

STATUS OF THE GULF OF MAINE
SILVER HAKE STOCK -1978

BY

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INTRODUCTION

This report presents an update of the status of the silver hake (*Merluccius bilinearis*) stock in the Gulf of Maine (ICNAF Div. 5Y). The data base utilized includes USA and foreign commercial catch statistics for 1955-77 and USA research vessel bottom trawl survey results for 1963-78. Estimates of stock size, fishing mortality, and recruitment are given, and projections are made for catch options in 1979 and resulting stock sizes in 1980.

CATCH

Total catch during 1955-64 varied between 21,500 and 37,000 tons and averaged 29,700 tons (Table 1, Figure 1). Catches dropped from 31,700 tons in 1964 to 22,600 tons in 1965, and ranged from 24,700 to 11,400 tons during 1965-70 while averaging 18,300 tons. Catches continued to drop and averaged only 8,100 tons during 1971-77 while ranging between 5,213 (1974) and 9,760 (1976) tons. The 1977 catch was 8,730 tons.

This fishery has been conducted almost exclusively by the USA. In 1963, 1971-75, and 1977, small catches were reported by the USSR, Poland, FRG, GDR, and Bulgaria, which averaged about 9% of the total annual catch in those years.

Total allowable catch (TAC) for this stock was set by ICNAF at 10,000 tons for 1973-74, 15,000 tons for 1975, 10,000 tons for 1976, and 9,000 tons for 1977. In 1978, the catch was not regulated.

The estimated USA catch in 1978, based on projections made comparing the 1977 catch with available 1978 monthly statistics, is 6,500 tons. There were no foreign catches in 1978.

CATCH COMPOSITION

Numbers-at-age catch data for 1955-77 are presented in Table 2. During 1955-70, age 3-4 fish dominated the catch, averaging about 54% of the total catch in number each year. Beginning in 1971, there was a shift towards younger fish, and ages 2-3 dominated the catch, averaging 75% of the total between 1974 and 1976. In recent years, 1975-77 age 3 has been the most prevalent age-group, averaging 44% of the total each year.

Calculated mean weights at age for the 1955-77 catches are given in Table 3. These values were generated by the application of length-weight equations to the length frequency data from the catches. The mean weights were applied to the numbers at age in Table 2 to obtain calculated catches (tons), which were compared to the observed catches. Observed/calculated catch ratios (Table 2) varied between 0.811 and 1.195 and averaged 0.888. The 1977 mean weights (unadjusted) were used in calculating the 1979-80 catch and stock size projections.

ABUNDANCE INDICES

USA commercial catch per day fluctuated considerably during 1956-65, ranging between 15.3 and 31.7 tons and averaging 21.8 tons (Table 1, Figure 1). The index dropped from 24.3 tons in 1965 to an average of only 7.8 tons in 1970-72. Catch per day increased to 9.9 in 1973, dropped to a low of 6.3 tons in 1974 and increased sharply to 16.7 tons in 1976. In 1977, the index again decreased slightly to 15.9 tons. In spite of the annual fluctuations evident in this index, it has been reasonably consistent over time with changes in stock biomass (Figure 1) calculated from virtual populations analysis (VPA). The recent increase in the index appears to reflect an actual increase in stock biomass.

The USA autumn bottom trawl survey catch-per-tow index declined sharply from 26.5 kg in 1963 to a low of 1.9 kg in 1968 (Table 4, Figure 2) and then, except for decreases in 1973-74, increased steadily to 10.9 kg in 1976. The index decreased in 1977 to 7.2; however, this value was still larger than any others (except 1975-76) since 1965. The catch-per-tow index from the spring survey (Table 4, Figure 2) has been much smaller than from the autumn survey but has exhibited the same pattern of year-to-year changes. Both the autumn and spring indices dropped considerably in 1977 from 1976 suggesting a possible decrease in stock abundance. Since stock size estimates for 1977 based on VPA and recruitment estimates indicate a continued increase in stock biomass, the decrease in 1977 of the survey catch-per-tow index may reflect the normal variability of the survey results.

FISHING MORTALITY

Fishing mortality (F) for fully-recruited ages in 1977 was estimated from a linear relationship between fishing effort and fishing mortality. Fishing effort, expressed as USA days fished, was calculated by dividing total catch by USA catch per day (Table 1). 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 0.34 was assumed for ages 3 and older in 1977 based on a linear regression of fishing effort on fishing mortality for 1956-75. A new VPA was performed using 0.34 as the terminal F for ages 3 and older in 1977 (Table 6) and a regression was calculated between fishing effort and the mean F values from the new VPA. This regression ($r = 0.294$, $p > 0.05$) predicted an F of 0.338 for 1977 (Table 5, Figure 3), and the estimate was, therefore, accepted.

Fishing mortality for fully-recruited ages determined by VPA (Table 6) ranged between 0.24 and 0.53 during 1955-67 and averaged 0.40. F increased from 0.32 in 1967 to 1.24 in 1971 and then dropped to 0.23 in 1974 as catches decreased to low levels. Fishing mortality increased sharply in 1975 to 0.66 but decreased in both 1976 (0.47) and 1977 (0.34).

RECRUITMENT

The sizes of the 1954-74 year classes at age 1 were estimated from VPA (Table 6). Sizes ranged from 628 million fish (1954 year class) to 53 million (1969 year class) and averaged 330 million fish. The median size was 196 million fish at age 1. The 1964-74 year classes were all below the 1954-74 mean averaging 133 million fish. The 1973 year class (178 million) was the strongest since 1964.

The 1974-77 year class sizes at age 1 were estimated from a linear relationship ($r = 0.710$, $p = 0.05$) between the autumn survey catch per tow (numbers) at age 0 and year class size at age 1 from VPA for 1963-74 (Table 7, Figure 4). Although there was some agreement between the autumn survey catch per tow at age 0 and the spring survey catch per tow at age 1 in indicating the relative strengths of particular year-classes, there was no consistent relationship between year class size at age 1 from VPA and spring survey catch per tow at age 1.

The 1975, 1976 and 1977 year classes at age 1 were estimated to be 130, 214, and 132 million fish, respectively (Table 7, Figure 4). The 1976 year class is, therefore, estimated to be the strongest year class since 1964, but still well below the mean 1954-74 year class size of 330 million fish.

STOCK SIZE

Stock size estimates for 1955-77 were computed from VPA (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). Stock size at each age in 1978 was determined from the relationship: $N_{78} = N_{77} e^{-Z_{77}}$.

Total stock biomass (age 1+) decreased from 219,500 tons in 1955 to only 20,300 tons in 1971 (Table 6, Figure 1), and then increased steadily to 76,500 tons in 1977. In 1978, the biomass decreased slightly to 68,800 tons.

Spawning stock biomass (age 2+) has followed basically a similar pattern, decreasing from 193,600 tons in 1955 to 15,800 tons in 1971. Since 1971, spawning biomass increased steadily to 54,100 tons in 1978 (Table 6, Figure 5).

PARTIAL RECRUITMENT

Age-specific fishing mortality rates from VPA (Table 6) indicate that silver hake were fully recruited to the fishery at age 4 during 1955-70, at age 3 in 1971-72, at age 2 in 1973-74, and again at age 3 in 1975-77. Partial recruitment of age groups not fully recruited to the fishery is defined here as the ratio between fishing mortality at a given age (in a given year) and the mean fishing mortality at the fully recruited ages in that year. In 1977, partial recruitment was estimated to be 2% at age 1, 28% at age 2, and 100%

at ages 3 and older based on the age-specific fishing mortality rates estimated for that year. These values were used in the projections of catch and stock size for 1979-80.

CATCH AND STOCK SIZE PROJECTIONS

A total stock biomass (age 1+) of 68,800 tons and a spawning biomass (age 2+) of 54,100 tons was estimated to be available at the beginning of 1978 (Table 6). These estimates represent a 10% decrease in total stock biomass and a 12% increase in spawning stock biomass from 1977.

Equilibrium yield calculations assuming a constant level of recruitment at age 1 and partial recruitment coefficients of 2% at age 1, 28% at age 2, and 100% at ages 3 and older indicate that $F_{0.1} = 0.50$.

An estimated catch in 1978 of 6,500 tons would require an F for ages 3 and older of 0.238 and result in an age 2+ biomass of 56,900 tons at the beginning of 1979 (5% increase from 1978). Catch options for 1979 and resultant spawning stock biomass levels in 1980 were calculated for values of F ranging from 0.05 to 1.00 (Table 8). Fishing at $F_{0.1} = 0.50$ in 1979 would result in a catch of about 15,500 tons and leave a spawning biomass in 1980 of 57,500 tons (1% increase from 1979). A catch of about 16,000 tons in 1979 ($F = 0.522$) would maintain the same spawning stock biomass in 1980 as in 1979 (56,900 tons).

STOCK-RECRUITMENT

Spawning stock biomass is plotted versus recruitment in Figures 5 and 6. The 1954-74 average year class size at age 1 was 330 million fish. The 1954-63 year classes were all above this mean value averaging 543 million, whereas the 1964-74 year classes were all below the mean averaging only 133 million fish at age 1. The relationships demonstrated in Figures 5 and 6 were discussed in Anderson and Almeida (1978) and show that the spawning stocks which produced above average year classes were much larger (average of about 165,000 tons) than those which produced below average year classes (average of about 60,000 tons). Peak levels of recruitment occurred when spawning biomass was about 185,000 tons, and above average recruitment resulted from spawning stocks greater than 140,000 tons. Recruitment failure began to accelerate about the time the shrimp fishery in the Gulf of Maine began to intensify in the early 1960's, when there apparently were substantial amounts of small silver hake caught by the small-mesh shrimp nets and discarded. It is quite possible that such practices significantly reduced the size of incoming year classes before they recruited to the fishery. Since the year-class estimates calculated by VPA were based only on landed catch data, the estimates would accordingly be low if the landings (in numbers) were considerably less than the catches.

The possibility that many of the year classes may have been underestimated by VPA, since the unreported catch of small fish was not included in the data used, tends to confound any attempt to define a realistic stock-recruitment relationship based on data and results presented in this report.

LITERATURE CITED

Anderson, E. D. and F. P. Almeida, 1978. Assessment of the Gulf of Maine silver hake stock. NMFS, NEFC, Woods Hole, Lab. Ref. No. 78-10 (mimeographed).

MISSING TABLES 1 - 3

Table 4. Stratified mean catch-per-tow (kg) of silver hake from the Gulf of Maine stock from USA bottom trawl surveys in the spring (strata 21-30, 36-40) and autumn (strata 24, 26-30, 36-40).

Year	Spring	Autumn
1963	-	26.45
1964	-	4.65
1965	-	7.89
1966	-	4.28
1967	-	2.42
1968	0.03	1.88
1969	0.18	2.44
1970	0.31	3.01
1971	0.35	2.74
1972	1.73	6.50
1973	0.70 ¹	4.17
1974	0.73 ¹	3.77
1975	2.41 ¹	9.09
1976	2.30 ¹	10.87
1977	1.00 ¹	7.19
1978	0.24 ¹	-

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

Table 5. Estimation of F in 1977 for the Gulf of Maine silver hake fishery.

Year	Fishing effort ¹	Fishing mortality ²
1956	1,403	.244
1957	1,166	.423
1958	1,600	.455
1959	1,536	.488
1960	1,244	.296
1961	1,154	.376
1962	1,293	.400
1963	1,614	.411
1964	1,388	.525
1965	933	.411
1966	1,182	.411
1967	856	.325
1968	1,386	.726
1969	1,456	.758
1970	1,486	.940
1971 ⁵	973	1.242
1972	932	.669
1973	901	.539
1974	830	.213
1975	1,166	.661
1976	584	(.346) ^{3,4}
1977	549	(.338) ³

¹Expressed as USA days fished.

²Weighted mean F for fully recruited ages.

³Calculated from linear regression of fishing effort on fishing mortality for 1956-75: $Y = 0.219 + 0.00022x$, $r = 0.294$.

⁴Value from VPA was 0.465 using $F = 0.34$ in 1977.

⁵Not used in calculation of linear regression because the F value appears excessively high for the amount of fishing effort in comparison to other years.

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

Year	Age												100% recruitment			
	1	2	3	4	5	6	7	8	9	10	11	12+	Wtd \bar{F}^3	Age		
	<u>Fishing Mortality</u>															
1955	.032	.056	.147	.339	.389	.531	.564	.679	.484	.360	(.395) ¹	-	.395	4+		
1956	.037	.034	.096	.221	.218	.352	.325	.377	.334	.110	(.244) ¹	-	.244	4+		
1957	.100	.057	.171	.402	.359	.553	.536	.653	.482	.221	(.422) ¹	-	.422	4+		
1958	.041	.061	.177	.433	.381	.629	.459	.690	.568	.232	(.455) ¹	-	.455	4+		
1959	.017	.088	.240	.475	.447	.523	.595	.689	.581	.295	(.488) ¹	-	.488	4+		
1960	.006	.102	.210	.298	.274	.299	.310	.420	.287	.351	(.296) ¹	-	.296	4+		
1961	.002	.077	.232	.392	.348	.394	.361	.328	.280	.222	(.376) ¹	-	.376	4+		
1962	.003	.070	.229	.428	.362	.383	.423	.378	.245	.215	.205	-	.400	4+		
1963	.001	.060	.249	.434	.377	.426	.347	.479	.278	.149	.438	(.411) ¹	.411	4+		
1964	.003	.079	.230	.469	.547	.618	.638	.726	.658	.273	.640	(.525) ¹	.525	4+		
1965	.001	.068	.179	.357	.407	.502	.644	.804	.640	.373	.373	(.411) ¹	.411	4+		
1966	.001	.053	.213	.406	.401	.392	.461	.693	.621	(.411) ¹	(.411) ¹	(.411) ¹	.411	4+		
1967	.003	.040	.150	.339	.314	.292	.309	.282	.426	.301	-	-	.325	4+		
1968	.008	.052	.277	.727	.714	.791	.653	.655	.791	.309	(.726) ¹	-	.726	4+		
1969	.059	.054	.216	.787	.712	.804	.715	.706	.766	.602	(.758) ¹	-	.758	4+		
1970	.016	.189	.395	.880	.931	1.075	.926	1.277	.602	.678	(.940) ¹	-	.940	4+		
1971	.029	.508	1.256	1.312	1.401	1.311	.894	.461	.286	.286	(1.240) ¹	-	1.242	3+		
1972	.141	.252	.803	.458	.510	.868	.248	.248	(.669) ¹	(.669) ¹	(.669) ¹	-	.669	3+		
1973	.088	.566	.511	.257	.510	.505	(.539) ¹	(.539) ¹	(.539) ¹	(.539) ¹	-	-	.539	2+		
1974	.041	.191	.307	.085	.319	.679	.284	-	-	-	-	-	.213	2+		
1975	.012	.146	.686	.668	.437	.803	(.661) ¹	(.661) ¹	-	-	-	-	.661	3+		
1976	.008 ²	.203 ²	.409	.500	.923	.805	(.465) ¹	(.465) ¹	-	-	-	-	.465	3+		
1977	.006 ²	.096 ²	(.340) ⁴	-	-	-	-	.340	3+							
	<u>Stock size (millions)</u>															
													<u>Age 1+</u>		<u>Age 2+</u>	
													<u>Wt</u>		<u>Wt</u>	
													<u>Total (10³ tons)⁵</u>		<u>Total (10³ tons)⁵</u>	
1955	628.3	443.2	290.2	170.0	76.5	37.3	16.0	7.5	2.8	1.2	1.1	-	1674.0	219.5	1045.7	193.6
1956	549.8	408.2	281.0	167.9	81.2	34.8	14.7	6.1	2.5	1.2	0.6	-	1548.0	203.2	998.2	185.8
1957	602.6	355.2	264.6	171.2	90.3	43.8	16.4	7.1	2.8	1.2	0.7	-	1555.8	199.5	953.2	185.4
1958	608.4	365.4	225.0	149.5	76.8	42.3	16.9	6.4	2.5	1.2	0.7	-	1495.5	196.8	886.7	173.4
1959	569.0	391.6	230.4	126.4	65.0	35.2	15.1	7.2	2.2	0.9	0.6	-	1444.2	183.7	874.6	159.0
1960	536.8	375.1	240.5	121.5	52.7	27.9	14.0	5.6	2.4	0.8	0.5	-	1399.4	187.7	862.6	148.2
1961	485.7	357.9	227.0	130.7	60.5	26.9	13.8	6.9	2.5	1.2	0.4	-	1313.5	178.2	827.8	152.4
1962	480.1	326.4	222.2	120.6	59.2	28.6	12.1	6.5	3.3	1.2	0.7	-	1260.9	171.1	780.8	146.5
1963	510.1	321.7	203.9	118.5	52.7	27.6	13.1	5.3	3.0	1.7	0.7	0.4	1258.7	163.0	748.6	143.6
1964	456.1	342.0	203.0	106.6	51.5	24.2	12.1	6.2	2.2	1.5	1.0	0.3	1206.7	171.1	750.6	143.0
1965	332.6	305.4	211.8	108.2	44.7	20.0	8.8	4.3	2.0	0.8	0.8	0.4	1039.8	152.1	707.2	131.2
1966	171.0	223.2	191.3	118.7	50.7	19.9	8.1	3.1	1.3	0.7	0.4	0.4	788.8	134.4	617.8	120.4
1967	96.0	114.8	141.9	103.6	53.0	22.8	9.0	3.4	1.0	0.5	-	-	546.0	97.6	450.0	93.2
1968	86.8	64.4	73.9	81.9	49.5	26.0	11.4	4.4	1.7	0.5	0.2	-	400.7	79.8	313.9	75.0
1969	63.2	57.7	41.0	37.6	26.5	16.3	7.9	4.0	1.5	0.5	0.2	-	256.4	48.1	193.2	44.8
1970	53.1	39.9	36.7	22.2	11.5	8.7	4.9	2.6	1.3	0.5	0.2	-	181.6	31.8	128.5	29.0
1971	76.4	35.0	22.2	16.6	6.2	3.0	2.0	1.3	0.5	0.5	0.2	-	163.9	20.3	87.5	15.8
1972	124.9	49.7	14.1	4.2	3.0	1.0	0.5	0.5	0.5	0.2	0.2	-	198.8	29.8	73.9	19.4
1973	142.6	72.7	25.9	4.2	1.8	1.2	0.3	0.3	0.3	0.3	-	-	249.6	40.1	107.0	22.6
1974	178.0	87.6	27.7	10.4	2.2	0.7	0.5	-	-	-	-	-	307.1	47.5	129.1	29.0
1975	137.9	114.6	48.5	13.6	6.4	1.1	0.2	0.2	-	-	-	-	322.5	44.7	184.6	33.6
1976	(130) ⁴	91.3	66.4	16.4	4.7	2.8	0.3	-	-	-	-	-	311.9	50.8	181.9	37.4
1977	(214) ⁴	86.4	49.9	29.6	6.7	1.2	0.8	-	-	-	-	-	388.6	76.5	174.6	48.1
1978	(132) ⁴	142.6	52.6	23.8	14.1	3.2	0.6	0.4	-	-	-	-	369.3	68.8	237.3	54.1

¹Mean F for fully recruited ages in that year.

²Determined from assumed stock size and known catch.

³Weighted by stock size at age.

⁴Estimated.

⁵Adjusted using ratios of observed to calculated weights in Table 2.

Table 7. Catch per tow (numbers) of age 0 and 1 Gulf of Maine silver hake from USA autumn (strata 24, 26-30, 36-40) and spring (strata 21-30, 36-40) bottom trawl surveys and year class size (millions of fish) at age 1 from the VPA.

Year class	Autumn survey age 0	Spring survey age 1	VPA age 1
1963	11.77	-	456.1
1964 ³	.15	-	332.6
1965	.47	-	171.0
1966	.11	-	96.0
1967	.02	0.07	86.8
1968	.59	6.02	63.2
1969	.43	3.83	53.1
1970	.33	3.13	76.4
1971	9.56	39.93	124.9
1972	3.28	2.19 ¹	142.6
1973	4.88	16.03 ¹	178.0
1974	8.62	50.29 ¹	137.9
1975	2.83	4.79 ¹	(129.6) ²
1976	7.51	2.91 ¹	(213.8) ²
1977	2.95	2.07 ¹	(131.7) ²

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

²Calculated from linear regression of autumn survey catch per tow at age 0 on VPA year-class size at age 1: $Y = 78.695 + 18.007X$, $r = 0.710$.

³Not used in calculation of linear regression because the survey value is excessively low in comparison to the year-class size.

Table 8. Projected catch (age 1+) in 1979 from the Gulf of Maine 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 size values are in thousands of tons.

Fishing mortality	1979 catch	1980 stock	% change in stock from 1979
.05	1.9	72.3	+27.1
.10	3.6	70.3	+23.6
.15	5.4	68.5	+20.4
.20	7.0	66.7	+17.2
.25	8.6	65.0	+14.2
.30	10.1	63.3	+11.2
.35	11.5	61.8	+ 8.6
.40	12.9	60.3	+ 6.0
.45	14.2	58.8	+ 3.3
* .50	15.5	57.5	+ 1.1
.55	16.7	56.2	- 1.2
.60	17.9	54.9	- 3.5
.65	19.0	53.7	- 5.6
.70	20.1	52.6	- 7.6
.75	21.1	51.5	- 9.5
.80	22.1	50.5	-11.2
.85	23.1	49.5	-13.0
.90	24.0	48.5	-14.8
.95	24.9	47.6	-16.3
1.00	25.8	46.7	-17.9

*F_{0.1}

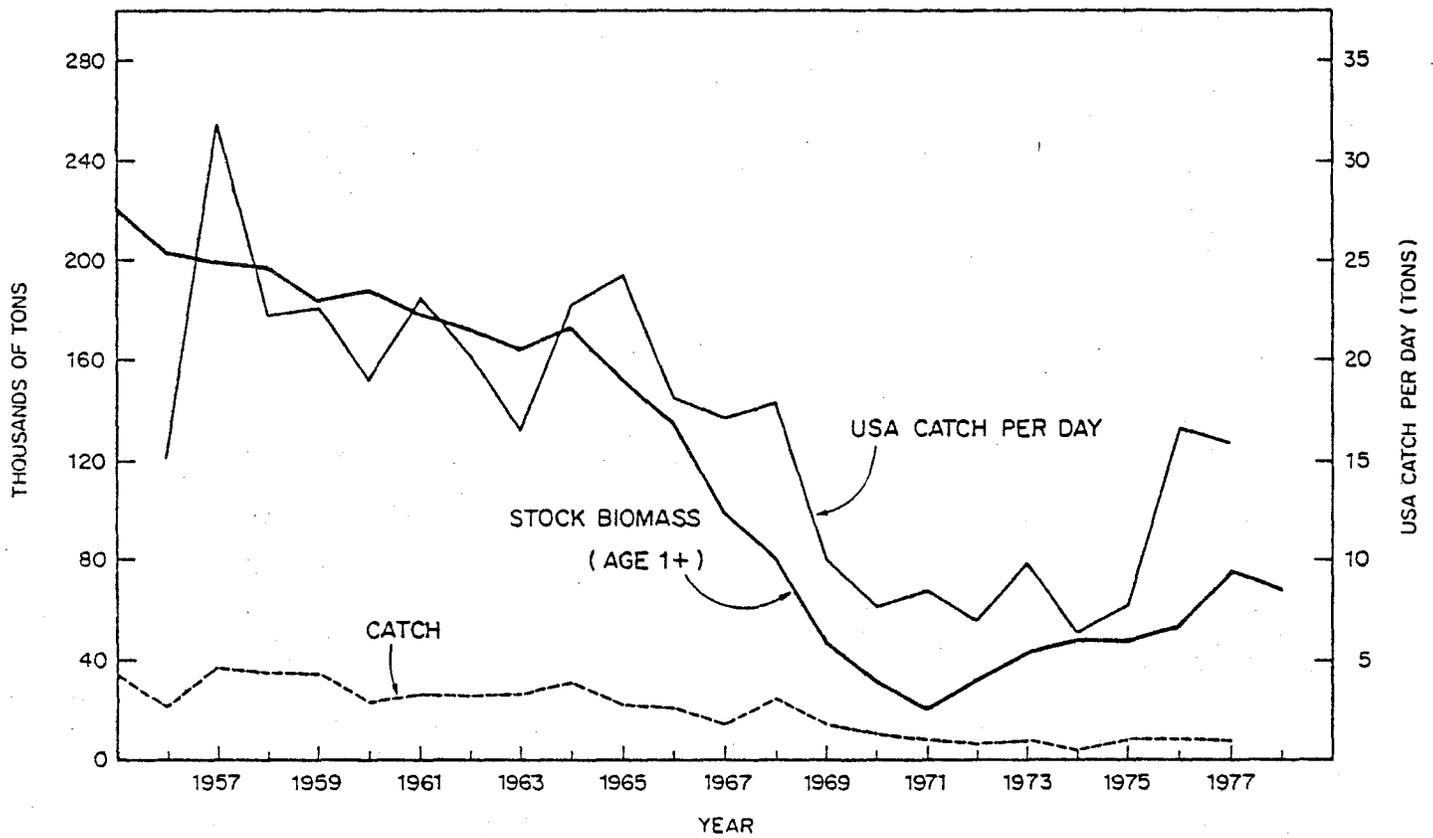


Figure 1. International catch, stock biomass (age 1+) from VPA, and USA commercial catch-per-day from the Gulf of Maine silver hake stock.

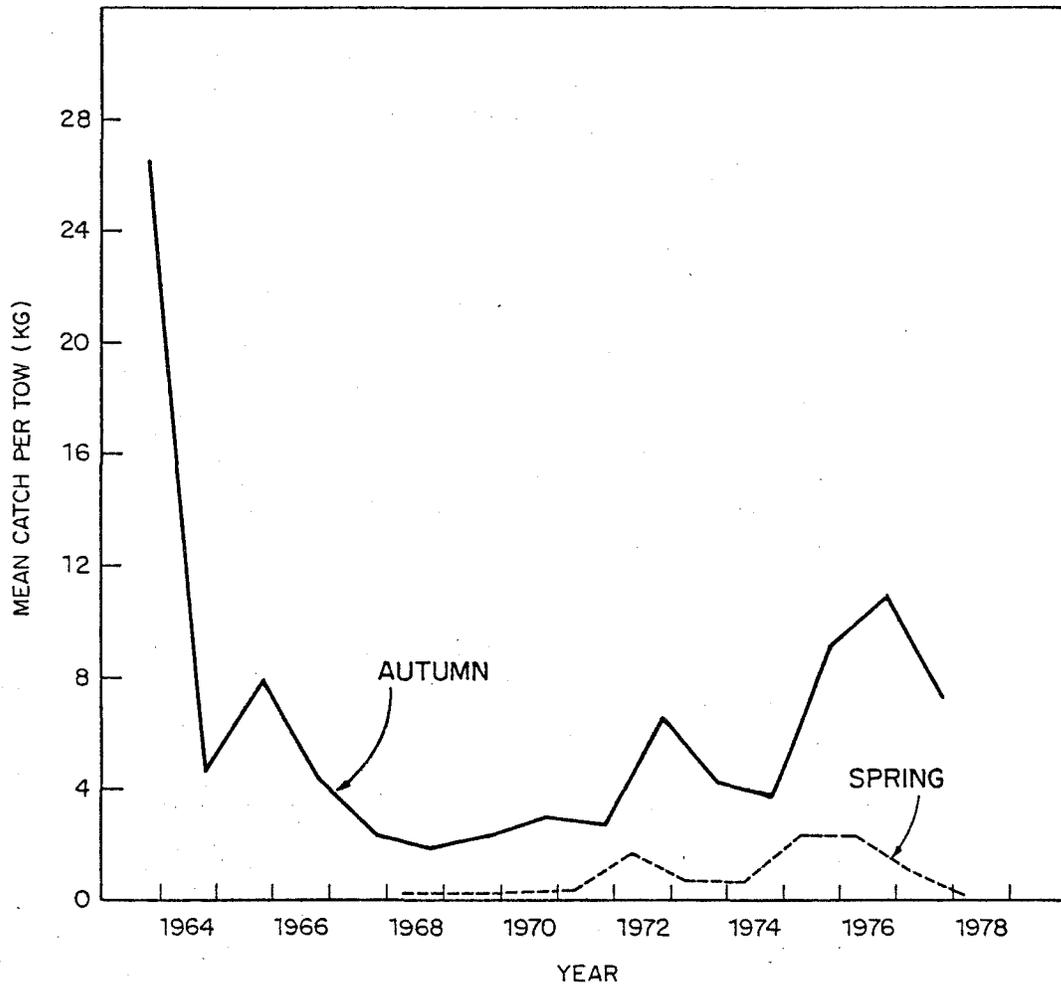


Figure 2. Stratified mean catch-per-tow (kg) of silver hake from the Gulf of Maine stock from USA autumn (1963-77) and spring (1968-78) bottom trawl surveys.

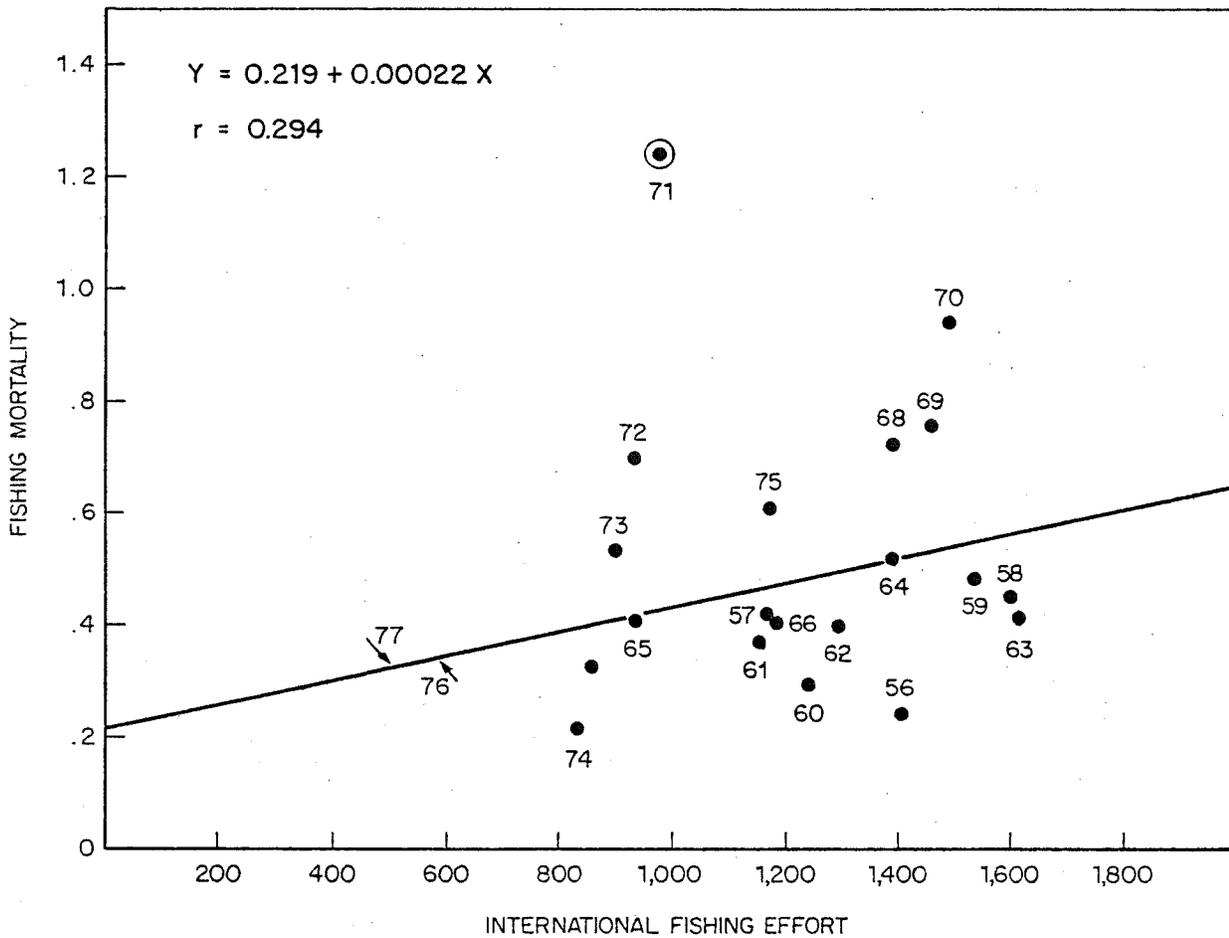


Figure 3. Relationship between fishing mortality from VPA and fishing effort expressed as USA days fished for the Gulf of Maine silver hake stock. The 1971 value was not used in calculating the regression line.

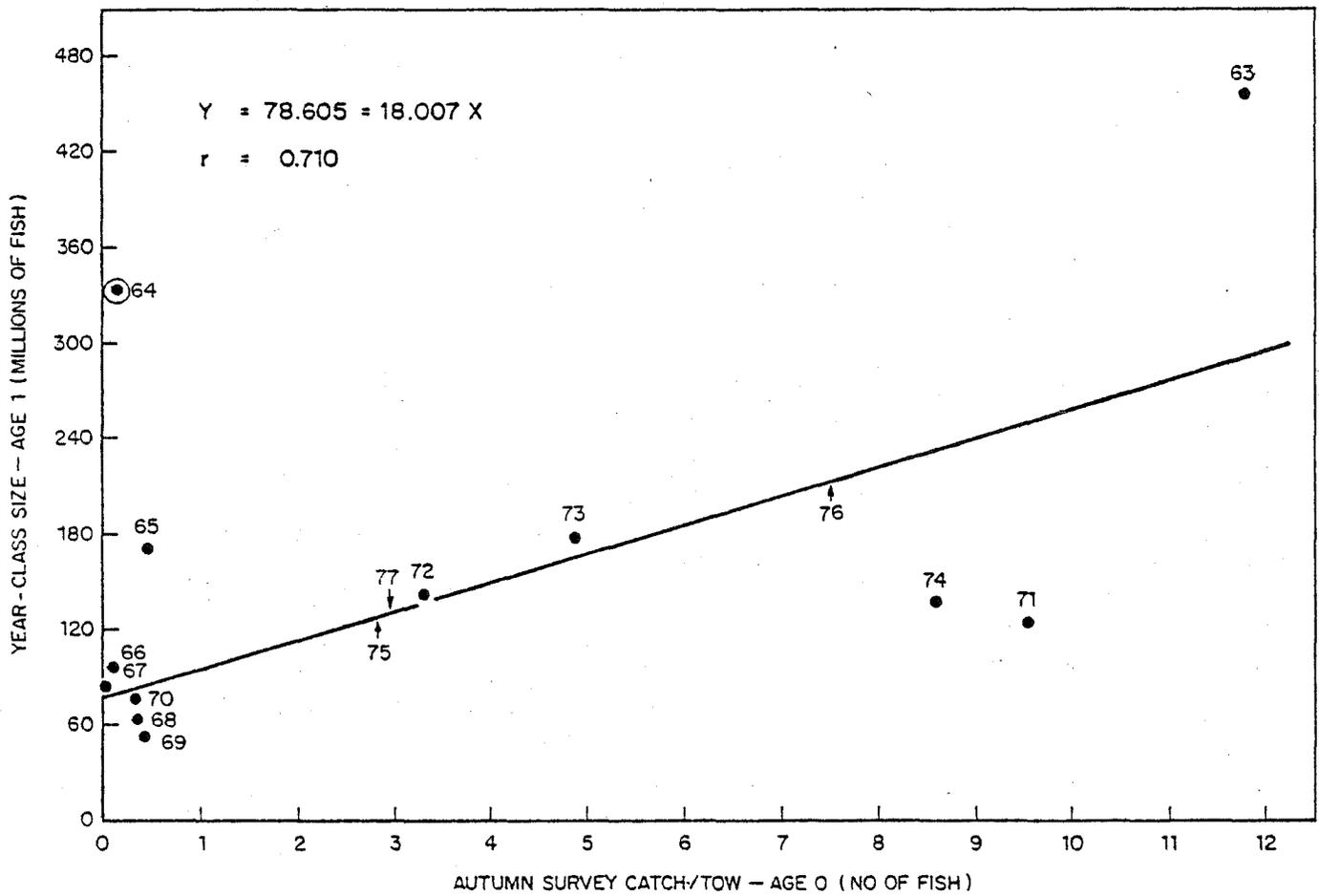


Figure 4. Relationship between year-class size at age 1 from VPA and USA autumn survey catch-per-tow at age 0 for the Gulf of Maine silver hake stock.

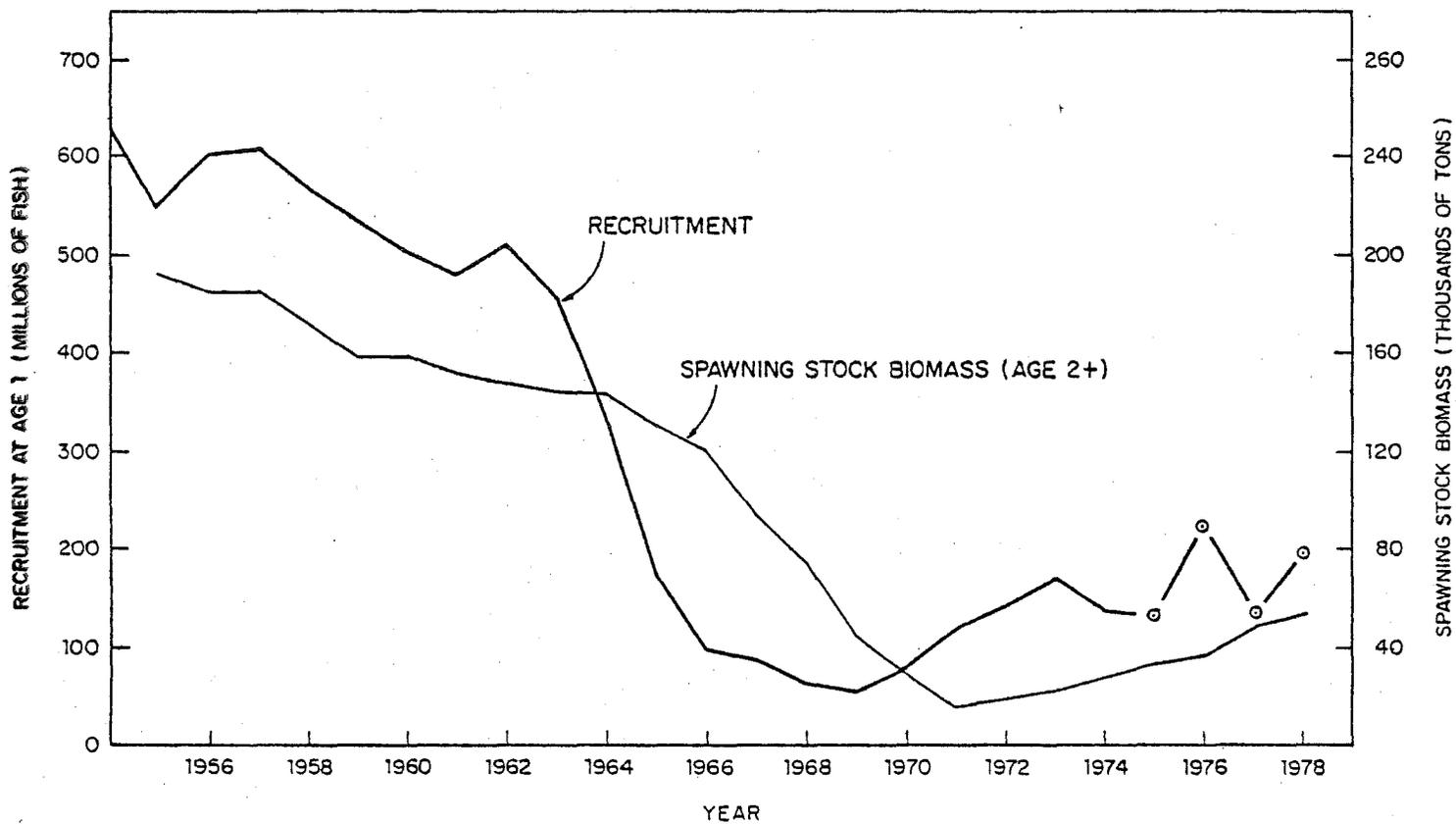


Figure 5. Gulf of Maine silver hake spawning stock biomass (age 2+) in 1955-78 and abundance at age 1 of the 1954-77 year-classes. Open circles indicate estimated year-class sizes.

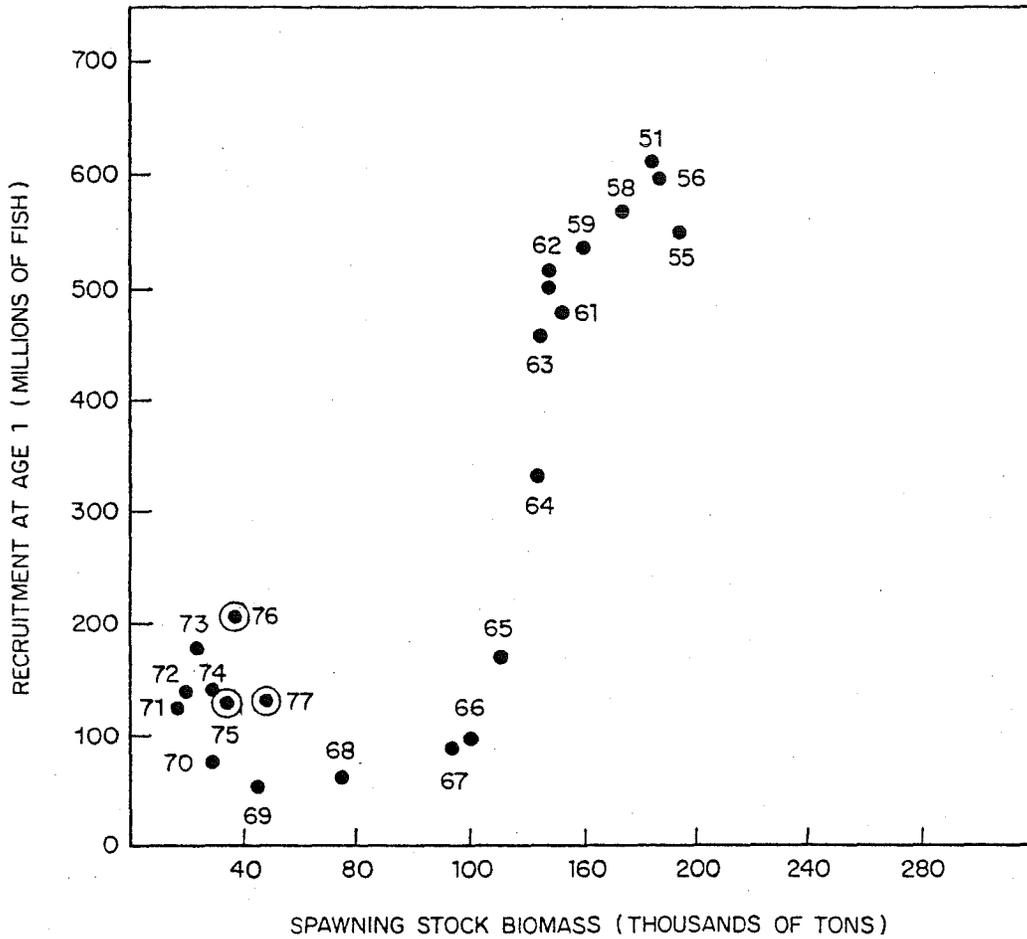


Figure 6. Relationship between spawning stock biomass (age 2+) and recruitment (expressed as abundance at age 1) for the Gulf of Maine silver hake stock. Open circles indicate estimated year-class sizes.