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An Evaluation of the Current 5Z Cod Population Characteristics During 1960-82 with Yield Projected to 1984

by

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Abstract

Nominal catches of 5Z cod have averaged 32,000 t annually in the 1960-82 period. Canadian catches increased from less than 100 t in 1960 to 16,000 t in 1966, decreased to 1,400 t in 1974 and increased to 18,000 t in 1982. The latter figure represents 30% of the total catch.

Canadian commercial catch rates were relatively stable in 1966-72 but have approximately doubled recently. This is consistent with results from the US research vessel surveys. Recruitment indices based on US fall research vessel surveys indicate a strong 1975 year-class followed by year-classes of average size. The Canadian commercial catch is presently dominated by the 1977-80 year-classes.

A sequential population analysis (SPA) for the 1960-1982 period was considered inappropriate due to problems with US catch data subsequent to 1976. Therefore the SPA used catch at age for the period 1960-1976. The ratio of age 3+ SPA numbers for 1965-72 to age 2+ US research vessel survey numbers per tow for 1964-1971 was used to obtain estimates of 1982 age 3+ numbers. This calibration indicated a 1982 age 3+ population of 56 x 10^6 fish. Using age 3+ population numbers of 50-60 x 10^6 fish at the beginning of 1982 corresponds to a 1982 F between .25 and .30.

A yield per recruit calculation using average weight at age and reported partial recruitment patterns provides an $F_{0.1}$ and F_{max} of 0.15 and 0.25 respectively.

Applying the $F_{0.1}$ yield per recruit (1.515 kg) to the long-term geometric mean recruitment provides an estimate of 45,000 t for long-term average annual yield from this stock.

The 1982 fishing mortality exceeded both $F_{0.1}$ and probably also F_{max}. If fishing mortality was reduced to $F_{0.1}$ in 1983 and 1984, the yield would be in the order of 35-40,000 t in both years. Thereafter, yield would be expected to increase to give a long-term average close to 45,000 t provided the fishing mortality rate remained at $F_{0.1}$.

Résumé

Entre 1960 et 1982, la moyenne annuelle des prises nominales de la morue de 5Z s'établissait à 32 000 t. Les prises canadiennes sont passées de moins de 100 t en 1960 à 16 000 t en 1966, tombant à 1 400 t en 1974 et remontant à 18 000 t en 1982. Le dernier chiffre représente 30 % de la prise totale.

Les taux de captures de la flotte commerciale canadienne étaient relativement stables de 1966 à 1972 mais ils ont à peu près doublé récemment. Ces données coïncident avec les résultats des relevés scientifiques américains. Les indices de recrutement établis d'après les relevés effectuées à l'automne par les américains indiquent l'existence d'une forte classe d'âge en 1975 suivie de classes d'âges de taille moyenne. Les prises commerciales canadiennes sont actuellement dominées par les classes d'âges de 1977 à 1980.

On a jugé inapproprié de procéder à une analyse séquentielle des populations (ASP) pour la période allant de 1960 à 1982 en raison des problèmes que posent les données sur les prises américaines postérieures à 1976. L'analyse a par conséquent été basée sur les prises par âge pour la période de 1960 à 1976. On a utilisé le rapport du nombre de poissons de trois ans et plus calculi par ASP pour la période de 1965 à 1972 au nombre de poissons par coup de chalut de deux ans et plus capturés lors de relevés scientifiques pour la période 1964 à 1971 pour obtenir des estimations du nombre de poissons de trois ans et plus en 1982. Cette façon de procéder indique que la population de trois ans et plus en 1982 s'établissait à 56 X 10^6 poissons. Utilisant une population de trois ans et plus au début de 1982 de 50-60 X 10^6 poissons, le facteur F pour 1982 serait entre .25 et .30.

Un calcul du rendement par recrue faisant appel au poids moyen en fonction de l'âge et aux schèmes de recrutement partiels dans la littérature donne comme résultat des $F_{0,1}$ et F_{max} de 0.15 et 0.25 respectivement.

Si l'on applique le rendement par recrue à $F_{0,1}$ (1,515 kg) à la moyenne géométrique du recrutement à long terme, on obtient, pour cette population, un rendement annuel moyen à long terme s'établissant à 45 000 t environ.

En 1982, la mortalité due à la pêche dépassait le facteur $F_{0,1}$ et probablement aussi F_{max}. Si la mortalité était ramenée à $F_{0,1}$ en 1983 et en 1984, le rendement serait de l'ordre de 35 000 à 40 000 t les deux années. On estime que le rendement augmenterait par la suite pour atteindre une moyenne à long terme proche de 45 000 t, pourvu que le taux de mortalité due à la pêche reste à $F_{0,1}$.

Introduction

The size of the cod populations in NAFO Division 5Z was first evaluated by Brown and Heyerdahl (1972) through the examination of research vessel survey data and commercial vessel 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 in the reliability of the catch statistics.

The present assessment uses the approach employed by Clark et al. (1982) and O'Boyle (1983) in that virtual population analysis is used to calibrate survey data for the historical time period and the derived calibration coefficients are subsequently used to estimate 1982 resource size using recent survey data.

Trends in Reported Landings

Annual Landings

Since the early days of the fishery, with the exception of a brief period in the mid-1960s the USA has been the main harvester of cod from NAFO Division 5Z and Subarea 6 (Table 1 and Figures 1 and 2). Involvement by the Canadian offshore fleet rose dramatically during the early 1960s and reached a peak at 15,601 t in 1966. Canadian landings subsequently declined in the 1970s and have only recently increased.

Landings by the USSR, Spain and Poland were all high in the mid to late 1960s but have dropped off to negligible amounts in recent years.

Recent yields have increased substantially from 20,000 t in 1976 to an estimated 58,000 t in 1982 (Table 1) due to increasing US and Canadian fishing pressure.

Fishery by Gear Type and Tonnage Class

The US fishery on Georges Bank has been dominated by otter trawlers (Table 2) that operate throughout 5Z. Landings by this gear type have dramatically risen since the mid 1970s and, along with miscellaneous gears, have been largely responsible for overall yield increases in recent years.

Canadian landings have been split between otter trawlers and longline gear (Table 3) with both gear sectors exhibiting substantial increases in yield since the late 1970s (Figure 3). In contrast to the US fishery, the Canadian fishery is exploited almost solely on the northeast peak (unit areas 5ZEj and 5ZEm) during June-September.

The Canadian otter trawl fleet has been dominated by tonnage class 4 side and tonnage class 5 stern trawlers. However, since 1977, tonnage class 2 and 3 vessels operating out of southwestern Nova Scotia have become increasingly involved in the fishery (Table 4).

Age Composition of the Commercial Catch

Sampling Intensity

Coverage of the Canadian fishery was poor prior to 1977 but has improved since then (Table 3). Sampling has in recent years been strongly biased toward the otter trawler fleet.

No data on US sampling effort are readily available.

Age Composition of the Commercial Catch

Serchuk et al. (1977) provides catch at age data for the fishery during 1960-76 (Tables 5a and 5b). Data for 1977-80 have not been presented due to uncertainties in yield levels during this period. It is felt (Serchuk et al., 1982) that catch could have been almost double that reported. Consequently the provision of catch at age data for 1977-80 would be misleading. Catch at age in percent is however available for 1981 (Table 5c).

Percent age composition is available for the Canadian fishery during 1975-82 (Table 6). Where the two data sets overlap, some interesting comparisons can be made. In both 1975 and 1976, Canadian samples show a predominance of age 3 fish while US age compositions peak earlier at ages 2 and 3 (Figure 4). The two data sets compare favourably in 1981.

The 1982 Canadian age composition indicates that the fishery is now supported by age 2 to 5 individuals (1977-80 year-classes).

Stock Abundance Trends

US Bottom Trawl Surveys

Stratified random bottom trawl surveys have been conducted on the Atlantic coast in the autumn of every year since 1963. A spring survey was added in 1968 and a summer survey in 1977 (Figure 5).

The various series (Tables 7 and 8) show a peak in abundance in 1973, followed by a sharp decline and subsequent increase to a plateau in recent years (Figures 6 and 7). Since 1979, 3-4 year-classes have been well represented in the survey (Figure 8).

Commercial Catch Rates

Catch rates for Canadian tonnage class 4 side otter trawlers and tonnage class 5 stern trawlers, operating on Georges Bank during July-September (Table 9 and Figure 9) are relatively stable during 1970-76 and increase thereafter.

Both indices drop during 1979-80 and without more detailed analysis the reason for this will remain hidden. In general, the catch rates of stern trawlers has increased more than those of side trawlers.

Survey Recruitment Indices

Indices of recruitment were developed through the application of the normalization method of O'Boyle (1981) to the age 0, 1 and 2 autumn trawl survey data. The two calculated indices (Table 10 and Figure 10) show strong 1966, 1971 and 1975 year-classes. The 1977-80 year-classes are only average in size.

Estimation of Current Stock Size and Fishing Mortality

Total Mortality Estimates for 1964-81

Values of total mortality calculated by Serchuk et al., (1982) (Table 11 and Figure 11) show high mortality during 1964-67, followed by a decline to 0.47 and subsequent increase to 0.69 and 0.59 in 1973-81. Current US views are that the F is in the vicinity of 0.39, at least in 1981 (Serchuk et al., 1982).

Sequential Population Analysis

A sequential population analysis for the 1960-82 period was considered inappropriate due to uncertainties in the US catch data subsequent to 1976. Thus it was decided to develop population-survey relationships based on a VPA of the 1960-76 data which could be used to estimate current stock size. Attempts to tune this analysis failed due to the low variability in stock size during the period analysed. However, it was noted that the age 3+ population numbers varied little around 29.5 x 10^6, the value determined by Serchuk et al. (1977) for 1965-72, regardless of the wide range of input fishing mortalities used (0.2 to 0.6). It was observed that the US autumn survey 2+ mean number/tow for the period 1964-71 also varied little around 1.8 (Figure 7). The 1981 2+ catch per tow (3 year median smoothed) was 3.4. This is an increase in stock abundance of 1.9 times over the abundance observed during 1965-72. A similar comparison of Canadian commercial catch rate data suggested a 2.3 increase. Assuming proportionality between the survey catch rate and population size, this provides an estimate of 1982 3+ population of 56 x 10^6 fish.

The 1982 total catch was 57,711 t. The 1982 Canadian commercial sampling data indicated an average weight of 3.420 kg in the catch and that 71.9% of the catch was age 3+. This produces an estimate of the 1982 3+ catch of 12.1 x 10^6 fish. An age 3+ population of 50-60 x 10^6 fish at the beginning of 1982 thus corresponds to a 1982 fully recruited F between 0.25 and 0.30.

Determination of Potential Yield for Near Future

Yield per Recruit Calculation

Weights at age were calculated (Table 13) using the length-weight relationship from US research survey data given by Serchuk et al. (1977) and von Bertalanffy growth curve parameters given by Pentilla and Gifford (1976), adjusted to produce mid year values. The partial recruitment (Table 13) was taken from Serchuk et al. (1977). Yield per recruit calculations gave an $F_{0.1}$ of 0.15 and F_{max} of 0.25 (Table 14).

Applying the $F_{0.1}$ yield per recruit (1.515 kg) to the long-term (1960-72) geometric mean recruitment (29.9×10^6) provides an estimate of about 45,000 t for long-term average annual yield from this stock.

Potential Yield in 1983-84

The 1982 fishing mortality exceeded both $F_{0.1}$ and probably also F_{max}. If fishing mortality was reduced to $F_{0.1}$ in 1983-84, the yield would be in the order of 35-40,000 t. Thereafter, yield would be expected to increase to give a long-term average close to 45,000 t provided the fishing mortality rate remained at $F_{0.1}$.

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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), 1960-1982.

	Georges Bank and South[1]				
Year	USA	Canada	USSR	Other[2]	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[3]	33849	8508	-	-	42357
1982[4]	39850	17861	-	-	57711

[1] 5NK landings have been assigned to the Georges Bank and southward region.

[2] Primarily Spain and Poland.

[3] Provisional.

[4] Preliminary.

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

	Landings (tons, live)				
Year	Otter Trawl	Line Trawl	Handline	Other Gear	Total Landings
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[1]	30908
1980	32479	1102	0	4764[2]	38345
1981	27505	120	584	3710[3]	31919

[1] Of 779 tons landed, 620 tons were by sinking gill nets.

[2] Of 4764 tons landed, 4491 tons were by sinking gill net and 222 tons were by Danish seine.

[3] Of 3710 tons 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 (NAFO Subdivision 5Ze) by Canadian (M and Q) fishing vessels, 1968-82. Values in parenthesis indicate numbers of samples taken.

	Gear					
Year	Otter Trawlers		Longliners		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

Table 4. Nominal catches (t, round) of Atlantic cod from Georges Bank (NAFO Subdivision 5Ze) by Canadian (M and Q) otter trawlers, 1968-82.

Year		Side Otter Trawlers					Stern Otter Trawlers					
	TC	1	2	3	4	5	1	2	3	4	5	6
1968		-	-	30	3071	10	-	-	-	485	4242	-
1969		-	2	2	1292	-	-	-	-	268	3668	-
1970		-	-	7	674	-	-	2	-	61	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

Table 5a. Catch-at-age (thousands of fish) of Atlantic cod from Georges Bank 1960 to 1976 (from Serchuk *et al.* 1977).

Age	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1	312	549	283	78	65	454	211	242	192	68	50	84	130	1084	272	222	334
2	3702	8226	6560	3648	2703	7561	4811	5839	10500	9879	2765	3200	3889	15453	7620	4134	4234
3	3151	4916	7373	5063	4051	5781	3926	7117	8220	8931	5600	4524	4927	4714	6368	4680	3244
4	1653	1489	2503	2742	2450	2617	2486	2952	3180	2914	3031	2872	2380	1272	1564	2616	1614
5	531	457	738	1086	1079	1135	1600	1156	1043	817	890	1168	862	450	484	786	796
6	292	285	448	703	764	866	1316	746	735	612	542	868	606	316	355	477	578
7	72	103	141	303	323	371	988	422	324	267	210	354	256	124	187	150	175
8	33	59	72	220	214	253	873	329	244	201	138	217	170	89	162	82	96
9	19	32	36	127	113	109	528	138	137	105	87	124	90	58	109	55	30
10	5	12	8	56	52	55	236	73	76	59	39	56	40	28	56	17	19
11	0	2	3	11	11	28	55	6	5	15	12	4	7	11	20	5	2
A. Total	9770	16127	18165	14037	11825	19230	17030	18990	24656	23868	13364	13471	13357	23599	17197	13224	11122
B. Nominal catch (t)	10853	14731	23486	27189	25165	38333	53134	36752	43136	37939	25652	28179	25059	28923	27331	25008	19926
C. Calculated weight (t)	15691	21011	28322	30724	28164	35825	52482	38136	41220	38394	27990	31433	26946	25956	26480	24125	20267
D. Obs./Calc.	0.69	0.70	0.83	0.88	0.89	1.07	1.01	0.96	1.05	0.99	0.92	0.90	0.93	1.11	1.03	1.04	0.98
E. Calculated mean wt. (kg)	1.61	1.30	1.56	2.19	2.38	1.86	3.08	2.01	1.67	1.61	2.09	2.33	2.02	1.10	1.54	1.82	1.82

B. from Table 1
C. from Serchuk *et al.* 1977
D. B/C
E. C/A

Table 5b. Age composition (percent by numbers) of Atlantic cod from Georges Bank (NAFO Division 5Z and Area 6).

AGE	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1	3.2	3.4	1.6	0.6	0.5	2.4	1.2	1.3	0.8	0.3	0.4	0.6	1.0	4.6	1.6	1.7	3.0
2	37.9	51.0	36.1	26.0	22.9	39.3	28.3	30.7	42.6	41.4	20.7	23.8	29.1	65.5	44.3	31.3	38.1
3	32.3	30.5	40.6	36.1	34.3	30.1	23.1	37.4	33.3	37.4	41.9	33.6	36.9	20.0	37.0	35.4	29.2
4	16.9	9.2	13.8	19.5	20.7	13.6	14.6	15.5	12.9	12.2	22.7	21.3	17.8	5.4	9.1	19.8	14.5
5	5.4	2.8	4.1	7.7	9.1	5.9	9.4	6.1	4.2	3.4	6.7	8.7	6.5	1.9	2.8	5.9	7.2
6	3.0	1.8	2.5	5.0	6.5	4.5	7.7	3.9	3.0	2.6	4.1	6.4	4.5	1.3	2.1	3.6	5.2
7	0.7	0.6	0.8	2.2	2.7	1.9	5.8	2.2	1.3	1.1	1.6	2.6	1.9	0.5	1.1	1.1	1.6
8	0.3	0.4	0.4	1.6	1.8	1.3	5.1	1.7	1.0	0.8	1.0	1.6	1.3	0.4	0.9	0.6	0.9
9	0.2	0.2	0.2	0.9	1.0	0.6	3.1	0.7	0.6	0.4	0.7	0.9	0.7	0.2	0.6	0.4	0.3
10	0.1	0.1	-	0.4	0.4	0.3	1.4	0.4	0.3	0.2	0.3	0.4	0.3	0.1	0.3	0.1	0.2
11	-	-	-	0.1	0.1	0.1	0.3	-	-	0.1	0.1	-	0.1	-	0.1	-	-

Table 5c. Age composition (percent by numbers) of USA 1981 (January to September only) commercial landings of Atlantic cod from Georges Bank (NAFO Subdivision 5Ze) (from Serchuk et al., 1982).

1	2	3	4	5	6	7	8	9	10	11
0.2	24.5	36.7	22.1	0.5	10.6	3.3	0.7	1.1	0.4	-

Table 6. Age composition (percent by number) from commercial sampling of Atlantic cod from Georges Bank (NAFO Subdivision 5Ze) taken by Canadian otter trawlers, 1975-82.

AGE	1975	1976	1977	1978	1979	1980	1981	1982
1	-	-	-	0.1	-	0.1	0.1	0.1
2	8.9	16.9	87.5	3.1	26.4	24.8	9.3	28.1
3	44.7	39.8	9.7	61.2	27.3	39.0	37.1	22.3
4	38.5	33.3	1.8	21.6	31.7	9.8	31.6	16.8
5	6.9	6.5	0.4	7.1	10.7	16.6	7.9	17.7
6	0.3	2.8	0.5	3.4	2.4	6.3	7.7	4.4
7	0.3	0.4	0.1	2.4	0.8	1.6	3.2	6.4
8	0.2	0.1	0.1	0.4	0.4	0.6	1.9	2.9
9	0.1	-	0.1	0.5	0.1	0.8	0.7	0.9
10	0.1	-	-	0.1	0.1	0.4	0.4	0.1
11+	0.1	0.1	-	1.2	0.1	0.3	0.1	0.4
No. of Samples	2	2	10	28	11	10	14	6
No. Aged	111	99	378	1364	591	536	791	341

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[1], 1963-1982[2] (from Serchuk et al., 1982).

Year	Age 0	1	2	3	4	5	6	7	8	9	10+	Totals 0+	1+	2+	3+	4+	5+
Spring[3]																	
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	2.783	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	1.693	.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	5.508	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	3.234	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	.018	.407	2.620	1.146	1.059	.847	.013	.242	.053	.013	.028	6.446	6.428	6.021	3.401	2.255	1.196
Summer[4]																	
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	.373	.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	7.782	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	.173	.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	1.309	.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[5]	.195	.648	1.026	.363	.081	.007	.028	.002	.008	.004	.015	2.377	2.182	1.534	.508	.145	.064

[1] Spring and autumn: Strata 13-25; summer: Strata 13, 16, 19-25.

[2] Catch per tow at age values for 1963-1969 obtained by applying combined 1970-1981 age-length keys to stratified mean catch per tow at length distributions from each survey.

Table 8. Stratified mean catch per tow in numbers and weight (kgs) for Atlantic cod from USA offshore spring, summer, and autumn bottom trawl surveys (Strata 13-25) 1963-82 (from Serchuk et al., 1982).

	Spring[1]		Summer[2]		Autumn	
Year	Nos	Wt (kgs)	Nos	Wt (kgs)	Nos	Wt (kgs)
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[3]	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	4.96	15.3	10.39	15.0	2.36	6.2
1981[4]	8.47	24.0	7.00	10.2	7.33	17.5
1982	6.44[5]	14.1[5]	-	-	2.38[6]	4.3[6]

[1] Spring surveys, 1973-1980, were accomplished with "41 Yankee" trawl; spring surveys in other years were accomplished with "36 Yankee" trawl. No adjustments have been made to the catch per tow data for these gear differences.

[2] Summer surveys only include strata 13, 16, 19-25.

[3] Summer survey in 1978 only sampled strata 13, 16, 19-20, 23-25.

[4] Summer survey in 1981 only sampled strata 13, 16, 19-21, 23, and 25.

[5] Excludes unusually high catch of 1032 cod (4096 kg) at station 323 (strata tow 16-7).

[6] Preliminary, 1982 autumn survey catches of most species anomalously low (pers. Com., Serchuk)

Table 9. Commercial catch rates (t/hr) of Atlantic cod for Canadian vessels fishing on Georges Bank (NAFO Subdivision 5Ze).

Year	OTB1 TC4 July-Sept	OTB2 TC5 July-Sept
1968	0.315	0.353
1969	0.328	0.424
1970	0.194	0.260
1971	0.222	0.220
1972	0.220	0.357
1973	0.219	0.300
1974	-	0.241
1975	0.139	0.280
1976	0.147	0.245
1977	0.526	0.865
1978	0.521	0.688
1979	0.384	0.487
1980	0.200	0.504
1981	0.331	0.862
1982	0.371	0.761

Table 10. Recruitment indices for Atlantic cod calculated from USA offshore autumn bottom trawl surveys on Georges Bank 1962-1980.

Year Class	0 + 1	1 + 2
1962	-	0.385
63	0.168	0.462
64	0.307	0.613
65	0.598	0.808
66	2.990	2.237
67	0.160	0.269
68	0.165	0.507
69	0.383	0.584
1970	0.647	0.548
71	2.183	3.617
72	1.566	0.605
73	0.343	0.227
74	0.796	0.883
75	4.331	2.772
76	0.068	0.171
77	0.770	1.223
78	1.084	0.692
79	0.420	1.139
1980	1.450	-

Table 11. Estimates of instantaneous total mortality (Z) and fishing mortality (F)[1] for Atlantic cod for four time periods, 1964-1981, derived from USA offshore spring and autumn bottom trawl survey data[2] (from Serchuk *et al*. 1982).

Time Period	Spring		Autumn		Average	
	Z	F	Z	F	Z	F
1964 - 1967	-	-	0.73	0.53	0.73	0.53
1968 - 1972[3]	0.45	0.25	0.49	0.29	0.47	0.27
1973 - 1977	0.80	0.60	0.57	0.37	0.69	0.49
1978 - 1981	0.55	0.35	0.63	0.43	0.59	0.39

[1] Instantaneous natural mortality (M) assumed to be 0.20.

[2] Estimates derived from:
spring: ln (Σ age 4+ for years i to j/Σ age 5+ for years i+1 to j+1).
autumn: ln (Σ age 3+ for years i-1 to j-1/Σ age 4+ for years i to j).

[3] Estimates for the 1968-1972 period did not include autumn 1971-1972 data (3+/4+) and spring 1972-1973 data (4+/5+) since these data gave negative Z values.

Table 12. Estimates of population numbers (thousands of fish) and fishing mortality (F) for Atlantic cod from Georges Bank (NAFO Division 5Z and Statistical Area 6), 1960-76, calculated by cohort analysis using starting conditions of Serchuk *et al*. 1977).

POPULATION NUMBERS

	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976
1	41248	33387	26639	26114	29850	32215	34514	41742	33071	19789	19185	22258	41348	26801	18388	34779	19574
2	24820	33488	26838	21554	21309	24380	25965	28066	33956	26902	16140	15662	18147	33736	20962	14809	28274
3	12409	16971	19975	16037	14346	15001	13119	16905	17695	18300	13087	10713	9927	11339	13638	10267	8384
4	6598	7308	9447	9683	8549	8080	7051	7189	7401	7050	6902	5648	4677	3670	5018	5404	4171
5	2472	3906	4636	5469	5446	4783	4248	3523	3214	3182	3135	2908	2025	1676	1854	2693	2057
6	1324	1543	2785	3128	3495	3483	2889	2030	1839	1688	1866	1762	1324	878	965	1080	1494
7	647	820	1006	1874	1925	2170	2068	1174	987	840	828	1037	657	536	433	469	452
8	140	465	578	696	1261	1284	1441	799	580	515	446	488	529	306	327	185	248
9	107	85	327	408	371	838	822	390	357	254	240	241	203	279	170	121	78
10	22	71	40	235	219	201	588	195	195	168	113	118	85	85	176	41	49
11+	0	12	15	46	46	102	137	16	13	43	35	8	15	33	63	12	5
1+	89787	98056	92286	85245	86818	92538	92841	102030	99307	78731	61977	60842	78939	79338	61993	69859	64786

FISHING MORTALITY

1	0.008	0.018	0.012	0.003	0.002	0.016	0.007	0.006	0.006	0.004	0.003	0.004	0.003	0.046	0.016	0.007	0.019
2	0.180	0.317	0.315	0.207	0.151	0.420	0.229	0.261	0.418	0.521	0.210	0.256	0.270	0.706	0.514	0.369	0.180
3	0.329	0.386	0.524	0.429	0.374	0.555	0.402	0.626	0.720	0.775	0.640	0.629	0.795	0.615	0.726	0.701	0.550
4	0.324	0.255	0.346	0.375	0.381	0.443	0.494	0.605	0.644	0.610	0.664	0.826	0.826	0.483	0.422	0.766	0.550
5	0.271	0.138	0.193	0.248	0.247	0.304	0.538	0.450	0.444	0.334	0.376	0.587	0.636	0.352	0.341	0.389	0.550
6	0.279	0.228	0.196	0.286	0.277	0.321	0.700	0.521	0.583	0.512	0.387	0.786	0.705	0.507	0.522	0.670	0.550
7	0.131	0.149	0.168	0.197	0.205	0.209	0.751	0.506	0.451	0.433	0.329	0.473	0.563	0.295	0.649	0.436	0.550
8	0.302	0.151	0.148	0.430	0.208	0.246	1.107	0.607	0.626	0.565	0.418	0.676	0.439	0.387	0.795	0.671	0.550
9	0.218	0.540	0.130	0.421	0.411	0.155	1.237	0.496	0.553	0.611	0.513	0.843	0.672	0.261	1.230	0.700	0.550
10	0.291	0.207	0.245	0.303	0.302	0.356	0.578	0.525	0.557	0.485	0.476	0.733	0.722	0.447	0.428	0.608	0.550
11+	0.291	0.207	0.245	0.303	0.302	0.356	0.578	0.525	0.557	0.485	0.476	0.733	0.722	0.447	0.428	0.608	0.550

Table 13. Partial recruitment from Serchuk et al. (1977) and weight at age used in yield per recruit calculation for 5Z cod.

Age	1	2	3	4	5	6	7	8	9	10
PR	0.03	0.33	1	1	1	1	1	1	1	1
Wt (kg)	0.36	0.98	1.93	3.17	4.64	6.28	8.03	9.84	11.65	13.43

Age	11	12	13	14	15	16	17	18
PR	1	1	1	1	1	1	1	1
Wt (kg)	15.16	16.81	18.38	19.84	21.21	22.47	23.63	24.69

Table 14. 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

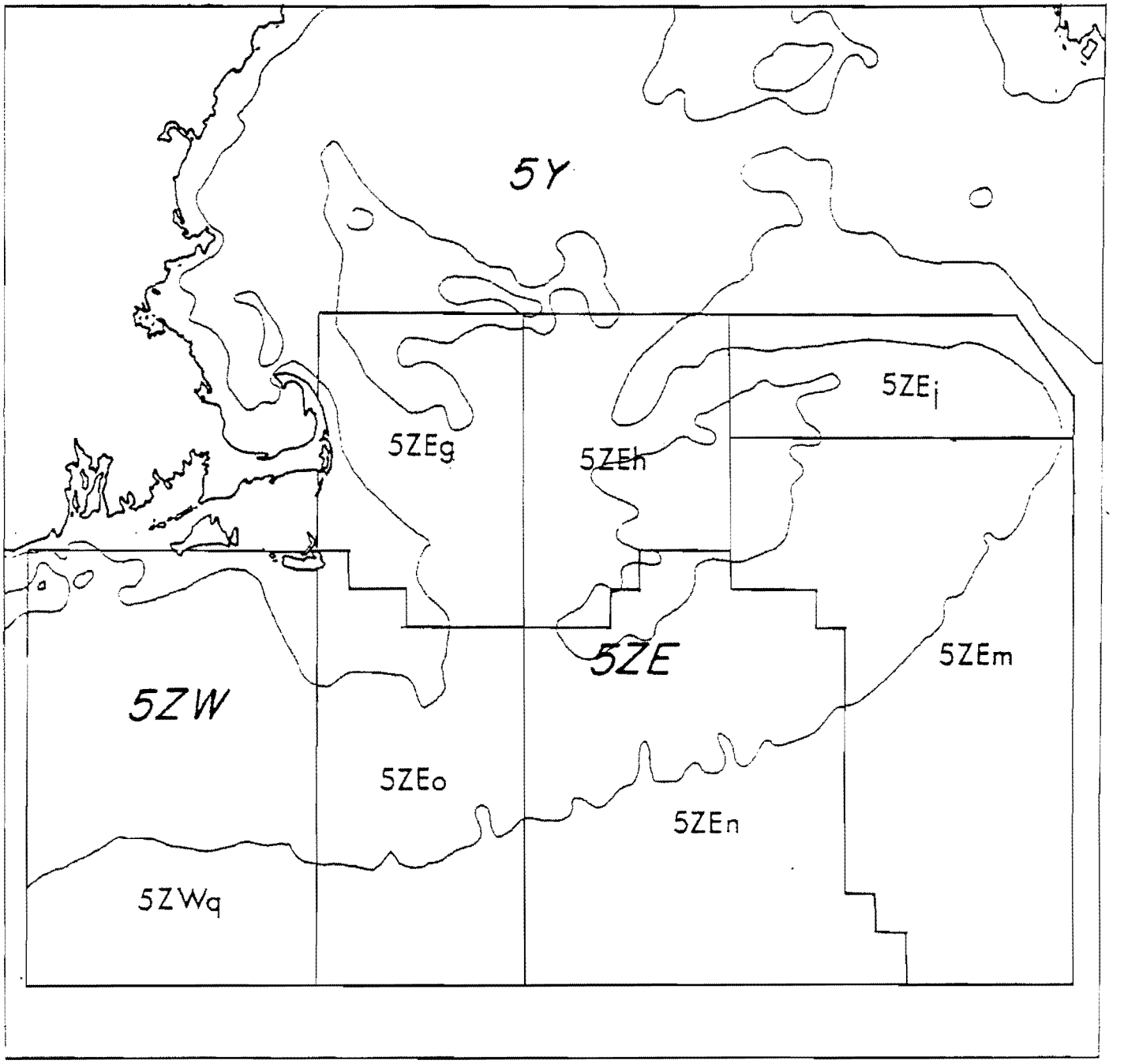

Figure 1. Statistical unit areas within NAFO Division 5Z.

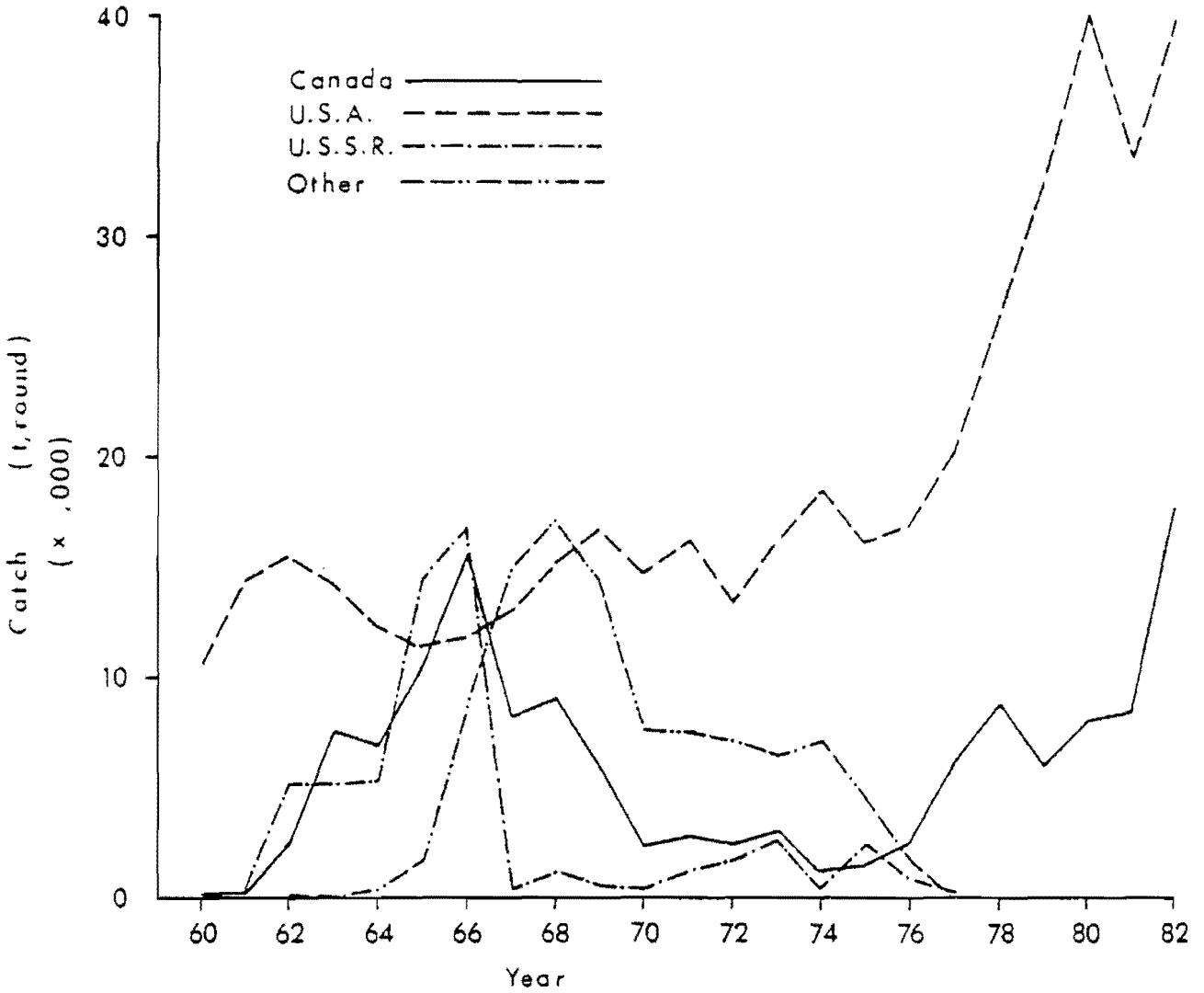

Figure 2. Nominal catches (t, round) of Atlantic cod from Georges Bank and southward (NAFO Division 5Z and Statistical Area 6), 1960-82.

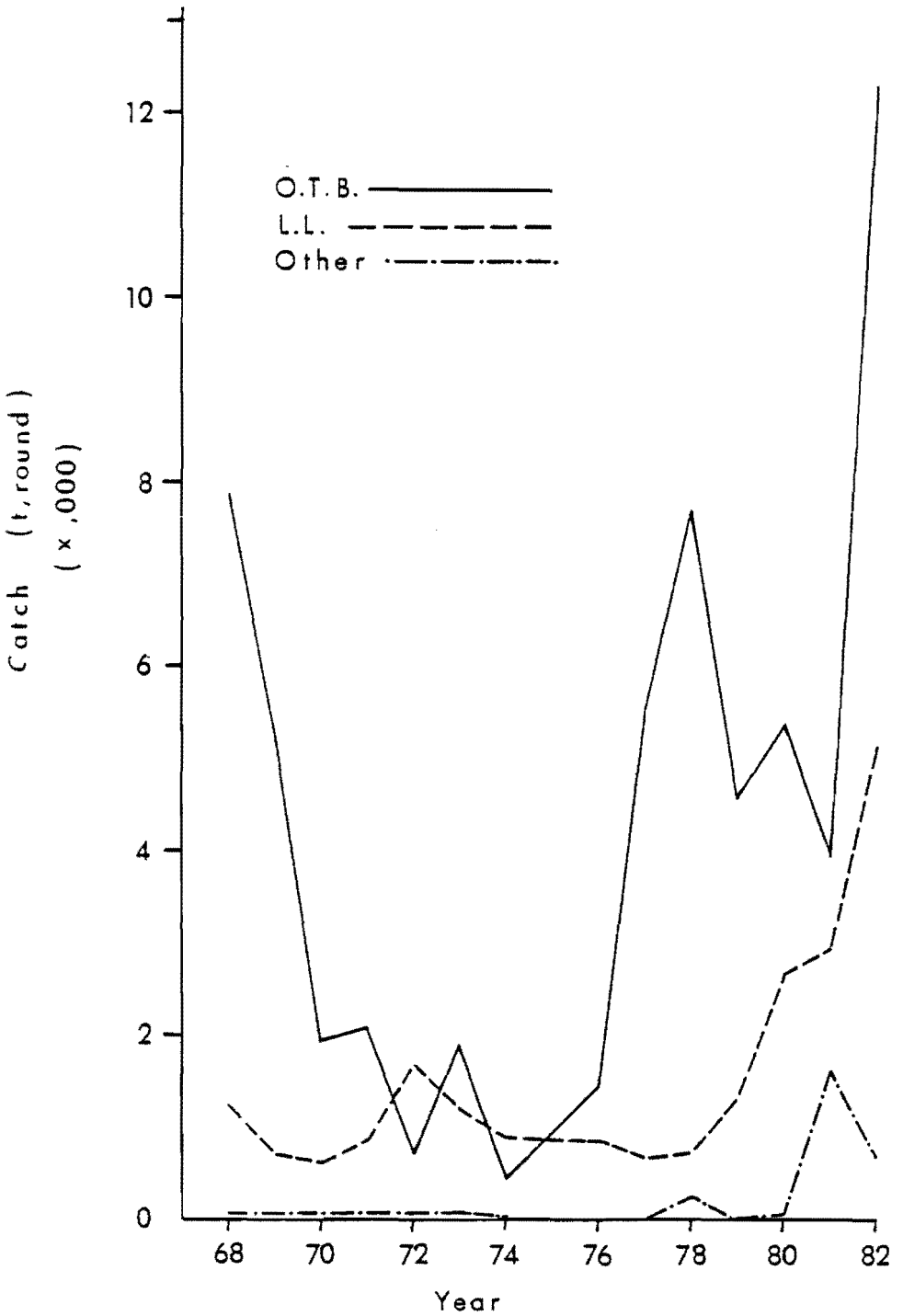

Figure 3. Nominal catches (t, round) of Atlantic cod from Georges Bank (NAFO Subdivision 5Ze) by Canadian fishing vessels, 1968-82.

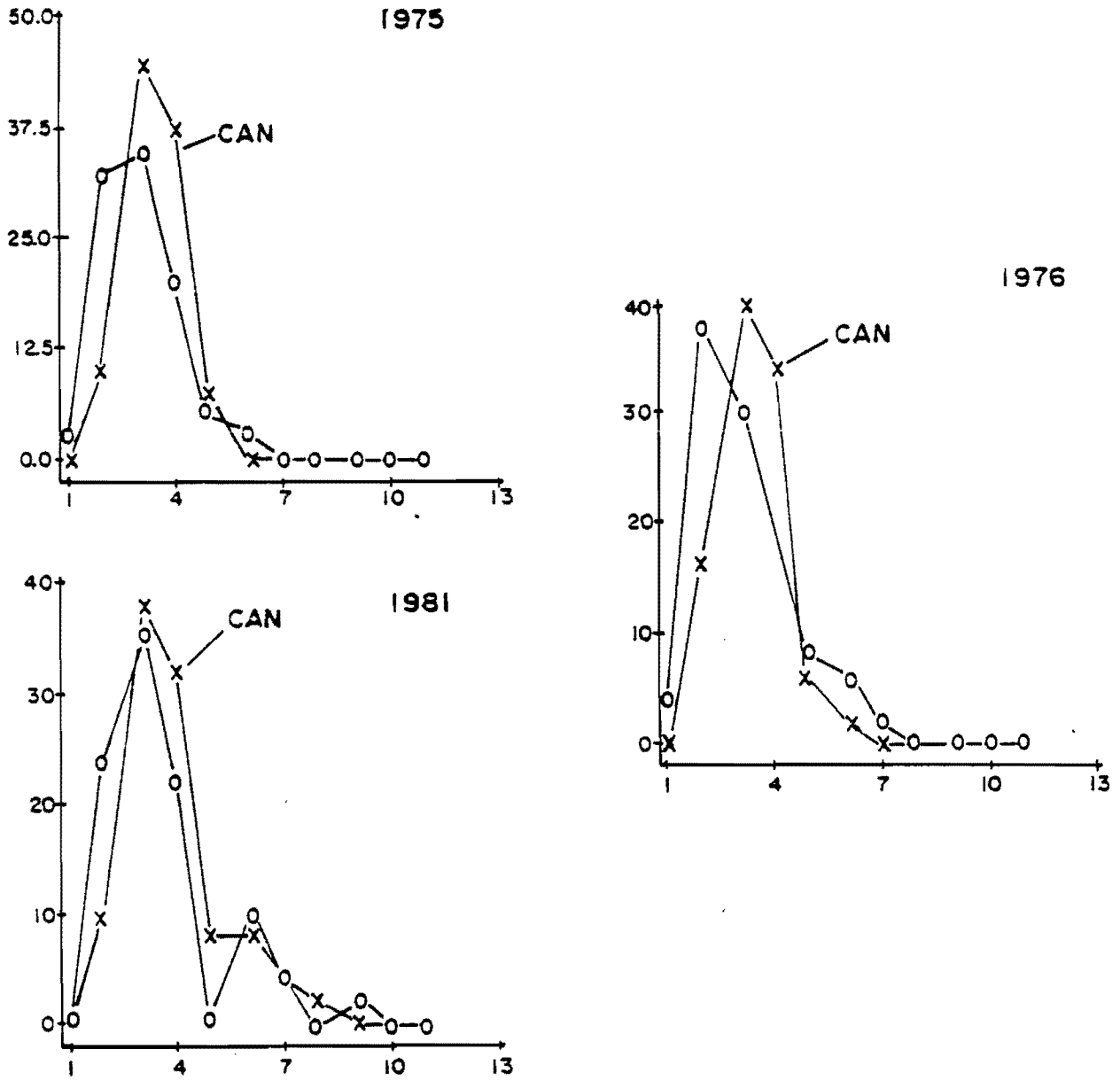

Figure 4. Comparison between age composition data from Canadian and USA commercial sampling (1975 and 1976 USA calculated from catch-at-age, Serchuk et al., 1981).

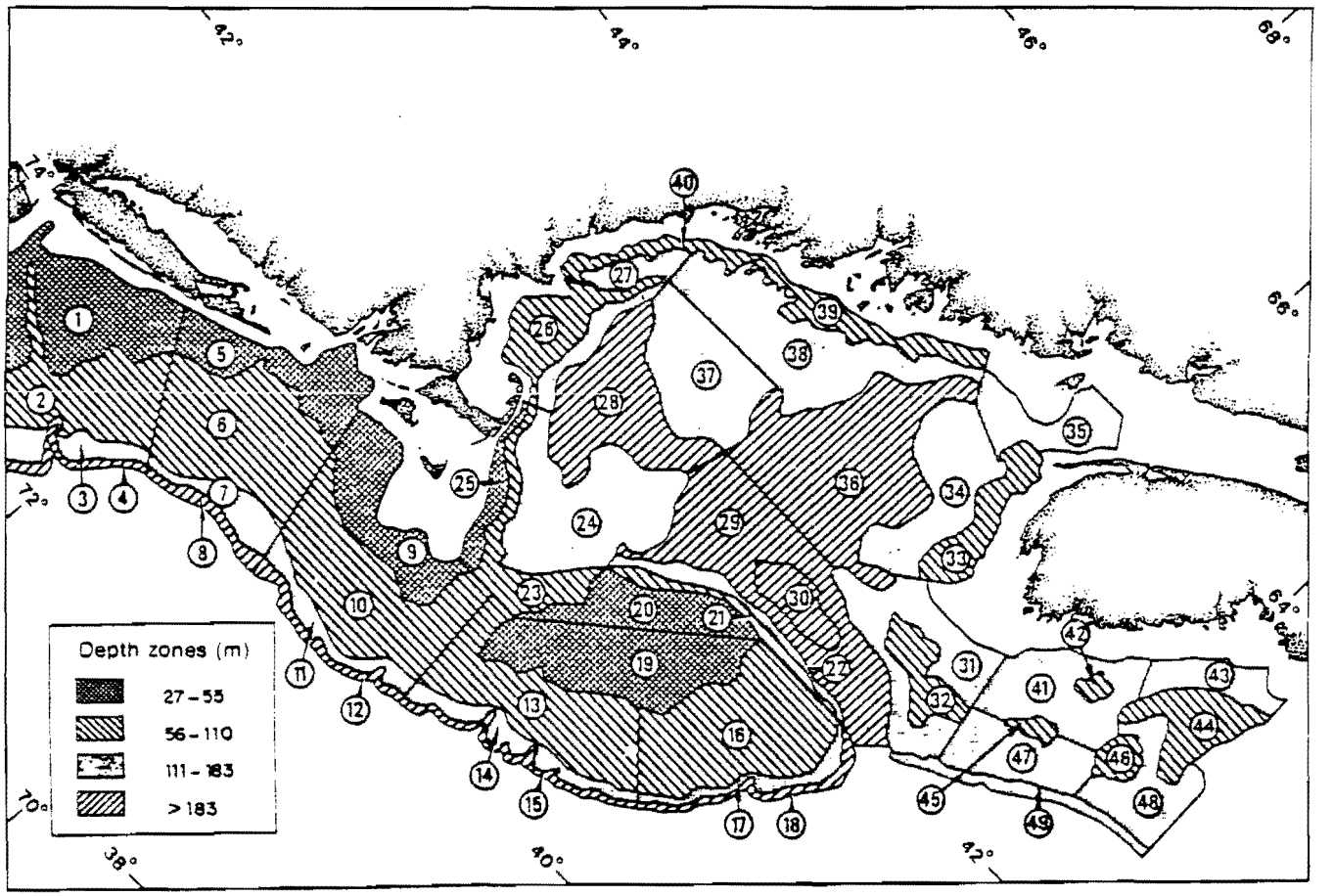

Figure 5. Stratification scheme used for USA spring and autumn bottom-trawl surveys of Georges Bank and Gulf of Maine areas.

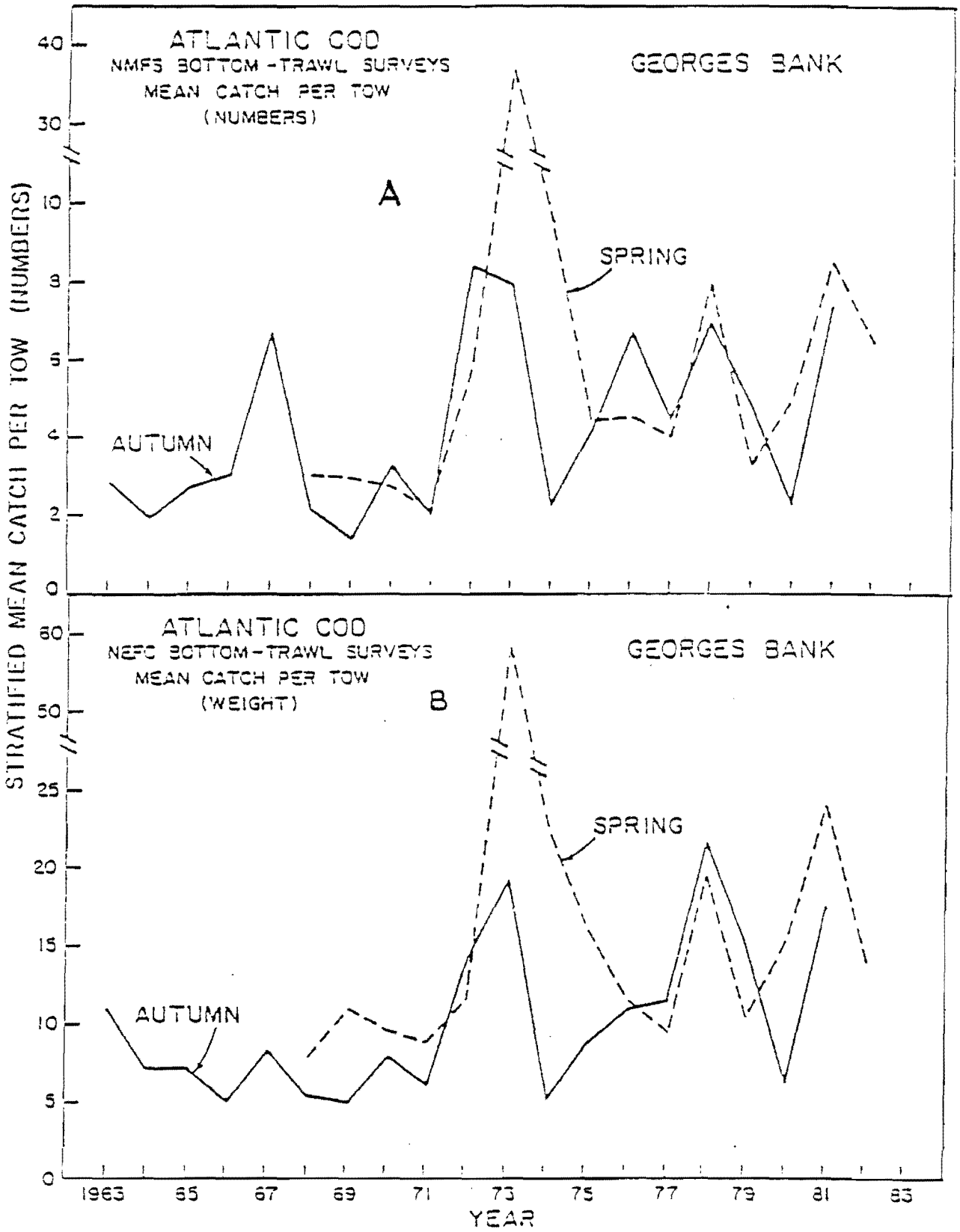

Figure 6. Stratified mean catch per tow (A) as numbers and (B) as weight in kg of Atlantic cod in USA spring and autumn offshore bottom-trawl surveys on Georges Bank (strata 13-25), 1963-82 (from Serchuk et al. 1982).

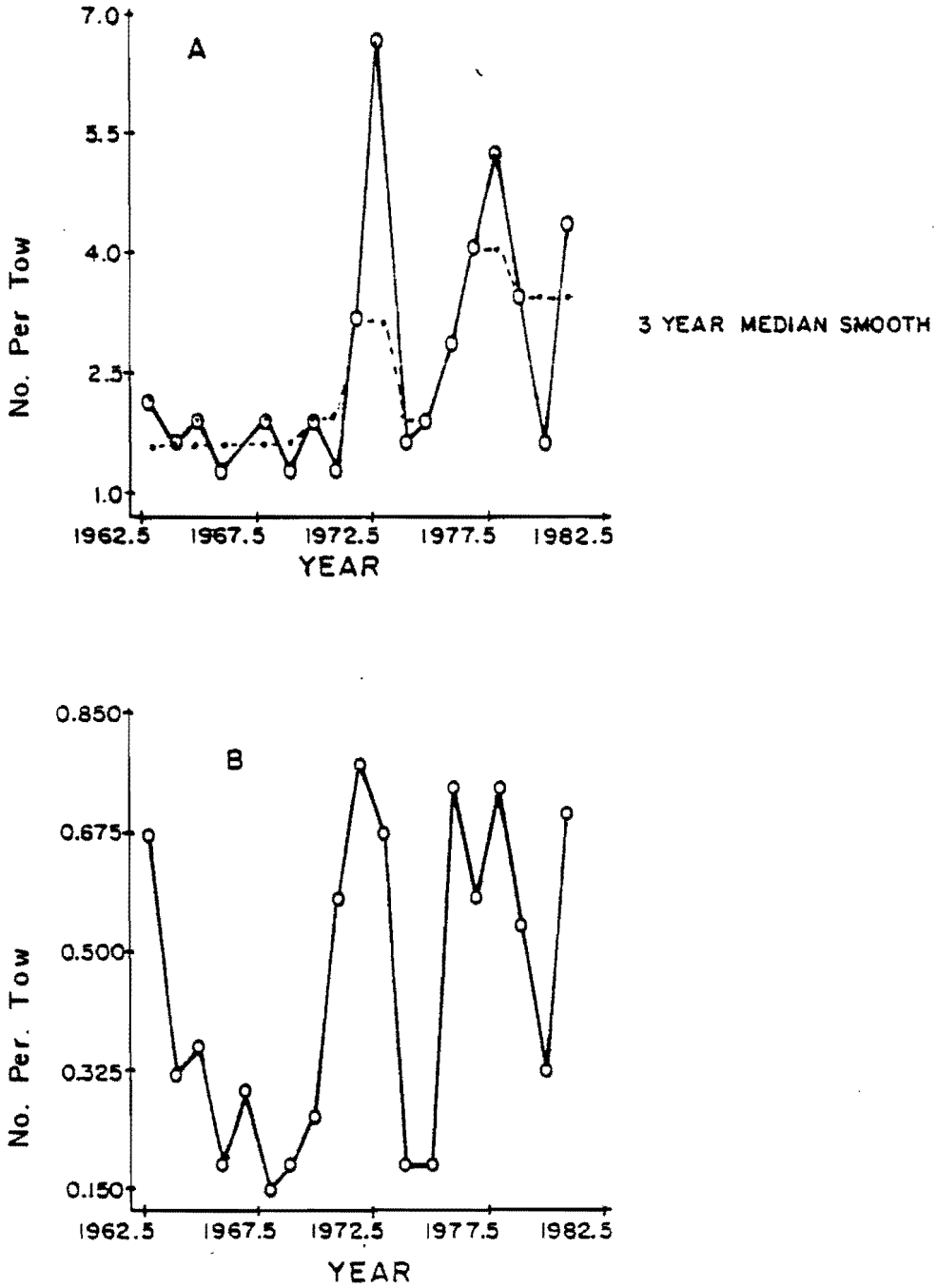

Figure 7. Stratified mean catch (numbers) per tow of (A) ages 2+ and (B) ages 5+ Atlantic cod in USA autumn offshore bottom-trawl surveys on Georges Bank (strata 13-25), 1963-81.

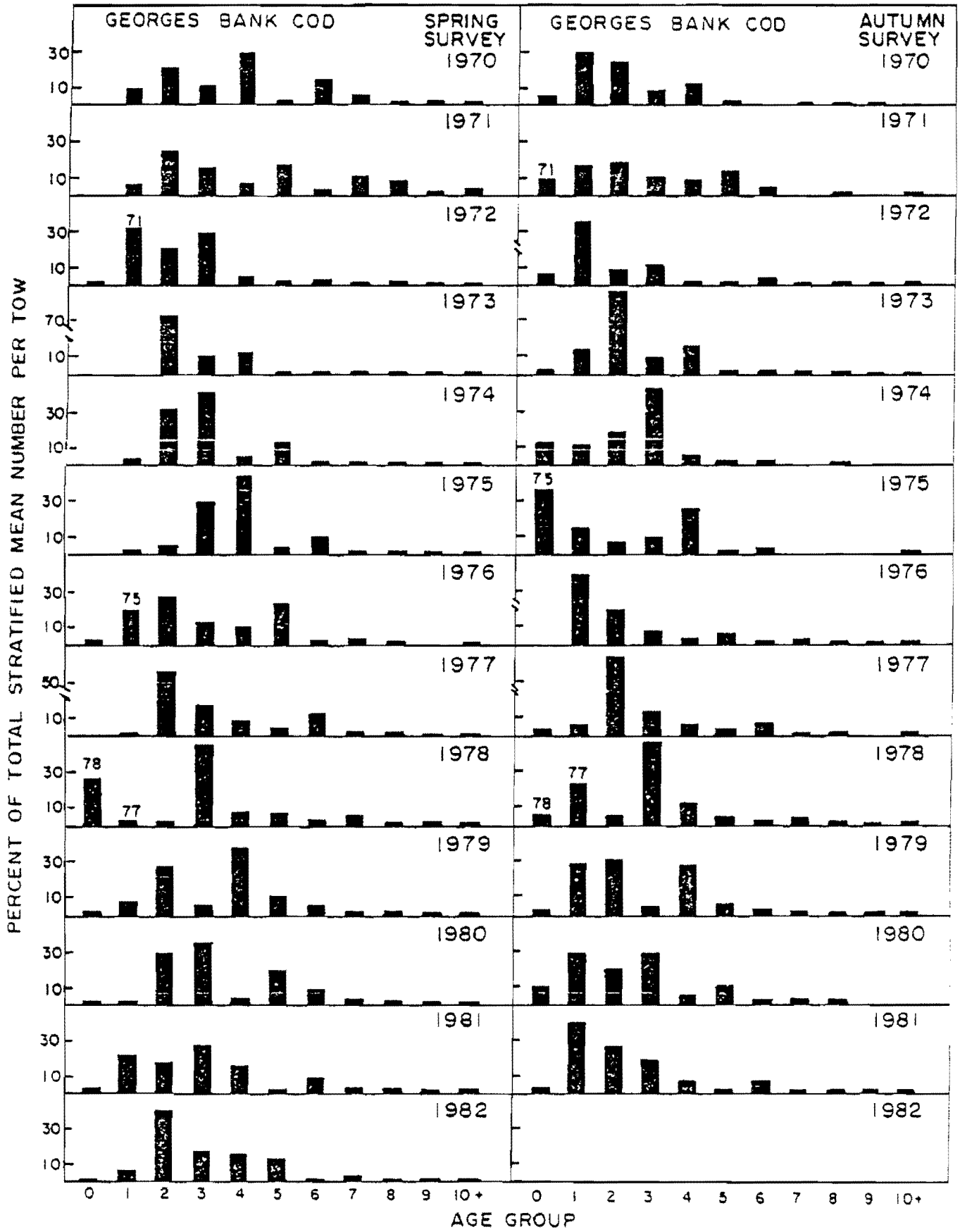

Figure 8. Age composition (percent by number) of Atlantic cod in USA spring and autumn offshore bottom-trawl surveys on Georges Bank (strata 13-25), 1970-81 (from Serchuk et al.). Labelled bars represent year-classes.

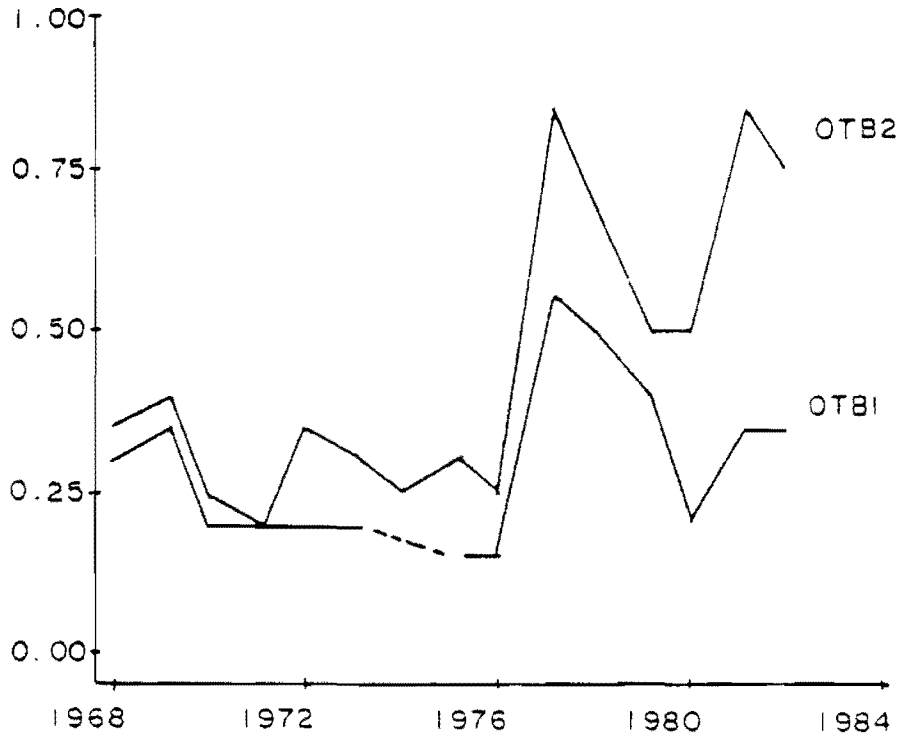

Figure 9. Commercial catch rate (t/hr) of Atlantic cod from Canadian side (OTB1) and stern (OTB2) otter trawlers fishing on Georges Bank (NAFO Subdivision 5Ze).

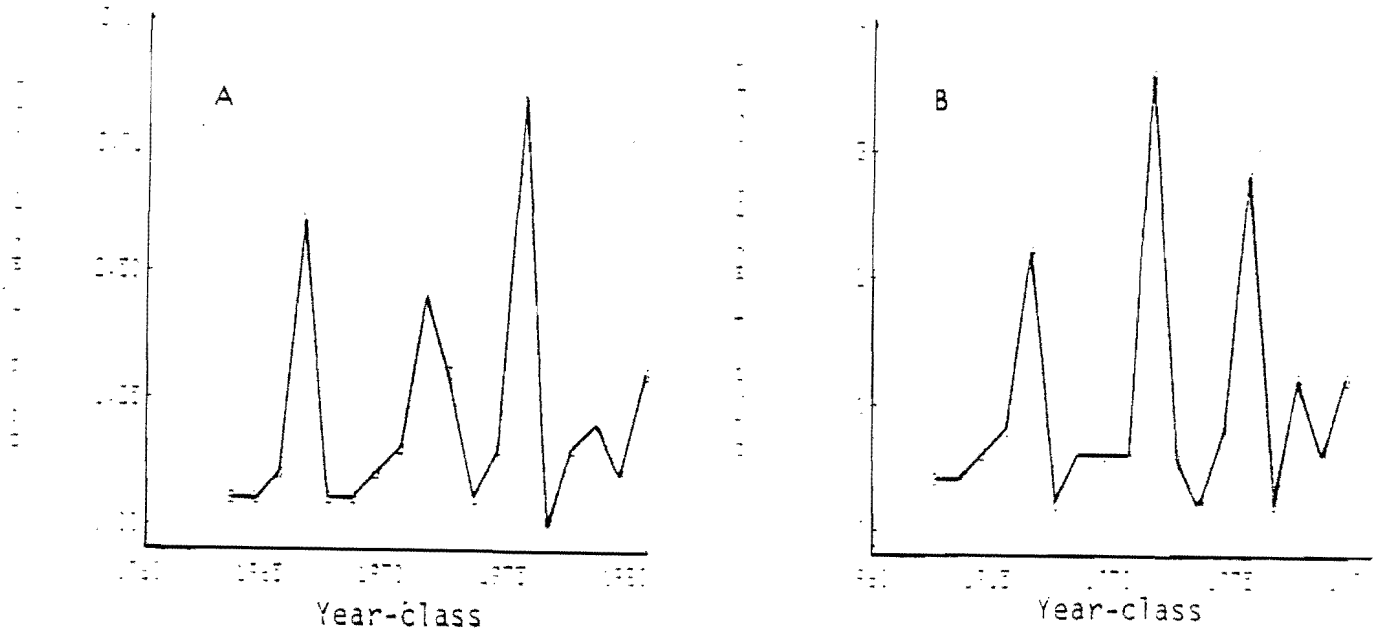

Figure 10. Recruitment indices for (A) ages 0+1 and (B) ages 1+2 Atlantic cod calculated from USA autumn offshore bottom-trawl surveys on Georges Bank (strata 13-25), 1972-80.

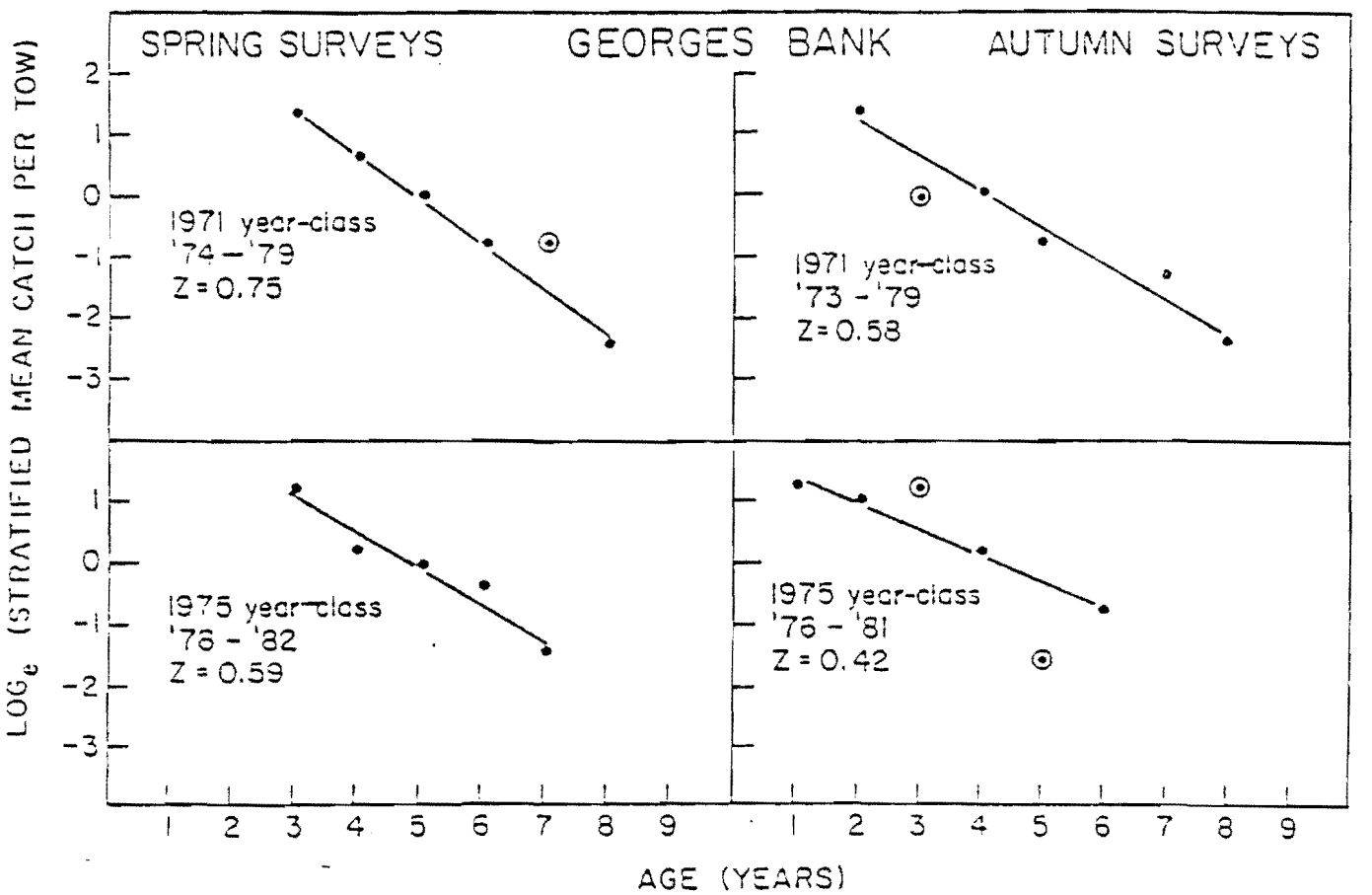

Figure 11. Catch curves for 1971 and 1975 year classes of Atlantic cod calculated from USA spring and autumn offshore bottom-trawl surveys on Georges Bank (strata 13-25). (Circled points not used in calculations). (From Serchuk et al. 1982.)