B. SEA SCALLOP ASSESSMENT SUMMARY FOR 2014

Status of Stock: During 2013, the sea scallop stock was not overfished and overfishing was not occurring. Estimated biomass (40+ mm SH) was 132.561 thousand mt meats (Figure B1). Using the new recommended reference points, biomass was well above the $B_{TARGET}=B_{MSY}$= 96.480 thousand mt meats, and the $B_{THRESHOLD}=½B_{MSY}$=48.240 thousand mt meats. The probability that the stock was overfished in 2013 is near zero based on the new SARC-59 reference points (Figure B8). Compared with reference points from the previous assessment (NEFSC 2010), biomass during 2013 was also above that earlier $B_{TARGET}=B_{MSY}$= 125.358 thousand mt meats, and the $B_{THRESHOLD}=½B_{MSY}$=62.679 thousand mt meats. Past assessments have overestimated biomass, in particular when strong recruitment year classes have entered the population, and may continue to do so.

The estimated fishing mortality rate during 2013 was F=0.32 (Figure B2). Based on the new SARC-59 overfishing threshold reference point F_{MSY}=0.48, overfishing was not occurring in 2013. The probability that overfishing occurred during 2013 was about 13% based on the recommended reference points (Figure B8). Overfishing was also not occurring using the reference point from the previous assessment, F_{MSY}=0.38. Past assessments have underestimated fishing mortality and may continue to do so.

Projections: Projections are carried out by the Sea Scallop Plan Development Team (PDT) using a spatially structured model (SAMS) that accommodates variability in recruitment, vital rates and fishing among management areas. Scallop management approaches are complex because they are spatially explicit and dependent on regional recruitment 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 2014-2017 under current management policies ($F=F_{MSY}$ in "open" areas outside of rotational and closed areas, rotational management as currently planned). Past projections have been optimistic and may continue to be so.

Stock Distribution and Identification: Sea scallops are distributed from Cape Hatteras to Newfoundland. US populations are found on Georges Bank (GBK), Southern New England (SNE), the Gulf of Maine (GOM), and the Mid-Atlantic Bight (MAB). Sea scallops in US waters were assessed based on three main stock regions – Georges Bank open and closed, including Southern New England, and the Mid-Atlantic. Results for GBK open and closed, and MAB were combined to characterize the entire (i.e. total) EEZ stock. Overfishing and overfished status were evaluated for the entire stock, as specified by the current Sea Scallop Fishery Management Plan (NEFMC 2010). The small component of the stock that occurs in the GOM was not included in the assessment of overfishing or overfished status although an assessment for sea scallops in federal waters off Maine was completed (Appendix B7 in the assessment report).

Catch: Annual landings increased from about 8,000 mt meats in the mid-1980s to over 17,000 mt meats in 1990-1991, and then fell to between 5,000 and 8,000 mt meats during 1993-1998 (Figure B6). Landings increased considerably from 1998-2003, remained high and relatively stable during 2003-2012, and then declined in 2013. US landings during 2004-2013 averaged 25,566 mt (meats), about twice the long-term mean.

Discarding occurs due to catch of undersized scallops and high-grading; the latter mainly occurs in

rotational access areas that are managed under a form of individual allocations. Discards averaged about 969 mt during 1992–2013. Discards were the highest during 2000-2004, peaking at 2,603 mt meats, but have declined since, likely due to changes in gear regulations. Discards are implicitly included in the CASA assessment model as part of the incidental mortality term.

Data and Assessment: Three main survey time series were used in this assessment (dredge, SMAST and Habcam, Figure B9). Sea scallop dredge surveys have been conducted since 1975 and with the same lined gear since 1979. For the first time, data from NEFSC dredge surveys and cooperative dredge surveys conducted by the Virginia Institute of Marine Science (VIMS) during 2005-2013 were combined. VIMS surveys use commercial vessels and the same gear as the NEFSC dredge survey. Broad scale video drop camera survey data for 2003-2012 provided by the School for Marine Science and Technology (SMAST) were also used. Finally, survey data from broadscale Habcam surveys for 2011-2013 (GBK) and 2012-2013 (MAB) were used for the first time. Habcam is a towed digital still camera system. Analytical and survey design procedures for Habcam data were tested extensively during this assessment (Appendix B6 in assessment report). Biomass and abundance estimates from these three independent sources are generally similar (Figure B9).

A size-structured forward projecting stock assessment model (CASA) used in previous assessments (NEFSC 2007; NEFSC 2010) was also used in this assessment. Model data include the three main surveys listed above, the NEFSC winter bottom trawl (MAB only), commercial landings, commercial kept and discarded shell heights from port and sea sampling, and growth increment data from analysis of shell growth rings. Separate CASA models were used for MAB and the open and closed portions of GBK (one model was used for GBK previously). The Georges Bank open area model had trends and biomass estimates similar to those from the surveys with no retrospective pattern. Biomass estimates and trends from the CASA models for the other two areas were similar to survey estimates for some periods but the models were not able to fit large peaks in survey indices. The combined CASA model biomass estimate for 2013 was 132,561 mt meats, slightly greater than the estimates from the dredge and Habcam surveys. Abundance and mortality during 2005-2013 were also estimated "empirically" using simple techniques applied to survey and catch data for comparison to CASA results (Appendix B5 in assessment report). The empirical estimates are consistent with conclusions about stock status.

The assumed natural mortality for all but the plus group was increased from 0.12 to 0.16 on Georges Bank and 0.15 to 0.2 in the Mid-Atlantic. Increases in natural mortality were supported by all the CASA models. Based on a likelihood profile for the natural mortality on the plus group in the Georges Bank closed areas, combined with experimental evidence, natural mortality on the plus group was increased to 1.5 times that of smaller sizes (i.e., 0.24 on Georges Bank and 0.3 in the Mid-Atlantic). Experimental runs were conducted assuming density-dependent natural mortality among juveniles, with promising results.

Fishing Mortality: Fully recruited fishing mortality rates for the whole stock ranged from 0.32 to 0.49 during 2009-2013 and averaged 0.40 (Figure B2). Fully-recruited fishing mortalities prior to 2005 cannot be directly compared to the new recommended F_{MSY} estimate due to changes in fishery size-selectivity over time. The estimated fishing mortality rate during 2013 was F=0.32 (CV 9%). The CV from the CASA models likely underestimates the uncertainty.

The ratio of total catch number to January 1 estimated abundance from CASA for sea scallops greater than 80 mm is more interpretable than *F* as a measure of exploitation trends. This index shows increasing exploitation from 1975-1994, and low exploitation since about 1999 (Figure B3).

Recruitment: Estimated recruitment has generally been higher since the late 1990s than before (Figure B7). Recruitment on Georges Bank was relatively low during 2002-2006, but has increased since. The strength of the apparently strong 2011 year class is uncertain and more data will be required to fully evaluate its size. Recruitment in the Mid-Atlantic was above average during 1998-2008 and 2012, but below average in 2009-2011 and 2013.

Stock and Spawning Stock Biomass: Total and spawning stock biomass are approximately equivalent for sea scallops. Stock biomass rapidly increased during 1995-2003 and has been relatively stable since (Figure B1). Coincident with initial area closures and effort reduction measures, 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, 2013 was 132,561 mt meats. Biomass in 2013 was almost twice as high on Georges Bank (86,460 mt) than in the Mid-Atlantic (46,101 mt).

Biological Reference Points (whole stock)

Reference point	SARC-50	SARC-59
F_{MSY}	0.38	0.48
$B_{TARGET}=B_{MSY}$ (mt, meats)	125,358	96,480
$B_{THRESHOLD}=1/2\ B_{MSY}$ (mt, meats)	62,679	48,240
MSY (mt, meats)	24,975	23,798

As in the last assessment, reference points were calculated using the SYM model (Hart 2013), which includes spawner-recruit relationships, per recruit calculations, and uncertainty in all parameters. SYM 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. The new recommended biological reference points for the whole stock in the SARC-59 assessment are F_{MSY} =0.48 and B_{MSY} = 96,480 mt (Figure B8). The basis for the changes in the F_{MSY} and B_{MSY} estimates are detailed in the full report, but are primarily due to the increases in M, and poor recruitment at high biomass in the Mid-Atlantic for three of the four year classes observed since the last benchmark assessment.

Special Comments

- Area management plays an important role in sea scallop stock dynamics, with much of the biomass located in long-term or rotational closures. Under area management, the reported whole-stock fishing mortalities underestimate fishing mortalities in open areas where fishing occurs continuously. It is possible that these open areas might be depleted even if overfishing is not occurring on the whole-stock (Hart 2001; 2003).
- The model results show slightly decreasing biomass from 2005 to 2012 with a sharp increase in 2013 to the maximum in the time series (Figure B1). The survey biomass estimates do not suggest an increase in biomass in 2013 (Figure B9). SARC-59 noted that stock biomass has

been overestimated by an average of 24% in the last seven years based on a retrospective analysis. Management should be aware of these trends and results.

- SARC-59 noted that natural mortality is simulated as a density-independent process and that might not reflect reality. It is suggested that further work be done to evaluate the effects of density on mortality, and incorporate those effects in future assessments.
- SARC-59 noted that F_{MSY} estimates for Georges Bank (0.30) and for the Mid Atlantic Bight (0.74) differ greatly. SARC-59 is concerned that applying the combined estimate (0.48) to the whole stock uniformly could imply that GB would be fished harder than biologically advisable and the MAB would be fished more lightly than biologically advisable.
- Multiple surveys estimating absolute abundance reduce the uncertainty in this assessment. However, the model assumption that survey catchabilities are independent causes the model to underestimate uncertainty in absolute abundance estimates.
- This stock is a good candidate for an explicitly spatial assessment model.

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Table B1. Catch and Status Table: Sea scallops

U.S Landings (mt meats)

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Min[2]	Max[2]	Mean[2]	Median[2]
GBK	5,398	9,940	17,807	9,842	6,765	6,695	6,119	8,242	13,474	12,154	1,040	17,807	6,099	5,783
MAB	23,533	15,566	8,772	16,634	17,388	18,808	19,561	17,748	11,533	5,935	731	23,533	8,256	5,965
GOM	177	187	155	117	120	84	168	212	417	498	84	1,614	467	407
SNE[6]	992	898	2,047	360	325	220	290	386	154	326	7	2,047	214	89
Total	29,108	25,693	26,734	26,593	24,273	26,129	25,898	26,653	25,915	18,664	3,212	29,108	14,903	13,666

U.S. Discards (mt meats)

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Min[3]	Max[3]	Mean[3]	Median[3]
GBK	102	238	378	236	341	389	672	675	610	306	4	991	321	319
MAB	2,559	424	244	294	457	1,013	724	508	245	150	11	2,559	690	440
Total	2,661	662	622	530	798	1,402	1,397	1,183	855	456	57	2,261	1,011	688

Estimated abundance (July 1, 40+ mm SH, millions, from CASA model)

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Min[2]	Max[2]	Mean[2]	Median[2]
GBK	3,008	2,933	2,593	2921	3,070	3,403	3,551	3,923	3,948	4,762	543	4,762	1,875	1,268
MAB	3,801	3,790	3,856	3,681	3,879	3,209	2,343	1,675	2,808	3,253	318	3,991	1,734	1,212
Combined	6,809	6,723	6,449	6,602	6,948	6,612	5,894	5,598	6,756	8,014	1,092	8,014	3,609	2,256

Estimated biomass for status determination (July 1, 40+ mm SH, thousand mt meats, from CASA model)

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Min[2]	Max[2]	Mean[2]	Median[2]
GBK	74,899	73,672	63,925	57,733	59,489	64,600	71,109	78,037	81,166	86,460	5,903	86,460	33,855	24,202
MAB	50,849	52,694	61,284	62,298	58,561	54,706	44,283	33,973	30,516	46,101	4,820	62,298	22,686	10,541
Combined	125,748	126,366	125,209	120,031	118,050	119,306	115,392	112,010	111,682	132,561	12,284	132,561	56,541	32,023

[1]Region abbreviations: Georges Bank (GBK), Mid-Atlantic Bight (MAB), Gulf of Maine (GOM), Southern New England (SNE). For assessment modeling purposes, SNE landings are lumped with the GBK region.
[2] 1975-2013
[3] 1992-2013
[4] 1976-2013
[5]Values are comparable to reference points for 2005-2013 only; other years not comparable due to changes in fishery selectivity.

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

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Min[4]	Max[4]	Mean[4]	Median[4]
GBK	455	794	719	1,505	1,057	1,351	1,034	1,363	1,131	2,336	207	2,336	795	746
MAB	580	2,615	936	1,660	2,256	286	777	385	3,685	323	73	3,877	994	712
Combined	1,035	3,409	1,656	3,164	3,314	1,637	1,811	1,748	4,816	2,660	280	5,005	1,789	1,560

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

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Min[2]	Max[2]	Mean[2]	Median[2]
GBK	0.14	0.21	0.44	0.30	0.25	0.24	0.16	0.17	0.29	0.30	0.09	1.69	0.48	0.31
MAB	0.93	0.80	0.35	0.62	0.70	0.82	0.85	0.87	0.74	0.39	0.17	1.51	0.78	0.77
Combined	0.43	0.41	0.40	0.46	0.47	0.49	0.43	0.39	0.40	0.32	0.17	1.47	0.58	0.49

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

Year	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Min[2]	Max[2]	Mean[2]	Median[2]
GBK	0.08	0.11	0.23	0.15	0.11	0.11	0.08	0.08	0.14	0.14	0.08	0.88	0.31	0.22
MAB	0.27	0.19	0.11	0.21	0.24	0.23	0.27	0.33	0.29	0.08	0.08	0.72	0.38	0.33
Combined	0.18	0.16	0.16	0.19	0.18	0.17	0.17	0.18	0.18	0.11	0.11	0.77	0.34	0.29

[1]Region abbreviations: Georges Bank (GBK), Mid-Atlantic Bight (MAB), Gulf of Maine (GOM), Southern New England (SNE). For assessment modeling purposes, SNE landings are lumped with the GBK region.
[2] 1975-2013
[3] 1992-2013
[4] 1976-2013
[5]Values are comparable to reference points for 2005-2013 only; other years not comparable due to changes in fishery selectivity.

Figures

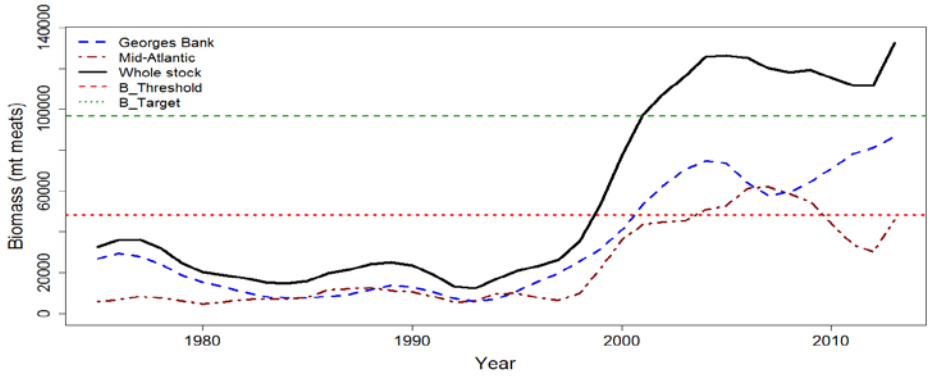

Figure B1. Sea scallop biomass (40+ mm SH) during 1975-2013, compared to whole stock biomass reference points.

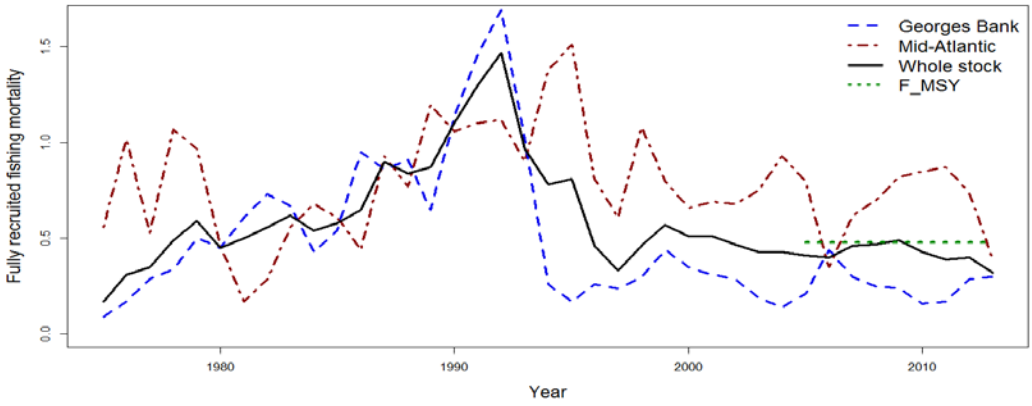

Figure B2. Fully recruited annual fishing mortality rate for sea scallops during 1975-2013. Trends are different for partially recruited scallops because of changes in commercial size-selectivity. The SARC-59 F_{MSY} is shown for the most recent period; F_{MSY} would have been smaller in past years when the selectivity was different.

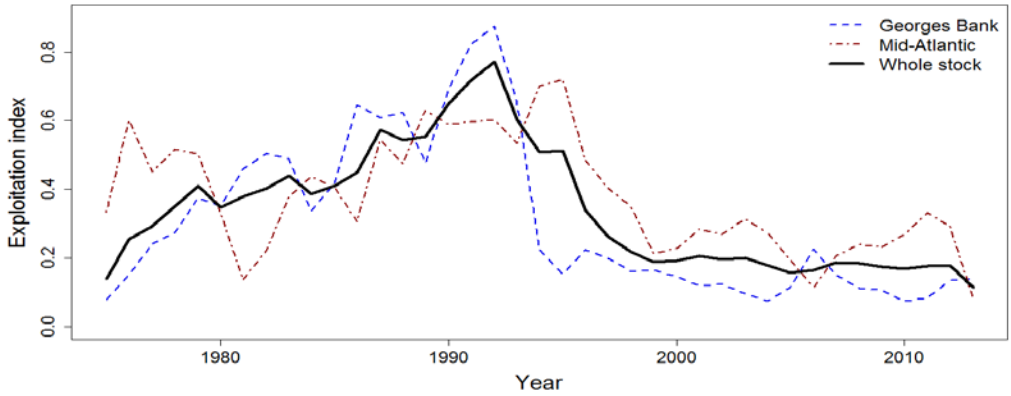

Figure B3. Simple exploitation index for sea scallops during 1975-2013 (Catch in numbers divided by population number for >80 mm shell height.

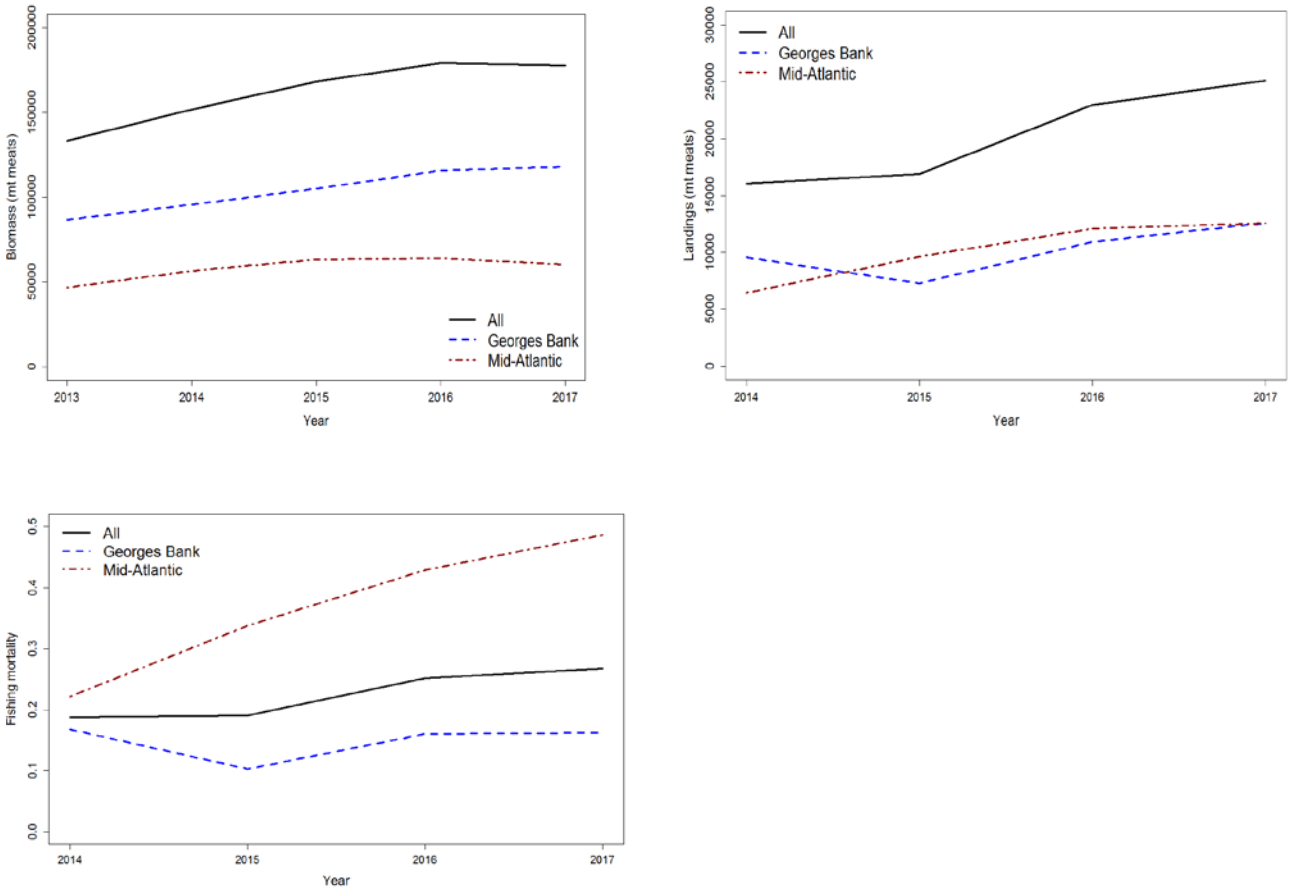

Figure B4. Projected sea scallop biomass, landings and fully recruited fishing mortality for Georges Bank, the Mid-Atlantic Bight and the entire (i.e., total) stock under an example management scenario during 2013-2017.

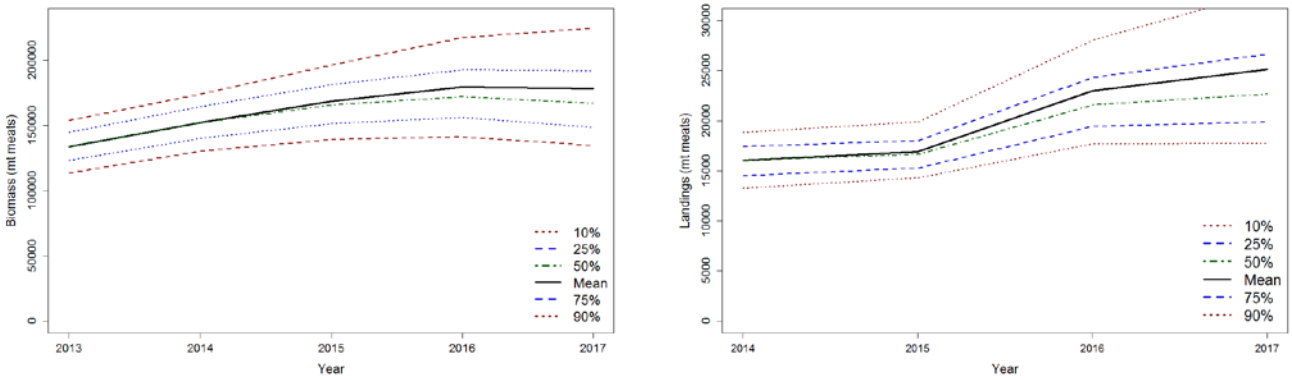

Figure B5. Mean and 10th, 25th, 50th, 75th, and 90th percentiles of projected sea scallop biomass and landings for the combined stock under an example management scenario during 2013-2017.

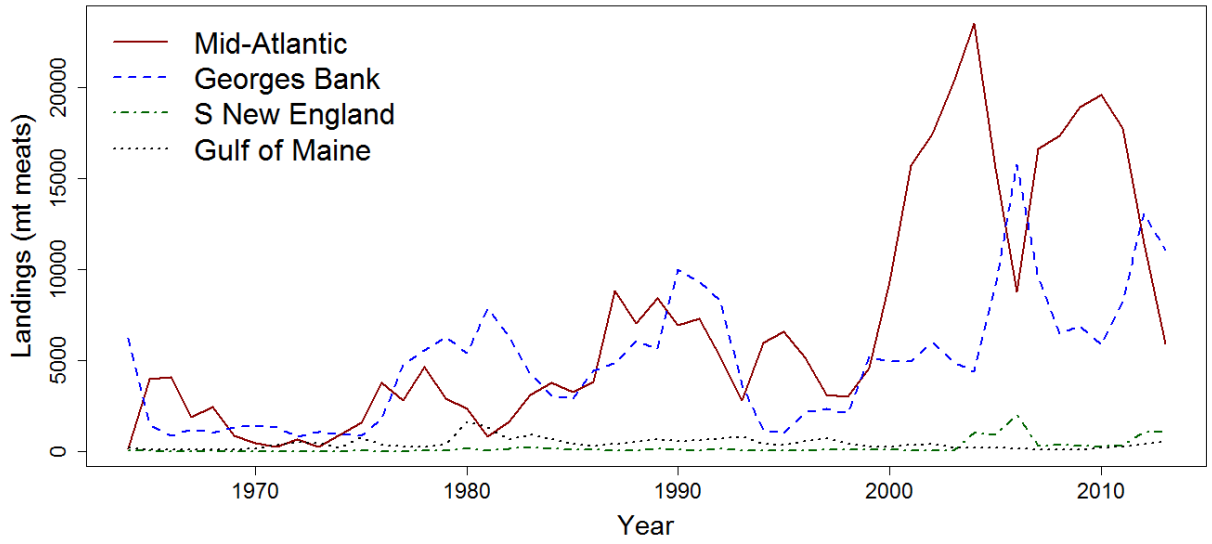

Figure B6. Sea scallop landings by region during 1975-2013.

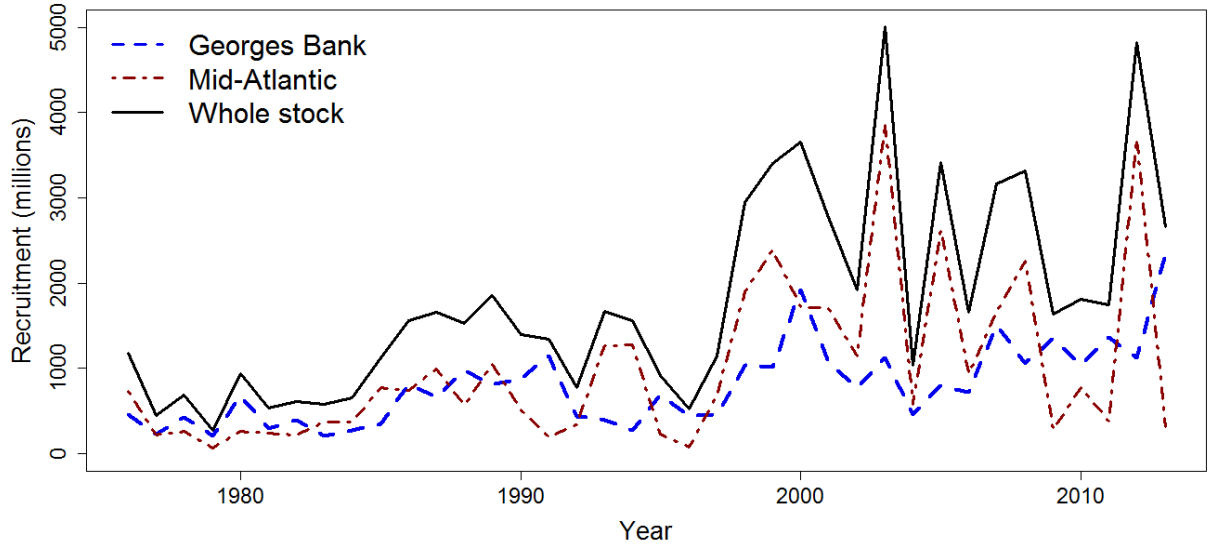

Figure B7. Sea scallop recruitment (millions, approximate age 2) during 1976-2013, as estimated by the CASA model.

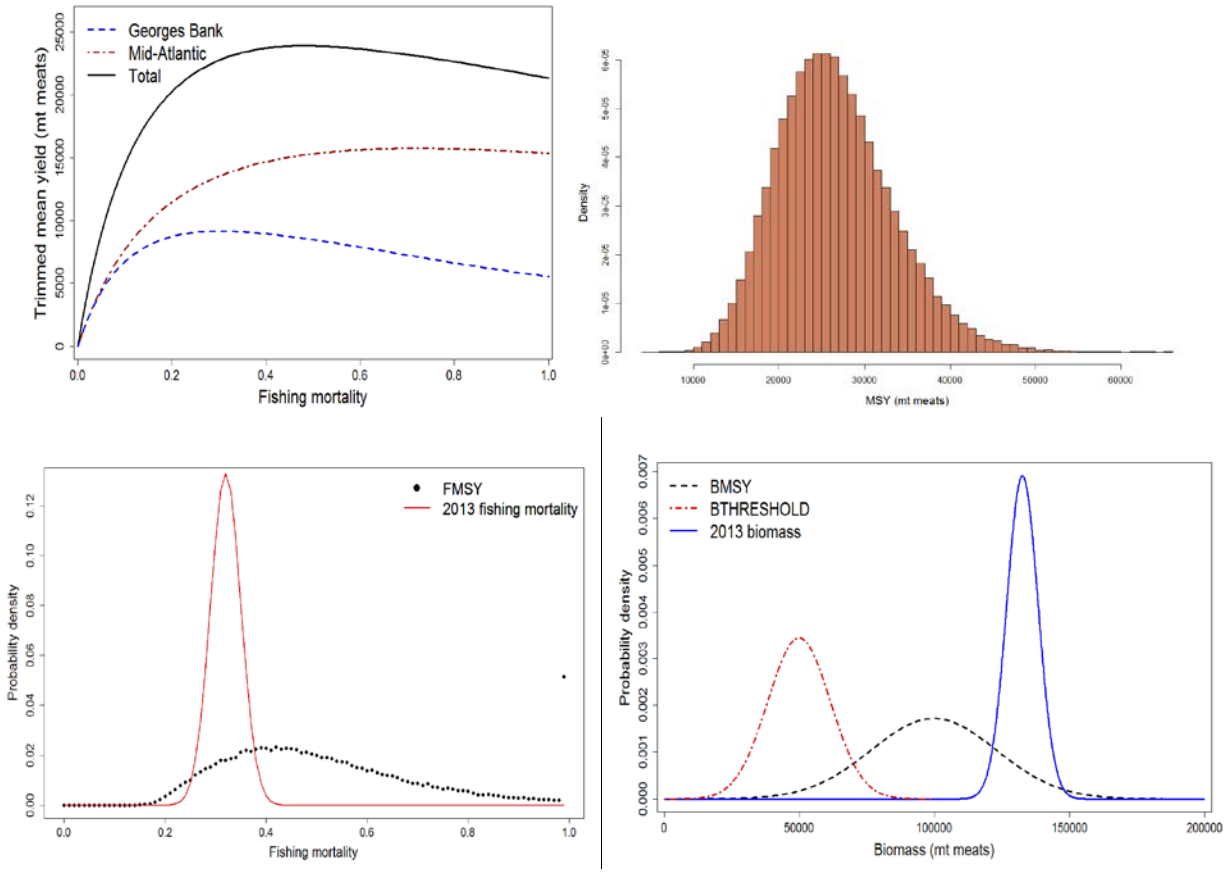

Figure B8. SYM reference point model results. *Top left*: Trimmed mean yield curves for Georges Bank, the Mid-Atlantic Bight, and the whole sea scallop stock. *Top right:* Probability density of whole-stock MSY. *Bottom Left*: Probability density of whole-stock F_{MSY}, compared to probability density of 2013 fishing mortality estimate. *Bottom right*: Probability density for whole-stock B_{MSY}, B_{MSY} /2= $B_{THRESHOLD}$, and the probability density for the 2013 estimated biomass. The uncertainty in 2013 fishing mortality and biomass is understated.

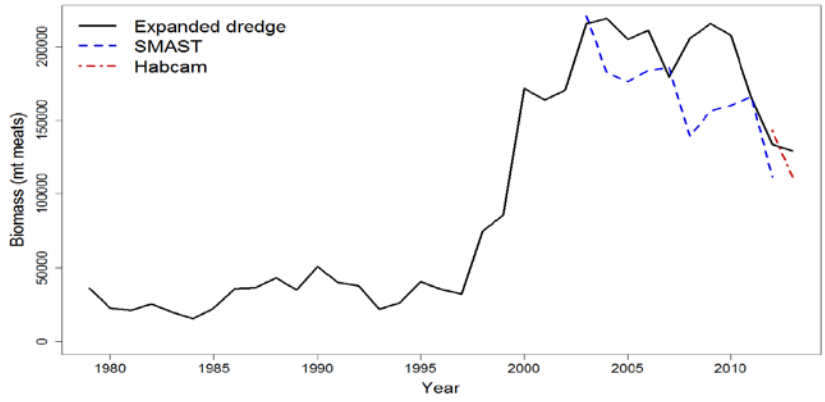

Figure B9. Estimates of sea scallop biomass expanded from the lined dredge, SMAST drop camera and Habcam towed camera surveys.