

Scotian Shelf, Gulf of Maine, and Georges Bank

Pollock Assessment Update

by

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Laboratory Reference No. 79-59
December 1979 (Revised March 1980)

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INTRODUCTION

Commercial landings of pollock from the Scotian Shelf, Gulf of Maine, and Georges Bank area have increased steadily since the late 1960's and in 1978 were the highest ever reported (45,300 tons¹); projections for 1979 suggest that total landings will approximate 43,000 tons. This increase appears to reflect increased abundance and shifts in directed effort, although for 1978 and 1979 there are reports from fishermen of misreporting of other groundfish species (e.g., haddock) as pollock to circumvent catch limitations. Present levels of harvest appear to be intermediate between those corresponding to $F_{0.1}$ and F_{max} , but recruiting year classes generally appear to be weaker than average and accordingly continued harvests at present levels may not be sustainable.

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 (Clark et al. 1977), although some evidence also exists for limited spawning on the Scotian Shelf (Steele 1963). Accordingly, pollock in the Scotian Shelf - Georges Bank area have been considered as a unit in past assessments; this approach has been continued in the present

¹Tons in this paper refers to metric tons.

assessment, as there is no additional information relative to stock boundaries.

Pollock catches were entirely unregulated in the Northwest Atlantic prior to 1973. During 1973-1976, the fishery was regulated with total allowable catches or TACs under the International Commission for the Northwest Atlantic Fisheries (ICNAF); the annual TAC for the area extending from Cape Breton Island to Southern New England (ICNAF Divisions 4VWX and Subarea 5, Figure 1) for 1974-1976 was 55,000 tons. A TAC of 30,000 tons was approved for 1977; however, both Canada and the USA withdrew from ICNAF during that year and as a result USA and Canadian landings have been essentially unregulated since 1976. A Draft Fishery Management Plan has recently been prepared for the USA fishery (New England Regional Fishery Management Council 1978) and is currently under review. Future management of this resource may be subject to international negotiations due to the transboundary nature of this stock.

The present paper updates current information relative to the status of Scotian Shelf, Gulf of Maine, and Georges Bank pollock and provides catch and stock size projections for 1980-1981 corresponding to a range of instantaneous fishing mortality (F) levels for 1980. Pollock in the Southern New England - Middle Atlantic area (ICNAF Div. 5Zw and Statistical Area 6, Figure 1) are herein considered as belonging to this stock, although commercial, recreational, and survey catches in this area have generally been minor.

COMMERCIAL FISHERY

The Scotian Shelf, Gulf of Maine, and Georges Bank pollock stock has been fished primarily by Canada and the USA, although other nations, notably the FRG, GDR, Spain, and the USSR have on occasion taken significant amounts. Canadian landings fluctuated around an average of 5,100 tons from 1920 to 1942 and then increased to an average of 29,300 tons from 1960-1964 before declining to 10,800 tons in 1970; Canadian landings subsequently increased rapidly to an average of 25,600 tons during 1973-1978 (Figure 2, Table 1). Trends in USA landings have been generally similar; landings averaged 3,600 tons from 1920-1929 but then rose to an average of 13,400 tons from 1935-1960 (Figure 2). Landings subsequently declined to an average of 3,300 tons in 1967-1968 and then increased steadily to 17,700 tons in 1978 (Figure 2, Table 1).

Both the Canadian and USA fisheries have been primarily incidental in nature although more effort appears to have been directed towards pollock in recent years, e.g., for USA trips in which pollock were landed the average percentage of the landed total by weight increased from 8% in 1964-1966 to 17% in 1976-1978. Historically, the fishery has been prosecuted primarily by otter trawling, although gillnet catches have increased greatly in recent years. For Canada, the percentage of the landed total taken by gillnetting increased from 2% in 1973 to 21% in 1976 (Cleary, pers. comm.) while for the USA fishery this percentage increased from 7% in 1970 to 43% in 1978 - a sixfold increase.

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. Landings since that year have fluctuated considerably, ranging from zero in 1962 to 12,300 tons in 1966 (Table 1). In the current decade landings by distant water fleets have declined from 10,600 tons in 1971 to an average of 740 tons for 1977-1978 (Table 1). During 1960-1978 the bulk of the distant water catch was taken by the USSR (42%), the GDR (23%), Spain (21%) and the FRG (10%). Other countries reporting catches of pollock from this area include Bulgaria, Cuba, Denmark, France, Italy, Iceland, Japan, Poland, and the United Kingdom.

Total landings for this stock averaged approximately 8,000 tons in the 1920's; landings increased gradually to an average of 26,000 tons during 1940-1957 and then rose sharply to an average of 37,800 tons from 1958-1964 before declining to 22,800 tons in 1968. Landings subsequently increased to an average of 40,200 tons from 1973-1978 (Figure 2, Table 1).

Reported landings for 1978 (45,300 tons) were the highest on record; preliminary data indicate that landings for 1979 will reach 43,000 tons. These figures are believed to be somewhat distorted due to alleged misreporting of haddock as pollock in both the USA and Canadian fisheries. The USA 1978 catch in particular (17,700 tons) increased 35 percent over 1977 landings (13,100 tons). There is no basis for quantifying amounts misreported in either case.

Since 1960, the bulk of the catch 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). Most of the Canadian catch has been taken on the western Scotian Shelf, while USA landings have been taken primarily in the western Gulf of Maine. Distinct seasonal differences are

evident between these areas in some years, i.e., Clark et al. (1977) observed a summer peak in Canadian landings on the Scotian Shelf and a distinct winter peak in the Gulf of Maine during 1972-1974, which was attributed to seasonal spawning movements.

RECREATIONAL FISHERY

Recreational landings data for pollock are limited. No data are available for Canada and it is assumed that Canadian recreational landings are of minor significance (Halliday pers. comm.). USA saltwater angling surveys for 1960, 1965, 1970, and 1974 provide estimates of 9,834, 4,240, and 2,533 tons for 1960, 1965, and 1970, respectively (Clark 1962; Deuel and Clark 1968; Deuel 1973); however, the NMFS 1974 Regional Survey indicated a catch of only 496 tons (Ridgely and Deuel MS 1976). The USA fishery has been centered primarily in the Gulf of Maine in recent years (Ridgely and Deuel MS 1976); landings in the Middle Atlantic area were too low to be included in results of the 1970 survey (Deuel 1973) while the 1974 survey indicated a very low recreational catch south of Massachusetts (Deuel, In Wilk et al. MS 1979).

The bulk of the Gulf of Maine recreational catch has been taken by party and charter boats (Nicholson and Ruais MS 1979) although Baird and Dow (1966, In Nicholson and Ruais MS 1979) reported that juvenile "harbor" pollock are available to anglers year-round along the Maine coast. The recreational fishery for pollock in the Southern New England and Middle Atlantic areas has been described as "poorly defined, highly specialized and nondirected" (Wilk et al. MS 1979); catches tend to peak in late spring

and decline sharply during summertime, possibly in response to seasonal shifts in distribution and directed effort (Wilk, pers. comm.). Here, pollock are primarily taken aboard party boats fishing for cod and other species, although sporadic inshore fisheries may develop for "harbor" pollock during years of high abundance (Wilk et al. MS 1979).

COMMERCIAL CATCH RATES

Commercial abundance indices (tons per hour fished) have been calculated for the directed Canadian otter trawl fishery and also for the Canadian groundfish fishery (Cleary, pers. comm.) The former index is based upon effort data for Canadian 500-999 GT otter trawlers for which 75% of the total catch consisted of pollock, while the latter is based upon combined effort directed towards all groundfish species and thus includes data for both directed and incidental catch. Indices (tons per day fished) have also been calculated for USA otter trawlers by tonnage class (0-50 and 51-500 GT) using effort data for which 50% or more of the catch consisted of pollock. Results are given in Table 3 and Figures 3 and 4.

The Canadian directed index declined from 1.0 tons in 1973 to 0.4 tons in 1976 and then rose sharply to 1.0 tons in 1977; the 1978 index value was 0.9 tons (Table 3, Figure 3). However, the total groundfish effort index has generally increased since 1972 (Table 3, Figure 3). USA index values generally declined during the 1960's and then increased to 1973. The 0-50 GT index declined from 11.6 tons in 1973 to 4.7 tons in 1976 before increasing to 7.2 tons in 1978, while the >50 GT index

declined from 7.8 tons in 1973 to 6.3 tons in 1975 before increasing to 8.2 tons in 1977; the 1978 value was 7.3 tons (Table 3, Figure 4). Thus, commercial catch-effort data generally indicate a decline in abundance from 1973-1976, followed by a sharp increase (Table 3, Figures 3 and 4).

RESEARCH VESSEL SURVEY CRUISES

Canada has conducted bottom trawl surveys on the Scotian Shelf and in the Gulf of St. Lawrence area beginning in 1970 (strata 15-95, Figure 5); 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 6). A review of USA survey procedures, and applications of resulting data to fish stock assessment, is provided by Clark (1979).

Abundance indices (stratified mean catch per tow in numbers) have been calculated for all of these surveys; corresponding indices in terms of weight (kg) have also been calculated for both USA surveys. As a different gear (a modified high-opening "41 Yankee" trawl) was introduced in the USA spring survey in 1973, USA spring survey catch per tow data for 1968-1972 have been adjusted by a factor of 1.7 to account for differences in surface area between the two trawls (although differences in fishing power have not been evaluated statistically). To compensate for potential bias associated with high catches in certain tows, USA survey data were also transformed to logarithms (+1) and retransformed estimates in original units calculated as suggested by Bliss (1967:128) according to the relation

$$E\bar{y}_{st} = \exp(\bar{y}_{st} + s^2/2) - 1$$

where $\bar{E}y_{st}$ represents the estimated (retransformed) 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. Indices for all surveys are given in Table 4; the Canadian summer survey index (numbers) and USA spring and autumn (retransformed) indices (kg) are given in Figures 7 and 8, respectively. Use of the logarithmic transformation appears to have been effective in correcting for heterogeneity of variance for the USA data (Table 4).

The Canadian summer survey index generally declined from 3.2 fish in 1970 to 1.2 fish in 1975 before rising sharply to 6.3 fish in 1977; values for 1978 and 1979 were 2.7 and 1.9 fish, respectively (Table 4, Figure 7). The USA spring survey index increased from 3.5 kg in 1973 to 6.6 kg in 1976 and subsequently declined to an average of 3.8 kg in 1978-1979; catch per tow in numbers averaged 1.5 fish from 1973-1976 before declining to 0.9 fish in 1979 (Table 4, Figure 8). The USA autumn survey index declined steadily from 1963-1967 and then increased to 3.4 kg (1.1 fish) in 1973 before declining to 1.3 kg (0.5 fish) in 1975. Values then increased sharply to 6.3 kg (1.6 fish) in 1976 before declining to 3.3 kg (0.7 fish) in 1978 (Table 4, Figure 8). The USA autumn survey index agrees with USA commercial indices in indicating a decline in abundance and a subsequent upswing from the mid-1960's to the early 1970's, and commercial and survey indices are generally consistent in indicating a subsequent decline in abundance followed by a sharp increase during 1976-1977.

Peak values in the USA autumn survey index in 1969 and 1976 (particularly evident in the case of untransformed data, Table 4) may relate to distributional differences between years associated with timing of spawning activity relative to survey scheduling. This point is discussed further by Clark et al. (1978).

Stratified mean catch per tow at age data (numbers) for Canadian summer (1970-1978) bottom trawl surveys (Cleary pers. comm.) and USA spring (1973-1977) and autumn (1970-1977) bottom trawl surveys are given in Tables 5, 6, and 7. Canadian survey data (Table 5) indicate the 1968 and 1971 year classes to be strong ones; the 1971 year class also appears to be strong in both USA surveys (Tables 6 and 7). Recent year classes generally appear to have been weaker (Tables 6 and 7). The sharp increases in the 1976 autumn survey index (Table 4, Figure 8) appears to be largely attributable to high catches of 1971 year-class fish (Table 7).

COMMERCIAL CATCH AGE COMPOSITION

Length-frequency samples are available for Canadian catches for nearly all months since the beginning of 1973; also, Canadian age-length keys are available at least by quarter from 1973-1975 and for most months thereafter. USA commercial length frequency samples are available at least by quarter for 1973-1975, with the exception of the fourth quarter in 1975 and the third quarter in 1976; however, commercial age data are not available prior to 1977. Sampling of catches by distant water fleets has been very limited and to date available information includes only length-frequency samples by the USSR in March, April, and August of 1973 and in April of 1975.

Substantial length-frequency differences were evident for the USA and Canadian fisheries in 1973 and 1974 (USA samples usually included a substantially higher proportion of smaller fish), but comparable sample data for succeeding years have been in relatively close agreement. 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. For 1975 and 1976, numbers landed at age were derived by applying USA and Canadian length-frequency samples and Canadian age-length keys to respective monthly landings for each country; Canadian length-frequency data were applied to USA landings for months in which USA length-frequency samples were not available. For 1977 and 1978, monthly length-frequency sample data and quarterly age keys have been applied independently. Canadian length-frequency samples and age-length keys have been applied routinely to catches by distant-water fleets, as the bulk of the distant-water catch since 1973 has been taken on the Scotian Shelf. Results (Table 8) reveal that the catch has been dominated by age 3-5 fish in recent years.

Mean weight at age data for this stock appear in Table 9. Values for 1973-1976 are as reported by Cleary (MS 1978); values for 1977 and 1978 represent averages for the USA and Canadian fisheries, weighted by respective catches at age (numbers). Values fluctuate considerably but have generally declined in recent years (Table 9).

COHORT ANALYSIS

Cohort analysis (Pope 1972) was performed on the commercial catch at age data in Table 8 to derive fishing mortality and stock size estimates for 1973-1978. No estimates of instantaneous natural mortality (M) are currently available for this stock, and accordingly M has been assumed equal to 0.2 as in recent assessments of European stocks (ICES MS 1979). Results of previous assessments (Clark et al. 1978; Clark et al. MS 1978) suggest that pollock are fully recruited to the commercial fishery at ages 4-5 as evidenced by age-specific fishing mortality; full recruitment at age 5 has been assumed in the present assessment, although the sharp increase in the percentage of total landings taken by gill nets in recent years implies that this pattern may be changing.

The limited commercial and survey catch at age data bases available, and uncertainty in reported landings data for 1978, rendered determination of a terminal or starting instantaneous fishing mortality (F) value difficult. In this assessment a procedure was adopted in which F_{1978} for fully recruited year classes was obtained from predictive regressions of catch at age data upon time; data were transformed to logarithms (ln) and linear regressions run to project catch at age by cohort (age 5+) several additional years. A cohort analysis was then run using observed catches for 1978 and projected catches for later years with a starting F of 0.30, which corresponded approximately to the 1978 catch level based upon projected stock size estimates from an earlier assessment (Clark et al. MS 1978). The weighted F estimate obtained for 1978 based upon the

observed catch data (0.245) was used as the starting F in the final cohort analysis. This procedure was used in that it appeared to provide a reasonable approximation based upon recent trends in abundance whereas other methods (e.g., development of empirical relationships between F and commercial effort data or commercial effort indices based upon research vessel survey data) did not appear to provide reliable estimates.

Recruitment

Recruitment has been difficult to evaluate for this stock due to the limited time series of commercial and research vessel survey catch at age data available. Canadian summer and USA spring and autumn surveys are generally consistent in indicating the 1974 year class to be weaker than the 1968-1973 year-class average at ages 2 and 3 (Tables 5-7), but this year-class appears to have been more nearly average in size at age 4 in these surveys while commercial catch in numbers at age 4 was among the highest observed during the 1973-1978 time series. The assumption that this year-class is equal to the 1968-1973 average (of 46.4 million fish at age 2) and commercial catch at age data for ages 2-4 implies an F of approximately 0.245 in 1978, and accordingly full recruitment has been assumed at age 4 (providing an estimate of 28.5 million fish).

The 1975 year class has been consistently weaker than the 1968-1972 year classes at ages 2 and 3 in all surveys and was approximately equal to the weakest observed at age 4 in the USA spring 1979 survey. A power curve between stock size estimates at age 3 and Canadian summer survey catch per tow at ages 2 and 3 combined for the 1968-1971 year classes ($r = 0.83$, Figure 9) provided an estimate of 22.6 million fish (approximately equal to the weakest in the 1968-1972 time series) which was accepted for this year class.

The 1976 year class at age 2 was substantially weaker than the 1968-1973 year-class average in all surveys and was the weakest ever observed at age 3 in the USA 1979 spring survey. Power curves between stock size estimates at age 2 and Canadian summer survey catch per tow (at age 2) and USA autumn survey catch per tow (at age 1) for the 1968-1972 year classes ($r = 0.65$ and 0.71 , respectively, Figures 10 and 11) provided estimates of 32.6 million fish and 34.5 million fish, respectively; the mean of these estimates (33.6 million fish) was accepted for the 1976 year class at age 2.

Little information is available relative to size of the 1977 year class, although available survey data suggest this year class to be poor. This year class was approximately equal to the weakest observed at age 1 in the USA autumn 1978 survey and was the weakest ever observed at age 2 in the USA 1979 spring survey; the above power curve between USA autumn survey catch per tow at age 1 and stock size at age 2 for the 1968-1972 year classes (Figure 11) provided an estimate of 29.0 million fish. An estimate of 27.1 million fish at age 2 (the weakest in the 1968-1973 year class series) has been accepted for the 1977 year class.

Results of the above analyses (Table 8) indicate an increase in stock size (age 2+) of from 187,900 tons in 1973 to 280,300 tons in 1976, followed by a decline to an average of 263,000 tons in 1977-78. (Stock size estimates in terms of weight were obtained by applying mean weight at age data in Table 9, adjusted by the observed/calculated ratios in Table 8). Spawning stock size (calculated as 25% of age 4 fish, 75% of age 5 fish and 100% of all older ages) increased continually from 72,900 tons in 1974 to 162,000 tons in 1978 (Table 8). The increase evidenced by these analyses

is generally compatible with trends evidenced by commercial and survey abundance indices although total biomass (age 2+) increased continually from 1973-1976. Fishing mortality appears to have been relatively close to the $F_{0.1}$ level (0.20) since 1974.

YIELD PER RECRUIT

Clark et al. (MS 1978) calculated yield per recruit curves for this stock (Figure 12) using the Beverton-Holt model and the following parameter estimates: $W_{\infty} = 10.46$ kg; $K = 0.2149$, $t_0 = 0.4087$, $t_r = 2.0$ years, $t_{\lambda} = 20$ years, and $M = 0.2$. Yield per recruit isopleths calculated under the same assumptions appear in Figure 13. Mean age at recruitment (t_c) values used for calculating curves in Figure 12 (3.0, 3.5, and 4.0 years) reflect available growth and selectivity data assuming use of 130 mm trawls. Smolowitz (MS 1978) obtained a selection factor of 3.3 for demersal trawl gear, implying a t_c of 3.1 years; however, increased gillnetting activity in recent years implies a higher t_c as evidenced by age specific fishing mortality rates (Table 8). Hylen (1969) obtained a selection factor of 3.8 for the species from experiments with polypropylene mesh codends, implying a t_c value of 3.5 years.

Values of instantaneous fishing mortality (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. Equilibrium yield calculations assuming constant average recruitment equal to the 1968-1973 year-class average at age 2, partial recruitment as observed in the present assessment for 1973-1975, and mean weights at age for 1978 indicate F_{\max} and $F_{0.1}$ to be 0.36 and 0.20, respectively, in close agreement with results obtained with the Beverton-Holt model assuming $t_c = 3.5$ years.

CATCH AND STOCK SIZE PROJECTIONS

A total biomass (age 2+) of 252,000 tons was estimated for this stock for the beginning of 1979 (Table 8). The above assumptions relative to age at full recruitment and recruiting year-class size for 1978 imply partial recruitment coefficients of 0.02, 0.69, and 1.00 for ages 2, 3, and 4+, respectively; these values were used with mean weight at age data for 1978 (Table 9) to calculate catch and stock size projections for 1980-1981. As there is currently little or no evidence relative to the strength of the 1978 and 1979 year classes these have been assumed equal to the 1968-1973 year-class average of 46.4 million fish at age 2.

Under the above assumptions relative to stock size and recruitment and assuming a catch of 43,000 tons in 1979, fishing at $F_{max} = 0.37$ in 1980 would provide a catch of 60,400 tons, with a stock biomass (age 2+) in 1981 of 243,100 tons; fishing at $F_{0.1}$ in 1980 would provide a catch of 35,200 tons, with a 1981 stock biomass (age 2+) of 271,900 tons (Table 10). Catches in the order of 43-45,000 tons (i.e., comparable to 1978-1979) would be well below the F_{max} level but might not be sustainable in subsequent years in view of evidence for poorer incoming recruitment.

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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 areas by country¹, 1960-1978.

Year	Country									Total
	Canada	Fed. Rep. Germany	German Dem. Rep.	Japan	Spain	USSR	United Kingdom	USA	Other ²	
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	24,654	368	-	1	2	268	-	13,056	53	38,402
1978 ³	26,801	-	-	112	-	502	-	17,714	180	45,309

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

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

³Provisional; incomplete.

Table 2. Pollock landings (metric tons, live) for the Scotian Shelf, Gulf of Maine, Georges Bank, and the Southern New England - Middle Atlantic area¹, 1960-1978.

Year	AREA				Total
	Scotian Shelf	Gulf of Maine ²	Georges Bank ³	Southern New England-Middle Atlantic	
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	1,728	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	7,074	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 ⁴	23,004	12,329	9,943	33	45,309

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

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

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

⁴Provisional; incomplete.

Table 3. Commercial abundance indices for pollock for the Canadian and USA fisheries, 1964-1978.

Year	Canada		USA	
	Directed effort ¹	Total Groundfish effort ²	0-50 GT ³	51-500 GT 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	0.82	0.16	8.44	7.68
1973	1.00	0.18	11.59	7.77
1974	0.57	0.32	8.76	7.61
1975	0.70	0.35	5.25	6.27
1976	0.42	0.22	4.67	6.56
1977	1.04	0.76	6.87	8.15
1978	0.92	-	7.19	7.28

¹Calculated based on effort data for 500-999 GT otter trawlers for which 75% of the total catch consisted of pollock (Cleary, pers. comm.)

²Calculated based on total effort data directed towards groundfish species (Cleary, pers. comm.).

³Calculated using effort data for trips for which 50% or more of the catch consisted of pollock.

Table 4. Stratified mean catch per tow in numbers and weight (kg) for pollock taken in Canadian summer and USA spring and autumn bottom trawl surveys, 1963-1979.

Year	Canadian summer survey ¹	USA Spring Survey ²				USA Autumn Survey ²			
	Number	Number		Weight (kg)		Number		Weight (kg)	
	Linear	Linear	Retransformed	Linear	Retransformed	Linear	Retransformed	Linear	Retransformed
1963	-	-	-	-	-	1.5	1.3	5.79	4.65
1964	-	-	-	-	-	1.6	1.0	4.40	2.15
1965	-	-	-	-	-	0.8	0.6	2.46	1.59
1966	-	-	-	-	-	0.9	0.5	2.18	1.34
1967	-	-	-	-	-	0.5	0.4	1.63	0.95
1968	-	(1.8) ³	(1.3) ³	(7.16) ³	(3.97) ³	0.7	0.6	2.92	1.90
1969	-	(2.9)	(2.1)	(9.25)	(5.52)	2.0	1.0	11.22	3.45
1970	3.2	(3.2)	(2.6)	(7.73)	(4.57)	0.6	0.6	2.43	1.68
1971	1.6	(2.3)	(1.9)	(6.98)	(4.58)	1.0	0.6	3.61	1.63
1972	2.3	(7.0)	(3.9)	(8.87)	(5.68)	2.2	1.1	4.76	2.60
1973	2.5	5.0	1.6	5.34	3.47	1.6	1.1	4.48	3.44
1974	2.3	2.1	1.4	6.77	4.66	0.9	0.5	3.26	1.50
1975	1.2	1.7	1.2	5.90	4.52	0.7	0.5	1.94	1.33
1976	2.8	1.8	1.6	6.86	6.58	3.7	1.6	16.66	6.31
1977	6.3	1.6	1.2	3.44	2.80	1.9	1.1	7.95	4.28
1978	2.7	2.5	1.1	7.11	3.85	1.0	0.7	5.83	3.31
1979	1.9	1.1	0.9	4.75	3.76	-	-	-	-

¹Strata 40-95 (Scotian Shelf, Figure 5).

²Strata 13-42 (Scotian Shelf, Gulf of Maine, and Georges Bank, Figure 6).

³Values in parentheses adjusted by a factor of 1.7 to adjust for differences in surface area between the "36 Yankee" and the "41 Yankee" trawls.

Table 5. Stratified mean catch per tow in numbers at age for pollock in Canadian summer bottom trawl surveys¹, 1970-1978.

Year	AGE													Total
	1	2	3	4	5	6	7	8	9	10	11	12	13+	
1970	0.01	1.79	0.43	0.27	0.19	0.19	0.15	0.10	0.02	0.00	0.05	0.01	0.00	3.24
1971	0.00	0.73	0.61	0.17	0.04	0.02	0.03	0.01	0.01	0.02	0.00	0.00	0.00	1.64
1972	0.01	0.09	0.20	1.25	0.38	0.11	0.03	0.06	0.05	0.04 ²	0.01	0.01	0.03	2.27
1973	0.00	0.40	0.37	1.14	0.42	0.07	0.02	0.04	0.06	0.00 ²	0.03	0.01	0.00	2.55
1974	0.01	0.04	0.94	0.23	0.29	0.19	0.21	0.09	0.09	0.05	0.13	0.05	0.00	2.31
1975	0.00	0.01	0.02	0.33	0.28	0.37	0.06	0.10	0.03	0.00 ²	0.01	0.00	0.00	1.20
1976	0.00	0.03	0.20	0.57	1.00	0.24	0.42	0.15	0.03	0.03	0.01	0.02	0.03	2.76
1977	0.00	0.26	0.78	0.98	2.03	1.43	0.20	0.36	0.12	0.06	0.03	0.02	0.00	6.28
1978	0.00	0.05	0.15	0.54	0.80	0.33	0.31	0.40	0.05	0.00 ²	0.00	0.02	0.01	2.66

¹Strata 40-95 (Scotian Shelf, Figure 5).

²Less than 0.005.

Table 6. Stratified mean catch per tow in numbers at age for pollock in USA spring bottom trawl surveys¹, 1973-1977².

Year	AGE														Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	
1973	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	4.95
1974	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	2.15
1975	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	1.66
1976	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	1.78
1977	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	1.62
1978	0.00	0.21	0.40	0.56	0.65	0.20	0.14	0.10	0.07	0.08	0.06	0.01	0.01	0.06	2.55
1979	0.10	0.05	0.07	0.08	0.15	0.14	0.08	0.16	0.08	0.03	0.03	0.02	0.03	0.03	1.05

¹Strata 13-42 (Scotian Shelf, Gulf of Maine, and Georges Bank, Figure 6).

²Includes data for years in which the "41 Yankee" trawl was used.

Table 7. Stratified mean catch per tow in numbers at age for pollock in USA autumn bottom trawl surveys¹, 1970-1978.

Year	AGE														Total
	1	2	3	4	5	6	7	8	9	10	11	12	13	14+	
1970	0.13	0.07	0.01	0.08	0.07	0.07	0.04	0.03	0.01	0.02	0.01	0.00	0.03	0.03	0.60
1971	0.10	0.34	0.16	0.02	0.06	0.09	0.03	0.07	0.02	0.01	0.01	0.01	0.01	0.06	1.01
1972	0.42	0.87	0.41	0.07	0.06	0.08	0.06	0.05	0.04	0.02	0.02	0.02	0.02	0.05	2.19
1973	0.03	0.64	0.13	0.17	0.10	0.11	0.08	0.06	0.00	0.12	0.01	0.01	0.03	0.05	1.54
1974	0.00	0.08	0.25	0.20	0.12	0.09	0.08	0.01	0.02	0.00	0.03	0.00	0.00	0.02	0.90
1975	0.20	0.05	0.04	0.09	0.07	0.04	0.06	0.04	0.01	0.01	0.01	0.00	0.01	0.02	0.67
1976	0.03	0.03	0.15	0.55	1.63	0.50	0.31	0.14	0.05	0.01	0.01	0.03	0.06	0.20	3.70
1977	0.06	0.15	0.22	0.26	0.39	0.34	0.19	0.10	0.08	0.02	0.00	0.02	0.01	0.11	1.95
1978	0.03	0.19	0.04	0.04	0.09	0.09	0.15	0.08	0.06	0.04	0.03	0.02	0.02	0.08	0.96

¹Strata 13-42 (Scotian Shelf, Gulf of Maine, and Georges Bank, Figure 6).

Table 8. Catch at age of pollock (000's) from the Scotian Shelf to Southern New England and fishing mortalities and stock sizes calculated from cohort analysis assuming $M=0.2$.

Year	Age													Number (000's)	Weight (tons)		Ratio obs/calc.
	2	3	4	5	6	7	8	9	10	11	12	13+	Obs.		Calc. ¹		
<u>Catch</u>																	
1973	1856	1595	5684	4341	1049	795	363	457	421	79	28	3	16671	43176	44358	0.97	
1974	617	7281	2899	3626	1327	511	415	112	123	103	40	16	17070	37802	41960	0.90	
1975	372	3346	8434	1890	1655	555	137	55	70	46	24	14	16598	39035	40348	0.97	
1976	514	2952	3583	4453	1233	960	258	28	32	34	25	46	14118	37608	37298	1.01	
1977	174	2707	4458	2431	2822	1063	558	159	73	40	58	192	14735	38402	38303	1.00	
1978	153	3189	5630	4390	1762	1872	577	259	118	84	23	120	18177	45309	44825	1.01	
<u>Fishing mortality</u>																	
														Weighted F age 5+ ²			
1973	0.031	0.084	0.360	0.650	0.407	0.575	0.339	0.722	0.909	0.439	0.586 ²	0.586		0.586			
1974	0.019	0.163	0.217	0.412	0.418	0.355	0.685	0.165	0.427	0.585	0.413 ²	0.413		0.413			
1975	0.008	0.138	0.288	0.214	0.335	0.308	0.151	0.173	0.147	0.279	0.255 ²	0.255		0.255			
1976	0.012	0.080	0.214	0.243	0.211	0.331	0.230	0.041	0.144	0.099	0.239 ²	0.239		0.239			
1977	0.007	0.083	0.167	0.221	0.239	0.285	0.326	0.216	0.145	0.271	0.242 ²	0.242		0.242			
1978	0.005	0.169	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245	0.245		0.245			
<u>Stock size</u>																	
													Total No. (000's)	Weight ³ (tons)	Spawning stock no.	Weight ³ (tons)	
1973	67426	21821	20771	10037	3466	2008	1396	982	779	246	69	7	108237	187900	21674	76989	
1974	35832	53524	16422	11863	4289	1888	925	815	391	257	130	52	126388	200763	21750	72913	
1975	52197	28778	37234	10822	6431	2311	1084	382	566	209	117	68	140199	245377	28593	94604	
1976	46695	42399	20534	22853	7150	3768	1390	763	263	400	129	238	146582	280316	36374	126169	
1977	27753 ⁴	37766 ⁵	32042 ⁶	13570	14681	4739	2216	905	600	186	296	982	135736	262029	42793	145755	
1978	33553 ⁴	22581 ⁵	28471 ⁶	22200	8910	9467	2918	1310	597	425	116	607	131155	264060	48118	161987	
1979	27141 ⁷	27334	15613	18245	14226	5710	6067	1870	839	383	272	74	117774	251976	47028	168855	

¹ Calculated using mean weight at age data in Table 9.

² Weighted over ages 5-11 (used as terminal F for each cohort indicated).

³ Adjusted by the above observed to calculated ratios.

⁴ Calculated from power curve relationships between stock size at age 2 and USA autumn survey catch per tow at age 1 for the 1969-1972 year classes and Canadian summer survey catch per tow (at age 2) for the 1968-1972 year classes.

⁵ Calculated from a power curve relationship between stock size at age 3 from cohort analysis and Canadian summer survey catch per tow at ages 2 and 3 for the 1968-1971 year classes.

⁶ Assumed equal to the 1968-1973 year-class average (fully recruited at age 4).

⁷ Assumed equal to the weakest year class observed at age 2 (1968-1973 year classes inclusive).

Table 9. Commercial mean weights at age (kg)¹ for the Scotian Shelf, Gulf of Maine, and Georges Bank pollock stock, 1973-1978.

Year	AGE											
	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	0.93	1.13	1.63	2.54	3.41	4.44	5.76	6.82	7.13	7.84	7.81	8.92
1978	0.84	1.12	1.61	2.38	3.51	4.33	5.36	6.26	6.67	7.29	7.71	8.59

¹Values for 1973-1976 as reported for Canada by Cleary (MS 1978); values for 1977-1978 calculated by weighting Canadian and USA mean weights at age by respective catch at age values (nos.).

²Calculated by weighting by-catch at age values (nos.) for ages 13+.

Table 10. Catch and stock size projections (age 2+) for 1980-1981 for the Scotian Shelf, Gulf of Maine, and Georges Bank pollock stock assuming a catch of 43,000 tons in 1979 and the 1978 and 1979 year classes at age 2 equal to the 1968-1973 average.

F_{1980}	Catch 1980	Stock size age at 1981	% change from 1979 ¹
0.10	18,437	291,131	+15.5
0.15	27,028	281,263	+11.6
0.20 ²	35,226	271,860	+ 7.9
0.25	43,050	262,900	+ 4.3
0.30	50,517	254,363	+ 0.9
0.35	57,645	246,227	- 2.3
0.37 ³	60,405	243,081	- 3.5
0.40	64,449	238,474	- 5.3
0.45	70,944	231,086	- 8.3
0.50	77,146	224,045	-11.1

¹1979 stock size (age 2+) = 252,000 tons.

² $F_{0.1}$

³ F_{max}

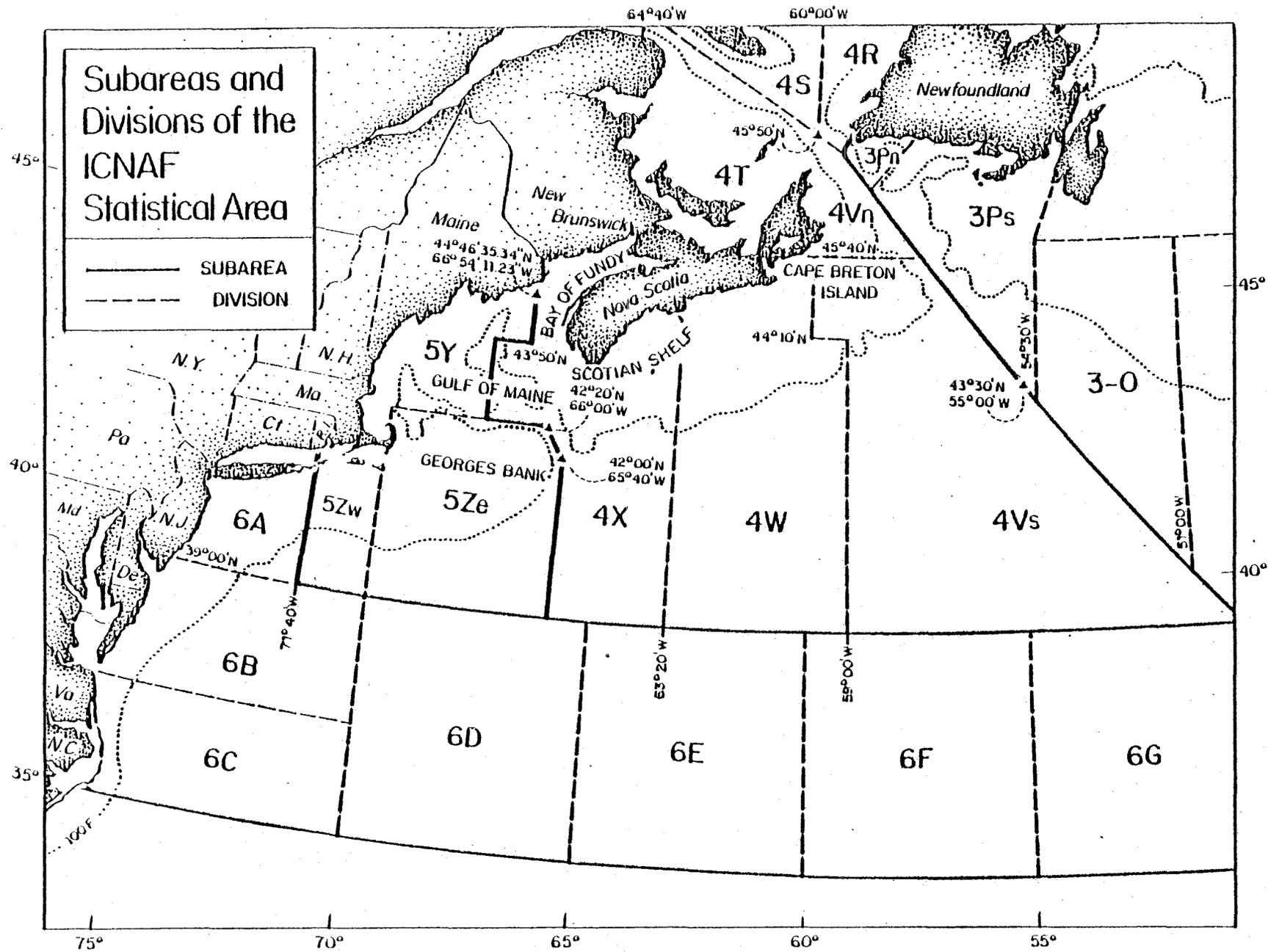


Figure 1. Northwest Atlantic, showing the southern portion of the ICNAF area.

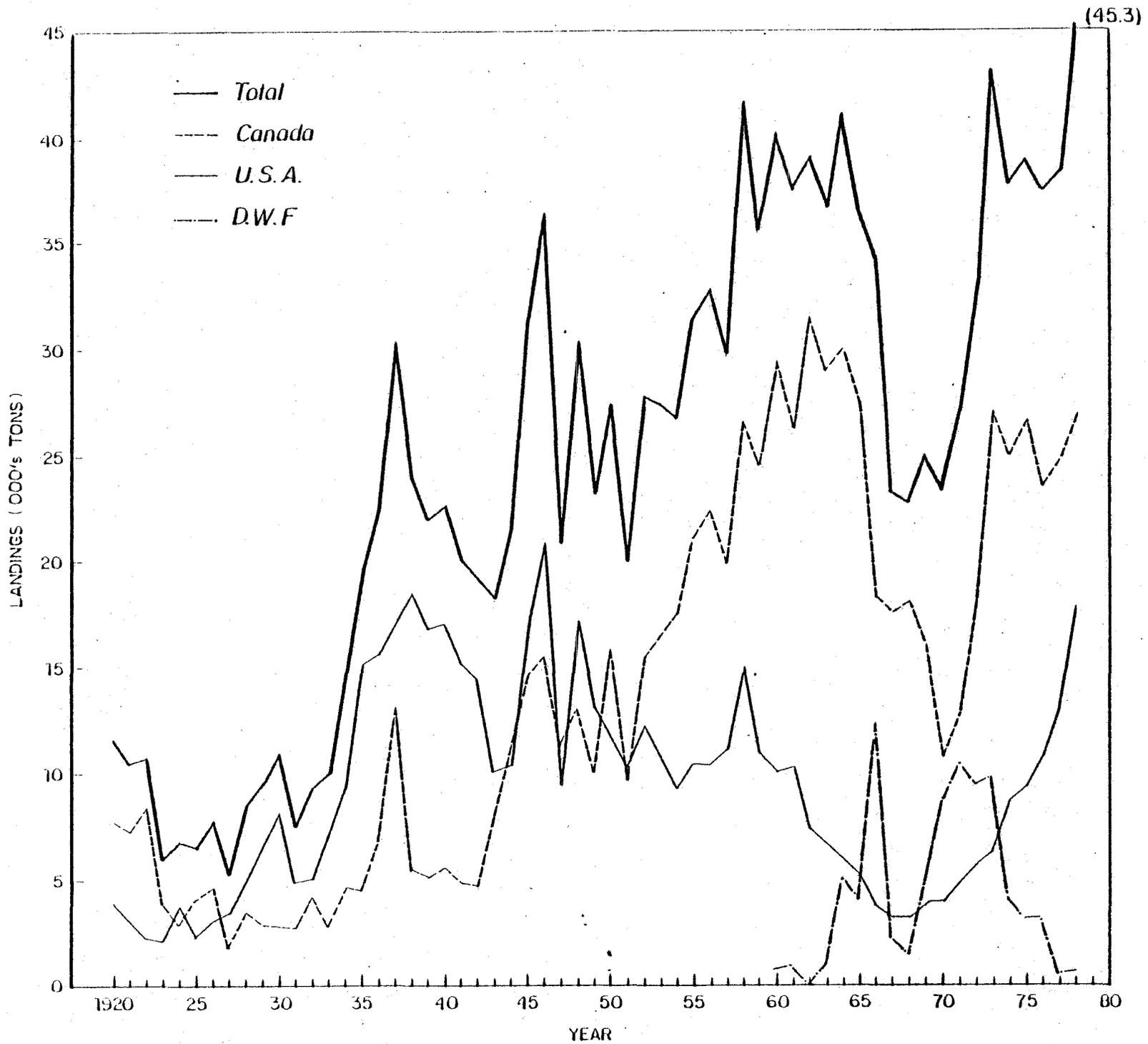


Figure 2. Commercial landings from the Scotian Shelf, Gulf of Maine, and Georges Bank pollock stock, 1920-1978.

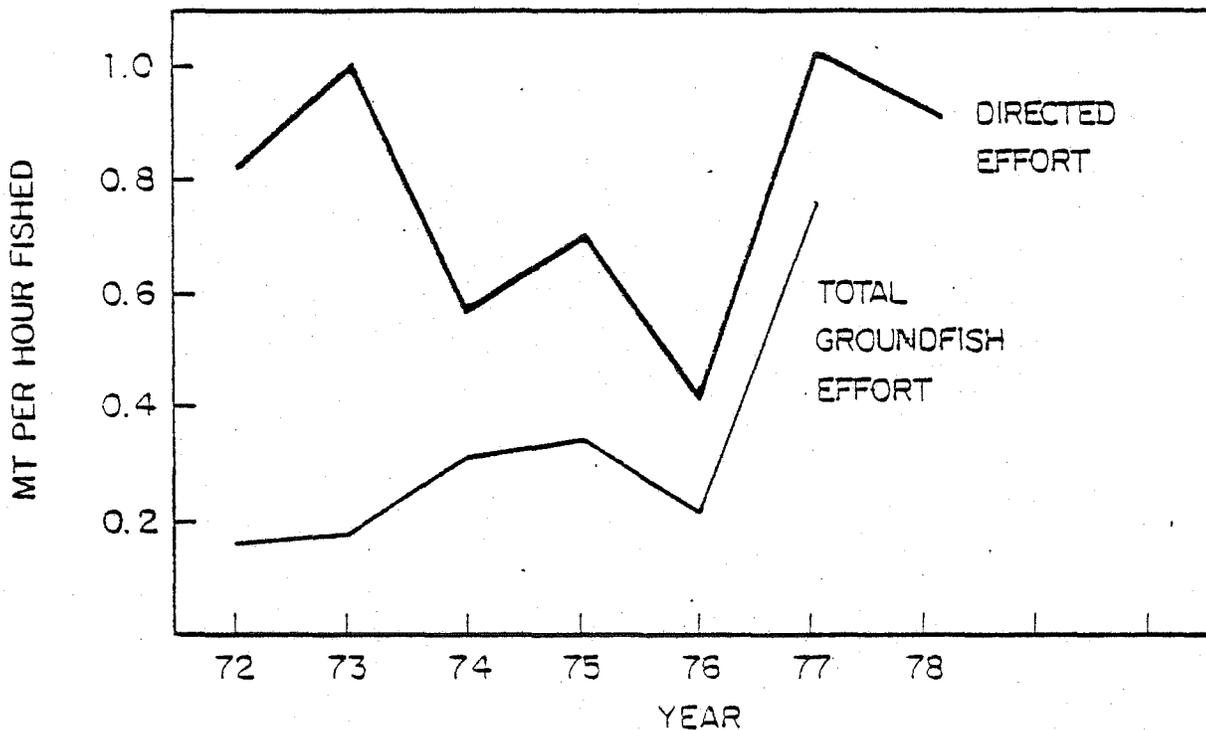


Figure 3. Pollock catch rates (tons per hour fished) calculated from "directed" effort and total effort data for the Canadian fishery. The first index is based on trip data for 500-999 GT otter trawlers for which 75% of the total landed weight consisted of pollock; the latter index was calculated using effort data directed towards all groundfish species.

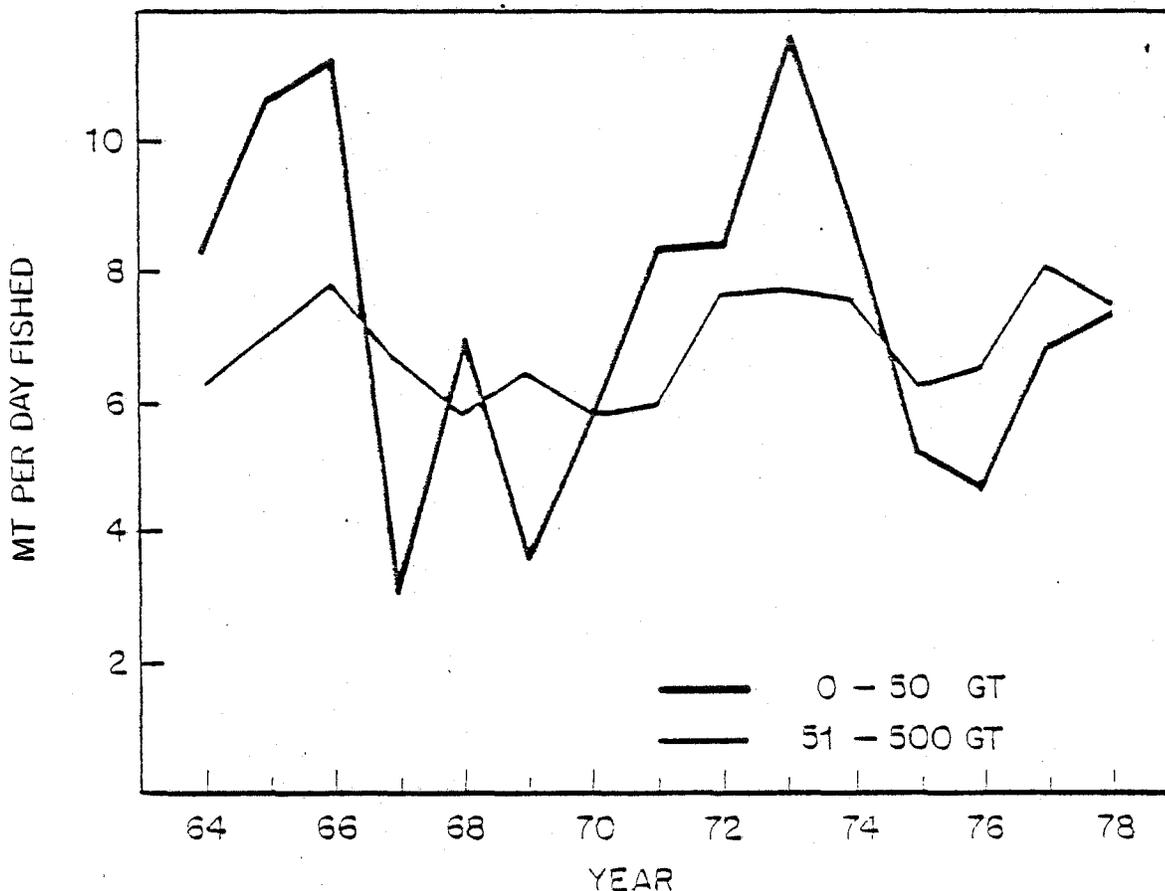


Figure 4. Pollock catch rates (tons per day fished) calculated from "directed" effort data for USA otter trawlers by tonnage class, 1964-1978. Indices are based on trip data for which 50% or more of the total landed weight consisted of pollock.

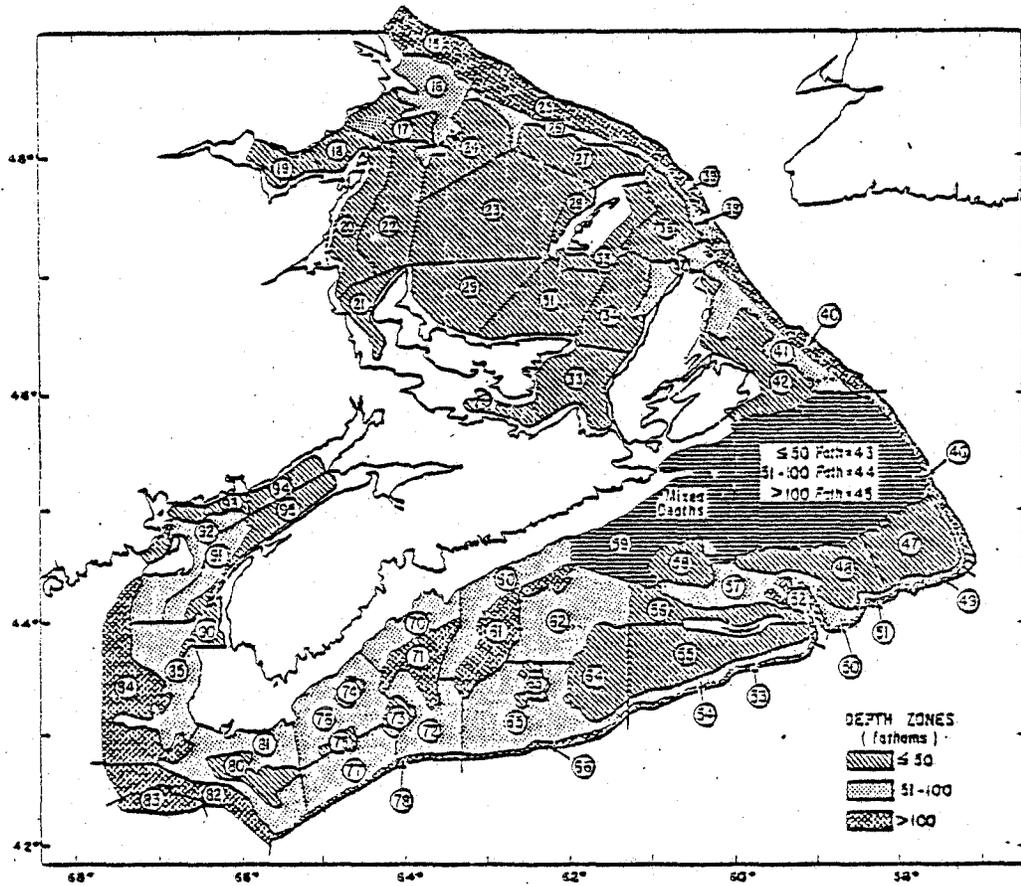


Figure 5. Strata used in Canadian summer bottom trawl surveys, 1970-1977.

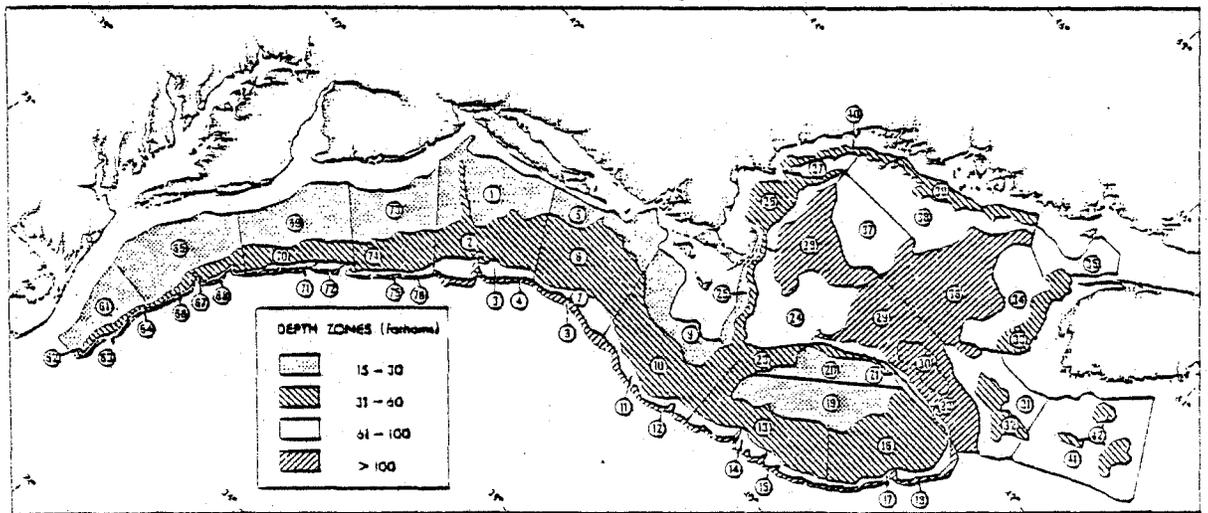


Figure 6. Strata used in USA spring and autumn bottom trawl surveys, 1963-1977.

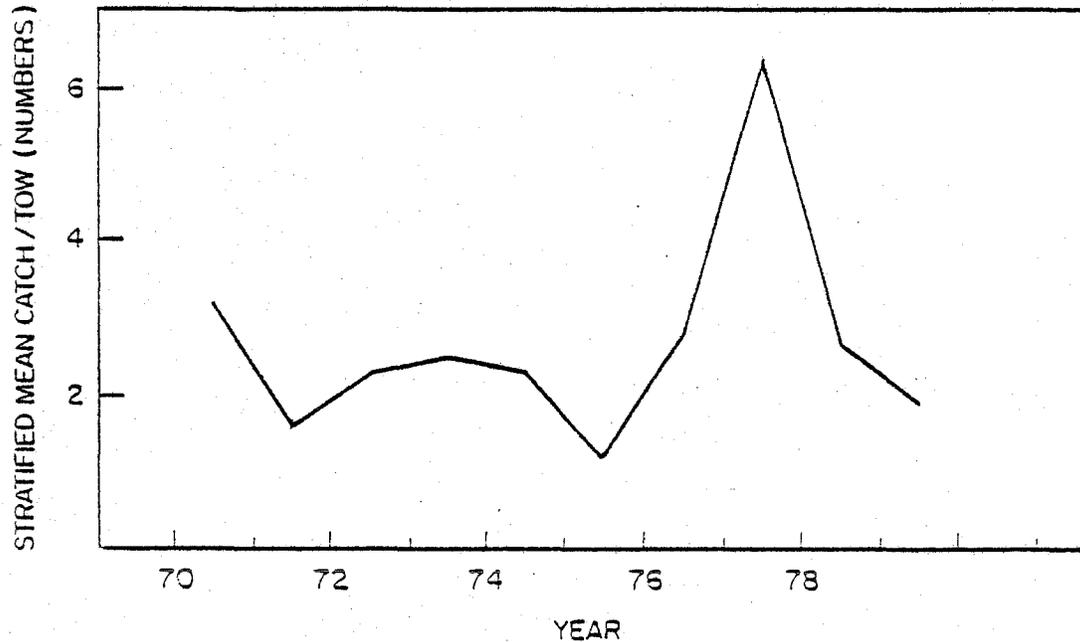


Figure 7. Stratified mean catch per tow (nos.) of pollock in Canadian summer bottom trawl surveys on the Scotian Shelf (strata 40-95), 1970-1979.

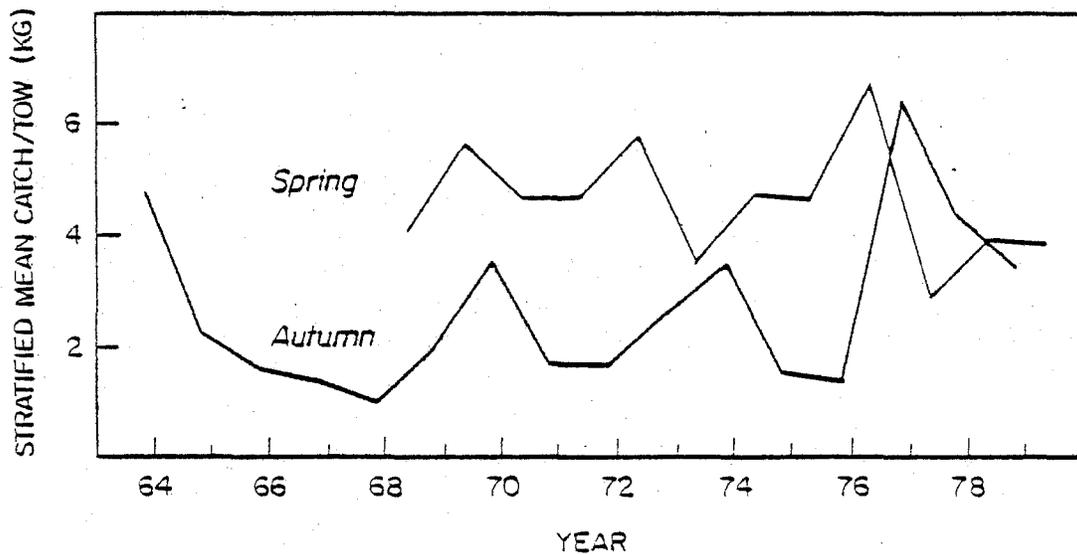


Figure 8. Stratified mean catch per tow (kg, retransformed from logarithms) of pollock in USA spring and autumn bottom trawl surveys for Georges Bank, the Gulf of Maine, and the Scotian Shelf (strata 13-42), 1963-1979. Spring data for 1968-1972 were adjusted by a factor of 1.7 to account for differences in surface area between the "36 Yankee" and the "41 Yankee" trawls.

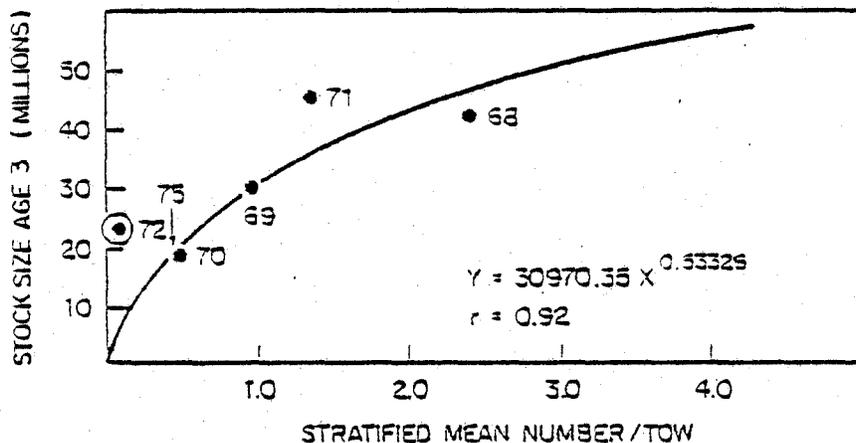


Figure 9. Power curve relationship between number of pollock per tow (ages 2 & 3 combined) in Canadian summer bottom trawl surveys and stock size at age 3 (millions) for the 1968-1971 year classes (1972 point not used in calculating the curve).

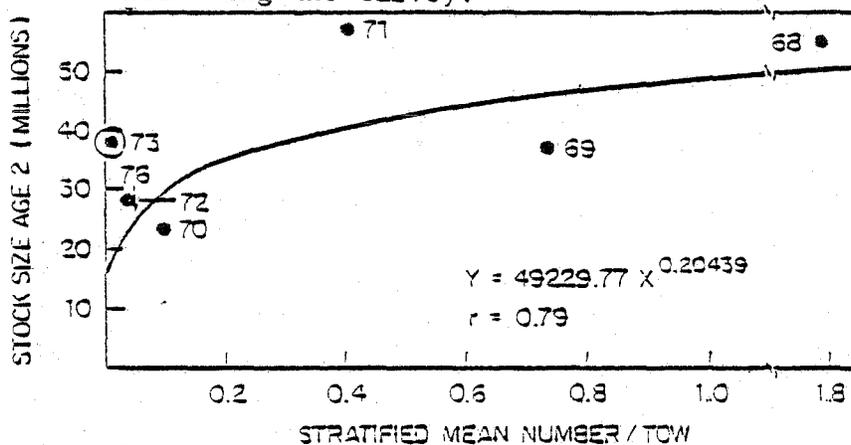


Figure 10. Power curve relationship between number of pollock per tow (age 2) in Canadian summer bottom trawl surveys and stock size at age 2 (millions) for the 1968-1972 year classes (1973 data point not used in calculating the curve).

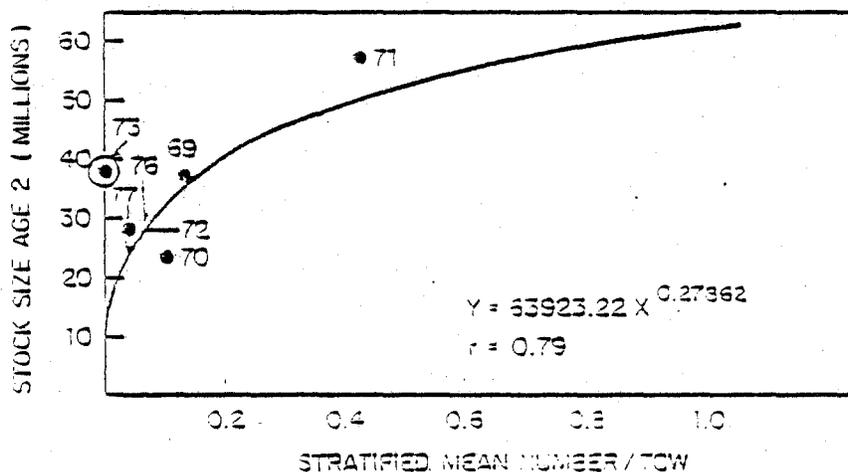


Figure 11. Power curve relationship between number of pollock per tow (age 1) in USA autumn bottom trawl surveys and stock size at age 2 (millions) for the 1969-1972 year classes (1973 data point not used in calculating the curve).

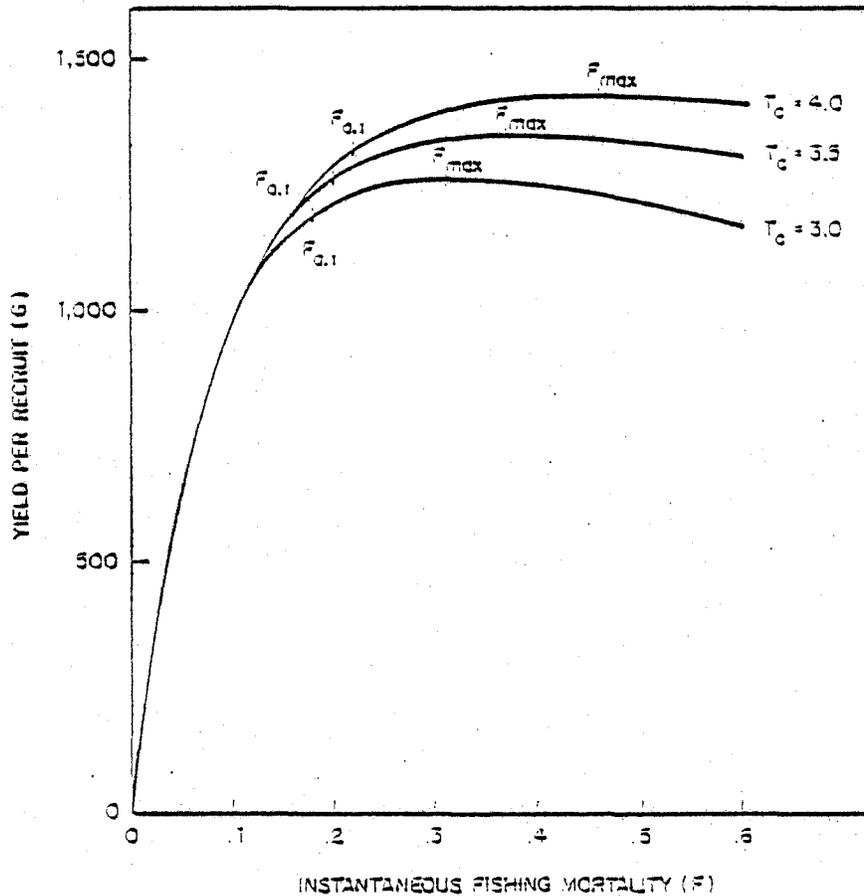


Figure 12. Yield per recruit curves for pollock (g) assuming t_c values of 3.0, 3.5, and 4.0 years, $W_\infty = 10.46$ kg, $k = 0.2149$, $t_0 = 0.4087$, $t_r = 2.0$ years, $t_\lambda = 20$ years, and $M = 0.2$.

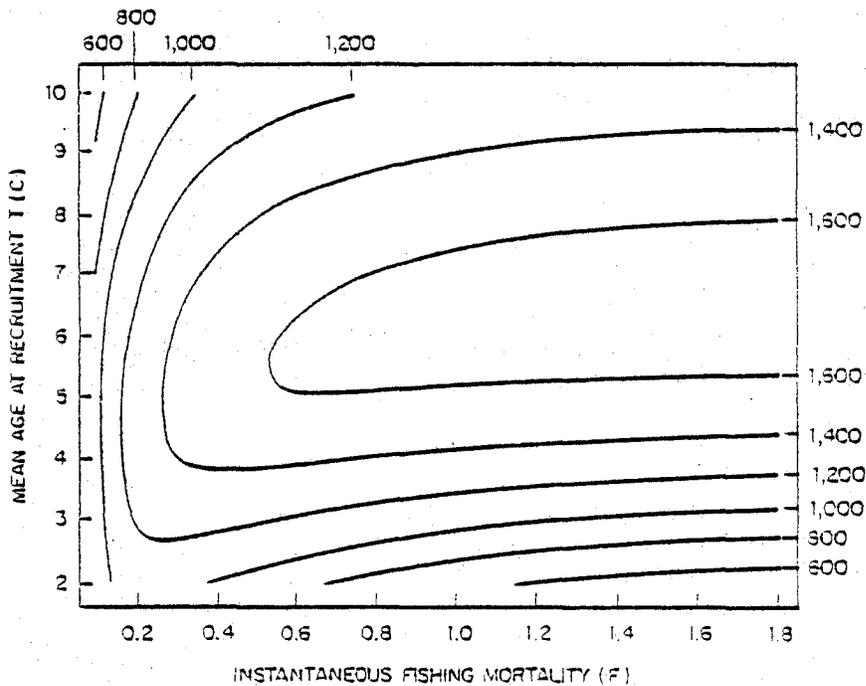


Figure 13. Yield isopleths (g) for Scotian Shelf, Gulf of Maine, and Georges Bank pollock assuming $W_\infty = 10.46$ kg, $k = 0.2149$, $t_0 = 0.4087$, $t_r = 2.0$ years, $t_\lambda = 20$ years, and $M = 0.2$.

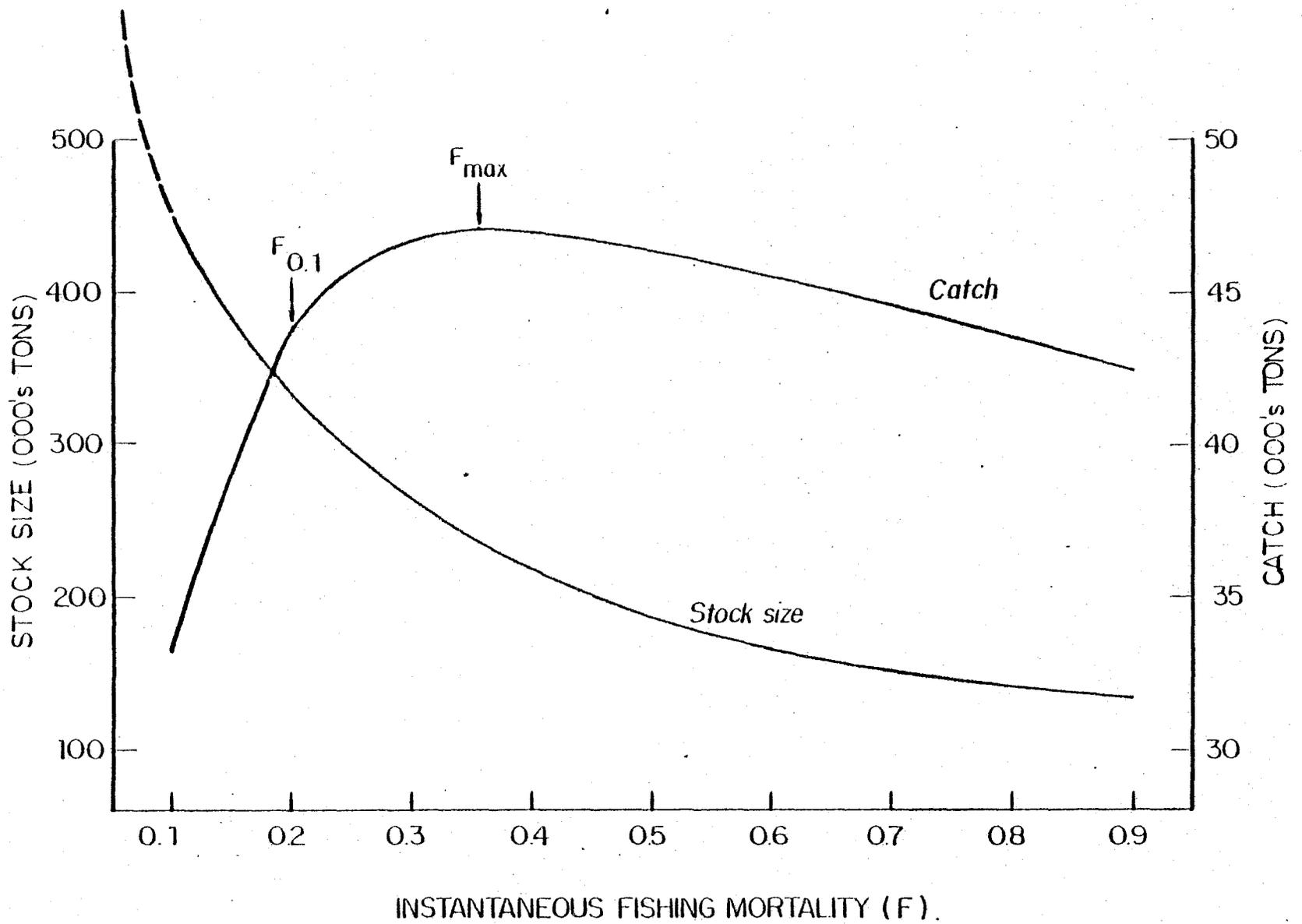


Figure 14. Catch and stock size at equilibrium for Scotian Shelf, Gulf of Maine and Georges Bank pollock assuming recruitment (age 2) equal to the 1968-1973 year-class average and partial recruitment as observed for 1973-1975.