Merepoint Boat Launch Facility Eelgrass Mitigation Measures: 2013 Monitoring Report

Prepared for

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Executive Summary

The Maine Department of Inland fisheries and Wildlife (IF&W) was issued a permit by the Maine department of Environmental Protection (DEP) on 13 April 2007 to construct and install a boat launching facility at Merepoint, Brunswick, Maine, construction of which was completed in September 2008. The permit included several conditions for mitigation of possible impacts to eelgrass resulting from construction and operation of the facility. These included: 1) removal and relocation of traditional mushroom anchor-chain moorings within the project area to areas outside eelgrass habitat, 2) replacement of traditional mushroom anchor-chain moorings with “eelgrass-friendly” helical, or embedment, moorings, 3) the closing of the Simpsons Point boat launching ramp to motorized vessels to allow recovery of eelgrass adjacent to the ramp, and 4) the preparation of an Eelgrass Mitigation Opportunities Guide for Northern Casco Bay, reported separately in February 2008. Additional monitoring efforts were conducted in 2011 and 2012, each effort reported separately in its respective year.

The results of the 2011 and 2012 monitoring efforts clearly showed that the recovery which was expected to occur within the mooring scar areas following either permanent removal of the mooring or replacement of a traditional block and chain or mushroom anchor and chain mooring with “eelgrass-friendly” helical anchors was not occurring and in some cases the mooring scar area was actually expanding. In certain cases, mooring scar areas exhibited some level of reduction (re-vegetation) between 2008 and 2011. However, in 2012, significant new expansions of scars were observed in aerial and diver surveys. Similarly, the eelgrass in the vicinity of the Simpson Point boat landing appeared to be in decline rather than recovery despite the landing having been closed to motorized boats as part of the mitigation effort. The observations over the period 2008 through 2012 offered evidence of what appeared to be a general decline in eelgrass within the region, particularly within Merepoint Bay and Middle Bay.

These findings were reported in a brief presentation at the 2013 Eelgrass Conference hosted by Phil Colarusso of EPA in Boston on March 28, 2013. Based on that presentation and a follow-up meeting between IF&W, DEP, EPA (teleconference), Mary Carman of Woods Hole, Hillary Neckles of USGS and MER a plan was developed to reduce the amount of video monitoring from the routine six (6) mooring scars down to two (2), one (1) in Maquoit Bay and one (1) in Merepoint bay, and the previous multiple transects at Simpson Point to only two 160-meter transects perpendicular to the shoreline from just above low water outward into the subtidal.

In addition to mooring scar video assessments and transects at Simpson Point, in an effort to more rigorously evaluate the larger trends and context of eelgrass dynamics in the area, MER collected:

- parametric measurements of eelgrass adjacent to the scars and at Simpson Point, and;
- sediment chemistry analyses within the mooring scars, within the eelgrass adjacent to the scars, and along the transects at Simpson Point.

All of the fieldwork associated with the 2013 effort was conducted on August 12 and 14, 2013.

The video monitoring at the mooring scars and vicinity of Simpson Point revealed a near catastrophic loss of eelgrass in Maquoit and Merepoint Bay. These observations were confirmed by aerial photography conducted by Sewall as part of a collaborative effort by the Maine DEP and DMR and Casco Bay Estuary Partnership (CBEP) with photo-interpretation of eelgrass distribution done by Seth Barker, formerly with the Maine DMR.

Results of the sediment sulfide and total organic carbon (TOC) indicate that sulfide levels within the mooring scar areas are high, well above what is considered toxic level for eelgrass; sulfide levels are also elevated outside the scar areas and at all sampling locations at Simpson Point, all above the level considered toxic level for eelgrass. Total organic carbon levels are similar to levels found in soft sediments elsewhere along the Maine coast.

Where eelgrass was found in Maquoit Bay, shoot density and length were both low compared to eelgrass in other areas in Maine and New Hampshire where similar measurements have been conducted. The incidence of tunicates was estimated at 0% to 10% coverage with two species, *Botrylloides violaceus* and *Diplosoma listerianum* (identification by Mary Carman, WHOI), both invasive, present. Incidence of wasting disease was estimated to be low at 0% to 10%.

Water quality data collected by the Maine DEP in Maquoit and Middle Bays did not reveal anything particularly out of the normal other than slightly elevated dissolved oxygen saturations, some likely attributable to winds, and elevated chlorophyll levels that increased with depth; this may be attributable to diatoms being stirred up off the bottom from the epilithic diatom mats that cover much, if not most, of the bottom at Simpson Point.

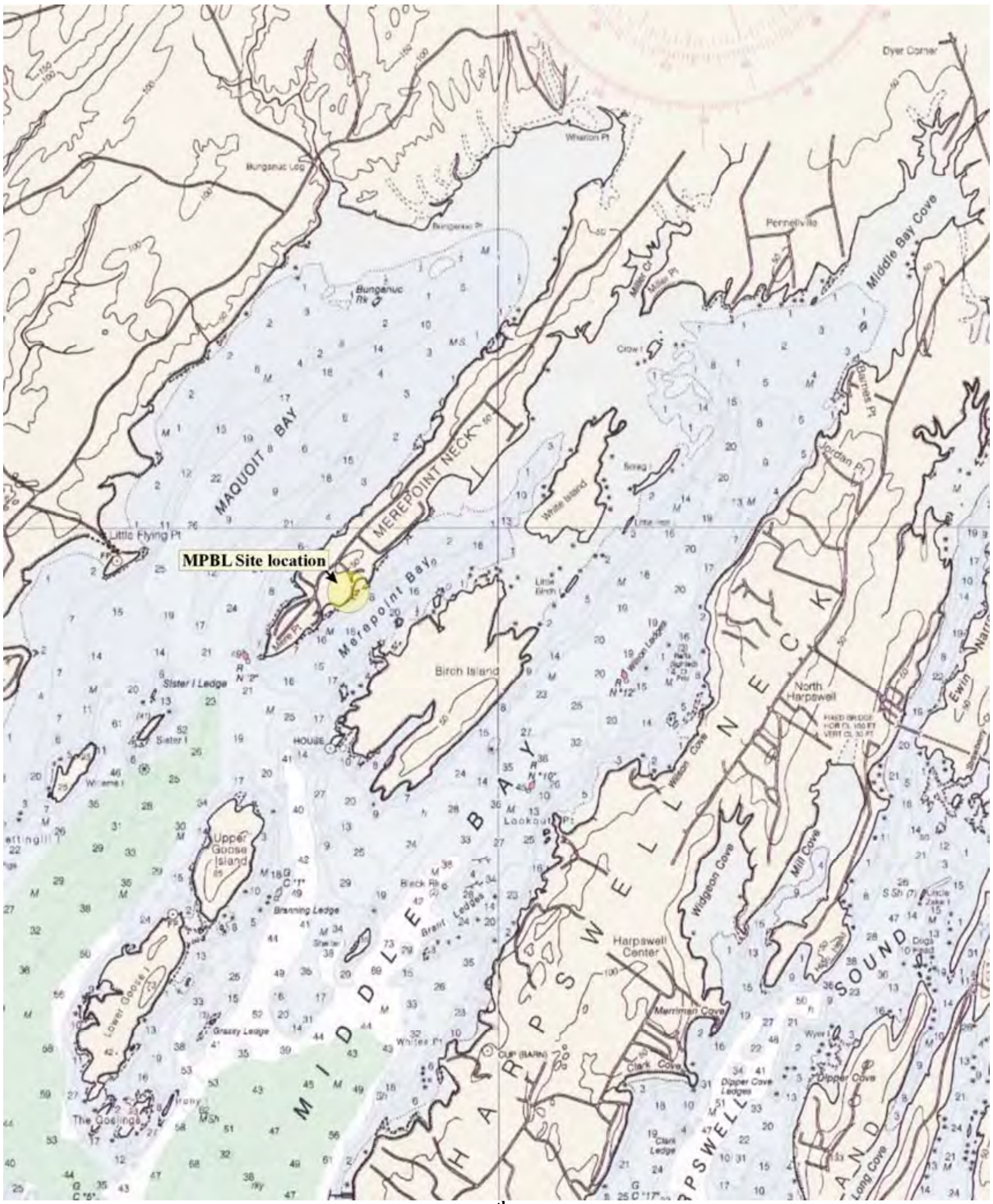
The near total loss of eelgrass in Maquoit Bay and catastrophic loss in Merepoint Bay and at Simpson Point render the mitigation efforts by IF&W over the past five to six years, as well as any further efforts, moot since natural conditions have clearly become unsuitable for eelgrass. This is most unfortunate in view of the time and expense put into these efforts. However, the efforts serve as an inadvertent and unintended documentation of the decline of eelgrass habitat and the sediment chemistry work of the current study will hopefully provide a baseline set of values against which any future sampling can be compared.

Similar declines in eelgrass have been previously observed as reported anecdotally by individuals familiar with Casco Bay. However, multiple dramatic changes seen over the past two to three years, but particularly in 2013, indicate that major changes (e.g. climate change) are taking place in Casco Bay.

Introduction

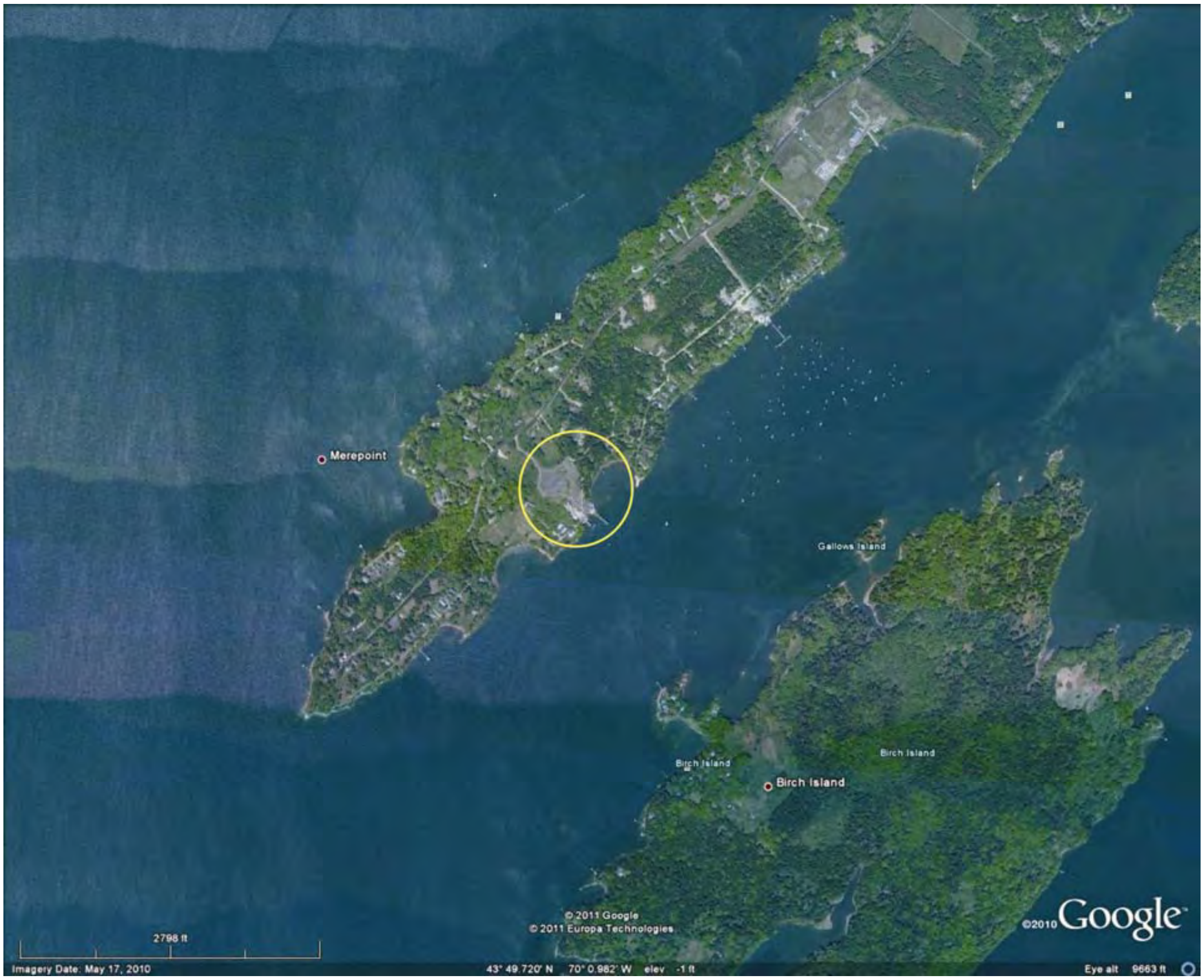
The Maine Department of Inland Fisheries and Wildlife (IF&W) was issued a permit approval for the development and installation of the Merepoint Boat Launching (MPBL) facility at Merepoint, Brunswick, Maine on 13 April 2007. The location of the MPBL is shown in Figures 1 and 2, below.

Figure 1 Location of Merepoint Boat Launching Facility, Merepoint, Brunswick, Maine



Source: NOAA/NOS Casco Bay chart 13290, 37th Ed. Mar./07

Figure 2 Completed Merepoint Boat Launching Facility (center) at Merepoint, Brunswick, Maine (*Google Earth image*)



Source: Google Earth

Several conditions were applied to the permit pertaining to mitigation for impacts to eelgrass, *Zostera marina*, resulting from the installation and operation of the boat launching facility including: 1) verification that moorings removed from the floats and access lanes were relocated beyond the eelgrass habitat boundary; 2) replacement of traditional anchor-chain moorings with helical, or embedment, moorings, and 3) delineation and assessment of the eelgrass habitat impacted by boat traffic at the existing Simpsons Point boat launch at the head of Merepoint Bay. MER Assessment Corporation (MER) assisted IF&W with these eelgrass impact mitigation efforts in 2007 and 2008, the results of which were included in a report submitted to the department on 18 March 2011.

Additional monitoring was conducted in August 2011 that included assessment of recovery within the mooring scar areas and at Simpson Point and evaluation of side-scan sonar as a potential tool for the mapping and assessment of eelgrass. Results of the 2011 monitoring and side-scan sonar study were summarized in a report submitted to the department on 5 December 2011.

The monitoring of recovery at the selected mooring scars and at Simpson Point was again repeated in 2012, the results of which are presented in a report submitted to the department on 16 November 2012.

The results of the 2011 and 2012 monitoring efforts clearly showed that the recovery which was expected to occur within the mooring scar areas following either permanent removal of the mooring or replacement of a traditional block and chain or mushroom anchor and chain mooring with "eelgrass-friendly" helical anchors was not occurring; in fact, in some cases the mooring scar area was actually expanding. In certain cases, mooring scar areas exhibited some level of scar reduction (re-vegetation) between 2008 and 2011, but in 2012, significant new expansions of scars were observed in aerial and diver surveys. Similarly, the eelgrass in the vicinity of the Simpson Point boat landing, closed to motorized boats as part of the mitigation effort, appeared to be thinning and barren patches, some extensive, began to develop within the meadow. Along with the thinning, an increasing incidence of the orange-sheathed tunicate, *Botrylloides violaceus*, both at the mooring scar areas as well as Simpson Point appeared to be affecting the health of the eelgrass. These observations over the period 2008 through 2012 offered evidence of what appeared to be a general decline in eelgrass within the region, particularly within Merepoint Bay and Middle Bay.

These findings were reported in a brief presentation at the 2013 Eelgrass Conference hosted by Phil Colarusso of EPA in Boston on March 28, 2013. Based on that presentation and a follow-up meeting between IF&W, DEP, EPA (teleconference), Mary Carman of Woods Hole, Hillary Neckles of USGS and MER a plan was developed to reduce the amount of video monitoring from the routine six (6) mooring scars down to two (2), one (1) in Maquoit Bay and one (1) in Merepoint bay, and the previous multiple transects at Simpson Point to only two 160-meter transects perpendicular to the shoreline from just above low water outward into the subtidal.

In place of the other routine mooring scar video assessments and transects at Simpson Point, a decision was made to conduct parametric measurements of eelgrass adjacent to the scars and at Simpson Point and sediment chemistry analyses within the mooring scars, within the eelgrass adjacent to the scars, and along the transects at Simpson Point. All of the fieldwork associated with the 2013 effort was conducted on August 12 and 14, 2013.

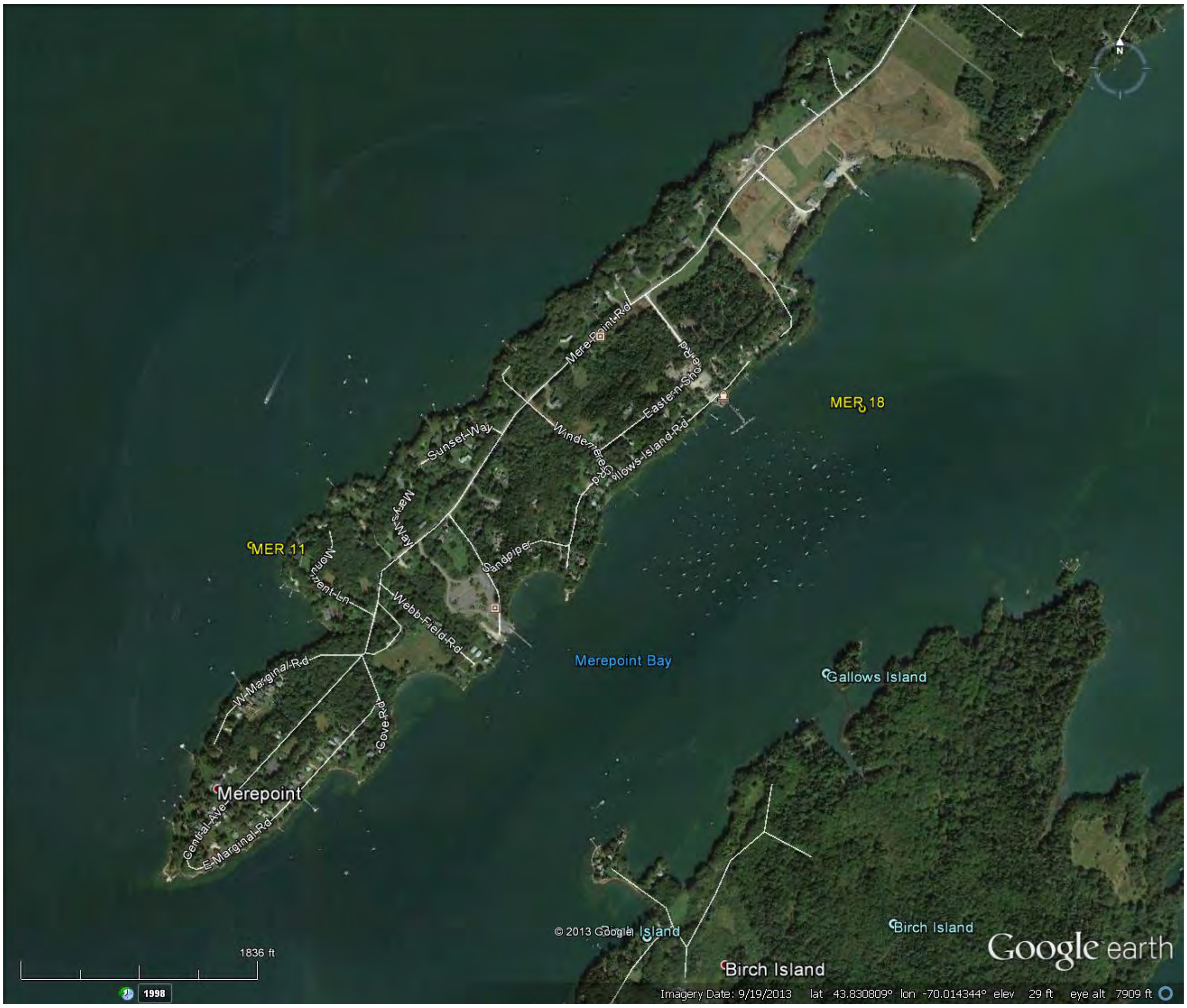
This report summarizes the results of work conducted to: 1) determine the level of recovery of eelgrass habitat in the vicinity of two selected helix-replaced moorings, 2) document the condition of the eelgrass habitat in the Simpsons Point boat ramp area following closure to motorized vessels in 2008 and 3) measure specific sediment chemistry parameters within the mooring scars, within the eelgrass adjacent to the scars, and along the transects at Simpson Point.

Methods

Verification of eelgrass habitat recovery in the vicinity of individual replacement moorings

Mooring scar measurements were made on August 12, 2013 around the two (2) moorings selected for the 2013 monitoring effort. Both MER 11 and MER 18 moorings in Maquoit Bay and Merepoint Bay, respectively, are embedment helix mooring replacements for traditional mushroom/ block-chain moorings. The locations of the two moorings are shown in Figure 3.

Figure 3 Location of the two (2) moorings selected for monitoring in 2013 (*Google Earth image*)



As in previous monitoring efforts, detailed *in situ* measurements of the "scar" area around each of the two moorings were made by a SCUBA diver using the same method developed in 2008 (MER, 2011). Accordingly, measurements of the scars were made along eight cardinal directions, *i.e.* N, NE, E, SE, S, SW, W, NW, by attaching a plastic surveyors measuring tape to the MER-installed orange-tipped ¾" PVC pipe used to mark the previous mooring location (based on GPS coordinates), stretching the tape to the first evidence of eelgrass boundary, and reading the distance. Each segment was subsequently video recorded while the measuring tape was still in place to visually document the measurement and provide evidence of the scar condition along each segment; the diver's compass was also recorded to show the direction in which the measurement was made.

The video recordings were made using an Amphibico VHHCEL57/Sony HDR-HC9 high definition digital video camera package on high definition (HDV) format tapes. When used, lighting was provided by an Amphibico VLDIG3AL 35W/50W switchable underwater arc lamp. All videos were uploaded to a Panasonic DMR-T3040 DVD Video Recorder using a Sony GV-HD700 Digital HD Videocassette Recorder for review and analysis and for producing DVD copies of the videos. DVD-R copies of the videos recorded at each mooring accompany this report.

As in all previous monitoring efforts, calculation of area using eight triangles was done using the equation:

$$\mathbf{A = (s \cdot (s\text{-}A) \cdot (s\text{-}b) \cdot (s\text{-}C))^{-2}}$$

where $\mathbf{C = (A^2 + B^2 \cdot 2(A{\cdot}B)\ 0.70716781)^{-2}}$
and $\mathbf{s = (A+B+C)/2;}$
Note: $\mathbf{0.70716781 = cosine\ 45^o}$

The area of each of the eight triangles defining a scar was calculated and all eight triangle areas summed to yield the full scar area.

A comparison of the 2008, 2011, 2012 and 2013 estimated area for each measured mooring scar based on distance to a defined eelgrass boundary is shown in Table 1 and the calculations for the 2013 scars are included as Appendix I. Calculations for the 2008 scars are included as Appendix II and graphic comparisons of the 2008 and 2013 scar areas are included in Appendix III.

Table 1 Comparison of the 2008, 2011, 2012 and 2013 estimated area for each of the two measured mooring scars based on distance to defined eelgrass boundary

MER Mooring #	Coordinates	2008 Post-replacement Measured scar area (ft^2)	2011 Monitoring Measured scar area (ft^2)	2012 Monitoring Measured scar area (ft^2)	2013 Monitoring Measured scar area (ft^2)	2012-13 % Scar increase
MER 11	43.82995º / 070.02439º	1070	980	1162	4254	298%
MER 18	43.83284º / 070.00643º	762	541	650	28282	3612%

These results clearly show that, following some moderate recovery of these two scars between 2008 and 2011, the trend towards increased scar area that began in 2012, presumably due to a general decline in eelgrass within the region, continued through 2013 to the extent that no eelgrass was observed in the vicinity of MER 18 indicating a complete loss of eelgrass within the area.

Simpson Point eelgrass survey

Video recordings within the area west of the stone pier adjacent to the Simpsons Point boat landing were made on August 14, 2013 following the same method and transect start points used in 2008 and 2011 for Transects 6 and 8.

Diver survey and video recording

Transect lines used for the video recording in 2013 consisted of 100m (330’) and 60 meter (~200’) ropes marked in 10m alternating black and white sections, with the exception of the first and last 10m, each of which are marked as two 5m sections, the last of which is marked in alternating 1m black and white increments; an example of a 60m line is shown in Figure 4.

Figure 4. Video survey transect lines

Two transects were set perpendicular to shore (T1 and T2) beginning just above the low water mark and extending out 160m into the subtidal area across what was previously an eelgrass meadow; these were anchored with a 20 lb. mushroom anchor at one end and a yellow-painted window weight at the other end. GPS coordinates for the start and end of the transects were recorded using an on-board Garmin 4208 GPS/Sonar unit using 12 channels and WAAS-correction to ± 3m. Table 2 lists the start and end coordinates for each of the two transect and the distance and direction of each video recording dive.

Table 2. Video transect GPS coordinates, distances, and direction

	Start		End				
Location	**Lat. (N)**	**Long. (W)**	**Lat. (N)**	**Long. (W)**	**Distance (m)**	**Distance (ft)**	**Direction (True)**
Transect 1 (T1)	43.84990º	69.97383º	43.85135º	69.97368º	161	528	4º
Transect 2 (T2)	43.85017º	69.97458º	43.85154º	69.97410º	157	515	14º

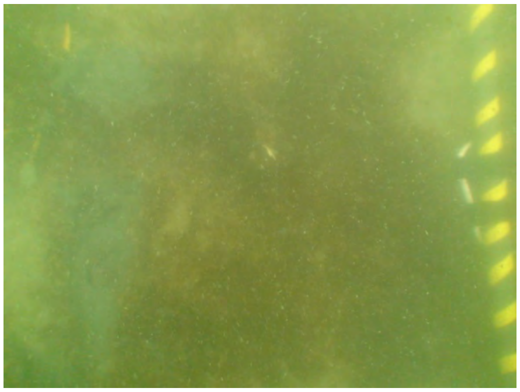
The video recordings were made using an Amphibico VHHCEL57/Sony HDR-HC9 high definition digital video camera package on high definition (HDV) format tapes. Lighting is provided by an Amphibico VLDIG3AL 35W/50W underwater arc lamp. All videos were uploaded to a Panasonic DMR-T3040 DVD Video Recorder using a Sony GV-HD700 Digital HD Videocassette Recorder for review and analysis. DVD copies of the videos were made and have been previously provided to IF&W.

Water clarity during the 2013 video survey was very poor throughout; turbidity in the area has generally been poor every year, particularly in the nearshore. As previously reported, this is due to the very soft surface sediments in the vicinity of Simpson Point that are subject to easy disturbance resulting in elevated turbidity that quickly reduces visibility to near zero at the start of the transect, particularly in the shallowest areas nearshore. Winds out of the southwest on the day of the survey also contributed to the increased turbidity.

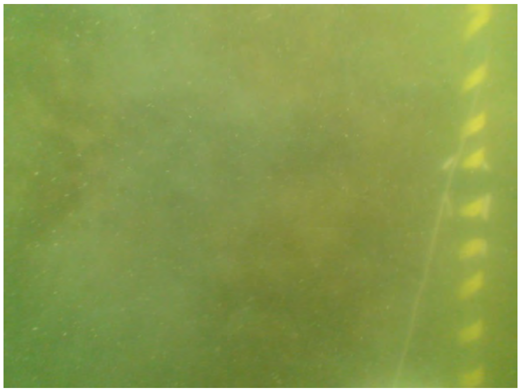
The 2012 video survey showed a continuation of the thinning and general decline of the eelgrass within the meadow that appears to have begun in 2011; however, in 2013 as the photos below show, no eelgrass was found along the two transects and the bottom was generally covered with a brown epilithic diatom mat.

Still images taken with the Sony HDR-HC9 high definition digital camera of Transect 1 at 30m intervals are shown below; these locations correspond to the locations were sediment chemistry and eelgrass (below-ground) sampling was done, the sampling frame appearing in some photos.

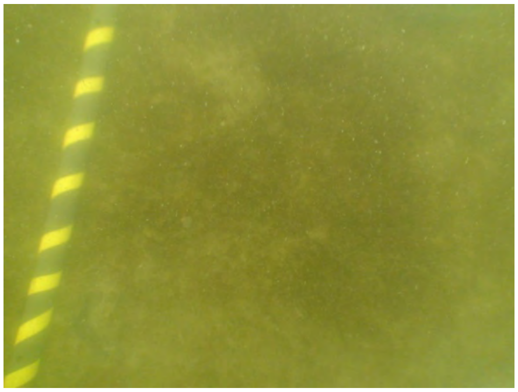
Transect 1 at 5m mark



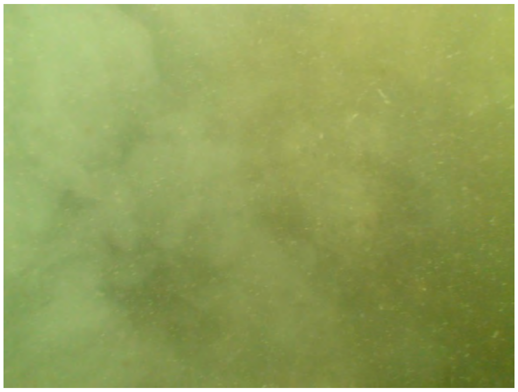
Transect 1 at 30m mark



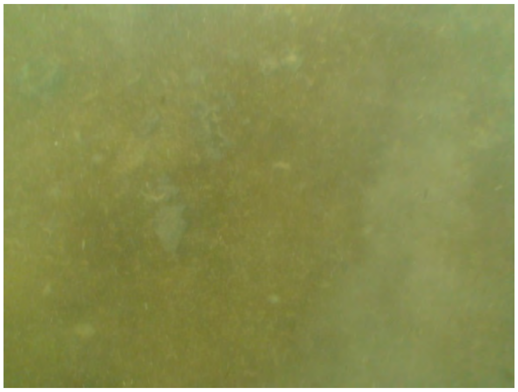
Transect 1 at 60m



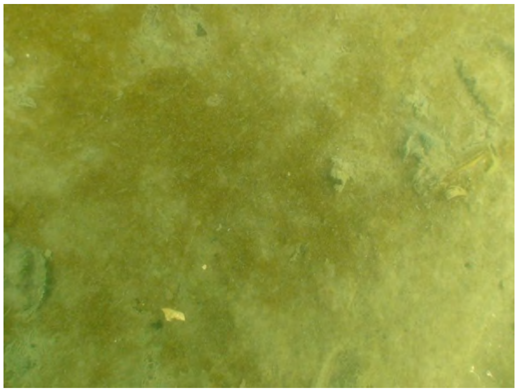
Transect 1 at 90m mark



Transect 1 at 120m mark

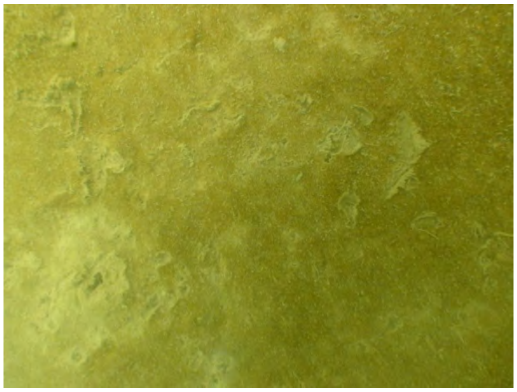


Transect 1 at 150m

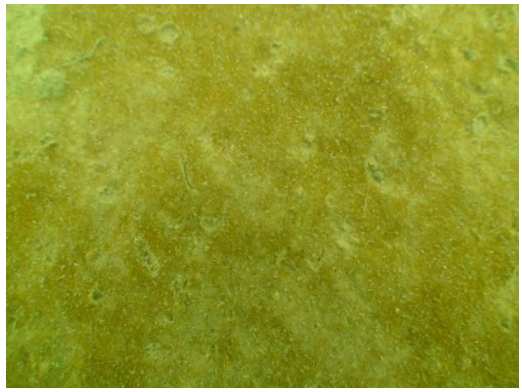


Still images taken of Transect 2 at 30m intervals are shown below; as above, these locations correspond to the locations were sediment chemistry and eelgrass sampling was done.

Transect 2 at 5m mark



Transect 2 at 30m mark

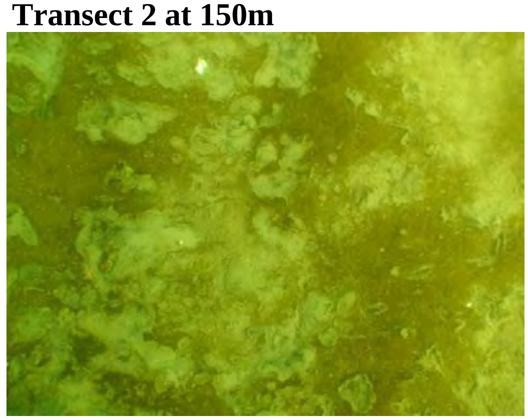


Transect 2 at 60m

Transect 2 at 90m mark

Transect 2 at 120m mark

Transect 2 at 150m



Sediment chemistry and eelgrass sample collection

In place of the other four mooring scar measurements and multiple video transects at Simpson Point, the additional time was used to collect sediment samples for sulfide and total organic carbon (TOC) analyses and eelgrass samples for shoot counts, shoot length measurements and biomass determination; tunicate coverage and incidence of wasting disease were also estimated *in situ* by the diver.

Sediment chemistry sampling

Samples for sediment chemistry analyses were collected from ¼m^2 ¾ inch gray PVC frames, spirally-wrapped with yellow tape to improve visibility, laid on the bottom. Six samples were collected at each of the two mooring scars; three (3) samples were collected within what was known to be the former mooring scar and three (3) were collected from areas with eelgrass (scar MER 11 in Maquoit Bay) or in areas outside the previous scar area where eelgrass was presumed to have existed in 2012 (scar MER 18 in Merepoint Bay). The samples were labeled as two series, series "U" for unvegetated, and "E" for eelgrass (vegetated), respectively. At Simpson Point, since no eelgrass was found, six (6) samples were collected along each of the two video transect lines at approximately 30-meter intervals beginning at 5 meters and ending at 150 meters, 10 meters from the end of the line. The three nearshore samples (5m, 30m, 60m) were labeled as the "U" (unvegetated) series and the three samples further offshore (90m, 120m and 150m) were labeled as the "E" (vegetated) series; it is uncertain to what extent each sampling point was previously vegetated.

Three replicate sediment samples were collected for sulfide and TOC analyses using a 60ml (10.5cm long) syringe (B-D #301035) the tip end of which was removed to create an open barrel cylinder through which the plunger travels. Prior to sediment sample collection, the plunger was pressed down such that the end of the plunger reached the bottom of the open end. Sediment was collected by diver by having the diver place the open end of the syringe on the sediment surface and, while firmly holding the plunger in place, the syringe barrel was driven vertically into the sediment until the flange of the syringe touched the sediment; this action creates suction and allows collection of an undisturbed 10+cm core. Immediately upon sample collection the syringe was returned to the surface for processing.

Sulfide samples were collected from the lower 5cm of the core while TOC samples were collected from a mixture of the entire 10cm core. To accomplish this, the plunger was pushed down to the 60ml (60cc) mark and the excess sediment removed with a clean spatula. The lower 5cm of the core were then extruded into a 125ml Nalgene container and gently mixed with a plastic spoon for approximately 2 minutes to achieve a fully mixed sample. A pre-labeled 5cc syringe, modified similarly as the 60cc syringe, with plunge pressed down to reach the end of the barrel, was placed in the sediment mixture and a 5+cc sample extracted by pulling back on the plunger, constantly keeping the end of the syringe in the sediment mixture to avoid inclusion of any air bubbles. Once the sample was collected, the open end of the 5cc syringe was covered with plastic wrap and finally capped with aluminum foil to exclude any air; the capped syringe was immediately placed in a cooler with ice to maintain a temperature of $<5^{O}C$ during transport to the laboratory for sulfide (S_2) analysis within ≤72 hrs of sample collection.

Once the sulfide sample was collected from the Nalgene container, the remainder of the upper 5cm of sediment in the 60cc syringe was extruded into a second 125ml Nalgene container, the sediment mixed and 5cc of sediment removed with a separate 5cc syringe; this 5cc sediment was discarded. Once both samples had 5cc of sediment removed to achieve equal volumes for the lower and upper 5cc of the core, the two were added together, mixed and approximately 50-100cc of mixed sediment placed in a pre-labeled Whirl-Pak and the sample placed in the cooler with ice. The TOC samples were placed in a freezer at the lab and maintained frozen until delivery to the Darling Center lab for analysis.

Eelgrass sampling

Once the sediment chemistry sample was collected, where eelgrass was present, *in situ* estimates of tunicate coverage, incidence of wasting disease and shoot counts were made; all of the eelgrass, both above-ground and the below-ground rhizomes, was then collected from within the ¼m^2 frame and placed into a diver catch bag and brought to the surface. At the surface photos of any condition of particular interest were taken and the eelgrass then placed into pre-labeled bags and stored in a cooler with ice.

Where no eelgrass was present, the sediment within the frame was removed by hand to a depth of approximately 10cm and placed in a meshed diver catch bag and brought to the surface. The catch bag was then repeatedly plunged into the water until all sediment had been removed. The remaining contents, consisting of shell, detritus and/or both dead and live eelgrass rhizomes, were placed in a pre-labeled bag and stored in a cooler with ice.

Sediment chemistry and eelgrass sample processing

Sulfide analysis

All sulfide samples were processed at MER's laboratory. Once at the lab, all syringes were allowed to warm to room temperature (≈20°C) before analysis. Sulfide measurements were made using an Accumet® AP63 pH/mV/Ion meter equipped with a Thermo Orion model 9616BN Combination Silver/Sulfide electrode filled with Thermo Orion Ionplus B Optimum Results™ Reference Electrode Filling Solution (900062). The meter was standardized at 1.00 (100µM), 10.0 (1,000µM), and 100 (10,000µM) with standards prepared according to Wildish *et al*., 1999. All samples were analyzed within a maximum of 3 hrs following preparation of the standards. Following analysis of all samples, measurements of the three standards were repeated and recorded on the calibration sheets. Actual S_2 µM values were calculated by multiplying the meter readings by 100.

Total organic carbon/nitrogen

Particulate carbon and nitrogen were analyzed by the University of Maine Darling Marine Center laboratory via combustion using a Perkin Elmer 2400 Series II CHNS/O equipped with a thermal conductivity detector utilizing ultra high purity helium as a carrier gas.

The analyzer is calibrated using tin capsules as blanks and acetanilide to calibrate instrument response to carbon and nitrogen. NIST certified check standards consisting of either low organic content soil or sediment are analyzed to determine accuracy of carbon detection. NIST certified organic check standards such as corn flour or rice flour are analyzed to determine the accuracy of nitrogen detection. If values vary by more than 4% from stated values, instrument is examined, any problems are addressed and instrument is recalibrated and check standards rerun until error is within acceptable limits. Duplicate samples are run during each sample run to ensure results are reproducible. If duplicates cannot be run on actual samples, as in the case of filter samples, duplicate check standards are analyzed. Duplicate samples typically vary less than 2%.

One instrument blank is analyzed for every 12 samples run. One acetanilide standard is analyzed for every 15 samples run. If blank or acetanilide values differ significantly from previous values, a new series of standards and blanks are analyzed to recalibrate the instrument. The actual minimum detection limit (3 times the standard error) determined from the standard error of the instrument blanks is 2 micrograms for carbon and 4 micrograms for nitrogen.

Eelgrass sample processing

Once at the lab, each eelgrass sample was removed from the bag, rinsed with freshwater, blotted dry and individual shoots counted. The shoots were then placed on a measuring board with blades at full length and photographed.

Once photographed, the eelgrass samples were place in square aluminum cooking plates and held in place with wooden skewers which also served to allow air circulation between stacked plates during drying. Plates were placed in a $60^{O}C \pm 2^{O}C$ laboratory drying oven (Quincy Lab, Inc. Model 40 GC Lab Oven) for ≥72 hours after which the skewers were removed, the plates and contents weighed to the nearest 0.1g, followed by weighing of empty plates (post-tarring). Eelgrass samples used for biomass determination have been kept in desiccated form and archived.

Samples containing no above-ground eelgrass were placed on newspaper for blot drying and, once air dried, were spread on plastic sorting trays, photographed and rhizomes separated from the other material and categorized, to the extent possible, as “live” (having small white roots) or “dead” (dark and “woody”). The “live” rhizomes were placed in aluminum cooking plates and placed in a $60^{O}C \pm 2^{O}C$ laboratory drying oven for ≥72 hours after which the skewers were removed, the plates and contents weighed to the nearest 0.1g, followed by weighing of empty plates (post-tarring). Rhizome samples have been kept in desiccated form and archived.

Photos of the eelgrass and below-ground samples are included in Appendix IV.

Aerial photography

Low level (~1,600 ft elevation) aerial photography of the Simpson Point area was done in September 2007 and August 2008, 2011 and 2012 (John Sowles). This aerial photography series documented the progressive recession and general decline of the eelgrass meadow west of the old stone pier adjacent to the now blocked boat landing. The decline of the eelgrass meadow seen in the aerial photography was confirmed by the underwater video recordings made in 2008, 2011 and 2012 within the area. These aerial photos are shown below in Figures 5 through 8.

This year, the Maine DEP and the Casco Bay Estuary Partnership collaborated to arrange for Sewall to conduct aerial photography of Casco Bay during low water on August 11, 2013. Preliminary interpretation of eelgrass distribution in Maquoit and Middle Bays, based on the aerial photography of August 11th by Sewall (Richard Crouse and Associates) and ground-truthing conducted on October 2 and 3, was done by Seth Barker, formerly with the Maine Department of Marine Resources and now serving as a consultant to Sewall. Figure 9 shows the 2013 Sewall image that includes Maquoit and Middle Bays with an overlay of eelgrass distribution in 2002; Figure 10 shows the same 2013 Sewall image with Seth Barker's photo-interpreted eelgrass distribution of August 2013. The loss of eelgrass over the intervening 12 years is dramatic and reinforces the reduced eelgrass density in the vicinity of MER mooring scar 11 in Maquoit Bay and the complete lack of eelgrass observed at mooring MER 18 in Merepoint Bay and in the vicinity of the boat landing and old stone pier Simpson Point during the underwater video surveys.

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Intentionally blank

Figure 5 September 2007 aerial photo of Simpsons Point landing area prior to boat landing closure

Source: John Sowles/Google Earth

Figure 6. August 2008 aerial photo of Simpsons Point landing area with video transects and eelgrass upper boundary delineation

Source: John Sowles/Google Earth

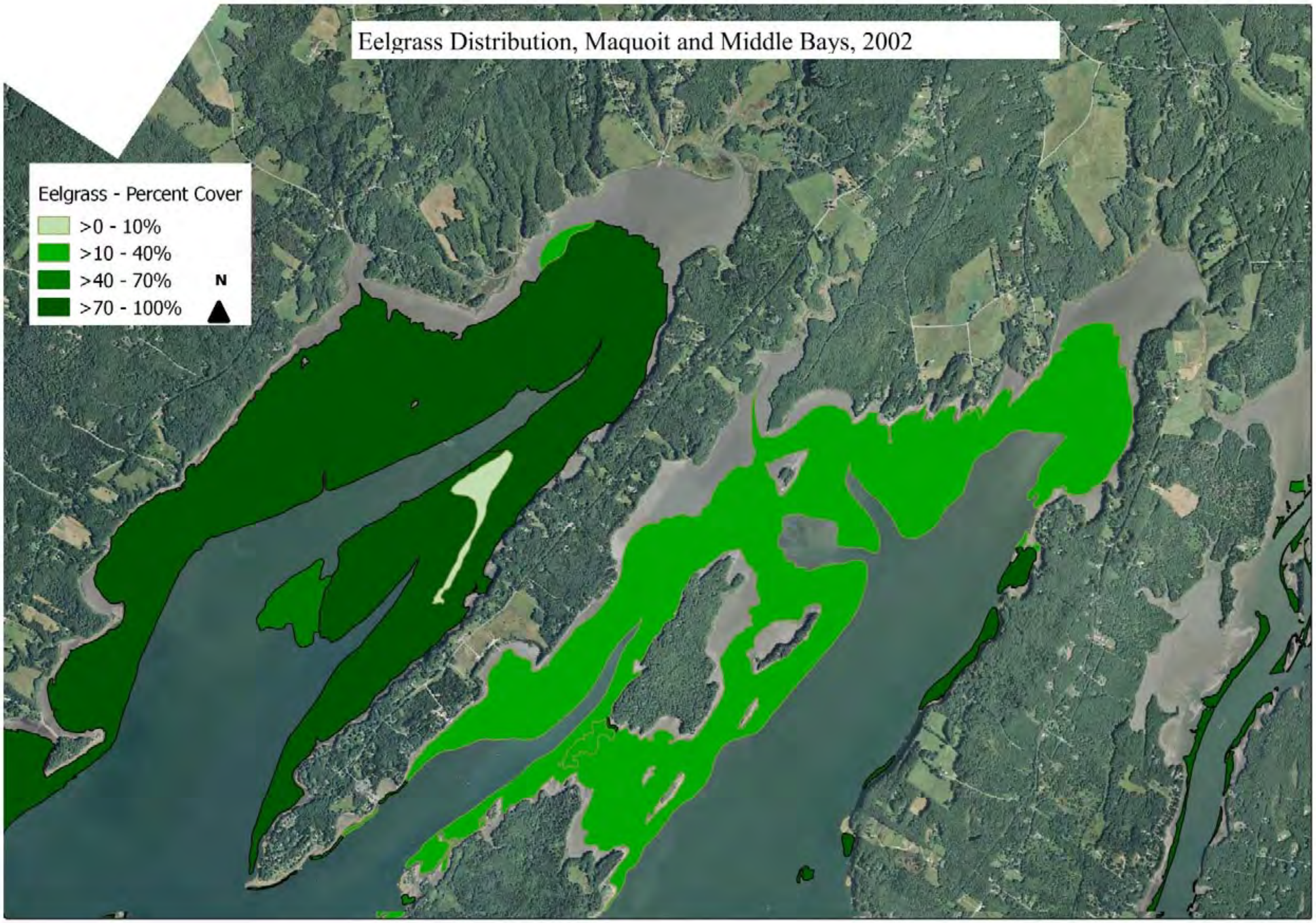
Figure 7. 31 August 2011 aerial photo of Simpsons Point landing area

Source: John Sowles

Figure 8. August 2012 aerial photo of Simpsons Point landing area

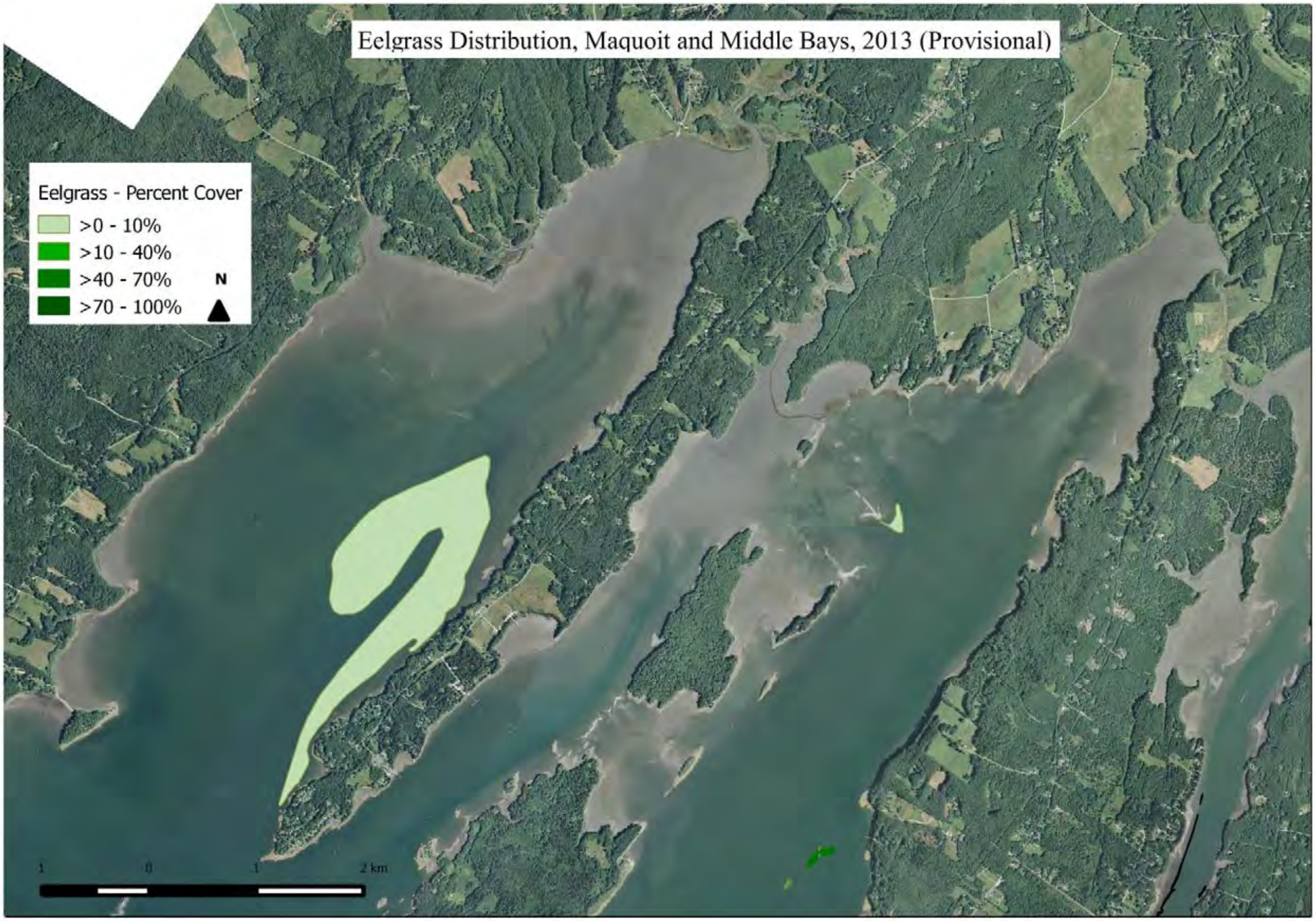
Source: John Sowles

Figure 9. 2013 Sewall aerial photo Maquoit Bay and Middle Bay area in 2013 showing photo-interpreted eelgrass distribution in 2002 per Seth Barker (formerly with Maine DMR).



Source: Seth Barker, November 2013

Figure 10. 2013 Sewall aerial photo Maquoit Bay and Middle Bay area in 2013 showing photo-interpreted eelgrass distribution in 2002 per Seth Barker (formerly with Maine DMR).



Source: Seth Barker, November 2013

Results

Table 3. Sediment chemistry sulfides and TOC/TON results for mooring scar MER 11

MER Assessment Corporation
Sediment chemistry data sheet

			MER 11		MER 11	
			Scar		Scar	S_2 in-lab pre-test stand.: 1.00; 10.1; 101 MER 11
Site:	IF&W Merepoint	S_2 µM	4330	%TOC	2.87	S_2 in-lab post-test stand. check: 0.912; 9.33; 91.2
Date:	8/12/2013		Outside		Outside	
Time	0800-1800	S_2 µM	1018	%TOC	2.27	

Location	S_2 meter	S_2 µM	depth	T^O	TOC	TON	Smell	Color	Comment
MER 11 U 1	41.7	4170	5-10 cm		2.977	0.329	Y	Blk/Gr	Soft silt
MER 11 U 2	50.1	5010	5-10 cm		2.816	0.299	Y	Blk/Gr	Soft silt
MER 11 U 3	38.1	3810	5-10 cm		2.807	0.317	Y	Blk/Gr	Soft silt
Mean	**43.3**	**4330**			**2.867**	**0.315**			
S.D.	**6.16**	**616**			**0.096**	**0.015**			
Var.	**25.28**	**252800**			**0.006**	**0.000**			
MER 11 E 1	12.3	1230	5-10 cm		2.027	0.203	Slight	Gray	Soft silt
MER 11 E 2	8.32	832	5-10 cm		2.086	0.197	Slight	Gray	Soft silt
MER 11 E 3	9.93	993	5-10 cm		2.689	0.264	Slight	Gray	Soft silt
Mean	**10.2**	**1018**			**2.267**	**0.221**			
S.D.	**2.00**	**200**			**0.366**	**0.037**			
Var.	**2.7**	**26722**			**0.089**	**0.001**			

Table 4. Sediment chemistry sulfides and TOC/TON results for mooring scar MER 18

MER Assessment Corporation

Sediment chemistry data sheet

			MER 18		MER 18
			Scar		Scar
Site:	**IF&W Merepoint**	S_2 µM	2930	%TOC	2.67
Date:	**8/12/2013**		Outside		Outside
Time	**0800-1800**	S_2 µM	808	%TOC	2.26

S_2 in-lab pre-test stand.: 1.00; 9.98; 99.3 MER 18

S_2 in-lab post-test stand. check: 0.984; 9.84; 101

Location	S_2 meter	S_2 µM	depth	T^O	TOC	TON	Smell	Color	Comment
MER 18 U 1	46.0	4600	5-10 cm		2.789	0.316	Y	Blk/Gr	Soft silt
MER 18 U 2	14.2	1420	5-10 cm		2.470	0.249	Y	Blk/Gr	Soft silt
MER 18 U 3	27.7	2770	5-10 cm		2.740	0.312	Y	Blk/Gr	Soft silt
Mean	**29.3**	**2930**			**2.666**	**0.292**			
S.D.	**15.96**	**1596**			**0.172**	**0.038**			
Var.	**169.8**	**1698200**			**0.020**	**0.001**			
MER 18 E 1	6.10	610	5-10 cm		2.219	0.226	None	Gray	Soft silt, shells
MER 18 E 2	5.85	585	5-10 cm		2.226	0.202	None	Gray	Soft silt, shells and pebbles
MER 18 E 3	12.3	1230	5-10 cm		2.326	0.229	Slight	Gray	Soft silt
Mean	**8.08**	**808**			**2.257**	**0.219**			
S.D.	**3.65**	**365**			**0.060**	**0.015**			
Var.	**8.90**	**89006**			**0.002**	**0.000**			

Table 5. Sediment chemistry sulfides and TOC/TON results for Simpson Point Transect 1 samples

MER Assessment Corporation

Benthic sediment chemistry data sheet

			TI		T1
			Nearshore		Nearshore
Site:	**IF&W Merepoint**	S_2 µM	2710	%TOC	2.53
Date:	**8/14/2013**		Offshore		Offshore
Time	**0800-1630**	S_2 µM	2207	%TOC	2.53

S_2 in-lab pre-test stand.: 1.00; 10.0; 102 T1

S_2 in-lab post-test stand. check: 0.953; 9.62; 97.3 T1

Location	S_2 meter	S_2 µM	depth	T^O	TOC	TON	Smell	Color	Comment
SP T1 U1	33.2	3320	5-10 cm		2.362	0.288	Yes		Soft silt
SP T1 U 2	29.9	2990	5-10 cm		2.523	0.308	Yes		Soft silt
SP T1 U 3	18.2	1820	5-10 cm		2.702	0.310	Yes		Soft silt
Mean	**27.1**	**2710**			**2.529**	**0.302**			
S.D.	**7.88**	**788**			**0.170**	**0.012**			
Var.	**41.42**	**414200**			**0.019**	**0.000**			
SP T1 E 1	21.0	2100	5-10 cm		2.483	0.300	Yes		Soft silt, shells
SP T1 E 2	27.5	2750	5-10 cm		2.581	0.302	Yes		Soft silt
SP T1 E 3	17.7	1770	5-10 cm		2.534	0.294	Yes		Soft silt
Mean	**22.1**	**2207**			**2.533**	**0.299**			
S.D.	**4.99**	**499**			**0.049**	**0.004**			
Var.	**16.6**	**165756**			**0.002**	**0.000**			

Table 6. Sediment chemistry sulfides and TOC/TON results for Simpson Point Transect 2 samples

MER Assessment Corporation

Benthic sediment chemistry data sheet

			T2		**T2**
			Nearshore		**Nearshore**
Site:	**IF&W Merepoint**	**S_2 µM**	**1877**	**%TOC**	**2.36**
Date:	**8/14/2013**		**Offshore**		**Offshore**
Time	**0800-1630**	**S_2 µM**	**2083**	**%TOC**	**2.22**

S_2 in-lab pre-test stand.: 1.00; 10.0; 100 T2

S_2 in-lab post-test stand. check: 0.991; 9.84; 95.7 T2

Location	S_2 meter	S_2 µM	depth	T^O	TOC	TON	Smell	Color	Comment
SP T2 U 1	14.8	1480	5-10 cm		2.261	0.246	Yes		Soft silt
SP T2 U 2	25.5	2550	5-10 cm		2.555	0.284	Yes		Soft silt
SP T2 U 3	16.0	1600	5-10 cm		2.266	0.244	Yes		Soft silt
Mean	**18.8**	**1877**			**2.361**	**0.258**			
S.D.	**5.86**	**586**			**0.168**	**0.023**			
Var.	**22.9**	**229089**			**0.019**	**0.000**			
SP T2 E 1	34.6	3460	5-10 cm		2.411	0.287	Yes		Soft silt
SP T2 E 2	12.5	1250	5-10 cm		2.183	0.225	Yes		Soft silt
SP T2 E 3	15.4	1540	5-10 cm		2.068	0.233	Yes		Soft silt, one small shoot
Mean	**20.8**	**2083**			**2.221**	**0.248**			
S.D.	**12.01**	**1201**			**0.175**	**0.034**			
Var.	**96.16**	**961622**			**0.020**	**0.001**			

Table 7 Eelgrass biomass, shoot counts, shoot length and tunicate data

	Air dried (48 hrs ambient temp.)				Desiccated (72 hrs @ 60°C)				Air dried		Shoots		
Sample No.	Above grnd (g)	Below grnd (g)	Total (g)	Live unattached below grnd (g)	Above grnd (g)	Below grnd (g)	Total (g)	Live unattached below grnd (g)	Tunicates (g)	Loose bio (g)	Total shoots	Shoots/ m^2	Mean Shoot length
MER 11 E1	47.5	15.5	63.0	0.0	36.5	12.3	48.8	0.00	20.5	24.5	26	104	0.95
MER 11 E2	20.0	5.6	25.6	13.0	16.3	4.4	20.7	11.60	0.0	5.4	9	36	1.01
MER 11 E3	19.2	15.1	34.3	9.6	14.3	11.7	26.0	8.60	3.8	1.9	27	108	0.50
Mean	**28.9**	**12.1**	**41.0**	**7.5**	**22.4**	**9.5**	**31.8**	**6.73**	**8.1**	**10.6**	**20.7**	**82.7**	**0.8**
Std. Dev.	**16.1**	**5.6**	**19.6**	**6.7**	**12.3**	**4.4**	**14.9**	**6.02**	**10.9**	**12.2**	**10.1**	**40.5**	**0.3**
MER 11 U1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0	0
MER 11 U2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0	0
MER 11 U3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0	0
Mean	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.00**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Std. Dev.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.00**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
MER 18 E1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.66	6.7	0.0	0.0	0	0
MER 18 E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.34	6.3	0.0	0.0	0	0
MER 18 E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.54	6.5	0.0	0.0	0	0
Mean	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**6.51**	**6.5**	**0.0**	**0.0**	**0.0**	**0.0**
Std. Dev.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.16**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**
MER 18 U1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0	0
MER 18 U2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0	0
MER 18 U3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.00	0.0	0.0	0.0	0	0
Mean	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.00**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Std. Dev.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.00**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Scar means	**7.2**	**3.0**	**10.2**	**1.9**	**5.6**	**2.4**	**8.0**	**3.31**	**3.7**	**2.7**	**5.2**	20.7	0.2

Table 7 Eelgrass biomass, shoot counts, shoot length and tunicate data (Cont.)

	Air dried (48 hrs ambient temp.)				Desiccated (72 hrs @ 60°C)				Air dried		Shoots		
Sample No.	**Above grnd (g)**	**Below grnd (g)**	**Total (g)**	**Live unattached below grnd (g)**	**Above grnd (g)**	**Below grnd (g)**	**Total (g)**	**Live unattached below grnd (g)**	**Tunicates (g)**	**Loose bio (g)**	**Total shoots**	**Shoots/ m^2**	**Mean Shoot length**
T1-E1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.40	0.0	0.0	0	0	0
T1-E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.30	0.0	0.0	0	0	0
T1-E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.07	0.0	0.0	0	0	0
Mean	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.26**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Std. Dev.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.57**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
T1-U1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.76	0.0	0.0	0.0	0	0
T1-U2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.12	0.0	0.0	0.0	0	0
T1-U3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	----	0.0	0.0	0.0	0	0
Mean	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**3.44**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Std. Dev.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.45**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
T2-E1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.93	0.0	0.0	0.0	0	0
T2-E2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.19	0.0	0.0	0.0	0	0
T2-E3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.15	0.0	0.0	0.0	0	0
Mean	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.42**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Std. Dev.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.67**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
T2-U1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.61	0.0	0.0	0.0	0	0
T2-U2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.36	0.0	0.0	0.0	0	0
T2-U3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.49	0.0	0.0	0.0	0	0
Mean	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.82**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Std. Dev.	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.69**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Scar means	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.74**	**0.0**	**0.0**	**0.0**	0.0	0.0

Water Quality

The Maine Department of Environmental Protection conducted water quality monitoring at several sites in northern Casco Bay in September and November of 2013. Sampling was conducted using a Yellow Springs Instruments (YSI) Model 6600-V2 sonde (SN 09J-101742) equipped with temperature and salinity probe, pH probe, optical dissolved oxygen, optical turbidity and optical chlorophyll-α sensors. Profiles were recorded at Simpson Point at a location west of the stone pier and within the former eelgrass bed (GPS coordinated 43.85138N, -69.97465W) at 2 hours either side of high water; data were collected at discrete depth at 0.5m intervals. Data collected on the two dates at Simpson Point are shown below in Table 8. These data are provisional pending final review and verification.

Table 8. Water quality data collected at Simpson Point September 19 and November 8, 2013

Date	Time	Depth (m)	T°C	salinity (ppt)	pH	D.O. (mg/L)	D.O (% sat.)	Turbidity (NTU)	Chlorophyll (µg/L)
9/19/2013	12:16	0.5	16.25	31.98	7.64	8.82	109.4	0.1	3.3
9/19/2013	12:16	1.0	16.16	31.9	7.56	8.91	110.1	0.7	2.8
9/19/2013	12:16	1.5	15.65	31.9	7.62	9.09	111.7	0.6	4.2
9/19/2013	12:16	2.0	15.56	31.86	7.68	9.17	112.0	1.0	6.2
9/19/2013	12:16	2.5	15.51	31.86	7.77	9.26	112.6	1.3	6.3
11/8/2013	14:00	0.5	8.7	31.75	8.25	10.22	107.6	2.9	8.6
11/8/2013	14:00	1.0	8.67	31.75	8.25	10.37	109.2	3.0	11.8
11/8/2013	14:00	1.5	8.73	31.77	8.24	10.34	109.1	2.9	12.5
11/8/2013	14:00	2.0	8.66	31.76	8.26	10.41	109.7	3.2	12.3
11/8/2013	14:00	2.5	8.72	31.77	8.26	10.37	109.5	2.8	13.1

Source: James Stahlnecker, Maine DEP

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Discussion

As Table 1 shows, some slight recovery of eelgrass along the edge of the scar area of moorings MER 11 and 18, both of which represent replacement of traditional block and chain mooring with helical anchors, was observed between 2008 and 2011. The 2012 monitoring survey, however, revealed a reversal in recovery with mooring MER 11 in Maquoit Bay showing an increase in the scar area over the initial Post-replacement (baseline) scar area and the scar area of mooring MER 18 in Merepoint Bay showing an increase over the 2011 area, although still smaller than the initial 2008 estimated Post-replacement (baseline) scar area. This reversal in recovery was attributed in part to the increase in the coverage of the orange-sheathed tunicate, *Botrylloides violaceus.* Carman *et al.* (2009; 2010) also reported similar tunicate coverage on eelgrass at Massachusetts sites and again in 2013 (pers. comm.); other factors, such as increased water temperature associated with global climate change (Orth *et al.* 2006), increased turbidity and self-poisoning (Robertson, 1984; Frederiksen *et al.*, 2004) may also have played a role in the decline of the eelgrass.

The continued lack of recovery at certain mooring scar sites and the reversal in recovery seen in 2012 was discouraging, but nothing prepared us for the near four-fold increase of the scar at MER 11 and the essentially catastrophic and total loss of eelgrass in the vicinity of mooring scar MER 18 in Merepoint Bay. Similarly, although anecdotal reports suggested substantial loss of eelgrass at Simpson Point, again, we were not prepared for the total loss observed along the two video recorded transects set there. Indeed, barely a blade of eelgrass remains and the bottom is now virtually entirely covered with moderate to heavy epilithic diatom mats.

Loss of eelgrass habitat is not confined just to the IF&W study areas in northern Casco Bay. Indeed, reports have been received of disappearance of eelgrass further up the Maine coast as far east as Frenchman Bay and Taunton Bay (Jane Disney, Mount Desert Island Biological Laboratory; email 7/10/2013), suggesting that the cause is much broader rather than local or even regional.

Additionally, populations of the blue mussel, *Mytilus edulis*, in Casco Bay have been declining over the past several years (personal observation; pers. comm. Andre Cocquyt); soft-shell clams, *Mya arenaria*, also appear to be in decline with few sub-legal clams being reported in shellfish surveys conducted in Casco Bay (MER survey of Yarmouth clam flats, 2013; pers. comm., Dan Devereaux, Brunswick Marine Warden). The decline in shellfish has been attributed to an explosion in the population of green crabs, *Carcinus maenas*, that appear to be devastating small clams. The green crab has also been suggested as the cause of eelgrass loss. Eelgrass is not part of the green crabs' diet (Ropes, 1968); however, recent work in Casco Bay comparing eelgrass survival between exclosure-protected transplanted eelgrass and non-protected transplanted eelgrass points to green crabs as a primary cause of loss of eelgrass in Maquoit Bay (pers. comm., Hilary Neckles, USGS). Evidence of such clipping seems to be apparent on eelgrass blades taken from sample in Maquoit Bay (see Figure 11).

Figure 11 Suspected evidence of green crab crimping/clipping of eelgrass blade

It has been suggested that the lack of recovery of eelgrass within the mooring scars might be the results of unsuitable sediment conditions, specifically elevated sulfide and total organic carbon resulting from accumulation and decomposition of organic matter within the depression created by the sweeping chain. Goodman (1995) classified pore water sulfide concentrations in excess of 600μM as toxic to eelgrass, based on EC50 laboratory experiments for eelgrass photosynthesis. As Figures 12 and 13 show, sulfide concentration within the "unvegetated" ('U') scar area (tan bars), particularly at MER 11, are significantly higher than in the surrounding "vegetated" area (green bars). The sulfide concentration levels are significantly higher than the 600μM. These levels are clearly toxic to eelgrass and likely the reason for the lack of recovery of the scars, at least those areas toward the center of the scars.

Figure 12 MER 11 sulfides (μM)

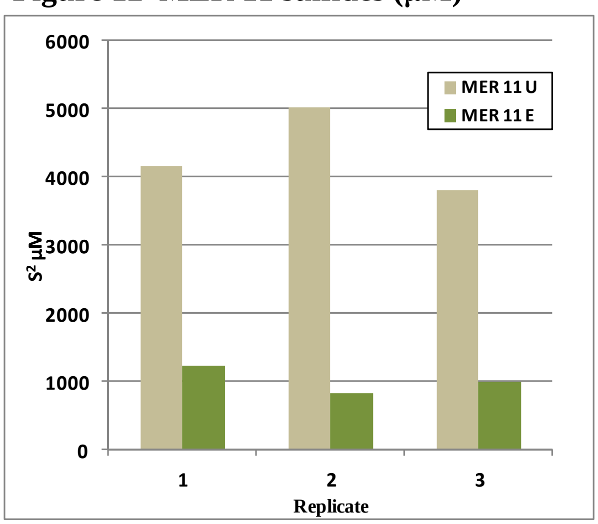
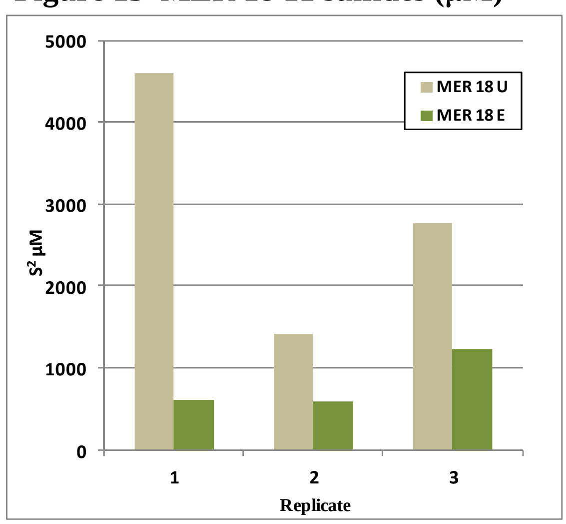


Figure 13 MER 18 11 sulfides (μM)



Total organic carbon is consistently higher within the scar area compared to the vegetated areas, but the difference is small compared to the sulfide results (Figures 14 and 15). These results are generally similar and only slightly higher than results obtained from soft bottom reference sites elsewhere along the Maine coast.

Figure 14 MER 11 TOC (%)

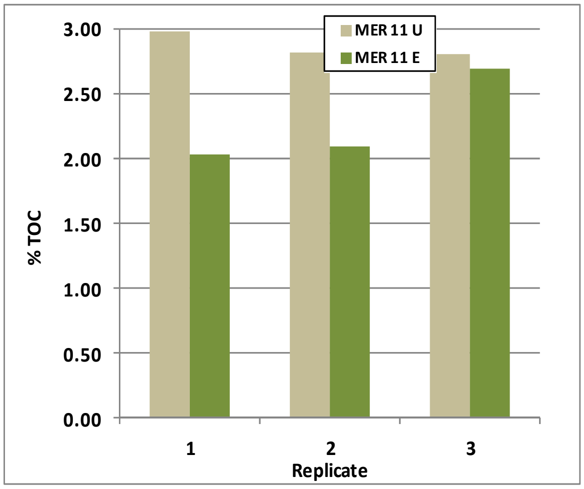
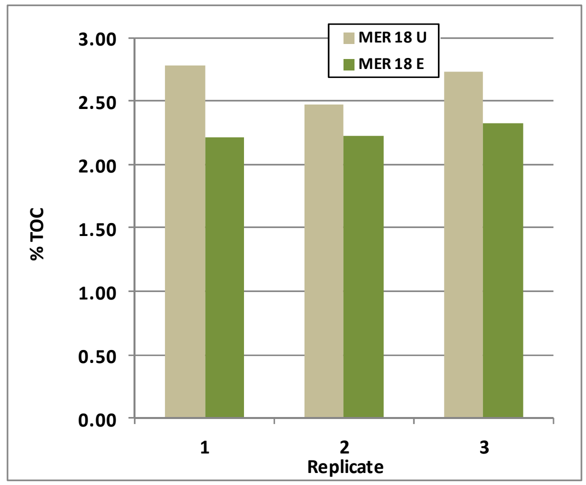


Figure 15 MER 18 TOC (%)



No eelgrass was found at Simpson Point and there is, therefore, no difference between the "unvegetated" and "vegetated" samples other than the "unvegetated 'U' " samples were collected over the first 60 meters of the transect and consequently in shallower water (approx 1.5 feet depth at low water) compared to the "vegetated 'E' " collected over the second 60 meters of transect in deeper (approx. 3.5 feet depth at low water). The Simpson Point sulfide concentrations are generally lower than those found in the mooring scar areas; however all are still well above the toxic level of 600µM, indeed all being above 1,000µM (Figures 16 and 17).

Figure 16. SP T1 sulfides (µM)

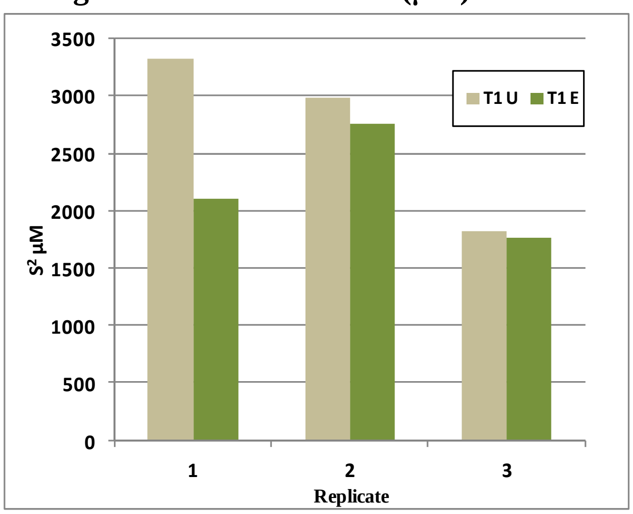
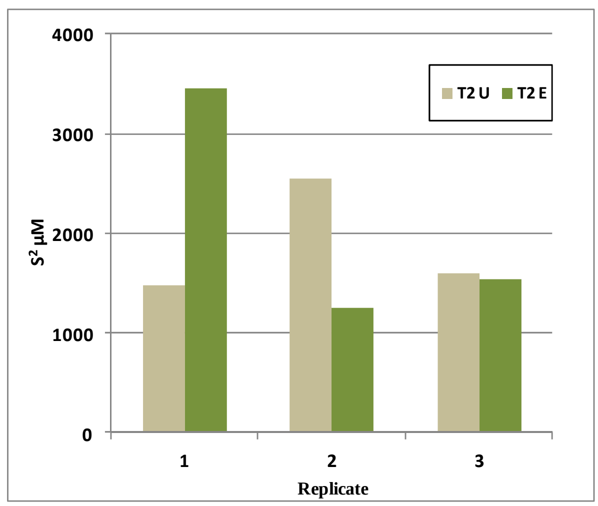


Figure 17. SP T2 sulfides (µM)



The Simpson Point total organic carbon results are similar to results obtained from soft bottom reference sites elsewhere along the Maine coast, that is, within the 2.00% to 2.50% range (Figures 18 and 19).

Figure 18. SP T1 TOC (%)

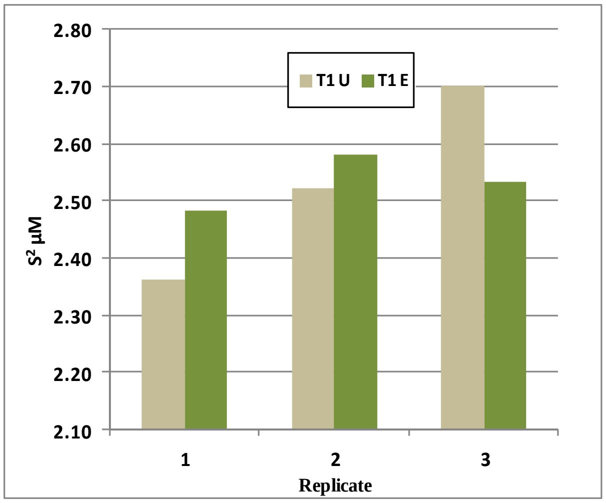
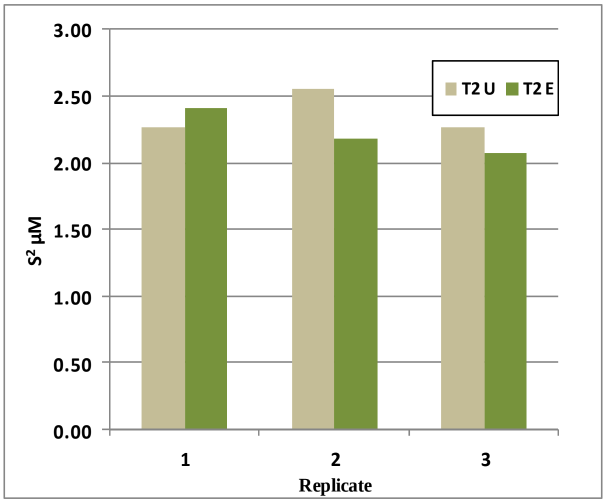


Figure 19. SP T2 TOC (%)



Given the small amount of eelgrass observed during the 2013 survey, tunicate coverage estimates are limited to the vegetated area surrounding mooring MER 11 in Maquoit Bay where coverage was estimated by the diver at 0%-10%; two species, *Botrylloides violaceus* and *Diplosoma listerianum* (identification by Mary Carman, WHOI), both invasive species, are present (see Figures 20 and 21). Additionally, little evidence of wasting disease was seen at the Maquoit Bay site where incidence was estimated a 0%-10%.

Figure 20. ***Diplosoma listerianum***

Figure 21. ***Botrylloides violaceus***

The water quality data collected by Maine DEP at Simpson Point do not indicate anything particularly out of the ordinary other than a slightly lower pH than expected in September; given the salinities values close to 32ppt, pH would be expected to be closer to 8.0. The temperature and salinity are within the normal range of what would be expected for those dates and, although the dissolved oxygen levels are slightly supersaturated, this is not unusual given the chlorophyll levels and windy conditions on the day of sampling in November. It is interesting to note that on both sampling dates chlorophyll increased with depth; this suggests that the chlorophyll found in the water column may be diatoms stirred up off the bottom, the bottom in the vicinity of Simpson Point being generally covered with a moderate to heavy layer of epilithic diatom mats. Turbidity was low in September with the highest reading of 1.3 NTU found near the bottom; the higher values found in November were likely attributable to stirring of the bottom as a result of the south-west winds at 18mph at the time of sampling; some elevation in normal turbidity should be expected given the soft, fine sediment that covers the bottom and the loss of the wave attenuation effect now that the eelgrass is gone.

The near total loss of eelgrass in Maquoit Bay, essentially total loss in Middle Bay and complete loss in Merepoint Bay is remarkable. As previously stated in prior reports, eelgrass changes in density and distribution are not uncommon and are caused by both natural and anthropogenic causes. The now total loss of the eelgrass at Simpsons Point is clearly unrelated to boat activity given the magnitude of the loss and the fact that the Simpsons Point landing has been blocked to motorized vessels since 2008. Swimming and non-motorized boating activity does occur in the vicinity of the boat landing and on several occasions numerous swimmers, kayakers and canoers have been observed in the area and using the landing (pers. obs.). These activities, however, are generally restricted to the nearshore area and, although some of this activity may have accounted for some recession of eelgrass at the upper, nearshore boundary, it cannot account for the total loss the eelgrass meadow as a whole. Indeed, the magnitude of the loss and the extent of the area involved, including other regions of the State, suggest a much larger scale cause.

Again as previously stated, declines in eelgrass habitat are usually attributed to physical disturbance that results in damage or uprooting of plants, such as those related to storms, moorings and dredging; scouring by ice; shading caused by physical structures such as floats; elevated turbidity caused by physical disturbance to the bottom in adjacent areas; excessive epiphytic and phytoplankton growth usually related to elevated nutrients associated with land-use, *e.g.* agriculture, waste water treatment effluents; and natural factors including disease (wasting), grazing, and self-poisoning (Robertson, 1984; Frederiksen *et al*., 2004). The Town of Brunswick enacted ordinances in the early 1990s to regulate certain practices in an effort to control excessive transport of nutrients into its coastal waters. It therefore seems unlikely that nutrient loading is involved, at least locally. Elevated turbidity has been observed in the vicinity of Simpsons Point on several of the visits to the site, but this is usually related to wind-related small wave activity stirring the bottom, particularly along the nearshore at low water. However, some turbidity in the area appears to be a normal condition in the area, even when eelgrass appears to be thriving. With the total loss of eelgrass in the area, the wave-attenuation effects of the eelgrass are now lost, thus wave-associated turbidity will increase.

The exact cause of the decline and sudden loss of eelgrass in the upper reaches of Casco Bay remains unclear; it is likely that several factors may be contributing to the decline rather than a single cause. Fortunately, eelgrass appears to remain healthy, indeed thriving, in more exposed areas of Casco Bay closer to open ocean. These areas may provide the opportunity for future study, either of the continued seaward decline of eelgrass or as areas from which recovery will spread. Such studies, however, will involve considerable effort and time, both well beyond the scope of the IF&W efforts.

Conclusions

The near total loss of eelgrass in Maquoit Bay and catastrophic loss in Merepoint Bay and at Simpson Point render the mitigation efforts by IF&W over the past five to six years, as well as any further efforts, moot since natural conditions have clearly become unsuitable for eelgrass. This is most unfortunate in view of the time and expense put into these efforts. However, the efforts serve as an inadvertent and unintended documentation of the decline of eelgrass habitat and the sediment chemistry work of the current study will hopefully provide a baseline set of values against which any future sampling can be compared.

Similar declines in eelgrass have been previously observed as reported anecdotally by individuals familiar with Casco Bay. However, multiple dramatic changes seen over the past two to three years, but particularly in 2013, indicate that major changes (e.g. climate change) are taking place in Casco Bay.

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Appendix I

2013 detailed calculations of the two selected mooring scars area based on full extent of the eight *in situ* radii measurement method

2013 Scar area calculation based on two known side lengths and 45º angle at center

MER 11 — **Sean White MQ156**

Triangle	A	B	C	s	Area	
						1353
1 N	10.0	22.0	16.5	24.3	77.8	
2 NE	22.0	27.0	19.3	34.2	210.0	
3 E	27.0	16.0	19.3	31.2	152.7	
4 SE	16.0	47.0	37.4	50.2	265.8	
5 S	47.0	62.0	44.0	76.5	1030.2	
6 SW	62.0	50.0	44.3	78.1	1095.9	
7 W	50.0	67.0	47.4	82.2	1184.3	
8 NW	67.0	10.0	60.3	68.7	236.9	
Mean r	37.6				**4254**	**Post-estimate**
Mean r area	**4447**					

MER 18 — **Bill Moore MP001**

Triangle	A	B	C	s	Area	
						731
1	100.0	100.0	76.5	138.3	3535.2	
2	100.0	100.0	76.5	138.3	3535.2	
3	100.0	100.0	76.5	138.3	3535.2	
4	100.0	100.0	76.5	138.3	3535.2	
5	100.0	100.0	76.5	138.3	3535.2	
6	100.0	100.0	76.5	138.3	3535.2	
7	100.0	100.0	76.5	138.3	3535.2	
8	100.0	100.0	76.5	138.3	3535.2	
Mean r	100.0				**28282**	**Post-estimate**
Mean r area	**31416**					

Appendix II

Detailed calculations of each traditional mooring scars area in 2008 following replacement with helix anchor or relocation based on the eight *in situ* radii measurement method

2008 Scar area calculation based on two known side lengths and 45º angle at center

MER 11 **Sean White MQ156**

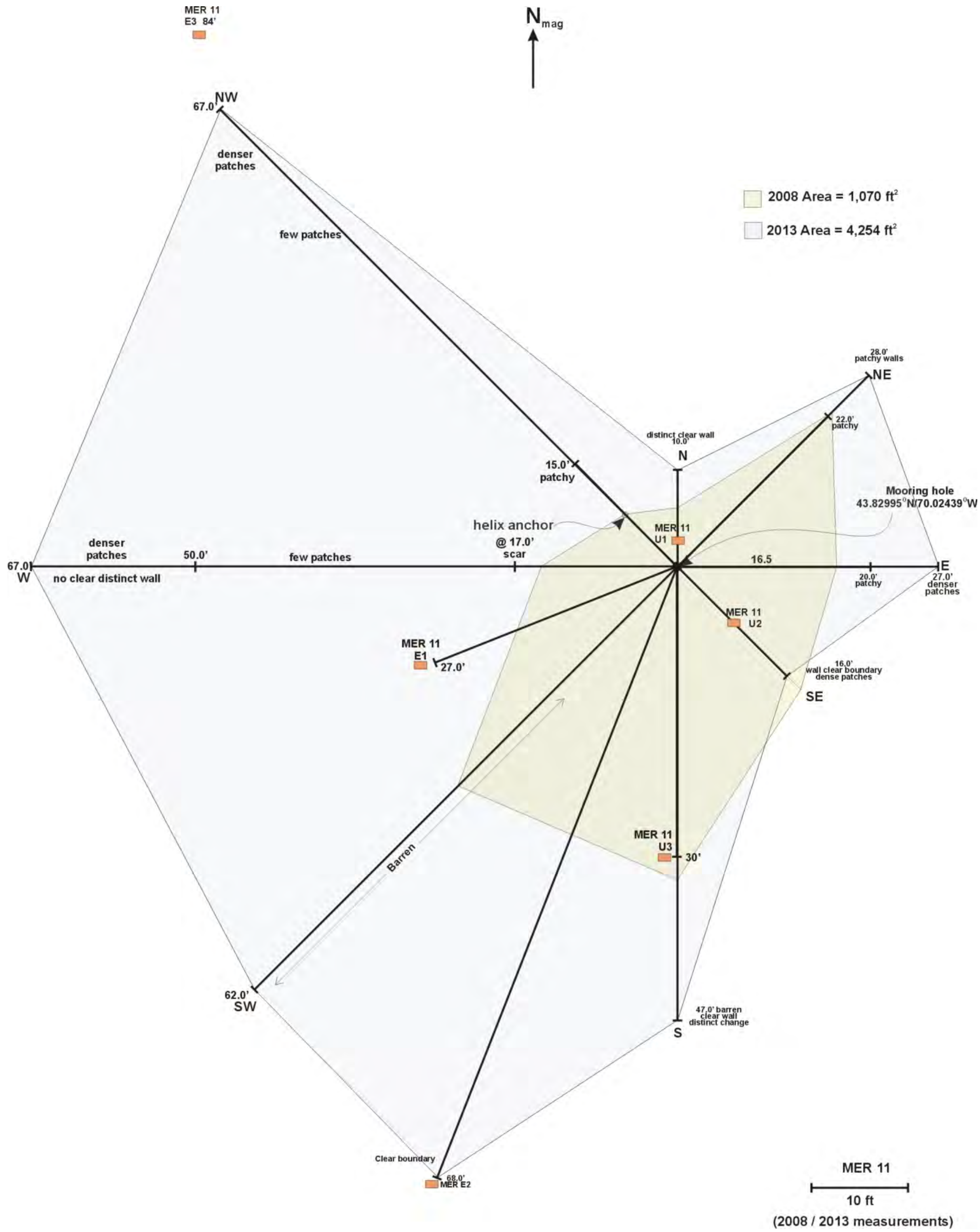
Triangle	A	B	C	s	Area	
1	6.0	22.5	18.7	23.6	47.7	
2	22.5	16.5	15.9	27.5	131.2	
3	16.5	18.0	13.3	23.9	105.0	
4	18.0	32.5	23.5	37.0	206.8	
5	32.5	32.0	24.7	44.6	367.7	
6	32.0	14.0	24.2	35.1	158.4	
7	14.0	7.5	10.2	15.8	37.1	
8	7.5	6.0	5.3	9.4	15.9	
Mean r	18.6				**1070**	**Post-estimate**
Mean r area	**1090**					

MER 18 **Bill Moore MP001**

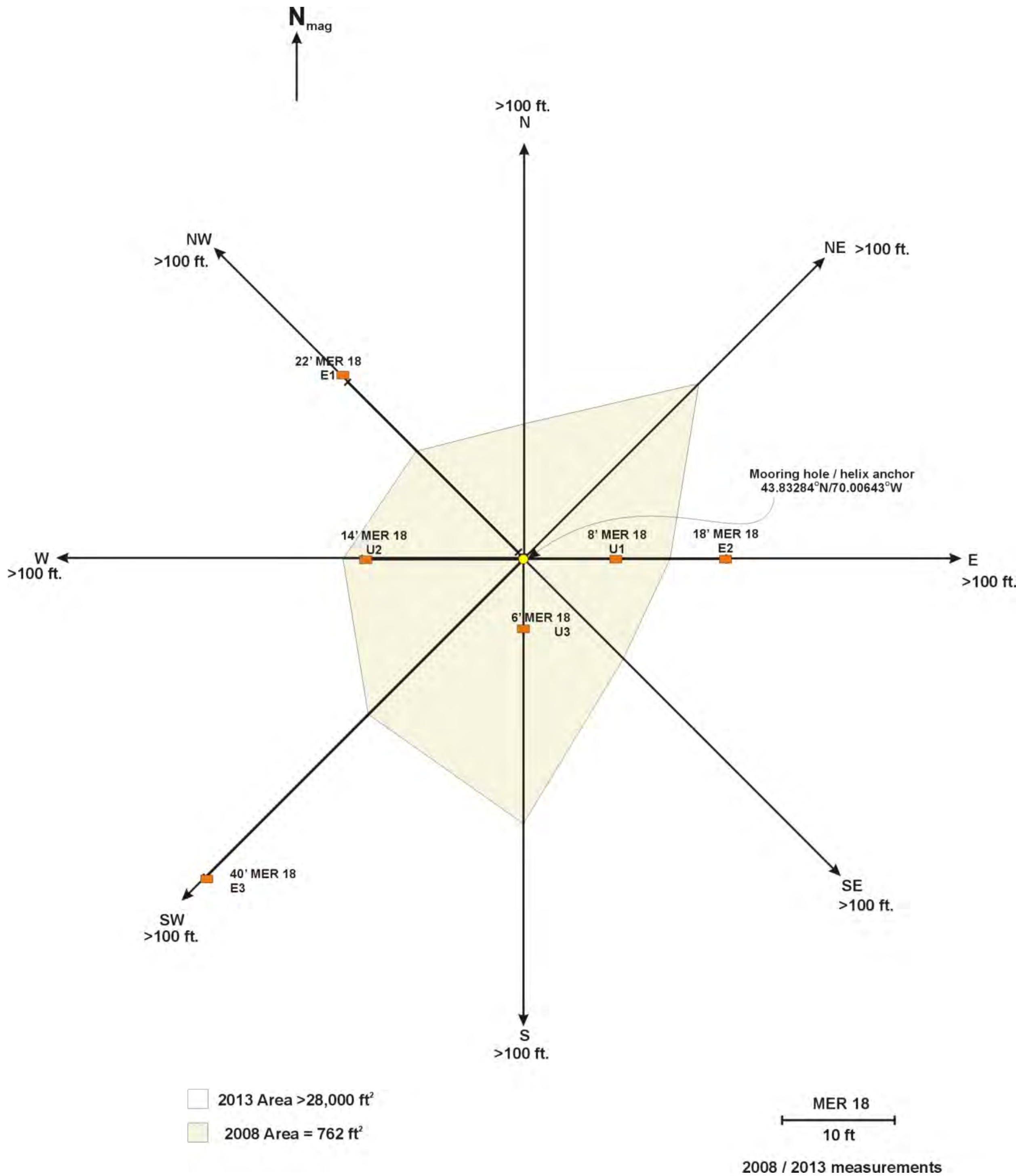
Triangle	A	B	C	s	Area	
1	12.0	22.0	16.0	25.0	93.3	
2	22.0	13.0	15.8	25.4	101.1	
3	13.0	12.5	9.8	17.6	57.4	
4	12.5	23.5	17.1	26.6	103.8	
5	23.5	19.5	16.9	29.9	162.0	
6	19.5	16.0	14.0	24.7	110.3	
7	16.0	13.5	11.5	20.5	76.4	
8	13.5	12.0	9.9	17.7	57.3	
Mean r	16.5				**762**	**Post-estimate**
Mean r area	**855**					

Appendix III

Graphic representations showing 2008 and 2013 mooring scars area based on eight *in situ* radii measurements



MER 11
E3 84'
Nmag
67.0' NW
denser patches
few patches
2008 Area = 1,070 ft²
2013 Area = 4,254 ft²
28.0' patchy walls
NE
22.0' patchy
distinct clear wall 10.0'
N
15.0' patchy
Mooring hole
43.82995°N/70.02439°W
helix anchor
@ 17.0' scar
MER 11 U1
67.0' W
denser patches
50.0'
few patches
16.5
E
no clear distinct wall
20.0' patchy
27.0' denser patches
MER 11 U2
MER 11 E1
27.0'
16.0' wall clear boundary dense patches
SE
Barren
MER 11 U3
30'
62.0' SW
47.0' barren clear wall distinct change
S
Clear boundary
68.0' MER E2
MER 11
10 ft
(2008 / 2013 measurements)


N mag
>100 ft.
N
NW
>100 ft.
NE >100 ft.
22' MER 18
E1
Mooring hole / helix anchor
43.83284°N/70.00643°W
14' MER 18
U2
8' MER 18
U1
18' MER 18
E2
W
>100 ft.
E
>100 ft.
6' MER 18
U3
40' MER 18
E3
SW
>100 ft.
SE
>100 ft.
S
>100 ft.
2013 Area >28,000 ft²
2008 Area = 762 ft²
MER 18
10 ft
2008 / 2013 measurements

Appendix IV

Photos of the eelgrass and below-ground samples

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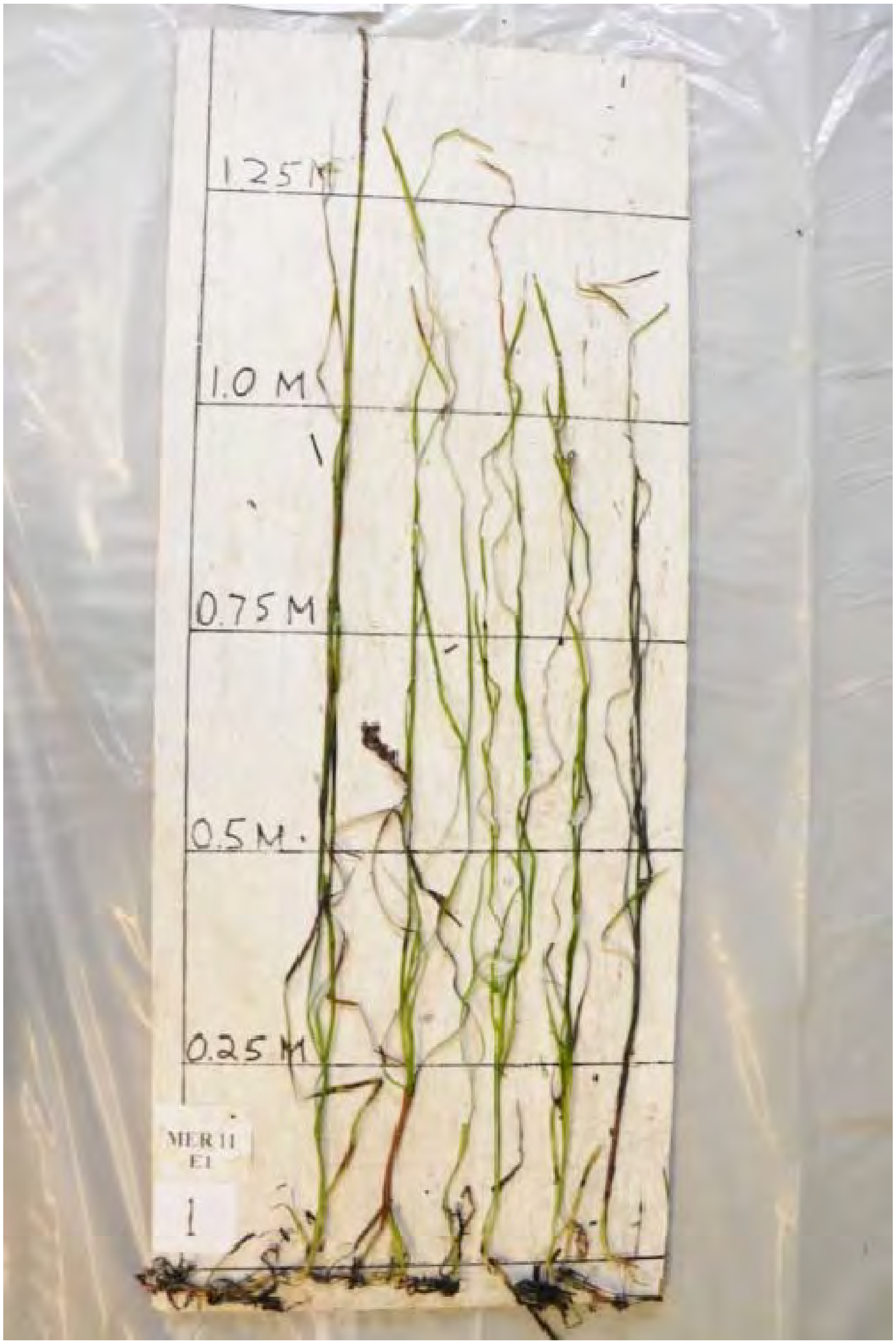


1.25M
1.0 M
0.75 M
0.5M.
0.25 M
MER 11
E1
1

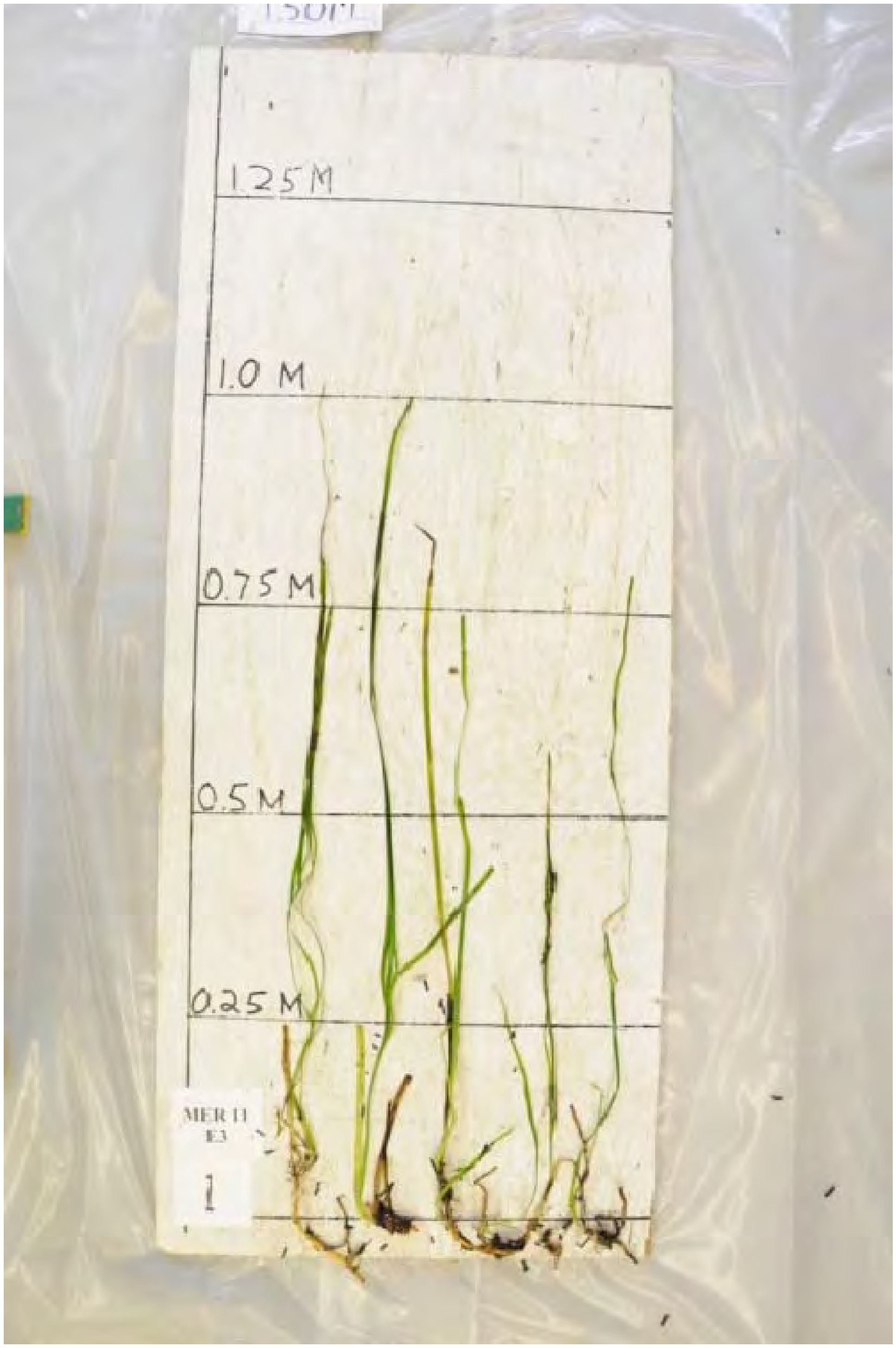

1.25M
1.0 M
0.75 M
0.5M.
0.25 M
MER 11
E1
2

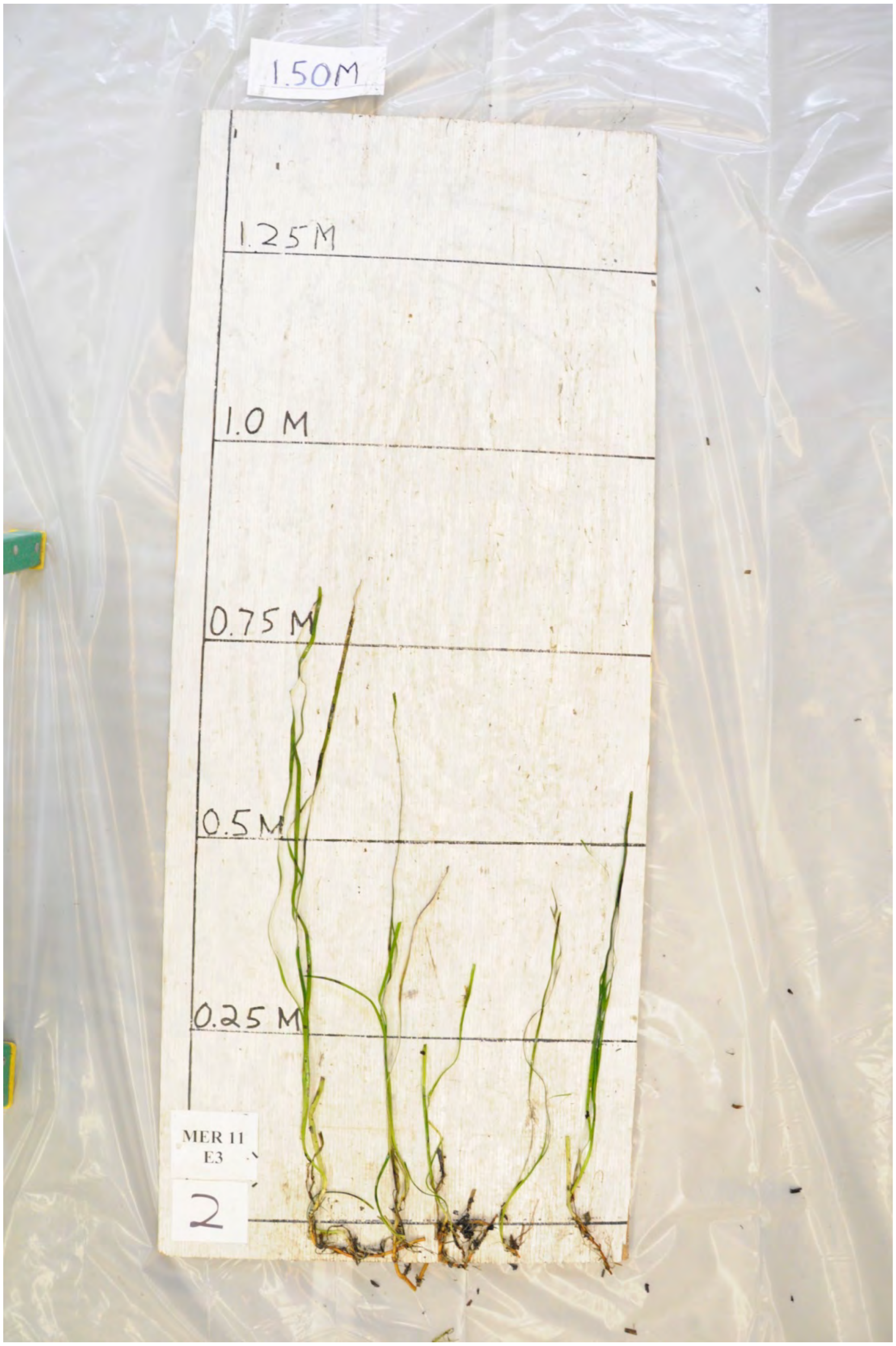

1.25M
1.0 M
0.75M
0.5M
0.25M
MER II
E1
3


1.25M
1.0 M
0.75 M
0.5M
0.25 M
MER 11
E1
4

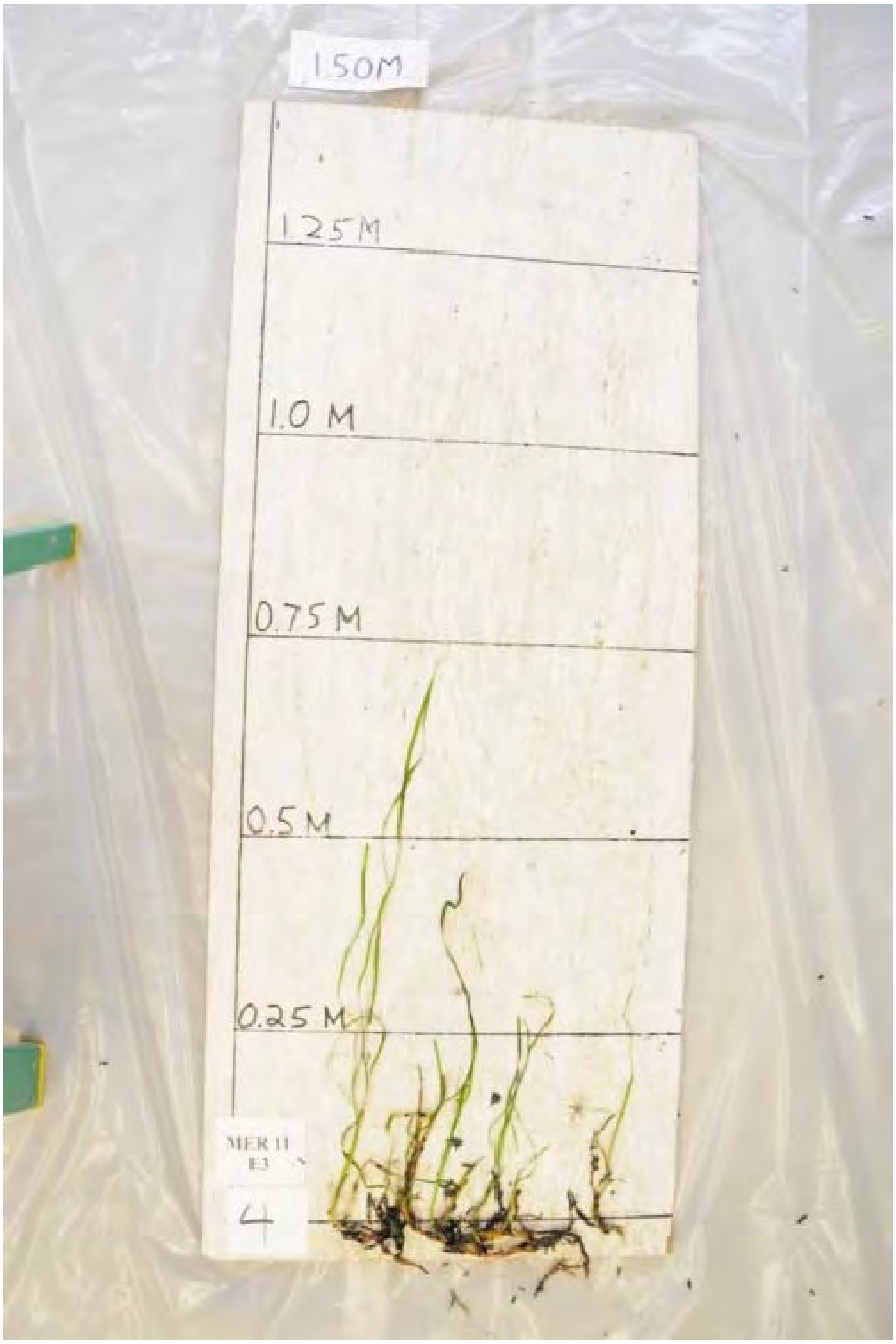

125M
1.0 M
0.75 M
0.5 M
0.25 M
MER 11
E2
1

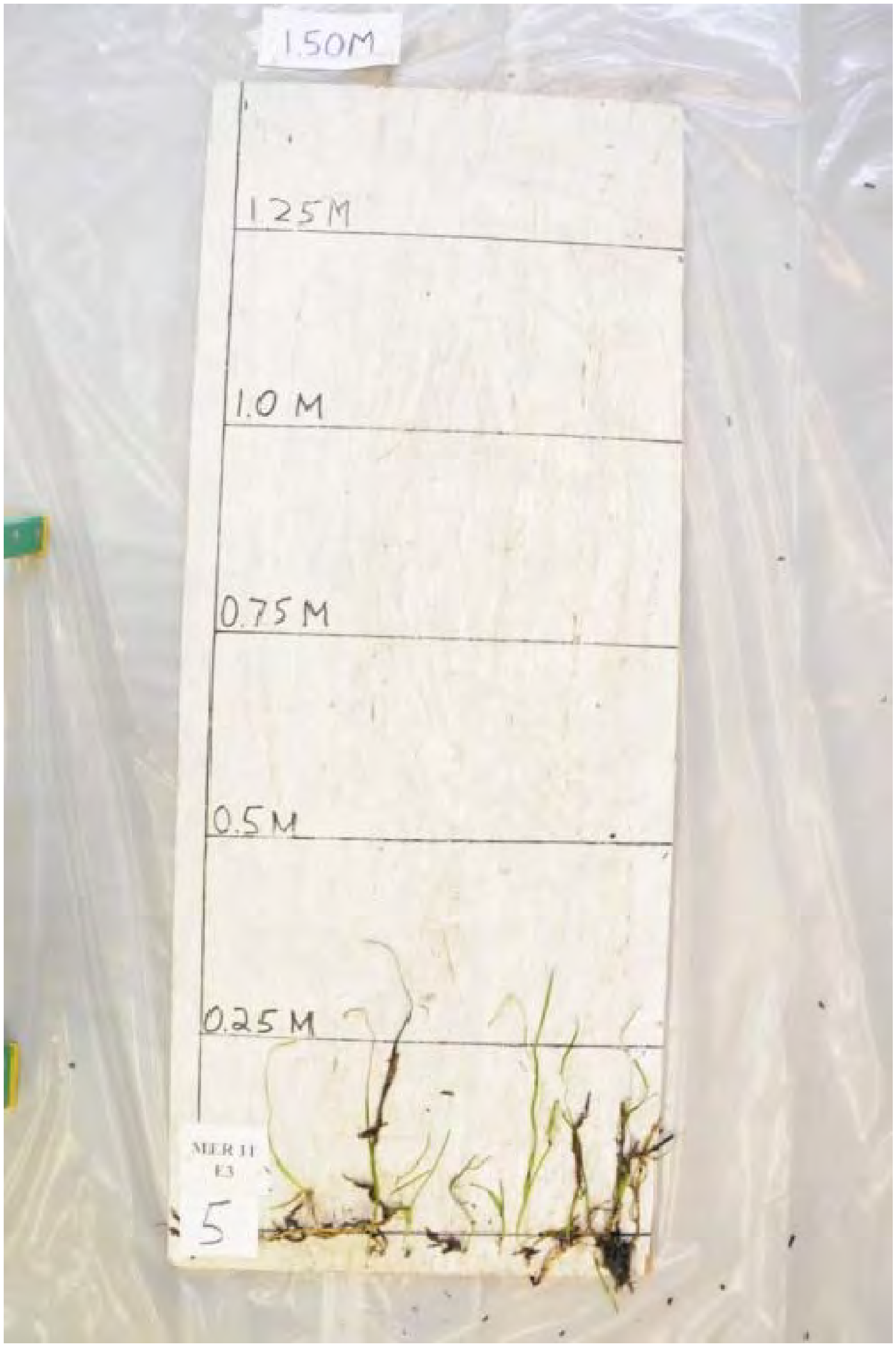

1.25M
1.0 M
0.75 M
0.5M
0.25
MER 11
E2
2


1.25M
1.0 M
0.75 M
0.5M
0.25 M
MER 11
E3
1


1.50M
1.25M
1.0 M
0.75 M
0.5 M
0.25 M
MER 11
E3
2


1.50M
1.25M
1.0 M
0.75 M
0.5M
0.25 M
MER 11
E3
3

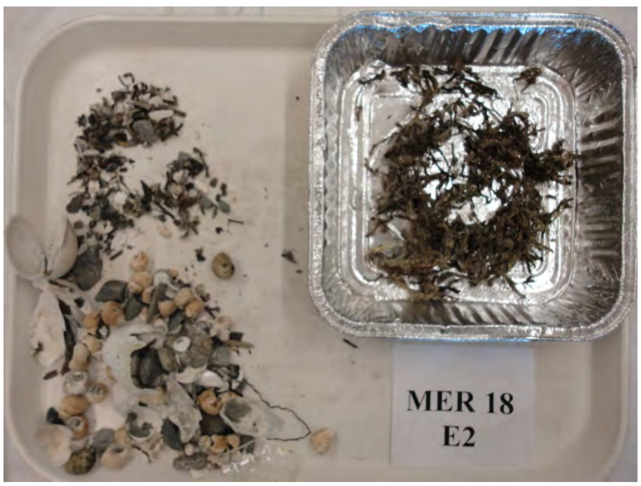

1.50M
1.25M
1.0 M
0.75 M
0.5 M
0.25 M
MER 11
E3
4


1.50M
1.25M
1.0 M
0.75 M
0.5M
0.25 M
MER 11
E3
5





MER 18
E1

MER 18
E1

MER 18
E2

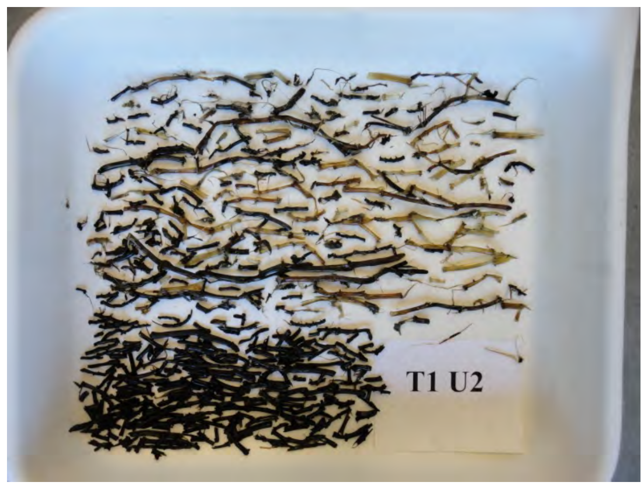
MER 18
E2

MER 18
E3

MER 18
E3


T1 U1

T1 U1

T1 U2

T1 U2

T1 U3


T1 E1

T1 E1

T1 E2

T1 E2


T1 E1

T1 E1

T1 E2

T1 E2

T1 E3

T1 E3


T1 U1


T1 U1


T1 U3


T2 E1


T2 E1


T2 E2


T2 E3


T2 U1


T2 U2


T2 U3