An optical assessment of sea scallop abundance and distribution in select areas of the Mid-Atlantic: Block Island Sound, Long Island Sound, New York Bight, Mid-Atlantic Bight Nearshore, and Delmarva

Final Report

2021 Sea Scallop Research Set-Aside (RSA) Program
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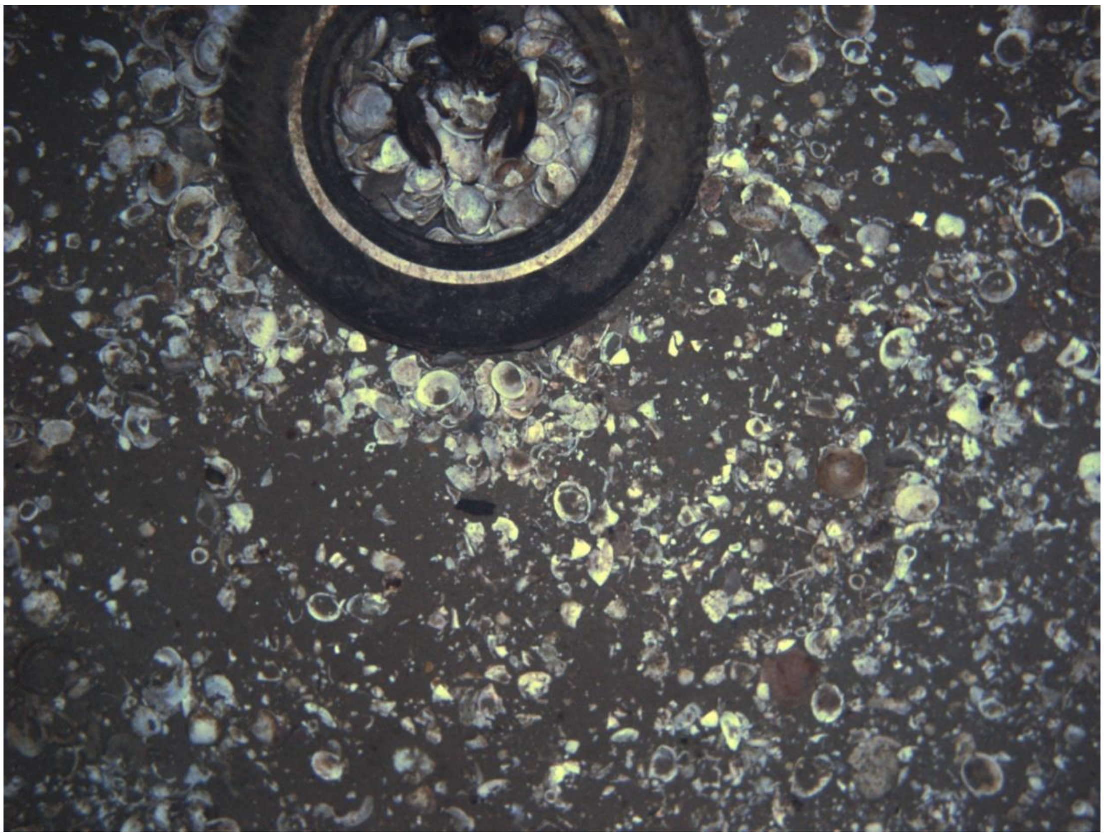

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Table of Contents

List of acronyms and terms

BI	Block Island scallop management area
CFF	Coonamessett Farm Foundation, Inc.
DAS	Days at Sea
DMV	Delmarva scallop management area
FOV	Field Of View
GUI	Graphical User Interface
HabCam	Habitat Mapping Camera
HCAA	Hudson Canyon Access Area
JPG	Joint Photographic Experts Group image file
LI	Long Island scallop management area
MAB-Nearshore	Mid-Atlantic Bight Nearshore scallop management area
m	meters
mm	millimeter
MT	Metric Tons
NEFMC	New England Fishery Management Council
NEFSC	Northeast Fisheries Science Center
NOAA	National Oceanic and Atmospheric Administration
nm	nautical mile
NYB	New York Bight scallop management area
QA/QC	Quality Assurance/Quality Control
PDT	NEFMC Plan Development Team(s)
RSA	NEMFC/NEFSC Research Set Aside Program
SAMS	Scallop Area Management Simulator (model) areas
SH	Shell Height
SNE	Southern New England
SSWG	Scallop Survey Working Group
TIFF	Tag Image File Format image file
US	United States
VIA	Visual Geometry Group Image Annotatot
VIMS	Virginia Institute of Marine Science, College of William and Mary
VMS	Vessel Monitoring System
WHOI	Woods Hole Oceanographic Institution

EXECUTIVE SUMMARY

The CFF 2021 Sea Scallop RSA project entitled *"**An optical assessment of sea scallop abundance and distribution in select areas of the Mid-Atlantic: Block Island Sound, Long Island Sound, New York Bight, Mid-Atlantic Bight Nearshore, and Delmarva**"* was designed to provide critical survey-based information to help inform scallop fishery management efforts. The primary objectives of this project were to:

1. Provide photographic imagery from proposed optical transects in the survey areas
2. Create GIS-based plots of scallop distribution and density by size and length-frequency distributions of scallops within the survey areas
3. Calculate overall biomass (total and exploitable) within each SAMS area surveyed.

The 2021 of the RSA HabCam v3 survey took place over two trips. Leg 2 took place between June 29th-July 8th, 2021, and covered approximately 807 nm in the following areas: DMV and the MAB-Nearshore. Other areas were covered in this leg that are not covered in this report. Leg 3 took place from July 13th-19th, 2021. Approximately 621 nm were covered in the BI, LI, and NYB scallop management areas

Biomass estimates

The highest estimates for scallop biomass and abundance (both total and exploitable biomass and numbers) were observed in LI, just as in previous years. Exploitable biomass exceeded 11,000 MT in this area. DMV has shown depleting numbers over the past several years and CFF found that DMV had the lowest total and exploitable biomass of all areas surveyed in the Mid-Atlantic, with both estimates below 100 MT.

Scallop size distributions and densities

Pre-recruit scallops (< 35 mm) were found in patchy distributions in the most southern portion of NYB, south of the 40-degree latitude line. Large adult scallops (>75 mm) were found throughout the tracks, with DMV exhibiting the lowest numbers. Recruit scallops (35-75 mm) were most prevalent in southern LI and NYB, which had notable pre-recruit scallops (< 35 mm) in 2020 (also surveyed by CFF in 2020 under NA20NMF4540030).

FINAL REPORT

Background

The 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 achieved marketable size. The primary management methods responsible for this turnaround included a reduction in 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. Thus, each image captured during an optical survey is essentially a complete environmental snapshot of a specific space in time.

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 were attributed to abundance of this year-class (NEFSC 2018). Southern scallop management areas in the Mid-Atlantic have experienced biomass declines over the past few years. While there has been evidence of small hotspots for recruitment in recent years, large recruitment events have not been observed since the early-mid 2010s.

In recent surveys in 2020 and 2021, hotspots for juveniles were observed in LI and NYB, with the southern portion of NYB identified as a potential source/sink area for scallops in 2021. In response to this, discussions were prompted within RSA-funded survey groups and the Scallop PDT to close an area encompassing the southern area of NYB and the northernmost area of Hudson Canyon in the Mid-Atlantic. This area will be continued to be monitored by groups in subsequent years, which is expected to yield critical information for fisheries management.

Project Goals and Objectives

The overarching goal of this survey was to provide data for biomass estimates to the Scallop PDT and the NEFSC to inform management decisions. The primary objectives of the project were to:

1. Provide photographic imagery from proposed optical transects in the survey areas
2. Create GIS-based plots of scallop distribution and density by size and length-frequency distributions of scallops within the survey areas
3. Calculate overall biomass (total and exploitable) within each SAMS area surveyed.

Methods

The RSA HabCam v3 survey took place in the SNE and Mid-Atlantic areas of BI, LI, NYB, DMV, and the MAB-Nearshore (**Figure 1**). Since these areas were all adjacent to areas surveyed under NA20NMF4540030, the areas were surveyed under two legs. Leg 2 of the 2021 season took place from June 29th-July 8th, 2021. Approximately 807 nm were covered in DMV, Elephant Trunk open and Flex, Hudson Canyon South, MAB-Nearshore, and the southern portion of NYB. During this leg, CFF collected roughly 6.3 million stereo image pairs, of which 7,892 were annotated. Leg 3 of the 2021 season took place from July 13th-19th, 2021. Approximately 621 nm were covered in the BI, LI, and NYB scallop management areas. CFF collected roughly 4.4 million stereo images and 5,507 were annotated.

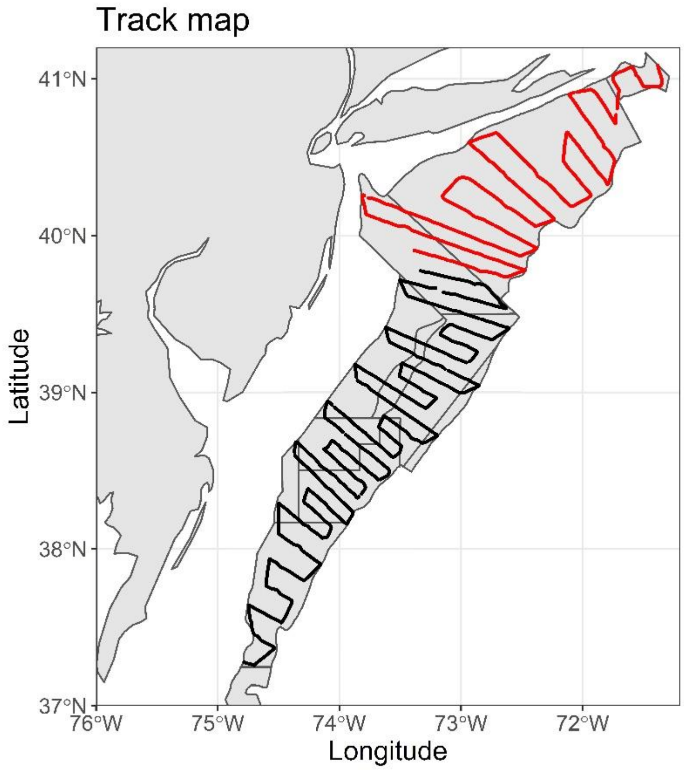

Figure 1*: Map of Leg 2 (black line) and 3 (red line) track lines. Since the area covered in this grant was adjacent to previously funded areas, tracks were extended to cover both grants during Leg 2.*

The HabCam v3 optical vehicle was "flown" approximately 1.5 to 2.5 meters off the seafloor while being towed at 4.2-5.5 knots. Raw images were captured in stereo pairs 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 raw TIF files were processed into 8-bit JPG image files (left image from the stereo pair), which were used for annotation.

Images were annotated using a modified version of software developed by the Visual Geometry Group at Oxford University for image annotation (Dutta & Zisserman, 2019). The new image annotation GUI has been optimized from VIA Version 3 (available at http://www.robots.ox.ac.uk/~vgg/software/via/) for current data acquisition methods and needs with the addition of sliders for adjusting image contrast and brightness, new zoom features to aid in identification of small objects, and improvements to GUI layout. Scallops were counted and measured, while fish, sea stars, and other organisms of interest were counted (bound by box). Scallop shell heights were measured when the hinge was visible – if this was not possible, scallop shell width was used in lieu of height.

All annotated images were reviewed for quality control prior to final data being sent to the NEFSC for biomass modeling. QA/QC was performed on a minimum of 50% of the annotated images although most surveys achieved 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. Additionally, CFF supplied the NEFSC with all raw TIFF files collected for each day for this survey.

Biomass estimates

Scallop lengths were initially recorded in pixels and were subsequently converted into shell heights in millimeters based on the image FOV. Each 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).

CFF biomass estimates were derived using a stratified mean estimation by depth, with images aggregated over 1000m to 2000m segments to minimize spatial autocorrelation along tracks. For NYB and MAB-Nearshore, the two SAMS areas made up of more than one sub-area, estimates were derived by sub-area, and estimates for the whole SAM area were derived by calculating the sum or area-weighted average of the sub-areas. Total and exploitable biomass estimates were supplied to NEFSC and the Scallop PDT. Raw annotation data were additionally supplied to the NEFSC to generate resource-wide, model-based biomass estimates (Chang et al., 2017), with HabCam v3 data combined with HabCam data from NEFSC surveys.

Maps showing the spatial distribution of scallops, grouped by shell height, as well as other spatial data, were generated using geospatial packages in R. Growth, as a function of shell height, and assessed using length-frequency analysis by SAMS area.

Results and Discussion

Biomass estimates

The highest estimates for scallop biomass and abundance (both total and exploitable biomass and numbers) were observed in LI in 2021 (**Table 1, Figure 1**). This is similar to findings from CFF RSA-funded surveys undertaken in 2020. Compared to the 2020 surveys in NYB and LI, CFF estimates for total biomass in LI increased slightly from 11,469.75 MT to 14,100 MT, while NYB total biomass decreased slightly according to CFF survey estimates from 8,369 MT in 2020 to 6,123.8 MT. DMV has shown depleting numbers over the past several years and had the lowest estimated numbers and biomass of any area surveyed by CFF in the Mid-Atlantic (**Table 1, Figure 2**). Although CFF has not surveyed DMV in previous years, the area is at the southern extent of scallop management areas and had shown notable declines in stocks over the past several years (according to PDT communications and survey results from the previous five years).

Table 1*: Estimated Total and Exploitable Biomass by SAMS area based on the 2021 CFF v3 survey.*

SAMS	*AreaKm2*	*Av.Size*	*MeanWt*	*BmsMT*	*NumMil*	*ExpBmsMT*	*NumExpMil*
NYB	5498.3	90.2	16.6	5932.5	400.2	3546.3	153.2
LI	13132.2	99.5	21.8	14100.0	632.9	11190.3	373.8
BI	759.2	103.8	25.1	813.6	32.9	664.5	20.4
MAB-Nearshore	3636.5	115.9	31.7	899.5	30.0	786.0	21.3
DMV	3867.2	83.6	12.3	211.8	17.5	91.0	4.5

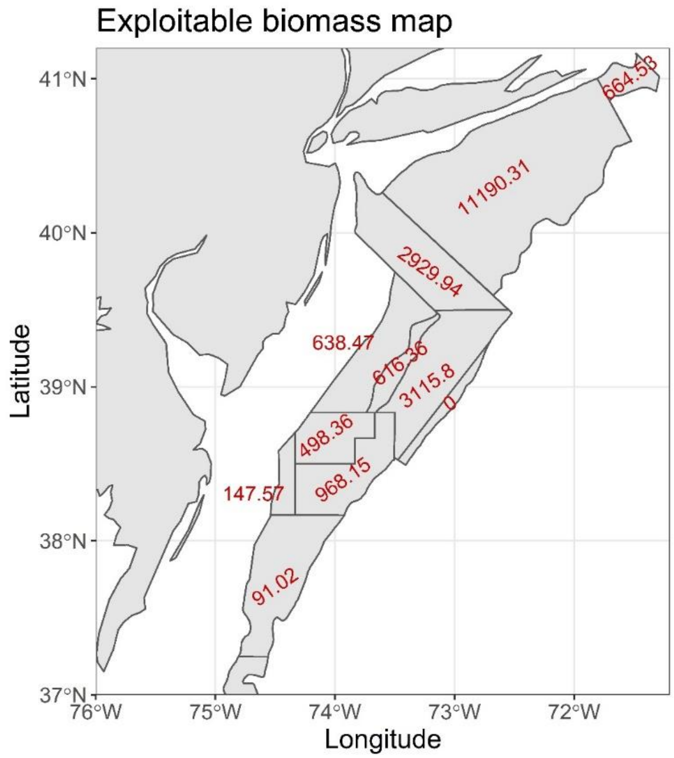

***Figure 2**: Map of exploitable biomass in Mid-Atlantic scallop management areas.*

CFF utilizes an industry-funded sister vehicle to the NEFSC's HabCam v4, and often runs supplementary tracks to those completed by the NEFSC. As the data produced from both vehicles are similar, the NEFSC combines CFF data with HabCam v4 data in their estimates, when deriving their biomass estimates. All scallop RSA-survey groups, including CFF, derive biomass estimates using independent methods which differ from those utilized by the NEFSC. Estimates derived by CFF have only been used as an extra data set for comparison when estimates from the other surveys vary significantly. The NEFSC generally applies a geostatistical model that includes a generalized additive model (GAM), with location and depth covariates to account for large scale trends, coupled with ordinary kriging (OK) of the model residuals to account for smaller scale variability specifically in the surveyed areas (GAM+OK model). When data limitations are an issue, the NEFSC may also use a design-based stratified mean estimation.

As noted in the methods section, CFF biomass estimates were derived using a simple stratified mean estimation method, with strata defined by depth and images aggregated over 1,000-to-2,000-meter segments to minimize spatial autocorrelation along tracks. CFF began testing this method hearing from commercial fisherman that they were weary of estimates derived using geostatistical models due to their complexity. CFF's goal has been to develop a method for deriving biomass estimates from HabCam data that is as concise and easy to replicate as methods used by SMAST and VIMS to derive their biomass estimates. Different methods (geostatistical model vs stratified mean estimation) and geostatistical models using different assumptions or covariates can produce different biomass estimates. Stratified mean estimates are also less accurate when sample coverage is not similar in all of the defined strata. Consequently, differences between the biomass estimates derived by CFF and the NEFSC are not surprising. NEFSC and CFF estimates have been similar overall since we began this effort in 2019, and CFF estimates also align well by scallop management area with other RSA-funded survey results. We plan to continue our efforts to develop an alternative and easily understood method for deriving biomass estimates from HabCam data and will refine our methods as needed.

Size distributions and densities

Pre-recruit scallops (< 35 mm) were found in patchy distributions in the most southern portion of NYB, south of the 40-degree latitude line (**Figure 3A**). This localized abundance of pre-recruit scallops was noted by multiple survey groups, which prompted several discussions regarding management and future surveying needs. Large adult scallops (>75 mm) were found throughout the tracks, with DMV exhibiting the sparsest numbers (**Figure 3C**). Recruit scallops (35-75 mm) were most prevalent in southern LI and NYB (**Figure 3B**), which had notable pre-recruit scallops (< 35 mm) in 2020, suggesting significant recruitment potential.

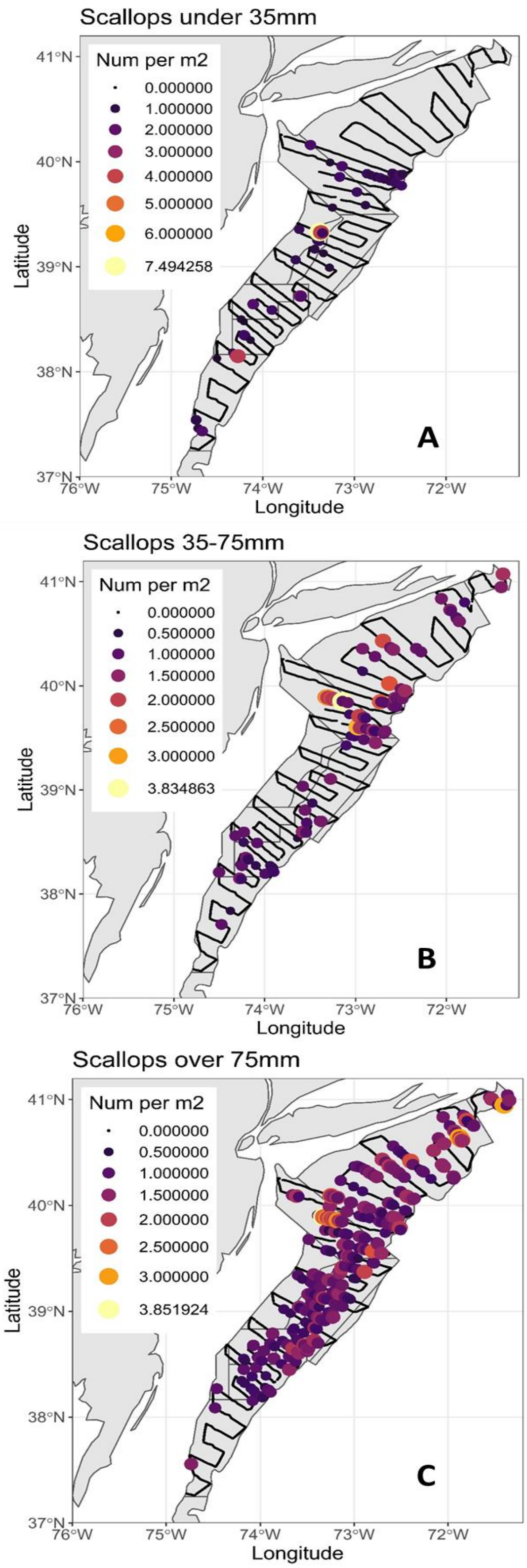

Figure 3*: Density and distribution maps for (A) pre-recruit (< 35 mm), (B) recruit (35-75 mm), and (C) large adult (> 75 mm) scallops in the Mid-Atlantic and BI scallop management areas. These maps show all scallops annotated and sized within all mid-Atlantic SAMS areas surveyed during 2021, including those funded under NA20NMF4540030.*

Length-frequency distributions

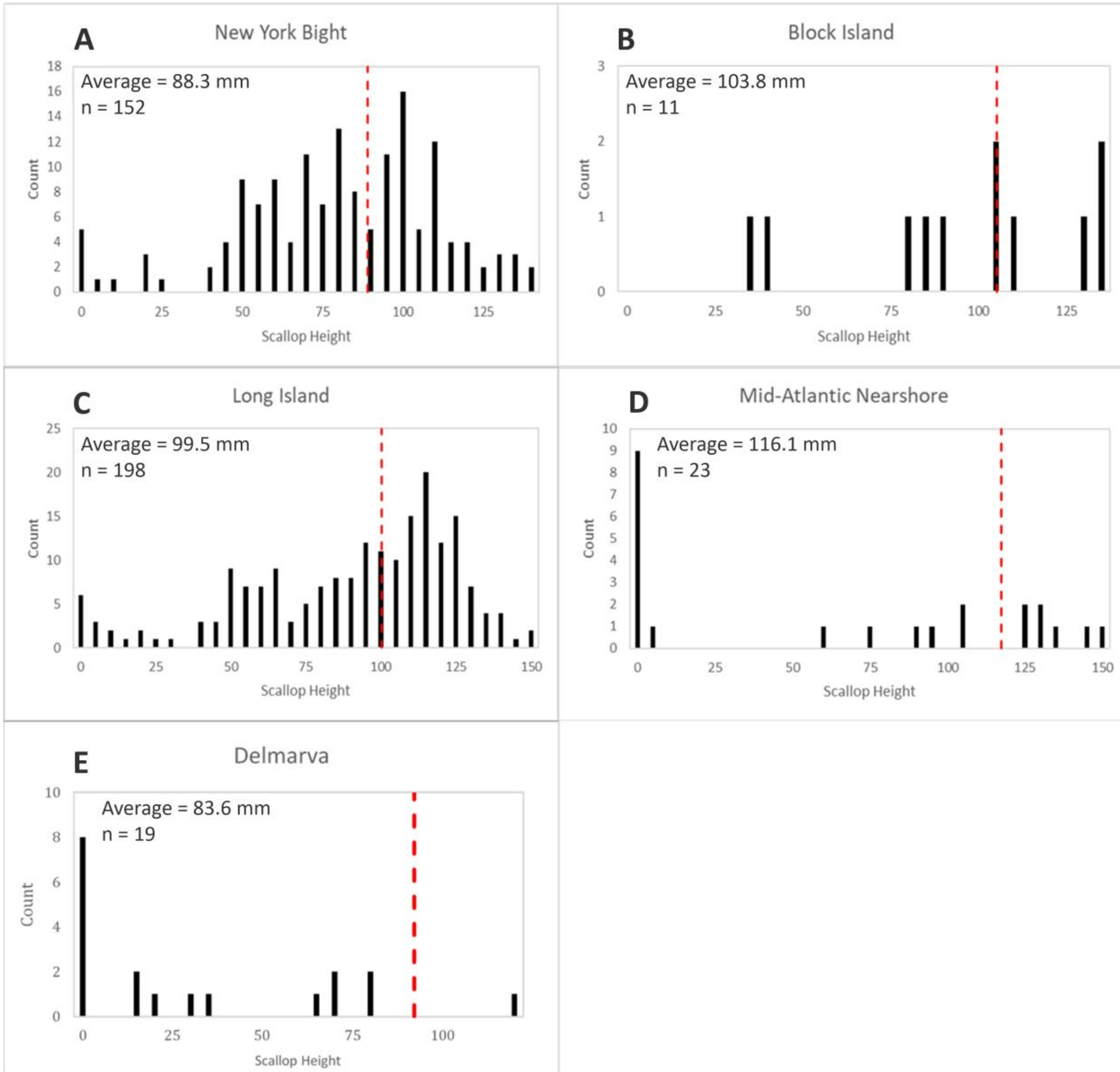

***Figure 4**: Length-frequency plots of measured scallops in HabCam images from the Mid-Atlantic SAMS areas. Only scallops greater than or equal to 40 mm were used in averages, though all lengths are shown on each graph. The red dashed line represents the mean scallop size in each SAMS area.*

All SAMS areas had a large proportion of large adult scallops and an average shell height above 75 mm (**Figure 4**). By and large, observed scallop numbers in the Mid-Atlantic were lower than noted by CFF surveys in 2020, and remarkably low in several SAMS areas, such as BI (**Figure 4B**), DMV (**Figure 4E**), and MAB-Nearshore (**Figure 4D**). While pre-recruit scallops were found in all areas surveyed except BI, areas such as LI (**Figure 4C**), and the NYB (**Figure 4A**) also had a strong proportion of recruit (35-75 mm) scallops. This is significant as CFF observed noteworthy numbers of pre-recruit (< 35 mm) scallops in these areas in 2020.

Accomplishments by objective

Objective 1: Provide photographic imagery from proposed optical transects in the survey areas

CFF collected millions of paired, stereo images throughout the surveyed SAMS areas of BI, LI, NYB, MAB-Nearshore, and DMV (see **Figure 5)** and annotated well over six thousand images for the analysis.

Objective 2: Create GIS-based plots of scallop distribution and density by size and length-frequency distributions of scallops within the survey areas

CFF was able to derive SAMS area-specific length-frequency distributions and provide distribution and density maps for all scallop sizes within each area. These data were presented to the Atlantic Sea Scallop PDT in September of 2021.

Objective 3: Calculate overall biomass (total and exploitable) within each SAMS area surveyed.

CFF was able to derive total and exploitable biomass estimates for each surveyed SAMS area. Biomass estimates for the entire tracks by SAMS area were presented to the Atlantic Sea Scallop PDT in September of 2021.

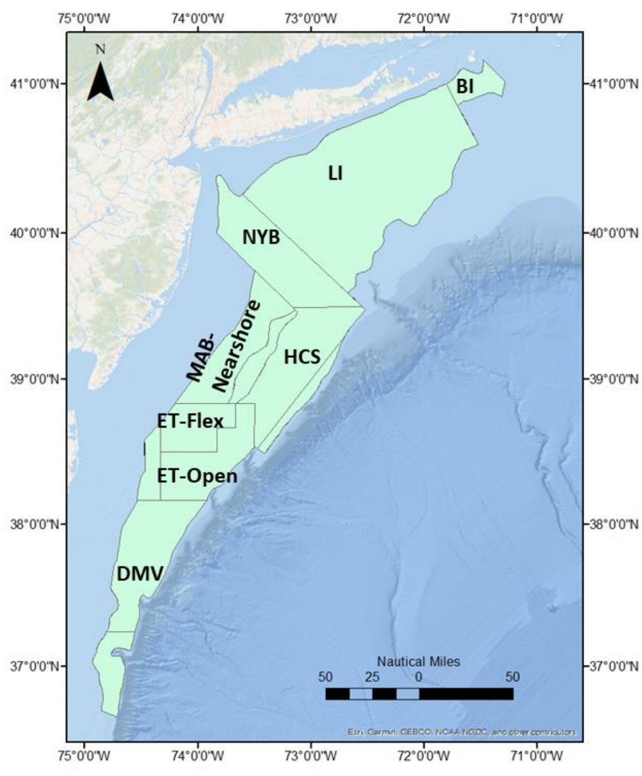

Figure 5*: Map of scallop management areas surveyed by CFF during the 2021 field season.*

Future research recommendations

The range of annotation rates required for accurate estimates of biomass and abundance for scallop assessments have been widely discussed during SSWG, survey, and PDT meetings. It would be beneficial to compare estimates of biomass and abundance by SAMS area using a range of annotation rates since this has not been done recently. Currently, there is not a firm understanding regarding what level of annotations are needed for each SAMS area at current scallop densities to accurately assess the distributions of biomass and abundance using the preferred geostatistical methods or other models for estimation.

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