

Assessment of the Southern New England - Middle Atlantic Silver Hake Stock

by

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Laboratory Reference No. 77-30
27 December 1977

INTRODUCTION

This report presents an assessment of the status of the silver hake (Merluccius bilinearis) stock inhabiting the southern New England - Middle Atlantic waters (ICNAF Subdiv. 5Zw and SA 6). The data base utilized in this assessment includes USA and foreign commercial and estimated USA recreational catch statistics for 1955-76 and research vessel bottom trawl survey data since 1963. Estimates of stock size, fishing mortality, and recruitment are presented. Projections are made for the 1978 catch and the stock remaining at the beginning of 1979.

CATCH

Catch by country during 1955-76 is listed in Table 1. Included in this table are estimates of USA recreational catch. Marine angler surveys provided estimates of the 1960, 1965, 1970, 1974, and 1976 recreational catches. The ratios between recreational and USA commercial catch were fairly constant in 1965 (0.129), 1970 (0.158), and 1974 (0.149); the 1960 ratio (0.221) was somewhat higher, whereas the 1976 ratio (0.104) was lower. It was felt that the recreational catch in each of the remaining years during 1955-76 could be estimated by applying the above ratios to the commercial catches in those years. The 1960 ratio was used for 1955-59 and 1961-62, and the weighted average (0.139) of the 1965, 1960, and 1974 ratios was used for 1963-64, 1966-69, 1971-73, and 1975.

Total catches averaged about 16,800 tons during 1955-59, declined to 9,952 tons in 1960, and then improved steadily to 137,400 tons in 1966. Catches then dropped sharply to 50,900 tons in 1967 and have since fluctuated between 19,200 and 67,000 tons. Catches increased steadily from 19,200 tons in 1970 to 66,000 tons in 1973 and then declined to 27,200 tons in 1976.

USA commercial catches during 1955-65 ranged between 8,151 and 25,008 tons and averaged about 14,800 tons per year. Catches during 1966-76 were much lower, ranging between 4,989 and 9,840 tons and averaging about 7,400 tons or about 18% of the total catch per year. Estimated USA recreational catches during 1955-76 ranged between 692 and 3,469 tons and averaged about 1,900 tons per year. The USA commercial and recreational catches in 1976 were 9,513 and 994 tons, respectively.

The ICNAF total allowable catch (TAC) was 80,000 tons annually during 1973-75 and was then reduced to 43,000 tons in 1976. An optimum yield (OY) of 45,000 tons was set for 1977, with 12,500 tons designated as the capacity of the USA commercial fishery, 2,000 tons estimated as the capacity of the recreational fishery, and 30,500 tons allocated as the total allowable level of foreign fishing (TALFF). The 1977 open season and area for directed foreign fishing extended through March, during which time 15,768 tons were taken by the USSR, Cuba, Bulgaria, Poland, and Spain. Any amounts caught later in the year by these or other countries as by-catch in other directed fisheries were considered to be insignificant. The USA commercial catch was assumed to be 10,000 tons in 1977 from projections comparing 1976 and available 1977 monthly

catches. The 1977 recreational catch was assumed to be 2,000 tons. The total 1977 harvest was assumed, for the purpose of the assessment, to be 27,768 tons.

CATCH COMPOSITION

Table 2 contains the numbers-at-age catch data for 1955-76. Age 2 and 3 fish have, in recent years, dominated the catch. In 1976, 54% of the catch (in numbers) was age 2 fish and 27% was age 3.

Mean weights at age for the 1955-76 catches are presented 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 between 0.862 and 0.997 and averaged 0.955. The 1976 mean weights (unadjusted) were utilized for the projections of 1977-78 catch and stock size.

ABUNDANCE INDICES

USA commercial catch-per-day increased steadily the last few years from 4.3 in 1974 to 6.6 in 1976 (Table 1, Figure 1). The 1976 index was the highest observed since 1970. Yearly values in this time-series (1964-76) have fluctuated between 4.3 and 7.7 but have not shown any long-term trends nor been totally consistent with changes in stock biomass (Figure 1) calculated from virtual population analysis (VPA). However, the continuous increase in the index since 1974 does agree with an increase in stock biomass

during that time indicated by VPA. The catch-per-day index was calculated using data from trips by vessels 50 gross tons or less from Point Judith, Rhode Island, fishing in waters 55 m (30 fath) or less which landed 50% or more of silver hake. The catch of silver hake on which the index was based averaged only about 1% of the total catch each year. The lack of consistency between the index and results of the VPA in measuring stock biomass may be due to the small percentage of catch from which the index was determined and also that these catches were taken relatively inshore whereas an average of over 75% of the annual catch was taken farther offshore by the foreign fishery. The USA index may reflect abundance of only that portion of the stock found inshore and taken by the USA fishery and may not be totally representative of the entire stock.

The USA autumn bottom trawl survey catch-per-tow index increased from a 1963-77 low of 1.36 kg in 1974 to 3.92 in 1976 and then decreased to 3.04 in 1977 (Table 4, Figure 2). The index initially increased to a peak of 7.62 kg in 1965 and then decreased, fluctuating considerably around a mean of 3.4 in succeeding years. Since 1966, the index has not shown a long-term consistency with the trend in stock biomass determined from VPA (Figure 1). The spring bottom trawl survey catch-per-tow index was lower in 1977 (1.12 kg) than in any other year (1968-77), decreasing steadily since 1975 (2.08). This index dropped sharply from a high of 7.36 in 1968 to 1.68 in 1970 and then increased to 3.73 in 1971. This pattern corresponded with the results of the VPA. In the succeeding years the index fluctuated about an average of 1.9 and did not agree with the results of the VPA. In view of the inconsistency of both

the autumn and spring survey abundance indices with stock biomass changes indicated by VPA, it is difficult to evaluate the most recent results of the survey.

FISHING MORTALITY

Fishing mortality (F) in 1976 was estimated for fully-recruited ages 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, as the weighted mean F for fully-recruited ages, was determined by VPA. Based on levels of F in previous years from an earlier assessment in relation to fishing effort, F in 1976 was estimated to be about 0.45. A VPA was run using 0.45 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 this VPA for 1964-74 predicted that $F = 0.451$ in 1976 (Table 5, Figure 3). The estimate of 0.45 was accepted for 1976.

Fishing mortality for fully-recruited ages determined by VPA (Table 6) fluctuated during 1955-68 between 0.32 and 0.80 and averaged about 0.52. F increased to 1.06 in 1969, dropped to 0.52 in 1970, increased again to 1.07 in 1971, decreased again to 0.40 in 1972, and then increased steadily to 1.08 in 1975 before dropping to an estimated 0.45 in 1976.

RECRUITMENT

The 1974-77 year-class sizes at age 1 were estimated from a power curve relationship ($r = 0.899$, $p = 0.05$) between the autumn survey catch-per-tow

(numbers) at age 0 and the year-class size at age 1 from VPA for 1969-73 (Table 7, Figure 4). There was no evidence of a consistent relationship between autumn catches of age 0 fish and year-class size at age 1 for year-classes prior to 1969 nor between the entire series of spring catches of age 1 fish and year-class size at age 1.

The 1974, 1975, 1976, and 1977 year-classes at age 1 were estimated to be 902, 648, 1,102, and 844 million fish, respectively, compared to the mean 1954-73 year-class size of 740 million fish. The 1976 year-class was estimated to be the strongest since the 1964 year-class and is exceeded in size only by the 1961-64 cohorts. The 1974 year-class is exceeded in size by only six other year-classes (including 1976) or 26% of those either observed or predicted during 1954-77. Only eight of the other 23 year-classes in the data series are larger than the estimated 1977 year-class. Although the 1975 year-class is predicted to be below average, it is still larger than eleven (48%) of the other 23 year-classes in the series.

STOCK SIZE

Estimates of stock size for 1955-76 were obtained from VPA (Table 6). Mean weights at age (Table 3) were applied to stock size (numbers) at age to obtain stock biomass values. The summed biomass values for each year were adjusted using the appropriate ratios between observed and calculated catch (Table 2). Stock size by age in 1977 was calculated using the relationship:

$$N_{77} = N_{76}e^{-z_{76}}.$$

Total stock biomass (age 1+) increased from an average of 76,000 tons during 1955-59 to a period high of 454,000 tons in 1965 and then decreased to 82,000 tons in 1970 (Table 6, Figure 1). Biomass increased again to 210,000 tons in 1973, decreased somewhat to average about 188,000 tons during 1974-76, and then increased to 246,000 tons in 1977, the highest biomass observed since 1966.

Spawning stock biomass (age 2+) averaged about 60,000 tons during 1955-60 before increasing to a high of 375,000 tons in 1965 (Table 6, Figure 5). Spawning biomass declined to 67,000 tons in 1970-71, increased to 148,000 tons in 1973-74, dropped to 98,000 tons in 1975, and then increased to 176,000 tons in 1977, the highest since 1967.

PARTIAL RECRUITMENT

Age-specific fishing mortality rates determined by VPA (Table 6) suggest that silver hake, at least during the last decade, have generally been fully-recruited to the fishery by age 3. Partial recruitment (the fishing mortality at each age not fully-recruited to the fishery expressed as a percentage of the mean level of fishing mortality at the fully-recruited ages) during 1972-76 varied from 0.6 to 21.3% at age 1 and from 21.6 to 89.2% at age 2 and averaged 10 and 57%, respectively. These values reflect primarily the 40-mm-mesh cod-ends used by most of the distant water fleets prior to March 1977. Non-USA catches of silver hake during 1972-76 averaged about 80% of the total annual catch. In addition, some of the USA catch was also taken in small-mesh nets of

this approximate size. Partial recruitment coefficients of 10% at age 1, 57% at age 2, and 100% at ages 3 and older were assumed for January - February 1977.

A 60-mm manila (55-mm synthetic) mesh regulation was implemented effective 1 March 1977, for the foreign hake fishery. As a result of the increased mesh size for this portion of the fishery, it was necessary to determine new partial recruitment coefficients applicable to the fishery after 1 March. The results of a mesh selection study by Jensen and Hennemuth (1966) were used to estimate retention curves for both 40 and 55-mm mesh (Anderson 1977). The difference in partial recruitment for the two mesh sizes was estimated utilizing the length-age composition of the 1976 catch (taken primarily with 40-mm mesh) and the retention ratios for each mesh (see Anderson 1977 for a detailed explanation of the procedure followed). The results suggested partial recruitment coefficients of 4% at age 1, 35% at age 2, 74% at age 3, 88% at age 4, 95% at age 5, and 100% at ages 6 and older. These values were assumed for the March - December 1977 fishery and also for 1978.

CATCH AND STOCK SIZE PROJECTIONS

A total stock (age 1+) biomass of 246,300 tons was calculated to be available at the beginning of 1977 (Table 6). The available spawning stock (age 2+) biomass was calculated to be 175,800 tons. An estimated catch of 5,423 tons (40-mm mesh) was taken during January - February 1977 which

generated an F of 0.0375 at ages 3 and older (M for these two months was assumed to be $2/12 \times 0.4$ or 0.067 at all ages) (Table 8). The age 1+ biomass available at the beginning of March was calculated to be 225,100 tons. A catch of 22,345 tons was assumed for March - December 1977 requiring an F of 0.2895 at ages 6 and older ($M = 10/12 \times 0.4$ or 0.333) and leaving an age 2+ biomass of 252,800 tons at the beginning of 1978. This indicates a 44% increase in spawning stock biomass from 1977 to 1978.

Equilibrium yield calculations under conditions of a constant level of recruitment at age 1 and partial recruitment coefficients of 5, 35, 74, 88, 95, and 100% at ages 1, 2, 3, 4, 5, and 6+, respectively, indicate an $F_{0.1}$ of about 0.50.

Catch options for 1978 and resultant spawning stock (age 2+) sizes in 1979 were calculated for values of F ranging from 0.05 to 1.00 (Table 9). Fishing at $F_{0.1}$ in 1978 would result in a catch of 54,000 tons and also achieve an estimated 5% increase in spawning stock biomass in 1977. A catch of 65,600 tons ($F = 0.629$) could be taken in 1978 and still maintain the same spawning stock biomass in 1979 as in 1978.

STOCK-RECRUITMENT

The relationship between spawning stock and recruitment is shown in Figures 5 and 6. Recruitment and spawning biomass both increased from low levels in the mid-1950's to peaks in the early 1960's and then decreased in

the late 1960's to about the same levels as in the mid-1950's. During 1955-65, there appeared to be a pronounced stock-recruitment relationship (Figure 6) with peak recruitment resulting from a spawning biomass of about 150,000 tons and lower levels of recruitment occurring both above and below 150,000 tons. However, after that time this relationship disappeared. It is possible that extraneous factors exerted a greater influence on year-class formation during the latter period than previously. It is, therefore, difficult to predict with any degree of certainty the level of recruitment which could be expected from future spawning stocks of the size currently projected for 1978.

LITERATURE CITED

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Table 1. Silver hake catch statistics from the Southern New England - Middle Atlantic Stock¹.

Year	Catch (MT)											USA catch/day (MT)	International effort as USA days fished		
	Bulgaria	Cuba	FRG	GDR	Japan	Poland	Romania	Spain	USSR	USA commercial	USA recreational			Other	Total
1955	-	-	-	-	-	-	-	-	-	12,412	2,743	-	15,155	-	-
1956	-	-	-	-	-	-	-	-	-	13,390	2,959	-	16,349	-	-
1957	-	-	-	-	-	-	-	-	-	15,390	3,400	-	18,790	-	-
1958	-	-	-	-	-	-	-	-	-	12,039	2,660	-	14,699	-	-
1959	-	-	-	-	-	-	-	-	-	15,398	3,402 ²	-	18,800	-	-
1960	-	-	-	-	-	-	-	-	-	8,151	1,801 ²	-	9,952	-	-
1961	-	-	-	-	-	-	-	-	-	10,562	2,334	-	12,896	-	-
1962	-	-	-	-	-	-	-	-	-	11,932	2,636	-	14,568	-	-
1963	-	-	-	-	-	-	-	-	4,191	17,666	2,451	-	24,308	-	-
1964	-	-	-	-	-	-	-	-	19,434	25,008	3,469 ²	-	47,911	6.90	6,944
1965	-	-	-	-	-	-	-	-	68,493	20,998	2,717 ²	-	92,208	5.68	16,234
1966	-	-	-	-	-	-	-	-	126,211	9,840	1,365	-	137,416	4.60	29,873
1967	-	-	-	-	26	-	-	-	41,242	8,493	1,178	-	50,939	5.23	9,740
1968	-	-	-	-	47	121	-	-	30,812	8,163	1,132	-	40,275	5.25	7,671
1969	746	-	-	2	178	-	-	-	57,820	7,235	1,003 ²	-	66,984	6.24	10,735
1970	439	-	-	-	299	-	-	-	11,493	6,005	950 ²	-	19,226	7.66	2,510
1971	621	-	-	-	70	24	432	-	21,714	4,989	692	-	28,542	4.85	5,885
1972	1,629	474	-	16	101	-	127	-	27,146	5,552	770	-	35,815	6.22	5,758
1973	668	-	1	15	268	92	45	-	57,928	6,098	846 ²	-	65,961	4.77	13,828
1974	1,792	-	-	2	64	70	125	-	49,175	7,200	1,075 ²	-	59,503	4.29	13,870
1975	896	212	-	8	-	16	-	19	32,241	8,278	1,147 ²	201	43,018	5.26	8,178
1976	227	92	-	1	9	113	414	28	15,780	9,513	994 ²	-	27,177	6.61	4,111

¹Non-USA catches before 1968 are estimated.

²From angler survey; remaining years estimated (see text).

Table 2. Silver hake catch at age (millions of fish) from the Southern New England - Middle Atlantic 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	0.4	19.8	10.9	22.7	24.5	9.9	2.1	0.8	0.3	0.1	+	-	-	91.5	15,155	15,696	.966
1956	-	68.5	51.7	22.7	16.9	6.0	1.4	0.8	0.2	0.1	+	+	-	168.3	16,349	16,536	.989
1957	-	2.8	25.6	36.1	26.1	11.1	3.0	1.2	0.4	0.1	+	+	+	106.4	18,790	19,843	.947
1958	-	23.5	31.8	28.4	17.8	6.2	1.6	0.8	0.2	+	+	+	-	110.3	14,699	15,457	.951
1959	-	13.8	13.4	42.8	28.8	10.2	2.3	0.8	0.2	+	+	+	+	112.3	18,800	20,025	.939
1960	-	13.7	19.3	14.2	11.9	5.5	1.8	1.0	0.4	0.1	+	+	+	67.9	9,952	10,363	.960
1961	-	0.5	6.3	27.0	22.1	5.7	1.5	1.0	0.4	0.2	+	+	+	64.7	12,896	13,788	.935
1962	-	0.6	6.4	29.0	27.0	7.2	1.5	0.8	0.4	0.2	0.1	+	+	73.2	14,568	15,106	.964
1963	-	5.7	24.3	46.8	43.0	13.6	2.0	0.5	0.2	0.1	+	+	-	136.2	24,308	26,189	.928
1964	-	26.2	39.4	106.3	82.4	26.1	4.5	1.8	0.5	0.4	0.2	+	-	287.8	47,911	49,493	.968
1965	-	22.7	66.8	253.2	160.5	31.2	8.4	3.8	1.3	0.4	0.1	+	+	548.4	92,208	95,227	.968
1966	-	8.6	216.8	332.1	192.4	61.0	19.8	8.6	3.5	0.9	0.1	+	+	843.8	137,416	141,433	.972
1967	-	13.6	27.5	118.4	106.6	22.2	4.5	1.7	0.7	0.2	+	+	+	295.4	50,939	52,485	.971
1968	-	9.6	23.2	96.1	64.8	20.3	8.8	3.9	1.2	0.6	0.1	+	+	228.6	40,275	43,546	.925
1969	-	1.5	20.4	120.5	108.5	40.1	10.2	9.1	3.5	1.6	0.1	0.1	-	315.6	66,984	77,721	.862
1970	-	31.8	11.0	10.3	22.5	18.3	5.3	4.3	2.4	0.9	0.2	+	0.1	107.1	19,226	19,940	.964
1971	-	7.5	35.0	50.5	26.6	8.0	3.7	5.9	5.4	2.8	1.0	0.3	+	146.7	28,542	28,968	.985
1972	0.1	52.5	82.4	41.8	13.1	1.7	0.5	0.4	0.1	+	+	-	-	192.6	35,815	40,237	.890
1973	0.1	64.3	173.8	75.5	24.6	3.7	0.9	0.5	0.1	+	-	-	-	343.5	65,961	69,672	.947
1974	+	18.2	136.7	78.0	32.2	3.0	1.4	1.3	0.3	0.3	+	-	-	271.4	59,503	59,840	.994
1975	-	4.7	39.9	92.4	35.2	10.7	1.6	0.1	-	-	-	-	-	184.6	43,018	43,289	.994
1976	0.2	7.4	73.8	37.4	13.7	3.3	0.6	0.1	-	-	-	-	-	136.5	27,177	27,263	.997

¹Using mean wts at age from Table 3.

Table 3. Mean weights (kg) at age of silver hake catches from the Southern New England - Middle Atlantic Stock.

Year	Age												
	0	1	2	3	4	5	6	7	8	9	10	11	12+
1955	.003	.044	.101	.162	.222	.307	.422	.508	.662	.762	1.396	-	.783
1956	-	.034	.074	.154	.223	.316	.438	.496	.664	.777	1.232	1.396	.782
1957	-	.062	.085	.157	.224	.326	.465	.512	.683	.782	1.152	1.553	.781
1958	-	.060	.088	.152	.215	.310	.409	.490	.682	.818	1.254	1.369	.782
1959	-	.035	.105	.156	.227	.333	.439	.485	.629	.658	-	-	.782
1960	-	.047	.074	.159	.216	.317	.445	.547	.702	.904	1.098	1.383	.787
1961	-	.077	.106	.166	.219	.335	.498	.586	.832	.920	1.177	-	.786
1962	-	.067	.107	.157	.215	.305	.444	.605	.822	1.007	1.468	1.374	.783
1963	-	.076	.101	.171	.228	.312	.407	.485	.645	.622	1.211	1.388	.790
1964	-	.056	.107	.149	.204	.287	.387	.500	.796	1.007	1.141	1.369	.781
1965	-	.060	.103	.152	.199	.304	.440	.537	.672	.845	1.259	1.377	.784
1966	-	.058	.087	.141	.207	.313	.446	.523	.628	.765	1.111	1.397	.793
1967	-	.035	.098	.151	.200	.300	.423	.531	.694	.820	1.406	1.633	.787
1968	-	.045	.097	.138	.193	.315	.459	.556	.788	.865	1.029	1.480	1.252
1969	-	.070	.112	.191	.246	.313	.405	.527	.697	.915	1.095	1.335	-
1970	-	.042	.079	.166	.213	.270	.348	.448	.607	.832	.958	1.157	1.240
1971	-	.053	.093	.148	.195	.271	.327	.450	.596	.741	1.024	1.013	1.249
1972	.022	.100	.215	.269	.344	.481	.643	.647	1.201	.889	1.359	-	-
1973	.018	.091	.179	.272	.390	.459	.584	.485	1.119	.548	1.595	-	-
1974	.020	.076	.178	.241	.362	.460	.599	.638	1.144	.929	1.297	-	-
1975	-	.114	.150	.207	.336	.458	.534	.593	-	-	-	-	-
1976	.012	.064	.169	.218	.306	.479	.511	.823	-	-	-	-	-

Table 4. Stratified mean catch per tow (kg) of silver hake from the Southern New England - Middle Atlantic stock from USA bottom trawl surveys in the spring and autumn (strata 1-12).

Year	Spring	Autumn
1963	-	5.22
1964	-	5.66
1965	-	7.62
1966	-	3.59
1967	-	4.42
1968	7.36	4.75
1969	3.82	2.30
1970	1.68	2.59
1971	3.73	4.60
1972	2.31 ¹	3.99
1973	1.16 ¹	3.20
1974	1.67 ¹	1.36
1975	3.08 ¹	2.77
1976	1.96 ¹	3.92
1977	1.12 ¹	3.04

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

Table 5. Estimation of F in 1976 for the Southern New England - Middle Atlantic silver hake fishery.

Year	Fishing effort ¹	Fishing mortality ²
1964	6,944	.488
1965	16,234	.509
1966	29,873	.796
1967	9,740	.471
1968 ⁵	7,671	.394
1969 ⁵	10,735	1.057
1970 ⁵	2,510	.515
1971 ⁵	5,885	1.067
1972	5,758	.404
1973	13,828	.647
1974	13,870	.802
1975	8,178	(.508) ^{3,4}
1976	4,111	(.451) ³

¹Expressed as USA days fished.

²Weighted mean F for fully-recruited ages.

³Calculated from linear regression of fishing effort on fishing mortality for 1964-74: $Y = 0.393 + 0.0000140 x$, $r = 0.730$.

⁴Value calculated from VPA was 1.076.

⁵Not used in calculation of linear regression.

Table 7. Catch per tow (number) of age 0 silver hake from the Southern New England - Middle Atlantic stock from USA autumn bottom trawl surveys and year-class size (millions of fish) at age 1 from VPA.

Year-class	Autumn survey	VPA
	Age 0	Age 1
1969	26.13	341.8
1970	28.65	557.1
1971	69.90	767.9
1972	78.20	713.1
1973	19.96	368.2
1974	105.54	(902.1) ¹
1975	57.24	(648.1) ¹
1976	152.83	(1,102.0) ¹
1977	93.04	(843.7) ¹

¹ Calculated from power curve relationship between autumn survey catch per tow and VPA year-class size:

$$Y = 72.667X^{.541}, r = 0.899$$

Table 8. Parameters of the 1977 Southern New England - Middle Atlantic silver hake fishery.

Parameter	Value
Stock biomass (000's tons) at beginning of 1977:	246.3 (age 1+) 175.8 (age 2+)
January-February 1977 fishery (40-mm mesh):	
Catch (tons):	5,523
Partial recruitment (%):	
Age 1	10
Age 2	57
Age 3+	100
Fishing mortality (age 3+)	0.0375
March-December 1977 fishery (60-mm mesh)	
Catch (tons):	22,345
Partial recruitment (%):	
Age 1	4
Age 2	35
Age 3	74
Age 4	88
Age 5	95
Age 6+	100
Fishing mortality (age 6+)	0.2895
Stock biomass (000's tons) at beginning of 1978:	252.8 (age 2+)

Table 9. Projected catch (age 1+) in 1978 from the Southern New England - Middle Atlantic silver hake stock, with fishing mortality ranging from 0.05 to 1.00. Resulting stock size (age 2+) in 1979 and the percentage change (by weight) from 1978 are also given. All catch and stock size values are in thousands of tons.

Fishing mortality	Catch in 1978	Stock in 1979	% change in stock from 1978
0.05	6.2	320.0	+26.6
0.10	12.2	313.1	+23.9
0.15	18.1	306.5	+21.2
0.20	23.7	300.0	+18.7
0.25	29.2	293.8	+16.2
0.30	34.5	287.8	+13.8
0.35	39.7	281.9	+11.5
0.40	44.6	276.3	+ 9.3
0.45	49.5	270.9	+ 7.2
*0.50	54.2	265.6	+ 5.1
0.55	58.7	260.5	+ 3.0
0.60	63.1	255.6	+ 1.1
0.629	65.6	252.8	0.0
0.65	67.4	250.8	- 0.8
0.70	71.5	246.2	- 2.6
0.75	75.6	241.7	- 4.4
0.80	79.5	237.4	- 6.1
0.85	83.3	233.2	- 7.8
0.90	87.0	229.2	- 9.3
0.95	90.6	225.2	-10.9
1.00	94.0	221.4	-12.4

*F_{0.1}

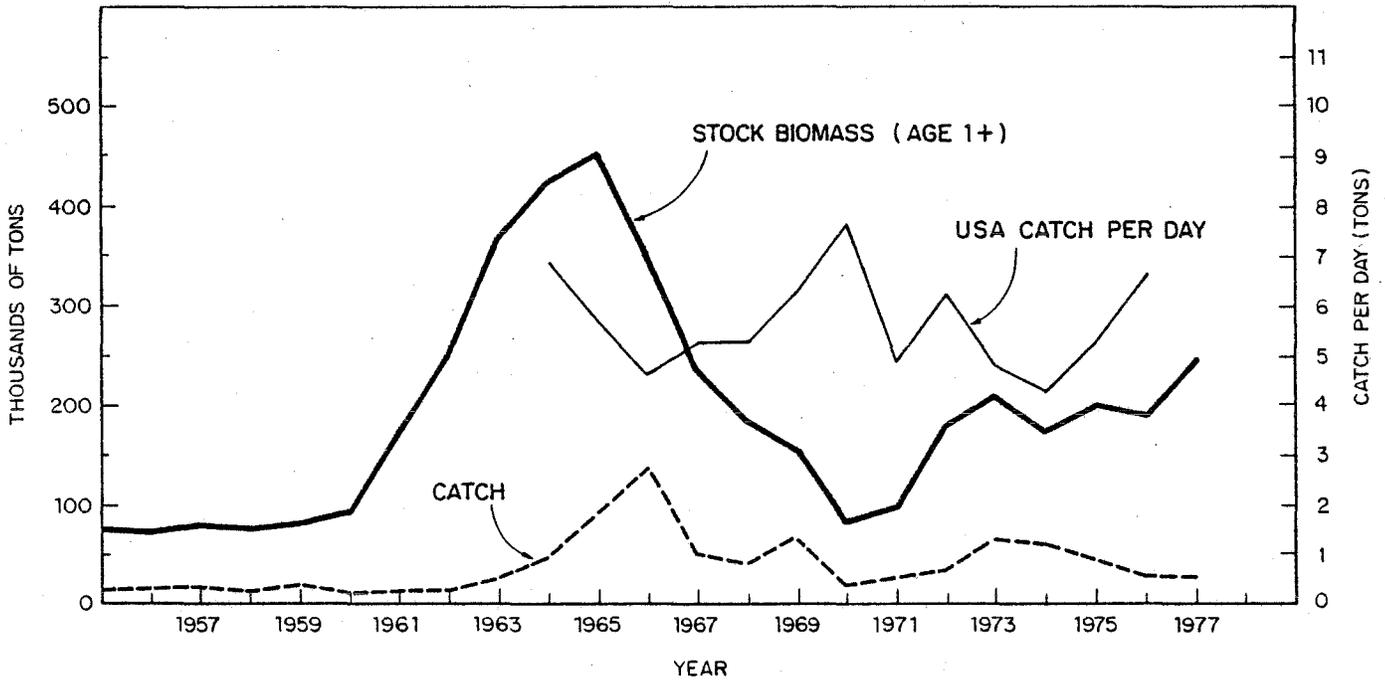


Figure 1. International catch, stock biomass (age 1+) from virtual population analysis, and USA commercial catch-per-day from the Southern New England - Middle Atlantic silver hake stock.

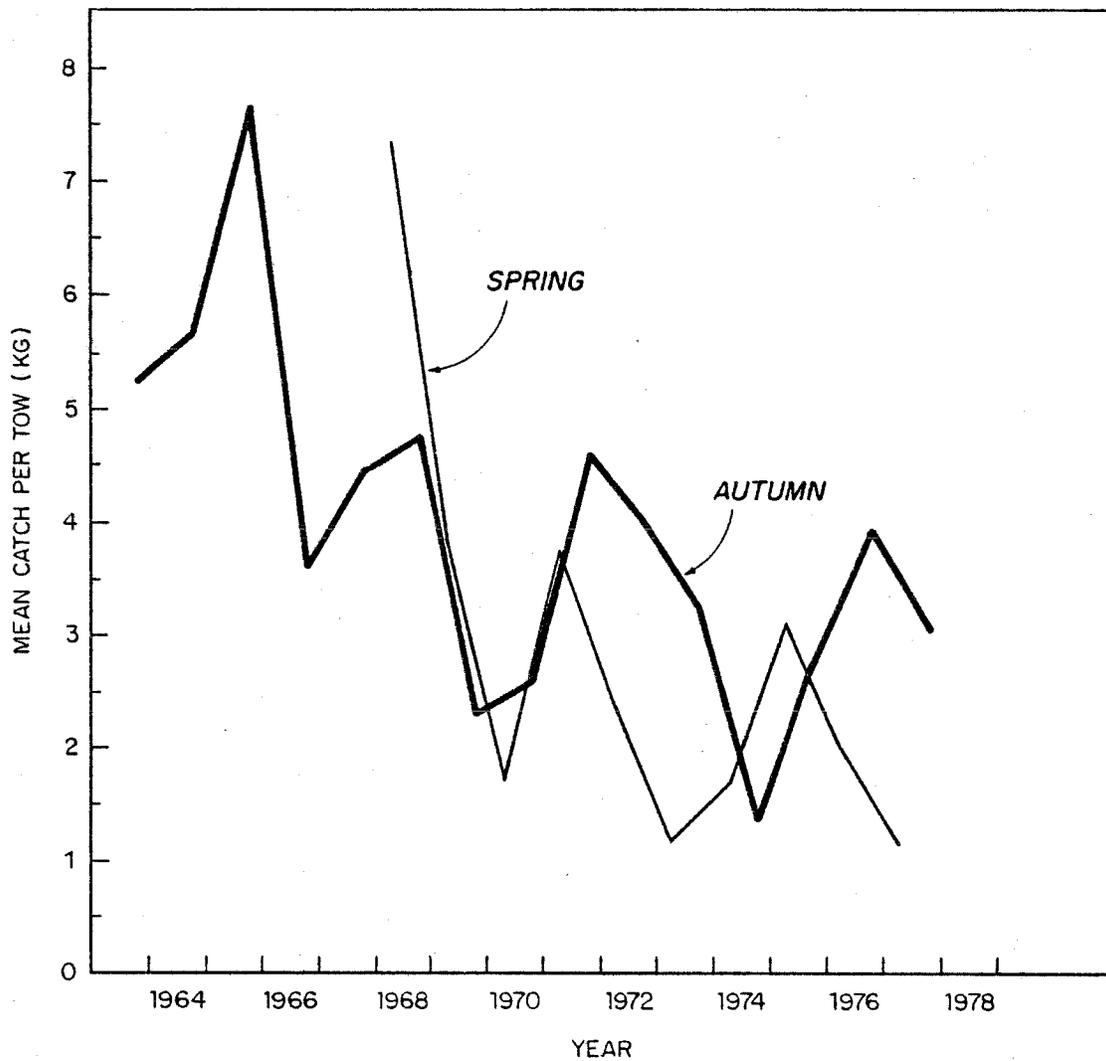


Figure 2. Stratified mean catch-per-tow (kg) of silver hake from the Southern New England - Middle Atlantic stock from USA autumn (1963-77) and spring (1968-77) bottom trawl surveys.

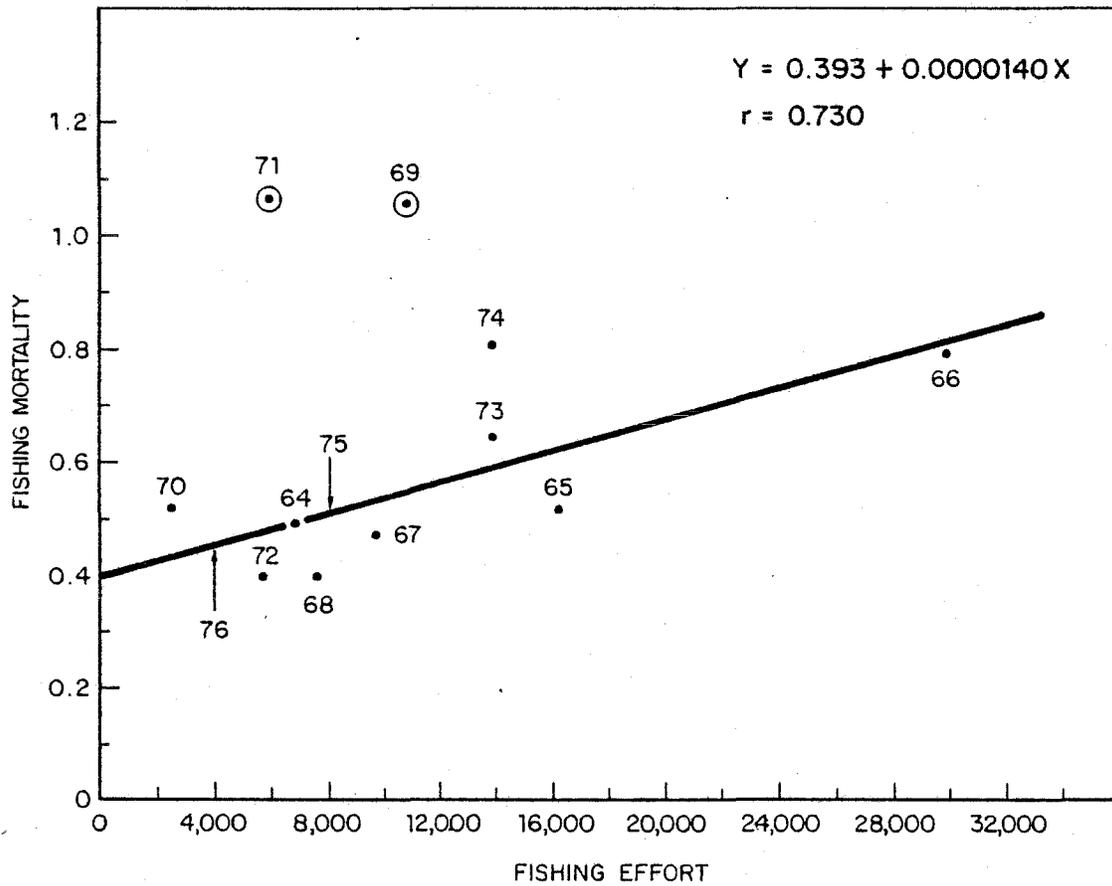


Figure 3. Relationship between fishing mortality from virtual population analysis and international fishing effort expressed as USA days fished for the Southern New England - Middle Atlantic stock. The 1969 and 1971 values were not used in calculating the line.

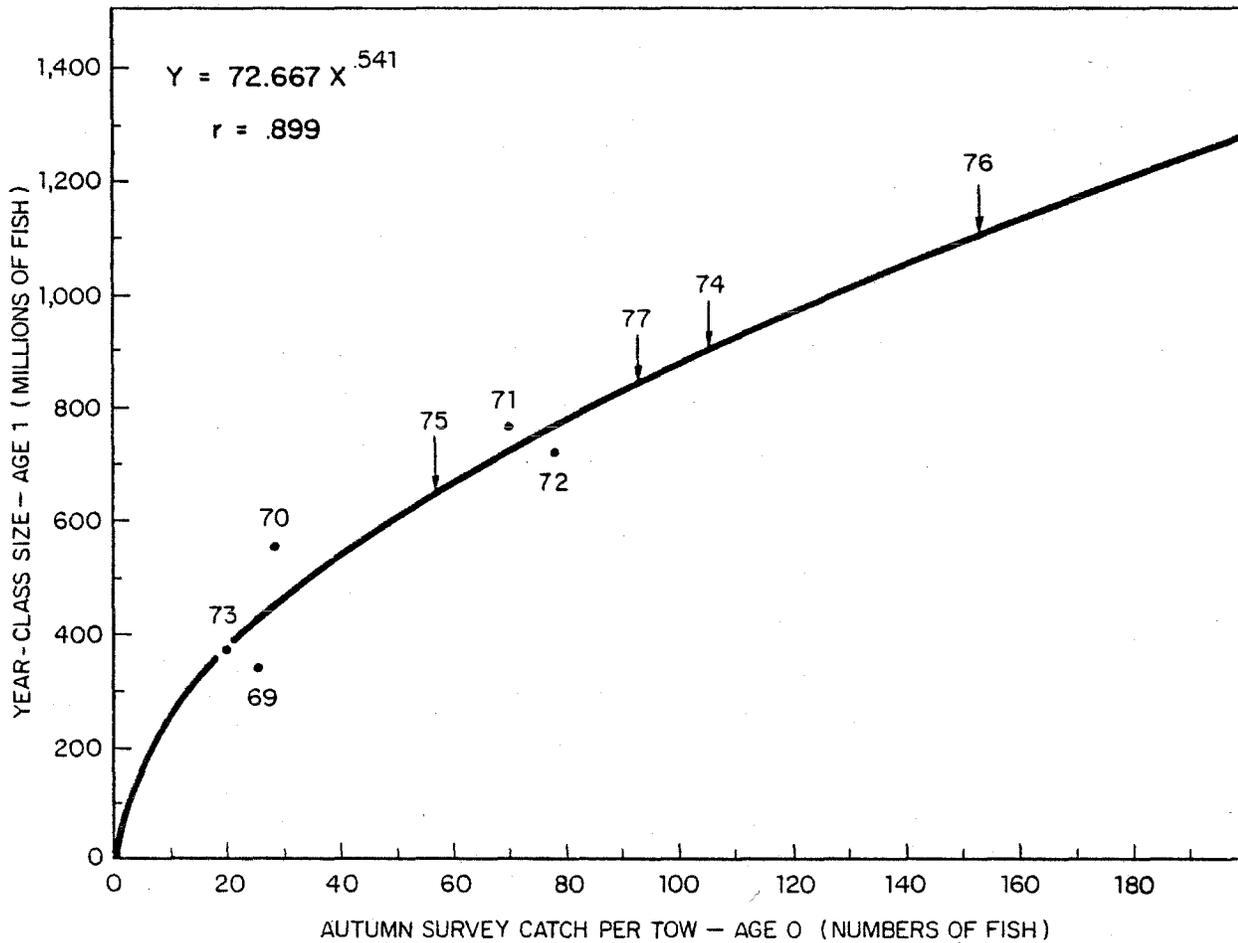


Figure 4. Power curve relationship between Southern New England - Middle Atlantic silver hake year-class size at age 1 and USA autumn survey catch-per-tow at age 0.

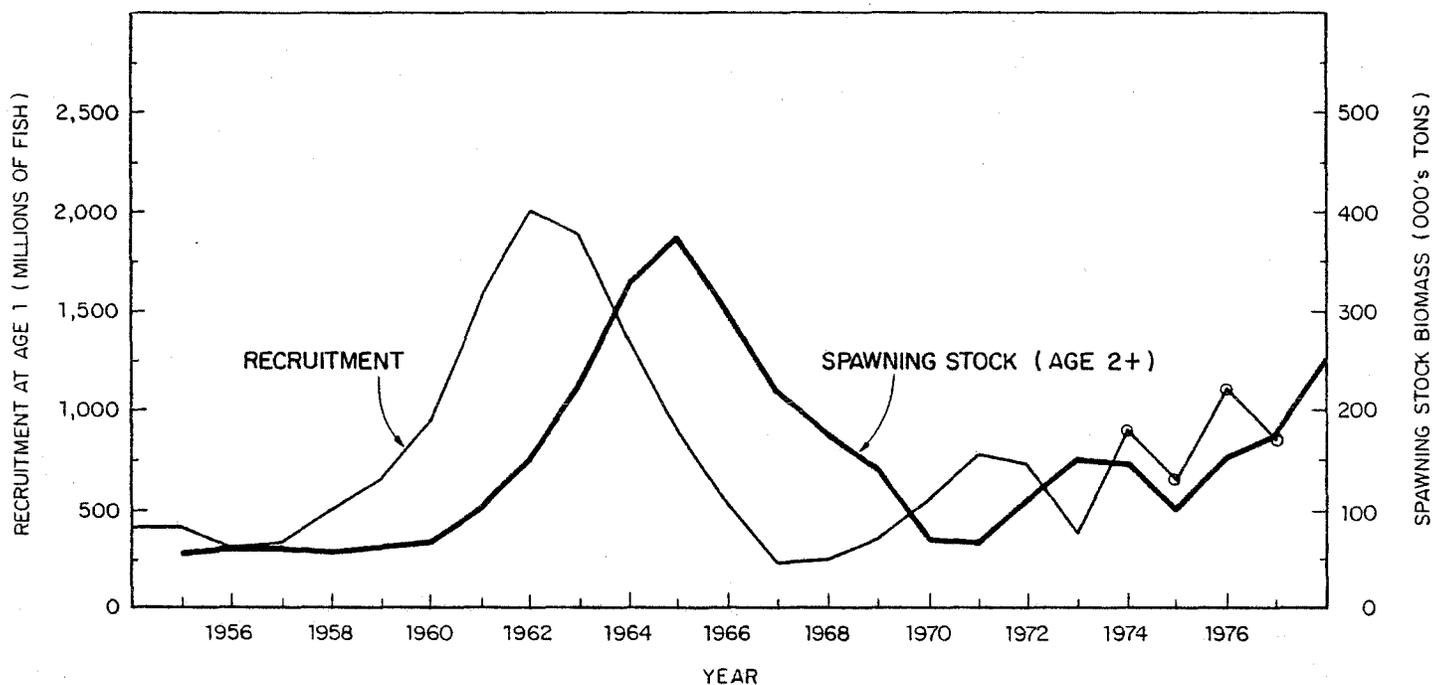


Figure 5. Southern New England - Middle Atlantic silver hake spawning stock biomass (age 2+) in 1955-78 and abundance at age 1 of the 1954-77 year-classes. Open circles indicate estimated year-class sizes.

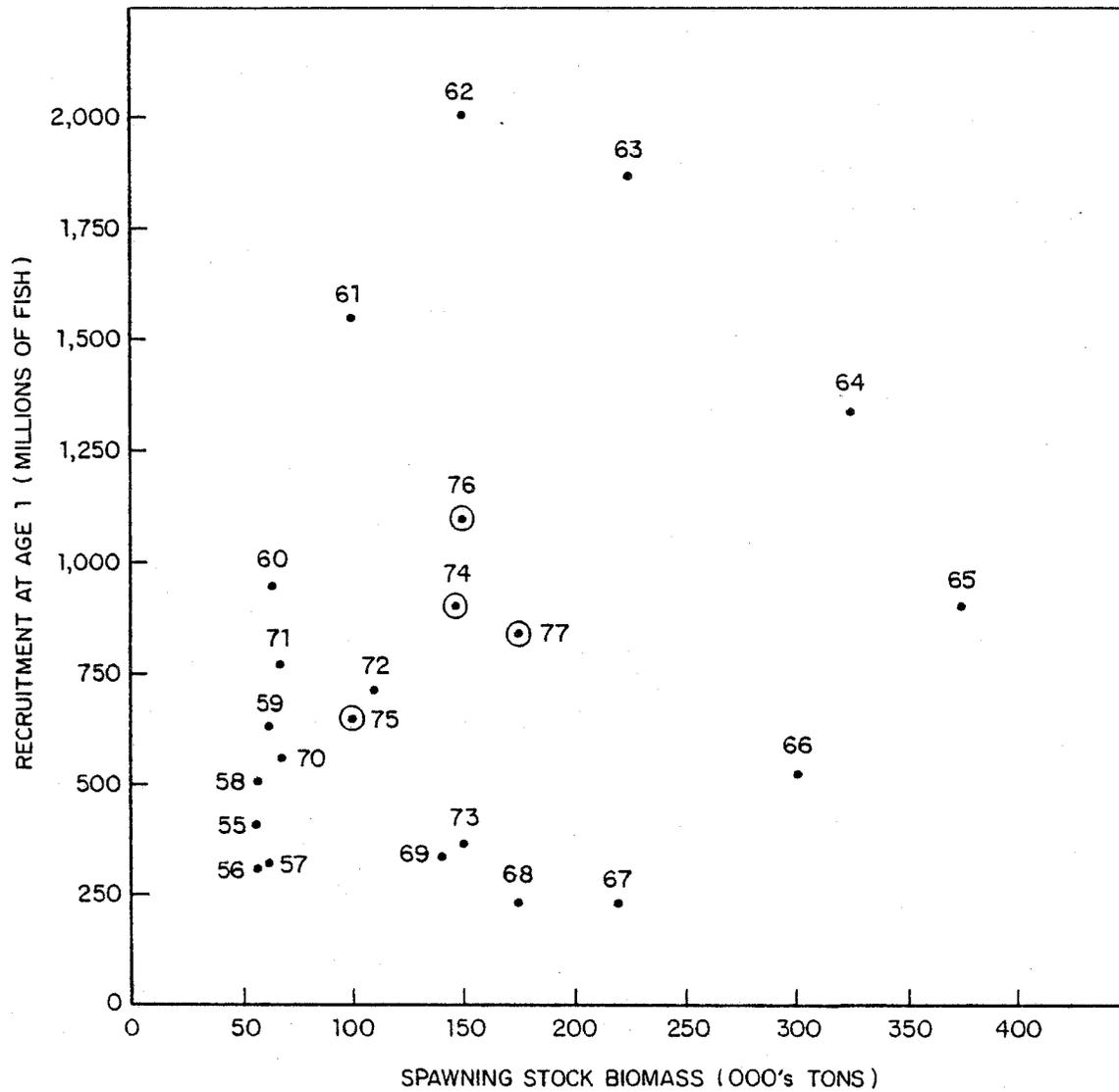


Figure 6. Relationship between spawning stock biomass (age 2+) and recruitment (expressed as abundance at age 1) for the Southern New England - Middle Atlantic silver hake stock during 1955-77. Open circles indicate estimated year-class sizes.

Table 7. Catch per tow (number) of age 0 silver hake from the Southern New England - Middle Atlantic stock from USA autumn bottom trawl surveys and year-class size (millions of fish) at age 1 from VPA.

Year-class	Autumn survey age 0	VPA age 1
1969	26.13	341.8
1970	28.65	557.1
1971	69.90	767.9
1972	78.20	713.1
1973	19.96	368.2
1974	105.54	(902.1) ¹
1975	57.24	(648.1) ¹
1976	152.83	(1,102.0) ¹
1977	93.04	(843.7) ¹

¹ Calculated from power curve relationship between autumn survey catch per tow and VPA year-class size:

$$Y = 72.667X^{.541}, r = 0.899$$

Table 8. Parameters of the 1977 Southern New England - Middle Atlantic silver hake fishery.

Parameter	Value
Stock biomass (000's tons) at beginning of 1977:	246.3 (age 1+) 175.8 (age 2+)
January-February 1977 fishery (40-mm mesh):	
Catch (tons):	5,523
Partial recruitment (%):	
Age 1	10
Age 2	57
Age 3+	100
Fishing mortality (age 3+)	0.0375
March-December 1977 fishery (60-mm mesh)	
Catch (tons):	22,345
Partial recruitment (%):	
Age 1	4
Age 2	35
Age 3	74
Age 4	88
Age 5	95
Age 6+	100
Fishing mortality (age 6+)	0.2895
Stock biomass (000's tons) at beginning of 1978:	252.8 (age 2+)

Table 9. Projected catch (age 1+) in 1978 from the Southern New England - Middle Atlantic silver hake stock, with fishing mortality ranging from 0.05 to 1.00. Resulting stock size (age 2+) in 1979 and the percentage change (by weight) from 1978 are also given. All catch and stock size values are in thousands of tons.

Fishing mortality	Catch in 1978	Stock in 1979	% change in stock from 1978
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0.80	79.5	237.4	- 6.1
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0.90	87.0	229.2	- 9.3
0.95	90.6	225.2	-10.9
1.00	94.0	221.4	-12.4

*F_{0.1}

FIGURE CAPTIONS

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