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GEORGES BANK AND GULF OF MAINE HADDOCK

ASSESSMENT UPDATE

by

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INTRODUCTION

The Georges Bank and Gulf of Maine haddock stocks were last assessed in early 1979 (Clark and Overholtz MS 1979). That document reviewed available historical information for these stocks and provided an updated analytical assessment for Georges Bank together with additional information for the Gulf of Maine; results indicated that Georges Bank stock size (age 2+) and spawning stock size (age 3+) were below historical (1935-1960) levels, although the 1978 year-class appeared to be comparable to the 1935-1960 average. An increase in spawning stock size was projected for 1981 contingent upon catch levels for 1980, although it was noted that high levels of instantaneous fishing mortality (F) in 1979 could impact rather strongly upon available spawning biomass for 1980.

In March of 1979, the New England Regional Fishery Management Council (NERFMC) determined the appropriate optimum yield (OY) for both stocks combined to be 32,500 tons, a level corresponding approximately to $F_{0.1}$ under the assumption of a 3-1 biomass ratio between Georges Bank and the Gulf of Maine. The NERFMC amended the OY in the existing Fishery Management Plan (FMP) so as to provide an OY of 28,254 tons (all areas) for the 1978-1979 fishing year; under this arrangement USA commercial allocations totalled 18,026 tons for Georges Bank and 5,128 tons for the Gulf of Maine, while 2,000 tons was designated for recreational harvest and 3,100 tons was allocated to Canada. This amendment became effective July 23 under emergency regulations (later extended to September 30), and as a result quarterly quotas for Georges Bank and the Gulf of Maine were revised

upwards for the third and fourth quarters of the 1978-1979 fishing year. Quarterly quotas for both areas under the preceding OY of 20,000 tons were exceeded during the first two quarters of the 1978-1979 fishing year, but combined landings for the remaining two quarters were substantially below revised quota levels (9,160 tons for Georges Bank and 1,880 tons for the Gulf of Maine for this period as opposed to total quotas of 13,957 tons and 3,633 tons, respectively).

In September the NERFMC prepared and submitted an additional amendment to the groundfish FMP which established quarterly quotas for the 1979-1980 fishing year corresponding to the above OY of 32,500 tons; under this arrangement proposed USA commercial allocations total 17,675 tons for Georges Bank and 7,575 tons for the Gulf of Maine. Canadian fishermen are allocated a total of 5,250 tons (both areas) with the remaining 2,000 tons being designated for recreational harvest. USA first quarter landings for Georges Bank (2,829 tons) were approximately equivalent to the proposed quarterly quota of 2,855 tons although less than half of the proposed quarterly quota for the Gulf of Maine was taken (816 tons as opposed to 1,760 tons). These regulations translate into annual USA commercial allocations of 13,939 tons (all areas) for 1978 and of 6,160 tons (Gulf of Maine) and 18,979 tons (Georges Bank) for 1979; for 1980, USA commercial allocations would be 7,575 and 17,675 tons, respectively, assuming that first quarter quotas for 1979-1980 and 1980-1981 were equivalent.

COMMERCIAL FISHERY

The history of the Georges Bank haddock fishery has been reviewed by Clark and Overholtz (MS 1979). During the 1935-1960 period, the fishery was exploited almost exclusively by USA vessels, with landings averaging approximately 46,500 tons annually. Landings subsequently increased

dramatically as vessels of other nations (notably those of the USSR and Canada) entered the fishery; total international landings peaked at 150,400 tons in 1965, declined to 121,300 tons in 1966, and then dropped precipitously to an average of 4,700 tons from 1974-1976 under incidental catch limitations (Table 1, Figure 1). Landings subsequently increased to 22,339 tons in 1978 coincident with recruitment of the strong 1975 year-class and increased USA and Canadian effort; during that year, USA landings totalled 12,160 tons, while Canadian landings totalled 10,179 tons. Preliminary statistics for 1979 indicate total landings of 18,968 tons, of which 4,804 tons were taken by Canada and 14,164 tons were taken by the USA (Table 1, Figure 1).

Historical trends for the Gulf of Maine have been generally similar. Landings averaged approximately 2,900 tons from 1931-1947 but then increased to an annual average of 7,300 tons from 1953-1958 before declining to an average of 5,100 tons from 1959-1966 (Clark and Overholtz MS 1979). Landings subsequently declined continually to 600 tons in 1973 and then increased continually to 5,179 tons in 1978; preliminary statistics for 1979 indicate landings of 4,287 tons (Table 1, Figure 1). During the 1977-1979 period USA vessels accounted for 93% of the total landings from the Gulf of Maine. Distant-water fleets have not reported haddock landings from either area since 1976.

It should be noted that the actual commercial catch of haddock during 1977-1979 appears to have been greatly underestimated. Industry sources have corroborated that large amounts of scrod haddock were routinely discarded during directed operations for other species in 1977 due to vessel trip limitations, while during 1978 and 1979 substantial amounts appear to have been either discarded or misreported by area

or as other species (e.g., as pollock) to circumvent landings restrictions. There is no basis for quantifying actual amounts involved in either case.

Commercial Catch Age Composition

Historical data relative to the age structure of the Georges Bank commercial catch were presented in a previous assessment (Clark and Overholtz MS 1979). During 1935-1960, landings were dominated by age 2-4 fish (81% by number, Figure 2) but during the mid-1960's heavy exploitation by distant-water fleets employing small-mesh gear resulted in a dramatic shift in age composition (e.g., in 1965 landings of age 2 fish comprised over 70% of the total by number as opposed to 33% during 1935-1961). In succeeding years recruitment was poor and from 1967-1976 landings of age 2-4 fish were minimal. In 1977, the strong 1975 year-class recruited to the fishery and accounted for 76% of the total landings by number; corresponding percentages for 1978 and for the first two quarters of 1979 were 83% and 68%, respectively (Figure 2). Thus, the fishery continues to be dominated by the 1975 year-class, although recruitment of the 1978 year-class is expected to change this pattern appreciably during the current year.

Age composition data for the Gulf of Maine are comparatively limited, although available information suggests that recruitment patterns have been generally similar. The 1963 year-class contributed the bulk of the landings by number and weight from this area from 1966-1970 (Clark and Overholtz MS 1979) which the 1975 year-class again appears to have dominated 1977 and 1978 landings as well as landings during the first two quarters of 1979. Intervening years have been characterized by poor recruitment as was the case for Georges Bank. Trends in landings by

market category (Figure 3) have been generally consistent between areas since 1972 and further attest to the recent importance of the 1975 year-class in both areas.

RECREATIONAL FISHERY

Recreational catch information for the New England area has been collected in national salt-water angling surveys for 1960, 1965, and 1970 (Clark 1962; Deuel and Clark 1968; Deuel 1973) and in a regional survey of the northeastern United States in 1974 (Ridgely and Deuel MS 1976). The first three surveys were conducted by household interviews, while the 1974 survey was conducted by a combination telephone-mail survey; also, regional boundaries were slightly different. Consequently, results from these surveys are comparable only in a general way.

The 1960, 1965, and 1970 surveys indicated recreational landings of haddock totalling 767 tons, 9,702 tons, and 1,147 tons, respectively. The 1974 survey, however, indicated a recreational catch of only 199 tons, while (provisional) party and charter-boat logbook data for 1978 indicate a total catch of 278 tons for that segment of the fishery (Nicholson and Ruais MS 1979). The 1970 survey indicated that party and charter boats accounted for 70% of the total recreational haddock catch in that year (Deuel 1973), suggesting that the total 1978 catch may have been in the order of 4-500 tons. The bulk of the reported 1978 catch was taken in late summer, and practically the entire amount (277 tons) was taken in the western Gulf of Maine as would be expected from observed distributions of haddock and recreational effort by area and season. Even in the Gulf of Maine, however, haddock appear to be of relatively minor importance as a recreational species, e.g. in 1977, cod and pollock accounted for 90%

of the Maine party boat catch (Hussey and Flagg MS 1977, In Nicholson and Ruais MS 1979).

TRENDS IN ABUNDANCE

Research Vessel Survey Catches

Bottom-trawl surveys have been conducted by the Northeast Fisheries Center (NEFC) on Georges Bank and in the Gulf of Maine since summer of 1963. Information relative to vessels and gear used, sampling design and survey procedures, and application of resulting data to assessments is provided elsewhere (Grosslein 1969, MS 1969; Clark 1979); use of these data for assessment of the Georges Bank and Gulf of Maine haddock stocks is described by Clark and Overholtz (MS 1979).

The spring survey index for Georges Bank (stratified mean catch per tow, kg) declined from 23.1 kg in 1968 to 5.6 kg in 1971, increased to 11.7 kg in 1974, and then dropped to 5.4 kg in 1975 before increasing steadily to 20.7 kg in 1978, reflecting the presence of the strong 1975 year-class (Table 2, Figure 4). The Spring 1979 index value declined somewhat (13.1 kg). Trends in the corresponding numbers index have been generally similar; values increased sharply from 4.2 fish per tow in 1975 to 55.8 fish in 1976 and subsequently declined steadily to 13.0 fish in 1978; the spring 1979 index value was 30.5 fish, reflecting the presence of the 1978 year-class (Table 2). The autumn survey (weight) index for Georges Bank declined more or less continually from 64.1 kg in 1964 to 2.6 kg in 1974 and then increased to an average of 23.4 kg in 1976-1977. The index subsequently declined to 15.2 kg in 1978 and then increased to 26.9 kg in 1979 (Table 2, Figure 4). Trends in numbers per tow have closely paralleled trends observed for the weight index (Table 2). Thus, trends in research

vessel survey indices for Georges Bank in recent years strongly reflect changes in abundance and biomass associated with the appearance of the 1975 and 1978 year-classes.

Trends in abundance indices calculated for the Gulf of Maine have been essentially similar to those observed for Georges Bank (Table 2, Figure 4). The spring survey (weight) index declined more or less continually from 9.2 kg in 1968 to 0.7 kg in 1974 but then increased to 4.5 kg in 1977 before declining to 1.0 kg in 1978; the Spring 1979 index value was 3.2 kg. The corresponding autumn survey index declined more or less continually from 33.6 kg in 1963 to 2.2 kg in 1974, averaged 5.5 kg for 1975-1976, and then increased sharply to 18.2 kg in 1978 before declining to 11.5 kg in 1979. Trends in numbers per tow were virtually identical for both indices (Table 2). Thus, recent index values for the Gulf of Maine clearly reflect recruitment of the 1975 year-class, although the 1978 year-class appears to be relatively weaker than on Georges Bank.

Stratified mean catch per tow at age data (Tables 3 and 4) reveal that the 1962 and 1963 year-classes dominated the Georges Bank and Gulf of Maine haddock population until the early 1970's. In recent years only the 1975 and 1978 year-classes appear to have been of any consequence on Georges Bank (Figure 5); during 1977-1979 the 1975 year-class accounted for 85% of the total catch of age 2 and older fish in the spring survey and 84% in the autumn survey. The 1978 year-class at age 1 was less than one-half the size of the 1975 year-class in the 1979 spring survey (Table 3, Figure 5) but was approximately equal in size to that year-class in the 1979 autumn survey (Table 4, Figure 5). The 1975 year-class has also been a relatively strong one in the Gulf of Maine (Tables 3 and 4, Figure 6) although the 1976 year-class appears to have been relatively stronger

than on Georges Bank. The 1978 year-class appears to be very weak in the Gulf of Maine in both the spring and autumn surveys (Figure 6).

Although recent survey data indicate a significant improvement in recruitment and stock abundance, it should be noted that the distribution of haddock on Georges Bank appears to have changed markedly both by area and on a catch per tow basis (Figure 7). In the mid 1960's concentrations of haddock appear to have been more widely distributed than at present, e.g. during 1964-1966 mean catch per tow values of $\geq$ 10 kg were observed for 36 of the 45 strata-year combinations examined (15 strata, 3 years) while during 1977-1979 values of $\geq$ 10 kg occurred in only 21 cases. Distribution plots presented by Clark and Overholtz (MS 1979) indicate a distinct tendency for haddock to be concentrated on the northern edge and northeast peak areas of Georges Bank since 1976 whereas during the mid-1960's substantial concentrations occurred in other areas as well. Frequency distributions (numbers per tow) have changed significantly since the mid-1960's (Figure 7) and relative variability has increased (Table 5), e.g. the coefficient of variation has more than doubled between the mid-1960's and the 1977-1979 period. These results indicate that the nature of the underlying distribution may have changed during the history of the survey. Pennington and Grosslein (1978) note that the negative binomial distribution is most often appropriate for describing survey data and under this hypothesis a logarithmic transformation is appropriate as a variance-stabilizing approach; however non-normality is not necessarily reduced, and in many cases the resulting distribution was still found to be far from normal. In the present situation, trends for indices calculated from transformed data, i.e. $\ln(x + 1)$ agreed very closely with trends for indices calculated from linear data although agreement with biomass estimates

calculated from virtual population analysis or VPA was not as good ($r = 0.94$ and 0.79 for linear and transformed indices, respectively, for numbers and 0.98 and 0.91, respectively, for weight).

Virtual Population Analysis

Clark and Overholtz (MS 1979) performed a virtual population analysis or VPA for the Georges Bank stock which indicated a long-term average stock size (age 2+) of 152 million fish or 175,000 tons from 1935-1960. In the late 1950's and early 1960's, however, stock size increased steadily in response to recruitment from a series of strong year-classes (notably the strong 1962 and the outstanding 1963 year-classes) culminating in a peak of 514 million fish or 433,000 tons in 1965. (The 1963 year-class was estimated at 371 million fish at age 2, more than twice the size of any other year-class observed in the fishery.) Stock abundance subsequently declined precipitously to an apparent all-time low of 9 million fish or 23,000 tons in 1972 in response to overexploitation and poor recruitment before again increasing due to recruitment of the strong 1975 year-class. Recruitment estimates presented in that assessment suggested an increase in stock size to above the 1935-1960 average in 1977. Similarly, spawning stock size (age 3+) averaged 86 million fish or 125,000 tons from 1935-1960 but increased to a peak of 264 million fish or 251,000 tons in 1966 before declining to an apparent all-time low of 5 million fish or 15,000 tons in 1973. Subsequently, spawning stock size increased substantially in 1978 as the 1975 year-class recruited to the spawning stock. Trends obtained from this analysis are in close agreement with those observed in NEFC spring and autumn survey indices.

CURRENT ASSESSMENT

Georges Bank

Stock size (age 2+) for Georges Bank is primarily dependent upon the strength of the 1978 year-class, which will begin recruiting to the fishery in the latter part of the current year. Spawning biomass (age 3+) is now largely supported by the remnant of the strong 1975 year-class. This year-class appears to have been substantially stronger than the 1935-1960 average of 65 million fish at age 2 and, although apparently subjected to heavy fishing mortality in 1977 from landings and discard and/or misreporting, it was nevertheless estimated at 75 million fish at age 3 (Clark and Overholtz MS 1979). Since 1977, the fishery has been supported primarily by this year-class.

The VPA presented in the preceding assessment has not been updated by inclusion of catch at age data for 1978-1979 due to uncertainty relative to discarding and/or misreporting in those years. Accordingly, stock size for 1980 (age 3+) was estimated from a regression of stock size (numbers, age 3+) from the 1931-1977 VPA on NEFC autumn survey catch per tow (numbers, age 2+), which provided a spawning stock size estimate of 18 million fish ($r = 0.97$, Figure 8). Apportionment based upon relative year-class strength observed in the 1979 NEFC autumn survey provided an estimate of only 12 million fish at age 5 for the 1975 year-class. This estimate is compatible with mortality and survival rates evidenced by NEFC survey data for this year-class (instantaneous total mortality [Z] = 0.86 and 0.92 for 1978 and 1979 respectively) and the original estimate of 75 million fish

provided for 1978 (Clark and Overholtz MS 1979), i.e., these estimates of Z imply survival of only 13 million fish by the beginning of 1980. This estimate is not compatible with reported rates of removal (11 million fish in 1978 and 7 million fish for 1979, which would imply a 1980 stock size of 36 million fish for this year-class assuming instantaneous natural mortality (M) = 0.2). The discrepancy apparently relates to discard and/or misreporting during 1978-1979 although the strength of this year-class could obviously have been overestimated for 1978 or underestimated now. In any event it appears that the 1975 year-class has been greatly reduced and that spawning biomass in 1981 will be supported primarily by the 1978 year-class.

Due to the importance of the 1978 year-class in 1980-1981 several estimators were evaluated for use in determining its strength. A regression of stock size at age 2 (numbers) calculated from VPA on autumn bottom trawl survey catch per tow values (age 0+1 combined) for the 1962-1974 year-classes (Figure 9) provided an estimate of 138 million fish at age 2 (comparable to the 1975 year-class size estimate at age 2 of 170 million fish). Estimates based on either age 0 or age 1 data vary considerably, i.e., linear regressions of stock size at age 2 calculated from VPA on autumn bottom trawl survey catch per tow values at age 0 (Figure 10) and age 1 provide estimates of 67 million fish and 185 million fish at age 2, respectively, for this year-class. The Spring 1979 survey supports the lowest estimate in that actual catches of the 1978 year-class at age 1 were only 45% of the corresponding 1975 year-class value (Spring 1976 Survey). Assuming the 1975 year-class was equal to 170 million fish at age 2, the 1978 year-class age 2 estimate would be 76 million fish. It should also be noted that predicted values from the above regressions are strongly influenced by data for the strong 1962 and 1963 year-classes, as the remaining year-classes in the available VPA-survey time series were very weak.

The information currently available concerning the strength of the 1979 year-class is the above age 0 index which suggests it to be comparable to the weak 1976 and 1977 year-classes. An estimate of 3 million fish was obtained from

the above age 0 regression (Figure 10) and has been accepted for this year-class.

Assuming a 1980 spawning stock size (age 3+) in the order of 18 million fish (42,200 tons) and recruitment at age 2 of 138 million fish and 3 million fish, respectively, for the 1978 and 1979 year-classes, fishing at F_{max} = 0.55 in 1980 would provided a total catch of 59,700 tons, with a total stock size (age 2+) in 1981 of 86 million fish or 112,300 tons (8% below the 1980 level of 122,300 tons); fishing at $F_{0.1}$ = 0.26 in 1980 would provide a catch of 31,500 tons, with a total stock size (age 2+) in 1981 of 107 million fish or 141,700 tons (16% above the 1980 level of 122,300 tons). Corresponding spawning stock size estimates for 1981 (83 million fish or 110,600 tons and 104 million fish or 140,000 tons) increase considerably over 1980 levels (Table 6). Average historical (1935-1960) total and spawning stock sizes are 152 million fish (175,000 tons) and 86 million fish (125,000 tons) respectively.

Gulf of Maine

To date, an analytical assessment has not been completed for the Gulf of Maine, and recent assessments have been based primarily upon research vessel survey data and examination of commercial landings trends. As noted above, trends in both sets of data have been generally similar, suggesting declines in abundance to an apparent all-time low in the early 1970's before increasing substantially in recent years (Tables 1 and 2, Figures 1 and 4). Trends in recruitment also appear to have been generally similar (Tables 3 and 4) although in recent years data have not been as consistent, e.g., the 1976 year-class appears to have been relatively stronger in the Gulf of Maine than on Georges Bank, while the 1978 year-class has been very weak in both spring and autumn surveys (Tables 3 and 4).

Clark and Overholtz (MS 1979) observed that average minimum biomass estimates for 1963-1977 for Georges Bank and the Gulf of Maine as determined from NEFC autumn surveys had varied in an approximate 3-1 ratio and suggested that future OY levels for both areas be established based upon this ratio (i.e., by increasing the estimated Georges Bank stock by one-third). Unfortunately, this ratio has not been consistent between years, e.g., it approximated 5-1 for 1976-1977 and 1-1 for 1978 before increasing to approximately 3-1 in the 1979 survey. The 1978 autumn survey index for the Gulf of Maine was the highest since 1963, indicating a relatively high stock biomass for 1979, although USA 1979 commercial landings were considerably lower than combined quarterly quotas for that year (4,112 tons as opposed to 6,160 tons). However, pooled total mortality estimates (Z) for fully recruited age groups since 1976 calculated from NEFC spring and autumn survey data were considerably lower for the Gulf of Maine than for Georges Bank (0.52 and 0.31, respectively, for spring and autumn survey data for the Gulf of Maine as opposed to 0.84 for both surveys on Georges Bank). The 1979 autumn survey (weight) index (11.5 kg) declined considerably from the observed 1978 value but was still the highest observed since 1963 (Table 2).

Total commercial landings for 1978-1979 (averaging 4,733 tons) conform reasonably well to levels observed during 1964-1968 (average of 4,915 tons). The estimated annual recreational catch for the Gulf of Maine for 1978-

1979 would approximate 400 tons based on 1978 data; recreational catch levels for the mid-1960's are uncertain due to variability in the estimates, e.g., the above 1965 estimate of 9702 tons appears unrealistically high in view of 1960 and 1970 estimates averaging less than 1000 tons and more recent estimates averaging less than 500 tons. The pooled mortality (Z) estimate for 1964-1968 calculated over fully recruited age classes from NEFC autumn survey data was 0.58, and assuming M = 0.2, then F approximated 0.38. Current biomass levels appear comparable to levels observed during 1964-1968 in that the average autumn survey (weight) index value for these years (11.2 kg) is approximately equal to the autumn 1979 index value of 11.5 kg and to the autumn 1977-1979 average of 12.3 kg.

By combining the average annual Gulf of Maine commercial landings figure for 1964-1968 (4915 tons) with the average estimated recreational catch for 1960 and 1970 (957 tons) an average of 5872 tons for this period is obtained. Use of this value with the above estimates of F and Z in the relation

$$C = \frac{F}{Z-G} B_o (1-e^{-[Z-G]})$$

where

C = average catch,

B_o = average stock biomass,

F = instantaneous fishing mortality rate,

G = instantaneous growth rate (taken as the average of the dominant age groups [2-4] in the fishery = 0.44),

and $Z = F + M$, the instantaneous natural mortality rate,

provides an average annual stock biomass estimate of 16,600 tons. Under the assumption that current levels of stock size are roughly equivalent,

fishing at $F_{0.1}$ would provide a catch of 4,300 tons, comparable to reported 1979 commercial and estimated recreational landings of approximately 4,700 tons. Fishing at F_{max} would provide a catch of 7,800 tons.

SUMMARY

The available information indicates that the Georges Bank haddock situation is now similar to that observed at the beginning of 1977. While the 1975 year-class still comprises the bulk of the currently exploited stock, it has been greatly reduced in abundance due to fishing and natural mortality. Total mortality rates since 1976 appear to be much higher than can be accounted for based on reported catches, indicating that there has been significant unreported catch and discarding. The rapid decline of the 1975 year-class (it supported the fishery for only about three years) indicates that the fishing mortality rate is probably in excess of F_{max}. The 1978 year-class appears to be of comparable size to the 1975 year-class (perhaps somewhat smaller). The exploited stock size will increase sharply in 1980 as the 1978 year-class recruits. The spawning stock size will increase sharply in 1981 depending on the level of fishing mortality in the interim.

The exploited biomass of Georges Bank haddock will be approximately twice the 1979 value in 1980 as indicated by autumn bottom trawl survey data. Thus, the same level of exploitation (and fishing effort) as in 1979 will produce a catch roughly twice that of 1979 (40,000 tons, assuming the most recent year's reported catch is accurate). The 1978 year-class may be large enough so that the stock may recover to the long-term average level of the 1935-1960 period. If this occurs and recent fishing mortality rates are in fact in excess of F_{max} (as indicated by survey data) then the 1980 catch could greatly exceed 40,000 tons (perhaps as high as 60,000 tons) if unrestrained. Large catches of two year-old scrod haddock are expected, and significant

discarding of fish below the minimum marketable size is likely. The 1978 year-class will recruit to the fishery primarily in the second half of the year.

Note that the 1975 year-class only supported the fishery for about three years. If the fishing mortality rate of recent years is maintained (as it certainly will be if not restrained), the 1978 year-class will quickly decline in abundance and the fishery will be nearly totally dependent on recruitment of the 1979-1981 year-classes by 1983. The 1979 year-class appears to be weak. The 1980 year-class will result from a relatively low spawning stock size since the 1978 year-class will not have yet recruited to the spawning stock. The size of the 1978 year-class when it recruits to the spawning stock in 1981 will depend on the level of fishing mortality in the interim. Even a large spawning stock size in 1981 does not assure that a strong year-class will be produced. The fortunate circumstances of 1978 (the 1975) year-class producing a strong year-class during its first spawning season) may not reoccur. The current fishing mortality rate will reduce the population to levels typical of the early 1970's within a few years unless the 1980 or 1981 year-class is large enough to offset the decline.

The Gulf of Maine haddock fishery has been supported by the 1975 and to a lesser degree the 1976 year-class in recent years. Unlike Georges Bank, the 1978 year-class does not appear strong for the Gulf of Maine. On the other hand, the 1979 year-class may be relatively stronger in the Gulf of Maine than on Georges Bank. Based on analysis of commercial and survey data, the 1980 catch at $F_{0.1}$ and F_{max} is estimated at 4,300 tons and 7,800 tons, respectively.

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Table 1. Commercial landings[1] of haddock (metric tons, live) from Georges Bank and the Gulf of Maine, 1960-1979.

	Georges Bank				Gulf of Maine			
Year	USA	Canada	Other[2]	Total	USA	Canada	Other[2]	Total
1960	40,800	77	--	40,877	4,541	383	--	4,924
1961	46,384	266	--	46,650	5,297	112	--	5,409
1962	49,409	3,461	1,134	54,004	5,003	107	--	5,110
1963	44,150	8,379	2,317	54,846	4,742	3	44	4,789
1964	46,512	11,625	5,949	64,086	5,383	70	--	5,453
1965	52,823	14,889	82,650	150,362	4,204	159	--	4,363
1966	52,918	18,292	50,064	121,274	4,579	1,125	--	5,704
1967	34,728	13,040	3,701	51,469	4,907	589	--	5,496
1968	25,469	9,323	6,131	40,923	3,437	120	--	3,557
1969	16,456	3,990	1,806	22,252	2,423	59	231	2,713
1970	8,415	1,978	907	11,300	1,457	38	67	1,562
1971	7,306	1,630	1,926	10,862	1,194	85	27	1,306
1972	3,869	609	1,255	5,733	909	23	4	936
1973	2,777	1,563	991	5,331	509	49	--	558
1974	2,396	462	1,432	4,290	622	198	9	829
1975	3,989	1,358	73	5,420	1,180	79	4	1,263
1976	2,904	1,361	59	4,324	1,865	91	--	1,956
1977	7,934	2,909	--	10,843	3,296	26		3,322
1978[3]	12,160	10,179	--	22,339	4,538	641		5,179
1979[4]	14,164	4,804	--	18,968	4,112	175		4,287

[1] As reported to ICNAF for Divisions 5Z and 5Y respectively (5NK landings have been assigned to Division 5Z).

[2] Distant-water fleets.

[3] Provisional (incomplete)

[4] Preliminary

Table 2. Stratified mean catch per tow in numbers and weight (kg) for haddock in NEFC spring and autumn bottom trawl surveys on Georges Bank (Strata 13-25, 29, and 30) and in the Gulf of Maine (Strata 26-28 and 36-40), 1963-1979.

	Georges Bank				Gulf of Maine			
	Spring[1]		Autumn		Spring[1]		Autumn	
Year	Nos.	Wt (kg)	Nos.	Wt (kg)	Nos.	Wt (kg)	Nos.	Wt (kg)
1963	-	-	97.34	52.83	-	-	46.68	33.57
1964	-	-	129.70	64.07	-	-	9.51	12.47
1965	-	-	68.26	48.20	-	-	11.70	11.72
1966	-	-	22.32	19.78	-	-	7.82	9.18
1967	-	-	11.40	16.87	-	-	8.18	11.16
1968	15.56	23.13	5.06	10.20	6.99	9.17	5.75	11.42
1969	8.26	19.05	2.28	5.59	4.32	8.30	3.66	8.51
1970	6.84	19.28	5.17	8.94	1.03	1.94	1.96	4.87
1971	3.18	5.62	2.83	3.70	1.00	2.84	1.93	5.39
1972	7.26	8.30	7.62	5.61	0.98	0.98	1.33	2.01
1973	25.23	10.18	9.98	6.48	0.88	1.06	2.80	5.68
1974	12.77	11.72	2.71	2.64	0.96	0.70	1.80	2.21
1975	4.18	5.44	20.78	10.00	1.86	2.30	3.71	5.71
1976	55.83	10.41	47.68	23.68	5.59	4.21	4.05	5.32
1977	24.74	17.60	19.02	23.13	4.56	4.45	6.79	7.34
1978	13.03	20.71	20.70	15.18	0.91	0.95	8.00	18.16
1979	30.53	13.09	42.74	26.87	2.32	3.17	4.52	11.50

[1]Data for 1968-1972 adjusted by a factor of 1.7 to compensate for differences in surface area between the "36 Yankee" and the "41 Yankee" trawls.

Table 3. Stratified mean catch per tow at age (numbers) for haddock in NEFC spring bottom trawl surveys on Georges Bank (Strata 13-25, 29, and 30) and in the Gulf of Maine (Strata 26-28 and 36-40), 1968-1979.[1]

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12+	Totals 1+[2]	2+	3+
							Georges Bank								
1968	0.27	3.23	0.53	0.80	7.62	1.92	0.29	0.51	0.37	0.00	0.00	0.00	15.54	15.27	12.04
1969	0.02	0.05	0.66	0.17	0.48	4.83	1.17	0.32	0.15	0.17	0.10	0.10	8.23	8.21	8.16
1970	0.77	0.29	0.00	0.37	0.53	0.53	2.28	1.12	0.54	0.14	0.22	0.07	6.85	6.08	5.79
1971	0.00	1.33	0.29	0.00	0.14	0.14	0.10	0.94	0.20	0.03	0.00	0.03	3.20	3.20	1.87
1972	4.61	0.10	0.70	0.14	0.03	0.05	0.15	0.03	0.97	0.29	0.10	0.12	7.29	2.68	2.58
1973	20.59	3.25	0.00	0.36	0.06	0.00	0.12	0.01	0.00	0.66	0.05	0.15	25.25	4.66	1.41
1974	1.43	8.92	1.92	0.00	0.16	0.00	0.01	0.07	0.00	0.00	0.16	0.09	12.76	11.33	2.41
1975	0.63	0.65	2.23	0.42	0.00	0.09	0.06	0.01	0.00	0.00	0.01	0.09	4.19	3.56	2.91
1976	54.22	0.20	0.40	0.62	0.29	0.00	0.03	0.00	0.00	0.00	0.01	0.06	55.83	1.61	1.41
1977	0.41	22.42	0.28	0.82	0.40	0.30	0.00	0.03	0.00	0.00	0.00	0.08	24.74	24.33	1.91
1978	0.05	0.65	10.69	0.24	0.63	0.55	0.11	0.04	0.02	0.02	0.00	0.03	13.03	12.98	12.33
1979	24.24	1.06	0.76	3.83	0.22	0.11	0.25	0.04	0.02	0.00	0.00	0.01	30.54	6.30	5.24
							Gulf of Maine								
1968	0.00	0.00	0.00	0.39	5.15	1.09	0.09	0.03	0.24	0.00	0.00	0.00	6.99	6.99	6.99
1969	0.00	0.00	0.09	0.02	0.22	3.04	0.80	0.05	0.09	0.00	0.00	0.00	4.30	4.30	4.30
1970	0.00	0.00	0.00	0.00	0.00	0.17	0.70	0.10	0.05	0.02	0.00	0.00	1.04	1.04	1.04
1971	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.73	0.05	0.05	0.05	0.05	1.00	1.00	1.00
1972	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.03	0.02	0.02	0.97	0.31	0.31
1973	0.09	0.53	0.00	0.04	0.00	0.00	0.00	0.00	0.01	0.21	0.01	0.00	0.89	0.80	0.27
1974	0.60	0.06	0.22	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.06	0.97	0.37	0.31
1975	0.01	1.32	0.10	0.25	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.16	1.86	1.85	0.53
1976	3.46	0.05	1.24	0.12	0.61	0.00	0.02	0.00	0.00	0.00	0.00	0.09	5.59	2.13	2.08
1977	0.59	2.39	0.02	0.90	0.27	0.39	0.00	0.00	0.00	0.00	0.00	0.00	4.56	3.97	1.58
1978	0.06	0.47	0.21	0.04	0.10	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.85	0.38
1979	0.25	0.00	1.08	0.80	0.06	0.08	0.06	0.00	0.00	0.00	0.00	0.00	2.33	2.08	2.08

[1]Data for 1968-1972 adjusted by a factor of 1.7 to compensate for differences in surface area between the "36 Yankee" and the "41 Yankee" trawls.

[2]May not agree exactly with data in Table 2 due to rounding errors.

Table 4. Stratified mean catch per tow at age (numbers) for haddock in NEFC autumn bottom trawl surveys on Georges Bank (Strata 13-25, 29, and 30) and in the Gulf of Maine (Strata 26-28 and 36-40), 1963-1979.[1]

Year	Age 0	1	2	3	4	5	6	7	8	9	10	11	12+	Totals 0+[1]	1+	2+
								Georges Bank								
1963	56.33	17.04	6.19	4.57	5.60	3.99	1.37	1.13	0.79	0.22	0.05	0.01	0.03	97.32	40.99	23.95
1964	1.59	75.75	42.78	3.91	1.20	2.56	1.05	0.46	0.17	0.22	0.00	0.00	0.00	129.69	128.10	52.35
1965	0.22	6.82	51.94	6.51	0.72	0.54	0.61	0.54	0.17	0.18	0.00	0.00	0.00	68.25	68.03	61.21
1966	4.12	0.64	1.94	12.34	2.25	0.35	0.33	0.22	0.08	0.05	0.00	0.00	0.00	22.32	18.20	17.56
1967	0.02	4.51	0.24	0.67	4.54	1.09	0.33	0.14	0.22	0.12	0.00	0.00	0.00	11.88	11.86	7.35
1968	0.06	0.04	0.64	0.09	0.22	2.59	0.85	0.18	0.11	0.26	0.00	0.00	0.00	5.04	4.98	4.94
1969	0.26	0.02	0.00	0.19	0.09	0.11	1.02	0.34	0.06	0.04	0.04	0.00	0.10	2.27	2.01	1.99
1970	0.03	2.77	0.14	0.01	0.19	0.18	0.34	0.92	0.32	0.18	0.02	0.04	0.03	5.17	5.14	2.37
1971	1.63	0.00	0.21	0.05	0.01	0.15	0.02	0.06	0.50	0.15	0.01	0.02	0.01	2.82	1.19	1.19
1972	4.53	1.69	0.00	0.35	0.06	0.00	0.06	0.04	0.02	0.51	0.26	0.05	0.05	7.62	3.09	1.40
1973	2.17	6.04	1.08	0.00	0.13	0.03	0.00	0.05	0.01	0.01	0.37	0.06	0.04	9.99	7.82	1.78
1974	0.50	1.19	0.66	0.21	0.00	0.01	0.00	0.00	0.00	0.02	0.00	0.09	0.04	2.72	2.22	1.03
1975	15.76	0.42	0.48	3.26	0.62	0.00	0.02	0.00	0.01	0.01	0.00	0.00	0.19	20.77	5.01	4.59
1976	2.90	43.07	0.35	0.36	0.55	0.20	0.00	0.03	0.07	0.03	0.00	0.00	0.14	47.70	44.80	1.73
1977	0.11	1.75	15.33	0.46	0.47	0.52	0.28	0.03	0.01	0.00	0.00	0.00	0.07	19.03	18.92	17.17
1978	10.82	0.69	0.85	7.59	0.15	0.21	0.37	0.01	0.00	0.01	0.00	0.00	0.00	20.70	9.88	9.19
1979[2]	1.08	37.01	0.22	0.77	3.00	0.20	0.20	0.13	0.08	0.02	0.00	0.00	0.03	42.74	41.66	4.65
								Gulf of Maine								
1963	23.90	8.18	1.14	2.02	4.66	3.31	1.12	0.88	0.70	0.47	0.24	0.00	0.03	46.65	22.75	14.57
1964	0.02	2.99	1.87	0.48	0.82	1.62	0.96	0.32	0.22	0.18	0.03	0.00	0.00	9.51	9.49	6.50
1965	0.04	0.25	5.39	3.40	0.17	0.98	0.77	0.44	0.21	0.04	0.00	0.00	0.00	11.69	11.65	11.40
1966	0.01	0.03	0.37	4.86	1.60	0.18	0.41	0.29	0.04	0.02	0.00	0.00	0.00	7.81	7.80	7.77
1967	0.00	0.00	0.20	0.83	5.37	1.21	0.33	0.08	0.12	0.03	0.00	0.00	0.00	8.17	8.17	8.17
1968	0.00	0.00	0.00	0.06	0.13	4.13	0.95	0.17	0.22	0.09	0.00	0.00	0.00	5.75	5.75	5.75
1969	0.00	0.00	0.00	0.02	0.02	0.02	2.78	0.57	0.09	0.01	0.06	0.00	0.07	3.64	3.64	3.64
1970	0.00	0.03	0.00	0.00	0.00	0.03	0.06	1.41	0.41	0.00	0.01	0.02	0.00	1.97	1.97	1.94
1971	0.18	0.00	0.04	0.00	0.01	0.00	0.07	0.11	1.34	0.07	0.06	0.00	0.06	1.94	1.76	1.76
1972	0.00	0.80	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.34	0.12	0.06	0.00	1.34	1.34	0.54
1973	0.76	0.01	0.64	0.00	0.24	0.02	0.01	0.03	0.01	0.09	0.78	0.12	0.09	2.80	2.04	2.03
1974	0.01	1.13	0.13	0.29	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.15	0.08	1.80	1.79	0.66
1975	0.60	0.15	1.29	0.37	0.93	0.00	0.03	0.03	0.00	0.00	0.02	0.06	0.24	3.72	3.12	2.97
1976	1.10	1.18	0.05	0.86	0.11	0.52	0.00	0.10	0.00	0.00	0.00	0.00	0.12	4.04	2.94	1.76
1977	0.03	2.74	2.65	0.10	0.85	0.13	0.21	0.00	0.00	0.00	0.00	0.01	0.06	6.78	6.75	4.01
1978	0.14	0.01	1.65	3.78	0.38	0.94	0.77	0.12	0.00	0.02	0.00	0.00	0.19	8.00	7.86	7.85
1979[2]	0.57	0.32	0.00	0.56	1.57	0.22	0.77	0.35	0.15	0.04	0.00	0.00	0.00	4.55	3.98	3.66

[1] May not agree exactly with data in Table 2 due to rounding errors.

[2] Preliminary.

Table 5. Stratified mean catch per tow, variance, and coefficient of variation (CV) in numbers and weight (kg) for haddock in NEFC spring and autumn bottom trawl surveys on Georges Bank (Strata 13-25, 29, and 30), 1963-1979.

	Season											
	Spring[1]						Autumn					
	Nos.			Weight (kg)			Nos.			Weight (kg)		
Year	Mean	Variance	CV	Mean	Variance	CV	Mean	Variance	CV	Mean	Variance	CV
1963	--	--	--	--	--	--	97.34	250.55	0.16	52.83	75.95	0.16
1964	--	--	--	--	--	--	129.70	579.85	0.19	64.07	137.11	0.18
1965	--	--	--	--	--	--	68.26	106.64	0.15	48.20	55.09	0.15
1966	--	--	--	--	--	--	22.32	17.54	0.19	19.78	14.27	0.19
1967	--	--	--	--	--	--	11.40	10.65	0.29	16.87	13.76	0.22
1968	15.56	17.36	0.27	23.13	26.91	0.22	5.06	2.69	0.32	10.20	8.96	0.29
1969	8.26	4.22	0.25	19.05	31.41	0.29	2.28	0.28	0.23	5.59	2.32	0.27
1970	6.84	13.66	0.54	19.28	175.02	0.69	5.17	7.00	0.51	8.94	11.17	0.37
1971	3.18	0.86	0.29	5.62	1.77	0.24	2.83	0.35	0.21	3.70	1.21	0.30
1972	7.26	7.81	0.38	8.30	2.64	0.20	7.62	2.34	0.20	5.61	1.23	0.20
1973	25.23	304.72	0.69	10.18	12.09	0.34	9.98	11.92	0.35	6.48	3.13	0.27
1974	12.77	21.35	0.36	11.72	16.31	0.34	2.71	0.43	0.24	2.64	0.51	0.27
1975	4.18	2.87	0.41	5.44	5.46	0.43	20.78	25.41	0.24	10.00	27.27	0.52
1976	55.83	710.38	0.48	10.41	11.52	0.33	47.68	512.72	0.47	23.68	104.80	0.43
1977	24.74	86.87	0.38	17.60	40.14	0.36	19.02	39.26	0.33	23.13	61.61	0.34
1978	13.03	13.69	0.28	20.71	34.45	0.28	20.70	17.86	0.20	15.18	8.47	0.19
1979	30.53	87.40	0.31	13.09	6.27	0.19	42.74	587.11	0.57	26.87	150.83	0.46

[1] Data for 1968-1972 adjusted by a factor of 1.7 to account for differences in surface area between the "36 Yankee" and the "41 Yankee" trawls.

Table 6. Catch projections (tons) for Georges Bank haddock for 1980 and total stock (age 2+) and spawning stock (age 3+) projections (tons) for 1981 under different 1980 fishing mortality levels assuming recruitment of 138,000 fish in 1980 and 3 million fish in 1981 (total 1980 stock size (age 2+) = 156 million fish or 122,254 tons; 1980 spawning stock size (age 3+) =18 million fish or 42,214 tons).

		Total Stock Age 2+ 1981[1]				Spawning Stock Age 3+ 1981[2]			
Fishing Mortality (F) 1980	Catch 1980	Number (000's)	% Change from 1980	Weight (tons)	% Change from 1980	Number (000's)	% Change from 1980	Weight (tons)	% Change from 1980
0.05	6,593	125,980	-19.4	167,866	37.3	122,980	574.1	166,126	293.5
0.10	12,924	121,231	-22.4	161,226	31.9	118,231	548.1	159,486	277.8
0.15	19,003	116,668	-25.3	154,854	26.7	113,668	523.0	153,114	262.7
0.20	24,842	112,282	-28.1	148,741	21.7	109,282	499.0	147,001	248.2
0.25	30,449	108,067	-30.8	142,876	16.9	105,067	475.9	141,136	234.3
0.26[3]	31,543	107,243	-31.4	141,732	15.9	104,243	471.4	139,992	231.6
0.30	35,834	104,015	-33.4	137,243	12.3	101,015	453.7	135,503	221.0
0.35	41,008	100,122	-35.9	131,848	7.9	97,122	432.4	130,108	208.2
0.40	45,977	96,379	-38.3	126,666	3.61	93,379	411.8	124,926	195.9
0.45	50,750	92,782	-40.6	121,693	-0.5	89,782	392.1	119,953	184.2
0.50	55,336	89,325	-42.8	116,921	-4.4	86,325	373.2	115,181	172.9
0.55[4]	59,743	86,003	-45.0	112,342	-8.1	83,003	355.0	110,602	162.0
0.60	63,976	82,809	-47.0	107,948	-11.7	79,809	337.5	106,208	151.6

[1] Long-term (1935-1960) total stock size (age 2+) average = 152 million fish or 175,000 tons.

[2] Long-term (1935-1960) spawning stock size (age 3+) average = 86 million fish (125,000 tons).

[3] $F_{0.1}$

[4] F_{max}

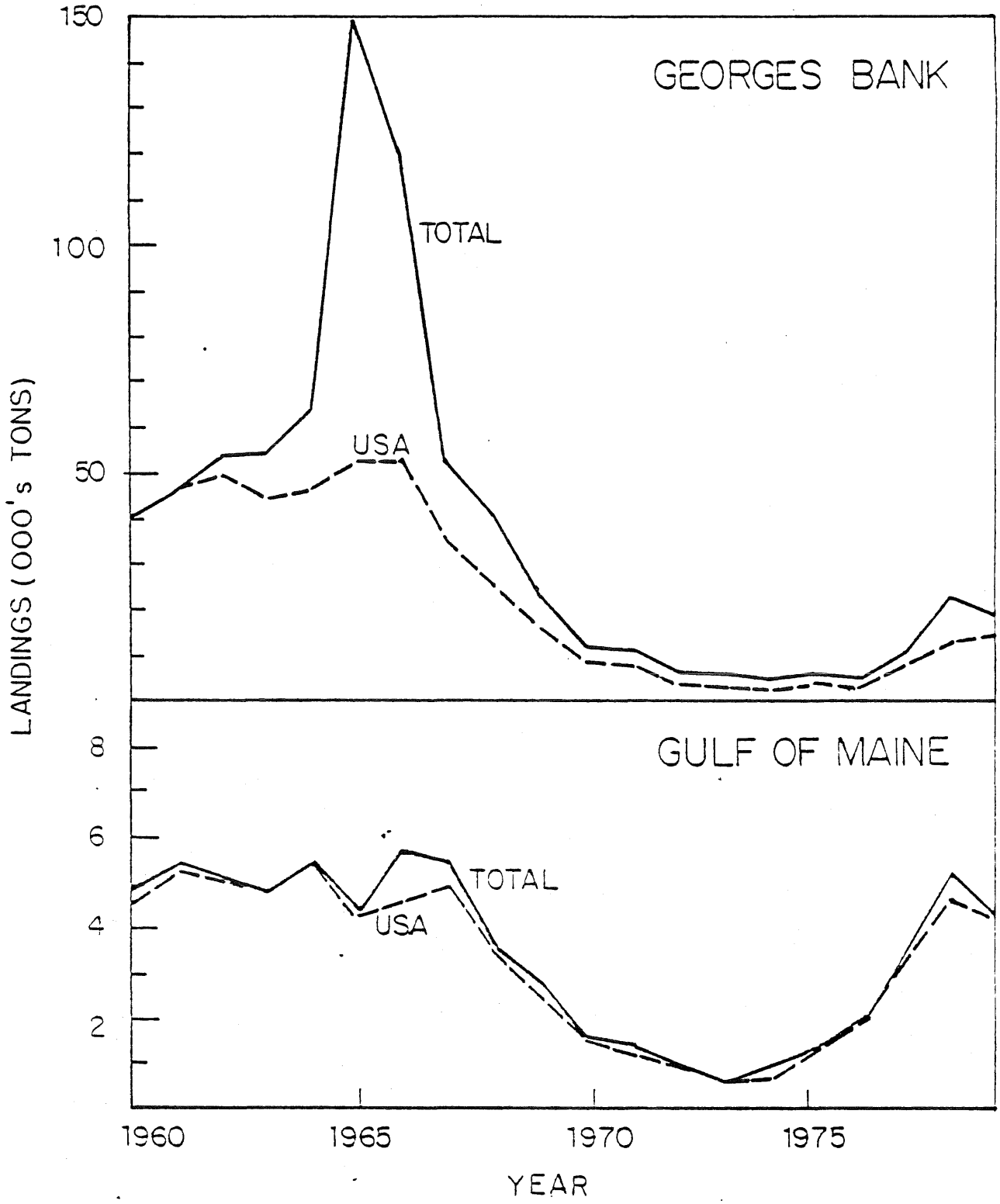

Figure 1. Commercial landings of haddock for Georges Bank and the Gulf of Maine, 1960-1979.

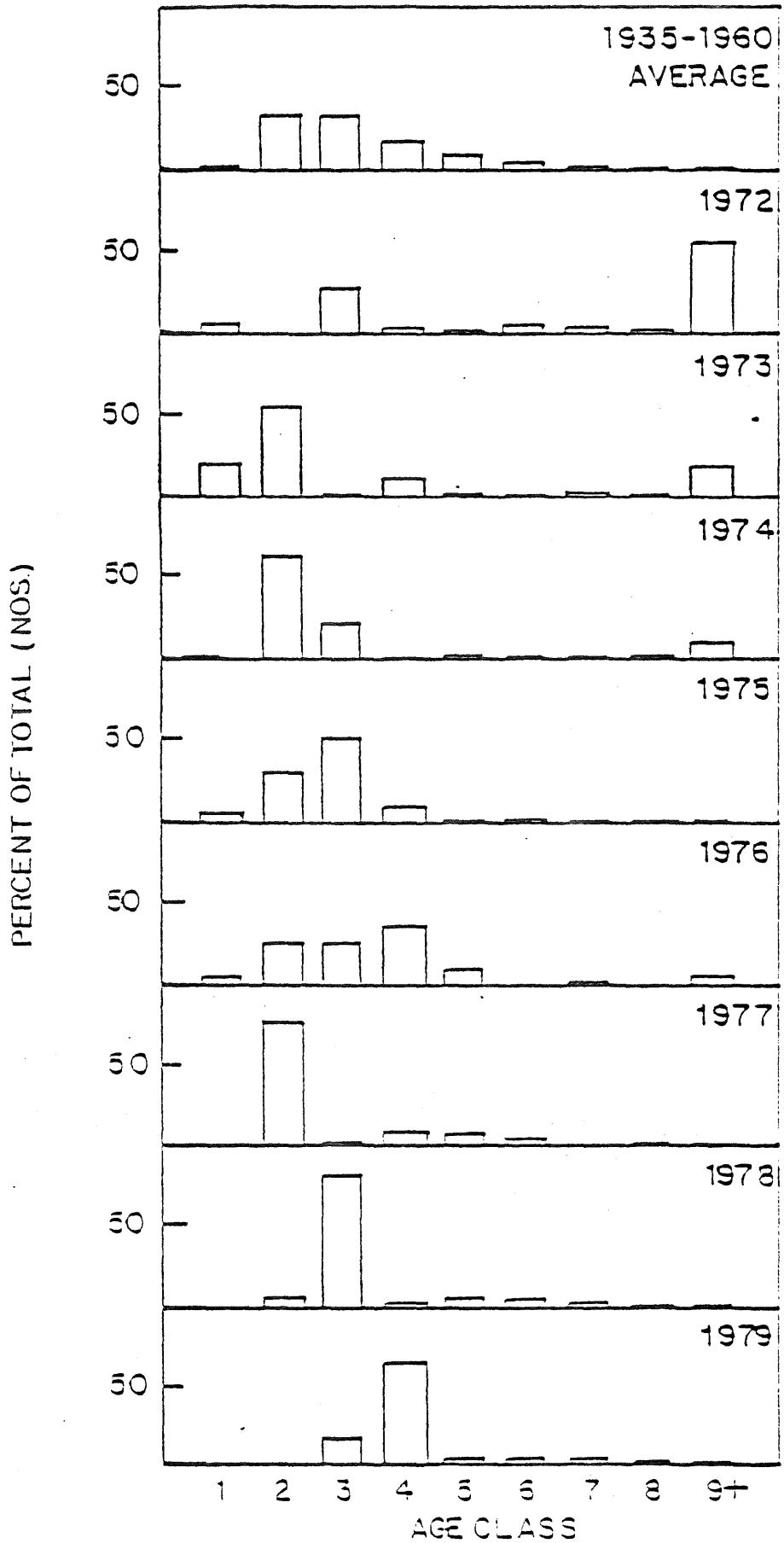

Figure 2. Age composition of Georges Bank haddock commercial landings (percent by number) for (A) 1935-1960 and (B) 1972-1979.

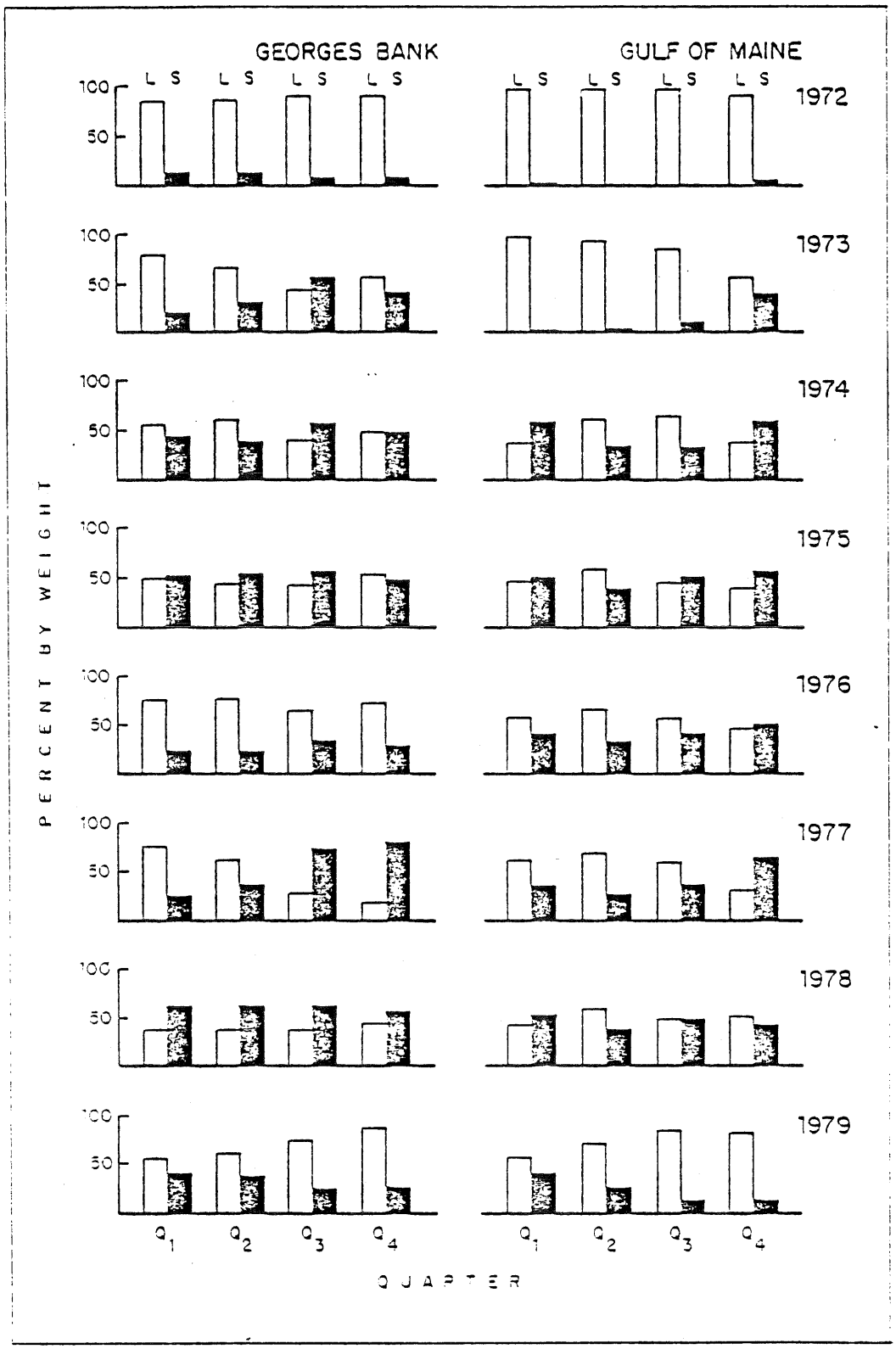

Figure 3. Distribution (percent by weight) of Georges Bank and Gulf of Maine haddock landings by market category, 1972-1979 (L = large; S = scrod).

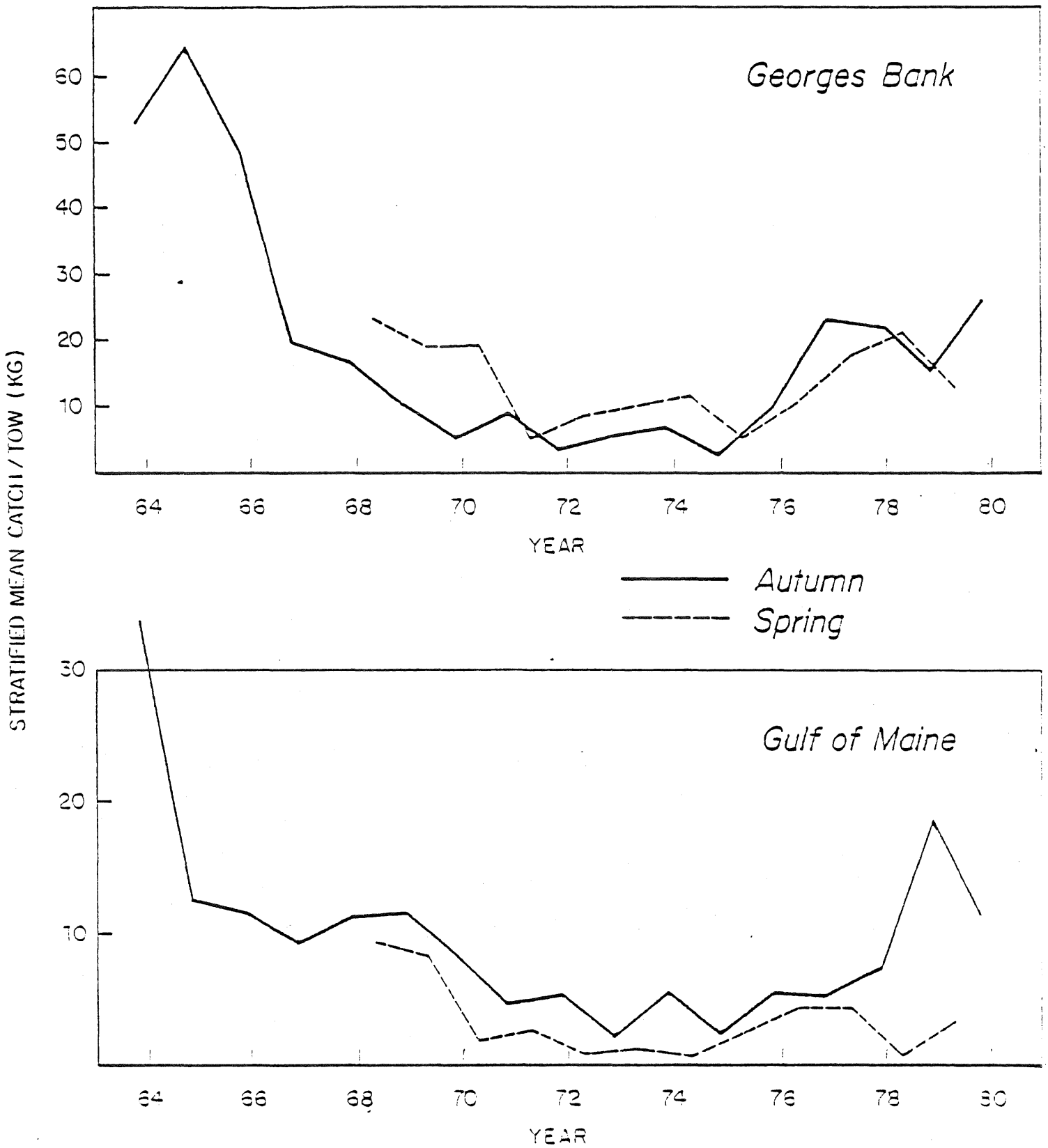

Figure 4. Stratified mean catch per tow (kg) for haddock in NEFC spring and autumn bottom trawl surveys on Georges Bank (strata 13-25, 29 and 30) and in the Gulf of Maine (strata 26-28 and 36-40), 1963-1979.

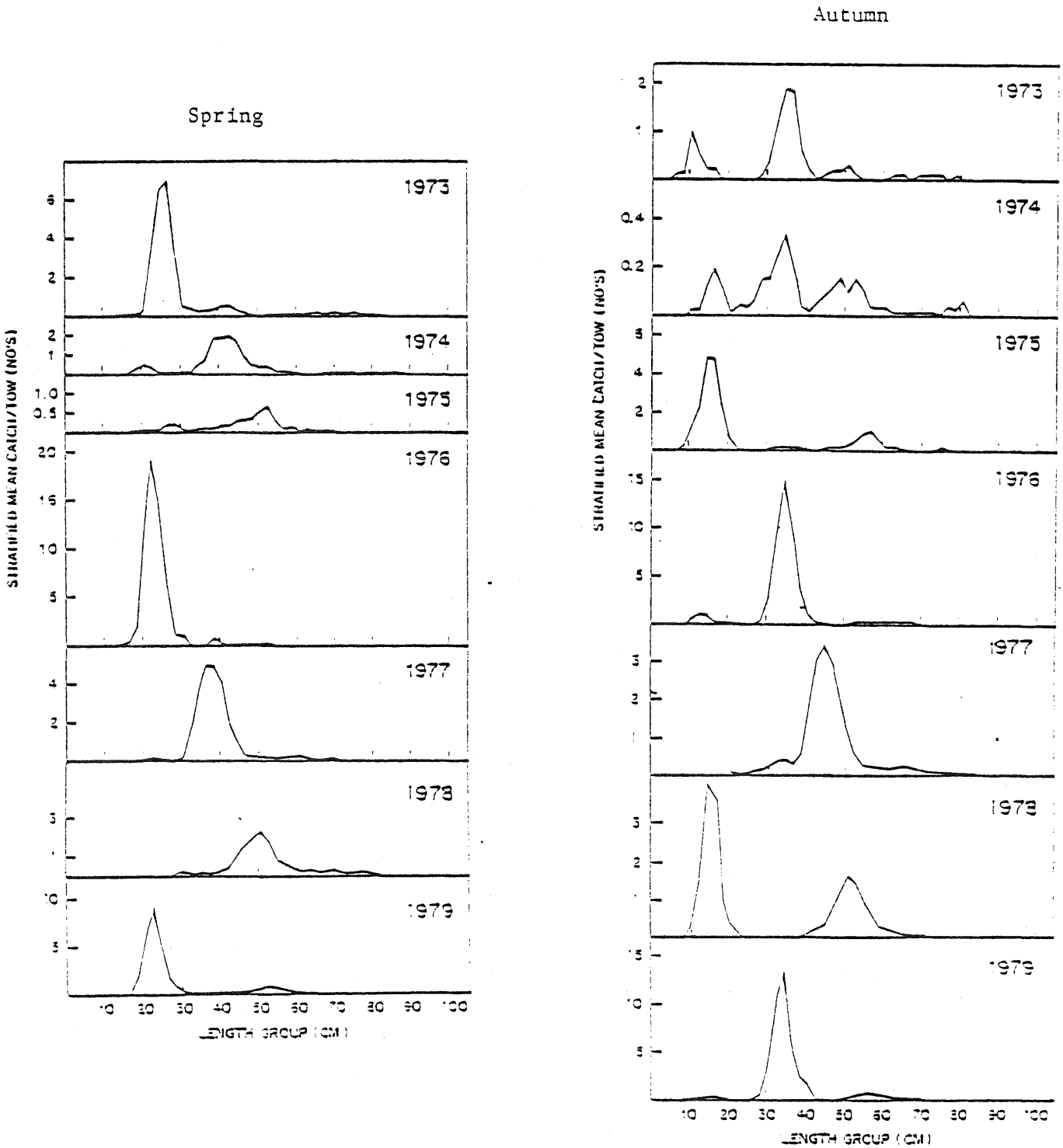

Figure 5. Length-frequency distribution of Georges Bank haddock in NEFC spring and autumn bottom trawl surveys, 1973-1979.

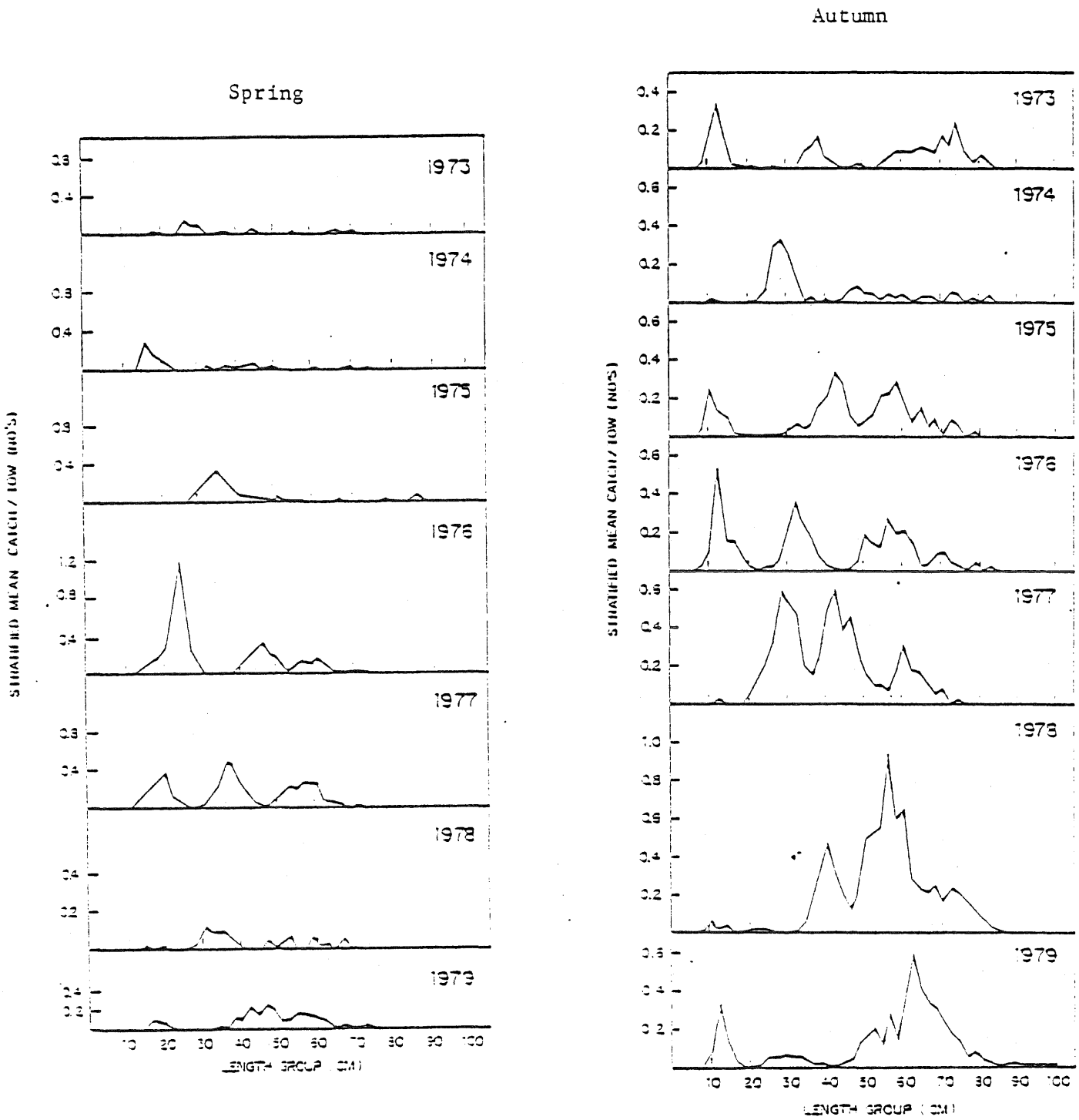

Figure 6. Length-frequency distribution of Gulf of Maine haddock in NEFC spring and autumn bottom trawl surveys, 1973-1979.

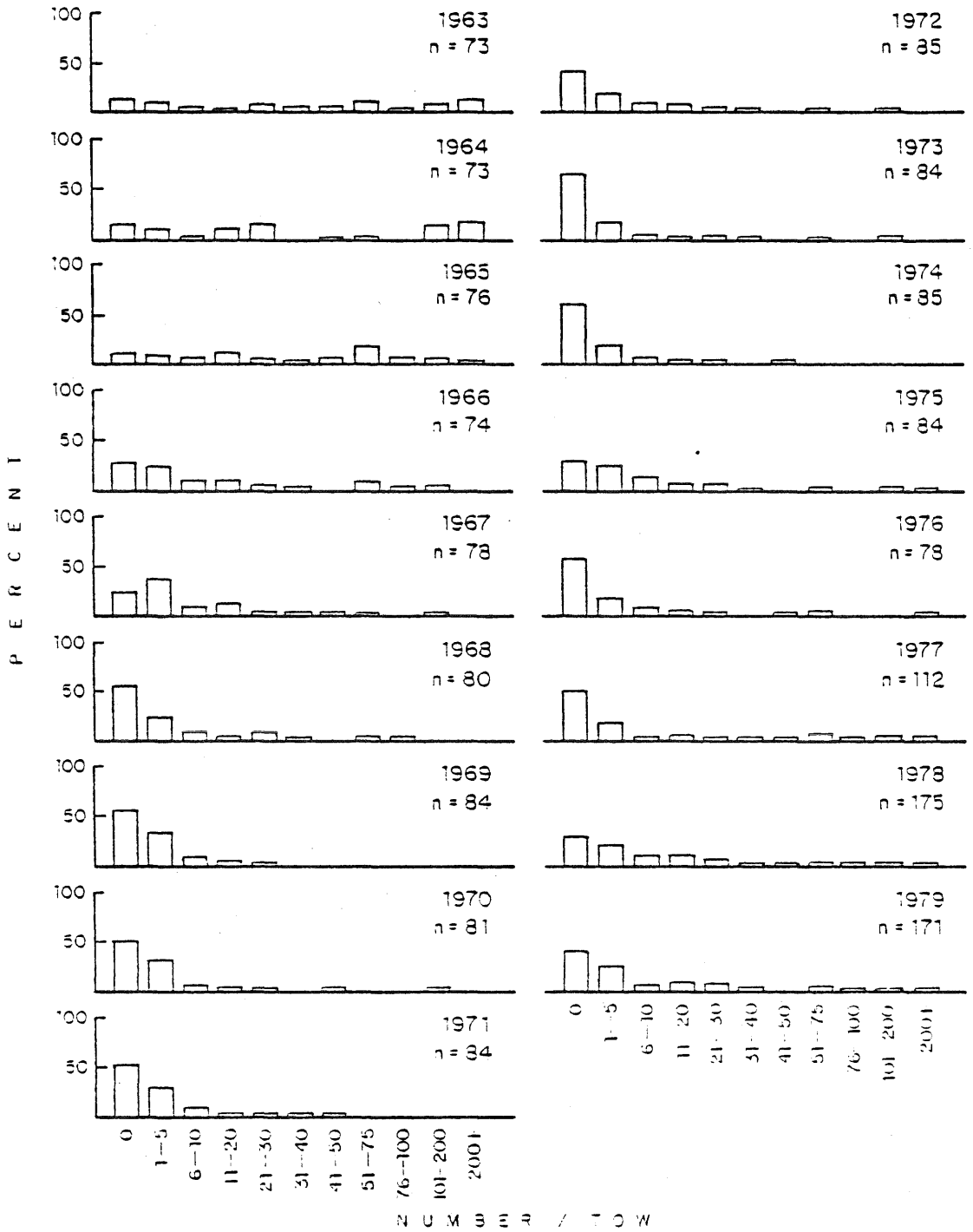

Figure 7. Frequency distributions of number per tow expressed as relative percentage of the total number of survey tows by year for Georges Bank haddock (13-25, 29, and 30), 1963-1979.

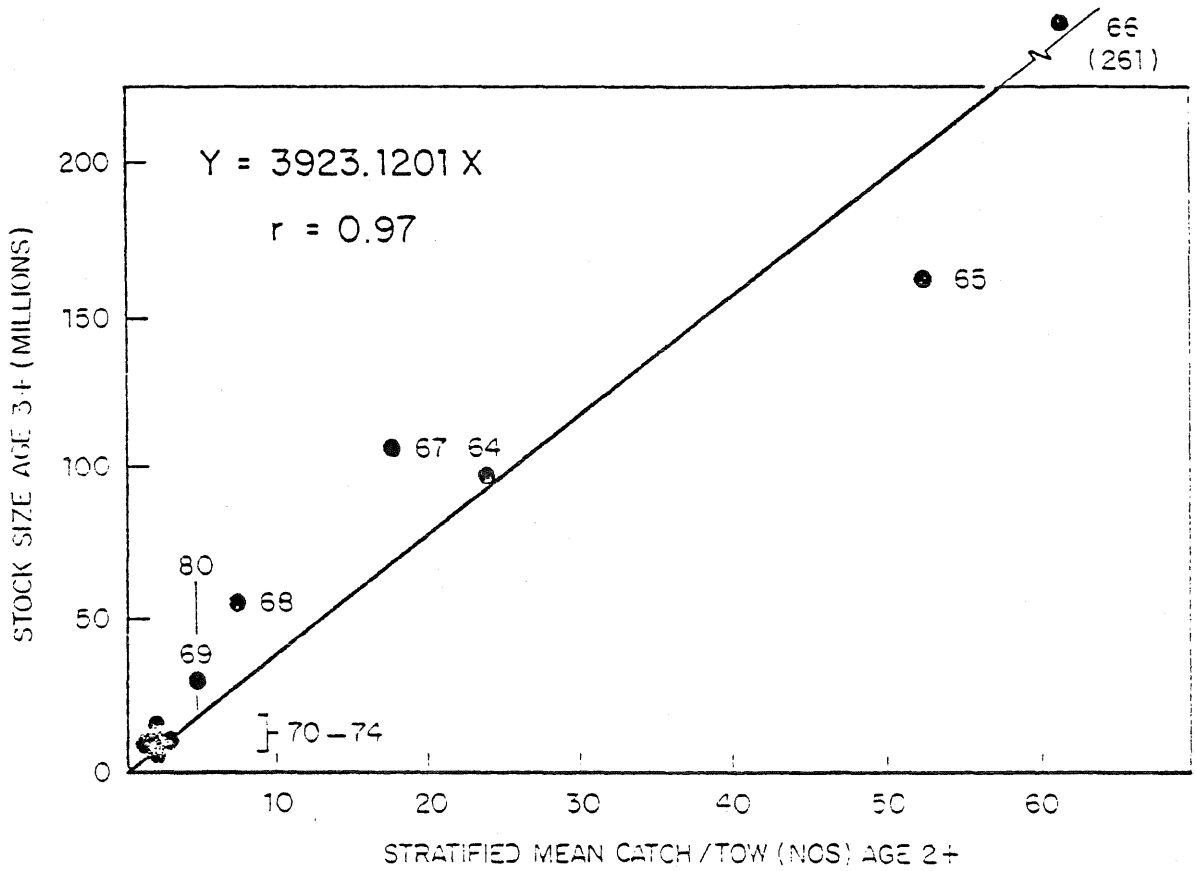

Figure 8. Relationship between stock size (millions, age 3+) and stratified mean catch per tow values (numbers, age 2+) observed in NEFC autumn bottom trawl surveys for Georges Bank haddock, 1964-1974.

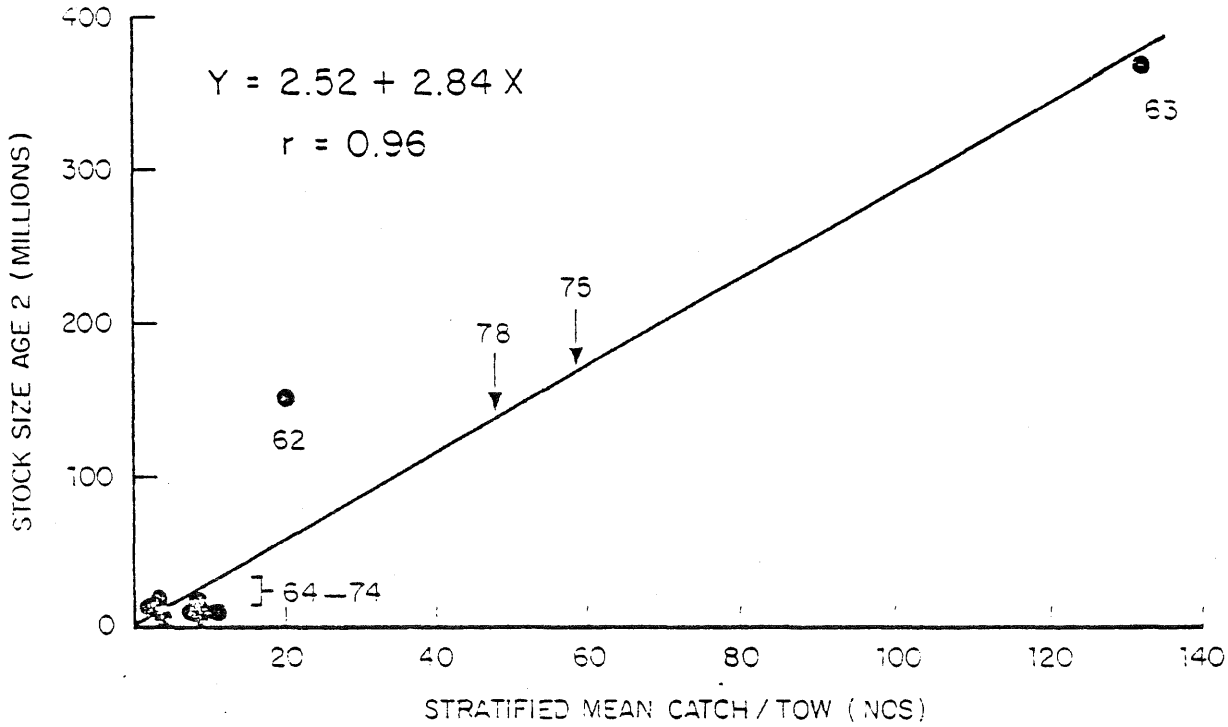

Figure 9. Relationship between year-class size (millions, age 2) and autumn survey catch per tow (numbers, age 0+1 combined) for Georges Bank haddock.

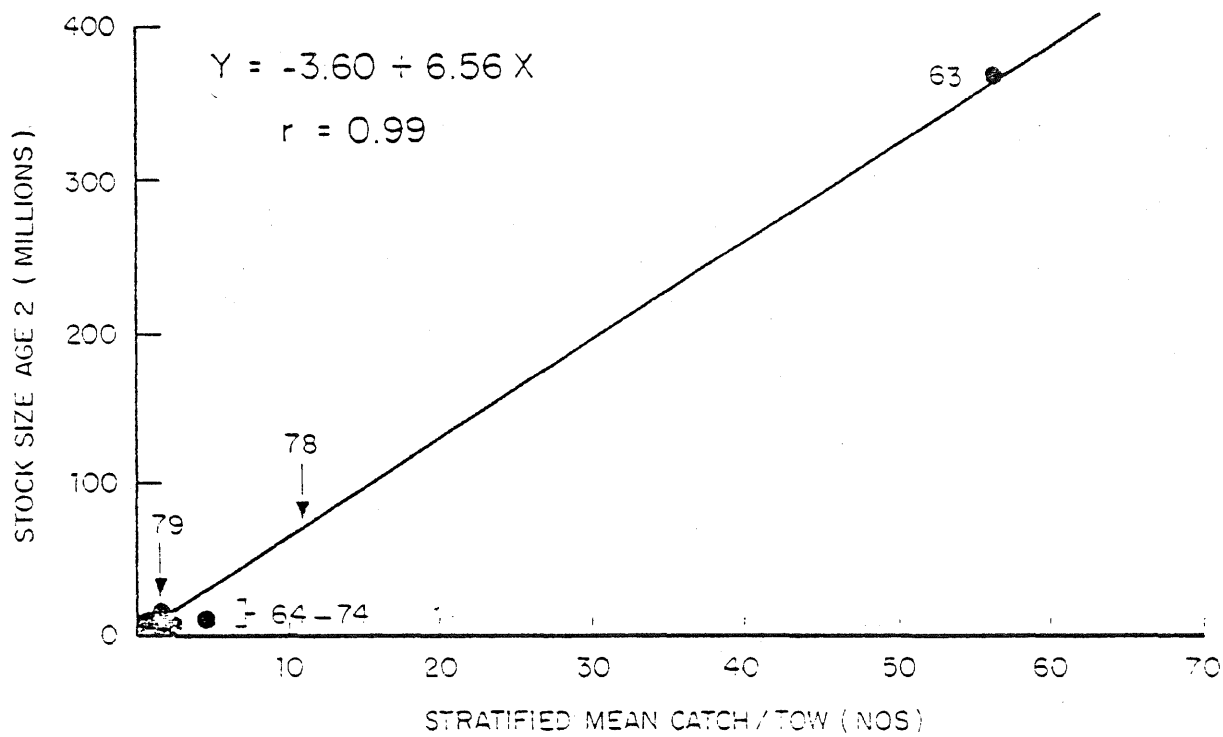

Figure 10. Relationship between year-clas size (millions, age 2) and autumn survey catch per tow (numbers, age 0) for Georges Bank haddock.