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Total mortality rates for two groups of yellowtail flounder estimated from survey cruise data from ICNAF Subarea 5

by

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Abstract

Total instantaneous mortality rates were estimated by four different procedures for the southern New England and Georges Bank yellowtail flounder fishing grounds. Mortality rates were determined from research vessel survey data from 1963 to 1969 by the following methods: 1) slopes of the catch curves; 2) ratios of the catch per tow in a given season to the catch per tow of the same season for the previous year; 3) Robson-Chapman formula; and 4) Heincke's formula. Each method showed a lower mortality rate for Georges Bank than for southern New England, with an average of the estimates giving $Z = 1.00$ for Georges Bank and $Z = 1.25$ for southern New England.

Introduction

The increasing level of fishing on yellowtail flounder in recent years has made it necessary to establish catch quotas in ICNAF subarea 5. The assessment has been primarily based on analysis of commercial catch and effort data in order to bring the catch in line with production. To improve and corroborate the assessment of these stocks, total instantaneous mortality rates for the southern New England and Georges Bank yellowtail flounder fishing grounds were estimated from analysis of research vessel survey data by four different procedures. This was done separately for fish from the

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southern New England ground and the Georges Bank ground. These grounds contain two fairly distinguishable groups of yellowtail flounder (Lux, 1963). The data used for these analyses was collected on 14 standard groundfish survey cruises during the years 1963 to 1969.

Collection of Data

During the years 1963 to the present time, routine surveys have been conducted on the R/V Albatross IV in the southern New England and Georges Bank areas, two or three times a year. The seasonal distribution of the 14 cruises analyzed in this paper are listed below:

Year	Season		
	Winter	Summer	Fall
1963			X
1964	X	X	X
1965	X	X	X
1966	X		X
1967			X
1968			X
1969	X	X	X

A #36 Yankee trawl with a 4-1/2" mesh and a 1/2" mesh liner in the cod end was used. All hauls were 30 minutes in duration. (For a detailed account of the survey methods, see Grosslein, 1969.) The surveys were set up on a stratified random sampling design. The strata (Figure 1) were based on depth and geographic subdivisions. The number of stations per stratum were allocated roughly proportional to the area of the stratum.

Length frequencies of catch and scales for age determination were collected routinely. Fish from which scales were taken for aging were identified by sex. In most cases the entire catch of yellowtail 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. Prior to 1969, the fish from which scales were taken were usually subsamples stratified by length and by sex, except where catches were small enough to permit total sampling. In 1969, the fish were stratified by length only. The sex was recorded for all fish for which the age was determined. Method of aging was described by Lux and Nichy (1969).

Determination of Age and Length Composition

Since females grow faster than males after the age of two years (Lux and Nichy, 1969), it was necessary to have length frequency data prior to 1969 separated by sex before the age frequency could be expanded properly to estimate the age composition of catch. Males and females were separated in length frequency data for the nine cruises from 1963 to 1966. Sex composition of the length frequency data for the two cruises in 1967 and 1968 was not collected and average sex ratios had to be calculated as follows: Summaries were made by strata of the number of males and females in length groups for the nine cruises from 1963 to 1966 on which yellowtail length frequencies were recorded by sex. Five length groups were chosen: 1-25 cm., 26-30 cm., 31-35 cm., 36-40 cm., and greater than 40 cm. Sex ratios were then determined for each length group within each stratum and cruise and year. Sex ratios were averaged over

years for each season (winter, summer, and fall) for each length group and stratum. In those cases where fewer than 100 fish were used to determine a ratio, neighboring strata were combined to give the ratio for an area. The areas used were: off Block Island, Nantucket Shoals, SW Georges Bank, SE Georges Bank, and Cultivator Shoals (Figure 1). These average sex ratios were used to determine sex composition length frequencies on the two survey cruises in 1967 and 1968. For the 1969 cruises, where age samples were stratified only by length and not by sex, ratios of the fish in the age sample were used wherever possible to estimate the number of males and females in the entire catch.

Age-length frequencies for the entire catch were then determined. Stratified means of numbers caught per tow for southern New England and Georges Bank per one cm. length interval, per age group, were estimated. There were cases where lengths of fish in the age samples did not match every length class of all fish caught. The age of those fish in length classes for which age data was not available was determined by inspection of neighboring classes. These estimates were used to determine the instantaneous mortality rates for southern New England and Georges Bank.

Mortality Estimation Procedures

Catch curves for the southern New England and Georges Bank grounds were obtained for each year class by plotting the natural logarithms of the mean catch per tow (Tables 1 and 2) against age (Ricker, 1958) (Figures 2 and 3). These curves show that recruitment to the net used on the survey cruises was essentially complete at age 3. The instantaneous mortality rate (Z) for each ground was then calculated for each year class by least squares linear regression of the points for age 3 and older. Correlation coefficients were computed (Table 3). The slope values were averaged to obtain overall estimates of Z. The instantaneous mortality rate and correlation coefficient were then estimated from pooled data over all year classes.

The estimated mean catch per tow was used to estimate the annual survival rate for southern New England and Georges Bank within each year class from the ratio of the catch/tow in a given season to the catch/tow of the same season for the previous year (Tables 4 and 5). The formula used was:

$$r_{ij} = \frac{N_{i+1,\,j+1}}{N_{ij}}$$

where r_{ij} is the individual ratio, N_{ij} is the estimated catch/tow for age group j and year i.

Ratios of sums of numerator and denominator above were also calculated: $r_{\cdot j}$, $r_{i\cdot}$, and $r_{\cdot\cdot}$, where the dot indicates the subscript over which the sums were taken. Annual ratios were determined only for fall cruises, as there was insufficient data to determine annual ratios for winter and summer cruises.

Annual survival rates were also estimated by Robson - Chapman and Heincke's formulas for data from age 3 on for each cruise (i.e., season) (Robson and Chapman, 1961). A Chi square test was employed to determine if the difference between the two estimates could be attributed to sampling error or considered as real. If the difference is real, then there is a discrepancy in the frequency of the lowest age group considered relative to frequencies in older age groups. The annual survival rate estimates are given in Tables 6 and 7.

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Results and Discussion

Using the slope of the catch curve for all year classes combined from age 3 on, an estimate of the instantaneous mortality rate (Z) of 1.17, equivalent to an annual survival rate (s) of .31, was obtained for the southern New England ground with a correlation coefficient (r) of -0.847. For the Georges Bank ground, estimates of Z = 1.02, s = .36, and r = -0.888 were calculated. Averaging the values of Z from Table 3 based on 3 or more points, with negative slopes omitted, gives a Z of 1.35 for southern New England. Similarly, for Georges Bank, an average Z of 0.97 was obtained.

Ratios for fall cruises for southern New England gave an estimate of survival, s = .33, from the overall pooled ratio $r_{\cdot\cdot}$, for ages 3 and older, which is equivalent to an instantaneous mortality rate of Z = 1.11. For Georges Bank, s = .36, Z = 1.02.

The average Robson and Chapman estimate of annual survival rate over the 14 cruises is .264, or Z = 1.33, for southern New England and .383, or Z = 0.96, for Georges Bank. Similarly, the average Heincke estimate of survival rate is .278, or Z = 1.28, for southern New England and .360, or Z = 1.02, for Georges Bank. The highest Chi square value obtained comparing the values from the two estimators, was 3.079, which is below the 5% significance level, indicated that age 3 fish are fully vulnerable to the gear used.

A summary of the instantaneous mortality rates estimated for the southern New England and Georges Bank grounds is shown in the table below.

	So. N. Eng. Mort. rates	Geo. Bk. Mort. rates
Avg. of catch slopes over year classes	1.35	0.97
Est. from slope of pooled catch curve	1.17	1.02
Est. from ratios	1.11	1.02
Robson/Chapman est.	1.33	0.96
Heincke est.	1.28	1.02
Avg. of the 5 estimates	1.25	1.00

The above five estimators used show reasonable agreement within each ground. In each case, the mortality rate is lower for Georges Bank than for southern New England. Averaging the estimates gave Z = 1.25 for southern New England and Z = 1.00 for Georges Bank. The higher total mortality rate for the southern New England ground could well reflect the greater fishing effort (Brown and Hennemuth, 1971) observed during this period. There is a trend towards higher estimates of mortality rates in more recent cruises particularly in the southern New England area using Robson-Chapman and Heincke estimates. Natural mortality for yellowtail flounder has been estimated to be 0.2, or perhaps even as low as 0.1 (Lux, 1969, and Brown and Hennemuth, 1971). Since natural mortality rates for southern New England and Georges Bank would be expected to be similar, the higher total mortality rate for southern New England can be attributed to greater fishing effort.

Lux (1969) obtained instantaneous mortality rates of 1.03 for southern New England and 1.01 for Georges Bank from catch curve survival ratios for age groups 4 to 7 from 1960 to 1965 commercial landings data. Lux (1969) also estimated mortality for southern New England from the data of Royce, Buller, and Premetz (1959), obtaining a Z of .78 for age

groups 4 to 6 in the period 1943 to 1947. These estimates were obtained for earlier periods when fishing effort was less than at present. Brown and Hennemuth (1971) estimated Z using the virtual populatin method for the 1958 to 1962 year classes, obtaining average values of 1.36 for southern New England and 1.16 for Georges Bank for ages 4 to 7 using commercial data. Their average Z for ages 3 to 7 for southern New England was 1.25.

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Table 1. -- Estimated mean catch/tow per age group for yellowtail flounder from southern New England.

Year and Season	Age-group 0	1	2	3	4	5	6	7	8	9	10
1963											
Fall	.05	16.34	14.89	14.49	4.25	.45	.00	.08			
1964											
Winter	.00	.44	8.48	8.35	6.64	2.71	1.10				
Summer	.00	.67	9.66	4.52	5.93	3.22	.39	.17			
Fall	.00	18.62	26.51	4.88	6.19	3.00	1.59				
1965											
Winter	.00	.12	24.47	7.04	1.98	1.26	.59	.03			
Summer	.00	.64	21.27	14.77	1.69	.12					
Fall	.26	11.54	17.02	6.16	1.80	1.75	.21				
1966											
Winter	.00	.24	6.17	5.71	3.33	.83	1.08	.52	.07		
Fall	.88	35.51	10.94	1.74	.98	.19					
1967											
Fall	.28	20.05	24.17	11.15	1.40	.42	.07	.11			
1968											
Fall	.00	10.02	11.95	16.70	1.15	.18					
1969											
Winter	.00	4.67	15.54	22.04	12.41	2.31	.13				
Summer	.00	.21	14.89	40.45	3.82						
Fall	.00	12.83	13.03	22.79	5.77	.18	.05				

Table 2. -- Estimated mean catch/tow per age group for males and females combined for yellowtail flounder from Georges Bank.

Year and Season	Age-group 0	1	2	3	4	5	6	7	8	9	10
1963											
Fall	.00	12.46	6.37	9.42	1.24	.34	.07	.17	.00	.07	
1964											
Winter	.00	.23	3.18	4.02	5.45	1.12	.58	.03	.05		
Summer	.00	2.06	3.77	2.15	1.29	.29	.09	.09			
Fall	.00	1.49	7.74	6.88	4.32	2.04	.40	.10			
1965											
Winter	.00	.00	3.82	8.73	3.25	4.74	.79				
Summer	.00	.32	6.15	6.52	1.43	1.20	.03				
Fall	.01	.91	5.06	5.38	2.44	1.00	.06	.16			
1966											
Winter	.00	.12	1.42	2.71	2.80	1.58	.80	.11			
Fall	1.16	8.27	2.98	1.54	.65	.14					
1967											
Fall	.05	7.44	7.59	2.34	.80	.25	.06	.05			
1968											
Fall	.00	9.48	9.39	4.96	.88	.76	.02				
1969											
Winter	.00	.88	7.59	8.66	2.86	1.31	.37	.06	.06	.00	.06
Summer	.00	3.79	21.59	12.51	3.18	.19	.48	.14	.06		
Fall	1.06	6.48	8.49	4.99	1.28	.43	.16	.18			

Table 3. -- Instantaneous mortality rates calculated from the slopes of catch curves from age 3 on, number of points used for the linear regression, and correlation coefficients for each year class and yellowtail flounder ground.

Yr. Class	Southern New England Ground # of pts.	Mort. (Z)	Cor. Coef.	Georges Bank Ground # of pts.	Mort. (Z)	Cor. Coef.
1956				2	5.70*	-0.93
1957				4	-0.79*	0.64
1958	6	1.23	-0.63	5	0.48	-0.48
1959	7	1.24	-0.87	8	1.49	-0.76
1960	9	1.20	-0.83	9	1.21	-0.94
1961	9	1.31	-0.98	11	0.94	-0.93
1962	6	1.27	-0.94	10	1.08	-0.91
1963	6	1.23	-0.98	7	0.60	-0.93
1964	4	1.92	-0.92	5	1.03	-0.81
1965	4	1.38	-0.88	4	1.13	-0.87
1966	3	-0.20*	0.17	3	0.76	-0.52
Pooled data All Yr. Classes Combined	54	1.17	-0.85	68	1.02	-0.89
Avg. Z (with * values omitted)		1.35			.97	

Table 4. -- Estimates of survival rates of yellowtail flounder in fall cruises for the southern New England ground.

Year	Age Group 1-2	2-3	3-4	4-5	5-6	Age 3-6 Avg($r_{i.}$)	Z
1963-64	1.62	.33	.43	.71	3.50	0.56	0.58
1964-65	.91	.23	.37	.28	.07	0.27	1.31
1965-66	.95	.10	.16	.11		0.15	1.90
1966-67	.68	1.02	.80	.43	.37	0.65	0.43
1967-68	.60	.69	.10	.13		0.11	2.21
1968-69	1.30	1.91	.35	.16	.28	0.33	1.11
Avg(r.j)	.92	.60	.31	.36	.50	0.33	(r..)
Z	0.08	0.51	1.17	1.02	0.69	Z = 1.11	

Table 5. -- Estimates of survival rates of yellowtail flounder in fall cruises for the Georges Bank ground.

Year	Age Group 1-2	2-3	3-4	4-5	5-6	6-7	Age 3-7 Avg ($r_{i.}$)	Z
1963-64	.62	1.08	.46	.61	1.18	1.43	0.62	0.48
1964-65	3.40	.70	.35	.23	.03	.40	0.27	1.31
1965-66	3.27	.30	.12	.06			0.32	1.14
1966-67	.92	.79	.52	.38	.43		0.48	0.73
1967-68	1.26	.65	.38	.95	.08		0.49	0.71
1968-69	.90	.53	.26	.49	.21	9.00	0.31	1.17
Avg(r.j)	1.03	.67	.34	.45	.20	.90	0.36	(r..)
Z	-	0.40	1.08	0.80	1.61	0.11	Z = 1.02	

Table 6. -- Robson and Chapman estimates of annual survival rates, Heincke estimates of survival rates, and Chi square values for the southern New England ground.

Year and Season	Est. of survival (Robson & Chapman) Z	S	Est. of survival (Heincke) Z	S	Chi square values
1963					
Fall	1.47	.230	1.39	.248	0.172
1964					
Winter	.77	.463	.59	.556	1.453
Summer	.66	.518	.38	.682	3.079
Fall	.62	.536	.37	.688	2.792
1965					
Winter	.94	.392	1.04	.354	0.189
Summer	2.21	.110	2.22	.109	0.003
Fall	.91	.402	.97	.379	0.008
1966					
Winter	.69	.503	.68	.505	0.001
Fall	.88	.416	.91	.402	0.014
1967					
Fall	1.65	.192	1.88	.152	1.010
1968					
Fall	2.51	.081	2.60	.074	0.489
1969					
Winter	1.12	.327	.91	.403	3.068
Summer	2.51	.081	2.45	.086	0.259
Fall	1.69	.184	1.57	.208	0.695
Avg over all cruises	1.33	.264	1.28	.278	

Table 7. -- Robson and Chapman estimates of annual survival rates, Heincke estimates of survival rates, and Chi square values for the Georges Bank ground.

Year and Season	Est. of survival (Robson & Chapman) Z	S	Est. of survival (Heincke) Z	S	Chi square values
1963					
Fall	1.43	.239	1.79	.167	1.787
1964					
Winter	.72	.489	.44	.643	2.308
Summer	.77	.462	.80	.450	0.007
Fall	.82	.440	.70	.499	0.477
1965					
Winter	.74	.478	.69	.501	0.086
Summer	1.24	.290	1.24	.290	0.000
Fall	.93	.395	.90	.405	0.010
1966					
Winter	.58	.557	.41	.661	0.669
Fall	.89	.412	1.08	.339	-0.909
1967					
Fall	.91	.402	1.11	.331	0.338
1968					
Fall	1.19	.304	1.38	.251	0.437
1969					
Winter	.97	.379	1.04	.353	0.112
Summer	1.29	.274	1.41	.245	0.295
Fall	1.03	.356	1.23	.291	0.463
Avg over all cruises	.96	.383	1.02	.360	

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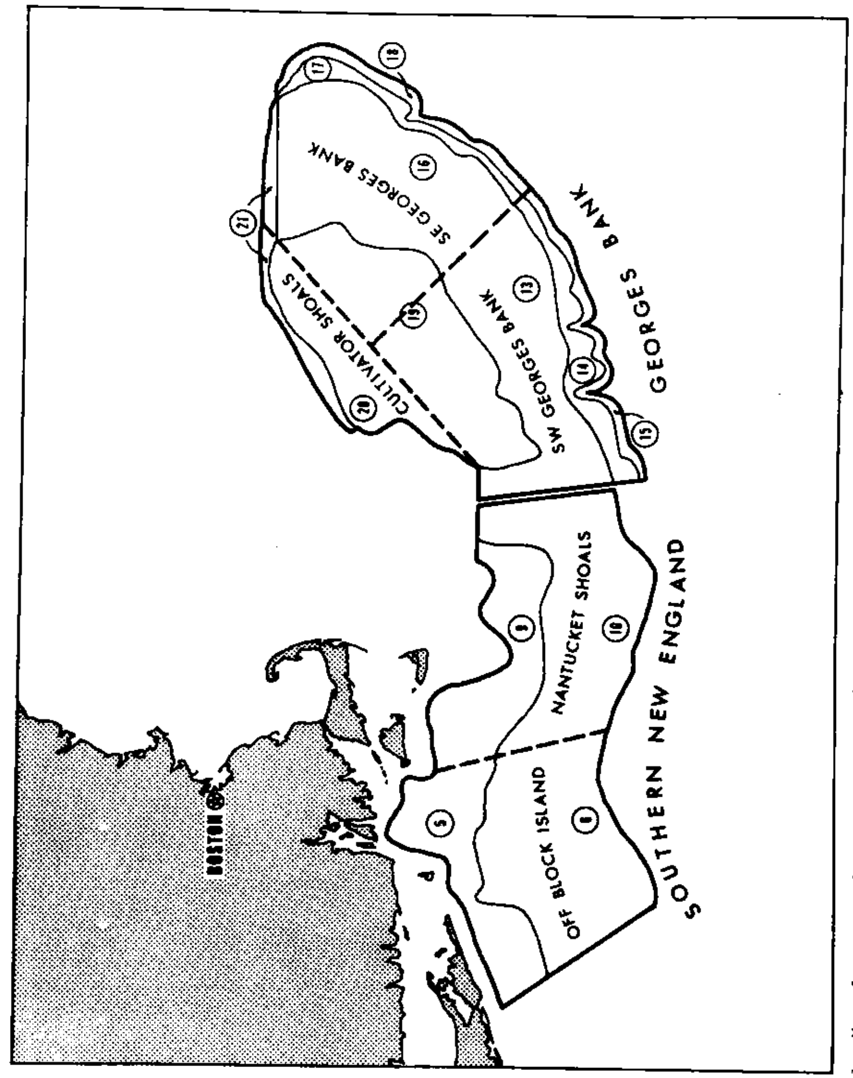

Fig. 1. Map of strata and areas comprising the southern New England and Georges Bank yellowtail flounder fishing grounds.

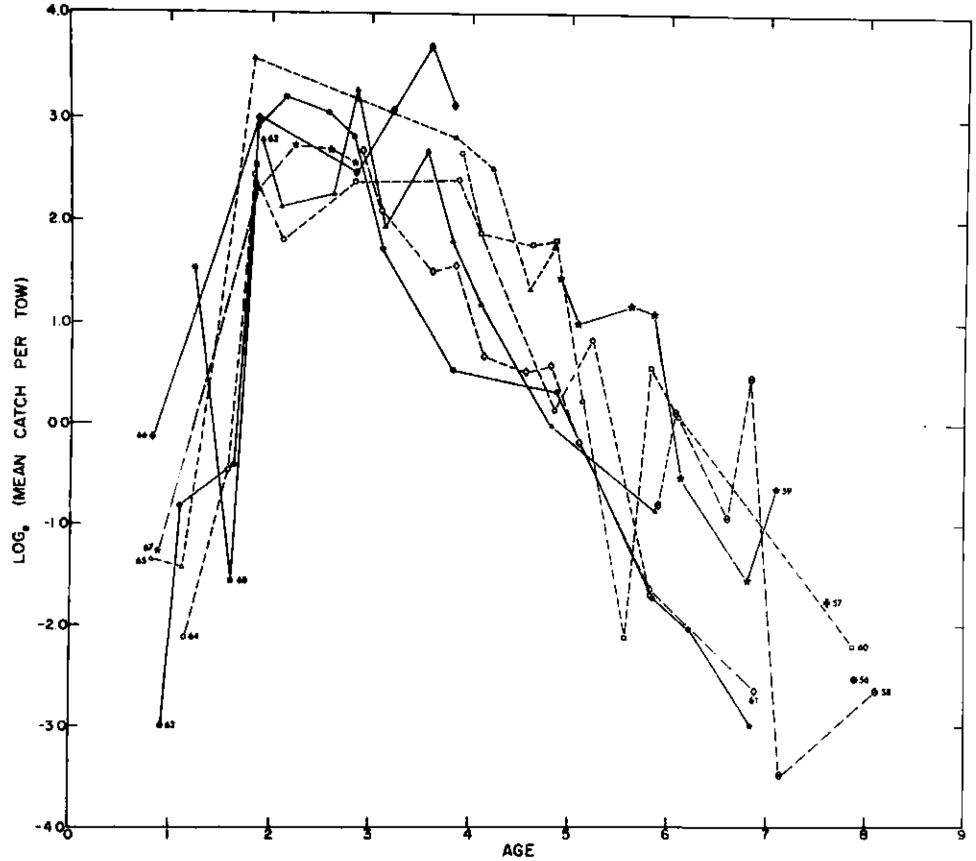

Fig. 2. Plot of logarithm of mean catch/tow on age for year-classes of yellowtail flounder from survey data for the southern New England ground.

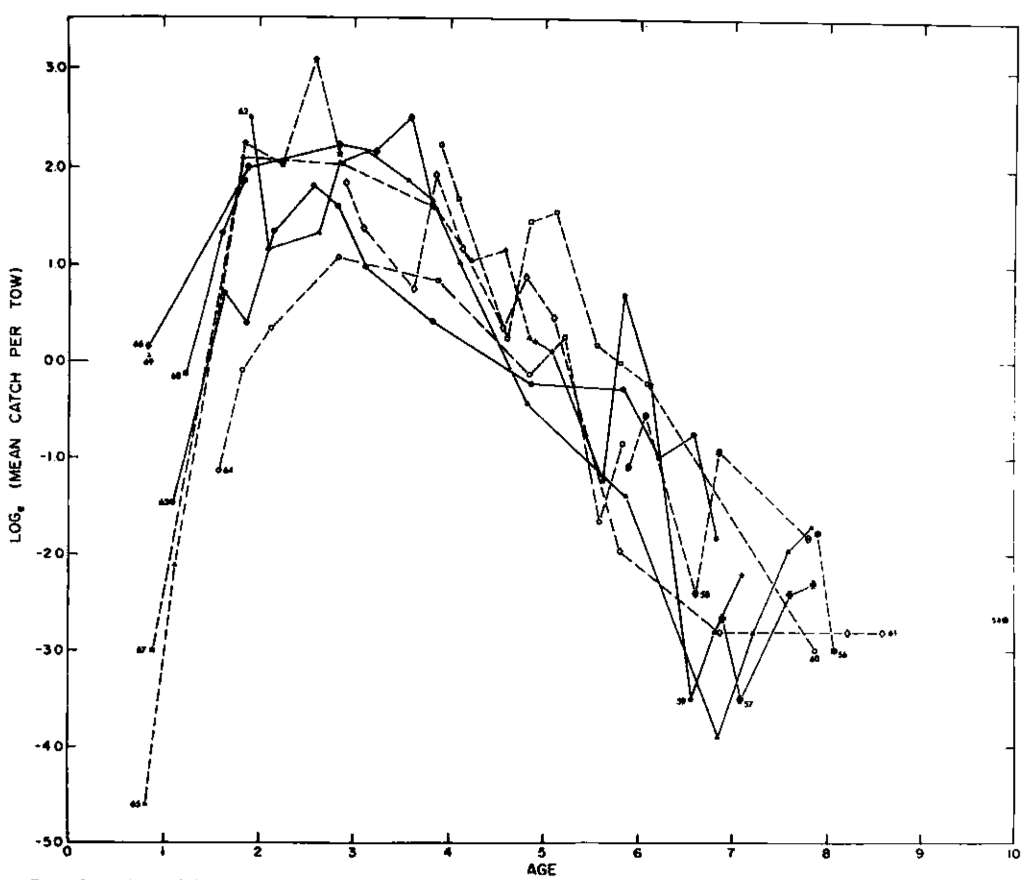

Fig. 3. Plot of logarithm of mean catch/tow on age for year-classes of yellowtail flounder from survey data for the Georges Bank ground.