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Assessment of the Georges Bank Silver Hake Stock

by

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INTRODUCTION

This report presents an assessment of the status of the silver hake stock on Georges Bank (ICNAF Subdiv. 5Ze). The available data base for this stock includes commercial catch statistics for 1955-76 and research vessel bottom trawl survey data since 1963. Past levels of stock size and fishing mortality (F) were estimated from catch- (numbers) -at-age data utilizing virtual population analysis (VPA). Catches in 1978 at varying levels of F and resulting 1979 stock sizes were calculated under assumptions of assigned catches in 1977 and various levels of recruitment.

CATCHES

Table 1 lists the catches by country for the period 1955-76. Total catches increased from an average of 19,000 tons during 1955-61 to nearly 239,000 tons in 1965, followed by a rapid decline to 18,400 tons in 1969. Catches then increased again and stabilized at an average of about 68,000 tons during 1971-75. During 1973-75, the total allowable catch (TAC) was 80,000 tons each year. The 1976 catch was 45,900 tons (the TAC was 50,000 tons), compared to 63,000 tons in 1975, and was the lowest since 1970.

USA catches averaged 18,200 tons during 1955-63, but then declined to average only 3,600 tons during 1968-76. The 1976 USA catch was 3,800 tons.

A TAC of 70,000 tons was set for 1977, of which amount 15,000 tons was designated as the USA capacity and 55,000 tons was allocated as foreign surplus. The 1977 open season and area for directed foreign fishing extended through

30 June, by which time an estimated 43,289 tons had been caught by the USSR (42,351 tons) and Bulgaria (938 tons). It was assumed for the purpose of this assessment that the 1977 USA catch would be 5,000 tons, considering catch levels of past years as well as preliminary data from 1977. The total catch for 1977 was, therefore, assumed to be about 48,300 tons.

CATCH COMPOSITION

Table 2 contains the estimated catch in numbers at age during 1955-76. The bulk (87%) of the 1976 catch was composed of ages 3 and 4 fish. In recent years, ages 2 and 3 have been predominant in the catch.

Mean weights at age from the 1955-76 catches are given in Table 3. These mean weights were applied to the numbers at age in Table 2 to obtain calculated catches (tons). Ratios between observed and calculated catches ranged from 0.865 to 0.999 and averaged 0.931. The 1976 mean weights (unadjusted) were used for 1977-78 catch and stock size projections.

ABUNDANCE INDICES

USA commercial catch-per-day increased from 22.8 tons in 1975 to 46.1 tons in 1976, which was the highest catch rate since 1959 (Table 1). This index of abundance (1955-76) has fluctuated considerably from year to year, but underwent a downward trend from the late 1950's to a low of 8.7 tons in 1972 before increasing. Since 1962 when the USSR fishery began, the USA catch has averaged only about 10% of the total international catch. The USA fishery has been confined to the northwest part of Georges Bank (Cultivator Shoal) and the area immediately east of Cape Cod, whereas the USSR fishery has been conducted throughout Georges Bank but primarily along the southern slope. Therefore, the USA catch-per-day index is based only on a small part of the total fishery.

Nevertheless, since the advent of the USSR fishery the USA catch-per-day index has roughly paralleled changes in stock abundance as determined from virtual population analysis (Figure 1).

The 1976 USA autumn bottom trawl survey catch-per-tow index was the highest observed during the 1963-76 time-series (Table 4, Figure 2). Similarly, the 1977 spring survey index was the highest during the spring series (1968-77). Although the survey indices have not been totally consistent with stock biomass estimates obtained from VPA, the recent substantial increases in both the spring and autumn indices do appear to reflect improvement in stock biomass.

FISHING MORTALITY

Fishing mortality in 1976, the terminal year for virtual population analysis, was estimated for fully recruited ages from a relationship between fishing effort and fishing mortality. Fishing effort, in terms of USA days fished, was determined by dividing total catch by USA catch-per-day (Table 1). Fishing mortality as the weighted mean F for fully recruited ages was obtained from VPA. An F of 0.36 was estimated for 1976 based on a regression between fishing effort and fishing mortality values from a previous VPA (Anderson, ICNAF Working Paper 76/IV/93). A new VPA was performed using 0.36 as the terminal F for ages 3 and older in 1976 (Table 6). A linear regression between fishing effort and the mean F values from the new VPA for 1959-75 predicted an F for 1976 of 0.356 (Table 5, Figure 3). The estimate of 0.36 was, therefore, accepted for 1976.

Results from the VPA (Table 6) indicate a sharp decrease in F in recent years from 1.37 in 1971 to 0.37 in 1975. Fishing mortality was at a low of 0.14 in 1961 but rose sharply to 1.19 in 1964 and 1.27 in 1965 at the peak of the intensive USSR fishery. F then declined to 0.27 in 1969 before increasing to the period high in 1971.

RECRUITMENT ESTIMATES

Estimates of the size of the 1974-76 year-classes at age 1 were obtained from a power curve relationship between spring survey catch-per-tow (numbers) at age 1 and year-class size at age 1 from VPA (Table 7, Figure 4). The autumn survey catch-per-tow (numbers) at age 0 (Table 7) has not been consistent with the spring index at age 1 or with year-class estimates from VPA.

The size of the 1974 year-class at age 1 was estimated to be 1,435 million fish, which would make it an above-average year-class exceeded in strength since 1954 only by the 1959-63 and 1972 year-classes (Table 6). The catch-per-tow at age 0 of this year-class during the 1974 autumn survey was the highest observed during the 1963-76 time-series, which supports the estimate based on the spring survey that this year-class is above-average.

The 1975 and 1976 year-classes at age 1 were estimated to be about 540 and 440 million fish, respectively, and are considered to be poor in strength. By comparison, the poorest year-class observed was 339 million fish (1954), the largest was 3,257 million (1962), and the median and mean year-class sizes were 885 and 1,180 million, respectively. The estimated 1975 year-class is exceeded in strength by all but five (including 1976) of the observed or estimated year-classes and only three were as poor or poorer than the size estimated for the 1976 year-class.

There is no information available concerning the size of the 1977 year-class. For the purposes of the catch and stock size projections for 1978-79, six different options were considered for the size of the 1977 year-class at age 1. These options included: (1) equal to the poorest of the 1954-76 year-classes (340 million fish), (2) equal to a size poorer than 90% of previous year-classes (440 million), (3) equal to a size poorer than 75% of previous

year-classes (555 million), (4) equal to a size poorer than 60% of previous year-classes (640 million), (5) equal to the median size (885 million), and (6) equal to the mean size (1,180 million).

STOCK SIZE

Estimates of stock size for 1955-76 were obtained by VPA (Table 6). Mean weights at age (Table 3) were applied to stock numbers at age to obtain stock biomass values. The yearly biomass values were corrected using the appropriate ratios between observed and calculated catch (Table 2). Stock size by age at the beginning of 1977 was determined by the relationship: $N_{77} = N_{76}e^{-Z_{76}}$.

Total stock biomass (age 1+) increased from 110,000 tons in 1955 to a high of 800,000 tons in 1963 and then declined to 170,000 tons in 1970 (Table 6, Figure 1). Biomass then increased again to 420,000 tons in 1975 and has since decreased to 372,000 tons in 1976 and 310,000 tons in 1977.

Spawning biomass (age 2+) increased from about 93,000 tons in 1957 to 595,000 tons in 1964, decreased to 135,000 tons in 1971, and then increased again to 320,000 tons in 1976 (Table 6, Figure 5). Spawning biomass declined to 268,000 tons at the beginning of 1977.

PARTIAL RECRUITMENT

Silver hake have generally been fully recruited to the fishery in recent years by about age 3 as evidenced by age-specific fishing mortality (Table 6). Partial recruitment at ages 1 and 2 during 1972-76 varied considerably, ranging from 0.9 to 12.7% at age 1 and from 7.1 to 92.8% at age 2 and averaging 4 and 43%, respectively. These values apply essentially to the 40-mm mesh cod ends used by most foreign vessels prior to March 1977. During 1972-76, the foreign catch averaged about 94% of the total catch per year. Partial

recruitment coefficients of 4% for age 1, 43% for age 2, and 100% for ages 3+ were assumed for January-February 1977.

A 60-mm manila (55-mm synthetic) mesh regulation was implemented for the foreign hake fishery effective 1 March 1977. Different partial recruitment coefficients, therefore, apply to the fishery after that time. In order to determine the effects of the increased mesh size, results from a mesh selection study by Jensen and Hennemuth (1966) were examined. Their retention curve for 52-mm nylon mesh versus 31-mm mesh was smoothed using a power curve (Figure 6). A comparable curve for 55-mm mesh was determined by adjusting the lengths corresponding to the retention ratios between 0 and 100% for 52-mm mesh to equivalent lengths for 55-mm mesh by means of the appropriate selection factors (length divided by mesh size). The same procedure was also followed to obtain a retention curve for 40-mm mesh. The results indicate 50% selection lengths of 20.04 and 27.55 cm for 40-mm and 55-mm mesh, respectively, and a 50% selection factor of 5.01. The effect on partial recruitment was estimated utilizing the length-age composition of the 1976 catch, which was based almost entirely on 40-mm mesh. The number of fish in each length interval was assumed to be proportional to the respective retention ratio for 40-mm mesh as shown in Figure 6. The equivalent number of fish which would have been caught at each length interval with 55-mm mesh was determined 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 of the number retained at each age between 55-mm mesh and 40-mm mesh were obtained. Partial recruitment coefficients applicable to the 55-mm fishery were estimated by multiplying these ratios by the partial recruitment coefficients assumed for the 40-mm mesh fishery during January-February 1977. The results suggested coefficients of 1.4% at age 1, 24% at age 2, 64% at

age 3, 71% at age 4, 70% at age 5, and 100% at ages 6 and older, and these values were assumed for March-December 1977 and for 1978.

CATCH AND STOCK SIZE PROJECTIONS

A total stock biomass (age 1+) of 310,800 tons was estimated to be available at the beginning of 1977 (Table 6). The available age 2+ biomass was 268,000 tons. During January-February an estimated 605 tons were caught using 40-mm mesh which required an F of 0.0026 at ages 3 and older (M = 0.067 at all ages) and left a biomass of about 290,000 tons available at the beginning of March. The estimated March-December catch of 47,685 tons (60-mm mesh) required an F of 0.431 for ages 6 and older (M = 0.333 at all ages) and left a biomass of age 2+ fish at the end of the year of 236,300 tons. The age 2+ or spawning biomass is, therefore, expected to decrease by almost 12% from 1977 to 1978.

Equilibrium yield calculations under conditions of a constant level of recruitment at age 1 and partial recruitment coefficients of 1.4, 24, 64, 71, 70, and 100% at ages 1, 2, 3, 4, 5, and 6+, respectively, indicate an $F_{0.1}$ of about 0.55.

Catch projections for 1978 and resulting age 2+ spawning stock biomass estimates for 1979 were calculated with F ranging from 0.05 to 1.00 and with the six previously described options concerning the size of the 1977 year-class (Table 8). Fishing at $F_{0.1}$ in 1978 would result in a catch of 60,000 tons under either of the six options. The size of the 1979 spawning stock would vary from 178,000 tons (25% decrease from 1978) under option 1 (1977 year-class equal to poorest observed) to 267,000 tons (13% increase from 1978) under option 6 (1977 year-class equal to mean size observed). Assuming the 1977 year-class is of median strength (option 5), the 1979 spawning biomass

would remain at the 1978 level of about 236,000 tons. Even under the most pessimistic assumption (option 1), the predicted decrease in biomass should not be detrimental to future recruitment.

STOCK-RECRUITMENT

The relationship between spawning stock and recruitment is shown in Figures 5 and 7. A cyclical tendency appears evident for this stock (Figure 5) as recruitment and spawning biomass rose from low levels in the mid-1950's to peaks in the early 1960's, declined in the late 1960's to approximately the same levels as in the mid-1950's, and then increased again in the early 1970's. The peaks in the 1970's were much lower than in the early 1960's, however the more recent recruitment and biomass estimates are relatively tenuous, particularly the estimates of recruitment. The cyclical pattern coincides very nicely with recent changes in herring and mackerel. The Georges Bank herring stock biomass (age 4+) was at a level of about 1.0-1.2 million tons during 1965-68 and then declined sharply to a low of about 146,000 tons in 1973 (ICNAF, 1976). The spawning biomass of mackerel increased from around 500,000 tons during 1962-67 to 1.8 million tons in 1970-72 and then decreased to an estimated 435,000 tons in 1977 (Anderson, 1977). Mackerel and herring were low in abundance when silver hake was high and vice versa. Silver hake and mackerel appear to exhibit the closest relationship based on (1) their observed patterns of stock biomass and (2) the prey-predator interactions of the two species (Langton and Bowman, 1977). Silver hake prey heavily on mackerel and, in turn, are preyed upon by mackerel, although to a lesser extent.

A stock-recruitment curve is shown in Figure 7. Peak recruitment occurred from a spawning biomass of around 400,000 tons, with lower levels of recruitment occurring both above and below 400,000 tons. There is considerable

variability in year-class sizes at spawning biomass levels of 100,000-300,000 tons. Recruitment varied from around 500 million to 3 billion fish at age 1 with spawning biomass around 300,000 tons and from 400 million to 1.3 billion fish with spawning biomass around 100,000 tons. Above-average recruitment has been produced in about 25% of the observed years from a spawning biomass of 100,000-200,000 tons. The size of the 1975-76 year classes appears unusually low in comparison with other year-classes, given the spawning biomass from which they were produced. If, in fact, these year-classes turn out to be larger than estimated, then the current stock size projections would be underestimated and the stock would be in better condition than anticipated.

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Table 1. Silver hake catch statistics from the Georges Bank stock[1]

Year	Catch (MT)														USA Catch/day (MT)	International effort as USA days fished
	Bulgaria	Canada	Cuba	FRG	GDR	Italy	Japan	Poland	Romania	Spain	USSR	USA	Other	Total		
1955	-	-	-	-	-	-	-	-	-	-	-	19,595	-	19,595	-	-
1956	-	-	-	-	-	-	-	-	-	-	-	20,729	-	20,729	51.50	403
1957	-	-	-	-	-	-	-	-	-	-	-	25,856	-	25,856	51.40	503
1958	-	-	-	-	-	-	-	-	-	-	-	14,498	-	14,498	42.76	339
1959	-	-	-	-	-	-	-	-	-	-	-	15,899	-	15,899	53.51	297
1960	-	-	-	-	-	-	-	-	-	-	-	22,070	-	22,070	35.89	615
1961	-	-	-	-	-	-	-	-	-	-	-	14,468	-	14,468	42.21	343
1962	-	-	-	-	-	-	-	-	-	-	41,900	16,339	-	58,239	39.46	1,476
1963	-	-	-	-	-	-	-	-	-	-	103,697	14,007	-	117,704	29.90	3,937
1964	-	-	-	-	-	-	-	-	-	-	164,763	5,522	-	170,285	41.52	4,101
1965	-	-	-	-	-	-	-	-	-	-	230,666	8,208	-	238,874	24.00	9,953
1966	-	-	-	-	-	-	-	-	-	-	88,086	12,713	-	100,799	26.09	3,864
1967	-	-	-	-	3	-	12	-	-	-	47,348	12,300	-	59,663	31.83	1,874
1968	-	-	-	-	-	-	35	887	-	-	28,013	6,451	14	35,406	25.31	1,399
1969	-	-	-	-	42	-	95	292	7	-	16,144	1,654	119	18,353	13.34	1,376
1970	-	-	-	-	-	-	31	15	73	-	20,548	4,238	-	24,905	23.81	1,046
1971	1,393	-	265	-	-	-	82	124	-	-	66,809	3,069	-	71,742	17.38	4,128
1972	1,914	-	354	226	111	-	104	-	42	-	73,882	879	-	77,512	8.66	8,951
1973	879	-	-	-	145	-	188	251	4	-	55,042	5,698	-	62,207	22.60	2,753
1974	740	1	-	49	36	-	43	70	204	-	62,938	2,283	-	66,364	15.02	4,418
1975	1,021	2	1,304	26	29	119	1	125	122	133	55,795	4,588	-	63,016	22.85	2,758
1976	-	-	3,682	81	-	-	1	102	172	5	37,992	3,793	51	45,879	46.07	966

[1]Non-USA catches before 1968 are estimated.

Table 2. Silver 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	11	12+	Total	Observed weight	Calculated weight[1]	Obs/Calc
1955	+	3.6	3.1	25.0	39.0	14.5	2.9	1.7	0.7	0.2	+	+	-	90.7	19,595	22,106	0.886
1956	+	2.3	3.5	20.8	42.8	17.2	2.9	1.4	0.6	0.2	+	+	+	91.7	20,729	23,916	0.867
1957	+	11.4	5.7	31.3	47.4	23.7	4.4	1.8	0.6	0.2	+	+	+	126.5	25,856	29,179	0.886
1958	+	4.4	5.5	16.3	22.5	12.5	2.9	1.6	0.5	0.1	+	+	+	66.3	14,498	16,756	0.865
1959	+	3.8	7.7	26.9	23.0	11.5	3.0	1.5	0.7	0.1	+	+	+	78.2	15,899	18,018	0.882
1960	-	2.2	11.7	46.9	33.0	12.6	3.8	2.1	1.0	0.2	+	+	-	113.5	22,070	23,868	0.925
1961	-	0.6	5.1	31.2	25.3	7.1	1.8	1.1	0.5	0.2	+	+	-	72.9	14,468	16,013	0.904
1962	-	1.8	19.1	106.9	109.7	40.5	6.7	3.6	1.0	0.2	+	+	+	289.5	58,239	61,296	0.950
1963	-	17.1	48.8	246.2	240.3	61.0	9.9	4.0	2.1	0.5	0.1	+	+	630.0	117,704	122,128	0.964
1964	+	0.9	80.1	313.6	268.8	98.4	31.9	18.7	9.0	2.3	0.1	0.2	+	824.0	170,285	181,068	0.940
1965	-	31.2	160.0	770.2	460.5	57.0	10.6	5.0	1.8	0.4	0.1	+	+	1,496.8	238,874	255,541	0.935
1966	-	17.1	173.7	264.3	160.1	29.3	8.5	4.1	2.6	0.5	0.1	0.1	+	660.4	100,799	108,727	0.927
1967	-	4.2	11.5	106.9	136.9	31.0	4.8	2.0	1.0	0.2	0.1	+	+	298.6	59,663	64,946	0.919
1968	-	1.6	4.8	76.1	56.5	31.0	6.2	1.9	0.8	0.3	+	0.1	-	179.3	35,406	39,028	0.907
1969	-	1.2	12.8	20.7	15.2	14.4	6.0	5.3	1.9	1.3	0.1	+	+	78.9	18,353	19,701	0.932
1970	-	38.0	27.1	33.0	37.9	14.6	4.2	3.3	1.3	0.3	0.1	+	+	159.9	24,905	25,397	0.981
1971	-	3.3	21.9	110.4	98.1	55.3	21.6	8.9	7.8	3.8	0.7	0.3	-	332.1	71,742	75,261	0.953
1972	0.4	148.2	148.4	102.1	28.2	5.7	3.4	2.2	0.8	0.4	0.2	0.1	0.1	440.2	77,512	82,821	0.936
1973	+	20.5	240.0	78.4	12.2	2.6	1.6	0.9	0.3	0.1	+	+	+	356.6	62,207	63,949	0.973
1974	+	12.0	150.3	122.5	25.3	3.5	3.8	1.6	0.4	0.2	0.1	+	+	319.7	66,364	68,096	0.975
1975	-	17.2	110.7	134.4	42.6	13.8	2.0	0.7	0.1	0.3	0.1	-	-	321.9	63,016	64,685	0.974
1976	-	1.6	20.0	114.2	85.8	7.9	0.9	0.1	-	-	+	-	-	230.5	45,879	45,941	0.999

[1]Using mean weights at age from Table 3.

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

Year	Age 0	1	2	3	4	5	6	7	8	9	10	11	12+
1955	.005	.034	.105	.180	.237	.332	.485	.597	.708	.919	.971	1.068	1.410
1956	.006	.048	.110	.192	.250	.337	.481	.616	.798	.972	1.090	1.217	1.709
1957	.007	.024	.101	.172	.241	.336	.450	.542	.683	.968	1.020	1.200	1.745
1958	.008	.049	.107	.183	.256	.357	.481	.559	.718	.979	1.114	1.161	1.688
1959	.006	.052	.107	.169	.239	.350	.497	.571	.708	.857	.971	1.023	1.576
1960	-	.069	.107	.159	.217	.330	.466	.529	.644	.813	.847	.896	1.529
1061	-	.073	.110	.170	.222	.335	.490	.599	.772	.912	.998	.944	1.316
1962	-	.075	.113	.161	.219	.303	.396	.556	.668	.866	.914	.758	1.454
1963	-	.080	.107	.161	.208	.288	.415	.518	.748	1.006	.954	.810	1.425
1964	.006	.077	.104	.155	.218	.322	.486	.552	.641	.831	1.007	.849	1.518
1965	-	.064	.102	.155	.200	.302	.424	.499	.616	.859	.865	.957	1.439
1966	-	.060	.093	.151	.209	.308	.483	.590	.754	.889	1.178	1.053	1.967
1967	-	.030	.105	.175	.225	.311	.446	.567	.821	1.062	1.537	1.276	1.652
1968	-	.068	.099	.152	.218	.315	.443	.552	.720	.969	1.527	1.328	1.163
1969	-	.058	.113	.161	.217	.289	.380	.475	.664	.933	1.206	1.183	1.424
1970	-	.062	.101	.162	.198	.262	.322	.388	.491	.771	1.260	1.155	1.406
1971	-	.086	.112	.159	.206	.275	.342	.425	.557	.792	.977	1.155	-
1972	.024	.085	.178	.269	.338	.427	.416	.568	.978	1.110	1.105	1.664	.909
1973	.028	.118	.157	.215	.334	.447	.492	.643	.939	1.096	1.073	-	.808
1974	.029	.061	.176	.239	.298	.407	.323	.457	.942	1.075	1.191	1.305	.791
1975	-	.091	.151	.207	.288	.349	.420	.343	1.085	.621	1.236	-	-
1976	-	.097	.159	.188	.217	.236	.649	.689	-	-	1.272	-	-

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

Year	Spring	Autumn
1963	-	3.60
1964	-	1.26
1965	-	1.51
1966	-	1.48
1967	-	1.06
1968	0.37	2.49
1969	0.53	1.69
1970	0.74	1.29
1971	0.76	1.21
1972	0.52	1.34
1973	0.82[1]	1.75
1974	0.34[1]	1.09
1975	0.40[1]	1.97
1976	0.39[1]	4.42
1977	1.26[1]	-

[1]Adjusted from No. 41 trawl catches to equivalent No. 36 catches using a 6.20:1 ratio.

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

Year	Fishing effort[1]	Fishing mortality[2]
1959	297	.357
1960	615	.342
1961	343	.143
1962	1,476	.436
1963	3,937	.712
1964[5]	4,101	1.192
1965	9,953	1.274
1966	3,864	.646
1967	1,874	.590
1968	1,399	.472
1969	1,376	.266
1970	1,046	.302
1971[5]	4,128	1.373
1972	8,951	1.155
1973	2,753	.545
1974	4,418	.691
1975	2,758	(.553)[3,4]
1976	966	(.356)[3]

[1]Expressed as USA days fished.

[2]Weighted mean F for fully recruited ages.

[3]Calculated from linear regression of fishing effort on fishing mortality for 1959-74: $Y = 0.250 + 0.00011X$, $r = 0.972$.

[4]Value calculated from VPA was 0.367.

[5]Not used in calculation of linear regression.

Table 6. Fishing mortality rates (F) and stock size for the Georges Bank silver hake stock derived from virtual population analysis (M = 0.4).

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12+	100% recruitment Wtd F[3]	Age
							Fishing mortality							
1955	.013	.014	.149	.583	.805	.517	.684	.699	(.629)[1]	-	-	-	.629	4+
1956	.007	.019	.147	.520	.730	.467	.664	.726	(.568)[1]	-	-	-	.568	4+
1957	.024	.026	.294	.751	.817	.533	.788	.910	(.756)[1]	-	-	-	.756	4+
1958	.006	.018	.116	.453	.585	.267	.482	.691	(.469)[1]	-	-	-	.469	4+
1959	.004	.016	.142	.299	.571	.338	.270	.516	(.357)[1]	-	-	-	.357	4+
1960	.001	.016	.157	.324	.335	.479	.540	.367	(.342)[1]	-	-	-	.342	4+
1961	<.001	.005	.068	.148	.132	.089	.311	.296	(.143)[1]	-	-	-	.143	4+
1962	.001	.015	.156	.452	.471	.220	.324	.670	.231	-	-	-	.436	4+
1963	.006	.030	.350	.807	.637	.250	.248	.403	1.204	.216	-	-	.712	4+
1964	.001	.046	.339	1.096	1.367	1.149	1.468	2.209	1.530	(1.192)[1]	(1.192)[1]	-	1.192	4+
1965	.034	.158	1.052	1.856	1.001	.654	.716	.676	.819	.280	-	-	1.274	3+
1966	.033	.339	.540	.870	.753	.492	.757	1.562	.515	(.646)[1]	(.646)[1]	-	.646	3+
1967	.008	.035	.461	.795	.519	.326	.255	.536	(.590)	.227	-	-	.590	3+
1968	.003	.014	.421	.614	.534	.229	.259	.191	.384	-	(.472)[1]	-	.472	3+
1969	.003	.042	.097	.171	.393	.231	.396	.575	.696	(.266)[1]	-	-	.266	4+
1970	.110	.097	.180	.324	.309	.236	.239	.197	.205	.125	-	-	.302	4+
1971	.006	.106	.928	1.793	1.614	1.475	1.641	2.270	2.247	1.432	.871	-	1.373	3+
1972	.154	.495	1.370	.875	.598	.481	.742	.847	(1.155)[1]	(1.155)[1]	(1.155)[1]	(1.155)[1]	1.155	3+
1973	.014	.508	.697	.761	.219	.423	.282	.258	.292	-	-	-	.545	2+
1974	.012	.167	.694	.664	.673	.744	1.432	.243	.345	(.691)[1]	-	-	.691	3+
1975	.015[2]	.180	.276	.732	1.388	1.590	(.367)[1]	(.367)[1]	(.367)[1]	(.367)[1]	-	-	.367	3+
1976	.004[2]	.026[2]	.360[4]	.360[4]	.360[4]	.360[4]	.360[4]	-	-	-	-	-	.360	3+

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12+	Age 1+ Total	Age 1+ Wt (10^3 tons)[5]	Age 2+ Total	Age 2+ Wt (10^3 tons)[5]
							Stock size (millions)									
1955	339.3	277.5	218.0	105.1	31.0	8.6	4.1	1.6	0.5	-	-	-	985.7	109.3	646.4	99.0
1956	412.3	224.7	183.6	125.9	39.3	9.3	3.4	1.4	0.5	-	-	-	1,000.4	115.0	588.1	97.8
1957	571.3	274.1	147.8	106.2	50.2	12.7	3.9	1.2	0.4	-	-	-	1,167.8	104.8	596.5	92.7
1958	883.4	373.6	179.2	73.8	33.6	14.9	5.0	1.2	0.3	-	-	-	1,565.0	136.7	681.6	99.3
1959	1,304.6	589.0	246.1	106.9	31.5	12.5	7.6	2.1	0.4	-	-	-	2,300.7	195.3	996.1	135.4
1960	1,993.3	873.3	388.8	143.2	53.1	11.9	6.0	3.9	0.8	-	-	-	3,474.3	326.8	1,481.0	199.6
1961	2,206.8	1,339.4	575.9	222.7	69.4	25.5	4.9	2.3	1.8	-	-	-	4,448.7	450.1	2,241.9	304.4
1962	2,993.0	1,516.6	894.1	360.8	128.8	40.8	15.6	2.4	1.2	-	-	-	5,953.3	651.0	2,960.3	437.8
1963	3,256.6	2,012.0	1,000.5	512.9	153.9	53.9	21.9	7.6	0.8	0.6	-	-	7,020.7	798.8	3,764.1	547.7
1964	1,950.7	2,168.1	1,309.1	472.8	153.4	54.6	28.1	11.5	3.4	0.2	0.3	-	6,152.2	736.7	4,201.5	595.5
1965	1,118.8	1,319.7	1,388.1	625.3	105.9	26.2	11.6	4.3	0.8	0.5	-	-	4,601.2	560.1	3,482.4	493.2
1966	631.3	724.8	755.2	326.0	65.5	26.1	9.1	3.8	1.5	0.2	0.2	-	2.542.7	305.9	1,911.4	270.8
1967	614.1	409.3	346.1	295.1	91.3	20.7	10.7	2.9	0.5	0.6	-	-	1,791.3	216.8	1,177.2	199.9
1968	560.4	408.6	265.1	146.4	89.3	36.4	10.0	5.6	1.1	-	0.3	-	1,523.2	186.9	962.8	152.3
1969	528.2	375.4	270.1	116.7	53.1	35.1	19.4	5.2	3.1	0.5	-	-	1,406.8	174.0	878.6	145.5
1970	439.3	353.5	241.3	164.3	65.9	24.0	18.7	8.8	2.0	1.0	-	-	1,318.8	170.6	879.5	143.9
1971	687.1	263.7	215.0	135.0	79.6	32.4	12.7	9.9	4.8	1.1	0.6	-	1,441.9	190.7	754.8	134.4
1972	1,252.1	453.5	159.0	57.0	15.1	10.6	5.0	1.7	0.7	0.3	0.2	0.2	1,955.4	249.1	703.3	149.5
1973	1,784.5	719.4	185.3	27.1	15.9	5.6	4.4	1.6	0.5	-	-	-	2,744.3	376.7	959.8	171.8
1974	1,221.1	1,179.7	290.3	61.9	8.5	8.6	2.4	2.2	0.8	0.2	-	-	2,775.7	370.9	1,554.6	298.3
1975	(1,435.0)[4]	809.1	669.2	97.2	21.3	2.9	2.7	0.4	1.2	0.4	-	-	3,039.4	419.3	1,604.4	292.2
1976	(540.0)[4]	948.0	452.9	340.3	31.3	3.6	0.4	-	-	-	-	-	2,316.5	371.7	1,776.5	319.4
1977	(440.0)[4]	360.7	619.2	211.8	159.1	14.6	1.7	0.2	-	-	-	-	1,807.3	310.8	1,367.3	268.1

[1]Mean F for fully recruited ages in that year.
[2]Determined from assumed stock size and known catch.
[3]Weighted by stock size at age.
[4]Estimated
[5]Adjusted using ratios of observed to calculated weight in Table 2.

Table 7. Catch per tow (number) of age 0 and 1 Georges Bank silver 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	Autumn survey Age 0	Spring survey Age 1	VPA Age 1
1963	3.09	-	1,950.7
1964	0.03	-	1,118.8
1965	0.18	-	631.3
1966	1.92	-	614.1
1967	1.91	0.10	560.4
1968	13.10	0.77	528.2
1969	9.10	0.20	439.3
1970	0.28	0.27	687.1
1971	34.99	1.42	1,252.1
1972	12.52	0.97	1,784.5
1973	9.15	2.14	1,221.1
1974	172.53	2.70	(1,435.2)[1]
1975	69.51	0.16	(538.2)[1]
1976	12.87	0.09	(440.8)[1]

[1]Calculated from power curve relationship between spring survey catch-per-tow and VPA year-class size: $Y = 1016.735X^{.347}$, $r = .734$.

Table 8. Projected catch (age 1+) in 1978 from the Georges Bank silver hake stock with fishing mortality ranging from 0.05 to 1.00 under six options concerning the estimated 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.

	Option 1			Option 2			Option 3			Option 4			Option 5			Option 6		
Fishing mortality	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	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	6.5	233.0	- 1.4	6.5	243.6	+ 3.1	6.5	255.9	+ 8.3	6.5	264.9	+12.1	6.5	291.0	+23.1	6.5	322.4	+36.4
0.10	12.7	226.5	- 4.2	12.7	237.1	+ 0.3	12.7	249.4	+ 5.5	12.7	258.4	+ 9.3	12.8	284.5	+20.4	12.8	315.9	+33.7
0.15	18.7	220.3	- 6.8	18.7	230.9	- 2.3	18.7	243.2	+ 2.9	18.8	252.2	+ 6.7	18.8	278.3	+17.8	18.8	309.6	+31.0
0.20	24.5	214.3	- 9.3	24.5	224.9	- 4.8	24.6	237.2	+ 0.4	24.6	246.2	+ 4.2	24.6	272.2	+15.2	24.7	303.6	+28.5
0.25	30.1	208.5	-11.8	30.1	219.2	- 7.3	30.2	231.4	- 2.1	30.2	240.4	+ 1.7	30.3	266.4	+12.7	30.4	297.7	+26.0
0.30	35.5	203.0	-14.1	35.6	213.6	- 9.6	35.6	225.8	- 4.5	35.6	234.8	- 0.7	35.7	260.8	+10.3	35.8	292.1	+23.6
0.35	40.8	197.6	-16.4	40.8	208.2	-11.9	40.8	220.4	- 6.7	40.9	229.4	- 2.9	41.0	255.4	+ 8.1	41.1	286.7	+21.3
0.40	45.8	192.4	-18.6	45.9	203.0	-14.1	45.9	215.2	- 8.9	45.9	224.2	- 5.1	46.1	250.2	+ 5.9	46.2	281.5	+19.1
0.45	50.7	187.5	-20.7	50.7	198.1	-16.2	50.8	210.2	-11.1	50.8	219.2	- 7.3	51.0	245.2	+ 3.7	51.1	276.4	+16.9
0.50	55.4	182.7	-22.7	55.5	193.2	-18.3	55.5	205.4	-13.1	55.6	214.4	- 9.3	55.7	240.3	+ 1.7	55.9	271.6	+14.9
*0.55	60.0	178.0	-24.7	60.0	188.6	-20.2	60.1	200.8	-15.0	60.1	209.8	-11.2	60.3	235.7	- 0.3	60.5	266.9	+12.9
0.60	64.4	173.6	-26.5	64.4	184.1	-22.1	64.5	196.3	-16.9	64.6	205.3	-13.1	64.7	231.2	- 2.2	64.9	262.3	+11.0
0.65	68.6	169.3	-28.4	68.7	179.8	-23.9	68.8	192.0	-18.8	68.8	200.9	-15.0	69.0	226.8	- 4.0	69.2	258.0	+ 9.2
0.70	72.7	165.1	-30.1	72.8	175.7	-25.7	72.9	187.8	-20.5	73.0	196.8	-16.7	73.2	222.6	- 5.8	73.4	253.8	+ 7.4
0.75	76.7	161.1	-31.8	76.8	171.6	-27.4	76.9	183.8	-22.2	77.0	192.7	-18.5	77.2	218.6	- 7.5	77.4	249.7	+ 5.6
0.80	80.6	157.2	-33.5	80.7	167.8	-29.0	80.8	180.0	-23.8	80.8	188.9	-20.1	81.1	214.7	- 9.2	81.3	245.8	+ 4.0
0.85	84.3	153.5	-35.1	84.4	164.0	-30.6	84.5	176.1	-25.5	84.6	185.1	-21.7	84.8	210.9	-10.8	85.1	242.0	+ 2.4
0.90	87.9	149.9	-36.6	88.0	160.4	-32.1	88.1	172.5	-27.0	88.2	181.5	-23.2	88.4	207.3	-12.3	88.7	238.3	+ 0.8
0.95	91.4	146.4	-38.1	91.5	156.9	-33.6	91.6	169.0	-28.5	91.7	178.0	-24.7	92.0	203.7	-13.8	92.2	234.8	- 0.7
1.00	94.8	143.1	-39.5	94.9	153.6	-35.0	95.0	165.7	-29.9	95.1	174.6	-26.1	95.4	200.4	-15.2	95.7	231.4	- 2.1

Options for 1977 year-class

Option 1: equal to poorest of 1954-76 year-classes (340 million fish at age 1).
Option 2: equal to year-class size which was poorer than 90% of those observed (440 million fish at age 1).
Option 3: equal to year-class size which was poorer than 75% of those observed (555 million fish at age 1).
Option 4: equal to year-class size which was poorer than 60% of those observed (640 million fish at age 1).
Option 5: equal to median year-class size (885 million fish at age 1).
Option 6: equal to mean year-class size (1,180 million fish at age 1).

*$F_{0.1}$

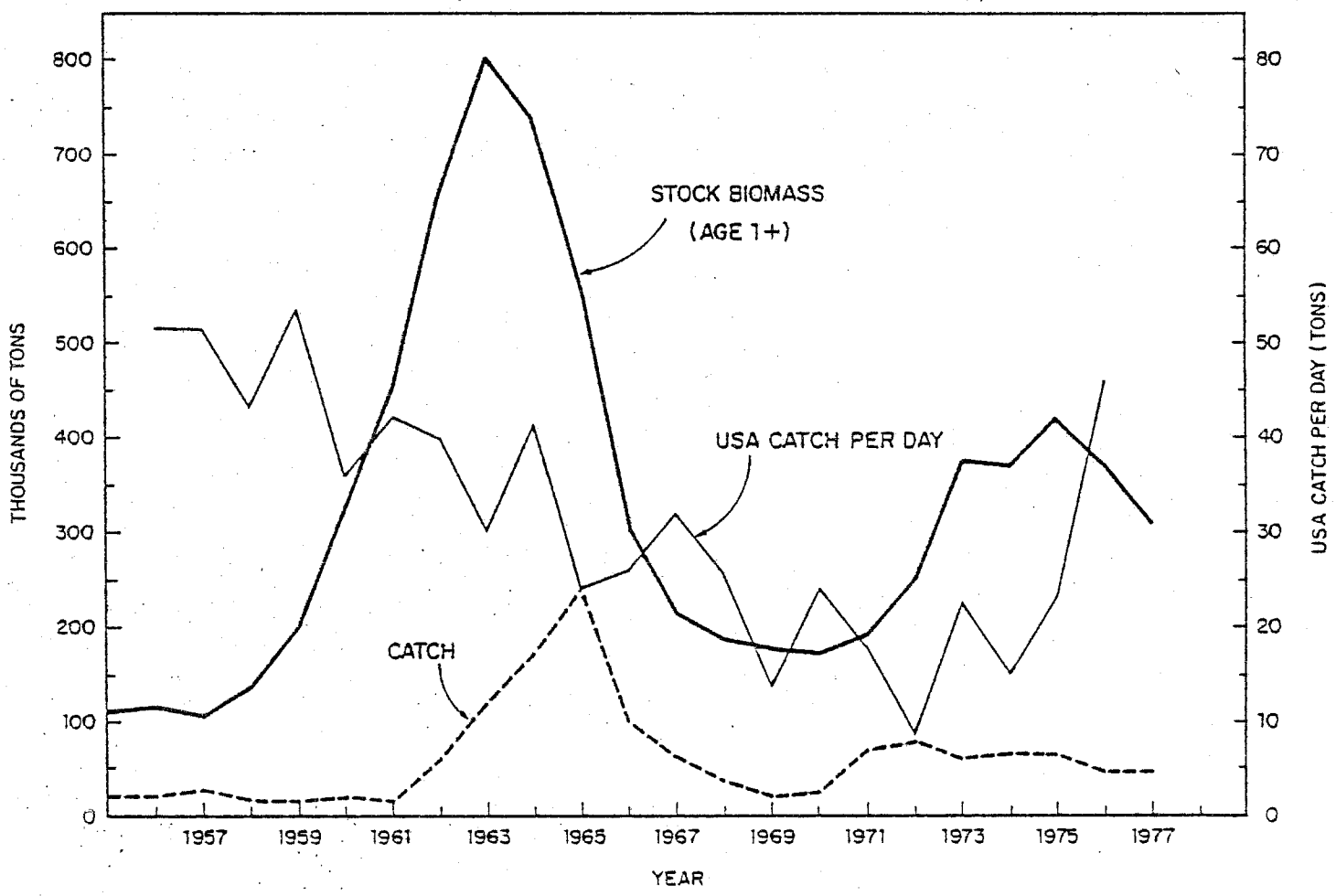

Figure 1. International catch, stock biomass (age 1+) from virtual population analysis, and USA commercial catch-per-day from the Georges Bank silver hake stock.

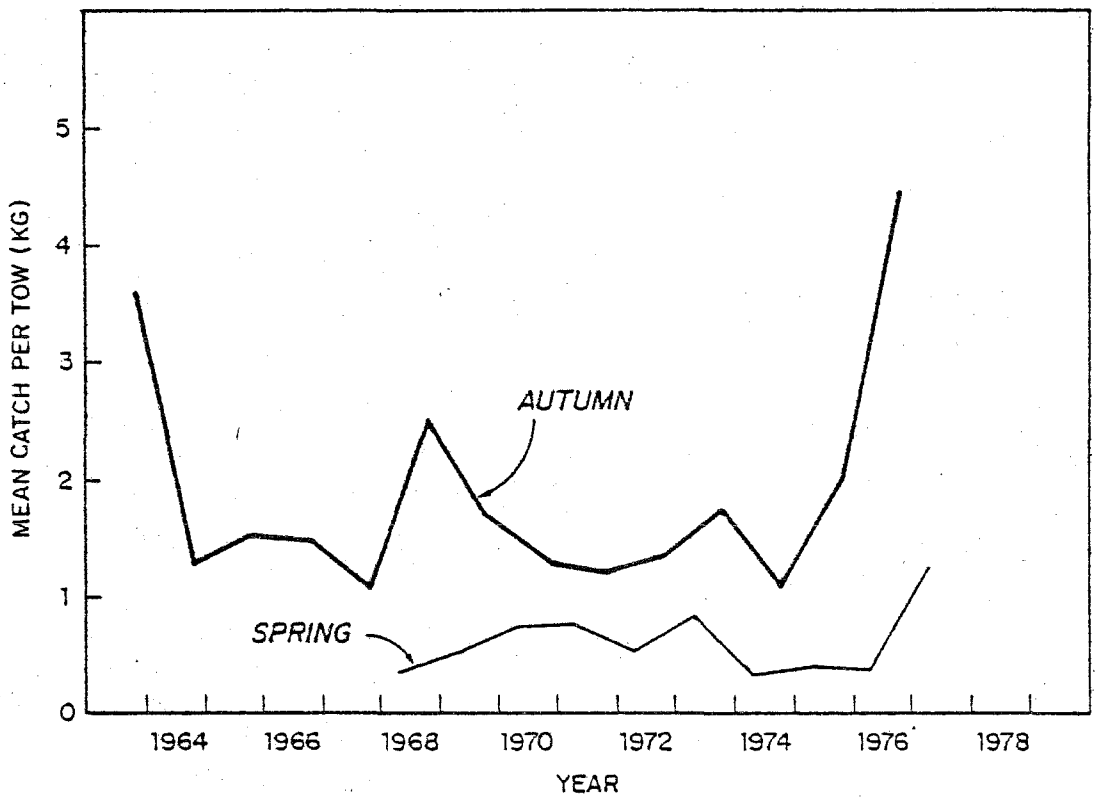

Figure 2. Stratified mean catch-per-tow (kg) of silver hake from the Georges Bank stock from USA autumn (1963-76) and spring (1968-77) bottom trawl surveys.

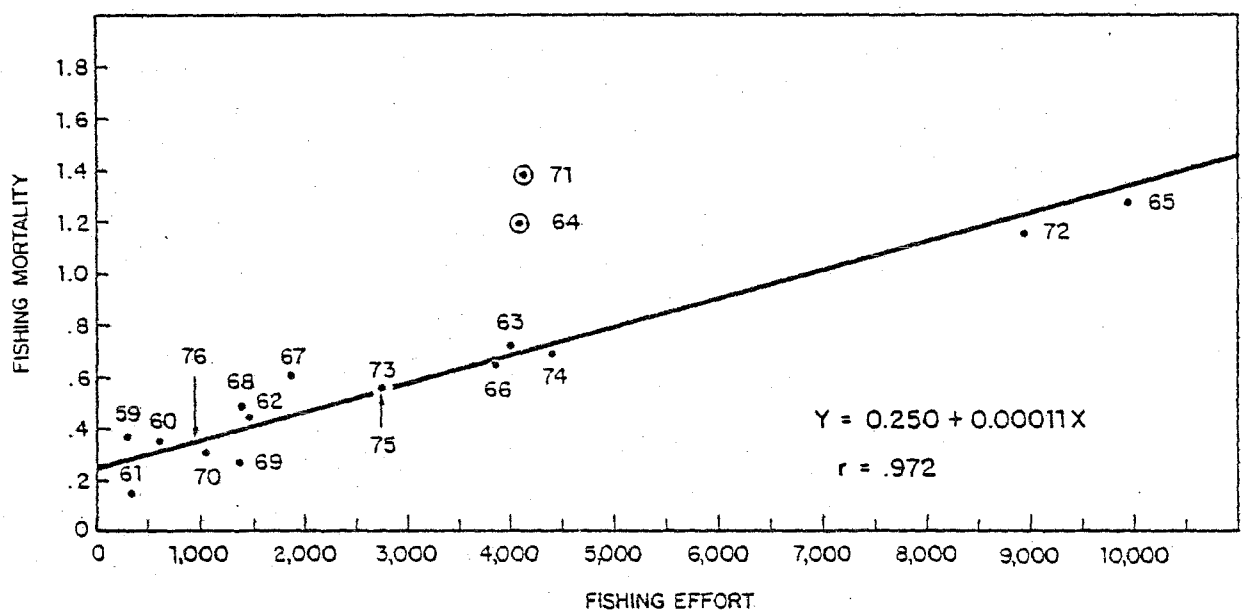

Figure 3. Relationship between fishing mortality from virtual population analysis and international fishing effort expressed as USA days fished for the Georges Bank silver hake stock. The 1964 and 1971 values were not used in calculating the relationship.

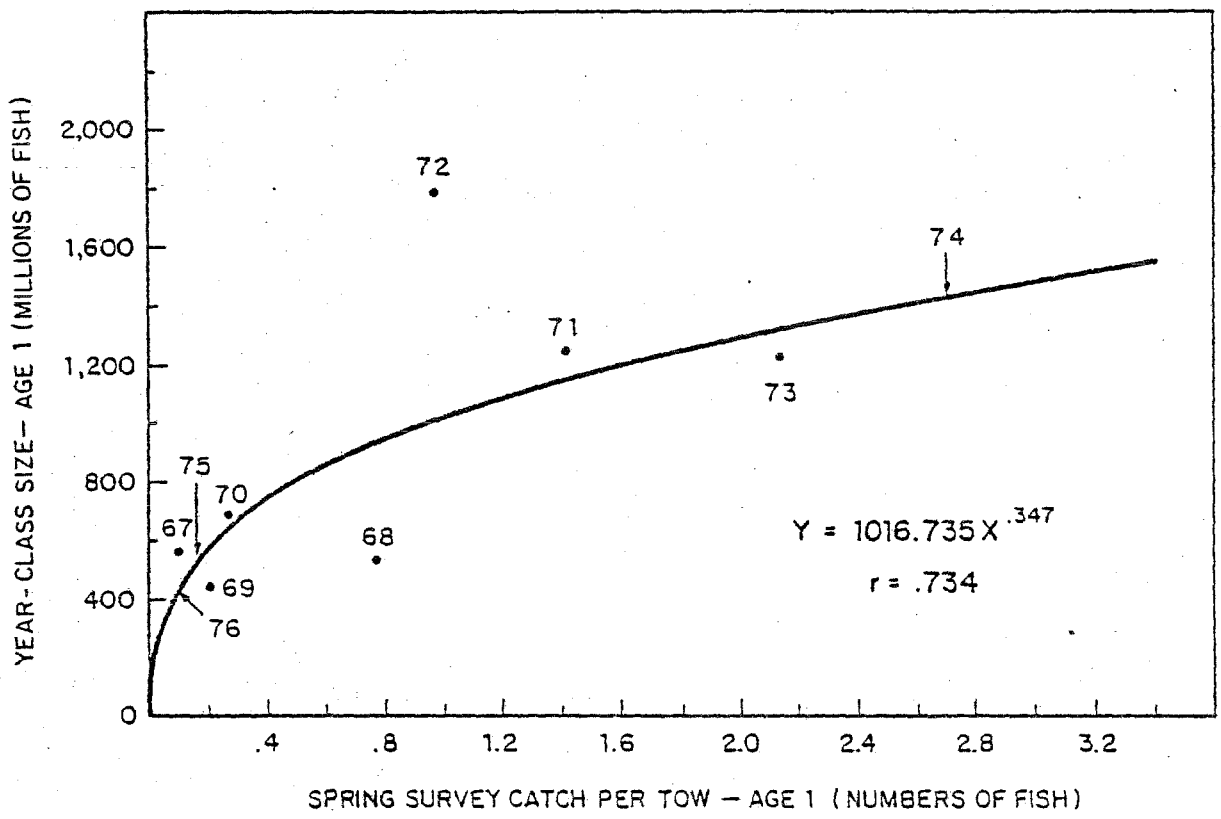

Figure 4. Power curve relationship between Georges Bank silver hake year-class size at age 1 and USA spring survey catch-per-tow at age 1.

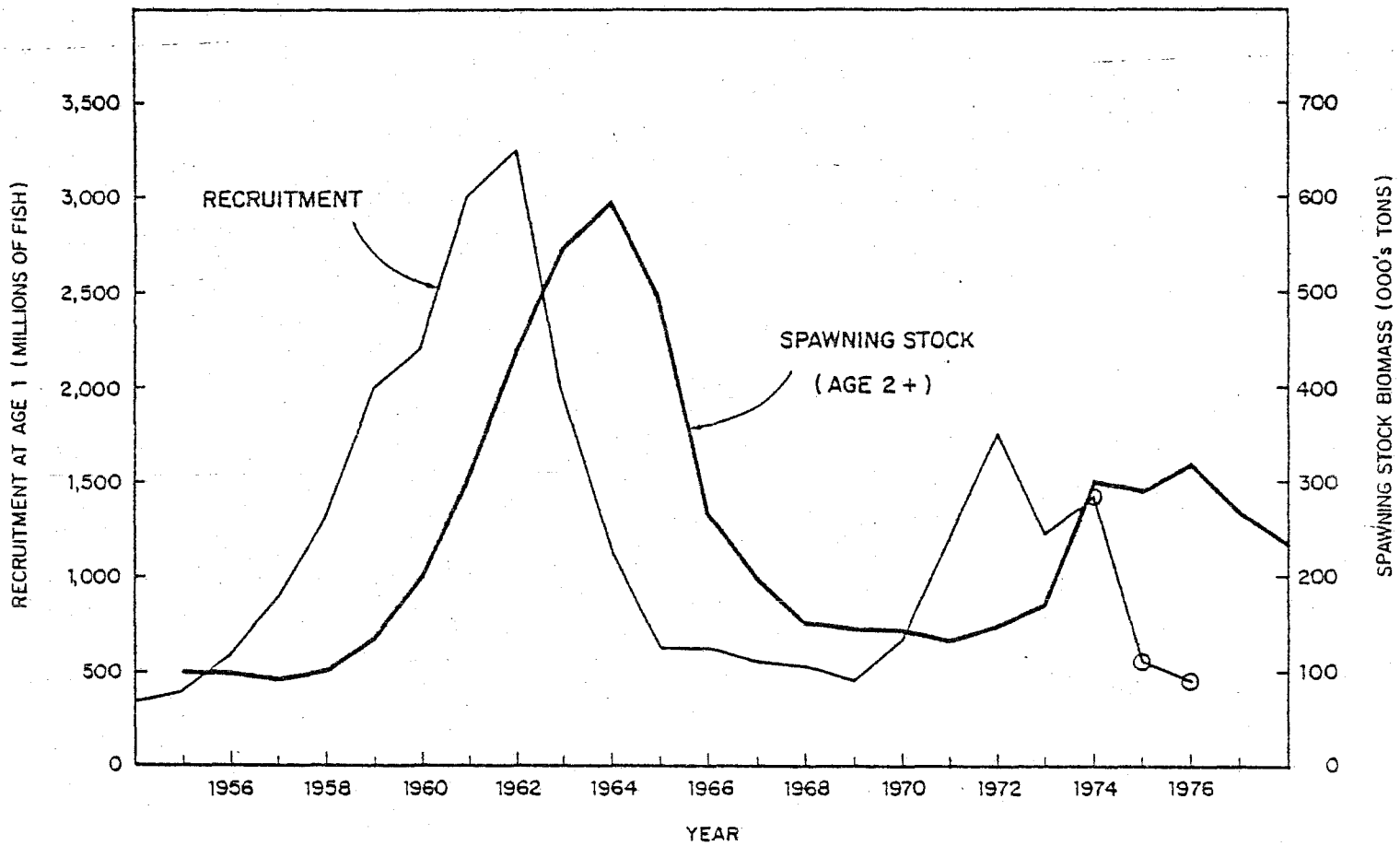

Figure 5. Georges Bank silver hake spawning stock biomass (age 2+) in 1955-78 and abundance at age 1 of the 1954-76 year-classes. (Open circles indicate estimated year-class sizes.)

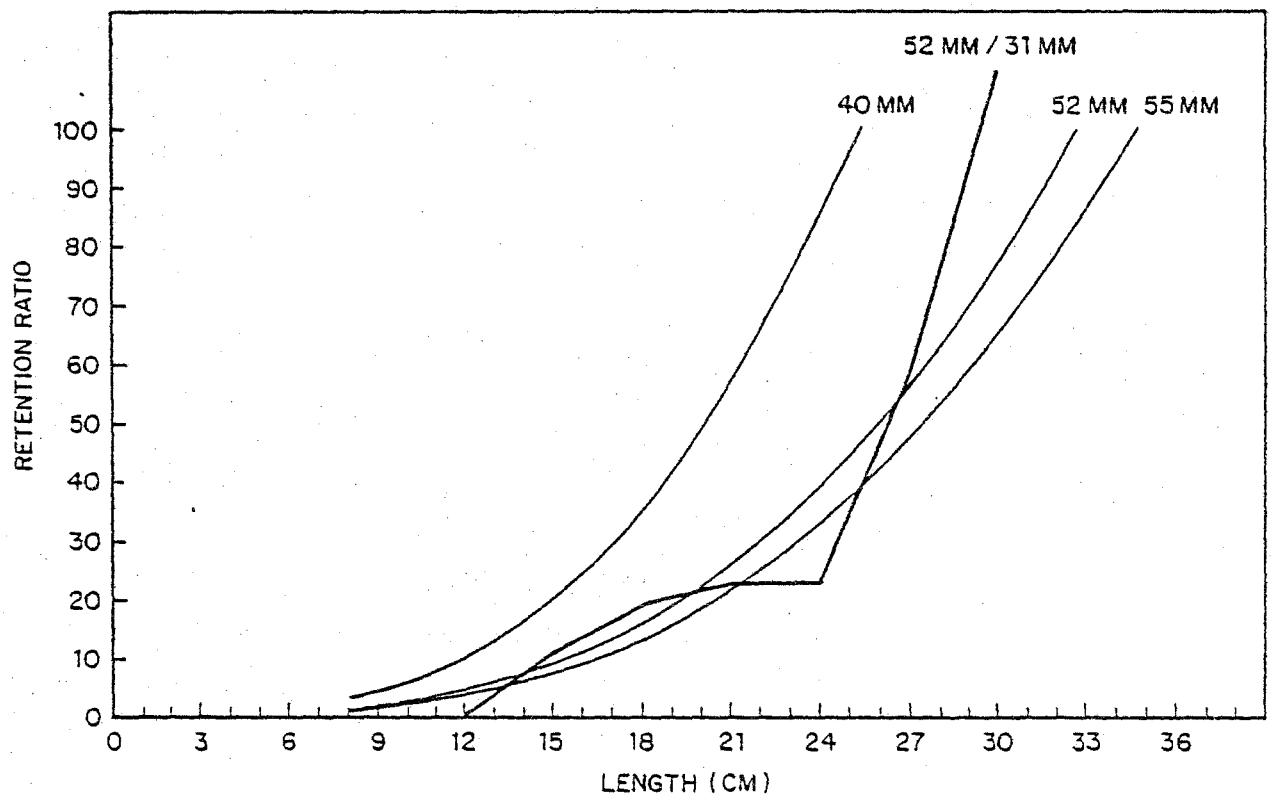

Figure 6. Retention curve of silver hake in 52-mm versus 31-mm nylon cod ends (Jensen and Hennemuth, 1966) smoothed using a power curve, with comparable curves for 40-mm and 55-mm mesh.

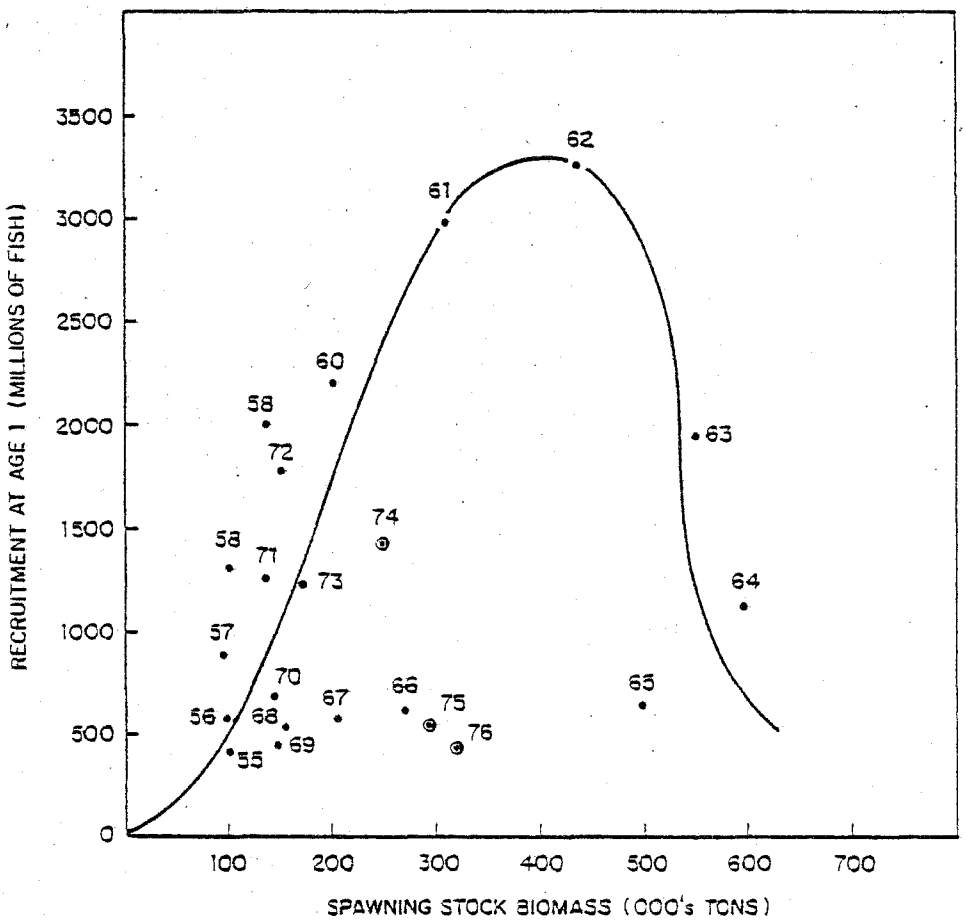

Figure 7. Stock-recruitment relationship for the Georges Bank silver hake stock. The curve is fitted by eye and the open circles indicate estimated year-class sizes.