B. SEA SCALLOP ASSESSMENT SUMMARY FOR 2010

State of Stock

During 2009, the sea scallop stock was not overfished and overfishing was not occurring. Using the new recommended reference point approach, estimated biomass (40+ mm SH) on July 1, 2009 was 129.7 thousand mt meats (Figure B1), which is above B_{TARGET}=B_{MSY}=125 thousand mt meats, and the $B_{THRESHOLD}$=½B_{MSY}=62.6 thousand mt meats.

The estimated fishing mortality rate during 2009 was F=0.378 (Figure B2). Based on the new recommended overfishing threshold reference point, the stock was near its mortality threshold but overfishing did not occur because the estimated fishing mortality is slightly lower than $F_{Threshold}$=F_{MSY}=0.38. The probability that overfishing occurred during 2009 is slightly less than 50%.

Projections

Projections are carried out by the Sea Scallop Fishery Management Plan Development Team (PDT) using a spatially structured model (SAMS) that accommodates variability in recruitment, vital rates and fishing among regions. Scallop management approaches are complex because they are spatially explicit and dependent on regional recruitment levels and other factors. SAMS was used in this assessment to provide example projection results (Figures B4 and B5). These example projections indicate that stock biomass would increase slightly during 2009-2012 under a management strategy of F = 0.24.

Stock Distribution and Identification

Sea scallops are distributed from Cape Hatteras to Newfoundland. Populations are found on Georges Bank (GBK), including the Canadian portion, the Gulf of Maine (GOM), and Mid Atlantic Bight (MAB). Sea scallops in US waters were assessed based on two main stock assessment regions - GBK and MAB. Results for GBK and MAB were combined to characterize the entire (i.e. total) EEZ stock. A component of the stock occurs in the GOM but landings and biomass there are small relative to the stock as a whole. Overfishing and overfished status was evaluated for the entire stock (GBK and MAB), as specified by the current Sea Scallop Fishery Management Plan (New England Fisheries Management Council 2010). Overfishing and overfished status were not evaluated for the GOM region.

Catch

Annual landings increased from about 8000 mt meats in the mid-1980s to over 17,000 mt meats in 1990-1991, then fell to between 5000 and 8000 mt meats during the 1993-1998 (Figure B6). Landings increased considerably from 1998-2003 and have remained at high and relatively stable levels since then. US landings during 2003-2009 exceeded 24,000 mt (meats) during each year, and were roughly twice the long-term mean.

Discarding occurs due to catch of undersized scallops and some highgrading (in Special Access Areas). Discards averaged about 2300 mt during 2002 – 2004 and 800 mt since 2005 (see "Catch and Status Table"). Although discards are not included in the CASA assessment model, some compensation for this is considered through use of an estimate of incidental mortality.

Catch and Status Table: Sea scallops

U.S. Landings (mt meats)														
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Min[1]	Max[1]	Mean[1]	Median[1]
GBK[6]	5,044	5,008	6,043	4,940	5,398	9,940	17,807	9,842	6,765	6,695	1,040	17,807	5,654	5,261
MAB	9,351	15,703	17,443	20,276	23,533	15,566	8,772	16,634	17,388	19,350	731	23,533	7,650	5,124
GOM	226	343	405	201	177	187	155	117	120	84	84	1,614	483	407
Total	14,621	21,054	23,891	25,417	29,108	25,693	26,734	26,593	24,273	26,129	3,212	29,108	13,831	10,118
U.S. Discards (mt meats)														
Year	2000 [2]	2001 [2]	2002	2003	2004	2005	2006	2007	2008	2009	Min[3]	Max[3]	Mean[3]	Median[3]
GBK	--	--	103	181	103	421	868	240	259	289	103	868	308	250
MAB	--	--	1,673	2,386	2,482	473	254	162	372	748	162	2,482	1,069	611
Total	--	--	1,776	2,567	2,585	894	1,122	402	631	1,037	402	2,585	1,377	1,080
Estimated abundance (July 1, 40+ mm SH, millions, from CASA model)														
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Min	Max	Mean	Median
GBK	3,129	3,294	2,819	2,945	2,708	2,571	2,128	2,364	2,769	3,453	531	3,453	1,579	1,260
MAB	3,523	3,766	3,427	4,174	3,703	3,609	3,805	3,853	4,509	3,993	343	4,509	1,713	977
Combined	6,652	7,061	6,246	7,119	6,411	6,180	5,933	6,217	7,278	7,446	1,070	7,446	3,292	2,191
Estimated biomass for status determination (July 1, 40+ mm SH, thousand mt meats, from CASA model)														
Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Min	Max	Mean	Median
GBK	41,066	53,064	62,370	69,416	74,629	73,828	62,769	53,650	55,508	62,470	4,868	74,629	27,679	17,822
MAB	37,324	45,796	48,798	48,756	50,029	49,027	56,405	61,784	63,983	67,233	5,426	67,233	21,321	9,340
Combined	78,389	98,859	111,167	118,171	124,658	122,855	119,174	115,434	119,492	129,703	10,502	129,703	49,001	25,500

Recruitment, (millions, approximate age 2 y, from CASA model)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Min	Max	Mean	Median
GBK	2,015	915	239	882	316	512	389	1,075	1,062	1,425	126	2,015	679	619
MAB	1,678	1,722	969	3,073	651	1,868	1,306	1,356	2,561	412	93	3,073	878	648
Combined	3,693	2,637	1,207	3,955	968	2,379	1,695	2,431	3,624	1,837	219	3,955	1,557	1,400

Estimated fully recruited fishing mortality for status determination (from CASA model)[4]

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Min	Max	Mean	Median
GBK	0.48	0.26	0.23	0.17	0.10	0.18	0.38	0.25	0.19	0.18	0.10	1.72	0.52	0.39
MAB	0.48	0.54	0.61	0.68	0.87	0.84	0.35	0.55	0.54	0.60	0.13	1.37	0.73	0.68
Combined	0.48	0.43	0.41	0.42	0.38	0.37	0.37	0.40	0.37	0.38	0.21	1.47	0.60	0.51

Exploitation index (catch number/ abundance 80+mm on January 1)[5]

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	Min	Max	Mean	Median
GBK	0.11	0.09	0.10	0.08	0.07	0.12	0.23	0.16	0.10	0.09	0.07	0.79	0.31	0.26
MAB	0.21	0.26	0.24	0.29	0.27	0.20	0.11	0.18	0.18	0.18	0.11	0.71	0.38	0.37
Combined	0.17	0.18	0.17	0.19	0.18	0.16	0.17	0.17	0.15	0.14	0.14	0.72	0.35	0.33

[1] 1975-2009
[2] Missing discard estimates due to small sample size
[3] Summary statistics for years shown in the table (2002-2009)
[4] Values for 2009 comparable to reference points; values for other years not comparable due to changes in fishery size selectivity.
[5] Values from different years are comparable
[6] Region abbreviations: Georges Bank (GBK), Mid-Atlantic Bight (MAB), Gulf of Maine (GOM), Southern New England (SNE).

Note: For assessment modeling purposes, SNE landings are lumped with the GBK region.

Data and Assessment

The NEFSC sea scallop survey transitioned from the *R/V Albatross IV*, which conducted the surveys through 2007 to the *R/V Hugh Sharp,* which conducted the NEFSC survey in 2008-2009. Comparison of paired tows between these two vessels, as well as comparisons of both research vessels to a commercial vessel towing lined survey dredges indicated no statistical difference between the catches of the vessels. However, dredge sensors indicated that the tow path of the *Sharp* was about 5% longer than that of the *Albatross*. Survey dredge efficiency was estimated based on about 140 paired tows between the survey research vessels and the HabCam towed camera system. Analysis of these data gave estimated dredge efficiency of 0.38 in strata containing substantial proportions of gravel/cobble/rock substrate (e.g., portions of Georges Bank), and 0.44 in other strata with mostly sand substrate (e.g., the Mid-Atlantic Bight). These efficiency estimates were similar to previous estimates based on NEFSC and SMAST comparisons and depletion experiments. Scallop biomass lying outside the standard NEFSC sea scallop strata set was estimated and include in the assessment. Additionally, the effective area sampled by the SMAST drop large camera was re-estimated to provide more accurate scallop density estimates.

A size-structured forward projecting stock assessment model (CASA) used in previous assessments (NEFSC 2007; NEFMC 2010) was also used in this assessment. Data sources used in the CASA model include the NEFSC sea scallop dredge and winter trawl surveys, the SMAST large camera video survey, commercial landings, commercial kept and discarded shell heights from port and sea sampling, and growth increment data inferred from analysis of shell growth rings. Biomass estimates from the model are similar to swept area biomass estimates from the NEFSC surveys. There is uncertainty in recent estimates for the stock that are reflected in retrospective patterns that are most apparent for Mid Atlantic Bight and appear to be due in part to conflicting data on the strength of the 2001 year class.

In this assessment, July 1st rather than January 1st biomass is used to determine overfished status and stock trends. July 1st estimates are more representative because growth parameters are estimated from mid-year surveys and because the CASA model does not consider seasonal growth. Moreover, July 1st biomass estimates are comparable to survey swept-area biomass. This date change does not change the estimated F or affect the definition of overfishing.

For the first time, this assessment includes information about the northern Gulf of Maine (NGOM) federal management area from a special University of Maine/Maine Department of Marine Resources dredge survey during 2008. NGOM is managed under a special TAC although it is part of the stock managed under the FMP. Survey results indicate that the biomass of NGOM sea scallops targeted by the fishery (101+ mm shell height) was approximately 100 mt of meats during 2008 with a 95% confidence interval ranging from about 60 to 250 mt. Exploitation rate (reported landings in weight / estimated biomass) during 2008 was 0.065, with a 95% confidence interval ranging from 0.035 to 0.12. The assessment also includes information about sea scallops and the fishery in Maine state waters, but estimates of total biomass and exploitation rates are not available.

Biological Reference Points

Reference point	SARC-45, whole Stock	Updated		
		GBK	MAB	Whole stock
F_{MSY}	--	0.21	0.47	0.38
$B_{TARGET}=B_{MSY}$ (July 1, 40+ mm SH)	108,628[1]	41,468	86,330	125,358
$B_{THRESHOLD}$=1/2 B_{MSY}	54,314[1]	20,734	43,165	62,679
MSY	--	6,410	19,040	24,975
F_{MAX}	0.29	0.295	0.835	0.48

1. Jan 1 biomass based on median recruitment * BPR at F_{MAX} (proxy for F_{MSY})

In the last sea scallop assessment (NEFSC 2007, SARC-45), F_{MAX} was used as a proxy for F_{MSY}, and the biomass target (B_{TARGET}) was calculated by multiplying biomass per recruit at F_{MAX} by median recruitment. Both F_{MAX} and median recruitment were estimated by the CASA model. The biomass threshold was set at ½ the biomass target.

Selectivity in the sea scallop fishery has shifted towards larger sea scallops. Although this had positive effects on the stock and fishery, it caused flattening of yield per recruit curves so that F_{MAX} estimates are now uncertain and questionable as a proxy for F_{MSY}.

The new recommended biological reference points in the current 2010 assessment are direct F_{MSY} (0.38) and B_{MSY} (125,358 mt) estimates (with uncertainty characterized in Figure B8) from the new Stochastic Yield Model (SYM). The biomass threshold is ½ the biomass target. SYM includes spawner-recruit relationships, per recruit calculations, uncertainty in all parameters and is similar to approaches that are increasingly used in other stock assessments. SYM is a separate model but is configured to be consistent with assumptions and calculations of the CASA model. In particular, selectivity, spawning biomass and recruitment estimates in SYM are obtained from the CASA model.

To inform ABC decisions, a new method is recommended which takes into account uncertainty in both current fishing mortality and the reference point. This method quantifies risk of overfishing and loss of yield at a specified fishing mortality (Figure B9 and see Special Comments).

Fishing Mortality

Fully recruited fishing mortality rates for the whole stock ranged 0.37 to 0.4 during 2005-2009 and averaged 0.38. Fully-recruited fishing mortalities prior to 2006 cannot be directly compared to the F_{MSY} estimate (Figure B2) due to changes in fishery size-selectivity over time. The estimated fishing mortality rate during 2009 was F=0.378. The standard errors for whole stock fishing mortality were estimated by the CASA model to be 0.04 for 2009 and 0.03 for 2005-2008. These standard errors likely underestimate the true uncertainty because they assume that input parameters to CASA and model equations are exact.

A simple exploitation index indicates that fishing pressure has been relatively low since 1994, when closed area management was initiated (Figure B3). The exploitation index is calculated as the ratio of total catch number and January 1 abundance for sea scallops 80+ mm SH estimated in the CASA model. The exploitation rate index is useful for showing annual trends in the proportion harvested.

Recruitment

Recruitment on Georges Bank was relatively low during 2002-2006, but appears to be above average during 2007-2009 (Figure B7). Recruitment in the Mid-Atlantic was above average during 1998-2008 but below average in 2009. For the combined stock, recruitment has been above average since 2005.

Stock and Spawning Stock Biomass

Total and spawning stock biomass are approximately equivalent. Stock biomass rapidly increased during 1995 – 2003 and has been relatively stable since then (Figure B1). Coincident with initial area closures (1994 on Georges Bank and 1998 in Mid Atlantic Bight), stock biomass increased rapidly between 1995 and 2000 on Georges Bank and between 1998 and 2003 in the Mid Atlantic Bight. Estimated biomass (40+ mm shell height) on July 1, 2009 was 129.7 thousand mt meats. Current biomass is approximately the same in both regions (slightly over 60,000 mt in each region). Biomass standard errors for 2009 are slightly lower for Georges Bank (5341 mt) than in the Mid-Atlantic (6460 mt). These standard errors likely underestimate the true uncertainty.

Special Comments

- The new method used to facilitate ABC decisions was developed based on F_{MSY} and can be employed to characterize risk of overfishing for other levels of fishing mortality (e.g. F_{TARGET}). Here, F_{MSY} is directly estimated and is not a proxy as has been used in the past (Figure B9).
- Area management plays an important role in sea scallop stock dynamics, with much of the biomass located in long-term or rotational closures, or are in reopened closed areas under special management. Under such area management, the calculated fishing mortalities will underestimate fishing mortalities in areas where fishing occurs (Hart 2001; 2003).
- Historically, Georges Bank was the dominant component of the US sea scallop resource. In recent years, the Mid-Atlantic Bight has become more productive which is unprecedented. Recent recruitment in this area is an order of magnitude higher than during 1975 – 1984 (Figure B7) and may not persist.

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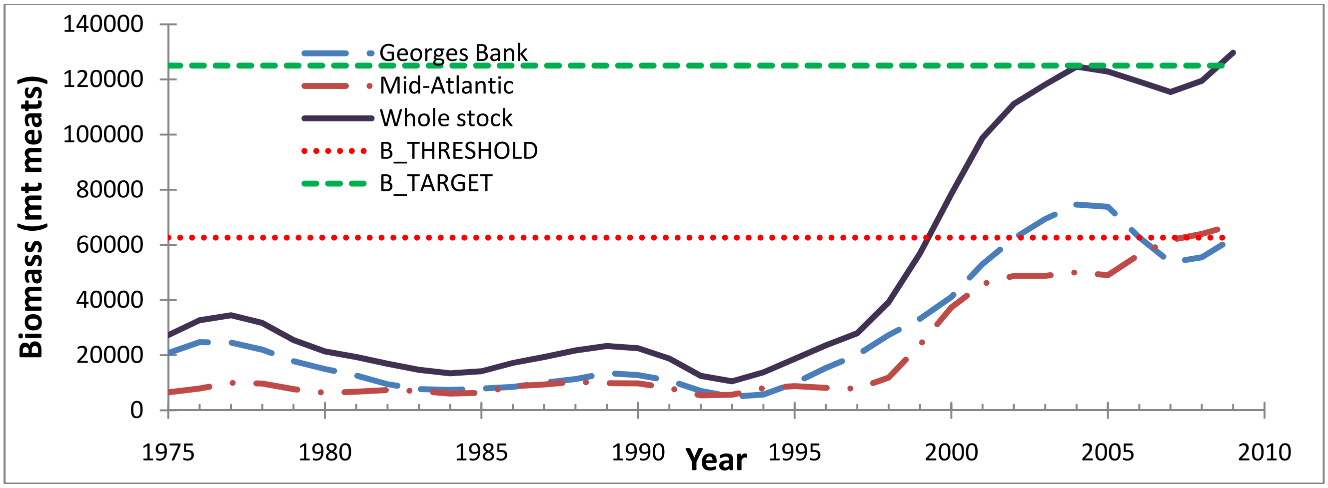
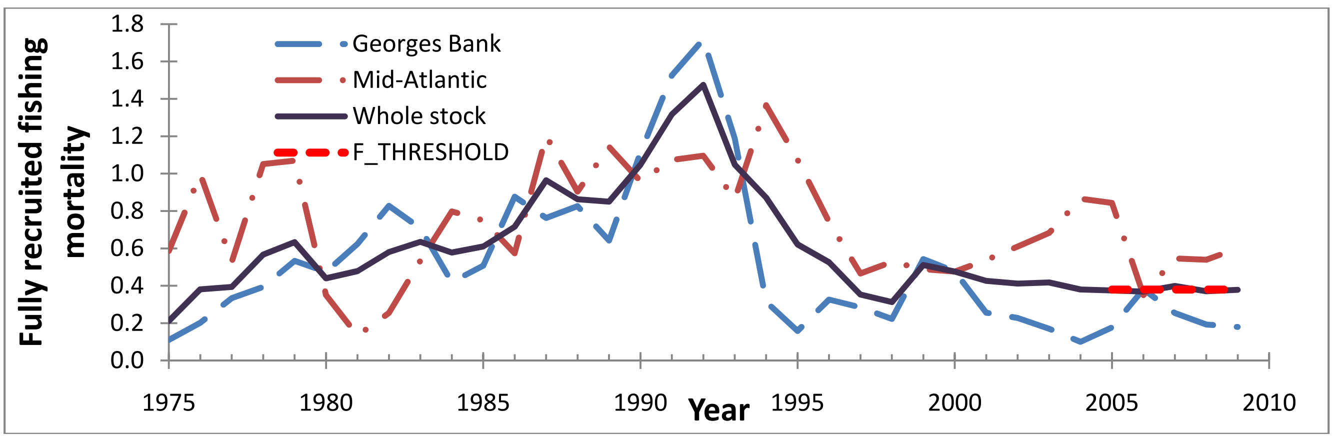
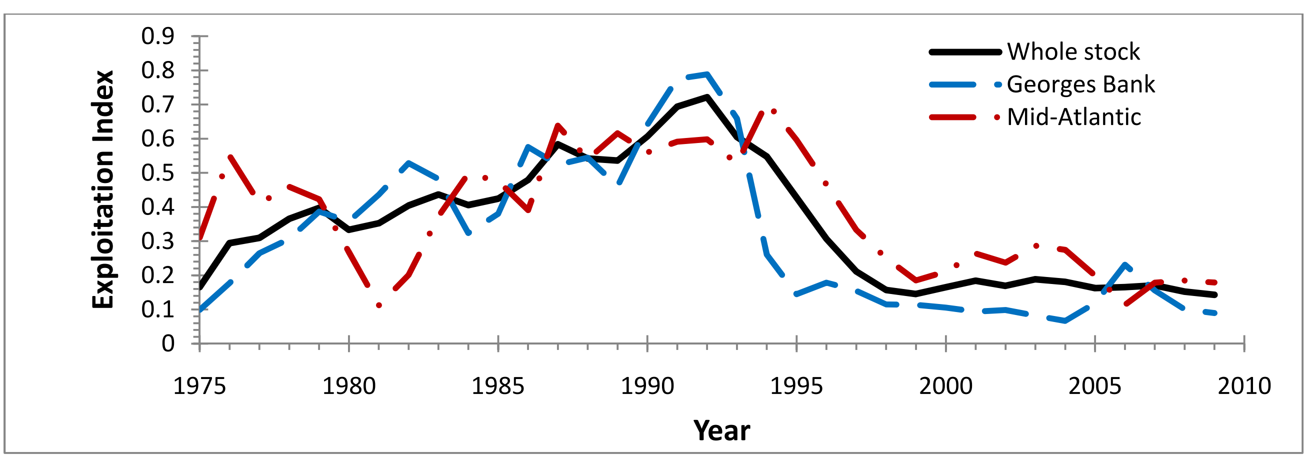
Figures



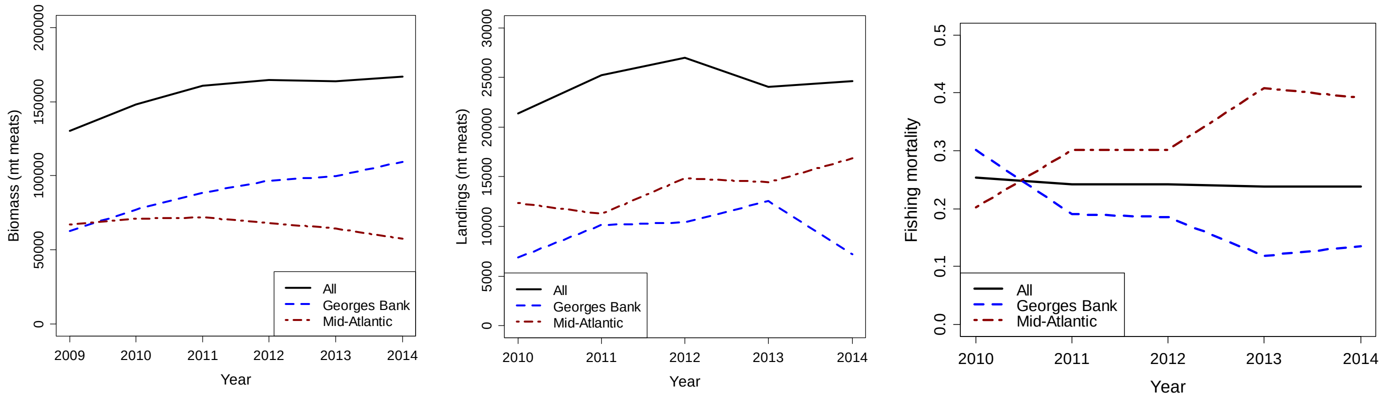
B1. Sea scallop biomass (40+ mm SH), on July 1 during 1975-2009.



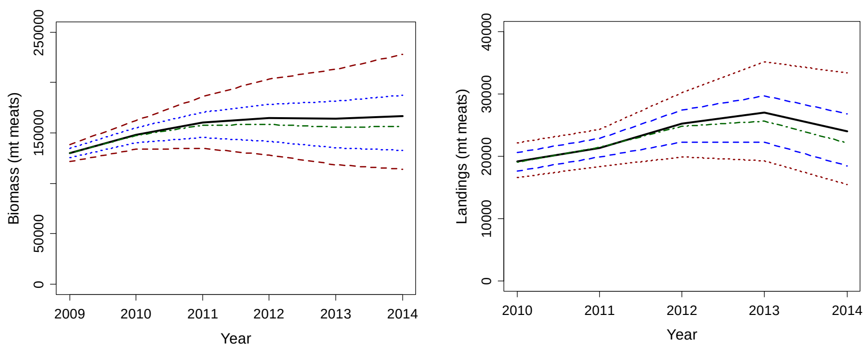
B2. Fully recruited annual fishing mortality rate for sea scallops during 1995-2009. Trends are difficult to interpret because of changes in commercial size-selectivity.



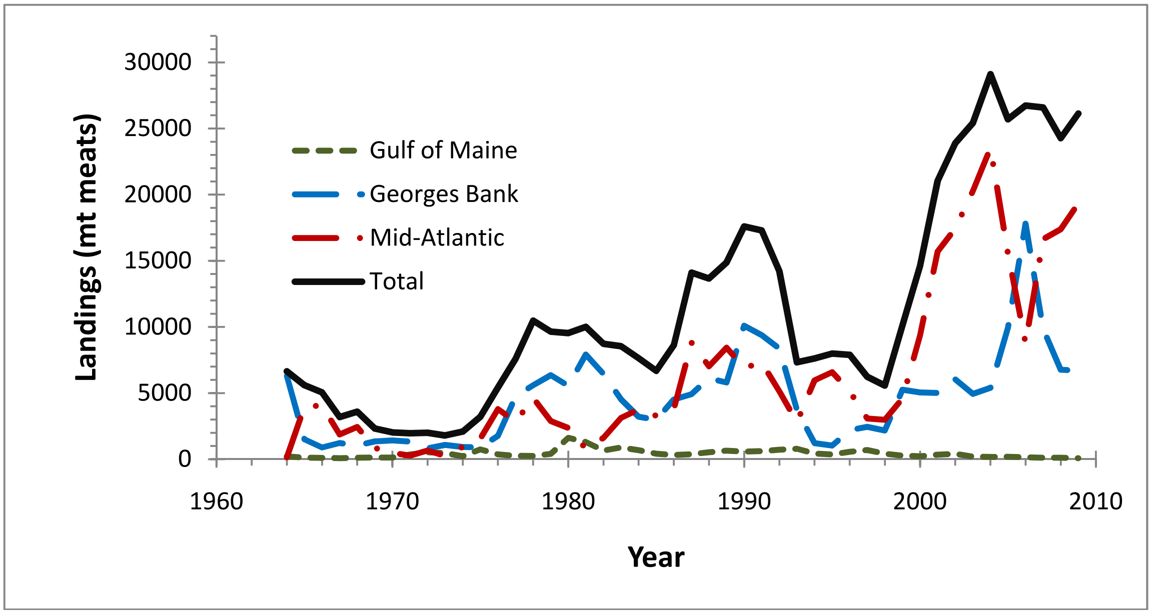
B3. Simple exploitation index for sea scallops during 1975-2009.



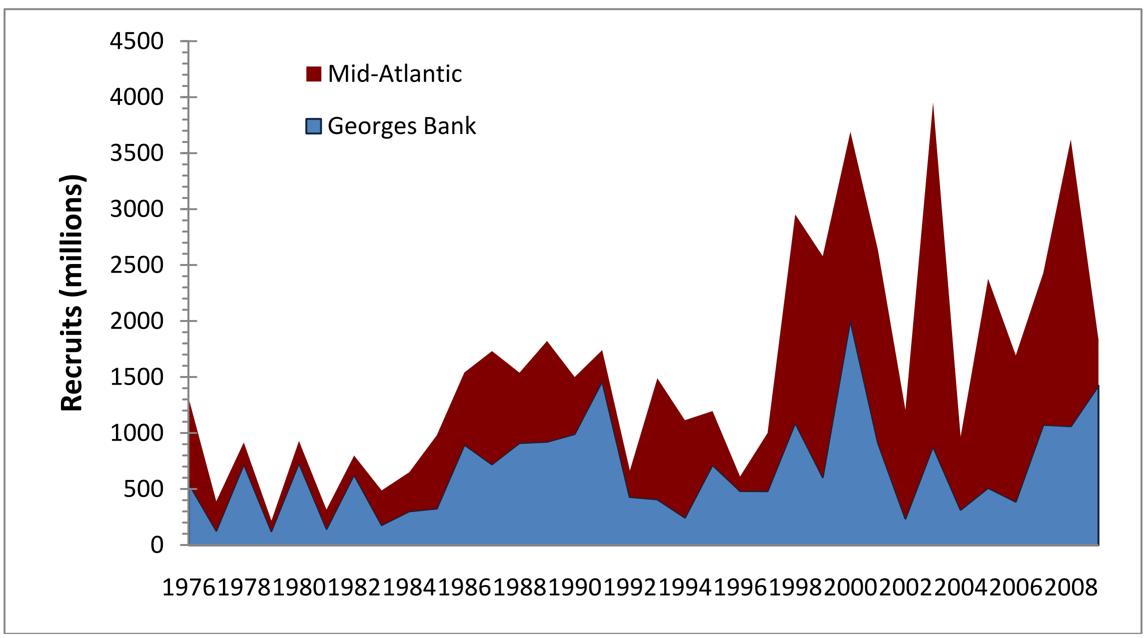
B4. Projected sea scallop biomass, landings and fully recruited fishing mortality for GBK, MAB and the entire (i.e., total) stock under an example management scenario during 2010-2014.



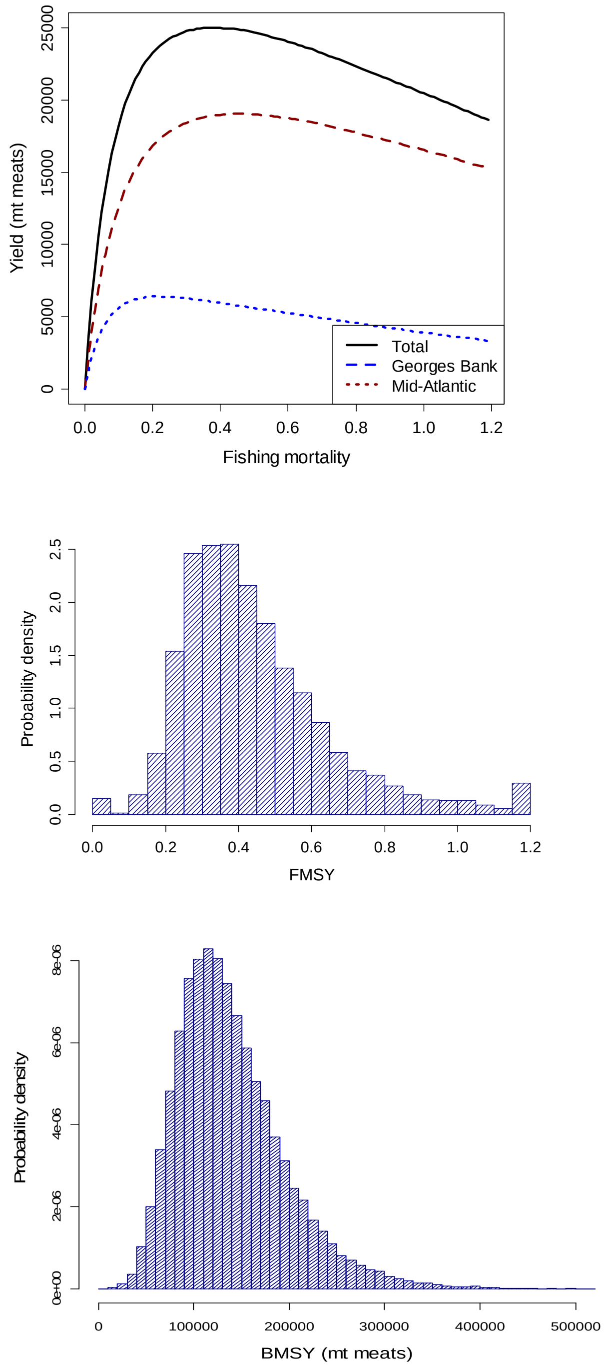
B5. Mean (black solid line) and median (green dashed-dotted line) projected sea scallop biomass and landings for the entire (i.e., total) stock during 2010-2014 under an example management scenario during 2010-2014. The 10th and 90th percentiles are red dashed lines. The 25th and 75th percentiles are dotted blue lines.



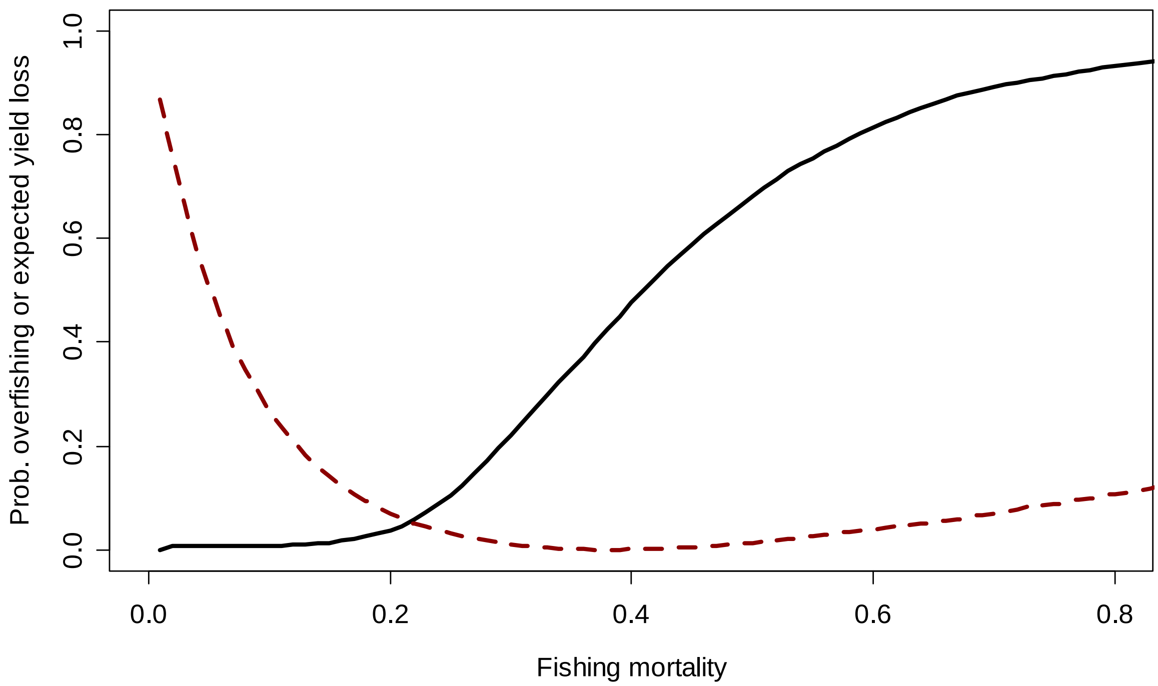
B6. Sea scallop landings during 1975-2009.



B7. Sea scallop recruitment (millions, approximate age 2) during 1975-2009.



B8. *Top*: Median yield curves for Georges Bank, the Mid-Atlantic Bight, and total sea scallop stock from the SYM model. *Middle*: Probability density function for total-stock F_{MSY} calculated in the SYM model. *Bottom*: Probability density function for total-stock B_{MSY} calculated in the SYM model.



B9. The probability of overfishing sea scallops as a function of realized fishing mortality (black solid line) and the loss of expected yield relative to that obtained at F_{MSY}.