New England Fishery Management Council
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John F. Quinn, J.D., Ph.D., *Chairman* | Thomas A. Nies, *Executive Director*

MEMORANDUM

DATE: **October 4, 2018**

TO: Science and Statistical Committee

FROM: Scallop Plan Development Team (PDT)

SUBJECT: **PDT recommendations for OFL and ABC for Framework 30 (FY2019 and FY2020 default)**

This memorandum addresses the following 2018 SSC terms of reference for Atlantic sea scallops and SSC recommendations from 2017.

2018 SSC Terms of Reference:

1. **Review results from the recent scallop benchmark assessment (SARC 65) as they relate to new biological reference points, the Scallop PDT's updated projections for the scallop resource, and provide the Council with OFL and ABC recommendations for fishing years 2019 and 2020 (default).**
2. **Review changes to the meat weight, growth, and selectivity parameters used to estimate and model biomass in portions of the Nantucket Lightship, and provide the Council with a recommendation as to whether these changes are appropriate.**

2017 SSC Recommendations requiring follow-up:

3. **The SSC recommends that the PDT continue to investigate alternate weighting scenarios for combining the three surveys used in analyses and vet these analyses during the 2018 benchmark stock assessment process. This investigation could include examining geostatistical methods for biomass estimation from this information and should look into dredge efficiency issues in high density scallop areas.**
4. **The SSC supports continuing investigation into the different growth rates found in different scallop harvesting areas, and recommends investigating these growth differences as a standard procedure for the annual update of the scallop analyses.**

The PDT met on September 28, 2018 and October 3, 2018 to review these estimates and drafted the following consensus statements (in italics) by correspondence. More details will be provided during the presentation of this recommendation at the SSC meeting on October 10, 2018.

PDT Consensus Statement:

By consensus, the Scallop PDT recommends that the SAMS model estimates for OFL and ABC for 2019 and 2020 (default) be presented to the SSC (Table 1). The PDT notes that the updated OFL and ABC values are based on higher fishing mortality rates (OFL F=0.64; ABC F=0.51) relative to recent years. While the updated OFL and ABC estimates for 2019 are very similar to the 2018 values approved by the SSC, estimates for 2020 represent 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 2019 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:

- *Shell-Height and Meat Weight (SH-MW) Relationships: SH-MW parameters were updated through SARC 65. Based on 2018 survey observations, the PDT is concerned that applying benchmark parameters in portions of the Nantucket Lightship area may lead to an overestimation of 2018 biomass. As with previous years, the PDT recommends using area-specific SH-MW parameter estimates from the dredge survey in these areas.*
- *Dredge Efficiency: Dredge efficiency in high density areas continues to be an issue, and the PDT recommends increasing biomass estimates from the dredge survey by a factor of three in the NLS-West and NLS-S-deep. This recommendation is based on peer-reviewed findings from SARC 65.*
- *Growth: The PDT recommends that growth in the SAMS model be modified to account for anomalously slow growth in the Nantucket Lightship-West, based on growth estimates using only shells from the large 2012 cohort in that area. After a year of slower than expected growth, animals in the Elephant Trunk-Flex area appear to be growing normally.*
- *Selectivity: This year, 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; the scallops in these portions of the Nantucket Lightship area are much smaller than normal, and thus it is unlikely that the Georges Bank closed area selectivity would apply to these areas.*

If higher than expected natural mortality occurs, biomass estimates will be overestimated, especially for 2020. An observation that supports this concern stems from 2018 survey data where scallop density per meter squared appears to have declined in the deep portion of the Nantucket Lightship, suggesting mortality in the absence of fishing that may continue in this part of the resource.

Table 1 – Scallop PDT recommendation for OFL and ABC for Framework 29, Fishing years 2019 and 2020 (default).

Year	ABC-Land	ABC-Disc	ABC-Tot	OFL-Land	OFL-Disc	OFL-Total
2019	57003	5986	62989	66791	6630	73421
2020	46028	4915	50943	53994	5453	59447

Table 2 - Estimated biomass and exploitable biomass for FY 2019 and FY 2020.

Year	Biomass	Exploitable Biomass	Percent Exploitable
2019	218,394 mt	144,731 mt	66%
2020	175,859 mt	114,930 mt	65%

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 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 SHMW 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 there, 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 3 for updated reference point values.

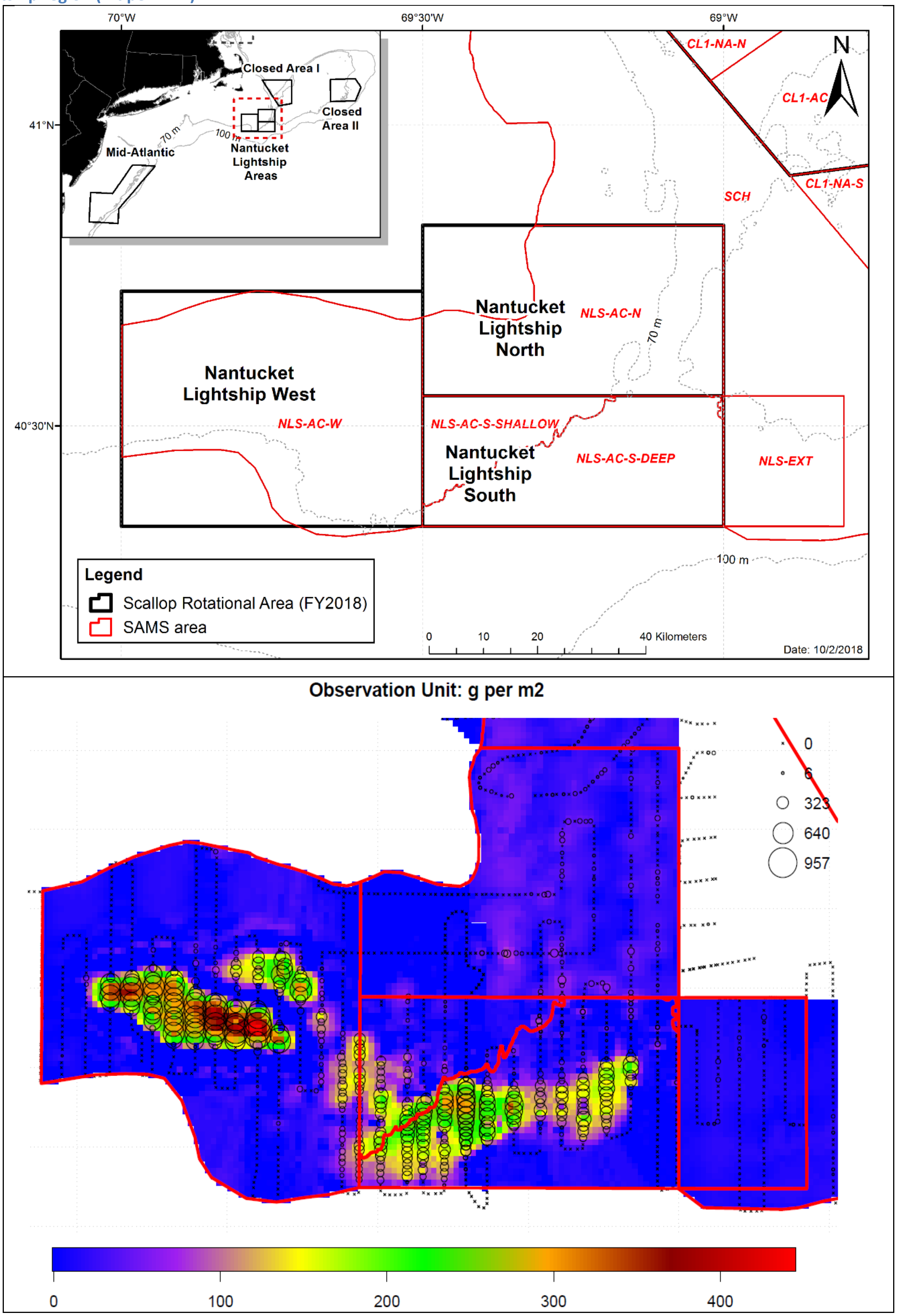
Table 3 - Comparison of biological reference points from last three scallop benchmark assessments.

	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

Tracking High Densities of Scallops

Annual surveys have tracked the size and growth of animals in high-density aggregations within the Elephant Trunk and Nantucket Lightship areas for several years. There is additional uncertainty associated with biomass estimates in these high-density areas. While animals in the Elephant Trunk appear to be growing normally again (changes to $L\infty$ were proposed in 2017), scallops in parts of the Nantucket Lightship exhibited almost no growth between 2017 and 2018. To address this uncertainty, the PDT recommends the following data treatments and modeling of scallops in the Nantucket Lightship to better account for unique characteristics of animals in this area. The graphics in Figure 1 describe the management area (SAMS areas) and 2018 biomass estimates from the 2018 HabCam survey.

Figure 1 - (Top) Nantucket Lightship region, with SAMS areas; (Bottom) 2018 HabCam biomass estimates for Nantucket Lightship region (mt per km2).



Shell Height Meat Weight Parameters:

The PDT has recommends using data from recent surveys to develop SH-MW parameters for specific areas of the Nantucket Lightship in 2016 and 2017 (Table 4). This year, the PDT recommends using SH-MW parameters based on the VIMS dredge survey data from 2016, 2017, and 2018 in all areas of the Nantucket Lightship except for the NLS-Ext. This recommendation is based on the difference between SH-MW estimates developed from data collected by the 2016-2018 dredge surveys and SARC 65 estimates. The methods used to develop the VIMS 2016 – 2018 parameter estimates are described in Appendix II. The model (nl4.1) included shell height, depth, and SAMS area as predictors (see Appendix II). The net result of this recommendation is a reduction in the 2018 biomass estimates in these areas. Appendix IV provides a comparison of drop camera, HabCam, and dredge survey biomass estimates using SARC 65 and VIMS 2016 - 2018 SH/MW parameters. The combined reduction in biomass estimates characterized as the arithmetic mean of the three surveys is shown in Table 6. Note that the PDT also recommended increasing the dredge survey biomass estimate by a factor of three 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 4 - Description of the SH/MW changes in Nantucket Lightship SAMS areas from 2016 and 2017 (FW29).

SAMS area	SH/MW applied in 2016, FW28	SH/MW applied in 2017, FW29	SH/MW applied in 2018
NLS-N	SARC 59	SARC 50	VIMS 2016-2018 Combined
NLS-S 'Shallow' (>70m)	SARC 59	SARC 50	VIMS 2016-2018 Combined (South Shallow only
NLS-S 'Deep' (<70m)	VIMS 2016	VIMS 2016/2017 Combined (NLS S)	VIMS 2016-2018 Combined (Deep only)
NLS-Ext	VIMS 2016	SARC 50	SARC 65
NLS-W	VIMS 2016	VIMS 2016/2017 Combined (NLS W)	VIMS 2016-2018 Combined (West only)
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 5 - VIMS 2016 - 2018 shell-height meat weight parameter estimates (from model nl4.1 in Appendix III).

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

Figure 2 - Predicted SH-MW relationships by SAMS area for the NLCA using model nl4.1 (Appendix II)

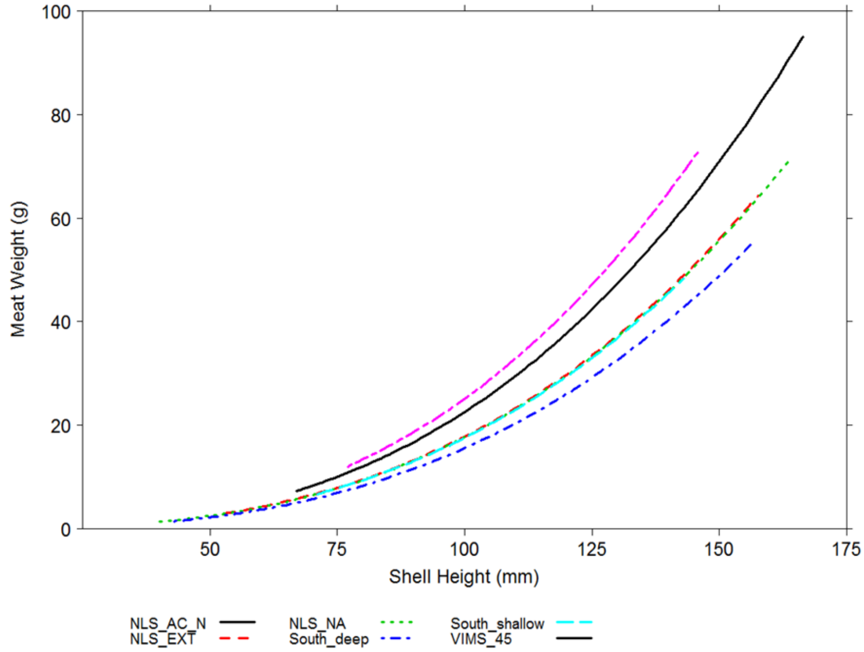


Table 6 – Comparison of combined survey averages (dredge, drop camera, HabCam) using SARC 65 SH-MW and VIMS 2016 - 2018 SH-MW parameters.

SAMS Area	SARC 65 Average	2016 – 2018 VIMS three survey average	% Change 1-(VIMS/SARC65)
NLS-AC-N	3,983	3,681	8%
NLS-W	56,029	38,195	32%
NLS-EXT	888	729	18%
NLS-AC-S-SHLW	5,857	3,725	36%
NLS-AC-S-DEEP	26,563	27,602	-4%

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 and 2018, 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 by previous surveys. In 2018, the optical (HabCam and drop camera) survey estimates of biomass in the NLS-S-deep and NLS-W were very similar, but several times larger 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 been consistently well below the optical surveys in high density areas. As was the case in 2016 and 2017, 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 2018. When the PDT compared survey estimates from all other (non-high density) areas, there was general agreement in total biomass estimates across dredge, drop camera, and HabCam results. This year the PDT recommends increasing the dredge survey biomass estimate by a factor of three and averaging the inflated 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 yields a similar result (Table 7).

Table 7 - Comparison of 2018 survey biomass estimates in the NLS-West and NLS-S-deep using VIMS 2016-2018 SH-MW parameters and dredge treatments.

	VIMS 2016-2018 SH-MW	VIMS 2016-2018 SH-MW + increase dredge efficiency 3x	VIMS 2016-2018, drop dredge data, use only optical estimates
NLS-West	38,195 mt	48,148 mt	49,828 mt
NLS-S-deep	27,602 mt	34,483 mt	36,243 mt

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

Animals in the Nantucket Lightship West and Nantucket Lightship South-deep showed some growth between 2016 and 2017, but virtually no growth between 2017 and 2018 (see Figure 4, Figure 5, and Figure 6). 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 the resulting concomitant 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 6). Applying the VIMS 2016–2018 SH-MW parameter estimates and a lower L_∞ value results in a reduction of projected 2019 exploitable biomass for the NLS-West.

As noted in 2016 and 2017, 2018 survey efforts suggested that animals from the 2012 cohort in the shallow (< 70 m depth) portion of the NLS-S exhibited expected growth rates (i.e. similar to animals in the NLS-N SAMS area), while animals deeper than 70 meters were not growing normally (Figure 3). This SAMS zone has been split into “shallow” and “deep” areas along the 70-meter bathymetric contour to account for the differential growth rates on a small spatial scale. The L_∞ value for the scallops in the NLS-S-deep was set at 110.3 mm (k=0.423) in SARC 65. The 2018 model assumes normal growth in the NLS-S-shallow area.

Figure 3 - Length-Frequency comparison of scallops in the Nantucket Lightship South shallow and deep areas from 2018 Coonamessett Farm Foundation HabCam survey.

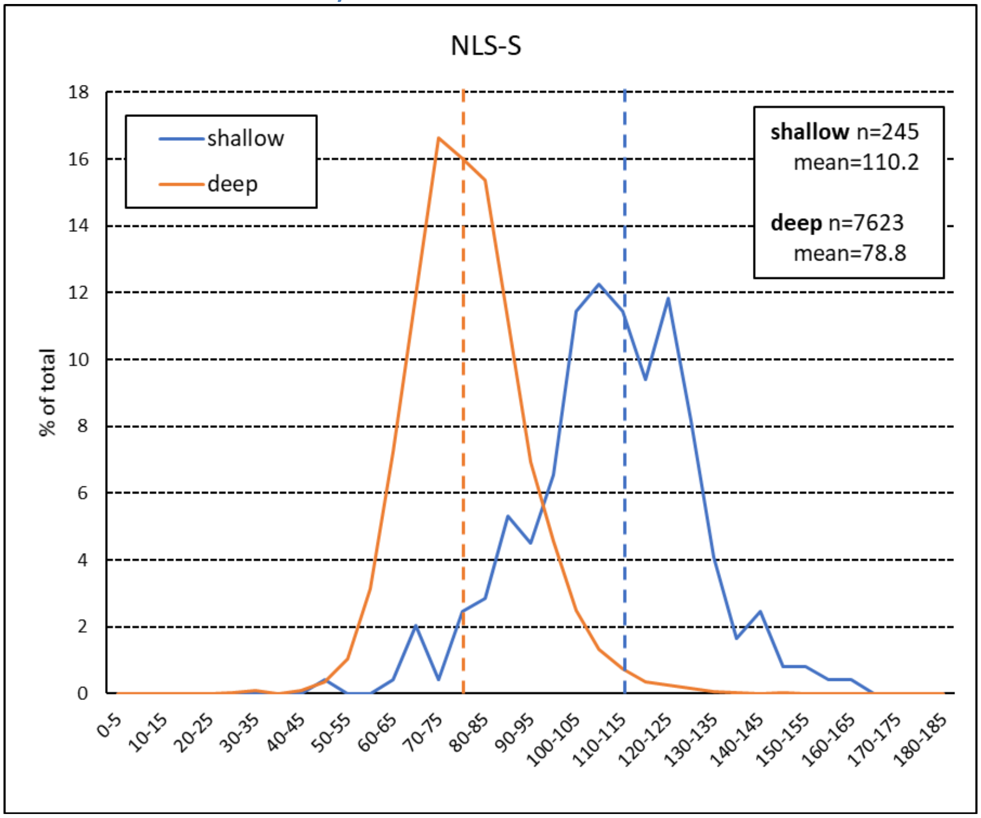


Figure 4 - Comparison of 2016, 2017, 2018 VIMS dredge survey observations in the NLS-West (formerly NLS-NA).

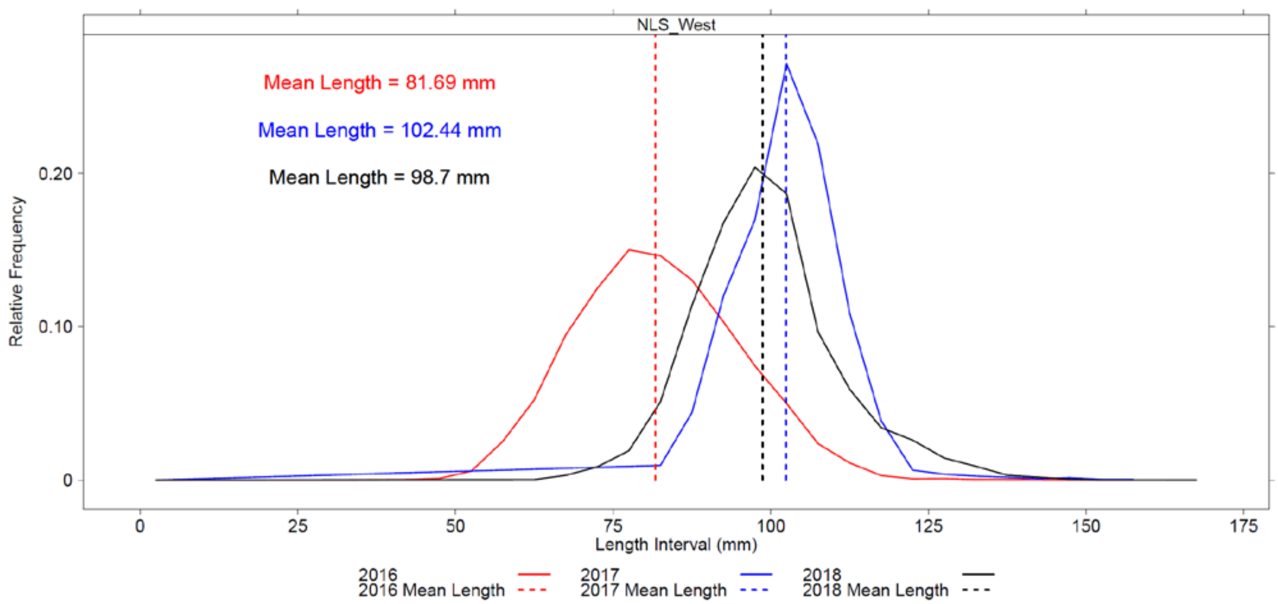


Figure 5 - Comparison of 2016, 2017, 2018 dredge survey observations in the NLS-South-deep (deep water "peter pan" scallops).

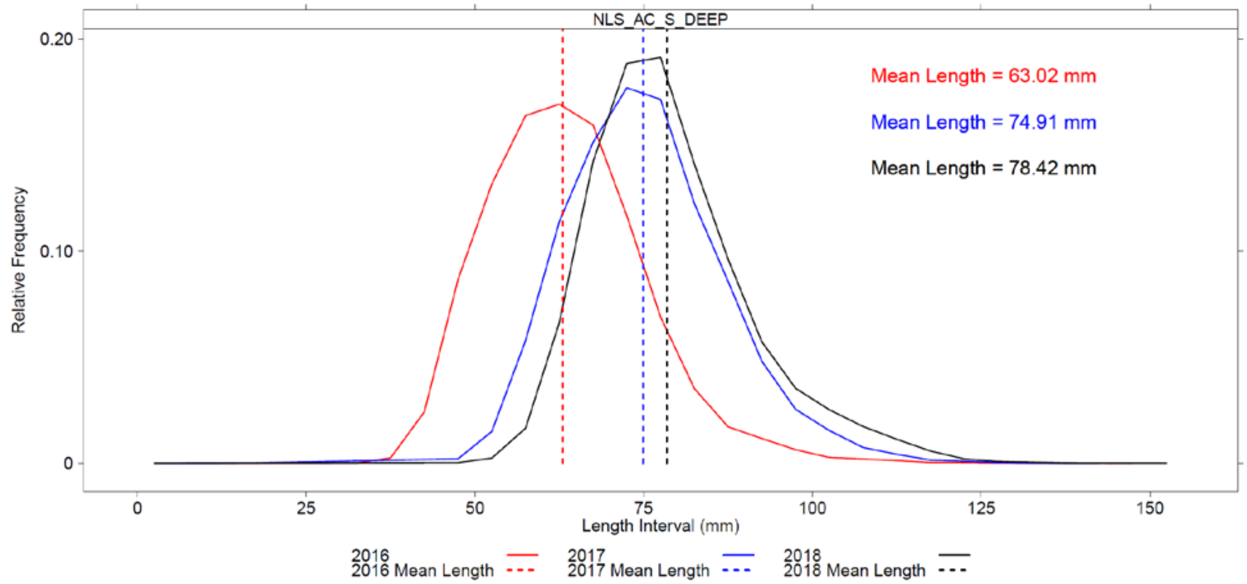


Figure 6 - Length-Frequency data from 2015, 2017, and 2018 HabCam surveys of the NLS-West area (Source: Coonamessett Farm Foundation).

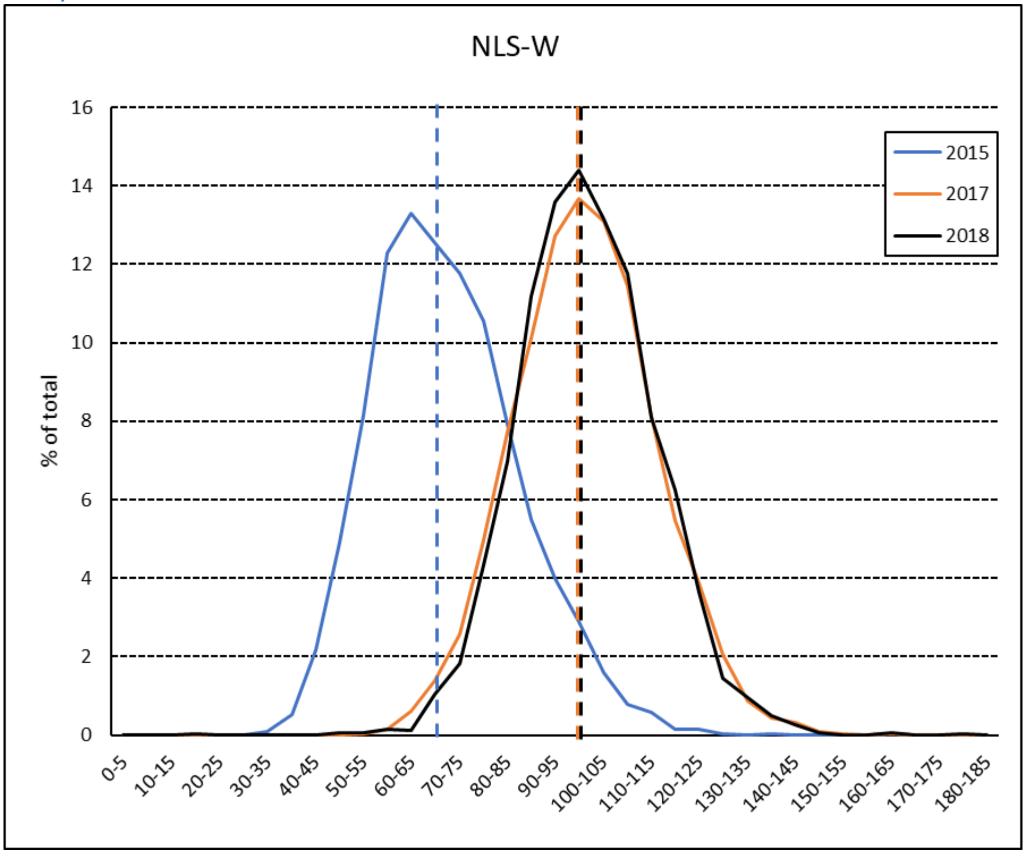
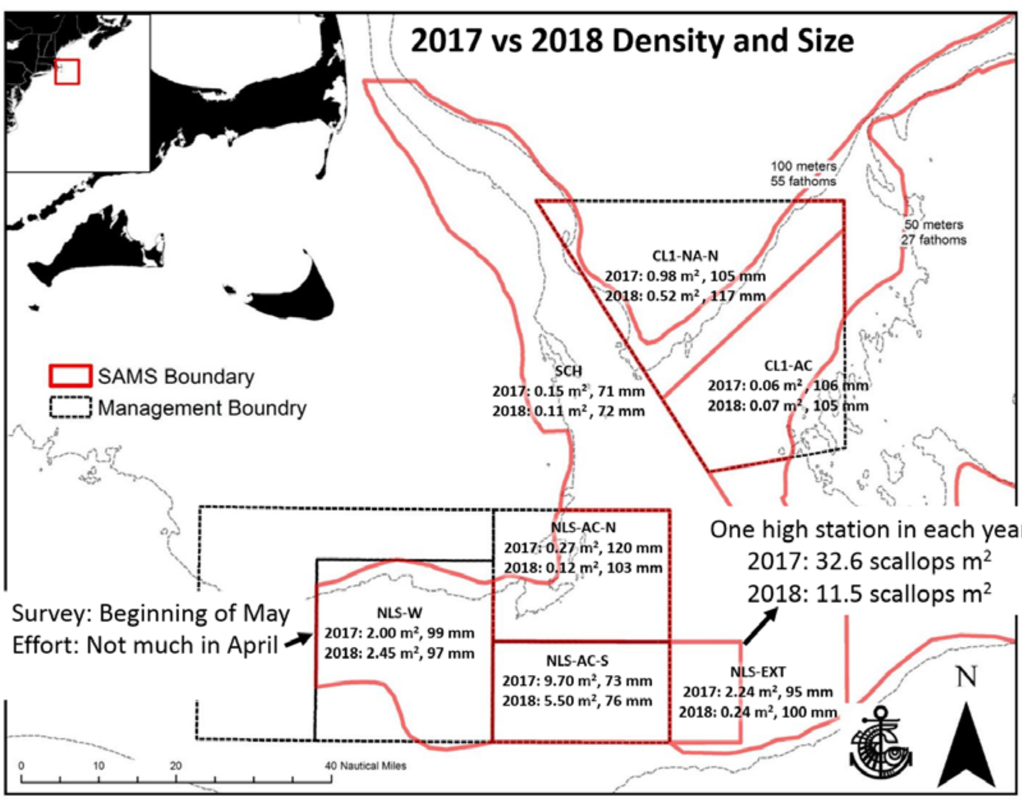


Figure 7 - Comparison of scallop average size and density by SAMS area from SMAST drop camera survey in 2017 and 2018.



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 animals relative to the gear ogive (Figure 8). 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 animals 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 to animals in access areas typically being larger in recent years and because the fishery has typically targeted larger animals when fishing in access areas. The Georges Bank Open curve more closely follows the 4" ring curve (i.e. selects smaller animals than the Georges Bank Closed curve) because animals in open areas have typically been smaller on average relative to animals in access areas and because there is less incentive for the fishery to target only larger scallops when operating under DAS management. Applying the Georges Bank Open curve selects for a larger proportion of scallops currently in the size distribution in the NLS-West. Table 8 provides a comparison of the exploitable biomass in the NLS-West and NLS-S-deep based on the different selectivity curves. This year, the PDT recommends applying the Georges Bank Open selectivity curve in the Nantucket Lightship-West and South-deep area to select a larger proportion of the 7-year-old animals in this area that are have already recruited to the fishery but are not growing normally.

Figure 8 - Comparison of CASA selectivity curves from SARC 65 with 4" ring curve (Yochum & DuPaul, 2008).

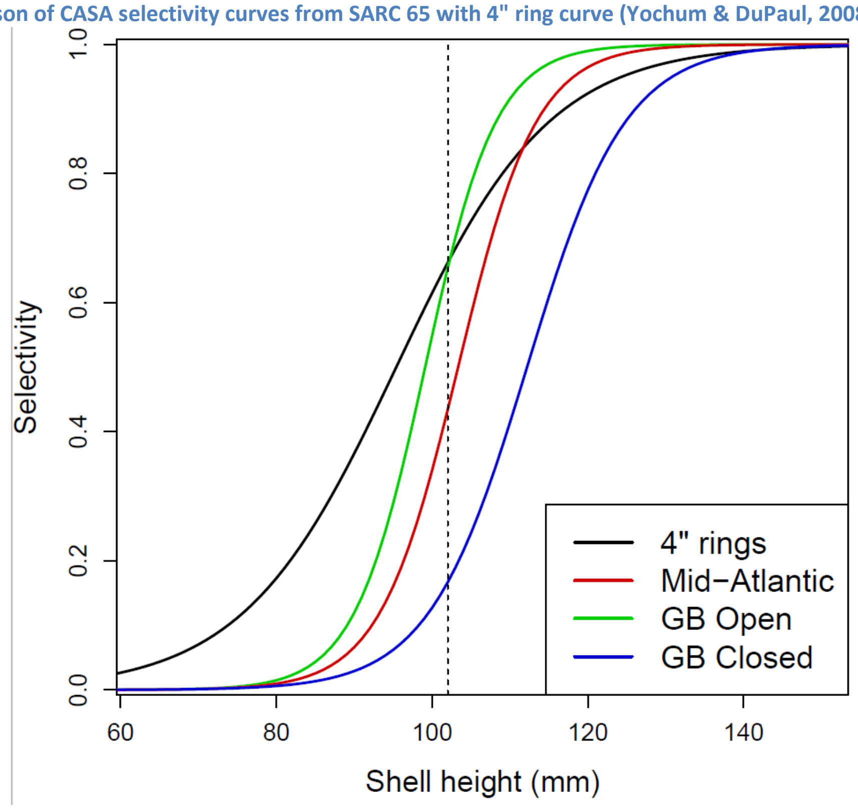


Table 8 - Comparison of exploitable biomass estimates for NLS areas using updated selectivity curves from the CASA model and 4" ring selectivity.

SAMS Area	4" Ring Estimate of Exploitable Biomass	GB Closed Estimate of Exploitable Biomass	GB Open Estimate of Exploitable Biomass
NLS-West	-	8,301 mt	31,926 mt
NLS-S-Deep	16,084 mt	-	10,435 mt

SSC Recommendation #3 from 2017: The SSC recommends that the PDT continue to investigate alternate weighting scenarios for combining the three surveys used in analyses and vet these analyses during the 2018 benchmark stock assessment process. This investigation could include examining geostatistical methods for biomass estimation from this information and should look into dredge efficiency issues in high density scallop areas.

An alternate weighting scenario for combining the three surveys were discussed during the 2018 benchmark assessment but were not pursued due to time and resource constraints. This approach, dubbed "GeoSAMS" would be undertaken by staff at the Northeast Fisheries Science Center and entail adding all data sets (dredge, drop camera, and HabCam) to the geostatistical model (GAM + Ordinary Kriging) to derive a total biomass estimate. Other outputs would include biomass heatmaps, and the potential for finer scale biomass estimation (i.e. point estimates). At present, the geostatistical approach is only used to generate biomass estimates for HabCam data. The PDT supports the development of additional methods of combining survey estimates.

SSC Recommendation #4 from 2017: The SSC supports continuing investigation into the different growth rates found in different scallop harvesting areas, and recommends investigating these growth differences as a standard procedure for the annual update of the scallop analyses.

The PDT reviewed length-frequencies from the 2017 and 2018 surveys to monitor recent growth. All three surveys (dredge, drop camera, HabCam) in the Nantucket Lightship suggested virtually no change in the mean shell height of animals in the Nantucket Lightship South-deep and Nantucket Lightship-West. The PDT also reviewed data in the Elephant Trunk area of the Mid-Atlantic, where little growth was observed between 2016 and 2017; however, these animals appeared to have resumed normal growth and the PDT does not recommend changing growth parameters for the Elephant Trunk as it did in 2017. Research on scallop growth is being supported though the Scallop RSA program in and is being carried out by Dr. Roger Mann and Dr. David Rudders at VIMS.

Scallop Rotational Management

While the OFL and ABC establish bounds for resource removals, in recent years, scallop rotational management has resulted in realized harvest (and corresponding fishing mortality rates) far below these legal limits. The PDT 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').

References:

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

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/

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

Table 9 - Combined survey estimates for 2018 by SAMS area (10/2/18 version).

		Dredge				DropCam				Habcam				Mean			
Region	Subarea	Num	Bmsmt	SE	MeanWt	Num	Bmsmt	SE	MeanWt	Num	Bmsmt	SE	MeanWt	Num	Bmsmt	SE	MeanWt
GB	CL1ACC	26.4	1137	138	43.2	82	2700	550	33	31.0	796	8	25.5	46.6	1544	189	33.1
GB	CL1NA	325.0	8889	1432	26.2	358	10850	2150	30	353.0	14843	2089	42.1	345.4	11527	1107	33.4
GB	CL-2(N)	380.2	7461	2927	19.6					154.0	5400	341	35.1	267.1	6431	1473	24.1
GB	CL-2(S)	344.3	8875	688	25.8					260.0	7125	907	27.4	302.2	8000	569	26.5
GB	CL2Ext	375.2	7230	688	19.3					332.0	7956	1131	24.0	353.6	7593	662	21.5
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
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
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
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
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
GB	NF	46.4	502	312	10.8					57.0	1466	200	25.8	51.7	984	185	19.0
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
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
GB	**TOTAL**	**8867.9**	**129565**	**4576**	**14.6**					**8285.0**	**135675**	**4110**	**16.4**	**9594.2**	**141032**	**5604**	**14.7**
MAB	BI	217.8	2572	244	23.7					61.0	942	36	15.4	139.4	1757	123	12.6
MAB	LI	428.2	8813	471	13.4					827.0	20597	3383	24.9	627.6	14705	1708	23.4
MAB	NYB	512.7	6667	771	28.9					354.0	5779	148	16.3	433.4	6223	392	14.4
MAB	MA inshore	50.4	931	170	45.8					86.0	766	3	8.9	68.2	849	85	12.4
MAB	HCSAA	786.6	13529	853	15.8					583.0	13109	923	22.5	684.8	13319	628	19.4
MAB	ET Open	714.7	15126	710	11.7					776.0	17936	716	23.1	745.4	16531	504	22.2
MAB	ET Flex	887.6	18018	1197	16.6					1013.0	27486	1682	27.1	950.3	22752	1032	23.9
MAB	DMV	63.0	1150	161	35.0					50.0	1168	70	23.2	56.5	1159	88	20.5
MAB	VIR	65.7	86	19	55.7									65.7	86	19	1.3
MAB	**TOTAL**	**3726.9**	**66891**	**1896**	**17.9**					**3750.0**	**87783**	**3958**	**23.4**	**3771.3**	**77380**	**2194**	**20.5**
TOTAL	**TOTAL**	**12595**	**196456**	**4953**	**15.6**					**12035**	**223458**	**5706**	**18.6**	**13366**	**218412**	**6018**	**16.3**

Figure 9 – SAMS areas and depth contours within the Nantucket Lightship zone, as configured in SARC 65 and FW30. Note that the 70 m depth contour makes the split between the Nantucket Lightship access South "Shallow" and the Nantucket Lightship access South "Deep" zones.

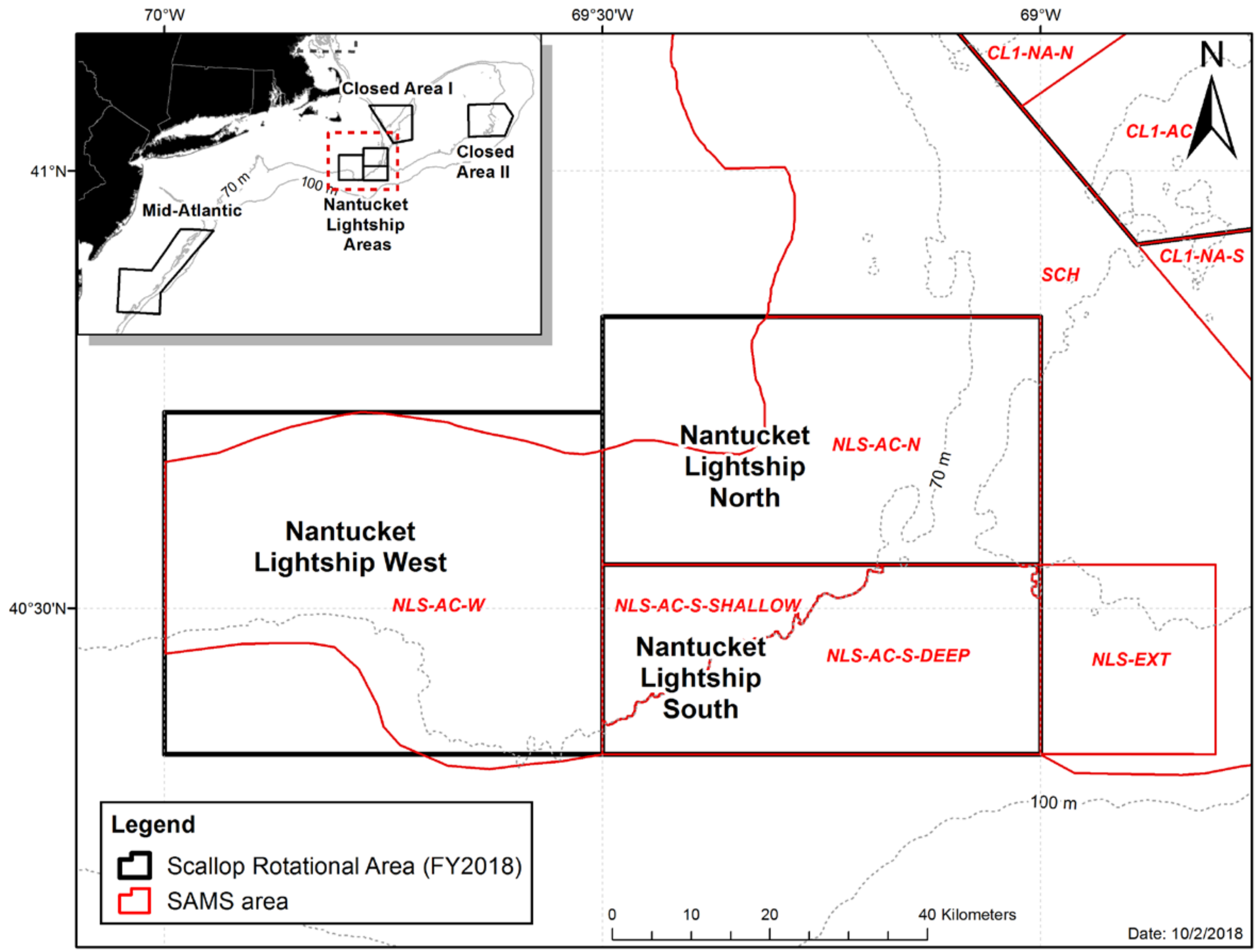


Figure 10 - 2018 Georges Bank SAMS Areas.

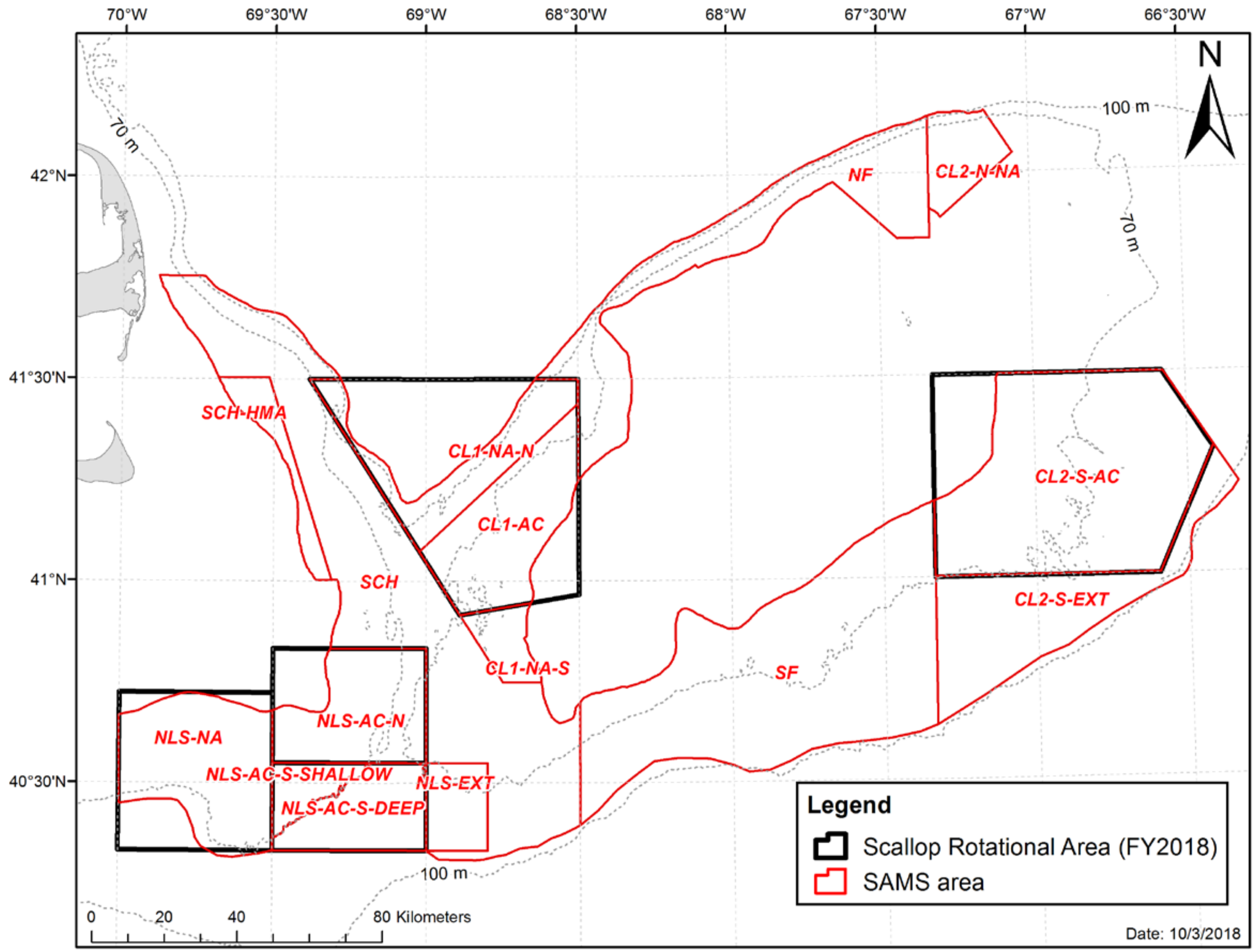
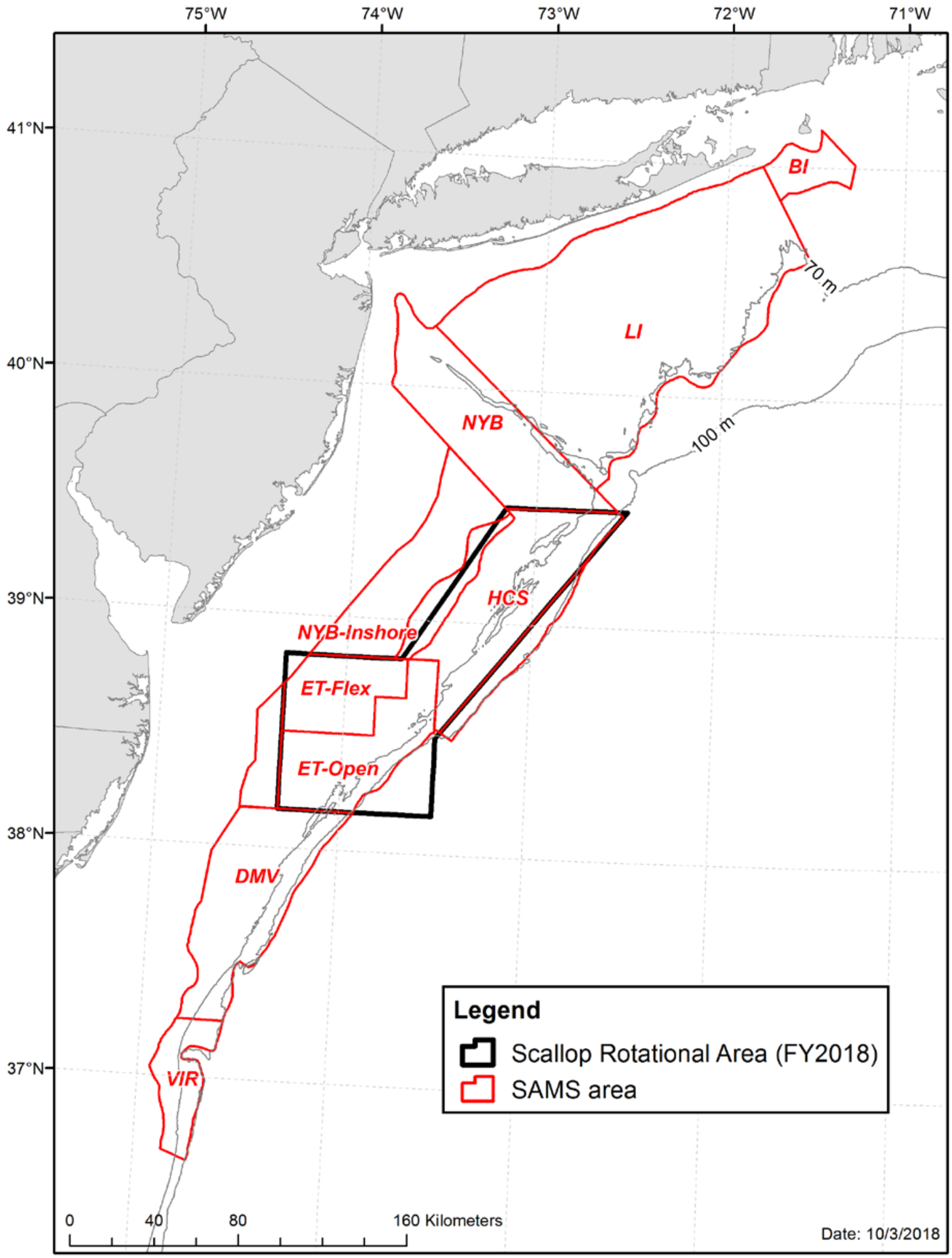


Figure 11 – 2018 Mid-Atlantic Bight SAMS Areas.



Appendix I: 2018 SAM Runs Outputs and Assumptions

SAMS Model Run:

1. Model configured the same as SARC 65, with 8 areas in MA and 14 in GB.
2. L∞ in deep portion of NLS-S 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. ACL: F=0.64, OFL: F=0.51

Table 10 - 2018 SAMS Run: 2019/2020 projected exploitable biomass by SAMS area, including ABC and OLF estimates.

Subarea	ExpBms19	Land19ACL	Land20ACL	Land19OFL	Land20OFL
HCS	8816	3541	2933	4150	3448
Vir	19	62	124	75	146
ETOp	14386	5356	4111	6247	4815
ETFlex	19382	7050	4350	8212	5067
Dmv	985	433	457	509	539
NYB	4438	2235	2083	2625	2440
LI	9440	4177	3282	4899	3832
Inshore	2725	1386	1462	1625	1714
TotalMA	**60191**	**24240**	**18802**	**28342**	**22001**
C1NA	6413	2002	1118	2326	1302
C1Acc	1182	423	351	494	413
C2NA	5289	1978	1455	2314	1704
C2Acc	6222	2465	2122	2891	2495
NLSW	31926	11590	7309	13575	8527
NLSN	2995	1094	857	1278	1004
NLSSSh	1137	646	611	764	714
NLSSDeep	10435	5044	5697	6034	6798
C2Ext	4864	1802	1323	2100	1542
NLSExt	527	166	89	193	104
Sch	8425	3524	4512	4110	5308
NF	922	343	365	401	429
SF	4202	1685	1415	1968	1652
TotalGB	**84539**	**32762**	**27224**	**38448**	**31992**
Total	**144730**	**57002**	**46026**	**66790**	**53993**

Table 11 - Comparison of the meat weight and growth parameters used in recent SAMS configurations.

	2015	2016	2017	2018
Meat weight (SH/MW)	SARC 59	SARC 59, with changes to SHMW parameters using VIMS 2016 data (NLS-S, NLS-NA, NLS-ext)	SARC 50, with changes to SHMW parameters in NLS using VIMS 2016 & 2017 data (NLS-S, NLS-NA).	SARC 65, with changes to SHMW parameters in the NLS using VIMS 2016 – 2018 data (
Growth	SARC 59	SARC 59, with reductions to growth in NLS	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.	SARC 65, with reduction in $L\infty$ in NLS-W to 119mm. SARC 65 set the $L\infty$ of scallops in the NLS-S-deep at 110 mm.

Appendix II: VIMS Shell-Height Meat-Weight Analysis

Ms. Sally Roman
Dr. David Rudders

August 6, 2018

Methods

Shell height meat weight relationships (SHMW) were estimated for the MAB and NL surveys with VIMS survey data. For the MAB survey, SHMW relationships were estimated with the current SAMS areas (n=8). No data were collected from the VIR SAMS area. A separate analysis was conducted with a new SAMS area, referred to as the High Density Area, and defined below in Figure 1. The High Density SAMS area was originally in the ET_Flex SAMS area (also referred to as ET_Close). Data from the VIMS 2018 MAB survey were used for the MAB SHMW analysis. Another set of SHMW equations were developed for the NLCA. The first developed SHMW relationships for the four current SAMS areas within the survey domain. The second analysis separated the Southern SAMS area (referred to as NLS_AC_S) into two new areas based on depth. Shallow (< 70 m) and Deep SAMS areas (> 70 m) replaced the Southern SAMS area. Combined VIMS survey data from the NLCA for 2016- 2018 were used for both NLCA SHMW analyses.

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 that satisfied model building criteria was selected as the preferred model and used to predict SHMW relationships by SAMS area. Variables considered were: ln shell height, ln depth (average depth of a tow), SAMS Area (retained in all models), latitude (MAB only, beginning latitude of a tow) and an interaction term of shell height and depth. The interaction term was not included in the full model if the term was not significant in the individual interaction model. This occurred for the NLCA analyses. Tables provided below include the SHMW models with parameters and AIC by SAMS area and analysis. Parameter estimates for the preferred model and predicted SHMW relationships are also provided. Specific to the NLCA, several SHMW parameter tables are provided:

1. VIMS 2016-2017 parameter estimates (used in last year's biomass calculations for the Southern and NA SAMS areas)
2. Parameter estimates for the current SAMS area preferred model with the 2016-2018 survey data, and
3. Parameter estimates for the current Ext, NA and Northern SAMS areas and Shallow and Deep SAMS area with the 2016-2018 survey data.

2018 total biomass for the VIMS NLCA survey was estimated with the SARC 65 GB SHMW parameters and the VIMS combined 2016-18 parameter estimates. VIMS parameter estimates were applied to all SAMS areas when biomass estimation was conducted. A comparison of biomass estimates is provided below. Dredge efficiency issues persist in high density areas.

MAB

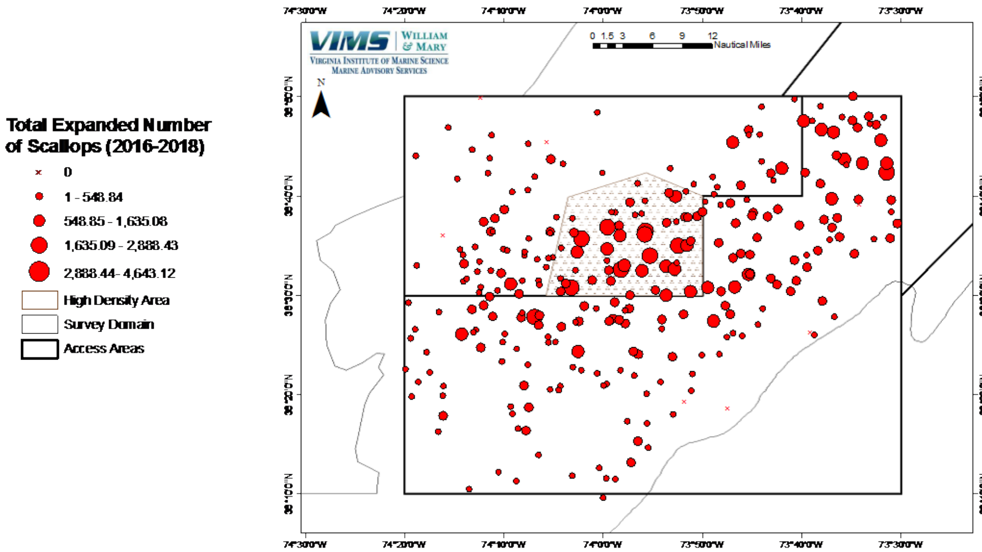


Figure 1. Boundary for High Density SAMS area within the ET_Flex area.

Table 1. SHMW models for the MAB with current SAMS areas. Bold variables indicate significance. Model in red was selected as the preferred model. * indicates an interaction term.

Modnames	Parameters	AIC
mab1	~ 1 + **shell height*depth** + **SAMS Area**	31342.81
mab5	~ 1 + **shell height*depth** + **SAMS Area +** latitude	31344.36
mab6	~ 1 + **shell height + depth** + **SAMS Area**	31381.42
mab7	~ 1 + **shell height + depth** + **SAMS Area +** latitude	31383.3

Table 2. Parameter estimates for model mab1 from Table 1.

Parameter	Parameter Estimate
Intercept	-19.71
ln shell height	5.057
ln depth	2.38
DMV	-0.24
ET_Flex	0.02
ET_Open	-0.05
HCS	-0.08
LI	-0.05
NYB	-0.05
NYB_Inshore	0.02
ln shell height:ln depth	-0.54

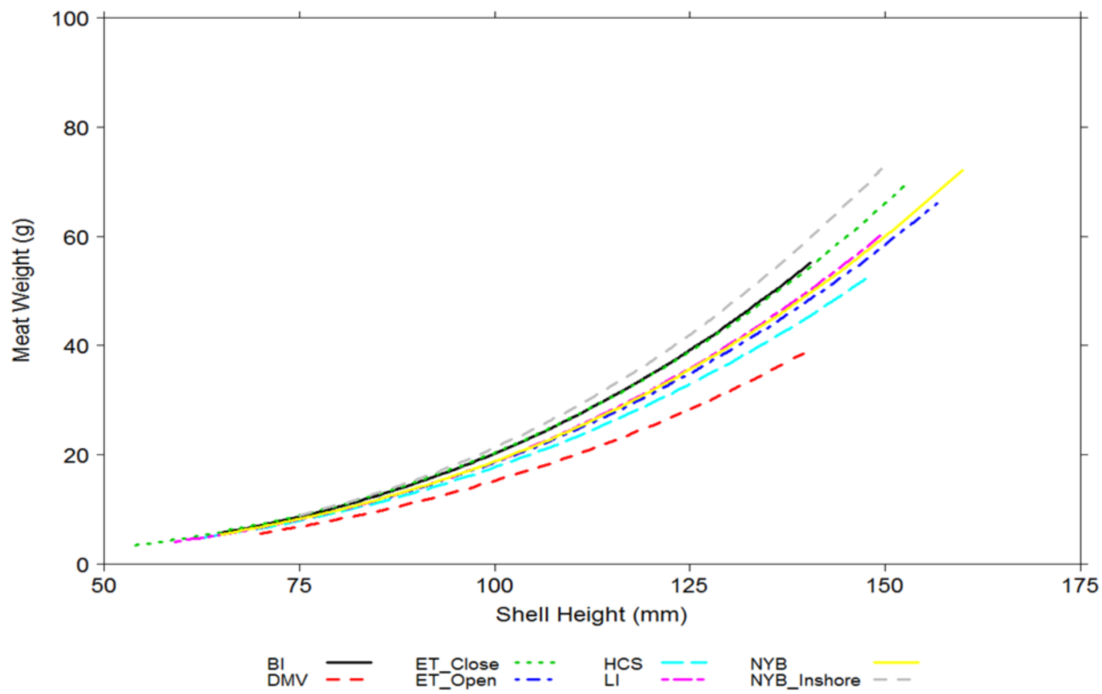


Figure 2. Predicted SHMW relationships by SAMS Area for the MAB using model mab1 from Table 1.

Table 3. SHMW models for the MAB with current SAMS areas and a High Density SAMS area. Bold variables indicate significance. Model in red was selected as the preferred model. * indicates an interaction term.

Modnames	Parameters	AIC
mab5	~ 1 + **shell height*depth + SAMS Area**	31344.01
mab2	~ 1 + **shell height*depth +** latitude **+ SAMS Area**	31345.64
mab4	~ 1 + **shell height + depth + SAMS Area**	31382.63
mab3	~ 1 + **shell height +** latitude **+ depth +** SAMS Area	31384.71
mab1	~ 1 + **shell height + latitude + SAMS Area**	31396.8

Table 4. Parameter estimates for model mab5 from Table 3.

Parameter	Parameter Estimate
Intercept	-19.71
ln shell height	5.05
ln depth	2.37
DMV	-0.22
ET_Flex	0.07
ET_Open	-0.03
HCS	-0.07
High_density	0.01
LI	-0.04
NYB	-0.03
NYB_Inshore	0.04
ln shell height:ln depth	-0.54

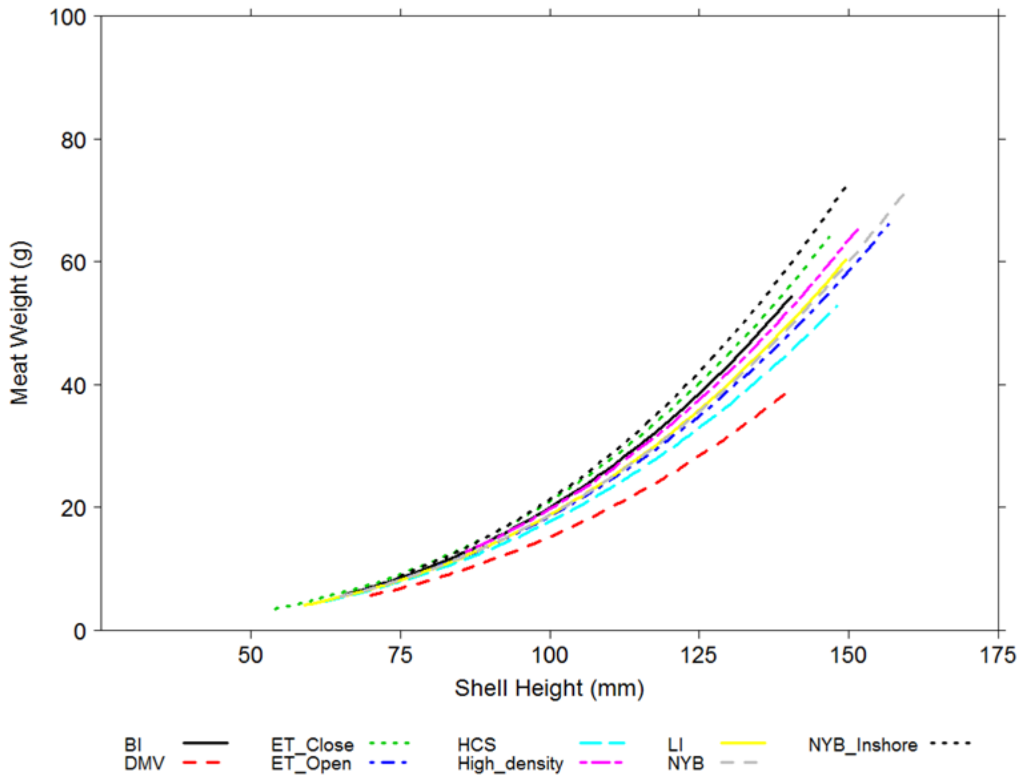


Figure 3. Predicted SHMW relationships by SAMS Area for the MAB using model mab5 from Table 3.

NLCA

Table 5. SHMW models for the NLCA with current SAMS areas using 2016-2018 combined survey data. Bold variables indicate significance. Model in red was selected as the preferred model. * indicates an interaction term.

Modnames	Parameters	AIC
nl4	~ 1 + **shell height +depth + SAMS Area**	24145.45
nl1	~ 1 + **shell height + SAMS Area**	24150.09

Table 6. Parameter estimates for model nl4 from Table 5.

Parameter	Parameter Estimate
Intercept	-9.30
ln shell height	2.81
ln depth	-0.13
NLS_AC_S	-0.34
NLS_EXT	-0.22
NLS_NA	-0.22
VIMS_45	0.03

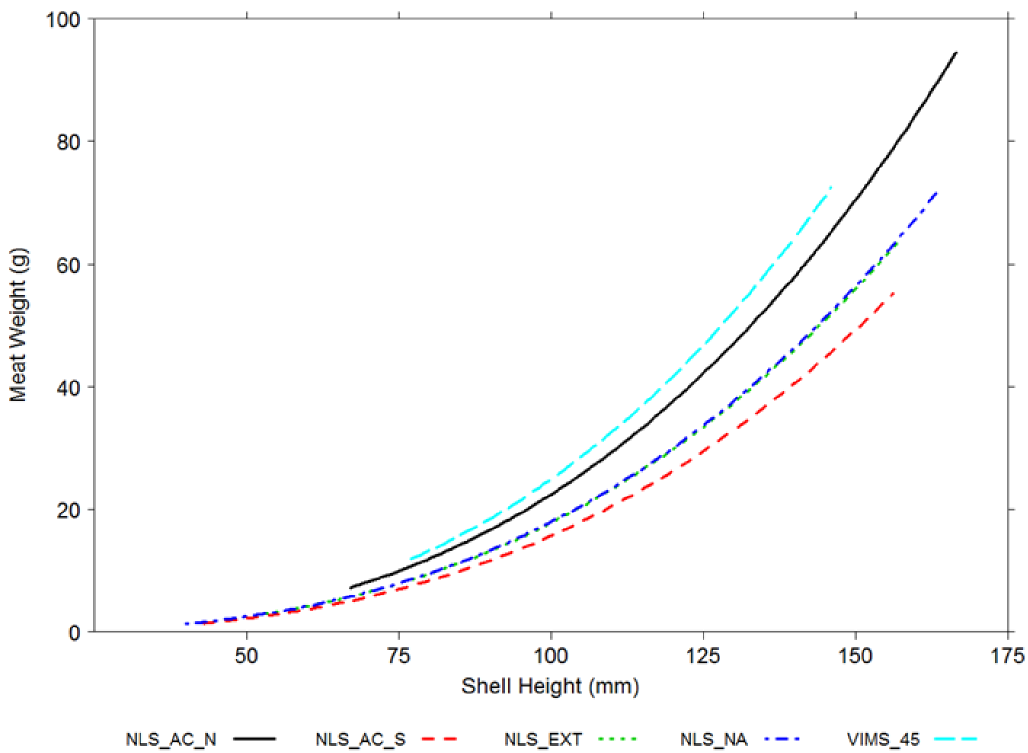


Figure 4. Predicted SHMW relationships by SAMS Area for the NLCA using model nl4 from Table 5.

Table 7. SHMW models for the NLCA with NA, Ext, Northern, Shallow and Deep SAMS areas using 2016-2018 combined survey data. Bold variables indicate significance. Model in red was selected as the preferred model. * indicates an interaction term.

Modnames	Parameters	AIC
nl4.1	~ 1 + **shell height + depth + SAMS Area**	24147.61
nl1.1	~ 1 + **shell height + SAMS Area**	24151.5

Table 8. Parameter estimates for model nl4.1 from Table 7.

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

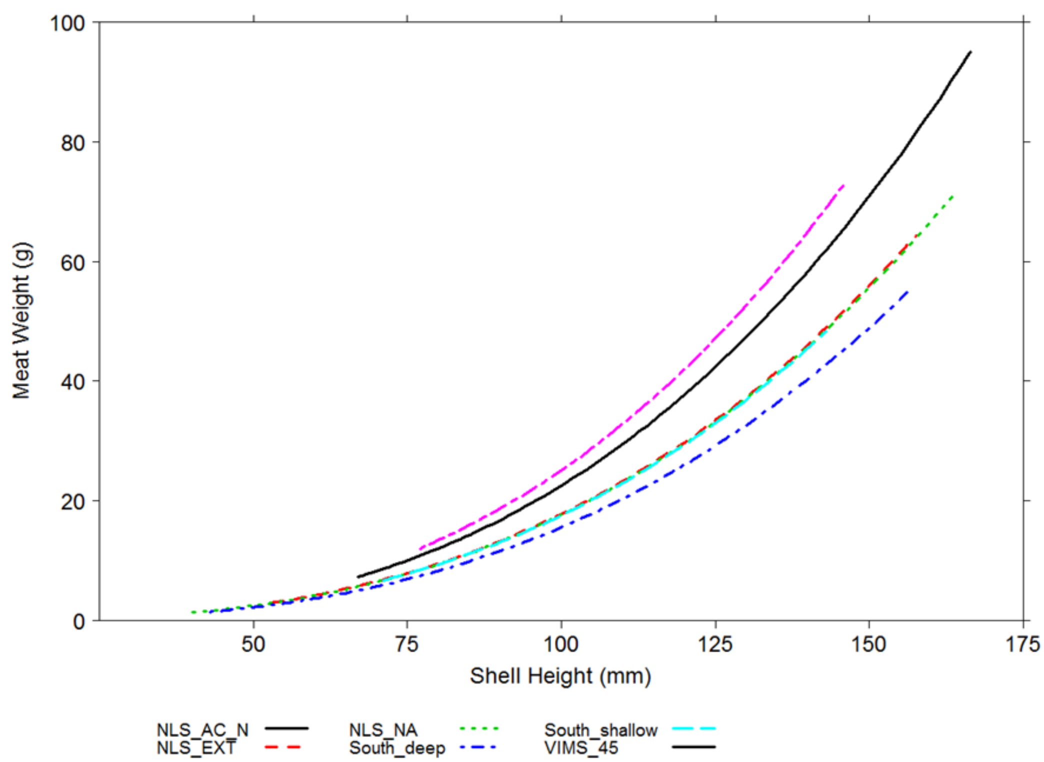


Figure 5. Predicted SHMW relationships by SAMS Area for the NLCA using model nl4.1 from Table 7.

Table 9. Parameter estimates for 2016-17 survey data used in 2017 biomass estimation and parameter estimates for 2016-18 survey data for current SAMS areas.

Parameter	2016-17 Parameter Estimate	2016-18 Parameter Estimate
Intercept	-8.46	-9.31
ln shell height	2.67	2.82
ln depth	-0.17	-0.14
NLS_AC_S	-0.39	-0.35
NLS_EXT	-0.29	-0.22
NLS_NA	-0.27	-0.22
VIMS_45	0.02	0.04

Table 10. Total biomass estimates (mt) for the NLCA using SARC 65 parameter estimates and VIMS 2016-18 parameter estimates for the current SAMS areas. Dredge efficiency issues persist in high density areas. VIMS 2016-18 parameters used for all current SAMS areas.

SAMS Area	Biomass (mt) - SARC 65	Biomass (mt) - VIMS 2016-18
NLS_N	3,903.67	3,568.51
NLS_AC_S	20,109.15	12,385.15
NLS_EXT	136.84	111.4
NLS_NA	21,642.34	15,091.96
VIMS_45	7.78	6.71

<u>Discussion</u>

For the MAB, partitioning the ET_Flex SAMS area into two distinct SAMS Areas (High Density and ET_Flex) may not be appropriate. Predicted SHMW relationships for the MAB, with the addition of the High Density SAMS area, did not indicate the High Density SAMS area had significantly lower growth compared to the current SAMS areas (Figure 3). The predicted SHMW relationship for the High Density SAMS area was consistent with the other SHMW relationships in the MAB and the ET area. Growth of scallops in the ET_Flex SAMS area increased in 2018 compared to 2017. The mean length of scallops observed in the survey dredge in 2017 was 91.41mm, compared to a mean length of 104.53 mm in 2018.

For the NLCA, it may be appropriate to consider alternative SHMW relationships for some SAMS areas as has been done in the past. There was decrease of approximately 7.70 thousand mt for total biomass in the Southern SAMS area when using the VIMS estimates compared to the SARC estimates. Biomass estimates for the Northern and EXT SAMS areas were comparable. It is unclear if the SARC 65 GB model (Table A2-2) includes the peter pan scallops. Table A2-1 of SARC 65 indicates that slow growing (peter pan) scallops were left out of the GB all and GB closed estimates. VIMS SHMW estimates for the 2016-17 data used last year and the 2016-18 results are similar. Biomass estimates for the additional Shallow and Deep SAMS area in place of the Southern SAMS area could not be calculated. Stratum areas within the new SAMS area would have to be calculated prior to biomass estimation.

For Reference:

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: VIMS Length Frequency Distributions for the ET and NL survey areas

Consistent with SSC Recommendation #4 from their 2017 memo to the Council, the Scallop PDT reviewed length frequency distributions to assess annual growth of animals in high density areas. The following analysis was prepared for the PDT by Mr. Sally Roman and Dr. David Rudders of VIMS for the August 28/29, 2018 Scallop PDT meeting in Falmouth, MA.

Ms. Sally Roman
Dr. David Rudders

VIMS Length Frequency Distributions for the ET and NL survey areas

August 14, 2018

The ET and NL Southern SAMS areas were separated into smaller spatial units and relative length frequency distributions were plotted.

For the ET area, the ET Flex SAMS area was separated into a High Density Area and the remainder of the ET Flex area. The High Density Area was defined using the same boundary included in the SHMW write up (Figure 1). The ET was also divided into the same High Density Area and the rest of the ET (ET Flex and ET Open combined). Data are from the VIMS 2018 survey for both the survey and commercial dredges.

The NL Southern Area was divided into Shallow and Deep areas based on depth. Data are from the VIMS 2016 – 2018 surveys for both the survey and commercial dredges. Data are plotted by year and depth area. This was also done last year for a SSC memo in October. There are two differences between these graphs and the graphs from last year.

1. The average depth for the entire survey area was used for a stations when no actually mean depth data were available from the inclinometer. This changed this past winter. Now the depth at the start of the tow recorded in the wheel house is used in this field if no data are available. This resulted in several tows being reclassified from deep to shallow in the NLS-South and changed the length distributions for 2016.

2. The 2017 used the number measured, not the expanded number at length, for the graphs and to calculate the mean length. This is corrected and resulted in a decrease in the average length for the shallow area.

Elephant Trunk

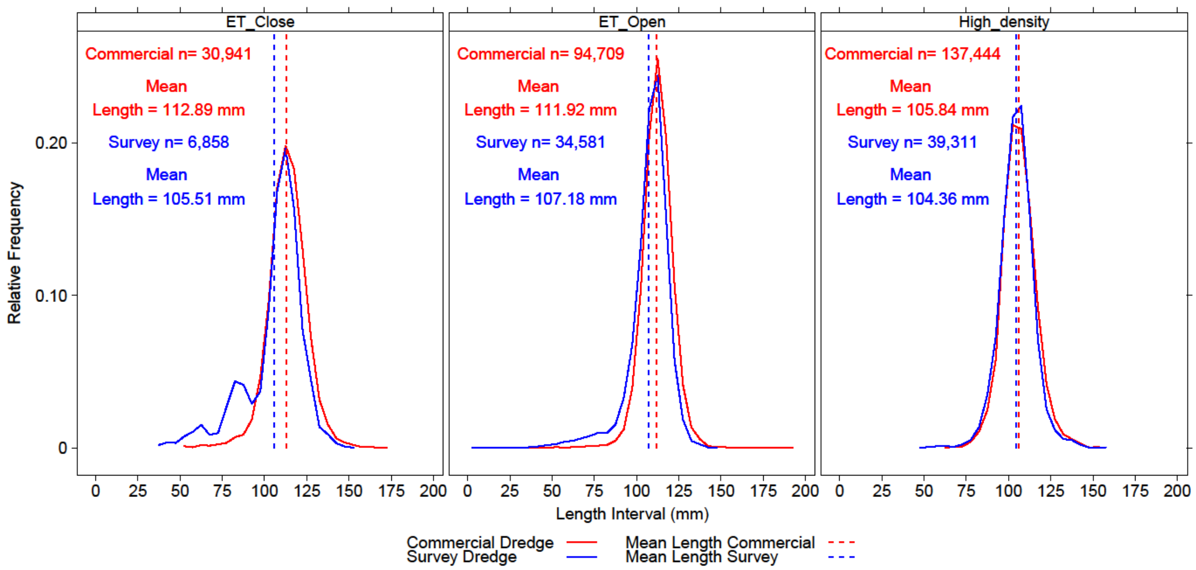


Figure 1. Relative length frequencies with the expanded number at length and mean length for the commercial and survey gears for the ET Flex (ET Close), ET Open and High Density Area.

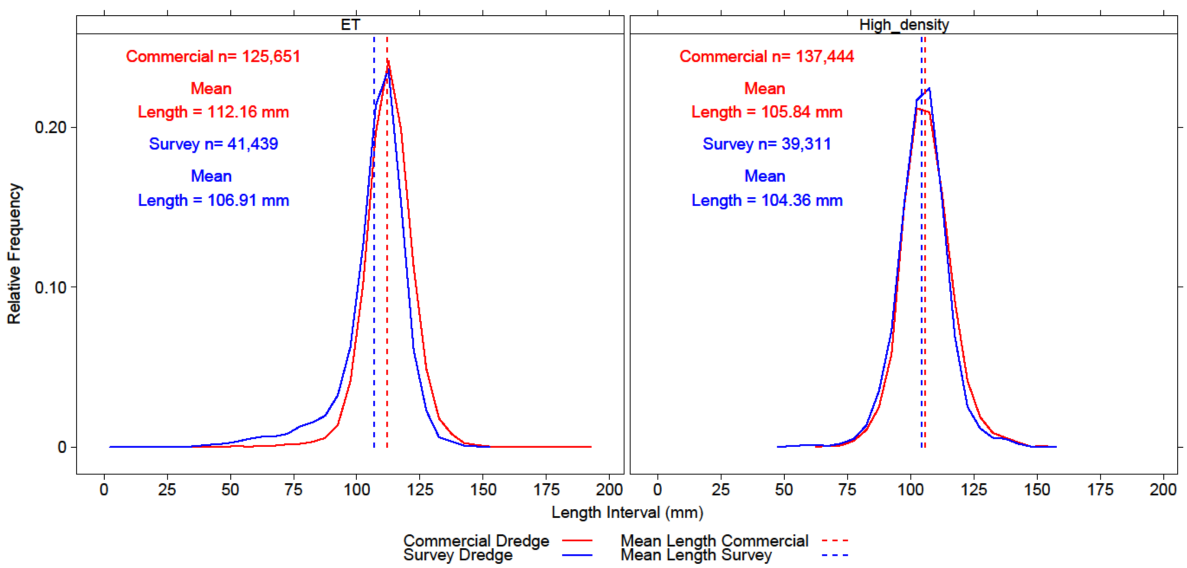


Figure 2. Relative length frequencies with the expanded number at length and mean length for the commercial and survey gears for the ET (ET Flex and ET Open) and High Density Area.

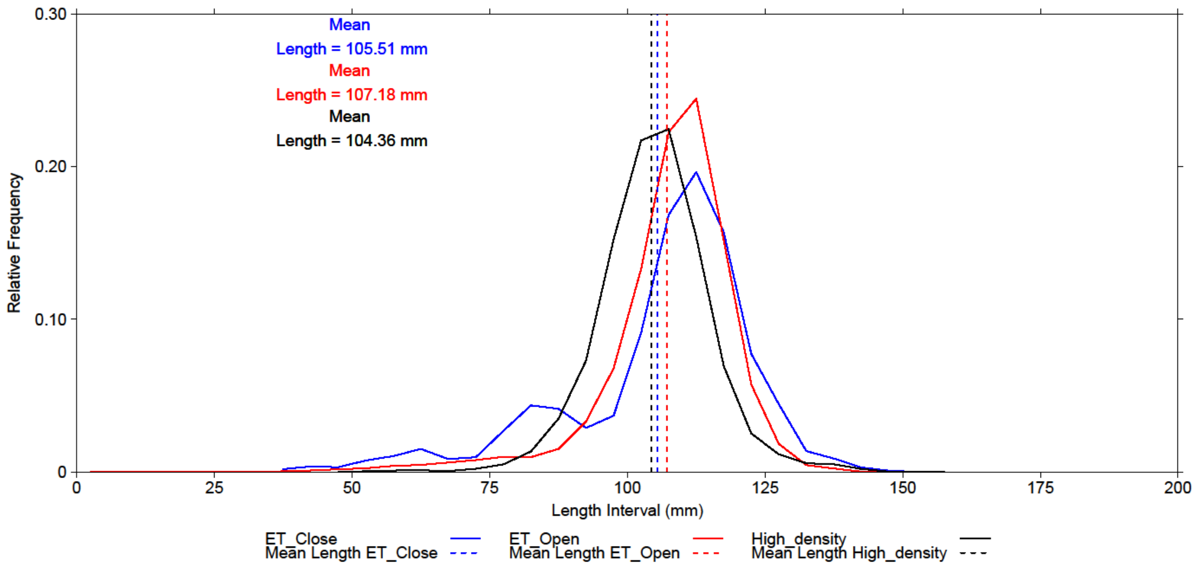


Figure 3. Relative length frequencies with the expanded number at length and mean length for the survey gear for the ET Flex (ET Close), ET Open and High Density Area.

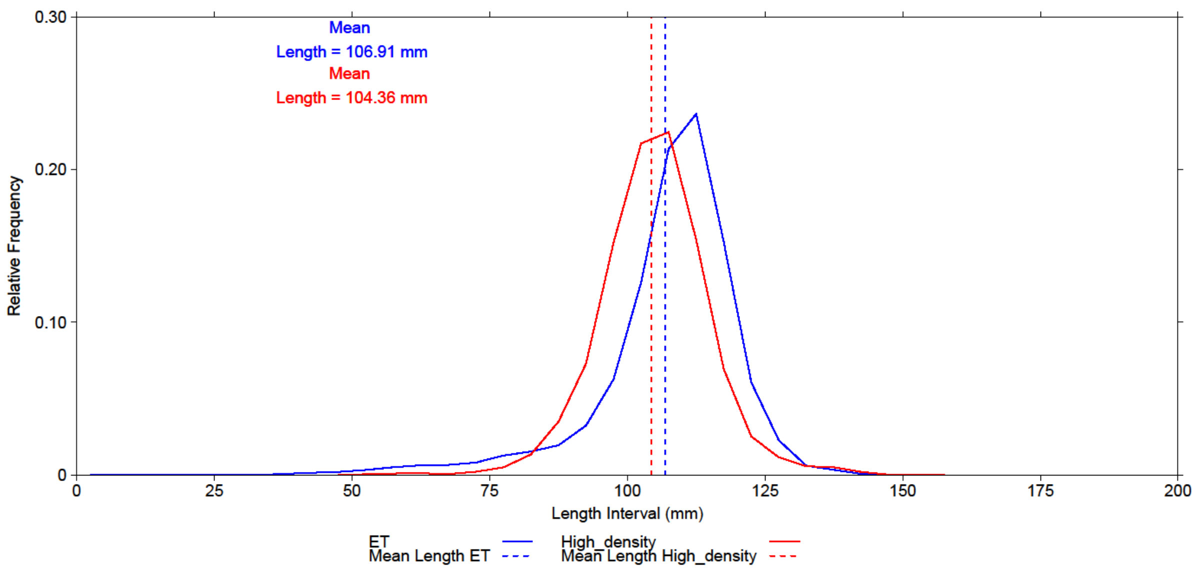


Figure 4. Relative length frequencies with the expanded number at length and mean length for the survey gear for the ET (ET Flex and ET Open) and High Density Area.

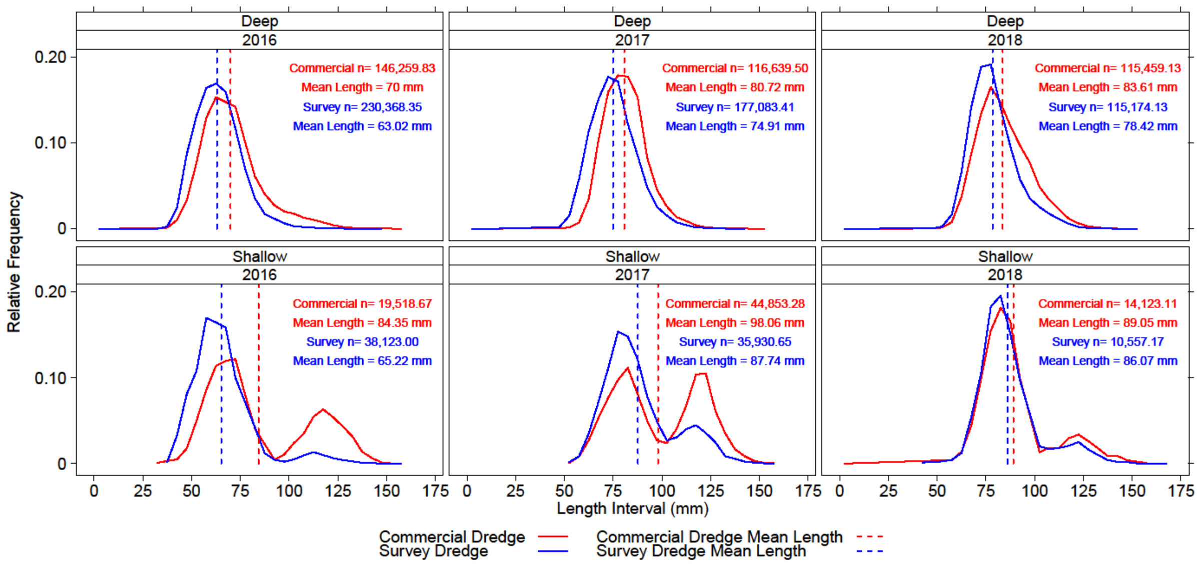


Figure 5. Relative length frequencies with the expanded number at length and mean length for the commercial and survey gears for the Deep and Shallow Areas within the NL Southern SAMS Area.

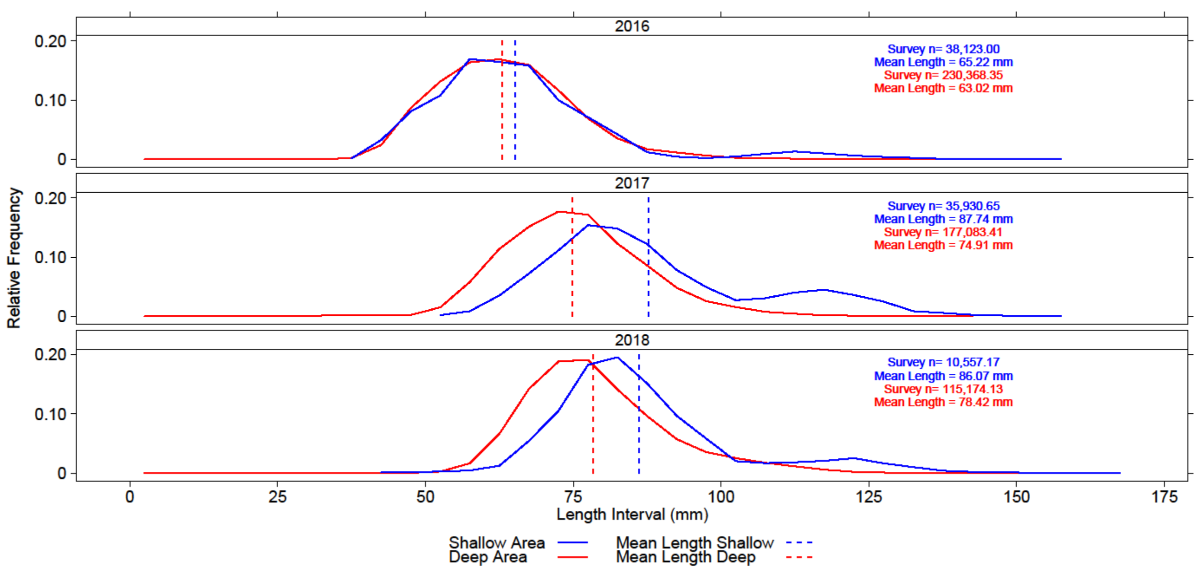


Figure 6. Relative length frequencies with the expanded number at length and mean length for the survey gear for the Deep and Shallow Areas within the NL Southern SAMS Area.

Appendix IV:

SH/MW Parameters for Biomass Estimation
Comparison of Biomass Estimates Using SARC 65 vs. VIMS 2016-2018
Nantucket Lightship SAMS Areas

Note: Biomass values in mt.

Table 12 – SMAST Drop Camera Estimates

SMAST – Drop Cam				
SAMS Area	65th SARC		VIMS 2016-18	
	BmsMT	Avg MW (g)	BmsMT	Avg MW (g)
NLS-AC-N	4,250	33.3	3,850	30.3
NLS-W	86,000	24.7	58,500	16.8
NLS-EXT	2,200	23.4	1,800	19.4
NLS-AC-S-SHLW	6,950	21.1	4,100	12.5
NLS-AC-S-DEEP	37,950	7	40,700	7.5

Table 13 - VIMS Dredge Estimates

VIMS - Dredge				
SAMS Area	SARC 65		VIMS 2016-18	
	Total Biomass (mt)	Avg MW (g)	Total Biomass (mt)	Avg MW (g)
NLS_AC_N	3,903.67	38.3	3,607.85	35.59
NLS_AC_S_DEEP	9,799.14	7.8	10,320.88	8.22
NLS_AC_S_SHALLOW	3,545.32	18.06	2,111.41	10.75
NLS_EXT	136.84	32.27	111.98	26.41
NLS_WEST	21,642.34	26.21	14,929.89	18.07
VIMS_45	7.78	47.13	6.79	41.16

Table 14 - HabCam Estimates (CFF and NEFSC)

HabCam				
SAMS Area	65th SARC		VIMS 2016-2018	
	BmsMT	Avg MW (g)	BmsMT	Avg MW (g)
NLS_AC_N	3,794		3,585	
NLS_AC_S_DEEP	31,940		31,785	
NLS_AC_S_SHALLOW	7,075		4,964	
NLS_EXT	328		274	
NLS_WEST	60,445		41,155	

Table 15 - Comparison of Dredge, Drop Camera, and HabCam estimates using SH/MW from SARC 65

SAMS Area	65th SARC – estimates in mt			
	VIMS Dredge	SMAST Dropcam	HabCam	Average
NLS-AC-N	3,904	4,250	3,794	3,983
NLS-W	21,642	86,000	60,445	56,029
NLS-EXT	137	2,200	328	888
NLS-AC-S-SHLW	3,545	6,950	7,075	5,857
NLS-AC-S-DEEP	9,799	37,950	31,940	26,563

Table 16 - Comparison of Dredge, Drop Camera, and HabCam Estimates using VIMS 2016 - 2018 SH/MW relationships

SAMS Area	VIMS 2016-2018 – estimates in mt			
	VIMS Dredge	SMAST Dropcam	HabCam	Average
NLS-AC-N	3,608	3,850	3,585	3,681
NLS-W	14,930	58,500	41,155	38,195
NLS-EXT	112	1,800	274	729
NLS-AC-S-SHLW	2,111	4,100	4,964	3,725
NLS-AC-S-DEEP	10,321	40,700	31,785	27,602

Table 17 - Comparison of SARC 65 vs. VIMS 2016-2018 averages of 3 surveys, and percent change (VIMS/SARC65).

SAMS Area	SARC 65 Average	VIMS Average	% Change 1-(VIMS/SARC65)
NLS-AC-N	3,983	3,681	8%
NLS-W	56,029	38,195	32%
NLS-EXT	888	729	18%
NLS-AC-S-SHLW	5,857	3,725	36%
NLS-AC-S-DEEP	26,563	27,602	-4%