Sampling and Imaging Surveys to Ground-truth Acoustic Backscatter Data in the Long Island Sound Cable Fund Phase III Area

Final Report

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EXECUTIVE SUMMARY

Introduction

Background

The principal focus for this Phase IIIA portion of the Long Island Sound Cable Fund Seafloor Habitat Mapping (LISCF) initiative was the acquisition of acoustic data to map the seafloor prior to more detailed sedimentological, ecological and physical characterization. The acoustic mapping for the Phase III area was conducted by the Stony Brook University and described in the "Seafloor Mapping Of Long Island Sound Scope Of Work - Phase 3: Western Long Island Sound Acoustic Survey." Another important component of this Phase IIIA effort, however, was to collect new ground-truthing data to support the interpretation of both this new acoustic backscatter data as well as data from eight previous NOAA surveys conducted in the region.

Objectives

The objective of this portion of the Phase IIIA project conducted by the Long Island Sound Mapping and Research Collaborative (LISMaRC) was provide current, accurate "ground-truthing" data to support the interpretation of the acoustic data in the form of sediment grain size distribution and the occurrence of biological/biogenic anomalies by the acquisition of new sediment samples and seafloor imagery.

Methods

A four-day survey using the Research Vessel *Lowell P. Weicker* was conducted from June 12-16, 2023 inclusive of mobilization and demobilization to acquire samples and images in the Phase III area.

A total of 60 sites were chosen in the Phase III area based upon examination of the existing NOAA acoustic data. The determinants for the site selection were: 1) sites that showed vastly different backscatter values within a small area, hence needed ground-truthing to determine which reading was more accurate and 2) sites within the two areas selected as reference areas that were the target of the new data acquisition, and would, therefore, provide a better sense of the true nature of the new backscatter data to aid in the interpretation of these data and to assist with normalizing the existing data with the new.

Video from forward-looking and down-looking GoPro cameras was collected from each of the 60 sites. The down-looking GoPro video was reviewed and individual frames captured in .TIFF format using VLC (v. 3.0.20, 2023). The analysis of the frame captures of the seafloor was to address the project goal of providing new data to help with the interpretation of the newly acquired acoustic data, and therefore, focused on the principal taxa (epifauna), seafloor type and benthic structures, all of which could affect the nature of the acoustic return from the seafloor. The resulting data was recorded in a MS Excel spreadsheet. Multiple ESRI ArcGIS products were generated (geodatabase, map package and shape files).

Results

The 61 down-looking videos were reviewed and a total of 727 frames were captured as .TIFF images. Of the captured images, between two to five were analyzed for each transect, with a total of 214 deemed of adequate quality for subsequent analysis.

The patterns observed in the epifauna included the presence of several taxa normally associated with harder surfaces, such as erect byrozoa and the northern star coral, *Astrangia poculata.* Another was the presence of the slipper shell limpet, *Crepidula fornicata,* that has been observed to form extensive communities on the seafloor that could influence the strength of the backscatter returns.

The nature of the seafloor bottom types recorded for each of the 214 images analyzed revealed that all but three images recorded some percent cover of mud-silt, with 194 at 100%, 15 with 50-99% and 2 with between 0-49%. Sand was the next most observed substrate, seen in 46 of the images with gravel occurring in 36, pebble in 4, boulders in 3, cobble and artificial/man-made in 1 each and bedrock in none.

The highest percentages of biogenic structures recorded were some form of shells observed in many of the images analyzed. Burrows were the second most common biogenic feature, followed by excavated material.

Discussion

The detailed results of the image analysis of the 214 images was provided to Roger Flood's team to assist in the interpretation of both existing NOAA and newly collected acoustic data, meeting the primary objective of the study.

In addition, the earlier sampling conducted as part of this Phase IIIA project also provided insights into the subsequent Phase IIIB sample design. In particular, those sites where harder seafloor substrates were encountered were added to the list of sites warranting further characterization by ROV surveys during the Phase IIIB project.

Mapping the occurrence of the northern star coral *Astrangia poculata* was another contribution of this project that resulted from the review and analysis of the video and subsequent frame grabs. This cold water coral has been identified in the Long Island Sound Blue Plan as being one of the key taxa contributing to Ecologically Significant Areas (ESA's) in the Sound. The Phase III area lacked many areas where any information existed regarding the current status of ESA's. The new information gathered on the distribution of *Astrangia* will be provided to the managers of the LIS Blue Plan for consideration as areas warranting this additional layer of ecological consideration.

1 INTRODUCTION

1.1 Background

In June 2004, a settlement fund was created for the purpose of mapping the benthic environment of Long Island Sound (LIS) to identify areas of special resource concern, as well as areas that may be more suitable for the placement of energy and other infrastructure. This activity shall assist managers in the State of Connecticut, the State of New York, Connecticut and New York Sea Grant, and the U.S. Environmental Protection (USEPA) agency with their mandates to preserve and protect coastal and estuarine environments and water quality of Long Island Sound, while balancing competing human and energy needs with protection and restoration of essential ecological function and habitats.

In 2004, the Long Island Sound Study Policy Committee signed a Memorandum of Understanding on administering the fund for research and restoration projects to enhance the waters and related natural resources of Long Island Sound. In 2006, the Long Island Sound Study Policy Committee signed a second Memorandum of Understanding formally establishing a framework for the fund's use. The Policy Committee agreed that the Fund be used to: "Emphasize benthic mapping as a priority need, essential to an improved scientific basis for management and mitigation decisions." A LIS Cable Fund Steering committee, comprised of representatives from the Connecticut Department of Energy & Environmental Protection, the State of New York Department of Environmental Conservation, the State of New York Department of State, the U.S. Environmental Protection Agency Regions 1 and 2, the Connecticut Sea Grant and the New York Sea Grant, was convened to provide management and guidance for use of the fund.

Between 2004 and 2012, numerous workshops and meetings were held to help refine the vision for a benthic mapping effort. Additionally, a spatial planning exercise was conducted to identify areas of LIS to concentrate data collections and analysis with the understanding that:

- current funding was insufficient to have operations cover the entirety of LIS;
- by concentrating in areas where there were multiple interests from a range of stakeholders the utility of data collected and presented can be maximized.

The results of this process identified three priority areas (Figure 1-1) in the Sound for seafloor habitat mapping. The Phase I and II areas have already been comprehensively mapped by the three consortia identified to implement these mapping efforts consisting of:

- *National Oceanic and Atmospheric Administration (NOAA) Ocean Services Collaborative:* a partnership between the National Center for Coastal and Ocean Science (NCCOS) Biogeography Branch and the Office of Coast Survey;
- *Long Island Sound Mapping and Research Collaborative (LISMARC):* a partnership between the University of Connecticut, the U.S. Geological Survey, the University of New Haven, and the University of Rhode Island; and
- *Lamont-Doherty Earth Observatory (LDEO) of Columbia University Collaborative*: a partnership of LDEO, Stony Brook University, and Queens College – City University of New York.

The results of these previous efforts were detailed in final reports and appendices and delivered data and associated derived products focused on the following thematic areas:

- Acoustic Intensity;
- Seafloor Topography;
- Benthic Habitat and Ecological Processes;
- Sediment Texture and Grain Size Distribution;
- Sedimentary Environments;
- Physical and Chemical Environments; and
- Data Management

Subsequent to the Phase II effort, however, the consortia and Steering Committee concurred that the effort could be further improved by separating the acoustic component of the Phase III Project to allow data collection and processing as these map products guide the site selection for each of the subsequent elements of the mapping effort. This resulted in the establishment of a Phase IIIA and IIIB efforts to address the last priority area identified.

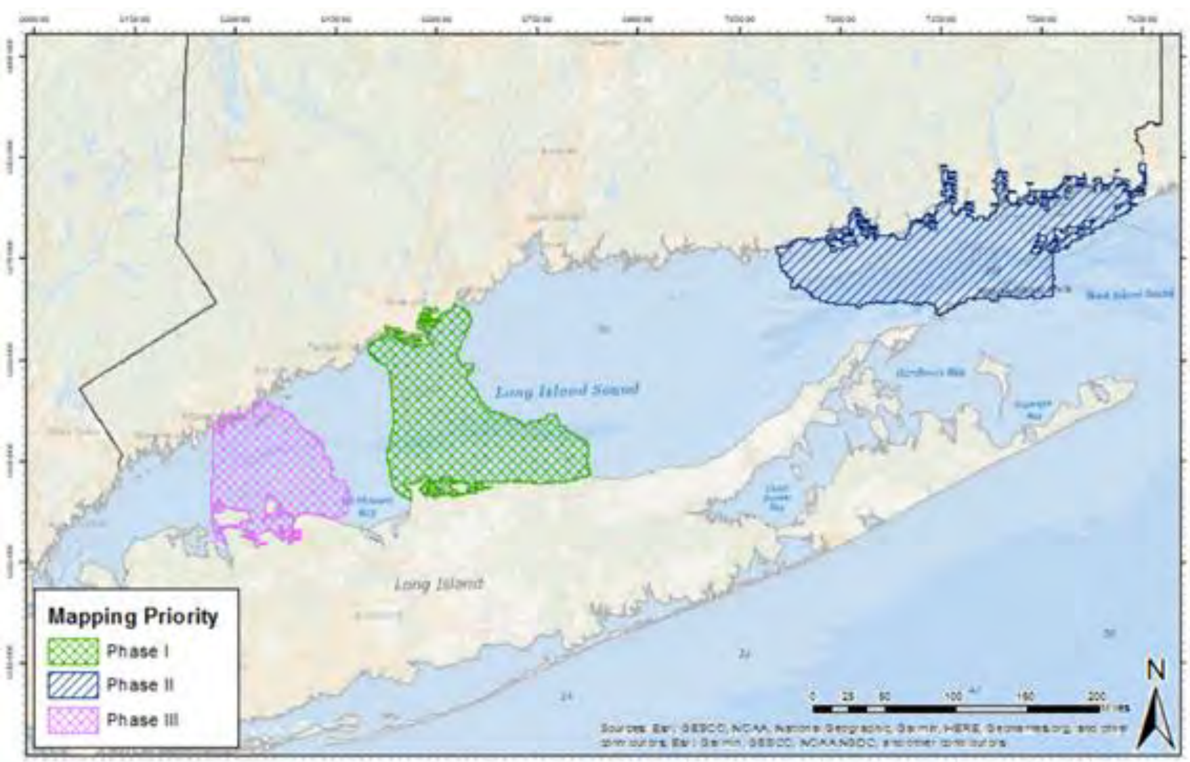

Figure 1-1 Map of Long Island Sound showing the three high priority areas for seafloor mapping.

1.2 Objectives

1.2.1 Acoustic Mapping

The Phase III area in western LIS occurs from the shoreline between Darien and Norwalk, CT and around Lloyd's Neck and Huntington Bay in New York. The refined 91 square-mile Phase 3 area limits the amount of riverine and nearshore embayments to approximate the following region (Figure 1-2):

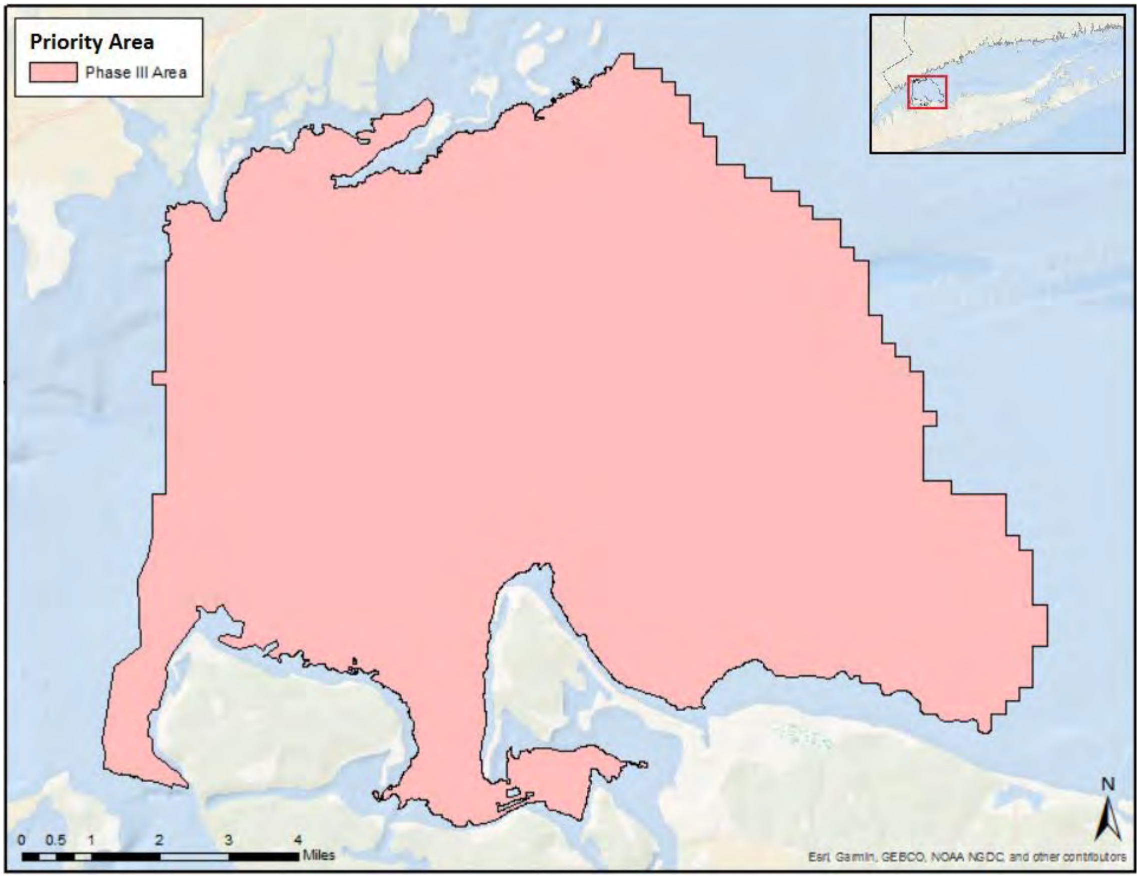

Figure 1-2 Revised Phase III area, limiting riverine and coastal embayments.

The principal focal area for this phase of the LIW Seafloor Habitat Mapping Initiative (LISSHMI) is the acquisition of acoustic data to map the seafloor. Acoustic bathymetry and backscatter maps depict properties about the depth, topography composition, roughness, and texture of the seafloor. These products are fundamental components necessary to satisfy the objectives of the LISSHMI. The acoustic mapping for the Phase III area was conducted by the Stony Brook University and described in the "Seafloor Mapping Of Long Island Sound Scope Of Work - Phase III: Western Long Island Sound Acoustic Survey" (Phase IIIA SOW). One important component of this Phase IIIA effort was to collect new acoustic backscatter data to be used as a reference data set to normalize the haphazardly collected backscatter data from eight previous NOAA surveys conducted in the region. It was proposed to collect the new data in two rectangular boxes

(Figure 2-2) that straddled many of these data sets that were collect at different times and with what appears to be different gain settings on the system(s) used to collect the data. The new data will form the baseline to which the previous data can be adjusted to best match and provide a more uniform mosaic. The results of these efforts will be presented by the Stony Brook University team in their Final Report.

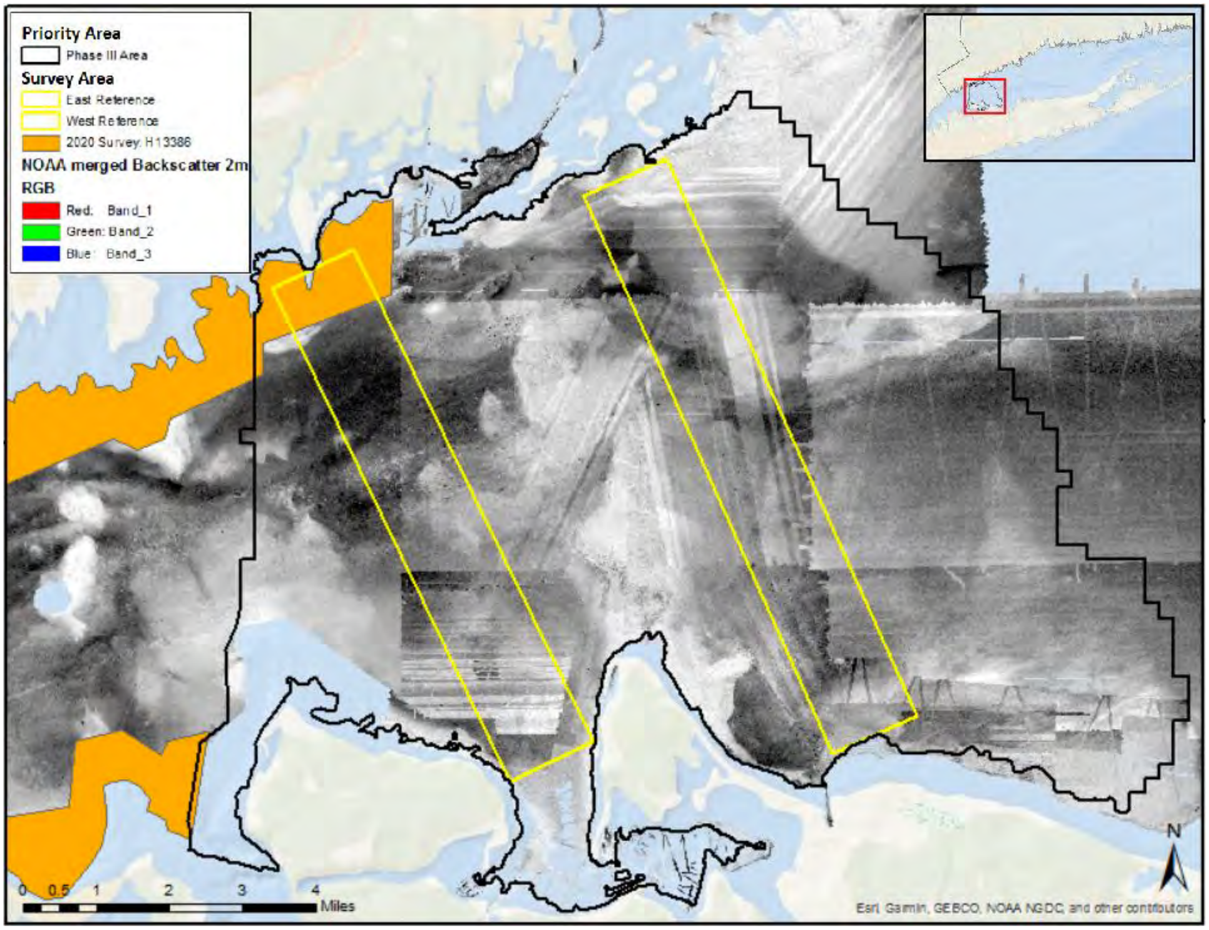

Figure 1-3 Previous NOAA backscatter data sets mosaicked together, with the two proposed reference boxes visible in yellow.

1.2.2 Phase III Sediment and Image Survey – University of Connecticut and University of New Haven

Acoustic data, especially backscatter or reflectance can provide broad-scale information on the range of grain size composition of the seafloor as coarse sediments such as gravel reflect more sound and, therefore, correspond to high backscatter and finer sediments such as mud are less reflective (i.e., absorb more sound) and thus correspond to lower backscatter. This acoustic information on its own, however, is insufficient to discriminate all differences in grain size and other sea floor characteristics that might be relevant for benthic habitats. In some cases, (e.g., in mud-dominated areas) differences in the backscatter can be caused by fine-scale morphology rather than by differences in grain size content (Ferrini & Flood, 2006; Nitsche, et al., 2004).

Further, the importance of benthic organisms and biogenic structures have also been shown to be important factors affecting the reflectance and therefore backscatter levels recorded during multibeam and other acoustic system surveys. Fenstermacher et al. (2001) used bottom grab samples and underwater video to document the increase in backscatter created by the sand dollar *Dendraster excentris* off the coast of California. Urgeles et al. (2002) found that a major factor controlling bottom roughness and therefore backscatter was the extent to which the seafloor was impacted by bioturbation, with lower bioturbation resulting in lower backscatter values in the Saguenay River. Similar results were reported by Feldens et al. (2018), who, using a multi-frequency multibeam sonar system in the North Sea, found that frequency-dependent high backscatter patches were caused by bioturbation of the seafloor by the tube-forming polychaete *L. chonchilega*. In Long Island Sound, LISMaRC investigators mapped extensive communities of the slipper shell, *Crepidula fornicata* using imaging systems (SEABOSS and K2 ROV).

Therefore, to provide accurate "ground-truthing" of acoustic data, sediment grain size distribution and the occurrence of biological/biogenic anomalies are both necessary and require analysis of actual samples and imagery. The acquisition of new sediment samples and seafloor imagery was the primary objective of this Phase IIIA effort as described below.

2 MATERIALS AND METHODS

2.1 Data Collection

2.1.1 Sampling Equipment and Procedure

A four-day survey using the Research Vessel Lowell P. Weicker (Figure 2-1) was conducted from June 12-16, 2023 inclusive of mobilization and demobilization to acquire samples and images in the Phase III area. The survey utilized the Ponar Imaging and Sampling System for Assessing Habitat (PISSAH) -- a simple drop sampling/imaging system that combines a standard Ponar grab (229x220 mm, 8.2 liter) to which a live-feed "pilot" camera used to guide the sampling/imaging and two high-definition GoPro 10 cameras with multiple dive lights for illumination were added (Figure 2-2). One of the two GoPro cameras was oriented to look forward, while the other was located lower on the frame and mounted with two parallel green lasers set at 10 cm width for size scaling. The PISSAH was used to acquire both physical sediment grab samples as well as the GoPro videos.

The position of the sampler was assumed to be directly below the stern of the vessel, although there may have been some deviation from this position based upon the unit being pushed by any bottom currents. Given this assumption, a GPS antenna was mounted on the stern rail of the RV Weicker to provide an accurate record of the position of the PISSAH throughout the course of the deployment. The GPS receiver was a GlobalSat BU-353N5 connected via USB to a laptop operating ArcGIS Pro. The GlobalSat GPS receiver has accuracy up to 5 meters 3D RMS with WAAS enabled.

Thus, the positional accuracy of the PISSAH and the acquired video was assumed to be ~5 meters.

Figure 2-1 RV Lowell P. Weicker used to support the Phase IIIA sampling campaign.

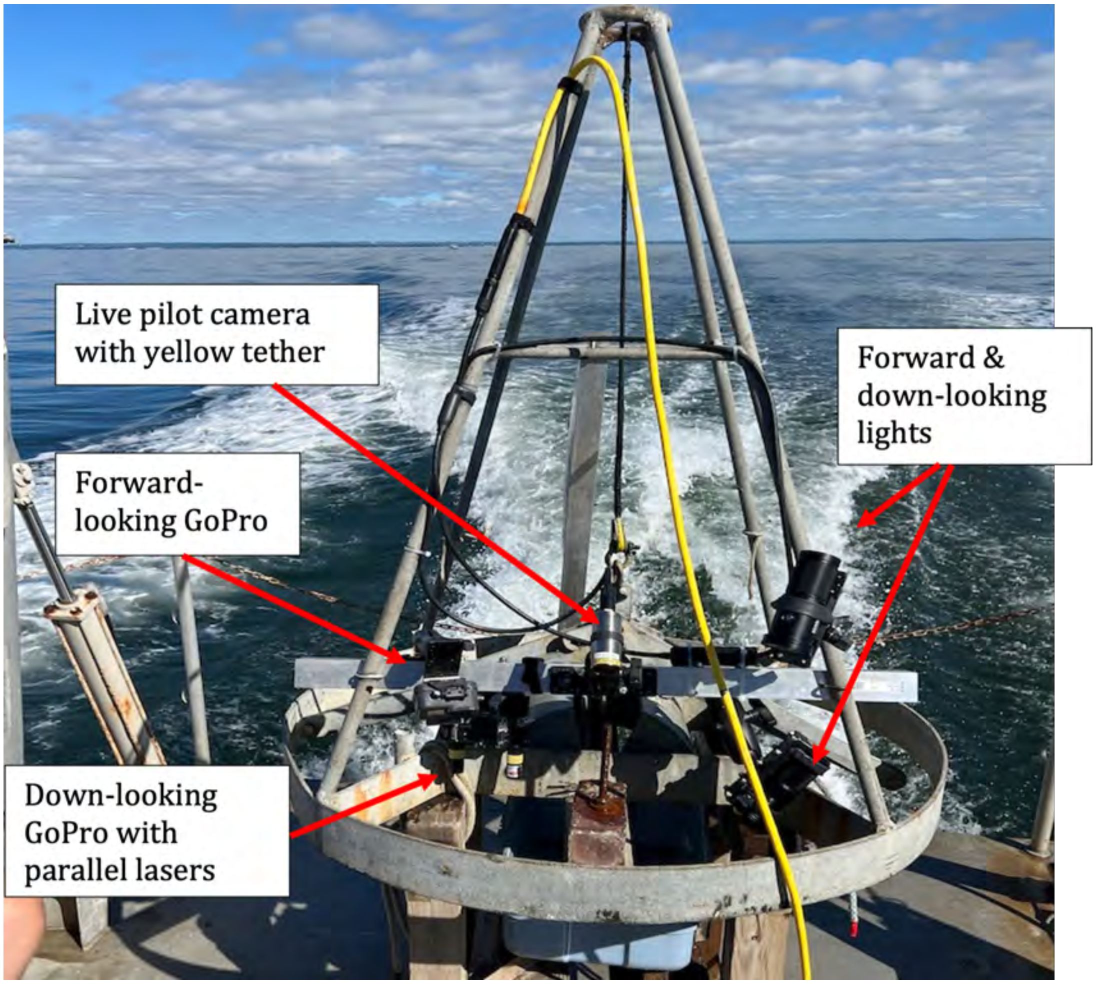

Figure 2-2 The PISSAH deployed on the RV Lowell Weicker with imaging and sampling components highlighted.

The PISSAH was deployed off the stern of the RV Weicker and lowered to approximately 0.5-1.0 meter off from the bottom, however, very low visibility resulted in very poor-quality video, even though the primary (down looking) GoPro camera was mounted very near the bottom of the sampler, and therefore as close as possible to the bottom without making contact. The deployment transects averaged between five to ten minutes, depending upon visibility, with lower visibility resulting in shorter deployments. In many of these cases the only useable video was the frame(s) immediately prior to taking the sample when the unit was closest to the seafloor at the end of the transect.

The time recorded by the GoPro's was set to GMT/UTC. The GoPro cameras were started prior to deployment and stopped upon retrieval on the deck. At the start of each deployment the site/transect location was noted on a dry erase board placed in the view of the camera as was an IPhone, also set to UTC, showing the time of deployment. The original file naming convention assigned by the GoPro cameras (e.g. GX010061.MP4) was maintained and recorded for each deployment/transect. The files were downloaded from the GoPro cameras to duplicate external hard drives daily for subsequent analysis.

Upon recovery of the PISSAH the top of the grab sample was photographed to provide a reference of the nature of the surficial sediments and any epifauna and/or biogenic structure(s) captured in the grab. The sediment samples were collected and stored for future grain size analyses to be conducted by Lamont-Doherty Earth Observatory (LDEO) team.

2.1.2 Sample Site Selection

The 60 sites were chosen in the Phase III area based upon examination of the existing NOAA backscatter combined with the newly acquired backscatter data imported into ESRI's ArcGIS Pro. The determinants for the site selection were: 1) sites that showed vastly different backscatter values within a small area, hence needed ground-truthing to determine which reading was more accurate and 2) sites within the two areas selected as reference areas that were the target of the new data acquisition, and would, therefore, provide a better sense of the true nature of the new backscatter data to aid in the interpretation of these data and to assist with normalizing the existing data with the new. The latitude and longitude of the sites were determined from the GIS, based upon the positional accuracy of the imported NOAA GeoTiff file of the backscatter mosaic. The location of the 60 sites in relation to the backscatter mosaic can be seen in Figure 2-3. The newly acquired data are the three northwest to southeast diagonal blocks seen in the image.

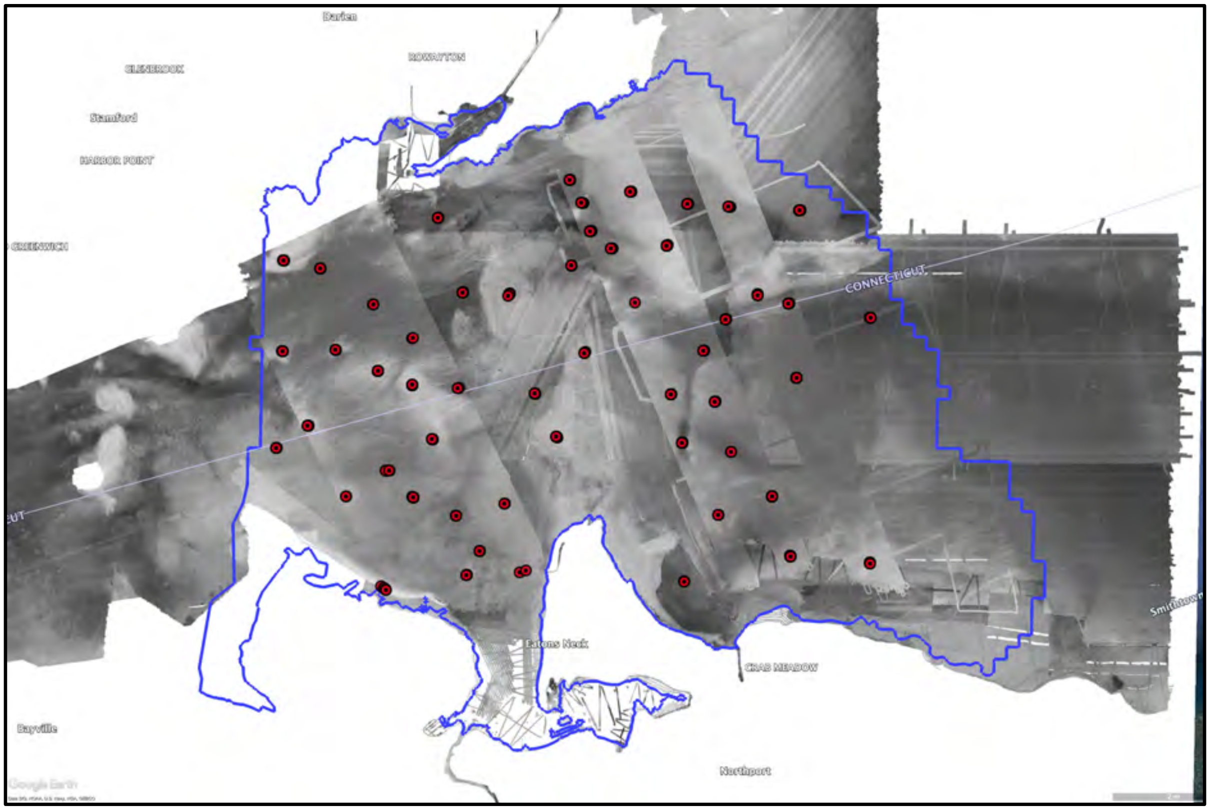

Figure 2-3 Map of the Phase III area (blue polygon) showing existing NOAA and newly acquired backscatter data and the location of the 60 sites (red dots) targeted for the current survey.

2.2 Image Processing and Analysis

2.2.1 Video Review and Frame Captures

Down looking GoPro video was reviewed and individual frames captured in .TIFF format using VLC (v. 3.0.20, 2023). Frame capture filenames included original GoPro video filenames and frame time code (i.e., hours, minutes, and seconds since the start of recording). During the initial review of each video, frames of clock time (Naval Observatory clock time from www.time.gov) and site ID (written on a white board) were captured and the timecode of deployment, the sediment grab, and retrieval were noted; additionally, observations on video quality and notable features or organisms were also recorded. Frames of the seafloor were captured when the seafloor was visible and clear during a subsequent review; care was taken to ensure frames provided representative images of the seafloor throughout the transect. At some sites, poor visibility inevitably reduced the number of usable frames available for analysis. Once saved as .TIFF files, frame captures were referred to as images.

2.2.2 Image (Frame Capture) Geolocating and Processing

Images were geolocated by correlating the time recorded on the video with the GPS receiver. Video timecode was converted to clock time (using the image of Naval Observatory clock time captured prior to deployment at each site), which was used to assign a latitude and longitude to each image (using GPS clock time recorded by the GPS receiver). Images were batch processed to ensure consistent quality during analysis using IrfanView (v. 64 4.62, 2022).

2.2.3 Image Analysis

Images were analyzed using ImageJ (v. 1.53k, 2021) to determine the prevalence of identifiable organisms, biogenic and artificial materials, and surficial sediments as percent cover. Image analysis consisted of overlaying a 10x5 cell grid (50 total cells) on the image (using ImageJ's Grid tool) and marking the occurrence of organisms, biogenic and artificial materials, and surficial sediment type within each cell (using ImageJ's MultiPoint Tool). Percent cover was determined as the number of cells featuring the occurrence of an organism, material, or sediment type expressed as a percentage of total visible cells. Note that only cells featuring clearly visible seafloor were included. The grid cell approach provides a measure of percent cover for each identifiable organism, material, and sediment type, and each cell may contain more than 1 organism, material, or sediment type. This inevitably results in images that feature percent cover values that sum to more than 100% (Fig. 2-4). The resulting data was recorded in a MS Excel spreadsheet. Multiple ESRI ArcGIS products were generated (geodatabase, map package and shape files).

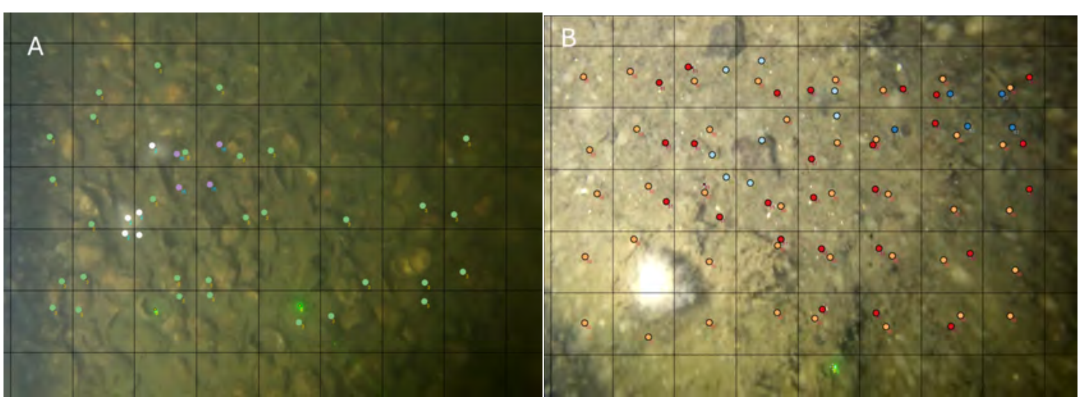

Figure 2-4 Analyzed frame captures from the PISSAH videos illustrating the grid cell approach: A – Crepidula fornicata (●, 32/37 cells, 86.5% cover), Astrangia poculata (○, 5/37 cells, 13.5% cover), erect Bryozoa (●, 4/37 cells, 10.8% cover); B – mud-silt (●,40/40 cells, 100.0% cover), sand (●,26/40, 65% cover), pebble (●,5/40 cells, 12.5% cover), cobble (●,8/40 cells, 20.0% cover); note that some cells have more than 1 organism/sediment type identified within it.

3 RESULTS

This project focused on providing new, focused ground-truth data to support the interpretation of historical NOAA and recently collected acoustic data in the Phase III area of the LISSHMI. The ground-truth data consisted of sediment samples and surficial imagery collected at 60 targeted sites. Figure 3-1 shows the location of the sample sites superimposed over the original, historical (2012) NOAA backscatter mosaic.

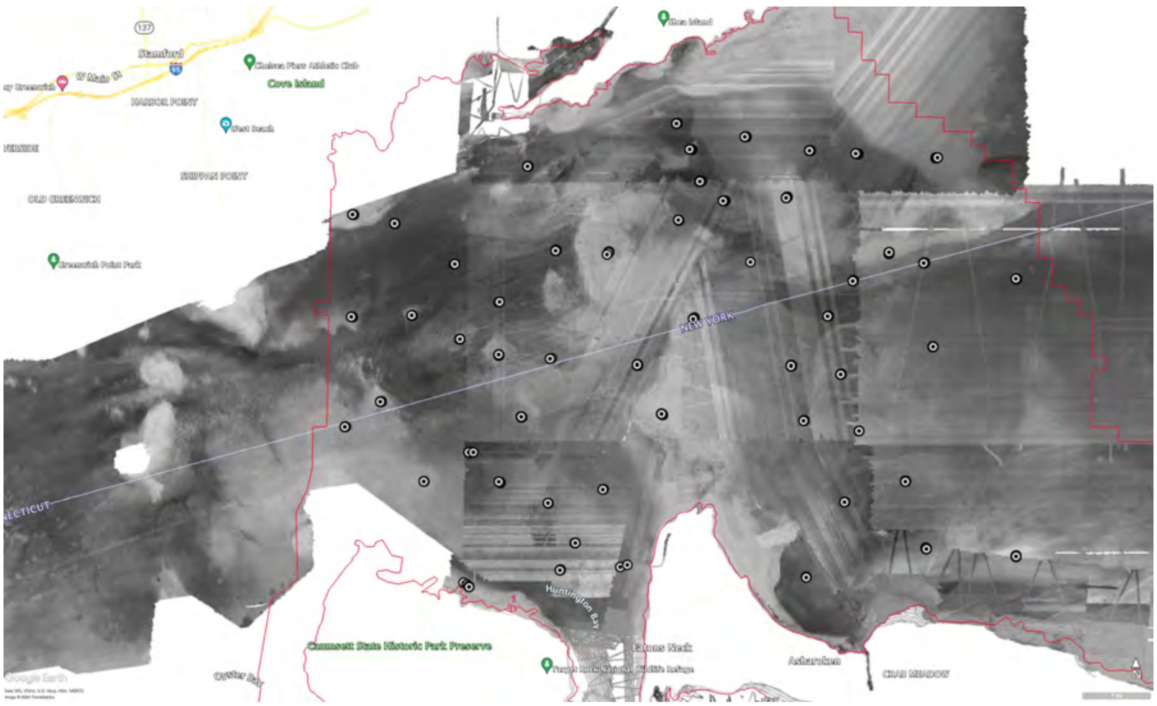

Figure 3 1 Map of the Phase III area (outlined in red) showing the original NOAAA backscatter mosaic and the Phase IIIA sample locations (white dots).

3.1 Field Data Collection

The June 12-15, 2023 survey using the PISSAH from the RV Lowell Weicker successfully sampled the 60 target sites identified through the process outlined above. The LISMaRC team recorded 57.MP4 videos from the forward-looking GoPro camera during the three-day survey (June 13-15). The extremely low visibility in the Phase III area made the forward-looking video marginal, as the seafloor was only occasionally visible from this camera during the bottom transects. These videos were not used in any of the analyses. A summary of the forward-looking videos (transects surveyed, video ID, location) is provided in Appendix 1. A total of 61 down-looking videos were recorded, which also included the 10-centimeter parallel lasers within the field of view. These videos also captured more detail of the seafloor, as the distance from the camera to the substrate was less than that of the forward-looking cameras. The down-looking videos served as the data source for screen captures that were further analyzed per the procedures described above.

3.2 Image Analysis Results

3.2.1 Summary of Images Analyzed

The 61 down-looking videos were reviewed and a total of 727 frames were captured as .TIFF images. A summary of the attributes (transects surveyed, source video, time of capture, location) of all of the captured images is provided in Appendix 2. Of the captured images, between two to five were analyzed for each transect, with a total of 214 deemed of adequate quality for subsequent analysis. Appendix 3 provides a summary of source video, time of image capture, location of the image capture and other data for each of the images analyzed.

The analysis of the frame captures of the seafloor was to address the project goal of providing new data to help with the interpretation of the newly acquired acoustic data, and therefore, focused on the principal taxa (epifauna), seafloor type and benthic structures, all of which could affect the nature of the acoustic return from the seafloor. A summary table of all of these attributes for each of the transects is provided in Appendix 4. The sections below provide more detailed, highlighted observations for each of these analyzed features.

3.2.2 Results of Faunal Analysis

The review of the 214 frame captures from the 60 sites within the Phase III area revealed several patterns in the occurrence of the benthic fauna that could aid in the interpretation of the acoustic data collected in areas adjacent to the sample sites. Of note, however, is that these are images of the surface of the seafloor, and as such, only captured information about the epifaunal taxa observed. No grab samples were taken to conduct a more thorough ecological characterization of the infaunal taxa that comprise a significant component of the benthic ecosystem. Appendix 5 provides a summary of the percent cover observed in each of the analyzed images for a broad set of taxa derived from similar epifaunal analyses conducted for the previous phases of the LISSHMI.

The patterns observed in the epifauna included the presence of several taxa normally associated with harder surfaces, such as erect byrozoans and the northern star coral, *Astrangia poculata.* Another was the presence of the slipper shell limpet, *Crepidula fornicata,* that has been observed to form extensive communities on the seafloor that could influence the strength of the backscatter returns. *Astrangia* has also been recognized as a species of significance used to help identify Ecologically Significant Areas (ESA's) in the Sound as part of the comprehensive inventory compiled by the Long Island Sound Blue Plan (Connecticut Department of Energy and Environmental Protection, 2019). The LISMaRC team has been monitoring the abundance of *Crepidula* over the past decade, observing increases in the occurence of the slipper shell in areas once dominated by the blue mussel, *Mytilus edulis*. Table 3-1 provides a summary of the images analyzed in the transects where these three key taxa were observed and the resulting percent cover of each taxa.

Table 3-1 Summary of the percent cover of the three key taxa observed in the images analyzed in the Phase III area.

Transect	VideoID	Picid	Astrangia %	Crepidula %	Erect bryozoan %
T-15	GX010034	GX010034.MP4-00_04_58-00004.tiff	44.74	0	78.95
T-55	GX010822	GX010822.MP4-00_06_21-00029.tiff	42.22	0	28.89
T-07	GX010037	GX010037.MP4-00_05_03-00014.tiff	35.71	0	0
T-11	GX010055	GX010055.MP4-00_06_00-00017.tiff	23.33	0	0
T-09	GX010053	GX010053.MP4-00_05_53-00030.tiff	13.51	86.49	10.81
T-11	GX010055	GX010055.MP4-00_05_46-00014.tiff	11.43	0	0
T-30	GX010814	GX010814.MP4-00_06_29-00017.tiff	11.43	0	71.43
T-55	GX010822	GX010822.MP4-00_04_31-00008.tiff	10	0	42.5
T-55	GX010822	GX010822.MP4-00_05_36-00019.tiff	10	0	17.5
T-07	GX010037	GX010037.MP4-00_04_08-00004.tiff	5.71	8.57	5.71
T-30	GX010814	GX010814.MP4-00_06_41-00022.tiff	5.71	0	8.57
T-09	GX010053	GX010053.MP4-00_03_55-00009.tiff	5.41	72.97	0
T-09	GX010053	GX010053.MP4-00_04_23-00014.tiff	2.63	55.26	31.58
T-09	GX010053	GX010053.MP4-00_07_10-00045.tiff	0	62.5	27.5
T-07	GX010037	GX010037.MP4-00_08_58-00007.tiff	0	57.5	0
T-09	GX010053	GX010053.MP4-00_05_21-00023.tiff	0	29.73	0
T-38	GX010059	GX010059.MP4-00_07_36-00010.tiff	0	14.29	0
T-38	GX010059	GX010059.MP4-00_07_06-00006.tiff	0	10	12.5
T-38	GX010059	GX010059.MP4-00_08_13-00014.tiff	0	8.57	11.43
T-38	GX010059	GX010059.MP4-00_08_36-00017.tiff	0	5.71	0

Figure 3-1 is a map of the Phase III area with the newly acquired backscatter (the three northwest to southeast trending blocks) integrated into the historic NOAA mosaic as a base layer and the distribution of two of the key taxa (*Astrangia* and *Crepidula)* mapped on top. These locations were the source for the site selection for the recent Phase IIIB field program that involved both the USGS' SEABOSS and an expedition using the Boxfish Remotely Operated Vehicle. These locations will also be provided to the leadership of the Blue Plan for consideration to add to the inventory of ESA's.

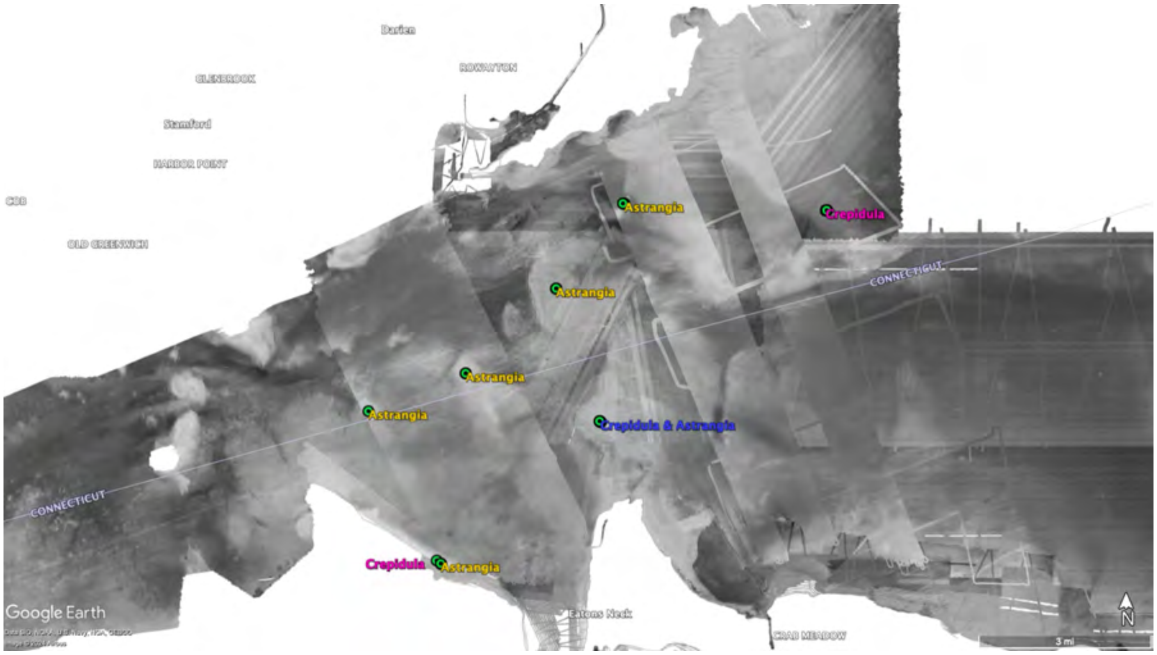

Figure 3 2 Map showing the newly acquired acoustic backscatter integrated into the historical NOAA data with the locations of Astrangia and Crepidula highlighted.

Figure 3-3 is a collage of the PISSAH frame captures illustrating some of the key taxa identified.

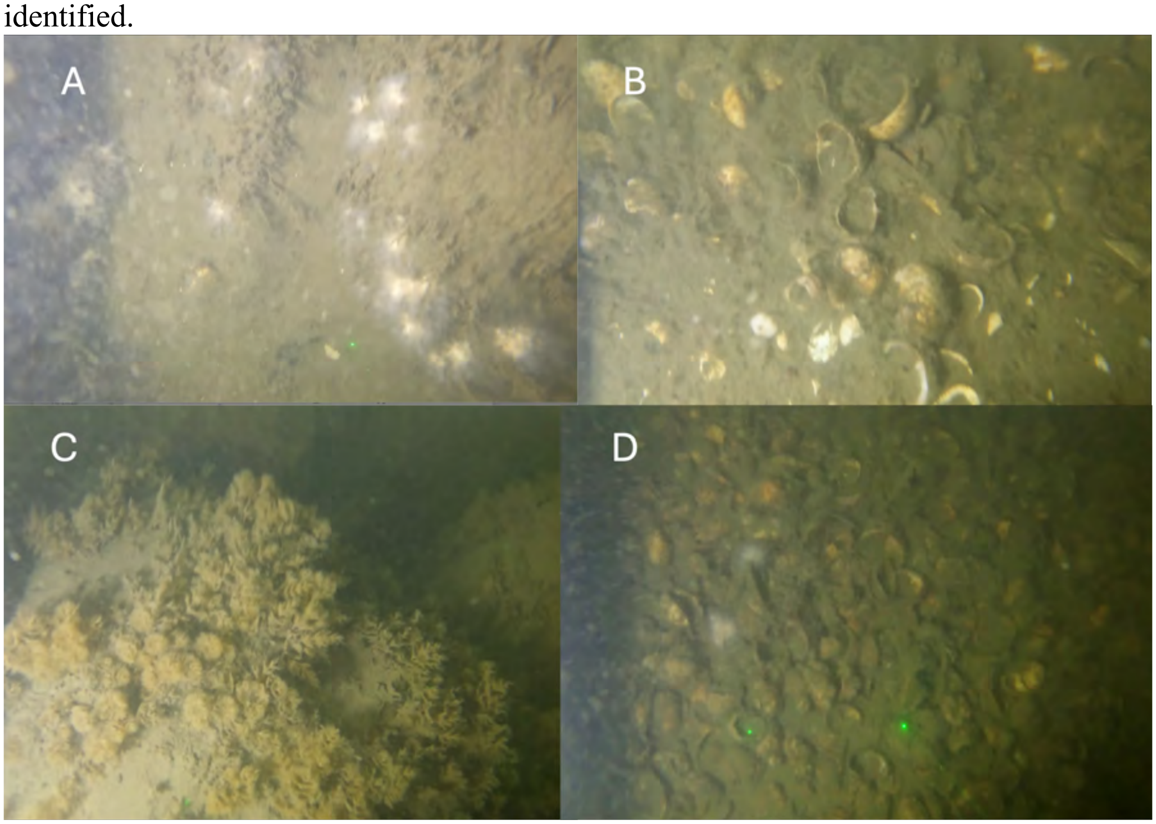

Figure 3-3 Frame captures from the PISSAH videos illustrating key taxa, A – boulders with Astrangia and erect bryozonans, B – Crepidula shells, C – boulder with erect bryozoans, D – dense Crepidula with some Astrangia visible.

3.2.3 Results of Seafloor Type Analysis

The analysis of the images captured from the video for the nature of the seafloor added to two additional data sets being collected to similarly aid in the interpretation of the acoustic data, these included the images taken of the top of the grab capturing the sediment type and taxa and the analysis of the sediment grain size from each of the grabs. These data sets were collected, analyzed and will be reported by the collaborative team from the Lamont Doherty Earth Observatory (LDEO). A set of substrate types was identified that included mud-silt, sand, gravel, pebble, boulder, cobble, artificial/man-made or bedrock. As noted in the Methods section, the grid cell approach provides a measure of percent cover for each identifiable organism, material, and sediment type, and each cell may contain more than 1 organism, material, or sediment type. This inevitably results in images that feature percent cover values that sum to more than 100%, but were listed as 100%. This is particularly evident in the mud-silt bottom types. A summary of the percent cover of all of the substrate types in all of the images is provided in Appendix 6. Table 3-2 provides a summary of the bottom types recorded for each of the 214 images analyzed. All but three images recorded some percent cover of mud-silt, with 194 at 100%, 15 with 50-99% and 2 with between 0-49%. Sand was the next most observed substrate, seen in 46 of the images with gravel occurring in 36, pebble in 4, boulders in 3, cobble and artificial/man-made in 1 each and bedrock in none.

Table 3-2 Summary of substrate types occurring in the 214 analyzed images.

Substrate type	Number of images observed
Mud-silt	211
Sand	46
Gravel	36
Pebble	4
Boulder	3
Cobble	1
Artificial/man-made	1
Bedrock	0

3.2.4 Results of Surficial Structures Analysis

The third component of the image analysis was the identification of various biogenic structures on the seafloor as these have been attributed to alterations in acoustic backscatter. Features recorded in the images included shells (whole, pieces, hash), burrows (small, medium, large), depressions, mounds, excavated material, worm castings and erect tubes and moon snail egg cases. Appendix 7 provides a summary of all of these seafloor structures observed in the 214 images analyzed. Table 3-3 provides a summary of the most observed seafloor structures. As can be seen, the highest percentages were some form of shells observed in many of the images analyzed. Burrows were the second most common biogenic feature, followed by excavated material. Figure 3-4 provides a collage of images of some of these structural features.

Table 3-3 Summary of biogenic structures occurring in the 214 analyzed images.

Structure type	Number of images observed
Whole shell	30
Shell piece	74
Shell hash	163
Burrows – small	18
Burrows – medium	21
Burrows – large	2
Depression	5
Mound	8
Excavated material	30
Worm casting	8
Worm tubes	10
Moon snail egg case	1

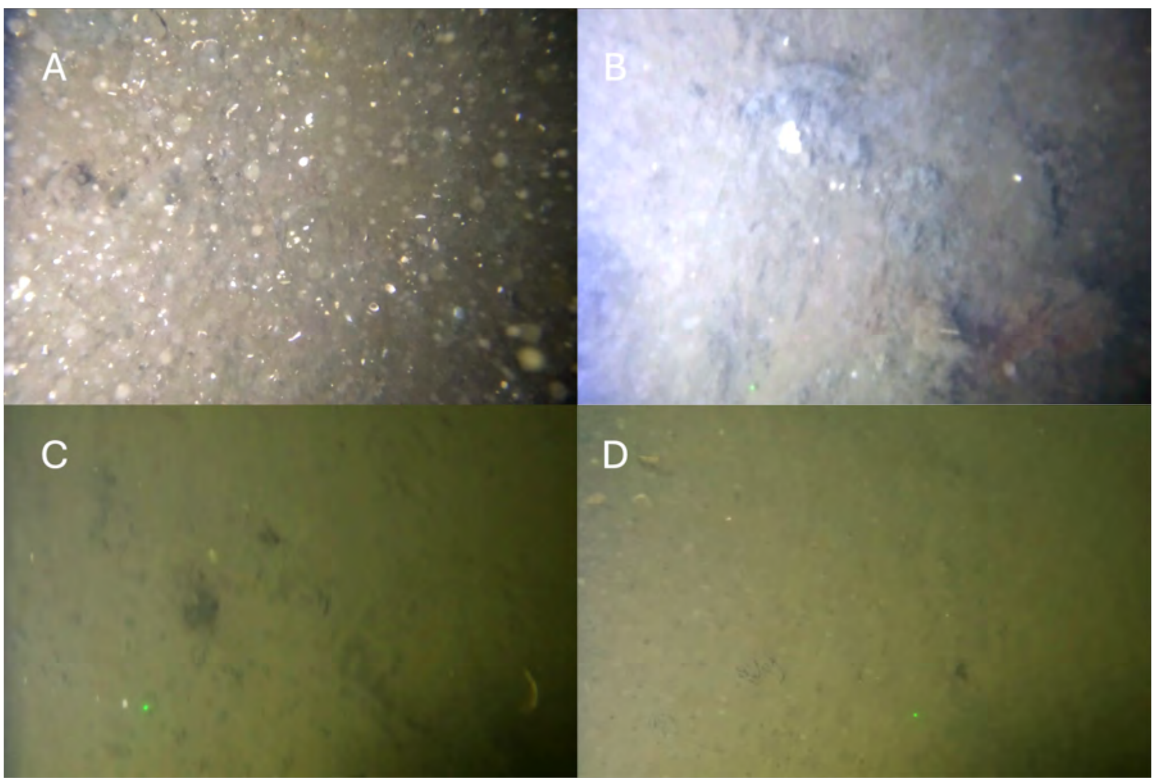

Figure 3-4 Frame captures from the PISSAH videos illustrating seafloor structures, A – shell hash, B – excavated material, C – large and small burrows, D – worm castings.

4 Discussion

4.1 Ground-truth Data to Support Acoustic Data Interpretation

The utility of acoustic seafloor mapping, particularly backscatter, to identify habitat types continues to evolve with improvements to mapping equipment, greater processing power and improved algorithms. A definitive model to derive seafloor habitat type from acoustic backscatter data, however, does not exist due to a myriad of variables inherent in the data collection (frequency, system gain settings, beam angles and patterns) and processing (Lurton and Lemarche, 2015). It is clearly recognized that ground-truthing data remains critical to the interpretation of acoustic backscatter mosaics due to these variables. The most common ground-truth data used to aid in the analysis of acoustic data includes physical sediment samples and images, which convey grain size distribution and a range of variable information, which affect the nature of the acoustic signals. These two combine to provide an assessment of the mineral composition of the seafloor as well as the organic element that includes the dominant taxa and their derived products such as shell deposits, burrows and excavated material (Lurton and Lemarche, 2015). In addition, other factors such as seafloor geomorphology, habitat complexity and seafloor currents affect not only the distribution of sediment grain size due to sorting, but also of benthic organisms (Jumars, 1993, Kosteleyev et al. 2001, Wildish and Kristmanson, 1997)

As described above, this project relied upon the expertise of three of LISSHMI consortia members to conduct the initial acoustic data collection, interpretation and ground-truthing of the Phase III priority area of the Sound. The team led by Roger Flood from Stony Brook University conducted the major element of the project, the acquisition and interpretation of new acoustic data that would be merged with historic NOAA acoustic data collected in 2012. The teams from the Lamont Doherty Earth Observatory (LDEO) collaborative provided the sediment grain size data and the Long Island Sound Mapping and Research Collaborative (LISMaRC) team provided the image analysis.

4.2 Image Analysis to Support Acoustic Backscatter Interpretation

4.2.1 Image Analysis in Relation to Old and New Backscatter Data

The analysis of the 214 images derived from the GoPro video collected in June, 2023 produced a comprehensive data set for the 60 sites identified to support the interpretation of not only the newly acquired acoustic data, but also the historical NOAA data that suffered from range of discrepancies and discontinuities, likely arising from the fact that these data were collected on six separate surveys. Figure 4-1 illustrates the old and new backscatter data with the locations of the 60 sample sites superimposed, showing data collected in both old and new areas. The image analysis data set included the three main elements of observed fauna, substrate type and biogenic structures. This data set is the most recent record of faunal distribution in this area of LIS. However other past studies of faunal distribution in this area include Pellegrino and Hubbard (1983) and Reid et al. (1979). Figure 4-2 illustrates the location of these previous studies and the current image analysis locations, however no comparison of faunal distributions was made within the scope of this project.

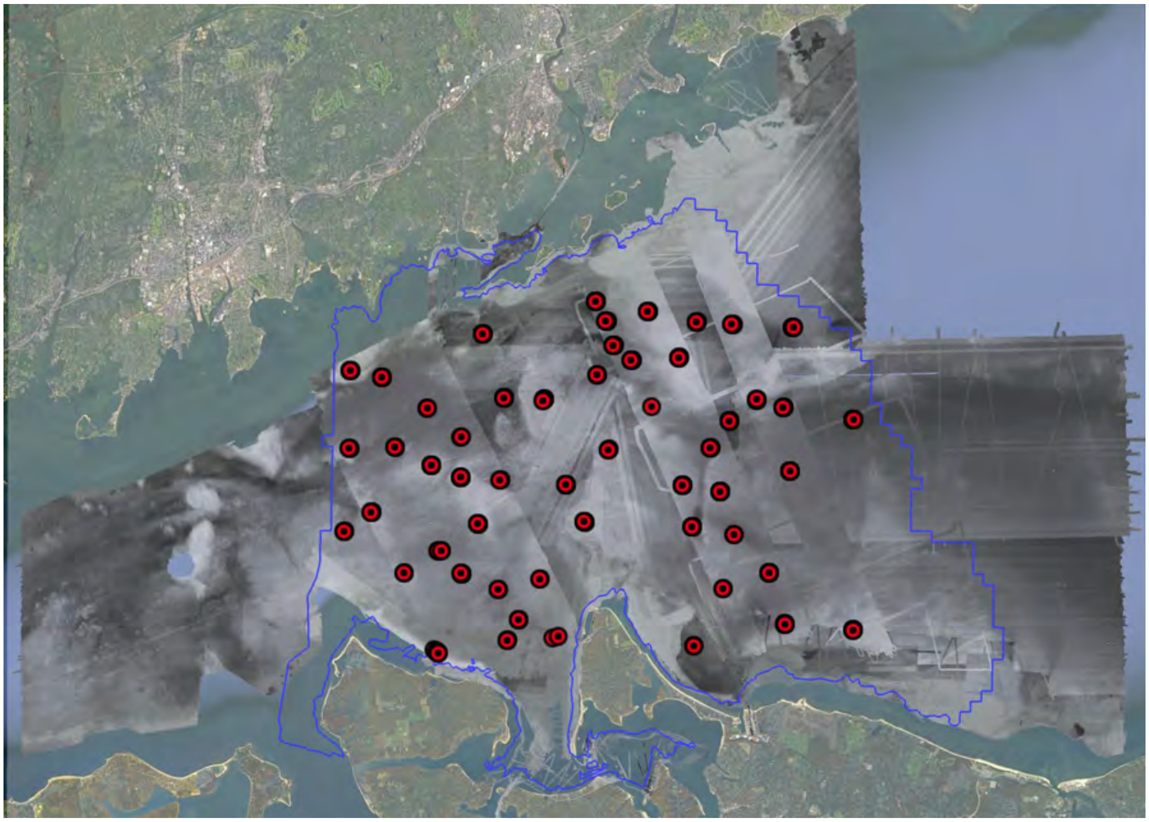

Figure 4-1 Map of the Phase III area with old and new backscatter and the image analysis sites.

Also of note is that these 60 sites also included sediment samples that were preliminarily field analyzed by the LDEO team and are currently undergoing a more thorough sediment grain size analysis. This recent sediment grain size data will augment the more spatially comprehensive studies conducted by the U.S. Geological Survey in the Sound such as the Long Island Sound Sediment Database (McMullen et al., 2005) (Figure 4-3).

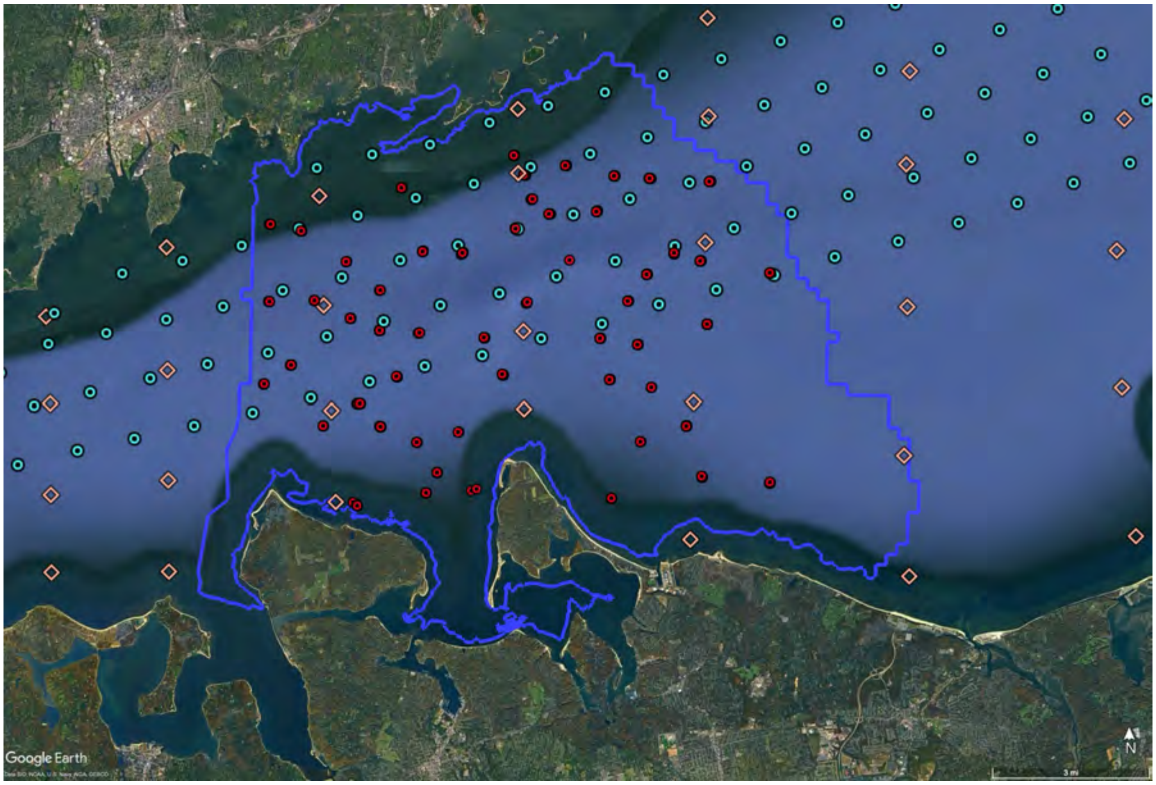

Figure 4-2 Map of the Phase III area (blue polygon) with the current image analysis sites (red dots), Pellegrino and Hubbard sites (blue circles) and Reid et al. sites (orange diamonds).

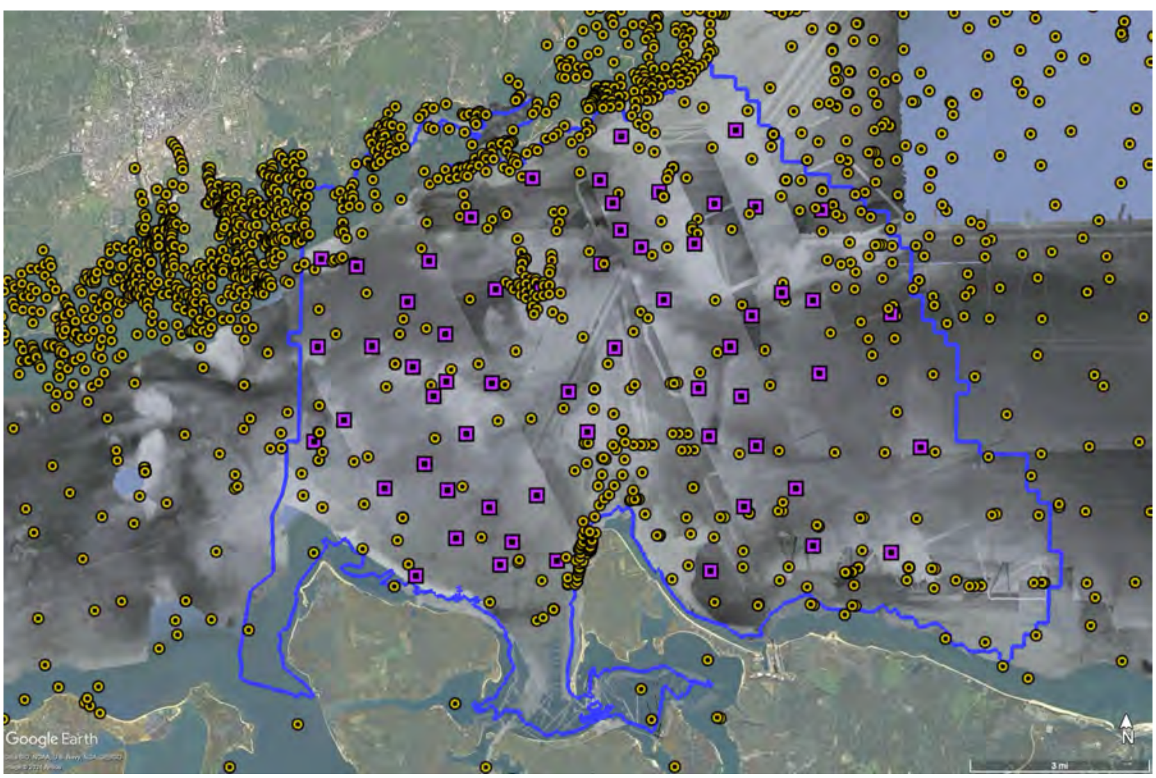

Figure 4-3 Map of the Phase III area with the backscatter mosaic, the LDEO sediment sites (purple squares) and the LISSEDATA sites.

4.3 Summary

4.3.1 Contributions to Interpretation of Acoustic Data by Image Analysis

As described above 60 sites were surveyed and sampled within the LISCF Phase III area to provide new ground-truth data to assist with the interpretation of both historical NOAA and newly acquired Stony Brook University (Roger Flood) acoustic data. The survey produced both forward looking and down looking video data acquired from GoPro cameras attached to the PISSAH. The down looking video, which also included 10 cm spaced lasers, was reviewed and 734 frame captures were saved in the .TIFF format. A subset of these images (214) were deemed of sufficient quality to be analyzed for benthic species, seafloor type and seafloor biogenic structures and results were presented in an .XLS spreadsheet and mapped using ESRI .shp files. All of the raw video, captured images, analyzed images and results have been uploaded to the UConn LISMaRC Sharepoint site and provided to Roger Flood. All of these data have also been archived at the MGDS LIS Data Portal (https://www.marine-geo.org/portals/lis/)

4.3.2 Contributions to the Phase IIIB LISCF Project

Per the recommendations of the LISCF Steering Committee it was elected to conduct the Phase III portion of the LIS Seafloor Habitat Mapping initiative in two phases, IIIA and IIIB, with the current project representing Phase IIIA. While the main driver for this separation was to allow adequate time to develop more refined acoustic map products to aid in site selection for the more comprehensive, subsequent characterizations (sedimentological, ecological, physical), the earlier sampling conducted as part of this Phase IIIA project also provided insights into the Phase IIIB sample design. In particular those sites where harder seafloor substrates were encountered were added to the list of sites to be further characterized by ROV surveys during the Phase IIIB project.

4.3.3 Contributions to the Long Island Sound Blue Plan

Mapping the occurrence of the northern star coral *Astrangia poculata* was another contribution of this project that resulted from the review and analysis of the video and subsequent frame grabs. This cold water coral has been identified in the Long Island Sound Blue plan as being one of the key taxa contributing to Ecologically Significant Areas (ESA's) in the Sound. As can be seen in Figure 4-4 the Phase III area lacked many areas where any information exists regarding the current status of ESA's. The information gathered on the distribution of *Astrangia* in the Phase III area will be provided to the managers of the LIS Blue Plan for consideration as areas warranting this additional layer of ecological consideration. This is similar to previous contributions by the LISSHMI to the LIS Blue Plan in both the Phase I and II areas. Figure 4-5 illustrates the locations of *Astrangia* in the Phase I area and those identified in the current Phase IIIA project.

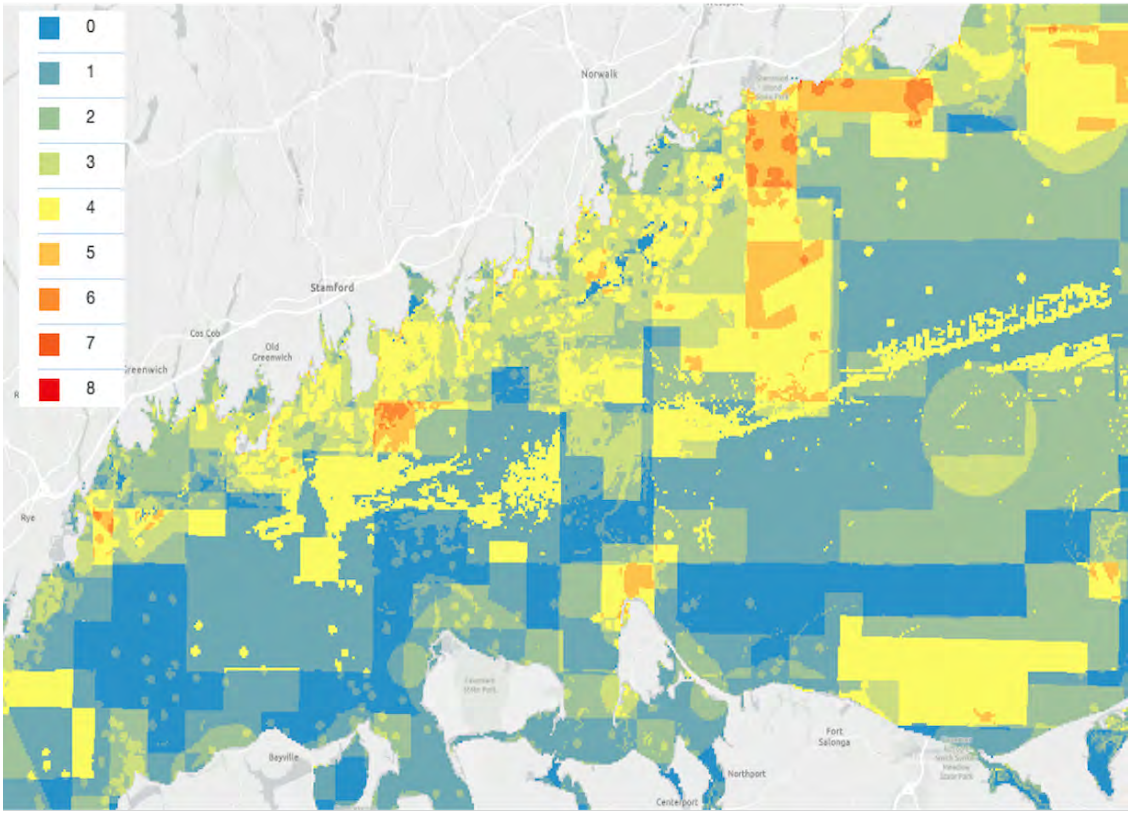

Figure 4-4 Map of western LIS from the Blue Plan showing areas with variable available data contributing to the identification of ESA's.

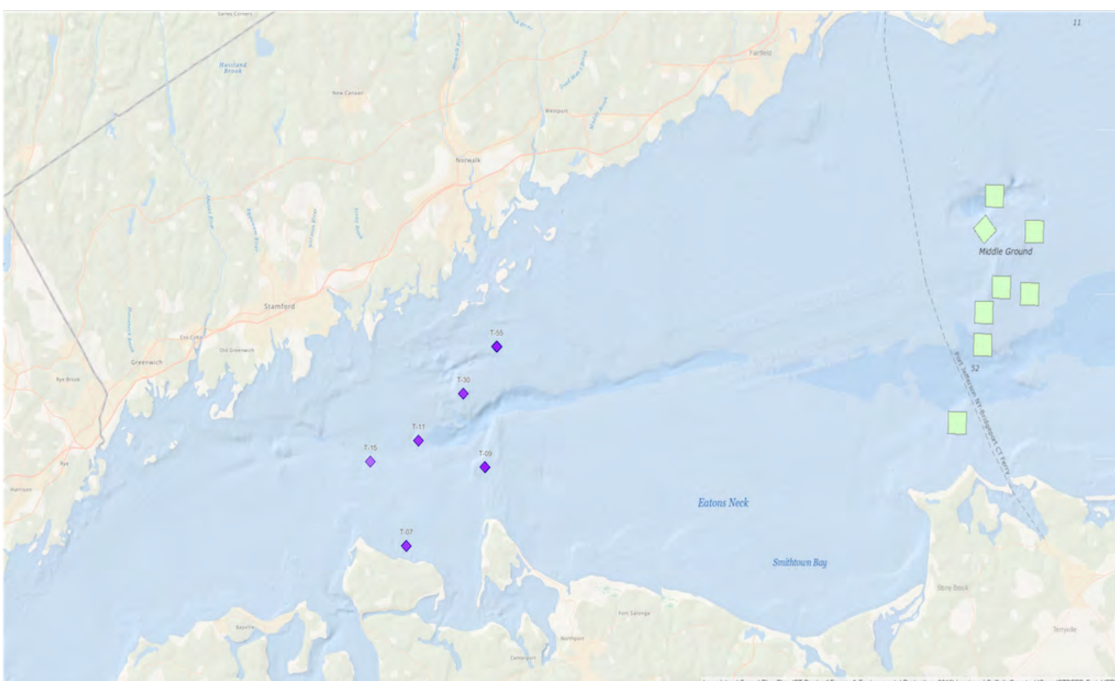

Figure 4-5 Map showing the locations of Astrangia poculata identified in the LISCF Phase I (green rectangles) and III (purple diamonds) areas of Long Island Sound.

5.0 References

Connecticut Department of Energy and Environmental Protection. (2019). Long Island Sound
Blue Plan. Hartford, CT.

Feldens, P., Schulze, I., Papenmeier, S., Schonke, M., & von Deming, J.S. (2018). Improved Interpretation of Marine Sedimentary Environments Using Multi-Frequency Multibeam Backscatter Data. *Geosciences*, 8(6), 214. **https://doi.org/10.3390/geosciences8060214**

Fenstermacher, L.E., Crawford, G.B., Borgeld, J.C., Britt, T., George, D.A., Klein, M.A., Driscoll, N.W., & Mayer, L.A. (2001). Enhanced Acoustic Backscatter Due to High Abundance of Sand Dollars, *Dendraster excentricus. Marine Georesources & Geotechnology*, 19(2), 135-145. https://doi.org/10.1080/10641190109353808

Ferrini, V. L., & Flood, R. D. (2006). The effects of fine-scale surface roughness and grain size on 300 kHz multibeam backscatter intensity in sandy marine sedimentary environments. *Marine Geology*, 228(1-4), 153-172.

Jumars P. (1993). Concepts in biological oceanography: an interdisciplinary approach. Oxford University Press, New York

Kostylev, V.E., Todd, B.J., Fader, G.B.J., Courtney, R.C., Cameron, G.D.M., and Pickrill, R.A. (2001) Benthic habitat mapping on the Scotian Shelf based on multibeam bathymetry, surficial geology and sea floor photographs. *Marine Ecology Progress Series*, 219, 121-137.

Lurton, X.; Lamarche, G. (Eds) (2015) Backscatter measurements by seafloor-mapping sonars. Guidelines and Recommendations. 200p. http://geohab.org/wp-content/uploads/2014/05/BSWGREPORT-MAY2015.pdf

McMullen, K.Y., Poppe, L.J., Paskevich, V.F., Doran, E.F., Moser, M.S., Christman, E.B., & Beaver, A.L. (2005). LISSEDDATA: Long Island Sound Surficial Sediment Data. Open-File Report, 2005-1018. U.S. Geological Survey, Coastal and Marine Geology Program, Woods Hole, MA. <http://pubs.usgs.gov/of/2005/1018/data/seddata/lisseddata.zip>.

Nitsche, F. O., Bell, R., Carbotte, S. M., Ryan, W. F., & Flood, R. D. (2004). Process-related classification of acoustic data from the Hudson River Estuary. *Marine Geology*, 209, 131-145.

Pellegrino, P & Hubbard, W. (1983) Baseline shellfish data for the assessment of potential environmental impacts associated with energy activities in Connecticut's coastal zone. Vols I & II. Report to the State of Connecticut, Department of Agriculture, Aquaculture Division, Hartford, CT.

Poppe, L. J., Knebel, H. J., Mlodzinska, Z. J., Hastings, M. E., & Seekins, B. A. (2000). Distribution of surficial sediment in Long Island Sound and adjacent waters: texture and total organic carbon. *Journal of Coastal Research*, 567-574.

Reid RN, Frame AB, Draxler AF (1979) Environmental baselines in Long Island Sound, 1972-1973. National Oceanic and Atmospheric Administration, Technical Report SSRF-738, 31 pp.

Urgeles, R., Locat, J., Schmitt, T., & Clarke, J.E.H. (2002) The July 1996 flood deposit in the Saguenay Fjord, Quebec, Canada: implications for sources of spatial and temporal backscatter variations. *Marine Geology*, 184, 41-60.

Wildish D.J., Kristmanson D. (1997) Benthic suspension feeders and flow. Cambridge University press, New York

Appendix 1 – Summary of Forward-Looking GoPro Videos

Appendix 2 - Summary of the attributes (transects surveyed, source video, time of capture, location) of all 727 captured images.

Appendix 3 – Summary of source video, time of image capture, location of the image capture and other data for each of the images analyzed.

Appendix 4 - Summary table of all attributes for each of the transects

Appendix 5 - Summary of the percent cover of species observed in each of the analyzed images for a broad set of taxa.

Appendix 6 - Summary of the percent cover of all substrate types in all of the images analyzed.

Appendix 7 - Summary of all seafloor structures observed in the images analyzed.