An optical assessment of sea scallop abundance and distribution in the Southern Closed Area II and the Elephant Trunk Scallop Management Areas

Final Report

2019 Sea Scallop Research Set-Aside (RSA) Program
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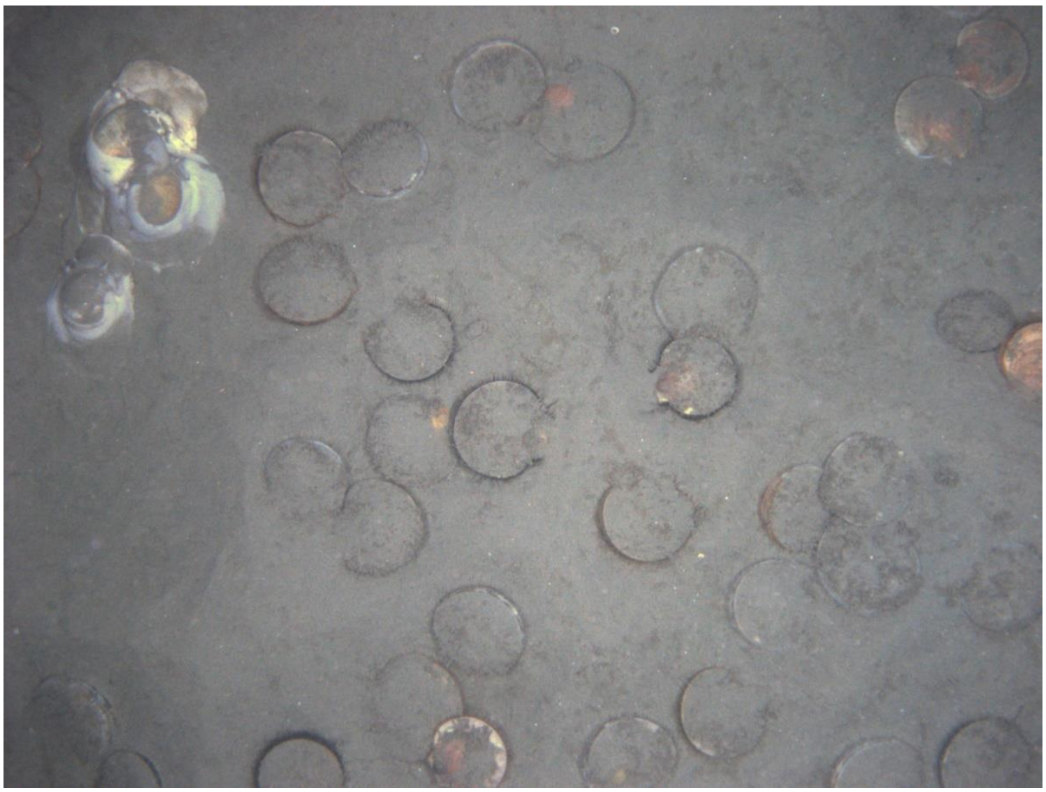

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Table of Contents

List of acronyms and terms

CAII	Closed Area II (sometimes called CA2)
CAII-Ext	Closed Area II Extension SAMS Area
CFF	Coonamessett Farm Foundation, Inc.
ET	Elephant Trunk
ET-Flex	Elephant Trunk Flex SAMS Area
FOV	field of view
HCAA	Hudson Canyon Access Area
m	meters
mm	millimeter
NEFMC	New England Fishery Management Council
NEFSC	Northeast Fisheries Science Center
NOAA	National Oceanic and Atmospheric Administration
nm	nautical mile
NMFS	National Marine Fisheries Service or NOAA Fisheries
PDT	NEFMC Plan Development Team(s)
RSA	NEMFC/NEFSC Research Set Aside Program
SAMS	Scallop Area Management Simulator (model) areas
SH	shell height
SF	Southern Flank
VIMS	Virginia Institute of Marine Science, College of William and Mary
VMS	Vessel Monitoring System
WHOI	Woods Hole Oceanographic Institution

EXECUTIVE SUMMARY

Coonamessett Farm Foundation’s (CFF) 2019 Sea Scallop Research Set Aside (RSA) project entitled *“**An optical assessment of sea scallop abundance and distribution in the Southern Closed Area II and the Elephant Trunk Scallop Management Areas**”* was designed to provide critical survey-based information to help inform scallop fishery management efforts. The primary objectives of this project are to:

1. Provide scallop count and shell-height measurement data needed to derive biomass estimates of scallops in Scallop Area Management Simulator (SAMS) estimation areas on Georges Bank (including the CAII-Ext, CAII Access Areas, and portions of the SF) and in the Elephant Trunk access areas (Open and Flex).
2. Derive length-frequency distributions of scallops within the CAII (including the CAII-Ext, CAII Access Areas, and portions of the SF) and the Elephant Trunk (ET-Open and ET-Flex).

The first leg of the 2019 of the RSA HabCam v3 survey took place June 27-July 4th, 2019 and covered approximately 540 nm in the following areas: 1) Closed Area II-Access (CAII-Access), 2) Closed Area II-Extension (CAII-Ext), and 3) portions of the Southern Flank (SF)

The third leg of the 2019 of the RSA HabCam v3 survey took place July 25-30, 2019 and covered approximately 360 nm in the following areas: 1) Elephant Trunk Open Area (ET-Open), and 2) Elephant Trunk Flex Area (ET-Flex)

Biomass estimates

The largest proportions of exploitable biomass, by a considerable amount, were found in the ET-Open and ET-Flex. However, the greatest total biomass was found in the CAII-Access and the SF, even though large proportions of both of these areas were pre-recruit (< 35 mm) and recruit (35-75 mm) scallops.

Scallop size distributions and densities

Scallop densities were highest in CAII-Ext and ET-Flex, and lowest in the SF and ET-Open. Both the ET-Flex and the SF had significant numbers of seed (< 20 mm) scallops, in scattered patches, and pre-recruit (< 35 mm) scallops. However, ET-Open and -Flex both had the largest average size of any of the areas surveyed in these two survey legs. Both areas had a mean shell height > 100 mm, which is a strong contrast to the CAII areas (Access and Ext) and the SF, which all had mean shell heights < 66 mm.

FINAL REPORT

Background

The United States (US) Atlantic sea scallop fishery is one of the most valuable fisheries in the US, with revenues averaging $400-$600 million since 2006 (Smolowitz, 2016). The scallop resource rebounded from a depleted state in the early 1990's due, in part, to management changes implemented to protect the resource in certain areas until scallops achieve marketable size. The primary management methods responsible for this turnaround included a reduction in Days-At-Sea (DAS), limits on crew size, gear modifications, and, perhaps most importantly, the institution of rotationally fished Scallop Access Areas. This last approach also included management provisions to temporarily close newly identified areas with high numbers of small scallops. These measures, coupled with the additional measures set forth in the open access areas aimed at ensuring continued growth and spawning of those populations, have aided in facilitating the current high and relatively stable output of the Atlantic sea scallop fishery (Hart, 2003; NEFSC, 2014).

Rotational management and the opening or closing of certain spatial management areas for harvest, as well as limiting effort in other management areas, is highly dependent on a sound estimation of the resource. Because the resource is spread over a large geographic area, reliance on industry-based surveys has become increasingly important in the face of limited federal resources. Traditional surveys (e.g., dredge-based), while providing critical biological information, have been shown to be potentially limited due to decreased catch efficiency in areas of dense scallop aggregations (NEFSC, 2004; Gedamke, et al. 2005).

Optical surveys are important components to an overall survey strategy and hold several key advantages over traditional dredge surveys. Optical surveys overcome the issue of decreased dredge efficiency which can lead to underestimation of biomass in dense aggregations. Additionally, optical surveys are able to characterize the spatial scale of areas containing seed and very small scallops, which may be missed or only qualitatively noted by dredge surveys due to size selectivity (Rudders, 2015). Optical surveys can also cover large swept areas in a relatively short time frame, allowing for detection of fine-scale distribution changes. The images and metadata collected during optical surveys also hold ancillary information such as species interactions, distribution of additional flora and fauna, temperature, salinity, and substrate type.

SAMS areas in the CAII, SF, and ET areas are abundant fishing grounds and critical to the longevity and prosperity of the sea scallop fishery. The CAII and SF are scallop rich areas that are also crucial for supporting scallop populations around Georges Bank, Southern New England, and the Mid-Atlantic (Chen, et al., 2009; Munroe, et al., 2018). The notable density of pre-recruit (< 35 mm shell height) and recruit (35-75 mm) scallops found in CAII-Access, CAII-Ext, and the SF during surveys in 2019 may have a substantial impact on the future of the resource in eastern Georges Bank. Pre-recruit scallop survival is difficult to predict, but ongoing monitoring of large congregations is important to track growth and potential recruitment to the stock, as well as to inform ongoing management processes.

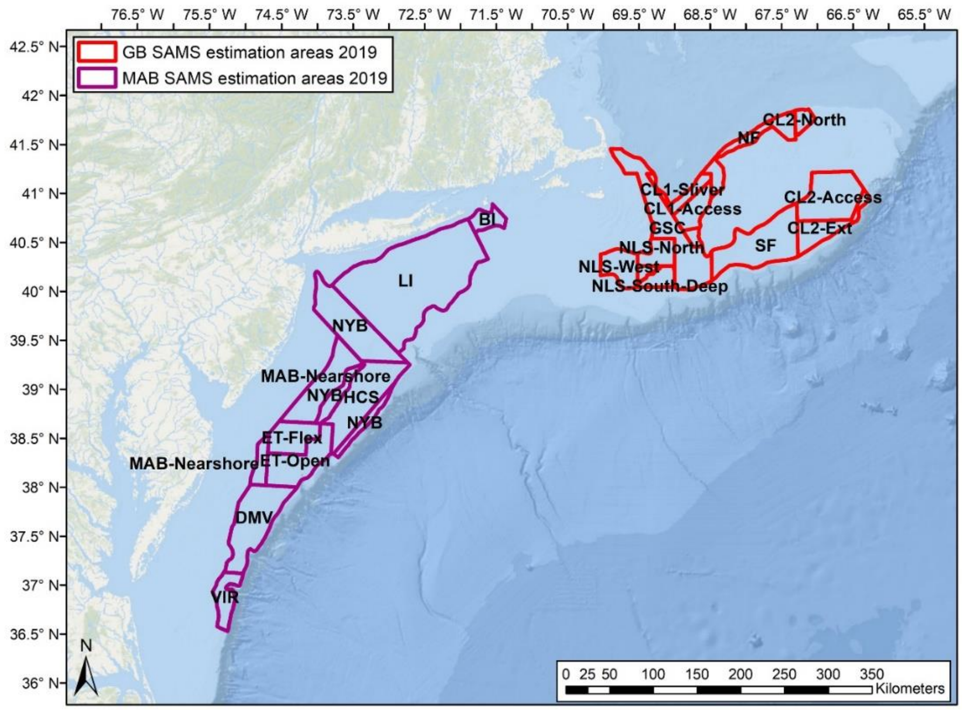

Figure 1. Scallop Area Management Simulator (SAMS) areas for assessing and projecting scallop biomass.

CAII Survey Areas

In 2017, the University of Massachusetts Dartmouth School for Marine Science and Technology (SMAST) conducted a drop camera survey of CAII. Estimated total biomass was 7,361 metric tons (mt) in CAII-Access and 5,153 mt in CAII-Ext, and estimated exploitable biomass was 4,577 in CAII-Access and 1,920 in CAII-Ext. Total biomass estimates from the Northeast Fisheries Science Center (NEFSC) HabCam survey were both higher but comparable to those from the drop camera survey in CAII-Access (8,379 mt) and CAII-Ext (5,354 mt).

The only optical survey in CAII-Access and CAII-Ext in 2018 was conducted by the NEFSC HabCam vehicle. The total biomass estimates in CAII-Access (7,125mt) were reduced from estimates in 2017, while estimates in CAII-Ext (7,956 mt) were substantially higher. Because estimated numbers of scallops in CAII-Ext decreased from 2017 to 2018 (414 million in 2017 to 353.6 million in 2018), this increase in biomass was likely caused by scallop growth.

Mid-Atlantic Survey Areas

In 2015, a very high density of scallops was observed by the NEFSC HabCam in the Elephant Trunk, with estimates as high as 100 scallops/m^2 in several images; a large proportion of these scallops had shell heights of 50-75 mm, suggesting they were 2-year-old scallops (WHOI, 2015). This 2013 year-class was substantial, and optical and dredge surveys continued to monitor it in subsequent years until they could be exploited by the industry. Increases in scallop bycatch (by commercial scallop industry) in 2016 and 2017 was attributed to abundance of this year-class (NEFSC, 2018).

In 2018, several surveys noted the largest MAAA scallop densities were located in the ET-Flex area. VIMS dredge survey noted a growth trend across the MAAA, as measured in mean shell height of scallops.

Project Goals and Objectives

The overarching goal of this survey was to provide data for biomass estimates to the Atlantic Sea Scallop Plan Development Team (PDT) and NEFSC to inform management decisions. The primary objectives of the project were to:

1. Provide scallop count and shell-height measurement data needed to derive biomass estimates of scallops in Scallop Area Management Simulator (SAMS) estimation areas on Georges Bank (including the CAII-Ext, CAII Access Areas, and portions of the SF) and in the Elephant Trunk access areas (Open and Flex).
2. Derive length-frequency distributions of scallops within the CAII (including the CAII-Ext, CAII Access Areas, and portions of the SF) and the Elephant Trunk (ET-Open and ET-Flex).

Methods

The RSA HabCam v3 survey took place on Georges Bank (CAII-Access, CAII-Ext, and SF) from June 26th-July 4th, 2019 and covered approximately 540 nm. Actual cruise tracks were minimally modified from proposed cruise tracks in the CAII and SF. Due to mechanical issues with the RSA HabCam winch, coupled with high sea state, we decided to raise the HabCam vehicle up from survey altitude to approximately 10m while transiting between N-S transects in the Southern Flank. The East-West tracks were aborted in some areas due to this issue, but North-South track lines remained the same (**Figure 2**). The CAII / SF survey collected roughly 2.5 million stereo image pairs, of which 9,735 were annotated, yielding an annotation rate of approximately 1:250 images.

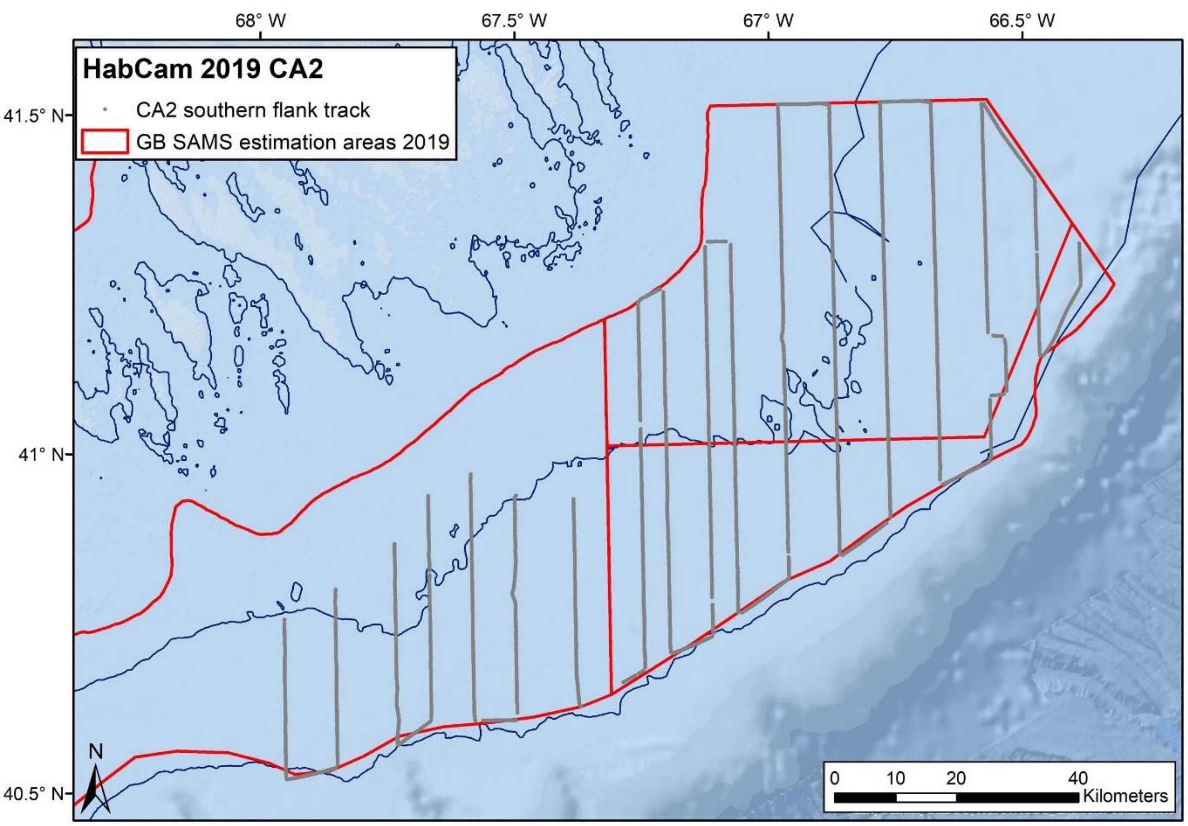

Figure 2. CFF RSA HabCam v3 survey track of CAII areas. Surveyed Areas included the CAII-Access Areas, CAII-Extension, and portions of the SF.

The third leg of the 2019 survey took place in the Elephant Trunk (ET-Open and ET-Flex) from July 25-30, 2019 in the ET (**Figure 3**). The ET survey covered approximately 360 nautical miles, during which we collected roughly 1.5 million stereo image pairs, of which 3751 were annotated, yielding an annotation rate of approximately 1:400 images.

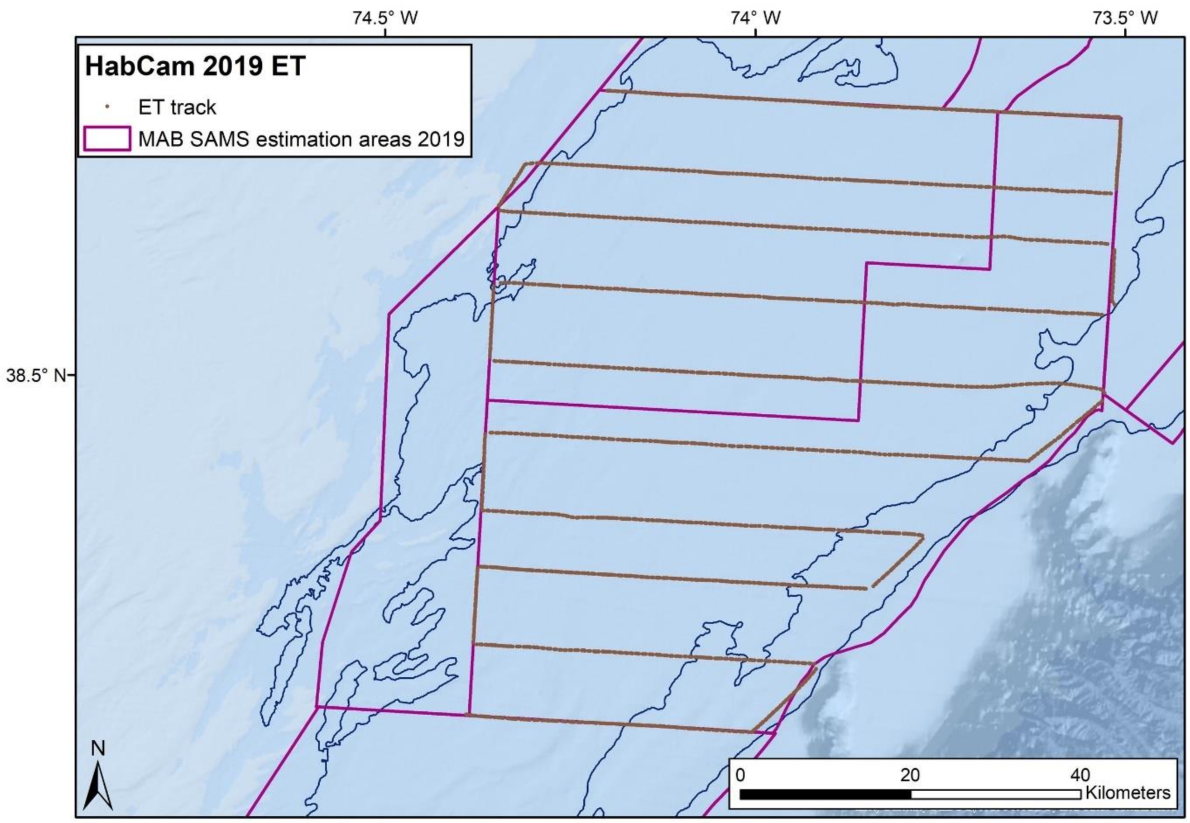

Figure 3. 2019 CFF RSA HabCam v3 survey tracks in the ET.

The HabCam v3 optical imaging system was "flown" 1.5 to 2.5 meters off the seafloor while being towed at 4-5 knots. Raw image stereo pairs were captured and saved as 12-bit high dynamic range TIF files to a Synology Network Attached Storage system. The TIF files also contained the metadata associated with a particular image (e.g., date, time, latitude, longitude, temperature, conductivity, speed, vessel sounder depth, and heading). After collection, copies of the left hand raw TIF files were processed into 8-bit JPG image files, which were used for annotation.

Images were annotated using the MATLAB® Manual Identification Program (MIP). Scallops were counted and measured, while fish, sea stars, and other organisms of interest were counted. Scallop shell heights were measured when the hinge was visible – if this was not possible, scallop shell width was used in lieu of height. Annotation data was recorded into dat files that could be merged with the image metadata files containing the HabCam v3 sensor measurements.

All annotated images were reviewed for quality control prior to final data being sent to the NEFSC for biomass modeling. Quality control (QC) was performed on a minimum of 25% of the annotated images (QC rate was increased in areas of high scallop density), although most surveys achieved 50-100% QA/QC rate for annotations.

Data files containing raw annotation data and image metadata were supplied to NEFSC Population Dynamic Branch staff for biomass modeling. The resulting image-based annotation data was also plotted for scallop size distributions (numbers of scallops per image) and scallop length-frequency distributions by SAMS area.

Biomass estimates

Scallop lengths were initially recorded in pixels and were subsequently converted into shell heights based on the image field of view (FOV) and camera altitude. Each shell height (SH) measured from the HabCam images was converted to a meat weight (MW) in grams using published location-specific SH-MW equations that include depth as a covariate (e.g., Hennen and Hart 2012).

To estimate biomass, the NEFSC used a combination of a hurdle generalized additive model (GAM) and ordinary kriging (Chang et al. 2017). The hurdle GAM (quasi-binomial distribution for the presence/absence model and quasi-Poisson distribution for the positive model) was used to estimate the large-scale trends in biomass with respect to latitude, longitude, and depth. Kriging on the model residuals was used to improve estimates over smaller scales.

Results and Discussion

Biomass estimates

The largest proportion of exploitable biomass, by a considerable amount, was found in the ET-Open and ET-Flex (**Table 1, Figures 4 & 5**). In both areas, the exploitable biomass in numbers of scallops and in metric tons (MW) was 2-3 times higher than all CAII and SF areas surveyed. However, the greatest total biomass by numbers of scallops was found in CAII-Access and the SF (**Table 1**). Total biomass derived from combined Northeast Fisheries Science Center (NEFSC) and CFF HabCam surveys in CA2-Access was 11,710 mt, which is a substantial increase from 2018 (combined survey) estimates (8,000 mt). However, the estimated total biomass in CA2-Ext decreased from 7,593 mt in 2018 to 6,714 mt in 2019 (NEFMC 2020). This decrease is likely due in part to moderate fishing pressure. Estimated total biomass using data from combined NEFSC and CFF HabCam surveys in the ET-Open (17,215 mt) and ET-Flex (24,357) represented modest increases from 2018 (16,531 mt and 22,752 mt, respectively, NEFMC, 2020).

Table 1: Exploitable and Total Biomass (metric tons) and average size (mm shell height) calculations from the 2019 HabCam surveys (CFF and NEFSC combined) in CAII and ET SAMS areas.

	Exploitable Biomass				Total Biomass						
SAMS Area	**Number (million)**	**Metric Tons**	**SE**	**Mean Weight (g)**	**Number (million)**	**Metric Tons**	**SE**	**Mean Weight (g)**	**Average Size (mm)**	**Density (#/m²)**	**Images Annotated**
CAII-Access	200.2	7320.7	222.6	36.6	1035	11710	356	11.3	64.1	0.31	4526
CAII-Ext	151.5	4100.5	71.5	27.1	653	6714	117	10.3	62	0.4	2141
SF	140.2	4256.4	94.1	30.4	1074	8514	188	7.9	65	0.25	8634
ET-Open	545.3	15596.5	207	28.6	634	17215	229	27.1	109.3	0.23	5189
ET-Flex	680.9	22029.9	413.8	32.4	778	24357	457	31.3	113.8	0.43	3974

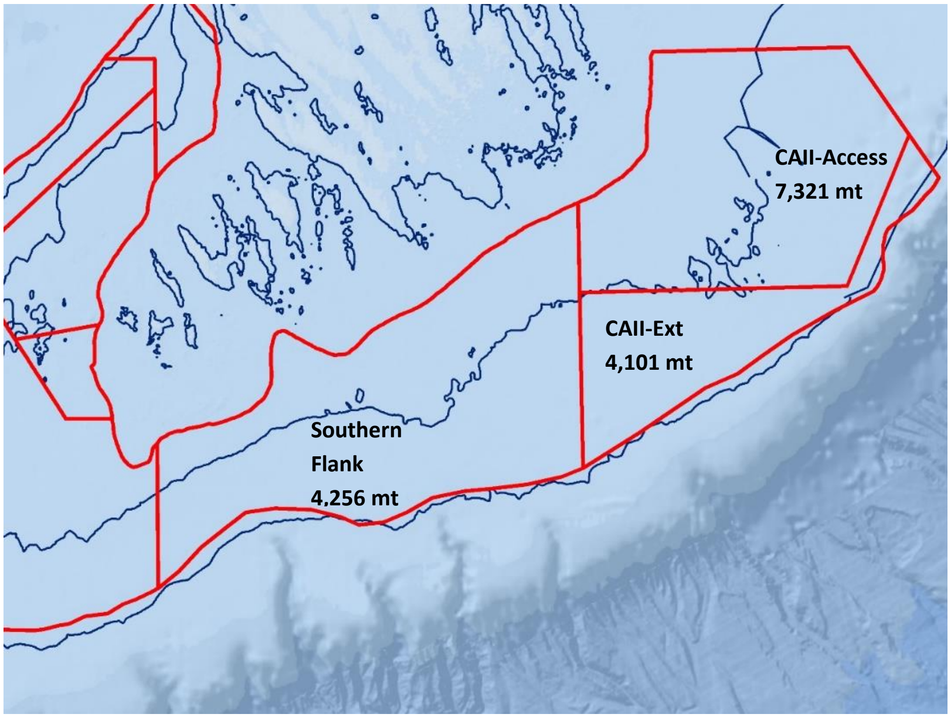

Figure 4. Exploitable biomass by CAII SAMS area derived from 2019 RSA HabCam data. SARC 65 SH-MW equations used for CAII / SF, and ET.

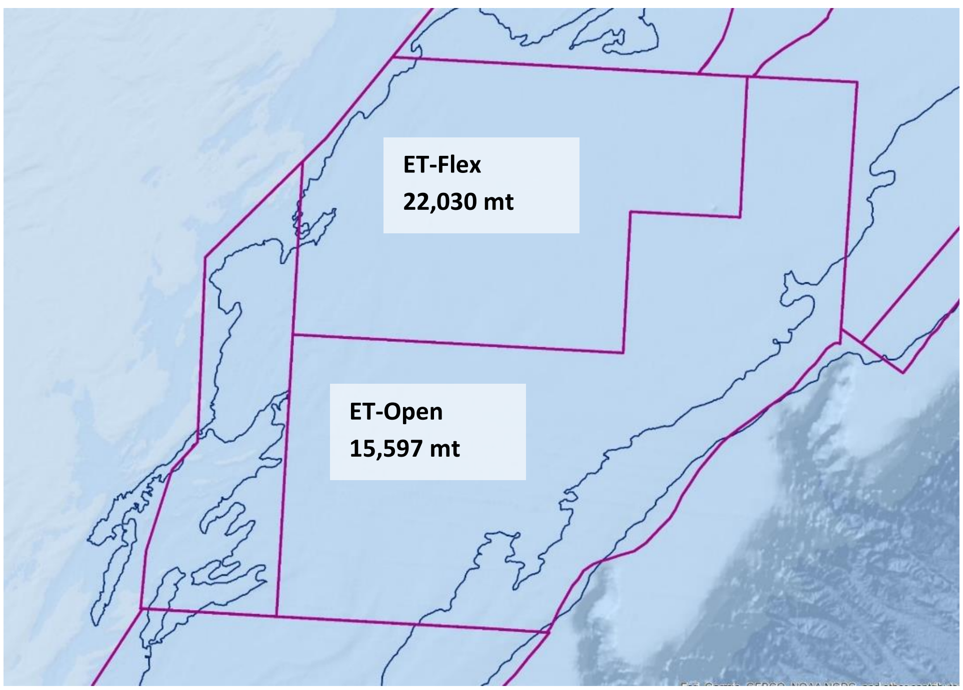

Figure 5. Exploitable biomass by SAMS area in ET derived from 2019 RSA and NEFSC HabCam data. SARC 65 SH-MW equations used for CAII / SF, and ET.

Size distributions and densities

Scallop densities were highest in CAII-Ext and ET-Flex, and lowest in the SF and ET-Open (**Table 1**). Both the ET-Flex and the SF had large numbers of seed (< 20 mm) scallops (**Figure**

7, A; Figure 6, A, respectively) and pre-recruit (< 35 mm) scallops (**Figure 7, B**; **Figure 6, B**, respectively). The CAII/SF areas had a robust distribution of scallops from seed (< 20 mm), pre-recruit (> 35 mm), recruit (35-75 mm), and exploitable (> 75 mm) scallops (**Figure 6**). Despite this, it is worth noting that the most southern survey track boundary (southern boundary of the CAII-Ext and SF) and the north western portion of CAII-Access were sparsely populated.

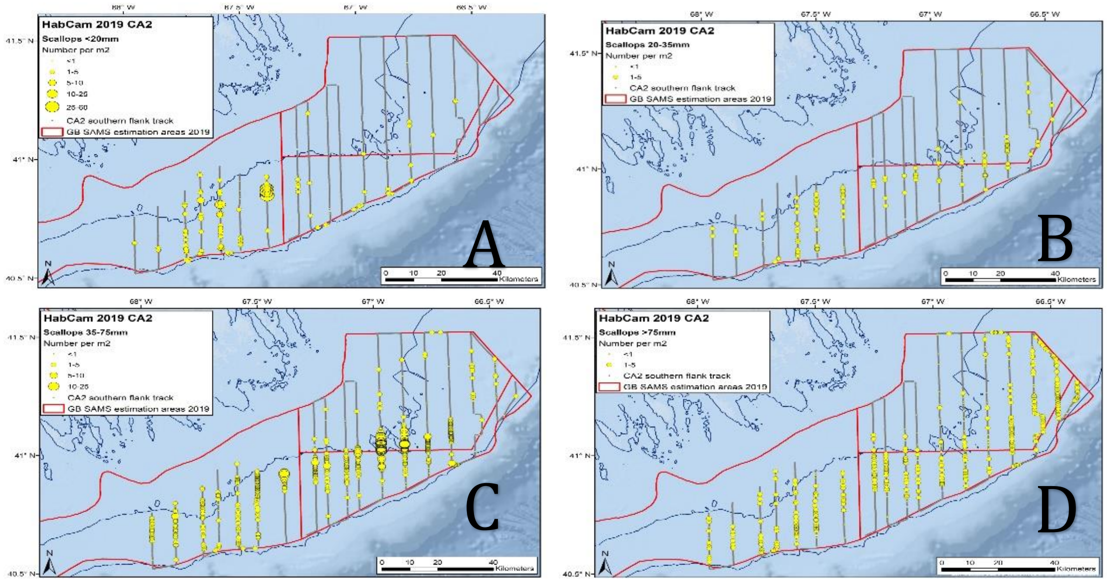

Figure 6. Distributions of measured scallops in size classes from (A) < 20 mm (B) 35-75 mm, (C) 75-100 mm, and (D) 100-190 mm from the 2019 RSA HabCam survey in the CAII/SF.

A large number of pre-recruit (> 35 mm) and recruit (35-75 mm) scallops (**Figure 7, B&C**) were found in various portions of the Elephant Trunk. A notable abundance of pre-recruit and seed (< 20 mm) scallops were observed in the northern edges of the ET, just south of the Hudson Canyon Access area (**Figure 7, A**). Additionally, a "hot spot" area of high exploitable biomass was observed by CFF and NEFSC HabCam surveys and VIMS dredge survey in the central portion of the ET. **Figure 7D** shows exploitable scallop distributions within the ET-Open and ET-Flex areas.

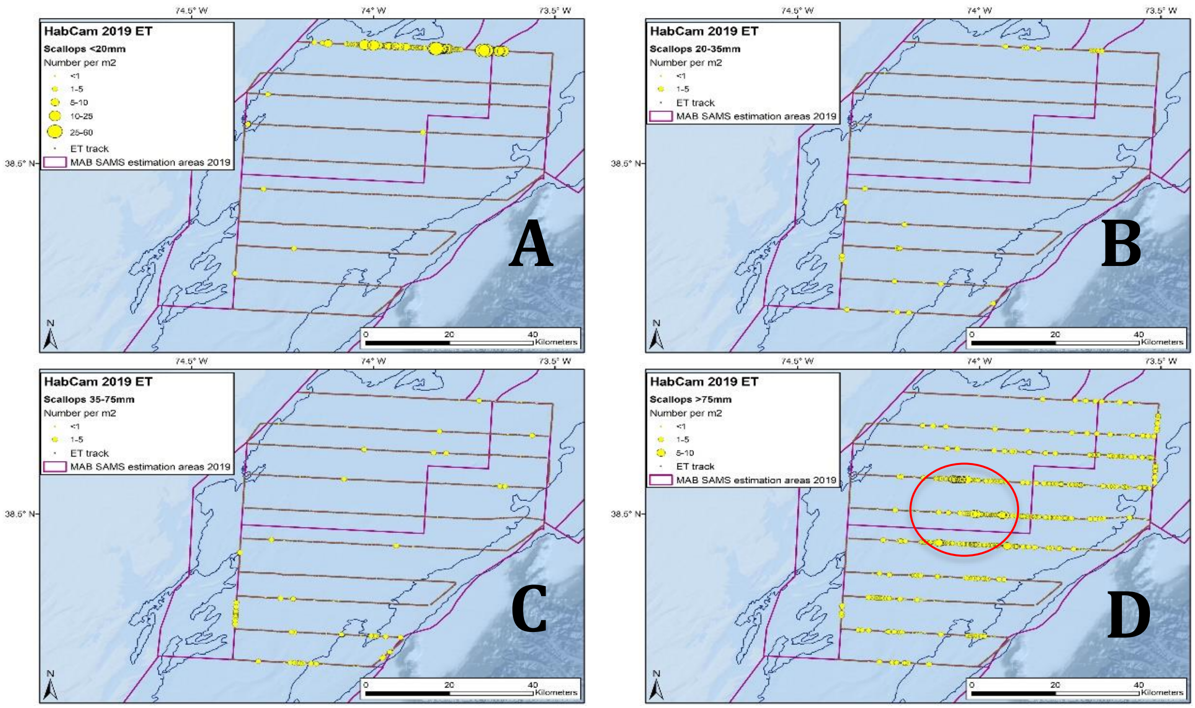

Figure 7. Distributions of measured scallops in size classes from (A) < 20 mm, (B) <35mm, (C) 35-75 mm, and (D) >75 mm from the 2019 RSA HabCam survey in the ET. The red circle in D includes the high biomass hotspot of exploitable biomass found by the HabCam surveys.

Length-frequency distributions

The mean shell heights throughout the surveyed portions of Georges Banks (SF, CALL-Access, CAII-Ext) were relatively similar to each other. The CAII-Access and CAII-Ext had high proportions of recruit scallops, and a mean scallop height of 64.5 and 62 mm, respectively (**Figure 8, A-B**). The Southern Flank had a large proportion of relatively small scallops and a mean scallop height of 65 mm (**Figure 8, D**); additionally, it also had a substantial quantity of seed (< 20 mm) scallops (**Figure 8, C&D**). Scallops under 20 mm were not taken into account when calculating shell height means due to the inherent difficulties with accurately measuring such small objects. For this reason, results in **Figure 8C** are not used.

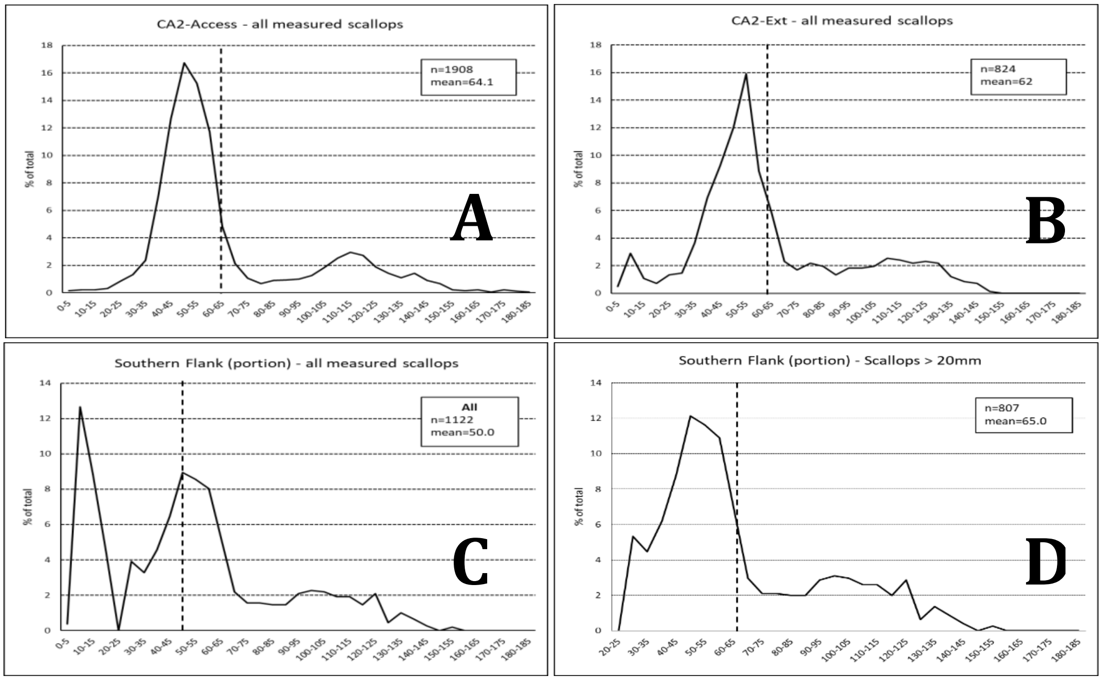

Figure 8. Length-frequency plots of measured scallops in HabCam images from the CAII/SF SAMS areas – (A) CAII-Access, (B) CAII-Ext, (C) Southern Flank, and (D) SF-only scallops > 20 mm in 2019. Dashed line represents the mean scallop size in each survey area; n=total number of scallops counted. Only in the SF were the quantity of seed scallops substantial. C and D show the mean shell height and animal number both including and excluding the < 20 mm seed scallops.

The ET-Open and ET-Flex both had the largest average size of any of the areas surveyed during this project. Both areas had a mean shell height ~100 mm (**Figure 9**), which is a strong contrast to the CAII areas (Access and Ext) and the SF, which all had mean shell heights < 66 mm (**Figure 8**). The ET-Open had a mean shell height of 109.3 mm (**Figure 9, D**) and the ET-Flex had a mean shell height of 113.8 mm (**Figure 9, B**). All measured scallops < 20 mm were disregarded in calculated shell height means due to issues with difficulties in measuring in objects so small; for this reason, only the results in **Figure 9, B&D** are used.

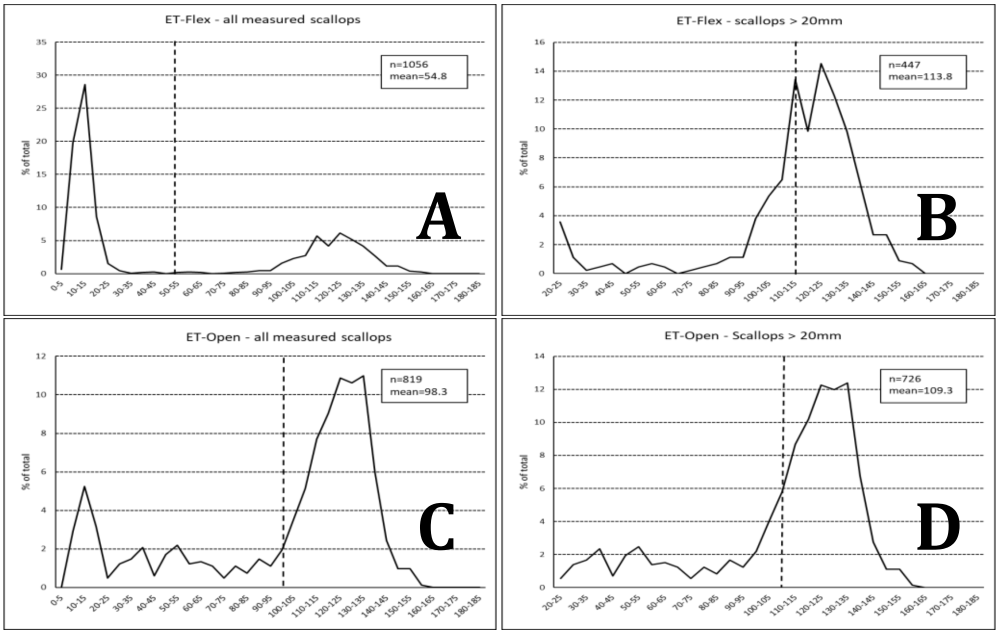

Figure 9. Length-frequency plots of measured scallops in HabCam images from the ET SAMS areas – (A) ET-Flex-all scallops, (B) ET-Flex-only scallops > 20 mm, (C) ET-Open, and (D) ET-Open only scallops > 20 mm in 2019. Dashed line represents the mean scallop size in each survey year; n=total number of scallops counted.

Accomplishments by objective

Objective 1: Provide biomass estimates and size distribution of scallops in Scallop Area Management Simulator (SAMS) areas within the CAII (including the CAII-Ext, CAII Access Areas, and portions of the SF) and the Elephant Trunk (Open and Flex).

We were able to provide timely estimates of biomass and scallop size distributions for SAMS areas on Georges Bank (including the CAII-Ext, CAII Access Areas, and portions of the SF) and the ET-Open and ET-Flex areas. Biomass estimates and size distributions (length-frequency and spatial distribution) for these areas were presented to the Atlantic Sea Scallop PDT in August 2019.

Objective 2: Derive length-frequency distributions of scallops within the CAII (including the CAII-Ext, CAII Access Areas, and portions of the SF) and the Elephant Trunk (Open and Flex).

We were able to derive SAMS area-specific length-frequency distributions within each area and report these findings at the August 2019 PDT meeting.

Future research recommendations

The RSA program has supported overlapping optical surveys in the various SAMS areas which presents a unique opportunity to compare results using alternative sampling designs and biomass modeling methods between the two groups (i.e., SMAST and CFF). While much effort has gone towards comparisons of dredge-survey to optical-survey methods, less emphasis has been placed on comparing the RSA-funded optical surveys to each other, particularly regarding different biomass modeling methods used. Financial support for such an exercise is recommended and would be necessary to carry out such a task. Additionally, streamlining biomass estimates to ensure that all survey groups are using the same methods and rigorous standards (SARC vs VIMS values or size minimums for total estimates) would allow for a better comparison of survey estimates overall.

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