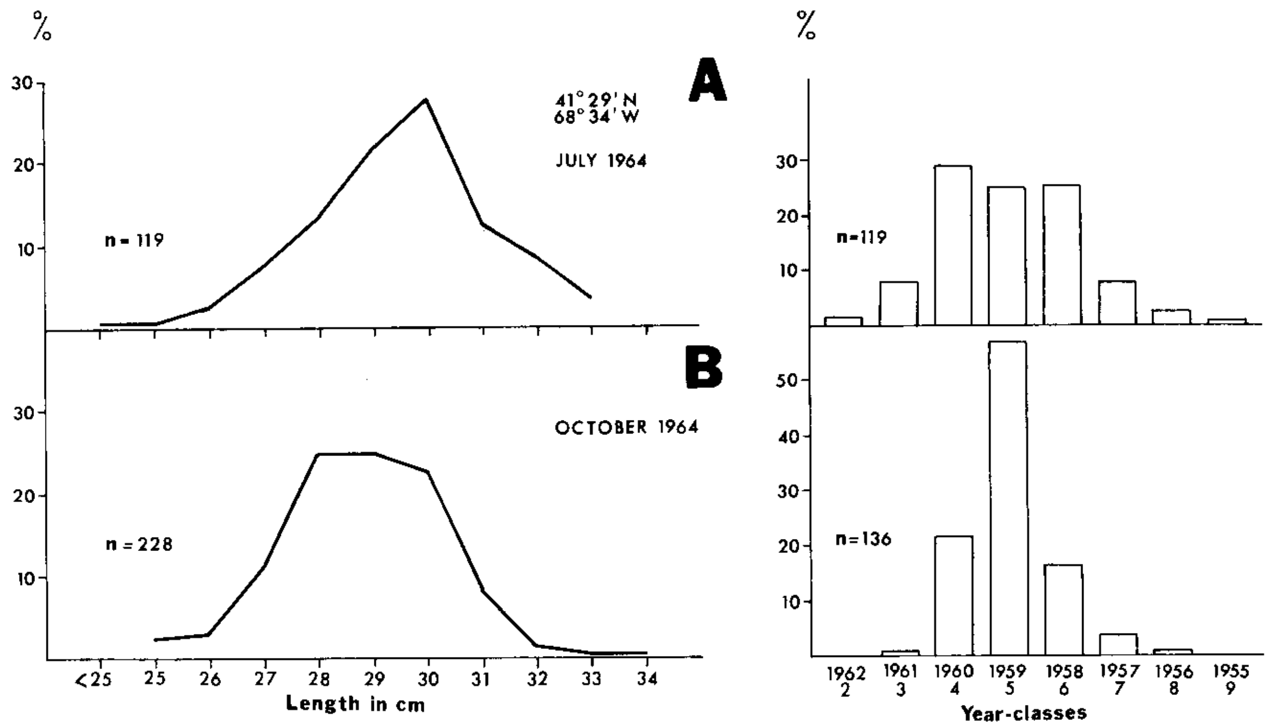

Fig. 2. Length and age composition of alewife on Georges Bank, July (**A**) and October (**B**), 1964.

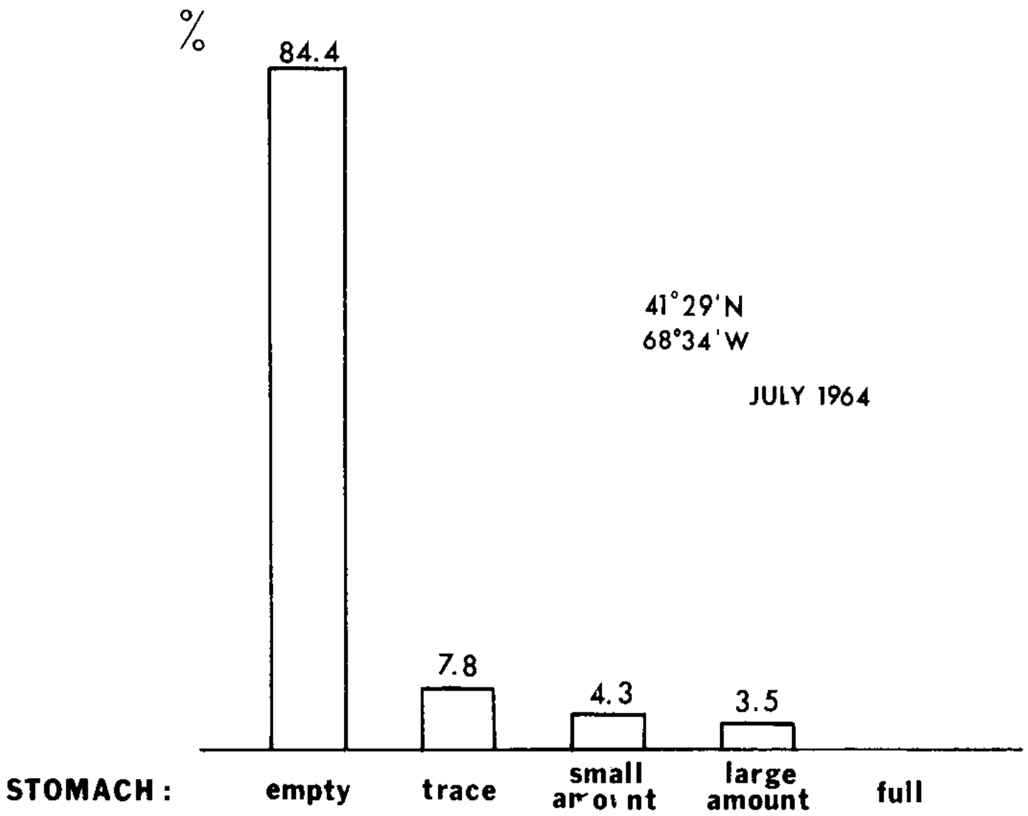

Fig. 3. Percent rate of stomach contents of blueback from Georges Bank, July 1964.

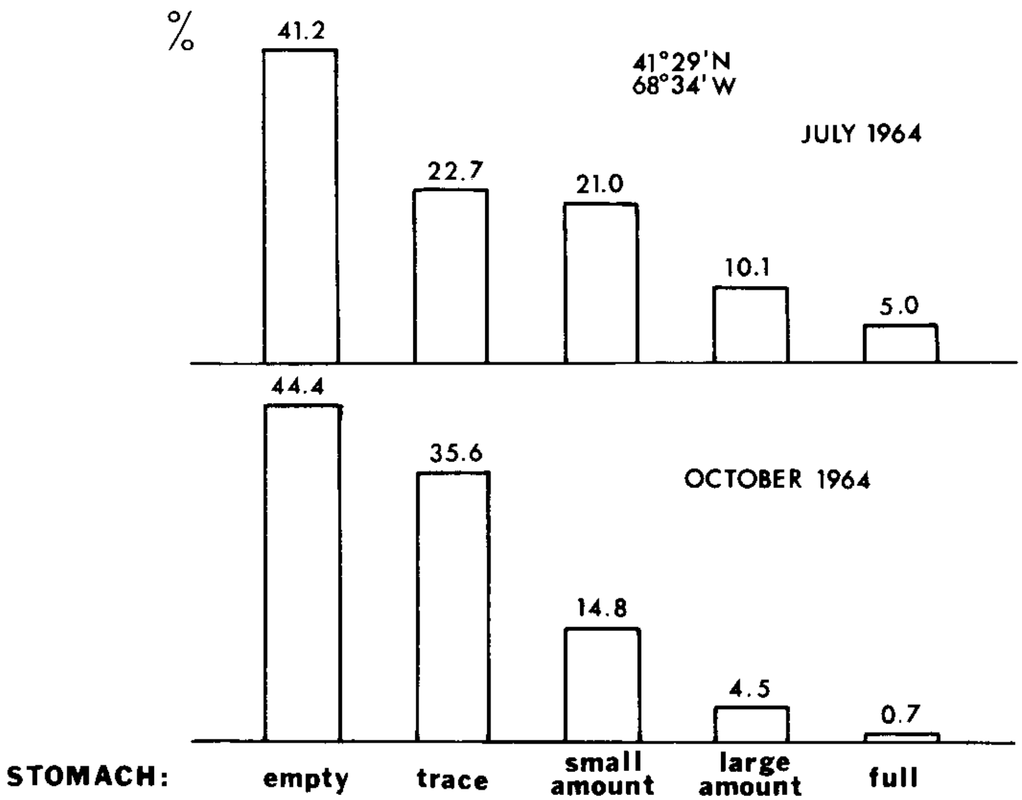

Fig. 4. Percent rate of stomach contents of alewife from Georges Bank, July and October, 1964.

Age Composition

Age composition of blueback and alewife in the catches is shown in Fig. 1 and 2.

In July, the age of captured blueback was 3–8 years (1961–56 year-classes). The most numerous group was 5-year-old fish (56.1%), belonging to the 1959 year-class.

Age composition of alewife, captured in July, was considerably different from the age composition of the fish captured in October. In July, the fish were 2–9 years old (1962–55 year-classes), though most of the fish were 4–6 years old (1960–58 year-classes). These year-classes were represented by more or less equal numbers of individuals and made up 79.6% of the alewife catches.

In October, however, captured alewife were 3–8 years old (1961–56 year-classes), the most numerous being 5-year-old ones (1959 year-classes—56.9%). The next most numerous were the 4 and 6 year olds (1960 and 1958 year-classes). In the samples investigated, the 4-, 5- and 6-year-old fish made up 95.0% of the total numbers.

Rate of Growth

The rate of growth of blueback and alewife is presented as mean fish length in particular year-classes. In addition, the weight of some age-groups of alewife captured in October 1964 is given.

TABLE 3. Mean length (cm) and weight (g) of subsequent age-groups of blueback and alewife.

Species	Captured	Age-groups 2	3	4	5	6	7	8	9
		Mean length							
Blueback	July		24.0	26.9	28.1	29.2	30.2	31.3	
Alewife	July	18.0	27.0	28.4	29.4	30.6	31.6	32.7	33.0
Alewife	October		25.0	27.8	28.8	29.6	31.0	33.0	
		Mean weight							
Alewife	October		158	201	225	243	271	328	

TABLE 4. Sexual maturity of blueback and alewife according to Maier's scale.

Species	Captured	Sex	Percent of fish in particular stages of sexual maturity I	II	III	IV	V	VI	VII	VIII	Total %
Blueback	July	♂		26.1							26.1
		♀		73.9							73.9
		♂ + ♀		100.0							100.0
Alewife	July	♂	0.9	24.4			0.8			0.8	26.9
		♀	0.9	70.6	0.8					0.8	73.1
		♂ + ♀	1.8	95.0	0.8		0.8			1.6	100.0
Alewife	October	♂		21.9	16.1	0.7					38.7
		♀		56.2	5.1						61.3
		♂ + ♀		78.1	21.2	0.7					100.0

The figures given in Table 3 show that the length of particular year-classes of blueback is smaller than that of alewife. There is, however, a difference between the length of alewife captured in July and those captured in October. Apparently, alewife captured in July had a better rate of growth than alewife captured in October. This may indicate that two different year-classes were being dealt with (Table 4).

Sexual Maturity

In July, all blueback had the gonads in the maturity stage II, which may indicate that they return to the feeding ground in the sea after spawning.

Also, in July, it has been found among alewife in the investigated samples that 1.8% were virgin fish (I) and 95.% in the maturity stage II. Few individuals were in stage III (0.8%) and stage V (0.8%). The presence of alewife in the stage VIII, in the amount of 1.6%, indicates that this species returned a little later than blueback from their spawning grounds in inland waters. The investigations of gonads of fish captured in October point to considerable progress in their development, since along with the most numerous group in stage II (78.1%) there appeared a rather large group with gonads in stage III (21.2%) and few individuals in stage IV (0.7%).

In the ratio of males and females, for both blueback and alewife, there was a considerable predominance of females, the proportion being 1:3. This might lead to the conclusion that the return migration of males to their feeding in the sea was retarded. In October, there was a predominance of alewife females, the ratio of sexes being 1:1.5.

Feeding

Feeding intensity of blueback and alewife is shown in Fig. 3 and 4.

In summer, the stomachs of 84.4% of blueback were empty. Further 15.6% of these fish had either traces of food or their stomachs had various amount of food contents. No fish with full stomachs were observed.

The feeding of alewife was much more intensive in July and October. The number of fish with empty stomachs was slightly over 40% in both seasons. About 60% of fish had some contents in their stomachs, though more fish with large amount of food and with full stomachs (15.1%) were found in July and October. The observations on the condition of fish have shown that in October the digestive tract of alewife was covered with fat.

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Occurrence of *Sphyrion lumpi* on Silver Hake, *Merluccius bilinearis*

In July 1965, two silver hake, *Merluccius bilinearis*, were brought to the Biological Laboratory, Bureau of Commercial Fisheries, Woods Hole, Massachusetts, each with a parasitic copepod attached to the dorsal muscle between the dorsal fin and lateral line. The copepods were identified as female *Sphyrion lumpi* by Dr H. W. Stunkard. This is the first record of *Sphyrion* infestation of *Merluccius*.

The parasitized silver hake were part of a commercial catch made by a Gloucester dragger fishing in 16–18 fathoms of water around Lumbo Buoy (43°42′ N lat, 69°54′ W long) near Portland, Maine. Length and sex were not available because the fish had been headed and gutted. The estimated total length of each fish is 28 cm.

S. lumpi was first described from the lumpfish, *Cyclopterus lumpus*, by Kroyer (1845) and since that time has been known primarily as a parasite of redfish, *Sebastes marinus*, on both sides of the North Atlantic. Little is known of the early life history of this species and there is no evidence that a secondary host is involved. The incidence of *S. lumpi* on redfish was reviewed by Williams (1963). His paper includes a comprehensive bibliography on other marine fishes infected by *S. lumpi*, which include: wolffish, *Anarrhichas lupus*; salted hake (species unknown); *Nematonurus goodei* (=*N. armatus*); blue hake, *Haloporphyrus viola* (=*Antimora rostrata*); *Antimora australis*; *Cottunculoides inermis*; and *Macrourus sp.* All of these are deep-water species.

It is unlikely that the silver hake were infected in the area where they were caught. Kelly and Barker (1965), who reviewed the incidence of *S. lumpi* in the Gulf of Maine, reported that the copepod infestation on Gulf of Maine redfish increases during the winter and spring and increases with depth from 65 to 100 fathoms, where redfish are most abundant. Silver hake move seasonally from deep water (>60 fathoms) in the winter to shoal water (<60 fathoms) in the summer. Infection probably took place when the silver hake were in deep water with the redfish.

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INTERNATIONAL COMMISSION FOR THE NORTHWEST ATLANTIC FISHERIES

THE COMMISSION IN BRIEF

Under the terms of a Convention signed in 1949, the International Commission for the Northwest Atlantic Fisheries (ICNAF) is responsible for promoting and co-ordinating scientific studies on the stocks of the species of fish which support international fisheries in the Northwest Atlantic. Based on these researches, the Commission recommends measures to keep these stocks at a level permitting the maximum sustained catch.

The governments sharing these conservation interests are Canada, Denmark, France, Federal Republic of Germany, Iceland, Italy, Norway, Poland, Portugal, Spain, Union of Soviet Socialist Republics, United Kingdom and United States of America.

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The International Commission for the Northwest Atlantic Fisheries (ICNAF) invites contributions to its new serial publication, "The Research Bulletin of ICNAF".

There will be one or more issues each year depending on the number of papers received and accepted for publication.

Purpose. The main purpose of the Research Bulletin is to publish the results of research carried out in the ICNAF area. It is expected that most papers published in the Research Bulletin will be selected from papers presented at Annual Meetings of the Commission, but other papers, either concerning the ICNAF area or outside it, will be accepted if their contents are of importance to the work of the Commission.

Submission of Manuscripts. Manuscripts for publication should be submitted to the Commission's Secretariat on or before October 1st each year. This provides authors with sufficient time to revise or extend papers submitted or solicited at the previous Annual Meeting of the Commission which is held in early June each year. The arrangement also provides the possibility that the Bulletin can be issued before the next Annual Meeting of the Commission.

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INSTRUCTIONS TO AUTHORS FOR THE PREPARATION OF MANUSCRIPTS INTENDED FOR PUBLICATION IN THE RESEARCH BULLETIN OF ICNAF

TEXT

(a) Manuscript should be type-written, *double-spaced*, and on one side only of good quality white bond quarto paper, size $8\frac{1}{2} \times 11$ inches (220×280 mm).

(b) Leave all margins 1 inch (25 mm) to $1\frac{1}{2}$ inches (38 mm) for editorial marks and queries.

(c) Prepare and submit the original and two carbon copies of the text and at least two sets of illustrations.

(d) Number all pages of the manuscript consecutively with Arabic numerals in the centre of the top margin space.

(e) Start a new page for each of the following sections with appropriate headings and sub-headings: (1) title, name and address of author, list of contents (if applicable); (2) abstract of the paper; (3) text; (4) references to literature; (5) tables; (6) legends for figures and (7) figures.

(f) Please *double-space everything*—Text, quotations, footnotes, tables and table headings, legends, references to literature, and use even greater spacing where helpful (particularly around equations and formulae).

(g) Wherever practical the text should be subheaded into Introduction, Materials and Methods, Results and Discussion. Authors must provide a Summary which lists one by one the principal facts and conclusions of the paper. Acknowledgements should be placed immediately after the Summary.

(h) All measurements, linear, weight and time, should be given in numerals (not words) in the metric system. The Celsius scale should be used as a standard. When other units of measure are preferred, authors should include equivalents in metric units.

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(j) Only those words to be printed in italics should be underlined.

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ABSTRACT

Each manuscript should have an abstract not to exceed 3% of the length of the text or 200 words whichever is the smaller. For position of the abstract in the manuscript see (e) above. The abstract should summarize the contents and conclusions of the paper, point to new information in the paper and indicate the relevance of the work.

TABLES

(a) Tables should be carefully constructed so that the data presented may be easily understood.

(b) Tables should be set out on separate sheets following the references.

(c) Position of the tables in the text should be indicated clearly.

(d) Each table should be provided with a descriptive heading which, together with the column headings, makes the table intelligible without reference to the text.

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FIGURES

(a) All illustrations, whether black-and-white drawings, graphs, photographs or tone drawings, are to be considered as figures.

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BIBLIOGRAPHIC STYLE

(a) References to literature in the text should be by the author-date system, for example

It was reported that (Collins, 1960) the . . .;
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