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Status of the southern New England-Middle
Atlantic 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 inhabiting the Southern New England - Middle Atlantic waters (ICNAF Subdiv. 5Zw and SA 6). The data base utilized includes USA and foreign commercial and estimated USA recreational catch statistics for 1955-77 and research vessel bottom trawl survey data since 1963. Estimates of stock size, fishing mortality, and recruitment are presented. Projections are made for the 1979 catch and the stock remaining at the beginning of 1980.

CATCH

Catches by country for the period 1955-77, including estimates of USA recreational catch are listed in Table 1. Marine angler surveys provided estimates of the 1960, 1965, 1970, and 1974-77 recreational catches. The ratios between recreational and USA commercial catch were fairly constant in 1965 (0.129), 1970 (0.158), 1974 (0.149), and 1976 (0.179); the 1960 ratio was somewhat higher at 0.221, the 1977 ratio much higher (0.419), while the 1975 ratio (0.024) was lower. The recreational catch in each of the remaining years during 1955-73 was estimated by applying the 1960 ratio to the commercial catches in 1955-59 and 1961-62, and the weighted average (0.139) of the 1965, 1970, and 1974 ratios, was used for 1963-64, 1966-69, and 1971-73.

Total catches averaged about 16,800 tons during 1955-59, declined to 9,952 tons in 1960, and then increased 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 27,700 tons in 1976. The 1977 catch increased slightly to 27,900 tons.

USA commercial catches during 1955-65 ranged between 8,151 and 25,008 tons and averaged 14,800 tons per year. Catches during 1966-77 were much lower, ranging between 4,989 and 9,840 tons and averaging approximately 7,400 tons or 18% of the international catch per year. Estimated recreational catches during 1955-77 ranged between 197 and 3,948 tons and averaged about 1,975 tons per year. The USA commercial and recreational catches in 1977 were 9,452 and 3,948 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 and reduced to 33,200 tons in 1978, of which 17,600 tons was allocated as the total allowable level of foreign fishing (TALFF). The 1978 OY was subsequently increased by 5,000 tons, all of which was allocated as TALFF. The 1978 foreign catch, as of 2 December was approximately 10,240 tons

taken by Bulgaria, Japan, Mexico, Romania, Spain, and the USSR. The USA commercial catch in 1978 was estimated to be 11,000 tons from projections comparing 1977 and available 1978 monthly catches. The recreational catch was assumed to be approximately 4,000 tons. For the purpose of this assessment the 1978 total catch was assumed to be 26,000 tons.

CATCH COMPOSITION

Numbers-at-age catch data for 1955-77 are contained in Table 2. Age 2 and 3 fish have, in recent years, dominated the catch. In 1977, 24% of the catch (in numbers) was age 2 fish and 46% was age 3, as opposed to 54% and 27%, respectively, in 1976.

Mean weights at age for the 1955-77 catches (Table 3) were applied to the numbers at age in Table 2 to obtain calculated catches. The ratios between observed and calculated catches range between 0.861 and 1.094 and average 0.961. These ratios are used to adjust the calculated stock biomass values obtained from virtual population analysis. The 1977 mean weights at age (unadjusted) were utilized in the projections of 1979-80 catch and stock biomass.

ABUNDANCE INDICES

USA commercial catch per day increased steadily in recent years from 4.3 tons in 1974 to 7.7 in 1977 (Table 1, Figure 1). The 1977 index was the highest observed since 1970. Yearly values in this time-series (1964-77) have fluctuated between 4.3 and 7.7 but have not shown any long-term trends nor have they 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, and had a catch 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 per year. The lack of consistency between the index and VPA results 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 3.09 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. The spring bottom trawl survey catch-per-tow index was lower in 1977 (1.16 kg) than in any other year (1968-78), but increased in 1978 to 1.83 after decreasing steadily since 1975. Since 1971 this index has fluctuated about an average of 1.88 and has not agreed with the VPA results. 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 results of the survey.

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, expressed as USA days fished, was calculated by dividing the total international catch by USA catch per day (Table 1). A fishing mortality rate (F) of 0.463 was estimated for 1977 based on a linear regression between fishing effort and fishing mortality values from a previous VPA (Anderson and Almeida 1977). A new VPA was performed using 0.463 as the terminal F for ages 4 and older in 1977 (Table 6), and a regression ($r = 0.753$, $p = 0.05$) between fishing effort and the mean fishing mortality values from the new VPA for 1955-75 was run. The predicted F for 1977 was 0.463 (Table 5) and therefore, the estimated F was accepted.

Fishing mortality for fully recruited ages determined by the VPA ranged between 0.32 and 0.80, averaging about 0.52 during 1955-68. F then increased to 1.05 in 1969, dropped to 0.49 in 1970, increased again to 1.05 in 1971, averaged 0.61 during 1972-74, increased to 1.04 in 1975, and decreased to average 0.46 in 1976-77.

RECRUITMENT ESTIMATES

The 1975-77 year-class sizes at age 1 were estimated from a power curve relationship ($r = 0.869$, $p > 0.05$) 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).

The 1974, 1975, 1976, and 1977 year-classes at age 1 were estimated to be 890, 650, 1,080 and 830 million fish, respectively, compared to the mean 1954-73 year-class size of 760 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. Only eight other cohorts in the 23-year time-series are larger than the estimated 1977 year-class.

STOCK SIZE

Estimates of stock size for 1955-77 were obtained from VPA (Table 6). Mean weights at age were applied to stock size numbers at age to obtain stock biomass values, and 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 1978 was calculated using the relationship:

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

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 83,000 tons in 1970. Biomass increased again to 231,000 tons in 1973, decreased somewhat to average about 189,000 tons during 1974-76, and then increased to 390,000 tons in 1978, the largest biomass observed since 1965.

Spawning stock biomass (age 2+) averaged about 60,000 tons during 1955-60 before increasing to a high of 376,000 tons in 1965. Spawning biomass declined to 66,000 tons in 1970-71, increased to an average of 151,000 tons in 1973-74, dropped to 100,000 tons in 1975, and then increased to 286,000 tons in 1978, the largest since 1966.

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 the fishing mortality at a given age (in a given calendar year) not fully recruited into the fishery and the mean F at the fully recruited ages in that year, was estimated to be 0.4% at age 1, 13% at age 2, 35% at age 3, and 100% at ages 4 and older in 1977. These ratios were derived from the fishing mortality rates estimated for 1977 (Table 6). They represent decreases from earlier 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 used in the projections of catch and stock size for 1979-80.

CATCH AND STOCK SIZE PROJECTIONS

A total stock (age 1+) biomass of 390,400 tons was calculated to be available at the beginning of 1978. The available spawning stock (age 2+) was calculated to be 285,800 tons. These estimates represent a 15% increase in total stock and 42% increase in spawning stock biomass from the previous year.

Equilibrium yield calculations under conditions of a constant level of recruitment at age 1 and partial recruitment coefficients of 0.4, 13, 35, and 100% at ages 1, 2, 3, and 4+, respectively, indicate an $F_{0.1}$ of about 0.55.

A total catch of 26,000 tons requiring an F for ages 4 and older of 0.268 was assumed for 1978, leaving a spawning stock biomass of 341,800 tons at the beginning of 1979 (20% increase from 1978). An estimated 1978 year-class of median strength (650 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 66,400 tons with a resulting decrease in spawning stock biomass from 1979 to 1980 of 6%. A catch in 1979 of 47,500 tons ($F=0.371$) 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. 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, this relationship disappeared in later years. 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 1979-80.

LITERATURE CITED

Anderson, E. D., and F. P. Almeida. 1977. Assessment of the Southern New England-Middle Atlantic silver hake stock. NMFS, NEFC, Woods Hole Lab. Ref. 77-30.

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	-	18,800	-	-
1960	-	-	-	-	-	-	-	-	-	8,151	1,801	-	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	-	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	-	-	-	-	22	-	-	-	41,242	8,491	1,178	-	50,935	5.23	9,739
1968	-	-	-	-	44	121	-	-	30,812	8,163	1,132	-	40,272	5.25	7,671
1969	746	-	-	2	123	-	-	-	57,820	7,235	1,003 ²	-	66,929	6.24	10,726
1970	439	-	-	-	299	-	40	-	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	-	59,503	4.29	13,870
1975	896	212	-	8	-	16	-	19	32,241	8,278	197 ²	44	41,911	5.26	7,968
1976	33	92	-	1	9	113	414	-	15,780	9,513	1,706 ²	-	27,661	6.61	4,185
1977	114	269	-	-	35	83	12	13	13,943	9,452	3,946 ²	11	27,880	7.65	3,644

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. catch	
	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	50,935	52,485	.970
1968	-	9.6	23.2	96.1	64.8	20.3	8.8	3.9	1.2	0.6	0.1	+	+	228.6	40,272	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	66,929	77,721	.861
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	-	4.6	39.0	90.3	34.4	10.5	1.6	0.1	-	-	-	-	-	180.5	41,911	42,348	.990
1976	0.2	7.6	75.7	38.4	14.1	3.4	0.6	0.1	-	-	-	-	-	140.1	27,661	27,985	.988
1977	-	2.6	21.6	41.5	17.2	5.2	1.7	0.9	+	-	-	-	-	90.7	27,880	25,491	1.014

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	-	-	-	-	-
1977	-	.126	.177	.265	.346	.513	.671	.648	1.491	-	-	-	-

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	1.16 ¹	3.09
1978	1.83 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 Southern New England-Middle Atlantic silver hake fishery.

Year	Fishing effort ¹	Fishing mortality ²
1964	6,944	.488
1965	16,234	.508
1966	29,873	.795
1967	9,739	.471
1968	7,671	.394
1969 ⁵	10,726	1.046
1970	2,510	.486
1971 ⁵	5,885	1.044
1972	5,758	.618
1973	13,828	.628
1974	13,870	.598
1975 ⁵	7,963	1.036
1976	4,185	(.469) ^{3,4}
1977	3,644	(.463) 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: $Y=0.423 + 0.000011X$
 $r=0.753$.

⁴Value calculated from VPA was 0.447 using $F = 0.463$ 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 (see Figure 3).

Table 6. Fishing mortality (F) rates and stock size for the Southern New England-Middle Atlantic 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+				
	Fishing Mortality												Med F ³	Age		
1955	.061	.072	.282	.761	.910	.516	.742	.558	(.779) ¹	-	-	-	.779	4+		
1956	.230	.278	.263	.445	.544	.381	.533	.533	(.466) ¹	-	-	-	.466	4+		
1957	.011	.157	.404	.709	.785	.767	.888	(.737) ¹	(.737) ¹	-	-	-	.737	4+		
1958	.088	.211	.327	.455	.460	.302	.618	(.447) ¹	-	-	-	-	.447	4+		
1959	.033	.082	.626	.859	.671	.391	.305	.388	-	-	-	-	.745	4+		
1960	.026	.073	.145	.451	.497	.294	.372	.309	(.435) ¹	-	-	-	.435	4+		
1961	.001	.018	.171	.442	.521	.306	.333	.314	(.314) ¹	-	-	-	.438	4+		
1962	.000	.012	.133	.324	.317	.315	.335	.269	(.322) ¹	(.322) ¹	-	-	.322	4+		
1963	.003	.028	.144	.375	.339	.169	.204	.162	.123	-	-	-	.349	4+		
1964	.017	.036	.207	.512	.527	.223	.282	.409	.723	(.488) ¹	-	-	.488	4+		
1965	.021	.068	.430	.711	.475	.408	.376	.430	.902	(.508) ¹	-	-	.508	3+		
1966	.012	.349	.709	.916	.879	.840	1.370	.957	(.795) ¹	(.795) ¹	-	-	.795	3+		
1967	.032	.057	.415	.683	.306	.173	.189	.457	.151	-	-	-	.471	3+		
1968	.051	.085	.363	.542	.330	.238	.278	.247	1.278	.130	-	-	.394	3+		
1969	.008	.179	1.091	1.263	1.059	.347	.529	.554	.792	(1.046) ¹	.231	-	1.046	3+		
1970	.119	.087	.160	.812	1.030	.475	.303	.323	.260	(.486) ¹	(.486) ¹	-	.486	3+		
1971	.016	.232	.927	1.047	1.074	.792	2.897	(1.044) ¹	(1.044) ¹	(1.044) ¹	(1.044) ¹	-	1.044	3+		
1972	.086	.299	.616	.805	.200	.204	.221	(.618) ¹	-	-	-	-	.618	3+		
1973	.118	.572	.636	1.314	.940	.192	.409	.097	-	-	-	-	.628	2+		
1974	.060	.500	.722	.825	.702	1.931	(.598) ¹	(.598) ¹	(.598) ¹	-	-	-	.598	2+		
1975	.006	.219	.993	1.163	.970	1.555	(1.036) ¹	-	-	-	-	-	1.036	3+		
1976	.015	.168	.441	.514	.404	.155	(.447) ¹	-	-	-	-	-	.447	3+		
1977	.002	.062	.162	(.463) ⁴	(.463) ⁴	(.463) ⁴	(.463) ⁴	-	-	-	-	-	.463	4+		
	Stock size (millions)												Age 1+	Age 2+		
													Total	Wt(10 ³ tons) ⁵	Total	Wt(10 ³ tons) ⁵
1955	406.2	189.5	111.1	54.4	19.5	5.9	1.8	0.8	0.2	-	-	-	788.6	74.2	382.4	56.9
1956	400.2	256.2	118.2	56.2	17.0	5.3	2.3	0.6	0.3	-	-	-	877.0	72.0	476.8	58.5
1957	303.8	213.0	130.1	60.9	24.1	6.6	2.4	0.9	0.2	-	-	-	742.0	79.5	438.2	61.6
1958	336.1	201.4	122.1	58.2	20.1	7.4	2.1	0.7	-	-	-	-	748.0	76.3	411.9	56.9
1959	512.5	206.3	109.3	59.0	24.8	8.5	3.7	0.7	-	-	-	-	923.7	79.1	412.2	62.3
1960	652.8	332.4	127.4	39.2	16.8	8.5	3.9	1.8	0.3	-	-	-	1183.1	92.9	530.3	63.5
1961	948.3	426.6	207.1	73.9	16.7	6.8	4.2	1.8	0.9	-	-	-	1686.3	170.7	738.0	102.5
1962	1549.4	638.0	280.9	117.0	31.8	6.7	3.4	2.0	0.9	0.4	-	-	2630.5	249.9	1081.1	149.8
1963	2002.1	1052.3	422.6	164.8	56.7	15.5	3.3	1.6	1.0	-	-	-	3719.9	367.0	1717.8	225.9
1964	1876.0	1340.1	685.7	245.4	75.9	27.1	8.8	1.8	0.9	0.6	-	-	4262.3	426.3	2386.3	324.6
1965	1344.1	1237.0	866.3	373.8	98.6	30.0	14.5	4.4	0.8	0.3	-	-	3969.8	454.1	2625.7	376.0
1966	901.3	882.3	775.0	377.7	123.0	41.1	13.4	6.7	1.9	0.2	-	-	3122.6	375.4	2221.3	324.6
1967	531.1	597.4	417.1	255.6	101.3	34.3	11.9	2.3	1.7	-	-	-	1952.7	238.0	1421.6	220.1
1968	235.6	345.0	378.2	184.6	86.6	50.0	19.3	6.6	1.0	1.0	-	-	1307.9	185.0	1072.3	175.1
1969	240.6	150.1	212.5	176.3	72.0	41.7	26.4	9.8	3.5	0.2	0.6	-	933.8	156.7	693.2	142.2
1970	341.8	160.1	84.2	47.8	33.4	16.7	19.7	10.4	3.8	1.1	-	0.3	719.1	82.7	377.2	68.8
1971	580.9	203.4	98.4	48.1	14.2	8.0	7.0	9.8	5.1	1.8	0.5	-	977.2	93.9	396.3	63.4
1972	772.1	383.5	108.1	26.1	11.3	3.3	2.4	0.3	-	-	-	-	1307.1	184.4	535.0	115.7
1973	696.1	475.0	190.7	39.1	7.1	6.2	1.8	1.3	-	-	-	-	1417.3	212.8	721.2	152.8
1974	378.4	414.5	179.7	67.7	7.1	1.9	3.4	0.8	0.8	-	-	-	1054.3	177.5	675.9	148.9
1975	(890.0) ⁴	238.9	168.5	58.5	19.9	2.3	0.2	-	-	-	-	-	1378.3	200.3	488.3	99.8
1976	(650.0) ⁴	593.0	128.6	41.8	12.2	5.1	0.3	-	-	-	-	-	1431.0	189.0	781.0	147.9
1977	(1080.0) ⁴	429.2	336.0	55.5	16.8	5.5	2.9	-	-	-	-	-	1925.9	339.2	845.9	201.2
1978	(830.0) ⁴	722.5	270.4	191.5	23.4	7.1	2.3	1.2	-	-	-	-	2048.4	390.4	1218.4	285.8

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 silver hake from the Southern New England - Middle Atlantic stock from USA autumn bottom trawl surveys (strata 1-12) and year-class size (millions of fish) at age 1 from VPA.

Year class	Autumn survey		VPA
	Age 0	Age 1	Age 1
1969	26.13		341.8
1970	28.65		580.9
1971	69.90		772.1
1972	78.20		696.1
1973	19.96		378.4
1974	105.54		(885.1) ¹
1975	57.24		(647.1) ¹
1976	152.83		(1069.8) ¹
1977	93.04		(829.8) ¹

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

$$Y = 81.494X^{.512}, r = 0.869$$

Table 8. Projected catch (age 1+) in 1979 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 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	7.1	386.1	+13.0
.10	14.0	378.4	+10.7
.15	20.7	371.1	+ 8.6
.20	27.1	364.1	+ 6.5
.25	33.3	357.3	+ 4.5
.30	39.3	350.7	+ 2.6
.35	45.1	344.4	+ 0.8
.40	50.7	338.3	- 1.0
.45	56.1	332.5	- 2.7
.50	61.3	326.8	- 4.4
*.55	66.4	321.4	- 6.0
.60	71.3	316.1	- 7.5
.65	76.0	311.0	- 9.0
.70	80.6	306.1	-10.4
.75	85.1	301.4	-11.8
.80	89.4	296.8	-13.2
.85	93.6	292.3	-14.5
.90	97.6	288.1	-15.7
.95	101.5	283.9	-16.9
1.00	105.3	279.9	-18.1

* $F_{0.1}$

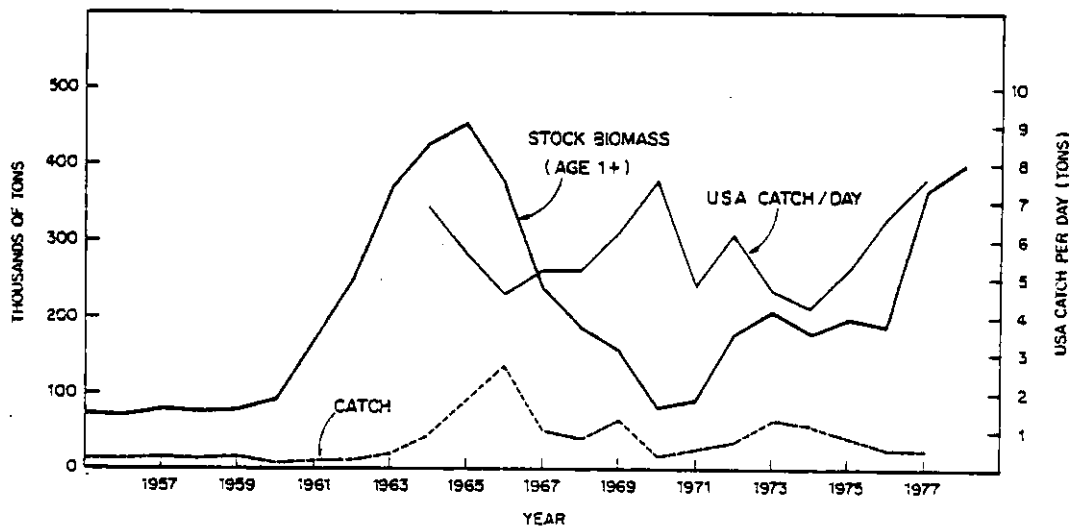


Figure 1. International catch, stock biomass (age 1+) from virtual population analysis, and USA commercial catch-per-day from the Southern New England - Middle Atlantic silver hake stock.

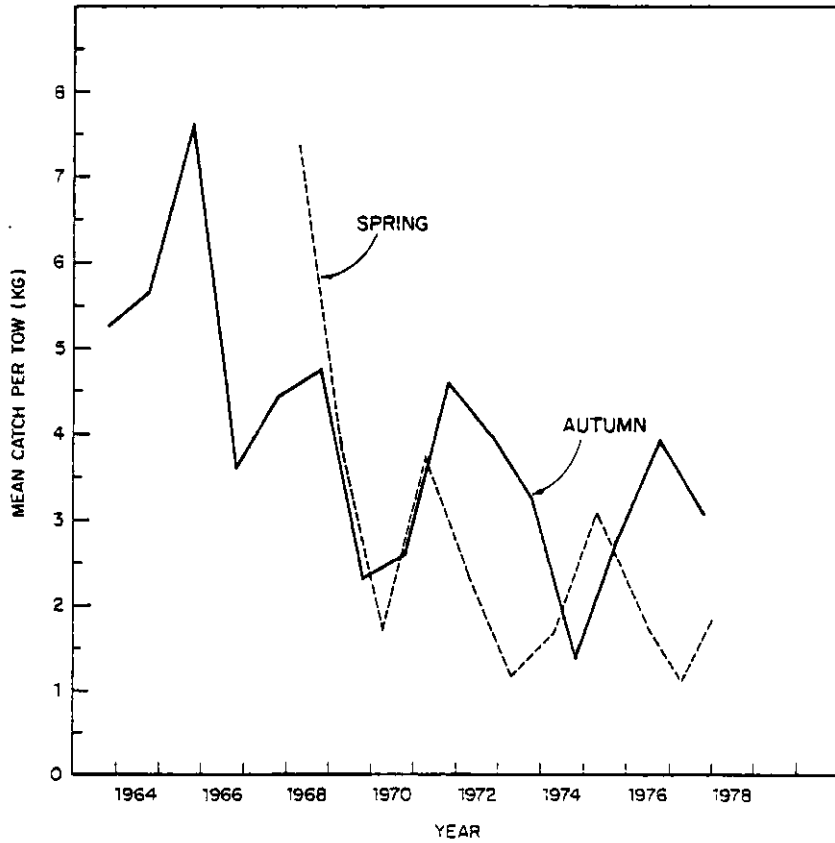


Figure 2. Stratified mean catch-per-tow (kg) of silver hake from the Southern New England - Middle Atlantic stock from USA autumn (1963-77) and spring (1968-78) bottom trawl surveys.

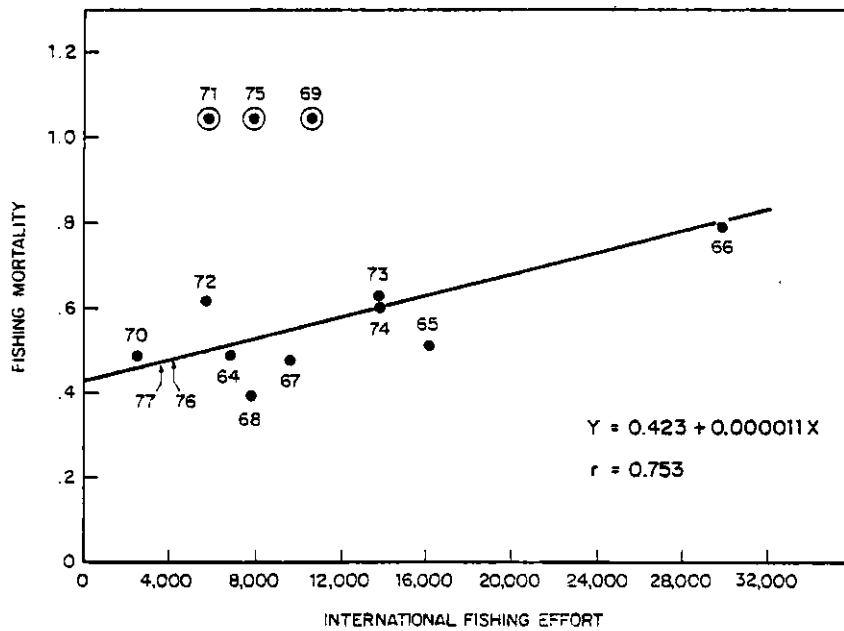


Figure 3. Relationship between fishing mortality from virtual population analysis and international fishing effort expressed as USA days fished for the Southern New England - Middle Atlantic stock. The 1969, 1971, and 1975 values were not used in calculating the line.

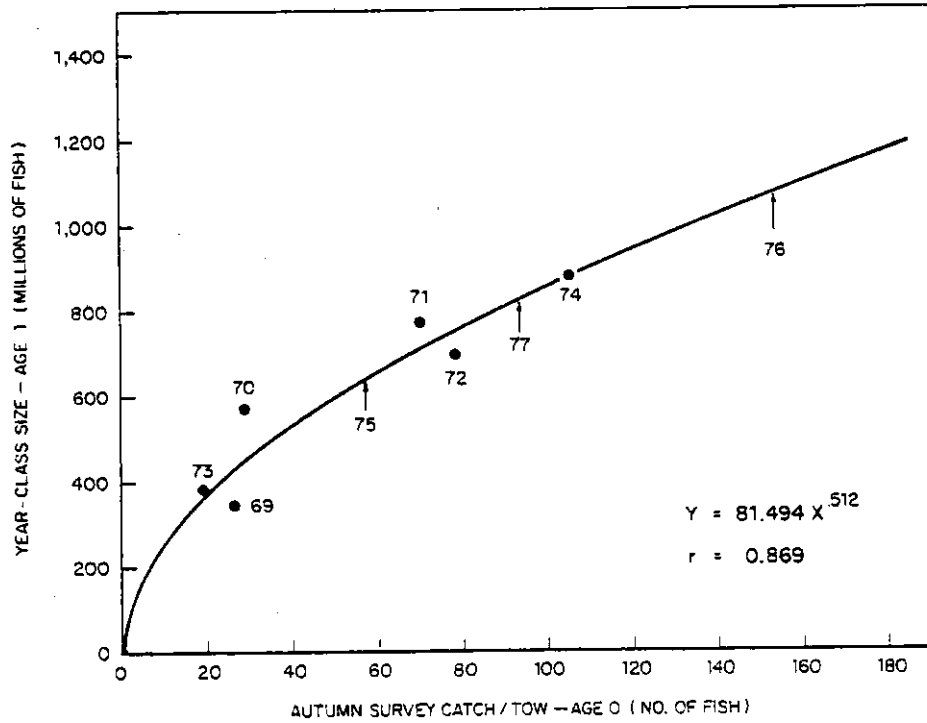


Figure 4. Power curve relationship between Southern New England - Middle Atlantic silver hake year-class size at age 1 and USA autumn survey catch-per-tow at age 0.

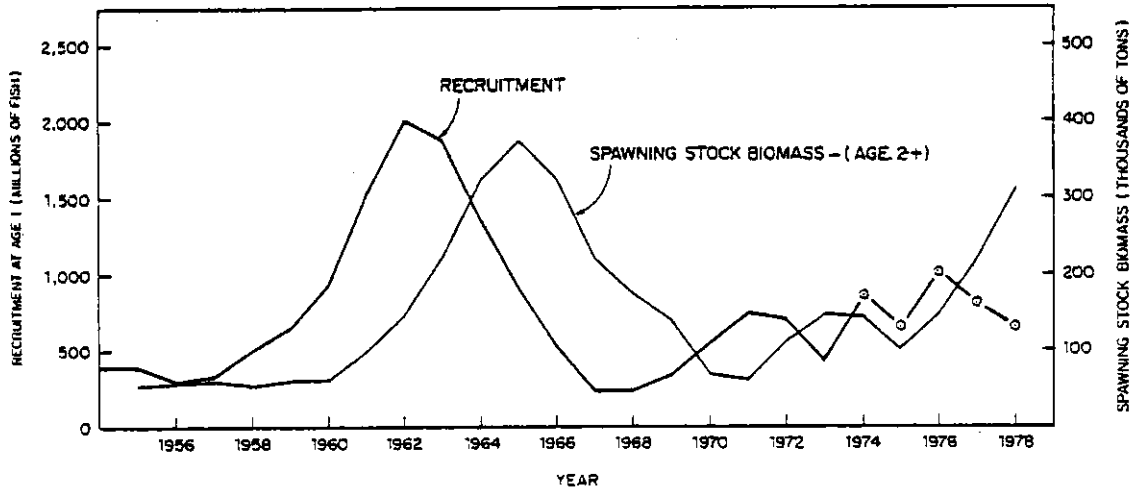


Figure 5. Southern New England - Middle Atlantic silver hake spawning stock biomass (age 2+) in 1955-78 and abundance at age 1 of the 1954-77 year-classes. Open circles indicate estimated year-class sizes.

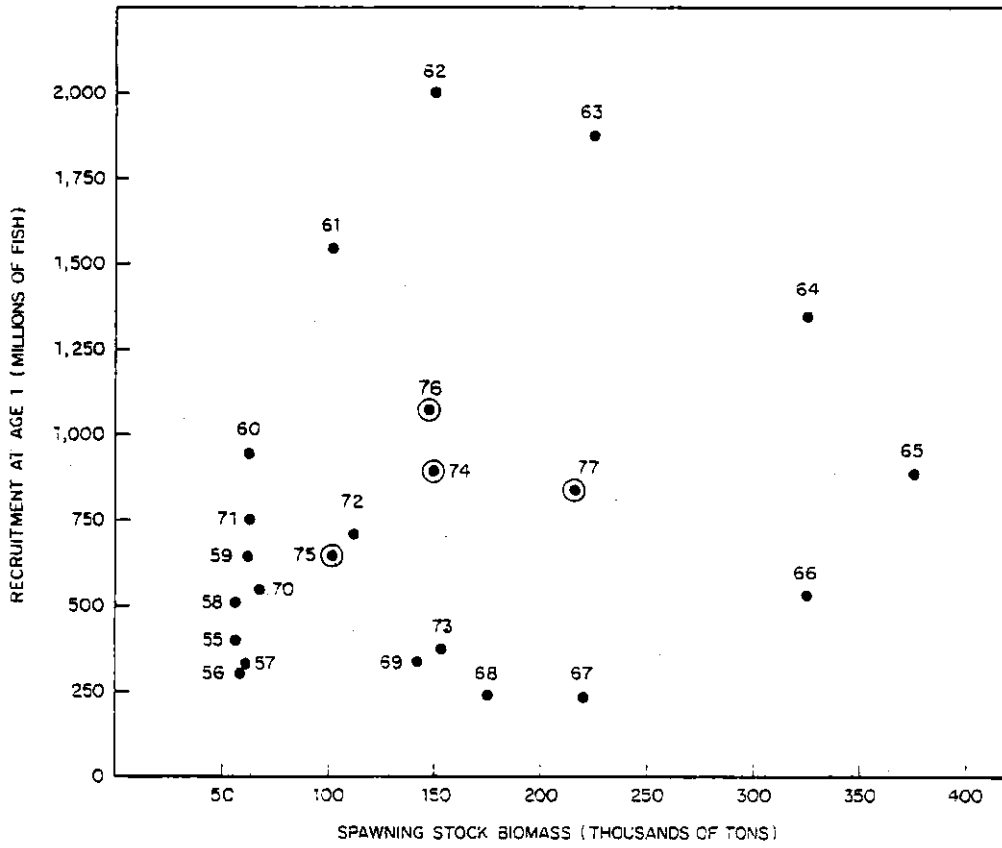


Figure 6. Relationship between spawning stock biomass (age 2+) and recruitment (expressed as abundance at age 1) for the Southern New England - Middle Atlantic silver hake stock during 1965-77. Open circles indicate estimated year-class sizes.

