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International Commission for the Northwest Atlantic Fisheries

Serial No. 5448

ICNAF Res. Doc. 79/VI/86

ANNUAL MEETING - JUNE 1979

Status of the Georges Bank Red Hake Stock - 1978

by

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INTRODUCTION

This report presents an update 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 1960-77, numbers-at-age catch data for 1968-77, and research vessel bottom trawl survey catch per tow since 1963. Estimates of stock size, fishing mortality, and recruitment during 1968-78 are given, and projections are made for catch options in 1979 and resultant stock sizes in 1980.

CATCH

Prior to 1963, there was not a directed fishery for red hake on Georges Bank. Red hake were taken by USA vessels as by-catch from effort directed towards other species. USA catches during 1960-77 ranged from 5 to 1,518 tons (Table 1) and averaged 400 tons, only 3% of the average annual international catch. The 1977 USA catch was 96 tons.

International catch increased from 855 tons in 1960 to a peak of 53,202 tons in 1965 and then declined to 1,915 tons in 1970. Catches increased again to 39,366 tons in 1972, dropped to 9,500 tons in 1974, increased moderately to 17,124 tons in 1976, and then dropped sharply to only 2,879 tons in 1977.

The ICNAF total allowable catch (TAC) was set at 20,000 tons for 1974 and 1975 (for ICNAF Div. 5Z east of 69°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). In 1978, the optimum yield and catch level designations remained the same as in 1977. The international catch in 1978 was estimated to be only about 1,000 tons.

CATCH COMPOSITION

Numbers-at-age catch data were calculated for 1968-77 (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. Pooled USSR age/length keys were used for 1968-72, and USA keys were used for 1973-77 (Anderson and Almeida 1978).

In nearly all years, age 2 and 3 fish were the most abundant age groups. These two ages made up approximately 75% of the catch in 1975-76 but in 1977 the dominance shifted towards ages 3 and 4 (81%).

Mean weights at age for 1968-77 (Table 3), were applied to the numbers at age in Table 2 to obtain calculated catches (tons). Ratios between observed and calculated catches varied from 0.975 to 1.005 and averaged 0.992. The 1977 mean weights (unadjusted) were utilized in the projections of 1978-80 catch and stock size projections.

ABUNDANCE INDICES

Due to the nature of both the foreign and domestic red hake fisheries, there are no commercial catch-per-effort indices for this stock. Fishing effort data for red hake are impossible to separate from effort directed towards other species because of the by-catch status this species holds in the fishery.

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 1.51 kg in 1971 and then decreased to a low of 0.06 in 1978. The two data series do not exhibit similar patterns.

The changes in stock biomass as measured by the spring survey correspond well with the results of the virtual population analysis (VPA), 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 (4 and older) in 1977 was estimated from a linear relationship between relative exploitation (international catch divided by USA spring survey catch per tow) and fishing mortality from VPA. An F of 0.89 was assumed for ages 4 and older in 1977 based on a linear regression between the relative exploitation indices and fishing mortality rates from a previous VPA (Anderson and Almeida 1978). A new VPA was performed using 0.89 as the terminal F for ages 4 and older in 1977 (Table 6) and a new regression ($r = 0.796$, $p = 0.05$) was calculated between relative exploitation and the mean fishing mortalities from the new VPA. The predicted F for 1977 was 0.885 (Table 5, Figure 3) and therefore, the estimated F was accepted.

The sharp decrease in the spring survey catch per tow value from 1976 to 1977 was interpreted as a decrease in stock biomass. Therefore, since the 1977 estimate of fishing mortality was based on the survey abundance index, a high F (0.89) was predicted even though the international catch was relatively low (2,879 tons in 1977 compared to 17,124 tons in 1976). Since the autumn survey did not indicate a decrease in stock abundance from 1976 to 1977 (Table 4, Figure 2), the decrease implied from the spring survey is uncertain, and the F of 0.89 for 1977 may be an overestimate.

Fishing mortality from the VPA was low during 1968-71 averaging 0.14 but increased sharply to 1.28 in 1972. F decreased to 0.44 in 1974, but increased to average 1.09 during 1975-77.

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 275 million fish at age 1. The 1970 year class was about 220 million fish, and the 1971-73 year classes averaged 140 million fish at age 1.

Spawning stock (age 2+) biomass estimates for 1968-75 were determined from VPA (Table 6). A highly significant ($r = 0.957$, $p = 0.01$) 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 7, Figure 4), from which an age 2+ biomass for 1976 of 46,200 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 13,900 tons. The age 2+ biomass estimate less the age 3+ estimate resulted in a biomass of 32,300 tons for age 2 fish in 1976. The number of fish at age 2, determined by dividing 32,300 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 180.9 million fish. Given this year-class size at age 2 and a catch of 40.4 million fish (Table 2) implies $F = 0.312$. A catch of 3.9 million fish at age 1 (Table 2) further indicates from VPA a year-class size of 275.9 million fish at age 1 and $F = 0.029$ (Table 6). This estimate would make the 1974 year class equal in size to the 1967-69 year classes.

The size of the 1975 year class at age 1 was estimated using the following procedure. The age 1+ biomass for 1976 was estimated to be 65,400 tons from a linear relationship ($r = 0.893$, $p = 0.01$) between spring survey catch per tow (kg) for all ages and age 1+ biomass from VPA for 1968-75 (Table 8, Figure 5). The age 1+ biomass estimate less the age 2+ estimate for 1976 (46,200 tons) resulted in a biomass estimate of 19,200 tons at age 1. The estimated number at age 1, determined by dividing 19,200 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 138.2 million fish (Table 6). This value was used as the size of the 1975 year class at age 1.

The sizes of the 1976-77 year classes were obtained from a power curve relationship ($r = 0.899$, $p = 0.05$) between autumn survey catch per tow at age 0 and year-class size at age 1 from the VPA for 1971-75 (Table 9, Figure 6). These year classes were estimated to be approximately 145 million and 100 million fish, respectively. These estimates indicate that the 1977 year class is the smallest observed (1967-77).

STOCK SIZE

Stock size estimates for 1968-77 were determined from the VPA. Mean weights at age were applied to stock numbers at age to obtain stock biomass values. The 1978 stock size at age was determined from the relationship:

$$N_{78}=N_{77}e^{-Z_{77}}$$

Total stock biomass (age 1+) increased from 68,300 tons in 1968 to a high of 101,100 tons in 1971, declined to 52,800 tons in 1974, and increased to average 60,300 tons during 1975-78 (Table 6, Figure 1). Total biomass at the beginning of 1978 was estimated to be 58,700 tons.

Spawning stock biomass (age 2+) icreased from 44,300 tons in 1968 to 85,800 tons in 1971, decreased to 34,500 tons in 1975 and increased to average 42,700 tons during 1976-78. The estimated 1978 biomass was 44,700 tons (Table 6, Figure 7).

PARTIAL RECRUITMENT

Red hake were generally fully recruited to the fishery by age 3 prior to 1977 as indicated by age-specific fishing mortalities obtained from VPA

(Table 6). Partial recruitment, defined here as the ratio between the fishing mortality at age (in a given calendar year) not fully recruited to the fishery and the mean F at the fully recruited ages in that year, was estimated to be 0% at age 1, 3% at age 2, 11% at age 3, and 100% at ages 4 and older in 1977. These ratios were derived from the fishing mortality rates estimated for 1977 (Table 6). The values at ages 1-3 are considerably less than for previous years, reflecting the low fishing mortality rates estimated for 1977 for those ages compared to ages 4 and older. Since the fishing mortality for ages 4 and older in 1977 may be an overestimate (see section on FISHING MORTALITY), the partial recruitment values determined for 1977 may be underestimated. The decrease in these values may also have resulted in part, from the effect of the 60-mm mesh regulation implemented effective 1 March 1977 for the foreign hake fishery. In spite of the uncertainty associated with these values, they were used in the projections of catch and stock size for 1978-80.

CATCH AND STOCK SIZE PROJECTIONS

Total stock biomass (age 1+) of 58,700 tons was calculated to be available at the beginning of 1978, and a spawning stock biomass (age 2+) was calculated to be 44,700 tons. These estimates represent increases of 2% and 20%, respectively, from 1977 (Table 6).

Equilibrium yield calculations under conditions of a constant level of recruitment at age 1 and partial recruitment coefficients of 0, 3, 11, and 100% at ages 1, 2, 3, and 4+, respectively, indicate an $F_{0.1}$ of about 0.80.

A total catch of 1,000 tons requiring an F of 0.08 for ages 4 and older was assumed for 1978, leaving a spawning stock biomass of 47,000 tons at the beginning of 1979 (5% increase from 1978). An estimated 1978 year class of median strength (150 million fish) was also assumed. Catch projections for 1979 and the resulting age 2+ spawning stock biomass in 1980 were calculated with F ranging from 0.05 to 1.00 (Table 10). Fishing at $F_{0.1}$ in 1979 would result in a catch of 11,100 tons with a 1% decrease in spawning stock biomass from 1979 to 1980. A catch of 10,500 tons (F = 0.742) in 1979 would maintain the same spawning stock biomass in 1980 as in 1979.

STOCK-RECRUITMENT

Spawning stock biomass is plotted versus recruitment in Figure 7. The data series is relatively short (1968-77) and does not suggest any definitive relationship. Therefore, no inferences can be drawn from estimates of current stock size concerning the levels of recruitment in 1978-80.

LITERATURE CITED

Anderson, E. D., and F. P. Almeida. 1978. Assessment of the Georges Bank red hake stock. NMFS, NEFC, Woods Hole Lab. Ref. 78-01.

Table 1. Red hake catches (MT) from the Georges Bank stock.[1]

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	55	-	15,004
1976	-	-	329	-	-	-	20	-	16,738	37	-	17,124
1977	-	-	-	-	-	-	-	-	2,783	96	-	2,879

[1]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 0	1	2	3	4	5	6	7	8	9	10+	Total	Observed weight	Calculated weight[1]	Obs/Calc.
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	17,124	17,261	.992
1977	-	-	1.7	6.6	3.7	0.4	0.1	0.1	0.1	+	+	12.7	2,879	2,890	.996

[1]Using mean weights at age (Table 3).

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

	Age										
Year	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
1977	-	(.14)	.18	.21	.26	.31	.48	.46	.18	.78	.37

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[1]	3.02
1974	0.22[1]	1.56
1975	0.42[1]	7.63
1976	0.45[1]	4.42
1977	0.07[1]	4.98
1978	0.06[1]	-

[1]Adjusted from No. 41 trawl catches to equivalent No. 36 catches using a 3.00:1 ratio.

Table 5. Estimation of F in 1977 for the Georges Bank red hake stock.

Year	Spring survey catch per tow (kg)	International catch tons	Relative exploitation index[1]	Fishing mortality[2]
1968	0.26	5,059	19,458	.206
1969	0.41	4,288	10,459	.110
1970	0.88	1,915	2,176	.039
1971	1.52	11,975	7,878	.190
1972	1.09	39,366	36,116	1.282
1973	0.58	24,666	42,528	1.010
1974	0.22	9,500	43,182	.439
1975	0.42	15,004	35,724	.847
1976	0.45	17,124	38,053	(.816)[3,4]
1977	0.07	2,879	41,129	(.885)[3]

[1]International catch divided by spring survey catch per tow.

[2]Weighted mean F for ages 3+ from virtual population analysis assuming F = 0.890 in 1977.

[3]Calculated from regression of relative exploitation on fishing mortality for 1968-74:

$$Y=-0.039+0.000022X,\ r=0.796$$

[4]Value calculated from VPA was 1.545.

Table 6. Fishing mortality rates and stock sizes for the Georges Bank red hake stock derived from virtual population analysis (M=0.40).

Year	Age 1	2	3	4	5	6	7	8	9	10+	100% recruitment Wtd $\bar{F}$[3]	Age	Age 1+ Total Wt (10^3 tons)[4]		Age 2+ Total Wt (10^3 tons)[4]	
					Fishing Mortality											
1968	.001	.028	.192	.160	.334	.466	.298	(.206)[1]	(.206)[1]	-	.206	3+				
1969	.001	.122	.135	.127	.044	.054	.177	(.110)[1]	-	-	.110	3+				
1970	.002	.035	.039	.040	.056	.020	.028	.156	-	-	.039	3+				
1971	.033	.121	.147	.199	.331	.344	.108	.292	.686	-	.190	3+				
1972	.057	.438	.940	1.534	1.816	1.746	1.449	.270	.540	(1.282)[1]	1.282	3+				
1973	.077	.487	1.067	.909	1.021	.885	.830	(1.010)[1]	.034	(1.010)[1]	1.010	3+				
1974	.128	.197	.440	.565	.291	.278	.231	.329	-	(.439)[1]	.439	3+				
1975	.029	.514	.837	.980	.780	.423	1.055	(.847)[1]	(.847)[1]	-	.847	3+				
1976	.035	.312	1.141	2.392	2.625	1.727	1.727	(1.585)[1]	-	-	1.585	3+				
1977	-	.023[2]	.094	(.890)[5]	(.890)[5]	(.890)[5]	(.890)[5]	(.890)[5]	-	-	.890	3+				
					Stock Size (millions)											
1968	269.7	105.8	47.7	49.1	14.4	3.5	2.3	1.3	0.6	-			494.4	68.3	224.7	44.3
1969	282.3	183.7	68.9	26.4	28.0	6.9	1.5	1.2	-	-			598.9	66.6	316.6	50.1
1970	271.1	189.7	108.9	40.4	15.6	18.0	4.4	0.8	-	-			648.9	83.2	377.8	62.0
1971	221.5	181.4	122.8	70.3	26.0	9.9	11.8	2.9	0.5	-			647.1	101.1	425.6	85.8
1972	145.3	143.7	107.8	71.0	38.6	12.5	4.7	7.1	1.4	0.2			532.3	72.8	387.0	69.8
1973	131.7	92.0	62.2	28.2	10.3	4.2	1.5	0.7	3.6	0.6			335.0	71.0	203.3	53.8
1974	146.0	81.7	37.9	14.3	7.6	2.5	1.2	0.4	-	2.4			296.1	52.8	148.0	35.1
1975	275.9	86.1	45.0	16.4	5.5	3.8	1.3	0.6	0.2	-			434.8	59.7	158.9	34.5
1976	138.2	180.9	34.5	13.1	4.1	1.7	1.7	0.3	-	-			374.5	65.4[7]	236.3	46.2[6]
1977	(145.0)[5]	89.5	88.8	7.4	0.8	0.2	0.2	0.2	-	-			332.1	57.3	187.1	37.1
1978	(100.0)[5]	97.1	58.6	54.2	2.0	0.2	0.1	0.1	0.1	-			312.4	58.7	212.4	44.7

[1] Mean F in that year.

[2] Determined from assumed stock size and known catch.

[3] Weighted by stock size at age.

[4] Determined by applying mean weights at age to stock size at age and adjusting totals with ratios of observed to calculated data.

[5] Estimated.

[6] Calculated (See Table 7, Figure 4).

[7] Calculated (See Table 8, Figure 5).

Table 7. Relationship between spring survey catch-per-tow (kg, all ages) and stock biomass at age 2+ (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	44.3
1969	0.41	50.1
1970	0.88	62.0
1971	1.52	85.8
1972	1.09	69.8
1973	0.58	53.8
1974	0.22	35.1
1975	0.42	34.5
1976	0.45	(46.2)[1]

[1]Calculated from linear regression of survey catch-per-tow on stock biomass for 1968-75:

$$Y = 29.537 + 37.008X, \quad r = 0.957$$

Table 8. 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	68.3
1969	0.41	66.3
1970	0.88	83.2
1971	1.52	101.1
1972	1.09	72.8
1973	0.58	71.0
1974	0.22	52.8
1975	0.42	59.7
1976	0.45	(65.4)[1]

[1]Calculated from linear regression of survey catch per tow on stock biomass from 1968-1975:

$$Y = 52.338 + 29.088X, \quad r = 0.893$$

Table 9. Relationship between autumn survey catch per tow at age 0 (numbers) and year-class size (millions of fish) at age 1 from the VPA.

Year class	Autumn survey Age 0	VPA Age 1
1971	7.11	145.3
1972	2.57	131.7
1973	10.88	146.0
1974	33.38	275.9
1975	4.47	138.2
1976	5.38	(144.3)[1]
1977	1.49	(100.3)[1]

[1]Calculated from a power curve relationship of autumn survey at age 0 on VPA year-class size at age 1 from 1971-75:

$$Y = 89.625X^{0.283}, \quad r = 0.899$$

Table 10. Projected catch (age 1+) in 1979 from the Georges Bank red hake stock with fishing mortality ranging from 0.05 to 1.00. Resulting stock sizes (age 2+) in 1980 and the percentage changes (by weight) from 1979 are also given. All catch and stock size values are in thousands of tons.

Fishing mortality	1979 catch	1980 stock	% change in stock from 1979
.05	0.9	57.2	+21.7
.10	1.8	56.2	+19.6
.15	2.7	55.3	+17.7
.20	3.5	54.4	+15.7
.25	4.3	53.6	+14.0
.30	5.0	52.8	+12.3
.35	5.8	52.0	+10.6
.40	6.5	51.2	+ 8.9
.45	7.1	50.5	+ 7.4
.50	7.8	49.9	+ 6.2
.55	8.4	49.2	+ 4.7
.60	9.0	48.6	+ 3.4
.65	9.5	48.0	+ 2.1
.70	10.1	47.4	+ 0.9
.75	10.6	46.9	- 0.2
*.80	11.1	46.4	- 1.3
.85	11.6	45.9	- 2.3
.90	12.0	45.4	- 3.4
.95	12.5	45.0	- 4.3
1.00	12.9	44.5	- 5.3

*$F_{0.1}$

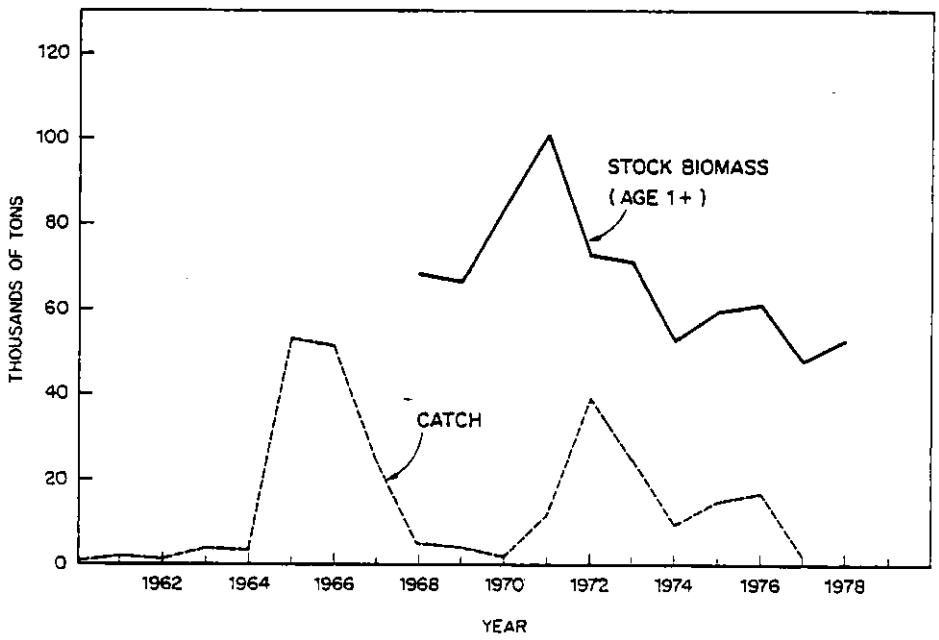

Figure 1. International catch (1960-77) and stock biomass (age 1+) from virtual population analysis (1968-78) from the Georges Bank red hake stock.

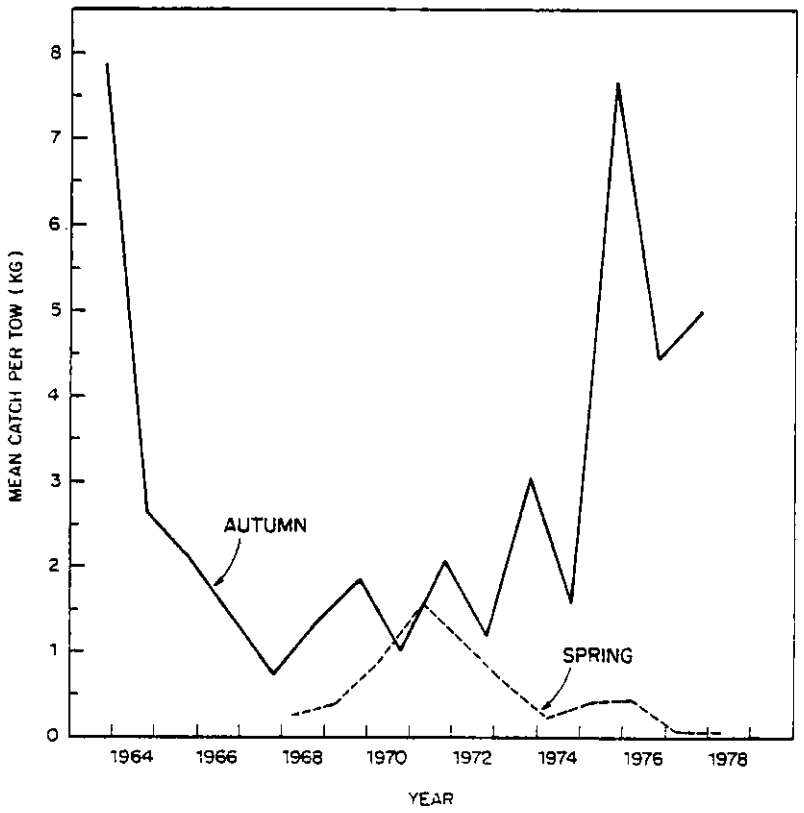

Figure 2. Stratified mean catch-per-tow (kg) of red hake from the Georges Bank stock from USA autumn (1963-77) and spring (1968-78) bottom trawl surveys.

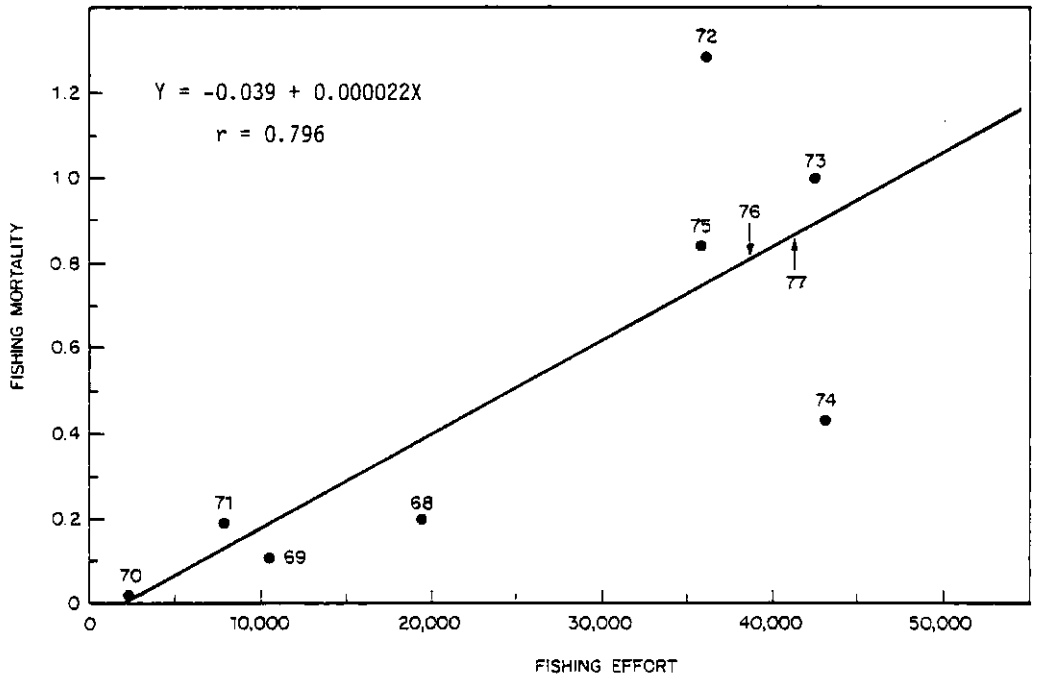

Figure 3. Relationship between fishing mortality from virtual population analysis and fishing effort derived from spring survey catch-per-tow and international catch.

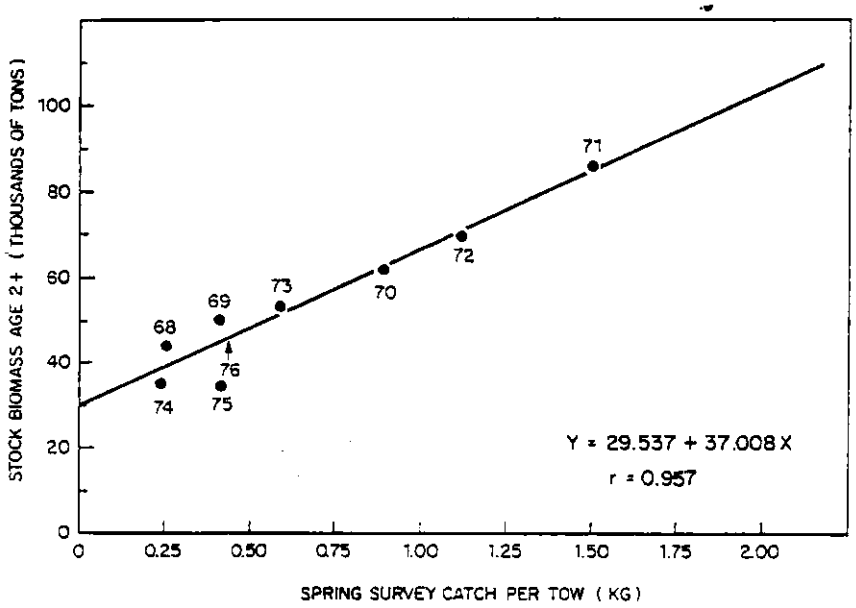

Figure 4. Relationship between spring survey catch-per-tow (kg) for all ages and stock biomass of age 2+ fish from virtual population analysis for the Georges Bank red hake stock.

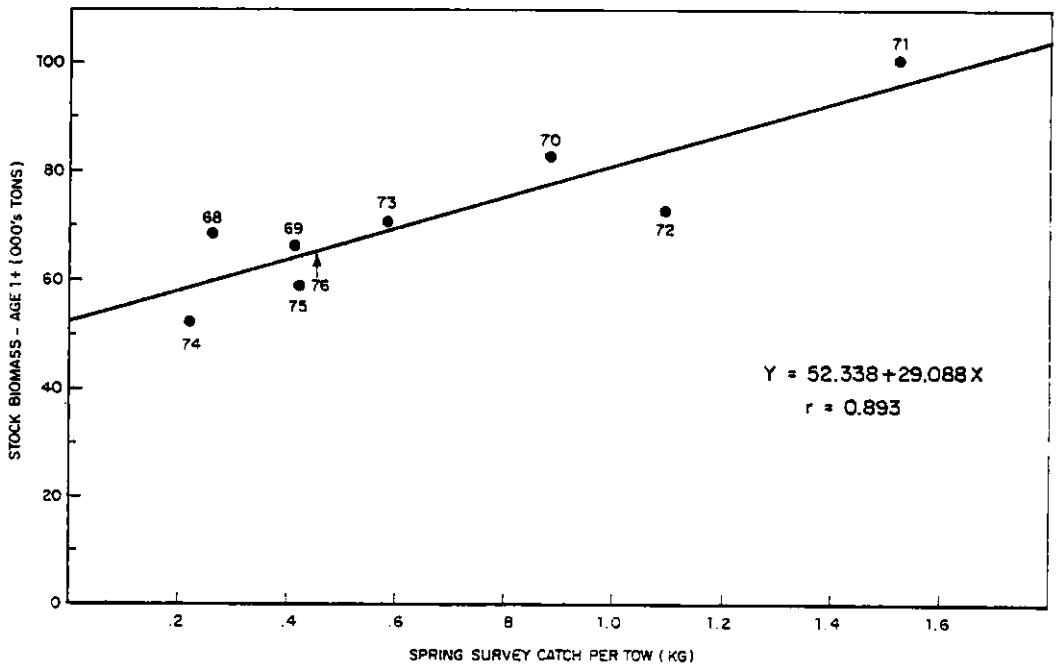

Figure 5. Relationship between spring survey catch per tow (kg, all ages) and stock biomass of age 1+ fish from virtual population analysis for the Georges Bank red hake stock.

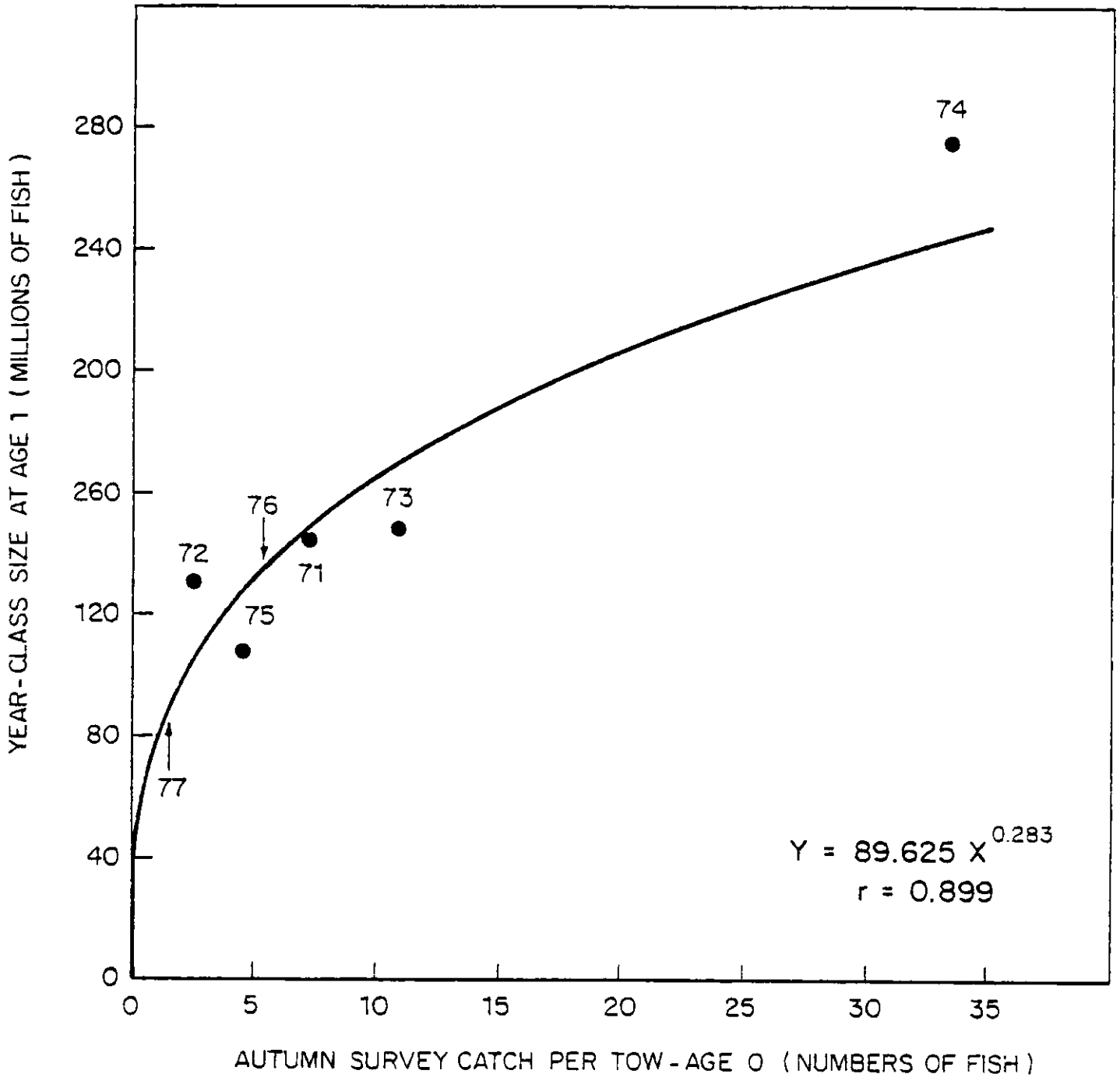

Figure 6. Power curve relationship between Georges Bank red hake year class size at age 1 and USA autumn survey catch-per-tow at age 0.