Review and Assessment of the Georges Bank and Gulf of Maine Haddock Fishery

by

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INTRODUCTION

The haddock (Melanogrammus aeglefinus) constituted New England's most important groundfish resource for many decades and from the early 1920's to the mid-1960's was one of the most valuable fishery resources in the United States; total landed value averaged between 10 and 12 million dollars from 1940-1960 and increased to a record high of 13.9 million dollars in 1966 (Lyles 1968), before declining in subsequent years. Prior to 1900, this species was of minor importance, being inferior to cod (Gadus morhua) for salting purposes, and consequently it was little utilized in historical times although use of ice aboard some of the bank vessels towards the close of the 19th century resulted in development of a limited fishery (Smith and Olson MS 1976). Introduction of filleting and freezing methods, however, resulted in an expanded market for haddock (Schuck 1951) and with the introduction of otter trawls and diesel engines, the USA haddock fishery expanded rapidly. Landings from all areas reached an all-time high of 132,200 tons[1] in 1929 before declining to an average of 66,000 tons from 1931-1965; subsequently landings declined precipitously with the collapse of the Georges Bank haddock fishery in the late 1960's. Total USA landings averaged approximately 5,000 tons from 1972-1976; provisional statistics for 1977 indicate a total USA catch of 12,900 tons, and preliminary estimates for 1978 indicate a USA catch of 17,700 tons.

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

History of Research

Georges Bank haddock have received intensive study, and a large volume of biological and statistical data has been assembled and published for this fishery. Probably no stock in the western hemisphere has a more extensive data base available for assessment purposes at the present time.

Organized research began in 1930, when funding was made available to the U.S. Bureau of Fisheries for haddock research in response to industry concern over rapidly declining landings and abundance (Schuck 1951). Beginning in 1931, major haddock ports (Boston and Gloucester, Massachusetts, and Portland, Maine) were sampled intensively; data were collected relative to quantities landed by area (Rounsefell 1948), size and age composition of the catch, and related information, e.g., length-weight data. Schuck (1951) has summarized much of this information for 1931-1948; later material is included in recent assessment papers and other documents (described below) but was usually not formally published. In addition, effort and catch-effort data were collected (Rounsefell 1957) and used for evaluation of trends in abundance (Schuck 1949; Rounsefell 1957) and for predictive purposes (Royce and Schuck 1954). Discarding of small haddock in the otter trawl fishery was also documented extensively (Prematz 1953; Graham and Prematz 1955). Other important contributions during this period include papers on tagging and stock identification (Needler 1930; Schroeder 1942; Schuck and Arnold 1951), stock-recruitment (Herrington 1948) and the influence of currents on larval distribution and survival (Walford 1938).

During the 1950's a variety of topics were considered including gear selectivity (Graham 1952; Clark 1952) and evaluation of later mesh regulations (Graham and Premetz 1955; Clark 1963). Colton (1955) studied seasonal distribution; Chase (1955) and Colton and Temple (1961) examined environmental influences on year-class size, and Clark and Vladykov (1960) and Grosslein (1962) provided further information on stock boundaries.

More recent work has been oriented largely towards assessment and evaluation of recovery potential from depressed levels of the early 1970's. The International Commission for the Northwest Atlantic Fisheries (ICNAF) Redbook series (1958-1976) contains information as do other sources (Beverton 1965; Hennemuth MS 1968, MS 1969; see also updates by Clark MS 1975, MS 1976; Clark and Palmer MS 1978). Hennemuth's (MS 1969) assessment was significant in providing a detailed review for the Georges Bank stock including trends in abundance, mortality, and recruitment and results of surplus-yield modeling and yield per recruit studies. Grosslein (MS 1966) examined stock-recruitment for Georges Bank haddock; Grosslein and Hennemuth (1973) reviewed factors affecting recruitment including a detailed analysis of the stock-recruitment problem. Grosslein (MS 1969a) also devised young-of-year indices based on USA autumn bottom trawl survey data. Hennemuth (1965) analyzed commercial age-length data to evaluate sampling and reporting requirements; Brown and Hennemuth (1971) provided length-weight equations and conversion factors for Georges and Browns Banks. Stern and Hennemuth (1975) applied Robson's two-factor analysis of variance approach to catch-effort data for Georges Bank and compared resulting abundance index values to those obtained from earlier studies. Papers by Colton (1965) on distribution of eggs, larvae, and juveniles and by Marak and Livingstone (1970) on spawning are also deserving of mention.

Past and Current Management

Prior to 1951, there was no legal basis for fishery management in international waters of the Northwest Atlantic. However, the need for management of the Georges Bank haddock fishery had long been evident, one of the most notable examples being extensive discard in the 1930's and 1940's (Prematz 1953; Graham and Prematz 1955) resulting from use of (stretched) codend mesh sizes averaging 79 mm (2.9 inches). Establishment of ICNAF in 1951 provided the basis for mesh regulations, and in June of 1953 a minimum stretched mesh size regulation of 114 mm (4.5 inches) was entered into force for ICNAF Subarea 5 (Figure 1) comprising the Gulf of Maine (ICNAF Division 5Y) and Georges Bank (ICNAF Division 5Z) (International Commission for the Northwest Atlantic Fisheries 1952:14). This regulation persisted, with minor modifications in standards of measurement and other provisions, until 1974, when the minimum codend mesh size was raised to 130 mm or 5.1 inches. Mesh regulations appear to have reduced discards from a possible 10-15% to about 1-5% of the annual landed catch (Grosslein and Hennemuth 1973).

The advent of large distant water fleets and substantial increases in fishing pressure during the mid-1960's dramatically changed the status of the Subarea 5 haddock resource and resulted in the need for more intensive management. Continued declines in landings and stock abundance and continued poor recruitment led to establishment under ICNAF of a Total Allowable Catch (TAC) of 12,000 tons for Subarea 5 for 1970 and 1971 (International Commission for the Northwest Atlantic Fisheries 1969:27); for 1972 and 1973, the TAC was reduced to 6,000 tons, and for 1974 the TAC was set at zero allowing for incidental by-catch only. Subsequent TACs for 1975 and 1976 were set at 6,000 tons, as it was recognized that incidental catches up to this level were probably unavoidable. During 1970-1973, USA landings were regulated by quotas, with prohibition of directed

fishing when the quotas had been filled; during 1974-1976, a variety of incidental catch regulations were employed. Also beginning in 1970 known haddock spawning concentration areas have been closed to fishing with gear capable of taking demersal species in March and April (International Commission for the Northwest Atlantic Fisheries 1969:27); spring closures have since been continued (with minor modifications in boundary lines, gear restrictions, and duration) until the present (Figure 1). In addition, portions of the Georges Bank - Gulf of Maine area have been closed to fishing by larger vessels employing gear capable of taking demersal species (crustacean and scallop gear excluded) beginning in 1974 (International Commission for the Northwest Atlantic Fisheries 1973:180, 1974:190; 1975:39).

In 1977, the New England Regional Fishery Management Council (NERFMC) assumed jurisdiction over the Georges Bank and Gulf of Maine haddock resource under the Fishery Conservation and Management Act of 1976. Emergency regulations were implemented on March 14 , under which previous mesh regulations were continued, an optimum yield (OY) of 6,200 tons (6,000 tons commercial; 200 tons recreational) was established (to be taken as incidental by-catch), and haddock spawning concentration areas were closed to vessels employing gear capable of taking demersal species during March-May (lobster and scallop gear and hooks with a gape $\geq$ 3 cm (1.2 inches) in the Great South Channel - Nantucket Shoals area excepted). A minimum size regulation of 40.6 cm (16 inches) was also established. These regulations remained in force under the Final Fishery Management Plan (FMP) which became effective June 13 (New England Regional Fisheries Management Council 1977). The commercial allocation

was exceeded, and effective November 3 the OY was raised to 10,500 tons by emergency amendment. During 1977 catches were regulated by vessel class on a daily and a per-trip basis; on December 24, the entire groundfishery was closed for the remainder of the year. During 1977, the strong 1975 year-class recruited to the fishery, and this in part accounted for the rapid rate at which the OY was taken.

In early 1978, previous regulations were amended and implemented on an emergency basis; effective January 1, the OY was set at 5,000 tons (commercial and recreational). The first quarter allocation (1,250 tons) was exceeded in February, resulting in outright prohibition upon taking of haddock from March 19-31. Under emergency regulations implementing a new FMP April 1, the OY was raised to 8,000 tons (commercial and recreational) and on April 10 "incidental" catch limitations as such were removed. Effective July 23 the OY was again raised to 20,000 tons, 14,900 tons being designated for USA harvest. Other regulations imposed July 23 include a "no discard" provision (the minimum size regulation was dropped) and a minimum (stretched) mesh size regulation of 14 cm (5.5 inches) for gillnets; also, the haddock resource was redefined into Georges Bank and Gulf of Maine components and quotas established on that basis (11,770 and 3,130 tons, respectively; 3,100 tons was allocated to Canada and 2,000 tons was allocated to recreational interests). During 1978, catches have been regulated primarily by vessel class under a variety of daily, weekly, and per-trip limitations.

Effective October 1, the FMP was amended at the request of the NERFMC to regulat the fishery on a "fishing year" (October 1 - September 30) rather than a calendar

year basis; first quarter (October - December) USA allocations were 1,902 tons for Georges Bank and 728 tons for the Gulf of Maine. This has resulted in an increase in total USA landings for these areas above the 14,900 ton level.

Objectives

The present paper is intended as a review of the Georges Bank and Gulf of Maine haddock resource. Objectives are (1) to review historical information of potential value for assessment and management purposes, (2) to provide an updated analytical assessment for the Georges Bank stock, and (3) to provide additional assessment information for the Gulf of Maine (however, a detailed analytical assessment is currently unavailable for Gulf of Maine haddock). Throughout this paper a particular effort has been made to provide a historical perspective of trends in abundance and recruitment for use in evaluating recent trends in the fishery vis-à-vis prospects for recovery to pre-1960 conditions.

STOCK BOUNDARIES

A number of studies have been completed which provide information on stock structure in the Georges Bank - Gulf of Maine area although knowledge is incomplete. The segment of the Georges Bank haddock population east of 69° W appears to be relatively isolated from other areas; earlier tagging work (Needler 1930; Schroeder 1942), comparisons of age composition and growth data for Georges Bank and western Nova Scotia waters (Needler 1930; Schuck and Arnold 1951), and analysis of meristic (vertebral count) data (Clark and Vladykov 1960) indicate practically no interchange between Georges Bank and areas to the east. Needler (1930) concluded that "the deep water

of the Fundian Channel and of the central basin of the Gulf of Maine forms an effective barrier separating the haddock of the New England region from those of the Nova Scotian region", which might be expected in that haddock are uncommon at depths exceeding 100 fathoms (Bigelow and Schroeder 1953). Later tagging studies (Halliday and McCracken 1970) also indicate little interchange between the Georges Bank and Gulf of Maine areas and western Nova Scotia waters, and USA spring and autumn bottom trawl survey data for 1975-1977 likewise indicate a more or less discontinuous distribution (Figures 2 and 3). Previous tagging work also indicates little interchange between eastern Georges Bank and the Nantucket Shoals and Gulf of Maine areas (Schroeder 1942; McCracken 1960). Grosslein (1962) reported that 95% of the returns from haddock tagged on eastern Georges Bank[2] came from that area although 20-25% of the returns from haddock tagged off western Nova Scotia came from Georges Bank and the Gulf of Maine. The importance of eastern Georges Bank as a spawning concentration area has also been documented (Grosslein 1962; Colton 1965; Posgay and Marak 1970).

Stock structure in the Nantucket Shoals - Gulf of Maine area is less clear. Results of earlier tagging studies suggest that haddock movements are relatively limited in this region (Schroeder 1942; Bigelow and Schroeder 1953). Data for the Nantucket Shoals area, although limited, suggests a relatively sedentary population as most returns[3] (34 of 44 or 77%) came from the immediate vicinity even though over 70% of these haddock had been at large for over 100 days (Schroeder 1942). Most of the remaining recaptures were taken inshore in

[2]Unpublished tagging records on file at the Northeast Fisheries Center (NEFC), Woods Hole, MA.

[3]Includes adequately documented recoveries only.

the western Gulf of Maine although two tagged haddock were recaptured on eastern Georges Bank. Haddock tagged off central Maine (in the Mt. Desert Island area) appeared to be even more sedentary, as of 139 returns[3] 114 or 82% were recaptured in the immediate vicinity after an average time at large of 244 days (Schroeder 1942). Again, most of the remaining recoveries were from the western Gulf of Maine although 8 (6%) were taken in the Nantucket Shoals - Georges Bank area. McCracken (1960) tagged haddock in the Passamaquoddy Bay area in autumn of 1957; subsequent winter and spring recaptures came primarily from the western Gulf of Maine (Jeffreys Ledge) area although smaller numbers were also taken on western Georges Bank and off western Nova Scotia. Summer recaptures were made primarily in Passamaquoddy Bay. From this information and from examination of commercial landings trends and length frequency data, McCracken concluded that (1) at least some degree of northward movement occurs in the western Gulf of Maine in spring, followed by a reverse migration in early winter, and (2) some haddock cross the Bay of Fundy to western Nova Scotia. (Recent seasonal landings trends for the Gulf of Maine likewise suggest such coastal movements, see COMMERCIAL FISHERY, page 11). Thus, available tagging data suggest the existence of separate groups of haddock in the Nantucket Shoals and western Gulf of Maine areas although some intermingling obviously occurs. As noted above, recent tagging studies indicate that movement between the Gulf of Maine and western Nova Scotia areas is not extensive (Halliday and McCracken 1970).

Remaining information for this area is also somewhat conflicting. Previous age composition and growth data indicate a fairly close relationship

between Nantucket Shoals and the Gulf of Maine (Needler 1930). Grosslein (1962) reported the existence of separate egg concentrations in the Great South Channel - Nantucket Shoals area and in the western Gulf of Maine, although later ichthyoplankton data suggest a more or less continuous distribution (Colton and St. Onge 1974). USA spring and autumn bottom trawl survey data for 1975-1977 (Figures 2 and 3) indicate minor seasonal differences in distribution, but no major shifts are evident and in general survey data indicate that haddock in this area are relatively sedentary.

While the above results would generally support the hypothesis of three relatively distinct haddock groups in the Georges Bank - Gulf of Maine area, there is also some evidence to suggest that stronger interrelationships may exist. Grosslein and Hennemuth (1973) have noted generally good agreement between year-class sizes in the Georges Bank, Gulf of Maine, and Browns Bank areas, i.e., the same year-classes have historically tended to be strong or weak throughout this area. While this may be attributable in part to uniform environmental conditions favoring (or inhibiting) survival, more direct relationships (e.g., larval drift between areas) may also be involved. Trends in abundance for Georges Bank (discussed under RESEARCH VESSEL SURVEY CATCHES) have also closely paralleled trends in the Gulf of Maine, and similarities in commercial landings trends are also evident (see COMMERCIAL FISHERY).

In summary, available data suggest the existance of three more or less distinct stocks in the Georges Bank - Gulf of Maine area; of these, the Georges Bank group (east of 69°W and south of 42° N) appears to be the more isolated. Two additional groups appear to be resident in the Nantucket Shoals and western Gulf of Maine areas but available data do not permit an evaluation of the degree of intermixing between them (however, interchange between these stocks and the Georges Bank unit does not appear to be extensive). Uncertainty relative to inter-relationships between these groups suggests that it remains appropriate to manage haddock in this area as a unit, concentrating analytical work on the Georges Bank area and extrapolating results obtained to the Gulf of Maine.

COMMERCIAL FISHERY

Hennemuth (MS 1969) recognized three periods in the history of the Georges Bank haddock fishery. The first of these, extending from the early 1900's to the early 1930's, constituted a "developmental period" in which landings increased rapidly in response to technological improvements and changes in consumer preference. Landings peaked at 115,500 tons in 1929; subsequent declines in catch rates led to a redirection of fishing effort and a consequent decline in landings to 25,800 tons in 1934. The fishery then entered a period of relative stability from 1935-1960; during these years, fishing effort was relatively constant and landings averaged around 46,500 tons annually (Figure 4). This stock was exploited exclusively by USA vessels during these years, with the exception of very minor Canadian catches of 31 tons in 1955 and 77 tons in 1960.

The final period was marked by a rapid increase in effort by foreign nationals and a dramatic increase in landings, followed by pronounced declines in abundance and productivity. The first distant-water catches were reported by the USSR in 1962, and in succeeding years USSR landings increased to a peak of 81,900 tons in 1965 (Table 1). In 1966, USSR landings totalled 48,400 tons; landings declined sharply after that year as USSR vessels redirected most of their effort towards herring (Clupea harengus) and mackerel (Scomber scombrus). Canadian landings also increased sharply (to 18,300 tons in 1966) while USA landings increased from 46,400 tons in 1961 to an average of 52,900 tons during 1965-1966. Total international landings for Georges Bank haddock peaked at 150,400 tons in 1965, declined to 121,300 tons in 1966, and then declined steadily to 22,300 tons in 1969 in response to declining abundance and poor recruitment (Table 1). Landings averaged 11,100 tons in 1970-1971 and 5,500 tons in 1972-1973 under quota management and then declined to an average of 4,700 tons for 1974-1976 under incidental catch limitations. In 1977, landings for Georges Bank increased sharply to 10,800 tons due primarily to recruitment of the strong 1975 year-class; of this figure, 7,900 tons (73%) was taken by the USA; the remainder was taken by Canada. Preliminary projections suggest combined USA - Canadian landings in the order of 21,000 tons for Georges Bank for 1978, assuming (1) Canadian landings in the order of 8,900 tons based on preliminary statistics reported through November, and (2) USA landings of 12,100 tons based on preliminary statistics reported through December. It is likely that the above figures will increase somewhat when final data become available.

The bulk of the Georges Bank catch in recent years has been taken by the USA, the USSR, and Canada, although Spain, Poland, Romania, and the United Kingdom have taken more limited quantities on occasion (Table 1). With the exception of a small Canadian catch in 1955, Georges Bank haddock were exploited exclusively by USA vessels until 1960. Other countries reporting landings of Georges Bank haddock include Bulgaria,Cuba, France, the FRG and GDR, Ireland, and Japan (Table 1). Prior to 1974, USA and Canadian fisheries were "directed" in nature, and the USSR also directed substantial effort towards haddock in the mid-1960's, but catches by other nations appear to have been primarily incidental. USSR, Polish, and Romanian catches in recent years were taken primarily in demersal and pelagic trawling operations directed towards silver hake (Merluccius bilinearis), herring, and mackerel, while Spanish catches were taken in demersal pair-trawling operations directed towards cod.

Historical landings trends for the Gulf of Maine have been generally similar although some differences are evident. Landings averaged over 10,000 tons annually from 1928-1930 but then declined to a relatively constant level (averaging approximately 2,900 tons) from 1931-1947. Landings then increased to an annual average of 7,300 tons from 1953-1958 but then declined to an average of 5,100 tons from 1959-1966 (Figure 4). Landings subsequently declined continually to only 600 tons in 1973 but have since increased steadily; provisional statistics for 1977 indicate landings of 3,300 tons, and preliminary projections indicate a 1978 total of 4,400 tons (Figure 4; Table 1).

Gulf of Maine haddock were exploited exclusively by USA vessels until the mid-1950's, when Canada reported landings of 11 tons in 1953 and 150 tons in 1955. Subsequently, Canada has reported catches from this area every year although amounts have usually been minor (Table 1). Small quantities have also been reported by Spain, the United Kingdom, the USSR, the GDR, Japan, and the FRG.

The USA haddock fishery on Georges Bank has been prosecuted almost exclusively by otter trawling in recent years (97.6% of the 1973-1977 total); practically all of the remainder (2.2%) has been taken by line trawling. In the Gulf of Maine, 78.9% of the 1973-1977 total was taken by otter trawling; the remainder has been taken by gillnetting (13.5%) and line trawling (7.6%). Seasonal trends in landings are evident in both areas as average monthly landings for 1973-1977 on Georges Bank increased from 5.2% during January-March to 14.9% in June before declining more less steadily to 7.0% in December. In the Gulf of Maine, spring and autumn peaks are evident; average monthly landings for these years increased from 4.7% of the annual total during January - February to 14.2% in April, decreased to 5.5% in July, and then increased to 11.6% of the annual total in November before again declining to 8.1% in December. The summer peak on Georges Bank appears to reflect seasonal closure of haddock spawning grounds to demersal gear in March, April and May, improved weather conditions during summertime and recruitment of incoming year-classes, while the spring and autumn peaks observed in the Gulf of Maine appear to reflect seasonal migrations as discussed above.

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 1977). 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, for Maine to Cape Hatteras; however, the 1974 survey indicated a recreational catch of only 199 tons (Maine to Virginia). Distribution of the catch within the Gulf of Maine-Georges Bank area is unknown, although from available information on seasonal trends in distribution by area (from commercial and research vessel survey data) and the observed distribution of recreational effort it appears that most of the recreational catch is taken in the western Gulf of Maine. Consequently, recreational catches have not been incorporated into the analytical assessment data base for the Georges Bank stock.

COMMERCIAL CATCH AGE COMPOSITION

Commercial length frequency samples and age-length keys are available for the USA Georges Bank fishery from 1931 to 1977; these have been applied to USA commercial landings to obtain numbers landed at age for the USA fishery. For 1931-1959, numbers landed at age were as used in previous assessments (Hennemuth MS 1969; Grosslein and Hennemuth 1973). Numbers landed at age were calculated on the basis of a "biological" year (February-January) from 1931-1955 (see Schuck 1951), after which data were calculated on the basis of a calendar year. For succeeding years, length frequency samples and age-length keys were usually unavailable for other countries, and different procedures were used to take these landings into account depending upon whether catches had been taken in demersal operations using groundfish trawls (e.g., Canada, Spain) or by means of smaller mesh gear

(e.g., USSR, Poland). In the first case, quarterly age distributions were obtained for the USA fishery by applying length frequency samples to commercial landings on a monthly basis, combining the resulting distribution by quarter, and applying the appropriate quarterly age-length keys. The resulting numbers at age were then prorated upwards to include catches by Canada, Spain, the United Kingdom, and Ireland and combined over quarters to provide an annual catch at age distribution for these countries. This procedure is not believed to have resulted in appreciable error as (1) the USA took the bulk of this component of the total catch and (2) catches by other nations were taken in essentially the same areas employing similar mesh size gear. As USA length frequency and age sampling data for the last two quarters of 1975 and throughout 1976 were limited, Canadian sample data were used as well, i.e., for months in which USA length frequencies were unavailable Canadian data (if available) were utilized and vice versa, and for months in which both Canadian and USA samples were available data were applied on a per-country basis. Quarterly age-length keys were then applied and resulting distributions prorated upwards to reflect catches by the remaining countries in this group, as before.

Catches by remaining nations (primarily the USSR, Romania, and Poland) appear to have been taken almost exclusively by smaller mesh gear (e.g., USSR 40 mm herring trawls); this necessitated a somewhat different approach. (Available sample and surveillance data indicate very large catches of age 2 and 3 haddock during 1965 and 1966). The basis for the method used is provided by (1) USSR commercial length frequency samples for catches taken with 40 mm

mesh trawl gear during Spring of 1973, and (2) USA bottom-trawl survey data collected in April of that year. At that time, the 1972 year-class (the strongest observed up to that time since the late 1960's) was passing through the selection range of the 40 mm trawl (ca. 22-28 cm fork length as evidenced by USSR data). A retention curve for the USSR 40 mm mesh trawl relative to the survey gear was calculated from USSR commercial and USA survey length frequencies for Spring of 1973 (Pope et al. 1975); this was then applied to USA spring, summer, and autumn survey length-frequency data to obtain assumed length frequencies for the USSR, Poland, Romania, Bulgaria, Cuba, France, the FRG and GDR and Japan. The resulting distributions were then converted to a per-mille basis and numbers at age generated by applying these length frequencies and USA age-length keys. For 1962, USSR landings were prorated on USA numbers at age as survey data are unavailable. For 1963-1967, length frequencies were generated from USA winter, summer, and autumn survey data as described above and applied as required (however, USSR length frequency samples were available for Quarters 1, 3, and 4 of 1966 and were applied directly to landings for 1965 (Quarter 4) through 1967 (Quarter 1). For 1968-1977, length frequencies were generated from USA spring and autumn survey data; spring length frequencies were applied to landings for Quarters 1 and 2, and autumn length frequencies were applied to landings for Quarters 3 and 4 (with the exception of 1973, where USSR length frequency samples were applied directly). Annual distributions of numbers landed at age were then generated by applying the appropriate quarterly age-length keys and combining over quarters, as before. These were then combined with annual landings at age data for groundfish trawl fisheries to obtain a completed catch-at-age distribution for Georges Bank for 1931-1977 (Table 2).

The data in Table 2 reveal that historically catches have been dominated by age 2-4 fish (81% of the 1931-1961 total in terms of numbers). During this period relative contributions of age 2, 3, and 4 fish were 32%, 31%, and 18%, respectively. Introduction of the 114 mm (4.5 inch) mesh regulation in 1953 had little observable impact upon this distribution, as calculated percentages for 1931-1952 were 31%, 32%, and 17%, respectively, while corresponding values for 1954-1961 were 33%, 29%, and 20%. The latter figures are misleading, however, in that catch of age 2 fish was substantially higher than average during this period due to recruitment of the strong 1952, 1958, and 1959 year-classes at age 2 (Table 2). Short-term losses associated with this increase appear to have been minimal as a weak year-class was recruiting to the fishery when the regulation became effective and the very strong 1952 year-class recruited the following year (Table 2).

The arrival of large distant water fleets resulted in a dramatic change in age composition of the landings; during 1965-1969, landings were dominated by the outstanding 1963 year-class (69% of the total number and 61% of the total weight landed). The age 2 contribution alone totalled 86,800 tons, most of which was taken by USSR vessels. The 1962 year-class was also a strong one and contributed substantially to total landings (Table 2). During the late 1960's recruitment was poor and catch of age 2 and 3 fish was minimal; the fishery during this period was largely supported by the remnant of the 1963 year-class. During 1970-1976 age 2, 3, and 4 fish accounted for 24%, 14%, and 10% of the total landings by number, respectively. In 1977, the strong 1975 year-class recruited to the fishery and accounted for 77% of the total catch by number and 52% of the total catch by weight.

A comparison of the calculated age distributions in terms of weight with reported (observed) tonnages landed is of interest due to the above mentioned inadequacies in the commercial sample data base. Commercial mean weights at age were generated by applying the length-weight equations of Brown and Hennemuth (1971:7) to mean lengths at age calculated by applying USA age-length keys to USA length frequency data (Table 3). Equations for Georges Bank were converted to a live weight (kg) basis, viz.

$$w = 0.000051296\ l^{2.5864}$$ for scrod ($\leq$50.49 cm fork length)

and $$w = 0.000022152\ l^{2.8053}$$ for large (>50.5 cm fork length).

Annual summaries in terms of weight were then obtained by multiplying numbers landed at age by appropriate mean weight at age values for each year (Table 3).

For most years, the ratio of observed to calculated weights was reasonably close (the combined average for the entire data series was 1.00). Discrepancies which did occur were usually most severe for years for which sampling inadequacies existed (e.g., 1966, 1976).

A completed catch at age table is not available for the Gulf of Maine. However, available information indicates that relative year-class strength and landings trends have been essentially similar in recent years, e.g., the 1963 year-class contributed the bulk of the landings from this stock from 1966-1970, while the 1975 year-class dominated landings in 1977; intervening years have been characterized by poor recruitment and declines in total landings as for Georges Bank.

RESEARCH VESSEL SURVEY CATCHES

The Northeast Fisheries Center (NEFC) of the National Marine Fisheries Service (NMFS) has conducted bottom trawl surveys in autumn (since 1963) and spring (since 1968) on Georges Bank and in the Gulf of Maine. A stratified random sampling design has been used in these surveys; thus, the complete area of coverage has been delineated into strata (Figure 5) on the basis of depth, latitude and historical fishing patterns. A standard "36 Yankee" groundfish trawl equipped with a 1.25 cm (0.5 inch) codend liner has been used in all autumn surveys and in all spring surveys from 1968-1972; a modified high-opening "41 Yankee" trawl has been used in spring surveys beginning in 1973. Further details relative to the survey are provided by Grosslein (1969; MS 1969b). Abundance indices for spring and autumn (stratified mean catch per tow in numbers and weight in kilograms) are given for Georges Bank (Strata 13-25, 29 and 30, Figure 5) and the Gulf of Maine (Strata 26-28 and 36-40, Figure 5) in Table 4; indices in terms of weight are also plotted in Figure 6. Stratified mean catch per tow values in numbers at age for Georges Bank and the Gulf of Maine are given in Tables 5 and 6, respectively.

The spring survey index for Georges Bank in terms of weight 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. Since 1975 this index increased steadily to 20.7 kg in 1978. The corresponding autumn survey index declined more or less continually from 64.1 kg in 1964 to 3.7 kg in 1971, increased to 6.5 kg in 1973, and then dropped sharply to 2.6 kg in 1974 before again increasing to an average of 23.4 kg in 1976-1977; however, the 1978 index value was 15.2 kg (Table 4; Figure 6). Trends in spring and autumn survey indices in terms of

numbers have been similar although values have declined since 1976 (Table 4). Thus, available evidence indicates a decline in biomass of over 90% during the 1964-1971 period, and spawning stock (as evidenced by catch per tow of age 3+ haddock in spring and age 2+ haddock in autumn) reached an apparent all-time low during the early 1970's (Tables 5 and 6). These trends are very consistent with those observed from analyses of commercial catch at age data (see below). Increases observed in recent years (Table 4) reflect recruitment and growth of the 1972 and 1975 year-classes.

Trends in abundance indices calculated for the Gulf of Maine are essentially similar to those observed for Georges Bank (Table 4; Figure 6). The spring survey index in terms of weight declined 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 corresponding autumn survey index declined almost continually from 33.6 kg in 1963 to 2.0 kg in 1972, increased to 5.7 kg in 1973, and then declined to 2.2 kg in 1974. Since that year values have increased (Table 4). Again, trends in numbers per tow were similar (Table 4) and the spawning stock declined to minimal levels in the early 1970's as evidenced by catch of age 3+ haddock in spring and age 2+ haddock in autumn (Tables 5 and 6). Stratified mean catch per tow at age data (Tables 5 and 6) for Georges Bank agree with analyses of commercial data (see CURRENT ASSESSMENT) in indicating that the 1962 and 1963 year-classes dominated the Georges Bank haddock population until well into the early 1970's although the 1958 and 1959 year-classes also appear to have been quite strong. The 1962 and 1963 year-classes accounted for over 80% of the total autumn survey catch by number during 1963-1969. Since the mid-1960's only the 1972 and 1975 year-classes appear to have been of any consequence. The 1962 and 1963 year-classes were also

dominant in the Gulf of Maine until the early 1970's (accounting for over 70% of the total autumn survey catch by number from 1963-1969).

In recent years, however, data for these two areas are not as consistent; the 1972 year-class appears to have been very weak in the Gulf of Maine and autumn survey data suggest that the 1976 year-class may have been stronger than the 1975 year-class (Table 6). However, the 1975 year-class dominated Gulf of Maine spring survey catches during 1976 and 1977 (Table 5).

Mortality Estimates

Annual estimates of instantaneous total mortality (Z) calculated from NEFC spring and autumn survey (age 3+) catch at age data (Tables 5 and 6), and pooled estimates for 1973-1977, are given in Table 7. For Georges Bank, estimates calculated from autumn survey data averaged over 1.0 during 1964-1967; assuming an instantaneous natural mortality (M) rate of 0.2 (Hennemuth MS 1969) this implies an instantaneous fishing mortality rate (F) greater than 0.8 for this stock, reflecting high fishing pressure by distant-water fleets. With declining foreign effort, values for subsequent years fluctuated considerably (Table 7) but still appear to have been relatively high for 1973-1977 (pooled estimates for spring and autumn were 0.76 and 0.65, respectively, implying that F for fully recruited ages has approximated 0.5 since 1973). Trends in mortality estimates obtained from survey data agree reasonably well with those obtained by virtual population analysis or VPA (see CURRENT ASSESSMENT, Table 10) although VPA estimates have generally been lower.

For the Gulf of Maine, Z values calculated from autumn survey data were substantially lower during 1964-1967 (averaging approximately 0.5), in

agreement with the observed distribution of fishing effort during this period. Estimates for 1968-1972 are generally higher, apparently reflecting attempts by USA fishermen to sustain previous catch levels in spite of declining recruitment. Pooled estimates for 1973-1977 were lower than for Georges Bank (0.09 and 0.37 for spring and autumn, respectively).

Growth

Evaluation of growth parameters for Georges Bank and Gulf of Maine haddock has been complicated by changes in growth rates associated with pronounced fluctuations in biomass in recent years. Mean lengths at age calculated from NEFC spring and autumn bottom trawl survey data suggest fairly stable growth rates from 1963-1966, followed by a period in which growth rates accelerated rapidly as biomass declined (1967-1972). During 1973-1977 growth rates appear to have stabilized at a higher level (Table 8). Similar trends are evident from examination of commercial mean weight at age data (Table 3).

A total of 2,910 scale samples collected during NEFC spring and autumn bottom trawl surveys on Georges Bank during 1973-1977 was used to evaluate haddock growth. Ages were coded relative to survey scheduling by assuming an April 1 birthdate, e.g., a haddock hatched during any given year was assumed to be 0.6 years old during the following autumn survey (October) and 1.0 years old the following spring (April). The Von Bertalanffy growth equation

$$l_t = l_\infty(1-e^{-k(t-t_o)})$$

where l_t = fork length (cm) at time t, l_∞ = maximum length attained, k = the Brody growth coefficient, and t_o = hypothetical length at time zero was then fitted to the above length at age data using the method of

Tomlinson for unequal sample sizes[4]. The resulting equation was

$$l_t = 73.80\ (1-e^{-0.3763(t+0.0851)})$$

A similar analysis based on 1,249 scale samples for the Gulf of Maine provided the equation

$$l_t = 72.91\ (1-e^{-0.3524(t-0.0446)})$$

Predicted lengths at age indicate a slightly lower growth rate for the Gulf of Maine (Table 9).

The above equations are preliminary but appear to represent reasonable approximations until more definitive work can be completed. The calculated l_∞ value of 73.8 cm for Georges Bank agrees well with that reported by Beverton (1965) for this stock (73 cm) although the k value obtained is considerably higher (0.38 as opposed to 0.28). The latter value was obtained from analysis of commercial data (Hennemuth, pers. comm.) which implies a downward bias in k due to omission of data for younger age groups.

YIELD PER RECRUIT

Currently, USA trawlers engaged in directed fishing operations for haddock, cod, and yellowtail flounder (Limanda ferruginea) are using gear fabricated of synthetic twine (usually polyamide fibers); the current FMP for these species calls for a stretched mesh size of at least 130 mm in the codend. Results of past selectivity experiments with double braided polyamide trawls (Holden 1971:40) provide an average selection factor of 3.4; a very similar value (3.5) has been obtained by Smolowitz (MS 1978) in recent selectivity studies (uncovered codends, alternate haul method). Use of Holden's data provides a mean selection length (l_c) of 44.2 cm; from application of the above growth equations, mean age at recruitment (t_c) is seen to approximate 2.3 years for Georges Bank and 2.7 years for the Gulf of Maine (Table 9). Assuming an April 1, birthdate, t_c would occur in August and December, respectively.

[4]Program TCPC1, Psaropulos, pers. comm.

Yield per recruit isopleths have been calculated for the Georges Bank stock employing the Beverton-Holt model assuming W_∞ = 3,853 g, K = 0.376, t_0 =-0.085, t_r = 1.0 years, t_λ = 18 years, and M = 0.2 (Figure 7), where W_∞ = maximum weight attained, t_r = age at first capture, t_λ = maximum age in the fishery, and K, t_0, and M are defined as before. Yield per recruit curves were also calculated for t_c values of 2.0, 2.5, and 3.0 (Figure 8). Values of F providing maximum yield per recruit (F_{max}) were 0.42, 0.55, and 0.76, respectively; corresponding figures for $F_{0.1}$ were 0.22, 0.26, and 0.33. Calculations have not been performed for the Gulf of Maine but it would appear that as growth rates differ only slightly between the two areas the above results would be generally applicable.

CURRENT ASSESSMENT

Completion of the 1978 assessment and catch and stock size projections for the Georges Bank and Gulf of Maine haddock stocks required (1) an estimate of instantaneous fishing mortality (F) for fully recruited year-classes in 1977, (2) recruitment estimates for the 1975-1978 year-classes, and (3) virtual population analysis or VPA (Gulland 1965) to determine historical trends in F and stock size. As catch at age data for the Gulf of Maine are at present incomplete, an analytical assessment has been performed only for Georges Bank.

Fishing Mortality in 1977

The incidental nature of this fishery in recent years has precluded determination of fishing mortality in 1977 from commercial effort data.

Accordingly, fishing mortality for fully recruited year-classes (age 3+) in 1977 was estimated using a linear relationship between F and effort approximations based on survey data (Anderson et al. MS 1976). An annual "fishing effort index" was determined for 1963-1977 by dividing total catch in weight (age 3+) by autumn bottom trawl survey catch per tow in weight (age 3+). A preliminary VPA was run using F = 0.30 for ages 3 and older for 1977 under the assumption that F for fully recruited year-classes would likely approximate values for recent years as determined by earlier VPA analysis[5]. A linear regression was then run between annual mean weighted F estimates obtained and the above fishing effort index values which predicted an F of 0.264 for 1977. A second VPA was then run using F = 0.264; this was followed by a second linear regression between the revised F estimates obtained and the above fishing effort index values which predicted a 1977 F of 0.232. A final VPA was then run using this estimate of F in 1977; a final linear regression between the revised F estimates obtained and the above fishing effort index values (Figure 9) predicted an F of 0.217, and an F of 0.22 was accepted as the best estimate.

There is some doubt relative to actual catch for fully recruited year-classes in 1977, as high discard of haddock appears to have occurred. This could obviously bias F values obtained by the above techniques downward. Precise data relative to amount and age composition of the discard is not available for 1977, but it is believed that discard which did occur was confined primarily to the recruiting (1975 and 1976) year-classes. In the

[5]Unpublished data on file at NEFC, Woods Hole, MA.

few cases in which market category was noted, scrod haddock were involved; also, interview data indicate that in situations in which both scrod and large haddock were available fishermen would discard the smaller scrod which command a lower price. Accordingly, it is believed that this source of bias was not appreciable and that the F value obtained in this case is realistic. It may also be noted that all data up to and including 1976 values were used in these regressions; however, the fit is reasonably good throughout the observed range and consequently little change would be expected if more recent (1973+) data points had been excluded (Figure 9).

Virtual Population Analysis

A virtual population analysis or VPA was performed on the catch at age data in Table 2 assuming a fully recruited F value of 0.22 in 1977. F values and estimated stock sizes at age appear in Tables 10 and 11, respectively; estimated stock size values in numbers and weight (age 2+) also appear in Figures 10 and 11. Weighted F values for age 3+ fish (by stock size in numbers at age) declined from 0.63 in 1931 to 0.34 in 1934 as effort declined following peak years of heavy exploitation in the late 1920's; F values subsequently averaged 0.42 during the 1935-1960 period, somewhat below F_{max} (= 0.5 for this period; Hennemuth MS 1969). In subsequent years F increased steadily to a peak of 0.77 in 1966 as foreign pressure intensified and then declined more or less continually into the early 1970's coincident with recruitment failure and redirection of effort to other stocks. Age at full recruitment appears to have declined from 4-5 years in the 1930's and 1940's to 3-4 years since the early 1950's.

Stock size estimates (age 2+, Table 10, Figures 10 and 11) increased from 102 million fish or 123,000 tons in 1933-34 to an average of 152 million

fish or 175,000 tons during 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 in the 1950's (particularly the 1958 and 1959 year-classes). Stock abundance declined somewhat in 1962 and 1963 but then increased to 514 million fish (433,000 tons) in 1965 due to recruitment of the strong 1962 and the outstanding 1963 year-classes (the 1963 year-class has been estimated at 371 million fish at age 2, more than twice the size of any other year-class observed in the fishery, Table 11). 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. Recently, abundance has increased dramatically due to recruitment of the strong 1975 year-class. Present data suggest that stock size in terms of numbers and weight increased to above the 1935-1960 average (175 million fish or 189,000 tons at the beginning of 1977). Stock size subsequently declined to 95 million fish (137,000 tons) at the beginning of 1978 (Table 11, Figures 10 and 11).

Trends in spawning stock size (age 3+) have paralleled the above estimates (Table 11), decreasing to a low of 55 million fish or 84,000 tons in 1934 and then increasing to an average of 86 million fish or 125,000 tons from 1935-1960; spawning stock size peaked at 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. Since then, values increased to an average of 13 million fish or 27,000 tons from 1975-1977 and then increased to 84 million fish or 127,000 tons in 1978 coincident with recruitment of the 1975 year-class.

Recruitment

Recruitment has been estimated by linear regressions between stock size estimates at age calculated from VPA and autumn survey catch per tow at age data. The estimate for the 1975 year-class is critical in this assessment, as it now constitutes the bulk of the harvestable biomass (77% of the total catch by number in USA 1977 commercial landings and 91% and 81% of the total catch by number in NEFC 1977 spring and autumn surveys).

The strength of the 1975 year-class was first documented in autumn of that year; Grosslein's (MS 1969) young-of-year index for this year-class was 3.77, which compared favorably with those for several year-classes in the 1950's and was approximately one-third that of the 1963 year-class (371 million fish at age 2). This year-class has dominated subsequent NEFC Georges Bank surveys (Tables 5 and 6) as well as subsequent cooperative surveys between NEFC and foreign nationals. Of the latter, spring surveys by the FRG R/V WALTHER HERWIG and autumn surveys by the USSR R/V BELOGORSK during 1973-1976 have provided the greatest degree of continuity with respect to vessel and gear type and areas surveyed. A summary of stratified mean catch per tow values (numbers) for ages 0-3 for these cruises (Georges Bank) is as follows:

	Season and Nation					
	Spring (FRG)			Autumn (USSR)		
Year/age	1	2	3	0	1	2
1973	3.6	7.2	0.0	1.6	22.8	0.8
1974	4.8	33.6	3.0	3.1	2.8	5.5
1975	8.7	20.3	14.9	217.8	7.0	5.4
1976	147.6	1.1	2.0	1.5	323.5	1.5

Although this time series is limited it does contain data for the 1972 year-class - the only other one of any consequence in the fishery since the late 1960's (11 million fish at age 2, Table 11). Both sets of data suggest the 1975 year-class to be at least one order of magnitude larger than the 1972 year-class. Consequently, preliminary indications from available survey data sources suggest this year class to be a strong one (>100 million fish at age 2).

The size of the 1975 year-class at age 2 was estimated to be 165 million fish based on a linear regression between stock size at age 2 (millions) from VPA (Table 11) and autumn survey catch-per-tow data for ages 0 + 1 (Table 6). See Figure 12. However, autumn survey catch per tow in numbers for this year-class increased sharply from 15.8 in 1975 to 43.1 in 1976 and has since declined continually (Table 6). This appears to suggest (1) incomplete recruitment to the survey gear at age 0, (2) a high survey catch at age 1 relative to the actual size of the year-class (but within the normal range of variability of survey data) or (3) heavy discard of juvenile haddock during 1977. For the purposes of the current assessment, it would appear reasonable to estimate the strength of this year-class at age 3 independently, recognizing that a projection from the above age 2 estimate may not be very meaningful in view of limited discard data available for 1977.

An estimate of 77 million fish at age 3 has been obtained for this year-class based on a linear regression between stock size at age 3 from VPA (Table 11) and NEFC autumn survey catch-per-tow at age data (ages 0, 1, and 2, Table 6 and Figure 13). An alternative estimate can be obtained by developing a relationship between stock size (millions, age 2+) and the NEFC autumn survey index (numbers, age 1+) and applying the percentage age

distribution observed in the 1977 autumn survey to the predicted 1978 stock size value (Figure 14). This procedure provided an estimate of 72 million fish at age 3. Consequently, it appears that the 1975 year-class had been reduced to somewhere in the order of 75 million fish by the beginning of 1978.

Note that the fishing mortality rate at age 2 in 1977 (Table 10) is not compatible with the rate of decline of the 1975 year-class as reported in Table 11. As indicated above, this reflects either discards (or unreported catch) and/or an overestimate of the size of the year-class in 1977 possibly combined with an underestimate in 1978. Fortunately, the current assessment is not dependent on the 1977 estimate of F at age 2.

The 1976 and 1977 year-classes both appear substantially weaker than the 1975 year-class. Estimates of 10 million and 2 million fish, respectively, were obtained previously for these year-classes based on Grosslein's index (Clark and Palmer MS 1978); similarly, the above regression between stock size estimates at age 2 calculated from VPA and autumn survey catch-per-tow at age 0 + 1 (Figure 12) provided estimates of 11 million fish and <0.5 million fish, respectively. Accordingly, age 2 estimates of 11 million fish and 1 million fish, respectively, appear reasonable for these year-classes.

At present there is no available information concerning the size of the 1978 year-class other than that provided by the NEFC 1978 autumn bottom trawl survey; however, these data do indicate this year-class to be a fairly strong one. A linear regression between stock size at age 2 and autumn survey catch-per-tow at age 0 (Figure 15) provides an estimate of 71 million fish at age 2. Thus the 1978 year-class appears stronger than the 1935-1960 average (65 million fish at age 2, Table 11) and could augment spawning stock size in 1981 if not subjected to heavy fishing mortality in 1979 and 1980.

Gulf of Maine

To date, an analytical assessment has not been completed for the Gulf of Maine, and current evaluations have been based primarily on research vessel survey catches and examination of commercial landings trends. As noted above, trends in both sets of data have been very similar between the two areas, declining to very low levels in the early 1970's and then increasing in response to improved recruitment. The NEFC spring survey catch per tow index (weight) has increased steadily from 0.7 kg in 1974 to 4.5 kg in 1977, while the corresponding autumn survey index increased from 2.2 to 7.3 kg during the same period and then rose to 18.2 kg in 1978. It is uncertain whether the latter increase is real; catches of several year-classes increased (Table 6), but the 1976 year-class also appears to be relatively stronger in the Gulf of Maine than on Georges Bank (Tables 5 and 6). The 1977 year-class appears to be very weak in both areas (Tables 5 and 6).

Commercial landings for the Gulf of Maine increased from 600 tons in 1973 to 4,400 tons in 1978, the highest total observed since 1967 (Table 1). The 1975 year-class dominated landings in 1977 as well as during the first two quarters of 1978; sample data for the latter part of 1978 should provide an additional basis for evaluation of the relative strength of the 1976 year-class.

Clark and Palmer (MS 1978) prepared catch and stock size projections for the combined Georges Bank - Gulf of Maine area by increasing figures for Georges Bank by one-third, i.e., the ratio between reported USA-Canadian landings for 1972-1976. This ratio changed somewhat when final statistics for 1976 became available (Table 1). However, minimum biomass estimates (tons) calculated from NEFC autumn survey data (averaged over 1963-1977) also indicate an approximate 3-1 ratio (Table 12). In view of the similarity between trends in abundance and recruitment between these areas, it would appear appropriate to set future OY levels for the Gulf of Maine based upon the above minimum biomass ratio, e.g., at one-third of the Georges Bank figure. Obviously, this rationale assumes that resulting exploitation rates would be comparable.

Implications of Current Assessment

Herrington (1948) obtained a dome-shaped stock-recruitment relation for Georges Bank haddock based on data for 1914-1940. Earlier (1914-1930) data used in these analyses appears to have been suspect, however Grosslein (MS 1966), and subsequent analyses based on more recent (1931+) data have been inconclusive (Hennemuth MS 1969; Cushing 1973; Grosslein and Hennemuth 1973). Nevertheless, the latter authors noted a tendency for reduced recruitment at lower levels of stock abundance, which has been corroborated by the fact that since 1965 only one year-class larger than the 1935-1960 average has appeared. (During 1935-1966 year-classes of above average size appeared on an average of every third year.) Consequently, it has been inferred that a stock-recruitment relationship must in fact exist, particularly at low levels of abundance, although it could readily be obscured by environmental influences (Sissenwine et al. in press). In turn, maintenance of spawning stock biomass above some minimal level may enhance the potential for a return to pre-1960 conditions associated with higher and more constant recruitment. It is difficult to quantify this level in view of uncertainty relative to the stock-recruitment relationship and present age composition of the population (dominated by the 1975 year-class); however, maintenance of spawning stock biomass as close as possible to the 1935-1960 average of 125,000 tons would appear desirable.

Results of the present assessment indicate that in 1977 the Georges Bank stock (age 2+) increased to above the 1935-1960 average of 152 million

fish or 175,000 tons. Subsequently, stock size declined to 95 million fish or 137,000 tons in 1978 due to fishing and natural mortality and poor recruitment from the 1976 year-class. Some of this decline may only reflect variability in estimated strength of the 1975 year-class. The 1977 year-class appears to be weaker still, implying the potential for continued declines in abundance during 1979. Spawning stock size (age 3+) increased sharply to 84 million fish or 127,000 tons in 1978, but projections for 1979 (discussed below) suggest a decline to as low as 53 million fish or 108,000 tons and a continued decline can be anticipated through 1980. Commercial landings and spawning stock biomass will be dominated by the 1975 year-class during 1979-1980.

Previous analyses (Clark and Palmer MS 1978) indicated the potential for very low levels of mortality in 1977 (0.04-0.16 depending upon recruitment options assumed). That actual fishing mortality levels may have been significantly in excess of these figures appears evident from the decline in estimated size of the 1975 year-class in 1977. The reported catch for this stock in 1977 was 8 million fish, but discard (and/or misreporting) may have been several times in excess of reported catch levels. Industry sources have confirmed that large quantities were routinely discarded during the latter part of 1977 in operations directed towards other species, e.g., cod and yellowtail. A high discard potential also existed during 1978, as mortality levels associated with 1978 OY values were considerably below the potential of the present groundfish fleet and effort required to harvest the cod OY should have been considerably greater than that required to harvest the haddock OY[6].

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[6] NEFC 1978. Biological aspects of optimum yield for Georges Bank haddock (unpublished), 11 p.

In view of uncertainty relative to total catch levels in 1977, stock size for Georges Bank (age 2+) for 1978 has been estimated by a linear regression between stock size (millions, age 2+) and the NEFC autumn survey index (numbers, age 1+). A 1978 stock size estimate (age 2+) of 89 million fish was obtained (Figure 14) which was then apportioned by age group according to the observed percentage age composition in the Autumn 1977 survey. A corresponding weight estimate of 131,500 tons was then obtained by applying mean weight at age data observed in 1977 commercial landings. These estimates differed little from 1978 estimates obtained from combining the above year-class size estimates for the 1975 year-class at age 3 and the 1976 year-class at age 2 with stock size estimates for older ages projected from the above VPA (95 million fish or 137,000 tons, Table 11). Accordingly, 1978 estimates generated from survey data have been used as the basis for catch and stock size projections for 1979-1981.

Available data for 1978 indicate a reported Georges Bank catch in the order of 21,000 tons, assuming USA landings of 12,100 tons and Canadian landings of 8,900 tons (see COMMERCIAL FISHERY). Again, amount discarded by USA vessels is unknown, but it appears reasonable to suppose that discard (and/or misreporting) could have been at least equivalent to reported USA landings. The projected stock size estimate (numbers, age 2+) for 1979 under this assumption (implying a total 1978 catch including discards of 33,200 tons) is 54 million fish very close to the 1979 estimate of 51 million fish predicted from the above regression.

Catch projections for 1979 and spawning stock size (age 3+) projections for 1980 have been calculated under two assumptions of unreported or discarded US catch for 1978 (50% and 100% of the reported USA total) for varying levels of F in 1979 (Table 13). Under these assumptions, spawning stock size at the beginning of 1979 was 56 million fish or 115,300 tons and 53 million fish or 107,800 tons, respectively; fishing at or about the July 23, 1978, OY level of 14,900 tons in 1979 would result in a 10-11% decline in spawning stock size for 1980 (Table 13). Assuming recruitment of 71 million fish at age 2 and the same level of fishing mortality in 1980, spawning stock size (age 3+) would again increase to above the 1935-1960 average in 1981. However, spawning stock size in 1980 declines rather sharply as F increases under both assumptions of unreported or discarded catch (Table 13) due to anticipated poor recruitment from the 1976 and 1977 year-classes.

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Table 1. Commercial landings[1] of haddock (metric tons, live) from Georges Bank and the Gulf of Maine by country, 1956-1978.

Year	Country								
	Canada	Poland	Romania	Spain	UK	USSR	USA	Other[2]	Total
				Georges Bank					
1956							51,144		51,144
1957							48,561		48,561
1958							37,322		37,322
1959							36,051		36,051
1960	77						40,800		40,877
1961	266						46,384		46,650
1962	3,461					1,134	49,409		54,004
1963	8,379					2,317	44,150		54,846
1964	11,625			2	464	5,483	46,512		64,086
1965	14,889	28	730	10		81,882	52,823		150,362
1966	18,292	29	449	1,111	29	48,409	52,918	37	121,274
1967	13,040		12	1,355	3	2,316	34,728	15	51,469
1968	9,323	1,286	402	3,014		1,397	25,469	32	40,923
1969	3,990	458	66	1,201		65	16,456	16	22,252
1970	1,978	15		782		103	8,415	7	11,300
1971	1,630	1	225	1,310		374	7,306	16	10,862
1972	609	1	14	1,098		137	3,869	5	5,733
1973	1,563			386		602	2,777	3	5,331
1974	462			764	559	109	2,396		4,290
1975	1,358			61		8	3,989	4	5,420
1976	1,361			46		4	2,904	9	4,324
1977[3]	2,873						7,935		10,808
1978[4]	8,897						12,137		21,034

Table 1 (cont.)

Year	Country								
	Canada	Poland	Romania	Spain	UK	USSR	USA	Other[2]	Total
					Gulf of Maine				
1956	29						7,278		7,307
1957	25						6,141		6,166
1958	285						7,082		7,367
1959	163						4,497		4,660
1960	383						4,541		4,924
1961	112						5,297		5,409
1962	107						5,003		5,110
1963	3					44	4,742		4,789
1964	70						5,383		5,453
1965	159						4,204		4,363
1966	1,125						4,579		5,704
1967	589						4,907		5,496
1968	120						3,437		3,557
1969	59			230			2,423	1	2,713
1970	38			63			1,457	4	1,562
1971	85			26			1,194	1	1,306
1972	23					4	909		936
1973	49						509		558
1974	198				9		622		829
1975	79			4			1,180		1,263
1976	91						1,865		1,956
1977[3]	16						3,297		3,313
1978[4]							4,373		4,373

Table 1 (cont.)

Year	Country								
	Canada	Poland	Romania	Spain	UK	USSR	USA	Other[2]	Total
					Total				
1956	29						58,422		58,451
1957	25						54,702		54,727
1958	285						44,404		44,689
1959	163						40,548		40,711
1960	460						45,341		45,801
1961	378						51,681		52,059
1962	3,568					1,134	54,412		59,114
1963	8,382					2,361	48,892		59,635
1964	11,695			2	464	5,483	51,895		69,539
1965	15,048	28	730	10		81,882	57,027		154,725
1966	19,417	29	449	1,111	29	48,409	57,497	37	126,978
1967	13,629		12	1,355	3	2,316	39,635	15	56,965
1968	9,443	1,286	402	3,014		1,397	28,906	32	44,480
1969	4,049	458	66	1,431		65	18,879	17	24,965
1970	2,016	15		845		103	9,872	11	12,862
1971	1,715	1	225	1,336		374	8,500	17	12,168
1972	632	1	14	1,098		141	4,778	5	6,669
1973	1,612			386		602	3,286	3	5,889
1974	660			764	568	109	3,018		5,119
1975	1,437			65		8	5,169	4	6,683
1976	1,452			46	4		4,769	9	6,280
1977[3]	2,870						11,139		14,009
1978[4]	8,897						16,510		25,407

[1]As reported to ICNAF for Divisions 5Y and 5Z, respectively (5NK landings assigned to 5Z).
[2]Includes landings for Bulgaria, Cuba, France, FRG, GDR, Ireland, and Japan.
[3]Provisional ICNAF statistics for 1977 (incomplete).
[4]Preliminary.

Table 2. Landings at age (000's) for Georges Bank[1] haddock, 1931-1977.

Year	Age 1	2	3	4	5	6	7	8	9+	Total no.	Observed[2] weight	Calculated[3] weight	Obs/ calc
1931	1,755	8,801	2,041	5,705	9,100	6,045	3,380	1,794	559	39,131	59,486	59,234	1.00
1932	118	2,004	25,871	2,421	3,676	2,894	1,320	664	391	39,480	54,512	52,762	1.03
1933	244	8,476	6,023	10,046	2,092	1,579	1,210	538	647	30,875	42,215	40,281	1.05
1934	341	4,454	5,414	3,734	3,149	1,051	619	250	168	19,229	25,795	25,151	1.03
1935	1,197	11,872	8,819	3,706	2,944	2,458	499	442	109	32,075	40,944	39,815	1.05
1936	880	12,327	11,486	5,431	2,141	1,377	1,362	259	124	35,387	43,445	42,381	1.03
1937	1,288	11,034	10,910	5,629	4,143	1,875	952	481	222	36,534	49,359	48,081	1.03
1938	1,030	20,199	7,755	3,755	2,113	1,600	945	327	173	37,897	47,773	44,341	1.08
1939	607	13,937	19,617	6,163	2,152	967	837	326	239	43,845	54,054	52,841	1.02
1940	2,040	7,254	12,317	8,253	2,510	1,479	752	222	136	34,963	47,906	47,417	1.01
1941	780	23,464	9,808	8,033	6,764	1,781	941	307	384	42,262	62,944	62,198	1.01
1942	310	14,307	16,348	6,531	3,996	2,331	1,036	227	176	46,262	55,376	56,147	0.99
1943	19	4,191	17,738	8,364	3,102	2,693	790	354	178	37,429	46,323	48,555	0.95
1944	64	761	8,437	14,843	6,689	2,281	497	469	108	33,149	49,637	49,439	1.00
1945	121	8,522	2,029	6,386	5,795	2,315	914	265	205	26,552	40,473	39,187	1.03
1946	209	7,466	15,213	2,738	5,785	3,840	1,827	272	23	37,373	53,719	51,696	1.04
1947	90	16,621	10,334	7,181	2,127	2,739	1,501	745	457	41,795	54,431	53,121	1.02
1948	80	11,227	19,237	5,116	2,744	1,157	780	450	369	41,160	48,360	48,329	1.00
1949	328	6,472	12,479	9,608	2,347	1,061	624	409	353	33,681	42,254	42,934	0.98
1950	88	28,971	4,107	4,272	3,315	1,131	520	225	250	42,879	41,273	40,673	1.01
1951	645	8,266	26,472	2,177	2,448	2,138	740	297	215	43,398	47,318	46,977	1.01
1952	-[4]	25,120	8,892	8,485	1,361	944	530	182	107	45,621	43,252	42,289	1.02
1953	1,083	1,807	17,588	5,726	3,757	1,012	542	337	152	32,004	35,926	35,992	1.00
1954	108	31,858	5,107	5,611	2,315	2,131	720	353	98	48,301	46,388	46,314	1.00
1955	90	3,941	19,251	3,316	3,278	1,649	1,068	320	173	33,086	40,851	40,192	1.02
1956	52	11,948	6,698	12,066	3,405	3,378	1,348	563	201	39,659	51,144	49,010	1.04
1957	35	6,594	14,046	4,523	5,822	2,357	1,630	473	366	35,846	48,561	47,177	1.03
1958	125	5,571	7,088	6,665	3,784	2,366	903	442	142	27,086	37,322	36,809	1.01
1959	94	5,716	7,994	5,169	3,934	1,758	1,172	427	334	26,598	36,051	36,684	0.98
1960	258	16,543	6,253	4,636	3,106	1,806	792	406	336	34,136	40,877	42,299	0.97
1961	67	10,667	14,916	4,195	2,915	1,854	1,265	496	661	37,036	46,650	45,931	1.02
1962	74	4,393	16,236	10,434	3,446	2,088	1,565	1,184	821	40,241	54,004	53,688	1.01
1963	2,910	4,046	7,418	11,152	8,198	2,205	1,405	991	1,076	39,401	54,846	58,071	0.94
1964	10,097	15,915	4,554	4,776	8,722	5,794	2,082	1,029	1,251	54,220	64,086	68,465	0.94
1965	9,601	125,805	22,142	5,356	4,391	6,690	3,772	1,094	1,313	180,164	150,362	160,375	0.94
1966	114	6,843	100,808	19,167	2,768	2,591	2,332	1,269	727	136,619	121,274	141,965	0.85
1967	1,151	168	2,883	20,669	8,731	1,209	993	917	663	37,384	51,469	50,974	1.01
1968	8	2,989	708	1,919	14,514	3,498	677	453	807	25,573	40,923	41,139	0.99
1969	2	9	1,696	448	653	5,949	1,572	225	513	11,067	22,252	21,958	1.01
1970	46	119	20	723	229	256	2,721	806	550	5,550	11,300	13,401	0.84
1971	-[4]	1,369	224	40	289	246	285	1,469	914	4,836	10,862	10,802	1.01
1972	155	2	447	82	32	120	77	66	1,229	2,210	5,733	5,723	1.00
1973	2,555	1,712	-[4]	318	44	26	70	15	327	5,067	5,331	5,421	0.98
1974	45	1,764	626	2	60	2	2	51	221	2,773	4,290	4,007	1.07
1975	203	1,125	1,673	454	4	45	4	4	87	3,599	5,420	5,520	0.98
1976	93	202	735	923	369	28	45	2	85	2,482	4,324	5,388	0.80
1977	-[4]	6,081	193	670	498	339	4	38	107	7,930	10,808	10,068	1.07

[1]ICNAF Div. 5Z.
[2]Data for 1931-1955 reported in terms of "biological" year, i.e., February-January (Hennemuth 1969); data for 1956-1977 as reported to ICNAF on a calendar year basis.
[3]Obtained by multiplying numbers at age by mean weight at age data in Table 3.
[4]Less than 0.5.

Table 3. Mean weights at age for Georges Bank haddock (kg, live)[1] as observed in USA commercial landings, 1931-1977.

Year	Age 1	2	3	4	5	6	7	8	9+
1931	0.52	0.78	1.11	1.40	1.66	1.96	2.36	2.49	3.03
1932	0.58	0.66	1.05	1.77	1.89	2.17	2.72	2.83	3.05
1933	0.52	0.75	1.14	1.34	1.73	2.30	2.46	2.55	2.89
1934	0.44	0.69	1.09	1.44	1.72	2.25	2.58	2.91	3.24
1935	0.48	0.78	1.13	1.56	1.81	2.10	2.51	2.71	3.60
1936	0.39	0.73	1.18	1.53	1.82	2.17	2.33	2.75	3.27
1937	0.35	0.83	1.19	1.56	1.90	2.15	2.75	2.95	3.46
1938	0.54	0.79	1.26	1.67	2.03	2.20	2.54	2.91	3.61
1939	0.58	0.77	1.16	1.61	1.93	2.47	2.79	3.04	3.44
1940	0.52	0.85	1.23	1.62	1.83	2.40	3.10	3.04	3.84
1941	0.35	0.75	1.21	1.57	1.89	2.34	2.73	2.98	3.39
1942	0.50	0.77	1.18	1.48	1.78	2.08	2.65	3.13	3.42
1943	0.51	0.66	1.04	1.51	1.84	1.97	2.43	3.24	3.50
1944	0.62	0.76	1.06	1.40	1.89	2.30	2.52	3.04	3.90
1945	0.56	0.80	1.16	1.51	1.89	2.32	2.68	3.20	3.34
1946	0.53	0.68	1.15	1.55	1.81	2.17	2.63	3.88	4.58
1947	0.45	0.71	1.11	1.60	1.98	2.31	2.69	3.00	3.30
1948	0.49	0.79	0.99	1.51	1.93	2.32	2.60	3.06	3.43
1949	0.56	0.72	1.00	1.47	1.96	2.43	2.72	3.28	3.60
1950	0.42	0.67	1.03	1.33	1.79	2.23	2.55	3.13	3.31
1951	0.54	0.70	0.95	1.36	1.77	2.26	2.65	2.95	3.40
1952	0.55	0.67	0.91	1.26	1.68	2.20	2.60	3.09	3.48
1953	0.56	0.65	0.94	1.19	1.60	1.97	2.40	3.01	3.58
1954	0.54	0.79	0.85	1.23	1.48	1.78	2.14	2.26	2.93
1955	0.60	0.82	1.05	1.26	1.67	1.97	2.30	2.58	2.95
1956	0.69	0.80	1.03	1.27	1.60	1.97	2.22	2.62	3.10
1957	0.57	0.84	1.03	1.36	1.72	2.05	2.36	2.58	2.97
1958	0.54	0.80	1.10	1.35	1.73	2.10	2.50	2.87	3.16
1959	0.53	0.81	1.08	1.42	1.75	2.13	2.43	2.88	3.19
1960	0.56	0.84	1.14	1.53	1.79	2.27	2.57	3.03	3.31
1961	0.95	0.80	1.06	1.44	1.72	2.13	2.47	2.66	3.14
1962	0.53	0.79	1.03	1.34	1.68	2.06	2.43	2.57	3.09
1963	0.68	0.87	1.13	1.43	1.67	2.13	2.51	2.89	3.22
1964	0.49	0.80	1.11	1.44	1.70	2.07	2.48	2.76	3.22
1965	0.59	0.69	1.02	1.40	1.72	2.10	2.37	2.80	3.23
1966	0.59	0.63	0.90	1.28	1.81	2.19	2.42	2.91	3.17
1967	0.69	0.65	0.96	1.19	1.51	2.12	2.32	2.75	3.22
1968	0.59	0.89	1.11	1.34	1.55	1.99	2.49	2.82	3.34
1969	0.49	0.79	1.37	1.63	1.89	1.93	2.41	2.79	3.44[2]
1970	0.70	1.02	1.12	1.78	1.92	2.09	2.30	2.83	3.34[2]
1971	0.67	0.94	1.17	1.55	2.17	2.49	2.69	2.80	3.36[2]
1972	0.62	1.12	1.62	1.75	2.12	2.78	2.69	2.88	3.22[2]
1973	0.60	0.98	1.48	2.10	2.45	2.54	3.00	3.57	3.38[2]
1974	0.71	0.98	1.64	2.18	2.78	3.26	3.67	3.43	3.89[2]
1975	0.64	1.00	1.61	2.25	2.88	3.10	3.81	3.78	4.24[2]
1976	0.52	1.26	1.65	2.33	2.98	3.17	3.36	4.26	4.40[2]
1977	0.52	0.92	1.39	1.98	2.53	2.93	3.58	3.69	4.41[2]

[1]Obtained by applying length-weight equations of Brown and Hennemuth (1971:7), converted to live weight (kg), viz. $w = 0.000051296\ l^{2.5864}$ for scrod ($\leq$50.49 cm fork length) and $w = 0.000022152\ l^{2.8053}$ for large (>50.5 cm fork length).

[2]Weighted by landings at age (numbers) over ages 9-12.

Table 4. 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), 1963-1978.

Year	Georges Bank				Gulf of Maine			
	Spring[1]		Autumn		Spring[1]		Autumn	
	Nos.	Wt (kg)	Nos.	Wt (kg)	Nos.	Wt (kg)	Nos.	Wt (kg)
1963	-	-	97.32	52.83	-	-	46.65	33.57
1964	-	-	129.69	64.07	-	-	9.51	12.47
1965	-	-	68.25	48.20	-	-	11.69	11.72
1966	-	-	22.32	19.78	-	-	7.81	9.18
1967	-	-	11.88	16.87	-	-	8.17	11.16
1968	15.54	23.13	5.04	10.20	6.99	9.17	5.75	11.42
1969	8.23	19.05	2.27	5.59	4.30	8.30	3.64	8.51
1970	6.85	19.28	5.17	8.94	1.04	1.94	1.97	4.87
1971	3.20	5.62	2.82	3.70	1.00	2.84	1.94	5.39
1972	7.29	8.30	7.62	5.61	0.97	0.98	1.34	2.01
1973	25.25	10.18	9.99	6.48	0.89	1.06	2.80	5.68
1974	12.76	11.72	2.72	2.64	0.97	0.70	1.80	2.21
1975	4.19	5.44	20.77	10.00	1.86	2.30	3.72	5.71
1976	55.83	10.41	47.70	23.68	5.59	4.21	4.04	5.32
1977	24.74	17.60	19.03	23.13	4.56	4.45	6.78	7.34
1978	13.03	20.71	20.70	15.18	0.91	0.95	8.00	18.16

[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 5. 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), 1968-1978.[1]

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12+	Totals 1+	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
							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

[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 6. 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), 1963-1978.[1]

Year	Age 0	1	2	3	4	5	6	7	8	9	10	11	12+	Totals 0+	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[1]	11.21	0.31	1.30	7.38	0.08	0.23	0.15	0.03	0.00	0.00	0.00	0.00	0.01	20.70	9.49	9.18
							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[1]	0.14	0.02	1.57	4.41	0.44	0.63	0.13	0.00	0.00	0.00	0.00	0.00	0.66	8.00	3.24	3.21

[1]Preliminary.

Table 7. Total mortality coefficients (Z) for haddock calculated from NEFC spring and autumn bottom trawl survey catch-at-age data, Georges Bank (Strata 13-25, 29, and 30) and Gulf of Maine (Strata 26-28 and 36-40), 1963-1978.

Year	Georges Bank		Gulf of Maine	
	Spring[1]	Autumn[1]	Spring[1]	Autumn[1]
1963	-	1.14	-	1.17
1964	-	1.24	-	0.57
1965	-	1.04	-	0.86
1966	-	0.89	-	0.04
1967	-	0.52	-	0.34
1968	0.47	0.87	0.50	0.46
1969	0.34	-0.11	1.42	0.63
1970	1.31	0.87	0.05	0.12
1971	-0.10	-0.07	1.16	1.20
1972	-[2]	0.69	-[2]	-0.95
1973	1.06	1.48	1.10	1.76
1974	1.27	-0.83	-0.33	-0.90
1975	1.06	1.39	-0.46	0.68
1976	-0.14	0.00	0.29	0.31
1977				
Pooled[3] average	0.76	0.65	0.09	0.37

[1]Calculated as $\ln\left(\frac{\Sigma \text{ ages 3 and older in year } i}{\Sigma \text{ ages 4 and older in year } i+1}\right)$.

[2]Not calculated due to gear conversion in 1973.

[3]Calculated as $\ln\left(\frac{\Sigma \text{ ages 3 and older 1973-1976}}{\Sigma \text{ ages 4 and older 1974-1977}}\right)$.

Table 8. Mean lengths at age (fork length, cm) for Georges Bank haddock calculated from NEFC spring and autumn bottom trawl survey data, 1963-1977.

Year	Age 1	2	3	4	5	6	7	8	9	10	11	12+[1]
Spring												
1968	23.65	38.64	45.07	48.85	50.70	57.19	64.29	63.67	72.82	-	-	-
1969	-[2]	32.50	51.10	52.30	54.20	57.35	60.07	68.78	70.63	71.57	69.42	66.88
1970	21.98	29.61	-	52.97	58.55	58.21	61.11	67.32	68.98	70.31	74.08	78.50
1971	-	37.91	44.67	-	64.50	61.67	60.73	62.09	64.14	66.78	-	72.50
1972	22.36	28.09	50.23	55.74	55.64	61.27	67.50	60.98	67.30	67.33	71.35	77.07
1973	25.47	37.91	-	56.46	59.42	-	64.77	72.50	-	68.81	70.14	77.54
1974	21.04	40.96	49.60	-	62.94	-	62.50	72.38	-	-	72.06	75.24
1975	26.17	39.19	50.29	54.57	-	64.69	66.29	70.50	-	-	62.50	73.61
1976	23.15	40.68	49.84	58.59	62.96	-	67.93	-	-	-	66.50	78.39
1977	21.97	37.97	50.21	56.32	59.77	65.73	-	76.50	-	-	-	74.45
Autumn												
1963	33.57	40.17	50.49	55.00	59.38	64.54	64.83	69.01	69.82	65.74	78.50	76.50
1964	28.90	35.46	47.08	55.27	56.42	62.78	65.67	68.07	72.80	-	-	-
1965	30.58	38.02	43.89	52.29	56.40	63.02	65.99	71.92	69.81	-	-	-
1966	27.56	37.92	43.33	49.64	53.14	61.23	68.90	70.34	71.24		-	-
1967	37.15	42.92	50.71	51.77	55.90	65.07	69.34	72.00	71.09	-	-	-
1968	28.50	46.37	49.64	53.03	57.81	61.93	67.27	67.61	71.82	-	-	-
1969	-[2]	-	54.92	56.35	59.49	60.68	62.75	63.82	67.39	66.74	-	81.70
1970	37.86	47.82	52.50	58.21	57.33	61.02	62.51	67.60	71.89	72.50	70.22	81.49
1971	-	50.83	53.43	62.50	62.00	58.50	65.90	66.88	70.31	64.50	65.16	72.50
1972	33.37	-	57.12	61.19	-	59.78	68.84	64.23	68.13	72.61	72.13	69.34
1973	34.83	48.55	-	61.52	69.01	-	71.02	75.22	68.50	70.03	73.42	76.84
1974	32.13	48.61	55.12	-	64.03	-	-	-	76.50	-	76.82	80.50
1975	35.51	46.09	55.09	59.91	-	76.50	-	74.50	74.50	-	-	69.14
1976	34.76	45.83	50.17	61.82	65.12	-	77.05	73.26	77.05	-	-	71.34
1977	33.26	45.11	56.04	61.53	65.36	67.98	81.85	76.50	-	-	-	79.01

[1]Weighted by catch at age (numbers) over ages 12-14.

[2]Omitted due to inadequate sample size.

Table 9. Predicted lengths at age for Georges Bank and Gulf of Maine haddock obtained from fitting the von Bertalanffy growth equation to length at age data collected during NEFC spring and autumn bottom trawl surveys, 1973-1977.

Age	Fork length (cm)	
	Georges Bank[1]	Gulf of Maine[2]
1	24.74	20.84
2	40.12	36.31
3	50.68	47.18
4	57.93	54.82
5	62.90	60.20
6	66.32	63.97
7	68.66	66.63
8	70.27	68.50
9	71.38	69.81
10	72.14	70.73
11	72.66	71.38
12	73.01	71.84
13	73.26	72.16
14	73.43	72.38

[1]Obtained from the equation $l_t = 73.80\left(1-e^{-0.3763(t+0.0851)}\right)$.

[2]Obtained from the equation $l_t = 72.91\left(1-e^{-0.3524(t-0.0446)}\right)$.

Table 10. Instantaneous fishing mortality rates (F) for Georges Bank[1] haddock obtained from virtual population analysis assuming M = 0.2, 1931-1977.

Year	Age 1	2	3	4	5	6	7	8	9+	Wtd F[2] Age 3+
1931	0.048	0.127	0.163	0.462	0.870	1.001	0.694	0.993	0.626	0.626
1932	0.003	0.073	0.661	0.297	0.607	0.775	0.620	0.277	0.607	0.607
1933	0.005	0.288	0.311	0.588	0.452	0.576	0.908	0.558	0.476	0.476
1934	0.006	0.114	0.302	0.323	0.368	0.431	0.468	0.471	0.337	0.337
1935	0.022	0.305	0.344	0.349	0.457	0.549	0.376	0.730	0.387	0.387
1936	0.017	0.330	0.544	0.369	0.349	0.402	0.682	0.341	0.462	0.462
1937	0.013	0.306	0.546	0.566	0.535	0.588	0.540	0.549	0.552	0.552
1938	0.015	0.298	0.367	0.366	0.430	0.407	0.676	0.359	0.389	0.389
1939	0.011	0.284	0.527	0.446	0.370	0.358	0.388	0.525	0.485	0.485
1940	0.020	0.168	0.436	0.442	0.406	0.471	0.524	0.167	0.434	0.434
1941	0.007	0.337	0.357	0.569	0.639	0.567	0.627	0.422	0.482	0.482
1942	0.005	0.183	0.416	0.429	0.626	0.584	0.777	0.299	0.458	0.458
1943	0.001	0.094	0.361	0.389	0.373	1.237	0.399	0.676	0.405	0.405
1944	0.001	0.043	0.276	0.585	0.502	0.519	0.809	0.440	0.448	0.448
1945	0.003	0.193	0.154	0.348	0.478	0.392	0.405	1.617	0.350	0.350
1946	0.002	0.277	0.616	0.321	0.613	0.682	0.619	0.201	0.571	0.571
1947	0.002	0.274	0.597	0.575	0.443	0.672	0.629	0.557	0.606	0.606
1948	0.003	0.291	0.587	0.688	0.598	0.462	0.407	0.389	0.599	0.599
1949	0.003	0.294	0.608	0.667	0.541	0.490	0.489	0.388	0.605	0.605
1950	0.002	0.361	0.308	0.433	0.512	0.829	0.475	0.327	0.437	0.437
1951	0.006	0.211	0.658	0.266	0.476	0.745	0.499	0.552	0.596	0.596
1952	-[3]	0.368	0.368	0.455	0.265	0.339	0.410	0.695	0.393	0.393
1953	0.008	0.051	0.478	0.429	0.374	0.326	0.333	0.500	0.443	0.443
1954	0.002	0.350	0.198	0.274	0.308	0.378	0.402	0.376	0.263	0.263
1955	0.001	0.086	0.370	0.191	0.255	0.376	0.330	0.314	0.320	0.320
1956	0.001	0.174	0.205	0.420	0.306	0.453	0.606	0.290	0.332	0.332
1957	0.001	0.121	0.318	0.207	0.367	0.360	0.412	0.444	0.311	0.311
1958	0.002	0.107	0.185	0.245	0.268	0.250	0.227	0.186	0.230	0.230
1959	0.001	0.134	0.221	0.200	0.223	0.192	0.188	0.160	0.209	0.209
1960	0.002	0.181	0.213	0.193	0.177	0.151	0.124	0.092	0.182	0.182
1961	0.001	0.120	0.246	0.217	0.178	0.152	0.150	0.107	0.212	0.212
1962	0.002	0.109	0.269	0.272	0.278	0.187	0.186	0.205	0.257	0.257
1963	0.022	0.141	0.271	0.299	0.357	0.288	0.185	0.172	0.290	0.290
1964	0.024	0.160	0.232	0.281	0.404	0.461	0.483	0.201	0.340	0.340
1965	0.349	0.464	0.349	0.468	0.451	0.625	0.624	0.509	0.424	0.424
1966	0.014	0.450	0.854	0.580	0.473	0.528	0.464	0.441	0.768	0.768
1967	0.119	0.025	0.347	0.416	0.576	0.390	0.395	0.334	0.437	0.437
1968	0.027	0.508	0.142	0.411	0.582	0.480	0.395	0.315	0.553[4]	0.494
1969	0.003	0.039	0.612	0.126	0.238	0.503	0.414	0.220	0.246[4]	0.408
1970	0.011	0.208	0.113	0.579	0.087	0.138	0.455	0.435	0.282[4]	0.351
1971	0.001	0.522	0.750	0.346	0.484	0.128	0.224	0.478	0.449[4]	0.384
1972	0.017	0.016	0.320	0.692	0.515	0.381	0.053	0.074	0.510[4]	0.327
1973	0.194	0.253	0.001	0.397	1.052	1.087	0.400	0.013	0.177[4]	0.209
1974	0.005	0.199	0.138	0.024	0.120	0.111	0.207	0.574	0.114[4]	0.135
1975	0.113	0.173	0.294	0.141	0.061	0.124	0.336	0.814	0.059[4]	0.213
1976	-[3]	0.156	0.163	0.262	0.162	0.752	0.175	0.280	0.077[4]	0.190
1977	-[3]	0.041	0.220	0.220	0.220	0.220	0.220	0.220	0.220	0.220

[1]ICNAF Div. 5Z.

[2]Weighted by stock size (numbers) at age; used as starting F for age 9+ for 1931-1967.

[3]<0.001.

[4]Obtained from analysis of catch at age data for ages 9-12 (and weighted by stock size over these ages).

Table 11. Stock size at age estimates (000's) for Georges Bank[1] haddock obtained from virtual population analysis assuming M = 0.2, 1931-1977.

Year	Stock size									Age 2+		Age 3+	
	1	2	3	4	5	6	7	8	9+	Total (000's)	Wt[2] (tons)	Total (000's)	Wt[2] (tons)
1931	41,631	20,995	14,897	17,118	17,038	10,374	7,367	3,094	1,312	152,195	181,359	71,200	118,183
1932	45,427	32,497	58,380	10,358	8,829	5,846	3,121	3,013	939	122,983	154,508	90,486	132,752
1933	55,869	37,172	24,726	24,681	6,305	3,941	2,205	1,375	1,870	102,275	129,618	65,103	100,345
1934	60,964	45,529	22,814	14,832	11,220	3,286	1,814	729	644	100,868	116,617	55,339	84,260
1935	60,104	49,609	33,257	13,813	8,788	6,359	1,748	930	372	114,876	119,416	65,267	78,787
1936	57,085	48,139	29,947	19,308	7,980	4,556	3,006	983	367	114,286	139,387	66,147	103,202
1937	106,582	45,957	28,339	14,235	10,932	4,611	2,495	1,245	572	108,386	141,390	62,429	102,101
1938	76,770	86,150	27,710	13,435	6,617	5,241	2,098	1,190	589	143,030	174,194	56,880	100,691
1939	63,805	61,965	52,377	15,725	7,628	3,523	2,856	873	681	145,628	173,580	83,663	124,913
1940	112,187	51,712	38,203	25,316	8,245	4,313	2,016	1,587	423	131,815	171,796	80,103	127,401
1941	115,779	90,045	35,805	20,232	13,326	4,498	2,206	977	1,099	168,188	192,903	78,143	124,694
1942	63,156	94,110	52,646	20,508	9,376	5,759	2,089	965	525	185,878	201,919	91,768	130,179
1943	24,108	51,497	64,169	28,437	10,933	4,104	2,629	786	586	163,141	173,709	111,644	141,420
1944	64,821	19,908	38,384	36,610	15,776	6,166	975	1,444	328	119,591	159,196	99,683	144,066
1945	91,985	53,490	15,614	23,839	16,695	7,820	3,006	356	762	121,582	163,088	68,092	119,012
1946	93,096	75,355	36,121	10,956	13,783	8,475	4,325	1,641	58	150,714	177,952	75,359	124,661
1947	59,511	76,055	46,752	15,970	6,510	6,111	3,509	1,907	1,098	157,912	180,780	81,857	125,701
1948	34,123	48,856	47,323	21,070	6,660	3,423	2,556	1,531	895	132,314	152,457	83,458	113,861
1949	128,509	27,373	29,908	21,535	8,670	2,999	1,765	1,393	850	94,993	115,977	67,120	96,310
1950	58,189	104,961	17,003	13,327	9,047	4,130	1,504	886	774	151,632	141,538	46,671	70,511
1951	109,999	47,811	59,923	10,230	7,080	4,438	1,476	766	523	132,247	136,166	84,436	102,364
1952	48,984	89,414	31,705	25,405	6,418	3,603	1,726	734	361	159,386	150,440	69,952	89,334
1953	145,593	40,118	50,552	17,975	13,193	4,031	2,102	937	300	129,308	133,069	89,190	106,992
1954	64,471	118,283	31,217	25,708	9,580	7,429	2,383	1,234	466	196,300	186,391	78,017	93,872
1955	100,357	52,951	68,232	20,961	16,003	5,763	4,169	1,305	693	170,077	187,418	117,126	145,591
1956	77,566	82,336	39,798	38,581	14,176	10,154	3,238	2,454	781	191,518	223,166	109,182	154,562
1957	72,889	63,630	56,651	25,555	20,764	8,546	5,285	1,446	1,503	184,380	228,470	120,750	173,417
1958	61,093	60,257	46,154	33,761	17,570	11,773	4,880	2,864	760	178,119	224,893	117,862	176,205
1959	133,027	50,009	44,315	31,406	21,645	11,064	7,510	3,183	1,947	171,079	223,476	121,070	183,779
1960	127,221	109,940	35,793	29,089	21,060	14,181	7,476	5,093	2,221	224,853	280,858	114,913	191,279
1961	57,343	104,166	75,114	23,677	19,642	14,445	9,983	5,407	3,804	256,238	318,838	152,072	233,383
1962	41,486	46,748	75,672	48,080	15,610	13,456	10,157	7,034	3,980	220,737	291,185	173,989	253,885
1963	147,565	33,966	34,313	47,355	29,983	9,682	9,137	6,906	4,693	176,035	248,855	142,069	221,078
1964	464,234	118,152	24,163	21,423	28,748	17,186	5,945	6,216	4,762	226,595	266,839	108,443	177,989
1965	35,778	371,024	82,397	15,686	13,246	15,711	8,877	3,002	4,163	514,106	433,038	143,082	192,392
1966	9,116	20,671	190,997	47,576	8,042	6,908	6,882	3,895	1,478	285,119	261,950	264,448	250,881
1967	11,298	7,362	10,788	66,578	21,803	4,103	3,335	3,544	2,051	119,564	161,679	112,202	156,846
1968	327	8,213	5,878	6,243	35,967	10,038	2,274	1,840	2,078	72,531	114,559	64,318	107,323
1969	853	251	4,047	4,174	3,390	16,462	5,084	1,254	2,612[3]	37,294	76,345	37,033	76,137
1970	4,548	696	205	1,797	3,014	2,188	8,149	2,752	2,466[3]	21,257	41,337	20,571	40,741
1971	173	3,684	463	150	824	2,251	1,561	4,232	2,782[3]	15,957	37,515	12,273	34,017
1972	10,435	141	1,790	179	87	416	1,630	1,021	3,380[3]	8,544	22,982	8,503	22,824
1973	15,936	8,407	114	1,064	73	43	233	1,255	2,301[3]	13,500	23,505	5,093	15,431
1974	9,554	10,747	5,343	94	586	21	12	128	2,515[3]	19,446	33,390	8,699	22,121
1975	2,098	7,789	7,211	3,811	75	426	15	8	1,746[3]	21,081	35,386	13,292	28,253
1976	201,500[4]	1,535	5,364	4,400	2,711	58	308	9	1,125[3]	15,510	27,994	13,975	26,447
1977	13,300[4]	165,000[5]	1,074	3,730	2,772	1,887	22	212	597[3]	175,294	189,082	10,294	25,656
1978	1,200[6]	11,000[5]	77,000[7]	706[8]	2,451[8]	1,821[8]	1,240[8]	148	532[8]	94,764	136,828	83,764	126,708

[1]ICNAF Div. 5Z; stock size values in numbers and weight (age 2+) appear in Figures 10 and 11, respectively.
[2]Adjusted by observed/calculated ratios in Table 2.
[3]Obtained from analysis of catch at age data for ages 9-12.
[4]Back-calculated from known catch at age data (M = 0.2).
[5]Predicted from linear regression of stock size (age 2) on autumn survey catch per tow (age 0 + 1).
[6]Assumed from Grosslein's (1979) index and results of current assessment.
[7]Predicted from linear regression of stock size (age 3) on autumn survey catch per tow (age 0 + 1 + 2).
[8]Calculated as $N_{i+1} = N_i e^{-Z}$.

Table 12. Minimum biomass estimates (000's tons) 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), 1963-1977.

Year	Georges Bank	Gulf of Maine
1963	101.2	47.1
1964	122.8	17.5
1965	92.4	16.4
1966	37.9	12.9
1967	32.3	15.7
1968	19.5	16.0
1969	10.7	11.9
1970	17.1	6.8
1971	7.1	7.6
1972	10.7	2.8
1973	12.4	8.0
1974	5.1	3.1
1975	19.2	8.0
1976	45.4	7.5
1977	44.3	10.3

Table 13. Catch projections for Georges Bank haddock for 1979 and spawning stock size projections for 1980 under two 1978 discard options and fishing mortality ranging from 0.05 to 0.60 for 1979.

Fishing Mortality (F) 1979	Option 1: 50% discard (USA) in 1978; 1979 spawning stock size = 115,266 tons			Option 2: 100% discard (USA) in 1978; 1979 spawning stock size = 107,786 tons		
	Catch 1979 (tons)	Spawning stock 1980 (tons)	% change from 1979	Catch 1979 (tons)	Spawning stock 1980 (tons)	% change from 1979
0.05	5,132	114,217	- 0.9	4,801	106,888	- 0.8
0.10	10,022	108,657	- 5.7	9,376	101,686	- 5.7
0.15	14,683	103,368	-10.3	13,736	96,737	-10.3
0.20	19,124	98,336	-14.7	17,891	92,029	-14.6
0.25	23,357	93,549	-18.8	21,851	87,550	-18.8
0.26[1]	24,179	92,620	-19.7	22,620	86,680	-19.6
0.30	27,391	88,996	-22.8	25,625	83,289	-22.7
0.35	31,236	84,664	-26.6	29,222	79,235	-26.5
0.40	34,901	80,543	-30.1	32,651	75,379	-30.1
0.45	38,394	76,623	-33.5	85,919	71,711	-33.5
0.50	41,724	72,894	-36.8	39,035	68,221	-36.7
0.55[2]	44,899	69,346	-39.8	42,005	64,901	-39.8

[1] $F_{0.1}$

[2] F_{max}

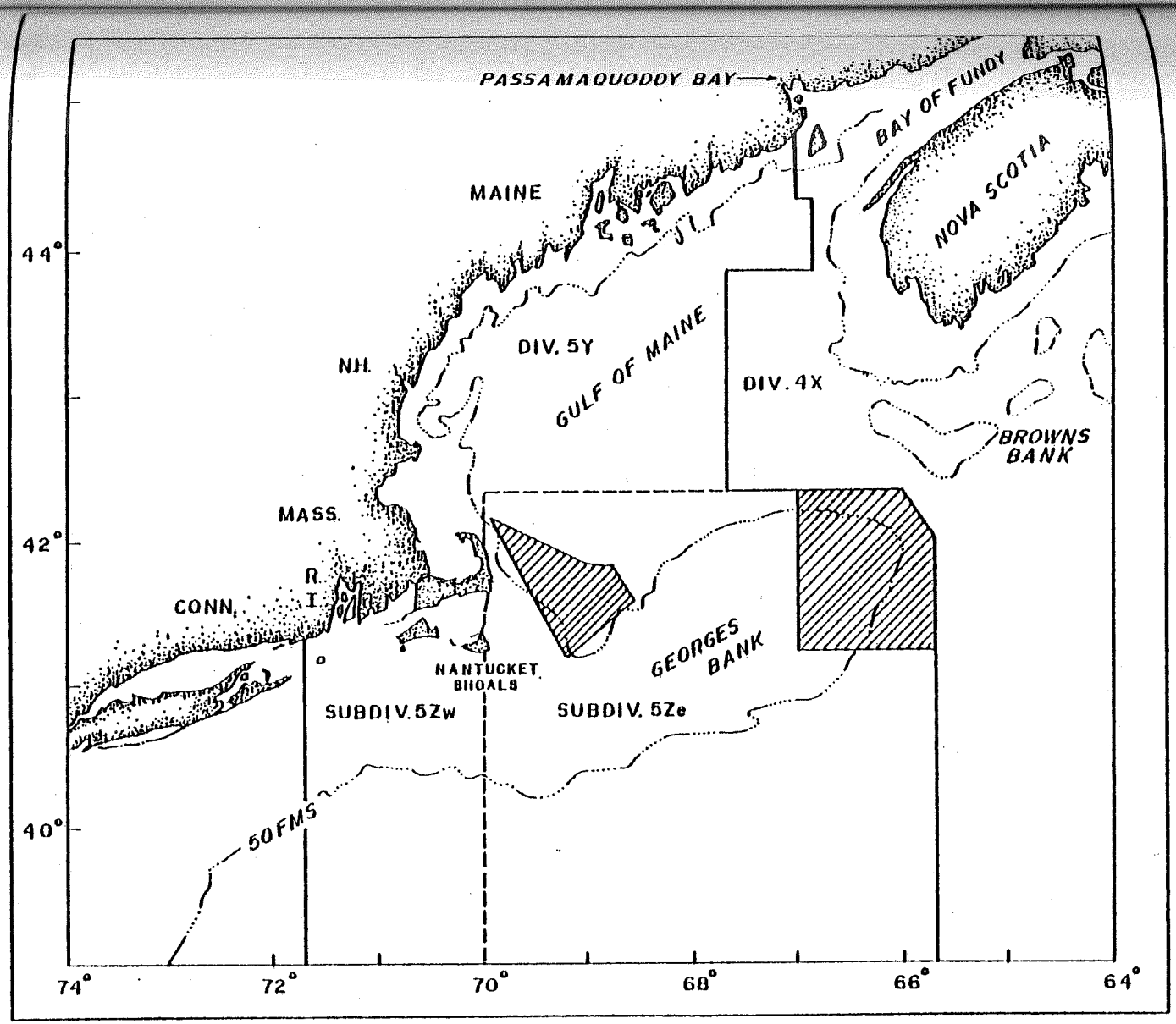

Figure 1. Gulf of Maine and Georges Bank area, indicating ICNAF boundaries and areas closed to fishing with gear capable of taking demersal species (crustacean and scallop gear and hooks with a gape $\geq$3 cm excluded), 1978.

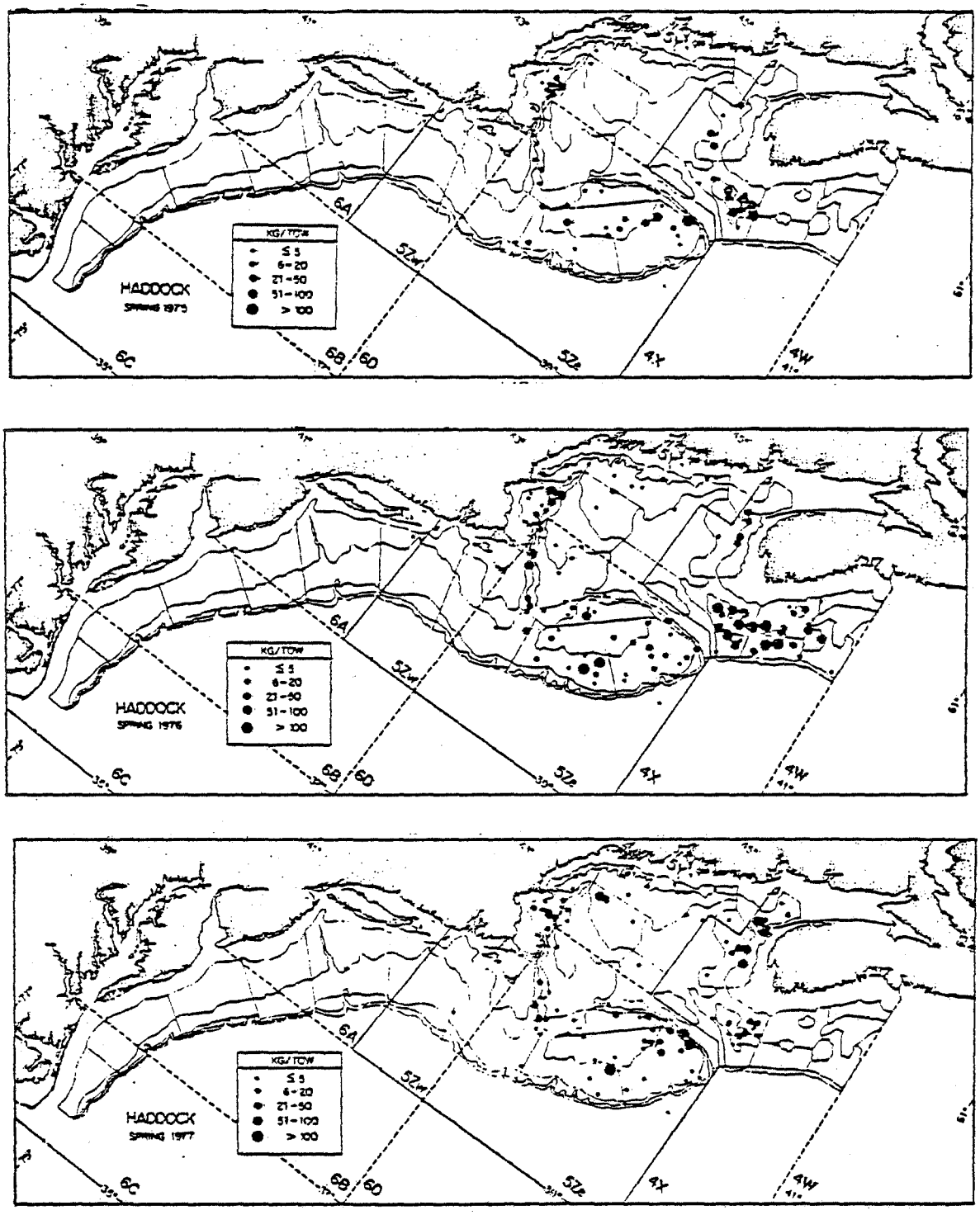

Figure 2. Distribution of haddock in NFEC spring bottom trawl surveys, 1975-1977, from southern New England to the western Scotian Shelf.

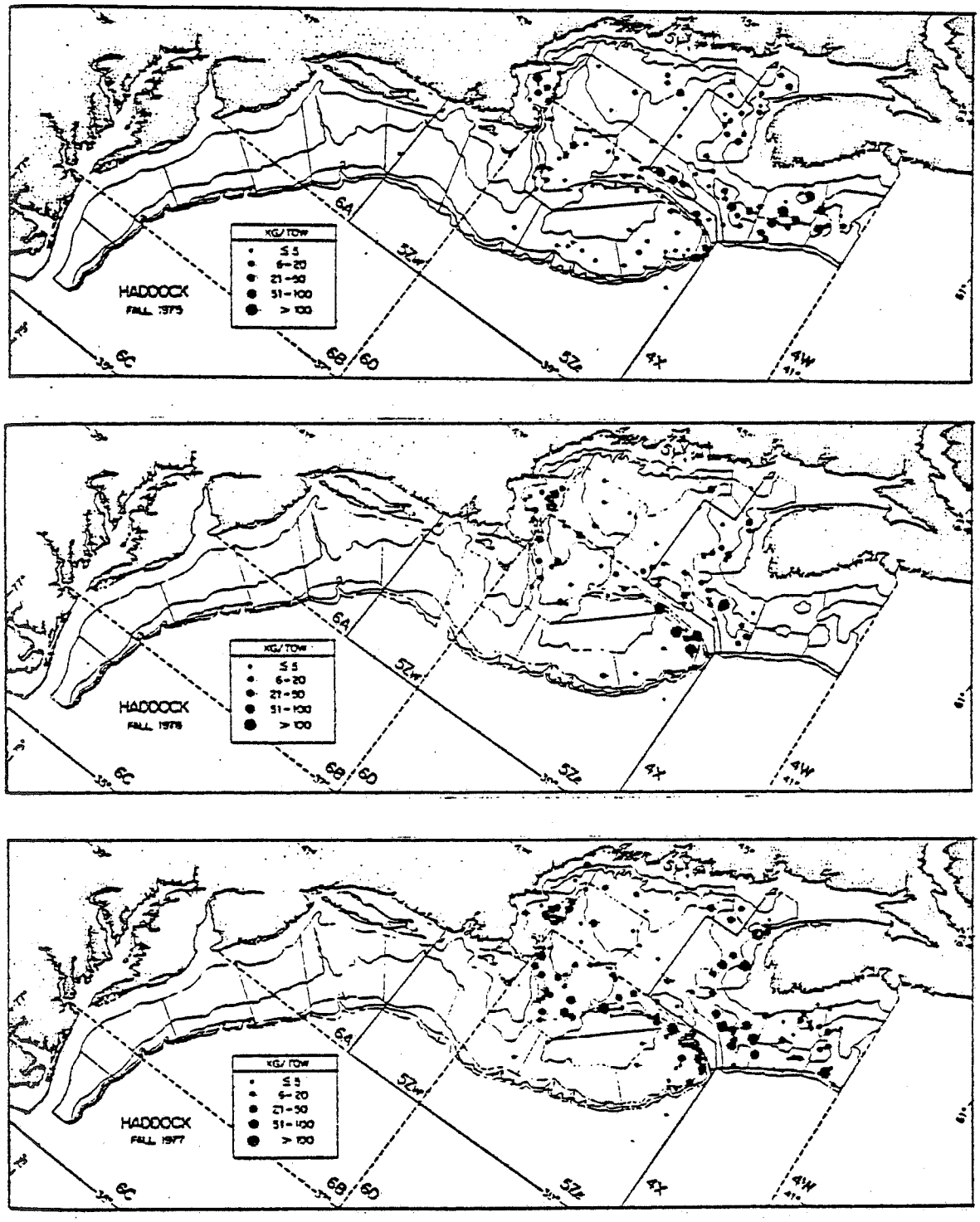

Figure 3. Distribution of haddock in NEFC autumn bottom trawl surveys, 1975-1977, from southern New England to the western Scotian Shelf.

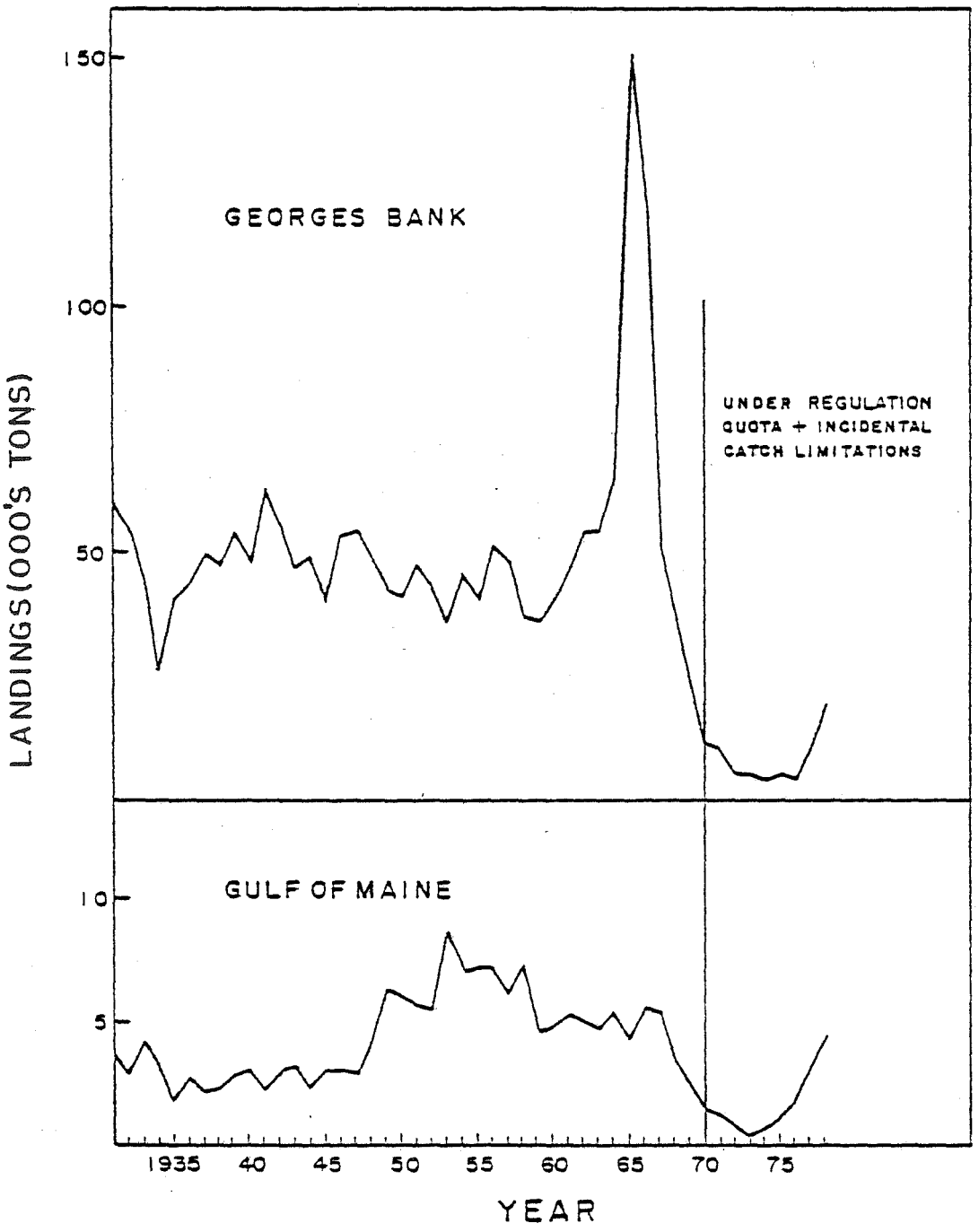

Figure 4. Commercial landings of haddock for Georges Bank and the Gulf of Maine, 1931-1978.

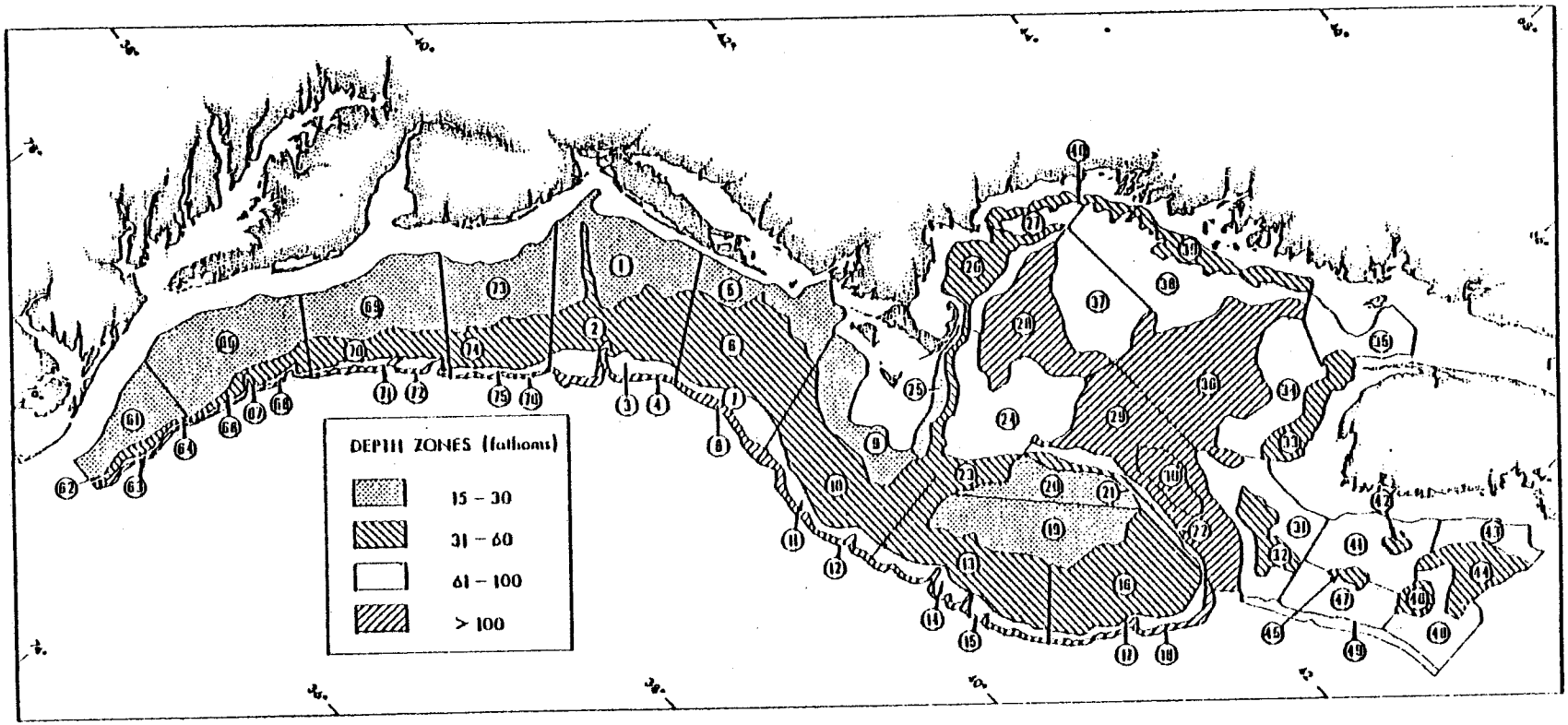

Figure 5. Strata used in NEFC spring and autumn bottom trawl surveys, 1963-1977.

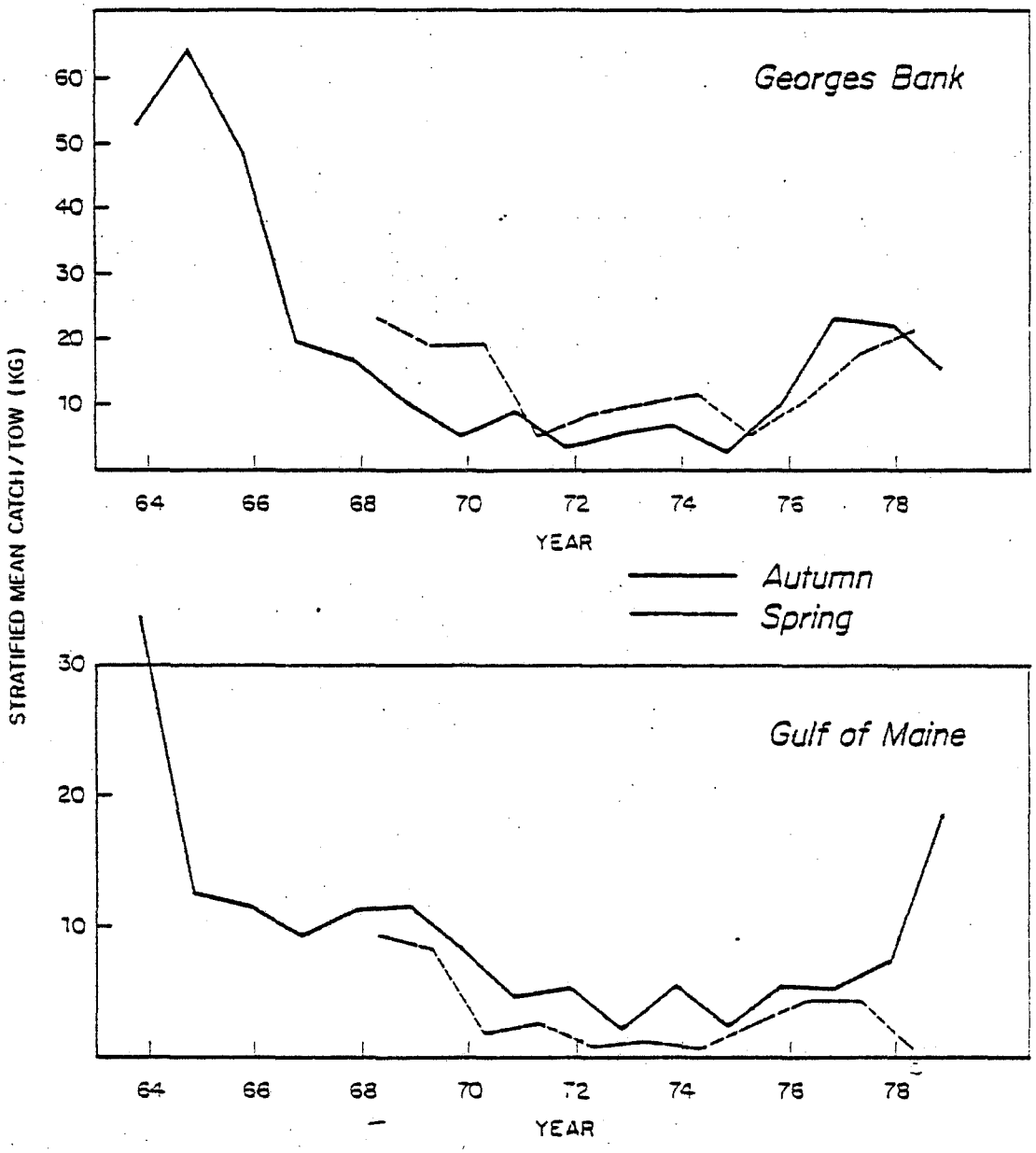

Figure 6. Stratified mean catch per tow (kg) for haddock in NEFC spring and autumn bottom trawl surveys on Georges Bank (strata 13-25, 29 and 30) and in the Gulf of Maine (strata 26-28 and 36-40), 1963-1978.

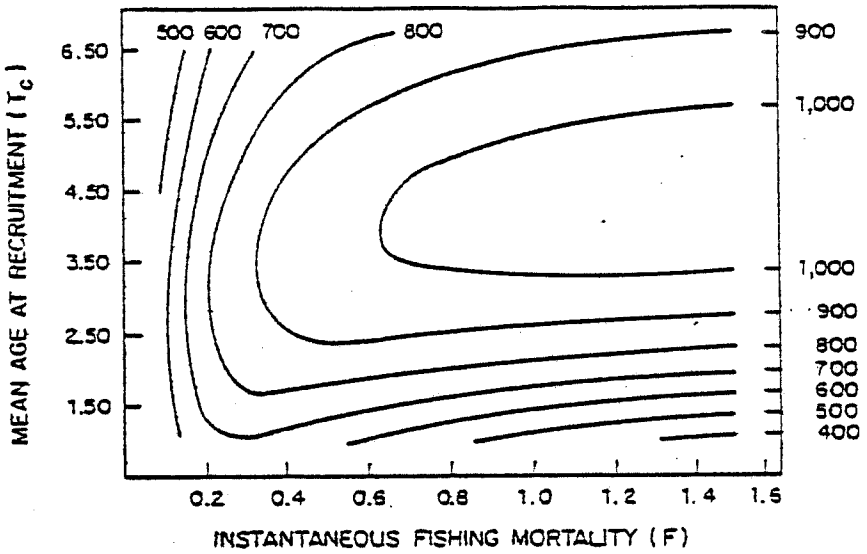

Figure 7. Yield isopleths for Georges Bank haddock (g) assuming W_∞ = 3853 g, K = 0.376, t_0 = -0.085, t_r = 1 year, t_λ = 18 years, and M = 0.2.

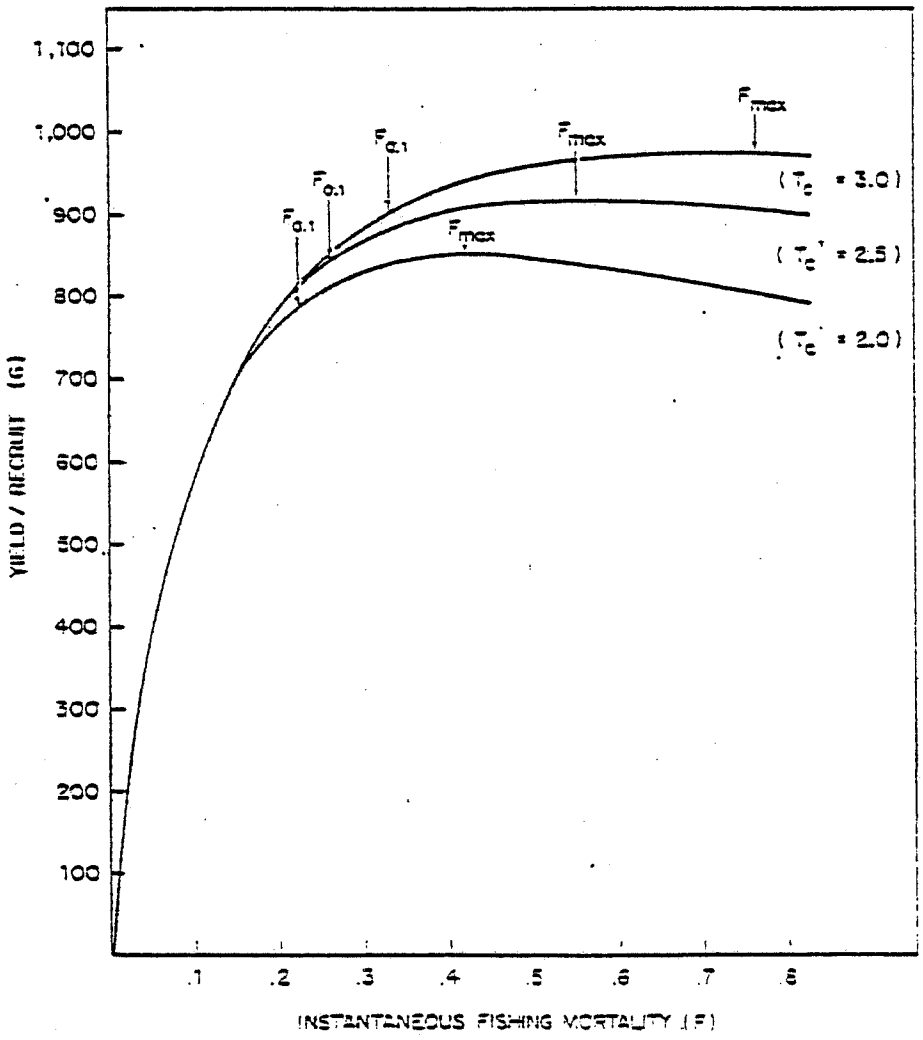

Figure 8. Yield per recruit curves for Georges Bank haddock assuming t_c values of 2.0, 2.5, and 3.0 years, W_∞ = 3853 g, K = 0.376, t_0 =-0.085, t_r = 1 year, t_λ = 18 years, and M = 0.2.

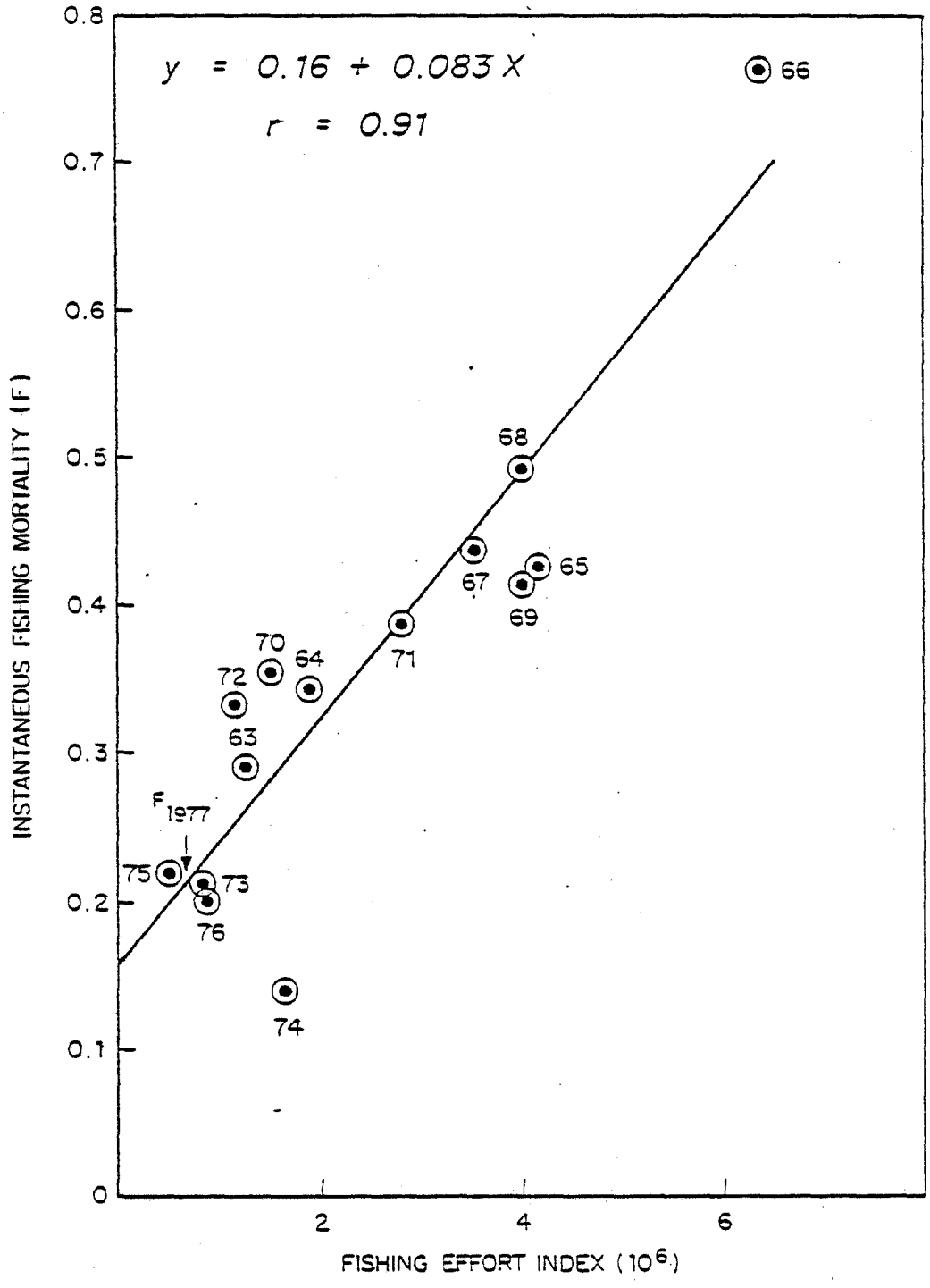

Figure 9. Relationship between instantaneous fishing mortality (F) for fully recruited year-classes (age 3+) and fishing effort for Georges Bank haddock derived from autumn survey catch per tow and commercial catch.

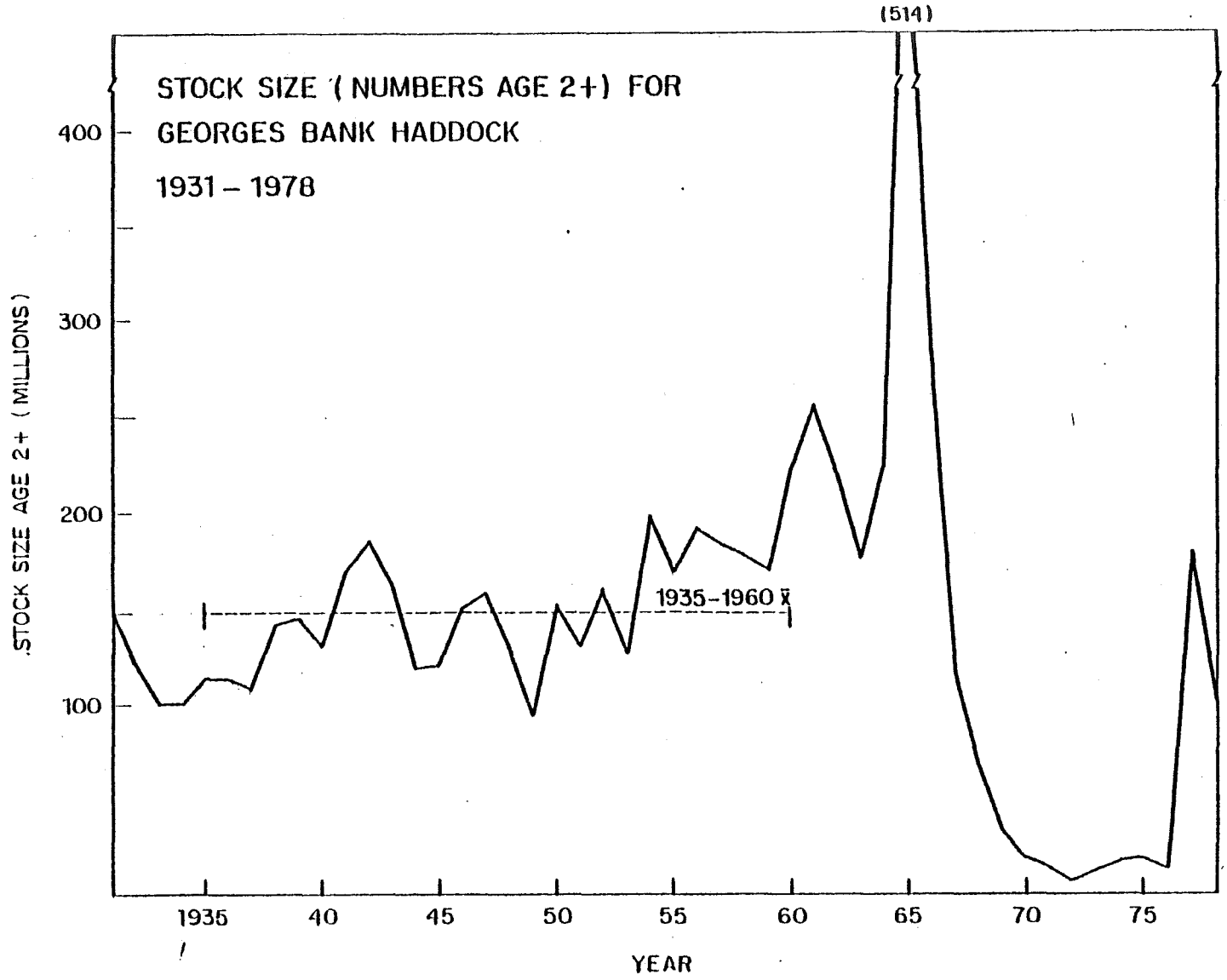

Figure 10. Stock size in millions of fish (age 2+) for Georges Bank haddock, 1931-1978.

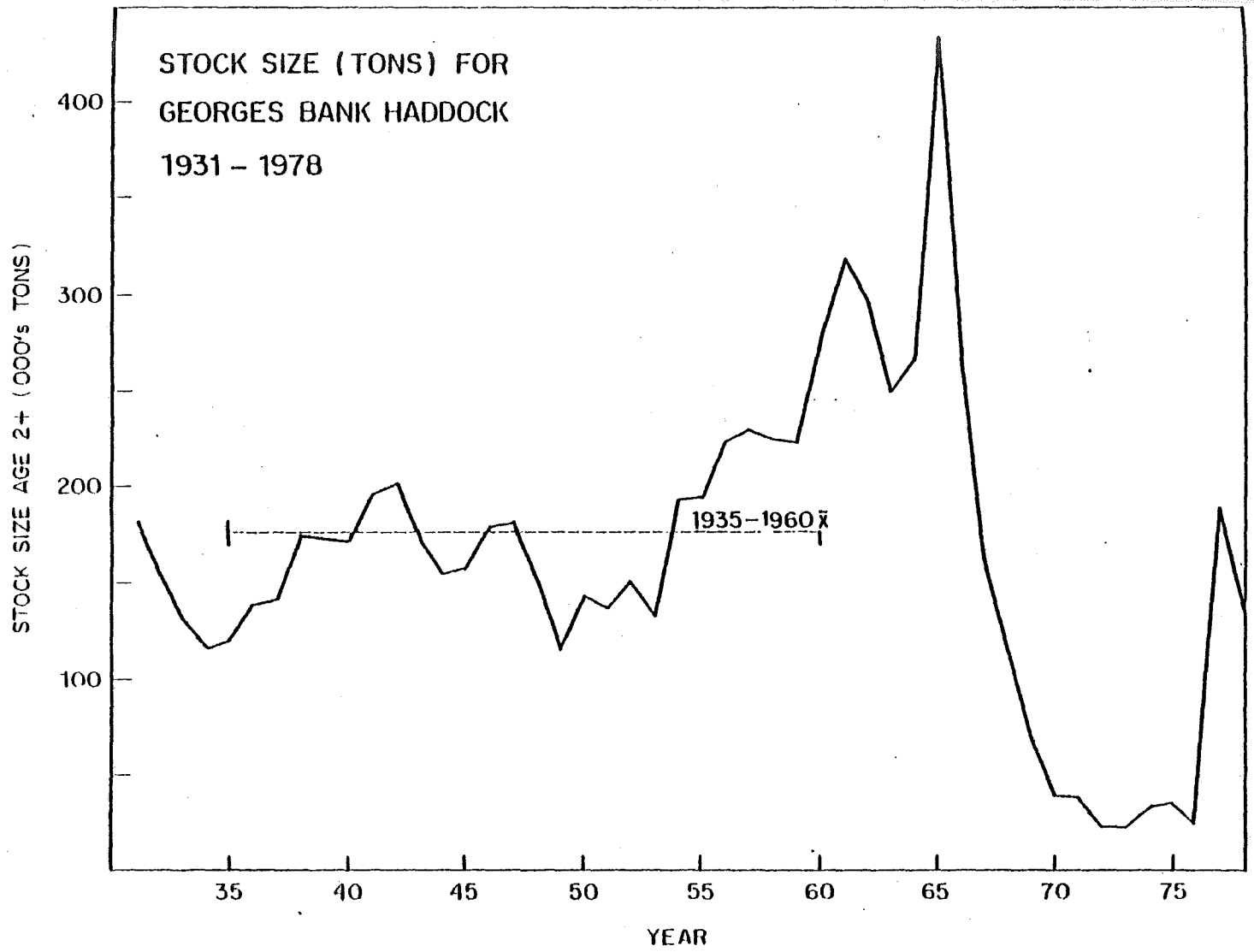

Figure 11. Stock size (000's tons, age 2+) for Georges Bank haddock, 1931-1978.

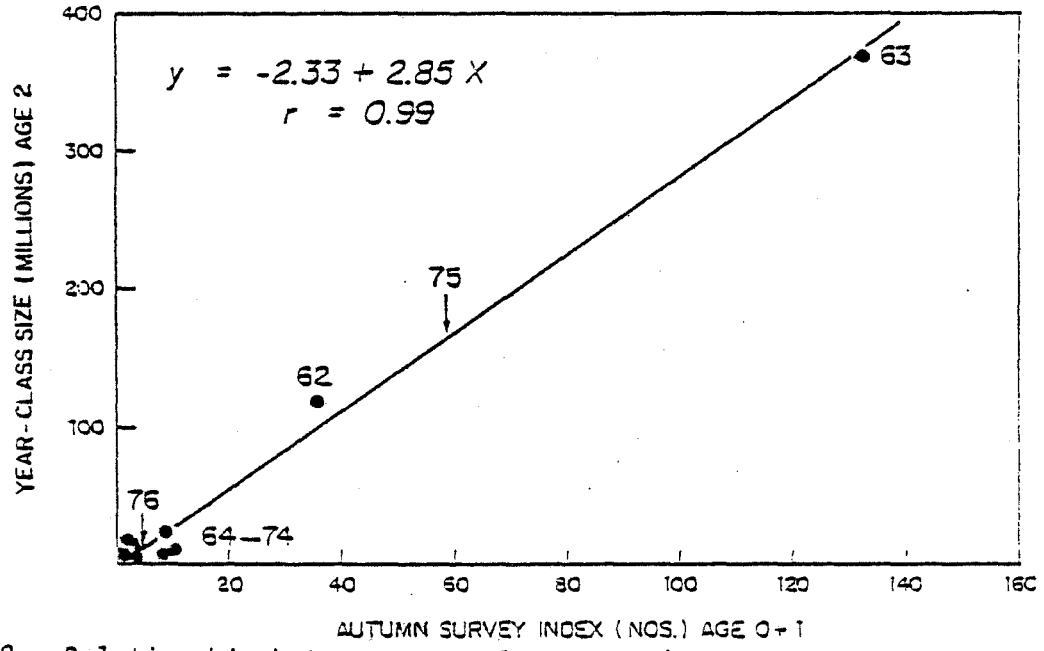

Figure 12. Relationship between year-class size (millions) at age 2 and autumn survey catch-per-tow (numbers, ate 0 + 1 combined) for Georges Bank haddock.

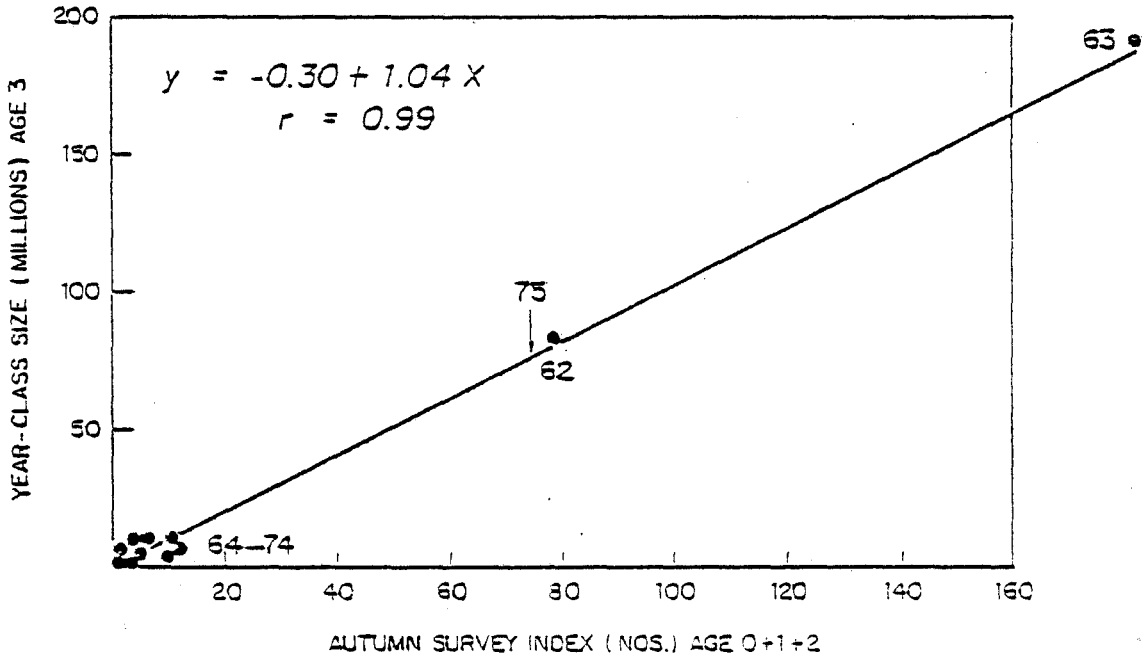

Figure 13. Relationship between year-class size (millions) at age 3 and autumn survey catch-per-tow (numbers, age 0 + 1 + 2 combined) for Georges Bank haddock.