2018 Sea Scallop Report to the NEFSC SSC

SARC-65 Benchmark Scallop Assessment Summary
2018 Sea Scallop Survey Summary
ACL/OFL Recommendations for 2019 and 2020

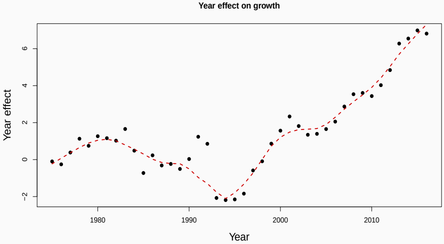
Dvora Hart, NEFSC, Woods Hole MA

Key Innovations

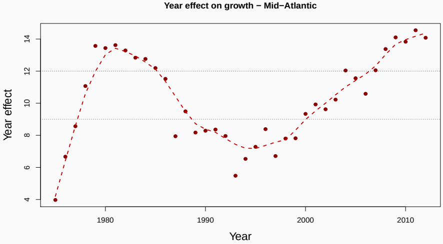
Found substantial temporal variability in growth and shell height to meat weight relationships. Growth and meat weights have been generally increasing since the early 1990s.

Incorporated and estimated variable natural mortality in the CASA models.

Temporal variation in growth

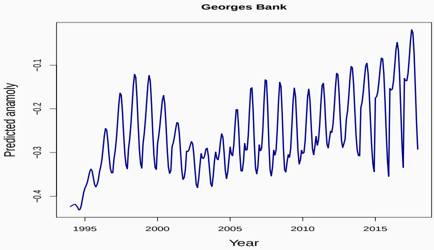


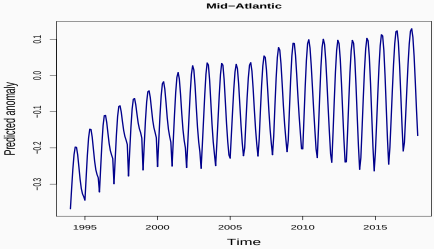
Georges Bank



Mid-Atlantic

Temporal variation in SH/MW





Georges Bank

Mid-Atlantic

CASA (Catch At Size Analysis) Model (TOR-5)

- Based loosely on Sullivan et al. 1990
- Size-based model
- Appropriate for sea scallops (abundant commercial and population shell height data, and growth increment data)
- Parameters are estimated using modern likelihood methods
- Used since 2007 assessment, but with some refinements for each assessment
- As in 2014 assessment (SARC-59), three CASA models were ran for sea scallops: Georges Bank Open, Georges Bank Closed, and Mid-Atlantic

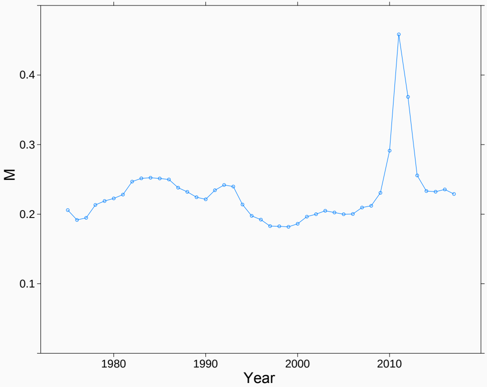
Estimate Size-specific Natural Mortality in CASA

For the first time in this assessment, natural mortality varied with year. In two models, juvenile M was variable, whereas in GB Closed, M for all sizes was variable.

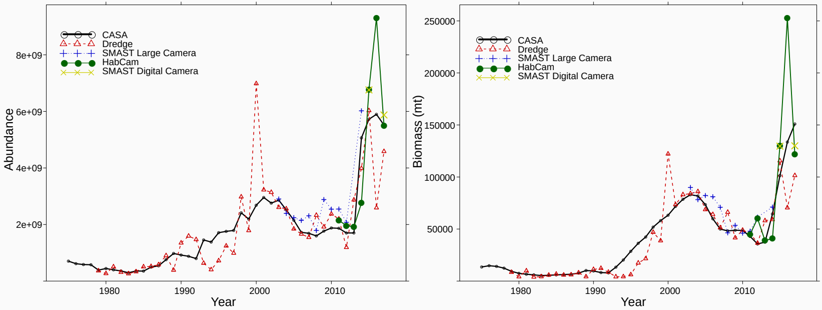
Natural Mortality Parameters	Georges Bank Closed	Georges Bank Open	Mid-Atlantic
Mean Juv. M (J)	-	Fixed at 0.2	Fixed at 0.25
Annual Dev for Juv. M (u_y)	-	Estimated	Estimated
Mean Adu. M (A)	-	Fixed at 0.2	Fixed at 0.25
Annual Dev Adu. (v_y)	-	-	-
Logistic curve (α_L)	-	Fixed	Fixed
Mean Total M ($\bar{M}$)	Estimated		
Annual Dev for Total M (Dev_y)	Estimated		

Georges Bank Closed Area
Natural mortality for all sizes by year

Natural mortality was assumed constant by size, but variable by year. Estimation of M was facilitated by the low or zero fishing mortalities in many years. Natural mortality varied little except for a large spike in 2010-12, coinciding with observed die-offs in Closed Area I and the northern portion of Closed Area II.



Georges Bank Closed Area
Observed and estimated abundance and biomass

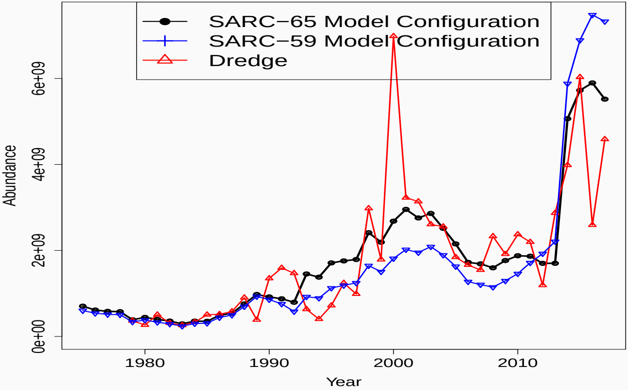


Estimated abundance (left) and biomass (right) with expanded estimates from the lined dredge (red), SMAST large camera (blue), Habcam (green), and SMAST digital camera (light green) surveys.

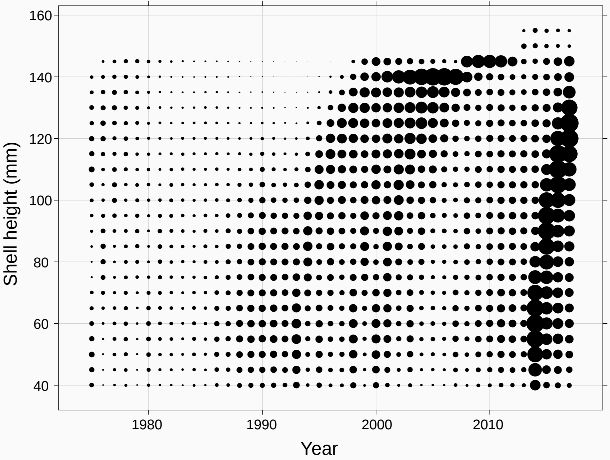
Georges Bank Closed Area

Abundance from current and SARC-59 model configurations and dredge survey

Estimation in M resulted in better fit to survey data than using the SARC-59 model with fixed M.

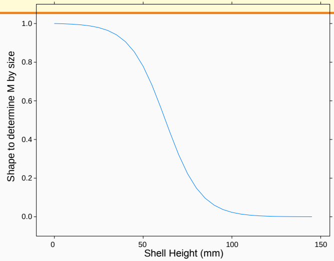


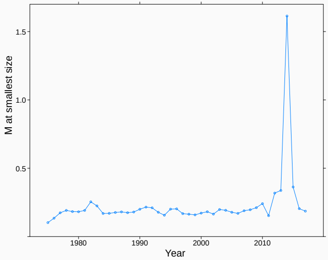
Georges Bank Closed Area
Estimated abundances at shell height by year

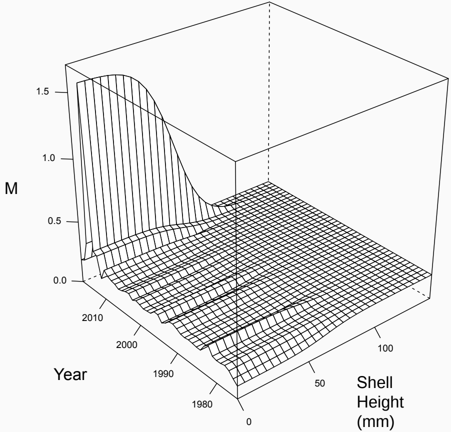


Symbol area is proportional to abundance

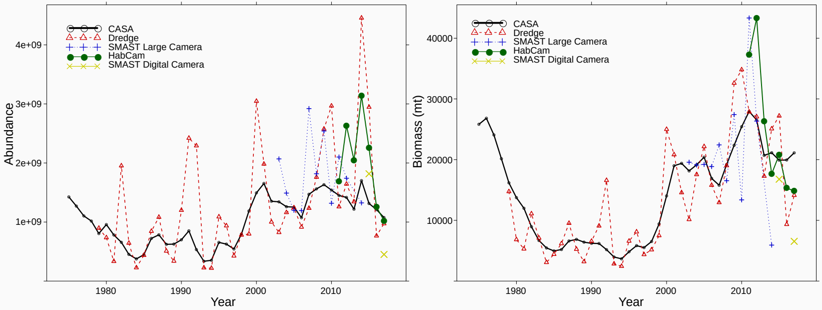
Georges Bank Open Area
Logistic curve and natural mortality by size and year







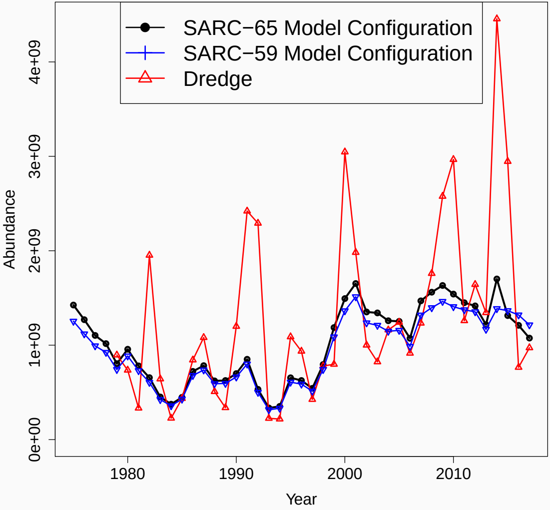
Georges Bank Open Area
Observed and estimated abundance and biomass



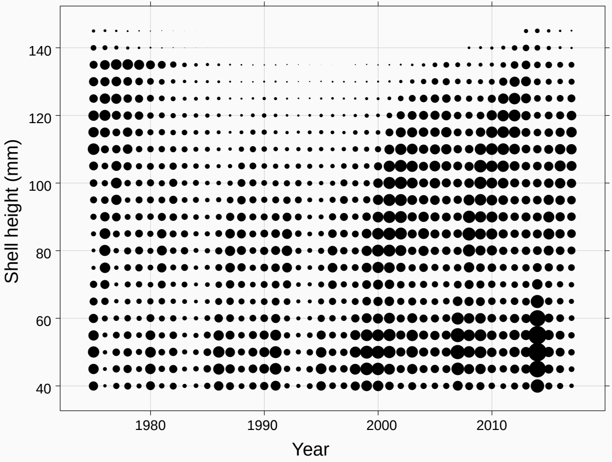
Estimated abundance (left) and biomass (right) with expanded estimates from the lined dredge (red), SMAST large camera (blue), Habcam (green), and SMAST digital camera (light green) surveys.

Georges Bank Open Area

Abundance from current and SARC-59 model configurations and dredge survey

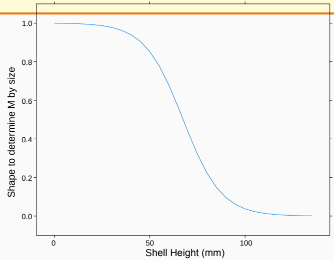


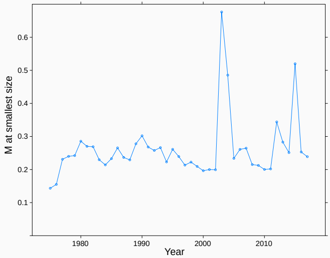
Georges Bank Open
Estimated abundances at shell height by year

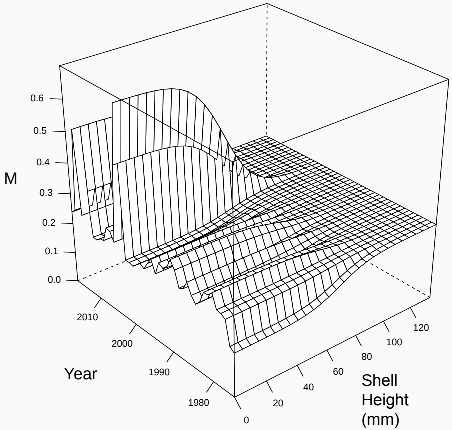


Symbol area is proportional to abundance

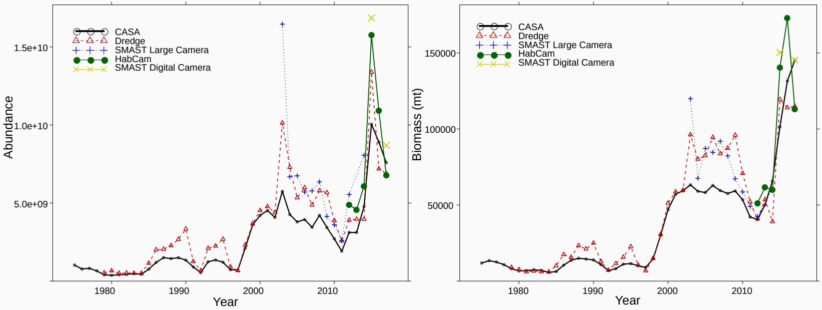
Mid-Atlantic
Logistic curve and natural mortality by size and year







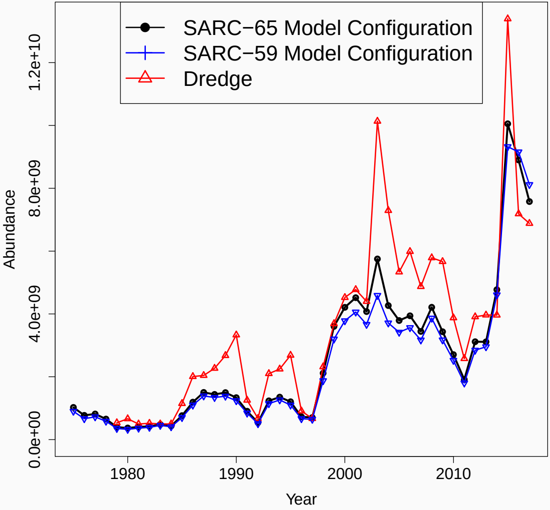
Mid-Atlantic
Observed and estimated abundance and biomass



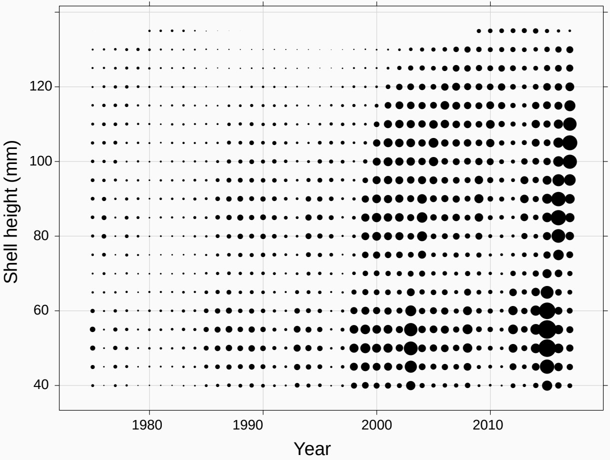
Estimated abundance (left) and biomass (right) with expanded estimates from the lined dredge (red), SMAST large camera (blue), Habcam (green), and SMAST digital camera (light green) surveys.

Mid-Atlantic

Abundance from current and SARC-59 model configurations and dredge survey

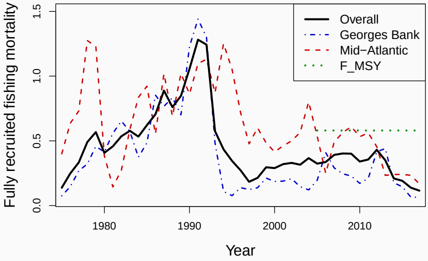


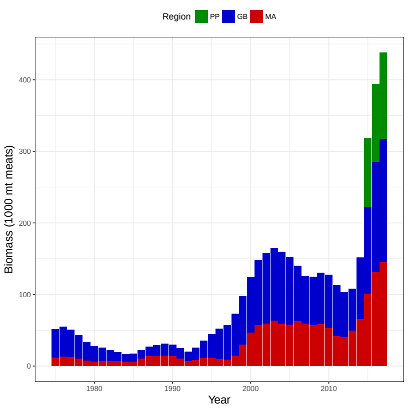
Mid-Atlantic Area
Estimated abundances at shell height by year



Symbol area is proportional to abundance

All Three Stocks Combined
Fully recruited fishing mortality and biomass





Estimated fully recruited fishing mortality (left), and biomass (right) including Habcam biomass estimates of Peter Pan scallops (pp) for Georges Bank (open and closed combined) and Mid-Atlantic sea scallops.

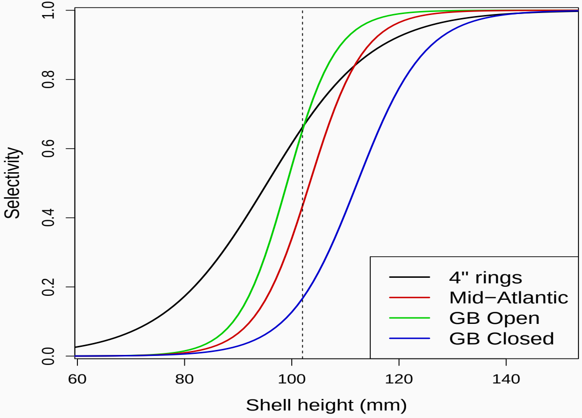
All Three Stocks Combined
2017 biomass and fishing mortality estimates

Stock	**Biomass (mt meats)**	**CV**	**F**	**CV**
Georges Bank Closed	150,951	0.08	0.05	2.06
Georges Bank Open	21,118	0.06	0.13	0.55
Mid-Atlantic	145,265	0.05	0.17	0.42
Total	317,334	0.06	0.12	0.07

Peter Pan scallops are excluded

Fishery Selectivity

Comparison of 4 in. ring selectivity with fishery selectivity estimated by the SARC-65 CASA models.



SYM model

- Takes into account parameter uncertain by Monte-Carlo simulation - each simulation draws parameters from estimated distributions, including covariance with other parameters
- Estimates yield Y using the equations $Y = yR$ and $R = s(bR)$, where y is yield per recruit, R is recruitment, s is the stock-recruit relationship, and b is biomass per recruit (Beverton & Holt 1957).
- Per recruit calculations use the parameters from the most recent period (with uncertainty). Yield and biomass per recruit in meat weight. Natural mortality was set at 0.2 for Georges Bank and 0.25 for the Mid-Atlantic. The stock-recruit curves were estimated using recruitment and biomass/SSB estimated from the CASA model runs.

Modifications since SARC-59

CASA now estimates one year old recruitment R_1, and variable natural mortality for juvenile scallops. This does not fit well into a per recruit framework, especially when there appears to be density-dependent mortality. For this reason, recruitment for the purposes of the reference point models is at *three* years old (previous assessments used two years old). This was estimated by reducing R_1 by the natural and incidental mortality suffered by those recruits when they were two and three years old, as estimated by the CASA model.

Parameters and their uncertainties, including those for growth, sh/mw, selectivity and incidental mortality were also re-estimated

Use of gonad weights

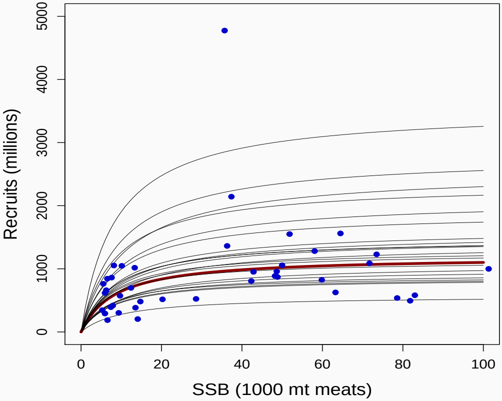
Reference points were calculated with SSB alternatively in terms of gonad weights and meat weights

In principle, gonad weights are a better measure of spawning than meat weights, but there are some technical problems using gonad weights.

The SARC panel recommended further development of gonad-based reference points, but meat weights were used as the principal measure of SSB for this assessment.

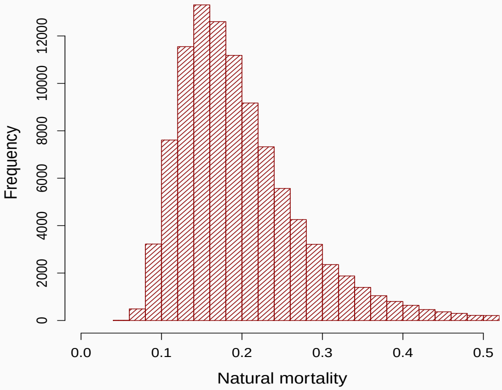
Georges Bank Stock-Recruit Relationship

Beverton-Holt function fairly well estimated. It is probably saturated during the present high biomass period, but there was likely some recruitment limitation when biomass was lower.



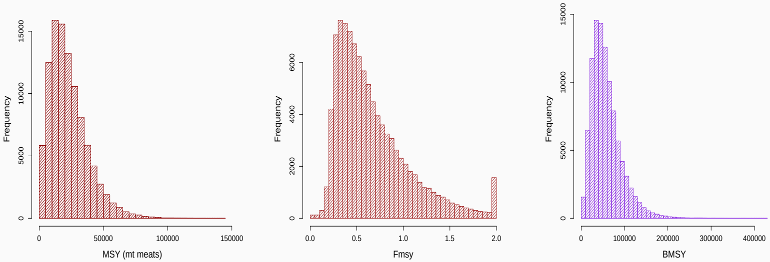
Georges Bank Natural Mortality

Simulated as 1/gamma with $\mu = 0.2$ and $\sigma = 0.082$

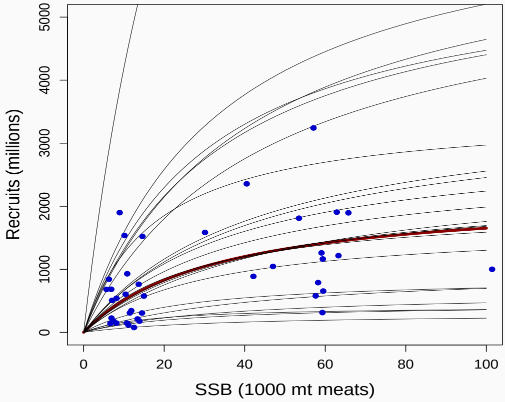


Georges Bank MSY, FMSY and BMSY

Uncertainty in MSY, F_{MSY}, and B_{MSY}

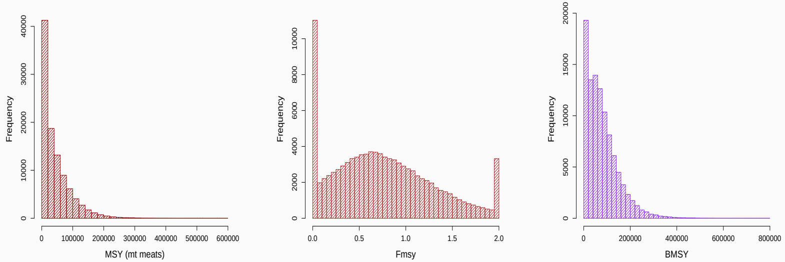


Strong evidence of higher recruitment in Mid-Atlantic at higher biomass. Beverton-Holt function more uncertain in Mid-Atlantic than Georges Bank. It is also unclear whether it is saturated during the high biomass period (since 2000).

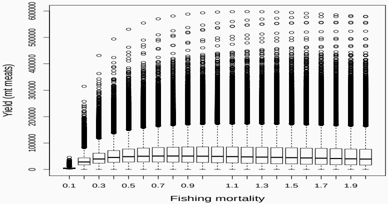


MSY, FMSY and BMSY - Mid-Atlantic

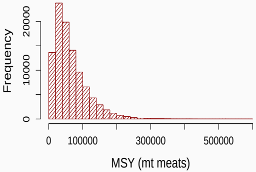
Uncertainty in MSY, F_{MSY}, and B_{MSY}

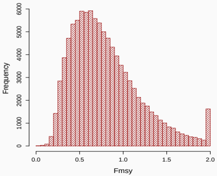


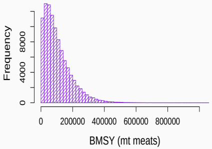
MSY, FMSY and BMSY - Combined



Uncertainty in MSY, F_{MSY}, and B_{MSY} for combined Georges Bank and Mid-Atlantic







Status determination using 2018 reference points (TOR-7)

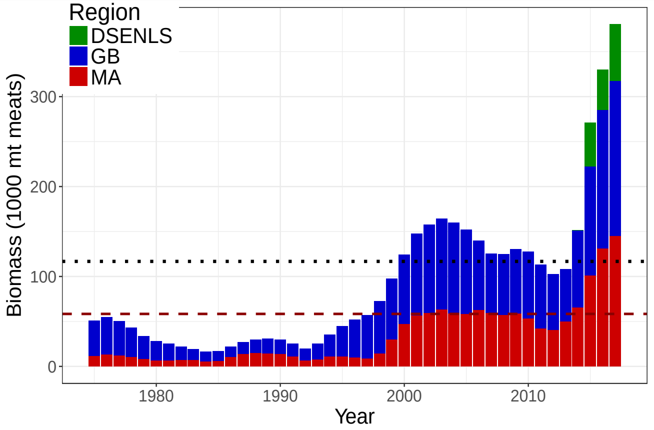
The new reference points are: $B_{\mathsf{MSY}} = B_{\mathsf{TARGET}} = 116,766$ mt meats, $B_{\mathsf{THRESOLD}} = 58,383$ mt meats and $F_{\mathsf{MSY}} = 0.64$.

The estimated biomass in 2017 was 380,389 mt meats (317,335 mt meats excluding Peter Pan scallops), just under three times B_{MSY} and six times B_{THRESOLD}.

Estimated fishing mortality in 2017 was 0.12, less than a fifth of $F_{\mathsf{MSY}} = 0.64$.

Therefore, according to the updated reference points, the stock is neither overfished nor is overfishing occurring. The probability that the stock is overfished or overfishing is occurring is very low.

Biomass compared to its reference points. Stock was overfished through 1997, was rebuilt in 2000, and is currently the highest of the time series.



Final(?) biomass estimates for 2018, with forecasts of 2019

Revised survey estimates, using modified sh/mw, growth and GB Open selectivity for NLS West and South. South Deep

		Dredge				DropCam				Habcam				Mean				2019 Projections		
Region	Subarea	Num	Bmsmt	SE	MeanWt	Num	Bmsmt	SE	MeanWt	Num	Bmsmt	SE	MeanWt	Num	Bmsmt	SE	MeanWt	Bmsmt	%Change	ExpBmsmt
GB	CL1ACC	26.4	1137	138	43.2	82	2700	550	33	31.0	796	8	25.5	46.6	1544	189	33.1	1681	8.8%	1182
GB	CL1NA	325.0	8889	1432	26.2	358	10850	2150	30	353.0	14843	2089	42.1	345.4	11527	1107	33.4	7149	-38.0%	6413
GB	CL-2(N)	380.2	7461	2927	19.6					154.0	5400	341	35.1	267.1	6431	1473	24.1	7333	14.0%	5289
GB	CL-2(S)	344.3	8875	688	25.8					260.0	7125	907	27.4	302.2	8000	569	26.5	10129	26.6%	6222
GB	CL2Ext	375.2	7230	688	19.3					332.0	7956	1131	24.0	353.6	7593	662	21.5	6016	-20.8%	4864
GB	NLSAccN	107.7	3607	192	33.5	127	3855	602	30.3	112.0	3585	17	32.0	115.6	3682	211	31.9	4096	11.2%	2995
GB	NLSAccS-Shallo	196.3	2111	426	10.8	330	4120	2122	12.5	374.0	4964	36	13.3	300.1	3732	722	12.4	2747	-26.4%	1137
GB	NLSAccS-Deep	3743.8	30963	935	8.3	5442	40709	7596	7.5	3686.0	31790	1681	8.6	4290.6	34487	2612	8.0	38036	10.3%	10435
GB	NLS-W	2395.2	44790	1806	18.7	3482	58500	12550	16.8	2262.0	41155	2568	18.2	2713.1	48148	4312	17.7	41751	-13.3%	31926
GB	NLSExt	4.2	137	13	32.3	93	2188	1836	23.5	13.0	321	20	24.7	36.7	882	612	24.0	542	-38.5%	527
GB	NF	46.4	502	312	10.8					57.0	1466	200	25.8	51.7	984	185	19.0	1260	28.1%	922
GB	SCH	648.6	9453	2153	14.6	453	6150	550	13.6	351.0	9130	254	25.6	484.2	8244	746	17.0	12990	57.6%	8425
GB	SCH-45	0.2	7	2	41.1					3.0	96	0	34.0	1.6	52		32.2			
GB	SF	274.4	4403	513	16.0					297.0	7048	887	23.7	285.7	5726	512	20.0	5697	-0.5%	4202
GB	**TOTAL**	**8867.9**	**129565**	**4576**	**14.6**					**8285.0**	**135675**	**4110**	**16.4**	**9594.2**	**141032**	**5604**	**14.7**	**139427**	**-1.1%**	**84539**
MAB	BI	217.8	2572	244	23.7					61.0	942	36	15.4	139.4	1757	123	12.6	3095	76.1%	1773
MAB	LI	428.2	8813	471	13.4					827.0	20597	3383	24.9	627.6	14705	1708	23.4	13569	-7.7%	9440
MAB	NYB	512.7	6667	771	28.9					354.0	5779	148	16.3	433.4	6223	392	14.4	7068	13.6%	4438
MAB	MA inshore	50.4	931	170	45.8					86.0	766	3	8.9	68.2	849	85	12.4	1120	32.0%	952
MAB	HCSAA	786.6	13529	853	15.8					583.0	13109	923	22.5	684.8	13319	628	19.4	12884	-3.3%	8817
MAB	ET Open	714.7	15126	710	11.7					776.0	17936	716	23.1	745.4	16531	504	22.2	17828	7.8%	14386
MAB	ET Flex	887.6	18018	1197	16.6					1013.0	27486	1682	27.1	950.3	22752	1032	23.9	22389	-1.6%	19382
MAB	DMV	63.0	1150	161	35.0					50.0	1168	70	23.2	56.5	1159	88	20.5	1627	40.4%	985
MAB	VIR	65.7	86	19	55.7									65.7	86	19	1.3	301	250.9%	19
MAB	**TOTAL**	**3726.9**	**66891**	**1896**	**17.9**					**3750.0**	**87783**	**3958**	**23.4**	**3771.3**	**77380**	**2194**	**20.5**	**79881**	**3.2%**	**60192**
TOTAL	**TOTAL**	**12595**	**196456**	**4953**	**15.6**					**12035**	**223458**	**5706**	**18.6**	**13366**	**218412**	**6018**	**16.3**	**219308**	**0.4%**	**144731**

Anomalous Growth in the High Density Areas of Nantucket Lightship

There was very little observed growth in the Nantucket Lightship West and South areas between 2017 and 2018, which together currently contain a majority of the scallops on Georges Bank.

Analysis of a limited number of shells from the 2012 year class in these areas indicate abnormally slow growth: $L_\infty = 119.1$ and $K = 0.487$ for Nantucket Lightship West and $L_\infty = 110.3$ and $K = 0.423$ in the deep water southern portion of this area. This compares with $L_\infty = 151.2$ and $K = 0.397$ for the Nantucket Lightship as a whole, so these estimates are well below normal growth. Nonetheless, observed growth was less than even these reduced estimates. Growth appears to variable from year to year. Projections use estimated growth parameters, but these estimates are highly uncertain.

ACL/OFL Calculations

The SAMS model was used with $F = 0.51$ for ACL and $F = 0.64$ for OFL. The 2020 OFL and ACL estimates assume all areas were fished at $F = 0.51$ in 2019. These calculations now assume Georges Bank Open selectivity for Nantucket Lightship West and Deep South areas. Biomass, landings and discards are in metric tons.

Year	Bms	ExplBms	Land	Discard	Total
ACL					
2019	218394	144731	57003	5986	62989
2020	175859	114930	46028	4915	50943
OFL					
2019	218394	144731	66791	6630	73421
2020	175859	114930	53994	5453	59447