

Assessment of the Georges Bank Red Hake Stock

by

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## INTRODUCTION

This report presents an assessment of the status of the red hake (Urophycis chuss) stock inhabiting Georges Bank (ICNAF Subdiv. 5Ze). Data used in this report include international catches during 1960-76, numbers-at-age catch data for 1968-76, and research vessel bottom trawl survey catch-per-tow since 1963. Estimates of stock size, fishing mortality, and recruitment during 1968-77 are given, and projections are made for catch options in 1978 and resultant stock sizes in 1979.

## CATCH

Prior to 1963, there was not a directed fishery for red hake on Georges Bank. Catches by USA vessels were taken as by-catch from effort directed towards other species. USA catches during 1960-76 ranged from 0 to 1,518 tons (Table 1) and averaged 400 tons annually; the 1976 catch was only 37 tons. A USSR fishery for red hake began in 1963 and has continued since that time; various other nations have occasionally reported small amounts of catch (Table 1). USA catches averaged only 3% annually of the total during 1963-76. Total catch increased from 860 tons in 1960 to a peak of 53,200 tons in 1965 and then declined to 1,900 tons in 1970. Catches increased again to 38,000 tons in 1972, dropped to 9,100 tons in 1974, and then increased moderately to 16,700 tons in 1976.

The ICNAF total allowable catch (TAC) was set at 20,000 tons for 1974 and 1975 (for ICNAF Div. 5Z east of 69<sup>0</sup>W) and 26,000 tons for 1976. An optimum yield (OY) of 16,000 tons was set by the USA for 1977, with 1,500 tons designated as the USA commercial capacity and 14,500 tons allocated as the total allowable level of foreign fishing (TALFF). The 1977 open season and area for directed foreign fishing extended through June, during which time 2,733 tons was reportedly taken by the USSR (2,711 tons) and Bulgaria (22 tons). The 1977 USA catch was assumed to be 100 tons. For the purpose of this assessment, the total 1977 catch was assumed to be 2,833 tons.

#### CATCH COMPOSITION

Numbers-at-age catch data were calculated for 1968-76 (Table 2). USSR monthly length frequencies and quarterly age/length keys reported to ICNAF as well as USA age/length keys from spring and autumn bottom trawl survey samples were utilized in determining the numbers at age. Previous examination of USSR red hake age/length keys (Anderson 1974) indicated serious discrepancies probably resulting from possible ageing errors, insufficient sample sizes, or biased sampling designs. The USSR data appeared reasonably reliable only for ages 1-3. An attempt to correct for these discrepancies was made by pooling the USSR age/length keys over years. These pooled keys were used for 1968-72, and the USA keys were used for 1973-76.

Results (Table 2) indicate that ages 2 and 3 were the most abundant age-groups in the catch in nearly all years, comprising about 75% of the catch by number in 1975-76. In 1976, 50% of the catch by number was age 2 fish.

Calculated mean weights at age for the 1968-76 catches are given in Table 3. These values were generated by the application of a length-weight equation to the length frequency data. The accuracy of these mean weights was examined by applying them to the numbers at age in Table 2 to obtain calculated catches (tons), which were compared to the observed catches. Ratios between observed and calculated catches varied from 0.975 to 1.005 and averaged 0.992. The 1976 mean weights (unadjusted) were employed in the projections of 1977-78 catch and stock size.

#### ABUNDANCE INDICES

There are no commercial catch-per-effort indices currently available for this stock. The USA catches have been very small and have occurred as by-catch in other fisheries; consequently, USA red hake fishing effort has not been definable. Although USSR catches have averaged 95% of the total catch each year since 1963 and in some years have been substantial, directed USSR red hake effort data are generally not available. USSR monthly catch and effort statistics reported to ICNAF by tonnage class included catches of numerous species (many of which usually exceeded red

hake catches such as silver hake, mackerel, and herring) for a given effort value. It has been impossible to ascertain from these pooled statistics the portion of the reported effort which was directed at each species, including red hake.

The USA autumn bottom trawl survey catch-per-tow index decreased from a period high of 7.87 kg in 1963 to a low of 0.72 in 1967 and then fluctuated between 1.01 and 3.02 (average = 1.71) during 1968-74 (Table 4, Figure 2). Catch-per-tow increased in 1975 to 7.63 kg, dropped to 4.42 in 1976, and then increased slightly to 4.98 in 1977. The spring survey catch-per-tow index increased from 0.26 in 1968 to a high of 1.52 kg in 1971 and then decreased to a low of 0.07 in 1977. The two data series do not exhibit similar patterns. The changes in stock biomass as measured by the spring survey during 1968-77 correspond very well with the results of the virtual population analysis (VPA) (Figure 1), whereas the autumn survey indices bear no relationship with the VPA results. The decline shown by the autumn survey from 1963 to 1967 may have reflected a decline in the stock as a result of the high USSR catches during those years. Unfortunately, commercial sampling data do not extend back to 1963 to facilitate calculation of numbers-at-age data for use in VPA for comparison with the autumn survey results. However, no explanation is currently available concerning the lack of agreement between the autumn survey indices and the changes in stock biomass exhibited by both the spring survey and the VPA.

## FISHING MORTALITY

Fishing mortality (F) for fully-recruited ages in 1976 was estimated from a linear relationship between fishing effort and fishing mortality. Since, as mentioned earlier, directed red hake fishing effort was not available, an annual index of fishing effort was calculated by dividing total catch by catch-per-tow from the USA spring bottom trawl survey (Table 5). Fishing mortality was determined for each year as the weighted mean F for fully-recruited ages obtained from VPA ( $M = 0.40$  for all ages). An F of 0.70 was assumed for ages 3 and older in 1976 based on a linear regression between the fishing effort indices and fishing mortality rates for 1968-74 (Table 5, Figure 3) which predicted that  $F = 0.697$  in 1976. This regression resulted from several iterations of a procedure wherein (1) a VPA was run using a first approximation of the starting F in 1976 (e.g. 0.50), (2) weighted mean F values were determined for each year from the results of the VPA, (3) a linear regression was calculated between the fishing effort indices and the F values for 1968-74, and (4) another VPA was run using the value predicted from the regression as the starting F in 1976.

Fishing mortality from VPA (Table 6) was low during 1968-71, varying between 0.04 and 0.19 and averaging 0.13. F increased from 0.04 in 1970 to 1.20 in 1972, decreased to 0.34 in 1974, and then increased to an estimated 0.70 in 1976.

## RECRUITMENT

The sizes of the 1967-73 year-classes at age 1 were estimated from VPA (Table 6). The 1967-69 year-classes were the largest, averaging about 280 million fish at age 1. The 1970 year-class was about 230 million fish, and the 1971-73 year-classes averaged 170 million fish at age 1. Comparison of these results with catches from spring and autumn bottom trawl surveys indicated an apparent lack of any meaningful relationship for predictive purposes between VPA year-class size and survey catch-per-tow at age 0 or 1 (Table 7). It was necessary, therefore, to use other means to estimate the sizes of the 1974-77 year-classes.

Spawning stock (age 2+) biomass estimates for 1968-75 were determined from VPA (Table 6). A highly significant ( $r = 0.983$ ) linear relationship was found to exist between spring survey catch-per-tow (kg) for all ages and age 2+ biomass from VPA for 1968-75 (Table 8, Figure 4), from which the age 2+ biomass for 1976 of 51,900 tons was predicted. The age 3+ biomass estimate for 1976, determined previously by applying the mean weights at age (Table 3) to the stock size numbers from VPA and adjusting the sum by the observed/calculated catch ratio of 0.992 (Table 2), was 22,000 tons. The age 2+ biomass estimate less the age 3+ estimate resulted in a biomass of 29,900 tons for age 2 fish in 1976. The number of fish at age 2, determined by dividing 29,900 tons by the mean weight at age 2 in 1976 (0.18 kg) and dividing this value by the

observed/calculated catch ratio of 0.992, was estimated to be 167.5 million fish. Given this year-class size at age 2 and a catch of 40.4 million fish (Table 2) implies  $F = 0.341$ . A catch of 3.9 million fish at age 1 (Table 2) further indicates from VPA a year-class size of 257.9 million fish at age 1 and  $F = 0.032$  (Table 6). This estimate of the size of the 1974 year-class would make it the strongest observed since 1969. Although despite the absence of a consistent and predictive relationship between estimates of year-class size from VPA and survey catches, catch-per-tow of the 1974 year-class at age 0 (autumn) and age 1 (spring and autumn) was much higher than for other year-classes (Table 7) indicating that it was a strong year-class and suggesting some degree of reliability in the estimate.

The size of the 1975 year-class at age 1 was estimated using the following procedure. The age 1+ biomass for 1976 was estimated as 72,400 tons from a linear relationship ( $r = 0.881$ ) between spring survey catch-per-tow (kg) for all ages and age 1+ biomass from VPA for 1968-75 (Table 9, Figure 5). The age 1+ biomass estimate less the age 2+ estimate for 1976 (51,900 tons) resulted in a biomass estimate of 20,500 tons at age 1. The estimated number at age 1, determined by dividing 20,500 tons by the mean weight at age 1 in 1976 (0.14 kg) and dividing this value by the observed/calculated catch ratio of 0.992, was 147.6 million fish (Table 6). This estimate would make the 1975 year-class the smallest observed. The survey catch-per-tow values at ages 0 and 1

(Table 7) for this year-class were much smaller in comparison to the several previous year-classes and tend to support this estimate.

Estimates concerning the size of the 1976 year-class were available from the 1976 autumn survey at age 0 and the 1977 spring survey at age 1 (Table 7). The catch-per-tow at age 0 was somewhat higher than for the 1975 year-class and at age 1 was equal to that for the 1975 year-class. The low catch-per-tow of 0.07 kg for all ages during the 1977 spring survey results in a predicted age 1+ biomass of 62,900 tons when applied to the VPA - spring survey linear relationship (Table 9, Figure 5), which implies an age 1 biomass of 19,100 tons in 1977 or about 136 million fish. In view of these several estimates, the size of the 1976 year-class at age 1 was set at 150 million fish which is approximately the lowest observed.

The only information concerning the size of the 1977 year-class was the catch-per-tow at age 0 from the 1977 autumn survey (Table 7), which was slightly less than that observed for the 1975 year-class. For the purposes of catch and stock size projections for 1978-79, three options were considered for the size of the 1977 year-class at age 1: (1) equal to the poorest of the 1967-76 year-classes (147.6 million fish), (2) equal to the median year-class size (202.6 million fish), and (3) equal to the mean year-class size (213.9 million fish).

#### STOCK SIZE

Stock size estimates for 1968-76 from VPA are presented in Table 6. Mean weights at age (Table 3) were applied to stock numbers at age to obtain stock

biomass values. The annual biomass values were adjusted using the appropriate observed/calculated catch ratios (Table 2). Calculation of age 2+ and age 1+ biomass values for 1976 and stock size numbers at age 1 in 1975 and age 1 and 2 in 1976 were described in the previous section concerning recruitment. Stock size by age in 1977 was determined using the relationship:  $N_{77} = N_{76}e^{-Z_{76}}$ .

Total stock biomass (age 1+) increased from about 70,000 tons in 1968-69 to 104,700 tons in 1971, decreased to 65,700 tons in 1974, increased slightly to 72,400 tons in 1976, and decreased to a 1968-77 low of 64,800 tons in 1977 (Table 6, Figure 1).

Spawning stock biomass (age 2+) increased from 46,300 tons in 1968 to 88,700 tons in 1971 and then declined to 44,800 tons in 1974. Following an increase to an estimated 51,900 tons in 1976, spawning biomass decreased to a period low of 43,800 tons in 1977 (Table 6, Figure 7B).

#### PARTIAL RECRUITMENT

Age-specific fishing mortality rates from VPA (Table 6) indicate that since 1968 red hake have been fully-recruited to the fishery by age 3. Partial recruitment (fishing mortality at each age which is not wholly recruited to the fishery expressed as a percentage of the mean fishing mortality at the fully - recruited ages) during 1968-76 varied from 0.5 to 31.0% at age 1 and from 14.4 to 100.0% at age 2 and averaged 8 and 57% at those ages, respectively (Table 10). These partial

recruitment coefficients reflect the use of 40-mm-mesh codends by the distant water fleets prior to 1 March 1977. Non-USA catches during 1968-76 averaged about 98% of the total annual red hake catch from this stock. Partial recruitment of 8% at age 1, 57% at age 2, and 100% at ages 3 and older was assumed for January - February 1977.

Since a 60-mm manila (55-mm synthetic) mesh regulation was implemented effective 1 March 1977 for the foreign hake fishery, it was necessary to determine new partial recruitment coefficients which would apply to the fishery after that date. Results of a mesh selection study for red hake by Jensen and Hennemuth (1966) provided the basis for this determination. The retention curve from that study for 52-mm nylon mesh versus 31-mm mesh was smoothed using a power curve (Figure 6). Comparable curves for 40 and 55-mm mesh were determined by adjusting the lengths corresponding to the retention ratios between 0 and 100% for 52-mm mesh to equivalent lengths for 40 and 55-mm mesh by means of the appropriate selection factors (length divided by mesh size). The results indicate 50% selection lengths of 21.17 and 29.11 cm for 40 and 55-mm mesh, respectively, and a 50% selection factor of 5.29. The difference in partial recruitment between the two mesh sizes was estimated utilizing the length-age composition of the 1976 catch (taken with 40-mm mesh) and the retention ratios for each mesh size. The number of fish at each length interval was assumed to be proportional to the retention ratio at that length for 40-mm mesh (Figure 6). The

equivalent number of fish which would have been caught at each length interval with 55-mm mesh was calculated assuming a direct proportion between the retention ratios for the two mesh sizes at each length interval and the number of fish caught at that length. From the length-age matrix, the ratios between the number caught at each age with 55-mm mesh and with 40-mm mesh were determined. Partial recruitment coefficients for 55-mm mesh were estimated by multiplying the coefficients assumed for the 40-mm mesh by the appropriate ratios. The results indicated partial recruitment of 4% at age 1, 39% at age 2, 82% at age 3, and 100% at ages 4 and older. These coefficients were assumed for March - December 1977 and also for 1978.

#### CATCH AND STOCK SIZE PROJECTIONS

A total stock (age 1+) biomass of 64,800 tons was estimated at the beginning of 1977 (Table 6). The spawning stock (age 2+) was estimated to be 43,800 tons. An estimated catch of 580 tons was taken during January - February 1977 which resulted in an F of 0.0159 at ages 3 and older ( $M = 2/12 \times 0.4$  or 0.067 at all ages) (Table 11). The age 1+ biomass available at the beginning of March was estimated to be 60,000 tons. A catch of 2,253 tons was assumed for March - December 1977 requiring an F of 0.0961 at ages 4 and older ( $M = 10/12 \times 0.4$  or 0.333 at all ages) and leaving an estimated age 2+ biomass of 51,400 tons available at the beginning of 1978. These projections suggest a 17% increase in spawning stock biomass from 1977 to 1978.

Equilibrium yield calculations under conditions of a constant level of recruitment at age 1 and partial recruitment coefficients of 4, 39, 82, and 100% at ages 1, 2, 3, and 4+, respectively, indicate an  $F_{0.1}$  of 0.60.

Catch options for 1978 and resultant spawning stock (age 2+) biomasses for 1979 were calculated for values of  $F$  ranging from 0.05 to 1.00 and for the three previously - described options concerning the size of the 1977 year-class (Table 12). Fishing at  $F_{0.1}$  in 1978 would result in a catch of about 15,500 tons under any of the three recruitment options. The size of the 1979 spawning stock would vary from 44,200 tons (14% decrease from 1978) under option 1 (1977 year-class equal to the poorest observed) to 52,000 tons (1% increase from 1978) under option 3 (1977 year-class equal to the mean size observed).

#### STOCK - RECRUITMENT

The relationship between spawning stock biomass and recruitment is indicated in Figure 7. The data series is relatively short (1968-76) and does not suggest any definitive relationship. If the 1976 value was omitted in Figure 7A, a relationship would emerge which would suggest that recruitment success would be maximized from a spawning biomass of around 45,000 - 55,000 tons. However, the difference in size between the stocks which produced the weakest and the strongest year-classes was only about 1,000 tons and is probably too small to be meaningful. Fishing

mortality not in excess of  $F_{0.1} = 0.60$  in 1978, even if the 1977 year-class is as poor as any observed previously, should not reduce spawning stock biomass in 1979 to a level which would be possibly detrimental to year-class success, based on the relationship between stock and recruitment observed during 1968-76.

#### LITERATURE CITED

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Table 1. Red hake catches (MT) from the Georges Bank stock.<sup>1</sup>

Year	Bulgaria	Canada	Cuba	GDR	Japan	Poland	Romania	Spain	USSR	USA	Other	Total
1960	-	-	-	-	-	-	-	-	-	855	-	855
1961	-	-	-	-	-	-	-	-	-	1,518	-	1,518
1962	-	-	-	-	-	-	-	-	-	963	-	963
1963	-	-	-	-	-	-	-	-	3,205	750	-	3,955
1964	-	-	-	-	-	-	-	-	3,533	5	-	3,538
1965	-	26	-	-	-	-	-	-	52,680	496	-	53,202
1966	-	11	-	-	-	-	-	-	51,181	607	-	51,799
1967	-	7	-	-	-	709	-	61	22,938	458	13	24,186
1968	-	-	-	5	-	-	-	-	4,509	545	-	5,059
1969	-	-	-	-	-	-	-	-	4,237	51	-	4,288
1970	-	-	-	-	-	-	-	-	1,815	100	-	1,915
1971	1,366	-	-	88	6	-	-	-	10,404	111	-	11,975
1972	1,043	-	-	5	187	11	-	-	37,960	160	-	39,366
1973	172	-	-	-	-	9	-	5	24,406	74	-	24,666
1974	72	-	-	-	-	-	149	57	9,145	77	-	9,500
1975	19	-	-	-	1	-	-	8	14,921	-	-	15,004
1976	-	-	330	-	-	-	20	-	16,738	37	-	17,125

<sup>1</sup>Non-USA catches before 1968 are estimated.

Table 2. Red hake catch-at-age (millions of fish) from the Georges Bank stock (+ denotes less than 0.1 million).

Year	Age											Total	Observed weight	Calculated weight <sup>1</sup>	Obs/ calc.
	0	1	2	3	4	5	6	7	8	9	10+				
1968	-	0.1	2.4	6.9	6.0	3.4	1.1	0.5	0.2	0.1	+	20.6	5,059	5,093	.993
1969	-	0.1	17.5	7.2	2.6	1.0	0.3	0.2	0.1	+	+	29.0	4,288	4,396	.975
1970	-	0.5	5.4	3.4	1.3	0.7	0.3	0.1	0.1	+	+	11.8	1,915	1,962	.976
1971	-	5.9	17.1	13.9	10.5	6.1	2.4	1.0	0.6	0.2	+	57.7	11,975	12,120	.988
1972	-	6.6	42.6	55.8	48.2	28.5	9.0	3.1	1.4	0.5	0.1	195.8	39,366	39,336	1.001
1973	+	8.1	29.7	34.8	14.3	5.6	2.1	0.7	0.4	0.1	0.3	96.1	24,666	24,540	1.005
1974	0.1	14.5	12.1	11.3	5.2	1.6	0.5	0.2	0.1	+	0.7	46.3	9,500	9,557	.994
1975	-	6.6	29.0	21.6	8.7	2.5	1.1	0.7	0.3	0.1	+	70.6	15,004	14,992	1.001
1976	-	3.9	40.4	20.1	10.5	3.4	1.2	1.2	0.2	+	+	80.9	17,125	17,261	.992

<sup>1</sup>Using mean weights at age from Table 3.

Table 3. Mean weights (kg) at age of red hake catches from the Georges Bank stock.

Year	Age										
	0	1	2	3	4	5	6	7	8	9	10+
1968	-	.09	.14	.20	.25	.32	.38	.46	.50	.50	.61
1969	-	.06	.11	.18	.23	.31	.39	.46	.52	.50	.71
1970	-	.08	.11	.17	.25	.32	.38	.42	.45	.46	.55
1971	-	.07	.12	.22	.26	.33	.40	.45	.56	.54	.72
1972	-	.02	.07	.18	.25	.30	.36	.42	.50	.55	.79
1973	.05	.13	.22	.27	.30	.36	.32	.35	.32	.55	.33
1974	.05	.12	.20	.26	.30	.35	.33	.40	.34	.52	.31
1975	-	.09	.17	.23	.30	.36	.42	.42	.54	.72	.68
1976	-	.14	.18	.22	.29	.31	.36	.32	.53	.62	.44

Table 4. Stratified mean catch-per-tow (kg) of red hake from the Georges Bank stock from the USA bottom trawl surveys in the spring (strata 13-20) and autumn (strata 13-23, 25).

Year	Spring	Autumn
1963	-	7.87
1964	-	2.61
1965	-	2.10
1966	-	1.42
1967	-	0.72
1968	0.26	1.34
1969	0.41	1.82
1970	0.88	1.01
1971	1.52	2.05
1972	1.09	1.19
1973	0.58 <sup>1</sup>	3.02
1974	0.22 <sup>1</sup>	1.56
1975	0.42 <sup>1</sup>	7.63
1976	0.45 <sup>1</sup>	4.42
1977	0.07 <sup>1</sup>	4.98

<sup>1</sup>Adjusted from No. 41 trawl catches to equivalent No. 36 catches using a 3.00:1 ratio.

Table 5. Estimation of F in 1976 for the Georges Bank red hake fishery.

Year	Spring survey catch-per-tow (kg)	International catch (tons)	Fishing effort index <sup>1</sup>	Fishing mortality <sup>2</sup>
1968	0.26	5,059	19,458	.194
1969	0.41	4,288	10,459	.106
1970	0.88	1,915	2,176	.038
1971	1.52	11,975	7,878	.185
1972	1.09	39,366	36,116	1.204
1973	0.58	24,666	42,528	.856
1974	0.22	9,500	43,182	.342
1975	0.42	15,004	35,724	(.653) <sup>3,4</sup>
1976	0.45	17,125	38,056	(.697) <sup>3</sup>

<sup>1</sup>International catch divided by spring survey catch-per-tow.

<sup>2</sup>Weighted mean F for ages 3+ obtained from virtual population analysis assuming F = 0.70 in 1976.

<sup>3</sup>Calculated from regression of fishing effort index on fishing mortality for 1968-74:  $Y = -0.014 + 0.0000187x$ ,  $r = 0.733$ .

<sup>4</sup>Value calculated from VPA was 0.540.



Table 7. Catch-per-tow (number) of age 0 and 1 Georges Bank red hake from USA autumn (strata 13-23, 25) and spring (strata 13-20) bottom trawl surveys and year-class size (millions of fish) at age 1 from VPA.

Year-class	<u>Autumn survey</u>	<u>Spring survey</u>	<u>Autumn survey</u>	<u>VPA</u>
	age 0	age 1	age 1	age 1
1967	0.07	0.08	0.17	275.8
1968	0.08	0.14	0.15	282.3
1969	8.03	0.12	0.94	283.8
1970	3.17	0.73	0.21	230.5
1971	7.11	0.09	0.64	165.2
1972	2.57	0.01	4.23	171.0
1973	10.88	0.13	2.52	174.7
1974	33.38	0.29	8.71	-
1975	4.47	0.07	0.92	-
1976	5.38	0.07	-	-
1977	4.04	-	-	-

Table 8. Relationship between spring survey catch-per-tow (kg) (all ages) and stock biomass of age 2+ fish (000's tons) from virtual population analysis for the Georges Bank red hake stock.

Year	Spring survey catch-per-tow (kg)	Stock biomass age 2+ (000's tons)
1968	0.26	46.3
1969	0.41	52.8
1970	0.88	64.0
1971	1.52	88.7
1972	1.09	72.8
1973	0.58	59.9
1974	0.22	44.8
1975	0.42	45.3
1976	0.45	(51.9) <sup>1</sup>

<sup>1</sup>Calculated from linear regression of survey catch-per-tow on stock biomass for 1968-75:  $Y = 36.794 + 33.503 X$ ,  $r = 0.983$

Table 9. Relationship between spring survey catch-per-tow (kg) (all ages) and stock biomass at age 1+ (000's tons) from virtual population analysis for the Georges Bank red hake stock.

Year	Spring survey catch-per-tow (kg)	Stock biomass age 1+ (000's tons)
1968	0.26	71.0
1969	0.41	69.4
1970	0.88	86.2
1971	1.52	104.7
1972	1.09	76.1
1973	0.58	82.2
1974	0.22	65.7
1975	0.42	68.5
1976	0.45	(72.4) <sup>1</sup>

<sup>1</sup>Calculated from linear regression of survey catch-per-tow on stock biomass for 1968-75:  $Y = 61.179 + 24.975X$ ,  $r = 0.881$

Table 10. Percentage of fishing mortality (F) at ages 1 and 2 compared to mean F at ages 3 and older (partial recruitment).

Year	Age 1	Age 2
1968	0.5	14.4
1969	0.9	100.0
1970	5.3	92.1
1971	17.3	62.2
1972	4.2	34.6
1973	6.9	48.1
1974	31.0	42.4
1975	5.9	74.1
1976	4.7	48.7
Mean	8	57

Table 11. Parameters of the 1977 Georges Bank red hake fishery.

Parameter	Value
Stock biomass (000's tons) at beginning of 1977:	64.8 (age 1+) 43.8 (age 2+)
January - February 1977 fishery (40-mm mesh)	
Catch (tons):	580
Partial recruitment (%):	
Age 1	8
Age 2	57
Age 3+	100
Fishing mortality (age 3+):	0.0159
March - December 1977 fishery (60-mm mesh)	
Catch (tons):	2,253
Partial recruitment (%):	
Age 1	4
Age 2	39
Age 3	82
Age 4	100
Fishing mortality (age 4+):	0.0961
Stock biomass (000's tons) at beginning of 1978:	51.4 (age 2+)

Table 12. Projected catch (age 1+) in 1978 from the Georges Bank red hake stock with fishing mortality ranging from 0.05 to 1.00 under three options concerning the size of the 1977 year-class. Resulting stock sizes (age 2+) in 1979 and the percentage changes (by weight) from 1978 are also given. All catch and stock size values are in thousands of tons.

Fishing mortality	Option 1			Option 2			Option 3		
	Catch in 1978	Stock in 1979	% change in stock from 1978	Catch in 1978	Stock in 1979	% change in stock from 1978	Catch in 1978	Stock in 1979	% change in stock from 1978
0.05	1.6	57.2	+11.3	1.6	63.8	+24.1	1.6	65.2	+26.8
0.10	3.1	55.8	+ 8.6	3.1	62.4	+21.4	3.1	63.8	+24.1
0.15	4.5	54.4	+ 5.8	4.6	61.0	+18.7	4.6	62.4	+21.4
0.20	5.9	53.1	+ 3.3	6.0	59.7	+16.1	6.0	61.0	+18.7
0.25	7.3	51.8	+ 0.8	7.4	58.4	+13.6	7.4	59.7	+16.1
0.30	8.6	50.6	- 1.6	8.7	57.1	+11.1	8.7	58.5	+13.8
0.35	9.8	49.4	- 3.9	9.9	55.9	+ 8.8	10.0	57.3	+11.5
0.40	11.1	48.3	- 6.0	11.2	54.8	+ 6.6	11.2	56.1	+ 9.1
0.45	12.2	47.2	- 8.2	12.3	53.7	+ 4.5	12.4	55.0	+ 7.0
0.50	13.3	46.1	-10.3	13.5	52.6	+ 2.3	13.5	54.0	+ 5.1
0.55	14.4	45.1	-12.3	14.6	51.6	+ 0.4	14.6	53.0	+ 3.1
*0.60	15.5	44.2	-14.0	15.6	50.6	- 1.6	15.7	52.0	+ 1.2
0.65	16.5	43.2	-16.0	16.6	49.7	- 3.3	16.7	51.0	- 0.8
0.70	17.5	42.3	-17.7	17.6	48.8	- 5.1	17.7	50.1	- 2.5
0.75	18.4	41.5	-19.3	18.6	47.9	- 6.8	18.6	49.2	- 4.3
0.80	19.3	40.6	-21.0	19.5	47.1	- 8.4	19.5	48.4	- 5.8
0.85	20.2	39.8	-22.6	20.4	46.2	-10.1	20.4	47.6	- 7.4
0.90	21.0	39.0	-24.1	21.3	45.4	-11.7	21.3	46.8	- 8.9
0.95	21.8	38.3	-25.5	22.1	44.7	-13.0	22.1	46.0	-10.5
1.00	22.6	37.6	-26.8	22.9	44.0	-14.4	22.9	45.3	-11.9

Options for 1977 year-class

Option 1: equal to poorest of 1967-76 year-classes (147.6 million fish at age 1).

Option 2: equal to median year-class size (202.6 million fish at age 1).

Option 3: equal to mean year-class size (213.9 million fish at age 1).

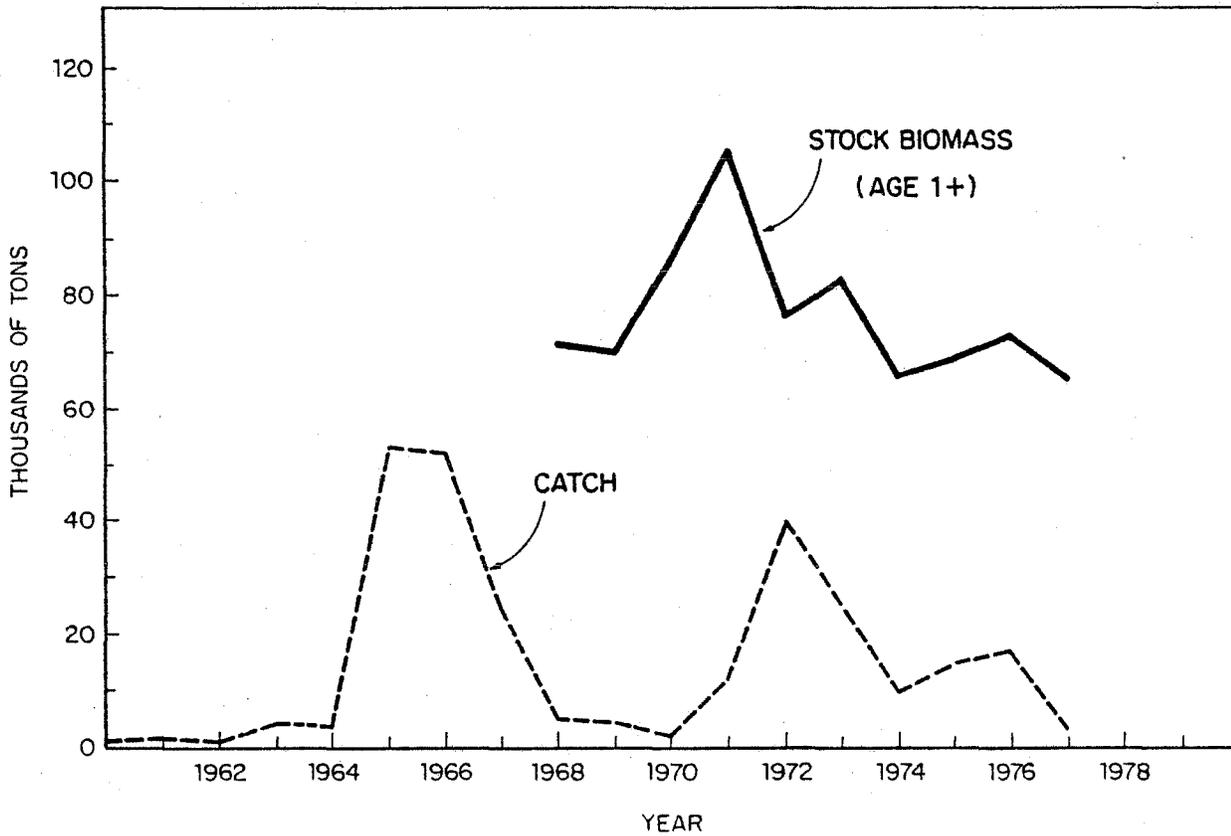


Figure 1. International catch (1960-77) and stock biomass (age 1+) from virtual population analysis (1968-77) from the Georges Bank red hake stock.

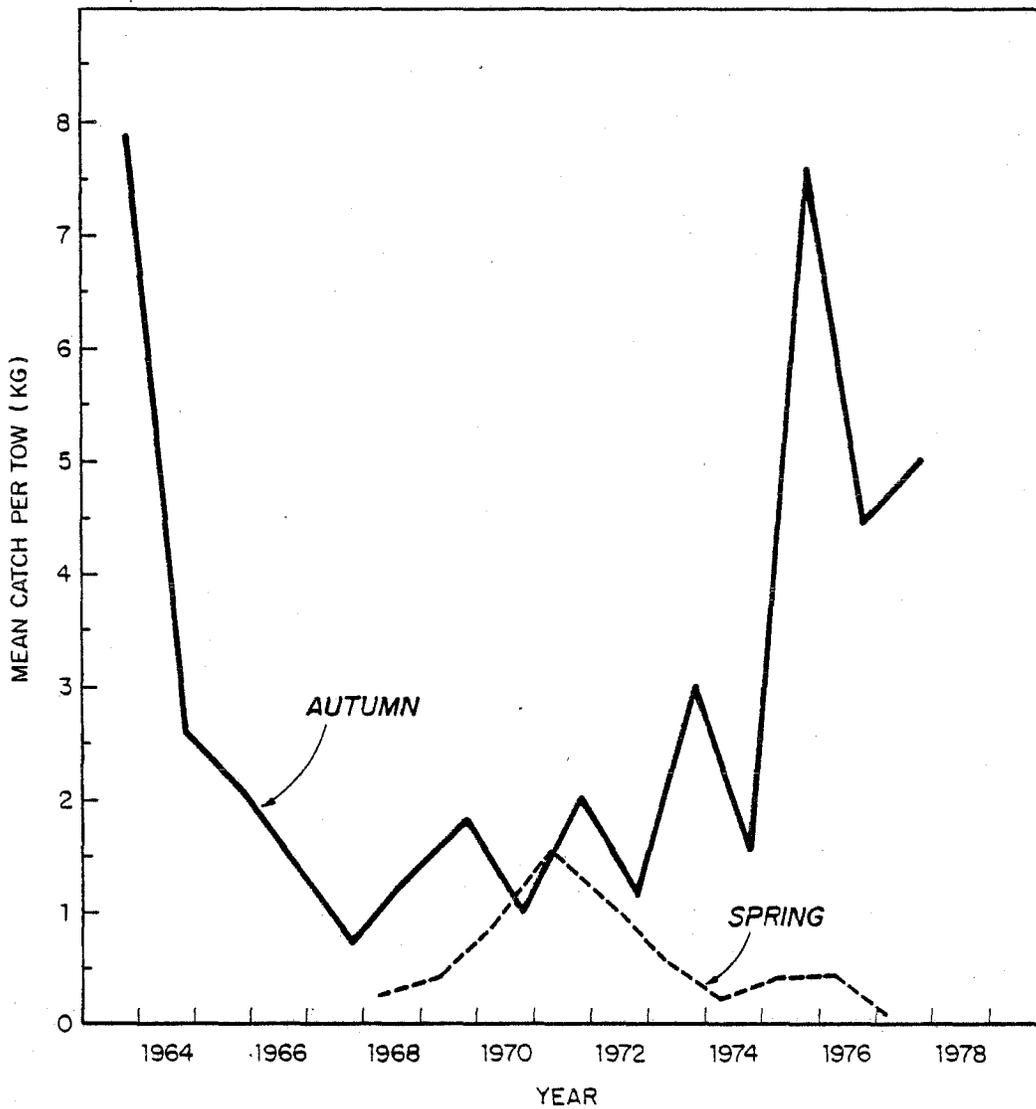


Figure 2. Stratified mean catch-per-tow (kg) of red hake from the Georges Bank stock from USA autumn (1963-77) and spring (1968-77) bottom trawl surveys.

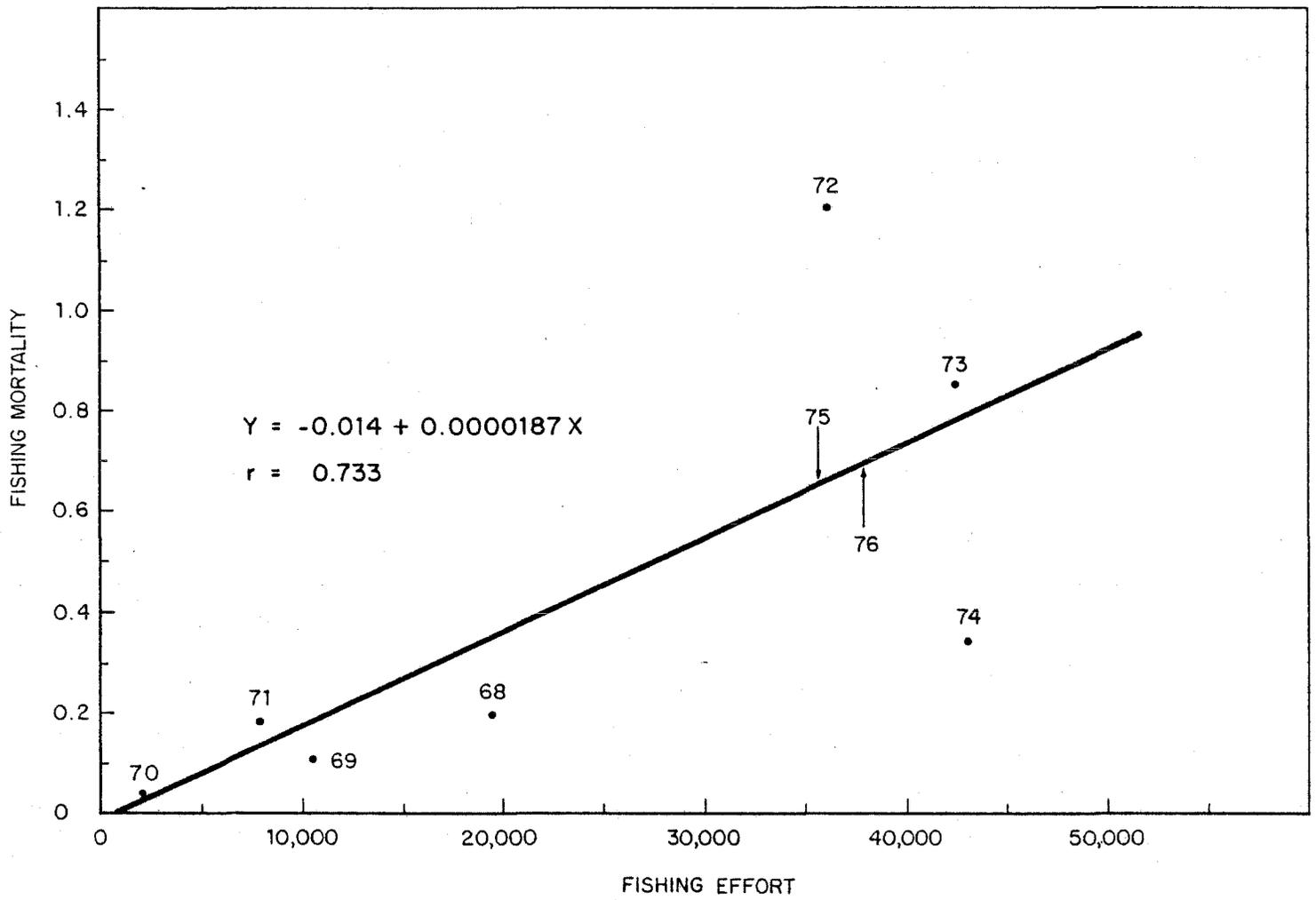


Figure 3. Relationship between fishing mortality from virtual population analysis and fishing effort derived from spring survey catch-per-tow and international catch.

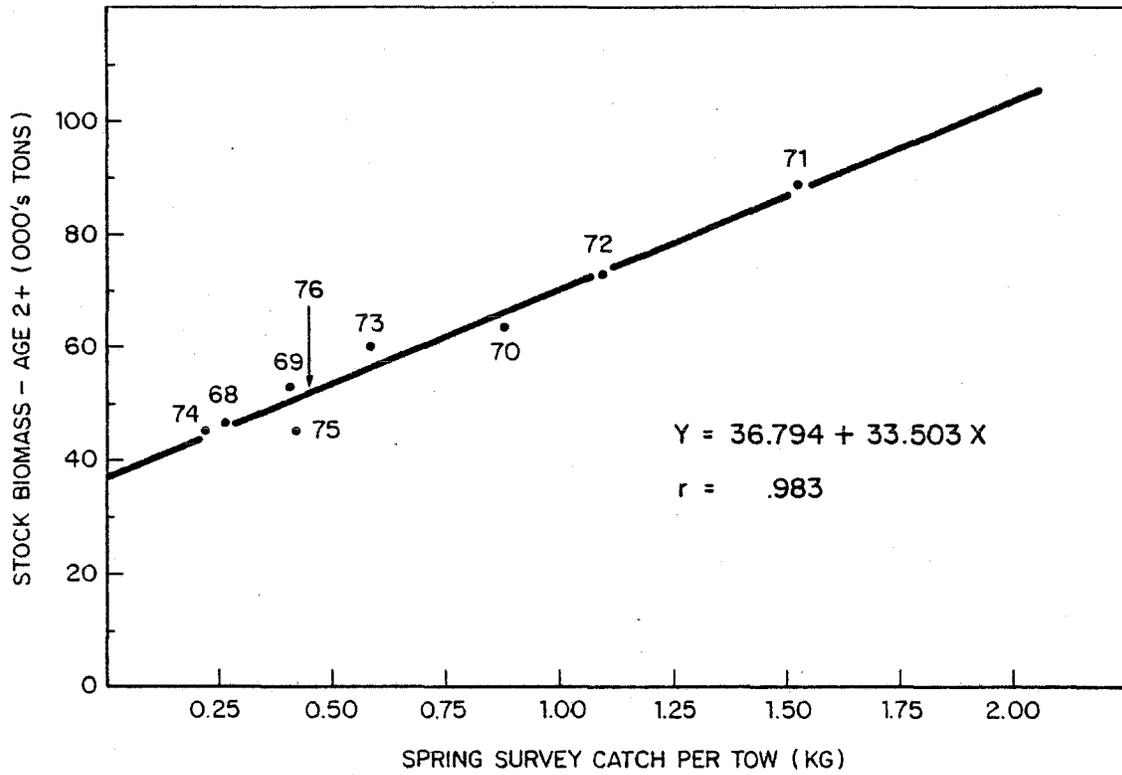


Figure 4. Relationship between spring survey catch-per-tow (kg) of all ages and stock biomass of age 2+ fish from virtual population analysis for the Georges Bank red hake stock.

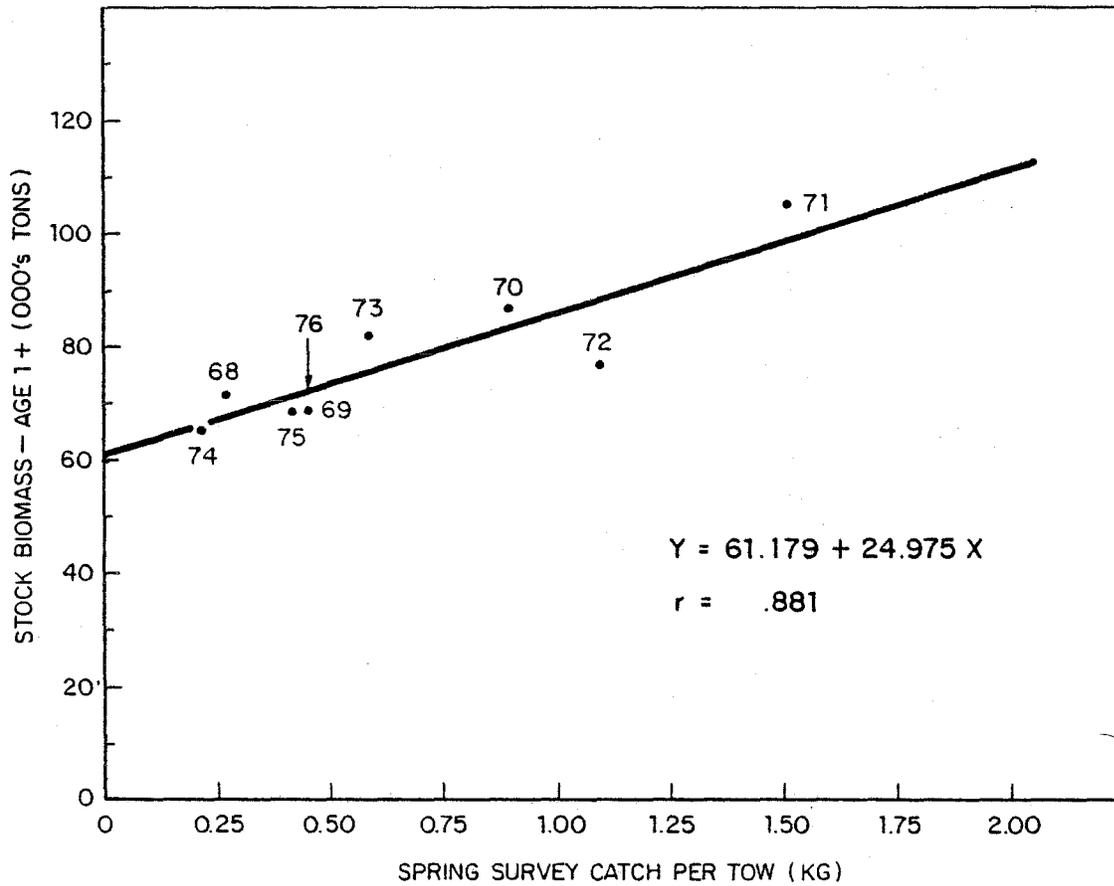


Figure 5. Relationship between spring survey catch-per-tow (kg) of all ages and stock biomass of age 1+ fish from virtual population analysis for the Georges Bank red hake stock.

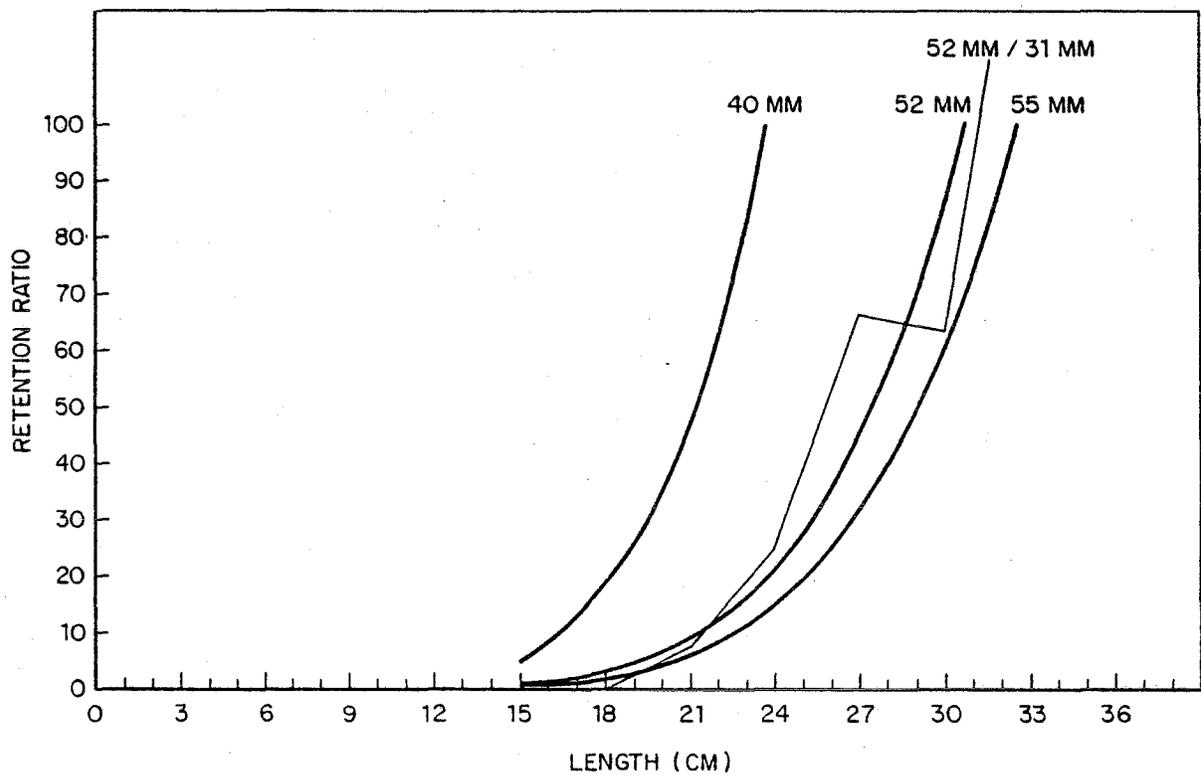


Figure 6. Retention curve of red hake in 52-mm versus 31-mm nylon cod ends (Jensen and Hennemuth 1966) smoothed using a power curve, with equivalent curves for 40 and 55-mm mesh.

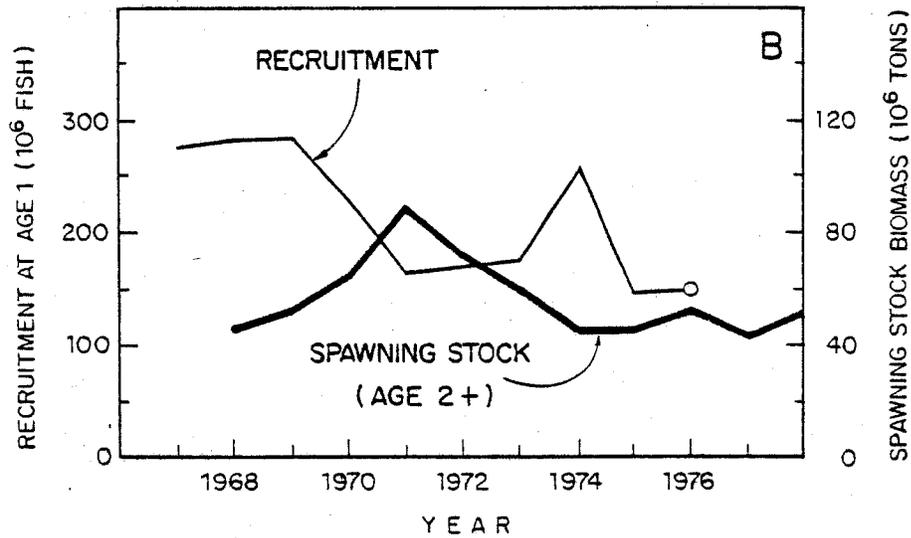
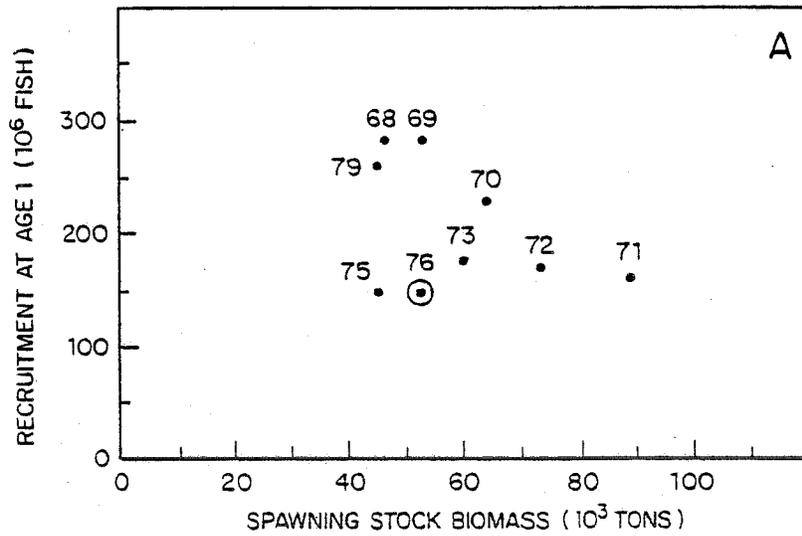


Figure 7. Relationship between spawning stock biomass (age 2+) and recruitment (expressed as abundance at age 1) for the Georges Bank red hake stock during 1968-76. The open circle indicates an assumed year-class size.