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New England Fishery Management Council
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MEMORANDUM

DATE: October 9, 2019

TO: Science and Statistical Committee

FROM: Scallop Plan Development Team (PDT)

SUBJECT: PDT recommendations for OFL and ABC for Framework 32 (FY2020 and FY2021 default)

This memorandum addresses the following 2019 SSC terms of reference for Atlantic sea scallops and SSC recommendations from 2018.

2019 SSC Terms of Reference:

1. Review changes to meat weights used to develop 2019 survey estimates, and growth and selectivity parameters used in the SAMS model to project biomass in portions of the Nantucket Lightship. Provide the Council with a recommendation as to whether these changes are appropriate.
2. Review the Scallop PDT's updated projections for the scallop resource, and provide the Council with OFL and ABC recommendations for fishing years 2020 and 2021 (default).

Updates on 2018 SSC Recommendations:

1. The SSC recommends further investigation into the: 1) different growth rates found in different scallop harvesting areas, particularly the Nantucket Lightship region, 2) further work to develop gonad-based estimates of SSB and reference points.

The PDT met on October 1, 2019 to review the OFL and ABC estimates for FY2020 and FY2021 and drafted this memo through correspondence. More details will be provided during the presentation of this recommendation at the SSC meeting on October 17, 2019.

PDT Consensus Statement:

The Scallop PDT recommends that the SAMS model estimates for OFL and ABC for 2020 and 2021 (default) be presented to the SSC (Table 1) The PDT notes that the updated OFL and ABC values are based on SARC 65 (OFL F=0.64; ABC F=0.51), and are relatively higher than values used in prior years (see Table 11) . The updated OFL and ABC estimates for 2020 are very similar to the 2020 projection that was approved by the SSC in October 2018. Both the 2020 and 2021 biomass estimates indicate a decline from the record high levels observed in recent years. This decline is attributed to the extraordinarily large 2012 and 2013 year classes recruiting to the fishery and the absence of strong recruitment in subsequent years. These exceptionally strong year classes make up the majority of total biomass and, with the exception of the slow-growing, deep-water scallops in the Nantucket Lightship, are responsible for the majority of the population being considered exploitable (Table 2). The 2018 re-opening of several habitat and groundfish closures that hold high densities of scallops (through the partial approval of OHA2) facilitated the harvest of animals that were previously inaccessible to the fishery. Scallop harvesting is expected to continue in these areas in 2020 and beyond, resulting in an expected decline in biomass as these animals are removed from the population.

The PDT recommends the following data treatments and modeling of scallops in the Nantucket Lightship to account for unique characteristics of animals in this area. The PDT notes that the SSC has approved these changes for several years, but feels that there is value in continued evaluation of the situation in the Nantucket Lightship:

- <u>Shell-Height and Meat Weight (SH-MW) Relationships:</u> SH-MW parameters were updated through SARC 65. Based on 2019 survey observations, applying benchmark parameters in portions of the Nantucket Lightship area may lead to an overestimation of 2019 biomass, which has implications for 2020 projections. As with previous years, the PDT recommends using area-specific SH-MW parameter estimates from the dredge survey in these areas.
- <u>Dredge Efficiency:</u> Dredge efficiency in high density areas continues to be an issue, and the PDT recommends decreasing dredge efficiency by two thirds from 0.4 to 0.13 in the NLS-West and NLS-S-deep. This recommendation is based on peer-reviewed findings from SARC 65.
- <u>Growth:</u> The PDT recommends that growth in the SAMS model be modified to account for anomalously slow growth in the Nantucket Lightship-West and Nantucket Lightship South-Deep, based on growth estimates using only shells from the large 2012 cohort in that area.
- <u>Selectivity:</u> The PDT recommends applying the SARC 65 Georges Bank Open selectivity curve as estimated in the CASA model in the Nantucket Lightship-West and South-Deep areas. The Georges Bank Closed selectivity curve reflects targeting of very large scallops; however, considering that the year class in these portions of the Nantucket Lightship area are smaller than normal, it is unlikely that the Georges Bank Closed selectivity would apply to these areas. Observer data from 2019 also suggest that the fishery is high grading in the Nantucket Lightship West. Therefore, using only the gear selectivity of the 4” ring (Yochum and DuPaul 2008) would overestimate the proportion of scallops that are likely to be retained by the fishery.

If higher than expected natural, incidental, or discard mortality occurs, biomass estimates will be overestimated, especially for 2021. In 2018, survey data suggested that scallop density per meter squared declined in the deep portion of the Nantucket Lightship, suggesting natural mortality in the absence of fishing.

Total mortality in the Nantucket Lightship West appeared to be high between 2018 and 2019, with surveys suggesting a major downturn in biomass that is likely the result of fishing, discard, incidental, and natural mortality.

Looking ahead, there are several reasons for the decline in OFL and ABC estimates between 2020 and 2021: (1) the strong 2012 & 2013 year classes are being fished; (2) Areas that were formally closed (before partial approval of OHA2) are now being fished; (3) an extended period of low recruitment.

Table 1 – Scallop PDT recommendation for OFL and ABC for Framework 32, Fishing years 2020 and 2021 (default). Values shown in metric tons (mt).

Year	ABC-Land	ABC-Disc	ABC-Tot	OFL-Land	OFL-Disc	OFL-Total
2020	45414	5046	50460	53224	5962	59186
2021	36435	3995	40430	42790	4713	47503

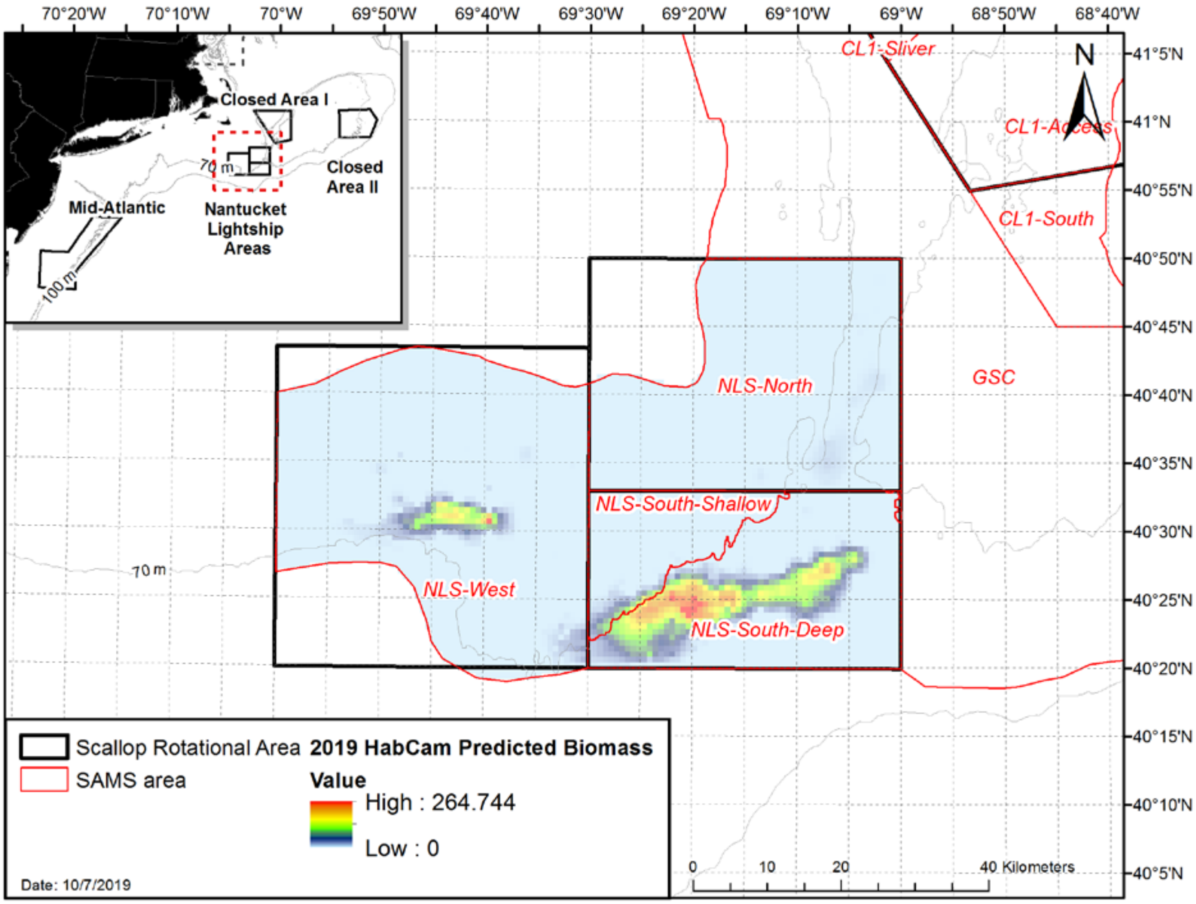
Table 2 - Estimated biomass (mt) and exploitable biomass (mt) for FY 2020 and FY 2021.

Year	Biomass	Exploitable Biomass	Percent Exploitable
2020	175653	118529	67%
2021	140717	90184	64%

Tracking High Densities of Scallops

Annual surveys have tracked the size and growth of scallops in high-density aggregations within the Nantucket Lightship region for several years. There is additional uncertainty associated with biomass estimates in these high-density areas. Scallops in parts of the Nantucket Lightship, such as the deep-water portion to the south, exhibited almost no growth between 2017 and 2018, but continued growing between 2018 and 2019. To address this uncertainty, the PDT recommends the following data treatments and modeling of scallops in the Nantucket Lightship to better account for the unique characteristics of animals in this area. Figure 1 describes FY2019 rotational management areas, SAMS estimation areas, and biomass estimates from the 2019 HabCam survey.

Figure 1 - Nantucket Lightship region, with FY2019 scallop rotational areas (black), SAMS areas (red), and predicted biomass estimates from the 2019 HabCam survey for the Nantucket Lightship region (mt per km^2).



Shell Height Meat Weight Parameters:

The PDT has recommended using data from recent dredge surveys to develop shell height to meat weight (SH-MW) parameters for specific areas of the Nantucket Lightship region (Table 3). This year, the PDT recommends using SH-MW parameters based on the last four years of dredge survey data. The net result of this recommendation is a reduction in the 2019 biomass estimates in these areas.

This recommendation is based on the difference between SH-MW estimates developed from data collected by the 2016-2019 dredge surveys and SARC 65 estimates. The methods used to develop the VIMS 2016 – 2019 parameter estimates are described in Appendix II. The model (nl3) included shell height, depth, and SAMS area as predictors (see Appendix II). Appendix IV provides a comparison of drop camera, HabCam, and dredge survey biomass estimates using SARC 65 and VIMS 2016 - 2019 SH-MW parameters. Note that the PDT also recommended reducing the dredge efficiency assumption by two thirds in the NLS-West and NLS-S-deep, which is consistent with peer-reviewed data treatment methods in SARC 65, and results in a different final combined estimate.

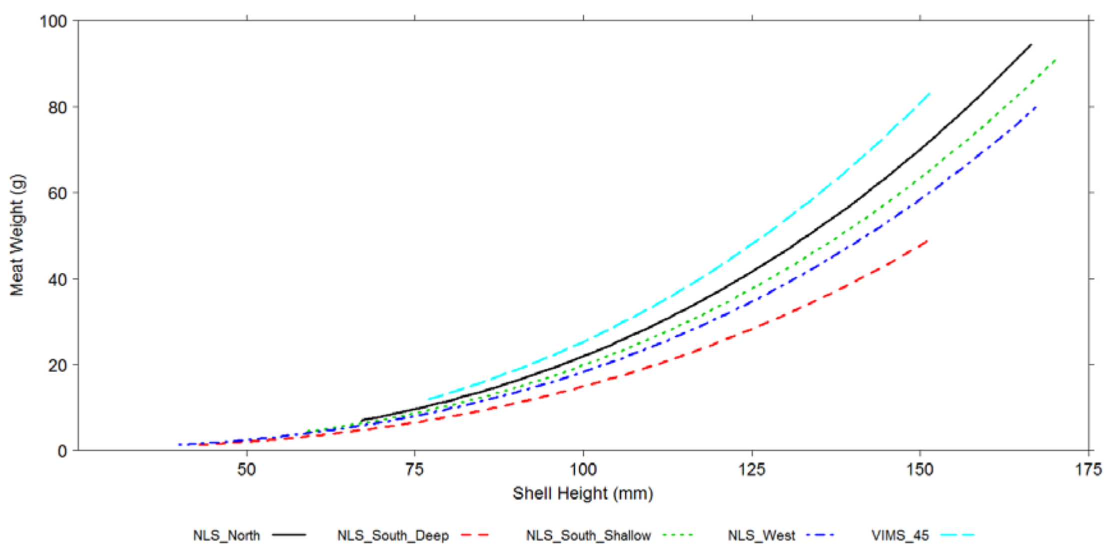
Table 3 - Description of the SH-MW changes in Nantucket Lightship SAMS areas from 2016 to 2019.

SAMS area	SH-MW applied in 2016, FW28	SH-MW applied in 2017, FW29	SH-MW applied in 2018, FW30	SH-MW applied in 2019
NLS-N	SARC 59	SARC 50	VIMS 2016-2018 Combined	VIMS 2016-2019 Combined
NLS-S 'Shallow' (>70m)	SARC 59	SARC 50	VIMS 2016-2018 Combined (South Shallow only	VIMS 2016-2019 Combined
NLS-S 'Deep' (<70m)	VIMS 2016	VIMS 2016/2017 Combined (NLS S)	VIMS 2016-2018 Combined (Deep only)	VIMS 2016-2019 Combined
NLS-Ext	VIMS 2016	SARC 50	SARC 65	N/A (part of GSC)
NLS-W	VIMS 2016	VIMS 2016/2017 Combined (NLS W)	VIMS 2016-2018 Combined (West only)	VIMS 2016-2019 Combined
Estimate of relative meat weight were derived using the following assumptions: Length = 100 mm, mean depth by SAMS area used. Mean depth for NLS-S SAMS area calculated by depth bin. Mean latitude by SAMS area used for SARC 50.				

Table 4 - VIMS 2016 - 2019 shell-height meat weight parameter estimates (from model nl3 in Appendix II).

Parameter	Parameter Estimate
Intercept	-50.333
ln shell height	2.862
Latitude	1.007
ln depth	-0.169
NLS_South_Deep	-0.127
NLS_South_Shallow	0.095
NLS_West	-0.049
VIMS_45	-0.027

Figure 2 - Predicted SH-MW relationships by SAMS area for the NLS using model nl3 (Appendix II).



Dredge Efficiency in High Density Areas of Nantucket Lightship

In addition to uncertainty around assumptions of natural mortality and anomalously slow growth, there is also uncertainty related to biomass estimates in the high-density areas of the Nantucket Lightship. In 2017, 2018, and 2019 there were large differences between the individual survey estimates of biomass in parts of the Nantucket Lightship area where high densities of animals had been observed. In 2018 and 2019, the optical (i.e. HabCam and drop camera) survey estimates of biomass in the NLS-S-deep and NLS-West were very similar, but several times greater than the dredge survey estimates. Generally, some level of variation between survey biomass estimates can be expected due to differences in survey methods and coverage levels by area; however, the dredge surveys have consistently been well below the optical surveys in high density areas. As was the case in 2016, 2017, and 2018, the PDT noted that a reduction in dredge efficiency could be a causative factor in explaining the divergence of the dredge and optical estimates in high density areas in 2019. This year the PDT recommends reducing dredge efficiency by two thirds (.4*0.33) and averaging the estimates with other optical survey estimates, consistent with the approach used in SARC 65. The PDT noted that dropping the dredge estimate in these high-density areas and averaging optical surveys only yields a similar result to averaging all surveys with the reduced dredge efficiency applied (Table 5 and Table 6).

Table 5 - Comparison of 2019 survey biomass estimates in the NLS-S-deep using VIMS 2016-2019 SH-MW parameters and dredge treatments.

Scenario	Dredge	Dredge 3x	DropCam	HabCam	Mean
Average 3 estimates	11,898		49,689	46,060	35,882
Average, reduce dredge efficiency by 3		35,694	49,689	46,060	43,814
Drop dredge estimate			49,680	46,060	47,870
Density per meter sq	1.62	4.86	6.27	5.24	

Table 6 - Comparison of 2019 survey biomass estimates in the NLS-West using VIMS 2016-2019 SH-MW parameters and dredge treatments

Scenario	Dredge	Dredge 3x	DropCam	HabCam	Mean
Average 3 estimates	3,276		13,438	12,575	9,763
Average, reduce dredge efficiency by 3		9,828	13,438	12,575	11,947
Drop dredge estimate			13,438	12,575	13,007
Density per meter sq	0.2		0.57	0.43	

Growth in the Nantucket Lightship West and South-Deep SAMS Areas

In 2019, surveys of the Nantucket Lightship region suggested that scallops in the NLS-S-deep grew between 2018 and 2019, while the mean length of scallops in the Nantucket Lightship West has remained fairly constant over the past three years. With this information in mind, re-evaluating L_∞ was again viewed as an appropriate update to the projection model. Empirical evidence supports an additional reduction in L_∞ and associated reduction in K (scaling back L_∞ reduces growth (k) proportionally). This year, the PDT recommends setting L_∞ to 119 mm in the Nantucket Lightship West area (vs. 151 mm L_∞ for NLS region in SARC 65) based on analysis of shell growth of the 2012 year class from this area (Figure 3). Applying the VIMS 2016–2019

SH-MW parameter estimates and a lower L_∞ value results in a reduction of projected 2020 exploitable biomass for the NLS-West.

Figure 3 - Comparison of 2016, 2017, 2018, and 2019 VIMS dredge survey observations in the NLS-West (formerly NLS-NA).

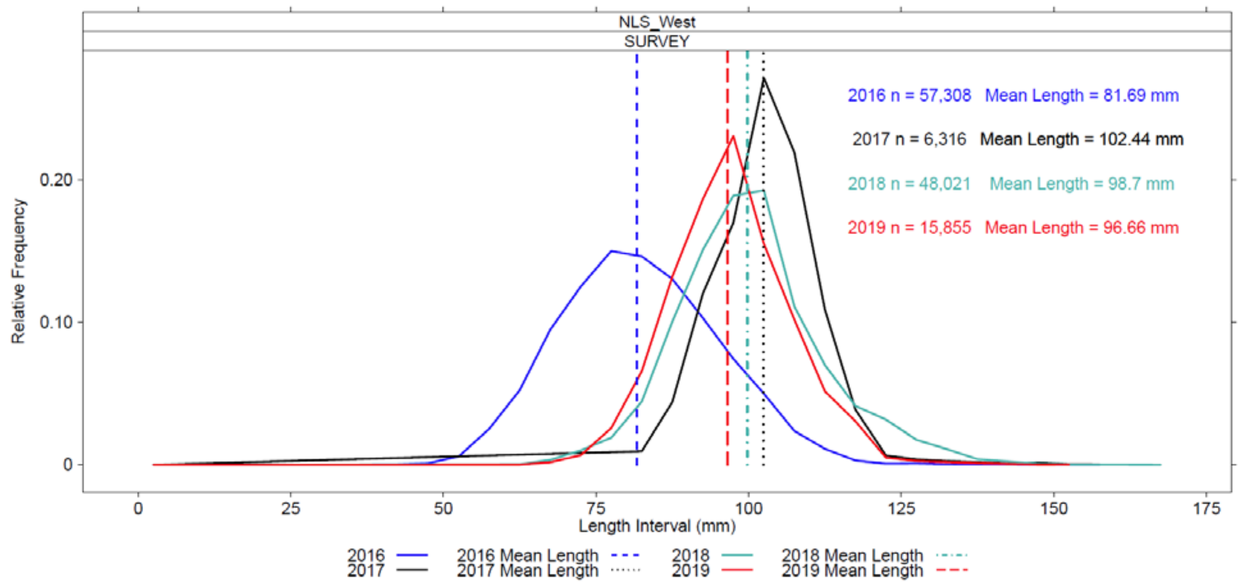


Figure 4 - Comparison of 2016, 2017, 2018, and 2019 dredge survey observations in the NLS-South-deep (deep water "peter pan" scallops).

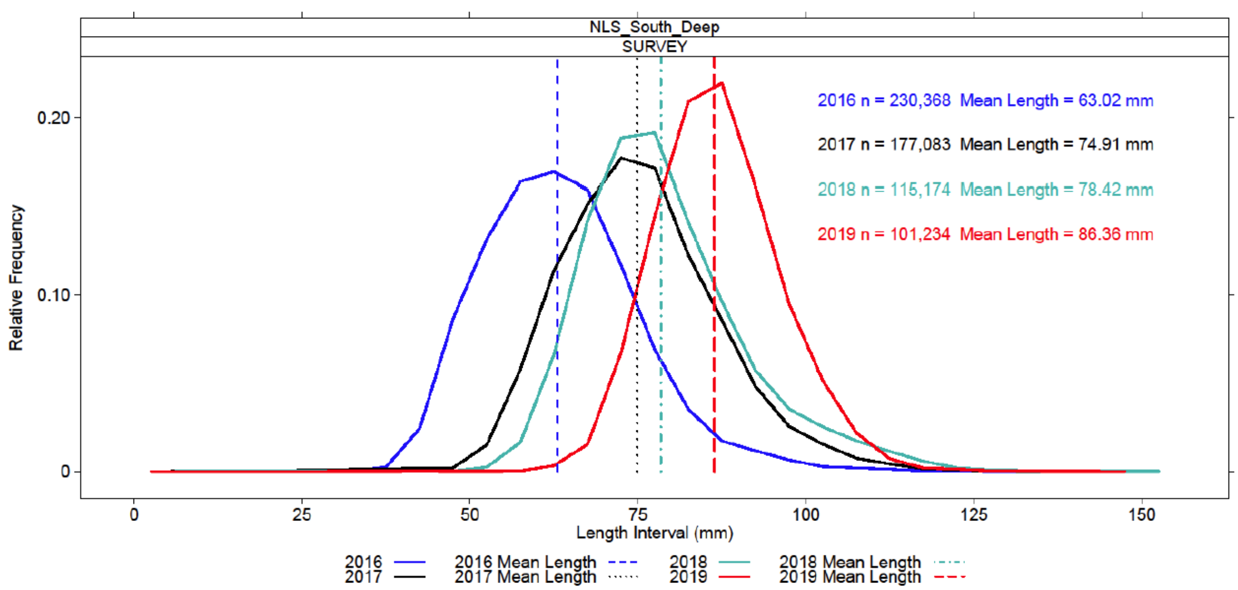
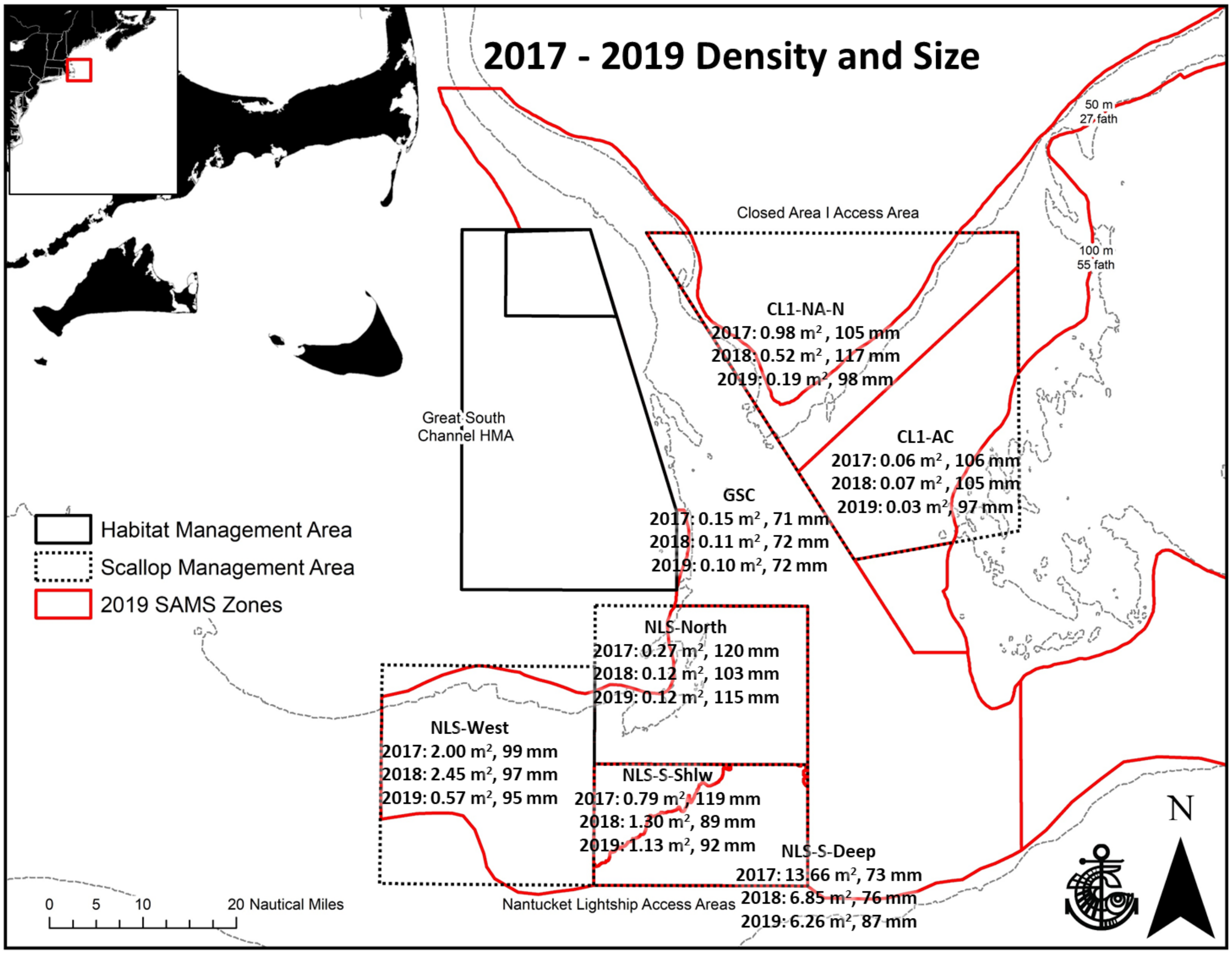


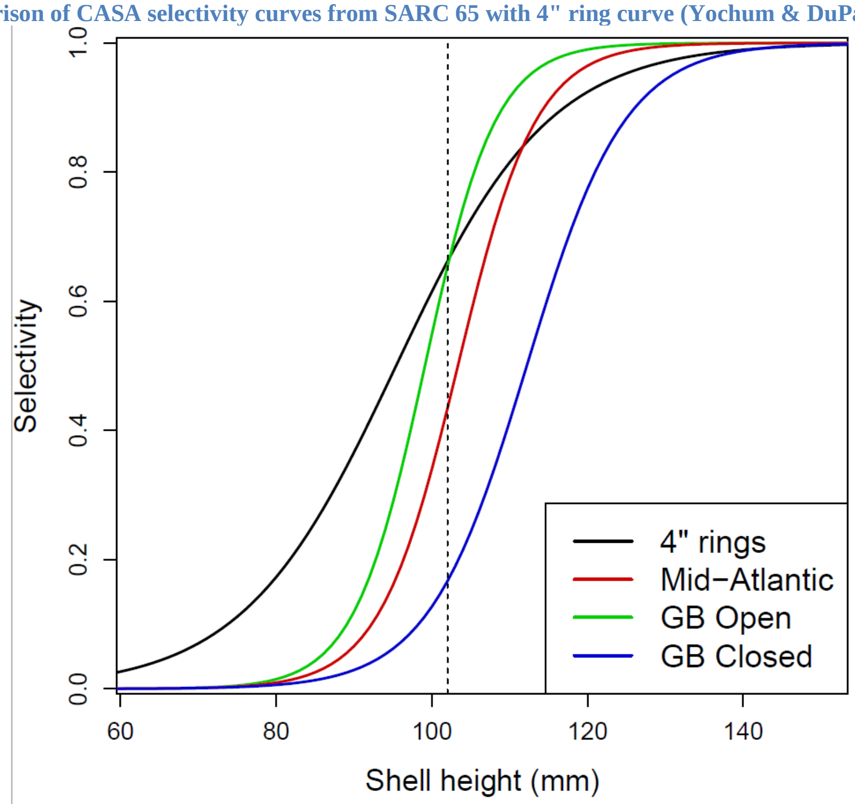
Figure 5 - Comparison of scallop average size and density by SAMS area from SMAST drop camera survey in 2017, 2018, and 2019.



Selectivity in the Nantucket Lightship SAMS Area

Selectivity curves for each CASA region (Georges Bank Open, Georges Bank Closed, and Mid-Atlantic) were updated through SARC 65. All three fishery selectivity curves are shifted to the right of the 4” ring selectivity curve (Yochum & DuPaul 2008), meaning that the fishery selects larger scallops relative to what the gear will retain (Figure 6). The Georges Bank selectivity curves are applied to finer-scale areas within the SAMS model. The Georges Bank Closed curve is normally used to calculate exploitable biomass in the Georges Bank access areas, and is expected to select around 50% of scallops at 110 mm, reflecting targeting and discarding practices that are typical in these areas, but are unlikely to occur in areas with mostly smaller scallops. The Georges Bank Closed curve selects larger scallops due the size of scallops and targeting behavior in these areas. The Georges Bank Open curve more closely follows the 4” ring curve (i.e. selects smaller scallops than the Georges Bank Closed curve) because of the size and fishing behavior in open areas under DAS management. Applying the Georges Bank Open curve allows selectivity for a larger proportion of scallops currently in the size distribution in the NLS-West. Like last year, the PDT recommends applying the Georges Bank Open selectivity curve in the Nantucket Lightship-West and South-Deep areas to select a larger proportion of the 8-year-olds in this area that have already recruited to the fishery but are not growing normally.

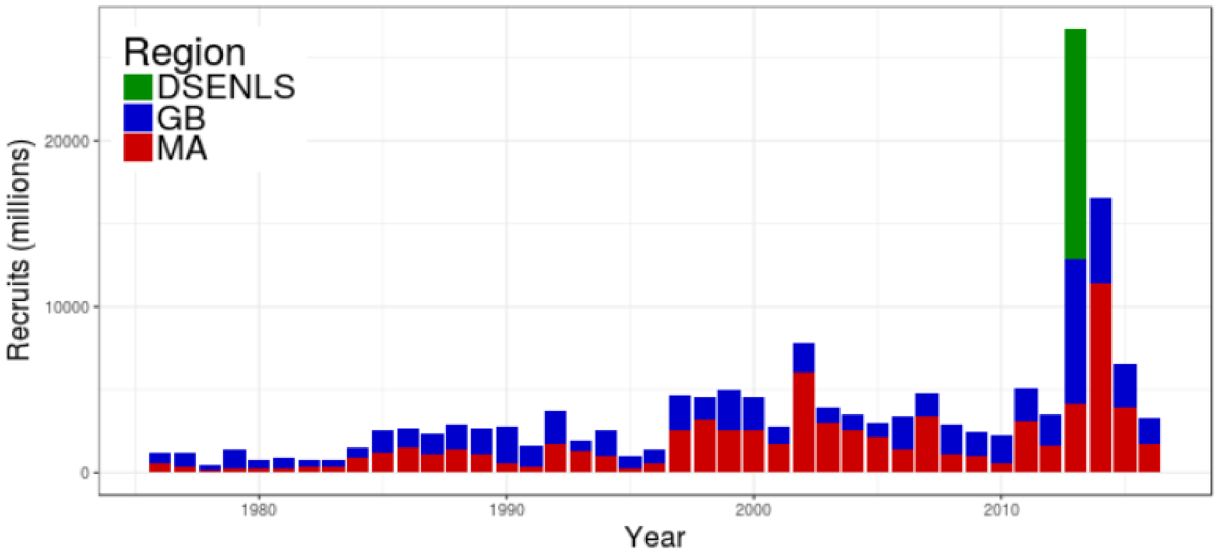
Figure 6 - Comparison of CASA selectivity curves from SARC 65 with 4" ring curve (Yochum & DuPaul, 2008).



Low Recruitment

One of the reasons for the decline in OFL and ABC estimates between 2020 and 2021 is low recruitment in recent years. Results from SARC 65 suggest that recruitment tailed off following two exceptional year classes (Figure 7) in 2012 and 2013. Annual optical and dredge surveys of the scallop resource suggest that recruitment has been low for the past three years (not shown in Figure 7). While some recruitment was observed during the 2019 surveys on Georges Bank, several years of low recruitment have resulted in the majority of the scallop population being larger and older scallops that are exploitable.

Figure 7 - Sea scallop recruitment (age 1) by region, 1975-2016. Regions are: Mid-Atlantic (MA, red), Georges Bank (GB, blue) and the deep-water, southeast corner of Nantucket Lightship Closed Area (DSENLS, green). (Source: SARC 65)



Scallop Rotational Management

While the OFL and ABC establish bounds for resource removals, in recent years, scallop rotational management has resulted in realized harvests (and corresponding fishing mortality rates) far below these legal limits. For example, in fishing year 2019 the ABC was set at 57,003 mt, whereas fishery allocations were 27,209 mt. Based on input for rotational management measures to be considered in FW32 at the September 19, 2019 Scallop Committee meeting, is it reasonable to expect that fishery removals in FY2020 will be continue to be well below OFL and ABC estimates for 2020. The Council considers a range of additional issues and uncertainties as part of the annual rotational management process, such as the proportion of available biomass that the fishery is likely to target ('effective biomass').

Updates on 2018 SSC Recommendations:

Last year the SSC recommended further investigation into:

1. *Different growth rates found in different scallop harvesting areas, particularly the Nantucket Lightship region.*

The PDT continues to track growth in the Nantucket Lightship region using results from annual surveys (dredge, drop camera, HabCam). Additional work is being carried out by VIMS through an on-going RSA project. VIMS reported to the Scallop Advisory Panel and Plan Development team at the May 21, 2019 RSA Share Day.

2. *Further work to develop gonad-based estimates of SSB and reference points.*

Beginning in 2018, the VIMS dredge survey began taking gonad samples that could be used to support the development of gonad-based estimates of SSB and reference points. Gonad samples were taken on a limited basis in 2018 , but expanded across all surveyed areas in 2019 with that protocol in place for the foreseeable future. Up to 15 gonad samples are taken at each station.

References:

Hennen, D.R. and Hart, D.R. 2012. Shell Height-to-Weight Relationships for Atlantic Sea Scallops (Placopecten magellanicus) in Offshore U.S. Water. Journal of Shellfish Research, 31(4):1133-1144.

NEFSC. 2014. 59th Northeast Regional Stock Assessment Workshop (59th SAW) Assessment Report. US Dept Commer, Northeast Fish Sci Cent Ref Doc. 14-09; 782 p. Available from: National Marine Fisheries Service, 166 Water Street, Woods Hole, MA 02543-1026, or online at http://nefsc.noaa.gov/publications/

NEFSC. 2018. 65th Northeast Regional Stock Assessment Workshop (65th SAW) Assessment Summary Report. Woods Hole, MA**:** 659.

Yochum, N. and DuPaul, W.D. 2008. Size-selectivity of the northwest Atlantic sea scallop (*Placopecten magellanicus*) dredge. Journal of Shellfish Research, Vol. 27, No.2, 265-271.

Table 7 - Combined survey estimates for 2019 by SAMS area (September 10, 2019 version).

Region	Subarea	Dredge				DropCam				Habcam				Mean			
		Num	Bmsmt	SE	MeanWt	Num	Bmsmt	SE	MeanWt	Num	Bmsmt	SE	MeanWt	Num	Bmsmt	SE	MeanWt
GB	CL1ACC	18.4	693	84	35.6	36	1049	203	29					27.1	871	73	32.1
GB	CL1NA	259.0	7857	912	29.5	154	3487	786	23					206.4	5672	401	27.5
GB	CL-2(N)	154.0	5778	2026	37.5	184.1	5,926	1,608	32					169.1	5852	862	34.6
GB	CL-2(S)	1671.0	20,689	1,129	15.4					1035	11710	356	11.3	1353.0	16200	592	12.0
GB	CL2Ext	312.1	5,568	566	17.4					653	6714	117	10.3	482.5	6141	289	12.7
GB	NLSAccN	81.5	3368	210	41.3	122	4,690	696	38.35	71	3066	379	42.9	91.6	3708	273	40.5
GB	NLSAccS-Shallow	117.6	1721	426	14.6	305	4655	3398	15.3	219	3420	9	15.6	213.8	3265	1142	15.3
GB	NLSAccS-Deep	3618.6	36608.8	1182	10.1	4839	49689	8919	10.3	3829	46060	871	12	4095.6	44119	3013	10.8
GB	NLS-W	600.8	10080.4	663	16.7	838	13,438	6,325	16.03	623	12575	3618	20.2	687.4	12031	2439	17.5
GB	NF	91.0	1585	735	17.5	57.2	1,008	372	18					74.1	1297	275	17.5
GB	GSC	296.0	7302	1354	24.7	439	6135	1000	14.0					367.6	6719	561	18.3
GB	GSC-45	1.7	82.57	29.51	49.5									1.7	83		49.5
GB	SF	686.8	12216.0	2127	17.8					1074	8514	188	7.9	880.4	10365	1068	11.8
GB	**TOTAL**	**7908.4**	**113549**	**3937**	**14.4**									**8650.3**	**116322**	**4391**	**13.4**
MAB	BI	94.9	1,515	254	17.3	47	1076	305	23	37	850	8	22.7	59.8	1147	132	19.2
MAB	LI	407.3	9,079	350	22.4	501	9417	962	19	570	12282	770	21.6	492.7	10259	427	20.8
MAB	NYB	537.8	7425	523	14.8	464	7032	1288	15	487	7091	330	14.6	496.4	7183	476	14.5
MAB	MA inshore	53.4	1265	181	23.7					26	1020	7	39.6	39.7	1143	91	28.8
MAB	HCSAA	380.4	8544	775	22.6	580	10185	783	18	762	18303	2273	24	574.1	12344	842	21.5
MAB	ET Open	592.0	15,105	897	25.8	888	18051	1187	20	634	17215	229	27.1	704.6	16790	502	23.8
MAB	ET Flex	523.6	13,529	1,174	25.5	771	19654	2711	25	778	24357	457	31.3	690.9	19180	996	27.8
MAB	DMV	20.3	203	43	10.5	89	374	111	4	47.0	599	58	12.8	52.2	392	44	7.5
MAB	VIR	4.2	14	1	3.0									4.2	14	1	3.3
MAB	**TOTAL**	**2614.0**	**56679**	**1811**	**21.7**					**3341.0**	**81717**	**2477**	**24.5**	**3114.6**	**68452**	**1546**	**22.0**
TotalOpen		**2505**	**46255**	**2687**	**219**					**2894**	**37070**	**224**	**130**	**2951**	**44741**	**1271**	**204**
TOTAL	**TOTAL**	**10522**	**170228**	**4333**	**16.2**					**3341**	**81717**	**2477**	**24.5**	**11765**	**184774**	**4655**	**15.7**

Figure 8 - 2019 Georges Bank SAMS Areas.

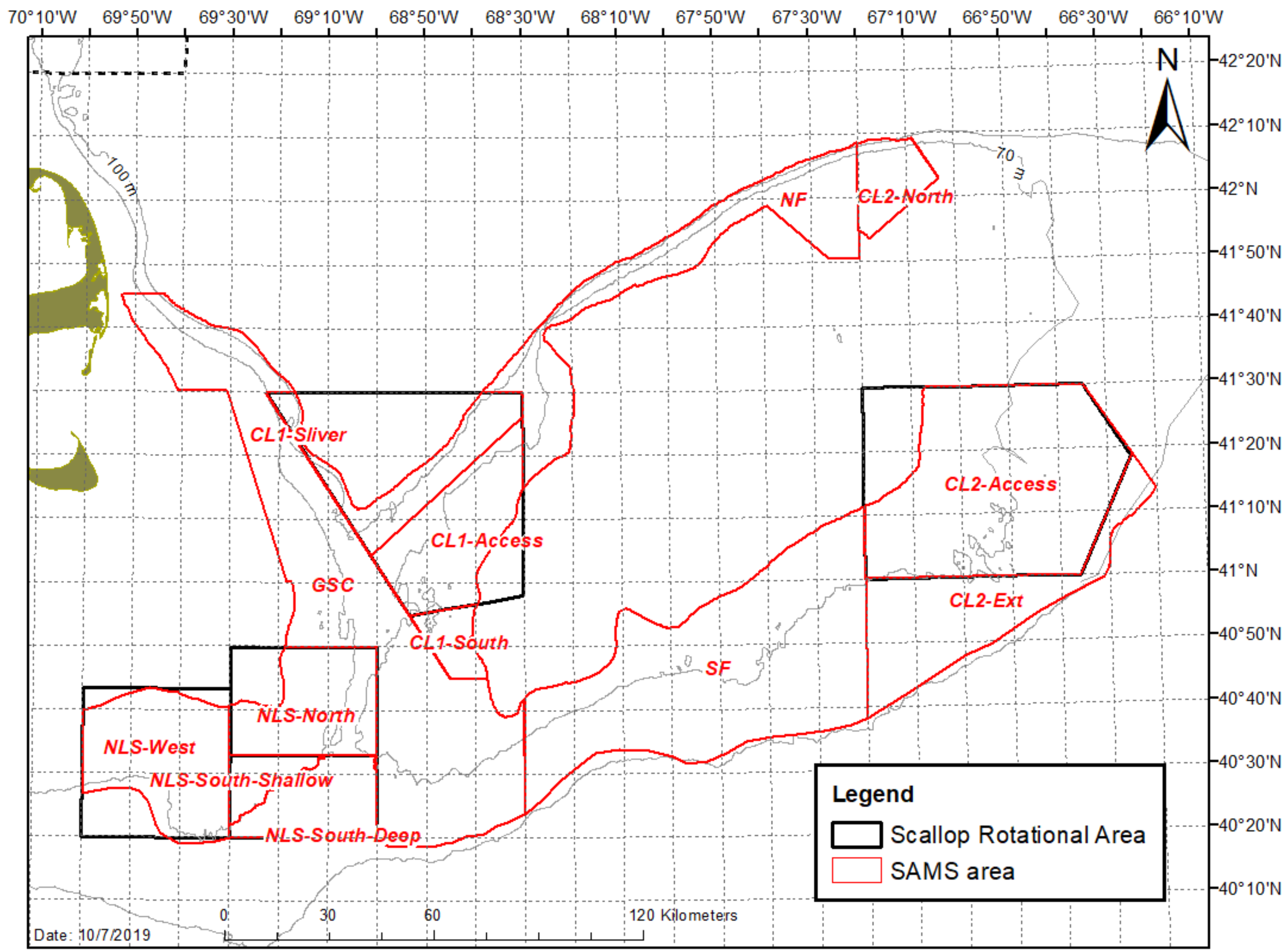
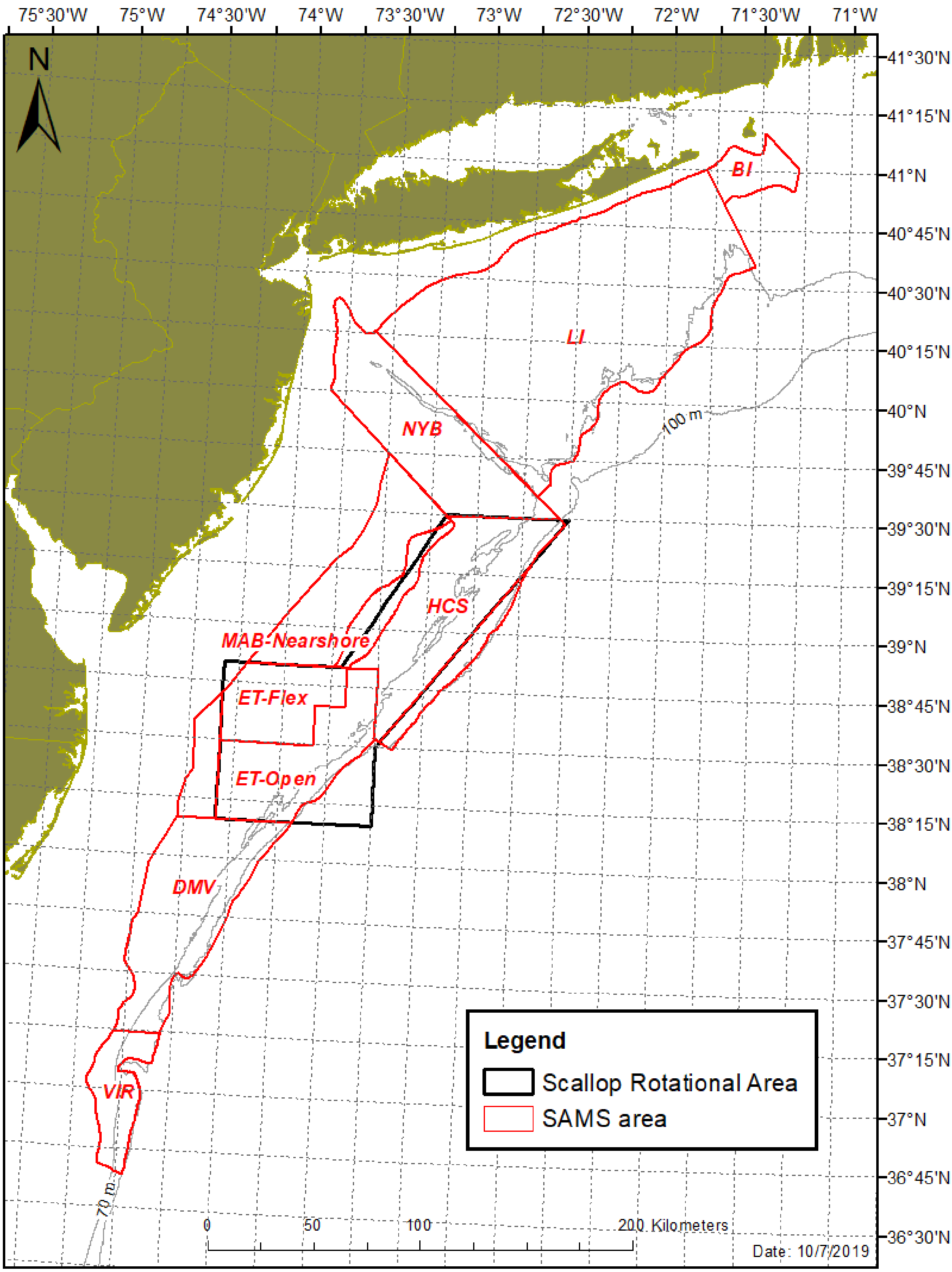


Figure 9 – 2019 Mid-Atlantic Bight SAMS Areas.



Appendix I: 2020 Projections - Outputs and Assumptions

SAMS Model Run (2020 projections using 2019 survey data):

1. Model configured the same as SARC 65, with 8 areas in MA and 12 in GB.
2. L_∞ in deep portion of NLS-S-deep was set to 110 mm to match observed growth (SARC 65).
3. L_∞ in the NLS-West was set to 119 mm to match observed growth.
4. ABC: F=0.51

Table 8 - 2019 SAMS Run: 2020/2021 projected exploitable biomass by SAMS area, including ABC and OLF estimates.

SAMS Area	Proj 2020 Ebms	Land@F=0.51
HCS	7530	2591
Virginia	1	6
ET-Op	13708	4620
ET-Flex	13439	4499
DMV	298	158
NYB	5224	2357
LI	7199	2696
MAInsh+BI	2230	947
CLI-North	3151	1131
CLI-Middle	671	235
CLII-North	5089	1665
CLII-South	13196	4998
NLS-West	3658	1434
NLS-North	3273	1096
NLS-Sshal	2570	1376
NLS-Sdeep	18480	8234
CLII-Ext	5800	2484
GSC	4637	1662
Nflank	1272	500
Sflank	7104	2725
TotalOpen	33765	13535
Total	118530	45414

Table 9 - Comparison of the meat weight and growth parameters used in recent SAMS configurations.

	Meat weight	Growth
2015	SARC 59	SARC 59
2016	SARC 59, with changes to SH-MW parameters using VIMS 2016 data (NLS-S, NLS-NA, NLS-ext)	SARC 59, with reductions to growth in NLS
2017	SARC 50, with changes to SH-MW parameters in NLS using VIMS 2016 & 2017 data (NLS-S, NLS-NA).	SARC 59, with reductions to growth in NLS-S deep (>70m) based on observed growth between 2016 and 2017. Change ET-Flex L infinity to 110 mm based on observed growth in 2016 and 2017.
2018	SARC 65, with changes to SH-MW parameters in the NLS using VIMS 2016 – 2018 data	SARC 65, with reduction in L_∞ in NLS-W to 119mm. SARC 65 set the L_∞ of scallops in the NLS-S-deep at 110 mm.
2019	SARC 65, with changes to SH-MW parameters in the NLS using VIMS 2016 – 2019 data	SARC 65, with reduction in L_∞ in NLS-W to 119mm. SARC 65 set the L_∞ of scallops in the NLS-S-deep at 110 mm.

Table 10 - 2019 Survey Data Treatments by SAMS area

GB	SHMW equation	Treatment for SAMS run
CL1-Access	SARC 65	Use mean of survey estimates
CL1-Sliver	SARC 65	Use mean of survey estimates
CL1-South	SARC 65	Use mean of survey estimates
CL2-North	SARC 65	Use mean of survey estimates
CL2-Access	SARC 65	Use mean of survey estimates • Highlight stratification issue
CL2-Ext	SARC 65	Use mean of survey estimates
NLS-North	VIMS 2016-2019	Use mean of survey estimates
NLS-South-Shallow	VIMS 2016-2019	Use mean of survey estimates
NLS-South-Deep	VIMS 2016-2019	Decrease dredge efficiency to .13 (.4/3), use mean of survey estimates. Use GB Open selectivity curve: • L_∞ of 110mm
NLS-West	VIMS 2016-2019	Decrease dredge efficiency to .13 (.4/3), use mean of survey estimates.
NF	SARC 65	Use mean of survey estimates
GSC	SARC 65	Use mean of survey estimates
SF	SARC 65	Use mean of survey estimates
MidAtlantic		
BI	SARC 65	Use mean of survey estimates
LI	SARC 65	Use mean of survey estimates
NYB	SARC 65	Use mean of survey estimates
MAB-Nearshore	SARC 65	Use mean of survey estimates
HCS	SARC 65	Use mean of survey estimates
ET Open	SARC 65	Use mean of survey estimates
ET Flex	SARC 65	Use mean of survey estimates
DMV	SARC 65	Use mean of survey estimates

Appendix II: VIMS Shell-Height Meat-Weight Analysis

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Methods

Shell height meat weight relationships (SHMW) were estimated for the Nantucket Lightship (NL) survey by SAMS area with VIMS survey data. SHMW relationships were developed using only the 2019 survey data and a combined dataset from survey data for 2016-19.

SHMW models were developed with forward selection and variables were retained in the model if the AIC was reduced three or more units. Variables were added to the model based on individual model AIC values. SAMS area was included in all models to estimate the SAMS area effect. The model with the lowest AIC was selected as the preferred model and used to predict SHMW relationships by SAMS area. If models were within three units of each other, a likelihood ratio test was used to test for significant differences between model. If there was no significant difference between the models, the more parsimonious model was selected as the preferred model. Variables considered were: ln shell height, ln depth (average depth of a tow), SAMS Area (retained in all models), latitude (beginning latitude of a tow) and an interaction term of shell height and depth. Year was included in the combined data model to test for a year effect, and was not significant. Tables provided below include the SHMW models with parameters and AIC by SAMS area. Parameter estimates for the preferred model and predicted SHMW relationships are also provided.

2019 total biomass for the VIMS NL survey was estimated with the SARC 65 GB SHMW parameters, the VIMS combined 2016-18 parameter estimates, and the VIMS combined 2016-19. A comparison of biomass estimates is provided below. Dredge efficiency issues persist in high density area in the South_Deep SAMS area.

Table 1. SHMW models for the 2019 VIMS NL survey data. Bold variables indicate significance. Model in red was selected as the preferred model. * indicates an interaction term.

Model	Parameters	K	AICc	Delta_AICc
nl3	~ 1 + **shell height + latitude** + depth + **SAMS Area**	10	12,527.89	0.00
nl2	~ 1 + **shell height + latitude** + **SAMS Area**	9	12,529.01	1.12
nl4	~ 1 + **shell height** + depth + **SAMS Area**	9	12,533.81	5.92
nl5	~ 1 + shell height * depth + **SAMS Area**	10	12,534.60	6.71
nl1	~ 1 + **shell height** + **SAMS Area**	8	12,535.11	7.22

Table 2. Parameter estimates for model nl2 from Table 1.

Parameter	Parameter Estimate
Intercept	-37.844
ln shell height	2.868
latitude	0.681
NLS_South_Deep	-0.170
NLS_South_Shallow	0.076
NLS_West	-0.034
VIMS_45	0.087

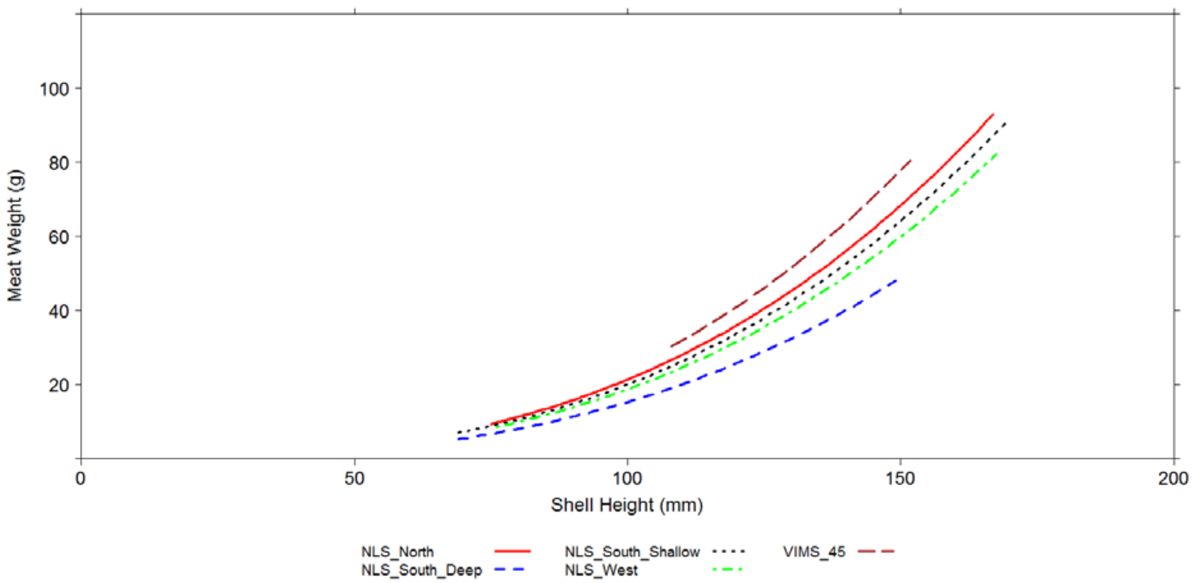

Figure 1. Predicted SHMW relationships by SAMS Area for the NL using model nl2 from Table2.

Table 3. SHMW models for the 2016-19 VIMS NL survey data. Bold variables indicate significance. Model in red was selected as the preferred model. * indicates an interaction term.

Model	Parameters	K	AICc	Delta_AICc
nl6	~ 1 + shell height * depth **+ latitude** + **SAMS Area**	11	34,269.59	0.00
nl3	~ 1 + **shell height + depth + latitude** + **SAMS Area**	10	34,269.99	0.40
nl2	~ 1 + **shell height + depth** + **SAMS Area**	9	34,272.49	2.90
nl4	~ 1 + **shell height + latitude** + **SAMS Area**	9	34,311.62	42.03
nl5	~ 1 + **shell height * depth** + **SAMS Area**	10	34,314.18	44.59
nl1	~ 1 + **shell height** + **SAMS Area**	8	34,319.07	49.48

Table 4. Parameter estimates for model nl3 from Table 3.

Parameter	Parameter Estimate
Intercept	-50.333
ln shell height	2.862
Latitude	1.007
ln depth	-0.169
NLS_South_Deep	-0.127
NLS_South_Shallow	0.095
NLS_West	-0.049
VIMS_45	-0.027

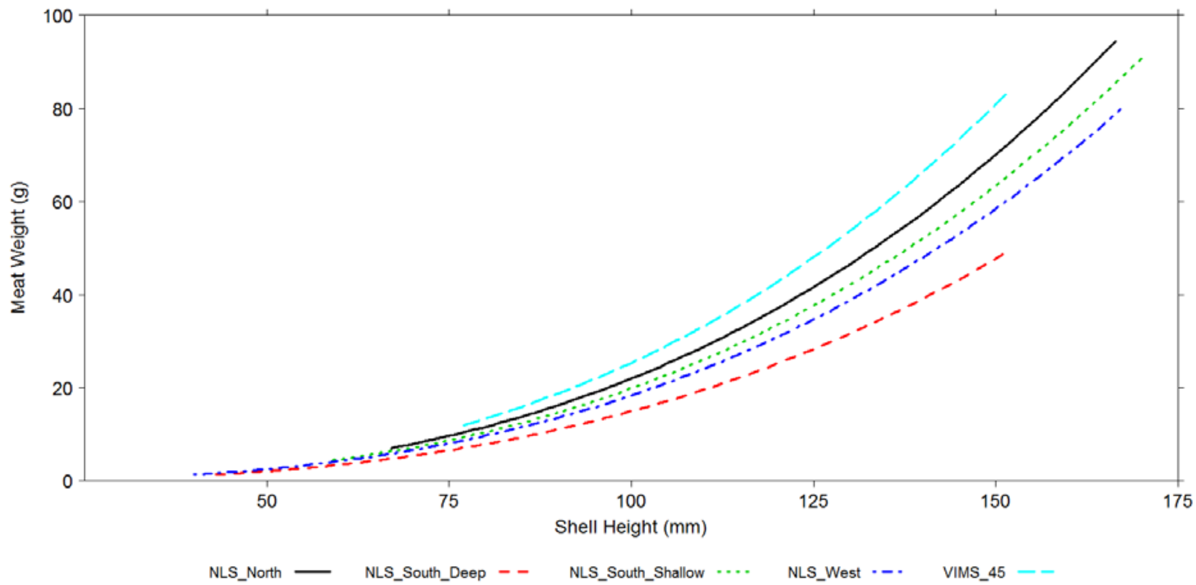

Figure 2. Predicted SHMW relationships by SAMS Area for the NL using model nl3 from Table4.

Discussion

SHMW relationships in the NL continue to show a similar trend across years. The South_Deep SAMS Area continues to have a lower meat weight at shell height compared to the other SAMS areas. This SAMS Area is significantly different from the reference case, NLS_North SAMS Area, for the 2019 analysis and the combined analysis. Biomass estimates were comparable between the different SHMW parameters used for estimation. This result is likely from having updated data included in the SARC 65 estimates and having the South_Shallow scallops in a separate SHMW analysis for SARC 65

For Reference:
2018 Approach:
Parameter estimates for shell height meat weight relationships for the NLS derived

Parameter	Parameter Estimate
Intercept	-9.29
ln shell height	2.82
ln depth	-0.14
NLS_EXT	-0.22
NLS_NA	-0.24
Deep	-0.35
Shallow	-0.38
VIMS_45	0.04

2017 Approach:
Parameter estimates for shell height meat weight relationships for the NLCA derived from 2016 and 2017 VIMS dredge survey data without an interaction variable.

Parameter	Parameter Estimate
Intercept	-8.46
logsh	2.67
logdepth	-0.17
Southern Area	-0.39
Extension	-0.29
NA Area	-0.27
VIMS 45 Area	0.02

2016 Approach:
Parameter estimates for shell height meat weight relationships for the NLCA derived from 2016 VIMS dredge survey data using the updated region/zone designations. log = ln

Equation:
Meatweight= intercept+(B1* logsh)+(B2*logdepth)+(B3*(logsh*logdepth)) + SAMS_zone_2016

Parameter	Parameter Estimate
Intercept	-25.7615
B1 logsh	6.7540
B2 logdepth	4.1120
B3 logsh:logdepth	-1.0054
SAMS_zone_2016NLS_AC_S	-0.4917
SAMS_zone_2016NLS_EXT	-0.2214
SAMS_zone_2016NLS_NA	-0.3743
SAMS_zone_2016VIMS_45	-0.2198

Appendix III:

SH-MW Parameters for Biomass Estimation
Comparison of Biomass Estimates Using SARC 65 vs. VIMS 2016-2019
Nantucket Lightship SAMS Areas

Note: Biomass values in mt.

Total VIMS dredge biomass estimates (mt) for the NL using SARC 65 parameter estimates, VIMS 2016-18 parameter estimates and VIMS 2016-19 for the current SAMS areas. Dredge efficiency issues persist in high density area in the South_Deep SAMS Area.

SAMS Area	Total Biomass (mt) - SARC 65	Total Biomass (mt) - VIMS 2016-19
NLS_North	3,613.91	3,368.23
NLS_South_Deep	11,955.05	11,897.84
NLS_South_Shallow	2,402.17	1,721.06
NLS_West	4,732.83	3,276.12
VIMS_45	90.47	82.58

Total biomass estimates from the 2019 SMAST drop camera survey in the Nantucket Lightship area using the 65th SARC or the 2016-2019 Virginia Institute of Marine Science (VIMS) shell-height to meat-weight formulas.

Area	65th SARC		VIMS	
	BmsMT	MeanWt	BmsMT	MeanWt
NLS-North	5,000	40.8	4,700	38.4
NLS-West	19,550	23.3	13,450	16.0
NLS-South-Shallow	6,450	21.1	4,650	15.3
NLS-South-Deep	51,000	10.5	49,700	10.3

Comparison of 2019 Habcam biomass estimates (40+ mm) using VIMS 2016-2019 and SARC 65 SH-MW equations for Nantucket Lightship Area. Percent difference was calculated using biomass estimates (VIMS - SARC 65)/(VIMS).

SAMS Area	BmsMT (VIMS)	BmsMT (SARC 65)	%Diff
NLS-North	3066.38	3295.44	-7.47
NLS-South-Deep	46060.47	48350.22	-4.97
NLS-South-Shallow	3420.05	4197.21	-22.72
NLS-West	12574.7	17701.15	-40.77

Appendix IV:

Background – Stock Assessment Review Committee 65

There was a benchmark assessment for Atlantic sea scallop completed in 2018 (SARC 65). In 2017, the stock was not overfished and overfishing was not occurring. Biomass is estimated to be at its highest point in the timeseries (1975 – 2017), while fishing mortality is estimated to be at its lowest point over the same time. The PDT reviewed updated methods and key findings from SARC 65 at their August 28th, 2018 meeting, which included:

- Shell height to meat weight (SH-MW) and growth relationships appear to have been increasing since the mid-1990s. The increase in SH-MW was likely a result, at least in part, a fishery effect; the fishery tends to target scallops with the greatest meat weights. Because of this, at high fishing mortalities, the population that remains consists disproportionately of scallops with relatively small meat weights at shell height.
- Landings by area have been higher in recent years and the Mid-Atlantic has been the dominant region relative to Georges Bank. Landings per unit of effort (LPUE, mt meats landed per 24-hour day with gear in the water) and fishing effort (24-hour days with gear in the water) have been increasing in recent years for all regions.
- Stratified mean biomass has been increasing relative to the entire dredge survey time series. Divergence was seen between the dredge and optical survey biomass estimates since 2014, likely due to very high-density areas causing a reduction in dredge efficiency. The assessment assumed dredge estimates in high density areas were roughly a third of actual biomass based on comparisons with optical estimates over the time series.
- Similar to the 2014 assessment, Catch At Size Analysis (CASA) models were run for Georges Bank Open, Georges Bank Closed, and the Mid-Atlantic. Unlike previous assessments, SARC 65 CASA model changes methods assumed that natural mortality (*M*). The Mid-Atlantic and Georges Bank Open models assumed juvenile *M* was variable, while *M* was variable at all sizes in the Georges Bank Closed model.
- Observed and estimated abundance/biomass, estimated recruitment, natural mortality, and estimated abundance at shell height were presented for each model (i.e. GB Closed, GB Open, Mid-Atlantic).
    - GB Closed: Observed abundance/biomass generally agree with estimates from CASA, with some variation in recent years. A spike in *M* in 2010-2011 corresponded with die offs of scallops observed in CAI and the northern part of CAII.
    - GB Open: This model was most problematic of the three, but contributes the least to overall biomass. Observed abundance/biomass from survey efforts have been estimating above CASA in recent years, suggesting the model is not totally capturing all mortality that is occurring in this region (though it is difficult to say whether the unaccounted mortality is *F* or *M*).
    - Mid-Atlantic: This model also appeared to be unable to account for all mortality occurring. Large spikes in juvenile M were estimated in 2003-4 and 2014, corresponding to the large 2001 and 2013 year classes, suggesting that there may be a density dependent dynamic between juvenile density and M.
- Combined GB Closed, GB Open, and Mid-Atlantic models: fully recruited fishing mortality has decreased since 2000 to an all-time low in 2017 and fully recruited biomass is at its highest point in the time series. Excluding the slow growing animals in the deep water

portion of NLS-S (i.e. “Peter Pans”), scallop biomass in 2017 was estimated to be 317,334 mt meats (roughly 700 million pounds) and fishing mortality was estimated to be 0.12.

- Reference points were estimated using the SYM model. The most recent period of data was used to estimate yield and biomass per recruit in meat weight, and stock-recruit curves were estimated using recruitment and spawning stock biomass estimates from CASA model runs. Age of recruitment for the purposes of the reference point models was set to three years old (previous assessments used two years old). See Table 11 for updated reference point values.

Table 11 - Comparison of biological reference points from last three scallop benchmark assessments.

	Definition in Scallop FMP	SARC 50 (2010)	SARC 59 (2014)	SARC 65 (2018)
OFL	F_{MSY}	F=0.38	F=0.48	F=0.64
ABC=ACL	25% probability of exceeding the OFL	F=0.32	F=0.38	F=0.51
B_{MSY}	B_{TARGET}	125,358 mt	96,480 mt	116,766 mt
1/2 B_{MSY}	$B_{THRESHOLD}$	62,679 mt	48,240 mt	58,383 mt
MSY		24,975 mt	23,798 mt	46,531 mt
Overfished?	$B < B_{THRESHOLD}$	No	No	No
Overfishing?	$F < F_{THRESHOLD}=F_{MSY}$	No	No	No