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Status of the Georges Bank silver hake stock - 1978

By

F. P. Almeida and E. D. Anderson
National Marine Fisheries Service
Northeast Fisheries Center
Woods Hole Laboratory
Woods Hole, Massachusetts 02543

INTRODUCTION

This report presents an update of the status of the silver hake (*Merluccius bilinearis*) stock on Georges Bank (ICNAF Subdiv. 5Ze). The data base for this stock includes commercial catch statistics for 1955-77 and research vessel bottom trawl survey data since 1963. Past levels of stock size and fishing mortality (F) were estimated from catch-at-age data utilizing virtual population analysis (VPA). Catches in 1979 at varying levels of F and resulting 1980 stock sizes were projected under the assumptions of estimated catch and levels of recruitment in 1978.

CATCH

Catches by country for the period 1955-77 are listed in Table 1. Total catch 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 increased again and stabilized at an average of about 68,000 tons during 1971-75. The catch declined again in 1976 to 45,800 tons and decreased further in 1977 to its lowest level since 1970 (44,300 tons).

USA catches averaged 18,200 tons during 1955-63, but declined to average only 3,600 tons during 1968-76. The 1977 USA catch was 3,749 tons.

The total allowable catch (TAC) was 80,000 tons each year during 1973-75 and was reduced to 50,000 tons in 1976. An optimum yield (OY) of 70,000 tons was set for 1977, of which 15,000 tons was designated as USA capacity and 55,000 tons as the total allowable level of foreign fishing (TALFF). In 1978 the OY was reduced to 58,800 tons of which 26,000 was allotted to the USA and 32,800 as the TALFF.

The 1978 foreign catch, reported through 2 December, was 3,788 tons. The USA commercial catch was estimated to be 6,400 tons in 1978 from projections made comparing the 1977 catch with available 1978 monthly catches. Assuming a minimal foreign catch during the rest of the year, a total catch in 1978 was estimated to be 11,000 tons.

CATCH COMPOSITION

Table 2 contains the estimated catch (in numbers) at age during 1955-77. Age 3 and 4 fish made up the majority of the 1977 catch (89%) following a similar trend in 1976 (87% age 3 and 4 fish).

Mean weights at age were applied to the numbers at age in Table 2 to obtain calculated catches. Ratios between observed and calculated catches range from

0.865 to 0.997 and averaged 0.931. The 1977 means weights (unadjusted) were used for the 1979-80 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, the highest catch rate since 1959, but decreased in 1977 to 31.6, still the highest rate (after 1976) since 1966 (Table 1, Figure 1). This index of abundance (1955-77) 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 1977 USA spring bottom trawl survey catch-per-tow index was the highest observed in the series (1968-present) but dropped to 0.72 in 1978, still higher than any since 1973 (except 1977). The autumn survey index dropped in 1977 after recording its highest level in 1976.

FISHING MORTALITY

Fishing mortality in 1977, the terminal year for virtual population analysis, was estimated for fully recruited ages from a linear relationship between international fishing effort and fishing mortality. Fishing effort, defined as USA days fished, was determined by dividing international 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 0.42 was estimated for 1977 based on a regression between fishing effort and fishing mortality values from a previous VPA (Anderson, 1977). A new VPA was performed using 0.42 as the terminal F for ages 4 and older in 1977 (Table 6), and a linear regression ($r = 0.959$, $p = 0.01$) between fishing effort and the mean F values from the new VPA for 1959-75 predicted an F for 1977 of 0.424 (Table 5, Figure 3). The estimate of 0.42 was therefore accepted as the terminal F for 1977.

Fishing mortality was at a low in 1961 at 0.14, rose to 1.27 in 1965 at the peak of the USSR fishery, declined to 0.27 in 1969, increased sharply to 1.43 in 1971, and decreased almost continuously to 0.42 in 1977 (Table 6).

RECRUITMENT ESTIMATES

Estimates of the size of the 1974-77 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 ($r = 0.791$, $p = 0.05$) (Table 7, Figure 4). The autumn survey catch per tow (numbers) at age 0 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 about 1,225 million fish, which would make it an above-average year class exceeded in strength since 1954 only by the 1960-63 and 1973 year classes.

The 1975 and 1976 year classes at age 1 were estimated to be about 520 and 440 million fish, respectively, and are considered to be poor in strength. The largest year class observed was 3,257 million (1962), and the median and mean year class sizes were 790 and 1,100 million, respectively. The estimated 1975 year class is exceeded in strength by all but six (including 1976) of the observed or estimated year classes and only four were as poor or poorer than the size estimated for the 1976 year class.

The 1977 year class at age 1 was estimated to be approximately 280 million fish which would make it the poorest observed in the series.

STOCK SIZE

Estimates of stock size for 1955-77 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 1978 was determined by the relationship: $N_{78} = N_{77}e^{-Z_{77}}$.

Total stock biomass (age 1+) increased from 109,000 tons in 1955 to a high of about 800,000 tons in 1963 and then declined to 168,000 tons in 1970. Biomass increased again to 332,000 tons in 1975 and has since steadily decreased to 254,000 tons in 1978 (Table 6, Figure 1).

Spawning biomass (age 2+) increased from about 93,000 tons in 1957 to 595,000 tons in 1964, decreased to 132,000 tons in 1971, and increased again to 250,000 tons in 1976. Spawning biomass declined to 218,000 tons at the beginning of 1978 (Table 6, Figure 5).

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 mortalities obtained by VPA (Table 6). Partial recruitment, defined here as the ratio between fishing mortality at a given age (in a given year) not fully recruited into the fishery and the mean F at the fully recruited ages in that year, was estimated to be 0.5% at age 1, 9% at age 2, 67% at age 3, and 100% for ages 4+ in 1977, based on the F values estimated for that year at each age (Table 6). These values represent decreases from previous years and reflect to a certain degree the effect of the 60-mm mesh regulation which was implemented effective 1 March 1977 for the foreign hake fishery. These estimates of partial recruitment were also used in the projections of catch and stock size for 1979-80.

CATCH AND STOCK SIZE PROJECTIONS

A total stock biomass of 253,500 tons was estimated to be available at the beginning of 1978, a 14% decrease from the 1977 total stock biomass. The spawning stock biomass, was estimated to be 218,200 tons, a decrease of 10% from 1977 (Table 6).

Equilibrium yield calculations under conditions of a constant level of recruitment at age 1 and partial recruitment coefficients of 0.5, 9, 67, and 100% at ages 1, 2, 3, and 4+, respectively, indicate an $F_{0.1}$ of about 0.65.

A total catch of 11,000 tons was assumed for 1978, requiring an F for ages 4 and older of 0.093 and resulting in a spawning stock biomass of 202,100 tons at the beginning of 1979 (7% decrease from 1978). An estimated 1978 year class of median strength (790 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 8). Fishing at $F_{0.1}$ in 1979 would result in a catch of 63,700 tons with a resulting decrease in the spawning stock biomass in 1980 of 0.6%. A catch of 62,300 tons ($F = 0.632$) in 1979 could be taken while still maintaining the same spawning stock biomass in 1980 as in 1979.

STOCK-RECRUITMENT

Spawning stock biomass is plotted versus recruitment in Figures 5 and 6. 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 increased again in the early 1970's. The peaks in the 1970's were much lower than in the early 1960's.

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.

LITERATURE CITED

Anderson, E.D. 1977. Assessment of the Georges Bank silver hake stock. NMFS, NEFC, Woods Hole Lab. Ref. 77-21.

Table 1. Silver hake catch statistics from the Georges Bank stock¹

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	-	16	-	-	-	47,348	12,300	-	59,667	31.83	1,875
1968	-	-	-	-	-	-	37	887	-	-	28,013	6,451	14	35,402	25.31	1,399
1969	-	-	-	-	42	-	148	292	7	-	16,144	1,654	119	18,406	13.34	1,380
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	-	1	125	122	133	55,795	4,588	49	63,195	22.85	2,766
1976	-	-	3,658	81	-	-	6	102	172	5	37,992	3,793	-	45,809	46.07	994
1977	1,305	-	-	-	-	-	-	-	-	9	39,200	3,749	-	44,263	31.60	1,401

¹Non-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												Total	Observed weight	Calculated weight ¹	Obs/Calc	
	0	1	2	3	4	5	6	7	8	9	10	11					12+
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	59,667	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	35,402	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	18,406	19,701	0.934
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	63,195	64,685	0.977
1976	-	1.6	20.0	114.2	85.8	7.9	0.9	0.1	-	-	+	-	-	230.5	45,809	45,941	0.997
1977	-	0.7	12.7	106.8	63.6	5.0	1.1	0.7	-	-	-	-	-	190.6	44,263	47,644	0.929

¹Using mean weights at age.

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
1961	-	.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	.609	-	-	1.272	-	-
1977	-	.126	.191	.242	.265	.342	.399	.402	.577	-	-	-	-

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	1.92
1978	0.72 ¹	-

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

Table 5. Estimation of F in 1977 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	1,875	.591
1968	1,399	.476
1969	1,380	.268
1970	1,046	.310
1971 ⁵	4,128	1.433
1972	8,951	1.209
1973	2,753	.589
1974	4,418	.813
1975	2,766	.746
1976	994	(.380) ^{3,4}
1977	1,401	(.424) ³

¹Expressed as USA days fished.

²Weighted mean F for fully recruited ages.

³Calculated from linear regression of fishing effort on fishing mortality for 1959-75: $Y = 0.275 + 0.00010X$, $r = .959$

⁴Value calculated from VPA was 0.610 using $F = 0.42$ in 1977.

⁵Not used in calculation of linear regression because F values were excessively high for the amount of fishing effort compared to other years.

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

Table with columns for Year, Age (1-12+), Fishing mortality (Mean F), Stock size (millions), and Age 1+ (Total, Mt). Rows span from 1955 to 1977.

1. Mean F for fully recruited ages in that year.
2. Determined from known 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 (numbers) of age 1 Georges Bank silver hake spring (strata 13-20) bottom trawl surveys and year-class size (millions of fish) at age 1 from VPA.

Table with columns for Year, Spring survey age 1, and VPA age 1. Rows span from 1967 to 1977.

1. Calculated from power curve relationship between spring survey catch per tow and VPA year-class size: Y = 908.141 X^0.302 r = 0.791.

Table 8. Projected catch (age 1+) in 1979 from Georges Bank silver hake stock with fishing mortality ranging from 0.05 to 1.00. Resulting stock size (age 2+) in 1980 and the percentage change (by weight) from 1979 are also given. All catch and stock sizes are in thousands of tons.

Fishing mortality	1979 catch	1980 stock	% change in stock from 1979
.05	6.2	253.9	+25.6
.10	12.2	248.3	+22.9
.15	17.9	242.9	+20.2
.20	23.4	237.8	+17.7
.25	28.6	232.9	+15.2
.30	33.7	228.3	+13.0
.35	38.2	224.0	+10.8
.40	43.7	219.5	+ 8.6
.45	47.6	215.5	+ 6.6
.50	51.9	211.6	+ 4.7
.55	56.0	207.8	+ 2.8
.60	59.9	204.3	+ 1.1
* .65	63.7	200.9	- 0.6
.70	67.3	197.6	- 2.2
.75	70.8	194.5	- 3.8
.80	74.1	191.5	- 5.2
.85	77.4	188.6	- 6.7
.90	80.5	185.9	- 8.0
.95	83.4	183.2	- 9.4
1.00	86.3	180.7	-10.6

*F_{0.1}

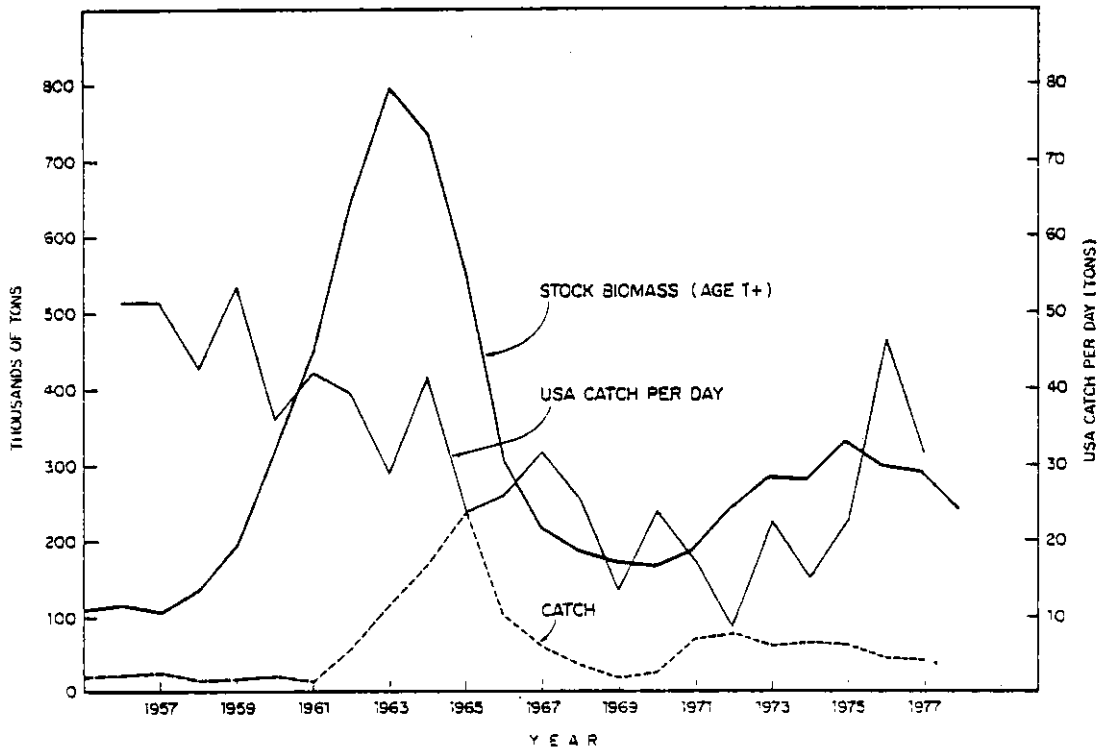


Figure 1. International catch, stock biomass (age 1+) from virtual population analysis, and USA commercial catch-per-day from the Georges Bank silver hake stock.

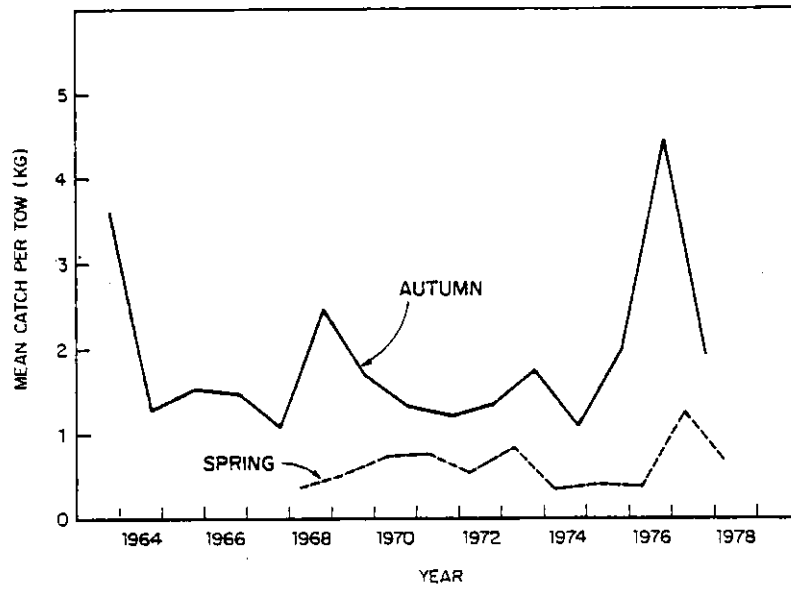


Figure 2. Stratified mean catch-per-tow (kg) of silver hake from the Georges Bank stock from USA autumn (1963-76) and spring (1968-78) bottom trawl surveys.

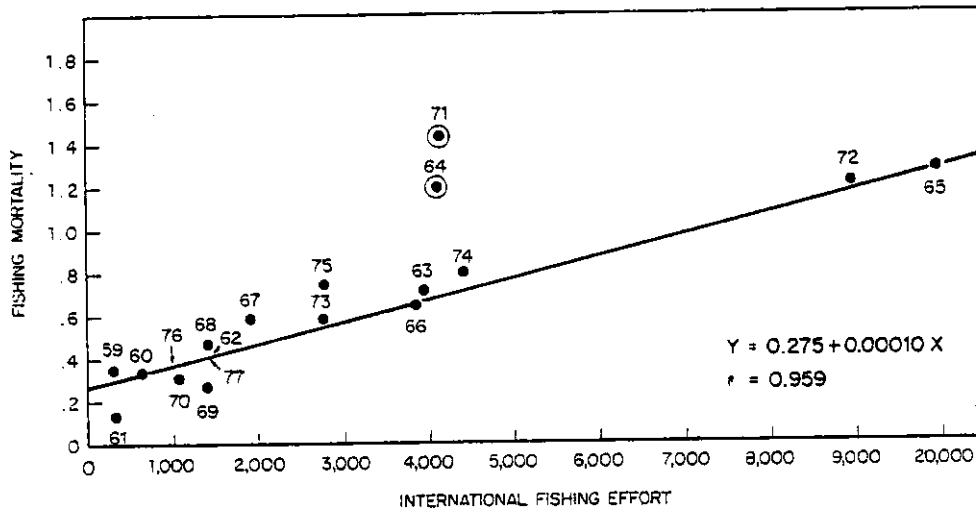


Figure 3. Relationship between fishing mortality from virtual population analysis and international fishing effort expressed as USA days fished for the Georges Bank silver hake stock. The 1964 and 1971 values were not used in calculating the relationship.

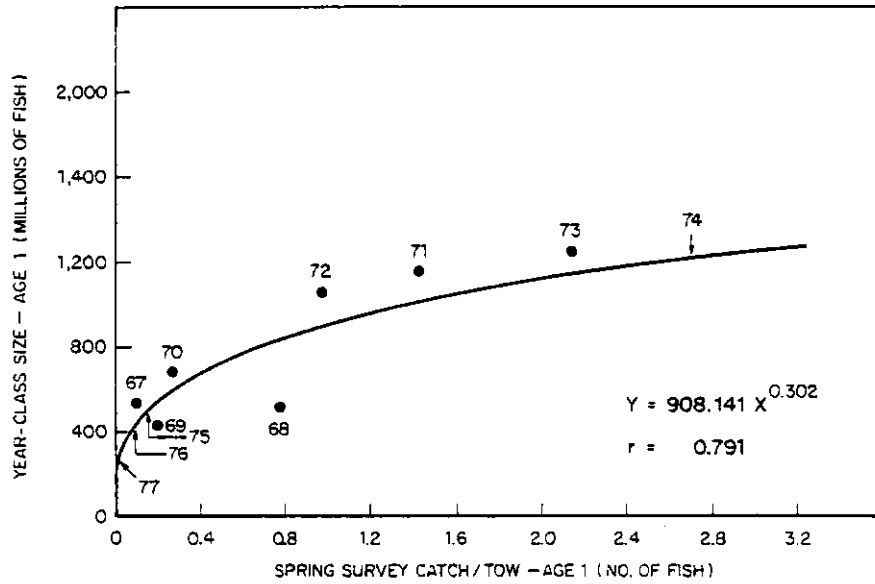


Figure 4. Power curve relationship between Georges Bank silver hake year-class size at age 1 and USA spring survey catch-per-tow at age 1.

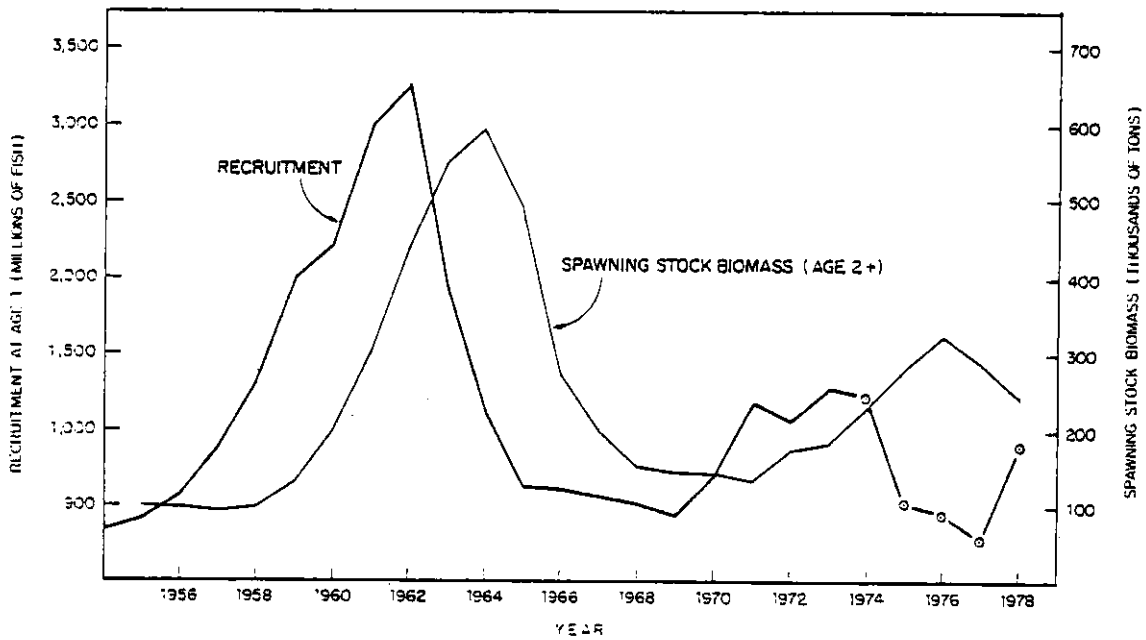


Figure 5. Georges Bank silver hake spawning stock biomass (age 2+) in 1955-78 and abundance at age 1 of the 1954-77 year-classes. (Open circles indicate estimated year-class sizes.)

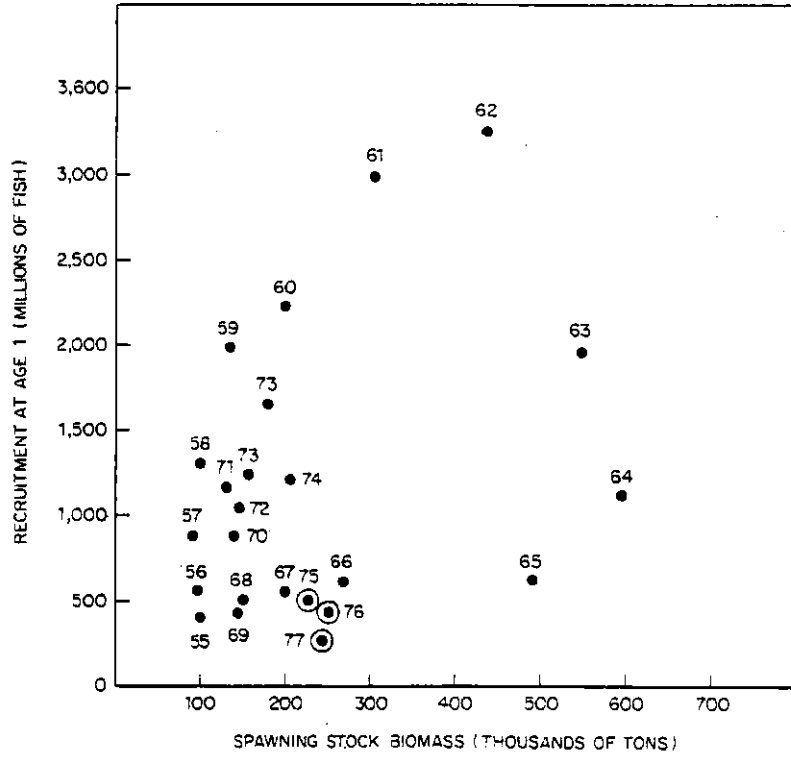


Figure 6. Relationship between spawning stock biomass (age 2+) and recruitment (expressed as abundance at age 1) for the Georges Bank silver hake stock during 1955-77. Open circles indicate estimated year-class sizes.

