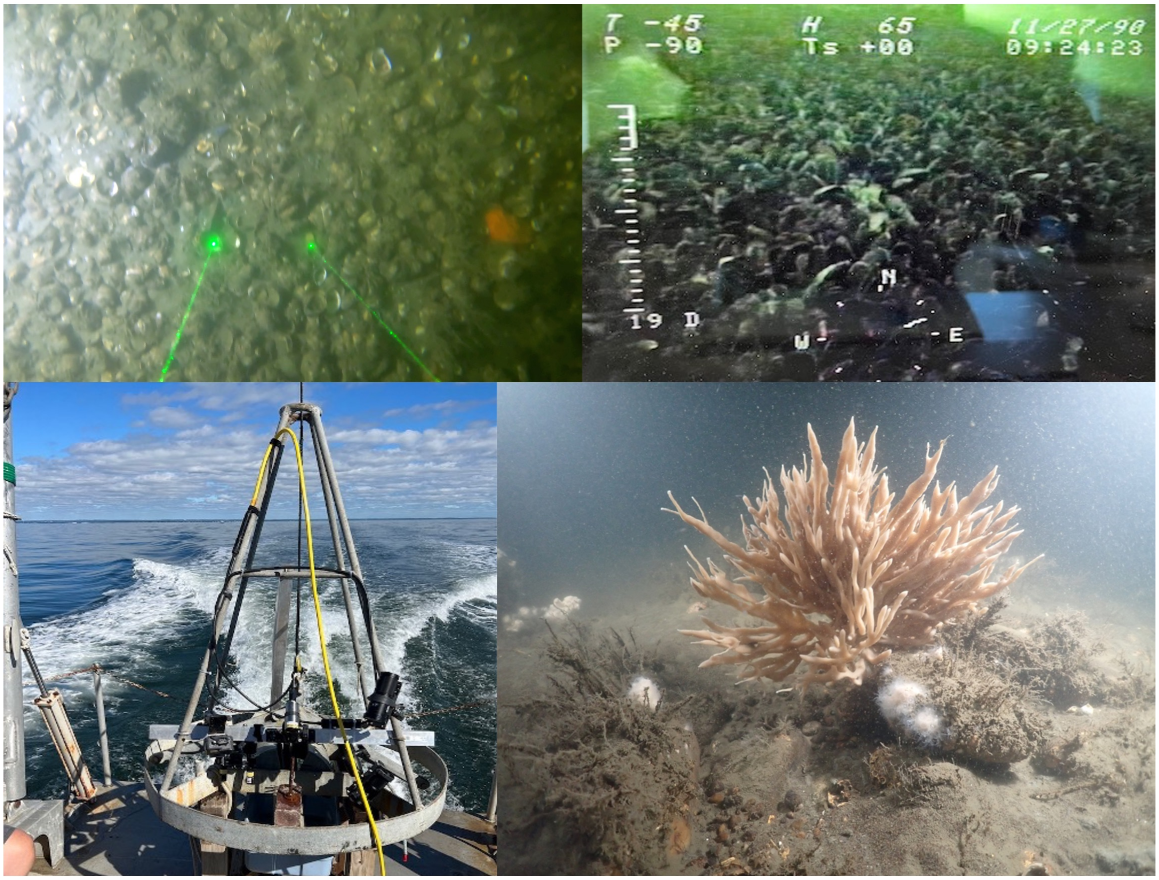
Assessing Ecological Change and Resiliency (AECR) in Long Island Sound



Final Report

Submitted by:
The Long Island Sound Mapping and Research Collaborative (LISMaRC)

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Long Island Sound Study
A Partnership to Restore and Protect the Sound

Connecticut Department of
ENERGY & ENVIRONMENTAL PROTECTION

Project Title: Assessing Ecological Change and Resiliency (AECR) in Long Island Sound

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Report Authors: Peter Auster[1,2], Ivar G. Babb[1], Chris Conroy[3] , Catherine Matassa[1], Roman Zajac[3]

1. University of Connecticut
2. Mystic Aquarium
3. University of New Haven

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EXECUTIVE SUMMARY

Introduction

Background

- Numerous studies indicate significant ecological changes are occurring globally in coastal environments in response to climate related factors, such as rising temperatures and sea level, and to local scale human activities.
- Ecological changes have also been observed in benthic soft sediment communities but have not been as well studied as in other coastal environments.
- Little is known about climate-related changes that may be occurring in the benthic habitats of Long Island Sound (LIS).
- Data collected by the Long Island Sound Mapping and Research Collaborative (LISMaRC) in both the Phase I and Phase II components of the Long Island Sound Cable Fund (LISCF) Seafloor Habitat Mapping Initiative in the Stratford Shoal area and eastern portion of LIS revealed that ecological changes have occurred based on historical data available for multiple sites in these areas. These changes include apparent shifts from blue mussel (*Mytilus edulis*)-dominated habitats to slipper shell limpets (*Crepidula* spp.) in eastern LIS between the late 1990s and 2017, the disappearance of branching sponge-dominated habitats in the Stratford Shoal area between 2010-2014, and the possibility that the decline in mussels observed in the Phase II area could be more widespread and include sites with high densities observed in the Phase I area.

Objectives

Three specific objectives were identified to address this overarching goal of determining ecological change or resilience:

- Have there been long-term changes in populations of the blue mussel and/or the slipper shell in both Phase I and II areas?
- Has the branching sponge decline observed during the Phase I project persisted or has there been recovery?
- Have declines in the mussel populations observed in the Phase II area also affected the dense populations observed in the Phase I study?

The presence of several other taxa were also observed in the historical and modern records, however, a detailed discussion of any population changes in these species was deemed beyond the scope of this supplemental LISCF-sponsored project.

Methods

Review of Historical/archival Data

The preponderance of significant historical data collected by and institutional memory of project personnel on benthic communities in LIS set the stage for this assessment of possible long-term shifts or stasis in the populations of the identified key taxa. The following historical sources were reviewed:

- Previously published and unpublished data from 1971 to 2018 were analyzed for information on the status of the three taxa,
- Historical images and field logbooks of divers (Peter Auster and Robert DeGoursey) collected over four decades in eastern LIS,
- Historical video collected by remotely operated vehicles (ROVs) operated by the National Undersea Research Center at the University of Connecticut going back to 1988, primarily in eastern LIS,
- Decade + old data collected by the LISCF-funded Phase I project in central LIS in 2012 and 2013.
- The more recent results (2017 and 2018) of the Phase II LISCF project were also reviewed.

Acquisition of New Imagery and Benthic Data

The review of the historical sources listed above for population status of the three key taxa was the basis for the selection of a small number of sites (3 in Phase I, 13 in Phase II) to be re-sampled using a variety of technologies. These included:

- Video and sediment samples collected by the Ponar Imaging and Sampling System for Assessing Habitat (PISSAH) developed for this project deployed from the RV Weicker at 18 sites (5 in Phase I and 13 in Phase II),
- Underwater images collected by divers at two sites in the Phase I and two in the Phase II areas,
- High definition (4K) video obtained by the newly acquired Boxfish ROV (Long Island Sound Study and Connecticut Sea Grant-funded) at one deeper water site in eastern Fishers Island Sound (within the Phase II area).

Comparison Across Time Series

- Due to the mix of data sources, sampling methods, and periods of observation, the approach to compare historical to newly acquired imagery was an assessment of presence-absence of the identified key taxa.

Results

Large-Scale Shift in Key Taxa in the Phase I and II Areas – *Mytilus* and *Crepidula*

1. The review and analysis of publications, technical reports and data archives presented mixed results regarding the populations of these two key taxa with the following trends observed:

    - In the early 1970's high abundances of *Mytilus* were observed in the western Sound, low in the east,
    - In the 1980's low densities were observed in the west and central Sound, with higher numbers in the east,

- In 1990 and 2003 moderate to low densities in the west and variable in the east,
- The Phase I study showed high densities in the northern Stratford Shoal area,
- The Phase II revealed very low numbers, with most sites reporting zero.

2. Analysis of 2022 Grab Samples Acquired by the PISSAH

- Only three sites (Ram Island Reef, Latimer Light, NAGL 06-11) had the presence of *Mytilus*, while none were observed in any of the other 15 sites,
- Lower densities of *Crepidul*a were found in the 2022 samples compared to the 2017 and 2018 Phase II study area,
- No *Crepidula* were found in the grab samples from the Phase I area.

3. Analysis of 2022 Imagery Collected by the PISSAH

- New imagery revealed the presence of *Crepidula* in 14 of the 18 newly re-sampled sites,
- There was a marked increase in percent cover of *Crepidula* from the new imagery compared to the 2017 and 2018 surveys in the Phase II area,
- *Crepidula* also increased in the Phase I area
- No *Mytilus* were observed in any of the images analyzed from the 2022 PISSAH imagery.

4. Review of Historical Images and Logbooks

- *Mytilus* was observed in 38 of the 57 logbook entries
- No Crepidula were observed in the logbooks
- *Mytilus* was noted in four of the eight sites with historical imagery in the late 1970's and early 1980's,
- *Mytilus* was observed in only one site in the late 1980's.

5. Review of Historical ROV Video

- *Mytilus* was present in nine of the 13 videos analyzed from 1989 to 2006,
- No *Crepidula* was observed in any of the 13 videos analyzed.

6. Review of Newly Acquired ROV Video

- No *Mytilus* or *Crepidula* were observed in the two dives conducted in the deeper water of eastern Fishers Island Sound.

Evidence of Ecosystem Resilience in the Phase I Area – the Recovery of *Haliclona oculata*

1. Review of Newly Acquired PISSAH and Diver Imagery

- *Haliclona* was observed in two of the five sites re-visited in the Phase I area, compared to none in 2012 and 2013,
- *Haliclona*, when present in the 2022 imagery, always co-occurred with the star coral *Astrangia* and with the invasive tunicate *Didemnum* in most samples.

Evidence of Ecosystem Change in the Phase I Area – the Apparent Loss of *Mytilus edulis*

1. Review of 2012 and 2013 LISMaRC Phase I Data

    - Analysis of imagery from both years showed high densities of *Mytilus*, ranging from 60-100% cover in the troughs of the large sand waves in the north of the area to 0-20% on the ridges

2. Review of Newly Acquired PISSAH and Diver Imagery

    - *Mytilus* was completely absent from both PISSAH and diver imagery analyzed,
    - *Crepidula* showed a marked increase in density in two of the four PISSAH sites and one of the two diver sites.

Summary

- Based upon the review and comparison of historical and newly acquired imagery and data there has been a large-scale decline in *Mytilus* populations since the mid-2000's in the Phase II area and at some time after 2013 in the Phase I area,
- It appears that there has also been a long-term increase in *Crepidula* populations in both the Phase I and Phase II areas,
- At this present time it appears that the branching sponge *Haliclona* is beginning to recover in the Phase I area,
- The high densities of *Mytilus* observed in the Phase I study (2012 and 2013) were zero in this recent study,
- Recent imagery from the PISSAH and divers showed an increase in the density of *Crepidula* from the Phase I study.

Conclusions and Recommendations

- Long-term ecological changes are occurring in Long Island Sound,
- Recommend that permanent study areas be established now using the current sites to establish both a long-term and recent baseline upon which to monitor these changes.

1 INTRODUCTION

1.1 Background

Significant ecological changes are occurring globally in coastal environments in response to local scale human activities and to climate related factors such as rising temperatures and sea level, and (Valiela, 2006; Halpern et al., 2008; He and Silliman, 2019; Murray et al., 2019). Shifts in ecological communities and ecosystem function have been observed in a variety of habit types including salt marshes (FitzGerald and Hughes, 2019; Campbell et al., 2022), mangroves (Cavanaugh et al., 2019), coral reefs (Hoegh-Guldberg, 2011), kelp forests (Smale, 2020), and pelagic systems (Holland et al., 2020). Ecological changes have also been observed in benthic soft sediment communities (Hewitt et al., 2016; Ehrnsten et al., 2020, Thrush et al., 2021), but have not been as well studied as in other coastal environments.

In Long Island Sound (LIS), climate related changes have been documented for fish (Howell and Auster, 2012; Crosby et al., 2018), planktonic communities (Rice et al., 2015), salt marsh flora (Warren and Niering, 1993, Carey et al., 2017) and fauna (Field et al., 2014; Zajac et al., 2017, 2022). Little is known about climate-related changes that may be occurring in the benthic habitats of LIS. Thomas et al. (2000) have documented changes in benthic foraminiferal communities. Snyder et al. (2019) found changes in the dominant crustaceans living on the seafloor in an area of eastern LIS. Zajac (1998) reviewed information available at the time on benthic infaunal communities and found that general community types appear to be consistent in the central basin of LIS, but longer-term changes may have occurred in the populations of some of the dominant organisms in this area. For other areas of the Sound, however, Zajac (1998) found that information was lacking to assess any longer-term ecological trends. Stefaniak et al. (2014) documented the loss of the branching sponge *Haliclona oculata* on Stratford Shoal in the central/western portion of LIS, but it could not be determined if this was a short-term fluctuation in its population or a longer-term shift in epibenthic community structure.

Data collected by the Long Island Sound Mapping and Research Collaborative (LISMaRC) in both the Phase I and Phase II components (Figure 1-1) of the Long Island Sound Cable Fund (LISCF) Seafloor Habitat Mapping Initiative in the Stratford Shoal area and eastern portion of LIS, respectively, revealed that ecological changes have occurred based on historical data available for multiple sites in these areas. The Final Reports for these two Phases are available on the LISMAP web page (https://lismap.uconn.edu). A Story Map highlighting the changes in the Phase I portion of the study was also developed that describes the nature of the observed changes (https://connecticut.maps.arcgis.com/apps/Cascade/index.html?appid=10ca1af4fd2e432bb3e7fb8b18b0cc38). These changes include: a) apparent shifts from blue mussel (*Mytilus edulis*)-dominated habitats to slipper shell limpets (*Crepidula* spp.) in eastern LIS between the late 1990s and 2017, b) the disappearance of branching sponge-dominated habitats in the Stratford Shoal area between 2010-2014 as noted by Stefaniak et al., 2014 and c) the possibility that the decline in mussels observed in the Phase II area could be more widespread and include sites with high densities observed in the Phase I area (see also sections from the LISMaRC Final Reports from Phase I Stefaniak and Auster, 2015 and Phase II Conroy et al., 2021).

Figure 1 1 Map of Long Island Sound showing the Phase I and II areas.

1.2 Objectives

The purpose of this project was to further examine historical data and conduct additional field observations of the Phase I and II seafloor mapping areas to better understand the observed ecological changes that have occurred and the spatial and temporal dimensions of these changes. The basis for this work is identification of large-scale shifts in the benthic communities of eastern and west-central LIS and potential indicators of ecosystem resilience in the Stratford Shoal region of central/western LIS. These trends raise important questions about patterns of stability and change occurring in LIS. Understanding the spatial and temporal scales of these changes is a critical element for the development and application of spatial data products currently being developed by the LISCF Seafloor Habitat Mapping Initiative as decision support tools to better manage the Sound. Specific objectives for this project included:

1.2.1 Phase I and II Areas – Large Scale Shift in Benthic Community Components?

Assess potential long-term changes in the populations of the mussel *Mytilus edulis*, and the slipper shells *Crepidula fornicata* and *C. plana* in LIS focusing on the Phase I and II areas, based on historical data and the collection of new data at selected locations in the Sound, and compare these results to temporal changes reported for other organisms in LIS.

1.2.2 Phase I Area – Is There Evidence of Ecosystem Resilience?

Determine whether the disappearance of branching sponge habitats represents ongoing cyclical population increases and declines, whether an important component of seafloor habitat and biodiversity has been lost, and, if so, what may be the individual or cumulative mechanisms responsible.

1.2.3 Phase I Area – Large Scale Shift in Benthic Community?

> Determine whether the observed shift in blue mussel populations seen in eastern LIS (Phase II area) may be part of a broader pattern of change in blue mussels found in other areas of LIS, specifically the Phase I area where dense mussel beds were observed in 2012 and 2013.

Our focus is on several potential "indicator" species (e.g. Moraitis et al., 2019), including the blue mussel *Mytilus edulis*, the slipper shell species *Crepidula fornicata* and *C. plana*, and the finger sponge, *Haliclona oculata*. The loss of blue mussels has been observed in several marine ecosystems (Ford and Hamer, 2016; Sorte et al., 2017; Christie et al., 2020) and is sensitive to a variety of environmental and ecological conditions that can lead to population decline and associated loss of habitat and biodiversity (Mainwaring et al., 2014). *Crepidula fornicata* is native to the east coast of North American but has become a very successful invasive species in other parts of the world, reaching extremely high densities in some cases (Blanchard, 1997, 2009). Close to LIS in Peconic Bay, NY, it has been found to be increasing in numbers in areas that had been dominated by other species of filter feeding bivalves (Lewis et al., 1997). *C. fornicata* has been shown to reduce growth and survivorship in mussels (Thieltges, 2005), have mixed impacts on macrobenthic communities (de Montaudouin et al., 1999, 2018), and negatively impact juvenile demersal fish density (Le Pape et al., 2004). *Haliclona oculata* populations have been found to be stable over years (e.g. Kluijver & Leewis, 1994; Ginn, 1997; Bell et al., 2006; Koopmans & Wijffels, 2008), although three large-scale die-offs have been documented in the literature (i.e., off Wales that was attributed to disease, off the Netherlands attributed to high temperatures, and at Stratford Shoal in LIS, with hypotheses for multiple drivers; see Webster, 2007; Koopmans & Wijffels, 2008; Stefaniak et al., 2014).

While the taxa listed above were the target of our study, we noted other taxa that were present in the historical records as well as the recent surveys of eastern and central LIS. These species included the boring sponge *Cliona celata*, the frilled anemone, *Metridium senile*, the northern star coral, *Astrangea poculata*, and the invasive tunicate, *Didemnum vexillum*. In some cases, we noticed high densities of sea stars (*Asterias spp)*. and kelps. The occurrence of these taxa is listed in data tables in Appendix One - Historical Data Sources and Appendix Two - Recent Data Sources, though more detailed discussion of their spatial or temporal trends is beyond the scope of this report.

2 MATERIALS AND METHODS

2.1 2.1 Review of Historical/archival Data

To address the three objectives, we collected and reviewed published data, research cruise logbooks, archived analog images, and videotapes from a variety of sources listed below. The data, images, and videos were analyzed for presence/absence of the key taxa ("indicator species") noted above and the results were compiled in standardized spreadsheets.

2.1.1 Review and Analysis of Historical Data from Publications, Technical Reports and Data Archives

Data were collected from benthic surveys conducted in LIS between 1971 and 2018. The abundances and spatial distributions of *Mytilus edulis*, *Crepidula fornicata* and *C. plana* were exported from these data sources into separate data files and imported into a Geographic Information System (GIS). GIS maps were compared to determine any temporal changes in their abundance and distribution across the Sound. Several other historical studies were reviewed for information on these species using information in Zajac (1998). Several statistical analyses were conducted using data from Phase II of the LIS Seafloor Habitat Mapping Initiative to assess the relationships between the density of *C. fornicate*, several measures of species diversity, and their relative abundance in different community types identified in eastern LIS. Details of the statistical analyses are given in the results section.

2.1.2 Review of Historical Images and Field Logbooks

Underwater image collections from Dr. Peter Auster (report co-author) and Robert DeGoursey (former University of Connecticut Dive Safety Officer), were examined for dives, in the Phase II area. Only those dives where seafloor fauna were described were recorded. Images were not collected in any systematic fashion on most dives, which produced general records of characteristic fauna and associated habitats at each site. Logbook entries listed species present that were dominant and do not reflect a complete census of rare or cryptic species. Target taxa assessed from images and logbooks were the three target taxa *Mytilus, Crepidula,* and *Haliclona.* These data were also reviewed for the other key taxa identified above*: Cliona, Metridium, Asterias, Laminaria, Astrangia* and *Didemnum*.

2.1.3 Historical Video from National Undersea Research Center Supported Dives

Prior to the LISCF the National Undersea Research Center (NURC) at the University of Connecticut conducted 194 dives in LIS in support of multiple projects dating back to 1987. We reviewed historical videotapes from the Phase I and Phase II areas to provide baseline community structure dating back over three decades. Representative video clips were encoded from archived analog videotapes and uploaded to YouTube and then referenced in an ArcGIS online map to allow access to the video clips by project partners (https://connecticut.maps.arcgis.com/apps/mapviewer/index.html?webmap=a96769188c42467a900189443f323b28). There were 13 dive sites identified for this review spanning from 1989 to 2006. Figure 2-1 illustrates the relationship of NURC project metadata and Figure 2-2 provides a sample of the imagery acquired from the video archive.

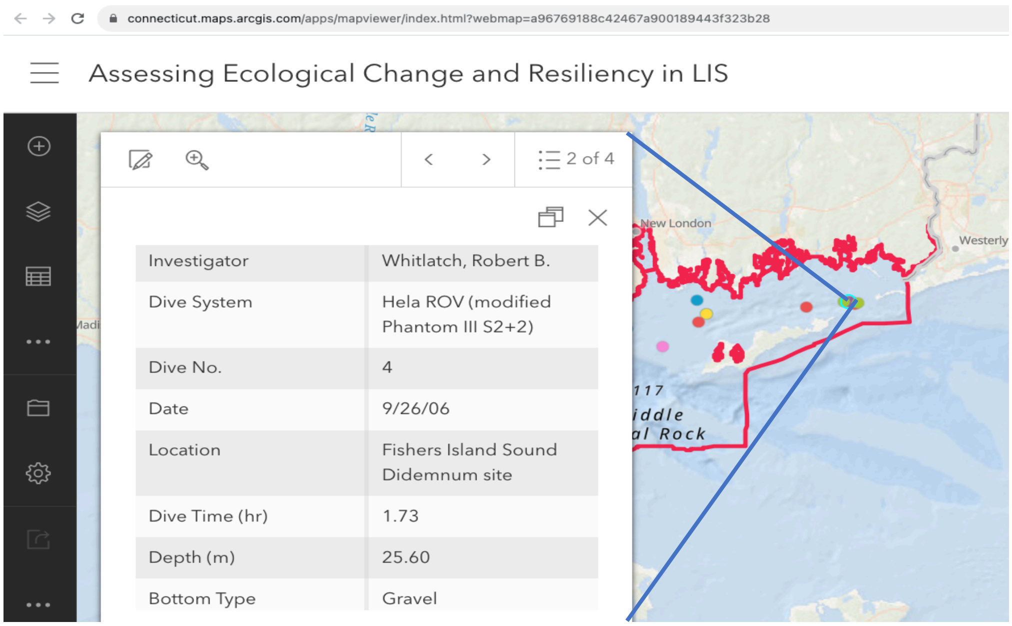


Figure 2-1 ArcGIS online map of a Phase II sample site with associated metadata from a historical survey conducted in 2006 by Robert Whitlatch.

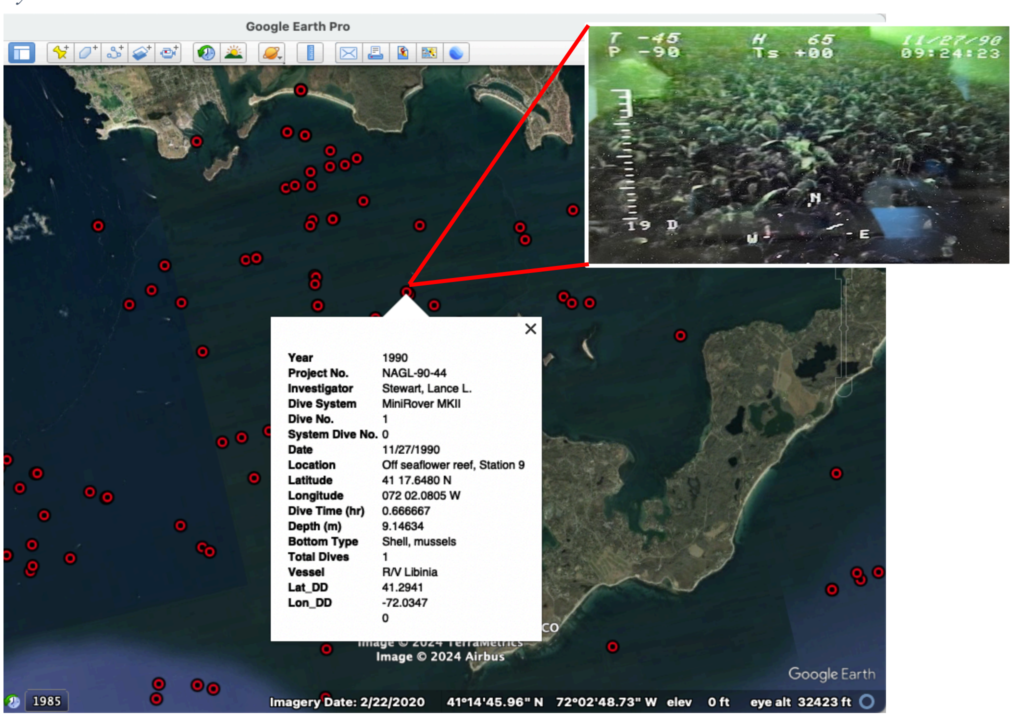


Figure 2-2 Map illustrating available metadata for a historical (1990) ROV dive with an inset of a frame capture from that dive showing a dense bed of large mussels (Mytilus edulis).

2.2 Acquisition of New Imagery and Benthic Data

2.2.1 Site Selection for Acquisition of New Imagery

Locations for the acquisition of new imagery were determined by the review of the archival data described above and records from the previous Phase I and Phase II components of the LISCF Seafloor Habitat Mapping Initiative in the areas of Stratford Shoal and eastern LIS (Figure 2-3). The presence of the key taxa identified above was the key criterion for site selection. A total of 13 sites were identified in the Phase II area and three in the Phase I area to compare the current status of communities to historical records (Table 2-2 and Figure 2-4).

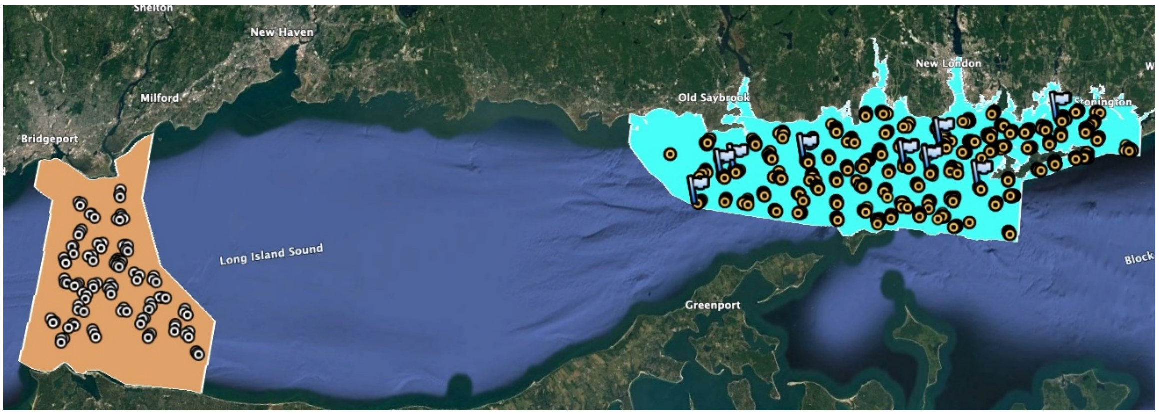


Figure 2-3 Map showing the location of the Phase I (orange) and Phase II (cyan) areas with locations of sites where images were acquired using the USGS Seabed Observation and Sampling System (SEABOSS) (dots) and the NURTEC K2 ROV (flags).

Table 2-1 1 Site names and locations identified for acquisition of new seafloor imagery.

Site No	Project Phase	Site Name	Lon DecDeg	Lat DecDeg
1	Phase 2	NB59-2, S of Fishers	-71.960573	41.271415
2	Phase 2	SB68, N of Fishers by Dumpling	-72.028412	41.280597
3	Phase 2	NB51, S of Bluff Point	-72.030357	41.301297
4	Phase 2	SB 72-2, near Latimer light	-71.916782	41.31226
5	Phase 2	SB 46-2; middle of Phase II area	-72.257185	41.227397
6	Phase 2	NB 56, off north shore of Fishers Island	-71.995303	41.281983
7	Phase 2	NAGL-90-44 and NAGL-91-25, Seaflower Reef	-72.034675	41.2941333
8	Phase 2	NAGL-06-11, Whitlatch Dive#6	-71.9014	41.3027983
9	Phase 2	NAGL-06-11, Whitlatch Dive#7	-71.913995	41.30372
10	Phase 2	Ellis Reef	-71.955641	41.314499
11	Phase 2	North Dumpling	-72.019802	41.287472
12	Phase 2	Latimer Light Reef	-71.93347	41.3046
13	Phase 2	Ram Island Reef	-71.9746	41.3062

14	Phase 1	SB-05E, Northern sand waves	-73.1179	41.1134
15	Phase 1	SB-12E, Boulder area	-73.0744	41.0746
16	Phase 1	SB11, Crepidula site	-73.1084	41.0753
17	Phase 1	SB-21 Rocky sponge site	-73.1107	41.0419

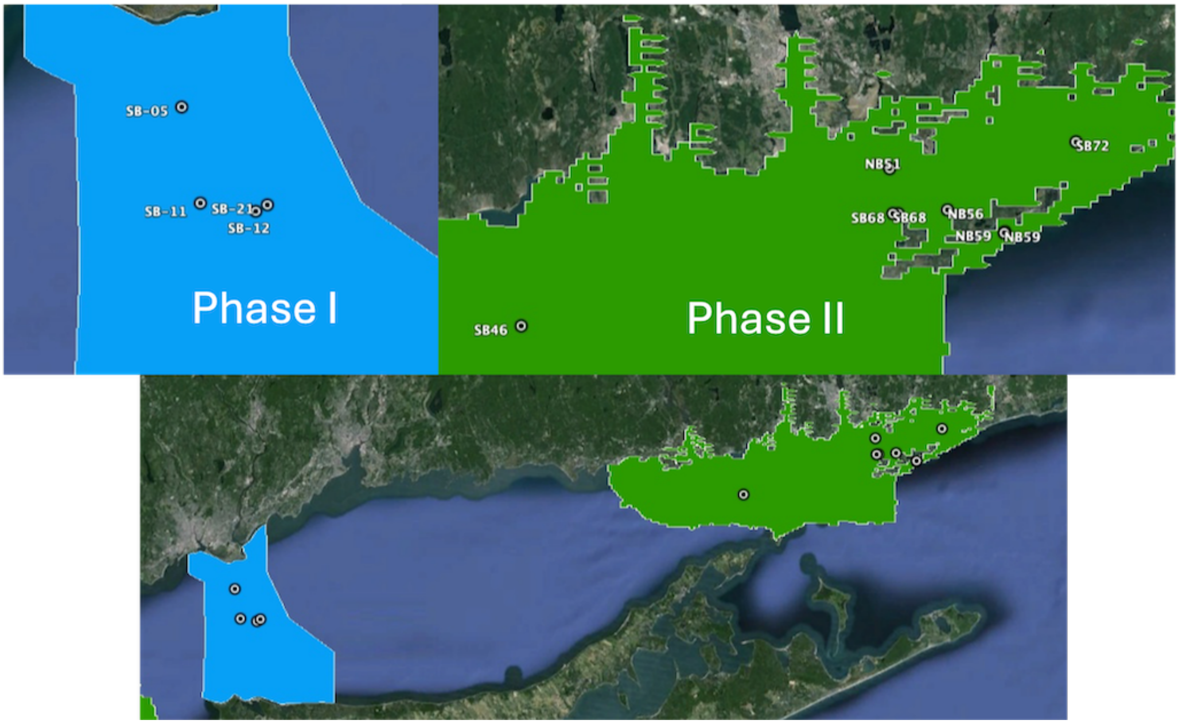


Figure 2-4 Map of the Phase I and II areas showing location of original sample sites that were re-sampled by the AECR project in 2022.

2.2.2 Development of the Ponar Imaging and Sampling System for Assessing Habitats (PISSAH)

A new image and benthic sampling system, a Ponar grab modified by adding mounting points for cameras, lights and parallel lasers was developed to provide data on the presence/absence of the key taxa. A standard definition video camera used on NURTEC’s Kraken 2 ROV was identified as the best choice for a “pilot” camera to provide a live feed to the surface to monitor the system location/height from the seafloor to improve the image acquisition and also determine where bottom samples might be taken to collect voucher and infaunal specimens (similar to the sampling protocol used in Phase I and Phase II using the USGS SEABOSS). Two new GoPro 10 cameras (23 Megapixel) along with two 8200 lumen dive lights and two green lasers to provide image scaling were acquired to provide high resolution video acquisition with laser scaling as the core imaging system (Figure 2-5).

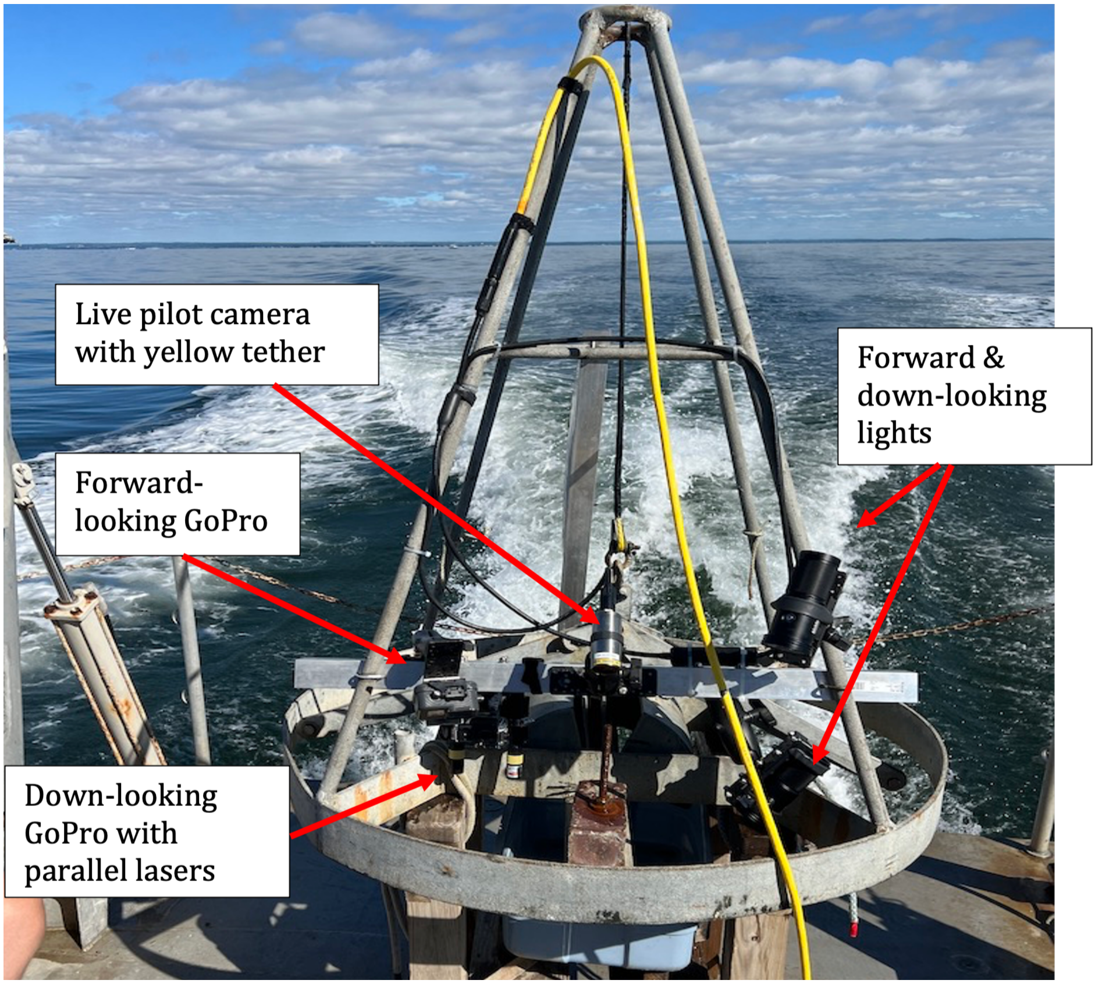


Figure 2-5 The PISSAH deployed on the RV Lowell Weicker with imaging and sampling components highlighted.

2.2.3 Acquisition of New Imagery – RV *Lowell Weicker* PISSAH Field Campaign

The acquisition of new imagery, based upon the review of historical data and subsequent site selection outlined above, took place September 19-21, 2022. The operation entailed lowering the PISSAH to ~1 meter off the bottom, guided by the real-time pilot camera, for a five-minute drift over the seabed to acquire video imagery from both GoPro cameras, culminating with lowering the system to the seafloor to take a grab sample. Table 2-3 provides the actual sample sites surveyed, indicating the target site/Phase, along with information on the grabs collected and reference to the down-looking video GoPro files that formed the basis of the analysis of the seafloor community status as part of the temporal comparison.

Table 2-2 1 Location and sample/video information collected on the RV Weicker/PISSAH cruise in September, 2022.

Site#	Phase	Site Name	Lon DecDeg	Lat DecDeg	Grab Info	Downward video filename
1	2	NB59-2, S of Fishers	-71.96057	41.2714	2 Samples – Surface Collection and Cores	GX010012 & GX010013
2	2	SB68, N of Fishers by Dumpling (SBXX)	-72.02841	41.2806	2 Samples – Crepidula Surface and Cores	GX010011
3	2	NB51, S of Bluff Point	-72.03036	41.3013	2 Samples – Crepidula Surface and Cores	GX010002
4	2	SB 72-2 , near Latimer light	-71.91678	41.3123	2 Samples – Crepidula Surface and Cores	GX010008
5	2	SB 46-2; middle of Phase II area	-72.25719	41.2274	1 Sample – Cores	GX010024 & GX020024
6	2	NB 56, off north shore of Fishers Island	-71.9953	41.282	2 Samples – Crepidula Surface and Cores	GX010010
7	2	NAGL-90-44 and NAGL-91-25, Seaflower Reef	-72.03468	41.2941	2 Samples – Crepidula Surface and Cores	GX010003
8	2	NAGL-06-11, Whitlatch Dive#6	-71.9014	41.3028	2 Samples – Surface Collection and Cores	GX010006*
9	2	NAGL-06-11, Whitlatch Dive#7	-71.914	41.3037	1 Sample – Pebbles/Rocks	GX010007*
10	2	Ellis Reef	-71.95564	41.3145	2 Samples – Surface Collection and Cores	GX010014 & GX020014
11	2	North Dumpling	-72.0198	41.2875	1 Sample – Cores	GX010004
12	2	Latimer Light Reef	-71.93347	41.3046	2 Samples – Surface Collection and Cores	GX010009
13	2	Ram Island Reef	-71.9746	41.3062	2 Samples – Surface Collection and Cores	GX010015
14	1	SB-05E, Northern sand waves	-73.1179	41.1134	1 Sample – Cores	GX010023
15	1	SB-12E, Boulder area	-73.0744	41.0746	1 Sample – Cores	GX010018

16	1	SB11? Crepidula site	-73.1084	41.0753	1 Sample – Cores	GX010016
17	1	SB21-2 Rocky Sponge site	-73.1107	41.0419	1 Sample – Entire Grab	GX010017 & GX020017
18	1	SB12 – ROV site	-73.0803	41.0721	1 Sample – Cores	GX010019

2.2.4 Acquisition of New Diver Collected Imagery

Many of the historical sites were originally surveyed by SCUBA diving and therefore, were also re-examined by divers who documented the current status of the communities in several hard to sample areas using a quadrapod and underwater digital cameras. Dr. Auster led the acquisition of new imagery collected in both the Phase I and Phase II areas. Dives were conducted from UConn's RV *Osprey* and were assisted by UConn's Dive Safety Officer, Jeff Godfrey, and project Co-PI, Chris Conroy. Two sites were visited in the Phase I area, one in the south that supported one of the key taxa, the Dead Man's Finger sponge, *Haliclona oculata*; and another in the north that supported large mats of another key taxa, the blue mussel, *Mytilus edulis,* based on surveys conducted during the Phase I Pilot project in 2012 and 2013. Two sites were also the focus of dives in the Phase II area, Ram Island Reef and Ellis Reef, both being topographically challenging to sample using the PISSAH.

Table 2-3 1 Location and image information collected by divers for the AECR project in May, June and August 2023.

Site#	Phase	Site Name	Lon DecDeg	Lat DecDeg	# of Handheld Images	# Quadropod Images
10	2	Ellis Reef	41.31512	-071.95563	36	113
13	2	Ram Island Reef	41.31227	-071.97553	37	100
14	1	SB-05 Northern Stratford Shoal	41.11311	-073.12064	156	
17	1	SB-21 Southern Stratford Shoal	41.03835	-073.10977	34	62

2.2.5 Acquisition of New ROV Collected Imagery

A final survey/comparison of one area in the eastern Fishers Island Sound (FIS) area was conducted using the newly acquired Boxfish ROV (Figure 2-6). This area had been previously surveyed with an ROV (Figure 2-7). The goal of this dive was to document the presence/absence of the several key taxa (*Mytilus*, *Crepidula*, *Cliona*, *Astrangea* and *Metridium*) that had been identified in the previous efforts. This effort also presented an opportunity to develop procedures for operating the new observation class ROV from the smaller, more affordable RV *Lowell Weicker* for use in upcoming mapping efforts (e.g., Phase IIIB). The one-day survey was conducted on October 18, 2023, in an area known as the “deep hole” east of Latimer Light Reef (Figure 2-7), (note the ROV tracking system was unable to record the “snail trail” location of the path traveled).

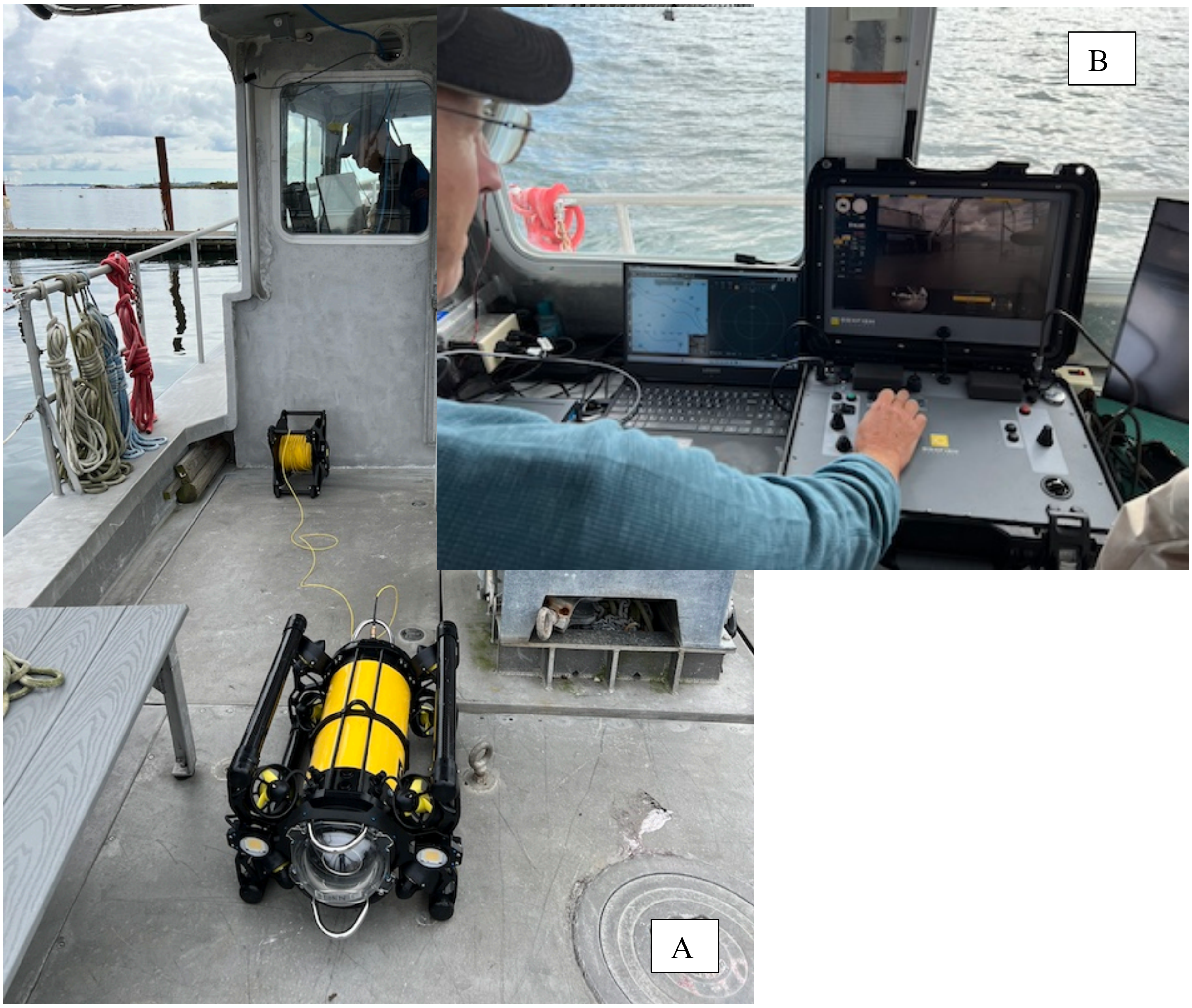


Figure 2-6 A - The Boxfish ROV acquired with funding from the Phase IVB project with its tether reel acquired with development funds from the CT Sea Grant program, B – The portable topside control console for the ROV.

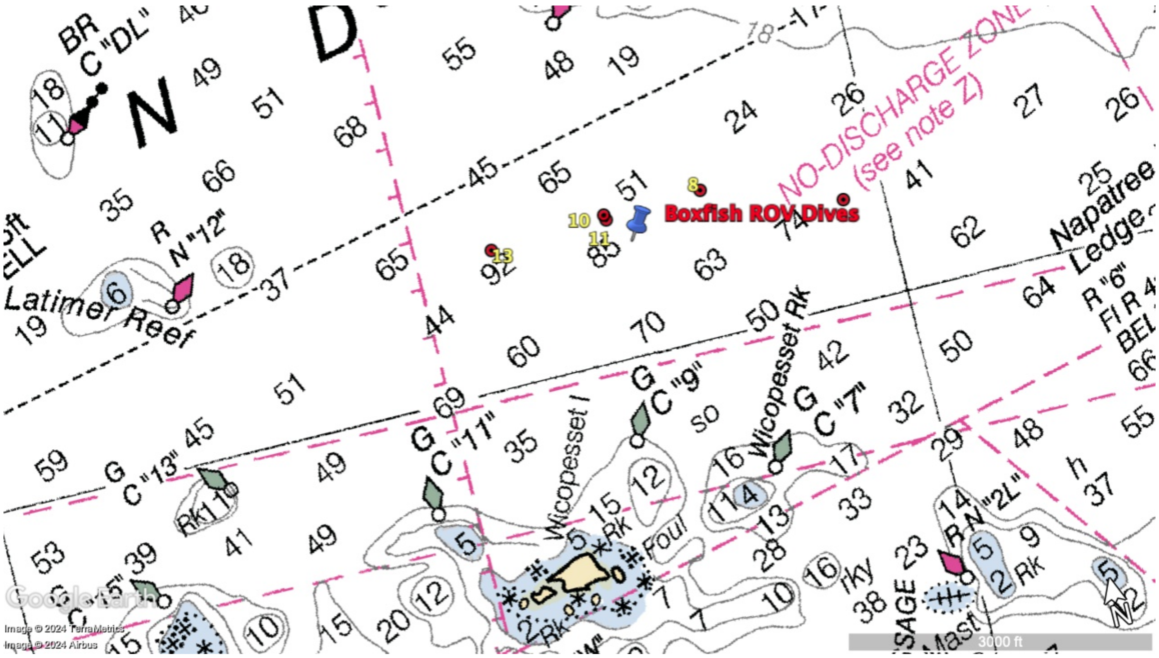


Figure 2-7 Map of the eastern FIS indicating the numbered locations of previous ROV surveys (see Table 3-3 for dive site information for numbered sites) and the location of the 2023 Boxfish ROV dive indicated by red dots..

2.3 Comparison Across Time Series

Due to the mix of data sources, sampling methods, and periods of observation, the approach to compare historical to newly acquired imagery was an assessment of presence-absence of the identified key taxa. Still and video images from the same areas (historical and new) were examined and key taxa listed as present or absent. The videotapes from the NURTEC archive were digitized and reviewed for presence-absence of the key taxa and representative frame captures taken. A total of 1199 images from the Phase II data were analyzed reviewed for a broad range of taxa. These data were condensed to focus on the key taxa, and their abundances listed since this level of detail was available. The newly acquired video from the PISSAH were analyzed similar to the archived video for presence-absence. The newly acquired ROV video files were similarly analyzed.

3 RESULTS

The overarching approach of the AECR project was to synthesize a comprehensive review of existing historical information on past conditions of LIS with newly acquired data to provide a long-term (decadal-scale) comparison of key taxa to assess ecological change and/or resiliency.

3.1 Large-Scale Shifts in Key Taxa: – *Mytilus* and *Crepidula*

The presence or absence of two key taxa, *Mytilus edulis* and *Crepidua fornicata,* from the historical sources were compared to the more recent observations made in geographically similar areas of the Sound. The following data sources were utilized to address this objective of the project.

3.1.1 Review and Analysis of Historical Data from Publications, Technical Reports and Data Archives

Based on data provided in several benthic surveys conducted between the early 1970s to the early 2000's (Table 3-1), the distribution and abundance *Mytilus edulis* in deeper water (~> 5 m) habitats of LIS varied spatially and temporally (Figures 3-1). Relatively high abundances of *Mytilus* were found in the western portion of LIS, whereas densities in the eastern end were low in samples taken between 1972 and 1973 (Reid at al. 1979). Low densities were also found along the Connecticut shore in the central basin of LIS. In the 1981-1982 survey conducted by Pellegrino and Hubbard (1983), low numbers of *Mytilus* were found in the western and central portions of LIS, but high abundances were found in a number of areas in eastern LIS between the Connecticut River and FIS. Surveys conducted between 1990 and 2003 by the EPA, indicated moderate to low densities in the western end of the Sound, and variable abundances in the eastern portion of LIS from deeper waters south of the Connecticut River and north of Long Island, NY. Few *Mytilus* were found in the grab samples collected during the more recent ecological characterizations as part of the LISCF Seafloor Habitat Mapping Initiative. In the Phase II area, a mean (± SD) of 0.076 ± 0.392 per sample was found, with most sites having no mussels in the grab sample.

Table 3-1 1 Sources used to assess long- term changes in populations of mussels and slipper shell in LIS.

STUDY	STUDY DATES	# SITES	SAMPLING INTERVAL	GEAR	SIEVE SIZE
Reid, Frame & Draxler (1979)	1972 - 1973	142	3 sampling dates	0.1 m^2 Sm - Mc	1 mm
Reid (1979)	1975 - 1978	~45	yearly	0.1 m2 Sm-Mc	1 mm
Pellegrino & Hubbard (1983)	1981-1982	413	Summers, once	Van Veen	1 mm
EMAP	1990-1993	36	Summers	0.044 m^2 V Veen	0.5 mm
NCA	2000-2003	38	Summers	0.044 m^2 V Veen	0.5 mm
LIS Habitat Mapping Phase I	2012 & 2013	161	October 2012; May 2013	0.1 m^2 V Veen	0.5 & 1.0 mm
LIS Habitat Mapping Phase II	2017 & 2108	179	Nov/Dec 2017; May 2018	0.1 m^2 V Veen	1.0 mm

EMAP - U.S. EPA Environmental Monitoring and Assessment Program; NCA – National Coastal Assessment; Sm-Mc, Smith McIntyre grab sampler; V Veen, Van Veen grab sampler.

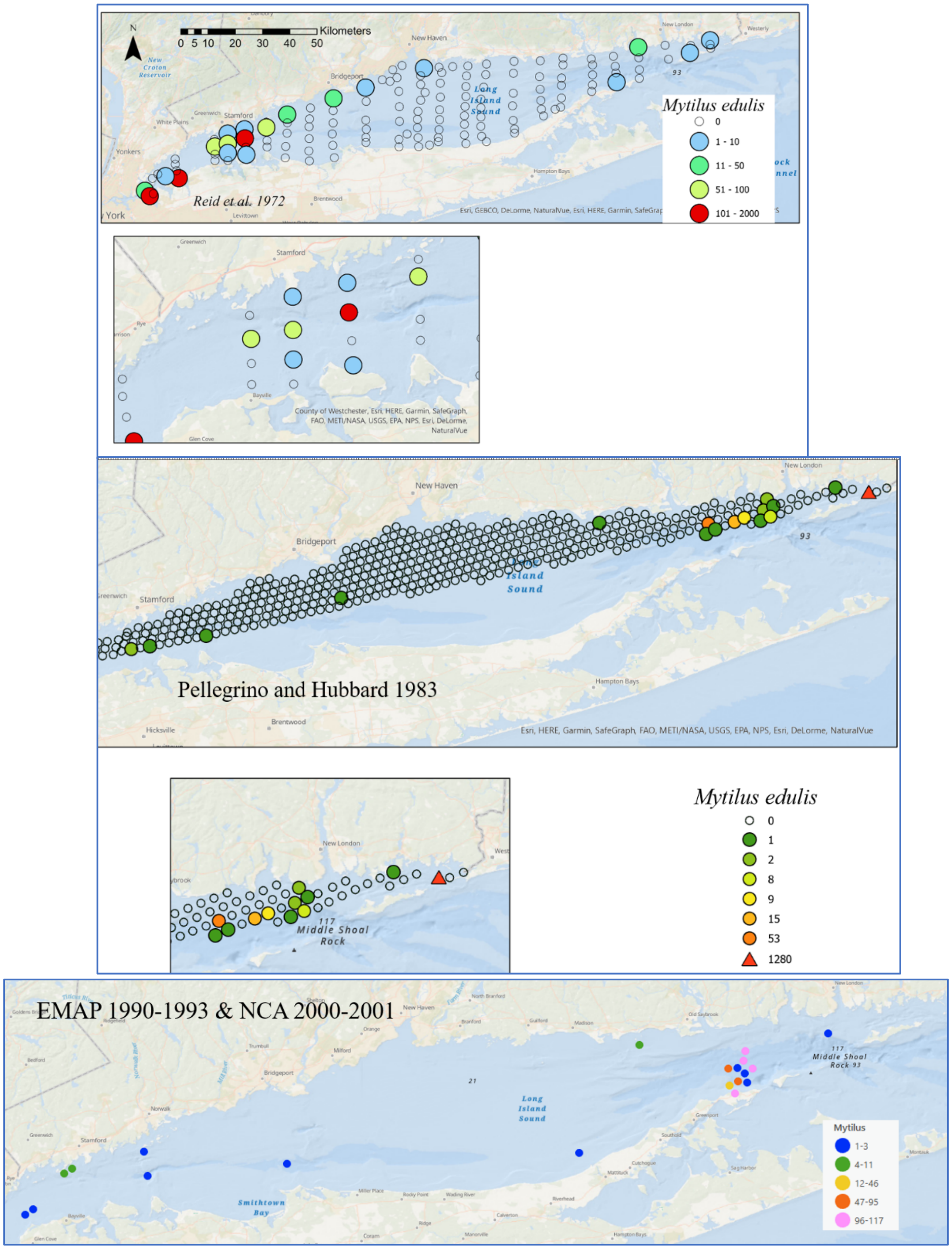


Figure 3-1 Spatial distributions and abundances of Mytilus edulis across LIS based on data provided in several benthic surveys conducted from the early 1970s to the early 2000s. Insets show detailed spatial distribution. See Table 3-1 for details regarding grab sample size.

For the *Crepidula* assessment, abundances were combined for *C. fornicata* and *C. plana*, but *C. fornicata* was always the most abundant of the two species overall in the surveys that were reviewed. Reid et al. (1979) found *Crepidula* throughout LIS (Figure 3-2), but generally at low abundances (1 to 10 individuals per sample). Spatially, most of the sites that had *Crepidula* were located in the southern portion of LIS along the North Shore of

Long Island. High densities (greater than 100 per sample) were found both in a shallow area along the Long Island North Shore and in the middle of the sound south of Branford, Connecticut. Few slipper shells were found in the Reid et al. (1979) survey in the Phase I and Phase II areas. Pellegrino and Hubbard (1983) found a higher incidence of *Crepidula* throughout the Sound (Figure 3-2). There were number of sample locations in the area of Stratford Shoal, in the Phase I area that had relatively high densities of slipper shells. In the eastern portion of LIS, there were more locations that had *Crepidula* than was reported in the Reid et al. (1979) survey, although densities generally ranged from 1 to 25 individuals per sample. Based on data collected in the EMAP and NCA surveys, *Crepidula* was mostly found in the eastern portion of LIS, with several locations along the Connecticut shore east and west of the Connecticut River having relatively high densities (Figure 3-2). In contrast, more recently, *Crepidula* was found at many of the sample locations in the Phase II study area in the eastern portion of LIS (Figure 3-3), often at very high abundances. Most of the locations with recent high abundances of slipper shells were concentrated in the western portion of the Phase II study area, the eastern portion including FIS and along the south shore of Fishers Island.

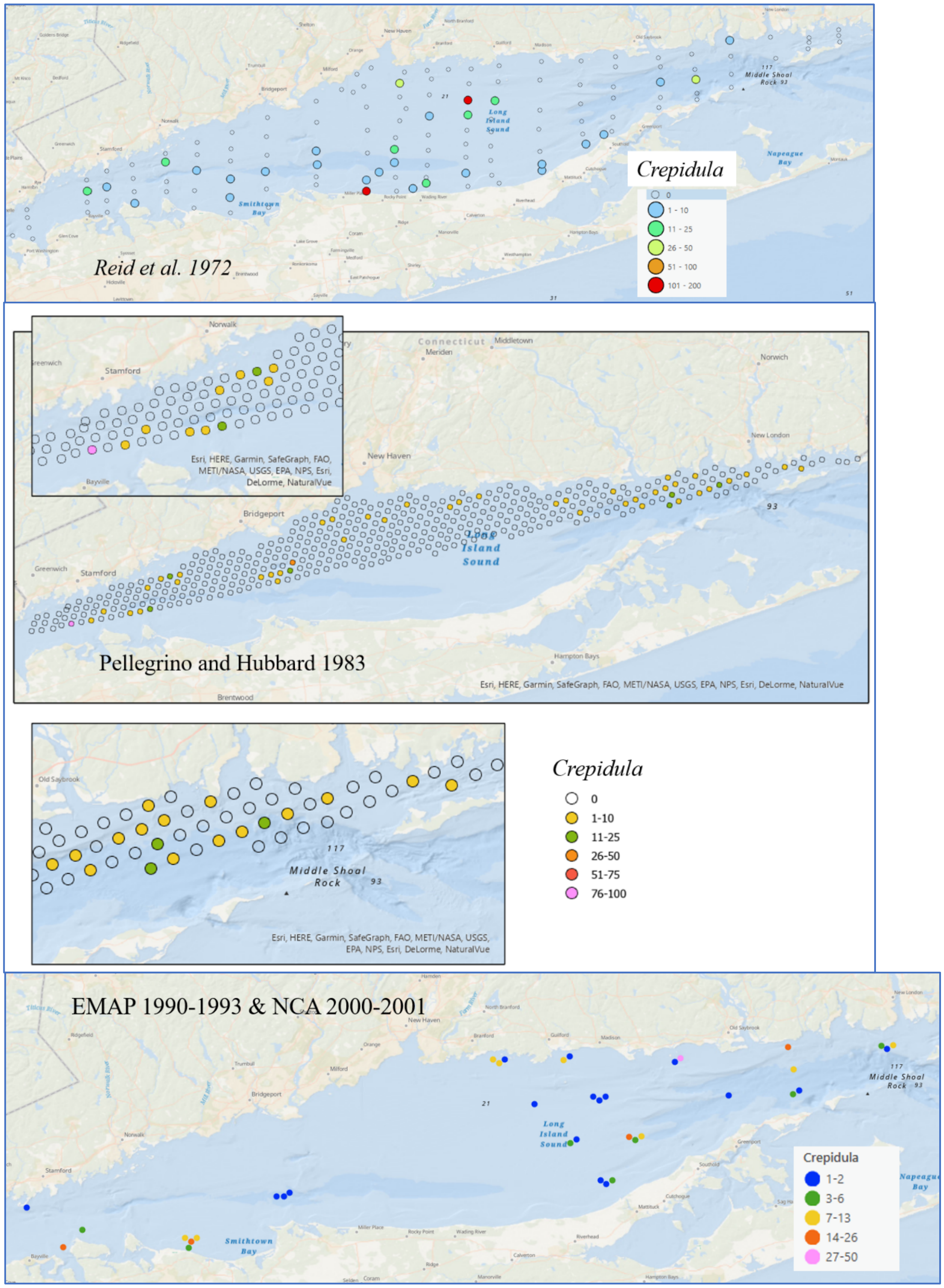


Figure 3-2 Spatial distributions and abundances of Crepidula across LIS based on data provided in several benthic surveys conducted from the early 1970s to the early 2000's. Insets show detailed spatial distribution. See Table 3-1 for details regarding grab sample size.

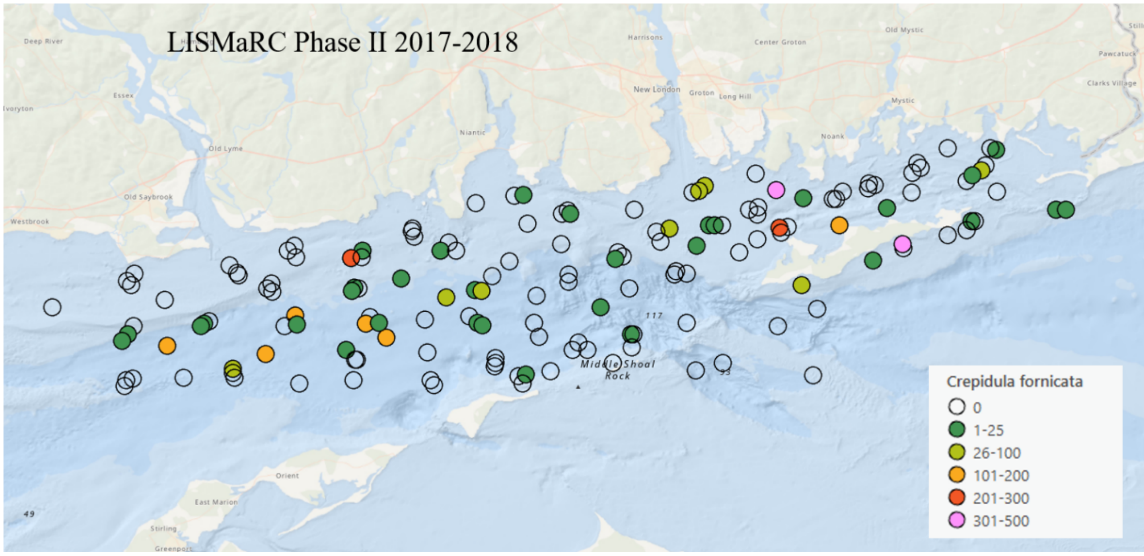


Figure 3-3 Spatial distributions and abundances of Crepidula fornicata in the Phase II study area of eastern LIS. See Table 3-1 for details regarding grab sample size.

3.1.2 Analysis of 2022 Grab Samples Acquired using PISSAH

Several sites in the Phase I and II areas were revisited as part of the AECR field survey campaign in 2022 (Table 2-2) to assess the densities of *Mytilus* and *Crepidula*. *Mytilus* was found at densities of 89 and 64 individuals per 0.1 m^{-2} at Ram Island Reef and Latimer Light, respectively; two tiny mussels were also found at the NAGL 06-11 site. No mussels were found at any of the other PISSAH sites either in the Phase I or Phase II areas.

In grab samples taken by the PISSAH in the Phase II area, lower densities of slipper shells were found in 2022 versus fall 2017 and spring 2018 at five of the six sites, with only one site having elevated densities (Figure 3-4). Considered together, this represents a decline from a mean of 277.7 ± 153.8 to 197.7 ± 220 individuals per 0.1 m^{-2} across the Phase II area. Five sites were resampled during the AECR field survey in the Phase I area, which was previously sampled in October 2012 and May 2013. *Crepidula* densities of 5.7 ± 45, 56.3 ± 49.5, 0, and 7.7 ± 6.7 individuals per 0.1 m^{-2} were previously recorded at SB-5, SB-11, SB-12, and SB-21, respectively. No *Crepidula* were found in the 2022 grab samples in the Phase I area (but see imagery analysis in section 3.1.3).

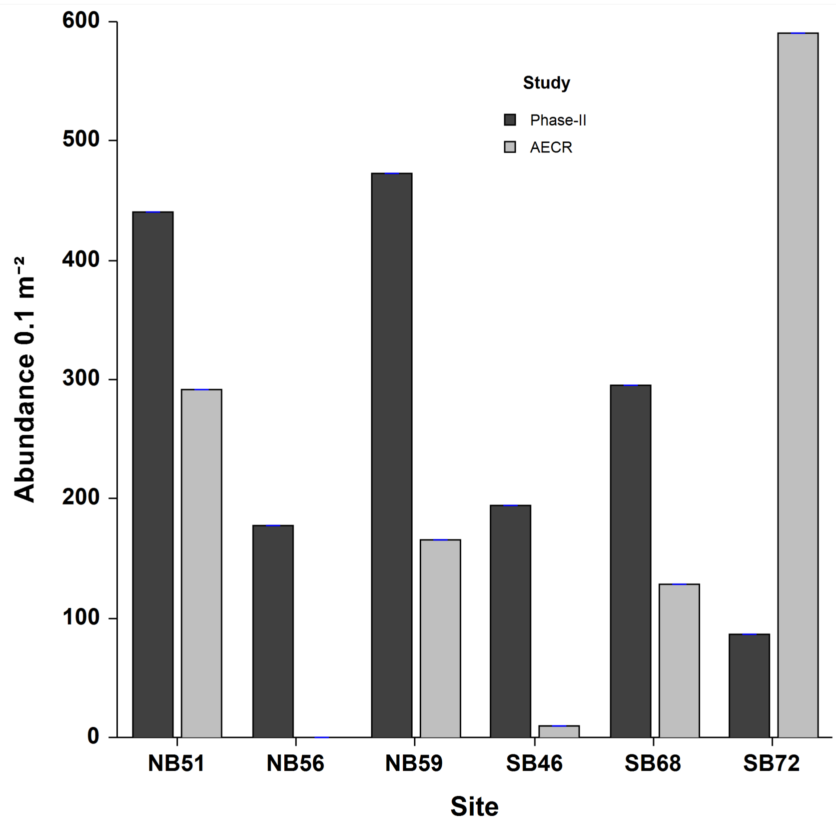


Figure 3-4 Grab sample analyses in the Phase II area. Lower densities of slipper shells were found in 2022 versus 2017 and 2018 at five of the six sites, with only one site having elevated densities.

3.1.3 Analysis of 2022 Imagery Collected by the PISSAH

Analysis of imagery revealed *Crepidula* presence throughout much of the Phase II area as well as parts of the Phase I area. Of the 18 sites targeted across both areas, 14 featured *Crepidula*, with this gastropod covering more than 45% of the seafloor in images (mean percent cover 45.4% ±2.84%). When present, *Crepidula* frequently covered much of the substrate (mean percent cover when present 72.2% ±2.66%). When compared to 2017-18 observations, sampling for this project revealed increased percent cover of *Crepidula*: at these 6 locations, percent cover increased from 14.2% ±2.36% in 2017-2018 to 81.3% ±2.61% in 2022. There was a marked increase in percent cover at each of the 6 sites (Figure 3-5); at none of the revisited sites was mean percent cover less than 68%. Not only was observed cover higher, but coverage was consistent: over 97% of 2022 images featured *Crepidula* in contrast to the 48.1% of 2017-2018. *Crepidula* increased at the Phase I sites revisited as well. At the four Phase I sites sampled using SEABOSS in 2012-13, mean *Crepidula* percent cover increased from 7.12 ±0.70% to 33.3% ±15.4% in 2022. The recently documented *Crepidula* distributions were more variable in the Phase I area than in the Phase II area. In the Phase I area, for example, SB 11 featuring 68.4% ±9.60% cover while no *Crepidula* was observed around the boulders at site SB 12 (Figure 3-6). It's important to note that *Crepidula* was observed in imagery collected in the vicinity of grab samples that yielded no *Crepidula* (see Section 3.1.2). Overall, across these Phase I and II sites, *Crepidula* densities have increased 4.6-5.7 fold over the past 5-10 years. No *Mytilus* were observed in any of the images analyzed from the 2022 PISSAH survey.

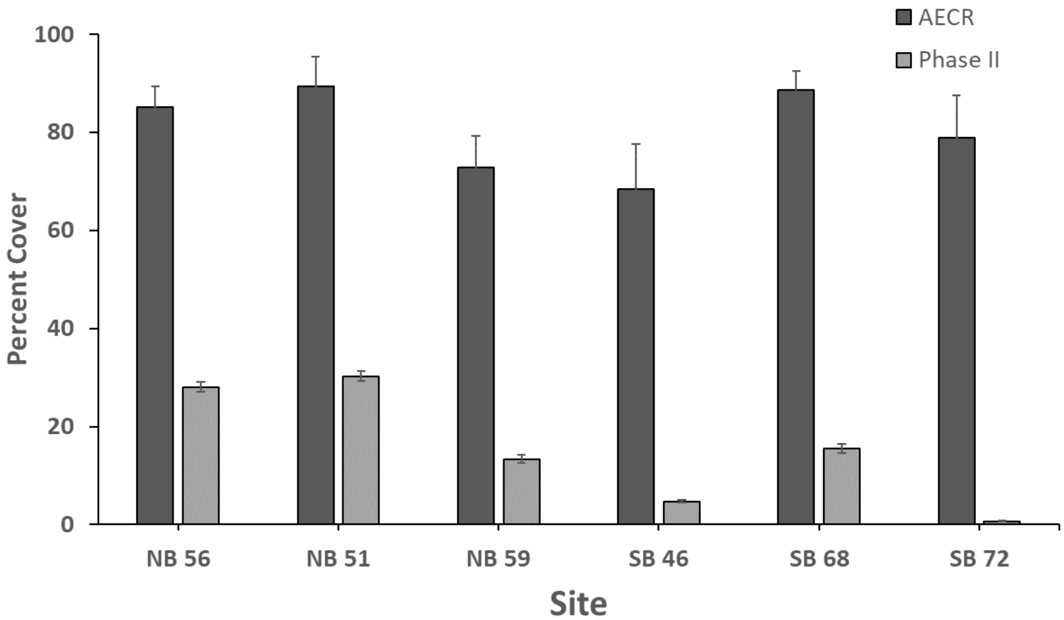


Figure 3-5 Image analysis in the Phase II area, Crepidula was observed in higher densities in 2022 (AECR) when compared to 2017 and 2018 (Phase II sampling using SEABOSS).

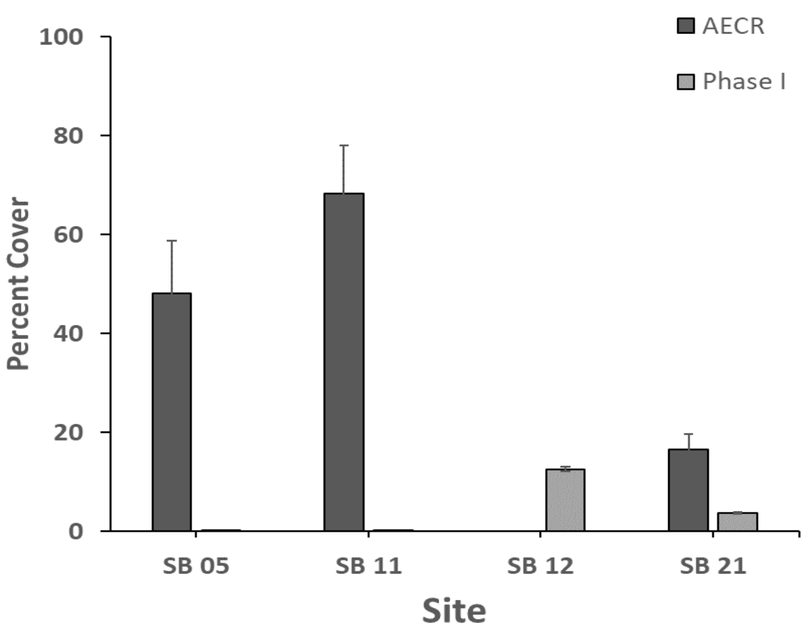


Figure 3-6 Image analysis in the Phase I area, Crepidula *was observed in much higher densities in 2022 (AECR) when compared to 2012 and 2013 (Phase I sampling using SEABOSS).*

3.1.4 Review of the Historical Images and Logbooks

The historical diver data consisted of both logbook records and still images. The log books were scanned for presence/absence of the three key taxa and the additional taxa identified along with any additional field notes. The still images were digitized and similarly reviewed for presence/absence. Figure 3-7 shows the location of the sites where historical images were analyzed from withing the Phase II area. Table 3-2 provides the results of the logbook(s) review and image analysis for *Mytilus* and *Crepidula*, listing 104 entries from 12 distinct sites. There were numerous entries from the New London Disposal Site, but these were merged into one site.

Figure 3-7 Map illustrating the location of the sites where historical logs and images were analyzed.

Table 3-2 1 Historical Log and Photo Data by Year for Presence of Mytilus and Crepidula in the Phase II area.

Year	Location Name	Lat DD	Lon DD	Mytilus edulis	Crepidula fornicata
1975	North Dumpling	41.28747	-72.0198	1	0
1975	North Dumpling	41.28747	-72.0198	1	0
1977	Latimer Light Reef	41.3046	-71.93347	0	0
1979	Beebe Cove	41.33067	-71.98537	0	0
1979	Latimer Light Reef	41.3046	-71.93347	1	0
1979	Latimer Light Reef	41.3046	-71.93347	0	0
1979	NL Disposal Site_SE Mussel Patch	41.25817	-72.08567	1	0
1979	NL Disposal Site_SW Stn	41.26167	-72.07333	0	0
1979	North Dumpling	41.28843	-72.02013	1	0
1979	North Dumpling	41.28843	-72.02013	1	0
1979	Race Rock	41.24383	-72.04688	0	0

1979	S Wreck Island - Fishers Island	41.28	-71.93083	1	0
1979	Stonington Point	41.325	-71.90633	0	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0
1980	Latimer Light Reef	41.3046	-71.93347	0	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0
1980	NL Disposal Site_DAISY	41.26667	-72.07717	0	0
1980	NL Disposal Site_DIII	41.275	-72.08333	0	0
1980	NL Disposal Site_Intermediate Buoy	41.265	-72.08667	1	0
1980	NL Disposal Site_SE	41.26167	-72.06667	0	0
1980	NL Disposal Site_SE	41.26167	-72.06667	1	0
1980	NL Disposal Site_SE Stn	41.26167	-72.06667	1	0
1980	NL Disposal Site_SE Stn	41.26167	-72.06667	1	0
1980	NL Disposal Site_Stn DI	41.25333	-72.09	0	0
1980	NL Disposal Site_Stn DII	41.275	-72.08333	1	0
1980	NL Disposal Site_SW Stn	41.26167	-72.07333	1	0
1980	NL Disposal Site_SW Stn	41.26167	-72.07333	1	0
1980	NL Disposal Site_SW Stn	41.26167	-72.07333	1	0
1981	Beebe Cove	41.33067	-71.98537	0	0
1981	Beebe Cove	41.33067	-71.98537	0	0
1981	Beebe Cove Entrance	41.33067	-71.98537	0	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0
1981	Latimer Light Reef	41.3046	-71.93347	0	0
1981	NL Disposal Site	41.26167	-72.06667	0	0
1981	NL Disposal Site_NE	41.27	-72.075	1	0
1981	NL Disposal Site_SE Stn	41.26167	-72.06667	1	0
1981	NL Disposal Site_SW Stn	41.26167	-72.07333	1	0
1981	Two Tree Island Channel	41.29632	-72.13789	1	0
1982	Beebe Cove	41.33067	-71.98537	0	0
1982	Beebe Cove Entrance	41.33067	-71.98537	0	0
1982	Ellis Reef	41.3145	-71.95564	0	0
1982	Latimer Light Reef	41.3046	-71.93347	1	0
1982	Latimer Light Reef	41.3046	-71.93347	0	0
1982	Latimer Light Reef	41.3046	-71.93347	0	0
1982	Latimer Light Reef	41.3046	-71.93347	0	0
1982	NL Displosal Site	41.26167	-72.06667	0	0
1982	North Dumpling	41.28843	-72.02013	1	0

1982	North Dumpling	41.28843	-72.02013	1	0
1982	Ram Island Reef	41.3062	-71.9746	1	0
1982	Ram Island Reef	41.3062	-71.9746	1	0
1982	Ram Island Reef	41.3062	-71.9746	1	0
1983	Black Ledge	41.30487	-72.07128	1	0
1983	Black Ledge	41.30487	-72.07128	1	0
1983	Ellis Reef	41.3145	-71.95564	0	0
1983	Ellis Reef	41.3145	-71.95564	0	0
1983	Latimer Light Reef	41.3046	-71.93347	0	0
1983	North Dumpling	41.28843	-72.02013	0	0
1983	Ram Island Reef	41.3062	-71.9746	0	0
1985	Ram Island Reef	41.3062	-71.9746	1	0
1986	Ellis Reef	41.3145	-71.95564	0	0
1986	Ram Island Reef	41.3062	-71.9746	0	0
1986	Ram Island Reef	41.3062	-71.9746	0	0
1986	Ram Island Reef	41.3062	-71.9746	0	0
1986	Ram Island Reef	41.3062	-71.9746	0	0
1986	Ram Island Reef	41.3062	-71.9746	1	0
1986	Ram Island Reef	41.3062	-71.9746	0	0
1987	Beebe Cove Entrance	41.33067	-71.98537	0	0
1987	Deep Hole	41.30385	-71.91379	0	0
1987	East of Latimer_Deep Hole	41.303	-71.91333	0	0
1987	East of Latimer_Deep Hole	41.303	-71.91333	0	0
1987	Ellis Reef	41.3145	-71.95564	0	0
1987	Ellis Reef	41.3145	-71.95564	0	0
1987	Ellis Reef	41.3145	-71.95564	0	0
1987	Ellis Reef	41.3145	-71.95564	0	0
1987	Latimer Light Reef	41.3046	-71.93347	0	0
1987	Latimer Light Reef	41.3046	-71.93347	0	0
1987	Latimer Light Reef	41.3046	-71.93347	0	0
1988	Ellis Reef	41.3145	-71.95564	0	0
1988	Ellis Reef	41.3145	-71.95564	0	0
1988	Race Rock	41.24383	-72.04688	1	0
1988	Race Rock	41.24383	-72.04688	1	0
1990	East of Latimer_Deep Hole	41.303	-71.91333	0	0
1991	Deep Hole	41.30385	-71.91379	0	0
1991	East of Latimer_Deep Hole	41.303	-71.91333	0	0
1991	East of Latimer_Deep Hole	41.303	-71.91333	0	0
1991	East of Latimer_Deep Hole	41.303	-71.91333	0	0
1992	NL Disposal Site	41.271	-72.10912	0	0
1992	NL Disposal Site_Dive 1			0	0
1992	NL Disposal Site_Dive 2			0	0
1992	NL Disposal Site_Dive 3	41.2708	-72.128	0	0

1992	NL Disposal Site_Dive 4	41.27162	-72.09545	0	0
1993	East of Latimer_Deep Hole	41.303	-71.91333	0	0
1993	NL Disposal Site	41.275	-72.10373	0	0
2023	Ellis Reef	41.31512	-71.95563	0	0
2023	Ram Island Reef	41.31227	-71.97553	0	0

The review of the historical logbooks revealed two major trends. First, the presence of the blue mussel, *Mytilus edulis* was recorded in 38 of the 57 log entries and at seven of the eleven sites. Only the sites to the east of Latimer Deep Hole, Ellis Reef and Stonington Point had an absence of both *Mytilus* and *Crepidula*. Second *Crepidula* was recorded as a dominant taxon in none of the logbook entries.

The analysis of the historical imagery consisted of reviewing 271 still images from eight of the sites listed in Table 3-2, many of which were the same as the log entry data. The results of the image analysis revealed some similar patterns as observed in the logbook review. First, the presence of *Mytilus* was noted in four of the eight sites. The Latimer Light Reef site consistently supported *Mytilus* in the late 1970s and early 1980s, but was notably absent in the logs and images from later in the 1980s. By this time, *Mytilus* was only observed at the Race Rock site. Figure 3-8 provides a side-by-side comparison of historical versus recent imagery from three of the sites illustrating changes in the dominant populations.

Figure 3-8 Comparison of historic images to present of sites initially dominated by Mytilus: (sites from top to bottom and historic to recent left to right) North Dumpling 1975, 2017; Ram Island Reef 1982, 2023; Race Rock area 1988, 2008

3.1.5 Review of Historical Video from National Undersea Research Center Supported Dives and Comparison to Contemporary Sampling

A total of 13 historical video tapes from dives conducted in the Phase II area were reviewed from the NURTEC archive for presence/absence of *Mytilus* and *Crepidula,* along with the other key taxa identified by this AECR project. Table 3-3 lists the location and presence/absence of *Mytilus* and *Crepidula* observed at these sites, while Figure 3-9 shows the locations of these dives in LIS and FIS. Figures 3-10, 3-11 and 3-12 provide frame captures from the review of archived videos at several sites. A link to these videos encoded to YouTube is available at: https://www.youtube.com/@lismarc5649/videos .

Table 3-3 1 Sites of Historical NURTEC Videos Analyzed for Presence/Absence of Mytilus and Crepidula (Site #'s refer to sites on Figure 3-9, not AECR site numbers).

Site #	Year	Location	Lat_DD	Lon_DD	Mytilus edulis	Crepidula fornicata
1	1989	Near Millstone Power Plant	41.2793083	-72.14888	1	0
2	1990	Off Seaflower Reef	41.2941333	-72.034675	1	1
3	1990	Rapid Rock	41.283085	-72.10488	1	0
4	1991	NE Corner of N.L. Dumpsite	41.2700433	-72.0732433	1	0
5	1991	Seaflower Reef	41.2938116	-72.0344133	1	0
6	1992	South West of Seaflower Reef	41.2886083	-72.0420183	1	0
7	1992	East of East Clump	41.29919	-71.94672	0	0
8	1992	East of Deep Hole	41.3039533	-71.9062716	0	0
9	2006	Northeast of East Clump	41.3001566	-71.9554316	0	0
10	2006	Fishers Island Sound - Near Deep Hole	41.3039216	-71.9098133	0	0
11	2006	Fishers Island Sound - Near Deep Hole	41.3037833	-71.9097683	1	0
12	2006	Fishers Island Sound - Northeast of Wicopesset Rock	41.3027983	-71.9014	1	0
13	2006	Fishers Island Sound - at the Deep Hole	41.30372	-71.913995	1	0

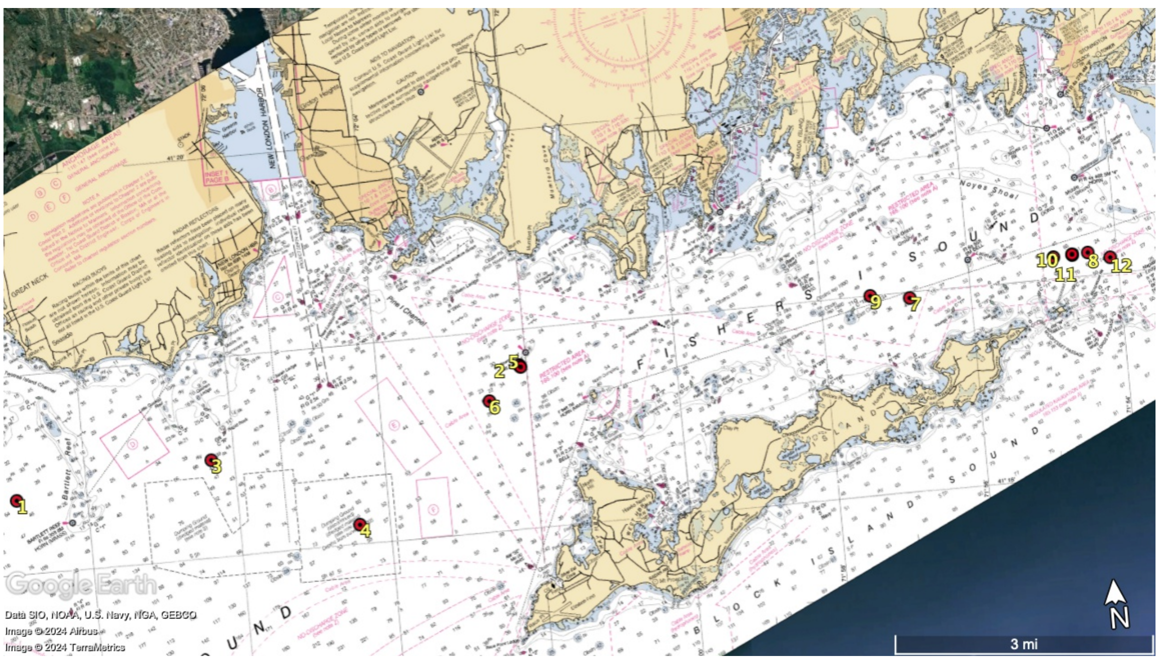
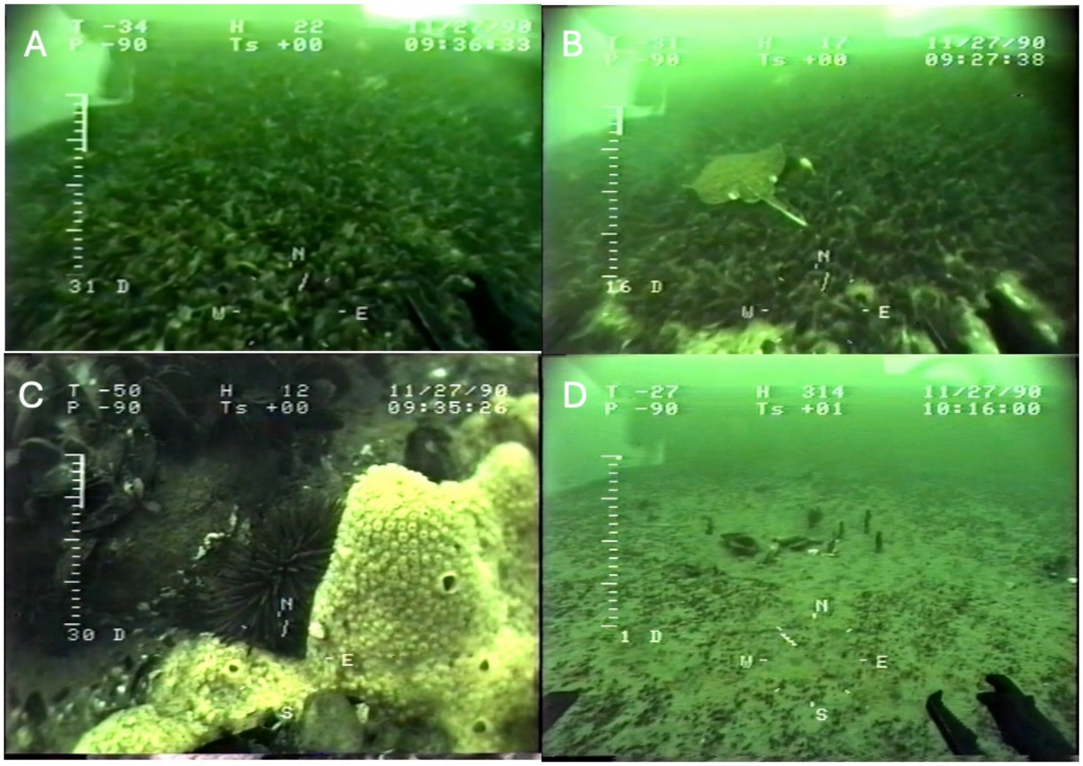


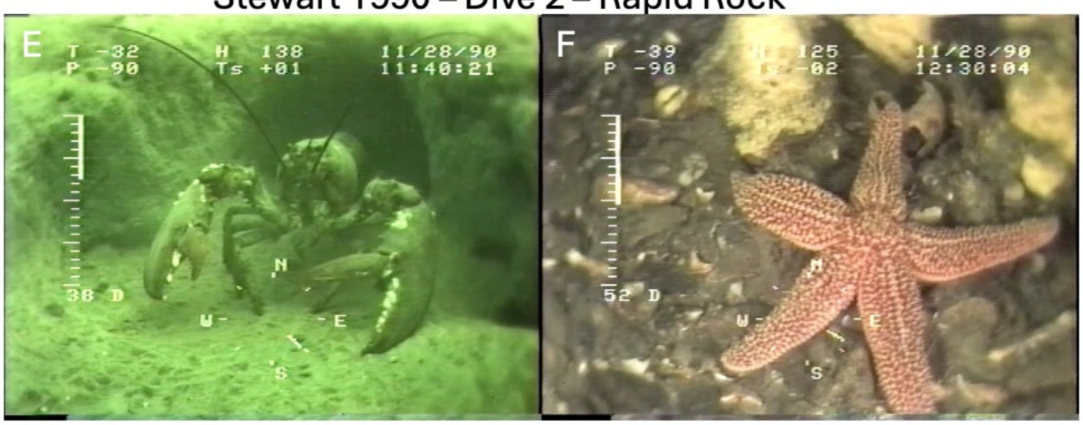
Figure 3-9 Map of historical ROV dives reviewed for presence/absence of key taxa (site numbers from Table 3-3).

Stewart 1990 – Dive 1 – off Seaflower Reef



A Dense Mytilus bed, B – Skate over Mytilus bed
C – Cliona tower, D – Soft bottom

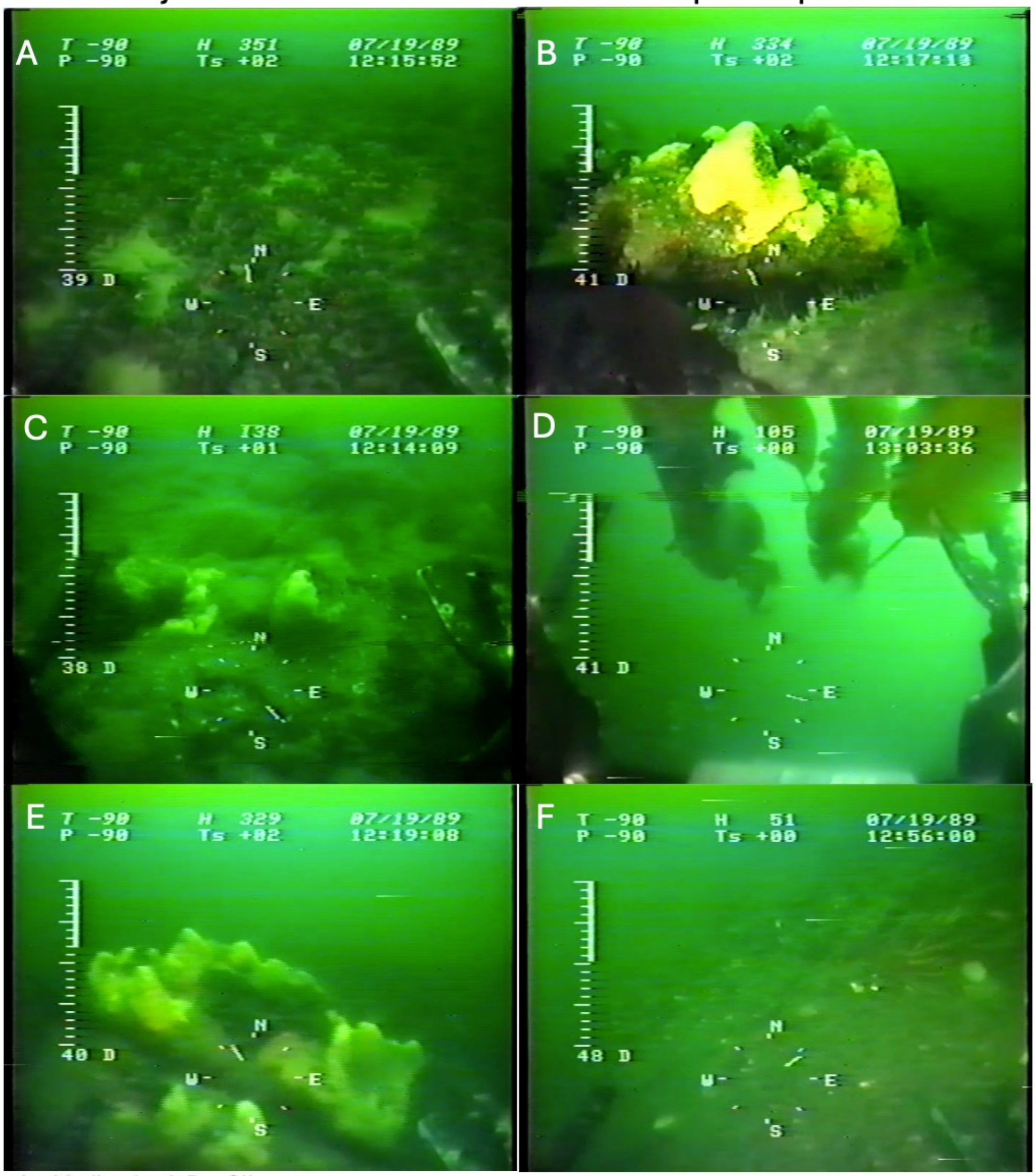
Stewart 1990 – Dive 2 – Rapid Rock



E – Lobster in burrow, F - Asterias

Figure 3-10 Images from the review of archived ROV videos from dives (Sites 2 & 3) in the Phase II area.

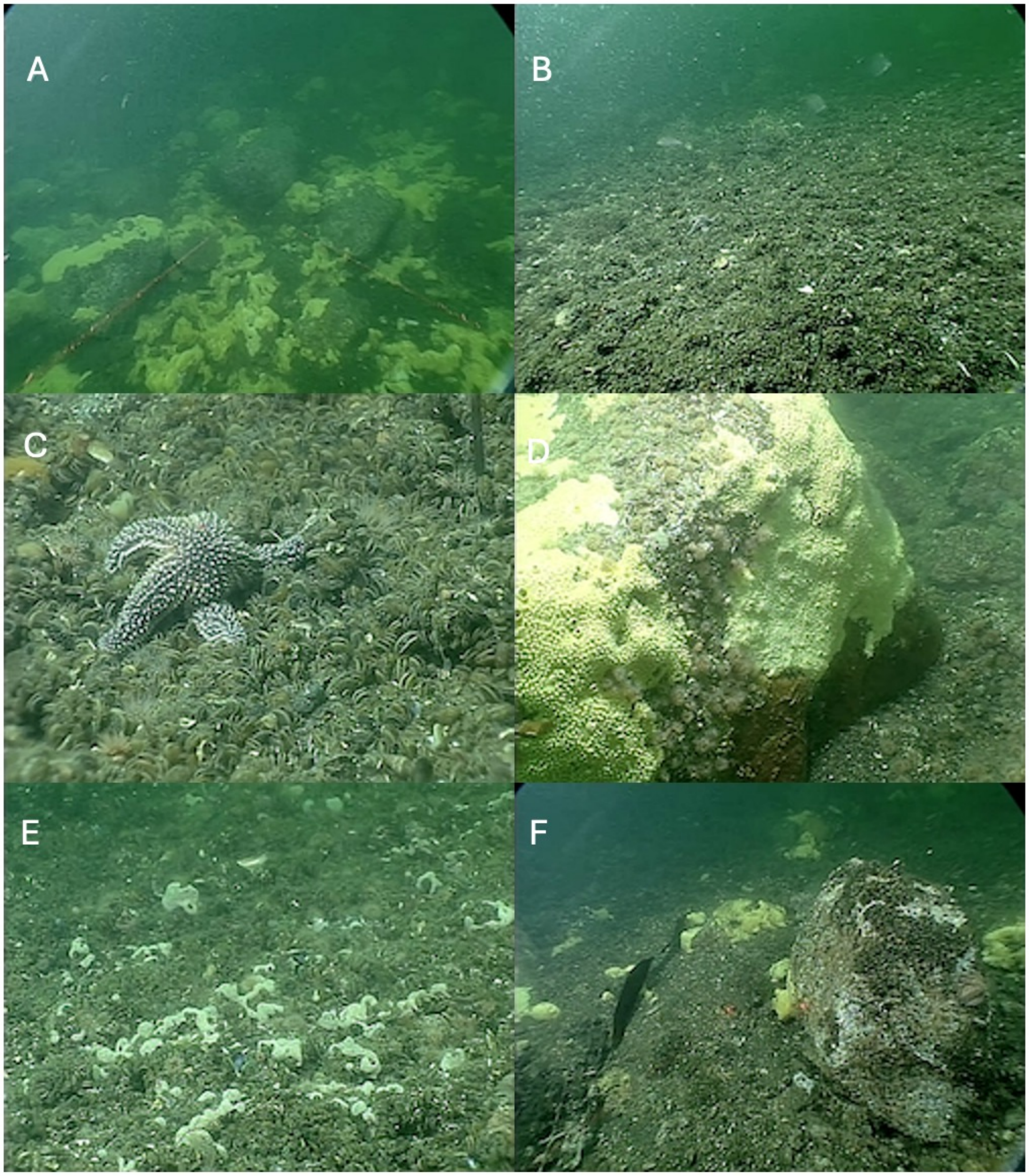
Zajac 1989 – Dive 3 – Near Millstone power plant



A – Mytilus bed, B - Cliona tower
C – Unidentified sponge, D – Kelp fronds streaming from ROV
E – Cliona dominating a boulder, F – Likely Haliclona sponge

Figure 3-11 Images from the review of archived ROV videos from dives (Site 1) in the Phase II area

Whitlatch 2006 – Dive 6 – Northeast of Wicopesset Rock



A – Boulders dominated by Cliona, B – Dense juvenile Mytilus mat on seafloor
C – Asterias on mussel bed, D – Boulder with Cliona
E – Mussel bed with senescent Didemnum, E – Boulder topped with Mytilus

Figure 3-12 Images from the review of archived ROV videos from dives (Site 12) in the Phase II area.

As can be seen in Table 3-3 and Figures 3-10 and 3-11 there were extensive beds of adult *Mytilus* seen in all of the dives in the late 1980s to early 1990s in the western FIS sites (Sites 1-6), with none observed in the sites further east (Sites 7-8). The later dives conducted in eastern FIS, however, showed dense settlement of juvenile mussels covering the seafloor and boulders (Figure 3-12). No *Crepidula* was recorded in any of the historical videos up to 2006.

As mentioned previously we also identified a number of other taxa of interest in the review of the historical ROV videos that we included in our assessment of change and resilience in the Sound that are not reported here but are summarized in Appendix I.

3.1.6 Review of Newly Acquired Boxfish ROV Video in Fishers Island Sound in the Phase II area.

The October 18, 2023 Boxfish ROV was deployed twice in same vicinity of previous ROV dives in eastern Fishers Island Sound (Figure 3-13). This area was characterized by many large boulders that in the past (2006) were characterized by dense populations of blue mussel (*Mytilus edulis*). The newly acquired video was analyzed for presence/absence of *Mytilus* and *Crepidula*, neither of which was observed during the two dives. The video was also reviewed for the broader suite of key taxa identified for this AECR project, with the seafloor dominated by *Cliona sp*., *Astrangia poculata* and *Didemnum sp*. (Figure 3-13).

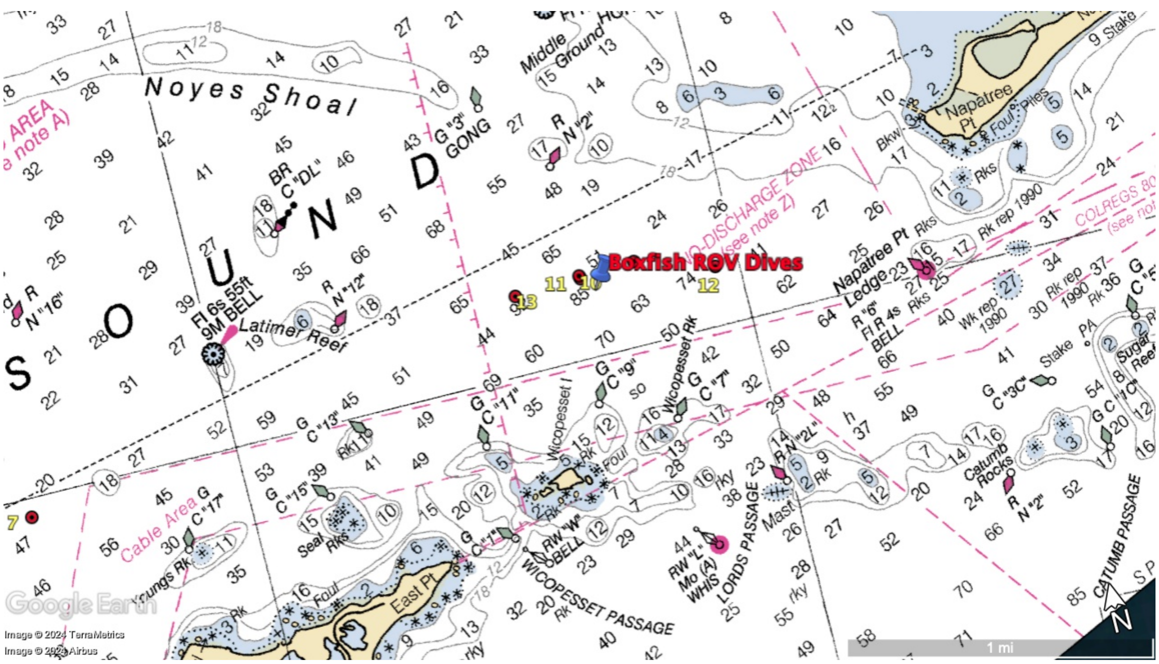


Figure 3-13 1Map of eastern Fishers Island Sound showing the location of historical ROV dives (red dots) and the 2023 Boxfish ROV dives (blue pin).

Boxfish ROV Dives at the Deep Hole

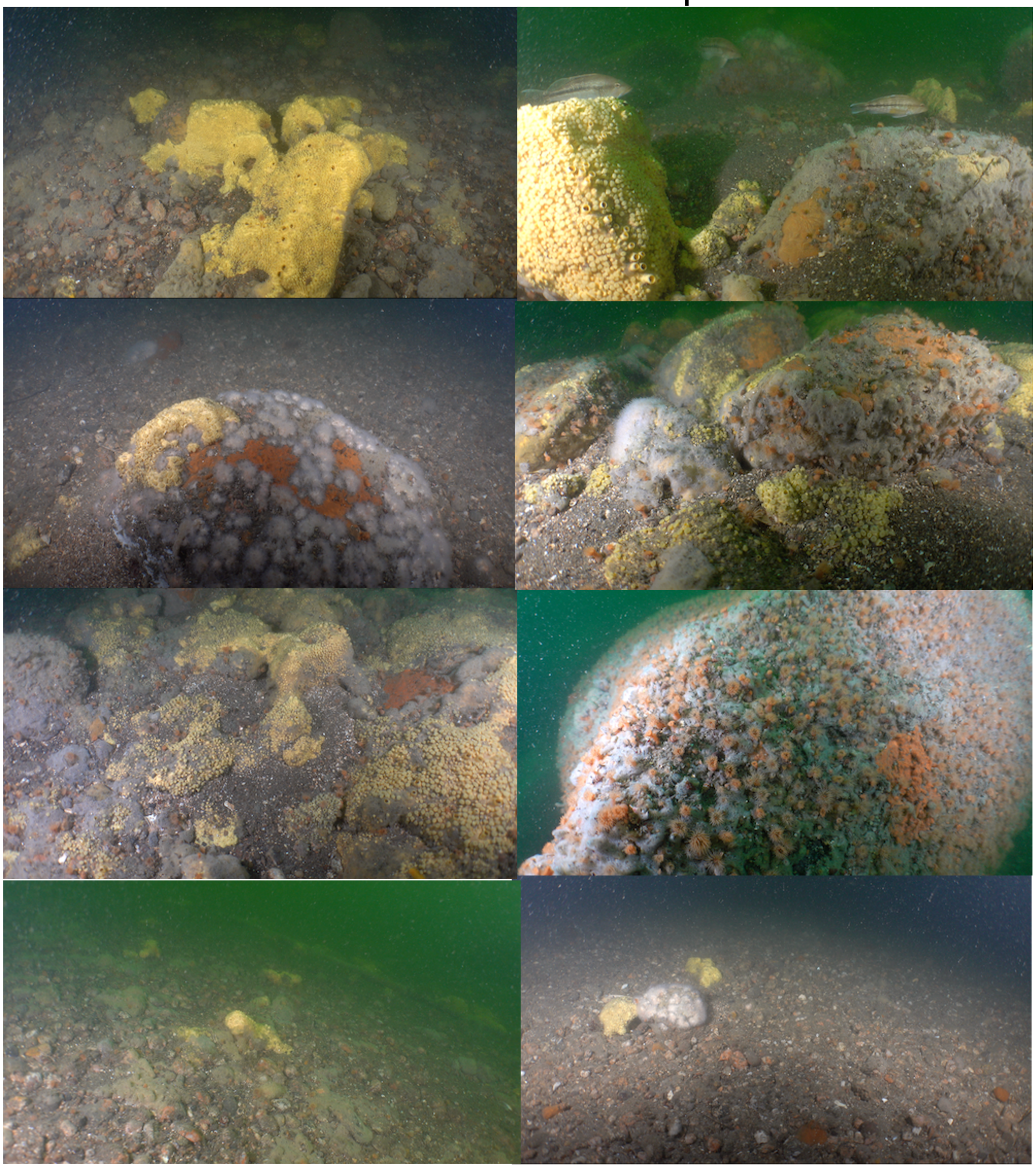


Figure 3-14 Frame captures from the 4K video illustrating the dominant taxa now found – Cliona, Didemnum, Astangea, Diadumene.

3.2 Phase I Area – Is There Evidence of Ecosystem Resilience? – the Recovery of *Haliclona oculata*

Examination of previously collected imagery from the Phase I area near the top of Stratford Shoal revealed a long-term shift in the epifaunal community. From 1991 through 2010, the boulder reef on the southern end of Stratford Shoal was dominated by the branching sponge *Haliclona oculata*, the northern star coral *Astrangia poculata*, blue mussels, and branching bryozoa - all habitat structure-forming species. However, *Haliclona* was absent from the imagery taken during the 2012 and 2013 LISMaRC cruises (Figures 3-13 and 3-14; from Stefaniak et al., 2014). There are number of mechanisms that may have contributed, either individually or synergistically, to the change in this community, but continued monitoring and process studies are needed to determine which are the primary mechanisms and if this represents a permanent community state change or a cyclical population boom and bust. The critical management question we proposed to address was: has this sponge community recovered over the past six years or have we lost an important component of the seafloor habitat? The results from the data sources below address this question.

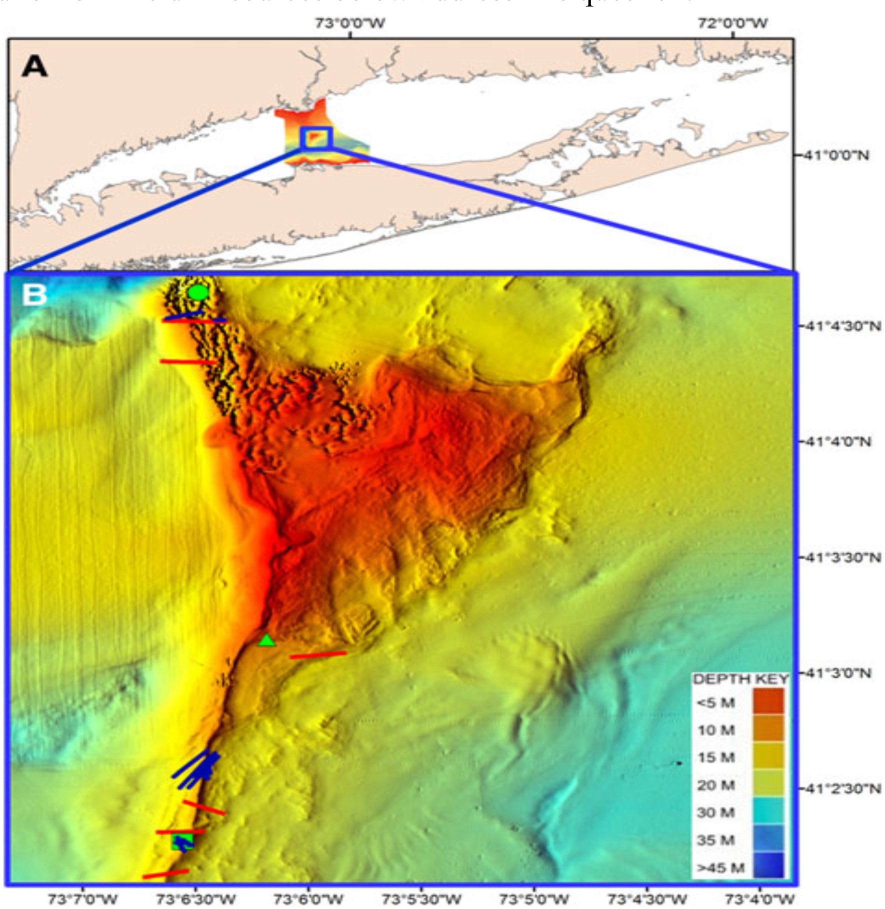


Figure 3-15 A) Long Island Sound showing the location of Stratford Shoal; B) bathymetry of southern half of Stratford Shoal showing survey locations. Green triangle, June 1991, MiniRover MkII ROV; green square, May 2007, ISIS towed camera platform (bathymetry map modified from Poppe et al., 2006).

Figure 3-16 Panel of images from the Phase I area showing prior dominance of the dead man's finger sponge on rocky habitats in 1991, 2007, and 2010 compared to the total lack observed in 2012.

3.2.1 Review of 2022 Newly Acquired PISSAH and Diver Imagery from the Phase I Area

Revisiting Phase I sample locations in fall 2022, *Haliclona* was observed at the NE corner of the southern half of Stratford Shoal (SB-12, Figure 3-17) and on the boulder ridge at its southern extent (SB-21, Figure 3-17). *Haliclona* was sparsley distributed at these sites, as this sponge accounted for 1.85% ±0.63% of the imaged seafloor in PISSAH imagery and 5.04 ±8.87% in wet-diving imagery collected across Stratford Shoal. This represents a notable increase in the distribution of this sponge from conditions at these sites observed during sampling in 2012 and 2013, when no *Haliclona* was identified. However, *Haliclona* coverage of available hard substrates at these sites was limited, 10.9% ±2.11% in PISSAH imagery and 16.8% ±4.94% in wet diving imagery when present, as compared to the >80% coverage observed during 1991 sampling (Stefaniak et al., 2014).

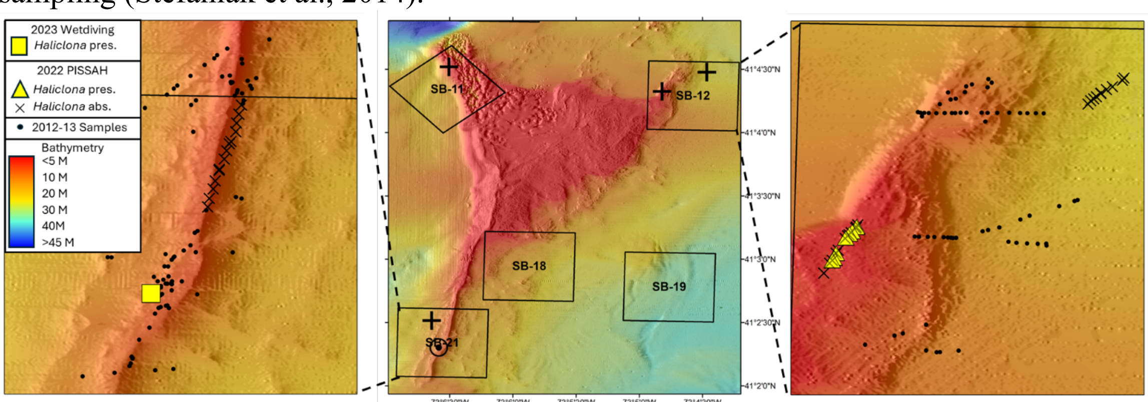


Figure 3-17 Map of the Phase I area showing the distribution of Haliclona observed in PISSAH and diver imagery.

Haliclona was observed as scattered, albeit developed colonies attached to hard substrates, interspersed with other hard-substrate taxa in both PISSAH (Figure 3-18A) and diver imagery (Figure 3-18B). Similar to benthic habitats prior to 2010, *Astrangia poculata* and erect Bryozoan colonies were observed throughout Stratford Shoal, accounting for 23.8 ±11.02% and 10.2% ±4.10% of the sampled seafloor in PISSAH imagery when *Haliclona* was present. In wet diving imagery, which was limited to sample block SB-21, *Astrangia poculata* was observed wherever *Haliclona* was present, covering 11.4% ±6.44% of the imaged seafloor in quadropod sampling. In a departure from pre-Phase I conditions, *Mytilus* was entirely absent from Stratford Shoal, while tunicate colonies from the Genus *Didemnum* were observed in most samples that also included *Haliclona* at sample site SB-12, covering 22.0% ±7.56% of the seafloor. *Didemnum* was observed as both scattered patches and as dense colonies occupying large portions of available hard substrates (Figure 3-19 A and B). In some locations, *Didemnum* appeared to have grown over other attached fauna, a phenomenon previously documented in locations where the invasive *Didemnum vexillum* has been introduced. While *Didemnum* was not observed overgrowing *Haliclona* colonies, the invasive tunicate may have limited available substrates in some places. Interestingly, *Didemnum* was not observed with *Astrangia* during PISSAH and wet diving sampling.

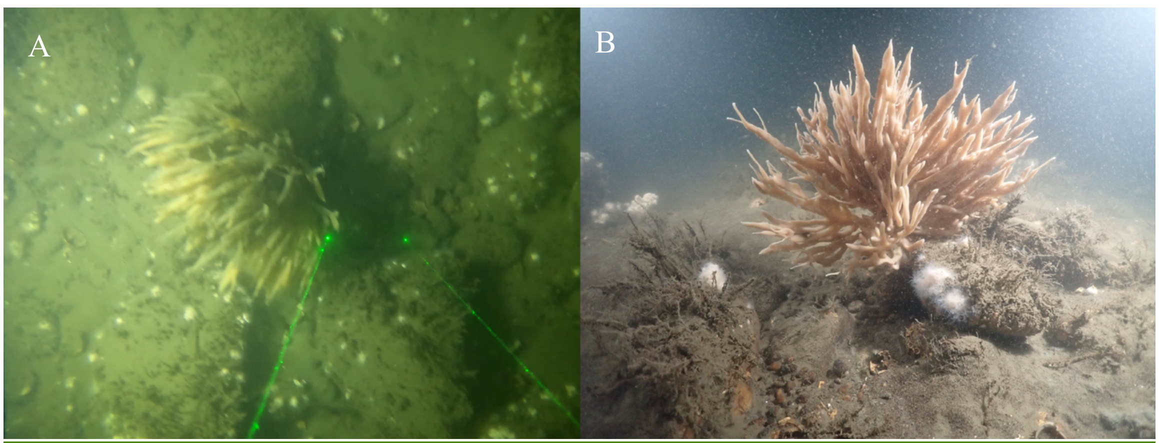


Figure 3-18 Images of Haliclona observed in the re-sampled sites from PISSAH (A) and divers (B).

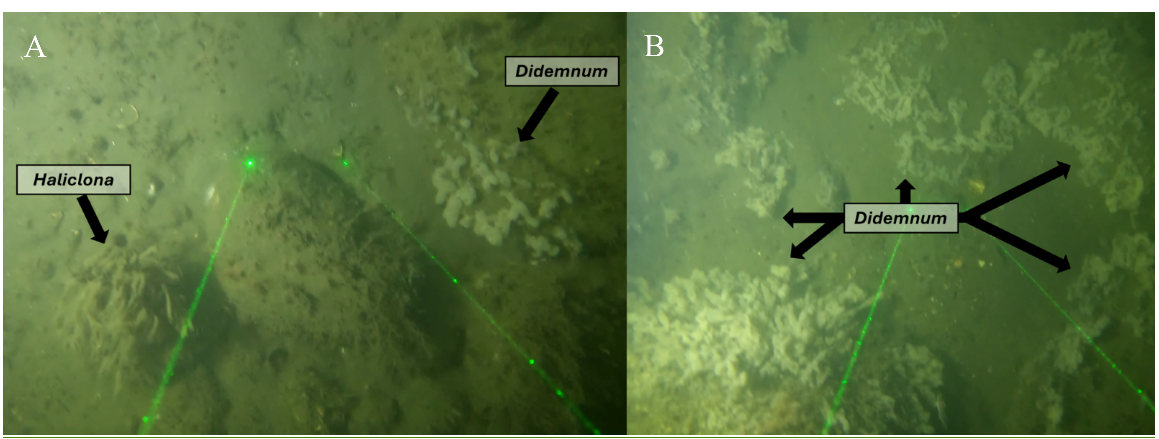


Figure 3-19 Images from the PISSAH showing the co-occurrence of Haliclona and Didemnum.

3.3 Phase I Area – Is There Evidence of Ecosystem Change? – the Apparent Loss of *Mytilus edulis*

The large-scale shift observed in the blue mussel community in the Phase II area raised another important management question: has a similar decline occurred in other parts of the Sound? LISMaRC surveys revealed blue mussel dominated areas in the northern portion of the Phase I region and was present others. The question we sought to address was: do they still exist in the Phase I area? The following data sources address this question.

3.3.1 Review of 2012 and 2013 LISMaRC Phase I Data

The decade old data collected during the multi-seasonal Phase I area study provided the baseline from which newly acquired data could be compared. Detailed results of this work are available at: https://lismap.uconn.edu/wp-content/uploads/sites/2333/2019/01/LISCF_PilotMappingProject_Report_Final_June2015.pdf , page 274 on, and in Stefaniak et al., 2014.

The highest mussel densities occurred in the northern, shallow area of Stratford Shoal in an area characterized by large sand waves. Figure 3-20 provides a synopsis of the distribution of mussels (2012-13 sampling results shown in panel (a) as empty and filled circles). As noted, the highest mussel densities occurred in the troughs of the sand

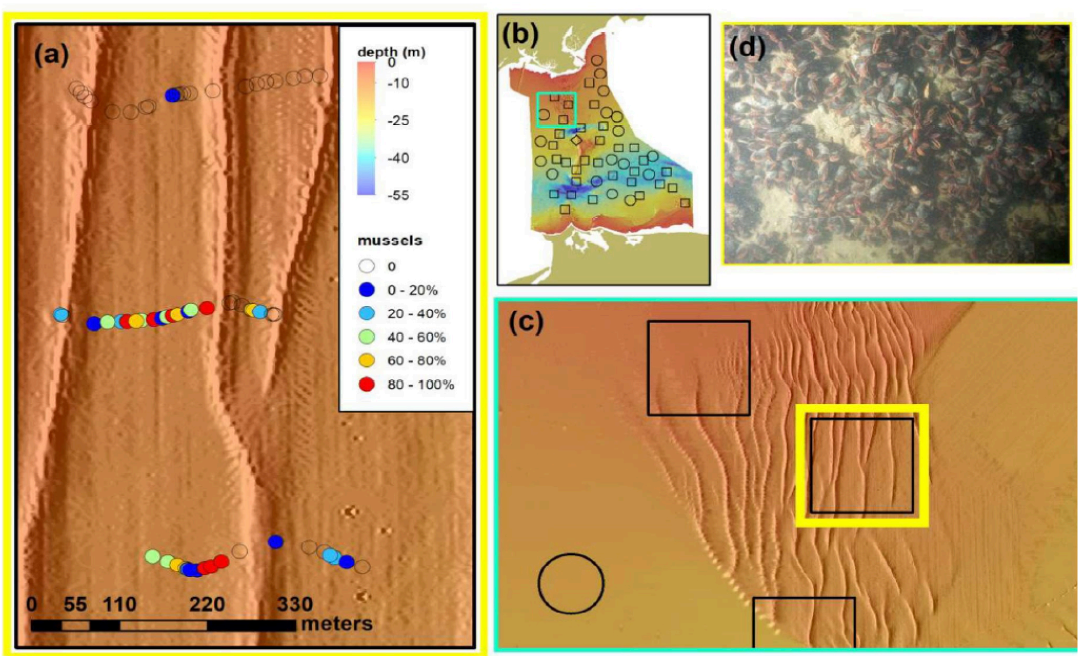


Figure 3-20 Mussel % cover overlaid on hill-shaded bathymetry (a) from the northern Phase 1 area (b) that featured large sand waves (c), note that the mussel density is highest in the sand wave troughs.

waves, with many of the images analyzed showing 60-100% cover, while cover on ridges was limited to 0-20%. Figure 3-21 provides a seasonal (fall vs. spring) comparison of these densities, showing consistently high percent cover in both seasons.

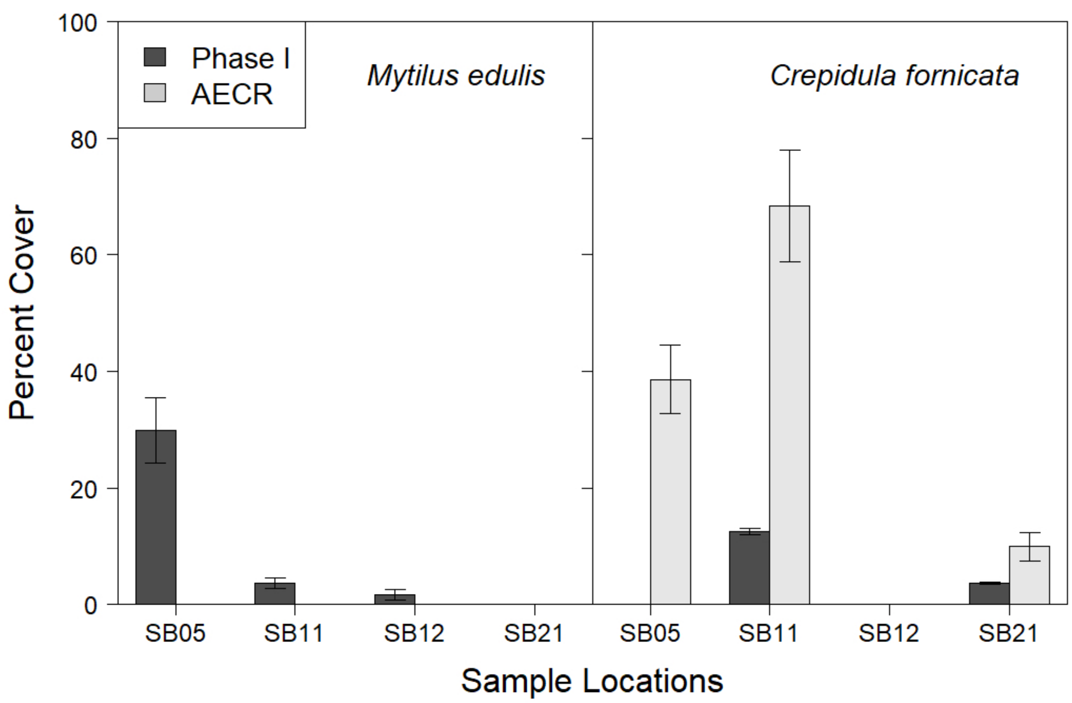
Figure 3-21 Images show the high densities of mussels from both Fall 2012 and Spring 2013 cruises as recorded by the USGS SEABOSS.

3.3.2 Review of 2022 Newly Acquired PISSAH and Diver Acquired Imagery from the Phase I Area

As described previously, several sites were identified that were believed to provide the best locations to assess the status of changes in populations of the key taxa identified in the previous work. For the assessment of the status of the *Mytilus* population in the Phase I area, four sites were selected for re-sampling for the AECR project. Table 3-4 provides a synopsis of the occurrence of *Mytilus* in the 2013 Phase I surveys (fall and spring combined) and the results of image analyses of newly acquired images by the PISSAH and divers. The table also includes percent cover of *Crepidula* as the apparent new dominant taxon in this area of LIS. As can be seen, the high densities of *Mytilus*, particularly in the northern area of Stratford Shoal (SB05), were completely absent in either the PISSAH or diver surveys. Conversely, *Crepidula* populations greatly expanded in three of the four sites re-sampled in the Phase I area (Figure 3-22). PISSAH and wet diving sampling targeted that same shallow sand habitat where abundant *Mytilus* was observed in sand wave troughs during Phase I (SB05, Figures 3-20 and 3-21). Instead of dense aggregations of adult mussels, sampling in 2022-23 revealed dense aggregations of *Crepidula* (Figure 3-22, 3-23, and 3-24). While the previously mapped sand waves have likely shifted, observed patterns in *Crepidula* abundance along the PISSAH transect sampled in Fall 2022 (two ~30-35m sections within which percent cover exceeded 90% separated by ~25m within which percent cover was 0-32%) were similar to patterns in *Mytilus* abundance observed in 2012-13 at this location (Figure 3-23).

Table 3-4 1 Mytilus and Crepidula Occurrence in the Phase I Project Sites and AECR Re-sampled Sites.

		% Cover	% Cover
SEABOSS Images – Phase 1, Fall, 2022 & Spring, 2013	Sample Area	Mytilus edulis	Crepidula fornicata
	SB05 Northern sand waves	29.87%	0.02%
	SB11 Crepidula site	4.43%	13.85%
	SB12 Boulder area	2.21%	0.00%
	SB21 Rocky Sponge site	0.00%	4.04%
PISSAH Images - September, 2022			
AECR Site #	Site Name		
14	SB05 Northern sand waves	0.00%	45.0%
15	SB11 Crepidula site	0.00%	68.40%
16	SB12 Boulder area	0.00%	0.00%
17	SB21 Rocky Sponge site	0.00%	16.59%
Diver Images - August, 2023			
14	SB05 North Stratford Shoal	0.00%	0%
17	SB21 Stratford Shoal	0.00%	28%



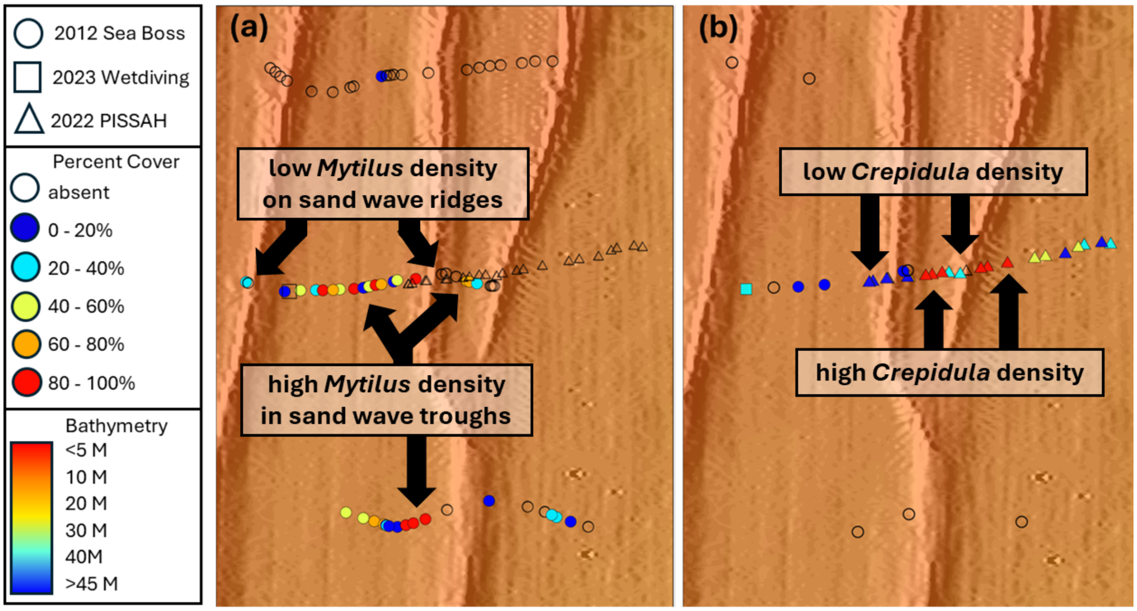
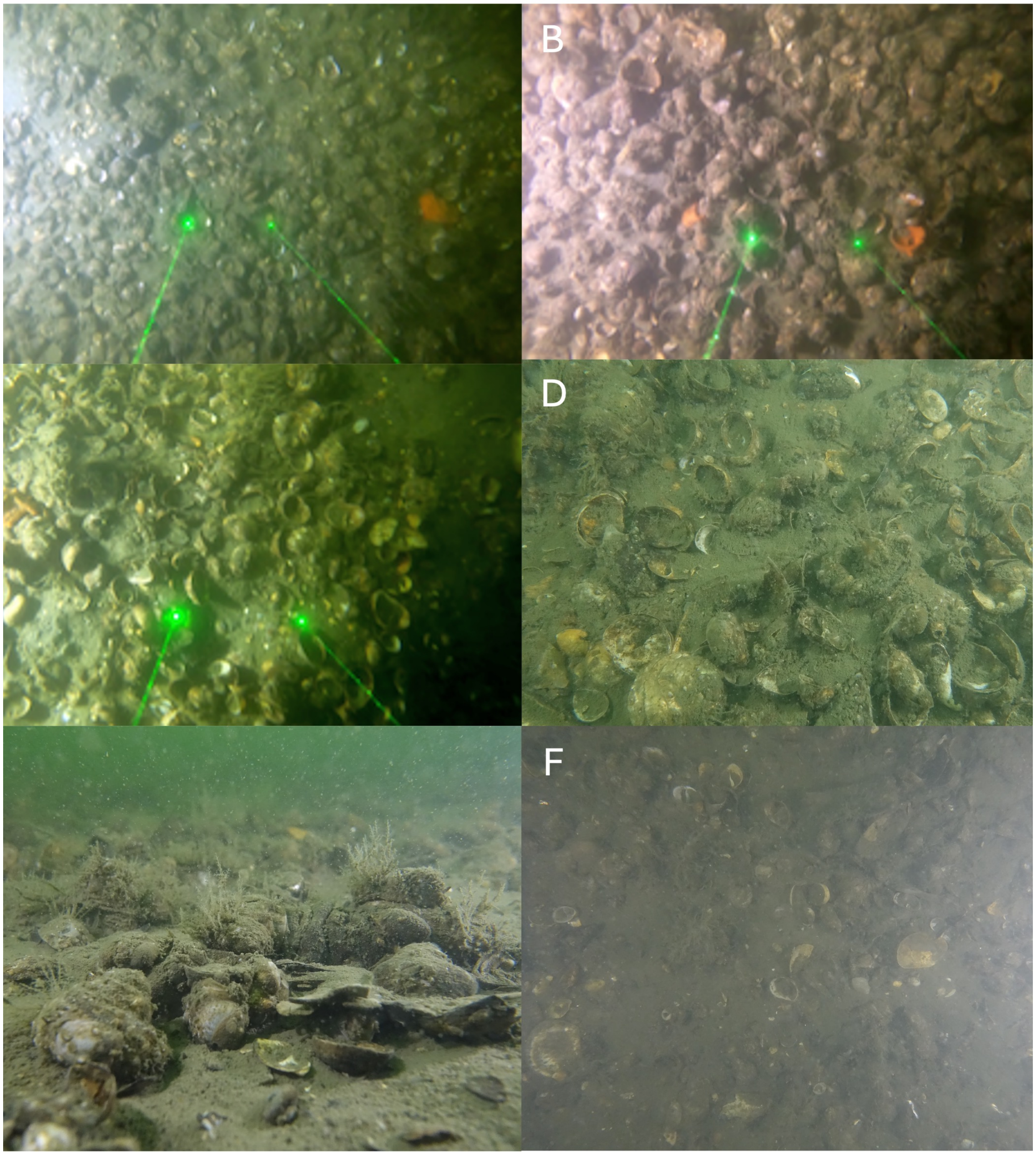


Figure 3-23, percent cover of (a) Mytilus and (b) Crepidula observed during Phase I (2012-13, circles) and AECR PISSAH (Fall 2022, triangles) and wetdiving (Summer 2023, squares) sampling. Observed spatial patterns in abundance along sample transects are noted for Mytilus (a, 2012 Sea Boss sample transects) and Crepidula (b, 2022 PISSAH sample transect).

Northern Stratford Shoal – SB05



B, C – Down-looking frame captures from the PISSAH of dense Crepidula
E, F – Diver images – D & E – hand-held, F - quadropod

Figure 3-24 Images taken by the PISSAH (A-D) and divers (E-F) of the northernmost Phase I site (SB-05) illustrating the densities of Crepidula observed in 2022 and 2023.

4 Summary and Conclusions

The aim of the Assessing Ecological Change and Resiliency (AECR) project was to utilize the best available historic data on key benthic invertebrate populations as baselines to compare the present status of these taxa in Long Island Sound. Numerous historic sources were identified and analyzed over the course of the project, including published data, technical reports, logbooks, archived imagery acquired by divers and ROVs. The current status of the target species populations was determined by re-sampling several of the areas of the Sound that supported them using divers, a custom-built sampling and imaging system, and a small, observation class ROV.

The comprehensive, but infrequent (Phase I – 2012 and 2013; Phase II – 2017 and 2018) sampling conducted by the Long Island Sound Mapping and Research Collaborative (LISMaRC) under the LISCF Seafloor Habitat Mapping Initiative was the impetus for this project, providing a large-scale, detailed assessment of the status of a broad array of benthic taxa in the Sound. This work, combined with the institutional memory of the AECR Principal Investigators of past conditions and available historical data led to the formulation of the three objectives summarized below to address the fundamental question of change and resiliency in the Sound.

4.1 Phase I and II Areas – Large Scale Shift in Target Species

Our review and assessment of historical benthic survey data suggests that *Mytilus* was commonly found in the eastern portion of LIS, albeit at varying densities up until the early 2000s. High abundances were found in several of the survey locations, such as in FIS and areas in the central portion of eastern LIS (Figure 3-1). Diver surveys between 1975 and 1983 indicated mussels were regularly present at a number of locations in eastern LIS and FIS. Review of archival ROV video surveys conducted between 1989 and 1992 revealed extensive aggregations of adult *Mytilus* (Figures 3-10, 3-11), and also dense juvenile mussel mats in FIS in 2006. Mussel populations appear to have declined across eastern LIS and FIS after the mid-2000s, or perhaps earlier more generally. Diver observations between 1984 and 2003 indicate the presence of mussels at fewer locations. The extensive LISMaRC 2017-2018 Phase II ecological assessment found mussels to be absent at many sample locations in eastern LIS, and when present, they occurred at very low abundances.

The bottom grab samples collected in 2022 as part of this AECR study found mussels at effectively just two sites, Ram Island Reef and Latimer Light. Analysis of the PISSAH image data indicated that the percent cover of *Mytilus* was zero at all 18 sites re-sampled in the Phase I (five sites) and Phase II (13 sites) areas. ROV imagery obtained in October 2023 showed no mussels in the Latimer Light area that supported the dense juvenile mats in 2006 ROV observations.

In the case of *Crepidula*, 1970 grab surveys suggested relatively low abundances at most of the sites sampled throughout the Sound. The 1981-1982 survey suggests a similar trend however the data suggest slipper shells at more locations in the eastern end of LIS than previously found. Surveys in the early 1990s and then in the early 2000's suggest a broader spatial distribution of *Crepidula*, and several areas with higher abundances. Since that time, it appears that *Crepidula* increased significantly in the eastern portion of LIS as found in the 2017-2018 Phase II study. Grab sampling using the PISSAH in 2022 suggests that densities declined at the sites that were revisited except at a site located in the far eastern end of FIS. However, analysis of the 2022 PISSAH imagery indicates that the percent cover of *Crepidula* increased significantly at all the sites revisited in the AECR survey. This difference may reflect the smaller spatial footprint of the grab sampler relative to the spatial variation in the density of *Crepidula,* which occur in stacks of individuals with the density and size of the stacks varying over small spatial scales in an area that is covered by *Crepidula*.

It appears that there has been a long-term increase in the area being occupied by *Crepidula* in the eastern end of the Sound, but densities vary spatially and possibly over time scales of several years depending on environmental factors that affect their life histories and survivorship. Thieltges et al. (2004) examined several factors affecting population increases of *Crepidula* introduced to the eastern Atlantic in Europe, including: 1) high predation; 2) high infestation by parasites; 3) low reproductive output and growth in cold waters and; 4) high winter mortality during freezing winters with the latter being posited as the main limiting factor for population increase and that warming waters in winter due to climate change may explain the expansion of northern populations (e.g., Valdizan et al., 2011; Meyer-Kaiser, 2020). Franklin et al. (2023) found that there was no significant reduction of body mass index (BMI) of *Crepidula* during winter months in New England.

The implications of the presence of *Crepidula* at high density and large spatial extent on benthic communities and related ecosystem functions are not well understood. Montaudouin et al. (1999) found little effect of *Crepidula* on the growth of oysters or infaunal communities in an intertidal habitat. Hubbard et al. (2020) found that juvenile, young-of-the-year black sea bass, *Centropristis striata,* were present in statistically significant higher densities on the *Crepidula fornicata* shell reefs than in the sandy/sponge bottom habitats in upper Buzzards Bay, Massachusetts. They also summarized historical data suggesting long-term increases in *Crepidula* in this area of Buzzards Bay (Hubbard et al. 2020). However, juvenile black sea bass appear to be generalists in terms of shell use for cover, utilizing shell aggregates of multiple species (e.g., Able et al., 1995; Auster et al. 2009).

To assess what potential impacts *Crepidula* may be having on benthic communities in eastern LIS, we analyzed the relationship between the density of *Crepidula* and benthic infaunal diversity using data collected during the Phase II study. Several measures of community diversity were regressed against the density of slipper shells at sample locations that had greater than 10 slipper shells. For each analysis there was a significant negative relationship with diversity declining with increasing numbers of *Crepidula*; although the highest amount of variation explained (R^2) was 41.7% (Figure 4-1). The relationship was highly variable at densities below 50 *Crepidula* per sample but less variable and stronger with increasing densities, suggesting that there might be a threshold value above which effects on infaunal community structure become negative.

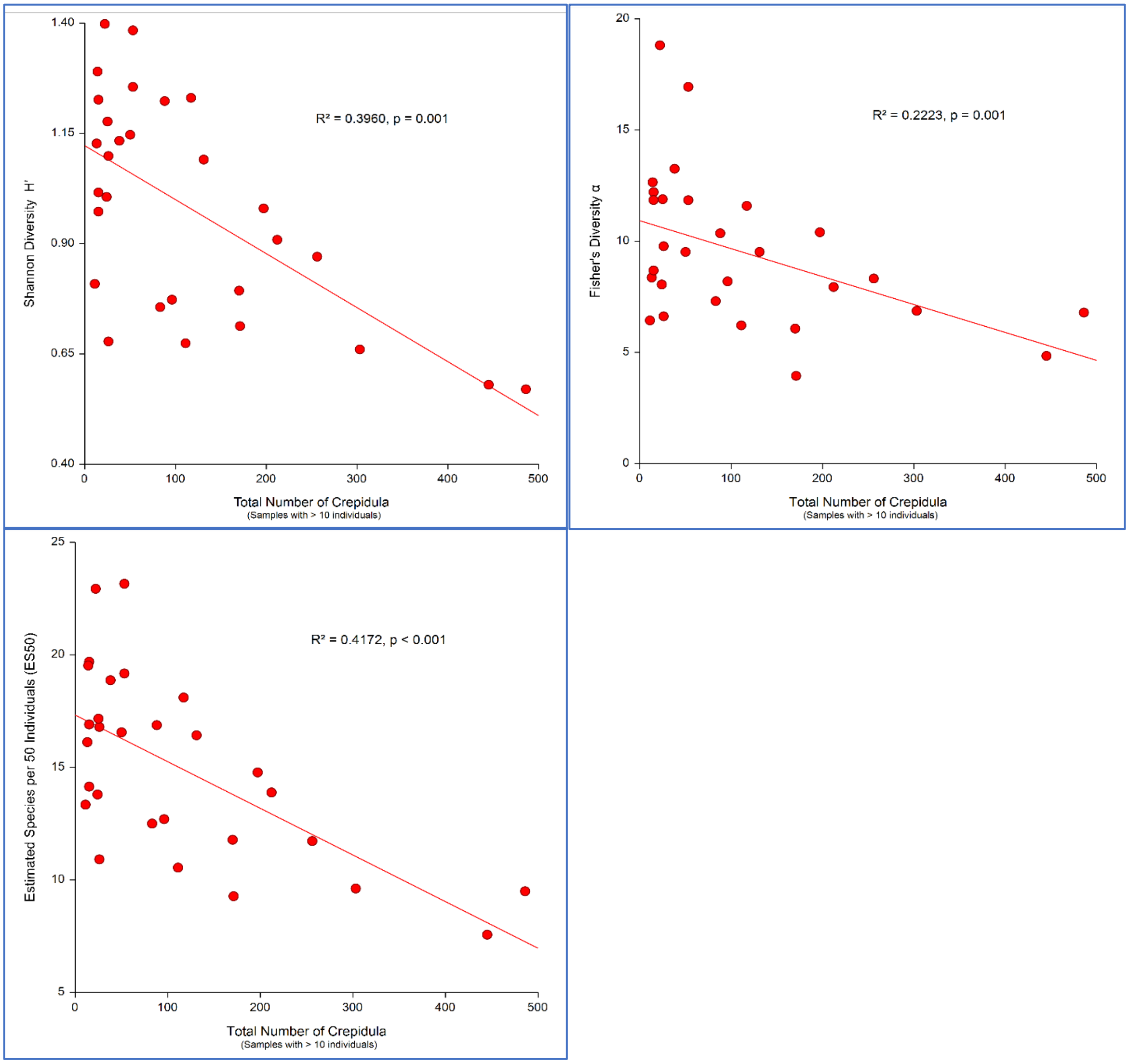


Figure 4-1 Relationships between the density of Crepidula fornicata and C. plana and several measures of community diversity based on data collected in the Phase II study area of eastern LIS. For explanation of each diversity index see https://www.primer-e.com/download/.

4.2 Phase I Area – Is There Evidence of Ecosystem Resilience? The Recovery of Haliclona

Prior to this project, sampling conducted between 1991 and 2013 documented periods of stability as well as variability in hardbottom benthic communities on Stratford Shoal (Stefaniak et al., 2014). What had been largely stable assemblages of sponges (primarily *Haliclona oculata*), corals (*Astrangia poculata*), bivalves (*Mytilus edulis*), and colonial Bryozoans throughout the 1990s and 2000s had changed substantially by the time Phase I sampling began in the Fall of 2012. Boulder reefs that had previously hosted *H. oculata* at densities in excess of 2 colonies per m^2 hosted no adult sponges as determined during intensive sampling conducted in 2012-13. A decade after Phase I, new sampling at these same sites revealed the presence of *H. oculata* on the boulder ridge at the southern extent of Stratford Shoal as well as on boulders east of the Stratford Shoal Middle ground (Figure 3-15) at much lower abundances with patchier distributions than observed in 2010 and earlier.

While the presence of adult *H. oculata* is a positive sign of recovery in hardbottom benthic communities in the face of changing conditions, this alone can't be interpreted as evidence of resilience. The central Sound of recent years is very different from that of the early 2000s. Water temperature has continued to increase with attendant influences on species interactions, major storm events have become more frequent and intense, and invasive species compete for available hard substrates. Both surface and bottom temperatures in LIS have increased over the past half century (Howell and Auster, 2012; CT Council on Environmental Quality, 2024), which may exacerbate the impacts of other factors including disease (Webster, 2007). Both precipitation (Jong et al., 2023) and the frequency of major storm events are increasing throughout the Northeast (Gori et al., 2022) with both direct impacts on shallow marine habitats and increased runoff from rivers. Evidence of increasingly stormy conditions in the central Sound can be seen in increased winter wave heights recorded on the NBDC buoy 44039 since the early 2000s. The dense aggregations of invasive colonial ascidian *Didemnum vexillum* observed with *H. oculata* at the NE corner of southern Stratford Shoal (Figure 3-19) is a concerning new development. While some benthic fauna are known to outcompete *D. vexillum* for available hard substrates, including *A. poculata* and sponges of the Genus *Cliona* (Grace, 2017), the consequences of interactions between the invasive tunicate and *H. oculata* have not been investigated.

The repeated ad hoc sampling of the Stratford Shoal seafloor since the early 1990s has provided the rare opportunity to characterize benthic communities across decades. Despite this time series, direct observations of the seafloor are limited to a handful of instances outside of the extensive sampling conducted in the fall of 2012 and spring 2013. While this has provided insights on changes in benthic communities, more observation is needed to determine whether *H. oculata*, a major structure-forming species, is in the process of recovering to its former distribution and ecological role or if the observed changes are representative of more permanent shifts.

4.3 Phase I Area – Large Scale Shift in Benthic Community? The Apparent Loss of Mytilus

Image data from the Phase I ecological assessment in 2013 indicated varying percent cover of mussels at the sites where they were found, particularly in the troughs of the large sand waves north of Stratford Shoal (Figure 3-20, Table 3-4, Figure 3-22 and Figure 3-23). These high densities were observed in both the fall and spring sampling conducted as part of the LISMaRC Phase I ecological assessment. In the AECR surveys no mussels were found at any of the sites that were reoccupied in 2022 and 2023, indicating the local extirpation in *Mytilus* over the intervening decade.

Relatively few *Crepidula* were generally found in grab samples in the Phase I area across several different habitat types between 2012-2013, although a few sites had elevated densities. No individuals were found in grab samples at the sites reoccupied by AECR. However, image data from the PISSAH and diver surveys indicate a 12% to 54% increase in the percent cover of *Crepidula* at these sites in 2022 and 2023 over that observed in the SEABOSS images from 2012 and 2013 (Table 3-4), suggesting a long-term increase in the presence of slipper shell within these habitats. The factors contributing to the observed shift from *Mytilus* to *Crepidula* dominated benthic communities in the Phase II area have been reported (Conroy et al., 2021), however, it is uncertain if these same drivers have contributed to this similar shift observed in the Phase I area.

4.4 Conclusions and Recommendations

Comparison of historical data spanning from the 1970s through 2018 and additional field studies conducted as part of this project in 2022 and 2023 indicates that there has been a long-term change in the distribution and abundance of the mussel *Mytilus edulis* and the limpet slipper shells *Crepidula fornicata* and *C. plana* in a portion of west central LIS, and over a greater area in eastern LIS. These taxa are habitat creating species having the ability to form extensive low-relief reefs on a variety of substrates and are known to provide habitat for a diversity of ecologically and economically important species. The loss of mussel reefs and the habitats they create may reduce the amount of complex seafloor surface structure that can be beneficial for a variety of species - for example larval and juvenile fish. In the case of *Crepidula*, its impact on benthic communities and taxa associated with the complex habitats it can form appears mixed based on studies conducted to date.

Given the nature of these changes and the potential implications for demersal and infaunal communities, we recommend that permanent study areas be established for time-series studies to monitor the changes that are occurring and assess what impacts they may be having on taxa, as well as ecological and ecosystem functions such as nutrient cycling and related seafloor biogeochemical processes.

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Appendix One: Data Tables for All Key Taxa from Historical Data Reviewed

Table 1-1: Historic Diver Imagery for All Key Taxa – Presence/Absence Sorted by Year
Table 1-2: Historic Diver Imagery for All Key Taxa – Presence/Absence Sorted by Site
Table 1-3: Historic ROV Video for All Key Taxa – Presence/Absence
Table 1-4: Abundance Values for All Key Taxa from 2017 & 2018 Phase II Area from SEABOSS and ROV Surveys

Table 1-1 Historic Diver Imagery All Taxa Presence/Absence Sorted by Year

Year	Location Name	Lat DD	Lon DD	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Asterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
1975	North Dumpling	41.28747	-72.019802	1	0	0	0	0	1	1	0	0
1975	North Dumpling	41.28747	-72.019802	1	0	0	0	0	1	1	0	0
1977	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	0	0	0	0	0
1979	Beebe Cove	41.33067	-71.98537	0	0	1	1	0	0	0	0	0
1979	Latimer Light Reef	41.3046	-71.93347	1	0	1	1	0	0	0	0	0
1979	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	0	0	0	0	0
1979	NL Disposal Site_SE Mussel Patch	41.25817	-72.08567	1	0	0	0	0	0	0	0	0
1979	NL Disposal Site_SW Stn	41.26167	-72.07333	0	0	0	0	0	0	0	0	0
1979	North Dumpling	41.28843	-72.02013	1	0	1	0	1	0	0	0	0
1979	North Dumpling	41.28843	-72.02013	1	0	0	0	1	0	0	0	0
1979	Race Rock	41.24383	-72.046878	0	0	0	0	0	0	0	0	0
1979	Isl	41.28	-71.93083	1	0	0	0	1	0	0	0	0
1979	Stonington Point	41.325	-71.90633	0	0	0	0	1	0	0	0	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1980	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	1	0	1	0	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	1	1	0	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1980	NL Disposal Site_DAISY	41.26667	-72.077167	0	0	0	1	1	0	0	0	0
1980	NL Disposal Site_DIII	41.275	-72.08333	0	0	1	0	0	0	0	0	0
1980	NL Disposal Site_Intermediate Buoy	41.265	-72.08667	1	0	1	0	0	0	0	0	0
1980	NL Disposal Site_SE	41.26167	-72.06667	0	0	0	0	0	0	0	0	0
1980	NL Disposal Site_SE	41.26167	-72.06667	1	0	0	0	0	1	0	0	0
1980	NL Disposal Site_SE Stn	41.26167	-72.06667	1	0	0	0	0	0	0	0	0
1980	NL Disposal Site_SE Stn	41.26167	-72.06667	1	0	0	0	0	0	0	0	0
1980	NL Disposal Site_Stn DI	41.25333	-72.09	0	0	0	0	0	1	0	0	0
1980	NL Disposal Site_Stn DII	41.275	-72.08333	1	0	0	0	0	0	0	0	0
1980	NL Disposal Site_SW Stn	41.26167	-72.07333	1	0	0	0	0	0	0	0	0
1980	NL Disposal Site_SW Stn	41.26167	-72.07333	1	0	0	0	0	0	0	0	0
1980	NL Disposal Site_SW Stn	41.26167	-72.07333	1	0	0	0	0	0	0	0	0
1981	Beebe Cove	41.33067	-71.98537	0	0	0	1	0	0	0	0	0
1981	Beebe Cove	41.33067	-71.98537	0	0	1	1	0	0	0	0	0
1981	Beebe Cove Entrance	41.33067	-71.98537	0	0	1	0	0	0	0	1	0

Table 1-1 Historic Diver Imagery All Taxa Presence/Absence Sorted by Year

Year	Location Name	Lat DD	Lon DD	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Asterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
1981	Latimer Light Reef	41.3046	-71.93347	1	0	1	0	0	1	0	0	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	1	1	0	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0	0	1	0	0	0	0	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1981	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	0	0	0	0	0
1981	NL Disposal Site	41.26167	-72.06667	0	0	0	0	0	0	0	0	0
1981	NL Disposal Site_NE	41.27	-72.075	1	0	0	0	0	0	0	0	0
1981	NL Disposal Site_SE Stn	41.26167	-72.06667	1	0	0	0	0	0	0	0	0
1981	NL Disposal Site_SW Stn	41.26167	-72.07333	1	0	0	0	0	0	0	0	0
1981	Two Tree Island Channel	41.29632	-72.13789	1	0	0	0	0	0	0	0	0
1982	Beebe Cove	41.33067	-71.98537	0	0	1	0	0	0	0	0	0
1982	Beebe Cove Entrance	41.33067	-71.98537	0	0	0	0	0	0	0	0	0
1982	Ellis Reef	41.3145	-71.955641	0	0	0	1	1	0	0	0	0
1982	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1982	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	0	0	0	0	0
1982	Latimer Light Reef	41.3046	-71.93347	0	0	0	0	0	1	0	0	0
1982	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	0	0	0	0	0
1982	NL Displosal Site	41.26167	-72.06667	0	0	0	0	0	0	0	0	0
1982	North Dumpling	41.28843	-72.02013	1	0	0	0	0	0	0	0	0
1982	North Dumpling	41.28843	-72.02013	1	0	0	0	0	0	0	0	0
1982	Ram Island Reef	41.3062	-71.9746	1	0	0	1	1	0	0	0	0
1982	Ram Island Reef	41.3062	-71.9746	1	0	1	0	1	0	0	0	0
1982	Ram Island Reef	41.3062	-71.9746	1	0	0	0	0	0	0	0	0
1983	Black Ledge	41.30487	-72.071283	1	0	0	0	1	0	0	0	0
1983	Black Ledge	41.30487	-72.071283	1	0	0	0	1	0	0	0	0
1983	Ellis Reef	41.3145	-71.955641	0	0	0	0	1	0	0	0	0
1983	Ellis Reef	41.3145	-71.955641	0	0	0	1	0	0	0	0	0
1983	Latimer Light Reef	41.3046	-71.93347	0	0	0	0	0	0	0	0	0
1983	North Dumpling	41.28843	-72.02013	0	0	0	0	0	0	0	0	0
1983	Ram Island Reef	41.3062	-71.9746	0	0	0	1	1	0	0	0	0
1985	Ram Island Reef	41.3062	-71.9746	1	0	0	0	0	0	0	0	0
1986	Ellis Reef	41.3145	-71.955641	0	0	0	0	1	1	0	0	0
1986	Ram Island Reef	41.3062	-71.9746	0	0	0	0	0	0	0	0	0
1986	Ram Island Reef	41.3062	-71.9746	0	0	0	0	1	0	0	0	0
1986	Ram Island Reef	41.3062	-71.9746	0	0	0	0	0	1	0	0	0

Table 1-1 Historic Diver Imagery All Taxa Presence/Absence Sorted by Year

Year	Location Name	Lat DD	Lon DD	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Asterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
1986	Ram Island Reef	41.3062	-71.9746	0	0	0	0	1	1	0	0	0
1986	Ram Island Reef	41.3062	-71.9746	1	0	0	1	0	0	0	0	0
1986	Ram Island Reef	41.3062	-71.9746	0	0	0	0	0	0	0	1	1
1987	Beebe Cove Entrance	41.33067	-71.98537	0	0	1	0	1	0	0	1	0
1987	Deep Hole	41.30385	-71.913788	0	0	0	0	1	1	0	1	1
1987	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	0	1	1	0	1	0
1987	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	1	0	0	0	0	0
1987	Ellis Reef	41.3145	-71.955641	0	0	0	1	0	0	0	0	0
1987	Ellis Reef	41.3145	-71.955641	0	0	0	0	1	0	0	1	0
1987	Ellis Reef	41.3145	-71.955641	0	0	0	1	0	0	0	0	0
1987	Ellis Reef	41.3145	-71.955641	0	0	1	1	0	0	0	0	0
1987	Latimer Light Reef	41.3046	-71.93347	0	0	0	1	0	0	0	0	0
1987	Latimer Light Reef	41.3046	-71.93347	0	0	0	0	0	0	1	0	0
1987	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	1	0	1	0	1
1988	Ellis Reef	41.3145	-71.955641	0	0	1	0	1	1	0	1	0
1988	Ellis Reef	41.3145	-71.955641	0	0	0	1	0	0	0	1	0
1988	Race Rock	41.24383	-72.046878	1	0	1	0	0	0	0	0	1
1988	Race Rock	41.24383	-72.046878	1	0	0	0	0	0	0	0	0
1990	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	1	0	0	0	0	0
1991	Deep Hole	41.30385	-71.913788	0	0	0	0	1	1	0	1	1
1991	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	0	0	0	0	0	0
1991	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	0	1	1	0	1	0
1991	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	0	0	0	0	0	0
1992	NL Disposal Site	41.271	-72.10912	0	0	0	0	0	0	0	0	0
1992	NL Disposal Site_Dive 1			0	0	0	0	0	1	0	1	0
1992	NL Disposal Site_Dive 2			0	0	0	0	1	0	0	0	0
1992	NL Disposal Site_Dive 3	41.2708	-72.128	0	0	0	0	0	1	0	0	0
1992	NL Disposal Site_Dive 4	41.27162	-72.09545	0	0	0	0	0	1	0	0	0
1993	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	0	1	1	0	1	1

Table 1-1 Historic Diver Imagery All Taxa Presence/Absence Sorted by Year

Year	Location Name	Lat DD	Lon DD	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Asterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
1993	NL Disposal Site	41.275	-72.10373	0	0	0	0	0	0	0	0	0
2023	Ellis Reef	41.31512	-71.95563	0	0	0	0	1	0	1	1	1
2023	North Stratford Shoal	41.11311	-73.12064	0	1	0	0	1	0	0	1	0
2023	Ram Island Reef	41.31227	-71.97553	0	0	0	1	1	0	1	0	1
2023	Startford Shoal	41.03835	-73.10977	0	1	0	1	1	0	0	1	0

Table 1-2 Historic Auster Image Data All Taxa Presence/Absence Sorted by Site

Year	Location Name	Lat DD	Lon DD	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Asterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
1979	Beebe Cove	41.33067	-71.98537	0	0	1	1	0	0	0	0	0
1981	Beebe Cove	41.33067	-71.98537	0	0	0	1	0	0	0	0	0
1981	Beebe Cove	41.33067	-71.98537	0	0	1	1	0	0	0	0	0
1982	Beebe Cove	41.33067	-71.98537	0	0	1	0	0	0	0	0	0
1981	Beebe Cove Entrance	41.33067	-71.98537	0	0	1	0	0	0	0	1	0
1982	Beebe Cove Entrance	41.33067	-71.98537	0	0	0	0	0	0	0	0	0
1987	Beebe Cove Entrance	41.33067	-71.98537	0	0	1	0	1	0	0	1	0
1983	Black Ledge	41.30487	-72.07128	1	0	0	0	1	0	0	0	0
1983	Black Ledge	41.30487	-72.07128	1	0	0	0	1	0	0	0	0
1987	Deep Hole	41.30385	-71.91379	0	0	0	0	1	1	0	1	1
1991	Deep Hole	41.30385	-71.91379	0	0	0	0	1	1	0	1	1
1987	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	0	1	1	0	1	0
1987	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	1	0	0	0	0	0
1990	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	1	0	0	0	0	0
1991	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	0	0	0	0	0	0
1991	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	0	1	1	0	1	0
1991	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	0	0	0	0	0	0
1993	East of Latimer_Deep Hole	41.303	-71.91333	0	0	0	0	1	1	0	1	1
1982	Ellis Reef	41.3145	-71.95564	0	0	0	1	1	0	0	0	0
1983	Ellis Reef	41.3145	-71.95564	0	0	0	0	1	0	0	0	0
1983	Ellis Reef	41.3145	-71.95564	0	0	0	1	0	0	0	0	0
1986	Ellis Reef	41.3145	-71.95564	0	0	0	0	1	1	0	0	0
1987	Ellis Reef	41.3145	-71.95564	0	0	0	1	0	0	0	0	0
1987	Ellis Reef	41.3145	-71.95564	0	0	0	0	1	0	0	1	0
1987	Ellis Reef	41.3145	-71.95564	0	0	0	1	0	0	0	0	0
1987	Ellis Reef	41.3145	-71.95564	0	0	1	1	0	0	0	0	0
1988	Ellis Reef	41.3145	-71.95564	0	0	1	0	1	1	0	1	0
1988	Ellis Reef	41.3145	-71.95564	0	0	0	1	0	0	0	1	0
2023	Ellis Reef	41.31512	-71.95563	0	0	0	0	1	0	1	1	1
1977	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	0	0	0	0	0
1979	Latimer Light Reef	41.3046	-71.93347	1	0	1	1	0	0	0	0	0

Table 1-2 Historic Auster Image Data All Taxa Presence/Absence Sorted by Site

Year	Location Name	Lat DD	Lon DD	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Asterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
1979	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	0	0	0	0	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1980	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	1	0	1	0	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	1	1	0	0
1980	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0	1	0	0	1	0	0	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	1	1	0	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0	0	1	0	0	0	0	0
1981	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1981	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	0	0	0	0	0
1982	Latimer Light Reef	41.3046	-71.93347	1	0	0	0	0	0	0	0	0
1982	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	0	0	0	0	0
1982	Latimer Light Reef	41.3046	-71.93347	0	0	0	0	0	1	0	0	0
1982	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	0	0	0	0	0
1983	Latimer Light Reef	41.3046	-71.93347	0	0	0	0	0	0	0	0	0
1987	Latimer Light Reef	41.3046	-71.93347	0	0	0	1	0	0	0	0	0
1987	Latimer Light Reef	41.3046	-71.93347	0	0	0	0	0	0	1	0	0
1987	Latimer Light Reef	41.3046	-71.93347	0	0	1	0	1	0	1	0	1
1982	NL Displosal Site	41.26167	-72.06667	0	0	0	0	0	0	0	0	0
1981	NL Disposal Site	41.26167	-72.06667	0	0	0	0	0	0	0	0	0
1992	NL Disposal Site	41.271	-72.10912	0	0	0	0	0	0	0	0	0
1993	NL Disposal Site	41.275	-72.10373	0	0	0	0	0	0	0	0	0
1980	NL Disposal Site_DAISY	41.26667	-72.07717	0	0	0	1	1	0	0	0	0
1980	NL Disposal Site_DIII	41.275	-72.08333	0	0	1	0	0	0	0	0	0
1992	NL Disposal Site_Dive 1			0	0	0	0	0	1	0	1	0
1992	NL Disposal Site_Dive 2			0	0	0	0	1	0	0	0	0
1992	NL Disposal Site_Dive 3	41.2708	-72.128	0	0	0	0	0	1	0	0	0
1992	NL Disposal Site_Dive 4	41.27162	-72.09545	0	0	0	0	0	1	0	0	0

Table 1-2 Historic Auster Image Data All Taxa Presence/Absence Sorted by Site

Year	Location Name	Lat DD	Lon DD	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Asterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
1980	NL Disposal Site_Intermediate Buoy	41.265	-72.08667	1	0	1	0	0	0	0	0	0
1981	NL Disposal Site_NE	41.27	-72.075	1	0	0	0	0	0	0	0	0
1980	NL Disposal Site_SE	41.26167	-72.06667	0	0	0	0	0	0	0	0	0
1980	NL Disposal Site_SE	41.26167	-72.06667	1	0	0	0	0	1	0	0	0
1979	NL Disposal Site_SE Mussel Patch	41.25817	-72.08567	1	0	0	0	0	0	0	0	0
1980	NL Disposal Site_SE Stn	41.26167	-72.06667	1	0	0	0	0	0	0	0	0
1980	NL Disposal Site_SE Stn	41.26167	-72.06667	1	0	0	0	0	0	0	0	0
1981	NL Disposal Site_SE Stn	41.26167	-72.06667	1	0	0	0	0	0	0	0	0
1980	NL Disposal Site_Stn DI	41.25333	-72.09	0	0	0	0	0	1	0	0	0
1980	NL Disposal Site_Stn DII	41.275	-72.08333	1	0	0	0	0	0	0	0	0
1979	NL Disposal Site_SW Stn	41.26167	-72.07333	0	0	0	0	0	0	0	0	0
1980	NL Disposal Site_SW Stn	41.26167	-72.07333	1	0	0	0	0	0	0	0	0
1980	NL Disposal Site_SW Stn	41.26167	-72.07333	1	0	0	0	0	0	0	0	0
1980	NL Disposal Site_SW Stn	41.26167	-72.07333	1	0	0	0	0	0	0	0	0
1981	NL Disposal Site_SW Stn	41.26167	-72.07333	1	0	0	0	0	0	0	0	0
1975	North Dumpling	41.28747	-72.0198	1	0	0	0	0	1	1	0	0
1975	North Dumpling	41.28747	-72.0198	1	0	0	0	0	1	1	0	0
1979	North Dumpling	41.28843	-72.02013	1	0	1	0	1	0	0	0	0
1979	North Dumpling	41.28843	-72.02013	1	0	0	0	1	0	0	0	0
1982	North Dumpling	41.28843	-72.02013	1	0	0	0	0	0	0	0	0
1982	North Dumpling	41.28843	-72.02013	1	0	0	0	0	0	0	0	0
1983	North Dumpling	41.28843	-72.02013	0	0	0	0	0	0	0	0	0
2023	North Stratford Shoal	41.11311	-73.12064	0	1	0	0	1	0	0	1	0
1979	Race Rock	41.24383	-72.04688	0	0	0	0	0	0	0	0	0
1988	Race Rock	41.24383	-72.04688	1	0	1	0	0	0	0	0	1

Table 1-2 Historic Auster Image Data All Taxa Presence/Absence Sorted by Site

Year	Location Name	Lat DD	Lon DD	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Asterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
1988	Race Rock	41.24383	-72.04688	1	0	0	0	0	0	0	0	0
1982	Ram Island Reef	41.3062	-71.9746	1	0	0	1	1	0	0	0	0
1982	Ram Island Reef	41.3062	-71.9746	1	0	1	0	1	0	0	0	0
1982	Ram Island Reef	41.3062	-71.9746	1	0	0	0	0	0	0	0	0
1983	Ram Island Reef	41.3062	-71.9746	0	0	0	1	1	0	0	0	0
1985	Ram Island Reef	41.3062	-71.9746	1	0	0	0	0	0	0	0	0
1986	Ram Island Reef	41.3062	-71.9746	0	0	0	0	0	0	0	0	0
1986	Ram Island Reef	41.3062	-71.9746	0	0	0	0	1	0	0	0	0
1986	Ram Island Reef	41.3062	-71.9746	0	0	0	0	0	1	0	0	0
1986	Ram Island Reef	41.3062	-71.9746	0	0	0	0	1	1	0	0	0
1986	Ram Island Reef	41.3062	-71.9746	1	0	0	1	0	0	0	0	0
1986	Ram Island Reef	41.3062	-71.9746	0	0	0	0	0	0	0	1	1
2023	Ram Island Reef	41.31227	-71.97553	0	0	0	1	1	0	1	0	1
1979	S Wreck Island - Fishers Isl	41.28	-71.93083	1	0	0	0	1	0	0	0	0
2023	Startford Shoal	41.03835	-73.10977	0	1	0	1	1	0	0	1	0
1979	Stonington Point	41.325	-71.90633	0	0	0	0	1	0	0	0	0
1981	Two Tree Island Channel	41.29632	-72.13789	1	0	0	0	0	0	0	0	0

Table 1-3 Historic ROV Video All Key Taxa Presence/Absence

Year	Lat_DD	Lon_DD	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Asterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
1989	41.2793083	-72.14888	1	0	0	1	1	0	1	0	0
1990	41.2941333	-72.034675	1	1	0	0	1	1	0	0	0
1990	41.283085	-72.10488	1	0	0	0	1	1	0	0	0
1991	41.2700433	-72.0732433	1	0	0	0	0	0	1	0	0
1991	41.2938116	-72.0344133	1	0	0	0	1	1	1	0	0
1992	41.2886083	-72.0420183	1	0	1	1	1	1	1	1	0
1992	41.29919	-71.94672	0	0	1	1	1	1	1	1	0
1992	41.3039533	-71.9062716	0	0	1	1	1	1	1	1	0
2006	41.3001566	-71.9554316	0	0	0	0	1	1	1	1	1
2006	41.3039216	-71.9098133	0	0	0	0	1	1	1	0	1
2006	41.3037833	-71.9097683	1	0	1	0	1	1	1	1	1
2006	41.3027983	-71.9014	1	0	0	0	1	1	0	1	1
2006	41.30372	-71.913995	1	0	0	0	1	1	1	1	1

Table 1-4. Abundance Values for All Key Taxa from 2017 and 2018 Phase II Area from SEABOSS and ROV Surveys

YEAR	Lat_DD	Lon_DD	SAMPLE AREA	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Aterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
2017	41.3000917	-72.0258083	NB51	0	179	0	0	24	0	0	0	0
2017	41.3001025	-72.0258475	NB51	0	0	0	0	0	0	0	0	0
2017	41.300185	-72.0263517	NB51	0	0	0	0	0	0	0	0	0
2017	41.3002983	-72.02671	NB51	0	0	0	0	0	0	0	0	0
2017	41.3004067	-72.0270609	NB51	0	133	0	0	7	0	0	0	0
2017	41.3004225	-72.0271892	NB51	0	193	0	0	64	0	0	0	0
2017	41.3005	-72.0274	NB51	0	0	0	0	0	0	0	0	0
2017	41.3005267	-72.0275333	NB51	0	6	0	0	0	0	0	0	0
2017	41.3007867	-72.028075	NB51	0	125	0	0	34	0	0	0	0
2017	41.30082	-72.0282509	NB51	0	0	0	0	0	0	0	0	0
2017	41.3009133	-72.0286175	NB51	0	7	0	0	1	0	0	0	0
2017	41.3009333	-72.0286975	NB51	0	91	0	0	23	0	0	0	0
2017	41.30106915	-72.0291942	NB51	0	53	0	0	14	0	0	0	0
2017	41.30114415	-72.0296125	NB51	0	167	0	0	40	0	0	0	0
2017	41.30116835	-72.0297792	NB51	0	65	0	0	5	0	0	0	0
2017	41.30122	-72.0300333	NB51	0	28	0	0	0	0	0	0	0
2017	41.2831683	-71.9902617	NB56	0	100	0	0	10	0	0	0	32
2017	41.2831317	-71.9904567	NB56	0	57	0	13	17	0	0	0	46
2017	41.28311085	-71.9905142	NB56	0	25	0	0	5	0	0	0	21
2017	41.28296	-71.990985	NB56	0	0	0	0	0	0	0	0	5
2017	41.282855	-71.9913983	NB56	0	0	0	0	0	0	0	0	17
2017	41.28284085	-71.9914925	NB56	0	0	0	0	10	0	0	6	12
2017	41.28282	-71.991565	NB56	0	0	0	0	0	0	0	0	0
2017	41.2825667	-71.9924283	NB56	0	0	0	0	0	0	0	0	0
2017	41.2824183	-71.992765	NB56	0	10	0	0	22	0	0	0	14
2017	41.28234665	-71.9931209	NB56	0	4	0	0	43	0	0	0	13
2017	41.2823075	-71.9933725	NB56	0	5	0	5	90	0	0	4	14
2017	41.28226835	-71.9940017	NB56	0	40	0	0	4	0	0	0	11
2017	41.28217335	-71.9941792	NB56	0	147	0	0	10	0	0	0	16
2017	41.282155	-71.9942533	NB56	0	140	0	0	30	0	0	1	25
2017	41.2821083	-71.99454	NB56	0	126	0	0	9	0	0	0	24

Table 1-4. Abundance Values for All Key Taxa from 2017 and 2018 Phase II Area from SEABOSS and ROV Surveys

YEAR	Lat_DD	Lon_DD	SAMPLE AREA	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Aterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
2017	41.2819983	-71.9951067	NB56	0	189	0	0	60	0	0	0	0
2017	41.281975	-71.995265	NB56	0	186	0	0	14	0	0	0	8
2017	41.2728833	-71.9608833	NB59	0	0	0	0	0	0	0	2	0
2017	41.27258	-71.96082	NB59	0	0	0	0	0	0	0	0	0
2017	41.2722583	-71.9607117	NB59	0	0	0	0	1	0	0	2	0
2017	41.2721625	-71.96069	NB59	0	0	0	0	23	0	0	13	0
2017	41.271825	-71.9606617	NB59	0	0	0	0	0	0	10	0	0
2017	41.2717833	-71.960645	NB59	0	0	0	0	0	0	0	0	0
2017	41.27142335	-71.9605725	NB59	0	202	0	0	11	0	0	0	0
2017	41.27134	-71.9605567	NB59	0	9	0	0	0	0	0	0	0
2017	41.2711033	-71.9605	NB59	0	76	0	0	0	0	0	0	0
2017	41.2709533	-71.9604783	NB59	0	212	0	0	8	0	0	0	0
2017	41.2705883	-71.9604	NB59	0	18	0	0	0	0	0	0	0
2017	41.2701817	-71.9602917	NB59	4	125	0	0	0	0	0	0	0
2017	41.2700483	-71.960265	NB59	0	2	0	0	0	0	0	0	0
2017	41.26954	-71.9602117	NB59	0	8	0	0	0	0	0	0	0
2017	41.2695033	-71.9601983	NB59	0	0	0	0	0	0	0	0	0
2017	41.26924165	-71.9601359	NB59	0	0	0	0	0	0	0	0	0
2017	41.2692208	-71.9601308	NB59	0	6	0	0	0	0	0	0	0
2017	41.273	-71.9608525	NB59	0	0	0	0	0	0	0	0	0
2017	41.2728425	-71.9608425	NB59	0	0	0	0	0	0	0	0	0
2017	41.2726083	-71.960795	NB59	0	0	0	0	0	0	8	0	0
2017	41.27220835	-71.9607483	NB59	0	0	0	0	0	0	0	0	0
2017	41.2721767	-71.9607483	NB59	0	0	0	0	0	0	10	6	0
2017	41.2716917	-71.9606483	NB59	0	3	0	0	0	0	0	0	0
2017	41.27157	-71.96061	NB59	0	7	0	8	0	0	0	0	0
2017	41.233925	-72.2556117	SB46	0	14	0	0	0	0	0	0	8
2017	41.2337083	-72.2554817	SB46	0	16	0	0	0	0	0	0	0
2017	41.233465	-72.2553667	SB46	0	9	0	0	0	0	0	0	1
2017	41.233315	-72.2553259	SB46	0	89	0	0	0	0	0	0	0
2017	41.2332767	-72.2553117	SB46	0	7	0	0	0	0	0	0	0

Table 1-4. Abundance Values for All Key Taxa from 2017 and 2018 Phase II Area from SEABOSS and ROV Surveys

YEAR	Lat_DD	Lon_DD	SAMPLE AREA	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Aterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
2017	41.2329508	-72.2551959	SB46	0	2	0	0	0	0	0	0	0
2017	41.2328392	-72.255155	SB46	0	0	0	0	0	0	0	0	0
2017	41.232755	-72.2551233	SB46	0	16	0	0	0	0	0	0	0
2017	41.232375	-72.255005	SB46	0	4	0	0	0	0	0	0	0
2017	41.2322975	-72.25499	SB46	0	6	0	0	0	0	0	0	0
2017	41.2320917	-72.2549317	SB46	0	0	0	0	0	0	0	0	0
2017	41.2320475	-72.2549134	SB46	0	0	0	0	0	0	0	0	0
2017	41.231935	-72.2548583	SB46	0	0	0	0	0	0	0	0	0
2017	41.23183165	-72.2548217	SB46	0	0	0	0	0	0	0	0	0
2017	41.2317783	-72.2548067	SB46	0	2	0	0	0	0	0	0	0
2017	41.231655	-72.254765	SB46	0	2	0	0	0	0	0	0	0
2017	41.2311133	-72.2545817	SB46	1	9	0	0	0	0	0	0	0
2017	41.23107	-72.2545659	SB46	0	8	0	0	0	0	0	0	0
2017	41.2815183	-72.0219859	SB68	0	0	0	0	0	0	0	0	0
2017	41.2814017	-72.0221233	SB68	0	0	0	0	0	0	0	0	0
2017	41.2813367	-72.02225	SB68	0	6	0	0	0	0	0	0	2
2017	41.281125	-72.02261	SB68	0	11	0	0	4	0	0	0	0
2017	41.2809917	-72.022895	SB68	0	30	0	0	4	0	0	0	4
2017	41.28095915	-72.0229959	SB68	0	0	0	0	0	0	0	0	2
2017	41.28095	-72.0231567	SB68	0	0	0	0	0	0	0	0	0
2017	41.2808225	-72.0235967	SB68	0	0	0	0	0	0	0	0	0
2017	41.2807533	-72.0238083	SB68	0	0	0	0	0	0	0	0	2
2017	41.28070915	-72.0239308	SB68	0	0	0	0	33	0	0	0	0
2017	41.28068	-72.0240192	SB68	0	0	0	0	16	0	0	0	0
2017	41.2806067	-72.0243267	SB68	0	0	0	0	0	0	0	0	6
2017	41.2805867	-72.0244108	SB68	0	0	0	0	17	0	0	0	0
2017	41.28056	-72.0245883	SB68	0	0	0	0	3	0	0	0	0
2017	41.2805433	-72.024725	SB68	0	0	0	0	126	0	0	0	0
2017	41.2805033	-72.02492	SB68	0	0	0	0	106	0	0	0	0
2017	41.2804533	-72.0250717	SB68	0	0	0	0	88	0	0	0	0
2017	41.3151817	-71.91473	SB72	0	8	0	0	0	0	0	0	0

Table 1-4. Abundance Values for All Key Taxa from 2017 and 2018 Phase II Area from SEABOSS and ROV Surveys

YEAR	Lat_DD	Lon_DD	SAMPLE AREA	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Aterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
2017	41.3151425	-71.9147775	SB72	0	0	0	0	0	0	0	0	0
2017	41.31498085	-71.9148759	SB72	0	0	0	0	0	0	0	0	0
2017	41.3145342	-71.9152133	SB72	0	0	0	0	2	0	0	0	0
2017	41.314395	-71.9153234	SB72	0	4	0	0	0	0	0	0	0
2017	41.31432835	-71.91537	SB72	0	8	0	0	0	0	0	0	0
2017	41.3140433	-71.915565	SB72	0	0	0	0	0	0	0	0	0
2017	41.31388415	-71.9156775	SB72	0	0	0	0	0	0	0	0	0
2017	41.3138067	-71.9157183	SB72	0	0	0	0	0	0	0	0	0
2017	41.3136175	-71.915855	SB72	0	0	0	0	0	0	0	0	0
2017	41.31357	-71.9158825	SB72	0	0	0	0	0	0	0	0	0
2017	41.31321585	-71.9161467	SB72	0	0	0	0	0	0	0	0	0
2017	41.3130025	-71.9162959	SB72	0	8	0	0	2	0	9	0	0
2017	41.312835	-71.9163917	SB72	0	0	0	0	1	0	0	0	0
2017	41.312695	-71.9165267	SB72	0	0	0	0	0	0	0	0	0
2017	41.312675	-71.9165467	SB72	0	0	0	0	0	0	0	0	0
2017	41.3123367	-71.9167067	SB72	0	0	0	0	1	0	0	0	0
2017	41.3123017	-71.9167267	SB72	0	0	0	0	0	0	0	0	0
Totals				5	3003	0	26	982	0	37	34	283
2018	41.2727258	-71.9612534	NB59	0	0	0	0	0	0	20	0	0
2018	41.2721767	-71.9615033	NB59	0	0	0	0	0	0	0	0	0
2018	41.271795	-71.9616725	NB59	0	0	0	0	0	0	22	0	0
2018	41.27163085	-71.96174	NB59	0	0	0	0	0	0	0	0	0
2018	41.27267	-71.9609533	NB59	0	0	0	0	0	0	0	0	0
2018	41.2725817	-71.9610183	NB59	0	0	0	0	0	0	0	0	0
2018	41.2718083	-71.9610417	NB59	0	0	0	0	0	0	0	0	0
2018	41.2716733	-71.9610467	NB59	0	0	0	0	0	0	0	4	0
2018	41.2712225	-71.9610392	NB59	0	60	0	0	0	0	3	0	0
2018	41.2711	-71.9610583	NB59	0	63	0	0	0	0	0	0	0
2018	41.2803275	-72.0243967	SB68	0	0	0	0	0	0	0	0	0
2018	41.28038	-72.0254417	SB68	0	0	0	0	44	0	0	0	0
2018	41.280385	-72.025525	SB68	0	0	0	0	56	0	0	0	0

Table 1-4. Abundance Values for All Key Taxa from 2017 and 2018 Phase II Area from SEABOSS and ROV Surveys

YEAR	Lat_DD	Lon_DD	SAMPLE AREA	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Aterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
2018	41.2804517	-72.02628	SB68	0	30	0	0	2	0	0	0	0
2018	41.28048415	-72.026935	SB68	0	179	0	0	17	0	0	0	0
2018	41.280485	-72.0270483	SB68	2	86	0	0	22	0	0	0	0
2018	41.2805567	-72.0278883	SB68	0	174	0	0	29	0	0	0	0
2018	41.28056	-72.0279525	SB68	0	168	0	0	22	0	0	0	0
2018	41.2805917	-72.0284317	SB68	0	191	0	0	21	0	0	0	0
2017 Total				5	3003	0	26	982	0	37	34	283
2018 Total				2	951	0	0	213	0	45	4	0
Grand Total				7	3954	0	26	1195	0	82	38	283

Appendix Two - Data Tables for All Key Taxa from Recently Collected Data

Table 2-1: Presence/Absence Data for AECR Sites Re-sampled by the PISSAH in 2022.
Table 2-2: Presence/Absence Data for Key Taxa from the 2023 Boxfish ROV
Table 2-3: Presence/Absence of All Key Taxa at AECR Sites Re-sampled by Divers in 2023
Table 2-4 Percent Cover of All Key Taxa at AECR Sites Re-sampled by the PISSAH in 2022.

Table 2-1: Presence/Absence Data for AECR Sites Re-sampled by the PISSAH in 2022.

AECR Site #	Site Name	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Astreias sp.	Kelp sp.	Didemnum sp.	Astrangia poculata
1	NB59-2, S of Fishers	0	1	0	0	1	0	1	0	0
2	SB68, N of Fishers by Dumpling (SBXX)	0	1	0	0	1	0	0	0	1
3	NB51, S of Bluff Point	0	1	0	0	1	0	0	0	0
4	SB 72-2 , near Latimer light	0	1	0	0	0	0	1	0	0
5	SB 46-2; middle of Phase II area	0	1	0	0	0	0	0	0	0
6	NB 56, off north shore of Fishers Island	0	1	0	0	1	0	1	0	0
7	NAGL-90-44 and NAGL-91-25, Seaflower Reef	0	1	0	0	1	0	0	0	1
8	NAGL-06-11, Whitlatch Dive#6	0	1	0	0	1	0	1	0	1
9	NAGL-06-11, Whitlatch Dive#7	0	1	0	0	1	0	0	0	1
10	Ellis Reef	0	0	0	0	1	0	0	0	1
11	North Dumpling	0	1	0	0	1	0	0	0	0
12	Latimer Light Reef	0	0	0	0	1	0	0	0	0
13	Ram Island Reef	0	1	0	0	1	0	0	0	1
14	SB-05E, Northern sand waves	0	1	0	0	0	0	0	0	0
15	SB-12E, Boulder area	0	0	0	0	0	0	0	0	0
16	SB11 Crepidula site	0	1	1	1	0	0	0	0	1
17	SB21-2 Rocky Sponge site	0	1	0	1	0	0	0	0	1
18	SB12 - ROV site	0	0	0	1	1	0	0	1	1

Table 2-2: Presence/Absence Data for Key Taxa from the 2023 Boxfish ROV

Site	Location	Lat_DD	Lon_DD	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Asterias sp.	Kelp sp.	Astrangia poculata	Didemnum sp.
1	Near the Deep Hole	41 18.257	71 54.669	0	0	0	0	1	0	0	1	1

Table 2-3. Presence/Absence of All Key Taxa at AECR Sites Re-sampled by Divers in 2023

AECR Site #	Site Name	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Asterias sp.	Kelp sp.	Didemnum sp.	Astrangia poculata
14	North Stratford Shoal	0	1	0	0	1	0	0	0	1
10	Ellis Reef	0	0	0	0	1	0	1	1	1
13	Ram Island Reef	0	0	0	1	1	0	1	1	0
17	Stratford Shoal	0	1	0	1	1	0	0	0	1

Table 2-4. Percent Cover of All Key Taxa at AECR Sites Re-sampled by the PISSAH in 2022.

AECR Site #	Site Name	Mytilus edulis	Crepidula fornicata	Metridium senile	Haliclona oculata	Cliona sp.	Kelp sp.	Didemnum sp.	Astrangia poculata
1	NB59-2, S of Fishers	0.00%	72.78%	0.00%	0.00%	0.19%	24.77%	0.00%	15.09%
2	SB68, N of Fishers by Dumpling (SBXX)	0.00%	88.61%	0.00%	0.00%	0.52%	0.00%	0.00%	0.50%
3	NB51, S of Bluff Point	0.00%	89.32%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
4	SB 72-2 , near Latimer light	0.00%	78.83%	0.00%	0.00%	0.00%	37.86%	0.00%	0.00%
5	SB 46-2; middle of Phase II area	0.00%	68.44%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
6	NB 56, off north shore of Fishers Island	0.00%	85.05%	0.00%	0.00%	7.47%	2.74%	0.00%	0.00%
7	NAGL-90-44 and NAGL-91-25, Seaflower Reef	0.00%	38.44%	0.00%	0.00%	3.33%	0.00%	0.00%	0.89%
8	NAGL-06-11, Whitlatch Dive#6	0.00%	18.19%	0.00%	0.00%	22.67%	5.33%	0.00%	17.94%
9	NAGL-06-11, Whitlatch Dive#7	0.00%	10.75%	0.00%	0.00%	58.44%	0.00%	0.00%	41.86%
10	Ellis Reef	0.00%	0.00%	0.00%	0.00%	19.78%	0.00%	0.00%	14.89%
11	North Dumpling	0.00%	0.99%	0.00%	0.00%	1.67%	0.00%	0.00%	0.00%
12	Latimer Light Reef	0.00%	0.00%	0.00%	0.00%	1.14%	0.00%	0.00%	0.00%
13	Ram Island Reef	0.00%	32.22%	0.00%	0.00%	11.85%	0.00%	0.00%	3.21%
14	SB-05E, Northern sand waves	0.00%	48.08%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
15	SB-12E, Boulder area	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
16	SB11? Crepidula site	0.00%	68.40%	0.99%	1.23%	0.00%	0.00%	0.00%	18.77%
17	SB21-2 Rocky Sponge site	0.00%	16.59%	0.00%	5.19%	0.00%	0.00%	0.00%	42.07%
18	SB12 - ROV site	0.00%	0.00%	0.00%	2.04%	5.19%	0.00%	29.44%	25.37%
All	Overall	0.00%	45.43%	0.04%	0.49%	6.24%	3.54%	1.52%	9.90%