B. SEA SCALLOP ASSSESSMENT SUMMARY FOR 2007

State of Stock: Based on both the previous Biological Reference Points (BRPs) as well as the new recommended BRPs, sea scallops in the US EEZ (Figure B1) during 2006 were not overfished and overfishing was not occurring. Biomass (for scallops ≥ 40 mm shell height, SH) during 2006 was 166 thousand mt meats, which is above the new recommended biomass target (108.6 thousand mt meats), and above the new recommended biomass threshold (54.3 thousand mt meats, Figure B2). The NEFSC sea scallop survey index in 2006 was 7.3 kg/tow (adjusted for an assumed dredge survey selectivity pattern as in previous assessments, see below), which is above both the previously used biomass target (5.6 kg/tow) and biomass threshold (2.8 kg/tow, both adjusted, Figure B3).

During 2006, the fully recruited (> 120 mm SH) fishing mortality for sea scallops from the size-structured catch at size analysis (CASA) model (0.23 per year, Figure B4) was below the updated fully recruited fishing mortality threshold (0.29 per year, Figure B5). Using the rescaled *F* approach that was used in previous assessments, fishing mortality during 2006 was 0.20 per year, which is below both the current overfishing threshold (0.24 per year) and the updated estimate (0.29 per year).

Projections: Projections with fishing mortality rates of 0.20 and 0.24 per year suggest there will be modest increases in biomass and landings during 2006-2009, although projection results are uncertain (Figures B6-B7). Projected landings during 2007-2009 (25,000 – 33,000 mt meats) are similar or slightly higher than historically high 2003-2006 landings (Figures B6-B8). Example projections are based on current area-based management from sea scallop Amendment 10 and Framework 18 (NEFSC 2003, 2005), historical recruitment patterns, and on recent biological and fishery conditions.

Stock Distribution and Identification: Atlantic sea scallops are distributed from Cape Hatteras to Newfoundland. In the US EEZ, sea scallops are mainly at depths of 30 to 110 m. Sea scallops in the US EEZ are a single management unit although spatial management has been used in recent years to increase yield and prevent overfishing.

Catches: Landings increased from about 8,000 mt meats per year in the mid-1980s to over 17,000 mt meats per year during 1990-1991 (Figure B8). Landings declined during 1993-1998 to 5,000-8,000 mt meats per year and then increased rapidly during 1999-2001. Landings reached historical peaks (averaging about 26,000 mt meats per year) during 2002-2006. The Mid-Atlantic Bight accounted for three-quarters of total landings during 2000-2005. In contrast, Georges Bank accounted for two-thirds of total landings during 2006. The shift in 2006 was due to low landings in the Hudson Canyon Access Area in the Mid-Atlantic combined with high landings in the Georges Bank access areas. Landings in the Gulf of Maine ranged from 134-622 mt meats and averaged 316 mt meats per year during 1997-2006, while landings in southern New England ranged from 20-403 mt meats and averaged 139 mt meats during 1997-2006. Total discards averaged 1,000 mt meats per year during 1992-2006. Discard levels were above average during 2000-2004 but declined in 2005-2006, due in part to changes in gear regulations (4" rings). Survival of discards is probably high.

Data and Assessment: The sea scallop fishery in the U.S. E.E.Z was modeled separately for Georges Bank and the Mid-Atlantic Bight (Figure B1), and results for the two regions were combined to assess the entire stock. Overfishing and overfished status were evaluated in this assessment for the stock as a whole, as specified by Amendment 10 to the Sea Scallop Fishery Management Plan (NEFMC 2003). Other areas, such as the Gulf of Maine and Southern New England, that contribute little to landings or biomass were not included in the assessment models.

New growth data were used for the first time in this assessment. The new growth data indicate that Mid-Atlantic sea scallops do not grow as large and that they reach their maximum size faster than previously assumed. The new growth data for Georges Bank indicate that growth is similar to the previously estimated growth curve.

This assessment used new shell height/meat weight relationships for survey and commercial catches. Shell height-meat relationships for commercial catches were adjusted based on sea sampling and landings data to account for commercial shucking practices, absorption of water during storage and transport, and seasonal patterns in meat weights during each year.

The selectivity of the lined survey dredge used in the NEFSC sea scallop survey was estimated by comparison to SMAST video survey data. Results show that the lined dredge has the same selectivity (equal efficiency of catch) for all sea scallops larger than 40 mm SH. Previous assessments assumed that the lined dredge had maximum selectivity and catch efficiency for catch for sea scallops 40-60 mm SH. All calculations, other than sensitivity analysis and comparisons to existing reference points, in the current assessment used NEFSC dredge survey data assuming equal selectivity for all sea scallops greater than 40 mm SH. Because of the change in assumed selectivity, the NEFSC dredge biomass indices are about 25-30% lower than those given in previous assessments; this is a change in the relative biomass indices only and is not related to any change in the estimates of absolute biomass.

A size-structured forward projecting assessment model (CASA) was used as the primary assessment model, with additional analyses based on rescaled F approach used previously. The CASA model for sea scallops was introduced in the last assessment (NEFSC 2004) but was not used to determine stock status at that time because the model was relatively new and had not been tested thoroughly. Simulation modeling and sensitivity analysis in this assessment indicated that the CASA model was generally more accurate than the rescaled F method previously used. The CASA model results were based on a wide range of information including data from the NEFSC sea scallop, winter bottom trawl and SMAST small camera video surveys, commercial landings, shell height measurements for landed scallops from port and sea sampling, commercial landings per unit effort, and growth increment data from growth rings on scallop shells. Biomass and fishing mortality estimates from the CASA model for Georges Bank and the Mid-Atlantic Bight had mild retrospective patterns, but there was no retrospective pattern for the stock as a whole because the retrospective patterns for the two regions were in opposite directions. The estimated fishing mortality for sea scallops during 2006 from the CASA model (0.23 per year) was similar to the estimate (0.20 per year) from the rescaled F approach and trends in mortality estimates from the two models were similar.

Biological Reference Points: Based on the new assessment, the recommended biomass target for sea scallops is B_{TARGET} = 108.6 thousand mt meats (for scallops ≥ 40 mm shell height) and the recommended biomass threshold reference point is $B_{THRESHOLD}$ = ½ B_{TARGET} = 54.3 thousand mt meats. The recommended target biomass was calculated with CASA model estimates, by multiplying biomass per recruit at F_{MAX} (86.3 grams per recruit) times median recruitment during 1983-2006 (1,258 million sea scallops per year). Explorations of possible stock-recruitment relationships indicate that recruitment overfishing is unlikely provided that sea scallop biomass remains above the proposed reference points.

F_{MAX}, a proxy for F_{MSY}, is used as the overfishing threshold. In the new assessment, a size-based per recruit model provides an updated estimate of $F_{THRESHOLD}$ (F_{MAX} = 0.29 per year;

Figure B5) for the whole stock. The updated estimate of F_{MAX} is based on new information on growth rate and fishery selectivity patterns during 2006, and it is higher than the older value primarily due to the new estimates of growth in the Mid-Atlantic region, and the shift towards larger scallops in fishery landings.

Based on Amendment 10 (NEFMC 2003) of the sea scallop FMP, the current (i.e., older) biomass target reference point is B_{TARGET} = 5.6 kg/tow (adjusted as in the last assessment for assumed NMFS survey dredge selectivity patterns). That value was calculated as biomass per recruit at F_{MAX}, from a previous per recruit model, times the median recruitment index from NEFSC sea scallop surveys. The current biomass threshold is ½ B_{TARGET} = $B_{THRESHOLD}$ = 2.8 kg/tow (adjusted).

The current (i.e., older) estimate of the overfishing threshold (F_{MAX} = 0.24 per year) was based on an age-based yield per recruit analysis (Applegate et al. 1998). The target fishing mortality rate is 0.20 per year, and this was not revised.

Fishing Mortality: Fully-recruited fishing mortalities for sea scallops during 2006 were 0.31 per year on Georges Bank, 0.17 per year in the Mid-Atlantic, and 0.23 per year for the whole stock, based on CASA model estimates (Figure B4). Based on uncertainties in survey and commercial catch data, there is only about a 7% probability that overfishing occurred (fishing mortality above the new recommended threshold reference point) in the sea scallop stock during 2006 (Figure B9). A 95% confidence interval for 2006 whole-stock fishing mortality is (0.17, 0.32). CASA model estimates of fishing mortality are not comparable to previously estimated fishing mortality reference points because of changes in selectivity and estimates of growth.

Recruitment: Sea scallop recruits correspond roughly to two year old individuals. Recruitment was below average for sea scallops on Georges Bank during 2004-2006 based on CASA model estimates (Figure B10 and Catch and Status Table). Recruitment in the Mid-Atlantic has been above average for every year since 1998 except 2004 and 2006.

Stock Biomass: Stock biomass was 166 thousand mt meats in 2006, which is the historical high during 1982-2006 (Figure B2). Sea scallop biomass was almost equally distributed between Georges Bank (81,000 mt meats) and the Mid-Atlantic Bight (85,000 mt meats). Considering uncertainties in survey and landings data, there is less than a 1% estimated probability that the sea scallop stock biomass was below the target biomass of 108.6 mt meats during 2006 (Figure B11).

Special comments: The current recommended F_{MAX} proxy for F_{MSY} in sea scallops should be revisited in the next assessment because the recent fishery selectivity patterns that focus harvest on large sea scallops make yield-per-recruit curves flat on the top, making it difficult to estimate F_{MAX} precisely (Figure B5).

Area management plays an important role in sea scallop stock dynamics, with much of the biomass located in long-term or rotational closures, or in reopened closed areas under special management. When there is spatial variability in fishing mortality, as occurs under area management (Hart 2001), fishing mortality reference points such as the F_{MAX} proxy, calculated under the assumption of spatially uniform fishing mortality, may overestimate the fishing mortality level that would actually maximize yield per recruit. For example, if half of the scallop biomass was located in closed areas, the whole-stock fishing mortality would have to be about half of the recommended fishing mortality threshold in order to maximize yield per recruit in the areas remaining open to fishing.

Sources of Information:

Applegate, A., S. Cadrin, J. Hoenig, C. Moore, S. Murawski, and E. Pikitch. 1998. Evaluation of existing overfishing definitions and recommendations for new overfishing definitions to comply with the Sustainable Fisheries Act. Final Report, June 17, 1998. New England Fisheries Management Council, Saugus, MA, 171 p.

Hart, D.R. 2001. Individual-based yield-per-recruit analysis, with an application to the Atlantic sea scallop, *Placopecten magellanicus*. Can. J. Fish. Aquat. Sci. 58: 2351-2358.

Hart D.R. 2006. Sea Scallop Stock Assessment Update for 2005, NEFSC Ref. Doc. 06-20, 14 p.

New England Fishery Management Council (NEFMC). 2003. Final Amendment 10 to the Atlantic sea scallop fishery management plan with a supplemental environmental impact statement, regulatory impact review, and regulatory flexibility analysis. New England Fisheries Management Council, Newburyport, MA.

New England Fishery Management Council (NEFMC). 2005. Framework Adjustment 18 to the Atlantic Sea Scallop FMP including an environmental assessment, regulatory impact review, regulatory flexibility analysis and stock assessment and fishery evaluation (SAFE) report. New England Fisheries Management Council, Newburyport, MA.

Northeast Fisheries Science Center (NEFSC). 2001. 32nd Northeast Regional Stock Assessment Workshop (32nd SAW). Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NEFSC Ref. Doc. 01-05, Woods Hole, MA, 289 p.

Northeast Fisheries Science Center (NEFSC). 2004. 39th Northeast Regional Stock Assessment Workshop (39th SAW) Assessment Summary Report & Assessment Report. NEFSC Ref. Doc. 04-10a, b, Woods Hole, MA, 16 p. (a) and 211 p. (b).

Catch and Status table: Atlantic Sea Scallop

U.S. Landings (mt meats)														
Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	2,053	2,039	5,085	5,039	4,597	5,541	4,823	4,357	9,502	17,286	982	17,286	5,341	4,710
Mid-Atlantic Bight	2,728	2,891	4,414	8,853	15,611	17,056	20,089	24,497	15,634	8,819	1,610	24,497	7,981	6,492
Gulf of Maine	622	483	243	144	260	499	403	134	143	229	134	895	475	469
Southern New England	87	100	80	74	29	20	103	120	403	370	20	403	116	82
Total	5,489	5,514	9,822	14,110	20,497	23,117	25,417	29,109	25,682	26,704	5,514	29,109	13,913	13,666
U.S. Discards (mt meats)														
Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[2]	*Max*[2]	*Mean*[2]	*Median*[2]
Georges Bank[3]	29	5	162	1,129	865	128	313	91	286	628	3	1,129	293	162
Mid-Atlantic Bight[3]	8	60	11	871	854	1,637	2,417	2,644	579	213	8	2,644	807	325
Total (all fisheries)	91	163	266	2,092	1,889	1,936	2,839	2,859	935	860	91	2,859	1,195	842
Trends for Stock Abundance, NEFSC sea scallop survey (numbers/tow, > 40 mm shell height)														
Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	80.6	271.2	159.8	715.5	357.8	297.9	225.8	269.9	210.5	151	30.1	715.5	172.6	133.4
Mid-Atlantic Bight	41.3	157.6	234	283.6	306.3	301	641.3	468.8	360.1	378.1	27.7	641.3	186.6	131.2
Combined	59.6	210.5	199.4	484.8	330.3	299.6	447.7	376.1	290.4	272.4	29.7	484.8	180.0	136.7
Trends for Stock Abundance, CASA model (millions January 1, > 40 mm shell height)														
Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	1,313	1,637	2,049	3,089	3,362	3,164	3,178	2,974	2,923	2,616	584	3,362	1,818	1,641
Mid-Atlantic Bight	881	2,257	3,599	4,418	4,825	4,657	6,014	5,563	5,360	4,833	524	6,014	2,452	1,747
Combined	2,194	3,894	5,648	7,507	8,187	7,821	9,192	8,537	8,283	7,499	1,401	9,192	4,270	3,236
Trends for Stock Biomass, NEFSC sea scallop survey (kg/tow, > 40 mm shell height)														
	1997	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	1.3	3.7	2.6	6.3	5.1	6	5.4	7.1	5.7	4.5	0.4	7.1	2.4	1.1
Mid-Atlantic Bight	0.4	0.8	1.7	3.0	3.3	3.7	5.7	5.2	6.0	5.9	0.3	6.0	1.9	0.9
Combined	0.8	2.2	2.1	4.5	4.2	4.8	5.6	6.1	5.9	5.2	0.4	6.1	2.1	0.9
Trends for Stock Biomass, CASA model (thousands mt meats January 1, > 40 mm shell height)														
Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	19	24	32	40	53	65	73	79	84	81	6	84	30	17
Mid-Atlantic Bight	10	14	27	45	59	65	71	78	78	85	8	85	29	15
Combined	30	39	59	84	112	129	143	157	162	166	17	166	58	32

Catch and Status Tables (cont.)

Recruitment (~2 year old) trends, CASA model (millions, January 1)

Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	418	752	751	1,858	461	362	751	250	458	209	174	1,858	578	462
Mid-Atlantic Bight	500	2,048	1,695	1,451	1,444	1,121	3,211	312	1,776	370	103	3,211	866	682
Combined	918	2,800	2,446	3,310	1,905	1,483	3,962	563	2,234	579	381	3,962	1,474	1,258

Fishing Mortality (annual instantaneous rates, CASA fully-recruited *F*)

Year	*1997*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*Min*[1]	*Max*[1]	*Mean*[1]	*Median*[1]
Georges Bank	0.31	0.24	0.31	0.22	0.18	0.23	0.19	0.08	0.16	0.31	0.08	2.34	0.60	0.36
Mid-Atlantic Bight	0.50	0.51	0.48	0.45	0.51	0.60	0.61	0.73	0.41	0.17	0.17	1.20	0.70	0.70
Combined	0.38	0.34	0.39	0.36	0.38	0.43	0.43	0.38	0.29	0.23	0.23	1.30	0.64	0.61

[1]1982-2006. [2]1994-2006. [3] Sea scallop fishery only.

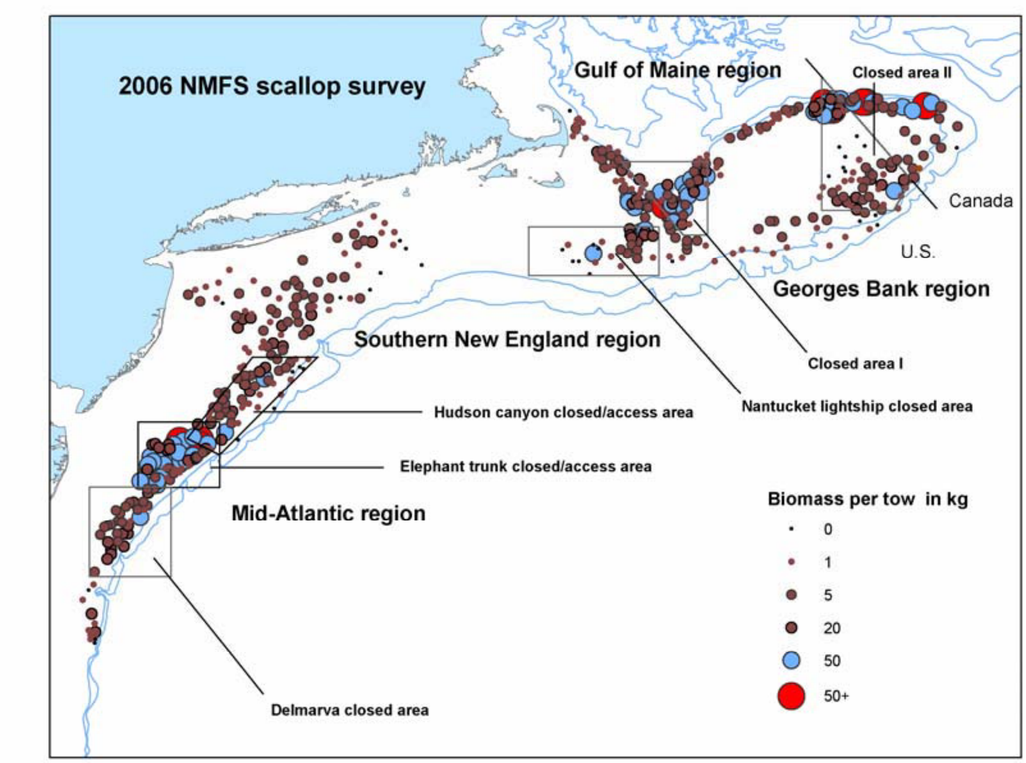


Figure B1. Sea scallop stock, with 2006 NEFSC sea scallop survey catches.

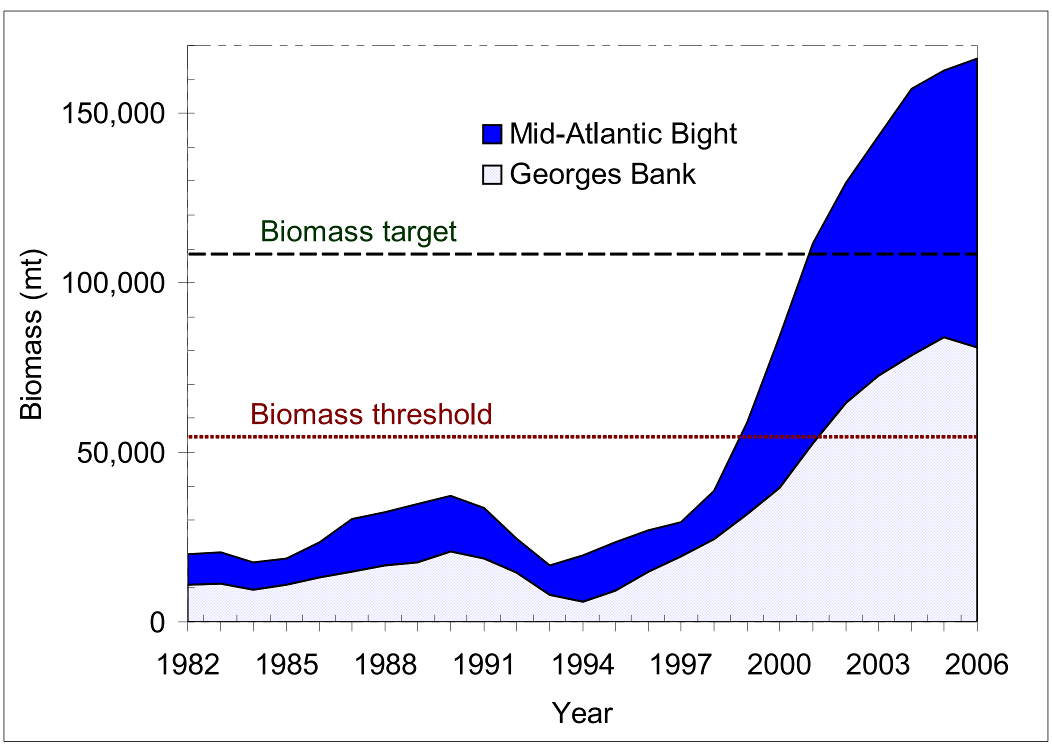


Figure B2. Sea scallop biomass estimates from CASA model, along with recommended biomass reference points.

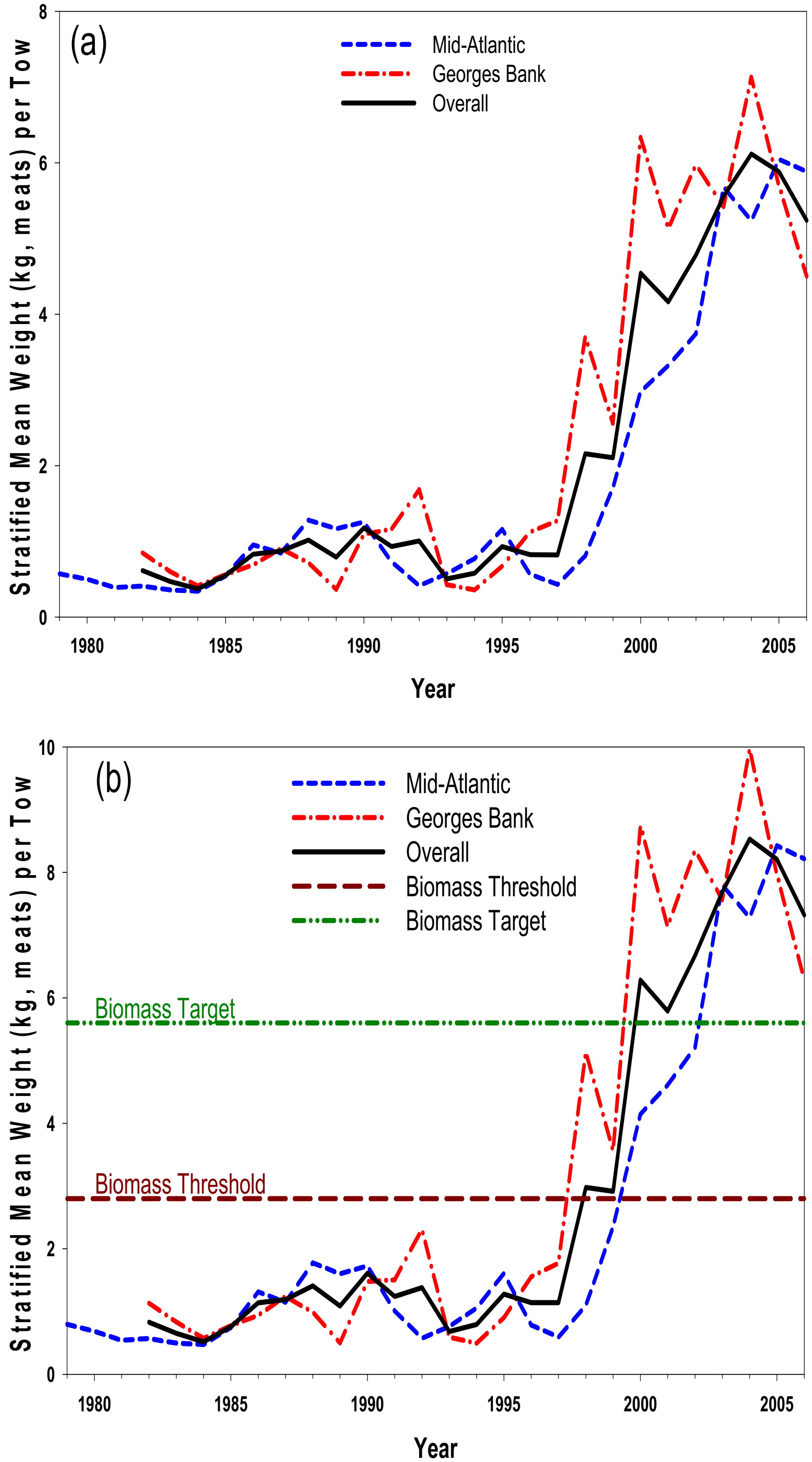


Figure B3. NEFSC sea scallop survey biomass, (a) unadjusted (b) adjusted for selectivity. Current (i.e., older) BRPs are shown (horizontal lines).

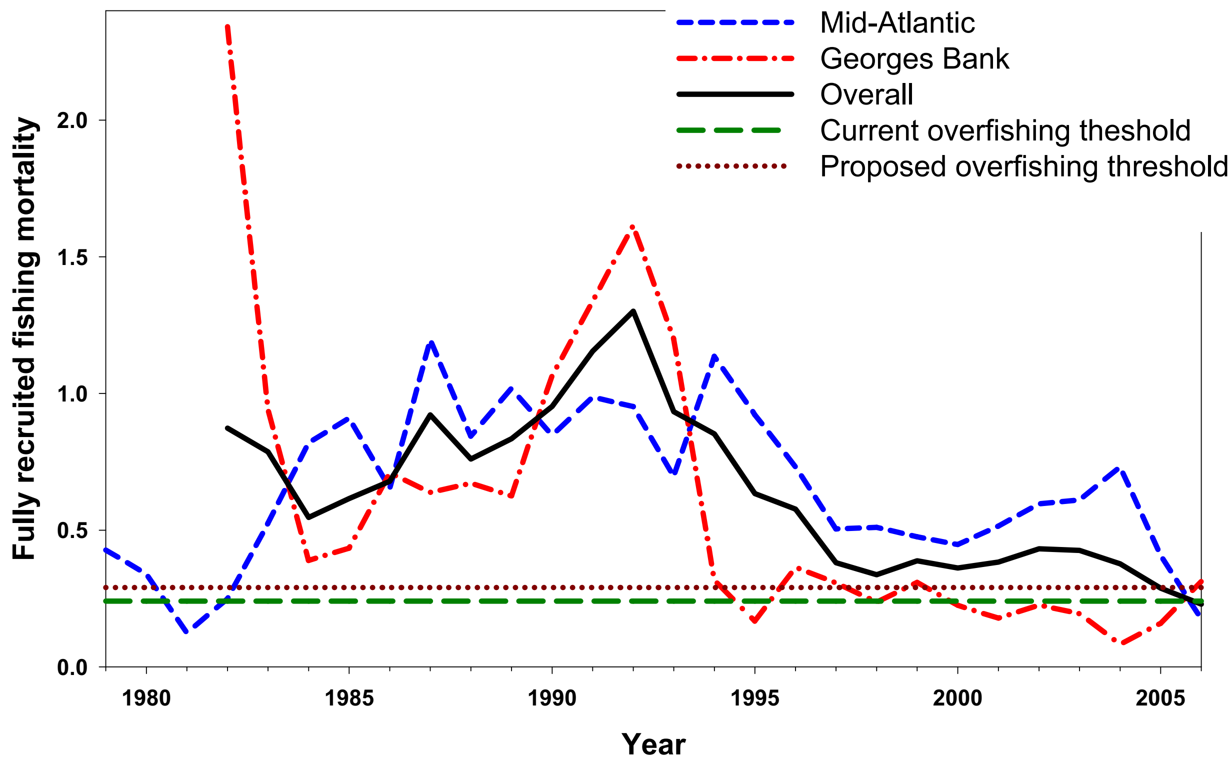


Figure B4. Fully recruited fishing mortality for sea scallops.

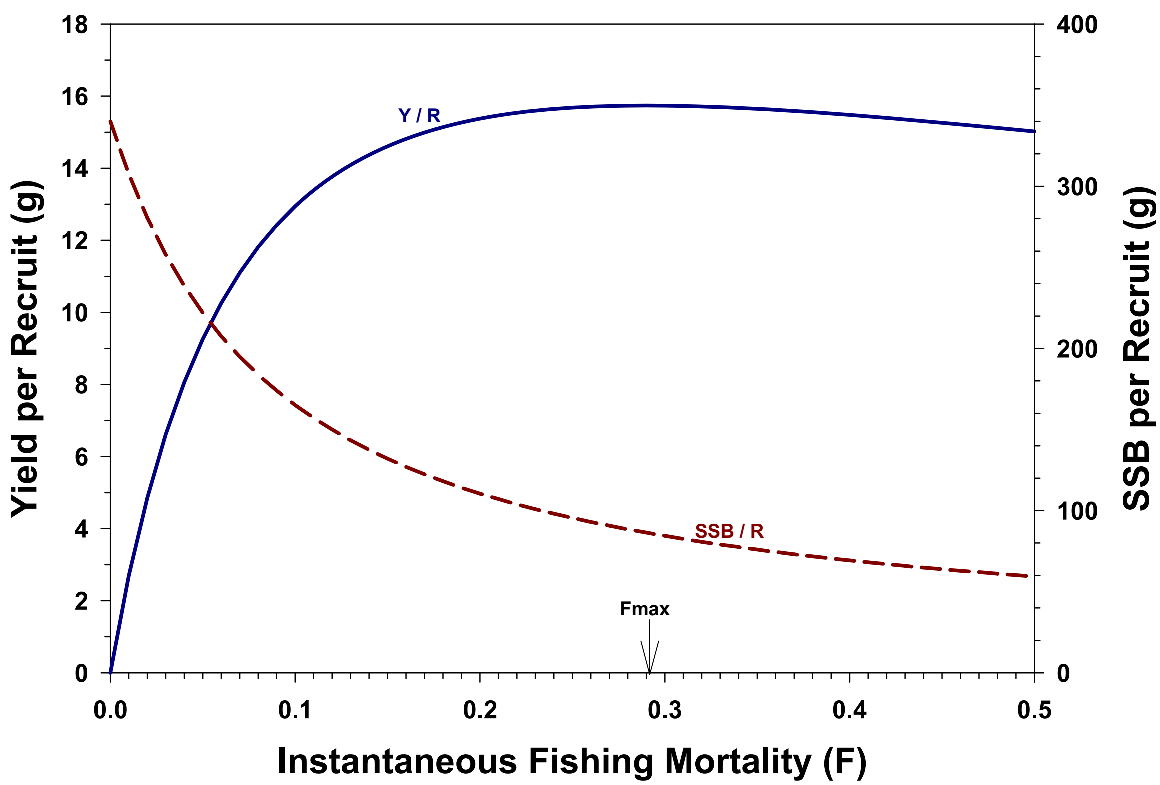
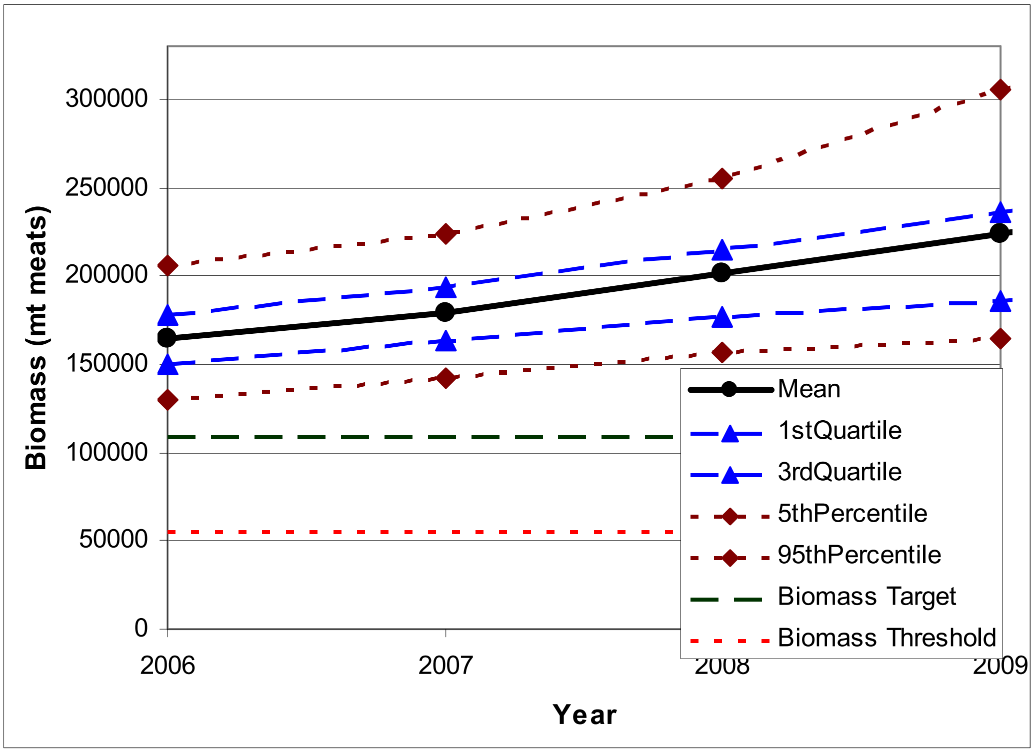


Figure B5. Sea scallop yield and biomass per recruit.



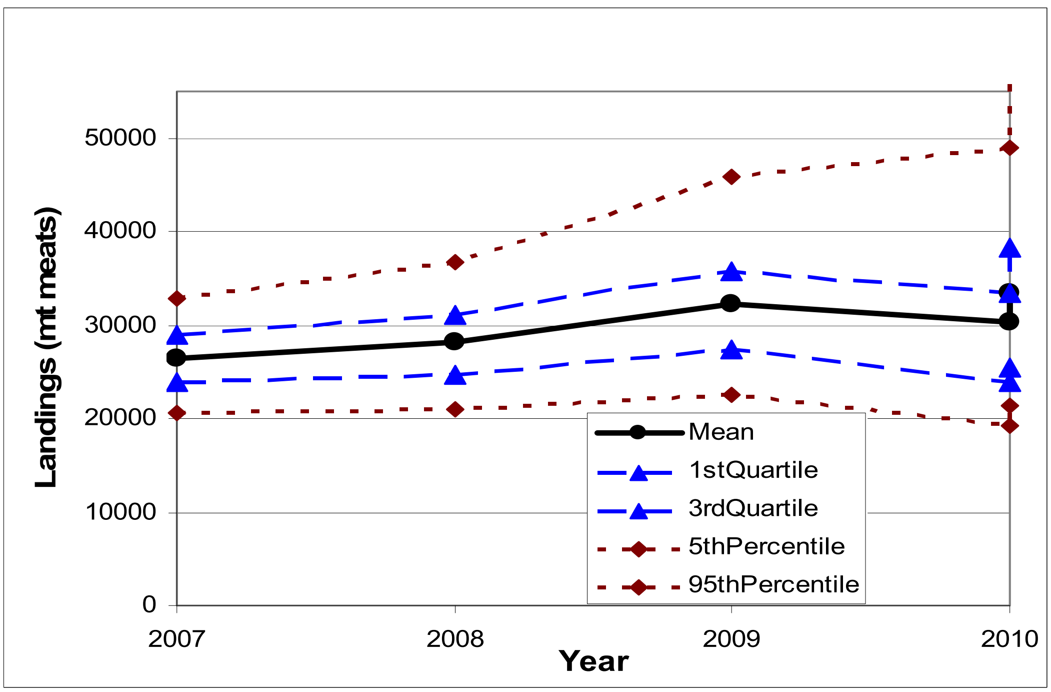


Figure B6. Example, short-term forecasts of sea scallop biomass and landings, assuming that whole-stock fishing mortality in 2007-9 is 0.20.

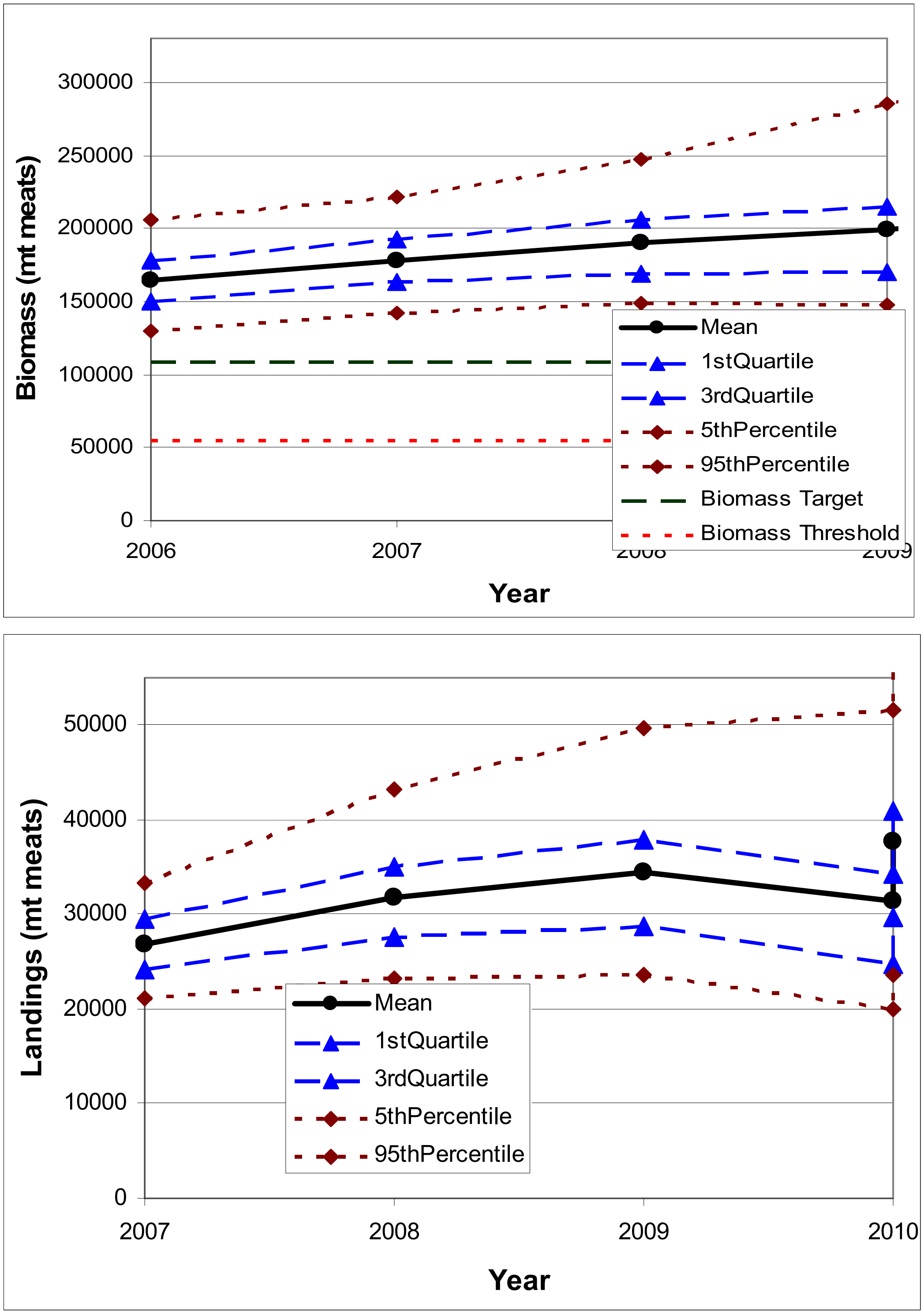


Figure B7. Example short-term forecasts of sea scallop biomass and landings, assuming that whole-stock fishing mortality in 2007-9 is 0.24.

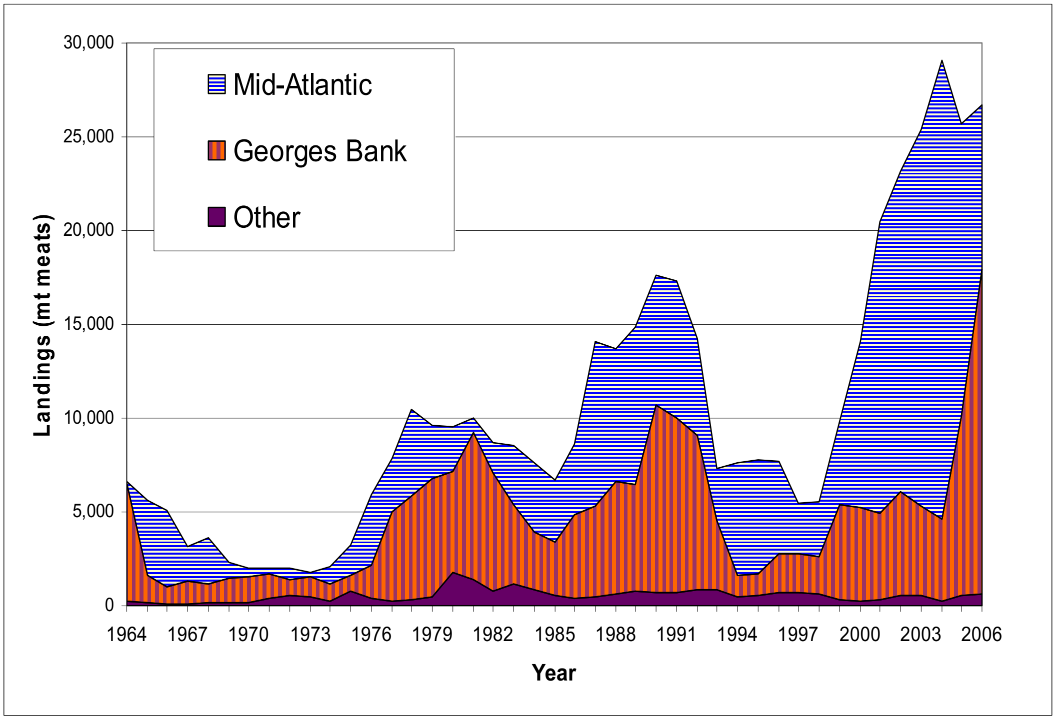


Figure B8. Sea scallop landings (MT meats), 1982-2006.

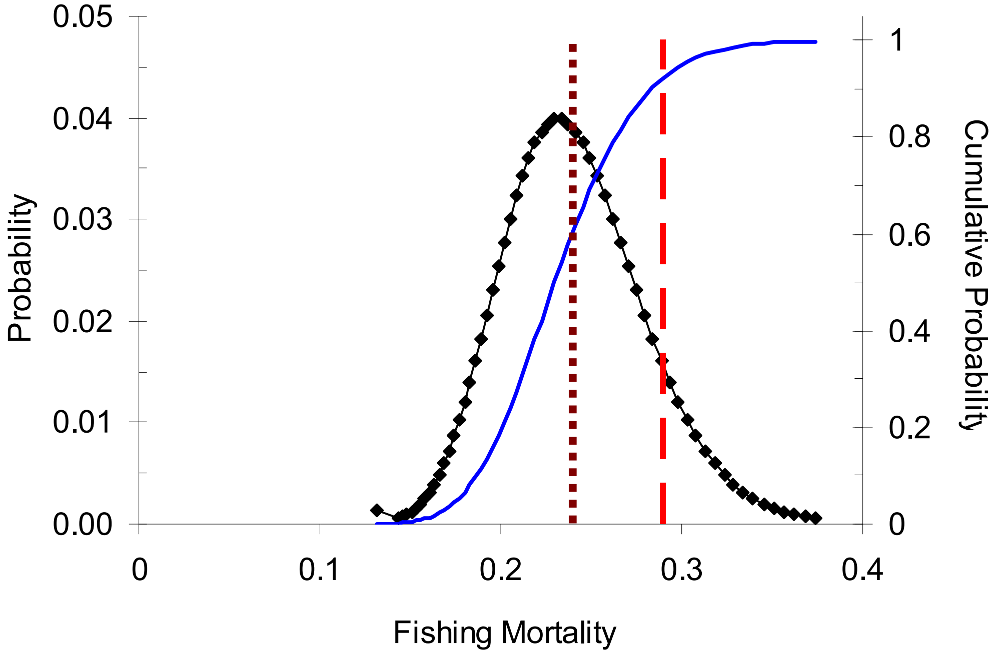


Figure B9. 2006 fishing mortality probabilities with new recommended overfishing threshold (long-dashed line) and current threshold (dotted line) for sea scallops.

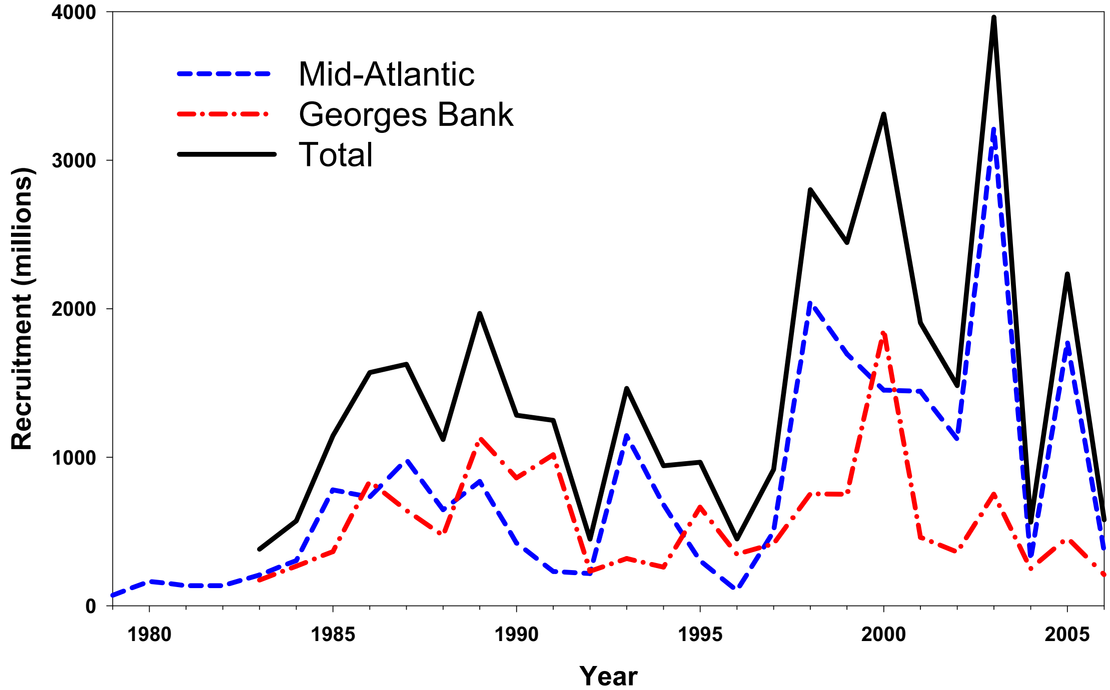


Figure B10. Trends in scallop recruitment, 1982-2006.

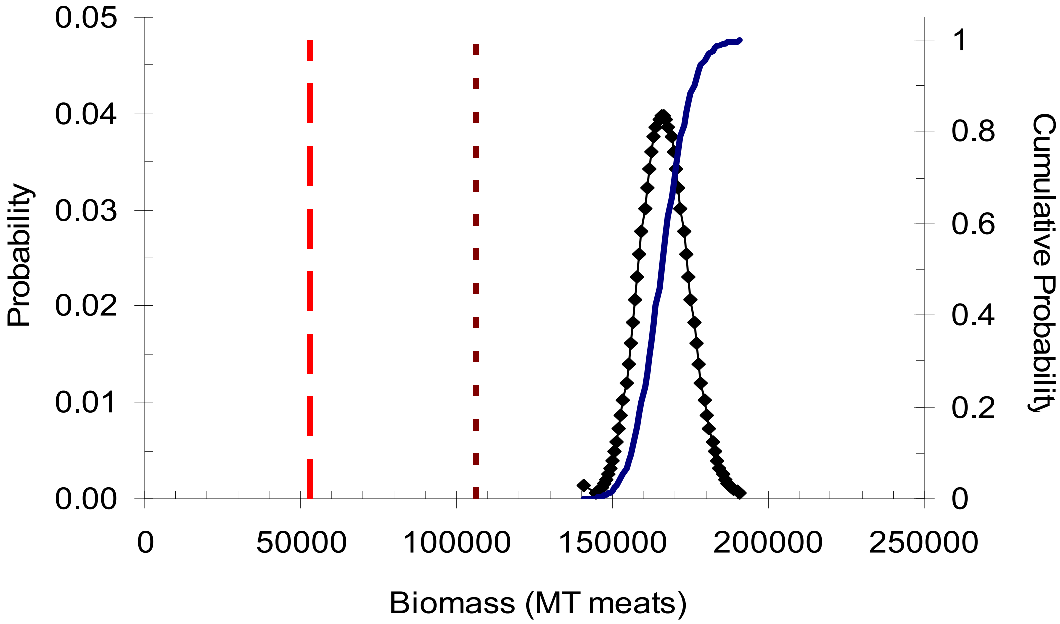


Figure B11. 2006 biomass probabilities with new recommended biomass threshold (long-dashed line) and biomass target (dotted line) for sea scallops.