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STATUS OF THE RED HAKE RESOURCE OFF THE NORTHEAST COAST OF THE UNITED STATES - 1981

by

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INTRODUCTION

This report presents an update of the status of the Georges Bank (NAFO Subdiv. 5Ze) and Southern New England-Middle Atlantic (NAFO Subdiv. 5Zw and 6) red hake (Urophycis chuss) stocks. Data presented and utilized include international commercial and USA recreational (Southern New England-Middle Atlantic only) catches for 1960-1980 with catch in numbers at age for 1963-1980 (1965-1978 for Georges Bank) and NMFS research vessel bottom trawl survey catch-per-tow data for 1963-1981.

For the Southern New England-Middle Atlantic stock, analyses include estimates of stock size and fishing mortality generated from virtual population analysis (VPA), estimates of recruitment, and projected catch in 1982 for various levels of fishing mortality and resultant stock sizes in 1983 for several assumed catch levels in 1981.

Due to low levels of catch in both 1979 and 1980, as well as very limited sampling of the catch in those years, it was not possible to estimate the catch at age in numbers necessary for performing a VPA for the Georges Bank stock. Consequently, estimates of stock size after 1978 were derived utiliizing a relationship between VPA-generated stock size in previous years and abundance indices from research vessel survey data. It was also not possible to provide catch and stock size projections for this stock for 1981-1983.

GEORGES BANK STOCK

Catch and Management History

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, then decreased to 9,500 tons in 1974 before improving to 17,124 tons in 1976. Since 1976, catches have declined steadily to only 280 tons in 1980, the lowest level in the 1960-1980 time series.

USA catches during 1960-1980 ranged between 5 tons (1964) and 1,518 tons (1961) while averaging 362 tons per year. Catches averaged only 68 tons during 1973-1977 before increasing to 272 tons in 1979, the highest level since 1968. The 1980 catch was 240 tons.

Distant-water-fleet (DWF) catches, primarily from the USSR, averaged approximately 96% of the catch during 1963-1977 ranging from 1,815 tons in 1970 to a high of 52,680 tons in 1965. Since the implementation of extended jurisdiction in 1977, DWF catches have declined sharply with reported landings of 812 tons in 1978, to a series low of only 11 tons in 1979. In 1980, catches totaled 40 tons taken by Japan (58%) and Spain (42%) only.

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 1977-1979, with 1,500 tons designated as domestic annual harvest (DAH) in 1977-1978 and

1,000 tons in 1979, and the remainder allocated as the total allowable level of foreign fishing (TALFF). In 1980, the OY was reduced to 6,000 tons with 500 tons alloted to the USA and 5,500 tons designated as TALFF. In 1981, OY and DAH were maintained at 6,000 and 500 tons, respectively, but TALFF was reduced to 2,500 tons, with 3,000 tons placed in reserve.

Commercial Catch Composition

Catch (in numbers) at age for 1965-1978 (Table 2) was estimated using USA and USSR commercial length frequency data, supplemented by NMFS Foreign Fishery Observer Program data during 1977 and 1978, and USSR commercial age/length keys and USA bottom trawl survey age length keys. Pooled USSR keys (Anderson and Almeida 1978) were utilized for 1965-1972 and USA keys for 1973-1978.

Ages 2-5 comprised the bulk of the catch during 1965-1978, averaging 89% of the catch in numbers. The dominant age group was generally 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 codominant, comprising 36% each. Due to the low levels of catch and lack of sampling data, estimates for 1979-1980 were unavailable.

Mean weights at age for the 1965-1978 catches (Table 3) were applied to the numbers at age (Table 2) to obtain calculated catches (tons). Observed/calculated catch ratios ranged from 0.937 to 1.023 and averaged 0.991. These ratios were utilized to adjust the calculated stock biomass values obtained from VPA.

Abundance Indices

Due to the nature of both the foreign and domestic red hake fisheries and the difficulty in defining directed red hake effort, there are no commercial catch-per_effort indices for either stock. The inability to distinguish directed red hake effort is because of the by-catch status of this species in the Georges Bank fishery and the mixed species nature of the USA commercial fishery in Southern New England-Middle Atlantic waters.

Research vessel mean catch per tow

The NMFS, NEFC spring bottom trawl survey catch-per-tow index (kg, linear scale) reached a series high of 2.40 kg in 1971, then decreased, with one fluctuation, to a low of 0.18 kg in 1978. Since 1978, the index has increased steadily to 1.17 kg in 1981, but is still well below the 1970-1973 average of 1.81 kg (Table 4, Figure 2). Catch per tow in numbers (linear scale) has followed a similar trend, reaching a high in 1971, dropping to low levels in the late 1970's, then increasing steadily through 1981 (Table 5).

The autumn survey, after reaching a high of 7.86 kg in 1963, dropped sharply in 1964 and averaged 1.71 kg during 1964-1974. The index then increased abruptly in 1975 to 7.63 kg but, after dropping in 1976, remained relatively steady averaging 4.17 kg during 1976-1980 (Table 4, (Figure 3). Catch per tow in numbers was at its highest level in 1975 (45.2) but dropped in 1976 and remained relatively constant during 1976-1981 (average=26.3) (Table 5).

The precision of the mean catch-per-tow values (kg, linear scale) was evaluated by calculating coefficients of variation (CV), defined as the ratio of the standard deviation to the mean (Table 4). The CV's for the spring surveys (1968-1981) averaged 0.46 and for the autumn (1963-1980) averaged 0.30. These rather high coefficients indicate that, on an absolute basis, only very large proportional changes in abundance would normally be detected by the surveys. One possible reason for the high levels of variation in the indices may be misidentification of red hake in the survey catches. Red hake ranging in length from about 20cm to 45cm are often difficult to distinguish from white hake, Urophysis tenuis, and as such,may have been misidentified during some surveys. Differences in the growth patterns of the otoliths of red and white hake make it possible to distinguish between the species in the laboratory. An effort to quantify the extent of misidentifications and possibly determine correction factors by examining survey otolith collections is presently underway.

Mean catch per tow at age

Mean catch per tow at age (numbers, linear, scale) for 1970-1981 was determined by applying age length keys, prepared by examining otoliths collected from a subset of the total survey catch, to the appropriate length frequency data from spring and autumn bottom trawl surveys (Table 5). Ages ranged from 1 to 12 in the spring surveys and 0 to 12 in the autumn (ages 10 and older were combined in the table).

The indices, used to evaluate relative year-class strength

during the survey period, indicated that the 1973 and 1974 year classes were quite strong compared to other year classes. The strength of these two year classes was also verified by the commercial catch-at-age statistics (Table 2) in that they comprised an average of 64% of the total catch (in numbers) during 1975-1978. In 1976 and 1977, the total catch (Table 2) consisted of 75% and 81% of these two year classes, respectively. All year classes since 1974 have appeared weaker than the 1973-1974 year classes.

Fishing Mortality

Fishing mortality (F) for fully recruited ages in 1978 (the most current year with fishery catch-at-age data and the terminal year for VPA) was estimated from a power curve relationship between relative exploitation (international catch divided by USA spring survey catch per tow) and fishing mortality from VPA. Fishing mortality was determined for each calendar 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 consisting of alternate computations of VPA and the fishing mortality-relative exploitation relationship until the F value predicted for 1978 from the relationship and the starting F in the VPA for 1978 reached convergence. The F value selected for 1978 was 0.165 ($r=0.896$, $p<0.01$) for ages 3 and older (Table 6, Figure 4).

The 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 increase to 1.25 in 1972 (Table 7). F then decreased to 0.42 in 1974, increased to 1.02 in 1976 and then declined to an estimated 0.17 in 1978. Based on the relationship used to predict F in 1978, F in 1979-1980 was estimated to be less than 0.01.

Recruitment

The sizes of the 1964-1975 year classes at age 1, estimated from VPA, ranged from a low of 33 million fish (1975 year class) to a high of 282 million fish (1968 year class) (Table 7, Figure 7). Year-class sizes have steadily decreased from an average of 264 million for the 1967-1970 cohorts to 143 million for the 1971-1974 cohorts and 33 million for the 1975 year class. The 1973 year class, estimated to be 156 million, was the strongest since 1970.

The estimate of the 1976 year class size was obtained by first calculating a linear regression ($r=0.808$, $p<0.01$) between spring survey catch per tow at age 2+ (numbers) and age 2+ stock size (millions) from VPA for 1970-1977 (Table 8a). The relationship predicted a spawning stock size (age 2+) of 68.4 million fish in 1978. This estimate, minus the stock size for ages 3 and older (26.2 million) determined by VPA, resulted in an age 2 stock size in 1978 (1976 cohort) of 42.2 million fish. Given a year-class size of 42.2 million fish and a catch of 0.3 million fish, (Table 2) an $F=0.009$ was implied. With no appreciable catch of age 1 fish in 1977 and an assumed $M=0.4$, a 1976 year-class size of approximately 63.0 million fish at age 1 was indicated.

From an examination of research vessel mean catch per tow at age and previous year-class sizes from VPA, the 1977 year class was assumed to be equal to 110 million fish, the approximate average of the 1971-1976 year-class sizes.

Attempts to establish predictive relationships between research vessel abundance indices at ages 0 and 1 and VPA estimates of year-class size to estimate the sizes of the 1978-1980 cohorts did not produce any useful results. Based on qualitative examinations of the research vessel survey data and on relationships predicting total stock and spawning stock biomass (see Table 8b), the 1978-1980 year classes were estimated to be about 120-140 million fish at age 1.

Stock Size

Stock size estimates (in numbers) for 1965-1977 were computed from VPA (Table 7). Mean weights at age (Table 3) were applied to stock numbers at age to obtain annual stock biomass estimates which were then adjusted using the appropriate obseved/calculated catch ratios from Table 2.

Total stock biomass (ages 1+) was estimated from VPA for 1965-1976, and for 1977-1981 were calculated using a power curve relationship between spring survey catch-per-tow data and total stock size for previous years obtained from VPA ($r=0.747$, $p<0.01$), (Table 8a, Figure 5). Biomass decreased from 174,700 tons in 1965 to 67,500 tons in 1969, increased briefly to 102,300 tons in 1971, and then underwent a steady decline to only 18,200 tons in 1977. Since 1977, biomass increased steadily to 62,300

tons at the beginning of 1981 (Figure 1).

Spawning stock biomass (ages 2+) was estimated from VPA for 1965-1978 and for 1979-1981 using a power curve relationship between spring survey catch per tow and spawning stock size for previous years obtained from VPA ($r=0.842$, $p<0.01$), (Table 8b, Figure 6). Spawning stock biomass demonstrated a similar trend as total stock biomass by decreasing from a high of 160,700 tons in 1965 to 45,100 tons in 1968 and increasing to 86,900 tons in 1971 before declining steadily to a low of 11,900 tons in 1977. Since 1977, biomass increased steadily to 48,500 tons at the beginning of 1981 (Figure 7).

Although a detailed age composition of this stock was not available for 1979-1981 due to low levels of catch and limited sampling data in 1979-1980, abundance indices from both spring and autumn research vessel surveys have indicated a steady increase since 1977.

A catch of about 325 tons was projected for 1981 based on reported landings through September and the assumption that catch rates for the remainder of the year would be similar to those in 1980. This level of catch would require an F of less than 0.01 based on the relationship used to predict F in 1978 (Table 6).

Given the continued small catches and the increase in abundance indices in recent years, it is likely that this stock will continue to build from the low levels estimated for 1977-1978.

SOUTHERN NEW ENGLAND - MIDDLE ATLANTIC STOCK

Catch and Management History

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 1967-1976 (Table 9, Figure 8). Catches declined steadily from 41,803 tons in 1973 to 5,357 tons in 1978, but increased to 8,087 tons in 1979. The 1980 catch was 4,481 tons, the lowest level reported in the 1960-1980 time series.

USA commercial catches increased from 4,174 tons in 1960 to 32,622 tons in 1964, then dropped to only 1,995 tons in 1972. Catches averaged about 2,900 tons during 1973-1978 before increasing to 6,622 tons in 1979. In 1980, catches dropped to 3,875 tons.

USA recreational catch estimates (primarily in the New York-New Jersey area) have ranged from 52 (1975) to 892 tons (1962) based on marine angler surveys conducted in 1960, 1965, 1970, and 1974-1977. The results of the NMFS Marine Recreational Fishery Statistics Survey conducted in 1979 (NOAA 1980) were not utilized because the estimated hake catch for 1979 was much less than the level suggested by individuals in the mid-Atlantic area who were knowledgable in that fishery and also much less than any estimate from previous angler surveys. Therefore, in 1979 and 1980, the catches were estimated to be 500 tons.

Distant-water-fleet catches, which were first reported in

1963, have varied from 106 tons in 1980 to a high of 57,430 tons in 1966 and averaged about 63% of the annual international catch during 1963-1978. Catches declined steadily from 37,883 tons in 1973 to only 106 tons in 1980, by far the lowest level reported in the time series.

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, 16,000 tons for 1979 and 11,000 tons for 1980. USA commercial and recreational capacity was designated to be 7,600 tons during 1977-1979 with TALFF decreasing from 20,400 tons in 1977 to 8,400 tons in 1979. In 1980, the domestic annual harvest (DAH) was set at 8,100 tons with 3,000 tons allocated as TALFF. The OY in 1981 was increased to 16,000 tons with DAH and TALFF set at 13,000 and 3,000 tons, respectively.

Catch Composition

Numbers at age catch data for 1963-1980 (Table 10) were calculated using USA and USSR commercial length frequency data, supplemented by NMFS Foreign Fishing Observer Program data during 1977-1980, USSR commercial age/length ketys and USA survey age/length keys. As for the Georges Bank stock, pooled USSR keys were used for 1963-1972, and USA keys were used for 1973-1980. 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 about 80% of the catch in numbers during 1963-1980. The dominant age group has generally been age 3, averaging 36% of the annual catch, although age 2 fish were dominant in 5 of the last 6 years. In 1980, 25 of the catch was age 2, while ages 3 and 4 comprised 22% and 24%, respectively.

Mean weights at age for the 1963-1980 catches (Table 11) were applied to the numbers-at-age (Table 10) to obtain calculated catches (tons). Observed/calculated catches varied from 0.887 to 1.042 and averaged 1.00. The 1980 mean weights (unadjusted) were used in the projections of the 1981-1983 catch and stock biomass.

Abundance Indices

Research vessel mean catch per tow

The NMFS, NEFC spring bottom trawl survey catch-per-tow index increased from 2.61 kg in 1969 to 8.76 kg in 1972 then declined steadily to 4.30 kg in 1975 (Table 12, Figure 9). From 1976 to 1981, the index fluctuated between 3 and 10 kg, but underwent a steady increase from 2.57 kg in 1979 to 10.02 kg in 1981. Catch per tow in numbers (linear scale) decreased from a high of 60.40 in 1971 to 19.19 in 1975, then fluctuated during 1976-1978 before steadily increasing to 44.25 in 1981 (Table 13).

The autumn survey index has exhibited considerably less fluctuation than the spring survey (Table 12, Figure 10). the index (kg, linear) decreased from a high of 8.05 kg in 1963 to 2.67 kg in 1967 before increasing to 6.62 in 1972. The index dropped

sharply to 0.59 kg in 1974, then increased to average 3.40 kg during 1975-1979. In 1980, the index increased to 5.72 kg, the highest level since 1972. Catch per tow in numbers was at its highest level in 1972 (43.67) before dropping sharply to a series low of 9.04 in 1974. The index increased to 28.17 in 1975 before steadily declining to 10.32 in 1978. Since 1978, the index climbed to 27.78 in 1980 (Table 13).

Coefficients of variation averaged 0.33 for the spring survey and 0.29 for the autumn survey. These data indicate that, on an absolute basis, changes in abundance of ±66% and ±58% in the spring and autumn, respectively, would not normally be detected by the surveys.

The spring and autumn survey indices have not exhibited much similarity over the time period represented, although both have increased steadily since the autumn of 1978 and the spring of 1979 to the present.

Mean catch per tow at age

Mean catch per tow at age (numbers, linear scale) for 1970-1981 are given in Table 13. The maximum age encountered in this stock was 11 years (ages 10 and 11 were combined in the table). The data indicate that the 1969, 1970, and 1974 year classes were quite strong compared to other years. The 1979 year class appears to be the strongest year class since 1974, although this estimate must be considered tentative because of the limited number of indices available to evaluate this cohort. The 1980 year class appears to be of average strength.

Fishing Mortality

Fishing mortality (F) in 1980, the terminal year for VPA, was estimated to be 0.225 for fully-recruited ages (ages 3+) from a power curve relationship between relative exploitation (international catch divided by the autumn survey catch-per-tow index) and fishing mortality from previous VPA ($r=0.634$, <0.05), (Table 14, Figure 11). Natural mortality (M) was assumed to be 0.40. The iterative method used to select the terminal F is as described for the Georges Bank stock. Mean F for fully-recruited ages determined from VPA during 1963-1972 ranged from 0.22 in 1970 to 0.97 in 1969, before increasing to average 0.86 during 1973-1976. Due to the sharp decline in catches after 1976, F dropped to average 0.23 during 1977-1980 (Table 15).

Recruitment

The sizes of the 1962-1977 year classes at age 1, estimated from VPA, ranged from 71 million fish (1977 cohort) to 953 million fish (1962 cohort), with a mean size of 327 million fish (Table 15, Figure 13). Estimates of the 1978-1979 year-classes at age 1 were obtained from power curve relationships between autumn survey catch per tow (numbers) at age and year-class size at age 1 from VPA ($r=0.536$, $p<0.05$) and between spring survey catch per tow at age 2 ($r=0.752$, $p<0.05$) and year-class size at age 1 from VPA (Table 16, Figure 12). The two estimates of the 1978 year class were 152 and 146 million; a value of 150 million was used for this assessment. Based on a single estimate of 188 million, the 1979 year class was set at 200 million fish. The 1980 year-

class size was estimated to be 125 million fish, which represents the average of the 1975-1979 year-classes.

Recruitment in recent years has been much lower than in the past, averaging 138 million fish at age 1 for the 1972-1980 year classes compared to an average of 510 million for the 1962-1971 year classes.

Stock Size

Stock size estimates for 1963-1980 were obtained from VPA (Table 15). Mean weights at age (Table 11) were applied to stock size (in numbers) at age calculated from VPA to otain stock biomass values. The resulting annual biomass estimates were then corrected using the appropriate ratios between observed and calculated catch (Table 10). The 1981 stock sizes at age were determined from the relationship:

$$N_{81} = N_{80}e^{-Z_{80}}.$$

Total stock biomass (ages 1+) decreased from 209,800 tons in 1963 to a low of 38,700 tons in 1977. Biomass increased briefly to 59,300 tons in 1979, then decreased to an estimated 49,300 tons at the beginning of 1981 (Table 15, Figure 8).

Spawning stock biomass (age 2+) decreased from a high of 173,600 tons in 1965 to a low of 30,200 tons in 1977. Biomass has since increased slightly to 38,000 tons at the beginning of 1981 (Table 15, Figure 13).

Partial Recruitment

Age-specific fishing mortality rates from VPA (Table 15) indicate that red hake were fully recruited to the fishery by about age 3 during 1963-1976, age 2 during 1977-1979, and age 3 in 1980. Partial recruitment of age groups incompletely or partially recruited to the fishery is defined here as the ratio between fishing mortality at a given age (in a given year) and the mean fishing mortality of the fully recruited ages in that year. Partial recruitment was estimated to be 5% at age 1, 25% at age 2, and 100% at ages 3 and older in 1980. These estimates were used in the projections of catch and stock size for 1981-1983.

Catch and Stock Size Projections

A total stock biomass of 49,300 tons was estimated to be available at the beginning of 1981, a 3% increase from 1980. Spawning stock biomass was estimated to be 38,000 tons in 1981, an increase of 4% from 1980.

Total catch in 1981 was projected to be approximately 4,000 tons based on reported catches through September and the assumption that catch rates for the remainder of 1981 would be similar to those in 1980. This level of catch would require an F for ages 3 and older of about 0.155 and leave a spawning stock biomass of 53,800 tons at the beginning of 1982 (a 42% increase from 1981). Catch levels in 1981 ranging between 2,500 and 5,000 tons requiring F's ranging from 0.095 to 0.197 were also examined. Spawning stock biomass at the beginning of 1982 at these catch levels will range betweeen 52,700 and 55,400 tons (increases ranging from 39%

to 46%) assuming a 1981 year class equal to the 1975-1980 average year class size of 125 million fish.

Catch options for 1982 and the resulting spawning stock biomass levels in 1983, under three levels of 1981 catch (2,500, 4,000, and 5,000 tons) were calculated for values of F ranging from 0.05 to 1.00 (Table 17). Fishing at $F_{0.1}$ in 1982 (0.45) would result in a catch of between 13,400 and 14,200 tons and would leave a spawning stock biomass in 1983 of between 45,400 and 46,700 tons, an average decrease of approximately 15% from 1982. If the catch in 1982 remains at the 1980 level, (about 4,500 tons), it will require an F of about 0.13 under any option of catch in 1981, and spawning stock biomass in 1983 will range between 54,200 and 56,200 a 2% increase from 1982 and approximately a 45% increase from 1981.

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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
1979	-	-	-	-	2	-	-	2	6	272	1	283
1980	-	-	-	-	23	-	-	17	-	240	-	280

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

Table 2. 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 3).

Table 3. Mean weights (kg) at age for the red hake catch from the Georges Bank Stock.

Year	Age									
	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	.58	.78	.37
1978	.10	.16	.22	.29	.30	.54	.51	.51	-	-

Table 4. Stratified mean catch per tow (kg, linear) of red hake from the Georges Bank stock from USA bottom trawl surveys in the spring (Strata 13-20) and autumn (Strata 13-23, 25) with accompanying estimates of precision.

Year	Mean	Variance	Standard deviation	2 S.D.	S.D. / Mean	Mean ± 2 S.D.	No. of tows
			Spring				
1968	.41[1]	.03	.17	.35	.42	.06-0.76	45
1969	.65[1]	.14	.37	.75	.58	-.10-1.40	51
1970	1.38[1]	.19	.44	.87	.32	.51-2.25	46
1971	2.40[1]	3.38	1.84	3.68	.77	-1.28-6.08	49
1972	1.72[1]	.42	.65	1.30	.38	.42-3.02	51
1973	1.75	.67	.82	1.64	.47	.11-3.39	48
1974	.66	.04	.20	.40	.30	.26-1.06	45
1975	1.26	.28	.53	1.06	.42	.20-2.32	48
1976	1.35	.39	.62	1.25	.46	.10-2.60	46
1977	.21	<.01	.07	.14	.34	.07-0.35	47
1978	.18	.01	.10	.20	.56	-.02-0.38	51
1979	.79	.10	.32	.63	.40	.16-1.42	82
1980	.81	.22	.47	.94	.58	-.13-1.75	47
1981	1.17	.25	.50	1.00	.43	.17-2.17	44
			Autumn				
1963	7.86	5.25	2.29	4.58	.67	5.57-10.15	46
1964	2.61	.81	.90	1.80	.34	.81-4.41	57
1965	2.10	.41	.64	1.28	.30	.82-3.38	60
1966	1.42	.19	.44	.87	.31	.55-2.29	61
1967	.66	.04	.20	.40	.30	.26-1.06	62
1968	1.34	.07	.26	.53	.20	.81-1.87	63
1969	1.82	.15	.39	.77	.21	1.05-2.59	67
1970	1.01	.05	.22	.45	.22	.56-1.46	62
1971	2.05	.46	.68	1.36	.33	.69-3.41	66
1972	1.19	.08	.28	.57	.24	.62-1.76	67
1973	3.02	.61	.78	1.56	.26	1.46-4.58	66
1974	1.56	.46	.68	1.36	.43	.20-2.92	68
1975	7.63	2.53	1.59	3.18	.21	4.45-10.81	66
1976	4.42	1.04	1.02	2.04	.23	2.38-6.46	62
1977	4.98	.93	.96	1.93	.19	3.05-6.91	89
1978	4.61	1.35	1.16	2.32	.25	2.29-6.93	133
1979	2.48	.82	.91	1.81	.37	.67-4.29	122
1980	4.34	2.01	1.42	2.84	.33	1.50-7.18	86

[1]Adjusted from No. 36 "Yankee" trawl catches to equivalent No. 41 "Yankee trawl catches using a 1.58:1 ratio.

Table 5. Stratified mean catch per tow (numbers, linear) at age of red hake from the Georges Bank stock from USA bottom trawl surveys in the spring (Strata 13-20) and autumn (Strata 13-23,25).

Year	Age 0	I	II	III	IV	V	VI	VII	VIII	IX	X+	Total 0+	I+	II+
						Spring								
1970[1]	-	.45	.29	1.29	1.23	1.07	.46	.30	.09	.12	.09	5.39	5.39	4.94
1971[1]	-	2.31	2.55	1.69	1.57	1.64	1.45	.68	.33	-	-	12.22	12.22	9.91
1972[1]	-	.28	.36	2.64	2.20	.62	.29	.28	-	-	.03	6.70	6.70	6.42
1973	-	.17	.17	.73	1.08	1.22	.73	.29	.28	.14	.04	4.85	4.85	4.68
1974	-	1.36	.45	.56	.72	.48	.22	.12	.05	-	-	3.96	3.96	2.60
1975	-	1.40	3.25	.53	.47	.19	.24	.05	.10	.05	-	6.28	6.28	4.88
1976	-	.57	.87	2.34	1.14	.53	.21	.12	.11	.09	.03	6.01	6.01	5.44
1977	-	.21	.02	.23	.33	.03	-	.02	-	.01	-	.85	.85	.64
1978	-	.29	.06	.28	.32	.11	.01	-	-	-	-	1.07	1.07	.78
1979	-	.44	.19	1.17	.48	.98	.29	.06	.02	-	-	3.63	3.63	3.19
1980	-	.14	.14	.69	1.11	.90	.34	.27	.21	.02	-	3.82	3.82	3.68
1981[2]	-	.11										4.94	4.94	
						Autumn								
1970	3.10	1.12	1.81	.61	.25	.23	.03	.18	.10	.05	-	7.48	4.38	3.26
1971	7.11	.82	2.73	1.70	1.02	.29	.38	.16	.24	.07	.04	14.56	7.45	6.63
1972	2.46	.88	.81	1.16	.80	.32	.20	.13	.08	.03	-	6.87	4.41	3.53
1973	10.88	2.40	5.54	2.77	1.71	.62	.29	.16	-	.03	-	24.40	13.52	11.12
1974	33.63	2.60	1.59	1.69	.64	.13	.08	-	-	.03	.03	40.42	6.79	4.19
1975	4.47	16.31	17.42	3.43	1.85	.80	.47	.21	.16	.10	-	45.22	40.75	24.44
1976	5.97	1.07	11.43	4.74	1.58	.47	.19	.21	.05	-	-	25.71	19.74	18.67
1977	1.59	1.21	1.95	5.20	2.53	.63	.30	.12	.11	.07	-	13.71	12.12	10.91
1978	4.70	4.89	3.51	3.22	5.16	1.57	.41	.11	.04	-	-	23.61	18.91	14.02
1979	6.93	1.71	1.85	1.33	.92	1.49	.73	.05	.01	.03	-	15.05	8.12	6.41
1980	10.92	4.10	3.60	3.07	2.76	1.37	1.47	.22	.02	-	-	27.53	16.61	12.51

[1]Adjusted from No. 36 "Yankee" trawl catches to equivalent No. 41 "Yankee" trawl catches using a 1.58:1 ratio.

[2]Provisional estimate; survey ages currently being analyzed.

Table 6. Estimation of F for the Georges Bank red hake fishery.

Year	Spring survey catch per tow (kg)	International catch (tons)[1]	Relative exploitation index	Fishing mortality[2]
1968	.41	5,059	12,339	.201
1969	.65	4,288	6,597	.108
1970	1.38	1,915	1,388	.036
1971	2.40	11,975	4,990	.159
1972	1.72	39,366	22,887	1.253
1973	1.75	24,666	14,095	.944
1974	.66	9,500	14,394	.423
1975	1.26	15,004	11,908	.617
1976	1.35	17,124	12,684	1.021
1977	.21	2,879	13,710	(.558)[3,4]
1978	.18	964	5,356	(.165)[3]
1979	.79	283	358	(.005)[3]
1980	.81	280	346	(.005)[3]

[1] International catch divided by spring survey catch-per-tow.

[2] Weighted mean F for fully recruited ages from virtual population analysis.

[3] Calculated from a power curve relationship of relative exploitation on fishing mortality for 1968-76:

$$Y = .0000024X^{1.2953}, \quad r = .896.$$

[4] Value calculated from VPA was .440.

Table 7. Fishing mortality rates and stock sizes for the Georges Bank red hake stock derived from virtual population analysis (M=.40).

YEAR	AGE 1	2	3	4	5	6	7	8	9	10+	100% RECRUITMENT MEAN F[2]	AGE
	FISHING MORTALITY											
1965	.004	.159	.492	.652	.714	.693	.647	1.217	1.123	(.585)[1]	.585	3+
1966	.003	.128	.794	1.208	1.132	.808	.555	.603	(.972)[1]	(.972)[1]	.972	3+
1967	.003	.170	.278	.804	1.505	1.274	1.246	1.278	(.678)[1]	–	.678	3+
1968	<.001	.028	.183	.157	.330	.464	.293	(.201)[1]	(.201)[1]	–	.201	3+
1969	<.001	.120	.134	.120	.043	.053	.176	(.108)[1]	–	–	.108	3+
1970	.002	.035	.038	.039	.053	.020	.028	.156	–	–	.036	2+
1971	.033	.120	.146	.194	.326	.321	.106	.286	.681	–	.159	2+
1972	.056	.433	.924	1.515	1.759	1.684	1.236	.264	.526	(1.253)[1]	1.253	3+
1973	.075	.481	1.045	.873	.981	.785	.741	.652	.033	(.944)[1]	.944	3+
1974	.119	.191	.432	.541	.271	.258	.189	.272	(.423)[1]	(.423)[1]	.423	3+
1975	.062	.467	.798	.945	.716	.382	.918	(.617)[1]	(.617)[1]	–	.617	2+
1976	.157	.836	.931	1.943	2.164	1.330	1.330	(1.021)[1]	–	–	1.021	2+
1977	<.001	.117	.390	.557	(.440)[1]	(.440)[1]	(.440)[1]	(.440)[1]	–	–	.440	3+
1978	.004	.009	(.165)[4]	(.165)[4]	(.165)[4]	–	–	–	–	–	.165	3+

YEAR	STOCK SIZE (MILLIONS) 1	2	3	4	5	6	7	8	9	10+	AGE 1+ TOTAL	AGE 1+ WGT[3]	AGE 2+ TOTAL	AGE 2+ WGT[3]
1965	249.3	279.2	290.1	167.1	70.1	27.5	11.2	3.8	.9	1.9	1101.0	174.7	851.8	160.7
1966	131.1	166.3	159.6	118.8	58.4	23.0	9.2	3.9	.8	.2	671.4	127.0	540.3	116.5
1967	159.4	87.9	98.1	48.4	23.8	12.6	6.9	3.6	1.4	–	442.0	77.5	282.7	63.0
1968	275.8	106.7	49.7	49.8	14.5	3.5	2.4	1.3	.7	–	504.4	69.7	228.6	45.1
1969	282.3	186.8	69.6	27.7	28.5	7.0	1.5	1.2	–	–	604.5	67.5	322.3	51.0
1970	273.6	190.6	111.0	40.8	16.5	18.3	4.4	.8	–	–	656.1	84.3	382.5	63.0
1971	223.2	183.1	123.4	71.7	26.3	10.5	12.0	2.9	.5	–	653.6	102.3	430.4	86.9
1972	146.6	144.9	108.9	71.5	39.6	12.7	5.1	7.3	1.5	.2	538.1	73.8	391.5	70.8
1973	134.9	92.9	63.0	29.0	10.5	4.6	1.6	1.0	3.7	.6	341.7	72.4	206.8	54.8
1974	156.1	83.8	38.5	14.8	8.1	2.6	1.4	.5	.3	2.4	308.8	55.0	152.6	36.4
1975	133.6	92.9	46.4	16.7	5.8	4.1	1.4	.8	.3	–	302.0	48.6	168.4	36.5
1976	32.5	84.2	39.1	14.0	4.4	1.9	1.9	.4	–	–	178.3	34.9	145.8	30.4
1977	63.0	18.6	24.5	10.3	1.3	.3	.3	.3	–	–	118.6	18.2	55.8	11.9
1978	(110)	42.2	11.1	11.1	4.0	–	–	–	–	–	178.4	25.2	68.4[4]	13.9

[1]Mean F for fully recruited ages in that year.
[2]Weighted by stock size at age.
[3]Adjusted using ratios of observed/calculated catch (in thousands of tons).
[4]Estimated.

Table 8a. Relationship between spring survey catch-per-tow (numbers) at age 2+ and stock size at age 2+ from virtual population analysis for the Georges Bank red hake stock.

Year	Spring Survey Age 2+ catch-per-tow (numbers)	Stock Size Age 2+ (millions)
1970	4.94	382.5
1971	9.91	430.4
1972	6.42	391.5
1973	4.68	206.8
1974	2.60	152.6
1975	4.88	168.4
1976	5.44	145.8
1977	.64	55.8
1978	.78	(68.4)[1]

[1]Calculated from a linear regression of survey catch-per-tow (age 2+) on stock size (age 2+) for 1970-1977:

$$Y = 35.895 + 41.677X, \quad r = 0.808$$

Table 8b. Relationship between spring survey catch-per-tow (kg, all ages) and stock biomass from virgual population analysis for the Georges Bank red hake stock.

Year	Spring survey catch-per-tow (kg)	Stock biomass (000's tons)	
		Age 1+	Age 2+
1968	.41	69.7	45.1
1969	.65	67.5	51.0
1970	1.38	84.3	63.0
1971	2.40	102.3	86.9
1972	1.72	73.8	70.8
1973	1.75	72.4	54.8
1974	.66	55.0	36.4
1975	1.26	48.6	36.5
1976	1.35	34.9	30.4
1977	.21	18.2	11.9
1978	.18	25.2	13.9
1979	.79	(52.1)[1]	(38.2)[2]
1980	.81	(52.7)[1]	(38.8)[2]
1981	1.17	(62.3)[1]	(48.5)[2]

[1]Calculated from a power curver relationship of survey catch-per-tow on stock biomass (age 1+) for 1968-1978:

$$Y = 58.014X^{0.455}, \quad r = 0.747$$

[2]Calculated from a power curve relationship of survey catch-per-tow on stock biomass (age 2+) for 1968-1978:

$$Y = 44.109X^{.608}, \quad r = 0.842$$

Table 9. Red hake catch (tons) from the Southern New England-Middle Atlantic stock.[1]

Year	Bulgaria	Cuba	GDR	Italy	Japan	Mexico	Poland	Romania	Spain	USSR	USA Commercial	USA Recreational	Total
1960	-	-	-	-	-	-	-	-	-	-	4,174	317[2]	4,49
1961	-	-	-	-	-	-	-	-	-	-	8,047	612	8,65
1962	-	-	-	-	-	-	-	-	-	-	11,737	892	12,62
1963	-	-	-	-	-	-	-	-	-	770	29,608	770	31,14
1964	-	-	-	-	-	-	-	-	-	8,427	32,622	848	41,89
1965	-	-	-	-	-	-	-	-	-	17,611	24,759	634[2]	43,00
1966	-	-	-	-	-	-	-	-	-	57,430	3,629	94	61,15
1967	-	-	-	-	-	-	39	-	-	29,539	6,331	165	36,07
1968	-	-	-	-	-	-	-	-	-	8,698	6,464	575	15,73
1969	114	-	-	-	-	-	-	-	-	44,913	5,491	489	51,00
1970	197	-	-	-	-	-	-	-	-	5,534	4,591	410[2]	10,73
1971	1,218	-	9	-	8	-	-	-	-	23,234	3,225	287	27,98
1972	471	-	40	-	549	-	5	43	-	33,368	1,995	177	36,64
1973	216	-	-	-	2	-	25	-	-	37,640	3,603	317	41,80
1974	401	-	-	-	-	-	-	51	-	20,917	2,182	191[2]	23,74
1975	14	-	-	-	-	-	-	-	4	11,195	2,065	52[2]	13,33
1976	-	-	-	-	-	-	-	35	-	7,122	3,904	645[2]	11,70
1977	-	37	-	-	-	-	-	8	1	2,370	2,514	750[2]	5,68
1978	-	-	-	55	9	-	-	-	-	1,267	3,326	700	5,35
1979	-	-	-	187	12	40	-	-	63	663	6,622	500	8,08
1980	-	14	-	38	10	12	-	1	31	-	3,875	500	4,48

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

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

Table 10. 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
1979	5.5	11.1	6.2	4.7	2.2	0.6	0.2	+	-	-	30.5	8,087	8,071	1.002
1980	1.7	4.3	3.7	4.1	1.2	1.7	0.2	-	-	-	16.9	4,481	4,457	1.005

[1]Using mean weights at age from Table 11 .

Table 11. Mean weights (kg) at age for the red hake catch from the Southern New England-Middle Atlantic stock.

Year	Age 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	-
1979	.14	.22	.31	.36	.39	.49	.35	.45	-	-
1980	.11	.16	.24	.34	.38	.45	.32	.45	-	-

Table 12. Stratified mean catch (kg, linear) per tow of red hake from the Southern New England-Middle Atlantic stock from USA bottom trawl surveys in the spring and autumn (strata 1-12) with accompanying estimates of precision.

Year	Mean	Variance	Standard Deviation	2 S.D.	S.D. / Mean	Mean ± 2 S.D.	No. of Tows
			Spring				
1968	3.05[1]	1.05	1.02	2.05	.34	1.00-5.10	53
1969	2.61[1]	.39	.62	1.25	.24	1.36-3.86	58
1970	3.77[1]	.55	.74	1.48	.20	2.29-5.25	70
1971	8.50[1]	6.36	2.52	5.04	.30	3.46-13.54	64
1972	8.76[1]	12.61	3.55	7.10	.41	1.66-15.86	66
1973	6.38	1.93	1.39	2.78	.22	3.60-9.16	90
1974	4.76	1.12	1.06	2.12	.22	2.64-6.88	55
1975	4.30	3.24	1.80	3.60	.42	.70-7.90	60
1976	10.61	65.46	8.09	16.18	.76	5.57-26.79	61
1977	3.12	.48	.69	1.39	.22	1.73-4.51	59
1978	10.83	10.18	3.19	6.38	.29	4.45-17.21	62
1979	2.57	.89	.94	1.89	.37	.68-4.46	72
1980	4.36	1.36	1.17	2.33	.27	2.03-6.69	113
1981	10.02	9.21	3.03	6.07	.30	3.95-16.09	54
			Autumn				
1963	8.05	13.42	3.66	7.33	.46	.72-15.38	45
1964	4.35	1.68	1.30	2.59	.30	1.76-6.94	49
1965	5.63	3.35	1.83	3.66	.33	1.97-9.29	50
1966	2.90	.37	.61	1.22	.21	1.68-4.12	52
1967	2.67	.67	.82	1.64	.31	1.03-4.31	65
1968	4.42	1.51	1.23	2.46	.28	1.96-6.88	62
1969	4.80	1.43	1.20	2.39	.25	2.41-7.19	66
1970	3.90	.41	.64	1.28	.16	2.62-5.18	63
1971	3.37	.45	.67	1.34	.20	2.03-4.71	71
1972	6.62	2.51	1.58	3.17	.24	3.45-9.79	64
1973	3.05	1.27	1.13	2.25	.37	.80-5.30	59
1974	.59	.05	.22	.45	.38	.14-1.04	58
1975	4.34	1.83	1.35	2.71	.31	1.63-7.05	60
1976	3.38	.90	.95	1.90	.28	1.48-5.28	61
1977	3.16	1.56	1.25	2.50	.40	.66-5.66	57
1978	2.14	.40	.63	1.26	.30	.88-3.40	84
1979	3.98	.49	.70	1.40	.18	2.58-5.38	89
1980	5.72	2.66	1.63	3.26	.28	2.46-8.98	56

[1] Adjusted from No. 36 "Yankee" trawl catches to equivalent No. 41 "Yankee" trawl catches using a 1.58:1 ratio.

Table 13. Stratified mean catch (numbers, linear) per tow at age for red hake from the Southern New England -Middle Atlantic stock from USA bottom trawl surveys in the spring and autumn (Strata 1-12).

Year	Age 0	I	II	III	IV	V	VI	VII	VIII	IX	X+	Total 0+	I+	II+
						Spring								
1970[1]	-	5.99	6.42	4.57	2.44	1.15	.39	.19	.24	-	-	21.37	21.37	15.38
1971[1]	-	.58	42.98	8.89	2.56	2.69	1.37	.98	.19	.16	-	60.40	60.40	59.82
1972[1]	-	1.04	14.82	17.58	6.47	2.11	1.78	.52	.08	.06	.20	44.66	44.66	43.62
1973	-	1.81	7.24	12.15	5.75	1.52	.58	.45	.37	.02	.10	30.01	30.01	28.18
1974	-	3.15	3.73	7.03	4.42	3.16	.70	.16	.25	.10	-	22.70	22.70	19.55
1975	-	2.26	5.38	4.41	3.08	2.00	1.45	.22	.15	.19	.05	19.19	19.19	16.93
1976	-	1.98	5.93	14.89	8.43	2.10	1.90	.83	.26	.62	-	36.94	36.94	34.96
1977	-	1.75	2.31	2.43	.11	7.15	1.18	.02	.02	-	-	14.97	14.97	13.22
1978	-	2.14	22.90	10.51	11.11	1.90	.90	.25	.01	.08	.07	49.87	49.87	47.73
1979	-	.69	3.02	4.38	1.31	1.64	.60	.26	.06	-	-	11.96	11.96	11.27
1980	-	3.25	5.26	4.70	4.30	.99	1.25	.32	.01	-	-	19.81	19.81	16.56
1981[2]	-	2.89										44.25	44.25	
						Autumn								
1970	-	16.89	3.28	1.58	1.54	.73	.17	.06	.07	.04	.06	24.42	24.42	7.53
1971	.14	7.66	8.47	1.66	1.39	1.08	.31	.30	.07	.03	.03	21.14	21.00	13.34
1972	.07	22.02	10.17	6.11	2.24	1.53	1.01	.32	.20	-	-	43.67	43.60	21.58
1973	.09	13.96	3.53	1.72	1.61	.25	.35	.12	.02	-	-	21.65	21.56	7.60
1974	6.17	.54	1.37	.63	.25	.08	-	-	-	-	-	9.04	2.87	2.33
1975	1.87	17.84	3.80	2.56	1.16	.35	.52	.07	-	-	-	28.17	26.30	8.46
1976	1.68	8.14	6.37	1.31	1.31	.45	.13	.06	.08	.04	-	19.57	17.89	9.75
1977	.80	2.28	3.05	3.13	1.08	.67	.29	.27	.07	-	-	11.64	10.84	8.56
1978	.52	2.44	3.89	1.23	1.93	-	.12	.15	.01	.03	-	10.32	9.80	7.36
1979	.67	3.79	6.56	5.06	1.39	1.33	.25	.22	.05	-	-	19.32	18.65	14.86
1980	.06	7.63	8.30	4.19	5.39	1.18	1.03	-	-	-	-	27.78	27.72	20.09

[1]Adjusted from No. 36 "Yankee" trawl catches to equivalent No. 41 "Yankee" trawl catches using a 1.58:1 ratio.

[2]Provisional estimate; survey age samples currently being analyzed.

Table 14. Estimation of F in 1980 for the Southern New England-Middle Atlantic red hake fishery.

Year	Autumn survey catch per tow (kg)	International catch (tons)	Relative exploitation index[1]	Fishing mortality[2]
1963	8.05	31148	3869	.443
1964	4.35	41897	9631	.500
1965	5.63	43004	7638	.443
1966	2.90	61153	21087	.786
1967	2.67	36074	13511	.583
1968	4.42	15737	3560	.245
1969	4.80	51007	10626	.972
1970	3.90	10732	2752	.217
1971	3.37	27981	8303	.348
1972	6.62	36648	5536	.598
1973	3.05	41803	13706	.944
1974	.59	23742	40241	.926
1975	4.34	13330	3071	.746
1976	3.38	11706	3463	.842
1977	3.16	5680	1797	.225
1978	2.14	5357	2503	.184
1979	3.98	8087	2032	(.324)[3,4]
1980	5.72	4481	783	(.225)[3]

[1] International catch divided by autumn survey catch-per-tow.

[2] Weighted mean F for fully recruited ages from virtual population analysis.

[3] Calculated from a power curve relationship of relative exploitation on fishing mortality for 1963-1977.

$$Y = .0165\ X^{.3908},\ r = .634$$

[4] Value calculated from VPA was .272.

Table 15. Fishing mortality rates and stock sizes for the Southern New England-Middle Atlantic red hake stock derived from virtual population analysis (M=.40).

YEAR	AGE 1	2	3	4	5	6	7	8	9	10+	100% RECRUITMENT MEAN F[2]	AGE
	FISHING MORTALITY											
1963	.010	.077	.394	.589	.402	.388	.652	(.443)[1]	-	-	.443	3+
1964	.091	.158	.532	.514	.281	.182	.309	(.500)[1]	-	-	.500	3+
1965	.029	.153	.437	.531	.344	.254	.208	(.443)[1]	-	-	.443	3+
1966	.007	.063	.626	1.089	.800	.500	.627	.462	-	-	.786	3+
1967	.010	.074	.354	.911	.714	.817	.750	.660	.071	-	.583	3+
1968	.010	.055	.170	.379	.347	.300	.354	(.245)[1]	(.245)[1]	(.245)[1]	.245	3+
1969	.004	.148	.829	1.224	1.104	1.044	.569	.737	-	-	.972	3+
1970	.010	.045	.203	.240	.218	.239	.381	.181	.181	-	.217	3+
1971	.009	.245	.331	.440	.252	.281	.378	1.124	(.348)[1]	(.348)[1]	.348	3+
1972	.030	.380	.625	.597	.542	.383	.408	.804	(.598)[1]	-	.598	3+
1973	.046	.252	.841	.814	1.711	.646	.427	1.478	(.944)[1]	-	.944	3+
1974	.048	.421	.927	.963	1.114	.672	.297	.342	(.926)[1]	-	.926	3+
1975	.037	.370	.681	.976	.594	.678	1.629	.122	(.746)[1]	-	.746	3+
1976	.043	.338	.826	.921	.891	.659	.659	(.842)[1]	(.842)[1]	-	.842	3+
1977	.065	.192	.208	.434	.368	.291	(.225)[1]	(.225)[1]	-	-	.225	2+
1978	.033	.151	.229	.212	.204	.277	(.184)[1]	-	-	-	.184	2+
1979	.046[3]	.339	.186	.422	.161	.339	(.272)[1]	-	-	-	.272	2+
1980	.011[3]	.056[3]	(.225)[4]	(.225)[4]	(.225)[4]	(.225)[4]	(.225)[4]	-	-	-	.225	3+

YEAR	STOCK SIZE (MILLIONS) 1	2	3	4	5	6	7	8	9	10+	AGE 1+ TOTAL	AGE 1+ WGT[5]	AGE 2+ TOTAL	AGE 2+ WGT[5]
1963	953.1	561.2	250.1	91.2	30.8	8.9	3.5	2.0	-	-	1900.7	209.8	947.6	151.1
1964	696.2	631.9	348.4	113.0	33.9	13.8	4.1	1.2	-	-	1842.5	189.5	1146.3	167.9
1965	403.6	426.2	361.6	137.2	45.3	17.2	7.7	2.0	-	-	1400.8	194.3	997.2	173.6
1966	453.4	262.9	245.1	156.6	54.1	21.5	8.9	4.2	-	-	1206.8	186.6	753.4	163.8
1967	489.6	302.0	165.4	87.9	35.3	16.3	8.7	3.2	1.8	-	1110.3	142.0	620.7	117.7
1968	338.9	324.9	188.0	77.9	23.7	11.6	4.8	2.8	1.1	1.1	974.8	111.8	635.9	96.8
1969	500.0	225.0	206.2	106.3	35.7	11.2	5.8	2.3	-	-	1092.4	141.9	592.5	117.1
1970	620.1	334.2	130.1	60.3	20.9	7.9	2.6	2.2	.7	-	1179.3	119.9	559.1	89.3
1971	413.1	411.5	214.2	71.2	31.8	11.3	4.2	1.2	1.2	.4	1160.3	146.7	747.2	125.7
1972	228.8	274.3	215.8	103.2	30.7	16.6	5.7	1.9	.3	-	877.4	115.0	648.6	105.8
1973	168.1	148.9	125.7	77.4	38.0	12.0	7.6	2.6	.6	-	580.9	104.6	412.8	94.1
1974	121.4	107.6	77.5	36.3	23.0	4.6	4.2	3.3	.4	-	378.3	64.8	257.0	52.8
1975	195.3	77.6	47.3	20.6	9.3	5.1	1.6	2.1	1.6	-	360.4	49.3	165.0	33.6
1976	86.1	126.2	35.9	16.0	5.2	3.4	1.7	.2	1.2	-	276.1	39.6	190.0	31.9
1977	121.6	55.3	60.3	10.5	4.3	1.4	1.2	.6	-	-	255.3	38.7	133.7	30.2
1978	71.4	76.4	30.6	32.8	4.6	2.0	.7	-	-	-	218.6	40.3	147.2	35.3
1979	(150)[4]	46.3	44.0	16.3	17.8	2.5	1.0	-	-	-	278.0	59.3	128.0	38.3
1980	(200)[4]	96.0	22.1	24.5	7.2	10.2	1.2	-	-	-	261.2	48.0	161.2	36.7
1981	(125)[4]	132.6	60.8	11.8	13.1	3.9	5.5	.6	-	-	261.3	49.3	161.3	38.0

[1]Mean F for fully recruited ages in that year.
[2]Weighted by stock size at age.
[3]Determined from assumed stock size and known catch.
[4]Adjusted using ratios of observed/calculated catch (in thousands of tons).
[5]Estimated.

Table 16. Catch per tow (numbers) of age 1 and 2 red hake from the Southern New England-Middle Atlantic stock in the autumn and spring (strata 1-12) respectively, and year class size (millions of fish) at age 1 from VPA.

Year-class	Autumn survey Age 1	Spring survey Age 2	VPA Age 1	
1969	16.89	42.98	620.1	
1970	7.66	14.82	413.1	
1971	22.02	7.24	228.8	
1972	13.96	3.73	168.1	
1973	.54	5.38	121.4	
1974	17.84	5.93	195.3	
1975	8.14	2.31	86.1	
1976	2.28	22.90	121.6	
1977	2.44	3.02	71.4	
1978	3.79	5.26	(152.2)[1]	(145.8)[2]
1979	7.63	-	(188.2)[1]	

[1] Calculated from power curve relationship between autumn survey catch per tow and VPA year class size for 1969-1976:

$$Y = 101.695\ X^{.303},\ r = .536$$

[2] Calculated from power curve relationship between spring survey catch per tow and VPA year class size for 1969-1976:

$$Y = 59.495\ X^{.540},\ r = .752$$

Table 17. Projected catch (age I+) in 1982 from the Southern New England-Middle Atlantic red hake stock with fishing mortality ranging from 0.05 to 1.00 and under three options of catch in 1981. Resulting spawning stock size (age II+) in 1983 and the percentage change (by weight) from 1982 are also given.

	1982 catch = 2,500 tons			1981 catch = 4,000 tons			1981 catch = 5,000 tons		
Fishing mortality	1982 catch	1983 stock	% change in stock from 1982	1982 catch	1983 stock	% change in stock from 1982	1982 catch	1983 stock	% change in stock from 1982
.05	1.9	58.8	+6.1	1.8	57.7	+7.2	1.8	57.0	+8.2
.10	3.6	57.0	+2.0	3.5	56.0	+4.1	3.4	55.3	+4.9
.15	5.3	55.3	-0.2	5.2	54.4	+1.1	5.0	53.7	+1.9
.20	7.0	53.7	-3.1	6.7	52.8	-1.9	6.6	52.1	-1.1
.25	8.5	52.2	-5.8	8.2	51.3	-4.6	8.1	50.7	-3.8
.30	10.0	50.7	-8.5	9.7	49.9	-7.2	9.5	49.3	-6.5
.35	11.5	49.3	-11.0	11.1	48.5	-9.9	10.8	47.9	-9.1
.40	12.8	47.9	-13.5	12.4	47.2	-12.3	12.1	46.6	-11.6
.45*	14.2	46.7	-15.7	13.7	45.9	-14.7	13.4	45.4	-13.9
.50	15.4	45.4	-18.1	14.9	44.7	-16.9	14.6	44.3	-15.9
.55	16.6	44.3	-20.0	16.1	43.6	-19.0	15.7	43.1	-18.2
.60	17.8	43.1	-22.2	17.2	42.5	-21.0	16.8	42.1	-20.1
.65	18.9	42.1	-24.0	18.3	41.4	-23.0	17.9	41.0	-22.2
.70	20.0	41.0	-26.0	19.3	40.4	-24.9	18.9	40.0	-24.1
.75	21.0	40.0	-27.8	20.3	39.5	-26.6	19.9	39.1	-25.8
.80	22.0	39.1	-29.4	21.3	38.6	-28.3	20.8	38.2	-27.5
.85	23.0	38.2	-31.0	22.2	37.7	-29.9	21.7	37.3	-29.2
.90	23.9	37.2	-32.7	23.1	36.8	-31.6	22.6	36.5	-30.7
.95	24.8	36.5	-34.1	24.0	36.0	-33.1	23.4	35.7	-32.3
1.00	25.6	35.7	-35.6	24.8	35.2	-34.6	24.2	34.9	-33.8

*$F_{0.1}$

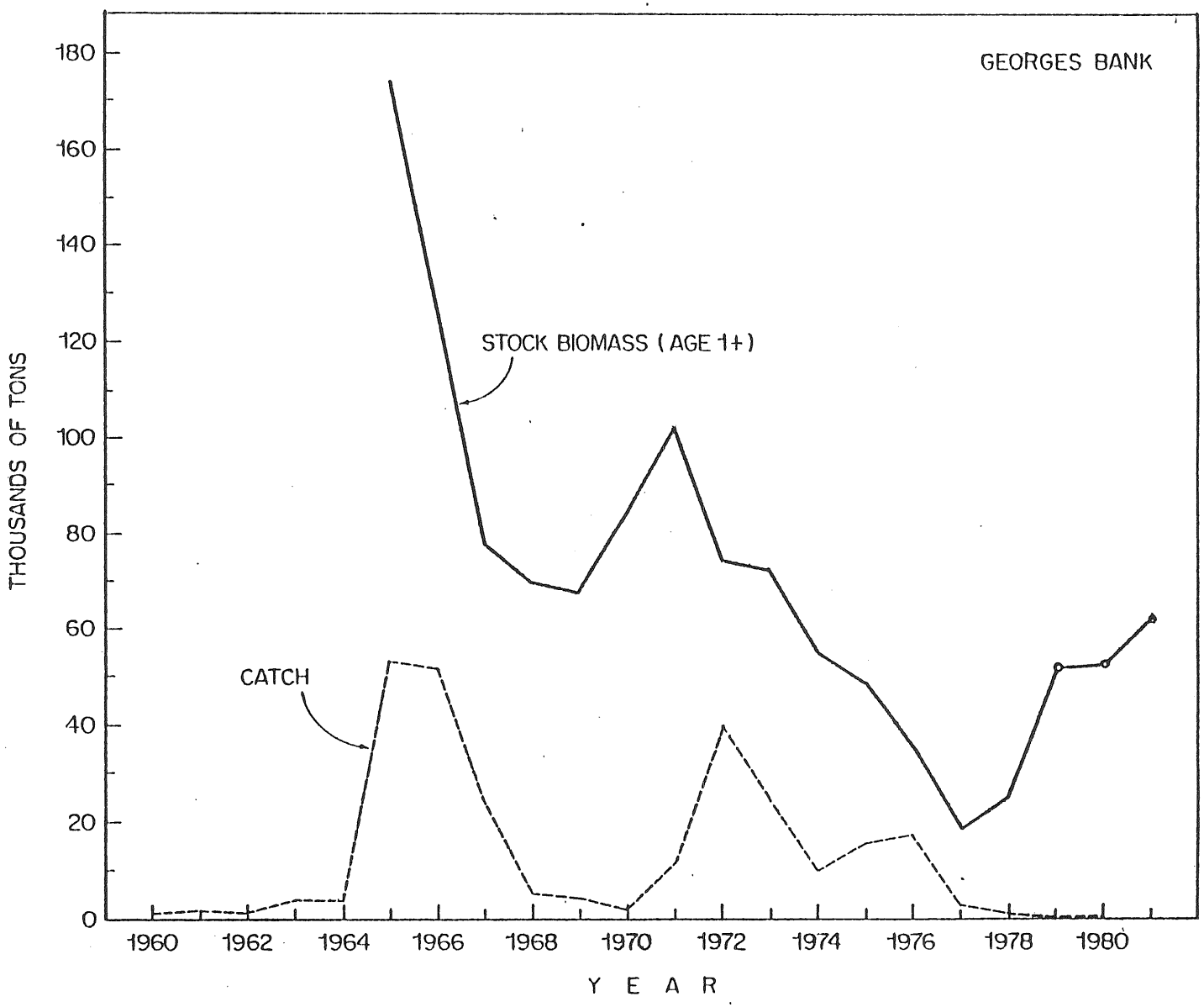

Figure 1. International catch and stock biomass (age 1+) from VPA from the Georges Bank red hake stock.

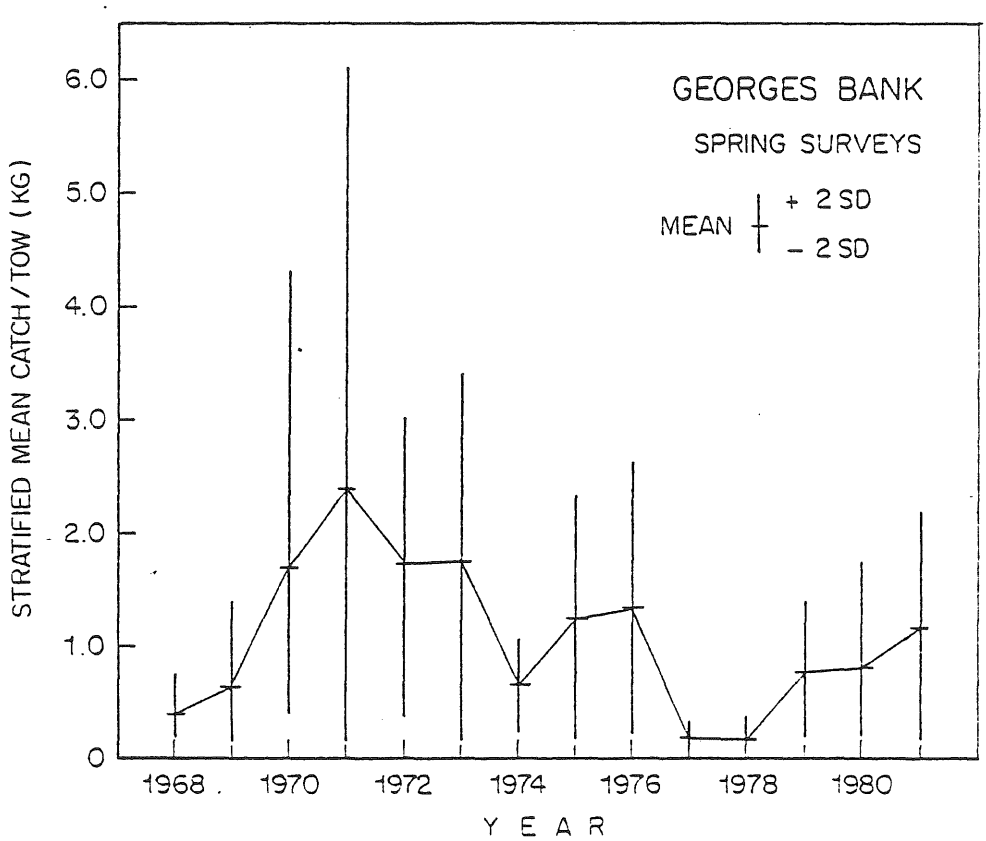

Figure 2. Stratified mean catch per tow (kg) of red hake from the Georges Bank stock from spring USA bottom trawl surveys (1968-1981).

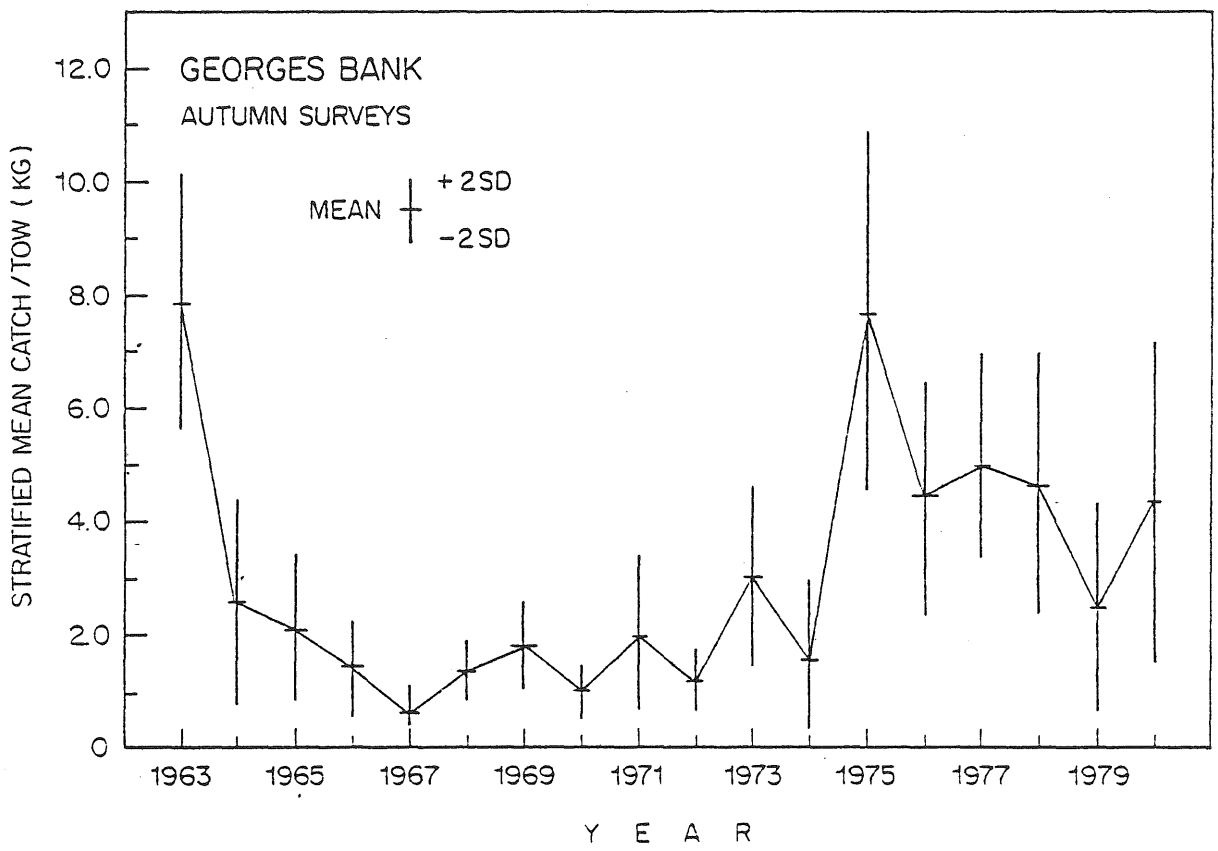

Figure 3. Stratified mean catch per tow (kg) of red hake from the Georges Bank stock from autumn USA bottom trawl surveys (1963-1980).

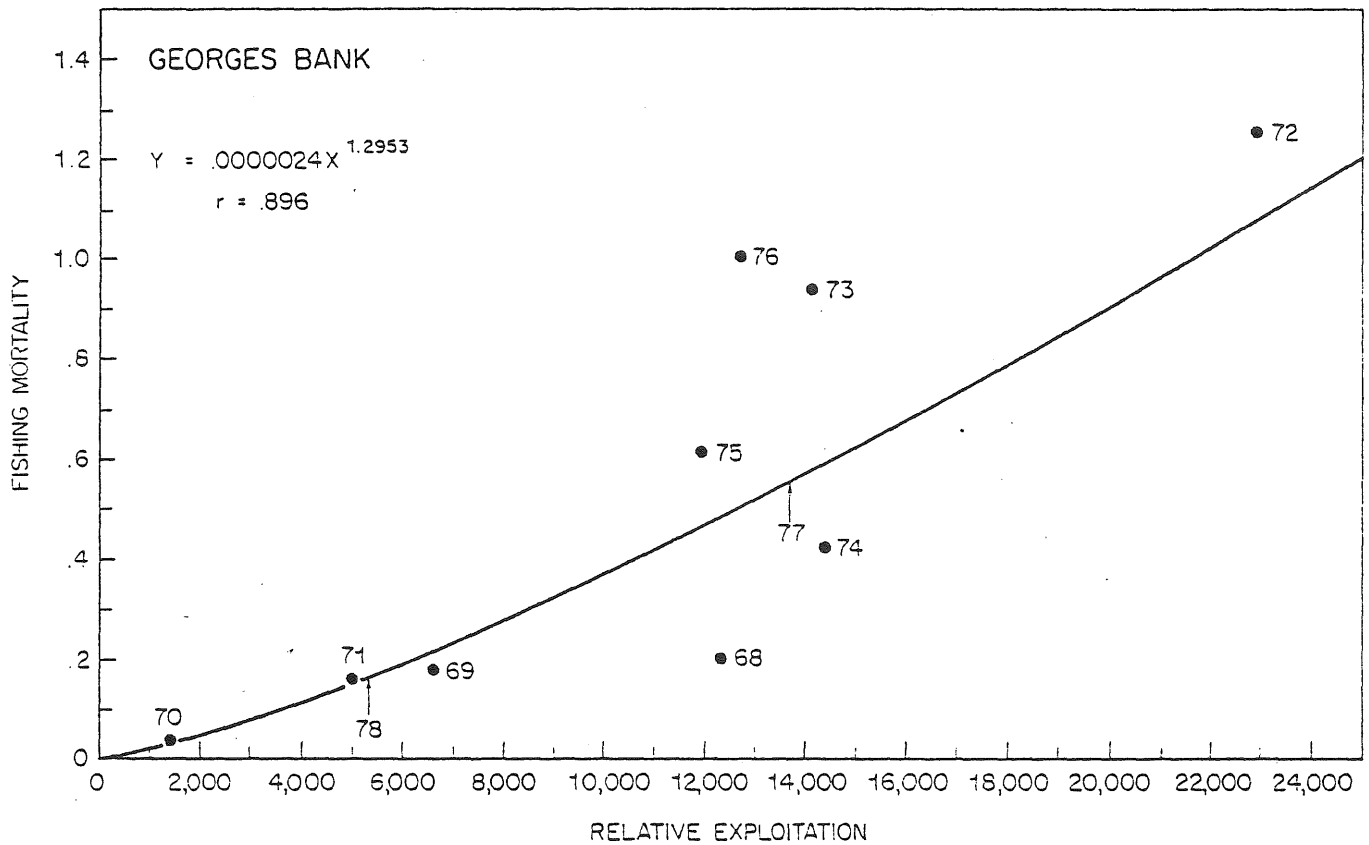

Figure 4. Relationship between fishing mortality from virtual population analysis and relative exploitation derived from spring survey catch-per-tow and international catch.

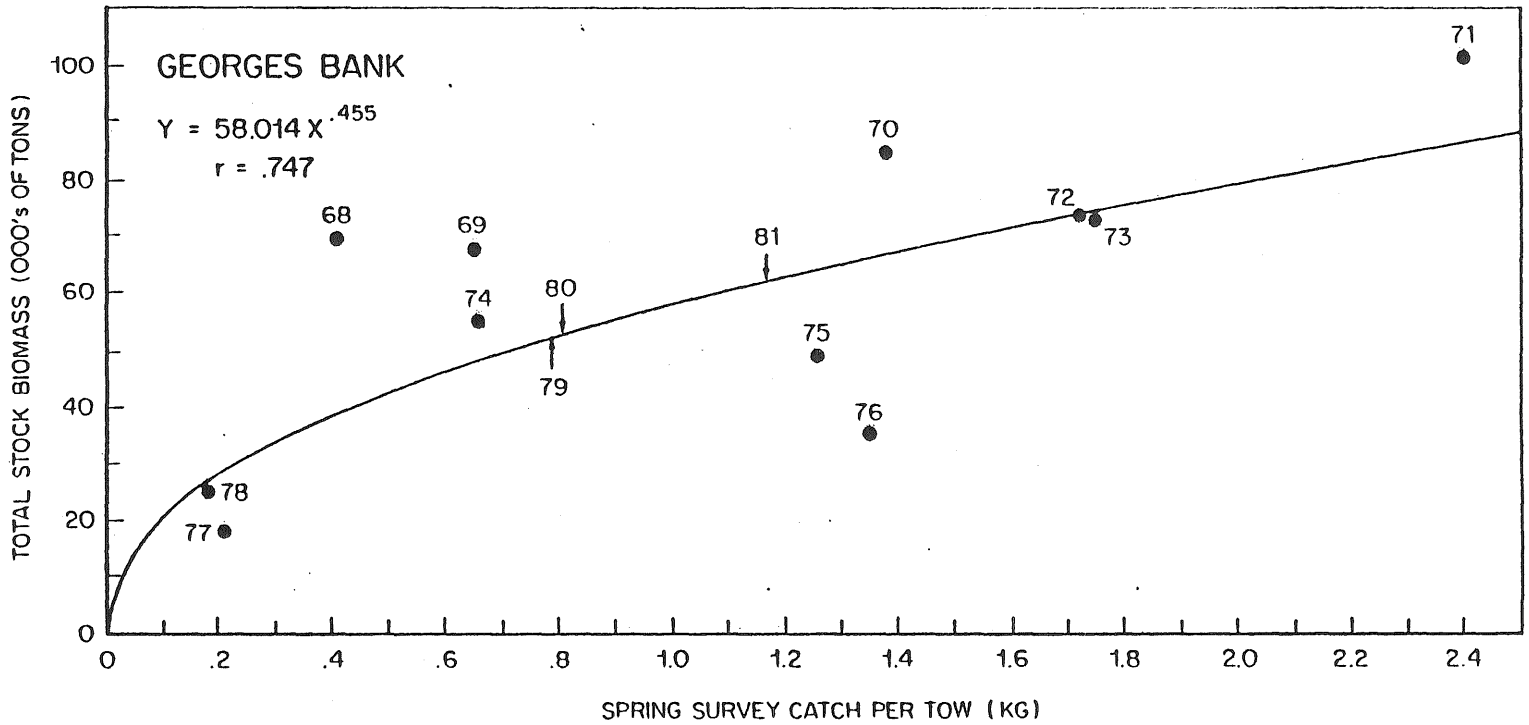

Figure 5. Relationship between total stock biomass (age 1+) from VPA and spring survey catch per tow (kg).

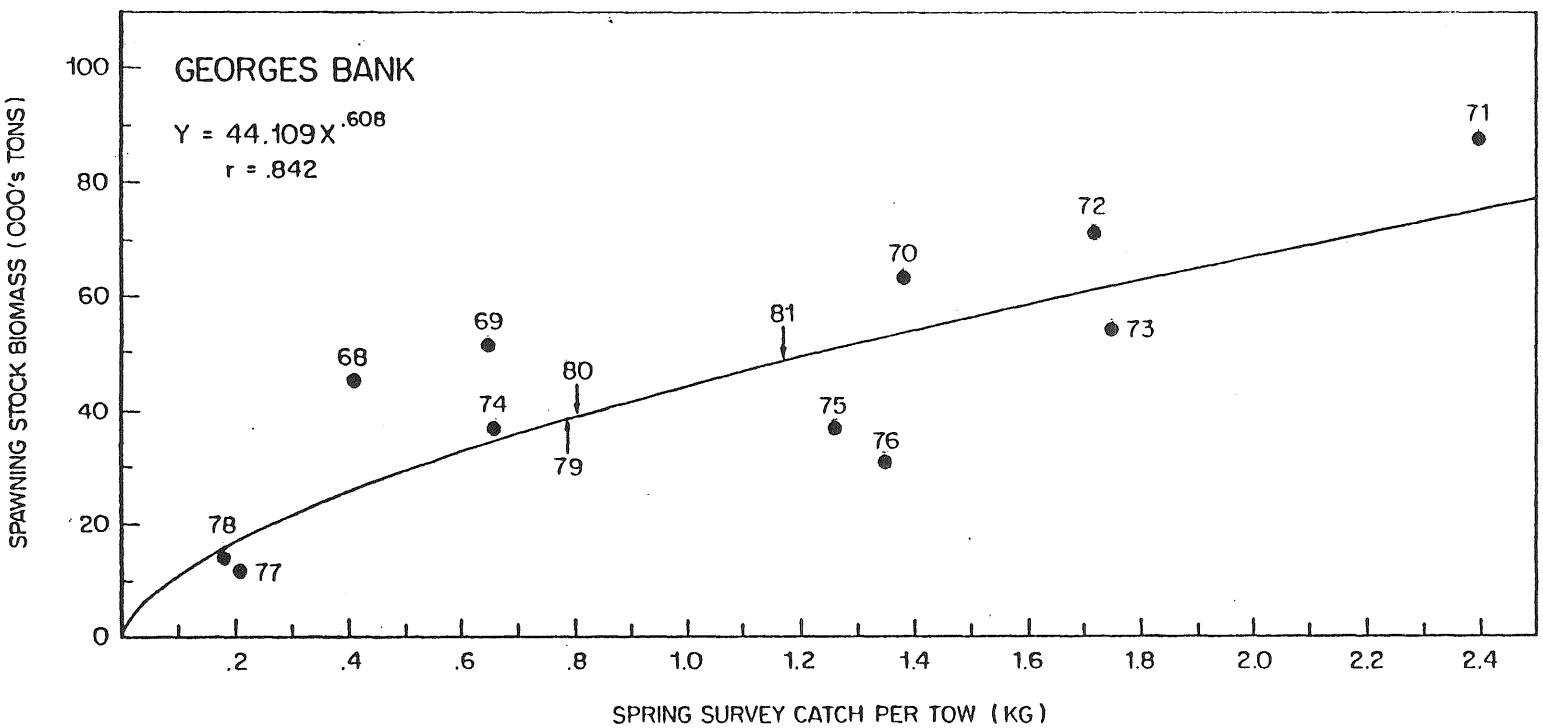

Figure 6. Relationship between spawning stock biomass (age 2+) from VPA and spring survey catch per tow (kg).

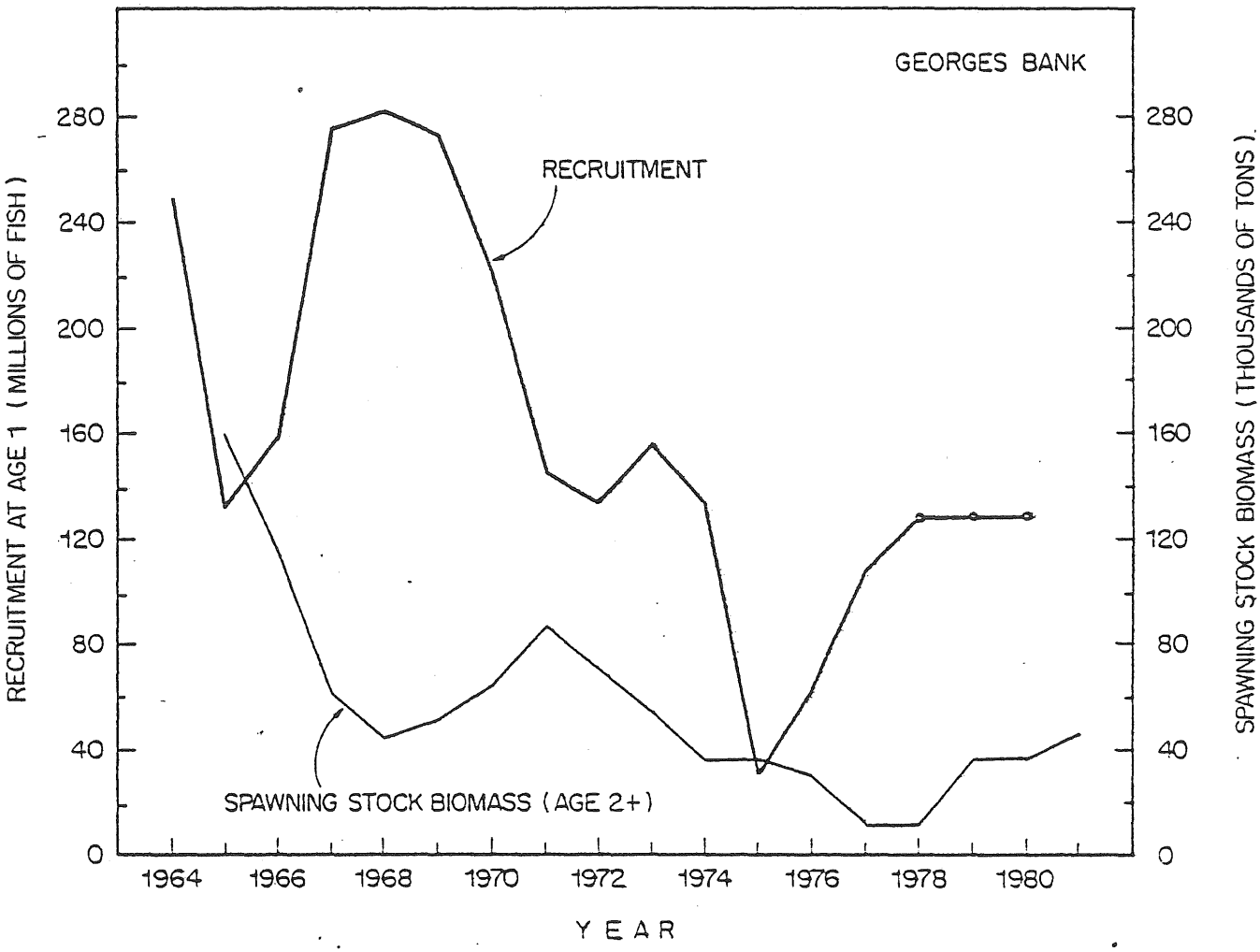

Figure 7. Georges Bank red hake spawning stock biomass (age 2+) during 1965-1981 and abundance at age 1 of the 1964-1980 year classes.

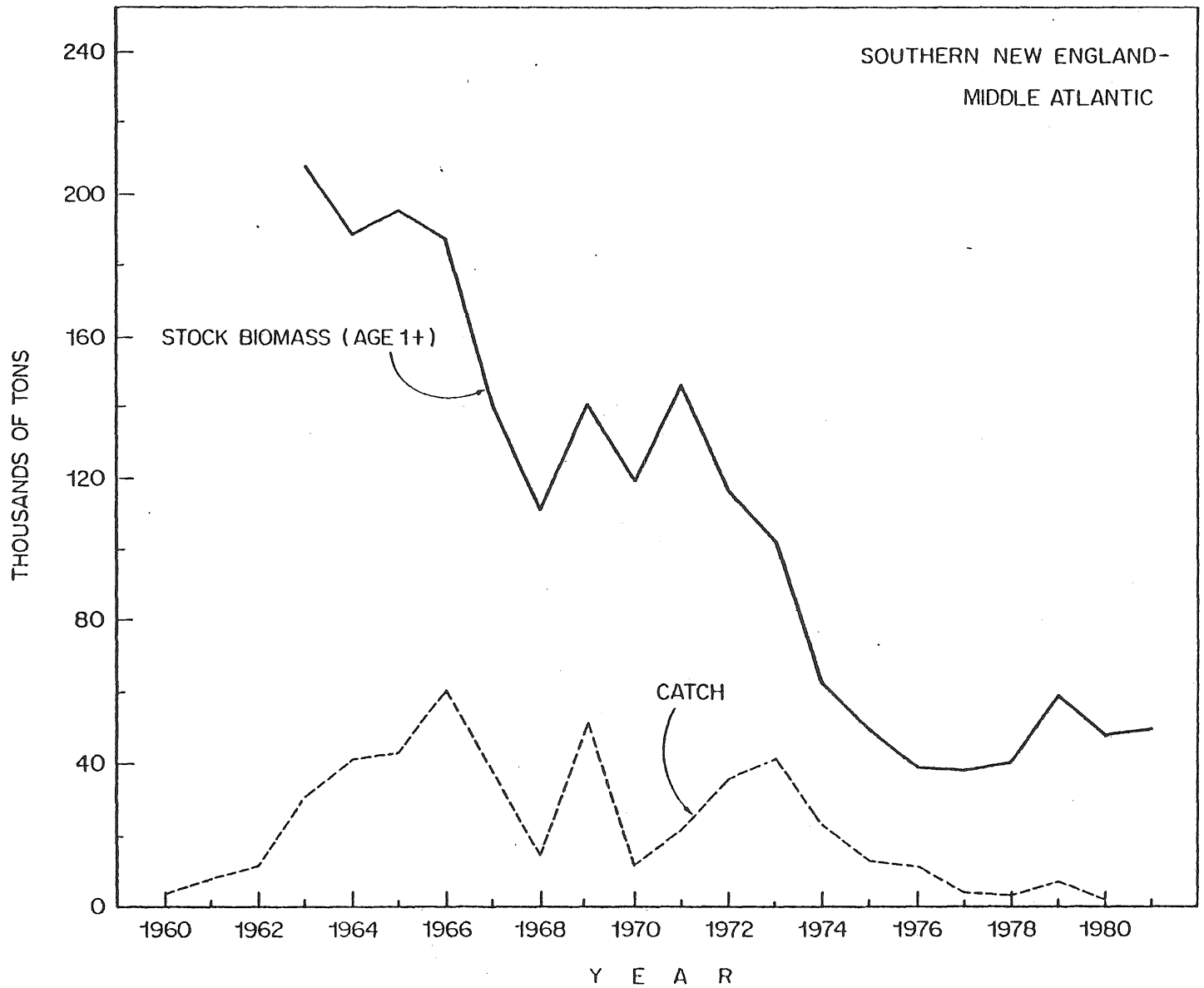

Figure 8. International catch and stock biomass (age 1+) from VPA from the Southern New England-Middle Atlantic red hake stock.

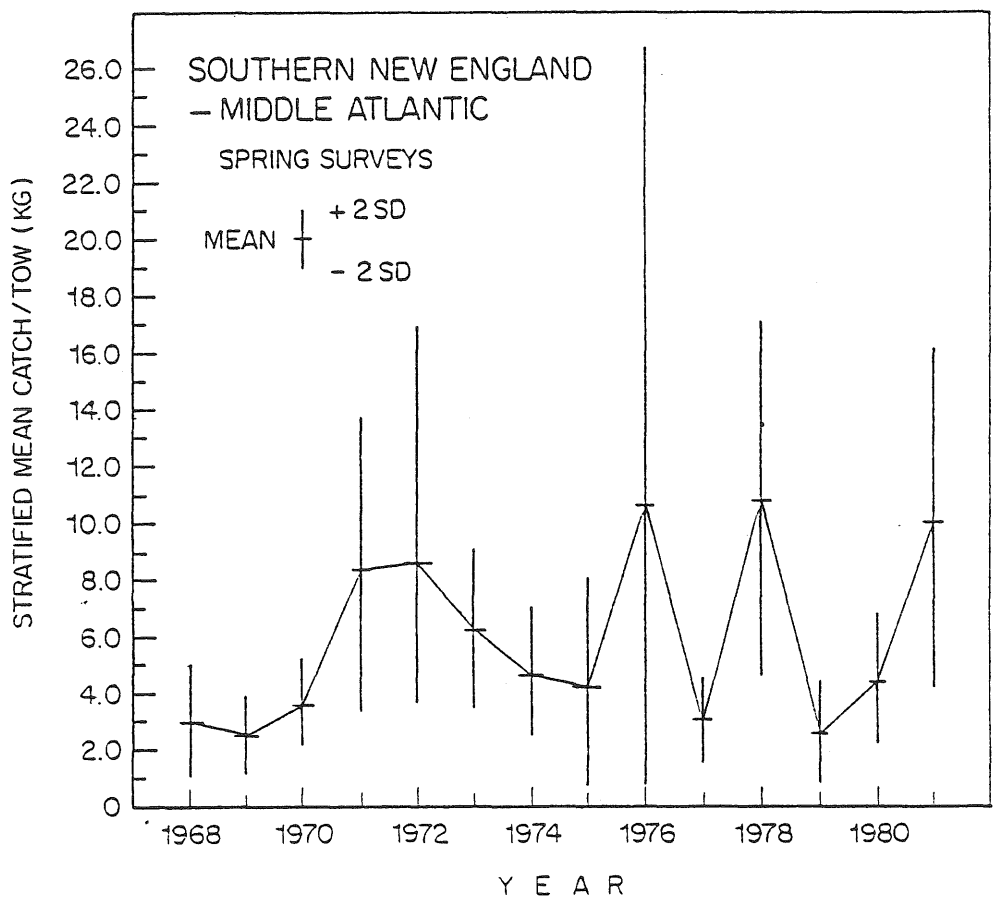

Figure 9. Stratified mean catch per tow (kg) of red hake from the Southern New England-Middle Atlantic stock from USA spring bottom trawl surveys (1968-1981).

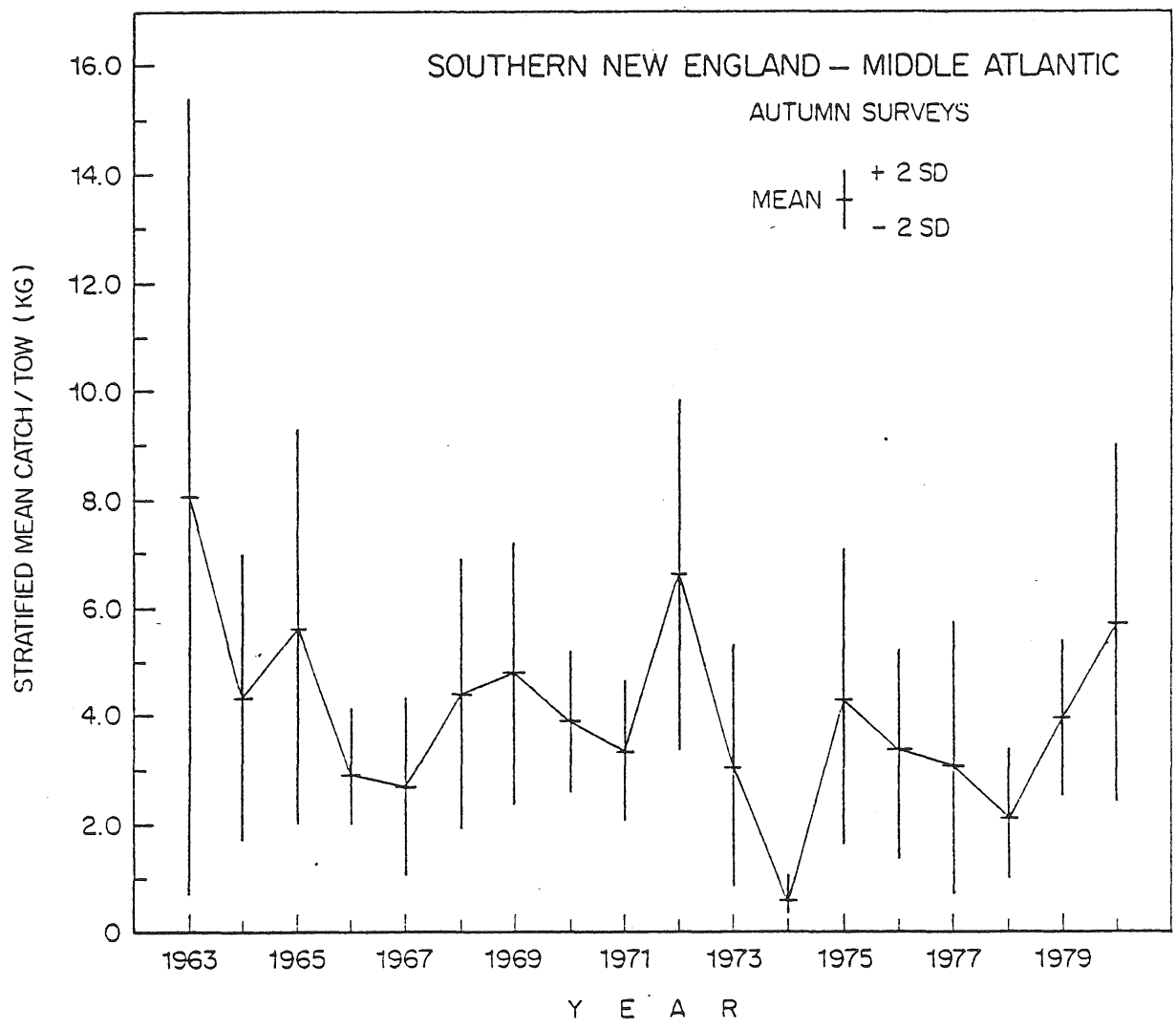

Figure 10. Stratified mean catch per tow (kg) of red hake from the Southern New New England-Middle Atlantic stock from USA autumn bottom trawl surveys (1963-1980).

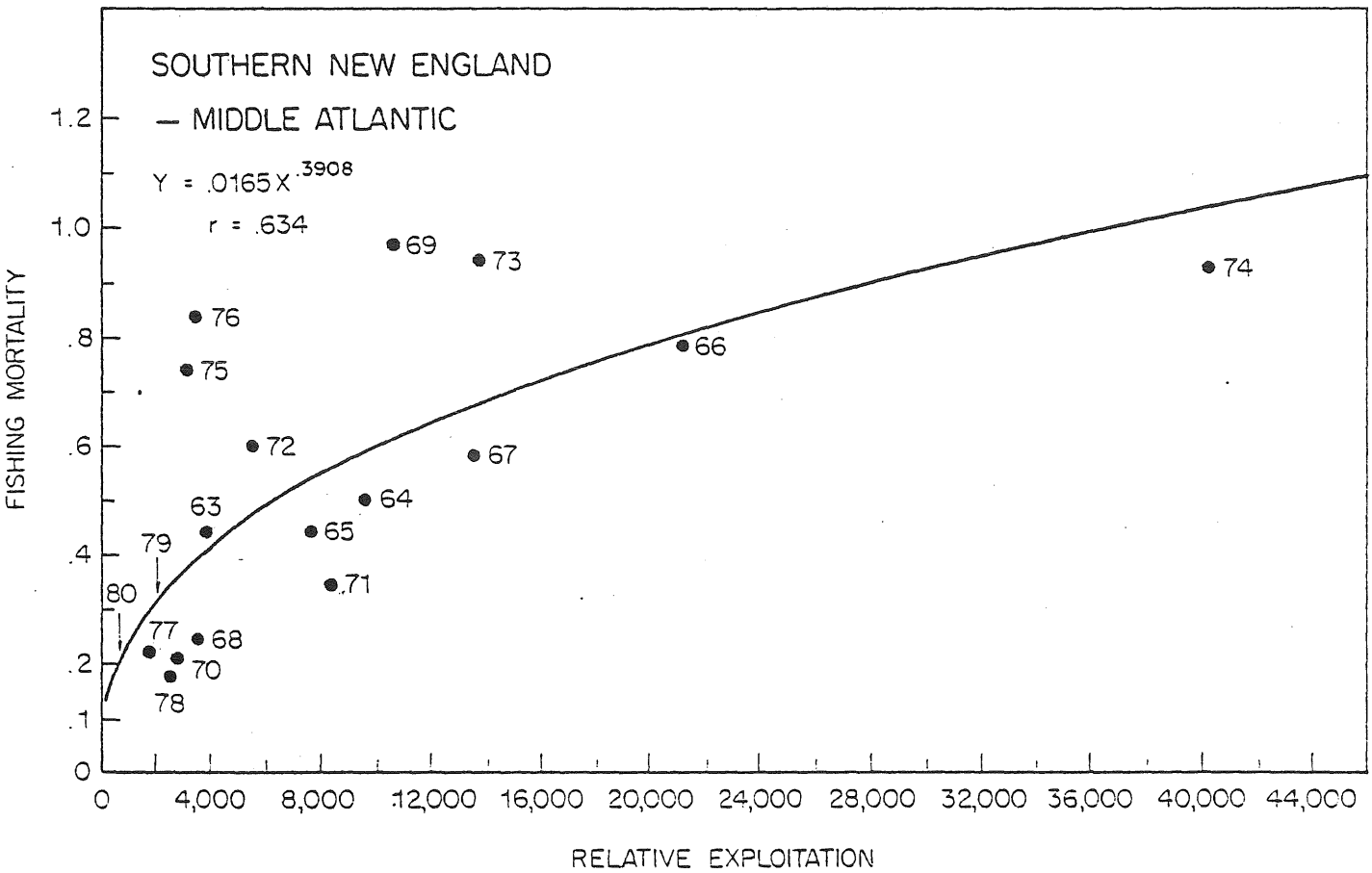

Figure 11. Relationship between fishing mortality from virtual population analysis and relative exploitation derived from autumn survey catch per tow and international catch.

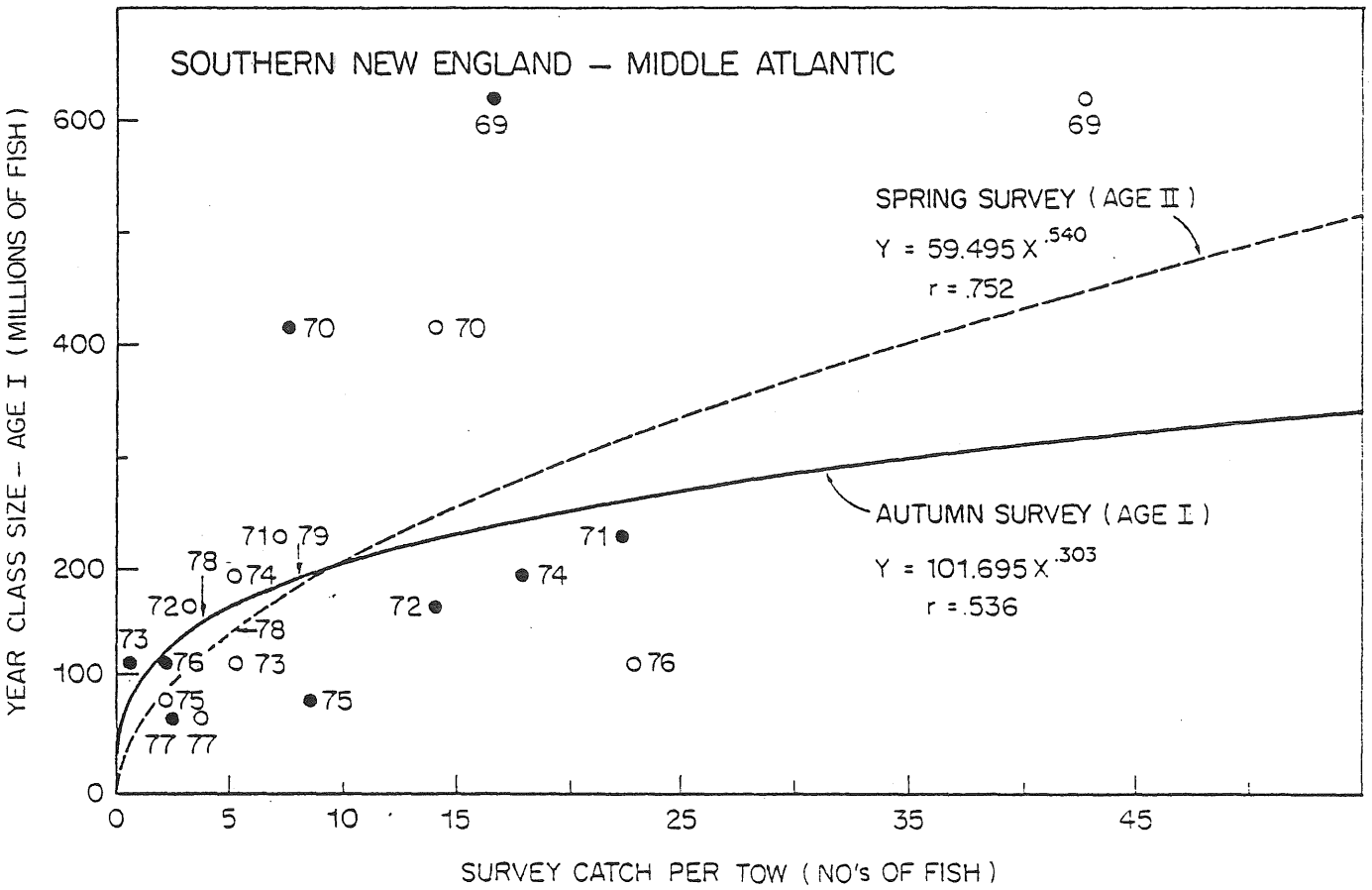

Figure 12. Relationship between year class size at age I from VPA and autumn survey catch per tow at age I (closed circles) and spring survey catch per tow at age II (open circles).

Figure 13. Southern New England-Middle Atlantic red hake spawning stock biomass (age 2+) during 1963-1981 and abundance at age 1 of the 1962-1980 year classes.