Appendix B.1.

Table 1. USA Management actions related to Georges Bank Atlantic Cod, 1953-2011.

Date	Regulatory Action	Cod end min. mesh size (in)	Minimum fish size (in)		Commercial trip limits-lbs	Recreational trip limits-lbs	Closures	Differential DAS Counting
			Commercial Inches (cm)	Recreational Inches (cm)				
1953	ICNAF era	4.5 inch						
1970					1*		2*	
1*	TAC regulations implemented for Div 5Zcod on an annual basis beginning in 1973-1986; set at 35,000 mt per year							
2*	Areas 1(A) & 2(B) Mar-Apr (haddock spawning season); 1972-1974 Areas 1(A) & 2(B) closure extended to March- May.							
1975							1A, 2B Feb-May	
1/1/77	Groundfish FMP MSCMA	5.125 inch	16 in. (40.6 cm)	16 in. (40.6cm)	Haddock 6,200, Cod 20,000	Haddock 6,200 cod 10,000	1*, 2*, 3*	
1*	Seasonal spawning closure (Areas 1 & 2)							
2*	69°55' W., 42°10' N.; 69°10' W.,41 °10' N.; 68°30' W., 41 °35' N.; 68°45' W.,41 °50' N.; 69°00' W., 41 °50' N.							
3*	67°00' W., 42°20' N.; 67°00' W.,41 °15' N.; 65°40' W., 41 o 15' N.; 65 °40' W.,42°00' N.; 66°00' W., 42°20' N.							
1/1/82	Interim Plan		17 (43.2)	15(38.1 cm)				
1/1/83		5.5 inch						
10/1/84	Hague Line							
8/30/85	Multispecies FMP	5.5 in. yr 1 & 2; 6 in. yr 3	17 yr 1; 19 yr 2+	15 yr 1; 17 yr 2 & 3; 19 yr 4+			Areas 1 & 2 closed Feb 1-May 31	
5/1/87							1*	
1*	Change regulated mesh area on GB to 69°00'W, then northward along 69°00'W to its intersection with LORAN 43450, then eastward along LORAN 43450 to the intersection with 68°00'W, then northward along 68°00'W to the intersection with LORAN 43500, then eastward as currently specified; Modify Closed Area I to overlap with distribution of mature female haddock; hook & line exempt from SNE closed area							
10/1/88		Postponed GB 6 in. increase	19 in (48.3 cm)	19 in (48.3 cm)				
1/1/89	Amendment 2	Eliminate 6 in. mesh increase	19 in (48.3 cm)	19 in (48.3 cm)				
4/1/92	Shrimp trawl fishery: Nordmore grate regulation, groundfish bycatch prohibited							
1993							Area 2 closure Jan 1-June 30	
1/3/94	Emergency Rule				Haddock 500		1*	
1*	Jan – May closure of CA II; CA II expanded; CA I closed to all vessels except sink gillnet; pair trawling ban							

Table 1. USA Management actions related to Georges Bank Atlantic Cod, 1953-2011.

Date	Regulatory Action	Cod end min. mesh size (in)	Minimum fish size (in)		Commercial trip limits-lbs	Recreational trip limits-lbs	Closures	Differential DAS Counting
			Commercial	Recreational				
5/1/94	Amendment 5	6 inch			1*		2*	3*
1*	Non-groundfish vessels limited to 500 lbs combined wt of 10 large mesh spp incl cod;							
2*	Haddock Area I closure suspended; Haddock Area II closure extended							
3*	DAS monitoring with reduction schedule, mandatory reporting							
5/1/94	Framework 3				Small mesh limited to lesser of 10% non-regulated GF or 500 lbs			
6/22/94	Amendment 6				Haddock 500 lbs limit			
8/2/94	Framework 6	Cultivator Shoal Whiting Fishery mesh increased to 3 in.						
12/12/94	Emergency Rule						CA I, CA II & Nantucket Lightship Area closed yr-round to all fishing incl scallop dredge	
3/6/95	Framework 9						*1	
1*	Closures in previous emergency action made permanent; recreational & charter boats permitted in Nantucket Lightship							
5/1/96	Amendment 7			20 in.				Accelerated DAS reduction
10/1/96	SFA							
2/20/97	Framework 21						1*	
1*	Gen cat scallop & limited access scallop vessels not under DAS allowed into Small Mesh Northern Shrimp Exemption Area if dredge or combined dredges <10.5 ft width							
5/1/97	Framework 20			21 in.	1*			
1*	Cod: 1000 lbs/ day for day 1-4 of trip, 1500 lbs/day 5+ of trip north of 4200'N; Haddock: 1000 lbs/trip from May 1 – Aug 31; Sept 1 1000 lbs/day, 10000 lbs/trip reverts to 1000 lbs limit when 1,150 mt projected							
9/5/97	Framework 24				1*			10 DAS carryover
1*	Haddock: 1000 lbs/DAS, 10000 lbs/trip from May 1 – Aug 31; Sept 1 3000 lbs/DAS, 30000 lbs/trip							
5/1/98	Framework 25						1*	
1*	WGOM (Jeffreys Ledge, Stellwagen Bank)							
2/1/99	Framework 26						1*	
1*	Additional month-block offshore closures for February & April							
5/1/99	Framework 27	6.5 sq/6.0 diamond			Haddock: 2,000/DAS, 20,000/trip			
6/15/99							Scallopers allowed limited access to Area 2	

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Date	Regulatory Action	Cod end min. mesh size (in)	Minimum fish size (in)		Commercial trip limits-lbs	Recreational trip limits-lbs	Closures	Differential DAS Counting
			Commercial	Recreational				
8/15/99	Framework 30				1*			
1*	2,000 lbs/DAS, 20,000 lbs/trip for vessels with GOM Cod Landing Limit Exception Authorization certificate							
11/5/99					Haddock: 5,000/DAS, 50,000/trip			
11/15/99	Amendment 9							
4/28/00	Framework 32						1*	
1*	Cultivator Shoal Whiting Fishery Exemption Area season shorted, 3 in. mesh							
5/1/00					1*		2*	
1*	Proposed SQ Trip limit: 2000 lb/ day, 20,000 lb/trip without trigger							
2*	Additional closures on Georges Bank for May only (109-114, 98-99), Adjacent to Area 1							
6/1/00	Framework 33	6.5 square/6.5 diamond						
11/1/00							1 month closure Cashes Ledge	
11/1/01					Haddock 5,000/DAS suspended from 11/6 to 3/1/ 2002, 50,000/trip			
2/27/02					1*			2*
1*	Haddock: 5,000 lbs/DAS reinstated, 50,000 lbs/trip until Apr 30, 2002, then 3,000 lbs/DAS, 30,000 lbs/trip							
2*	20 consecutive day block during which vessels will not fish under multispecies DAS between Mar 1 & May 31							
5/1/02	Interim Rule	6.5 diamond/sq cod end; 6.5 gillnet	22	23	1*	2*	3*	4*
1*	500 lbs/day (4000 lbs/trip); Haddock 3,000 lbs/DAS, 30,000 lbs/trip							
2*	10 cod or haddock combined/person							
3*	Additional month-block closures for May-June 2003; Cashes Ledge closed year round							
4*	20% reduction in DAS; First day of DAS trip counted as minimum of 15 hours; limited to 25% of annual DAS between May 1 – July 31;							
6/1/02	Revised interim rule		19				Cashes Ledge East & West removed	
7/4/02					1*			
1*	Haddock daily limit suspended; 30,000 lbs/trip between July 4, 2002 through Sept 30, 2002, 50,000 lbs/trip Oct 1 2002 to Apr 30, 2003							
8/1/02	Emergency Rule	1*	22			2*	3*	20% DAS reduction
1*	6.5 in. diamond or sq cod end from Aug 15, 2002; *Hook*: GB: 3,600 rigged hooks							
2*	Party/charter: 10 cod/haddock combined per person; Dec-Mar no more than 5 cod /person							
3*	Add GB seasonal closure areas, May- Blocks 80, 81, 118, 119, 120 (south of 42-20N)							

Table 1. USA Management actions related to Georges Bank Atlantic Cod, 1953-2011.

Date	Regulatory Action	Cod end min. mesh size (in)	Minimum fish size (in)		Commercial trip limits-lbs	Recreational trip limits-lbs	Closures	Differential DAS Counting
			Commercial	Recreational				
1/31/03								1*
1*	Emergency rule (implemented Aug 1, 2002) extended for another 180 days							
3/13/03					Haddock trip limit suspended from Mar 17 2003 to Apr 30 2003			
5/1/03				21	1*		2*	
1*	Haddock; daily landing limit suspended, 30,000/trip May 3- Sept 30, 2003 & 50,000/trip Oct 1, 2003 to April 30, 2004; Party/charter: GOM: Apr-Nov, 10 cod /person, Dec-Mar., 5 cod /person. Private: GOM: Dec-Mar., 10 cod/haddock combined, no more than 5 cod. Other areas: 10 cod/haddock combined							
2*	Extension of Cultivator Shoal whiting fishery by one month (June 15-October 31)							
6/27/03	Final Emergency Rule							Interim Measures published 8/1/02
10/1/03					Haddock trip limit suspended Oct 3, 2003 through Apr 30, 2004			
12/29/03	Emergency Rule (6/27/03) extended another 180 days							
1/31/04								1*
1*	Change Category B DAS used in CA II YTF SAP prior to Nov 19, 2004 (FW 40-A) to B Reserve DAS							
5/1/04	Amendment 13		22 inch		1,000/day 10,000/trip		1*	2*
1*	WGOM, Cashes Ledge & rolling closures continued							
2*	Further reduction in DAS; DAS leasing; SAP to catch U.S. share of EGB cod, haddock; GB Cod Hook Sector established; *US/Canada Area*: hard TAC on cod, haddock (SAs 561, 562), Cod possession limit: 500 lbs-DAS/5,000 lbs-trip, not more than 5 percent of catch. No DAS charged to/from SAs 561, 562; Leasing & transfer programs allow DAS exchanges between vessels under limited conditions							
5/14/04					Haddock suspended for remainder of FY 2014			
6/1/04							CL II SAP Yellowtail	
8/6/04					1*			
1*	YTF trip limit 1,500 lbs/day, 15,000 lbs/trip in western or eastern US/Canada Area including CAII YTF SAP area							
9/3/04							YT SAP closed	
10/1/04								1*
1*	Closure of SAs 561 & 562 to all fishing on a multispecies DAS							
11/2/04							1*	
1*	Scallop dredge vessel access to portions of groundfish mortality CAII & NLCA in 2004, CAI & CAII in 2005, & CAI & NLCA in 2006.							

Table 1. USA Management actions related to Georges Bank Atlantic Cod, 1953-2011.

	Season: June 15 -Jan 31. Possession limits: 1,000 lbs. regulated groundfish, no more than 100 lbs. cod.							
Date	**Regulatory Action**	**Cod end min. mesh size (in)**	**Minimum fish size (in)**		**Commercial trip limits-lbs**	**Recreational trip limits-lbs**	**Closures**	**Differential DAS Counting**
			Commercial	**Recreational**				
11/19/04							1*	DAS counted as EST not GMT on VMS
1*	*Eastern US/CA Area Haddock SAP Pilot Program* Access to northern corner of CAII & adjacent area to target haddock using separator trawl. Season: May 1 through December 31. Authorized use of Category B DAS; CA II YTF SAP cod possession limit 1,000 lbs/trip, B DAS prohibition of legal size cod.							
1/13/05							1*	
1*	Eastern US/Canada Area to limited access DAS vessels, YTF 15,000 lbs/trip, cod 5,000 lbs/trip in this area							
2/7/05					YTF 5,000 /trip			
4/1/05							Eastern US/Canada Area closed until Apr 30, 2005	
4/22/05	1*				2*		3*	4*
1*	Return to Amd 13 regs unless modified in FW 40-A							
2*	GB cod: 500 lbs/DAS or 5,000 lbs/trip in Eastern US/Canada area, 1,000 lbs/DAS, 10,000 lbs/trip in Western US/Canada Area; GB haddock: 3,000 lbs/DAS, 30,000 lbs/trip; GB YTR no possession outside of SAP							
3*	May 1, 2005 Eastern US/Canada reopens to all limited access DAS vessels; Western; CA II YTF SAP: GB YTF 30,000/trip, GB cod 1,000 lbs/trip							
4*	Regular B DAS Pilot Program: GB cod 100 lbs/DAS, 1,000 lbs/trip							
5/3/05					Haddock trip limits suspended			
6/1/05					1*			DAS transfer program revisions
1*	CA II YTF Sap revisions: GB YTF 10,000 lbs/trip, 1 trip/month							
6/28/05							No trips into the CA II YTF SAP for FY 2005	
7/12/05	Temporary rule						1*	
1*	DAS vessels limited to one trip/month into Eastern US/Canada Area until Apr 30, 2006; limited access DAS vessels required to use haddock separator trawl in the area							
7/18/05								1*
1*	Prohibited use of regular B DAS under regular b DAS pilot program in GB cod stock area through 7/31/05							

Table 1. USA Management actions related to Georges Bank Atlantic Cod, 1953-2011.

Date	Regulatory Action	Cod end min. mesh size (in)	Minimum fish size (in)		Commercial trip limits-lbs	Recreational trip limits-lbs	Closures	Differential DAS Counting
			Commercial	Recreational				
8/26/05							1*	
1*	Eastern US/Canada Area closed to all limited access DAS vessels until Apr 30, 2006							
9/13/05	Framework 41						1*	
1*	CA I Hook Gear Haddock SAP: allows non-Sector vessels into SAP on B DAS between Nov 16 & Dec 31, 2005, cod: 1,000 lbs/trip; GB cod hook sector: Oct 1 – Nov 15 can't fish inside & outside SAP on same trip							
10/3/05								1*
1*	Prohibition the use of Regular B DAS under Regular B DAS pilot program from Oct 6, 2005 to Oct 31, 2005							
12/21/05					GB YTF 15,000 lbs/trip			
2/9/06					GB YTF 1,500 lbs/day up to 15,000 lbs/trip			
2/22/06					GB YTF daily trip limit removed, 15,000 lbs/trip			
3/24/06					No trip limit for GB YTF for limited access DAS vessels in US/Canada Management Area			
3/30/06	Control Date established for charter & party recreational fishery							
5/1/06					1*			2*
1*	GB YTF 10,000 lbs/trip; GB winter flounder 5,000 lbs/trip;							
2*	Differential DAS counting for A DAS outside of US/Canada management area (1.4 DAS for each day fished); modified cod running-clock provision – can land additional cod but 24 – 34 hour trip charged 48 DAS use, trips > 34 hours charged 1.4:1 DAS.							
5/19/06							CA II YTF SAP closed through Apr 30,2007	
6/19/06							DAS vessels in Eastern US/Canada Area must use haddock separate trawl	
10/6/06	Emergency Rule (5/1/06) extended until 4/4/07							
11/22/06	Framework 42			GOM: 24; GB: 23	1*			DAS counted 2:1 in inshore GOM
1*	Possession prohibited November to March 31; GOM cod: 800 lbs/day, 4,000 lbs/trip; GB cod: 1,000 lbs/DAS, 10,000 lbs/trip; Eastern GB cod: 500 lbs/DAS, 5,000 lbs/trip							
2/28/07	Revised protocol for measuring net mesh size							

Table 1. USA Management actions related to Georges Bank Atlantic Cod, 1953-2011.

Date	Regulatory Action	Cod end min. mesh size (in)	Minimum fish size (in)		Commercial trip limits-lbs	Recreational trip limits-lbs	Closures	Differential DAS Counting
			Commercial	Recreational				
3/5/07					1*		2*	
1*	GB YTF 5,000 lbs/trip for non haddock separator trawl trips							
2*	In Eastern US/Canada are fish with haddock separator trawl or flounder trawl							
4/5/07					GB YTF 25,000 lbs/trip			
4/25/07							Eastern US/Canada Area closed to limited access DAS vessels	
5/1/07					GB YTF 3,000 lbs/trip in US/Canada Management Area			
6/4/07							CA II YTF SAP closed for FY 2007	
8/9/07	Emergency Action		Haddock GOM: 18 GB: 18	Haddock GOM: 19 GB: 19				
10/20/07					1*		2*	
1*	GB cod: 1,000 lbs/trip in Eastern Us/Canada Area or Eastern US/Canada Haddock SAP							
2*	Eastern US/Canada Area open to limited access DAS vessels until Nov 30, 2007							
11/27/07					GB YTF 7,500 lbs/trip			
1/10/08					GB YTF 1,500 lbs/trip			
1/24/08					GB YTF possession prohibited			
3/28/08							Eastern US/Canada Area access delayed until Aug 1, 2008 except for longline gear vessels	
5/1/08					GB YTF 5,000 lbs/trip for limited access DAS vessels in US/Canada Management Area			
5/30/08							Zero trips in CA II YTF SAP for FY 2008	
8/11/08			Haddock GOM: 19 GB: 19					
10/23/08					GB YTF 2,500 lbs/trip for limited access DAS vessels in US/Canada Management Area			
12/23/08					EGB cod: 1,000 lbs/DAS, 10,000 lbs/trip for vessels fishing exclusively in Easter US/Canada Area			
2/26/09				GOM cod: 24	EGB cod: 1,000 lbs/DAS, 10,000 lbs/trip			

Table 1. USA Management actions related to Georges Bank Atlantic Cod, 1953-2011.

Date	Regulatory Action	Cod end min. mesh size (in)	Minimum fish size (in)		Commercial trip limits-lbs	Recreational trip limits-lbs	Closures	Differential DAS Counting
			Commercial	Recreational				
3/9/09					EGB 500 lbs/DAS, 5,000 lbs/trip; GB YTF 5,000 lbs/trip			
4/6/09	Interim Rule		Haddock: 18	Haddock: 18	1*	2*		
1*	GB cod 1,000 lbs/DAS, 10,000 lbs/trip; Eastern US/Canada Area 500 lbs/DAS, 5,000 lbs/trip							
2*	Charter/party vessels: GB cod trip limit of 10 cod/person/day							
4/16/09							Eastern US/Canada Area closed to limited access DAS vessels for remainder of FY 2008	
5/1/09	Interim rule				Possession prohibited November to April 15			
6/3/09					GB YTF 2,500 lbs/trip for limited access DAS vessels in US/Canada Management Area			
6/24/09							Eastern US/Canada Area closed	
3/24/10					GB YTF 5,000 lbs/trip for limited access DAS vessels in US/Canada Management Area			
5/1/10	Amendment 16				1*		2*	3*
1*	2,000 lbs/DAS, 20,000 lbs/trip; Common pool: 800 lbs/day (4000 lbs/trip)							
2*	Some changes to rolling closures for sector vessels							
3*	DAS counted in 24-hour blocks; no differential DAS counting except as AMS; reduction in DAS							
7/30/10					Common pool: 200 lbs/day (1000 lbs/trip)			
10/18/10					Common pool: GOM & GB cod 50lbs/trip			
9/22/10					Common pool: 100 lbs/day (1000 lbs/trip)			
10/18/10					Handgear A: 50 lbs/trip			
3/31/11					GB cod: 3,000 lbs/DAS, 30,000 lbs/trip until Apr 30, 2011			
4/19/11					1*			2*
1*	Common pool: 3,000 lbs/DAS, 30,000 lbs/trip (outside of Eastern US/Canada Area), 500 lbs/DAS, 5,000 lbs/trip (inside E. US/Canada Area)							
2*	Common pool: A DAS charged at rate of 1.3: 1 or 31.2 hours for each DAS							
8/30/11					Common Pool: 300 lbs/DAS, 600 lbs/trip			
9/8/11								1*
1*	Differential DAS for Offshore GOM & Inshore GB reduced to 1.2; Offshore GB remains 1.3							
10/3/11					Common pool under Handgear B permit: 25 lbs/trip			

Appendix B.1. Table 2. Canadian fishery management history of cod on eastern Georges Bank, 1978-2011.

1978 Foreign fleets were excluded from the 200 mile exclusive economic zones of Canada and USA;
1984 Oct. Implementation of the maritime boundary between the USA and Canada in the Gulf of Maine Area;
1985 5Z cod assessment started in Canada Set TAC; TAC=25,000mt
1986 TAC=11,000mt
1987 TAC=12,500mt
1988 TAC=12,500mt
1989 TAC=8,000mt 5Zjm cod assessment
1990 Changes to larger and square mesh size; Changes from TAC to individual and equal boat quotas of 280,000lb with bycatch restrictions; Temporary Vessel Replacement Program was introduced
1991 TAC=15,000mt Dockside monitoring Maximum individual quota holdings increased to 2% or 600t(whichever was less)
1992 TAC=15,000mt Introduction of ITQs for the OTB fleet
1993 TAC=15,000mt, ITQ for the OTB fleet not based on recommended catch quotas; OTB <65 fleet was allowed to fish during the spawning season (Mar.–May. 31).
1994 TAC=6,000mt, Spawning closures January to May 31; Mesh size was 130mm square for cod, haddock an Pollock for ITQ fleet; Minimum mesh size of 6" was required for gillnets; Minimum fish size is 43cm (small fish protocols) for cod, haddock an Pollock for ITQ fleet; OT> 65' could not begin fishing until July 1; Fixed gear must choose to fish either 5Z or 4X during June 1 to September 30.
1995 TAC=1,000mt as a bycatch fishery; January 1 to June 18 was closed to all groundfish fishery; 130mm square mesh size for all mobile fleets; Small fish protocols continued; 100% dock side monitoring; Fixed gear vessels with a history since 1990 of 25t or more for 3 years of cod, haddock, Pollock, hake or cusk combined can participate in 5Z fishery.
1996 TAC=2,000mt; Prohibition of the landing of groundfish (except monkfish) by the scallop fishery; ITQ vessel require minimum 130mm square mesh for directed cod, haddock and Pollock trips; Small fish protocols continued; For community management, quota allocation of each fixed gear based on catch

history using the years 1986-1993; 100% mandatory dockside monitoring and weighout.
1997 TAC=3,000mt
1998 TAC=1,900mt
1999 TAC=1,800mt; Mandatory cod separator panel when no observer on board; Jan. and Feb. mobile gear winter Pollock fishery.
2000 TAC=1,600mt Jan. and Feb. mobile gear winter Pollock fishery
2001 TAC=2,100mt
2002 TAC=1,192mt
2003 TAC=1,301mt;
2004 TAC=1,000mt; Canada-USA resource sharing agreement on Georges Bank.
2005 TAC=740mt; Exploratory winter fishery Jan. to Feb. 18, 2005; Spawning protocol: 25% of maturity stages at 5 and 6.
2006 TAC=1,326mt; Exploratory winter fishery Jan. to Feb.6, 2006; Spawning protocol: 30% of maturity stages at 5 to 7.
2007 TAC=1,406mt; Exploratory winter fishery Jan. to Feb. 15, 2007; High mobile gear observer coverage (99%); Spawning protocol: 30% of maturity stages at 5 to 7.
2008 TAC=1,633mt; Winter fishery from Jan.1 to Feb. 8, 2009; At sea observer coverage 38% by weight of the mobile gear fleet landings and 21% by weight of the fixed gear landings; Spawning protocol: 30% of maturity stages at 5 to 7.
2009 TAC=1,173mt; Winter fishery from Jan. 1 to Feb. 21, 2009; At sea observer coverage 23% by weight of the mobile gear fleet landings and 15% by weight of the fixed gear landings; Spawning protocol: 30% of maturity stages at 5 to 7.
2010 TAC=1,350mt; Winter fishery from Jan. 1 to Feb. 8, 2010; At sea observer coverage 18% by weight of the mobile gear fleet landings and 6% by weight of the fixed gear landings;

Spawning protocol: 30% of maturity stages at 5 to 7.
2011 TAC=1,050mt; Winter fishery from Jan. 1 to Feb. 5, 2011; At sea observer coverage 19% by weight of the mobile gear fleet landings, 20% by weight of the fixed gear landings and 3% by weight of the gillnet fleet landings; Spawning protocol: 30% of maturity stages at 5 to 7.

Appendix B.2
Swept area estimates for NEFSC spring, autumn, and DFO surveys.

	AGE									
SPRING	1	2	3	4	5	6	7	8	9	10+
1978	478	247	7111	1249	1042	140	916	67	182	140
1979	541	1656	364	2406	681	280	121	167	13	45
1980	40	2846	3469	273	2220	487	197	40	39	123
1981	2960	2381	3630	2182	136	1098	332	170	0	145
1982	694	7425	12980	11372	8481	400	2549	503	342	47
1983	453	2666	4121	1088	952	605	37	299	0	188
1984	549	589	1039	1691	577	547	285	0	293	0
1985	152	3624	906	1517	1929	363	262	246	50	220
1986	1191	559	2520	499	738	844	84	171	139	21
1987	27	2203	517	1043	85	245	185	45	36	34
1988	984	832	4303	558	879	87	51	67	0	9
1989	424	1927	910	2163	321	480	69	54	75	127
1990	237	1259	2373	921	1246	178	195	18	22	37
1991	1402	721	941	1269	654	448	74	55	0	61
1992	168	1711	640	230	373	195	217	27	51	38
1993	12	545	1784	280	122	189	40	47	28	75
1994	170	372	273	296	45	8	60	0	26	0
1995	68	521	1166	729	818	146	304	53	30	0
1996	100	292	1006	1704	238	285	38	25	0	0
1997	397	597	233	667	577	68	183	27	0	0
1998	152	909	1773	1158	1031	728	139	42	0	0
1999	290	397	832	696	325	163	87	32	20	0
2000	301	1102	1134	1559	506	140	35	27	0	0
2001	83	320	1084	219	523	241	32	24	17	0
2002	88	127	524	1357	327	307	53	0	0	38
2003	22	289	361	839	963	106	104	14	0	0
2004	870	79	791	1921	1850	1219	244	357	18	0
2005	16	661	188	862	375	280	174	41	0	0
2006	244	316	1784	453	988	291	166	74	0	0
2007	171	873	513	2450	247	286	42	25	0	0
2008	864	1136	790	480	1312	52	61	0	0	0
2009	843	477	787	383	204	339	23	12	13	0
2010	141	795	500	792	195	45	169	0	12	0
2011	99	354	247	386	191	69	10	24	0	0
2012	38	471	715	773	195	134	24	0	0	0

	AGE					
Autumn	1	2	3	4	5	6
1978	2553	347	5700	1334	482	212
1979	2206	2291	221	2304	438	251
1980	1120	770	1057	72	369	71
1981	4818	3004	2083	1032	83	818
1982	760	2609	330	93	157	0
1983	1160	1488	1011	94	45	6
1984	2608	931	1269	1127	33	81
1985	253	1146	91	145	96	17
1986	3087	176	423	38	67	99
1987	565	1848	148	274	38	16
1988	1195	597	1235	82	265	0
1989	3823	1429	220	693	75	21
1990	497	2219	2478	563	390	53
1991	557	239	375	42	40	0
1992	563	1296	238	137	60	13
1993	1325	726	523	23	35	30
1994	554	907	592	210	93	29
1995	334	2473	1706	119	74	14
1996	328	267	566	195	82	36
1997	323	438	149	176	66	12
1998	458	1402	481	56	48	5
1999	191	211	423	348	119	0
2000	794	721	96	108	42	0
2001	64	520	627	81	75	11
2002	652	966	1907	2223	161	179
2003	196	447	283	212	111	0
2004	1017	186	970	344	439	345
2005	76	792	176	240	35	0
2006	591	221	702	46	170	20
2007	157	283	69	178	9	9
2008	533	848	242	15	152	48
2009	1758	879	487	100	35	50
2010	524	802	177	185	86	0
2011	644	943	369	236	122	19

	AGE									
DFO	1	2	3	4	5	6	7	8	9	10+
1986	844	3195	3955	521	915	619	366	56	99	42
1987	354	2993	1294	1534	466	164	298	104	41	99
1988	392	1396	6567	825	1438	182	109	245	63	72
1989	2146	3805	1896	3951	510	588	65	134	168	92
1990	637	3686	5422	2967	5478	596	1313	163	163	489
1991	1650	1635	2586	3011	1467	1830	219	312	46	127
1992	155	4025	2491	1126	1379	844	605	169	99	28
1993	*70*	*844*	*3983*	*1464*	*873*	*1731*	*619*	*591*	*99*	*169*
1994	*28*	*1126*	*1253*	*2322*	*844*	*324*	*633*	*155*	*211*	*56*
1995	99	943	2111	1210	844	267	56	70	28	28
1996	197	690	3251	5658	1534	1112	464	113	155	42
1997	450	746	774	1759	1731	380	84	42	28	14
1998	14	943	1337	493	493	394	99	28	6	28
1999	458	449	2092	1530	570	364	205	10	34	7
2000	142	619	1484	5478	2452	1116	546	340	20	33
2001	3	80	899	587	1559	731	365	235	231	73
2002	13	122	806	2887	962	1718	564	232	69	110
2003	0	31	419	912	1707	447	474	228	20	0
2004	754	134	552	596	635	545	104	165	28	10
2005	34	2013	873	3780	1701	739	456	37	19	0
2006	0	43	1695	747	1925	804	231	230	85	60
2007	170	642	1168	3635	480	748	119	94	53	4
2008	12	455	1260	836	3069	196	397	41	4	20
2009	42	330	2769	2457	513	2937	0	82	0	18
2010	5	144	1101	4671	2060	813	2119	75	98	5
2011	180	612	942	1100	1406	267	68	111	13	6
2012	*9*	*174*	*405*	*350*	*203*	*164*	*8*	*17*	*4*	*0*

Appendix B.3
Alternative ASAP Models

M Ramp
Natural mortality was profiled over historical and recent time series, to inform the WG discussion on whether there has been a long term change in M. Profiling of M over the time series (1978-2011) indicated little change in the ASAP objective function for M values between 0.1-0.5, however, the objective function (OF) increased for values greater than 0.6 (Appendix Figure B3.1). Profiling of M during 1978-2002 resulted in an increasing value in the OF as M increased from 0.1 to 0.9 (Appendix Figure B3.2). A profile of M during 2003-2011 resulted in the lowest OF at M=0.3 and M=0.4, with as increase in the OF for values of M = 0.2, 0.5 and 0.6 (Appendix Figure B3.3). The retrospective bias of the M=0.4 model was less than that of the M=0.3 model. Based on the M profile results and discussions centered on the Miller (2012) analysis of 2003-2006 tagging data, the WG agreed that an ASAP model formulation with changing M over the recent time period would be presented . In this formulation (MRamp) M=0.2 during 1978-1989 and M=0.4 during 2003-2011. The years in between, 1990-2002 ramp up from 0.2 to 0.4 by (0.4-0.2)/13 years.

Results from the MRamp model indicate higher SSB and lower F in recent years compared to the Base model results (Appendix Figure B3.4). The terminal year estimates are very similar, however, in both models. The retrospective analysis shows less bias than the Base model with a SSB rho = 0.053 and the F rho = 0.088 (Appendix Figure B3.5). The Mramp model, however, has a retrospective pattern early in the time series which is not seen in the Base model.

Catch Multiplier
The catch multiplier model (Catmult) incorporates all the unaccounted for mortality, either natural or fishing, that would need to be accounted for in order to provide population estimates with little or no retrospective bias. A profile of catch multipliers, ranging from one-half to three times the current catch estimates for two time periods (1978-1994, 1995-2011) were evaluated relative to the retrospective bias in SSB and F measured by the rho value. The results indicate that the lowest retrospective bias would be achieved in the 1978-1994 time period if the catch were reduced by one-half, or in the 1995-2011 time period the catch were increased by three times (Appendix Figure B3.6). The WG agreed to evaluate a model that incorporated a three-fold increase in catch during the 1995-2011 time period.

Results from the Catmult model indicate higher SSB than the Base model starting in about 1985 (Appendix Figure B3.7). Fishing mortality is also higher than the Base model, and as expected F is lower F than the Base model, prior to 1995. The Catmult retrospective analysis shows less bias for SSB (rho = -0.053) and F (rho = 0.075) than the Base model (Appendix Figure B3.8).

Support for and against Alternative Assessment Models
While the SAW 55 WG could not reach consensus on which model should serve as the basis of current stock status determination and management advice, it agreed that the 'newly proposed model' (TOR 7) should be that of each lead scientist, which in this case is the M = 0.2 model (referred to as the Base formulation). Notwithstanding this, the WG concurred that lack of

consensus should not be interpreted as implying equal support for the models and developed pros and cons of the main features of each model to indicate their relative level of support.

BASE M Constant (M=0.2)

The features that lend support to the assumption of M has remained constant throughout the time series are those features which do not support the M ramp assumption, which is discussed below. The main feature against the assumption of constant M is the presence of a strong retrospective pattern.

M Ramp

One of the main features supporting the assumption of a recent change in natural mortality is that it employs an M (0.4) which is generally consistent with the results of the 2003 – 2006 Northeast Regional Cod Tagging Program (NRCTP) data and associated analyses (if one assumes a 50% reporting rate of high reward tags). The tagging analysis indicated that M could be as high as 0.6. Tag reporting rates would have to be very low in order to be consistent with an M of 0.2. Another line of support for this assumption is the model fits. The value of the objective function for the M ramp model was lower (by 10 log-likelihood points depending) than that of the constant M model. Further, compared to the constant M model, assuming that M had changed more recently resolves the retrospective pattern.

The final observation supporting a recently elevated M in Gulf of Maine Cod is evidence of increasing M in the adjacent NAFO Div. 4X cod stock, this based on both tagging analyses and assessment model fits.

A number of features don't lend support to a recently increasing M. There is no evidence for increased predation, either by fish or pinnipeds, in the diet compositional data collected by the NEFSC. Regarding the analysis of the NRCTP tagging data, if reporting rates of high reward tags were less than 50%, M would be less than 0.4. It is unfortunate that there are little or no historical tagging studies to which these results could be compared. Besides using different assumptions, these earlier studies did not formally incorporate parameters to estimate movement. For these reasons, the tagging studies which suggested higher (than 0.2) M in 4X may not apply to Georges Bank Cod (SAW 55 WG, 2012a).

Regarding model fits, the likelihood profile of M for the 2004 - 2011 period was relatively flat, with estimates between 0.3 and 0.4 potentially possible. Exploratory runs indicated that M profiling was sensitive to which years to include in the recent period of high M.

The final lines of evidence against a recently elevated M relate to the life history information. Condition, while declining in the spring, is stable in the autumn which does not suggest increased mortality. Maturity at age has increased over the last decade, suggesting a decreasing total mortality. Since fishing mortality over this period has declined, this trend in maturity potentially suggests a constant M. Meta-analyses of life history parameters suggest an M of 0.2 – 0.3 with no trend over time.

Catch Multiplier

One of the features in support of increasing recent catches by 300% is that it resolves the retrospective pattern. Unreported discards may have been substantial prior to 2010 and sector

management.
One of the features that does not lend support to increased recent catches is the lack of evidence on substantial under-reporting of the landings. Regarding model fits, the value of the objective function is the highest for the Catch Multiplier model, being 29 log-likelihood points higher that of the base formulation.

Yield per Recruit Analysis

MRamp Model – YPR

A YPR analysis for the MRamp model used the same input as the Base ASAP except that the average M for the last 5 years was 0.4 instead of 0.2 (Appendix Table B3.1). Results of the YPR analysis are presented in Appendix Table B3.2.

The replacement line analysis indicated that $F_{40\%}$ may not be an appropriate F_{MSY} proxy for MRamp model results given that F would have to decrease to as low as $F_{80\%}$ (0.07) to ensure adequate replacement (Appendix Figure B3.9). This was due to the constraint imposed by Z. As M increases, F must decrease. The WG considered that this F_{MSY} proxy is likely too low and is inconsistent with commonly used ranges of percent spawner per recruit for BRPs and estimates of $SSBmsy/SSB_0$ where these can be obtained for specific stocks or from meta-analyses. It noted however, that F_{MED} and F_{MEAN} for the 2001 – 2011 stock – recruit data were $F_{40\%}$ and $F_{50\%}$ respectively. The WG agreed to adopt the $F_{50\%}$ (0.29) proxy based upon the need for a more conservative approach when M is assumed to be high.

Non-parametric estimates of MSY and SSB_{MSY} based on $F_{50\%}$ were estimated using the 33-year time series mean recruitment (16,460 million age1 fish), Y/R (0.53) and SSB/R (2.27) (Appendix Table B3.3) as: $F_{50\%} = 0.29$, MSY = 8,730 mt, $SSB_{MSY} = 37,412$ mt.

Catmult Model – YPR

A YPR analysis for the Catmult model would have the same input as the Base ASAP model (Appendix Table B3.1). Results of the YPR analysis are presented in Appendix Table B3.2.

Although the absolute magnitude of SSB and recruitment estimates from the Catmult model has increased compared to the BASE model results, the relative magnitude is essentially the same; the scatterplot of SSB and recruitment look similar. Thus, the analysis of replacement lines under recent productivity indicated similar results to the Base model. About 90% of the years were above the $F_{40\%}$ replacement line such that $F_{40\%}$ would be an appropriate F_{MSY} proxy for this model (Appendix Figure B3.10).

Non-parametric estimates of MSY and SSB_{MSY} based on $F_{40\%}$ were estimated using the 33-year time series mean recruitment (19,095 million age 1 fish), Y/R (1.28) and SSB/R (7.89) (Appendix Table B3.3) as: $F_{40\%} = 0.18$, MSY = 150,685 mt, $SSB_{MSY} = 24,424$ mt.

MSY Biological Reference Points

MRamp– Long-term Stochastic Projection

Long term stochastic projections were run using the same input data as the YPR for 100 years with $F_{MSY} = 0.29$. As described for the Base model, recruitment was estimated from a 2 stage CDF and in this case, with a cut-point of 41,500 mt, with either a CDF of 20 low estimates or a CDF of 13 high estimates of age 1 recruitment. The long term projection provided the following non-parametric biomass reference points (Appendix Table B3.3):

$F_{50\%} = 0.29$,
MSY = 5,740 mt, (80% CI: 4,585 – 6,986)
SSB_{MSY} = 24,596 mt (80% CI: 19,559 - 30,043)

Catmult Model – Long-term Stochastic Projection
Long term stochastic projections were run using the same input data as the YPR for 100 years with F_{MSY} = 0.18. In this case, there was no evidence of a breakpoint in the stock – recruitment data and thus WG agreed that the projections sample recruitment from the entire stock – recruit time series. The long term projection provided the following non-parametric biomass reference points (Appendix Table B3.3):

$F_{40\%}$= 0.18,
MSY = 23,995 mt, (80% CI: 19,352- 29,464)
SSB_{MSY} = 146,288 mt (80% CI: 118,159 – 179,049)

Projections
Short term stochastic projections under F = 75%F_{MSY} were performed from the MRamp and Catmult model results to estimate landings and SSB during 2013-2015. The input values for mean catch and stock weights, PR, and maturity are the same as described above for the YPR analysis. Recruitment was estimated from the 2-stage CDF described above and associated with a SSB breakpoint of 41,500 mt for MRamp model and for the complete times series of empirical recruitment for the Catmult model . Catch in 2012 was estimated based on year-to-date catch (commercial and recreational landings and discards) and assumed catch for the remainder of the year (pers. comm. Tom Nies, NEFMC).
Consequence Analysis
The risks associated with management actions taken during 2013 – 2015 were examined by undertaking stock projections under the competing assumptions of the state of nature. For instance, if the true state of nature is that natural mortality has remained unchanged at 0.2 and that stock productivity is best reflected by the M = 0.2 model, then the consequences of management actions taken by setting projected catch according to 75% F_{MSY} based on the two alternative states of nature (M ramp and Catch Multiplier) were examined. Data input is as described above. Since these are short term projections, any longer-term consequences would be revealed through a more extensive analysis. This is beyond the current terms of reference.
The column headers in Appendix Tables B3.4 and B3.5 and Appendix Figure B3.11 represent the 'true' states of nature, these being

- Base: M = 0.2 (adjusted for the retrospective pattern)
- Mramp: M ramped from 0.2 to 0.4 during 1990 – 2002
- Catch Mult: recent catch, since 1995, increased by 300%

The row headers in Appendix Table B3.4 indicate the basis of the management action during the projected period (2013 – 2015).Thus, the row header 'M ramp' indicates that catch was projected assuming that the stock conditions and reference points were as per these dynamics. The cells of the table indicate the SSB and F_{full} which are a consequence of applying the catch based on the assumed state of nature to the SSB of the 'true' state of nature. The diagonal rows represent the situation in which the management actions based upon the assumed state of nature are in fact correct.

The consequence analysis is summarized in Appendix Figure B3.11. As with Appendix Table B3.4, the column headers indicate the management model or one of the 'true' states of nature. The row headers indicate whether or not catch, SSB or F_{full} is being displayed along the row. The content of each cell summarizes the consequences of assuming one state of nature when another is true. The black line in each cell indicates the catch, SSB and F_{full} for the 'true' state of nature. The coloured lines (for the projected period only) indicate the catch, SSB and F_{full} which result when the 75% F_{MSY} estimated catch is incorrectly based upon an alternate state of nature. The dashed lines in each figure are the B_{MSY}, F_{MSY} and MSY for the 'true' states of nature. The reference points associated with the 'true' states of nature are indicated in Appendix Table B3.4.

When management actions are correctly based upon a particular state of nature (the diagonals of Appendix Table B3.4), an increase in SSB is projected until 2015 for the three options, this particularly the case for Catch Mult. The 2012 SSB estimates range 18,184 to 43,863 mt across the three options. Fishing at 75% F_{MSY} , catch increases from 2,910 to 3,265, 4,556 and 3,275 mt for the base, Mramp and catch mult options, respectively. If the management actions are correctly based upon the 'true' state of nature, the base and catch mult models indicate that, in 2013, the stock is in an overfished state (Appendix Table B3.5). In contrast, the MRamp model indicates that the stock would not be in an overfished state in 2013. In all cases, overfishing is not occurring.

In regards to the consequences of mis-specifying the state of nature, there is little impact on the absolute estimate of SSB (but not status), although assuming an M ramp when increased recent catch is true results in less than 'planned' growth in SSB (Appendix Figure B3.11). Assuming an Mramp when either of the other models is true also has significant implications for 2013 F_{FULL} and catch. In each case, catch would be higher than 'planned', resulting in higher than 'planned' catch. The consequences of assuming the base and catch mult models when Mramp is true are relatively modest in absolute terms. However, due to the changes in the reference points, the 2013 status changes depending on the basis of the management action and the state of nature (Appendix Table B3.5).

If the Base model is the true state of nature, assuming increased recent catch when setting catch will result in the same status (overfished but not overfishing) while assuming Mramp when setting catch will result in being overfished and overfishing. If the Mramp is the true state of nature, assuming either of the other options when setting 2013 – 2015 catch will not change status (not overfished and no overfishing). If catch mult is the true state of nature, while status does not change if setting catches is based upon the base option (not overfished and no overfishing), status changes to overfished and overfishing if catch are based upon the M ramp option.

In summary, the base option is the most sensitive of the three to setting 2013 -2015 catch according to the alternate states, while the Mramp option is the least sensitive.

Appendix Table B3.1. Input data for yield-per-recruit and projection analysis computed from 5-year averages of 2007-2011 data.

Age	ASAP selectivity	selx on M	stk wt	catch	spw stk wt	% mature
1	0.01	1	0.221	0.397	0.221	0.02
2	0.11	1	0.738	1.407	0.738	0.27
3	0.51	1	1.750	2.219	1.750	0.85
4	0.90	1	2.547	2.953	2.547	0.99
5	0.99	1	3.304	3.664	3.304	1.00
6	1.00	1	4.043	4.482	4.043	1.00
7	1.00	1	4.924	5.431	4.924	1.00
8	1.00	1	6.185	6.666	6.185	1.00
9	1.00	1	7.487	8.375	7.487	1.00
10	1.00	1	11.352	11.352	11.352	1.00

Appendix Table B3.2. Yield-per-recruit (YPR) analysis results: spawning stock biomass per recruit (SSB/R), total stock weight per recruit (TSB/R), mean age and mean generation time (mn gen) at four fishing mortality rates for the MRamp and CatMult ASAP models.

MRAMP

Reference	F	YPR	SSBR	TSBR	mean age	mn gen
F zero	0.00	0.00	4.54	5.55	3.03	4.71
F-01	0.46	0.63	1.79	2.72	2.21	3.47
F-Max	4.37	0.82	0.39	1.21	1.64	2.45
F40%	0.45	0.62	1.81	2.74	2.22	3.48
F50%	0.29	0.53	2.27	3.22	2.37	3.73

CatMult

Reference	F	YPR	SSB/R	TSB/R	mean age	mn gen
F zero	0.00	0.00	19.72	21.24	5.52	7.29
F-01	0.18	1.28	7.81	9.14	3.54	4.98
F-Max	0.46	1.43	3.75	4.96	2.70	3.91
F40%	0.18	1.28	7.89	9.22	3.55	5.00

Appendix Table B3.3. Biological reference points based on yield-per-recruit (YPR) analysis and long term projection of F_{MSY} proxies for the MRamp and Catmult ASAP model results.

MRAMP

Model	F40%		Y/R	SSB / R	Recruitment	SSBmsy	MSY
YPR -F40%	0.45		0.62	1.81	16,460	29,867	10,212
YPR -F50%	0.29		0.53	2.27	16,460	37,412	8,730
Projection (CDF >50K)	13 values	F40%			23,904	19,579	6,717
Projection (CDF >50K)	13 values	F50%			23,904	24,596	5,740

CatMult

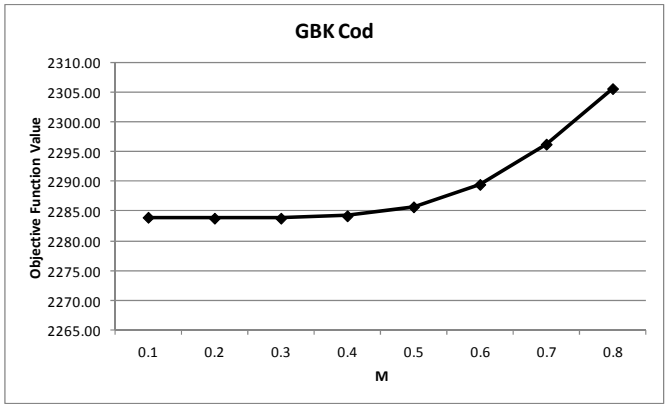
Model	F40%	Y/R	SSB / R	Recruitment	SSBmsy	MSY
YPR	0.18	1.28	7.89	19,095	150,685	24,424
Projection	33 values			19,095	146,288	23,995

Appendix Table B3.4. Projection of spawning stock biomass (SSB), fishing mortality (F), and catch during 2013 -2015 of Georges Bank Atlantic cod for F= F75% for each of three 'true' management models (diagonal): BASE, MRamp, and Catch Multiplier, and consequence projections (diagonal) of alternative management actions (off diagonal).

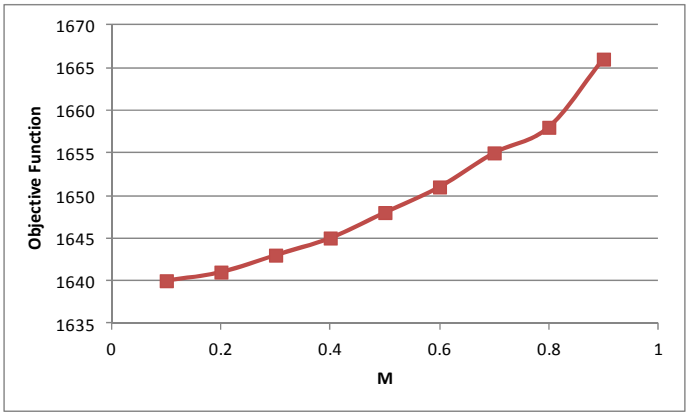
Hypothesis		Base				M Ramp				Catch Mult			
Catch 2012		2910 mt				2910 mt				8730			
SSB MSY		186,617				24,596				146,288			
MSY		30,622				5,740				23,995			
75% Fmsy		0.14				0.22				0.14			
Basis of Management Action	**Base**	10%	SSB	90%		10%	SSB	90%		10%	SSB	90%	
		13.144	18.184	25.334	2012	18.042	24.173	32.331	2012	31.157	43.863	60.951	
		13.904	20.174	28.551	2013	18.700	25.885	35.599	2013	35.693	52.849	76.582	
		15.280	21.415	29.373	2014	19.726	26.587	35.903	2014	42.147	61.534	88.070	
		19.423	26.005	34.211	2015	21.426	28.375	36.886	2015	52.823	76.288	105.791	
		10%	F	90%		10%	F	90%		10%	F	90%	
		0.12	0.17	0.25	2012	0.11	0.15	0.20	2012	0.16	0.23	0.33	
			0.14		2013	0.08	0.12	0.16	2013	0.11	0.16	0.25	
			0.14		2014	0.09	0.12	0.17	2014	0.10	0.15	0.23	
			0.14		2015	0.10	0.14	0.18	2015	0.10	0.14	0.21	
		10%	Catch	90%		10%	Catch	90%		10%	Catch	90%	
			2.910		2012		2.910		2012		2.910	x3 in proj.	
		1.795	2.594	3.704	2013		2.594		2013		2.594	x3 in proj.	
		1.991	2.816	3.890	2014		2.816		2014		2.816	x3 in proj.	
		2.436	3.265	4.312	2015		3.265		2015		3.265	x3 in proj.	
	M Ramp	10%	SSB	90%		10%	SSB	90%		10%	SSB	90%	
		13.144	18.184	25.334	2012	18.04	24.17	32.33	2012	31.157	43.863	60.951	
		13.371	19.806	28.386	2013	18.56	25.52	34.96	2013	34.514	51.746	75.546	
		12.057	19.111	28.302	2014	18.90	24.57	32.19	2014	35.219	54.617	81.162	
		14.000	22.134	32.409	2015	20.02	25.24	31.46	2015	41.006	64.477	93.979	
		10%	F	90%		10%	F	90%		10%	F	90%	
		0.12	0.17	0.25	2012	0.11	0.15	0.20	2012	0.16	0.23	0.33	
		0.18	0.27	0.41	2013		0.22		2013	0.21	0.31	0.49	
		0.17	0.26	0.44	2014		0.22		2014	0.18	0.28	0.47	
		0.16	0.24	0.40	2015		0.22		2015	0.16	0.24	0.41	
		10%	Catch	90%		10%	Catch	90%		10%	Catch	90%	
			2.910		2012		2.910		2012		2.910	x3 in proj.	
			4.675		2013	3.418	4.675	6.395	2013		4.675	x3 in proj.	
			4.520		2014	3.433	4.520	6.001	2014		4.520	x3 in proj.	
			4.556		2015	3.626	4.556	5.695	2015		4.556	x3 in proj.	
	Catch Mult	10%	SSB	90%		10%	SSB	90%		10%	SSB	90%	
		13.144	18.184	25.334	2012	18.042	24.173	32.331	2012	31.157	43.863	60.951	
		13.792	20.197	28.772	2013	18.760	25.944	35.655	2013	36.227	53.011	76.283	
		14.546	21.587	30.773	2014	20.040	26.903	36.220	2014	45.594	62.570	85.789	
		18.179	26.317	36.594	2015	21.776	28.727	37.239	2015	58.419	77.628	101.521	
		10%	F	90%		10%	F	90%		10%	F	90%	
		0.12	0.17	0.25	2012	0.11	0.15	0.20	2012	0.16	0.23	0.33	
		0.09	0.13	0.20	2013	0.07	0.10	0.14	2013		0.14		
		0.09	0.13	0.20	2014	0.08	0.12	0.16	2014		0.14		
		0.10	0.14	0.21	2015	0.10	0.13	0.18	2015		0.14		
		10%	Catch	90%		10%	Catch	90%		10%	Catch	90%	
			2.910		2012		2.910		2012		2.910		
			2.244		2013		2.244		2013	1.530	2.244	3.238	
			2.692		2014		2.692		2014	1.930	2.692	3.738	
			3.275		2015		3.275		2015	2.468	3.275	4.292	

Appendix Table B3.5. Status of 2013 spawning stock biomass and fishing mortality of Georges Bank cod evaluated under a management action relative to a management model assumed to be the 'true' state of the population.

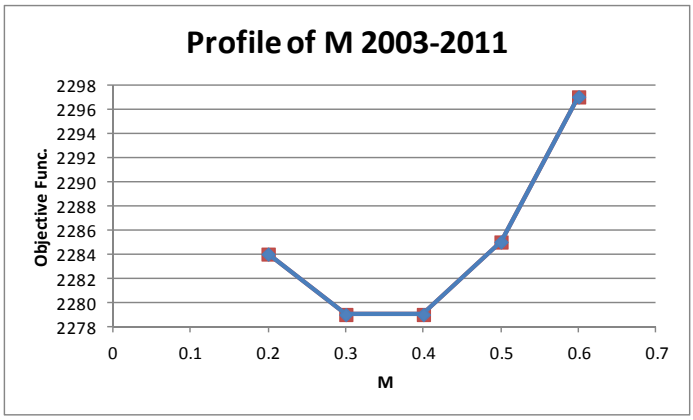
Management Action	Management Model 'true' state of nature: BASE	MRAMP	CATCH MULT
BASE	overfished not overfishing	not overfished not overfishing	overfished not overfishing
M Ramp	overfished overfishing	not overfished not overfishing ($F<F_{MSY}$)	overfished overfishing
Cat Mult	overfished not overfishing	not overfished not overfishing	overfished not overfishing



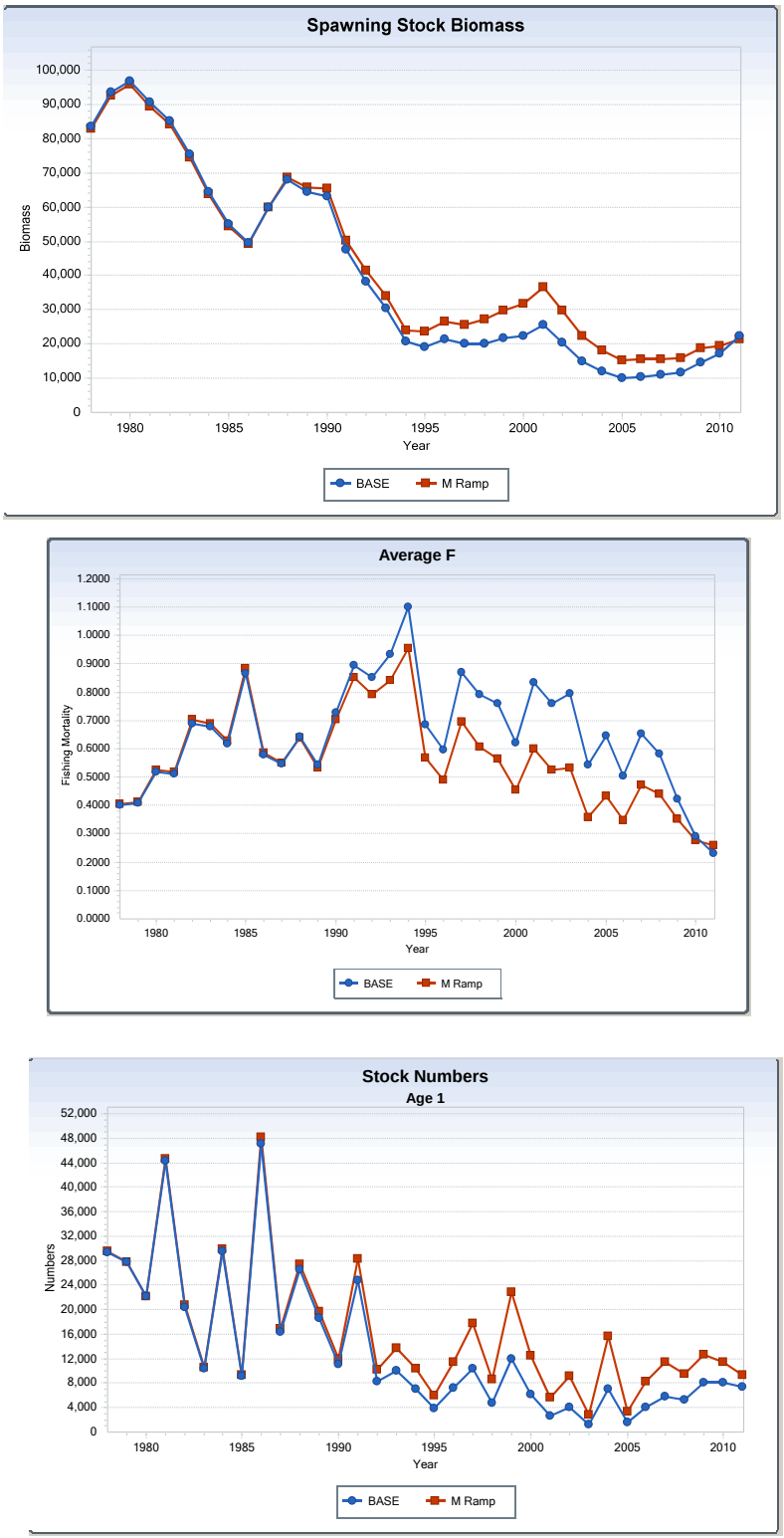
Appendix Figure B3.1. Profile of M values from 0.1 – 0.8 evaluted by objective function in ASAP, 1978-2011.



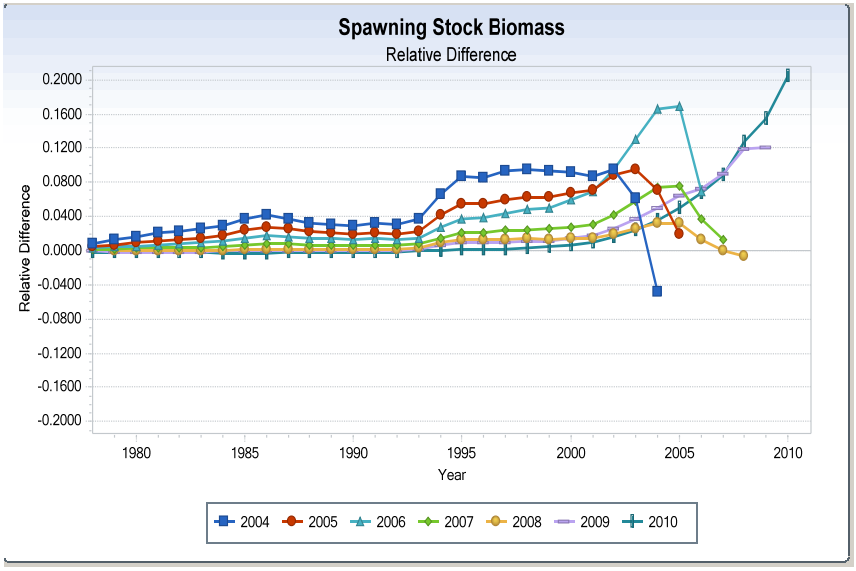
Appendix Figure B3.2. Profile of M values from 0.1 – 0.9 evaluted by objective function in ASAP, 1978-2002.

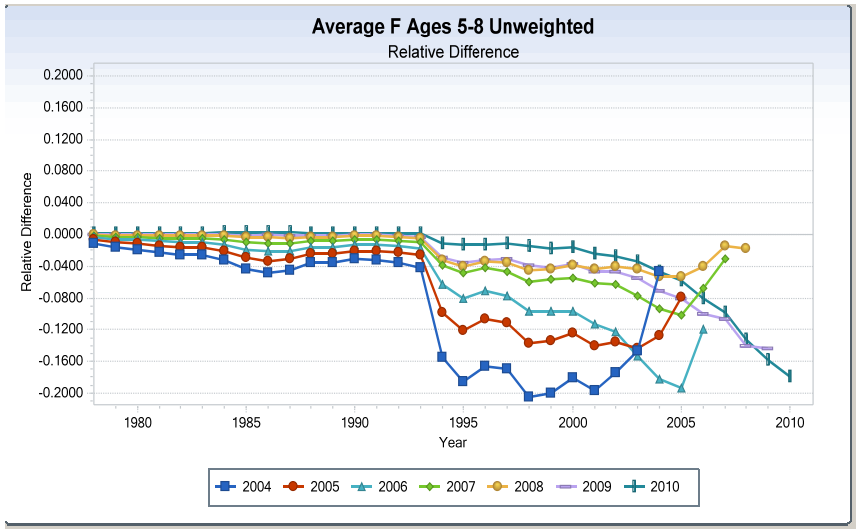


Appendix Figure B3.3. Profile of M values from 0.2 – 0.6 evaluted by objective function in ASAP, 2003-2011.

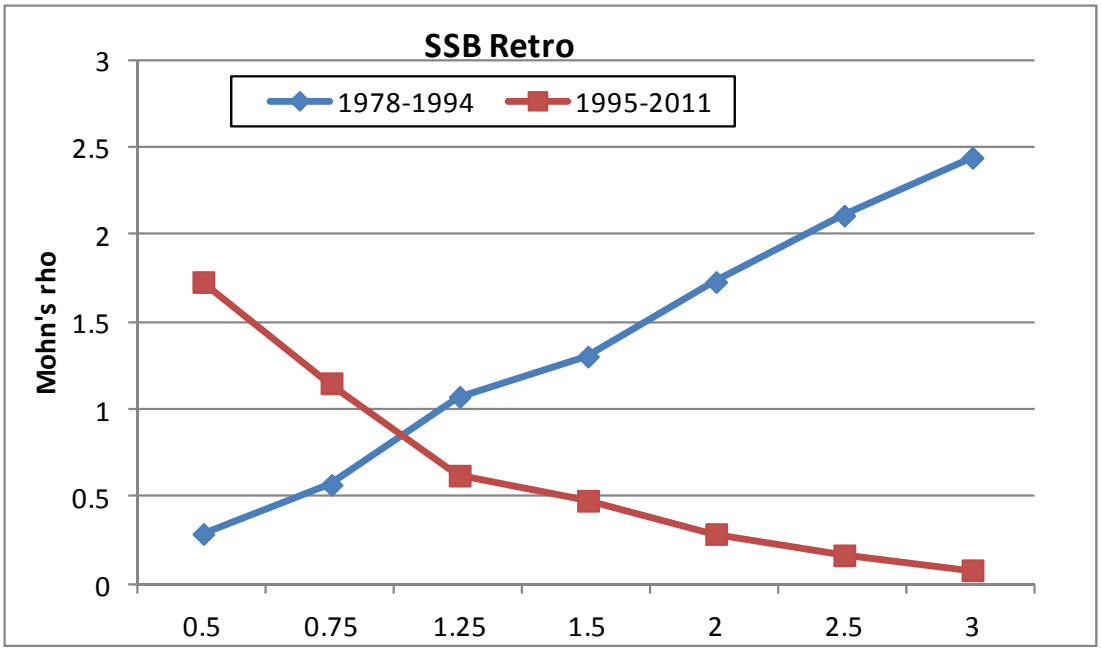


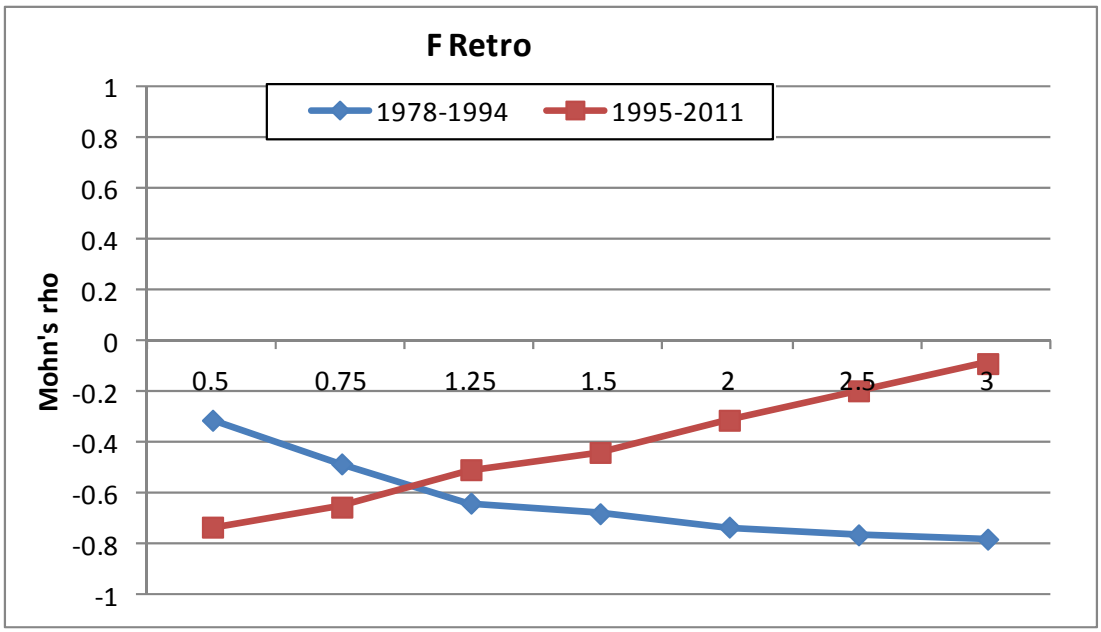
Appendix Figure B3.4. Spawning stock biomass, fishing mortality and recruitment (age 1) from BASE and M Ramp ASAP model runs.





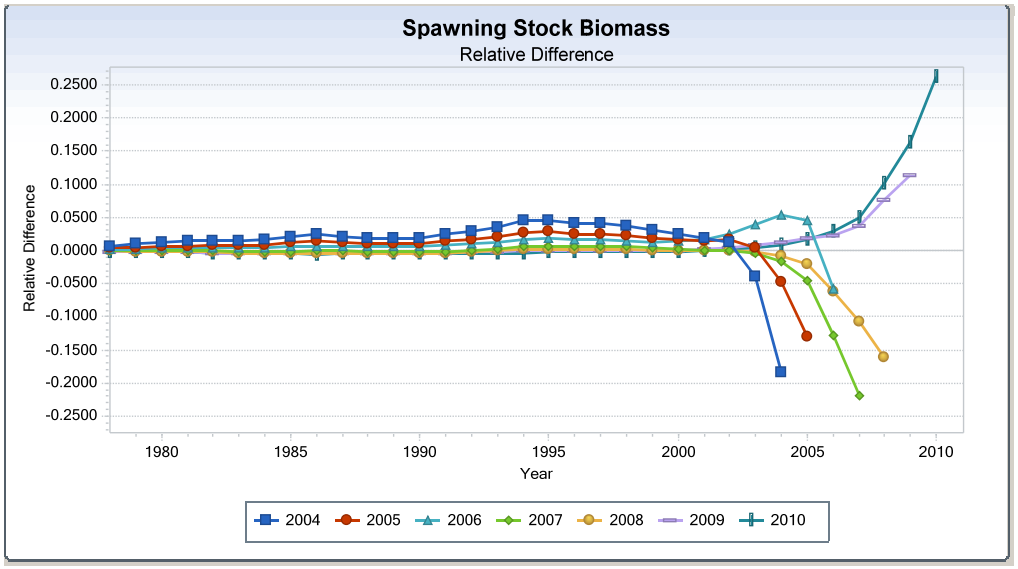
Appendix Figure B3.5. Retropsective analysis of MRamp ASAP model for spawning stock biomass (rho=0.053) and fishing mortality (rho=0.088).

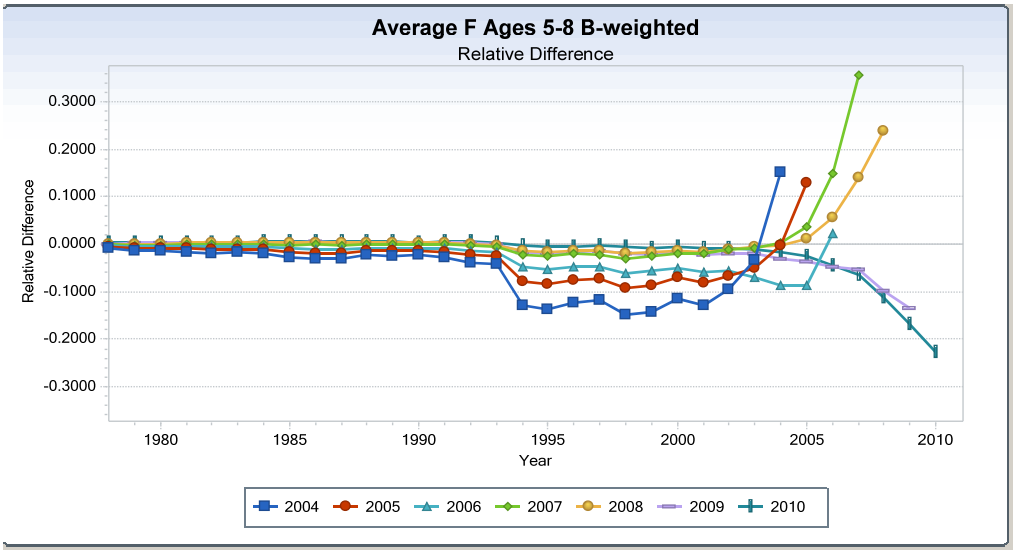




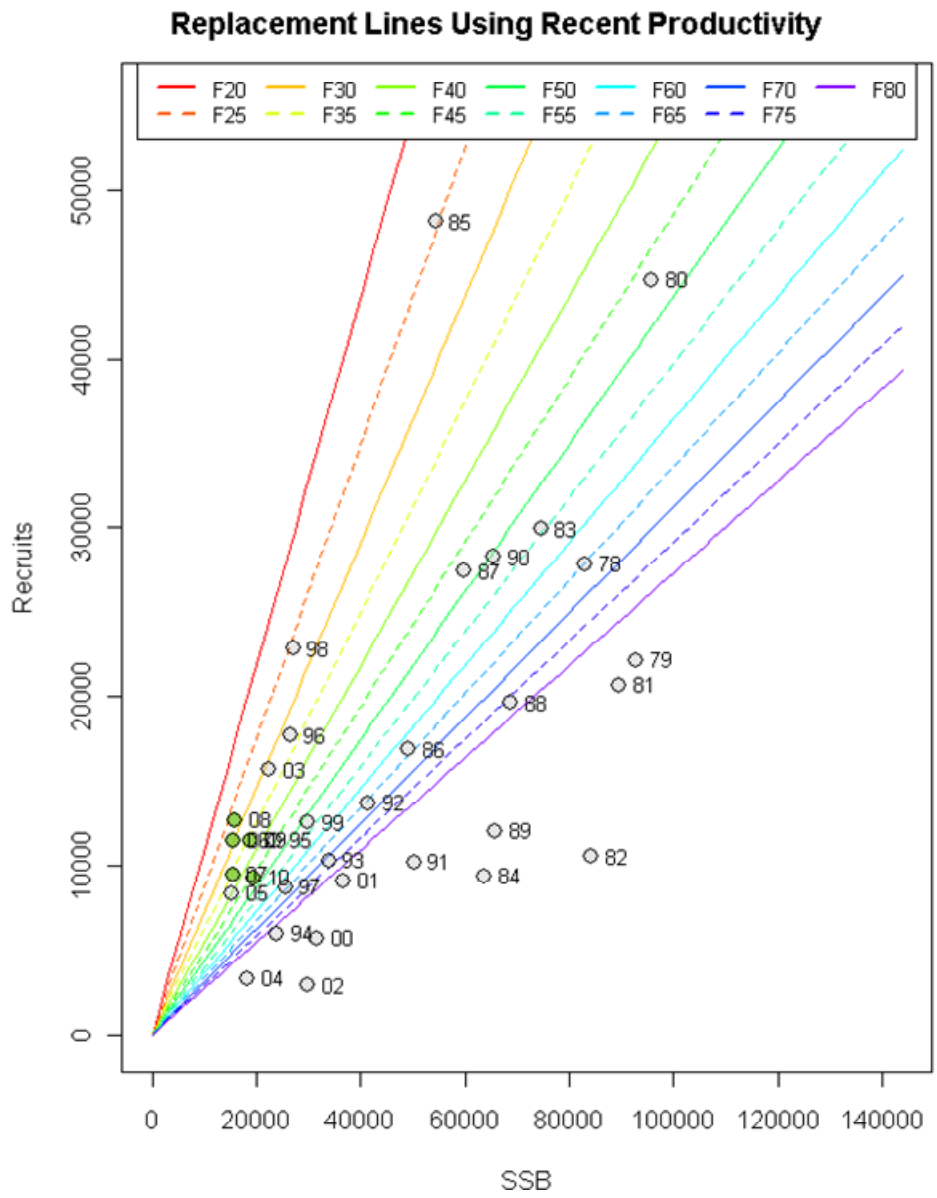
Appendix Figure B3.6. Profile of catch multipliers evaluated by the retropsective bias measured by rho value.

Appendix Figure B3.7. Spawning stock biomass, fishing mortality and recruitment (age 1) from BASE and Catch multipler (3x) ASAP model runs

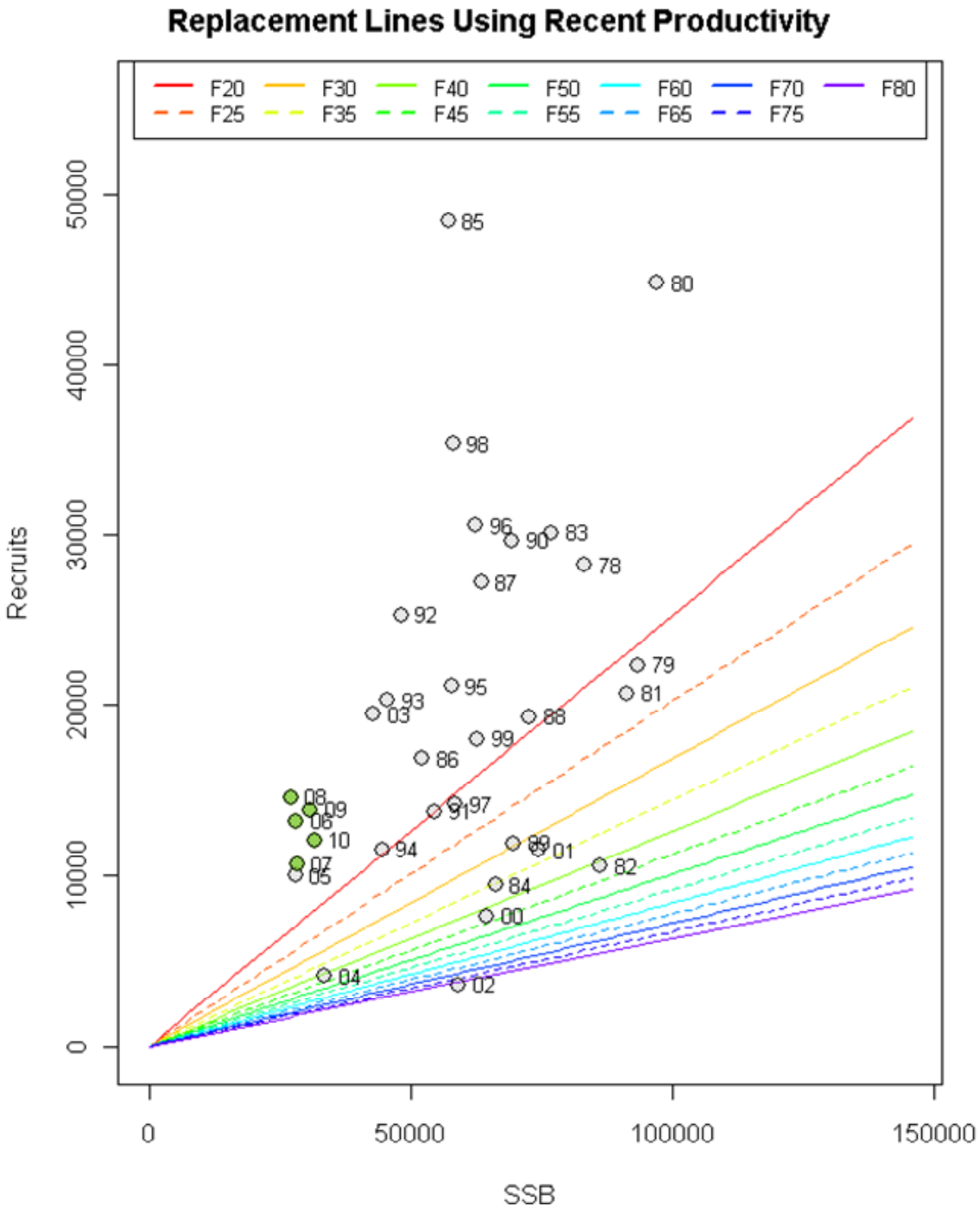




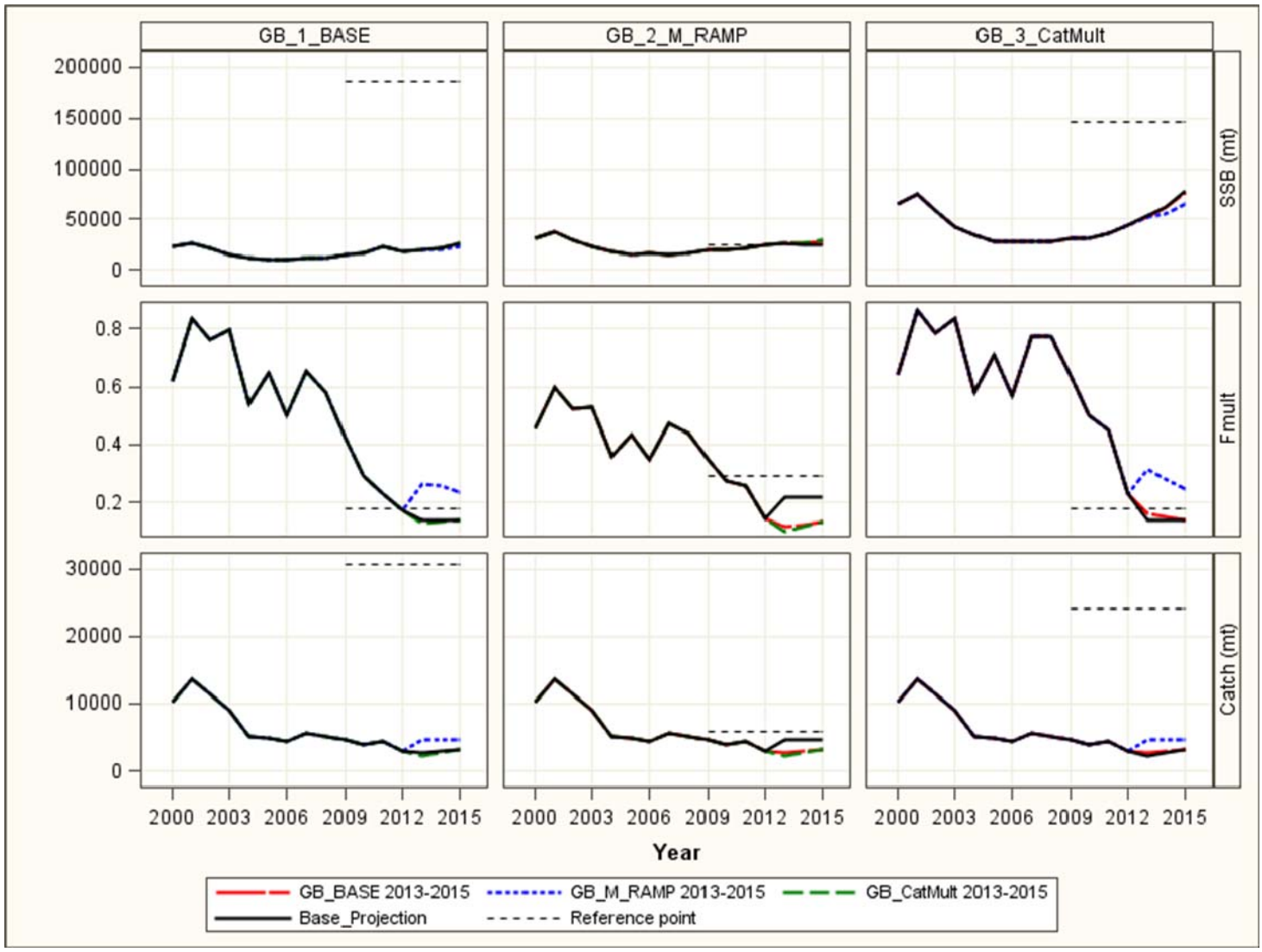
Appendix Figure B3.8. Retropsective analysis of Catch multipler (3X) ASAP model for spawning stock biomass (rho=0.053) and fishing mortality (rho=0.075).



Appendix Figure B3.9. Replacement lines using recent productivity from the MRamp ASAP model results for a range of fishing mortalities for Georges Bank Atlantic cod, 1978-2011.



Appendix Figure B3.10. Replacement lines using recent productivity from the CatMult ASAP model results for a range of fishing mortalities for Georges Bank Atlantic cod, 1978-2011.



Appendix Figure B3.11. Trends in SSB (top row), fully recruited fishing mortality (middle row) and catch (bottom row) during 2000 – 2015 for Georges Bank cod with projected SSB, F, and catch, for three management models under catch from two alternative management actions (see Appendix Table B3.4) during 2013-2015 . Correctly specified (black) and mis-specified (red: BASE ASAP, blue: MRamp, green: Catch Multiplier. MSY – based reference points indicated in dashed line on each plot.