

## B. GEORGES BANK ATLANTIC COD ASSESSMENT SUMMARY FOR 2012

**State of Stock:** The Georges Bank cod stock is overfished and overfishing is occurring (Figure B1). Spawning stock biomass (SSB) in 2011 is estimated to be 13,216 mt which is 7% of the SSB<sub>msy</sub> (186,535 mt) (Figure B1). The 2011 fully recruited fishing mortality (ages 5+) is estimated to be 0.43 which is more than twice as high as the F<sub>msy</sub> (0.18) (Figure B1).

This benchmark assessment is based on a newly formulated model (see Data and Assessment section below).

The assessment model exhibits a strong retrospective pattern (tending to overestimate SSB and underestimate F) which was corrected for when providing the estimates of SSB and F for 2011, stock status and projection starting points.

**Projections:** Short term projections (3-years) of catch and SSB were made under an assumption of  $F = 0.75 * F_{MSY\ Proxym}$  (Table B1). Based on the recommendations of the GARM III Panel (O'Brien et al. 2008) and reviewed by the SAW 55 WG, recruitment is estimated from one of two distributions based upon the magnitude of SSB. Recruitment is generally lower when SSB is less than 50,000 mt. Thus the 1978-2011 ASAP estimated age-1 fish recruitment is separated into two distributions based on the SSB breakpoint of 50,000 mt. Recruitment is estimated from the low recruitment distribution when SSB is < 50,000 mt or from the high recruitment distribution when SSB > 50,000 mt (Figure B2).

### Catch and Status Table: Georges Bank Atlantic cod (weights in 000s mt, recruitment in millions, arithmetic means)

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2011 <sup>2</sup>	Min <sup>1</sup>	Mean <sup>1</sup>	Max <sup>1</sup>
USA Commercial Landings	9.5	6.9	3.5	2.8	2.7	3.7	3.3	3.0	2.7	3.4		2.7	16.1	40.1
USA Commercial Discards	0.2	0.2	0.1	0.4	0.2	0.7	0.3	0.4	0.3	0.1		0.1	0.3	0.8
CDN Commercial Landings	1.3	1.3	1.1	0.6	1.1	1.1	1.4	1.0	0.7	0.7		0.6	5.8	17.8
CDN Commercial Discards	0.1	0.2	0.1	0.2	0.3	0.1	0.1	0.2	0.1	<0.1		<0.1	0.1	0.5
Recreational Landings	0.3	0.3	0.3	0.9	0.1	<0.1	0.1	<0.1	0.1	0.2		<0.1	1.7	5.4
Recreational Discards	<0.1	<0.1	<0.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		<0.1	0.0	0.1
Catch used in assessment	11.4	8.9	5.2	5.0	4.4	5.7	5.2	4.6	3.9	4.5		3.9	24.0	62.1
Spawning Stock Biomass	20.5	15.0	11.9	10.1	10.4	11.0	11.5	14.7	17.2	22.2	13.2	10.1	40.6	96.9
Recruitment (age 1)	4.0	1.3	7.0	1.5	4.0	5.8	5.3	8.1	8.1	7.3	5.1	1.3	13.6	47.1
F (ages 5-8)	0.76	0.80	0.54	0.65	0.50	0.65	0.58	0.42	0.29	0.23	0.43	0.23	0.65	1.10

<sup>1</sup> During 1978-2011

<sup>2</sup> retrospective adjusted; previous 6 years are not adjusted but should be considered biased

**Stock Distribution and Identification:** The Atlantic cod, *Gadus morhua*, is a demersal gadoid species found on both sides of the North Atlantic. In the Northwest Atlantic, cod

occur from Greenland to North Carolina. Cod are assessed and managed as two stocks: (i) Gulf of Maine and (ii) Georges Bank and southward. Georges Bank cod is a transboundary stock fished by both the US and Canada (Figure B3).

**Catches:** Total USA commercial landings ranged between 11,000 mt to 40,000 mt during 1960-1993, averaging about 21,000 mt. As stock biomass declined and year round closures were implemented in Dec 1994, landings declined, ranging between 3,000 mt – 15,000 mt during 1994-2011, averaging about 6,000 mt. Total Canadian (CDN) landings ranged between 19 mt to 18,000 mt during 1960-1993 and after large quota restrictions in 1993, CDN landings ranged between 600 mt to 8,500 mt with an average of about 1,600 mt during 1994-2011. USA and CDN commercial discards combined accounted for less than 5% of the annual catch during 1978-2005 and have averaged about 10% of the catch during 2005-2011. USA recreational catch is generally less than 10% of total catch of GB cod. Total catch of all fleets combined has ranged from 3,950 mt to 5,660 mt during 2007-2011 (Catch and Status Table above; Figure B4).

**Data and assessment:** The previous assessment of Georges Bank cod was conducted using virtual population analysis (VPA). The new benchmark assessment applies a statistical catch-at-age model (ASAP; Legault and Restrepo 1999) which can more fully account for the uncertainties in the catch and surveys. The ASAP model incorporates the total catch of USA and CDN commercial and recreational landings and discards. The model uses two fishery selectivity blocks assuming flat-topped selectivity for both the catch and research survey indices. The catch-at-age for 1978-2011 includes catch by all gear types, though Georges Bank cod are primarily caught using otter trawl (USA) and longline (CDN) (with minor contributions from hook and gillnet gear). USA commercial discards were estimated for 1989 to 2011, and were hindcasted from 1978-1988. CDN discards were estimated from 1978-2011. Discard mortality was assumed to vary by gear type, but only for USA fisheries. This represents a change from previous assessments that assumed 100% mortality of discarded fish. Recreational landings and discards estimates were included for 1978 onward. All catch sources were combined into a single fleet.

Swept-area estimates of abundance from the NEFSC spring and autumn surveys (1978-2011), and the Department of Fisheries and Oceans (DFO) survey (1986-2011) were used in the ASAP model along with associated estimates of uncertainty and annual age composition. Survey indices were variable but relatively stable between 1963 and the early 1980s, then gradually declined until about 1995 and have remained low since that time (Figure B5).

Natural mortality was assumed to be 0.2 for all ages and years. Other models were considered which changed the natural mortality rate over time. Annual estimates of maturity at age varied over time and a decline in median age ( $A_{50}$ ) from 2.4 in 1978 to 1.7 in 1988 was observed, and  $A_{50}$  subsequently increased to 2.4 in 2011.

**Biological Reference Points:** An MSY could not be derived directly from the assessment, therefore an MSY proxy must be used for reference points.

$F_{40\%}$  is the proxy for the overfishing threshold ( $F_{MSY}$ ). This is as has been used in the previous assessment and consistent with the choice of proxy and the SAW 55 working group's recommendation. A deterministic value of  $F_{40\%}$  was estimated from a spawner per recruit analysis using 2007-2011 average SSB weights, catch weights, maturity and selectivity at age. Expressed as a fully recruited fishing mortality (ages 5+),  $F_{40\%}$  is 0.18.

Stochastic projections at  $F_{40\%}$  were used to determine newly recommended biomass-related reference points (proxies for both  $SSB_{MSY}$  and  $MSY$ ). The projection methodology used to determine  $SSB_{MSY}$  and  $MSY$  proxies was identical to those used for short-term projections. The proxy for  $SSB_{MSY}$  is estimated at 186,535 mt, the median of the stochastic projections, with 10<sup>th</sup> and 90<sup>th</sup> percentiles spanning 155,398 – 220,756 mt. One half of  $SSB_{MSY}$  is 93,268 mt, the  $B_{THRESHOLD}$ .

Age specific retrospective pattern adjustments to the abundance at age were used to start the projections. This same procedure should be used in additional short term management projections. However, the source of the retrospective pattern is unresolved and therefore an  $F_{REBUILD}$  cannot be determined at this time. The proxy for  $MSY$  is 30,622 mt, with 10<sup>th</sup> and 90<sup>th</sup> percentiles spanning 25,450 – 36,302 mt. The median recruitment at  $SSB_{MSY}$  is 23.3 million age 1 fish.

The biological reference points estimated in the last assessment (O'Brien et al. 2012) were  $F_{MSY}=F_{40\%}=0.23$ ,  $SSB_{MSY}=140,424$  mt, and  $MSY=28,774$  mt.

**Fishing Mortality:** In 1978, the fully recruited  $F_{5+}$  was 0.40. It increased to 0.87 in 1985, declined to 0.54 in 1989 and then increased to a record high of 1.10 in 1994. Fishing mortality subsequently fluctuated but generally decreased through 2007, and then declined steadily since that time. The 2011  $F_{5+}$  is estimated at 0.23 (90% posterior probability interval 0.15 – 0.34). The uncertainty in  $F_{2011}$  is presented in Figure B6. For stock status determination, the 2011  $F$  estimate is adjusted to 0.43 to account for the retrospective pattern (Figure B4).

**Biomass:** The ASAP model estimate of spawning stock biomass (SSB) was 96,864 mt in 1980, the time series high. SSB then declined with some fluctuation to 19,220 mt in 1995 and then gradually increased to 25,624 mt in 2001. Since that time, SSB declined with no fluctuation to a time series low of 10,121 mt in 2005 and has since gradually increased (Figure B7). SSB in 2011 is estimated to be 22,217 mt (90% posterior probability interval 15,809 – 31,993 mt). The uncertainty in 2011 SSB is presented in Figure B8. For stock status determination, the 2011 SSB estimate is adjusted to 13,216 mt to account for the retrospective pattern (Figure B7).

**Recruitment:** The time series mean recruitment (age 1) is approximately 13.6 million fish. Strong year classes were produced in 1979, 1981, 1982, 1983, 1987, and 1991 with below average recruitment for the last two decades (Figure B7). Recruitment has not exceeded the long-term mean since the 1991 year class. Recruitment in 2011 is estimated to be 7.3 million fish. For short term projections, the 2011 recruitment estimate is adjusted to 5.1 million fish to account for the retrospective pattern.

### Special Comments:

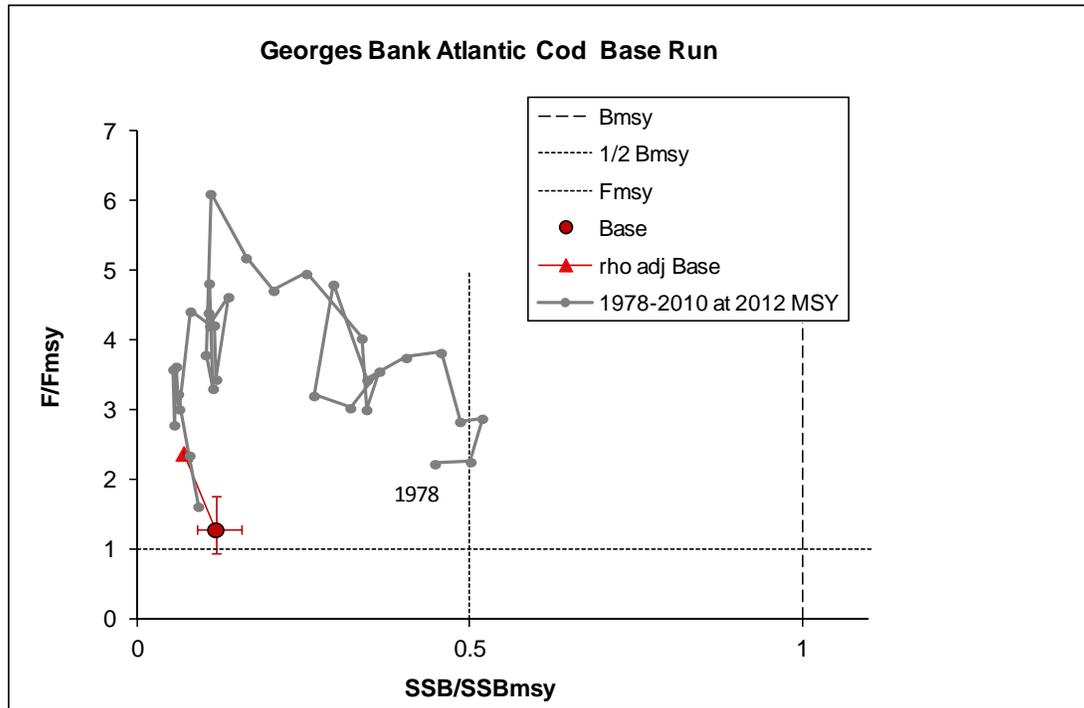
- The last above average year class was 1991. Until spawning stock biomass gets above about 50,000 mt, recruitment is likely to remain low and rebuilding will be slow.
- The assessment model continues to exhibit a strong retrospective pattern. One possible cause of which could be increased recent natural mortality. Status evaluation and short term projected catches based on 75% Fmsy were very similar compared to an alternative assessment formulation that included an increase in M from 0.2 to 0.4 between 1990 and 2002. However, the source of the retrospective pattern remains unresolved.
- The model accepted (base case) for setting reference points and as a basis for catch advice does not imply that the SARC Panel believes constant natural mortality rate of 0.2 necessarily reflects the state of nature. The model formulation encapsulates through the retrospective adjustment the possibility that factors, including natural mortality, are different or changing in the system.
- Given the uncertainty in the retrospective adjustment, downward trends in mean weight at age, and a potential recent increase in natural mortality (the key elements of the productivity processes), the projections may be optimistic.

### References:

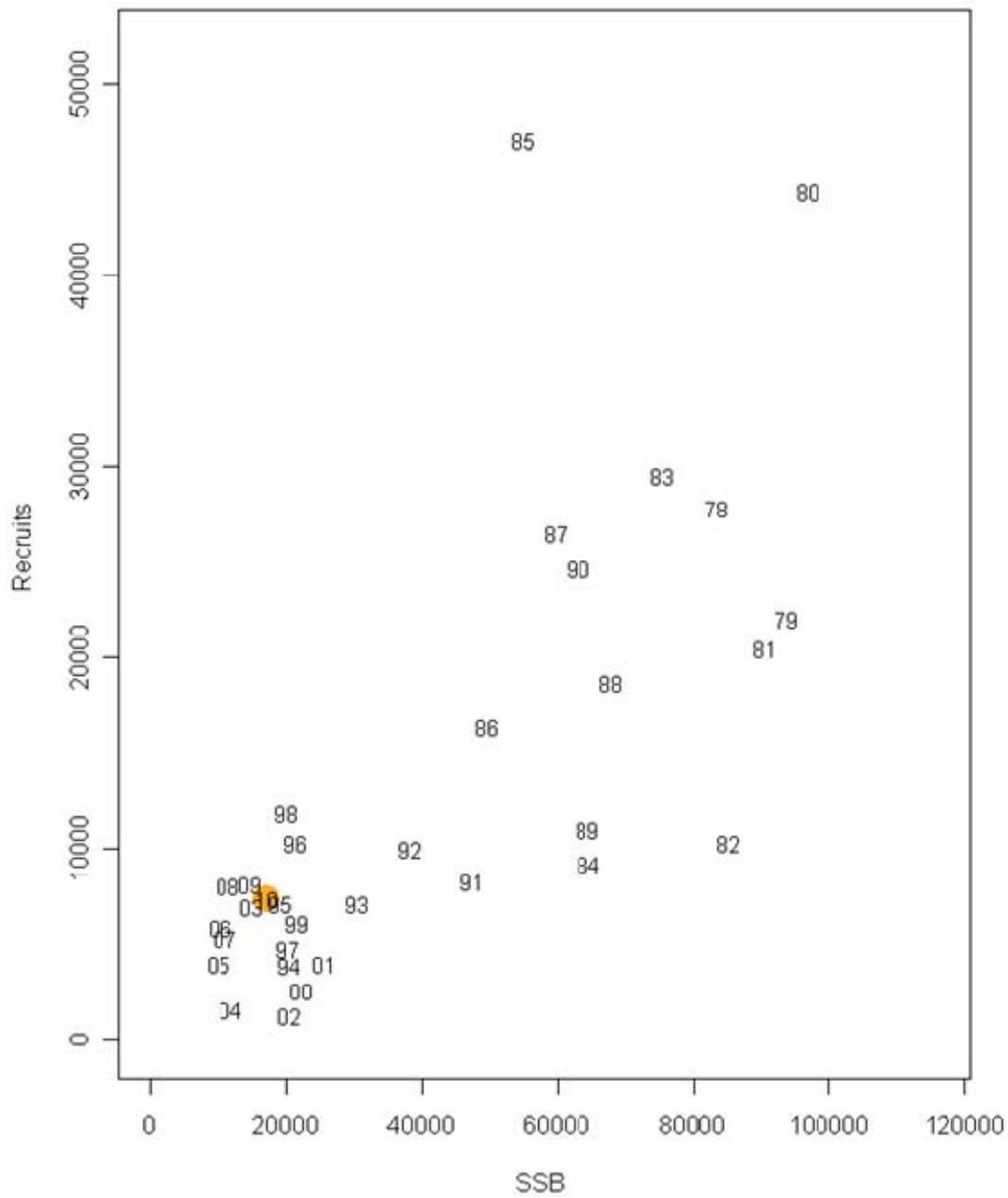
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- O'Brien, L., N.Shepherd, and Y. Wang. 2012. A. Georges Bank Atlantic Cod *in* Northeast Fisheries Science Center. 2012. Assessment or Data Updates of 13 Northeast Groundfish Stocks through 2010. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 12-06; 789 p. <http://www.nefsc.noaa.gov/nefsc/publications/>.

**Table B1.** Short term projections of total fishery yield and spawning stock biomass for Georges Bank Atlantic cod based on a harvest scenario of fishing at 75%  $F_{MSY}$  between 2013 and 2015. Catch in 2012 has been estimated at 2,910 mt.

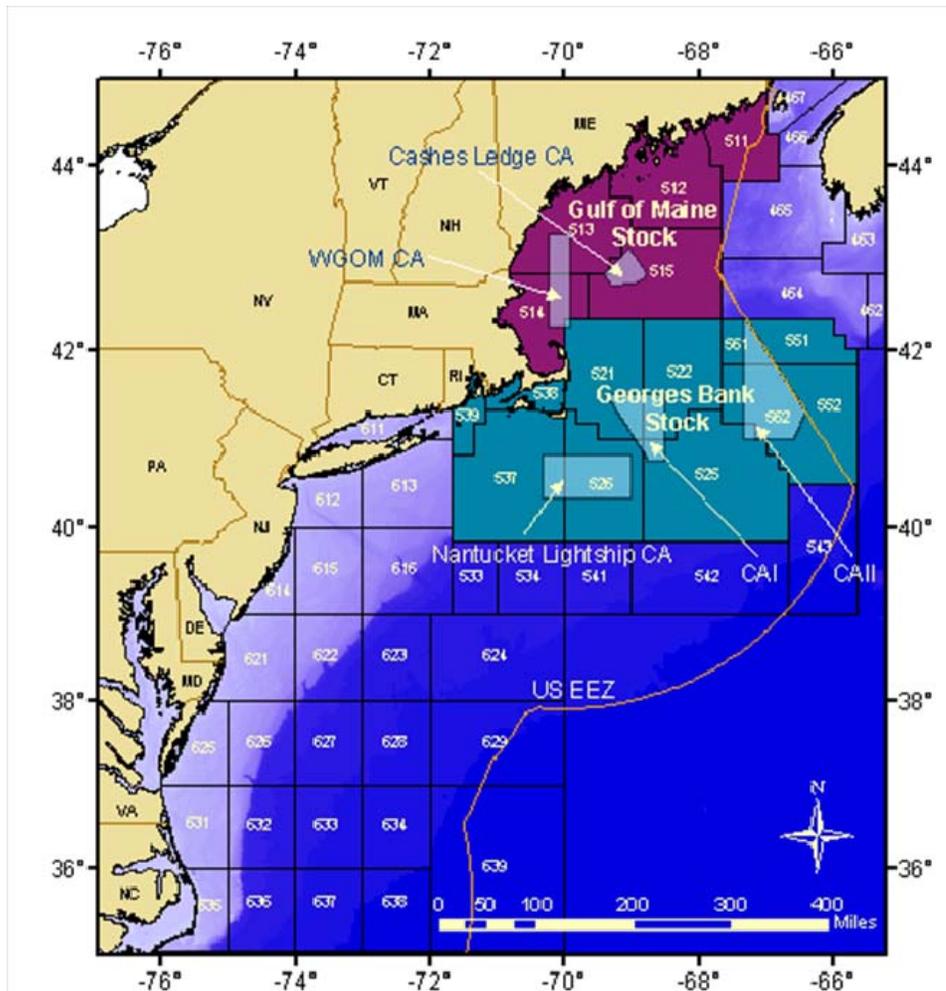
Year	Catch	SSB	F
2012	2.910	18.184	0.17
2013	2.594	20.174	0.14
2014	2.816	21.415	0.14
2015	3.265	26.005	0.14



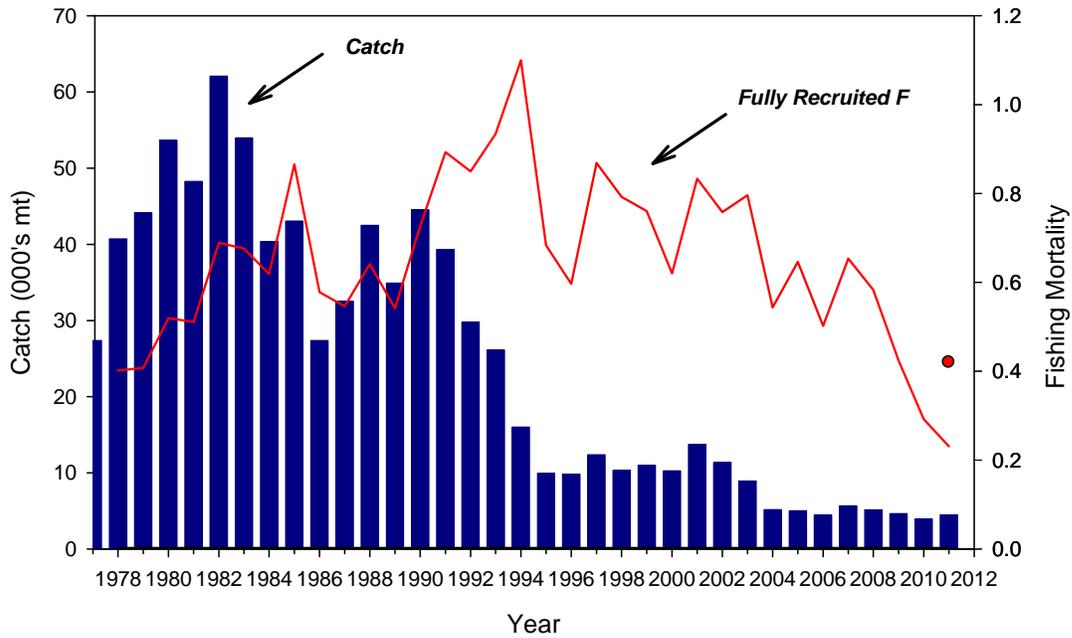
**Figure B1.** Stock status of Georges Bank Atlantic cod for 2011 relative to MSY reference points for spawning stock biomass (SSB) and fishing mortality ( $F_{5+}$ ); 2011 estimate is the colored dot, error bars represent 80% posterior probability intervals; colored triangle represents the value for 2011 when it is rho adjusted for the retrospective pattern. Gray dotted line is the 1978-2010 time series ratio based on 2012 MSY reference points.



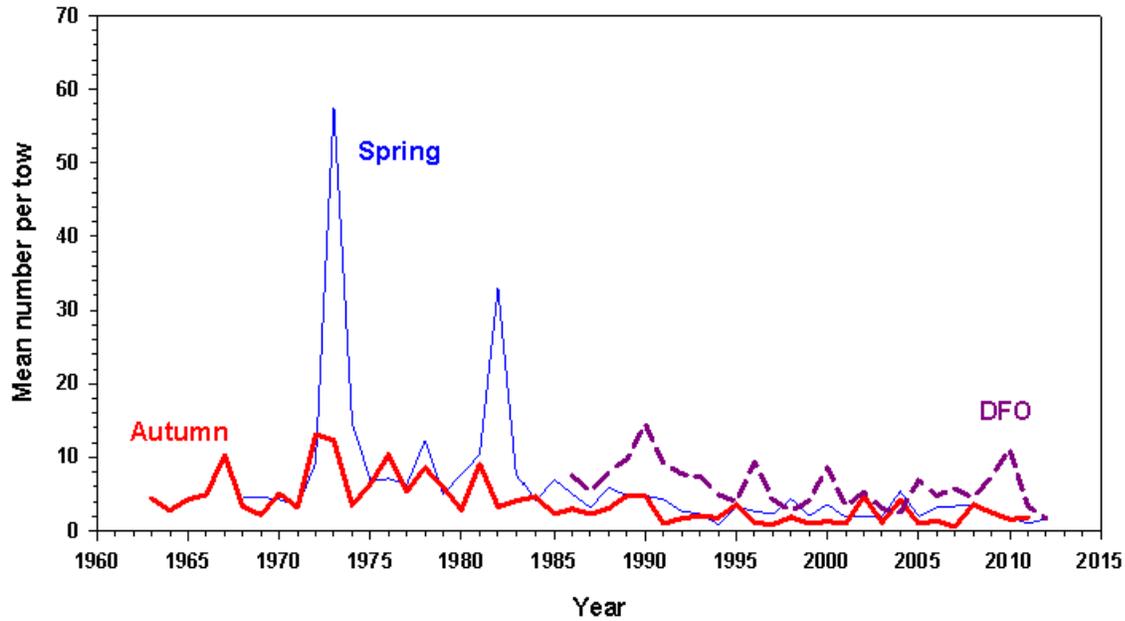
**Figure B2.** Spawning stock and recruitment of Georges Bank Atlantic cod, 1978-2010.



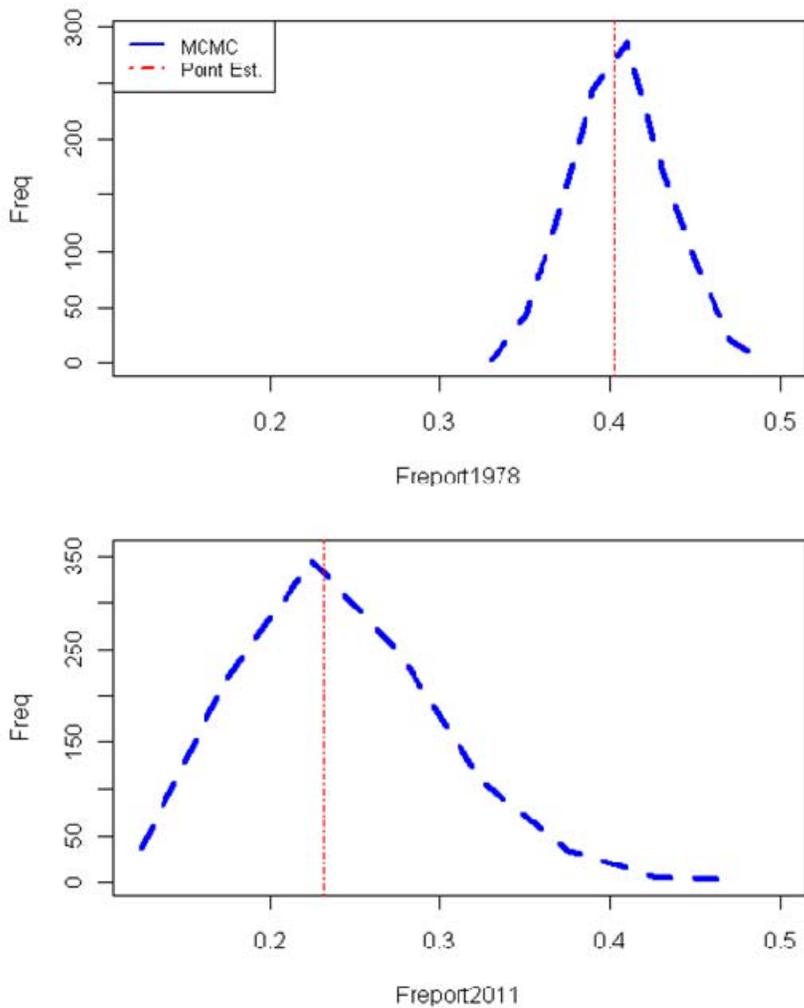
**Figure B3.** Stock area of Georges Bank cod as defined by Northwest Atlantic Fisheries Organization (NAFO) Div 5Z and Subarea 6 (NMFS statistical areas: 521-526, 551-552, 561-562, 537-539 and south).



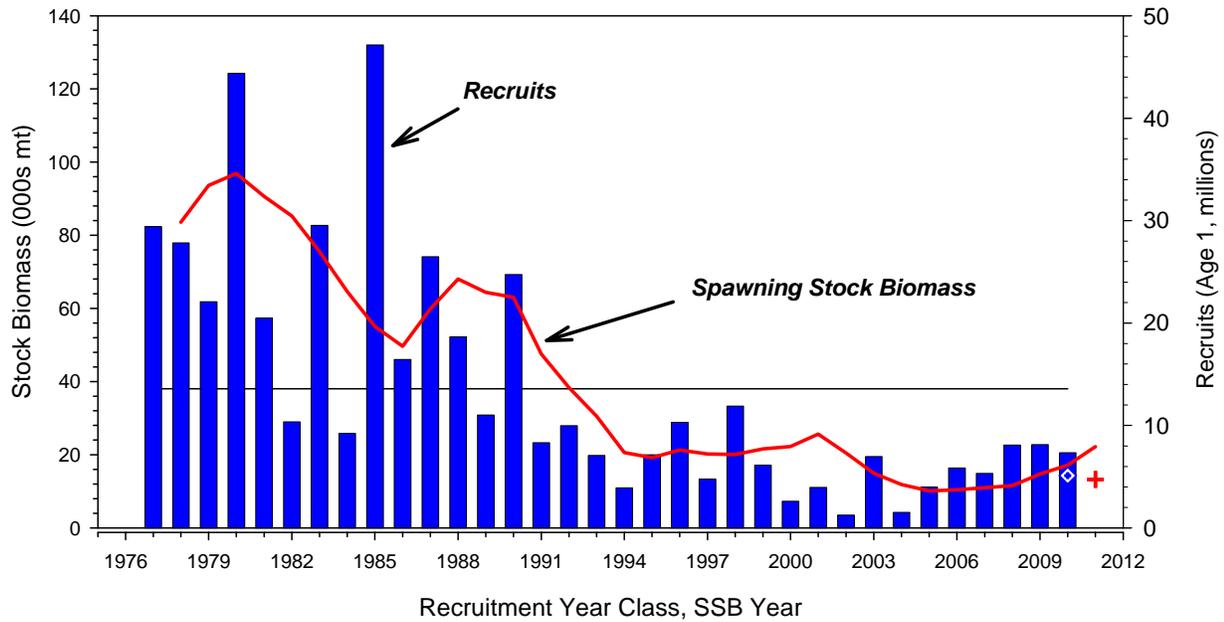
**Figure B4.** Catch and fully recruited F (ages 5+) for Georges Bank Atlantic cod, 1978-2011. Red dot is the retrospective adjusted 2011 F.



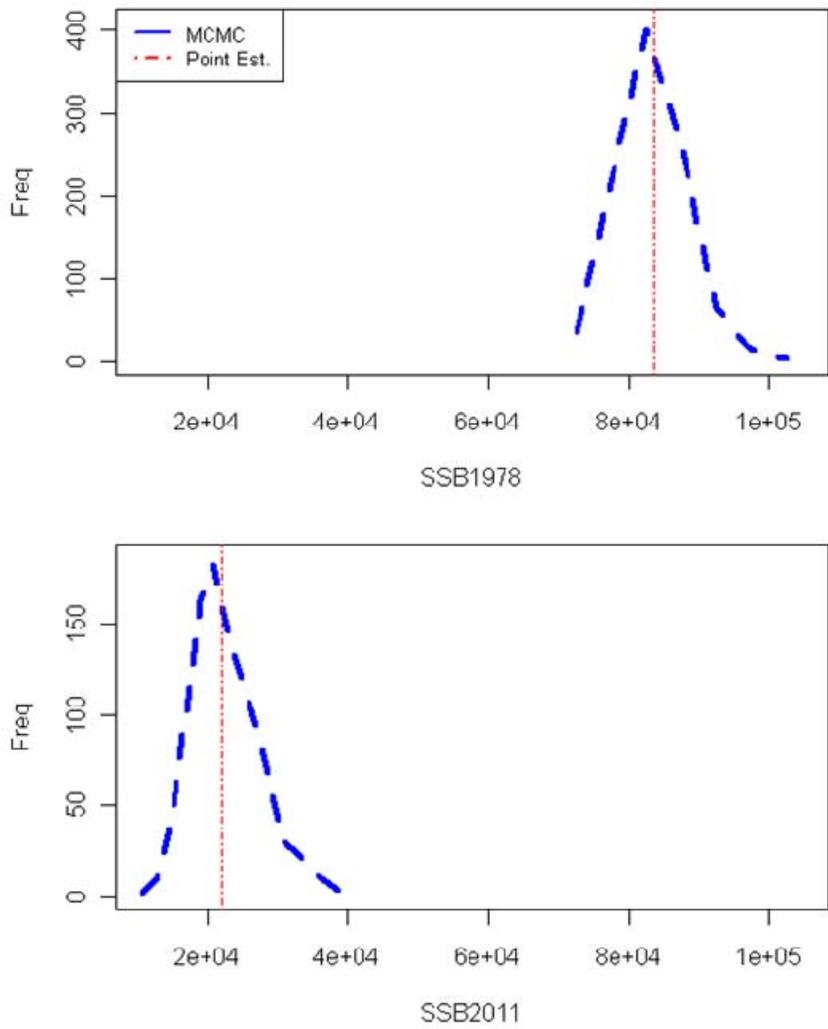
**Figure B5.** Standardized stratified mean number per tow of Atlantic cod in NEFSC spring, DFO, and NEFSC autumn research survey vessel bottom trawl surveys (NEFSC strata 13-25; DFO strata 5Z1-5Z8) on Georges Bank, 1963-2012.



**Figure B6.** MCMC distribution of Georges Bank Atlantic cod fishing mortality (ages 5+) in 1978 and 2011 estimated from the BASE ASAP model. The model point estimate is indicated by the dashed red line.



**Figure B7.** Spawning stock biomass (SSB-line) and recruitment (age 1-bar plot) for Georges Bank Atlantic cod, 1978-2011. The colored plus sign is the retrospective adjusted 2011 SSB and the white diamond with blue dot is the retrospective adjusted 2010 recruitment.



**Figure B8.** MCMC distribution of Georges Bank Atlantic cod spawning stock biomass in 1978 and 2011 estimated from the BASE ASAP model. The model point estimate is indicated by the dashed red line.