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GEORGES BANK AND GULF OF MAINE HADDOCK STOCK STATUS - 1981

by

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INTRODUCTION

The Georges Bank and Gulf of Maine haddock stocks have become increasingly important to the New England fishing industry in recent years. Stock abundance and landings have fluctuated markedly throughout the history of this fishery; during 1935-1960, abundance appears to have been relatively stable and combined landings from both areas averaged 51,900 tons[1] annually, but recruitment of several strong year classes in the early to mid 1960's resulted in a pronounced increase in abundance and in effort by foreign nationals and combined landings rose to 154,700 tons in 1965 (landings for 1966 totalled 127,000 tons). Landings subsequently declined rapidly with declining abundance and in 1974 totalled only 5,100 tons. Improved recruitment has since resulted in a substantial increase in abundance and by 1978 landings for both areas had recovered to 27,500 tons; provisional statistics for 1979 and preliminary statistics for 1980 indicate landings of 24,300 tons and 34,400 tons, respectively.

Previous assessments (Clark and Overholtz MS 1979; Clark and Essig MS 1980) attributed recent increases in abundance primarily to recruitment of the strong 1975 and 1978 year classes (which appear to have been comparable in size at age 2 on Georges Bank). The 1976, 1977, and 1979 year classes were observed to be substantially weaker on Georges Bank, and the 1978 year-class also appeared to be weak in the Gulf of Maine; consequently, results implied continued dominance by one year class in both areas (the 1975 year class in the Gulf of Maine and the 1978 year class on Georges Bank) at least

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[1]Tons in this paper refers to metric tons.

until 1982. Clark et al. (MS 1980) provide additional information for these stocks including revised virtual population analysis or VPA results and revised yield per recruit analyses. Recruitment of the strong 1978 year class in 1980 implied catches of 59,700 tons and 31,500 tons from fishing at F_{max} and $F_{0.1}$, respectively, on Georges Bank; corresponding figures for the Gulf of Maine were 7,800 tons and 4,300 tons (Clark and Essig MS 1980).

Management

The Georges Bank and Gulf of Maine haddock stocks have been managed by the New England Regional Fishery Management Council (NERFMC) under the Fishery Management Plan for Atlantic groundfish (as amended) since March 15, 1977. Initial management measures included an incidental optimum yield (OY) of 6,200 tons (6,000 tons commercial, 200 tons recreational). Recruitment of the strong 1975 year-class in 1977, coupled with a rapid increase in USA harvesting capacity and effort, led to a series of OY increases and modifications in allocation schemes culminating in removal of incidental catch limitations and an OY increase to 20,000 tons (July, 1978). Of that total 14,900 tons were allocated to USA commercial interests (11,770 tons, Georges Bank; 3,130 tons, Gulf of Maine), 3,100 tons were allocated to Canada, and 2,000 tons were allocated for recreational harvest.

Anticipated overruns in the OY for Calendar Year 1978, coupled with the need to improve the operational climate for setting annual OY's, led to management on a "fishing year" (October-September) basis, beginning in October of 1978. This approach permitted more timely use of Northeast Fisheries Center (NEFC) autumn bottom trawl survey data in establishment of

annual OY's, i.e., autumn survey data could be utilized to set OY's in spring for the subsequent fishing year.

Based on the above 1979 assessment, the NERFMC determined that an OY of 32,500 tons (corresponding to $F_{0.1}$) was appropriate for 1979-1980. USA commercial allocations for the last two quarters of the 1978-1979 fishing year were subsequently revised upwards so as to provide an OY of 28,254 tons for 1978-1979; USA commercial allocations totalled 18,026 tons for Georges Bank and 5,128 tons for the Gulf of Maine, with 3,100 tons again being designated for Canadian harvest and 2,000 tons again being set aside for recreational use. Subsequent NERFMC proposals (submitted under Draft Supplement #4 to the EIS/Amendment to the FMP for Atlantic Groundfish) included revised allocations for 1979-1980 corresponding to the above OY of 32,500 tons, an increase in minimum mesh size and a minimum size limit. The USA commercial fishery has since been administered under quarterly allocations corresponding to this OY (totalling 7,575 tons for the Gulf of Maine and 17,675 tons for Georges Bank); proposed Canadian commercial and USA recreational allocations were 5,250 tons and 2,000 tons, respectively. Draft Supplement #4 was subsequently rejected (February, 1980) due to anticipated enforcement problems presented by the minimum mesh and fish size proposals. At about the same time, the 1980 assessment was provided which indicated that a further OY increase would be consistent with fishing at $F_{0.1}$, although it was not operationally feasible to increase the OY above the originally proposed level at that time. Accordingly, NERFMC submitted the originally proposed OY increase as part of Final Supplement #4 (New England Regional Fishery Management Council MS 1980). Department of

Commerce action on this supplement is pending. A subsequent supplement containing a proposed OY increase (based on 1980 assessment results) is in preparation. Effective annual quotas and allocations resulting from the above series of amendments to the groundfish management plan for 1977-1980 are given in Table 1.

COMMERCIAL FISHERY

Commercial Landings

Historical trends in landings for Georges Bank have been reviewed by Clark et al. (MS 1980). Fishing effort was relatively constant during 1935-1960, with landings averaging 46,400 tons annually; the stock was exploited almost exclusively by USA vessels during this period. The USSR entered the fishery in 1962 and in succeeding years USSR effort increased greatly with increases in stock abundance. Total international landings peaked at 150,400 tons in 1965 (81,900 tons of which was taken by the USSR), declined to 121,300 tons in 1966 (48,400 tons of which was taken by the USSR) and then declined sharply to 22,300 tons in 1969 with declining abundance and redirection of distant-water effort to other stocks (Table 2, Figure 1). Landings subsequently declined to an average of 4,700 tons for 1974-1976 under ICNAF quota management and incidental catch limitations and then rose to 10,800 tons in 1977 with recruitment of the strong 1975 year class and increased USA and Canadian effort.

Removal of incidental catch limitations, increases in OY and continued expansion in USA and Canadian effort resulted in a further increase to

22,300 tons in 1978; provisional statistics for 1979 indicate landings of 19,500 tons, and preliminary data for 1980 indicate landings of 27,000 tons (Table 2, Figure 1). USA landings increased steadily from 7,900 tons in 1977 to 17,400 tons in 1980, reflecting recruitment and growth of the strong 1975 and 1978 year-classes, increased USA effort and changes in OY's and vessel class allocations during this period. Canadian landings increased sharply from 2,900 tons in 1977 to 10,200 tons in 1978; provisional statistics for 1979 indicate Canadian landings of 5,200 tons, and preliminary statistics for 1980 indicate Canadian landings of approximately 9,500 tons. Landings by distant-water fleets have been of minor importance since 1974 (when Spain and the UK reported landings of 764 and 559 tons, respectively). No haddock landings have been reported by distant-water fleets since 1976.

It should be stressed that the actual USA Georges Bank catch has undoubtedly been much higher in recent years than indicated by reported landings figures. Interview data (corroborated by other industry sources) indicate that large amounts of scrod[2] and snapper haddock were routinely discarded on Georges Bank in 1977 due to vessel trip limitations and recruitment of the 1975 year class; available data do not appear sufficient for

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[2]By convention, "large" haddock are those weighing more than 1.1 kg (gutted weight); "scrod" haddock range from 0.5 to 1.1 kg. "Snapper" haddock average 0.5 to 0.8 kg in commercial landings and are often discarded.

obtaining reliable estimates but nevertheless suggest that the total amount involved could have been many times the reported catch, e.g., for August trip interview records containing discard information it exceeded reported landings by a factor of 4. Available trip interview data suggest reduced discard in 1978 and 1979, although substantial amounts may have been misreported.

In 1980, the situation appears to have been analogous to 1977, with high discard of scrod and snapper haddock from the recruiting 1978 year class. During summer, tows in excess of 5 tons (10,000 lbs) were reported as being frequent in several areas, most of which was apparently discarded following culling of larger haddock and other species (individual reports were received of vessel captains culling only 1-2,000 lbs out of such tows). Instances were also reported in which individual vessels discarded over 50 tons (>100,000 lbs) per trip. Since the areas involved (e.g., Cultivator Shoals region) are frequented by a large proportion of the New England fleet during summertime, the total number and weight discarded in 1980 again appears to have been substantial, but as for 1977, data do not permit reliable estimates.

Commercial landings trends for the Gulf of Maine have been generally similar. Landings averaged approximately 2,900 tons from 1931-1947 and 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; subsequently, landings declined continually to only 600 tons in 1973 (Table 2, Figure 1). Landings then recovered to 5,200 tons in 1978; provisional statistics for 1979 indicate

landings of 4,900 tons, and preliminary statistics for 1980 indicate landings of 7,400 tons (Table 2, Figure 1).

Gulf of Maine haddock have been exploited almost exclusively by the USA, although Canada has reported minor catches each year since the mid-1950's (small catches were also taken on occasion by distant-water fleets). USA Gulf of Maine haddock landings increased from 1,900 tons in 1976 to 4,500 tons in 1978; provisional statistics for 1979 indicate landings of 4,600 tons, and preliminary data for 1980 indicate landings of 7,300 tons, the highest reported since 1956. Canadian landings declined from 600 tons in 1978 to only 200 tons in 1980. Little information is available concerning discard by USA vessels in the Gulf of Maine; it could have been significant in 1977-1978 due to strong recruitment and incidental catch regulations but in 1979-1980 recruiting year-class strength appears to have been relatively weak and vessel trip limits appear to have been much less restrictive than on Georges Bank. Consequently, it is believed that recent discard levels in the Gulf of Maine have been comparatively minor.

The USA and Canadian haddock fisheries on Georges Bank have been prosecuted almost exclusively by otter trawling both historically and in recent years (99% of the 1977-1979 USA landed total). Most of the remainder from both countries has been taken by line trawling. Seasonally, USA landings have tended to peak during May-July both under ICNAF management (e.g., 40.9% of the 1973-1976 total) and under FCMA (37.7% of the 1977-1979 total), apparently due to spring closure of haddock spawning areas to demersal gear, seasonal weather conditions, and recruitment.

Canadian landings show much less consistent seasonal trends but have generally been highest during summer and autumn. In the Gulf of Maine, 81% of the USA 1977-1979 landed total was taken by otter trawling, with the remainder being taken by gill-netting (17%) and line trawling (2%). Peaks are evident for USA landings in spring and autumn, which appear to reflect seasonal migrations.

Age Composition of Commercial Landings

Clark et al. (MS 1980) derived estimated numbers landed at age for the Georges Bank fishery for 1931-1978 by application of length frequencies and age-length keys to commercial landings data for all countries; data for 1979 and the first three quarters of 1980 have since become available. During 1935-1960, over 80% of total landings by number consisted of age 2-4 haddock, but recruitment of the 1963 year class in 1965, heavy exploitation by distant-water fleets during 1965-1966, and poor recruitment in subsequent years resulted in a significant change in age composition; during 1965-1969 the 1963 year class accounted for 65% of the total landings by number and in fact largely supported the fishery until well into the early 1970's (Clark et al. MS 1980). During 1977-1979, the 1975 year class accounted for 70% of the total number landed; in 1980, the 1978 year class recruited to the fishery and provided an estimated 54% of the total landings by number (Figure 2) based on preliminary sample data.

Age composition data for the Gulf of Maine are limited, although age structure and recruitment patterns appear to have been generally similar to Georges Bank. The 1963 year class again appears to have largely supported

the fishery from the mid-1960's into the early 1970's (Clark et al. MS 1980) and the 1975 year class again appears to have predominated in 1977-1979 landings; intervening years have been characterized by poor recruitment as was the case for Georges Bank. Comparisons may also be made by examining trends in market categories (percent by weight of large and scrod haddock in total landings) for the two areas (Figure 3). Seasonal differences are evident (due at least in part to slower growth and later recruitment in the Gulf of Maine), but general trends have nevertheless been consistent between areas. These data further attest to the relative importance of the 1963 and 1975 year classes in both areas and the 1978 year class on Georges Bank (note the lack of evidence for recruitment of scrod haddock in the Gulf of Maine during the third and fourth quarters of 1980, Figure 3).

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), in a regional survey of the northeastern United States in 1974 (Ridgely and Deuel MS 1976), and more recently in the 1979 Marine Recreational Fishery Statistics Survey of the Atlantic and Gulf coasts (United States Department of Commerce 1980). Nicholson and Ruais (MS 1979) also derived estimates of party and charter boat recreational catches for the Gulf of Maine-Georges Bank region by analysis of vessel logbook data; however, their data were incomplete and thus results appear to have been biased downward to an unknown degree. The first three surveys were conducted by household interviews and involved a recall period of one year; the 1974 survey was conducted by telephone and by mail and involved a two

month recall period, and the 1979 survey included both a telephone survey (two month recall period) and on-site interviews. The 1979 survey was the first to provide actual sample data relative to species and size composition of the catch and information on amount and type of discard (alive or dead); preceding surveys required reports of numbers and average weights by species and appear to have been biased upwards, particularly in the case of salt-water angling survey results (U.S. Department of Commerce 1980). In addition, regional boundaries have differed slightly between surveys. Consequently, results are comparable only in a general way.

The 1960, 1965, and 1970 surveys indicate 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 279 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 (278 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, 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). Results of the

1979 survey indicate a total recreational catch of 406 tons; preliminary party and charter-boat logbook data for 1980 indicate a catch of 51 tons, substantially lower than reported for 1978 by Nicholson and Ruais (MS 1979). In both cases, landings are assumed to have been taken primarily in the western Gulf of Maine.

TRENDS IN ABUNDANCE

Research Vessel Survey Catches

The Northeast Fisheries Center (NEFC) has conducted stratified random bottom-trawl surveys in offshore areas (>27 m) on Georges Bank and in the Gulf of Maine since summer of 1963 (Figure 4). 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 1969a, MS 1969b; Clark 1979); use of these data for assessment of the Georges Bank and Gulf of Maine haddock stocks is described by Clark et al. (MS 1980). Indices of relative abundance (stratified mean catch per tow in numbers and weight (kg)) have been developed for Georges Bank for spring and autumn (strata 13-25, 29, and 30), and for summer (strata 13, 16, and 19-25). For the Gulf of Maine, spring and autumn indices have been calculated based on data for strata 26-28 and 36-40; the summer index is based on data for strata 26-28, 37, and 38 (Figure 4).

The spring survey (weight) index for Georges Bank declined from 23.1 kg in 1968 to 5.6 kg in 1971, increased to 11.7 kg in 1974, and then dropped sharply to 5.4 kg in 1975; subsequently, values increased to 20.7 kg in 1978, reflecting recruitment and growth of the strong 1975 year class (Table 3, Figure 5). The spring 1980 index value (35.7 kg) was the highest observed in this time series and reflects the presence of the 1978

year class. The summer survey time series (Table 3) is more limited and in recent years index values have fluctuated without a definite trend (the 1978 index value of 1.9 kg is not really comparable to remaining values due to reduced survey coverage in that year). The autumn survey 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; index values for 1978, 1979, and 1980 were 15.2 kg, 26.9 kg, and 18.5 kg, respectively (Table 3, Figure 5). Trends in numbers per tow have closely paralleled those observed for weight (Table 3). All three sets of data are consistent in indicating a substantial increase in stock abundance in recent years, and observed values in terms of numbers and weight for 1977-1980 are in most cases substantially higher than values observed during the late 1960's.

Stratified mean catch per tow at age data (Table 4) reveal that the 1962 and 1963 year classes dominated the Georges Bank haddock population until the early 1970's. Recent increases in abundance and biomass are primarily attributable to recruitment and growth of the 1975 and 1978 year classes; during 1977-1979, the 1975 year class accounted for 85% of the total catch of age 2 and older fish in both the spring and autumn surveys. The 1978 year class appears to be comparable in size to the 1975 year class (stratified mean catch per tow in numbers at age 2 was higher in spring, lower in autumn and approximately equal during summer surveys, Table 4). Given the preponderance of the 1978 year class in the population at age 2 (85% and 97% respectively, of the catch of age 2 and older fish

during the spring and summer surveys), the decline in weight observed for the autumn index between 1979 and 1980 (Table 3, Figure 5) was unexpected and may relate to discard during summer of 1980 (discussed above). The 1976, 1977, and 1979 year classes appear to be substantially weaker, although catch per tow of age zero haddock during autumn of 1980 was comparable to that observed in 1978, thus indicating the potential for good recruitment from the 1980 year class in 1982.

The spring survey index for the Gulf of Maine declined more or less continually from 9.2 kg in 1968 to 0.7 kg in 1974 and then increased to 4.5 kg in 1977 before declining to 1.0 kg in 1978; spring 1979 and 1980 index values were 3.2 kg and 2.2 kg, respectively (Table 5, Figure 5). Again, the summer survey index fluctuated without a definite trend during 1977-1980 (Table 5), although values were intermediate between the 1969 index value (7.3 kg) and the 1963-1965 average (21.3 kg). The high 1979 index value is not directly comparable to remaining values in the time series due to reduced survey coverage in that year. The autumn survey index declined more or less continually from 33.6 kg in 1963 to only 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 8.2 kg in 1980 (Table 5, Figure 5). Trends in numbers per tow were again similar for all three indices (Table 5). Thus, overall trends for the Gulf of Maine appear to have been essentially similar to those observed for Georges Bank (Table 5, Figure 5).

Stratified mean catch per tow at age data (Table 6) again indicate that the 1962 and 1963 year classes predominated in the population until

the early 1970's. The 1975 year class appears to be the strongest in recent years in all three surveys, although catch per tow for the 1980 year class at age 0 is the highest observed since 1963. The 1976 year class, however, appears to be about one-half as strong as the 1975 year-class based on summer and autumn survey data (Table 6), relatively stronger than on Georges Bank (Table 4), while the 1978 year class is much weaker than either the 1975 or 1976 year classes in both the spring and autumn surveys. The 1979 year class also appears to be weak in both areas (Tables 4 and 6), although it may be somewhat stronger in the Gulf of Maine than the 1978 year class. Thus, recruitment prospects for 1981 appear poor, although the potential again exists for good recruitment and increases in stock abundance in 1982.

The NEFC has also sampled inshore areas (<27 m) between Block and Grand Manan Islands since 1977 (Figure 4); however, coverage has been limited (e.g., Gulf of Maine strata were not sampled at all in spring and autumn of 1977-1978) and in any case inshore survey catches of haddock from Block Island to Race Point (corresponding to the Georges Bank stock) were usually negligible. Accordingly, an NEFC inshore survey index has been derived only for summer survey data for the Gulf of Maine (strata 58-61, 63-66, 72, 74-75, 80, 81, 83, and 85, Figure 4).

The NEFC inshore survey index declined from 9.6 kg in 1977 to an average of 2.7 kg in 1978-1979 and then again increased to 6.6 kg in 1980 (Table 7). Again, catch-per-tow-at-age data indicate the 1975 and 1976 year classes to be the strongest present throughout this period; the 1978

year class again appears somewhat weaker, and catch per tow at age 0 in 1980 was the highest observed since 1977. Thus, results appear generally comparable to those observed in offshore surveys, although a longer time series will be necessary to evaluate the applicability of NEFC inshore survey data to haddock assessments. Catch per tow in numbers was dominated by age 0-2 haddock (94% of those taken during 1977-1980) indicating that such data will probably be most useful for evaluation of incoming recruitment.

The State of Massachusetts has conducted stratified random bottom-trawl surveys in inshore areas along the Massachusetts coast during spring and autumn since 1978; areas sampled, sampling procedures and other information including catch per tow data for 1978 and 1979 are given in annual completion reports (Howe et al. MS 1979, MS 1980) and preliminary data are available for 1980 (Howe, pers. comm.). Again, haddock catches have been negligible in areas corresponding to Georges Bank, and accordingly indices have been developed only for the Gulf of Maine area (regions 4 and 5, strata 25-36, Figure 6).

Data for both spring and autumn suggest an increase in abundance since 1978, although catches have generally been minor. Autumn survey data suggest that the 1979 and 1980 year classes were comparable (Table 8), in contrast to NEFC inshore and offshore survey data indicating the 1980 year class to be substantially stronger. Again, a longer time series appears necessary for evaluation of the applicability of Massachusetts inshore survey data to haddock assessments, but the predominance of age 0 and 1

haddock in survey catches (Table 8) again suggests that such data will be most useful for evaluation of the strength of recruiting year classes.

Virtual Population Analysis

Clark et al. (MS 1980) performed a virtual population analysis or VPA for the Georges Bank stock which indicated a long-term average stock size (age 2 and older) of 140 million fish or 153,000 tons for 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 530 million fish or 427,000 tons in 1965. (The 1963 year class was estimated at 368 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 8 million fish or 22,000 tons in 1972 in response to overexploitation and poor recruitment. Recently, abundance has increased dramatically due to recruitment of the 1975 and 1978 year classes (Clark et al. MS 1980). Similarly, spawning stock size (calculated as 50% of age 2 fish and 100% of older ages) averaged 109 million fish or 131,000 tons from 1935-1960 but increased to a peak of 346 million fish or 314,000 tons in 1965 before declining to an apparent all-time low of 6 million fish or 12,000 tons in 1973. Subsequently, spawning stock size increased substantially in 1977-1978 with recruitment of the 1975 year class. Trends are in close agreement with those observed in NEFC spring and autumn survey indices, e.g. total stock size estimates for 1964-1974 correlate well with corresponding NEFC autumn survey indices ($r = 0.98$, Figure 7).

CURRENT ASSESSMENT

Georges Bank

Stock size (age 2 and older) for Georges Bank is now primarily dependent on the 1978 year class. The 1975 year class (which supported the fishery until summer of 1980) is now much reduced and accounted for less than 10% of the total catch by number of age 2 and older fish in 1980 spring and summer surveys and only 14% of the total catch by number during the 1980 autumn survey. The 1978 year class accounted for 85%, 97%, and 79% of the 1980 catch of age 2 and older fish in these surveys and available commercial sampling data for 1980 indicate that it accounted for over 50% of the total number landed commercially (although it was only partially recruited to the fishery). The 1976, 1977, and 1979 year classes appear to be very weak, but 1980 autumn survey results suggest the 1980 year class to be at least of average size. It therefore appears that the fishery will be dominated by the 1978 year class at least until late 1982.

Strengths of the 1975-1979 year classes have been estimated by a linear regression of VPA stock size in numbers at age 2 on autumn survey catch per tow in numbers at age 0 and 1 combined (Figure 8). The 1975 and 1978 year classes were estimated at 170 and 140 million fish, respectively, while the 1976, 1977, and 1979 year classes were estimated to be substantially weaker (17 million, 6 million, and 13 million fish). However, survey data have been consistent in indicating a pronounced drop in abundance between age 2 and age 3 for these year classes, e.g., a linear regression of VPA stock size in numbers at age 3 on autumn survey catch per tow in

numbers at age 2 (Figure 9) provided age 3 estimates of 49 million fish for the 1975 year class and 34 million fish for the 1978 year class. Neither figure is compatible with reported landings data (6 million fish at age 2 in 1977 and 10 million fish at age 2 in 1980) and the assumed instantaneous natural mortality rate (0.2), and while discard during recruitment of both year classes at age 2 (discussed above) was substantial, it is not likely that it could have accounted for a discrepancy of this magnitude. Clark and Essig (MS 1980) also showed that variability in survey catch-per-tow data for this stock has increased markedly since 1976, indicating that some form of variance-stabilizing transformation, e.g. logarithmic (Pennington and Grosslein MS 1978) may be appropriate. Predictive relationships based on transformed or retransformed survey data (Clark and Brown 1977) provide much lower estimates, e.g., a linear regression of VPA stock size in numbers at age 2 on transformed ($\log_e$) survey catch per tow in numbers at age 1 provides an estimate of 61 million fish for both the 1975 and 1978 year classes (equal to the 1935-1960 average for this stock). In any case, these regressions are based on limited time series of data varying widely in magnitude and point estimates derived from such predictive regressions would be expected to be quite sensitive to deletion of existing data points and/or incorporation of additional ones. No basis exists for deletion of any of the data points used in the present analysis.

Although the current NEFC (stratified random) survey time series extends back only to 1963, earlier surveys (employing the same gear) have provided additional information on trends in relative abundance. Grosslein (MS 1969c) developed a young-of-year index for Georges Bank (Table 9) based on transformed survey catch-per-tow at age data dating back to 1953; calculated index values for the 1975 and 1978 year classes are comparable to those observed for several year classes in the 1950's and early 1960's but are substantially lower than those calculated for the very strong 1958, 1959, and 1963 year classes. This would again suggest that the 1975 and 1978 year classes were smaller than estimated in previous assessments (note, however, that the 1962 index value was substantially lower than values calculated for 1958 and 1959 although VPA indicated the 1962 year class to be almost 50% stronger than the 1958-1959 year-class average). In general, however, Grosslein's index has been consistent as an indicator of relative year class strength, although it would be expected that indices developed from catch per tow at age 1 would be more reliable.

The information currently available for the 1980 year class is the NEFC 1980 summer and autumn survey data (Table 4, Figure 10). Summer survey catch per tow at age for this year class was very low, but in autumn catch per tow of age 0 haddock (9.6 fish per tow) was comparable to that observed in 1978 (10.8 fish per tow) while Grosslein's young-of-year index value (2.8) was intermediate between values calculated for 1975

(3.8) and 1978 (2.3). A linear regression of VPA stock size in numbers at age 2 on autumn survey catch per tow in numbers at age 0 provided an estimate of 59 million fish for this year class, indicating it to be comparable to the long term average of 61 million fish at age 2, and accordingly this year class has been assumed equal to 61 million fish in the present assessment.

The VPA referred to in this assessment has not been updated by inclusion of commercial catch-at-age data for 1978-1980 due to uncertainty relative to discarding and/or misreporting during those years (and in any case, uncertainty in the above age 2 estimates for the 1978 year class precluded projections to age 3 based on natural mortality and reported commercial catch at age). Accordingly, stock size for 1981 was estimated from a regression of VPA stock size in numbers (age 2 and older) on autumn survey catch per tow in numbers (age 1 and older) which provided an estimate of 74 million fish (Figure 11). This was apportioned by age based on the observed percentage age composition in the 1980 autumn survey and resulting values multiplied by appropriate mean weights at age to generate estimated stock size in weight (109,600 tons) for 1981. This value is comparable to the 1967-1968 average of 118,300 tons obtained from VPA (Clark, et al. MS 1980) and NEFC 1980 spring and autumn survey data indicating stock size to be comparable to or above levels observed in the late 1960's (Table 3). The 95% confidence limits about these estimates were 54 million fish (80,600 tons) and 94 million fish (138,600 tons).

Assuming a 1981 stock size of 74 million fish (109,600 tons) and recruitment of 61 million fish at age 2 in 1982, fishing at F_{max} = 0.55 in 1981 would provide a total catch of 46,700 tons, with a total stock size (age 2 and older) in 1982 of 97 million fish or 115,800 tons (6% above the 1981 level of 109,600 tons); fishing at $F_{0.1}$ = 0.26 in 1981 would provide a catch of 25,100 tons, with a total stock size (age 2 and older) in 1982 of 108 million fish or 139,100 tons (27% above the 1981 level of 109,600 tons). See Table 10. Corresponding spawning stock size estimates for 1982 (calculated as 50% of age 2 fish and 100% of older ages) are 66 million fish or 93,600 tons and 78 million fish or 116,800 tons (Table 10). Assuming a 1981 stock size of 54 million fish or 80,600 tons, fishing at F_{max} and $F_{0.1}$ would provide catches of 34,400 tons and 18,500 tons, respectively; assuming a 1981 stock size of 94 million fish or 138,600 tons, fishing at F_{max} and $F_{0.1}$ would provide catches of 59,100 tons and 31,700 tons. Average historical (1935-1960) total and spawning stock sizes are 140 million fish (153,000 tons) and 109 million fish (131,000 tons), respectively (Clark, et al. MS 1980). Assuming that recent recruitment patterns hold and the 1981 year class is again a weak one (say, equal to the 1976, 1977, and 1979 year class average of 12 million fish at age 2) and assuming exploitation at $F_{0.1}$ in 1981, fishing at $F_{0.1}$ in 1982 would provide a catch of 31,800 tons, with a total stock size in 1983 of 82 million fish or 135,600 tons; spawning stock size would be 76 million fish or 131,200 tons.

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. Trends in recruitment also appear to have been generally similar, with the 1963 and 1975 year classes predominating in the time series; the 1975 year class dominated commercial landings and autumn survey catches during 1977-1979 (54% of the total survey catch by number of age 2 and older fish). The 1976 year class appears to have been relatively stronger in the Gulf of Maine, however, while the 1978 year class appears to have been much weaker. Trends in commercial landings by market category tend to support these results, i.e. the large influx of scrod haddock observed for Georges Bank landings during the last two quarters of 1980 (Figure 3) was not apparent for the Gulf of Maine. Catch per tow of young-of-year haddock during the autumn 1980 survey was the highest observed since 1963. Thus, immediate recruitment prospects appear poor, although stock size should be augmented considerably by recruitment of the 1980 year class in late 1982.

The current proposed commercial allocation for the Gulf of Maine under Final Supplement #4 (7,575 tons) is based on an assumed 3:1 biomass ratio between the Georges Bank and Gulf of Maine areas as evidenced by

minimum biomass estimates obtained from NEFC survey data (Clark and Overholtz MS 1979). This ratio, however, represents an average which have not been consistent over time and appears inappropriate at present given indications that the 1978 year class is much weaker than on Georges Bank. Also, annual commercial landings for the Gulf of Maine have rarely exceeded 7,000 tons since 1931 and even during assumed peak years of abundance (1959-1966) averaged only about 5,000 tons. Preliminary data for 1980 indicate commercial landings of 7,400 tons, which (assuming recreational landings in the order of 4-500 tons), implies a 1980 fishing mortality rate approximately equal to F_{max} based on the previous assessment (an estimated F value of 0.43 was obtained from autumn bottom trawl survey data).

Clark and Essig (MS 1980) obtained an average annual stock biomass estimate of 16,600 tons for 1964-1968 based on commercial and recreational landings data and mortality estimates generated from NEFC autumn survey data; this estimate was used to project 1980 catch levels corresponding to F_{max} and $F_{0.1}$ based on autumn 1979 survey data indicating stock size in 1980 to be comparable to the 1964-1968 average. However, lack of evidence for strong recruitment from the 1978 year class, coupled with the observed decline in NEFC spring and autumn survey index values during 1979-1980, suggests that stock size in 1981 has probably declined below the 1964-1968 level (the autumn 1980 index value is approximately 30% below the 1964-1968 average). Using the NEFC autumn survey data to represent stock abundance the relation

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

where C = Catch,

B_o = Stock biomass,

F = Instantaneous fishing mortality rate,

G = Instantaneous growth rate,

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

indicates that fishing at F_{max} and $F_{0.1}$ in 1981 would provide catches of 5,200 tons and 2,800 tons, respectively.

SUMMARY

Results of this assessment indicate a total 1981 stock biomass (age 2 and older) for Georges Bank of approximately 110,000 tons; the corresponding spawning stock size estimate is 105,000 tons. These values are comparable to those observed in the late 1960's (1967-1968 averages were 118,000 tons and 116,000 tons, respectively) and are also intermediate between the corresponding long term (1935-1960) averages of 153,000 tons and 131,000 tons and the very low levels observed during the early to mid-1970's (Clark et al. MS 1980). The 1975 year class is now much reduced and the population is now dominated by the 1978 year class (which, however, appears to have been appreciably reduced by landings and discard in 1980); the 1976, 1977, and 1979 year classes are much weaker, although survey catch per tow in autumn of 1980 suggests that the 1980 year class is at least of average size (i.e., comparable to the 1935-1960 average of 61 million fish). Thus, future prospects appear much more favorable than in the late 1960's due to the potential for increases in biomass associated with growth of individual fish (i.e., the dominant 1978 year class) and for average to strong recruitment from the 1980 year class in 1982.

Catch and stock size projections for 1981-1982 (assuming a 1981 stock size of 109,600 tons and recruitment of 61 million fish at age 2 in 1982) indicate a 1981 catch of 25,100 tons from fishing at $F_{0.1}$; fishing at F_{max} would provide a catch of 46,700 tons. In the former case, total stock size for 1982 would increase substantially over 1981

(and spawning stock size would also increase somewhat). Projected estimates for 1982 are largely dependent on one point estimate for the 1980 year class and consequently should be interpreted with caution, although other ancillary evidence (e.g., Grosslein's index) also supports the assumption that this year class is at least of average size. Future surveys will provide an additional basis for evaluating the strength of this year class.

The Gulf of Maine haddock fishery has been supported by the 1975 and to a lesser degree the 1976 year class in recent years. This assessment is consistent with previous results in indicating the 1978 year class to be relatively weak; consequently this year class is not expected to contribute materially to stock biomass in 1981, although catch of age 0 haddock in the autumn 1980 survey was the highest observed since 1963. Recent declines in biomass evidenced by research vessel survey data imply that landings in 1981 in the order of 6,000 tons (1978-1980 average) may result in fishing mortality levels in excess of F_{max} and may not be sustainable, particularly if the 1980 year class proves to be weaker than anticipated in the Gulf of Maine.

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Table 1. Effective annual quotas (tons) for Georges Bank and Gulf of Maine haddock under FCMA based on USA quarterly commercial allocations, USA recreational allocations, and Canadian allocations, 1979-1980.

Year	USA Commercial	USA Recreational	Canadian	Total
1977	10,500[1]	200[2]	-	10,700
1978	13,938[3]	2,000[4]	3,100[4]	19,038
1979 (Georges Bank)	18,979[5]	2,000[6]	3,100[6]	30,239
(Gulf of Maine)	6,160[5]			
1980 (Georges Bank)	17,675[7]	2,000[7]	5,250[7]	32,500
(Gulf of Maine)	7,575[7]			

[1] By emergency amendment to Atlantic Groundfish FMP effective November 3, 1977.

[2] As stipulated in original Atlantic Groundfish FMP effective March 15, 1977.

[3] Represents allocations for Quarters 1-3 of 1978 under emergency amendment effective July 19, 1978, and first quarter allocations for Georges Bank and the Gulf of Maine for the 1978-1979 Fishing Year effective October 1, 1978.

[4] As allocated under emergency amendment effective July 19, 1978.

[5] Represents allocations for Quarters 2-4 of the 1978-1979 Fishing Year under emergency amendment effective July 22, 1979, and the proposed first quarter allocation for the 1979-1980 Fishing Year under Final Supplement #4 to the EIS/Amendment to the Atlantic Groundfish FMP.

[6] As allocated under emergency amendment effective July 22, 1979.

[7] As proposed under Final Supplement #4.

Table 2. Commercial landings[1] of haddock (metric tons, live) from Georges Bank and the Gulf of Maine, 1960-1980.

	Georges Bank					Gulf of Maine					Total				
Year	USA	Canada	USSR	Other[2]	Total	USA	Canada	USSR	Other[2]	Total	USA	Canada	USSR	Other[2]	Total
1960	40,800	77	--	--	40,877	4,541	383	--	--	4,924	45,341	460	--	--	45,801
1961	46,384	266	--	--	46,650	5,297	112	--	--	5,409	51,681	378	--	--	52,059
1962	49,409	3,461	1,134	--	54,004	5,003	107	--	--	5,110	54,412	3,568	1,134	--	59,114
1963	44,150	8,379	2,317	--	54,846	4,742	3	44	--	4,789	48,892	8,382	2,361	--	59,635
1964	46,512	11,625	5,483	466	64,086	5,383	70	--	--	5,453	51,895	11,695	5,483	466	69,539
1965	52,823	14,889	81,882	768	150,362	4,204	159	--	--	4,363	57,027	15,048	81,882	768	154,725
1966	52,918	18,292	48,409	1,655	121,274	4,579	1,125	--	--	5,704	57,497	19,417	48,409	1,655	126,978
1967	34,728	13,040	2,316	1,385	51,469	4,907	589	--	--	5,496	39,635	13,629	2,316	1,385	56,965
1968	25,469	9,323	1,397	4,734	40,923	3,437	120	--	--	3,557	28,906	9,443	1,397	4,734	44,480
1969	16,456	3,990	65	1,741	22,252	2,423	59	--	231	2,713	18,879	4,049	65	1,972	24,965
1970	8,415	1,978	103	804	11,300	1,457	38	--	67	1,562	9,872	2,016	103	871	12,862
1971	7,306	1,630	374	1,552	10,862	1,194	85	--	27	1,306	8,500	1,715	374	1,579	12,168
1972	3,869	609	137	1,118	5,733	909	23	4	--	936	4,778	632	141	1,118	6,669
1973	2,777	1,563	602	389	5,331	509	49	--	--	558	3,286	1,612	602	389	5,889
1974	2,396	462	109	1,323	4,290	622	198	--	9	829	3,018	660	109	1,332	5,119
1975	3,989	1,358	8	55	5,420	1,180	79	--	4	1,263	5,169	1,437	8	69	6,683
1976	2,904	1,361	4	--	4,324	1,865	91	--	--	1,956	4,769	1,452	--	59	6,280
1977	7,934	2,909	--	--	10,843	3,296	26	--	--	3,322	11,230	2,935	--	--	14,165
1978	12,160	10,179	--	--	22,339	4,538	641	--	--	5,179	16,698	10,820	--	--	27,518
1979[3]	14,275	5,182	--	--	19,457	4,622	257	--	--	4,879	18,897	5,439	--	--	24,336
1980[4]	17,448	9,520			26,968	7,270	157	--	--	7,427	24,718	9,677	--	--	34,395

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

[2]Primarily Spain, Poland, and Romania.

[3]Provisional (incomplete).

[4]Preliminary.

Table 3. Stratified mean catch per tow in numbers and weight (kg) for haddock in NEFC offshore spring, summer, and autumn[1] bottom trawl surveys on Georges Bank, 1963-1980.

	Spring[2]		Summer		Autumn	
	Nos.	Wt. (kg)	Nos.	Wt. (kg)	Nos.	Wt. (kg)
1963	--	--	76.65	29.49	97.34	52.83
1964	--	--	387.74	119.45	129.70	64.07
1965	--	--	261.65	156.05	68.26	48.20
1966	--	--	--	--	22.32	19.78
1967	--	--	--	--	11.88	16.87
1968	15.56	23.13	--	--	5.06	10.20
1969	8.26	19.05	6.46	12.95	2.28	5.59
1970	6.84	19.28	--	--	5.17	8.94
1971	3.18	5.62	--	--	2.83	3.70
1972	7.26	8.30	--	--	7.62	5.61
1973	25.23	10.18	--	--	9.98	6.48
1974	12.77	11.72	--	--	2.71	2.64
1975	4.18	5.44	--	--	20.78	10.00
1976	55.83	10.41	--	--	47.68	23.68
1977	24.74	17.60	49.29	42.90	19.02	23.13
1978	13.03	20.71	26.43	1.89	20.70	15.18
1979	30.53	13.09	55.56	25.28	42.74	26.87
1980	40.32	35.71	48.54	39.12	24.98	18.47

[1]Spring and autumn, strata 13-25, 29, and 30; summer, strata 13, 16, and 19-25.

[2]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 (the "41 Yankee" has been used since 1973).

Table 4. Stratified mean catch per tow at age (numbers) for haddock in NEFC offshore spring, summer, and autumn[1] bottom trawl surveys on Georges Bank, 1963-1980.

	Age										Totals		
Year	0	1	2	3	4	5	6	7	8	9+	0+[2]	1+[2]	2+
Spring[3]													
1968	-	0.27	3.23	0.53	0.80	7.62	1.92	0.29	0.51	0.37	-	15.54	15.27
1969	-	0.02	0.05	0.66	0.17	0.48	4.83	1.17	0.32	0.52	-	8.22	8.20
1970	-	0.77	0.29	0.00	0.37	0.53	0.53	2.28	1.12	0.97	-	6.86	6.09
1971	-	0.00	1.33	0.29	0.00	0.14	0.14	0.10	0.94	0.26	-	3.20	3.20
1972	-	4.61	0.10	0.70	0.14	0.03	0.05	0.15	0.03	1.48	-	7.29	2.68
1973	-	20.59	3.25	0.00	0.36	0.06	0.00	0.12	0.01	0.36	-	25.25	4.66
1974	-	1.43	3.92	1.92	0.00	0.16	0.00	0.01	0.07	0.25	-	12.76	11.33
1975	-	0.63	0.65	2.23	0.42	0.00	0.09	0.06	0.01	0.10	-	4.19	3.36
1976	-	54.22	0.20	0.40	0.62	0.29	0.00	0.03	0.00	0.07	-	55.83	1.61
1977	-	0.41	22.42	0.28	0.32	0.40	0.30	0.00	0.03	0.08	-	24.74	24.33
1978	-	0.05	0.65	10.69	0.24	0.63	0.53	0.11	0.04	0.07	-	13.03	12.98
1979	-	24.24	1.06	0.76	3.33	0.22	0.11	0.25	0.04	0.03	-	30.54	6.30
1980	-	3.49	31.34	0.34	0.70	3.27	0.45	0.25	0.31	0.16	-	40.31	36.82
Summer													
1963	12.72	53.04	4.22	2.15	2.08	1.41	0.40	0.33	0.04	0.25	76.64	63.92	10.88
1964	24.89	320.27	36.61	1.31	0.89	2.02	1.29	0.18	0.13	0.15	387.74	362.85	42.38
1965	0.00	27.38	207.90	19.51	1.65	1.19	1.91	1.34	0.24	0.53	261.65	261.65	234.27
1969	0.74	0.31	0.02	0.51	0.08	0.17	3.40	0.89	0.09	0.25	6.46	5.72	5.41
1977	0.04	9.48	38.74	0.17	0.21	0.32	0.22	0.03	0.02	0.07	49.30	49.26	39.78
1978	25.16	0.13	0.35	0.73	0.01	0.01	0.03	0.00	0.00	0.01	26.43	1.27	1.14
1979	3.35	49.89	0.07	0.54	1.37	0.21	0.08	0.01	0.03	0.03	55.58	52.23	2.34
1980	1.09	5.93	40.23	0.22	0.15	0.87	0.01	0.02	0.00	0.00	48.52	47.43	41.50
Autumn													
1963	56.33	17.04	6.19	4.57	3.60	3.99	1.37	1.13	0.79	0.31	97.32	40.99	23.95
1964	1.39	75.73	42.78	3.91	1.20	2.36	1.05	0.46	0.17	0.22	129.69	128.10	52.35
1965	0.22	6.82	51.94	6.31	0.72	0.54	0.61	0.34	0.17	0.18	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	22.32	18.20	17.36
1967	0.02	4.51	0.24	0.67	4.34	1.09	0.33	0.14	0.22	0.12	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	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	0.18	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	0.27	5.17	5.14	2.37
1971	1.63	0.00	0.21	0.05	0.01	0.15	0.02	0.06	0.30	0.19	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	0.37	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	0.48	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	0.15	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	0.20	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	0.17	47.70	44.80	1.73
1977	0.11	1.75	15.53	0.46	0.47	0.32	0.28	0.03	0.01	0.07	19.03	18.92	17.17
1978	10.32	0.69	0.85	7.39	0.15	0.21	0.37	0.01	0.00	0.01	20.70	9.38	9.19
1979	1.08	37.29	0.03	0.74	3.12	0.21	0.23	0.04	0.01	0.00	42.75	41.67	4.38
1980[4]	9.56	2.37	10.37	0.23	0.11	1.30	0.44	0.05	0.06	0.00	24.99	15.43	13.06

[1] Spring and autumn, strata 13-25, 29, and 30; summer, strata 13, 16, and 19-25.

[2] May not agree exactly with data in Table 3 due to rounding errors.

[3] 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 (the "41 Yankee" has been used since 1973).

[4] Preliminary

Table 5. Stratified mean catch per tow in numbers and weight (kg) for haddock in NEFC offshore spring, summer, and autumn[1] bottom trawl surveys in the Gulf of Maine, 1963-1980.

Year	Spring[2]		Summer		Autumn	
	Nos.	Wt (kg)	Nos.	Wt (kg)	Nos.	Wt (kg)
1963	-	-	16.81	25.79	46.68	33.57
1964	-	-	82.68	28.58	9.51	12.47
1965	-	-	15.62	9.62	11.70	11.72
1966	-	-	-	-	7.82	9.18
1967	-	-	-	-	8.18	11.16
1968	6.99	9.17	-	-	5.75	11.42
1969	4.32	8.30	3.47	7.34	3.66	8.51
1970	1.03	1.94	-	-	1.96	4.87
1971	1.00	2.84	-	-	1.93	5.39
1972	0.98	0.98	-	-	1.33	2.01
1973	0.88	1.06	-	-	2.80	5.68
1974	0.96	0.70	-	-	1.80	2.21
1975	1.86	2.30	-	-	3.71	5.71
1976	5.59	4.21	-	-	4.05	5.32
1977	4.56	4.45	7.42	10.99	6.79	7.34
1978	0.91	0.95	4.31	9.14	8.00	18.16
1979	2.32	3.17	7.07	17.67	4.52	11.50
1980	1.81	2.24	5.95	10.48	5.85	8.24

[1]Spring and autumn, strata 26-28 and 36-40; summer, strata 26-28, 37, and 38.

[2]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 (the "41 Yankee" has been used since 1973).

Table 6. Stratified mean catch per tow at age (numbers) for haddock in NEFC offshore spring, summer, and autumn[1] bottom trawl surveys in the Gulf of Maine, 1963-1980.

	Age										Totals		
Year	0	1	2	3	4	5	6	7	8	9+	0+[2]	1+[2]	2+
Spring[3]													
1968	-	0.00	0.00	0.00	0.39	5.15	1.09	0.09	0.03	0.24	-	6.99	6.99
1969	-	0.00	0.00	0.09	0.02	0.22	3.04	0.80	0.05	0.09	-	4.31	4.31
1970	-	0.00	0.00	0.00	0.00	0.00	0.17	0.70	0.10	0.07	-	1.04	1.04
1971	-	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.73	0.20	-	0.99	0.99
1972	-	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.31	-	0.97	0.31
1973	-	0.09	0.53	0.00	0.04	0.00	0.00	0.00	0.00	0.23	-	0.89	0.80
1974	-	0.60	0.06	0.22	0.00	0.00	0.00	0.00	0.00	0.09	-	0.97	0.37
1975	-	0.01	1.32	0.10	0.25	0.00	0.01	0.00	0.00	0.17	-	1.86	1.85
1976	-	3.46	0.05	1.24	0.12	0.61	0.00	0.02	0.00	0.09	-	5.59	2.13
1977	-	0.39	2.39	0.02	0.90	0.27	0.39	0.00	0.00	0.00	-	4.56	3.97
1978	-	0.06	0.47	0.21	0.04	0.10	0.03	0.00	0.00	0.00	-	0.91	0.85
1979	-	0.25	0.00	1.08	0.80	0.06	0.08	0.06	0.00	0.00	-	2.33	2.08
1980	-	0.87	0.12	0.14	0.36	0.28	0.02	0.00	0.00	0.03	-	1.82	0.95
Summer													
1963	0.71	2.51	1.72	1.70	4.41	3.16	1.28	0.64	0.42	0.79	17.34	16.63	14.12
1964	0.06	57.27	14.63	3.91	1.87	2.62	0.90	0.91	0.19	0.31	82.67	82.61	25.34
1965	0.00	5.12	7.17	0.86	0.15	0.67	0.66	0.48	0.07	0.46	15.64	15.64	10.52
1969	0.00	0.00	0.00	0.00	0.00	0.06	2.23	0.56	0.22	0.40	3.47	3.47	3.47
1977	0.00	1.55	3.64	0.19	1.00	0.09	0.54	0.00	0.00	0.42	7.43	7.43	5.88
1978	0.00	0.12	1.09	1.75	0.19	0.56	0.44	0.07	0.00	0.11	4.33	4.33	4.21
1979	0.92	0.76	0.10	1.00	2.56	0.46	0.53	0.18	0.00	0.56	7.07	6.15	5.39
1980	0.18	1.04	1.93	0.42	1.20	0.83	0.13	0.11	0.00	0.11	5.95	5.77	4.73
Autumn													
1963	23.90	8.18	1.14	2.02	4.66	3.31	1.12	0.88	0.70	0.74	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	0.21	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	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	7.81	7.80	7.77
1967	0.00	0.00	0.20	0.83	5.37	1.21	0.53	0.08	0.12	0.03	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	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	0.14	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	0.03	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	0.19	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	0.52	1.34	1.34	0.54
1973	0.75	0.01	0.64	0.00	0.24	0.02	0.01	0.03	0.01	1.08	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	0.23	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	0.32	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	0.12	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	0.07	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	0.21	8.00	7.86	7.85
1979	0.59	0.30	0.01	0.79	1.97	0.41	0.30	0.09	0.05	0.02	4.53	3.94	3.64
1980[4]	3.25	0.41	0.22	0.03	0.15	0.89	0.47	0.24	0.10	0.08	5.84	2.59	2.18

[1] Spring and autumn, strata 26-28 and 36-40; summer, strata 26-28, 37, and 38.

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

[3] 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 (the "41 yankee" trawl has been used since 1973).

[4] Preliminary

Table 7. Stratified mean catch per tow in numbers and weight (kg) for haddock in NEFC inshore summer surveys[1] for the Gulf of Maine[2], 1977-1980.

Year	Stratified mean catch per tow at age[3] (numbers) 0	1	2	3	4	5	6+	Total	Stratified mean catch per tow in weight (kg)
1977	0.00	13.67	11.77	0.00	0.00	0.00	0.00	25.44	9.57
1978	0.05	0.00	0.90	1.60	0.00	0.00	0.00	2.55	2.72
1979	1.13	9.06	0.35	0.57	0.00	0.00	0.00	11.11	2.71
1980	5.27	11.73	0.54	0.11	0.99	0.34	0.00	18.98	6.60

[1] Data for spring and autumn not included due to reduced sample coverage and low haddock catches.

[2] Strata 58-61, 63-66, 72, 74-75, 80, 81, 83, and 85.

[3] Obtained by applying corresponding age-length keys from offshore strata.

Table 8. Stratified mean catch per tow in numbers and weight (kg) for haddock in Massachusetts inshore surveys in Cape Cod and Massachusetts Bay[1], 1978-1980.

Year	Stratified mean catch per tow at age[2] (numbers) 0	1	2	3	4	5	6+	Total	Stratified mean catch per tow in weight (kg)
Spring									
1978	0.00	0.00	0.92	0.07	0.00	0.00	0.00	0.99	0.59
1979	0.00	0.01	0.00	0.00	0.02	0.00	0.00	0.03	0.03
1980	0.34	3.00	0.03	0.00	0.03	0.05	0.00	3.45	0.46
Autumn									
1978	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1979	15.32	0.00	0.00	0.00	0.00	0.00	0.00	15.32	0.11
1980	15.64	0.78	0.00	0.00	0.00	0.00	0.00	16.42	0.35

[1] Regions 4 and 5 (strata 25-36).

[2] Obtained by applying NEFC age-length keys for the Gulf of Maine for corresponding years and seasons.

Table 9. Catch per tow and calculated index values for young of year haddock in selected juvenile concentration areas on Georges Bank, 1953-1980.

Year/ Year-class	Number of Tows	Number caught	Mean Number per tow linear	Mean Number per tow $\log_{10}(x+1)$	Young[1] of year index	VPA[2] stock size age 2 (millions
1953	15	35	2.33	0.31	3.6	43.1
1955	34	533	15.68	0.64	3.5	50.0
1956	11	12	1.09	0.23	2.0	51.1
1958	24	841	35.04	0.99	8.5	104.8
1959	57	1535	26.93	1.02	9.6	100.9
1960	50	221	4.42	0.43	2.4	44.4
1961	48	56	1.17	0.14	1.4	31.8
1962	44	206	4.68	0.43	2.6	150.3
1963	38	3832	100.84	1.05	12.6	368.3
1964	46	261	5.67	0.36	2.0	17.9
1965	43	18	0.42	0.06	1.2	3.2
1966	44	246	5.59	0.20	1.7	8.6
1967	42	0	0.00	0.00	1.0	0.3
1968	41	4	0.10	0.02	1.0	0.8
1969	39	7	0.18	0.04	1.1	3.5
1970	42	1	0.70	0.01	1.0	0.1
1971	45	84	1.87	0.17	1.5	7.0
1972	45	218	4.84	0.31	2.1	9.3
1973	46	151	3.28	0.24	1.8	-
1974	38	36	0.95	0.13	1.3	-
1975	48	1062	22.13	0.60	3.8	-
1976	40	200	5.00	0.27	1.7	-
1977	58	10	0.17	0.03	1.1	-
1978	110	1541	14.01	0.35	2.3	-
1979	101	234	2.32	0.24	1.6	-
1980	51	1765	34.61	0.47	2.8	-

[1] See Grosslein (MS 1969). Values calculated as averaged means of individual $\log_{10}(x+1)$ observations by time and depth zone, antilogged; 1953-1968 values as reported by Grosslein.

[2] Clark et al. (MS 1980).

Table 10. Catch projections (tons) for Georges Bank haddock for 1981 and total[1] (age 2+) and spawning stock[1] size projections for 1982 under different fishing mortality levels assuming recruitment of 61 million fish in 1982 (1981 total stock size = 74 million fish or 109,565 tons; 1981 spawning stock size = 68 million fish or 105,414 tons).

Fishing mortality (F) 1981	Total catch 1981	Total Stock Size in 1982				Spawning Stock Size in 1982			
		Number (000's)	% Change from 1981	Weight (tons)	% Change from 1981	Number (000's)	% Change from 1981	Weight (tons)	% Change from 1981
0.05	5,319	118,528	60.1	160,586	46.6	88,028	28.8	138,321	31.2
0.10	10,391	115,828	56.4	155,059	41.5	85,328	24.8	132,794	26.0
0.15	15,228	113,257	53.0	149,797	36.7	82,757	21.1	127,532	21.0
0.20	19,842	110,807	49.7	144,787	32.1	80,307	17.5	122,522	16.2
0.25	24,243	108,472	46.5	140,017	27.8	77,972	14.1	117,752	11.7
0.26[2]	25,098	108,019	45.9	139,090	27.0	77,519	13.4	116,825	10.8
0.30	28,441	106,248	43.5	135,475	23.6	75,748	10.8	113,210	7.4
0.35	32,445	104,130	40.6	131,150	19.7	73,630	7.7	108,885	3.3
0.40	36,265	102,111	37.9	127,031	15.9	71,611	4.8	104,766	-0.6
0.45	39,910	100,187	35.3	123,110	12.4	69,687	2.0	100,845	-4.3
0.50	43,387	98,355	32.8	119,376	9.0	67,855	-0.7	97,111	-7.9
0.55[3]	46,705	96,608	30.5	115,821	5.7	66,108	-3.3	93,556	-11.2
0.60	49,871	94,945	28.2	112,436	2.6	64,446	-5.7	90,171	-14.5

[1] Total stock size includes ages 2 and older; spawning stock includes 50% of age 2 fish and 100% of ages 3 and older.

[2] $F_{0.1}$

[3] F_{max}

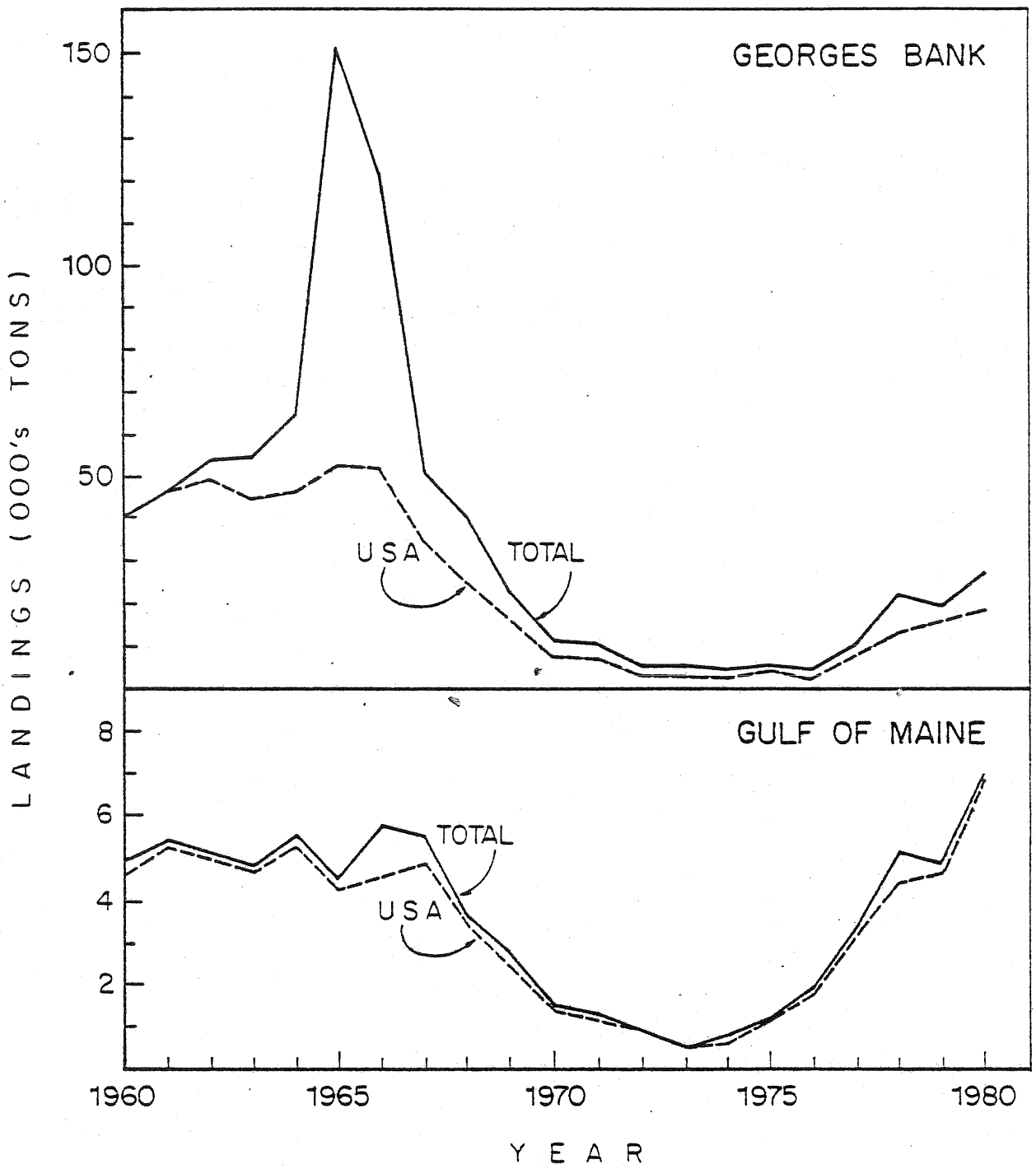

Figure 1. Commercial landings of haddock (metric tons, live) for Georges Bank and the Gulf of Maine, 1960-1980.

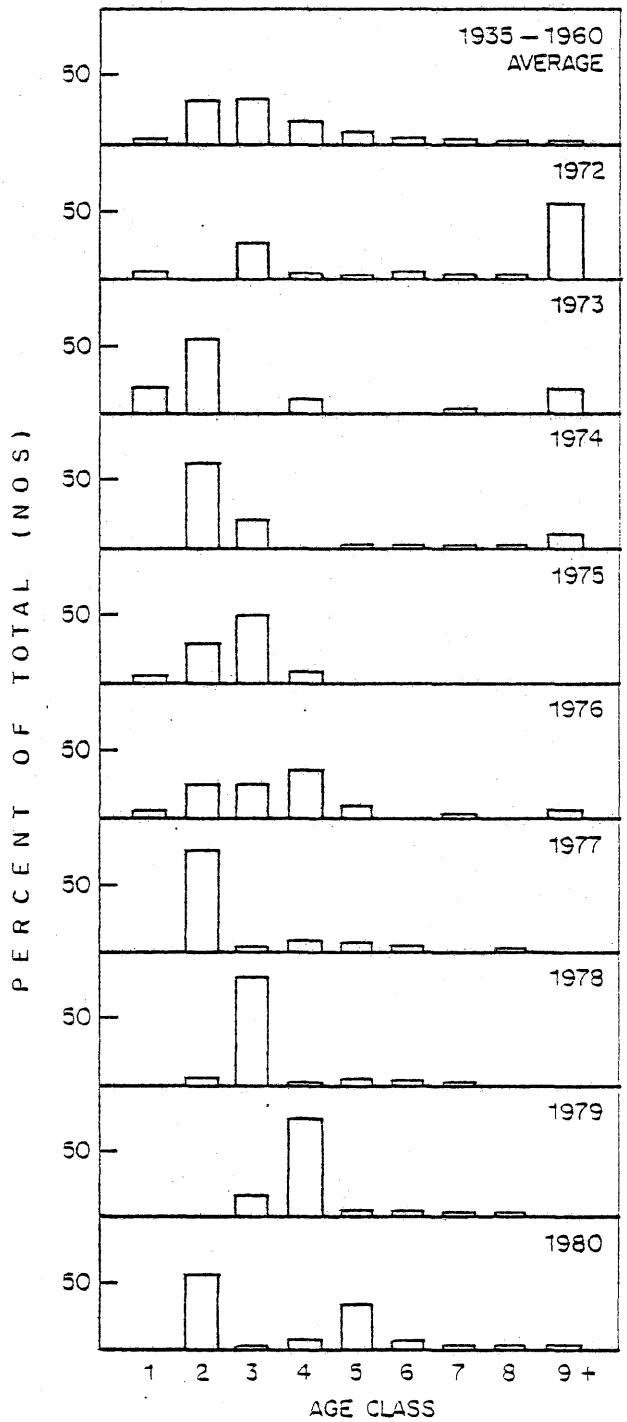

Figure 2. Age composition of Georges Bank haddock landings (percent by number) for 1935-1960 and 1972-1980.

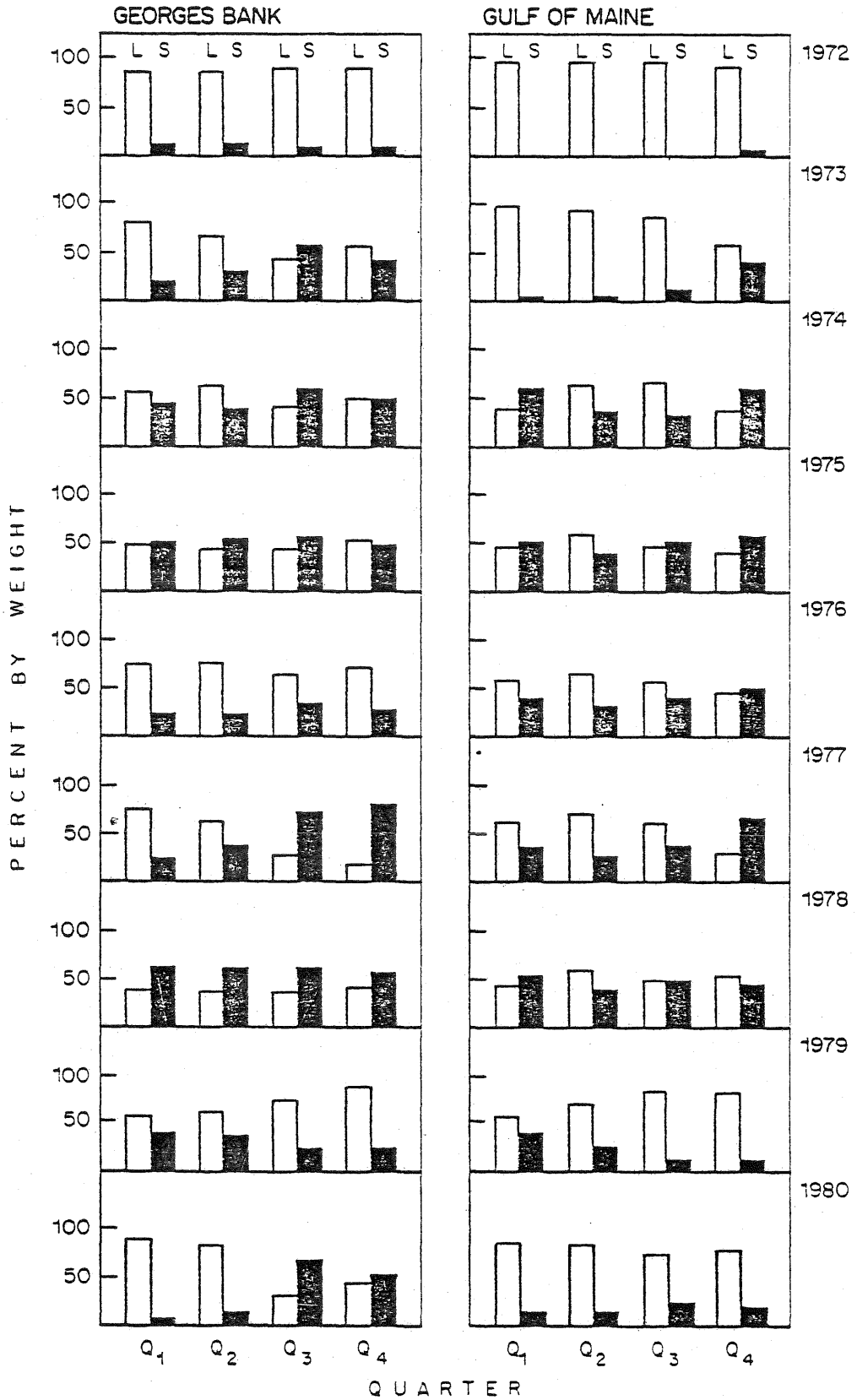

Figure 3. Distribution (percent by weight) of USA haddock landings for Georges Bank and the Gulf of Maine by market category, 1972-1980 (L = large, S = scrod and snapper).

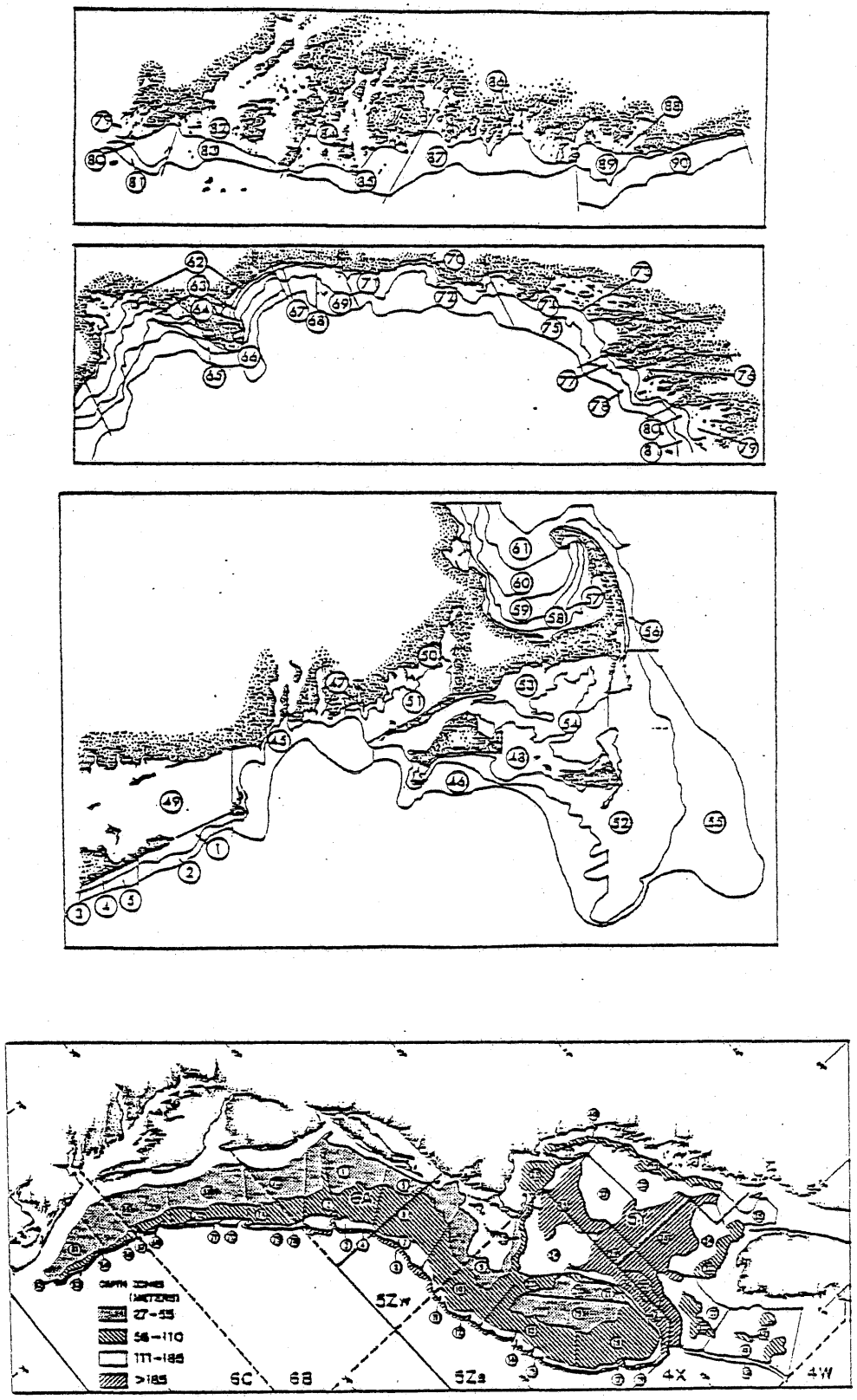

Figure 4. Strata used in NEFC spring, summer, and autumn inshore (<27 m) and offshore (>27 m) bottom trawl surveys.

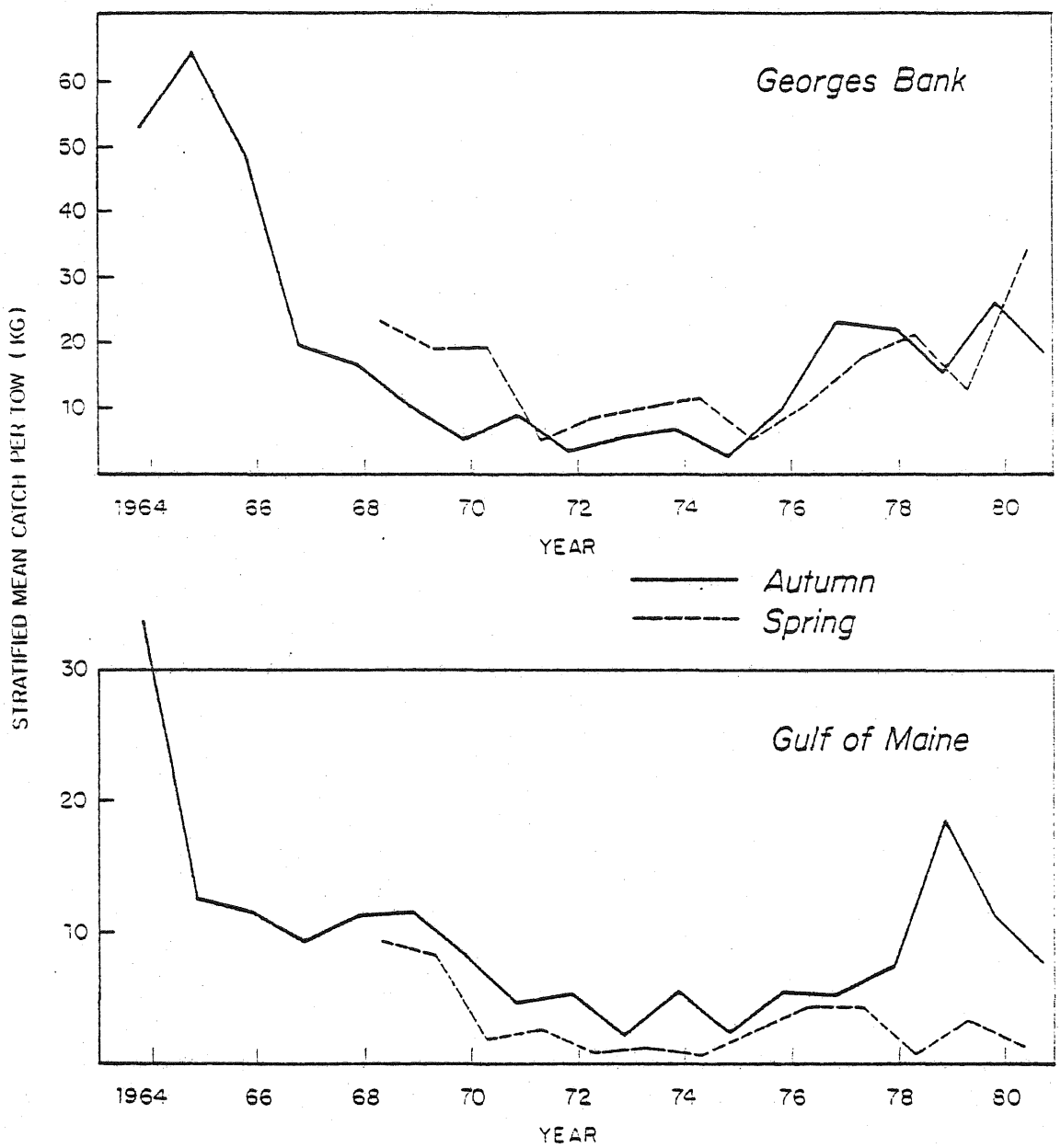

Figure 5. Stratified mean catch per tow (kg) of haddock in NEFC spring and autumn bottom trawl surveys on Georges Bank and in the Gulf of Maine, 1963-1980.

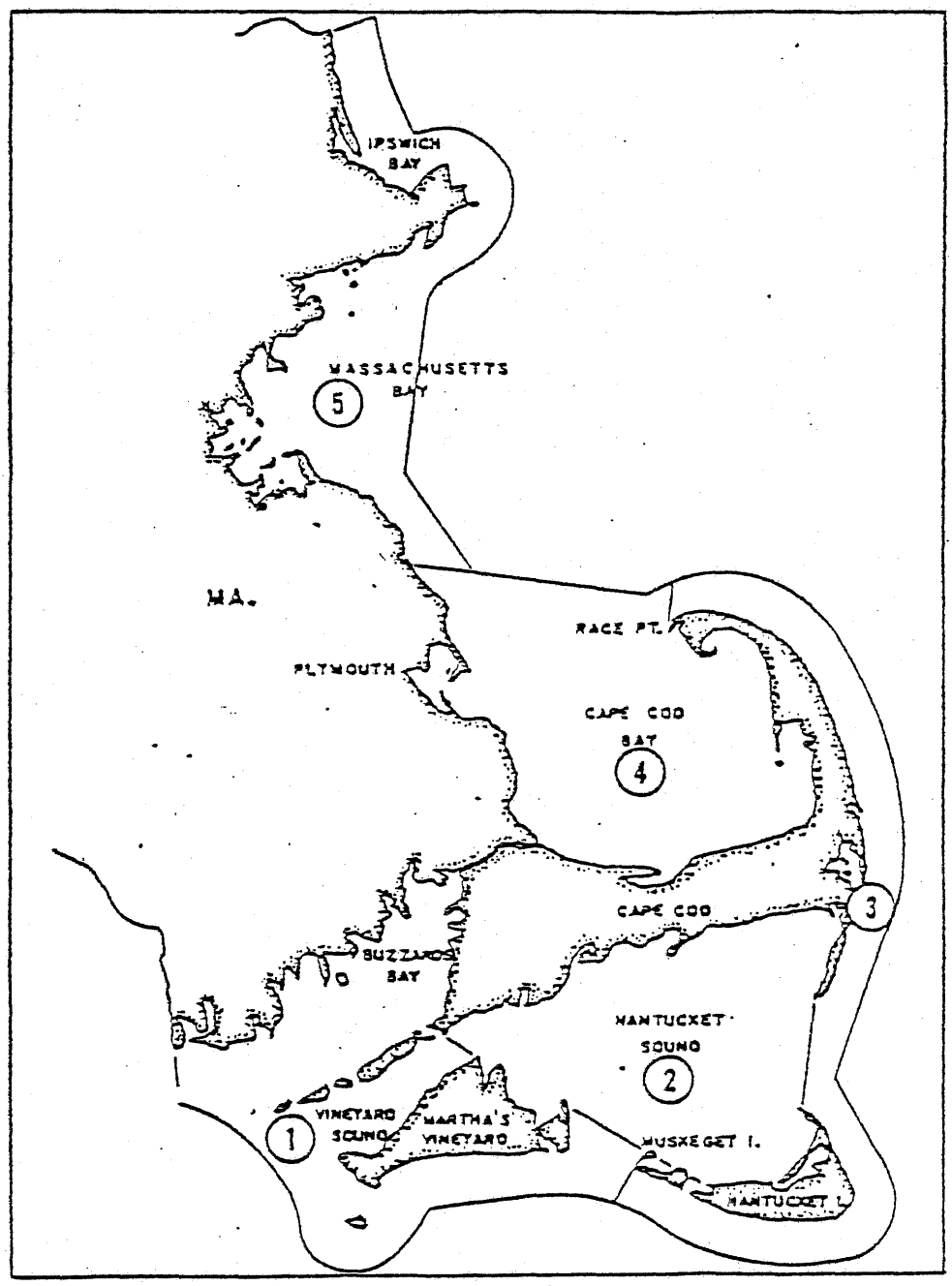

Figure 6. Massachusetts inshore survey area delineated by regions.

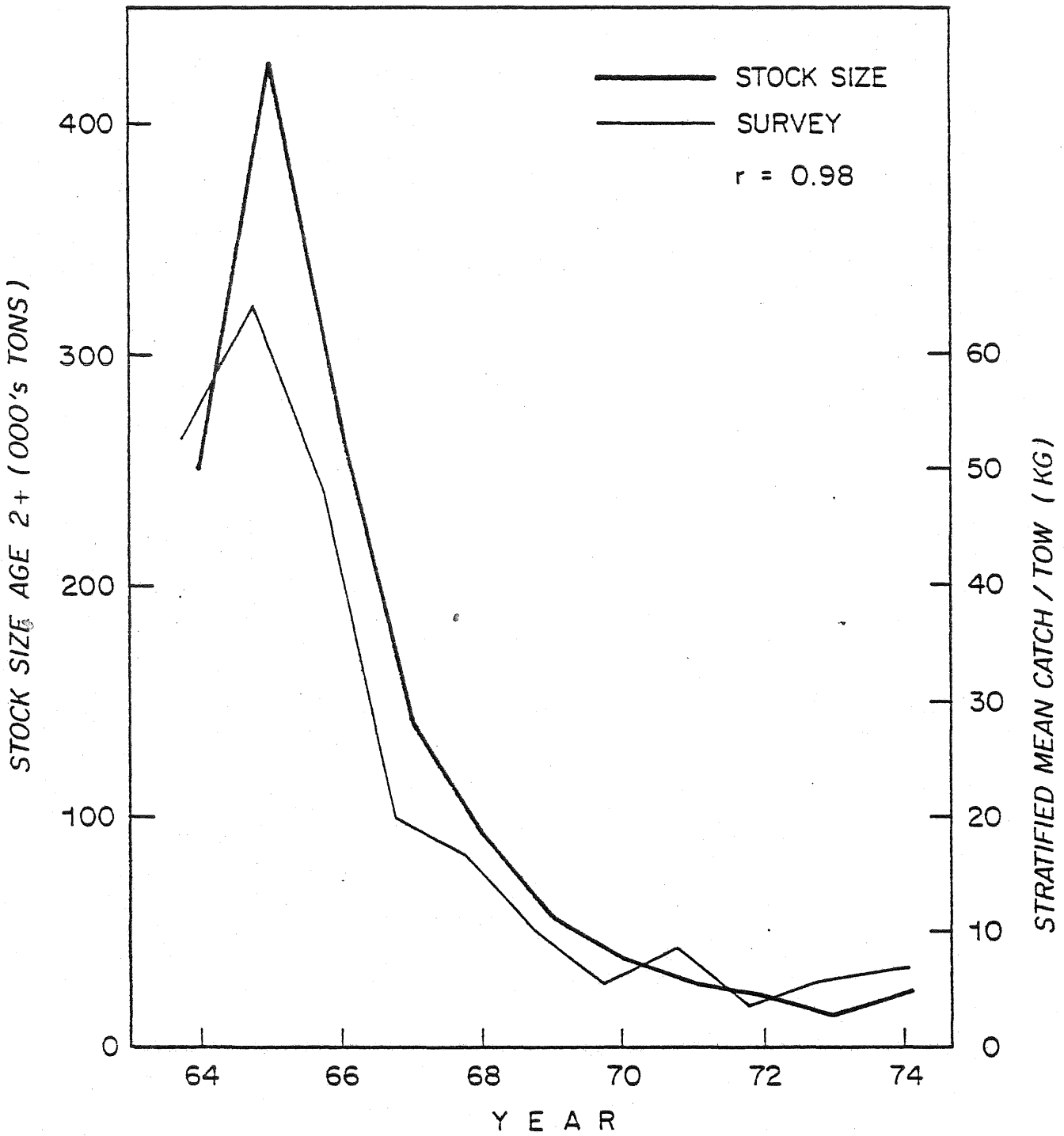

Figure 7. Relationship between stock size age 2 and older (tons) calculated from virtual population analysis or VPA and NEFC autumn bottom trawl survey index values for Georges Bank haddock, 1964-1974.

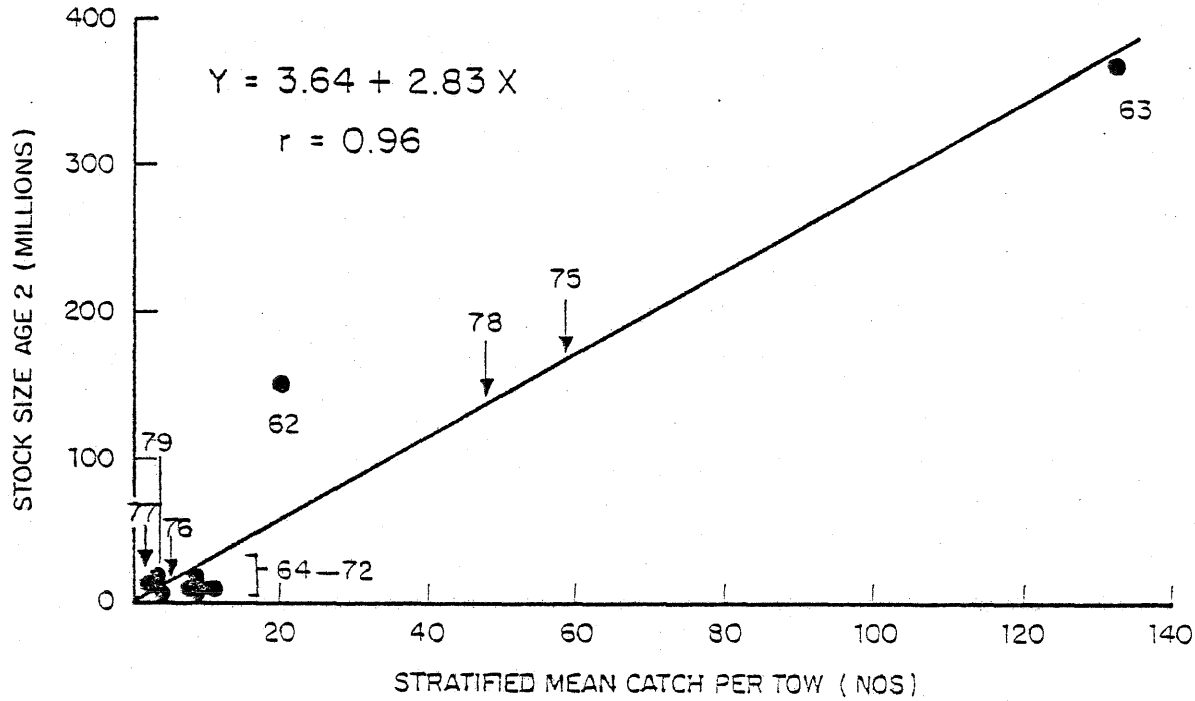

Figure 8. Relationship between year class size (millions, age 2) calculated from virtual population analysis or VPA and NEFC autumn survey catch per tow (numbers, age 0 and 1 combined) for Georges Bank haddock.

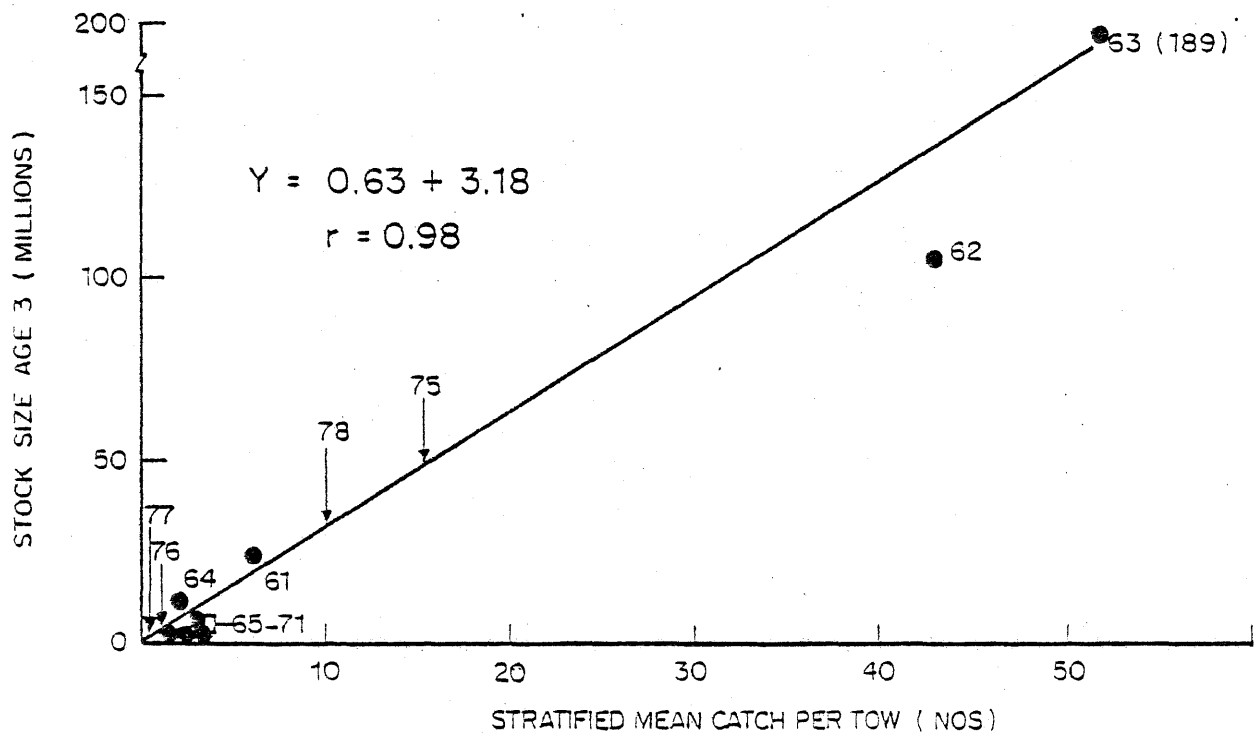

Figure 9. Relationship between year class size (millions, age 3) calculated from virtual population analysis or VPA and NEFC autumn survey catch per tow (numbers, age 2) for Georges Bank haddock.

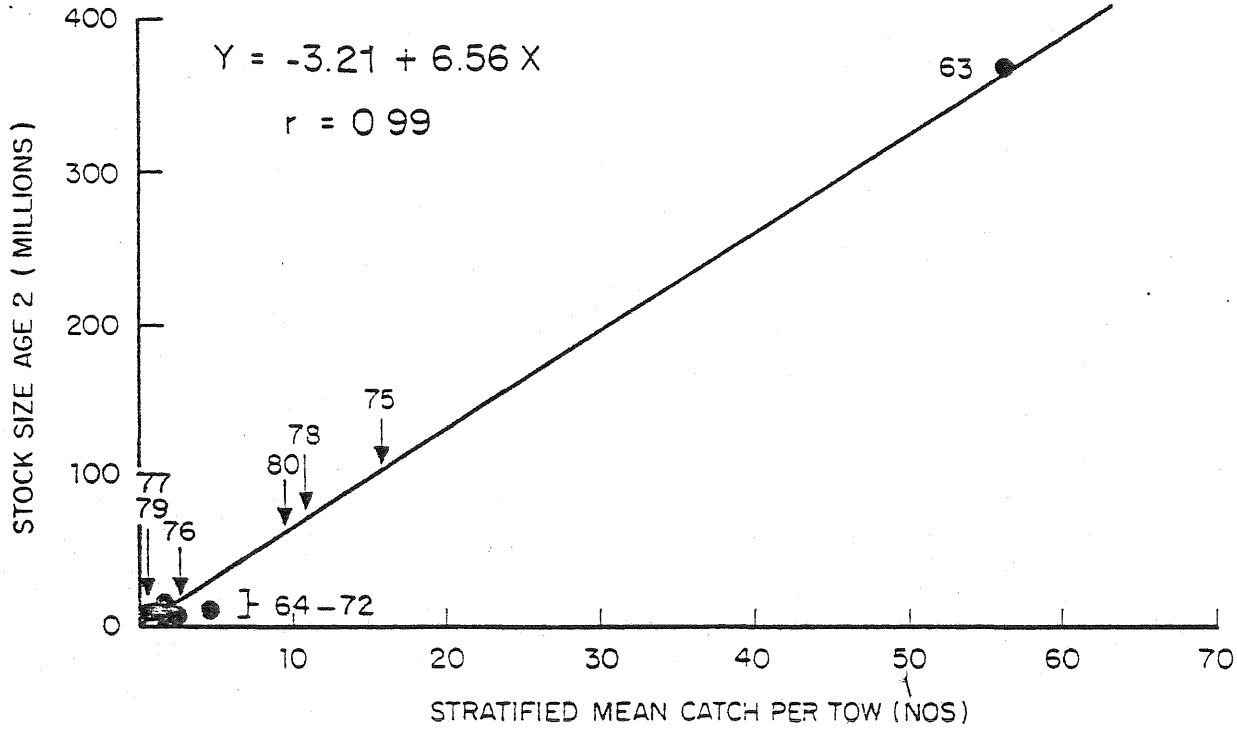

Figure 10. Relationship between year class size (millions, age 2) calculated from virtual population analysis or VPA and NEFC autumn survey catch per tow (numbers, age 0) for Georges Bank haddock.

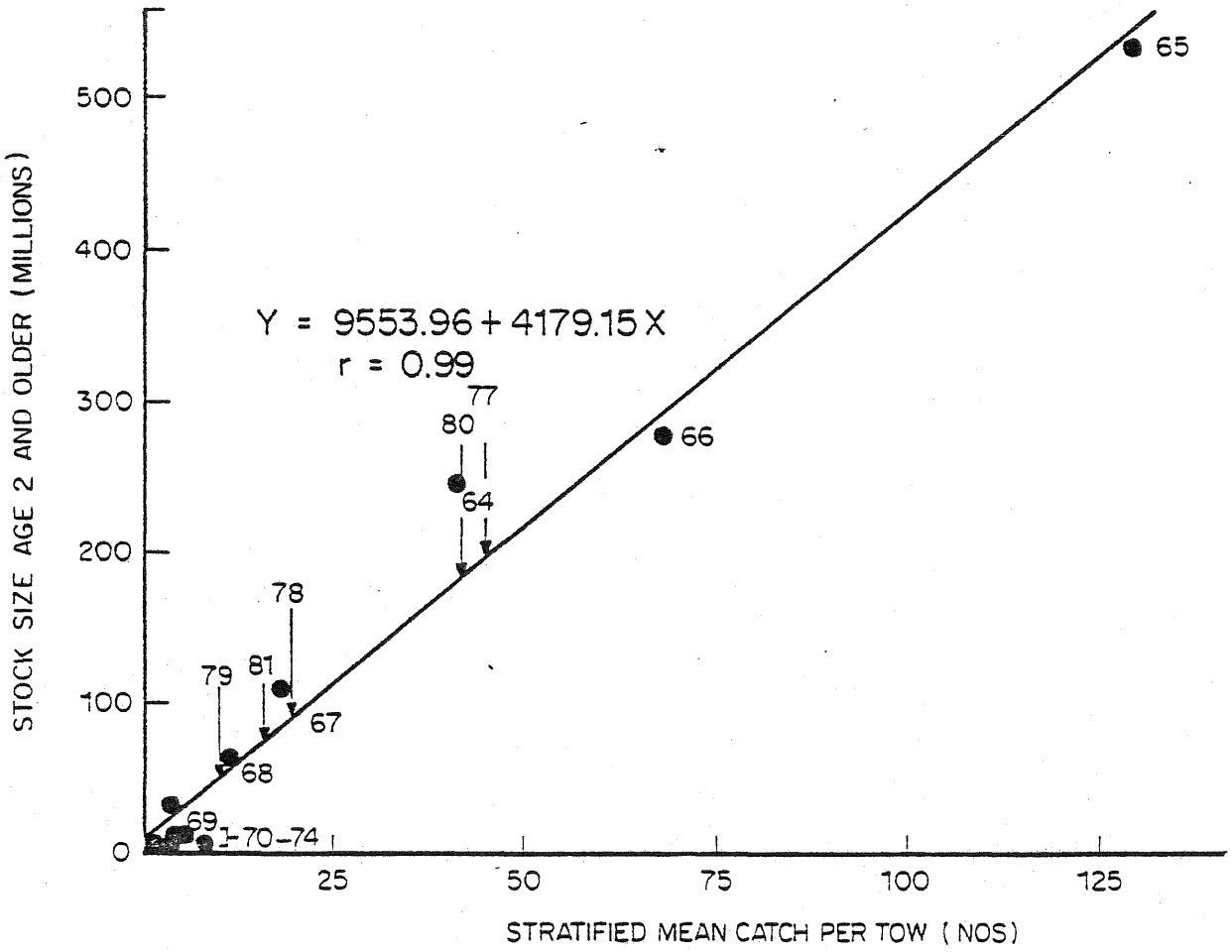

Figure 11. Relationship between stock size age 2 and older (millions) calculated from virtual population analysis or VPA and NEFC autumn survey catch per tow (numbers age 1 and older) for Georges Bank haddock.