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An Assessment of the Pollock (*Pollachius virens* L.) Stock in the Scotian Shelf, Gulf of Maine, and Georges Bank region, 1984

by

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SUMMARY

Commercial landings of pollock from the Scotian Shelf, Gulf of Maine, and Georges Bank regions, after steadily increasing from 22,900 tons in 1969 to 58,900 tons in 1981, declined to 52,700 and 49,000 tons in 1982 and 1983, respectively. The 1983 estimate represents a 17% reduction from the 1981 maximum. Canadian and USA landings exhibited the same overall trend, but landings by distant water fleets have been steadily declining since 1971. A large proportion of the increase in landings during the 1970's was due to the growth of Canadian and USA gill net fisheries. Total landings of pollock captured by gill nets rose from less than 500 tons in 1971 to over 15,000 tons in 1981. USA recreational landings, however, have remained relatively constant, between 2,000 and 3,000 tons, since the mid-1960's.

Pollock abundance, as indicated by Canadian commercial CPUE trends and Canadian and USA research vessel survey indices, also increased during the 1970's as several strong year classes (1971, 1975, and 1976) were produced. However, commercial CPUE indices have not increased since 1979, and bottom trawl survey weight per tow indices have declined since 1981. Despite this recent decline in total stock biomass, recruitment prospects remain high as survey catch-per-tow-at-age indices for the 1979 and 1982 year classes are among the highest observed in the time series.

Virtual population analysis of commercial catch-at-age data reveal an increase in age 2+ stock size from 110 million fish (175,000 tons) in 1974 to 173 million fish (276,000 tons) in 1978. Stock size subsequently declined to 125 million fish in 1982 although biomass continued to increase to 322,000 tons in 1981 before declining to 297,000 tons in 1982. Instantaneous fishing mortality (F) decreased substantially during the late 1970's as stock size increased. In 1982 and 1983, F was estimated at 0.26 and 0.25, respectively, at approximately the $F_{0.1}$ level. Continued fishing in 1984 at the 1983 F level will allow the stock to increase to 155 million fish (321,000 tons) in 1985 while yielding a catch of approximately 50,000 tons in 1984. Fishing at F_{max} would provide a catch of 89,000 tons in 1984 and a biomass of 278,000 tons in 1985.

Equilibrium yield calculations indicate that fishing at $F_{0.1}$ (0.25) would provide a long-term yield of 56,500 tons from a stock biomass of 338,300 tons; fishing at F_{max} (0.49) would provide a long-term yield of 60,700 tons from a stock biomass of 224,800 tons. Fishing at $F_{0.1}$, therefore, provides for a 50% increase in stock biomass over that allowed under F_{max}, implying greater stability in reproductive potential. Short-term gains in yield may be achieved by increasing F, but only marginal increases would result under long-term equilibrium conditions. Given current levels of abundance and biomass and the apparent strength of the 1979 and 1982 year classes, harvests in the order of 50-55,000 tons should be sustainable during 1984 and 1985 without significant increases in fishing mortality or reductions in stock size.

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INTRODUCTION

Commercial landings (nominal catches) of pollock from the Scotian Shelf, Gulf of Maine, and Georges Bank area have increased substantially during the late 1970's and early 1980's and, in 1981, were the highest ever reported (58,900 tons). Although landings declined in 1982 and 1983 to 52,700 and 49,000 tons, respectively, current harvests remain relatively high compared to pre-1978 levels. This primarily reflects increased Canadian and USA landings; Canadian landings more than doubled during the 1970's, while a fourfold increase in USA landings occurred. Landings by distant-water fleets declined by approximately 90% during the same decade. The fishery has been centered primarily on the Scotian Shelf (67% of the 1960-1980 total landings) although the proportion taken on Georges Bank and in the Gulf of Maine has increased since the mid-1970's. Pollock have traditionally been taken as by-catch, although more effort appears to have been directed towards this species in recent years (Clark et al., MS 1981).

Seasonal trends in commercial landings by area, tagging data, and distribution of ripe adults, eggs, and larvae suggest the existence of one major spawning area in the western Gulf of Maine (Clark et al. 1977) and recent egg and larval distribution data collected during Canadian surveys also indicate several additional spawning areas on the Scotian Shelf (McGlade, MS 1983) as suggested by Steele (1963). Recapture of pollock tagged in inshore Nova Scotia locations have been primarily confined to the Scotian Shelf region, although several have been recaptured in the western Gulf of Maine and along the northern edge of Georges Bank. Investigations into the stock structure of pollock in the

western North Atlantic are continuing, but until definitive information concerning stock boundaries becomes available, pollock in the Scotian Shelf, Gulf of Maine, and Georges Bank region and areas to the south (NAFO Divisions 4VWX, and Subareas 5 and 6, Figure 1) will be considered as a unit, as in previous assessments.

Pollock landings were uncontrolled in the Northwest Atlantic prior to 1973. During 1973-1976, the fishery was regulated by total allowable catches (TACs) under the International Commission for the Northwest Atlantic Fisheries (ICNAF). The annual TAC during 1974-1976 was 55,000 tons. Based on evidence of increased fishing mortality and reduced recruitment, the TAC was reduced to 30,000 tons for 1977. The USA withdrew from ICNAF December 31, 1976, however, and the USA fishery has since been unregulated. A Draft Fishery Management Plan was prepared for the USA fishery in 1978 (New England Regional Fishery Management Council, 1978) but was not implemented. The 30,000 ton TAC was maintained by Canada for each year during 1977-1979 but was raised to 40,000 tons for 1980, 54,000 tons for 1981, and 55,000 tons for 1982 (McGlade et al., MS 1983). The present document reviews the current status of the Scotian Shelf, Gulf of Maine, and Georges Bank pollock stock and provides catch and stock size projections for 1984-1985.

COMMERCIAL FISHERY

The Scotian Shelf, Gulf of Maine, and Georges Bank pollock stock has been fished primarily by Canada and the USA. Commercial landings for Canada rose from an average of 5,100 tons from 1920-1942 to an average of 29,300 tons from 1960-1964 (Clark et al., MS 1981) before

declining to 10,800 tons in 1970 (Table 1, Figure 2). Canadian landings then increased to an average of 25,600 tons during 1973-1978; landings subsequently increased to 36,000 and 40,300 tons in 1980 and 1981 (Table 1, Figure 2) before declining to 38,000 and 35,000 tons in 1982 and 1983, respectively. USA landings averaged 13,400 tons from 1935 to 1960 (Clark et al., MS 1981), declined to an average of 3,300 tons during 1967-1968, and then increased steadily to an average of 18,200 tons in 1980-1981 (Table 1, Figure 2). USA landings have since declined to 14,400 and 14,000 (provisional) tons in 1982 and 1983, respectively. It should be noted that, between 1978 and 1981, data for both countries appear to have been distorted by alleged misreporting of other species (e.g., haddock as pollock) to circumvent catch limitations on other species. There is no basis for quantifying amounts involved for either country.

No information exists relative to landings by other nations prior to 1960, as pollock catches by distant-water fleets were usually reported as "mixed" with other species (Clark et al., MS 1981). Landings since that year have fluctuated considerably, ranging from zero in 1962 to 12,300 tons in 1966 (Table 1). Annual landings subsequently declined from an average of 9,600 tons from 1970-1972 to less than 500 tons since 1980 (Table 1). Since 1960, the bulk of the distant water catch has been taken by the USSR (43%), the GDR (22%), Spain (20%), and the FRG (10%) (Clark et al., MS 1981).

Total commercial landings averaged 37,800 tons annually from 1958-1964, declined to 22,800 tons in 1968, and subsequently increased to an average of 39,200 tons from 1973-1977. Landings of 58,900 tons in 1981 were the highest ever reported (Table 1, Figure 2). Total landings in 1982 and 1983 were 52,700 tons and 49,000 tons, respectively. The bulk of the catch since 1970 (60%) has been taken on the Scotian Shelf, with most of the remainder being about evenly distributed between Georges Bank and the Gulf of Maine (Table 2). The Canadian catch was taken primarily on the western Scotian Shelf (89%); USA landings were more evenly distributed between Georges Bank (47%), the Gulf of Maine (36%), and the Scotian Shelf (18%) during 1960-1971, but have since been taken largely in the western Gulf of Maine (61%) (Clark et al., MS 1981). This appears to reflect increases in directed effort and gillnetting in the Gulf of Maine; the percentage of USA commercial landings taken by gillnetting has increased from 7% in 1970-1971 to 40% in 1978-1979 and 44% in 1981 (Table 3). Traditionally, the largest portion of the Canadian catch has been taken by otter trawling, with only 10% being taken by gillnets (McGlade et al., MS 1981). In 1981 and 1982, however, approximately 20% of the Canadian catch was taken by gillnets (Table 3). Distinct seasonal differences in landings trends are also evident, i.e., a summer (June-July) peak in Canadian landings on the Scotian Shelf and a winter (November-January) peak in USA landings in the Gulf of Maine (Steele, 1963; Clark et al., 1977). According to Clark et al. (MS 1981), this latter trend appears to reflect seasonal spawning movements.

COMMERCIAL CATCH AGE COMPOSITION

Commercial catch at age estimates for all countries combined from 1973 through 1980 were taken from Clark et al. (MS 1981). For recent years, annual age compositions have been computed independently by country and gear type as substantial differences have been evident between otter trawl and gillnet catches. This approach has been continued in the current assessment, since pronounced differences are also evident in USA catches for 1981-1982 (Figure 3). Catch-at-age estimates for the USA trawl fishery for these years were calculated by applying quarterly age-length keys to corresponding monthly length composition summaries; estimates for the gillnet catches were obtained by applying annual age keys to annual length composition summaries as samples were not available for every month. Estimates for Canada and other countries for 1981 and 1982 were taken from McGlade et al. (MS 1983).

Summarized data for all countries (Table 4) reveal that the catch has been dominated by age 3-5 fish (70% of the 1973-1982 total). The 1969, 1971, and 1975 year classes have shown up well in commercial landings, although catches of 1974 and 1976 year class fish have also been reasonably high. Considerable numbers of age 2 pollock from the 1979 year class were landed in 1981 and, in 1982, this year class accounted for the largest proportion of the total number landed. Increased landings of older (age 12+) fish in recent years have been taken primarily in the USA fishery.

Mean weights at age for this stock appear in Table 5. Values for 1973-1980 are as reported by Clark et al. (MS 1981) values for 1981-1982 represent averages for USA and Canadian gillnet and otter trawl fisheries weighted by numbers landed at age.

RECREATIONAL FISHERY

Recreational catch data for pollock are limited. No data are available for Canada and it is assumed that Canadian recreational catches are of minor significance. Recreational catch information for New England and the Mid-Atlantic states has been collected in a series of national saltwater angling surveys for 1960, 1965, and 1970 (Clark, 1962; Deuel and Clark, 1968; Deuel, 1973), in a regional survey of the northeastern United States in 1974 (Ridgely and Deuel, MS 1976), and more recently in the 1979 and 1980 Marine Recreational Fishery Statistics Surveys of the Atlantic and Gulf Coasts (Deuel, personal communication).[1] The 1979 and 1980 surveys represented a significant departure from earlier surveys in that they combined a household telephone survey to identify fishermen and to determine levels of effort over a two-month recall period with an intercept (creel) survey in which trained observers collected data on species and size composition of the catch. The 1979 and 1980 surveys avoided many methodological problems of earlier surveys, e.g., species misidentification and recall inaccuracies of numbers and average weights caught. Due to these differences, results are comparable only in a general way.

Recreational catch estimates obtained for 1960, 1965, and 1970 totalled 4.3 million fish (9,800 tons), 3.8 million fish (4,200 tons), and 2.5 million fish (2,500 tons), respectively (Table 6). These are considered to be overestimates, although the magnitude of the resulting bias is not known (Clark et al., MS 1981). The 1974 survey indicated a total recreational catch of 0.5 million fish

[1]Data for 1979 survey currently under revision and were not used in the present assessment.

or 500 tons and may not be overestimated. The 1980 survey indicated a total catch, including pollock reportedly caught and released alive, of 4.4 million fish or 2,100 tons, of which the harvested (remaining) catch totalled 2.0 million fish or 1,000 tons. The average weight of pollock reported in these surveys has declined steadily since 1960. In 1980, the mean weight was less than one-half that reported in 1974 and less than one-quarter of the 1960 value.

The USA recreational fishery has been centered primarily in the Gulf of Maine with lesser amounts taken from Connecticut to New Jersey (Ridgely and Deuel, MS 1976). The bulk of the 1978 recreational catch was taken by party and charter boats, although juvenile "harbor" pollock are available year-round along the Maine coast (Nicholson and Ruais, MS 1979). The low mean weight reported in the 1980 survey suggests a high percentage of "harbor" pollock in the recreational catch. In this survey, 61% of the total catch by number was reportedly taken in coastal inlets and bays, with the remainder being divided almost equally between the territorial sea (14%) and areas further offshore (15%), or undefined (10%).

The recreational fishery for pollock in the southern New England and Middle Atlantic areas is less defined as pollock tend to be taken primarily as by-catch in fisheries for cod and other recreational species (Clark et al., MS 1981).

STOCK ABUNDANCE AND BIOMASS INDICES

Commercial Catch Rates

Commercial CPUE[2] indices (tons per day fished) have been calculated for USA tonnage class (TC) 2 (0-50 GT) and TC 3 and 4 (51-500 GT) otter trawlers based on all trips for which 50% or more of the total landings

[2] Catch per unit effort.

consisted of pollock. McGlade et al. (MS 1983) reported similar series of seasonal commercial CPUE indices (tons per hour fished) for Canadian TC 5 (500-999 GT) otter trawlers using the 50% criterion. The January to June series was judged by McGlade et al. to best represent the Canadian fishery and is reproduced in the present document in Table 7. The Canadian TC 4 series was discontinued after 1981 because of insufficient data, and is presented for comparative purposes only.

Both USA commercial indices have fluctuated without a definite trend since 1964 (Table 7, Figure 5). The use of the 50% criterion, however, is arbitrary and thus the extent to which these reflect directed fishing effort is uncertain. Further studies are needed to define seasonal and areal components of the USA pollock fishery in order to improve these indices. The Canadian TC 5 index remained relatively constant between 1974 and 1976, and then increased substantially during 1977-1979; values remained at high levels through 1982 (Table 7, Figure 4). The Canadian TC 4 index also increased in 1979 but subsequently declined sharply.

Research Vessel Survey Indices

Canada has conducted stratified random bottom trawl surveys on the Scotian Shelf in summer since 1970 (Figure 6); the Northeast Fisheries Center (NEFC) has conducted similar surveys in autumn (since 1963) and spring (since 1968) in offshore areas (>27 m) from Hudson Canyon to the southwestern Scotian Shelf (Figure 7). A summer survey has also been run intermittently (1963-1965, 1969, and 1977-1980). The NEFC has also conducted inshore surveys (<27 m) from Cape Hatteras northward since 1972. however, the inshore Gulf of Maine was not surveyed in spring and autumn

prior to 1979, and, while a summer survey time series is available for 1977-1980, coverage and/or pollock catches have tended to be sporadic. Consequently, only a limited number of inshore strata between Nantucket Shoals and Rockland have been considered (Figure 8).

The Massachusetts Division of Marine Fisheries (DMF) has conducted similar inshore surveys along the Massachusetts coast during spring and autumn since 1978 (Figure 8). Areas sampled, sampling procedures, and catch-per-tow data for 1978-1981 are given in annual completion reports (Howe et al., MS 1979, MS 1980, MS 1981) and preliminary data are available for 1982 and 1983. Autumn survey catches of pollock in these surveys have been sporadic, and consequently only spring survey data have been utilized.

Abundance indices (stratified mean catch per tow in numbers) have been calculated for all of the above data sets; corresponding biomass indices in terms of weight (kg) have also been calculated for all USA surveys (Tables 8-11, Figures 9 and 10). To compensate for the effects of anomalously high catches in certain strata (e.g., in autumn of 1976, Table 8), NEFC survey data were also transformed to logarithms (x+1) and retransformed estimates in original units calculated as suggested by Bliss (1967:128) according to the relation

$$E\bar{y}_{st} = \exp\left(\bar{y}_{st} + \frac{S^2}{2}\right) - 1$$

where $E\bar{y}_{st}$ represents the estimated (retransformed) stratified mean catch per tow and $\bar{y}_{st}$ and S^2 represents the stratified mean and the estimated population variance, respectively, in logarithmic units. Additional information concerning Northeast Fisheries Center sampling designs and survey procedures and applications of resulting data to assessments is provided elsewhere (Grosslein 1969; Clark 1979).

Canadian summer survey indices have fluctuated since 1970 with no evident trend in relative abundance (Table 8, Figure 9). Peak values for 1977 and 1980 resulted from unusually high catch-per-tow values in two survey strata and may not reflect actual abundance levels (McGlade et al., MS 1981). The increase in 1982 was caused by extremely high catches of 3-year-old pollock from the 1979 year class (Table 8). USA retransformed spring and autumn survey indices do not reveal any consistent trends in numerical abundance since the early 1970's (Table 9, Figure 10). Peak index values in the spring of 1972 and autumn of 1972, 1973, and 1976, reflect unusually high catches of 1971 year class fish (Clark et al., MS 1981). In the autumn of 1981, the retransformed abundance index remained relatively low despite a sharp increase in the linear (untransformed) index. The apparent increase in the 1981 linear index was due to extremely large catches of small pollock in two survey tows and does not reflect true abundance. An upward trend in biomass is suggested by USA spring and autumn weight-per-tow indices which increased from the late 1960's to 1976. The spring index declined sharply in 1977, gradually increased through 1981, but declined again in 1982-83. The autumn biomass index, however, exhibited a more gradual, but steady decline between 1977 and 1983 (Table 9, Figure 10).

Total catch-per-tow indices for inshore surveys fluctuate considerably, but results for individual year classes appear to track incoming recruitment reasonably well (Table 11). Given the limited area involved in these surveys (Figure 8) compared to the distribution of the stock as a whole, it is doubtful whether such indices will accurately reflect overall trends

in stock abundance and biomass. But, the proximity of the inshore survey region to known western Gulf of Maine spawning grounds provides a biological basis for utilizing the NEFC and Massachusetts inshore surveys as a means for predicting future pollock recruitment.

MORTALITY

Total instantaneous mortality (Z) rates were calculated from USA spring and autumn and Canadian summer bottom trawl survey catch at age data (Tables 8 and 10). Calculations were performed over the entire period since 1970, for the 1970-77 period of moderate commercial landings (average = 37,000 tons), and the subsequent 1978-83 period of relatively high landings (average = 54,000 tons). Estimates of Z were also derived from the most recent three years of each data set. Mortality estimates from Canadian surveys presented in this paper were calculated from the data presented by McGlade et al. (MS 1983) but differ from the values reported by these authors.

Calculations for fully recruited (age 5+) fish provide total mortality estimates of 0.30, 0.41, and 0.62 (GM = 0.44) from USA spring and autumn and Canadian summer survey data, respectively, since 1970; corresponding estimates for 1980-83 from USA surveys and for 1979-82 from Canadian surveys are 0.42, 0.47, and 0.72 (GM = 0.52). Total mortality also increased substantially between 1970-77, when Z ranged from 0.16 to 0.35 (GM = 0.26) and 1978-83 when Z ranged from 0.44 to 0.70 (GM = 0.56).

Results from USA and Canadian surveys, although dissimilar in magnitude, indicate consistent increases in mortality since 1978, when annual landings rose by 50% over the early-to-mid-1970's average. Assuming

an instantaneous natural mortality (M) of 0.20 implies that F has averaged about 0.32 since 1980. This value is slightly greater than the estimate of F reported by Clark et al. (MS 1981) for the 1978-80 period but is still intermediate to the $F_{0.1}$ (0.25) and F_{max} (0.49) levels given by these authors.

RECRUITMENT

Stratified mean catch-per-tow-at-age data for Canadian and USA offshore surveys (Tables 8 and 10) although variable, reveal some consistencies in year-class strength. The 1968, 1969, and 1971 year classes have been relatively strong in Canadian summer surveys and, more recently, catches of 1974, 1975, and 1976 year-class pollock were also high in 1980. The 1979 year class dominated 1982 Canadian summer survey catches, representing over 61% of the total catch-per-tow index. The 1971 year class has been the strongest and most persistent to appear in the USA spring and autumn surveys, but recent data (1980-83) also reveal relatively strong 1975, 1976, 1979, and 1982 year classes.

The recruitment of the 1971 year class substantially increased overall stock abundance during the mid-1970's, and relatively high abundance has been sustained through the early 1980's by subsequent recruitment of the 1975, 1976, and 1979 year classes. Age 1 abundance estimates from the 1980 Massachusetts spring and NEFC summer inshore surveys also identified the strong 1979 year class, and the 1983 Massachusetts spring survey further indicated the presence of a comparatively strong 1982 year class at age 1 (Table 11). Results from virtual population analyses or VPA (discussed below) also indicate strong 1971, 1975, 1976, and 1979 year classes, ranging in size from 52.0 to 64.3 million fish at age 2.

Recruitment of the 1981 year class at age 2 in 1983 is assumed equal to the average of the 1971-1978 year classes (44.5 million fish) as suggested by 1983 NEFC and Commonwealth of Massachusetts bottom trawl survey results. The 1983 surveys also indicate a very strong 1982 year class; therefore, recruitment at age 2 in 1984 was taken as the average of the three strongest year classes (1971, 1975, and 1976) in the VPA results (59.7 million fish). As there is no information relative to the size of the 1983 year class as yet, recruitment in 1985 is assumed to approximate the 1971-1978 year class average.

EXPLOITATION PATTERN

Preliminary examinations of the catch-at-age matrix (Table 4) were performed using standard virtual population analysis (VPA) and the separable virtual population analysis (SVPA) procedures (Pope and Shepherd, 1982; Shepherd and Stevens, MS 1983). The standard VPA was used to derive fishing mortality and stock size estimates for 1973-1982 while the separable VPA was employed primarily to determine the consistency of the catch-at-age matrix with respect to age-specific partial recruitment. Thus, the usual VPA assumption of a constant exploitation pattern over time was examined by noting significant deviations in log catch ratios from those based on the calculated separable patterns of F and partial recruitment. Pollock appear to have been fully recruited to the commercial fishery at age 5, although recent increases in USA and Canadian gillnet landings may imply a potential shift in the recruitment pattern. No estimates of instantaneous natural mortality are currently available; therefore M has been assumed equal to 0.2 as in recent USA, Canadian and European assessments (Clark et al., MS 1981; McGlade et al., MS 1983; ICES, MS 1983).

The separable VPA revealed unusually large log catch ratio residuals in 1977 and 1978, coincident with the increase in USA and Canadian gillnet landings. The residuals were particularly high at younger ages, suggesting that the increase in the proportion of pollock landed by larger mesh gill nets may have reduced the partial recruitment selection coefficients of younger fish as the age at full recruitment increased from age 5 to ages 6 or 7.

The discontinuities in the catch-at-age matrix between 1981 and 1982 appear to be related to two distinct events. First, a disproportionate decrease in the estimated landings of 1977 year class pollock resulted from an overestimate of age 4 fish in 1981, since age composition data from USA and Canadian bottom trawl surveys and USA commercial samples have consistently indicated that the 1977 year class is one of the weakest in recent years. Thus, it appears that catch sampling problems in 1981 may have produced an overestimate of the contribution of this year class at age 4. Second, the appearance of the strong 1979 year class at age 3 in 1982 resulted in a high log catch ratio residual between 1981 and 1982, suggesting that partial recruitment of age 3 fish in 1982 was higher than the overall separable pattern would indicate. This supports the recent increase in the age 3 selection coefficient from 0.37 to 0.61 proposed by McGlade et al. (MS 1983). Separable VPA's which were run with various levels of terminal S ranging from 0.5 to 1.0 indicate that the overall exploitation pattern for 4VWX+5 pollock is dome-shaped. Results to date, however, are preliminary and, as such, do not warrant any immediate change from past practices. Therefore, the exploitation pattern was determined primarily from standard VPA results as in previous assessments.

An initial VPA was performed using the mean F of 0.32, estimated from the 1980-83 USA and Canadian bottom trawl survey catch-per-tow-at-age data, as a provisional 1982 terminal F. The procedure described by Clark et al. (MS 1981) also yielded a similar estimate of F for 1982. Fine-tuning of the 1982 terminal F was accomplished by regressing mean fully recruited (ages 5+) annual F estimates from the trial VPA against calculated annual fishing effort from 1973 to 1979 using a functional power curve relationship. Annual estimates of total effort were obtained by dividing Canadian June-August TC 5 commercial otter trawl CPUE indices, adjusted to age 5+, into age 5+ landings for all countries combined.

The VPA was re-run with a new terminal F estimated from the fitted curve, and the resulting estimates of annual F were again regressed on fishing effort. The VPA-regression procedure was repeated until the terminal F predicted by the regression for 1982 equalled the terminal F used in the preceding VPA. Convergence was thus achieved after four trials, resulting in a final terminal F estimate of 0.26. The final regression of fishing mortality on effort (Figure 11) yielded a correlation coefficient of 0.75.

Selection coefficients for incompletely recruited ages were computed as the geometric means of selection coefficients obtained from trial VPA's for the years 1973-79, excluding 1977 and 1978 (Table 12). Thus, the average selection coefficients were calculated to reflect the most prevalent recruitment pattern observed over time in the otter trawl fishery. The 1977 and 1978 data were excluded because of the deviations noted in the separable VPA results and empirical observations of annual partial recruitment vectors calculated from trial VPA's. The average partial recruitment

vector implies full recruitment for ages 5+ and the following partial selection coefficients: age 2, 0.05; age 3, 0.34; and age 4, 0.77. However, based partially on the separable VPA results for the 1979 year class, and the overwhelming dominance of age 3 fish in the 1982 landings, the selection coefficient for age 3 was increased from the computed value of 0.34 to 0.61 in accord with McGlade et al. (MS 1983).

STOCK SIZE ESTIMATES

Results from the final VPA (Table 13) indicate a steady increase in stock size (age 2+) from 110 million fish, or 175,500 tons in 1974 to 173 million fish or 275,800 tons in 1978. Stock size estimates in terms of weight were computed by applying mean weights at age from the commercial fishery (Table 5), adjusted by the observed/calculated ratios given in Table 4. Stock size in terms of numbers subsequently declined to 125 million fish in 1982, although stock biomass continued to increase through 1981, before declining slightly in 1982 to 296,700 tons. McGlade et al. (MS 1983) performed a cohort analysis using preliminary 1981 and 1982 catch-at-age data with a terminal F in 1982 of 0.30 and obtained similar stock size estimates for 1973-82. Biomass estimates generated from their analyses, however, were considerably lower than the results presented herein since the mean weights at age used by McGlade at al. were adjusted to the beginning of each year. Trends in biomass as well as stock size, however, are similar in both analyses.

CATCH AND STOCK SIZE PROJECTIONS

Catches and stock sizes (numbers and weight) were projected through 1985, based on observed 1982 stock sizes and mean weights at age with F_{1982} equal to 0.26 and F_{1983} equal to 0.25 as estimated by simulating the

preliminary 1983 landings. Recruitment at age 2 was assumed to equal 44.5 million fish (1971-78 year class average) in 1983 and 1985, and 59.7 million fish (average of three strongest year classes) in 1984. The above assumptions relative to F in 1982 and 1983, full recruitment at ages 5 and older, and partial recruitment coefficients of 0.05, 0.61, and 0.77 for ages 2, 3, and 4, imply a total stock size (age 2 and older) of 153 million fish or 312,000 tons at the beginning of 1984, comparable to the highest levels observed in the VPA time series.

Continued fishing in 1984 at the 1983 F (0.25) will provide a catch of about 50,000 tons and a 1985 stock size of 155 million fish or 320,900 tons. The estimated F for 1983 is equal to the $F_{0.1}$ level reported by Clark et al. (MS 1981) and appears reasonably low to allow for continued increases in stock size, given the above assumptions regarding recruitment. If F increases in 1984 to the F_{max} level of 0.49 reported by Clark et al. (MS 1981), stock abundance will decline slightly in 1985 to 143 million fish, and stock biomass will drop substantially to 277,700 tons, although the 1984 yield to the fishery would increase to 89,000 tons.

EQUILIBRIUM YIELD

Equilibrium yield calculations, performed under the assumption of constant recruitment of 44.5 million fish (1971-1978 year class average), indicate that fishing at $F_{0.1}$ (0.25) would provide a long-term yield of 56,500 tons from a stock biomass of 338,300 tons; fishing at F_{max} (0.49) would provide a long-term yield of 60,700 tons from a stock biomass of 224,800 tons. Although the long-term yields are similar, fishing at $F_{0.1}$

provides for a 50% increase in stock biomass over that allowed under F_{max}, thereby providing for greater stability in reproductive potential and resilience to environmental perturbations.

DISCUSSION

Commercial pollock landings increased continually from an average of 38,100 tons during 1974-1976 to 58,900 tons in 1981, but have since declined to approximately 49,000 tons in 1983. The 1974-1981 increase appears to reflect increasing abundance as stock biomass also increased substantially during this period. The decline since 1981, however, largely reflects reduced demand (e.g., for salting in Canadian markets) although there are indications of modest declines in abundance and biomass since that year.

Commercial abundance indices do not reveal any consistent trends. The Canadian TC 5 index increased substantially during the late 1970's and has since remained at high levels, while the Canadian TC 4 index increased sharply in 1979, but has since declined. USA indices have fluctuated about a relatively constant level. In the case of research vessel survey data, the Canadian summer survey index (mean number per tow) for age 4+ pollock has declined since 1980 while the USA autumn survey biomass index (mean weight per tow) has declined steadily since the late 1970's. The USA spring biomass index, however, remained relatively high through 1982 before declining sharply in 1983. These data suggest that increases in stock biomass evident during the late 1970's did not continue after 1980. The increases in mortality noted in the most recent years are consistent with this interpretation, although the current level of fishing mortality is still relatively low compared to F_{max}.

Although the overall survey indices may be declining, the appearance of several strong year classes in recent years suggests that recruitment prospects remain high. The 1979 year class appears to be as large as any previously observed, and recent survey data indicate that the 1982 year class may be equally strong.

Results of VPA analyses suggest modest declines in abundance and biomass since the early 1980's, although current levels remain relatively high. For 1982, stock size (age 2+) was estimated at 125 million fish or 296,700 tons, the latter value being only 8% below the peak level observed in 1981. For 1983, levels of abundance and biomass were comparable, and increases are expected in 1984 and 1985 with recruitment of the 1982 year class. F has remained at or near the $F_{0.1}$ level in recent years and should continue to do so if current harvest levels are maintained.

Separable VPA results for pollock suggest a dome-shaped selection pattern with lower partial recruitment coefficients at older and younger ages. The lower partial recruitment of older fish may be due to decreased vulnerability to trawl gear. As results of these analyses were considered preliminary, a flat-topped selection pattern was assumed as in previous assessments (Clark et al., MS 1981; McGlade et al., MS 1983). In addition, a higher partial recruitment coefficient was applied to age 3 fish than had been previously used. These adjustments resulted in a more conservative approach, i.e. by reducing VPA stock size estimates for more recent years. Nevertheless, recent declines in VPA stock size and biomass estimates were not as substantial as indicated by bottom trawl survey indices.

Given current levels of abundance and biomass, relatively low levels of fishing mortality and favorable recruitment prospects from the

1982 year class, it is concluded that this resource is in good condition and should remain so for the foreseeable future. Harvests in the order of 50-55,000 tons should be sustainable during 1984 and 1985 without significant increases in fishing mortality or reductions in stock size.

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Table 1. Commercial landings and estimated recreational catches of pollock (metric tons; live) for the Scotian Shelf, Gulf of Maine, Georges Bank, and Southern New England-Middle Atlantic areas[1] by country, 1960-1983.

Year	Country							Total commercial	Estimated USA recreational[2]	Grand total
	Canada	USA	FRG	GDR	Spain	USSR	Other			
1960	29,470	10,132	-	-	783	-	1	40,386	9,834	50,220
1961	26,323	10,265	-	-	982	-	1	37,571	9,963	47,534
1962	31,721	7,391	-	-	-	-	-	39,112	7,174	46,286
1963	28,999	6,653	126	-	-	906	28	36,712	5,319	42,031
1964	30,007	6,006	208	-	-	4,603	429	41,253	4,802	46,055
1965	27,316	5,303	71	-	1,361	2,667	11	36,729	4,240	40,969
1966	18,271	3,791	-	-	2,384	9,865	12	34,323	3,031	37,354
1967	27,567	3,312	-	-	1,779	644	10	23,312	2,648	25,960
1968	18,062	3,280	-	-	1,128	372	7	22,849	2,088	24,937
1969	15,968	3,945	1,188	2,195	1,515	227	7	25,045	2,511	27,556
1970	10,753	3,979	3,233	4,317	532	527	40	23,381	2,533	25,914
1971	11,757	4,890	633	6,849	912	2,216	18	27,275	3,113	30,388
1972	18,022	5,729	475	4,816	616	3,495	66	33,219	3,647	36,866
1973	26,990	6,303	1,124	948	3,113	3,092	1,606	43,176	358	43,534
1974	24,975	8,726	149	2	1,500	2,348	102	37,802	496	38,298
1975	26,548	9,318	236	96	709	2,004	124	39,035	530	39,565
1976	23,568	10,863	994	24	303	1,466	390	37,608	618	38,226
1977	24,654	13,056	368	-	2	268	54	38,402	2,694	41,096
1978	26,801	17,714	-	-	-	502	290	45,307	1,739	47,046
1979	29,967	15,541	-	-	-	1,025	99	46,632	1,789	48,421
1980	35,986	18,280	-	-	-	950	212	55,428	2,127	57,555
1981	40,270	18,171	-	-	-	358	105	58,904	2,260	61,164
1982	37,998	14,361	-	-	-	297	88	52,744	2,024	54,768
1983[3]	35,000	14,000	-	-	-	-	-	49,000	2,000	51,000

[1]As reported to ICNAF-NAFO for Divisions 4VWX, and Subareas 5 and 6.

[2]Data for 1960, 1965, 1970, 1974, and 1980 as provided by recreational fishery surveys; remaining points estimated.

[3]Provisional (incomplete).

Table 2. Commercial pollock landings (metric tons, live) for the Scotian Shelf, Gulf of Maine, Georges Bank, and Southern New England - Middle Atlantic areas[1], 1960-1983.

	Area				
Year	Scotian Shelf	Gulf of[2] Maine	Georges[3] Bank	Southern New England-Middle Atlantic	Total
1960	29,989	6,563	3,834	-	40,386
1961	29,352	5,042	3,177	-	37,571
1962	32,961	2,575	3,576	-	39,112
1963	30,471	2,178	3,947	116	36,712
1964	32,245	1,754	7,250	4	41,253
1965	27,729	1,933	7,065	2	36,729
1966	24,476	953	8,846	48	34,323
1967	14,787	1,733	6,790	2	23,312
1968	17,623	1,416	3,724	86	22,849
1969	15,221	4,635	5,025	164	25,045
1970	11,402	6,281	5,157	541	23,381
1971	12,072	7,074	7,096	1,033	27,275
1972	20,206	6,419	6,519	75	33,219
1973	30,100	5,202	6,235	1,639	43,176
1974	25,409	6,106	6,233	54	37,802
1975	25,164	6,015	7,848	8	39,035
1976	24,226	6,453	6,915	14	37,608
1977	22,129	8,314	7,846	113	38,402
1978	23,002	12,329	9,943	33	45,307
1979	28,180	10,077	8,356	19	46,632
1980[1]	31,889	11,633	11,883	20	55,425
1981	36,836	12,722	9,298	48	58,904
1982	33,277	9,560	9,886	20	52,743
1983[4]	30,788	8,706	9,504	2	49,000

[1]As reported to ICNAF-NAFO for Divisions 4VWX, Division 5Y, Subdivision 5Ze, and Subdivision 5Zw and Subarea 6, respectively.

[2]Subarea 5 NK landings assigned to the Gulf of Maine.

[3]As reported for Division 5Z prior to 1968; landings by subdivision not available for 1960-1967.

[4]Provisional; incomplete.

Table 3. Commercial landings of pollock (metric tons, live) for the Scotian Shelf, Gulf of Maine, Georges Bank and Southern New England-Middle Atlantic areas[1] by gear type and country, 1971-1982.

	Bottom Trawls				Gill Nets			Other Gear				All Gear			
Year	Canada	USA	Others	Total	Canada	USA	Total	Canada	USA	Others	Total	Canada	USA	Others	Total
1971	10042	4447	9464	23953	270	163	433	1445	280	1164	2889	11757	4890	10628	27275
1972	15952	4926	8761	29639	484	699	1183	1586	104	707	2397	18022	5729	9468	33219
1973	23204	4959	6754	34917	501	1033	1534	3285	311	3129	6725	26990	6303	9883	43176
1974	20449	6249	2448	29146	2211	1906	4117	2315	571	1653	4539	24975	8726	4101	37802
1975	20217	5877	2147	28241	4146	2613	6759	2185	828	1022	4035	26548	9318	3169	39035
1976	15881	6868	1975	24724	5060	3177	8237	2627	818	1202	4647	23568	10863	3177	37608
1977	19774	7483	291	27548	2866	4560	7426	2014	1013	401	3428	24654	13056	692	38402
1978	20649	9283	672	30604	4196	7227	11423	1956	1204	120	3280	26801	17714	792	45307
1979	22281	7729	1075	31085	4840	6305	11145	2846	1507	49	4402	29967	15541	1124	46632
1980	26635	10384	1107	38126	3709	6041	9750	5642	1855	55	7552	35986	18280	1162	55428
1981	30441	9685	461	40587	7684	7937	15621	2145	549	2	2696	40270	18171	463	58904
1982	27027	9795	385	37207	8065	4342	12407	2906	224	-	3130	37998	14361	385	52744

[1]As reported to ICNAF-NAFO for Divisions 4VWX and Subareas 5 and 6.

Table 4. Commercial landings at age (000's) for the Scotian Shelf, Gulf of Maine, and Georges Bank pollock stock, 1973-1982.

	Age													Weight		
Year	1	2	3	4	5	6	7	8	9	10	11	12+	Total	Obs.	Cal.	Obs/Cal
1973	-	1856	1595	5684	4341	1049	795	363	457	421	79	31	16671	43176	46003	0.94
1974	-	617	7281	2899	3626	1327	511	415	112	123	103	56	17070	37802	41954	0.90
1975	-	372	3346	8434	1890	1655	555	137	55	70	46	38	16598	39035	40350	0.97
1976	-	514	2952	3583	4453	1233	960	258	28	32	34	70	14117	37608	37637	1.00
1977	-	170	2526	3972	2431	2937	1101	609	174	83	44	260	14307	38402	38442	1.00
1978	-	196	3023	4686	3665	1824	2071	660	366	152	111	242	16996	45307	45094	1.00
1979	9	233	3628	6348	3922	2323	717	448	191	74	38	112	18043	46632	46553	1.00
1980	45	368	1694	4971	6370	3495	1203	356	259	99	47	74	18981	55428	55466	1.00
1981	-	2180	2419	2975	6424	3422	1437	517	359	196	52	124	20105	58904	58292	1.00
1982	-	302	5984	2566	711	2428	2200	1286	726	306	203	195	16908	52744	52475	1.00

Table 5. Mean weights at age (kg) observed in commercial landings for the Scotian Shelf, Gulf of Maine, and Georges Bank pollock stock, 1973-82.

	Age											
Year	1	2	3	4	5	6	7	8	9	10	11	12+
1973	0.305	0.780	1.580	2.380	3.120	3.670	4.420	4.960	5.700	5.640	7.400	7.590
1974	0.305	0.810	1.440	2.180	3.070	4.100	5.100	6.110	6.680	7.270	8.010	8.360
1975	0.305	0.890	1.470	2.100	2.970	3.950	5.000	6.240	7.070	7.290	7.830	9.190
1976	0.305	0.810	1.550	2.200	2.970	3.760	4.510	5.180	6.140	7.640	7.660	7.970
1977	0.305	0.930	1.120	1.620	2.580	3.420	4.430	5.780	6.740	7.060	7.840	8.470
1978	0.305	0.820	1.110	1.590	2.390	3.580	4.370	5.540	6.450	6.740	7.540	7.890
1979	0.240	0.740	1.320	1.940	2.910	3.770	4.750	5.960	6.480	7.490	7.910	8.350
1980	0.370	1.040	1.700	2.100	3.010	3.430	4.250	5.830	6.380	7.320	7.920	8.770
1981	0.305	0.912	1.438	2.468	2.904	3.587	4.435	5.552	6.466	7.323	7.974	9.171
1982	0.305	0.663	1.311	2.379	3.467	3.896	4.350	5.341	6.214	7.050	7.752	8.802

Table 6. Numbers, total weight, and estimated mean weight(kg) of pollock taken by USA recreational fishermen by area, 1960-1980.

Year	Area ME	NH	MA	RI-VA	Totals Number (000's)	Weight (tons)	Mean weight(kg)
1960	-	-	-	-	4,335	9,834	2.27
1965	-	-	-	-	3,756	4,240	1.13
1970	-	-	-	-	2,451	2,533	1.03
1974	146	81	211	43	481	496	1.03
1980	80	631	3,619	102	4,432	2,127[2]	0.48
	(36)	(284)	(1,630)	(46)	(1,996)	(958)	

[1]Numbers in parentheses exclude data for pollock caught and released alive.

[2]Calculated by multiplying numbers caught by mean weight of pollock available for identification in intercept (creel) survey work.

Table 7. Commercial abundance indices for pollock for the Canadian and USA fisheries, 1964-1982.

Year	CANADA Tons per hour fished TC4[1]	TC5[2]	USA Tons per day fished TC2[3]	TC 3&4[3]
1964	-	-	8.33	6.27
1965	-	-	10.62	7.09
1966	-	-	11.30	7.88
1967	-	-	3.09	6.60
1968	-	-	6.94	5.81
1969	-	-	3.66	6.47
1970	-	-	5.72	5.86
1971	-	-	8.36	5.97
1972	0.52	-	8.44	7.68
1973	0.70	-	11.59	7.77
1974	0.51	0.76	8.76	7.61
1975	0.48	0.69	5.25	6.27
1976	0.47	0.67	4.67	6.56
1977	0.50	0.83	6.87	8.15
1978	0.25	1.05	7.19	7.28
1979	1.73	1.29	4.69	6.36
1980	1.00	1.23	4.36	7.59
1981	0.36	1.28	6.03	7.43
1982	-	1.27	7.39	6.23

[1]Calculated based on trip data for June, July, and August for side and stern otter trawlers of 150-499 GT for which 50% or more of the total catch consisted of pollock.

[2]Calculated based on trip data for January-June for side and stern otter trawlers of 500-999 GT for which 50% or more of the total catch consisted of pollock.

[3]Calculated based on trip data for side and stern otter trawlers of 0-50 GT and 51-500 GT, respectively, for which 50% or more of the catch consisted of pollock.

Table 8. Stratified mean catch per tow at age for pollock in Canadian summer bottom trawl surveys (strata 43-95).

	A.T. CAMERON												LADY HAMMOND
Age	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
1	0.008	0.000	0.012	0.000	0.008	0.000	0.000	0.000	0.000	0.000	0.011	0.007	0.000
2	1.916	0.775	0.103	0.428	0.044	0.008	0.035	0.278	0.004	0.000	0.610	0.167	0.258
3	0.471	0.578	0.203	0.399	1.010	0.019	0.214	0.836	0.184	0.118	0.723	0.188	2.919
4	0.287	0.177	1.335	1.237	0.253	0.351	0.612	1.056	0.673	0.709	2.056	0.062	0.285
5	0.210	0.043	0.397	0.433	0.332	0.299	1.077	2.176	0.990	0.819	3.648	0.587	0.119
6	0.205	0.020	0.123	0.060	0.180	0.393	0.260	1.528	0.365	0.608	1.266	0.413	0.362
7	0.171	0.034	0.036	0.024	0.204	0.066	0.428	0.216	0.333	0.250	0.764	0.270	0.319
8	0.103	0.012	0.064	0.044	0.118	0.098	0.155	0.383	0.104	0.163	0.289	0.234	0.160
9	0.040	0.008	0.055	0.055	0.090	0.031	0.044	0.129	0.046	0.012	0.111	0.075	0.128
10	0.000	0.024	0.028	0.004	0.056	0.004	0.048	0.068	0.002	0.040	0.066	0.073	0.076
11	0.046	0.000	0.012	0.028	0.134	0.008	0.020	0.036	0.000	0.000	0.000	0.027	0.022
12	0.012	0.000	0.008	0.012	0.048	0.000	0.020	0.016	0.016	0.000	0.000	0.000	0.030
12+	0.000	0.000	0.020	0.000	0.000	0.000	0.028	0.000	0.12	0.000	0.000	0.001	0.046
NK	0.008	0.000	0.012	0.000	0.000	0.000	0.008	0.004	0.041	0.046	0.006	0.043	0.000
TOTALS													
1+	3.469	1.671	2.396	2.724	2.477	1.277	2.941	6.722	2.729	2.179	9.544	2.104	4.724
4+	1.074	0.318	2.078	1.897	1.415	1.250	2.692	5.608	2.541	2.601	8.200	1.742	1.547
5+	0.787	0.141	0.743	0.660	1.162	0.899	2.080	4.552	1.868	1.892	6.144	1.680	1.262
6+	0.577	0.098	0.346	0.227	0.830	0.600	1.003	2.376	0.878	1.073	2.496	1.093	1.143

Estimates of Mortality:

$Z^{1}_{1970-82} = 0.62$; $Z_{1979-82} = 0.72$

$Z_{1970-76} = 0.35$; $Z_{1976-82} = 0.70$

[1]Calculated as: $\ln \left(\frac{\Sigma \text{age } 5+ \ 1970-81}{\Sigma \text{age } 6+ \ 1971-82}\right)$

Table 9. Stratified mean catch per tow in weight (kg) and numbers for Scotian Shelf, Gulf of Maine, and Georges Bank pollock in NEFC offshore spring[1], summer[2], and autumn[1] bottom trawl surveys, 1963-1983.

	Spring[3]				Summer				Autumn			
	Weight		Numbers		Weight		Numbers		Weight		Numbers	
Year	Linear	Retrans-formed	Linear	Retrans-formed	Linear	Retrans-formed	Linear	Retrans-formed	Linear	Retrans-formed	Linear	Retrans-formed
1963	-	-	-	-	10.28	3.45	2.31	1.07	5.79	4.63	1.46	1.27
1964	-	-	-	-	5.27	2.32	2.06	0.96	4.40	2.15	1.64	0.96
1965	-	-	-	-	2.56	1.05	1.72	0.63	2.74	1.85	0.83	0.72
1966	-	-	-	-	-	-	-	-	2.35	1.43	0.97	0.55
1967	-	-	-	-	-	-	-	-	1.80	1.05	0.52	0.41
1968	4.47	2.45	1.09	0.84	-	-	-	-	3.17	2.09	0.69	0.59
1969	2.66	2.22	1.12	0.94	1.75	1.19	0.70	0.47	6.58	2.67	1.31	0.79
1970	4.91	3.04	1.67	1.35	-	-	-	-	2.59	1.80	0.64	0.59
1971	4.39	2.97	1.18	0.99	-	-	-	-	3.96	1.69	1.09	0.65
1972	5.67	3.78	4.43	2.52	-	-	-	-	4.37	2.83	1.41	1.11
1973	4.82	3.33	4.00	1.47	-	-	-	-	4.71	3.59	1.64	1.17
1974	4.10	4.13	1.39	1.20	-	-	-	-	3.17	1.35	0.90	0.51
1975	5.90	4.52	1.67	1.19	-	-	-	-	2.04	1.38	0.70	0.48
1976	6.84	6.51	1.59	1.43	-	-	-	-	16.66	6.69	3.69	1.64
1977	3.44	2.80	1.63	1.18	9.98	8.35	2.07	1.67	8.78	4.81	2.14	1.19
1978	6.56	3.29	2.48	0.98	4.05	3.80	1.29	0.92	5.83	3.31	0.98	0.65
1979	4.75	3.68	1.06	0.93	17.57	4.14	2.96	1.19	5.81	4.29	1.28	0.86
1980	4.40	3.40	1.52	1.09	9.83	6.61	12.21	2.25	4.63	2.99	0.83	0.64
1981	6.30	4.87	2.00	1.34	-	-	-	-	7.75	1.37	5.24	0.57
1982	6.62	3.18	3.99	1.76	-	-	-	-	3.40	1.46	1.40	0.71
1983	1.84	1.10	0.90	0.65	-	-	-	-	2.68	0.95	0.87	0.45

[1]Strata 13-40.

[2]Strata 21-28 and 37-40.

[3]The "36 Yankee" trawl was used from 1968-1972, and the "41 Yankee" trawl was used from 1973-1981. No gear conversion factors are available to adjust for differences in fishing power.

Table 10. Stratified mean catch per tow at age (numbers) for Scotian Shelf, Gulf of Maine, and Georges Bank pollock in NEFC offshore spring[1], summer[2], and autumn[1] bottom trawl surveys, 1963-1983.

		Age													Totals					
	Year	0	1	2	3	4	5	6	7	8	9	10	11	12+	1+	2+	3+	4+	5+	6+
Spring[3]	1970	0.01	0.52	0.05	0.17	0.20	0.05	0.07	0.09	0.12	0.08	0.04	0.04	0.23	1.66	1.14	1.09	0.92	0.72	0.67
	1971	0.01	0.15	0.13	0.13	0.09	0.07	0.08	0.04	0.09	0.06	0.07	0.07	0.20	1.18	1.03	0.90	0.77	0.68	0.61
	1972	-	1.20	1.49	0.90	0.20	0.05	0.05	0.07	0.12	0.04	0.07	0.04	0.17	4.40	3.20	1.71	0.81	0.61	0.56
	1973	-	0.01	2.80	0.51	0.15	0.14	0.04	0.03	0.10	0.04	0.09	0.02	0.09	4.02	4.01	1.21	0.70	0.55	0.41
	1974	-	0.01	0.10	0.53	0.14	0.08	0.16	0.07	0.03	0.00	0.01	0.10	0.16	1.39	1.38	1.28	0.75	0.61	0.53
	1975	-	0.01	0.33	0.20	0.34	0.08	0.09	0.10	0.08	0.05	0.06	0.02	0.29	1.65	1.64	1.31	1.11	0.77	0.69
	1976	-	0.08	0.11	0.14	0.15	0.24	0.13	0.15	0.17	0.11	0.03	0.04	0.24	1.59	1.51	1.40	1.26	1.11	0.87
	1977	-	0.14	0.38	0.23	0.06	0.16	0.32	0.13	0.11	0.02	0.02	0.01	0.04	1.62	1.48	1.10	0.87	0.81	0.65
	1978	-	0.00	0.22	0.42	0.65	0.63	0.15	0.11	0.08	0.07	0.05	0.04	0.07	2.49	2.49	2.27	1.85	1.20	0.51
	1979	-	0.10	0.05	0.07	0.08	0.15	0.14	0.08	0.16	0.08	0.03	0.03	0.08	1.05	0.95	0.90	0.83	0.75	0.60
	1980	-	0.15	0.15	0.09	0.28	0.25	0.20	0.23	0.08	0.04	0.02	0.00	0.05	1.54	1.39	1.24	1.15	0.87	0.62
	1981	-	0.01	0.72	0.13	0.12	0.18	0.26	0.08	0.07	0.05	0.09	0.06	0.20	2.02	2.01	1.30	1.12	1.00	0.82
	1982	-	0.13	1.63	0.84	0.55	0.11	0.33	0.11	0.14	0.05	0.01	0.02	0.07	3.99	3.86	2.23	1.39	0.84	0.73
	1983[4]	-	0.57	0.05	0.02	0.03	0.00	0.00	0.05	0.04	0.01	0.02	0.02	0.10	0.90	0.33	0.28	0.26	0.23	0.23
Summer	1977	-	0.05	0.23	0.09	0.26	0.29	0.32	0.15	0.23	0.07	0.08	0.07	0.23	2.07	2.02	1.79	1.70	1.44	
	1978	-	0.00	0.57	0.17	0.09	0.08	0.08	0.05	0.09	0.03	0.01	0.05	0.08	1.30	1.30	0.73	0.56	0.47	
	1979	-	0.05	0.00	0.38	0.26	0.36	0.55	0.36	0.49	0.06	0.21	0.00	0.23	2.95	2.90	2.90	2.52	2.26	
	1980	-	10.67	0.11	0.06	0.29	0.25	0.30	0.22	0.03	0.02	0.07	0.05	0.13	12.20	1.53	1.42	1.36	1.07	
Autumn	1970	0.01	0.13	0.08	0.01	0.09	0.08	0.08	0.04	0.02	0.01	0.02	0.01	0.07	0.64	0.51	0.43	0.42	0.33	0.25
	1971	0.02	0.11	0.38	0.16	0.02	0.06	0.09	0.04	0.08	0.03	0.01	0.01	0.09	1.08	0.97	0.59	0.43	0.41	0.35
	1972	0.00	0.38	0.27	0.20	0.08	0.07	0.08	0.07	0.05	0.04	0.03	0.03	0.10	1.40	1.02	0.75	0.55	0.47	0.40
	1973	0.00	0.03	0.71	0.12	0.17	0.11	0.11	0.09	0.07	0.00	0.12	0.02	0.10	1.65	1.62	0.91	0.79	0.62	0.51
	1974	0.00	0.00	0.08	0.28	0.20	0.11	0.08	0.09	0.01	0.02	0.00	0.02	0.02	0.91	0.91	0.83	0.55	0.35	0.24
	1975	0.01	0.22	0.06	0.03	0.11	0.07	0.04	0.09	0.01	0.01	0.01	0.01	0.03	0.68	0.46	0.40	0.37	0.26	0.19
	1976	0.00	0.03	0.03	0.15	0.55	1.63	0.50	0.31	0.14	0.05	0.01	0.01	0.29	3.70	3.67	3.64	3.49	2.94	0.31
	1977	0.00	0.06	0.17	0.24	0.29	0.42	0.38	0.22	0.11	0.09	0.02	0.00	0.14	2.14	2.08	1.91	1.67	1.38	0.96
	1978	0.00	0.03	0.19	0.04	0.04	0.09	0.09	0.15	0.08	0.06	0.04	0.03	0.12	0.96	0.93	0.74	0.70	0.66	0.57
	1979	0.00	0.01	0.02	0.26	0.33	0.19	0.13	0.08	0.09	0.05	0.04	0.01	0.06	1.27	1.26	1.24	0.98	0.65	0.46
	1980	0.01	0.13	0.01	0.01	0.05	0.11	0.06	0.07	0.13	0.08	0.06	0.04	0.07	0.82	0.69	0.68	0.67	0.62	0.51
	1981	0.00	0.07	3.59	0.98	0.14	0.20	0.13	0.04	0.00	0.00	0.01	0.00	0.08	5.24	5.17	1.58	0.60	0.46	0.26
	1982	0.01	0.07	0.44	0.40	0.29	0.01	0.05	0.04	0.02	0.02	0.00	0.02	0.04	1.40	1.33	0.89	0.49	0.20	0.19
	1983[4]	0.00	0.46	0.03	0.04	0.02	0.07	0.01	0.06	0.07	0.03	0.02	0.02	0.06	0.87	0.41	0.38	0.34	0.32	0.25

Estimates of Mortality:

Spring: $Z^{5}_{1970-82} = 0.30$; $Z_{1980-82} = 0.42$

$Z_{1970-76} = 0.16$; $Z_{1977-82} = 0.44$

Autumn: $Z^{6}_{1971-83} = 0.41$; $Z_{1981-83} = 0.47$

$Z_{1971-77} = 0.31$; $Z_{1978-83} = 0.57$

[1] Strata 13-40

[2] Strata 21-28 and 37-40.

[3] The "36 Yankee" trawl was used from 1970-1972, and the "41 Yankee" trawl was used from 1973-1981. No gear conversion factors are available to adjust for differences in fishing power.

[4] Preliminary

[5] Calculated as $\ln\left(\frac{\Sigma \text{ age } 5+ \ 1970-82}{\Sigma \text{ age } 6+ \ 1971-83}\right)$

[6] Calculated as $\ln\left(\frac{\Sigma \text{ age } 5+ \ 1970-82}{\Sigma \text{ age } 6+ \ 1971-83}\right)$

Table 11. Stratified mean catch per tow in numbers and weight (kg) for Scotian Shelf, Gulf of Maine, and Georges Bank pollock in Massachusetts inshore spring surveys[1], 1978-1983.

	Age					
Year	0	1	2	3+	Total	Stratified mean catch per tow in weight(kg)
1978	2.07	0.01	0.13	0.06	2.27	0.11
1979	4.34	0.04	0.01	0.06	4.45	0.07
1980	0.30	8.37	0.20	0.02	8.89	0.72
1981	1.52	1.42	1.40	0.00	4.34	0.54
1982	1.79	0.00	0.06	0.00	1.85	0.03
1983	0.03	6.45	0.27	0.04	6.79	0.68

[1]Regions 1-5 (strata 11-21 and 25-36).

Table 12. Proportion of fully recruited (age 5+) F at age for Scotian Shelf, Gulf of Maine, and Georges Bank pollock, obtained from Virtual Population Analysis, 1973-80.

	Age								
Year	2	3	4	5	6	7	8	9	10
1973	.059	.163	.616	1.101	.653	.943	.916	1.204	1.274
1974	.047	.424	.589	.994	1.015	.781	1.572	.757	1.017
1975	.031	.488	1.136	.892	1.225	1.142	.478	.596	1.201
1976	.036	.308	.761	1.021	.937	1.278	.885	.130	.498
1977	.008	.202	.545	.761	1.098	1.416	1.472	.924	.483
1978	.014	.195	.507	.759	.921	1.452	1.784	1.921	1.468
1979	.086	.441	.845	.947	1.155	.869	.837	1.608	1.188
1980	.072	.671	.697	1.089	1.099	.763	.513	.579	1.201
Geometric Mean (1973-76 + 1979)	.048	.340	.766	.988	.974	.986	.874	.647	.984

Table 13. Estimates of instantaneous fishing mortality (F) and stock size (000's) at age for the Scotian Shelf, Gulf of Maine and Georges Bank pollock stock calculated from virtual population analysis or VPA, 1973-1982.

Year	AGE 2	3	4	5	6	7	8	9	10	11	12+		
					FISHING MORTALITY[1]							Mean F Age 5+[2]	
1973	0.036	0.102	0.387	0.689	0.401	0.589	0.574	0.756	0.799	0.624	0.624	0.624	
1974	0.021	0.194	0.271	0.458	0.465	0.348	0.715	0.347	0.467	0.458	0.458	0.458	
1975	0.009	0.151	0.359	0.285	0.392	0.361	0.147	0.187	0.380	0.318	0.318	0.318	
1976	0.011	0.097	0.240	0.326	0.305	0.415	0.284	0.040	0.158	0.321	0.321	0.321	
1977	0.003	0.067	0.182	0.255	0.372	0.491	0.508	0.315	0.162	0.338	0.338	0.338	
1978	0.004	0.065	0.171	0.255	0.309	0.490	0.621	0.663	0.500	0.337	0.337	0.337	
1979	0.019	0.099	0.190	0.212	0.254	0.191	0.184	0.365	0.266	0.222	0.222	0.222	
1980	0.015	0.187	0.191	0.296	0.296	0.203	0.137	0.154	0.327	0.270	0.270	0.270	
1981	0.043	0.131	0.577	0.402	0.256	0.190	0.126	0.199	0.167	0.285	0.285	0.285	
1982[3]	0.013	0.159	0.200	0.260	0.260	0.260	0.260	0.260	0.260	0.260	0.260	0.260	
					STOCK SIZE (000's)							Total (Age 2+) Number	Total (Age 2+) Weight (adj)[4]
1973	57595	18124	19428	9508	3477	1950	909	939	833	186	73	113,022	176,125
1974	32685	45492	13401	10804	3908	1905	886	419	361	307	167	110,336	175,455
1975	43494	26207	30690	8365	5595	2010	1101	355	243	185	153	118,398	206,343
1976	52834	35301	18443	17553	5149	3096	1147	778	241	136	280	134,957	239,371
1977	64326	42792	26240	11876	10371	3108	1673	707	612	168	995	162,867	258,636
1978	51964	52636	32758	17907	7537	5854	1558	824	423	426	928	172,815	275,816
1979	13598	42402	40365	22600	11364	4531	2937	685	348	210	618	139,660	305,854
1980	26874	10923	31446	27333	14973	7215	3064	2002	390	218	344	124,782	315,077
1981	57120	21676	7418	21270	16653	9117	4824	2188	1405	230	549	142,450	321,599
1982	25793	44794	15567	3412	11650	10556	6171	3484	1468	974	936	124,804	296,738
1983	44500[5]	20845[6]	31283[6]	10435[6]	2154[6]	7354[6]	6664[6]	3896[6]	2199[6]	927[6]	615[6]	130,872	295,718

[1] Age 12+ values assumed equal to the mean for ages 5-11.

[2] Weighted by stock size (nos.).

[3] Values for age 2-4 determined from partial recruitment vector for 1973-1976, and 1979.

[4] Calculated from mean weight-at-age data in Table 11, adjusted by observed/calculated ratios.

[5] The observed 1973-80 mean at age 2.

[6] Calculated as $N_{i+1} = N_i e^{-Z_i}$.

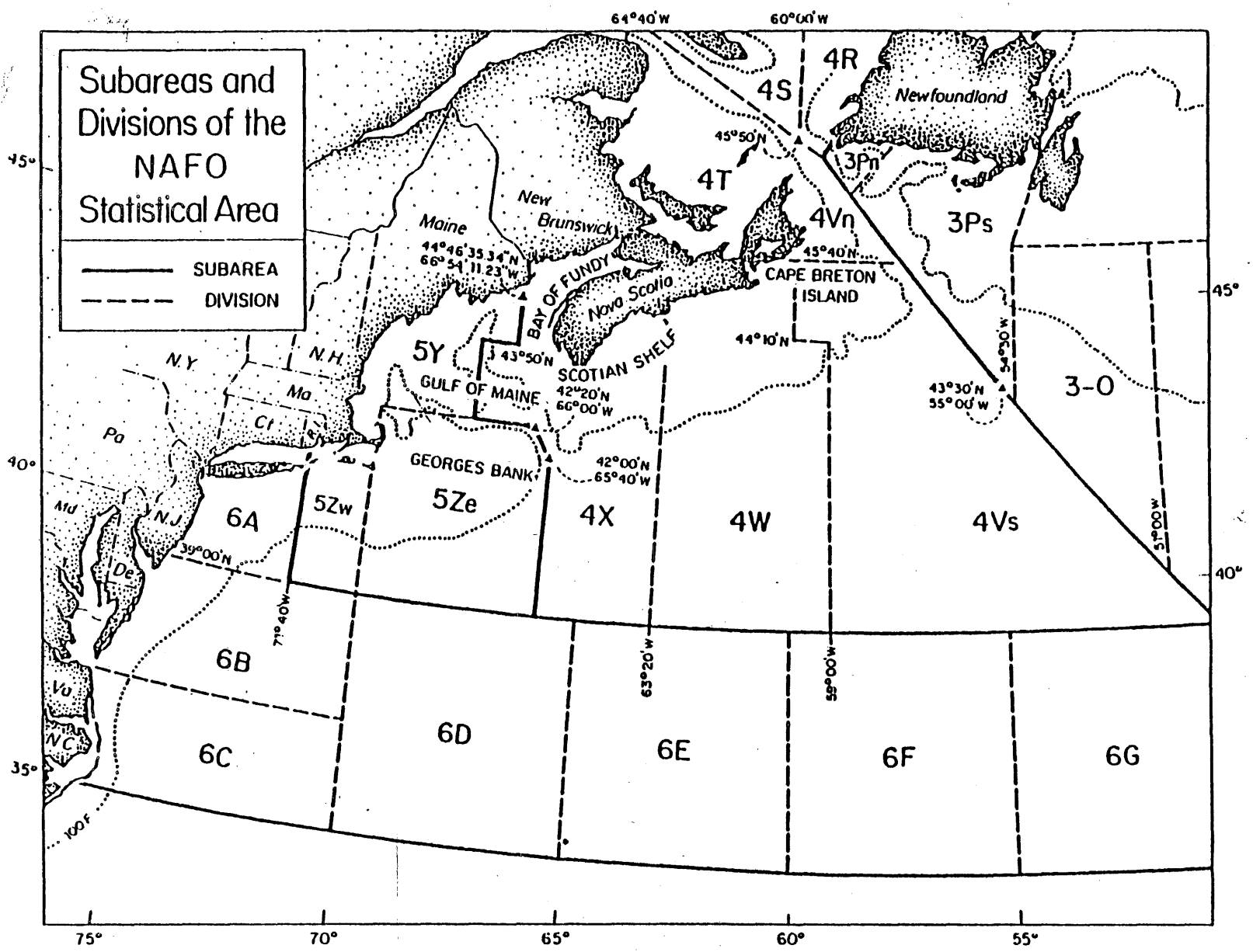


Figure 1. Northwest Atlantic, showing the southern portion of the NAFO area.

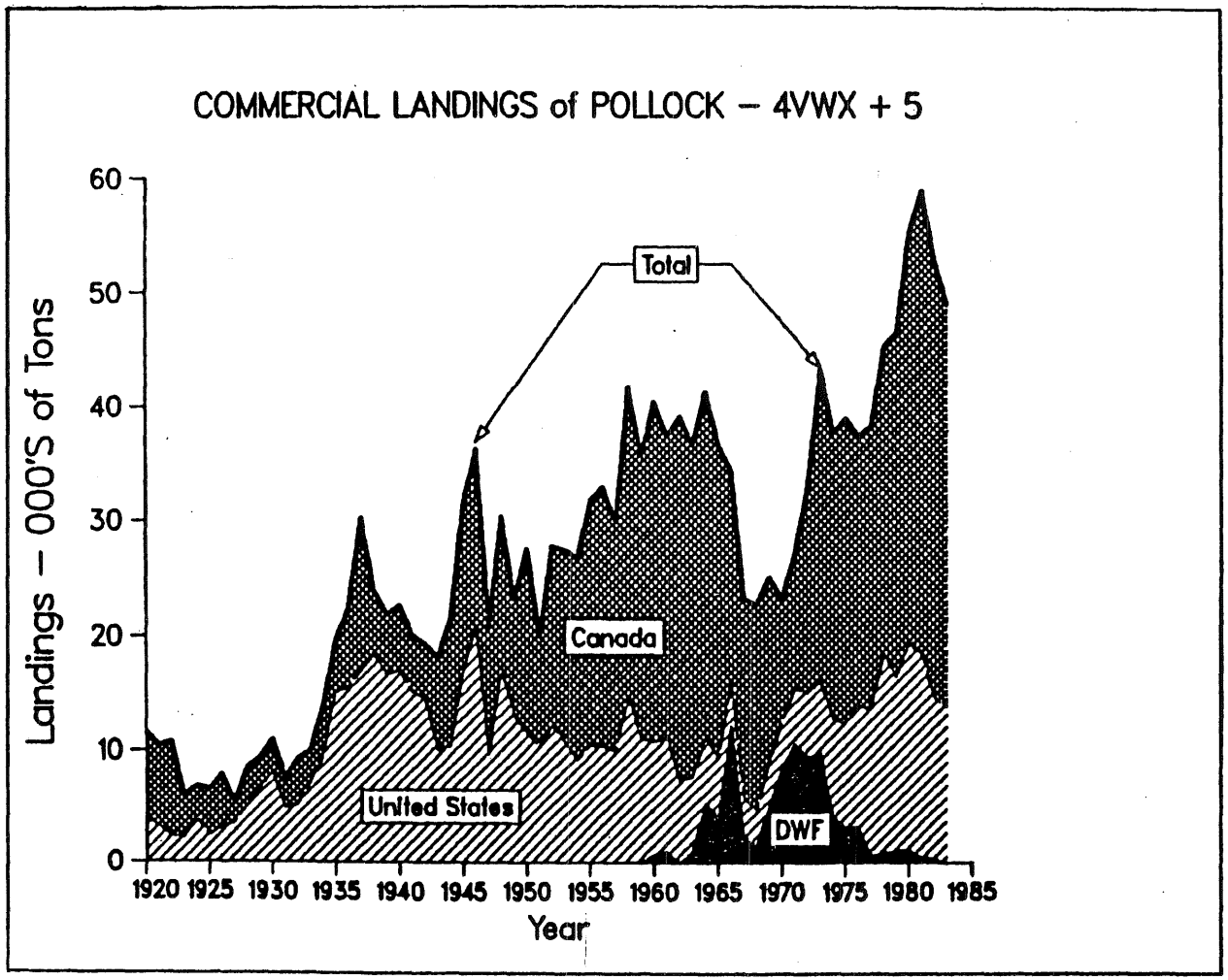


Figure 2. Commercial landings of pollock from the Scotian Shelf, Gulf of Maine, and Georges Bank regions (NAFO Divisions 4VWX and Subarea 5), 1920-1983.

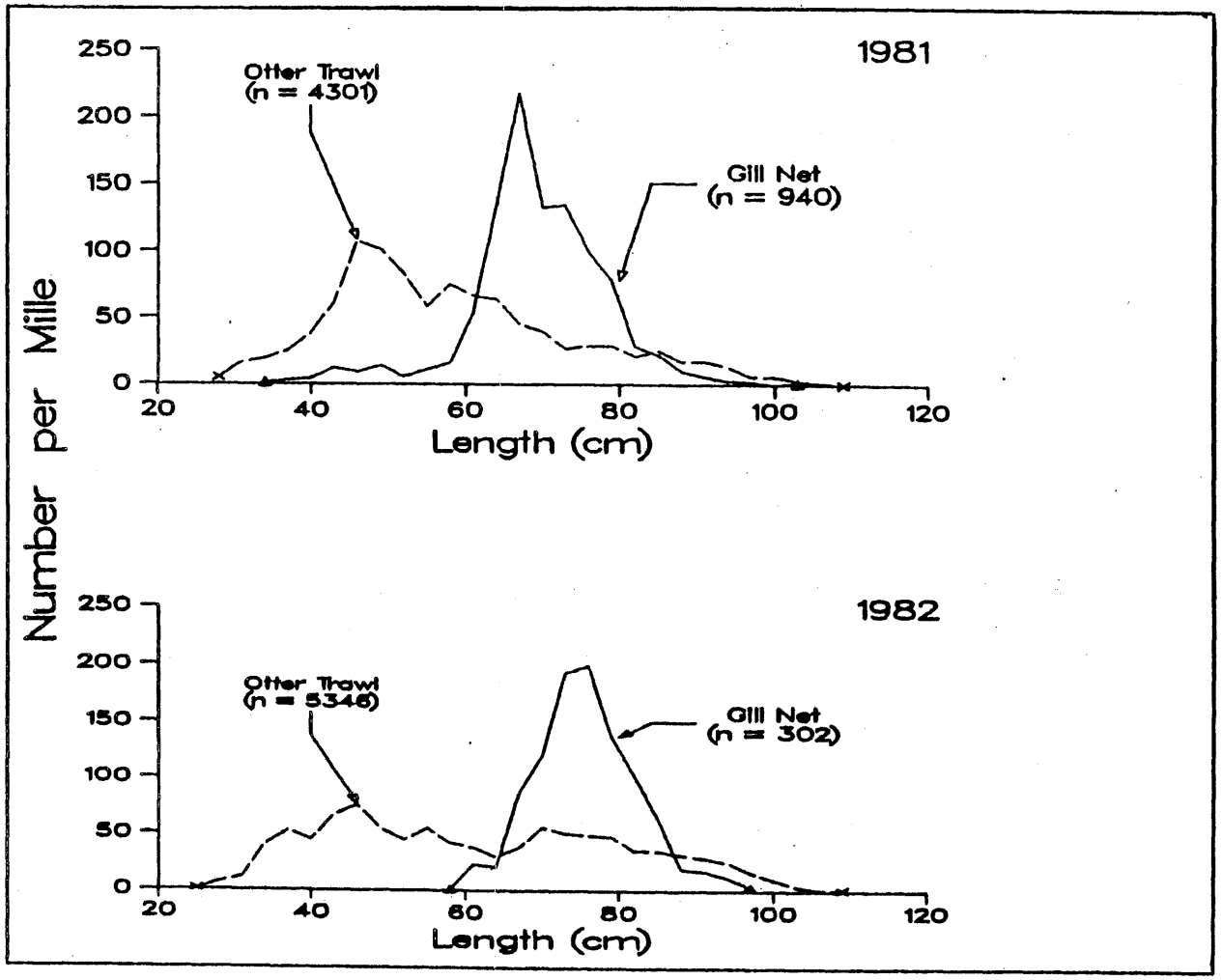


Figure 3. Length frequency distributions of pollock sampled in USA otter trawl and gillnet landings, summarized over all months, 1981-1982.

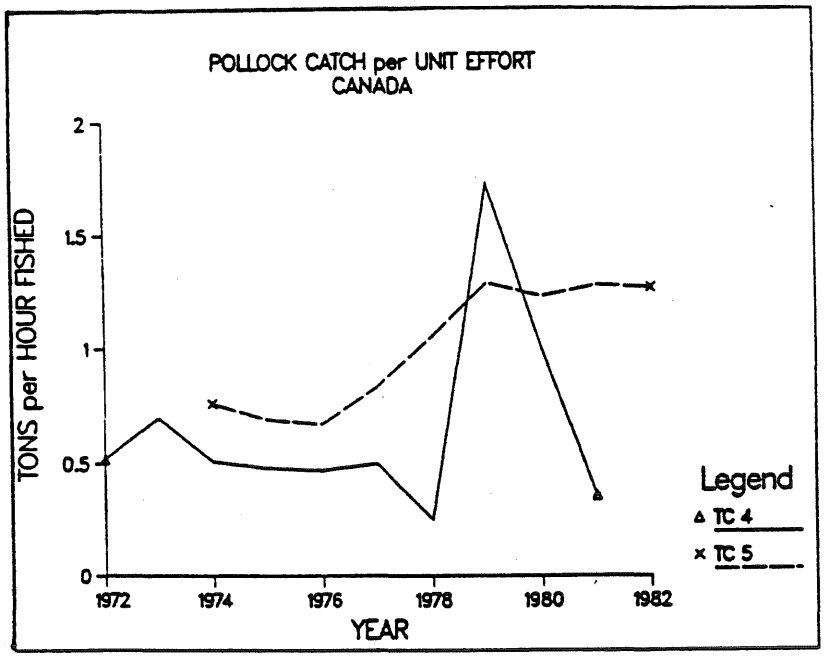


Figure 4. Commercial abundance indices for Scotian Shelf, Gulf of Maine, and Georges Bank pollock for Canadian tonnage class 4 and 5 otter trawlers, 1972-1982. Class 4 calculations based on June-August data and class 5 calculations based on January-June data for trips in which 50% or more of the total catch consisted of pollock.

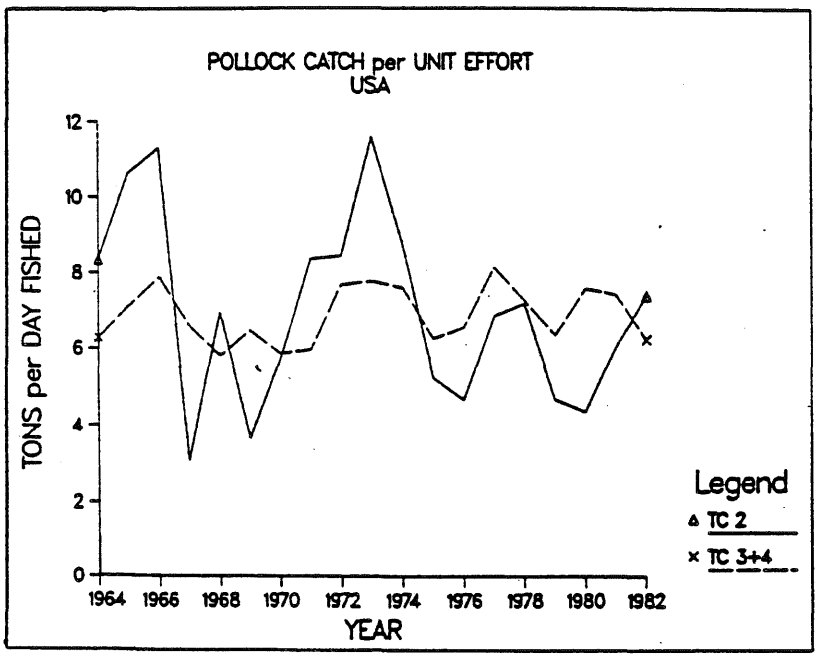


Figure 5. Commercial abundance indices for Scotian Shelf, Gulf of Maine, and Georges Bank pollock for USA tonnage class 2, 3, and 4 otter trawlers, 1964-1982. Calculations based on trip data for entire year for which 50% or more of the catch consisted of pollock.

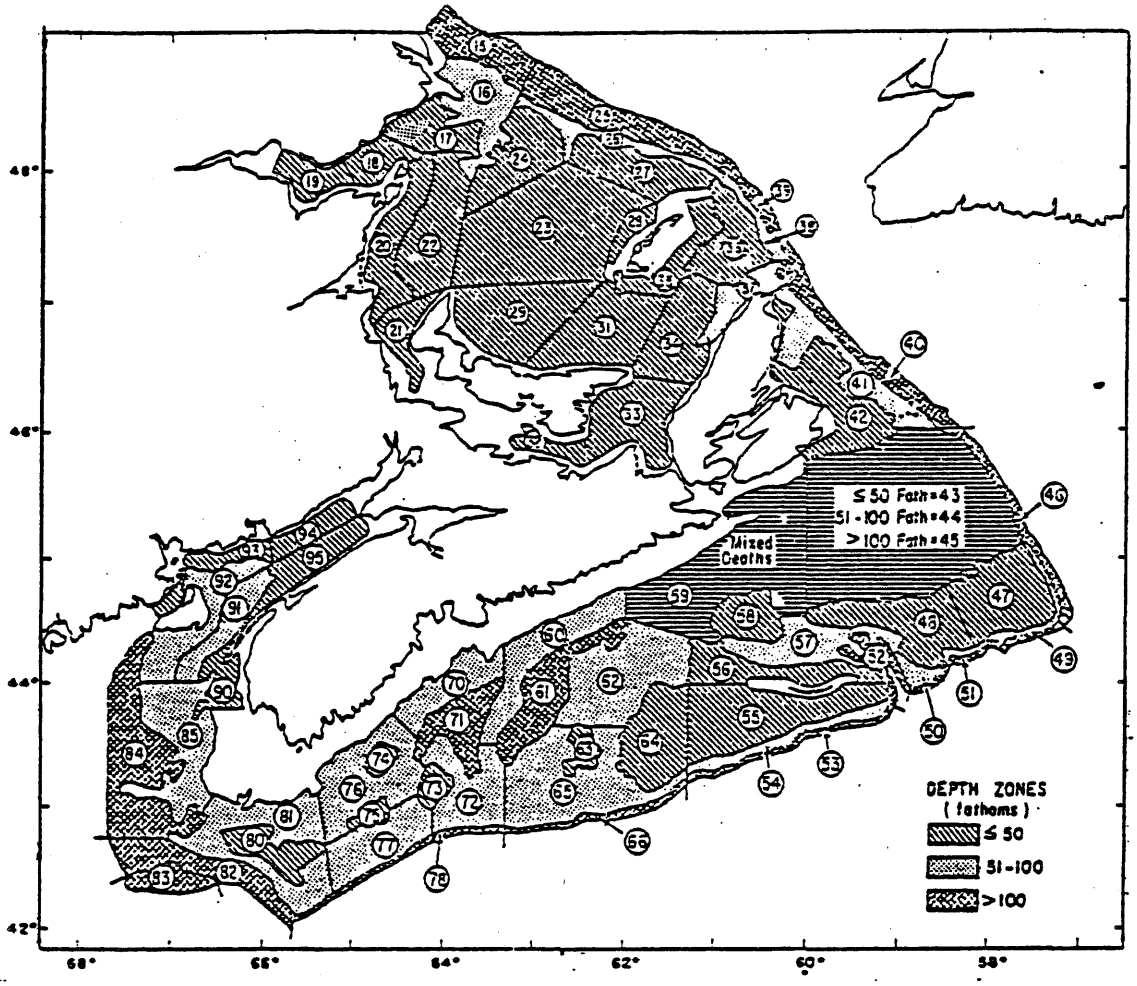


Figure 6. Strata used in Canadian summer bottom trawl surveys, 1970-1981.

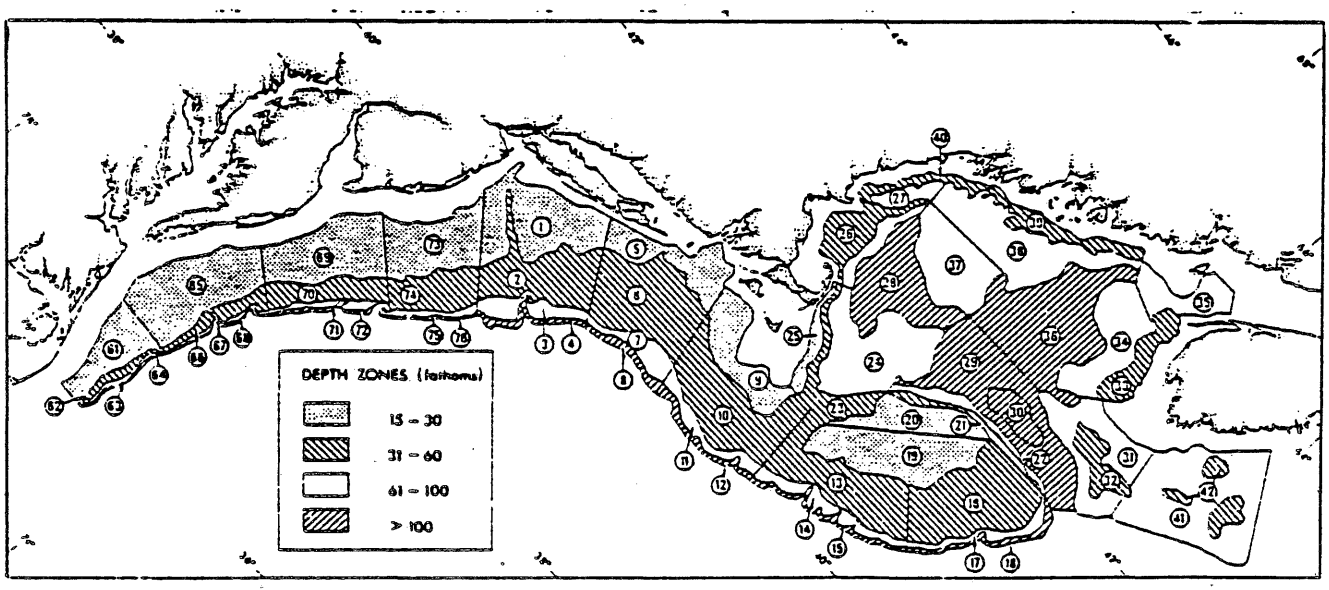


Figure 7. Strata used in USA spring and autumn bottom trawl surveys, 1963-1981.

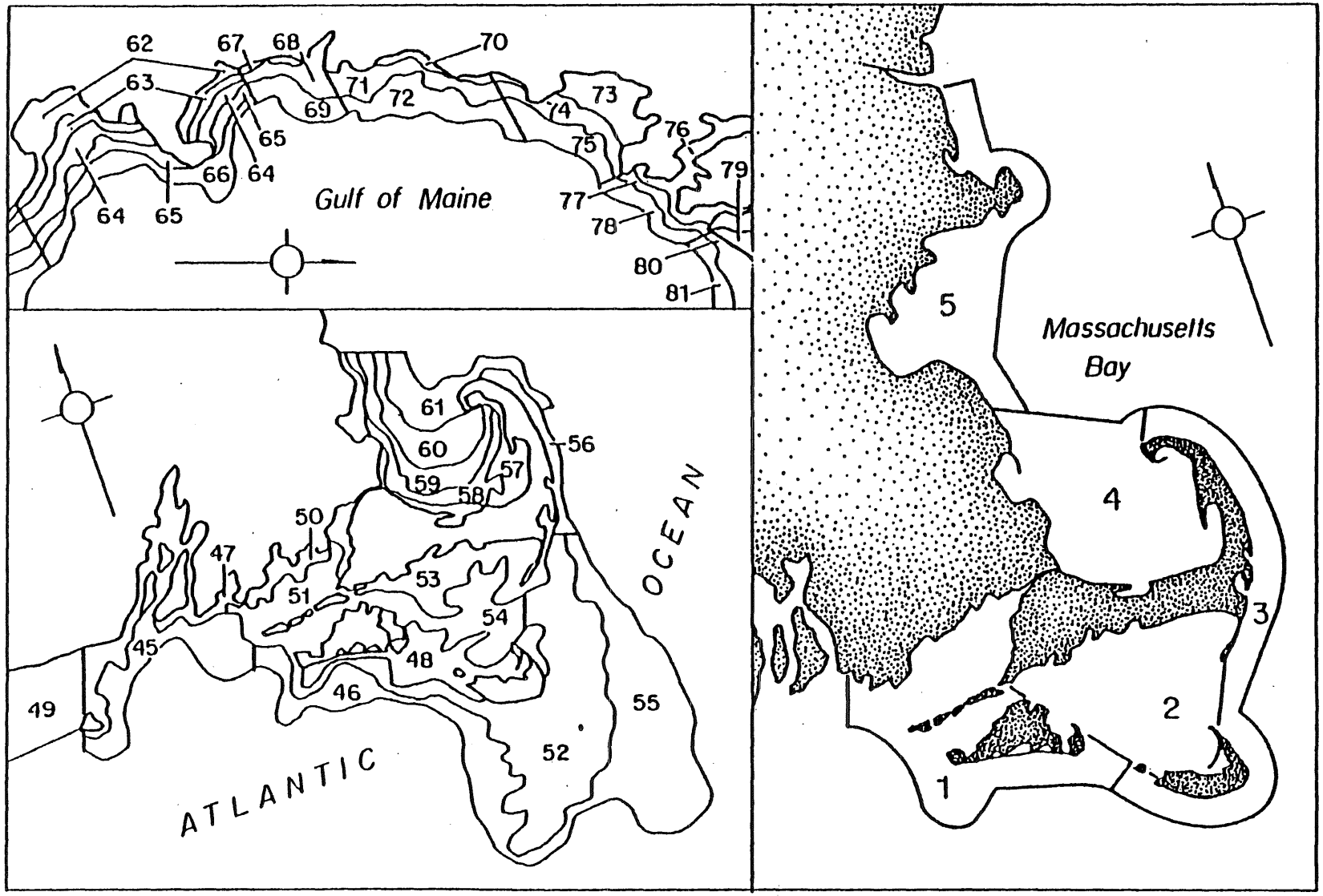


Figure 8. Strata used in NEFC inshore (<27m) spring, summer, and autumn bottom trawl surveys and strata groups used in Massachusetts spring and autumn inshore surveys.

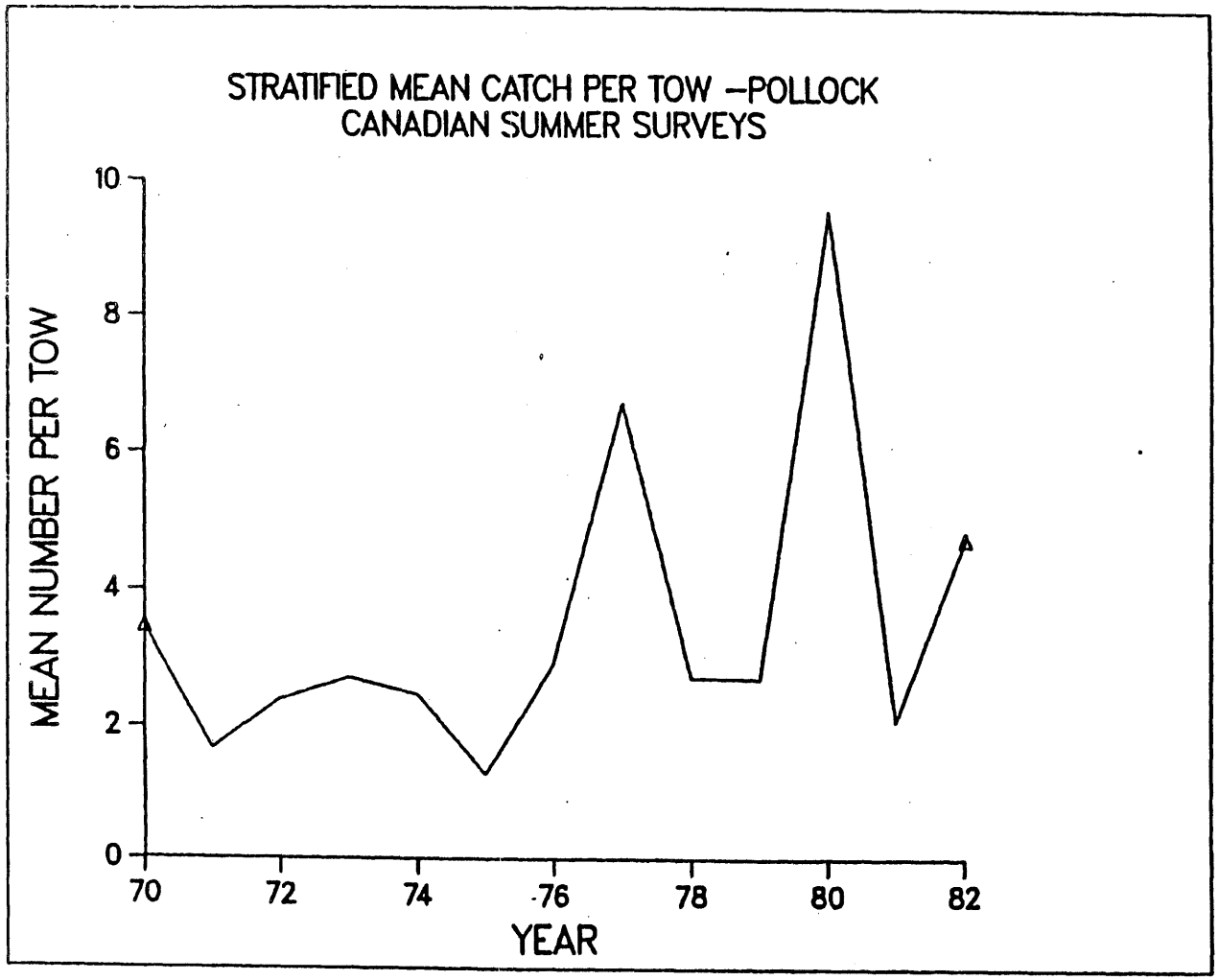
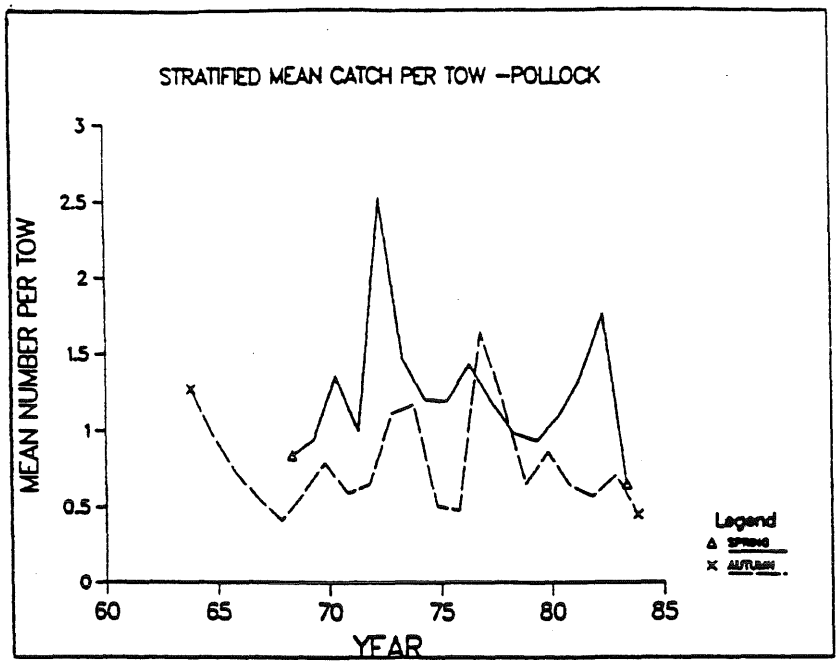


Figure 9. Stratified mean catch per tow (numbers) of pollock in Canadian summer bottom trawl surveys on the Scotian Shelf (Strata 43-95), 1970-1982.



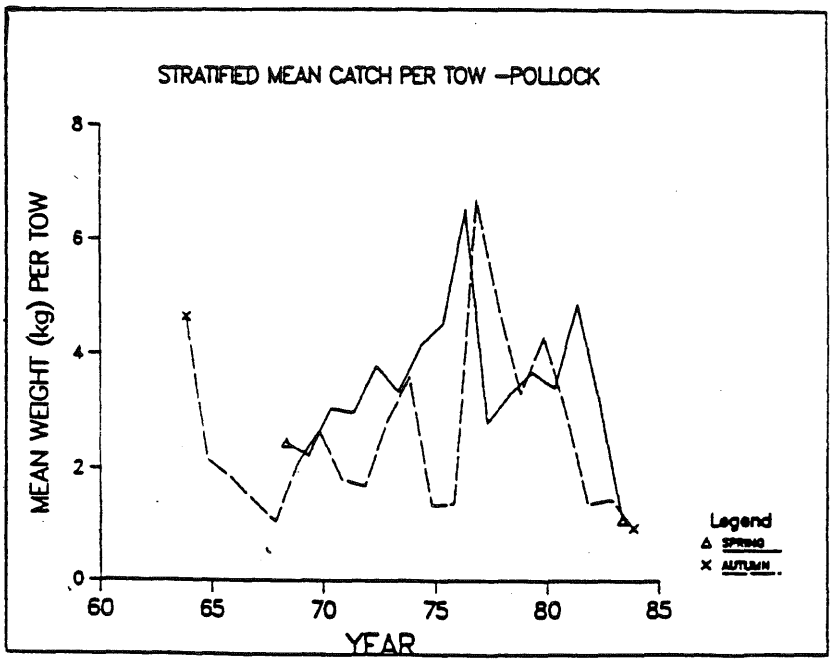


Figure 10. Stratified mean catch per tow in numbers and weight (kg, retransformed from logarithms) of pollock in USA spring and autumn bottom trawl surveys for Georges Bank, the Gulf of Maine and the Scotian Shelf (Strata 13-40), 1963-1983.

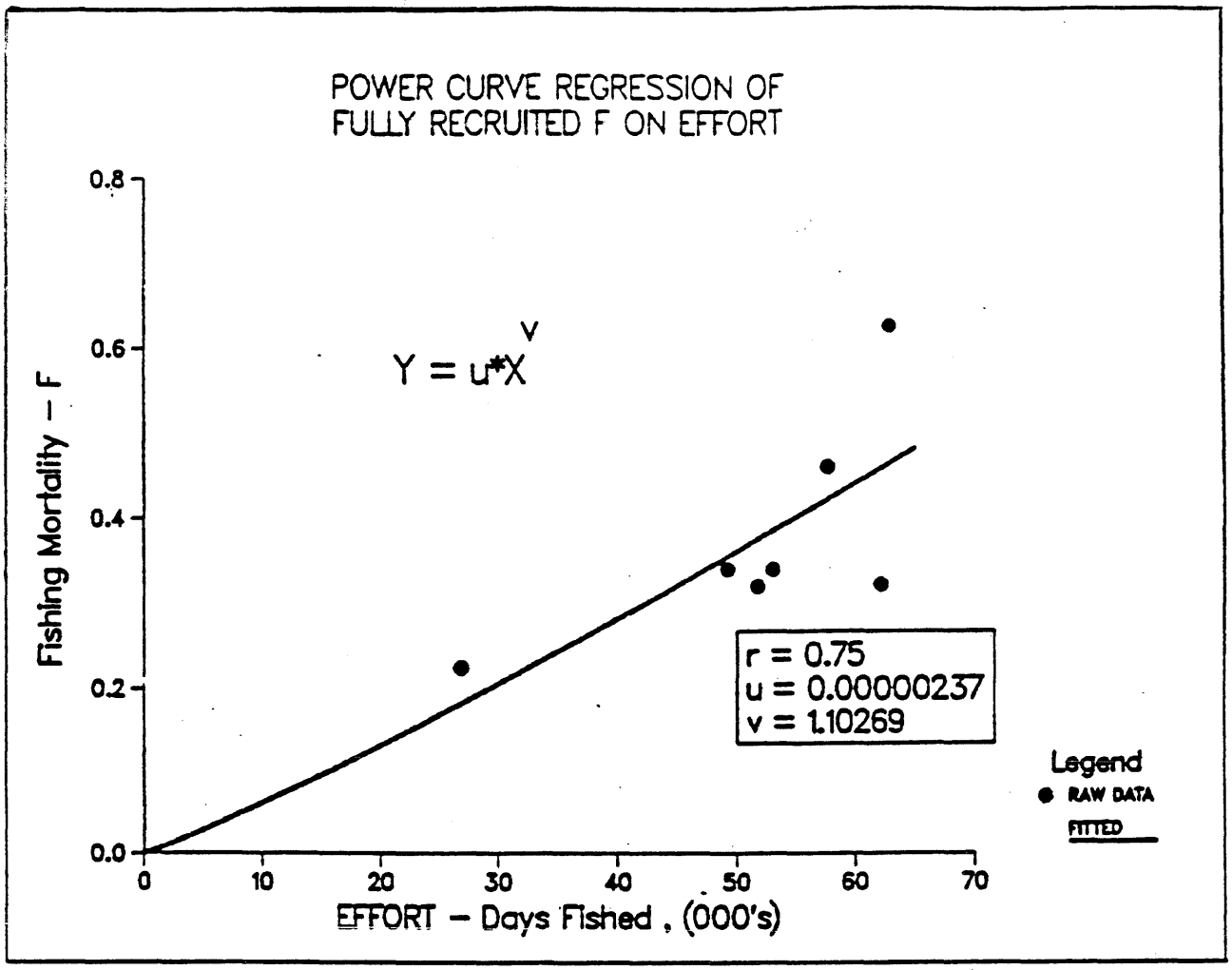


Figure 11. Regression of fully recruited (age 5+) instantaneous fishing mortality (F) from final VPA on age 5+ fishing effort from 1973 to 1979.