An optical survey for scallop density, distribution, and growth in open-bottom SAMS areas of the Mid-Atlantic and rotational areas in the NLS and Georges Bank

Final Report

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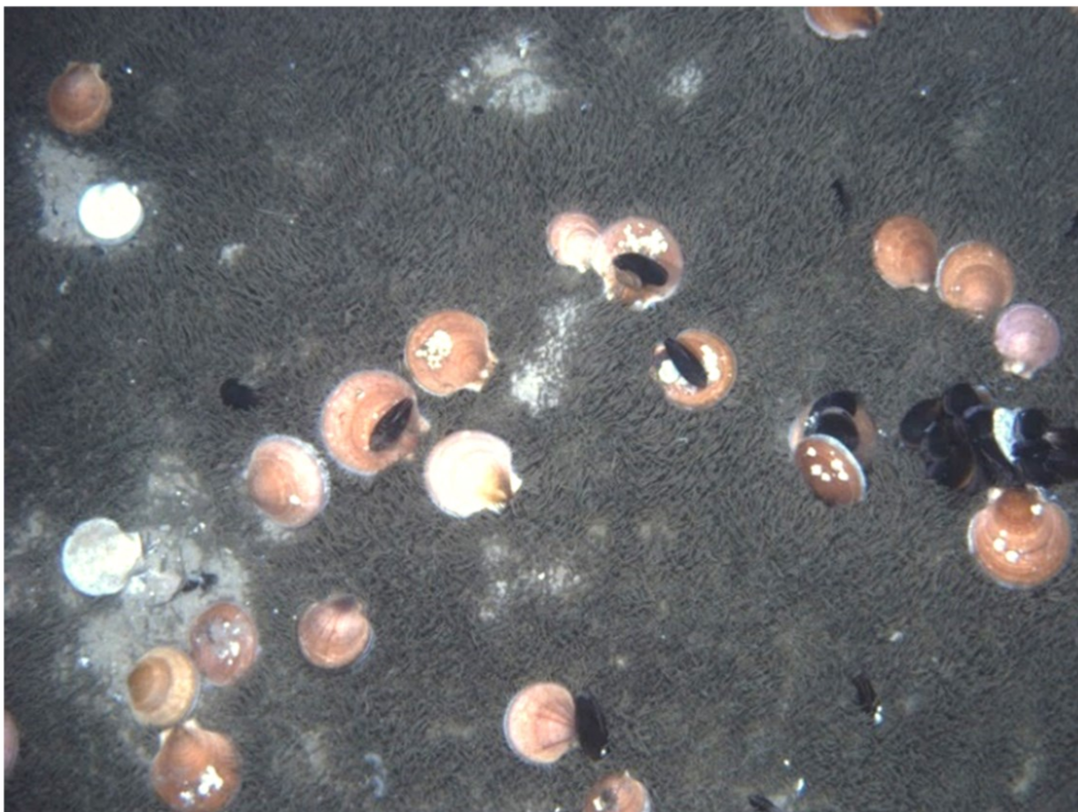

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General Information

Report Title: An optical survey for scallop density, distribution, and growth in open-bottom SAMS areas of the Mid-Atlantic and rotational areas in the NLS and Georges Bank

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Organization: Coonamessett Farm Foundation

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List of acronyms and terms

BI	Block Island SAMS area
CA2	Closed Area 2
CA2-Ext	Closed Area 2 Extension Scallop Access Area
CA2-SE	Closed Area 2 Southeast Scallop Access Area
CA2-SW	Closed Area 2 Southwest Scallop Access Area
CFF	Coonamessett Farm Foundation, Inc.
DAS	Days at Sea
DMV	Delmarva
ET	Elephant Trunk
ET-Flex	Elephant Trunk Flex Scallop Access Area
ET-Open	Elephant Trunk Open Scallop Access Area
FW	Framework Amendment
GIS	Geographic Information System
HCS	Hudson Canyon South Scallop Access Area
JPG	Joint Photographic Experts Group
LI	Long Island
m	Meters
MAB	Mid-Atlantic Bight
mm	Millimeter
mt	Metric Ton
MW	Meat Weight
NEFMC	New England Fishery Management Council
NEFSC	Northeast Fisheries Science Center
NLS	Nantucket Lightship Scallop Access Area
NLS-S	Nantucket Lightship Scallop Access Area South (previously NLS-S-Deep)
nm	Nautical Mile
NMFS	National Marine Fisheries Service or NOAA Fisheries
NYB	New York Bight
PDT	NEFMC Plan Development Team(s)
RSA	NEFMC/NEFSC Research Set Aside Program
SAMS	Scallop Area Management Simulator (model) areas
SH	Shell Height
SF	Southern Flank
SMAST	School for Marine Science and Technology, University of Massachusetts
TIF	Tagged Image Format
VIMS	Virginia Institute of Marine Science
WHOI	Woods Hole Oceanographic Institution

Executive Summary

The primary objective of this project, titled "*An Optical Survey for Scallop Density, Distribution, and Growth in Open-Bottom Areas of the Mid-Atlantic and Rotational Areas in the NLS and Georges Bank*" was to collect data on scallop biomass and distribution within the surveyed regions. In 2023, the Coonamessett Farm Foundation (CFF) was approached on short notice by the Greater Atlantic Regional Fisheries Office to expand the planned survey tracks to include three southern Mid-Atlantic management areas. This adjustment was necessary as the Northeast Fisheries Science Center (NEFSC) was unable to conduct their resource-wide survey that year. Below is an overview of the surveys conducted in 2022 and 2023.

Table 1: Table overview of 2022 and 2023 surveys.

Survey Year	*Coverage (nm)*	*Images Collected (pairs)*	*Annotations*	*Surveyed Areas*
2022	1253	10.6 million	49,000	NLS-S, SF, CA2-Ext, CA2-SE, CA2-SW, BI, LI, NYB, NYB-Close
2023	1600	12.8 million	62,000	NLS-S, SF, CA2-Ext, CA2-SE, CA2-SW, BI, LI, NYB, NYB-Close, HCS, MAB-Near, ET

Products from this project included:

1. Photographic imagery from proposed optical transects in the selected Mid-Atlantic areas and Georges Bank areas, including the Nantucket Lightship South (NLS-S).
2. GIS-based plots of scallop distribution and density by size and length-frequency distributions of scallops within the survey areas.
3. Overall biomass (total and exploitable) within each management area surveyed.

Scallop size distribution, density, and growth

In 2022 and 2023, recruit and large adult scallops were found throughout the Southern Flank (SF) and Closed Area 2 (CA2) Southeast (SE) and Southwest (SW) tracks, while juvenile scallop distributions were less abundant. In the NLS-S, the area was predominately juvenile, newly settled scallops, with some large adult scallops which decreased each year due to significant fishing pressure. Scallops of all sizes were found in patchy distributions throughout the Mid-Atlantic. Mean scallop shell height remained relatively similar in most areas between 2022 and 2023. The largest changes were noted in CA2-SE, NLS-S, Block Island (BI), and Long Island (LI) management areas.

Biomass estimates

Total biomass decreased in most areas surveyed, with the notable exception of the SF that increased by over 1000 MT. NLS biomass continued to decline, as it has since the area opened to fishing in the 2020 fishing season.

Table 2: Total biomass in 2022 (grey/white) and 2023 (blue). Only areas surveyed in both years are included below.

	NumMil		*BmsMT*		*SE*		*MeanWt*		*Avg. Size*		*Density*	
					GB							
CA2-SE	1684.5	778.4	18060.4	14055.1	6929.5	4687.8	13.2	19.2	77.2	91.0	0.65	0.39
CA2-SW	59.8	27.5	1918.3	1038.8	470.0	428.5	31.5	33.8	110.1	111.8	0.09	0.03
CA2-Ext	727.2	412.8	14264.5	8366.1	3977.0	1383.6	18.9	20.3	90.8	92.1	0.5	0.28
NLS-S	173.1	25.5	3625.2	217.0	1572.6	85.0	22.1	9.8	110.2	76.4	0.26	0.04
SF	517.2	623.5	6753.4	7776.2	1422.0	1471.9	12.4	11.6	79.2	78.4	0.14	0.18
					MidAtlantic							
BI	16.5	16.1	455.9	439.4	167.9	324.7	27.7	15.4	108.9	84.1	0.02	0.03
LI	265.7	318.6	6272.0	5226.7	1230.0	1160.5	24.7	17.6	104.9	89.8	0.02	0.03
NYB-Close	401.6	327.6	7575.7	6195.1	1704.8	1394.6	18.9	19.9	98.1	98.5	*	0.06

Contents

1 Purpose

1.1 Description of Problem

The Atlantic sea scallop (*Placopecten magellanicus*) fishery is one of the most valuable fisheries in the United States, with annual ex-vessel revenue averaging $400-$600 million since 2006 (Smolowitz 2016; NMFS 2022). The Atlantic sea scallop resource rebounded dramatically from its depleted state in the early 1990s due to key management changes designed to protect juvenile scallops until they reached marketable size. Critical measures included reduced days-at-sea (DAS), crew size limits, gear modifications, and, most notably, the implementation of rotational Scallop Access Areas. This approach also allowed for temporary closures of areas with high densities of juvenile scallops. Combined with targeted management in open-access areas to support growth and spawning, these strategies have driven the fishery's high and relatively stable productivity (Hart 2003; NEFSC 2014). Rotational management, including the opening and closing of specific spatial management areas for harvest and the regulation of fishing effort in others, relies heavily on accurate resource estimation.

Given the broad geographic distribution of the resource, industry-based surveys have become increasingly vital as federal resources remain constrained. While traditional surveys, such as dredge-based methods, provide essential biological data, they can be limited in their effectiveness, particularly due to reduced catch efficiency in areas with dense scallop aggregations (NEFSC 2004; Gedamke et al. 2005). Optical surveys play a vital role in comprehensive survey strategies, offering several key advantages over traditional dredge surveys. One significant benefit is their ability to address the issue of decreased dredge efficiency, which can result in underestimating biomass in densely aggregated areas. Additionally, optical surveys provide detailed spatial characterization of areas containing seed and very small scallops, which are often missed or only qualitatively noted in 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. Moreover, the images and metadata collected during optical surveys offer valuable ancillary information, including species interactions, the distribution of other 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.

Nantucket Lightship

The Nantucket Lightship (NLS) management area has remained an area of increased interest for researchers, managers, and the commercial industry members over the past decade due to its high scallop settlements and densities. In the summer of 2013, the Northeast Fisheries Science Center (NEFSC) and Virginia Institute of Marine Science (VIMS) survey efforts located areas of high-density juvenile scallop settlement south of the Great South Channel (GSC), extending both east and west along the 30 - 40 fathom edge of the Southern New England shelf (NEFSC 2013). This 2012 scallop year-class settled in the deeper waters south of the GSC and yielded a substantial exploitable biomass. Following this extraordinary settlement event, this area was subsequently closed to scallop fishing in Framework (FW) 26 (NEFMC 2015, O'Keefe 2022). It has since been monitored annually during stock assessment surveys. Despite the dense, overlapping settlement in deeper, colder waters with silty substrates, the year-class persisted over time. However, their average annual growth was notably slower than that of nearby settlements in shallower regions of the NLS. This slow growth earned them the moniker "Peter Pan" scallops, referencing their inability to mature into adults.

CFF provided optical monitoring of the area and in 2017 (**NA17NMF4540035**) and 2018 (**NA18NMF4540021**), noted that the settlement had grown into recruits (35 mm – 75 mm) with no notable settlement of pre-recruit scallops (< 35 mm), but average growth was around 5 mm (Clermont et al. 2019). In 2019, CFF (**NA19NMF4540016**) noted the most significant changes in the stock abundance and biomass from the 2018 survey in the NLS-South (NLS-S) and NLS-West (NLS-W). Pre-recruit scallops were again not found in notable densities anywhere in the NLS. Recruit sized scallops were dense in NLS-S (formerly referred to as NLS-S-Deep). Although measured scallops in NLS-S were still smaller based on shell height (SH) than cohorts in other areas of the NLS, NLS-S scallop SHs increased by an average of approximately 10 mm from 2018-2019. As in 2018, the NLS-S area continued to yield high biomass, with 2019 HabCam derived estimates of over 21,000 mt of exploitable biomass, which increased from the 5,021 mt estimated in 2018 (O'Hara et al. 2020). As these scallops reached exploitable sizes, FW 32 established the area as open to commercial fishing for 2020 (NEFMC 2020; O'Keefe 2022). CFF's 2020 and 2021 surveys (**NA20NMF4540030**) occurred after the NLS-S was opened to fishing. During these years, the biomass in the NLS-S remained higher than all surrounding areas but declined significantly each year due to heavy fishing pressure (O'Hara et al. 2022). Continued monitoring of this dynamic area is key to better understanding and identifying larval settlement events and growth.

Georges Bank and the Southern Flank

CA2 on Georges Bank has long been recognized as one of the most consistent and productive sea scallop management areas, characterized by its strong larval supply, regular recruitment events, and nutrient-rich upwelling, all of which contribute to both robust fisheries and ecosystem sustainability. CA2-Access was open for scallop harvesting in 2017 but closed in 2018 and 2019 (O'Keefe 2022). This caused fishing efforts to shift to the newly opened CA2-Extension (CA2-Ext) and the Southern Flank (SF) areas in 2018, which continued through 2019. CFF has monitored the SF, as well as key subareas of CA2, including CA2-Southeast (SE), Southwest (SW), and Ext annually during the sea scallop stock assessment since 2019.

Results from the 2019 RSA HabCam survey (**NA19NMF4540018**) of southern CA2 (CA2-Access and CA2-Ext) and the SF showed a notable density of pre-recruit and recruit sized scallops, particularly in southern CA2-Access, CA2-Ext, and the eastern portion of the SF. Large scallops around 100+ mm SH were widely distributed in moderate densities (1-5 scallops/m^2) in eastern CA2-Access, and throughout most of the CA2-Ext and SF Scallop Area Management Simulator (model) areas (SAMS). Total biomass derived from RSA HabCam data in CA2-Access was substantially higher than 2018 estimates. However, estimated total biomass in CA2-Ext decreased, likely due in part to moderate fishing pressure (Clermont et al. 2019, O'Hara et al. 2020).

In 2020 and 2021, significant quantities of pre-recruit scallops were observed in CA2-SE and CA2-Ext, with scallops of various sizes noted throughout the SF and CA2 survey tracks. In 2021, CFF identified an area of interest in the northern portion of CA2-SE, characterized by dense bryozoan mats and a high abundance of seed scallops alongside various scallop predators

(O'Hara et al. 2022). Ongoing monitoring of scallop recruitment, growth, and predator density is critical for the effective management of this region.

Mid-Atlantic

Density and distribution dynamics in the Mid-Atlantic management areas, much like those in the NLS, have garnered significant interest among managers, researchers, and the commercial industry over the past decade. However, unlike the relatively stable trends observed in the NLS and southern CA2, the Mid-Atlantic has experienced pronounced "boom-and-bust" cycles in recent years. In 2015, an exceptional number of predominantly 2-year-old scallops (2013 year-class) were observed in the Mid-Atlantic scallop management areas, mainly within the Elephant Trunk (ET) management areas and extending northwards through Long Island (LI) and Block Island (BI) (WHOI 2015). To date, this finding of billions of juvenile scallops remains the most significant settlement in the Mid-Atlantic in recent history, with the previously most significant set having taken place in 2007.

In subsequent years, declining abundance due to heavy fishing and a lack of notable recruitment has impacted the more southern management areas in the Mid-Atlantic, most notably in Virgina and Delmarva (DMV). Optical surveying efforts in the Mid-Atlantic have shifted over the past decade due to various challenges. In Virginia and DMV, survey efforts have diminished in priority due to severely reduced biomass and minimal fishing pressure. Conversely, while survey coverage of northern open-bottom areas was sporadic in the past, recent increased attention has led to more reliable and consistent surveying in these regions.

In 2020, CFF (**NA20NMF4540030**) noted a significant settlement of seed scallops was observed in the Mid-Atlantic, particularly in the southern New York Bight (NYB) and the northern portion of the Hudson Canyon South (HCS) area. By 2021, this region supported high densities of both pre-recruit and recruit scallops (O'Hara et al. 2022, O'Hara et al. 2022a). These findings prompted discussions during the 2021 Sea Scallop Planning and Development Team (PDT) survey meetings about the potential need for a closure to allow the scallops to mature. Ultimately, this led to the establishment of the New York Bight Closure (NYB-Close) area under Scallop FW 34 (NEFMC 2022), designed to protect these dense aggregations and enable them to grow to harvestable size. Further research into source-sink dynamics in the Mid-Atlantic suggested that this closure could also enhance scallop settlement and growth downstream in the HCS and Elephant Trunk (ET) areas (Hart et al. 2020). Continuous monitoring of this area, including juvenile recruitment, survival, and growth are needed to support management decisions and provide information on the efficacy of this closure.

1.2 Project Objectives

This project was designed to provide critical survey-based information to 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.

2 Methods

2.1 Survey Methods

Surveys were conducted in the summer seasons between June and July in both 2022 and 2023. In 2022, CFF collaborated with Arnie's Fisheries, Inc. and the F/V *Kathy Marie* to complete three legs of surveys which covered 1,250 nm of systematic transects in the following areas:

- **Leg 1**: CA2-SE and CA2-SW, CA2-Ext and the SF scallop management areas. The NLS-S scallop management area was also included.
- **Leg 2**: BI, LI, NYB, NYB-Close

Transects in Leg 1 were approximately 4-5 nm distance, though transects in the NLS-S were finer-scale in order to better assess changing dynamics and juvenile settlement growth (**Figure 1**). Transect length for HabCam stock assessment surveys is often variable, as the effort is concentrated along the more densely populated areas. Longer transects are designed to collect information from more sparsely populated scallop areas to assess the extent of settlements.

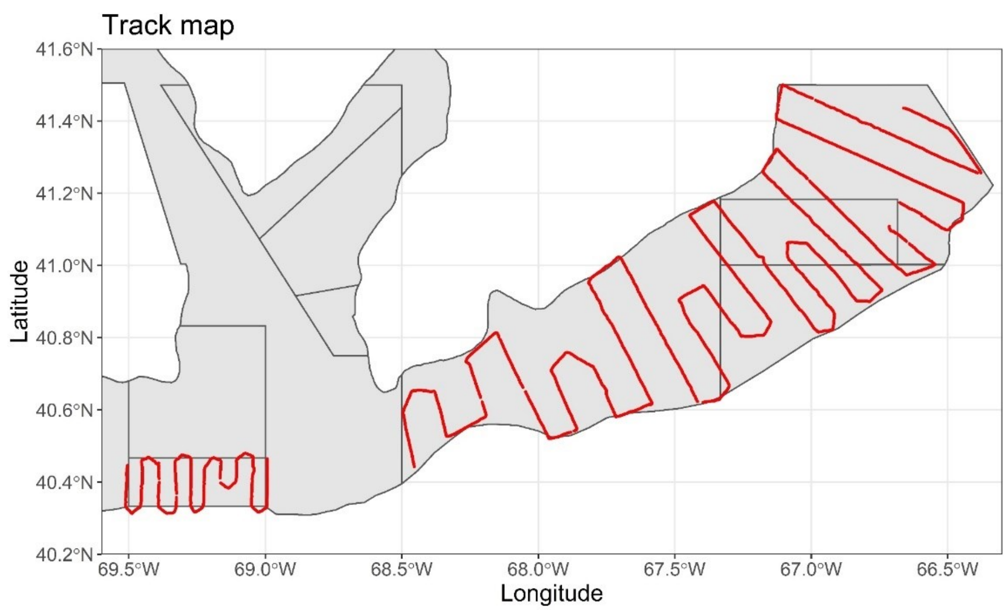

Figure 1: 2022 track in the SF, CA2 south, and NLS-S.

Tracks in the Mid-Atlantic were closest together in the newly implemented NYB closure area to better assess fine-scale changes in growth and density, as the closure was established to monitor growth of newly recruited scallops and evaluate source/sink dynamics in the region. In BI, the track was supplemented with survey data collected within the BI SAMS area by CFF's Orsted survey. CFF received confirmation to include that data as the two surveys occurred within the summer survey season, and the data was utilized in the annual stock assessment (**Figure 2**).

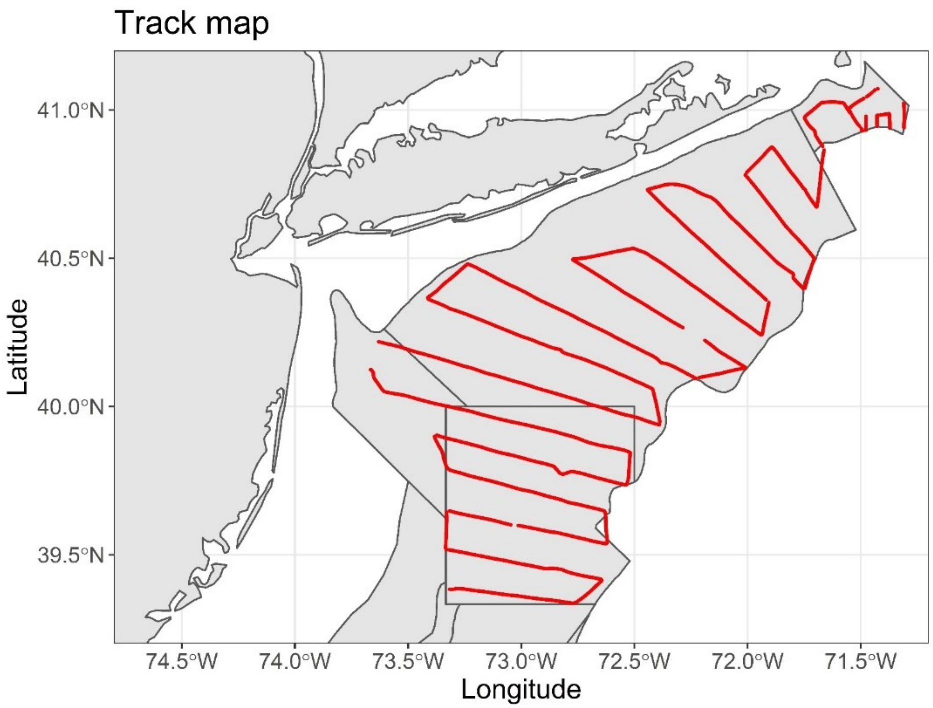

Figure 2: 2022 HabCam v3 track in the Mid-Atlantic, including a short additional track in the BI management area. This additional area covered in the southern portion of the area was included in cooperation with Orsted.

In 2023, CFF collaborated with Arnie's Fisheries, Inc. and the F/V *Kathy Marie* to complete nearly 1,600 nm of systematic transects track in the following areas:

- **Leg 1**: CA2-SE, CA2-SW, CA2-Ext, and the SF scallop management areas. The NLS-S scallop management area was also included.
- **Leg 2**: BI, LI, NYB, NYB-Close, Mid-Atlantic Bight Nearshore (MAB-Near), HCS, and the ET.

The relative spacing of HabCam tracks were kept similar for both years. CFF designed tracks in cooperation with the NEFSC and ensured that areas of interest in the CA2 and NLS-S would be adequately monitored (**Figure 3**).

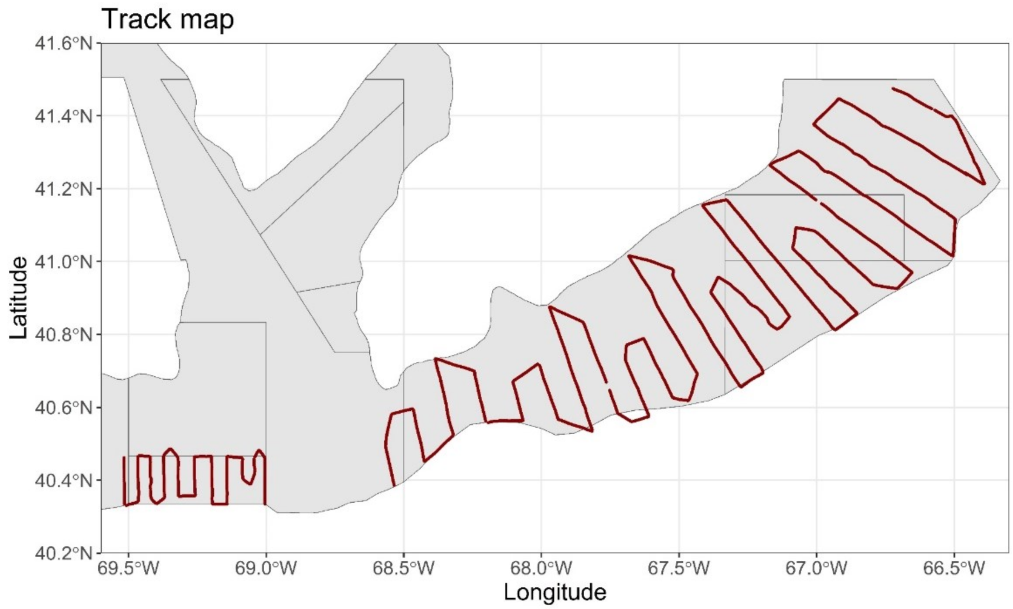

Figure 3: 2023 Tracks in the NLS-S, SF, and CA2 south.

In 2023, CFF was asked on short notice to expand its planned survey to address data gaps resulting from the NEFSC's inability to complete their scheduled survey due to vessel-related issues. Given the timing of the request, adding a third survey leg was not feasible. Instead, the second survey leg was extended by several days, and the southern survey tracks were widened to accommodate the additional coverage. While this modification enabled CFF to collect sufficient data for the assessment, it required increased transect spacing in the southern portion, resulting in lower spatial resolution compared to the more northern tracks (**Figure 4**).

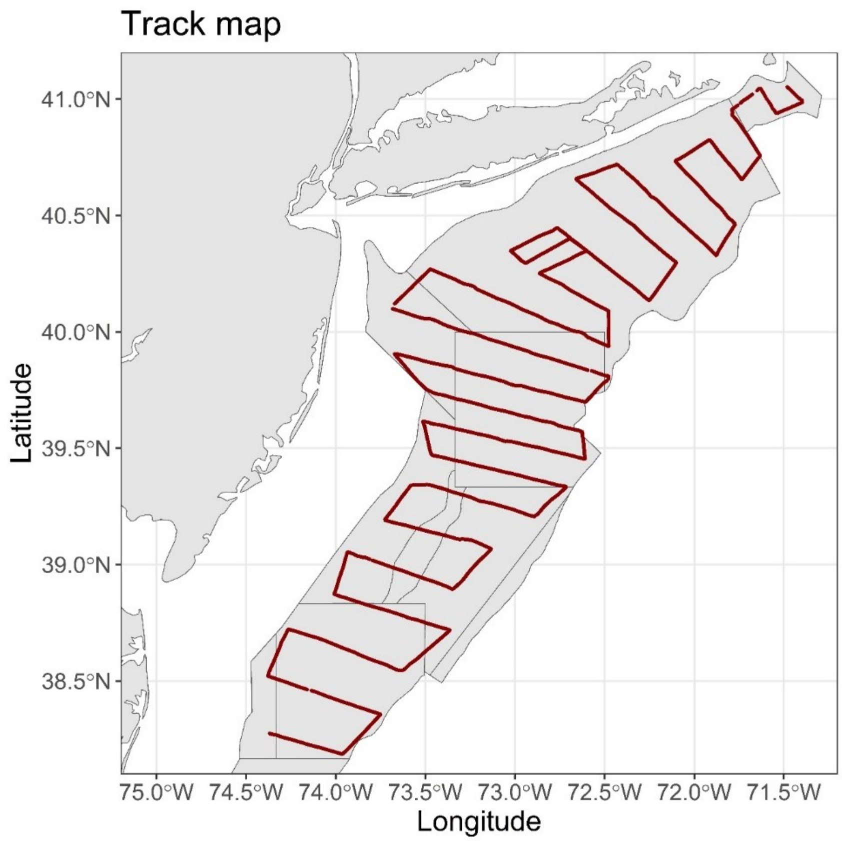

Figure 4: 2023 HabCam v3 tracks in the mid-Atlantic.

Image annotation and metadata

The HabCam v3 optical imaging system was towed 1.5–2.5 meters above the seafloor at a speed of 4–5 knots. Raw stereo image pairs were captured as 12-bit high dynamic range TIF files and stored on a Synology Network Attached Storage system, along with metadata (e.g., date, time, location, location, temperature, conductivity, speed, depth, and heading). After collection, the left-hand TIF files were processed into 8-bit JPGs for annotation. In 2022, 10.6 million image pairs were collected, with over 49,000 images annotated. In 2023, 12.8 million image pairs were collected, of which more than 62,000 were annotated.

Images were annotated using a modified version of software developed by the Visual Geometry Group at Oxford University for image annotation (Dutta and Zisserman 2019). The new image annotation Graphic User Interface (GUI) was 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, 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 enumerated within defined bounding boxes. Scallop SHs were measured when the hinge was visible; if the hinge was not visible, shell width was used as a proxy. In cases where scallops were too small to measure accurately, individuals were counted using a point tool, which recorded length with a default measurement of 0. These small scallops were excluded from length-frequency calculations, as only individuals with SHs of 40 mm or greater were included to ensure consistency across survey groups.

All annotators were trained using a practice set of images. All annotations are subject to review, though novice annotators are subject to a higher level of review. Quality control was performed on a target subset of 50% of annotations, which is performed by highly trained annotators. All completed annotation data was reviewed a second time by two PIs prior to submission to the NEFSC and New England Fishery Management Council (NEFMC).

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 NEFSC with all raw TIF files collected for each day for both 2020 and 2021 surveys.

Biomass estimates

Scallop lengths were initially recorded in pixels and were subsequently converted into SHs in millimeters based on the image field of view. 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 1,000m to 2,000m segments to minimize spatial autocorrelation along tracks. Total and exploitable biomass estimates were supplied to NEFSC and the Scallop PDT. Annotation data were 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 noted by CFF, grouped by SH, as well as other spatial data, were generated using geospatial packages in R (R Core Team 2024). Growth, as a function of SH, and assessed using length-frequency analysis by SAMS area.

3. Findings

3.1 Results and Discussion

Scallop size distribution and density

In 2022 and 2023, recruit and large adult scallops were observed throughout the SF and CA2 south tracks (**Figure 5**), with notable hotspots scattered intermittently across the area. Large adult scallops were also present in the NLS-S during both years; however, these large adult scallops had declined quickly due to intense fishing pressure since 2020. By 2023, the 2012 "Peter Pan" settlement, which had long dominated the area, was nearly depleted, creating space for new recruitment events.

While pre-recruit scallops were found in patchy densities in the NLS during both years, a significant settlement occurred in 2023, extending eastward into the former extension area and beyond. Small juvenile settlements had been noted in the northeastern portions of the NLS-S since 2021, but the 2023 settlement was the largest observed since 2012. For more detailed maps and information on this settlement, see Section 3.2 Continuous monitoring of the NLS-S.

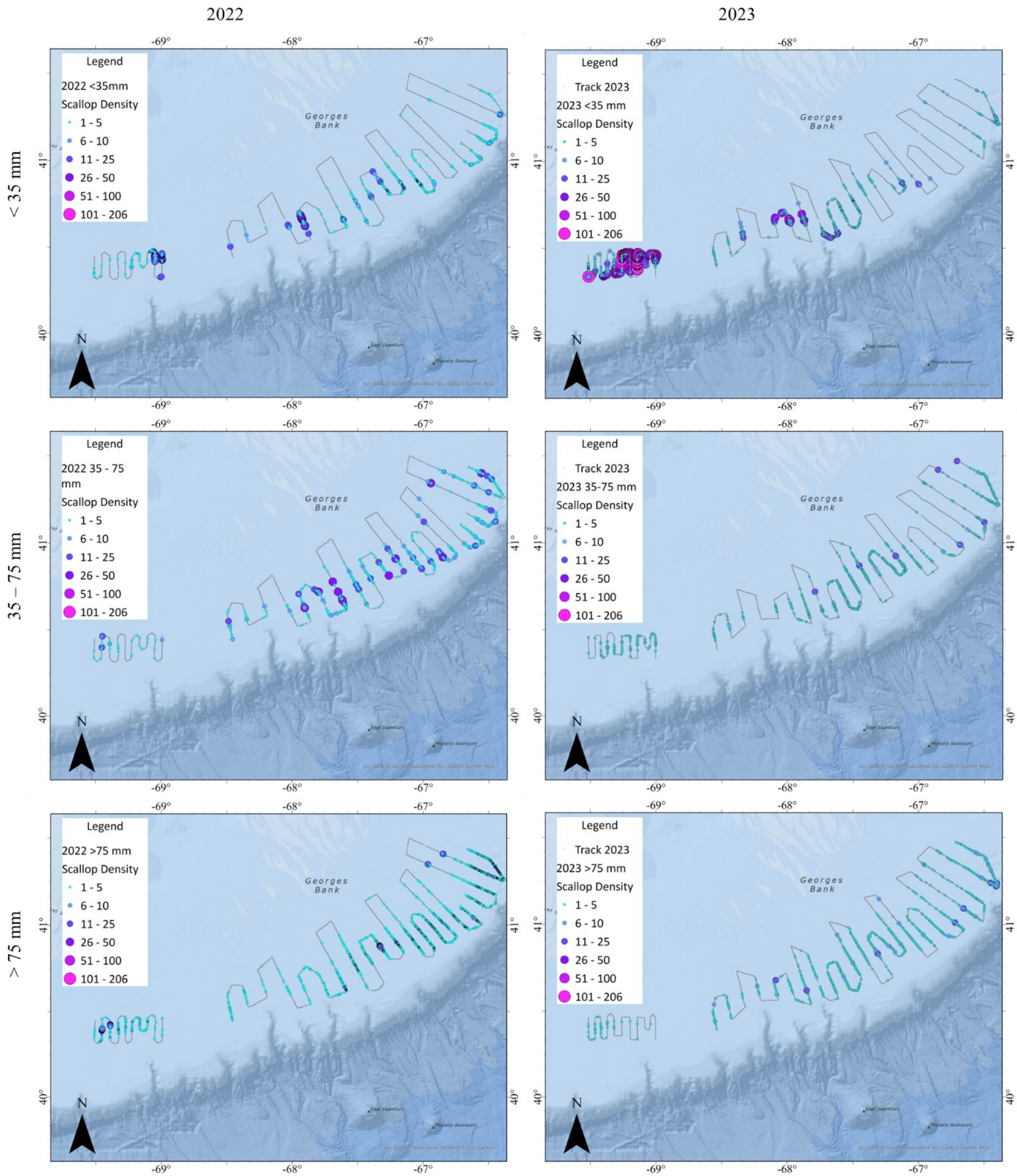

Figure 5: Density and distribution maps for scallops in the NLS-S, SF, and CA2 management areas.

In the mid-Atlantic, scallops of all sizes were considerably sparser than in Georges Bank. The surveyed areas in 2022 and 2023 had low to moderate densities, with the exception of recruit and pre-recruit scallops in 2022. Recruit scallops were most abundant in the LI and HCS areas, while pre-recruit scallops were sparse in LI, but more abundant in the NYB-Close and BI. In 2023, scallops of all sizes were found throughout the track, though dense hotspots were not noted in any size class. Despite enacting the NYB closure to support growth of the large number of pre-recruits and recruits noted in 2021, growth and survival in the closure area did not progress as expected. Large adult scallops were found throughout the track in 2022 and 2023 (**Figure 6**).

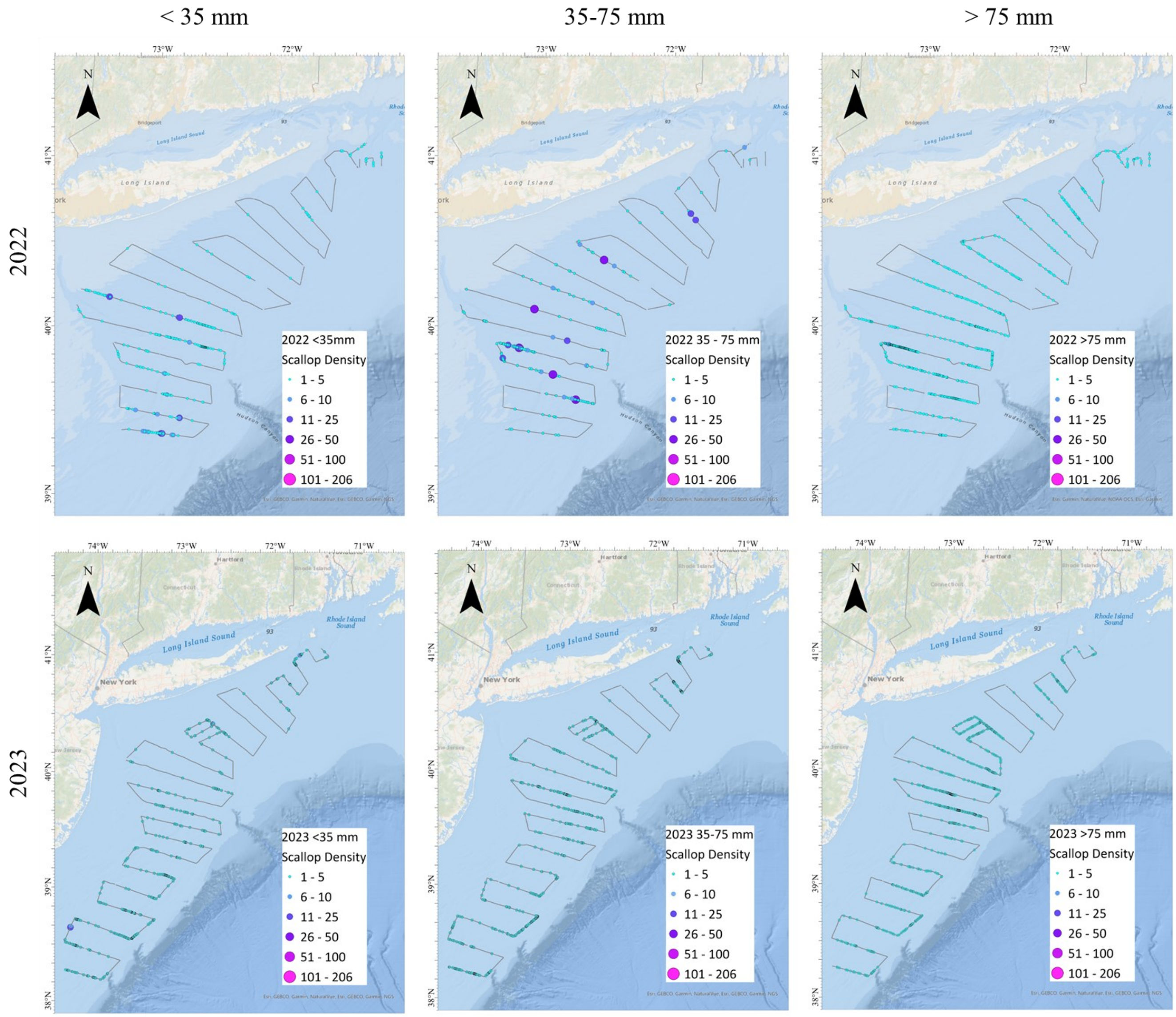

Figure 6: Density and distribution maps for scallops in the Mid-Atlantic management areas.

Length frequency and growth

The mean SH in several management areas remained relatively similar, though the abundance and length frequencies changed significantly between years in most areas. In the NLS-S, the area was comprised mainly of large adult scallops in 2022, though a small, localized settlement of pre-recruit scallops were noted in the eastern portion of the management area. In 2023, few adult scallops were noted and the area was mainly dominated by juvenile scallops. This decrease in large scallops is likely due to heavy fishing pressure in the area, as the exploitable biomass in the area has decreased dramatically each year since it opened to fishing following the 2019 survey season (FW32, NEFMC 2020; O'Keefe 2022). The mean scallop SH also decreased by ~35 mm (**Figure 7**). CA2-Ext and CA2-SW were dominated by large adult scallops in 2022 and 2023. While the mean SH remained similar between years in these areas, the count of scallops annotated decreased dramatically by ~40-60% in these areas. In the SF, the mean SH remained similar between years, though the area showed growth in 2023 as the area was dominated by adults and recruits. In CA2-SE, the mean SH increased by nearly 15 mm.

Figure 7: Length frequency plots for surveyed areas in Georges Banks in 2022 and 2023.

The mean SH in BI and LI decreased by over 20 mm from 2022 to 2023 and an increase in recruit size scallops was noted in 2023 in both areas (**Figure 8**). BI adult scallop numbers decreased significantly from 2023, likely due to fishing pressure in the open bottom area. Adult scallop counts in LI remained similar in both years, but the area had notably higher numbers of recruit scallops in 2023. The mean SH in both the NYB and NYB-Close areas remained similar between 2022 and 2023.

Figure 8: Length frequency plots for surveyed areas in the Mid-Atlantic in 2022 and 2023.

The HCS, MAB-Near, and ET were only surveyed in 2023; therefore, no CFF comparison was made between years (**Figure 9**). The mean scallop SHs were similar between areas. Few scallops were annotated in the MAB-Near area in 2023. Based on data collected and analyzed by NEFSC in 2022 (Chang et al. 2022), the mean SH increased in both the ET and the MAB-Near (in 2022, 68.3 mm and 64.7 mm respectively). The mean SH in the HCS appears to have decreased slightly from 95.3 mm in 2022 to 83 mm in 2023 (**Figure 9**).

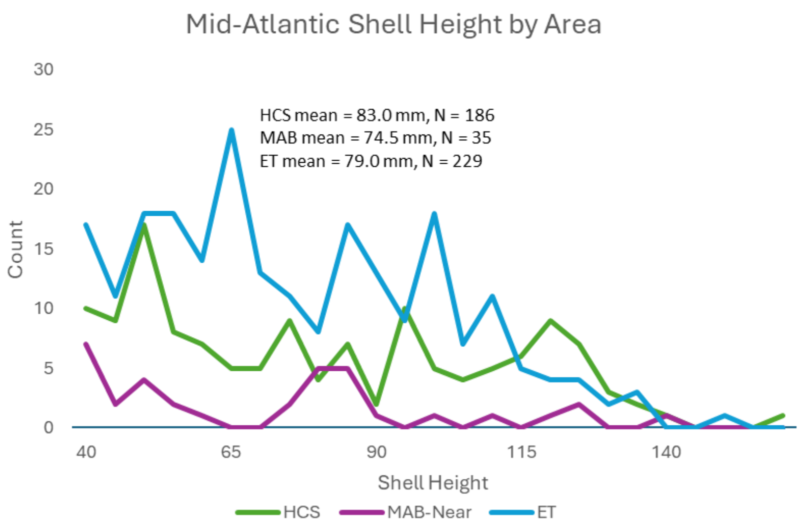

Figure 9: Length frequency plot for Mid-Atlantic areas surveyed in 2023 only.

Biomass estimates

Total biomass calculated based on CFF data increased in the SF from 2022 (6,753 MT) to 2023 (7,776.2 MT) but decreased in all other areas surveyed (CA2-SE, CA2-SW, CA2-Ext, BI, LI, NYB-Close) (**Table 3**). By far, the lowest total biomass was noted in the NLS-S (217.0 MT), which was predominately settled by a small number of large adult scallops. The NLS-S had a strong number of pre-recruits in 2023 but only 40 mm scallops and larger are used in biomass estimates for the stock assessment, so this recruitment is not captured in this calculation.

Table 3: Table of total biomass in surveyed management areas for 2022 (grey/white) vs 2023 (blue).

	NumMil		*BmsMT*		*SE*		*MeanWt*		*Avg. Size*		*Density*	
	GB											
CA2-SE	1684.5	778.4	18060.4	14055.1	6929.5	4687.8	13.2	19.2	77.2	91.0	0.65	0.39
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CA2-Ext	727.2	412.8	14264.5	8366.1	3977.0	1383.6	18.9	20.3	90.8	92.1	0.5	0.28
NLS-S	173.1	25.5	3625.2	217.0	1572.6	85.0	22.1	9.8	110.2	76.4	0.26	0.04
SF	517.2	623.5	6753.4	7776.2	1422.0	1471.9	12.4	11.6	79.2	78.4	0.14	0.18
	Mid-Atlantic											
BI	16.5	16.1	455.9	439.4	167.9	324.7	27.7	15.4	108.9	84.1	0.02	0.03
LI	265.7	318.6	6272.0	5226.7	1230.0	1160.5	24.7	17.6	104.9	89.8	0.02	0.03
NYB-Close	401.6	327.6	7575.7	6195.1	1704.8	1394.6	18.9	19.9	98.1	98.5	*	0.06
NYB	*	58.4	*	996.4	*	257.7	*	16.2	*	87.7	*	0.02
MAB-Near	*	35.4	*	505.1	*	340.9	*	12.3	*	75.7	*	0.01
HCS	*	148.6	*	1901.8	*	728.6	*	13.7	*	83.0	*	0.05
ET	*	175.2	*	2154.1	*	686.4	*	11.7	*	79.0	*	0.04

In contrast, exploitable biomass increased in several areas surveyed by CFF between 2022 and 2023 (**Table 4**). The exploitable biomass in the SF remained steady, with sharp declines noted in the CA2-SW, CA2-Ext, and the NLS-S. The NLS-S had the lowest exploitable biomass of any scallop area surveyed in either year at 120.9 MT. This is a sharp decline from 2019, prior to opening the area to fishing, when CFF estimated the exploitable biomass over 21,000 MT (O'Hara et al. 2020). In the mid-Atlantic, the exploitable biomass was relatively similar between years in all areas, with a slight decrease of ~1,500 MT noted in LI from 2022 to 2023, possibly due to fishing pressure.

Table 4: Table of exploitable biomass in surveyed management areas in 2022 (grey/white) and 2023 (blue).

	Exp NumMill		***Exp Bms MT***		***SE***		***MeanWt***	
	GB							
CA2-SE	310.4	299.1	7695.6	8182.0	1828.6	2259.0	27.0	28.5
CA2-SW	41.4	21.2	1606.5	903.4	416.7	402.2	35.5	37.8
CA2-Ext	339.3	197.1	9403.0	5792.0	2693.5	1095.2	27.4	29.9
NLS-S	114.7	6.3	2895.9	120.9	1283.0	57.6	26.6	21.5
SF	165.6	174.5	3921.2	3978.1	852.5	959.9	23.4	21.3
	MidAtlantic							
BI	11.7	8.1	375.7	361.0	146.7	312.2	31.7	28.8
LI	162.3	123.8	5006.2	3471.8	1069.5	853.9	31.8	29.0
NYB-Close	214.5	176.1	5556.5	4770.6	1297.3	1144.8	25.9	27.3
NYB	*	23.8	*	663.3	*	318.7	*	26.1
MAB Near	*	11.6	*	288.1	*	241.7	*	26.2
HCS	*	47.7	*	1179.5	*	455.8	*	25.5
ET	*	55.0	*	1219.2	*	481.6	*	21.7

3.2 Additional Observations

Continuous monitoring of the NLS-S

Following survey constraints in the 2020 survey season, CFF focused its survey efforts in the NLS on the NLS-S to ensure continuous monitoring of this dynamic area, and to provide fine-scale optical assessments after the area opened to fishing for the 2020 fishing year. In 2020 and 2021, CFF noted a precipitous drop in biomass each year since fishing opened, with little to no signs of recruitment or replenishment in the area. The area was subject to heavy fishing pressure, and CFF also noted viscera and increased turbidity in the imagery due to a large number of vessels actively fishing in the area (O'Hara et al. 2022). Pre-recruit scallop abundance was notable in both 2022 and 2023, though the density and distribution increased dramatically in 2023 (**Figure 10**). While the settlements noted in 2022 or 2023 are not thought to be as large as the 2012 Peter Pan year class, the 2023 estimates are by far the largest settlement observed in the NLS-S since the Peter Plan scallops were first noted in 2013. Through survey map comparisons in the 2023 PDT Scallop Survey meetings, it was noted that the distribution of pre-recruit scallops noted in the 2023 survey extended northwards slightly into the NLS- North (NLS-N) and eastward into an area formerly known as the NLS-extension. To a lesser extent, it also continued eastward into the southern portion of the GSC and the SF. In future years, the CFF tracks will be modified to more fully cover the settlement to track growth and movement of this year-class.

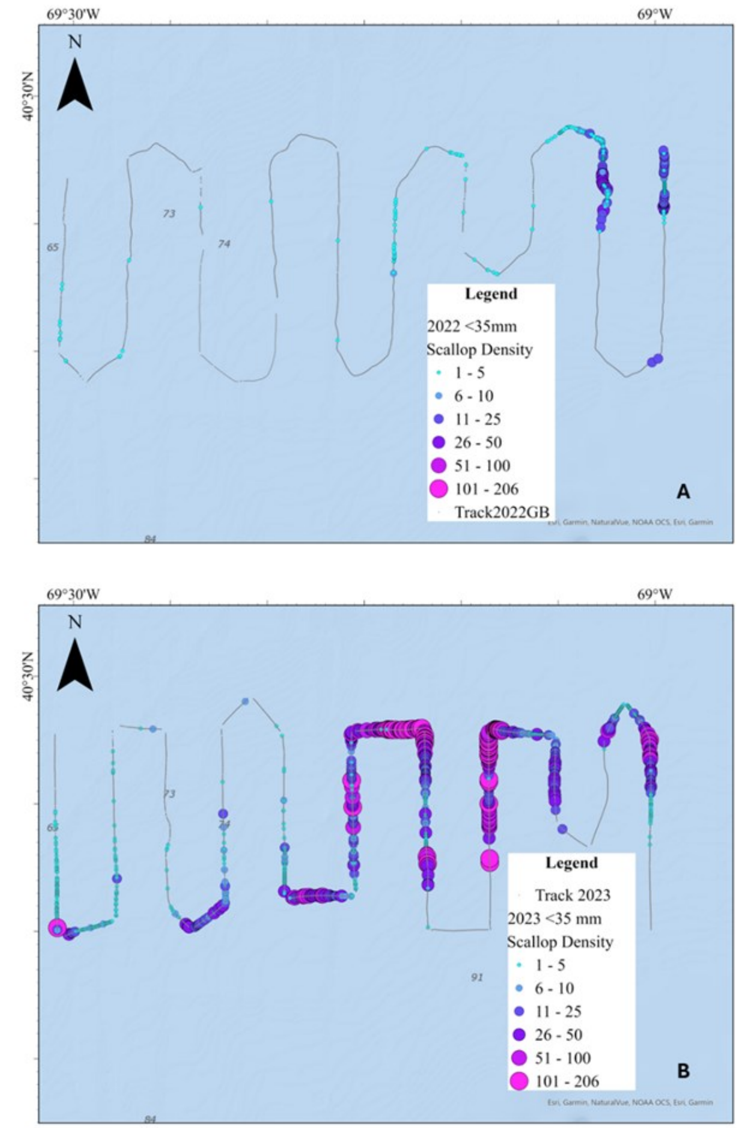

Figure 10:Map of the NLS pre-recruit settlement areas in 2022 (A) and 2023 (B).

As requested by the Sea Scallop PDT, CFF produced biomass estimates using both the 65th Stock Assessment Review Committee (SARC) and VIMS SH/MW equations in 2022 and 2023 to compare estimate calculations (**Table 5**). This calculation is only compared in the NLS-S region as the growth in this area has been shown to vary significantly from surrounding areas. The VIMS SH/MW includes more updated SH/MW calculations, which may be more useful in areas like the NLS-S, rather than the SARC65 equation, which was set at the 65th SARC meeting in 2018 (NEFSC 2018).

Table 5: Comparison of derived SH/MW between vetted equations in the NLS-S in 2022 and 2023 using CFF-only data. The estimates for SH/MW are given in MT.

NLS-S	*2022*	*2023*
SARC 65	3625.2	217
VIMS 2016-2022	3010.8	89.8

Continuous monitoring of the CA2-SE hotspots

In 2022 and 2023, CFF surveyed over an interesting scallop hotspot first noted during the 2021 survey in the CA2-SE. In 2021, CFF had noted a large number of seed scallops (**Figure 11A**) in thick bryozoan mats and sandy substrate. The area was also inhabited by some known scallop predators and scavengers.

In 2022, CFF noted a number of large mussel beds in the area. Many of the scallops also had mussels attached around and on them, as well as barnacle growth on their shells (**Figure 11B-D**), which could impact the ability of those scallops to swim and avoid predation. The 2023 survey in this area showed growth in several different year classes in these hotspots, but the area also had a high clapper density (**Figures 11C, 14**), possibly due to a recent mortality event in the area. CFF also noted larger mussel beds, which could be crowding out the bryozoan habitats and competing for food with nearby filter feeders. There were noticeable mussel clappers in the mussel beds in many areas, suggesting the recent mortality event may have impacted both scallops and mussels. The area was inhabited by many known scallop predators and scavengers, including sea stars (*Asterias* spp and *Astropecten* spp), ocean pout (*Zoarces americanus*), moon snails (mainly *Lunatia heros*), and cancer crabs (including rock crabs, *Cancer irroratus,* and Jonah crabs, *Cancer borealis*) and hermit crabs (mainly *Pagurus* spp), which could have contributed to recent mortality (**Figure 12**).

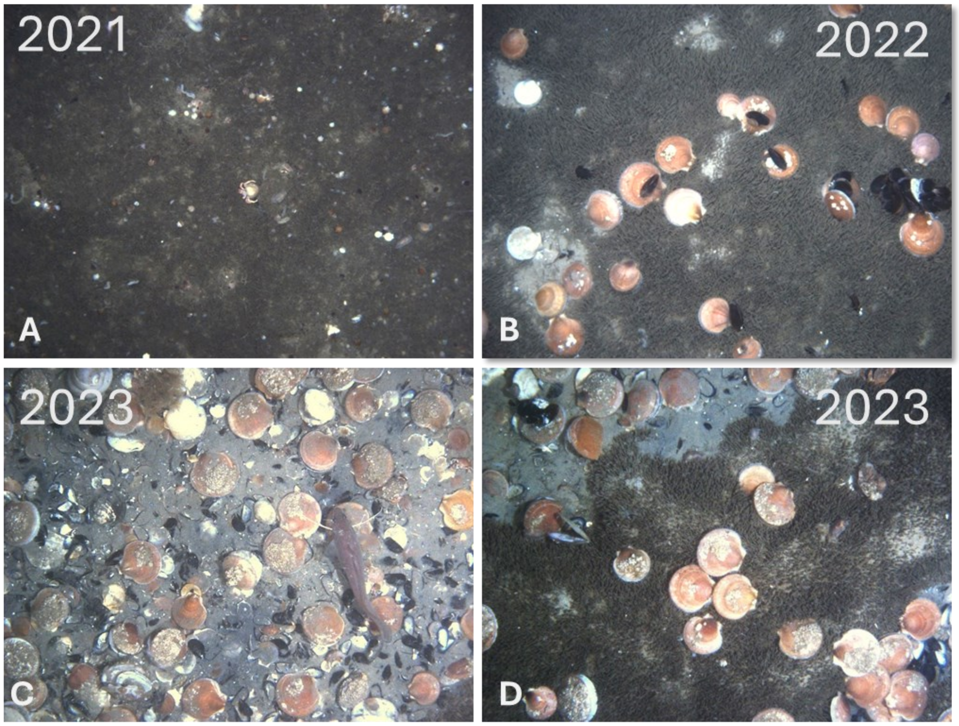

Figure 11: Images taken in the CA2-SE area of interest in 2021, 2022, and 2023. Images are not all taken from the same altitude.

Predators
CFF annotates a variety of important sea scallop predators, with a focus on cancer crabs, sea stars, and snails (including moon snails and waved whelks). Sea stars such as *Asterias* spp and *Astropecten* spp are of particular importance to the assessment as they are voracious scallop predators with a wide distribution which have been shown to have a significant impact on scallop recruitment and survival (Hart 2006).

In both 2022 and 2023, sea stars were by far the most abundant predator annotated during Leg 1, with high density hotspots noted along the southern portions of the SF and CA2 (**Figure 12**). In 2023, the total number of sea stars increased by 51% in Georges Bank, potentially in response to the large recruitment event in the NLS-S that extended northward into the NLS-N and eastward through the SF. The overall number of snails annotated during Leg 1 remained similar between years, though the number of moon snails declined by 82% while the number of whelks increased by 52%. Cancer crabs also decreased significantly (73% decrease) in 2023 (**Table 6**), and their distribution became concentrated over a smaller area (**Figure 12**).

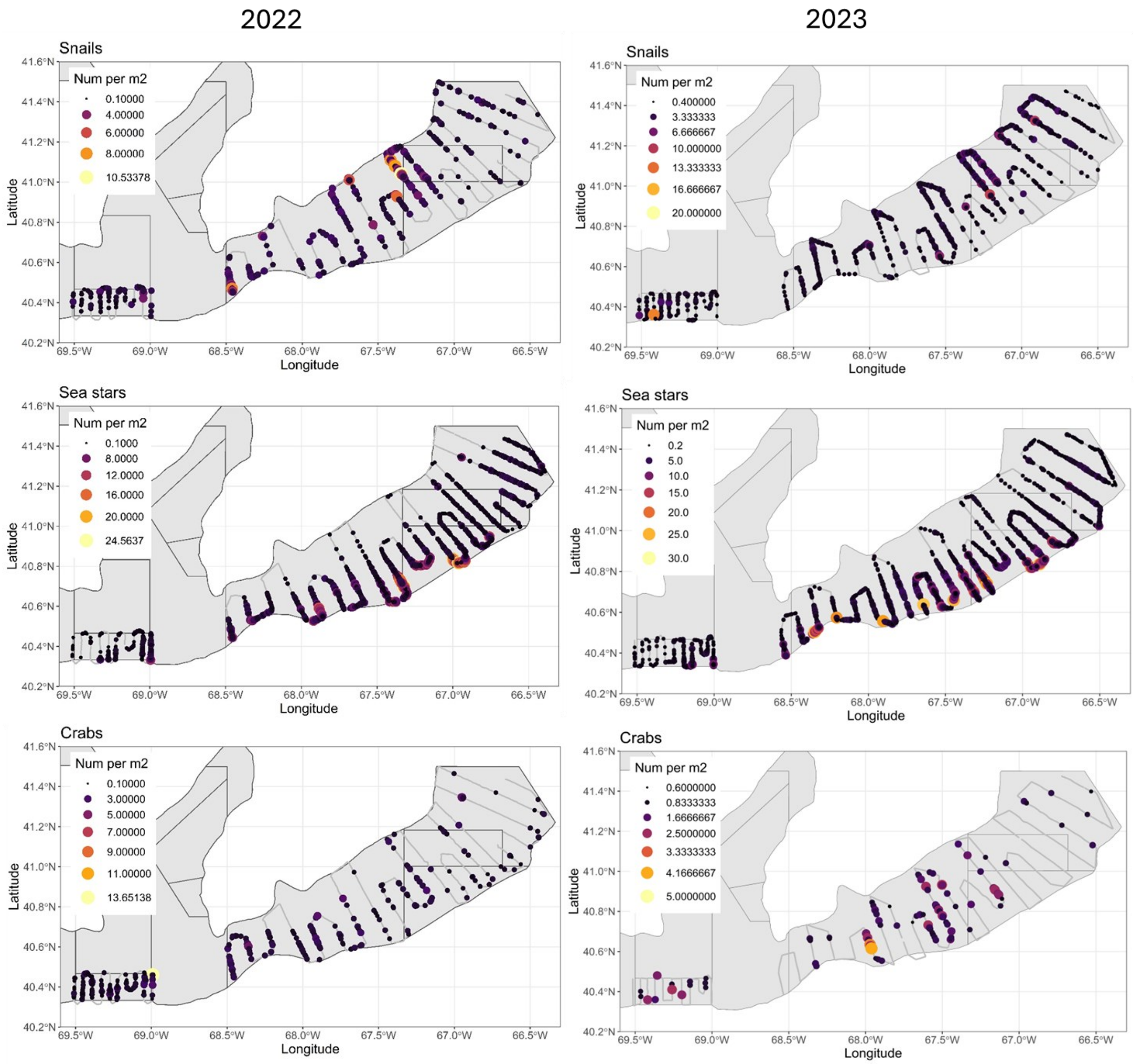

Figure 12: Predator density and distribution maps for the NLS-S SF, and CA2 in 2022 and 2023.

Table 6: Table with known scallop predators, scavengers, and scallop clappers noted during each survey leg in both 2022 (white/grey) and 2023 (blue).

Species	*Georges Bank*		*% change*	*Mid-Atlantic*		*% change*
Sea stars	12451	18824	51%	53543	55486	4%
Hermit crab	1446	167	-88%	471	471	0%
Jonah or rock crab	526	142	-73%	224	167	-25%
Moon snail	205	37	-82%	101	165	63%
Ocean pout	7	1	-86%	1	0	-100%
Sea scallop clapper	90	261	190%	17	85	400%
Whelk	405	616	52%	217	594	174%

The most abundant invertebrate scallop predators in the mid-Atlantic were crabs (mainly Jonah and rock crabs), sea stars (mainly *Astropecten spp.* and *Asterias spp.*), and predatory snail species (including moon snails and waved whelks). In the Mid-Atlantic, sea stars were the dominant predator noted with maximum densities reaching 58 sea stars/m^2 in 2022 and 70 sea stars/m^2 in 2023 (**Figure 13**). The total number of snails annotated increased 139% between 2022 and 2023 in the Mid-Atlantic, though the area covered by the survey increased substantially as well. The number of moon snails increased by about 63% in 2023, whereas the number of whelks increased by 174% in 2023 (**Table 6**). Despite covering more ground in 2023, the number of cancer crabs annotated decreased by 25%.

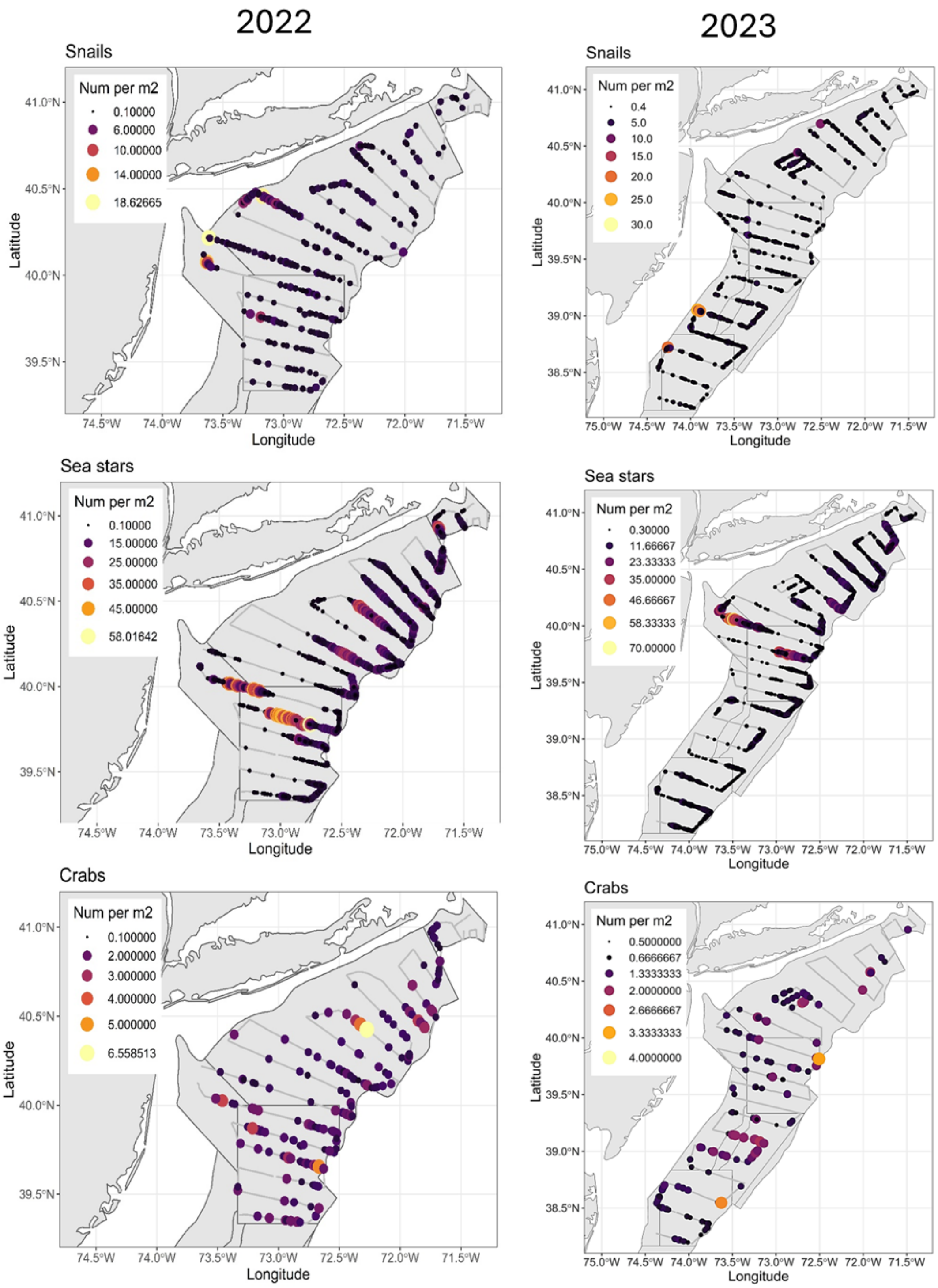

Figure 13: Predator density maps in the Mid-Atlantic from 2022 and 2023. Note scales are different between species. Scales are based on map density per species by year.

Sea scallop clappers are recently dead scallops that still have their shell hinge intact. Clapper annotations are useful in identifying mortality events that may have occurred recently. In all years, the largest hotspot of clappers was noted in the northern CA2-SE scallop hotspot described in the previous section. Several images were noted with between 6-20 clappers per image (**Figure 14**). This is an exceptional density of clappers in a single area, as most areas have less than 3 clappers per m^2. From 2022 to 2023, the total number of clappers annotated across all surveys increased 223%, with clappers in Georges Bank increasing 190%, and in the Mid-Atlantic increasing 400% (**Table 6**).

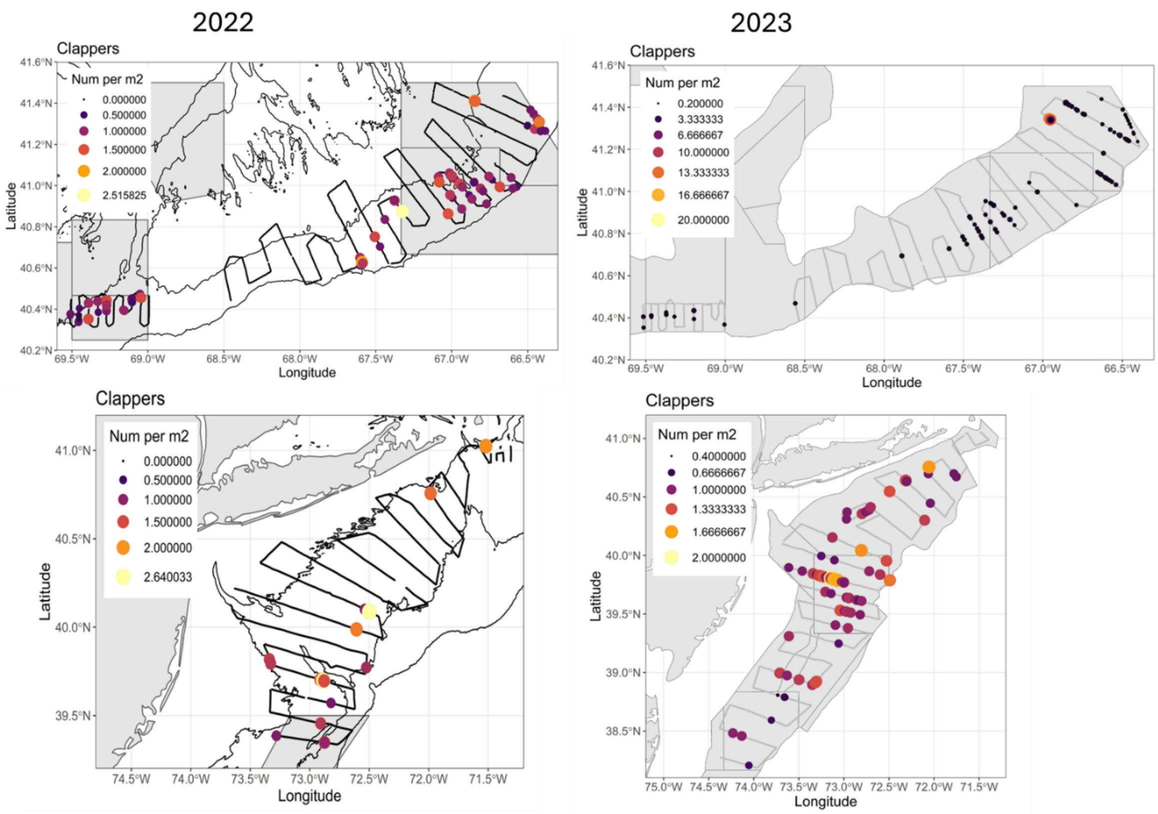

Figure 14: Density map of clappers noted in 2022 and 2023 noted during both legs 1 and 2. Note map scales are based on the max clapper density per area.

4 Project Evaluation

4.1 Attainment of Goals and Objectives

All goals and objectives of this research project were successfully completed during the project period.

<u>Objective 1</u>: Provide photographic imagery from proposed optical transects in the survey areas

CFF was able to provide timely estimates of scallop counts and size distributions throughout fully surveyed SAMS areas in both years. The NEFSC and NEMFC received annotation and environmental data by the deadline both years, and hard copies of the imagery and metadata were provided after each survey. Biomass estimates and size distributions (length-frequency and spatial distribution) for the entire tracks by SAMS areas were presented to the Atlantic Sea Scallop PDT following the 2022 and 2023 surveys.

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 plots and density distribution maps within all fully surveyed SAMS areas (**Figures 5-10**).

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

Total and exploitable biomass estimates were derived and provided to the Scallop PDT in September/October of each year (**Tables 3, 4**).

4.2 Dissemination of Results

Results were disseminated to the NEFMC following each survey year, and short reports and presentations were available to all participants. These meetings bring together stakeholders from the fishing industry, the scientific community, government officials, and special interest groups. These reports and presentations were also made available to the public via the NEFMC's website. Following the peer review of this report, a copy will be made available to the public via the CFF website: https://www.coonamessettfarmfoundation.org/

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