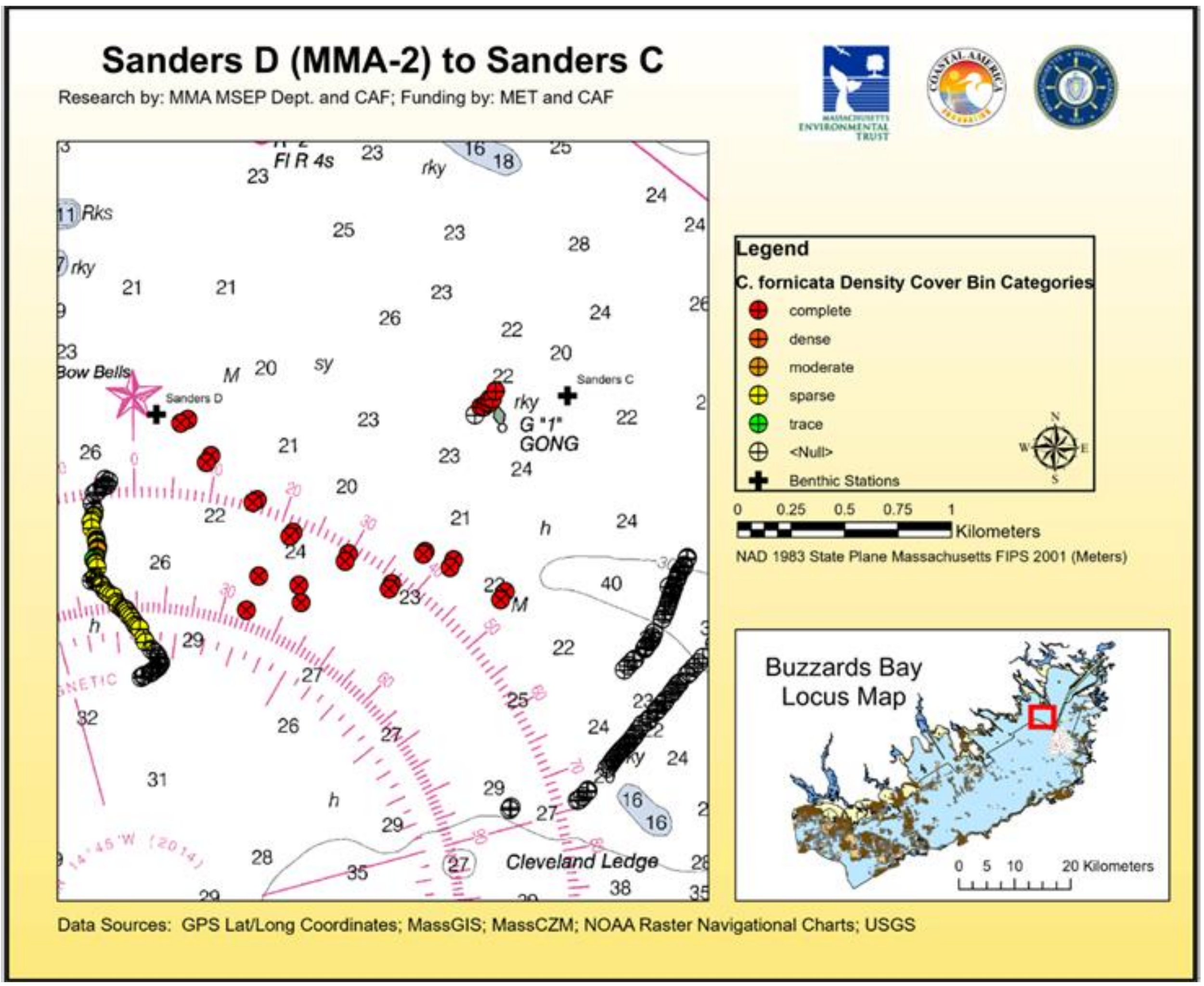
Benthic studies in Buzzards Bay, MA – Final Report from the Massachusetts Maritime Academy and Coastal America Foundation



William A. Hubbard, Michael J. Elliott and Francis J. Veale, Jr.

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Marine Science, Safety and Environmental Protection Department
Massachusetts Maritime Academy

A digital library of data, GIS shape files and video links can be found at:

http://www.coastalamericafoundation.org/mmascience.html

Also, MMA/CAF video of marine research and underwater mapping is available on the YouTube Station: *CoastalAmericaFound1*

All CAF Video at YouTube is on Playlist *https://www.youtube.com/playlist?list=PLph8fQU1HJO-NfAay7_hSR3H5gqbjqyFW*

Final Report
MMA/CAF Benthic Studies in Buzzards Bay, MA

Executive Summary:

All grant requirements for the subject effort funded by the Massachusetts Environmental Trust have been met or exceeded. Mapping of Buzzards Bay *Crepidula fornicata* slipper shell reefs from 2015 to 2017 have been classified and entered as a GIS database. Biological studies have determined a statistically significant correlation of higher amounts (8X) of juvenile black seabass on C-reefs than on nearby sand/sponge habitat. Benthic community structure has been documented and show comparable diversity of species associated with each location. The ecological productivity of these systems warrants their conservation as a nursery and forage habitat for important juvenile finfish resources.

Report:

The purpose of this final report is to document the field and laboratory activities for the collaborative benthic mapping scientific investigations of Buzzards Bay, MA that were undertaken by the Massachusetts Maritime Academy (MMA) and the Coastal America Foundation (CAF). Particular emphasis is given to identify those fulfilling the Massachusetts Environmental Trust (MET) award requirements (see Appendix A for Scope of Services awarded).

This project began at the suggestion of the Massachusetts Office of

Coastal Zone Management (on MMA Marine Safety and Environmental Protection (MSEP) Advisory Committee) that MMA collaborate with the benthic research of CAF and provide habitat mapping for the newly discovered *Crepidula fornicata* reefs (C-reefs) in Buzzards Bay. GIS Adjunct Professor Michael Elliott approached CAF Marine Sciences Director (Bill Hubbard) at the Northeast Regional Ocean Council meeting and a 2014 collaboration began. In 2014. The MMA research vessel Liberty, with a $2500 grant awarded to MMA from CAF (7 June 2014) for fuel and a davit, was used along with a Seaviewer underwater camera and recording system (ca. $6000) donated to MMA by CAF.

In winter 2015 CAF donated hand-held GPS, a SIMRAD nss- EVO-2 Chart plotter, structure scan transducer and chirp sonar transducer (ca $4000). This was to replace the out of date Ray Marine system on the MMA Research Vessel (R/V) Liberty.

The MET first year grant was announced on 24 July 2015. MET awarded MMA $40,400 to accomplish the first year of benthic mapping. All matching funds and contracted efforts were accomplished as documented in that final report.

I. 2016/2017 FUNDING FROM MET:

MMA/CAF Buzzards Bay Benthic Mapping program had received a $43,000 grant in 2014/2015 (similar to the effort detailed here for 2016/2017) and a $40,000 grant from MET in 2016/2017– that was matched as described in Table 1. The grant and match are based on a 24-sea day level of effort. MMA received MET funds for MMA overhead ($7400) and Fuel ($1800). All of the researcher (Hubbard, Elliott, Veale) and student efforts have been executed to date, and 100% of MET grant requirements have been accomplished. The CAF has supplied the $5000 Student Stipend that matches the $2400 MET stipend.

Table 1. Budget and Match for MET Grant

BUDGET
Massachusetts Maritime Academy and Coastal America Foundation
Buzzards Bay Benthic Mapping (24 Sea Days Effort/yr)

DESCRIPTION	REQUESTED	IN-KIND	PROJECT TOTAL	RATE
		*CAF Funded		
YEAR 1 (2016-2017)				
Labor				
Principal Investigator (Hubbard)	$14,400.00	$6,000.00	$20,400.00	$600/Day
Research Scientist (Elliott)	$9,600.00	$0.00	$9,600.00	$400/Day
Research Scientist (Veale)	$4,800.00	$0.00	$4,800.00	$400/day
Student Stipend*	$2,400.00	$5,000.00	$7,400.00	$100/day
Non-Labor				
Fuel*	$1,400.00	$1,800.00	$3,200.00	$75/day
Research Vessels Liberty and/or Teleost	$0.00	$24,000.00	$24,000.00	$1000/day
ROV/Towed Camera/GPS Equipment	$0.00	$12,000.00	$12,000.00	$500/day
GPS/Strucure Scan Equipment	$0.00	$2,400.00	$2,400.00	$100/day
Overhead (20%) {full (26%) is reduced}	$7,400.00	$2,200.00	$9,600.00	
YEAR 1 SUBTOTAL	**$40,000.00**	**$53,400.00**	**$93,400.00**	
			Total 2 year Project was $183,400.00+	

In summary, all cost matching efforts for the calendar year 2016 and 2017 work has been accomplished. More field days have been executed to accomplish the grant data collection than the agreed 24 sea days. In total 35 sea days were accomplished in 2016 (see Table 2). These included biological and benthic mapping cruises. Nine Van Veen grab samples were obtained and processed, more that the agreed 3 replicates. This allowed 3 replicates at 3 different C-reefs. The remaining work accomplished was Video and Field Data Processing (Hubbard), GIS Mapping (Elliott) and Report Compilation (Hubbard, Elliott and Veale). CAF has supplied the 21-foot R/V Teleost, the

VideoRay ROV and the CAF HD underwater camera recording system as needed. MMA has supported the field effort with the 29-foot R/V Liberty, which was critical to carry several students on each cruise, as they have benefited from the field experience.

II. RESEARCH COMMITTED IN MET PROPOSAL:

The MMA/CAF team committed to the following efforts (as quoted from Appendix A): "

"*Research objectives scope of work:*

We will conduct 24 research cruises with students that would expand ongoing collaboration with the Coastal America Foundation and Massachusetts Office of Coastal Zone Management. The Investigators and MMA faculty and students will be performing the following research activities:

- Remotely Operating Vehicle (ROV) video imagery (Figure 4) to assess the biological dominants on the C-reefs by developing a species list from station videos (estimated at 6 cruise events at Tobys C-reef plus other opportunities))
- Benthic infaunal grabs (Van Veen) and trap deployments, with a special emphasis on the Tobys Island C-reef to develop a biodiversity inventory (estimated 3 with 500-micron sieves and opportunistically with 1.00 mm sieves – ID by W. Hubbard taxonomist)
- Underwater digital video system transects imagery recordings (Figure 5) to verify and define the spatial extent of *C. fornicata* reefs in Buzzards Bay (every sea day – estimated 1 kilometer minimum each transect)
    - Accurate GPS tracking will be collected to coincide with underwater video transect imagery data.
    - The above two data sets are to be uploaded in ArcGIS software allowing for spatial analysis and input to the Massachusetts Ocean Resources Information System to support the Massachusetts Ocean Management Plan.
    - Determination of the imagery classification under the Coastal and Marine Ecological Classification System.
    - Coordination of the transects data and CMECS classification with Massachusetts Office of Coastal Zone Management, US Geological Survey, Massachusetts Division of Marine Fisheries, EPA Buzzards Bay National Estuary Program, and regional researchers."

FIGURE 1. Benthic Mapping Camera system with structure scan.

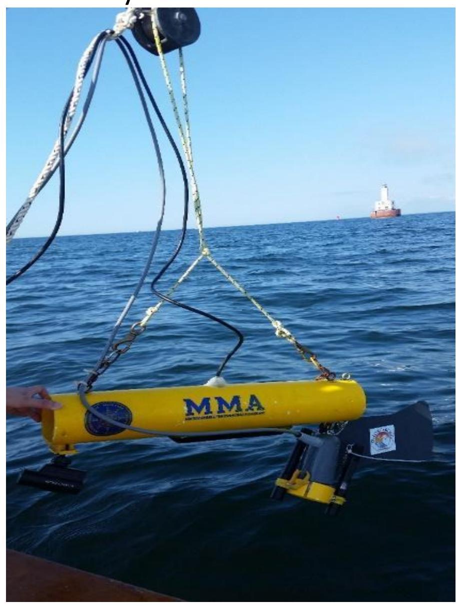


Figure 2. Benthic Mapping Camera 2016 improvements.

Table 2. ***<u>2016 C-Reef Research Cruises</u>***

JUN 14 - Teleost with new camera - recon Marion Reef - no video recorded - too rough.

JUN 15 - Teleost -BH and Brad Barr from NOAA

JUN 16 - Teleost -BH and Bradford Lupton - Polaroid

JUN 17 - Teleost - BH and Larry Oliver - USACE

JUN 18 - Teleost - BH and Kristin Osborne

JUN 19 - Teleost -BH and Kristin Osborne

JUN 27 - Teleost - BH and Tyler Aldrich.

JUN 29 - Teleost - BH and Tyler Aldrich.

JUN 30 - Liberty - BH and Tyler Aldrich and ASLP students

JUL 1 - Liberty - BH and Tyler Aldrich and ASLP students

JUL 7 - Liberty - BH and Tyler Aldrich and ASLP students

JUL 12 - Teleost - BH and Tyler Aldrich

JUL 14 - Teleost - BH and Tyler Aldrich

JUL 20 - BH, Tyler and Kris Osborne - benthic sampling CAF D.

JUL 27 - Teleost - Tyler Aldrich and BH

JUL 28 - Teleost and TA and KK

JUL 29 - Teleost and TA - BL

AUG 3 - Teleost CAF A and E - Benthic - Tyler Aldrich and Bradshaw Lupton

AUG 4 - Teleost ROV and fixed camera -Tyler Aldrich

AUG 5 - Teleost ROV and fixed camera - Tyler Aldrich

AUG 23 - Teleost ROV - BH

AUG 24 - Teleost ROV and drop camera - BH Bradshaw Lupton

AUG 30 - Teleost drop camera - BH and Kris Kelly - camera (2) video distorted

SEP 1 - Teleost drop camera 3 with onboard recorder

SEP 7 - Teleost drop camera - sponge bed on edges - and Sias Point - BH

SEP 16 - Teleost -BH- Pole Camera Abele ledge

SEP 25 - Teleost - Mashnee Flats vs Stony Point ledge for juv densities (BH, Dr Kelly+2)

SEP 26 - Teleost - MMA Flats - BH, BL, Cadets Allen and Coute

SEP 28 - RV Liberty BH and 6 students form MMA - Halpin, Benton, Fedorachuck, Narhuminiti, Desrosiers, Legnine.

OCT 3 - RV Liberty BH and 6 students from MMA - Thompson, Coute, Souza, Mattson, Brown and Barchielli - Toby Island Reef.

OCT 5 - RV Liberty BH and 3 students from MMA - Selander, Klangos and McNeil.

OCT 8 - RV Teleost BH and USACE Oliver

OCT 12 - Van Veen Toby Island

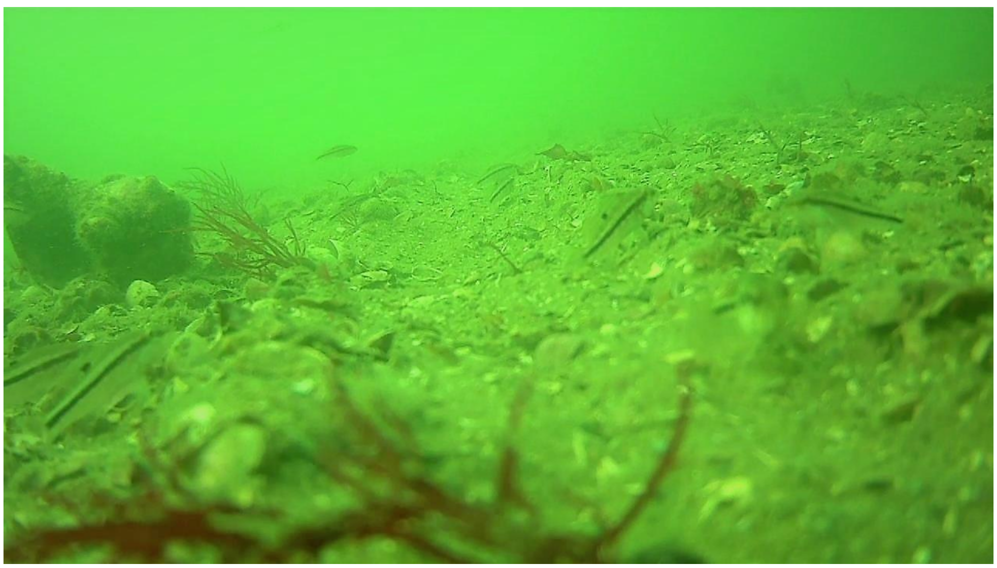
OCT 17 - Van Veen Mashnee Flats

OCT 19 - Van Veen CAF Station D

Biological Observations:

Juvenile (YoY) black sea bass density on C-reef versus sand/sponge habitat in upper Buzzards Bay, Massachusetts:

Abstract: Juvenile, young of the year, black sea bass are present in statistically significant higher densities on *Crepidula fornicata*/sponge reefs than sand/sponge areas. This sampling identified an average of 8 times more fish on the C-reef habitat.

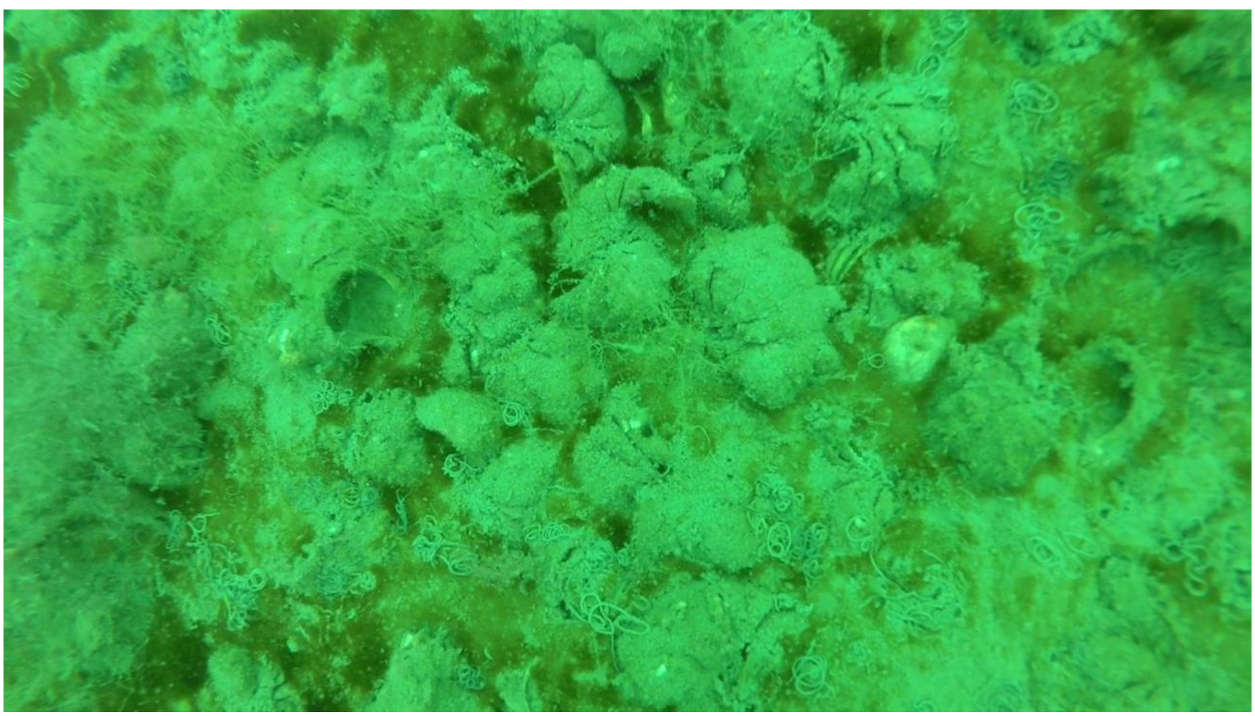


On 23 and 24 August 2016 two sampling events occurred using high definition (Seaviewer® 6000) underwater video cameras to produce video recording (Seaviewer® HDMI H.264 Recorder) of a *Crepidula fornicata* (common slipper shell) reef (C-reef) with some sponge (H..) and a sandy habitat with sponge. These videos were recorded from a surface deployed camera in profile view. The video was post processed to produce screen shot stills to document juvenile black sea bass densities.

These stations were located 2.5 kilometers apart, in upper (eastern) Buzzards Bay, at the end of Hog Island channel – just outside Stony Dike. The *Crepidula* reef video was in the general vicinity of 41°40'28.82"N/ 70°40'20.35"W. Sand/sponge video was in the general vicinity of 41°40'56.93"N/ 70°42'3.26"W.

Appendix III. A has a listing of screen shots examined for number of juvenile black sea bass. Initial screening eliminated screen shots that were not in focus, too turbid or otherwise allowing less than 90% of the field of view to be examined. Due to the low density initially observed on sand/sponge habitat, more than twice the number of those frames were examined. All screen shots were reviewed in full, in eight zoom quadrants and with enhanced contrast/color scaling. Numbers of black sea bass 'young of the year (YoY)" were recorded for each screen shot, as listed in Appendix A. An unpaired T-test (assumes Gaussian (theoretical frequency distribution represented by a normal ‘bell’ curve) distributions), as well as a Mann-Whitney test (this is a T-test that does NOT assume Gaussian distribution), were run on the data. In both tests, $p < 0.001$, the number of individuals on C-reef/sponge versus sand/sponge habitat is statistically very different between stations. The average of 6.3 fish in the slipper shell/sponge reef versus 0.77 fish on sand/sponge habitat is an 8-fold fish density increase on C-reef habitats.

The C-reefs residents produce a nutrient rich waste that settles in among the stacked shell “curls”. This substrate may provide significant food source for small polychaetes such as *Polygordius apendiculata* (below photograph) that would be reasonable prey for juvenile black sea bass.



Benthic Community Structure on C-reefs in Buzzards Bay, Massachusetts:

The 3 reefs sampled contained a highly diverse assemblage of benthic organisms. At Toby Island Reef 188 individual *Crepidula fornicata* were measured for height, length and – in general among all age groups the average height is 1.3 cm, width is 0.78 cm and length is 2.1 cm. The below table reports all individuals identified to species. Statistical analyses that follow the data indicate good affinity to the replications and comparative communities to the published data from 2011/2012 (Hubbard 2016). These data will be used to develop several journal articles, with funding source recognized as MET.

Chao 2 and similar analyses indicate 3 replicates are adequate to identify dominants. Similarity cluster analysis of fourth root transformed data exhibits the affinity of replicates and similarity of the 3 sampled reefs. Species number ranged from 7 to 19 species and, as they were all replicates on c-reefs identified in video transects, *Crepidula fornicata* was the dominant species.

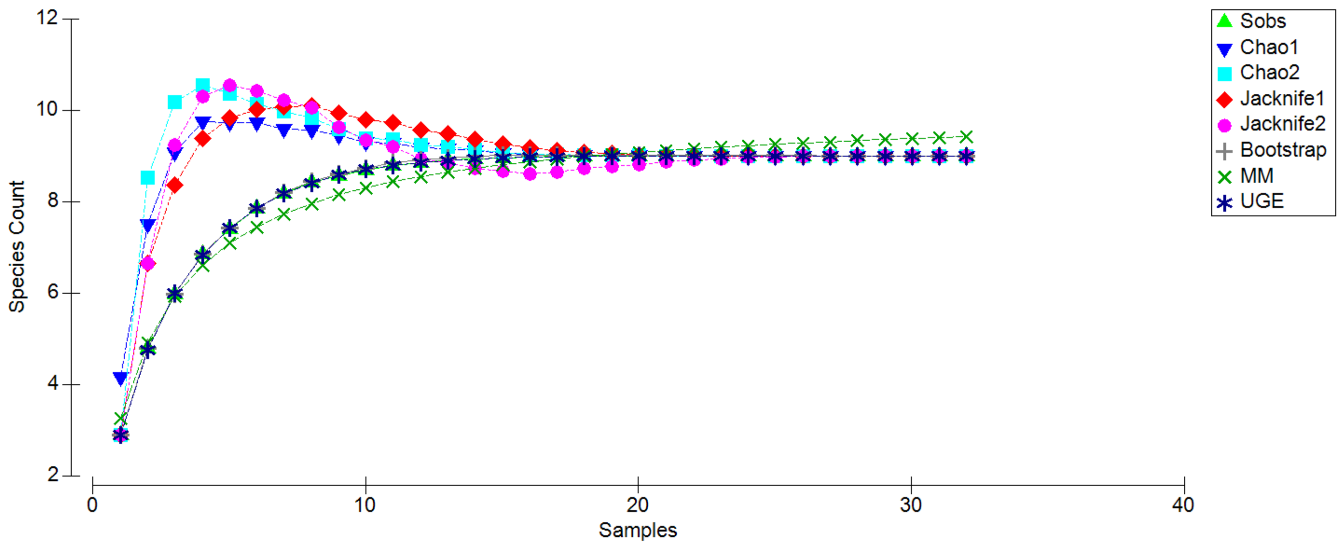
All of this statistical analysis needs to be taken as a qualitative description. Although only full van Veen grabs were retained, the dense shell aggregations inherently cause some grab leakage (entrainment) and imperfect closure of the grab. Divers and core sampling was beyond the scope of this grant but are being considered for 2018 field season.

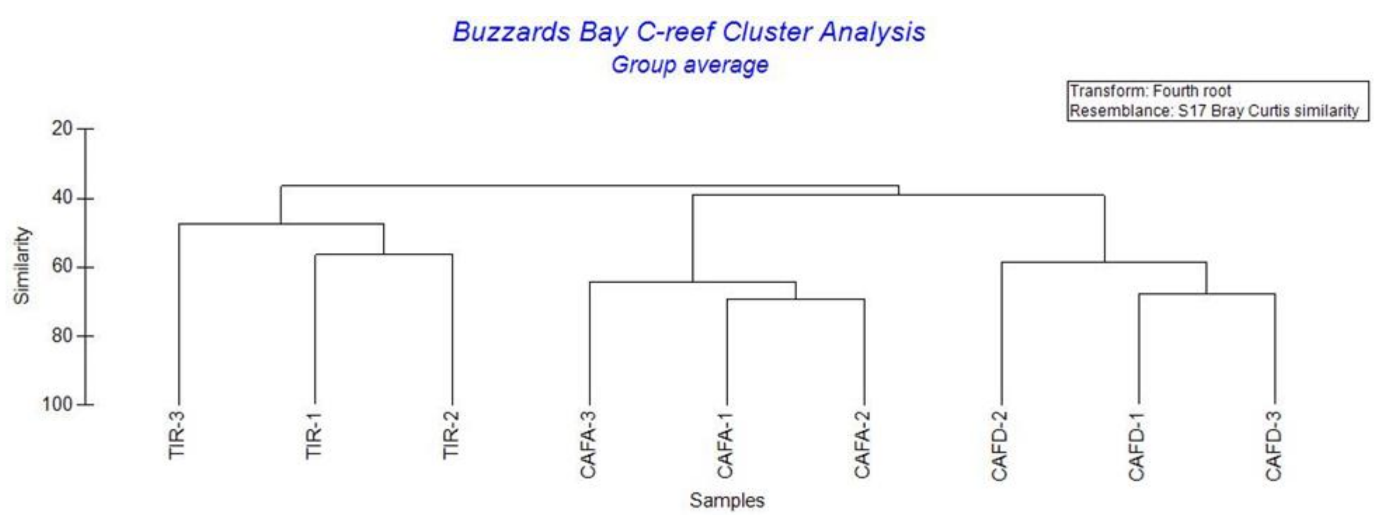
Using the analysis from Hubbard 2016 and running the same comparisons to the current data, the diversity, similarity and number of species is similar to all but the 1955 samples. Sanders (1958) publication reported those 1955 samples at Station A and D had higher species numbers (23 and 28 different species respectively). Also, the dominant substrate in 1955 was silty sand, not a shell reef. There were no *Crepidula fornicata* reported in any of the 19 Buzzards Bay stations of Sanders (1958) publication.

These C-reefs represent an ecological adaptation to changed biotic and abiotic factors.

	CAFA-1	CAFA-2	CAFA-3	CAFD-1	CAFD-2	CAFD-3	TIR-1	TIR-2	TIR-3	SS5-A	OCAF-A1	OCAF-A2	OCAF-A3	SS5-D	OCAF-D1	OCAF-D2	OCAF-D3
Molgula complanata	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Spiochaetopterus costarum	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Arabella iricolor	0	4	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Marphysa sanguinea	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0
Goniadella gracilis	0	0	0	0	0	0	0	0	0	1	0	0	0	9	0	0	0
Microphthalmus aberrans	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
Podarke obscura	0	0	0	0	0	0	0	0	0	6	16	6	15	5	7	7	8
Clymenella torquata	0	0	0	2	6	5	0	0	3	0	0	0	1	0	0	0	0
Praxillella gracilis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Nephtys ciliata	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nereis zonata	7	3	0	0	0	0	0	1	2	1	0	0	0	0	0	0	0
Eulalia bilineata	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Eumida sanguinea	0	0	0	0	0	0	0	0	0	0	4	0	0	3	0	4	6
Polygordius appendiculatus	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0
Harmothoe extenuata	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0
Lepidonotus squamatus	6	6	4	0	2	0	0	1	0	0	2	1	0	1	0	0	0
Sthenelais boa	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Leonice cirrata	0	2	0	0	4	0	1	0	0	0	0	0	0	0	0	0	0
Prionospio steenstrupi	0	0	0	0	0	0	0	0	0	0	3	0	3	0	2	0	1
Spiophanes bombyx	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Exogone dispar	0	0	0	0	0	5	8	0	0	0	0	0	0	5	8	0	0
Lumbrineris fragilis	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tharyx acutus	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0
Cirratulus grandis	0	0	0	1	0	0	0	0	0	0	8	2	17	0	1	0	0
Diopatra cuprea	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Eteone trilineata	0	0	0	0	0	0	0	0	0	0	0	2	0	0	5	0	0
Glycera americana	0	0	0	0	0	0	0	0	0	1	5	0	5	8	0	0	0
Mediomastus ambiseta (Capitell	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0
Glycera robusta	0	0	0	0	2	0	0	8	0	0	0	0	0	0	0	0	0
Polydora concharum	1	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Nephtys bucera	4	0	0	0	47	0	0	0	0	4	0	0	0	0	47	0	0
Polycirrus eximius	0	0	0	0	0	0	0	0	0	7	0	1	0	3	0	0	0
Polydora concharum	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0
Sabellaria vulgaris	2	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Scoloplos fragilis	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Scolelepis squamata (Nerindisaq	8	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0
Ampharete arctica	6	0	0	0	4	0	0	1	0	6	0	0	0	4	0	0	1
Lumbrineris acuta	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pectinaria gouldii	2	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Pista palmata	1	0	0	0	2	0	0	0	0	1	0	0	0	2	0	0	0
Scoloplos (Scoloplos) armiger	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Lumbrinereis hebes	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Aricidea jeffreysii	0	3	3	0	0	0	0	1	0	0	0	0	0	0	0	0	0
Scoletoma (Lumbrineris) tenuis	1	0	0	0	2	0	0	0	0	1	0	0	0	2	0	0	0
Crassicorophium crassicorne	0	0	0	0	0	0	0	0	0	0	3	5	18	0	0	0	0
Atylus swammerdamei	0	0	0	0	0	0	0	0	0	0	0	0	13	0	0	0	0
Jassa falcata	0	0	0	0	0	0	3	5	3	0	0	0	0	0	0	0	0
Ampelisca macrocephala	4	6	1	3	0	1	0	0	0	0	0	1	0	45	0	0	0
Byblis serrata	0	0	0	0	8	0	0	0	0	0	0	0	0	0	0	8	0
Ericthonius punctatus (brasiliens	7	0	0	0	1	0	0	0	0	7	0	0	0	0	0	0	0
Phoxocephalus holbolli	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	0	0
Rhithropanopeus harrisii	7	9	3	1	0	0	0	0	0	0	0	0	0	0	2	1	1
Ampelisca abdita (=A)	0	0	0	0	0	0	0	0	0	8	0	0	0	228	0	0	0
Boreochiton ruber	1	2	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Crepidula fornicata	63	104	52	107	114	177	57	38	93	0	55	86	72	0	43	2	33
Ensis directus	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0
Heteromysis formosa	0	0	0	0	0	0	0	0	0	0	10	0	0	0	1	1	0
Anadara transversa	4	2	0	0	0	0	1	1	3	0	1	6	3	0	1	1	0
Laevicardium mortoni	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Macoma tenta	0	0	0	0	0	0	0	0	0	0	0	0	0	19	0	0	0
Nucula delphinodonta	6	1	3	0	0	1	3	3	0	0	0	0	0	0	0	0	0
Nucula proxima (A)	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	1	0
Pandora gouldiana	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0
Cyclaspis varians	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	0
Oxyurostylis smithi	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	6	0
Edotia triloba	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Batea catharinensis (secunda)	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0
Corophium tuberculatum	0	0	0	0	10	4	2	6	0	0	0	0	0	0	0	0	0
Eobrolgus (Paraphoxus) spinosu	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0
Stenothoe minuta	0	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0
Unciola irrorata	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	7	0
Crangon septemspinosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	3
Pagurus annulipes	0	0	0	0	0	0	0	0	1	2	0	0	0	3	0	0	0
Pagurus longicarpus	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Panopeus herbstii	0	0	0	0	0	0	0	0	0	0	0	2	1	2	0	0	0
Pinnixa sayana	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Lunatia pallida (Natica pusilla)	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Chaetopleura apiculata	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0
Costoanachis avara	6	6	2	0	0	0	1	0	0	8	0	0	0	1	4	0	0
Seila adamsii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Crepidula plana	1	0	0	0	0	0	1	0	0	0	6	7	0	0	9	0	4
Eupleura caudata	0	0	0	0	0	0	0	0	0	5	0	0	0	3	0	0	0
Mitrella lunata	0	0	0	0	0	0	0	0	0	14	3	2	4	2	0	1	1
Urosalpinx cinerea	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphipholis squamata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Ophiopholus aculeata	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Neopanope texana	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Apohyale (Hyale) prevostii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Ilyanassa (Nassarius) trivittata	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0

C-reef Statistical Analyses – 2016 Benthic Stations





DIVERSE

Univariate Diversity indices

Data worksheet

Name: Data1

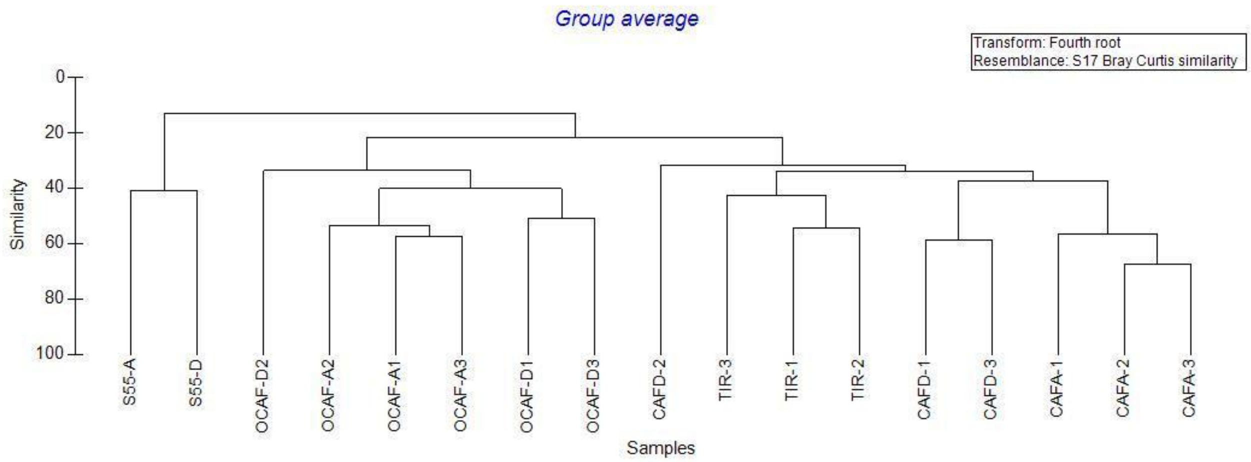
Data type: Abundance

Sample selection: All

Variable selection: All

Sample	S	N	d	J'	Brillouin	Fisher	H'(loge)	1-Lambda'
CAFA-1	16	23	4.807	0.9842	1.985	24.26	2.729	0.9744
CAFA-2	19	25	5.563	0.9814	2.138	34.13	2.89	0.9787
CAFA-3	13	16	4.287	0.9811	1.805	28.83	2.516	0.9731
CAFD-1	7	10	2.638	0.9402	1.331	11.21	1.829	0.9084
CAFD-2	6	10	2.208	0.9465	1.262	6.81	1.696	0.8876
CAFD-3	6	9	2.259	0.9102	1.069	7.589	1.631	0.8603
TIR-1	9	12	3.199	0.9704	1.459	15.52	2.132	0.9496
TIR-2	10	13	3.511	0.9761	1.628	19.99	2.247	0.9615
TIR-3	7	10	2.579	0.9543	1.331	9.742	1.857	0.9154

C-reef Statistical Analyses – 2016 Benthic Stations as compared to: 1955, 2011 and 2012 from Hubbard (2016).



DIVERSE

Univariate Diversity indices

Data worksheet

Name: COPY 5 Primer Benthic Data from Buzzards Bay C-reefs 2016

Data type: Abundance

Sample selection: All

Variable selection: All

	S	N	d	J'	Brillouin	Fisher	H'(loge)	1-Lambda'
CAFA-1	21	139	4.053	0.7206	1.985	6.874	2.194	0.7785
CAFA-2	19	156	3.564	0.5117	1.352	5.671	1.507	0.549
CAFA-3	13	75	2.779	0.5206	1.141	4.54	1.335	0.516
CAFD-1	7	116	1.262	0.2071	0.3446	1.638	0.4029	0.1492
CAFD-2	16	208	2.81	0.5531	1.426	4.04	1.534	0.6456

CAFD-3	8	195	1.328	0.223	0.4172	1.68	0.4637	0.1752
TIR-1	11	86	2.245	0.548	1.16	3.35	1.314	0.5477
TIR-2	12	67	2.616	0.6292	1.358	4.26	1.564	0.6567
TIR-3	7	106	1.287	0.2983	0.5074	1.683	0.5804	0.2295
S55-A	23	93	4.854	0.9046	2.503	9.777	2.836	0.9388
OCAF-A1	14	119	2.72	0.7237	1.74	4.121	1.91	0.755
OCAF-A2	19	137	3.659	0.5575	1.466	5.988	1.642	0.5984
OCAF-A3	16	159	2.959	0.6826	1.749	4.436	1.893	0.757
S55-D	28	376	4.553	0.5122	1.598	6.995	1.707	0.614
OCAF-D1	14	135	2.65	0.6949	1.687	3.925	1.834	0.7686
OCAF-D2	17	53	4.03	0.8714	2.093	8.661	2.469	0.9122
OCAF-D3	9	58	1.97	0.6583	1.263	2.982	1.446	0.6491

Pyrosome Discovery:

Underwater video mapping of benthic habitats in Buzzards Bay, Massachusetts records a Pyrosome. (in collaboration with Dr. Kristin Osborne)

Abstract

High-definition underwater video mapping of Buzzards Bay in Massachusetts, USA photographed a pyrosome. Positive identification to the species level requires a live, undamaged specimen. The most probable species is *Pyrosoma atlanticum*, which has not been documented in the area until now.

Introduction

Massachusetts Maritime Academy (MMA) had been conducting high-definition (HD) underwater video transects in Buzzards Bay under a grant from the Massachusetts Environmental Trust. This funding has enabled MMA to conduct at-sea mapping of Buzzards Bay substrates focusing on extensive seafloor areas covered with *Crepidula fornicata*, the common slipper shell. In June 2016, at the edge of one of one of these shell reefs, a pyrosome was photographed (see Figure 1). Coordination with regional experts have not produced any previous records of this colonial tunicate in bays or sounds of New England.

Materials and Methods

The MMA 30-foot Research Vessel Liberty used a SIMRAD® NSS-2 navigation chart plotter to conduct mapping transects. High-definition underwater video transects were recorded as part of the *Crepidula fornicata* shell reef (C-reef) mapping on a Seaviewer® Underwater video camera system. The unit paired a Seadrop 5500 HD camera with a surface recording unit. The 550 camera was installed in a vertical tow tube with laser pointers for a 10 cm scale in all recorded video (See Figure 2). The surface recording display system was programmed to overly latitude, longitude, date, time (UTC) time and Course Over Ground (COG) continuously on all video. This overlay on high definition video was accomplished by running the video signal through a Videologic® PROTEUS II unit. The images were captured on a HDMI H.264 recorder while simultaneously being displayed on the recording counsel and research vessel navigation chart plotter.

Commercially available software was used for post-processing which allowed the capture of still images (with location and time data overlaid). Thousands of C-reef images we analyzed and classified according to the national Coastal and Marine Ecological Classification System (CMECS, 2010). This review of individual video frames captured for classification allowed the team to identify the pyrosome adhered to the substrate at an 8-meter depth in upper Buzzards Bay, Massachusetts, USA (see Figure 3).

Results

Tunicate experts were consulted nationally (M. Corrales-Ugalde, pers. comm. and others) to confirm the Figure 1 organism as a pyrosome. E-mail communication of the finding was coordinated with both the Benthic and Pelagic Working Groups of the Northeast Regional Association of Coastal and Ocean Observing Systems (NERACOOS) organization and other academic, governmental, and private organizations. None of these organizations had identified a previous documentation of a pyrosome being observed in New England bays or sounds.

Identification to the species level is difficult with only a video and frame capture; it requires a live and undamaged specimen. The 10-cm laser pointer scale in the video allows an estimated size of this colony as 8 cm by 40 cm. Various post-processing and photographic magnifications show some details, but not enough structural components to positively identify the species.

Pyrosomes are members of the Tunicata (previously the Urochordata), a sub-phylum within the larger phylum Chordata. Hallmark traits of this phylum include a post-anal tail, pharyngeal gill slits, a dorsal hollow nerve cord, and a notochord. The tunicates are a unique subphylum of the chordates, as they revert to a more simplistic body plan by the eventual loss of these features during their metamorphosis from the embryonic stages to their adult forms (Lemaire et al. 2008). Interestingly, molecular analyses indicate that the Tunicata are the closest invertebrate relatives of the sub-phylum Vertebrata (Delsuc et al. 2006; Vienne and Pontarotti 2006). Within the Tunicata is the class Thaliacea; a group of approximately 72 pelagic species (Govindarajan et al. 2011). The pyrosomes are subsequently classified within the order Pyrosomatida.

The family Pyrosomatidae contains 8 species (van Soest 1981). Some literature identified a benthic pyrosome species, *Pyrosoma benthica* (Monniot and Monniot 1966 as discussed by van Soest), but as described by van Soest (1981) this organism is at the mercy of currents and only has motion in one direction. Logically, a pelagic colony caught on the substrate is exposed to benthic predators and therefore would not survive. The most common North Atlantic species is *Pyrosoma atlanticum* (Péron 1804). We identify this organism as likely to be *P. atlanticum*, a pelagic species, which has become adhered to the benthic substrate by ocean currents.

P. atlanticum colonies can range in color from clear to a translucent white, grey, pink, or even blue-green (Palma and Apablaza 2004). Colonies can reach up to 60 cm in length, with individual blastozooids measuring approximately 8-9 mm each (Palma and Apablaza 2004). The specimen captured in this dataset presents characteristics consistent with *P. atlanticum*. With a live specimen, the direction of incurrent and excurrent siphons could also be used to provide additional taxonomic support for identification (Esnal 1996), but the size, color, geographic location, and expert consultations support the high likelihood of this being a *P. atlanticum* colony.

Discussion

Pyrosomes are an interactive group of small animals that form together as a holoplanktonic colony. The group of individuals filters water into their tube-like colony structure, as it maintains one direction of movement and passively migrates at the mercy of currents. These organisms are often found in warmer waters, drifting in the pelagic zones. Although it appears attached to the substrate, it most likely was pushed downward by the currents, as they are pelagic and not benthic organisms. It is possible that there are other Pyrosomes in our bays, and the new high-definition technology being deployed by research teams such as those operating at Massachusetts Maritime Academy is just now allowing their discovery. This specimen may have been swept into Buzzards Bay from a warm core breaking off the North Atlantic Gulf stream current. Or, as our oceans warm, we may expect to observe more exotic visitors such as this colonial pelagic tunicate.

References

CMECS, 2012. Coastal and Marine Ecological Classification System of the Federal Geographic Data Committee. FGDC-STD-018-2012

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Delsuc, F., Brinkmann, H., Chourrout, D., Philippe, H. (2006). Tunicates and not cephalochordates are the closest living relatives of vertebrates. Nature, 439(7079), 965-968.

Govindarajan, A. F., Bucklin, A., & Madin, L. P. (2011). A molecular phylogeny of the Thaliacea. Journal of Plankton Research, 33(6), 843-853.

Lemaire, P., Smith, W. C., Nishida, H. (2008). Ascidians and the plasticity of the chordate developmental program. Current Biology, 18(14), R620-R631.

Monniot, C. and F. Monniot, (1966). A benthic pyrosome: *Pyrosoma benthica* n. sp. C. R. hebd. Seanc. Academy of Science, Paris FR 263D, 368-370.

Palma, S., & Apablaza, P. (2004). Primer registro de Pyrosoma atlanticum Péron, 1804 en aguas costeras del Sistema de la Corriente de Humboldt (Tunicata, Thaliacea, Pyrosomatidae). Investigaciones marinas, 32(2), 133-136.

Van Soest, R.W.M. (1981). A monograph of the order Pyrosomatida (Tunicata, Thaliacea). Journal of Plankton Research, 3(4).

Vienne, A., Pontarotti, P. (2006). Metaphylogeny of 82 gene families sheds a new light on chordate evolution. International Journal of Biological Sciences, *2*(2), 32-37.

50 second video link: https://youtu.be/0U-LSDyCaaA

The Massachusetts Environmental Trust has financially supported this effort. Sales of license plates generate funding for the Trust. More information can be found online at www.mass.gov/eea/met .

Figure 1. A Pyrosome filmed with the Massachusetts Maritime Academy towed High Definition video camera with laser scalers 10 cm apart (green dots). (Photo Courtesy of Massachusetts Maritime Academy).

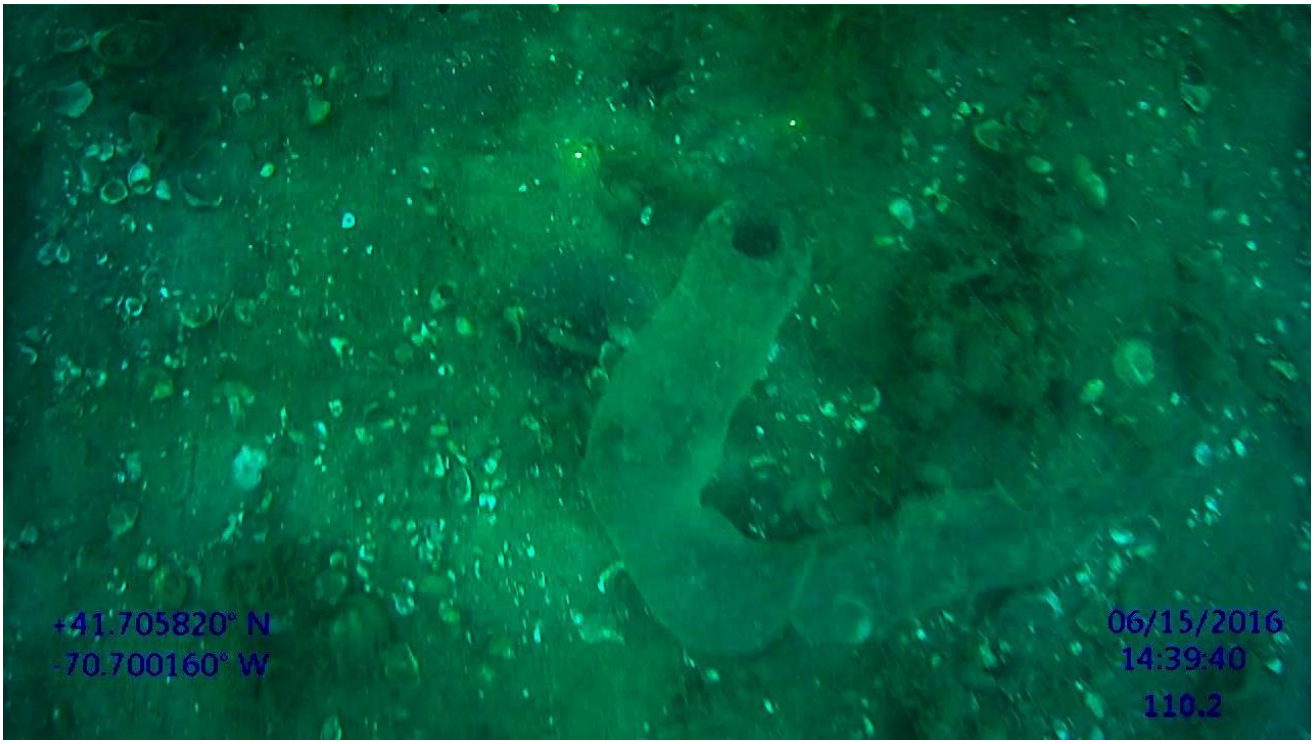
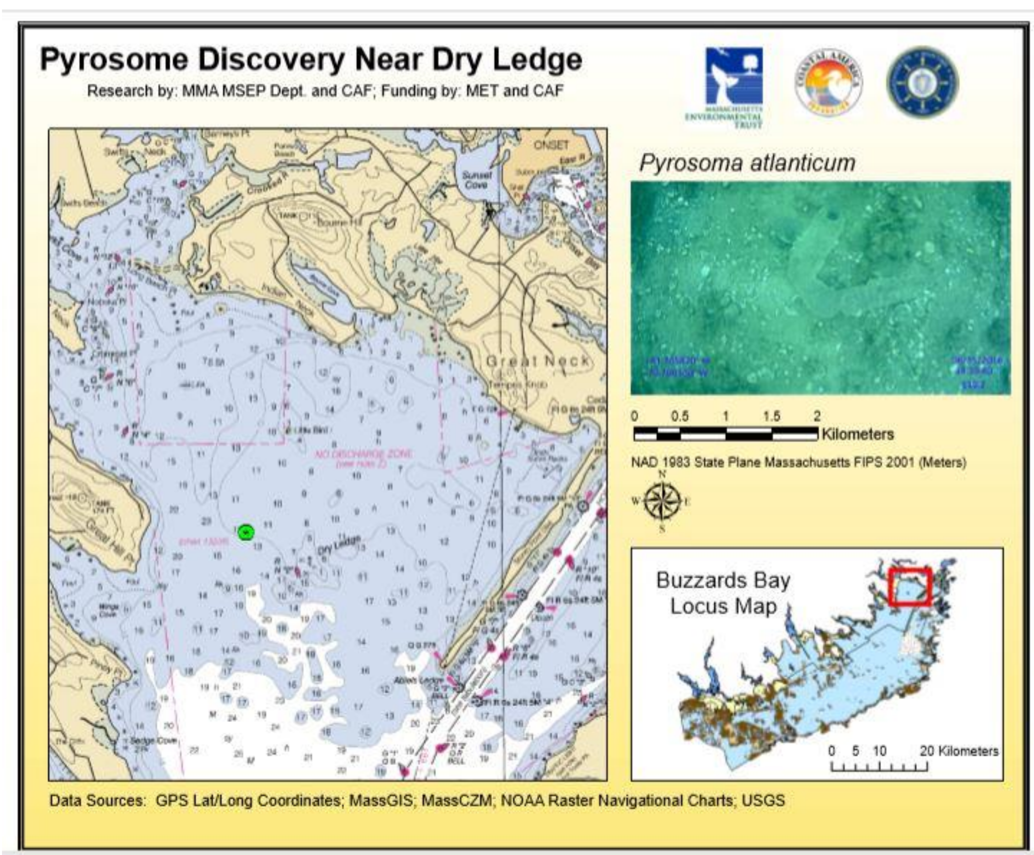


Figure 2. MMA 2016 underwater video HD camera system.

Figure 3. Pyrosome located just west of Stony Point Dike along Hog Island Channel – the entrance to Cape Cod Canal.



BIOLOGICAL APPENDIX III

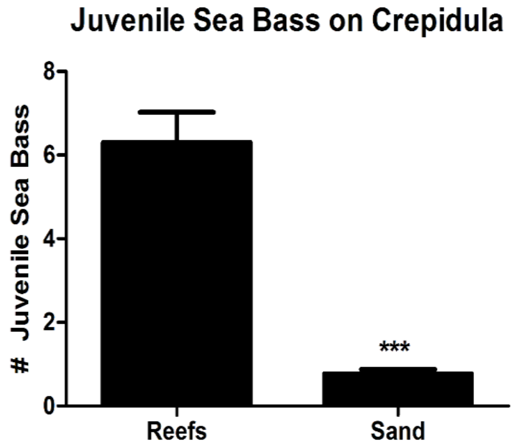
Appendix IIIA - Density data:

	Comparison of C-Reef to Sand Habitat					
Screen Shot #	**C-Reef w/sponge**		**Sand w/sponge**	Screen Shot #		
1426	5		0	1463		
1427	1		0	1464		
1428	0		0	1465		
1429	1		0	1466		
1430	1		0	1467		
1431	5		0	1468		
			0	1469		
1433	1		2	1470		
1434	5		1	1471		
			1	1472		

			1	1473		
1437	3		1	1474		
1438	6		2	1475		
1439	7		2	1476		
1440	12		1	1477		
1441	12		1	1478		
1442	2		1	1479		
1443	2		1	1480		
1444	10		0	1481		
1445	7		1	1482		
1446	12		1	1483		
1447	16		1	1484		
1448	12		2	1485		
1449	13		0	1486		
1450	9		2	1487		
1451	5		1	1488		
1452	8		0	1489		
1453	4		0	1490		

1454	4		0	1491		
1455	8		0	1492		
1456	8		1	1493		
1457	11		1	1494		
1458	5		1	1495		
1459	4		1	1496		
1460	5		0	1497		
1461	4		0	1498		
			1	1499		
			0	1500		
			1	1501		
			1	1502		
			1	1503		
			2	1504		
			1	105		
			2	1506		
			2	1507		
			0	1508		
			4	1509		
			1	1510		
			1	1511		
			2	1512		
			0	1513		
			0	1514		

			0	1515		
		=	0	1516		
		=	0	1517		
		=	0	1518		
		=	0	1519		
			0	1520		
		=	0	1521		
		=	0	1522		
		=	0	1523		
			0	1524		
			0	1525		
			1	1526		
			0	1527		
			1	1528		
screen shots analyzed	33		61			
fish n =	208		108			
std	4.157		0.824			
avg	6.303		0.770			



STUDENT INVOLVEMENT:

Cadets Aldrich and Palmer have become experts in underwater video mapping as well as piloting the VideoRay Remotely Operated Vehicle (ROV).

The 30 students in the Life Sciences class (split into smaller groups because of the limitations of the Liberty deck space) have been exposed to the video and water quality equipment and the concept of C-Reef and ocean mapping.

PhD graduate student Kris Osborne has been on several cruises and added collections for her research.

Senior cadet Tyler Aldrich has obtained field research skills and data compilation efficiency.

Numerous MMA students have been directed to the YouTube and embedded video links at the CAF website:

http://coastalamericafoundation.org/crepidulareefs.html

Follow the above link to view 2016 highlights.

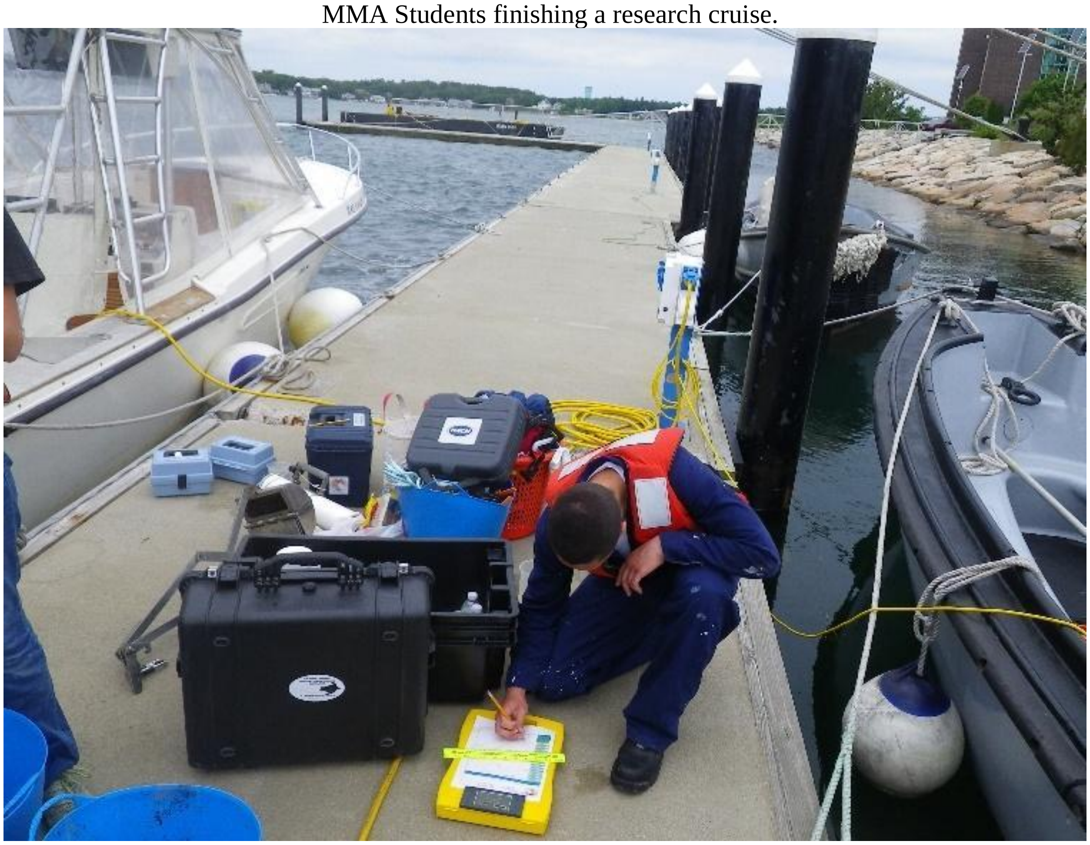
MET Grant Required Reporting:

The MET grant program awarded 50% of the funds based on the proposal. In fall 2016 they required a press release and solicitation of support for their license plate program from MMA and CAF Board of Directors. This Interim Report dated 15 December 2016 was submitted by January 3, 2017 in accordance to the agreed MET grant activities (MET then dispersed 25% of funds). This final report is due 30June 2017 (25% final payment to follow).

The Coastal America Foundation has incorporated the MET License Plate Program information onto their website. A copy of the web page; http://www.coastalamericafoundation.org/crepidulareefs.html in Appendix B exhibits the MET information.

Additionally, the Board of Directors/Trustees of both MMA and the Coastal America Foundation were contacted with an informative letter of the Grant, MET License Plate Program and Press Release/article. This effort encouraged participation in the License Plate Program.

MMA Students finishing a research cruise.



Reporting Results:

Three Appendices are included with this report that; describes the data protocol (Appendix C), Coastal and Marine Ecological Classification results (Appendix D) and Appendix E provides a few sample images of the online video and GIS data files (more than 200 gigabytes online).

The innovative use of High Definition (HD) underwater video cameras and field recorders was paired with a state of the art Geospatial Positioning System that overlays the exact davit position when the camera is video recording at 1 meter or less above the seafloor. The video image overlay imprint has latitude, longitude, time (Greenwich Meridian Time – GMT), date and vessel Course Over Ground (COG – degrees). Each video file is post processed into a MP4 format and then viewed in detail by marine benthic ecologist – Bill Hubbard. As ecological conditions changed, individual screen shots were captured for all video. These Screen Shots (with Lat/Lon imprinted) were then recorded in compliance with Appendix C protocol into a master spreadsheet (Appendix D).

Appendix C – Protocol Developed for HD Geospatial Logged Video Sampling Classification

The protocol, developed by Michael Elliott, is intended to provide consistency and precision to the manually recorded screen shot Lat/Long coordinate information to an Excel table that can be used to display XY data from a table to points on an ArcGIS map file. Once displayed on the ArcGIS map, the individual screen shot coordinate locations can be symbolized to correspond to percent cover of *C. fornicata* at any given location as defined by NOAA's Coastal Marine Ecological Classification System (CMECS). With enough transect data, the individual points can then be used to define the geographic boundaries of *C. fornicata* reefs on the seafloor. Appendix E has some representative mapping of the major *Crepidula fornicata* reefs of Buzzards Bay.

Appendix D – Results for: Screen Shot (SS)number (by date); time of day

(TOD); latitude (LAT); longitude (LONG); *Crepidula fornicata* seafloor coverage 0 to 1 (CREPID_COVER); Coastal and Marine Ecological Classification cover description (COVER_BIN) and Comments.

There are over 2,500 screen shots classified, representing significant transect coverage (see GIS mapping) of Buzzards Bay. The column headings are defined in the protocol as listed above and described in Appendix C. The size of the database prohibits us from including it in this report as an embedded Appendix, but the EXCEL file is being attached to the final transmittal and available online. All snapshots were selected by marine ecologist Bill Hubbard, location data were entered by MMA students, this data was quality controlled by Mike Elliott and Bill Hubbard and then classified by Bill and GIS mapped by Mike – both providing each other quality control.

The data is now mapped and available to the Massachusetts Office of Coastal Zone Management for their Massachusetts Ocean Resource Information System (MORIS).

Conclusion:

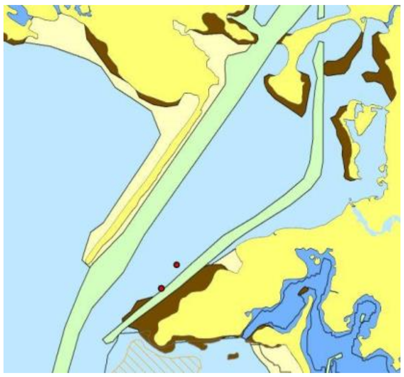
This report fulfils the grant requirements of the Massachusetts Environmental Trust funding. It represents all the requirement plus additional field and laboratory efforts. More importantly the effort has educated and enthused dozens of marine science students. The products are available to assist state and local officials to make Buzzards Bay management decisions. Additionally, the process has developed a state of the art process and technology program at Massachusetts Maritime Academy that can be duplicated at other institutions.

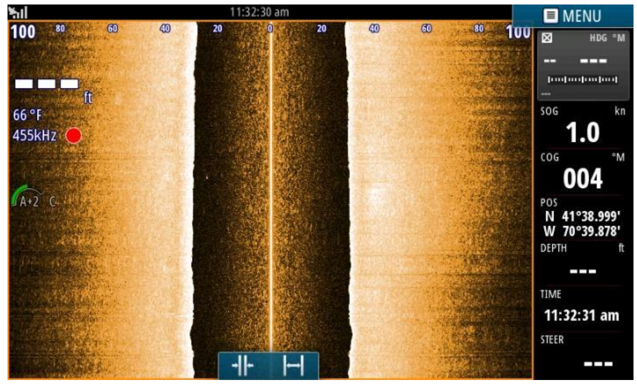
Selected Photographs and Maps

MMA Students onboard the R/V Liberty

GIS Mapping

:




11:32:30 am
MENU
100
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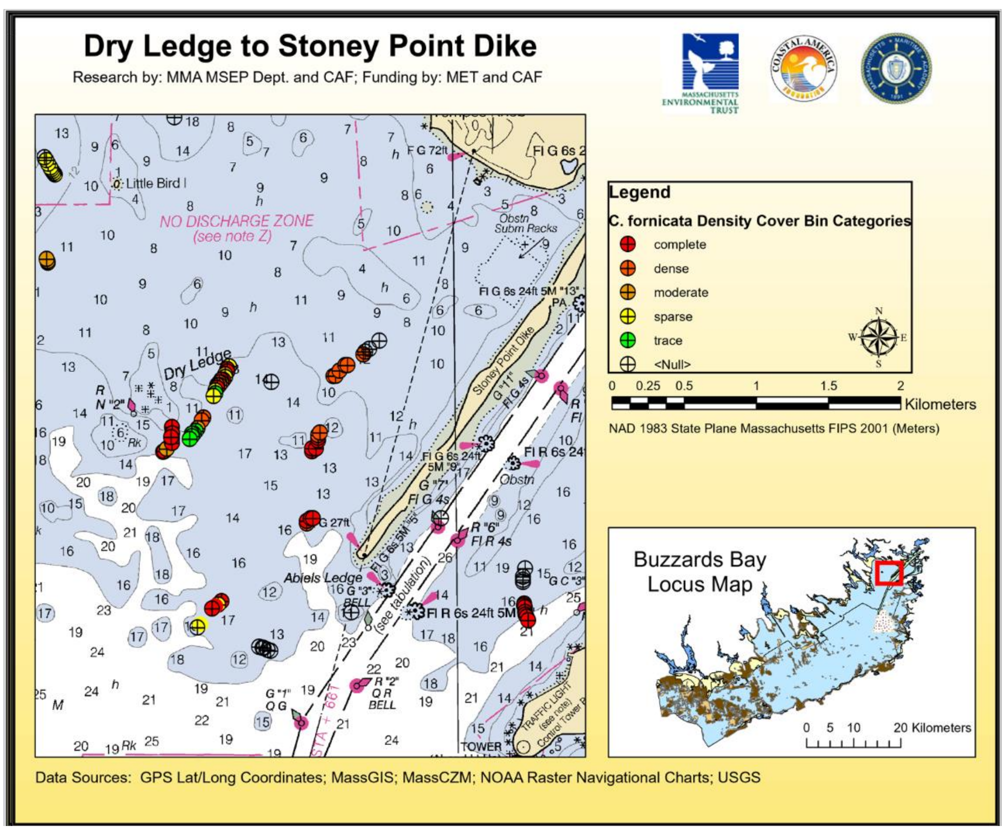
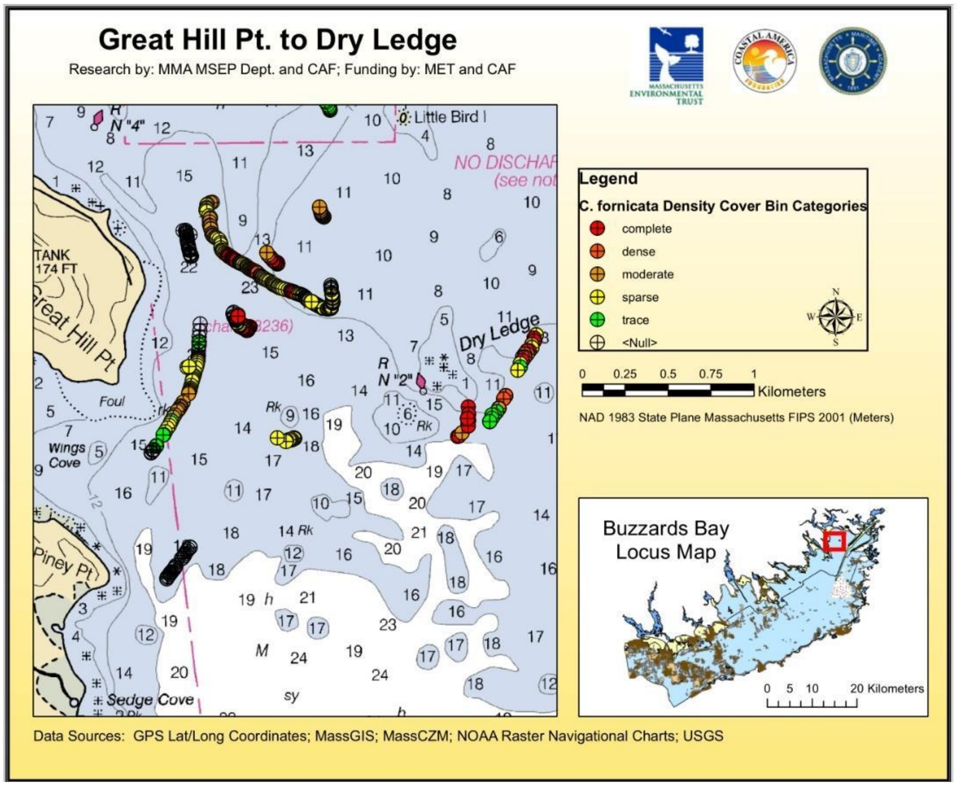

Dry Ledge to Stoney Point Dike
Research by: MMA MSEP Dept. and CAF; Funding by: MET and CAF
MASSACHUSETTS ENVIRONMENTAL TRUST
COASTAL AMERICA
Legend
C. fornicata Density Cover Bin Categories
complete
dense
moderate
sparse
trace
<Null>
0 0.25 0.5 1 1.5 2
Kilometers
NAD 1983 State Plane Massachusetts FIPS 2001 (Meters)
Buzzards Bay
Locus Map
0 5 10 20 Kilometers
Dry Ledge
Little Bird I
NO DISCHARGE ZONE
(see note Z)
Stoney Point Dike
Abiels Ledge
Data Sources: GPS Lat/Long Coordinates; MassGIS; MassCZM; NOAA Raster Navigational Charts; USGS


Great Hill Pt. to Dry Ledge
Research by: MMA MSEP Dept. and CAF; Funding by: MET and CAF
MASSACHUSETTS ENVIRONMENTAL TRUST
Legend
C. fornicata Density Cover Bin Categories
complete
dense
moderate
sparse
trace
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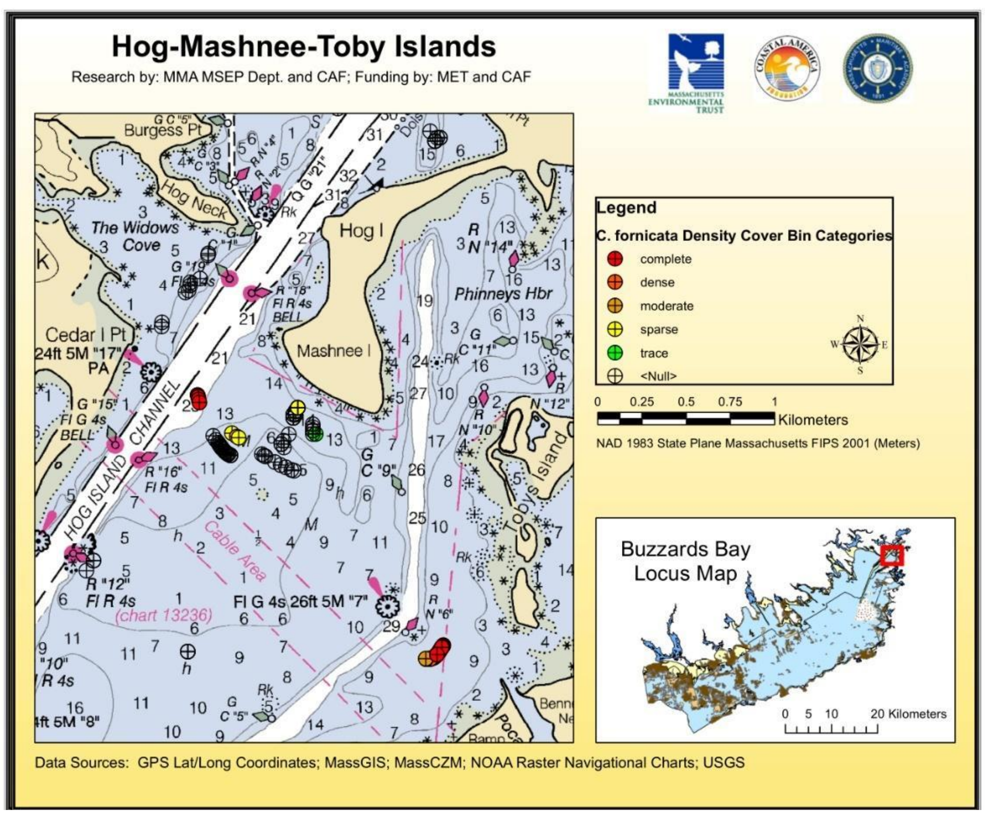
0 0.25 0.5 0.75 1
Kilometers
NAD 1983 State Plane Massachusetts FIPS 2001 (Meters)
Buzzards Bay
Locus Map
0 5 10 20 Kilometers
Great Hill Pt
Dry Ledge
Little Bird I
Wings Cove
Piney Pt
Sedge Cove
Data Sources: GPS Lat/Long Coordinates; MassGIS; MassCZM; NOAA Raster Navigational Charts; USGS


Hog-Mashnee-Toby Islands
Research by: MMA MSEP Dept. and CAF; Funding by: MET and CAF
MASSACHUSETTS ENVIRONMENTAL TRUST
Legend
C. fornicata Density Cover Bin Categories
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sparse
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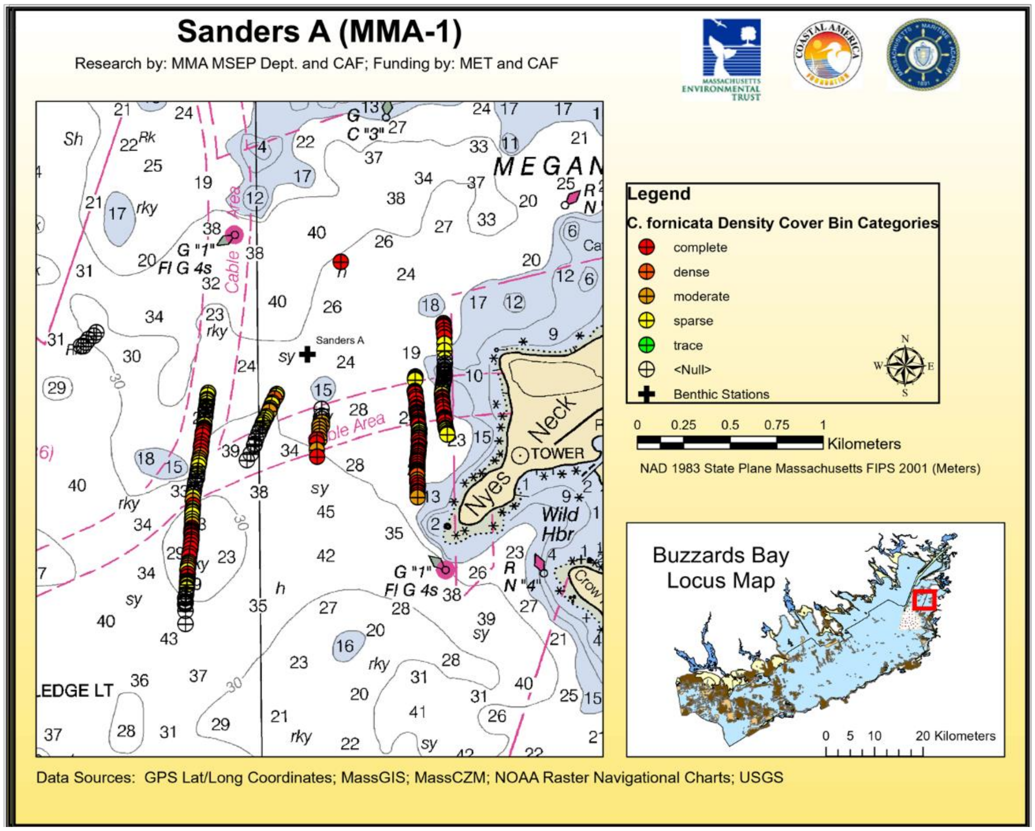
Kilometers
NAD 1983 State Plane Massachusetts FIPS 2001 (Meters)
Buzzards Bay
Locus Map
0 5 10 20 Kilometers
Burgess Pt
Hog Neck
The Widows Cove
Hog I
Phinneys Hbr
Cedar I Pt
Mashnee I
HOG ISLAND CHANNEL
Cable Area
(chart 13236)
Data Sources: GPS Lat/Long Coordinates; MassGIS; MassCZM; NOAA Raster Navigational Charts; USGS


Sanders A (MMA-1)
Research by: MMA MSEP Dept. and CAF; Funding by: MET and CAF
MASSACHUSETTS ENVIRONMENTAL TRUST
COASTAL AMERICA
Legend
C. fornicata Density Cover Bin Categories
complete
dense
moderate
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trace
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Benthic Stations
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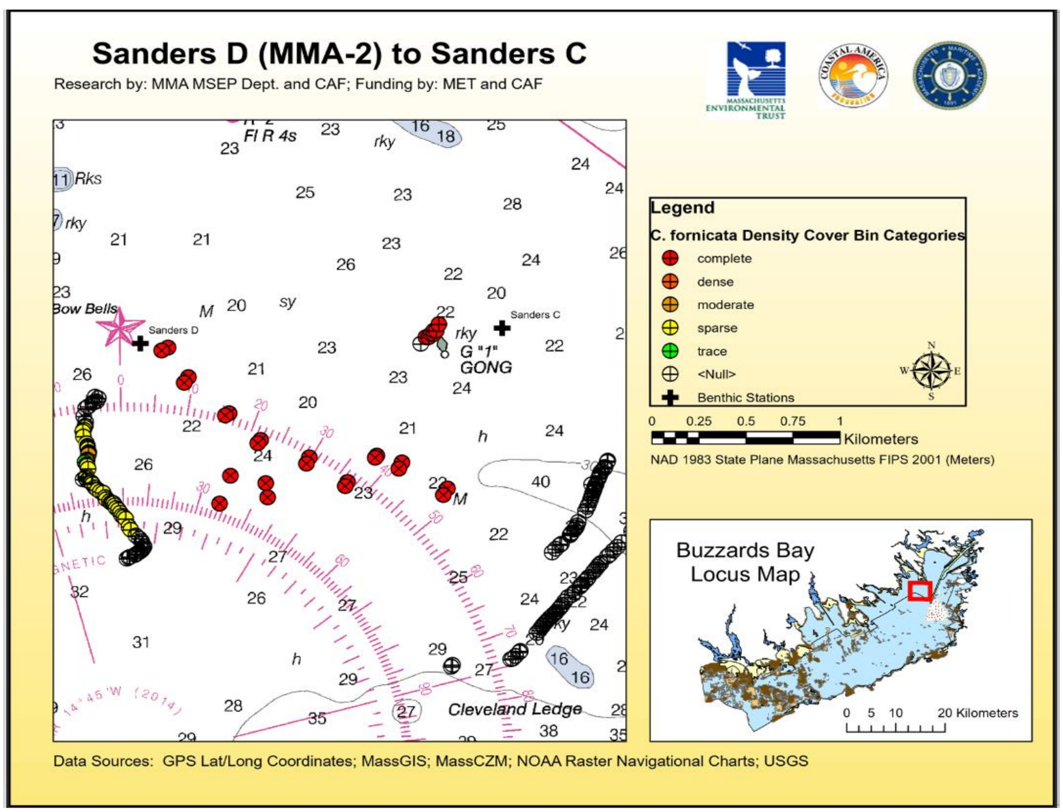
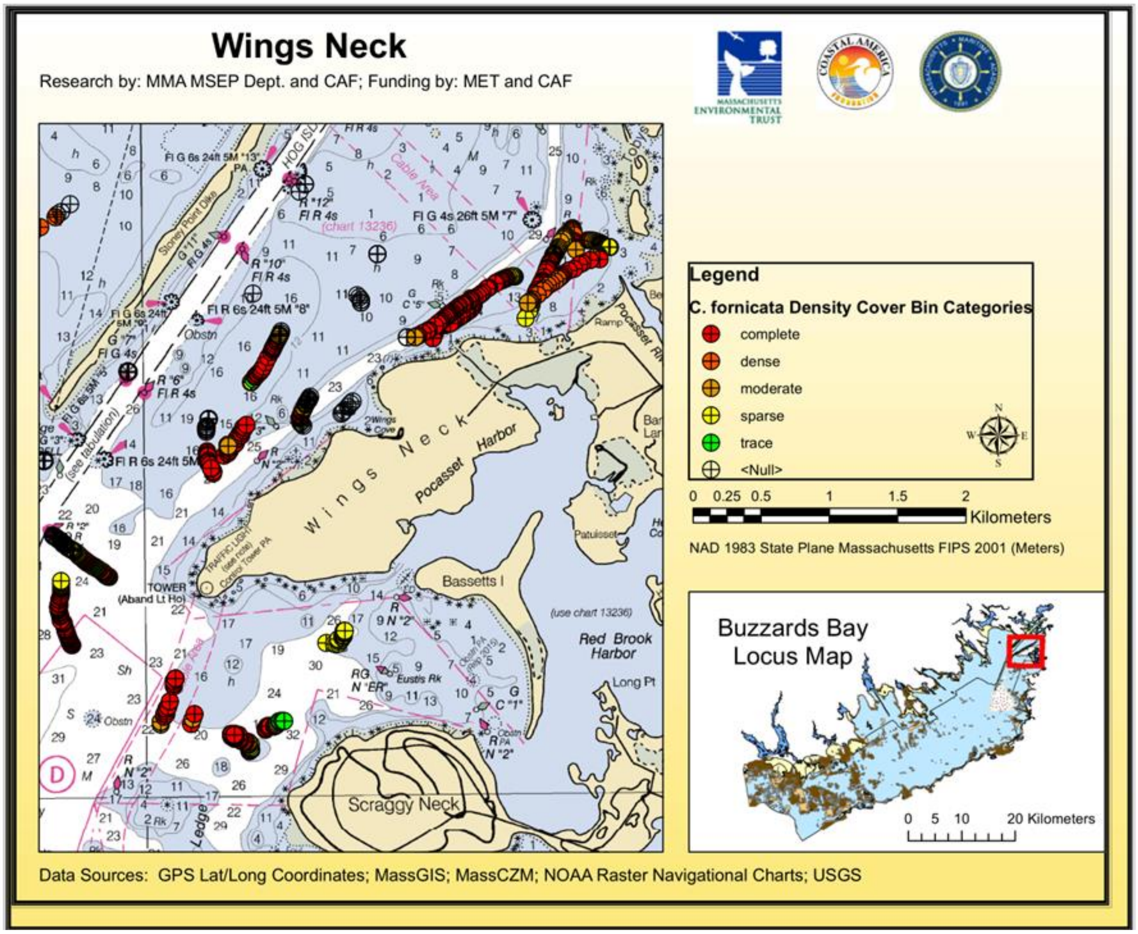
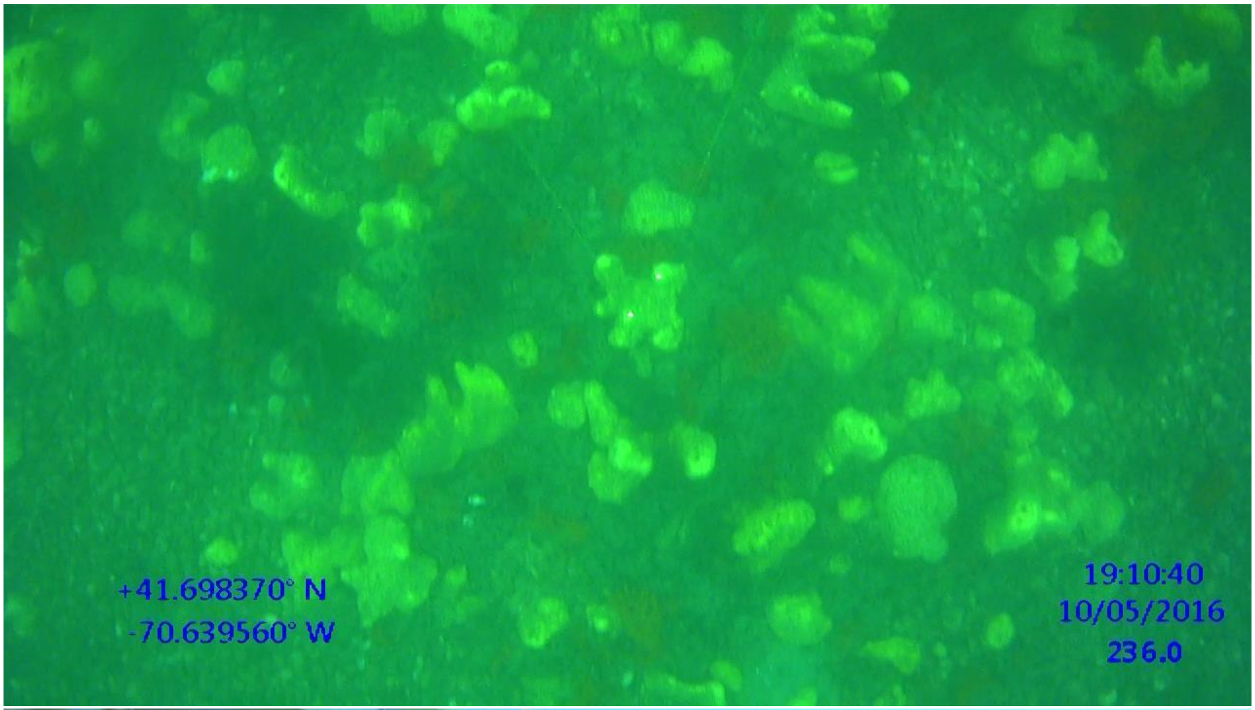
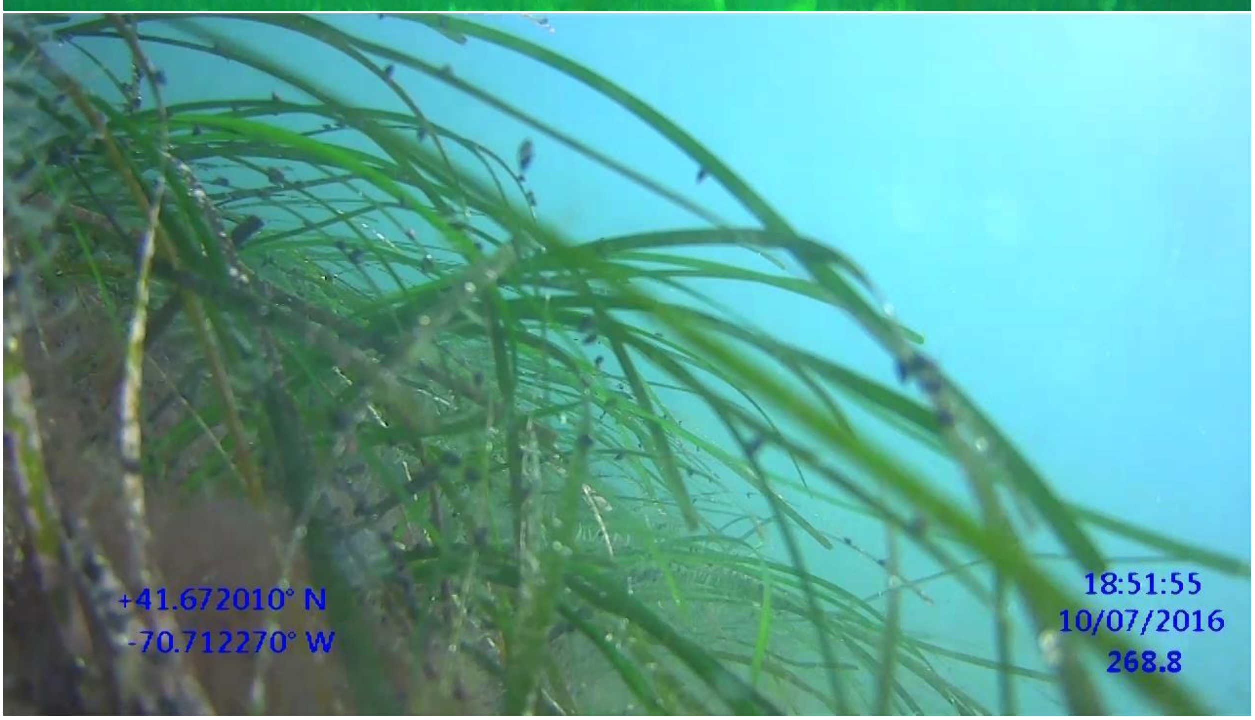
NAD 1983 State Plane Massachusetts FIPS 2001 (Meters)
Buzzards Bay Locus Map
0 5 10 20 Kilometers
Sanders A
Cable Area
MEGAN
Nyes Neck
TOWER
Wild Hbr
LEDGE LT
Data Sources: GPS Lat/Long Coordinates; MassGIS; MassCZM; NOAA Raster Navigational Charts; USGS

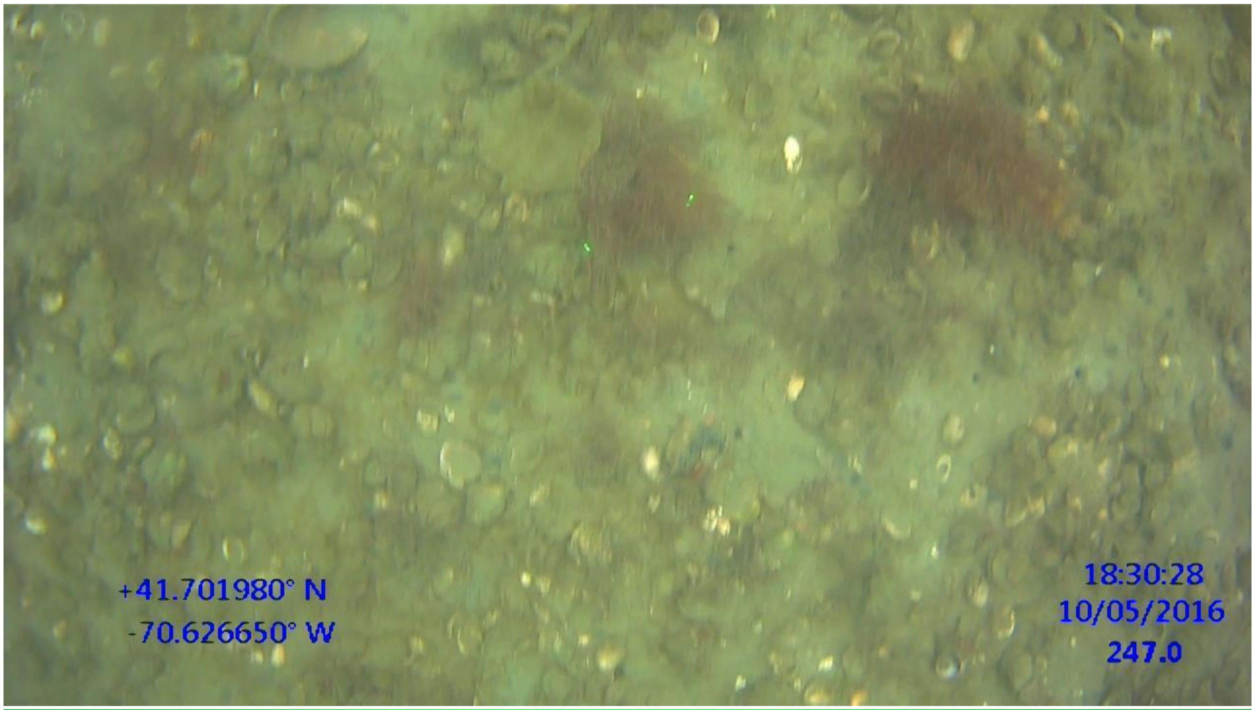

Sanders D (MMA-2) to Sanders C
Research by: MMA MSEP Dept. and CAF; Funding by: MET and CAF
MASSACHUSETTS ENVIRONMENTAL TRUST
COASTAL AMERICA
Legend
C. fornicata Density Cover Bin Categories
complete
dense
moderate
sparse
trace
<Null>
Benthic Stations
0 0.25 0.5 0.75 1 Kilometers
NAD 1983 State Plane Massachusetts FIPS 2001 (Meters)
Buzzards Bay Locus Map
0 5 10 20 Kilometers
Bow Bells
Sanders D
Sanders C
G "1" GONG
Cleveland Ledge
Data Sources: GPS Lat/Long Coordinates; MassGIS; MassCZM; NOAA Raster Navigational Charts; USGS


Wings Neck
Research by: MMA MSEP Dept. and CAF; Funding by: MET and CAF
MASSACHUSETTS ENVIRONMENTAL TRUST
Legend
C. fornicata Density Cover Bin Categories
complete
dense
moderate
sparse
trace
<Null>
0 0.25 0.5 1 1.5 2
Kilometers
NAD 1983 State Plane Massachusetts FIPS 2001 (Meters)
Buzzards Bay
Locus Map
0 5 10 20 Kilometers
Wings Neck
Pocasset Harbor
Bassetts I
Red Brook Harbor
Scraggy Neck
Data Sources: GPS Lat/Long Coordinates; MassGIS; MassCZM; NOAA Raster Navigational Charts; USGS

VideoRay® ROV and Seaviewer® HD Screen Captures



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09/25/2016
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10:36:28 am 21.0 ft
MENU
SOG kn
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COG °M
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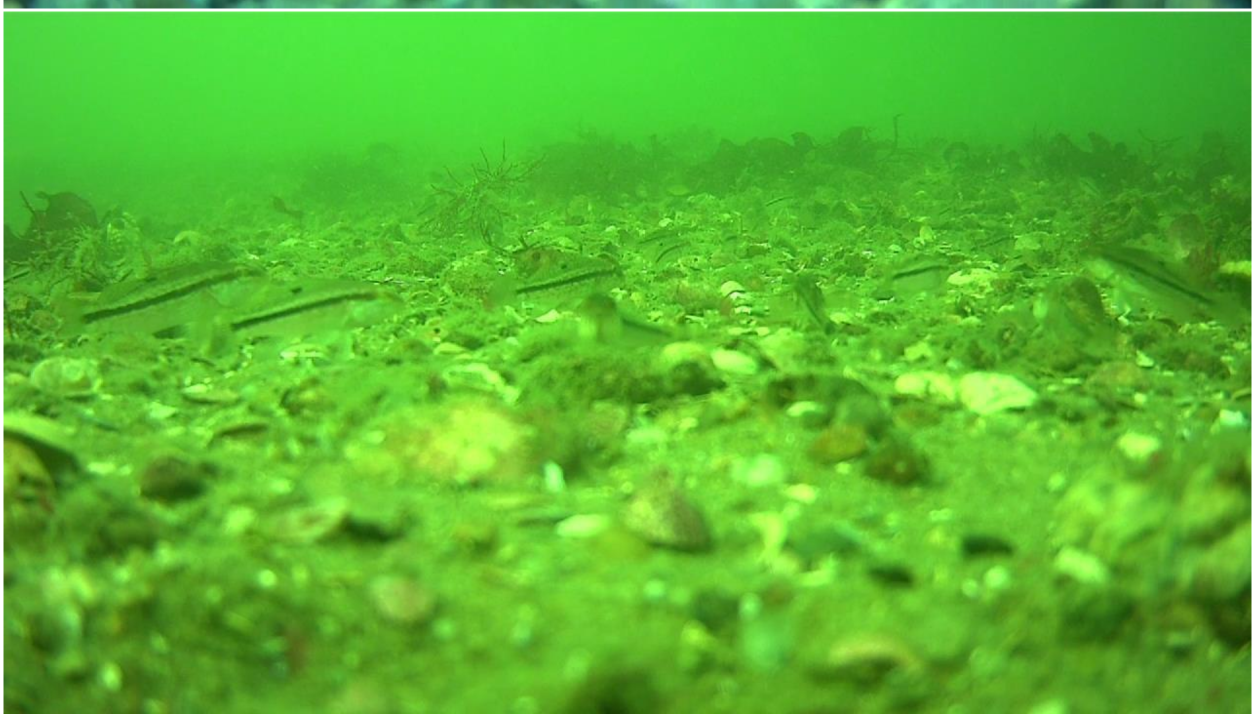


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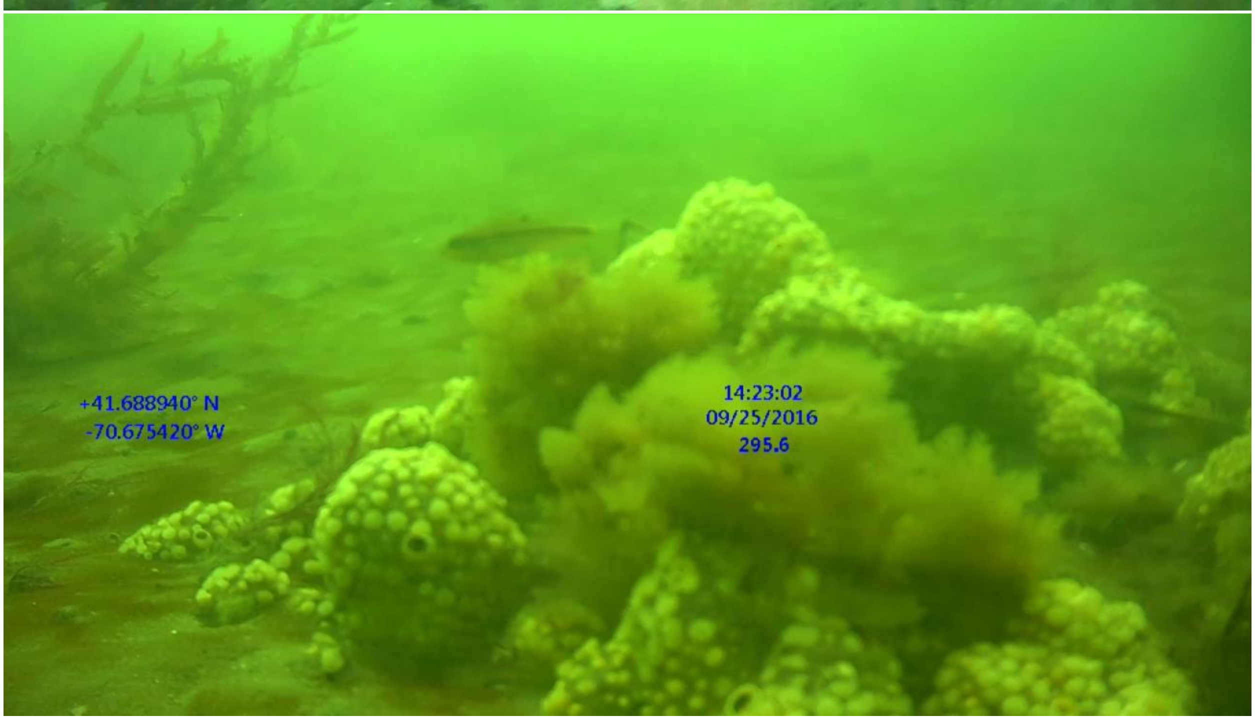
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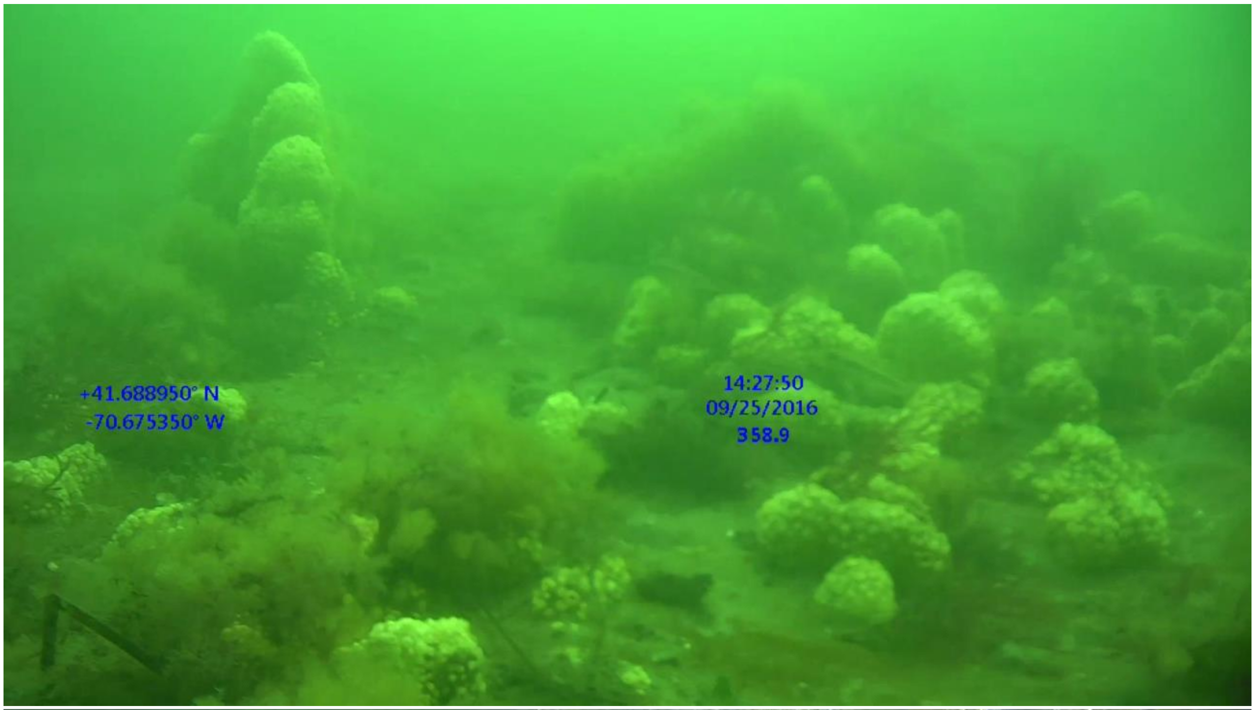
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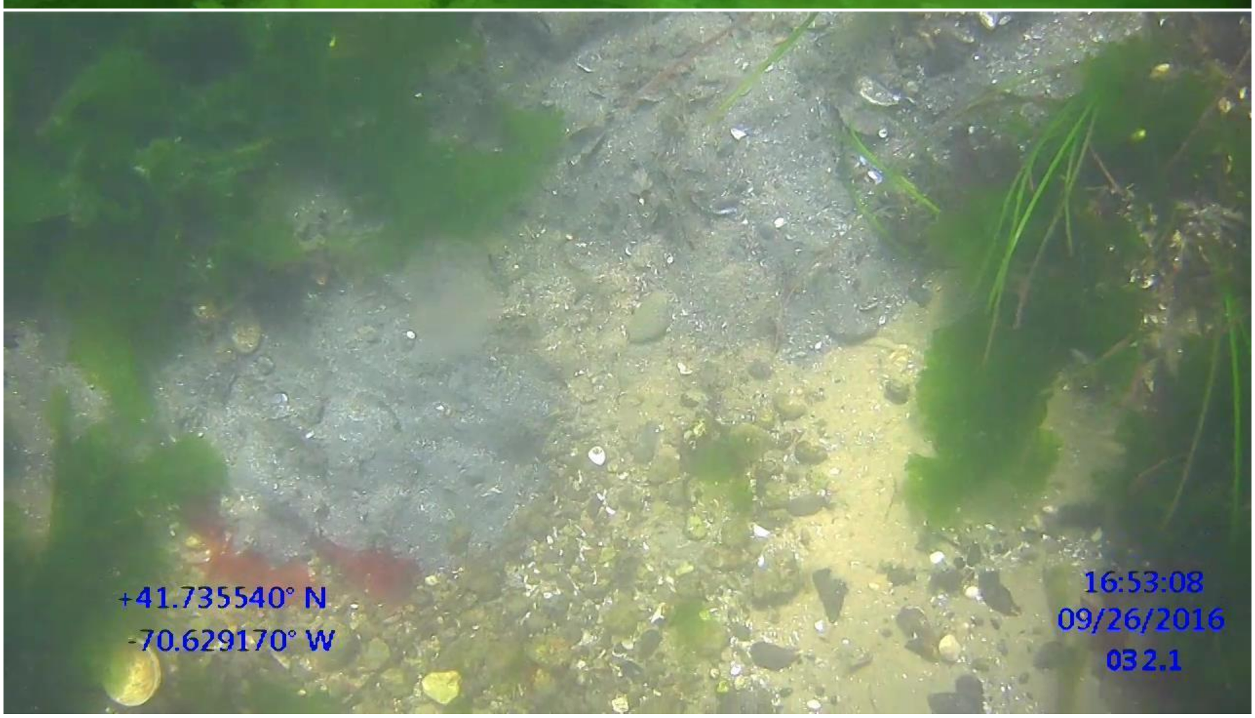
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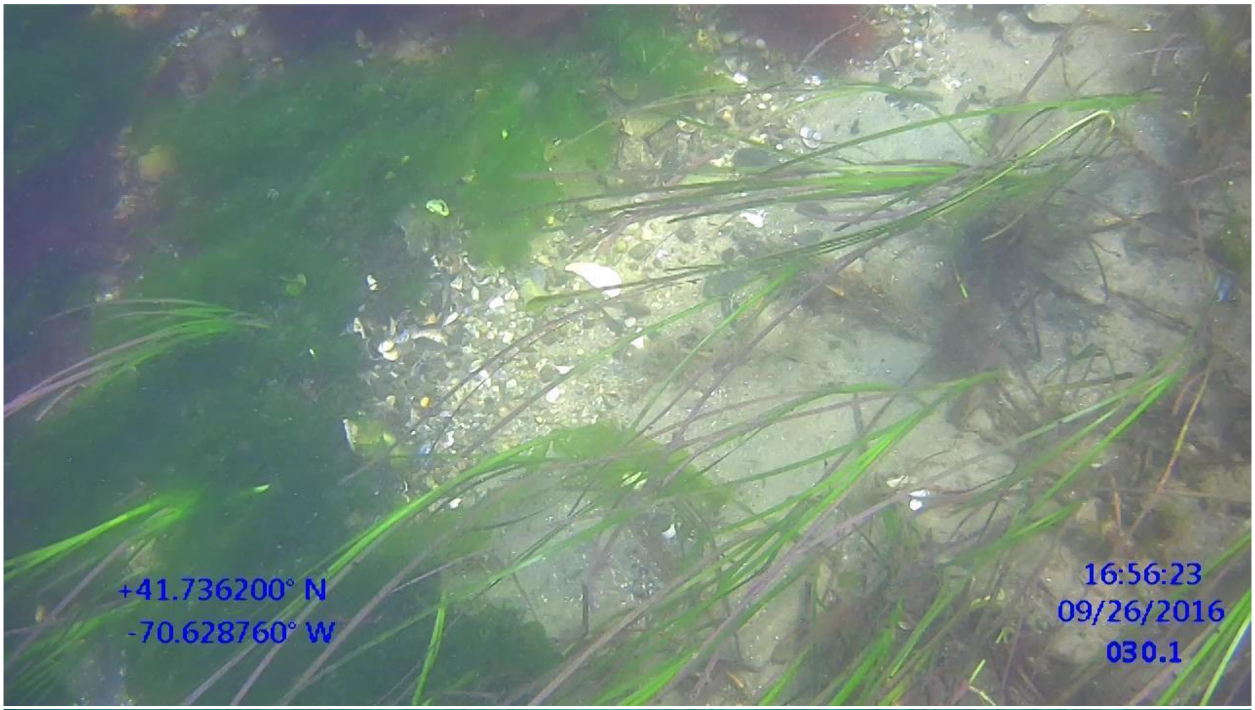
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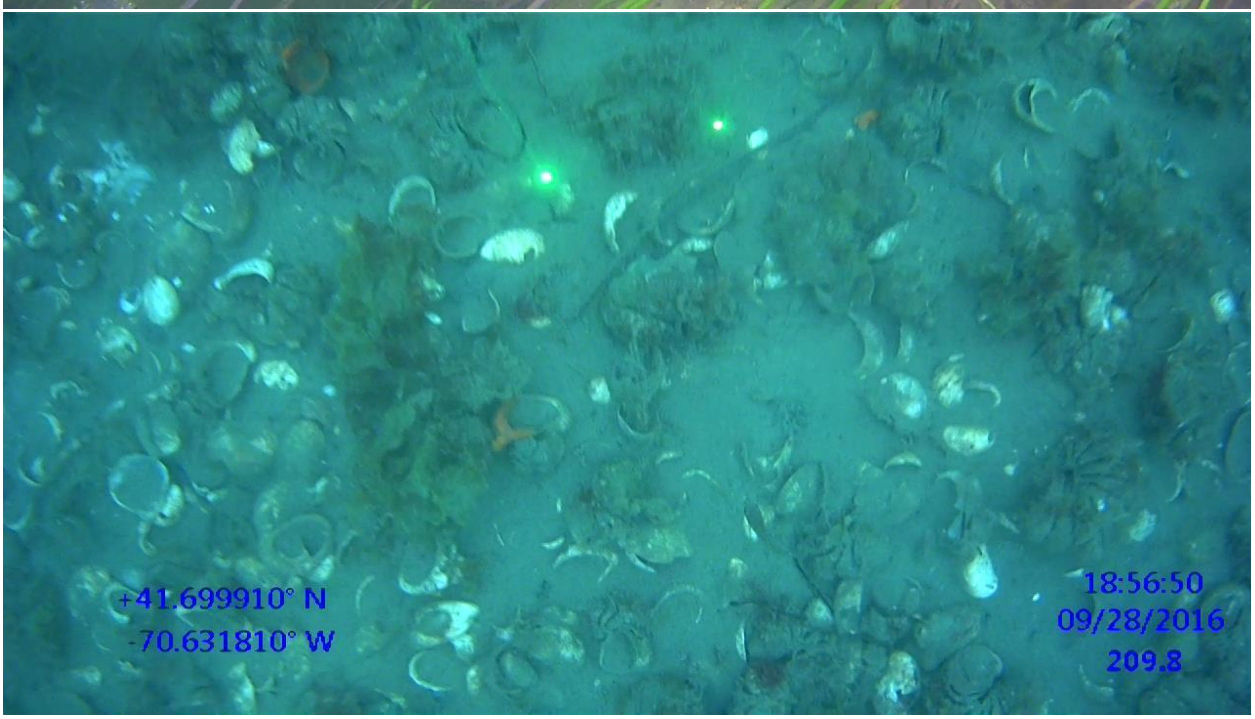
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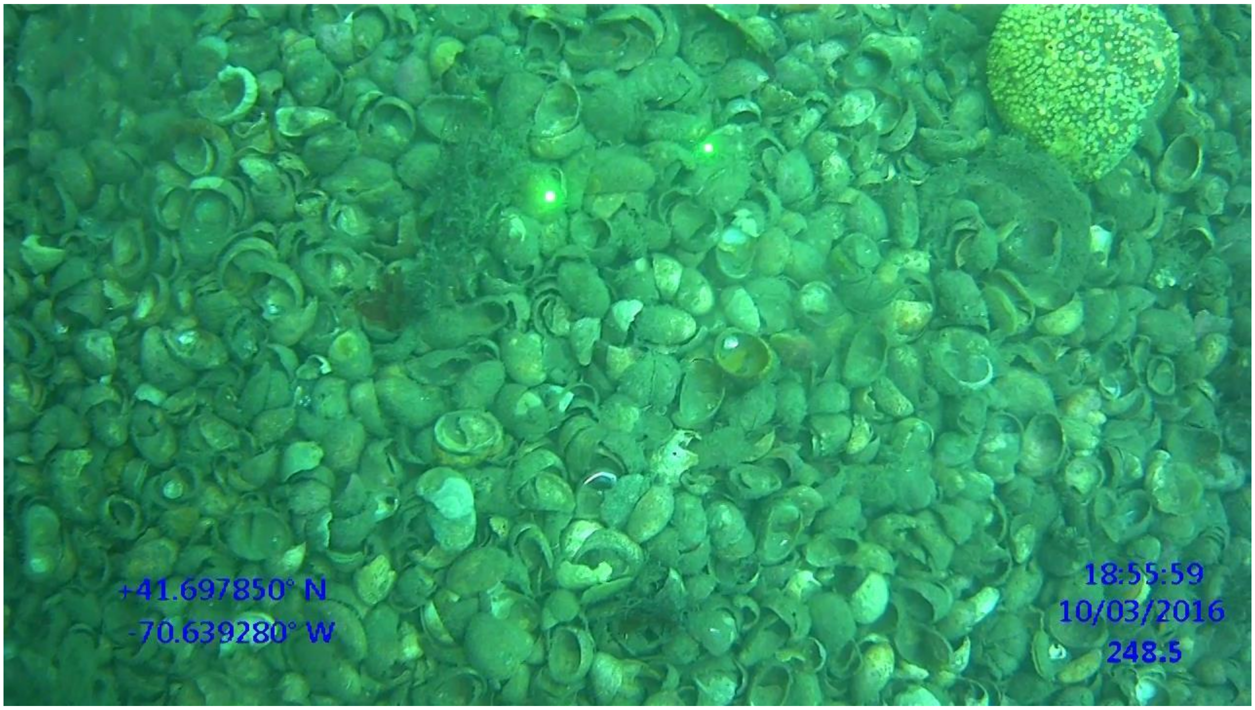

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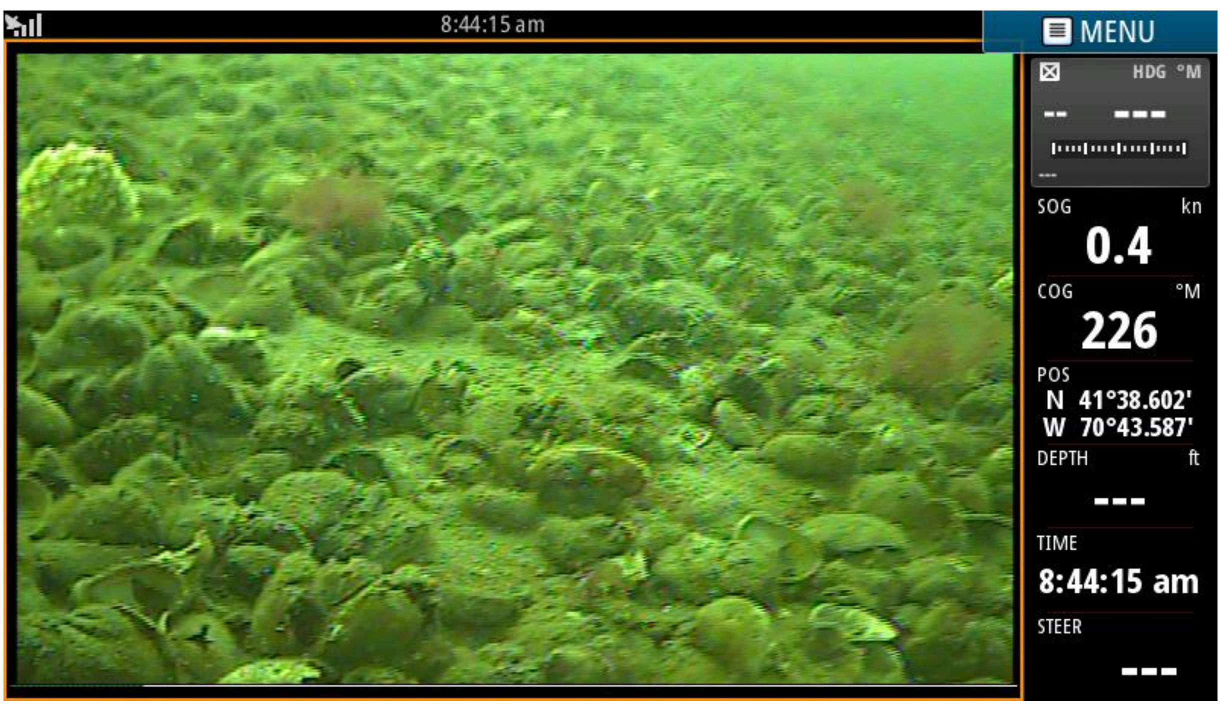
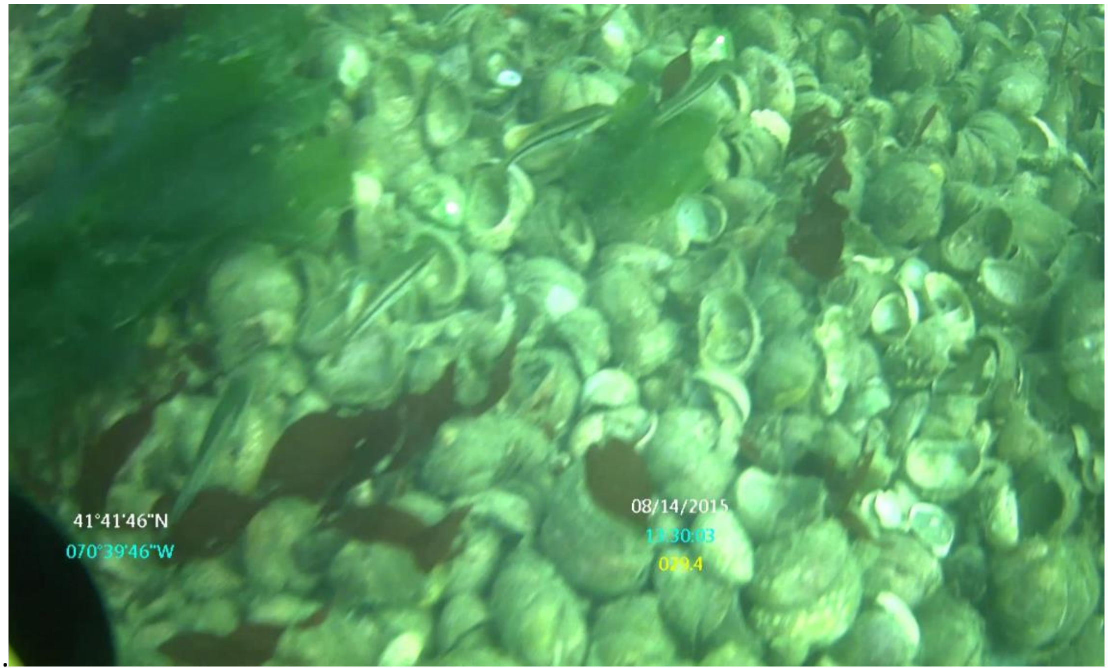
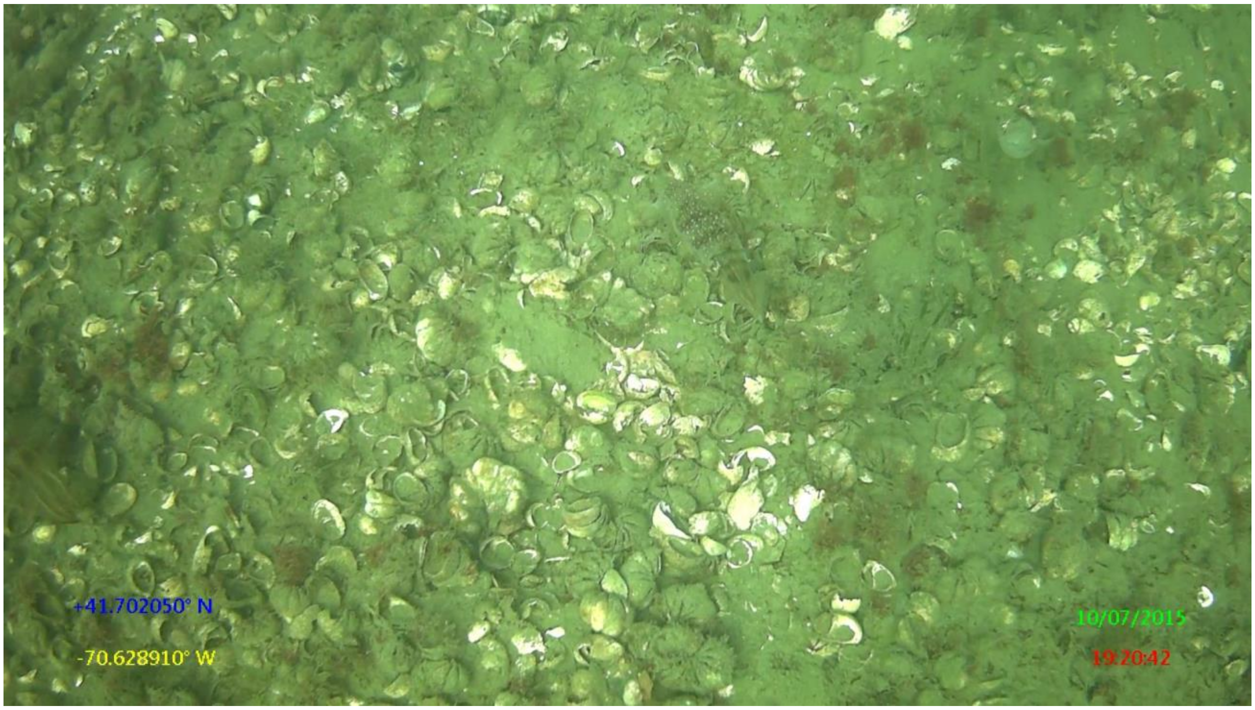


Juvenile Black Seabass on C-reef:



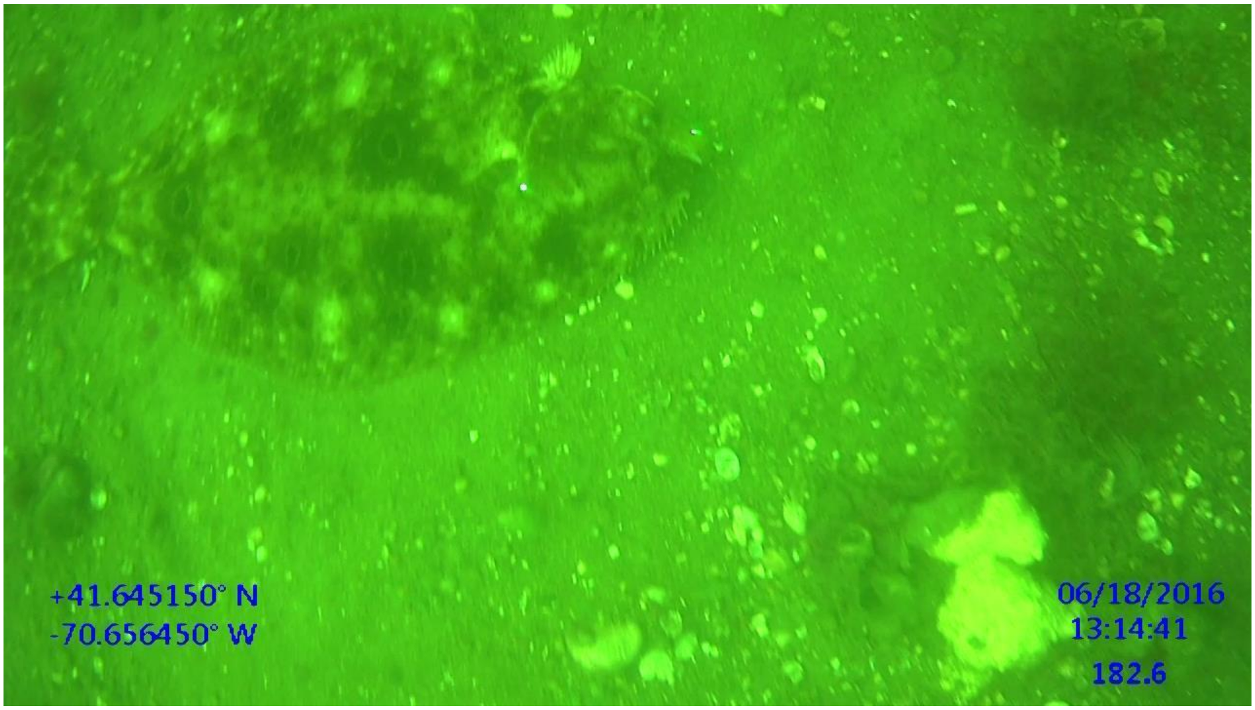
ROV Video Screen Shot:

Squid (*Loligo loligo*) on C-reef:

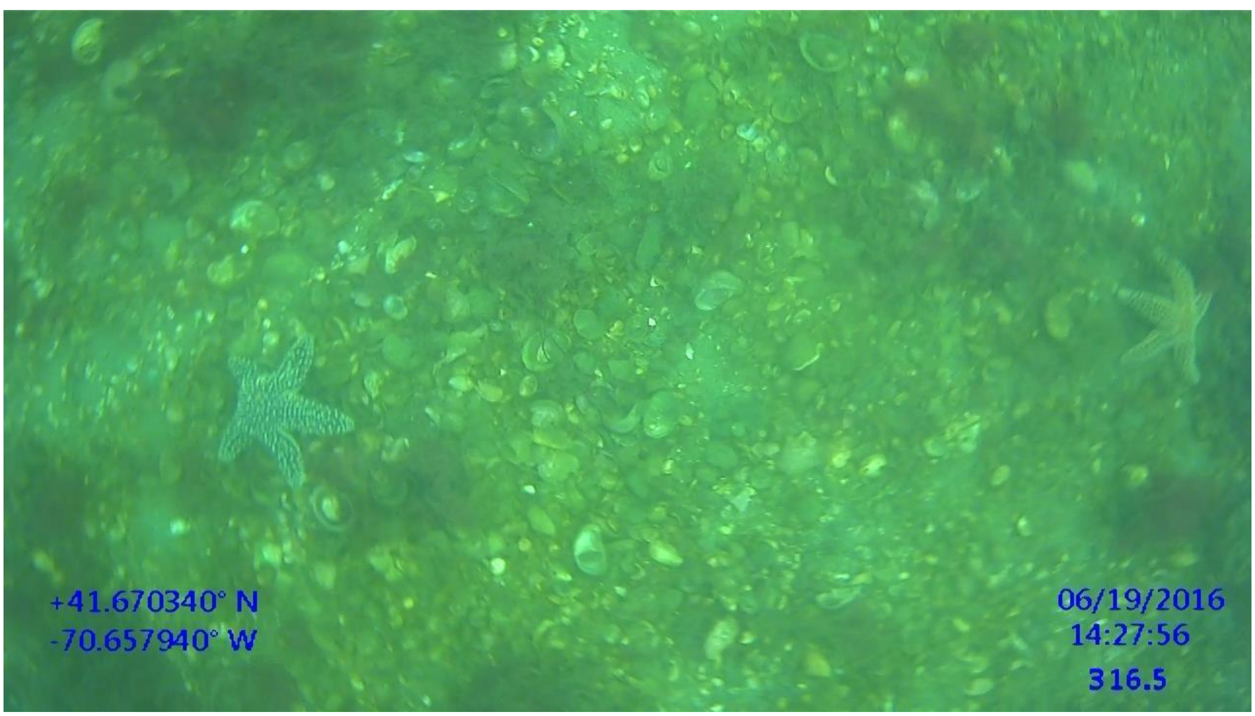


Precise GPS Locations integrated into video

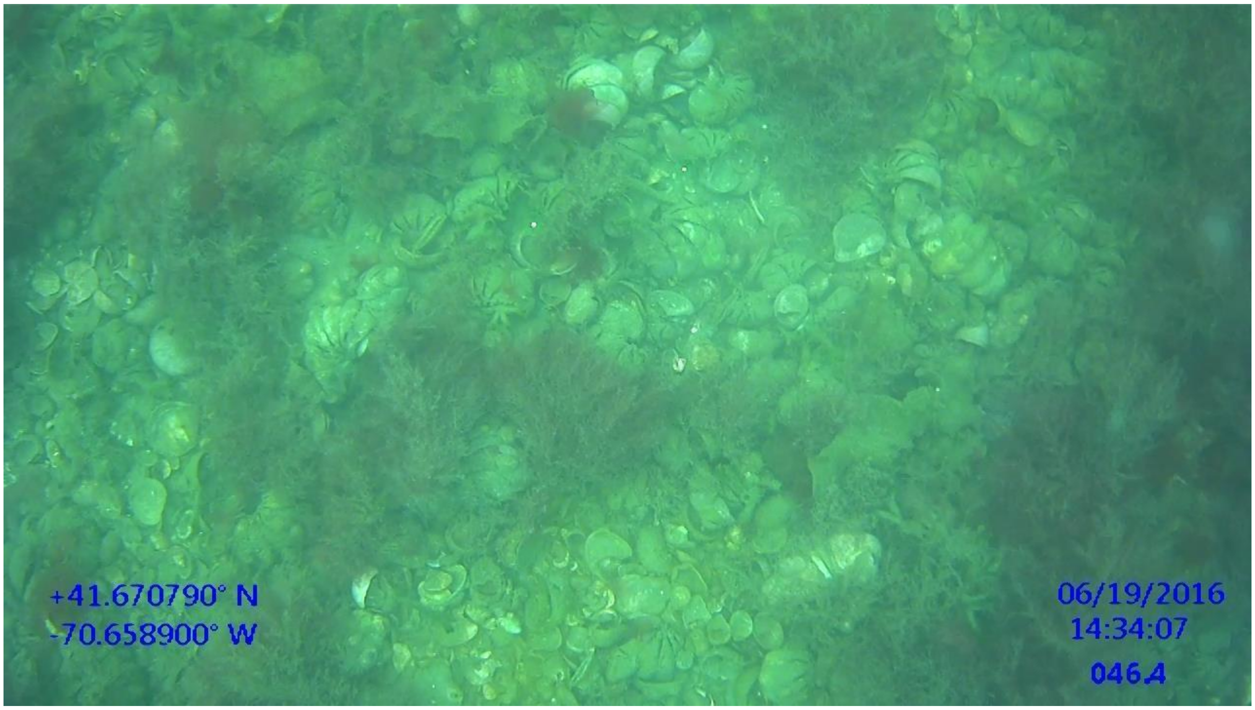
Flounder and sponge



Sea star grazing on C-reef



Highly dense (complete coverage) C-reef



OTHER Biological Data

Crepidula Size Distribution

Tobys Island Reef (TIR)
Data collected by Van Veen

Sample Number	SAMPLE JAR	Height (cm)	WIDTH (cm)	Length (cm)
1	A	2.7	1.6	1.1
2	A	2.8	1.9	1
3	A	1.8	1.3	0.5
4	A	2.8	1.9	0.9
5	A	3.1	2	1.5
6	A	3.3	2.1	1.5
7	A	3.5	2	1.6
8	A	3.5	2	1.6
9	A	1.3	1	0.5
10	A	3.2	2.1	1.2
11	A	2.5	1.5	0.8
12	A	3.7	2.2	1.4
13	A	2	1.3	0.8
14	A	2.9	1.9	1.3
15	A	2.5	1.7	0.9
16	A	3.2	2.1	1.4
17	A	1.5	1.1	0.6
18	A	3.1	2	1.3
19	A	0.9	0.7	0.2
20	A	1.3	0.9	0.5
21	A	2.1	1.3	0.7
22	A	3.2	2.2	1.3
23	A	2.9	1.9	1.2
24	A	3.4	2.1	1.5
25	A	3.5	2.3	1.5
26	A	1.8	1.1	0.7
27	A	2	1.4	0.8
28	A	2.2	1.5	1

29	A	2.7	1.6	1.1
30	A	2.7	1.8	1.2
31	A	1.5	1.2	0.6
32	A	1.3	1	0.5
33	A	2.4	1.6	1
34	A	2	1.3	0.9
35	A	2.1	1.5	0.8
36	A	2.4	1.7	0.9
37	A	2.9	1.7	1.2
38	A	2.6	1.5	1.3
39	A	2.4	1.5	1.1
40	A	2.8	1.8	1.1
41	A	2.5	1.6	0.9
42	A	2.3	1.3	1
43	A	3	1.4	1.1
44	A	1	0.8	0.3
45	A	1.7	1.1	0.7
46	A	0.9	0.7	0.2
47	A	0.8	0.6	0.2
48	A	1	0.7	0.3
49	A	0.7	0.5	0.2
50	A	0.7	0.5	0.2
51	A	0.7	0.5	0.2
52	A	1	0.7	0.3
53	A	0.8	0.6	0.2
54	A	0.7	0.5	0.2
55	A	0.5	0.5	0.1
56	A	0.5	0.3	0.1
57	A	0.5	0.4	0.1
58	B	3.3	2	1
59	B	3.2	2	1.2
60	B	3.2	2	0.9
61	B	2.7	1.8	1
62	B	2.8	2	1
63	B	3	1.9	1.2
64	B	2.8	2	1.2
65	B	3.2	2	1.4
66	B	3.1	2	1
67	B	3	2.1	1

68	B	3.1	1.8	0.9
69	B	2.7	1.8	0.8
70	B	2.7	1.7	1
71	B	2.9	1.7	0.8
72	B	2.7	1.9	1.2
73	B	2.6	1.6	0.8
74	B	2.5	1.8	0.7
75	B	2.6	1.7	1
76	B	2.3	1.6	0.5
77	B	2.1	1.4	0.7
78	B	1.9	1.3	0.6
79	B	2	1.3	0.8
80	B	1.8	1.2	0.7
81	B	1.5	1	0.5
82	B	1.3	1	0.3
83	B	1	0.8	0.3
84	B	1	0.8	0.3
85	B	1	0.8	0.3
86	B	1.1	0.8	0.3
87	B	1	0.7	0.2
88	B	0.9	0.7	0.2
89	B	0.9	0.7	0.2
90	B	0.8	0.5	0.2
91	B	0.8	0.5	0.2
92	B	0.7	0.5	0.2
93	B	0.7	0.5	0.2
94	B	0.6	0.5	0.2
95	B	0.6	0.5	0.2
96	C	3.6	2.2	1.6
97	C	2.3	1.5	1
98	C	2.6	1.7	1.1
99	C	3.4	2.1	1.5
100	C	3.4	2.1	1.7
101	C	3	2	1.4
102	C	3.4	2.2	1.5
103	C	3.2	1.9	1.4
104	C	2.9	1.8	1.2
105	C	2.6	1.6	1.2
106	C	3.1	1.8	1.3

107	C	3.1	2.1	1.2
108	C	2.9	1.9	0.9
109	C	2.8	1.8	1
110	C	2.5	1.6	0.8
111	C	2.6	1.7	1.2
112	C	2	1.4	0.5
113	C	2.8	2	1.3
114	C	3.2	2.1	1.3
115	C	2.7	1.6	1
116	C	3	1.7	1.2
117	C	3.2	2	1.5
118	C	2.7	1.7	1.3
119	C	1.9	1.1	0.6
120	C	2.7	1.6	1.2
121	C	2.4	1.3	0.8
122	C	2.6	1.7	0.9
123	C	2.6	1.7	1
124	C	2.3	1.6	0.7
125	C	2.2	1.5	0.9
126	C	1.9	1.2	0.7
127	C	1.8	1.2	0.6
128	C	2.5	1.6	0.8
129	C	2.6	1.5	1.2
130	C	2.1	1.2	0.8
131	C	2.5	1.5	0.9
132	C	2.4	1.5	0.8
133	C	1.4	0.9	0.6
134	C	2	1.3	0.8
135	C	2.4	1.5	0.9
136	C	2.9	1.6	1
137	C	2.6	1.7	1.1
138	C	2.5	1.6	1.1
139	C	3	1.8	1.5
140	C	2.8	1.6	1
141	C	2.9	1.9	1
142	C	2.2	1.5	0.8
143	C	2.9	1.7	1.3
144	C	2.6	1.4	1.1
145	C	1.9	1.3	0.6

146	C	3.2	1.7	1.3
147	C	2.6	1.6	1.1
148	C	2.6	1.6	1.2
149	C	2.6	1.5	0.8
150	C	3.5	1.9	1.1
151	C	3	2	1
152	C	2.9	1.7	1.2
153	C	2.7	1.7	1.1
154	C	1.8	1.2	1.6
155	C	2.7	1.5	1.2
156	C	1.8	1.2	0.5
157	C	2.1	1.5	0.6
158	C	1.9	1.3	0.6
159	C	1.5	0.9	0.5
160	C	1.5	1	0.5
161	C	2	1.2	0.5
162	C	1.4	0.8	0.4
163	C	1.6	0.9	0.5
164	C	1.5	1	0.6
165	C	1.1	0.8	0.4
166	C	1.1	0.8	0.2
167	C	0.9	0.7	0.2
168	C	1	0.7	0.2
169	C	1.1	0.8	0.3
170	C	0.9	0.6	0.2
171	C	0.9	0.7	0.3
172	C	0.9	0.7	0.2
173	C	0.8	0.6	0.2
174	C	0.9	0.7	0.2
175	C	0.8	0.6	0.2
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177	C	0.7	0.6	0.2
178	C	0.8	0.5	0.2
179	C	0.9	0.7	0.2
180	C	0.9	0.6	0.3
181	C	0.9	0.6	0.2
182	C	0.5	0.4	0.1
183	C	0.6	0.5	0.2
184	C	0.8	0.6	0.2

185	C	0.5	0.4	0.1
186	C	0.5	0.4	0.1
187	C	0.4	0.3	0.1
188	C	0.3	0.2	0.1

mean	2.071276596	1.338829787	0.778723404
std	0.9281829	0.547656859	0.441284547
	H	W	L

APPENDIX A – Grant Scope of Services

MMA/CAF Benthic Studies in Buzzards Bay, MA – 2017 Project Description:

(a.) Overview:

The Massachusetts Maritime Academy (MMA) and the Coastal America Foundation (CAF) are requesting financial assistance in mapping benthic habitats in Buzzards Bay. In particular, the recent discovery of significant *Crepidula fornicata* beds in the upper Buzzards Bay are proposed to be mapped. The mapping and associated ecological studies will enable the Commonwealth to make management decisions and better understand the ecological importance of this unique benthic community. This research funded by MET will also be able to engage students in 'hands on' applied marine ecology onboard the Research Vessel Liberty in Buzzards Bay watershed, MA and in our laboratory facilities. Students will assist with Foundation and MMA scientists and pilot the CAF ROV (Remotely Operated Vehicle – VideoRay) and MMA drop cameras (Seaviewer) with GPS references to map the extent of *Cripedula* reefs. Students will obtain skills in marine ecology, field observation, benthic taxonomy, seafloor mapping, statistical analyses, and GIS data input. The onboard, laboratory interactions and close mentoring with marine scientists will give the students a meaningful scientific education experience while collecting significant new scientific data for the management of the Buzzards Bay estuary.

(b.) Nature of Research Activities:

In 1955 Howard Sanders (Sanders, 1958) sampled 19 benthic stations in Buzzards Bay. The study of changes in macrobenthic community structure has been widely used for the detection of anthropogenic impacts in marine and estuarine ecosystems. Benthic invertebrates are an important ecological component of the Buzzards Bay ecosystem. A better understanding of the historic changes in community structure could improve the ability to forecast the outcome of proposed management and regulation activities. A surprising result at the first 8 stations of this 2012/2013 Coastal America Foundation inventory (Figure 1) was the discovery of significant *Crepidula fornicata* reefs that were not present in any 1955 samples (WHOI Records, 1956). Blanchard (2009) has documented similar *Crepidula fornicata* proliferation in Europe. The reef may be a result of recent eutrophication in Buzzards Bay as documented by the Buzzards Bay Comprehensive Conservation and Management Plan (2013) or benthic temperature changes that are influencing this gastropod's life cycle (Thieltges et al 2004).

At the request of the Massachusetts Office of Coastal Zone Management (MACZM), the Massachusetts Maritime Academy – Marine Safety and Environmental Protection Department (MMA-MSEP) is conducting seafloor mapping of Buzzards Bay to define the spatial extent of *Crepidula fornicata* reefs (Common Slipper Shell). The known locations at present are limited to discrete data point features attributed to sediment sampling, photographs and remote-sensing interpretation of structure-scan sonar surveys. By accurately delineating the spatial extent of such hard and complex structures, MACZM can better define the limits of "Special, Sensitive and Unique (SSU)" habitats subject to greater protection under the Massachusetts Ocean Management Plan.

Project goals:

1. To determine the extent to which Buzzards Bay *Crepidula fornicata* reef communities have become established over the past 60 years;

2. To assess what benthic conditions these reefs require to proliferate with emphasis on baseline mapping *Crepidula fornicata* reef development.

3. Provide this scientific data consistent with the Coastal and Marine Ecological Classification System (CMECS) and in support of Massachusetts fisheries management, the MACZM Ocean Plan, and NOAA Coastal and Marine Spatial Planning.

Research activities:

We will conduct daily research cruises with students that would expand ongoing collaboration with the Coastal America Foundation and Massachusetts Office of Coastal Zone Management. The MMA faculty and students will be performing the following research activities:

- Underwater digital video system imagery recordings to verify and define the spatial extent of *C. fornicata* reefs in Buzzards Bay
    - Accurate GPS tracking is collected to coincide with underwater video imagery data, and these two data sets are uploaded in ArcGIS software allowing for spatial analysis and input to the Massachusetts Ocean Plan.
- Remote Operating Vehicle (ROV) video imagery as an initial screening tool prior to underwater video system imagery.
- Experimenting with structure scan surveys utilizing common "low-cost" hull mounted systems.

All of the above will be used to classify benthic habitats in accordance with the national Coastal and Marine Ecological Classification System (CMECS, 2010).

(c.) The Research Environment:

The Massachusetts Maritime Academy campus is located on the waterfront at Taylor's Point in Buzzards Bay. This unique access to the Bay gives the researchers and students daily opportunities (weather permitting) to assist on research cruises. The research is being conducted in collaboration with the Coastal America Foundation. MMA Research Vessel Liberty working in tandem with the Coastal America Foundation Research Vessel Teleost will provide sampling platforms and Bay-wide access. This University of Massachusetts campus has complete university laboratories, data bases management and GIS capabilities. The Principal Investigator, Bill Hubbard (MMA adjunct professor) has 35 years of marine sciences experience including research, teaching and mentoring. His career includes 30 years a senior manager of a scientific branch of the US Army Corps of Engineers (USACE). Bill is a trained government scientist and seasoned coach of hundreds of scientists over the decades.

Co-PI Michael Elliot is an experienced Environmental Engineer and affiliated with the Massachusetts Department of Environmental Protection. His skills include environmental chemistry, field operations, and GIS mapping.

Other senior personnel include the faculty of the MMA Marine Safety and Environmental Protection will all be involved, under direction of Francis Veale, our department chair. This scientific pool includes marine ecologists, chemists, geologists, GIS and statistical experts.

(d.) Project Evaluation and Reporting

The summary report and all data will be maintained at Massachusetts Maritime Academy and on the Coastal America Foundation website as a permanent archive. Additionally MACZM will enter mapping data into the Massachusetts Ocean Plan. Video transects will be spatially located with GPS tracking and reef density (Figure 2) calculated. This will allow future researchers to conduct additional studies of ecological changes in the Buzzards Bay watershed.

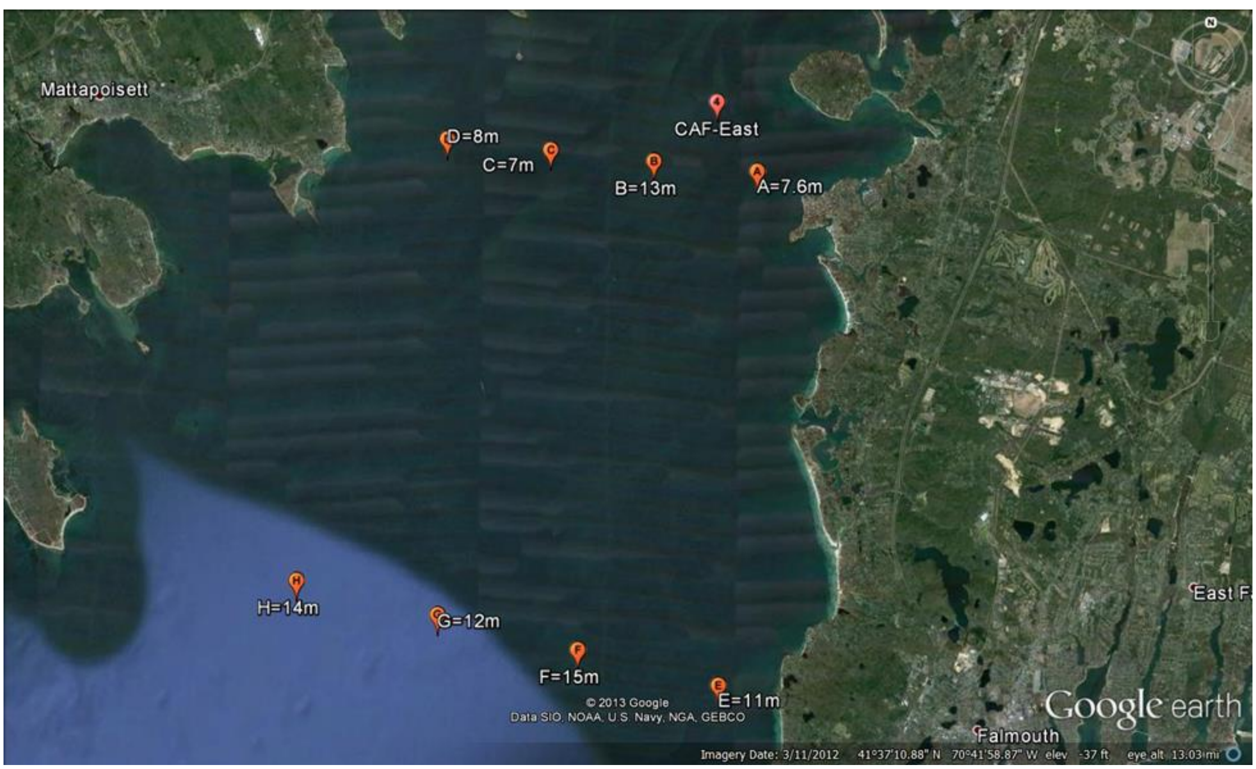
(e.) Broader Impacts

We will enthuse STEM students and add to the scientific knowledge of the ecology of Buzzards Bay. The scientific discovery of significant *Crepidula fornicata* reefs in Buzzards Bay is already in review as an article in the Journal of Marine Ecology publication. Several peer reviewed publications are anticipated from ongoing research. Students can contribute to these articles and also obtain independent study experience. Data will be used by the Commonwealth of Massachusetts in their Ocean Plan. The biological data will be a benchmark for global climate change and allow a geo-referenced comparison to previous data and future data observations.

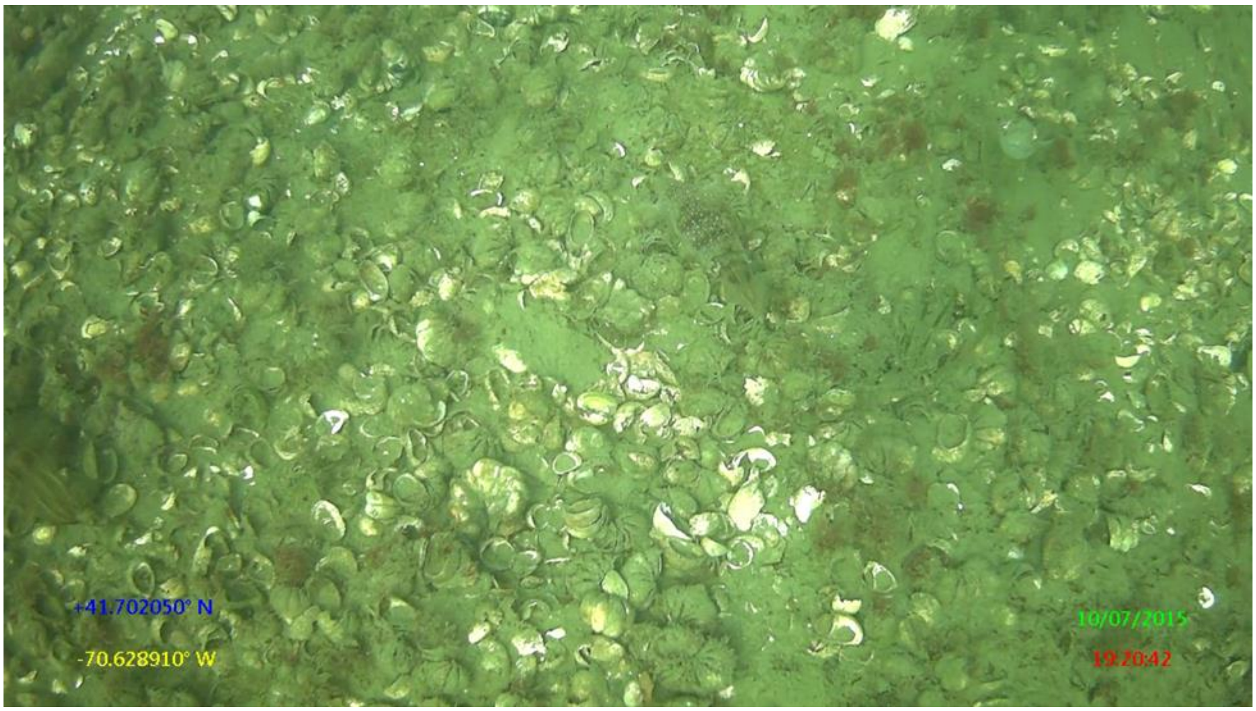
(f.) References

Blanchard M. (2009) Recent expansion of the slipper limpet population (Crepidula fornicata) in the Bay of Mont-Saint-Michel (Western Channel, France). IFREMER, Dép. Dynamiques de l'Environnement Côtier (DYNECO), 70, 29280.
Buzzards Bay Comprehensive Conservation and Management Plan (2013) EPA Buzzards Bay National Estuary Program. Retrieved at http://buzzardsbay.org/newccmp.htm.
CMECS (2012) Federal Geographic Data Committee. FGDC-STD-018-2012
Dauer D.M., Ranasinghe J.A., Weisberg S.B. (2000) Relationships between benthic community condition, water quality, sediment quality, nutrient loads and land use patterns. Estuaries, 23(1) 80-96.
Sanders H.L. (1958) Benthic studies in Buzzards Bay: I. Animal-Sediment Relationships. Limnology and Oceanography, 3(3), 245-258.
Thieltges D.W., Strasser M., van Beusekom J.E., Reise K. (2004). Too cold to prosper – winter mortality prevents population increase of the introduced American Slipper Limpet Crepidula fornicata in Northern Europe. Journal of Experimental Marine Biology and Ecology, 311(2), 375-391.
WHOI Records. Papers of Howard L. Sanders, 1956-1996. MC-42, Buzzards Bay, 1956. Data Library and Archives, Woods Hole Oceanographic Institution, Woods Hole, MA.

Figure 1. Station Map of Upper Buzzards Bay.



MMA/CAF Benthic Studies in Buzzards Bay, MA Phase 2 - Project Description:



Squid on C-reef

Background:

The 2016 MET Grant awarded to the Massachusetts Maritime Academy has mapped (Figure 1) several significant Slipper Shell gastropod reefs (*Crepidula fornicata*). These reefs were previously unknown. The science team wishes to continue mapping these unique habitats and conduct some biological observations to understand the relationships of the habitat to the entire Buzzards Bay ecosystem. This request will allow a second year of mapping and ecological exploration.

The Massachusetts Maritime Academy (MMA) campus is located on the waterfront at Taylor's Point in Buzzards Bay. This unique access to the Bay gives the researchers and students daily opportunities (weather permitting) to assist on research cruises. The proposed research is being conducted in collaboration with the Coastal America Foundation (CAF). MMA Research Vessel Liberty working in tandem with the Coastal America

Foundation Research Vessel Teleost will provide sampling platforms and Bay-wide access. This state university campus, one of twenty-nine colleges and universities supported by the Commonwealth of Massachusetts, has complete university laboratories, data base management and GIS capabilities.

Why are these reefs just now being discovered?
Ecosystems will shift their functional components in response to stressors. A new balance of dominants and transients will evolve in response to physical impacts such as climate change, overharvesting of predators and eutrophication. This may be the case in Buzzards Bay, Massachusetts according to the 2015/2016 Massachusetts Environmental Trust funded research by the Massachusetts Maritime Academy (MMA). The recent discovery of extensive seafloor areas covered with *Crepidula fornicata*, the common slipper shell, led MMA scientists to begin mapping the spatial dimensions of these interesting shell reef habitats. Since 2014 MMA has been conducting video mapping of the benthic habitats in Buzzards Bay. The investigations will assist future coastal management and the experience is training the next generation of scientists onboard their research fleet. In 1955 nineteen benthic stations were examined in Buzzards Bay and there were no *Crepidula fornicata* present (journal article in press; Marine Ecology). Now we have mapped at least 7 living slipper shell reefs that cover over 100 acres each in several different areas. We are examining this ecological change, which may have many contributing factors. Whatever the cause of the habitat change, these reefs seem to be productive benthic habitat, especially for juvenile fish.
Crepidula fornicata is a unique gastropod snail since it is a filter feeder and mostly stays sessile, stacked in clusters or “curls”. This stacking allows the males and females to be in close approximation and builds the Crepidula reef (C-reef) structure that can cover the ocean floor for acres. One reef, documented by this research, covers more than 140 acres (Figure 1). Many coves and embayments have shorelines covered by the empty shells after a storm, indicating there are more reefs to map. Their proliferation may be due to warmer water temperatures in winter allowing them a better chance of survival. European researchers, where *Crepidula fornicata* is non-native (invasive) organism, have reported warmer winters allow C-reef expansion (Theilghert, 2009). There are certainly more nitrates and phosphates in the waters allowing a rich bloom of plankton to feed these filter feeders (EPA Buzzards Bay National Estuary Program, 2013). Researchers at the University of Connecticut have documented the feeding process of these filter feeders to take advantage of small sized planktonic algae. This may allow them to outcompete with hard clams and other bivalve filter feeders in times of planktonic size dominance shifts. Or the overharvesting, temperature shifts and other exclusions of predators may be the cause. If lobsters are leaving Buzzards Bay earlier and staying in deeper water longer because of increased benthic temperatures, and cod have been fished out – maybe the lack of predators due to climate change is a driver. Most likely there is a relationship among all these factors.
The reefs do filter the water, absorb nitrates and fix carbon into the slipper shell itself. Video and benthic Van Veen sampling indicate the reefs are excellent juvenile fish forage (associated polychaetes and crustaceans) and shelter habitat (shell, sponge and algal areas

add structure to the otherwise open benthic habitat). Biodiversity studies are continuing. While mapping the reefs we have observed a lack of starfish (another predator), which has cyclic densities. We have observed spider crab foraging the C-reefs and other visitors such as squid. We have not observed direct predation of any species on the *Crepidula fornicata* individuals themselves but do see many recently empty shells (white with little fouling) during summer. There is a lot to be learned by closely observing the biota in the hundreds of hours of video mapping. The spatial extent is being designated, but just as important – benthic ecologists are gaining an insight to the C-reef ecosystem.

One reef in particular – the Tobys Island C-reef (TI C-reef – Figure 2) will be focus in this year to provide several 'seasons' of video mapping. We will develop an inventory of biological diversity from video, benthic grab (Van Veen) and trap deployments. As we defined the edges of the TI C-Reef we have observed areas of live Crepidula under Ulva, summer days with high densities of spider crabs (Labinia sp.) and other times of "turned over" empty shell among live curls. This is also where we observed squid (*Loligo loligo*) on the C-reef. This continuation of mapping is supporting scientific research and will establish knowledge to guide future sampling of these and other Buzzards Bay benthic habitats.

The Principal Investigator (PI), Bill Hubbard (MMA adjunct professor) has 35 years of marine science experience including research, teaching and mentoring. His career includes 30 years as senior manager of a scientific branch of the US Army Corps of Engineers (USACE). Bill is a trained government scientist and seasoned coach of hundreds of scientists over the decades.

Co-PI Michael Elliott (also an MMA adjunct professor) is an experienced Environmental Engineer and affiliated with the Massachusetts Department of Environmental Protection. His skills include environmental chemistry, contaminated site assessment/remediation, and GIS mapping.

Other senior personnel who will be involved include the faculty of the MMA Marine Safety and Environmental Protection Program under direction of Francis Veale, our department chair. This scientific pool includes marine ecologists, chemists, geologists, GIS and statistical experts.

The Massachusetts Maritime Academy has 360 full time and 40part time staff, 33 volunteers and 33 Board members. The MMA total annual organizational budget is approximately $40,000,000. The physical location and significant resources of MMA assures this project can be efficiently implemented and meet the stated goals.

Project Description:

The Massachusetts Maritime Academy and the Coastal America Foundation are requesting financial assistance in mapping ecologically important benthic habitats in Buzzards Bay. Using state of the art equipment and innovative technologies this collaborative partnership will use grant funding from the Massachusetts Environmental Trust (MET) to map estuarine benthic habitats in Buzzards Bay. The function of various bottom types and their ecological significance has become an emerging environmental issue in light of proposed offshore energy developments and transmission line planning. In particular, the recent discovery of significant *Crepidula fornicata* beds in the upper Buzzards Bay (Hubbard 2016) are proposed to be mapped. The mapping and associated ecological studies will enable the

Commonwealth to make management decisions and better understand the ecological importance of this unique benthic community. The data will be submitted to the Massachusetts Ocean Resource Information System (MORIS). It also fulfills two Science Priorities articulated in the Massachusetts Ocean Management Plan: Science Priority #3 "Further map marine habitats"; and Priority #11 "Identify ecologically important areas. The function of these large gastropod reefs is an important scientific area of investigation needed to allow management decisions in Buzzards Bay.

This research funded by MET will also continue to engage students in 'hands on' applied marine ecology onboard the Research Vessel 'Liberty' in the Buzzards Bay watershed and in our laboratory facilities. Students will assist with Foundation and MMA scientists and pilot the CAF ROV (Remotely Operated Vehicle – VideoRay) and MMA drop cameras (Seaviewer) with GPS references to map the extent of *Crepidula* reefs. Students will obtain skills in marine ecology, field observation, benthic taxonomy, seafloor mapping, statistical analyses, and GIS data input. The onboard, laboratory interactions and close mentoring with marine scientists will give the students a meaningful scientific education experience while collecting significant new scientific data for the management of the Buzzards Bay estuary.

Metrics for success of this effort will include publication of a data layer identifying the spatial extent of *Crepidula* reefs/beds and shell substrates in the study area. This data layer will be available to the public through the MORIS (once accepted), the MMA and CAF Websites, and in a summary report which will be the subject of a press release, with credits to the MET program. The MET logo will also be prominent in these communication venues.

Nature of Research Activities and Management Implications:

Currently, the known reef locations are limited to discrete data point features attributed to sediment sampling, photographs and remote-sensing interpretation of structure-scan sonar surveys. By accurately delineating the spatial extent of such hard and complex structures, MACZM can better define the limits of "Special, Sensitive and Unique (SSU)" habitats subject to greater protection under the Massachusetts Ocean Management Plan. A broad range of ethnically diverse populations fish these reefs in small boats, locally called the "Mosquito Fleet" – harvesting scup, black seabass and tautog for household consumption. Management decisions will benefit the sustainability of these fisheries.

Since the *Crepidula fornicata* reefs were not present in any Sanders 1955 samples (WHOI Records, 1956), watershed management decisions would benefit from understanding the cause of C-reef proliferation and its ecological functions, e.g. juvenile finfish refuge (Figure 3) and forage habitat. Blanchard (2009) has documented similar *Crepidula fornicata* proliferation in Europe and identified warmer winter water temperatures as a driver of reef expansion. The reef may be a result of recent eutrophication, changes in predation, changes in fisheries harvest or benthic temperature changes that are influencing this gastropod's live cycle in Buzzards Bay.

Project goals*:*

1. To determine the extent to which Buzzards Bay *Crepidula fornicata* reef

communities have become established over the past 60 years;

2. To assess the biological diversity of the C-reefs with emphasis on the role of this unique habitat in life stages of commercial and recreational fisheries species;

3. Process this scientific data and make it publicly available in a manner consistent with the Coastal and Marine Ecological Classification System (CMECS 2010) and in support of Massachusetts fisheries management, the MACZM Ocean Management Plan, Massachusetts Ocean Resources Inventory System (MORIS) and NOAA Coastal and Marine Spatial Planning.

Research objectives scope of work:

We will conduct 24 research cruises with students that would expand ongoing collaboration with the Coastal America Foundation and Massachusetts Office of Coastal Zone Management. The Investigators and MMA faculty and students will be performing the following research activities:

- Remotely Operating Vehicle (ROV) video imagery (Figure 4) to assess the biological dominants on the C-reefs by developing a species list from station videos (estimated at 6 cruise events at Tobys C-reef plus other opportunities))
- Benthic infaunal grabs (Van Veen) and trap deployments, with a special emphasis on the Tobys Island C-reef to develop a biodiversity inventory (estimated 3 with 500 micron sieves and opportunistically with 1.00 mm sieves – ID by W. Hubbard taxonomist)
- Underwater digital video system transects imagery recordings (Figure 5) to verify and define the spatial extent of *C. fornicata* reefs in Buzzards Bay (every sea day – estimated 1 kilometer minimum each transect)
    - Accurate GPS tracking will be collected to coincide with underwater video transect imagery data.
    - The above two data sets are to be uploaded in ArcGIS software allowing for spatial analysis and input to the Massachusetts Ocean Resources Information System to support the Massachusetts Ocean Management Plan.
    - Determination of the imagery classification under the Coastal and Marine Ecological Classification System.
    - Coordination of the transects data and CMECS classification with Massachusetts Office of Coastal Zone Management, US Geological Survey, Massachusetts Division of Marine Fisheries, EPA Buzzards Bay National Estuary Program, and regional researchers.

Compilation of biodiversity will include benthos to bony fish and algae to eelgrass.
Project Deliverables:
All of the above will be used to classify benthic habitats in accordance with the national Coastal and Marine Ecological Classification System (CMECS, 2010). A final report including techniques and meta-data will be produced. Final data layers in geo-referenced formats will be supplied to the Massachusetts Office of Coastal Zone Management for inclusion in

the Massachusetts Ocean Resources Information System. Data layers will undergo quality control by the senior investigators to adhere to the classification standards used for CMECS. Our Quality Assurance Project Plan includes senior level review of not less than 15% of classified images. Geo-referencing QAPP will adhere to EPA QA/G-5G (EPA 2003) in EPA Guidance for Geospatial Data Quality Assurance Project Plans (http://www.epa.gov/quality/qs-docs/g5g-final.pdf).
The Massachusetts Environmental Trust will be prominently credited with all outputs from this scientific research. In the first phase of funding the project team met and exceeded commitments to featuring MET support with press releases, newspaper articles and web site accreditation (Figure 6). Sample video (e.g. 2015 Highlights) can be found at http://coastalamericafoundation.org/crepidulareefs.html .

Project Evaluation and Reporting:

The summary report, biological diversity inventory and all data will be maintained at Massachusetts Maritime Academy and on the Coastal America Foundation website as a permanent archive. Additionally, MACZM may enter mapping data into their Massachusetts Ocean Resources Information System for management decisions through the Massachusetts Ocean Management Plan. Video transects will be spatially located with GPS tracking and reef density calculated. This will allow future researchers to conduct additional studies of ecological changes in the Buzzards Bay watershed.

Broader Impacts

We will inspire enthusiasm for conducting primary research among science, technology, engineering and math (STEM) students and add to the scientific knowledge of the ecology of Buzzards Bay. The scientific discovery of significant *Crepidula fornicata* reefs in Buzzards Bay is already in press as an article in the Journal of Marine Ecology publication. Several peer reviewed publications are anticipated from ongoing research. Students can contribute to these articles and also obtain independent study experience. As described above, MET funding support will be identified in any published article or online database. Data will be used by the Commonwealth of Massachusetts in their Ocean Management Plan. The biological data will be a benchmark for global climate change and allow a geo-referenced comparison to previous data and future data observations.

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Figure 1a. GIS Mapping

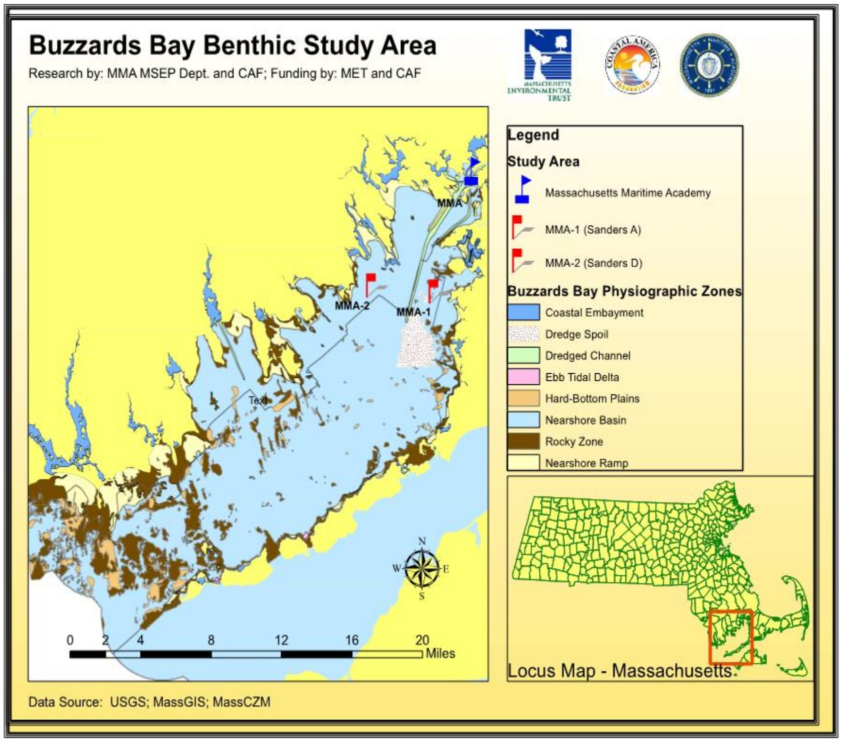


Figure 1b. GIS Mapping

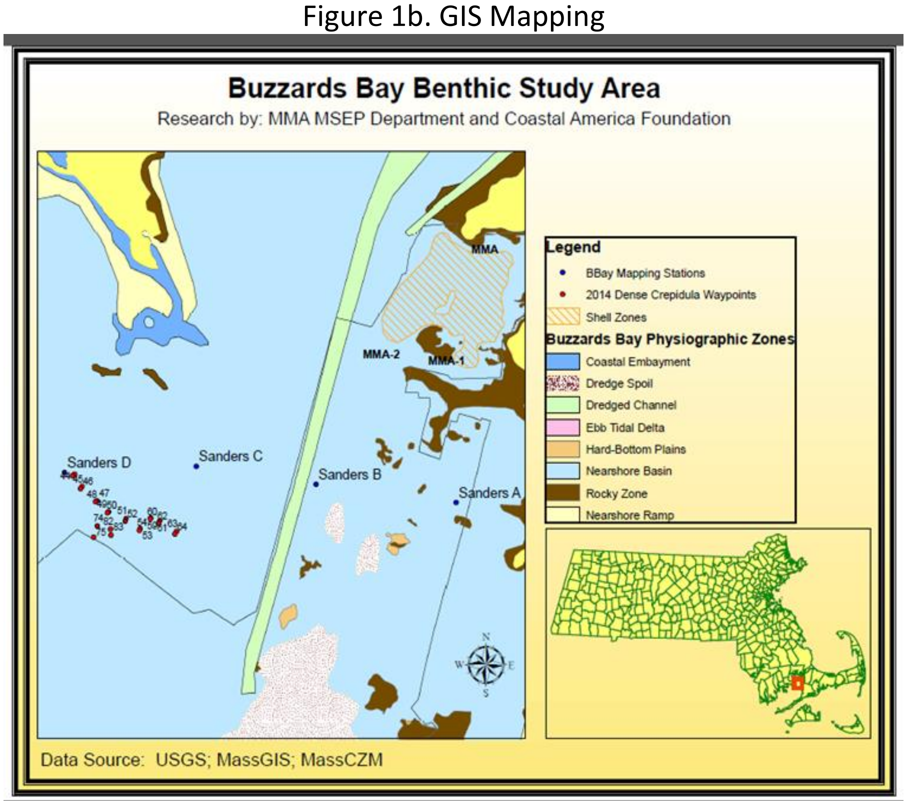


Figure 2. Tobys Island C-reef (TI C-reef)

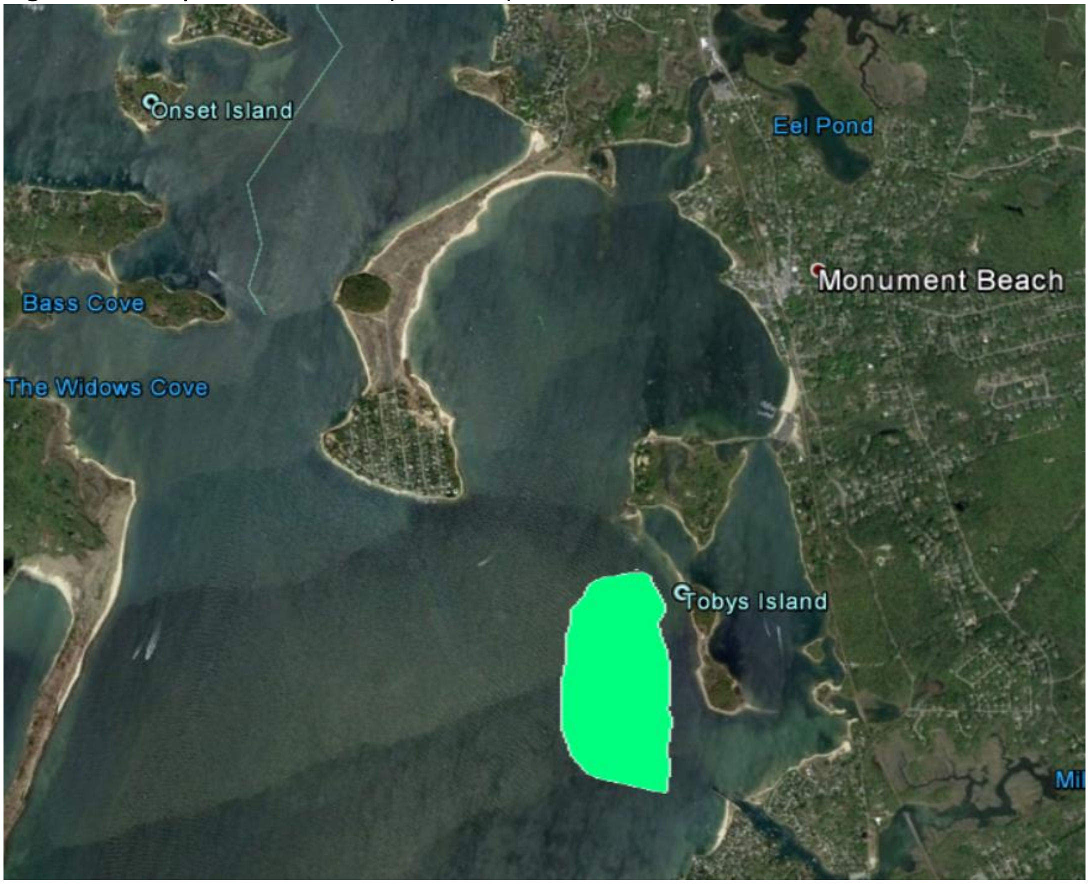


Figure 3. Juvenile Black Sea Bass on C-reef

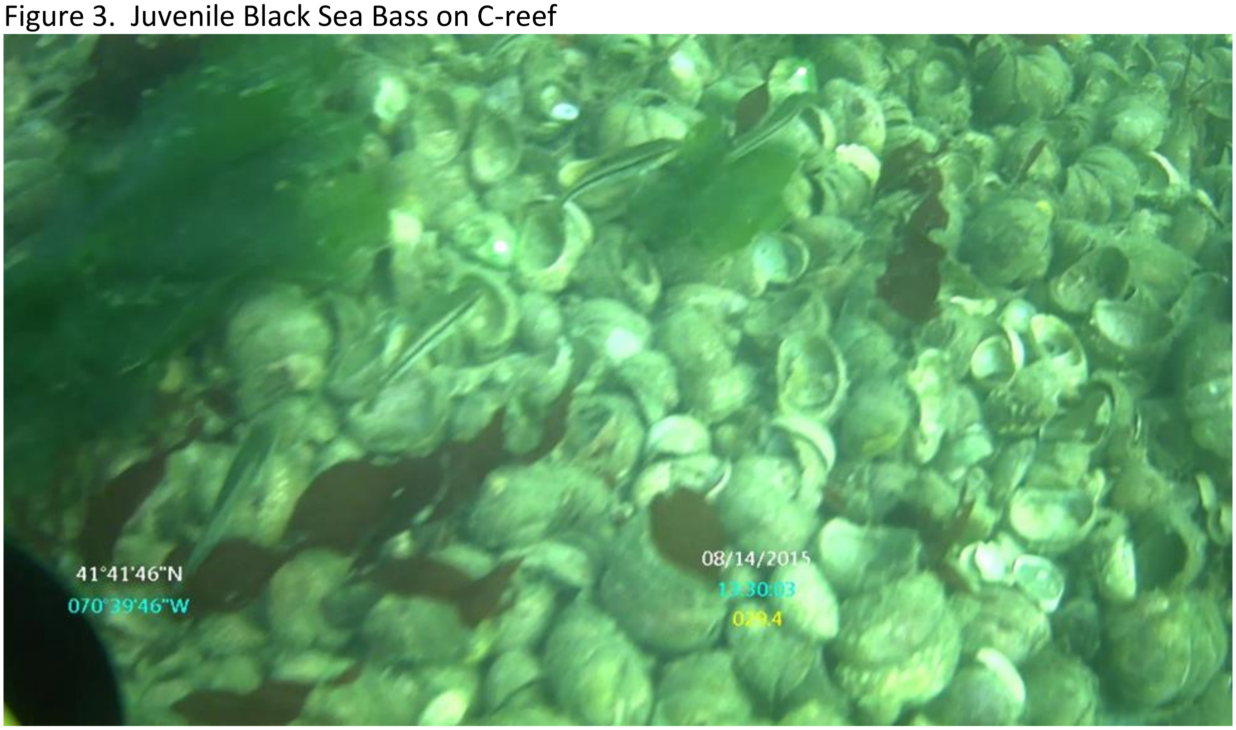
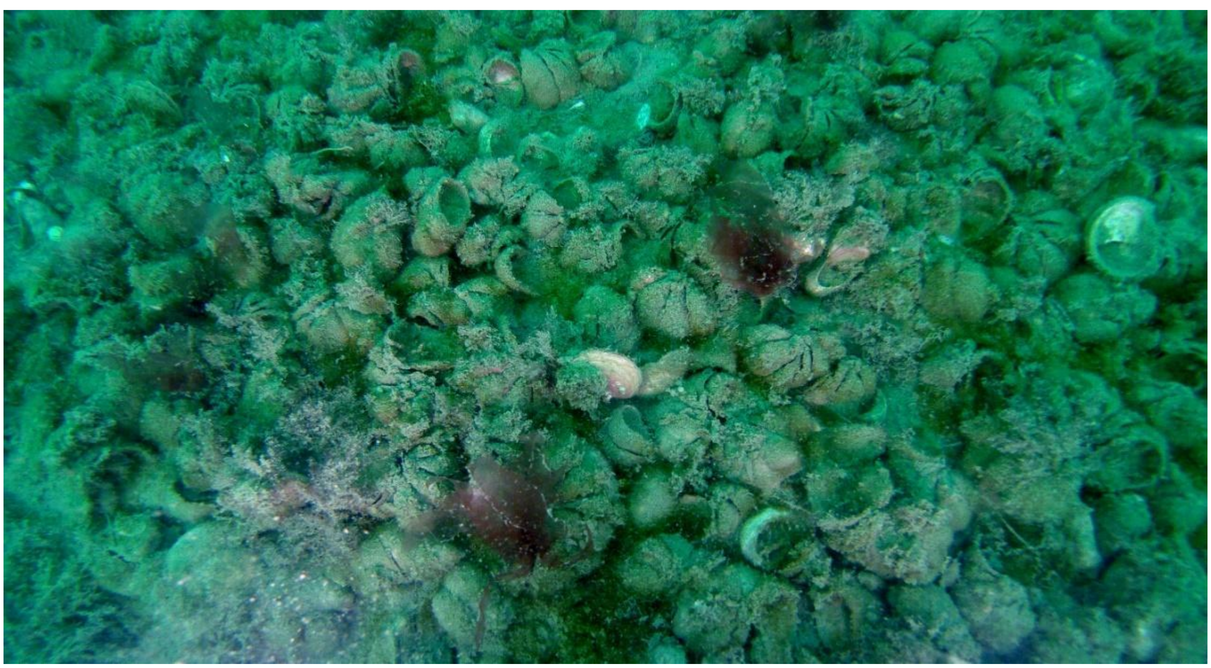
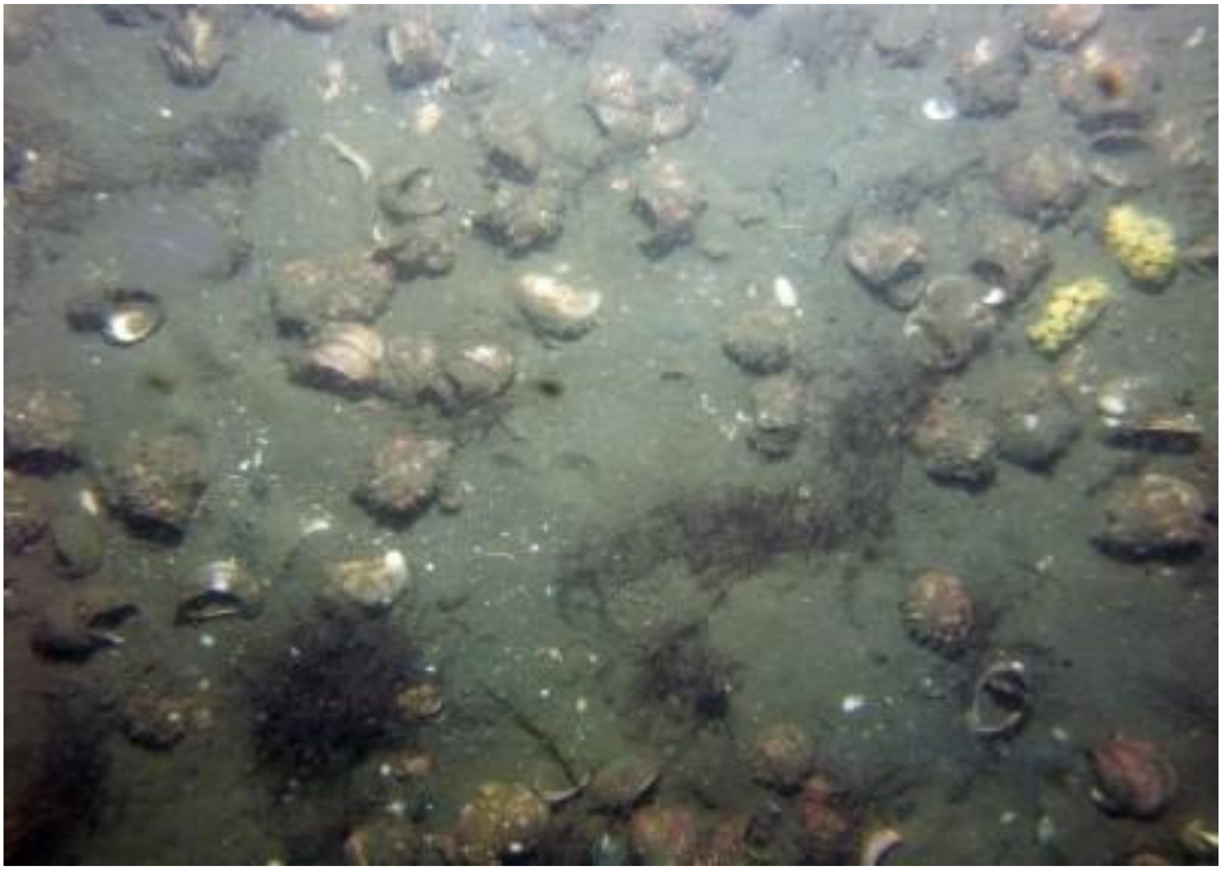


Figure 4. ROV C-reef horizon

Figure 5. *Crepidula fornicata* reef high density video capture.





APPENDIX B – Press Release/MET Program videos

Massachusetts Environmental Trust
August 30 ·

Benthic Studies in Buzzards Bay by researchers and students from the Massachusetts Maritime Academy and Coastal America...
https://www.youtube.com/embed/JhglzsaLLKw

ProducedFISH

C-reef fish including Scup, juvenile black sea bass and Northern pufferfish. Research sponsored by the Massachusetts Environmental Trust - http://www.mass.go...

YOUTUBE.COM

Massachusetts Environmental Trust
Like Page
September 9, 2016 ·

More interesting benthic mapping footage....
https://www.youtube.com/embed/v3Fkjv6SKJw

Produced Biological Studies C reef

Biological observations on Mashnee Flats Crepidula fornicata reef in Buzzards Bay, MA. research sponsored by the Massachusetts Environmental Trust.

YOUTUBE.COM

You and 1 other

Like Comment Share

This is the research that we're doing within the Marine Safety and Environmental Protection Department at Massachusetts Maritime Academy. Nice article in the Cape Cod Times.

Slipper shells' growth in Buzzards Bay puzzles researchers

Using a grant from the Massachusetts Environmental Trust, researchers and cadets from the Massachusetts Maritime Academy for the last three months

Massachusetts Environmental Trust

September 2, 2016 ·

Like Page

More images from the Buzzards Bay Benthic Mapping project supported by MET!

https://www.ecomagazine.com/.../buzzards-bay-benthic-mapping-...

Buzzards Bay Benthic Mapping Spots a Pyrosome

Buzzards Bay is popular destination for fishing, boating, and tourism adjacent to Massachusetts and connected to Cape Cod Bay via the Cape Cod Canal. Pyrosomes are free-floating colonial tunicates that live usually in the upper layers...

ECOMAGAZINE.COM

Massachusetts Maritime Academy

PRESS RELEASE

Massachusetts Maritime Academy (MMA) had been conducting high definition (HD) underwater video transects in Buzzards Bay under a grant from the Massachusetts Environmental Trust. This funding has enabled MMA to conduct at sea mapping of Buzzards Bay substrates focusing on extensive seafloor areas covered with *Crepidula fornicata*, the common slipper shell. In June 2016, at the edge of one of one of these shell reefs, a Pyrosome was photographed (see Figure 1). Coordination with regional experts have not produced any records of this colonial tunicate in Bays or Sounds of New England.

The Massachusetts Maritime Academy 30 foot Research Vessel Liberty used a SIMRAD® NSS-2 navigation chart plotter to conduct mapping transects. High definition underwater video transects were recorded as part of the *Crepidula fornicata* shell reef (C-reef) mapping on a Seaviewer® Underwater video camera system. The unit paired a Seadrop 5500 HD camera with a surface recording unit. The 550 camera was installed in a vertical tow tube with underwater laser pointers for a 10 cm scale in all recorded video (See Figure 2). The surface recording display system overlaid Latitude, Longitude, Date, UTC time and Course Over Ground (COG) continuously on all video. This overlay on high definition video was accomplished by running the video signal through a Videologic® PROTEUS II unit. The images were captured on a HDMI H.264 recorder while simultaneously being displayed on the recording counsel and research vessel navigation chart plotter.

Post processing used commercially available software that allowed capture of still images (with location and time data overlaid). Thousands of C-reef images we analyzed and classified according to the national Coastal and Marine Ecological Classification System (CMECS, 2010). This review of individual video frames captured for classification allowed the team to identify the pyrosome in Figure 1.

This is an interactive group of small animals that form together as a colony. “They act like a coral reef colony – without the hard coral.” said Bill Hubbard, Marine Ecologist at MMA. The group of individuals filters water into their 5 by 40 cm tube-like colony structure, as it passively moves at the mercy of currents. These organisms are often found in warmer waters, drifting in the pelagic zones. A current must have pushed it into upper Buzzards Bay. Although it looks like it is attached to the substrate, it most likely was just pushed downward by currents, since they are pelagic and not benthic organisms. *Pyrosoma atlanticum* is the most common of this species – given what researchers could see in the HD photograph, they cannot confirm the species. It may be there are other Pyrosomes in our bays, and the new technology being deployed by Massachusetts Maritime Academy is just now allowing their discovery. Or, as our oceans warm, we can expect more exotic visitors such as this translucent colony.

CMECS (2012). Coastal and Marine Ecological Classification System of the Federal Geographic Data Committee. FGDC-STD-018-2012

50 second video link:

https://youtu.be/0U-LSDyCaaA

90 second video link (has some typical local tunicate video):

https://youtu.be/JPT3KzMtX8k

We have observed a diverse group of benthic tunicates growing on our New England docks and piers, but this is our first encounter with a pelagic Pyrosome species!" – Kristin Osborne, tunicate specialist, MMA Adjunct Faculty and UMASS-Boston PhD candidate.

QUOTES:

"Massachusetts Maritime Academy is committed to mapping the seafloor of Buzzards Bay. This effort places our students onboard research vessels and making surprising discoveries such as this unique organism." - Rear Admiral Francis X. McDonald

"Tyler Aldrich – one of our seniors – has been working on this underwater video mapping effort all summer. He has developed skills in video mapping and Remotely Operated Underwater Vehicle (ROV) operations." - Francis Veale; Department Chairman, MMA Marine Safety and Environmental Protection.

"The video and screen captures have the latitude/longitude embedded onscreen. This technology allows us to map the exact position of the Pyrosome, which was far up in Buzzards Bay." – Mike Elliott, GIS Environmental Analyst, MMA Marine Safety and Environmental Protection Adjunct Faculty.

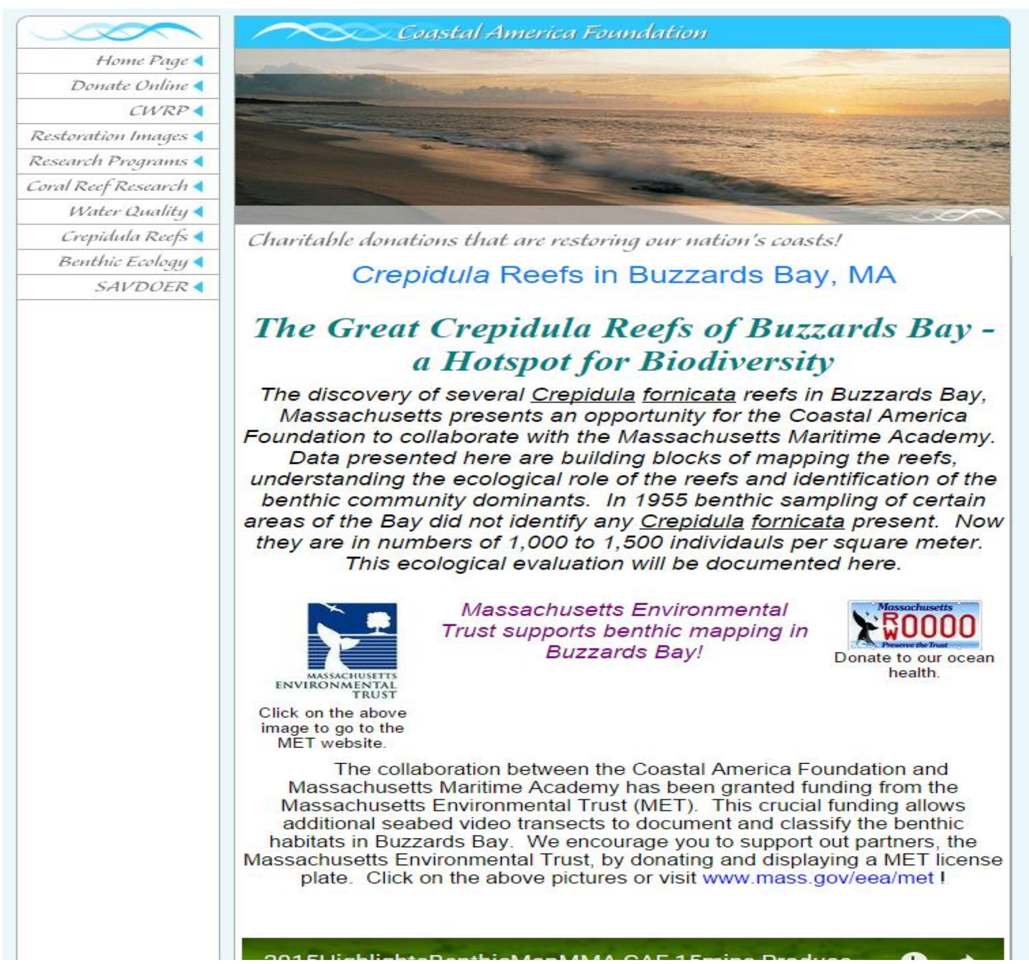
"While programming in the Latitude and Longitude coordinates I was surprised to see this interesting animal." – Tyler Aldrich, MMA senior, Marine Safety and Environmental Protection Program.

The Massachusetts Maritime Academy Research Vessel Liberty with high definition drop camera/structure scan recorders and the Coastal America Foundation Research Vessel Teleost with a remotely operated underwater vehicle (ROV) video camera have been the primary field assets. Over 30 students have been engaged in the mapping assisting field operations with MMA researchers Bill Hubbard (Marine Ecologist); Mike Elliott (GIS Environmental Analyst) and Frank Veale (Marine Safety and Environmental Protection Program Chairman).

The Massachusetts Environmental Trust has financially supported this effort. Supporting the environmental programs, like the Buzzards Bay Benthic Mapping project, funded by the Trust in your community is easy: choose one of three environmental plates, the Right Whale & Roseate Terns, The Leaping Brook Trout, or the Blackstone Valley Mill when you purchase a new car or renew Visit your local Registry of Motor Vehicles or order a plate online at www.massrmv.com or log onto www.mass.gov/eea/met where you can learn more about the Trust, the programs it supports, and the specialty license plate offerings.

The Coastal America Foundation is collecting donations for MMA student stipends to participate in field research. You can donate at http://coastalamericafoundation.org/donateonline.html . If you would like to support or obtain more information about the benthic mapping in Buzzards Bay, please contact William Hubbard at WHubbard@Maritime.edu. Video and more information available at http://CoastalAmericaFoundation.org/crepidulareefs.html

Figure 1. A Pyrosome filmed with the Massachusetts Maritime Academy towed High Definition video camera with laser scalers 10 cm apart (green dots). (Photo Courtesy of Massachusetts Maritime Academy).



Appendix C – Protocol Developed for HD Geospatial Logged Video Sampling Classification

Protocol for Recording Screen Shot Coordinate Information from Buzzards Bay Benthic Studies Research Cruise Data during 2015 Season

Purpose: The following protocol is intended to manually record screen shot Lat/Long coordinate information to an Excel table that can be used to display XY data from a table to points on an ArcGIS map file. Once displayed on the ArcGIS map, the individual screen shot coordinate locations can be symbolized to correspond to percent cover of *C. fornicata* at any given location as defined by NOAA's Coastal Marine Ecological Classification System (CMECS). With enough transect data, the individual points can then be used to define the geographic boundaries of *C. fornicata* reefs on the seafloor.

Overview of Protocol:

The geographic coordinate information of each screen shot is found on the lower corners of the photographic images that are saved on the Google Drive shared documents folder entitled "MMA Buzzards Bay Benthic Mapping 2015". The geographic coordinate information from each screenshot can then be manually transcribed to an Excel worksheet following a template that is suitable for displaying XY data on an ArcGIS map file (See corresponding Excel file entitled "BBay Benthic Mapping Screen Shots-2015_v4"). In order to display the XY data on the ArcGIS map file, the Lat/Long coordinates must be recorded in decimal degrees in separate columns.

Protocol for Recording Screen Shot Lat/Long Coordinate Information:

1. In Google Drive, open the shared documents folder entitled "MMA Buzzard Bay Benthic Mapping 2015"
2. Open the underwater imagery data for the research cruise data for any given day of interest.
3. Open the Screen Shot folder for the given day.
4. Open the Excel Workbook entitled "BBay Benthic Mapping Screen Shots-2015_v4"
5. Create a new worksheet with the date of the cruise noted on the tab label. Record the date according to the following convention: YYYYMMMDD, where MMM is the three letter acronym for any given month.
6. Open each screen shot one at a time.
7. Record the screen shot number in the Excel worksheet under the column heading "Loc_Descript"
8. Record the time of day in the Excel worksheet on the screen shot under the column heading "TOD" (Note: use 24-hour military time)
9. Record the Lat/Long data in units of decimal degrees in the Excel worksheet under the column headings "Lat" and "Long", respectively.
10. Record the CMECS percent cover of the screen-shot image under the column

"CREPID_COVER" as a decimal fraction (e.g. 0 = 0%; 0.01 = 1%; 0.25 = 25%; 1 = 100%, etc.)

11. Under the column "COVER-BIN", record the text description for the corresponding CMECS cover bins:
    a. CMECS % cover bins:
        i. Trace < 1%
        ii. Sparse 1-30%
        iii. Moderate 31-70%
        iv. Dense 71-99%
        v. Complete 100%
12. Under the column "COMMENTS", record any other cover observed in the image (e.g. eelgrass, sand, rock, etc.)

Converting Lat/Long Data to Decimal Degrees:

1. Beginning August 19, 2015, all screen shots display Lat/Long coordinates expressed in decimal degrees. That data can be entered directly into the Excel spreadsheet as is.
2. Prior to that date, the Lat/Long data needs to be converted to decimal degrees. It appears to be displayed on the screen shot in the convention of Degrees, Minutes, Seconds (DMS), but due to a bug in the Proteus software, it is actually displaying Degrees-Decimal Minutes. What appears to be Arc-Seconds is, in fact, the decimal portion of the Arc-Minutes. (For example: in the 2015AUG14 data, "SnapShot(14).jpg" indicates Lat/Long coordinates as follows:
    a. 41° 41' 29" N, which actually represents 41° 41.29' N; and
    b. 070° 39' 63" W, which actually represents -070° 39.63' W
3. So to convert the displayed Lat/Long data on the screen shots for any images prior to August 19, 2015, one must perform the following calculation:
    a. Degrees + Decimal Minutes/60 = Decimal Degrees
    b. Please recall that all Longitude data in Buzzards Bay should be negative (typically -070 degrees) as is it west of the Prime Meridian in Greenwich, England.
4. The conversion of Lat/Long coordinates listed above would be performed as follows:
    a. 41° 41.29' N = 41° + 41.29/60° N = 41.6881667° N
    b. -070° 39.63' W = -(070° + 39.63/60°) W = -070.660500° W
5. To ensure reasonable accuracy, all Lat/Long data will be entered in the table with the Cell Format set as a number with 6 decimal places.[1]

[1] Price, Maribeth, "*Mastering ArcGIS*, 6th Edition", pg. 111 (McGraw Hill 2014)

Rules for Preparing Excel Spreadsheets that are compatible with ArcGIS software[2]:

- The first row of the spreadsheet contains the field headings
- Field headings must start with a letter, must have no more than 13 characters, and must not contain spaces or shift characters such as %, $, #, and so on.
- No blank lines occur between the headings and the data or within the data rows.
- The spreadsheet contains no formulas.
- The bottom of the spreadsheet has no extraneous data, such as column totals.
- There are no merged or split cells, and every column contains consistent data types.
- Numeric columns have only numeric values in them, without text characters like “x” or “n/a” to indicate missing values. If present, missing values should have a numeric No Data marker value such as -99.
- Text fields contain no commas, unless all the text is enclosed in quotes.
- It is helpful if each column has been specifically formatted as text data or as numeric data with a specified number of decimal places.

Displaying X-Y Data from an Excel Table in ArcGIS:

When using the <Display XY Data> tool in ArcGIS, is necessary to specify the spatial reference using the <Edit…> button in order to project properly on the coordinate system for the data frame. For Garmin GPS data used in this study, the spatial reference for the Lat/Long data should be specified as the Geographic Coordinate System WGS1984.

Protocol document 2016MAR20-001
Version 3.0
Owner: M. Elliott

---

[2] Price, Maribeth, “*Mastering ArcGIS*, 6th Edition”, pg. 488 (McGraw Hill 2014)

Appendix D – Coastal and Marine Ecological Classification System (CMECS) of HD screen captures geospatially located and ARC GIS Mapped.

This file is too large to import – available online and is an attachment in EXCEL to this Report. Example data that is now entered into GIS maps:

LOC_DESCRIPT	TOD	LAT	LONG	CREPID_COVER	COVER_BIN
SS1844	18:56:57	41.69772	-70.63958	1	Complete
SS1845	18:57:05	41.69771	-70.63963	1	Complete
SS1846	18:57:16	41.6977	-70.6397	1	Complete
SS1847	18:57:41	41.69766	-70.63984	1	Complete
SS1848	18:57:41	41.69766	-70.63984	1	Complete
SS1849	18:58:05	41.69763	-70.63998	1	Complete
SS1850	18:58:27	41.69762	-70.6401	1	Complete
SS1851	18:58:57	41.69763	-70.64026	1	Complete
SS1852	18:59:04	41.69763	-70.6403	1	Complete
SS1853	19:00:02	41.69765	-70.64052	1	Complete
SS1854	19:01:13	41.69752	-70.64063	1	Complete
SS1855	19:01:13	41.69752	-70.64063	1	Complete
SS1856	19:02:21	41.69723	-70.64079	1	Complete
SS1857	19:02:49	41.69711	-70.64085	1	Complete
SS1858	19:03:07	41.69703	-70.6409	1	Complete
SS1859	19:03:23	41.69697	-70.64094	1	Complete
SS1860	19:03:5	41.6968	-	1	Complete

	8	3	70.64101						
SS1861	19:04:12	41.69676	-70.64105	1	Complete				
SS1862	19:04:14	41.69676	-70.64105	1	Complete				
SS1863	18:19:17	41.73854	-70.62631	0.6	Moderate				
SS1864	18:19:21	41.73854	-70.62631	1	Complete				
SS1865	18:20:24	41.70315	-70.62731	1	Complete				
SS1866	18:21:11	41.70314	-70.62715	1	Complete				
SS1867	18:21:37	41.70313	-70.62707	1	Complete				
SS1868	18:22:19	41.7031	-70.62692	0.6	Moderate				
SS1869	18:22:37	41.70309	-70.62684	0.6	Moderate				
SS1870	18:23:38	41.70306	-70.62663	0.6	Moderate				
SS1871	18:14:20	41.70302	-70.62649	0.6	Moderate				
SS1872	18:25:09	41.70298	-70.62634	0.6	Moderate				
SS1873	18:25:44	41.70294	-70.62624	0.6	Moderate				
SS1874	18:26:12	41.7029	-70.62617	0.7	Moderate				
SS1875	18:26:31	41.70287	-70.62613	0		algae cover 100% - might have Cf underneath			
SS1876	18:26:53	41.70285	-70.62608	0		algae cover 100% - might have Cf underneath			
SS1877	18:27:17	41.70282	-70.62602	0		algae cover 100% - might have Cf underneath			
SS1878	18:27:59	41.70278	-70.62594	0		algae cover 100% - might have Cf underneath			
SS1879	18:28:35	41.70274	-70.62588	0		algae cover 100% - might have Cf			

						underneath
SS1880	18:29:24	41.7027	-70.62579	0		algae cover 100% - might have Cf underneath
SS1881	18:19:07	41.73854	-70.62631	0.3	Sparse	
SS1882	18:29:33	41.70269	-70.62577	0		algae cover 100% - might have Cf underneath
SS1883	18:30:01	41.70268	-70.6257	0		algae cover 100% - might have Cf underneath
SS1884	18:30:18	41.70266	-70.62566	0		algae cover 100% - might have Cf underneath
SS1885	18:30:32	41.70266	-70.62563	0		algae cover 100% - might have Cf underneath
SS1886	18:31:29	41.70266	-70.62547	0.2	Sparse	
SS1887	18:32:05	41.70266	-70.62537	0		algae cover 100% - might have Cf underneath
SS1888	18:46:00	41.69937	-70.63764	0		
SS1889	18:46:09	41.69937	-70.63764	0		
SS1890	18:46:15	41.69937	-70.63764	0.05	Moderate	
SS1891	18:46:24	41.69937	-70.63764	0.05	Moderate	
SS1892	18:46:34	41.69936	-70.63764	1	Complete	
SS1893	18:46:38	41.69936	-70.63763	1	Complete	
SS1894	18:48:46	41.69898	-70.63742	1	Complete	
SS1895	18:48:53	41.69896	-70.63743	1	Complete	
SS1896	18:49:04	41.69892	-70.63745	1	Complete	
SS1897	18:49:56	41.69876	-70.63755	1	Complete	

SS1898	18:50:51	41.69861	-70.63774	1	Complete				
SS1899	18:51:34	41.6985	-70.63793	1	Complete				
SS1900	18:51:49	41.69846	-70.63802	1	Complete				
SS1901	18:52:16	41.69837	-70.63814	1	Complete				
SS1902	18:53:08	41.69826	-70.6384	1	Complete				
SS1903	18:53:24	41.69822	-70.63849	1	Complete				
SS1904	18:54:06	41.69813	-70.63871	1	Complete				
SS1905	18:55:02	41.69799	-70.639	1	Complete				
SS1906	18:55:45	41.69788	-70.6392	1	Complete				
SS1907	18:55:59	41.69785	-70.63928	1	Complete				
SS1908	18:56:07	41.69784	-70.63931	1	Complete				
SS1909	18:56:42	41.69775	-70.63949	1	Complete				

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