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Status of the Atlantic Cod Stock on Georges Bank, NAFO Division 5Z and Statistical Area 6, in 1983

by

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ABSTRACT

Catches of cod in NAFO Division 5Z decreased from 57000 t in 1982 to about 49000 t in 1983, of which Canada landed 12000 t. Large otter trawl vessels accounted for most of the landings. Age groups 2-5 were dominant in the catch. The USA landed a higher proportion of age 2 fish compared to Canadian landings.

Bottom trawl surveys conducted by the USA provided the basis for estimating population size. Catch per tow in 1982-83 autumn surveys have been at low levels and predicted unrealistics estimates of stock size. Calculation of total mortality (Z) and derived fishing mortality (F) from various parts of the data series yielded estimates of f in 1983 ranging from 0.2 to 0.7. Estimates of catch at age were unreliable from 1976 to 1981 and no tuning for SPA was possible. An F in 1983 of 0.40 was assumed and used for catch projections to 1987 with three options.

Yield per recruit calculation gave an F0.1 of 0.15 and an Fmax of 0.25. Assuming a recruitment level of 30 million fish (geometric mean), a long term yield of 45000 t can be expected. If the 1984 TAC of 45000 t is taken, fishing at F0.1 in 1984 will produce a catch of about 20000 t.

RESUME

Les prises de morue dans la Division 5Z de l'OPANO ont diminué, passant de 57 000 t en 1982 à 49 000 t en 1983. Le Canada en a lui-même débarqué 12 000 t, en majeure partie à l'aide de grands chalutiers. Les groupes d'âge 2 à 5 ans constituaient le gros des prises. En comparaison, les Etats-Unis ont capturé une proportion plus grande de poissons de 2 ans.

Des relevés au chalut de fond effectuées par les Etats-Unis ont servi de point de départ pour évaluer la taille de la population. Des relevés faits à l'automne 1982-83 montrent une moyenne de prises trait de chalut assez faible; les estimations de population basées sur ces relevés se sont révélées peu réalistes. Le calcul du coefficient de mortalité totale (Z) et du coefficient de mortalité due à la pêche (F) établi à l'aide de diverses séries de données a permis de situer le F entre 0,2 et 0,7 pour 1983. Les prévisions relatives aux prises selon l'âge n'étaient pas très fiables de 1976 à 1981; il a donc été impossible de préciser ces données pour l'ASP (analyse séquentielle de la population). On a donc situé hypothétiquement le F à 0,40 en 1983 et ce coefficient a servi à établir des prévisions de prises jusqu'en 1987, selon trois possibilités ou scénarios.

Le calcul du rendement par recrue a donné un $F_{0,1}$ de 0,15 pour un F_{max} de 0,25. En admettant que le niveau de recrutement se situerait à 30 millions de poissons (moyenne géométrique), on peut espérer un rendement à long terme de 45 000 t. Si l'on s'en tient au TPA de 45 000 t pour 1984 et compte tenu du $F_{0,1}$ en 1984, les prises pourraient atteindre environ 20 000 t.

Introduction

The size of the cod population in NAFO Division 5Z plus Statistical Area 6 (Fig 1) was first evaluated by Brown and Heyerdahl (1972) through the examination of research vessel survey data and commercial catch rates. Serchuk et al. (1977, 1978) conducted virtual population analyses in an effort to determine stock size but dropped this approach in subsequent assessments (Serchuk et al. 1979, 1980, 1981, 1982) due to growing uncertainties about the reliability of reported catch statistics. Catches from the period 1977 to 1980 remain uncertain, but catches and sampling data from 1981 to 1983 appear to more closely reflect the fishery.

The present assessment reviews the approach employed by Clark et al. (1982), O'Boyle (1983) and Hurley and O'Boyle (1983) in which survey data are calibrated with SPA results from 1960-76 and used to estimate current resource size.

Trends in Reported Landings

Annual Landings

The US has been the main harvester of cod from NAFO Division 5Z and Statistical Area 6, with significant foreign landings in the mid-1960 period (Table 1, Figure 2). Catches by the Canadian offshore fleet were also high in the mid-1960's, peaking at 15601 tons in 1966. Landings declined until 1974 and have shown a steady increase since then. Landings by the USSR, Spain and Poland were high in the mid- to late- 1960's. Since the declaration in 1977 of a 200 mile exclusion zone by Canada and the USA, there have been no landings by these countries.

Total catch in 1982 was 57000 tons, the highest since 1960, but there was a decline by 15% in 1983 to 49000 tons of which Canada landed 12000 tons or 25%.

Fishery by Gear Type and Tonnage Class

The US cod fishery on Georges Bank has been dominated by otter trawlers (Table 2) that operate throughout 5Z. Increased catches by this gear type as well as miscellaneous gears have accounted the increased landings in recent years.

Canadian landings are primarily by otter trawl and longline (57% and 43% in 1983) and are confined to the "northeast peak" of Georges Bank (unit areas 5ZEj and 5ZEm) during July to September (Table 3, Figure 3). The Canadian otter trawl fleet has been

dominated by large vessels (TC 4 and TC 5), but in recent years smaller TC 2 and TC 3 vessels have taken a large part of this catch component (52% in 1983, Table 4).

Age Composition of the Commercial Catch

Sampling Intensity

Coverage of the Canadian fishery has been at a low level (Table 3) and is strongly biased towards the otter trawl fleet. A total of 3822 lengths were taken and 601 fish aged in 1983 from 14 samples.

US sampling coverage has increased substantially since 1980 and the number of samples collected has doubled from 70 in 1980 to 145 in 1983. Estimated catch at age in numbers was made available for 1981-83 by Serchuk (pers. comm.).

Age Composition of Commercial Catch

Serchuk et al. (1977) provides catch at age data for the fishery during 1960-76 but data are unavailable for 1977-80 because of uncertainties in the catch during this time period. Serchuk (1982) suggests catch may have been twice that reported. Catch at age in percent and numbers for 1981-83 by Canada and US is given in Table 5a and 5b and by percent for Canada from 1975-83 in Table 6.

Age groups 2-5 account for most of the yield but a difference in catch composition between US and Canadian is apparent (Fig 4). US catches show a higher proportion of age 2 individuals which in recent years accounted for over twice the percentage caught at age 2 by Canada (Table 5a). Consistency in yearclass abundance and mean length at age suggest the difference is related to catch rather than interpretation of ageing structures. The 1975, 1977 and 1980 yearclasses are dominant in the fishery.

Stock Abundance Trends

Bottom Trawl Surveys

Random, stratified bottom trawl surveys have been conducted on Georges Bank and Gulf of Maine in the autumn since 1963 and a spring survey added in 1968. A summer survey was conducted from 1977 to 1981. Extension of the Canadian bottom trawl survey to include the northern part of Georges Bank (US Strata 16-22, Fig 5) was accomplished in March, 1984. Mean catch per tow in numbers by

age group for each of the surveys is given in Table 7 and mean catch per tow in number and weight in Table 8 (Fig 6). Preliminary results of the 1984 Canadian survey are included. No adjustment for different gear types used in the survey by the US or Canada have been taken into consideration. The surveys appear to consistently indicate relative yearclass abundance at age group 0 and at subsequent ages as the yearclass moves through the population. The anomolously low catches reported in the autumn 1982 survey appear to have continued in 1983.

Yearclass abundance from survey results is shown in Figure 8 and indicates several well represented yearclasses since 1979. The 1983 yearclass at age 0 appears to be strong and accounted for 28% of the total catch in numbers for the 1983 autumn survey.

Commercial Catch Rates

Commercial catch and effort for Canadian otter trawlers is available for 1968-83 for directed trips (cod primary species). The percent of the total otter trawl catch with effort data, used in the series, increased from 16% in 1979 to about 71% in 1983.

Catch rates for Canadian TC 4 side and TC 5 stern otter trawlers, operating on Georges Bank during July-September (Table 9, Figure 9) are relatively stable during 1970-76 and increase thereafter. Both rates decrease in 1982 but the stern trawler rate shows an increase to 0.827 t per hour in 1983. There was no recorded effort for TC 4 side trawlers in 1983, reflecting a decision by industry not to deploy this component of the fleet. The apparent increase in catch rate for 1983 may be a result of the relative contribution of the 1980 yearclass. In 1981, 1982, and 1983 the 3+ catch was 91%, 72% and 89%, respectively, of the total catch. The effect of catching more age 2 fish in 1982 may have lowered the weight per hour caught.

Survey Recruitment Indices

Indices of recruitment were developed through the application of the normalization method of O'Boyle (1981) to age 0, 1 and 2 autumn trawl survey data. The mean of the 1963-82 catch per tow for each age group was used to normalize the observed values and the average of the catch per tow at age 0 and 1 and at age 1 and 2 selected as the index of abundance. The two calculated indices (Table 10, Figure 10) show strong 1966, 1971 and 1975 yearclasses. The 1980 yearclass is above average in size and the 1981 and 1982 yearclasses appear to be below average. The single point estimate of the 1983 yearclass at age 0 in the 1983 autumn survey indicates above average abundance.

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Estimation of Current Stock Size and Fishing Mortality

Total Mortality Estimates 1964-82

Values of total mortality calculated by Serchuk et al.(1982)(Table and Figure 11(a)) from survey data show high mortality during 1964-67, a decrease to 0.47 in 1968-72, an increase to 0.69 in 1973-77 and a further increase in 1978-83. The high value (0.85) observed in the 1978-83 series is a result of the low catches in the 1982-83 autumn survey and it is probable that the actual Z value is lower than calculated and may be better estimated from the spring survey alone (0.61, F=0.41). Calculation of Z values from the 1981-83 spring survey data for age groups and individual yearclasses (Table and Figure 11(b)) indicate average values of about 0.60 and an F of 0.40 in 1983.

Current US views are that F is in the vicinity of 0.39, at least in 1981 (Serchuk et al., 1982).

Sequential Population Analysis

Hurley and O'Boyle (1983) attempted to relate results of VPA for the years 1960-76 with results of surveys to develop a population-survey relationship. This relation could not be resolved but they found the 3+ population numbers to be constant at about 29.5 million for 1965-72 and also noted the mean catch per tow of 2+ fish in the US autumn from 1964-71 varied little around a value of 1.8 (Figure 7). This association was then used to estimate the 3+ stock size in 1982 based on the 1981 2+ autumn survey value.

Revision of the 1982 US autumn survey catch per tow for 2+ fish and addition of the 1983 value changed the median smoothed value for 1982 from 3.4 to 1.6 and the estimated 3+ population from 56 million to 26 million fish. A value of 26 million 3+ fish was also predicted for 1983 and the 3+ catch at age in 1982 and 1983 required an F of 0.53 and 0.79, respectively. This level of fishing mortality exceeded the F max by a factor of 2 or 3 as well as the value of F predicted from the survey Z values for 78-83. Availability of fish in the 1982 survey was assessed to be a contributing factor and use of this index for population numbers was rejected as unrealistic.

The limited time series of catch at age (1981-83) precluded fine tuning of an SPA model and resolution of a terminal F in 1983. However, the Z value calculated from US spring survey appeared to reflect stock status with 0.40 fishing mortality.

Trial cohort runs were made using a terminal F in 1983 of 0.30, 0.40 and 0.50 to calculate population size and F in 1981 and 1982. Results are shown in Table 14 and indicate differences in the weighted (on numbers) F for 3+ fish. With F in 1983 of 0.30, F in 1981 is highest, with F=0.40, F in 1982 is highest and with to most closely relate to both the catch and to the CPUE for the 1981-83 time period. Total catch in 1982 was greater than 1981 or 1983 and CPUE was lowest in 1982 which suggests that F should be higher in 1982. No further tuning of the cohort series was possible and it was decided to accept the run at F=0.40 as the best approximation of stock status.

Determination of Potential Yield for Near Future

Yield Per Recruit Calculation

Yield per recruit calculations completed by Hurley and O'Boyle (1983), using US survey data, partial recruitment pattern and growth parameters (Table 12), indicated an F0.1=0.15 and Fmax=0.25 (Table 13). The F0.1 yield per recruit (1.415kg) and geometric mean recruitment of 30 million fish at age 1 gives a projected long term average yield of about 45000 t for this stock.

Potential Yield 1984-87

The estimate of stock numbers derived from 1983 catch at age and F were used to calculate stock size at the start of 1984 and these values used to project catches in 1984-87, assuming the 45000 t TAC is taken in 1984. The results indicate an F=0.40 in 1984 and population weight of 167000 t. Three options were considered for further catch projections - fishing at F0.1 in subsequent years, fishing at Fmax, and maintaining a TAC of 45000 t. Results are shown in Table 15. All three options indicate a degree of stock increase in terms of population weight and a TAC in 1985 of 20000 to 45000 t and it is probable that a long term yield of 40000-45000 t can be maintained. Size of the 1983 yearclass, which initial indices suggest is above average, will be a significant factor in determining catch rates in the short term.

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Table 1. Nominal catches (t, round) of Atlantic cod from Georges Bank and southward (NAFO Division 5Z and Statistical Area 6), 1960-83.

Year	USA	Canada	USSR	Other a	Total
1960	10834	19	-	-	10853
1961	14453	223	55	-	14731
1962	15637	2404	5302	143	23486
1963	14139	7832	5217	1	27189
1964	12325	7108	5428	304	25165
1965	11410	10598	14415	1910	38333
1966	11990	15601	16830	8713	53134
1967	13157	8232	511	14852	36752
1968	15279	9127	1459	17271	43136
1969	16782	5997	646	14514	37939
1970	14899	2583	364	7806	25652
1971	16178	2979	1270	7752	28179
1972	13406	2545	1878	7230	25059
1973	16202	3220	2977	6524	28923
1974	18377	1374	476	7104	27331
1975	16017	1847	2403	4741	25008
1976	14906	2328	933	1759	19926
1977	21138	6173	54	2	27367
1978	26579	8904	-	-	35483
1979	32645	6011	-	-	38656
1980	40053	8094	-	-	48147
1981	33849	8508	-	-	42357
1982 b	39333	17861	-	-	57194
1983 c	36647	12131	-	-	48778

a. Primarily Spain and Poland

b. Provisional

c. Preliminary

Table 2. Distribution of USA commercial landings (t, round) of Atlantic cod from Georges Bank (5Ze), by gear type, 1965-1981. Data only reflect landings which could be identified by gear type. (from Serchuk et al, 1982 and pers. comm.)

	Landings (t, live)				
Year	Otter Trawl	Line Trawl	Handline	Other Gear	Total
1965	10251	582	505	9	11347
1966	10206	787	757	19	11769
1967	10915	894	704	9	12522
1968	12084	936	524	1	13544
1969	13194	1371	387	1	14952
1970	11270	1676	404	1	13350
1971	12436	2334	230	2	15002
1972	10179	2071	217	10	12477
1973	12431	2185	206	24	14846
1974	14078	2548	11	12	16649
1975	12069	2435	84	4	14592
1976	12257	1519	153	9	13938
1977	18529	912	83	52	19576
1978	20862	1569	1180	140	23751
1979	26562	2707	860	779 a	30908
1980	32479	1102	-	4764 b	38345
1981	27694	120	584	3712 c	32110
1982	33371	385	624	3145	37525
1983	30981	831	441	1893	34146

a. Of 779 landed, 620 tons were by sinking gill nets
b. Of 4764 landed, 4491 tons were by sinking gill net, and 222 tons were by Danish seine
c. Of 3712 landed, 3513 tons were by sinking gill net, and 362 tons were by Danish seine

Table 3. Nominal catches (t, round) of Atlantic cod from Georges Bank (5Ze) by Canada, 1968-82. Number of biological samples taken shown in parenthesis.

Year	Gear			
	Otter Trawl	Longline	Other	Total
1968	7838 (3)	1263	24	9125
1969	5232 (3)	719	30	5981
1970	1879	683	19	2581
1971	2073	867	38	2978
1972	736 (2)	1776 (2)	35	2547
1973	1904 (1)	1291	21	3216
1974	475	897 (1)	1	1373
1975	927 (2)	918	-	1845
1976	1423 (2)	901 (1)	-	2324
1977	5520 (10)	644	4	6168
1978	7756 (28)	728	287	8771
1979	4630 (12)	1340	2	5972
1980	5407 (10)	2634	21	8062
1981	3971 (14)	2933 (3)	1602	8506
1982	12337 (6)	5126 (2)	364	17827
1983	6900 (13)	5175 (1)	56	12131

Table 4. Nominal catches (t, round) of Atlantic cod from Georges Bank (NAFO 5Ze) by Canadian otter trawls, 1968-83

Year	Side Otter Trawl					Stern Otter Trawl					
	TC 1	2	3	4	5	TC 1	2	3	4	5	6
1968	-	-	30	3071	10	-	-	-	485	4242	-
1969	-	2	2	1292	-	-	-	-	268	3668	-
1970	-	-	7	674	-	-	2	-	62	1135	-
1971	-	-	-	731	20	-	-	-	28	1294	-
1972	-	-	2	238	-	-	-	-	3	493	-
1973	-	-	8	789	-	-	-	-	62	1045	-
1974	-	-	-	21	-	-	-	2	14	438	-
1975	-	-	12	133	-	-	-	-	31	751	-
1976	-	-	6	109	21	-	-	1	38	1248	-
1977	-	11	95	525	-	-	100	620	52	4117	-
1978	-	18	4	1854	-	-	142	742	214	4782	-
1979	-	14	46	1389	-	-	147	966	465	1603	-
1980	-	73	75	545	8	-	429	501	606	3170	-
1981	-	1	69	186	-	-	505	418	547	2245	-
1982	-	42	216	92	-	3	1916	1684	895	6689	785
1983	-	36	374	-	-	-	2192	998	154	3141	-

Table 5(a) . Comparison of Canadian and US catch at age of 5Z cod for 1981 - 83. Numbers in thousands (t) derived from numbers X mean weight.

	1981						1982						1983					
Age	CDN			USA			CDN			USA			CDN			USA		
Group	%	N	t	%	N	t	%	N	t	%	N	t	%	N	t	%	N	t
1	.1	3	1	.2	25	9	.1	5	2	2.3	325	117	.6	26	9	.7	81	29
2	9.3	246	241	29.6	3060	2999	28.1	1468	1439	54.6	7855	7698	10.2	435	426	28.4	3532	3461
3	37.1	983	1897	34.9	3613	6973	22.3	1165	2248	17.7	2466	4759	46.9	1993	3846	44.6	5542	10696
4	31.6	837	2653	19.0	1960	6213	16.8	877	2780	11.7	1682	5332	28.9	1229	3896	10.0	1240	3931
5	7.9	209	970	1.0	101	469	17.7	924	4287	8.7	1258	5837	8.5	360	1670	6.9	852	3953
6	7.7	204	1281	9.9	1026	6443	4.4	230	1444	.8	117	384	2.5	106	666	5.8	720	4522
7	3.2	85	683	3.2	330	2650	6.4	334	2682	3.1	452	3630	.7	28	225	.7	85	683
8	1.9	50	492	.7	72	708	2.9	151	1486	.8	116	1141	1.2	52	512	1.7	217	2135
9	.7	19	221	1.1	109	1270	.9	47	548	.3	50	583	.3	14	163	.7	87	1014
10	.4	11	148	.4	46	618	.1	5	67	.2	23	309	.2	8	107	.2	25	336
11	.1	3	45	.0	0	0	.4	21	318	.2	34	515	.1	2	30	.3	36	546
Total	100.	2650	8633	100.	10342	28352	100.	5223	17302	100.	14378	30305	100.	4253	11552	100.	12417	31305
3+	90.6	2401		70.2	7257		71.8	3750		43.1	6198		89.2	3792		70.9	8804	
4+	53.5	1418		35.3	3644		49.5	2585		25.4	3732		42.3	1799		26.3	3262	
5+	21.9	581		16.3	1684		32.7	1708		13.7	2050		13.4	570		16.3	2022	
Catch		8508			33849			17861			39333			12131			36647	
Mean kg		3.21			3.27			3.42			2.74			2.86			2.95	
Cal/Obs Catch		1.01			.84			.97			.77			.95			.85	

Table 5(b) . Estimated total catch at age in numbers (thousands) and percent. USA and Canada, 1981-83.

	1981		1982		1983	
Age	N	%	N	%	N	%
1	28	0.2	330	1.7	107	0.6
2	3306	25.4	9056	46.2	3967	23.8
3	4596	35.4	3631	18.5	7535	45.2
4	2797	21.5	2559	13.1	2469	14.8
5	310	2.4	2182	11.1	1212	7.3
6	1230	9.5	347	1.8	826	5.0
7	415	3.2	786	4.0	113	0.7
8	122	0.9	267	1.4	269	1.6
9	128	1.0	97	0.5	101	0.6
10	57	0.4	28	0.1	33	0.2
11+	3	-	55	0.3	38	0.2
Total	12992	100.0	19601	100.0	16670	100.0
Catch	42354		57194		48778	

Table 6. Age composition (percent by number) derived from biological samples of Atlantic cod from Georges Bank (5Ze) taken by Canadian vessels, 1975-83

	Year								
Age	1975	1976	1977	1978	1979	1980	1981	1982	1983
1	-	-	-	0.1	-	0.1	0.1	0.1	0.6
2	8.9	16.9	87.5	3.1	26.4	24.8	9.3	28.1	10.2
3	44.7	39.8	9.7	61.2	27.3	39.0	37.1	22.3	46.9
4	38.5	33.3	1.8	21.6	31.7	9.8	31.6	16.8	28.9
5	6.9	6.5	0.4	7.1	10.7	16.6	7.9	17.7	8.5
6	0.3	2.8	0.5	3.4	2.5	6.3	7.7	4.4	2.5
7	0.3	0.4	0.1	2.4	0.8	1.6	3.2	6.4	0.7
8	0.2	0.1	0.1	0.4	0.4	0.6	1.9	2.9	1.2
9	0.1	-	0.1	0.5	0.1	0.8	0.7	0.9	0.3
10	0.1	-	-	0.1	0.1	0.4	0.4	0.1	0.2
11+	0.1	0.1	-	1.2	0.1	0.3	0.1	0.4	0.1
# Samples	2	2	10	28	11	10	14	6	15
# Aged	111	99	378	1364	591	536	791	341	601

Table 7. Stratified mean catch per tow at age (numbers) of Atlantic cod in USA offshore spring, summer and autumn bottom trawl surveys on Georges Bank a, 1963-1982.b (from Serchuk et al, 1982).

	Age											Totals					
Year	0	1	2	3	4	5	6	7	8	9	10+	0+	1+	2+	3+	4+	5+
Spring c																	
1968	.329	.087	1.035	.529	.426	.247	.158	.090	.053	.036	.037	3.027	2.698	2.611	1.576	1.047	.621
1969	-	.079	.350	1.141	.569	.289	.209	.138	.082	.046	.072	2.975	2.975	2.896	2.546	1.405	.836
1970	-	.244	.522	.308	.830	.104	.420	.176	.039	.087	.053	2.783	2.785	2.539	2.017	1.709	.879
1971	-	.133	.525	.322	.143	.375	.091	.225	.195	.051	.112	2.172	2.172	2.039	1.514	1.192	1.049
1972	.036	1.860	1.175	1.695	.327	.076	.208	.078	.141	.074	.080	5.748	5.712	3.852	2.677	.984	.657
1973	.036	.334	27.000	4.035	4.117	.418	.325	.244	.032	.126	.246	36.913	36.877	36.543	9.543	5.505	1.391
1974	-	.286	2.921	3.828	.488	1.284	.282	.065	.165	.022	.112	9.453	9.453	9.167	6.246	2.418	1.930
1975	-	.041	.242	1.309	1.982	.167	.440	.083	.060	.069	.025	4.418	4.418	4.377	4.135	2.826	.844
1976	.071	.834	1.232	.605	.443	1.008	.105	.168	.023	-	.035	4.524	4.453	3.619	2.387	1.782	1.339
1977	-	.018	2.261	.692	.335	.179	.466	.033	.042	-	.013	4.039	4.039	4.021	1.760	1.068	.733
1978	2.123	.241	.120	3.545	.621	.499	.092	.457	.033	.091	.070	7.892	5.769	5.528	5.408	1.863	1.242
1979	.070	.279	.871	.191	1.226	.347	.150	.056	.093	.008	.014	3.305	3.254	2.956	2.084	1.897	.668
1980	.067	.025	1.452	1.723	.134	.950	.383	.123	.020	.019	.071	4.967	4.890	4.865	3.413	1.690	1.556
1981	.244	1.869	1.555	2.255	1.353	.081	.706	.218	.117	-	.069	8.467	8.223	6.354	4.799	2.544	1.191
1982	.120	.396	2.755	1.141	1.051	.843	.013	.242	.052	.013	.028	6.654	6.534	6.138	5 -	2.242	1.191
1983	.052	.211	1.261	1.954	.491	.447	.276	.035	.123	-	.087	4.937	4.885	4.674	2.720	1.459	.968
Summer d																	
1977	.131	.195	5.121	1.111	.660	.164	.326	.051	.081	-	.026	7.866	7.735	7.540	2.419	1.308	.648
1978	.755	.350	.266	1.542	.369	.149	.057	.109	-	.028	-	3.625	2.870	2.520	2.254	.712	.343
1979	.236	1.459	1.767	.375	.943	.234	.050	.053	.115	-	.031	5.261	5.025	3.566	1.799	1.426	.483
1980	2.646	.640	4.135	2.371	.064	.415	.092	-	.031	-	-	10.394	7.748	7.108	2.973	.602	.538
1981	.024	3.347	1.657	1.224	.568	.035	.098	.048	-	-	-	7.001	6.977	3.630	1.973	.749	.181
Autumn																	
1963	.012	.461	.499	.590	.575	.227	.209	.112	.066	.009	.044	2.804	2.792	2.331	1.832	1.242	.667
1964	.006	.410	.448	.377	.345	.093	.087	.040	.032	.109	.053	1.910	1.904	1.494	1.046	.669	.324
1965	.111	.833	.640	.453	.310	.107	.115	.072	.052	.015	.015	2.723	2.612	1.779	1.139	.686	.376
1966	.657	1.085	.641	.330	.169	.064	.061	.040	.025	.001	.011	3.084	2.427	1.342	.701	.371	.202
1967	.046	4.869	.855	.335	.260	.085	.085	.035	.033	.008	.045	6.656	6.610	1.741	.886	.551	.291
1968	.045	.201	1.033	.502	.174	.047	.043	.017	.015	.005	.031	2.113	2.068	1.867	.834	.332	.158
1969	-	.220	.399	.401	.212	.060	.039	.012	.015	.014	.038	1.410	1.410	1.190	.791	.390	.178
1970	.265	1.082	.867	.336	.445	.098	-	.021	.035	.035	.063	3.247	2.982	1.900	1.033	.697	.252
1971	.256	.386	.405	.250	.193	.305	.117	.027	.057	-	.048	2.044	1.788	1.402	.997	.747	.554
1972	.607	4.771	.830	1.135	.256	.156	.366	.070	.131	.014	.053	8.389	7.788	3.011	2.181	1.046	.790
1973	.130	1.121	3.891	.758	1.290	.135	.145	.112	.040	.089	.161	7.872	7.742	6.621	2.730	1.972	.682
1974	.296	.262	.419	.975	.105	.073	.066	-	.044	-	-	2.240	1.944	1.682	1.263	.288	.183
1975	1.524	.637	.270	.400	1.080	.072	.100	-	-	-	.024	4.107	2.583	1.946	1.676	1.276	.196
1976	-	3.941	1.328	.489	.178	.474	.035	.073	.025	.034	.013	6.690	6.690	2.749	1.421	.932	.754
1977	.123	.192	2.778	.570	.204	.141	.321	.006	.022	-	.063	4.420	4.297	4.105	1.327	.757	.553
1978	.321	1.505	.207	3.392	.782	.272	.134	.279	.041	.024	.011	6.968	6.647	5.142	4.935	1.543	.761
1979	.096	1.314	1.393	.182	1.389	.240	.146	.029	.093	.006	.018	4.826	4.730	3.416	2.023	1.841	.532
1980	.227	.664	.458	.628	.062	.204	.043	.054	.020	-	-	2.360	2.133	1.469	1.011	.383	.321
1981	.212	2.860	1.826	1.265	.478	.044	.470	.046	.052	.015	.067	7.335	7.123	4.263	2.437	1.172	.694
1982	.205	.561	1.342	.141	.044	.062	-	.010	-	-	.014	2.379	2.174	1.613	.271	.130	.086
1983 e	.661	.415	.655	.510	.035	.030	.002	-	.008	-	.015	2.331	1.670	1.255	.600	.090	.055

a. Spring and autumn: strata 13-25; summer: strata 13, 16, 19-25

b. Catch per tow at age for 1963-69 obtained by applying 1970-81 age-length keys to stratified mean catch per tow at length distributions from each survey.

c. Spring surveys during 1973-81 were accomplished with a "Yankee 41" trawl. In all other years, spring surveys were accomplished with a "Yankee 36" trawl. No adjustments have been made for these gear differences.

d. Summer survey in 1978 only sampled strata 13, 16, 19-20, 23-25. Summer survey in 1981 sampled strata 13, 16, 19-21, 23 and 25.

e. Preliminary. 1982 survey catches of most species anomolously low (pers. comm. Serchuk).

Table 8. Stratified mean catch per tow in numbers and weight (kg) for Atlantic cod from USA offshore spring, summer and autumn bottom trawl surveys (Strata 13-25) 1963-83. (from Serchuk et al.,1982)

	Spring a		Summer b		Autumn	
Year	Nos	Wgt (kg)	Nos	Wgt (kg)	Nos	Wgt (kg)
1963	-	-	-	-	2.80	11.0
1964	-	-	-	-	1.91	7.1
1965	-	-	-	-	2.72	7.2
1966	-	-	-	-	3.09	5.0
1967	-	-	-	-	6.66	8.3
1968	3.03	7.8	-	-	2.12	5.3
1969	2.97	11.0	-	-	1.41	4.9
1970	2.78	9.7	-	-	3.25	7.8
1971	2.17	8.8	-	-	2.04	6.1
1972	5.74	11.7	-	-	8.39	14.2
1973	36.91	58.1	-	-	7.87	19.1
1974	9.45	22.5	-	-	2.24	5.1
1975	4.42	16.1	-	-	4.11	8.7
1976	4.52	11.5	-	-	6.68	10.9
1977	4.04	9.5	7.87	17.6	4.42	11.5
1978 c	7.89	19.3	3.62	10.7	6.97	21.5
1979	3.30	10.4	5.25	12.3	4.82	15.2
1980 d	4.96	15.3	10.39	15.0	2.36	6.2
1981	8.47	24.0	7.00	10.2	7.33	17.5
1982	6.65e	14.2e	-	-	2.38f	4.3f
1983	4.94	14.8	-	-	2.33f	4.0f
**********						
1984 Cdn	5.83	24.4				

a. Spring surveys, 1973-80, were accomplished with "41 Yankee" trawl and with "36 Yankee" trawl in other years. No adjustment in catch per tow has been made for these gear differences.
b. Summer surveys only include Strata 13, 16, 19-25
c. Summer survey in 1978 only sampled Strata 13, 16, 19-20, 23-25
d. Summer survey in 1981 only sampled Strata 13, 16, 19-21, 23, 25
e. Excludes unusually high catch of 1032 cod (4096 kg) at station 323 (Strata tow 16-7)
f. Preliminary, 1982 autumn survey catches of most species anomalously low (Serchuk, pers. com.)
Cdn. Preliminary results of Canadian survey in March 1984, Strata 16-22 using a "Western IIA" bottom trawl.

Table 9. Commercial catch rates (t/hr) of Atlantic cod for Canadian vessels fishing on Georges Bank (NAFO 5Ze), 1968-83. Directed effort (cod primary species) used in calculation.

Year	Side Otter Trawl TC 4, July-Sept			Stern Otter Trawl TC 5, July-Sept		
	Catch	Effort	t/hr	Catch	Effort	t/hr
1968	697	2215	0.315	317	897	0.353
1969	460	1402	0.328	571	1346	0.424
1970	106	546	0.194	169	650	0.260
1971	221	997	0.222	234	1065	0.220
1972	105	477	0.220	79	221	0.357
1973	394	1803	0.219	427	1423	0.300
1974	-	-	-	34	141	0.241
1975	5	36	0.139	132	472	0.280
1976	27	184	0.147	369	1505	0.245
1977	391	743	0.526	2428	2806	0.865
1978	190	365	0.521	683	993	0.688
1979	647	1686	0.384	258	530	0.487
1980	86	431	0.200	510	1012	0.504
1981	47	142	0.331	1296	1504	0.862
1982	53	143	0.371	3063	4027	0.761
1983	-	-	-	2230	2698	0.827

Table 10. Recruitment indices for Atlantic cod calculated from USA offshore autumn bottom trawl surveys on Georges Bank from 1962-83.

Yearclass	Age Group	
	0 + 1	1 + 2
1962	-	0.385
1963	0.168	0.462
1964	0.307	0.613
1965	0.598	0.808
1966	2.990	2.237
1967	0.160	0.269
1968	0.165	0.507
1969	0.383	0.584
1970	0.647	0.548
1971	2.183	3.617
1972	1.566	0.605
1973	0.343	0.227
1974	0.796	0.883
1975	4.331	2.772
1976	0.068	0.171
1977	0.770	1.223
1978	1.084	0.692
1979	0.420	1.139
1980	1.450	1.622
1981	0.601	0.496
1982	0.542	-

Table 11(a). Estimates of instantaneous total mortality (Z) and fishing mortality (F) with instantaneous mortality (M) assumed to be 0.20 for four time periods, derived from USA offshore spring and autumn bottom trawl survey data.

	Spring a		Autumn b		Average	
Time Period	Z	F	Z	F	Z	F
1964 - 67	-	-	0.73	0.53	0.73	0.53
1968 - 72 c	0.45	0.25	0.49	0.29	0.47	0.27
1973 - 77	0.80	0.60	0.57	0.37	0.69	0.49
1978 - 83	0.61	0.41	0.85	0.65	0.73	0.53

a. ln ((age 4+ for years i to j) / (age 5+ for years i+1 to j+1))

b. ln ((age 3+ for years i-1 to j-1) / (age 4+ for years i to j))

c. estimates for 1968-72 did not include autumn 1971-72 data (3+/4+) and spring 1972-73 data (4+/5+) since these data gave negative Z values.

Table 11(b). Estimates of total mortality (Z) derived from US research vessel data. 1981 - 83.

	Spring		Autumn	
Agegroup	Z	Yearclass	Z	Yearclass	Z
0+	0.297	1980	0.022	1980	0.862
1+	0.553	79	0.576	79	1.977
2+	0.736	78	0.809	78	1.871
3+	0.800	77	0.795	77	4.455

Table 12. Partial recruitment from Serchuk et al (1972) and weight at age used in yield per recruit calculation for 5Z cod.

Age	PR	Weight (kg)
1	0.03	0.36
2	0.33	0.98
3	1	1.93
4	1	3.17
5	1	4.64
6	1	6.28
7	1	8.03
8	1	9.84
9	1	11.65
10	1	13.43
11	1	15.16
12	1	16.81
13	1	18.38
14	1	19.84
15	1	21.21
16	1	22.47
17	1	23.63
18	1	24.69

Table 13. Yield per recruit calculation using U.S. mid-year weight at age.

	FISHING MORTALITY	CATCH (NUMBER)	YIELD (KG)	AVG.WEIGHT (KG)	YIELD PER UNIT EFFORT
	0.020	0.06417	0.445	6.934	1.000
	0.040	0.11864	0.775	6.534	0.871
	0.060	0.16529	1.019	6.167	0.764
	0.080	0.20558	1.199	5.832	0.674
	0.100	0.24068	1.330	5.526	0.598
	0.120	0.27148	1.424	5.246	0.533
	0.140	0.29871	1.491	4.992	0.479
F0.1---	0.150	0.31072	1.515	4.877	0.455
	0.160	0.32295	1.537	4.759	0.432
	0.180	0.34467	1.567	4.547	0.391
	0.200	0.36423	1.585	4.353	0.356
	0.220	0.36195	1.595	4.175	0.326
	0.240	0.39807	1.597	3.012	0.299
FMAX---	0.245	0.40158	1.597	3.976	0.293
	0.260	0.41282	1.595	3.863	0.276
	0.280	0.42636	1.588	3.725	0.255
	0.300	0.43884	1.579	3.599	0.237
	0.320	0.45038	1.568	3.482	0.220
	0.340	0.46109	1.556	3.374	0.206
	0.360	0.47106	1.542	3.274	0.193
	0.380	0.48037	1.528	3.181	0.181
	0.400	0.48908	1.513	3.094	0.170

Table 14. Results of cohort analysis of 1981-83 catch at age data using terminal F in 1983 of 0.3, 0.4 and 0.5 (numbers in 000's).

		1981		1982		1983	
(a)	Age	N	F	N	F	N	F
	1	59870	-	60468	-	*	-
	2	24156	.16	48991	.23	45917	.10
	3	16192	.38	16787	.27	31917	.30
	4	11256	.32	9099	.37	10458	.30
	5	1525	.25	6684	.45	5133	.30
	6	4120	.40	968	.50	3499	.30
	7	1457	.38	2260	.49	477	.30
	8	474	.33	818	.45	1139	.30
	9	419	.41	277	.49	428	.30
	10	347	.20	227	.15	140	.30
	11+	13	.30	233	.30	161	.30
3+		35803	.36	37353	.35	53352	.30

		1981		1982		1983	
(b)	Age	N	F	N	F	N	F
	1	49626	-	44124	-	*	-
	2	20800	.19	40605	.28	35827	.13
	3	14544	.43	14038	.34	25050	.40
	4	10133	.36	7749	.45	8208	.40
	5	1371	.29	5765	.54	4029	.40
	6	3754	.45	842	.61	2746	.40
	7	1320	.43	1960	.59	376	.40
	8	429	.38	705	.54	894	.40
	9	368	.49	241	.59	336	.40
	10	286	.25	185	.18	110	.40
	11+	10	.40	182	.40	126	.40
3+		32215	.40	31667	.43	41875	.40

		1981		1982		1983	
(c)	Age	N	F	N	F	N	F
	1	43516	-	38483	-	*	-
	2	18798	.22	35602	.33	27918	.17
	3	13561	.47	12399	.39	20954	.50
	4	9463	.40	6944	.52	6866	.50
	5	1280	.31	5217	.62	3370	.50
	6	3536	.49	767	.69	2297	.50
	7	1238	.46	1782	.67	314	.50
	8	402	.41	638	.62	748	.50
	9	337	.54	219	.67	281	.50
	10	250	.29	160	.21	92	.50
	11+	8	.50	152	.50	106	.50
3+		30075	.44	28278	.50	35028	.50

Table 15. Catch projection for 5Z cod. Geometric mean of historical recruitment (30 million) used for the projection. Assume TAC of 45000 t taken in 1984. Option of fishing at f0.1, fmax or a TAC of 45000 t in 1985-87.

1984 Stock			Option		
			f=0.15	f=0.25	TAC=45000
Age	N (000's)				
		Catch	45000	45000	45000
		1984 F	0.37	0.37	0.37
1	30000	Stock (t)	180770	180770	180770
2	23836	Stock (n)	69159	69159	69159
3	25757				
4	13748	Catch	20953	33384	45000
5	4505	1985 F	0.15	0.25	0.35
6	2211	Stock (t)	215542	199530	184597
7	1507	Stock (n)	74973	71279	67806
8	206				
9	491	Catch	25340	37149	45000
10	184	1986 F	0.15	0.25	0.34
11+	60	Stock (t)	245735	213227	186772
		Stock (n)	79054	72620	67310
		Catch	29162	39907	45000
		1987 F	0.15	0.25	0.34
		Stock (t)	273569	224892	189547
		Stock (n)	81885	73445	67164

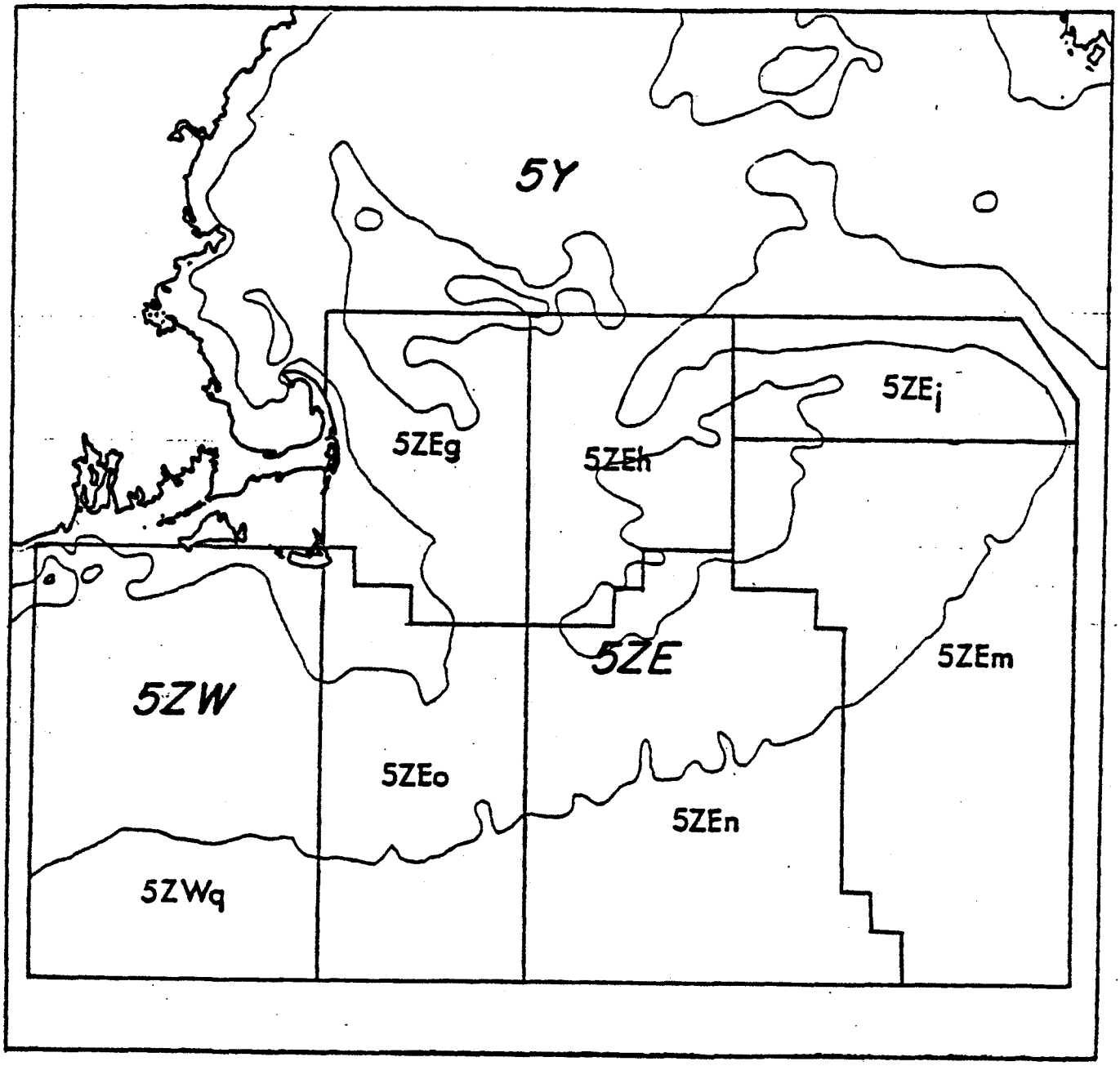

Figure 1. Statistical unit areas within NAFO Division 5Z.

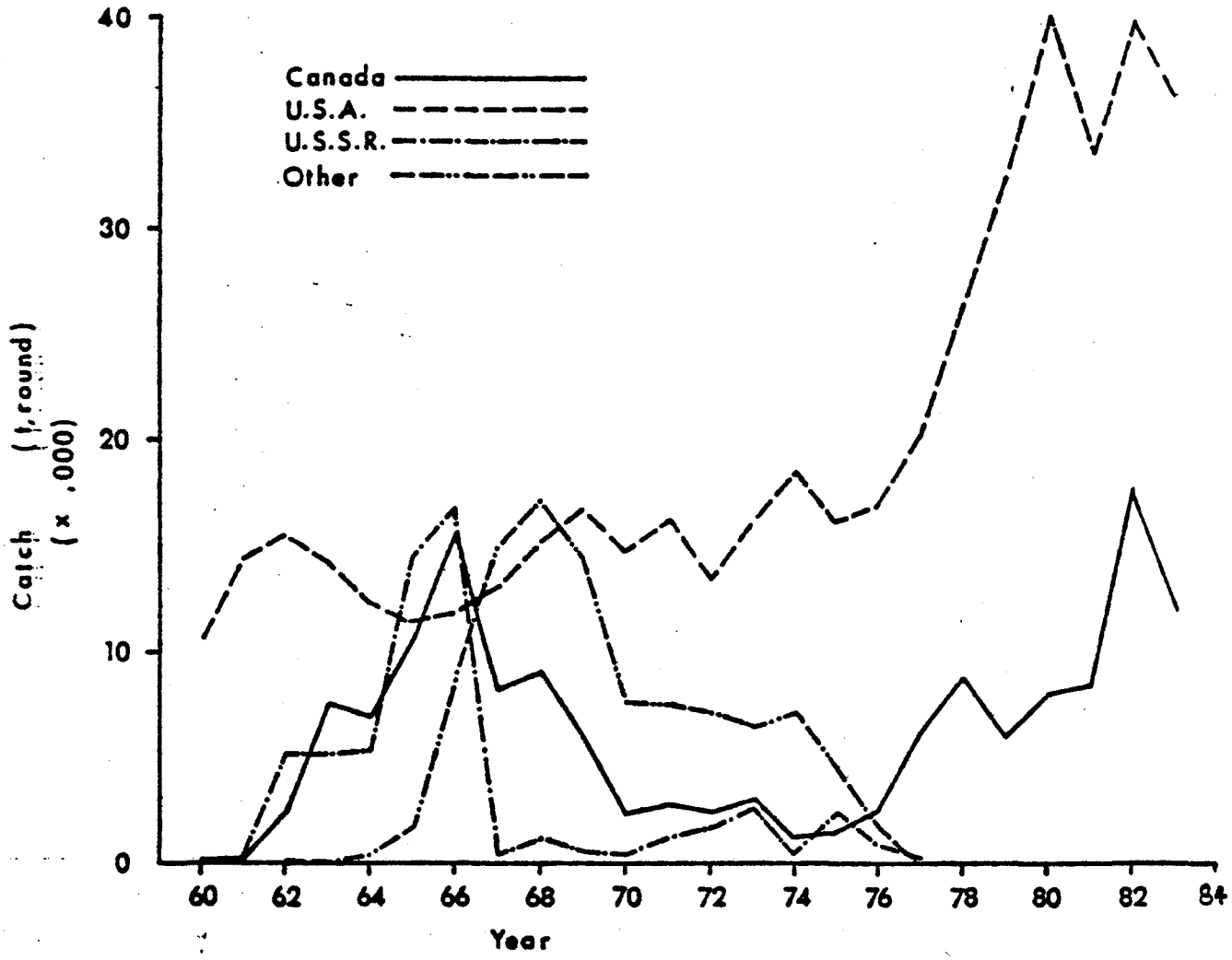

Figure 2. Nominal catches (t, round) of Atlantic cod from Georges Bank and southward (NAFO Division 5Z and Statistical Area 6), 1960-83.

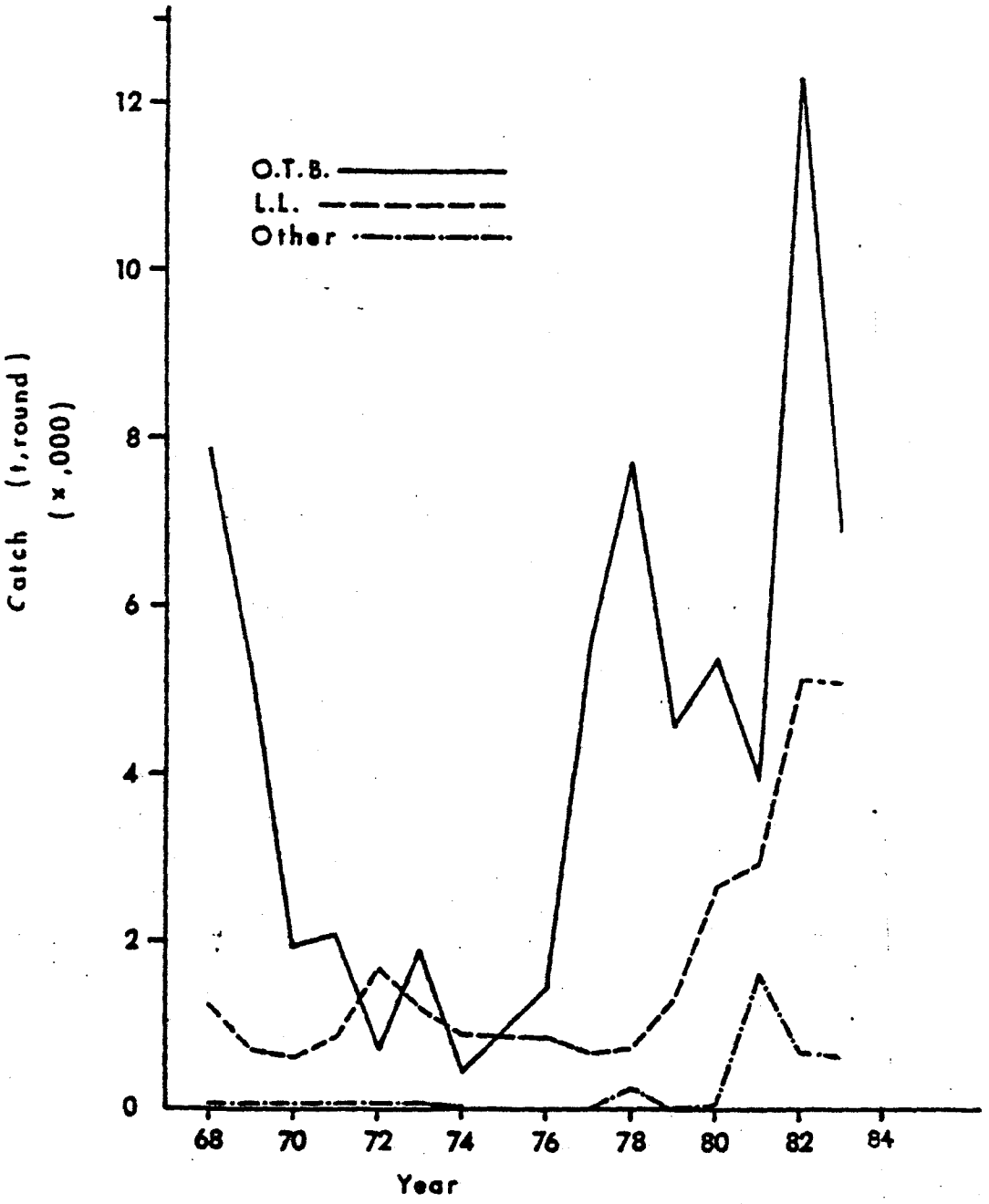

Figure 3. Nominal catches (t, round) of Atlantic cod from Georges Bank (NAFO Subdivision 5Ze) by Canadian fishing vessels, 1968-83.

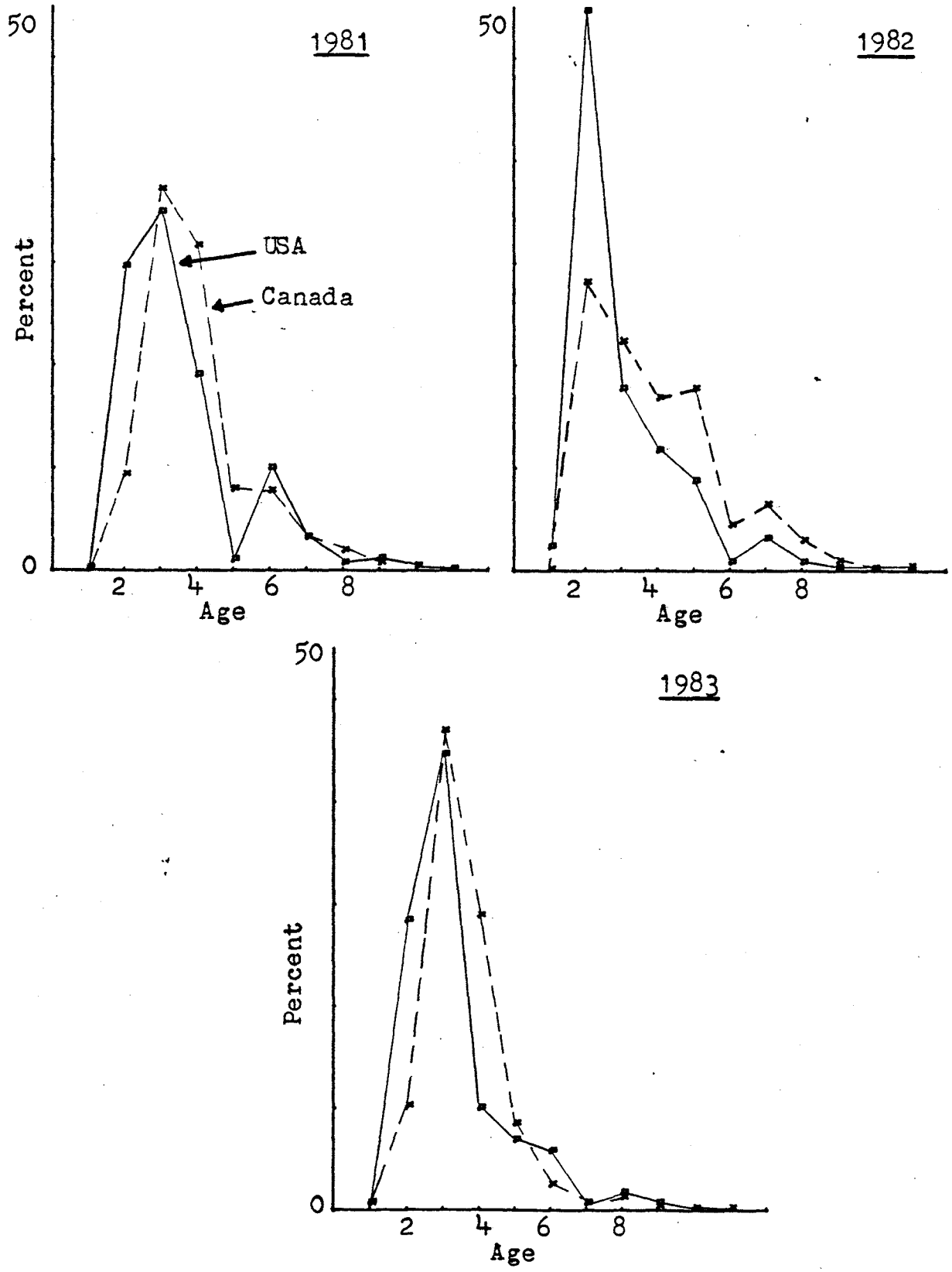

Figure 4. Comparison of percent age composition of USA and Canada of Georges Bank cod, 1981-83.

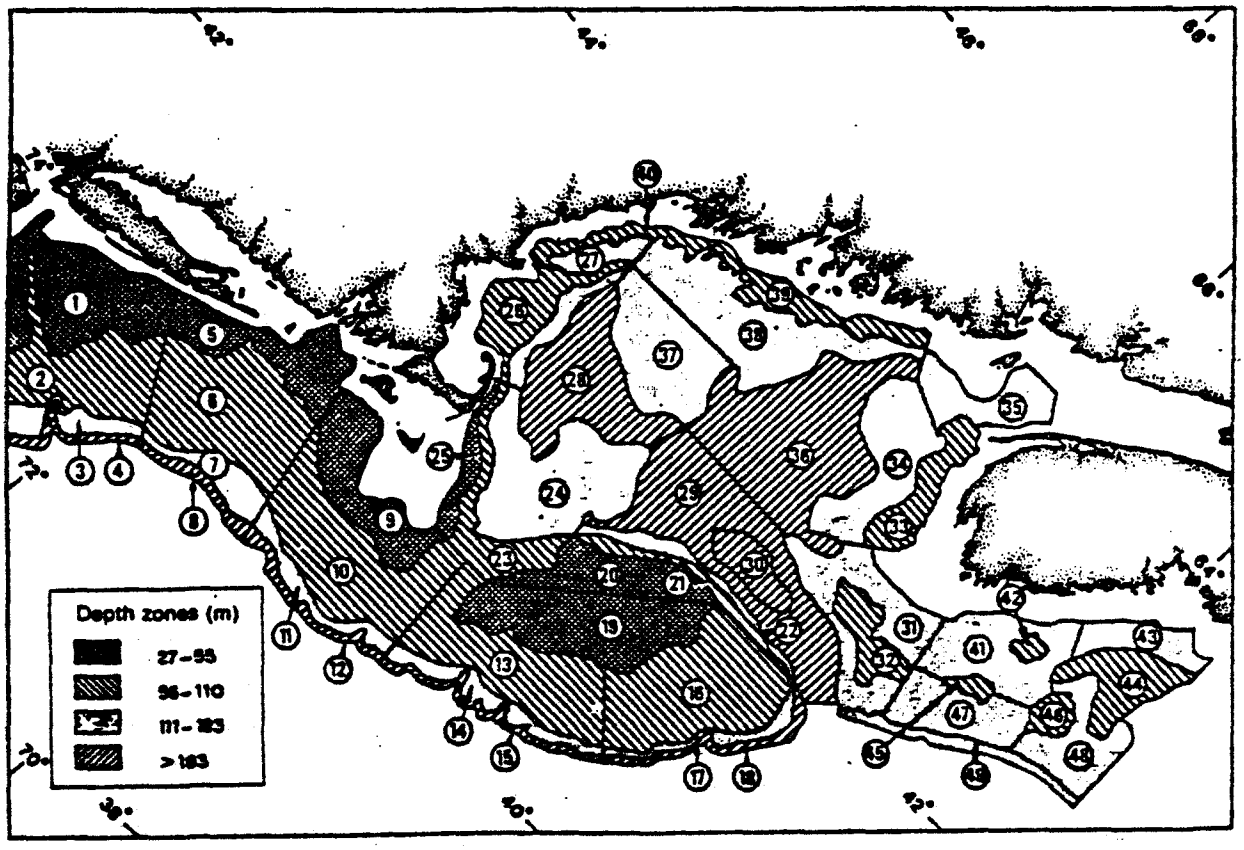

Figure 5. Stratification scheme used for USA spring and autumn bottom-trawl surveys of Georges Bank and Gulf of Maine areas.

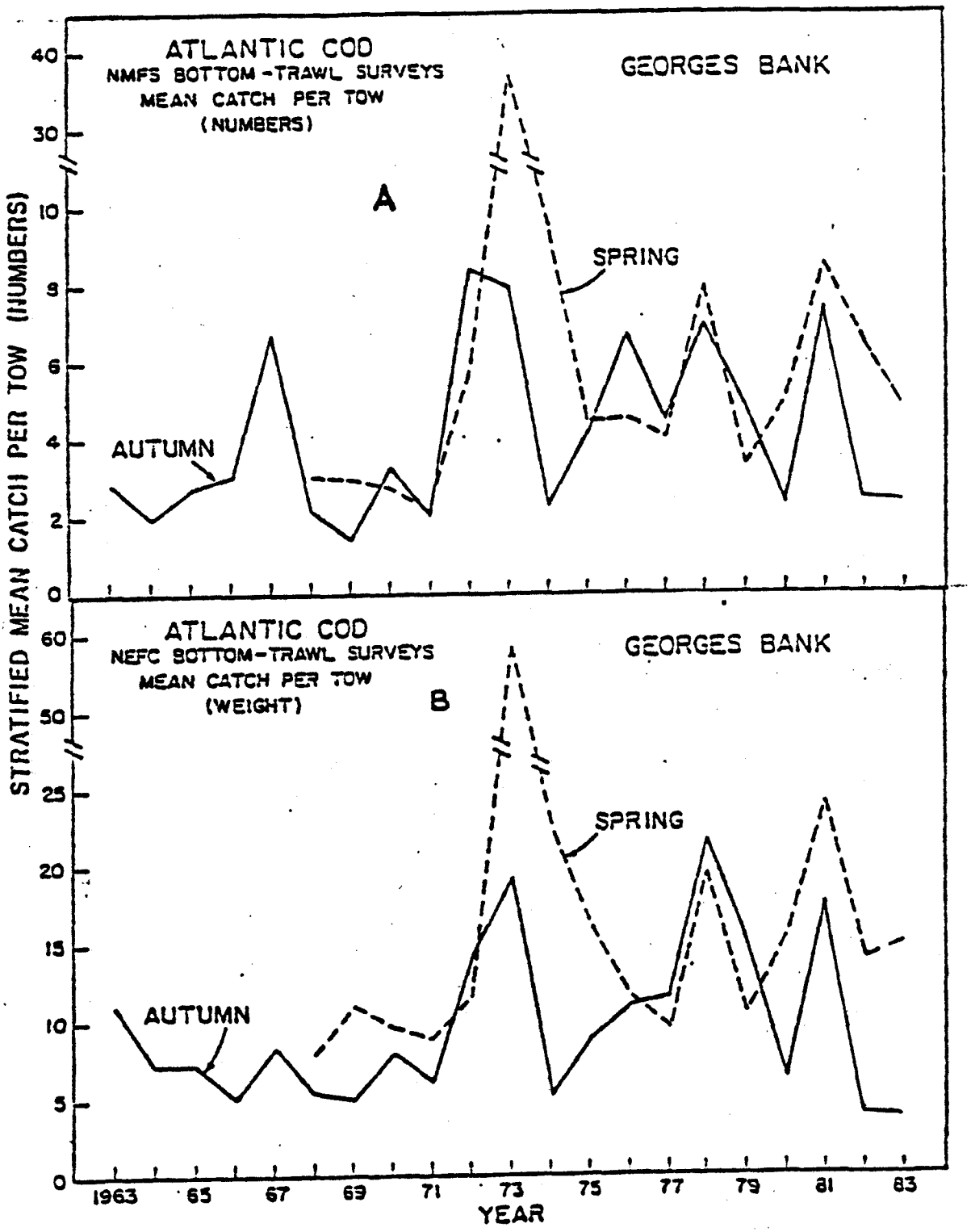

Figure 6. Stratified mean catch per tow (A) as numbers and (B) as weight in kg of Atlantic cod in USA spring and autumn offshore bottom-trawl surveys on Georges Bank (strata 13-25), 1963-82 (from Serchuk et al. 1982).

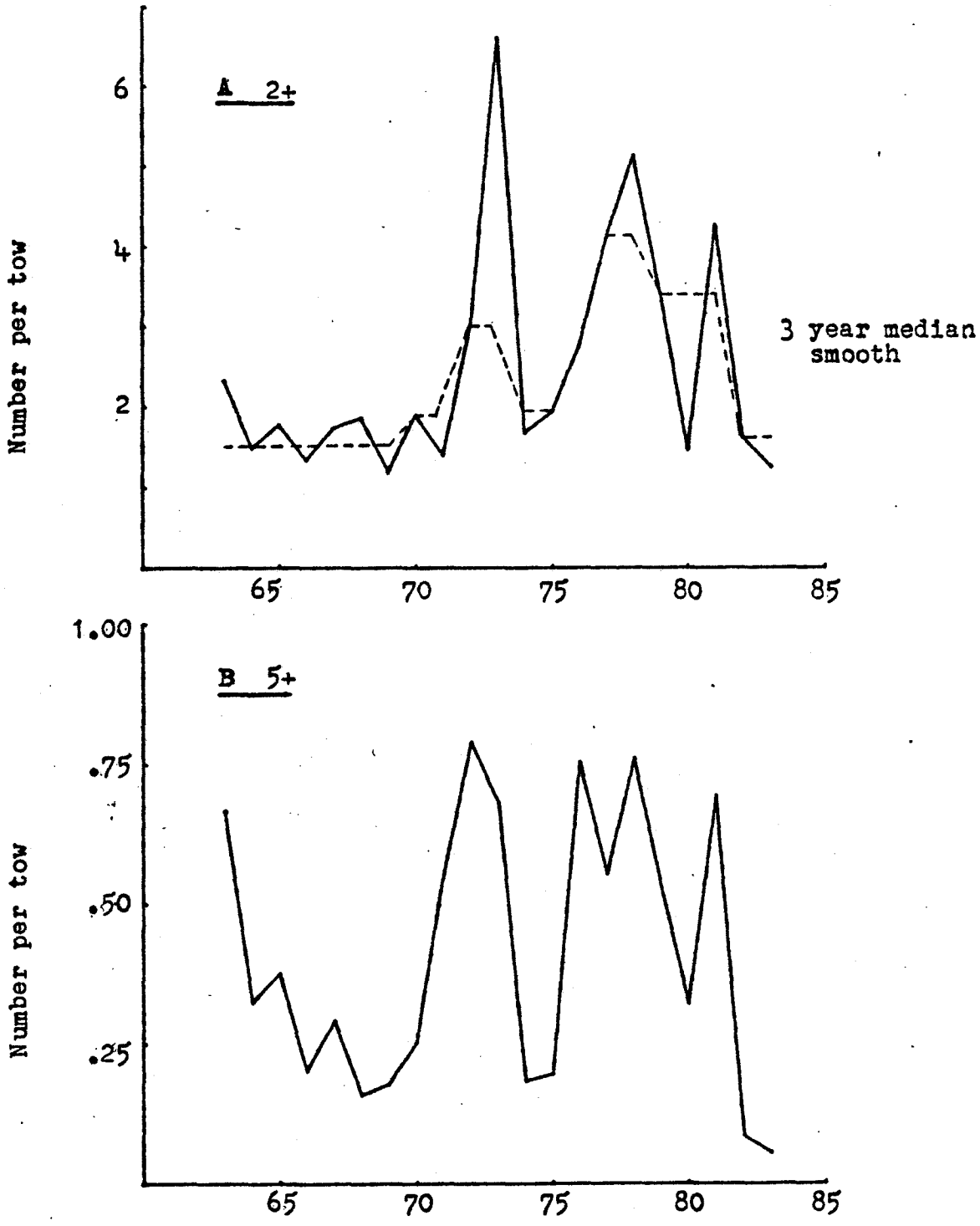

Figure 7. Stratified mean catch per tow (numbers) of 2+ and 5+ ages of Atlantic cod in USA autumn offshore bottom trawl surveys. Georges Bank, 1963-83

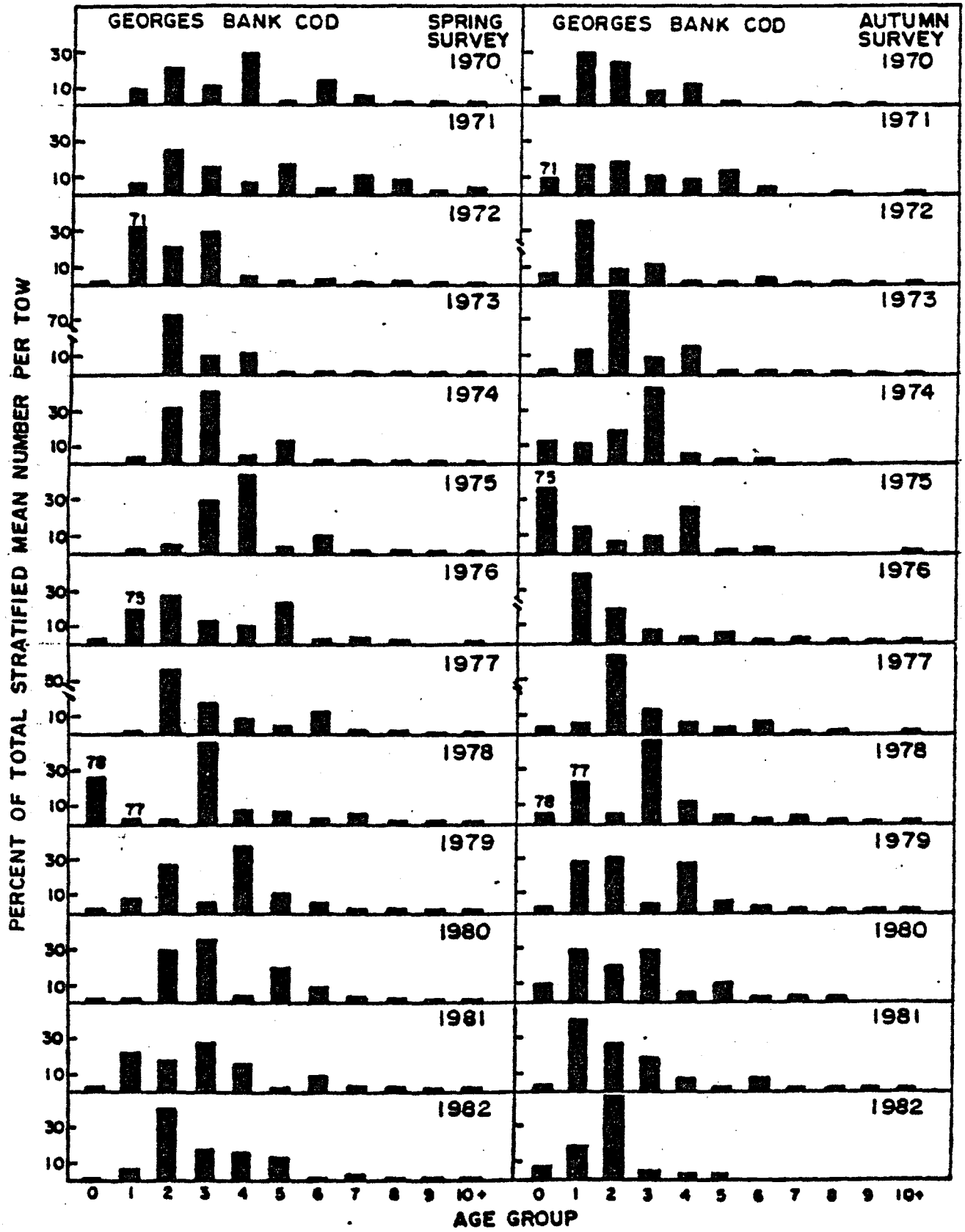

Figure 8. Age composition (percent by number) of Atlantic cod in USA spring and autumn offshore bottom-trawl surveys on Georges Bank (strata 13-25), 1970-81 (from Serchuk et al.). Labelled bars represent yearclasses.

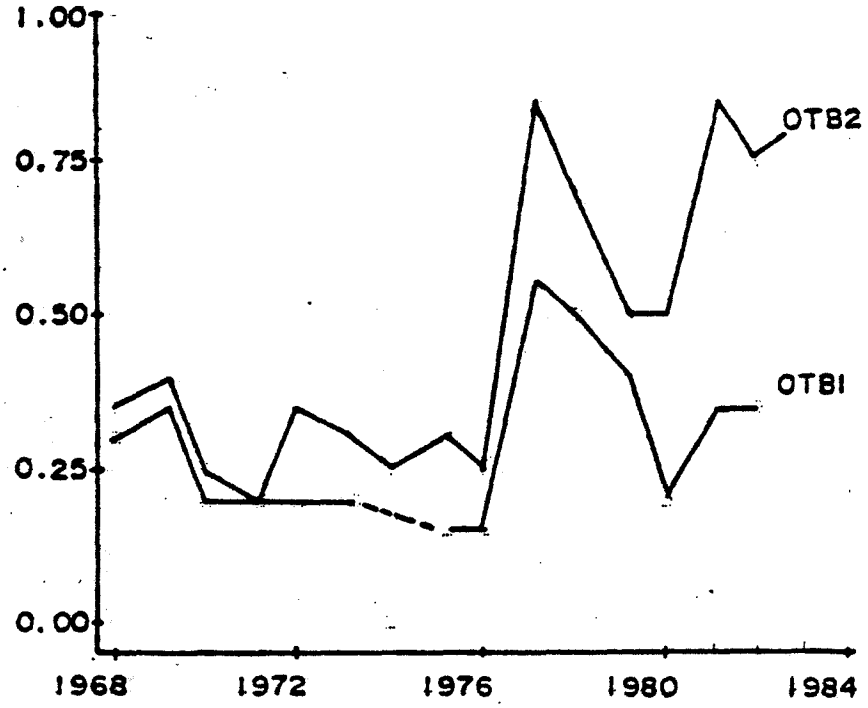

Figure 9. Commercial catch rate (t/hr) of Atlantic cod from Canadian side (OTB1) and stern (OTB2) otter trawlers fishing on Georges Bank (NAFO Subdivision 5Ze).

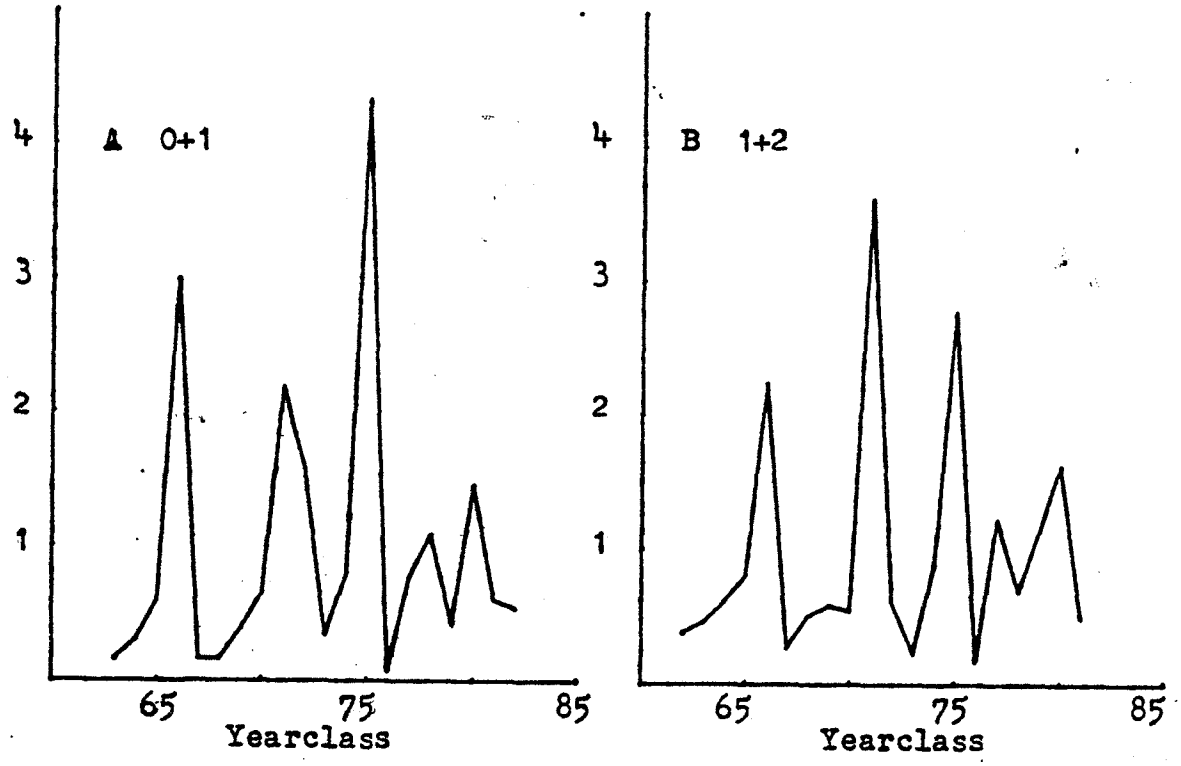

Figure 10. Recruitment indices for (A) ages 0+1 and (B) 1+2 cod from USA autumn offshore bottom trawl surveys. Georges Bank, strata 13-25, 1972-83.

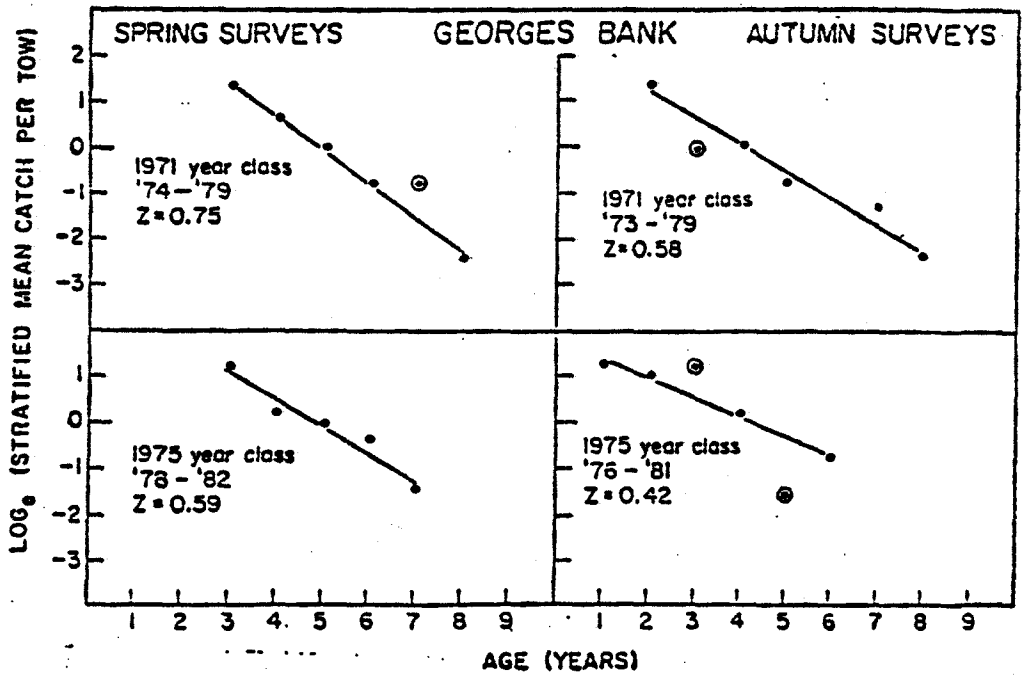

Figure 11a. Catch curves for 1971 and 1975 year classes of Atlantic cod calculated from USA spring and autumn offshore bottom-trawl surveys on Georges Bank (strata 13-25). (Circled points not used in calculations). (From Serchuk et al. 1982.)

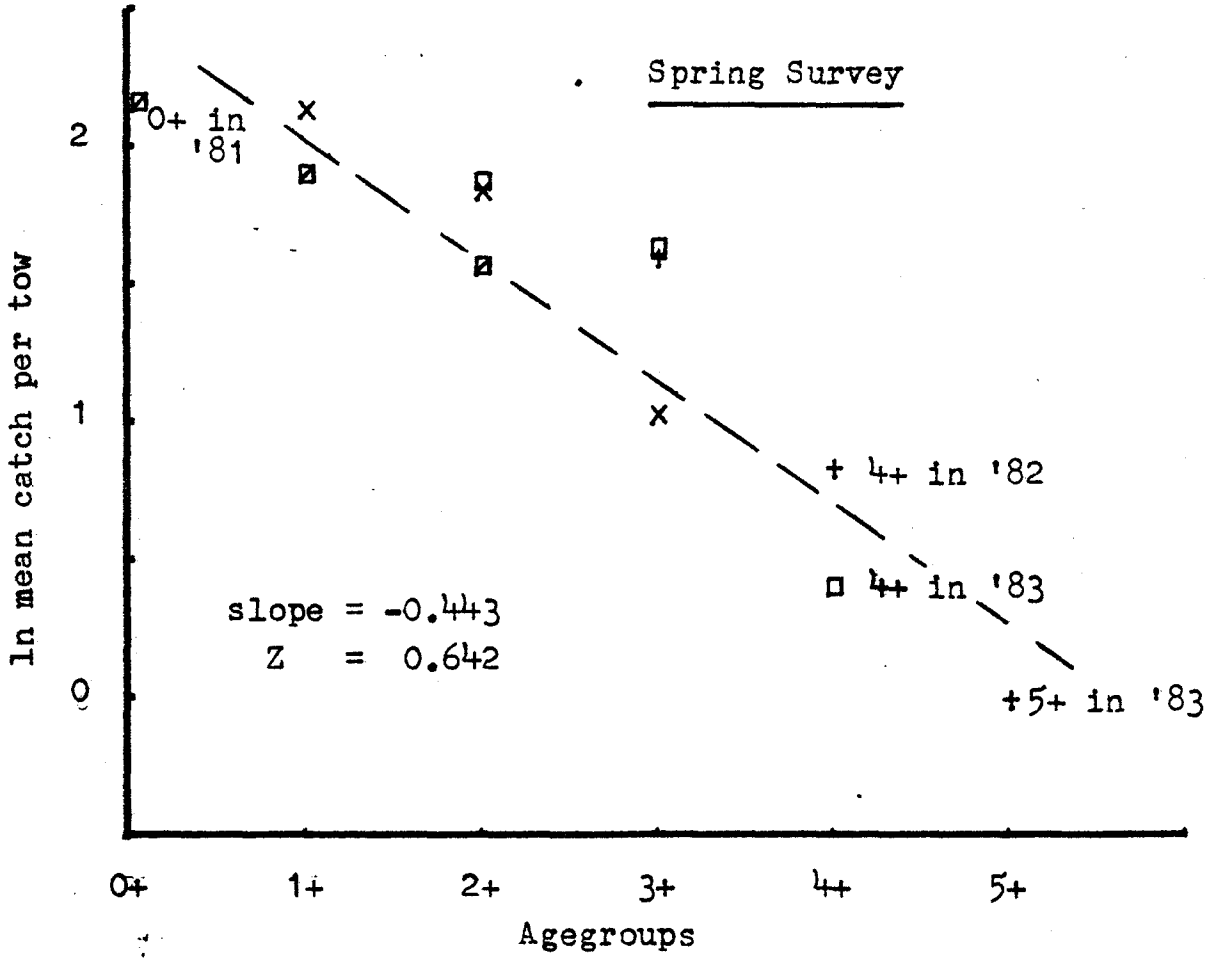

Figure 11(b). Calculation of total mortality (Z) from US research survey data, 1981-83.