RESTRICTED

International Commission for the Northwest Atlantic Fisheries

Serial No. 3525
(D.c.2)

ICNAF Res.Doc. 75/46

ANNUAL MEETING - JUNE 1975

Growth and mortality rates for cod from the Georges Bank and Gulf of Maine areas

by

J. A. Penttila and V. M. Gifford
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole, Massachusetts 02543

Publ. in ICNAF Res. Bull. No. 12: 29-36

Abstract

Growth rates for the Georges Bank and Gulf of Maine areas were estimated by fitting a von Bertalanffy growth curve to pooled length at age data from research vessel survey cruises for the years 1970 to 1974. The values obtained for the Georges Bank area were: $K = .120$, $L_\infty = 148.1$, and $t_0 = -0.616$. For the Gulf of Maine area, the values obtained were: $K = .116$, $L_\infty = 146.5$, and $t_0 = 0.285$. Total instantaneous mortality rates for these areas were estimated from research vessel survey data from 1970 to 1974. An average of the estimates given by a linear regression analysis of the catch curve and a Robson-Chapman analysis of a segment of the catch curve gives a Z of .56 for Division 5Z and .68 for Division 5Y.

Introduction

This paper presents the results of initial studies of growth and mortality rates for cod in ICNAF Subarea 5. The first assessment of cod in this area was done for Division 5Z in 1972 (Brown and Heyerdahl, 1972). At that time, very little age data were available and estimates of mortality were not calculated. An assessment of the cod from Division 5Y has not yet been done. These preliminary studies of growth and mortality rates for both Divisions 5Z and 5Y were begun in order to improve the assessment of the status of the fishery in these areas. The data for these studies were collected on the annual US spring and autumn bottom trawl surveys from the spring of 1970 to the spring of 1974.

Areas of study

The areas chosen for growth studies were based on those suggested by Wise (1962). He proposed the existence of four separate groups of cod in the New England area (Fig. 1): 1) cod of Georges Bank; 2) cod of the Gulf of Maine; 3) cod of Southern New England and the South Channel (the area called South and Nauset in this paper); and 4) New Jersey coastal cod which spend the summer in Southern New England. Because of the difficulty of separating the New Jersey cod from the Nauset cod in the fall, all of the data from Chesapeake Bay north to Long Island were combined with the South and Nauset data in the growth analysis. Areas in the Gulf of Maine of depth greater than 100 fathoms were not included in any of the analyses since not many cod are caught there.

Mortality rates were estimated for only two areas: ICNAF Division 5Z (comprising the Georges Bank and the South and Nauset areas) and Division 5Y (the Gulf of Maine area).

Collection of data

During the years 1963 to the present time, routine surveys of the area between Cape Hatteras and Halifax have been conducted by the R/V *Albatross IV* two or three times a year. A Number 36 Yankee trawl with a 4½-inch mesh and a ½-inch mesh liner in the cod end was used on all cruises except the 1973 and 1974 spring cruises. On these two cruises a Number 41 Yankee trawl was used. Because of the difference

in fishing power of these two nets, adjustments were made in the estimated mean catch per tow figures for the Number 41 Yankee trawl. The survey cruises employed a stratified random sampling design with strata based on depth and geographical subdivisions. The number of stations per stratum were allocated roughly proportional to the area of the stratum. All hauls were 30 minutes in duration. (For a detailed account of the survey methods, see Grosslein, 1969.)

On the survey cruises, length frequencies of the catch were recorded and otoliths for age determination were collected routinely. In most cases the entire catch of cod was measured; but in those instances where the catch was quite large, a representative subsample was measured and then the length frequency of the entire catch was estimated. The fish from which otoliths were taken were usually subsamples stratified by length, except where catches were small enough to permit total sampling.

The otoliths were prepared for aging by baking them at about 270° C (520° F) for 6 minutes. The baking enhances the visibility of the annuli by turning the hyaline zones brown while the opaque zones remain white. The otoliths were then broken in half at the sulcus and aged under a binocular dissecting microscope at a magnification of about 15X.

Determination of age and length composition

Age-length keys were determined for each of the surveys from the spring of 1970 to the spring of 1974. Since the age data collected on these cruises were stratified by length, age-length keys were used to assign ages for the total length frequency of all cod caught by the research vessel. Tables 1 and 2 contain data on the total number of cod caught and the total number aged for each age with cruise data pooled over seasons. The majority of the fish which were not aged were in the age 1 to age 4 groups, for which the sample sizes were quite large. There were cases where lengths of fish in the age samples did not include every length class of all fish caught. The age of those fish in length classes for which age data were not available was determined by using the estimates of neighboring classes.

Mean length at age comparisons

After assigning ages to the length frequency of the total catch for each cruise, the data were pooled over years for each season (five years for spring and four years for fall), and mean lengths at age were calculated for the spring and for the fall for three areas: South and Nauset (including data from Long Island to Chesapeake Bay), Georges Bank, and the Gulf of Maine (Table 3). Table 3 shows that the Gulf of Maine fish are consistently smaller at age than either the South and Nauset fish or the Georges Bank fish, with the Georges Bank fish consistently larger than the fish from the other two areas. An analysis of variance on the mean length at age for ages 1 through 3 shows highly significant differences among these three areas. To test the individual differences, ranked mean lengths at age were compared using Duncan's new multiple range test (Steel and Torrie, 1960) modified for unequal sample sizes as proposed by Kramer (1956) (Table 3). This test showed highly significant differences between the areas except for the age 3 fall comparison between the Georges Bank and the South and Nauset areas which was not significant. From this age on, the mean lengths at age for the Georges Bank and the South and Nauset areas are very similar. The Georges Bank growth rate can be used, therefore, to estimate growth for the South and Nauset area after age 3.

Growth rates

Preliminary estimates of growth rates were calculated for the Georges Bank and the Gulf of Maine areas. A growth rate was not estimated for the South and Nauset area because of the lack of older fish in the samples. Von Bertalanffy growth curves were fitted by least squares to the pooled mean length at age data from age 1 on using Allen's (1966) method:

$$l_t = L_\infty \left[1 - e^{-K(t-t_0)}\right],$$

where l_t is the body length estimated for time t, L_∞ is the average maximum length of the fish, K is a constant determining the rate of change in length increment, and t_0 is the theoretical time when the body length is zero. Mean lengths were calculated only if there were at least two fish for that age. Zero age group fish were not used because of possible bias due to incomplete recruitment of these fish. The values used in the analysis for the Georges Bank area are given in Table 1 and the resulting growth curve is shown in Figure 2. In Table 1, the ages are given in years plus the proportion of the year from January 1 until the date the fish were caught. For example, 3.10 refers to age 3 fish caught on

an early spring cruise, 3.25 refers to age 3 fish caught later in the spring, and 3.80 refers to age 3 fish caught in the fall. The early spring values (*e.g.*, 3.10) are based on only one cruise--a special survey made of the Georges Bank area in the early spring of 1972. The data from this cruise were used only in the growth rate studies. They were not used in determining mortality rates because the stations were not randomly selected, but were chosen because of fishing activity in the area.

In Figure 2 (and also in Figure 3), the asterisks show the mean lengths at age through which the growth curve was fitted, each dot represents one or more fish and indicates the range of fish lengths about the means, and N refers to the number of fish used in the analysis.

The values used in the analysis for the Gulf of Maine area are given in Table 2 and the growth curve is shown in Figure 3. In this table, 3.30 refers to age 3 fish caught in the spring and 3.85 refers to age 3 fish caught in the fall.

The values obtained from fitting the von Bertalanffy curve to the Georges Bank data were: $K = .120$, $L_\infty = 148.1$, and $t_0 = -0.616$. The standard deviations of these values were: for K, 0.015; for L_∞, 7.417; and for t_0, 0.276. The values obtained for the Gulf of Maine area were: $K = .116$, $L_\infty = 146.5$, and $t_0 = 0.285$. The standard deviations of these values were: for K, 0.011; for L_∞, 6.167; and for t_0, 0.187.

Because of the similarity of the growth rates for the Georges Bank and Gulf of Maine areas, and the previously noted similarity between the South and Nauset and Georges Bank areas, a growth curve was fitted to pooled data from all three areas. The values obtained were: $K = .123$, $L_\infty = 142.0$, and $t_0 = -0.357$. The standard deviations of these values were: for K, 0.012; for L_∞, 5.202; and for t_0, 0.240.

The only other information available on growth rates in these areas is from Schroeder's (1930) data from the summer of 1923 for the Southern New England area. An analysis of his data using Allen's method gives an estimate of $K = .177$ and $L_\infty = 123.1$. There are two factors which may account for the differences between the Southern New England growth rate calculated from Schroeder's data and the Georges Bank growth rate presented here. One is the lack of older fish in his samples and the second is that his data are based on scales which are very difficult to interpret after the age of 6 or 7.

Mortality estimation procedures

Preliminary estimates of the total instantaneous mortality rates for ICNAF Divisions 5Z and 5Y were calculated. Only data from spring cruises were used because of the longer series (five years) and also because lower catches in the fall do not give sufficient data for analysis. Using the survey data from the five spring cruises from 1970 to 1974, stratified means of numbers caught per tow, per 3 cm length interval, per age group were estimated for the two areas. Estimates of the mean catch per tow for each age group and each cruise were then obtained for each area (Tables 4 and 5). Because of the difference in fishing power between the No. 36 and No. 41 Yankee trawls, adjustments were made in the estimated mean catch per tow figures for the 1973 and 1974 cruises. Gear comparison studies (unpublished data in the files of the National Marine Fisheries Service, Northeast Fisheries Center, Woods Hole, Massachusetts) have indicated a ratio of 3:1 in the catches of groundfish between the No. 41 and No. 36 trawls. Therefore, the mean catch per tow for the 1973 and 1974 cruises was estimated as being 1/3 of the actual catch per tow of these cruises.

Total instantaneous mortality rates (Z) were determined from the ratios of the catch per tow in one year to the catch per tow of the previous year for a given year class. The equation used was:

$$Z = - \log_e \left[\frac{N_{i+1,j+1}}{N_{i,j}} \right],$$

where $N_{i,j}$ is the estimated catch per tow for age-group j and year i. These estimates of Z for Division 5Z (Table 6) show that recruitment is essentially complete at age 3. After age 9 there is insufficient data, and therefore, only data from ages 3 to 9 were used to estimate mortality rates for Division 5Z. Table 7 gives estimates of Z determined from ratios for Division 5Y. These estimates show that recruitment in this area is essentially complete at age 4. Only data from ages 4 to 10 were used to estimate mortality rates for 5Y because of insufficient data after age 10.

The natural logarithms of the mean catch per tow for each year class were plotted against age (Ricker, 1958) (Figures 4 and 5) and then the total instantaneous mortality rate (Z) for each area was calculated for each year class by least squares linear regression of the points from age 3 to 9 for Division 5Z, and of the points from age 4 to 10 for Division 5Y (Tables 8 and 9). Estimates were

calculated only for year classes with at least three data points. Correlation coefficients are given in the tables.

Estimates of Z for each year class were calculated using the Robson-Chapman (1961) analysis of a segment of the catch curve (Tables 8 and 9). The segments used were ages 3 to 9 for 5Z and 4 to 10 for 5Y. Again, estimates were calculated only for year classes with at least three years of data.

Results of mortality rate analyses

For Division 5Z, the linear regression analysis of the catch curve gave an average over year class estimates of Z = 0.60, and the Robson-Chapman analysis gave an average over year class estimates of Z = 0.53. The average of these two estimators gives a total instantaneous mortality rate for Division 5Z of 0.56.

For Division 5Y, the linear regression analysis of the catch curve gave an average over year class estimates of Z = 0.72, and the Robson-Chapman analysis gave an average over year class estimates of Z = 0.65. The average of these two estimators gives a total instantaneous mortality rate for Division 5Y of 0.68.

Assuming a natural mortality rate of 0.2, gives an estimate of F = 0.36 for Division 5Z and F = 0.48 for Division 5Y.

References

Allen, K. R. 1966. A method of fitting growth curves of the von Bertalanffy type to observed data. J. Fish. Res. Bd. Canada, 23:163-179.

Brown, B. E., and E. G. Heyerdahl. 1972. An assessment of the Georges Bank cod stock (Div. 5Z). ICNAF Res. Doc. 72/117.

Grosslein, M. D. 1969. Groundfish survey program of BCF Woods Hole. Comm. Fish. Rev., 31:22-30.

Kramer, C. Y. 1956. Extension of multiple range tests to group means with unequal numbers of replication. Biometrics, 12:307-310.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Bull. Fish. Res. Bd. Canada, No. 119, pp. 1-300.

Robson, D. S., and D. G. Chapman. 1961. Catch curves and mortality rates. Trans. Amer. Fish. Soc., 90:181-189.

Schroeder, W. C. 1930. Migrations and other phases in the life history of the cod off Southern New England. Bull. US Bur. Fish., 46:1-136.

Steel, R. G. D., and J. H. Torrie. 1960. Principles and procedures of statistics. McGraw-Hill, Inc., New York. 481 pp.

Wise, J. 1962. Cod groups in the New England area. Fish. Bull. 63(1):189-203.

Table 1. Data used to fit the von Bertalanffy growth curve for cod from the Georges Bank area with a summary of the estimates obtained.

Age	Mean Length at Age (in cm.)	Standard Deviation	Total Number Caught	Number Aged	Fitted Length
1.25	22.43	4.31	262	191	29.76
1.80	34.96	4.43	309	223	37.33
2.10	42.89	3.50	89	65	41.26
2.25	44.09	4.15	2351	692	43.17
2.80	52.03	4.83	242	196	49.88
3.10	56.92	4.66	178	136	53.36
3.25	57.95	5.25	734	467	55.05
3.80	63.33	4.93	109	79	61.00
4.10	66.94	6.64	34	30	64.09
4.25	66.50	5.89	459	269	65.59
4.80	70.17	6.64	88	68	70.87
5.10	75.33	6.26	15	13	73.60
5.25	74.87	7.18	160	138	74.94
5.80	78.73	8.71	22	22	79.62
6.10	83.67	6.72	43	37	82.04
6.25	79.78	7.87	91	75	83.22
6.80	84.80	7.41	5	5	87.37
7.10	95.40	7.91	5	5	89.52
7.25	86.93	8.33	68	59	90.57
7.80	100.33	6.02	3	2	94.25
8.10	91.43	7.80	23	20	96.15
8.25	93.20	7.98	45	41	97.08
8.80	102.33	7.59	3	2	100.34
9.10	98.05	8.77	20	20	102.04
9.25	103.10	8.27	30	24	102.86
9.80	102.50	2.50	2	1	105.75
10.25	104.56	8.55	18	16	107.98
11.25	117.29	5.01	7	7	112.52
12.10	107.50	11.50	2	2	115.97
12.25	122.14	5.91	7	6	116.55
13.10	112.00	2.94	3	3	119.61
14.10	123.50	6.50	2	2	122.83
14.25	128.40	7.74	5	5	123.28
15.25	131.50	4.50	2	2	126.09

$K = .12026$ Standard deviation = 0.01496

$L_\infty = 148.05838$ Standard deviation = 7.41717

$t_o = -0.61611$ Standard deviation = 0.27606

Table 2. Data used to fit the von Bertalanffy growth curve for cod from the Gulf of Maine area with a summary of the estimates obtained.

Age	Mean Length at Age (in cm.)	Standard Deviation	Total Number Caught	Number Aged	Fitted Length
1.30	14.94	3.62	70	39	16.27
1.85	23.12	4.92	412	113	24.32
2.30	26.85	4.08	327	106	30.54
2.85	37.21	7.17	222	159	37.71
3.30	39.63	6.97	338	222	43.24
3.85	54.53	8.55	101	84	49.63
4.30	57.87	7.85	97	85	54.55
4.85	68.10	7.83	69	60	60.24
5.30	68.04	9.15	57	49	64.63
5.85	70.35	11.14	52	46	69.69
6.30	76.09	8.80	44	37	73.60
6.85	78.89	7.94	36	31	78.11
7.30	78.18	10.83	50	44	81.59
7.85	83.32	13.07	34	32	85.60
8.30	86.82	8.03	38	36	88.70
8.85	93.57	9.61	21	19	92.27
9.30	94.17	9.43	35	34	95.03
9.85	97.29	9.24	14	14	98.22
10.30	97.95	9.81	21	20	100.67
10.85	100.43	10.94	7	7	103.51
11.30	102.47	5.28	15	14	105.70
11.85	101.33	7.36	3	3	108.22
12.30	107.54	7.24	13	12	110.17
12.85	119.00	1.00	2	2	112.42
13.30	113.80	4.75	10	8	114.15
14.30	119.50	1.12	4	3	117.70
16.30	128.33	3.86	3	3	123.67
17.30	127.00	3.00	2	2	126.17

$K = .11599$ Standard deviation = 0.01133

$L_\infty = 146.53571$ Standard deviation = 6.16723

$t_o = 0.28517$ Standard deviation = 0.18718

Table 3. Cod mean lengths at age with probability levels from analysis of variance and Duncan's new multiple range test.

	Cod mean lengths at age (in centimeters)					
	Age 1		Age 2		Age 3	
Area	Spring	Fall	Spring	Fall	Spring	Fall
Georges Bank	22.4	35.0	44.1	52.0	57.9	63.3
South & Nauset	19.3	29.9	40.1	46.9	56.3	62.9
Gulf of Maine	14.9	23.1	26.8	37.2	39.6	54.5
Probability levels of F from analysis of variance	<.001	<.001	<.001	<.001	<.001	<.001
Duncan's new multiple range test results:	Probability levels that cod from the two areas are not different					
	Spring	Fall	Spring	Fall	Spring	Fall
Georges Bank Gulf of Maine	<1.0%	<1.0%	<1.0%	<1.0%	<1.0%	<1.0%
Georges Bank South & Nauset	<1.0%	<1.0%	<1.0%	<1.0%	<1.0%	>5.0%
South & Nauset Gulf of Maine	<1.0%	<1.0%	<1.0%	<1.0%	<1.0%	<1.0%

Table 4. Estimated mean catch/tow per age-group for cod from ICNAF Division 5Z. (Spring cruises only.)

Age-group	1970	1971	1972	1973	1974
0		.013	.024	.008	.017
1	.190	.111	1.321	.078	.064
2	.353	.409	.942	6.275	.658
3	.243	.219	1.265	.920	.912
4	.852	.166	.198	.942	.118
5	.122	.423	.117	.110	.295
6	.364	.093	.233	.092	.062
7	.135	.161	.060	.075	.021
8	.048	.151	.169	.017	.043
9	.068	.060	.058	.031	.011
10	.006	.018	.025	.028	.019
11	.013	.039	.006	.012	.005
12	.023		.016	.009	
13		.012		.003	
14	.005		.012	.004	
15		.011		.003	
16					
17				.004	
Total	2.423	1.888	4.445	8.611	2.224

Table 5. Estimated mean catch/tow per age-group for cod from ICNAF Division 5Y.(Spring cruises only.)

Age-group	1970	1971	1972	1973	1974
0					
1	.237	.038	.525	.009	.231
2	.197	.147	.227	2.128	.033
3	.066	.169	.714	.441	.641
4	.117	.313	.264	.279	.121
5	.340	.092	.277	.108	.086
6	.492	.132	.032	.084	.031
7	.773	.282	.055	.038	.012
8	.121	.269	.127	.093	.021
9	.078	.206	.135	.146	.015
10	.117	.049	.041	.085	.030
11	.162	.033	.052	.040	.017
12	.067	.026	.050	.043	.029
13				.063	
14				.018	.008
15			.023		.006
16				.009	.018
17				.018	
Total	2.767	1.756	2.524	3.601	1.299

Table 6. Estimates of total instantaneous mortality rates (Z) for ICNAF Division 5Z determined from the ratio of the catch/tow in one year to the catch/tow of the previous year for a given year class.

	Year Class																
Age	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1958	1956	Average
0-1	-2.07	-1.17	-4.60														-2.61
1-2		-2.14	-1.56	-2.14	-.76												-1.65
2-3			1.93	.02	-1.13	.48											.32
3-4				2.05	.30	.10	.38										.71
4-5					1.16	.58	.36	.70									.70
5-6						.57	.24	.60	.27								.42
6-7							1.50	1.13	.43	.82							.97
7-8								.57	1.24	-.05	-.11						.41
8-9									.46	1.70	.96	-.24					.72
9-10										.52	.75	.88	1.33				.87
10-11											1.66	.76	1.18	-1.89			.42
11-12													-.50	.90			.20
12-13														1.69	.66		1.17
13-14															.01		.01
14-15															1.30	-.75	.28

Table 7. Estimates of total instantaneous mortality rates (Z) for ICNAF Division 5Y determined from the ratio of the catch/tow in one year to the catch/tow of the previous year for a given year class.

	Year Class																
Age	1973	1972	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960	1959	1957	Average
0-1																	
1-2		-1.33	-1.40	-1.79	.48												-1.01
2-3			1.20	-.66	-1.58	.15											-.22
3-4				1.29	.94	-.45	-1.56										.06
4-5					1.18	.90	.12	.25									.61
5-6						1.23	1.19	1.06	.95								1.11
6-7							1.96	-.17	.87	.56							.80
7-8								.57	-.52	.80	1.06						.48
8-9									1.80	-.14	.68	-.53					.46
9-10										1.59	.46	1.62	.46				1.03
10-11											1.64	.03	-.04	1.25			.72
11-12												.30	.18	-.40	1.82		.47
12-13														-.22			-.22
13-14														2.09			2.09
14-15															1.15		1.15
15-16																.98	.98

Table 8. Estimates of total instantaneous mortality rates (Z) for ICNAF Division 5Z.

Year Class	Ages of Fish	Estimates from Linear Regression Analysis of Catch Curve: Mortality (Z)	Estimates from Linear Regression Analysis of Catch Curve: Correlation Coefficients	Estimates from Robson-Chapman Analysis of a Segment of Catch Curve: Mortality (Z)
1969	3,4,5	.72	-.94	.62
1968	3,4,5,6	.43	-.96	.40
1967	3,4,5,6,7	.54	-.92	.44
1966	4,5,6,7,8	.76	-.99	.74
1965	5,6,7,8,9	.64	-.97	.55
1964	6,7,8,9	.71	-.92	.60
1963	7,8,9	.42	-.81	.34
Average of the estimates		.60		.53
		Overall average .56		

Table 9. Estimates of total instantaneous mortality rates (Z) for ICNAF Division 5Y.

Year Class	Ages of Fish	Estimates from Linear Regression Analysis of Catch Curve: Mortality (Z)	Estimates from Linear Regression Analysis of Catch Curve: Correlation Coefficients	Estimates from Robson-Chapman Analysis of a Segment of Catch Curve: Mortality (Z)
1968	4,5,6	1.05	-.99	1.01
1967	4,5,6,7	1.09	-.94	.73
1966	4,5,6,7,8	.42	-.94	.44
1965	5,6,7,8,9	.64	-.90	.63
1964	6,7,8,9,10	.61	-.94	.56
1963	7,8,9,10	.71	-.98	.82
1962	8,9,10	.52	-.64	.33
Average of the estimates		.72		.65
Overall average		.68		