

A. Georges Bank Atlantic Cod - L. O'Brien, N. J. Munroe, and L. Col

1.0 Background

This stock was last assessed and peer reviewed in April 2001 (O'Brien and Munroe 2001; Transboundary Resources Assessment Committee 2001). Landings were 9,189 mt in 2000 and fully recruited F (ages 4-8, unweighted average) was estimated to be 0.22 in 2000, the lowest in the time series (1978-2000). Spawning stock biomass was 29,003 mt in 2000 and continued the increasing trend from the record low estimate of 19,233 mt in 1994. Since 1991, recruiting year classes have all been below the long term average and the 1997 and 2000 year classes were the lowest in the time series. The NEFSC spring and autumn bottom trawl survey recruitment indices continued to remain near record low values. Autumn recruitment indices for age 2 fish from the 1994, 1995, 1996, 1997, and 1998 year classes were all below the time series (1963-2000) average. The most recent above-average autumn recruitment index occurred in 1993.

A benchmark assessment review was conducted by the TRAC in February 2002 (NEFSC 2002). Several recommendations were made by the TRAC to rectify the strong retrospective pattern in F. These included estimating the population sizes for ages 1-9 in the terminal year and for age 9 in the three years prior to the terminal year. For the remaining years, F on the oldest age (9) would be estimated as a weighted F of ages 7 and 8. These recommendations will be addressed in the next assessment. The current assessment presented here is considered an update and the methodology has remained the same as used by the Working Group on Re-Evaluation of Biological Reference Points (NEFSC 2002).

2.0 Fishery

Total commercial landings of Georges Bank cod (Table A1, Figure A1) increased 39% in 2001 to 12,769 mt. USA landings increased 40% (10,635 mt) and Canadian landings increased 36% (2,134 mt) in 2001 (Table A1). Recreational landings were estimated at 550 mt in 2001, a decline of about 48% from 2000.

3.0 Research Surveys

NEFSC spring and autumn survey biomass and abundance indices fluctuated slightly during 2000 to 2002, and continue to remain below the long term average (Table A2, Figure A2-A3). The recruitment indices for age 1 and 2 from the 2001 NEFSC autumn bottom trawl survey were well below average (Table A3a). The Canadian spring survey index of abundance increased in 2002 but also is below the time series average (Figure A3, Table A3b).

4.0 Assessment

Input data and Analyses

The current assessment is an update assessment and employs the same VPA formulation as in the 2000 assessment (O'Brien and Munroe 2001). A slight variation from the previous assessment is that the number of surveys available as tuning indices in the terminal year increases from two to three since the USA 2002 spring survey was available at the time the assessment was conducted.

Catch at age (1-10+) has been updated with total 2001 landings (USA and Canadian). The total number of commercial length samples in 2001 was less than in 2000, however, the number of samples collected during these two years was the highest since 1985 (Table A4). The number of quarterly samples was adequate for all market categories except for the fourth quarter scrod samples (Table A5). Spatial coverage was poor for eastern Georges Bank (SA 561, 562), as it has been for several years. As in the last assessment, length samples from western Georges Bank and combined US and Canadian age samples from eastern Georges Bank were applied to characterize the landings from eastern Georges Bank. Landings were dominated in numbers by age 3 fish in both the US and Canadian fisheries and in weight by age 3 fish in the USA fishery and by age 3 and age 5 fish in the Canadian fishery. The total catch at age includes total landings from both the USA and Canadian fisheries (Table A6). No discards at age estimates are derived for stock.

Research survey indices were estimated from the 2002 NEFSC and Canadian Department of Fisheries and Oceans (DFO) spring (ages 1-8) and the NEFSC 2001 autumn (ages 1-6) bottom trawl surveys.

The ADAPT calibration method (Parrack 1986, Gavaris 1988, Conser and Powers 1990) was used to derive estimates of instantaneous fishing mortality and beginning year stock sizes in 2002. A conditional non-parametric bootstrap procedure (Efron 1982) was used to evaluate the precision of fishing mortality, spawning stock biomass, and mean biomass estimates. A retrospective analysis was performed for terminal year fishing mortality, spawning stock biomass, and age 1 recruitment.

Assessment results

Fully recruited fishing mortality (age 4-8) was estimated at 0.38 in 2001 (Figure A4). Spawning stock biomass in 2001 was estimated at 29,170 mt, a 12% increase from 2000 and a 53% increase from the record low in 1994 (Table A7, Figure A5). Recruitment of the 2001 year class (1.7 million age 1 fish) is estimated to be similar to the 2000 year class (1.6 million age 1 fish) and the 1994 year class (3.9 million age 1 fish) (Table A7, Figure A5). The survival ratio of recruit/SSB was above average for the 1996 and 1998 year classes and below average for the more recent year classes.

VPA Diagnostics

Stock size estimates for ages 1-8 were well estimated with CVs ranging from 0.21 to 0.47. The distribution of F estimates from the bootstrap analysis ranged from 0.25 to 0.56 with an 80% probability that F in 2001 was between 0.33 and 0.44. The distribution of SSB estimates from the bootstrap analysis ranged from 21,000 mt to 43,000 mt with an 80% probability that SSB in 2000 was between 25,250 mt and 31,845 mt.

A retrospective pattern exists in this model formulation back to 1994 (Figure A6). The terminal year estimates of fishing mortality are less than converged estimates since 1993, and SSB estimates are greater than converged estimates since 1993. The terminal year estimates of recruits are less than converged estimates from 1992 to 1999 and more than the converged estimates from 2000-2001. The TRAC recommended a different formulation of the ADAPT calibration to address the retrospective pattern and these recommendations will be applied in the next assessment (NEFSC 2002).

Sensitivity Analyses

Analyses were conducted to determine the sensitivity of fishing mortality and spawning stock biomass estimates to changes in the magnitude of the research survey indices used to calibrate the VPA. NEFSC spring and autumn survey indices for 2000-2002 were arbitrarily increased by 10%, 25% and 100% and used to re-calibrate the VPA (Figure A7). Results are summarized in Section 5.2 (Summary of Assessment Advice).

5.0 Projections

Long term forecasts of catch and SSB were conducted with $F_{2002} = 0.85 F_{2001}$. Input data and results for 2002-2004 are presented in Table A8. The F_{rebuild} that would enable 50% probability of reaching Bmsy by 2019 was 0.15 (Table A8). The current estimate of F_{rebuild} is similar to the previous estimate of 0.17 (NEFSC 2002) which was based on the assessment results from 2000 (O'Brien and Munroe 2001). Median SSB and catch with 80% confidence intervals projected under $F_{\text{rebuild}} = 0.15$ are presented in Figure A8.

6.0 Biological Reference Points

Biological reference points were established for Georges Bank cod based on a Beverton-Holt stock recruit model (NEFSC 2002) as :

$$\begin{aligned} \text{MSY} &= 35,236 \text{ mt} \\ \text{SSB}_{\text{MSY}} &= 216,780 \text{ mt and} \\ F_{\text{MSY}} &= 0.175 \end{aligned}$$

In 2001, spawning stock biomass was estimated at 29,170 mt, about 13% of the target SSB_{MSY} .

The stock is considered to be overfished. F was estimated at 0.38, therefore overfishing is occurring on this stock.

7.0 Summary

Georges Bank Atlantic cod are overfished and overfishing is occurring. Fishing mortality had been steadily declining since 1997, however, F increased about 9% in 2001 to 0.38. Spawning stock continues to slowly increase from the record low in 1994, however, the increase appears to be primarily due to growth.

The 1996 year class accounts for the majority of the US catch and both the 1998 and 1996 year classes account for the majority of the Canadian catch. The 1996 (10.5 million age 1 fish) and 1998 (10.3 million age 1 fish) year classes, while below the long term average (14 million age 1 fish), represent the strongest year classes since the last above-average year class that occurred in 1990 (17.9 million age1 fish). The 1999, 2000, and 2001 year classes are among the lowest in the time series.

The NEFSC and DFO survey biomass and abundance indices fluctuated slightly during 2000 to 2002, however, all the indices continue to remain below the long term average. The most recent surveys indicate that the 1999 year class may be similar in size to the 1998 year class.

The lack of strong recruitment in the last decade suggests that recovery of this stock will be largely dependent on reducing fishing mortality.

8.0 Sources of Uncertainty

Landings data for 1994-2001 are derived by proration and are provisional.

The retrospective analysis indicates a pattern in the estimates of F , SSB, and recruits in the VPA. The terminal year estimates of fishing mortality are less than the converged estimates and SSB estimates are greater than the converged estimates.

There is inadequate data to characterize both the recreational and discarded catch, particularly if these components increase. The TRAC previously rejected using poorly sampled recreational catch since a recreational catch at age with a similar age structure to the commercial catch at age would only be a scaling factor.

9.0 GARM Panel Comments

Sampling of commercial landings is stratified by market category. When evaluating sampling intensity, it may be useful to note the ages that comprise the various market categories to relate sampling to the age structure of the catch.

The residual pattern from the calibrated VPA was discussed at length. It was noted that the residual pattern on the older ages is strongest, and this may lead to the retrospective pattern on F. The retrospective pattern on SSB, however, is not as severe after 1999. A domed-shaped pattern in partial recruitment was again apparent in this assessment. Many factors may be responsible for this pattern which is generally caused by a mismatch between the age composition of the catch and the population as estimated by the survey. This may be influenced by the extensive closed areas on Georges Bank since 1995. The panel reiterated the recommendation of the TRAC that F on the oldest age be estimated directly for several of the most recent years so that a flat-topped PR not be assumed.

10.0 References

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Table A1. Commercial landings (metric tons, live) of Atlantic cod from the Georges Bank and South (NAFO Division 5Z and Subarea 6) stock, 1960 - 2001 (* = Provisional data).

Year	Country						Total
	USA	Canada	USSR	Spain	Poland	Other	
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	18	48	238	25165
1965	11410	10598	14415	59	1851	-	38333
1966	11990	15601	16830	8375	269	69	53134
1967	13157	8232	511	14730	-	122	36752
1968	15279	9127	1459	14622	2611	38	43136
1969	16782	5997	646	13597	798	119	37939
1970	14899	2583	364	6874	784	148	25652
1971	16178	2979	1270	7460	256	36	28179
1972	13406	2545	1878	6704	271	255	25059
1973	16202	3220	2977	5980	430	114	28923
1974	18377	1374	476	6370	566	168	27331
1975	16017	1847	2403	4044	481	216	25008
1976	14906	2328	933	1633	90	36	19926
1977	21138	6173	54	2	-	-	27367
1978	26579	8778	-	-	-	-	35357
1979	32645	5978	-	-	-	-	38623
1980	40053	8063	-	-	-	-	48116
1981	33849	8499	-	-	-	-	42348
1982	39333	17824	-	-	-	-	57157
1983	36756	12130	-	-	-	-	48886
1984	32915	5763	-	-	-	-	38678
1985	26828	10443	-	-	-	-	37271
1986	17490	8411	-	-	-	-	25901
1987	19035	11845	-	-	-	-	30880
1988	26310	12932	-	-	-	-	39242
1989	25097	8001	-	-	-	-	33098
1990	28193	14310	-	-	-	-	42503
1991	24175	13455	-	-	-	-	37630
1992	16855	11712	-	-	-	-	28567
1993	14594	8519	-	-	-	-	23113
1994	9893*	5276	-	-	-	-	15169
1995	6759*	1100	-	-	-	-	7859
1996	7020*	1885	-	-	-	-	8905
1997	7537*	2898	-	-	-	-	10435
1998	6959*	1873	-	-	-	-	8832
1999	8061*	1819	-	-	-	-	9880
2000	7617*	1572	-	-	-	-	9189
2001	10635*	2134	-	-	-	-	12769

Table A2. Standardized stratified mean catch per tow in numbers and weight (kg) for Atlantic cod in NEFSC offshore spring and autumn research vessel bottom trawl surveys on Georges Bank (Strata 13-25), 1963 - 2000. [1, 2, 3]

Year	Spring		Autumn	
	No/Tow	Wt/Tow	No/Tow	Wt/Tow
1963	-	-	4.37	17.8
1964	-	-	2.79	11.4
1965	-	-	4.25	11.8
1966	-	-	4.90	8.1
1967	-	-	10.33	13.6
1968	4.73	12.7	3.31	8.6
1969	4.63	17.8	2.24	8.0
1970	4.34	15.8	5.12	12.6
1971	3.39	14.3	3.19	9.8
1972	9.16	19.3	13.09	22.9
1973	57.81	94.5	12.28	30.9
1974	14.74	36.4	3.49	8.2
1975	6.89	26.1	6.41	14.1
1976	7.06	18.6	10.43	17.7
1977	6.19	15.3	5.44	12.5
1978	12.31	31.2	8.59	23.3
1979	5.00	16.2	5.95	16.5
1980	7.68	24.1	2.91	6.7
1981	10.44	26.1	9.20	20.3
1982	32.96	101.9	3.34	6.1
1983	7.70	23.5	4.14	6.1
1984	4.08	15.3	4.73	10.0
1985	7.03	21.7	2.31	3.1
1986	5.04	16.7	2.99	3.7
1987	3.24	9.9	2.33	4.4
1988	5.87	13.5	3.07	5.6
1989	4.80	10.9	4.84	4.7
1990	4.79	11.7	4.78	11.5
1991	4.31	8.9	0.96	1.4
1992	2.67	7.4	1.72	3.0
1993	2.40	7.0	2.15	2.2
1994	0.95	1.2	1.82	3.3
1995	3.29	8.4	3.62	5.6
1996	2.70	7.5	1.10	2.7
1997	2.32	5.2	0.87	1.9
1998	4.36	11.7	1.87	2.8
1999	2.15	4.7	1.02	3.0
2000	3.57	8.2	1.31	1.4
2001	1.86	5.5	1.05	2.1
2002	2.08	5.0		
Average	7.50	19.3	4.29	9.2

Table A3a. Standardized (for vessel and door changes) stratified mean catch per tow at age (numbers) of Atlantic cod in NEFSC offshore spring and autumn bottom trawl surveys on Georges Bank (Strata 13-25), 1963 - 2002.

Year	AGE											No./tow
	0	1	2	3	4	5	6	7	8	9	10+	
SPRING												
1968	0.513	0.136	1.615	0.825	0.665	0.385	0.246	0.140	0.083	0.056	0.058	4.722
1969	0.000	0.123	0.546	1.780	0.888	0.451	0.326	0.215	0.128	0.072	0.112	4.641
1970	0.000	0.338	0.804	0.430	1.241	0.162	0.844	0.263	0.058	0.056	0.147	4.342
1971	0.000	0.206	0.860	0.438	0.254	0.570	0.114	0.324	0.365	0.128	0.132	3.391
1972	0.056	3.000	1.838	2.732	0.445	0.166	0.323	0.084	0.285	0.071	0.158	9.159
1973	0.056	0.546	42.258	6.344	6.387	0.657	0.515	0.367	0.058	0.217	0.404	57.808
1974	0.000	0.444	4.558	5.971	0.761	1.988	0.442	0.100	0.265	0.064	0.144	14.735
1975	0.000	0.064	0.327	2.092	2.941	0.377	0.744	0.084	0.115	0.147	0.000	6.890
1976	0.111	1.298	1.955	0.915	0.661	1.607	0.153	0.261	0.029	0.000	0.068	7.058
1977	0.000	0.044	3.389	1.084	0.553	0.267	0.717	0.052	0.066	0.000	0.021	6.193
1978	3.312	0.372	0.192	5.531	0.972	0.778	0.142	0.712	0.065	0.141	0.096	12.312
1979	0.108	0.428	1.298	0.275	1.852	0.547	0.236	0.084	0.139	0.013	0.022	5.000
1980	0.105	0.031	2.217	2.690	0.212	1.705	0.374	0.186	0.031	0.030	0.096	7.676
1981	0.301	2.302	1.852	2.811	1.685	0.106	0.879	0.258	0.132	0.000	0.113	10.438
1982	0.169	0.508	5.435	9.502	8.324	6.208	0.293	1.866	0.369	0.082	0.203	32.958
1983	0.081	0.332	1.952	3.017	0.796	0.697	0.443	0.027	0.219	0.000	0.138	7.701
1984	0.000	0.402	0.431	0.761	1.238	0.422	0.400	0.209	0.000	0.215	0.000	4.078
1985	0.244	0.111	2.653	0.663	1.110	1.412	0.265	0.192	0.180	0.037	0.161	7.029
1986	0.092	0.872	0.409	1.844	0.365	0.540	0.618	0.062	0.125	0.101	0.015	5.044
1987	0.000	0.020	1.613	0.378	0.763	0.062	0.179	0.136	0.033	0.027	0.025	3.235
1988	0.180	0.720	0.609	3.150	0.409	0.644	0.064	0.037	0.049	0.000	0.007	5.868
1989	0.000	0.310	1.410	0.666	1.583	0.235	0.351	0.051	0.040	0.055	0.093	4.794
1990	0.042	0.173	0.922	1.737	0.674	0.912	0.130	0.143	0.013	0.016	0.027	4.790
1991	0.195	1.027	0.528	0.689	0.929	0.479	0.328	0.054	0.041	0.000	0.045	4.313
1992	0.000	0.123	1.252	0.468	0.168	0.273	0.142	0.159	0.020	0.037	0.028	2.670
1993	0.110	0.009	0.399	1.306	0.205	0.090	0.138	0.029	0.034	0.021	0.055	2.396
1994	0.030	0.125	0.272	0.200	0.217	0.033	0.006	0.044	0.000	0.019	0.000	0.945
1995	0.482	0.050	0.382	0.854	0.534	0.599	0.107	0.234	0.028	0.022	0.000	3.290
1996	0.000	0.073	0.214	0.736	1.247	0.174	0.209	0.028	0.018	0.000	0.000	2.699
1997	0.302	0.291	0.437	0.170	0.489	0.422	0.050	0.134	0.020	0.000	0.000	2.315
1998	0.018	0.111	0.665	1.298	0.848	0.755	0.533	0.102	0.031	0.000	0.000	4.360
1999	0.067	0.212	0.291	0.609	0.510	0.238	0.119	0.064	0.031	0.007	0.000	2.148
2000	0.053	0.221	0.807	0.830	1.141	0.370	0.102	0.026	0.020	0.000	0.000	3.569
2001	0.000	0.061	0.235	0.794	0.160	0.383	0.177	0.023	0.018	0.012	0.000	1.862
2002	0.018	0.065	0.093	0.383	0.993	0.239	0.225	0.039	0.000	0.000	0.028	2.083
average	0.301	0.433	2.420	1.828	1.206	0.713	0.312	0.194	0.089	0.047	0.068	7.500

Table A3a continued. Standardized (for vessel and door changes) stratified mean catch per tow at age (numbers) of Atlantic cod in NEFSC offshore spring and autumn bottom trawl surveys on Georges Bank (Strata 13-25), 1963 - 2001.

Year	AGE											No./tow
	0	1	2	3	4	5	6	7	8	9	10+	
AUTUMN												
1963	0.019	0.719	0.778	0.920	0.897	0.354	0.326	0.175	0.103	0.014	0.069	4.374
1964	0.009	0.640	0.699	0.588	0.538	0.145	0.136	0.062	0.050	0.030	0.083	2.980
1965	0.173	1.299	0.998	0.707	0.484	0.167	0.179	0.112	0.081	0.023	0.023	4.246
1966	1.025	1.693	1.000	0.515	0.264	0.100	0.095	0.062	0.039	0.002	0.017	4.812
1967	0.072	7.596	1.334	0.523	0.406	0.133	0.133	0.055	0.051	0.012	0.070	10.385
1968	0.070	0.314	1.611	0.783	0.271	0.073	0.067	0.027	0.023	0.008	0.048	3.295
1969	0.000	0.343	0.622	0.626	0.331	0.094	0.061	0.019	0.023	0.022	0.059	2.200
1970	0.434	1.699	1.361	0.532	0.696	0.153	0.000	0.033	0.055	0.055	0.098	5.116
1971	0.400	0.602	0.617	0.408	0.310	0.478	0.164	0.042	0.090	0.000	0.075	3.186
1972	0.948	7.473	1.191	1.841	0.399	0.241	0.568	0.116	0.204	0.021	0.084	13.085
1973	0.203	1.748	6.060	1.164	2.039	0.210	0.225	0.175	0.062	0.137	0.253	12.276
1974	0.461	0.410	0.667	1.509	0.161	0.089	0.112	0.000	0.059	0.021	0.000	3.489
1975	2.377	0.992	0.421	0.628	1.682	0.111	0.156	0.000	0.000	0.000	0.037	6.406
1976	0.000	6.144	2.073	0.762	0.275	0.738	0.054	0.269	0.037	0.052	0.021	10.425
1977	0.152	0.237	3.434	0.691	0.253	0.173	0.394	0.007	0.027	0.000	0.077	5.444
1978	0.395	1.845	0.391	4.058	0.964	0.336	0.165	0.343	0.050	0.030	0.014	8.590
1979	0.115	1.625	1.677	0.162	1.687	0.321	0.184	0.031	0.113	0.010	0.025	5.948
1980	0.280	0.820	0.564	0.774	0.053	0.265	0.057	0.067	0.027	0.000	0.000	2.905
1981	0.261	3.525	2.250	1.559	0.589	0.054	0.579	0.057	0.064	0.018	0.083	9.039
1982	0.362	0.577	1.910	0.242	0.068	0.115	0.000	0.031	0.033	0.000	0.000	3.337
1983	1.283	0.850	1.089	0.740	0.069	0.033	0.004	0.010	0.015	0.000	0.044	4.136
1984	0.179	1.909	0.682	0.929	0.825	0.024	0.059	0.039	0.000	0.039	0.044	4.728
1985	1.002	0.181	0.843	0.067	0.106	0.077	0.028	0.000	0.000	0.000	0.003	2.306
1986	0.076	2.279	0.129	0.329	0.008	0.049	0.073	0.016	0.000	0.007	0.022	2.987
1987	0.204	0.414	1.353	0.108	0.200	0.028	0.012	0.000	0.000	0.000	0.007	2.325
1988	0.550	0.875	0.437	0.904	0.060	0.194	0.000	0.011	0.039	0.000	0.000	3.069
1989	0.251	2.798	1.046	0.161	0.507	0.055	0.015	0.007	0.000	0.000	0.000	4.841
1990	0.157	0.364	1.624	1.814	0.412	0.286	0.069	0.022	0.011	0.000	0.022	4.781
1991	0.041	0.408	0.175	0.274	0.031	0.029	0.000	0.000	0.000	0.000	0.000	0.957
1992	0.035	0.412	0.949	0.174	0.100	0.044	0.010	0.000	0.000	0.000	0.000	1.724
1993	0.178	0.970	0.532	0.383	0.017	0.025	0.022	0.000	0.000	0.022	0.000	2.149
1994	0.067	0.406	0.664	0.433	0.153	0.068	0.021	0.000	0.006	0.000	0.000	1.819
1995	0.160	0.245	1.811	1.249	0.087	0.054	0.011	0.000	0.000	0.000	0.000	3.616
1996	0.022	0.240	0.196	0.414	0.143	0.060	0.027	0.000	0.000	0.000	0.000	1.101
1997	0.006	0.236	0.321	0.109	0.129	0.049	0.009	0.007	0.000	0.000	0.000	0.867
1998	0.070	0.336	1.026	0.352	0.041	0.035	0.004	0.000	0.004	0.000	0.000	1.867
1999	0.070	0.140	0.154	0.310	0.255	0.087	0.000	0.000	0.000	0.000	0.000	1.016
2000	0.020	0.571	0.538	0.071	0.079	0.031	0.000	0.000	0.000	0.000	0.000	1.308
2001	0.028	0.047	0.381	0.459	0.059	0.055	0.008	0.008	0.000	0.000	0.000	1.045

Table A3b. Stratified mean catch per tow at age (numbers) of Atlantic cod in Canadian spring bottom trawl survey on Georges Bank, 1986 - 2002.

Year	AGE										0+	
	1	2	3	4	5	6	7	8	9	10+		
SPRING												
1986	0.60	2.27	2.81	0.37	0.65	0.44	0.26	0.04	0.07	0.03		7.54
1987	0.25	2.13	0.93	1.09	0.34	0.12	0.22	0.08	0.03	0.07		5.26
1988	0.28	1.01	4.66	0.58	1.02	0.13	0.08	0.17	0.04	0.07		8.04
1989	1.63	2.78	1.38	2.85	0.36	0.42	0.05	0.10	0.12	0.06		9.75
1990	0.42	2.44	3.78	2.08	3.87	0.42	0.93	0.12	0.12	0.35		14.53
1991	1.18	1.16	1.84	2.15	1.05	1.31	0.16	0.22	0.03	0.09		9.19
1992	0.11	2.86	1.77	0.80	0.98	0.60	0.43	0.12	0.07	0.02		7.76
*1993	0.05	0.60	2.83	1.04	0.62	1.23	0.44	0.42	0.07	0.12		7.42
*1994	0.02	0.80	0.89	1.65	0.60	0.23	0.45	0.11	0.15	0.04		4.94
1995	0.07	0.67	1.50	0.86	0.60	0.19	0.04	0.05	0.02	0.02		4.02
1996	0.14	0.49	2.31	4.02	1.09	0.79	0.33	0.08	0.11	0.03		9.39
1997	0.32	0.53	0.55	1.25	1.23	0.27	0.06	0.03	0.02	0.01		4.27
1998	0.01	0.67	0.95	0.35	0.35	0.28	0.07	0.02	0.00	0.02		2.72
1999	0.33	0.32	1.49	1.09	0.41	0.26	0.15	0.01	0.02	0.01		4.09
2000	0.10	0.44	1.05	3.92	1.71	0.78	0.40	0.24	0.01	0.03		8.68
2001	0.00	0.06	0.64	0.42	1.11	0.52	0.26	0.17	0.16	0.06		3.40
2002	0.01	0.09	0.57	2.05	0.68	1.22	0.40	0.17	0.05	0.08		5.32

6.84

* indices not included in VPA calibration

Table A4. USA and Canadian sampling of commercial Atlantic cod landings from the Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6), 1978 - 2001.

Year	USA				Canada			
	Length Samples		Age Samples		Length Samples		Age Samples	
	No.	# Fish Measured	No.	# Fish Aged	No.	# Fish Measured	No.	# Fish Aged
1978	88	6841	76	1463	29	7684	29	1308
1979	80	6973	79	1647	13	3991	12	656
1980	69	4990	67	1119	10	2784	10	536
1981	57	4304	57	1231	17	4147	16	842
1982	151	11970	147	2579	17	4756	8	858
1983	146	12544	138	2945	15	3822	14	604
1984	100	8721	100	2431	7	1889	7	385
1985	100	8366	100	2321	29	7644	20	1062
1986	94	7515	94	2222	19	5745	19	888
1987	80	6395	79	1704	33	9477	33	1288
1988	76	6483	76	1576	40	11709	40	1984
1989	66	5547	66	1350	32	8716	32	1561
1990	83	7158	83	1700	40	9901	40	2012
1991	88	7708	88	1865	45	10873	45	1782
1992	77	6549	77	1631	48	10878	48	1906
1993	82	6636	82	1598	51	12158	51	2146
1994	58	4688	54	1064	104	25845	101	1268
1995	40	2879	40	778	36	11598	36	548
1996	55	4600	54	1080	129	26663	129	879
1997	80	6638	80	1581	118	31882	38	1244
1998	80	7076	81	1545	139	26549	139	1720
1999	68	5987	67	1503	84	24954	84	918
2000	155	12219	154	2951	107	20782	107	1436
2001	108	8389	108	2389	108	18190	108	1509

Table A5. USA sampling of commercial Atlantic cod landings, by market category, for the Georges Bank and South cod stock (NAFO Division 5Z and Subarea 6), 1978 - 2001.

Year	Number of Samples, by Market Category & Quarter															Annual Sampling Intensity			
	Scrod					Market					Large					No. of Tons Landed/Sample			
	Q1	Q2	Q3	Q4	Σ	Q1	Q2	Q3	Q4	Σ	Q1	Q2	Q3	Q4	Σ	Scrd	Mkt	Lge	Σ
1978	17	15	6	3	41	9	12	13	9	43	1	0	1	2	4	69	374	1922	302
1979	2	5	14	8	29	6	19	11	8	44	2	0	4	1	7	88	407	1742	408
1980	7	10	13	4	34	12	14	5	1	32	3	0	0	0	3	136	588	5546	580
1981	4	10	11	3	28	6	9	10	2	27	2	0	0	0	2	149	634	6283	594
1982	5	9	32	9	55	6	20	27	13	66	8	8	9	5	30	156	279	410	260
1983	4	12	17	10	43	12	19	22	14	67	2	15	16	3	36	185	291	259	252
1984	6	8	8	7	29	8	15	8	11	42	18	5	3	3	29	138	441	358	329
1985	6	7	16	5	34	11	11	12	8	42	4	8	7	5	24	201	299	310	268
1986	6	7	7	6	26	8	10	10	11	39	6	5	10	8	29	142	215	186	186
1987	7	8	6	8	29	6	8	9	10	33	6	6	4	2	18	240	220	267	238
1988	8	6	7	5	26	13	7	9	9	38	4	4	3	1	12	283	331	532	346
1989	2	7	9	9	27	7	8	8	7	30	3	4	1	1	9	210	450	660	380
1990	8	9	10	4	31	10	13	9	8	40	4	4	4	0	12	295	315	538	340
1991	6	11	7	5	29	12	13	8	8	41	4	6	3	5	18	158	293	423	275
1992	6	7	7	10	30	8	10	6	9	33	5	5	3	1	14	149	215	377	219
1993	5	16	7	6	34	10	10	7	9	36	6	1	3	2	12	126	173	339	178
1994	3	9	8	2	22	5	11	7	4	27	1	4	3	1	9	92	187	290	167
1995	2	3	13	2	20	2	4	10	2	18	0	1	0	1	2	83	181	880	167
1996	6	2	12	3	23	5	6	11	6	28	0	2	1	1	4	59	143	400	127
1997	3	11	3	10	27	5	16	9	9	39	3	6	0	5	14	50	105	148	94
1998	3	7	23	5	38	10	10	15	3	38	1	2	1	0	3	44	92	573	88
1999	5	3	10	1	21	7	13	10	5	38	2	4	2	0	9	80	118	205	118
2000	22	20	16	27	85	19	14	13	18	64	2	1	2	2	7	18	71	219	49
2001	11	9	13	3	36	9	10	8	10	37	6	12	6	10	34	72	163	55	98

Table A6. Landings at age (thousands of fish; metric tons) and mean weight (kg) and mean length (cm) at age of total commercial landings of Atlantic cod from the Georges Bank and South stock (NAFO Division 5Z and Subarea 6), 1978-2000.

Year	Age										Total	% of Total Landings	
	1	2	3	4	5	6	7	8	9	10+		USA	Canada
Total Commercial Landings in Numbers (000's) at Age													
1978	2	393	7748	2303	830	131	345	47	40	15	11854	73.7	26.3
1979	34	1989	900	4870	1212	458	77	253	4	48	9845	81.2	18.8
1980	89	3777	5828	500	2308	1076	445	87	167	10	14287	80.9	19.1
1981	27	3205	4221	2464	235	1406	417	123	130	62	12290	84.1	15.9
1982	331	9138	3824	2787	2000	281	673	213	71	83	19401	74.1	25.9
1983	108	4286	8063	2456	1055	776	95	235	100	65	17239	72.2	27.8
1984	81	1307	3423	3336	840	516	458	44	171	121	10297	89.0	11.0
1985	134	6426	2443	1368	1885	412	218	203	21	97	13207	68.4	31.6
1986	156	1326	4573	797	480	627	87	72	47	29	8194	71.7	28.3
1987	26	7473	1406	2121	279	252	270	63	38	24	11952	64.2	35.8
1988	10	1577	8022	1012	1497	244	161	197	50	47	12817	71.6	28.4
1989	-	2088	2922	4155	331	541	82	43	50	18	10230	81.1	18.9
1990	7	4942	5042	1882	2264	229	245	36	17	38	14702	74.3	25.7
1991	52	1525	3243	3281	1458	1088	126	70	23	23	10889	67.7	32.3
1992	70	4177	2170	1038	1482	404	309	34	33	10	9727	58.7	41.3
1993	4	1033	4246	1115	440	472	159	143	32	17	7661	67.0	33.0
1994	2	398	1526	1825	394	96	137	46	38	6	4468	68.5	31.5
1995	0.1	392	1058	692	290	44	26	15	2	1	2520	86.9	13.1
1996	0.7	207	903	1234	241	123	15	3	5	0.2	2731	80.0	20.0
1997	3	517	639	881	794	131	84	16	9	4	3078	74.2	25.8
1998	0.2	739	1188	423	324	237	39	14	6	4	2975	81.9	18.1
1999	2	285	1927	706	201	97	119	16	2	3	3359	83.7	16.3
2000	6	811	710	1024	306	72	38	25	2	1	2994	84.5	15.5
2001	-	682	2381	647	595	163	46	22	11	2	4548	86.6	13.4
Total Commercial Landings in Weight (Tons) at Age													
1978	1	515	18890	7990	3597	757	2549	395	465	198	35357	75.2	24.8
1979	30	2970	1936	20504	5923	3288	711	2611	44	606	38623	84.5	15.5
1980	75	5516	14382	1833	13036	7184	3735	793	1408	154	48116	83.2	16.8
1981	24	4789	9953	8416	1224	10156	3575	1212	1848	1151	42348	79.9	20.1
1982	253	12812	10187	10681	10705	1827	6303	2110	891	1388	57157	68.8	31.2
1983	105	6387	19167	8126	4891	4963	763	2418	1120	946	48886	75.2	24.8
1984	85	2137	8389	12074	4271	3401	4078	447	1938	1858	38678	85.1	14.9
1985	121	9111	5095	5319	9588	2644	1765	2073	246	1309	37271	72.0	28.0
1986	145	1955	11189	2917	2692	4505	776	717	596	409	25901	67.5	32.5
1987	19	11071	3509	8882	1619	1945	2416	633	426	360	30880	61.6	38.4
1988	8	2399	18923	3552	8085	1618	1412	1960	566	719	39242	67.0	33.0
1989	-	3375	6633	15673	1783	3625	669	455	588	298	33098	75.8	24.2
1990	5	7709	12412	6629	11075	1448	2069	382	222	552	42503	66.3	33.7
1991	59	2481	8265	11221	6955	6411	933	736	223	346	37630	64.2	35.8
1992	80	6441	5348	3991	6971	2486	2322	334	402	192	28567	59.0	41.0
1993	3	1585	9566	3717	2184	3012	1195	1315	316	220	23113	63.1	36.9
1994	2	581	3308	6673	1892	716	1095	430	364	103	15165	65.2	34.8
1995	0.1	577	2215	2649	1595	327	273	174	20	20	7851	86.1	13.9
1996	0.6	311	2199	4178	1183	817	127	21	59	2	8898	78.9	21.1
1997	3	816	1483	3114	3256	790	674	135	111	53	10435	72.2	27.8
1998	0.1	1096	2735	1477	1532	1408	323	117	82	61	8832	78.8	21.2
1999	1	446	4283	2437	985	622	874	159	27	45	9880	81.6	18.4
2000	6	1386	1731	3644	1478	424	283	213	14	9	9189	82.9	17.1
2001	-	1034	5627	2038	2582	899	283	180	110	20	12772	83.3	16.7

Table A6 continued. Landings at age (thousands of fish; metric tons) and mean weight (kg) and mean length (cm) at age of total commercial landings of Atlantic cod from the Georges Bank and South stock (NAFO Division 5Z and Subarea 6), 1978-2001.

Year	Age										Mean
	1	2	3	4	5	6	7	8	9	10+	
Total Commercial Landings Mean Weight (kg) at Age											
1978	0.707	1.310	2.461	3.469	4.336	5.787	7.374	8.492	11.785	13.200	2.983
1979	0.889	1.494	2.149	4.211	4.888	7.178	9.183	10.313	11.699	12.625	3.923
1980	0.836	1.460	2.468	3.668	5.647	6.676	8.390	9.089	8.432	15.400	3.368
1981	0.882	1.495	2.358	3.415	5.213	7.222	8.565	9.888	14.170	18.565	3.446
1982	0.765	1.402	2.664	3.834	5.352	6.511	9.363	9.897	12.503	16.723	2.946
1983	0.971	1.490	2.377	3.309	4.637	6.393	7.964	10.286	11.227	14.554	2.836
1984	1.053	1.635	2.451	3.619	5.083	6.582	8.909	10.104	11.303	15.356	3.756
1985	0.907	1.418	2.086	3.887	5.087	6.412	8.097	10.236	11.418	13.494	2.822
1986	0.929	1.475	2.447	3.660	5.603	7.191	8.915	9.955	12.687	14.104	3.161
1987	0.726	1.481	2.495	4.187	5.810	7.726	8.949	10.013	11.414	15.000	2.584
1988	0.786	1.520	2.359	3.511	5.401	6.647	8.776	9.987	11.143	15.298	3.062
1989	-	1.617	2.269	3.772	5.396	6.694	8.222	10.718	11.665	17.111	3.235
1990	0.831	1.560	2.462	3.522	4.892	6.333	8.456	10.648	12.580	14.526	2.891
1991	1.114	1.627	2.548	3.420	4.769	5.891	7.410	10.520	9.686	15.373	3.456
1992	1.148	1.542	2.464	3.843	4.704	6.156	7.509	9.846	12.059	19.025	2.937
1993	0.872	1.534	2.253	3.333	4.967	6.379	7.510	9.217	9.699	13.236	3.017
1994	0.906	1.459	2.168	3.657	4.804	7.432	8.013	9.368	9.698	16.659	3.394
1995	0.906	1.471	2.095	3.830	5.492	7.384	10.715	11.617	10.383	14.953	3.087
1996	0.882	1.507	2.435	3.387	4.912	6.622	8.369	8.438	12.883	12.002	3.212
1997	0.954	1.577	2.321	3.532	4.103	6.019	8.050	8.631	11.870	12.795	3.390
1998	0.579	1.483	2.302	3.497	4.735	5.934	8.185	8.610	12.684	14.606	2.969
1999	0.830	1.565	2.223	3.452	4.891	6.422	7.341	9.685	12.153	13.735	2.941
2000	1.055	1.710	2.437	3.558	4.836	5.923	7.406	8.498	8.267	10.594	3.069
2001	0.880	1.517	2.363	3.152	4.337	5.510	6.217	8.230	9.818	12.477	2.808
1978-2000	0.888	1.514	2.361	3.634	5.028	6.589	8.338	9.747	11.365	14.434	
1996-2000	0.879	1.565	2.346	3.487	4.712	6.191	7.890	8.797	11.570	12.735	
Total Commercial Landings Mean Length (cm) at Age											
1978	39.5	50.0	60.8	67.9	72.7	80.4	80.2	93.1	103.4	106.5	64.1
1979	44.7	52.2	57.7	73.2	76.8	87.5	95.3	99.5	103.4	106.4	69.6
1980	43.8	51.8	61.2	69.7	80.9	86.0	92.4	93.8	92.4	114.6	65.6
1981	44.4	52.2	60.2	68.4	78.2	88.0	93.5	97.5	110.3	119.5	65.6
1982	42.2	51.2	62.4	70.5	79.1	84.3	96.0	97.4	105.8	115.0	61.9
1983	45.5	52.3	60.4	67.0	75.3	84.4	90.7	99.1	101.9	111.4	62.4
1984	47.2	54.0	61.5	69.8	77.8	85.5	94.4	98.6	102.3	112.8	68.6
1985	44.9	51.1	57.5	71.4	78.0	84.3	91.3	98.8	102.3	108.2	61.1
1986	45.0	51.9	61.1	69.2	80.7	87.7	94.4	98.0	105.9	108.4	64.3
1987	40.7	51.8	61.2	73.0	81.8	90.1	94.5	98.2	102.5	111.2	59.7
1988	40.8	52.8	60.4	68.5	79.5	85.3	93.6	97.7	101.5	111.2	64.1
1989	-	53.8	60.0	70.4	79.2	85.2	91.7	100.3	103.2	113.3	65.7
1990	41.7	53.5	61.0	68.7	76.6	83.2	92.1	100.2	106.0	110.8	62.9
1991	47.7	53.6	62.2	67.7	75.8	80.9	87.8	99.4	95.9	113.9	67.0
1992	46.2	52.4	60.8	70.6	75.1	82.2	87.9	96.0	104.3	116.0	62.4
1993	42.2	52.7	59.6	67.0	76.3	83.6	88.2	95.1	95.9	107.0	63.0
1994	43.1	51.7	58.9	69.6	75.8	88.2	90.7	95.3	95.9	115.8	65.8
1995	43.0	50.6	58.2	70.9	80.5	88.5	100.9	103.8	99.1	113.0	64.6
1996	45.1	52.7	61.2	68.0	76.9	85.5	90.7	91.0	106.9	104.6	66.4
1997	43.7	53.4	60.2	68.8	72.1	82.3	91.2	93.1	104.2	106.5	66.7
1998	37.8	52.4	60.1	68.8	76.0	82.2	91.4	93.1	106.4	111.9	61.7
1999	41.5	53.4	59.6	68.6	76.9	84.1	88.5	96.6	103.4	109.0	64.0
2000	47.3	55.1	61.6	69.6	76.9	82.2	88.6	93.1	92.5	107.9	65.2
2001	43.0	53.1	60.9	66.7	74.0	80.2	83.0	91.6	97.7	102.2	63.4

Table A7. Estimates of beginning year stock size (thousands of fish), instantaneous fishing mortality (F), mean biomass (mt), spawning stock biomass (mt), and percent mature of Georges Bank cod, estimated from virtual population analysis (VPA), calibrated using the commercial catch at age ADAPT formulation, 1978-2001.

Stock Numbers (Jan 1) in thousands

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
1	27711	23512	20109	41393	17470	9614	27389	8671	42749	16376	23445	15674	9196	17857	6619	8175	5335	3940	6884	10464	4307	10259	4969	1556	1651
2	4270	22686	19219	16383	33865	14004	7774	22351	6978	34859	13384	19186	12833	7523	14573	5356	6690	4366	3226	5636	8565	3526	8398	4063	1274
3	25527	3140	16774	12318	10513	19458	7587	5182	12485	4513	21778	9531	13819	6035	4779	8152	3450	5117	3220	2454	4146	6344	2629	6142	2709
4	7933	13889	1756	8460	6266	5148	8635	3115	2032	6084	2423	10572	5159	6752	2006	1949	2832	1444	3232	1819	1431	2320	3450	1510	2874
5	2877	4411	6965	986	4697	2608	1992	4051	1312	943	3062	1068	4896	2521	2559	703	587	667	556	1530	692	789	1260	1898	651
6	1127	1604	2515	3614	594	2036	1181	871	1611	640	519	1152	575	1960	745	754	178	124	284	237	534	273	464	755	1016
7	1414	804	899	1085	1687	232	965	500	340	752	296	204	454	263	620	244	191	59	62	121	76	223	136	315	471
8	67	846	588	334	511	772	104	375	212	200	371	97	93	150	102	228	56	32	25	37	23	27	75	77	216
9	147	12	463	403	162	226	419	46	124	108	107	126	40	44	60	52	57	4	13	17	16	6	7	39	43
10+	55	148	27	191	187	145	293	208	76	68	99	45	89	43	18	27	9	2	1	1	10	9	4	7	25
1 +	71127	71052	69317	85166	75953	54244	56341	45370	67920	64543	65484	57655	47154	43147	32080	25642	19384	15755	17501	22317	19800	23776	21392	16361	10931

Fishing Mortality

	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1	0	0	0	0	0.02	0.01	0	0.02	0	0	0	0	0	0	0.01	0	0	0	0	0	0	0	0	0
2	0.11	0.1	0.24	0.24	0.35	0.41	0.21	0.38	0.24	0.27	0.14	0.13	0.55	0.25	0.38	0.24	0.07	0.1	0.07	0.11	0.1	0.09	0.11	0.21
3	0.41	0.38	0.48	0.48	0.51	0.61	0.69	0.74	0.52	0.42	0.52	0.41	0.52	0.9	0.7	0.86	0.67	0.26	0.37	0.34	0.38	0.41	0.35	0.56
4	0.39	0.49	0.38	0.39	0.68	0.75	0.56	0.66	0.57	0.49	0.62	0.57	0.52	0.77	0.85	1	1.25	0.75	0.55	0.77	0.4	0.41	0.4	0.64
5	0.38	0.36	0.46	0.31	0.64	0.59	0.63	0.72	0.52	0.4	0.78	0.42	0.72	1.02	1.02	1.18	1.35	0.65	0.65	0.85	0.73	0.33	0.31	0.43
6	0.14	0.38	0.64	0.56	0.74	0.55	0.66	0.74	0.56	0.57	0.73	0.73	0.58	0.95	0.91	1.18	0.91	0.5	0.65	0.94	0.67	0.5	0.19	0.27
7	0.31	0.11	0.79	0.55	0.58	0.6	0.74	0.66	0.33	0.51	0.92	0.59	0.91	0.75	0.8	1.27	1.58	0.67	0.31	1.45	0.84	0.89	0.37	0.18
8	1.49	0.4	0.18	0.52	0.62	0.41	0.63	0.91	0.47	0.43	0.88	0.68	0.56	0.72	0.46	1.18	2.37	0.73	0.15	0.65	1.1	1.09	0.46	0.38
9	0.36	0.44	0.51	0.44	0.66	0.67	0.6	0.71	0.54	0.49	0.73	0.58	0.63	0.87	0.95	1.12	1.31	0.72	0.57	0.85	0.54	0.43	0.36	0.38
10+	0.36	0.44	0.51	0.44	0.66	0.67	0.6	0.71	0.54	0.49	0.73	0.58	0.63	0.87	0.95	1.12	1.31	0.72	0.57	0.85	0.54	0.43	0.36	0.38
mn4-8,u	0.542	0.348	0.49	0.466	0.652	0.58	0.644	0.738	0.49	0.48	0.786	0.598	0.658	0.842	0.808	1.162	1.492	0.66	0.462	0.932	0.748	0.644	0.346	0.38

Table A7 continued. Estimates of beginning year stock size (thousands of fish), instantaneous fishing mortality (F), mean biomass (mt), spawning stock biomass (mt), and percent mature of Georges Bank cod, estimated from virtual population analysis (VPA), calibrated using the commercial catch at age ADAPT formulation, 1978-2001.

Mean biomass (mt)

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1	17756	18930	15201	33078	11990	8411	26099	7069	35925	10766	16698	11493	6923	18001	6848	6460	4380	3235	5503	9047	2260	7717	4749	1241
2	4816	29255	22650	19782	36452	15600	10449	24024	8343	41183	17250	26448	14056	9839	17044	6647	8562	5536	4253	7653	10972	4782	12331	5068
3	47057	5118	29978	21112	20017	31666	12313	7019	21789	8384	36579	16162	24293	9321	7775	11337	4993	8595	5973	4402	7240	10561	4918	10168
4	20817	42243	4894	21839	16000	10999	21920	8106	5191	18429	5806	27812	12975	14781	4777	3783	5477	3563	7708	4119	3770	5995	9241	3217
5	9449	16495	28841	4033	17037	8352	6888	13463	5247	4126	10555	4295	15689	6947	6950	1899	1431	2464	1838	3882	2135	2993	4770	6120
6	5533	8742	11357	18264	2510	9170	5214	3621	8109	3448	2245	5019	2527	6859	2764	2614	799	660	1266	851	2112	1265	2277	3316
7	8154	6341	4785	6532	10957	1273	5563	2718	2353	4828	1564	1164	2322	1259	2944	961	713	420	405	478	384	995	769	1630
8	275	6555	4453	2347	3458	5943	717	2321	1538	1486	2266	691	696	1030	732	1141	189	243	175	216	112	145	464	482
9	1326	107	2801	4217	1355	1693	3264	341	1107	894	774	1020	345	260	427	282	287	29	114	128	142	58	46	287
10+	553	1376	303	2611	2091	1408	3101	1838	751	735	985	532	880	406	201	201	76	21	4	11	108	97	30	66
Total	115735	135163	125262	133816	121866	94514	95527	70520	90352	94279	94721	94636	80706	68704	50461	35323	26906	24767	27239	30784	29235	34605	39593	31595

SSB at the start of the spawning season - males and females (mt)

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1	912	1104	850	1962	1200	902	3122	773	8515	2226	3479	2475	634	1962	761	639	73	54	88	1006	191	746	127	28
2	1411	7540	6911	5784	16138	6347	4303	11650	5030	25330	8897	13716	6608	4218	9018	3434	2814	1868	1404	3598	5521	1822	4177	2114
3	33839	3730	22412	15924	15649	26065	10500	6878	18776	7101	32836	14539	22020	9014	7415	11466	5170	7871	5264	3858	6596	9575	4447	10333
4	20179	38255	4300	21375	15792	12655	21656	8075	4841	17022	6131	27183	12814	16502	5219	4528	6388	3549	7601	4541	3691	5907	8782	3637
5	8796	16541	30441	3962	17468	9635	7117	14908	5434	3936	12372	4192	18056	8431	8374	2444	1813	2594	2092	4785	2425	2985	4728	6718
6	4892	8127	12487	20324	2961	10514	5653	4251	8583	3704	2763	5933	2950	8685	3351	3286	898	658	1486	1066	2277	1342	2340	3602
7	8094	5563	5914	7240	12174	1464	6221	3163	2355	5363	2023	1326	2841	1539	3492	1299	1012	453	446	672	446	1225	854	1793
8	366	6672	5047	2693	4108	6842	815	2980	1702	1701	2931	811	769	1213	777	1508	307	265	220	273	156	191	528	546
9	1339	111	3841	4111	1557	2059	3957	420	1245	1030	965	1192	408	372	554	411	422	36	136	146	147	59	60	320
10+	657	1674	376	3178	2704	1825	3942	2407	941	907	1296	673	1126	554	279	290	115	27	5	15	135	117	35	79
Total	80484	89318	92581	86551	89751	78309	67286	55506	57423	68318	73693	72041	68226	52488	39239	29305	19012	17375	18744	19961	21585	23970	26078	29170

Percent Mature (females)

Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001
1	7	7	7	7	13	13	13	13	28	28	28	28	12	12	12	12	2	2	2	13	13	13	3	3
2	34	34	34	34	47	47	47	47	67	67	67	67	52	52	52	52	39	39	39	57	57	57	44	44
3	78	78	78	78	84	84	84	84	91	91	91	91	90	90	90	90	95	95	95	92	92	92	95	95
4	96	96	96	96	97	97	97	97	98	98	98	98	99	99	99	99	100	100	100	100	100	100	100	100
5-10+	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table A8. Input parameters and results of stochastic projection analysis using a Beverton-Holt stock recruit model for Georges Bank Atlantic cod for 2002-2019 for $F_{2002} = 0.85 F_{2001}$.

Input for Projections:

Age	Fishing Mortality(PR)	% Mature	<u>Average Weight</u>	
			Stock	Landed
1	0.00	0.03	0.677	0.884
2	0.15	0.44	1.151	1.515
3	0.60	0.95	1.887	2.361
4	1.00	1.00	2.920	3.614
5	1.00	1.00	4.232	4.996
6	1.00	1.00	5.693	6.543
7	1.00	1.00	7.332	8.245
8	1.00	1.00	8.914	9.679
9	1.00	1.00	10.432	11.301
10+	1.00	1.00	15.231	14.642

Projection results for 2002-2004

Year	Recruitment (000 fish)	F	Median Landings (000 mt)	Median SSB (000 mt)
F ₂₀₀₂ = 0.85 F ₂₀₀₁				
2002	7295	0.32	8.083	27.031
2003	6994	0.15	3.787	25.250
2004	7626	0.15	3.979	28.781

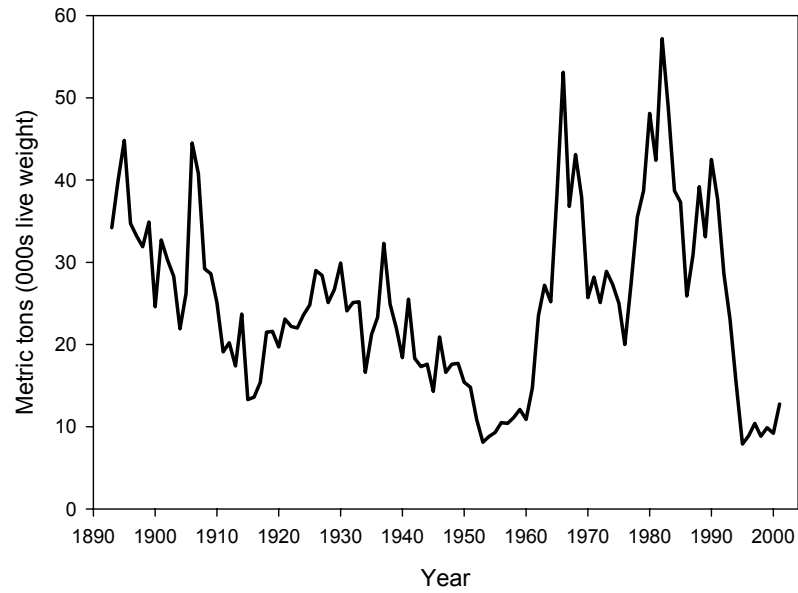


Figure A1a. Total commercial landings of Georges Bank cod (NAFO Division 5Z and Subarea 6), 1893-2001.

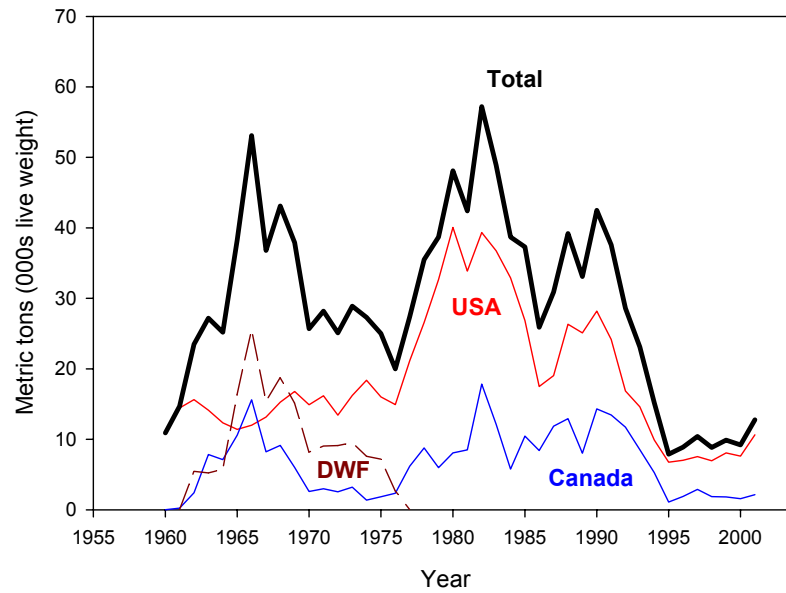


Figure A1b. Total commercial landings of Georges Bank cod (NAFO Division 5Z and Subarea 6), 1960-2001.

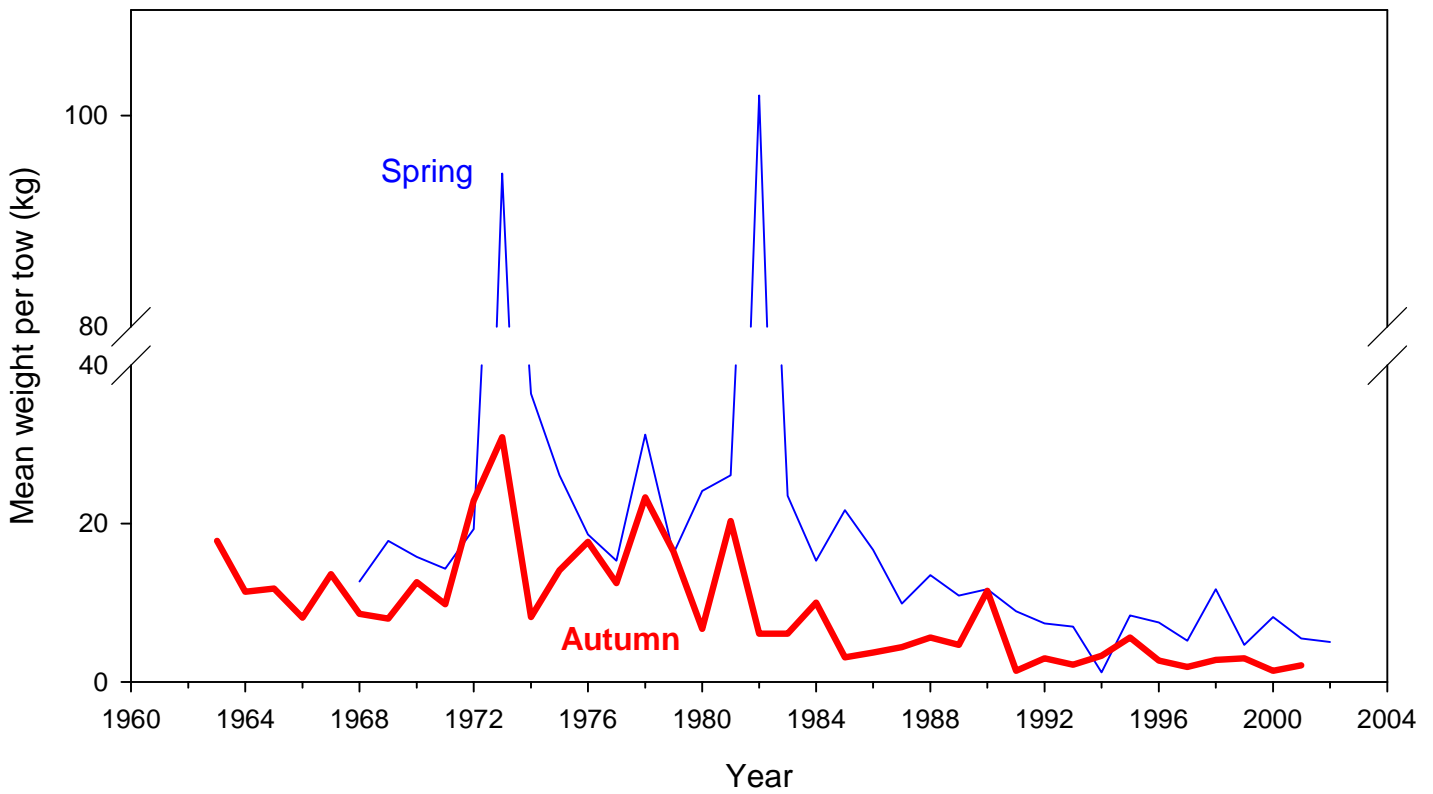


Figure A2. Standardized stratified mean catch per tow (kg) of Atlantic cod in NEFSC spring and autumn research vessel bottom trawl surveys on Georges Bank, 1963-2001.

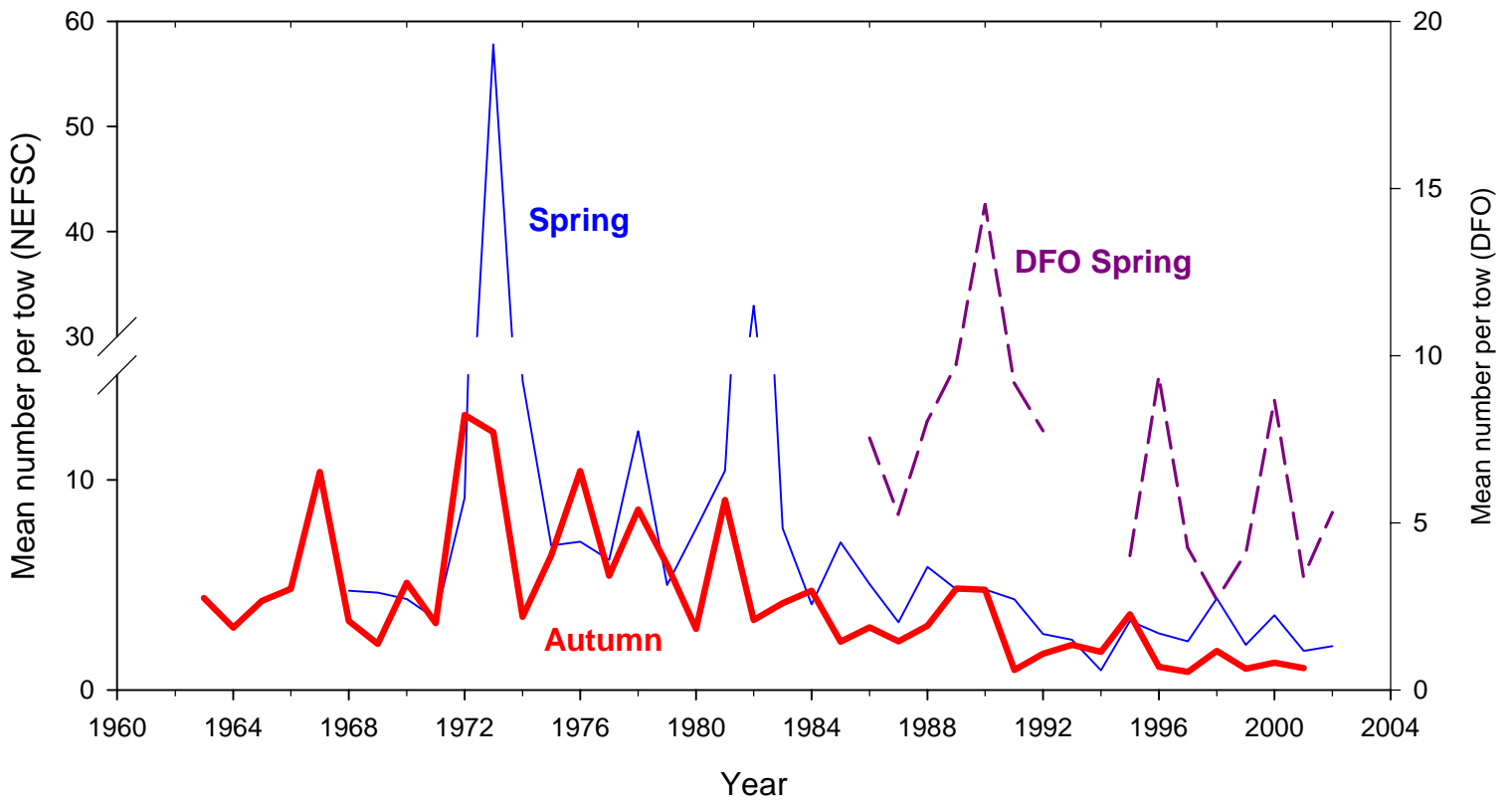


Figure A3. Standardized stratified mean number per tow of Atlantic cod in NEFSC and DFO spring and NEFSC autumn research vessel bottom trawl surveys on Georges Bank, 1963-2002.

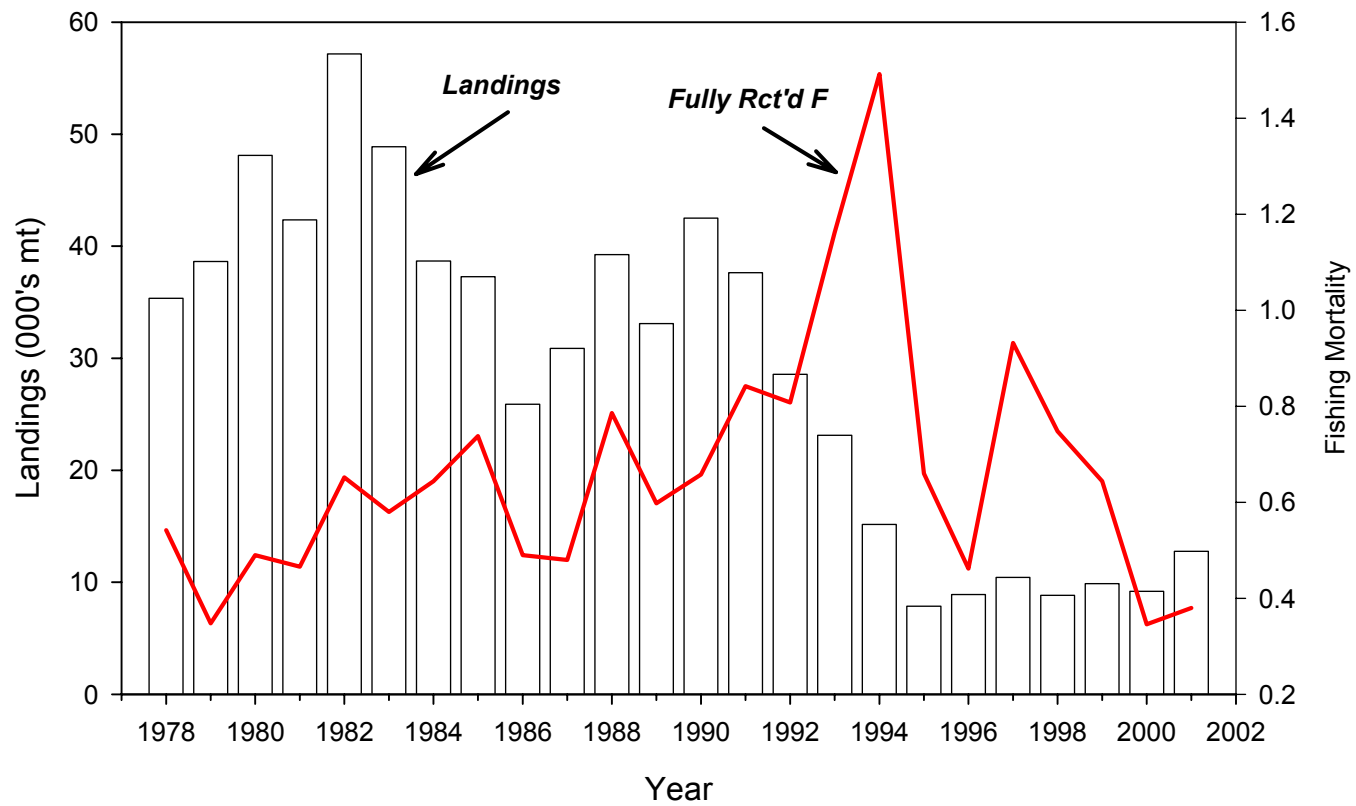


Figure A4. Trends in total commercial landings and fishing mortality for Georges Bank cod, 1978-2001.

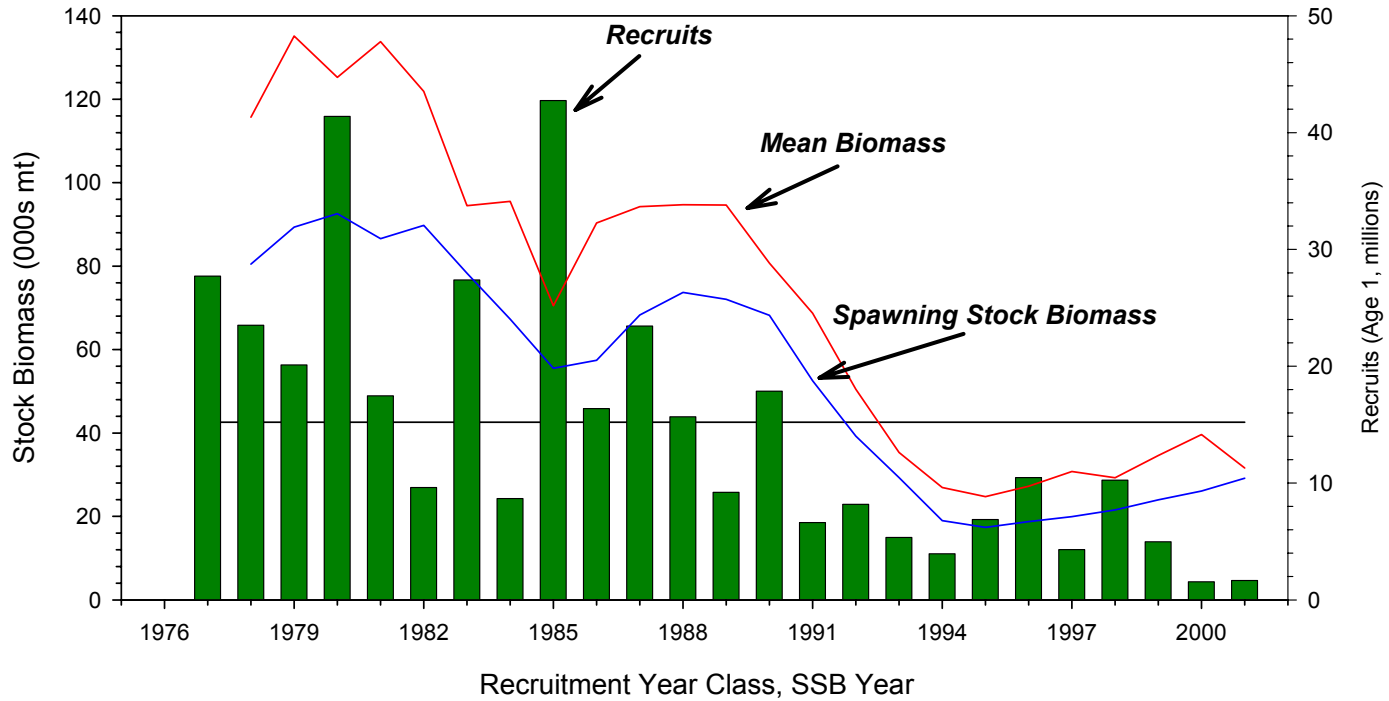


Figure A5. Trends in stock biomass and recruitment for Georges Bank Atlantic cod, 1978-2001. Horizontal line is the average recruitment for the time series.

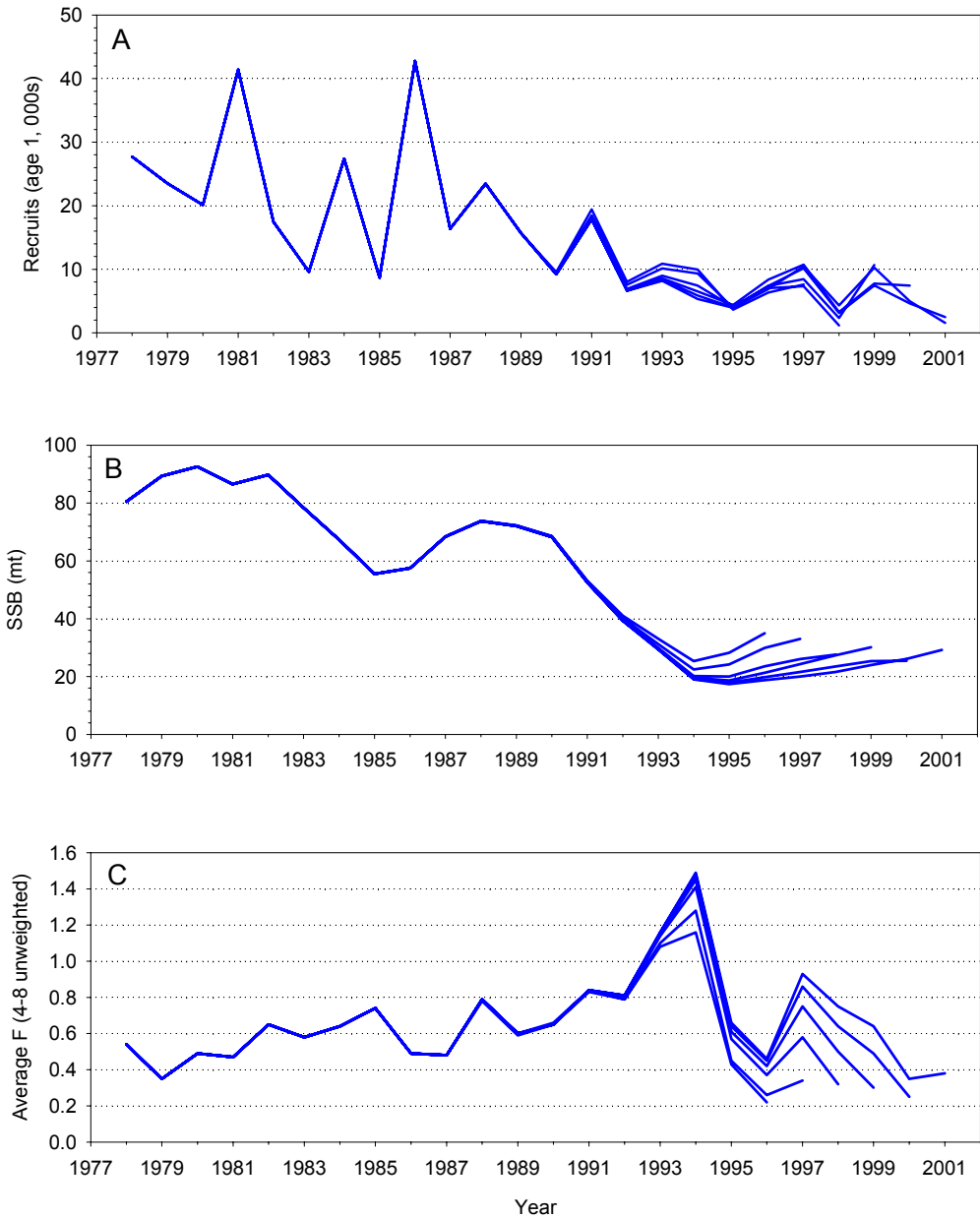


Figure A6. Retrospective analysis of Georges Bank cod recruits at age 1(A), spawning stock biomass (B), and fishing mortality (C) (average F, aged 4-8, unweighted), based on the final ADAPT VPA formulation, 2001-1996.

GB Cod Sensitivity Runs (80% CI)

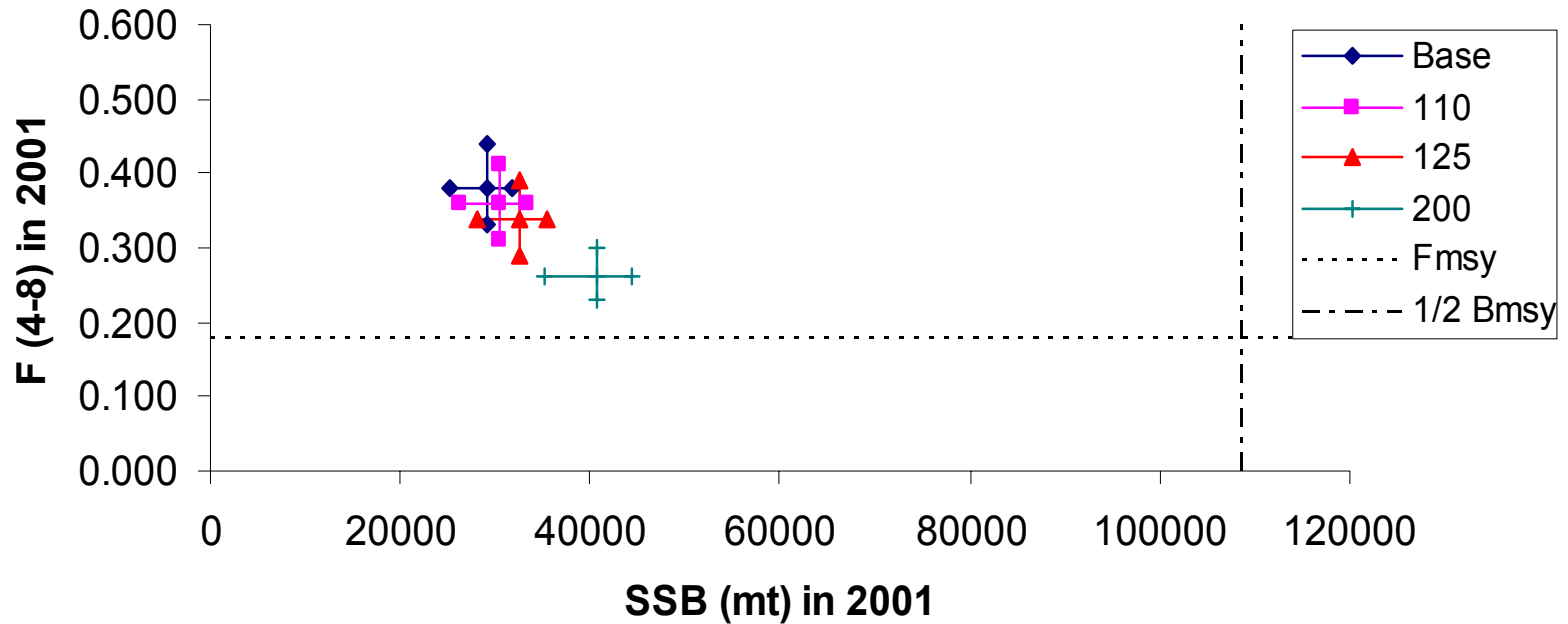


Figure A7. Fishing mortality and spawning stock biomass estimates from VPA calibrated using survey indices increased by 0% (base), 10% (110), 25% (125), and 100% (200).

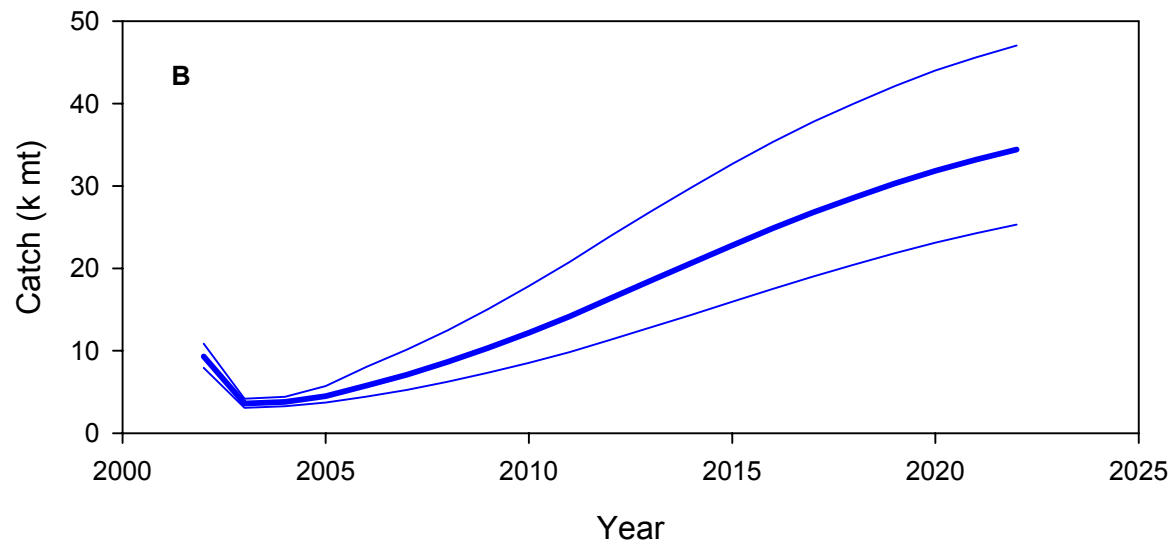
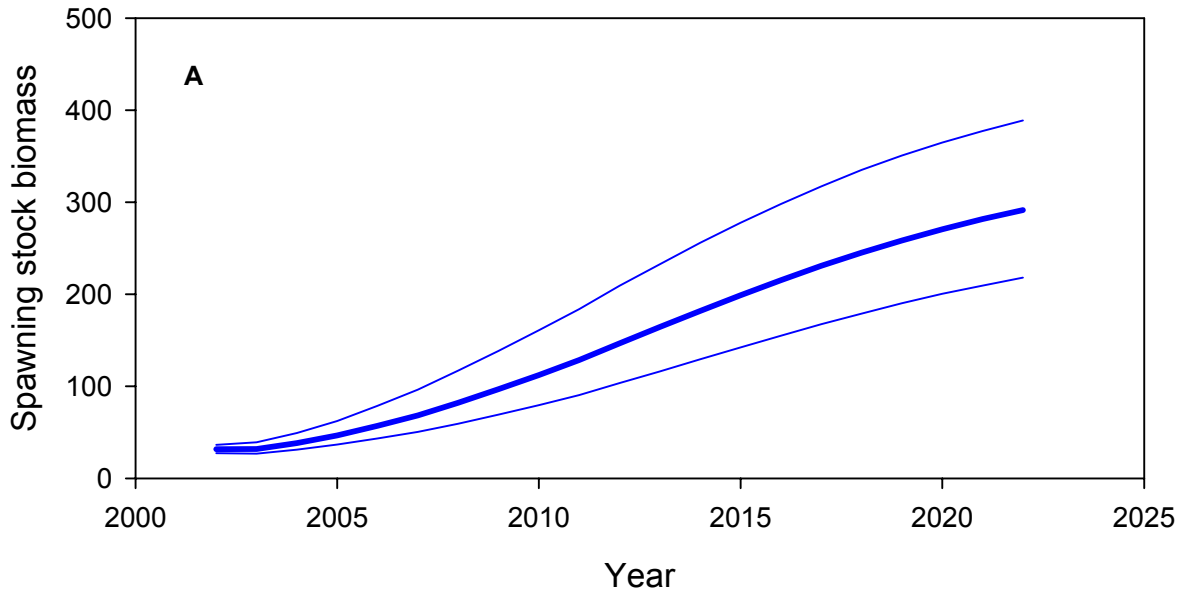


Figure A8. Median and 80% confidence intervals of predicted spawning stock biomass (panel A) and predicted catch (panel B) for Georges Bank Atlantic cod under Frebuild = 0.10.