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Data Update for Eastern Georges Bank Cod in 2019

M. Barrett[1], C.M. Legault[2], F. Irvine[1], I. Andrushchenko[1]

[1]Fisheries and Oceans Canada
125 Marine Science Drive
St. Andrews, New Brunswick E5B 0E4
Canada

[2]NOAA/NMFS Northeast Fisheries Science Center
166 Water Street
Woods Hole, Massachusetts 02543
USA

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Canada

ABSTRACT

The combined 2018 Canada/USA Atlantic cod catches were 565 mt with a quota of 951 mt. Two of the three research survey biomass indices increased from last year, but all three remain below their time series average. Condition factor is at or above the long-term mean for two surveys but remains at low levels for the other survey. Large cod continue to be missing from both fishery and survey catch compared to historical distributions. Relative fishing mortality continues to be low recently while survey total mortality continues to be high recently indicating that something other than reported fishing is driving the increase in total mortality for Eastern Georges Bank cod.

INTRODUCTION

This document provides an update of biological and fishery indicators for eastern Georges Bank Cod Figure 1)) with 2018-2019 data, and is intended to address the following 2019 Transboundary Resource Assessment Committee (TRAC) Terms of Reference (ToR):

- Update the following biological and fishery indicators of the state of cod in the eastern GB management area with 2018-2019 data: condition factor, swept area survey biomass indices, fishery and survey catch at length, relative F, total mortality (Z), and catch.
- Identify and comment on changes in survey and fishery indicators (relative to the 2018 TRAC).

Terms of Reference #3 is addressed separately in TRAC document 2019/XX.

COMMERCIAL FISHERY INDICATORS

Combined Canada/USA catches averaged 17,200 mt between 1978 and 1993, peaked at 26,463 mt in 1982, and then declined to 1,683 mt in 1995. They fluctuated around 3,000 mt until 2004 and subsequently declined again. Combined catches were 565 mt in 2018, and included 9 mt of discards (Table 1; Figure 2). This combined catch was 59% of the 951 mt 2018 quota.

In 2018, the total Canadian catch was 517 mt and amounted to 74% of the 694 mt quota (Table 1; Figure 2). The landings occur primarily during the third and fourth quarter, using longline (41%), otter trawl (33%), handline (<1%) and gillnet (25%) gears (Figure 3 and Figure 4). All 2018 landings were subject to dockside monitoring.

Discarding of cod from the Canadian groundfish fishery on eastern Georges Bank (EGB) is not permitted, but estimates of discards are routinely calculated using the observed ratio of cod to haddock catch (Van Eeckhaute and Gavaris 2004; Hunt et al. 2005; Gavaris et al. 2006, 2007a; Clark et al. 2008). In 2018, discards of cod from the groundfish fishery were estimated as 2 mt (Table 1). Since 2005, the discards of cod from the scallop fishery have been estimated following the method outlined in Gavaris et al. 2007b, and were calculated as 5 mt in 2018 (Table 1; Figure 5).

Total USA catch (landings and discards combined) was 48 mt for the 2018 calendar year (Table 1; Figure 2). The majority of USA landings were taken in the second and third quarters (40% in each), with otter trawl gear accounting for 97% of the 2018 landings and handline accounting for the remaining 3% (Figure 3, Figure 4).

Discard ratios (discard cod:kept of all species, d:k) in the US fisheries are calculated on a trip basis (Wigley et al. 2008), with total discards (mt) estimated by multiplying discard ratios by total commercial landings. In the 2012 SAW55 cod benchmark meeting (NEFSC 2013), 'Delphi' determined mortality rates (otter trawl: 75%) were applied to the final estimates of USA discards (Table 1). The estimated discards of cod in the 2018 groundfish fishery were 2 mt in 2018 (Table 1; Figure 5).

The US eastern Georges Bank cod quota for fishing year 2018 (1 May 2018 to 30 April 2019 for groundfish) was set at 257 mt. Monitoring of the US catches relative to the quota was based on Vessel Monitoring Systems (VMS) and a call-in system for both landings and discards. Reporting on the Regional Office webpage (NOAA Fisheries Northeast Multispecies (Groundfish) Monitoring Reports) indicates the US groundfish fishery caught 41.4% of its 257 mt quota.

SIZE AND AGE COMPOSITION

Details of the methodology used for the determination of size and age composition of USA and Canadian fishery landings and discards on eastern Georges Bank are described in Wang et al. (2015). Past comparisons of age readings have indicated generally good agreement between DFO and NMFS age readers, (http://www.nefsc.noaa.gov/fbp/QA-QC/).

The size and age compositions of the 2018 fishery catches (landings and discards) were derived from the pooled port and at-sea samples from all principal gears and seasons (Table 2). Catches by length for the Canadian fishery peaked at 61 cm (24 in) in 2018, as compared to 58 cm (23 in) in 2017 (Figure 6). Landings for the US fishery peaked at 65 cm (26 in), as compared to 68 cm (28 in) in 2017 (Figure 7).

The 2013 year class at age 5 was the biggest contributor to the combined US and Canada 2018 fishery catch, constituting 37% of the fish by number and 45% by weight (Table 3; Figure 8). The second biggest contributor was the 2014 year class at age 4, with 29% of the numbers and 27% of the weight (Table 3, Figure 8). The prevalence of these year classes in the 2018 catch was expected, based on their persistence in the 2017 fishery catch (Figure 9). The contribution of older fish (ages 7+) to the fishery catch reached a series low in 2014, accounting for <0.2% of the fish caught (Figure 9). In 2018, fish ages 7+ accounted for ~5% of the individuals caught in the fishery (Figure 8, Figure 9).

RESEARCH SURVEYS

Surveys of Georges Bank have been conducted by DFO every February/March since 1986, and by NMFS each spring (April-May) since 1968 and fall (October) since 1963. All surveys use a stratified random design (Figure 10; Figure 11) and historic changes in vessels and nets are documented in Wang et al. (2015).

The spatial distributions of ages 3 and older cod caught during the 2018 NMFS fall, 2019 DFO and NMFS spring surveys were consistent with previous years, with most fish concentrated along the northern part of Georges Bank (Figure 12; Figure 13; Figure 14).

SURVEY CATCH AT AGE AND AT LENGTH

The swept area abundance from the DFO survey decreased from 3.5 million fish in 2018 to 2.5 million in 2019, remaining below the series mean of 5.5 million fish (1986-2019) (Table 4). The 2016 year class (age 3) contributed the most to the catch (40% by number), followed by the 2015 year class at age 4 (23%). A low signal existed at age 9, consistent with the 2010 year class exiting the population, but there were few fish older than 6 in the DFO Spring Survey catch at age; a trend evident in the recent few years (Table 4). Length frequency of the survey catch in the 2019 DFO spring survey peaked at a smaller size of 52 cm (20.5 in) compared to 58 cm in 2018 (23 in), and the recent cruises continue to see fewer large individuals, as compared to the previous ten years (Figure 16).

The NMFS spring survey catch increased from 1.7 million in 2018 to 5.3 million in 2019, but remains below the time series mean (5.6 million fish, 1970-2019) (Table 5). The 2015 year class (age 4) contributed the most to the catch (37%), followed by 2017 (age 2; 22%) and 2016 year classes (age 3; 19%). There were no fish older than age 7 and no evidence of an upcoming large recruitment event (Table 5; Figure 15). Length frequency of the NMFS spring 2019 survey catch peaked at approximately 55 cm (22 inches) in both 2018 and 2019 (Figure 16).

The NMFS fall survey catch increased from 348 thousand fish in 2017 to 1.3 million fish in 2018, remaining below the series mean of 2.2 million (1970-2018) (Table 6). The 2017 year class (age 1) was predominant in the fall survey catch by number (24%), but was closely followed by the 2014 (age 4; 22% by number) and 2015 (age 3; 21% by number) year classes (Table 6; Figure 15). The catch at length from the 2018 NMFS fall survey showed a small peak at 12 cm (5 in), and two more at 34 cm (13 in) and 58 cm (23 in) (Figure 16). Although this is quite different from the 2017 catch, it is consistent with the longer-term mean for the survey (Figure 16).

The coefficient of variation (CV) of stratified mean catch number per tow for the three surveys is shown in Figure 17. The catch from all three surveys became more variable after mid-1990s, which can be caused by patchy distribution of cod at low abundance. Both the DFO and NMFS fall surveys CVs in the most recent year were consistent with trends observed in the previous five years, however, the NMFS spring survey CVs reached particularly high levels (Figure 17).

SWEPT AREA SURVEY BIOMASS

Survey swept area biomass showed a decrease from the previous year for the DFO spring and an increase for the NMFS fall and spring surveys (Table 7; Figure 18). All three surveys are currently below their respective series means (DFO: 1986-2019; NMFS spring: 1970-2019; NMFS fall: 1970-2018) (Table 7; Figure 18).

CONDITION FACTOR

Fulton's condition factor (K) for all three surveys showed a notable downward trend throughout the series until 2009, when condition either stabilized or began to increase in all three surveys (Figure 19). Cod condition is currently at or above the long-term mean for the NMFS fall and spring surveys, but continues to remain at low levels for the DFO survey (Figure 19).

TOTAL MORTALITY (Z) AND RELATIVE F

The total mortality (Z) was calculated by two age groups (ages 4-5 and ages 6-8) using DFO survey and NMFS spring survey abundance indices separately, and fitted with a loess smooth to help track trends (Figure 20). Total mortality on ages 4 and 5 has been lower than the older group since the 1990s in both surveys, but has begun to converge for the NMFS spring survey in recent years; DFO spring survey continues to show a higher Z on the older ages (Figure 20). Total mortality on ages 4-5 remains around 1, as it has been in the past few years (Figure 20). The total mortality is based on ages 6-8, however, the absence of age 7 and 8 fish in both 2019 spring surveys makes the calculated total mortality reliant on just age 6 fish, thus the 2018 value is unrepresentative of Z on fish ages 6-8.

Total survey Z was also calculated using the Sinclair (2001) approach for all three surveys as was suggested for Georges Bank Yellowtail Flounder at the 2016 TRAC (Sinclair 2001; Brooks and Curran 2016). Age groups used in the calculation varied by survey (DFO: ages 6-9; NMFS spring: ages 5-9; NMFS fall: ages 3-6). In general, Z values on older age groups from the DFO and NMFS spring surveys have remained high, except for the most recent NMFS spring values (Figure 21). Total mortality on the younger ages from the NMFS fall survey remains at low values (Figure 21). The increasing occurrence of year and age combinations with no cod observed in the surveys, particularly for the older ages, is problematic for these simple calculations of survey Z.

In general, total mortality on older age groups has remained high throughout the assessment time period, while relative F (fishery catch at age per survey abundance indices, (Figure 22) has declined significantly since the 1990s. The divergent trend between total and relative fishing mortality is indicating that something other than reported fishing is driving the increase in total mortality for eastern Georges Bank cod.

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TABLES

Table 1. Catches (mt) of cod from eastern Georges Bank, 1978 to 2018

Year	Canada				USA			Total
Year	Landings	Discards Scallop	Discards Groundfish	Total	Landings	Discards	Total	
1978	8,777	98	-	8,875	5,502	-	5,502	14,377
1979	5,979	103	-	6,082	6,408	-	6,408	12,490
1980	8,066	83	-	8,149	6,418	-	6,418	14,567
1981	8,508	98	-	8,606	8,092	-	8,092	16,698
1982	17,827	71	-	17,898	8,565	-	8,565	26,463
1983	12,131	65	-	12,196	8,572	-	8,572	20,769
1984	5,761	68	-	5,829	10,558	-	10,558	16,387
1985	10,442	103	-	10,545	6,641	-	6,641	17,186
1986	8,504	51	-	8,555	5,696	-	5,696	14,251
1987	11,844	76	-	11,920	4,793	-	4,793	16,713
1988	12,741	83	-	12,824	7,645	-	7,645	20,470
1989	7,895	76	-	7,971	6,182	84	6,267	14,238
1990	14,364	70	-	14,434	6,414	69	6,483	20,917
1991	13,467	65	-	13,532	6,353	112	6,464	19,997
1992	11,667	71	-	11,738	5,080	177	5,257	16,995
1993	8,526	63	-	8,589	4,019	57	4,077	12,665
1994	5,277	63	-	5,340	998	5	1,003	6,343
1995	1,102	38	-	1,140	543	0.2	544	1,683
1996	1,924	56	0.0	1,980	676	1	677	2,657
1997	2,919	58	428	3,405	549	6	555	3,960
1998	1,907	92	273	2,272	679	7	686	2,959
1999	1,818	85	253	2,156	1,195	9	1,204	3,360
2000	1,572	69	0.0	1,641	772	16	788	2,429
2001	2,143	143	0.0	2,286	1,488	146	1,634	3,920
2002	1,278	94	0.0	1,372	1,688	9	1,697	3,069
2003	1,317	200	-	1,528	1,851	85	1,935	3,463
2004	1,112	145	-	1,257	1,006	57	1,063	2,321
2005	630	84	144	859	171	199	370	1,228
2006	1,096	112	237	1,445	131	94	226	1,671
2007	1,108	114	0.0[1]	1,222	234	279	513	1,735
2008	1,390	36	103	1,529	224	20	244	1,774
2009	1,003	69	137	1,209	433	147	580	1,789
2010	748	44	48	840	357	97	454	1,294
2011	702	29	13	743	267	20	287	1,030
2012	395	42	31	468	96	52	148	616
2013	385	18	21	424	24	16	40	464
2014	430	15	13	458	114	2	116	574
2015	472	13	7	492	111	5	116	608
2016	428	9	3	440	92	5	97	537
2017	474	7	7	488	34	4	38	526
2018	510	5	2	517	47	2	48	565
Min	385	7	0	424	24	<1	38	464
Max	17,827	200	428	17,898	10,558	279	10,558	26,463
Ave	4,845	70	82	4,957	2,944	60	2,988	7,945

[1] Discards for the Mobile Fleet were calculated to be 0. Discards for the Fixed Gear fleet were not calculated due to low observer coverage.

Table 2. Length and age samples from the USA and Canadian fisheries on eastern Georges Bank. For Canadian fisheries, at-sea observer samples are included since 1990. The first quarter age samples are supplemented with USA fishery age samples from 5Zjm for 1978-1986 and DFO survey age samples for 1987-2018; the numbers are shown in brackets. The highlighted numbers include samples from western Georges Bank.

Year	USA		Canada	
	Lengths	Ages	Lengths	Ages
1978	2,294	384	7,684	1,364
1979	2,384	402	3,103	796(205)
1980	2,080	286	2,784	728(192)
1981	1,498	455	4,147	897
1982	4,466	778	4,705	1,126(268)
1983	3,906	903	3,822	754(150)
1984	3,891	1,130	1,889	1,243(858)
1985	2,076	597	7,031	1,309(351)
1986	2,145	643	5,890	991(103)
1987	1,865	524	9,133	1,429(193)
1988	3,229	797	11,350	2,437(510)
1989	1,572	347	8,726	1,561
1990	2,395	552	31,974	2,825(1,153)
1991	1,969	442	27,869	1,782
1992	2,048	489	29,082	2,215(359)
1993	2,215	569	31,588	2,146
1994	898	180	27,972	1,268
1995	2645	14	6,660	548
1996	4,895	1,163	26,069	828
1997	1,761	82	31,617	1,216
1998	1,301	338	26,180	1,643
1999	726	228	26,232	1,290(410)
2000	500	121	20,582	1,374
2001	1,434	397	19,055	1,505
2002	1,424	429	16,119	1,252
2003	1,367	416	19,757	1,070
2004	1,547	517	18,392	1,357
2005	297	65	23,937	1,483(697)
2006	446	151	44,708	1,460(648)
2007	589	183	141,607	1,647(456)
2008	972	295	64,387	1,709(495)
2009	1,286	326	48,335	1,725(246)
2010	1,446	333	30,594	1,455(433)
2011	1,203	213	40,936	1,655(536)
2012	598	746[1]	49,447	1,115(216)
2013	2,951	842	75,275	1,334(319)
2014	547	85	50,501	1,141(184)
2015	4,677	1,049[2]	74,028	970 (202)
2016	715	149	76,869	990 (282)
2017	4,120	1,150[2]	50,902	1,039 (334)[3]
2018	1,695	412	54,609	1,254(309)[3]

[1] Age and length data supplemented with ages from statistical areas 522 and 525.
[2] Age and length data supplemented with ages from statistical area 522.
[3] Survey ALK used to supplement quarter 1 age and length data for scallop discards only.

Table 3. Annual catch at age numbers (thousands) for eastern Georges Bank cod for 1978-2018. Dash indicates no fish.

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1978	1	8	108	3,644	1,167	394	163	127	22	23	6	2	1	0.1	0.3	0.4	0.2	5,668
1979	1	15	890	735	1,520	543	182	74	61	11	3	2	1	0.01	1	-	-	4,037
1980	2	6	973	1,650	301	968	354	97	26	46	16	4	1	-	-	-	-	4,445
1981	3	35	860	1,865	1,337	279	475	181	96	59	21	2	1	-	-	-	-	5,216
1982	0.01	15	3,516	1,971	1,269	1,087	196	399	155	49	14	22	6	3	4	1	-	8,707
1983	10	22	783	2,510	1,297	562	398	118	182	102	25	28	12	1	3	1	0.07	6,055
1984	0.1	17	231	805	1,354	546	377	279	39	90	38	17	7	2	3	-	1	3,806
1985	33	9	2,861	1,409	661	987	271	110	110	21	27	3	4	1	1	0.1	-	6,508
1986	1	41	451	2,266	588	343	456	68	48	29	4	8	1	-	-	-	-	4,303
1987	2	22	4,116	846	1,148	163	132	174	41	24	8	3	1	0.06	-	-	-	6,680
1988	1	23	289	4,189	680	855	130	116	182	52	21	13	4	1	0.05	0.1	-	6,556
1989	1	18	680	811	1,983	228	373	56	40	59	15	7	5	0.1	0.4	-	-	4,278
1990	1.1	16	726	3,109	1,038	1,374	145	153	12	12	24	3	2	1	-	0	0.002	6,617
1991	0.4	63	991	1,008	1,927	904	746	105	69	21	11	8	4	2	0.4	1	-	5,862
1992	-	68	2,581	1,379	460	889	314	315	45	34	3	5	2	1	-	-	-	6,096
1993	-	10	501	1894	909	299	359	133	97	25	17	3	0.08	0.2	-	-	-	4,246
1994	1	6	182	483	788	270	45	61	30	21	2	1	-	0.1	0.01	0.009	-	1,889
1995	3	1	57	237	94	105	18	7	4	4	0.1	0.08	0.009	-	-	-	-	531
1996	0.1	5	40	234	398	79	60	13	4	3	0.3	0.1	-	-	0.003	-	-	837
1997	1	9	148	205	358	358	84	37	13	4	1	1	0.05	-	-	-	-	1,219
1998	0.1	5	101	314	161	158	134	23	13	4	1	0.3	0.6	0.04	-	-	-	916
1999	0.1	9	79	483	337	109	61	57	14	2	1	0.08	-	0.01	-	-	-	1,152
2000	1	3	62	110	380	151	37	22	12	3	0.2	0.3	0.005	-	0.08	-	-	783
2001	1	3	107	511	211	398	105	32	17	7	1	0.3	0.07	-	-	-	-	1,394
2002	1	1	10	125	447	108	156	30	9	6	2	1	0.4	-	0.04	-	-	896
2003	13	-	35	148	243	405	81	89	19	4	1	0.3	-	-	-	-	-	1,039
2004	-	23	12	140	151	147	139	35	30	7	1	1	0.2	-	0.009	0.002	0.02	686
2005	-	4	71	45	201	50	34	35	10	5	1	0.02	0.1	0.1	0.004	0.002	-	457
2006	-	3	19	226	78	195	48	18	18	2	2	0.3	0.1	-	-	-	-	608
2007	0.005	2	53	62	421	34	85	11	7	7	0.4	0.1	-	-	-	-	-	682
2008	-	1	45	141	61	249	15	33	4	2	1	0.1	-	0.012	-	-	-	552
2009	1	7	43	200	139	46	137	9	10	1	1	0.05	-	-	-	-	-	594
2010	0.02	3	44	96	211	74	15	35	3	2	0.3	0.04	0.003	-	-	-	-	481
2011	-	9	43	76	93	115	26	12	7	0.2	0.2	0.006	-	-	-	-	-	382
2012	-	2	70	105	49	29	25	6	1	1	0.02	-	-	-	-	-	-	289
2013	0.5	1	27	112	52	11	7	2	0.4	0.03	0.08	-	-	-	-	-	-	212
2014	-	4	17	82	103	28	4	0.3	0.1	-	-	-	-	-	-	-	-	238
2015	-	1	67	38	71	47	6	1	0.03	0.03	0.3	0.002	-	-	-	-	-	231
2016	-	4	15	99	37	32	21	3	0.2	0.001	-	-	-	-	-	-	-	210
2017	0.04	0.5	12	43	92	10	15	5	1	0.005	-	-	-	-	-	-	-	177
2018	-	5	14	27	52	67	5	5	3	0.07	-	0.004	-	-	-	-	-	179

Table 4. Indices of swept area abundance (thousands) for eastern Georges Bank cod from the DFO survey, 1986-2019.

Year/ Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1986	0	770	3538	3204	331	692	445	219	35	66	0	10	0	0	0	0	0	9311
1987	0	48	1791	642	753	162	89	181	89	13	13	0	13	16	0	0	0	3812
1988	0	148	450	5337	565	838	95	79	179	18	12	4	0	16	0	0	0	7741
1989	0	350	2169	764	1706	258	332	42	85	112	5	32	8	5	0	0	0	5868
1990	20	106	795	3471	1953	4402	535	1094	144	157	289	65	52	37	0	0	5	13125
1991	0	1198	1019	1408	1639	882	1195	148	249	38	45	30	12	5	8	0	0	7876
1992	0	48	2049	1221	409	643	451	300	93	38	0	3	3	18	0	0	0	5276
1993	0	31	355	1723	622	370	754	274	268	51	31	0	20	6	0	0	0	4504
1994	0	13	629	691	1289	477	182	363	84	119	12	0	0	0	8	5	0	3871
1995	0	32	187	1240	757	520	186	44	67	28	18	8	6	0	0	0	0	3093
1996	0	90	203	1744	4337	1432	1034	445	107	149	39	4	0	0	5	0	0	9590
1997	0	30	376	568	1325	1262	216	50	35	23	17	0	3	0	0	0	0	3905
1998	0	6	582	831	322	317	238	56	29	7	8	3	4	0	0	0	0	2402
1999	0	3	156	1298	1090	449	317	190	10	28	5	9	0	3	0	0	0	3561
2000	0	0	423	1294	4967	2157	1031	510	317	20	23	12	0	0	0	0	0	10754
2001	0	3	37	802	519	1391	645	334	224	225	36	24	7	0	0	0	0	4248
2002	0	0	118	477	2097	694	1283	458	188	63	76	7	0	0	0	0	0	5462
2003	0	0	8	200	510	867	194	219	69	12	0	0	0	0	0	0	0	2078
2004	0	427	40	246	381	422	353	59	108	25	5	0	3	0	0	0	0	2069
2005	0	25	1025	1398	7149	1766	816	743	60	87	8	4	0	0	0	0	0	13082
2006	0	0	41	1500	673	1779	757	217	216	83	34	10	15	0	0	0	0	5325
2007	0	18	130	549	2606	379	653	119	81	53	0	4	0	0	0	0	0	4591
2008	0	12	147	1027	755	2978	194	392	41	4	20	0	0	0	0	0	0	5569
2009	0	11	51	2487	2261	519	2955	0	82	0	0	0	18	0	0	0	0	8384
2010	0	5	92	956	4105	1781	703	1828	65	84	5	0	0	0	0	0	0	9623
2011	0	193	271	766	952	1324	256	67	112	14	8	2	0	0	0	0	0	3965
2012	0	9	149	327	315	195	158	7	18	4	0	0	0	0	0	0	0	1182
2013	0	0	431	3754	2173	285	81	52	10	0	0	0	0	0	0	0	0	6786
2014	0	76	9	360	538	169	35	0	27	0	0	0	0	0	0	0	0	1213
2015	0	0	476	152	598	439	97	7	0	0	0	0	0	0	0	0	0	1770
2016	0	8	197	1004	199	273	147	16	4	0	0	0	0	0	0	0	0	1845
2017	0	5	52	1660	5897	194	270	188	0	0	0	0	0	0	0	0	0	8266
2018	0	39	149	520	1060	1610	77	50	7	0	0	0	0	0	0	0	0	3512
2019	0	9	269	1005	574	389	284	0	0	6	6	0	0	0	0	0	0	2542

Table 5. Indices of swept area abundance (thousands) for eastern Georges Bank cod from the NMFS spring survey, 1970-2019. Conversion factors to account for vessel and trawl door changes have been applied. During 1973-1981 a Yankee 41 net was used rather than the standard Yankee 36 net.

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1970	0	354	1115	302	610	73	263	48	0	71	24	0	48	0	0	0	0	2907
1971	0	185	716	503	119	326	124	257	227	40	40	79	0	0	0	0	0	2615
1972	56	1578	1856	2480	393	114	136	60	88	73	18	14	0	0	14	0	0	6879
1973	0	665	37880	5474	6109	567	467	413	0	163	231	0	0	0	95	0	0	52064
1974	0	461	5877	4030	759	2001	360	91	267	45	48	54	0	0	0	0	0	13991
1975	0	0	467	3061	4348	446	960	79	0	122	0	0	0	0	0	0	0	9483
1976	84	1733	1111	620	444	759	0	167	35	0	0	0	0	48	0	0	0	5001
1977	0	0	2358	736	354	307	334	22	35	0	0	0	0	0	0	0	0	4145
1978	373	187	0	2825	615	916	153	787	62	43	40	0	0	0	0	0	0	6001
1979	71	339	1332	122	1430	543	176	91	130	0	0	0	0	0	0	0	0	4234
1980	0	11	2251	2168	169	1984	410	78	48	31	0	47	0	0	0	0	0	7197
1981	283	1956	1311	2006	1093	43	453	197	59	0	0	0	0	0	0	0	0	7399
1982	44	455	6642	13614	12667	9406	0	3088	992	120	0	0	0	0	0	0	0	47027
1983	0	389	2017	3781	779	608	315	106	98	0	70	0	0	0	0	0	35	8197
1984	0	103	117	344	483	92	182	74	18	105	0	0	0	0	0	0	0	1518
1985	58	36	2032	633	1061	1518	328	217	213	83	116	34	23	0	0	0	0	6352
1986	97	619	339	1132	298	427	536	20	109	142	0	0	0	0	0	0	0	3719
1987	0	0	1194	247	568	0	152	148	30	54	0	0	0	0	0	0	0	2394
1988	138	320	243	2795	274	461	51	5	67	0	0	10	0	0	0	0	0	4364
1989	0	174	1238	338	1685	234	396	99	12	36	48	24	0	0	0	0	0	4284
1990	24	45	360	1687	586	634	152	164	19	0	0	24	0	0	0	0	0	3696
1991	217	725	620	514	903	460	382	44	17	0	24	53	0	0	0	0	0	3957
1992	0	81	666	349	103	261	152	159	27	52	0	0	0	0	0	0	0	1850
1993	0	0	462	1284	262	46	182	46	43	46	12	0	0	0	0	0	0	2382
1994	38	54	194	152	185	44	11	33	0	8	0	0	0	0	0	0	0	720
1995	384	70	294	927	495	932	191	253	0	68	0	0	0	0	0	0	0	3614
1996	0	139	300	990	1343	121	94	28	0	0	0	0	0	0	0	0	0	3016
1997	271	54	218	48	402	519	53	126	57	0	0	0	0	0	0	0	0	1747
1998	54	0	1040	1985	995	983	609	30	31	0	0	0	0	0	0	0	0	5729
1999	22	22	145	673	624	370	172	107	34	8	0	0	0	0	0	0	0	2176
2000	36	0	304	643	1348	492	138	52	20	0	0	0	0	0	0	0	0	3032
2001	0	0	64	889	96	350	109	0	12	10	0	0	0	0	0	0	0	1530
2002	36	0	121	470	1081	175	214	61	0	0	0	0	0	0	0	0	0	2158
2003	0	0	125	287	812	1154	135	78	9	0	0	0	0	0	0	0	0	2599
2004	0	549	10	838	2091	2105	1351	239	382	29	0	0	0	0	0	0	0	7595
2005	36	15	345	70	747	287	190	131	34	0	0	0	0	0	0	0	0	1855
2006	0	37	73	952	411	1007	340	151	79	0	0	0	0	0	0	0	0	3050
2007	0	0	369	308	2258	239	291	47	28	0	0	0	0	0	0	0	0	3540
2008	43	37	112	675	372	1385	51	66	0	0	0	0	0	0	0	0	0	2741
2009	0	61	86	875	408	219	377	24	12	15	0	0	0	0	0	0	0	2078
2010	0	25	126	367	667	168	44	147	0	12	0	0	0	0	0	0	0	1556
2011	0	88	164	164	266	144	56	9	24	0	0	0	0	0	0	0	0	914
2012	3	3	450	749	834	209	127	13	0	0	0	0	0	0	0	0	0	2389
2013	0	0	653	3864	1202	129	64	15	0	0	0	0	0	0	0	0	0	5926
2014	0	55	64	568	922	109	27	0	0	0	0	0	0	0	0	0	0	1746
2015	0	9	165	71	222	331	23	0	0	0	0	0	0	0	0	0	0	820
2016	4	4	179	1,454	173	168	82	10	0	0	0	0	0	0	0	0	0	2074
2017	0	43	54	469	2681	808	502	165	0	0	0	0	0	0	0	0	0	4274
2018	0	99	149	607	550	346	0	0	0	18	0	0	0	0	0	0	0	1770
2019	9	110	1157	1042	1982	834	213	8	0	0	0	0	0	0	0	0	0	5355

Table 6. Indices of swept area abundance (thousands) for eastern Georges Bank cod from the NMFS fall survey, 1970-2018. Conversion factors to account for vessel and trawl door changes have been applied.

Year/Age	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16+	Total
1970	348	1416	836	208	412	11	0	0	5	25	0	0	0	0	0	0	0	3261
1971	203	1148	900	181	232	130	142	14	0	0	0	0	0	0	0	0	0	2951
1972	1110	3299	614	667	24	40	0	0	0	0	0	0	0	0	0	0	0	5753
1973	46	2435	2947	997	979	93	0	25	63	0	0	0	0	0	0	0	0	7584
1974	77	196	399	622	54	31	15	0	0	0	0	0	0	0	0	0	0	1394
1975	414	660	177	414	764	27	46	0	0	0	0	0	0	0	0	0	0	2501
1976	0	8260	362	144	0	91	0	48	0	0	0	0	0	0	0	0	0	8904
1977	51	0	3475	714	184	156	178	3	0	0	0	0	0	0	0	0	0	4760
1978	113	1519	58	3027	417	58	63	77	0	0	0	0	0	0	0	0	0	5330
1979	182	1704	1695	116	1522	243	48	20	11	18	0	0	0	0	0	0	0	5557
1980	315	782	409	649	22	184	14	17	20	0	0	0	0	0	0	0	0	2412
1981	360	2352	1208	933	269	15	29	0	0	0	53	0	0	0	0	0	0	5220
1982	0	549	718	54	59	0	0	27	0	0	0	0	0	0	0	0	0	1406
1983	948	73	267	567	24	8	8	0	23	0	0	0	0	0	0	0	0	1917
1984	29	1805	120	690	1025	23	32	0	0	9	0	0	0	0	0	0	0	3734
1985	1245	209	993	161	18	5	9	0	0	0	4	0	0	0	0	0	0	2645
1986	119	3018	56	198	0	0	6	0	0	0	0	0	0	0	0	0	0	3396
1987	156	129	845	121	100	0	0	0	0	0	0	0	7	0	0	0	0	1357
1988	95	561	177	1182	163	206	0	30	41	10	0	0	0	0	0	0	0	2464
1989	318	570	1335	222	607	78	24	0	0	0	0	0	0	0	0	0	0	3154
1990	198	403	442	831	120	204	20	0	15	0	0	0	0	0	0	0	0	2232
1991	0	158	60	71	10	24	0	0	0	0	0	0	0	0	0	0	0	322
1992	0	205	726	154	0	37	12	0	0	0	0	0	0	0	0	0	0	1134
1993	0	81	104	158	19	0	0	0	0	0	0	0	0	0	0	0	0	362
1994	10	78	282	220	143	13	26	0	0	0	0	0	0	0	0	0	0	771
1995	223	28	122	304	66	29	7	0	0	0	0	0	0	0	0	0	0	779
1996	10	291	76	293	211	53	28	0	0	0	0	0	0	0	0	0	0	961
1997	0	161	394	181	58	84	29	0	0	0	0	0	0	0	0	0	0	907
1998	0	171	684	480	65	109	0	0	29	0	0	0	0	0	0	0	0	1538
1999	0	15	14	249	124	32	0	0	0	0	0	0	0	0	0	0	0	434
2000	30	55	204	68	89	46	0	0	0	0	0	0	0	0	0	0	0	493
2001	25	74	106	257	38	75	12	12	0	0	0	0	0	0	0	0	0	598
2002	122	110	635	712	2499	170	211	17	0	0	0	0	0	0	0	0	0	4476
2003	76	0	24	100	70	17	0	6	0	0	0	0	0	0	0	0	0	293
2004	108	422	68	840	385	545	436	103	30	0	30	0	0	0	0	0	0	2969
2005	21	29	508	114	251	43	0	10	0	0	0	0	0	0	0	0	0	976
2006	0	146	123	530	37	263	16	16	16	16	0	0	0	0	0	0	0	1162
2007	60	22	136	7	69	0	7	0	0	0	0	0	0	0	0	0	0	302
2008	0	74	170	55	15	98	15	15	0	0	0	0	0	0	0	0	0	442
2009	54	37	194	280	39	18	11	0	0	0	0	0	0	0	0	0	0	633
2010	434	27	79	74	121	20	0	0	0	0	0	0	0	0	0	0	0	755
2011	58	323	362	248	177	110	32	0	0	0	0	0	0	0	0	0	0	1309
2012	0	14	188	90	13	20	0	0	0	0	0	0	0	0	0	0	0	324
2013	162	51	565	554	226	0	0	0	0	0	0	0	0	0	0	0	0	1559
2014	98	144	47	145	223	28	14	0	0	0	0	0	0	0	0	0	0	697
2015	42	223	1208	94	162	131	0	0	0	0	0	0	0	0	0	0	0	1859
2016	2	9	219	2123	50	143	51	0	0	0	0	0	0	0	0	0	0	2597
2017	43	73	76	66	91	0	0	0	0	0	0	0	0	0	0	0	0	348
2018	24	322	212	275	294	191	0	0	0	0	0	0	0	0	0	0	0	1319

Table 7. Swept area biomass (mt) for eastern Georges Bank cod from the DFO, NMFS spring and fall surveys. Conversion factors to account for vessel and trawl door changes have been applied. The biomass conversion factor used for the Henry B. Bigelow since 2009 is 1.58 (Bsurvey=Bbigelow/1.58).

Year	NMFS Fall	NMFS spring	DFO
1970	5,054	7,801	-
1971	5,287	10,435	-
1972	3,947	13,779	-
1973	11,697	82,311	-
1974	2,741	27,269	-
1975	5,246	23,503	-
1976	5,082	10,354	-
1977	9,509	9,335	-
1978	12,213	22,731	-
1979	13,050	12,831	-
1980	4,494	20,520	-
1981	7,256	18,568	-
1982	2,216	172,300	-
1983	2,449	20,376	-
1984	7,018	4,808	-
1985	2,390	23,190	-
1986	2,174	12,532	18,633
1987	2,634	7,615	8,824
1988	6,764	9,294	19,452
1989	5,145	12,104	14,547
1990	5,121	10,828	56,665
1991	435	9,391	25,068
1992	1,734	6,113	14,581
1993	606	6,598	16,545
1994	1,734	1,294	13,140
1995	1,220	10,113	8,118
1996	1,790	6,613	32,173
1997	1,875	4,051	11,004
1998	2,970	12,267	5,006
1999	1,044	5,308	9,178
2000	895	7,374	32,298
2001	1,159	3,721	18,037
2002	11,525	4,432	20,333
2003	608	6,405	6,218
2004	8,347	21,080	5,661
2005	1,446	4,407	26,200
2006	2,165	7,331	12,546
2007	424	6,066	11,228
2008	792	5,327	13,657
2009	1,203	4,343	23,180
2010	732	3,587	26,352
2011	2,304	1,724	8,437
2012	609	4,864	2,449
2013	2,566	9,616	11,113
2014	1,376	3,254	2,409
2015	3,570	1,748	3,594
2016	5,438	3,579	3,656
2017	653	13,479	14,566
2018	2,549	3,097	7,198
2019	-	9,228	4,059

FIGURES

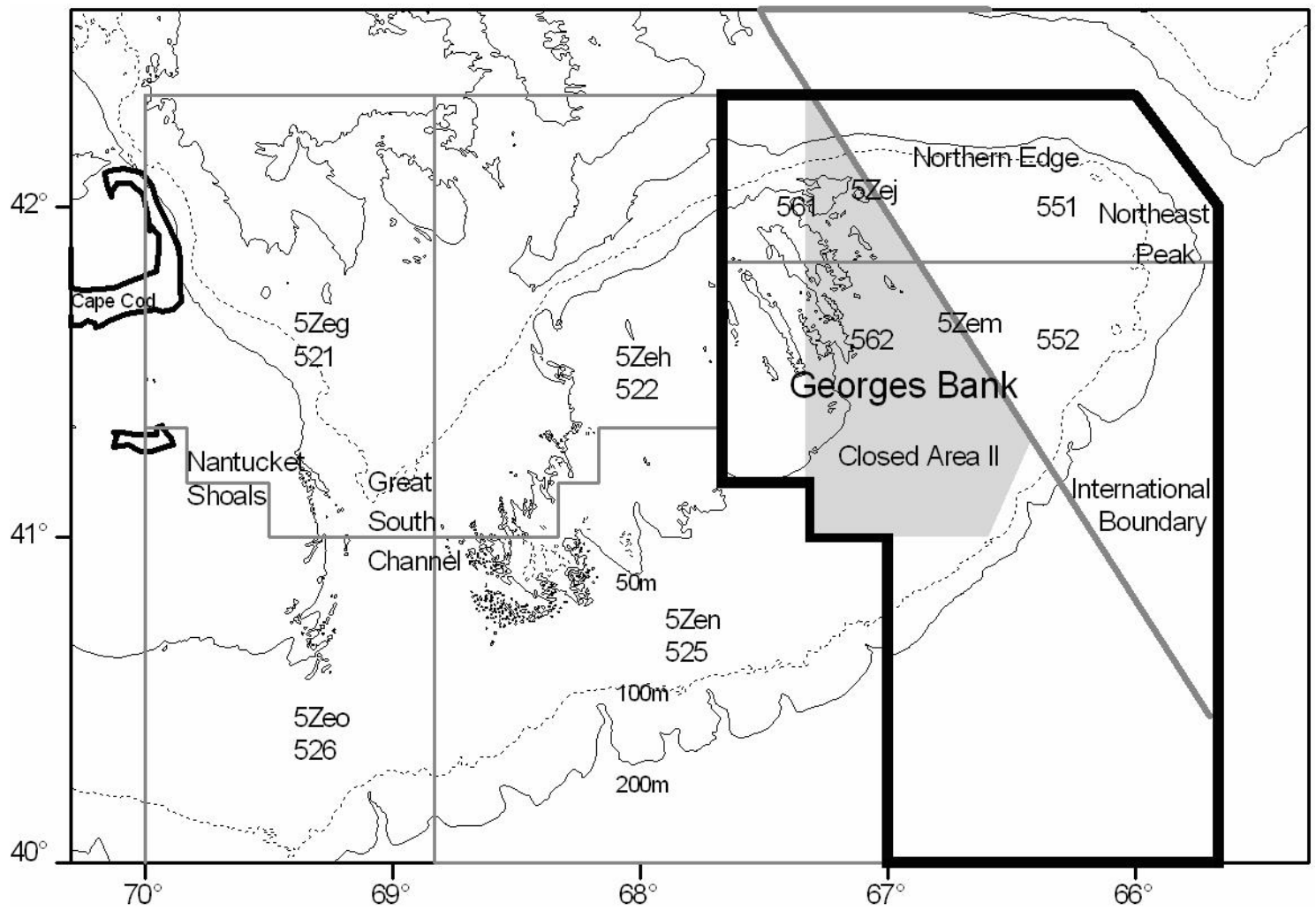


Figure 1. Fisheries statistical areas (Canada and USA) in NAFO Subdivision 5Ze. The eastern Georges Bank Atlantic Cod management unit is outlined by a heavy black line.

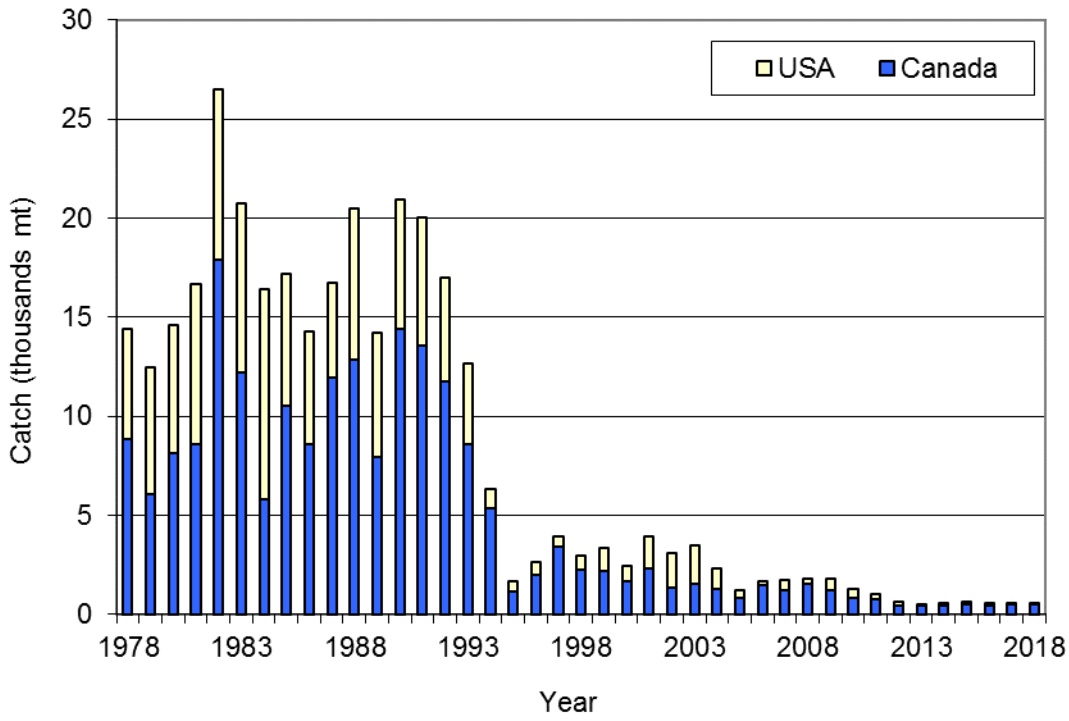


Figure 2. Catches eastern Georges Bank cod, 1978 to 2018.

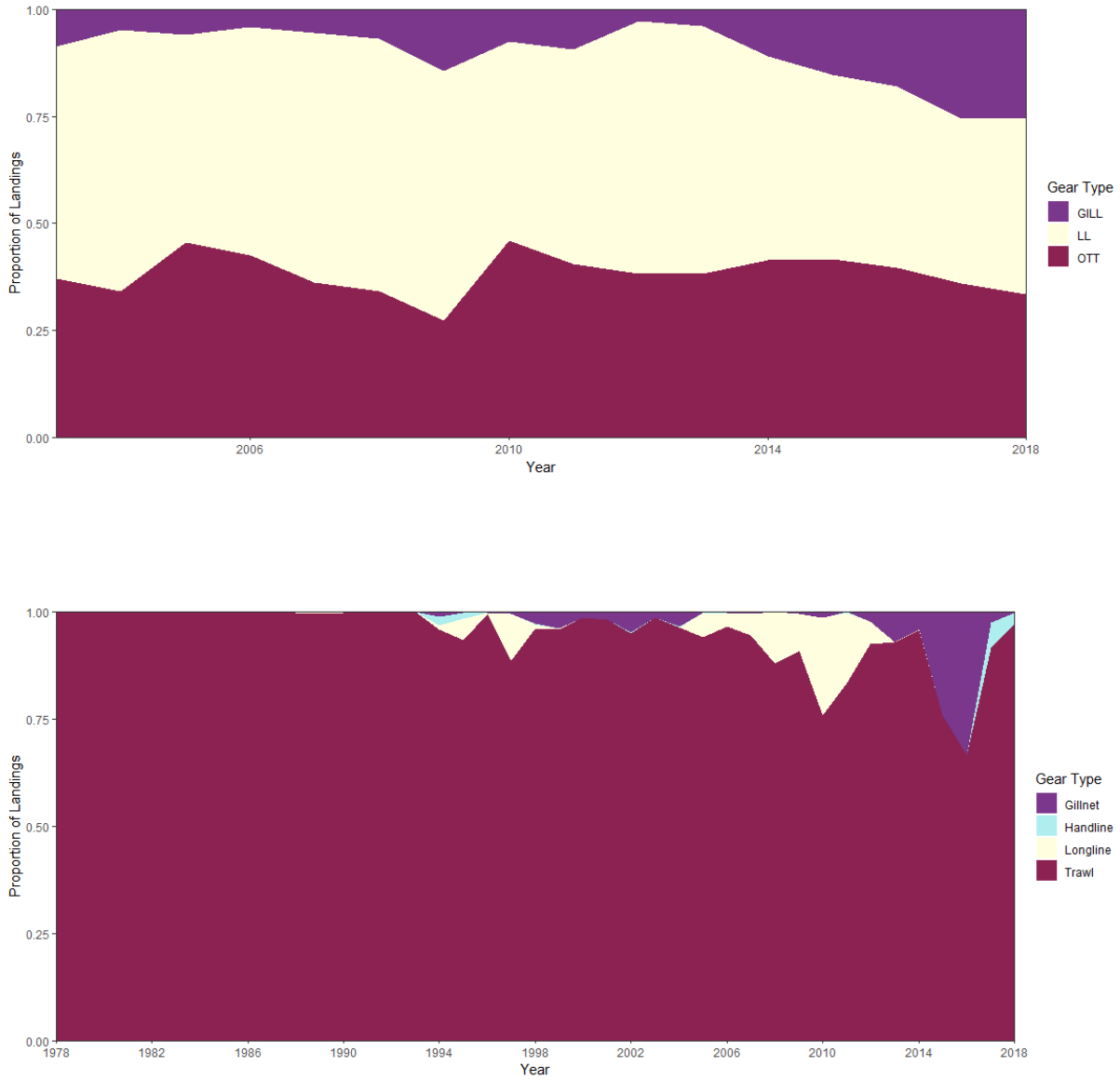


Figure 3. Canadian (upper) and US (lower) proportional landings of cod by gear from eastern Georges Bank for 1978 to 2018.

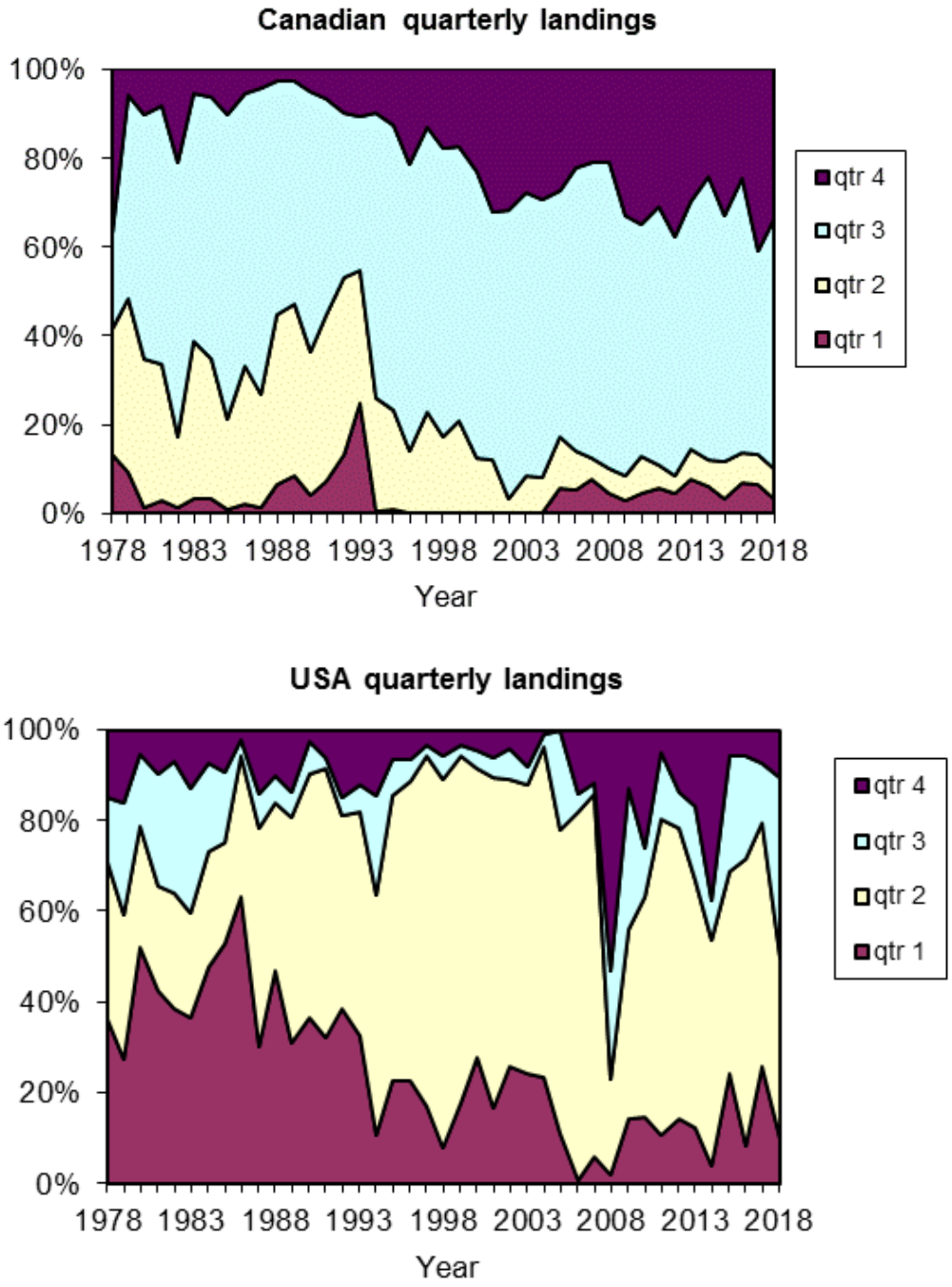


Figure 4. Proportion of Canadian (upper) and USA (lower) quarterly landings of cod from eastern Georges Bank, 1978 to 2018.

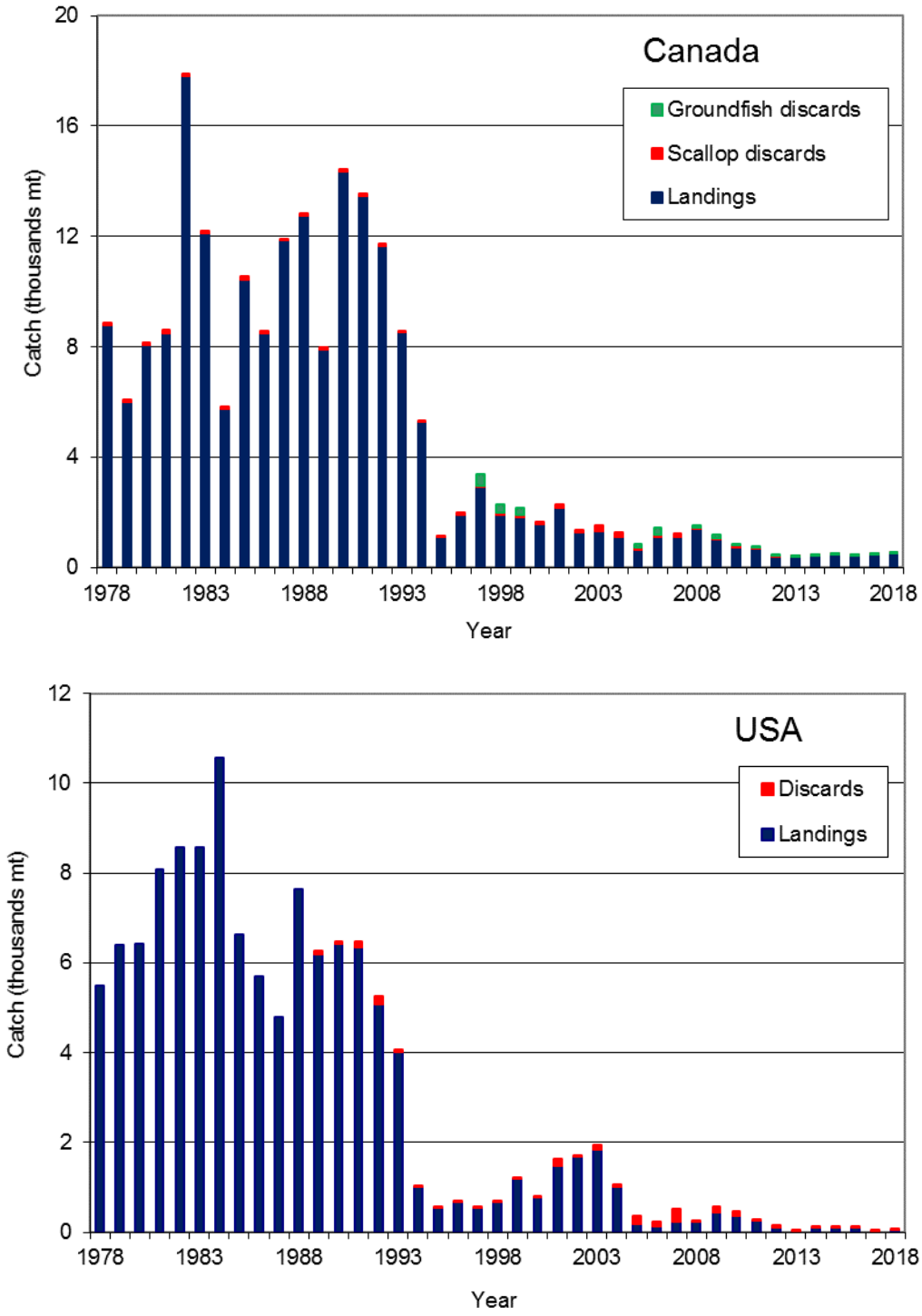


Figure 5. Canadian (upper) and USA (lower) landings and discards of eastern Georges Bank cod, 1978 to 2018.

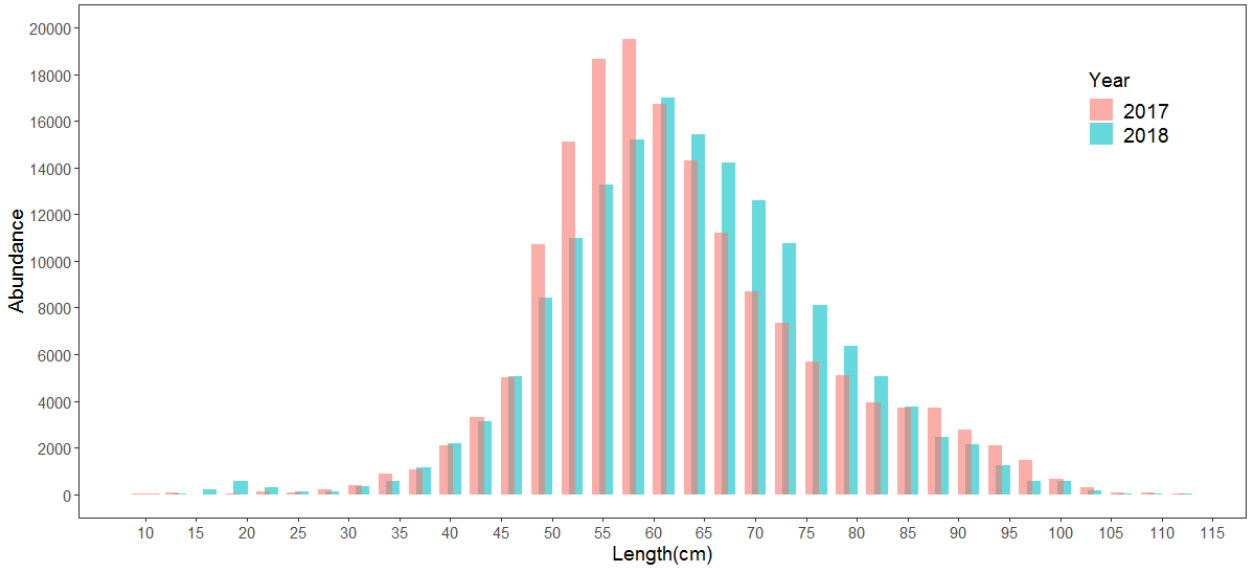


Figure 6. Length frequency of cod catch (landings and discards) from the 2017 and 2018 Canadian fisheries on eastern Georges Bank.

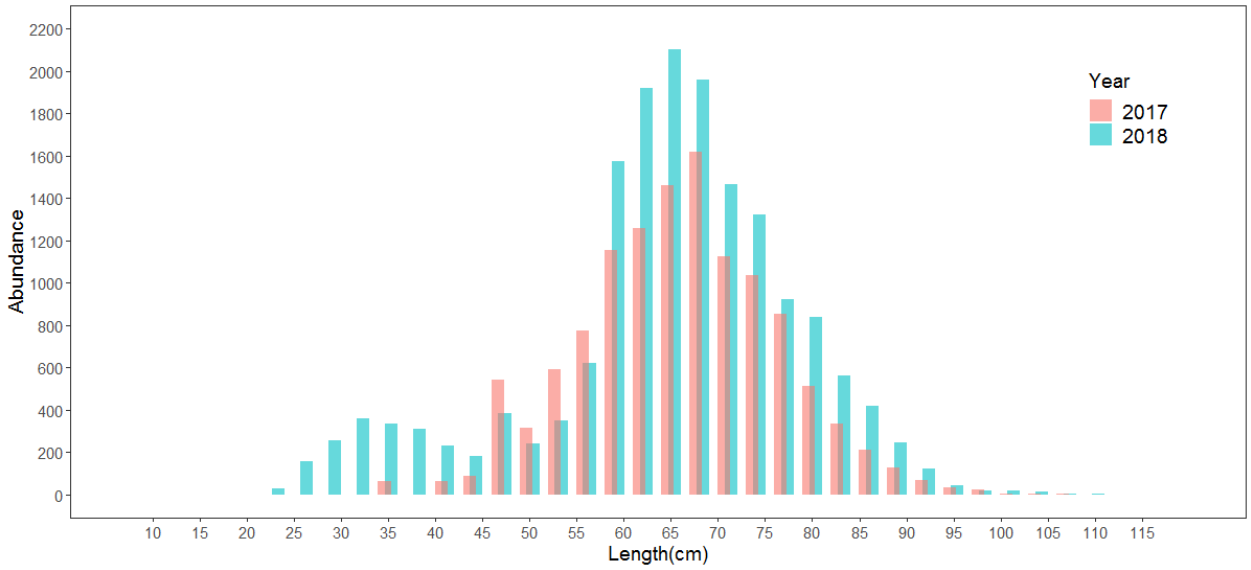
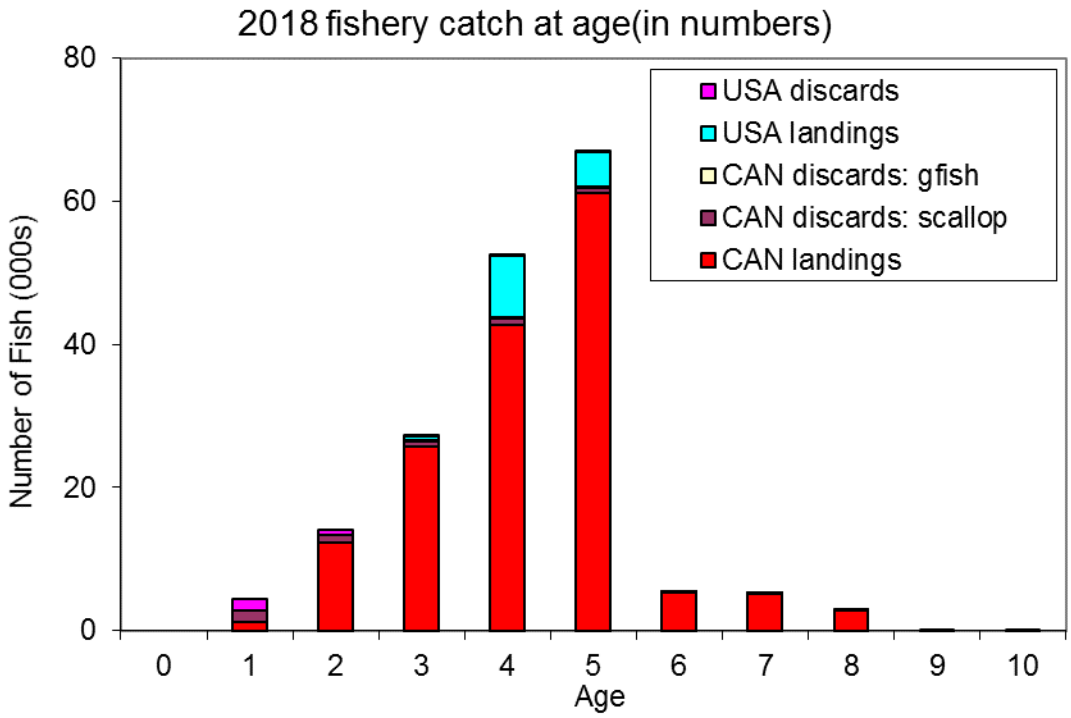


Figure 7. Length frequency of cod catch (landings and discards) from the 2017 and 2018 USA fisheries on eastern Georges Bank.



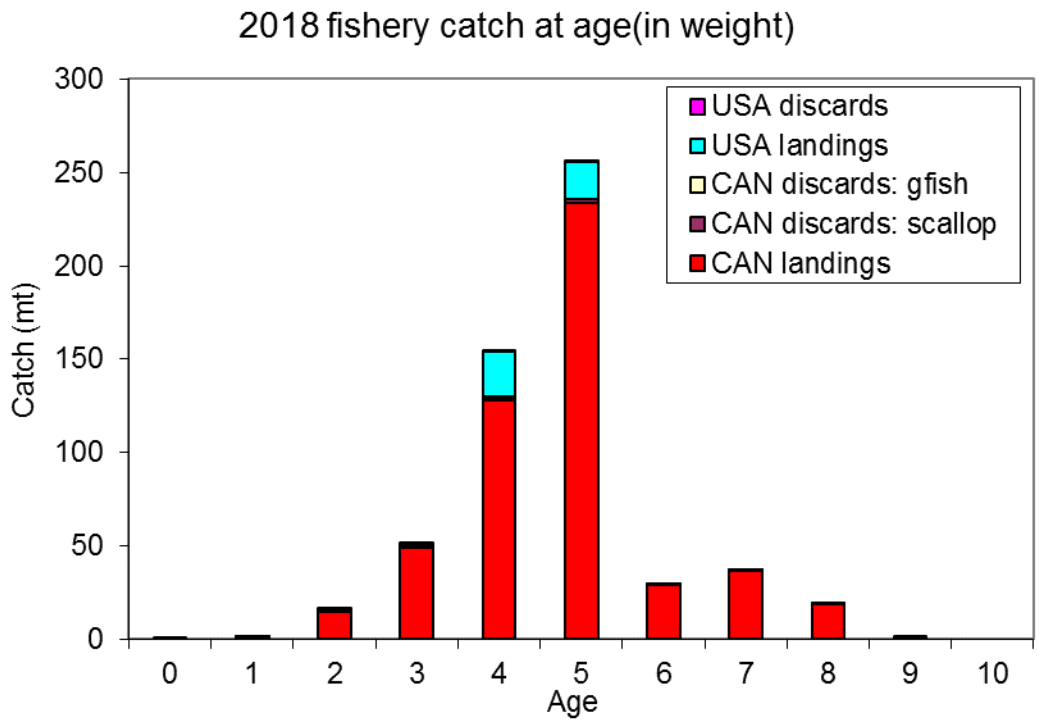


Figure 8. Catch at age in numbers (top) and weight (bottom) for landings and discards of cod from the 2018 eastern Georges Bank fisheries.

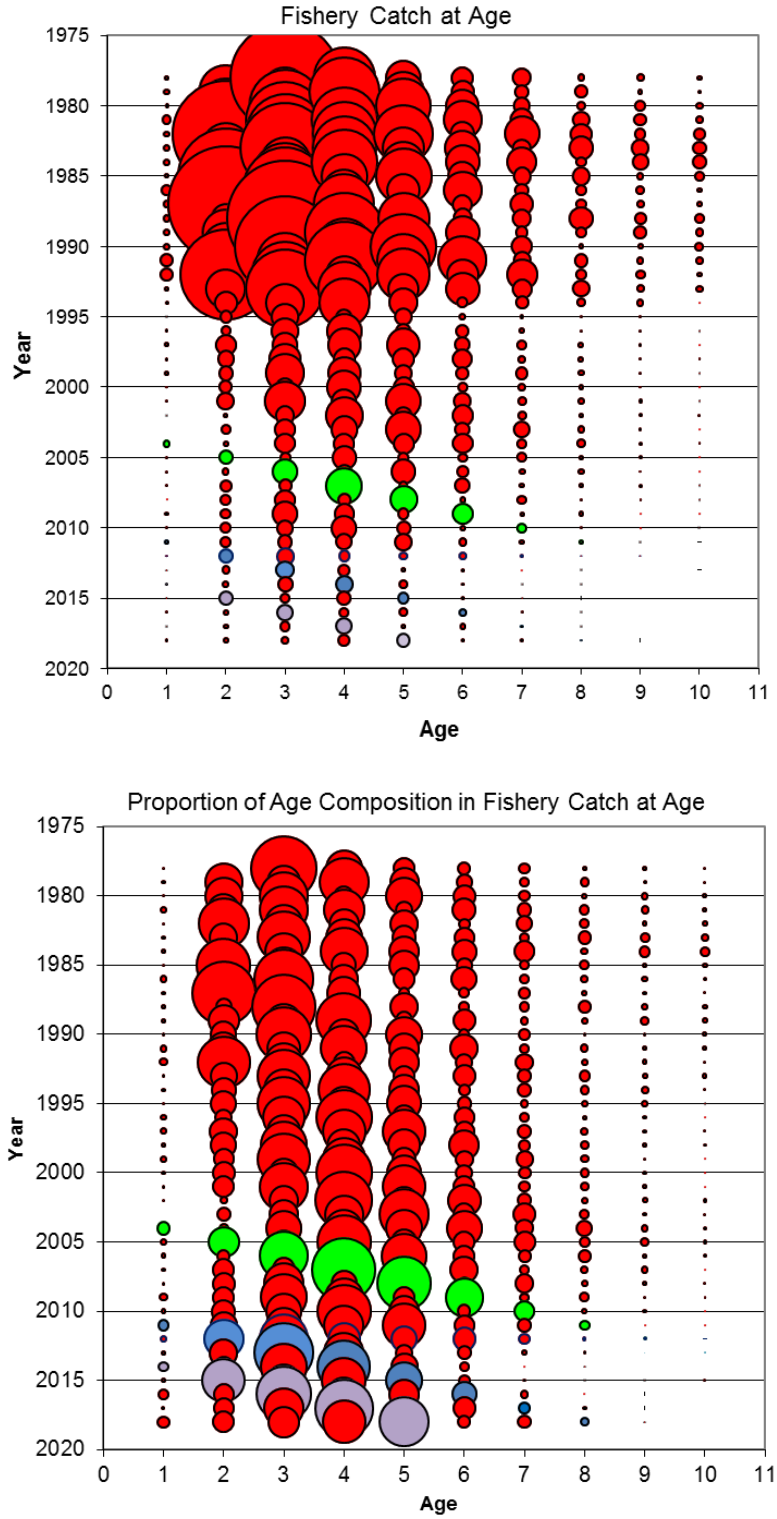


Figure 9. Total catch at age (numbers) of cod (top) and proportion of catch at age (bottom) from eastern Georges Bank for 1978 to 2018. The bubble area is proportional to the magnitude. The green denotes the 2003 year class, the blue denotes the 2010 year class and the purple denotes the 2013 year class.

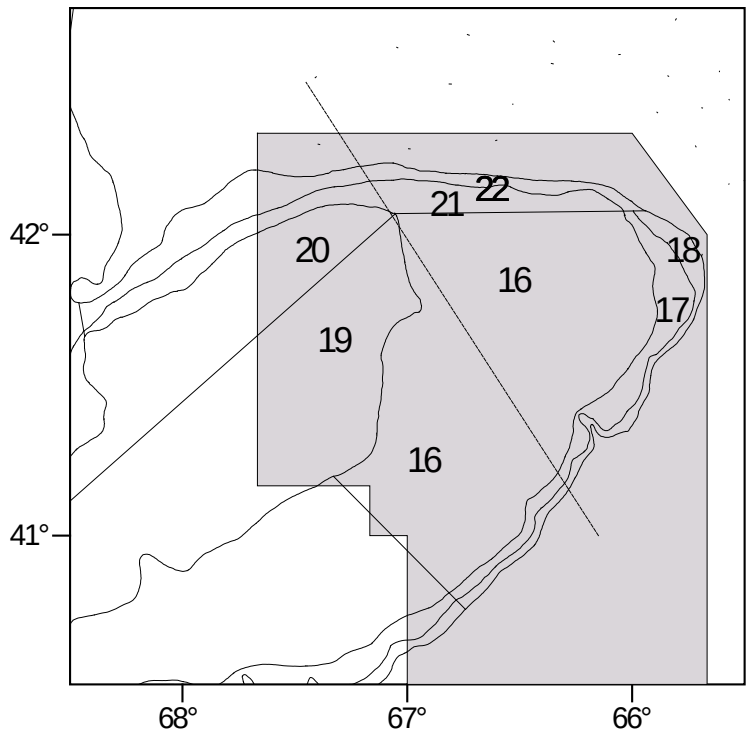


Figure 10. Stratification used for the NMFS surveys. The eastern Georges Bank management unit is indicated by shading.

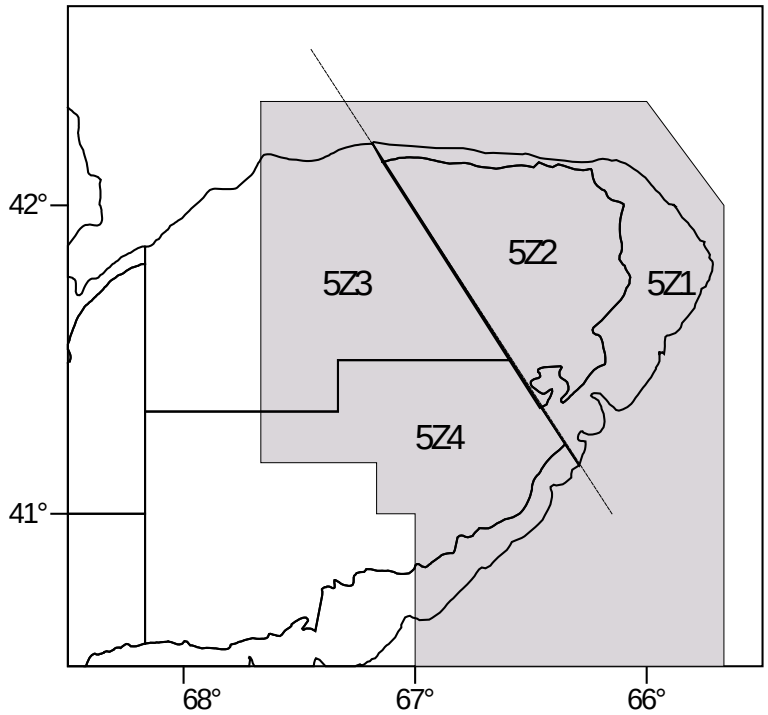


Figure 11. Stratification used for the DFO survey. The eastern Georges Bank management unit is indicated by shading.

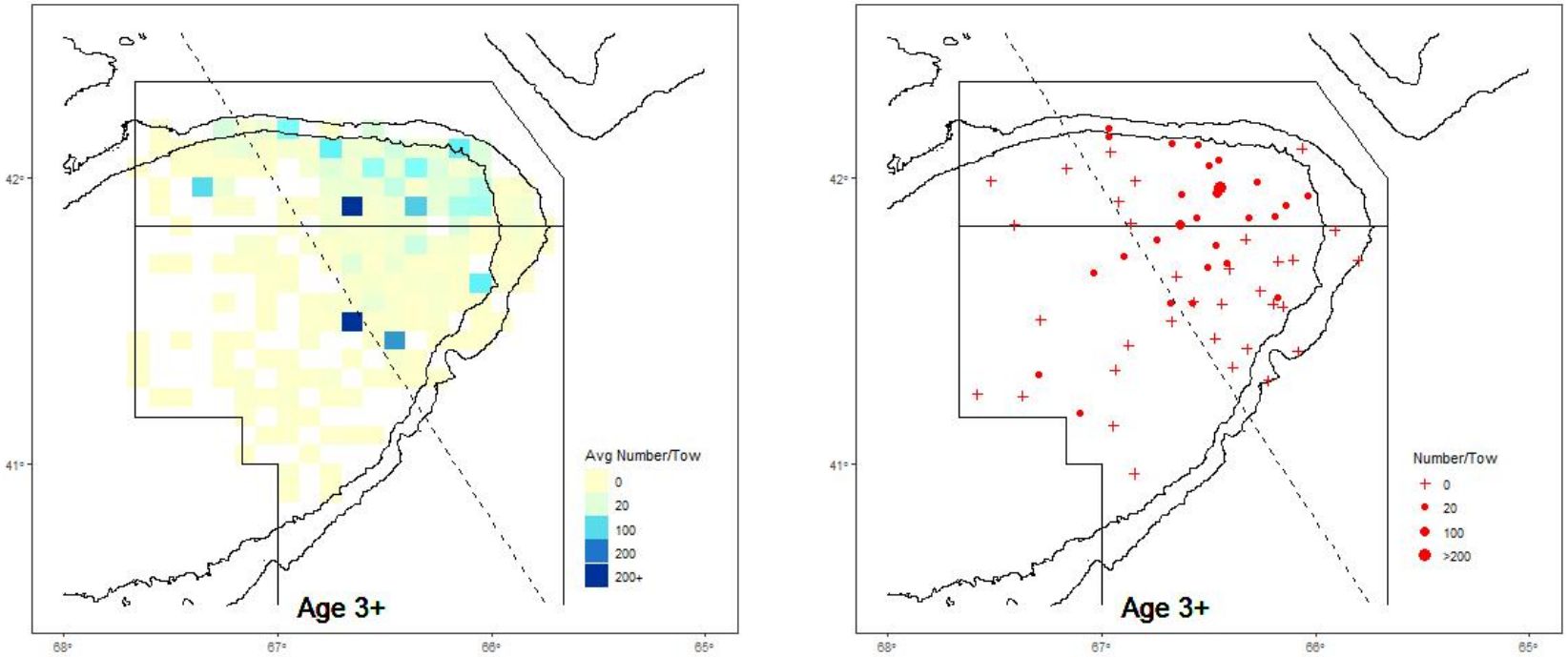


Figure 12. Spatial distribution of age 3+ cod on eastern Georges Bank from the DFO survey for 2019 (right) compared to the average for 2009-2018 (left).

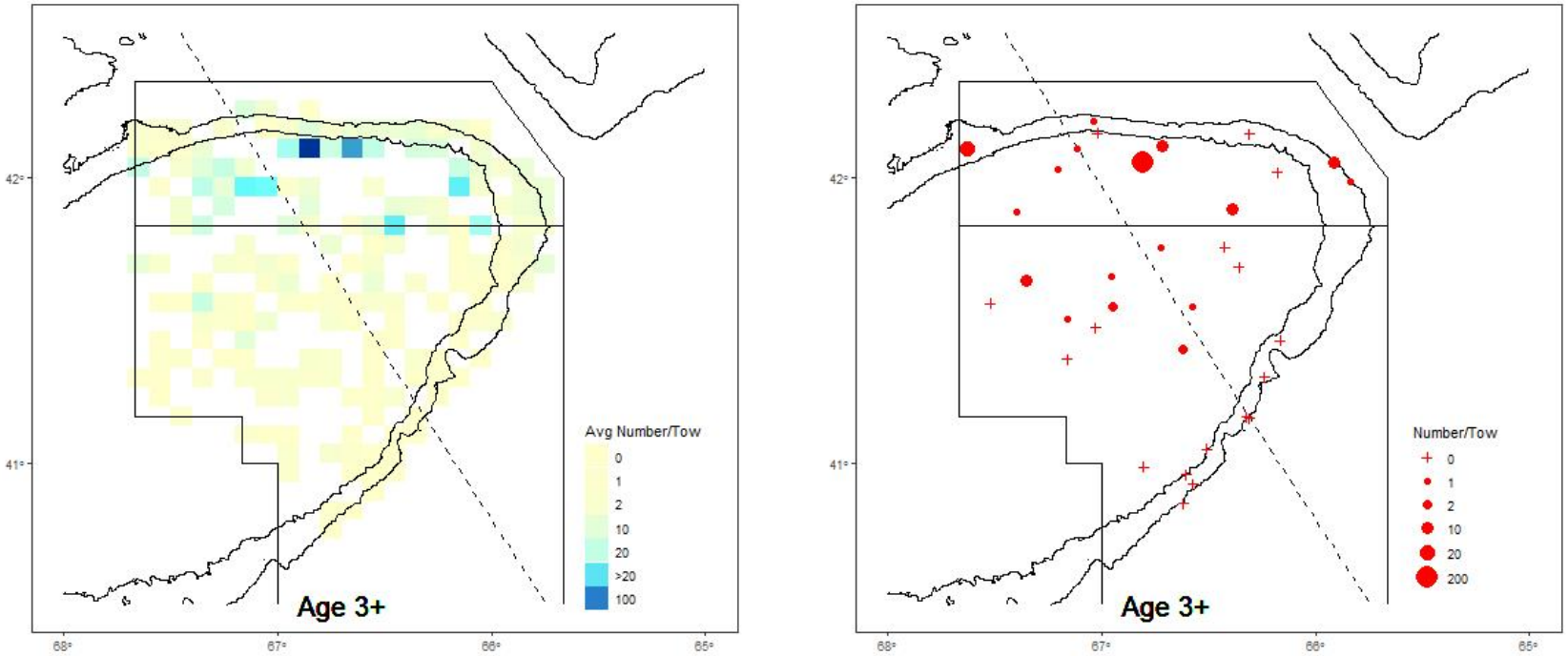


Figure 13. Spatial distribution of age 3+ cod on eastern Georges Bank from the NMFS spring survey for 2019 (right panel) compared to the average age 3+ cod for 2008-2018 (left panel).

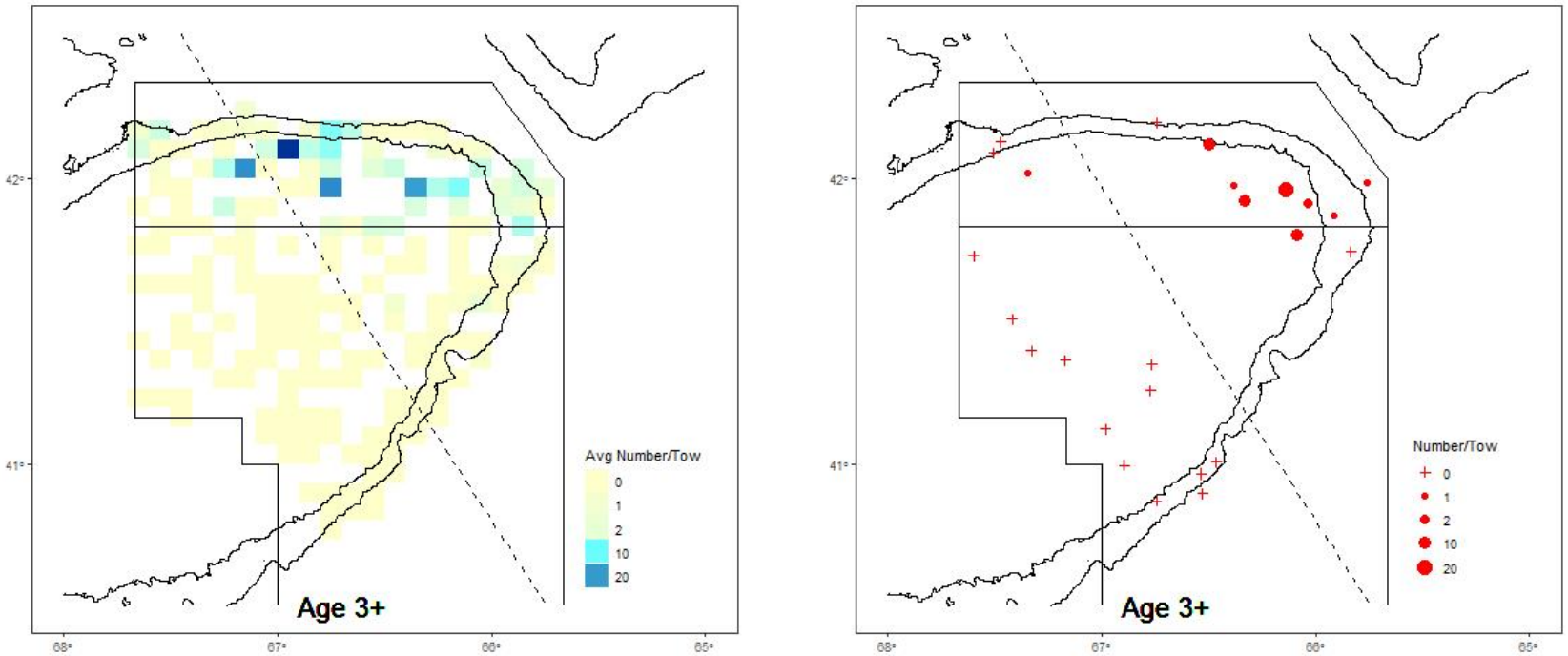


Figure 14. Spatial distribution of age 3+ cod on eastern Georges Bank from the NMFS fall survey for 2018 (right) compared to the average for 2009-2017 (left).

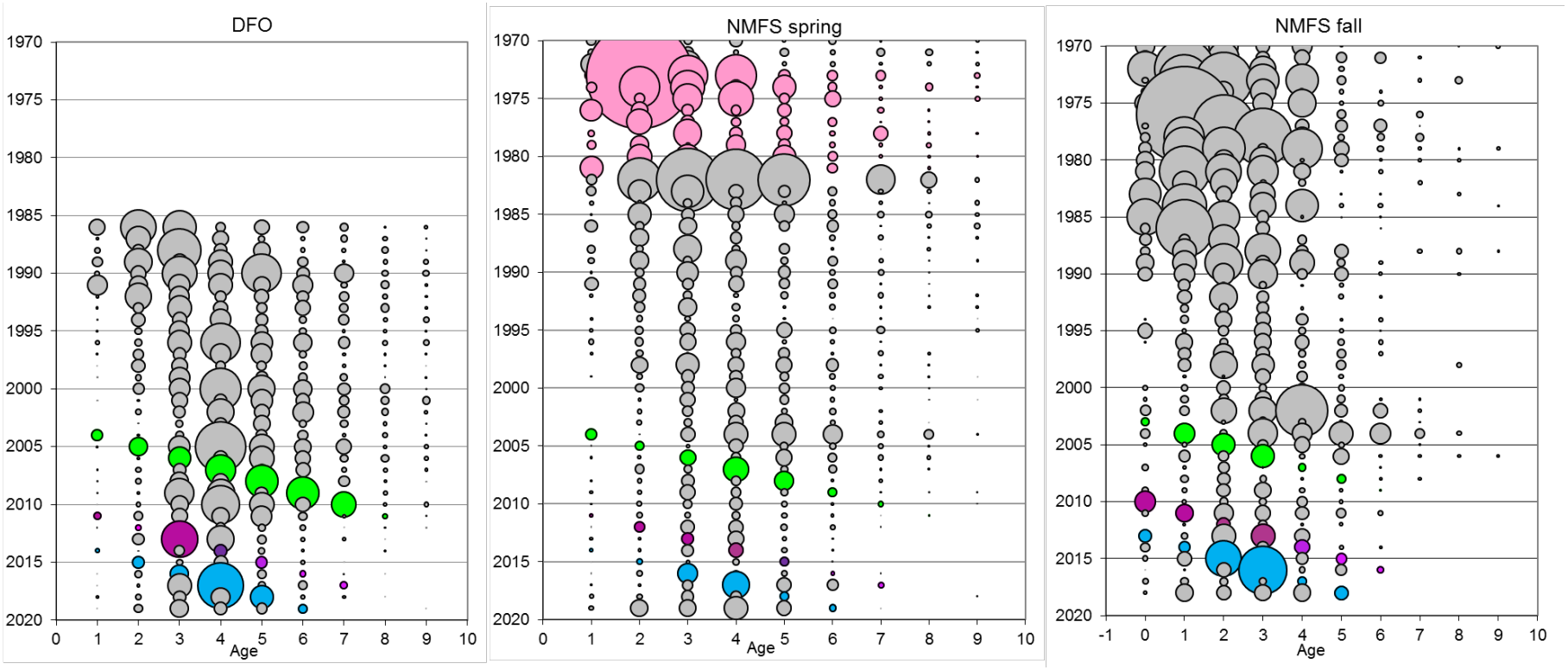


Figure 15. Survey abundance at age (numbers) of eastern Georges Bank cod. The bubble area is proportional to magnitude within each survey. Conversion factors to account for changes in door type, net and survey vessel were applied to the NMFS surveys. The NMFS spring survey was conducted using a modified Yankee 41 during 1978 to 1981 (lighter bubbles). The 2003 year class is identified with green bubbles, the purple bubbles show the 2010 year class and the blue show the 2013 year class.

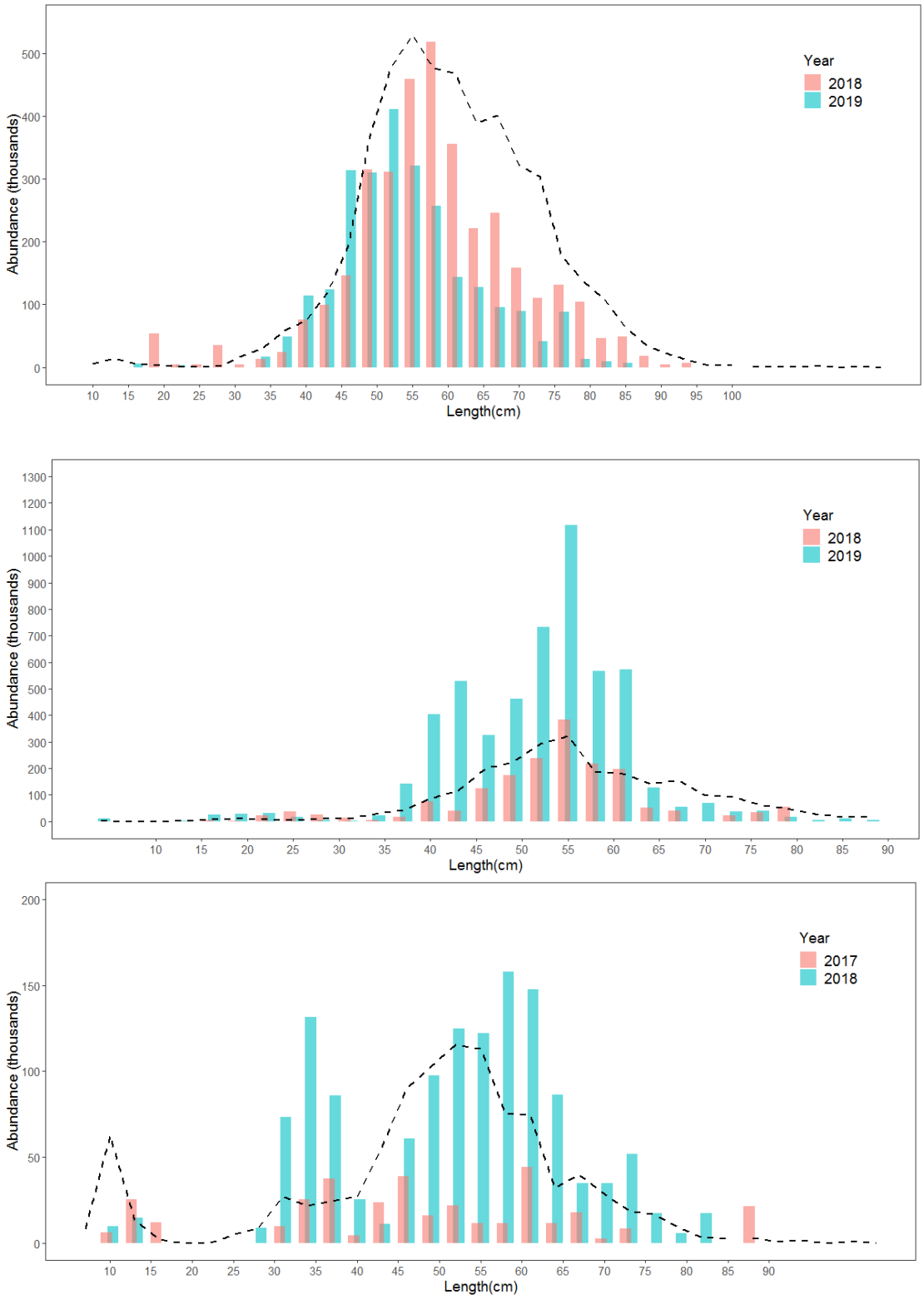


Figure 16. Length frequency distribution of the DFO Spring (top), NMFS Spring (middle) and NMFS fall (bottom) surveys. Bars represent the most recent two years and the dashed line shows the average distribution from the previous ten years (2008-2018 for spring and 2007-2017 for fall)

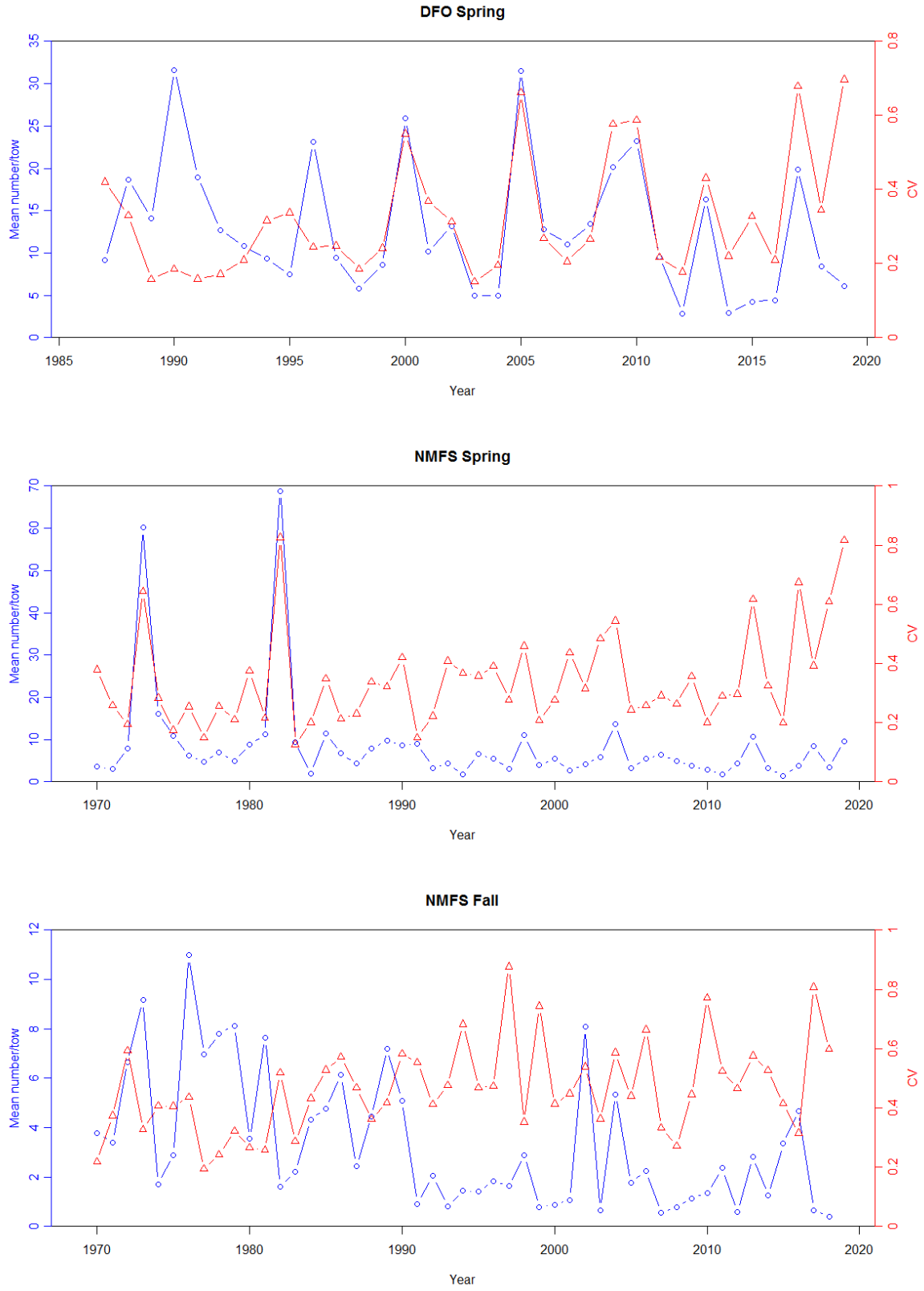


Figure 17. Stratified mean number per tow and coefficient of variation (CV) for DFO (top), NMFS spring (middle) and NMFS fall (bottom) survey catch of eastern Georges Bank cod.

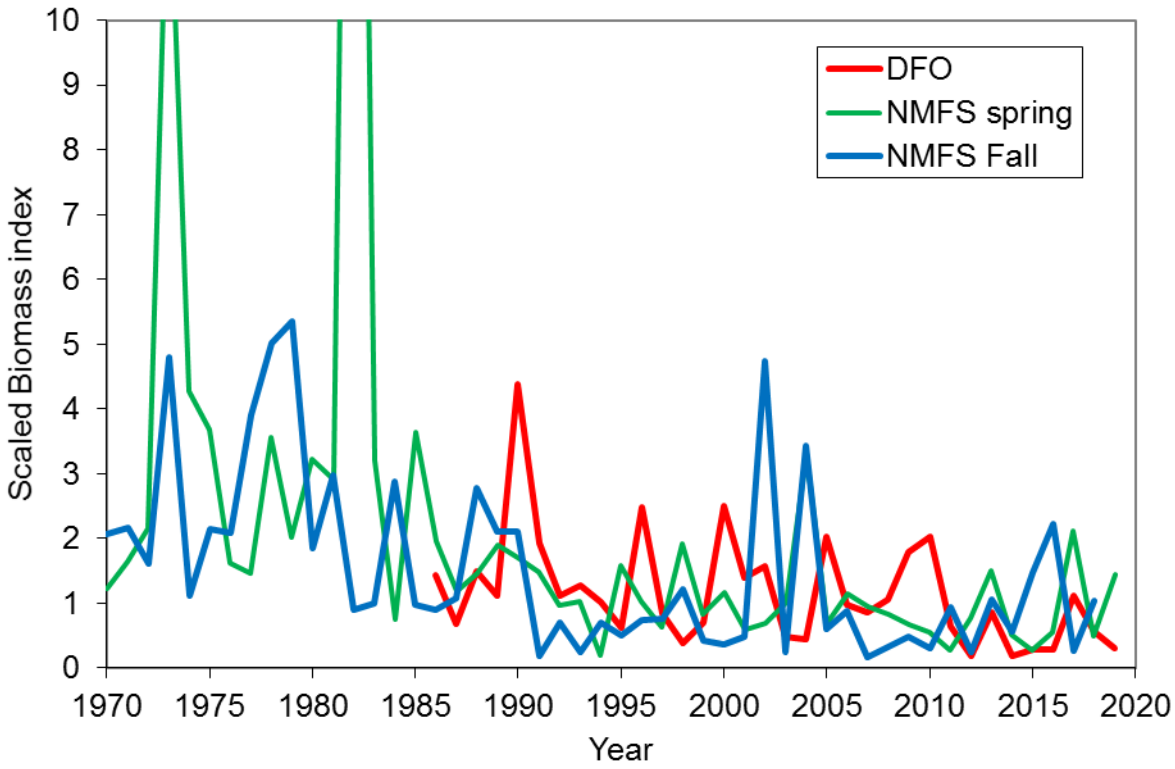


Figure 18. Survey biomass indices (ages 1+) for eastern Georges Bank cod from the DFO spring, NMFS spring and NMFS fall surveys, scaled to their respective time series means from 1996 to 2018.

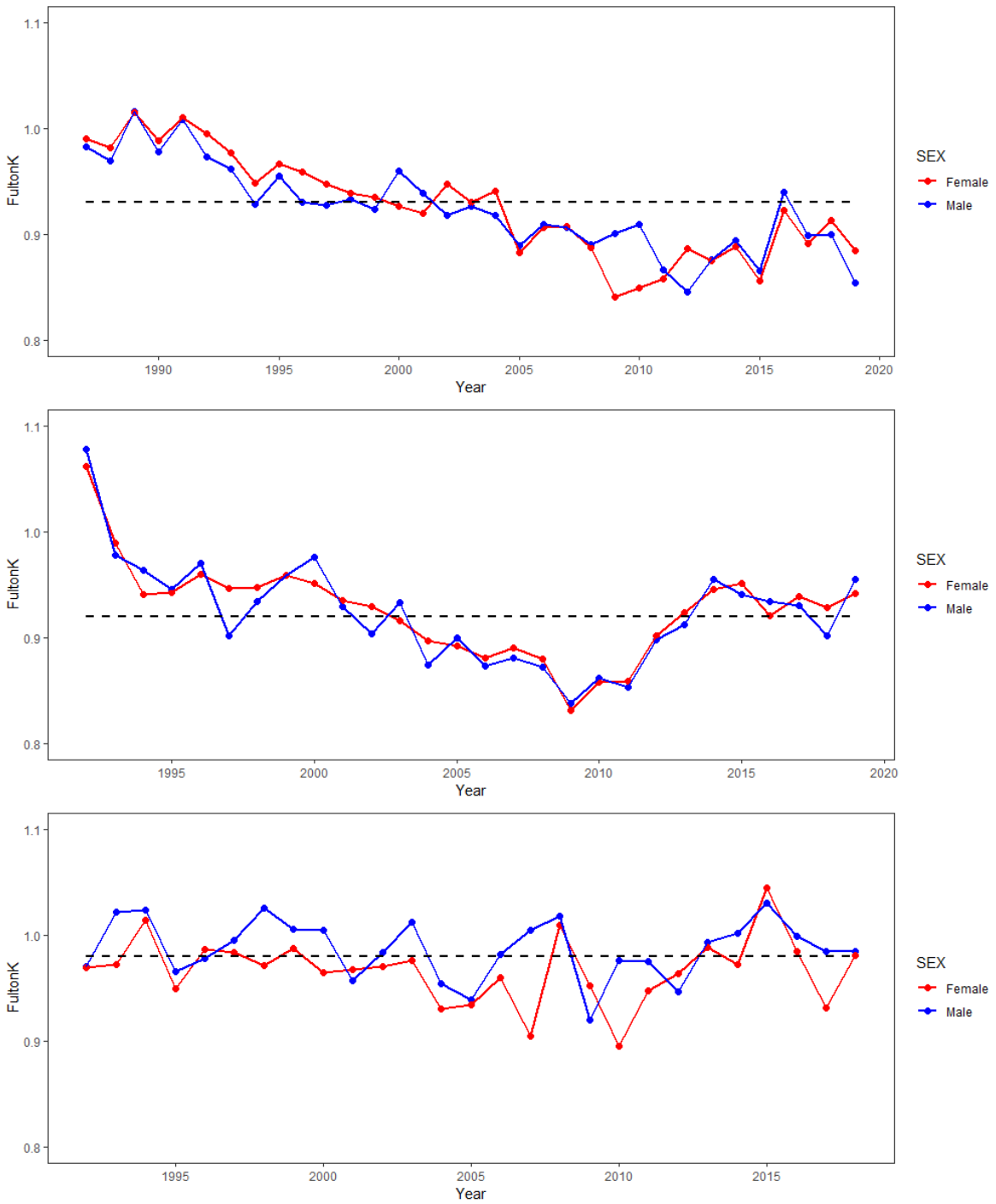
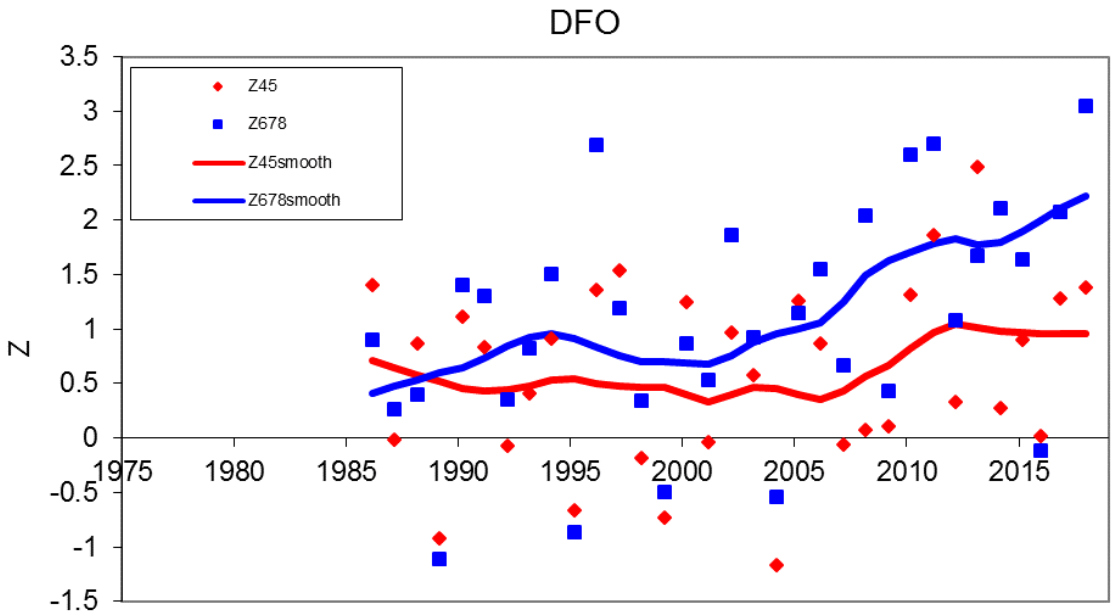


Figure 19. Fish condition (Fulton's K) of post-spawning cod for eastern Georges Bank from DFO spring (top), NMFS Spring (middle) and NMFS Fall (bottom). The dashed lines shows the time series mean.



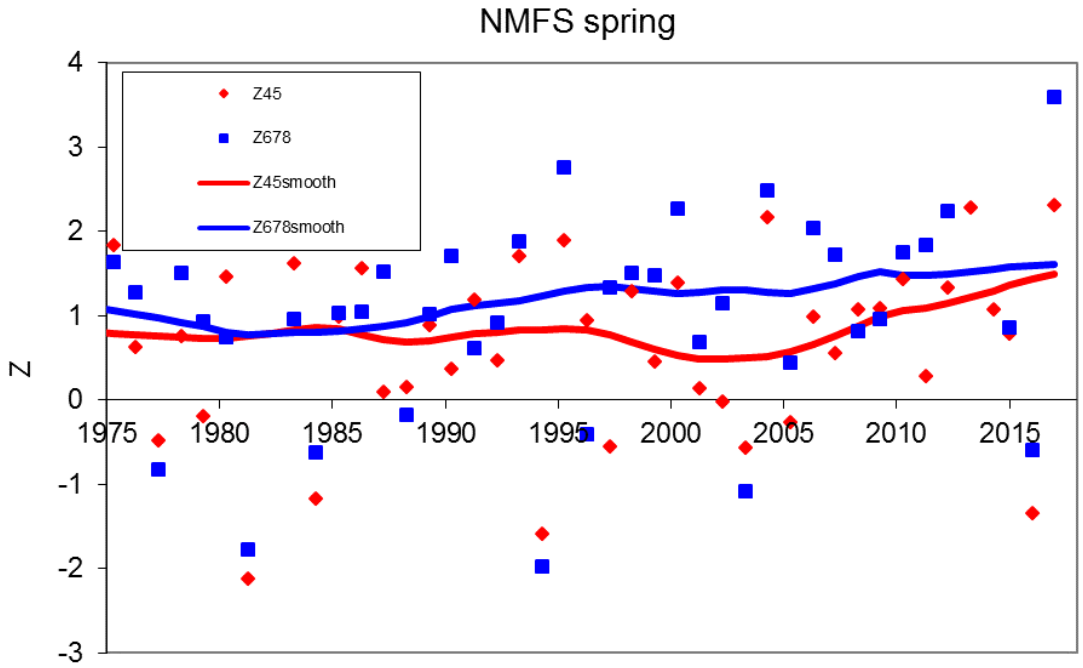


Figure 20. Total mortality(Z) calculated using the DFO and NMFS spring surveys data for eastern Georges Bank cod.

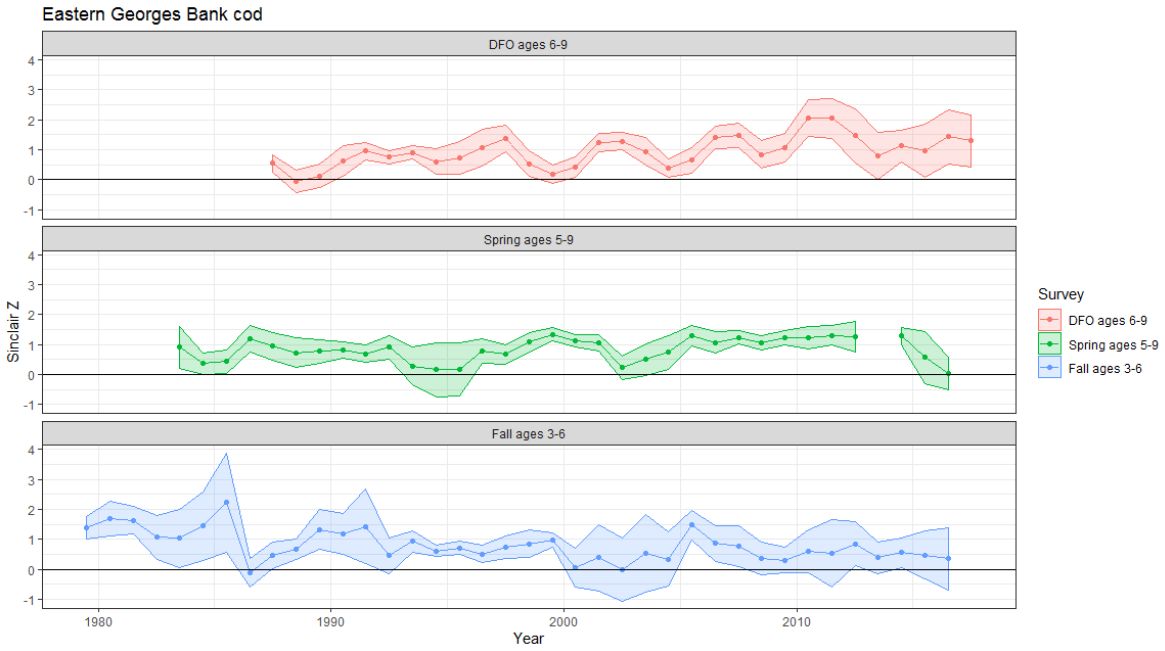
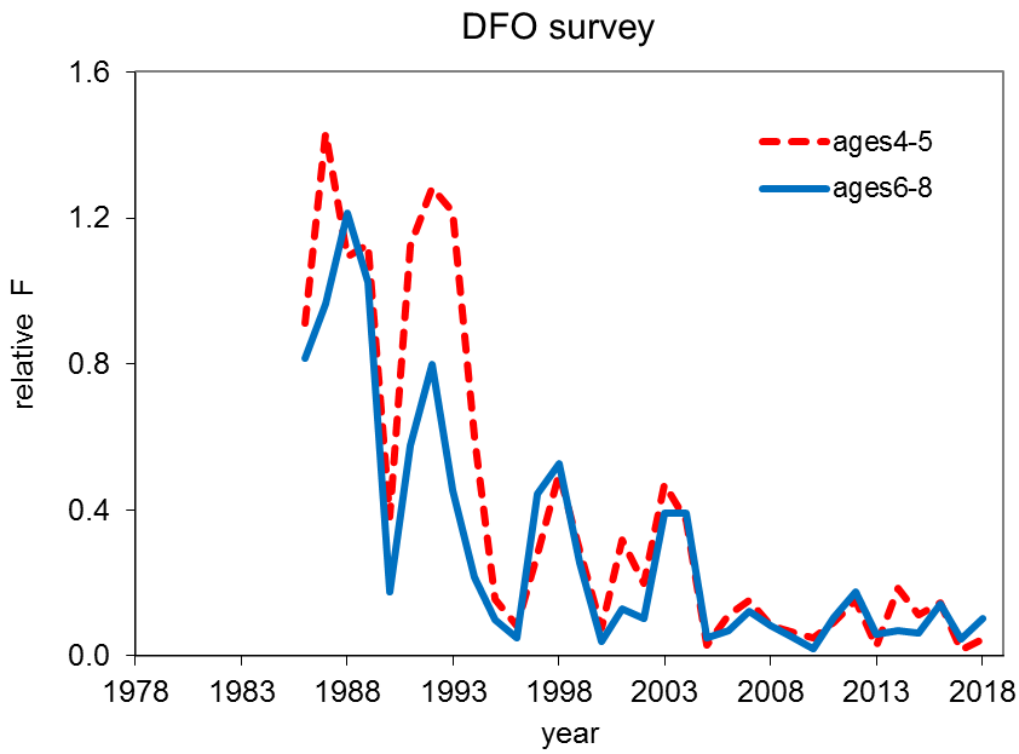


Figure 21. Empirical estimate of total mortality for the DFO (ages 6-9), NMFS spring (ages 5-9) and NMFS fall (ages 3-6) surveys.



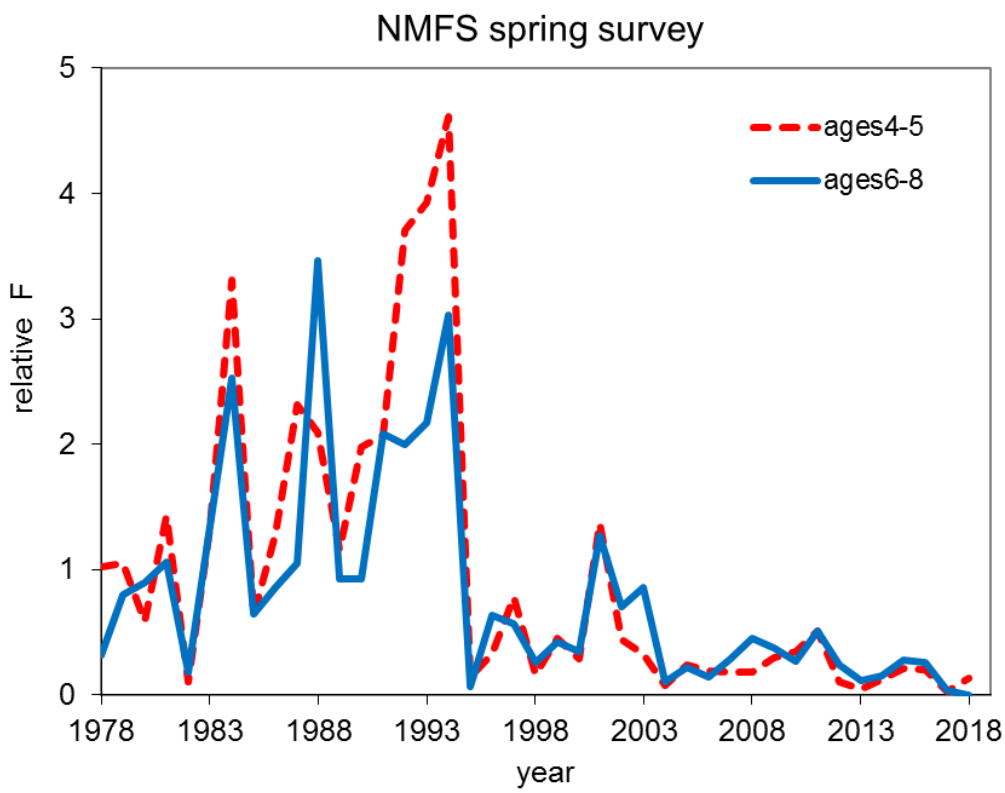


Figure 22. Relative F for eastern Georges Bank cod DFO spring survey (top) and NMFS spring survey (bottom).