An Assessment of the Scotian Shelf, Gulf of Maine, and Georges Bank Pollock Stock

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INTRODUCTION

The pollock or saithe (Pollachius virens) has increased considerably in commercial importance in the Scotian Shelf, Gulf of Maine, and Georges Bank area since the last decade. This may be attributed at least in part to apparent shifts in directed effort in the USA and Canadian fisheries, e.g., catch limitations for cod and haddock implemented for 1977 by the New England Regional Fishery Management Council appear to have been a primary factor in the substantial increase in USA pollock landings observed for 1977 (13,038 tons) as compared to 1976 (10,863 tons). In addition, USA groundfishing activity appears to have increased in 1977 compared to 1976, and USA ex-vessel prices for pollock have also increased in recent years, providing an increased incentive to land this species.

Seasonal trends in commercial landings by area, results of previous tagging studies, and observed distributions of ripe adults, eggs, and larvae all suggest the existence of one major spawning area in the western Gulf of Maine, although some evidence also exists for limited spawning on the Scotian Shelf (Clark, Burns, and Halliday 1977). Accordingly, pollock in the Scotian Shelf - Georges Bank area have been considered as a unit in past assessments;

this approach has been maintained for purposes of the current assessment as no additional evidence exists relative to stock boundaries.

Pollock catches were entirely unregulated in the Northwest Atlantic prior to 1973, but in January of that year a 50,000 ton[1] total allowable catch (TAC) was approved for the area extending from the western portion of the Scotian Shelf to Georges Bank based on commercial and research vessel survey data (ICNAF Div. 4X and Subarea 5). This TAC level was subsequently revised to 55,000 tons for 1974 for the area including the Scotian Shelf from Cape Breton Island southward (ICNAF Divs. 4VWX and Subarea 5). This TAC was maintained for 1975 and 1976 but was reduced to 30,000 tons for 1977, the level corresponding to an instantaneous fishing mortality rate (F) equal to F_{max} (Clark, Burns, and Halliday 1977). Since USA withdrawal from ICNAF, however, a management plan has not been developed for the USA fishery; consequently, USA pollock landings were unregulated in 1977. Canadian landings totalled almost 25,000 tons in 1977 under an allocation of 20,975 tons. Landings data for 1973-1976 (Table 1) also indicate that previous TAC's implemented under ICNAF were not restrictive.

The present paper reviews the current status of the Scotian Shelf, Gulf of Maine and Georges Bank pollock stock and provides stock size estimates for 1980 corresponding to several catch options for 1979.

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

COMMERCIAL FISHERY

Landings for the Scotian Shelf, Gulf of Maine, and Georges Bank pollock stock have fluctuated considerably. Total commercial landings averaged 38,600 tons from 1960-1966, declined sharply to an average of 23,800 tons from 1968-1970, and subsequently increased to a peak of 43,200 tons in 1973; landings for 1974-1976 averaged 38,100 tons (Table 1). Provisional statistics for 1977 indicate landings approximately equal to the 1974-1976 average (38,100 tons). During 1960-1976, the bulk of the catch was taken on the Scotian Shelf, with most of the remainder being about evenly distributed between Georges Bank and the Gulf of Maine in most years (Table 2).

Historically, Canada and the USA have dominated this fishery. Canadian landings averaged 29,300 tons from 1960-1964 before declining to 10,800 tons in 1970; since that year, landings rose to an average of 25,500 tons from 1973-1976 (Table 1). USA landings declined from 10,300 tons in 1961 to 3,300 tons in 1968 but since that year have risen steadily and USA landings for 1977 were the highest recorded for any year since 1959 (Table 1). Most of the Canadian catch has been taken on the western Scotian Shelf, while the majority of the USA landings have come from the western Gulf of Maine. Distinct seasonal differences are evident between these areas in some years, i.e., Clark, Burns, and Halliday (1977) observed a summer peak in Canadian landings on the Scotian Shelf and a distinct winter peak in USA landings in the Gulf of Maine during 1972-1974 which they attributed to seasonal spawning movements.

The Canadian pollock fishery has been prosecuted primarily by otter-trawling (approximately 80% of Canadian landings in recent years have been taken by trawl gear). However, an increasing percentage of the Canadian catch is now being taken by gill-netting, i.e., the proportion of gill-net catches in Canadian landings increased from 2% in 1973 to 21% in 1976 (Cleary pers. comm.). Similarly, USA landings since 1970 have been taken primarily by otter trawling although the proportion taken by gill-netting has increased from 7% in 1970 to 37% in 1977 - a five-fold increase. Landings in both fisheries have been primarily incidental in nature although the proportion of the landed catch has increased in recent years; for the USA, the percentage of the total for trips in which pollock was landed has doubled since the mid-1960's (16% of the total in 1975-1977 as opposed to 8% of the total from 1964-1966). This apparently reflects both shifts in directed effort and gear changes.

In addition to Canada and the USA, the FRG and GDR, Spain, and the USSR have taken significant quantities on occasion (Table 1). The FRG and GDR have taken pollock both in directed fisheries in autumn and winter and as by-catch while fishing for mackerel and herring. USSR vessels have taken pollock incidentally in operations directed towards a variety of species, e.g., silver and red hake, herring, and mackerel. Spanish catches of pollock have been taken primarily as by-catch during directed fishing operations for cod. Other foreign nationals reporting catches of pollock from this area include Bulgaria, Cuba, Denmark, France, Italy, Iceland, Japan, Poland, and the United Kingdom.

Recreational data for this stock is limited, however, sport fish catches appear to have been of minor consequence in recent years. USA saltwater angling surveys have estimated recreational landings of 9,834, 4,240, and 2,533 tons for 1960, 1965, and 1970, respectively; however, the NMFS 1974 Regional Survey indicated a catch of only 500 tons. No Canadian recreational data are available and it is assumed that Canadian recreational catches are of minor significance (Halliday pers. comm.).

RESEARCH VESSEL SURVEY CATCHES

The USA has conducted bottom trawl surveys in autumn (since 1963) and spring (since 1968) in the area extending from Hudson Canyon to the southwestern Scotian Shelf (strata 1-42, Figure 1). Abundance indices for spring and autumn (stratified mean catch per tow in numbers and weight in kilograms) have been calculated for several strata sets (Table 3) and indices in terms of weight for spring (strata 13-42) and autumn (strata 24 and 26-42) are plotted in Figure 2. Data for Georges Bank were not included in the autumn plot as the bulk of the stock appears to be concentrated in the Gulf of Maine-Scotian Shelf area during that season (Table 3).

The spring data suggest a decline in abundance since 1968 (Figure 2) although trends may have been biased by the 1.7-1 conversion factor used to adjust for differences in fishing power between the "36 Yankee" and "41 Yankee" trawls. From 1973-1977 the spring index has fluctuated without a definite trend (Figure 2) although the 1977 value was the lowest observed. The autumn index has fluctuated considerably with pronounced peaks in 1969

and again in 1976-1977; in particular, the 1976 index was approximately one order of magnitude higher than in 1975 and both the 1976 and 1977 values were substantially higher than the 1971-1975 average (Figure 2). Similarly, the Canadian summer bottom trawl survey abundance index (stratified mean number per tow) increased substantially in 1977 compared to 1976 (Cleary MS 1978). However, spring survey data and commercial data (discussed below) do not indicate such an increase; thus, the 1976-1977 peak may be attributable at least in part to changes in availability. An examination of catch rates on a per-stratum basis revealed that in 1976 and 1977 catches were extremely high in or adjacent to known spawning areas (Stratum 24 in 1976 and Stratum 26 in 1977, Figure 1) in comparison to the 1971-1975 period. This suggests that differences in timing of the annual spawning migration and/or variation in local movements may have resulted in availability differences between years. However, no correlation was observed between catch rates and temperature patterns, either on an areal basis or between years; consequently, the basis for such variation is uncertain at present.

To compensate for potential bias associated with high catch rates in certain strata, data were transformed to logarithms and stratified mean catch per tow values calculated using ln (kilograms +1) values for each tow; retransformed estimates of stratified mean catch per tow in original units were then calculated as suggested by Bliss (1967:128) according to the relation

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

where $E\bar{y}_{st}$ represents the estimated (re-transformed) stratified mean catch

per tow and $\bar{y}_{st}$ and S^2 represent the stratified mean and the estimated population variance, respectively, in logarithmic units. Resulting values are plotted in Figure 3. It appears that while the procedure was effective observed patterns for recent years remain essentially unchanged.

Stratified mean catch per tow at age data (numbers) for USA spring (1973-1977) and autumn (1970-1977) bottom trawl surveys (Strata 13-42 and 24 and 26-42, respectively) are given in Tables 4 and 5. These data agree in indicating the 1971 year-class to be the strongest in recent years although the 1969 and 1970 year-classes also appear to have been at least moderately strong. These observations are in general agreement with results reported in Canadian surveys (Cleary MS 1978). Succeeding year-classes generally appear to have been weaker although the 1972 and 1973 year-classes show up more strongly in the autumn survey data than in the spring (Tables 4 and 5). The sharp increase in the autumn survey abundance index observed in 1976 (Table 3) appears to be largely attributable to increased catches of 1971 year-class fish (Table 5).

COMMERCIAL CATCH RATES

Commercial catch rates (metric tons per day fished) were calculated by tonnage class for USA otter trawlers in the Georges Bank - Scotian Shelf area for 1964-1977 (Table 6, Figures 4 and 5). Analyses include (1) data for all trips in which pollock were landed, and (2) data for "directed" trips, i.e., trips for which 50% or more of the total landed catch consisted of pollock. Data for "small" otter trawlers (0-50 GT) are consistent in indicating a

decline in relative abundance in the late 1960's, followed by a pronounced increase (Figures 4 and 5) to a peak level in 1973; since that year, catches have generally declined although catch rates in 1977 increased over 1976 values in both cases. For medium and large otter trawlers (51-500 GT) the trend for all trip data was generally similar to that for smaller vessels (Figure 4) although catch rates for directed trips were more constant (Figure 5). Again, however, directed catch rates increased in 1977 as compared to 1976. Directed catch rates for Canadian stern trawlers of 501-900 GT gradually declined from 0.85 tons per hour in 1973 to 0.57 tons per hour in 1976; however, catch rates for all Canadian vessels (fishing for groundfish) increased from 0.18 tons per hour in 1973 to 0.35 tons per hour in 1975 before declining to 0.22 tons per hour in 1976 (Cleary MS 1978).

MORTALITY RATES

No estimates of instantaneous natural mortality (M) are currently available for this stock. Accordingly, a value of M = 0.20 has been assumed in the current assessment as has been done in recent assessments of pollock stocks in the northeast Atlantic (ICES MS 1978).

Estimates of instantaneous total mortality (Z) calculated from USA spring and autumn bottom trawl survey catch at age data (Tables 5 and 6) are given in Table 7. Calculations were performed for fully recruited age groups (full recruitment assumed at age 5); spring survey values were calculated only for 1973-1977 data due to gear differences between this period and earlier years.

The calculated Z values for spring data (Table 7) fluctuate considerably with no clear trend. Estimates calculated from autumn survey data appear to indicate an increase in recent years; assuming M = 0.2 for this stock (ICES MS 1978), estimates for 1973-1975 imply an F level of 0.40-0.65, somewhat above F_{max} = 0.37. Fluctuations for more recent years (Table 7) may relate to changes in availability as discussed above. Estimates for the 1973-1975 period calculated from Canadian summer bottom trawl survey data were substantially higher than for the USA survey although estimates calculated for succeeding years were negative (Cleary MS 1978).

GROWTH

A sample of 3,122 otoliths collected during USA spring and autumn bottom trawl surveys from Georges Bank to the Scotian Shelf during 1970-1976 was used to evaluate pollock growth. Ages were coded relative to survey scheduling by assuming a January 1 birth date, e.g., a pollock hatched in January was assumed to be 0.3 years old during the spring survey (April-May) and 0.8 years old during the following autumn (October-November). The Von Bertalanffy growth equation was then fitted to the length at age data using the method of Tomlinson for unequal sample sizes and age intervals (Program TCPC 1, Psaropulos, pers. comm.). The resulting relationship

$$l_t = 97.77\ (1-e^{-0.2149(t-0.4087)})$$

where l_t = fork length in centimeters at time t agrees closely with results of earlier analyses for this stock (Clark, Burns, and Halliday 1977). Calculated lengths at age generated from this equation agreed reasonably well with values reported

by other investigators for the Gulf of Maine - Scotian Shelf area (Bigelow and Schroeder 1953; Hoberman and Jensen 1962; Steele 1963).

YIELD PER RECRUIT

Hylen (1969) estimated a selection factor of 3.79 for pollock using polypropylene mesh cod ends; this provides a 50% selection length (l_c) of 49 cm for a mesh size of 130 mm, which from the above growth equation implies a mean age at recruitment (t_c) of 3.5 years. However, increased gill-netting activity in recent years implies that mean age at recruitment may be increasing.

Yield per recruit curves were calculated for this stock using the Beverton-Holt model for t_c values of 3.0, 3.5, and 4.0 assuming W_∞=10.46 kg, k = 0.2149, t_0 = 0.4087, t_r = 2.0 years, t_λ = 20 years, and M = 0.2. Values of F providing maximum yield per recruit (F_{max}) were calculated as 0.31, 0.37, and 0.46, respectively; corresponding figures for $F_{0.1}$ were 0.18, 0.20, and 0.22 (Figure 6).

COMMERCIAL CATCH AGE COMPOSITION

Commercial sampling does not appear to have been adequate for assessment purposes prior to 1973. Length-frequency samples are available for Canadian catches for nearly all months since the beginning of that year; also, Canadian age-length keys are available at least by quarter from 1973-1975 and for most months thereafter. USA coverage during 1973-1976 was confined to occasional length-frequency sampling. Sampling of the distant-water fleet catch since the beginning of 1973 has been very limited and includes only length-frequency samples by the USSR in March, April, and August of 1973 and in April of 1975.

Examination of available sample data for the USA and Canadian fisheries revealed substantial differences in age composition in 1973 and 1974; USA samples usually included a substantially higher percentage of younger fish than did the Canadian sample data. Consequently, numbers landed at age for the USA fishery for 1973-1974 were obtained by applying USA length-frequency sample data and Canadian age-length keys to USA landings on a quarterly basis, while Canadian length-frequency data and age-length keys were applied to Canadian landings. In succeeding years, USA and Canadian length-frequency sample data usually agreed closely and numbers landed at age were derived on a monthly basis by applying USA and Canadian length-frequency samples and Canadian age-length keys to respective monthly landings for each country (USA age-length keys were applied to USA catches in 1977). For months in which USA length-frequency samples were not available, Canadian length-frequency data were used and vice versa; Canadian length-frequency samples and age-length keys were also applied routinely to catches by distant water fleets as the bulk of the distant-water catch from 1973-1976 was taken in the Scotian Shelf area.

Mean weight at age data for this stock appear in Table 8. For 1973-1976, these values were obtained by applying Canadian length-weight equations obtained from annual summer bottom trawl surveys to commercial mean lengths at age; for 1977, Canadian and USA length-weight equations were applied independently and weighted averages calculated based on respective tonnages landed. Summarized data for all countries (Table 9) reveal that the catch has been

dominated by age 3-5 fish in recent years, with the bulk of the catch consisting of ages 3 and 4. This in part reflects the presence of the relatively strong 1969 and 1971 year-classes.

COHORT ANALYSIS

Cohort analysis (Pope 1972) was applied to the above catch at age data to estimate instantaneous fishing mortality (F) and stock sizes for 1973-1976. Use of this technique in turn required analyses to determine fishing mortality for fully recruited year-classes in 1977 as well as estimate of recruiting year-class strength. Such analyses were hampered by the limited time series of commercial catch at age data available and variability in catch at age data in research vessel surveys. Available evidence suggest a current trend towards increased abundance implying a lower starting F value than used in previous assessments; however, availability changes may also have been involved as discussed above. A more thorough evaluation of the situation does not appear possible until the commercial and survey catch at age data time series are expanded.

Fishing Mortality in 1977

Accuracy in the determination of F for 1977 was obviously critical due to the short time series involved. In some situations estimates may be obtained by relating effort determined either from commercial or from survey data to fishing mortality, but there is no basis for such a relationship in the present case due to the incidental nature of the fishery and possible changes in availability as discussed above. Accordingly, the assumption was made that

since (1) there was evidence for above average recruitment in recent years, (2) catches during 1975-1977 were relatively constant, and (3) no consistent trends in abundance were evident from research vessel surveys during this period, fishing mortality should also have been relatively constant and lower than in 1973-1974. An initial approximation of F was made by plotting $\log_e$ numbers caught versus age for the 1965-1971 year-classes; a linear regression was then calculated through fully recruited ages for each to obtain an estimate of Z (slope of regression line). Catches were extrapolated for several years beyond 1977 and a cohort analysis performed using the observed and extrapolated catches and a starting F equal to Z - 0.2 (Anderson MS 1975). A weighted[1] F value of 0.337 was obtained for 1977; use of this value as the starting F in a second cohort analysis resulted in an estimated weighted F value of 0.292 for 1975-1976. This was used as the starting F in a third cohort analysis which provided an estimate of 0.264 for 1975-1976. A fourth and final cohort analysis using this value as the starting F resulted in an estimate of 0.246 for 1975-1976; as this change was not appreciable, the above estimate of 0.264 was accepted as the starting F for the 1965-1972 year-classes. For earlier year-classes, starting F values were obtained by weighting values for fully recruited year-classes (age 5+) by stock size (Table 9). Starting F values for the 1973-1975 year-classes were obtained from known catch at age data and stock size estimates generated from analyses of USA and Canadian survey data (discussed below).

[1]By stock size

Recruitment Estimates

Recruitment estimates were obtained from examination of and/or empirical relationships between USA and Canadian survey catch at age data and stock size estimates generated from cohort analysis (Table 9). Estimated stock sizes at age for the 1971 and 1972 year-classes were available from Table 9; estimates for the 1968-1970 year-classes were obtained where necessary by back-calculation utilizing the appropriate stock size at age data and mortality rates in Table 9 and partial recruitment coefficients calculated for the 1971-1972 year-classes. Estimates of stock size at age 2 ranged from 29.3 million fish for the 1970 year-class to 60.5 million fish for the 1971 year-class; the average was 43.8 million fish.

In general, there was no relation between stock size estimates obtained as above and USA autumn survey catch per tow at age data, while the USA spring survey data series appeared too short for purposes of the present assessment. The relation between calculated stock sizes at age and Canadian survey catch per tow data was reasonably good for ages 3 and 4 ($r = 0.84$ and 0.97, respectively). A linear regression of stock size at age 4 on Canadian survey catch per tow data provided an estimate of 21.5 million fish at age 4 for the 1973 year-class which was used with the known catch at age to generate a starting F value for this year-class (Table 9). For the 1974 year-class, a similar procedure provided an estimate of 43 million fish at age 3; however, USA survey data and a regression of age 2 stock size on Canadian survey data suggest this year-class to be somewhat weaker, and USA survey data appear

consistent in indicating it to be one-half the size of the 1971 year-class. Accordingly, a compromise estimate of 35 million fish at age 2 was accepted. Little information was available for the 1975 year-class other than data from the USA and Canadian surveys suggesting this year-class to be one-half or less than one-half of the strength of the 1971 year-class, and accordingly an estimate of 30 million fish was accepted.

Results of the cohort analysis (Table 9) under the above assumptions of starting F and year-class strength indicate an increase in stock size (age 2+) of from 200,300 tons in 1973 to 247,100 tons in 1976, followed by a decline to 228,300 tons in 1977. Spawning stock size (calculated as 25% of age 4 fish, 75% of age 5 fish, and 100% of all older ages) increased more or less continually from 90,200 tons in 1973 to 134,900 tons in 1977. Fishing mortality appears to have fluctuated between $F_{0.1}$ (0.20) and F_{max} (0.37) in recent years.

CATCH AND STOCK SIZE PROJECTIONS

A total biomass of 235,400 tons was estimated for this stock at the beginning of 1978 (Table 9). The above assumptions relative to fully recruited F and recruiting year-class size in 1977 imply partial recruitment coefficients of 2.2, 34.6, 92.6, and 100% at ages 2-5, respectively. Equilibrium yield calculations assuming average recruitment at age 2 and the above partial recruitment coefficients indicate F_{max} = 0.363, very close to the above F_{max} value of 0.37 obtained from the Beverton-Holt model.

Catch projections for 1979 and resulting stock size estimates for 1980 appear in Table 10. No information is currently available relative to size of the 1976 and 1977 year-classes, and accordingly average recruitment of 43.8 million fish at age 2 has been assumed in both cases. A catch of 40,000 tons has been assumed for 1978 as current catch levels are somewhat higher than at the same time last year.

Under the above assumption fishing at F_{max} = 0.37 in 1979 would provide a catch of 51,600 tons with a slight decrease in stock size in 1980; fishing at $F_{0.1}$ would provide a catch of 30,000 tons with an 8.9% increase in stock size. A catch of 37,000 tons in 1979 would hold fishing mortality at or about current levels and should in addition allow a modest increase in biomass.

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Table 1. Pollock landings (metric tons, live) for the Scotian Shelf, Gulf of Maine, Georges Bank, and Southern New England - Middle Atlantic area by country[1], 1960-1977.

Year	Country									
	Canada	Fed. Rep. Germany	German Dem. Rep.	Japan	Spain	USSR	United Kingdom	U.S.A.	Other[2]	Total
1960	29,470	-	-	-	783	-	-	10,132	1	40,386
1961	26,323	-	-	-	982	-	-	10,265	1	37,571
1962	31,721	-	-	-	-	-	-	7,391	-	39,112
1963	28,999	126	-	-	-	906	28	6,653	-	36,712
1964	30,007	208	-	-	-	4,603	374	6,006	55	41,253
1965	27,316	71	-	-	1,361	2,667	11	5,303	-	36,729
1966	18,271	-	-	-	2,384	9,865	12	3,791	-	34,323
1967	17,567	-	4	-	1,779	644	1	3,312	-	23,307
1968	18,062	-	-	-	1,128	372	-	3,280	7	22,849
1969	15,968	1,188	2,195	-	1,515	227	-	3,945	7	25,045
1970	10,753	3,233	4,317	40	532	527	-	3,979	-	23,381
1971	11,757	633	6,849	15	912	2,216	-	4,890	3	27,275
1972	18,022	475	4,816	8	616	3,495	4	5,729	54	33,219
1973	26,990	1,124	948	1,570	3,113	3,092	-	6,303	36	43,176
1974	24,975	149	2	40	1,500	2,348	48	8,726	14	37,802
1975	26,548	236	96	-	709	2,004	-	9,318	124	39,035
1976	23,568	994	24	-	303	1,466	-	10,863	390	37,608
1977[3]	24,962		4			5		13,038	71	38,080

[1]As reported to ICNAF for Divisions 4VWX, Subarea 5 and Statistical Area 6.

[2]Includes Bulgaria, Cuba, Denmark, France, Italy, Iceland and Poland.

[3]Provisional

Table 2. Pollock landings (metric tons, live) for the Scotian Shelf, the Gulf of Maine, Georges Bank, and the southern New England - Middle Atlantic area[1], 1960-1976.

Year	Area				
	Scotian Shelf	Gulf of Maine	Georges[2] Bank	Southern New England-Middle Atlantic	Total
1960	29,989	6,545	3,852	-	40,386
1961	29,352	5,017	3,202	-	37,571
1962	32,961	2,560	3,591	-	39,112
1963	30,471	2,168	3,957	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	1,728	6,790	2	23,307
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	7,016	7,154	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	6,441	6,915	26	37,608

1 As reported to ICNAF for Divisions 4VWX, Division 5Y, Subdivision 5Ze, and Subdivision 5Zw and Statistical Area 6, respectively.

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

Table 3. Stratified mean catch per tow in numbers and weight (kg) of pollock taken in USA spring and autumn bottom trawl surveys from Georges Bank to the Scotian Shelf, 1963-1977.

Year	Georges Bank[1] (Strata 13-23 & 25)		Gulf of Maine[1] (Strata 24, 26-30,36-40)		Scotian Shelf[1] (Strata 31-35,41 & 42)		All areas combined (Strata 13-42)	
	Number	Weight(kg)	Number	Weight(kg)	Number	Weight(kg)	Number	Weight(kg)
				Spring				
1968	(0.5)	(2.89)	(2.9)	(11.21)	(1.1)	(4.53)	(1.8)	(7.16)
1969	(0.6)	(2.18)	(2.2)	(5.53)	(7.1)	(24.77)	(2.9)	(9.25)
1970	(0.9)	(2.07)	(2.9)	(12.27)	(6.5)	(5.78)	(3.2)	(7.73)
1971	(0.9)	(1.98)	(1.8)	(7.42)	(5.1)	(12.08)	(2.3)	(6.98)
1972	(9.7)	(5.80)	(3.8)	(9.61)	(9.8)	(11.09)	(7.0)	(8.87)
1973	7.9	5.77	2.5	4.45	6.3	6.54	5.0	5.34
1974	1.9	3.23	1.0	4.21	4.6	15.87	2.1	6.77
1975	1.7	4.60	1.2	5.81	3.5	10.19	1.7	5.90
1976	1.9	7.44	1.6	7.68	2.0	4.59	1.8	6.86
1977	2.2	3.00	1.3	3.28	1.7	4.85	1.6	3.44
				Autumn				
1963	0.3	1.08	2.1	8.61	1.9	6.23	1.5	5.79
1964	0.7	2.15	2.7	7.07	0.2	0.24	1.6	4.40
1965	0.3	1.13	1.1	3.70	0.5	1.69	0.8	2.46
1966	1.8	3.02	0.7	2.31	0.2	0.94	0.9	2.18
1967	0.3	0.92	0.7	2.76	0.3	0.33	0.5	1.63
1968	0.1	0.47	1.1	5.22	0.5	1.43	0.7	2.92
1969	0.2	0.35	2.3	12.27	3.7	22.11	2.0	11.22
1970	0.2	0.20	0.8	3.37	0.7	3.27	0.6	2.43
1971	1.0	1.34	0.9	5.63	1.1	2.47	1.0	3.61
1972	0.7	0.55	2.1	7.67	4.3	4.21	2.2	4.76
1973	0.3	0.45	1.4	6.05	3.4	6.27	1.6	4.48
1974	0.1	0.21	1.6	5.52	0.6	2.56	0.9	3.26
1975	0.1	0.14	1.1	3.34	0.5	1.41	0.7	1.94
1976	0.1	0.16	6.9	31.14	0.5	2.89	3.7	16.66
1977	1.3	1.68	3.0	14.39	0.7	3.10	1.9	7.95

[1] ICNAF Subdivision 5Ze, Division 5Y, and Division 4X, respectively.

[2] Values in parentheses obtained by applying a 1.7 to 1 conversion factor to adjust for differences in surface area between the "36 Yankee" and the "41 Yankee" trawls.

Table 4 . Stratified mean catch per tow in numbers at age for pollock in USA spring bottom trawl surveys, Georges Bank to Scotian Shelf (Strata 13-42), 1973-1977.[1]

Year	Age														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+
1973	0.00	0.01	3.62	0.62	0.15	0.13	0.04	0.02	0.10	0.03	0.11	0.02	0.01	0.01	0.08
1974	0.00	0.03	0.09	0.48	0.25	0.39	0.50	0.10	0.04	0.00	0.01	0.13	0.01	0.02	0.10
1975	0.00	0.02	0.33	0.20	0.34	0.08	0.09	0.10	0.08	0.05	0.06	0.02	0.08	0.07	0.14
1976	0.00	0.20	0.14	0.13	0.15	0.26	0.14	0.17	0.17	0.11	0.02	0.04	0.05	0.03	0.17
1977	0.00	0.14	0.38	0.23	0.06	0.16	0.32	0.13	0.11	0.02	0.02	0.01	0.00	0.01	0.03

[1]Includes data for years in which the "41 Yankee" trawl was used.

Table 5. Stratified mean catch per tow in numbers at age for pollock in USA autumn bottom trawl surveys, Gulf of Maine to Scotian Shelf (Strata 24 and 26-42), 1970-1977.

	AGE														
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14+
1970	0.01	0.15	0.06	0.03	0.10	0.10	0.10	0.05	0.04	0.01	0.03	0.01	0.00	0.04	0.05
1971	0.03	0.14	0.24	0.07	0.01	0.08	0.12	0.05	0.10	0.03	0.01	0.01	0.02	0.02	0.08
1972	0.00	0.58	1.02	0.56	0.08	0.09	0.11	0.07	0.07	0.06	0.03	0.03	0.03	0.02	0.07
1973	0.00	0.04	0.88	0.13	0.22	0.15	0.16	0.11	0.07	0.00	0.18	0.02	0.01	0.05	0.07
1974	0.00	0.00	0.10	0.34	0.28	0.16	0.12	0.11	0.02	0.03	0.00	0.04	0.00	0.00	0.03
1975	0.02	0.28	0.07	0.05	0.13	0.06	0.06	0.08	0.06	0.02	0.01	0.01	0.00	0.01	0.03
1976	0.00	0.04	0.04	0.22	0.82	2.41	0.70	0.45	0.21	0.07	0.01	0.01	0.04	0.09	0.30
1977[1]	0.00	0.06	0.05	0.03	0.32	0.53	0.47	0.28	0.14	0.11	0.02	0.00	0.03	0.00	0.15

[1] Preliminary

Table 6 . Pollock catch rates (metric tons per day fished) by tonnage class for USA otter trawlers from Georges Bank to the Scotian Shelf, 1964-1977.

Year	0-50 GT		51-500 GT	
	All trips[1]	Directed trips[2]	All trips[1]	Directed trips[2]
1964	0.39	8.33	0.51	6.27
1965	0.60	10.62	0.45	7.09
1966	0.36	11.30	0.36	7.88
1967	0.22	3.09	0.30	6.60
1968	0.32	6.94	0.34	5.81
1969	0.20	3.66	0.62	6.47
1970	0.08	5.72	0.68	5.86
1971	0.22	8.36	0.68	5.97
1972	0.37	8.44	0.81	7.68
1973	0.60	11.59	0.79	7.77
1974	0.41	8.76	0.81	7.61
1975	0.26	5.25	0.69	6.27
1976	0.26	4.67	0.80	6.56
1977	0.33	6.87	0.67	8.15

[1]Includes data for all trips in which pollock were landed.

[2]Includes data for trips in which 50% or more of the landed weight consisted of pollock.

Table 7. Total mortality coefficients (Z) for pollock calculated from catch at age data in USA spring and autumn bottom trawl surveys, Georges Bank to Scotian Shelf[1].

Year	Spring[2] (Strata 13-42)	Autumn (Strata 24 and 26-42)
1970	-	-0.023
1971	-	0.059
1972	-	-0.144
1973	-0.504	0.851
1974	0.633	0.600
1975	-0.156	-1.710
1976	0.579	1.274
1977		
Pooled average	$\bar{0.182}$[3]	0.344[4]

[1]Calculated as $\ln \frac{(\Sigma \text{ ages 5 and older})}{(\Sigma \text{ ages 6 and older})}$, from data in Tables 5 and 6.

[2]Calculated only for years in which the "41 Yankee" trawl was used.

[3]Calculated as $\ln \frac{(\Sigma \text{ ages 5 and older 1973-1976})}{(\Sigma \text{ ages 6 and older 1974-1977})}$.

[4]Calculated as $\ln \frac{(\Sigma \text{ ages 5 and older 1970-1976})}{(\Sigma \text{ ages 6 and older 1971-1977})}$.

Table 8. Mean weight at age (kg) of pollock for Georges Bank, the Gulf of Maine, and the Scotian Shelf, 1973-1977[1].

	Age											
Year	2	3	4	5	6	7	8	9	10	11	12	13+[2]
1973	0.72	1.30	1.95	2.81	4.17	5.20	5.93	6.50	7.22	8.98	9.22	9.15
1974	0.81	1.44	2.18	3.07	4.10	5.10	6.11	6.68	7.27	8.01	8.65	8.01
1975	0.89	1.47	2.10	2.97	3.95	5.00	6.24	7.07	7.29	7.83	8.88	9.56
1976	0.81	1.51	2.21	2.93	3.70	4.51	5.22	6.41	7.38	7.42	7.29	8.03
1977	0.84	1.12	1.64	2.49	3.39	4.48	5.69	6.61	6.94	7.80	8.29	8.68

[1]Weights from 1973-1976 as reported by Cleary (MS 1978); values for 1977 represent averages calculated from USA and Canadian data, weighted by respective tonnages landed.

[2]Averages for ages 13-16 weighted by numbers at age in Canadian landings.

Table 9. Catch at age of pollock (thousands) from the Scotian Shelf to southern New England and fishing mortalities and stock sizes calculated from cohort analysis assuming M = 0.2.

Year	Age 2	3	4	5	6	7	8	9	10	11	12	13+	Numbers (000's)	Weight (tons) Observed	Weight (tons) Calculated[1]	Ratio obs/calc.
Catch																
1973	1856	1596	5684	4341	1049	795	363	457	421	79	28	3	16672	43176	44359	0.97
1974	617	7283	2989	3569	1295	509	415	112	123	103	40	16	17071	37802	41892	0.90
1975	415	3596	8808	1755	1591	544	137	53	69	46	23	14	17051	39035	40779	0.96
1976	515	2955	3583	4457	1232	957	257	28	37	33	18	52	14124	37608	37308	1.01
1977	156	2235	4236	2560	2381	1184	582	187	74	39	64	200	13898	38080	36964	1.03
Fishing Mortality															Weighted F age 5+[2]	
1973	0.035	0.078	0.340	0.660	0.509	0.574	0.336	0.192	0.545	0.404	0.365	(0.532)[2]			0.532	
1974	0.021[3]	0.184	0.204	0.372	0.416	0.499	0.682	0.163	0.072	0.244	0.368	(0.364)			0.364	
1975	0.013[3]	0.160	0.355	0.177	0.282	0.308	0.239	0.166	0.143	0.035	0.078	(0.210)			0.210	
1976	0.016[4]	0.117[3]	0.237[3]	0.306	0.181	0.273	0.233	0.070	0.167	0.094	0.017	(0.253)			0.253	
1977	0.006[5]	0.091[4]	0.244[3]	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264	0.264			0.264	
Stock Size													Total No. (000's)	Weight (tons)[6]	Spawning stock No. (000's)	Spawning stock wt. (tons)[6]
1973	60467	23648	21782	9930	2908	2012	1407	2890	1108	263	101	8	126524	200253	23590	90156
1974	33527	47827	17917	12690	4202	1432	928	823	1953	526	143	58	122026	207663	24062	85643
1975	36474	26892	32567	11965	7161	2269	712	384	573	1488	338	81	120904	231836	30122	105382
1976	35000[7]	29487	18763	18694	8208	4423	1365	459	266	407	1176	256	118504	247082	35271	128466
1977	30000[7]	28190	21468[8]	12120	11273	5606	2755	885	350	185	303	947	114082	228310	36761	134847
1978[9]	43779[10]	24421	21064	13764	7620	7088	3525	1732	556	220	116	786	124671	235394	37252	136791

[1]Calculated using mean weight at age data in Table 8.
[2]Weighted by stock size
[3]Calculated under the assumption that this year-class is equal to 21.5 million fish at age 4
[4]Calculated under the assumption that this year-class is equal to 35 million fish at age 2
[5]Calculated under the assumption that this year-class is equal to 30 million fish at age 2
[6]Estimates for 1973-1977 adjusted by above observed/calculated ratios
[7]Estimated from USA spring and autumn and Canadian summer bottom trawl survey data
[8]Estimated from Canadian summer bottom trawl survey data and 1968-1972 year-class stock size estimates
[9]Age 3+ estimates calculated as $N_{1978} = N_{1977}e^{-Z}$.
[10]Assumed equal to the mean of the 1968-1972 year classes.

Table 10. Projected catch (age 2+) in 1979 from the Scotian Shelf, Gulf of Maine, and Georges Bank pollock stock with fishing mortality ranging from 0.10 to 0.50 assuming an average recruitment level for the 1976 and 1977 year-classes.

Fishing Mortality	Catch 1979	Stock size 1980	% change from 1979
0.10	15675	283865	+15.8
0.15	22999	275303	+12.3
0.20[1]	30022	267127	+ 8.9
0.25	36700	259318	+ 5.7
0.30	43105	251858	+ 2.8
0.35	49232	244731	- 0.2
0.37[2]	51608	241970	- 1.3
0.40	55094	237922	- 2.9
0.45	60702	231416	- 5.6
0.50	66069	225199	- 8.1

[1] $F_{0.1}$

[2] F_{max}

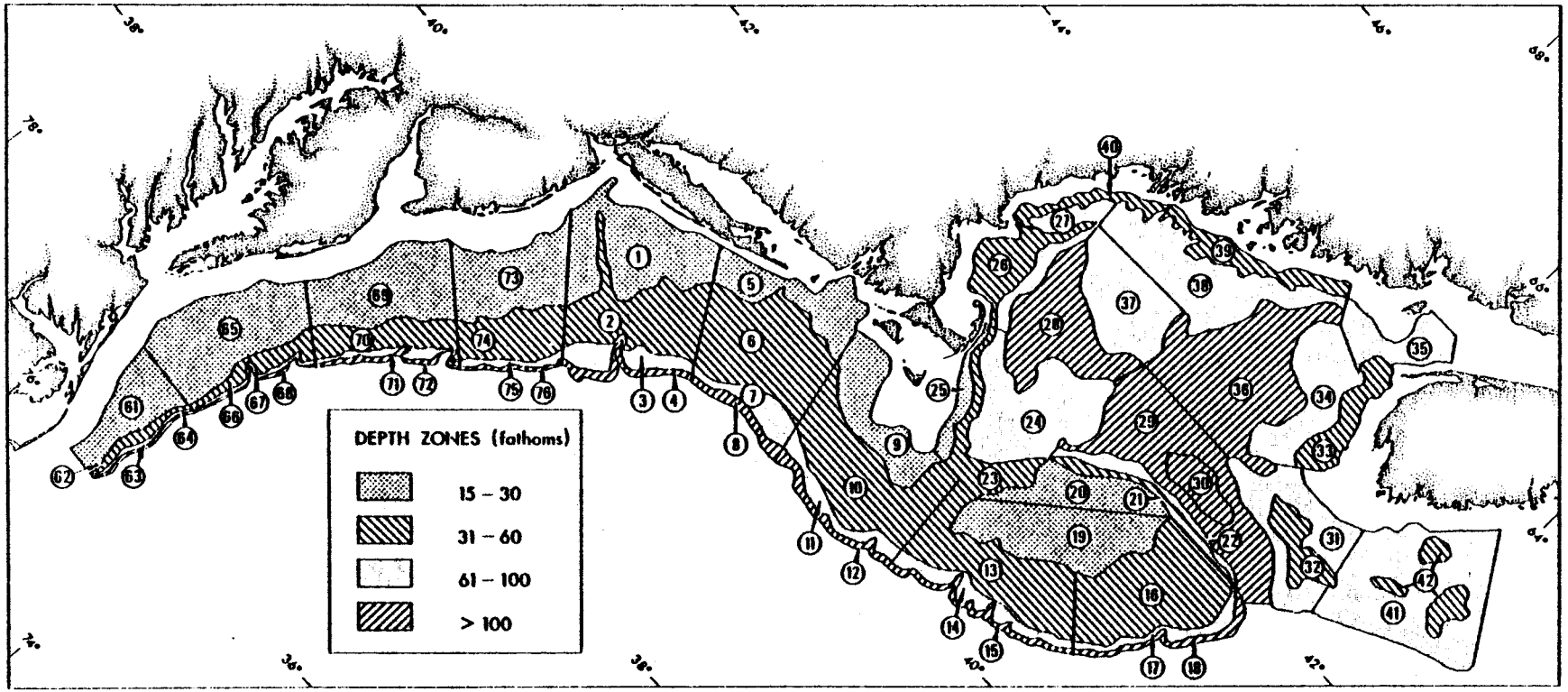

Figure 1. Strata used in USA spring and autumn bottom trawl surveys, 1963-1977.

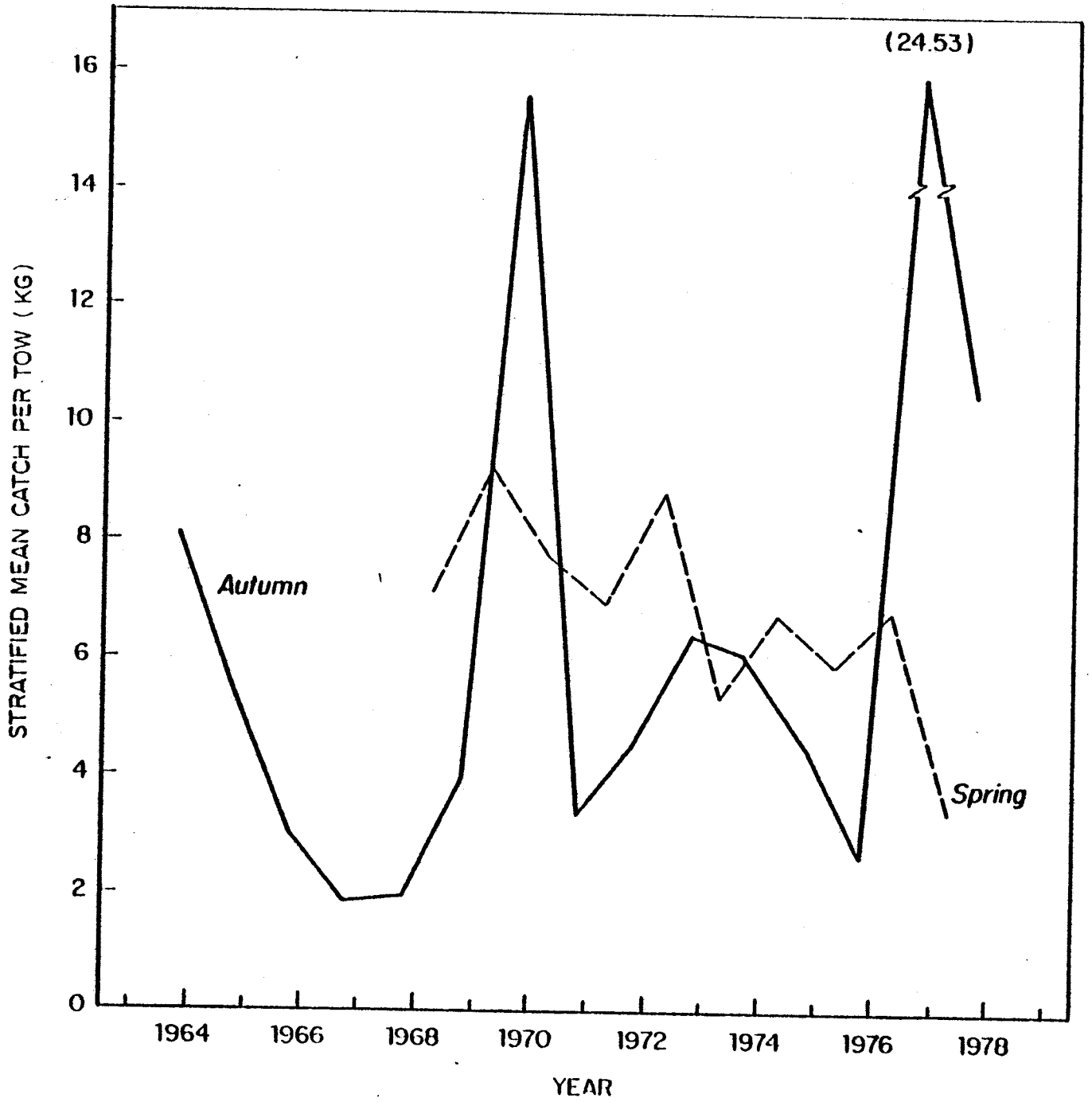

Figure 2. Stratified mean catch per tow (kg) of pollock in USA spring and autumn bottom trawl surveys for Georges Bank, the Gulf of Maine, and the Scotian Shelf (spring: strata 13-42; autumn: strata 24 and 26-42). Spring data for 1968-1972 adjusted by a factor of 1.7 to account for differences in surface area between the "36 Yankee" and the "41 Yankee" trawls.

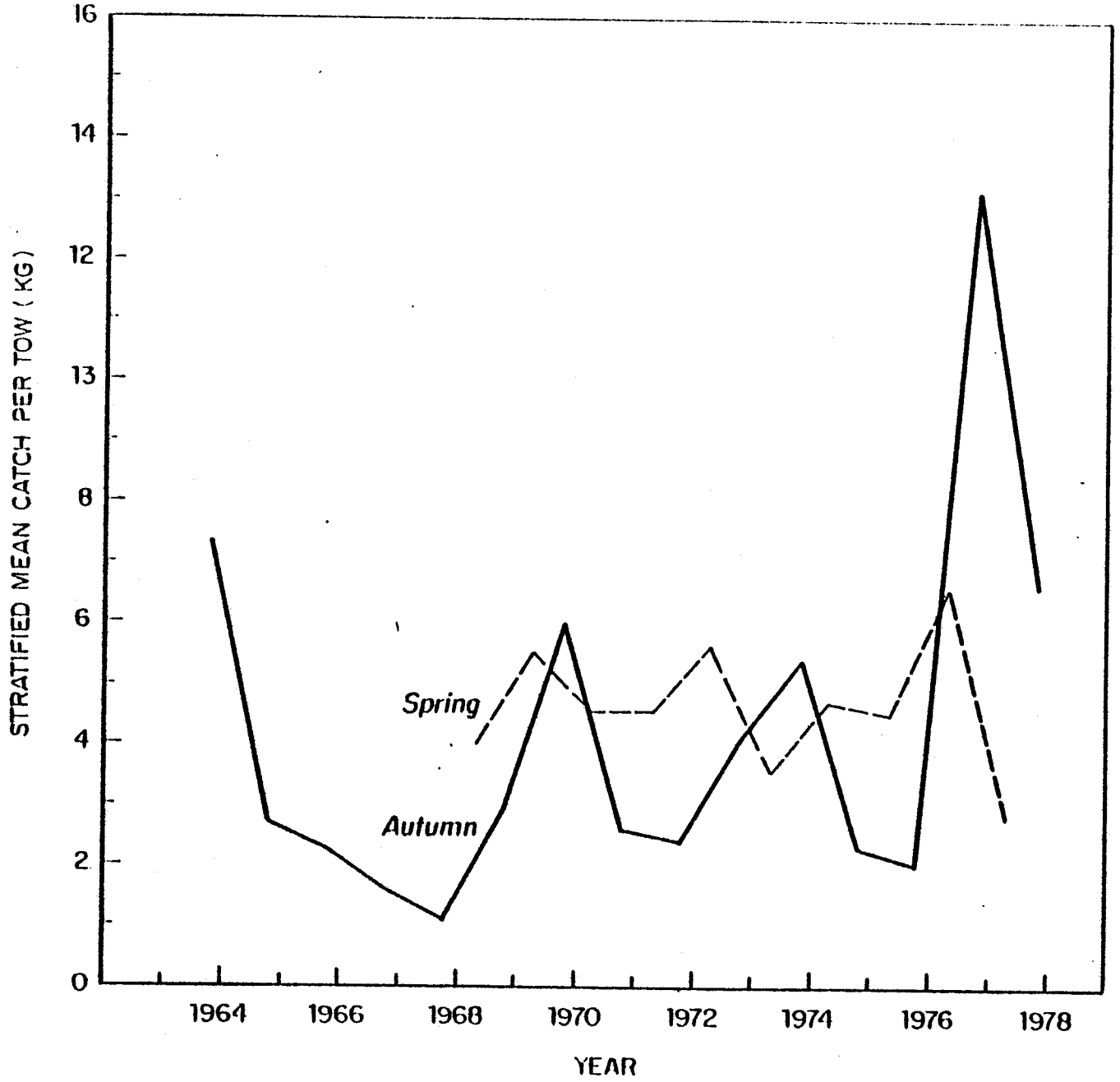

Figure 3. Stratified mean catch per tow, kg (retransformed from logarithms) of pollock in USA spring and autumn bottom trawl surveys for Georges Bank, the Gulf of Maine, and the Scotian Shelf (spring: strata 13-42; autumn: strata 24 and 26-42). Spring data for 1968-1972 adjusted by a factor of 1.7 to account for differences in surface area between the "36 Yankee" and the "41 Yankee" trawls.

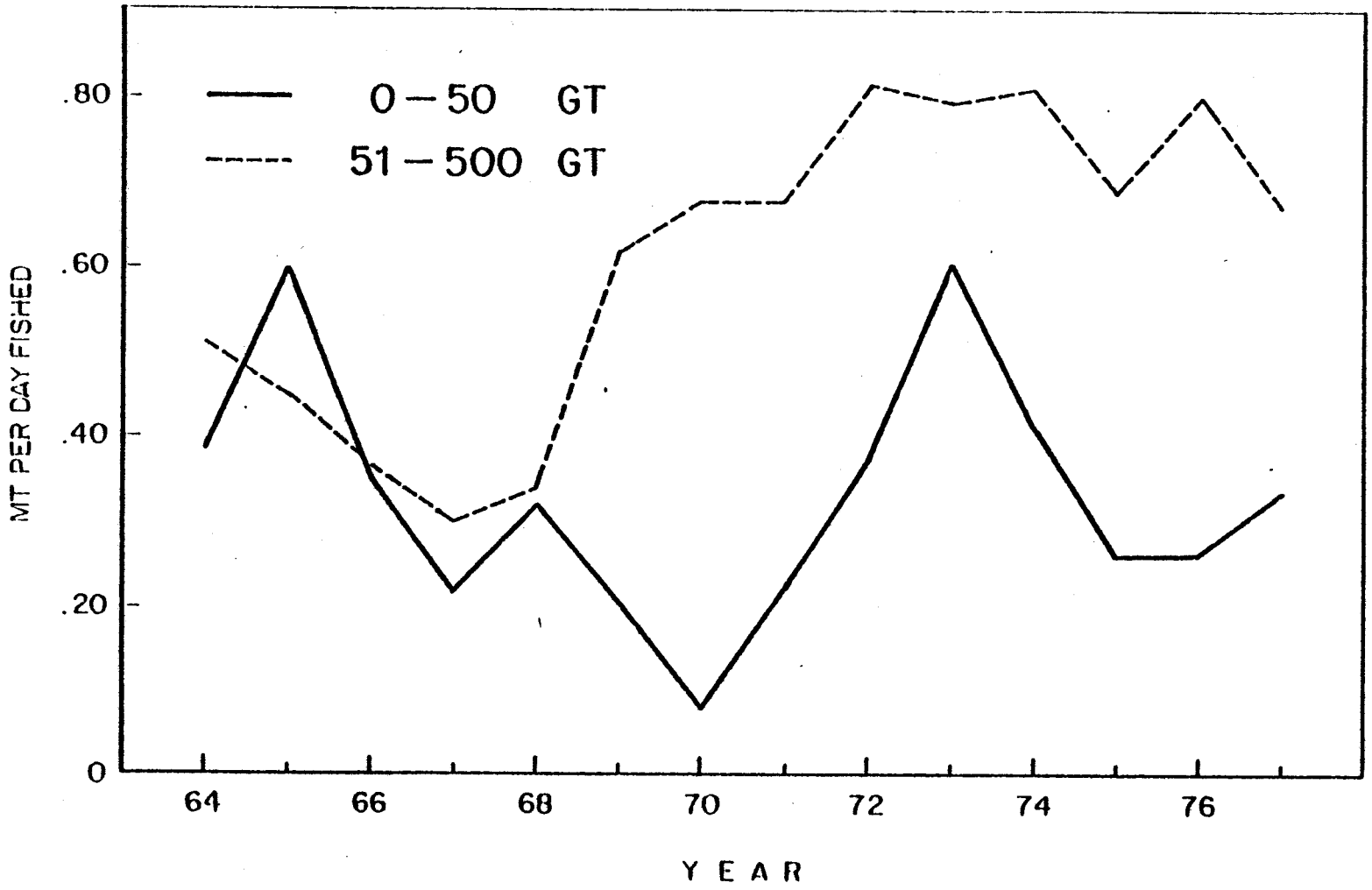

Figure 4. Pollock catch rates (metric tons per day fished) by tonnage class for USA otter trawlers from Georges Bank to the Scotian Shelf, 1964-1977, including data for all trips in which pollock were landed.

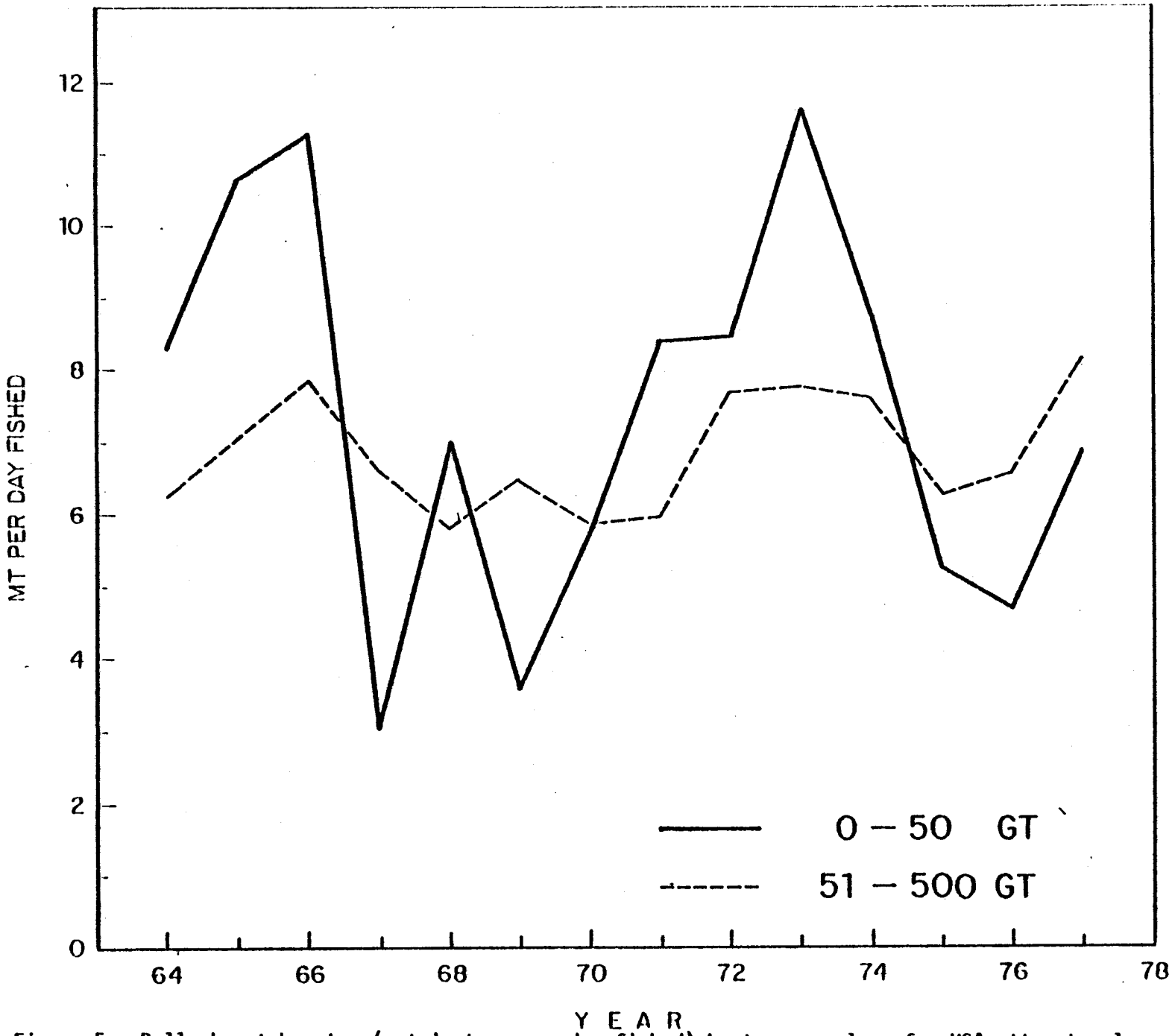

Figure 5. Pollock catch rates (metric tons per day fished) by tonnage class for USA otter trawlers from Georges Bank to the Scotian Shelf, 1964-1977. Data include trips for which 50% or more of the total landed weight consisted of pollock.

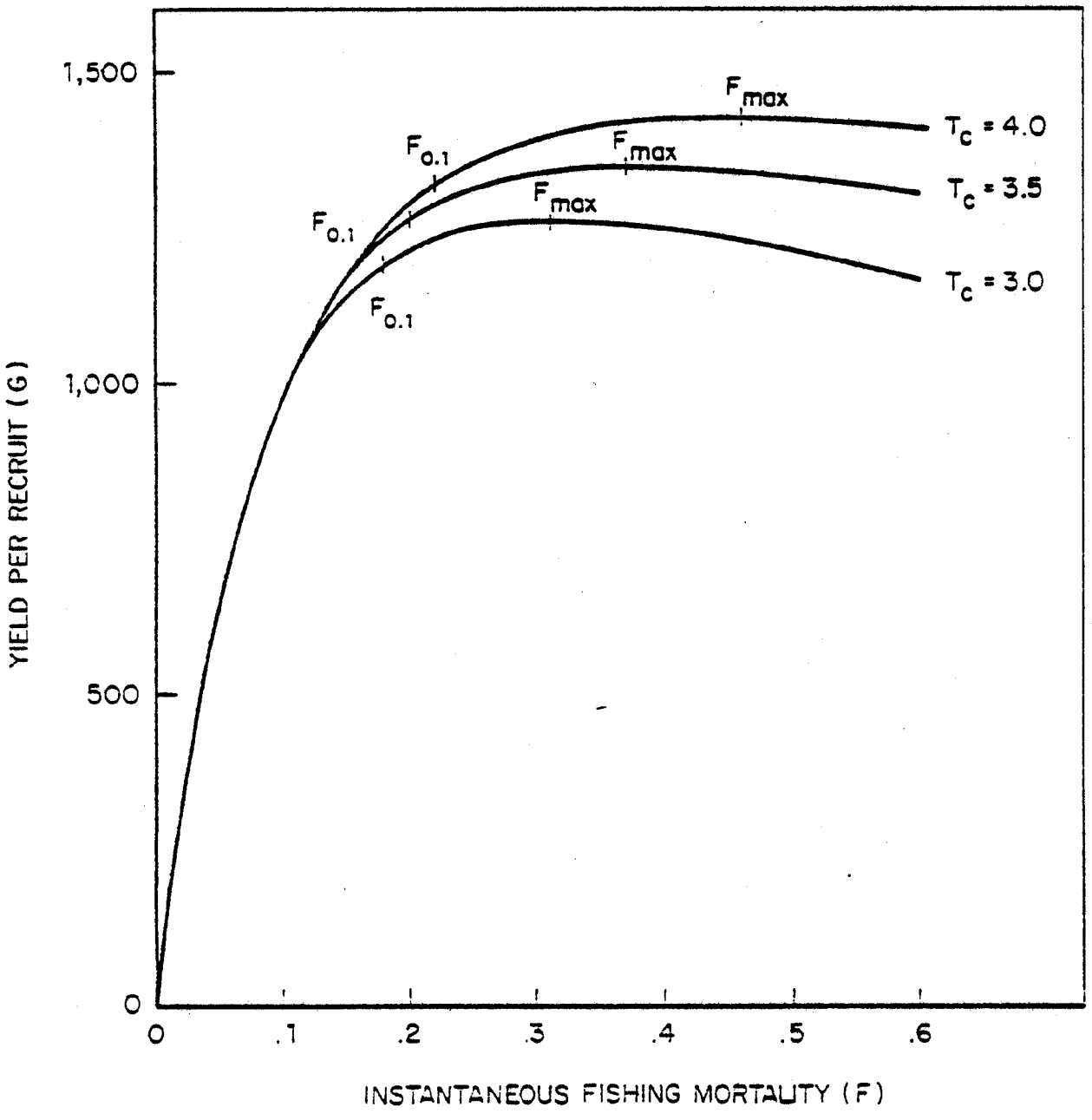

Figure 6. Yield per recruit curves for pollock assuming t_c values of 3.0, 3.5, and 4.0 years, W_∞ = 10.46 kg, K = 0.2149, t_0 = 0.4087, t_r = 2.0 years, t_λ = 20 years, and M = 0.2.