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STATUS OF THE RED HAKE RESOURCE OFF THE NORTHEAST COAST OF THE UNITED STATES - 1979

by

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INTRODUCTION

This report presents an update of the status of the Georges Bank (ICNAF Subdiv. 5Ze) and Southern New England-Middle Atlantic (ICNAF Subdiv. 5Zw and Stat. Area 6) red hake (*Urophycis chuss*) stocks. Data presented and utilized include international commercial and USA recreational (Southern New England-Middle Atlantic only) catches for 1960-78 with catch in numbers at age for 1963-78 (1965-78 for Georges Bank), USSR catch per effort for 1968-78, and NMFS research vessel bottom trawl survey catch per tow indices for 1963-79.

Analyses include estimates of stock size and fishing mortality generated from virtual population analysis (VPA), estimates of recruitment, and projected catch options in 1980 for various levels of fishing mortality and resultant stock sizes in 1981 for several assumed catch levels in 1979.

CATCH

Georges Bank Stock

International catches increased from 855 tons in 1960 to a high of 53,202 tons in 1965 and then dropped to 1,915 tons in 1970 (Table 1, Figure 1). Catches increased again to 39,366 tons in 1972, decreased to 9,500 tons in 1974, improved to 17,124 tons in 1976, and then dropped sharply to 2,879 tons in 1977 and 964 tons in 1978.

USA catches during 1960-78 have ranged between 5 tons (1964) and 1,518 tons (1961) while averaging 375 tons per year. Catches averaged only 91 tons during 1969-78. The catch in 1978 was 151 tons, the highest since 1972.

Distant-water-fleet catches (primarily USSR) have averaged 96% of the yearly international catch during 1963-78, ranging from a high of 52,706 tons in 1965 to only 813 tons in 1978.

The ICNAF total allowable catch (TAC) was set at 20,000 tons for 1974 and 1975 (for ICNAF Div 5Z east of 69°W) and 26,000 tons for 1976. Following extended jurisdiction by the USA, the optimum yield (OY) was set at 16,000 tons for 1977-79, with 1,500 tons designated as USA commercial capacity in 1977-78 and 1,000 tons in 1979, and the remainder allocated as the total allowable level of foreign fishing (TALFF).

USA catches in 1979 through August have totalled 218 tons, whereas distant-water-fleet catches through September have been only 7 tons.

Southern New England-Middle Atlantic Stock

International catches increased from 4,491 tons in 1960 to a high of 61,153 tons in 1966 and then fluctuated between 10,732 (1970) and 51,007 tons (1969) during 1967076 (Table 2, Figure 2). The catch has declined steadily from 41,803 tons in 1973 to 5,357 tons in 1978.

USA commercial catches increased from 4,174 tons in 1960 to 32,622 tons in 1964, collapsed to 3,629 tons in 1966, and varied between 1,995 (1972) and 6,464 tons (1968) since for an average of about 3,800 tons per year (1966-78). The 1978 catch was 3,326 tons.

USA recreational catch estimates (primarily in the New York-New Jersey area) have ranged from 52 (1975) to 892 tons (1962) based on variours marine angler survey (Almeida et al. 1979). The 1978 recreational catch was estimated to be 700 tons, about the same level as estimated from 1976-77.

Distant-water-fleet catches, which began in 1963, have varied from 770 tons in 1963 to a high of 57,430 tons in 1966 and have averaged about 63% of the annual international catch since 1963. Catches have declined steadily from 37,883 tons in 1973 to 1,331 tons in 1978, the lowest since 1963.

The ICNAF TAC was 40,000, 50,000, and 45,000 tons for 1973, 1974, and 1975, respectively (for ICNAF Div. 5Z west of 69°W and SA 6), and 16,000 tons for 1976. The OY under exclusive USA management was set at 28,000 tons for 1977, 20,500 tons for 1978, and 16,000 tons for 1979. USA commercial and recreational capacity has been designated as 7,600 tons during 1977079, with TALFF decreasing from 20,400 tons in 1977 to 8,400 tons in 1979.

USA catches in 1979 through August were 5,273 tons, whereas distant-water-fleet catches through September totalled about 770 tons.

CATCH COMPOSITION

Georges Bank Stock

Numbers-at-age catch data are presented for 1965-78 (Table 3). These data were calculated using USSR commercial length frequency data, USSR commercial age/length keys and USA survey age/length keys. Pooled USSR keys (Anderson and Almeida 1978) were ustilized form 1965-72 and USA keys for 1973-78.

Age groups 2-5 have comprised the bulk of the catch, averaging 89% of the catch in numbers during 1965-78. The dominant age group has generally been either age 3 or age 2, although age 1 was dominant in 1974. In 1977, age 3 was dominant (53%), whereas in 1978, ages 3-4 were equally dominant comprising 36% each.

Mean weights at age for the 1965-78 catches (Table 4) were applied to the numbers at age (Table 3) to obtain calculated catches (tons). Observed/calculated catch ratios ranged from 0.937 to 1.023 and averaged 0.992. The 1978 mean weights (unadjusted) were used in the projections of 1979-81 catch and stock biomass.

Southern New England-Middle Atlantic Stock

Numbers-at-age catch data for 1963-78 (Table 5) were calculated using USA and USSR commercial length frequency data, USSR commercial age/length keys and USA survey age/length keys. As for the Georges Bank stock, pooled USSR keys were used for 1963-72, and USA keys were used for 1973-78. Sampling data were unavailable for the USA recreational catch, and the total commercial numbers-at-age were raised to include the recreational catch.

Catches have consisted primarily of age 2-4 fish, with these age groups averaging 82% of the catch in numbers during 1963-78. The dominant age group has generally been age 3, averaging 36% of the annual catch, although age 2 fish were dominant in 3 of the last 4 years. In 1978, 39% of the catch was age 2 while ages 3 and 4 comprised 23% each.

Mean weights at age for the 1963-78 catches (Table 6) were applied to the numbers-at-age (Table 5) to obtain calculated catches (tons). Observed/calculated catches varied from 0.887 to 1.042 and averaged 0.999. The 1978 mean weights (unadjusted) were used in the projections of 1979-81 catch and stock biomass.

ABUNDANCE INDICES

Measures of stock abundance were determined from (1) USSR commercial catch-per-effort data and (2) NMFS research vessel bottom trawl survey catch-per-tow data.

USSR catch and effort statistics reported to ICNAF have not identified the amount of fishing effort directed towards individual species even though some species (eg. silver hake, mackerel, herring, red hake) have obviously been the target of directed effort at particular times and areas. If one species comprises the major proportion of the catch for a particular month and area, it can be assumed that the attendant fishing effort was directed primarily at that species, and the catch per unit effort (CPUE) calculated as the ratio between the species catch and the total effort should be representative of the abundance of the species for that area and month. Unfortunately, in the time-series of available data (1968-78), the number of cases where red hake was the predominant species in the catch was insufficient to provide a basis for calculating a CPUE index as described above. Therefore, another approach was taken in calculating a CPUE index.

Monthly catch and effort (hours fished) reprorted by ICNAF division and subdivision during 1968-78 for USSR > 1,800 GT stern trawlers were utilized as the data base. Data price to 1968 were not used since statistics before that year were not reported separately for Subdiv. 5Ze (Georges Bank) and Subdiv. 5Zw (Southern New England). Percentage of the total catch consisting of red hake versus catch per hour of red hake (red hake catch divided by total effort) in each reporting unit (month, ICNAF division or subdivision, and vessel class) was plotted by calender year for each stock. The number of observations per year for each stock varied from 2 to 50 and averaged 20 for the Georges Bank stock and 29 for the Southern New England-Middle Atlantic stock. It was found that positive linear relationship existed between percentage catch and catch per hour. Based on the premise that catch per hour when red hake comprised

100% of the catch would be a valid measure of stock abundance, linear regressions (forced through the origin) were calculated for each calender year and stock, and catch-per-hours values corresponding to 100% red hake catches were obtained from extrapolations of the regression lines. Correlation coefficients (r) averaged 0.935 for the Georges Banks stock and 0.892 for the Southern New England-Middle Atlantic stock; 21 of the 22 regressions for the 2 stocks had coefficients significant at the 99% confidence level.

NMFS autumn bottom trawl surveys (1963-present) and spring surveys during 1968-72 were conducted using a No. 36 Yankee trawl. Spring surveys during 1973-present employed a No. 41 Yankee trawl. Spring catches (by weight) during 1968-72 were adjusted to equivalent No. 41 Yankee catches using a 1.58:1 ratio (41/36). This ratio was taken as the mean of ratios estimated for other species (Sissenwine and Bowman 1978) assumed to have similar vulnerability to the gear as red hake inasmuch as data were not available to estimate a ratio for red hake. A comparable ratio of 1.81:1 was used to adjust the catches by number.

Georges Bank Stock

The catch-per-hour index for USSR > 1,800 GT stern trawlers exhibited a pronounced decline during 1968-78 (Table 7, Figure 1). This trend was interrupted by significatn, but temporary, increases in 1969, 1973, and 1976, each of which was followed by sharp decrease in the following year to a level lower than that of the yar preceding the increase. Throughout the period, the index ranged from a high of 3.62 tons per hour in 1969 to a low of 0.92 tons per hour in 1978.

The NMFS autumn bottom trawl survey catch-per-tow index decreased from 7.86 hg in 1963 to 0.72 hg in 1967 and then fluctuated between 1.01

and 3.02 (average = 1.71) during 1968-74 (Table 8, Figure 3). Catch-per-tow increased to 7.63 hg in 1975 and then declined and remained relatively steady during 1976-78 averaging 4.67 hg.

The spring survey catch-per-tow index (Table 8, Figure 3) increased from 0.41 hg in 1968 to 2.40 hg in 1971 and dropped steadily from averages of 1.74 hg in 1972-73 to 1.31 hg in 1975-76 to 0.20 hg in 1977/78. Catch per tow increased to 0.79 hg in 1979.

Off all the abundance indices, spring survey catch-per-tow corresponds best with changes in stock biomass as indicated by the results from virtual population analysis (VPA)(Table 10, Figure 1). The decline shown by the autumn survey catch per tow from 1963 to 1967 does correpond with VPA results, but thereafter the correspondence is very poor. USSR catch-per-hour roughly paralleled VPA and spring survey results from 1973 to the present, but did not agree with earlier changes in stocks biomass as described by VPA or the surveys. The sharp drop in USSR CPUE in 1977-78, although in agreement with similar declines exhibted by VPA and spring survey results, likely reflects as well the stringent area, season, and gear regulations which have appeared to hamper USSR fishing operations in USA waters.

Southern New England-Middle Atlantic Stock

The USSR catch-per-hour index exhibited no paritcular trend during 1968-76 while fluctuating between 2.18 and 3.46 tons per hour (Table 9, Figure 2), but underwent a substantial drop from 3.46 tons per hour in 1976 to 1.47 tons per hour in 1978.

The NMFS autumn bottom trawl survey catch-per-tow index (Table 8, Figure 4) declined from 8.06 hg in 1963 to 2.67 hg in 1967, increased

to 6.62 hg in 1972 after dropping in both 1970 and 1971, decreased sharply to a low of 0.59 hg in 1974 followed by recovery to 4.34 hg in 1975, and then declined steadily to 2.14 hg in 1978.

The spring survey catch-per-tow index (Table 8, Figure 4) increased from 2.61 hg in 1969 to 8.76 hg in 1972 followed by an eventual decrease to 2.57 hg in 1979 interrupted by 2 abupt increases to 10.61 hg in 1976 and 10.83 hg in 1978.

The autumn and spring catch-per-tow indices exhibited gross similarities in their year-to-year flucturations from about 1971 to the present with only several exceptions (Figure 4). Aside from the 2 sharp increases in the spring catch-per-tow in 1976 and 1978, this index has corresponded well with VPA results. The USSR catch-per-hour index has not corresponded well with VPA results (Figure 2), although about half of the time in the series (1968-78), the direction of change from one year to the next has agreed with the spring survey.

Further analyses are necessary before the lack of good correspondence among all the indices of abundance and the results of the VPA can be corrected or explained.

FISHING MORTALITY

Fishing mortality (F) for fully-recruited ages in 1978 was estimated for each stock using a linear relationship between fishing effort and F. Fishing effort was calculated for each stock as the ratio between international catch and USSR catch-per-hour. Fishing mortality was determined for each calender year as the weighted (by stock size) mean F for fully-recruited ages obtained from VPA. Natural mortality (M) was assumed to be 0.40. The F value for 1978 was selected following an iterative process

(Anderson 1979) consisting of alternative computations of VPA and the fishing effort--fishing mortality linear regression until the F value predicted for 1978 from the regression and the starting F in the VPA for 1978 reached convergence.

Georges Bank Stock

Fishing mortality in 1978 at ages 3 and older was estimated to be 0.10 from a linear relationship between fishing effort and F(r=0.932) (Table 7, Figure 5). Mean F for fully-recruited ages obtained from VPA declined from 0.97 in 1966 to only 0.04 in 1970 followed by a sharp rise to 1.24 in 1972 (Table 10). F decreased to 0.41 in 1974, increased to 0.82 in 1976, and then decreased to 0.30 in 1977 and an estimated 0.10 in 1978.

Southern New England-Middle Atlantic Stock

Fishing mortality in 1978 at ages 3 and older was estimated to be 0.18 from a linear relationship between fishing effort and F(r-0.835) Table 9, Figure 6). Mean F for fully-recruited ages determined from VPA averaged 0.46 in 1963-65, increased to 0.79 in 1966, dropped to 0.24 in 1968, and increased to a high of 0.97 in 1969 (Table 11). Following a drop to 0.22 in 1970, F increased steadily to average 0.93 in 1973-74, dropped to an average of 0.74 in 1975-76, and decreased further to an average of 0.20 in 1977-78.

RECRUITMENT

Georges Bank Stock

The sizes of the 1964-75 year classes at age 1, estimated from VPA, varied between 47 (1975 year class) and 282 (1968 year class) million

fish (Table 10, Figure 9) with a mean size of 188 million and a median size of 164 million. Year-class sizes averaged 278 million for the 1967-69 cohorts but dropped to average 153 million for the 1971-74 year classes. The 1973 year class (168 million) was the strongest since 1970.

NMFS bottom trawl survey data were examined in an attempt to estimate the sizes of the 1976-78 year classes. Inspection of catch-per-tow (in numbers) of age 0 and 1 red hake from autumn and spring surveys, respectively, indicated poor correspondence with year-class sizes at age 1 estimated from VPA, particularly in the case of the spring age 1 data. Of the autumn age 0 catch-per-tow data series, only 1971-75 indices exhibited any similarity with VPA results, even though the correlation had a low significante level (r=0.403). In an attempt to provide a basis for estimating the sizes of the 1976-78 year classes at age 1, a power curve relationship was calculated between autumn survey catch-per-tow at age 0 and VPA year-class size at age 1 for 1971-75 (Table 12, Figure 7). From this relationship, the 1976, 1977, and 1978 year classes at age 1 were estimated to 110, 85, and 110 million fish, respectively. Recent recruitment, therefore, is considered to be poor. All year classes produced since 1970 have been below average, with 1975 estimated to be the weakest.

For the purposes of catch and stock size projections for 1980-81, the 1979 year class was assumed equal to the mean of the 1976-78 cohorts or about 100 million fish at age 1.

Southern New England-Middle Atlantic Stock

The sizes of the 1962-75 year classes at age 1, estimated from VPA, ranged from 103 (1975 year class) to 953 (1962 year class) million fish

(Table 11, Figure 10), with both a mean and median size of 408 million. The 1962-70 cohorts averaged 541 million (range = 341-953), whereas the 1971-75 year classes averaged only 169 million (range = 103-229).

The sizes of the 1976-78 year classes at age 1 were estimated from a power curve relationship between spring survey catch-per-tow (in numbers) at age 1 and VPA year-class size at age 1 for 1967-75 (r = 0.821) (Table 12, Figure 8). These year classes were estimated to be 185, 240, and 70 million, respectively. The 1977 year class appears to be the largest since 1970, whereas the 1978 cohort is estimated to be the poorest in the time-series (1962-present). All recruitment produced since 1970 has been below the 1962-75 mean and on average has been less than the 1962-70 year classes by a factor of 3.2.

For the purposes of catch and stock size projections for 1980-81, the 1979 year class at age 1 was set equal to the mean (160 million) of the previous five year classes (1974-78), which is also similar to the average 1971-78 year-class size.

PARTIAL RECRUITMENT

Partial recruitment of a particular age group to the fishery in a given calender year is defined here as the ratio of the fishing mortality (F) at that age to the average fishing mortality of fully-recruited ages in that year.

Georges Bank Stock

Georges Bank red hake have been fully-recruited to the fishery at age 3 in most years and at age 2 in the remaining years based on the age-specific fishing mortality rates determined from VPA (Table 10). Partial recruitment during 1965-78 varied from 0.0 to 26.8% (average = 6.7%) at

age 1, 5.0 to 100.0% (average = 47.7%) at age 2, and 40.7 to 100.0% (average = 89.0%) at age 3 (Table 13). Partial recruitment decreased substantially at ages 1 and 2 in 1977-78 to an average of 2.2 and 15.2%, respectively, on response to an increase in the codend mesh from 40 to 60 mm by the distant-water-fleets after 1 March 1977. In view of the virtual absence of a USA fishery for red hake on Georges Bank which would possibly employ gear with codend mest larger or smaller than 60 mm, it was assumed that the partial recruitment coefficients estimated for 1977-78 would be representative of expected conditions in 1979-80. Values utilized in the catchprojections for 1979-80 were 5% at age 1, 15% at age 2 and 100% at ages 3 and older. In determining the value for age 1, 5% was selected instead of the 1977-78 mean of 2.2% because the value of 0.0% for 1977 (ie. no age 1 fish were caught or at least represented in the length-age sampling data) was considered atypical and instead only the value of 4.3% in 1978 was used as a basis for estimating the coefficient for 1979-80.

Southern New England-Middle Atlantic Stock

Southern New England-Middle Atlantic red hake habe been fully-recruited to the fishery at age 3 throughout the period based on the age-specific fishing mortality rates determined from VPA (Table 11). Partial recruitment during 1963-78 varied from 0.4 to 19.4% (average = 5.7%) at age 1, 8.0 to 72.4% (average - 36.4%) at age 2, and 60.7 to 100.0% (average = 89.5%) at age 3 (Table 13). Partial recruitment at age 1 remained relatively during 1972-76 and in 1978, averaging 5.0% and ranging between 4.6 and 5.6%. Only in 1977 (19.9%) did partial recruitment deviate from this average. Partial recruitment at age 2 has also remained relatively stable in the recent 5-8 years averaging about 50%. Coefficients selected

for use in the catch projections for 1979-80 were 5% at age 1, 50% at age 2, and 100% at ages 3 and older.

STOCK SIZE

Stock size estimates for 1965-78 for the Georges Bank stock and 1963-78 for the Southern New England-Middle Atlantic stock were determined from VPA (Table 10-11). Mean weights at age (Tables 4-6) were applied to stock size in numbers at age to obtain stock biomass (tons). Annual biomass values were adjusted using the appropriate observed/calculated catch ratios (Tables 3 and 5). The 1979 stock size at age for each stock was determined from the relationship:

$$N_{79} = N_{78}e^{-Z_{78}}$$

Georges Bank Stock

Total stock biomass (ages 1 and older) decreased from an estimated 174,800 tons in 1965 to 67,800 tons in 1969, increased briefly to 102,900 tons in 1971, and then underwent a steady continuous decline to 32,000 tons in 1978 (Table 10, Figure 1). Total biomass at the beginning of 1979 was estimated to be 39,400 tons, a 23% increase from 1978.

Spawning stock biomass (ages 2 and older) decreased from 160,800 tons in 1965 to 45,300 tons in 1968, increased to 87,400 tons in 1971, and then decreased to 17,100 tons in 1977 before recovering to an estimated 28,400 tons at the beginning of 1979 (Table 10, Figure 9).

Southern New England-Middle Atlantic Stock

Total stock biomass (ages 1 and older) decreased steadily from 209,800 tons in 1963, interrupted by a sporadic increase from 112,000 tons in 1968 to 147,000 tons in 1971, to a low of 43,500 tons in 1976 (Table 11, Figure 2). Total biomass increased to an estimated 69,200 tons at the beginning of 1979.

Spawning stock biomass (ages 2 and older) decreased from a high of 173,700 tons in 1965 to 89,600 tons in 1970, increased briefly to 126,000 tons in 1971, and then declined further to an average of 34,600 tons during 1975-77 (Table 11, Figure 10). Spawning biomass increased to an estimated 64,300 tons at the beginning of 1979.

EQUILIBRIUM YIELD

Equilibrium yield was calculated for each stock assuming a constant level of recruitment equal to the long-term mean, partial recruitment at age equal to the long-term eman, and long-term mean weights at age.

Georges Bank Stock

An equilibrium yield curve, based on constant recruitment at age 1 of 172 million fish (1964-78 average year-class size), partial recruitment of 6.7% at age 1, 47.7% at age 2, and 100% at ages 3 and older, and the average mean weights at age for 1965-78 (Table 4), is shown in Figure 11. Equilibruim yield at $F_{0.1}$ = 0.53 is 11,700 tons. Since the curve is virtually asymptotic, F_{max} is not reached until F = 6.50; equilibruim yield at this level of fishing mortality is 14,600 tons.

Southern New England-Middle Atlantic Stock

An equilibruim yield curve, based on constant recruitment at age 1 of 365 million fish (1962-78 average year-class size), partial recruitment of 5.7% at age 1, 36.4% at age 2, and 100% at ages 3 and older, and the average mean weights at age for 1963-78 (Table 6), is shown in Figure 12. Equilibruim yield at $F_{0.1}$ = 0.48 is 22,900 tons, and at F_{max} = 1.55 is 26,300 tons.

CATCH AND STOCK SIZE PROJECTIONS

Georges Bank Stock

Projections of spawning stock biomass (ages 2 and older) available at the beginning of 1980 were made assuming 2 levels of catch in 1979 (Table 14). A catch of 300 tons in 1979 will require an F of 0.017 at ages 3 and older and result in an estimated spawning biomass of 36,800 tons at the beginning of 1980 (30% increase from 1979). A catch of 1,000 tons in 1979 will require an F of 0.059 and result in a spawning stock of 36,100 tons in 1980 (27% increase from 1979).

Projected catches in 1980 at fishing mortality rates ranging from 0.05 to 1.00 and resultant spawning stock biomass levels at the beginning of 1981 were calculated given each of the two 1979 catch options (Table 15). Catches in 1980, given either catch optin in 1979, will vary from 1,100 tons at F = 0.05 to about 15,000 tons at F = 1.00. Resultant spawning stock biomass in 1981 will vary from about 39,000 tons (7-8% increase from 1980) if the 1980 catch is 1,100 tons to about 26,000 tons (27-28% decrease from 1980) if the 1980 catch is about 15,000 tons.

The level of catch in 1980 which would maintain the spawning stock in 1981 at the 1980 level would be about 4,000 tons which would require an F of about 0.20. Fishing at $F_{0.1}$ = 0.53 in 1980 would result in a catch of about 10,000 tons and decrease spawning biomass in 1981 about 15% form 1980.

Southern New England-Middle Atlantic Stock

Projections of spawning stock biomass (ages 2 and older) at the beginning of 1980 were made assuming a 1979 catch of either 8,000 or 10,000 tons (Table 14). A catch of 8,000 tons will require an F of 0.203

at ages 3 and older and result in an estimated spawning biomass of 58,400 tons at the beginning of 1980 (9% decrease from 1979). A catch of 10,000 tons in 1979 will require an F of 0.260 and result in a spawning stock of 56,300 tons in 1980 (12% decrease from 1979).

Projected catches in 1980 at fishing mortality rates ranging from 0.05 to 1.00 and resultant spawning stock biomass at the beginning of 1981 were calculated given each of the two catch options for 1979 (Table 16). Catches in 1980, under either catch level is 1979, will range from 2,100 tons at F = 0.05 to 30,300 tons at F = 1.00. Resultant spawning stock biomass in 1981 will vary from 62,000 tons (11% increase from 1980), given a 1980 catch of 2,100 tons, to 36,000 tons (36-38% decrease from 1980), given a 1980 catch of about 30,000 tons.

The level of catch in 1980 which would maintain the spawning stock in 1981 at the 1980 level would vary from 7,900 to 8,300 tons, depending on the level of catch in 1979, and would require an F of about 0.20. Fishing at $F_{0.1}$ = 0.48 in 1980 would generate a catch of 17,000-18,000 tons and decrease spawning biomass in 1981 about 16-17% from 1980.

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Table 1. Red hake catch (tons) from the Georges Bank stock.[1]

Year	Bulgaria	Canada	Cuba	GDR	Japan	Poland	Romania	Spain	USSR	USA	Other	Total
1960	-	-	-	-	-	-	-	-	-	855	-	855
1961	-	-	-	-	-	-	-	-	-	1,518	-	1,518
1962	-	-	-	-	-	-	-	-	-	963	-	963
1963	-	-	-	-	-	-	-	-	3,205	750	-	3,955
1964	-	-	-	-	-	-	-	-	3,533	5	-	3,538
1965	-	26	-	-	-	-	-	-	52,680	496	-	53,202
1966	-	11	-	-	-	-	-	-	51,181	607	-	51,799
1967	-	7	-	-	-	709	-	61	22,938	458	13	24,186
1968	-	-	-	5	-	-	-	-	4,509	545	-	5,059
1969	-	-	-	-	-	-	-	-	4,237	51	-	4,288
1970	-	-	-	-	-	-	-	-	1,815	100	-	1,915
1971	1,366	-	-	88	6	-	-	-	10,404	111	-	11,975
1972	1,043	-	-	5	187	11	-	-	37,960	160	-	39,366
1973	172	-	-	-	-	9	-	5	24,406	74	-	24,666
1974	72	-	-	-	-	-	149	57	9,145	77	-	9,500
1975	19	-	-	-	1	-	-	8	14,921	55	-	15,004
1976	-	-	329	-	-	-	20	-	16,738	37	-	17,124
1977	-	-	-	-	-	-	-	-	2,783	96	-	2,879
1978	-	-	-	-	1	-	-	-	812	151	-	964

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

Table 2. Red hake catch (tons) from the Southern New England-Middle Atlantic stock.[1]

Year	Bulgaria	Cuba	GDR	Italy	Japan	Poland	Romania	Spain	USSR	USA Commercial	USA Recreational	Total
1960	-	-	-	-	-	-	-	-	-	4,174	317[2]	4,491
1961	-	-	-	-	-	-	-	-	-	8,047	612	8,659
1962	-	-	-	-	-	-	-	-	-	11,737	892	12,629
1963	-	-	-	-	-	-	-	-	770	29,608	770	31,148
1964	-	-	-	-	-	-	-	-	8,427	32,622	848	41,897
1965	-	-	-	-	-	-	-	-	17,611	24,759	634[2]	43,004
1966	-	-	-	-	-	-	-	-	57,430	3,629	94	61,153
1967	-	-	-	-	-	39	-	-	29,539	6,331	165	36,074
1968	-	-	-	-	-	-	-	-	8,698	6,464	575	15,737
1969	114	-	-	-	-	-	-	-	44,913	5,491	489	51,007
1970	197	-	-	-	-	-	-	-	5,534	4,591	410[2]	10,732
1971	1,218	-	9	-	8	-	-	-	23,234	3,225	287	27,981
1972	471	-	40	-	549	5	43	-	33,368	1,995	177	36,648
1973	216	-	-	-	2	25	-	-	37,640	3,603	317	41,803
1974	401	-	-	-	-	-	51	-	20,917	2,182	191[2]	23,742
1975	14	-	-	-	-	-	-	4	11,195	2,065	52[2]	13,330
1976	-	-	-	-	-	-	35	-	7,122	3,904	645[2]	11,706
1977	-	37	-	-	-	-	8	1	2,370	2,514	750[2]	5,680
1978	-	-	-	55	9	-	-	-	1,267	3,326	700[3]	5,357

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

[2]From angler surveys; remaining years estimated (see text).

Table 3. Red hake catch-at-age (millions of fish) from the Georges Bank stock (+ denotes less than 0.1 million).

Year	AGE 1	2	3	4	5	6	7	8	9	10+	Total	Observed Weight	Calculated Weight[1]	Obs/ Calc
1965	0.9	34.0	94.5	67.4	30.2	11.6	4.5	2.3	0.7	0.7	246.6	53,202	56,772	0.937
1966	0.3	16.5	74.0	71.4	33.8	10.8	3.3	1.5	0.4	0.1	212.1	51,799	51,712	1.002
1967	0.4	11.4	19.8	22.6	16.0	7.8	4.2	2.2	0.6	+	85.0	24,186	24,010	1.007
1968	0.1	2.4	6.9	6.0	3.4	1.1	0.5	0.2	0.1	+	20.6	5,059	5,093	0.993
1969	0.1	17.5	7.2	2.6	1.0	0.3	0.2	0.1	+	+	29.0	4,288	4,396	0.975
1970	0.5	5.4	3.4	1.3	0.7	0.3	0.1	0.1	+	+	11.8	1,915	1,962	0.976
1971	5.9	17.1	13.9	10.5	6.1	2.4	1.0	0.6	0.2	+	57.7	11,975	12,120	0.988
1972	6.6	42.6	55.8	48.2	28.5	9.0	3.1	1.4	0.5	0.1	195.8	39,366	39,336	1.001
1973	8.1	29.7	34.8	14.3	5.6	2.1	0.7	0.4	0.1	0.3	96.1	24,666	24,540	1.005
1974	14.5	12.1	11.3	5.2	1.6	0.5	0.2	0.1	+	0.7	46.3	9,500	9,557	0.994
1975	6.6	29.0	21.6	8.7	2.5	1.1	0.7	0.3	0.1	+	70.6	15,004	14,992	1.001
1976	3.9	40.4	20.1	10.5	3.4	1.2	1.2	0.2	+	+	80.9	17,124	17,261	0.992
1977	-	1.7	6.6	3.7	0.4	0.1	0.1	0.1	+	+	12.7	2,879	2,890	0.996
1978	0.3	0.3	1.4	1.4	0.5	+	+	+	-	-	3.9	964	942	1.023

[1]Using mean weights at age (Table 4).

Table 4. Mean weights (kg) at age for the red hake catch from the Georges Bank Stock.

	AGE									
Year	1	2	3	4	5	6	7	8	9	10+
1965	.06	.12	.19	.24	.31	.41	.50	.53	.72	.80
1966	.08	.13	.20	.25	.31	.37	.43	.47	.54	.76
1967	.09	.12	.19	.28	.34	.42	.52	.56	.64	.64
1968	.09	.14	.20	.25	.32	.38	.46	.50	.50	.61
1969	.06	.11	.18	.23	.31	.39	.46	.52	.50	.71
1970	.08	.11	.17	.25	.32	.38	.42	.45	.46	.55
1971	.07	.12	.22	.26	.33	.40	.45	.56	.54	.72
1972	.02	.07	.18	.25	.30	.36	.42	.50	.55	.79
1973	.13	.22	.27	.30	.36	.32	.35	.32	.55	.33
1974	.12	.20	.26	.30	.35	.33	.40	.34	.52	.31
1975	.09	.17	.23	.30	.36	.42	.42	.54	.72	.68
1976	.14	.18	.22	.29	.31	.36	.32	.53	.62	.44
1977	-	.18	.21	.26	.31	.48	.46	.18	.78	.37
1978	.10	.16	.22	.29	.30	.54	.51	.51	-	-

Table 5. Red hake catch-at-age (millions of fish) from the Southern New England-Middle Atlantic stock (+ denotes less than 0.1 million).

Year	AGE 1	2	3	4	5	6	7	8	9	10+	Total	Observed Weight	Calculated Weight[1]	Obs/ Calc
1963	8.2	34.3	68.0	34.1	8.5	2.4	1.4	0.6	+	-	157.5	31,148	30,382	1.025
1964	49.9	76.6	120.5	38.1	6.9	1.9	0.9	0.4	+	-	295.2	41,897	40,475	1.035
1965	9.4	50.2	107.0	47.4	11.0	3.2	1.2	0.6	+	-	230.0	43,004	42,026	1.023
1966	2.6	13.3	95.9	88.7	25.2	7.1	3.5	1.3	+	-	237.6	61,153	60,836	1.005
1967	4.2	17.9	41.1	44.6	15.2	7.7	3.9	1.3	+	+	135.9	35,516	35,888	0.990
1968	2.7	14.3	24.4	20.5	5.8	2.5	1.2	0.5	0.2	0.2	74.1	15,737	17,748	0.887
1969	1.6	25.6	98.4	64.3	20.4	6.2	2.1	1.0	+	+	219.6	51,007	51,441	0.992
1970	5.3	12.1	19.8	10.7	3.4	1.4	0.7	0.3	0.1	+	53.6	10,732	10,903	0.984
1971	3.2	74.4	50.3	21.2	5.9	2.3	1.1	0.7	0.3	0.1	159.5	27,981	27,537	1.016
1972	5.6	72.4	84.4	39.0	10.8	4.4	1.6	0.9	0.1	+	219.2	36,648	36,363	1.008
1973	6.3	27.6	60.6	36.5	27.1	4.8	2.2	1.7	0.3	+	167.1	41,803	40,111	1.042
1974	4.7	30.9	39.8	19.1	13.2	1.9	0.9	0.8	0.2	-	111.5	23,742	23,852	0.995
1975	5.8	20.0	19.7	10.9	3.5	2.1	1.1	0.2	0.7	+	63.9	13,330	13,340	0.999
1976	3.0	30.2	17.1	8.2	2.6	1.4	0.7	0.1	0.6	+	64.0	11,706	11,860	0.987
1977	6.3	8.0	9.4	3.1	1.1	0.3	0.2	0.1	-	-	28.5	5,680	5,721	0.993
1978	1.9	8.9	5.2	5.2	0.7	0.4	0.1	+	+	-	22.8	5,357	5,301	1.010

[1]Using mean weights at age (Table 6).

Table 6. Mean weights (kg) at age for the red hake catch from the Southern New England-Middle Atlantic stock.

	AGE									
Year	1	2	3	4	5	6	7	8	9	10+
1963	.06	.11	.18	.27	.32	.39	.51	.50	.67	-
1964	.03	.10	.16	.23	.28	.39	.46	.47	.59	-
1965	.05	.11	.18	.24	.30	.38	.47	.53	.82	.89
1966	.05	.13	.21	.29	.32	.39	.47	.49	.68	1.08
1967	.05	.10	.21	.32	.35	.42	.46	.49	.60	.89
1968	.05	.11	.18	.27	.32	.40	.53	.57	.88	1.08
1969	.05	.12	.20	.28	.33	.37	.49	.55	.64	.85
1970	.05	.10	.21	.29	.32	.38	.47	.51	.65	.89
1971	.05	.11	.18	.27	.37	.43	.49	.56	.70	1.02
1972	.04	.09	.16	.25	.31	.39	.48	.52	.69	1.05
1973	.06	.13	.21	.28	.35	.44	.42	.33	.39	1.28
1974	.10	.14	.21	.27	.31	.41	.42	.30	.26	-
1975	.08	.13	.23	.30	.30	.36	.33	.47	.27	1.01
1976	.09	.13	.22	.28	.28	.33	.30	.41	.27	1.26
1977	.07	.16	.26	.30	.36	.42	.37	.30	-	-
1978	.07	.16	.28	.34	.44	.35	.38	.64	.64	-

Table 7. USSR catch per hour for red hake and estimation of fishing mortality (F) in 1978 for the Georges Bank red hake fishery.

Year	USSR catch per hour (tons) > 1800 GT stern trawlers	International Fishery		
		Catch (tons)	Fishing effort[1]	Fishing mortality[2]
1968	2.64	5,059	1,916	0.199
1969	3.62	4,288	1,185	0.115
1970	2.43	1,915	788	0.036
1971	2.33	11,975	5,139	0.158
1972	2.06	39,366	19,110	1.237
1973	2.95	24,666	8,361	0.920
1974	1.97	9,500	5,491	0.411
1975	1.66	15,004	9,039	0.571
1976	2.87	17,124	5,967	0.821
1977	1.52	2,879	1,894	0.297
1978	0.92	964	1,048	(0.102)[3]

[1]Expressed as hours fished by USSR > 1800 GT stern trawlers; determined as ratio between international catch and USSR catch per hour.

[2]Weighted mean F for fully-recruited ages from virtual population analysis assuming F = 0.100 in 1978.

[3]Calculated from linear regression of fishing effort on fishing mortality for 1968-75: $Y = 0.032 + 0.0000664X$, $r = 0.932$.

Table 8. Stratified mean catch per tow (kg) of red hade from NMFS bottom trawl surveys for the Georges Bank (Spring - strata 13-20; Autumn - strata 13-23, 25) and Southern New England-Middle Atlantic (Spring and Autumn - strata 1-12) stocks.

	Georges Bank		Southern New England-Middle Atlantic	
Year	Spring[1]	Autumn[2]	Spring[1]	Autumn[2]
1963	-	7.86	-	8.05
1964	-	2.61	-	4.35
1965	-	2.10	-	5.63
1966	-	1.42	-	2.90
1967	-	0.72	-	2.67
1968	0.41	1.34	3.05	4.42
1969	0.65	1.82	2.61	4.80
1970	1.38	1.01	3.77	3.90
1971	2.40	2.05	8.50	3.37
1972	1.72	1.19	8.76	6.62
1973	1.75	3.02	6.38	3.05
1974	0.66	1.56	4.76	0.59
1975	1.26	7.63	4.30	4.34
1976	1.35	4.42	10.61	3.38
1977	0.21	4.98	3.12	3.16
1978	0.18	4.61	10.83	2.14
1979	0.79	-	2.57	-

[1]Based on catches with No. 41 trawl; 1968-72 catches with No. 36 trawl and were adjusted to equivalent No. 41 catches using a 1.58:1 ratio (41/36).

[2]Based on catches with No. 36 trawl.

Table 9. USSR catch per hour for red hake and estimation of fishing mortality (F) in 1978 for the Southern New England-Middle Atlantic red hake fishery.

Year	USSR catch per hour (tons) > 1800 GT stern trawlers	International Fishery		
		Catch (tons)	Fishing effort[1]	Fishing mortality[2]
1968	2.75	15,737	5,733	0.245
1969	2.60	51,007	19,618	0.969
1970	3.17	10,732	3,385	0.216
1971	2.18	27,981	12,835	0.347
1972	2.22	36,648	16,508	0.596
1973	2.93	41,803	14,267	0.940
1974	3.36	23,742	7,066	0.921
1975	2.32	13,330	5,746	0.706
1976	3.46	11,706	3,383	0.775
1977	1.95	5,680	2,913	0.217
1978	1.47	5,357	3,644	(0.173)[3]

[1]Expressed as hours fished by USSR > 1800 GT stern trawlers; determined as ratio between international catch and USSR catch per hour.

[2]Weighted mean F for fully-recruited ages from virtual population analysis assuming F = 0.180 in 1978.

[3]Calculated from linear regression of fishing effort on fishing mortality for 1968-73: $Y = 0.009 + 0.0000450X$, $r = 0.835$.

Table 10

Table 11

TABLES 10 And 11 ARE MISSING

Table 12. Catch per tow (numbers) of age 0 red hake from the Georges Bank stock during NMFS Autumn bottom trawl surveys and age 1 red hake from the Southern New England-Middle Atlantic stock during Spring surveys and year-class size (millions of fish) at age 1 from virtual population analysis.

	Georges Bank		Southern New England-Middle Atlantic	
Year Class	Autumn survey[1] Age 0	VPA Age 1	Spring survey[2] Age 1	VPA Age 1
1967	0.07	275.8	2.89	340.7
1968	0.08	282.3	0.98[4]	500.0
1969	8.03	277.3	7.32	620.1
1970	3.17	224.8	3.09	413.5
1971	7.11	147.7	1.48	229.1
1972	2.47	137.9	1.35	175.3
1973	10.88	168.4	1.71	124.2
1974	33.38	156.3	1.27	212.8
1975	4.47	47.4	1.69	102.8
1976	5.38	(111.3)[3]	1.60	(183.5)[5]
1977	1.49	(-84.3)[3]	2.20	(239.1)[5]
1978	4.78	(108.5)[3]	0.50	(-69.8)[5]

[1]Based on catches with No. 36 trawl.

[2]Based on catches with No. 41 trawl; 1968-72 catches were with No. 36 trawl and were adjusted to equivalent No. 41 catches using a 1.81:1 ratio (41/36).

[3]Calculated from a power curve relationship of Autumn survey catch per tow at age 0 on VPA year-class size at age 1 for 1971-75: In Y = 4.348 + 0.216 in X, r = 0.403.

[4]Value not used in calculating curve as it is abnormally low in comparison to year-class size.

[5]Calculated from a power curve relationship of spring survey catch per tow at age 1 on VPA year-class size at age 1 for 1967-75: In Y = 4.882 + 0.831 in X, r = 0.831.

Table 13. Percentage of fishing mortality (F) at ages 1, 2, and 3 (partial recruitment) compared to mean F at ages 3 and older for the Georges Bank and Southern New England-Middle Atlantic red hake fisheries.

	Georges Bank			Southern New England-Middle Atlantic		
Year	Age 1	Age 2	Age 3	Age 1	Age 2	Age 3
1963	-	-	-	2.3	17.4	88.9
1964	-	-	-	18.2	31.6	100.0
1965	0.7	27.2	84.1	6.5	34.5	98.6
1966	0.3	13.0	81.6	0.9	8.0	79.6
1967	0.4	25.2	40.7	1.7	12.7	60.7
1968	0.2	14.1	92.0	4.1	22.4	69.4
1969	0.4[1]	100.0[1]	100.0[1]	0.4	15.2	85.1
1970	5.6[1]	97.2[1]	100.0[1]	4.6	20.8	93.1
1971	20.3[1]	75.3[1]	92.4[1]	2.6	70.6	95.4
1972	4.5	34.7	73.6	5.0	63.8	100.0
1973	8.0	51.7	100.0	4.8	26.8	89.3
1974	26.8	45.3	100.0	5.1	43.3	100.0
1975	9.3[1]	73.6[1]	100.0[1]	4.8	50.8	88.1
1976	12.8[1]	80.3[1]	93.1[1]	4.6	39.4	100.0
1977	0.0	25.3	88.2	19.4	72.4	83.9
1978	4.3	5.0	100.0	5.6	52.8	100.0

[1]Compared to mean F at ages 2 and older.

Table 14. Various levels of catch of red hake in 1979 and associated fishing mortality at ages 3 and older with resulting spawn-stock biomass in 1980 and its percentage change from 1979. Catch and stock are expressed as thousands of tons.

Stock in 1979	Catch in 1979	F in 1979	Stock in 1980	% change in stock from 1979
		Georges Bank Stock		
28.4	0.3	0.017	36.8	+29.6
28.4	1.0	0.059	36.1	+27.1
		Southern New England-Middle Atlantic Stock		
64.3	8.0	0.203	58.4	- 9.2
64.3	10.0	0.260	56.3	-12.4

Table 15. Projected red hake catch on Georges Bank in 1980 with fishing mortality ranging from 0.05 to 1.00, assuming two options for catch in 1979, and the resulting spawning stock biomass in 1981 and its percentage change from 1980. Catch and stock are expressed as thousands of tons.

Fishing mortality (F)	1979 catch = 0.3			1979 catch = 1.0		
	Catch in 1980	Stock in 1981	% change in stock from 1980	Catch in 1980	Stock in 1981	% change in stock from 1980
0.05	1.1	39.5	+ 7.3	1.1	38.9	+ 7.8
0.10	2.2	38.5	+ 4.6	2.1	38.0	+ 5.3
0.15	3.2	37.5	+ 1.9	3.1	37.1	+ 2.8
0.20	4.1	36.6	- 0.5	4.0	36.2	+ 0.3
0.25	5.1	35.8	- 2.7	4.9	35.4	- 1.9
0.30	6.0	35.0	- 4.9	5.8	34.5	- 4.4
0.35	6.8	34.2	- 7.1	6.6	33.8	- 6.4
0.40	7.6	33.4	- 9.2	7.4	33.0	- 8.6
0.45	8.4	32.7	-11.1	8.2	32.3	-10.5
0.50	9.2	32.0	-13.0	8.9	31.7	-12.2
0.53[1]	9.6	31.6	-14.1	9.3	31.3	-13.3
0.55	9.9	31.3	-14.9	9.6	31.0	-14.1
0.60	10.6	30.7	-16.6	10.3	30.4	-15.8
0.65	11.2	30.1	-18.2	10.9	29.8	-17.5
0.70	11.9	29.5	-19.8	11.6	29.2	-19.1
0.75	12.5	29.0	-21.2	12.2	28.7	-20.5
0.80	13.1	28.4	-22.8	12.7	28.2	-21.9
0.85	13.7	27.9	-24.2	13.3	27.7	-23.3
0.90	14.2	27.4	-25.5	13.8	27.2	-24.7
0.95	14.7	27.0	-26.6	14.3	26.7	-26.0
1.00	15.2	26.5	-28.0	14.8	26.3	-27.1

[1] $F_{0.1}$

Table 16. Projected red hake catch in Sourthern New England-Middle Atlantic in 1980 with fishing mortality ranging from 0.05 to 1.00, assuming two options for catch in 1979, and the resulting spawning stock biomass in 1981 and its percentage change from 1980. Catch and stock are expressed as thousands of tons.

Fishing mortality (F)	1979 catch = 8.0			1979 catch = 10.0		
	Catch in 1980	Stock in 1981	% change in stock from 1980	Catch in 1980	Stock in 1981	% change in stock from 1980
0.05	2.2	64.1	+ 9.8	2.1	62.5	+11.0
0.10	4.4	62.0	+ 6.2	4.2	60.5	+ 7.5
0.15	6.4	59.9	+ 2.6	6.2	58.5	+ 3.9
0.20	8.3	58.0	- 0.7	8.0	56.6	+ 0.5
0.25	10.2	56.1	- 3.9	9.8	54.8	- 2.7
0.30	12.0	54.4	- 6.8	11.5	53.1	- 5.7
0.35	13.7	52.7	- 9.8	13.2	51.5	- 8.5
0.40	15.3	51.1	-12.5	14.8	50.0	-11.2
0.45	16.9	49.5	-15.2	16.3	48.5	-13.9
0.48[1]	17.8	48.6	-16.8	17.2	47.6	-15.5
0.50	18.4	48.1	-17.6	17.7	47.0	-16.5
0.55	19.8	46.6	-20.2	19.1	45.7	-18.8
0.60	21.2	45.3	-22.4	20.4	44.4	-21.1
0.65	22.4	44.0	-24.7	21.7	43.2	-23.3
0.70	23.8	42.8	-26.7	22.9	42.0	-25.4
0.75	25.0	41.6	-28.8	24.1	40.8	-27.6
0.80	26.2	40.5	-30.7	25.2	39.8	-29.4
0.85	27.3	39.4	-32.5	26.3	38.7	-31.3
0.90	28.3	38.4	-34.2	27.3	37.7	-33.1
0.95	29.4	37.4	-36.0	28.3	36.8	-34.7
1.00	30.3	36.5	-37.5	29.2	35.9	-36.3

[1] $F_{0.1}$

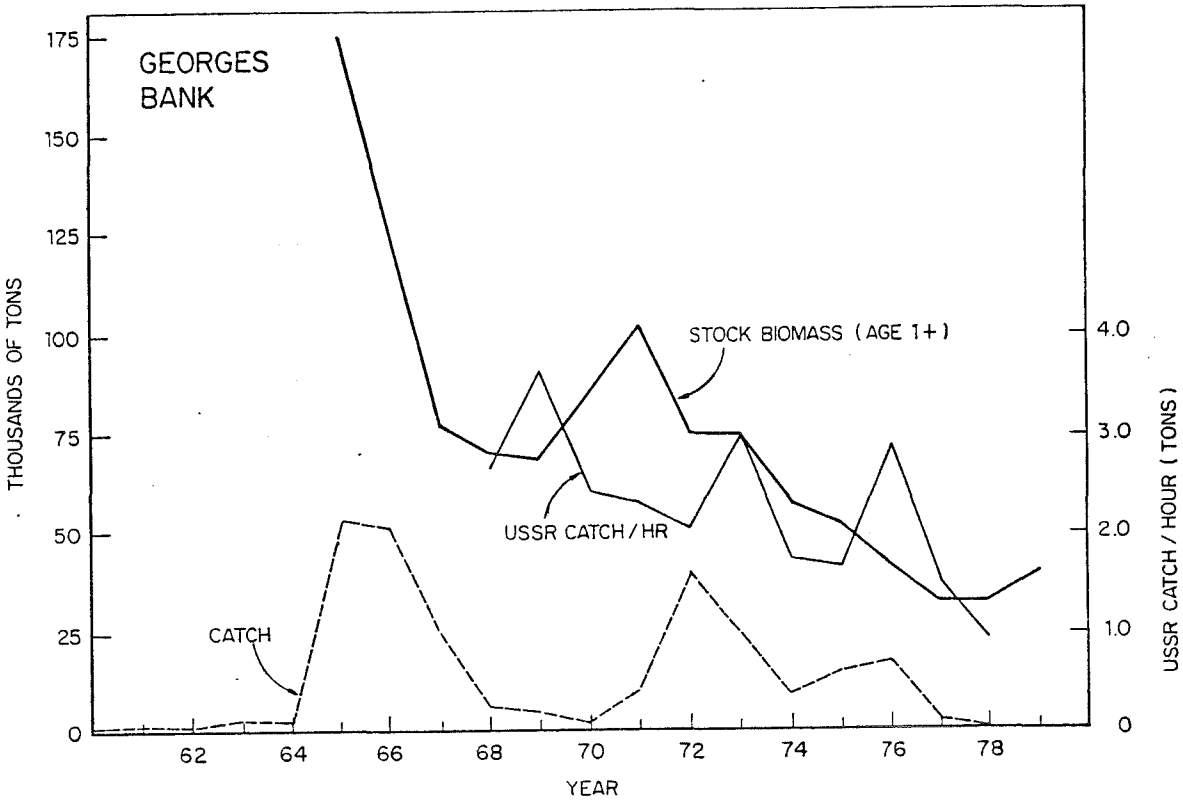

Figure 1. International catch, stock biomass (age 1+) from VPA, and USSR catch per hour from the Georges Bank red hake stock.

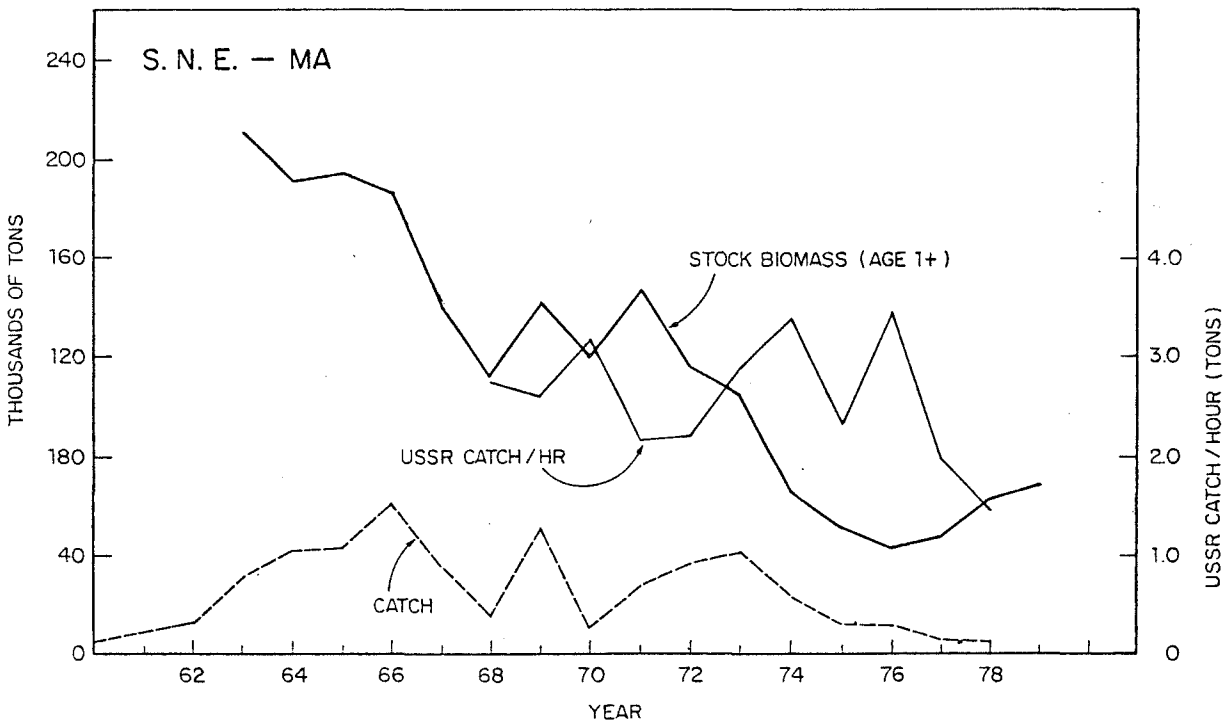

Figure 2. International catch, stock biomass (age 1+) from VPA, and USSR catch per hour from the Southern New England-Middle Atlantic red hake stock.

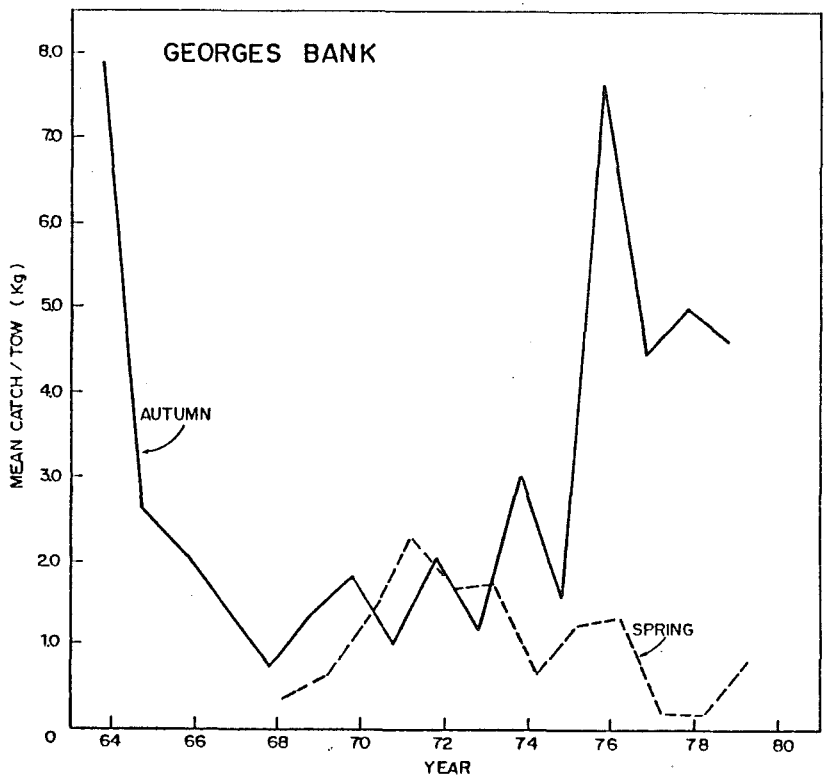

Figure 3. Stratified mean catch per tow (kg) of red hake from the Georges Bank stock from USA autumn (1963-78) and spring (1968-1979) bottom trawl surveys.

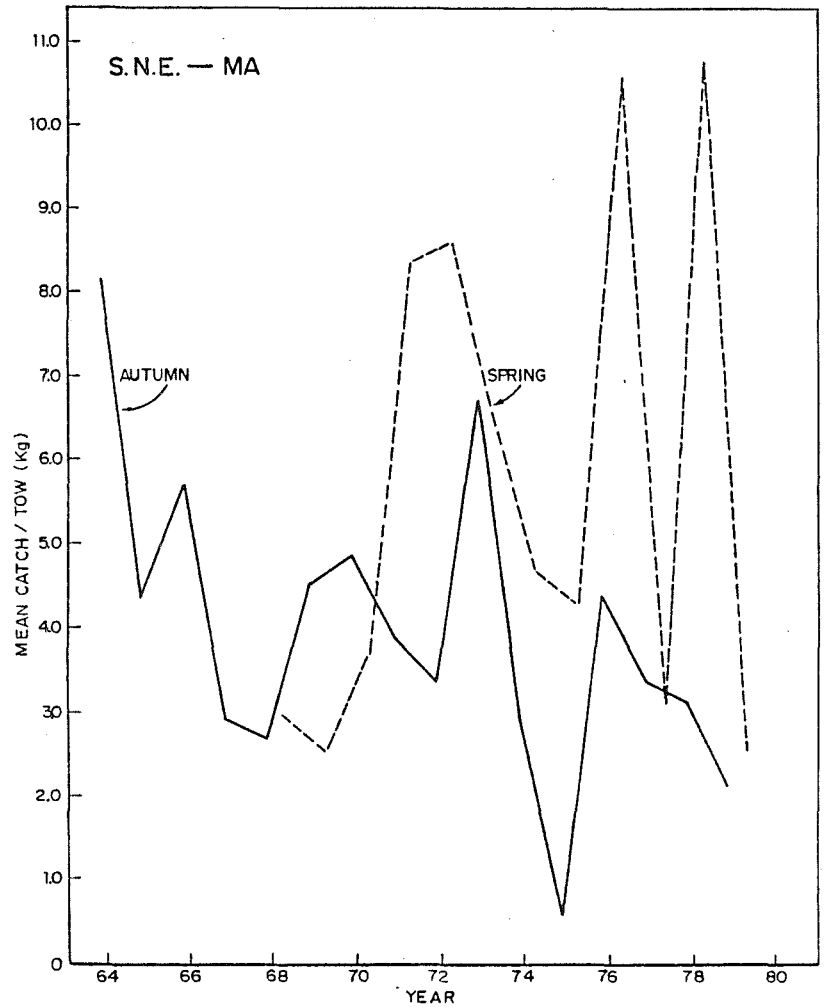

Figure 4. Stratified mean catch per tow (kg) of red hake from Southern New England-Middle Atlantic stock from USA autumn (1963-78) and spring (1968-79) bottom trawl surveys.

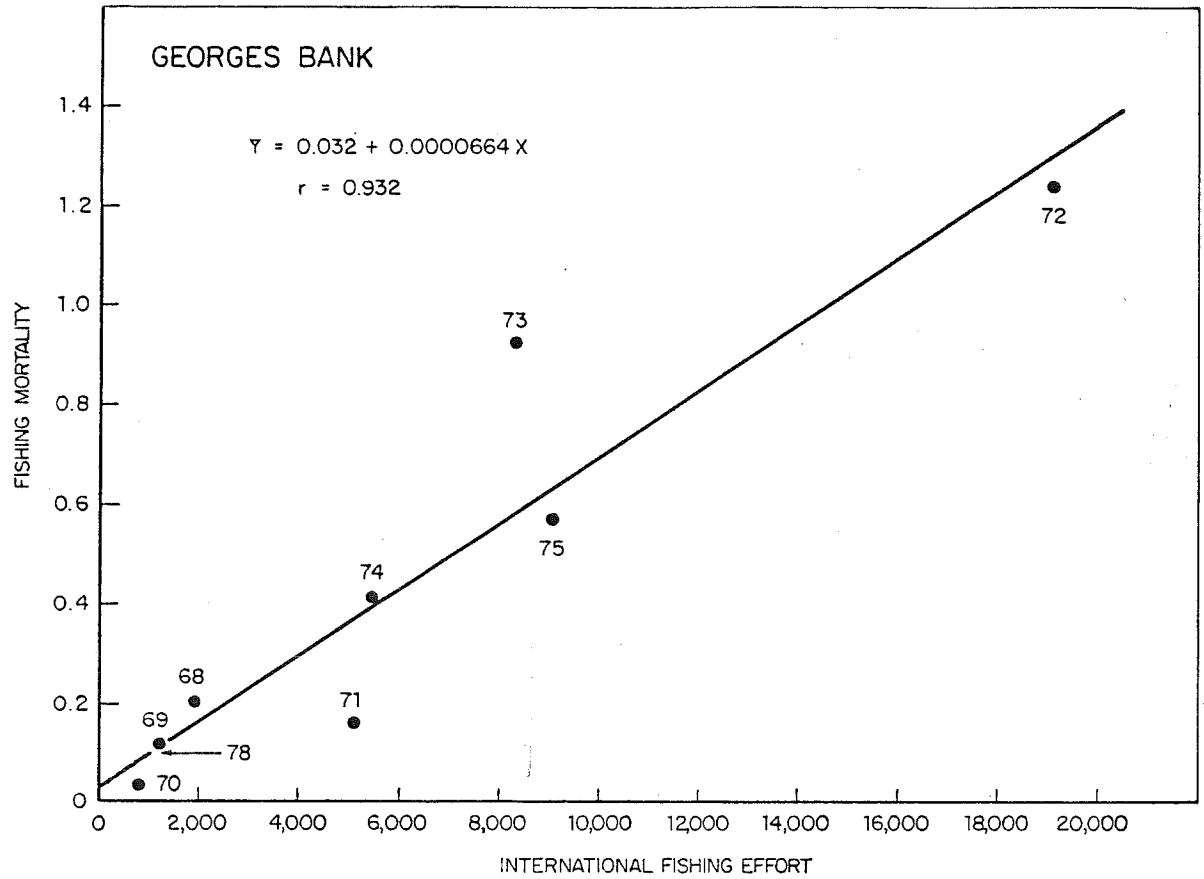

Figure 5. Relationship between fishing mortality from VPA and fishing effort derived from USSR catch per hour and international catch for the Georges Bank red hake stock.

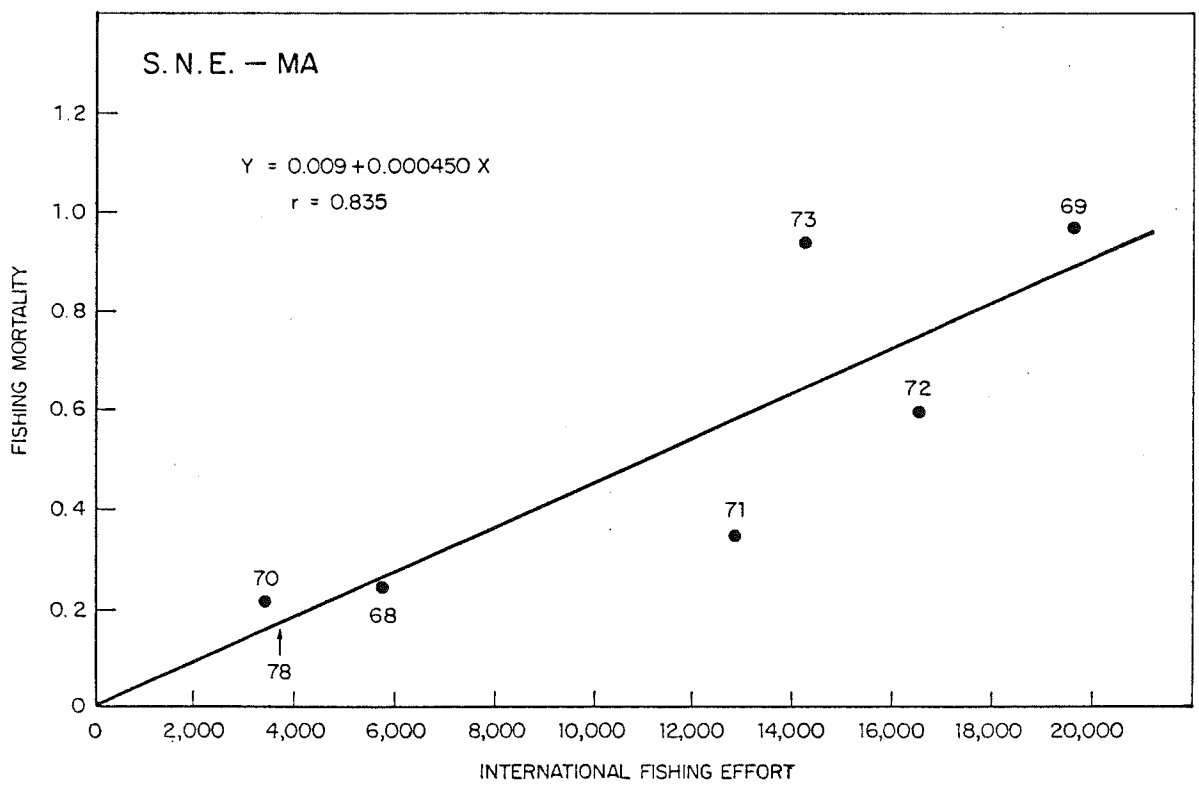

Figure 6. Relationship between fishing mortality from VPA and fishing effort derived from USSR catch per hour and international catch for the Southern New England-Middle Atlantic red hake stock.

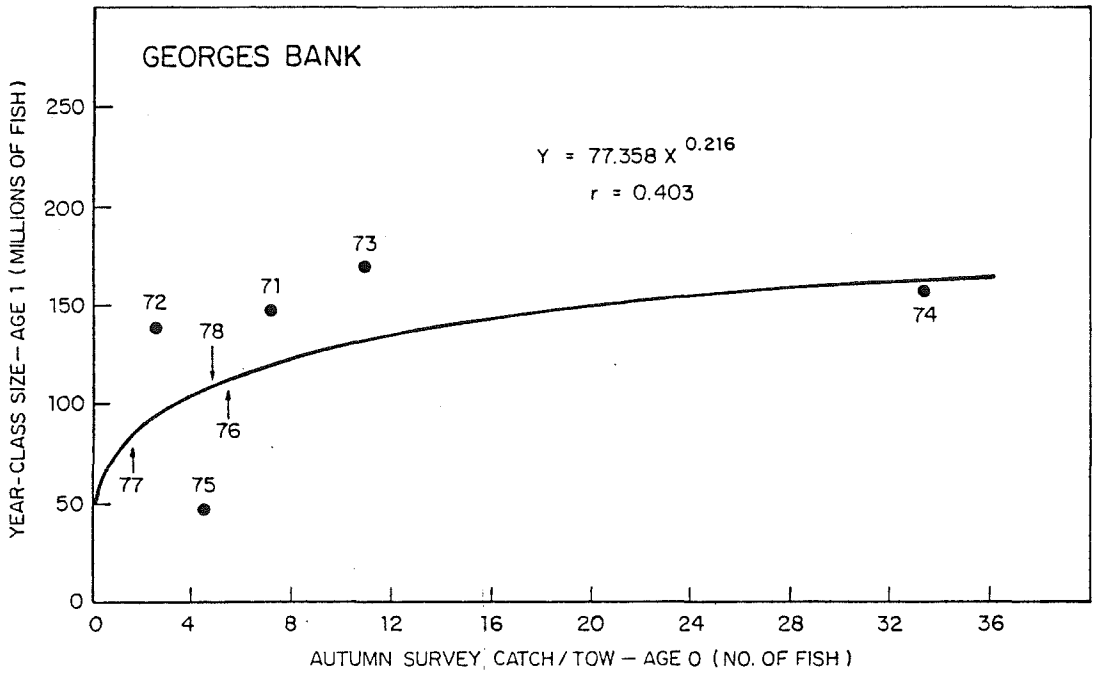

Figure 7. Relationship between autumn survey catch per tow at age 0 and year-class size at age 1 from VPA for the Georges Bank red hake stock.

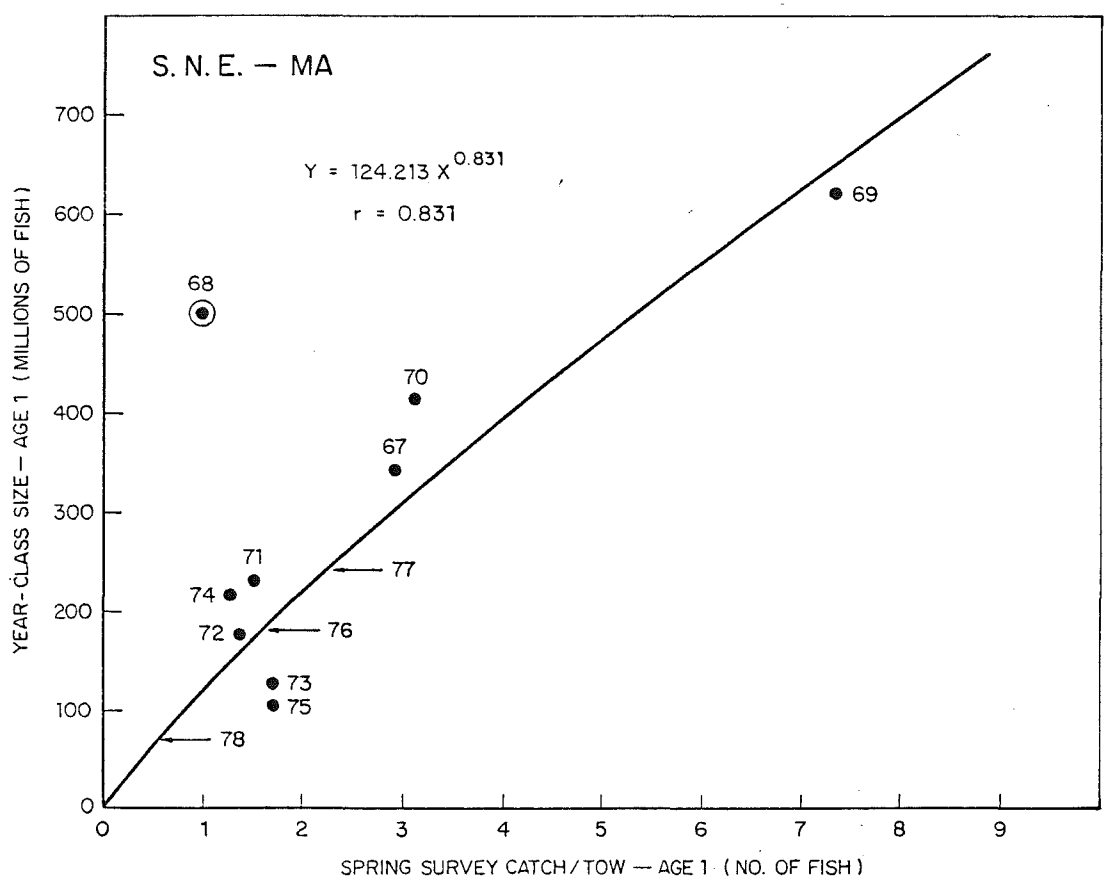

Figure 8. Relationship between spring survey catch per tow at age 1 and year-class size at age 1 from VPA for the Southern New England-Middle Atlantic red hake stock. The 1968 value was not used in calculating the relationship.

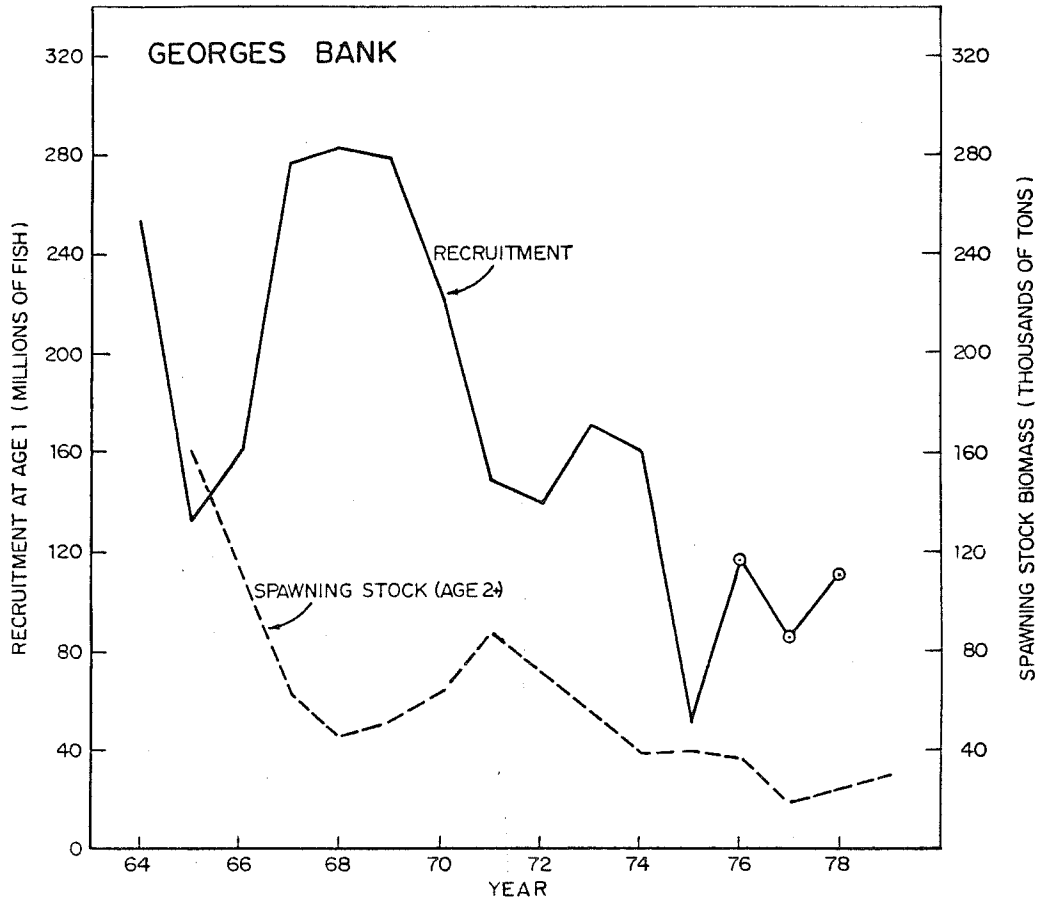

Figure 9. Relationship between spawning stock biomass (age 2+) and recruitment (expressed as abundance at age 1) for the Georges Bank red hake stock during 1964-78. Open circles indicate an assumed year-class size.

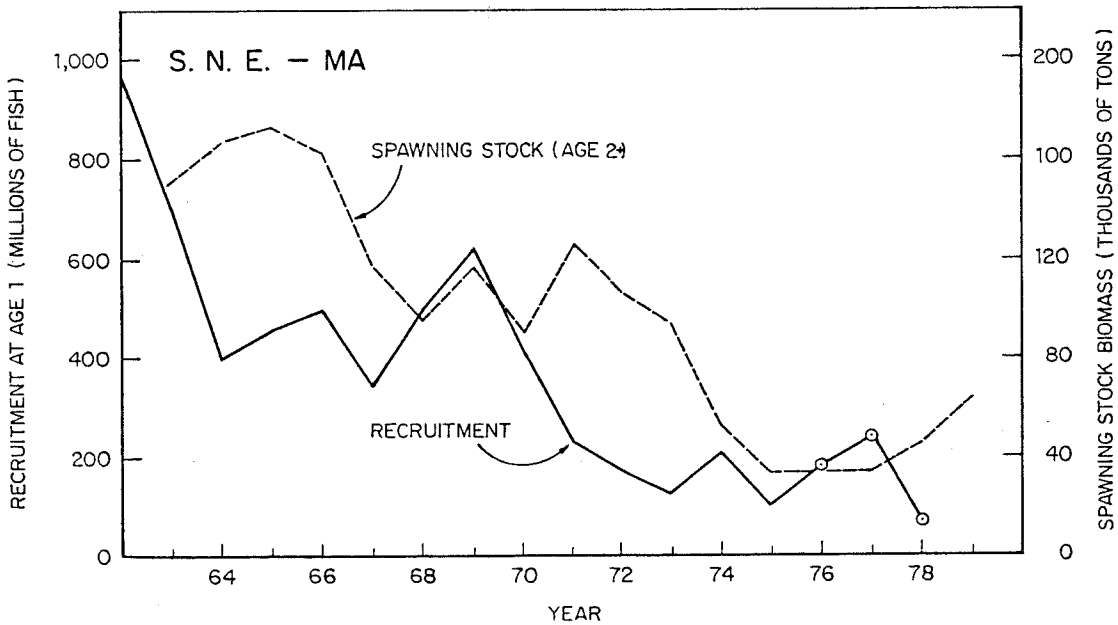

Figure 10. Relationship between spawning stock biomass (age 2+) and recruitment (expressed as abundance at age 1) for the Southern New England-Middle Atlantic red hake stock during 1963-78.

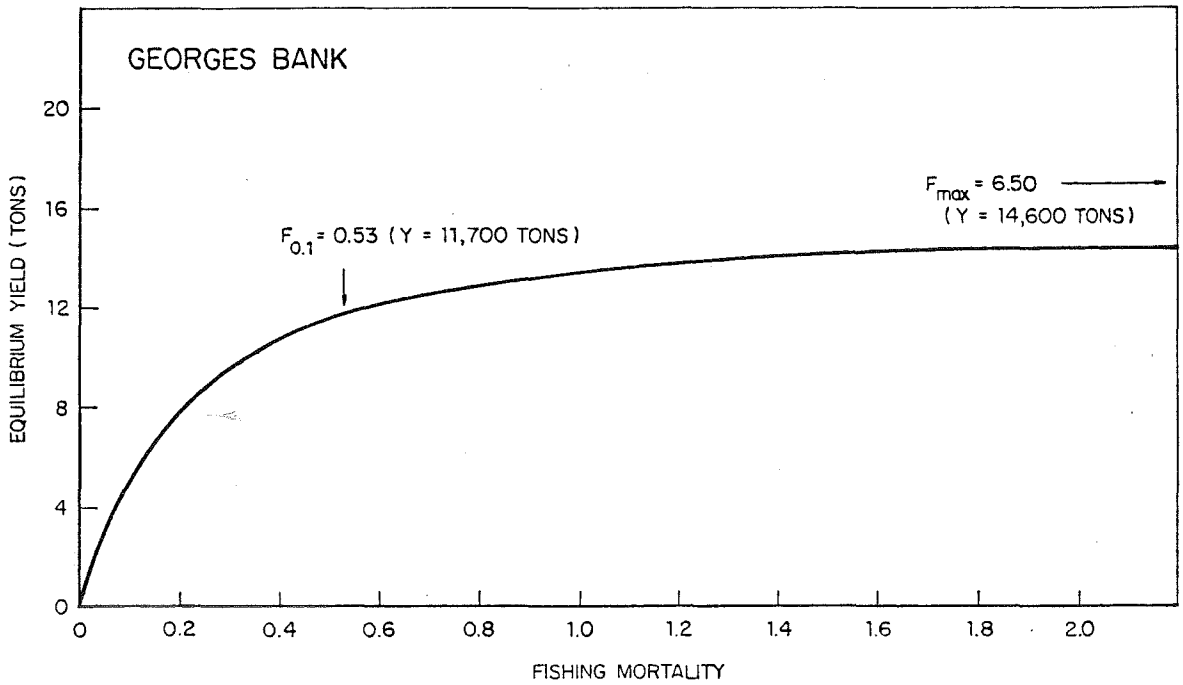

Figure 11. Equilibrium yield curve for the Georges Bank red hake stock.

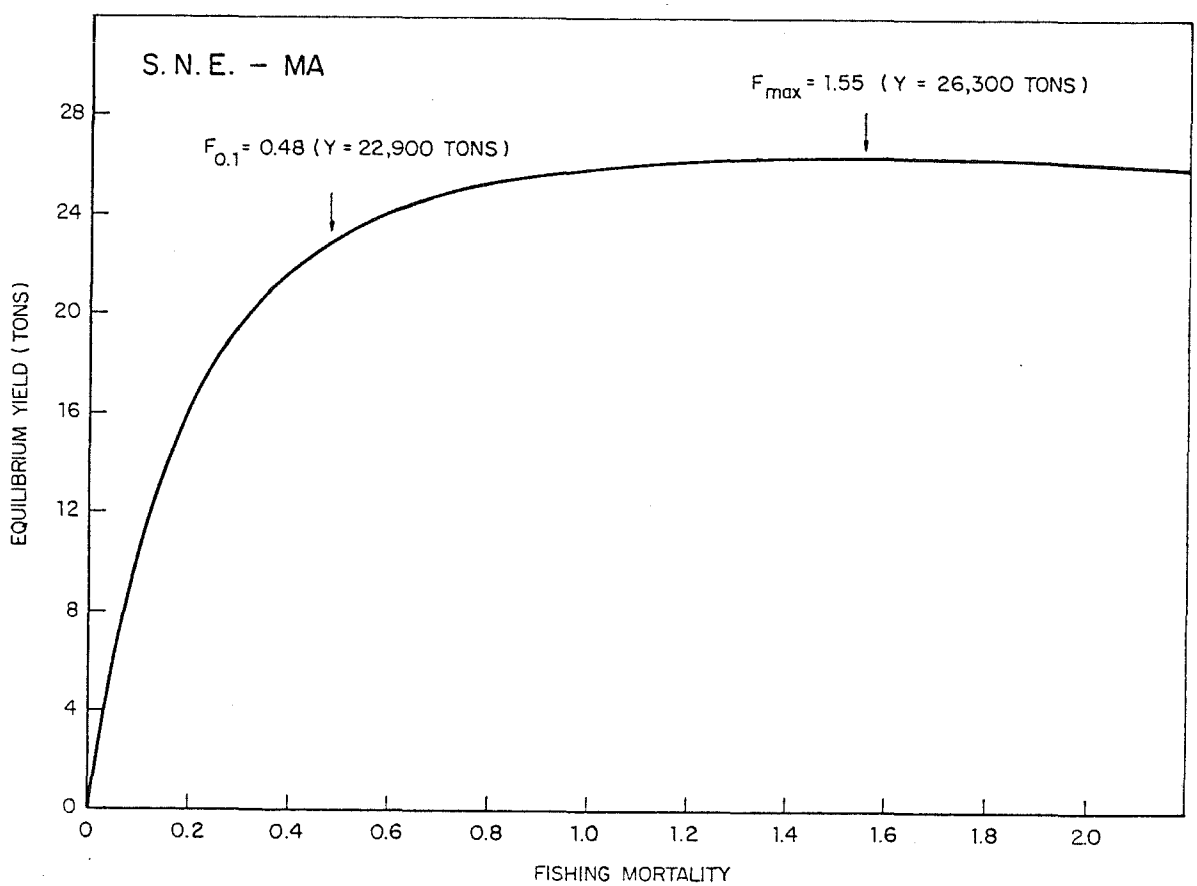

Figure 12. Equilibrium yield curve for the Southern New England-Middle Atlantic red hake stock.